Post-smolt growth effects on the pattern of marine survival of Keogh River steelhead

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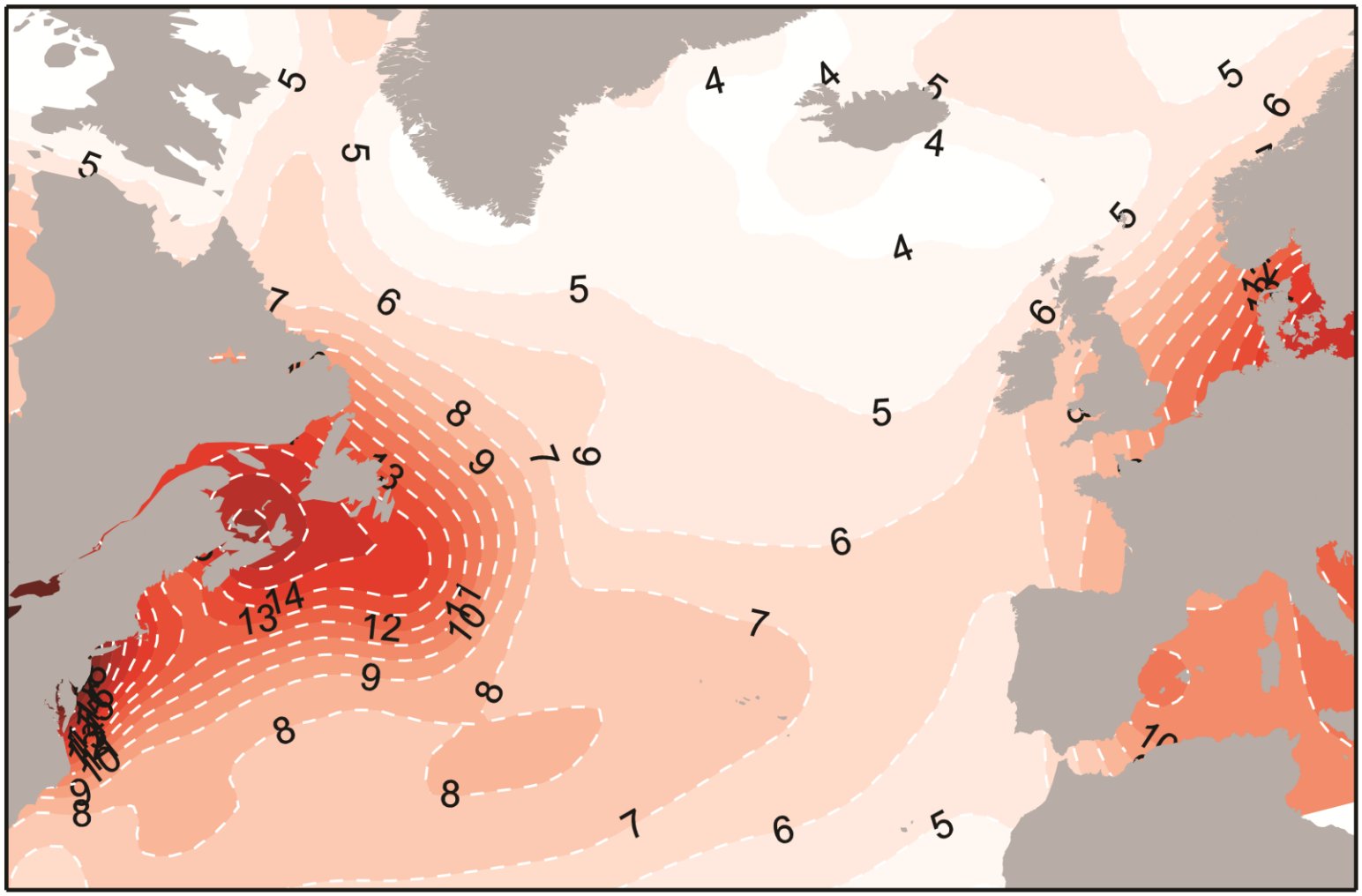
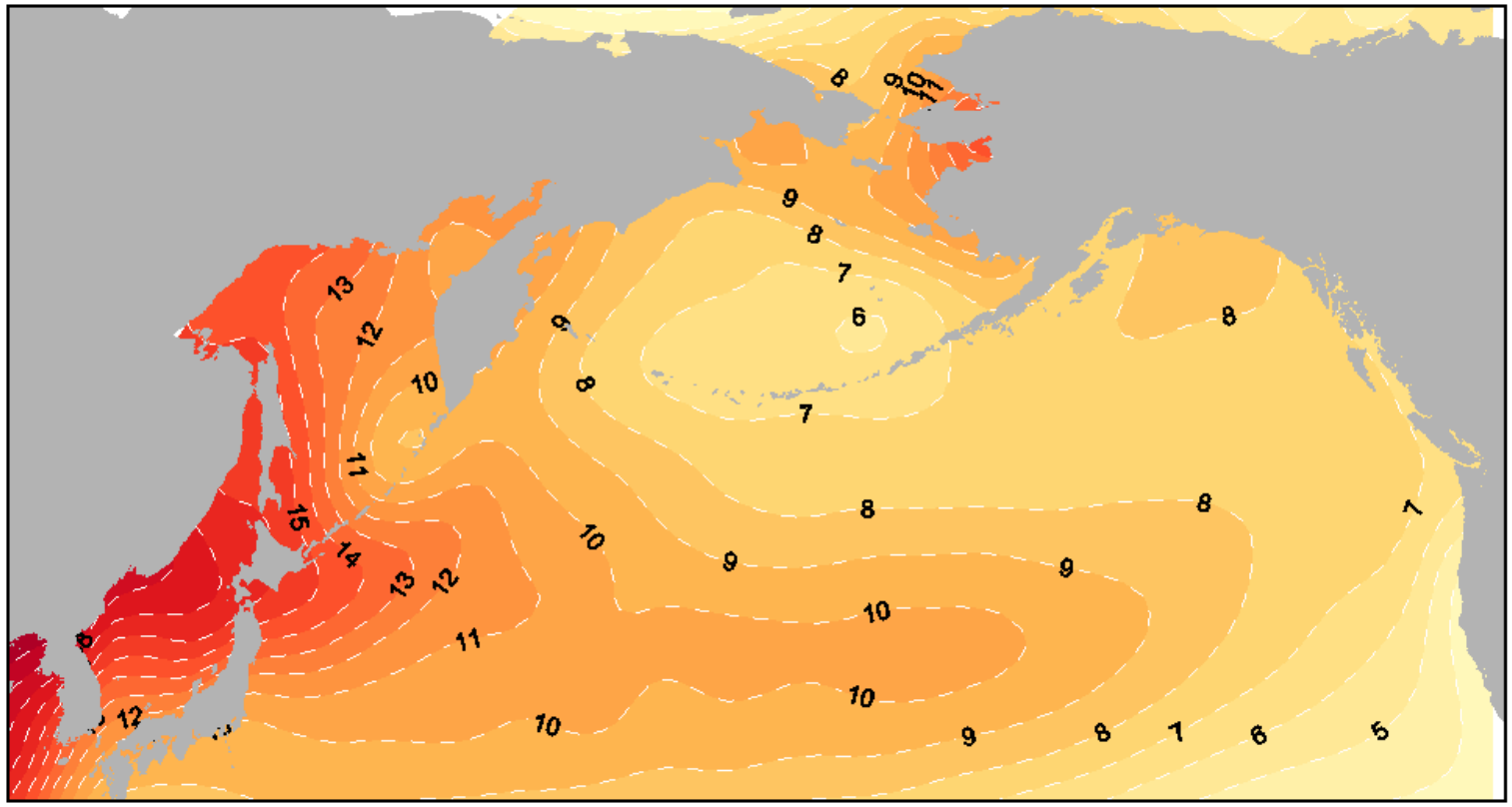
Average Annual Temperature Range



