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Review of Atlantic salmon stocks of inner Bay of Fundy rivers, 1991

by

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Research Documents are produced in the official language in which they are provided to the Secretariat by the author.

[1]Cette série documente les bases scientifiques des conseils de gestion des pêches sur la côte atlantique du Canada. Comme telle, elle couvre les problèmes actuels selon les échéanciers voulus et les Documents de recherche qu'elle contient ne doivent pas être considérés comme des énoncés finals sur les sujets traités mais plutôt comme des rapports d'études sur les études en cours.

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ABSTRACT

The status of Atlantic salmon stocks for rivers of the inner Bay of Fundy is reviewed for 1991 when a general decline in recruitment occurred and harvests were closed to all users. Diver counts of grilse were well below conservation requirements in the Big Salmon and Alma rivers. Late season catch rates by electrofishing boat in the Stewiacke River indicated a possibly better return in 1991 than in 1989 when a moderate recovery occurred in the number of fish returned.

Juvenile densities in the Big Salmon River were average in 1991 but were below average in the Stewiacke River. Only two tags were recovered from a release of 5,100 tagged smolts in the Stewiacke River in 1990 and no returns from a release of 6,000 in the Stewiacke River or 3,000 in the Big Salmon River in 1991.

A noted divergence in recruitment trend between the index river (Big Salmon) and Stewiacke River indicates that the addition of a second index river (Stewiacke) may be required to advise management during an era of declining returns. A continuation of the present management measures is suggested to bridge recent low escapements.

RÉSUMÉ

On examine l'état des stocks de saumon des rivières de l'arrière-baie de Fundy en 1991, année où le recrutement a connu une baisse générale et où la récolte a été fermée à tous les pêcheurs. Les dénombrements de madeleineaux effectués par des plongeurs ont donné des résultats bien inférieurs aux nombres requis à des fins de conservation dans les rivières Big Salmon et Alma. En 1991, les taux de prises de fin de saison à l'électropêche dans la rivière Stewiacke dénotaient une amélioration possible des remontées par rapport à 1989, année où celles-ci avaient déjà fait l'objet d'une modeste reprise.

En 1991, les densités de juvéniles atteignaient la moyenne dans la rivière Big Salmon et étaient inférieures à la moyenne dans la rivière Stewiacke. On n'a récupéré que deux des étiquettes apposées sur quelque 5 100 saumoneaux mis en liberté dans la rivière Stewiacke en 1990, tandis qu'en 1991 on n'a décelé aucun signe de retour des 6 000 saumoneaux lâchés dans cette rivière ou des 3 000 autres qui ont été lâchés dans la rivière Big Salmon.

Un écart patent entre les tendances de recrutement dans la rivière repère (Big Salmon) et celles de la rivière Stewiacke donne à penser qu'en cette période de baisse des remontées, il serait peut-être utile de disposer d'une seconde rivière repère (rivière Stewiacke) sur laquelle fonder les conseils de gestion. Compte tenu des faibles échappées récentes, on propose de maintien les mesures de gestion actuelles pour assurer la transition.

INTRODUCTION

Atlantic salmon stocks of the inner Bay of Fundy occupy most rivers emptying into the Bay of Fundy east of Annapolis Basin in Nova Scotia and east of the Saint John River, New Brunswick. These stocks are similar in life history characteristics, migration and recruitment pattern (Amiro 1987). Levels of recruits (maiden grilse) have been linked to environmental variables acting on parr the summer previous to smoltification and to sea-surface temperatures the spring and early summer in the year of smolt migration.

Forecast models (Amiro and McNeill 1986; Amiro 1987) correctly indicated the drastic downturn that catches took in 1987 for the Big Salmon and Stewiacke rivers. Forecast models, reviewed in 1990 (Amiro 1990) were found to be losing significance with each passing year. Catches in 1988, 1989 and 1990 did not respond as forecasted by the models.

