Recruitment of Atlantic Salmon

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and

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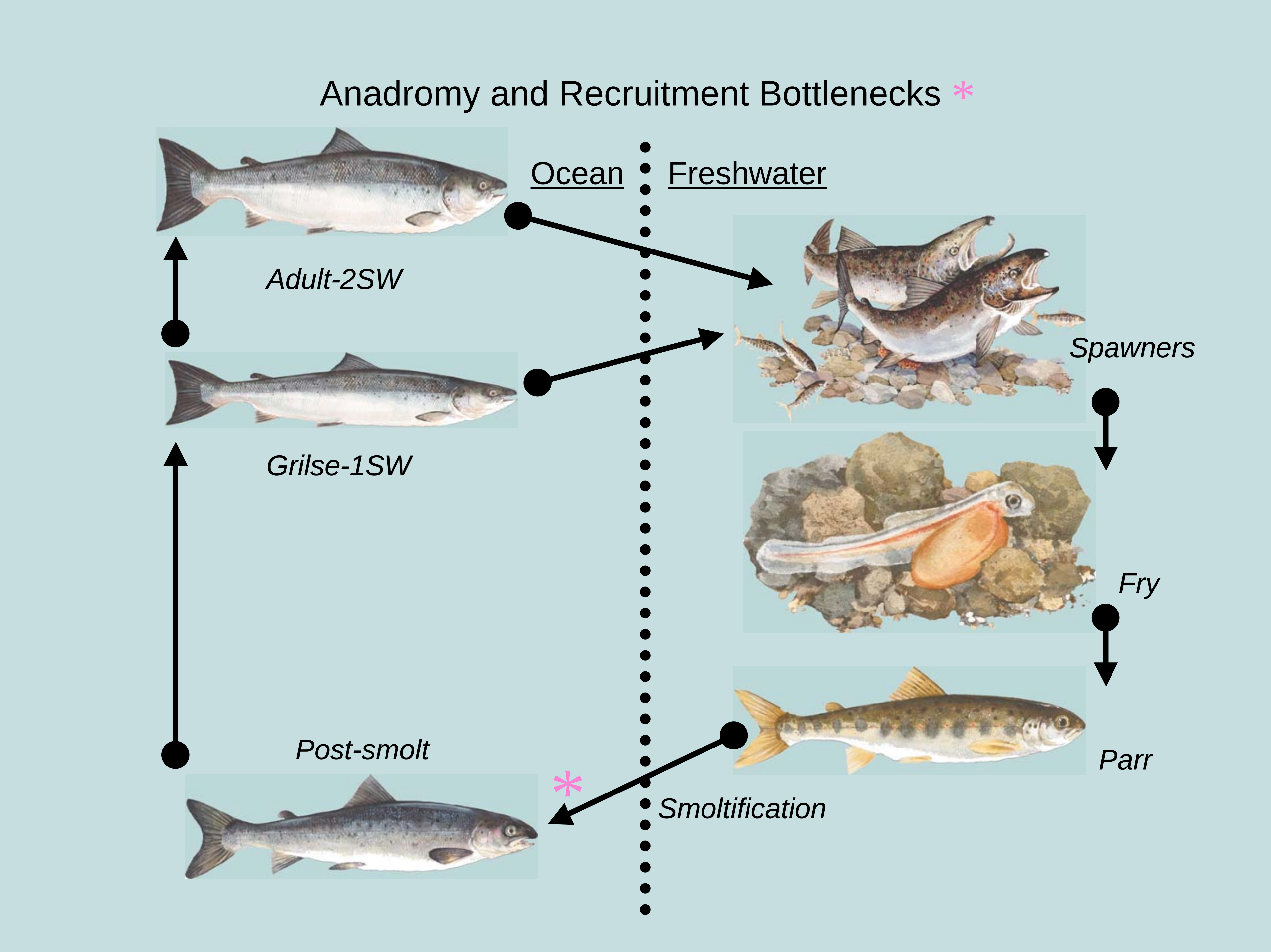
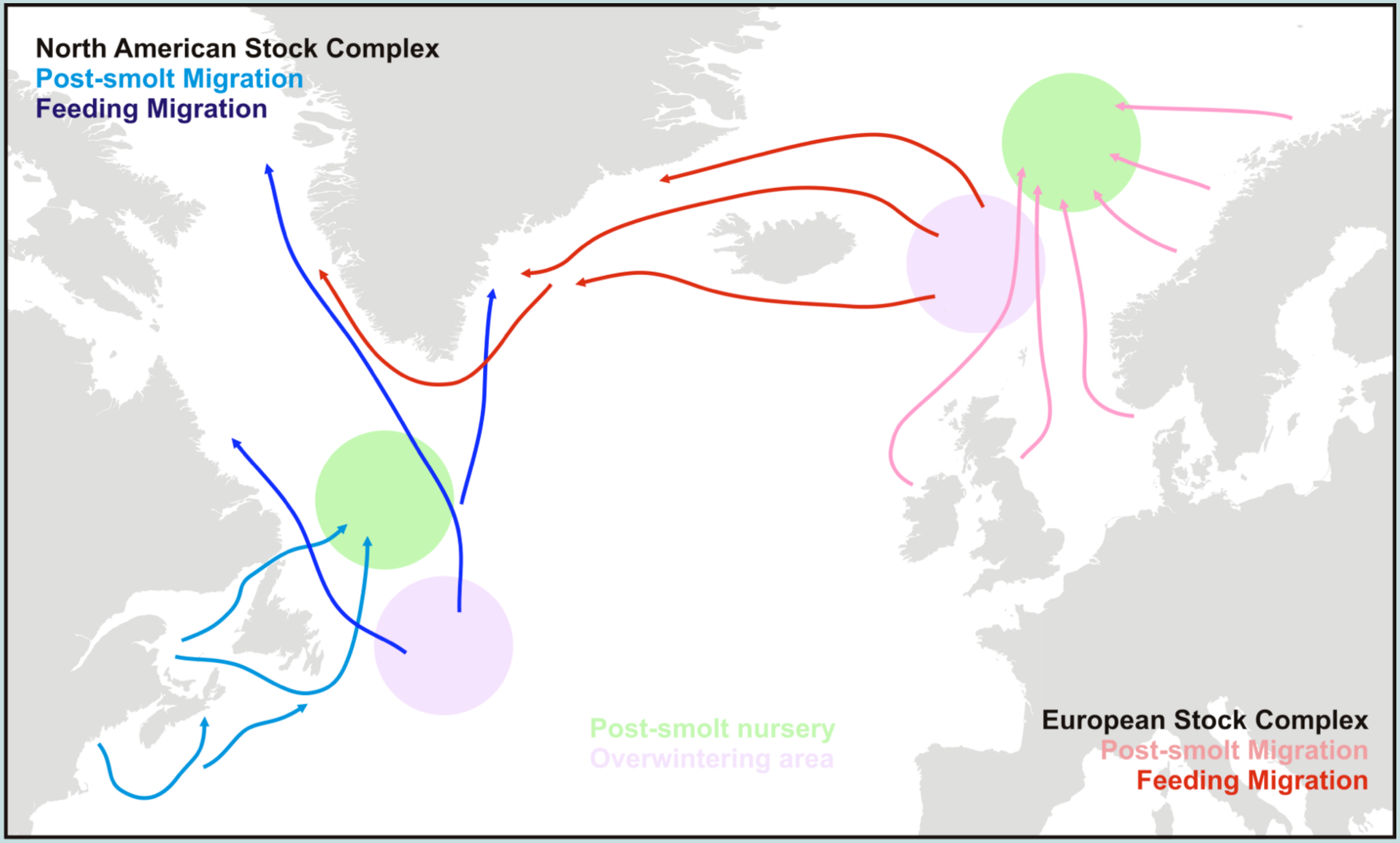

Anadromy and Recruitment Bottlenecks *
Ocean
Freshwater
Adult-2SW
Grilse-1SW
Post-smolt
*
Spawners
Fry
Parr
Smoltification

Salmon Migration



Why Atlantic salmon have been so hard to study during their marine phase:

Long oceanic migrations
Foraging migrations to remote regions

Surface dwelling
Generally unavailable to most gears as catch or bycatch

No social behaviors
Not a schooling fish, few caught in the same location

Correcting for Autocorrelation in Time Series Correlation

To account for autocorrelation, we adjusted the effective degrees of freedoms of each correlation test according to the procedure suggested by Pyper and Peterman (1998). The effective degree of freedom (*N**) of a correlation between two time series, in notation series *X* and *Y*, was estimated by:

$$\frac{1}{N^*} \approx \frac{1}{N} + \frac{2}{N}\sum_{j=1}^{N/5}\frac{(N-j)}{N}\rho_{xx}(j)\rho_{yy}(j)$$

Where *N* is the sample size and $\rho_{xx}(j)$ and $\rho_{yy}(j)$ are the autocorrelations of *X* and *Y* at lag *j*. We took the autocorrelation at lag *j* of the cross-products of standardized time series of *X* and *Y*. The probability associated with a correlation coefficient is designated as *p* and as *p** for a test with degrees of freedom based on *N**.

Recruitment Research on European Atlantic Salmon

Terrell and Shelton, 1993
Examined SST and CPR data, conclusions were limited by lack of knowledge on the ecology of salmon at sea

Friedland et al., 1993; 1998
Relationship between quantity of thermal habitat during the first months at sea and post-smolt survival

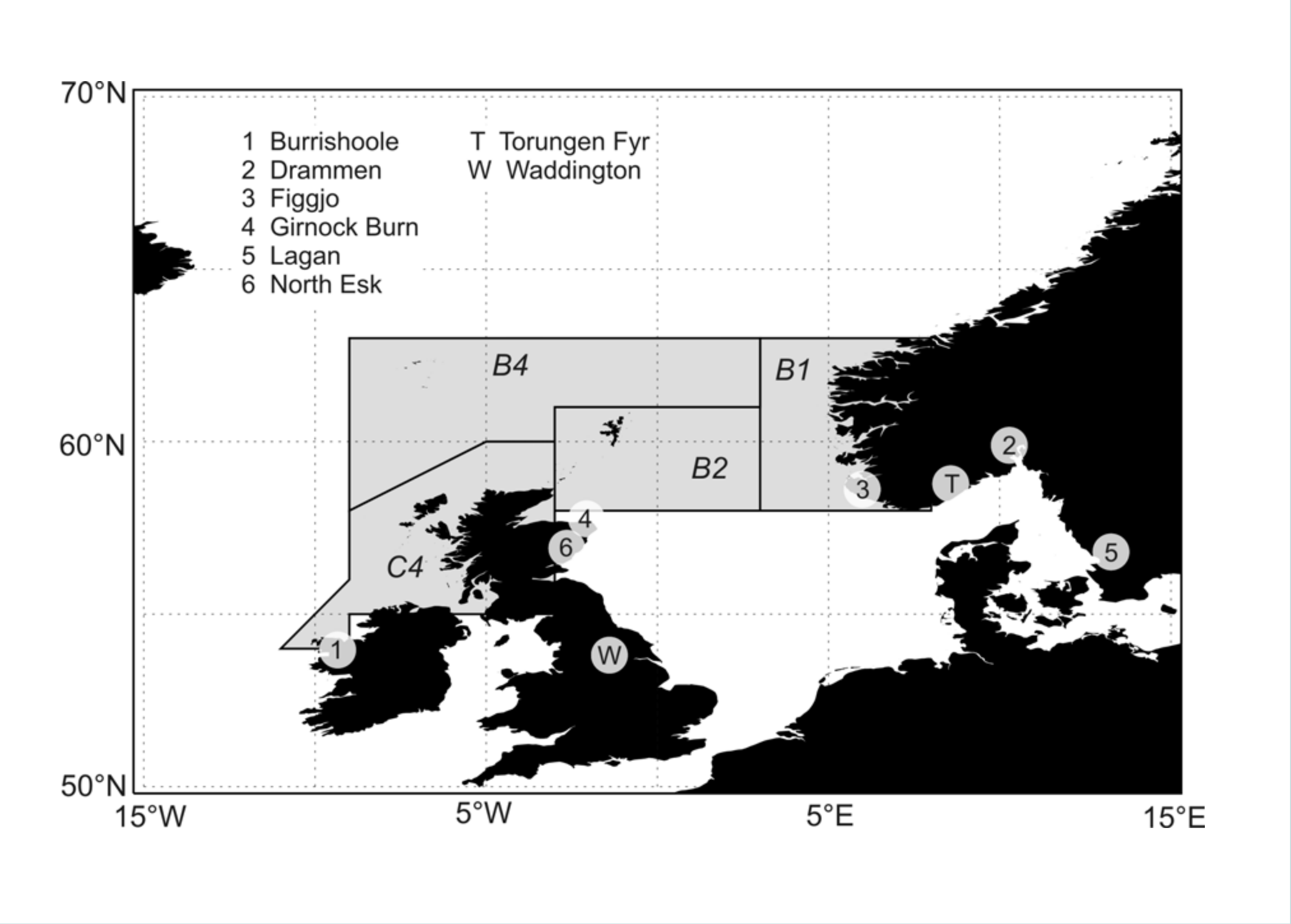
Friedland et al., 2000; McCarthy et al., 2008; Peyronnet et al., 2008a
Post-smolt growth mediates post-smolt survival

Beaugrand & Reid, 2003
Established linkages between zooplankton community shift in the NE Atlantic and Atlantic salmon

Friedland et al., 2005
Showed post-smolt growth was negatively correlated with thermal conditions in the post-smolt nursery area

Peyronnet et al., 2008b
Demonstrated SST and zooplankton relationships for Irish salmon stocks

Location of Tagging Index Rivers, SAHFOS Standard Areas, and Growth Analysis Rivers



Friedland et al., in press

Post-smolt Nursery for European Atlantic Salmon

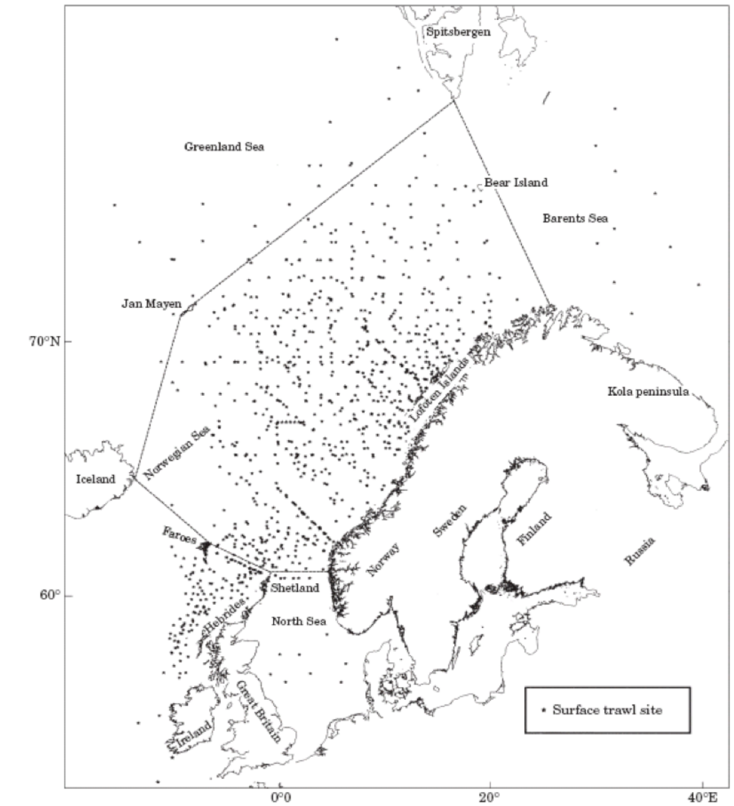


Figure 1. Positions of surface trawling and hydrographical sampling stations 1990–1998. Each dot represents one trawl site. The hydrographical sampling has been made either at or near the same location. The limits of the sea areas are drawn with a hatched line according to Anon. (1953).

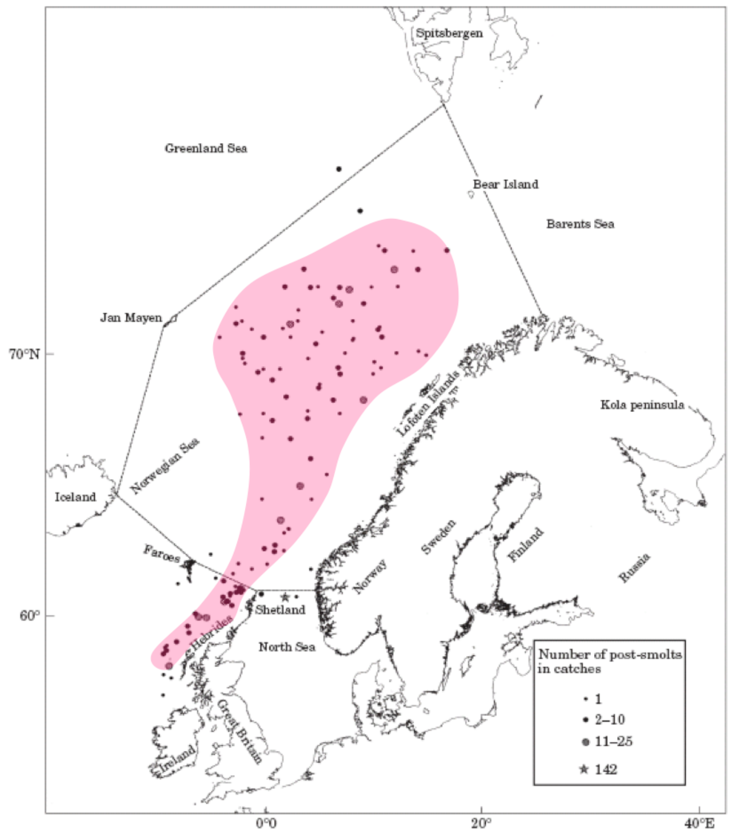
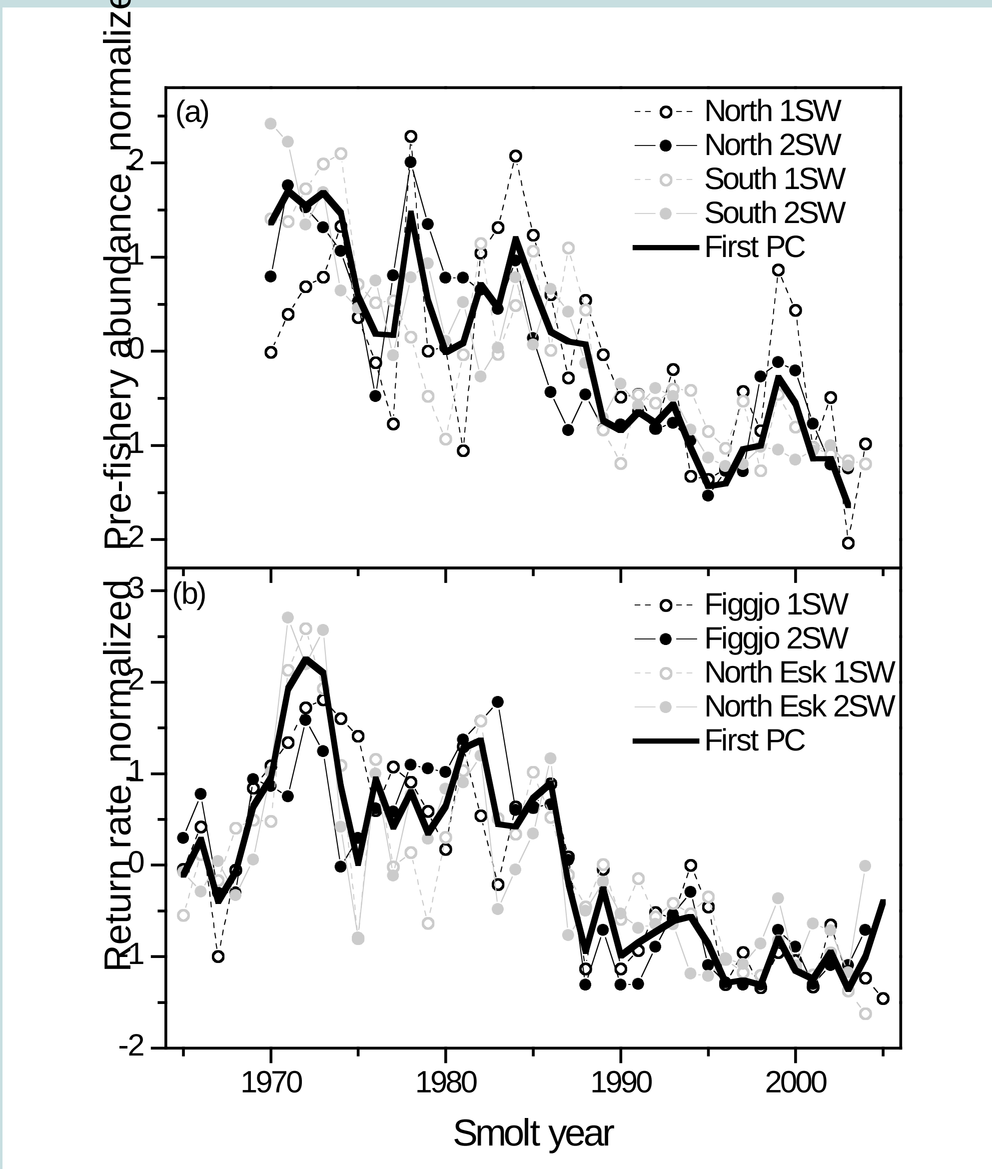


Figure 3. Distribution of post-smolt catches in 1990–1998.

(Holm et al. 2000).

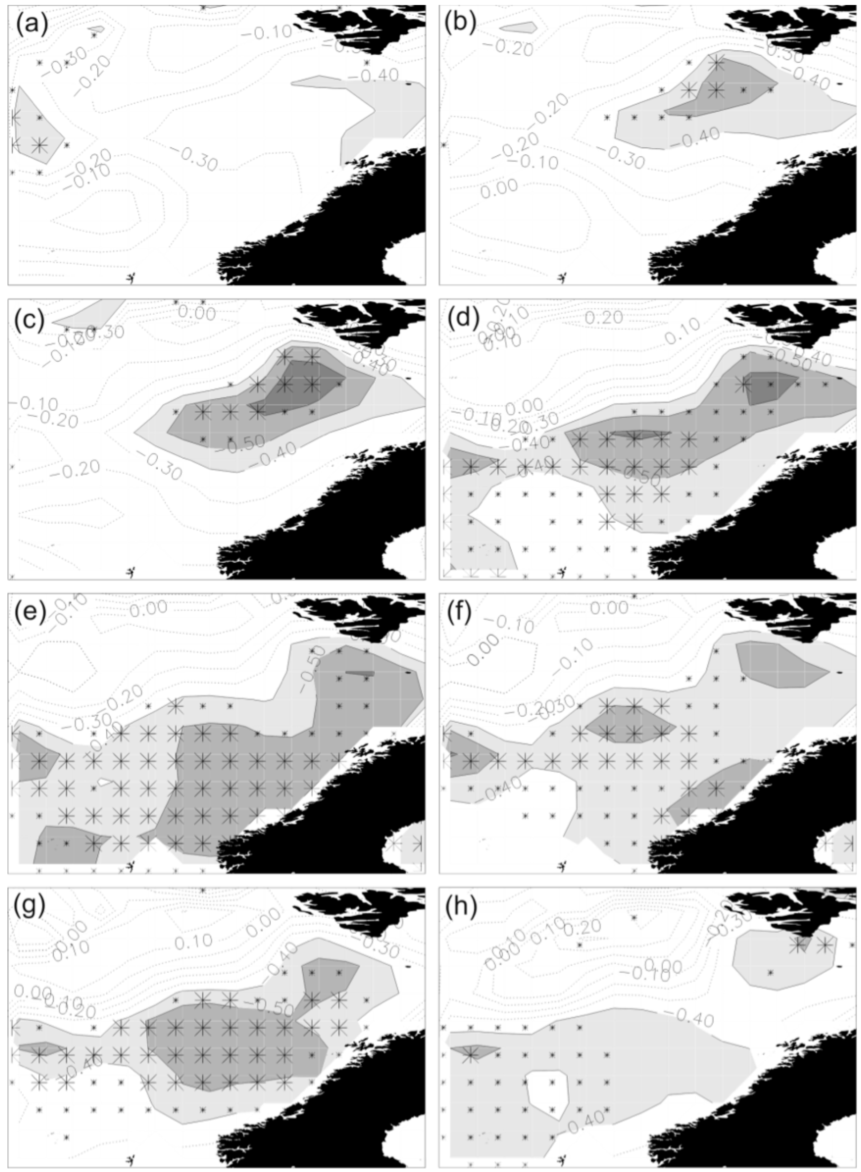
European Stock Complex Abundance and Tagging Based Return Rate



Friedland et al., in press

Relationship Between SST and PC of Return Rates

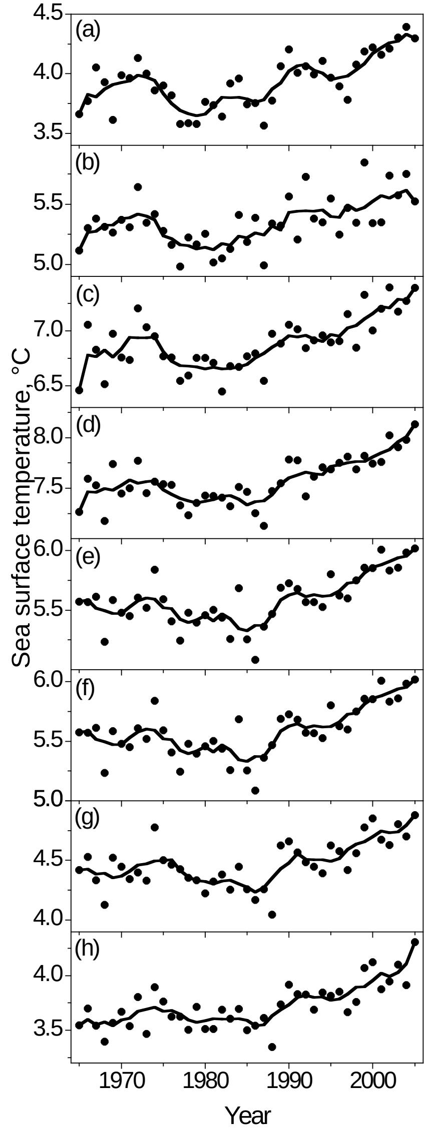
a) May
b) June
c) July
d) August
e) September
f) October
g) November
h) December



