Published on paper: 1984. Published online: 2024-10-25.
ISSN 1502-4873 (paper). ISSN 1891-5396 (electronic).
doi: https://doi.org/10.5324/fn.v5i0.6126.

Smolt age and size of Atlantic salmon *Salmo salar* L. and sea trout *Salmo trutta* L. in a Norwegian river

TRYGVE HESTHAGEN AND ERIK GARNÅS

Hesthagen, T. & Garnås, E. 1984. Smolt age and size of Atlantic salmon *Salmo salar* L. and sea trout *Salmo trutta* L. in a Norwegian river. *Fauna norv. Ser. A* 46—49.

This paper gives data on smolt age and length of Atlantic salmon and sea trout in the Orkla river in the period 1979—1981. The smolt age of the salmon was significantly higher in 1979 (4.1 years) as opposed to 3.4 and 3.3 years in 1980 and 1981, respectively. However, the average length of the salmon smolts did not differ during the study period. Sea trout smolts showed a significantly lower average length in 1979 compared to that found in the two preceding years. No such difference could be detected in the smolt age which ranged between 3.3—3.6 years during the study period. Smolts of both species showed a heterogeneous length distribution with a variation between 100—170 mm for salmon and 110—200 mm for sea trout. It is concluded that growth rate is more important than the mere attainment of a critical length for initiating smolt descent.

Trygve Hesthagen[1]) & Erik Garnås, Directorate for Wildlife and Freshwaterfish, Tungasletta 2, N-7000 Trondheim, Norway.

INTRODUCTION

Already in the early 1900's Dahl (1910) was aware of the fact that older salmon smolts were produced in Norwegian rivers at higher latitudes. Baglinière (1976) also pointed out this latitude effect by comparing smolt age from different North American and European rivers.

According to Jones (1959) the smolt age is determined by factors as day-length, river temperature and available food. However, considerable variations in the smolt age between different years have been recorded (Nott 1973, Bjerknes 1978, Toivonen & Jutila 1982). Nott (op.cit.) related such differences to prevailing temperature conditions. Later Symons (1979) estimated an average smolt age based on the temperature conditions in the rearing area.

The present paper will focus on this subject based on data from the Orkla river, situtated in central Norway (63°N, 10°E). The river is about 50 m in width, with an average discharge of about 30 m^3/s before regulation. The salmon and sea trout can travel some 92 km up the river to spawn.

METHODS

The study lasted in a three years period from 1979 to 1981. The migrating smolt were captured by a trap of 1 x 1 m with a net pouch of 10.5 mm mesh size (Hesthagen & Garnås 1980). The age of the smolt was determined by the use of otoliths. The fish length was defined as total length and measured to the nearest mm. Overlapping of sizes between parr and smolt was observed. However, there was no silvery coloration on fish of sea-running stock of less than about 10 cm for Atlantic salmon and about 11 cm for sea trout (cf. Elson 1957).

RESULTS

In 1979 the mean smolt age of salmon was 4.0 years, which was significantly higher ($p < 0.05$) than that found in the two following years (3.4 and 3.3 years, Table 1). In 1979, three years old specimens contributed only 6.4% of the smolt compared to 66.3 and 60.5% in 1980 and 1981, respectively. Mean smolt length during the study (131—133 mm) was not significantly different ($p > 0.05$) between years. However, the salmon smolt showed very heterogeneous lengths with individual variation between 100—170 mm (Fig. 1). Based on data from 1980, the average smolt length during the run was not significantly different ($p > 0.05$).

For sea trout smolts, four years old specimens dominated in the 1979 run, while the average age was 3.6 years. In the two following years, the smolt age was somewhat lower (3.4 and 3.3

[1]) Present address: Directorate for Wildlife and Freshwater Fish, P.O. Box 63, N-1432 Ås - NLH, Norway.

Table 1. Age composition and average length ($\bar{x}L$) of Atlantic salmon and sea trout smolts in the Orkla river in the period 1979—1981. C.I. = Confidence interval, P = 0.05.