The low numbers of recruits to inner Bay of Fundy rivers in 1990 raised concerns with the public and fisheries managers that stocks were declining to irrevocable levels. Consequently a widening of the in-season management action of 1989 and 1990 in the Big Salmon River, New Brunswick, to all rivers of the inner Bay of Fundy, including Nova Scotia, was implemented in 1991.

This document reviews the status of Atlantic salmon stocks for rivers of the inner Bay of Fundy in 1991 relative to past indicators.

DATA and METHODS

Monthly counts of salmon in the Big Salmon River by snorkel diving was conducted jointly by New Brunswick Department of Natural Resources and Energy and students of the University of Maine at Orono, Co-operative Fishery Unit.

Mid-October diver counts of adult salmon in the Alma River and electrofishing in the Point Wolfe River were provided by Parks Canada (L. LeBlanc pers. comm.)[1].

Surveys for adult salmon were conducted on the Stewiacke River by electrofishing boat on three occasions in 1991 and are comparable to trips made in 1988 to 1990 with the same gear and operators.

Juvenile densities in the Stewiacke were collected by DFO and are reported by Amiro et al. (1989) for 1984 to 1988, Amiro (1990) for 1989 and 1990, and with the addition of 1991. Juvenile densities from the Big Salmon River are those reported by O'Neil et al. (1989) with the addition of data collected by DFO in 1990 and 1991.

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[1] L. LeBlanc, Parks Canada, Fundy National Park, Alma, N.B. E0A 1B0

Statistical analysis was carried out using SYSTAT[2] using the MGLH module and Type III sums of squares. Post-hoc tests were conducted using *a posteriori* contrasting and pair-wise comparisons of adjusted means using DUNNETT's test.

RESULTS

Catch trends in the inner Bay of Fundy

Annual recreational catches, 1970-1990, of both grilse and salmon in inner Bay of Fundy rivers are highly variable (O'Neil et al. 1984,1985,1986,1987,1989; O'Neil and Swetnam 1984) (Appendix 1). Total recreational catches reached a record low in 1987, improved in 1989, fell again in 1990 and were negligible in 1991 when all fisheies were closed (Fig. 1).

Stock status

Big Salmon River - Adult salmon

Counts by divers of adult returns in the Big Salmon River on August 16, 1991, were 115 fish classified as salmon, possibly larger than 62.9 cm and 49 grilse, possibly smaller than 63.0 cm (Table 1). Because these figures are substantially lower than the required escapement of 700 fish, Atlantic salmon fisheries in rivers of SFAs 22 and 23 east of St. Martins, New Brunswick, were not opened or were terminated.

Counts were repeated on September 12 to 17 for the entire river with the exception of one pool. A total of 256 adult returns was counted; an estimated 41% was classed as grilse. Accounting for the one missed pool, an in-river estimate of 300 fish was postulated and harvests prohibited.

A late season count was severely hampered by high water conditions which resulted in no late-season count and no collection of broodstock.

Stewiacke River - Adult salmon

A swim-thru survey of lower portions of the main Stewiacke River and two tributaries (Little River and South Branch) on July 27, 1991, did not locate any adult salmon.

A survey by electrofishing boat from Upper Stewiacke to Stewaicke River Park, 4.5 km from the head of tide, on August 28, 1991, resulted in the capture of 18 adult salmon and a catch per kilometre of 0.15 salmon (Table 2). A second electrofishing boat trip on October 15, 1991, resulted in a catch rate of 0.22 salmon km^{-1} for the same section of river.

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[2] Wilkinson, Leland. SYSTAT: The System for Systistics. Evanston IL, SYSTAT, Inc., 1990.

A third trip on November 25, 1991, resulted in a catch rate of 1.13 salmon km^{-1}. The November trip had a catch rate more than 2.5 times that of the November 1990 trip and twice the catch rate of the 1989 trip. Water conditions were similar for each survey.

