Canadian Atlantic Fisheries Scientific Advisory Committee

Comité scientifique consultatif des pêches canadiennes dans l'Atlantique

CAFSAC Research Document 84/16

CSCPCA Document de recherche 84/16

Number of salmon required for spawning in the Restigouche River, N.B.

by

R.G. Randall

Research Branch
Department of Fisheries and Oceans
Gulf Region
P.O. Box 5030
Moncton, N.B.
E1C 9B6

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ABSTRACT

A length-fecundity relationship is defined for Atlantic salmon in the Restigouche River, where $\log_e$ fecundity = -1.1862 +2.3423 $\log_e$ fork length ($n=91$; $R^2= 0.89$). Average relative fecundity was calculated to be 1475 $eggs.kg^{-1}$, which is significantly less than the fecundity used previously in Restigouche assessments (1764 $eggs.kg^{-1}$). About 12,200 salmon are required for spawning in the Restigouche to achieve adequate recruitment. In addition, about 2,600 grilse are needed to ensure a 1:1 sex ratio at spawning. Preliminary estimates of spawning escapement between 1972 and 1982 suggest the Restigouche River has been significantly underseeded in recent years.

Résumé

Nous définissons dans le présent document une relation longueur-fécondité pour le saumon atlantique de la rivière Restigouche comme suit: $\log_e$ fécondité = -1,1862 + 2,3423 $\log_e$ longueur à la fourche ($n = 91$; $R^2 = 0,89$). D'après nos calculs, la fécondité relative moyenne est de 1 475 $oeufs.kg^{-1}$, chiffre significativement inférieur à celui utilisé auparavant dans les évaluations de cette rivière (1 764 $oeufs.kg^{-1}$). Il faut environ 12 200 saumons reproducteurs pour un recrutement adéquat dans la Restigouche. De plus, environ 2 600 madeleineaux (ou castillons) sont nécessaires pour qu'au moment de la ponte le rapport des sexes soit de 1:1. Des estimations préliminaires de l'échappement en vue de la reproduction entre 1972 et 1982 donnent à penser qu'en ces dernières années, cette rivière a été nettement sous-ensemencée.

INTRODUCTION

The Restigouche River is the second largest Atlantic salmon river in Maritime Canada. Maximum smolt yield from the Restigouche will only be attained if adequate spawning levels are achieved. An important prerequisite for assessing the status of Atlantic salmon in the Restigouche River is, therefore, knowing how many salmon are required for spawning. Egg deposition requirements were recently estimated by Chadwick and Randall (1983). This paper presents a modification and improvement of this estimate in view of recent information on the fecundity of Restigouche salmon. Estimates of spawning requirements and spawning escapement for the past 11 years (1972 to 1982) are presented to see if adequate recruitment has been achieved in the Restigouche River.

METHODS

Egg deposition and spawner requirements for the Restigouche River were calculated using the following information:

1. Rearing Area

Total salmon rearing area in the Restigouche River was estimated to be 29,768,000 m^2 (Anon 1978). Since at the time this report was prepared, the Restigouche had not been surveyed, this estimate was based on a drainage area method (J. Peppar, personal communication), where:

$$\text{Rearing area}(m^2)\ (\text{of unsurveyed river}) = \text{Drainage area}(km^2)\ (\text{unsurveyed river}) \times \frac{\text{Rearing area of surveyed river}(m^2)}{\text{Drainage of surveyed river}(km^2)}$$

More recently, the N.B. Department of Natural Resources (in collaboration with the Ministère du Loisir, de la Chasse et de la Pêche, Gouvernement du Québec) have estimated total rearing area, based on actual field surveys, to be 25,074,400 m^2. However, this estimate is tentative, and it will probably be increased when more habitat is surveyed (Alan Madden, DNR, Campbellton; personal communication). In view of this, the larger of the two estimates (29,768,000 m^2) is used in this report. Using this value may slightly overestimate spawning requirements, but the bias is in favour of conservation. Plans are in progress to have Restigouche rearing area estimated from a detailed analysis of aerial photographs, using a technique that has already been applied to the Miramichi River (Amiro 1983); however, this estimate will not be available for another year.

2. Egg Deposition Rate

The required potential egg deposition rate for the Restigouche River is assumed to be 2.4 $eggs.m^{-2}$. The use of this value is discussed by Randall (in preparation).

