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Evaluation of the nursery areas, Atlantic salmon juvenile abundance and smolt production in River Ellidaar and River Vesturdalsa, Iceland

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Introduction

Annual surveys of the salmon stocks in two Icelandic rivers have been conducted. These rivers were chosen as index rivers for Iceland and are River Ellidaar SW-Iceland and River Vesturdalsa, NE-Iceland (Figure 1 and 2). Accurate salmon catch statistics are available for both rivers for decades. Counting of up migrating salmon have been conducted in R. Ellidaar since 1935, but for the last two years in R. Vesturdalsa. Juvenile surveys with electro-fishing have been done since 1987 in R. Ellidaar and in 1981 and 1982, and since 1979 in R. Vesturdalsa. Smolts have been captured and tagged in R. Ellidaar since 1988 and since 1989 in R. Vesturdalsa. No smolts were caught in 1993 and 1994 in R. Vesturdalsa, despite of numerous trials. Smolts were also trapped and tagged in 1975 (Isaksson *et. al* 1978) and in 1985 (Kristjansson 1987) in R. Ellidaar.

These two rivers are similar in size and the conductivity of their water is similar. R. Ellidaar are located in SW-Iceland where climate and ocean condition are more stable than in NE- Iceland, where R. Vesturdalsa is located. The salmon returns predominantly as 1 SW fish in R. Ellidaar but 1 SW and 2 SW salmon are of approximately equal number in R. Vesturdalsa on average. The fluctuation in catch from the same smolt cohort are 3-4 fold in R. Ellidaar, but up to 45 fold in R. Vesturdalsa.

Methods

Evaluation of river habitat

To evaluate the habitat in the rivers a classification system used in the United Stated of America (Klemm and Lazorhak 1984) with revision built on experience and application from Iceland (Antonsson and Gudjonsson 1998). The river under study was divided into sections that were uniform in character. These sections could be of various size (length). In each sections 1 to 3 cross-sections were made were the width of the river was measured and the type of bottom substrate was classified into the following types; **1.** silt/sand **2.** small gravel < 7 cm in diameter, **3.** small stones 7-20 centimetres in diameter, **4.** boulders >20 centimetre in diameter and **5.** bedrock. These 5 types of

bottom substrate have different value as salmon juvenile habitat. Class 1 and 5 were considered as having no value for salmon juveniles and were therefore multiplied by 0., class 2, small gravel and class 4, boulders have some value (multiplied by 0.2) and class 3, small stones, has the highest value as juvenile habitat (multiplied by 0,6). When % of each substrate class was multiplied by the habitat value a number of quality units for the section was available. When multiplied by the size of the section (m^2) the number of production units for that section were available. The number of production units therefore include both the size and the quality of the section or river as habitat for salmon juveniles. By adding the number of production units from all sections of the river the total number of productions units for the whole river is on hand.

Juvenile surveys

Annual electro-fishing were conducted in order to measure the number of salmon juveniles of each year-class. The fishing took place late in the summer. In R. Ellidaar electro-fishing took place annually at 8 stations but at 5 to 6 stations in R. Vesturdalsa. At each station the area from one bank to the middle of the river was fished once by passing the area systematically back and forth with the anode of the electro-fishing equipment. The area's length and width was then measured. A common size of each station was 150-300 m^2. The size of the stations where large enough to give good idea of the number of juveniles within each year-class in that area. The number of juveniles per year-class was then calculated per 100 m^2. This method gives index of juvenile abundance, since total number of parr in the area is not evaluated.

The juveniles recovered quickly after the electro-shock and were anaesthetised with MS-222 (tricaine metane sulphonate) before they were measured. Afterward they were put into fresh water where they recovered before they were released into the area. A few fry and parr where sacrificed to get scales and otholids for age determination.

The size of the smolt run

Smolts were captured each summer from 1988 to 1996 in R. Ellidaar using threshold trap, with grids with 10 mm interval. The fishing took place each year from middle of May until the smolt run was diminishing during the period from 10th to 20th of June.