Point Wolfe and Alma Rivers - Adult salmon

Diver counts of adult salmon have been conducted annually by Parks Canada employees since 1983 in the Alma and since 1985 in the Point Wolfe River (Table 3). The Point Wolfe River is not included in the list of inner Bay of Fundy rivers because angling is not permitted on the river. Counts by divers could not be conducted on the Point Wolfe River in 1991 because of high water conditions.

Counts by divers in the upper Alma River reached only 28 grilse and 12 salmon in 1991 but may have missed some fish due to high water. These numbers of fish would have resulted in 47% of Parks Canada estimate of the required escapement. An independent count by stream side observation indicated 53 fish in total.

Big Salmon River - Juvenile salmon

Total age-1+ and age-2+ parr densities ($100^{-1} * m^2$) measured at four sites in 1991 averaged 13.95 age-1+ parr (Table 4.) Age-0+ parr averaged 22.6 parr at three of these sites in 1991.

Stewiacke River - Juvenile salmon

Mean (arithmetic) densities ($100^{-1} * m^2$) of age-1+ parr ranged from a high of 33.8 in 1987 to a low of 12.3 in 1991 (Table 5). Densities of age-2+ parr were lower and ranged from a high of 8.1 in 1986 to a low of 3.3 in 1990. Total age-1+ and 2+ parr densities ranged from a high of 39.2 in 1987 to a low of 22.4 in 1991.

Standard deviations of annual mean parr densities are large. Some annual means had coefficients of variation approaching or greater than 100%, particularly in years of high densities. Annual group variance was not homogeneous between years, precluding post-hypothesis contrast comparisons of years. In order to stabilize the variance, the data were log (Ln) transformed and co-variates to adjust for habitat suitability and location in the river system (stream grade of the sites and distance above the head of tide) were tested.

Models of the form;

Density = Constant + Grade + Grade^2 + Distance + Year

where; density = age-0+ or age-1+ parr 100^{-1} m^2 + 1 (to allow log conversion of zero values)

grade = area-weighted surface grade of the electrofishing site

distance = total stream length (km/100) above the head of tide

year = a categorical variable for the year of electrofishing;

were tested and all variables were found to be significant (Appendices 1 and 2).

Plots of the residuals against the estimates indicated even distribution of the residuals for the age-1+ parr (Fig 2) but the lower limit of densities (zero values) resulted in uneven distribution in the residuals for age-0+ (fry) densities. Removal of these observations did not affect the significance of the model but would have positively affected the adjusted mean densities. Because zero densities can indicate a decrease in abundance of fish, zero values remained in the models in spite of the residual pattern.

The category variable 'year' was significant and adjusted (for co-variables) annual mean densities were derived. Adjusted mean densities had associated standard deviations which were always less, sometimes substantially, than the mean.

Annual (1984 to 1990) post-hoc comparisons of age-0+ (fry) densities made with 1991 as the control year indicated that the years 1984 ($p<0.0005$), 1986 ($p=0.002$) and 1989 ($p=0.037$) had significantly higher annual mean densities. When contrasted against the mean of 1984 to 1990, 1991 had a significantly ($p=0.002$) lower mean density of age-0+ fry.

Annual post-hoc comparisons of age-1+ parr densities, with 1991 as the control year, indicated that the years 1985 ($p=0.005$) and 1987 ($p=0.023$) had significantly higher annual mean densities. When contrasted against the mean for 1984 to 1990, the 1991 mean age-1+ density was significantly ($p=0.036$) lower.

Hatchery releases

Juvenile salmon of Stewiacke stock have been released to the Stewiacke River since 1985 (Table 6.) Returns have been minimal; of the 19,829 tagged smolts released into the Stewiacke River, only two post-smolt tags have been returned, both in the Grand Manan area in July and August of 1990.

Juvenile salmon of Big Salmon River origin have been released in the Big Salmon River in 1990, as were tagged smolts in 1991. To date no tags have been returned and few hatchery fish have been observed in the river counts.

