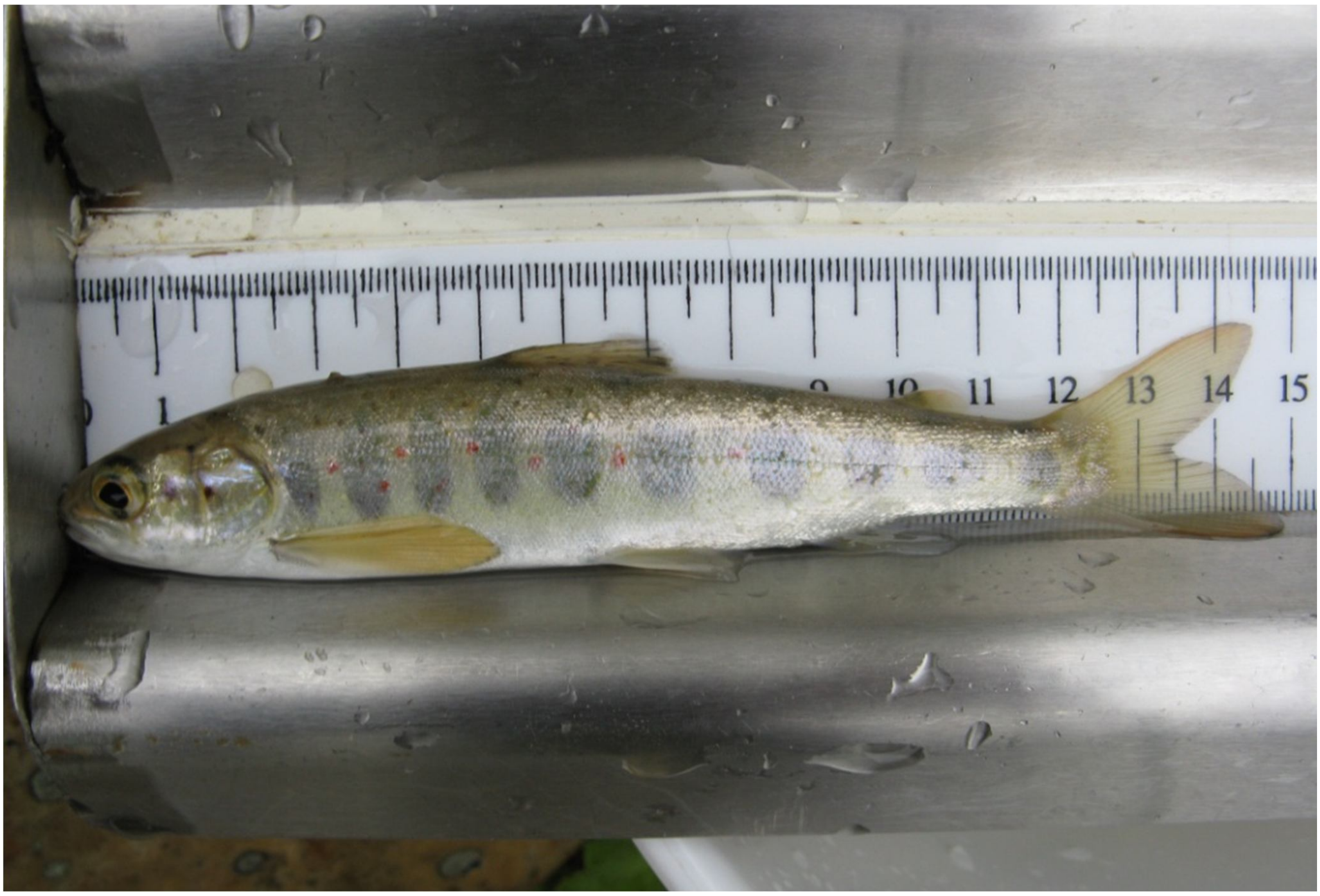
Kolarctic ENPI CBC – Kolarctic salmon project (KO197) - Report IX

Growth differences of juvenile salmon in the rivers in Finnmark and Troms in the material collected in the years 2009-2012

Salla Kaartinen[1], Eero Niemelä[1] and Esa Hassinen[1]

[1] Finnish Game and Fisheries Research Institute



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Cover photo: Salmon juvenile on measuring board (Photo: Eero Niemelä).

Abstract

All rivers from which at least 10 salmon (N=79) were caught, were grouped based on the median growth increments of juveniles by hierarchical clustering analysis. Grouping the first and second year growth increments produced four distinct clusters where group A (n=21) has the lowest growth, groups B (n=30) and C (n=24) grow slightly faster than group A and group C has a larger median growth than group B. Rivers in group D (n=4) have the fastest growing salmon juveniles. According to the third year median growth increments of juveniles, the growth rate remains slow in 10 rivers. In 20 rivers, the growth spurt at the year three compared with previous two years, and in 17 rivers, the growth seems to slow down. In 25 rivers, the growth rate of the juvenile salmon seems to be rather stable over the three-year period. Rivers with missing third growth increments were excluded (n=7). This report is producing baseline data on the growth of juvenile salmon in rivers which locates in extreme north. The mean growth values and growth increment data can be used in the future as an index data when evaluating possible effects caused by global warming to salmon stocks, to salmon ecology, juvenile production and to possible changes in the salmon life history.

1. Introduction

Salmon lives the first 2-8 years of its life in freshwater. After reaching the smolt age and size it migrates to the sea. At sea salmon is growing 1-5 years and after maturing it migrates back to the river of origin. The growth of juvenile salmon in the rivers depends on many environmental factors like water temperature especially in summer and bottom animal production as well as genetics. Many of the rivers in Kolarctic salmon project area are oligotrophic and water temperature is so low that juveniles are growing slowly. Results from this study can be used in future when analyzing the effects of possible air temperature changes on the river temperatures and therefore to the juvenile salmon production.

Photo 1. Researcher Eero Niemelä is electrofishing in October 2011 in Northern Norway (Photo: Eevaliisa Kivilahti).

2. Material and methods

In the Kolarctic salmon project we collected juvenile salmon with electric fishing method for genetic analysis from most of salmon rivers in Finnmark and Troms counties. From all juvenile salmon the total lengths were measured and scale samples were taken for age determination and for growth analysis. In the figure 1 all the rivers which were included in the juvenile growth analysis are presented. Juvenile salmon were sampled each year late in August and in September after the juveniles had ceased the annual growth. Therefore the lengths of juveniles can also compare between areas and rivers. In the back calculation of the lengths it is used the formulae produced by Fraser-Lee.

