Impacts of Hurricane Irene and TS Lee on oyster mortality and disease in Delaware Bay

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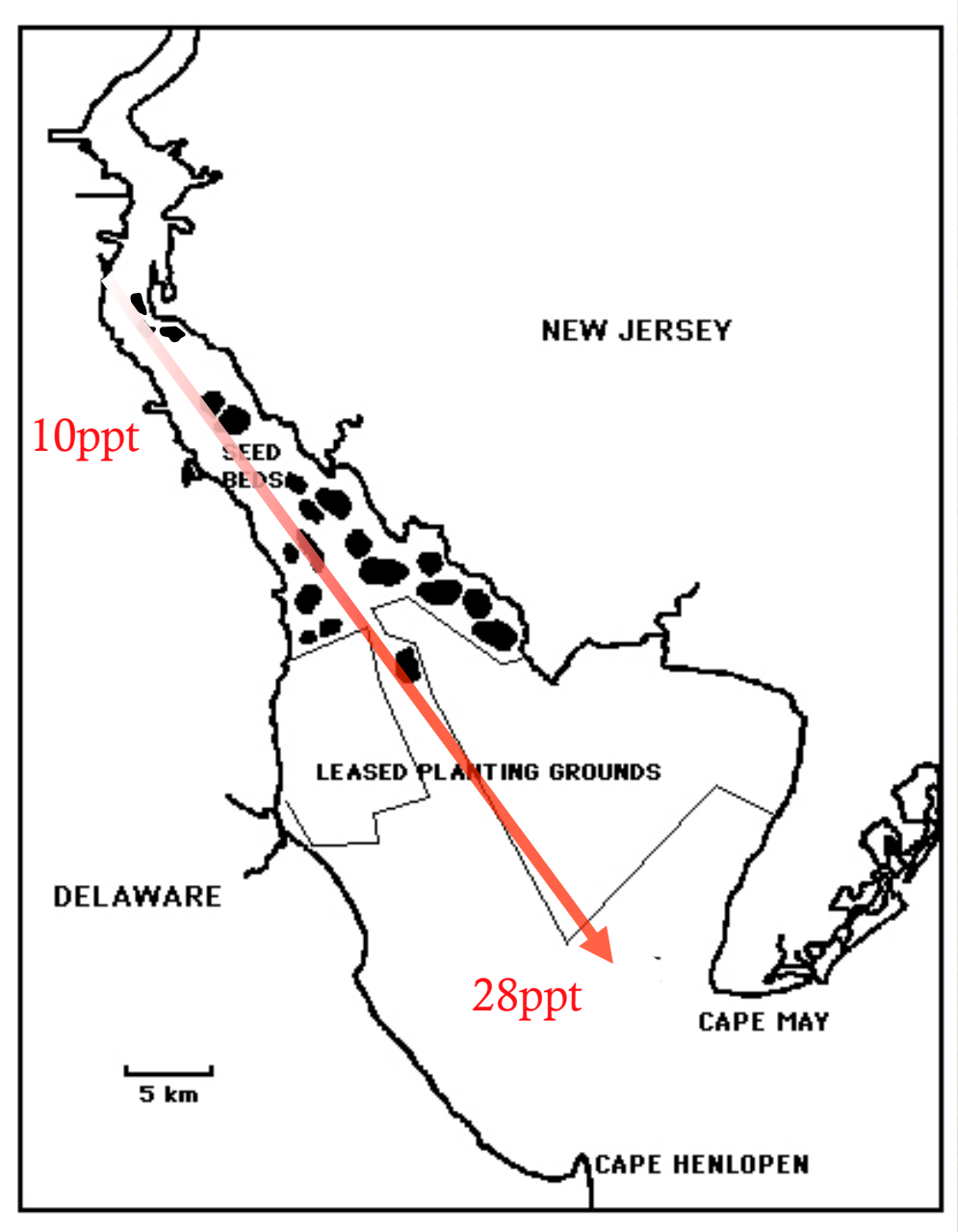
ENHANCING THE FISHERIES OF NEW JERSEY

