Estimation of angler harvest rates for recreational fisheries using creel surveys: current limitations and options for improvement

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Abstract

The acquisition of reliable estimates of harvest rate, measured as number of fish harvested per hour of fishing (hpue), has proved elusive as a creel survey objective. There are several reasons for this. Harvest rate is, by definition, a ratio and there are many ways of combining the numerator (harvest) with the denominator (effort). Different ratio estimators can produce widely differing estimates of hpue at different levels of precision. Depending on the survey method, effort and harvest data can be based on different types of interviews. On-site roving surveys provide interviews from uncompleted trips, while access point surveys provide completed trip interviews. Hpue estimates generally are highly variable, more so for marine and riverine fisheries than for lake fisheries. Common design stratifications, e.g., months, day types, geographical areas, have little positive effect on variability, and sample sizes required to obtain reasonably precise estimates can be prohibitive. Recent research suggests: (1) avoid per party estimators—they give relatively inflated and variable values; (2) use data from on-site, completed trip interviews if possible; (3) sample at an intensity to cover at least 70% of the possible fishing days; (4) divide the survey period into temporal strata that are as small as possible, but still allow replicate samples to be drawn; and (5) allocate relatively more effort to collecting interviews within days to compensate for high levels of within-day variability typical of hpue estimates.

Introduction

Harvest rate, measured as the number of fish harvested per angler-hour, is a primary fishery statistic traditionally estimated using creel surveys. Estimates of harvest rate are taken as a measure of angling success and are used as an index of stock density. The current popularity of length limits as a management tool in the United States, with the increased importance of catch-and-release fishing as a conservation tool, has made it necessary to distinguish between harvest rates and catch rates. I will use hpue (number of fish harvested per hour of fishing) here to signify harvest rate, and cpue (catch per unit of effort) to signify catch rate. Catch rate is the number of fish caught per angler-hour, including those fish released. The estimation of catch rate, then, entails that anglers be questioned about those fish caught and released (not observable at the time of the interview), as well as those in-hand at the time of the interview. There is potential for catch rates to be influenced by various recall biases, e.g. prestige bias and traditional recall bias; however, most recall periods are relatively short (mean fishing trip length usually averages between 3 and 5 hours) which makes severe recall bias unlikely.

The focus here will be on the estimation of angler harvest rates (hpue) for recreational fisheries using creel surveys. Most of the data available pertain to harvest rates rather than to catch rates; however, the two variables should behave similarly. The results reviewed here are from on-site angler surveys where harvest can be observed and measured by trained field technicians so that non-response or recall bias is not an issue.

Traditionally, hpue and cpue are used as measures of fishing success, as indices of stock density, and as one of the two primary variables (the other is fishing effort) used to calculate total harvest and total catch, respectively. It is apparent that the same estimator of hpue might not be appropriate for all three objectives. In this paper, I want to consider three important questions relevant to measuring hpue: (1) Which ratio estimator is best to use for particular objectives? (2) Are uncompleted fishing trip interviews acceptable? and (3) How does the sampling design account for variability in hpue?

(1) Choice of estimator

Crone and Malvestuto (1991) evaluated 5 ratio estimators of hpue (Figure 1). The first estimator was the mean party estimator (MP)—hpue is calculated for each individual party and a mean is taken over the number of parties (m) interviewed. The second estimator was the mean daily estimator (MD)—a single estimate of hpue is calculated for each day sampled by summing all the harvest from the interviews that day in the numerator and dividing by the sum of the total effort measured that day in the denominator. A mean is then taken over the number of days in the sampling period (n) to provide a mean daily value.

The third estimator of hpue was the total ratio estimator (TR)—a single estimate of hpue is calculated where the numerator is the sum of all of the harvest over m interviews over n days, and the denominator is calculated by summing the measured fishing effort from all m interviews over n days in the survey period. In essence, all of the harvest over all interviews is divided by all of the effort over all interviews to provide a single ratio estimate of hpue.

The final two estimators were the party regression (PR) and the daily regression (DR) estimators. Using these estimators, hpue is estimated as the slope of the line which best fits the plot of harvest on fishing effort. Harvest (Y) is plotted on fishing effort (X) where the points are derived either from interviews (party regression) or from days (daily regression); daily values are the sum of harvest and effort over all interviews taken within each day. The slope measures the rate of change in harvest per unit of fishing effort, or hpue.

