DFO Atlantic Fisheries Research Document 93/31

MPO Document de recherche sur les pêches dans l'Atlantique 93/31

EVALUATION OF THE PRECISION OF CATCH DATA IN THE NOVA SCOTIA ATLANTIC SALMON CATCH-EFFORT CARD SYSTEM AND FEASIBILITY OF A NEW BRUNSWICK APPLICATION

BY

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ABSTRACT

Declines in Atlantic salmon catches in recent years have led fisheries managers to ask for more reliable and timely catch and effort data. A jointly managed federal-provincial catch and effort "report card" system was established in Nova Scotia in 1983 to meet those demands. Accurate and timely data are not available for Atlantic salmon catches in New Brunswick. About 8,000 - 9,000 salmon angling licenses are sold annually in Nova Scotia. Estimates of recreational catch of Atlantic salmon are sought at a precision of 20% at a 90% level of probability. The negative binomial distribution best fits the catch-per-fisher data from the Nova Scotia data set. The sample sizes required to provide various levels of precision were determined through simulation, a process which does not assume an underlying distribution of means. The relationship between population size (number of fishers) on a particular river and the probability level (α as %) was found to be of the form Y = e^[a + b * ARCSIN(SQR(X/100))], where Y is the population size and X is the probability level. The optimum sampling regime was considered by examining 4 sampling frequencies, 55%, 70%, 85%, and 95%. For each river with 11 or more anglers, a complete census (using 3 reminder letters to ensure at least a 95% sample) would provide 25% precision at the 90% level of probability. Alternatively, a 20% precision at the 90% level of probability would be achieved, if only a single reminder letter were used to prompt report card non-respondents (a 70% sample), for all rivers which are fished by at least 120 anglers. Based on the Nova Scotia experience, and assuming a licensing system is in place, a complete census (using 3 reminder letters) in New Brunswick, where about 30,000 fishers are licensed annually, would cost approximately $30,000 and 1 year of person-power.

RÉSUMÉ

La diminution des prises de saumon de l'Atlantique au cours des dernières années a amené les gestionnaires des pêches à réclamer des données plus fiables et opportunes concernant les prises et l'effort. Un système de «fiche de rapport» des prises et de l'effort, administré conjointement par les gouvernements fédéral et provincial, a donc été mis sur pied en Nouvelle-Écosse, en 1983, afin de répondre à ces demandes. On ne dispose pas de données opportunes et précises sur les prises de saumon de l'Atlantique au Nouveau-Brunswick. Environ 8 000 à 9 000 permis de pêche sportive du saumon de l'Atlantique sont vendus chaque année en Nouvelle-Écosse. On cherche à évaluer les prises sportives de saumon de l'Atlantique avec une précision de 20 %, à un niveau de probabilité de 90 %. C'est la répartition binomiale négative qui s'applique le mieux au système de données sur les prises par pêcheur de la Nouvelle-Écosse. La taille de l'échantillon requis pour obtenir différents niveaux de précision a été évaluée au moyen de simulations, procédé qui ne suppose pas de distribution sous-jacente de la moyenne. On a pu déterminer que le lien entre la taille de la population (nombre de pêcheurs) le long d'un cours d'eau donné et le niveau de probabilité (α comme %) était du type Y = e^[a + b * ARCSIN (SQR (X/100))], où Y correspond à la taille de la population et X au niveau de probabilité. On a évalué le régime d'échantillonnage optimal en examinant 4 fréquences d'échantillonnage, soit 55 %, 70 %, 85 % et 95 %. Pour chaque cours d'eau où le nombre de pêcheurs était de 11 ou plus, un recensement complet (incluant 3 lettres de rappel visant à garantir un échantillon d'au moins 95 %) offrirait une précision de 25 % au niveau de probabilité de 90 %. De même, on obtiendrait une précision de 20 % au niveau de probabilité de 90 % avec un seul rappel encourageant les non-répondants à retourner leur fiche de rapport (échantillon de 70 %), pour tous les cours d'eau où il y a au moins 120 pêcheurs. D'après l'expérience de la Nouvelle-Écosse, en supposant qu'il existe un système de permis, un recensement complet (avec 3 rappels) au Nouveau-Brunswick, où environ 30 000 pêcheurs obtiennent des permis chaque année, coûterait approximativement 30 000 $ et une année-personne.

INTRODUCTION

Effective management of Atlantic salmon in eastern Canada has become progressively more critical as stocks have declined. Most management strategies either rely heavily on estimates of removals to determine the number of spawners or depend on counts of adults at counting facilities. Considerable emphasis has been placed on the collection of accurate recreational Atlantic salmon harvest and release estimates in order to reconstruct (estimate) stock size. In spite of this effort, recreational Atlantic salmon statistics for rivers in New Brunswick are not collected and summarized according to accepted sampling procedures.

The New Brunswick Department of Natural Resources and Energy (NBDNRE) has maintained a data collection system (FISSYS) since the late 1960s (Hooper 1978), and Fisheries and Oceans (DFO) field staff have collected word-of-mouth data since the early 1950s (O'Neil and Swetnam 1991). The FISSYS system is based on a sampling regime which collects data from approximately 20% of fishers, most often via post-season post card questionnaires (W. Hooper, pers. comm). The quality of that data has not been documented for review. As a result, the data have received only sporadic use by managers. The DFO officer data are generally not accepted as robust because of the informal manner in which they are collected (O'Neil et. al. 1989; O'Neil and Swetnam 1991).

From 1982 to 1984 the Department of Fisheries and Oceans worked with NBDNRE in an attempt to develop a joint Atlantic salmon sportcatch and effort reporting system. Difficulties arose with the trial system initiated in 1984 with the ultimate result that efforts to develop a joint program were suspended.

The purpose of this paper is to: (1) examine the nature of the Nova Scotia license stub data relative to the precision of catch estimates; and (2) to evaluate the sample size required and cost implications for application of the Nova Scotia catch-effort card system to New Brunswick rivers.

Data needs

The purpose of collecting Atlantic salmon catch data for DFO is 2-fold: (1) establishing detailed information on magnitude of catch (removals and releases) for the purpose of appraising the status of a specific Atlantic salmon stock; and (2) establishing a detailed library of catch information for all rivers, in spite of size, to be in a position to advise on issues which may impact on a particular river stock.

The collection and analysis of angler effort data are assumed to be compatible with the general objective of "appraising the status of a fish stock". Effort data can be useful for the evaluation of relative angler effort, both between rivers and between years on an individual river. Although effort data are seldom used in themselves, anglers typically "follow the fish" so effort can be an indicator of the presence of fish and describe trends in "fish availability". For example, the run may be substantial but inaccessible due to high water. In such a case, effort would be low relative to run size, and indicate poor "availability" of fish. Such information might be easily correlated with discharge and hence a useful covariate to account for variability in catch data. In addition, effort data can be used to address socio-economic concerns.

The fishery

It was assumed for this report that it would be desirable to build a database containing data on New Brunswick rivers which have annually yielded Atlantic salmon in the sport fishery over the past several years. Consequently, a catch and effort data collection system would have to be comprehensive enough to cover rivers with a fairly consistent sport catch, yet at the same time be capable of capturing data from new sources, such as recently restored or reopened rivers (e.g., Pointe Wolfe, Petitcodiac, Bartholomew). Sixty rivers in New Brunswick have produced Atlantic salmon at some time between 1970 and 1987 (Table 1). An abbreviated list of "significant" rivers, those that have reportedly yielded at least several Atlantic salmon, almost annually, in recent years includes 33 rivers (Table 2). In 1984, those 33 rivers accounted for 99% of the retained grilse catch.[1] Catch on those rivers has ranged from 0 (several rivers) to 18,588 (Southwest Miramichi, 1986) retained grilse during the 10-year period 1979-88 (Table 2). Although many other smaller rivers have been left out for the purposes of this exercise because of an inconsistent record of sport catch, the data collection system as described is capable of capturing catch and effort data for those rivers (e.g., New, Waweig, Pocologan, Taxis, etc.).

Data collection methods

Several options exist for data collection, such as creel surveys, angler diaries, license stubs or telephone surveys.

