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Prediction of 2-SW and older Atlantic salmon returning to the Millbank trap, Miramichi River, New Brunswick

by

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[1]This series documents the scientific basis for fisheries management advice in Atlantic Canada. As such, it addresses the issues of the day in the timeframes required and the Research Documents it contains are not intended as definitive statement on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Significant predictive equations for return of 2-SW and older Atlantic salmon to the Millbank trap, Miramichi River, New Brunswick, were developed from the number and their percent female composition of 1-SW fish returning in the previous year. Percentage female composition is shown to be a measure of the degree to which 'salmon' of both sexes have matured after one winter at sea and conversely the degree to which some have remained at sea to mature first after two winters. January-February sea water temperatures from a single "station" support the hypothesis that winter temperatures are an important environmental operant on age at first maturity for Atlantic salmon.

RESUME

On a construit des équations prévisionnelles concernant les retours de saumons atlantiques de 2 ans en mer et davantage à la trappe de Millbank, sur la rivière Miramichi (Nouveau-Brunswick). On s'est basé sur le nombre et le pourcentage de femelles parmi les saumons d'un an en mer qui étaient revenus l'année d'avant. On démontre que le pourcentage des femelles est un indice du degré auquel les sujets des deux sexes se sont développés sexuellement après un hiver en mer et, inversement, jusqu'à quel point certains sont demeurés en mer pour atteindre la maturité les premiers après deux hivers. Les températures de l'eau en janvier-février à une seule "station" appuient l'hypothèse que les températures hivernales sont un facteur important de l'environnement qui influe sur l'âge de première maturité du saumon atlantique.

INTRODUCTION

In the absence of stock recruitment models for Atlantic salmon of the Maritime Provinces, 1-SW salmon enumerated at the Millbank monitoring trap, Miramichi River, New Brunswick in year n, have been used to estimate the number of 2-SW fish of the same smolt-class returning in year n+1.

Earlier simple predictions of 2-SW and older salmon returning to Millbank were based on correlations between the numbers of 1-SW salmon (year n) and 2-SW and older fish in year n+1. An improved regression equation was later derived assuming a multiplicative log-normal distribution of random noise, i.e., higher absolute variation in total adult returns as abundance of seaward migrants increase (Peterman, 1981). This document reports on an improvement of the log-normalized regression by inclusion of a third variable --- percentage females in the 1-SW returns.

METHODS

Data used in the analysis (Table 1) were collected between 1971-81 at the Millbank estuarial sampling trap on the Miramichi River. No commercial salmon fishery operated in or near Miramichi Bay between 1972 and 1980. Salmon were reportedly taken as by-catch in other gear 1972-'80, but the magnitude and differential effect on numbers of salmon and grilse captured at Millbank are unknown. In 1981 a re-opened commercial fishery taking mostly 2-SW fish and a river dredging project were assumed to have affected the capture of 2-SW and older fish at Millbank. Hence the model was tested with two estimates of what the 1981 count at Millbank would have been in the absence of these two factors.

The trap, its operation, and sampling regimes since 1954 are described in detail by Turner and Schofield (1979). Trapping was carried out during the entire migration period, i.e., mid-May to early November. Fish-up occurred at least once and usually twice daily, 7 days each week. Some 1-SW and 2-SW and older salmon were aged, weighed, and measured throughout the season. (Ageing revealed that while all but a few 2-SW and older salmon had been at sea for just two winters, some males, frequently less than 10 percent, had first spawned after only one winter at sea.) Every tenth 1-SW and 2-SW and older fish was sexed. Sample fish arriving previous to August were sacrificed and sexed internally while those arriving later were sexed externally.

Multiple regression was done using SPSS. Options 4 and 5 plotted standardized residuals and calculated the Durbin-Watson statistic-Von Neumann ratio for auto-correlation.