The authors evaluated the behaviour of these five ratio estimators on three reservoirs in Alabama. The reservoirs ranged from 5000 to 15 000 hectares. Estimates of hpue were calculated for two species of fish, largemouth bass (*Micropterus salmoides*) and crappie (*Pomoxis sp.*), based on interviews of anglers who were targeting these species (Figure 2). Largemouth bass is the major predator in the southeastern United States and crappie (2 species) is one of the most sought-after pan fishes.

Figure 2 shows how estimates of hpue varied across the five methods for the two species fisheries for the three lake reservoirs in Alabama. The general within-lake trend was that the mean party estimator (MP) and mean daily (MD) gave high values of hpue and the daily regression estimator (DR) gave the lowest. This range was considerable in some cases. For example, the difference between MP and DR for Lake Demopolis was 0.2 fish/h for largemouth bass anglers and over 1 fish/h for crappie anglers. For the crappie fisheries, in particular, the party regression estimator (PR) also gave relatively low values of hpue. The total ratio (TR) estimator gave values that were intermediate to the others. To some degree, patterns were lake-specific, e.g. values of hpue were relatively consistent across estimators for Lake Weiss for both species.

Figure 3 shows similar graphs, except that the response variable is the coefficient of variation (CV) of hpue. This figure, then, shows trends in the precision of the estimators being compared. These trends were very similar across lakes and species fisheries. The highest CVs were associated with the party estimators, both MP and PR. Variability dropped sharply within lakes, usually by more than half, when estimates were based on the daily formulations (DR, MD and TR).

Given that the estimators evaluated can give different values with different levels of precision when applied to a set of data, it is logical to ask which estimator behaves the best given certain objectives. For example, if cpue from a creel survey is being used as an index of stock density, then seemingly it should correlate well over time with cpue values derived from traditional fishery-independent methods of tracking stock density, such as electrofishing.

Figure 4 shows trends in electrofishing estimates of cpue relative to estimates of cpue from the five methods outlined above, over a 4-year period on West Point Lake for largemouth bass. The electrofishing was conducted during the fall of each year and the creel surveys were conducted during the following years in the spring. The objective of the study was to determine if catch rates from fall electrofishing could be used to predict catch rates for recreational fishing the following fishing season. The correlation coefficients (r) between the electrofishing values of cpue and each of the creel survey estimators of cpue are shown at the top of the figure.

The regression estimators (PR and DR) of cpue through the creel survey were highly correlated with the electrofishing values ($r = 0.94$ and 0.98, respectively). The mean daily (MD) and total ratio (TR) estimators were moderately correlated with the electrofishing values ($r = 0.75$ and 0.79, respectively), and the mean party estimator (MP) was weakly correlated ($r = 0.37$). Based on this empirical analysis, the regression estimators provided the most accurate trends in stock density of largemouth bass over time.

(2) The acceptability of uncompleted trip data

Traditional on-site creel survey methods require that data on cpue and hpue be gathered either at access points or by roving through the survey area. In the first case, anglers are intercepted at the end of their fishing trips, so that the interview data are based on completed trips. In the second case, anglers are intercepted in the act of fishing, so that the interview data are based on uncompleted trips.

The critical issue is that hpue and cpue estimated from uncompleted trip interviews are unbiased only if the rate at which fish are caught is largely independent of the time spent fishing. The evidence to date suggests that the validity of this assumption, i.e. that catch rate is independent of fishing time, is fishery specific. The assumption may not hold for strongly diurnal species or species that are very active only during certain parts of the day, or for fisheries where successful anglers, on-the-average, spend less time fishing than unsuccessful anglers. For example, a low creel limit might allow experienced anglers to limit out early and stop fishing, thus leaving the less experienced anglers on the water longer for the creel clerk to interact with. If there are strong doubts about the acceptability of uncompleted trip interviews, then it may be necessary to incorporate access point sampling into the survey.

(3) Appropriateness of the sampling design

It is frequent that estimates of cpue and hpue are highly variable and that commonly used sampling designs account for only a small portion of the sampling variance. Table 1 lists five fisheries in Alabama. These fisheries were surveyed using sampling designs that stratified the year into months and also into day types. The first two lakes on the list, Yates and Thurlow, are small, less than 2000 hectares; Lake West Point is larger, about 12 000 hectares. The Thurlow tailwater is the immediate stilling basin in the river below the dam at Lake Thurlow, and the data collected from the Tombigbee River represent a 350 km stretch. So, the fisheries surveyed represent an array of different environmental conditions and associated fish species. The larger systems, i.e. West Point Lake and the Tombigbee River, were divided into sampling sections which were chosen at random using non-uniform probabilities. Thus, the designs were relatively sophisticated, taking advantage of temporal stratification and non-uniform probability sampling (Meredith and Malvestuto 1991).