In R. Vesturdalsa smolts were first captured in 1988 and fishing was tried each year after that. In 1993 and 1994 only very few smolt were captured. Fyke-net trap was used in R. Vesturdalsa.

During peak of the smolt run, the smolt were tagged every day, but when only few smolt were captured they were kept until tagging every other day. The smolt were anaesthetised with MS-222 and then their adipose fin was cut off and then their length and weight measured for each smolt and then it was individually micro-tagged. Few smolts were sacrificed to get scales and otholids for age determination as well as for sex determination.

In the sport fishery catch in the rivers each micro-tagged salmon was detected and its tag recovered. From the recovery data and the catch statistic it was possible to calculate the size of the smolt run with the Peterson´s method (Youngs and Robson 1978).

$\hat{N} = m \cdot c/r$, where

$\hat{N}$ = estimated number of fish in population

m = number og marked fish in population

c = number of fish in sampel

r = number of marked fish in c.

Standard deviation on N is:

$$Sd(\hat{N}) = \hat{N} \sqrt{(N-m)(N-c) / mc(N-1)}$$

Results

Evaluation of salmon production area

In R. Ellidaar the total bottom area is 200.000 m^2 , but due to regulation of the river for power production 14.700 m^2 is dry during part of the year. Therefore salmon production can take place in 185.000 m^2 , but production units were 5.8 millions (Table 1). The river was divided into a total of 19 sections with uniform habitat characters.

In R. Vesturdalsa the total bottom area was 496.000 m^2 but production units were 13.8 millions (Table 2). The river was divided into a total of 11 sections with uniform habitat characters.

River Vesturdalsa is therefore 2.68 times bigger in total bottom area and 2.38 times larger in production units.

The density of salmon juveniles

There was some variation in the annual juvenile index in R. Ellidaar (Table 3). The density for 0+ was lowest 6.6 fry per 100 m^2 in 1994, but highest in 1987 68,6 per 100 m^2. The density of older parr also varied between years. Parr 4+ or older were absent in some years but were always low in number.

Four year-classes of salmon juveniles (0+ - 3+) were present in R. Vesturdalsa, but older parr were also present in some years (Table 4). Young-of-year (0+) were usually newly hatched and small in size when fishing took place. This affected the catch and the number of 0+ were very different between years. The presence of the 0+ year-class and the size of the fry can be used as some indication of the size of the year-class. Older parr also varied between years in R. Vesturdalsa.

The biomass of salmon juveniles

The biomass of the juveniles in R. Ellidaar was from 4,9 to 79.1 g per 100 m^2 for 0+, for 1 + parr it varied from 13,3 to 194,9 g per 100 m^2 , for 2+ parr it was from 39,3 to 197,0 g per 100 m^2 , for 3+ parr it was 6,5 to 120,4 g per 100 m^2 and for 4+ it varied from 1,4 to 10.9 g per 100 m^2 . The total biomass was highest in 1987, 502.6 g per

100 m^2 but lowest in 1993, 102,9 g per 100 m^2 (Table 5). The average was 227,7 g per 100 m^2 or 421 kg in the river according to the juvenile index. In 1981 the density was measured using 3 passes in electro-fishing. The catchability in the first pass was then 40-50 % depending on the stations. If 45 % is assumed then the total biomass would be 936 kg.

The biomass of the juveniles in R. Vesturdalsa was for 0+ fry from 0,0 to 6.4 g per 100 m^2 , for 1 + parr it varied from 0,0 to 19,3 g per 100 m^2 , for 2+ parr it was from 0,7 to 62,6 g per 100 m^2 , for 3+ parr it was 0,0 to 80,5 g per 100 m^2 and for 4+ it varied from 0,0 to 7.9 g per 100 m^2 and for older parr it varied from 0,0 to 7,9 g per 100 m^2. The total biomass was highest in 1980, 126.4 g per 100 m^2 , but lowest in 1985, 3,9 g per 100 m^2 (Table 6). This is 30 fold difference. The average was 52,1 g per 100 m^2 . If same assumption are used as in R. Ellidaar then the total average juvenile biomass would be 574 kg in R. Vesturdalsa.

