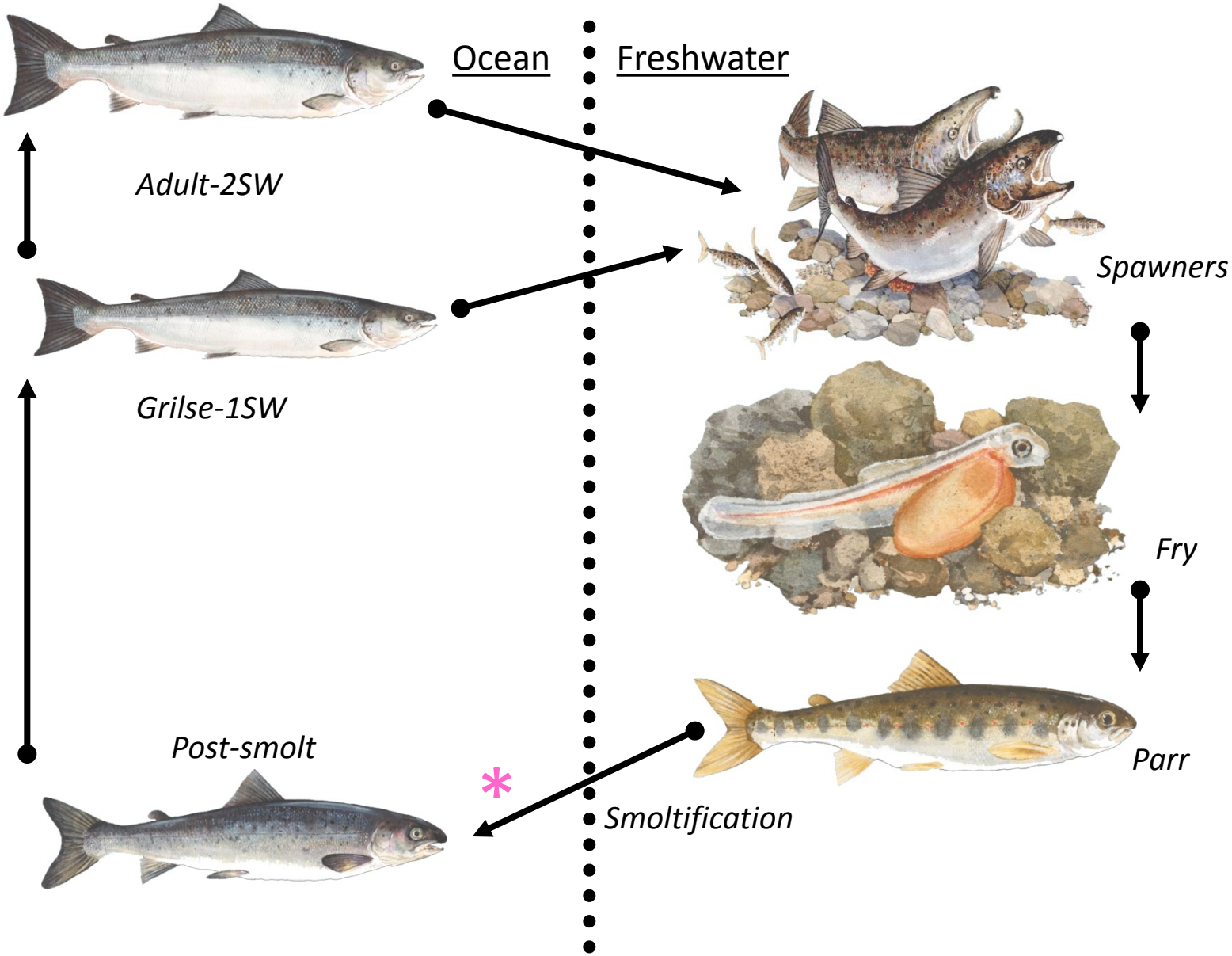
Atlantic Salmon Information for the River Herring Technical Expert Working Group (TEWG)

