Fishery management and moving baselines

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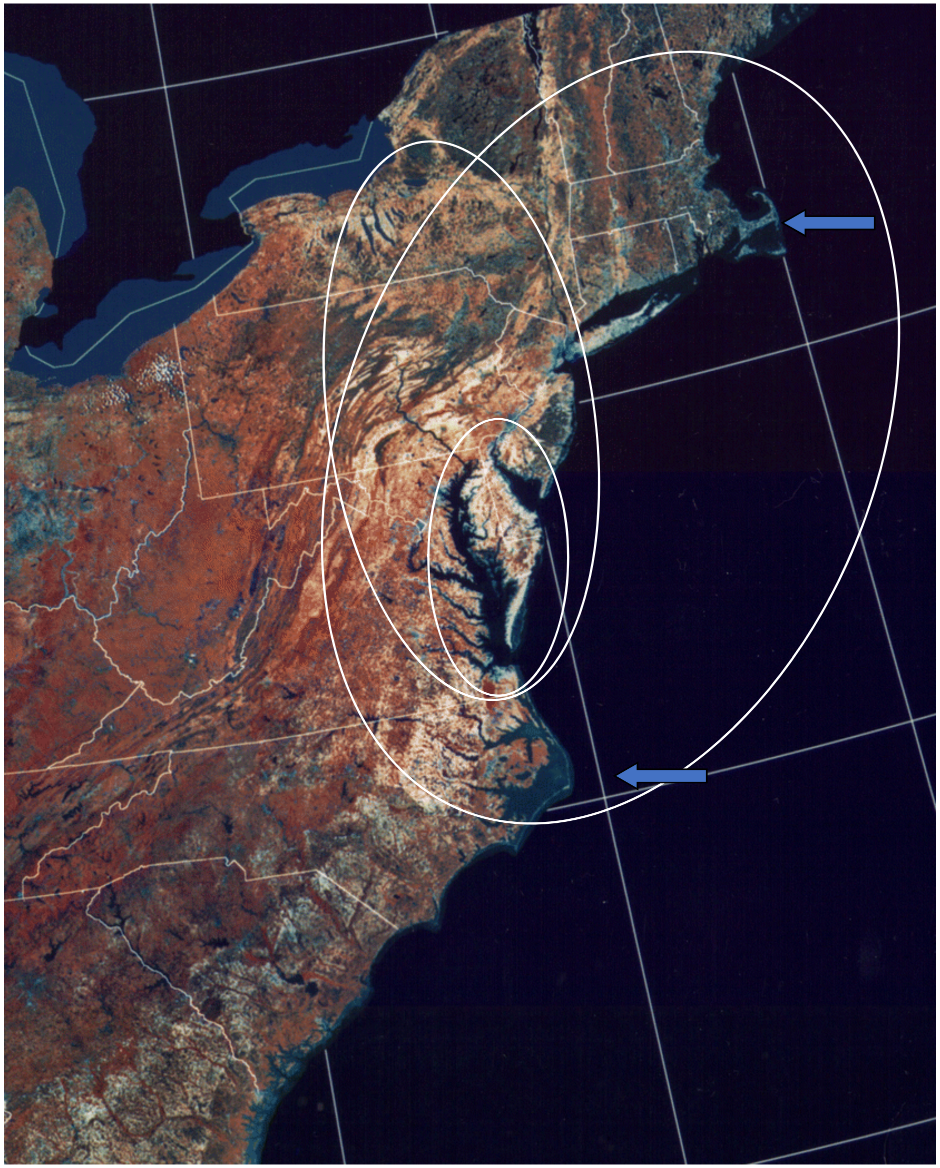
Setting the question…
What is the time frame, spatial footprint, and scope of the environmental change?

- The time frame: from past decade to post the little ice age?
- The footprint: Chesapeake Bay? the northwest Atlantic? Beyond?
- And the environment; so we consider temperature or productivity or be bold and consider multi-species interactions?
- Watersheds and their impact on nursery areas – the Chesapeake Bay as an example
- And what of future projections – how good area the IPCC models?

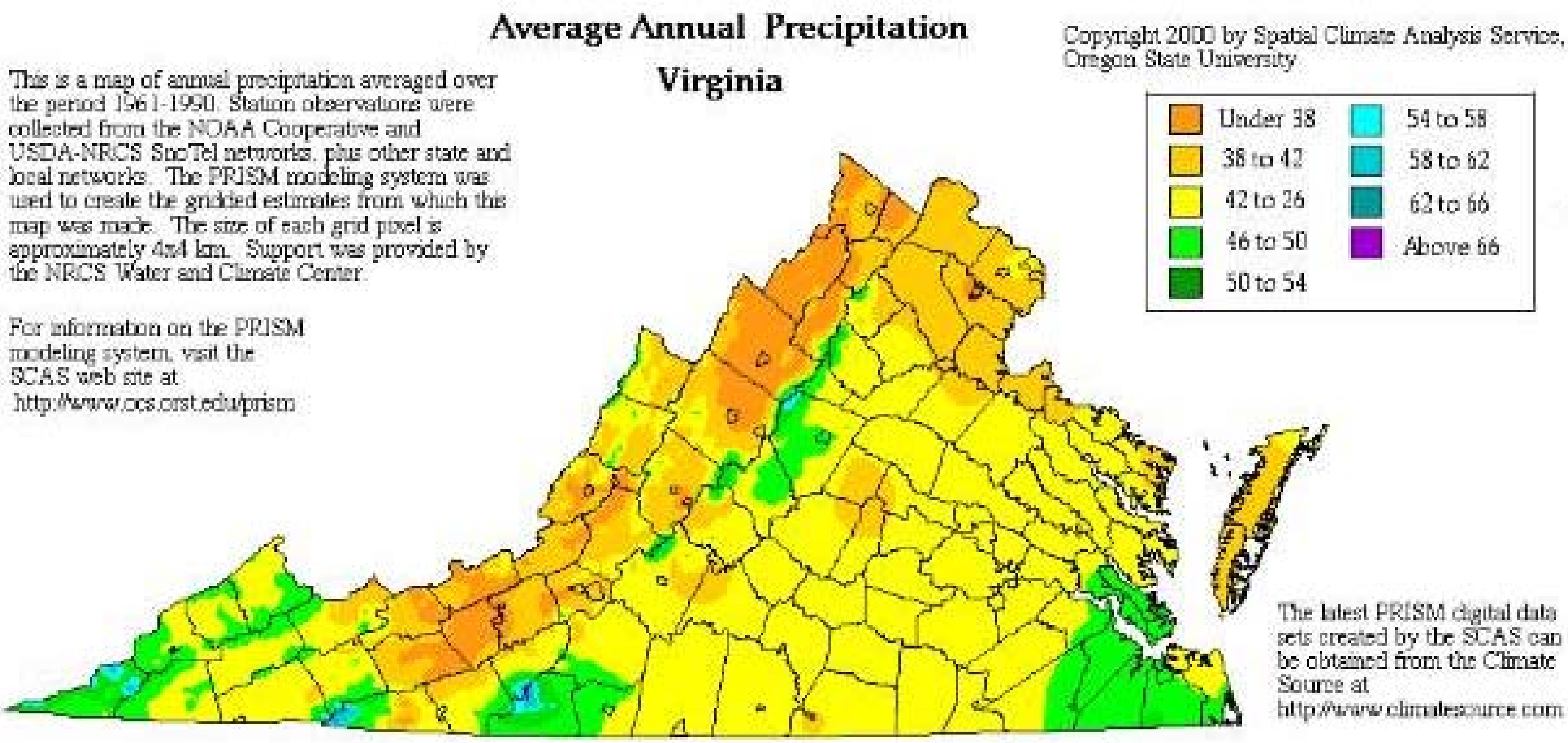


The footprint is important.

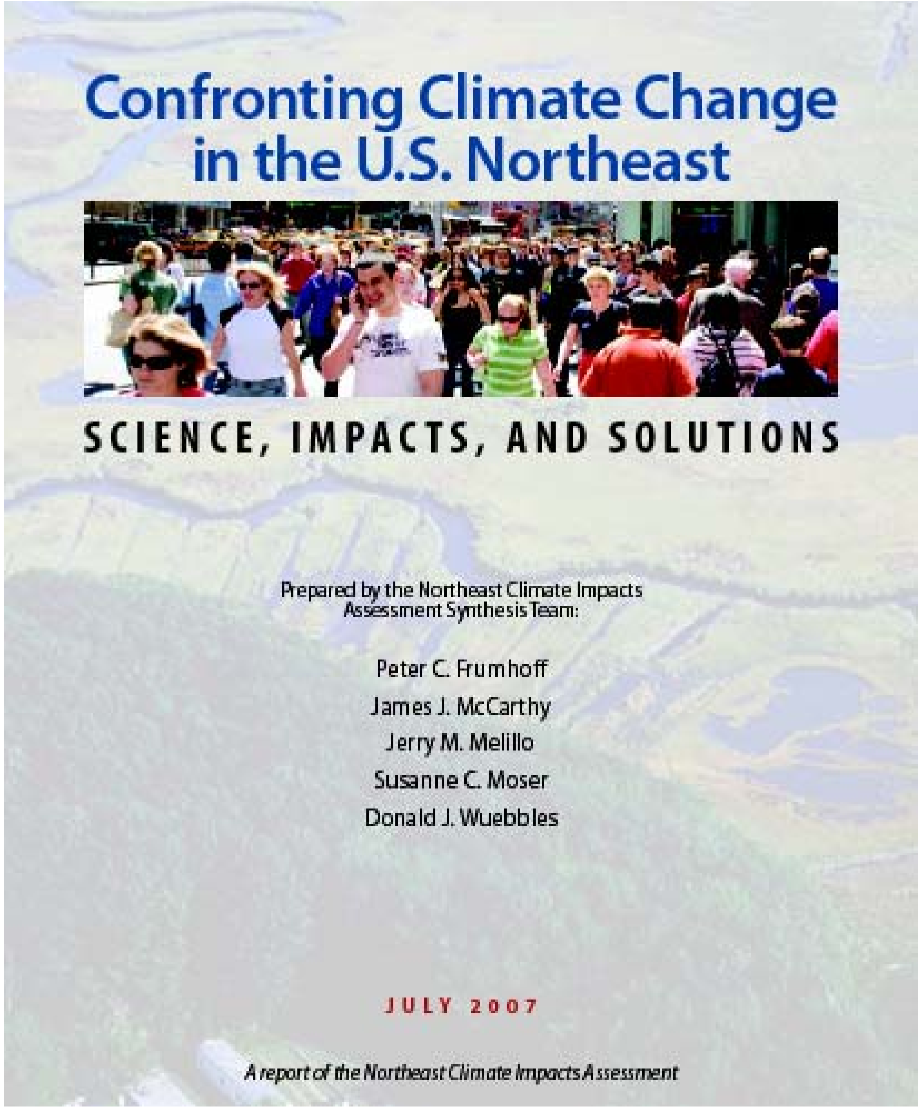
- Virginia is 470 mi west-east x 200 mi north-south, 35,598 sq. mi (v 64,000 for the bay watershed).
- Virginia is geologically ancient through geologically young features.
- population approx. 6.5 million (< NY city).
- 62% is covered by forest.
- 1,000,000 acres wetlands.

Weather patterns and the jet stream oscillation….

Cold winters and hot, humid summers - consider the temperature and precipitation ranges and what drives them.



Where does all the water come from? Most of fresh water used for agriculture, industry and domestic purposes falls as rain in Virginia.



- As a continuing task, we need a coherent assessment of impacts at natural resource and societal levels.
- We do not have a commitment to create and maintain such a plan.
- THIS IS NOT ADEQUATE
- There are templates for such a document, and we should build upon them.

Does the North East document provide indications on what we might expect in Virginia? Yes.

Species move northward.

High emissions result in habitat disappearance.

Diminished habitat at higher elevations create pressures on associated species such as hares, lynx and thrush.

Substantial changes in bird life are expected.

Northward expansion of fatal pests such as hemlock woolly adelgid.

CHAPTER FOUR

Impacts on Forests

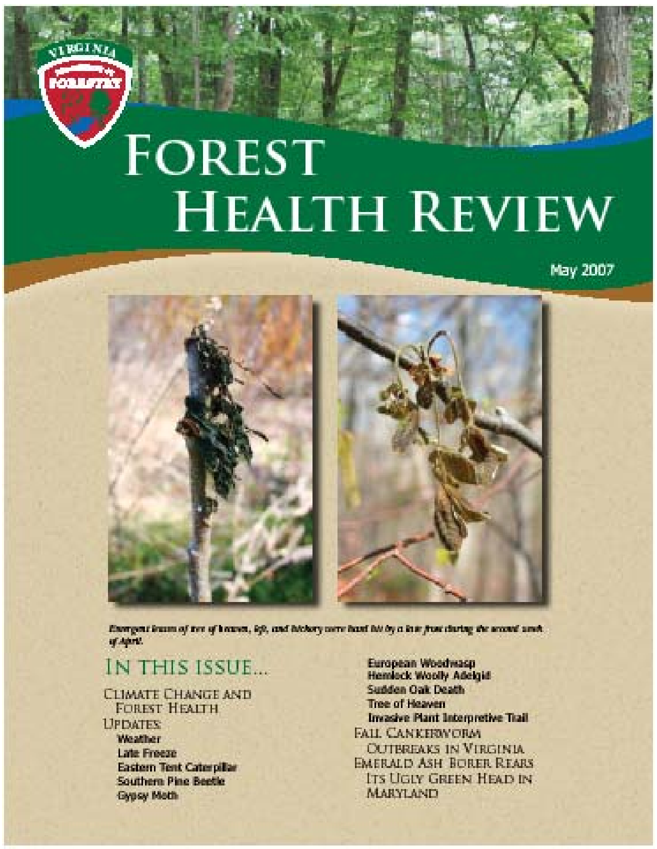
KEY FINDINGS

- The character of the Northeast's forests may change dramatically over the coming century as the center of suitable habitat for most of the region's tree species shifts northward—as much as 500 miles by late-century under the higher-emissions scenario, and as much as 350 miles under the lower-emissions scenario.
- Many tree species, including the hardwoods that generate the region's brilliant fall foliage, may be able to persist this century even as their optimal climate zones shift northward. Other species, however, may succumb to climate stress, increased competition, and other pressures.
- If the higher-emissions scenario prevails, productivity of spruce/fir forests is expected to decline and suitable habitat will all but disappear from the Northeast by the end of the century. Major losses are projected even under the lower-emissions scenario. This would greatly exacerbate stresses on the pulp and paper industry in the Northeast, particularly in Maine, where the forest-based manufacturing industry is key to the state's economy.
- Diminished spruce/fir habitat, especially at higher elevations, would increase pressure on associated animal species such as the snowshoe hare, Canada lynx, and Bicknell's thrush, one of the region's prized songbirds. With the late-century summer warming projected under the higher-emissions scenario, suitable habitat for the Bicknell's thrush could be eliminated from the region.
- Substantial changes in bird life are expected across the Northeast due to rising temperatures, shifting distribution of suitable habitat, or declining habitat quality. The greatest changes are projected under the higher-emissions scenario, including declines in the abundance of many migratory songbirds such as the American goldfinch, song sparrow, and Baltimore oriole.
- Winter warming will threaten hemlock stands, not only by reducing suitable habitat for these trees, but also by allowing northward expansion of a fatal pest known as the hemlock woolly adelgid—as far north as Canada by late-century under the higher-emissions scenario.

A walk through Virginia from the mountains to the ocean shore -

Virginia’s renewable forests and climate change.

(some material source from VA Department of Forestry).