3. Fecundity

Ninety-one female salmon were collected from the Restigouche commercial, Native and recreational fisheries in 1983 for a fecundity estimate. Ovaries were collected from the following areas:

Area	Number	Mean fork length, cm	Mean weight, kg
Main Restigouche	61	87.4	7.9
Upsalquitch	18	72.6	4.5
Kedgwick	6	96.5	10.0
Chaleur Bay	6	83.3	7.0
Total	91	84.8	7.3

All ovaries were placed in Gilson's fluid until ovarian tissue broke down, and then transferred to 10% formalin to harden the eggs. Egg samples were counted in their entirety using a paddle and trough similar to that illustrated in Mills (1971). When egg counts were initially plotted against fork length, it was evident that variability increased as the egg count increased. Therefore, both egg counts and fork lengths were $\log_e$ transformed before analysis (Pope et al 1961). Samples from all areas were combined to produce a length-fecundity relationship for Restigouche salmon.

4. Mean Lengths, Sex Ratios, and %-at-age

Salmon and grilse entering the Restigouche River during the period 1972 to 1980 were systematically sampled at a Dalhousie trap site (Peppar 1983). These data were reworked (by R. Pickard, DFO, Millbank, N.B.) so that mean lengths, sex ratios and percents-at-age were available for three age-groups of salmon: 1-sea-winter (1SW), 2-sea-winter (2SW), and 3-sea-winter and older (3SW) (Tables 1 and 2).

Total egg deposition requirements for the Restigouche River were calculated from the above information as:

(1) Egg deposition requirements = Rearing area X Egg deposition rate.

Average egg deposition per fish was calculated as:

(2) Egg deposition per fish = Fecundity X proportion female X proportion-at-age.

where fecundity is calculated from the length-fecundity relationship. Egg deposition per fish is calculated for 1SW, 2SW and 3SW salmon separately, and then summed to get a total egg deposition per fish.

Number of required spawners could then be calculated as:

(3) Number of spawners = Egg deposition requirements/Egg deposition per fish.

RESULTS

During the period 1972 to 1980, grilse (1SW), small salmon (2SW) and large salmon (3SW) in the Restigouche River averaged 53, 76 and 93 cm in fork length, respectively (Table 1). Grilse are predominantly males (98%) while 2SW and 3SW salmon are predominantly females (54 and 76%, respectively). Grilse, small salmon and large salmon comprised 39, 45 and 16 percent of the salmon run, respectively (Table 2).

Female salmon collected for the fecundity study included all sea age-groups (2SW, 3SW and multiple spawners(MS)), except grilse (1SW):

Sea-age	Number	Percent of sample	Relative fecundity eggs. kg^{-1}
1SW	0	0	-
2SW	43	48	1600
3SW	38	42	1371
MS	9	10	1306
all	90	100	1475

Mean relative fecundities (eggs.kg^{-1}) of 3SW and MS salmon were significantly less than 2SW salmon ($P < 0.01$). Relative fecundity of multiple spawners was not significantly less than 3SW salmon. Mean relative fecundity for all Restigouche salmon was 1475 eggs.kg^{-1}.

The length-fecundity relationship for Restigouche salmon (Fig.1) can be described by the equation:

$$(4) \qquad \log_e F = -1.1862 + 2.3423 \log_e FL$$

where F = fecundity
FL = fork length in cm
$R^2 = 0.89$

Solutions to this equation indicate average fecundities for each sea age-group as follows:

Sea-age group	Average fork length (cm)	Average fecundity
1SW	53.2	3369
2SW	76.4	7863
3SW	92.6	12338

Grilse fecundities were determined by extrapolation, since no grilse were included in the regression.

Average eggs per fish for Restigouche salmon were calculated (equation 2) for all three sea age-groups separately (Table 3). Grilse contribution to total egg deposition was insignificant during the 1972 to 1980 period (average 1%, range 0-2%). Therefore, eggs/salmon were recalculated for 2SW and 3SW salmon only (Table 4). Average eggs/salmon was 5785 (range 4700 to 6565). Of this total, 2SW salmon contributed an average 51% (17-80%), while 3SW salmon contributed 49% (20-83%).

Total egg deposition requirements for the Restigouche River were calculated (equation 1) to be 71,443,200 eggs. From 1972 to 1980, the number of salmon required to achieve this egg deposition (equation 3) averaged 12,157 fish (Table 5). Annual variation in the numbers of required spawners was not high (range 10,882 to 15,201).