RESULTS

Results of three separate regression analyses appear in Table 2. The first case uses 752 2-SW and older fish for the 1981 trap count --- the best estimate of the number that would have been captured at Millbank without a commercial fishery or dredging (for derivation of value see footnote Table 1). The regression with the addition of the arcsin percentage female variables (X_2) produced significant results which account for an additional 27.9% of the variation.

The second case (Table 2), using only 463 2-SW and older fish for 1981, accounts only for the effect of dredging. Recorded commercial landings of 2-SW and older fish 1981 are regarded as being similar to unrecorded and unaccounted for by-catch occurring 1972-1980. The significance of the overall regression coefficient is reduced from case one, with the X_2 variable now accounting for only an additional 18.3% of the variation. Most significantly the tenth data set, that for 1980 (Table 1), was identified as an outlier.

A third case (Table 2) was calculated with the omission of the 1980 data (Table 1). Significance was approximately restored to that of the first case with the X_2 variable accounting for 32.4% of the variability.

DISCUSSION

All analyses indicated that percentage females among 1-SW salmon made a significant contribution to the "predictive" equations. If the by-catch in 1982 were replaced by the legal commercial fishery or if the by-catch during the salmon-ban years were weighted toward the capture of 2-SW and older fish as in the 1981 commercial fishery, it would be inappropriate to reconstitute Millbank trap counts for 1981 with commercial-caught fish. However, because the second analysis still includes correction for the effects of dredging in 1981 and the 1980 data set proves to be an outlier relative to the other 9 data sets, the third case is the most appropriate "predictive" model.

The two-variable log-normalized regression with a positive regression coefficient implies that, as the number of 1-SW returns increased at Millbank, so too would the numbers of 2-SW and older fish in year n+1. Factors contributing to greater returns of 1-SW fish, such as more smolts out in year n-1 and/or better sea survival, affected in a proportionally constant manner the numbers of salmon that would return after two winters at sea. That is to say, the model did not allow the marine environment to affect the determination of whether a salmon would return after one or two winters at sea.

The improved three-variable log-normalized regression with a negative regression coefficient for the percentage 1-SW females indicates (barring differential mortality) that, with increasing numbers of females among the returning 1-SW fish, fewer salmon remain at sea to return as 2-SW fish.

While there is evidence that age and size at sexual maturity (grilse vs salmon) in Atlantic salmon has some genetic basis (Elson, 1973; Naevdal *et al.* 1976; Ritter and Newbould, 1977), the potential for modification of age *at* first maturity by the marine environment (temperature) has only recently been hypothesized Saunders et al. (1982). The postulate arising from this analysis is that the percentage females among grilse may be an indirect measure of an environmental operant which affects initiation of sexual maturation and consequently the proportion of fish returning as 2-SW and older salmon or 1-SW salmon (neither length nor weight data for 1-SW fish sampled at Millbank were variable enough to be regarded as an index of environment affecting maturity through growth). In general, the higher the percentage of females among grilse, the higher the proportion of both sexes of that smolt-class which matured after only one winter at sea.

A simplistic explanation of how percentage female grilse measures the influence of environment in affecting salmon to return after one winter at sea is illustrated with the following example and these assumptions:

1. 360 units of salmon from smolts of sex ratio 0.5 female:0.5 male are allocated in the following proportions.

Disposition		Maturing 1-SW	Non-Maturing 1-SW	2-SW
Harvested in W. Greenland	(DF)[1]		0.10	
Harvested in Newfoundland	(DF)	0.05	0.10	0.10
Harvested in Maritimes, P.Q.	(DF)	0.03		0.02
Return to Home River	(HR)[2]	0.42		0.18
		0.50	0.20	0.30

[1]Distant Fisheries (Fig. 1)
[2]Home River fisheries and escapement (Fig. 1)

2. Genetics and a "normal" environment pre-destine that 1-SW returns appear in a ratio of 0.2 female:0.8 male.

3. An "abnormal" environment causes 10% of each of the female and male salmon which were destined to mature after two winters at sea to mature instead after one winter at sea.