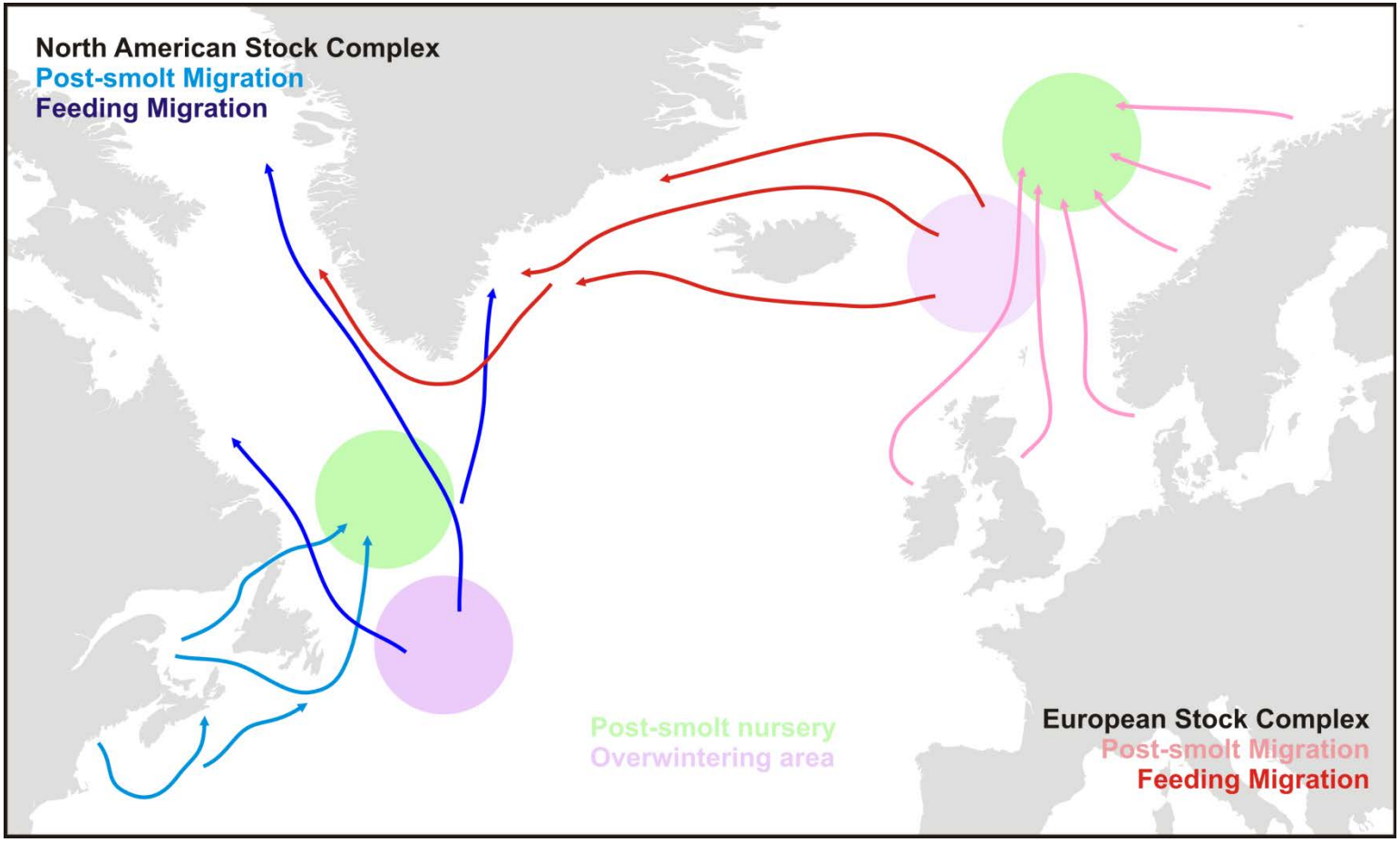
Kevin Friedland
National Marine Fisheries Service
Narragansett, Rhode Island