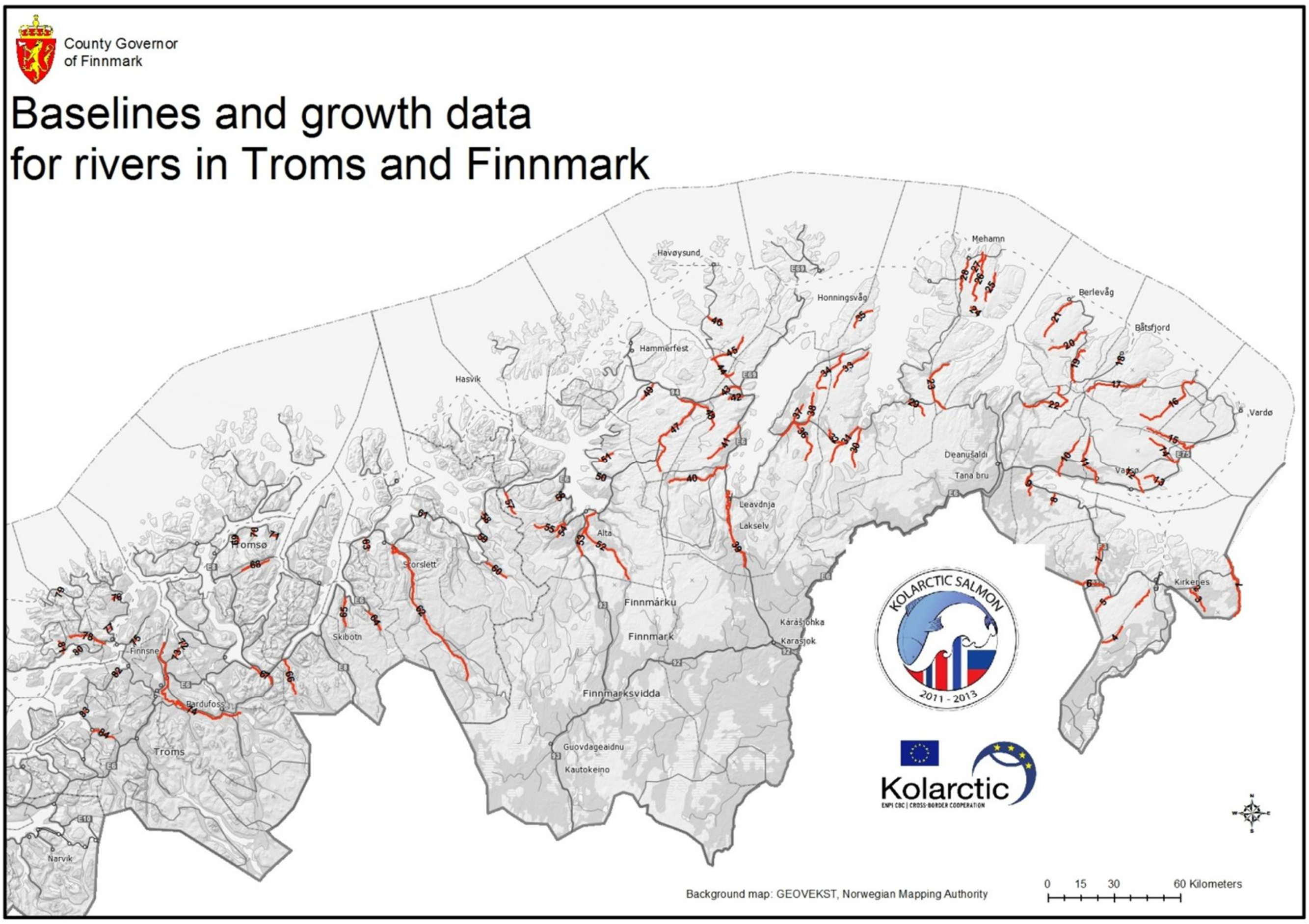

Figure 1. The map is showing rivers in Finnmark and Troms from where juvenile salmon material was collected.

3. Results

The mean lengths at capture indicate that there are large variations in the growth between the rivers in Finnmark and Troms (Figure 2). Rivers in the figure 2 are from east to west. The mean growth values of juveniles are changing slowly from one river to the neighboring river because the environmental conditions and other parameters determining the growth most likely are the same for those rivers. Back calculated lengths also indicate spatial differences in the juvenile growth (Figure 3). It can be observed from the figure 3 that if the back calculated lengths are high for juveniles after the first year; most probably the back calculated lengths of juveniles in the same river are high also after the second year. That indicates a good production capacity for all juvenile salmon age groups. Annual growth increment values are rather small for all years which juvenile salmon are growing and figure 4 illustrates clearly that there are large spatial differences between the rivers in the growth. Figure 5 indicates that there is also variation in the growth between years in the same river and this difference in the growth is also contributing to the annual differences in the smolt age and smolt size.

Photo 2. Juvenile salmon can be easily recognized from their large pectoral fins (Photo: Eero Niemelä).

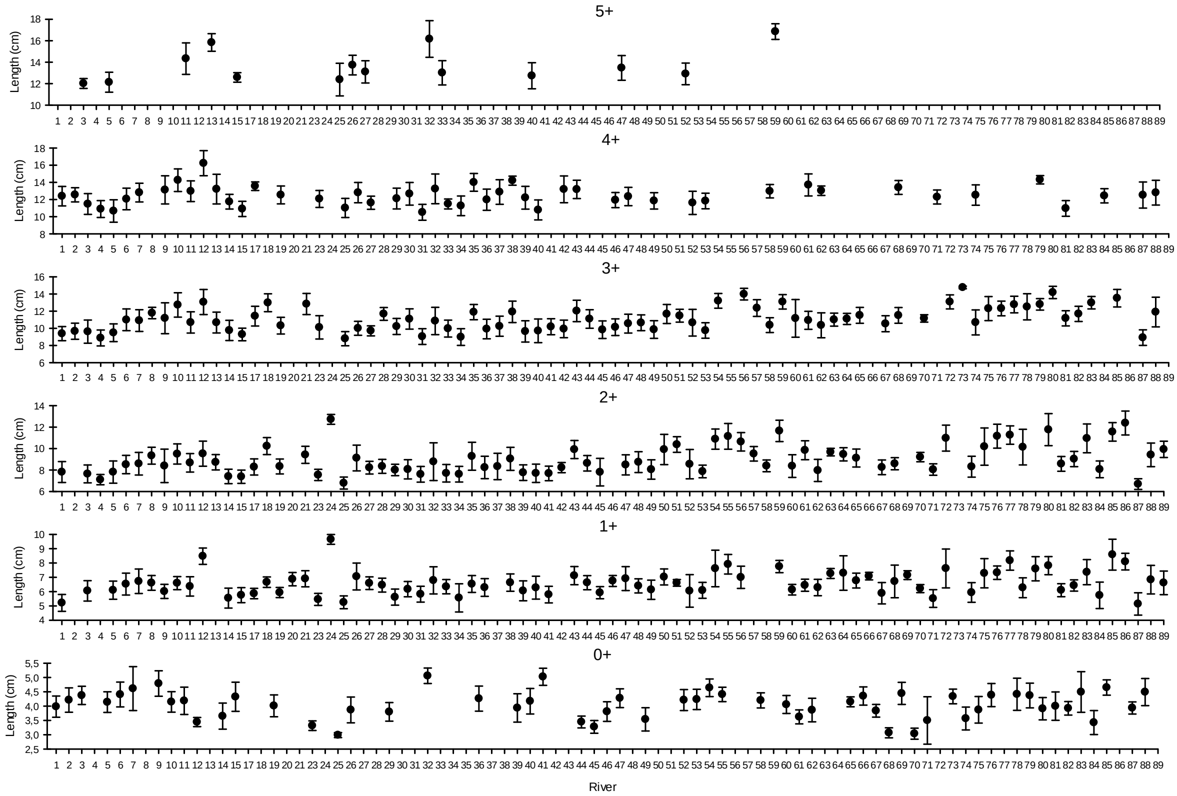

Figure 2. Mean lengths with SD of juvenile salmon in Troms and Finnmark counties. Material from the years 2009, 2010, 2011 and 2012 is combined. Sites 1-84 are the rivers in Finnmark and Troms and the sites 85-89 are from the river Tana. The numbering of the rivers is from east to west (see Figure 1).