Friedland et al., in press

Mean SST for the Northeast Atlantic

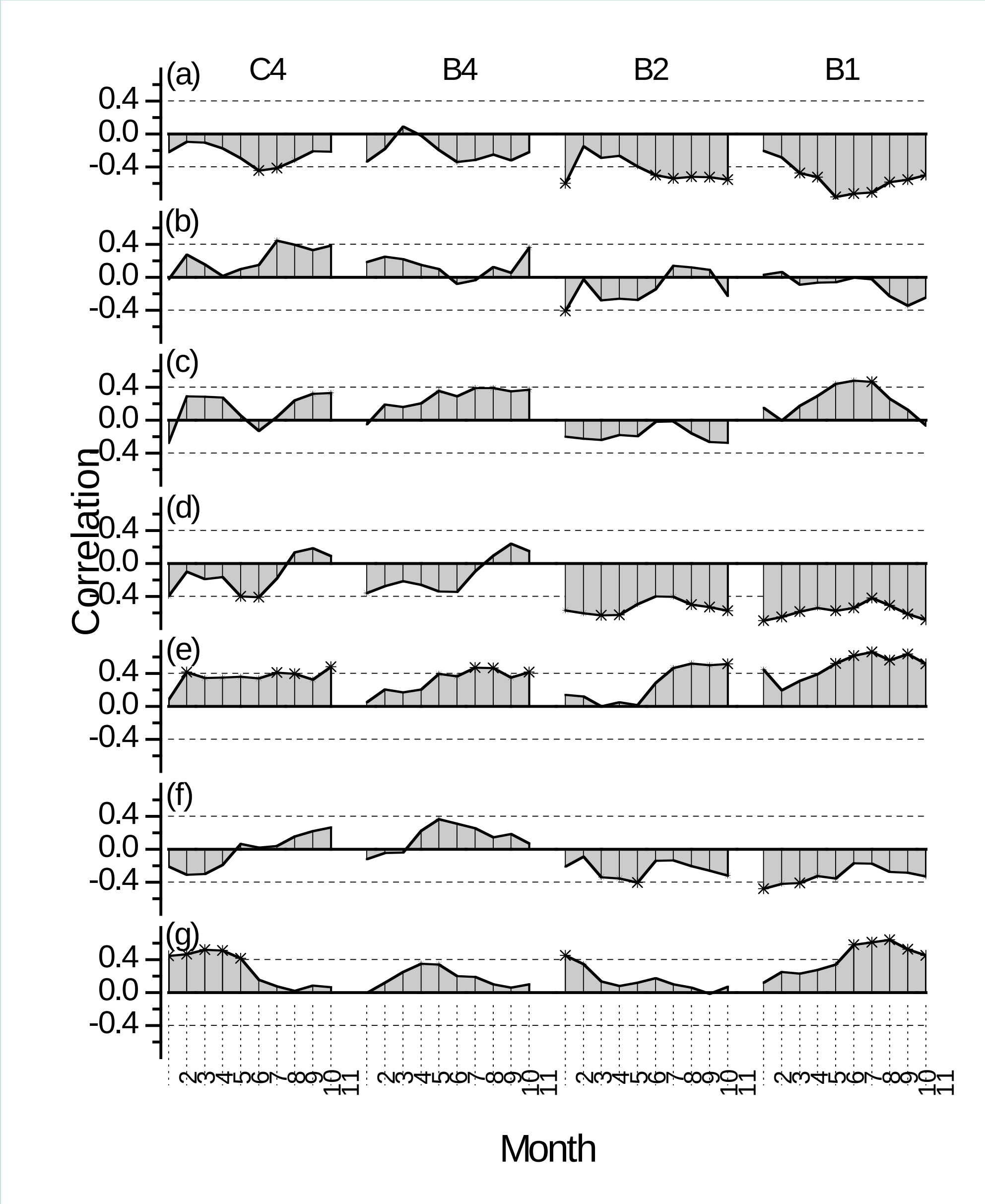
a) May
b) June
c) July
d) August
e) September
f) October
g) November
h) December



Friedland et al., in press

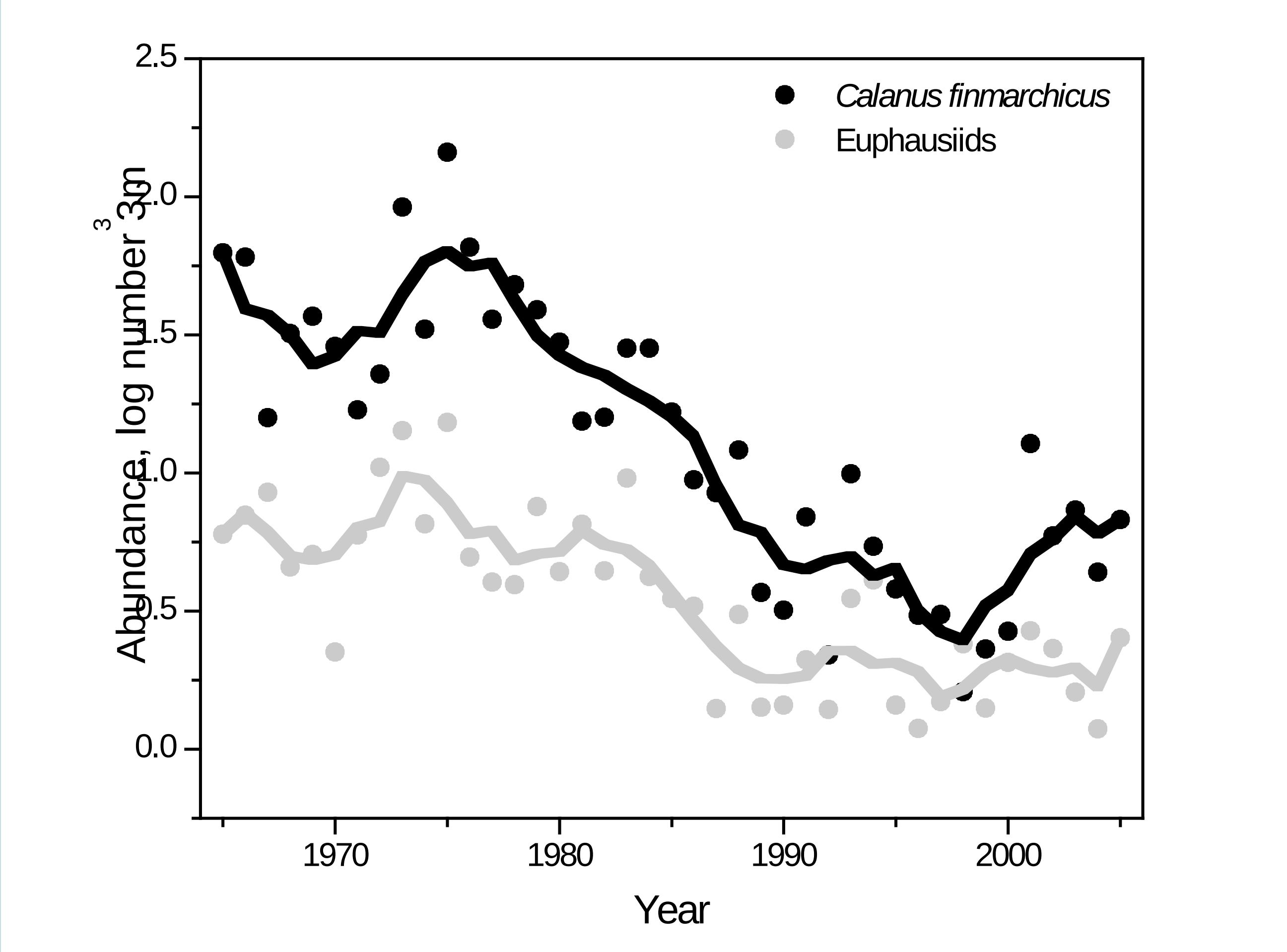
Relationship Between Plankton and PC of Return Rate

a) phytoplankton color index
b) total small copepods
c) total large copepods
d) Calanus helgolandicus
e) Calanus finmarchicus
f) total amphipoda
g) total euphausiid



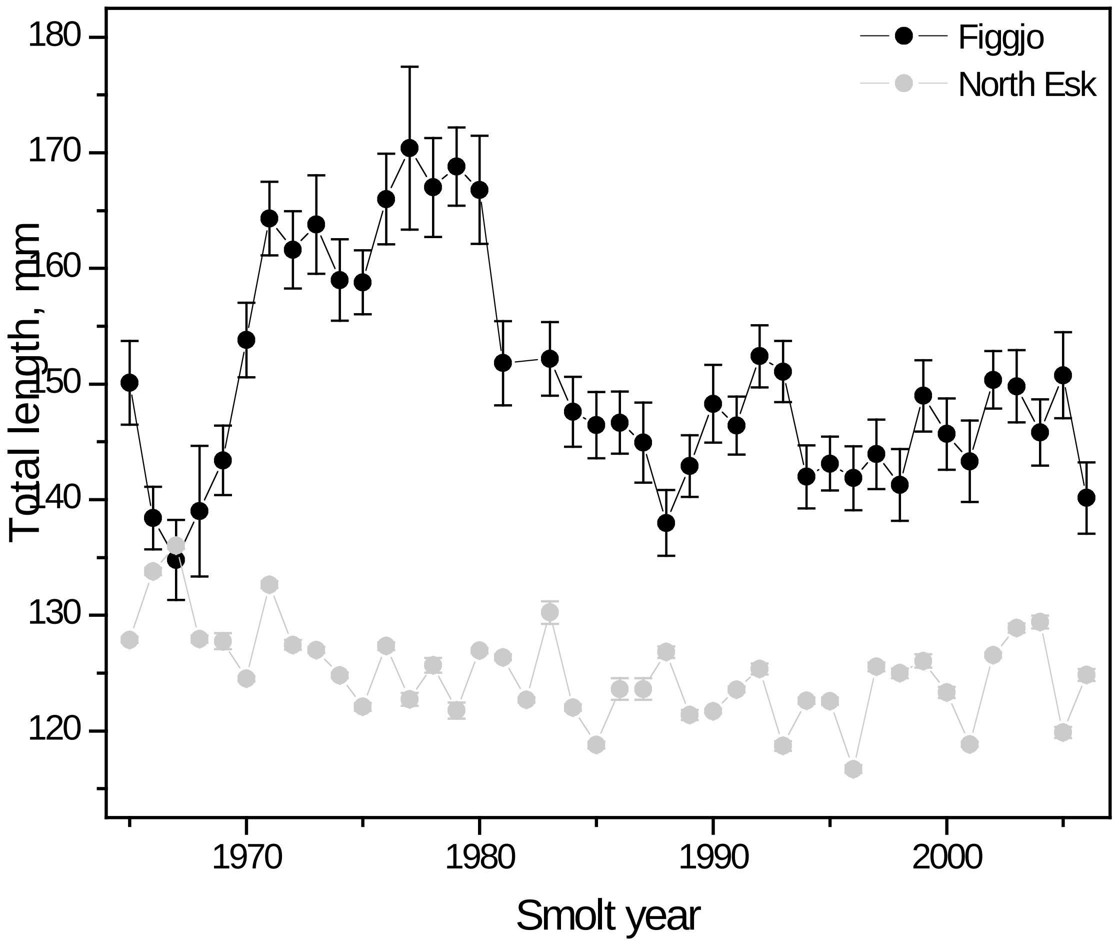
Friedland et al., in press

Time Series Trends, *Calanus finmarchicus* and Euphausiids



Friedland et al., in press

Smolt Size



Friedland et al., in press

Relationship Between Smolt Size and PC of Return Rate

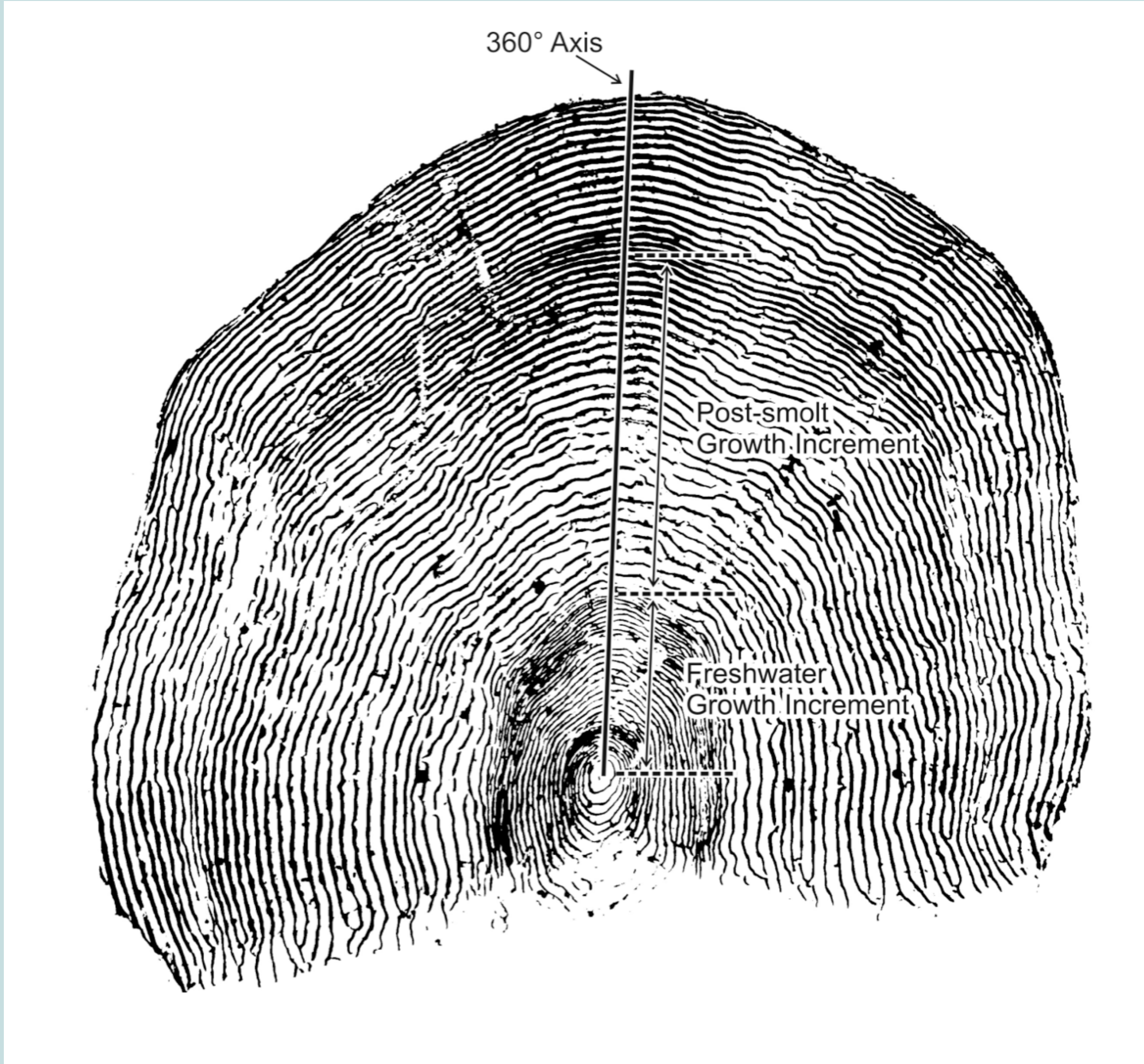
Index	r	N	p	N*	p*
Figgjo	0.605	40	**0.001**	21	**0.004**
North Esk	0.242	41	0.130	41	0.130

Friedland et al., in press

Salmon Scale

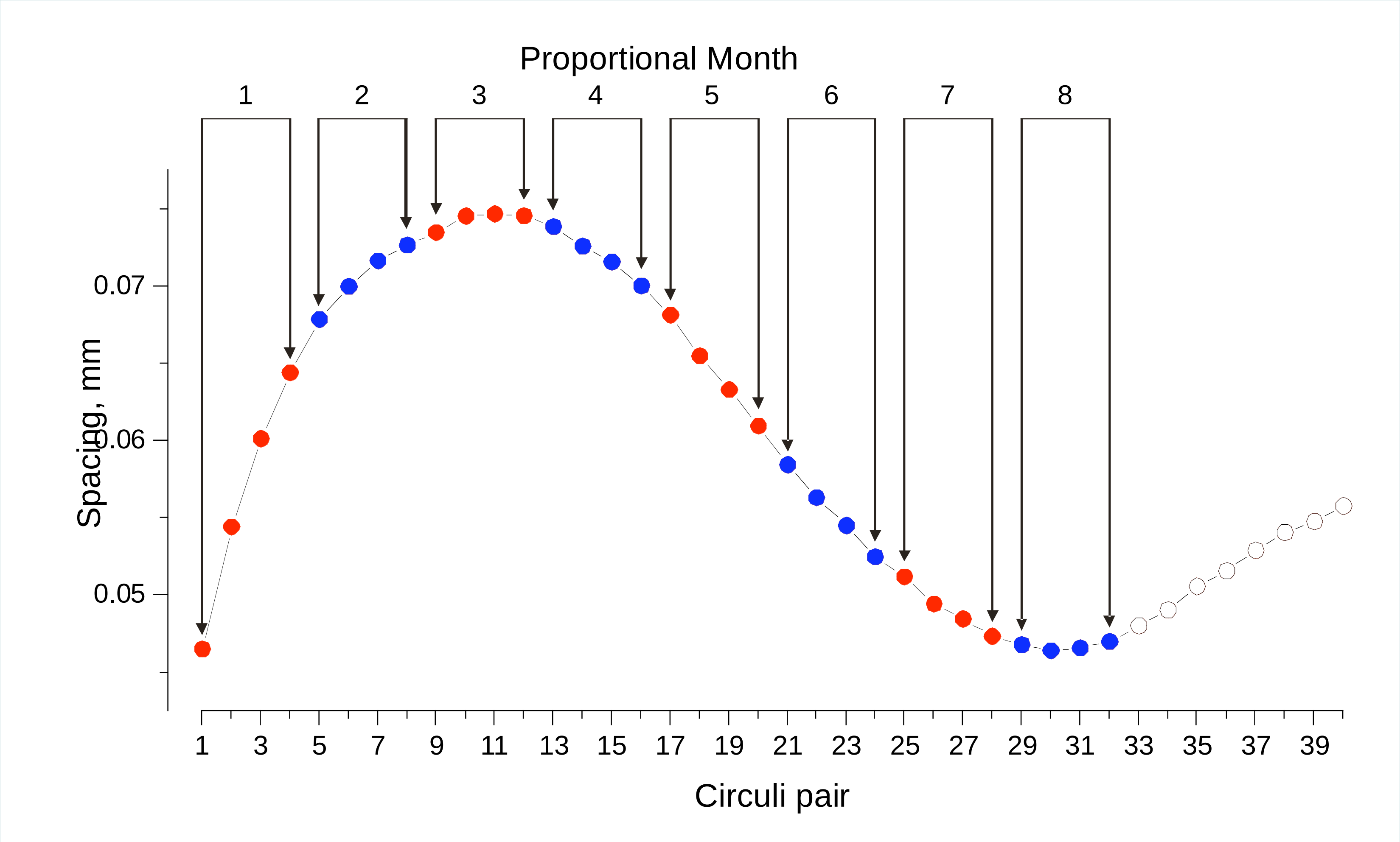
Post-smolt
Growth
Increment

Proportionally
Allocated
Monthly Growth
Indices



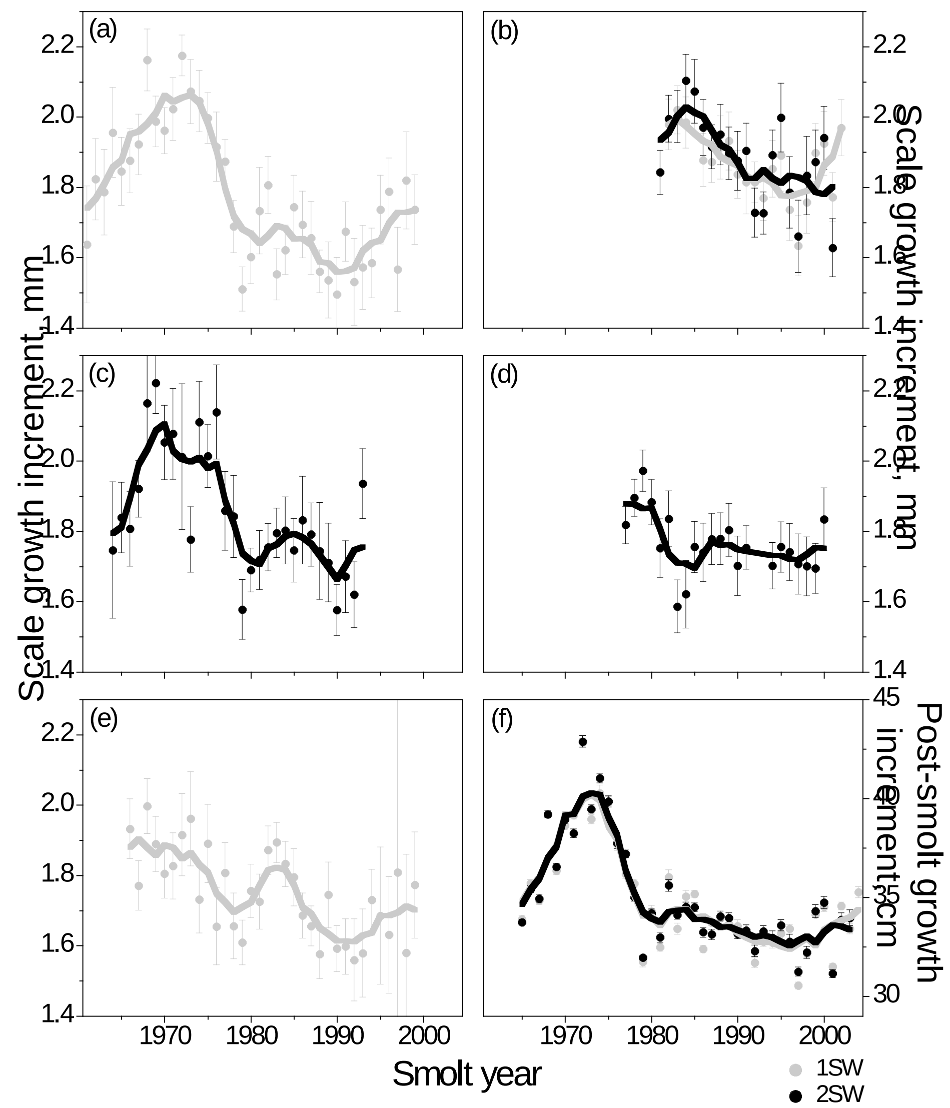
Friedland et al., in press

Proportionally Allocated Monthly Growth Indices



Post-smolt Growth Increment

- a) Burrishoole
- b) Drammen
- c) Girnock
- d) Greenland
- e) Lagan
- f) North Esk



Friedland et al., in press

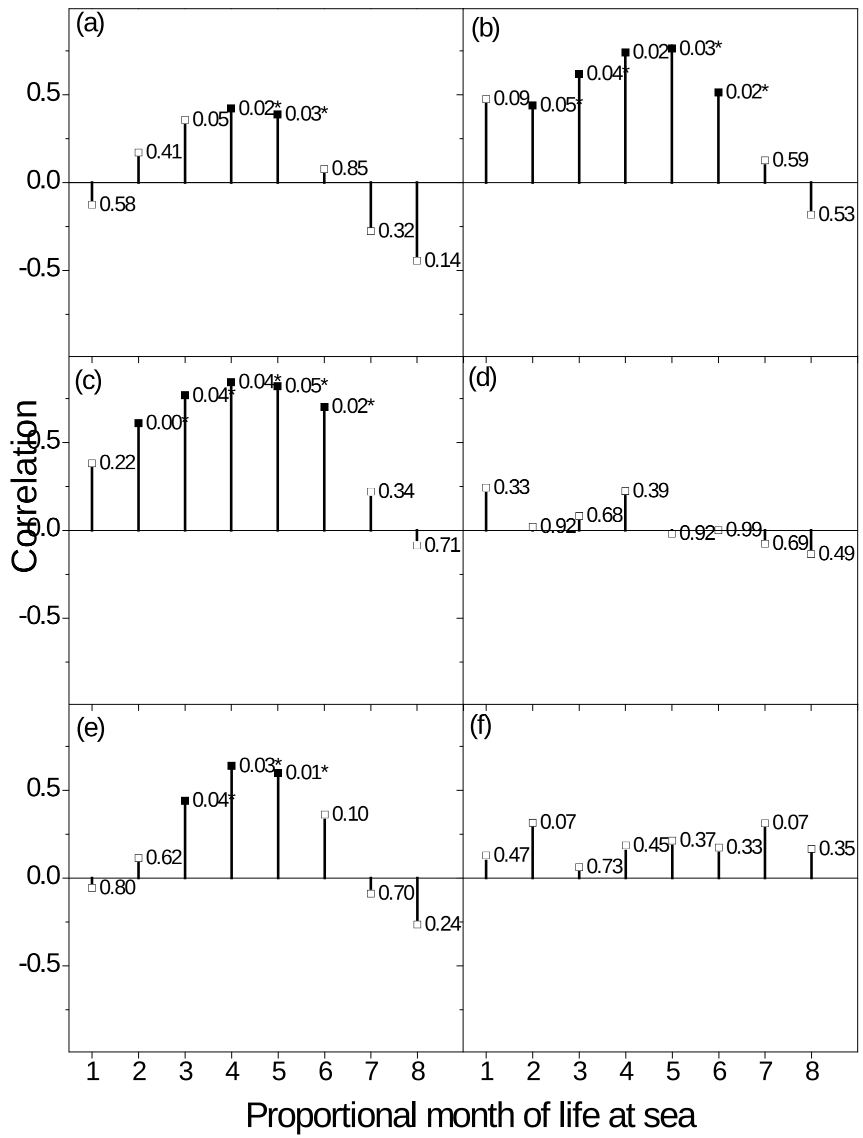
Relationship Between Post-smolt Growth Increment and PC of Return Rate