Salmon	1979			1980			1981		
Age	N	$\bar{x}L$	(C.I.)	N	$\bar{x}L$	(C.I.)	N	$\bar{x}L$	(C.I.)
2 +							5	114	(110—118)
3 +	3	106	(91—112)	114	128	(126—130)	92	130	(128—132)
4 +	39	134	(131—137)	53	135	(132—138)	55	140	(136—144)
5 +	5	137	(125—149)	5	148	(148—159)			
Average	4.0	133	(130—136)	3.4	131	(129—133)	3.3	133	(131—135)
Sea trout									
2 +				2	118	(—)	5	125	(116—134)
3 +	13	124	(118—130)	26	141	(136—146)	33	146	(141—151)
4 +	19	142	(136—148)	11	166	(157—175)	24	165	(158—172)
5 +	1	170	(—)	3	192	(167—217)			
Average	3.6	135	(129—141)	3.4	150	(143—157)	3.3	151	(146—156)

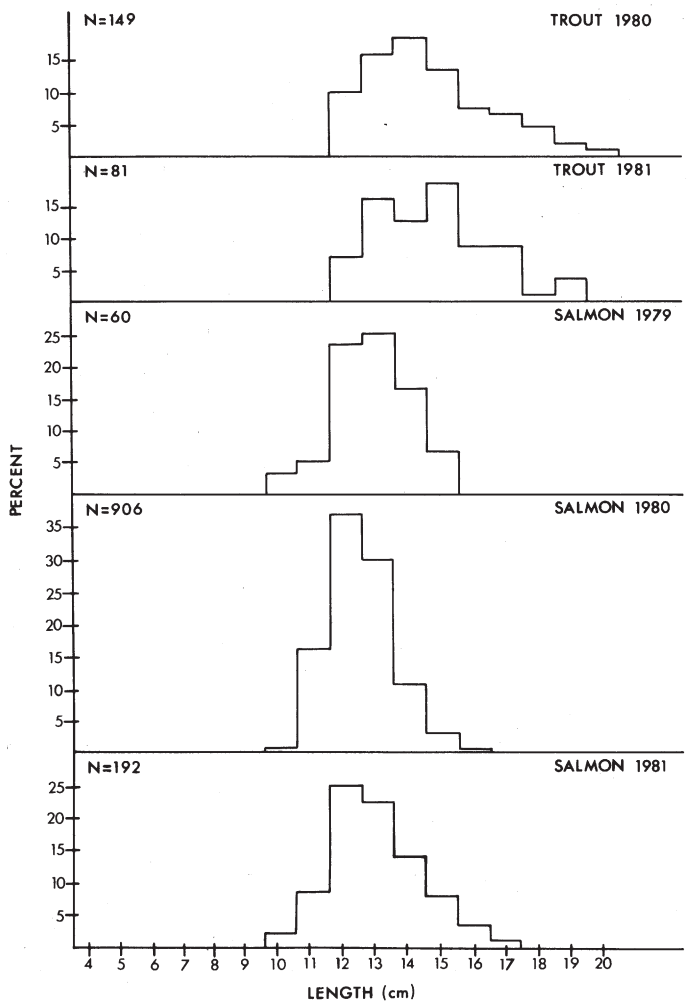

Fig. 1. The length-frequency distribution of Atlantic salmon and sea trout smolts sampled in the Orkla river in the period 1979—1981.

years), but not significantly different from that registered in 1979 ($p > 0.05$). However, the sea trout smolts from 1980 and 1981 were significantly ($p \leq 0.05$) bigger than those produced in 1979 (Table 1). As for salmon the length-frequency distribution for sea trout smolts also revealed a very distinct individual variation ranging between 110—200 mm (Fig. 1). The length distribution of sea trout smolts from 1979 is not given because few specimens were caught.