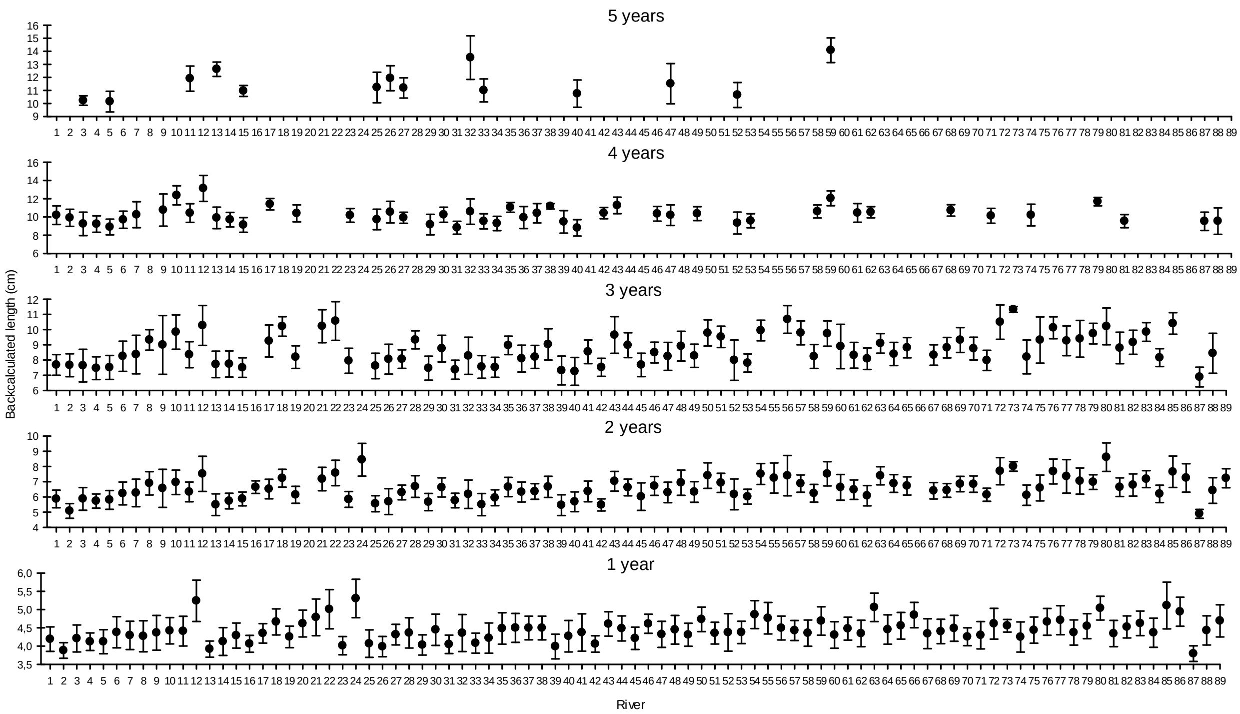

Figure 3. Back calculated lengths (SD) of juvenile salmon for each river in Finnmark and Troms counties. Material from the years 2009, 2010, 2011 and 2012 is combined in each river. The numbering of the rivers is from east to west (see Figure 1).

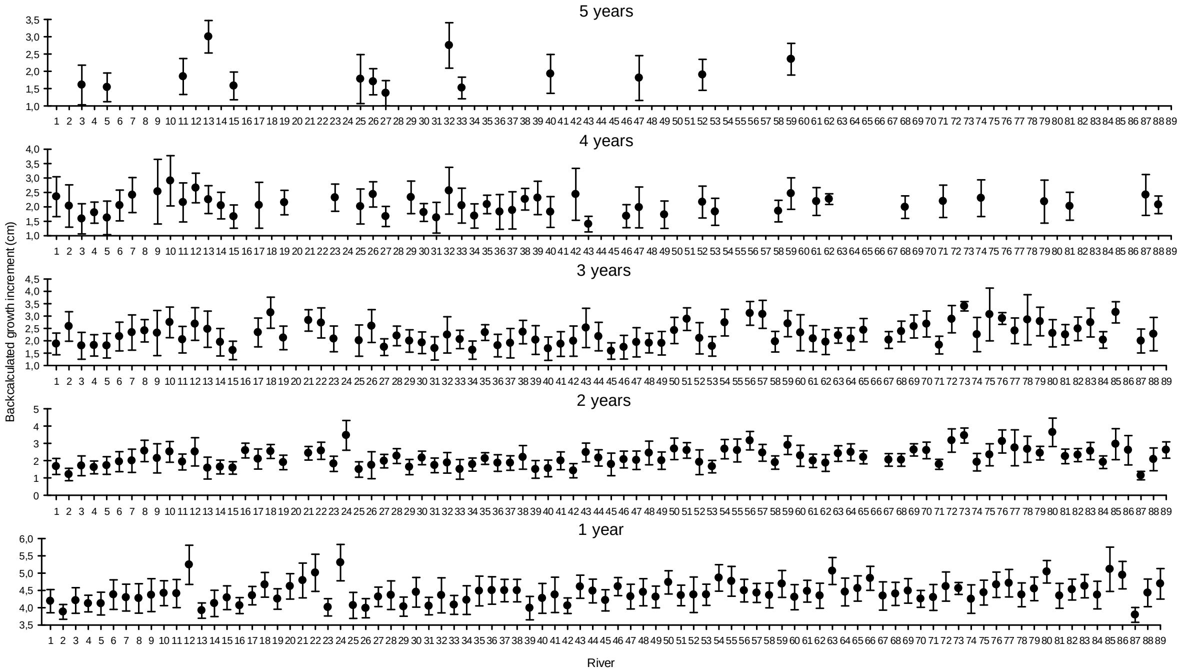

Figure 4. Growth increments during the first, second, third, fourth and fifth year for juveniles in Kolarctic salmon baseline rivers. The numbering of the rivers is from east to west (see Figure 1).