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**

Friedland et al., in press

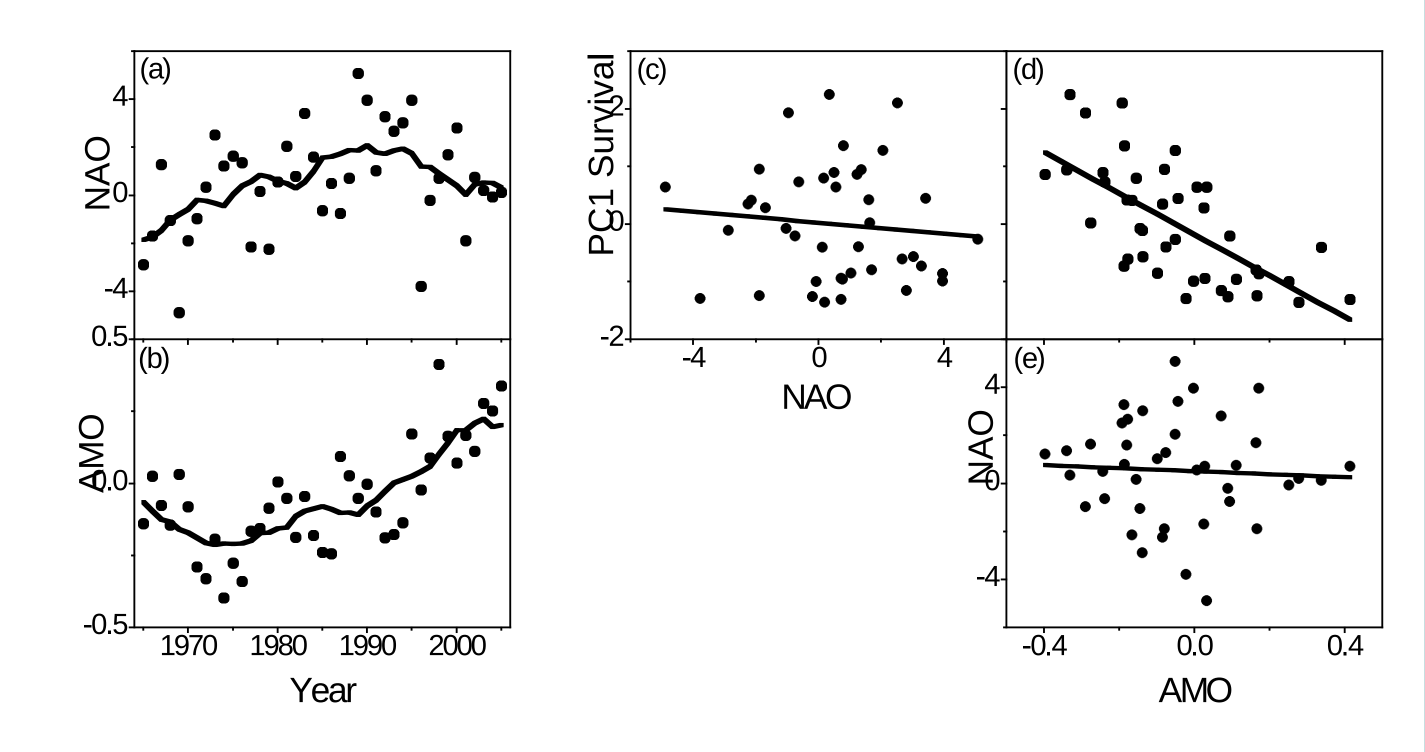
Relationship Between Proportionally Allocated Monthly Growth Indices and PC of Return Rate

a) Burrishoole, 1SW
b) Drammen, 1SW
c) Drammen, 2SW
d) Girnock, 2SW
e) Greenland, 2SW
f) Lagan, 1SW



Friedland et al., in press

Climate Forcing



Friedland et al., in press

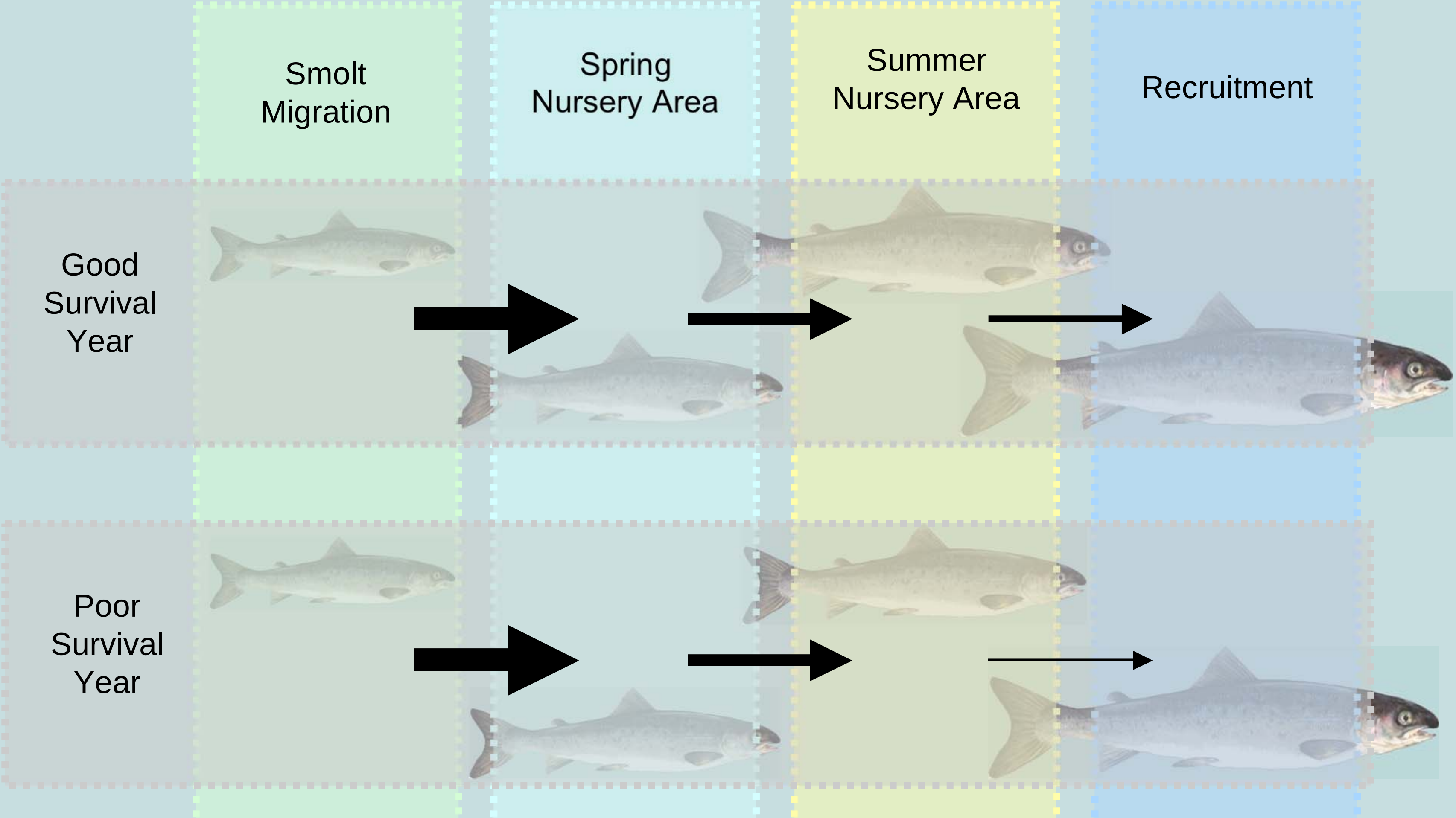
Relationship Between Climate Forcing and PC of Return Rate

Index 1	Index 2	r	N	p	N*	p*
NAO	PC1 Survival	-0.104	41	0.520	41	0.520
AMO	PC1 Survival	-0.674	41	**0.001**	28	**0.001**
AMO	NAO	0.054	41	0.740	41	0.740

Friedland et al., in press

Recruitment Mechanism European Atlantic Salmon

Change in physical forcing in Northeast Atlantic → Variation in summer SST conditions → Shift in primary and secondary production → Change in summer growth of post-smolts associated with survival



Preceding Climate Research on North American Atlantic Salmon

Reddin, 1988; Ritter, 1989
Examined position of winter SST isotherms and related to post-smolt survival

Reddin and Friedland, 1993; Friedland et al., 1993
Focused on the quantity of thermal habitat during the post-smolt year, a relationship was observed between winter habitat and post-smolt survival that has since devolved

Friedland et al., 1996
Post-smolt growth for hatchery stocks not related to post-smolt survival

Friedland et al., 2005
Post-smolt growth for wild stock not related to post-smolt survival, short time series

Atlantic salmon, unlike Pacific species, are relatively large fish by their first sea-winter; this has made this hypothesis problematic

Salmon Growth and Size Attained by the First Seawinter

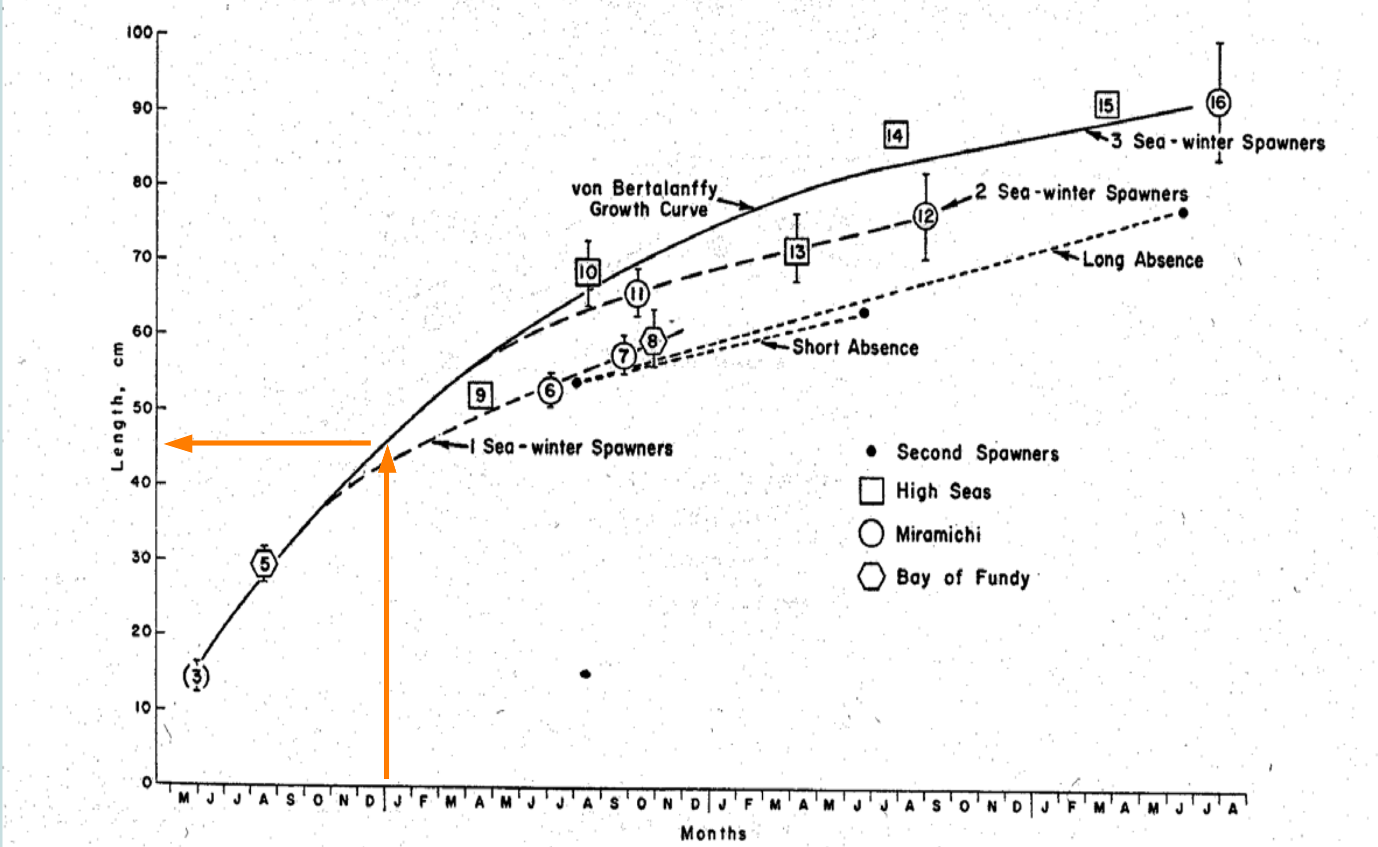


FIG. 3. Growth curves of Northwest Atlantic salmon, based on samples in Table 1. Solid line, von Bertalanffy envelope curve fitted to points representing migrating smolts and fish in the actively growing marine phase; broken lines, curves applying to fish which have passed through most or all of their last sea-winter preceding first sexual maturity; dotted lines, growth curves for fish which matured first as grilse but have survived to approach a second maturity after 1 or 2 more years at sea.

Allen et al., 1972

Distribution of North American Post-smolts

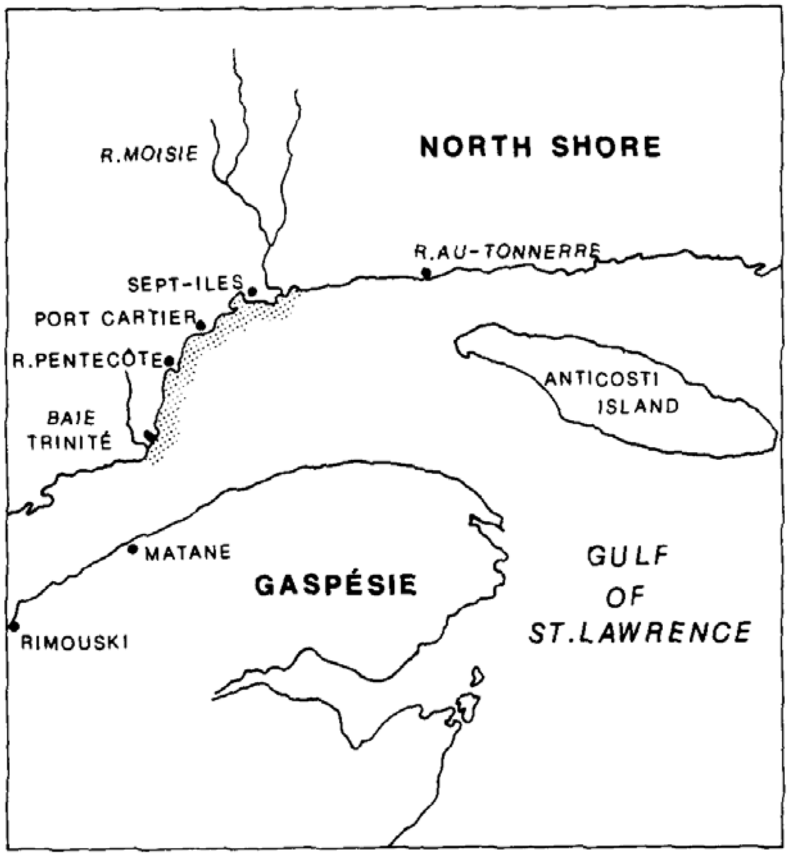
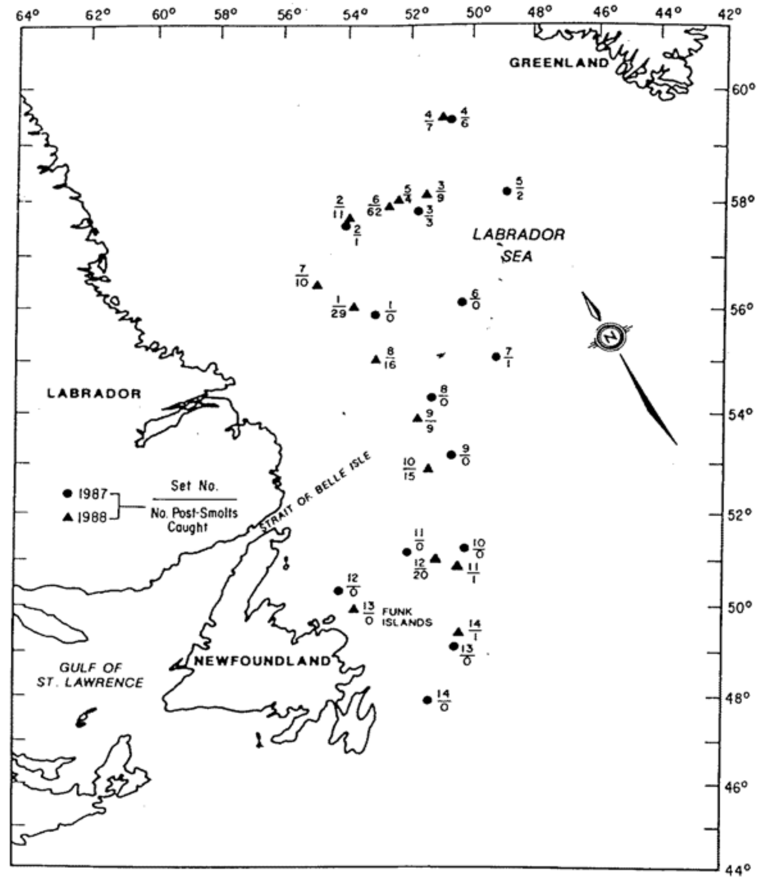
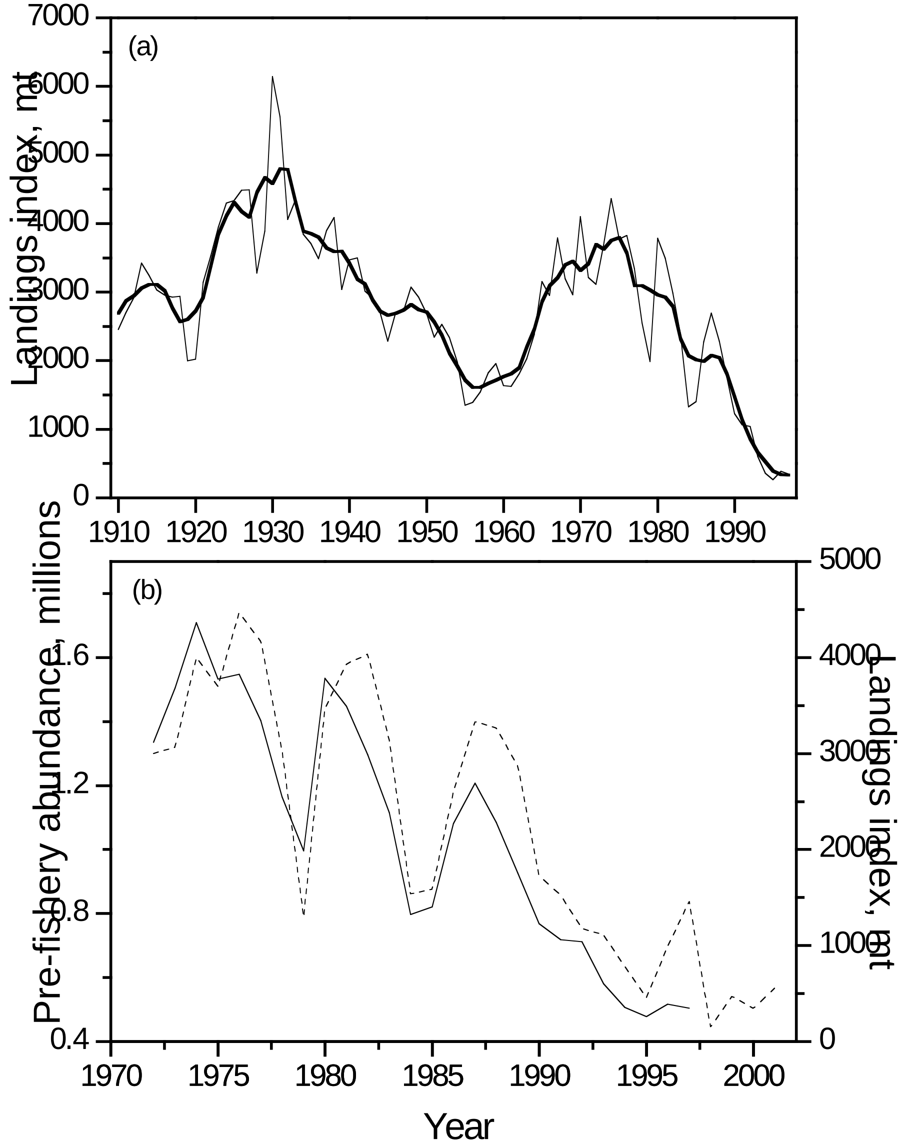


FIGURE 1.—Locations of the areas investigated in the northern Gulf of St. Lawrence (shaded area).



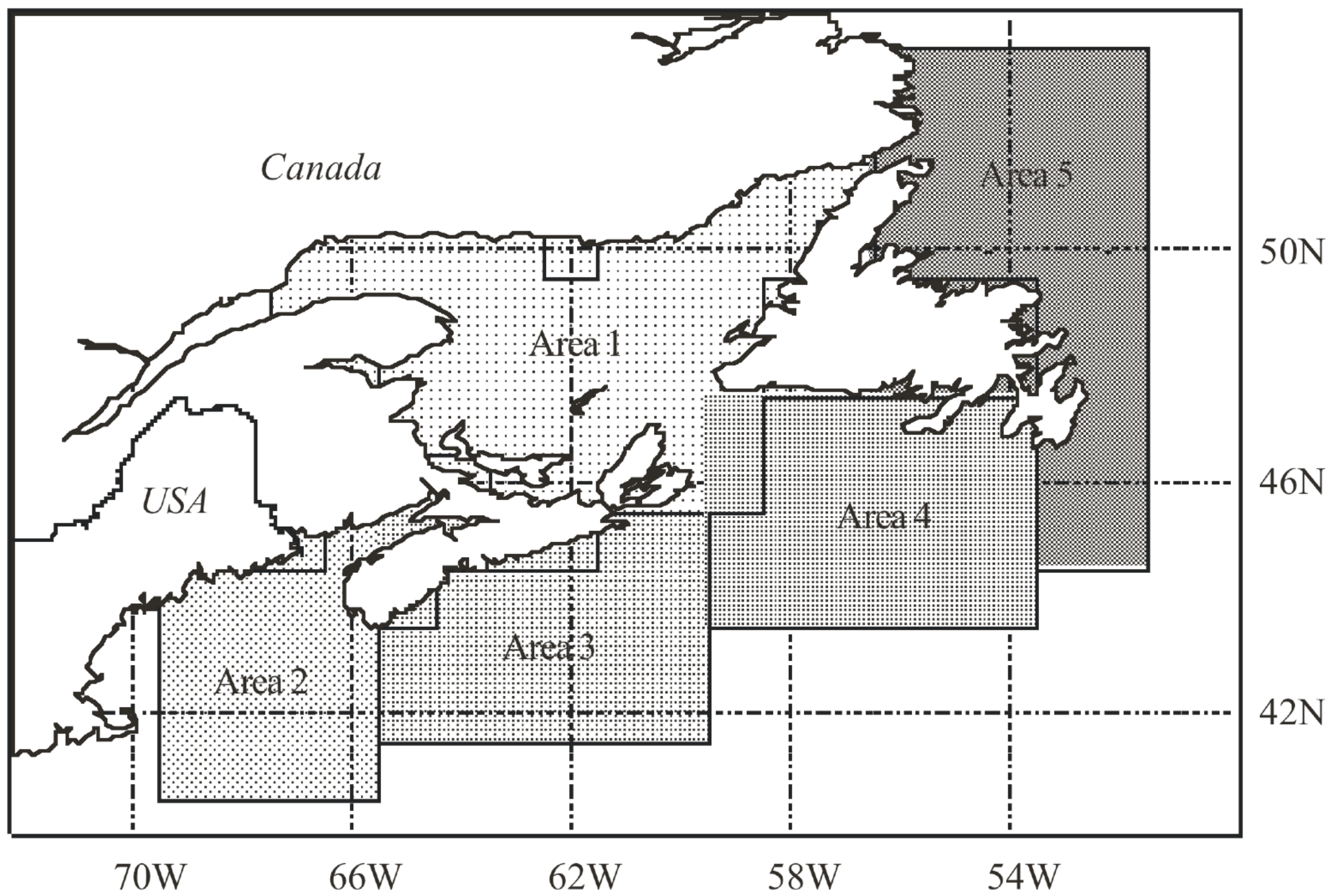
Dutil and Coutu, 1988
Friedland et al., 1999
Reddin and Short, 1991

North American Stock Complex Catch Index and Abundance



Friedland et al., 2003

Study Strata



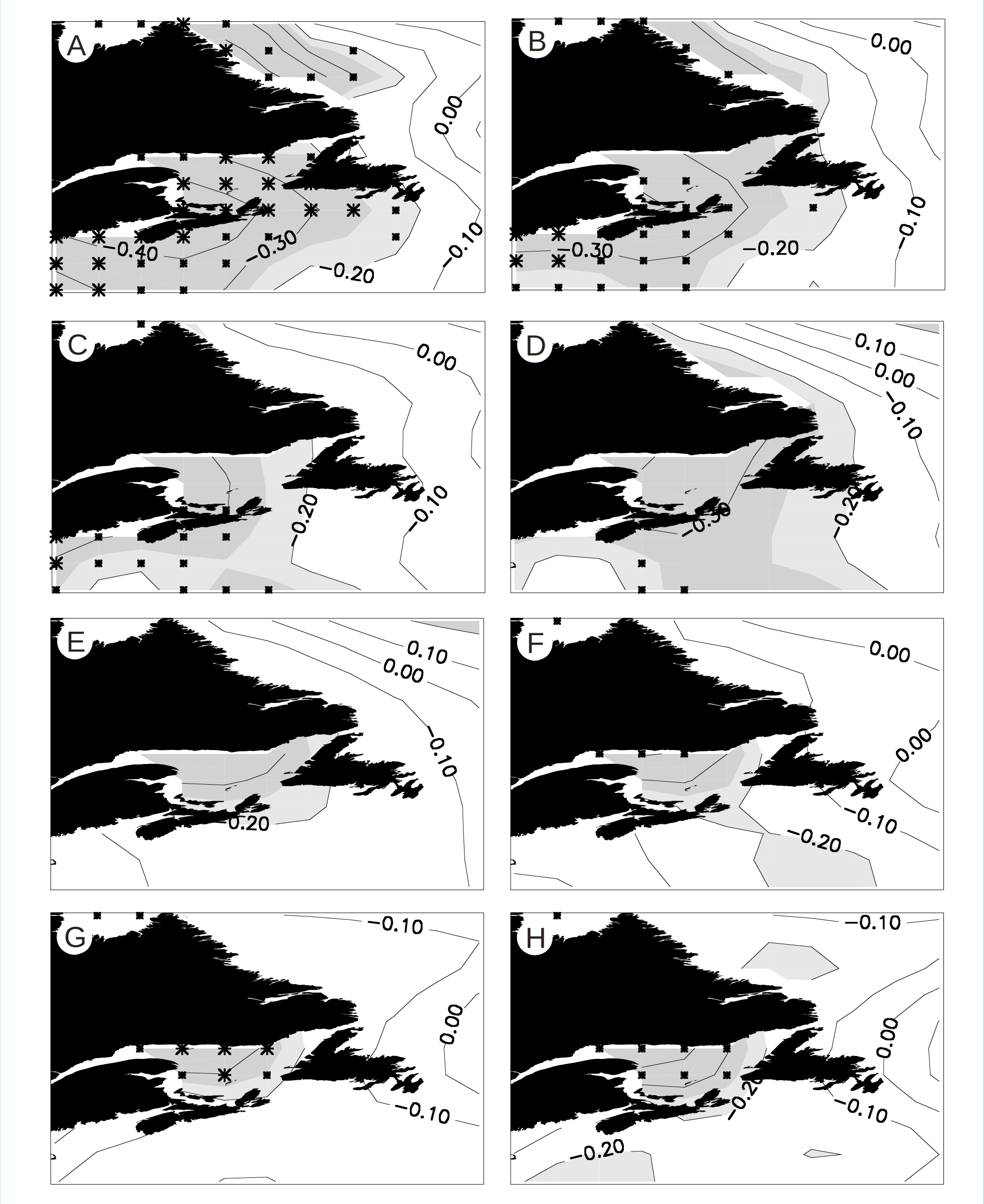
Friedland et al., 2003a

Relationship Between SST and Catch Index

	Area 1			Area 2		Area 3		Area 4		Area 5	
	Lag 1		Lag 2	Lag 1	Lag 2	Lag 1	Lag 2	Lag 1	Lag 2	Lag 1	Lag 2
Month	r		r	r	r	r	r	r	r	r	r
May	-0.40	*	-0.34	-0.14	-0.12	-0.10	-0.09	-0.24	-0.20	-0.04	0.00
Jun	-0.28		-0.17	-0.05	-0.07	0.10	0.10	-0.11	-0.06	0.05	0.11
Jul	-0.24		-0.19	-0.01	-0.03	0.06	0.05	-0.06	-0.05	0.07	0.12
Aug	-0.27		-0.23	0.01	0.01	-0.15	-0.18	-0.04	-0.07	-0.06	0.03
Sep	-0.36		-0.31	-0.03	0.04	-0.10	-0.12	-0.08	-0.11	0.03	0.07
Oct	-0.25		-0.12	-0.15	-0.12	-0.21	-0.18	-0.06	0.03	0.02	0.13
Nov	-0.38		-0.26	-0.42	-0.34	-0.27	-0.14	-0.24	-0.11	-0.02	0.09
Dec	0.00		-0.01	-0.41	-0.34	-0.22	-0.18	-0.18	-0.13	0.09	0.11