- **15,800,000 acres** - 78% hardwood, 22% softwood
- Planted stands make up 12% of total and 54% of softwoods.
- Current forest stock is about 1.2 billion tonnes carbon. It sequesters 6.42 million metric tons of carbon each year - nearly 20% of VA emissions.
- **Long generation time** with respect to rate of climate change (70 years for managed oak, 35 years for pine) - limited response ability.
- **Fragmenting footprint** and migratory corridors.
- Disruption of community structure from mammals to birds to insects.
- Leaf litter decomposition rates.
- *Soils, stabilization and runoff with downstream watershed impacts.*
- *Invasive species establishment.*

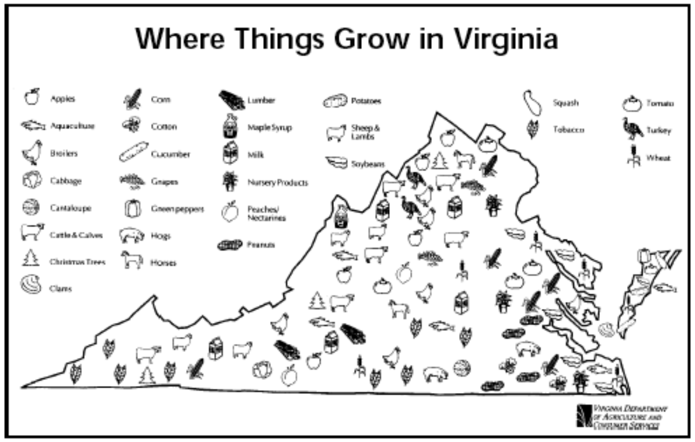
Climate change related impacts on Virginia forests.

Southern pine beetle

- Insect and pest outbreaks (Asian blight, gypsy moths, southern pine beetles, hemlock woolly adelgid)
- Invasive species displacement and lack of diversity - niche loss.
  - Tree-of-Heaven
  - Canada Thistle
  - Autumn Olive
  - Cogon Grass
  - Chinese Privet
  - Purple Loosestrife
  - Mile-A Minute
  - Kudzu
  - Multiflora Rose
  - Johnson Grass
  - Winged Burning Bush

Johnson Grass

Mile-A-Minute



Agriculture in Virginia:
The biggest industry in Virginia (20% of jobs),
8,500,000 acres,
$2.5-3 billion/yr in sales.

- Increased CO_2 will not increase yield.
- Increased temperature will not offer extended growing seasons.
- **Increased temperature may damages crop yield - corn is negative at 90ºF, badly damaged at 100ºF**.
- Pest and parasite outbreaks.

- **Frequency of droughts, rainstorms increase - water supply rate is critical, to both production and groundwater stability.**
- Topsoil integrity and stability of crop production may be compromised.
- Livestock impacts.
- **IPCC projections on rainfall?**

We have limited ability to mitigate these impacts.


A wetland along the Chickahominy River in Virginia.

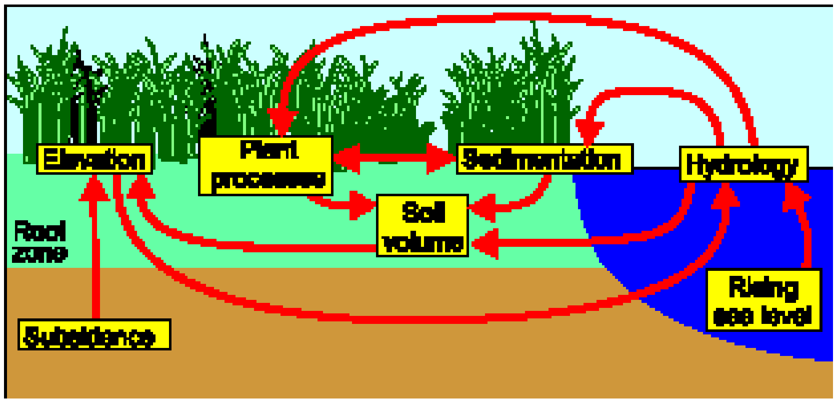
Virginia wetlands.

Shallow water bodies and high groundwater environments that are characterized by permanent or temporary inundation, soils with hydric properties, and plants and animals that have adapted to life in saturated conditions.

1,000,000 acres in total, 750,000 acres non tidal, 180,000 acres with no connection to surface water.

- **Very sensitive to water level, but they also assist in maintaining base surface water and groundwater flow** - especially in times of drought. Water removal for irrigation and municipal use can be problematic.
- Sediment sinks and buffers for flood control.
- Critical habitat, unique communities, wildlife refuges.
- They have nowhere to go - they cannot “migrate”.
- Sources or sinks of greenhouses gases, in particular carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)?

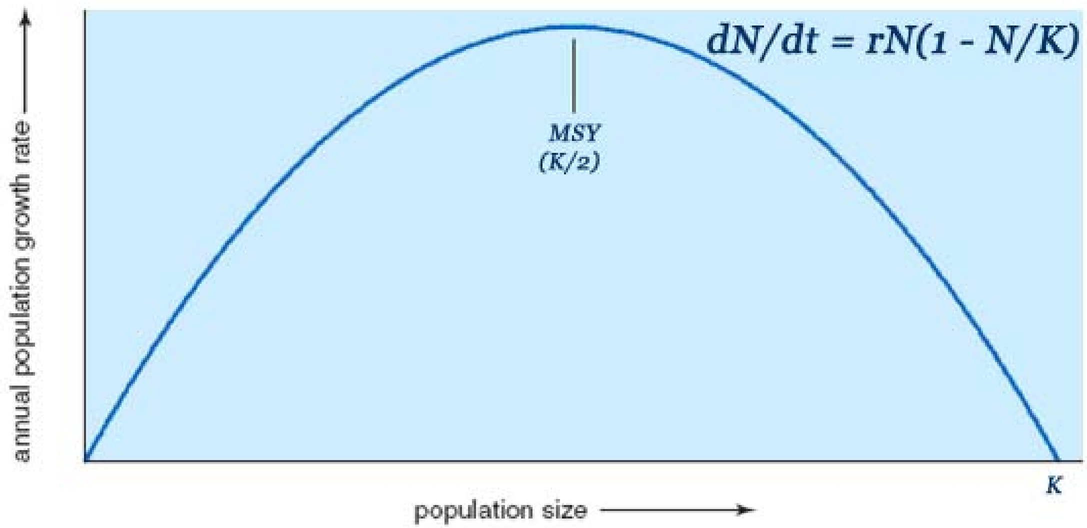
Brackish marshes



- **Caught in the squeeze!** Land is subsiding on one side and sea level rise causes gradual inundation by salt water on the other.
- Marsh stability is controlled by the balance between accretion (deposition, associated with hydrology), erosion and subsidence.
- Plants and the food chains they support must be more salt tolerant or change will result.
- Add to this possible falling groundwater levels and…. An open hypothesis that perhaps this will exacerbate the already problematic invasion by *Phragmites?*

Graphics: USGS and Bernd Blossey, Cornell University.

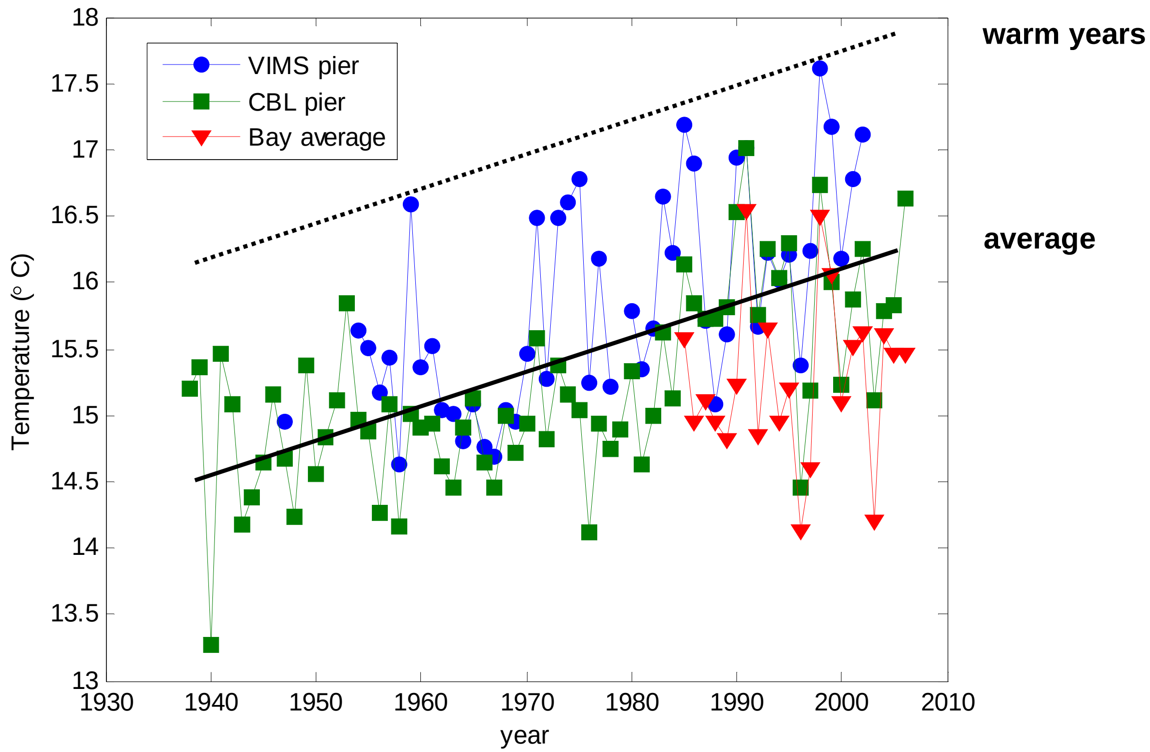
Fishery management made simple



- To insure sustainability (in compliance with Magnuson)…
- R>M+F: recruitment and subsequent growth exceeds the combination of losses to natural mortality and fishery harvests.
- A fundamental problem is that most of our experience driving management is based in an equilibrium environment overlaid with stochastic variability
- But what happens when the baseline moves and we do not know (a) where the end point will be in the baseline, and (b) how the biological system will respond (linear, non-linear, stepwise, chaotic?)

Rising temperatures in Chesapeake Bay

The data



Both the average, and the maximum, annual temperatures have increased by more than 1°C over the last four decades

Source: Pyke et al. *draft*. Climate change and the Chesapeake Bay. Chesapeake Bay Program STAC Report.

II. Changes in distribution

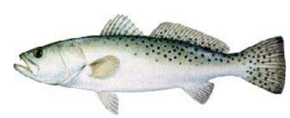
Likely changes in fish distribution in Chesapeake Bay

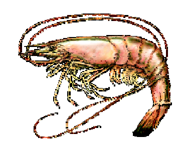
SPECIES	LIKELY TREND	CLIMATE CHANGE IMPACTS IN CHESAPEAKE BAY
Winter flounder	🔴	Water temperatures could exceed habitable range.
Soft-shelled clam	🔴	Water temperatures could exceed habitable range.
Rockfish	🟠	Water temperatures could reach near the upper limit of habitable range and also conducive to outbreaks of mycobacterial infections.
Atlantic sturgeon	🟠	Water temperatures could reach near the upper limit of habitable range.
Blue crab	🟠	Declining eelgrass habitat with rising sea level and exacerbated eutrophication.
Atlantic menhaden	🟠	Warmer water more conducive to mycobacterial infections.
Eastern oyster	🟠	Warmer water more conducive to Dermo and MSX.
Brown shrimp	🟢	Warmer water more favorable.
Southern flounder	🟢	Warmer water more favorable.
Black drum	🟢	Warmer water more favorable.
Grouper	🟢	Warmer water more favorable.
Spotted seatrout	🟢	Warmer water more favorable.

LIKELY LOSS FROM BAY

LIKELY DECLINE

LIKELY INCREASE





Range changes and extinctions are predicted for Chesapeake commercial species

Source: National Wildlife Federation. 2007. The Chesapeake Bay and global warming: A paradise lost for hunters, anglers, and outdoor enthusiasts? (http://www.nwf.org/sealevelrise/pdfs/chesapeake_bay_final.pdf).

