INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

RESTRICTED

Serial No. 2069
(B.g.14)

ICES ICNAF Sal. Doc. 68/21
(also ICNAF Res. Doc.68/81)

ANNUAL MEETING - JUNE 1968

Marine growth of Atlantic salmon (*Salmo salar*) in the Northwest Atlantic area*

by K. Radway Allen
Fisheries Research Board of Canada
Biological Station, Nanaimo, B.C.

Richard L. Saunders and Paul F. Elson
Fisheries Research Board of Canada
Biological Station, St. Andrews, N.B.

Introduction

Until recently, Atlantic salmon from North American rivers were seldom recorded as caught during the marine phase of life except as they were maturing and approaching coastal waters and rivers. All that was known with certainty has been the sizes at the beginning and end of the marine phase.

By contrast, information on marine growth has been obtained for Baltic salmon (Carlin, 1963, 1964; Thurow, 1966).

The recent growth of a substantial fishery for salmon, many of demonstrably North American origin (Saunders et al., 1965) in West Greenland waters has made material available and has stimulated interest in research on the marine phase. Data on growth rates are essential to understanding the effects of this new fishery through balances between growth rates and natural mortality on salmon catches and stocks elsewhere.

This study brings together available data on the size of Canadian Atlantic salmon at various stages during

*Condensed from a manuscript being prepared for publication their marine life. While few, they are sufficient to warrant a preliminary growth curve.

Material and Results

Data are drawn principally from the Miramichi River system in the Gulf of St. Lawrence (Henderson et al., MS 1965; Schofield, MS, 1967) and from the Pollett River in the Bay of Fundy. Data from fish of unknown origin captured on the high seas have been used to fill in gaps in the growth curves. The principal data are summarised in Table 1. The terminology used is that proposed by Allan (1965). The terms "spawners" and "feeders" are used to distinguish between those which would have spawned in the year of capture from those which would not.

Sample 11 (Table 1) consists of fish which were tagged as naturally produced smolts in the Northwest Miramichi River and then captured in their second sea year in the West Greenland area. Saunders and Allen (1967) have shown that tagged smolts make slightly smaller grilse than untagged smolts. The average ratio between untagged and tagged grilse, when data for early- and late-run grilse are combined, is 1.024:1.000. So, for sample 11, the measured length has been multiplied by 1.024 to obtain an estimate of the normal length of fish at this stage. All other samples are means of direct measurements of total length measured from tip of snout to tip of relaxed tail fin.

In Table 2 data are given on growth made by salmon which were tagged in the Northwest Miramichi fresh waters as grilse and recaptured subsequently. These fish have been divided into two groups, those recaptured after about 1 year at sea and those retaken after about 2 years.

Discussion

Mean lengths in Table 1 are plotted in Fig. 1. Mean lengths of samples 1 and 2 are essentially the same as for 3, and sample 4 the same as 5; 1, 2, and 4 are not shown. To provide an envelope curve describing the maximum mean size at any age, a von Bertalanffy curve has been fitted to the points corresponding to samples 3, 5, 10, 11, 14, 15, and 16, using the method of Allen (1966). The points were weighted according to the size of the sample but variation within the samples was not taken into account. The resulting curve is given by

$$L = 99.06(1-e^{-0.0642}[t-2.313])$$

and is represented by the solid line in Fig. 1.

The von Bertalanffy curve passes close to most points for fish taken during ocean feeding. But points 6, 7, and 8 for grilse entering rivers and point 12 for 2-sea-year spawners entering the Miramichi are below it. The 3 grilse points fit closely to a line which may be extrapolated backwards to reach the von Bertalanffy curve during the preceding winter. Point 9 lies between the two lines, but 3 out of the 4 fish were small and lie only slightly above the extrapolated grilse line.

A line of similar slope to the extrapolated grilse line but drawn back from point 12 also passes through point 11. Point 11 is for tagged Northwest Miramichi fish taken in Greenland and probably represents potential 2-sea-winter fish which, on return, would correspond to point 12. Point 13 also lies almost exactly on this line and it appears likely that this sample represents fish which would have retunned as 2-sea-winter spawners.

Miramichi fish taken in Greenland (point 11) were much larger than late-run grilse (point 7) of almost the same age. Thus, of fish originating from the same smolt class and in the same river, those which mature after 1-sea-winter grow more slowly during the spring and summer preceding their return than do those which will first return after spending 2 or more years at sea.