Employing creel surveys to obtain comprehensive coverage would be prohibitively expensive because of the large number of rivers to be covered. An alternative approach would be to cover a few select rivers with creel surveys for estimates of harvest in order to manage those particular rivers. By itself, the trade-off with such a strategy would be incomplete coverage at relatively high cost. Creel surveys on large systems typically yield wide confidence

[1] 1984 DFO license stub survey results.

limits which would severely limit the usefulness of the data for relatively refined fisheries management (Grosslein 1962; Regier 1971). A properly designed creel survey for an Atlantic salmon river would require extensive coverage or exacting design criteria (e.g., critical attention to the length of time for each angler interview, travel time between interviews, and a good understanding of the fishing pattern of anglers), yet may still yield wide (untenable) confidence limits on parameter estimates because of environmental influences, unusual run timing, etc. In addition, the Atlantic salmon fishery is constrained by daily and yearly bag limits and by daylight (in Nova Scotia, for example, Atlantic salmon fishing is restricted to 6:00 a.m. to 2 hours after sunset), factors which confound creel survey estimates because of the influence they have on angler behaviour (Porch and Fox 1990).

Telephone surveys and questionnaires generally capture data after the fishery is closed, thus compromising the data with recall bias (Jamsen and Jester 1987; Fisher et. al. 1990). With some considerable effort, the consequences of recall bias can be dealt with. A second disadvantage to telephone surveys is the cost relative to angler report card surveys (Brown 1991).

Thus, for general coverage, the only option considered viable to provide catch and effort data on the broad-based recreational fishery at a reasonable cost is some form of within-season questionnaire survey or license stub program. Although some bias is known to exist with such programs (e.g. response bias), it is well documented and, with a proper survey design, can be adjusted for (Brown 1991; Calhoun 1950; Fisher et. al. 1990).

Precision

Precision is a term frequently used in creel survey literature and can be expressed mathematically as the product of the "t"-value and the coefficient of variation (i.e., t x CV, where CV is the ratio of the standard error to the mean). For the purposes of this paper, the terms precision and coefficient of precision are used synonymously, except in the reference below, to mean the confidence interval expressed as a percentage of the mean.

Creel survey literature deals extensively with the appropriate confidence limits which can be placed on a catch or effort value. Creel surveys often yield large confidence limits because of the inherent variability in the data. Consequently, a confidence limit, expressed as a percentage of the mean (coefficient of precision), of 40% or more is often considered acceptable. However, Robson and Regier (1964) have suggested three separate levels of precision, depending of the objective of the work, by examining sample sizes required for various precision levels using a mark and recapture (Petersen) technique. They recommended three standards for precision at the 0.95 level of probability: (1) 0.50 for preliminary studies or in management surveys where only a rough idea of population size and composition is required, (2) 0.25 for more accurate management work, and (3) 0.10 for careful research into population dynamics.

A coefficient of precision of 10% is extremely difficult to achieve in angler card surveys. Hicks and Calvin (1964) reported coefficient of precision levels ranging from 5 to 16% for catches of steelhead or salmon based on angler punch cards (license stubs), in spite of an extensive follow-up program for non-respondents. Claytor and O'Neil (1991) observed coefficient of precision levels which ranged from 10 to 20% for total Atlantic salmon catches on the Margaree River, Nova Scotia, based on license stub data. This relatively high precision is due to (1) the return rate for cards in the Nova Scotia system which ranged from 74 - 94% of licensees, a figure which is exceptionally high relative to other angler card systems; and (2) the proportionately large number of responses associated with the larger rivers in the province, such as the Margaree. Response rates from angler card surveys typically range from 30 - 60% without multiple prompting of non-respondents (Ford and Narver 1979; MacGregor 1982; Small 1991).

A coefficient of precision level of 50% is not of much value for Atlantic salmon stock management. The Southwest Miramichi River, for example, has had total bright Atlantic salmon catches, as reported by fishery officers, which range from a low of 2000 to a high of 19,000 fish since 1970. If the coefficient of precision of catch data could be placed at 50%, the standard error would be 500 fish for the low estimate and 4,750 fish for the high estimate. Confidence limits, at the p=0.05 level, would be approximately twice the standard error, so the lower catch value would be 2000 ± 1000 fish, and the higher catch value, 19,000 ± 9,500 fish. Those values would not permit refined stock management, which is particularly critical with the current competition among users for the stock which is surplus to spawning escapement.

Hence, that leaves some value between 10 and 50%. A reasonable level, based on Hicks and Calvin's (1964) and O'Neil's (unpublished data) experience with angler card systems, would be 20 to 25%. In the Southwest Miramichi example, the low and high range catch estimates with 95% C.L. at a coefficient of precision of 20% would be 2000 ± 400 fish and 19,000 ± 3,800 fish. A precision level of 20 - 25% would also be in keeping with Robson and Regier's (1964) recommendation that 25% be used for "more accurate management work".

METHODS

The Nova Scotia license stub system

Atlantic salmon fishers in Nova Scotia are licensed by the Nova Scotia Department of Natural Resources. Each licensee receives a prestamped catch and effort report card at the time of licensing. Information is distributed with the license which explains the regulations and instructs anglers on the completion of catch-effort cards. Return of completed cards is a requirement under provincial government law. The data which are collected include the number and date of salmon which are kept and the number of salmon released and days fished, by river (Fig. 1).

Response rates during the first five years of the program, when up to three reminder letters were used to prompt non-respondents, ranged from 93 to 95%. From 1988-91 only a single reminder letter was used (to reduce costs and because catch and effort estimates were based on the consistent relationship observed during the first five years; Claytor and O'Neil 1991) and overall response rates approximated 70% (Table 3).

Response bias

Avid participants in an activity who take part in a voluntary survey of the activity typically respond at higher rates, and in the case of a recreational fishery, with greater relative levels of success. Consequently, some form of adjustment to account for non-response must be made or estimates of catch or effort based on data from the voluntary respondents would artificially inflate the estimate. This phenomenon is common to mail-in questionnaires (Brown 1991; Small and Downham 1985) and was observed in the Nova Scotia data as well. The catch per unit effort (CPUE) for Nova Scotia anglers declined with successive prompts so that the CPUE for voluntary respondents was greater than for those that responded to the first reminder letter, and so on. The methodology employed to compensate for that bias has been described in O'Neil et al. (1986).

Confidence limit calculation

The Nova Scotia salmon report cards are used to estimate catches on river systems throughout the province. Confidence limits can be placed around those estimates by one of two methods.

Method A: During the years that anglers were prompted with up to three reminder letters, confidence limits could be calculated by using the standard error from the regression of cumulative catch (1SW, MSW or total) per response category on cumulative effort (Claytor and O'Neil 1991). The resulting confidence limits on the total provincial catch ranged from 1.5% to 27.0% of the estimate during the years 1983 to 1987 (Table 4). In the Margaree example, they ranged from 10 - 20% (Claytor and O'Neil 1991).

Method B: Estimating the confidence limits by assuming the distribution of sample means is normally distributed and working with mean and standard deviation of catch per fisher (i.e., 95% C.L. = 1.96 x S.E.) and the total number of fishers for that year. The resulting confidence intervals, based on total provincial catch, ranged from 4.6% to 6.5% of the estimate over the years 1983 to 1991 (Table 4).

Because Method A cannot be used each year unless a 3-reminder system is implemented and the alternative, Method B, is unacceptable because of the non-normality of the individual river sample means (see below), empirical sampling from the database was used to estimate the sample size required to meet the precision desired.

Frequency distributions

For each year, it was desirable to know whether the data follow a normal distribution or not. Conformation to the normal distribution would significantly reduce the computations for determining sample size. The parent distribution type (i.e., negative binomial, poisson, or lognormal) from which the data come was determined by generating theoretical distribution frequencies and comparing them to the observed frequencies through a G-test for goodness of fit (Sokal and Rohlf 1981) for the Nova Scotia data 1984-1988 and 1991, and the sample data obtained from the 1984 trial license stub program in New Brunswick. All subsequent analyses were performed using SYSTAT (1990) and were restricted to four years (Nova Scotia 1984, 1986, 1988 and 1991) which are representative of most years.

For each river and year, the population size (number of fishers), mean, and standard deviation of total catch per fisher were generated (Appendix Tables 1-4). These means are considered to be the population means, to which all sample means are compared. Only rivers with a population size of 16 or more were used in the subsequent analyses.