Although grilse are not important in the Restigouche for egg deposition, some grilse are required to ensure a 1:1 sex ratio at spawning. Numbers of male grilse required can be calculated as:

Proportion of female spawners = (proportion of female 2SW salmon X proportion-at-age) + (proportion of female 3SW salmon X proportion-at-age)
= (0.54 x 0.70) + (0.76 x 0.30) (Table 4)
= 0.6060

Therefore, given 12,157 salmon, 7,367 are female, and 4,790 are male. To ensure a 1:1 sex ratio, another 2,577 males are required.
Number of grilse spawners = 2577/0.98 (proportion of male grilse)
= 2630 grilse.

Spawning requirements, in terms of both egg deposition and number of spawners are compared to estimated salmon escapement for the period 1972 to 1982 in Table 6. Spawning escapement was estimated by back-calculating from parr densities (see Chadwick and Randall 1983, Method II). This comparison indicates spawning levels were on average only 25% of required levels during this 11 year period.

DISCUSSION

Prior to this study, no estimates of salmon fecundity for the Restigouche River had been made. Ovaries collected in 1983 indicate an average relative fecundity of 1,475 eggs.kg^{-1}, and this is significantly less ($P < 0.05$) than the 1,764 eggs.kg^{-1} previously used in Restigouche assessments (Chadwick and Randall 1983). Primarily for this reason, my estimate of the number of salmon required for spawning (ca.12,200) is 21% higher than the previous estimate (ca. 10,100; Chadwick and Randall 1983).

Grilse are not important for egg deposition in the Restigouche River, because of the low proportion of females and their low relative abundance. Proportions of eggs coming from grilse during the 1972 to

1980 period averaged only 1%. This is in sharp contrast to the Miramichi River, where grilse contributed approximately 26% of the total egg deposition during the same period (Randall, unpublished data). This difference can also be expressed another way, using the ratio of the number of grilse (whether male or female) required to produce the same number of eggs as one salmon. In the Miramichi River, the ratio of grilse to salmon is 10:1, while in the Restigouche River, the ratio is 86:1. Clearly, grilse are much less important in terms of egg deposition in the Restigouche River than in the Miramichi River. Numbers of salmon required for spawning in the Restigouche were calculated in this report assuming all eggs came from salmon. However, some grilse (ca. 2,600) are also required to ensure a 1:1 sex ratio at spawning.

During the period the Dalhousie trap was in operation (1972 to 1980), 2SW and 3SW salmon contributed about equally to total egg depositions on average (51 and 49% for 2SW and 3SW salmon, respectively). Despite annual fluctuations in sex ratios and percents-at-age for 2SW and 3SW fish, total eggs per fish and numbers of salmon required for spawning remained remarkably constant during this 9 year period. This suggests that the required number of salmon spawners, calculated from the 1972 to 1980 mean (ca.12,200), can be used as a reasonable target spawning level when a forecast is needed in Restigouche assessments. Spawning requirements for the current assessment year, however, can be estimated more accurately using specific sex ratio and percent-at-age information as determined by adult sampling in the current year.

Comparison of estimated spawning escapement and requirements from 1972 to 1982 indicate that egg deposition levels in past years have been substantially less than what is considered adequate. However, escapement was estimated by back-calculating from parr densities (Chadwick and Randall 1983), assuming parr densities determined by electrofishing reflect average densities in all habitat types. Until this assumption has been thoroughly tested, the spawning escapement levels presented in Table 6 will remain tentative.

SUMMARY

1. A length-fecundity relationship was defined for 91 Restigouche female salmon sampled in 1983. Fork length (FL) can be related to fecundity (F) by the equation:

$$\log_e F = -1.1862 + 2.3423 \log_e FL$$

   Relative fecundity calculated using these 1983 data (1475 eggs. kg^{-1}) was significantly less than what has been used in previous Restigouche assessments (1764 eggs. kg^{-1}).

2. Total egg deposition requirements for the Restigouche River were estimated to be 71,443,200 eggs.

3. Average number of salmon required for spawning in the Restigouche River, during the period 1972 to 1980, was 12,157 (95% C.L. ± 1,031). This estimate appears relatively insensitive to annual changes in sex ratios and percents-at-age of 2SW and 3SW salmon, and thus it is a good target spawning level for the Restigouche River.

4. To ensure a 1:1 sex ratio at spawning, about 2,600 grilse are required in addition to the 12,200 salmon indicated in 3.