DISCUSSION

The smolt age and length of Atlantic salmon in the Orkla river average some 3.6 years and 130 mm, respectively. Based on scale analysis of salmon caught in the sea at Kristiansand (S. Norway), Trøndelag (C. Norway) and East Finnmark (N. Norway), Dahl (1910) found a range in smolt age from 2 to 5 years. The latitude effect of producing older smolts in Norwegian salmon rivers at higher latitudes has later been verified through studies in different areas (e.g. Sømme 1942, Flo 1965, Power 1973, Johnsen 1976, Nordeng 1977, Bjerknes 1978, Hansen & Senstad 1982). The smolt age of Atlantic salmon found in the Orkla river is in good conformity to the general geographic variation described for this life parameter.

The differences in smolt age and size become even more conspicuous when we compare populations from the extreme southern and northern parts of the area distribution of the Atlantic salmon. The smolt age and length in rivers in Southern France are one year old and 12—13 cm (Baglinière 1976). In arctic rivers flowing into Ungava Bay in North Canada, the smolt age is 5—6 years and the dominating length about 20—21 cm (Power 1969). Smolt age also decreases from northern to southern rivers on the Kola peninsula, arctic Russia (Jakovenko 1977). The production of older smolts in northern rivers is thus verified through different studies. Further, Baglinière (1976) has pointed out that smolt age is higher in North-American rivers than in European rivers at the same latitude. He equated a higher smolt age with lower temperature in the rearing environment. The increased smolt age found by Nott (1973) during the study period was also connected to the prevailing temperatures in winters prior to the smoltification.

Baglinière (op.cit.) found a correlation between a strong year class and favourable water temperature through enhanced growth rate. Symons (1979) found that average smolt age in any particular river, with exception of Ungava rivers, can be estimated from the number of days per year on which water temperature reached or exceeded 7°C. Jensen & Johnsen (1982) found a very good correlation between growth rate of yearlings of Atlantic salmon and brown trout expressed through formation of scales and the number of days per year with a water temperature above 6.5°C. Within a limited geographic area like Finnmark county in Northern Norway, there are also great variations in smolt age between different rivers (cf. Sømme 1942, Bjerknes 1978). This is also thought to reflect differences in the water temperature of these rivers.

The smolt age of Atlantic salmon in the Orkla river was significantly higher in 1979 (4.0 years) as opposed to 3.4—3.3 years in 1980 and 1981, respectively. The sea trout also showed a higher smolt age in 1979. For both species, both number and size of three-years old smolt were lower that year, compared to that in the two following years. It is thought that this was caused by unfavourable water temperatures during their first year of life, i.e. 1976. That year the number of days with maximum water temperature above 6.5°C was only 94 as opposed to 104 and 115 days the following years (Table 2).

Based on these results we conclude that the transformation to smolt is connected to the growth rate of the fish. The great variation in smolt length does also indicate that the time of migration depends on the individual growth rate during the life cycle. But the smoltification process is also to some extent connected to size. As correctly pointed out by Elson (1957), most salmon smolts exceed 10 cm in length. The marine osmoregulatory mechanisms do not function before the fish exceeds a length of 12—13 cm (Farmer et al. 1978). Thus a certain minimum size is necessary because of physiological adaptations to the sea. It is concluded that the smolt age is dependent on the time it takes for the parr to

Table 2. Number of days per year with a maximum water temperature above 6.5°C (D 6.5°C) in the Orkla river in the period 1975—1980. (Data from the first 8 days in June 1975 is lacking and D 6.5°C is based on the temperature conditions in June 1976, which was similar). Data from NVE-Hydrological division.

Year	1975	1976	1977	1978	1979	1980
D 6.5°C	116	94	104	115	121	126

reach a certain minimum length at which smoltification can occur. The time it takes to reach this length is dependent of the individual growth rate, which varies from river to river as a result of factors as water temperature, fish density and food supply.

ACKNOWLEDGEMENTS

We would like to thank Dagfinn Gausen for assistance with the age analysis and Arne Jensen for reviewing the manuscript. The present research was financed by Trondheim Electricity Board.