Since all calculations are based on the population river means, it was desirable to determine the stability of these means through the process of bootstrapping. In other words, determine whether our population river means are representative of all possible population river means that follow the same distribution. The process involved drawing from the population, with replacement, many samples (here, 1000 samples) of the same size as the population, called bootstrap samples. Each sample was broken down into individual rivers and river means were calculated. For each river in 1986 and 1988, a t-test was performed using the Bonferroni critical value at alpha = 0.05 divided by the number of t-tests (49 and 53 in 1986 and 1988, respectively) to determine whether, for all rivers, the average of the 1000 bootstrap sample means differed from the respective population river means. Non-significant results would indicate that the population river means would be appropriate to use in the calculations.

If it were assumed that normal theory is applicable to these data, i.e. the sample river means are normally distributed about the population river mean, then the method of Cochran (1977, pg. 77) can be used to determine the theoretical sample sizes. As a first test of whether normal theory is applicable in determining sample size, a method of Cochran (1977, pg. 42) was applied to the data of each river. This method provides a rough estimate of the minimum sample size required for application of the normal approximation for positively skewed populations and is given by:

$$n > 25G_1^2$$

where G_1 is Fisher's measure of skewness.

Simulation

The results of the exercises described above and a review of similar data systems (Small and Downham 1985) indicated that the assumption of a normal distribution of sample means does not hold. Therefore, sample size determination was carried out through simulation, a process which does not assume an underlying distribution of means. In this simulation process, a large number of samples were drawn from the population, each sample being representative of the population. The percentage of the population that ends up in the sample is the sampling frequency. Several large numbers (100, 200, and 500) of samples were drawn from the population and the most appropriate number chosen as the smallest one which gave the most stable results.

The choice of the sampling frequencies (55.5%, 70.3%, 85.1% and 95.5%) to use in the simulation process was originally based on the assumption of a 74% response rate, which is the average response rate of the first two years (1988 and 1989) in which only one reminder letter was sent. From the response rate and the chosen sampling frequency, the "applied" sampling frequency can be calculated. For instance, with a 74% response rate and a 55.5% sampling frequency, an "applied" sampling frequency of 75% is required (55.5 / 74 x 100 = 75%). A good estimate of the response rate is necessary in order to determine the required "applied" sampling frequency.

Two hundred random samples of 55.5% of the population were generated. Each of the 200 random samples was broken down into individual rivers, and river means were calculated. The number of sample means, out of 200, that fell within 20% of the population river mean was counted and divided by 2 to obtain a percentage. A plot was generated of this number of samples against the population size. Any river in which the random sample-based river means fell within 20% of the population river mean at least 95 times out of 100 was marked as having a coefficient of precision of 20%, at the 95% probability level. This procedure was also repeated at the 90% probability level and at a 25% coefficient of precision.

For each river, a frequency distribution of the 200 random sample means was generated to determine, as a second test, whether the assumption made concerning non-normality was valid. To provide a statistic, the Lilliefors generalization of the Kolmogorov-Smirnov test was applied to these means. This Lilliefors generalization tests for normality without assuming a particular mean or standard deviation. A critical value of $\alpha = 0.10$ was used; any river with a value of P less than 0.10 indicated a distribution significantly different from normal.

The empirical simulation process was repeated for random samples of 70.3%, 85.1%, and 95.5% of the population.

Plots of population size (N) against the probability level (%), i.e., the number of times out of 100 that the random sample river means fell within 20% of the population river mean, were generated from the empirical simulation data for each year. For each of the four sampling frequencies (55.5%, 70.3%, 85.1%, and 95.5%), a best-fit curve was found to be of the form:

$$LN(Y) = a + b*ARCSIN(SQR(X/100))$$

where a and b are parameters, Y is the population size, and X is the probability level. For each year, this curve was fitted to the number of rivers (data points) of each of the four sampling frequencies to produce four curves. The same types of plots were repeated for a 25% coefficient of precision. For each of the four curves, an analysis of covariance was performed to test for a significant difference between years.

RESULTS AND DISCUSSION

Frequency distributions

The G-test for goodness of fit to the normal distribution indicated that the negative binomial distribution gave the best fit to the data for all years (Table 5). The distribution of the New Brunswick 1984 data was similar to the Nova Scotia distributions. Hence it was felt appropriate to apply the Nova Scotia experience to a New Brunswick application since both populations of Atlantic salmon fishers exhibited similar catch per fisher frequency distributions.

The result of the bootstrapping process showed that all rivers in 1986 and 1988 had non-significant t-test results, indicating that the bootstrapped estimates of the river population means were not significantly different from the original population river means. Therefore, the original population means were used in all calculations, rather than the bootstrap estimates.

The underlying parent distribution is shown to be non-normally distributed (Appendix Table 5) and so it could not be assumed that the sample means follow a normal distribution. Hence, distributions of those means were tested for normality before determining sample size based on normal theory.

As a first test for normality of sample means, the number of rivers within each year was found which satisfied the rough estimate of minimum sample size required to apply the normal approximation (Table 6; Cochran 1977). This number of rivers was small, though somewhat variable. Therefore, calculating theoretical sample sizes by normal theory formulas was not considered appropriate here.

Simulation

Sample sizes were determined through simulation, a process which does not assume an underlying distribution of means. Tables 7-10 show for the empirical simulations the number of rivers which have 200 sample means falling within given coefficients of precision (20% and 25%) of respective population means, for given levels of probability (90% and 95%), at four sampling frequencies (55.5%, 70.3%, 85.1% and 95.5%). It is evident that as the sampling frequency increases, the number of rivers which meet the specified criteria also increases.

The second test for normality of sample means used the samples generated through the empirical simulation at the 55.5% sampling frequency. Table 11 shows the number of rivers for which the distribution of sample means is significantly different from a normal distribution. A considerable number of rivers in all years exhibit non-normality of the sample means, thus re-emphasizing the fact that theoretically determining the sample sizes by normal theory formulas is not appropriate here. In addition, this means that 90% confidence limits on mean catch estimates cannot be calculated using the normal distribution theory.

Table 12 shows the parameter estimates a and b, adjusted R^2, and standard error of the estimate for the model

$$LN(Y) = a + b*ARCSIN(SQR(X/100))$$

(where Y is the population size and X is the probability level), for each combination of sampling frequency and coefficient of precision, for each year. The analyses of covariance, one for each of the eight combinations of sampling frequency and coefficent of precision, indicated no significant differences between years ($P>0.4$). Therefore, years were pooled and parameter estimates a and b, adjusted R^2, and standard error of the estimate were calculated for the same model for the pooled years. Figures 2 and 3 are plots of these pooled-year equations. Each plot shows the curves for all four sampling frequencies for a particular coefficient of precision. From these plots it is evident that a full census of the population must be taken in order to estimate most of the river means to within 25% of the respective population river means, at the 90% probability level. For example, the lower curve (95.5% sampling frequency) shown in Figure 3 indicates that, at the 90% probability level, approximately 10 fishers are required on each river to estimate all river means to within 25% precision. In other words, when sampling involves almost a complete census, at that level of precision and probability, most rivers would have catch estimates within the desired criteria. However, it may be desirable to reduce costs by applying a lower sampling frequency. In this case, the estimates of mean catches for some rivers with fewer numbers of fishers may be unreliable. Ultimately, there is a trade-off between the cost of sampling and the reliability of catch estimates for some smaller rivers. If a reduced sampling frequency is desired, these plots can be used to approximate the average minimum river population size required to estimate river means to within the chosen precision of the respective population means and at a chosen probability level. Alternatively, the model can be applied using the parameters provided in Table 12. For example, an average river population size of approximately 161 fishers would be required to sample at a frequency of 70.3% and to estimate the sample river mean to within 20% of the population mean, with 95% probability.

Table 12 gives the parameter estimates of the model for the New Brunswick 1984 data, which represents a 20.6% sample of all New Brunswick fishers. However, the data were incomplete and subject to various errors (O'Neil, unpublished data) so the similarly distributed Nova Scotia data could be used to estimate sampling rates to achieve the desired level of precision in New Brunswick. For example, if only a single reminder letter were used, the resulting 74% response rate (overall) would produce a 20% precision at the 90% level of probability on rivers fished by 120 anglers or more. Similarly, if a complete census (3 reminder letters) were attempted, the resultant data would meet the 25% precision and 90% probability criteria if only about 11 or more fishers visited a river.