The data suggest a similar relationship between fish returning after 2 and after 3 sea winters. Point 11 lies well below a smooth von Bertalanffy curve leading past points 14 and 15 and up to point 16. Points 14 and 15 represent few fish but are well outside the range for 2-sea-winter spawners and are consistent with the larger sample represented by point 16.

The fish of sample 10 were larger ($p < 0.01$) than those of sample 11, even though caught earlier in the year. Sample 10 appears to include fish having more rapid marine growth than most Miramichi stock (samples 11 and 12). It may also include a larger proportion of fish which would have spent 3 winters at sea.

Figure 1 also shows growth made by grilse returning for their second spawning after 1 and 2 years at sea. The growth rate of those out for 1 year is similar to that of 2-sea-winter spawners during their second sea year, while that of grilse which will not return for their second spawning until after 2 years parallels closely the growth of 3-sea-winter spawners. Thus it appears that second spawners grow, in intervals between spawnings, at about the same rate as fish of the same age which have not previously spawned, and that they neither make up nor increase the difference in size which developed while they were maturing for the first time.

The foregoing discussion assumes that marine growth of salmon proceeds along smooth curves without seasonal variation. This is contrary to the accepted basis for interpreting scale patterns in terms of growth and age. Generally, more rapid growth is believed to occur when fish encounter warmer water, and the reverse. In Fig. 2, curves have been fitted to the same points plotted in Fig. 1, using the four hypotheses: (a) that growth is seasonal; (b) that the period of rapid marine growth lies approximately between late March and mid October; (c) that slower growth takes place during the remainder of the year; and (d) that fish which are maturing grow during the summer at about the same rate as the preceding winter. The Figure shows the data are consistent with this set of hypotheses.

There are differences in growth patterns of Northwest Atlantic salmon, as suggested by our curves, and salmon of the Baltic, as shown by Thurow's (1966) data. Winter growth in the Baltic is slower but summer growth is faster than in the Northwest Atlantic. Aside from these differences, general growth patterns in the two areas appear to resemble each other.

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Table 1. Mean lengths (tip of snout to tip of relaxed tail fin), with mean dates of capture, etc., of salmon specimens used for study of marine growth rates in the Northwest Atlantic area.

Sample No.	Age-group	Origin	Mean date	Sample size	Mean length	Adjusted mean length	Standard deviation	Relative deviation	Source of data
					cm	cm	cm		
1	Smolt	Pollett R.,N.B. (1952)	24 May	602	15.9	-	1.1	.069	Elson, 1962
2	Smolt	NW Miramichi R.,N.B. (1965)	2 June	1000	14.69	-	-	-	Forsythe, 1967
3	Smolt	" " (1966)	27 May	662	14.57	-	1.58	.108	FRBC, St.Andrews
4	Post-smolt	Bay of Fundy (1952) (marked Pollett R.)	15 Aug.	61	28.79	-	2.19	.076	FRBC, St.Andrews
5	Post-smolt	Bay of Fundy (1952-4) (mixed origin)	16 Aug.	325	29.71	-	2.19	.074	FRBC, St.Andrews
6	1-sea-winter spawner (= grilse)	NW Miramichi R.,N.B. (early run) (1963)	1 July	195	52.95	-	2.24	.042	Saunders and Allen (in press)
7	1-sea-winter spawner (= grilse)	NW Miramichi R.,N.B. (late run) (1963)	23 Sept.	95	57.71	-	2.73	.047	Saunders and Allen (in press)
8	1-sea-winter spawner (= grilse)	Pollett R.,N.B. (1953)	26 Oct.	69	59.81	-	3.85	.064	FRBC, St.Andrews
9	1-sea-winter feeder	E of Newfoundland(1966)	15 Apr.	4	51.20	53.76	-	-	W. Templeman (pers. comm.)
10	1-sea-winter feeder	Labrador S & W Greenland (1965)	14 Aug.	36	65.47	68.74	4.41	.067	W. Templeman (pers. comm.)
11	1-sea-winter feeder	W Greenland (1966) (marked NW Miramichi R.)	10 Oct.	48	64.55	66.03	3.23	.050	FRBC, St.Andrews
12	2-sea-winter spawner	Miramichi R.,N.B. and estuary (1954-66)	29 Aug.	1268	76.61	-	5.74	.075	FRBC, St.Andrews
13	2-sea-winter feeder	E of Newfoundland, Grand Banks (1966)	7 Apr.	36	68.86	72.30	4.16	.060	W. Templeman (pers. comm.)
14	2-sea-winter feeder	Labrador S & W Greenland (1965)	27 July	2	83.1	87.3	-	-	"
15	3-sea-winter feeder	Labrador S (1966)	23 Mar.	1	87.4	91.8	-	-	"
16	3-sea-winter spawner	Gulf of St. Lawrence-	29 July	523	91.95	-	7.70	.086	FRBC, St Andrews

Table 2. Growth rates, as shown by mean total lengths (tip of snout to tip of relaxed tail fin) of fish which spawned as grilse and spent 1 and 2 additional years at sea.