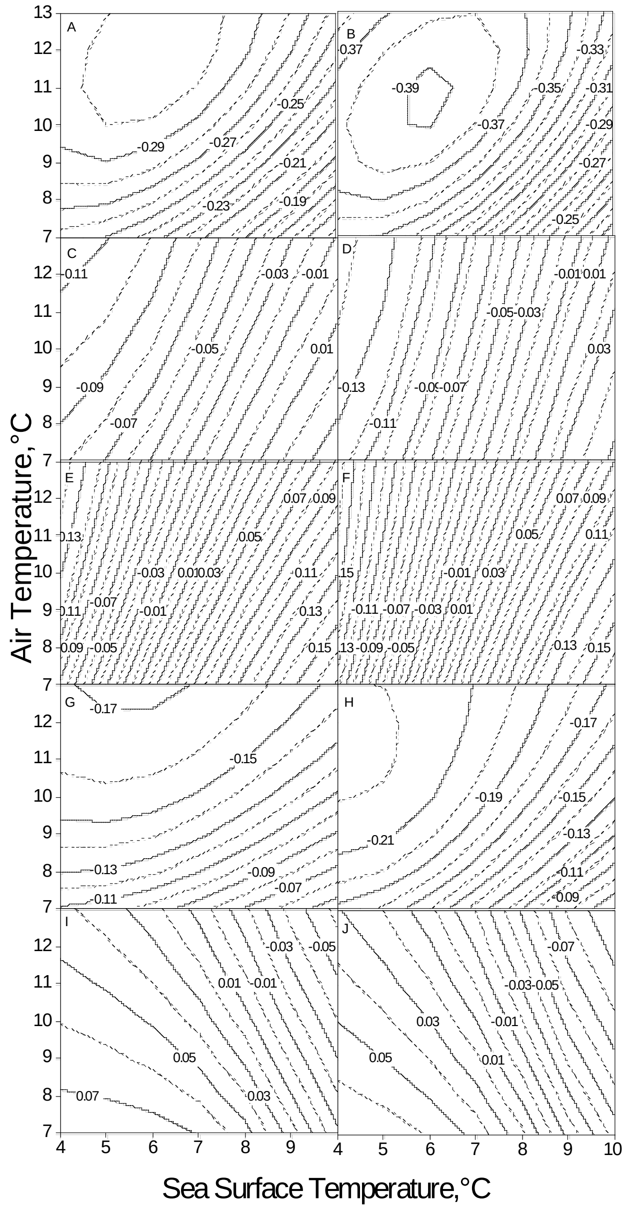
Friedland et al., 2003a

Relationship Between ERSST and Catch Index



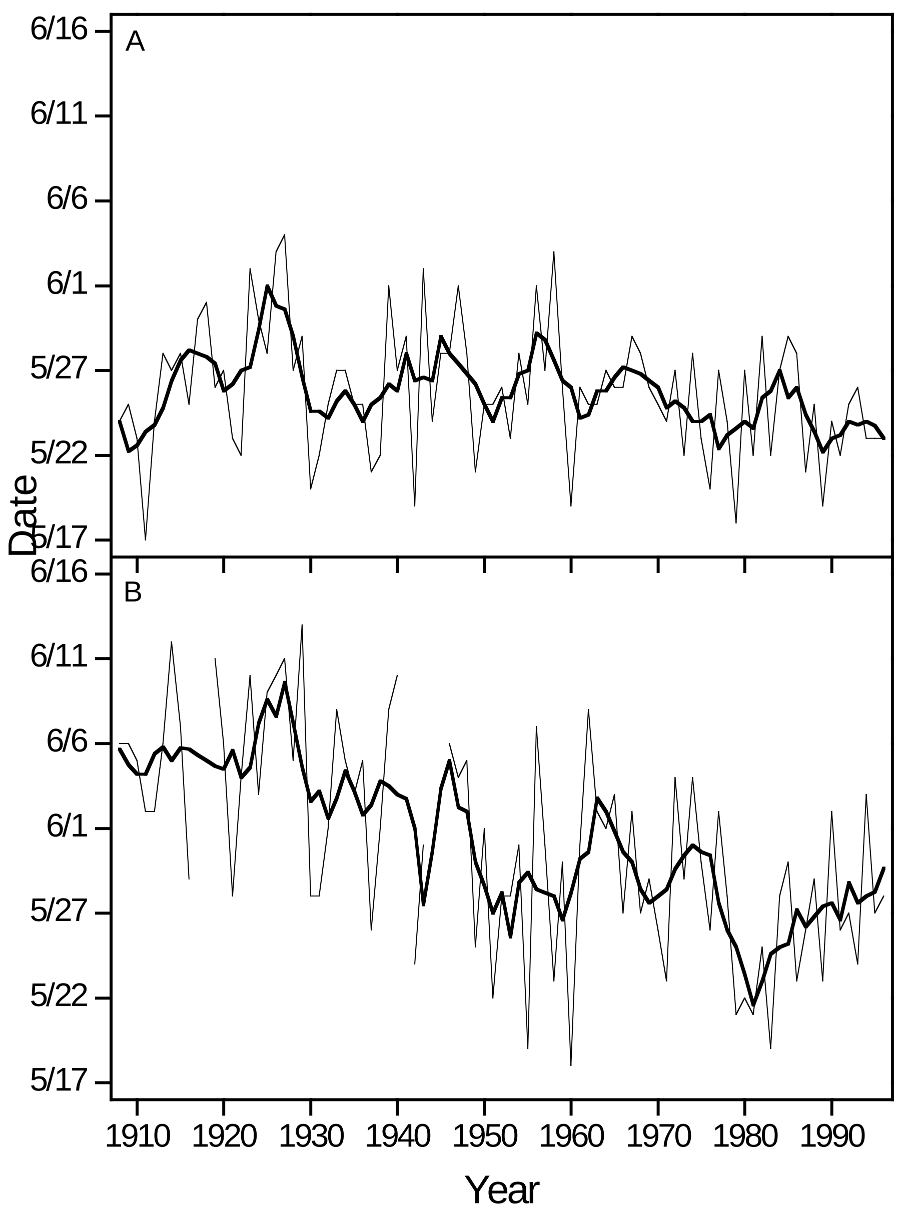
Relationship Between Difference Between Dates of Arrival of Air and Sea Temperature and Catch Index