How temperature in the ocean phase affects salmon

Anadromy and Recruitment Bottlenecks *



Salmon Migration



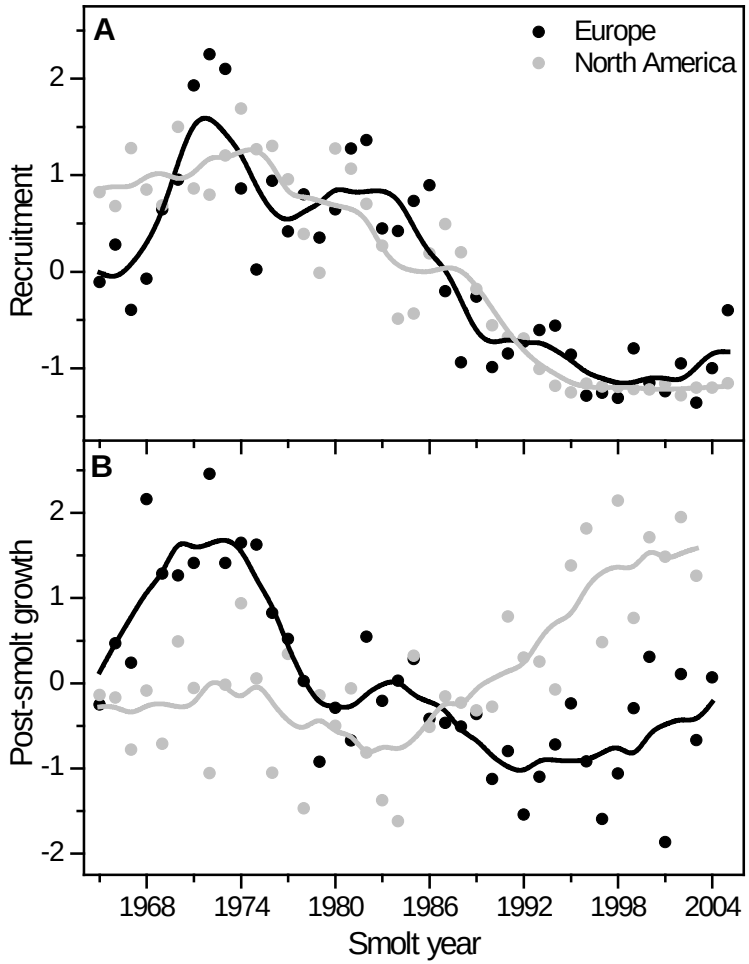
Post-smolt growth plays a differential role in the marine survival of the two continental stock groups

For southern tier North American stocks, post-smolt growth does not contribute to the pattern of variability in marine survival and adult recruitment. Whatever variability that occurs due to size mediated mortality is overshadowed by the variability associated with other sources of mortality.

For southern tier European stocks, marine survival and adult recruitment correlate with post-smolt growth, particularly the growth that occurs during the summer-early fall period. Thus, marine survival is controlled by size mediated mortality occurring during this period.

Time series of recruitment and post-smolt growth signals

Stock abundance (A) and composite post-smolt growth (B) time series for European and North American stock complexes. All data are normalized.



Data drawn from:
Peyronnet et al., 2007
McCarthy et al., 2008
Friedland et al., 2009
Hogan & Friedland, 2010

Salmon recruitment is associated with decadal scale changes in the thermal regime of the North Atlantic. The climate forcing associated with this regime is the Atlantic Multi-decadal Oscillation (AMO). However, the two stock groups are responding to warming conditions in ecologically distinct ways at different junctures of their life history.

For southern tier North American stocks, warming conditions during the spring associated with inshore and coastal ocean waters has been associated with declining marine survival.

For southern tier European stocks, warming conditions during summer into fall in the Northeast Atlantic spatially associated with their summer nursery area has been associated with declining marine survival.

Correlation between recruitment and climate signals in the North Atlantic

Table 2
Pearson product moment correlation coefficients (R) between salmon stock abundances and climate indices of Thermal Habitat (TH), Gyre Index (GI), Atlantic Multidecadal Oscillation (AMO), North Atlantic Oscillation (NAO) and Arctic Oscillation (AO). For stock designation, NA and SE refer to North American and Southern European stock complexes, respectively, and M and NM refer to maturing and non-maturing stock components, respectively.