5. If small parr densities accurately reflect escapement levels, salmon spawning in the Restigouche River has only been about 25% of the required levels during the last 11 years (1972-1982).

ACKNOWLEDGEMENTS

P.R. Pickard contributed in many ways to the preparation of this report. R. Blair collected ovaries and sampled adult salmon in the field. E. Tracy counted eggs for the fecundity study. D. Meerburg suggested the technique for calculating the numbers of grilse required for spawning. R. Gray, J.L. Peppar and P.R. Pickard reviewed the manuscript.

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Table 1. Mean fork lengths (FL, cm) and sex ratios of grilse and salmon sampled at the Dalhousie trap 1972 to 1980.

	Grilse (1SW)			Salmon (2SW)			Salmon (3SW and older)		
Year	n[1]	FL	% female	n	FL	% female	n	FL	% female
1972	-	-	-	149	75.1	28	72	89.6	76
1973	74	52.8	5	81	76.7	60	43	89.6	91
1974	342	54.2	4	101	76.6	65	45	93.9	69
1975	247	52.8	4	110	78.0	65	59	94.4	88
1976	287	53.4	1	98	77.3	62	40	94.4	85
1977	116	52.6	0	55	73.6	75	7	94.9	43
1978	120	53.5	1	64	77.3	50	28	93.1	89
1979	222	52.3	3	9	76.4	33	25	91.8	76
1980	80	53.0	3	34	76.7	47	16	98.3	56
Mean [2]		53.2 cm	2%		76.4 cm	54%		92.6 cm	76%

[1] n indicates sample size
[2] mean percent female calculated after arcsine transformation.

Table 2. Sea-age composition of salmon captured at the Dalhousie trap, 1972 to 1980.

	Grilse (1SW)		Salmon (2SW)			Salmon (3SW and older)		
Year	Number	%	Number	%	(% of salmon)	Number	%	(% of salmon)
1972	--	[39][2]	716	28	(46)	840	33	(54)
1973	326	22	854	57	(73)	316	21	(27)
1974	700	42	713	43	(75)	237	14	(25)
1975	1275	47	1144	42	(80)	286	11	(20)
1976	1087	47	949	41	(76)	300	13	(24)
1977	477	36	682	52	(81)	160	12	(19)
1978	510	25	1060	53	(71)	433	22	(29)
1979	961	56	351	20	(46)	411	24	(54)
1980	496	32	826	53	(77)	247	16	(23)
Mean [1]		39		45	(70)		16	(30)

[1] mean percents calculated after arcsine transformations.

[2] percent grilse in 1972 was assumed to be average (1973 to 1980).

Table 3. Estimated numbers of eggs per fish for three sea age-groups of Restigouche salmon, and the variables used to estimate these values, 1972 to 1980. Mean fork length (FL) from Table 1; eggs per female calculated from the regression: $\log_e F = -1.1862 + 2.3423 \log_e FL$ (where F = fecundity). Proportion female and proportion-at-age from Tables 1 and 2, respectively. Average proportion females and proportion-at-age (See All years) calculated after arcsine transformations.

Variable	Age group	1972	1973	1974	1975	1976	1977	1978	1979	1980	All years
FL	1SW	[53.2][1]	52.8	54.2	52.8	53.4	52.6	53.5	52.3	53.0	53.2
	2SW	75.1	76.7	76.6	78.0	77.3	73.6	77.3	76.4	76.7	76.4
	3SW	89.6	89.6	93.9	94.4	94.4	94.9	93.1	91.8	98.3	92.6
Eggs/female	1SW	3369	3310	3519	3310	3398	3280	3413	3237	3339	3369
	2SW	7554	7936	7912	8255	8082	7205	8082	7863	7936	7863
	3SW	11422	11422	12747	12907	12907	13067	12494	12089	14191	12338
Proportion female	1SW	[0.02][1]	0.05	0.04	0.04	0.01	0.00	0.01	0.03	0.03	0.02
	2SW	0.28	0.60	0.65	0.65	0.62	0.75	0.50	0.33	0.47	0.54
	3SW	0.76	0.91	0.69	0.88	0.85	0.43	0.89	0.76	0.56	0.76
Proportion-at-age	1SW	[0.39][1]	0.22	0.42	0.47	0.47	0.36	0.25	0.56	0.32	0.39
	2SW	0.28	0.57	0.43	0.42	0.41	0.52	0.53	0.20	0.53	0.45
	3SW	0.33	0.21	0.14	0.11	0.13	0.12	0.22	0.24	0.16	0.16
Eggs/fish	1SW	26	36	59	62	16	0	9	54	32	26
	2SW	592	2714	2211	2254	2054	2810	2142	519	1977	1911
	3SW	2865	2183	1231	1249	1426	674	2446	2205	1272	1500
	TOTAL	3483	4933	3501	3565	3496	3484	4597	2778	3281	3437
%-at-age of total egg deposition	1SW	1	1	2	2	<1	0	<1	2	1	1
	2SW	17	55	63	63	59	81	47	19	60	56
	3SW	82	44	35	35	41	19	53	79	39	44

