Predicting Atlantic salmon (*Salmo salar*) juvenile densities using catch per unit effort open site electrofishing

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ABSTRACT

A one sweep open site electrofishing method for predicting juvenile Atlantic salmon densities from catch per unit of effort (CPUE) is described. We collected calibration data (n=187) for juvenile Atlantic salmon at 23 closed sites in the Miramichi River system, New Brunswick, Canada during 1993-2003. We examined thirteen general linear models (after log-log transformation) relating CPUE to density with potential modifying effects of age class (fry, parr) and the type of backpack electrofisher (two models of same manufacturer). Akaike's Information Criterion (AIC) was used to select the most parsimonious model given the data. Two models with interactions between the age and electrofisher unit factors were retained. The probability of capture was higher for parr than for fry and differed between electrofisher units. A catch of 5 fish per 300 seconds of effort equated to a density of 21 parr 100 m^{-2} versus 25 fry 100 m^{-2} with the older unit and to densities of 19 parr or 23 fry 100 m^{-2} for the newer unit. Relative differences in predicted values among age groups and units increased at higher juvenile abundances. The primary benefits of using one sweep open techniques include the opportunity for greater spatial coverage with limited resources and decreasing the impact of repeated electrofishing on biota. The calibration technique can be applied to other species and locations but the relationship would need to be derived anew for each application.

RÉSUMÉ

Une approche pour prédire la densité de juvéniles de saumon atlantique à partir d'un échantillonnage par retrait unique dans des sites ouverts est présentée. Durant les années 1993 à 2003, 187 observations d'abondance de juvéniles de saumon atlantique ont été recueillies sur 23 sites clos dans la rivière Miramichi au Nouveau-Brunswick (Canada). Treize modèles linéaires caractérisant la relation entre les captures par unité d'effort (CPUE) et la densité des juvéniles ont été ajustés, après transformation en échelle logarithmique, en considérant les facteurs supplémentaires de groupe d'âge (alevin, tacon) et type d'appareil de pêche électrique. Le critère d'information Akaike (AIC) a servi à la sélection du modèle le plus parcimonieux conditionnellement aux observations. Les deux modèles retenus avaient pour effets significatifs l'interaction de l'âge et de l'appareil de pêche électrique. La probabilité de capture était supérieure pour les tacons par rapport aux alevins et différente entre les deux appareils de pêche électrique. Une capture de 5 poissons pour 300 secondes d'effort équivaut à une densité de 21 tacons ou 25 alevins 100 m^{-2} avec le plus ancien appareil de pêche, mais à 19 tacons ou 23 alevins par 100 m^{-2} pour le nouvel appareil. Les différences relatives par rapport à l'âge et l'appareil de pêche augmentaient avec l'abondance des juvéniles. La pêche par retrait unique de CPUE permet d'augmenter l'étendue géographique de la campagne de recensement avec des ressources limitées et réduit l'impact sur la faune par rapport à la pêche répétée. La méthode peut être appliquée à d'autres espèces et lieux d'étude mais l'ajustement de la relation devrait être fait en se basant sur des observations particulières à l'étude.

INTRODUCTION

The Miramichi River in New Brunswick (Canada) consists of two main stems (the Northwest and Southwest branches) and over 20 tributaries with an estimated 55 million m^2 of juvenile Atlantic salmon (*Salmo salar* L.) rearing habitat. Atlantic salmon juvenile populations within the Miramichi have been monitored since at least the 1950s (Elson 1967). Since 1970, annual electrofishing surveys have been conducted to quantify the abundance of juvenile Atlantic salmon by age group at numerous sites throughout the watershed (Swansburg et al. 2002). The abundance of juvenile salmon was quantified generally using the successive removal technique (depletion method) within closed sites and the population was estimated using the algorithm described by Zippin (1956). From 1970 to 1984, sampling was conducted at over 70 sites annually. Beginning in 1985, the survey coverage was reduced to about 15 closed sites annually.

In 1993, the Department of Fisheries and Oceans Science Branch (DFO) introduced a catch per unit effort (CPUE) technique in order to increase the spatial coverage of the juvenile survey within the Miramichi. The use of CPUE techniques have allowed DFO to reestablish an annual survey of 70 sites. Semi-quantitative electrofishing surveys using single sweep CPUE indices of abundance have been described previously for stream salmonids (Strange et al. 1989; Lobón-Cerviá and Utrilla 1993; Crozier and Kennedy 1994; Prévost and Nihouarn 1999). The CPUE index is collected from open sites with a single sweep following standardized protocols for gear and fishing technique. The investment in time and materials is substantially less than what is required for closed sites with successive removals.

The objective of this study is to analyze and derive functions to convert the CPUE index expressed in units of catch per seconds of effort to a density index expressed in units of fish per m^2. Crozier and Kennedy (1994) as well as Prévost and Nihouarn (1999) have presented similar approaches for converting CPUE indices for juvenile Atlantic salmon to densities. For this study, paired observations of CPUE and density estimates were obtained over a period covering 11 years of surveys during which time the field techniques were standardized but there was a change in electrofisher unit. We examine age group (or size group) and electrofisher unit effects on the catchability of fish during the CPUE sweep and the implications this has on the conversion function. The derived relationships form the basis for predicting individual site densities and deriving average densities by age group within the tributaries and main stems of the Miramichi River.

REVIEW OF PREVIOUS METHODS

The experimental design and methods used in published studies of single sweep juvenile salmonid surveys are summarized and contrasted in Table 1. The concept was introduced by Strange et al. (1989) using paired observations from a site sampled on the same day. Calibration within the same site on the same day was used by Lobón-Cerviá and Utrilla (1993), Crozier and Kennedy (1994), and in this study. Simonson and Lyons (1995) used adjacent paired sites to collect the single sweep and the depletion sweep observations. Jones and Stockwell (1995), as well as Prévost and Nihouarn (1999), used the same site but collected the paired observations on different days. The studies also differed in whether barrier nets were used to close the study site. In some studies, nets were in place for both the single sweep and depletion sampling, only during the depletion sampling or never at all. The studies with analyses of interest for our purposes were those of Crozier and Kennedy (1994) and Prévost and Nihouarn (1999) in which an index of abundance (fish per seconds of effort) is converted to density (fish per 100 m^2). Wyatt (2002) converts catches to densities but the single sweep units are by default the catch within a sampled area. In the subsequent treatment of the paired observations, Prévost and Nihouarn (1999) used a linear function without an intercept whereas Crozier and Kennedy (1994) used log transformation adding 1 to the observations for both the CPUE and depletion estimates. We chose a linear function after log transformation of the data and excluded paired observations where the catch during the CPUE sweep was 0 because the log of zero is undefined and it could not be assumed that CPUE catch of 0 equated to a density of 0.

MATERIALS AND METHODS

The catch per effort method involves sampling with a single upstream pass without the use of barrier nets (open sampling). The removal method involves sampling with multiple passes within an area contained by barrier nets (closed sampling).

The data for the calibration of the catch per effort index (CPUE) to a density index was collected at 23 sites within the Miramichi River watershed between 1993 and 2003 (Fig. 1; Appendix 1). Surveys were conducted in sites with wadeable water and good habitat for juvenile salmon. On average, 79% of the habitat was riffle/run and bottom substrate was 92% gravel, pebble, rock, and boulder (Table 2) which is consistent with descriptions of preferred juvenile salmon habitat (Gibson 1993). Conductivity ranged from 30 to 81 $\mu S\ cm^{-1}$ which is typical of the Miramichi Watershed. The sites averaged 213 m^2 in area and ranged from 3 to 16 meters in width (Table 2).

CALIBRATION SAMPLING

Barrier nets were installed at the upstream and downstream boundaries of the sites to prevent immigration or emigration of fish during sampling. The barrier nets were constructed of 5 mm Ace © knotless nylon netting, a size sufficient to retain all ages of juvenile salmon. The area of a closed sites was calculated as the average width of the site (measured at 3 places: lower barrier, middle of site, and upper barrier) times the average length of the site (measured on each bank).

Two type of electrofishers, from the same manufacturer, were used in this study. Smith Root Type 11A © electrofishers were used from 1993 to 1999 whereas Type 12B © electrofishers were used from 2000 to 2003. The pulse width of the Type 11A is 4 milliseconds at a frequency of 60 Hz and it is not adjustable by the user. The Type 12B machine has POW (Programmable Output Waveforms) circuitry and the pulse width can be adjusted. At the model specific setting of “I 5”, the setting recommended for juvenile salmon, the resultant pulse width was 6 ms at 60 Hz.

Electrofishing crews consisted of three members; one operating the backpack electrofisher, a second holding the collection seine, and a third collecting fish with a dip net and bucket. Where stream velocity was sufficient, shocked fish generally drifted downstream into the collection seine where they were removed with the dip net and transferred to a collecting bucket. In lower velocity areas fish were also collected by dipnetting directly from the site. The dip nets and a collecting seine measuring 1 meter by 1 meter were constructed of 5 mm Ace © knotless nylon netting.