Confidence limits

Comparison of the intervals which result from the two methods described for calculating confidence limits (Table 4) indicates that the regression method (Method A) can provide a more precise estimate, but is also more variable. However, calculation of the Method B confidence intervals violates the assumption of normality since the sample means are not normally distributed (see below). In addition, the Method B confidence limits, when calculated for each river, are quite wide relative to the mean. Review of the individual river data from the 1986 Nova Scotia catch-effort card database indicates that confidence limits range from 11-141% of the mean and, in most cases, greatly exceed the 20-25% precision desired (Table 13).

Calculation of the confidence limits by Method A provided relatively precise limits (excluding 1983), but would require annual use of the three reminders to prompt non-respondents in order to generate sufficient data to perform the regressions. Thus, it has a significant cost implication. In addition, the original Nova Scotia report card program was designed to eliminate the second and third reminder letters after year five. Relying on a multiple reminder system simply as an annual means to generate confidence limits is impractical. As indicated above, the Method B confidence limit calculation procedure would be inappropriate due to the nature of the frequency distributions of the sample means. Consequently, a confidence limit based on normal theory would violate certain criteria, thus restricting our options for limits to the use of percentiles of the distribution of sample means. In other words, confidence limits could be placed on mean catch estimates using the 5 and 95 percentile points of the distribution of means.

Cost

Operation of the Nova Scotia catch and effort card system, now that the infrastructure is in place, costs DFO approximately 4 person months and $4,000 annually. Those costs do not reflect the entire expense of the program because the provincial department of Natural Resources has maintained responsibility for license sales and the associated costs. Therefore, if such a program were jointly managed in New Brunswick, the expense of running the program would only involve the additional costs associated with the implementation of the catch-effort card.

Those costs can be estimated based on the Nova Scotia experience. Aside from the initial setup which might involve software development or similar "one-time" expenses, the annual running of the program would cost approximately 1 person year and $30,000 (Table 14). However, those costs do not take into account the savings which would occur if a new catch-effort card system replaced data collection systems currently employed in New Brunswick. In addition, certain steps in the process lend themselves to contracting out or automation which may reduce the cost. Those cost estimates assume that a full census is attempted on a population of 30,000 Atlantic salmon fishers. At least three reminder letters would be necessary to achieve a response rate of 90% or more. The result would be reasonably precise catch estimates on virtually all rivers fished for salmon in the province.

The catch-effort card system

The difficulty in collecting Atlantic salmon catch and effort data which have a moderate to high degree of accuracy, in New Brunswick, is obtaining adequate coverage on the large number of relatively small rivers which regularly yield fish (Table 2). In addition, catch on those rivers is heavily influenced by environmental variables such as discharge, and the timing of the run. An angler catch-effort card can provide that coverage.

Angler catch-effort card data are not a panacea. The Nova Scotia data have exhibited inconsistencies when individual river catch and effort data are closely examined. On the Margaree River, for example, it was discovered that fishers consistently over-reported the release of MSW salmon during the first few years of the program (Claytor and O'Neil 1991). Examination of MSW release data on other river systems where independent counts were available through logbooks or diaries supported the evidence that some inflation of MSW release information during the early years of the program had occurred. Recent catch data suggest the phenomenon was of a temporary nature, but it has not been thoroughly examined.

For New Brunswick rivers, managers rely on word-of-mouth estimates or in some instances on FISSYS data (Hooper 1978). Further evaluation of the FISSYS system may provide managers some insight into the precision of the data. Expansion or replacement of that program with a carefully structured catch-effort card census could provide the precision required.

For the purposes of monitoring catch on individual rivers, within a certain level of confidence, a complete census of New Brunswick Atlantic salmon fishers would suffice. For more precise management goals, which demand unique measures on specific rivers, the report card data system could be used in conjunction with complementary systems. For instance, creel surveys, logbooks, counting facilities or telephone/questionnaire surveys could be used to complement the background database which would be established through a catch-effort card system. A combination of data collection systems was the choice of the NMFS survey approach because field testing of independent systems revealed inconsistencies and biases which could not be easily and cheaply compensated for (Essig and Holliday 1991). They reviewed telephone, angler card, and creel surveys during the development of their overall data collection scheme and ultimately chose to use a combination of all three types.

CONCLUSION

In the Nova Scotia data set, the catch and effort card provides annual estimates on 70-90 rivers. Regular use of multiple reminders will provide confidence limits on almost all of those rivers within a coefficient of precision of 25% at the 90% level of probability.

Ultimately, the type of data collection system chosen will depend on cost. The manager must reconcile the management objectives with the quality of data required and the cost of collecting the information.

Use of the Nova Scotia catch-effort card database has shown that a similar system in New Brunswick, which targets the entire population of Atlantic salmon fishers, at an approximate cost of $30,000 and 1.0 person year would provide catch estimates on almost all rivers within a 25% coefficient of precision at the 90% level of probability.

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Table 1. New Brunswick rivers which have reportedly been fished for Atlantic salmon with some degree of regularity, 1970-1987.

1	Alma	31	Nashwaak
2	Bartholomew	32	Nepisiguit
3	Bartibog	33	Nerepis
4	Bass	34	New
5	Big Salmon	35	Nigadoo
6	Black Northumberland	36	North Pole
7	Black (Saint John Co)	37	Northwest Miramichi
8	Cains	38	Oromocto
9	Canaan	39	Patapedia
10	Caraquet	40	Petitcodiac
11	Coverdale	41	Pocologan
12	Demoiselle Creek	42	Point Wolfe
13	Digdeguash	43	Pollet
14	Dungarvon	44	Renous
15	Eel (Restigouche Co)	45	Restigouche
16	Gaspereau (Queens Co)	46	Rocky Brook
17	Hammond	47	Saint John
18	Irish	48	Saint Croix
19	Jacquet	49	Salmon (Queens Co)
20	Kedgwick	50	Salmon (Victoria Co)
21	Kennebecasis	51	Sevogle (Squirrel Falls)
22	Keswick	52	Shepody
23	Kouchibouguac	53	Southwest Miramichi
24	Kouchibouguacis	54	Tabusintac
25	Little S.W. Miramichi	55	Taxis
26	Magaguadavic	56	Tetagouche
27	Middle	57	Tobique (Wapske)
28	Millstream	58	Tracadie
29	Mosher	59	Upsalquitch
30	Napan	60	Waweig

Table 2. New Brunswick's primary Atlantic salmon rivers.

River	1979		1980		1981		1982		1983		1984		1985		1986		1987		1988	
	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon
Alma	199	6	2	7	76	6	34	21	72	4	44	0	44	0	6	0	0	0	3	0
Bartholomew a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bartibog	9	0	28	31	15	9	54	368	13	17	87	0	75	0	177	0	330	0	2570	0
Big Salmon	932	389	5	223	645	304	456	328	304	149	351	0	278	0	124	0	31	0	30	0
Buctouche a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cains	144	57	237	354	170	33	106	79	74	60	439	0	367	0	795	0	625	0	1322	0
Digdeguash	0	1	0	9	9	6	11	7	6	9	10	0	9	0	23	0	7	0	17	0
Dungarvon	117	63	62	50	85	19	73	34	66	29	442	0	279	0	367	0	280	0	301	0
Hammond	32	44	0	2	8	35	35	36	5	32	21	0	27	0	150	0	17	0	125	0
Jacquet	67	28	79	61	37	29	144	93	0	70	39	0	34	0	76	0	45	0	110	0
Kedgwick	316	111	281	422	354	416	322	181	68	196	145	0	326	0	561	0	575	0	803	0
Kennebecasis	50	84	4	26	4	18	23	31	118	26	121	0	396	0	394	0	129	0	90	0
Kouchibouguac a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little S. W. Miramichi	295	136	291	180	247	113	338	122	384	65	297	0	507	0	1146	0	484	0	351	0
Magaguadavic	21	24	13	23	0	0	0	0	6	6	50	0	24	0	45	0	23	0	60	0
Middle	13	1	30	31	49	49	55	46	51	38	0	0	52	0	81	0	50	0	32	0
Nashwaak	123	103	281	835	336	547	416	873	419	496	310	0	496	0	751	0	750	0	201	0
Nepisiguit	44	6	135	103	130	179	130	187	117	176	600	0	229	0	800	0	800	0	1000	0
Nerepis	0	0	0	0	0	0	7	8	5	0	0	0	29	0	227	0	0	0	13	0
Northwest Miramichi	906	315	1027	342	832	215	2005	227	1025	353	2129	0	1279	0	3548	0	1280	0	1018	0
Petitcodiac	1	0	0	0	0	0	0	0	0	0	6	0	11	0	0	0	0	0	0	0
Renous	266	130	290	117	228	51	161	68	93	43	957	0	1294	0	2000	0	1359	0	1523	0
Restigouche b	1167	751	1374	3084	1422	2195	1309	1225	444	1067	827	0	1702	0	2902	0	2913	0	3905	0
Rocky Brook a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saint John	520	112	1012	672	298	195	931	820	394	162	724	0	789	0	1159	0	756	0	983	0
Saint Croix	19	0	6	38	27	25	36	11	11	5	7	0	3	0	38	0	5	0	21	0
Sevogle	574	198	665	246	484	125	1335	180	734	90	1118	0	1060	0	1855	0	851	0	879	0
Southwest Miramichi	5323	1523	4961	4133	4985	1046	5199	1932	1521	1006	4510	0	7140	0	18588	0	6484	0	8338	0
Tabusintac	41	19	110	144	126	81	205	98	59	33	55	0	107	0	148	0	112	0	181	0
Tetagouche	21	3	49	44	47	55	70	60	44	29	0	0	55	0	76	0	65	0	28	0
Tobique	1115	157	1416	1023	537	316	1108	184	755	159	1123	0	2260	0	892	0	1197	0	860	0
Tracadie	23	0	19	19	9	20	18	18	14	17	0	0	11	0	13	0	12	0	24	0
Upsalquitch	507	135	1178	592	1234	221	818	214	203	218	483	0	1175	0	1397	0	819	0	1296	0

