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Evaluation of age-specific and length-specific estimates of juvenile Atlantic salmon (*Salmo salar* L.) abundance in the Experimental Ponds Area as predictors of adult returns to the Gander River

by

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ABSTRACT

Models are evaluated which use age-specific and length-specific estimates of Experimental Ponds Area juvenile salmon abundance to predict total adult returns to the Gander River, Newfoundland, the following year. Restricting the juvenile estimate to age classes older than 2+, either singly or combined, resulted in lower statistical precision than using all age classes together. Length-specific models deleted the smaller juveniles from the population estimate starting with those ≤110 mm and then worked upwards in 10 mm increments. Restricting the juvenile estimate to fork lengths >120 mm provided adult return estimates with the greatest statistical precision and also produced a predicted 1996 adult return that was closer to the observed value. Incorporating the 1996 observed adult return into the length-specific models again resulted in maximum precision for the >120 mm fork-length model. This model predicts a 1997 Gander River adult return of 53,620 which is well above the conservation spawning requirement of 21,828 small salmon.

RÉSUMÉ

On évalue des modèles qui permettent d'évaluer, à partir d'estimations selon l'âge et la longueur de l'abondance de saumon juvénile dans le secteur des étangs expérimentaux, le total des retours adultes à la rivière Gander (Terre-Neuve) l'année suivante. Le fait de limiter l'estimation des juvéniles aux classes d'âge 2+, soit séparément soit de façon combinée, a entraîné une précision statistique plus faible que l'emploi de toutes les classes d'âge ensemble. Dans les modèles selon la longueur, on éliminait les plus petits juvéniles des estimations de la population en commençant avec ceux qui étaient ≤ 110 mm; on augmentait ensuite par paliers de 10 mm. La restriction de l'estimation des juvéniles à ceux présentant des longueurs à la fourche â >120 mm a fourni les estimations de retours d'adultes dont la précision statistique était la plus grande et donné la prédiction des retours d'adultes en 1996 la plus proche des valeurs observées. L'inclusion du retour d'adultes observé pour 1996 aux modèles selon la longueur a encore entraîné un maximum de précision pour le modèle selon la longueur à la fourche de plus de 120 mm. Ce modèle prédit le retour de 53 620 adultes dans la rivière Gander en 1997, ce qui dépasse largement les besoins de la fraye pour la conservation (21 828 petits saumons).

Introduction

The number of adult salmon returning to the Gander River should be primarily a function of the number of smolts migrating to sea the previous summer and their subsequent mortality rate at sea because the returning adults are largely one-sea-winter fish. A marine survival ratio index has been developed which is calculated as the number of adult salmon returning to the Gander River divided by the total juvenile salmon populations in the Experimental Ponds Area at the headwaters of the river in the previous spring. This survival ratio index increased more than four-fold following closure of the commercial fishery in 1992 and has been used to predict adult salmon returns to the Gander River one year in advance (Ryan et al. 1995, 1996, 1997).

The probability that a particular juvenile salmon parr will undergo smoltification and migrate to sea increases with both age and size. It is thus possible that an age-specific or length-specific estimate of juvenile salmon abundance in the Experimental Ponds Area might provide a more precise predictor of subsequent adult returns given that both the size and age composition characteristics of the juvenile populations are known to vary among years (Ryan 1990). It would be expected that years with unusually high proportions of younger-than-average or smaller-than-average juveniles would produce overestimates of adult returns relative to average conditions and vice versa.

In this paper we calculate new historical marine survival indices based on age-specific and length-specific subsets of the juvenile populations for the 1991-1994 period and then compare Gander River adult returns projected from the 1995 juvenile census with those actually observed in 1996. We evaluate the effect of using the age- and length-specific juvenile data on the precision of the estimates as represented by their confidence intervals. This provides a measure of how well the models fit the reference period data. We then incorporate the 1996 adult return data into the reference period and use the spring 1996 juvenile data to predict 1997 adult returns to the Gander River.