Once a site was enclosed with barrier nets, a CPUE sweep was performed within the enclosed area exactly as it would have been performed in a single sweep open site. The site was fished across the river from bank to bank moving upstream (Fig. 2). All fish captured were retained and processed separately from those in subsequent sweeps. Effort was recorded as the time (in seconds) when electrical current was being applied to the water. Effort during the CPUE sweeps over all sites averaged about 600 seconds, within a range of 242 to 1463 seconds (Table 3).

After the initial CPUE sweep, three to four removal sweeps were conducted. The removal method sweeps were conducted from the upstream barrier to the downstream barrier (downstream direction). Electrofishing time per removal sweep was generally higher than the CPUE sweep as the crew would attempt to capture all the fish seen each sweep. As well, fish found along the lower barrier net were included in each sweep. The time between successive electrofishing sweeps was about 30 minutes.

Catches from each sweep were recorded separately. Species were identified and fork length (to 0.1 cm) was measured from all Atlantic salmon parr (age 1 year and older) and from a subsample of at least 50 fry (young of the year, YOY). Fry and parr were distinguished on the basis of length. After sampling, fish were released downstream of the site. The population of fish in the site was estimated from the successive removal sweeps using the maximum likelihood procedure described by Zippin (1956). The total population for the enclosed area was estimated as the population estimate produced by the removal method plus the fish removed during the CPUE sweep (Fig. 2). Separate population estimates were generated for salmon fry and parr (predominantly age 1+ and 2+) for each site. Density was expressed as the number of fish per 100 m^2 of habitat area. CPUE was expressed as catch per 300 seconds of effort.

DATA TREATMENT AND MODELING

Age group (fry, parr) and electrofisher unit (Type 11A, 12B) were considered as possible factors affecting the catchability of salmon juveniles. These factors were incorporated in a general linear model after log transformation of the CPUE and density data. A log transformation was used to stabilize the variance.

$$Log(Density_i) = \alpha + \delta * Age * EF + (\beta + \gamma * Age * EF) * Log(CPUE_i) + \varepsilon$$

where	Age	=	Fry, Parr
	EF	=	Electrofisher units (11A, 12B)
	$\alpha, \beta, \delta, \gamma$	=	intercept and slope coefficients
	ε	=	residual error, $N(0,\sigma^2)$

A total of 13 models were examined. The Akaike Information Criterion (AIC) was used to select the model among the 13 candidate models with the most support given the data (Burnham and Anderson 1998):

$$AIC = 2*\mathbf{L}(Y|M_j) + 2k_j$$

where $\mathbf{L}(Y|M_j)$ = negative log likelihood of the data (Y) given the model (M_j)
k_j = parameters in model j (including σ)

and

$$\mathbf{L}(Y|Mj) = \frac{n}{2} * \log_e 2\pi + \frac{n}{2}\log_e \sigma^2 + \frac{1}{2\sigma^2}\Sigma\left(Y_i - \hat{Y}\right)^2$$ (Neter et al. 1996)

where n = number of observations
σ^2 = mean square error (MSE)

Because of the log transformation, sites in which the CPUE catch was zero were excluded.

RESULTS

Within the 187 sampling events available, population, density, and CPUE estimates were obtained for 96 fry and 90 parr age groups from 23 sites between 1993 and 2003. One sampling event was excluded because the successive removal data were insufficient to derive a population estimate. Densities of fry ranged from 0 (at 3 sites) to 290 fish per 100 m^2 (Fig. 3). Parr (age one year and older) densities ranged from 6 to 116 fish per 100 m^2 (Fig. 3). The CPUE index values for fry ranged between 0 (at 6 sites) and 121 fish per 300 seconds of effort whereas the parr CPUE index range was 0 (1 site) to 63 fish per 300 seconds (Fig. 3). At 3 of the 6 sites where the CPUE sweep fry catch was zero, no fry were subsequently captured during the successive removal sweeps while densities ranged from 0.4 to 1.0 fish per 100 m^2 at the other three sites. The only site where no parr were captured during the CPUE sweep had a density estimate of 10.8 fish per 100 m^2. The sites where no fry or parr were captured during the CPUE sweep were excluded from the analysis (8 of 187 events).

Age group and electrofisher unit were significant explanatory factors of density relative to CPUE (Table 4). Two models, 8 and 10, explained a similar proportion of the variance of density and were indistinguishable using the AIC criterion. Model 8 had a common slope but an additive intercept term dependent upon age and electrofisher type. Model 10 had a common intercept but a slope dependent upon the interaction between age and electrofisher type (Table 4). The residual patterns were indistinguishable among the two models and their distributions were consistent with the assumption of the model (Fig. 4).

There remained important annual variation in the model performance. Model predictions for sampling events in 1995 and 1996 were under and overestimates, respectively, relative to values observed (Fig. 4). There were six observations in the data set for which the estimated density was outside the 95% confidence interval of the predicted value from the models, of which five were obtained using electrofisher unit 11A (Fig. 5). Four of these observations were from 1993, the first year of calibration. The two outlier observations for parr were both sampled from site 38 (Fig. 5).

The predicted probability of capture was higher for parr than for fry and higher for the Type 12B versus 11A electrofisher units (Table 5; Fig. 6). A catch of 5 fish (fry, parr) per 300 seconds of effort equates to a density of 21 parr 100 m^{-2} versus 25 fry 100 m^{-2} for the Type 11A units and to densities of 19 parr versus 23 fry 100 m^{-2} for the Type 12B unit. Relative differences in predicted values among age groups and units increased with increasing CPUE values (Fig. 6).

DISCUSSION

The inter-site variability in juvenile Atlantic salmon abundance estimates is generally considered more important than the intra-site uncertainty (precision) of the individual estimate and a choice must frequently be made between precision at individual sites and spatial coverage (Strange et al. 1989; Simonson and Lyons 1995; Wyatt 2002). The juvenile salmon monitoring program of the Miramichi was designed to provide an index of juvenile abundance by age group in order to assess and track changes in stock status of Atlantic salmon. Prior to 1984, between 46 and 98 sites were sampled annually within the 14000 km^2 Miramichi watershed. Coverage was reduced to 15 sites or less from 1985-1992 (Swansburg *et al.* 2002). This small number of sites was considered inadequate for quantifying juvenile abundance and the CPUE sampling design was introduced in order to increase the spatial coverage of the survey. As well, the choice of a CPUE approach was motivated by the expanding literature on the biological effects of electrofishing (Thompson *et al.*, 1997; Ainslie *et al.*, 1998) as the successive removal technique potentially exposes some fish and other biota to repeated electroshocking events.

A number of investigators have developed reduced effort methods for estimating abundance of stream salmonids. Strange et al. (1989) presented the single sweep technique as a semi-quantitative approach to characterize relative abundance of juvenile salmon. Crozier and Kennedy (1994) present their five-minute sweep technique in a similar fashion as an index of relative abundance ranging from absent (0) to excellent (> 23 fish 5 min^{-1}; > 114.7 fish 100 m^{-2}) with currencies expressed in catch per 5 minutes of effort and equivalencies expressed as densities. Others reported on the relationship between catch in an initial or single sweep and the population size of fish within the area sampled (Lobón-Cerviá and Utrilla 1993; Jones and Stockwell 1995; Simonson and Lyons 1995; Kruse et al. 1998; Edwards et al. 2004). The general conclusion from these studies was that the single sweep catches were positively correlated with the number of fish estimated to have been present in the site. Although Lobón-Cerviá and Utrilla (1993) indicated that the probability of capture for a single sweep at a given site was poorly predicted, Mitro and Zale (2000) derived estimates of average catchability which they then applied to single sweep sampling events to predict abundance. Wyatt (2002) derived density estimates from single pass samples using the density and catchability information from multiple pass sites in a Bayesian hierarchical model.

The approach in this study is most similar to that of Crozier and Kennedy (1994) as well as Prévost and Nihouarn (1999) who used paired observations from CPUE and depletion experiments to derive an equation to translate catch rates (fish per 5 minutes of effort) to densities (fish per 100 m^2). Crozier and Kennedy (1994) used a log transformation of the CPUE and density data (plus one to correct for zero catch) and fitted a linear regression to derive the conversion coefficients. Prévost and Nihouarn (1999) used a direct proportionality relationship, no intercept, to convert the CPUE index to density. The data which we collected required a log transformation to stabilize the variance but we chose to exclude the paired observations where no fish were caught during the CPUE sweep. We chose a non-linear association but forced a linear relationship in the transformed scale by doing a linear regression on log-log data. When CPUE catch of an age group is zero, we expect that the abundance of fish at that site is very low and accept a predicted density of zero.

