Evaluation of single-pass electric fishing to detect changes in population size of Atlantic salmon (Salmo salar L.) juveniles

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ABSTRACT

Electric fishing is a frequently used method for sampling freshwater fish populations. The reliability of single-pass electric fishing was evaluated on defined sampling sites in three Icelandic rivers by comparing the number of salmon juveniles (*Salmo salar* L.) caught in the first pass and the total estimated number after two and three passes. The linear relationship between the number in the first pass and the total estimated number gave 0.69, 0.55 and 0.88 as the coefficients of determination (r^2) for age >0+ in the River Elliðaár, River Úlfarsá and River Grímsá, respectively. No significant difference in catchability between months or years was observed when the same sites were sampled repeatedly. A significant difference in catchability was observed between different sites in the River Grímsá for age 0+ salmon but not for age >0+ year. Considerable variation in catchability was observed. Average catchability for >0+ juveniles was 0.49, 0.52 and 0.58 for the rivers Elliðaár, Úlfarsá and Grímsá, respectively.

Key words: Atlantic salmon, catchability, density estimates, Iceland, monitoring

YFIRLIT

Mat á áreiðanleika einnar yfirferðar í rafveiðum til að nema breytingar á stofnstærðum laxaseiða (Salmo salar L.)

Veiðar með rafmagni er ein algengasta aðferðin sem notuð er við sýnatöku úr stofnum ferskvatnsfiska. Áreiðanleiki einnar rafveiðiyfirferðar við að áætla breytingar á fjölda laxaseiða var metinn á afmörkuðum rafveiðistöðvum í þremur íslenskum vatnsföllum. Fjöldi laxaseiða sem veiðist í fyrstu yfirferð var borinn saman við mat á heildar fjölda seiða sem veiðast í tveimur og þremur yfirferðum. Línulegt samband á milli fjölda seiða í fyrstu yfirferð og mati á heildarfjölda seiða á viðkomandi rafveiðistað gaf aðhvarfsstuðul (r^2) upp á 0.69, 0.55 og 0.88 fyrir seiði eldri en 0+ ára í Elliðaám, Úlfarsá og Grímsá. Þegar skoðuð var veiðni á ákveðnum stöðum milli tímabila reyndist ekki marktækur munur á veiðni milli mánaða eða ára. Marktækur munur kom fram í veiðni 0+ gamalla seiða milli stöðva í Grímsá en samsvarandi munur fannst ekki á milli seiða eldri en 0+ ára. Breytileiki í veiðni var mikill en meðalveiðni seiða >0+ ára var 0.49, 0.52 og 0.58 fyrir Elliðaár, Úlfarsá og Grímsá.

INTRODUCTION

Electric fishing is the most widely used method for sampling juvenile salmonids in rivers for the purpose of assessing population size, growth, biomass and year-class strength (Bohlin et al. 1989). Such information is crucial to management and conservation of salmonid stocks. Population size is usually estimated either by mark-recapture methods (e.g. Petersen estimate, Bagenal & Tesch 1978) or depletion sampling with maximum-likelihood models (Zippin 1956). In depletion sampling a known number of fish are removed in each successive electric fishing pass of a defined area. Declining catches in successive passes allows capture probability and fish abundance to be estimated through maximum-likelihood iterations (Zippin 1956, Seber & LeCren 1967, Otis et al. 1978). If the objective of a survey is to get precise estimates of fish population size, three or more successive electrofishing passes are often required, especially when catchability or density is low (Bohlin et al. 1989). When monitoring changes in population size or detecting difference in abundance, less accurate methods could be sufficient. A single-pass removal method has the advantage of a lower cost as compared with more labour-intensive methods. Several investigations have been made to evaluate the accuracy and usefulness of one-pass electric fishing to estimate abundance or relative abundance of salmonid juveniles in streams. These studies indicate that there is a significant relationship between number of fish caught in the first pass and the total population size estimated from three or more passes (Strange et al. 1989, Lobon-Cervia & Utrilla 1993, Crozier & Kennedy 1994, Jones & Stockwell 1995, Kruse et al. 1998, Mitro & Zale 2000). However, the method used depends on the objective of the study, and single-pass sampling seems to be practical for estimating relative abundance and long-term trends in population density (Niemelä et al. 2000).

