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Size-dependent survival of juvenile Atlantic salmon *Salmo salar* and brown trout *Salmo trutta* from the cold river Beiarelva, northern Norway

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The growth of Atlantic salmon *Salmo salar* L. and brown trout *Salmo trutta* L. in the very cold river Beiarelva is so low that not all individuals reach the critical lengths during their first summer to form scales. Hence, after their first winter, each year-class of Atlantic salmon and brown trout can be divided into two length groups, with the smaller fish lacking the first annulus, and the larger fish having this annulus. For this reason length-dependent survival for the rest of their freshwater life could be examined.

In brown trout the same survival was found in small and larger parr of all year-classes investigated. In Atlantic salmon the same was found in all year-classes except one. In one year-class the survival was significantly less in the smaller group than in the larger.

In 2 + and older fish of both Atlantic salmon and brown trout some of the small individuals had grown as long as most of the individuals having the first annulus, whereas others were still the smallest ones in the year-class. Hence, the smallest yearlings are not always the smallest fish in later years.

The very good food conditions for the parr in river Beiarelva may explain the good survival of small individuals.

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INTRODUCTION

In the river Beiarelva, a cold salmon river in northern Norway, some yearlings of Atlantic salmon *Salmo salar* L. and brown trout *Salmo trutta* L. do not reach the critical length in the first summer to form scales. Paget (1920) discovered that scales from trout *Salmo fario* reared under identical conditions make their appearance upon the body according to size, not age. Several papers report the size of salmonids at which scales appear (Cooper 1951, Nordeng 1961, Parrott 1934, Warner & Havey 1961). In the river Beiarelva scales are formed in the length interval 33—34 mm for salmon, and 36—38 mm for brown trout (Jensen & Johnsen 1982). Individuals which do not reach these critical lengths during their first summer will lack the first annulus in their scales and the number of such fish varies from year to year according to temperature conditions.

Hence, after their first winter, each year-class of salmon and brown trout in Beiarelva can be divided into two length groups with the smaller fish lacking the first annulus (group A), and the larger fish having this annulus (group B).

The two groups can be separated from each other during the whole of their freshwater life by ageing from both scales and otoliths, both structures having been shown to give the correct age in juvenile brown trout (Jonsson 1976). Individuals showing one more year on the otoliths than on the scales lack the first annulus in their scales. These fish, hence, belong to group A. This gives an opportunity to study length dependent mortality in the populations of Atlantic salmon and brown trout, and we have therefore studied four year-classes of Atlantic salmon and three year-classes of brown trout for 2—4 years to follow the composition of the two groups. In this way two questions may be answered.

1. Do the small individuals have a lower survival rate than do the larger ones?
2. Do the small individuals remain to be the smallest ones in their year-class for the rest of their freshwater life?

If the survival from yearlings to smolts is not lower in group A than in group B caution has to be taken when reading smolt age from scales of adult salmon and brown trout. The mean smolt age has to be corrected according to the fraction of yearlings which lack the first annulus in the scales (Jensen & Johnsen 1982).

Description of the river

The river Beiarelva is situated in the county of Nordland, northern Norway (67°N). The drainage area is 1050 km^2. It is one of the largest salmon rivers in Nordland, with a total catch of salmon, anadromous brown trout and anadromous Arctic char *Salvelinus alpinus* (L.) of 5—8 $t\ yr^{-1}$.

The drainage area consists mainly of high mountains and birch forest, with some farm land in the lower regions. Some of the larger tributaries drain the glacier Svartisen, giving Beiarelva a grey-green colour in summer, and making it one of the coldest salmon rivers in the world (Table 1).

The growth of juvenile salmon is about 21 mm yr^{-1}, and the mean smolt age is about 5.4 yr (Jensen & Johnsen 1984). The brown trout grows slightly better, with a smolt age of about 5.0 yr.

MATERIALS AND METHODS

The material was collected within a 5 km stretch in the upper part of the river every year in May and August from 1976 to 1982. An electrical fishing apparatus was used and the material was preserved in formaldehyde for laboratory study. The total length of the fish was measured after spreading the tail into a natural position. Scale samples were taken in an area near the lateral

Table 1. Mean and range of temperatures in the river Beiarelva in July and August 1976—1980. The temperature was measured at 07.30 and 17.30 each second day by the Norwegian Water Resources and Electricity Board, Hydrol. Dep.