	Lag 1	Lag 2
Area 1	A	B
Area 2	C	D
Area 3	E	F
Area 4	G	H
Area 5	I	J



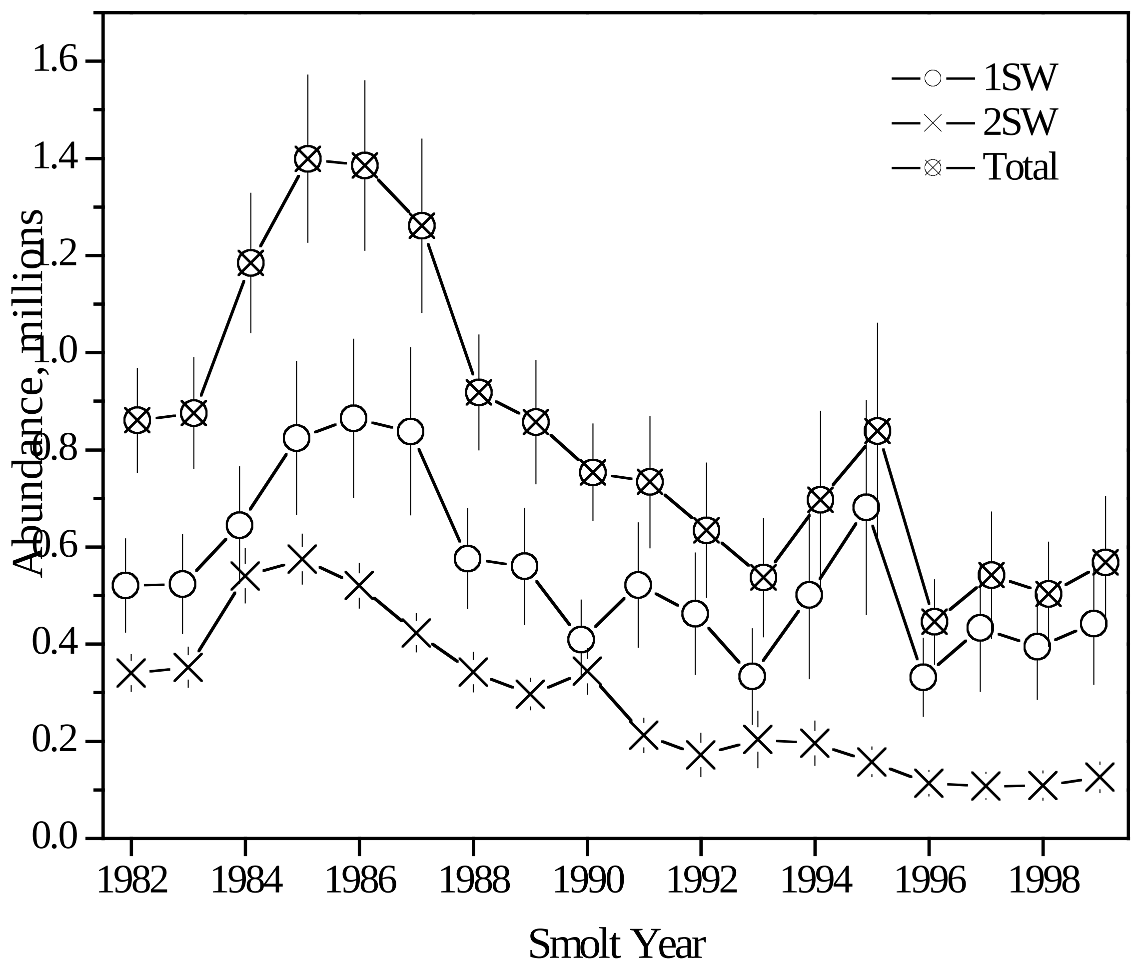
Friedland et al., 2003a

Date of Arrival of Air and Sea Surface Temperature



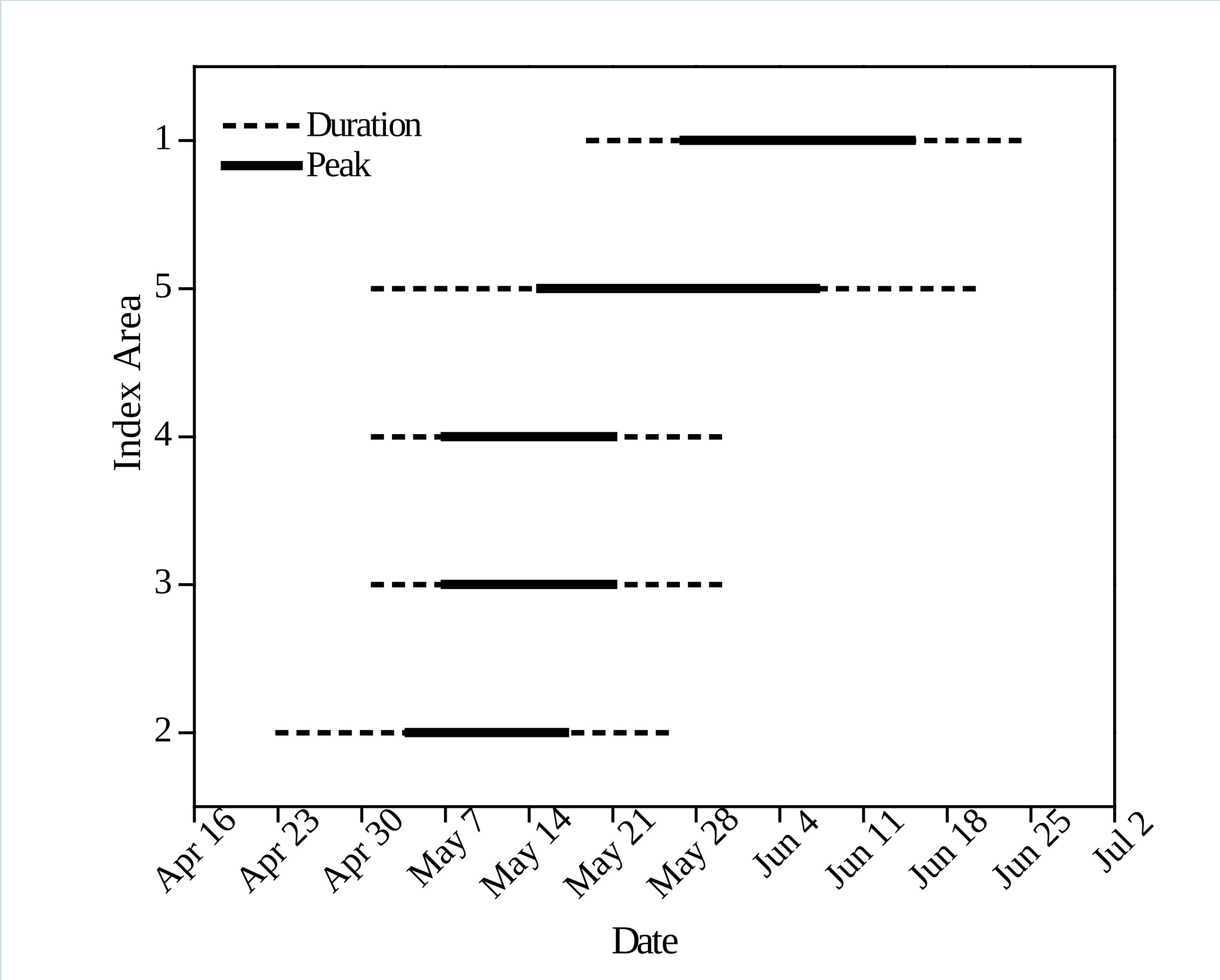
Friedland et al., 2003a

North American Stock Complex Pre-fishery Abundance



Friedland et al., 2003b

Smolt Migration Timing by Study Strata

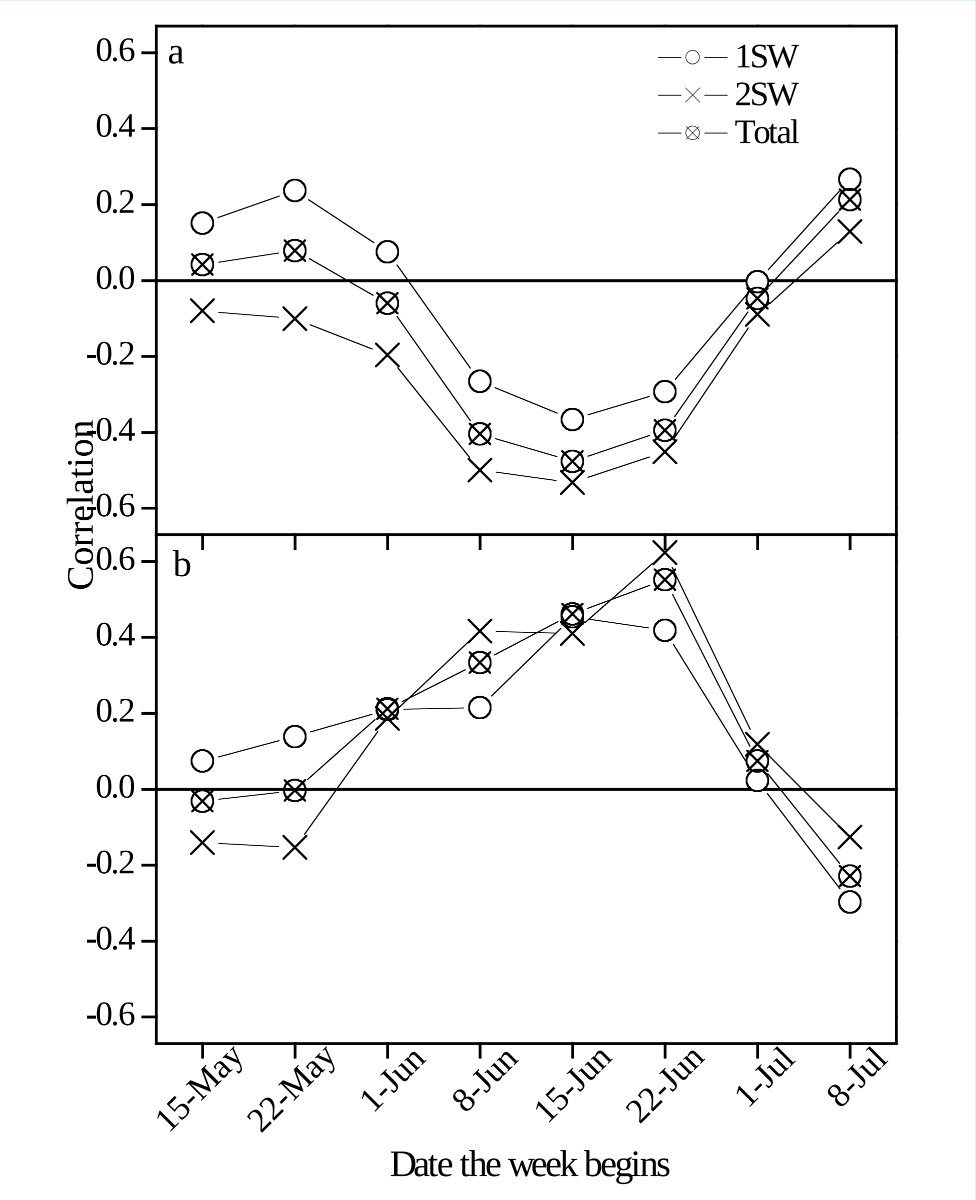


Friedland et al., 2003b

Relationship Between SST and Thermal Habitat and Abundance

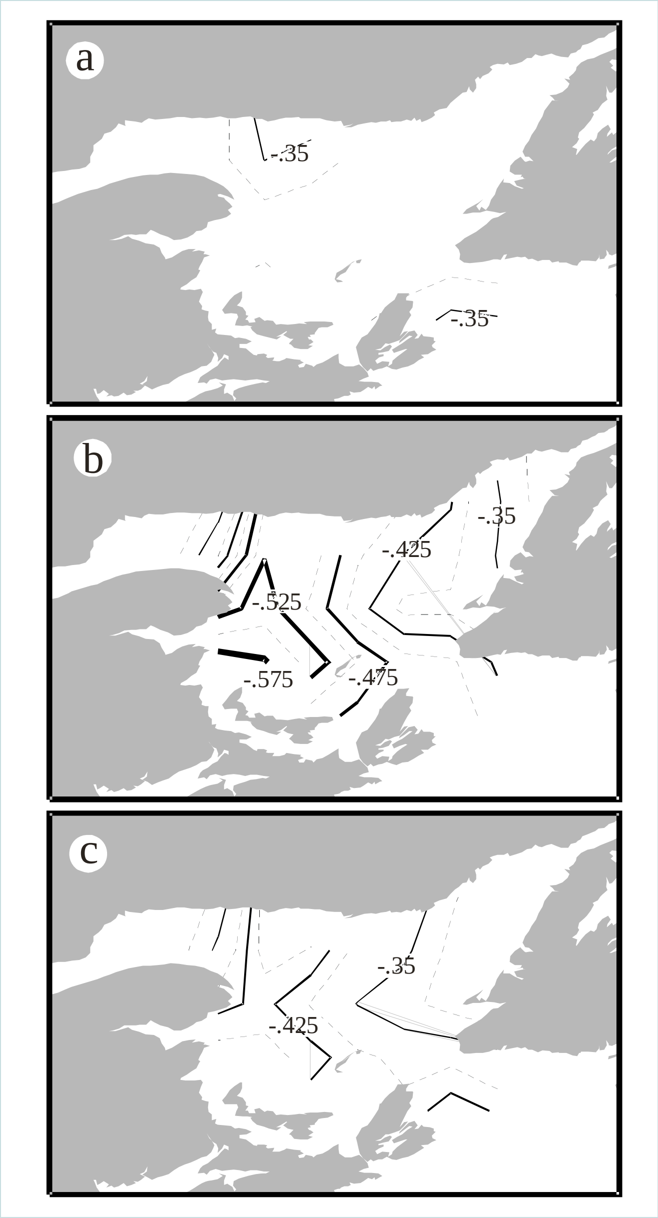
a SST

b 7.5°C thermal habitat



Friedland et al., 2003b

Relationship Between SST and Abundance During June



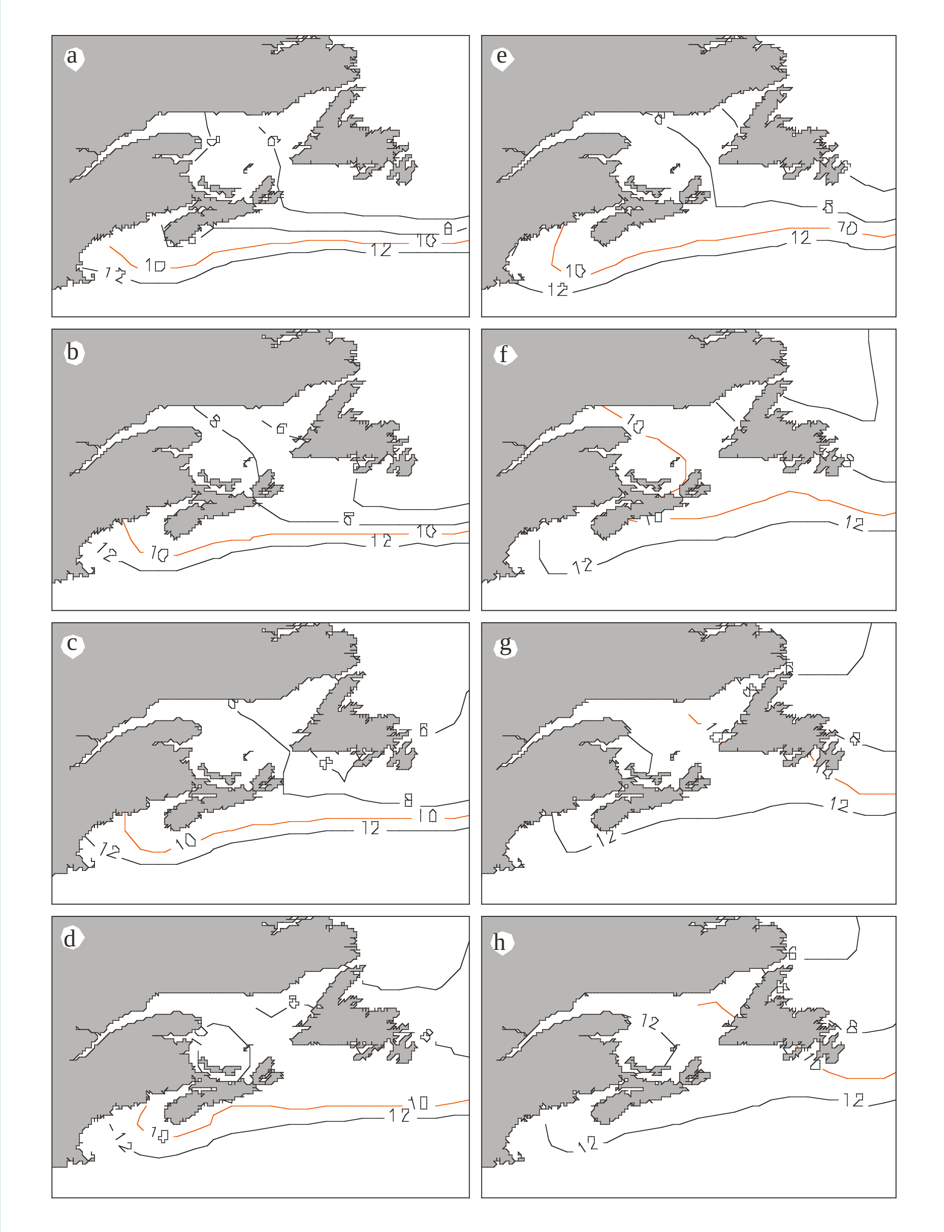
a 1SW
b 2SW
c combined

Friedland et al., 2003b

June SST Distribution During Contrasting Survival Years

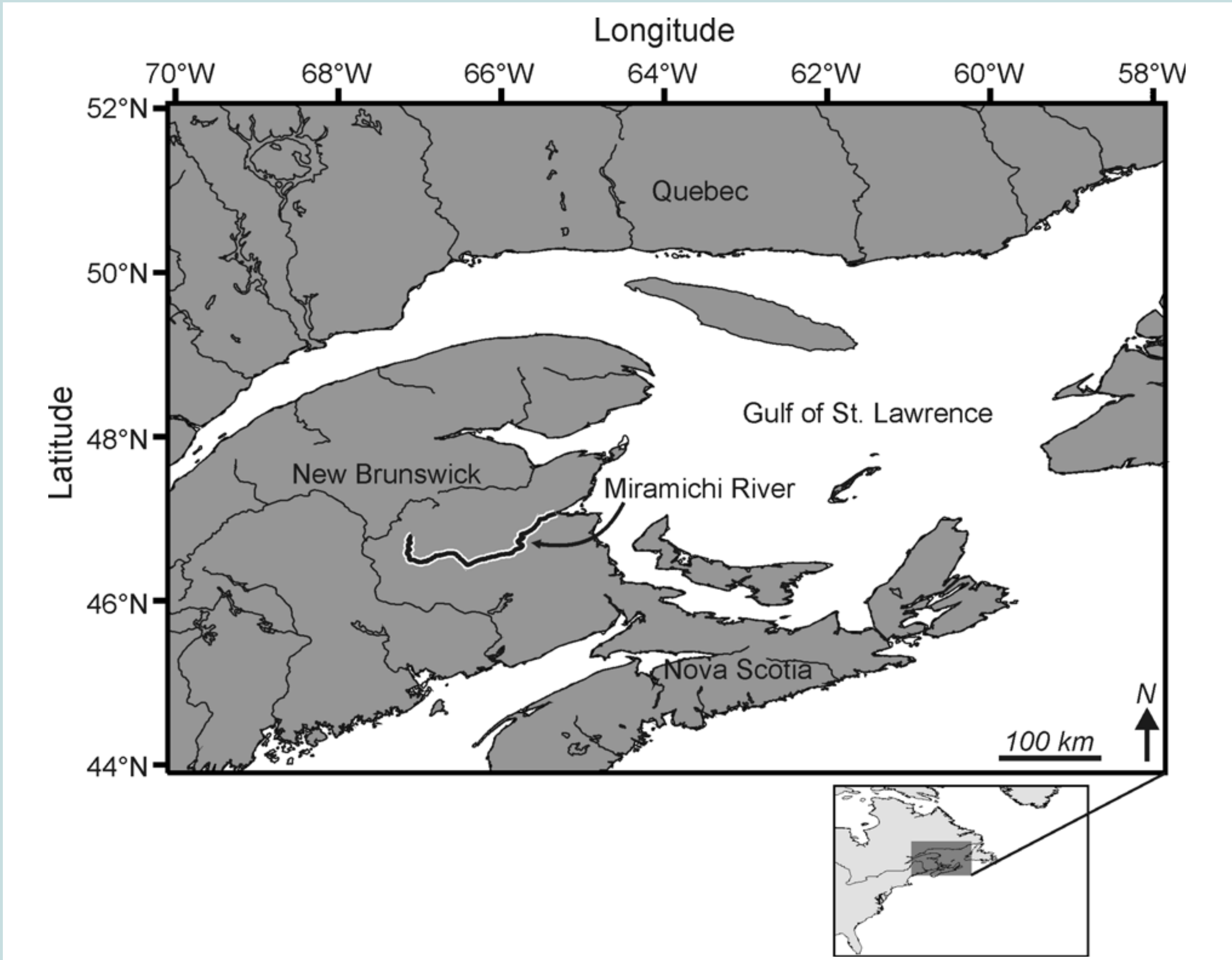
June 1986
a) First week→
d) Last week

June 1998
e) First week→
h) Last week



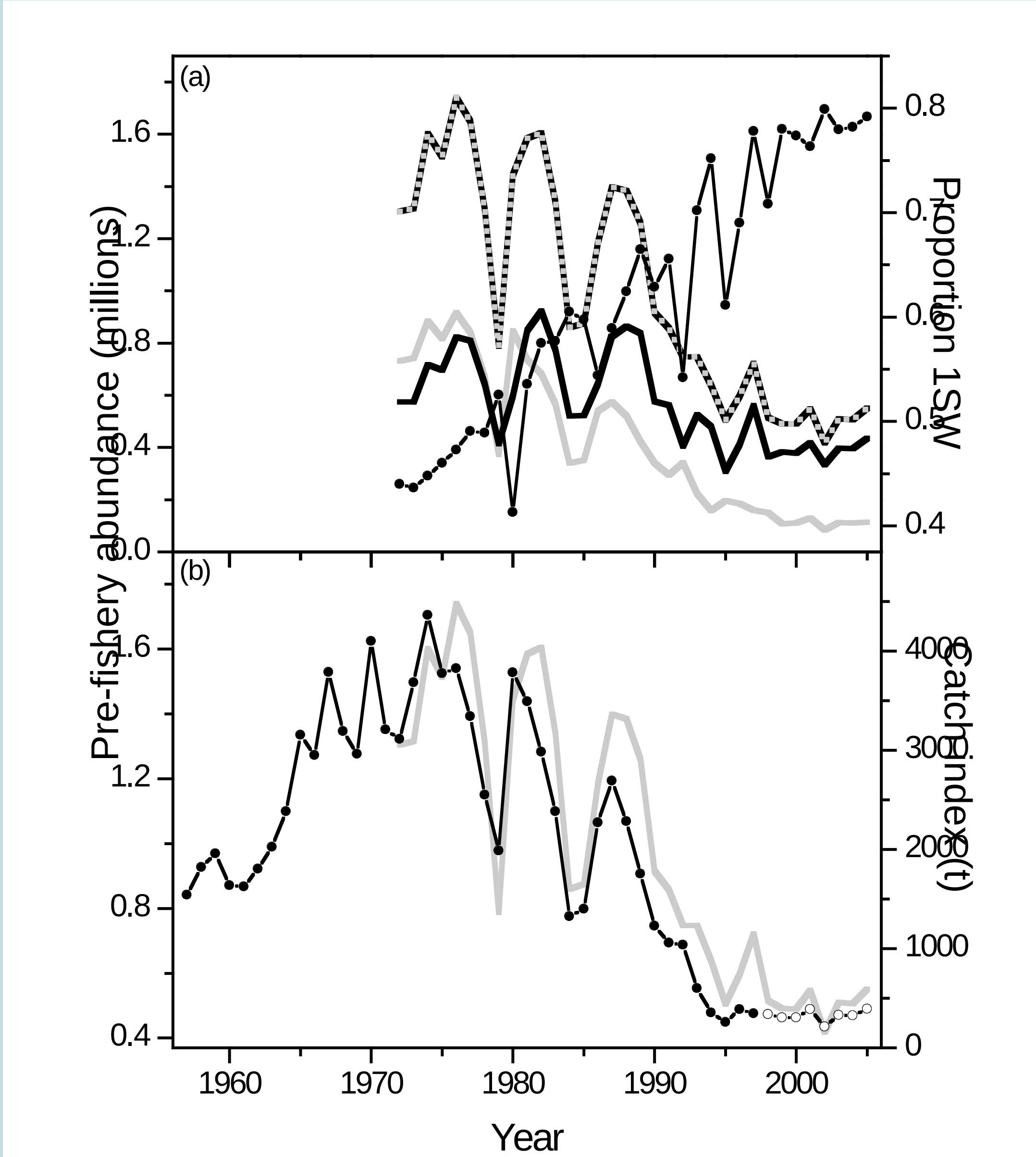
Friedland et al., 2003b

Miramichi River



Friedland et al., in press

North American Stock Complex Abundance and Catch Index



Friedland et al., in press

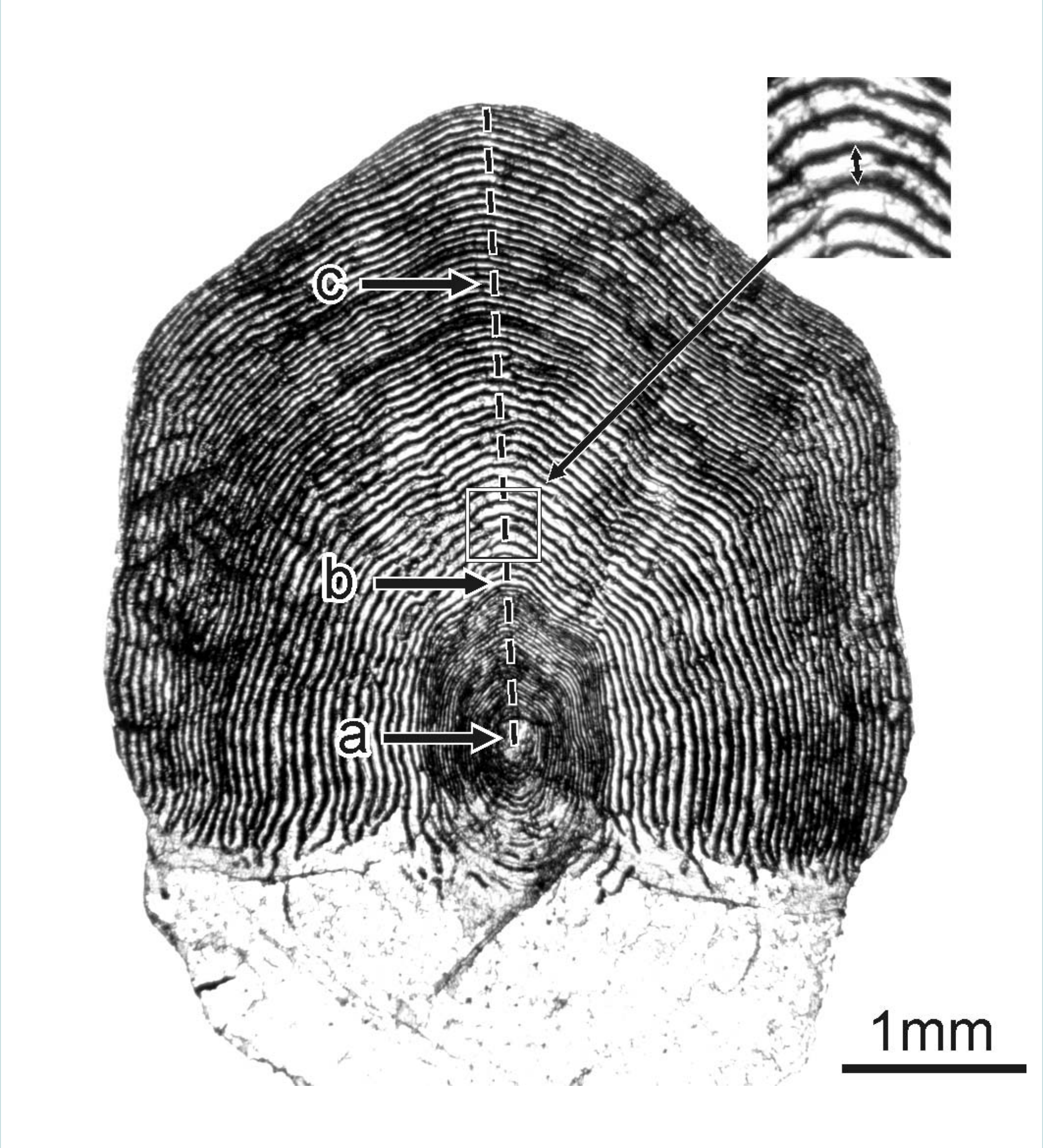
Salmon Scale

a → b
Freshwater
growth increment

b → c
Post-smolt
growth increment

Post-smolt
growth increment
circuli pairs

Proportionally
Allocated
Monthly Growth
Indices



Friedland et al., in press

Miramichi Retrospective Growth

a
Freshwater
growth increment

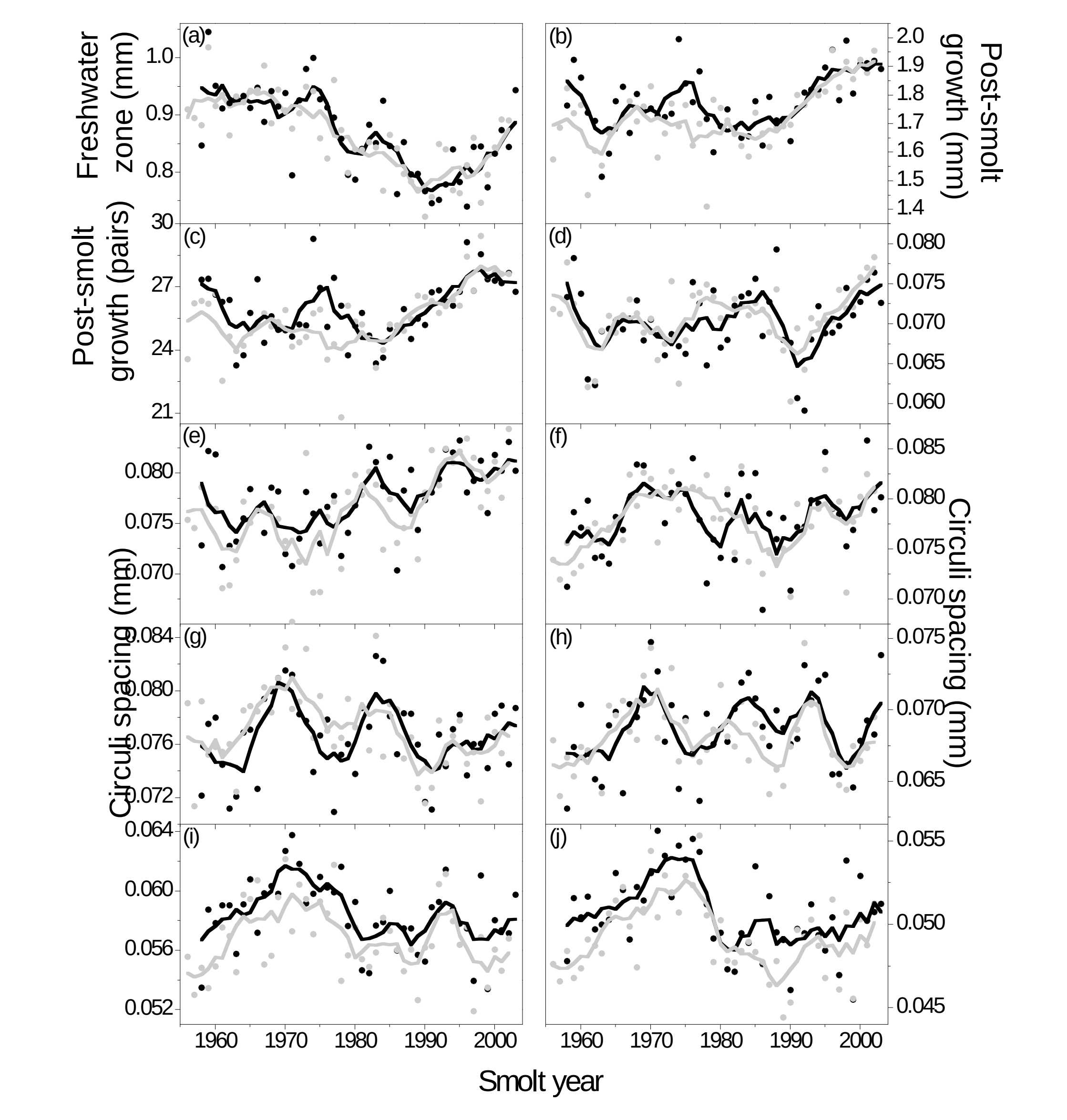
b
Post-smolt
growth increment

c

Post-smolt
growth increment
circuli pairs

d → j
Proportionally
Allocated
Monthly Growth
Indices 1 → 7

1SW is in BLACK
2SW is in GRAY



Friedland et al., in press

Relationship Between Miramichi Growth and Stock Indicators

Growth Index	Catch Index Lag 1 1SW	Catch Index Lag 1 2SW	Catch Index Lag 2 1SW	Catch Index Lag 2 2SW	PFA 2SW 1SW	PFA 2SW 2SW	PFA 1SW 1SW	PFA 1SW 2SW	PFA Total 1SW	PFA Total 2SW	Proportion 1SW 1SW	Proportion 1SW 2SW
Freshwater	0.46	0.48 *	0.51 *	0.50 *	0.49 *	0.44	0.23	0.16	0.41	0.35	-0.42	-0.41
Post-smolt, GI	-0.38	-0.36	-0.40	-0.51	-0.39	-0.59	-0.42	-0.45	-0.42	-0.57	0.46 **	0.67 **
Post-smolt, CP	-0.39	-0.47	-0.41	-0.58 *	-0.38	-0.63 *	-0.40	-0.43	-0.41	-0.59	0.46 **	0.71 **
Month 1	-0.13	-0.13	-0.15	-0.18	-0.20	-0.23	-0.11	-0.18	-0.17	-0.22	0.18	0.27
Month 2	-0.51 *	-0.44	-0.58 **	-0.59 **	-0.68 **	-0.66 **	-0.48 *	-0.46 *	-0.63 *	-0.62 **	0.63 **	0.62 **
Month 3	-0.01	0.19	-0.02	0.18	-0.05	0.19	-0.09	0.01	-0.07	0.12	0.10	-0.12
Month 4	0.12	0.50 **	0.16	0.44 *	0.17	0.48 *	0.15	0.38 *	0.17	0.47 *	-0.12	-0.39 *
Month 5	-0.06	0.29	-0.01	0.21	0.04	0.22	0.01	0.11	0.03	0.19	-0.07	-0.22
Month 6	0.31	0.36	0.43 *	0.28	0.46	0.29	0.12	0.02	0.34	0.20	-0.48 **	-0.41 *
Month 7	0.38	0.42	0.43 *	0.38 *	0.43	0.39	0.14	0.01	0.34	0.26	-0.40 *	-0.44

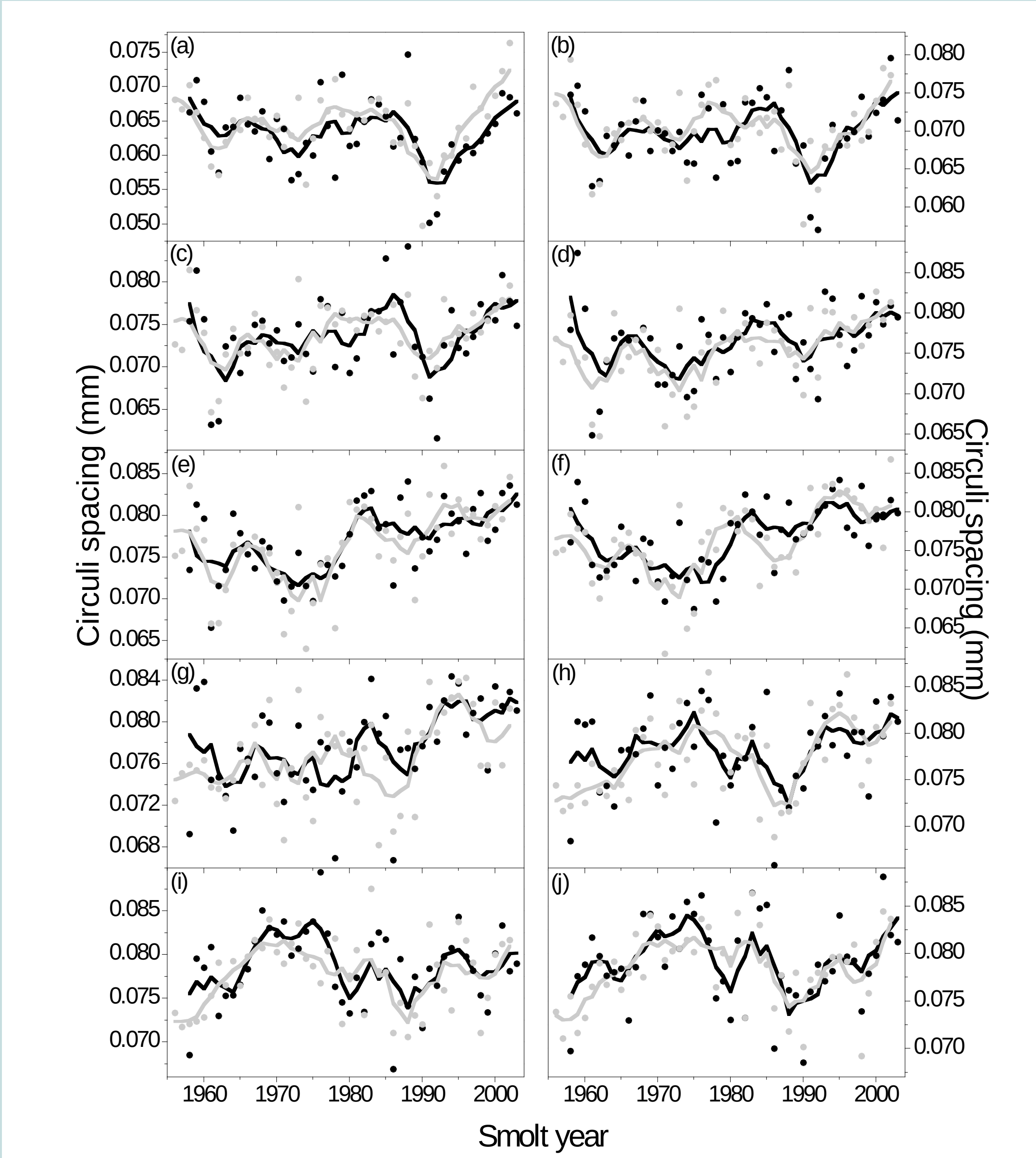
Friedland et al., in press

Miramichi Retrospective Growth by Circuli Pair

a → j

Circuli pair 1 →
Circuli pair 10

1SW is in BLACK
2SW is in GRAY



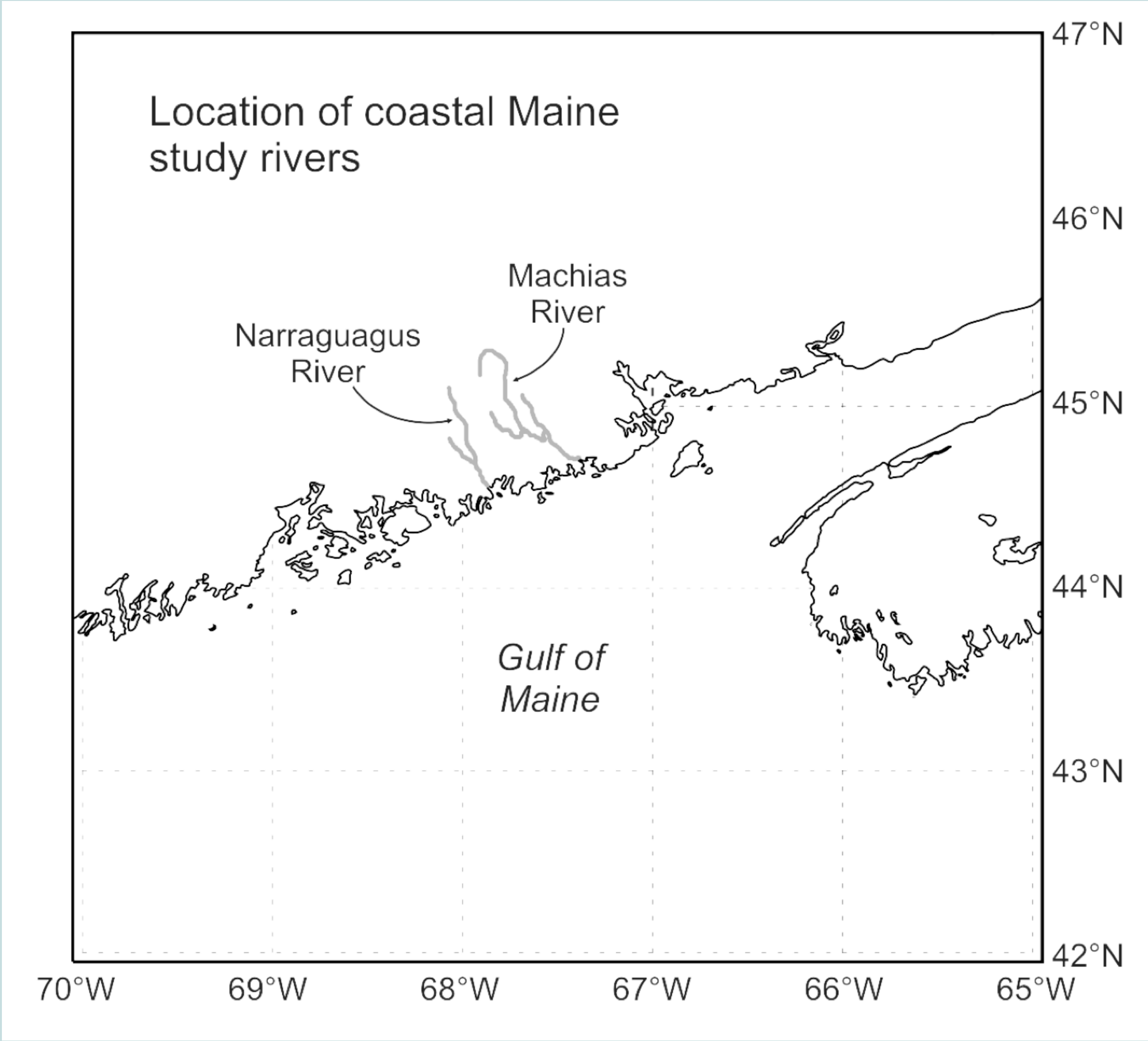
Friedland et al., in press

Relationship Between Miramichi Growth by Circuli Pair and Stock Indicators

Growth Index	Catch Index Lag 1		Catch Index Lag 2		PFA 2SW		PFA 1SW		PFA Total		Proportion 1SW	
	1SW	2SW	1SW	2SW	1SW	2SW	1SW	2SW	1SW	2SW	1SW	2SW
Circuli pair 1	0.06	-0.04	0.05	-0.02	-0.01	-0.06	0.04	-0.09	0.01	-0.08	0.01	0.14
Circuli pair 2	-0.09	0.04	-0.09	0.00	-0.14	-0.03	-0.13	-0.07	-0.14	-0.05	0.10	0.05
Circuli pair 3	-0.10	-0.13	-0.15	-0.23	-0.14	-0.25	-0.08	-0.13	-0.13	-0.22	0.11	0.26
Circuli pair 4	-0.30	-0.29	-0.36	-0.41 *	-0.51	-0.54 *	-0.35	-0.28	-0.48	-0.46	0.43 **	0.57 **
Circuli pair 5	-0.49	-0.41	-0.56 *	-0.58 **	-0.67 *	-0.66 **	-0.39	-0.36	-0.59 *	-0.58 *	0.63 **	0.64 **
Circuli pair 6	-0.58 **	-0.50 *	-0.65 **	-0.60 **	-0.72 **	-0.64 **	-0.41 *	-0.46 *	-0.63 **	-0.60 **	0.69 **	0.60 **
Circuli pair 7	-0.49 *	-0.30	-0.54 **	-0.40 *	-0.65 **	-0.45 *	-0.53 *	-0.50 *	-0.64 **	-0.50 *	0.60 **	0.39 *
Circuli pair 8	-0.11	-0.15	-0.15	-0.19	-0.21	-0.22	-0.29	-0.44 *	-0.26	-0.32	0.21	0.14
Circuli pair 9	0.12	0.14	0.15	0.18	0.17	0.10	-0.06	-0.08	0.08	0.03	-0.19	-0.08
Circuli pair 10	0.07	0.21	0.14	0.16	0.14	0.18	0.05	0.10	0.11	0.16	-0.06	-0.13