DISCUSSION

Recruitment in all inner Bay of Fundy stocks declined to very low levels in 1987, 1988, 1990 and possibly in 1991. Catches and counts of recruits in 1989 indicated a temporary recovery. The pattern of returns is no longer predictable by the existing stock-recruitment models (Amiro 1990).

Extremes in marine survival have been observed at Big Salmon River where survival of untagged wild smolts ranged from 0.5 to 8.4%. In multiple spawners, survival between consecutive spawnings has ranged from 23 to 78% (Jessop 1986, Ritter 1989 and Amiro unpublished analysis). Possible mechanisms for high variation in marine survival for inner Bay of Fundy stocks have been reviewed by Amiro 1990.

Grilse counts in the Alma River have declined since 1983. Mean counts, 1986-1988, of grilse decreased nine-fold from those of 1983-1985. Numbers of repeat-spawning salmon declined steadily since 1983 and moderately recovered in 1989. Counts of both grilse and salmon increased in 1989 but did not reach 1983-1985 average count.

The November 1991 catch km^{-1} in the Stewiacke River was the highest observed since 1988 and was higher than the 1989 catch when returns were thought to have improved. This result may have been negatively influenced in 1989 by the removal of fish by the recreational fishery. The index data suggest that the 1989 recovery was not as good as perceived or that the index catch is unreliable.

The Big Salmon River reached conservation escapement level in 1989, and the 1991 densities of age-1+ further indicate good egg depositions then. Densities of age-1+ in the Stewiacke River in 1991 on the other hand were lowest since 1984, further substantiating the reduced catch km^{-1} recorded in 1989.

Because the catch km^{-1} by the electrofishing boat is not calibrated to known escapements it cannot yet be functionally related to egg deposition, cannot be used to assess the escapement directly, and cannot address the question of conservation spawning escapement in the Stewiacke River for 1991. However, the data suggest that, in spite of the historical correlation in catch trends between Big Salmon and Stewaicke rivers the relative performance of the stocks in 1989 may have been different, that the proportions removed may have been different in 1989 or that juvenile survival rates were significantly different between the systems in 1989 to 1991 periode.

It is also possible that Big Salmon River in 1991 received increased returns after the September adult salmon count and will have a 1992 age-0+ index similar to that of the Stewiacke River.

Parr densities in the Stewiacke River are beginning to reflect declines in catches and probably escapements. Recruitment to the river in 1991 was the result of the 1988 year-class (1987 recruits) and is the first of the series of lower parr densities. Lower freshwater production in the present era of low marine survival places the stocks in greater jeopardy. The strategy in place on the Big Salmon River in 1989 assured the first objective of management (spawning escapement) while maintaining the possibility for a fishery. However, if marine survival becomes different between rivers, then an additional index river may be required to adequately manage the total inner Fundy salmon resource. The two rivers with the best potential to monitor salmon survival trends in the inner Bay of Fundy are the Big Salmon and Stewiacke rivers (Amiro 1990).

Continuation of the hook-and-release of fish >= 63cm was beneficial to these stocks particularly when declines in the number of repeat spawners was expected. However while stability in production may be maintained by repeat spawners, recruitment must first be ensured. This implies that harvests of recruits must be balanced with returns.

Analysis methodology

The estimates of mean annual densities for age-0+ and age-1+ adjusted for the co-variables (grade and distance) were derived from the data and ANCOVA models. These models improve the amount of variation accounted for by approximately 25% from that of a one-way analysis of variance. The ANCOVA approach allows for annual change in the number and locations of electrofishing sites. If the sampling is conducted in proportion to the co-variable representation in the river, then a better estimate of the population mean will be obtained. If attributes of the co-variables are known for the entire system, then functional models can estimate the populations. These features allow greater flexibility and resolution to test specific questions concerning the status of a year of sampling data. These features make this approach a useful one.