		1976	1977	1978	1979	1980
	Min	4.0	4.2	9.1	5.4	6.0
July	Mean	6.7	6.4	11.1	8.4	9.0
	Max	9.2	9.2	13.2	11.7	12.9
	Min	4.2	7.8	6.8	6.5	4.9
August	Mean	7.9	9.5	9.0	9.4	9.2
	Max	11.1	10.9	11.4	11.3	15.0

Table 2. % number of brown trout parr of different ages which lacked the first annulus in their scales

Sampling date	Age	Sample size	% number of fish lacking the first annulus
1977 year class			
May 1978	1 +	27	48
May 1979	2 +	48	29
May 1981	4 +	15	47
1978 year class			
May 1979	1 +	11	36
Aug. 1979	1 +	21	19
May 1980	2 +	34	41
Aug. 1980	2 +	15	27
May 1981	3 +	12	0
May 1982	4 +	14	21
1979 year class			
May 1980	1 +	71	20
Aug. 1980	1 +	53	25
May 1981	2 +	42	24
May 1982	3 +	45	16

Table 3. % number of Atlantic salmon parr of different ages which lacked the first annulus in their scales

Sampling date	Age	Sample size	% number of fish lacking the first annulus
1976 year class			
May 1977	1 +	17	77
Aug. 1977	1 +	10	60
May 1978	2 +	30	70
May 1981	5 +	29	55
1977 year class			
May 1978	1 +	23	61
Aug. 1978	1 +	11	27
May 1979	2 +	13	31
May 1980	3 +	10	20
May 1981	4 +	43	26
May 1982	5 +	18	33
1978 year class			
May 1979	1 +	26	15
May 1980	2 +	59	12
May 1981	3 +	44	7
May 1982	4 +	33	9
1979 year class			
May 1980	1 +	30	10
Aug. 1980	1 +	27	19
May 1981	2 +	67	10
May 1982	3 +	39	13

line between the adipose and the dorsal fin (Dannevig & Høst 1931). Scales and otoliths were immersed in water and viewed under a binocular microscope. A total of 529 salmon and 408 brown trout were investigated. Samples smaller than 10 were omitted.

The material was treated statistically by using the Student's t-test.

RESULTS

Survival

For all three year-classes of brown trout investigated no difference was found in the survival rate between the two length groups (Table 2).

Equally no difference in the survival rate was found in the 1979 year-class of Atlantic salmon (Table 3). In the 1976 and the 1978 year-classes of Atlantic salmon there were slight trends to-

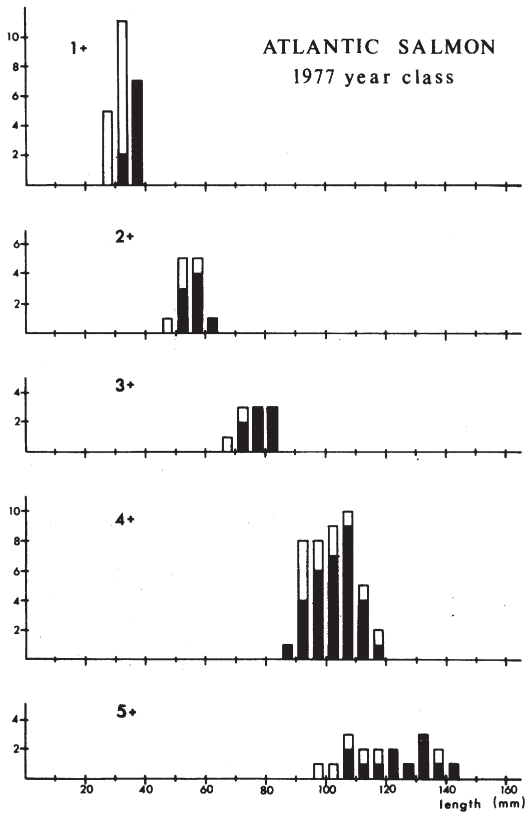

Fig. 1. Length-frequency diagrams of the 1977 year-class of Atlantic salmon from the river Beiarelva. White bars indicate individuals without the first annulus on their scales (group A) and black bars indicate individuals which have got the first annulus on their scales (group B). Data from May each year.