Years absence	No. of fish	Mean date			Mean length			Mean growth rate	
		Marking	Return	Interval	Marking	Return	Increment	Linear	Instantaneous
				days	*cm*	*cm*	*cm*	*cm/day*	*(monthly)*
1	19	1 Aug.	22 June	325	54.4	63.5	9.1	.028	.0142
2	12	4 Aug.	18 June	683	54.1	77.4	23.3	.034	.0157

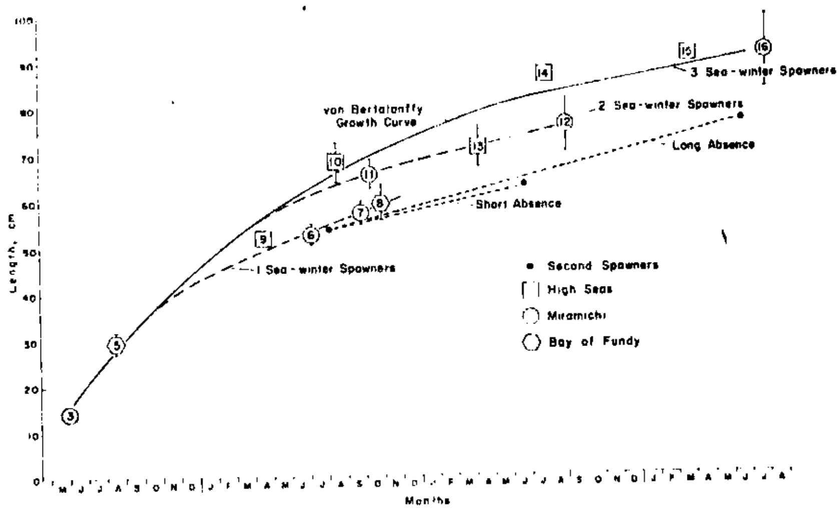

Fig. 1. Growth curves fitted to observed lengths (to tip of relaxed tail) of Northwest Atlantic salmon, based on samples in Table 1. Standard deviations for points are shown. Solid line: von Bertalanffy envelope curve for actively growing fish in marine phase at least one winter before first spawning; broken lines: curves for fish which have passed through most or all of their last sea winter before spawning; dotted lines: curves for fish which matured first as grilse and have survived to approach a second maturity.

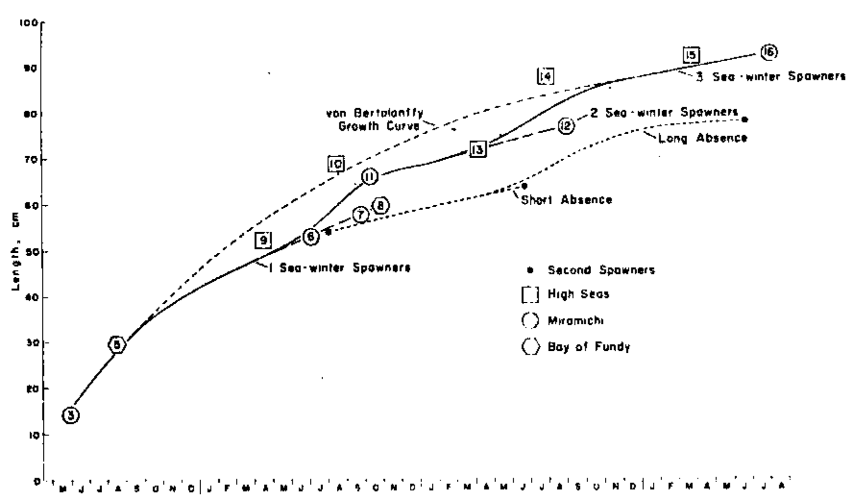

Fig. 2. Growth curves based on von Bertalanffy envelope curve of Fig. 1 but modified to conform with recognized patterns of seasonal growth rates for salmon.