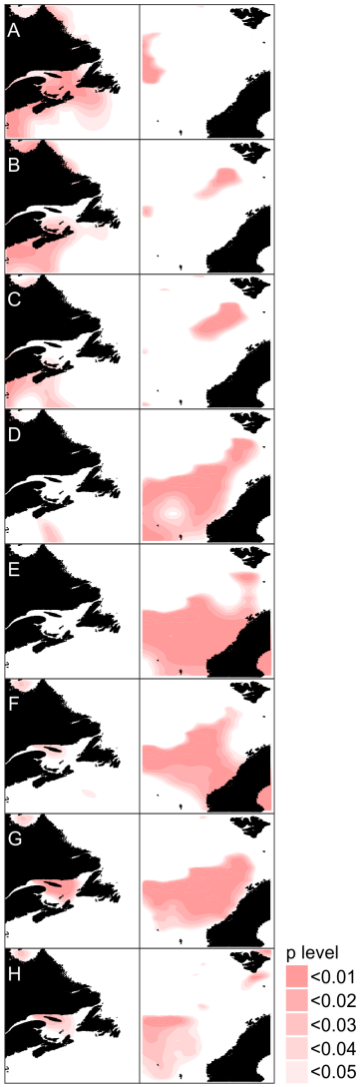
Stock-component	TH	GI	AMO	NAO	AO
NA-M	0.25	0.21	−0.37*	−0.02	−0.31
SE-M	0.46	0.46	−0.78*	−0.15	−0.25
NA-NM	0.50	0.50	−0.78*	−0.07	−0.22
SE-NM	0.51	0.47	−0.76*	−0.12	−0.26

* Indicates an autocorrelation corrected probability of $p < 0.05$.

Friedland et al., 2014

Significant correlation between SST and Atlantic salmon recruitment

Each panel is a contour plot the p-levels of correlations between recruitment and SST. Left hand panels are for North American recruitment, right hand panels for European, rows are for months May through December (A-H, respectively).



Friedland et al., 2014

The growth/size related recruitment mechanism in Europe is supported by the overlap in time and space of the growth and thermal response of the stock complex.

Southern tier European post-smolts enter a coastal ocean that does not vary greatly, and though mortality is high during the early marine phase, the accumulated mortality during summer, controlled by size, is more variable and thus controls recruitment.

Northeast Atlantic thermal conditions have shifted the community structure in the region, thus impacting salmon, along with other species.