A number of conditions are required for the depletion method to provide a statistically unbiased estimate, including a closed population, constant fishing effort and equal catchability on all passes. Stop nets are sometimes used to close the electric fishing area, and are desirable in depletion sampling where the aim is to get precise population estimates. Where the width of the stream is small in relation to the length of the stretch fished or in high water velocity, the usefulness of stop nets is doubtful (Bohlin et al. 1989, Niemelä et al. 2000). Stop nets probably do not increase the accuracy of single pass electric fishing for estimating relative abundance (Bohlin et al. 1989). Catchability of individual fish may differ according to factors such as species, size, and previous recent exposure to sampling (Cross & Scott 1975, Bohlin & Sundstrom 1977, Mahon 1980, Riley & Fausch 1992), which may bias the results in multi-pass electric fishing.

Our main aim was to investigate if a single electric fishing pass could predict the total abundance of juvenile Atlantic salmon (*Salmo salar* L.) on defined sites in three Icelandic rivers. To analyse the reliability of the single electric fishing method for discerning temporal changes and spatial difference in population size, variation in catchability of juvenile salmon between months at the same sites within a river, between sites within a river, and between years in a river and at site were estimated.

MATERIALS AND METHODS

The study was carried out in 3 rivers in SW Iceland (Figure 1). The River Grímsá is a direct runoff river originating in Lake Reyðarvatn. The River Úlfarsá is a partly spring fed direct runoff river with a lake on the watershed. The River Elliðaár is a spring fed river with a lake on the watershed. Conductivity (µScm^{-1}) was 75, 90 and 100 for the rivers Grímsá, Elliðaár and Úlfarsá, respectively. Electric fishing was carried out using a power generator with an output of 300 V DC and 0.5 amps led to a single anode pole with a ring end 18 cm in diameter. The crew consisted of two persons, one operating the anode and netting the fish, the other taking care of the electric cable and carrying a bucket half-filled with water where captured fish were kept alive. Each sampling area was fished by repeatedly crossing the stream from one side to the other, moving upstream after each crossing in order to cover the whole sample area. The length and width of the sample area were then measured.

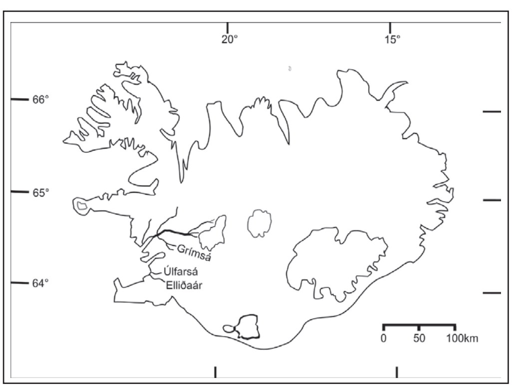

Figure 1. Map of Iceland showing locations of the three study rivers.

Fish caught in each sample were anesthetized, identified as to species and their fork length (± 0.1 cm) and wet mass (± 0.1 g) measured. Scale and otolith samples were taken from 6-15 fish at each site for age determination. Data on age were then used along with length frequency distributions to separate age classes. All fish other than those sampled for ageing were released back into the area of capture once the final pass and measures had been completed.

Previously defined sampling sites in each of the rivers were sampled with either three-pass or two-pass electric fishing. In the River Elliðaár the same three sites (328 m^2, 230 m^2 and 420 m^2) were sampled monthly by the three-pass method from May to October and again in December during the same year. Population was estimated using the Zippin model (Zippin 1956). Catchability and population number were estimated separately for young of the year (0+) and older salmon juveniles (>0+). In the River Úlfarsá, two-pass electric fishing was carried out in September and October from 1994 to 1996. A total of 200 sites were sampled over the 3-year period with an average site size of 124 m^2, ranging from 62 – 251 m^2. Only fish age >0+ was assessed. In the River Grímsá sampling was conducted annually using two-pass electric fishing at the same three sites in late August and early September of each year from 1991 to 2000. The average size was 179 m^2, 333 m^2 and 189 m^2 for each site. Catchability and population number were estimated separately for 0+ and >0+ juveniles. In the case of two sampling passes, the population was estimated using the Seber & LeCren model (Seber & LeCren 1967). If more juveniles were caught in the second electric fishing pass compared to the first pass, the data were omitted. This happened in six samplings out of 200 in the River Úlfarsá, and in all cases fewer than 15 salmon juveniles were caught in the first pass.