The proportion of the animals captured within a site depends upon the age group and the gear used. The exponent term was significantly less than unity for all age group and gear combinations which indicates that the proportion of the animals captured within a site increases with density.

The CPUE method which we describe cannot precisely or even accurately predict the abundance of salmon at an individual site. However, sampling a large number of sites and calculating the index of abundance as an average density for a number of sites should produce unbiased estimates of the average density within the watershed (Mitro and Zale 2000; Wyatt 2002). It would not have been possible to collect upwards of 70 multiple sweep depletion samples annually from the Miramichi within the time frame and resource constraints of recent years. We cannot explain the bias in the predicted values of density for the samples collected during 1995 and 1996 relative to the pattern observed in the other years. This question could benefit from an alternative treatment such as the Bayesian hierarchical approach utilized by Wyatt (2002).

The relationship derived from the Miramichi data set should not be transferred to other areas, other studies, or other species which do not replicate the field sampling techniques and the equipment used. The field sampling technique during the CPUE sweep must be identical whether the sweep is conducted within a closed site as during the calibration portion of the work, or during the collection of a CPUE index value in an open site. All CPUE sweeps were conducted in an upstream direction and all the habitat within the closed site was covered while avoiding excessive fishing effort along the upstream and downstream barriers of the closed site.

There are some sources of potential bias in the calibration method which could affect the predicted densities of fish relative to the CPUE index. The presence of barrier nets would more likely increase the probability of a fish being caught in the CPUE sweep in the closed site. When barrier nets are present, fish pushed upstream or displaced downstream during sampling could potentially return within the range of the electrofishing gear. This behavior would not be expected in an open site. Consequently, the CPUE index at a closed site could be inflated relative to the index obtained in an open site and the density at the open site would be underestimated.

It is assumed that the CPUE sweep in the closed site does not affect the catchability of the remaining fish during the successive removal sweeps. If the catchability is changed after the initial CPUE sweep but remains constant for all successive removal sweeps, then the estimated density should not be biased. If the catchability decreases at each sweep, then the density would be underestimated whereas if it increased at each sweep, the density would be overestimated. The general sense in the literature is that the probability of capture more likely decreases with each sweep as fish become less responsive to the electrical stimulus (Cross and Stott 1975; Riley and Fausch 1992). In that case, the densities estimated in this study are likely underestimated and the densities predicted from the CPUE index would also be underestimates.

We cannot think of any other practical means of calibrating CPUE data to densities than through the method described in our study. Sampling adjacent sites for either CPUE or successive removal assumes that the abundance of salmon is relatively homogeneous in neighboring locations of similar habitat. As well, it is difficult to find adjacent sites with similar habitat characteristics such that we could assume that the abundance of juveniles (density) would be more similar. The removal of a large portion of the estimated stock during the CPUE sweep results in decreased precision of the density estimates. In our study, about one-third of the fish in the site were captured during the CPUE sweep. Sampling the same site at different times as was done by Prévost and Nihouarn (1999) provides a larger population to be sampled during the successive removal sweeps. However, for the paired observations to be truly comparable, it must be assumed that there is negligible change in abundance within the site due to mortality (post-release), emigration or immigration.

The CPUE method has a number of attractive features. It is less time consuming than conducting successive removal sweeps or mark and recapture experiments, there is a reduced impact on the biota of interest as fewer fish are handled, and there is reduced impact on the habitat because the substrate is not displaced during barrier net installation. We suggest that the CPUE method as described in this study provides a quantitative measure of abundance, in a currency of fish per habitat area, which is comparable to values collected historically using the successive removal method. We have not attempted to calibrate the CPUE index for other fish species in the Miramichi although such an analysis could be done for those species with sufficient data.

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Table 1. Summary of previous studies relating single sweep or CPUE sweeps to indices of abundance.

Design	Sampling	Variables	Relationship	Conclusion	Reference
Calibration within single site • same day • barrier nets • 3 pass depletion • 50 m site, single sweep excludes upper and lower 10 m near barrier nets	Upstream for single sweep and depletion sweeps	Single sweep = Catch per area Depletion = N per area (N = N' + C)	$N\ m^{-2} = f\{C\ m^{-2}\}$	Categories of abundance	Strange et al. 1989
Calibration within single site • same day • no barrier nets • 3 pass depletion	Upstream for single sweep and depletion sweeps	Catch in first sweep = C1 Depletion = N from 2 or 3 sweeps including C1	$N = f\{C1\}$	Predict N from C1	Lobón-Cerviá and Utrilla 1993
Calibration within single site • same day • barrier nets • 3 pass depletion	Downstream for single sweep and depletion sweeps	Single sweep = catch in 5 minutes of effort Depletion = N per area (N = N'+C)	$N\ m^{-2} = f\{C\ 5\ min.^{-1})$	Categories of abundance	Crozier and Kennedy 1994
Calibration using adjacent stations • same day • no nets for single sweep • barrier nets for depletion • 3-4 pass depletion • Standardized for area	Upstream for single sweep, Upstream and downstream for depletion sweeps	Single sweep = Catch Depletion = N	$N = f\{C\}$	Correlation analysis of abundance	Simonson and Lyons 1995
Calibration within single site • 3-5 weeks between sampling • barrier nets • 3 pass depletion	Upstream for single sweep and depletion sweeps	Single sweep = Catch Depletion = N	$N = f\{C\}$	Correlation analysis of abundance	Jones and Stockwell 1995

Table 1 (continued).

Design	Sampling	Variables	Relationship	Conclusion	Reference
Calibration within single site • 3-39 days between sampling • no barrier nets • 2 pass depletion • zones sampled have overlap	Upstream for single sweep and depletion sweeps	Single sweep = catch in 5 minutes of effort Depletion = N per area	$N\ m^{-2} = f\{C\ 5\ min.^{-1}\}$	Prediction of density (fish m^{-2})	Prévost and Nihouarn 1999
Calibration within single site • same day • no barrier nets • 3 pass depletion • standardized for area, constant effort	Upstream for single sweep and depletion sweeps	Catch in first sweep = C1 Depletion = N from 3 sweeps including C1	N = f{C1, p}	Predict N from C1 and estimated p (probability of capture)	Mitro and Zale 2000
Calibration within single site • same day • no barrier nets • 3 pass depletion	Identical for single sweep and depletion sweeps	Catch in first sweep = C1 Depletion = N from 3 sweeps including C1	N = f{C1, p}	Predict N and density from C1, p, area	Wyatt 2002
Calibration within single site • same day • no upper net for single sweep • barrier nets for depletion • 3 pass depletion • standardized for area	Upstream for single sweep and depletion sweeps	Single sweep = Catch Depletion = N		Considered relative species abundance in single sweep versus depletion sweeps	Edwards et al. 2004
Calibration within single site • same day • barrier nets • 3 pass depletion • standardized using effort in single sweep and area of closed site	Upstream for single sweep, downstream for depletion sweeps	Single sweep = Catch (C) per measured effort Depletion = density = N per area (N = N'+C)	$N\ m^{-2} = f\{C\ 5\ min.^{-1}$, age, gear}	Prediction of density (fish m^{-2})	This study

Table 2. Habitat characteristics (elevation, stream order, habitat type, bottom type, conductivity and maximum depth) of sites in the Miramichi River used for calibrations during 1993 to 2003.