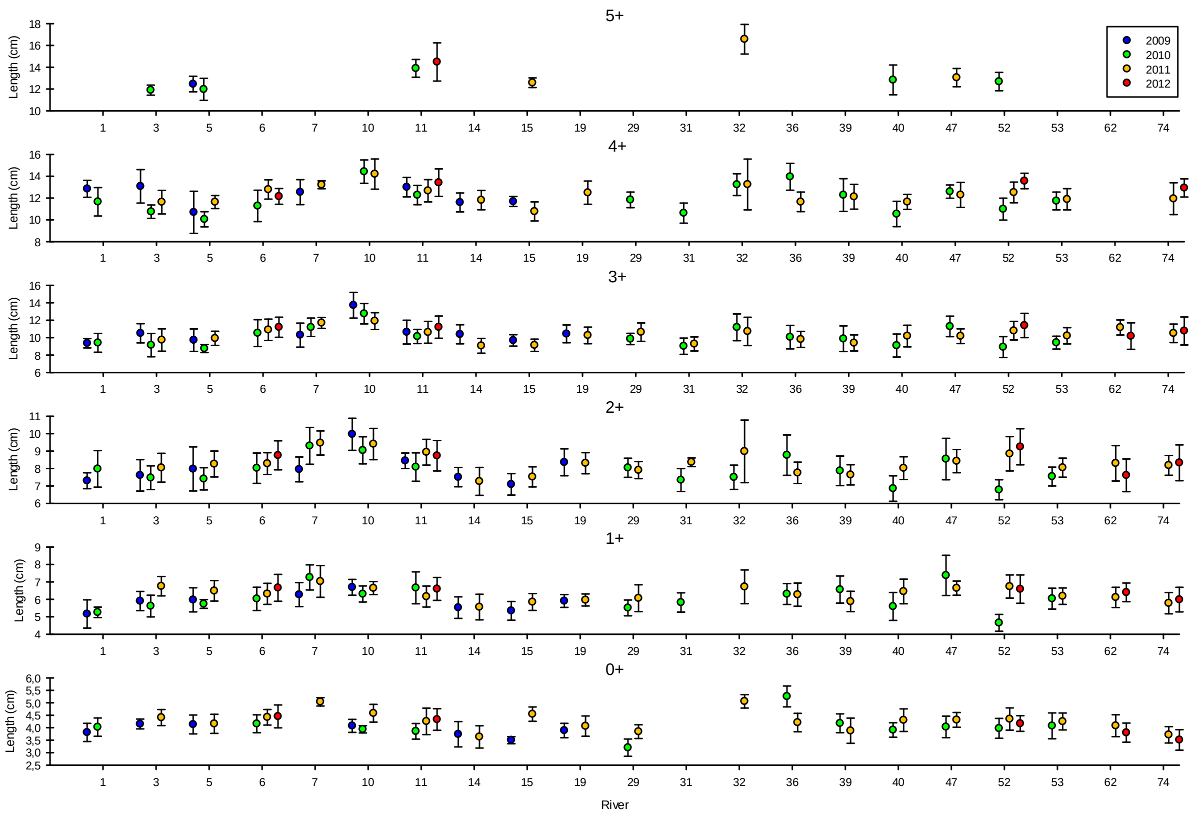

Figure 5. Mean lengths at capture for salmon juveniles ((ages 0+(fry), 1+, 2+, 3+, 4+, 5+) in selected rivers during four successive years. The numbering of the rivers is from east to west (see Figure 1).

The median growth increments of salmon juveniles are correlated between consecutive years in selected rivers (Figure 6), but correlation cannot be found between first and third year median growth increments. It seems that a good growth in the first year reflects in a good growth during the second year but it does not determine the growth during the third and fourth year.

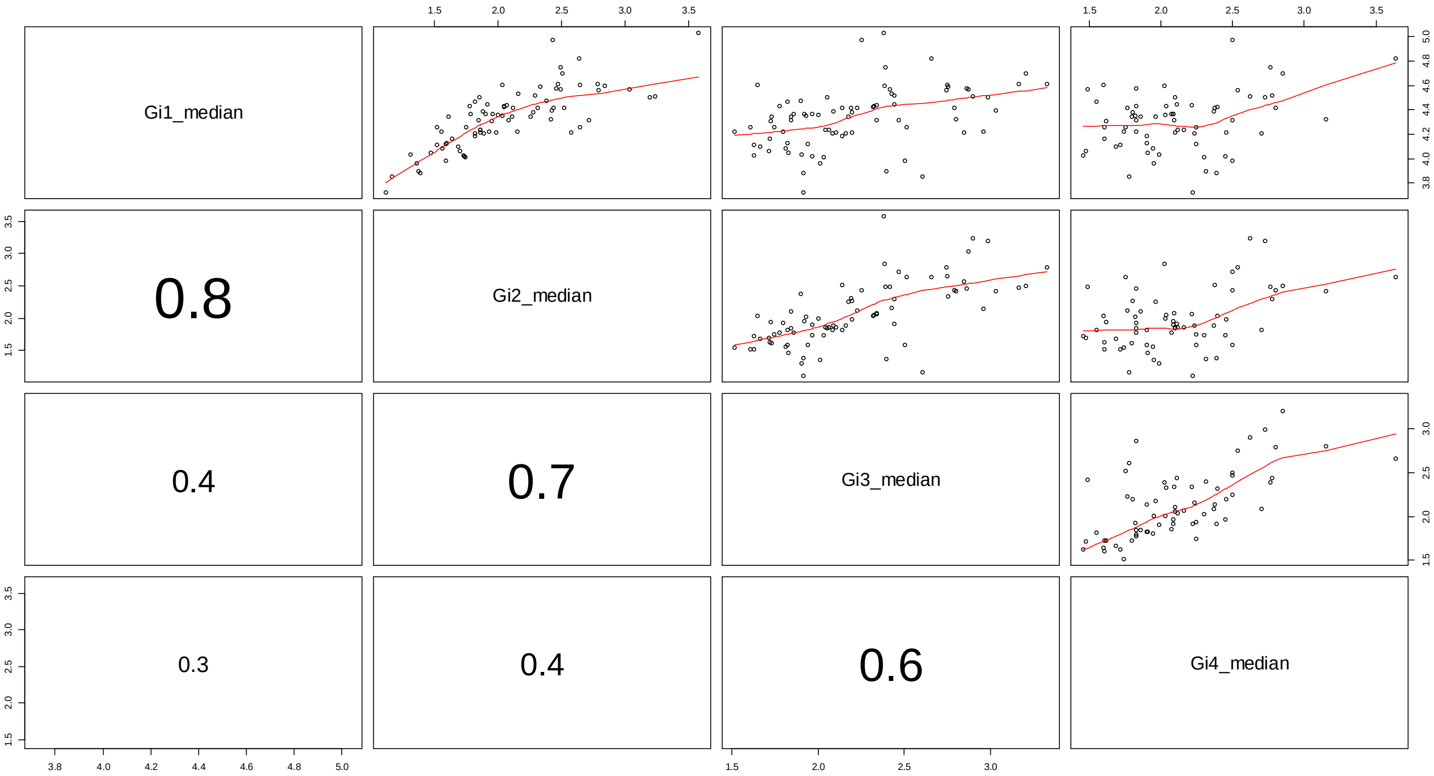

Figure 6. Correlations between median growth increments in years 1, 2, 3 and 4.