4. Exclusion of natural mortality from the model does not significantly alter the results.

Figure 1a illustrates the consequences of assumptions 1 and 2 giving 36.0 units of 1-SW females and 144.0 units of 1-SW males (total 180.0) at a sex ratio of 0.2:0.8. The remaining 144.0 units of females and 36.0 units of males (total 180.0) become 2-SW fish of sex ratio 0.8:0.2.

Figure 1b illustrates the impact of an additional 10% of otherwise 2-SW salmon maturing as 1-SW fish. One sea-winter fish now number 50.4 females and 147.6 males (total 198.0) and their sex ratio becomes 0.26:0.74. Only 162.0 fish remain for the 2-SW component. Home river returns after two winters at sea are fewer (assuming all 2-SW allocations proportionately share the 10% loss) and the sex ratio remains at 0.8:0.2 as in Fig. 1b. Annually variable sex ratios among 2-SW fish e.g. mean % female $_{1972\text{-}81}$ Miramichi = 83.57 $\pm$5.36 (2 SE), can be simulated by altering the genetic determinants influencing the proportion of salmon that will mature after one winter at sea (0.5 value of assumption 1), the base proportion that will mature as females under "normal" environmental conditions (0.2 value of assumption 2), and the proportion of females:males among the smolt class (0.5:0.5 value of assumption 1).

Saunders et al. (1982) working with smolts of the same stocks cage-reared at facilities in Passamaquoddy Bay, New Brunswick, and sea-ranched from a nearby river (i.e. Saint John River, N.B.) and which produced different incidences of grilse suggested that low seawater temperatures previous to March-April are likely a strong influence on age at first maturity. Analysis of "MEDS" data from Station 27 near St. John's, Newfoundland, indicates that, of monthly mean water temperatures for November to March at 5 and 10 m depths, a mean for January-February in year n at 5 m depth contributed the greatest addition (X_1 = 0.7996; X_2 = -0.1843; const = 0.1145; R^2 = 0.6897) to the original two-variable predictor of 2-SW fish (1981=752) from 1-SW fish. These data accounted for an additional 12% of the variation compared to the 28% increase exhibited by percentage females among grilse. Excluding the 1980/1981 Millbank counts, the values were X_1 = 0.7902; X_2 = -0.1816; const = 0.1543; R^2 = .6839. These data also accounted for an additional 12% of the variation relative to the two-variable predictor of case 3, Table 2. The correlation coefficient between the January-February mean temperatures and percentage females among 1-SW returns, was 0.58 (p. 05 = 0.63) 1971-80, and 0.61 (p. 05 = 0.67) 1971-79. However, a similarly weak positive correlation between year and percentage females and therefore temperature and years suggests that the increase in percentage females over time could as easily have resulted from time-related events.

Mean water temperatures for January-February were all less than the -0.7°C lower lethal level for salmon (Saunders et al. 1975), and therefore these can only be viewed as a potential indicator of "hard" and "easy" winters. The negative regression coefficient indicates that high winter temperatures result in fewer virgin 2-SW fish, i.e., more salmon matured after just one winter at sea. This tendency conforms to the hypothesis of Saunders et al. (1982) for salmon cage-reared in Passamaquoddy Bay.

Further investigation of the influence of sea-water temperatures on maturation may contribute to better stock return forecasts for stocks which have not been sexed and ultimately to a better understanding of annual variations in salmon stock abundance and hence improved stock forecasts.

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Table 1. Numbers of 1-SW and 2-SW and older salmon and percentage of females in 1-SW fish captured at the Millbank sampling trap, 1971-81.

Year	1-SW Year n	2^{+}-SW Year n+1	1-SW %
1971	1962	1151	11.0
1972	2543	1132	22.0
1973	2450	1791	16.9
1974	4038	1208	30.2
1975	3548	943	27.4
1976	4939	1934	24.1
1977	1505	693	22.8
1978	1268	318	37.4
1979	2500	1093	27.4
1980	2139	752[1]	19.3

[1]Estimate includes; a) correction of trap catch (199) as affected by river dredging with regression of ratio 2^{+}-SW salmon to 1-SW salmon in federal sport catch statistics (X) 1972-80 on ratio of 2^{+}-SW salmon to 1-SW salmon at Millbank (Y), 1972-80, i.e., $Y = 0.0549 + 0.695X$, $r = 0.95$ and $Y_{1981} = 463$, and b) 4.5%[2] of estimated 6420 2^{+}-SW salmon taken in the 1981 commercial fishery.