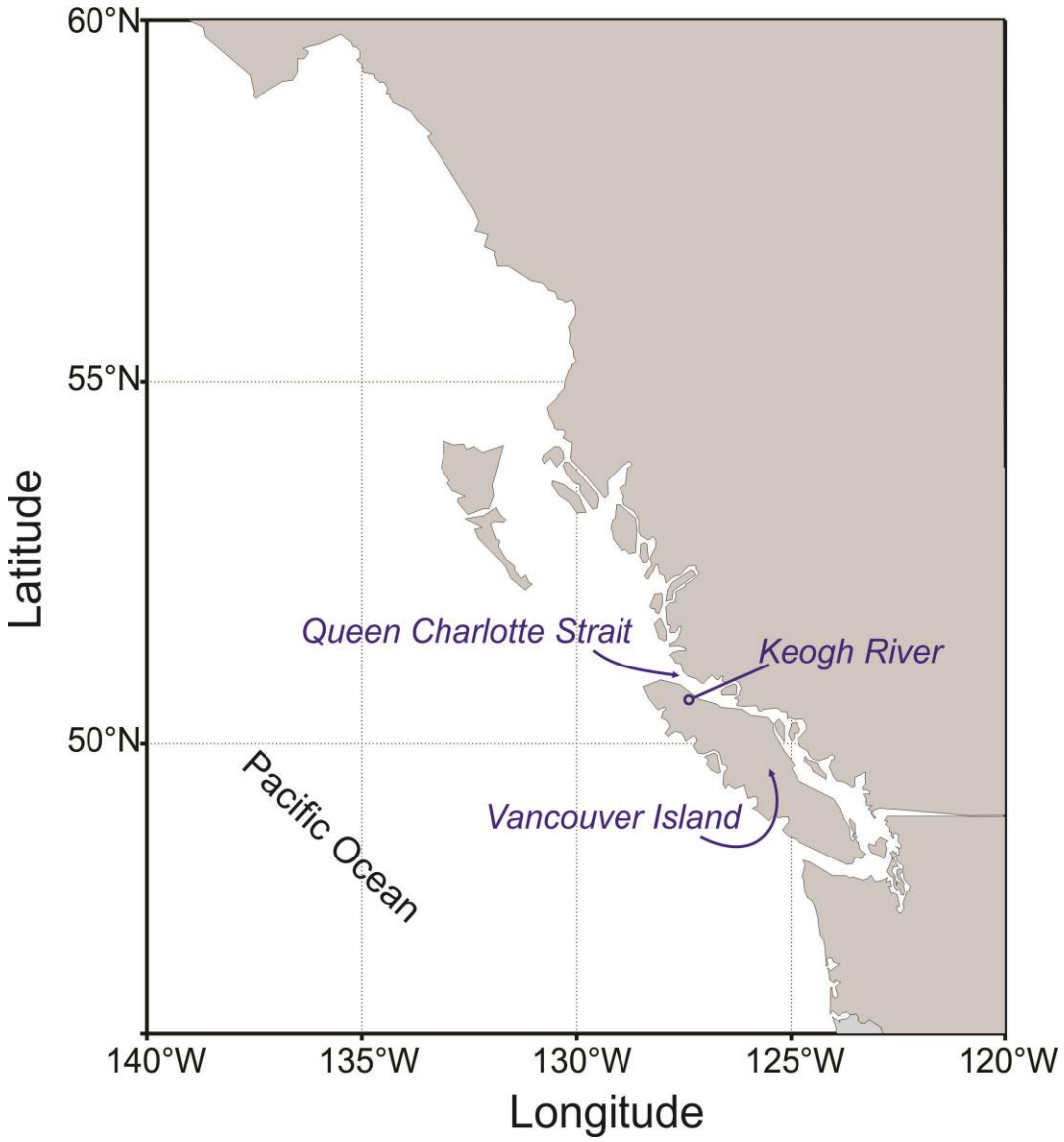
Main Factors Affecting Atlantic Salmon Recruitment

Western Boundary	Eastern Boundary
Recruitment variability is unrelated to a post-smolt growth.	Recruitment variability is related to post-smolt growth.
Recruitment is associated with environmental variation in spring when the smolts first go to sea.	Recruitment is associated with environmental variation over a protracted period of summer into fall.
The environmental variation, seen in temperature, is associated shifts in predator populations.	The environmental variation, seen in temperature, is associated with shifts in the food web of the Northeast Atlantic.
Variation in recruitment appears to be patterned by changing predation pressure during the spring.	Variation in recruitment appears to be patterned by growth/size mediated predation during summer into fall.

