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Tobique River Discharge as an Index of the Percentage of 1-SW Salmon which Smoltified at Age 2 and Returned to Mactaquac

by

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Abstract

A significant relationship resulted from the regression of the proportion of smolt age-2 among 10 years of 1-SW salmon returning to Mactaquac, Saint John River on mean discharge for the Tobique River in March, April, June and July of year i and October and November of year i+1 of their freshwater residence. Predictions of the proportionate age-at-smoltification of 1-SW returns to Mactaquac may be used in deriving the adjusted number of eggs required to better forecast the number of 1-SW salmon returning to Mactaquac each year.

Résumé

On a obtenu une relation statistiquement significative à partir de la régression de la proportion de smolts d'âge 2 parmi les saumons d'un an en mer retournant à Mactaquac, sur la rivière Saint-Jean, par rapport au débit moyen de la rivière Tobique en mars, avril, juin et juillet de l'année i et en octobre et novembre de l'année i + 1 de leur résidence en eau douce. Les données utilisées portent sur une période de 10 ans. Les prévisions de l'âge au stade de smolt proportionnel des saumons d'un an en mer qui retournent à Mactaquac peuvent être utilisées pour déduire le nombre ajusté d'oeufs nécessaire pour mieux prévoir le nombre de saumons d'un an en mer qui retournent à Mactaquac chaque année.

Introduction

First forecasts of 1-SW fish originating above Mactaquac on the Saint John River, New Brunswick were based upon a 9 data-pair regression of adjusted egg depositions in year i and i+1 on homewater returns of 1-SW fish in year i+5 (Penney and Marshall, MS 1984). For that regression egg depositions were adjusted with respect to the freshwater age composition of resultant 1-SW returns to Mactaquac. The forecast return of 1-SW fish was dependent on an estimate of the freshwater age composition of those returns for adjustment of the numbers of eggs which contributed to them. Without age data of forecast returns, the analysis relied on mean ages from existing data.

This document demonstrates a relationship between river discharge and proportionate age-at-smoltification of 1-SW returns to Mactaquac. Discharge could then be used to forecast age composition of 1-SW returns to Mactaquac which in turn would permit the derivation of adjusted egg depositions essential to the forecasting of numbers of 1-SW returns.

Methods

Proportions of age 2:1's among 1-SW fish arising from the 1969-1978 year-classes returning to Mactaquac (Table 14; Penney and Marshall, MS 1984) were arcsine transformed and regressed on monthly mean stream discharges for each of the 31 months that an age-2-smolt would have resided in freshwater after spawning. Correlation coefficients (p=0.10 and p=0.05) contributed to the selection of key months which were separately or in combination submitted with the transformed proportions of age 2:1 fish to SPSS multiple regression analysis.

Results

Monthly mean discharges for the Tobique River at Plaster Rock since 1968 appear in Table 1.

Preliminary regression analysis showed significant (p=0.10) positive correlation coefficients between the transformed proportions of age 2:1's resulting from the 1969-1978 year-classes and discharges of March, April, June and July in the first year in freshwater (Table 2). Significant (p=0.10) correlation coefficients were negative for regression of the transformed proportions of age 2:1's on February, October and November discharges in the second year in freshwater.

Multiple regressions were run using three separate combinations of significant (p=0.10) positive and negative relationships to maximize variation explained by discharges (Table 3). All runs were significant ($p < 0.05$). However, although February discharges in year i+1 apparently affected the proportions of age 2:1's where other winter/spring months did not, analysis using Febrary was discounted. Remaining months used tended to be grouped (exclusive of May in year i) (Table 2) and the equation $Y_{\theta age-2} = 27.0067 + 0.2592\ X_{MAJJ} - 0.1758\ X_{ON}$, $R^2 = 0.84$, ($p < 0.01$), was chosen to represent the effects of spring/summer discharges in year i and fall discharges in year i+1 on the proportion of Mactaquac returns of 1-SW fish which smoltified at age 2.

Discussion

While the Tobique River discharge is in part controlled by the New Brunswick Power Commission's release of storage water from four reservoirs (Sisson, Long, Serpentine and Trousers lakes), the seasonal pattern of releases has remained unchanged for the period of record (Wilson, pers. comm.).[1] The general pattern of operation of reservoirs has been to fill them in the spring. The major draw-down period is between December and March. Releases from Sisson Lake which pass through a single turbine are drawn from a depth of up to 12 m, while releases through gates of the other three reservoirs originate at a depth of approximately 5 m below full storage. High November-December discharges, 1980-83, can be ascribed to above-average rainfalls (Wilson, op. cit.).

Mean monthly river discharges in the spring/summer of the salmon's first year and in fall months of the second year in freshwater best accounted for the variability in the proportion of a year-class returning to Mactaquac as 1-SW fish that smoltified at age 2.