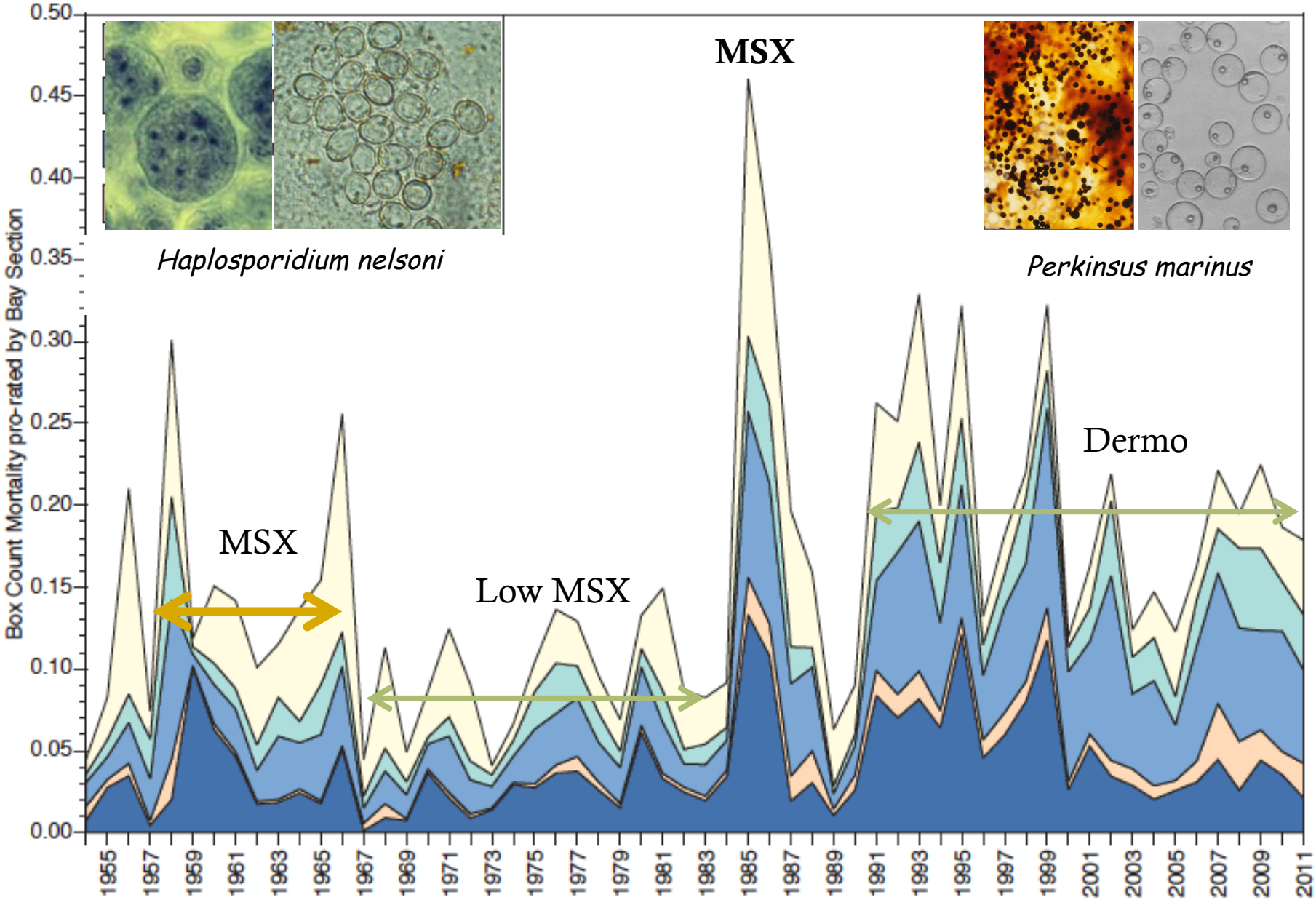
RUTGERS
New Jersey Agricultural Experiment Station

