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Bias Associated with Sampling Interval in Removal Method for Fish Population Estimates

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Abstract: One of the fundamental problems facing fisheries biologist is determining population abundance. Often indirect methods of determining population size must be employed, including mark and recapture, area-density measurements and catch-effort techniques. Removal methods of population estimation are based on the relationship between catch per effort and cumulative catch. These methods may be biased if the collection technique used, such as electrofishing, violates the underlying assumptions of the catch-effort method. These assumptions are a closed population, a constant catchability coefficient that relates effort to catch, and the probability of capture of any individual fish is the same as that for any other fish. A study was conducted to determine if increasing the time interval between electrofishing passes reduces bias in estimating population size. Four stream reaches were repeatedly sampled by electrofishing at 15, 30, 60 or 120 minute intervals. Electrofishing was followed by rotenone application in order to measure total numbers and biomass of fish present. Percent differences in estimated and measured numbers and weights of fish were calculated for each sampling interval. The 15 minute sampling interval resulted in percent differences between observed biomass and estimated biomass that were significantly higher than all other sampling schemes. The high 15 minute interval average difference was followed by a lower difference for the 30, 60, and 120 minute intervals as might be expected if fish "forgot" the electrofishing experience as time increased between runs.

Key words*: Catch per unit effort, rotenone, sampling bias, electrofishing*

Introduction

A fundamental task facing fisheries biologist is determining population abundance with precision. While the fisheries biologist is occasionally able to directly observe and enumerate fish at least at some life history stage, direct observation is often at the expense of the population as in the case of a total rotenone kill or in the draining of an impoundment. Streams possess their own set of physical factors that confound direct observation of fish including flowing water, variable turbidity and diversity of habitat and substrates.

Because of practical problems with direct observation, indirect methods of determining population size often must be employed. These methods include mark and recapture, area-density measurements and catch-effort techniques. Each of these methods includes certain assumptions that must be met before accurate estimates may be made.

Mark and recapture methods generally assume that there is no increased mortality among marked fish either due to the marking procedure or due to greater susceptibility to predation. Also assumed is that no marks are lost or is there a significant amount of emigration of marked fish between marking and subsequent recapture. Suitability of area-density methods depends on the development of a stratified sampling protocol such that all habitat types within the sampling frame are included. Bias in the sampling process is increased as the survey results are expanded for estimates of the entire population (Everhart & Young, 1981).

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Removal methods of population estimation are based on the relationship between catch per effort and cumulative catch. In this method repeated amounts of fishing effort (the amount of time spent fishing with a particular type of gear) is applied to a body of water, river or stream, and resulting catch per unit of effort and cumulative catch are plotted against one another.

Simonson and Lyons (1995) compared catch per effort index methods and removal procedures for sampling stream fish assemblages and found the estimates provided by both were correlated. Estimates based on the removal method were higher than those based on catch per effort index sampling.

Two commonly used approaches of removal methods are the Leslie and DeLury methods (Leslie & Davis, 1939; DeLury, 1947). These two techniques presuppose several assumptions. First it is assumed that the population sampled is closed and that the catchability coefficient is constant and relates effort to catch. Additionally it is assumed that the probability of capture of any individual fish is the same as that for any other fish and that fishing effort may vary in duration. A third related technique, the Moran (1951) and Zippin (1956) method, makes the same assumptions as the Leslie and DeLury methods; however, the Moran and Zippin method requires that effort is constant (Everhart & Young, 1981).