Change in the Northeast Atlantic Foodweb

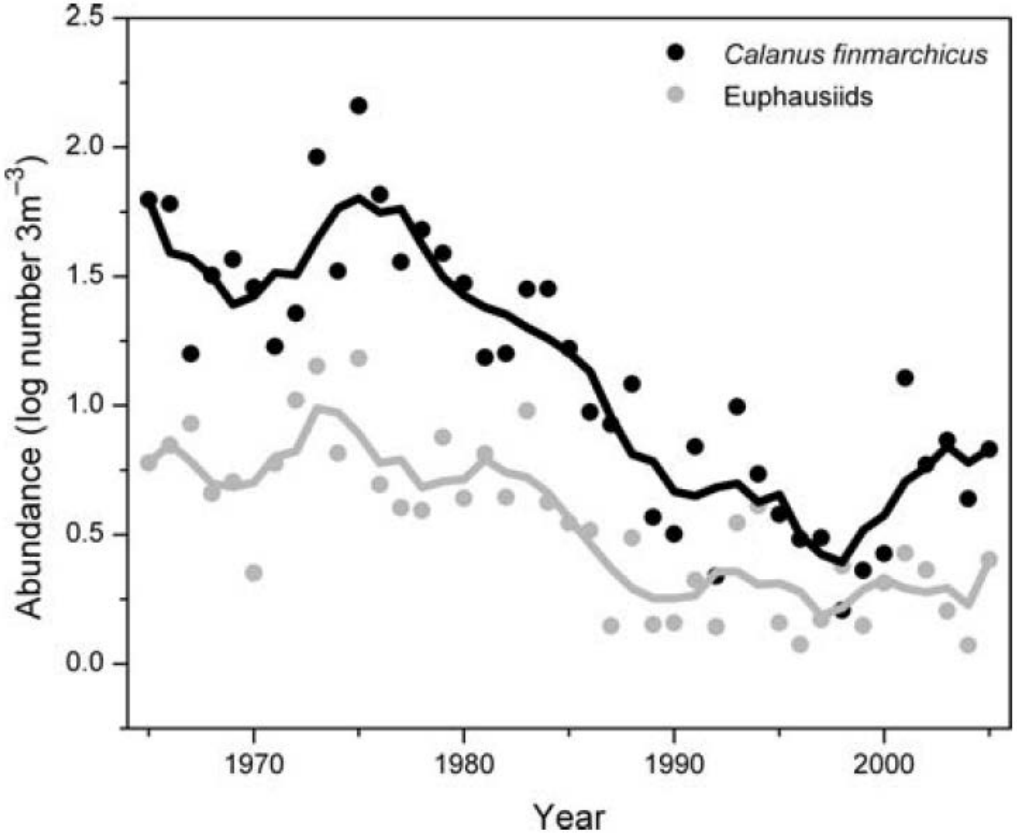


Figure 9. Mean abundance of *C. finmarchicus* and euphausiids in area B1 over the months July – October.

Friedland et al., 2009

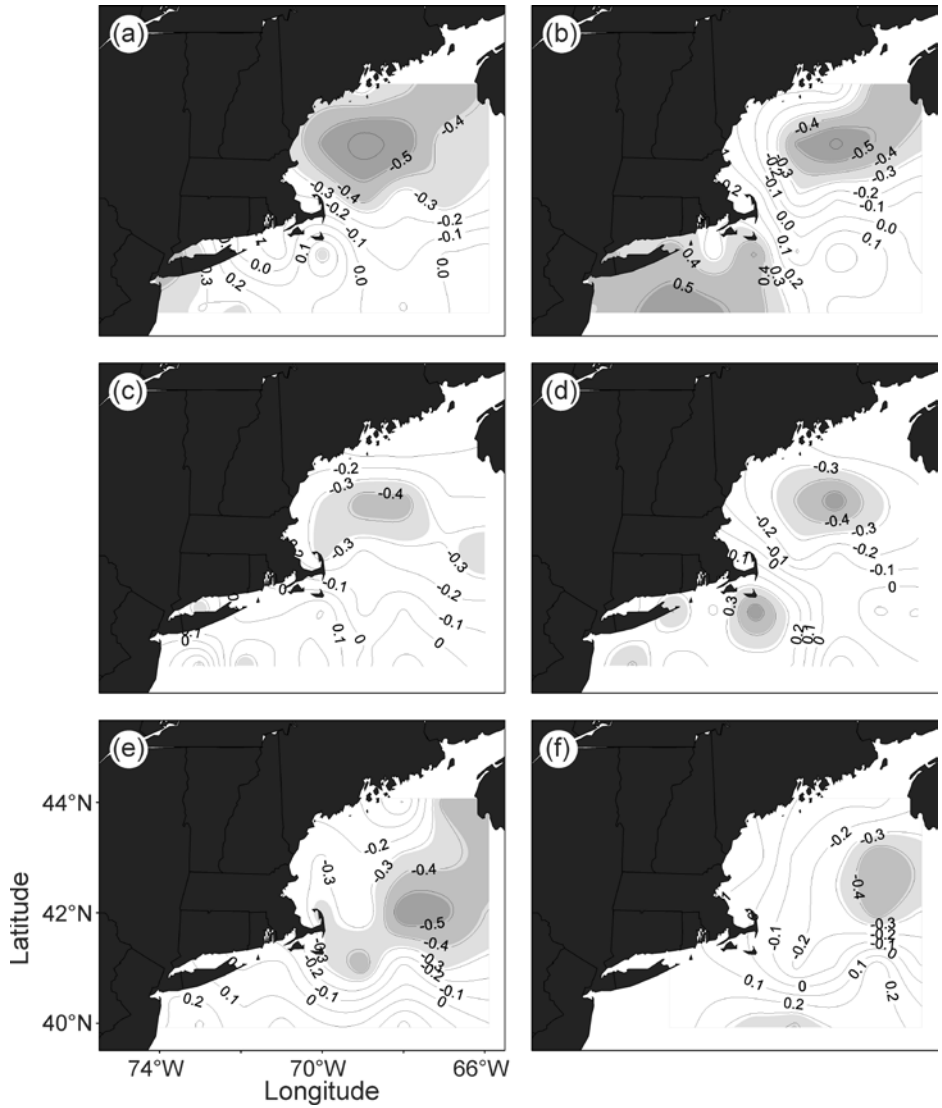
The absence of evidence to support a growth/size related recruitment mechanism in North America coupled with the changes in survival associated with changes in spring inshore thermal conditions suggest that recruitment is controlled by changes in predation pressure associated with the warmer conditions.