Rivers could be grouped into clusters according to the growth increments of the salmon juveniles. Only those rivers that had at least 10 individuals with a known growth increment in second year were used in hierarchical clustering analysis (n=79). Hierarchical clustering was performed in R using *hclust* algorithm. Function *hclust* performs a hierarchical cluster analysis using a set of dissimilarities for the n objects being clustered. Each object is initially assigned to its own cluster and then the algorithm proceeds iteratively, at each stage joining the two most similar clusters, continuing until there is just a single cluster. Distances between clusters are recomputed at each stage by Lance–Williams dissimilarity update formula according to the particular clustering method being used (http://stat.ethz.ch/R-manual/R-patched/library/stats/html/hclust.html). The complete linkage method was used as a clustering method. The complete linkage or furthest neighbor finds similar clusters and it has a tendency to produce compact bunches as the complete link minimizes the spread within the cluster (Oksanen 2012).

Grouping the first and second year growth increments produced four distinct clusters (Figures 7 and 8) where group A has the lowest growth, groups B and C grow slightly faster than group A and group C has a larger median growth than group B. Rivers in group D has the fastest growing salmon juveniles (Table 1).

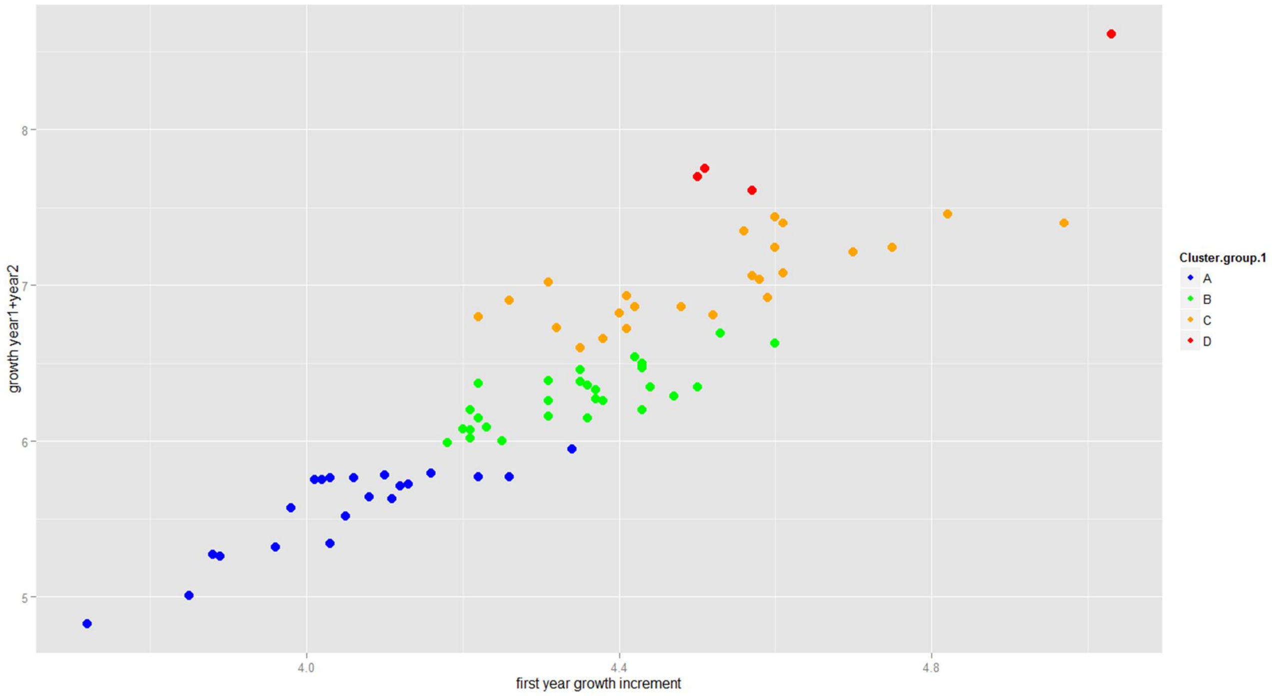

Figure 7. Median growth increment in year 1 vs. total growth in years 1 and 2. Colours represent the cluster class.

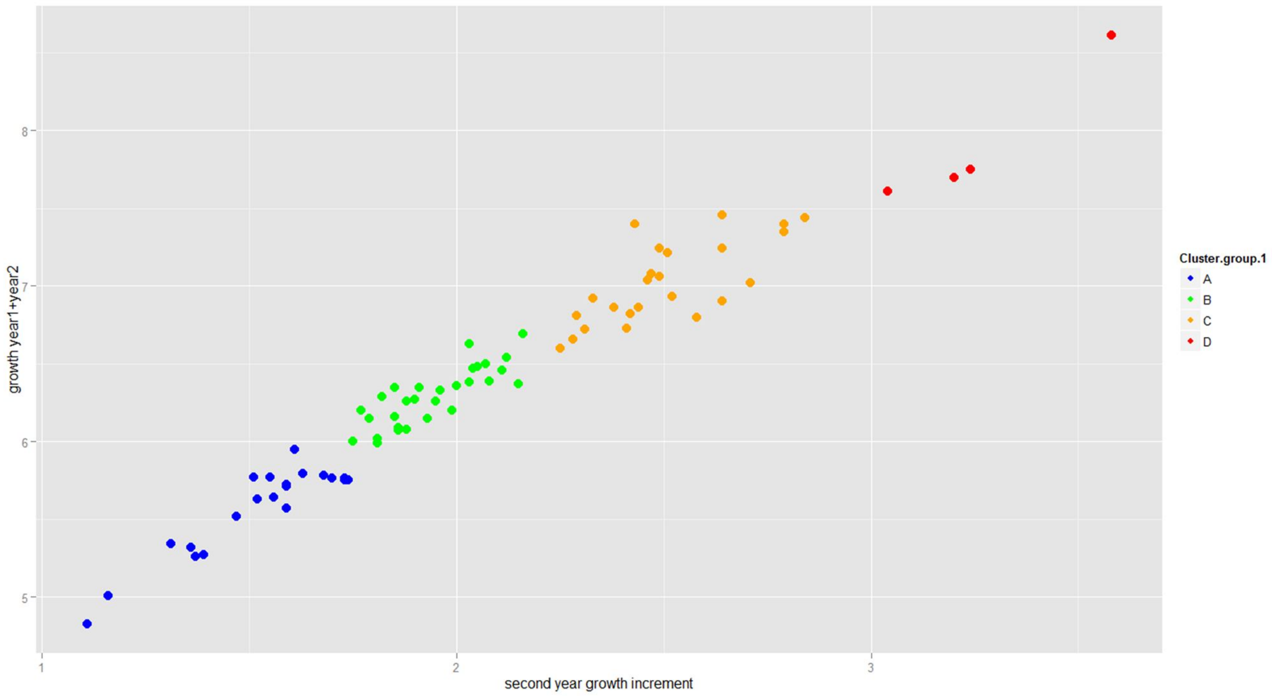

Figure 8. Median growth increment in year 2 vs. total growth in years 1 and 2. Colours represent the cluster class.