a Catch data not available or river closed.

b A small section of the Patapedia River, a tributary of the Restigouche River, is under New Brunswick jurisdiction.

Table 3. Atlantic salmon licenses sold in New Brunswick, 1979-91, and license sales and response rates in the Nova Scotia catch-effort report card system, 1983-91.

	New Brunswick		Nova Scotia		
Year	License sales		License sales	Cards returned	Response rate (%)
1979	20839				
1980	20633				
1981	21964				
1982	22535				
1983	22397		7598	7134	93.9
1984	16119		5790	5490	94.8
1985	17778		6087	5739	94.3
1986	19751		6755	6444	95.4
1987	20502		7188	6698	93.2
1988	21866		8027	6101	76.0
1989	36100 *		8615	6307	73.2
1990	35675 *		8312	5874	70.7
1991	29620 *		6311	4385	69.5
Means		Mean			
1979-88	20438	1983-91	7187	6019	
1989-91	33798	95% CL	782.7	609.1	

* Change in licensing fees affected sales.

Table 4. Confidence limits and precision for Atlantic salmon sportcatch data which were calculated by two different methods. For a description of Method A and Method B, refer to text.

Year	Observed number of fishers	Total catch	Mean catch per fisher	Variance	Method A: 95% CL (log e)	Method A: Precision	Method B: 95% CL	Method B: Precision
1983	9749	7854	0.78	4.860	0.2387	0.270	0.0438	0.056
1984	6827	7660	1.22	7.269	0.0166	0.017	0.0640	0.052
1985	7429	15140	2.04	19.570	0.0258	0.026	0.1006	0.049
1986	9081	18480	2.04	24.743	0.0605	0.062	0.1023	0.046
1987	8782	14850	1.69	13.940	0.0151	0.015	0.0781	0.049
1988	8560	13277	1.55	12.910			0.0761	0.050
1989	8706	14382	1.65	13.238			0.0764	0.046
1990	7916	12373	1.56	11.815			0.0757	0.048
1991	5660	7369	1.30	10.619			0.0849	0.065

Table 5. Chi-square values, degrees of freedom, and probabilities associated with the G-test for goodness of fit of the distribution of total catch to the negative binomial, poisson, and lognormal distributions for New Brunswick 1984 and Nova Scotia 1984-1988 and 1991.

	Negative Binomial			Poisson			Lognormal		
	CHI-SQ	DF	PROB	CHI-SQ	DF	PROB	CHI-SQ	DF	PROB
NB1984	37.20	25	.05<P<.1	8879.48	25	P<<.001	1976.97	25	P<<.001
NS1984	28.59	18	.05<P<.1	11032.93	18	P<<.001	16898.42	18	P<<.001
NS1985	66.98	36	.001<P<.005	22873.92	36	P<<.001	21933.09	36	P<<.001
NS1986	62.20	33	.001<P<.005	31746.45	33	P<<.001	28802.81	33	P<<.001
NS1987	50.11	34	.025<P<.05	22312.33	34	P<<.001	24418.09	34	P<<.001
NS1988	47.83	33	.025<P<.05	20488.39	33	P<<.001	23665.58	33	P<<.001
NS1991	31.51	22	.05<P<.1	11424.82	22	P<<.001	15381.33	22	P<<.001

Table 6. Total number of rivers and number of rivers with a population size greater than 25G^2, where G is Fisher's measure of skewness, for Nova Scotia 1984, 1986, 1988 and 1991.

Year	Total Number of Rivers	Number of Rivers with n > 25G^2
1984	48	8
1986	49	6
1988	53	9
1991	42	4

Table 7. Number of rivers with 200 sample means falling within a given coefficient of precision of respective population means, for a given level of probability, for four sampling frequencies, Nova Scotia 1984.

Sampling Frequency (%)	Coefficient of Precision (%)	Level of Probability (%)	Number of Rivers
55.5	20	95	3
		90	6
	25	95	7
		90	12
70.3	20	95	10
		90	16
	25	95	17
		90	22
85.1	20	95	23
		90	33
	25	95	36
		90	42
95.5	20	95	43
		90	46
	25	95	44
		90	48

Table 8. Number of rivers with 200 sample means falling within a given coefficient of precision of respective population means, for a given level of probability, for four sampling frequencies, Nova Scotia 1986.

Sampling Frequency (%)	Coefficient of Precision (%)	Level of Probability (%)	Number of Rivers
55.5	20	95	5
		90	11
	25	95	11
		90	14
70.3	20	95	12
		90	16
	25	95	17
		90	25
85.1	20	95	28
		90	34
	25	95	36
		90	40
95.5	20	95	44
		90	48
	25	95	45
		90	49

Table 9. Number of rivers with 200 sample means falling within a given coefficient of precision of respective population means, for a given level of probability, for four sampling frequencies, Nova Scotia 1988.

Sampling Frequency (%)	Coefficient of Precision (%)	Level of Probability (%)	Number of Rivers
55.5	20	95	5
		90	9
	25	95	11
		90	15
70.3	20	95	12
		90	18
	25	95	20
		90	29
85.1	20	95	27
		90	38
	25	95	37
		90	45
95.5	20	95	49
		90	52
	25	95	50
		90	53

Table 10. Number of rivers with 200 sample means falling within a given coefficient of precision of respective population means, for a given level of probability, for four sampling frequencies, Nova Scotia 1991.

Sampling Frequency (%)	Coefficient of Precision (%)	Level of Probability (%)	Number of Rivers
55.5	20	95	2
		90	3
	25	95	5
		90	11
70.3	20	95	7
		90	13
	25	95	14
		90	19
85.1	20	95	20
		90	25
	25	95	25
		90	32
95.5	20	95	36
		90	42
	25	95	38
		90	42

Table 11. Total number of rivers and number of rivers with a frequency distribution of 200 random sample means significantly different from a normal distribution (alpha = 0.10) for Nova Scotia 1984, 1986, 1988 and 1991.

Year	Total Number of Rivers	Number of Rivers with $P < 0.10$
1984	48	15
1986	49	20
1988	53	11
1991	42	13

Table 12. Parameter estimates, adjusted R^2, and standard error of the estimate for the model LN(Y) = a + b ARCSIN(SQR(X/100)) for each combination of sampling frequency and coefficient of precision, for Nova Scotia 1984, 1986, 1988, 1991, all four years pooled, and New Brunswick 1984. All regressions were significant (P<0.001).