Average Annual Temperature Range



Study System



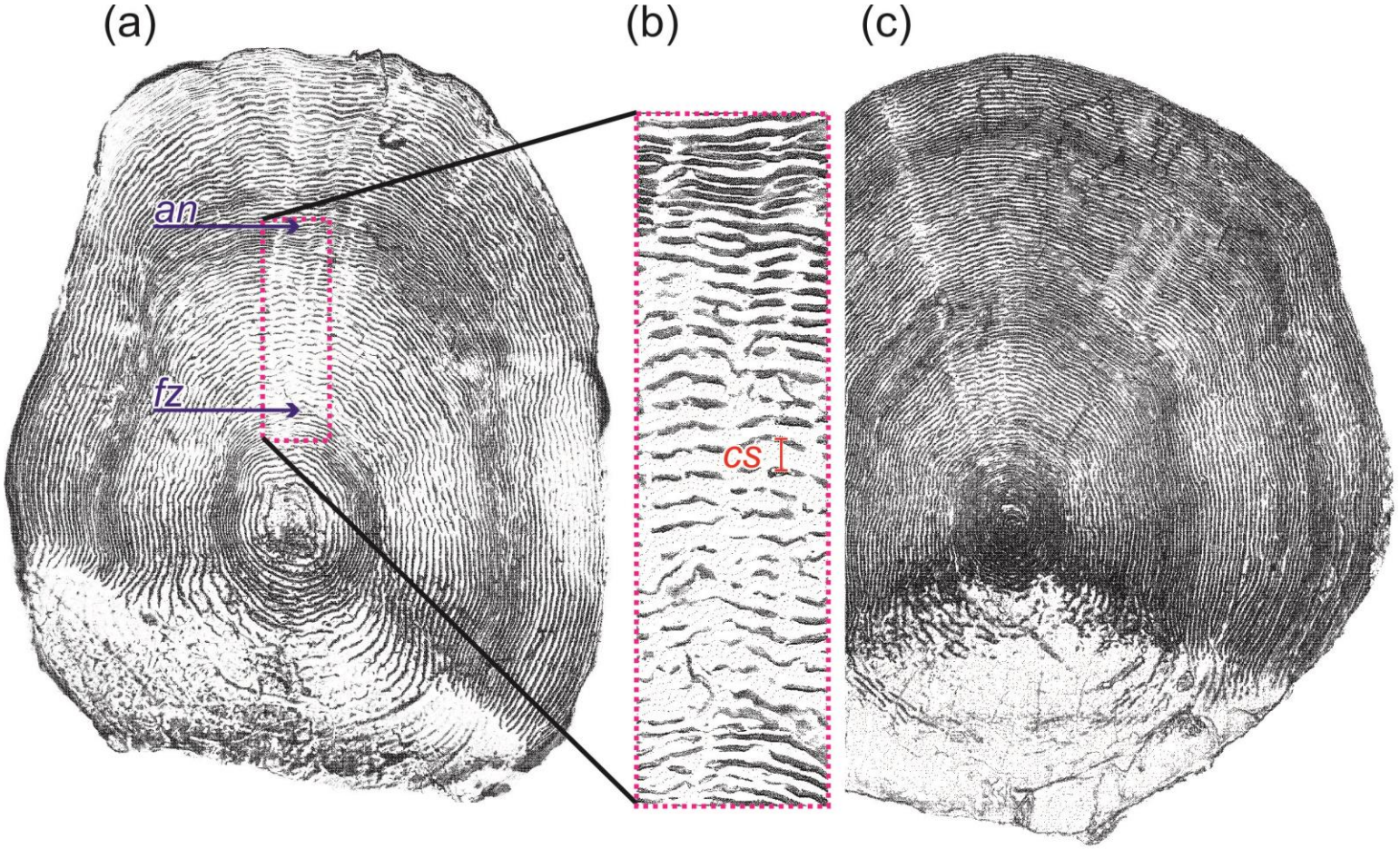
Data

Data	Steelhead	Atlantic Salmon
Recruitment Index	Return rate, stock	Return rate, stocks Run reconstruction, stock complexes
Size at ocean entry	Fork length of migrants	
Post-smolt growth	Growth Increment, ocean entry to first annulus, from scale measurements	Growth Increment, ocean entry to first annulus, from scale measurements
Seasonal post-smolt growth	Growth Increments, putative months, from scale measurements	Growth Increments, putative months, from scale measurements

Scale Samples

Smolt Year	Hatchery	Wild	Total
1977		10	10
1978		18	18
1979	10	34	44
1980		12	12
1981		22	22
1982	7	3	10
1983	17	10	27
1984	27	24	51
1985		15	15
1986	1	15	16
1987	35	26	61
1988	16	7	23
1989	1	18	19
1990	11	6	17
1991	2	6	8
1992	3	5	8
1993	1	2	3
1994	6	6	12
1995	8	6	14
1996	1	2	3
1997	1	14	15
1998	5	9	14
1999	1	2	3

Steelhead Scales



Atlantic Salmon Scales

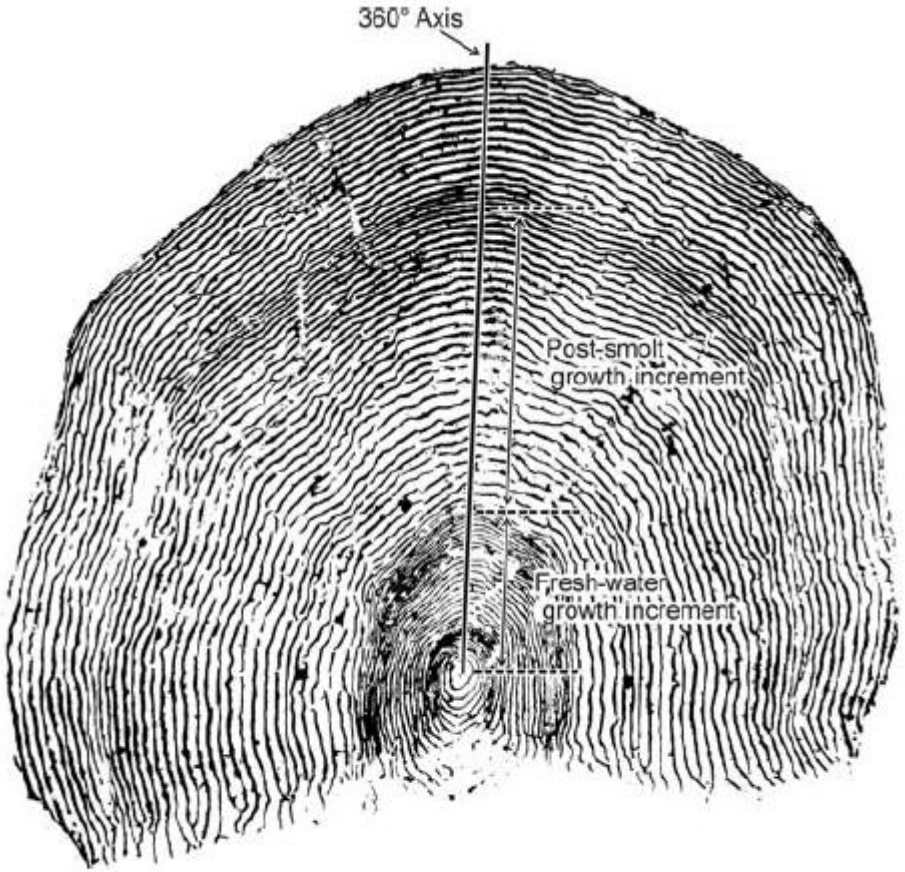
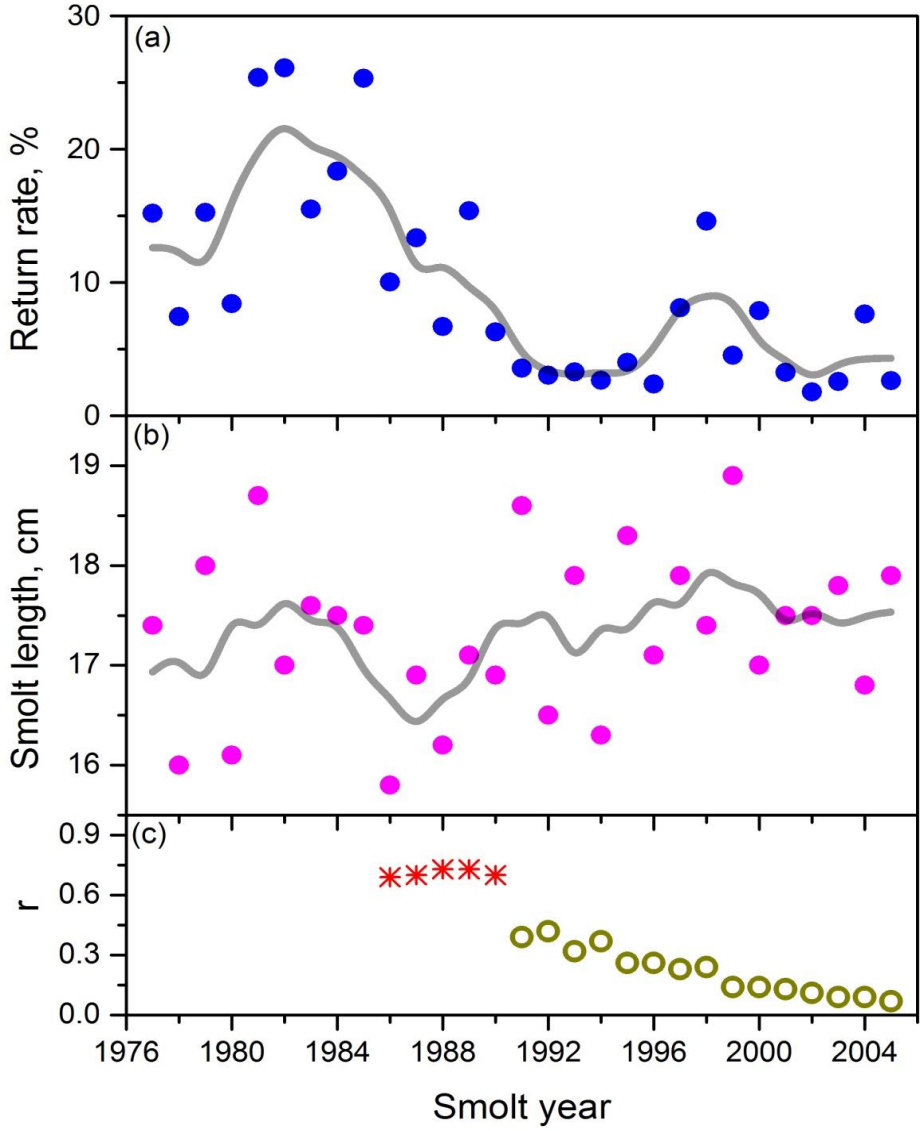