	Elevation	Stream	[1] Habitat(%)				[2] Bottom Type (%)									Max
Site	(meters)	Order	Riffle	Run	Flat	Pool	fines	sand	gravel	pebble	cobble	rock	boulder	bedrock	Cond[3]	Depth (cm)
7	15.5	5	0	0	100	0	0	10	0	20	35	30	5	0	75.0	45.0
9	45.1	4	10	30	40	20	5	5	0	10	60	10	5	5	74.7	36.0
31	112.5	4	54	35	11	0	0	4	13	24	36	21	3	0	38.0	37.5
34	302.5	4	38	59	2	1	0	2	14	19	31	26	8	0	39.0	52.9
38	202.5	4	69	30	2	0	0	2	9	19	36	18	6	11	62.0	47.9
40	37.5	3	45	38	17	0	0	3	9	16	43	22	6	0	72.3	44.3
43	7.5	5	21	40	23	17	0	8	15	29	35	12	2	0	36.5	55.9
44	97.5	5	18	78	3	0	0	2	7	16	36	35	5	0	35.0	54.0
46	157.5	2	53	12	34	1	1	6	13	24	37	16	2	0	81.0	40.2
54	90.5	4	40	52	8	0	0	2	6	22	38	26	7	0	32.3	40.8
55	151.5	4	63	34	3	0	0	5	14	21	43	15	2	0	41.5	35.4
60	149.4	6	31	37	23	0	0	4	11	17	34	23	11	0	39.0	49.4
62	43.3	6	51	47	2	0	0	3	12	30	43	12	1	0	42.5	46.0
74	30.5	5	53	35	11	1	0	5	10	20	44	19	3	1	69.5	38.1
75	22.5	6	24	47	22	8	0	8	22	34	29	7	0	0	44.8	54.5
77	77.7	5	38	29	33	0	0	1	6	8	15	7	1	62	32.3	39.6
79	37.5	4	59	40	5	0	2	7	15	26	37	12	2	0	51.0	31.6
82	37.5	3	47	37	16	0	3	5	15	27	37	10	3	0	43.8	39.4
84	57.9	4	46	46	6	2	1	2	10	21	32	23	8	3	42.2	58.1
92	271.3	4	75	23	2	0	0	6	15	26	35	16	3	0	30.3	36.7
97	21.3	4	15	36	30	19	0	6	13	14	39	28	1	0	79.0	63.0
103	125.7	4	72	24	5	0	0	1	6	19	41	27	5	1	34.0	42.7
208	321.1	2	55	40	5	0	0	2.5	12.5	22.5	22.5	32.5	7.5	0	61.5	36.0
Mean	105.0	4.2	42.4	36.8	17.4	3.0	0.6	4.3	10.6	21.1	36.4	19.4	4.2	3.5	50.3	44.6
Max	321.1	6.0	75.3	78.3	34.0	18.8	3.0	7.9	21.6	34.4	44.0	35.0	10.8	61.6	81.0	63.0
Min	7.5	2.0	15.0	12.0	1.5	0.0	0.0	0.8	5.9	7.6	14.9	6.7	0.0	0.0	30.3	31.6

[1] Habitat type definitions:

Riffle	fast current, shallow depth (< 23 cm), turbulent usually broken flow
Run	fast current, depth > cm, turbulent and sometimes broken flow
Flat	slow current, depth < 46 cm, smooth surface
Pool	slow current, depth > 46 cm, smooth surface

[2] Substrate type definitions:

Fines	fine silt or clay
Sand	< 2 mm hard particles
Gravel	2 to 16 mm
Pebble	16 to 60 mm
Cobble	60 to 250 mm
Rocks	250 to 500 mm
Boulder	> 500 mm
Bedrock	

[3] Conductivity: measured in microseimens

Table 3. Frequency of sampling, area (m²) of enclosed site, and effort (seconds) during the CPUE sweep for the sites used in the calibration experiment, 1993 to 2003.

Site	Frequency of sampling (1993-2003)	Area (m²) of enclosed site			Effort (seconds) of CPUE sweep		
		Mean (over years)	Min	Max	Mean (over years)	Min	Max
7	2	127	116	138	419	382	456
9	2	207	200	214	611	377	844
31	1	210	.	.	296	.	.
34	1	84	.	.	254	.	.
38	7	202	164	242	554	310	754
40	11	182	154	222	434	299	610
43	1	89	.	.	307	.	.
44	1	174	.	.	382	.	.
46	6	204	117	294	971	299	1315
54	2	320	300	339	591	546	636
55	5	227	112	321	439	362	586
60	2	236	191	326	585	437	880
62	2	164	111	190	549	298	675
74	10	256	156	474	743	308	1144
75	1	123	.	.	335	.	.
77	3	221	141	291	746	321	1039
79	6	208	175	256	700	242	1063
82	10	189	92	264	646	308	1181
84	10	262	173	465	596	267	1161
92	3	186	161	234	575	300	719
97	1	270	.	.	1463	.	.
103	10	221	162	335	512	347	689
208	1	192	.	.	750	.	.

Table 4. Structure of the models evaluated, Akaike Information Criterion (AIC), credibility factor (ΔAIC) and fitting diagnostics for the 13 models examined for the calibration of CPUE to density. K is the number of parameters to be estimated in the model (including intercept, σ^2), DF is the degrees of freedom, and SSE is the residual error. R^2 is the proportion of the variance in log (density) explained by the model. The number of observations is 179 for each model.

Model	Hypothesis of model	K	DF	SSE	AIC	ΔAIC	R^2
0	No relation to CPUE	2	178	28.4	182	296.8	0.78
1	Common slope and intercept	3	177	6.3	-85	29.1	0.81
2	Intercept dependent on age (fry, parr), common slope	4	176	5.4	-110	4.5	0.81
3	Common intercept, slope dependent on age	4	176	5.3	-113	1.7	0.81
4	Intercept and slope dependent on age	5	175	5.3	-111	3.6	0.81
5	Intercept dependent on electrofisher unit, common slope	4	176	6.0	-92	22.3	0.79
6	Common intercept, slope dependent on electrofisher unit	4	176	6.1	-90	24.0	0.79
7	Intercept and slope dependent on electrofisher unit	5	175	6.0	-90	24.2	0.79
8	Intercept dependent on age and electrofisher unit (additive), common slope	5	175	5.2	-114	0.0	0.82
9	Intercept dependent on interaction between age and electrofisher unit, common slope	6	174	5.2	-112	2.0	0.82
10	Common intercept, slope dependent on interaction between age and electrofisher unit	6	174	5.2	-114	0.0	0.82
11	Intercept dependent on age, slope dependent on interaction between age and electrofisher unit	8	172	5.1	-111	2.8	0.82
12	Intercept dependent on interaction between age and electrofisher unit, slope dependent on interaction between age and electrofisher unit	9	171	5.1	-110	4.4	0.82

Table 5. ANOVA table of fit for the two retained models relating CPUE to density with age and electrofisher units as significant explanatory effects of density. Model 10 (in table 4) relates CPUE to density with a common intercept but slope dependent on the interaction between age and electrofisher unit. Model 8 (in table 4) relates CPUE to density based on an additive term for age and electrofisher unit for the intercept and common slope.

Model 10: common intercept, interaction term between age and electrofisher unit for slope

Source	DF	SS	MS	F Value	Pr > F
Model	4	23.24	5.81	195.34	<0.0001
Error	174	5.18	0.03		
Corrected Total	178	28.42			

R-Square 0.818

Parameter	Estimate	Standard Error
Intercept	0.845	0.0387
Slope (Parr, 11A)	0.669	0.0416
Slope (Parr, 12B)	0.630	0.0433
Slope (Fry, 11A)	0.802	0.0315
Slope (Fry, 12B)	0.744	0.0326

Model 8: additive term for age and electrofisher unit in the intercept, common slope

Source	DF	SS	MS	F Value	Pr > F
Model	3	23.18	7.73	258.37	<0.0001
Error	175	5.23	0.03		
Corrected Total	178	28.42			

R-Square 0.816

Parameter	Estimate	Standard Error
Slope	0.737	0.0316
Intercept (Fry, 12B)	0.857	0.0525
Intercept (11A)	0.072	0.0282
Intercept (Parr)	-0.141	0.0280

