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Atlantic salmon kelt (*Salmo salar* L.) as an index of spawners

by

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ABSTRACT

Atlantic salmon kelt were used as indices of spawners on two Newfoundland rivers. Year-class strength of progeny was determined from smolt migrations. Significant correlations between year-class strength as smolts and kelt counted in their downstream migrations were found on both rivers. An average egg to smolt survival rate of 3% was indicated and used to suggest optimal spawning requirements.

INTRODUCTION

Kelt are adult salmon which are in freshwater between spawning and migration to the sea. They can migrate downstream in the fall immediately after spawning, which is possibly the case in some rivers in Maritime Canada, or they can remain in the river over winter and migrate to sea during the smolt migration in the spring, which is the case in most Newfoundland rivers. This paper examines kelt as an index of spawners. Smolt migrations were used as an index of progeny to measure spawning success. Relationships between spawners and progeny (recruits) were developed in two Newfoundland salmon rivers, Western Arm Brook (WAB) and Little Codroy River (LCR).

METHODS

WAB flows into St. Barbe Bay on the northwestern coast of insular Newfoundland (51°11'25"N, 56°45'58"W), has a drainage basin of 150 km^2, a relief of 108 m, an axial length of 27 km and its headwaters contain 83 ponds and lakes with a total surface area of 2560 ha. The river lies on Ordovician bedrock and has a specific conductance of 108 µmhos.cm^{-1} (Murray and Harmon 1969) which is higher than most Newfoundland rivers (Jamieson 1974).

Little Codroy River (LCR) is located in southwestern Newfoundland; its smolt migrations were monitored from 1954 to 1963 (Murray 1968a); and it provides a good comparison with WAB. It is similar in size (drainage basin of 220 km^2) but with different geomorphology. LCR drains predominantly *Abies* and *Picea* forest; much of its watershed is metamorphic bedrock; its basin relief is 625 m; and contains only one large lake in its watershed. By comparison, WAB drains predominantly sphagnum bog, lies on sedimentary bedrock, has one sixth the basin relief of LCR and contains 83 lakes in its watershed.

Smolt, kelt and adult salmon migrations were enumerated on WAB from 1971 to 1979 at a fish counting fence (Anderson & MacDonald 1978). The downstream migration was monitored from the last week in May until the end of the smolt run which was usually mid-July. The entire run was counted in all years except 1979 when the early parts of the smolt and kelt runs were missed. The upstream migration was usually monitored from mid June to the end of September. All adult fish were sorted into grilse (<62 cm) and multi-sea-winter salmon, and a sample taken for external sexing and aging; see Chadwick (1980) for complete details of fence operation. A sample of kelt was also sexed in most years but not in 1971, 1973 and 1974 and therefore these data were not used.

Smolt, kelt and adult migrations were enumerated on LCR from 1954 to 1963. Complete details of fence operation have been published (Murray 1968a, and 1968b). The fence was considered by Murray to have had a constant efficiency in all years, except 1958 when the fence was washed out for several days during the smolt and kelt runs. All adult fish were sorted into grilse and multi-sea-winter salmon and a sample taken for sex determination, aging, weight and length.

The smolt migrations in both rivers were sampled for scales, usually 5 of each 200 fish counted; the scales were aged; migrations were divided into age groups, and then summed into their appropriate year-classes according to year of hatching. The overwinter survival of kelt was calculated by taking the ratio of kelt counted in year i to adults counted moving upstream in year i-1. Correlations were calculated between smolts hatched in year i and kelts counted in year i, adults counted in year i-1 and overwinter survival of kelt.

The potential egg deposition was calculated from estimations of sex, weight and fecundity for the different sea ages of kelt. In WAB, all kelt were 1-sea-winter (1SW) fish; the sex ratio was determined from external sexing of upstream migrating adults from the year before; the mean 1971-76 weight of adults spawning was 1.6 kg (S.D. = 0.07) and the fecundity of 1540 eggs kg^{-1} was estimated from unpublished data on Noel Paul's Brook. In LCR there were three sea ages of adults. Sea ages were taken from adults migrating upstream in all years (1954-63), but were taken from kelt only in 1955 and 1956 (Anon. 1957). In these two years kelt were sexed by surgical examination. Murray (Anon. 1957) mentioned that 63% of adults tagged moving upstream in 1954 were 1SW fish, but kelt moving downstream in 1955 were only 43% 1SW fish and 40% of the kelt were untagged. He concluded that there were a run of multi-sea-winter salmon in late October after the counting fence was removed. Consequently, although the sea ages and sex ratios of kelt were available for only two years, they were used to estimate for the other years. Fortunately there was close agreement between the two years; in 1955, 40% of the 84 kelt were female and of these 21% were 1SW fish; and in 1956, 38% of the kelt were female of which 22% were 1SW fish; thus for other years, 40% of the kelt were assumed to be female and of these 20% were assumed to be 1SW fish. Multi-sea-winter salmon were not separated into 2SW and 3SW fish and both were assigned a mean weight of 6.2 kg at time of spawning; grilse were assigned a weight of 1.4 kg (Anon. 1957). All females were assumed to spawn 1540 eggs per kilogram.