The relationship between the number of fish caught in the first-pass and the total estimated number of fish in two- and three-passes was analysed using a linear regression model. One way analysis of variance (ANOVA) was used for comparison of catchability between months in the River Elliðaár, between years in the River Úlfarsá and between sites in the River Grímsá. Normality of the catchability distributions was confirmed using the Kolmogorov-Smirnov test. The SPSS statistical package (release 10.1 SPSS inc. 2003) was used for all statistical analyses.

RESULTS

There was a significant relationship between the number of fish caught in the first pass and the corresponding estimates of total number of fish in all the three rivers: River Elliðaár age 0+, $r^2 = 0.56$ (P = 0.003), age >0+, $r^2 = 0.69$ (P < 0.001; Figure 2a), River Grímsá age 0+, $r^2 = 0.96$ (P < 0.001), age >0+, $r^2 = 0.55$ (P < 0.001; Figure 2b) and River Úlfarsá age >0+, $r^2 = 0.88$ (P < 0.001; Figure 2c).

In the River Elliðaár the average catchability of age 0+ salmon as estimated by a three-pass removal was 0.35 (s.d. = 0.103), ranging from 0.19 to 0.50. Catchability of age >0+ salmon parr was 0.49 on average (s.d. = 0.115), ranging from 0.20 to 0.73. No significant difference in catchability was found between months for age 0+ (P = 0.177), or age >0+ (P = 0.271) juveniles. In the River Úlfarsá the mean catchability for >0+ salmon as estimated by a two-pass removal was 0.52 (s.d. = 0.183) and ranged from 0.09 to 0.96. No difference was found in catchability between years in the River Úlfarsá (P = 0.138). The mean catchability as estimated by a two-pass removal in the River Grimsá in 1991 – 2000 was 0.50 for 0+ (s.d. = 0.156; range 0.30 - 0.86) and 0.58 for >0+ salmon (SD = 0.146; range 0.20 - 0.77). Mean catchability for >0+ salmon was significantly different among the three sampling sites (P < 0.05), but not for the 0+ year class.

In the three rivers, a total of 239 estimates were made based on two or three electric fishing passes. The frequency distribution of the catchability was normally distributed with a mean catchability of 0.51, ranging from 0.07 to 0.82 (Figure 3). The catchability was within the range of 0.3 to 0.7 in 87.9% of the estimates (Figure 3).

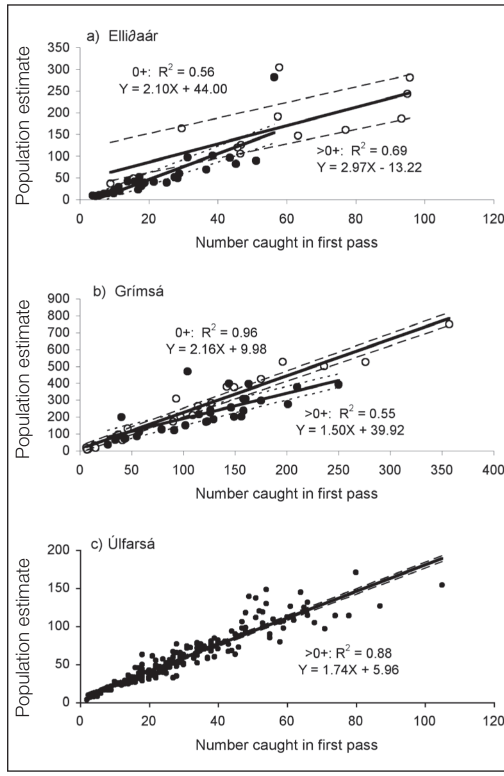

Figure 2. Linear regressions between number of salmon juveniles caught in the first pass and population estimate based on three (a) and two (b and c) removals with electric fishing. In the River Elliðaár and River Grímsá both age 0+ (open circles) and older juveniles were sampled. In the River Úlfarsá only juveniles age >0+ were sampled (closed circles). The 95% confidence intervals (dashed lines) for the regression lines are shown.