The numbers in Table 1 are residual variances expressed as percentages of the total variances, for fishing effort and hpue. For any given fishery, the residual was what remained after the design extracted as much variability as possible (using ANOVA) based on the defined stratification. The percentages thus measure the amount of variability *not accounted for* by the design. It is apparent that the designs are more efficient for the estimation of fishing effort than for the estimation of hpue. On average, the designs could not account for 61% of the variability in fishing effort and 92% of the variability in hpue. At best, the design on West Point Lake explained 20% of the variability in hpue.

In general, traditional survey designs are not doing a very good job accounting for variability in hpue. What do we need to do? First, we need to have large enough sample sizes. The most recent evidence suggests that we should sample at least 50 to 70% of the available days within the survey period (Bayley *et al.* 1991). This would be fifteen to twenty days a month minimally. Even at these levels, sampling can be problematic during seasons of high daily variability. The winter season in the southeastern United States provides very poor fishing days interspersed with a few very good fishing days. This leads to high levels of day-to-day variability, such that it is not really feasible to sample enough during this season to obtain good estimates of hpue, particularly considering that winter generally accounts for only a small portion (10%) of annual effort and harvest.

Large sample sizes may not be adequate for species specific estimates of hpue. Typically, when data are partitioned into species specific sets, sampling days are lost when no one is targeting a particular fish. When too many days are lost, mean daily estimators become inefficient because the sample size is reduced too much. The total ratio estimator based on fishing parties is more generally applicable for computation of hpue for species fisheries, but using parties as measurement units leads to higher levels of variability, as discussed above.

The inability of monthly and day type stratification to explain meaningful portions of variability in hpue (Table 1) suggests that other stratifications might be more effective.

Day-type stratification, that is stratification into weekdays and weekends, generally is of little advantage for estimation of hpue unless there is a systematic difference between hpue across these two strata, which we have not found to be the case for the fisheries tested to date. A stratification designed to account for variability in hpue should focus more on within-day variability, so that morning, afternoon, and evening strata, for example, might be more effective. Recent studies (Lester *et al.* 1991; Malvestuto and Knight 1991) show that typically most of the variability in estimates of hpue resides within days, rather than between days, so that within-day stratification, as well as increased sampling within days, will increase the precision of estimates of hpue.

Summary

(1) Mean daily or total ratio estimators of hpue probably are the best choices—they were relatively stable and behaved consistently across the reservoirs;

(2) Perhaps regression estimators are best for indexing stock density—these estimators were very highly correlated with annual changes in the stock density of largemouth measured with electrofishing;

(3) To avoid potentially biased estimates of hpue, use completed trip interviews from access points, if possible;

(4) To reduce variance in estimates of hpue, sample at an intensity to cover at least 50 to 70% of the possible fishing days; and

(5) Allocate adequate effort to within-day sampling.

These considerations will provide best estimates of hpue possible, but more experimentation and research is warranted if agencies are to increase information return for dollars spent.

References

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Table 1. Residual variances from ANOVA expressed as percentages of the total variances for fishing effort and hpue for five fisheries in Alabama, USA. The tabled values represent the percentage of variability not accounted for by the survey designs (see text for details).

Fishery	**Effort (%)**	**hpue (%)**
Lake Yates	53	97
Lake Thurlow	61	99
Lake West Point	68	80
Thurlow Tailwater	48	94
Tombigbee River	74	89
Mean	**61**	**92**

(1) $$MP = (1/m)\sum_{i=1}^{m}(H_i/E_i)$$

(2) $$MD = (1/n)\sum_{j=1}^{n}\left(\frac{\sum_{i=1}^{m} H_i}{\sum_{i=1}^{m} E_i}\right)$$

(3) $$TR = \frac{\left(\sum_{j=1}^{n}\sum_{i=1}^{m} H_i\right)}{\left(\sum_{j=1}^{n}\sum_{i=1}^{m} E_i\right)}$$

(4) PR & DR

$$Y = a + bx$$

$$\text{Harvest} = a + \text{HPUE}\,(\text{Effort})$$

Figure 1. Mathematical definition of five estimators of hpue from creel surveys (from Crone and Malvestuto 1991). MP = mean party estimator; MD = mean daily estimator; TR = total ratio estimator; PR = party regression estimator; and DR = daily regression estimator.