Methods

Juvenile Study Areas

Headwater and Spruce ponds are shallow (mean depth 1.1 and 1.0 m, respectively), dilute (mean conductance 35 uS . cm^{-1}), brown-water lakes within the Department of Fisheries and Oceans Experimental Ponds Area (EPA) at the headwaters (48^{0}19'N; 55^{0}28'W) of the Gander River system. The physical and chemical characteristics of the EPA have been detailed by Ryan and Wakeham (1984). The history of ecological assessment in the EPA has been reviewed by Ryan et al. (1994). Reviews of the population dynamics of salmon in the EPA are available in Ryan (1993a, b) and references therein.

The closest known major concentration of salmon spawning substrate is about 12 km downstream of Spruce Pond (Ryan and Wakeham 1984). In addition to anadromous Atlantic salmon, other fishes present in these lakes are the brook trout (Salvelinus fontinalis), the American eel (Anguilla rostrata), and the threespine stickleback (Gasterosteus aculeatus).

Adult Counting Sites

An adult counting fence has been operated on the main stem of the Gander River since 1989. Total adult small salmon returns to the Gander River system have been calculated as the sum of the number passing through the fence and the number angled downstream of the fence (O'Connell and Ash 1994). We have used adult return counts for the post commercial fishery period of 1992-1996 as updated by O'Connell et al. (1997).

Juvenile Salmon Abundance

Population structures of juvenile salmon were determined in the spring and fall from 1991-96 in Spruce and Headwater ponds using fyke nets and Schnabel multiple mark-recapture techniques as detailed by Ryan (1990). The juvenile salmon captured during the spring censuses were assigned to age classes based on a subset of scale-aged fish from each pond and the resulting length-age relationships. The proportion of the total catch in each age class was then applied to the total population estimate for the pond to calculate age-specific population size. The juvenile salmon captured during the spring census were also apportioned into 10 mm fork length size-class intervals for each pond. The proportion of the total catch exceeding a particular size was calculated and applied to the total population estimate to determine the length-specific population estimate. The first cut-off point used was >110 mm. Subsequent estimates increased the cut-off length in 10 mm increments.

The various age-specific and length-specific population estimates for Spruce and Headwater Ponds were combined and then used to calculate marine survival ratio indices for the four post-commercial-fishery-closure years of 1992-1995 (juvenile years 1991-1994). Means and standard deviations were calculated for the ratios produced from each age-specific or length-specific class and these were then used to estimate 1996 returns with corresponding 95% confidence limits based on the 1995 spring juvenile data. Finally, the 1996 adult returns were added to the reference period (juvenile years 1991-1995) and the length-specific models were re-calibrated to provide predicted adult returns for 1997 based on the spring 1996 juvenile abundance data. A similar analysis could not be performed for the age-specific models because the 1996 age data were not yet available.

Results and Discussion

Age-Specific Estimates

The pond juvenile populations in the spring were always composed of fish older than two years (age 2+ and up). Restricting the survival ratio index to ages > 3 (3+ and up) and ages > 4 (ages 4+ and up) or to single age classes (3+, 4+) had minimal effect on the 1996 predicted return (Table 1) and resulted in a widening of the confidence interval (Figure 1). The wider confidence intervals indicate that the age-specific models fit the prior observations of adult returns less well than did the original model containing all age classes (Ryan et al. 1997). It had been anticipated from field observations that the 1995 juvenile population would have had an unusually high proportion of younger fish which would have lead to overestimation of 1996 adult returns. This turned out not to be the case because the strong 2+ year class was balanced by an unusually strong 4+ year class in 1995 with the result that the proportion of younger fish in 1995 was not atypical of the 1991-1994 reference period (Table 2).