Hierarchical clustering was done also using third year median growth increments for the rivers including at least 10 individuals with a known third year growth (n=72). Four groups were found also in this analysis representing the size of the growth increments (Figure 9, Table 1).

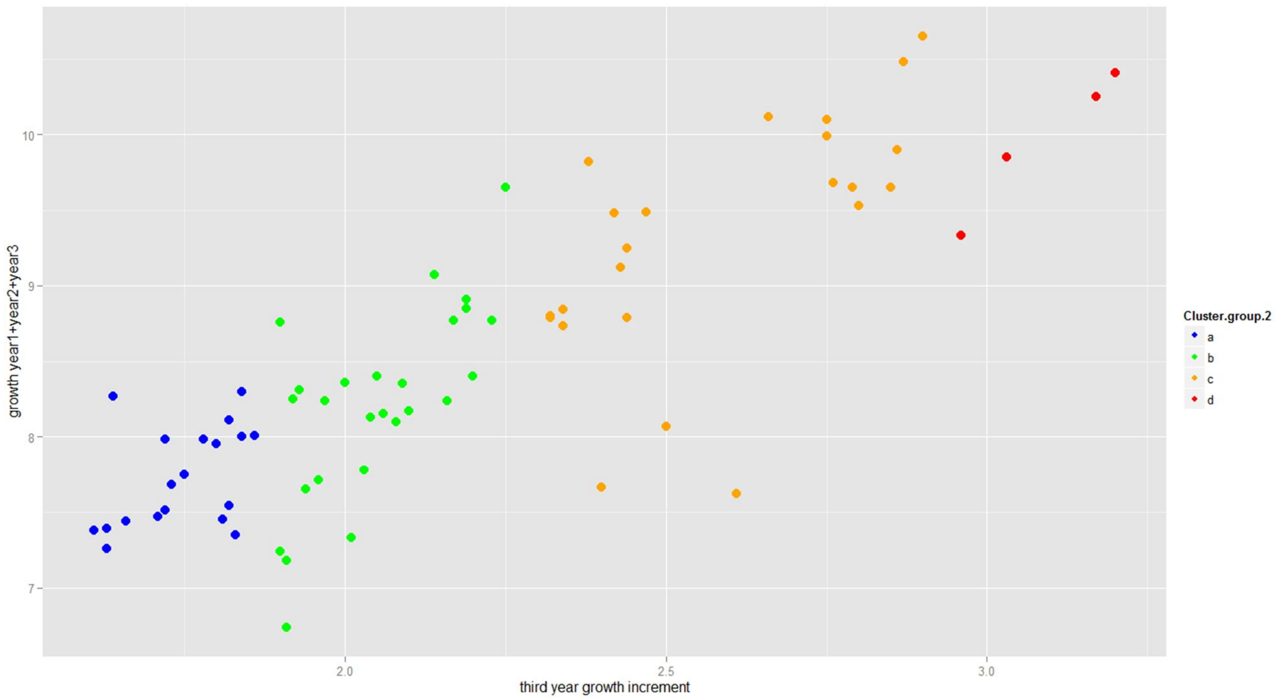

Figure 9. Median growth increment in year 3 vs. total growth in years 1, 2 and 3. Colours represent the cluster class.

According to the two hierarchical clustering analyses there are marked differences between the growth rates of juvenile salmon in different rivers (Figure 10). As correlation analysis indicates, river groups differ on how the growth rate changes between the first two and the third year. There are 10 rivers where the growth rate remains slow i.e. rivers were grouped in cluster group "A" in the first analysis and cluster group "a" in the second. In 20 rivers, the growth spurt at the year three compared with previous years, and in 17 rivers, the growth seems to slow down. In 35 rivers, the growth rate of the juvenile salmon seems to be rather stable over the three year period (Table 1). There are some differences in the location of the rivers in different groups. Rivers, where the 1st and 2nd year growth of the salmon juveniles is the slowest, are all situated east from Alta, and all the rivers with the fastest first and second year growth are west from Alta (Figure 11). According to the third year growth and second analysis the fast and slow growing rivers are more evenly situated across the Troms and Finnmark (Figure 12).