RESULTS

Smolt year-class size was significantly ($P < 0.05$) related to the number of kelt in LCR and was almost significant in WAB (Table 1). There was no relationship on either river between number of smolts and parents as adults migrating upstream. Overwinter survival from adult to kelt (Table 2) was also significantly correlated with smolt recruits on LCR, and nearly so on WAB (Table 1). This suggested either year class strength as smolts was related to potential egg deposition of kelts, or the same environmental conditions affected hatching success and overwinter survival of kelts.

However when kelts were equaled to potential egg deposition (Tables 3 and 4), there were significant ($P < 0.05$) correlations on both rivers with numbers of smolt in a given year-class (Table 1, Fig. 1). There was a much greater annual variation in egg deposition on LCR compared to WAB (Tables 3 and 4); this effect was partially removed with a natural logarithm on egg deposition and the resulting relationship between it and smolt year-class strength was very significant ($P < 0.01$) on LCR (Fig. 1).

The survival rates from egg to smolt were relatively constant on WAB with a mean of 2.6% and a standard error of 0.19; on LCR the mean survival rate was 3.2% with a standard error of 0.45 if the values for 1958 and 1960 were omitted

(Table 4). In 1958, there was an incomplete count of kelts due to a washout of the counting fence for several days; the 1960 value was also omitted due to a possible imcomplete count of kelts. The mean smolt age of WAB was 3.9 years (Chadwick 1980) which indicated an annual survival rate of 39% ($\chi^{3.9} = 0.026$). The mean smolt age of LCR was 2.6 years (Chadwick 1980) which indicated an annual survival rate of 27% ($\chi^{2.6} = 0.032$). The corresponding instantaneous mortality rates were 0.94 for WAB and 1.31 for LCR.

DISCUSSIONS AND CONCLUSIONS

Kelt were a good index of spawning potential on both WAB and LCR. It was quite possible that kelt counts were not complete on both rivers; kelt could have returned to sea during the year of spawning or before the spring smolt migration. This was particularly possible on LCR. If this were true, than the environmental conditions which encouraged early sea migration of kelt were detrimental to egg survival. It was also possible that kelt which migrated to sea during the smolt migration were the only successful spawners. The results of this paper should certainly focus attention on this aspect of Atlantic salmon life history.

The egg to smolt survival rates were approximately 3% for both rivers, although the annual survival rate on WAB was 30% higher than LCR. The WAB data also suggested that freshwater mortality was quite constant, in spite of changes in year-class strength. This could be an important observation, as many fisheries models, particularly Ricker's stock recruitment relationship, rely implicitly on density-dependent mortality. There appeared to be no levelling off of year-class size as smolts with increased egg deposition, this suggested that both rivers were underseeded, and that smolt production could be considerably greater on both rivers.

The prediction of optimal spawning requirements is complicated by the uncertainty of conditions affecting kelt overwinter survival. For example, 8×10^5 eggs may be optimal spawning requirements on WAB, but how many kelt are required to guarantee this spawning when kelt survival ranged from 29%to 92%? The only alternative would be to base the prediction on an average kelt survival.

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Table 1. Summary of correlations between progeny as smolts and parents as numbers of upstream migrating adults and numbers of kelt, kelt overwinter survival and kelt egg potential on WAB and LCR; r* values required for 95% significance are also shown.

Correlation	WAB r	WAB r*	LCR r	LCR r*
1. Adult	0.14	0.95	0.17	0.81
2. Adult egg deposition	0.20	0.95	0.10	0.81
3. Kelt	0.83	0.88	0.87	0.75
4. Kelt overwinter survival	0.91	0.95	0.94+	0.81
5. Kelt egg deposition	0.90	0.88	0.86	0.75
6. Log_e kelt egg deposition	0.88	0.88	0.95^{+}	0.75

$^{+}$ significant at 99% level.

Table 2. Summary of smolt, adult and kelt migrations at WAB and LCR; percent overwinter survival from adult to kelt is also shown.

	Number smolt	Number adults available for spawning	Number kelt	Percent survival adult to kelt
A) WAB				
1971	5734	732	185	-
1972	11906	262	210	29
1973	8484	381	95	36
1974	12055	319	302	79
1975	9733	408	199	62
1976	6359	324	206	50
1977	9640	362	298	92
1978	13071	290	210	58
1979	9400*	1565	*	*
B) LCR				
1954	12210	215	253	-
1955	11248	130	84	39
1956	14771	108	108	83
1957	8900	167	71	66
1958	9341	139	16	10
1959	12099	103	65	47
1960	7850	78	34	33
1961	8232	59	16	21
1962	8190	74	34	58
1963	7326	159	24	32

* incomplete count, smolt migration was estimated.

Table 3. Number, estimated sex ratio and egg deposition of kelt in WAB (1971-77); the resulting year-class size as smolt and egg to smolt survival rates are also shown.