Year	Sampling Frequency (%)	Coefficient of Precision (%)	Parameter a	Parameter b	Adjusted R^2	Standard Error of Estimate
1984	55.5	20	0.727	0.064	0.785	0.476
		25	0.349	0.065	0.762	0.500
	70.3	20	0.415	0.060	0.723	0.540
		25	-0.340	0.065	0.680	0.580
	85.1	20	-2.319	0.086	0.694	0.567
		25	-3.179	0.092	0.579	0.665
	95.5	20	-6.692	0.129	0.478	0.741
		25	-6.515	0.124	0.333	0.837
1986	55.5	20	1.690	0.050	0.686	0.627
		25	1.393	0.050	0.652	0.660
	70.3	20	1.134	0.052	0.628	0.682
		25	0.659	0.054	0.559	0.743
	85.1	20	-1.498	0.077	0.542	0.757
		25	-2.481	0.085	0.458	0.823
	95.5	20	-6.641	0.130	0.379	0.881
		25	-5.563	0.115	0.259	0.962
1988	55.5	20	0.911	0.062	0.818	0.475
		25	0.575	0.061	0.780	0.522
	70.3	20	0.178	0.064	0.759	0.546
		25	-0.218	0.064	0.674	0.635
	85.1	20	-2.411	0.087	0.687	0.622
		25	-3.432	0.096	0.589	0.713
	95.5	20	-8.246	0.147	0.532	0.761
		25	-8.309	0.146	0.430	0.840
1991	55.5	20	0.965	0.062	0.811	0.471
		25	0.621	0.061	0.811	0.470
	70.3	20	0.581	0.059	0.752	0.539
		25	-0.028	0.062	0.740	0.553
	85.1	20	-1.851	0.082	0.719	0.575
		25	-2.669	0.087	0.634	0.656
	95.5	20	-7.623	0.141	0.572	0.709
		25	-7.864	0.141	0.474	0.786
Pooled	55.5	20	1.136	0.059	0.768	0.521
		25	0.798	0.058	0.744	0.547
	70.3	20	0.613	0.058	0.711	0.581
		25	0.064	0.061	0.658	0.633
	85.1	20	-1.994	0.083	0.659	0.632
		25	-2.929	0.090	0.567	0.712
	95.5	20	-7.333	0.137	0.494	0.769
		25	-7.100	0.132	0.379	0.852
NB1984	20.6	20	1.120	0.056	0.822	0.431
		25	0.944	0.054	0.785	0.474

Table 13. Mean catch per fisher and 95% confidence limits compared with a precision level of 20% for the rivers fished for Atlantic salmon in Nova Scotia in 1986. For a description of Method B refer to text.

					Method B				
River Code	N	Mean Catch	St. Dev.	t-value	95% C.L. for Mean	Coeff. of Precision	Total Catch	95% C.L. on Total Catch	20% Precision on Total Catch
4	68	2.309	4.490	2.000	1.1	47.2	157.0	74.1	31.4
11	89	1.640	3.838	2.000	0.8	49.6	146.0	72.4	29.2
12	34	1.588	4.215	2.042	1.5	93.0	54.0	50.2	10.8
18	23	1.261	2.816	2.074	1.2	96.6	29.0	28.0	5.8
19	20	2.700	4.857	2.093	2.3	84.2	54.0	45.5	10.8
20	42	0.881	3.179	2.021	1.0	112.5	37.0	41.6	7.4
23	152	4.336	6.882	1.980	1.1	25.5	659.1	168.0	131.8
25	50	0.280	0.991	2.010	0.3	100.6	14.0	14.1	2.8
26	61	1.328	2.767	2.000	0.7	53.4	81.0	43.2	16.2
27	49	0.306	1.310	2.010	0.4	122.9	15.0	18.4	3.0
28	77	1.545	3.024	2.000	0.7	44.6	119.0	53.1	23.8
31	63	0.857	1.522	2.000	0.4	44.8	54.0	24.2	10.8
35	309	1.463	3.335	1.960	0.4	25.4	452.1	114.9	90.4
36	326	1.558	3.180	1.960	0.3	22.2	507.9	112.5	101.6
44	31	8.452	14.980	2.042	5.5	65.0	262.0	170.3	52.4
49	1209	2.413	4.772	1.960	0.3	11.1	2917.3	325.2	583.5
53	178	1.365	2.981	1.960	0.4	32.1	243.0	78.0	48.6
56	18	1.389	3.071	2.110	1.5	110.0	25.0	27.5	5.0
58	97	1.052	2.033	1.990	0.4	39.0	102.0	39.8	20.4
59	1131	2.882	6.825	1.960	0.4	13.8	3259.5	449.9	651.9
60	17	0.882	1.536	2.120	0.8	89.5	15.0	13.4	3.0
62	460	1.915	3.401	1.960	0.3	16.2	880.9	143.0	176.2
63	52	0.962	1.990	2.010	0.6	57.7	50.0	28.8	10.0
66	76	1.974	4.102	2.000	0.9	47.7	150.0	71.5	30.0
68	145	1.503	2.693	1.960	0.4	29.2	217.9	63.6	43.6
69	41	1.561	2.346	2.021	0.7	47.4	64.0	30.4	12.8
70	544	1.430	4.173	1.960	0.4	24.5	777.9	190.8	155.6
73	29	0.931	1.462	2.048	0.6	59.7	27.0	16.1	5.4
76	65	1.215	2.427	2.000	0.6	49.6	79.0	39.1	15.8
77	296	3.547	8.295	1.960	0.9	26.6	1049.9	279.7	210.0
80	51	2.314	3.967	2.010	1.1	48.3	118.0	56.9	23.6
83	24	0.833	0.917	2.069	0.4	46.5	20.0	9.3	4.0
86	48	0.750	1.657	2.021	0.5	64.4	36.0	23.2	7.2
87	21	8.190	10.567	2.086	4.8	58.7	172.0	101.0	34.4
88	103	4.146	7.589	1.990	1.5	35.9	427.0	153.3	85.4
89	22	1.636	1.941	2.080	0.9	52.6	36.0	18.9	7.2
95	40	0.050	0.221	2.021	0.1	141.2	2.0	2.8	0.4
96	999	2.248	5.681	1.960	0.4	15.7	2245.8	351.9	449.2
97	79	0.696	1.612	2.000	0.4	52.1	55.0	28.7	11.0
98	85	1.129	2.109	1.990	0.5	40.3	96.0	38.7	19.2
99	58	1.948	4.273	2.000	1.1	57.6	113.0	65.1	22.6
100	109	1.908	4.176	1.990	0.8	41.7	208.0	86.8	41.6
103	43	0.698	1.520	2.021	0.5	67.1	30.0	20.1	6.0
104	151	1.046	2.689	1.960	0.4	41.0	157.9	64.8	31.6
107	937	1.044	2.826	1.960	0.2	17.3	978.2	169.6	195.6
112	53	3.189	3.752	2.010	1.0	32.5	169.0	54.9	33.8
113	71	1.803	3.188	2.000	0.8	42.0	128.0	53.7	25.6
115	72	7.653	11.432	2.000	2.7	35.2	551.0	194.0	110.2
117	101	1.545	3.324	1.990	0.7	42.6	156.0	66.5	31.2

Table 14. The steps in operating an Atlantic salmon sportcatch and effort card system in New Brunswick and the associated costs.

No.	Description	Person months	Additional costs ($)
1	Printing of licenses and report cards		
2	Purchase of lock seal tags		
3	Distribution of report cards and 1 & 2		
4	Sale of licenses (a) vendor fees (b) revenues from license sales		
5	Return postage on voluntary report cards		4,700
6	Collection or return of licensee information		
7	Keypunching and editing of licensee information	1.0	
8	Coding, editing, and keypunching of license stubs	3.0	
9	Generation of mail-out list to prompt non-respondents (software?)		325
10	Mail-out of reminder letters (up to 3 letters to non-respondents, postage, envelopes, etc.)	1.5	15,900
11	Return postage from prompted anglers		7,200
12	Advertising to encourage anglers to return cards		?
13 *	Software development		
14	Analysis of data	2.0-4.0	
15 *	Summary report generation/ad hoc report generation		
16 *	Documentation of system		
17	Overseeing system	2.0	
	Total annual cost	9.5-11.5	$28,125

* Miscellaneous costs which would not be incurred annually. Software development may consume the equivalent of 4-6 person months in salary or contract costs.

Note: Many of these PY costs could be contracted out, possibly at less cost.