The production of smolts

The number of smolt caught in R. Ellidaar varied from 352 to 3434 for the period 1988 to 1996. In R. Vesturdalsa the number were 6 to 2275 smolt during the period 1989-1996.

The total number of smolt is evaluated by the Peterson's method. In R. Ellidaar migrating salmon have been counted and by using the data from the counter as well as the catch statistics it is possible to calculate the total number of emigrating smolt one year earlier. The number of smolt for the period 1988-1996 has varied from 14.500 to 27.500 smolt. The return ratio has been 4,6 - 9,6 % (Table 7) for the same period.

In R. Vesturdalsa the return ratio has been 0.5 - 2,1 % as 1SW salmon and 0,4 - 0,6 as 2 SW salmon. These numbers are for catch since the total run is unknown. The number of smolts have been calculated from 9.300 to 24.000 (Table 8). If 50 % of the run is caught (as has been the experience for the last 2 years), then the return rates can be multiplied by 2 to get the total return rates.

Discussion

The two rivers in this study are similar in water discharge, and number of production units and conductivity. Other factors are different. The climatic condition are very different (Jonsson 1993) and according to Köppens climatic zone classification they are in 2 different climatic zones (Ahrens 1994). The ocean condition outside these two rivers are also different, being more stable in the sea south and west of Iceland than in the north and east of Iceland (Stefansson 1981). These can partly explain the difference in smolt production and return rates in the two rivers.

The juvenile index is several fold higher in R. Ellidaar than in R. Vestudalsa. The average number of laid eggs are also higher in R. Ellidaar i.e. 32.9 eggs per m^2 but 2.0 per m^2 in R. Vesturdalsa (Antonsson et al. 1998).

The total juvenile biomass was 936 kg in R. Ellidaar but 636 kg in R. Vesturdalsa. That is 1.5 times higher in favour of Ellidaar despite of smaller bottom area.

The total number of smolt was on the average 12.172 in R. Vesturdalsa but 21.348 in R. Ellidaar. That is 1.8 times higher in R. Ellidaar. Therefore, there are similar differences in juvenile biomass and number of smolt in the two rivers.

Calculations of return rates in R. Vesturdalsa is based upon the ratio of tagged/untagged salmon in the catch, since the size of total salmon run is not available, except for the last two years. In R Ellidaar the return rates are calculated from the total salmon run. If it is assumed that 50-60 % of the run is caught in R. Vesturdalsa (the experience last two years) the total return rate in R. Ellidaar is threefold higher than in Vesturdalsa. The number of smolt is also lower in R. Vesturdalsa (1.8 times higher on average in R. Ellidaar). This is 5.4 times (3 x 1.8) in favour for R. Ellidaar. The difference in these two key factors i. e. number of smolt and return rates explain why the average catch is 1350 salmon and 241 salmon in R. Ellidaar and in R. Vesturdalsa, respectively. That is 5.6 fold difference in catch, which is similar difference as in number of smolt and return rate. Therefore, we conclude that the evaluation of the size and quality of nursery areas, the juvenile index, the estimate of number of smolt and return rates are of the right order of magnitude. Furthermore, these can be utilized as useful tools in salmon management.

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Figure 1. The River Ellidaar SW Iceland.