However, the skewed distribution of residuals caused by the transformation of zero values is a transgression of the strict protocol for multiple general linear hypothesis testing. Resolution of this problem is a goal for future analysis.

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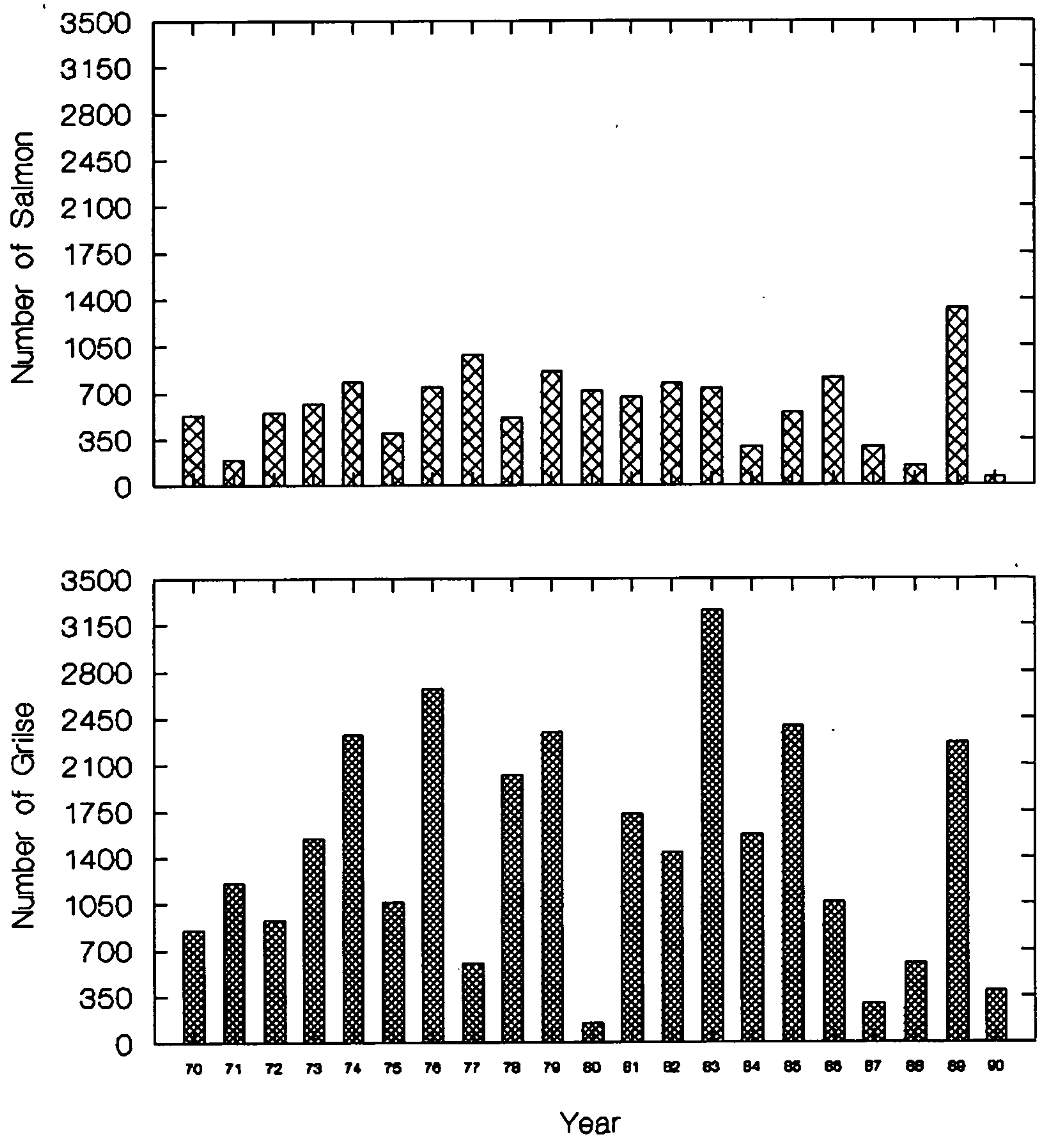
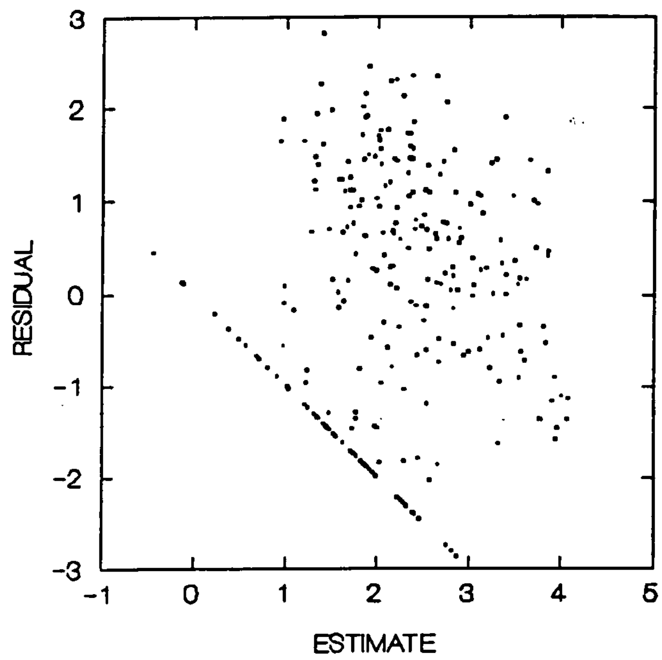