[1] 1SW salmon in 1972 were assumed average of the years 1973 to 1980.

Table 4. Estimated numbers of eggs per fish for two sea age-groups of Restigouche salmon. Data sources given in Table 3.

Variable	Age group	1972	1973	1974	1975	1976	1977	1978	1979	1980	All years
FL	2SW	75.1	76.7	76.6	78.0	77.3	73.6	77.3	76.4	76.7	76.4
	3SW	89.6	89.6	93.9	94.4	94.4	94.9	93.1	91.8	98.3	92.6
Eggs/female	2SW	7554	7936	7912	8255	8082	7205	8082	7863	7936	7863
	3SW	11422	11422	12747	12907	12907	13067	12494	12089	14191	12338
Proportion female	2SW	0.28	0.60	0.65	0.65	0.62	0.75	0.50	0.33	0.47	0.54
	3SW	0.76	0.91	0.69	0.88	0.85	0.43	0.89	0.76	0.56	0.76
Proportion-at-age	2SW	0.46	0.73	0.75	0.80	0.76	0.81	0.71	0.46	0.77	0.70
	3SW	0.54	0.27	0.25	0.20	0.24	0.19	0.29	0.54	0.23	0.30
Eggs/fish	2SW	973	3476	3857	4293	3808	4377	2869	1194	2872	2972
	3SW	4688	2806	2199	2272	2633	1068	3225	4961	1828	2813
	Total	5661	6282	6056	6565	6441	5445	6094	6155	4700	5785
%-at-age of total egg deposition	2SW	17	55	64	65	59	80	47	19	61	51
	3SW	83	45	36	35	41	20	53	81	39	49

Table 5. Estimated numbers of salmon required for spawning, assuming an egg deposition requirement of 71,443,200 eggs, and average eggs per salmon as calculated in Table 4.

Year	Eggs/salmon	Total salmon required	2SW	3SW
1972	5661	12,620	5,805	6,815
1973	6282	11,373	8,302	3,071
1974	6056	11,797	8,848	2,949
1975	6565	10,882	8,706	2,176
1976	6441	11,092	8,430	2,662
1977	5445	13,121	10,628	2,493
1978	6094	11,724	8,324	3,400
1979	6155	11,607	5,339	6,268
1980	4700	15,201	11,705	3,496
Mean (±95%CL)	5933 (±447)	12,157 (±1,031)	8,454 (±1,544)	3,703 (±1,282)

Table 6. Estimated spawning escapement and spawning requirements in the Restigouche River, 1972 to 1982. Spawning escapement was estimated from parr densities, assuming 10% survival from eggs to 1+ parr, and a rearing area of 29,768,000 m^2.

Year	1+ parr (year i+2)	Eggs per salmon	Spawning escapement		Spawning requirements	
			Eggs	Salmon	Eggs	Salmon
1972	7.1	5,661	21,135,280	3,767	71,443,200	12,620
1973	9.7	6,282	28,874,960	4,596	71,443,200	11,373
1974	8.4	6,056	25,005,120	4,129	71,443,200	11,797
1975	4.4	6,565	13,097,920	1,995	71,443,200	10,882
1976	8.3	6,441	24,707,440	3,836	71,443,200	11,092
1977	7.1	5,445	21,135,280	3,882	71,443,200	13,121
1978	4.1	6,094	12,204,880	2,003	71,443,200	11,724
1979	3.6	6,155	10,716,480	1,741	71,443,200	11,607
1980	4.4	4,700	13,097,920	2,787	71,443,200	15,201
1981	6.9	(5,933)[2]	20,539,920	3,462	71,443,200	(12,157)[3]
1982	(3.5)[1]	(5,933)	10,418,800	1,756	71,443,200	(12,157)

[1] parr density estimated from significant correlation between angled salmon in year i and parr density in year i + 2 (Chadwick and Randall 1983).