Figure 2. Atlantic salmon scale showing measurement axis and principal growth increments.

Keogh Steelhead Return Rate and Size at Ocean Entry



Atlantic Salmon Abundance and Return Rate

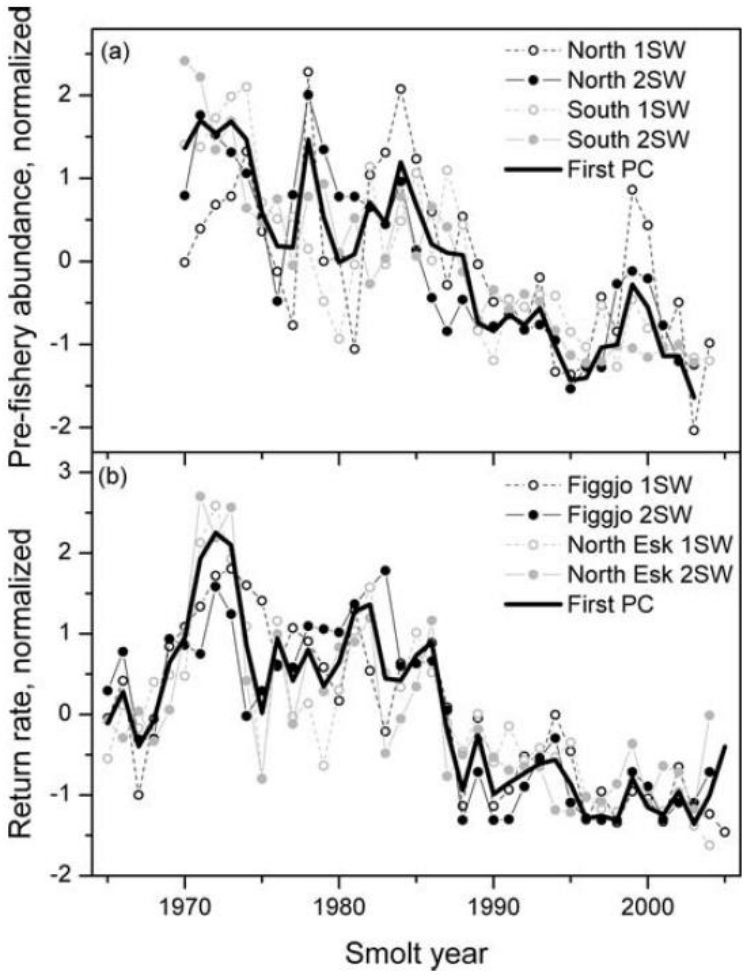
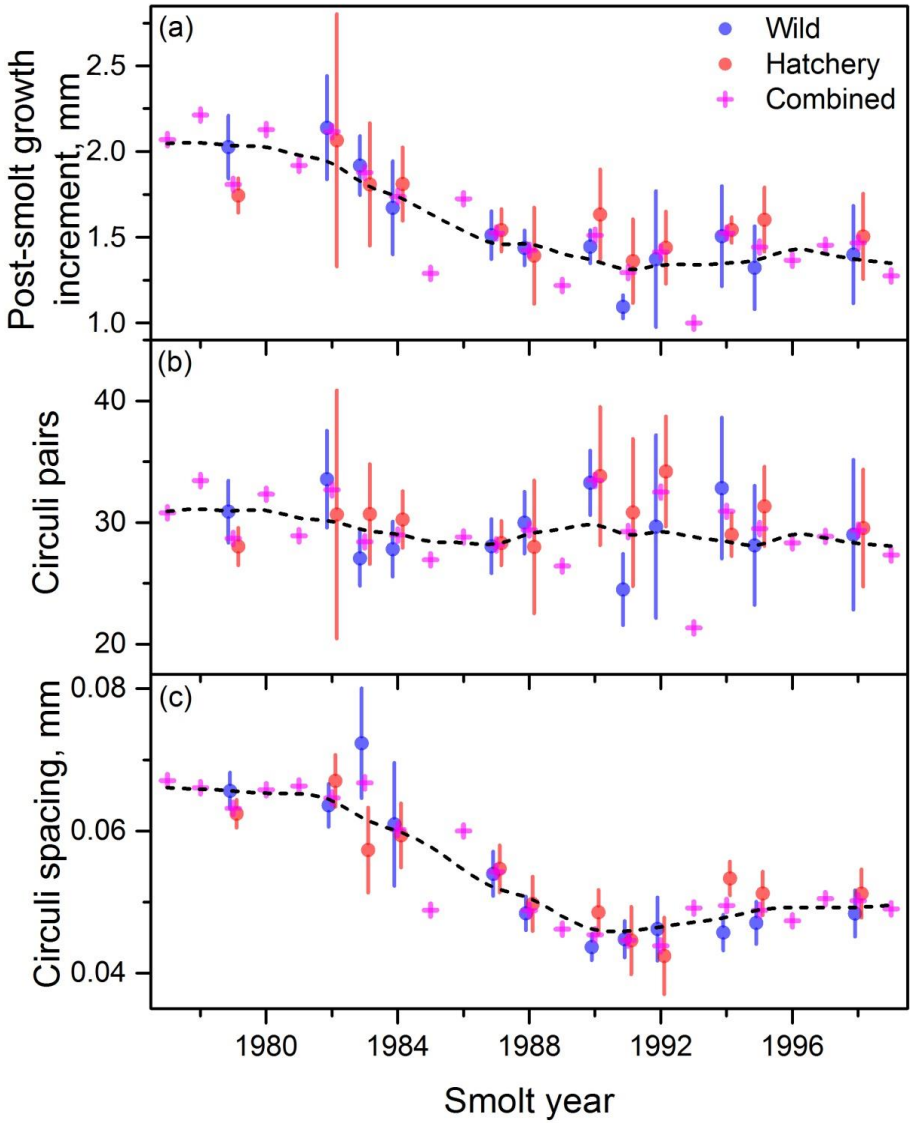
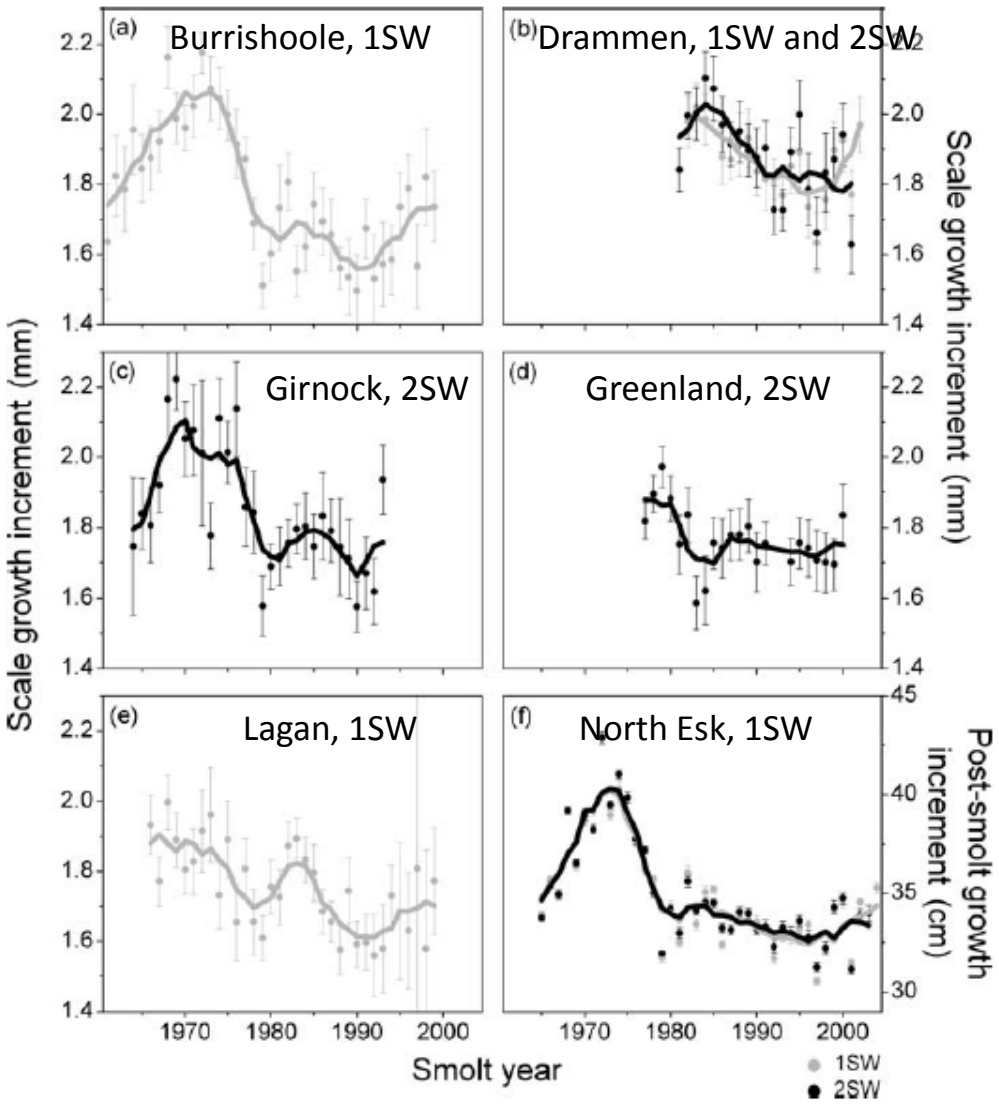