Delaware Bay Oyster Population

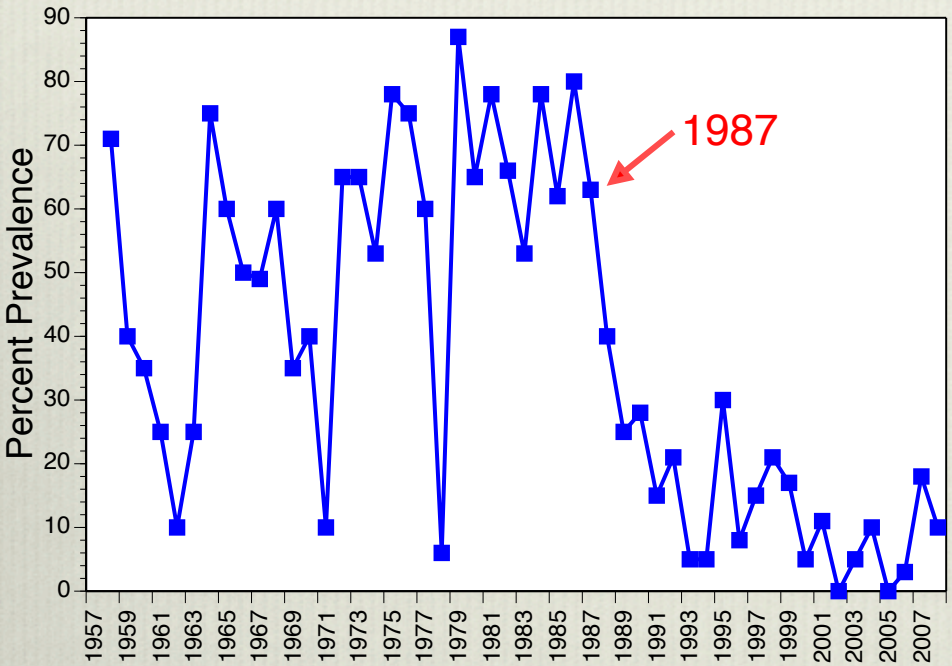


- Bay divided into natural beds and planted grounds
  - Planted grounds are largely out of production
- Oyster recruitment, growth and mortality all increase with salinity
- Long-term data sets:
  - oyster abundance since 1953
  - oyster disease:
    - MSX since 1958
    - Dermo since 1990