The Leslie method used the relationship between catch per effort and stock abundance (Equation 1).

$$C_t / f_t = qN_t \qquad (1)$$

Catch (C_t) (in number or weight) at time t divided by effort (f_t) applied until time t is equal to the number or weight of fish (N_t) at time t multiplied by a constant q. The constant q is referred to as the catchability coefficient. Fish abundance at time t (N_t) is equal to some starting population size (N_o) less the sum of fish removed (cumulative catch) up until time t (K_t) (Equation 2).

$$N_t = N_o - K_t \qquad (2)$$

By substituting for N_t in equation 1 a linear relationship between cumulative catch and catch per effort is revealed (Equation 3) with an intercept of qN_o and a slope of q.

$$C_t / f_t = qN_o - qK_t \qquad (3)$$

The original population size (at t = 0) is then estimated by dividing the intercept by the slope (equation 4).

$$N_o = qK_t/q \qquad (4)$$

A critical assumption of all removal methods is that the probability of capture of any individual fish is the same for all fish in the population. If the capture process changes this probability, then the method will be biased. If the probability of capture is increased with subsequent applications of effort, population estimates will be high. If the probability of capture is decreased, estimates of population will be low. If these probabilities change within the sampling period, the catchability coefficient is not a constant (Everhart & Young, 1981).

Catch per unit of effort by electrofishing is an easily obtained index of stock abundance. Electrofishing, a proven method of species detection, has been employed as the collection vehicle in mark-recapture studies. With proper consideration of limitations associated with size selectivity, it can be used in estimating population rates of reproduction, mortality, and growth (Reynolds, 1983). Electrofishing has also been successfully used as the collection technique in the removal method of population estimation (Johnson, 1965; Peterson & Cederholm, 1984; Bozek & Rahel, 1991).

When electrofishing is chosen as the method of removal in the aforementioned techniques, the electroshock experience may significantly affect the catchability of fish in subsequent collections (Cross & Stott, 1975). This changed catchability may be due to refractory behavior, which is a physiological reaction to being shocked, that makes the fish extremely susceptible to subsequent stunning by electricity, or to learned escape behavior associated with the negative stimulus of electroshocking (Lelek, 1965). If fish can associate the negative stimulus of electrofishing with visual or audial queues created by the fishing operation then the fish may be able to seek refuge in areas inaccessible to the fishing crew before becoming susceptible to galvanotaxis (forced swimming toward the anode) or galvanonarcosis (forced muscle relaxation). This phenomenon when coupled with increased galvanonarcosis and decreased galvanotaxis can dramatically bias population estimates.

The purpose of this study was to determine if increasing the length of interval between electrofishing passes affects bias in removal methods of population estimates of fishes in small streams.

Materials and Methods

Repeated fish collections were conducted on four stream reaches during the summer of 1990 on Goodwin Creek, Mississippi. Goodwin Creek was chosen as a study site because it's clear water and relatively shallow depth (60% of the aquatic area was 17 cm deep or less), would reduce the effects of refraction in repeated passes of the electrofisher (Herbert *et al*., 1961).

Each of the four stream reaches were divided into three sub-reaches (Figure 1). Sub-reaches were individually blocked off with 1/4 inch mesh minnow seine to prevent movement of fish either in or out of the sub-reach. Each reach was assigned one of either 15, 30, 60 or 120 minutes sampling intervals. Four sampling runs were conducted on each sub-reach by backpack mounted electroshocker. Sampling runs were conducted at these assigned intervals for each reach. Sampling run collections and shocking times were recorded separately for each sub-reach.