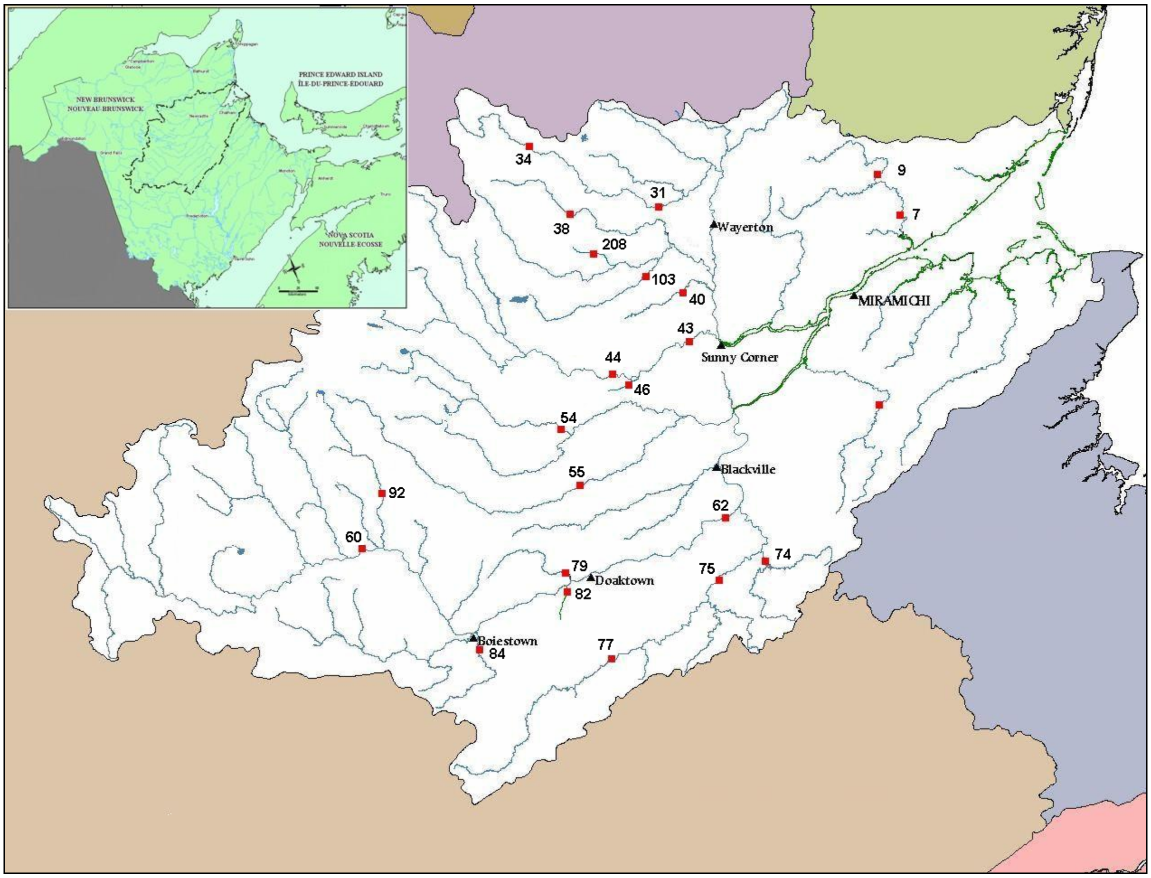
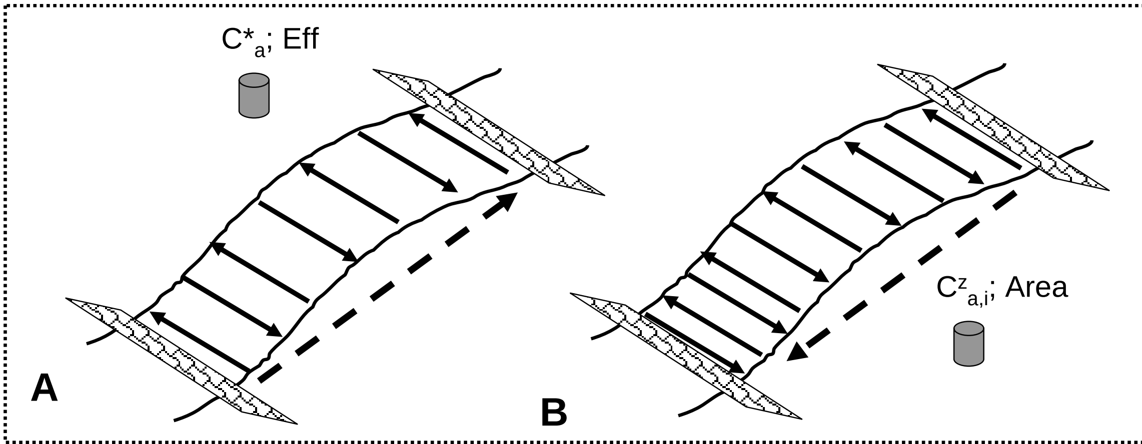


Figure 1. Map of Miramichi watershed showing sites where calibration data were collected, 1993 to 2003.



C

$N'_a = f\{C^z_{a,i} \mid p\}$

$N_a = N'_a + C^*_a$

$D_a = N_a / Area$

$D_a = f\{C^*_a / Eff\}$

where:
- C^*_a = catch of fish age a (fry, parr) in CPUE sweep
- Eff = effort (seconds)
- $C^z_{a,I}$ = catch of fish age a in successive removal sweep i (i = 1 to 3)
- p = mean probability of capture
- N_a = population of fish age a in the enclosed site
- Area = area of site within barriers (m^2)
- D_a = density of fish age a (fish per m^2)

Figure 2. CPUE and successive removal techniques for the development of a juvenile Atlantic salmon abundance index. Panel A illustrates the CPUE sampling technique, panel B illustrates the successive removal technique within a site closed by barrier nets, and panel C summarizes the functions used to estimate the population and density within the closed site.

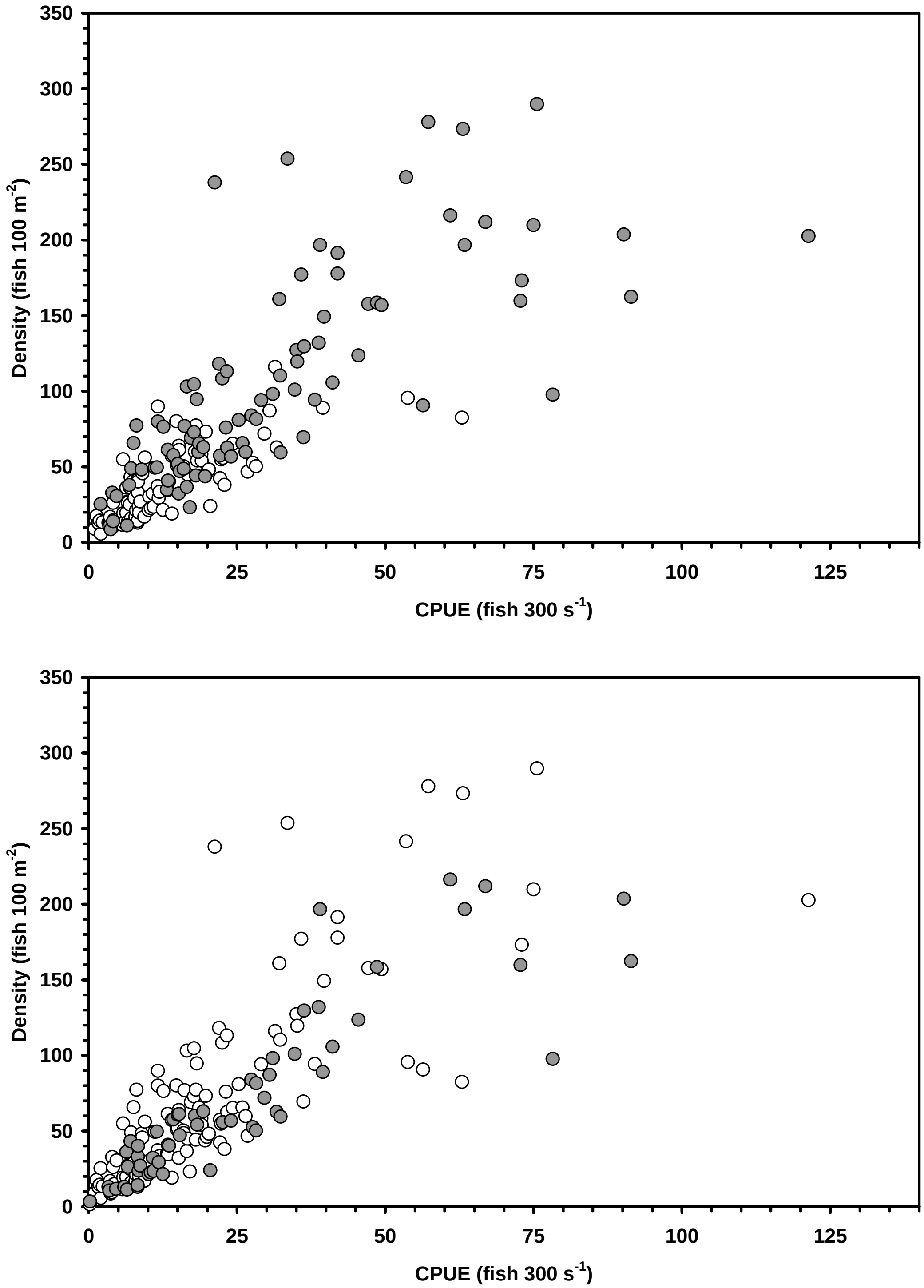


Figure 3. CPUE to density calibration data for the juvenile salmon electrofishing surveys of the Miramichi River, 1993 to 2003. In upper panel, grey bullets are fry, white bullets are parr. In lower panel, grey bullets are electrofisher type 12B, white bullets are type 11A.