REFERENCES

Baglinière, J.L. 1976. Les populations de saumon atlantique (*Salmo salar* L., 1766) en Bretagne-Basse Normandie. *Ann. Hydrobiol. 7,* 141—158.

Bjerknes, V. 1978. *Undersøkelse av fiskebestanden i Jesjåk'ka, Tanavassdraget.* Fiskerikonsulenten i Finnmark. Unpubl. report. 29 pp.

Dahl, K. 1910. *Alder og vekst hos laks og ørret belyst ved studiet av deres skjæl.* Centraltrykkeriet, Kristiania. 60 pp.

Elson, P.F. 1957. The importance of size in the change from parr to smolt in Atlantic salmon. *Can. Fish. Cult. 21,* 1—6.

Farmer, G.J., Ritter, J.A. & Ashfield, D. 1978. Seawater adaptation and parr-smolt transformation of juvenile Atlantic salmon, *Salmo salar. J. Fish Res. Board Can. 35,* 93—100.

Flo, A. 1965. Alder, vekst og kjønnsmodning hos lakseunger fra Oselvvassdraget, Romsdal. *Fauna 18,* 21—28.

Hansen, L.P. & Senstad, C. 1982. Stocking of fingerlings of Atlantic salmon, *Salmo salar* L. in lakes, a possible smolt production method. *I.C.E.S. C.M. 1982/M.31.*

Hesthagen, T. & Garnås, E. 1980. Smoltutvandring i Orkla våren 1979. *Direktoratet for Vilt og Ferskvannsfisk, Reguleringsundersøkelsene. Rapport 4,* 30 pp.

Jakovenko, M.J. 1977. *(Unglaxen i Kola-älven Porja — havsvandring, föda och överlevnad).* Report from Institute of Pinro, Murmansk No. 32. (Translated from Russian to Swedish by E. Pålsson, Geographic Inst. Univ. of Lund, Sweden.

Jensen, A.J. & Johnsen, B.O. 1982. Difficulties in ageing Atlantic salmon *(Salmo salar)* and brown trout *(Salmo trutta)* from cold rivers due to lack of scales as yearlings. *Can. J. Fish. Aquat. Sci. 38,* 321—325.

Johnsen, B.O. 1976. Fiskeribiologiske undersøkelser i de lakseførende deler av Vefsnavassdraget, 1974 og 1975. *Direktoratet for Vilt og Ferskvannsfisk — Reguleringsundersøkelsene i Nordland.* Rapp. 5—1976. 63 pp.

Jones, J.W. 1959. *The salmon.* Harper and Brothers, New York, N.Y. 192 pp.

Nordeng, H. 1977. A pheromone hypothesis for homeward migrations in anadromous salmonids. *Oikos 28,* 155—159.

Nott, F.J. 1973. Production of salmon smolts under natural conditions in Devon Rivers. *Int. Atlantic Salmon Symposium 1972. Special Publ. Series Vol. 4. No. 1,* 157—168.

Power, G. 1969. The salmon of Ungava Bay. *Arct. Inst. N. Am. Tech. Pap. 22,* 77 pp.

Power, G. 1973. Estimates of age, growth, standing crop and production of Salmonids in some North Norwegian rivers and streams. *Rep. Inst. Freshw. Res. Drottningholm 53,* 78—111.

Symons, P.E.K. 1979. Estimated escapement of Atlantic salmon *(Salmo salar)* for maximum smolt production in rivers of different productivity. *J. Fish. Res. Board Can. 36,* 132—140.

Sømme, S. 1942. On the high age of smolts at migration in Northern Norway. *Det Norske Akademi i Oslo I. Mat.-Naturv. Klasse* 1941. No. 16. 5 pp.

Toivonen, J. & Jutila, E. 1982. Report on parr population densities, tagging experiments and river catches of the salmon stock of the river Simojoki in 1972—1980. *I.C.E.S. C.M. 1982/M:40.*