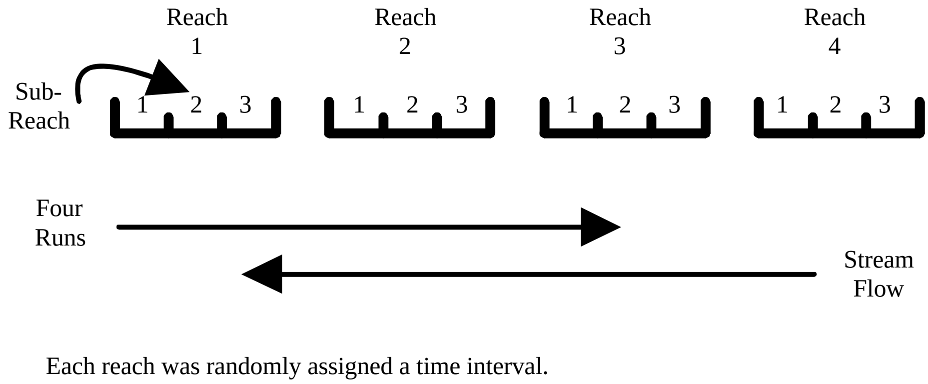

Figure 1. Schematic of sampling design for Catch-effort experiment

After completion of all four electrofishing runs in each of the three sub-reaches of a particular reach, rotenone was applied at an amount sufficient to maintain a concentration of approximately 2.5 mg/L until all fish in the reach were killed. Potassium permanganate was applied downstream of the last block net to neutralize the excess rotenone (Davies, 1983.).

All fish collected, either by electrofishing or rotenone, were identified, enumerated and weighed. Weights and numbers of fish collected in each of the four electrofishing runs were added to the weights and numbers of fish from the rotenone samples to provide a measure of the total weight (biomass) and total number of fish in each sub-reach.

Estimates of biomass and total numbers of fish were calculated using the Leslie method of regressing catch per unit of effort against cumulative catch and dividing the resulting intercept by the slope. These estimates were subtracted from the measured parameters, then divided by the measured parameters times 100 to calculate the percent difference between estimates and measured values.

Percent differences were subjected to analysis of variance to determine significant differences between sampling interval groups. Separation of means was performed when analysis of variance revealed significant differences between sampling interval groups.

Results and Discussion

The Leslie method often underestimated both catch by weight and catch by numbers for all time intervals (Figure 2). Catch by weight was underestimated from 1 to 99 % (Table 1). Catch by weight was overestimated only once. Catch by numbers were underestimated from 5 to 225% and overestimated twice.

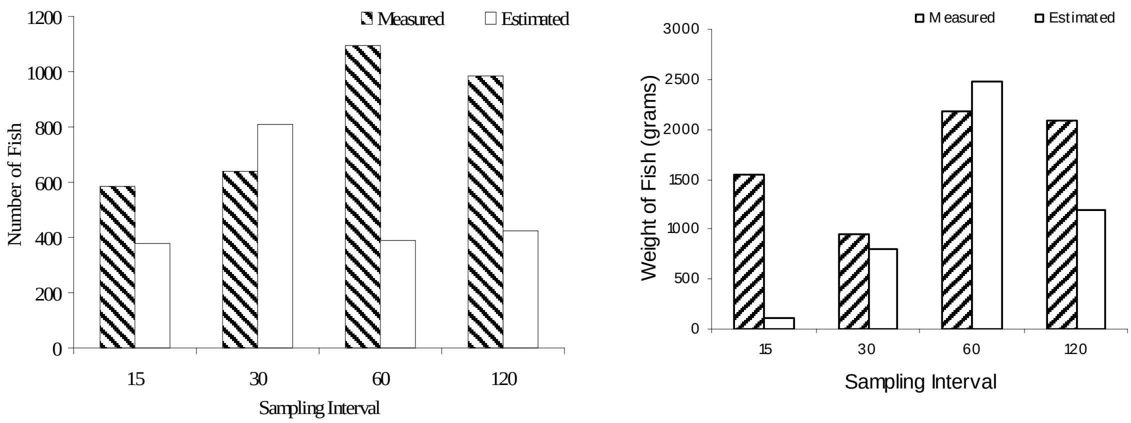

Figure 2. Mean measured and estimated numbers and weight of fish by sampling interval

Table 1. Measured and estimated total weight of fish, percent difference between measured and estimated weight, and average percent difference by sub-reach and sampling interval

Sub-reach	Sampling Interval	Measured Weight (g)	Estimated Weight (g)	Percent[a] Difference	Average Percent Difference
1	15	1146	247	-78	
2	15	2067	48	-98	
3	15	1428	16	-99	92*
1	30	554	332	-40	
2	30	722	561	-22	
3	30	1591	1522	-4	22
1	60	1393	658	-53	
2	60	4337	5975	+38	
3	60	816	807	-1	31
1	120	2197	1508	-31	
2	120	2727	1716	-37	
3	120	1362	353	-74	48

[a](-) represent underestimates and (+) represent overestimates.