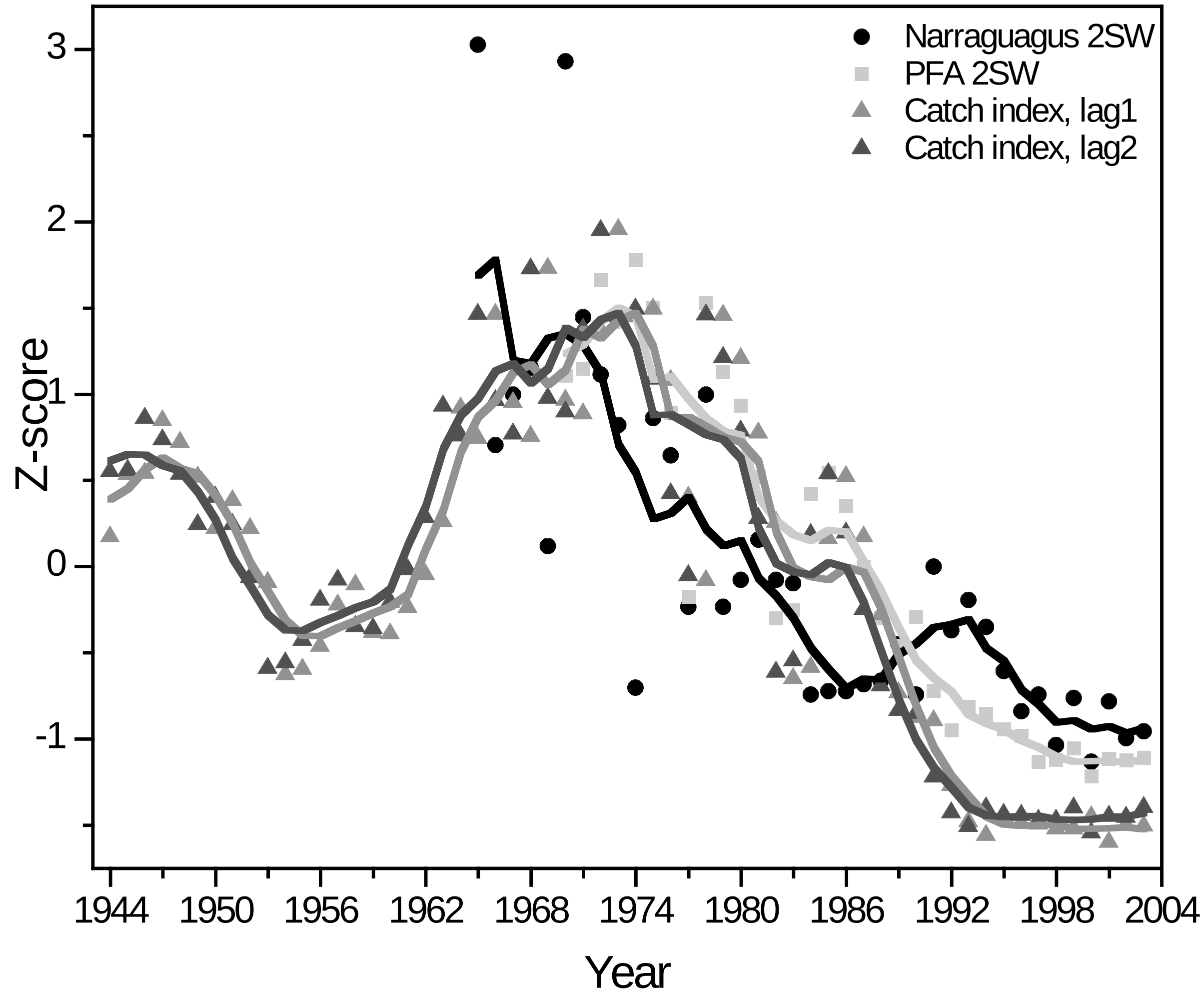
Friedland et al., in press

Maine Rivers with Wild Runs of Atlantic Salmon



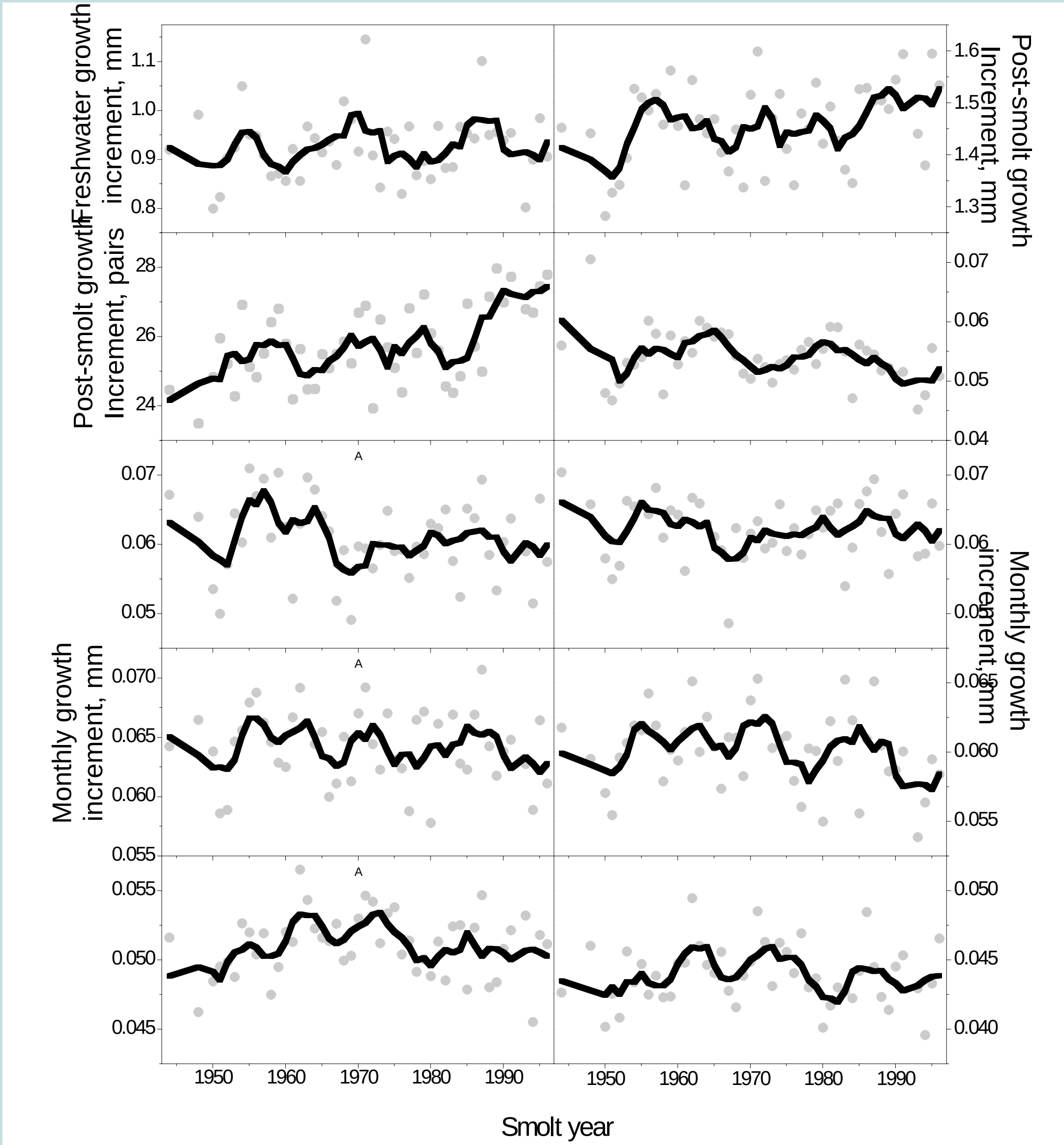
Hogan and Friedland, in prep.

Narraguagus Returns and North American Stock Complex Abundance and Catch Index



Hogan and Friedland, in prep.

Narraguagus and Machias Retrospective Growth



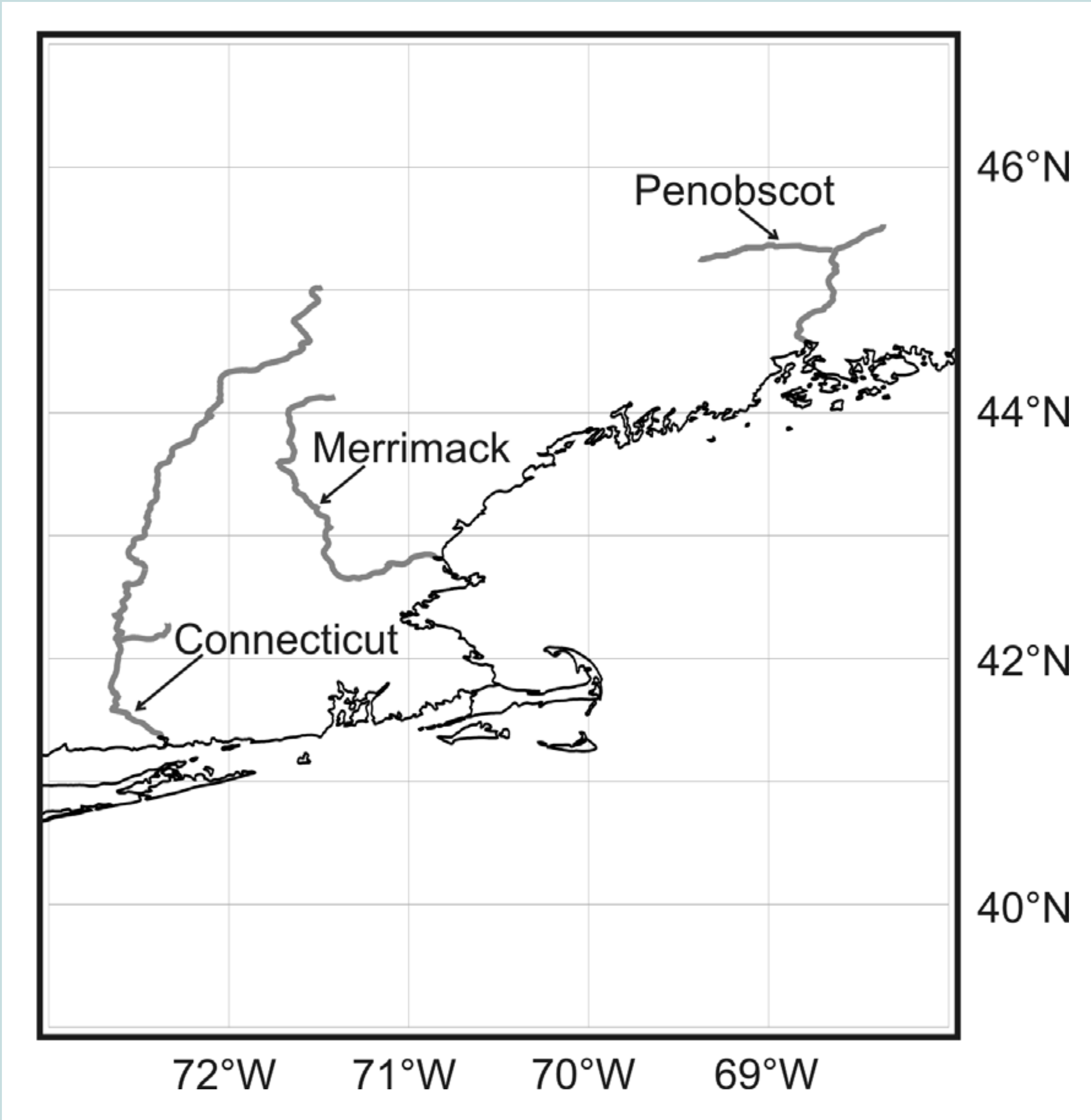
Hogan and Friedland, in prep.

Relationship Between Narraguagus and Machias Growth and Stock Indicators

Growth Index	Catch Index Lag 1	Catch Index Lag 2	PFA 2SW	Narraguagus Returns
Freshwater	0.04	0.09	-0.02	-0.06
Post-smolt, GI	-0.24	-0.20	-0.19	-0.15
Post-smolt, CP	-0.35	-0.37	-0.45	-0.25
Month 1	0.22	0.23	0.18	0.19
Month 2	-0.06	-0.03	0.07	-0.04
Month 3	-0.07	-0.05	0.07	-0.23
Month 4	-0.04	0.12	0.24	0.16
Month 5	0.10	0.22	0.33	0.30
Month 6	0.14	0.22	0.29	0.26
Month 7	0.19	0.19	0.24	0.10
Second year	0.23	0.24	0.32	0.21

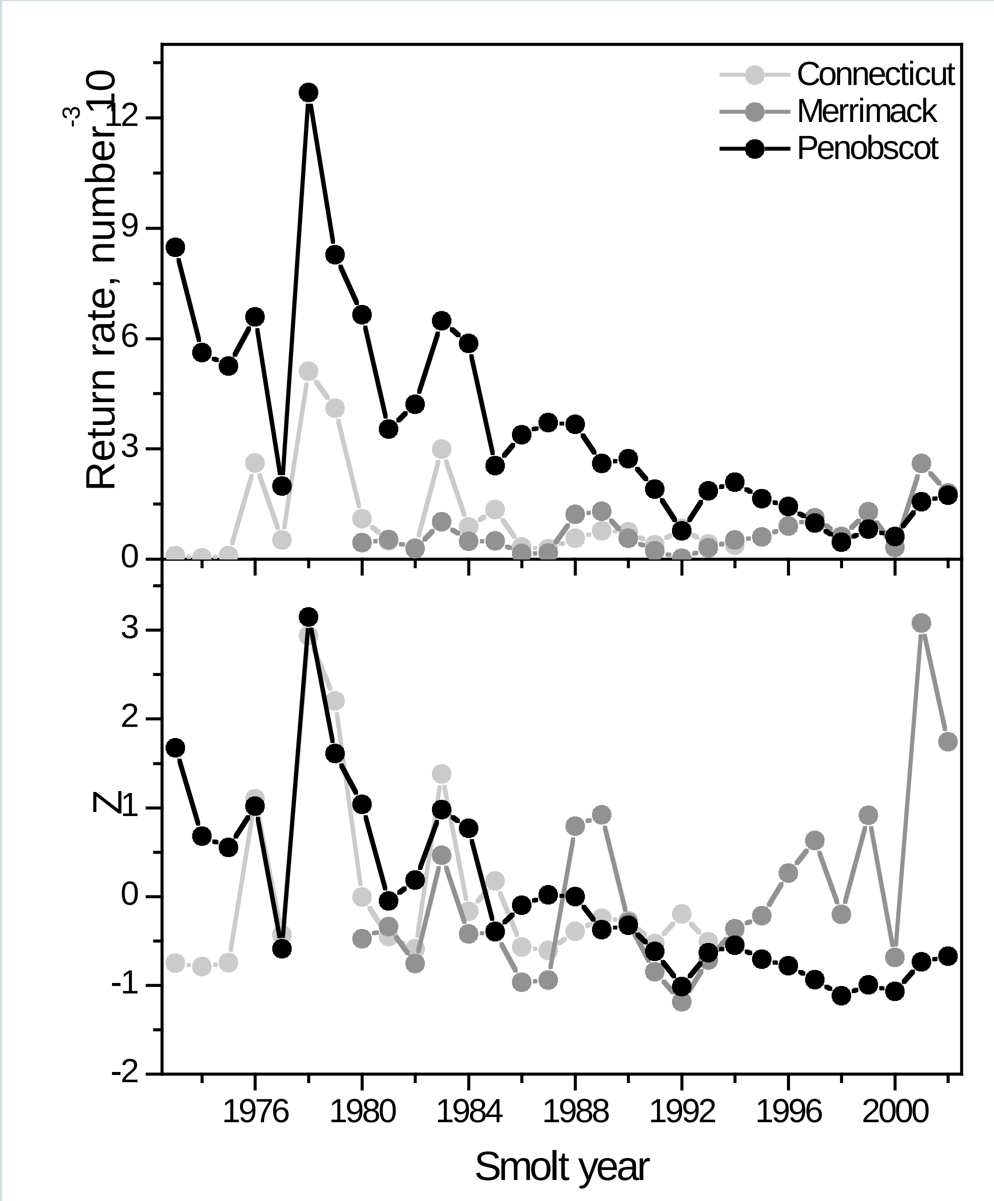
Hogan and Friedland, in prep.

US Hatchery Stocks



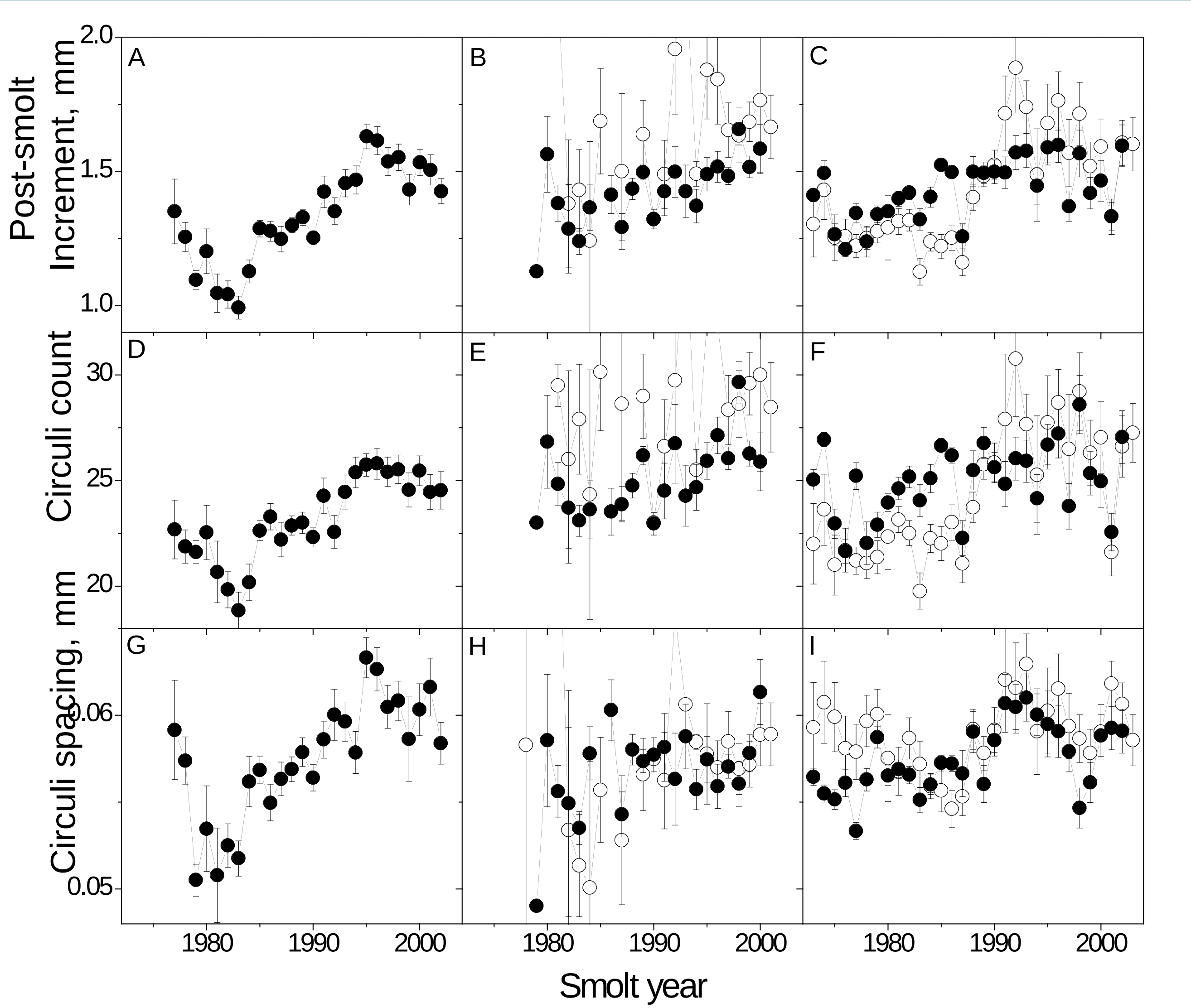
Friedland et al., in prep.

Return Rates of US Hatchery Stocks



Friedland et al., in prep.

US Hatchery Stocks Retrospective Growth



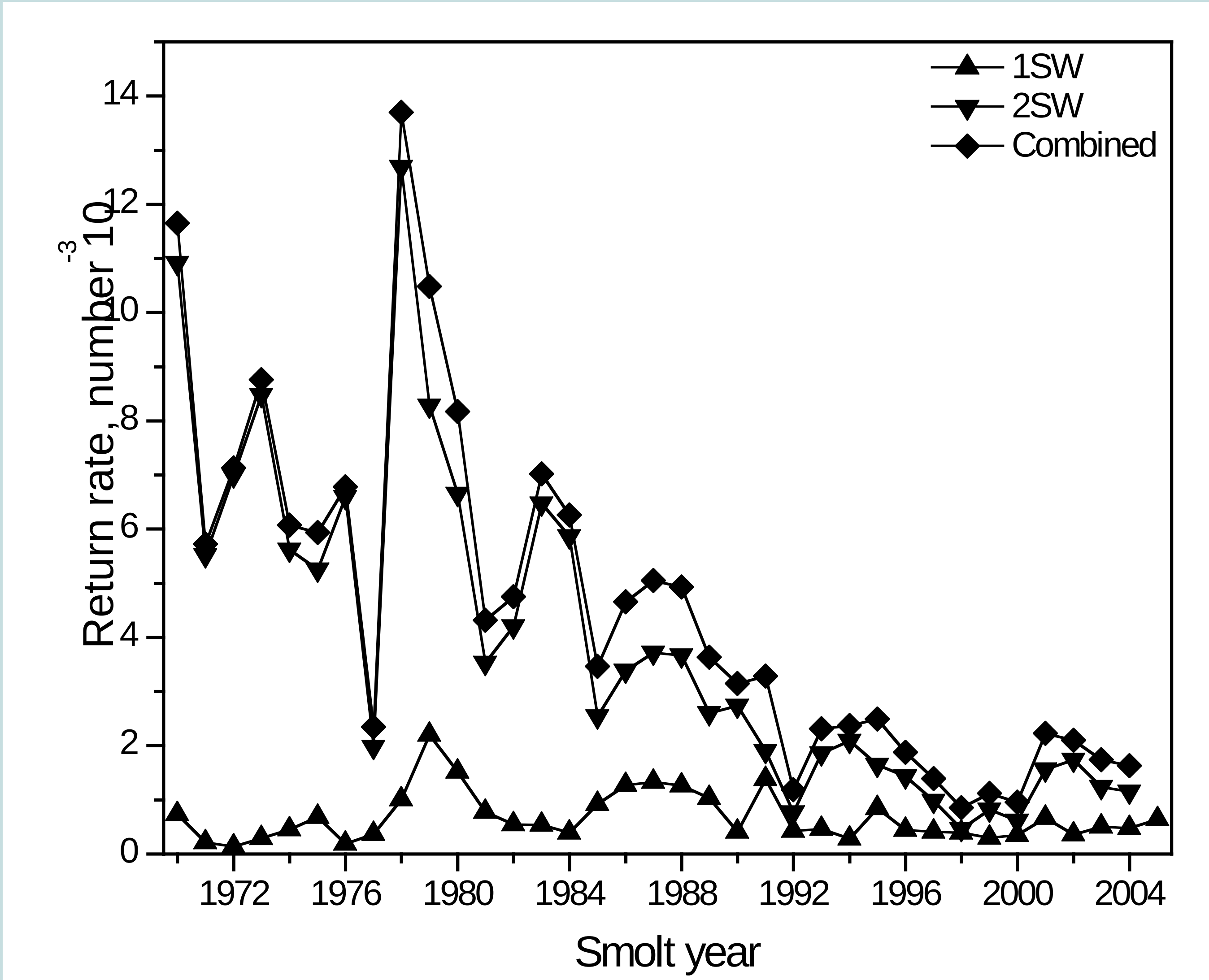
Friedland et al., in prep.

Relationship Between US Hatchery Stocks Growth and Stock Indicators

River	Seaage	Freshwater Increment	Post-smolt Increment	Post-smolt Pairs	Post-smolt Spacing	Summer Spacing	Winter Spacing
Connecticut	2SW	-0.362	-0.351	-0.343	-0.311	-0.243	-0.092
Merrimack	1SW	0.367	-0.156	-0.026	-0.228	-0.225	-0.184
	2SW	-0.051	0.145	0.212	-0.131	-0.113	-0.046
Penobscot	1SW	-0.082	-0.278	-0.284	-0.143	0.032	-0.246
	2SW	-0.294	**-0.610**	**-0.529**	-0.360	-0.256	-0.077

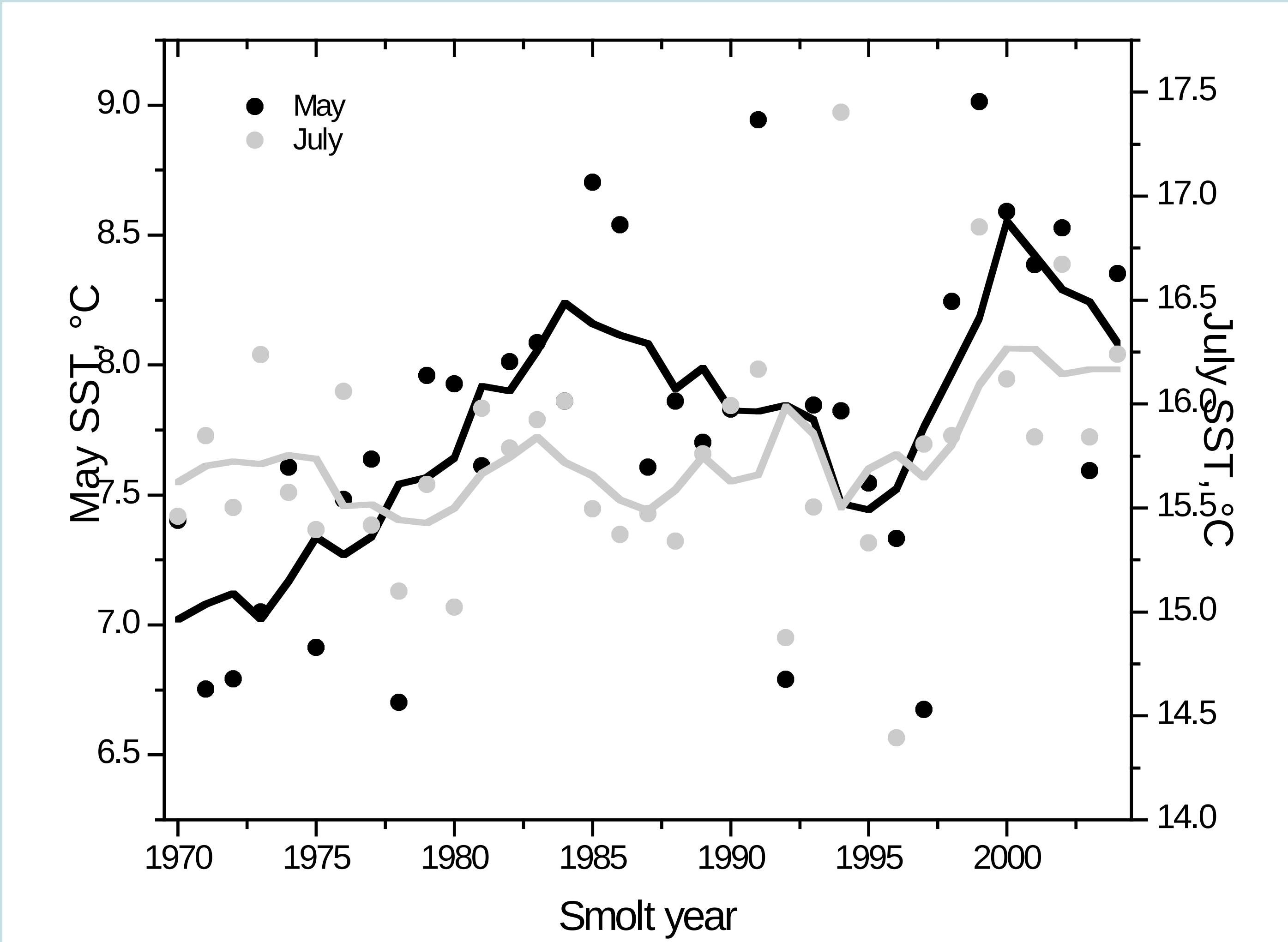
Friedland et al., in prep.

Penobscot Return Rate



Friedland et al., in prep.