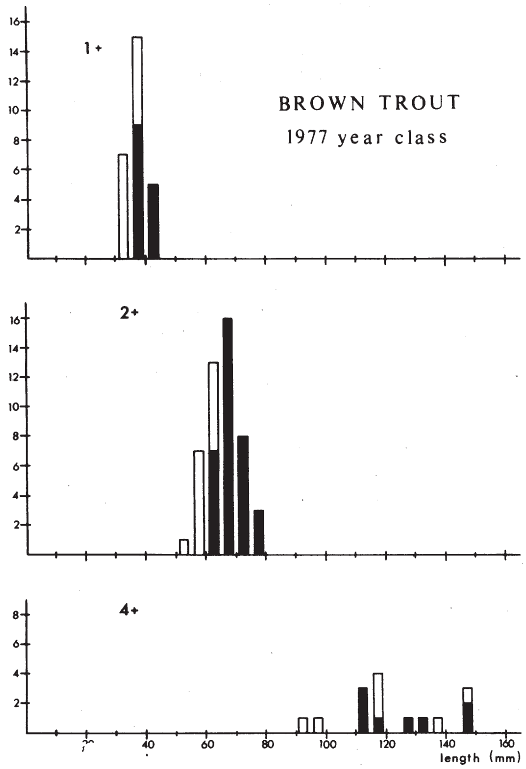

Fig. 2. Length-frequency diagrams of the 1977 year-class of brown trout from the river Beiarelva. Symbols as in Fig. 1.

ward a higher mortality in group A but these were not significant ($p > 0.05$).

The 1977 year-class of Atlantic salmon differed somewhat from the others. Our results indicate a higher mortality in group A between May and August 1978. The sample collected in May 1978 had a significantly higher fraction of parr of group A than the sample from May 1981 ($p < 0.01$). The other samples from this year-class were too small to test (Tab. 3). Since August 1978 the mortality rate has been the same for both groups.

Growth

Length — frequency diagrams of one year-class of each species are shown in Fig. 1—2. Among the yearlings group A was always the smallest ($p < 0.001$). Later on some of the small individuals of group A had grown to be as long as most of the individuals belonging to group B whereas others were still the smallest ones in the year-class. Hence, the smallest yearlings are not always the smallest fish in later years.

DISCUSSION

Both from Chapman (1962), Le Cren (1973), and Gardiner & Geddes (1980) one would expect that the larger individuals of one year-class would have a better chance to survive than the smaller ones. From studies on brown trout fry Le Cren (1973) concluded that there was a hierarchy assosiated with size and the more favourable territories. In some laboratory experiments with coho salmon *Oncorhynchus kisutch* Chapman (1962) found that size was the principal factor governing hierarchy arrangement. Differences as small as 1 mm were found to be important. And Gardiner & Geddes (1980) recorded higher energy content in larger individuals of Atlantic salmon than in the smaller ones of the same year-class. Hence, all these papers indicate that one would expect higher mortality in the smaller fish occupying the less favourable territories, or hiding places. This is in contrast to the results from Beiarelva. In Beiarelva there was no sign of increased mortality in the smaller parr of brown trout in each year-class, and only slightly higher mortality in the smallest parr of Atlantic salmon.

Elliot (1975 a, b, 1976) analysed the growth rate of brown trout fed on maximum and reduced rations at different weights and different water temperatures. This enables one to estimate the extent to which variations in growth rates of trout populations in rivers are determined by ambient temperature regimes rather than by other environmental variables or by genetic factors. Elliott's growth model for trout on maximum ration has been used to the brown trout from Beiarelva. Observed and computed maximum growth rates were quite the same, indicating that the nutrient conditions for brown trout in Beiarelva are very good. In some British rivers Edwards, Densem & Russell (1979) found growth rates between 60 and 90 % of the computed maximum. The very good food conditions in Beiarelva may explain why the survival data do not correspond to the findings of Chapman (1962), Le Cren (1973) and Gardiner & Geddes (1980). A more severe competition for food would probably give a poorer survival to the smallest individuals in Beiarelva.

In Beiarelva the smallest yearlings of Atlantic salmon and brown trout were not always the smallest fish in their year-class in later years. This agrees with Alm (1937), who in experiments with growth of Atlantic salmon in nurseries found that the increase in length during the second year was quite as good among individuals of small size as among larger ones. The increase in length during the second year was frequently even greater in small ones. But when the competition for food was severe, however, the size difference might inhibit the small ones.

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