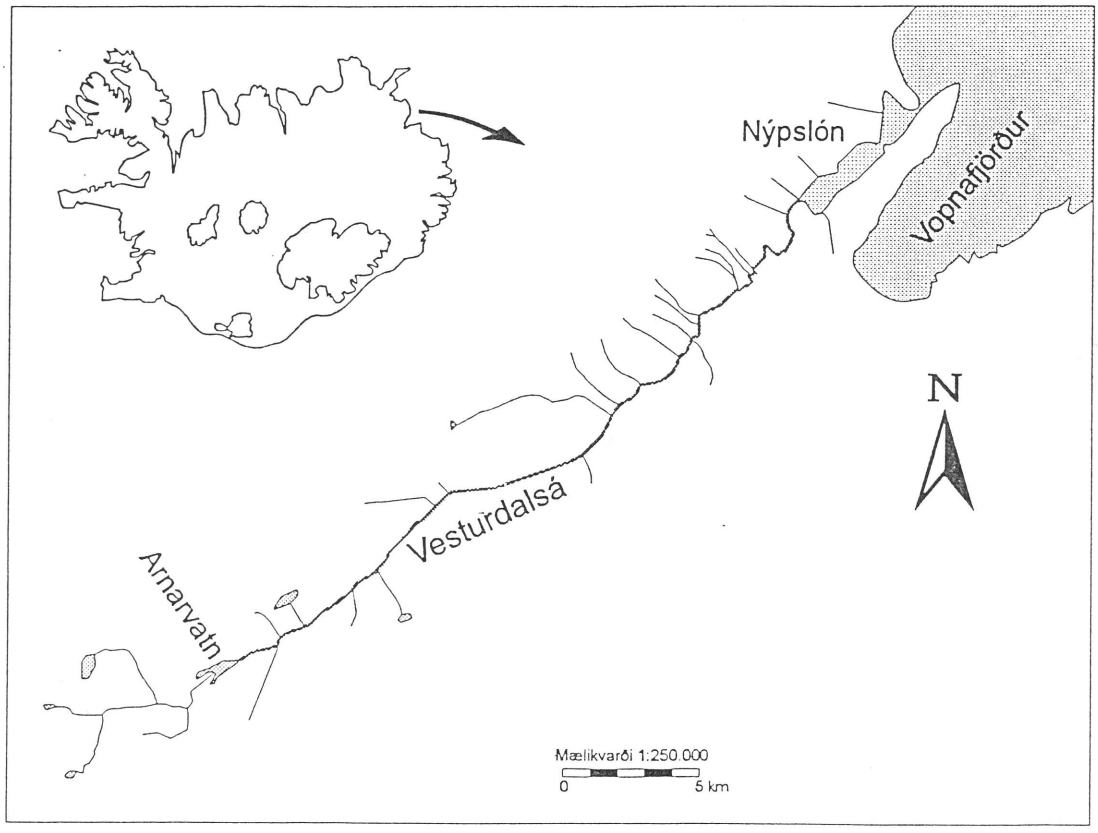

Figure 2. The Vesturdalsa river system NE Iceland.

Table 8. Number of smolts in (N_1) River Vesturdalsa, and return rate (E_1) after one and two years at sea. Return rate in River Vesturdalsa is calculated from the rod catch (m: number of tagged smolts; c_1:catch of 1SW; r_1:number of tagged fish in the 1SW catch; N_2:estimated number of smolts from proportion of tagged in the 1SW catch; Sd:standard deviation; w: average smolt weight; W: total smolt wigth. Footnote $_2$ for 2SW).

River Vesturdalsa

Year	m_1	c_1	c_2	c_1+c_2	r_1	r_2	r_1+r_2	N_1	N_2	N_1N_2	$Sd(N_1)$	$Sd(N_2)$	E_1	E_2	w	W
1989	1250	82	59	141	7	8	15	14642	9219	11750	5278	3021	0,56	0,64	18,40	216,20
1990	390	57	69	126	2	2	4	11115	13455	12285	7701	9351	0,51	0,51	17,40	213,70
1991	1579	195	85	280	33	10	43	9330	13421	10282	1465	3974	2,10	0,63	17,26	177,50
1992	2099	236	103	339	26	9	35	19052	24022	20330	3503	7633	1,20	0,43	14,34	291,50
1995	1036	108	66	174	17	12	29	6581	5681	6216	1564	1479	1,60	1,16	29,31	182,20
1996	1323	156			18			11466			2525					

Table 1. Estimated size and quality of nursery area for salmon juveniles in River Ellidaar. The sum of quality value units and size of bottom area forms production units.