	Number kelt	Percent female	Number eggs x 10^3	Year-class size as smolt	Percent survival egg to smolt
1971	185	75*	342	8026	2.3
1972	210	72	373	8178	2.2
1973	95	81	190	5966	3.1
1974	302	78	580	13234	2.3
1975	199	84	412	12378	3.0

* value estimated from mean.

Table 4. Number, sex ratio, and egg deposition of kelt in LCR (1954-60); the resulting year-class size as smolts and egg to smolt survival rates are also shown.

	Number kelt	Number female	Number female 1SW	Number female 2SW and older	Number eggs x 10^3	Smolt year-class size	Percent survival egg to smolt
1954	253	101*	20	81	816	12490	1.5
1955	84	34	7	27	273	8911	3.3
1956	108	65	9	32	325	11533	3.5
1957	71	28*	6	22	222	8945	4.0
1958	16*	6*	1	5	49	5354	10.9
1959	65	26*	5	21	211	8164	3.9
1960	34	14*	3	11	111	7799	7.0

* values taken from 1955-56, see text.

+ two kelt were counted moving downstream in November 1957 (Anon. 1959).

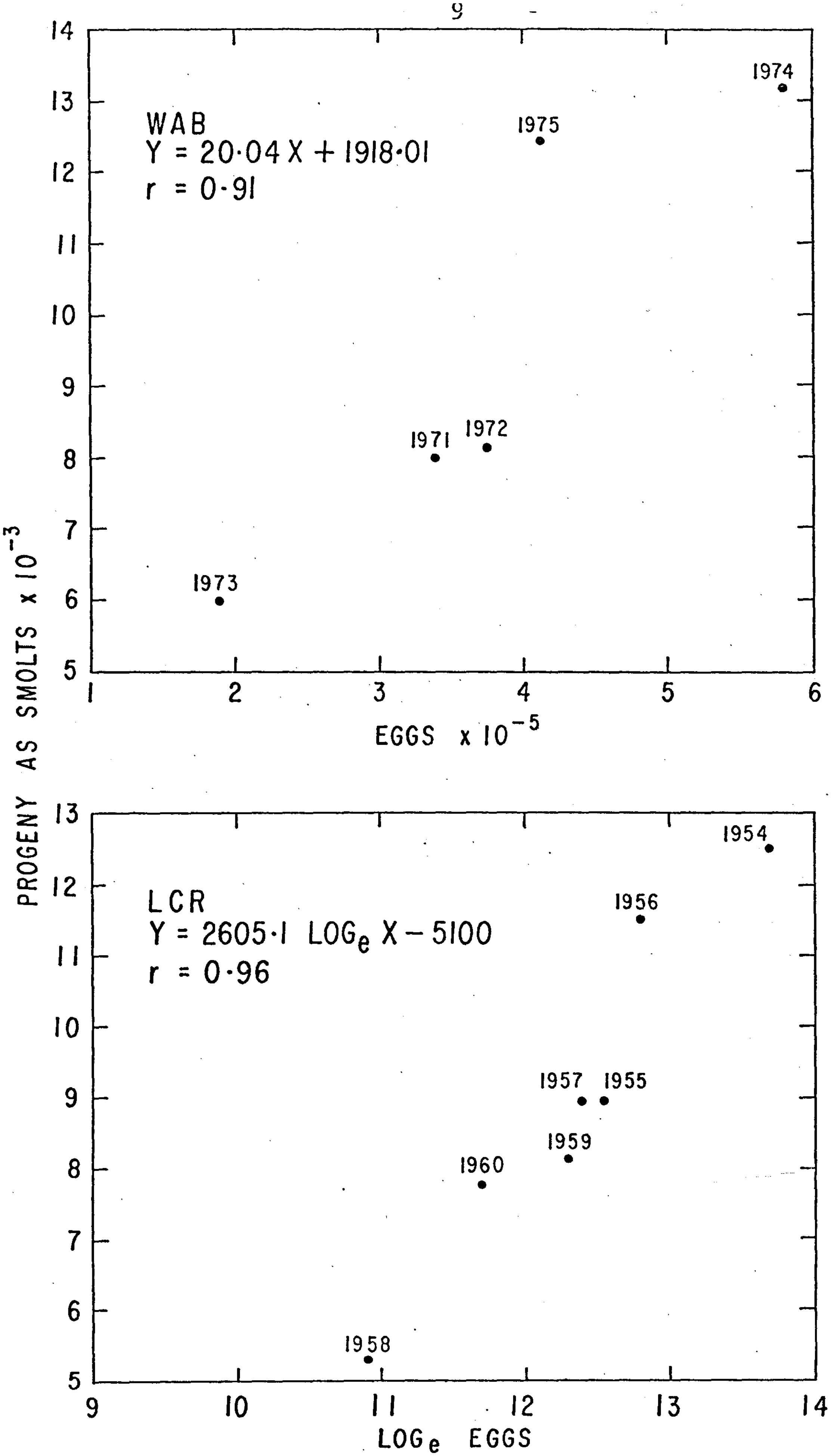

Fig. 1. Relationships between potential egg deposition of kelt and smolt as an index of progeny on a) Western Arm Brook, and b) Little Codroy River.