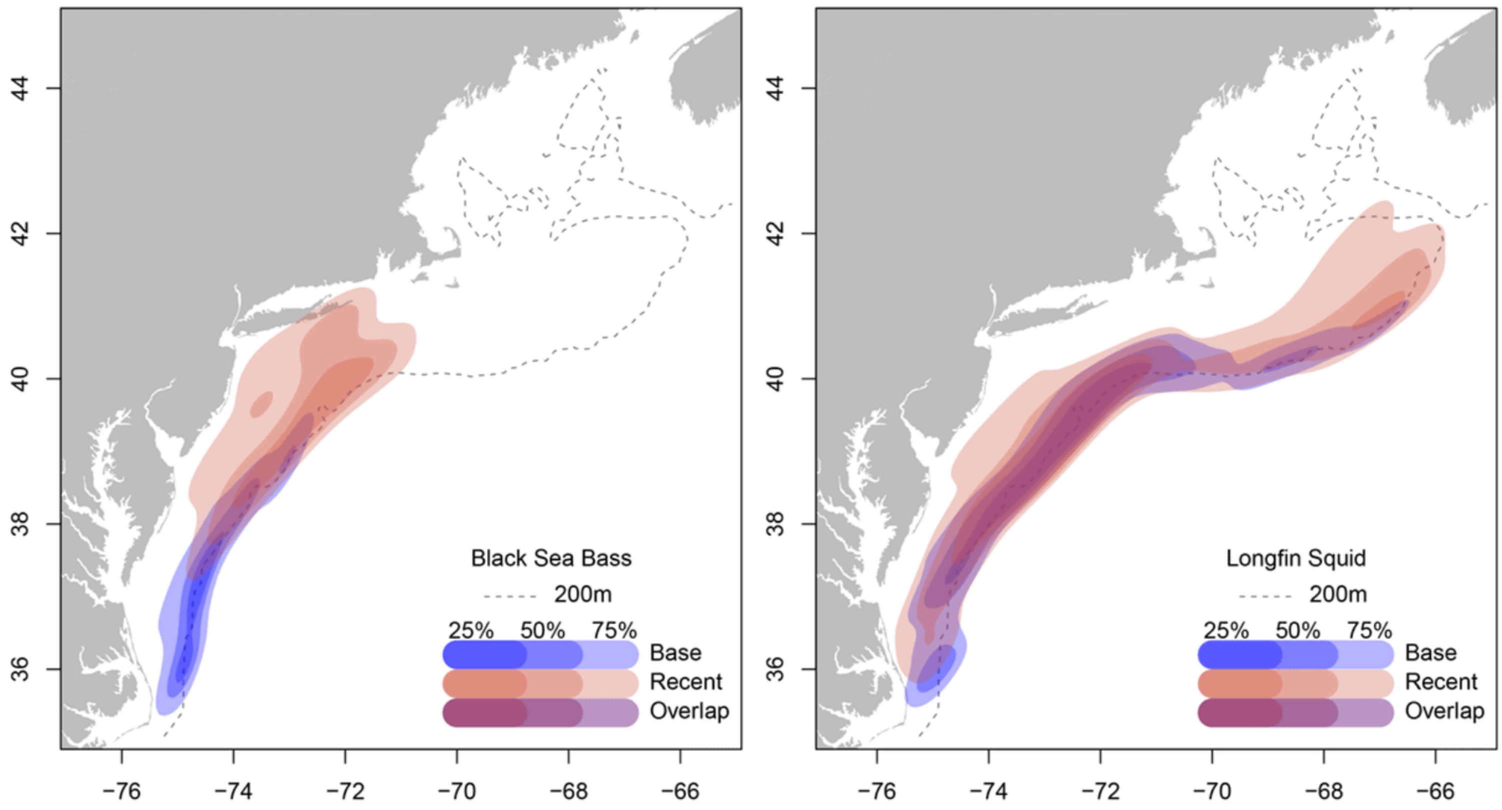


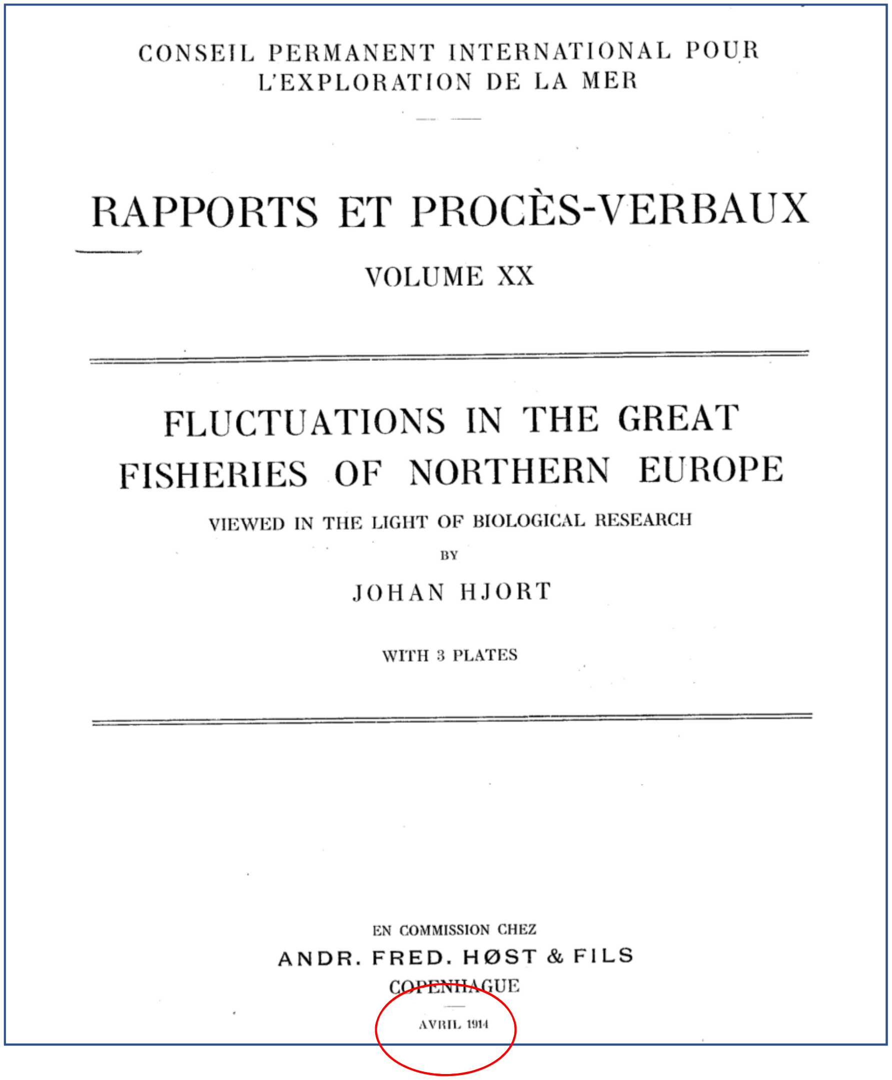
Figure 10: Shifts in species distribution, 1970s (blue), recent (red) and overlap (purple)

DRAFT Mid-Atlantic EAFM Risk Assessment Documentation

S. Gaichas, G. DePiper, R. Seagraves, L. Colburn, A. Loftus, M. Sabo, B. Muffley

September 29, 2017

Natural variation in fish stocks have been well documented for well over a century



CONSEIL PERMANENT INTERNATIONAL POUR
L'EXPLORATION DE LA MER

RAPPORTS ET PROCÈS-VERBAUX

VOLUME XX

FLUCTUATIONS IN THE GREAT FISHERIES OF NORTHERN EUROPE

VIEWED IN THE LIGHT OF BIOLOGICAL RESEARCH

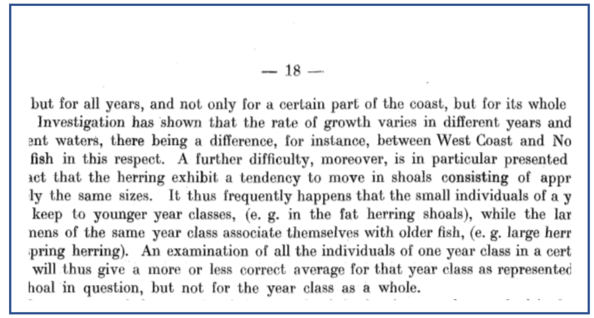
BY

JOHAN HJORT

WITH 3 PLATES

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

AVRIL 1914



— 18 —

but for all years, and not only for a certain part of the coast, but for its whole
Investigation has shown that the rate of growth varies in different years and
ent waters, there being a difference, for instance, between West Coast and No
fish in this respect. A further difficulty, moreover, is in particular presented
act that the herring exhibit a tendency to move in shoals consisting of appr
ly the same sizes. It thus frequently happens that the small individuals of a y
keep to younger year classes, (e. g. in the fat herring shoals), while the lar
nens of the same year class associate themselves with older fish, (e. g. large herr
pring herring). An examination of all the individuals of one year class in a cert
will thus give a more or less correct average for that year class as represented
hoal in question, but not for the year class as a whole.

The match-mismatch theory….

Match: strong years classes occur when spawning is coincident with the spring plankton bloom, thus insuring an adequate supply of food for the young life history stages….

Mismatch: when spawning and the bool are not coincident year class failures may result.

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE

10.1002/2015JC011346

Key Points:

- Northwest Atlantic circulation bias is reduced in a high-resolution global climate model
- Atmospheric CO_2 doubling over 70–80 years results in an enhanced warming of the Northwest Atlantic
- The enhanced warming is associated with a weakening AMOC and regional circulation change

Supporting Information:

Enhanced warming of the Northwest Atlantic Ocean under climate change

Vincent S. Saba[1], Stephen M. Griffies[2], Whit G. Anderson[2], Michael Winton[2], Michael A. Alexander[3], Thomas L. Delworth[2], Jonathan A. Hare[4], Matthew J. Harrison[2], Anthony Rosati[2], Gabriel A. Vecchi[2], and Rong Zhang[2]

[1]National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Geophysical Fluid Dynamics Laboratory, Princeton University, Princeton, New Jersey, USA, [2]National Oceanic and Atmospheric Administration, Geophysical Fluid Dynamics Laboratory, Princeton University, Princeton, New Jersey, USA, [3]National Oceanic and Atmospheric Administration, Earth System Research Laboratory, Physical Sciences Division, Boulder, Colorado, USA, [4]National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Narragansett, Rhode Island, USA

"The CO_2 doubling response from this <u>model</u> shows that upper-ocean (0–300 m) temperature in the Northwest Atlantic Shelf warms at a rate nearly twice as fast as the coarser models and nearly three times faster than the global average", and that "…prior climate change projections for the Northwest Atlantic may be far too conservative."

PLOS | ONE

RESEARCH ARTICLE

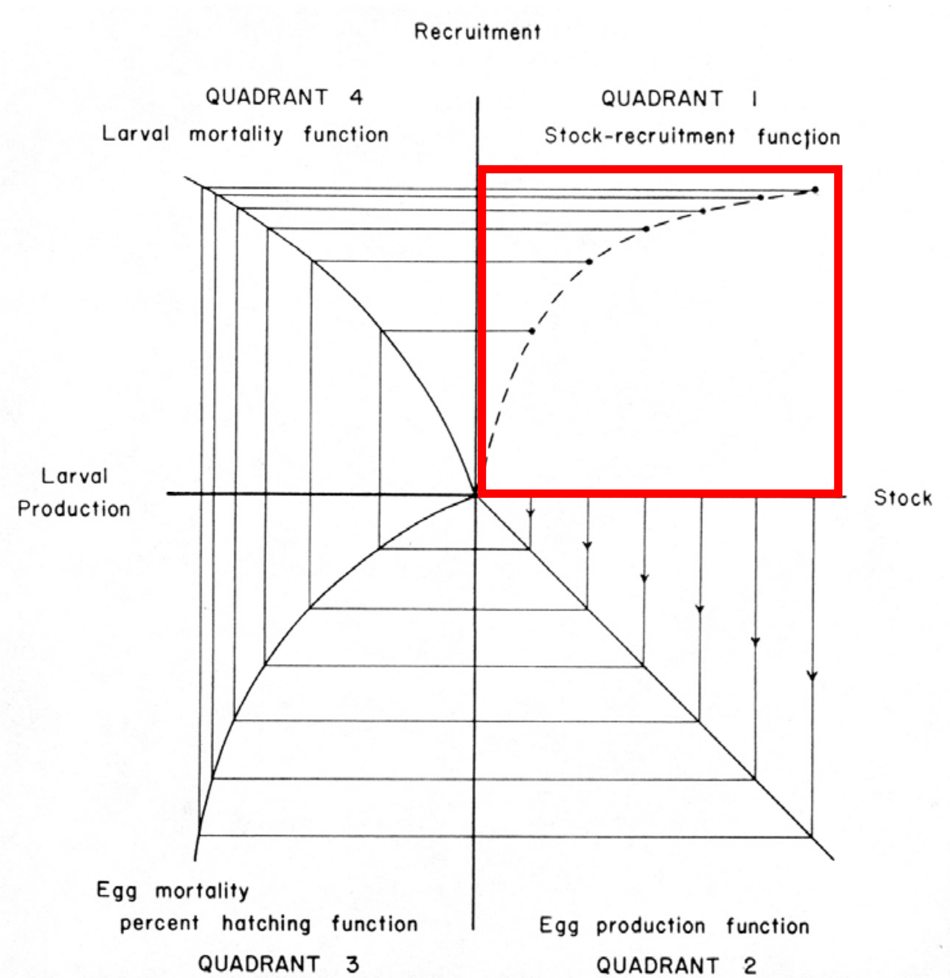
A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf

Jonathan A. Hare[1]*, Wendy E. Morrison[2], Mark W. Nelson[2], Megan M. Stachura[3¤a], Eric J. Teeters[2], Roger B. Griffis[4], Michael A. Alexander[5], James D. Scott[5], Larry Alade[6], Richard J. Bell[1¤b], Antonie S. Chute[6], Kiersten L. Curti[6], Tobey H. Curtis[7], Daniel Kircheis[8], John F. Kocik[8], Sean M. Lucey[6], Camilla T. McCandless[1], Lisa M. Milke[9], David E. Richardson[1], Eric Robillard[6], Harvey J. Walsh[1], M. Conor McManus[10¤c], Katrin E. Marancik[10], Carolyn A. Griswold[1]

Indeed, there is a body of evidence suggesting that many ecologically and economically important species in this region are susceptible to climate change …

"***….records of surface sea water temperature (SST) extend back to 1854 based on lightship and other records (Friedland and Hare 2007); however, companion SBT records are more limited, the best holistic projection being provided by a 50-year hindcast of circulation on the MAB continental shelf (Kang and Curchister 2013).”***

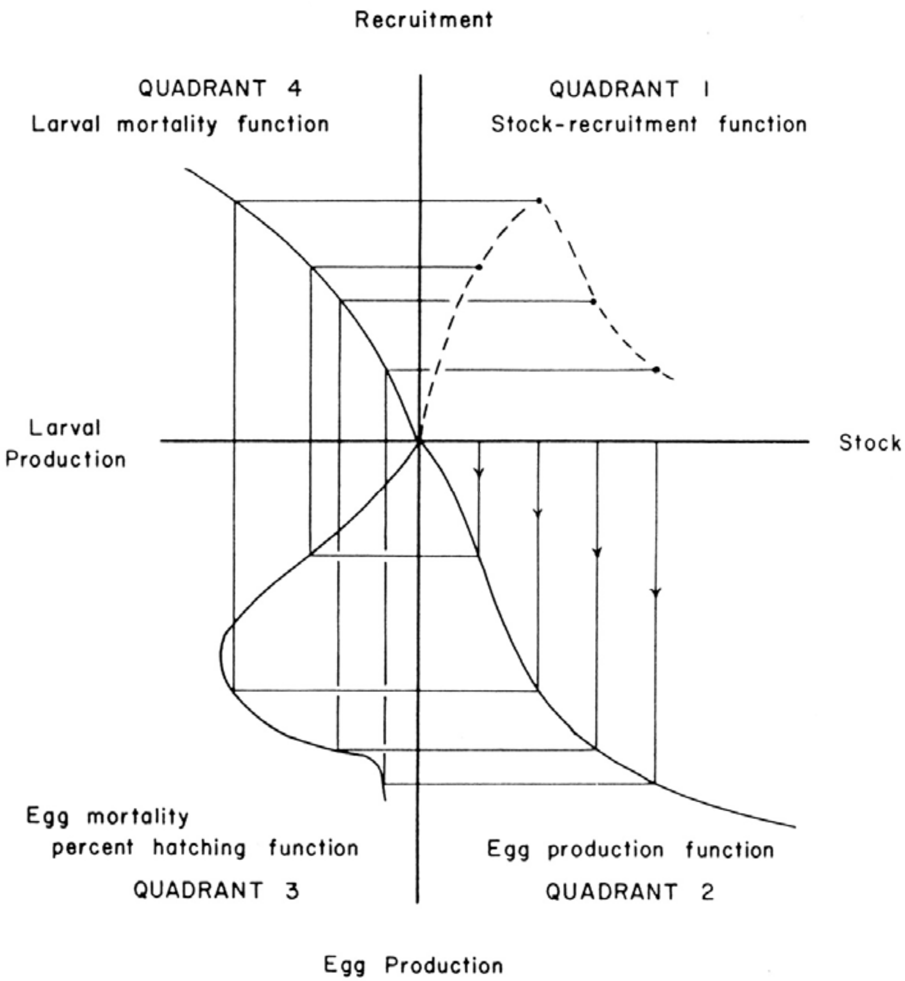
Complex systems!! Is there a framework to examine them and provide proactive advice?

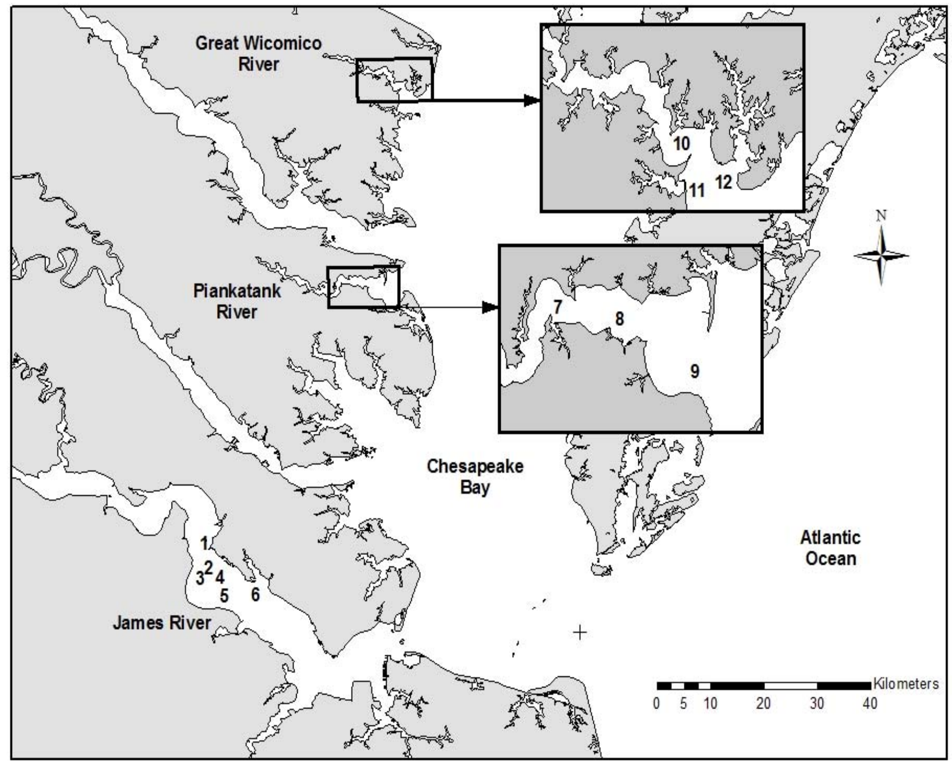


"Paulik (1973) created a diagram that qualitatively depicted the theoretical non-linear links between life history stages of Pacific salmon. This diagram suggested that density-dependence during juvenile and adult stages could be as important as that occurring during larval stages. I thought that his diagram was so important that I amplified its interpretation and named it the "Paulik Diagram" in *The Dynamics of Fish Populations*."