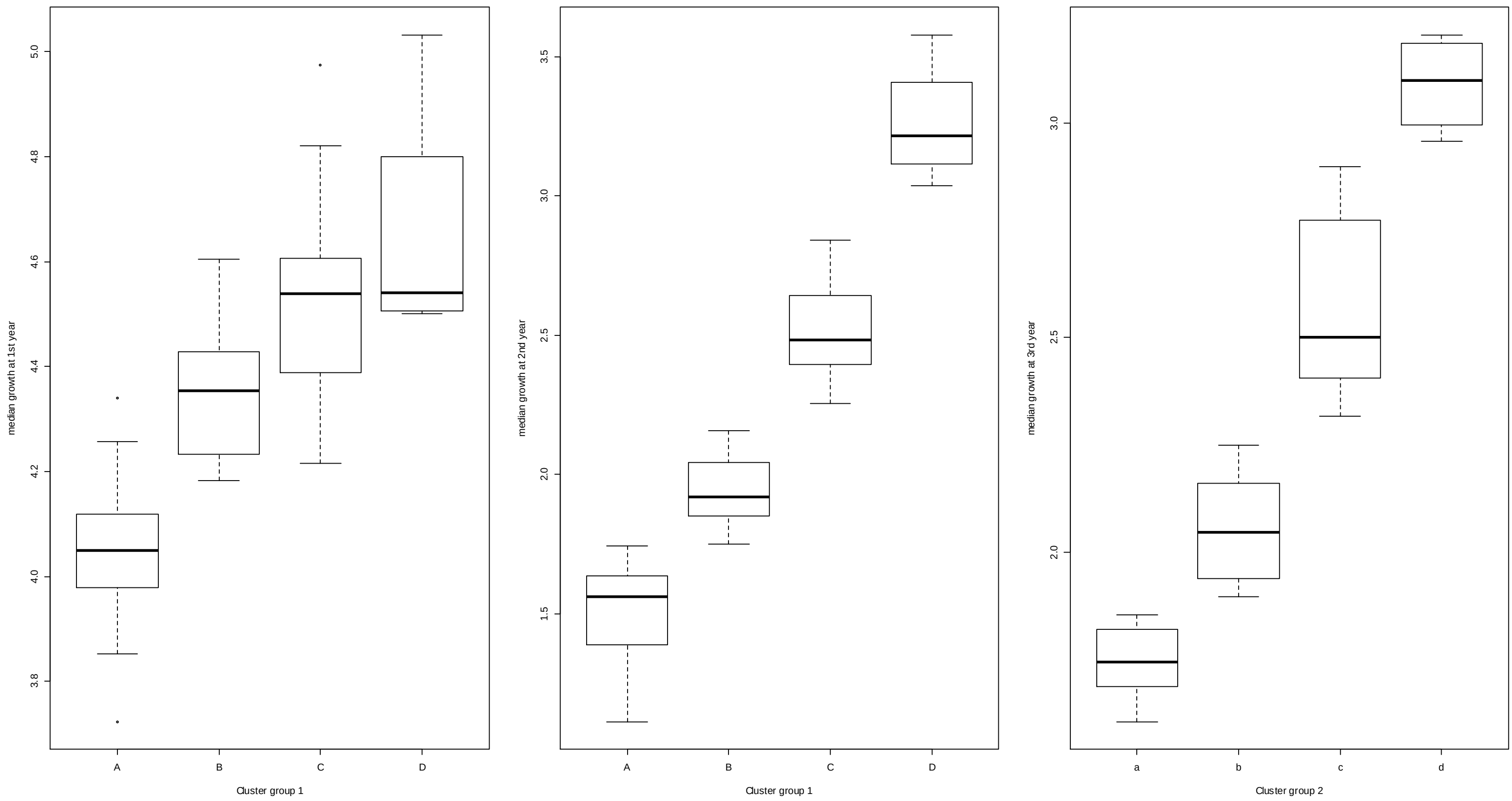

Figure 10. Median growth increments of different river groups in first, second and third year

Table 1. Medium growth increments, total growth and cluster groups of the rivers. Cluster group 1 has been assigned according to the growth in year 1 and 2 and Cluster group 2 has been assigned according to the growth in year 3.

River no	Gi1	Gi2	Gi3	Gi4	Total growth	Cluster group 1	Cluster group 2
1	4,12	1,59	1,94	2,24	9,89	A	b
2	3,85	1,16	2,61	1,78	9,40	A	c
3	4,16	1,63	1,72	1,61	9,12	A	a
4	4,13	1,59	1,82	1,90	9,45	A	a
5	4,06	1,70	1,71	1,48	8,95	A	a
6	4,21	1,86	2,10	2,10	10,27	B	b
7	4,21	1,99	2,20	2,45	10,85	B	b
8	4,31	2,71	2,47	2,50	11,99	C	c
9	4,38	1,88	2,09	2,37	10,72	B	b
10	4,42	2,44	2,79	2,80	12,44	C	c
11	4,37	1,90	1,97	2,09	10,32	B	b
13	3,89	1,37	2,40	2,32	9,98	A	c
14	4,08	1,56	1,81	1,95	9,40	A	a
15	4,26	1,51	1,61	1,61	8,99	A	a
17	4,44	1,91	2,44	2,11	10,90	B	c
18	4,61	2,47	3,17	NA	10,25	C	d
19	4,23	1,86	2,06	2,16	10,32	B	b
21	4,59	2,33	2,76	NA	9,68	C	c
23	4,01	1,74	2,03	2,30	10,08	A	b
25	4,05	1,47	1,83	1,91	9,25	A	a
26	3,98	1,59	2,50	2,50	10,57	A	c
27	4,31	1,95	1,72	1,62	9,59	B	a
28	4,41	2,31	2,19	NA	8,91	C	b
29	4,02	1,73	1,96	2,45	10,17	A	b
30	4,35	2,11	1,84	1,86	10,16	B	a
31	4,03	1,73	1,63	1,46	8,83	A	a
32	4,21	1,81	2,08	2,70	10,81	B	b
33	3,96	1,36	2,01	1,95	9,27	A	b
34	4,10	1,68	1,66	1,69	9,13	A	a
35	4,43	2,07	2,34	2,21	11,05	B	c
36	4,43	1,77	1,78	1,83	9,81	B	a
37	4,47	1,82	1,82	1,55	9,66	B	a
38	4,43	2,04	2,32	2,39	11,18	B	c
39	3,88	1,39	1,91	2,39	9,57	A	b
40	4,11	1,52	1,63	1,72	8,98	A	a
41	4,37	1,96	1,92	2,08	10,33	B	b
42	4,03	1,31	1,90	1,99	9,23	A	b
43	4,57	2,49	2,42	1,49	10,97	C	c
44	4,42	2,12	2,23	1,76	10,52	B	b
45	4,22	1,55			9,03	A	

Table a. (continued)

River no	Gi1	Gi2	Gi3	Gi4	Total growth	Cluster group 1	Cluster group 2
46	4,60	2,03	1,64	1,60	9,88	B	a
47	4,22	1,93	1,80	1,83	9,77	B	a
48	4,48	2,38	1,90	NA	8,75	C	b
49	4,35	2,03	1,93	1,82	10,13	B	b
50	4,75	2,49			12,39	C	
51	4,22	2,58	2,85	NA	9,64	C	c
52	4,23	1,86	2,04	2,12	10,25	B	b
53	4,34	1,61	1,73	1,80	9,48	A	a
54	4,82	2,64	2,66	3,64	13,76	C	c
55	4,70	2,51	3,20	2,85	13,26	C	d
56	4,50	3,20			13,41	D	
57	4,40	2,42	3,03	NA	9,85	C	d
58	4,31	1,85	1,84	1,83	9,83	B	a
59	4,56	2,79	2,75	2,54	12,64	C	c
60	4,35	2,25	2,17	1,96	10,73	C	b
61	4,50	1,85	2,05	2,10	10,51	B	b
62	4,25	1,75	1,75	2,24	9,99	B	a
63	4,97	2,43	2,25	2,50	12,15	C	b
64	4,41	2,52	2,14	2,38	11,45	C	b
65	4,53	2,16	2,43	NA	9,12	B	c
67	4,36	2,00	2,00	2,03	10,39	B	b
68	4,43	2,05	2,32	2,04	10,84	B	c
70	4,26	2,64			11,17	C	
71	4,36	1,79	1,86	2,07	10,07	B	a
72	4,51	3,24	2,90	2,62	13,27	D	c
74	4,20	1,88	2,16	2,23	10,48	B	b
75	4,22	2,15	2,96	NA	9,33	B	d
76	4,57	3,04	2,87	NA	10,48	D	c
77	4,60	2,84	2,38	2,03	11,85	C	c
78	4,32	2,41	2,80	3,15	12,68	C	c
79	4,58	2,46	2,86	1,82	11,72	C	c
80	5,03	3,58			10,99	D	
81	4,38	2,28	2,19	1,80	10,65	C	b
82	4,52	2,29	2,44	2,78	12,02	C	c
83	4,60	2,64	2,75	NA	10,00	C	c
84	4,18	1,81			10,04	B	
85	4,61	2,79			10,73	C	
87	3,72	1,11	1,91	2,22	8,97	A	b
88	4,31	2,08	2,34	2,09	10,82	B	c