Figure 1. Atlantic salmon recreational catches for 24 rivers of the inner Bay of Fundy by salmon and grilse, 1970 -1990.



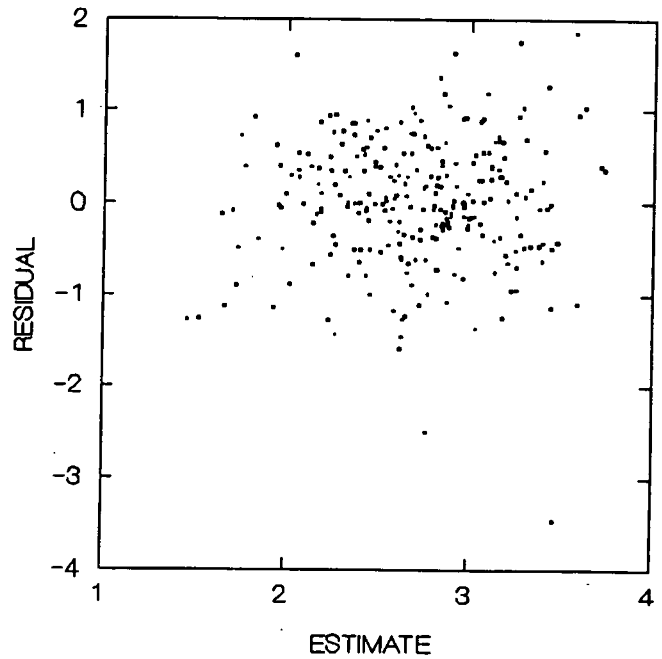


Figure 2. Plots of residuals of age-0+ (upper) and age-1+ (lower) parr densities adjusted for stream gradient and distance for the Stewiacke River electrofishing sites 1984 to 1991.

Table 1. Numbers of Atlantic salmon counted by divers and observers in the Big Salmon River 1989 and 1991. Smaller fish are thought to be grilse or one sea-winter and larger fish are thought to be repeat-spawning grilse or multi sea-winter salmon. Unknown numbers refer to estimates made by proportion or incomplete counts.