SALMON REPORT CARD

(PLEASE PRINT)

CATCH

COMPLETE THIS SECTION ON THE **SAME DAY** EACH **ATLANTIC SALMON IS KILLED**

TAG NO	DATE		WEIGHT (LB)	FORK LENGTH	RIVER	COUNTY	OFFICE USE
	DAY	MONTH					
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

▶ ▶ COMPLETE AFTER LAST FISHING TRIP ▶ ▶

DAYS FISHED

COMPLETE THIS SECTION AFTER **LAST** FISHING TRIP

☐ CHECK HERE IF YOU **DID NOT** FISH FOR SALMON

TOTAL NUMBER OF DIFFERENT DAYS SPENT FISHING ON EACH RIVER DURING SEASON				RELEASED CATCH NUMBER	
OFFICE	RIVER	COUNTY	DAYS	SALMON	GRILSE

Figure 1. Nova Scotia Atlantic salmon catch-effort report card.

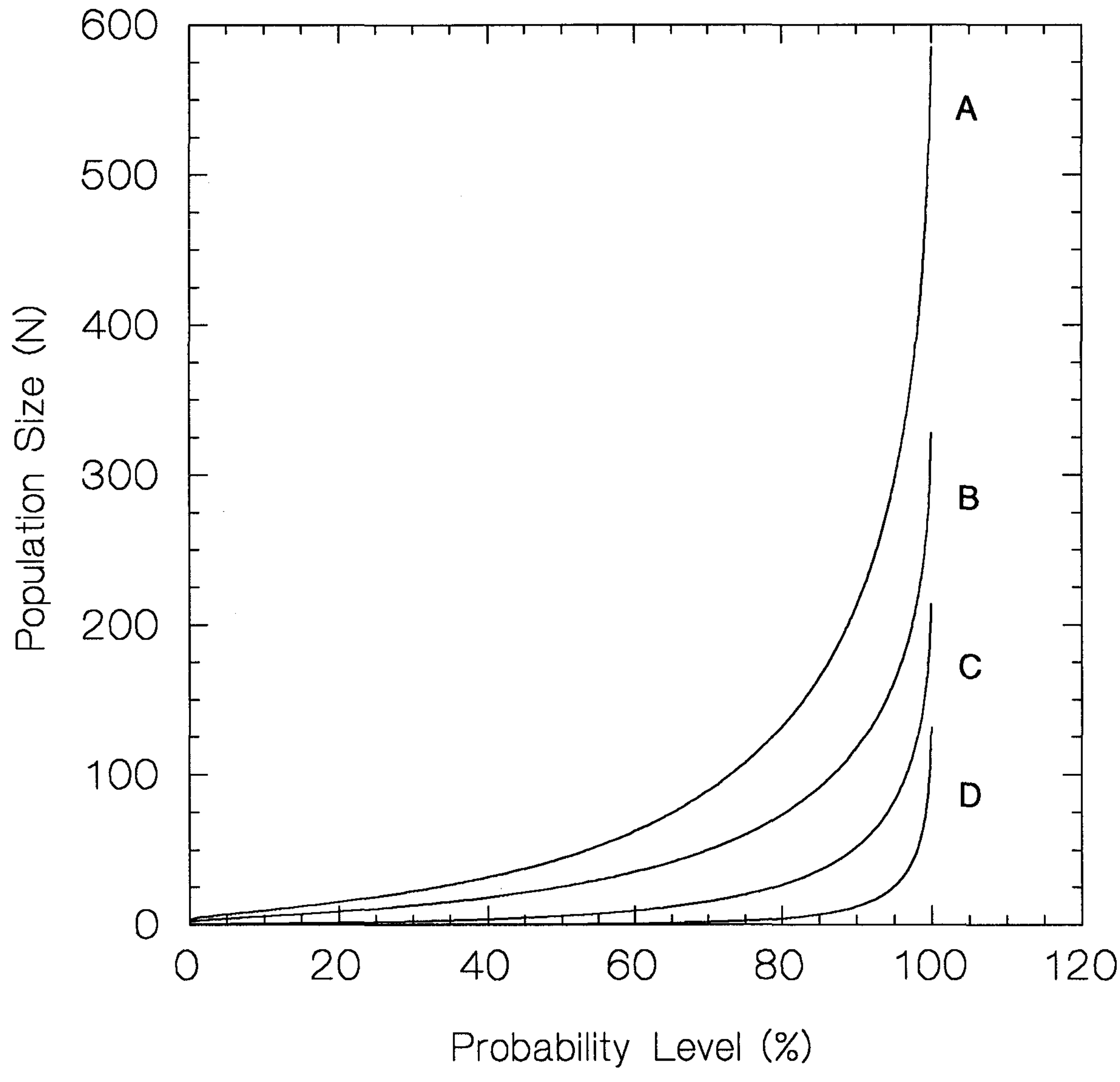

Figure 2. Plot of the equations of the form:
Y = e^[a + b * ARCSIN(SQR(X/100))], where Y is the population size and X is the probability level, for four sampling frequencies (A=55.5%, B=70.3%, C=85.1%, D=95.5%) at a 20% coefficient of precision.

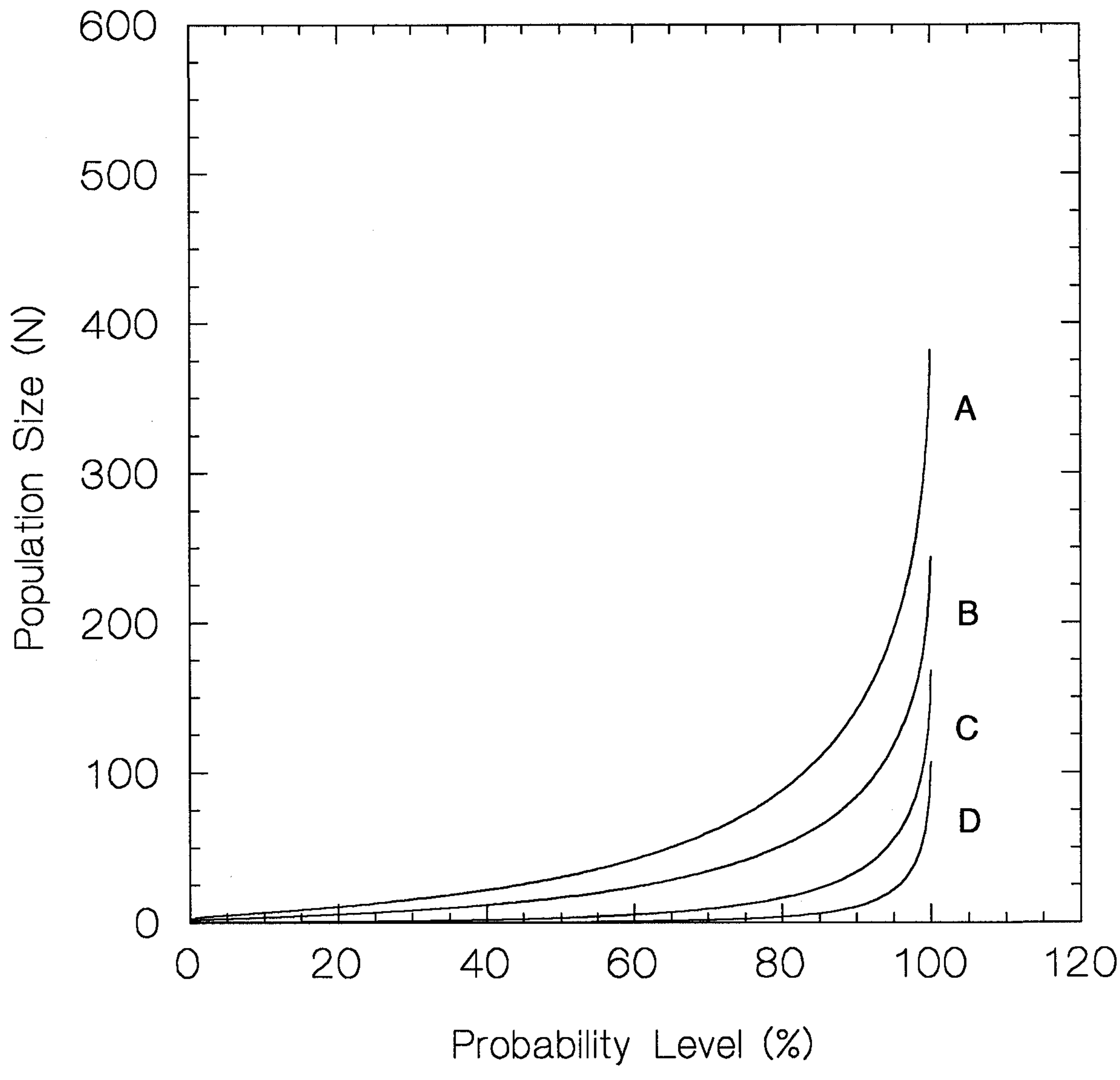

Figure 3. Plot of the equations of the form:
Y = e^[a + b * ARCSIN(SQR(X/100))], where Y is the population size and X is the probability level, for four sampling frequencies (A=55.5%, B=70.3%, C=85.1%, D=95.5%) at a 25% coefficient of precision.