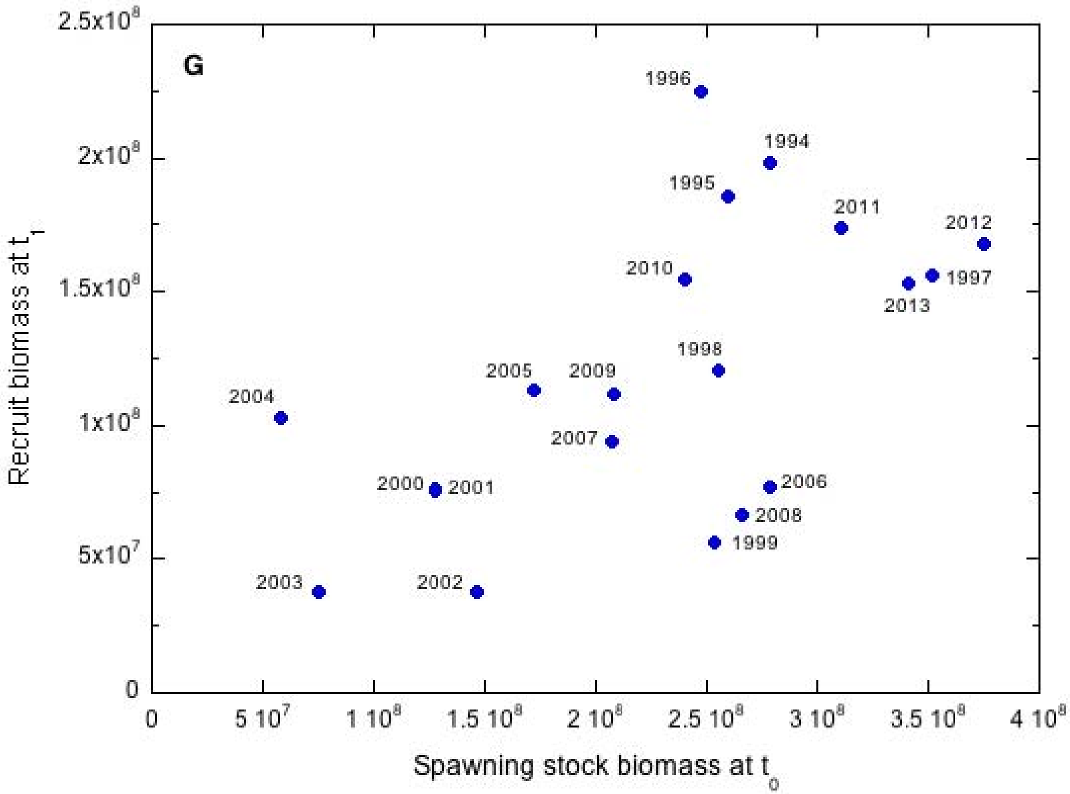
Brain J, Rothschild (2015). On the birth and death of ideas in marine science. ICES Journal of Marine Science (2015), 72(5), 1237–1244. doi:10.1093/icesjms/fsv027

An example from continuing work on the Virginia oyster resource – a 23 year VIMS-VMRC collaboration

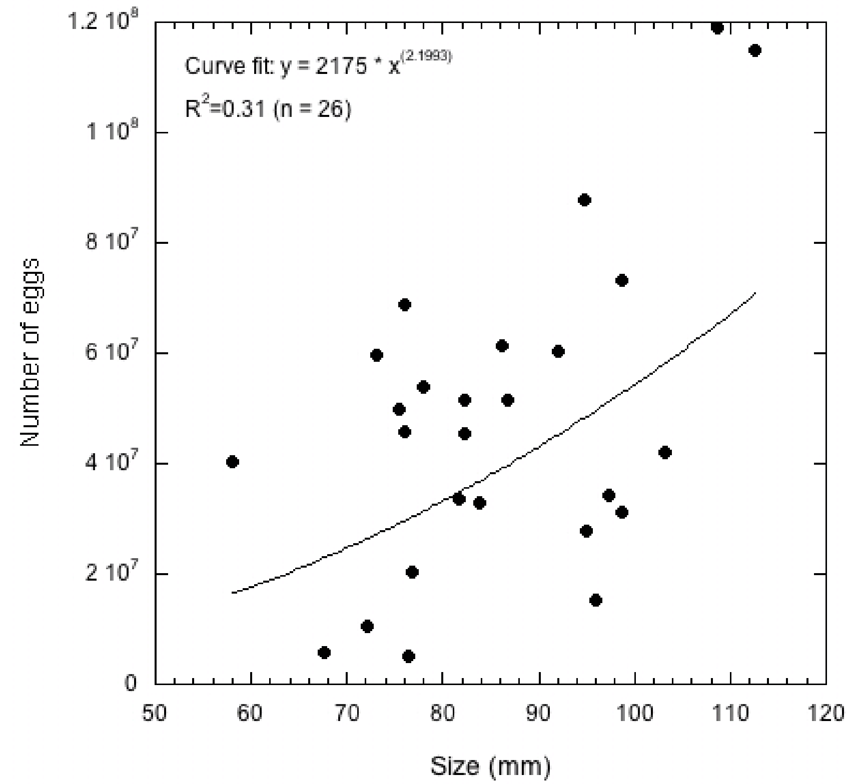




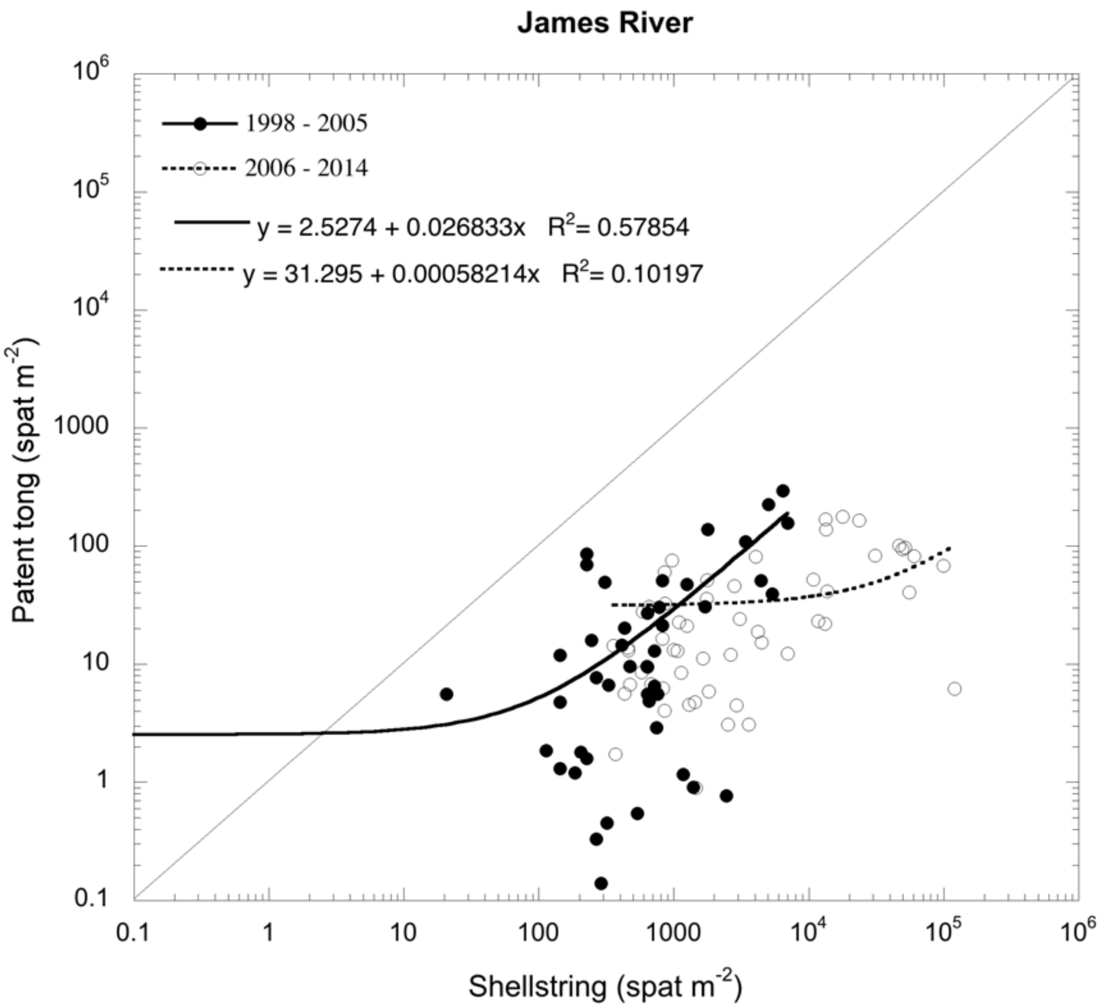
The S/R relationship

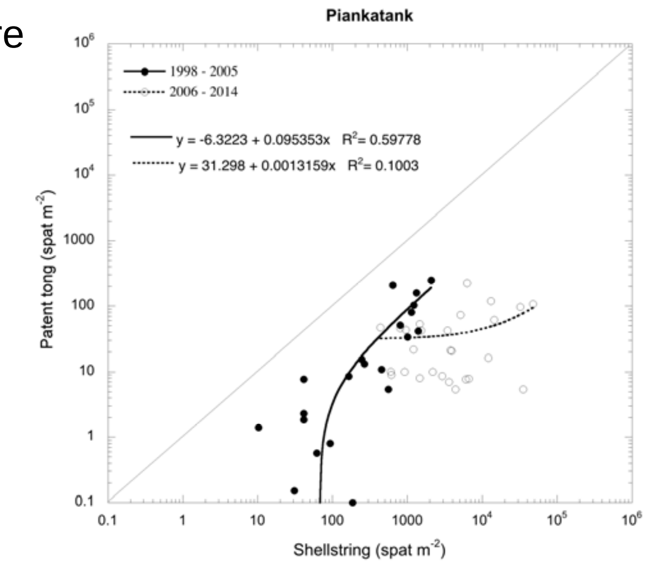


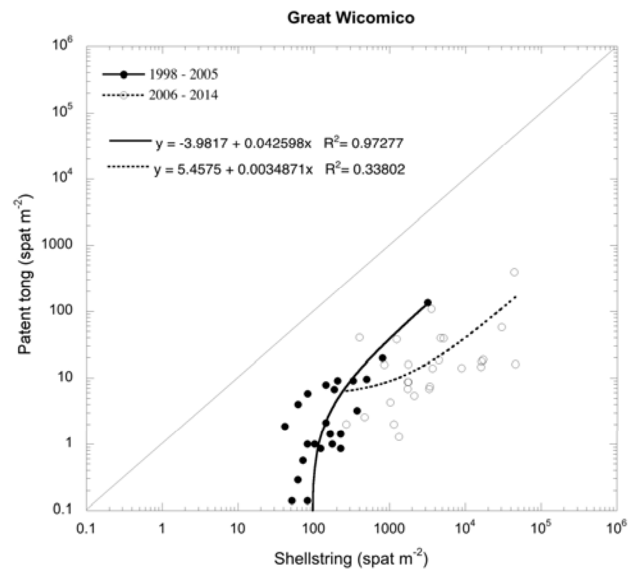
Egg production (fecundity)