[2]Efficiency rate of the Millbank trap derived and used in a previous Miramichi assessment wherein fry densities could be used to back-calculate eggs and ultimately adult spawning escapement which when totalled with sport catch and estimated losses could be treated as the total pool of fish which Millbank sampled. Principles and parameters included: (1) fry counts were an index of escapement [total adults (X) in year n were correlated with fry (Y) in year n+1, 1971-79; $Y = 2.8873 + .0012X$, $r = 0.77$, $p < 0.02$], (2) a relationship between potential egg deposition (X) and resultant fry (Y) in the Tobique River, Saint John 1970-'79; $Y = 0.551 + 0.083X$, $r = 0.92$, $p < 0.01$, (3) an estimate of 46,801,715 m^2 of river substrate, (4) 2-SW salmon and older:1-SW salmon ratios determined at Millbank, 1971-'79, (5) male:female sex ratio of 0.14:0.86 2-SW and older salmon and 0.78:0.22 for grilse, (6) mean weights of 1.6 and 4.5 kg for female 1-SW fish and 2-SW and older salmon respectively, and egg capacity of 1760/kg female and (7) a loss of 2100 fish to poaching and disease.

Table 2. Results of regression analyses using one and two independent variables for Millbank salmon data of Table 1. Case (1) Y_{1981} = 752; Case (2) Y_{1981} = 463; Case (3) Y_{1981}, X_1 and $X_{2,1980}$ deleted.

Y = $\log_{10}$ number of 2-SW salmon, yr n+1
X_1 = $\log_{10}$ number of 1-SW salmon, yr n
X_2 = arcsin percentage female 1-SW salmon, yr n

Variable		Regression coef.	SE	F-value	Signif.
Case 1	X_1	0.9169	0.2814	10.6166	0.012
	Constant	-0.1157	0.9565	0.1046	
					r^2 = 0.5702
	X_1	0.9320	0.1780	27.4040	0.001
	X_2	-0.0232	0.0064	12.9990	0.009
	Constant	0.5065	0.6291	.6481	
					R^2 = 0.8496
Case 2	X_1	0.9614	0.3255	8.7233	0.018
	Constant	-0.2876	1.1064	0.0656	
					r^2 = 0.5216
	X_1	0.9747	0.2734	12.7137	0.009
	X_2	-0.2063	0.0099	4.3481	0.076
	Constant	0.2649	0.9660	.0752	
					R^2 = 0.7049
Case 3	X_1	0.9022	0.2998	9.0599	0.020
	Constant	-0.0589	1.0211	.0033	
					r^2 = 0.5641
	X_1	0.9013	0.1636	30.3443	0.002
	X_2	-0.0251	0.0060	17.4920	0.006
	Constant	0.6795	0.5847	1.3507	
					R^2 = 0.8887

Residuals:	Case 1, n = 10	Case 2, n = 10	Case 3, n = 9
Number of 2 SD outliers	0	1	0
Number positive	5	5	5
Number negative	5	5	4
Number of run signs	7	7	6
Durbin-Watson test	2.1466	1.9811	2.0368
Von Neumann ratio	2.3851	1.7829	1.8105