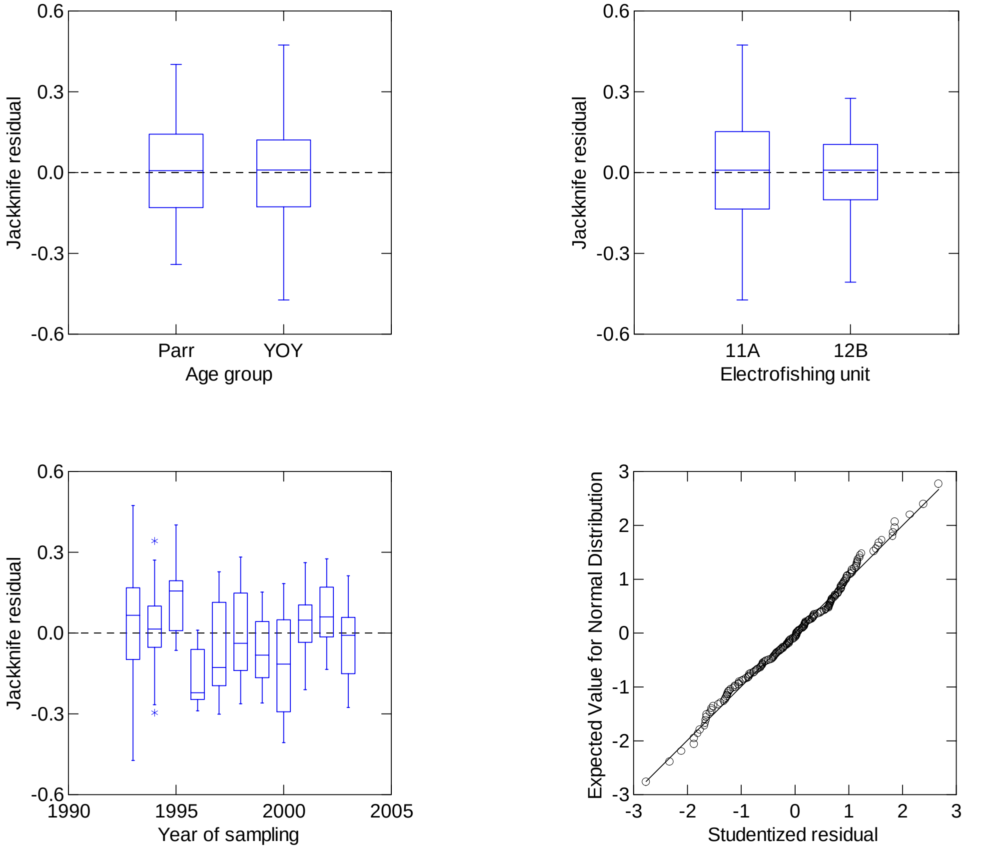


Figure 4. Box plots of the jackknife residuals relative to the main effects, age group (YOY = fry) and electrofishing unit, for the model with a common intercept and slope dependent on the interaction between age and electrofisher unit (model 10 in Table 4) (upper panels). The jackknife residuals relative to the year of sampling and the distribution of the studentized residuals relative to the expected distribution under the assumption of normality are shown in the lower panels.

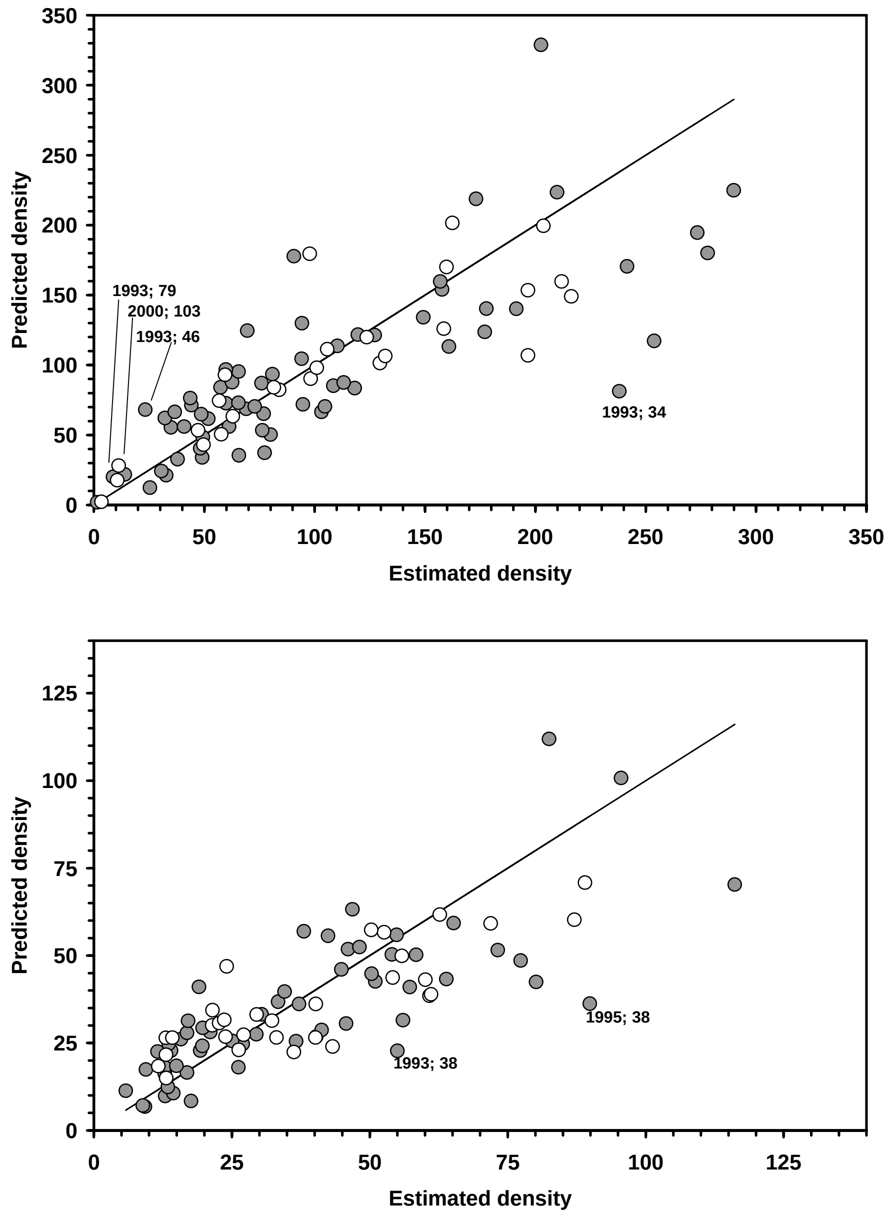


Figure 5. Predicted density from one of the retained models (Model 10 in Table 4) versus observed density for fry (upper panel) and parr (lower panel). The diagonal line is the 1:1 relationship. The points with year; site labeled correspond to the data for which the observed density was outside the 95% predicted interval from the model. Shaded symbols are observations for electrofisher unit 11A, open symbols are observations for electrofisher unit 12B.

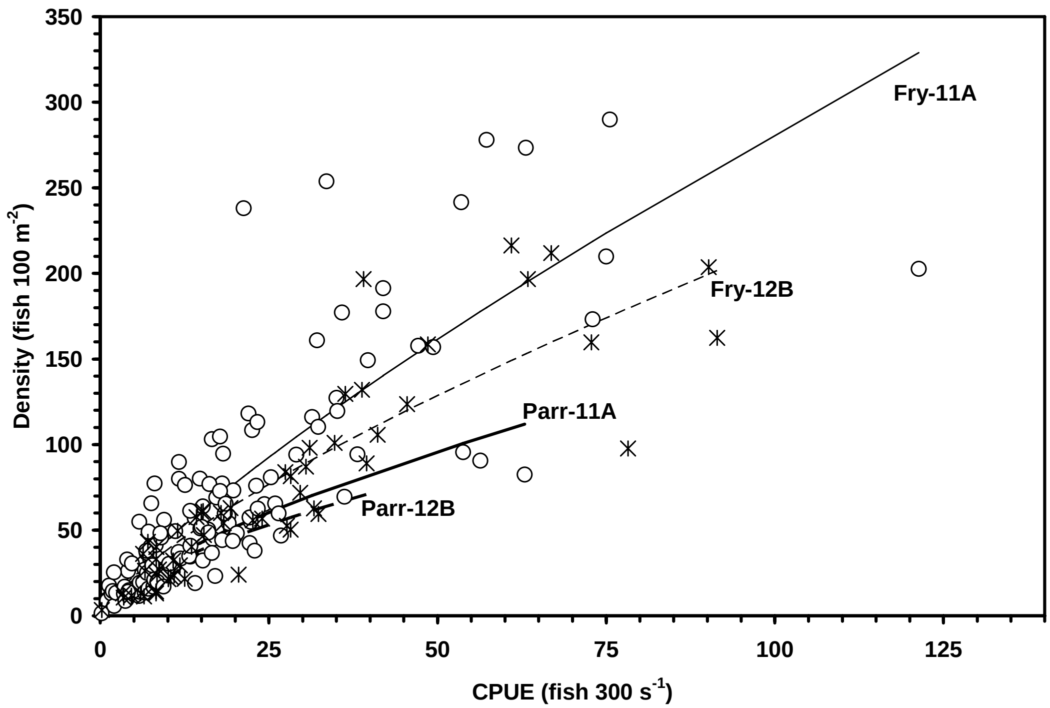


Figure 6. Median predicted relationships derived from retained model (model 10 from Table 4) for fry and parr for the electrofisher units type 11A and 12B. The open circles are data collected using type 11A and stars are data collected using type 12B.

Appendix 1. CPUE to density calibration data from the Miramichi River, 1993 to 2003. Sites are indicated on Figure 1. For age, YOY = fry.