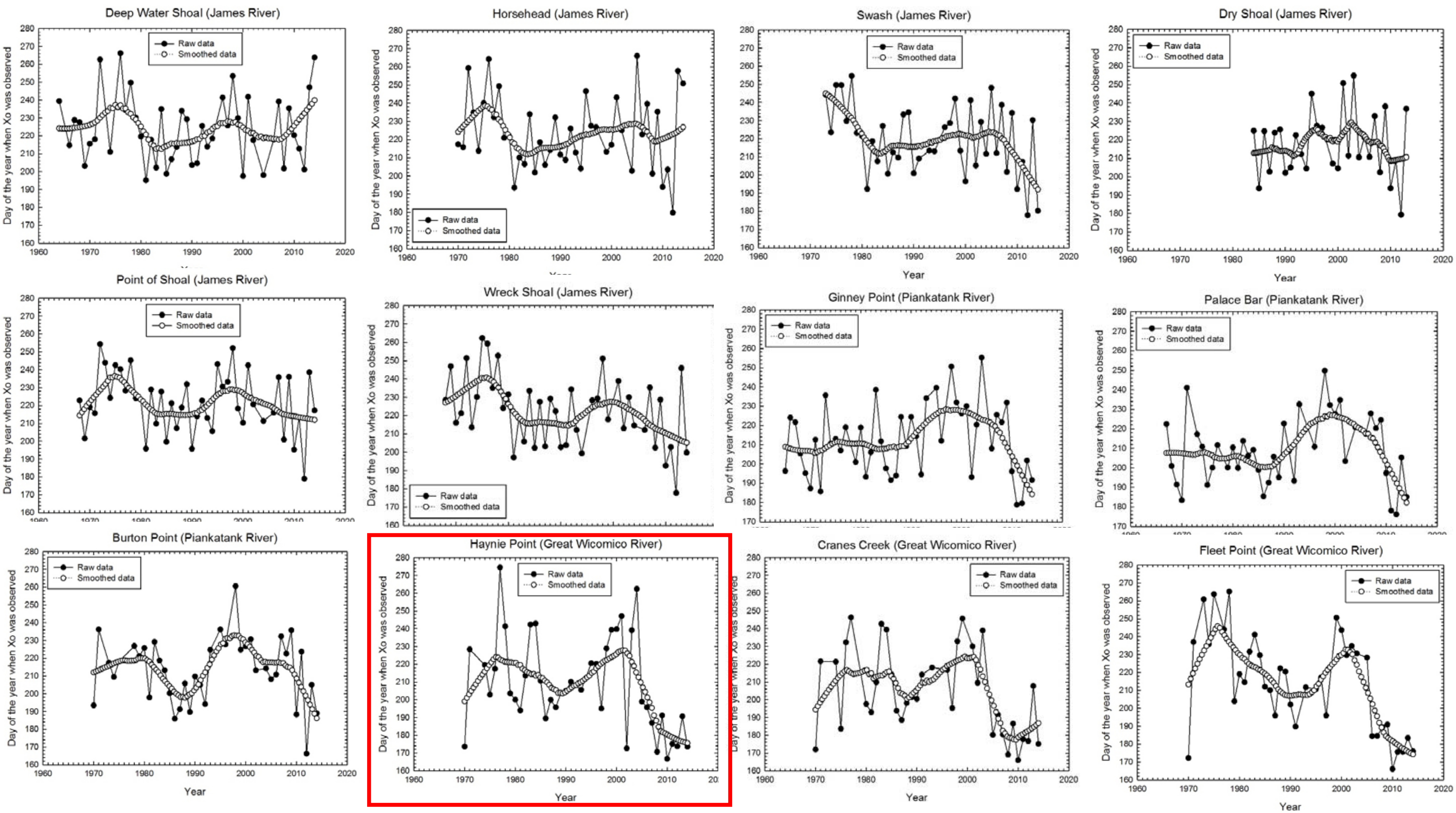


The curious, non-linear, time dependent early post recruit survival picture

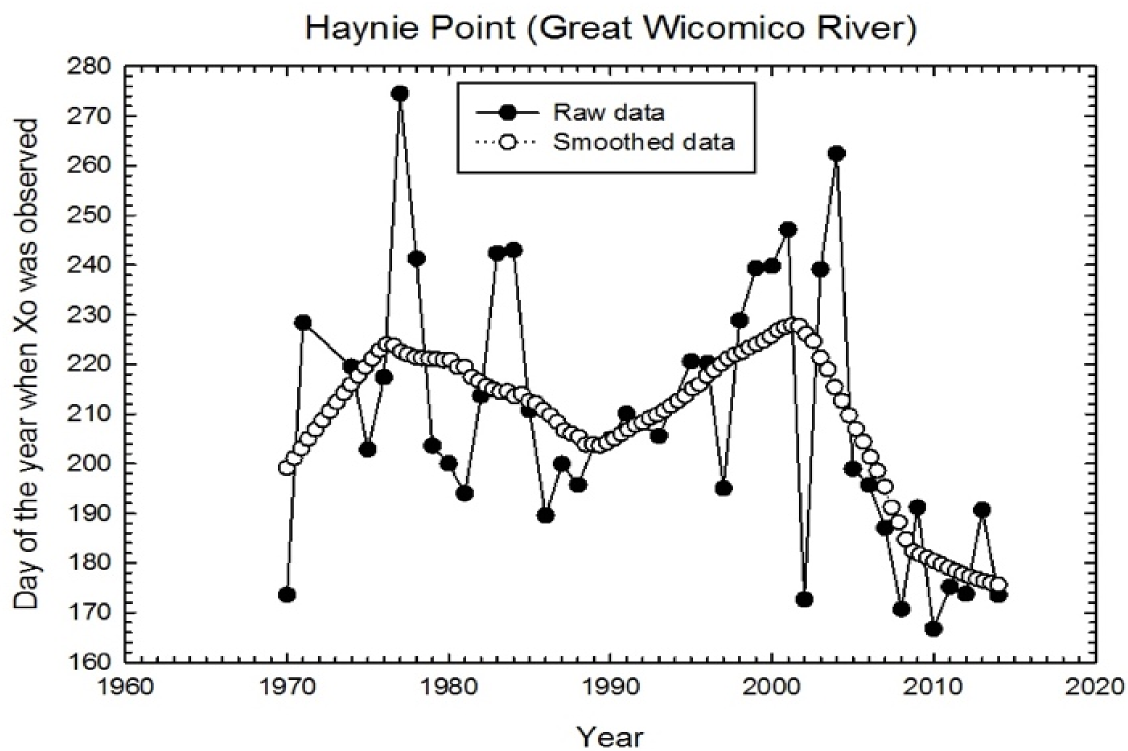






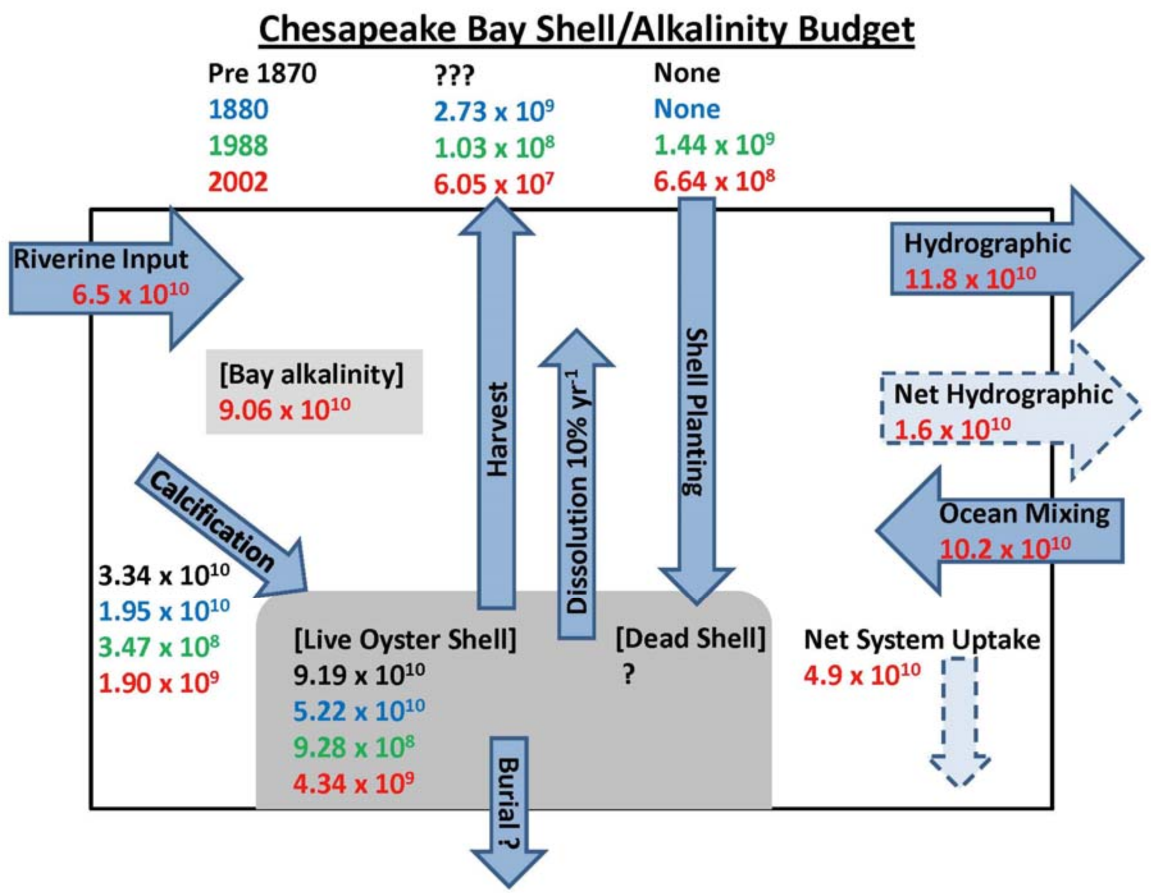


Deep Water Shoal (James River)
Horsehead (James River)
Swash (James River)
Dry Shoal (James River)
Point of Shoal (James River)
Wreck Shoal (James River)
Ginney Point (Piankatank River)
Palace Bar (Piankatank River)
Burton Point (Piankatank River)
Haynie Point (Great Wicomico River)
Cranes Creek (Great Wicomico River)
Fleet Point (Great Wicomico River)
Raw data
Smoothed data
Day of the year when Xo was observed
Year



The period of oyster recruitment is changing: over the 200-2015 time frame the 50th percentile of recruitment moved forward (earlier) by 50 days! I suggest this is response to disease challenge – earlier spawning avoids the major impacts of disease. Complex interaction of one host and two diseases, and climate change is only part of this interaction…but we have a new equilibrium!

“Estuaries as the great titration” J. Dennis Burton and Peter S. Liss (1976) Estuarine Chemistry



The Chesapeake Bay alkalinity budget:
All unit in Moles or mole equivalents (Waldbusser, Powell and Mann (2013) Ecology)
using land-ocean interaction coastal zone (LOICZ) box model of Webb and Smith (1999)

…..historical records of seawater surface temperate (SST) in the NESLME extend back as far as 1854 based on lightship and other records (Friedland and Hare 2007); however, companion SBT records are more limited, the best holistic projection being provided by a 50-year hindcast of circulation on the MAB continental shelf (Kang and Curchister 2013).

SCIENTIFIC REPORTS

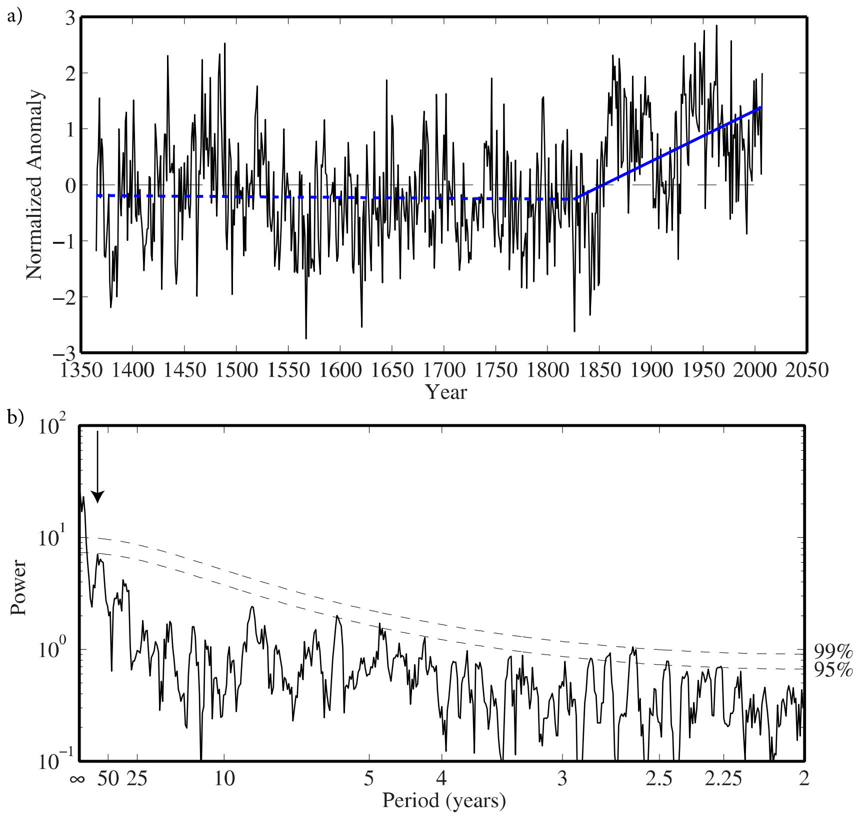
OPEN

Amplification of the Atlantic Multidecadal Oscillation associated with the onset of the industrial-era warming

Received: 30 September 2016
Accepted: 12 December 2016
Published: 23 January 2017

G. W. K. Moore[1], J. Halfar[2], H. Majeed[2], W. Adey[3] & A. Kronz[4]

North Atlantic sea surface temperatures experience variability with a periodicity of 60–80 years that is known as the Atlantic Multidecadal Oscillation (AMO). It has a profound imprint on the global climate system that results in a number of high value societal impacts. However the industrial period, i.e. the middle of the 19th century onwards, contains only two full cycles of the AMO making it difficult to fully characterize this oscillation and its impact on the climate system. As a result, there is a clear need to identify paleoclimate records extending into the pre-industrial period that contain an expression of the AMO. This is especially true for extratropical marine paleoclimate proxies where such expressions are currently unavailable. Here we present an annually resolved coralline algal time series from the northwest Atlantic Ocean that exhibits multidecadal variability extending back six centuries. The time series contains a statistically significant trend towards higher values, i.e. warmer conditions, beginning in the 19th century that coincided with an increase in the time series' multidecadal power. We argue that these changes are associated with a regional climate reorganization involving an amplification of the AMO that coincided with onset of the industrial-era warming.



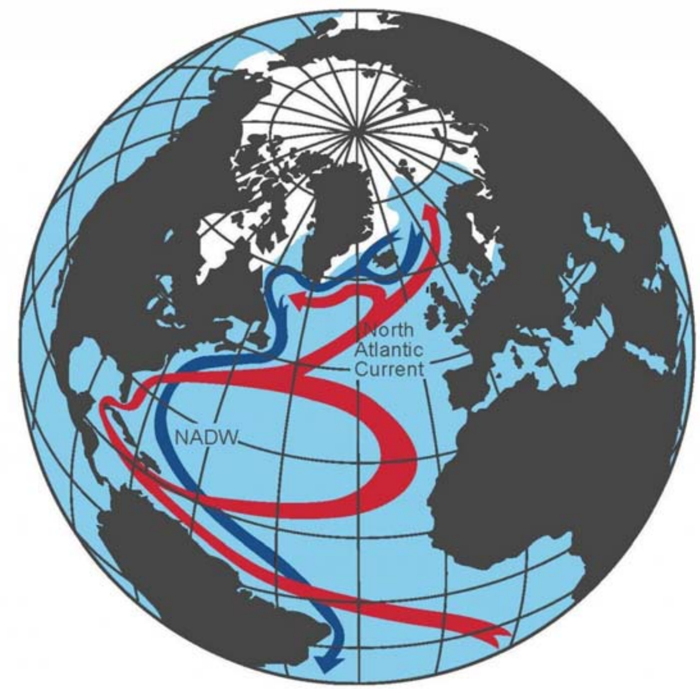


Figure 1. Temporal and spectral characteristics of the Labrador Sea algal time series 1365–2007. (**a**) The normalized time series (black curve). The piecewise linear least-squares fit to the time series with a breakpoint in 1825 is shown in blue. The trend post 1825 is statistically significant at the 99th percentile confidence interval based on a method that takes into account the temporal autocorrelation of the time series. (**b**) The power spectra of the time series as computed by the multi-taper method with estimates of statistical significance provided by an AR(1) fit to the data. The statistically significant power at a multidecadal period of ~80 years is indicated.