Figure 3. (a) Normalized pre-fishery abundance of European salmon partitioned by northern and southern subcomponents of the European stock complex, and sea age of return for the smolt years 1970–2004. The first PC is the first principal component of the four age-subcomponent abundances. (b) Normalized return rate of tagged salmon from the Figgjo and North Esk rivers by sea age of return for the smolt years 1965–2005. The first PC is the first principal component of the four age–stock return rates.

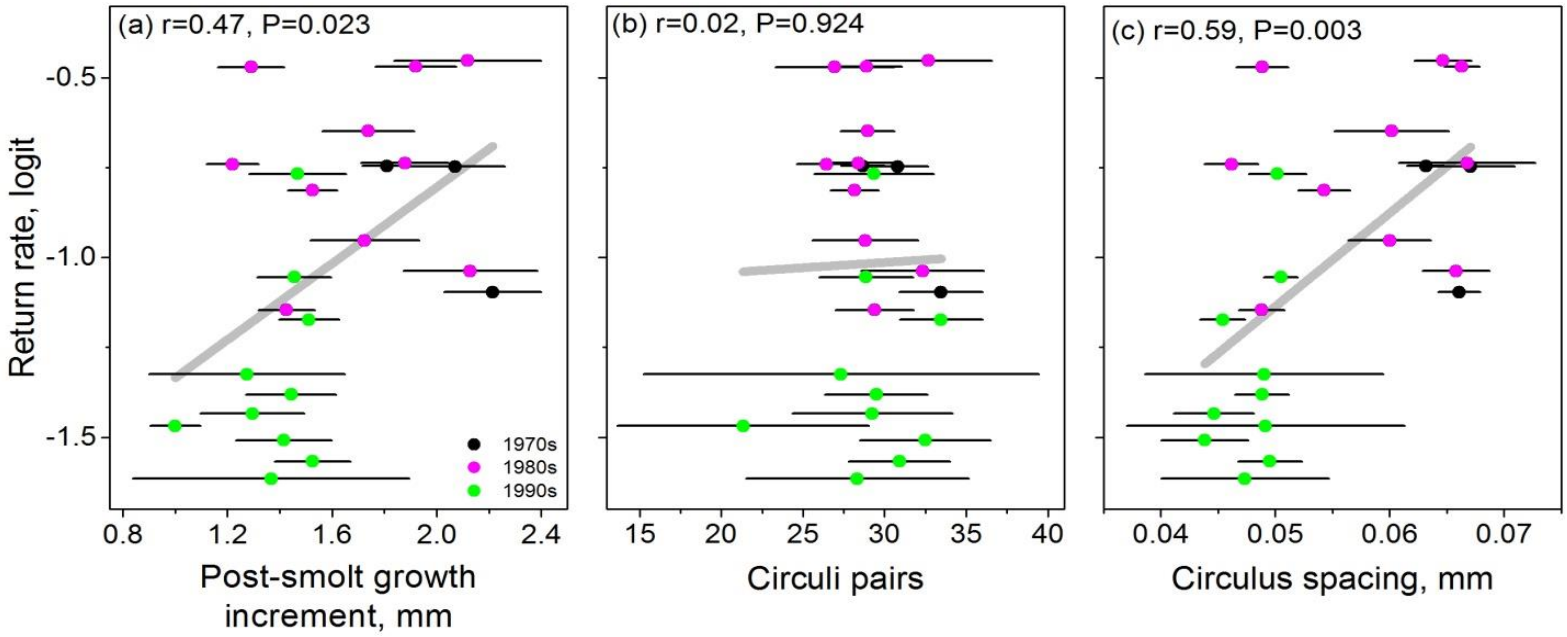
Keogh Steelhead Post-smolt Growth



Atlantic Salmon Post-smolt Growth



Relationship Between Keogh Steelhead Return Rate and Post-smolt Growth

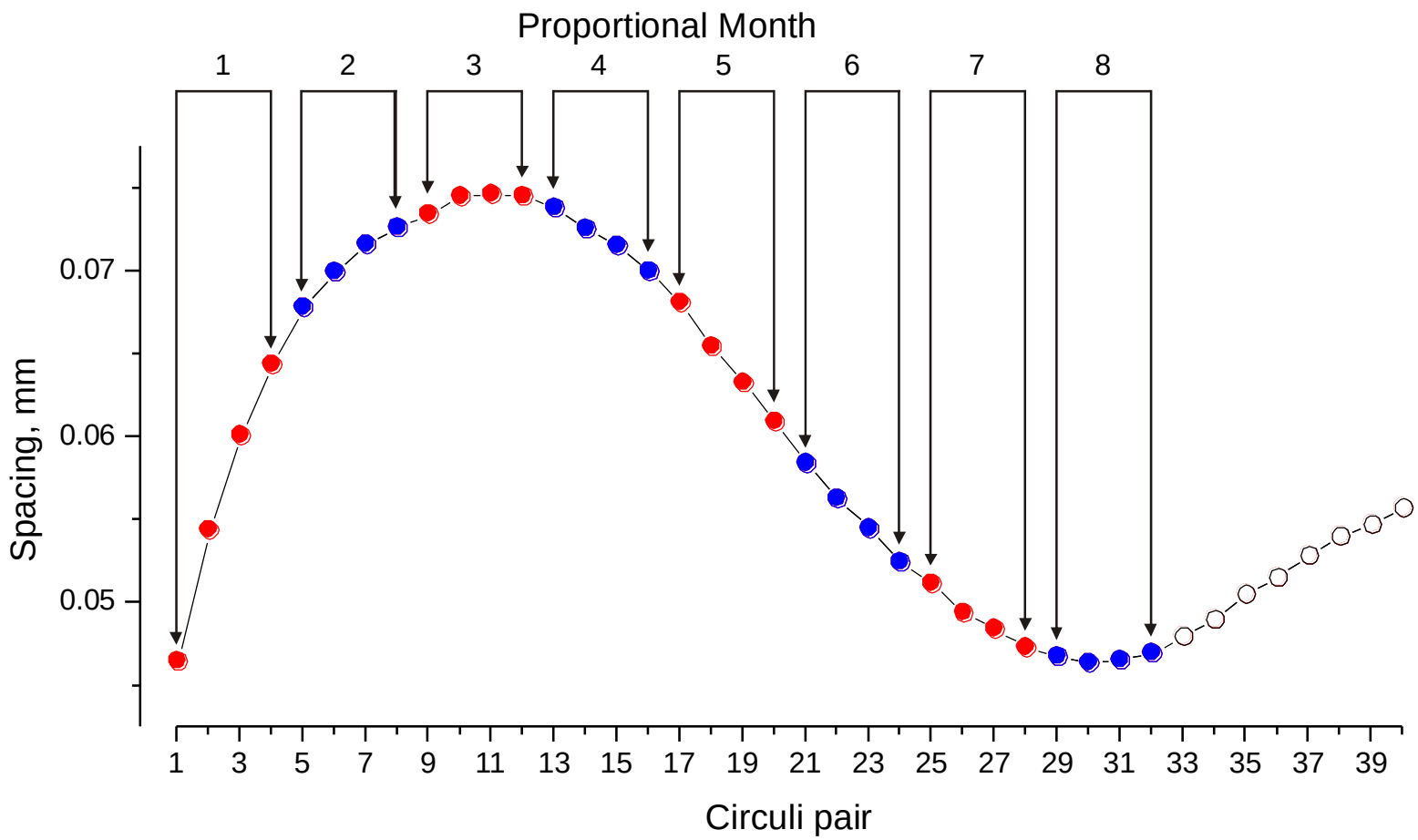


Relationship Between Atlantic Salmon Return Rate and Post-smolt Growth

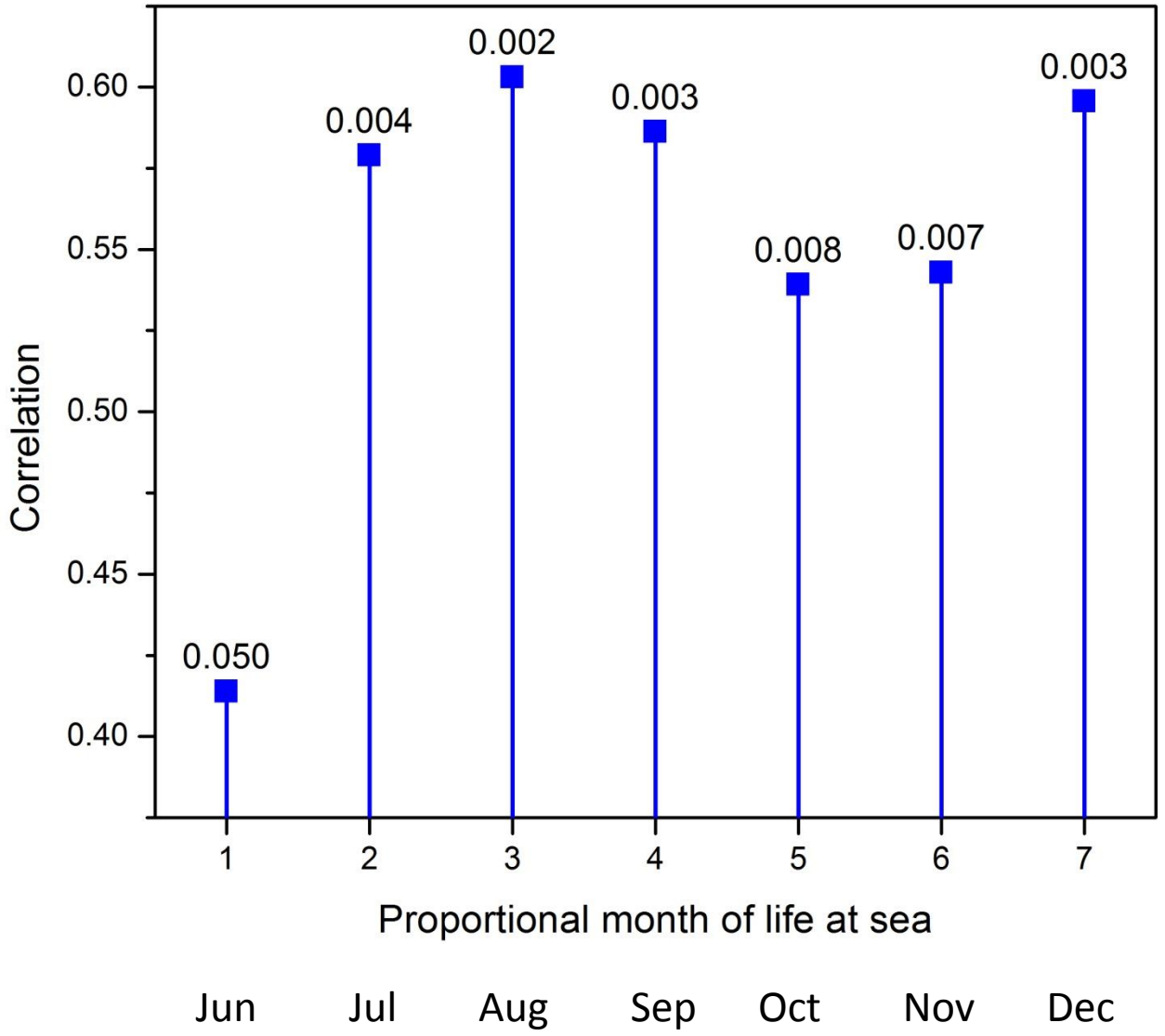
Table 4. Correlation between post-smolt growth increment by stock and sea age of return and first principal component of return rates of tagged salmon.