Site	Area (m^2)	Effort (seconds)	Electrofisher Model	Year	Age	Removal Popn Estimate	CPUE Sweep Catch	Total Population	Density	CPUE (300 seconds)
7	137.9	456	11A	1993	Parr	24.3	2	26.3	17.6	1.3
7	115.6	382	11A	1994	YOY	35.4	6	41.4	30.6	4.7
9	200.3	377	11A	1993	Parr	39.4	8	47.4	19.7	6.4
9	200.3	377	11A	1993	YOY	65.7	5	70.7	32.8	4.0
9	214.1	844	11A	1994	Parr	32.0	12	44.0	14.9	4.3
9	214.1	844	11A	1994	YOY	156.0	50	206.0	72.9	17.8
31	210.0	296	11A	1993	Parr	101.1	20	121.1	48.1	20.3
31	210.0	296	11A	1993	YOY	144.9	17	161.9	69.0	17.2
34	84.1	254	11A	1993	Parr	10.8	3	13.8	12.8	3.5
34	84.1	254	11A	1993	YOY	200.2	18	218.2	238.0	21.3
38	164.0	310	11A	1993	Parr	90.2	6	96.2	55.0	5.8
38	164.0	310	11A	1993	YOY	125.2	13	138.2	76.3	12.6
38	164.5	720	11A	1995	Parr	147.8	28	175.8	89.9	11.7
38	164.5	720	11A	1995	YOY	131.7	28	159.7	80.0	11.7
38	198.8	471	11A	1998	Parr	113.8	22	135.8	57.2	14.0
38	198.8	471	11A	1998	YOY	119.0	29	148.0	59.9	18.5
38	204.2	444	11A	1999	Parr	133.1	36	169.1	65.2	24.3
38	204.2	444	11A	1999	YOY	428.5	111	539.5	209.9	75.0
38	232.0	577	12B	2000	Parr	166.8	57	223.8	71.9	29.6
38	232.0	577	12B	2000	YOY	370.6	140	510.6	159.8	72.8
38	242.0	600	12B	2001	Parr	210.7	61	271.7	87.1	30.5
38	242.0	600	12B	2001	YOY	137.3	48	185.3	56.7	24.0
38	209.8	754	12B	2002	Parr	126.0	45	171.0	60.1	17.9
38	209.8	754	12B	2002	YOY	171.1	71	242.1	81.6	28.2
40	193.2	299	11A	1993	Parr	88.3	9	97.3	45.7	9.0
40	193.2	299	11A	1993	YOY	100.2	15	115.2	51.9	15.1
40	180.9	452	11A	1994	Parr	83.3	30	113.3	46.1	19.9
40	180.9	452	11A	1994	YOY	118.4	28	146.4	65.5	18.6
40	155.2	443	11A	1995	Parr	62.6	11	73.6	40.3	7.4
40	155.2	443	11A	1995	YOY	39.5	3	42.5	25.4	2.0
40	153.5	336	11A	1996	Parr	24.2	8	32.2	15.8	7.1
40	153.5	336	11A	1996	YOY	67.0	22	89.0	43.6	19.6
40	174.4	509	11A	1997	Parr	45.7	7	52.7	26.2	4.1
40	174.4	509	11A	1997	YOY	24.5	7	31.5	14.0	4.1
40	222.3	318	11A	1998	Parr	43.8	9	52.8	19.7	8.5
40	222.3	318	11A	1998	YOY	108.1	17	125.1	48.6	16.0
40	211.4	406	11A	1999	Parr	80.5	31	111.5	38.1	22.9
40	211.4	406	11A	1999	YOY	147.0	49	196.0	69.5	36.2
40	193.1	509	12B	2000	Parr	25.2	14	39.2	13.1	8.3
40	193.1	509	12B	2000	YOY	393.1	153	546.1	203.6	90.2
40	184.0	319	12B	2001	Parr	92.5	30	122.5	50.3	28.2
40	184.0	319	12B	2001	YOY	1.0	0	1.0	0.5	0.0
40	162.2	570	12B	2002	Parr	38.7	16	54.7	23.9	8.4
40	162.2	570	12B	2002	YOY	163.9	66	229.9	101.0	34.7
40	173.0	610	12B	2003	Parr	55.8	22	77.8	32.3	10.8
40	173.0	610	12B	2003	YOY	99.8	29	128.8	57.7	14.3
43	89.1	307	11A	1993	Parr	8.4	4	12.4	9.4	3.9
43	89.1	307	11A	1993	YOY	33.8	7	40.8	37.9	6.8
44	173.9	382	11A	1993	Parr	23.3	3	26.3	13.4	2.4
44	173.9	382	11A	1993	YOY	106.5	17	123.5	61.2	13.4
46	210.4	299	11A	1993	Parr	40.1	14	54.1	19.1	14.0
46	210.4	299	11A	1993	YOY	49.0	17	66.0	23.3	17.1
46	186.3	626	11A	1994	Parr	21.5	12	33.5	11.5	5.8
46	175.8	944	11A	1997	Parr	16.3	3	19.3	9.3	1.0
46	175.8	944	11A	1997	YOY	0.0	0	0.0	0.0	0.0
46	117.0	1315	12B	2001	Parr	50.6	31	81.6	43.2	7.1

Appendix 1 (continued).

Site	Area (m^2)	Effort (seconds)	Electrofisher Model	Year	Age	Removal Popn Estimate	CPUE Sweep Catch	Total Population	Density	CPUE (300 seconds)
46	117.0	1315	12B	2001	YOY	4.0	1	5.0	3.4	0.2
46	228.6	1311	12B	2002	Parr	62.0	38	100.0	27.1	8.7
46	228.6	1311	12B	2002	YOY	1.0	0	1.0	0.4	0.0
46	294.4	1158	12B	2003	Parr	63.1	39	102.1	21.4	10.1
46	294.4	1158	12B	2003	YOY	0.0	0	0.0	0.0	0.0
54	338.9	636	11A	1994	Parr	45.9	14	59.9	13.5	6.6
54	338.9	636	11A	1994	YOY	118.3	28	146.3	34.9	13.2
54	300.1	546	11A	1995	Parr	81.0	12	93.0	27.0	6.6
54	300.1	546	11A	1995	YOY	359.1	64	423.1	119.6	35.2
55	111.9	586	11A	1995	Parr	.	14	n.a.	.	7.2
55	111.9	586	11A	1995	YOY	121.4	44	165.4	108.5	22.5
55	126.8	363	11A	1996	YOY	96.3	28	124.3	76.0	23.1
55	302.6	447	11A	1997	Parr	128.4	33	161.4	42.4	22.1
55	302.6	447	11A	1997	YOY	173.6	33	206.6	57.4	22.1
55	321.1	471	11A	1998	Parr	110.9	21	131.9	34.5	13.4
55	321.1	471	11A	1998	YOY	131.3	21	152.3	40.9	13.4
55	165.4	362	11A	1999	Parr	21.4	2	23.4	12.9	1.7
55	165.4	362	11A	1999	YOY	155.9	46	201.9	94.3	38.1
60	190.6	437	11A	1993	Parr	11.0	3	14.0	5.8	2.1
60	190.6	437	11A	1993	YOY	225.2	32	257.2	118.2	22.0
60	325.7	880	11A	1994	YOY	143.9	53	196.9	44.2	18.1
62	111.0	298	11A	1993	YOY	85.8	8	93.8	77.3	8.1
62	190.1	675	11A	1994	Parr	57.8	23	80.8	30.4	10.2
62	190.1	675	11A	1994	YOY	180.1	41	221.1	94.7	18.2
74	186.0	308	11A	1993	Parr	26.0	6	32.0	14.0	5.8
74	186.0	308	11A	1993	YOY	191.8	17	208.8	103.1	16.6
74	174.8	378	11A	1994	Parr	94.4	24	118.4	54.0	19.0
74	174.8	378	11A	1994	YOY	260.9	50	310.9	149.3	39.7
74	155.7	703	11A	1995	Parr	52.0	28	80.0	33.4	11.9
74	155.7	703	11A	1995	YOY	275.7	84	359.7	177.1	35.8
74	474.4	511	11A	1997	Parr	81.0	16	97.0	17.1	9.4
74	474.4	511	11A	1997	YOY	429.9	96	525.9	90.6	56.4
74	252.0	1144	11A	1998	Parr	161.0	58	219.0	63.9	15.2
74	252.0	1144	11A	1998	YOY	448.0	160	608.0	177.8	42.0
74	265.5	699	11A	1999	Parr	145.6	52	197.6	54.8	22.3
74	265.5	699	11A	1999	YOY	416.7	115	531.7	156.9	49.4
74	292.4	904	12B	2000	Parr	69.1	33	102.1	23.6	11.0
74	292.4	904	12B	2000	YOY	575.1	191	766.1	196.7	63.4
74	272.0	917	12B	2001	Parr	147.3	56	203.3	54.2	18.3
74	272.0	917	12B	2001	YOY	336.3	139	475.3	123.6	45.5
74	232.5	1004	12B	2002	Parr	142.1	51	193.1	61.1	15.2
74	232.5	1004	12B	2002	YOY	502.9	204	706.9	216.3	61.0
74	251.5	864	12B	2003	Parr	74.2	34	108.2	29.5	11.8
74	251.5	864	12B	2003	YOY	211.1	79	290.1	84.0	27.4
75	122.7	335	11A	1993	Parr	13.2	0	13.2	10.8	0.0
75	122.7	335	11A	1993	YOY	60.2	8	68.2	49.1	7.2
77	141.1	321	11A	1993	Parr	20.3	2	22.3	14.4	1.9
77	141.1	321	11A	1993	YOY	147.8	19	166.8	104.7	17.8
77	291.3	1039	11A	1994	Parr	73.0	24	97.0	25.1	6.9
77	291.3	1039	11A	1994	YOY	224.1	56	280.1	76.9	16.2
77	230.0	877	11A	1995	Parr	85.5	34	119.5	37.2	11.6
77	230.0	877	11A	1995	YOY	216.4	85	301.4	94.1	29.1
79	256.3	242	11A	1993	YOY	22.2	3	25.2	8.7	3.7
79	175.2	753	11A	1994	YOY	115.1	19	134.1	65.7	7.6
79	208.8	562	11A	1995	Parr	152.8	37	189.8	73.2	19.8
79	208.5	533	11A	1996	Parr	35.2	14	49.2	16.9	7.9