Length-Specific Estimates

Restricting the juvenile estimates to size categories ranging from > 110 mm to > 170 mm in 10 mm increments all resulted in lower predicted 1996 returns compared to that using the total juvenile population (Table 1, Figure 2). Statistical precision (narrowness of confidence interval) was greatest for predictions based on the juvenile size range > 120 mm (Figure 2) indicating that this model provided the best fit to the original data for the 1991-1994 reference period. This model also produced a 1996 adult return estimate that was closer to the observed return and thus statistically more accurate. These observations suggest that removal of the smaller juveniles from the population estimate is a simple means of improving predictive power for adult returns the following year.

Incorporation of the 1996 adult return observation into the reference period (now juvenile years 1991-1995) enables prediction of 1997 adult returns from the spring 1996 juvenile data (Table 3). The confidence intervals were again narrowest for the model using juveniles >120mm (Figure 3). This model predicts a 1997 Gander River adult return of 53,620 which is more than double the conservation requirement of 21,828 small salmon. This prediction of a very large adult return is reinforced by qualitative observations of greatly increased smolt abundance in smolt traps at the Gander River adult counting fence during summer 1996 (M.F. O'Connell, pers. obs).

Comparison of predicted and actual returns during a period of major change in juvenile stock size, such as that initiated by closure of the commercial fishery in 1992, will serve to better delineate the relationship of juvenile abundance to adult returns. Monitoring EPA juvenile salmon abundance by age and length class during this period of population increase, combined with adult return estimates from the river as a whole or extrapolated from Salmon Brook, should provide a reasonable basis for establishing the utility of these estimates for the prediction of adult salmon returns to the Gander River one year in advance. These observations will also allow an analysis for potential density-dependent effects on juvenile recruitment and subsequent sea-survival.

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References

O'Connell, M. F. and E. G. M. Ash. 1994. Status of Atlantic salmon (Salmo salar L.) in Gander River, Notre Dame Bay (SFA 4), Newfoundland, 1993. DFO Atlantic Fisheries Research Document 94/50. 17 p.

O'Connell, M. F., D. G. Reddin, and E. G. M. Ash. 1997. Status of Atlantic salmon (Salmo salar L.) in Gander River, Notre Dame Bay (SFA 4), Newfoundland, 1996. DFO Atlantic Fisheries Research Document 97/ (in preparation).

Ryan, P. M. 1990. Sizes, structures, and movements of brook trout and Atlantic salmon populations inferred from Schnabel mark-recapture studies in two Newfoundland lakes. Amer. Fish. Soc. Symp. 7: 725-735.

Ryan, P. M. 1993a. An extrapolation of the potential emigration of Atlantic salmon (Salmo salar) smolts from Newfoundland lakes in the absence of brook trout (Salvelinus fontinalis). p.203-207. In R. J. Gibson and R. E. Cutting (eds.) The production of juvenile Atlantic salmon in natural waters. Can. Spec. Publ. Fish. Aquat. Sci. 118: 262 p.

Ryan, P. M. 1993b. Natural lake use by juveniles: a review of the population dynamics of Atlantic salmon in Newfoundland lakes. p.3-14. In Ryan, P. M., M. F. O'Connell, and V. A. Pepper. 1993. Report from the workshop on lake use by Atlantic salmon in Newfoundland, Canada. Can. MS Rep. Fish. Aquat. Sci. 2222: iv + 54 p.

Ryan, P. M., R. Knoechel, and M. F. O'Connell. 1994. Population sizes of juvenile Atlantic salmon (Salmo salar L.) in lakes of the Experimental Ponds Area as a measure of stock recovery in the Gander River, Newfoundland. DFO Atlantic Fisheries Research Document 94/13. 17 p.

Ryan, P. M., R. Knoechel, M. F. O'Connell, and E. G. M. Ash. 1996. Ratio of adults to Experimental Ponds Area juveniles in a prediction of Atlantic salmon (Salmo salar L.) returns to the Gander River, Newfoundland in 1996. DFO Atlantic Fisheries Research Document 96/47. 19 p.