Correlations have previously been demonstrated between annual/total stream discharges and subsequent commercial landings of coho salmon O. kisutch in Oregon (Scarneccia, 1981); between low winter discharges, winter air temperatures and survival of juvenile Atlantic salmon in Western Arm Brook, Newfoundland (Chadwick, 1982); between mean smolt age and mean annual air temperature (i.e., in cold years the smolt age is low) in Western Arm Brook (Chadwick, MS 1981) and between temperature and the percentage of 3+ smolts in a year-class (Chadwick, MS 1981). No links have been demonstrated between the stream discharge in specific months and age-at-smoltification.

To investigate the possible mechanisms that stream discharge might have on age-at-smoltification, mean monthly air temperatures (there were no water temperatures) at Arthurette were regressed on discharges for the Plaster Rock site. Correlation coefficients and their signs suggest links between increased air temperatures in March and April and increased April discharges (Table 4). Conversely, warmer temperatures in April contributed to lower discharges in May. Those and those of December would appear to be related to the dissipation of snow pack. The lack of correlation in the remaining months is not totally unexpected given that Tobique River discharges can be influenced by releases from the headwater reservoirs.

Regression of monthly mean air temperatures on the transformed proportions of age-2 smolts among 1-SW fish indicated 3 of 31 months (April yr i, $r=+0.67$; Dec. yr i+1, $r=+0.65$; March yr i+2, $r=-0.73$) in which correlation coefficients were significant ($p \leq 0.10$). The lack of grouping to infer seasonal effects suggests that the significant values may be spurious.

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[1] Wilson, G., Northwest Area Generation Manager, New Brunswick Power Commission, Grand Falls, N.B.

The correlation of April air temperature and discharge does add credence to the argument that higher spring discharges and perhaps associated higher water temperatures may optimize the development of eggs or growth of alevins which ultimately contribute to a younger age-at-smoltification. Discharge *per se* may however implicate the availability of habitat and the ease with which routine metabolism can be maintained. Presumably, at least in the first year in freshwater, energy savings from basic metabolism would contribute to greater growth and earlier smoltification. Low fall discharges in the parrs' second year of freshwater residence when feeding has virtually ceased may maximize energy conservation and encourage a better over-winter condition, survival and smoltification.

A forecast for 1984 of 6,616 1-SW fish returning to homewaters which originated above Mactaquac was based on mean proportions of 0.653 age-3 (1980 year-class) and 0.347 age-2 (1981 year-class) freshwater age composition (Penney and Marshall, MS 1984). Stream discharges (Table 1) submitted to the equation for Case 1 (Table 3) provide estimates of 0.820 age-3 (1980 year-class) and 0.368 age-2 (1981 year-class) contributing to the homewater returns of wild 1-SW fish destined for areas above Mactaquac in 1984. Total adjusted eggs contributing to the 1984 run of 1-SW fish to Mactaquac might then have been estimated to be 225.34 eggs/ 100 m^2 or 13 percent higher than the estimate based on mean proportions. Solution of this adjusted egg value (X) in the equation $\log_e Y = 6.4418 + 0.4298 \log_e X$ (Penney and Marshall, MS 1984) provides an AM estimate of 6,987 1-SW fish destined for Mactaquac in 1984 - an increase of 5.6% over the original forecast.

Model predictions of the proportion of age-2 smolts among 1-SW returns to Mactaquac in 1985 would require the use of recent November discharges. Because these values are outside the range of values used in the model, it will be necessary to update and revalidate the model in succeeding years.

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Table 1. Monthly and annual mean discharges for the Tobique River at Plaster Rock, 1968-1983. (Source: Inland Waters Branch, Atlantic Provinces Surface Water Data).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
						Discharge m^3/s							
1968											17.6	19.9	45.9
1969	37.1	36.0	22.3	81.3	248.0	61.4	44.3	59.3	98.3	46.8	70.6	64.9	72.8
1970	54.2	69.8	41.4	94.7	205.0	69.7	30.8	31.7	55.0	103.0	57.7	33.7	70.6
1971	22.4	35.9	40.0	97.2	182.0	42.0	30.0	25.8	24.2	39.8	39.3	31.8	51.0
1972	29.0	31.2	37.8	67.1	270.0	154.0	50.4	41.8	44.0	60.2	63.9	57.3	75.7
1973	51.5	71.1	78.2	190.0	239.0	96.2	73.5	45.5	52.0	29.5	22.4	87.6	86.4
1974	40.3	33.7	32.2	80.4	243.0	87.0	52.5	43.9	30.4	38.9	33.0	58.5	64.8
1975	48.9	43.3	38.9	51.3	214.0	51.9	21.2	15.0	16.9	17.3	32.9	51.9	50.5
1976	42.4	68.7	62.6	219.0	195.0	62.4	25.1	49.6	56.0	79.8	82.2	48.6	82.5
1977	48.8	46.5	29.8	145.0	184.0	101.0	32.3	27.3	26.9	88.6	50.7	32.1	67.8
1978	72.0	57.6	35.0	81.1	231.0	53.8	50.4	19.8	13.2	14.2	16.7	14.9	55.1
1979	50.1	51.6	123.0	161.0	176.0	63.8	25.5	25.7	76.6	43.0	56.9	54.2	75.6
1980	58.2	41.5	23.5	126.0	93.6								
1980[a]						27.0	63.0	44.7	40.5	72.4	49.8	68.2	59.1
1981[a]	53.2	92.9	62.6	166.0	131.0	81.3	53.6	27.4	32.8	94.8	103.0	103.0	83.2
1982[a]	65.2	50.1	30.4	112.0	158.0	42.3	29.7	34.2	60.9	43.4	107.0	107.0	70.0
1983[a]	70.3	61.1	54.9	144.0	113.0	79.4	41.1	53.2	42.6	28.8	108.0	120.0	76.3