MSX and Dermo Oyster Mortality



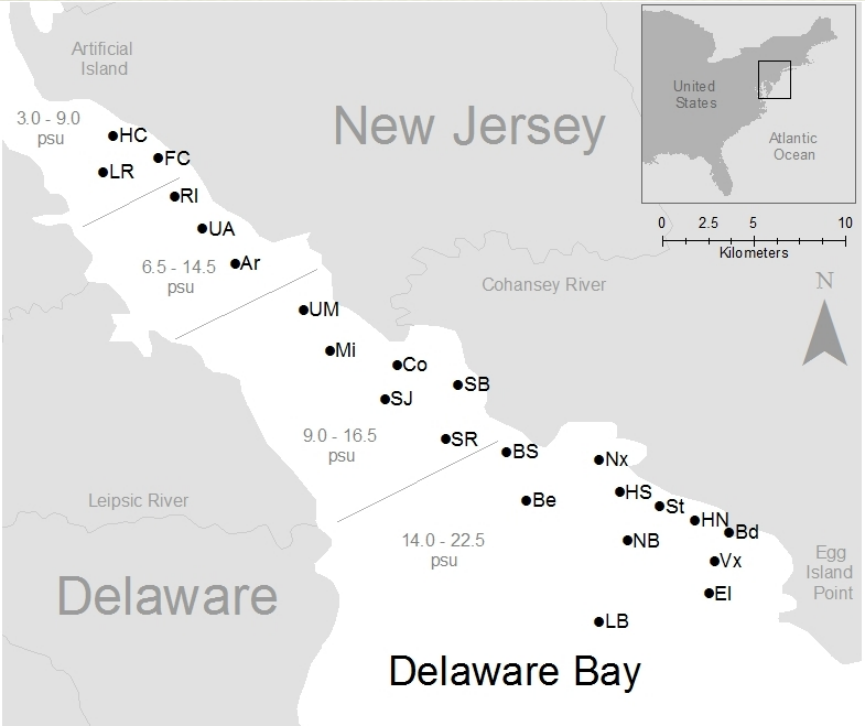
Resistance to MSX in Delaware Bay

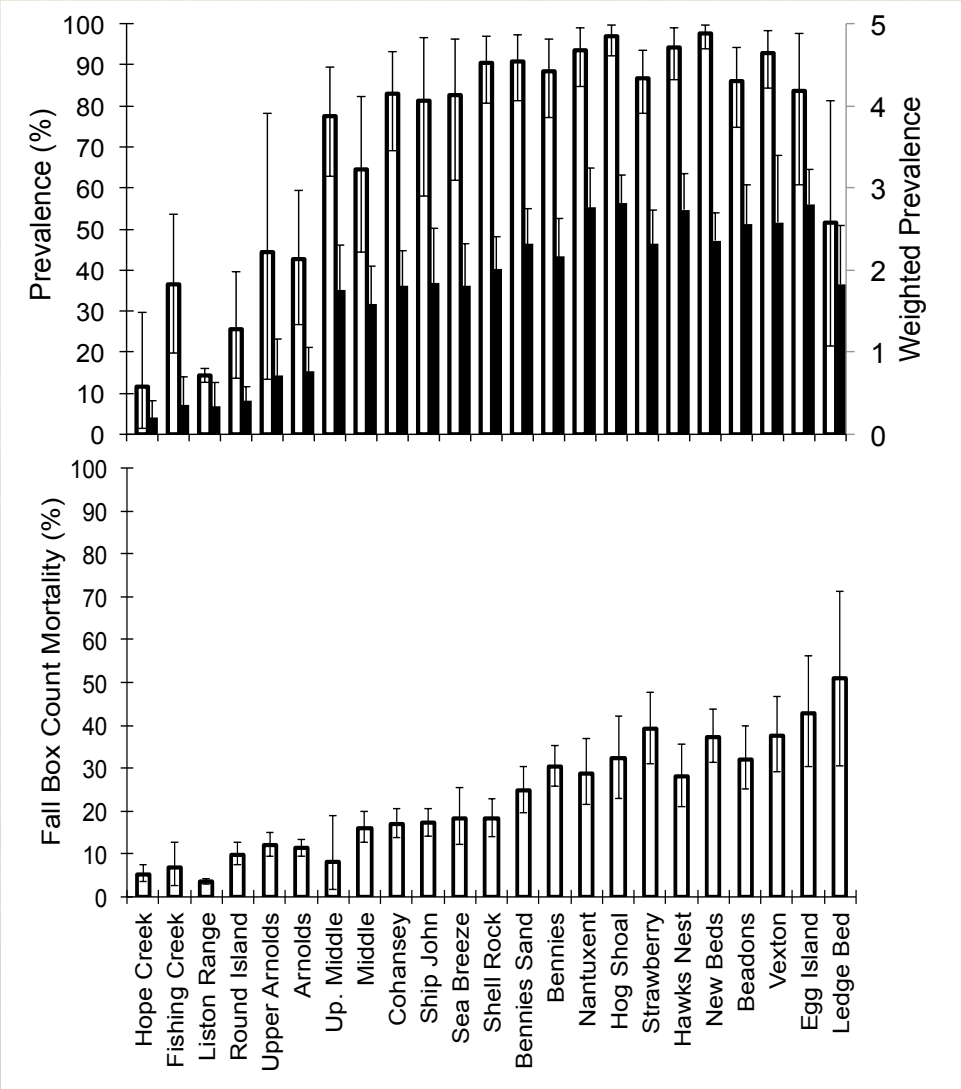


After several cycles of increasing disease pressure, Delaware Bay natives now acquire almost no detectable infections, whereas susceptible imports become heavily infected.