Southern tier North American post-smolts are entering a warmer ocean, with different predator species composing the predator field and higher predator abundances.

The impacts may be exacerbated by a phenological mismatch between the cues for post-smolt migration and ocean conditions.

Correlation Between Penobscot 2SW Return Rates and Predator Abundance

Merluccius bilinearis (a), *Urophycis chuss* (b), *Squalus acanthias* (c), *Lophius americanus* (d), *Hemitripterus americanus* (e), and *Helicolenus dactylopterus* (f). light gray, P<0.05; medium gray, P<0.01; and, dark gray, P<0.001.

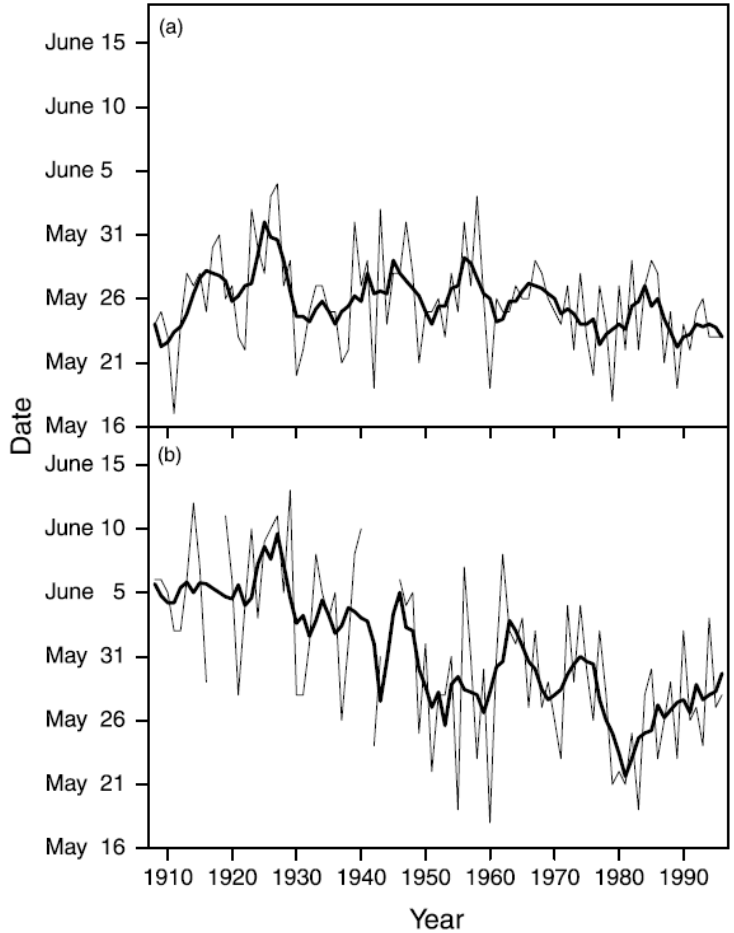


Friedland et al., 2012

Phenological Mismatch Gulf of St. Lawrence

Change in temperature in the rearing areas not in synchronization with temperature in ocean