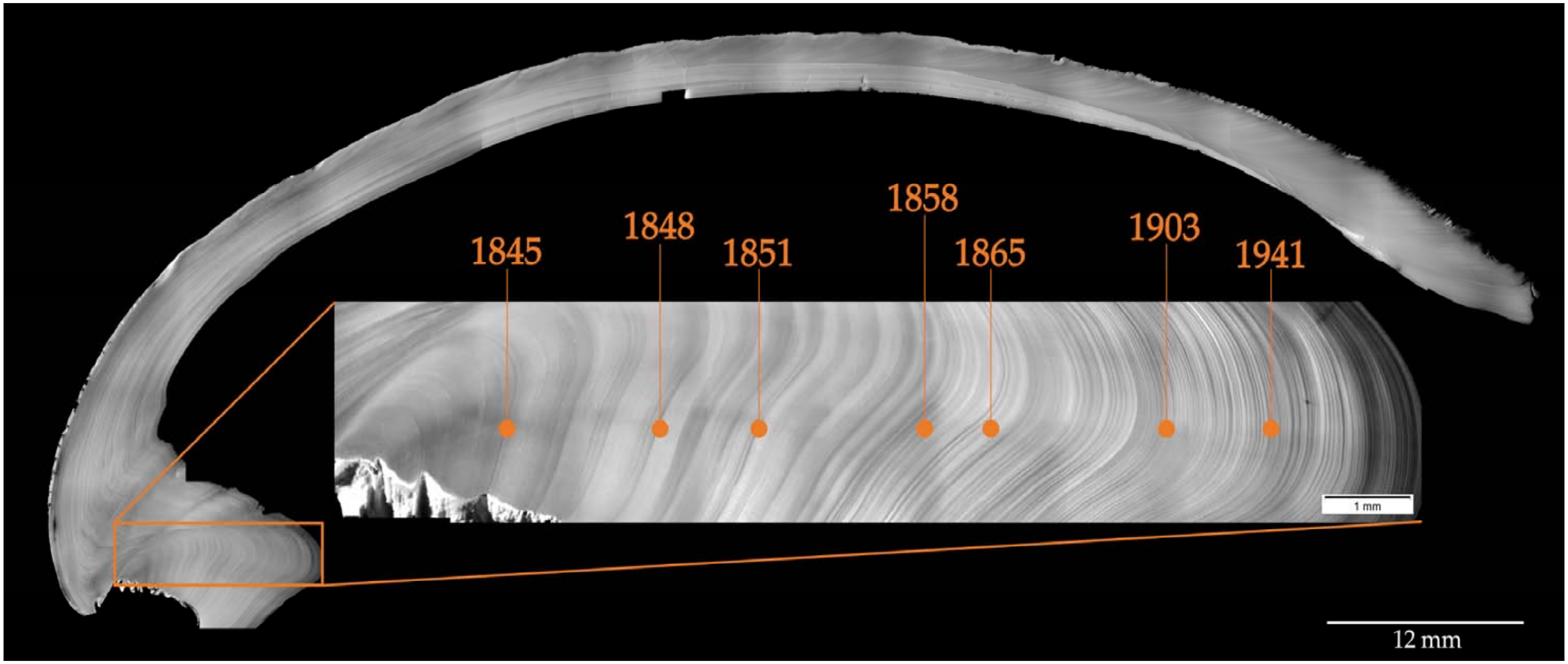
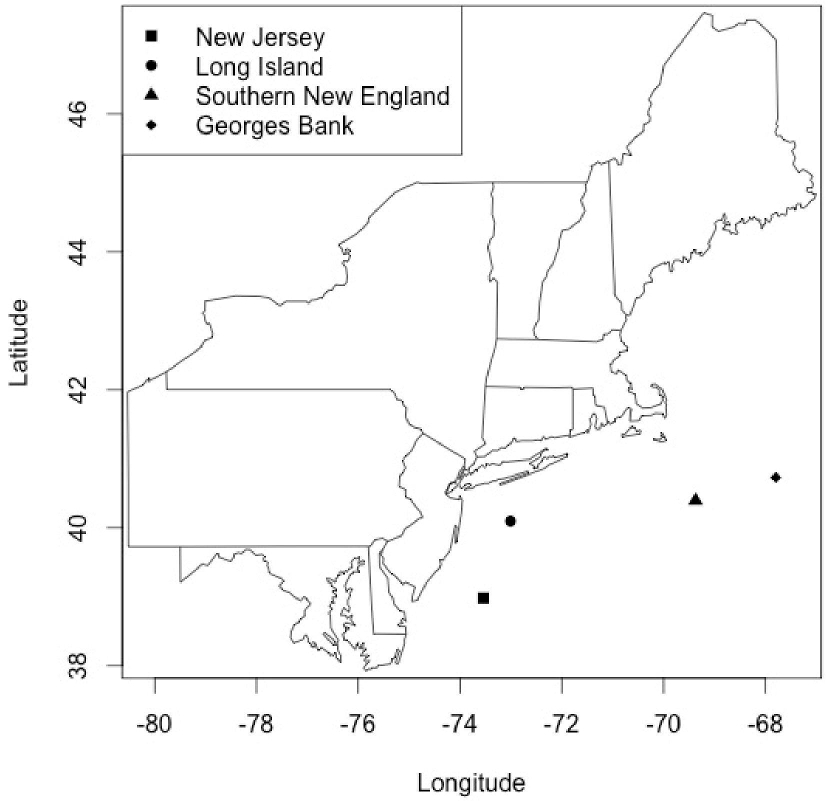
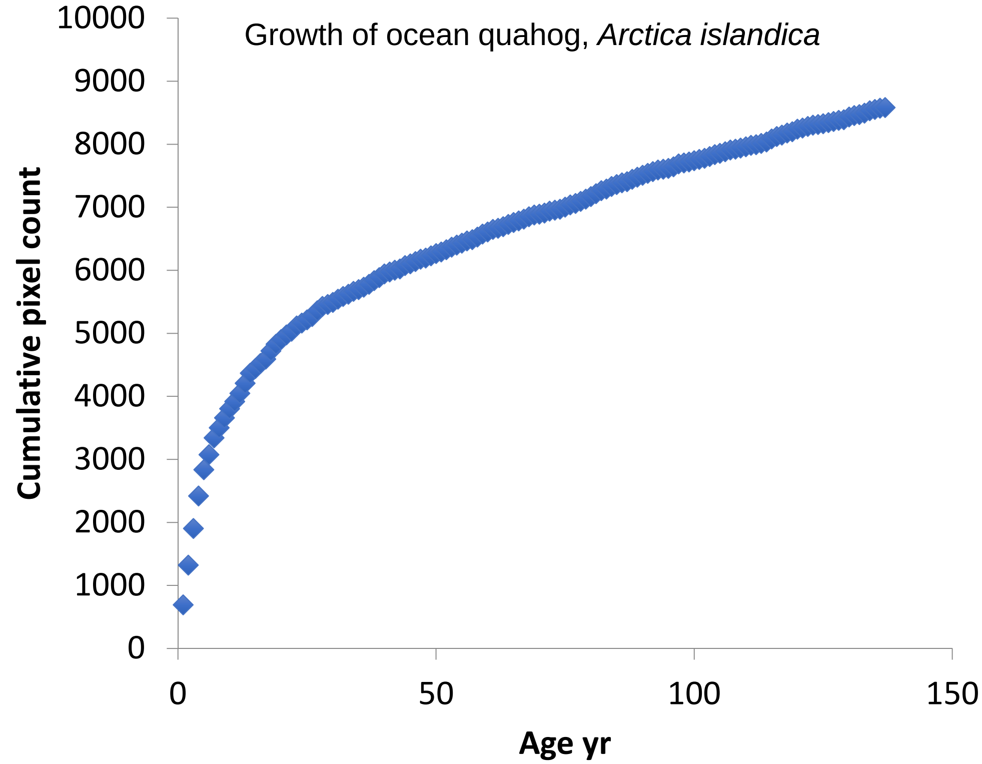


Image credit: Sara Pace and M. Chase Long, 2016, VIMS Molluscan Ecology Lab

A short story from the mahogany clam, *Arctica islandica*

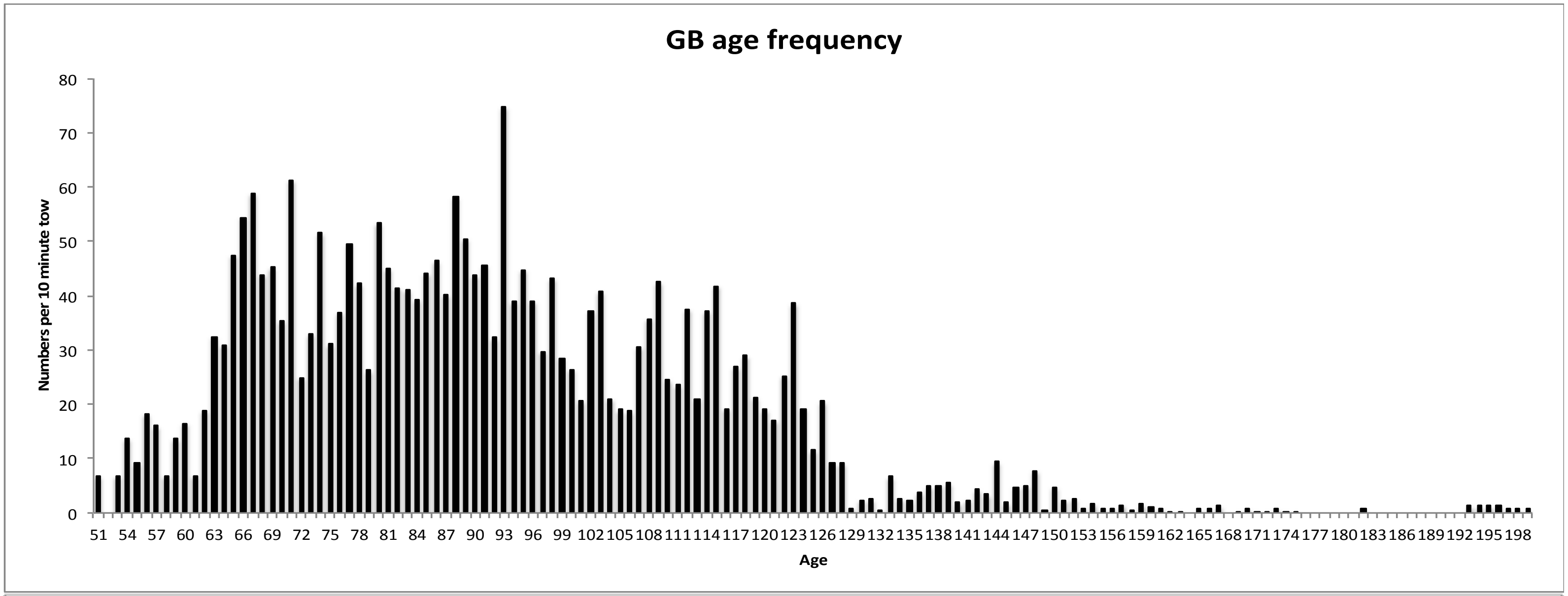


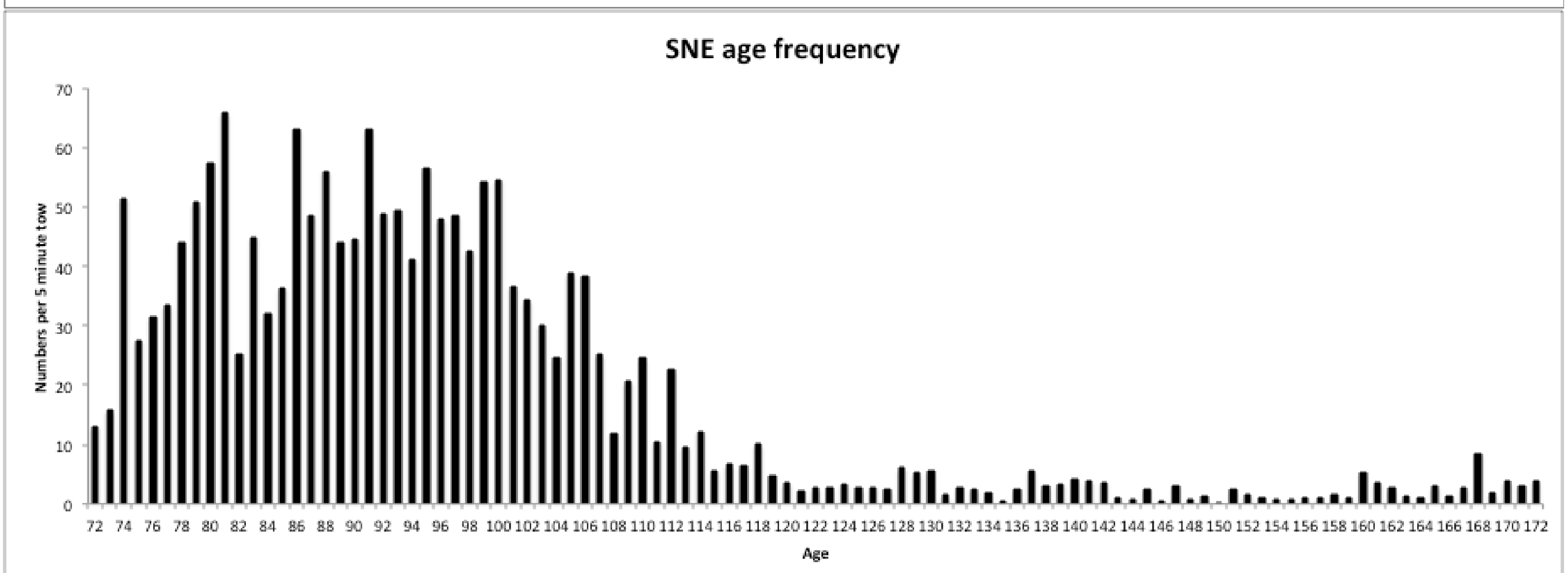


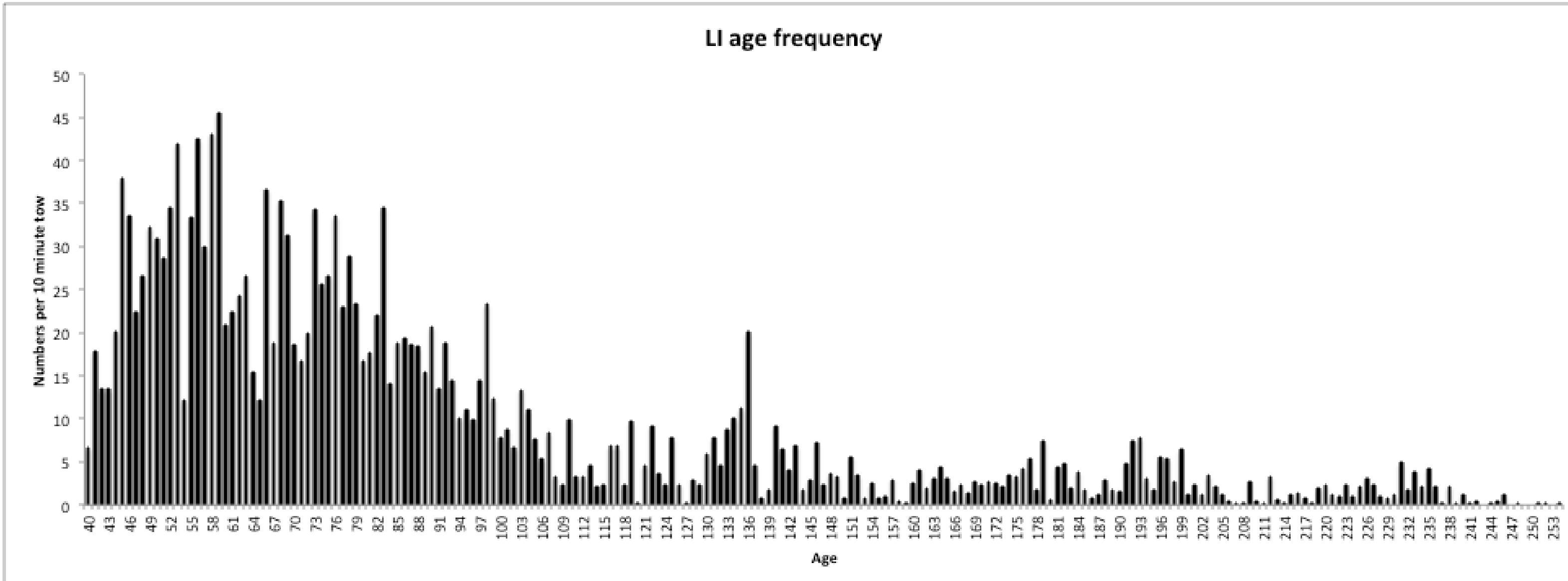
$$l_t = \frac{1}{\sqrt{f}} \ln \left| 2f(t-c) + 2\sqrt{f^2(t-c)^2+fa} \right| + d \qquad (1)$$

where, l_t means the size of a individual at age t, t is the age, ln denotes the natural logarism, and a, c, d and f are parameters.