Index	Sea age	*r*	*n*	*p*	*N**	*p**
Burrishoole	1SW	0.530	35	**0.001**	20	**0.016**
Drammen	1SW	0.653	21	**0.001**	11	**0.029**
Drammen	2SW	0.557	21	**0.009**	17	**0.020**
Girnock Burn	2SW	0.344	29	0.067	13	0.249
Greenland	2SW	0.265	22	0.234	10	0.460
Lagan	1SW	0.545	34	**0.001**	34	**0.001**
North Esk	1SW	0.650	40	**0.000**	25	**0.000**
North Esk	2SW	0.661	39	**0.000**	24	**0.000**

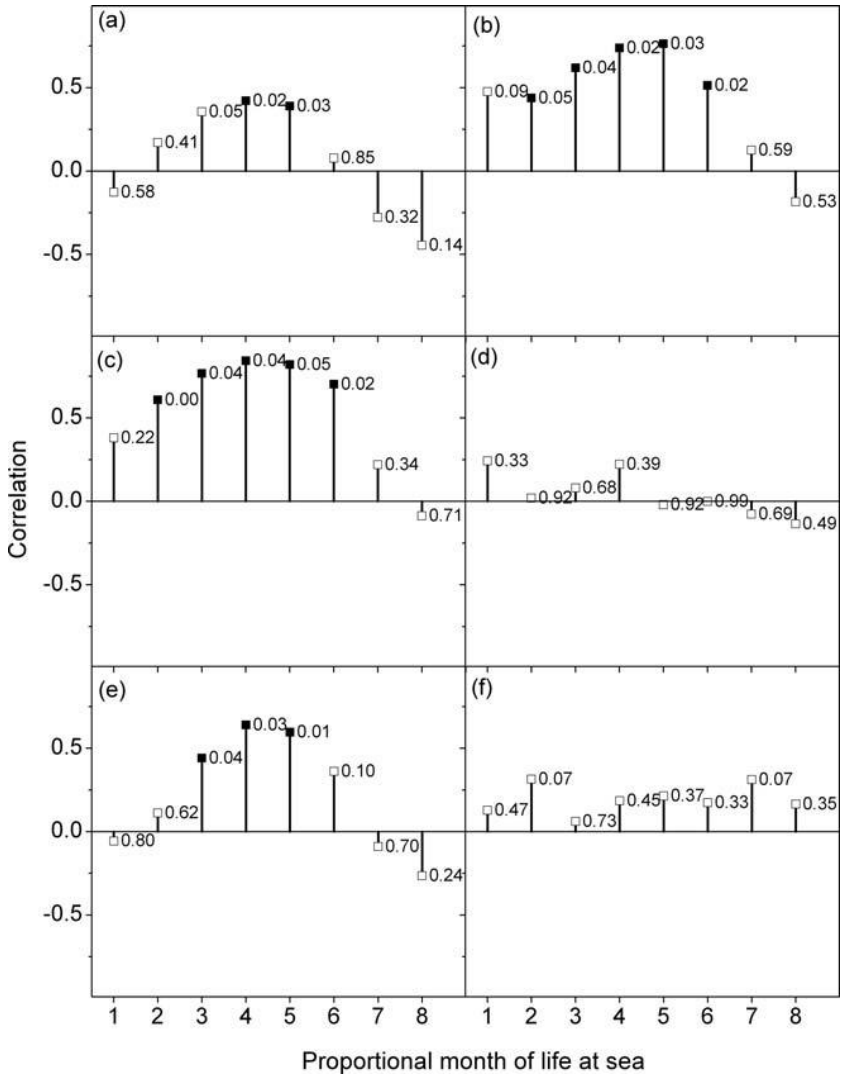
n, observed sample size; *p*, probability value of correlation; *N**, effective sample size after correction for autocorrelation; *p**, probability of correlation after correction for autocorrelation.
Significance at $p = 0.05$ emboldened.


Proportionally Allocated Monthly Growth Indices
Proportional Month
1
2
3
4
5
6
7
8
Spacing, mm
0.07
0.06
0.05
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
Circuli pair