Ryan, P. M., R. Knoechel, M. F. O'Connell, and E. G. M. Ash. 1997. Ratio of adults to Experimental Ponds Area juveniles in a prediction of Atlantic salmon (Salmo salar L.) returns to the Gander River, Newfoundland with a projection of adult returns in 1997. DFO Atlantic Fisheries Research Document 97/(in press).

Ryan, P. M., R. Knoechel, M. F. O'Connell, E. G. M. Ash, and W. G. Warren. 1995. Atlantic salmon (Salmo salar L.) stock recovery in the Gander River, Newfoundland with projections to 1999. DFO Atlantic Fisheries Research Document 95/95. 16 p.

Ryan, P. M., and D. Wakeham. 1984. An overview of the physical and chemical limnology of the Experimental Ponds Area, central Newfoundland, 1977-82. Can. Tech. Rep. Fish. Aquat. Sci. 1320: v + 54 p.

Table 1. Age-specific population structure of Experimental Ponds Area juvenile salmon in the spring of years 1991-1995. Numbers in parentheses are percentages of the total population.

	Age 2+	Age 3+	Age 4+ and older	Total Population
1991	466 (19.7)	884 (37.4)	1012 (42.8)	2362
1992	599 (19.5)	1443 (47.0)	1027 (33.5)	3069
1993	213 (8.6)	1258 (50.9)	999 (40.4)	2470
1994	469 (19.8)	430 (18.1)	1471 (62.1)	2370
1995	864 (19.2)	1718 (38.2)	1910 (42.5)	4492

Table 2. Projected 1996 Gander River adult returns based on age-specific and length-specific EPA juvenile population estimates for spring 1995.

Category	Adult Return Prediction	95% Confidence Interval
Age Class		
≥2 (= all)	37014	23835 - 50193
≥3	36207	18048 - 54366
≥4	36634	9642 - 63626
Length Class (mm)		
>0 (= all)	37014	23835 - 50193
>110	32682	17285 - 48080
>120	31757	20139 - 43375
>130	32483	18616 - 46351
>140	33694	15902 - 51486
>150	33539	14767 - 52311
>160	31732	8115 - 55350
>170	33746	-655 - 68157

Table 3. Projected 1997 Gander River adult returns based on length-specific EPA juvenile population estimates for spring 1996.

Length Class (mm)	Adult Return Prediction	95% Confidence Interval
>0 (= all)	50103	21904 - 78303
>110	48814	23298 - 74330
>120	53620	29883 - 77357
>130	55825	28280 - 83371
>140	59751	25204 - 94299
>150	63478	25777 - 101178
>160	70978	22757 - 119207
>170	70029	6347 - 133712