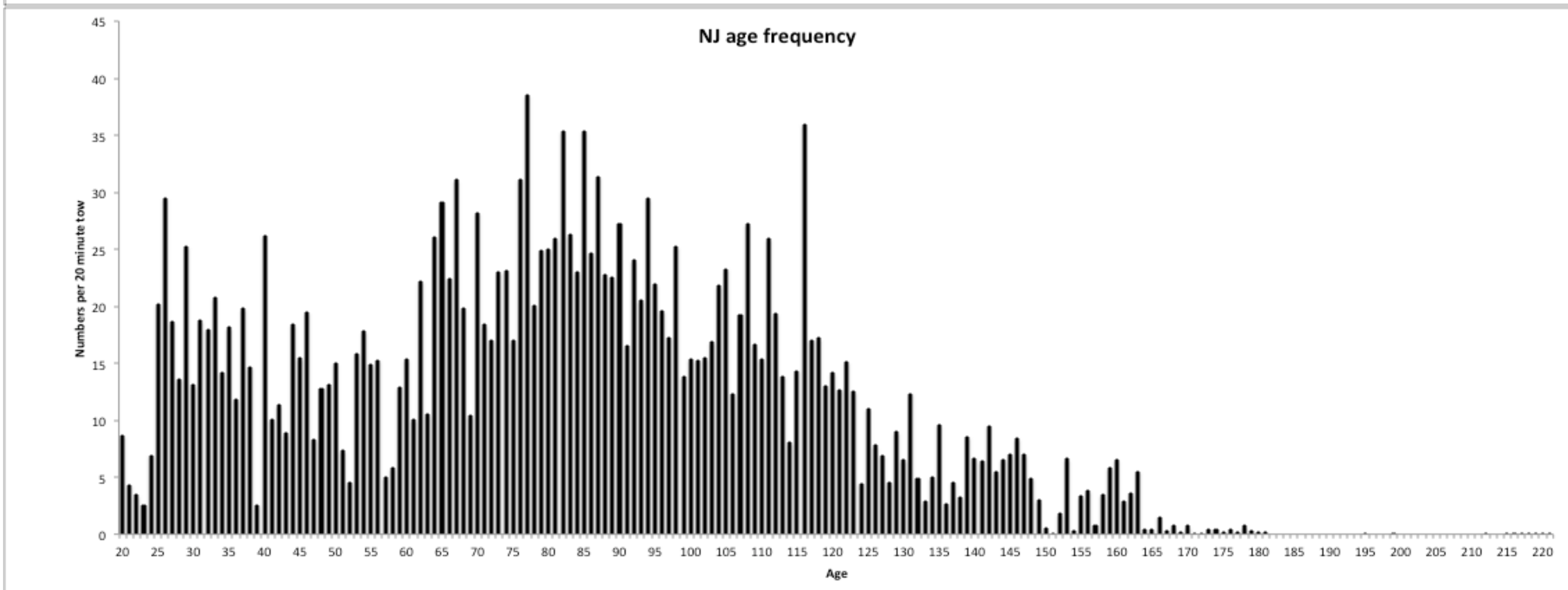
Tanaka, 1982. A new growth curve which expresses infinite increase. Publl. Amakusa Mar. Biol. Lab. 6(2): 167-177


GB age frequency
Numbers per 10 minute tow
Age
0
10
20
30
40
50
60
70
80
51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99 102 105 108 111 114 117 120 123 126 129 132 135 138 141 144 147 150 153 156 159 162 165 168 171 174 177 180 183 186 189 192 195 198

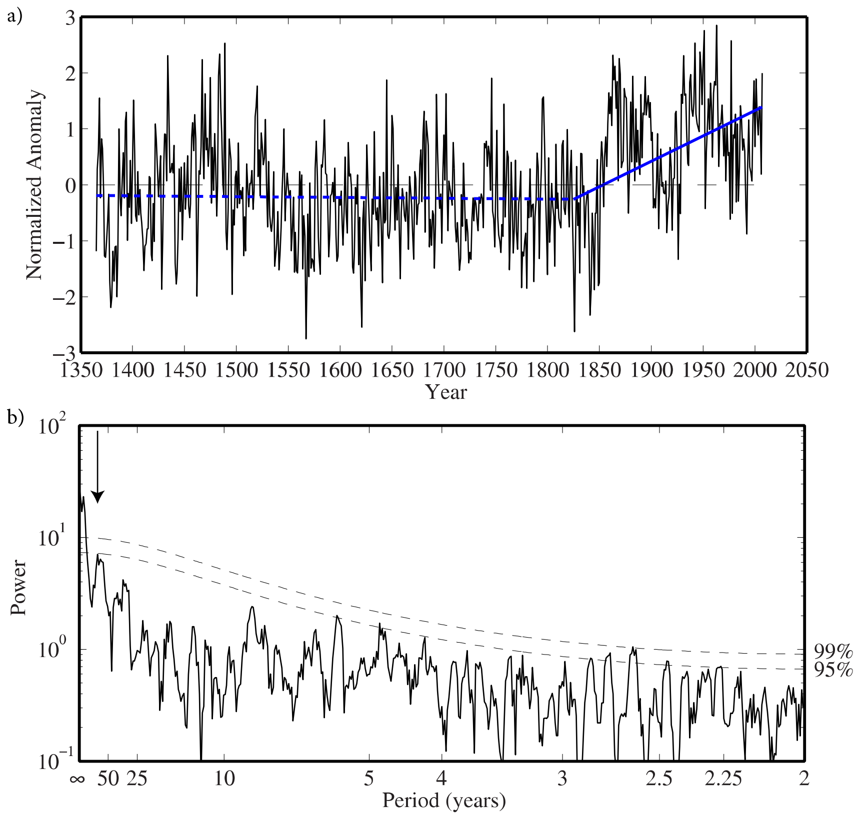

SNE age frequency
Numbers per 5 minute tow
Age
0
10
20
30
40
50
60
70
72 74 76 78 80 82 84 86 88 90 92 94 96 98 100 102 104 106 108 110 112 114 116 118 120 122 124 126 128 130 132 134 136 138 140 142 144 146 148 150 152 154 156 158 160 162 164 166 168 170 172



LI age frequency
Numbers per 10 minute tow
Age



NJ age frequency
Numbers per 20 minute tow
Age



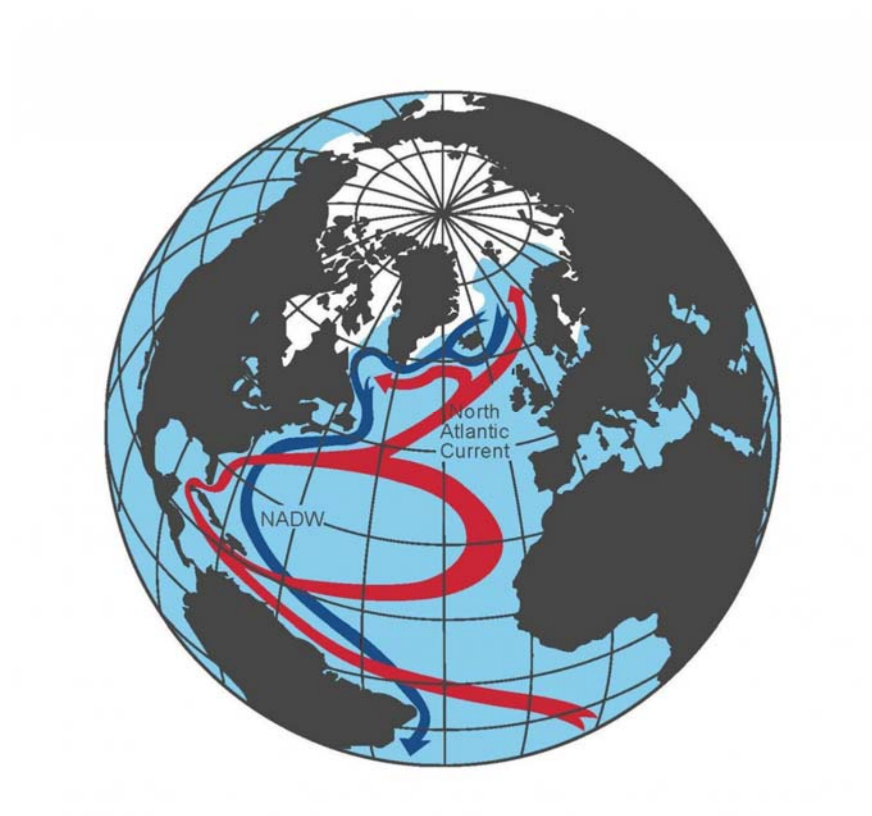
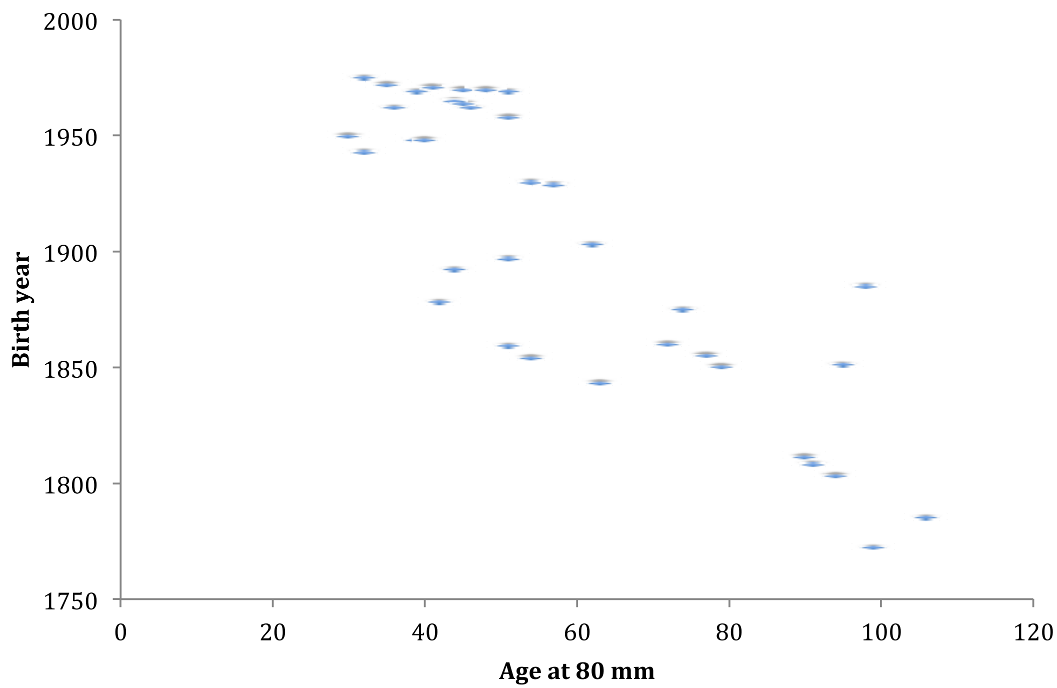
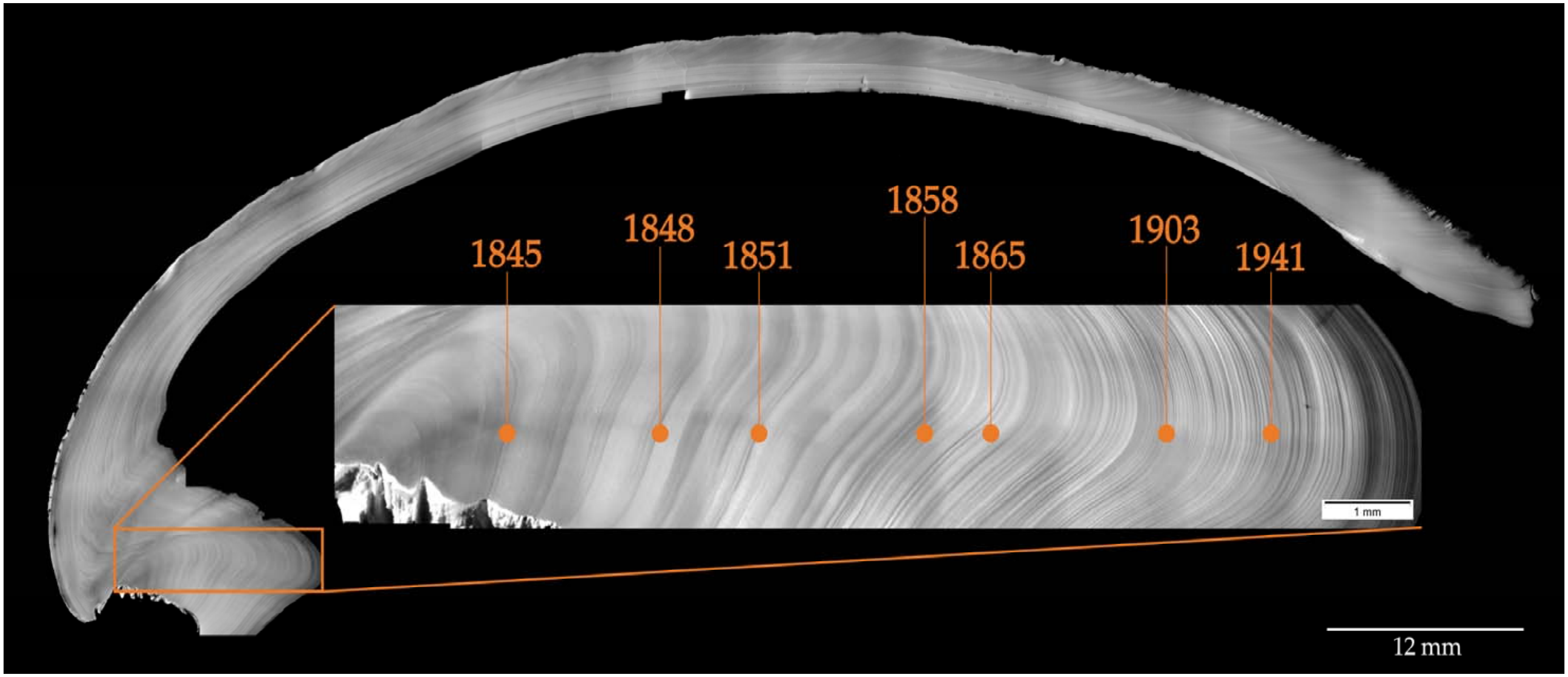


Figure 1. Temporal and spectral characteristics of the Labrador Sea algal time series 1365–2007. (**a**) The normalized time series (black curve). The piecewise linear least-squares fit to the time series with a breakpoint in 1825 is shown in blue. The trend post 1825 is statistically significant at the 99th percentile confidence interval based on a method that takes into account the temporal autocorrelation of the time series. (**b**) The power spectra of the time series as computed by the multi-taper method with estimates of statistical significance provided by an AR(1) fit to the data. The statistically significant power at a multidecadal period of ~80 years is indicated.



Long Island clams – age at 80 mm is decreasing with more recent birth year.
The clams are growing faster. Can we attribute this to warming over the past 250 years?
I suggest these populations are the initial invaders of these locations following the little Ice Age and that increasing growth rate may reflect temperature over that period.
What else can we extract from these shells to support out historical interpretations?



1845 - Florida becomes 27th state
1848 - California gold rush
1851 - Moby Dick is published
1858 - Trans-Atlantic cable
1865 – Civil war ends
1903 – Wright flies at Kitty Hawk
1941 – Pearl Harbor

ICES Journal of Marine Science

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Original Article

Life on the edge: environmental determinants of tilefish (*Lopholatilus chamaeleonticeps*) abundance since its virtual extinction in 1882

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Fisher, J. A. D., Frank, K. T., Petrie, B., and Leggett, W. C. Life on the edge: environmental determinants of tilefish (*Lopholatilus chamaeleonticeps*) abundance since its virtual extinction in 1882. – ICES Journal of Marine Science, 71: 2371–2378.