Appendix Table 1. Population size (number of fishers), population mean and standard deviation of total catch per fisher for each river in Nova Scotia, 1984, with N>=16.

River Code	N	Mean	St. Dev.
3	16	2.063	2.909
4	60	0.783	1.342
11	90	1.256	2.415
12	35	1.057	1.924
16	23	0.435	0.788
19	24	1.500	3.093
20	77	0.740	1.838
23	70	0.743	1.791
25	63	0.381	0.906
26	69	1.565	2.422
27	71	0.859	1.900
28	81	2.247	3.360
31	45	0.822	1.696
35	211	1.588	3.078
36	268	1.504	2.900
44	25	3.680	5.475
49	931	1.789	3.055
53	66	0.909	1.769
56	22	1.273	1.723
58	130	1.192	2.139
59	680	0.774	2.436
62	334	1.374	2.167
63	25	0.360	0.952
66	83	1.108	2.897
68	150	1.647	2.583
70	197	0.995	2.419
73	40	0.550	1.197
76	47	1.277	2.500
77	162	1.222	2.721
80	52	2.173	2.749
82	18	0.444	0.856
83	30	1.200	1.690
86	56	1.196	2.331
88	54	1.500	2.296
89	21	0.857	1.236
95	56	1.446	3.021
96	726	1.428	3.291
97	86	0.593	1.590
98	94	0.926	1.608
99	50	0.700	1.446
100	132	2.159	3.594
103	33	1.879	3.150
104	87	0.724	1.853
107	834	0.607	2.580
112	55	1.745	2.496
113	25	0.160	0.473
115	20	0.800	1.795
117	119	1.773	3.394

Appendix Table 2. Population size (number of fishers), population mean and standard deviation of total catch per fisher for each river in Nova Scotia, 1986, with N>=16.

River Code	N	Mean	St. Dev.
4	68	2.309	4.490
11	89	1.640	3.838
12	34	1.588	4.215
18	23	1.261	2.816
19	20	2.700	4.857
20	42	0.881	3.179
23	152	4.336	6.882
25	50	0.280	0.991
26	61	1.328	2.767
27	49	0.306	1.310
28	77	1.545	3.024
31	63	0.857	1.522
35	309	1.463	3.335
36	326	1.558	3.180
44	31	8.452	14.980
49	1209	2.413	4.772
53	178	1.365	2.981
56	18	1.389	3.071
58	97	1.052	2.033
59	1131	2.882	6.825
60	17	0.882	1.536
62	460	1.915	3.401
63	52	0.962	1.990
66	76	1.974	4.102
68	145	1.503	2.693
69	41	1.561	2.346
70	544	1.430	4.173
73	29	0.931	1.462
76	65	1.215	2.427
77	296	3.547	8.295
80	51	2.314	3.967
83	24	0.833	0.917
86	48	0.750	1.657
87	21	8.190	10.567
88	103	4.146	7.589
89	22	1.636	1.941
95	40	0.050	0.221
96	999	2.248	5.681
97	79	0.696	1.612
98	85	1.129	2.109
99	58	1.948	4.273
100	109	1.908	4.176
103	43	0.698	1.520
104	151	1.046	2.689
107	937	1.044	2.826
112	53	3.189	3.752
113	71	1.803	3.188
115	72	7.653	11.432
117	101	1.545	3.324

Appendix Table 3. Population size (number of fishers), population mean and standard deviation of total catch per fisher for each river in Nova Scotia, 1988, with N>=16.

River Code	N	Mean	St. Dev.
4	86	2.058	3.589
11	95	1.442	2.685
12	28	1.357	3.268
16	65	2.415	4.224
19	19	1.842	3.253
20	37	0.486	1.017
23	200	2.270	4.230
24	53	3.132	5.626
25	26	0.346	0.745
26	66	1.712	2.996
27	39	1.128	2.041
28	62	2.194	2.816
31	41	1.610	2.355
35	212	1.000	2.262
36	277	1.289	2.423
44	34	6.294	12.222
49	1049	1.591	3.031
53	157	0.860	1.635
56	20	1.700	2.958
58	67	0.478	1.491
59	1455	1.627	4.170
62	428	1.614	3.075
63	101	1.248	2.861
66	131	1.176	3.052
67	16	1.875	2.754
68	148	1.696	2.794
69	25	0.880	2.333
70	470	0.936	2.503
73	16	0.750	1.880
76	62	1.387	2.328
77	202	2.812	6.066
78	21	3.476	4.167
80	54	2.370	4.076
82	16	0.875	1.310
83	27	1.222	2.006
86	24	0.125	0.448
87	47	3.000	5.521
88	167	2.443	4.520
89	26	0.962	1.732
96	908	1.989	4.692
97	70	0.657	1.473
98	35	1.200	1.587
99	63	1.730	3.620
100	131	2.328	4.225
103	38	1.263	2.274
104	69	0.493	1.268
107	524	0.469	1.458
112	150	1.867	3.411
113	81	0.457	1.173
114	21	1.190	1.834
115	89	1.775	3.007
116	49	1.082	1.956
117	79	1.228	2.369

Appendix Table 4. Population size (number of fishers), population mean and standard deviation of total catch per fisher for each river in Nova Scotia, 1991, with N>=16.

River Code	N	Mean	St. Dev.
4	110	1.827	3.103
5	26	0.808	1.960
11	27	0.222	0.424
12	28	0.786	1.258
16	28	0.393	0.956
19	20	2.000	3.464
23	232	1.858	4.026
24	17	0.824	2.430
26	27	0.556	1.086
28	27	1.444	2.708
31	36	0.778	1.551
35	142	0.423	1.020
36	178	0.635	1.401
41	17	1.647	2.871
44	30	4.767	7.267
49	543	0.595	1.528
53	80	0.663	1.414
59	1236	1.567	4.004
62	219	0.342	1.056
63	97	0.742	1.856
66	169	0.976	2.056
67	18	1.278	2.218
68	69	1.594	3.182
70	250	0.828	2.300
73	28	0.679	1.278
77	172	2.395	4.697
78	16	2.125	2.500
80	40	0.825	1.631
87	36	2.556	4.488
88	166	2.687	4.558
96	650	1.457	3.637
97	42	0.381	1.229
99	28	0.821	1.887
100	127	2.189	4.687
103	16	0.250	0.577
112	75	1.227	2.628
113	104	0.923	1.499
114	41	2.341	4.035
115	132	2.083	4.643
116	91	1.626	2.479
117	52	1.250	1.919
131	47	0.617	1.812

Appendix Table 5. Frequency distribution of total catch for New Brunswick 1984 and Nova Scotia 1986, 1988 and 1991.

	Frequency (Number of Fishers)			
Total Catch	1984	1986	1988	1991
0	1613	5338	5220	3686
1	544	1188	1162	728
2	395	656	648	386
3	266	407	362	238
4	212	278	270	147
5	150	213	195	94
6	101	185	132	85
7	78	146	117	53
8	63	94	78	55
9	41	90	73	26
10	54	70	55	27
11	28	57	50	24
12	24	51	31	21
13	15	36	26	15
14	19	34	23	8
15	18	22	14	9
16	5	25	20	15
17	10	15	13	7
18	5	18	3	4
19	7	15	6	5
20	5	13	9	1
21	5	9	7	6
22	2	9	5	3
23	1	6	5	1
24	1	14	5	1
25	3	8	1	0
26	4	12	1	2
27	2	8	3	1
28	0	7	2	1
29	0	4	2	0
30	0	5	3	1
31	0	3	2	1
32	0	2	3	2
33	2	2	2	1
34	2	6	3	0
35	0	5	1	0
36	0	0	0	0
37+	1	30	8	6
Total	3676	9081	8560	5660