Gulf of Maine Sea Surface Temperature



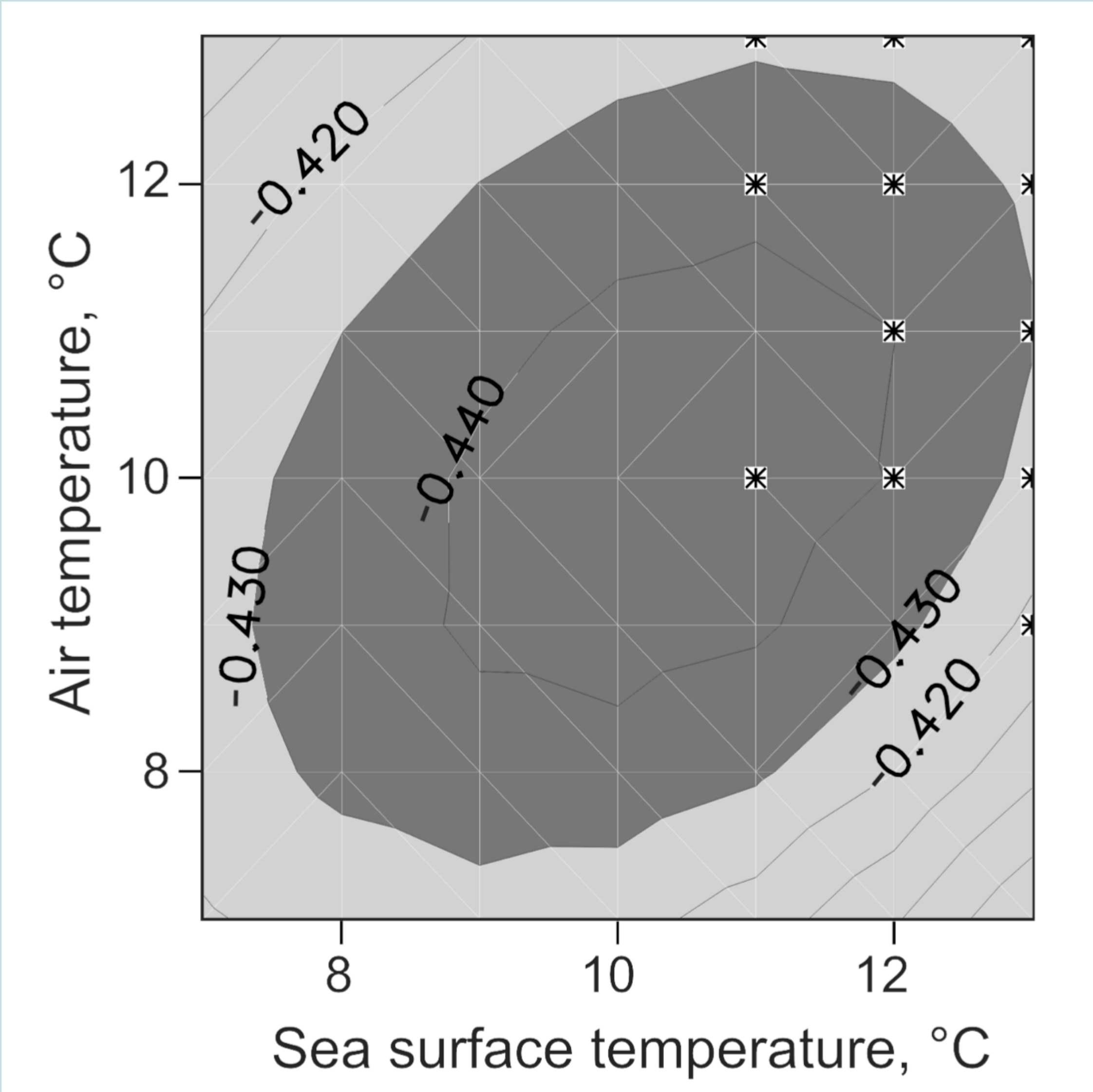
Friedland et al., in prep.

Relationship Between SST and Penobscot Return Rate

Month	Longitude	Latitude	1SW R		2SW R		Combined R	
May	-68	42	0.193		-0.416	*	-0.370	*
May	-68	44	0.207		-0.350		-0.305	
May	-70	42	0.246		-0.426	*	-0.372	*
May	-70	44	0.214		-0.453	*	-0.403	*
June	-68	42	-0.115		-0.231		-0.238	
June	-68	44	-0.107		-0.207		-0.213	
June	-70	42	-0.036		-0.153		-0.151	
June	-70	44	-0.032		-0.266		-0.259	
July	-68	42	-0.371	*	-0.175		-0.221	
July	-68	44	-0.368	*	-0.123		-0.171	
July	-70	42	-0.246		-0.247		-0.271	
July	-70	44	-0.244		-0.255		-0.279	

Friedland et al., in prep.

Relationship Between Difference Between Dates of Arrival of Air and Sea Temperature and Return Rate



Friedland et al., in prep.

Relationship Between Vector Wind and Return Rate

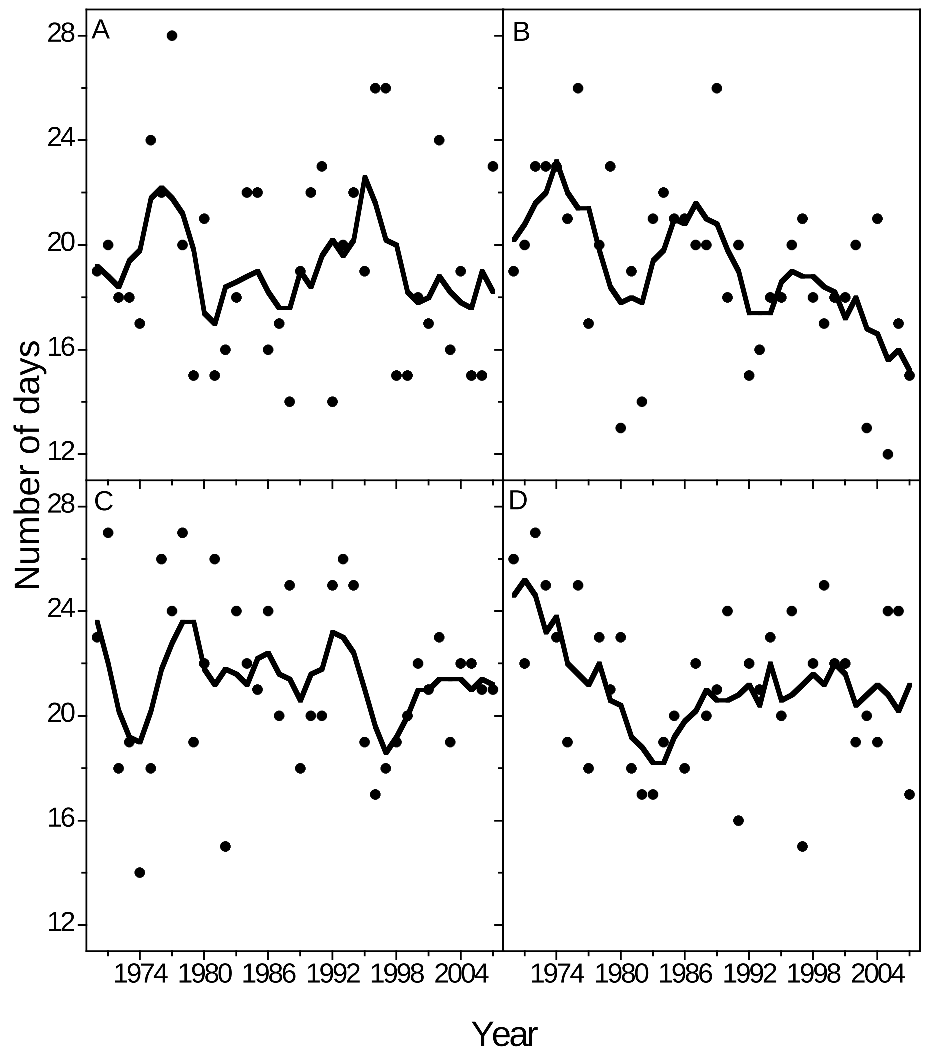
			1SW		2SW		Combined	
Month	Longitude	Latitude	u	v	u	v	u	v
May	-71	41	-0.112	-0.037	-0.037	0.417 *	-0.052	0.393 *
	-69	41	-0.128	-0.048	-0.037	0.422 *	-0.054	0.396 *
	-67	41	-0.141	-0.073	-0.026	0.390 *	-0.045	0.361 *
	-66	41	-0.142	-0.115	-0.004	0.336 *	-0.024	0.304
	-71	43	-0.170	-0.084	-0.100	0.438 *	-0.120	0.406 *
	-69	43	-0.168	-0.078	-0.062	0.442 *	-0.084	0.411 *
	-67	43	-0.157	-0.086	-0.012	0.400 *	-0.034	0.369 *
	-66	43	-0.149	-0.113	0.036	0.333	0.012	0.301
	-71	45	-0.151	-0.102	-0.135	0.367	-0.151	0.337
	-69	45	-0.119	-0.107	-0.112	0.398	-0.124	0.365
	-67	45	-0.092	-0.105	-0.064	0.389	-0.074	0.356
	-66	45	-0.074	-0.118	-0.009	0.330	-0.020	0.298
June	-71	41	0.244	-0.307	0.060	0.336	0.092	0.277
	-69	41	0.226	-0.330	0.032	0.304	0.063	0.243
	-67	41	0.201	-0.337 *	-0.002	0.264	0.027	0.204
	-66	41	0.155	-0.302	-0.018	0.240	0.005	0.187
	-71	43	0.308	-0.240	0.089	0.403	0.129	0.351
	-69	43	0.309	-0.226	0.133	0.420	0.171	0.369
	-67	43	0.252	-0.217	0.134	0.399 *	0.164	0.350
	-66	43	0.173	-0.196	0.139	0.382 *	0.158	0.337
	-71	45	0.355	-0.199	0.180	0.381	0.223	0.335
	-69	45	0.326	-0.178	0.213	0.437 *	0.250	0.392
	-67	45	0.273	-0.163	0.242	0.476 **	0.271	0.431 *
	-66	45	0.208	-0.136	0.251	0.507 **	0.270	0.465 **
July	-71	41	-0.198	0.039	0.089	0.118	0.057	0.118
	-69	41	-0.190	0.020	0.041	0.138	0.012	0.135
	-67	41	-0.154	-0.008	0.000	0.136	-0.022	0.129
	-66	41	-0.094	-0.031	0.018	0.131	0.004	0.121
	-71	43	-0.213	0.008	0.055	0.190	0.022	0.183
	-69	43	-0.140	0.002	0.062	0.189	0.040	0.182
	-67	43	-0.055	-0.009	0.077	0.187	0.066	0.178
	-66	43	0.034	-0.021	0.121	0.178	0.121	0.167
	-71	45	-0.154	-0.096	0.037	0.155	0.013	0.135
	-69	45	-0.076	-0.079	0.094	0.150	0.079	0.132
	-67	45	0.004	-0.064	0.160	0.160	0.153	0.144
	-66	45	0.065	-0.065	0.179	0.185	0.180	0.168

Friedland et al., in prep.

Count of Days with Positive Vector Wind at Gulf of Maine Location, 69°W, 43°N

May
A zonal wind
B meridional wind

June
C zonal wind
D meridional wind



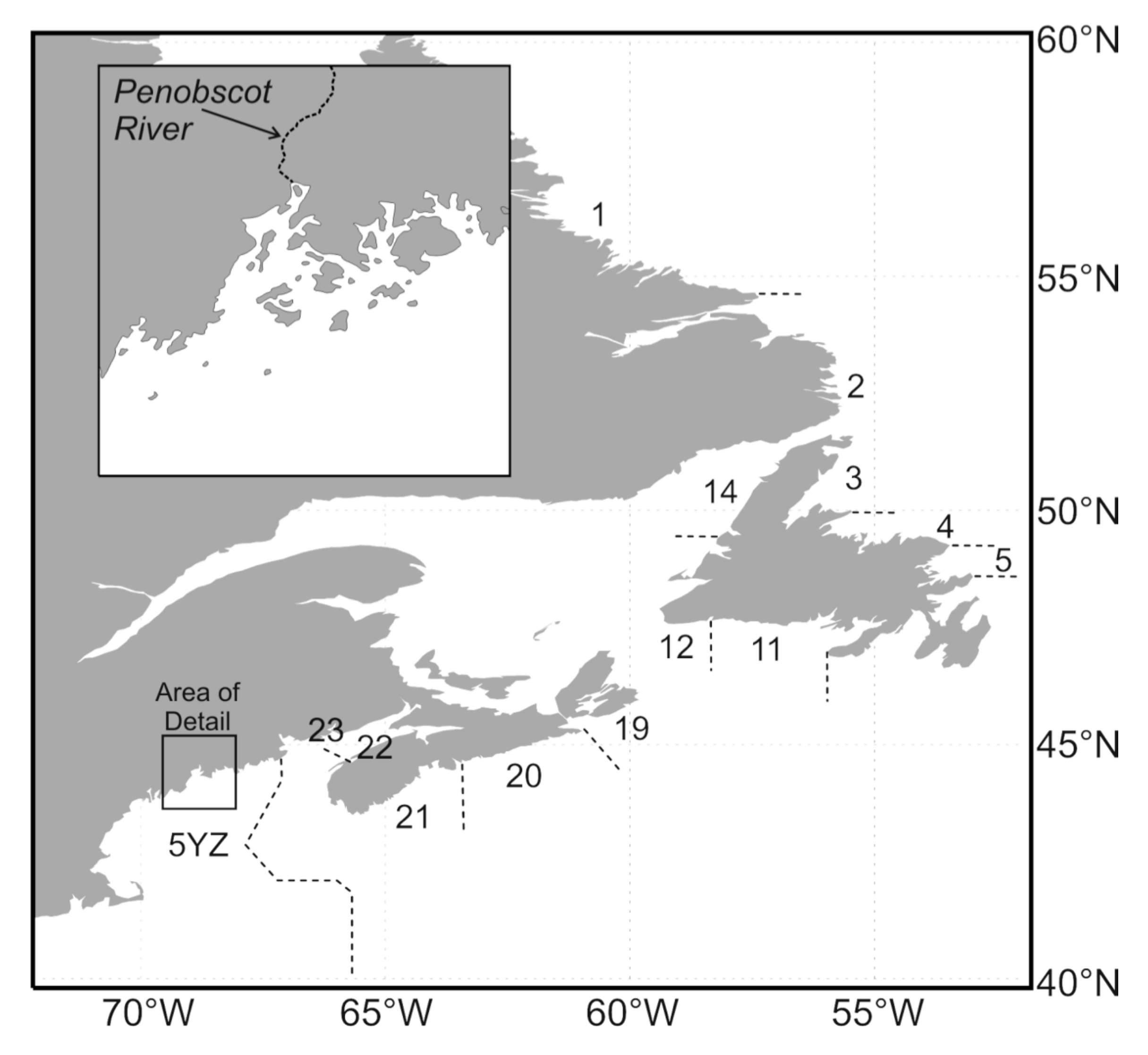
Friedland et al., in prep.

Relationship Between Counts of Vector Wind and Return Rate

		1SW		2SW			Combined	
Vector	Month	Positive	Negative	Positive		Negative	Positive	Negative
u	May	-0.231	0.236	-0.058		0.117	-0.089	0.146
	June	-0.035	0.021	0.150		-0.191	0.138	-0.179
v	May	0.048	-0.054	0.335	*	-0.297	0.327	-0.292
	June	-0.228	0.218	0.350		-0.324	0.302	-0.279

Friedland et al., in prep.

Penobscot River and NAFO and Salmon Fishing Areas



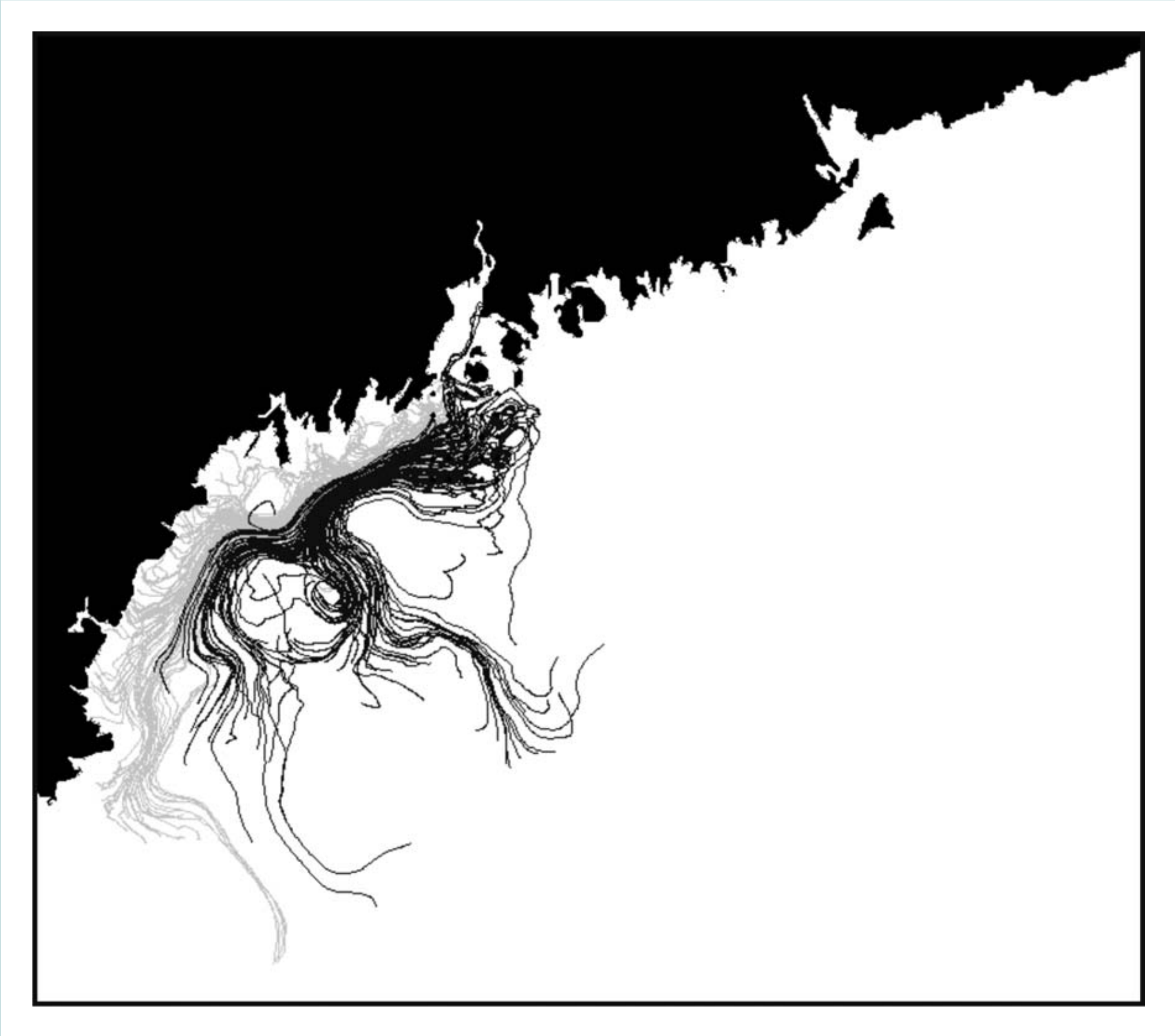
Friedland et al., in prep.

Penobscot Post-smolt Tag Returns

	Month							Weighted
Areas	4	5	6	7	8	9	10	Month
5YZ	1	5	3					5.2
19-21			31	80	8		1	6.8
11-12			4	11	2			6.9
14				1	2			7.7
22-23				43	77	3		7.7
1-5				1	5	3		8.2

Friedland et al., in prep.

Wind and Migration Trajectory



Friedland et al., in prep.

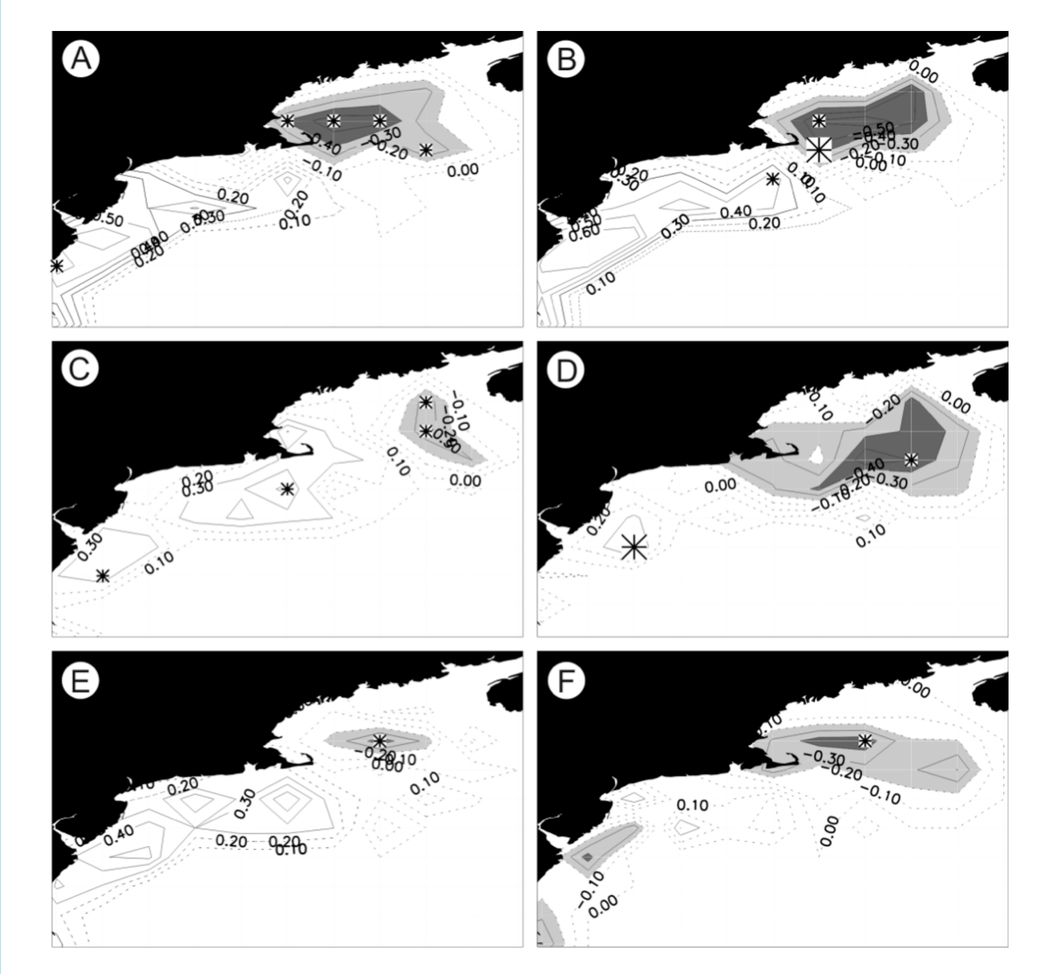
Pelagic Piscivores in the Gulf of Maine

Common Name	Scientific Name
Acadian Redfish	*Sebastes fasciatus*
Atlantic Cod	*Gadus morhua*
Blackbelly Rosefish	*Helicolenus dactylopterus*
Goosefish	*Lophius americanus*
Longfin Hake	*Urophycis chesteri*
Pollock	*Pollachius virens*
Red Hake	*Urophycis chuss*
Sea Raven	*Hemitripterus americanus*
Silver Hake	*Merluccius bilinearis*
Spiny Dogfish	*Squalus acanthias*
Striped Bass	*Morone saxatilis*
Thorney Skate	*Amblyraja radiata*
White Hake	*Urophycis tenuis*
Winter Skate	*Leucoraja ocellata*

Friedland et al., in prep.

Relationship Between Pelagic Piscivore Abundance and Penobscot Return Rate

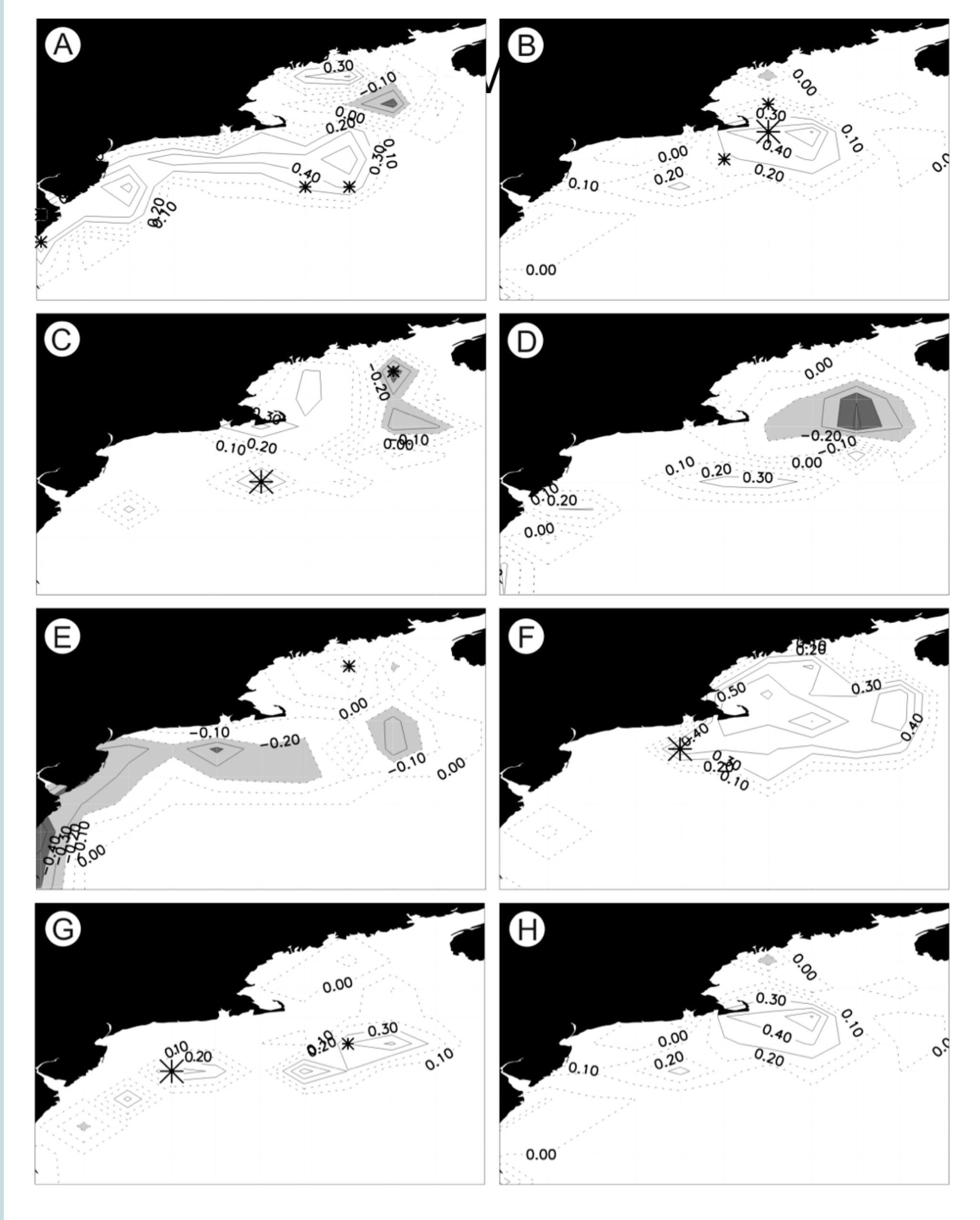
a) Silver Hake
b) Red Hake
c) White Hake
d) Sea Raven
e) Goosefish
f) Dogfish



Friedland et al., in prep.