Appendix 1 (continued).

Site	Area (m^2)	Effort (seconds)	Electrofisher Model	Year	Age	Removal Popn Estimate	CPUE Sweep Catch	Total Population	Density	CPUE (300 seconds)
79	208.5	533	11A	1996	YOY	67.2	27	94.2	32.2	15.2
79	220.0	1063	12B	2001	Parr	88.5	48	136.5	40.2	13.5
79	220.0	1063	12B	2001	YOY	216.0	110	326.0	98.2	31.0
79	181.3	679	12B	2002	Parr	47.6	15	62.6	26.3	6.6
79	181.3	679	12B	2002	YOY	90.0	26	116.0	49.6	11.5
79	212.1	795	12B	2003	Parr	70.2	22	92.2	33.1	8.3
79	212.1	795	12B	2003	YOY	224.4	109	333.4	105.8	41.1
82	264.1	308	11A	1993	Parr	50.9	6	56.9	19.3	5.8
82	264.1	308	11A	1993	YOY	424.9	33	457.9	160.9	32.1
82	228.1	322	11A	1994	YOY	579.0	36	615.0	253.8	33.5
82	131.7	656	11A	1995	Parr	54.4	18	72.4	41.3	8.2
82	131.7	656	11A	1995	YOY	318.2	117	435.2	241.6	53.5
82	91.8	401	11A	1997	Parr	106.6	42	148.6	116.1	31.4
82	91.8	401	11A	1997	YOY	266.1	101	367.1	289.9	75.6
82	198.9	522	11A	1998	Parr	72.9	12	84.9	36.6	6.9
82	198.9	522	11A	1998	YOY	380.7	73	453.7	191.4	42.0
82	163.0	637	11A	1999	Parr	82.0	34	116.0	50.3	16.0
82	163.0	637	11A	1999	YOY	445.7	134	579.7	273.4	63.1
82	189.2	397	12B	2000	Parr	76.0	11	87.0	40.2	8.3
82	189.2	397	12B	2000	YOY	307.3	121	428.3	162.4	91.4
82	227.0	889	12B	2001	Parr	126.7	67	193.7	55.8	22.6
82	227.0	889	12B	2001	YOY	359.8	144	503.8	158.5	48.6
82	214.8	987	12B	2002	Parr	28.2	11	39.2	13.1	3.3
82	214.8	987	12B	2002	YOY	455.2	220	675.2	211.9	66.9
82	203.6	1181	12B	2003	Parr	73.8	25	98.8	36.2	6.4
82	203.6	1181	12B	2003	YOY	263.9	143	406.9	129.6	36.3
84	212.6	303	11A	1993	Parr	108.4	15	123.4	51.0	14.9
84	212.6	303	11A	1993	YOY	102.4	9	111.4	48.2	8.9
84	173.3	412	11A	1994	Parr	97.1	13	110.1	56.0	9.5
84	173.3	412	11A	1994	YOY	196.2	32	228.2	113.2	23.3
84	203.0	880	11A	1995	Parr	157.0	53	210.0	77.3	18.1
84	203.0	880	11A	1995	YOY	564.3	168	732.3	278.1	57.3
84	240.8	329	11A	1997	Parr	230.1	59	289.1	95.6	53.8
84	240.8	329	11A	1997	YOY	144.1	29	173.1	59.8	26.4
84	232.3	548	11A	1998	Parr	186.2	27	213.2	80.1	14.8
84	232.3	548	11A	1998	YOY	256.3	59	315.3	110.3	32.3
84	327.6	267	11A	1999	Parr	270.2	56	326.2	82.5	62.9
84	327.6	267	11A	1999	YOY	663.7	108	771.7	202.6	121.3
84	464.6	556	12B	2000	Parr	111.8	38	149.8	24.1	20.5
84	464.6	556	12B	2000	YOY	454.2	145	599.2	97.8	78.2
84	280.0	874	12B	2001	Parr	249.2	115	364.2	89.0	39.5
84	280.0	874	12B	2001	YOY	369.6	113	482.6	132.0	38.8
84	214.6	1161	12B	2002	Parr	130.5	58	188.5	60.8	15.0
84	214.6	1161	12B	2002	YOY	422.1	151	573.1	196.7	39.0
84	275.3	625	12B	2003	Parr	172.6	66	238.6	62.7	31.7
84	275.3	625	12B	2003	YOY	129.8	32	161.8	47.1	15.4
92	161.7	300	11A	1993	Parr	94.4	19	113.4	58.4	19.0
92	161.7	300	11A	1993	YOY	280.0	73	353.0	173.2	73.0
92	161.2	719	11A	1994	Parr	72.3	40	112.3	44.9	16.7
92	161.2	719	11A	1994	YOY	205.1	84	289.1	127.2	35.0
92	234.0	705	12B	2001	Parr	123.1	65	188.1	52.6	27.7
92	234.0	705	12B	2001	YOY	139.1	76	215.1	59.4	32.3
97	270.3	1463	11A	1994	Parr	24.0	5	29.0	8.9	1.0
97	270.3	1463	11A	1994	YOY	4.1	1	5.1	1.5	0.2
103	191.6	350	11A	1994	Parr	56.4	9	65.4	29.4	7.7
103	191.6	350	11A	1994	YOY	94.7	13	107.7	49.4	11.1

Appendix 1 (continued).

Site	Area (m^2)	Effort (seconds)	Electrofisher Model	Year	Age	Removal Popn Estimate	CPUE Sweep Catch	Total Population	Density	CPUE (300 seconds)
103	176.8	415	11A	1995	Parr	29.9	5	34.9	16.9	3.6
103	176.8	415	11A	1995	YOY	143.0	35	178.0	80.9	25.3
103	230.0	541	11A	1996	YOY	362.8	85	447.8	157.7	47.1
103	227.7	488	11A	1997	Parr	48.0	13	61.0	21.1	8.0
103	227.7	488	11A	1997	YOY	142.6	38	180.6	62.6	23.4
103	334.8	435	11A	1998	Parr	42.9	6	48.9	12.8	4.1
103	334.8	435	11A	1998	YOY	122.7	24	146.7	36.7	16.6
103	161.5	347	11A	1999	Parr	75.7	31	106.7	46.9	26.8
103	161.5	347	11A	1999	YOY	105.9	30	135.9	65.6	25.9
103	216.5	648	12B	2000	Parr	25.3	10	35.3	11.7	4.6
103	216.5	648	12B	2000	YOY	24.4	14	38.4	11.3	6.5
103	214.0	528	12B	2001	Parr	46.0	22	68.0	21.5	12.5
103	214.0	528	12B	2001	YOY	134.7	34	168.7	62.9	19.3
103	211.6	689	12B	2002	Parr	48.0	24	72.0	22.7	10.4
103	211.6	689	12B	2002	YOY	2.2	0	2.2	1.0	0.0
103	247.8	689	12B	2003	Parr	35.3	19	54.3	14.2	8.3
103	247.8	689	12B	2003	YOY	26.2	8	34.2	10.6	3.5
208	192.2	750	12B	2003	Parr	25.2	15	40.2	13.1	6.0
208	192.2	750	12B	2003	YOY	0.0	0	0.0	0.0	0.0