[2] eggs per salmon in 1981 and 1982 were assumed to be average (1972 to 1980).

[3] required spawners in 1981 and 1982 were assumed to be average (1972 to 1980).

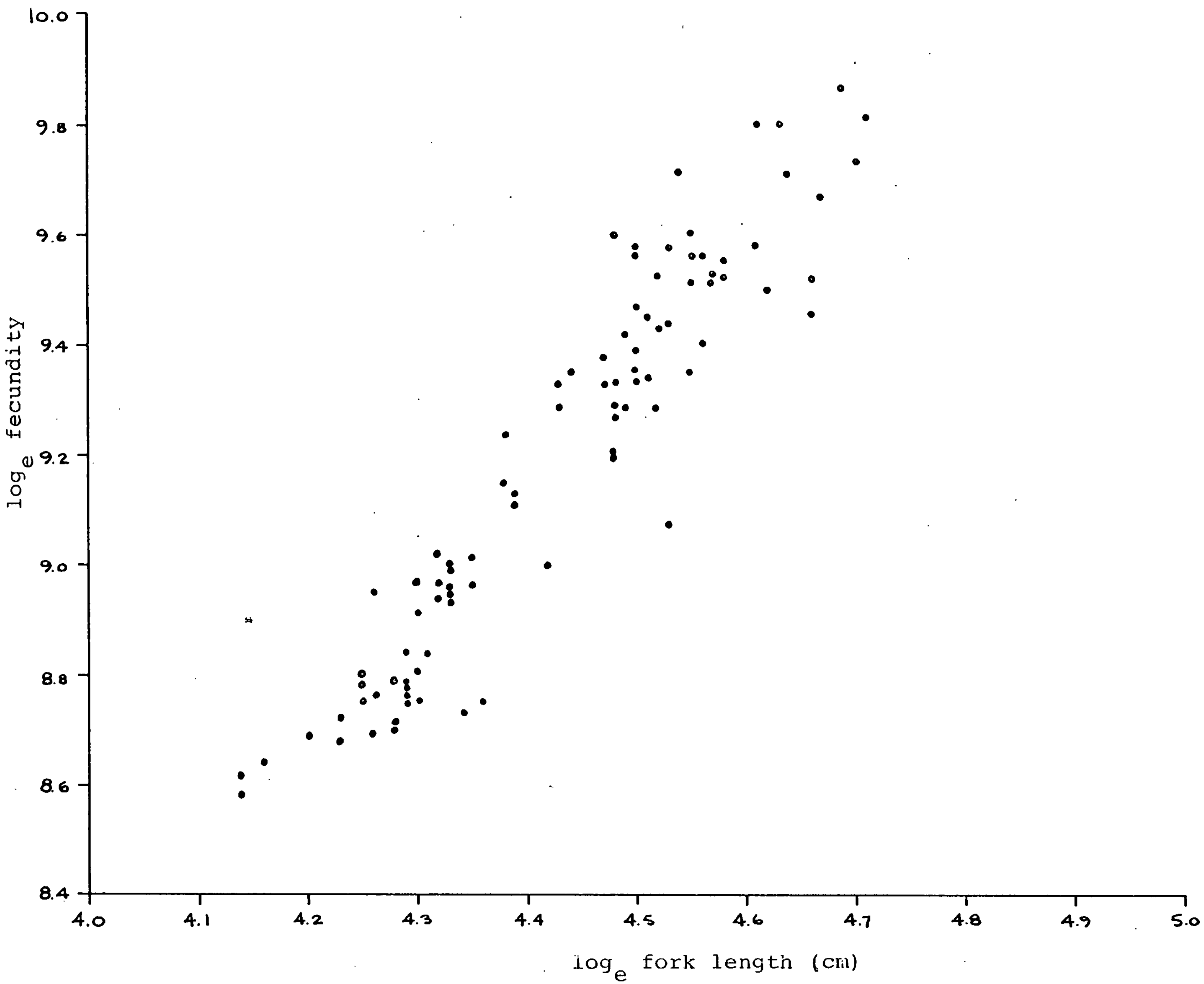

Figure 1: Length-fecundity relationship for 91 Restigouche salmon collected in 1983.