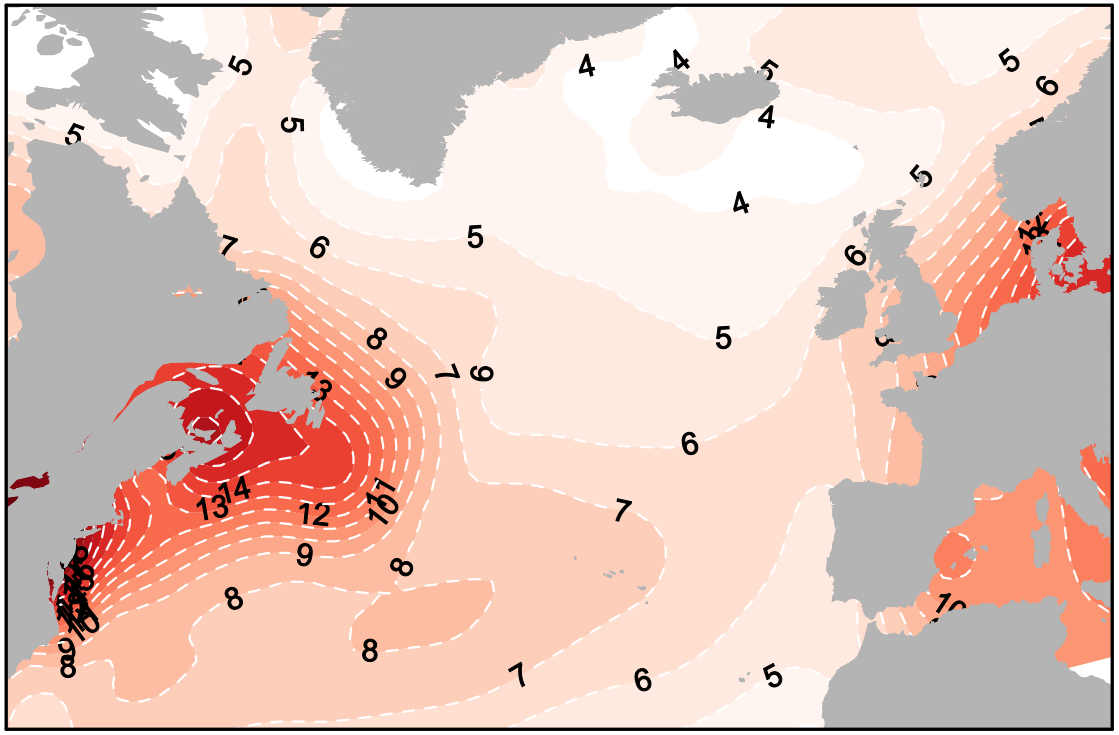
Fig. 13. (*a*) Estimated dates of air temperatures of 11°C in the grouping of land observing stations associated with sea surface temperature (SST) index area 1 and (*b*) estimated dates of SSTs of 6°C in SST index area 1. Bold lines represent five-point moving average filters.



Friedland et al., 2003

North Atlantic Temperature Range

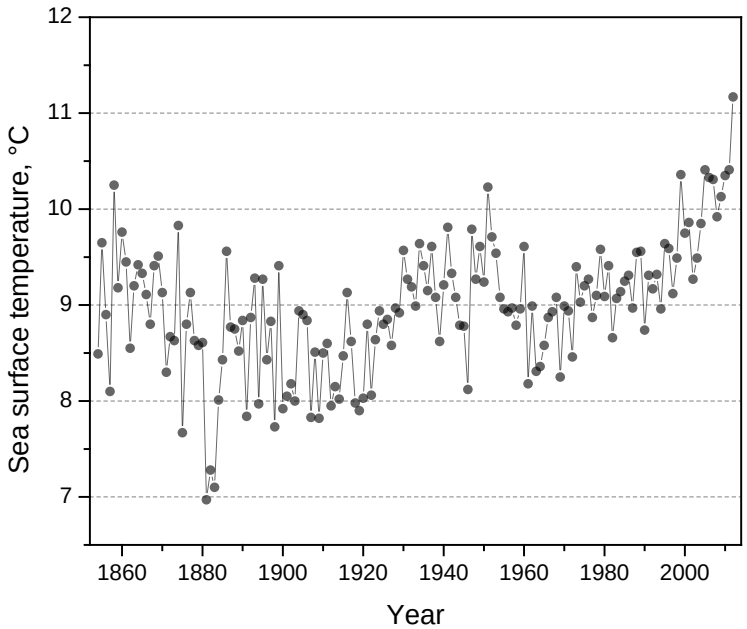
Average annual temperature range in the North Atlantic area in degrees centigrade