	Summer			Early fall			Late fall			
Year	Salmon	Grilse	Unknown	Salmon	Grilse	Unknown	Salmon	Grilse	Unknown	Estimated escapement
1989	74	405		70	468	300	unknown	unknown	975	975
1990			<30	167	162		169	54	12	235
1991	115	49	164		(41%)	256	unknown	unknown	unknown	300

Table 2. Numbers of Atlantic salmon caught, salmon per kilometer, discharge, river, reach, length of reach, and date of sampling by electrofishing boat on the Stewiacke River, 1988 to 1991.

Reach	Date ddmmyy	Length (km.)	Salmon caught	Salmon/km.	Len.wtd.mean salmon/km.	Discharge (m^3/sec.)
Reynolds-Forest Glen	01/11/88	31.78	23	0.72		33.0
Reynolds-park	31/10/89	35.20	19	0.54		12.9
Reynolds-park	01/11/90	35.20	4	0.11	0.11	96.5
Reynolds-Middle	15/11/90	13.57	11	0.81	0.42	25.7
Middle-park	15/11/90	21.64	4	0.18		25.7
	1990	70.41	19	0.27	0.26	
Reynolds-Birchill	28/08/91	23.66	1	0.04		3.5
Birchill-Forest Glen	28/08/91	11.56	2	0.17	0.15	3.5
Forest Glen-park	28/08/91	3.44	2	0.58		3.5
Upper-Reynolds	15/10/91	5.88	9	1.53		16.7
Reynolds-Middle	15/10/91	13.57	1	0.07		16.7
Middle-Birchill	15/10/91	10.09	3	0.28	0.22	16.7
Birchill-park	15/10/91	11.55	4	0.35		16.7
Reynolds-Middle	25/11/91	13.57	19	1.40		11.1
Middle-Birchill	25/11/91	10.09	10	0.99	1.13	11.1
Birchill-Forest Glen	25/11/91	8.11	7	0.86		11.1
	1991	111.5	58	0.52	0.56	

Table 3. Numbers of Atlantic salmon counted by under-water observation in the Point Wolfe and Alma rivers, SFA 23, 1983-1991. *

Year	Point Wolfe		Alma	
	Grilse	Salmon	Grilse	Salmon
1983	-	-	372	168
1984	-	-	200	183
1985	196	4	276	95
1986	66	29	37	66
1987	36	39	23	29
1988	25	24	33	24
1989	161	17	250	41
1990	37	14	37	9
1991	--	--	28	12

* L.LeBlanc, Environment Canada, Fundy National Park, Alma, N.B.

Table 4. Numbers of age-1+ Atlantic salmon parr 100^-1 m^2 as determined at six sites in the Big Salmon River, 1982 and 1989 to 1991.

Year	Site number						
	2	3	7	9	11	13	15
1982				13.2	25.9	69.7	
1989	4.3	14.4	8.7	--	10.2	23.3	24.6
1990	2.2	14.8	6.3	--	12.2	14.7	24.5
1991	9.5	--	7.0	--	12.0	--	27.3

Table 5. Annual mean density and standard deviation of age-0+,-1+ and -2+ Atlantic salmon (10^-2 m^2) as determined by mark-recapture electrofishing at sites in the Stewiacke River, 1984-1991.

Age	Year and number of sites sampled							
	1984 44	1985 27	1986 38	1987 36	1988 29	1989 31	1990 31	1991 a 34
0+								
Mean	45.8	12.1	26.8	16.8	16.8	21.1	18.6	8.4
SD.	47.0	14.5	30.7	21.0	23.1	21.4	28.2	10.2
1+								
Mean	17.0	28.9	16.0	33.6	18.5	16.1	19.8	12.3
SD.	13.2	26.7	13.0	44.7	9.0	13.7	16.7	10.2
2+								
Mean	6.8	6.8	8.1	5.5	7.0	6.7	3.3	4.1
SD.	7.9	8.3	8.9	4.8	5.1	5.7	3.2	3.1
Total Age-1+ and 2+								
Mean	23.8	35.7	24.2	39.2	25.5	22.4	23.1	15.3
SD.	19.0	34.2	18.4	47.8	10.7	16.1	18.4	12.6

a Number of sites with estimates was 32 for age-1 and 31 for age-2+.