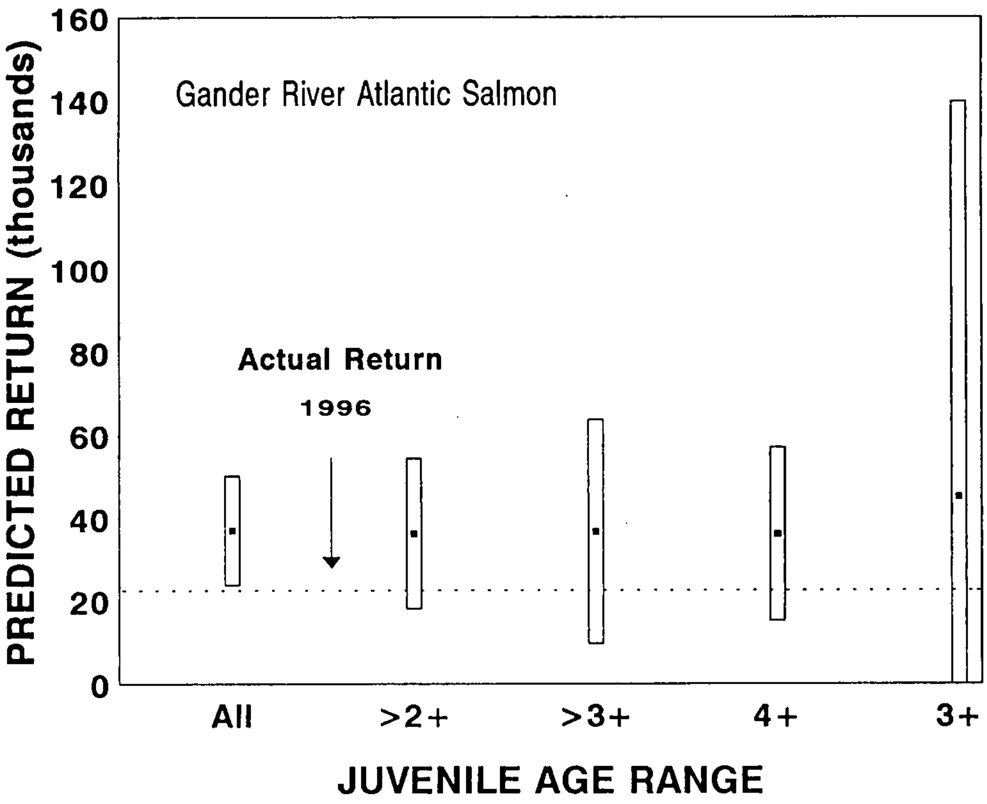

Figure 1. Predicted 1996 Gander River adult salmon returns and 95% confidence intervals based on age-specific juvenile abundance in Spruce and Headwater ponds in 1995. Estimates are from models including: all ages (all), ages 3 and higher (>2+), ages 4 and higher (>3+), age 4+ alone (4+), and age 3+ alone (3+). The greatest precision (narrowest confidence interval) is achieved with the all-ages model. The actual 1996 adult return to the Gander River is indicated by the dashed line.