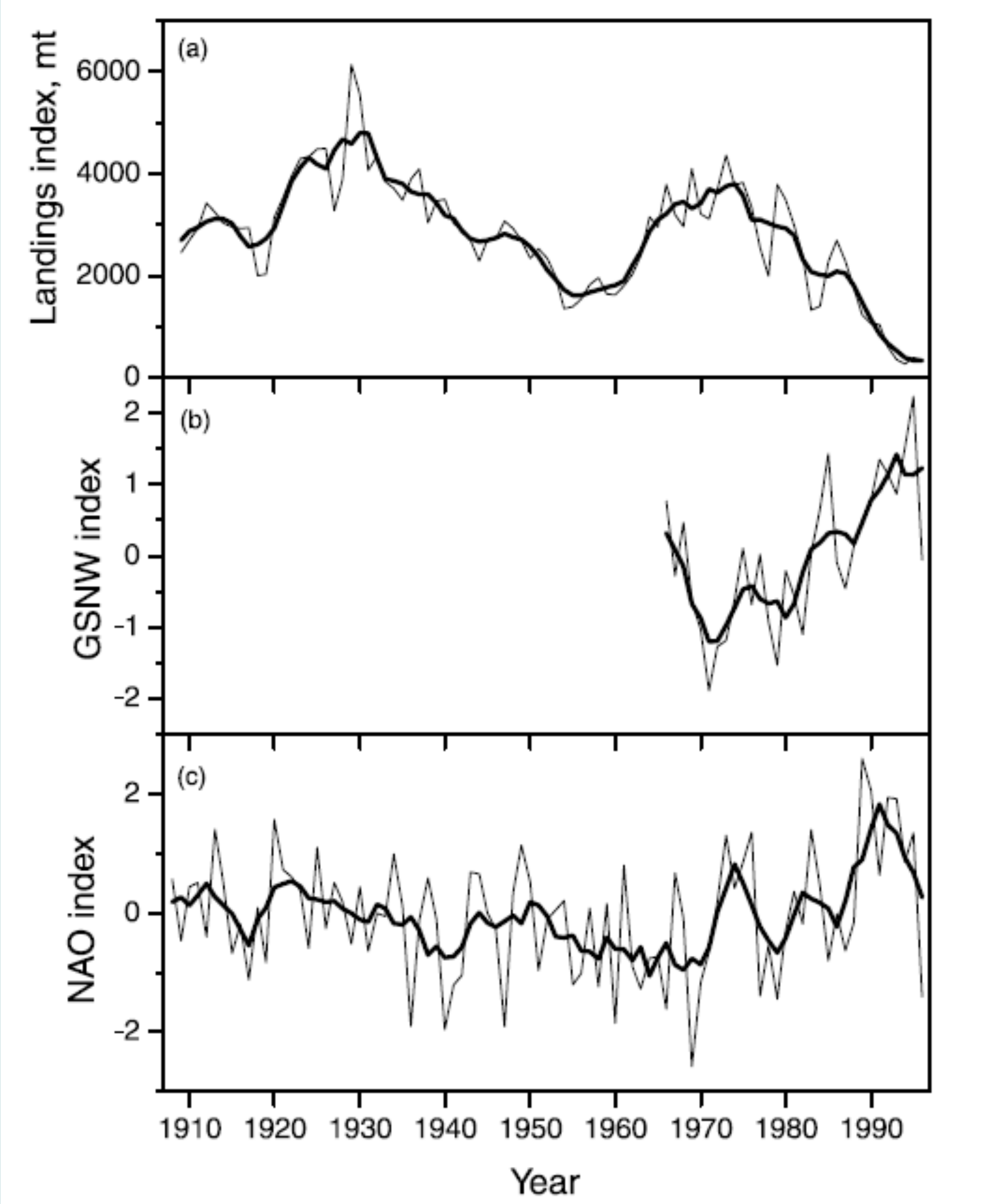
Pelagic Piscivore Abundance and Penobscot Return Rate

a) Cod
b) Pollock
c) Redfish
d) Rosefish
e) Winter Skate
f) Thorney Skate
g) Long Fin Hake
h) Striped Bass



Friedland et al., in prep.

GSNW and NAO and North America Atlantic Salmon Catch Index



Friedland et al., 2003

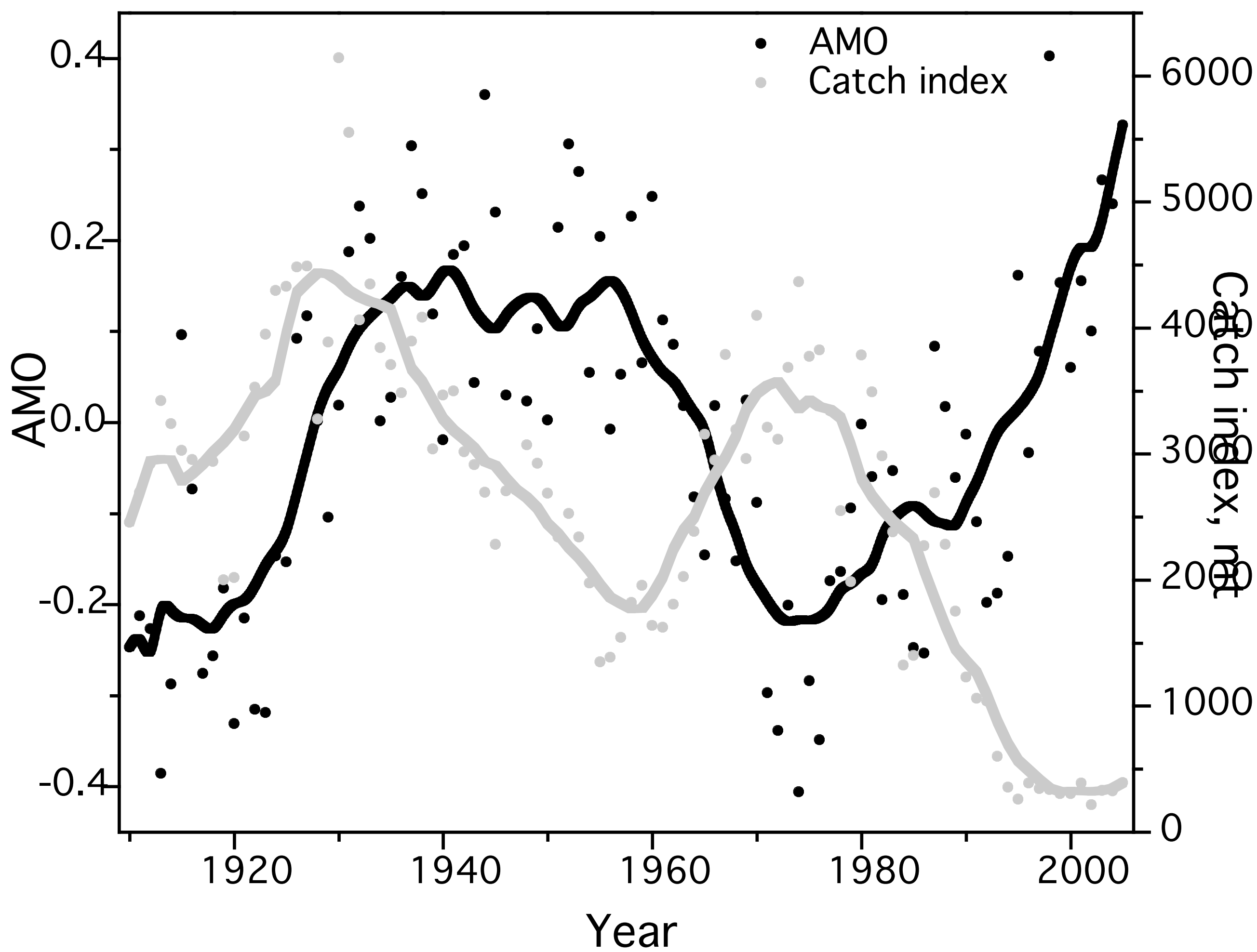
GSNW and NAO and North America Atlantic Salmon Catch Index

Index	Method	Period	Lag 1	Lag 2
GSNW	PC of position	Jan.	–0.48**	–0.41*
		Feb.	–0.60**	–0.57**
		Mar.	–0.39*	–0.24
		Apr.	–0.47	–0.41
		May.	–0.40	–0.40
		June	–0.35	–0.48*
		July	–0.15	–0.27
		Aug.	–0.48	–0.52
		Sept.	–0.40	–0.41
		Oct.	–0.42	–0.47
		Nov.	–0.46*	–0.43
		Dec.	–0.40	–0.41*
		Annual	–0.68*	–0.67*
NAO	Station-based index	Winter	–0.18	–0.23*
	PC of leading EOF	Winter	–0.19	–0.21*

Note: PC, principal component; EOF, Empirical Orthogonal Function analysis. Significance: *, $p = 0.05$; **, $p = 0.01$.

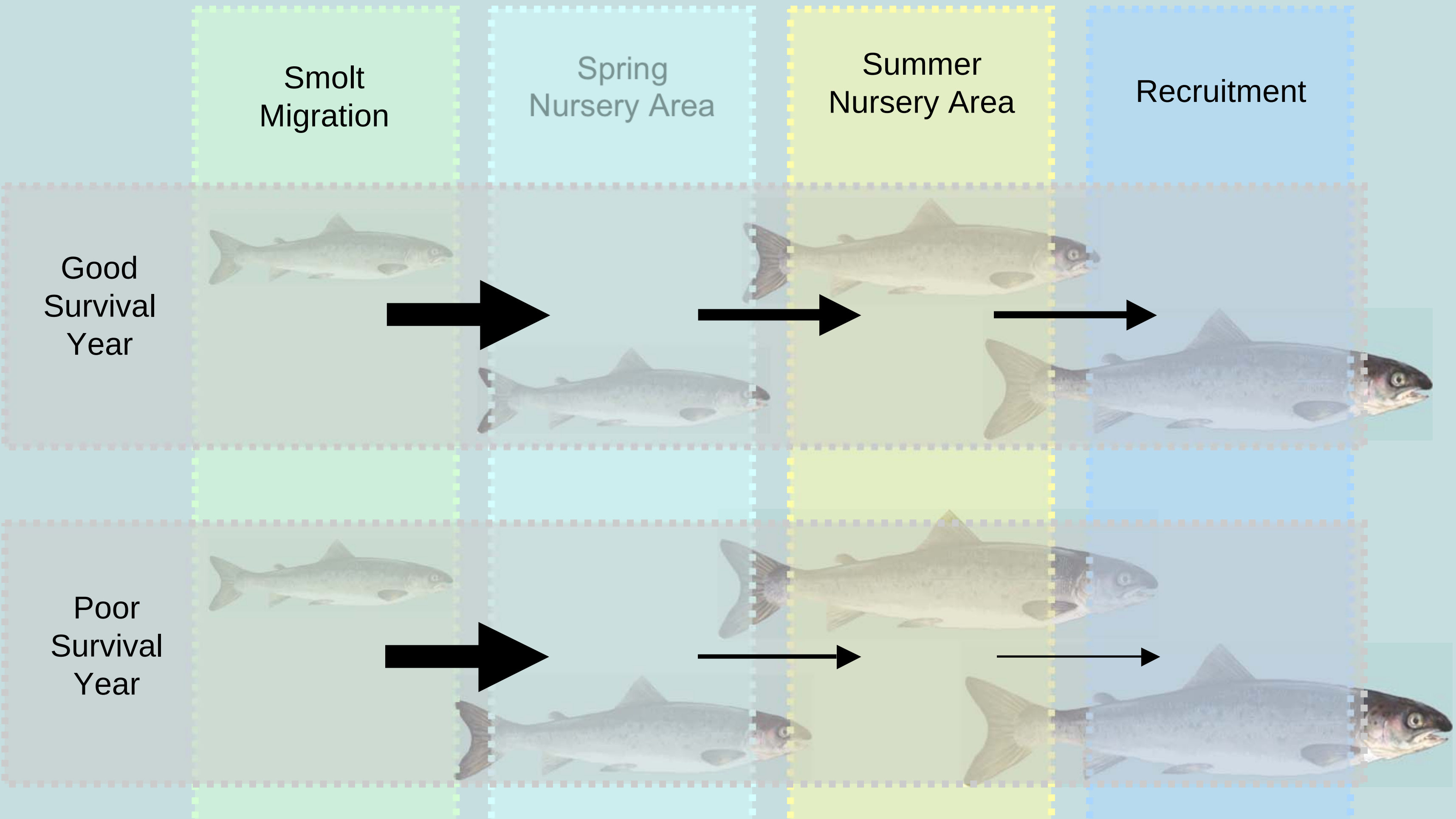
Friedland et al., 2003

AMO and North America Atlantic Salmon Catch Index



Recruitment Mechanism North American Atlantic Salmon

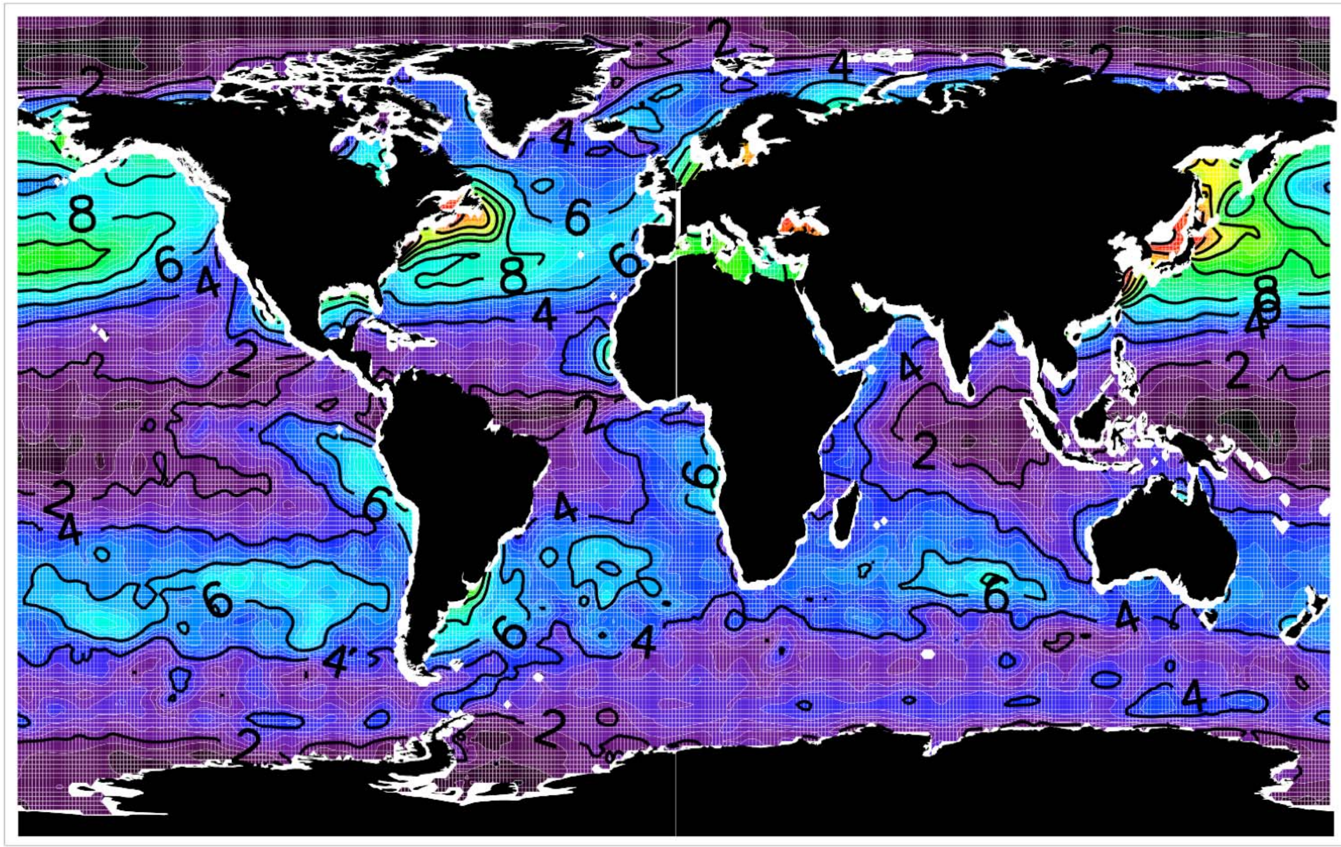
Change in physical forcing in Northwest Atlantic → Variation in spring SST conditions versus air temperature → Shift in vulnerability to predators → Survival independent of growth → Growth is density dependant under some circumstances



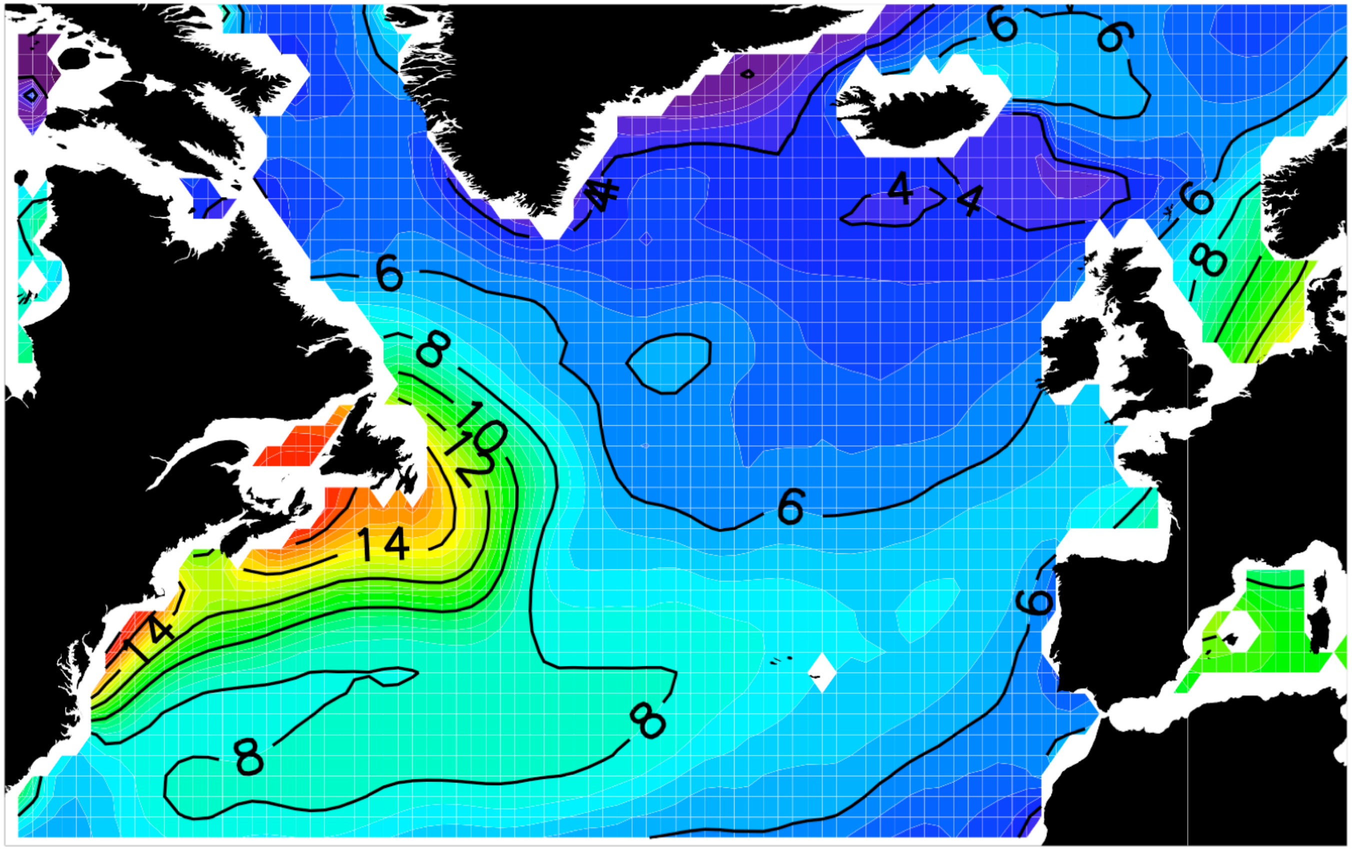
Contrast in Recruitment Mechanisms Between The Continental Stock Complexes

Factor	Europe	North America
Climate	+	+
Prey	+	-
Growth	+	-
Predators	-	+

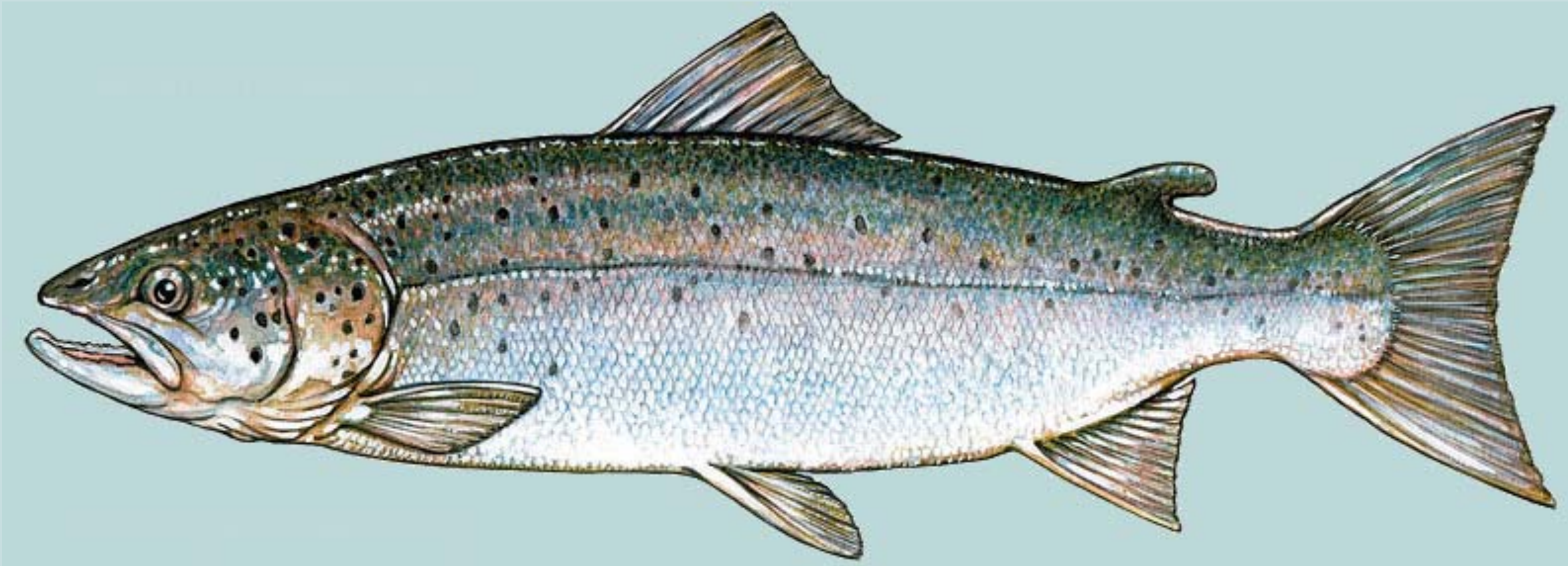
Annual SST Range



Annual SST Range



Further ramifications, will the anticipated shift in climate conditions result in a shift in the distribution of Atlantic salmon?



Ted Walke

Jason,
Can you provide comment in person or via correspondence (or via me) for the salmon workshop on the feasibility of detecting predation on salmon post-smolts in the GOM by pelagic piscivores. The parameters of the analysis would be as follows:

See below

1. Since there are low numbers of salmon leaving wild run rivers, we would expect most salmon detected in predator stomachs will be of hatchery origin. 500,000 salmon smolts are released into the Penobscot annually. Based telemetry studies done in the Penobscot Bay estuary, ~200,000 fish will like attempt to transit the GOM.
One approach to bound this issue would be to take a known prey, e.g. one of the hakes, and one or two of its known predators, and knowing the abundance of the prey stock (e.g. from surveys, assessments, etc.), abundance of the predator stocks and making some assumptions about functional responses and relative abundance of other, similar prey, etc., what type of frequency of occurrence and % diet composition (by weight) do we find in the predator for that prey. Then knowing that, what type of detection limits would we expect for salmon as prey with this ~200,000 to ~500,000 fish. And then scope out the number of predator stomachs needed to achieve this detection

2. Based on historical tagging data it appears that the fish cross the center and/or the western half of the GOM.

3. The transit lasts ~1 month, starting mid May into June.
We could target that area, as we have already, from the historical diet data base, to again scope out the issue. We could then also target that area as a dedicated process-oriented cruise or in conjunction with extant surveys (e.g., shrimp survey).
We could do the same for that timing with some historical, process-oriented cruises as well as consider novel, contemporary field studies. It is obvious we'd need to do some contemporary studies, they are feasible to do (we've done them before), but how and to what extent (and thus how much they'd run in terms of cost) need to be sorted out.

4. We expect a range of predators including fish, birds, and mammals take some numbers of salmon post-smolts. Can we sample potential piscivores predators for the target region and time period with an expectation of detecting post-smolts in stomachs? Furthermore, would we have an expectation of determining meaningful predations rates?
Short answer, Yes. Even if we sample the predators just at detection limits, demonstrating that they are not comprising a large component of these predators' diets would be useful to show. Whether the rate of feeding is meaningful I don't know. Assuming by that you meant will we be able to detect smolts in the predators, or will it be at a rate that impacts smolt populations?, we'd need to scope it out as noted above.

5. Using our analyses of the time and area distribution of potential predators, should we refine the approach to specifically target those species we suspect may be of greater importance, for example focus on the hake species, sea raven, goosefish, and dogfish.
Not necessarily. My observations are that the as soon as we omit sampling a predator spp., it somehow becomes overlooked and then retrospectively important. Or we end up not catching a predator we're all set up to sample in the nets. What I'd rather do is to pick off the usual list of suspects (as you've generally noted, the list of possible juvy salmon predators and piscivores as we've discussed in the past) and then sample adaptively (change number of stomachs, but not necessarily number of predator spp.) based upon what we're observing and what we're catching in the trawl sampling.

Discussion welcomed.
Kevin

In sum, I'd view this as a two step process. One to do some background study on extant databases and two to set up a dedicated field program. Obviously the former will inform the latter and the former will be less costly, but the latter is needed to really address the question at hand. The latter would be valuable even if we're barely at detection limits—proving this is not a major process would be useful to know.
I'm afraid that if you're wanting some specifics as to the sampling design, sample sizes, etc. it would be a bit premature to do so at this point without some further scoping of the issue. What I've provided is a concurrence that the approach is generally feasible and the topic certainly useful to explore, which I hope at least is positive reinforcement for you.