Area	Length (m)	Width (m)	m^2	Quality value units	Production units
I	163	15,6	2543	16	40685
II	760	12,75	9690	39	377910
III	1225	12	(-14700)*	0	0
IV	1825	5	9125	37	337625
V	750	5	3750	0	0
VI	890	13,5	12015	37	444555
VII	630	5,75	3623	42	152145
VIII	200	13,5	2700	4	10800
IX	2150	15,3	32895	45	1480275
X	610	13,1	7991	28	223748
XI	1300	7,5	9750	0	0
XII	600	7,2	4320	51	220320
XIII	880	12	10560	47	496320
XIV	850	12	10200	8	81600
XV	3500	11,7	40950	36	1474200
XVI	2000	6	12000	39	468000
XVII	600	4	2400	10	24000
XVIII	500	11	5500	0	0
XIX	2500	2	5000		
Total	**21933**		**185011**	**439**	**5832183**

* dry in periods with low water level

Table 2. Estimated size and quality of nursery area for salmon juveniles in River Vesturdalsa. The sum of quality value units and size of bottom area forms production units.

Area	Length (m)	Width (m)	m^2	Quality value units	Production units
I	6750	20	135000	2	270000
II	3400	20	68000	24	1632000
III	3250	20	65000	44	2860000
IV	2000	20	40000	52	2080000
V	3200	20	64000	44	2816000
VI	2100	18	37800	56	2116800
VII	500	18	9000	30	270000
VIII	500	10	5000	16	80000
IX	1000	14	14000	40	560000
X	1750	14	24500	28	686000
XI	2400	14	33600	12	403200
Total	**26850**		**495900**	**348**	**13774000**

Table 3. Average number of juveniles in a yearclass per 100 m^2 nursery area in River Ellidaar. Total area in the survey is given. Data for 1981 are from Gardarson (1983).

		Age					
Year	no. m^2	0+	1+	2+	3+	4+	no./100 m^2
1981	978	63,7	17,6	6,9	0,5	0,0	88,7
1982	617	10,2	18,5	8,8	6,0	0,0	43,5
1987	962	68,6	34,2	15,6	3,7	0,0	122,1
1988	565	68,5	44,8	19,6	3,4	0,5	136,8
1989	1554	9,2	8,5	10,6	3,0	0,1	31,36
1990	1275	12,2	16,0	3,1	1,3	0,1	32,7
1991	991	8,0	15,7	16,9	2,8	0,0	43,4
1992	1080	15,6	7,6	7,1	4,1	0,0	34,4
1993	1415	6,8	5,2	5,5	1,9	0,7	20,1
1994	1510	6,6	4,0	5,4	3,1	0,5	19,6
1995	930	11,8	13,2	7,6	1,4	0,2	34,2
1996	1046	7,3	4,4	3,7	2,3	0,1	17,8
Average		**24,04**	**15,81**	**9,23**	**2,79**	**0,18**	**52,06**

Table 4. Average number of juveniles in a yearclass per 100 m^2 nursery area in River Vesturdalsa. Total area in the survey is given.

		Age					
Year	no. m^2	0+	1+	2+	3+	>3+	no./100m^2
1979	1270	0,6	10,0	4,9	9,7	0,4	25,6
1980	1925	7,1	1,5	13,6	1,8	2,7	26,7
1981	1670	1,9	7,1	1,8	6,5	0,4	17,7
1982	2980	0,0	1,3	4,5	0,5	0,5	6,8
1983	1260	0,2	0,6	3,0	2,1	0,5	6,4
1984	480	0,0	0,0	1,2	6,4	0,0	7,6
1985	2780	0,1	0,0	0,2	0,0	0,2	0,5
1986	3120	2,8	2,5	0,1	0,6	0,1	6,1
1987	3320	4,2	2,1	0,7	0,1	0,1	7,2
1988	1200	0,2	7,1	1,6	0,2	0,0	9,0
1989	1260	1,0	3,3	7,5	0,6	0,0	12,4
1990	805	0,0	10,7	7,3	4,3	0,0	22,3
1991	1685	0,6	2,3	3,5	1,5	0,0	7,9
1992	1350	3,6	1,8	3,1	5,4	0,8	14,7
1993	1153	0,4	3,3	1,9	3,1	1,0	9,7
1994	1020	0,0	3,2	4,0	3,0	0,5	10,7
1995	1645	0,1	1,3	1,3	0,5	0,8	4,0
1996	1130	2,1	1,5	1,5	1,8	0,5	7,4
Average		**1,38**	**3,31**	**3,43**	**2,67**	**0,47**	**11,26**

Table 5. Biomass (g) for yearclasses of juveniles per 100 m^2 nursery area in River Ellidaar.