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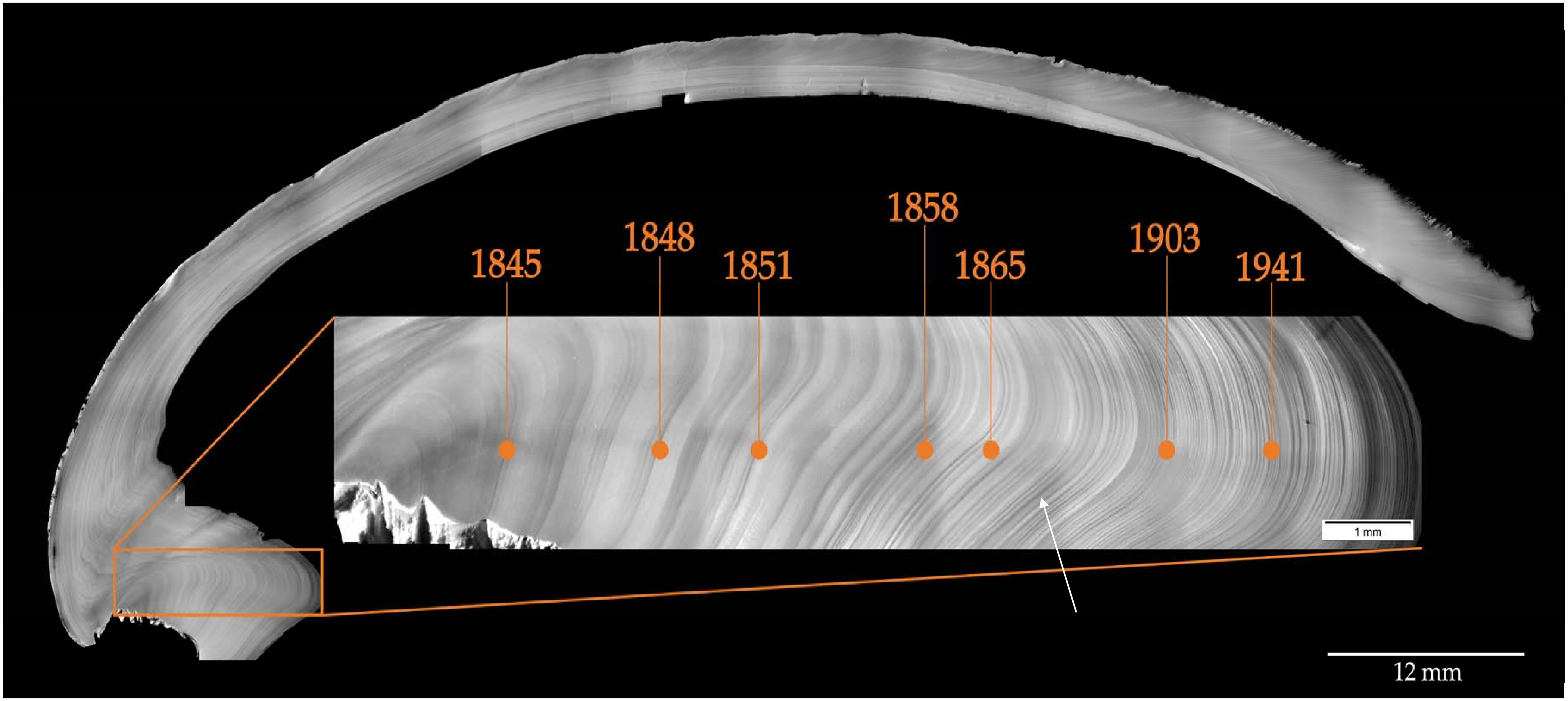
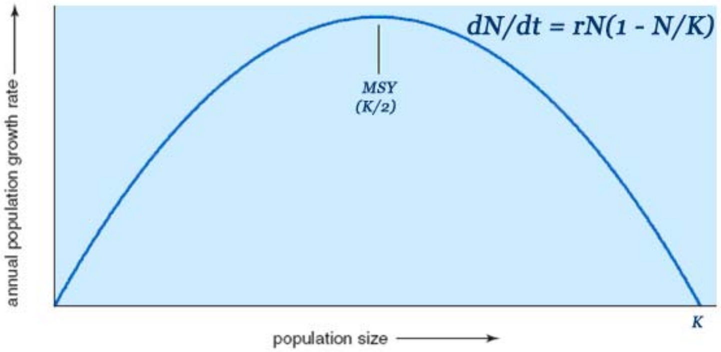
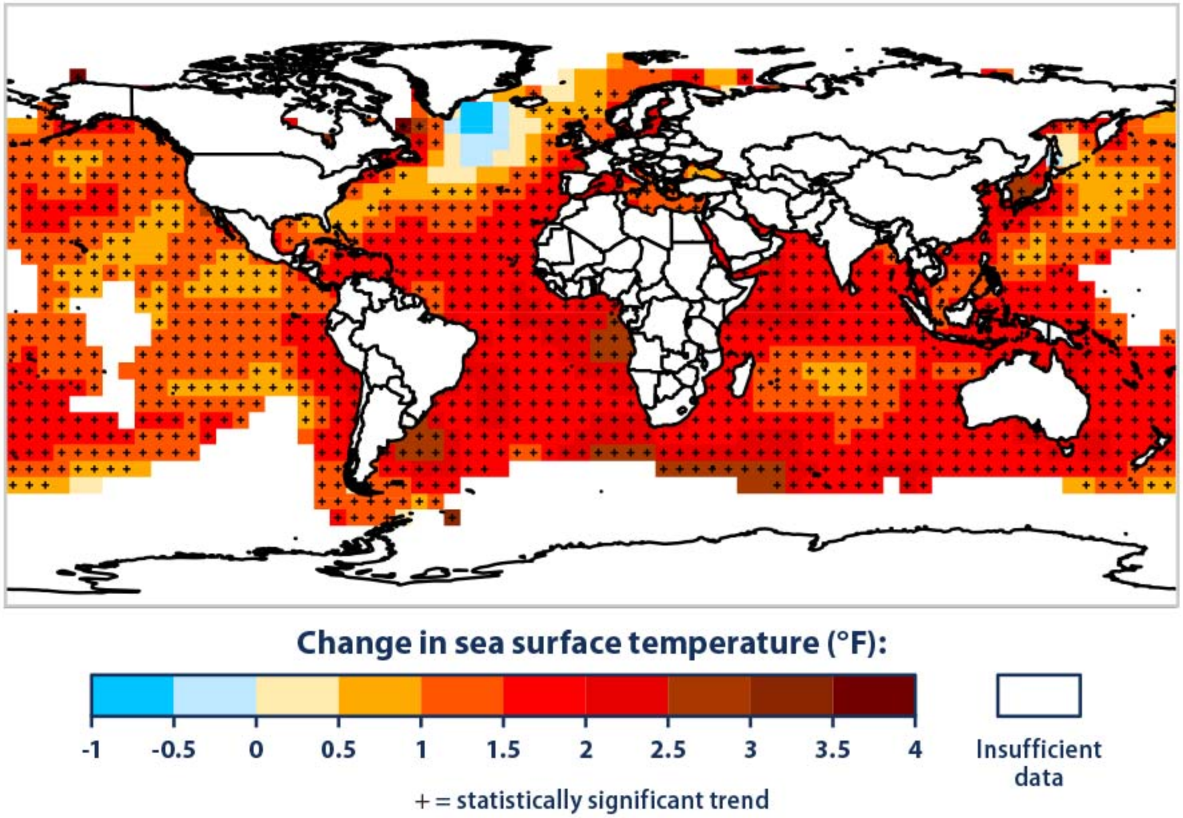
Unlike many temperate marine species that alter spatial or depth distributions in response to environmental change, tilefish (*Lopholatilus chamaeleonticeps*) has such specific habitat requirements that off the coast of New England, USA, it is restricted to the normally warm-water, upper continental shelf slope, where it excavates and occupies burrows. In 1882, tens of millions of adult tilefish died suddenly following the intrusion of lethally cold Subarctic water into the tilefish habitat. Here we show that the same climate driver implicated in the 1882 event (the North Atlantic Oscillation: NAO) has also affected commercial tilefish landings throughout most of the 20th century by altering slope water temperatures and likely the tilefish's reproductive success. We also show that this temperature–landings relationship broke down in the 1970s coincident with dramatically increased exploitation. Reconstructions of decadal to millennial scale variations in slope water temperatures explain why no mass mortality occurred following the 2010 negative NAO anomaly, despite being similar in magnitude to the NAO anomaly that preceded the 1882 event.

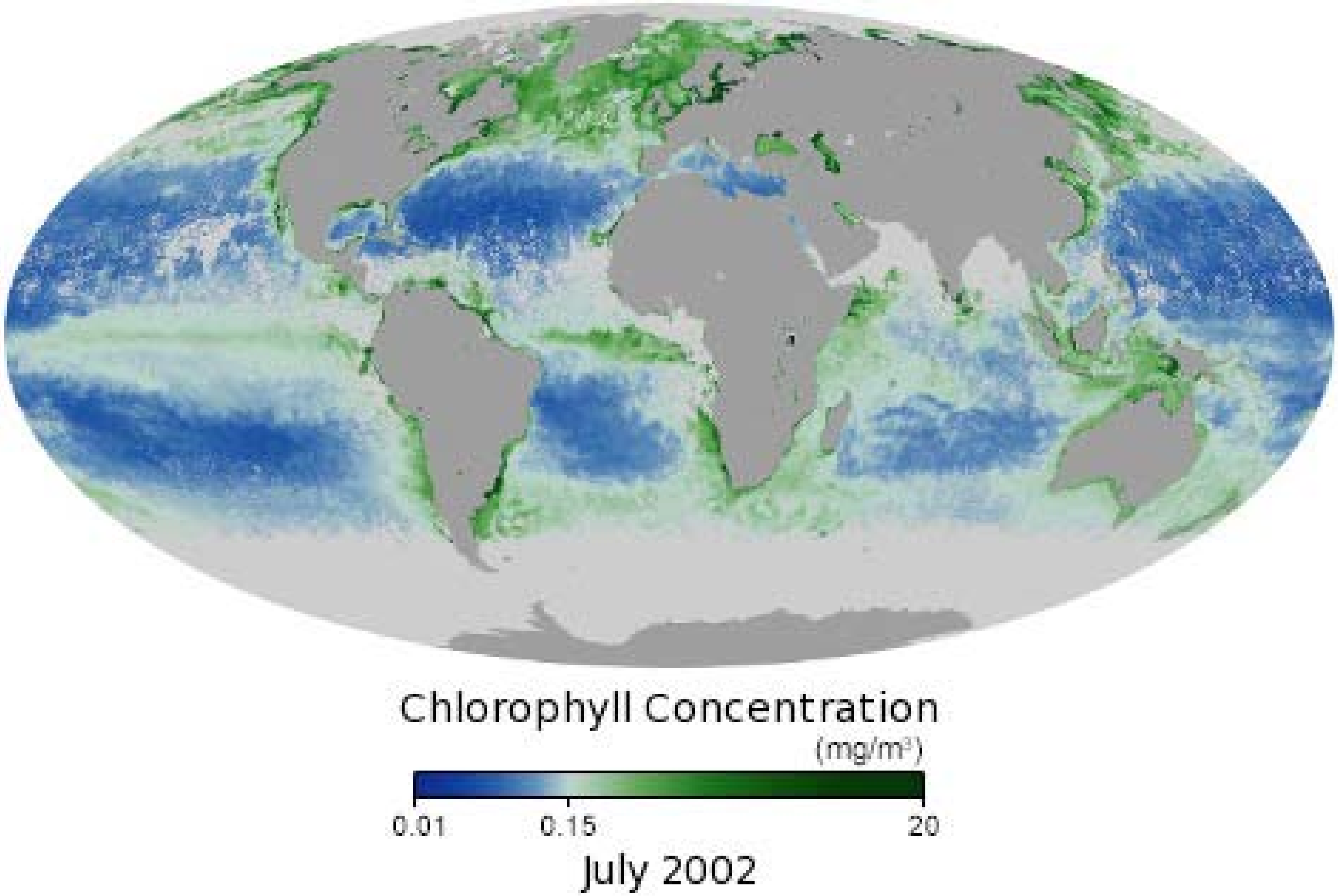


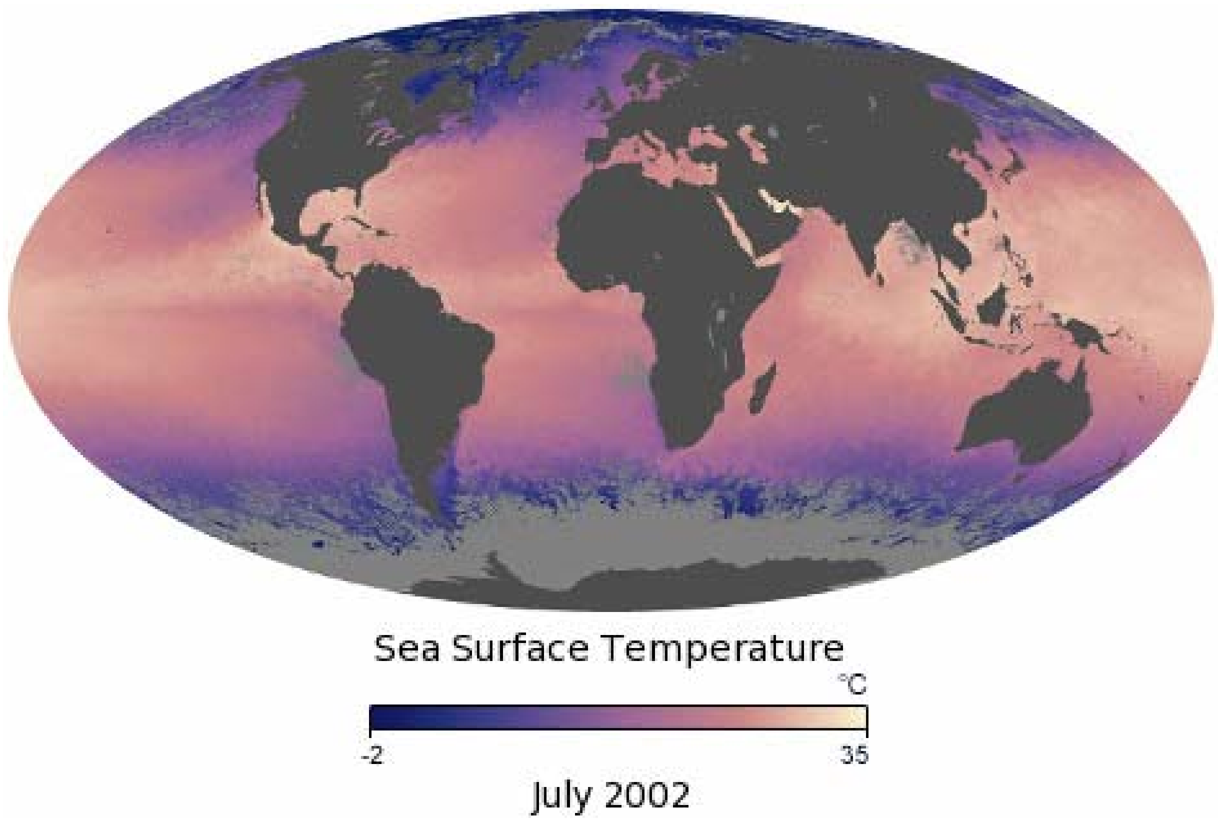
Indeed, we can ground truth historical events: the arrow is the 1882 tilefish die off

I have tried to convince you that we live in a world of change on both temporal and spatial scales of importance to fisheries and our attempts to manage them. Consider, for example, the change in sea surface temperature over the period 1901-2015. What is both exciting and scary is that the baselines in these parameters are not stable, and that we do not know where (or even if) they will find new "equilibrium" values.






Chlorophyll Concentration
(mg/m³)
0.01
0.15
20
July 2002


Sea Surface Temperature
°C
-2
35
July 2002