Relationship Between Keogh Steelhead Return Rate and Seasonal Post-smolt Growth

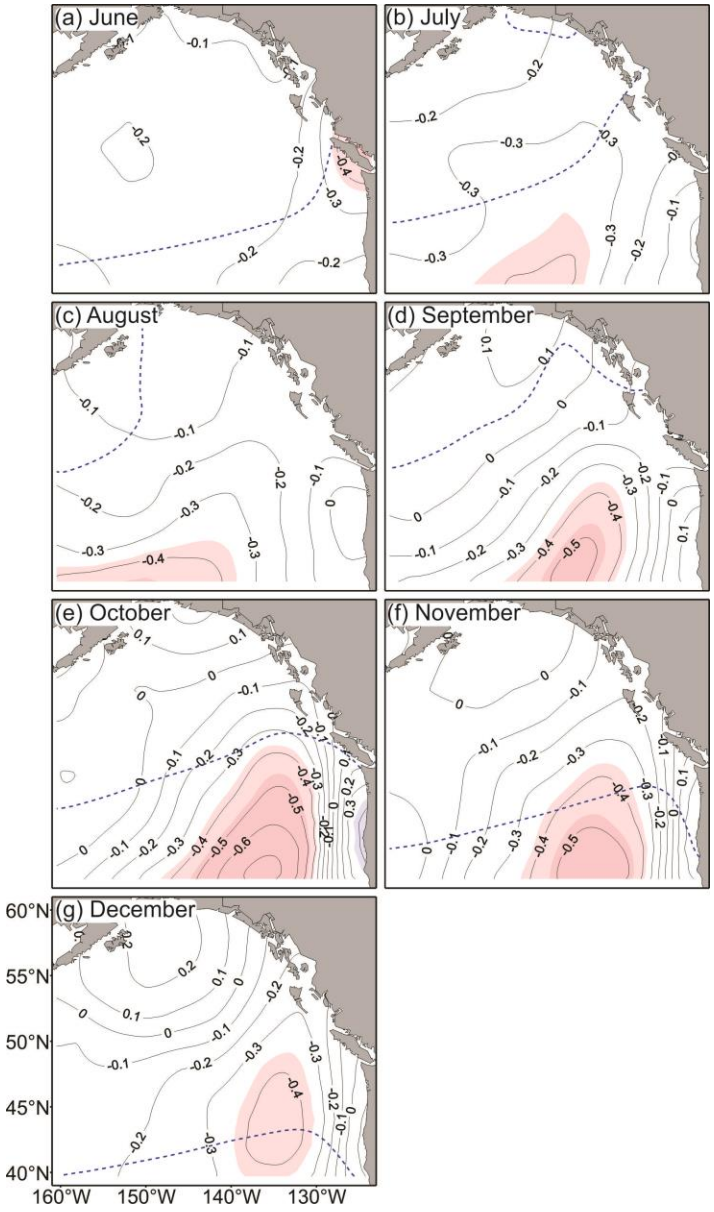


Relationship Between Atlantic Salmon Return Rate and Seasonal Post-smolt Growth

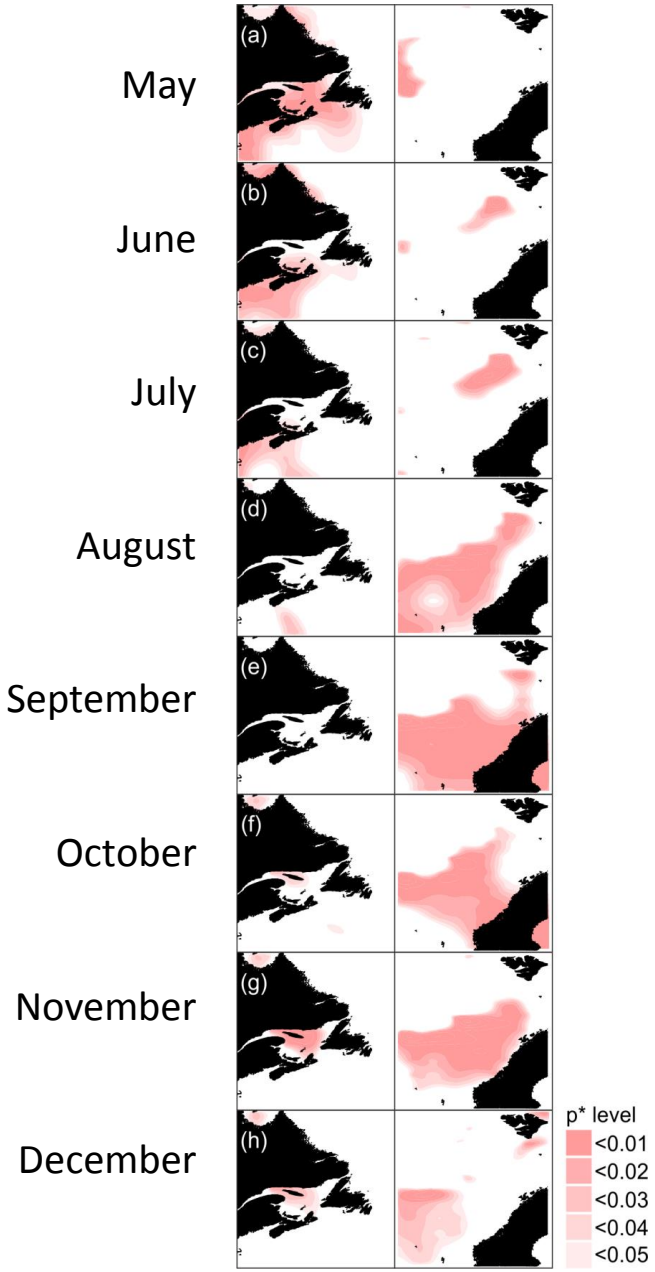


May Jun Jul Aug Sep Oct Nov Dec

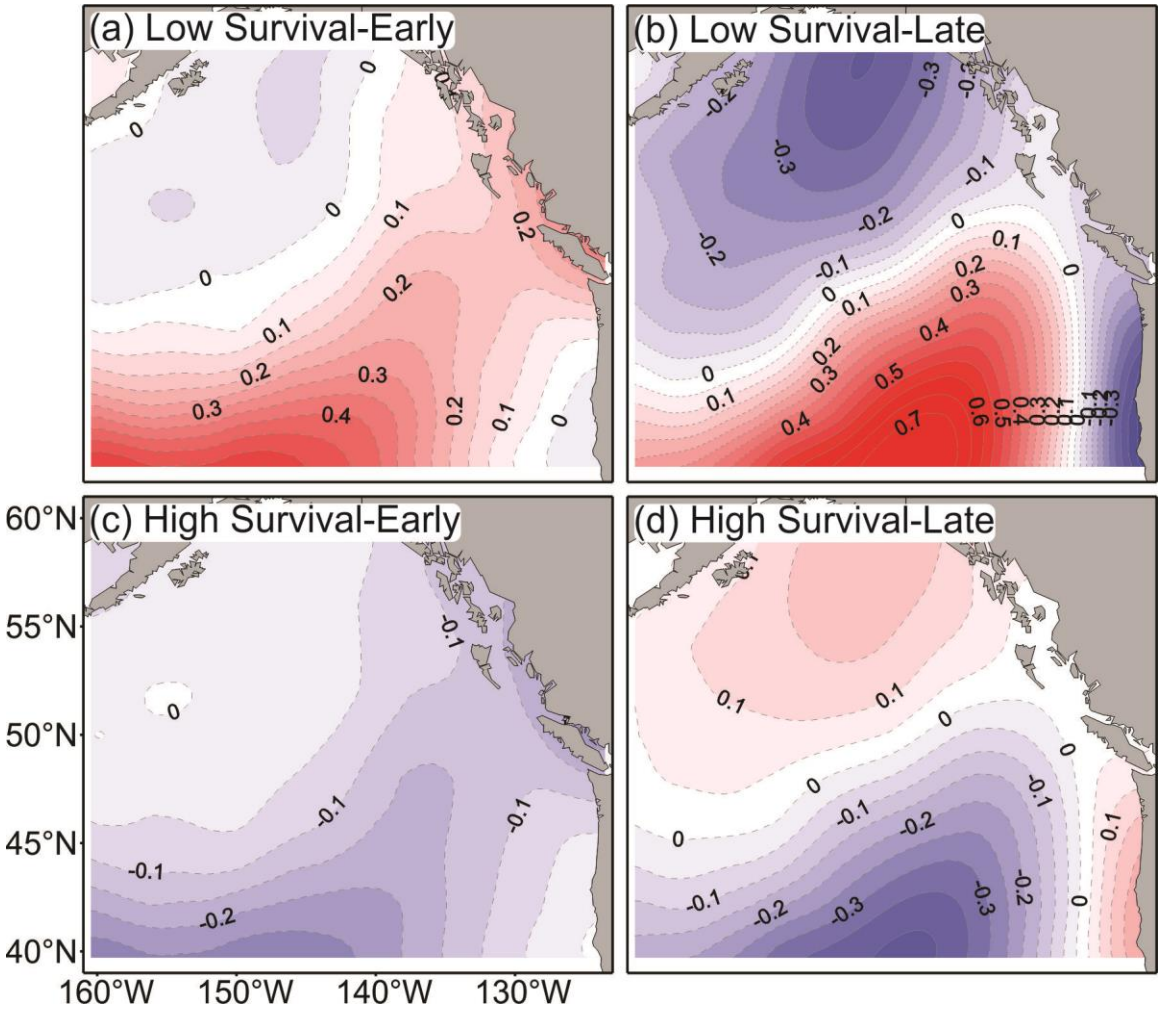
Relationship Between Keogh Steelhead Return Rate and Temperature



Relationship Between Atlantic Salmon Return Rate and Temperature



Average Temperature Distribution During High and Low Survival Regimes



Main Findings
Reconfirm that size at ocean entry does not control recruitment of Keogh Steelhead
Post-smolt growth appears to control survival
Critical post-smolt growth occurs during protracted period of summer into fall
Survival and growth appears related to broad scale ocean forcing as seen in changes in distribution of sea surface temperature
Consistent with hypothesis that growth mediates survival through predation
Growth-survival mechanism of Keogh steelhead appears similar to that observed for eastern boundary Atlantic salmon

Citation

Friedland, K.D., Ward, B.R., Welch, D.W., Hayes, S.A., 2014. Postsmolt Growth and Thermal Regime Define the Marine Survival of Steelhead from the Keogh River, British Columbia. **Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science** 6, 1-11.

Acknowledgements

We thank Emma Johnson for making scale measurements, Tom Johnston for providing scale images, Nate Mantua for review comments and suggestions, and the many folks who assisted with Keogh research operations, particularly Don McCubbing of InStream Resources Inc.