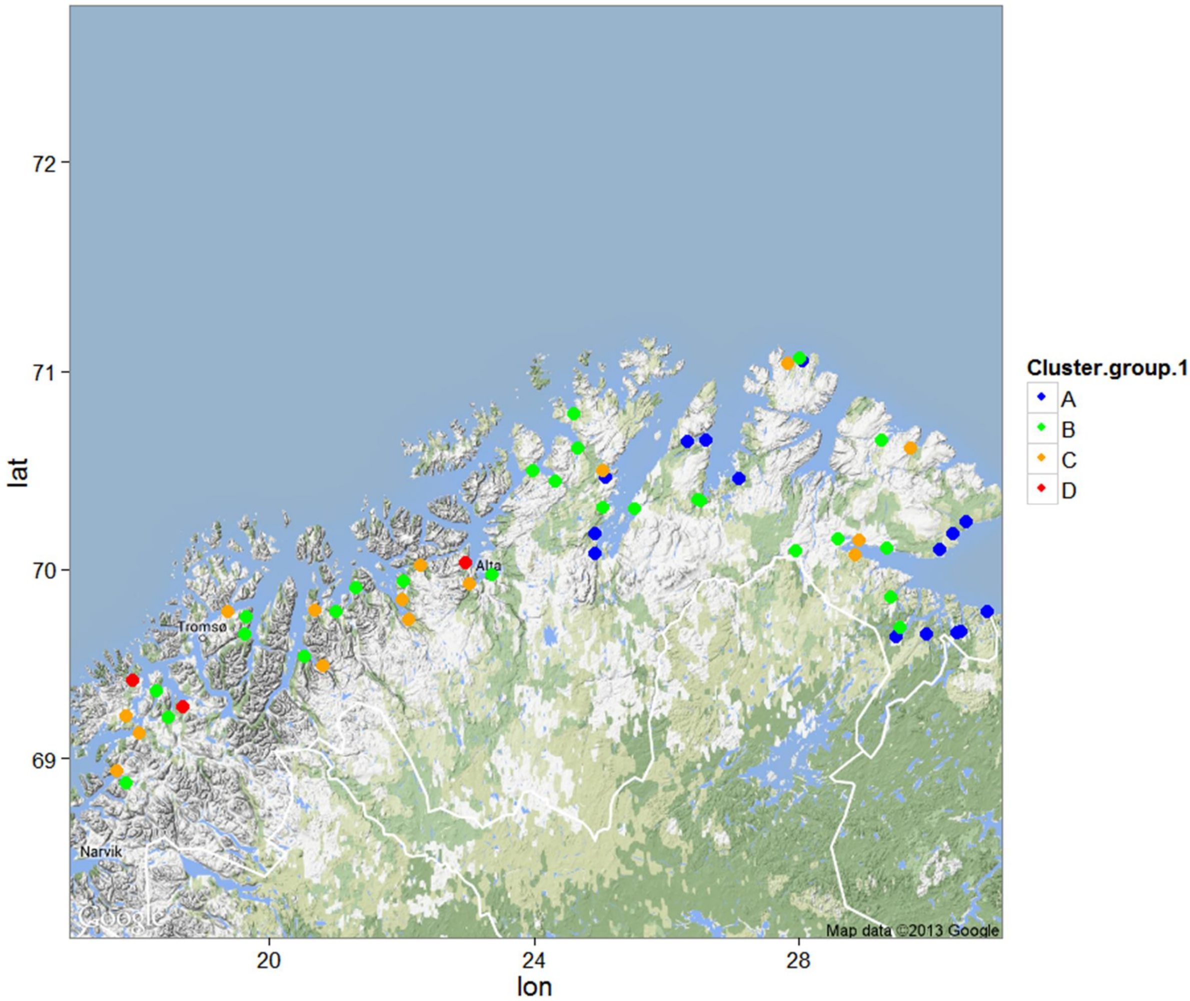

Figure 11. Rivers according to the first clustering.

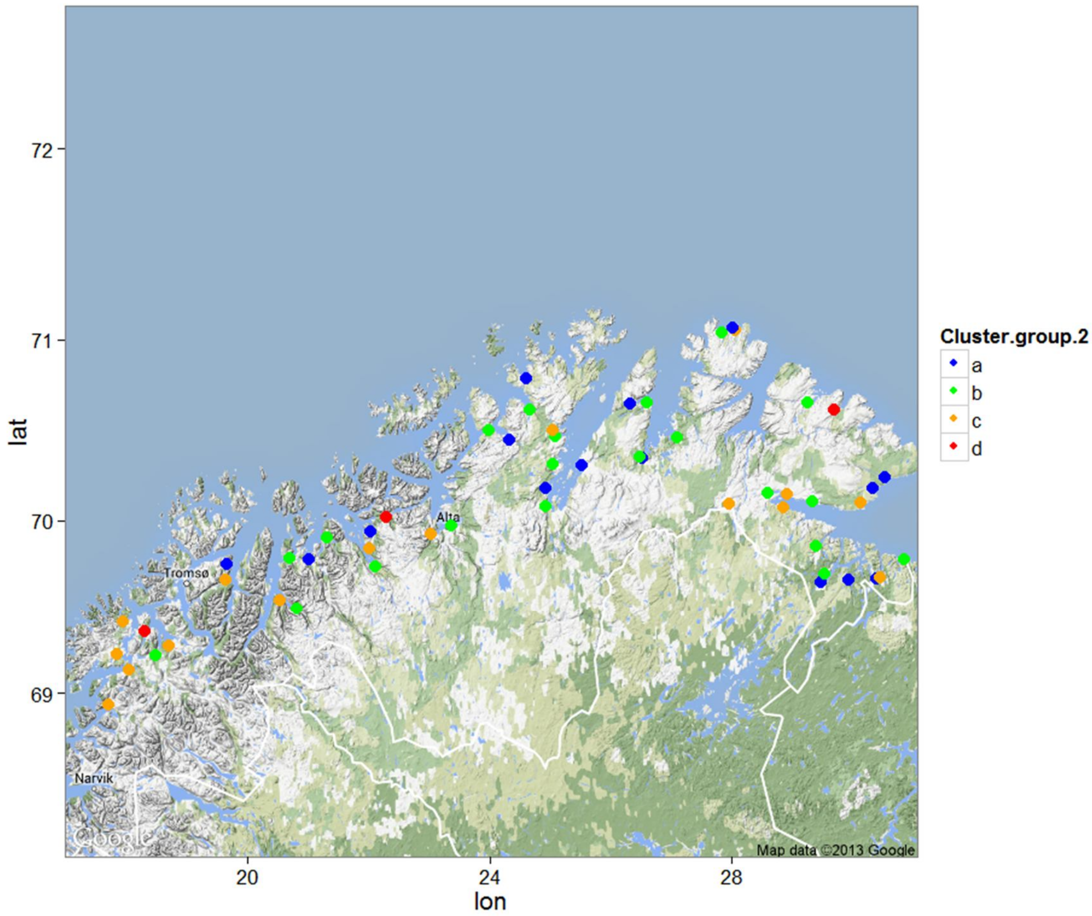

Figure 12. Rivers according to the second clustering.

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Responsibilities in this report: FGFRI collected juvenile salmon samples in connection to the juvenile baseline sampling for genetic analysis, planned the report and produced graphs and statistical analysis.

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