Table 6. Releases of Atlantic salmon juveniles by stage and stock origin and numbers of tags returned from releases into the Stewiacke River, 1985-1991. (Note; All releases were adipose fin-clipped.)

	Stage at release								Tag returns	
Year	Fry	2	3	4	Yearling	1+	2+	Smolt equivalents	post smolt	adult
1985						1,895 t		1,516		
				17,061	11,156	19,219		25,297		
1986						2,973 t	1,687 t	3,897		
						7,099	894	6,484		
1987						2,669 t	1,350 t	3,350		
						4,363		3,490		
1990						5,150 a		4,120	2	
						5,450		4,360		
1991						6,000 b		4,800		
						13,400	7,900	17,830		
Totals				17,061	11,156	68,218	11,831	75,144		

t Tagged
a 5,150 tagged (2,600 saline, 2,550 vaccinated)
b 6,000 tagged (3,000 saline, 3,000 vaccinated)

Survival rates	stage 4 to 1+ parr	0.40
used to estimate	yearling to 1+ parr	0.50
smolt equivalents	1+ to smolt	0.80
	2+ to smolt	0.90

DEP VAR: LDEN1 N: 267 MULTIPLE R: 0.540 SQUARED MULTIPLE R: 0.292

ESTIMATES OF EFFECTS $B = (X'X)^{-1} X'Y$

		LDEN1
CONSTANT		2.601
AWSG		1.817
AWSG AWSG		-0.691
DIST		-1.624
YEAR$	1984	0.007
YEAR$	1985	0.359
YEAR$	1986	-0.197
YEAR$	1987	0.218
YEAR$	1988	0.069
YEAR$	1989	-0.221
YEAR$	1990	0.025

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AWSG	25.618	1	25.618	48.189	0.000
AWSG*AWSG	26.997	1	26.997	50.783	0.000
DIST	24.802	1	24.802	46.655	0.000
YEAR$	10.381	7	1.483	2.790	0.008
ERROR	136.093	256	0.532		

ADJUSTED LEAST SQUARES MEANS.

		MEAN	SD	(N)
YEAR$	=1984	2.744	0.791	44
YEAR$	=1985	3.096	0.874	27
YEAR$	=1986	2.540	0.912	38
YEAR$	=1987	2.956	1.119	36
YEAR$	=1988	2.806	0.523	29
YEAR$	=1989	2.516	0.813	31
YEAR$	=1990	2.763	0.665	31
YEAR$	=1991	2.480	0.802	31

DEP VAR: LFRY N: 266 MULTIPLE R: 0.542 SQUARED MULTIPLE R: 0.293

ESTIMATES OF EFFECTS $B = (X'X)^{-1} X'Y$

		LFRY
CONSTANT		0.170
AWSG		1.753
AWSG AWSG		-0.860
DIST		1.614
YEAR$	1984	1.852
YEAR$	1985	0.298
YEAR$	1986	1.125
YEAR$	1987	0.336
YEAR$	1988	0.325
YEAR$	1989	0.831
YEAR$	1990	0.669

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
AWSG	24.206	1	24.206	13.649	0.000
AWSG*AWSG	42.159	1	42.159	23.771	0.000
DIST	24.360	1	24.360	13.735	0.000
YEAR$	91.672	7	13.096	7.384	0.000
ERROR	452.245	255	1.774		

		MEAN	SD	(N)
YEAR$	=1984	3.339	0.961	44
YEAR$	=1985	1.785	1.518	27
YEAR$	=1986	2.612	1.538	37
YEAR$	=1987	1.823	1.623	35
YEAR$	=1988	1.812	1.673	29
YEAR$	=1989	2.318	1.522	31
YEAR$	=1990	2.156	1.418	31
YEAR$	=1991	1.487	1.380	32