[a]Data exclusive of the model but essential to forecasting.

Table 2. Percentage smolt-age-2 of 1-SW fish returning to Mactaquac from the 1969-1978 year-classes and correlation coefficients for regression of their angular transformation (θ) on discharges (Table 1) for each of 31 months of freshwater residence.

	1-SW fish			Correlation coefficient and sign			
Year Class	% age 2	θ age 2 (Y)	Months (X)	yr i-1	yr i	yr i+1	yr i+2
1969	20.7	27.06	Jan		+0.11	−0.06	+0.04
1970	44.5	41.84	Feb		+0.47	−0.54	−0.09
1971	26.9	31.24	Mar		+0.57	−0.25	+0.10
1972	41.9	40.34	Apr		+0.55	−0.46	−0.38
1973	61.9	51.88	May		+0.17	+0.25	+0.32
1974	41.1	39.87	June		+0.55	−0.04	
1975	11.4	19.37	July		+0.65[a]	+0.41	
1976	36.1	36.93	Aug		+0.35	−0.22	
1977	38.8	38.53	Sept		+0.12	−0.53	
1978	30.7	33.65	Oct		+0.34	−0.62	
			Nov	+0.46	−0.08	−0.79[a]	
			Dec	+0.32	+0.32	+0.14	

[a]significant at $p \leq 0.05$; underline alone at $p \leq 0.10$.

Table 3. Results of multiple regression of smolt-age-2 1-SW returns on three combinations of mean monthly discharges for the Tobique River, 1969-1979 (MAJJ = Mar, Apr, June, July; ON = Oct, Nov; J = Jul; N = Nov and FON = Feb, Oct, Nov).

Year i	Discharge m^3/s X_{MAJJ} yr i	X_{ON} i+1	X_J i	X_N i+1	X_{FON} i+1	Case	Variables	Reg'n coef.	F value	Signif.
1969	52.3	80.4	44.3	57.7	76.8	1	X_{MAJJ}	0.2592	13.77	0.008
1970	59.2	39.6	30.8	39.3	38.3		X_{ON}	-0.1758	8.10	0.025
1971	52.3	62.1	30.0	63.9	51.8		Const.	27.0067	16.12	
1972	77.3	26.0	50.4	22.4	41.0					$R^2 = 0.84$
1973	109.5	36.0	73.5	33.0	35.2					
1974	63.0	25.1	52.5	32.9	31.2	2				
1975	40.8	81.0	21.2	82.2	76.9		X_N	-0.2742	8.23	0.024
1976	92.3	69.7	25.1	50.7	61.9		X_J	0.2039	2.85	0.135
1977	77.0	15.4	32.3	16.7	29.5		Const.	40.1951	24.60	
1978	55.1	50.0	50.4	56.9	50.5					$R^2 = 0.73$
1979[a]	93.3	61.1				3	X_{FON}	-0.2804	17.17	0.004
1980[a]	59.9	98.9					X_{MAJJ}	0.2330	16.90	0.005
1981[a]	90.9	75.2					Const.	34.0830	29.69	
1982[a]	53.6	68.4								$R^2 = 0.90$

[a]Data exclusive of the model but essential to its utility.

Table 4. Correlation coefficients of regressions of mean monthly temperatures at Arthurette on mean monthly discharges at Plaster Rock, Tobique River, 1968-1980 (Table 1) A) temperature in month i on discharge in month i, B) temperature in month i on discharge in month i+1.

	Correlation coefficient and sign	
Month	Months i on i(A)	Months i on i+1(B)
Jan.	+ 0.02	− 0.24
Feb.	+ 0.18	− 0.43
Mar.	+ 0.36	+ 0.55[a]
Apr.	+ 0.59	− 0.68
May	− 0.19	+ 0.01
June	+ 0.28	+ 0.20
July	− 0.08	− 0.39
Aug.	+ 0.17	+ 0.24
Sept.	+ 0.06	+ 0.04
Oct.	+ 0.16	− 0.07
Nov.	+ 0.22	+ 0.27
Dec.	+ 0.06	+ 0.54

[a]underline significant at $p \leq 0.10$.