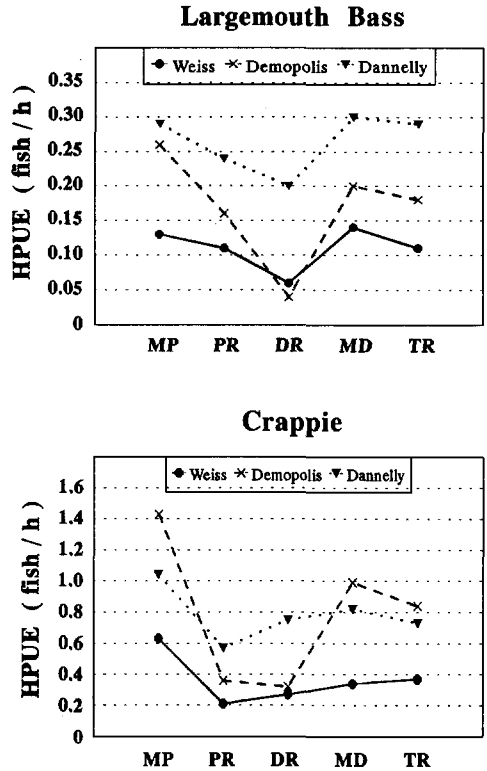

Figure 2. Trends in estimates of hpue (fish/h) over five estimators for three lakes in Alabama, USA, for largemouth bass and crappie fisheries (based on data from Crone and Malvestuto 1991). Estimators are designated as MP = mean party, PR = party regression, DR = daily regression, MD = mean daily and TR = total ratio.

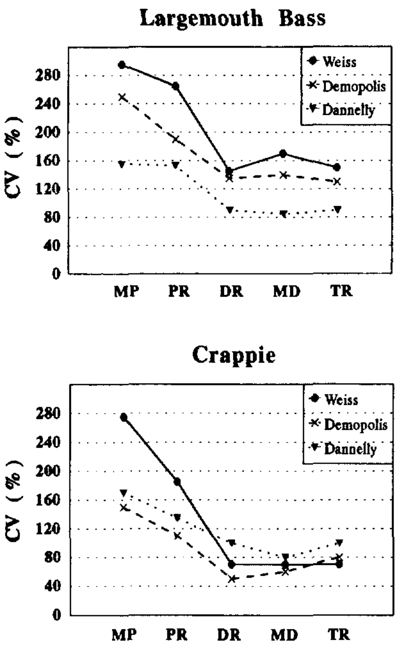

Figure 3. Trends in estimates of the precision (CV) of five estimators of hpue (fish/h) for three lakes in Alabama, USA, for largemouth bass and crappie fisheries (based on data from Crone and Malvestuto 1991). Estimators are designated as MP = mean party, PR = party regression, DR = daily regression, MD = mean daily and TR = total ratio.

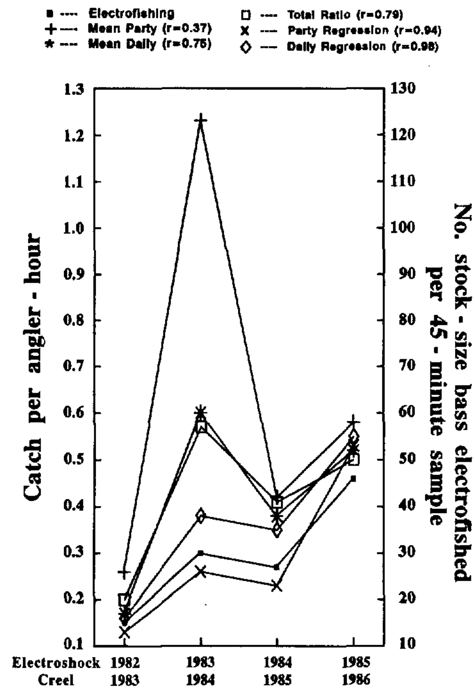

Figure 4. Relationships between cpue measured by electrofishing in the fall, and cpue of anglers measured by a creel survey the following spring, on West Point Lake for five estimators of angling cpue. The correlation coefficient (r) between electrofishing cpue and each estimator of angling cpue is given at the top of the Figure.