Friedland et al., 2014

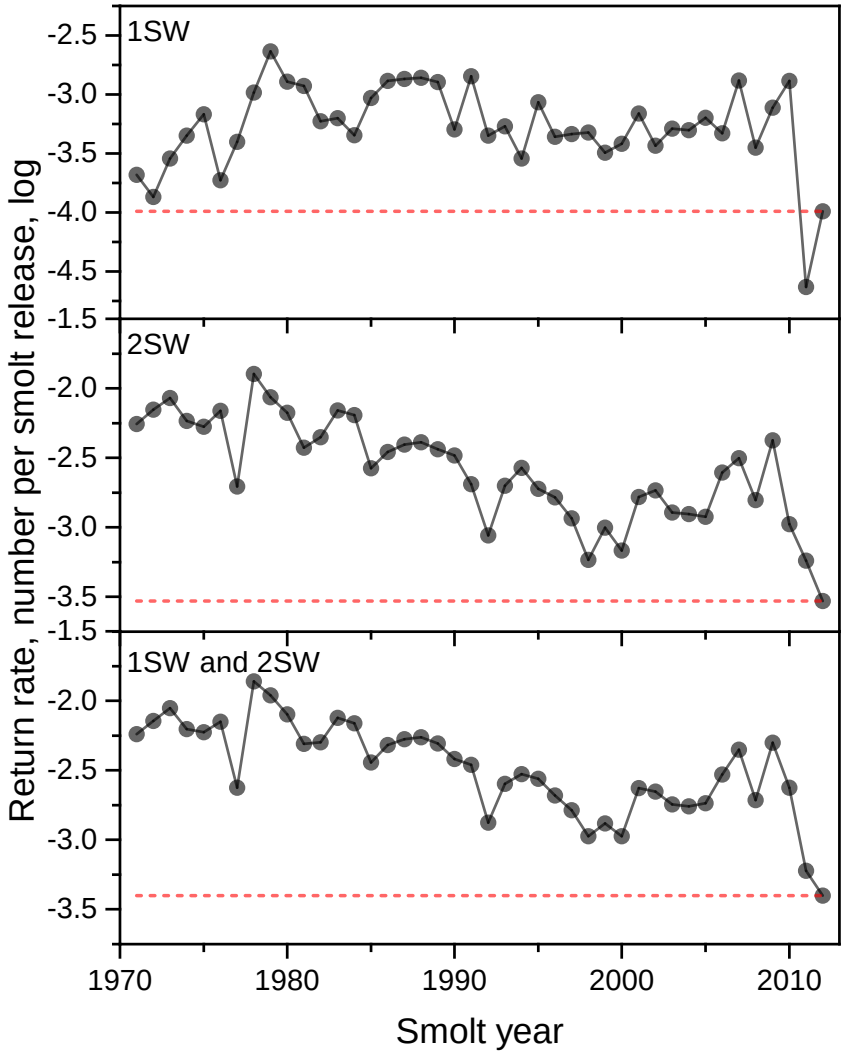
June 2012 Sea Surface Temperature and Projected Pre-fishery Abundance

Highest sea surface temperature in the time series, expectation of low returns and potentially complete recruitment failure of the 2012 year class



	Allometric	Linear
2014	91,181	0

Penobscot Return Rates Through the 2012 Smolt Class



Conclusions

Recent trends and 2012 event consistent with predator driven mortality mechanism affecting Gulf of Maine salmon survival.

Absence of complete loss of 2012 smolt class suggests the variation in predation pressure is not controlled by annual migrations of predators only, instead it reflects a shift in suitable habitat for predators.

River herring migrate to sea during different time frame, but they would be affected by same changes in resident predator fields. Pelagic predators likely to take salmon post-smolt would also likely take juvenile herring. But, is this the case with river herring considering latitudinal patterns in stock status?