*Represents significant difference (P= 0.05)

Since no significant differences between reaches were measured for the observed catch by weight or number, differences between treatments can be assumed to be due to treatments rather than to special variability among reaches. Estimates of catch by weight for the 15 minute interval samples averaged 92 % less than the rotenone based data and provided the poorest estimates of biomass when compared to the averages for longer sample intervals. The 15 minute interval sampling scheme was relatively consistent from sample to sample, ranging for 78 to 99% below the expected catches. Statistically the 15 minute interval sampling produced percent differences significantly (P=0.05) higher than all other sampling schemes.

The 30 minute sampling interval provided the best estimates of standing stock (weight) and included the closest estimate for any single sample. Increasing the sampling interval from 15 minutes to 30 minutes provided expected improvements in estimates of catch. However, interval increases greater than 30 minutes provided no better estimates of standing stock. The percent differences calculated for the 30, 60 and 120 minute were not statistically different from one another (P=0.05).

The 30 minute interval for estimates of fish numbers produced the greatest single sample percent difference (225%) and the 15 minute produced the least (5%) (Table 2). However, due to the high variability between the runs, population estimate accuracy was not significantly different for the tested sampling intervals.

Table 2. Measured and estimated total numbers of fish, percent difference between measured and estimated numbers, and average percent difference by sub-reach and sampling interval.

Sub-reach	Sampling Interval	Measured Numbers	Estimated Numbers	Percent[a] Difference	Average Percent Difference
1	15	742	705	- 5	
2	15	655	381	-42	
3	15	356	46	-87	45
1	30	790	319	-60	
2	30	370	1203	+225	
3	30	757	906	+20	102
1	60	1044	463	-56	
2	60	728	202	-72	
3	60	1509	499	-67	65
1	120	1547	436	-72	
2	120	931	720	-23	
3	120	478	114	-76	57

[a](-) represent underestimates and (+) represent overestimates.

The average percent differences for estimation of numbers of fish followed no discernible pattern; however, the average percent differences for estimation of weight of fish improved as the time interval was increased. The high 15 minute interval average difference was followed by a lower difference for the 30, 60, and 120 minute interval as was expected. No dramatic decreased availability following the first electrofishing run as described in the pond study by Cross and Stott (1975) was evident. Due to the clear, shallow and flowing water of Goodwin Creek, refraction effects were minimized.

Based on this study, the minimum time interval between electrofishing passes used in estimating populations by the Leslie method should be at least 30 minutes. No significant improvements in estimates were observed for intervals longer than 30 minutes. Much longer time intervals (24 to 48 hours) may be required in order to improve on the 30 minute interval. These longer intervals; however, increase the possibility of bias due to fish entering the sampled reach from up- or down-stream.

Summary

The Leslie method usually underestimated both weight and numbers of fish for all sampling time intervals. The 15 minute interval sampling resulted in percent differences between observed and estimated biomass of fish that were significantly higher than for longer intervals. The average percent differences for estimation of numbers of fish followed no discernible pattern; however, the average percent differences for estimation of weight of fish improved as the time interval was increased. The high 15 minute interval average difference was followed by a lower difference for the 30, 60, and 120 minute intervals as might be expected if fish "forgot" the electrofishing experience as time increased between runs. No dramatic decrease in availability following the first electrofishing run as describe by Cross and Stott (1973) was evident. Due to the physical conditions of the study site, refraction effects appeared to be minimized. Underestimates of the populations associated with the 15 minute interval appears to be a result of the short sampling interval rather than bias introduced in the first pass of the electrofisher.

This study suggests that the minimum time interval between electrofishing passes used in estimating populations by the Leslie method should be 30 minutes. Since no significant improvements in estimates were observed between 30 and 120 minute intervals much longer time intervals, such as 24 to 48 hours may be required in order to improve population estimate accuracy.

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