DISCUSSION

In large-scale monitoring programs for salmon juveniles, it is important to evaluate both temporal and spatial changes in strength of year classes and the relation between environmental factors and juvenile survival. The significant relationships found in this study between numbers of juvenile salmon caught in the first electric fishing pass and the total population estimate using two and three passes, indicate that a single electric fishing pass provides an index of juvenile salmon abundance. Similar relationships have been reported for juvenile salmon and trout by Strange et al. (1989), Lobon-Cervia & Utrilla (1993), Jones & Stockwell (1995) and Kruse et al. (1998). The estimates of fish abundance based on two-pass electric

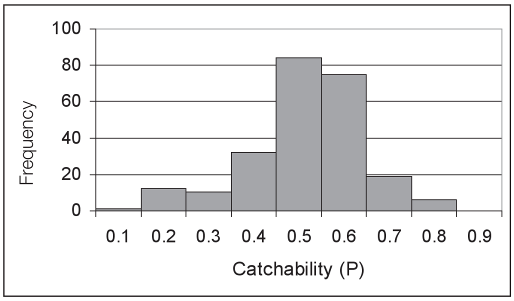

Figure 3. Frequency distribution of the catchability of salmon juveniles from 239 estimates, made by two or three electric fishing passes in three Icelandic rivers.

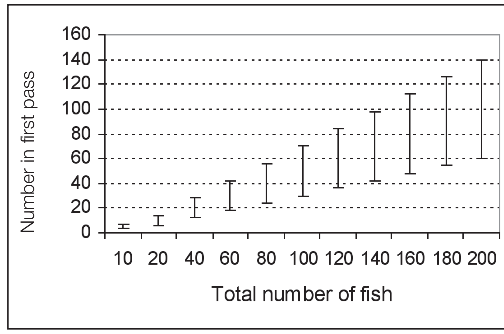

Figure 4. Calculated range of number of fish caught in a single-pass electric fishing based on the total number of fish present and catchability ranging from 0.3 to 0.7.

fishing has wide confidence limits and therefore an uncertainty exists in using two-pass electric fishing for estimating the accuracy of the single-pass electric fishing method. It is however possible to discern changes in fish abundance given a certain catchability range. For site-specific population estimates, given a random catchability in the range between 0.3 and 0.7, single-catch electric fishing can be used to distinguish a threefold change in abundance (Figure 4). With this range in catchability it is, for example, possible to distinguish between the number of fish in two sampling sites where the initial number of fish is 20 in one site and 60 in the other (Figure 4). It has been shown that for predicting total fish abundance in a whole river or watershed it is possible to improve the single-pass method and decrease the variation by increasing the number of sample sites and averaging the capture probability (Lobón-Cerviá & Utrilla 1993, Mitro & Zale 2000). Mitro & Zale (2000) found that by sampling multiple sites within a river section with a single-pass method, a multiple capture probability model performed about the same for predicting total abundance as three-pass removal with fewer and larger sample sites. By sampling more and smaller sites compared to fewer and larger sites the accuracy was also increased (Mitro & Zale 2000).

In this study, no significant difference was found in catchability between months or years at the same sample sites. Catchability of age >0+ salmon in the River Grímsá differed significantly between sample sites but catchability of age 0+ salmon did not. There is a large variation in catchability in these three rivers. Large variation in catchability is a common problem in large-scale monitoring programs (Lobón-Cerviá & Utrilla 1993, Heimbuch et al. 1997, Niemelä et al. 2000). The highest variation in catchability was observed in the River Úlfarsá where the sample sites were on average smaller and more variable in water velocity and substrate coarseness. These variations in physical factors are known to increase the fluctuation in catchability (Zalewski & Cowx 1990). Mean catchability found in other studies range from 0.51 to 0.88 (Kruse et al. 1998 (P_{mean} = 0.88), Larimore 1961 (P_{mean} = 0.51), Riley & Fausch 1992 (P_{mean} = 0.65), which are close to the mean values in the present study where the mean catchability pooled over rivers was 0.43 for age 0+ and 0.53 for age >0+. For estimating the densities of salmon juveniles in a watershed using a single-pass method, the number of sampling sites should be chosen carefully and notice given to the impact of variable habitat and environmental factors on catchability. The sampling schedule should be the same every year to reduce variations in the methodology. By fulfilling the above requirement the single-pass method provides an index of juvenile abundance that is useful to compare strength of year classes from time to time within the same river and between regions (Antonsson et al.2005). Despite information on fish abundance the single-pass method provides adequate information on fish size and condition, species richness and proportion of each year-class within a year. Such information is fundamental to long-term monitoring programs of fish populations.

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