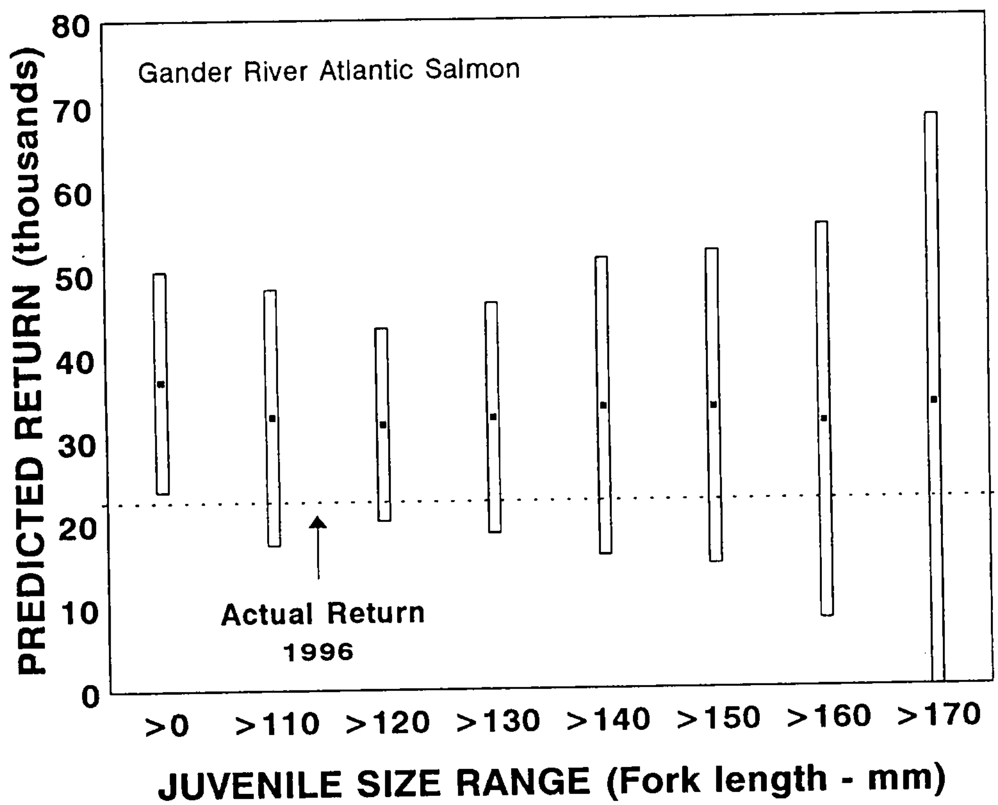

Figure 2. Predicted 1996 Gander River adult salmon returns and 95% confidence intervals based on size-specific juvenile abundance in Spruce and Headwater ponds in 1995. Estimates are from models including all fork length sizes (>0), and for size ranges excluding the smaller fish starting with those $\leq$ 110 mm (>110) and then working upwards in 10 mm increments. The greatest precision (narrowest confidence interval) is achieved with the >120 mm size-class model. The actual 1996 adult return to the Gander River is indicated by the dashed line.

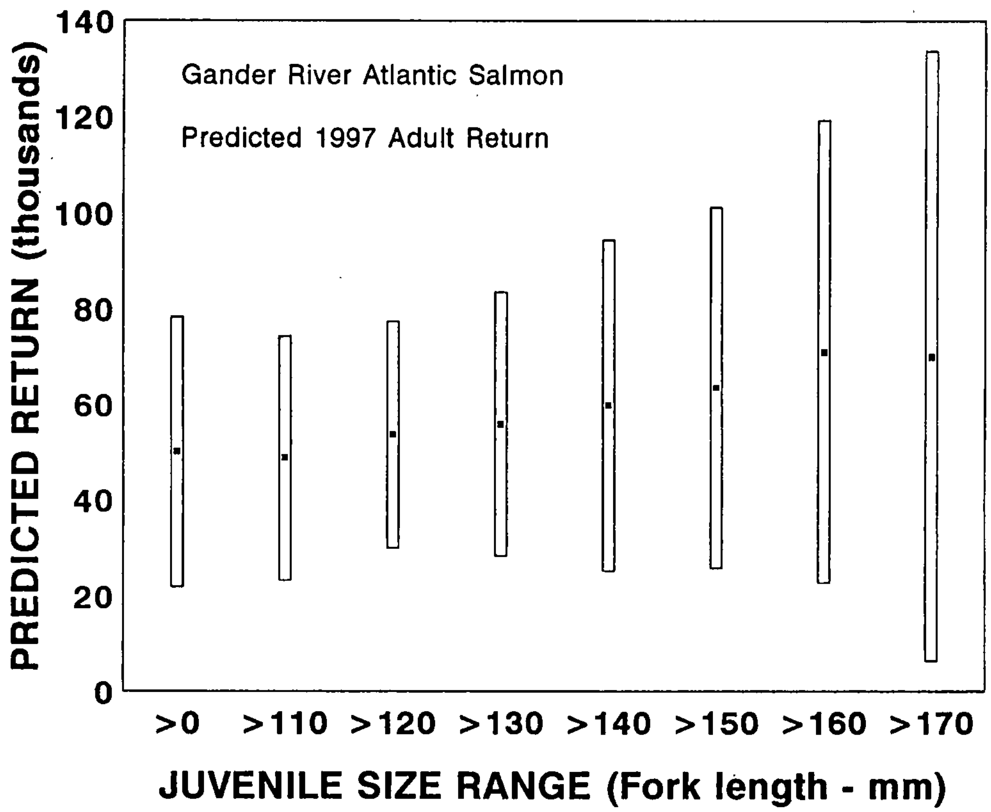

Figure 3. Predicted 1997 Gander River adult salmon returns and 95% confidence intervals based on size-specific juvenile abundance in Spruce and Headwater ponds in 1996. Estimates are from models including all fork length sizes (>0), and for size ranges excluding the smaller fish starting with those $\leq$ 110 mm (>110) and then working upwards in 10 mm increments. The greatest precision (narrowest confidence interval) is achieved with the >120 mm size-class model.