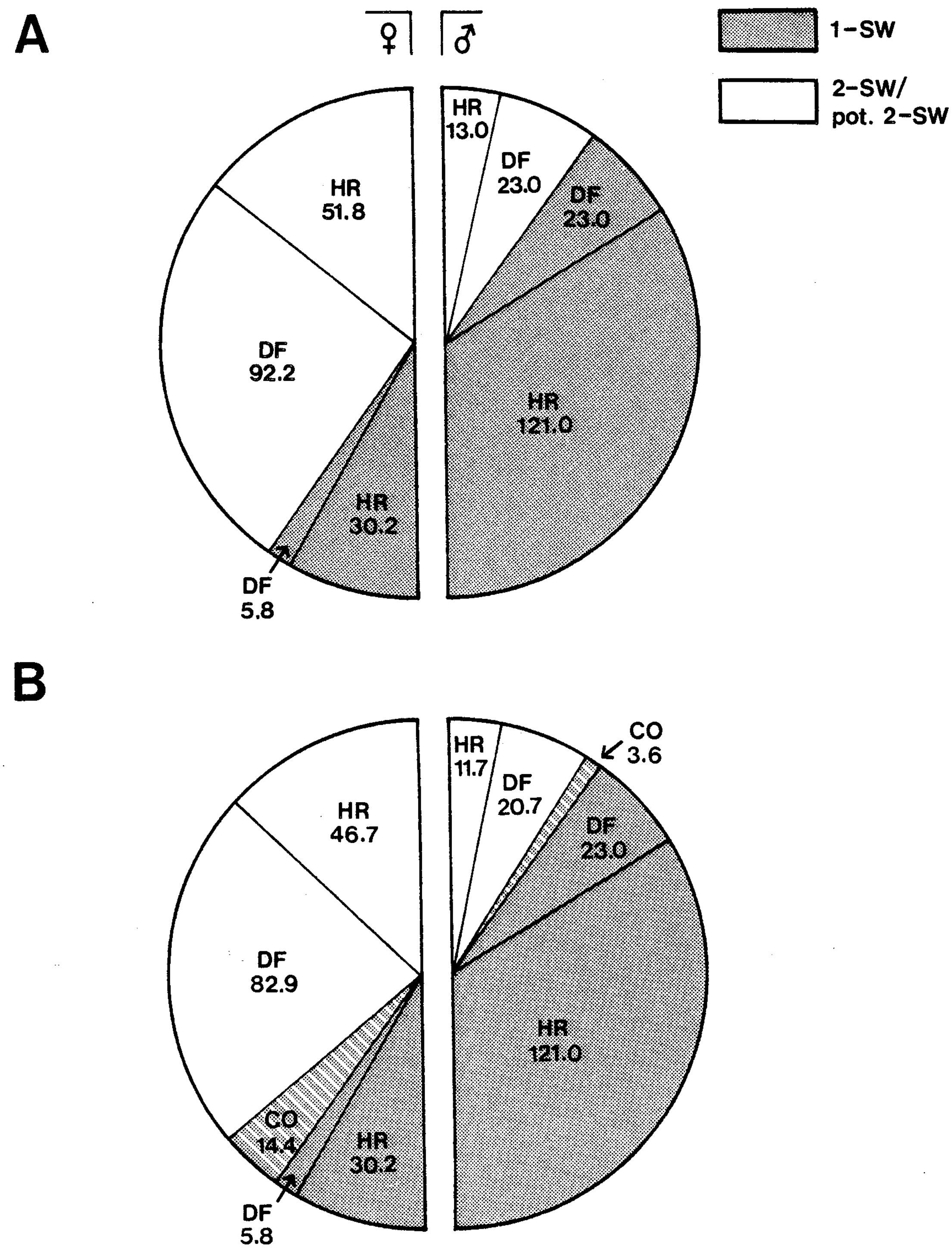

Fig. 1. A. Schematic of the disposition of 360 "salmon" from smolts of an initial sex ratio of 50:50, a predisposition of 50% to mature as 1-SW fish at a sex ratio of 0.20 female:0.80 male. B. Same as in A except that 10% of 2-SW fish in A mature instead as 1-SW fish. See text for details. (HR = home river, their fisheries and escapement; DF - distant fisheries; CO - crossover from 2-SW to 1-SW for proportionate disposition to DF and HR).