	Age					
Year	0+	1+	2+	3+	4+	total
1981	64,3	93,5	52,7	6,5		217,0
1982	4,9	67,9	52,4	44,3		169,4
1987	74,1	161,4	197,0	70,1		502,6
1988	65,1	194,9	188,4	42,9	10,7	502,0
1989	8,4	27,0	71,9	32,3	1,4	141,0
1990	12,1	70,9	36,1	16,5		135,6
1991	8,2	64,2	146,9	50,9		270,2
1992	17,8	41,7	61,9	46		167,4
1993	7,3	22,6	39,3	22,8	10,9	102,9
1994	10,8	13,3	57,0	42,7	8,6	132,4
1995	11,8	78,3	70,7	120,4	5,5	286,7
1996	12,8	24,3	35,6	29,9	2,5	105,1
Average	**24,80**	**71,67**	**84,16**	**43,78**	**3,30**	**227,70**

Table 6. Biomass (g) for yearclasses of juveniles per 100 m^2 nursery area in River Vesturdalsa.

	Age					
Year	0+	1+	2+	3+	>3+	total
1979	0,2	14,0	19,1	80,5	9,8	123,6
1980	6,4	3,0	62,6	16,0	38,6	126,5
1981	0,6	8,5	8,3	39,7	6,7	63,7
1982		2,7	12,2	6,8	10,7	32,3
1983	0,1	1,7	18,3	21,8	9,0	50,9
1984			6,7	42,9	0,0	49,6
1985	0,0		0,8		3,1	3,9
1986	1,4	7,5	0,7	9,6	3,6	22,8
1987	2,5	6,5	5,3	1,6	0,0	15,9
1988	0,1	15,6	13,8	3,0	0,0	32,5
1989	0,3	5,9	50,3	10,1	0,0	66,6
1990		19,3	37,2	38,7	0,0	95,2
1991	0,7	7,1	16,1	18,8	0,0	42,7
1992	2,9	6,5	18,9	53,5	12,6	94,4
1993	0,1	5,9	11,6	27,6	16,2	61,5
1994		7,7	24,0	31,5	8,7	71,8
1995	1,0	4,3	7,6	4,1	14,0	31,0
1996	1,7	4,1	11,3	23,9	11,8	52,7
Average	**0,99**	**6,69**	**18,04**	**23,89**	**8,03**	**57,65**

Table 7. Number of smolts (N_1) in River Ellidaar and return rate (E_1) after one year at sea. Return rate in River Ellidaar is calculated from the total salmon run (m: number of tagged smolts; c_1:catch of 1SW; r_1:number of tagged fish in the 1SW catch; Sd:standard deviation; w: average smolt weight; W: total smolt weight.

River Ellidaar

Year	m_1	c_1	r_1	N_1	$Sd(N_1)$	E_1	w	W
1975				14000		20,8		
1985				29000		9,4		
1988	3279	1195	170	23049	1594	12,7	24,50	564,7
1989	281	744	10	21749	6710	8,1	28,80	626,4
1990	544	485	11	23985	7076	5,4	20,37	488,6
1991	1736	923	73	21950	2413	8,8	25,35	556,4
1992	2311	1094	92	27480	2740	9,6	24,26	666,7
1993	868	867	42	17918	2631	9,8	25,11	499,9
1994	514	530	19	14477	3217	9,0	24,21	350,5
1995	1769	957	94	18009	1716	9,4	22,95	413,3
1996	1462	540	34	23220	3810	4,6	22,43	520,8