	Naïve	Natives
1964	70	75
1965	65	55
1998	70	ND
2000	100	5
2001	53	0
2002	26	0
2003	4	0
2004	81	0
2005	90	0
2006	75	5
2007	55	0
2008	55	0
2009	90	5

Spatial Patterns of Dermo Disease and Oyster Mortality





Prevalence and WP highly correlated

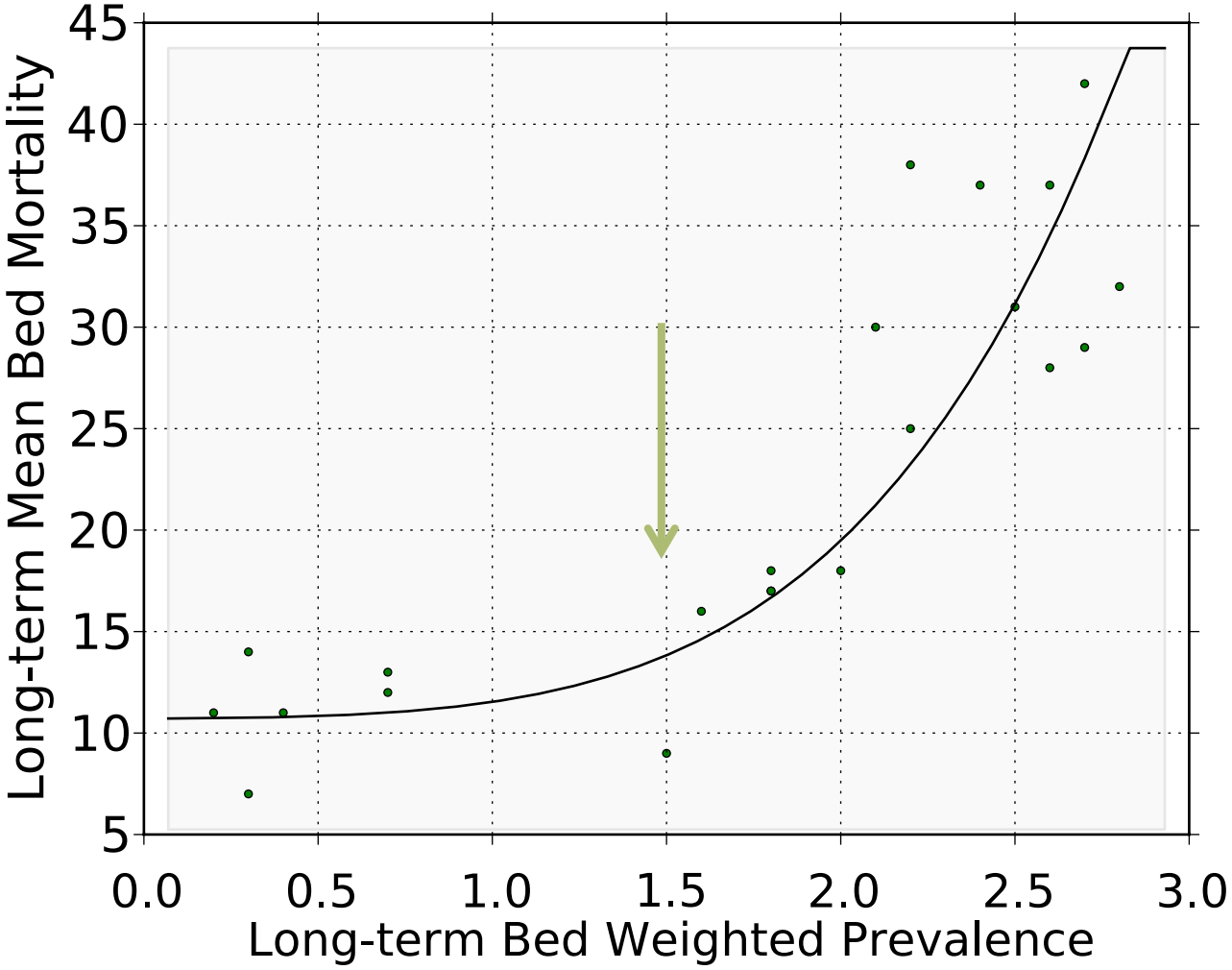
$r^2 = 0.83$, $p < 0.0001$

Both highly correlated with mortality

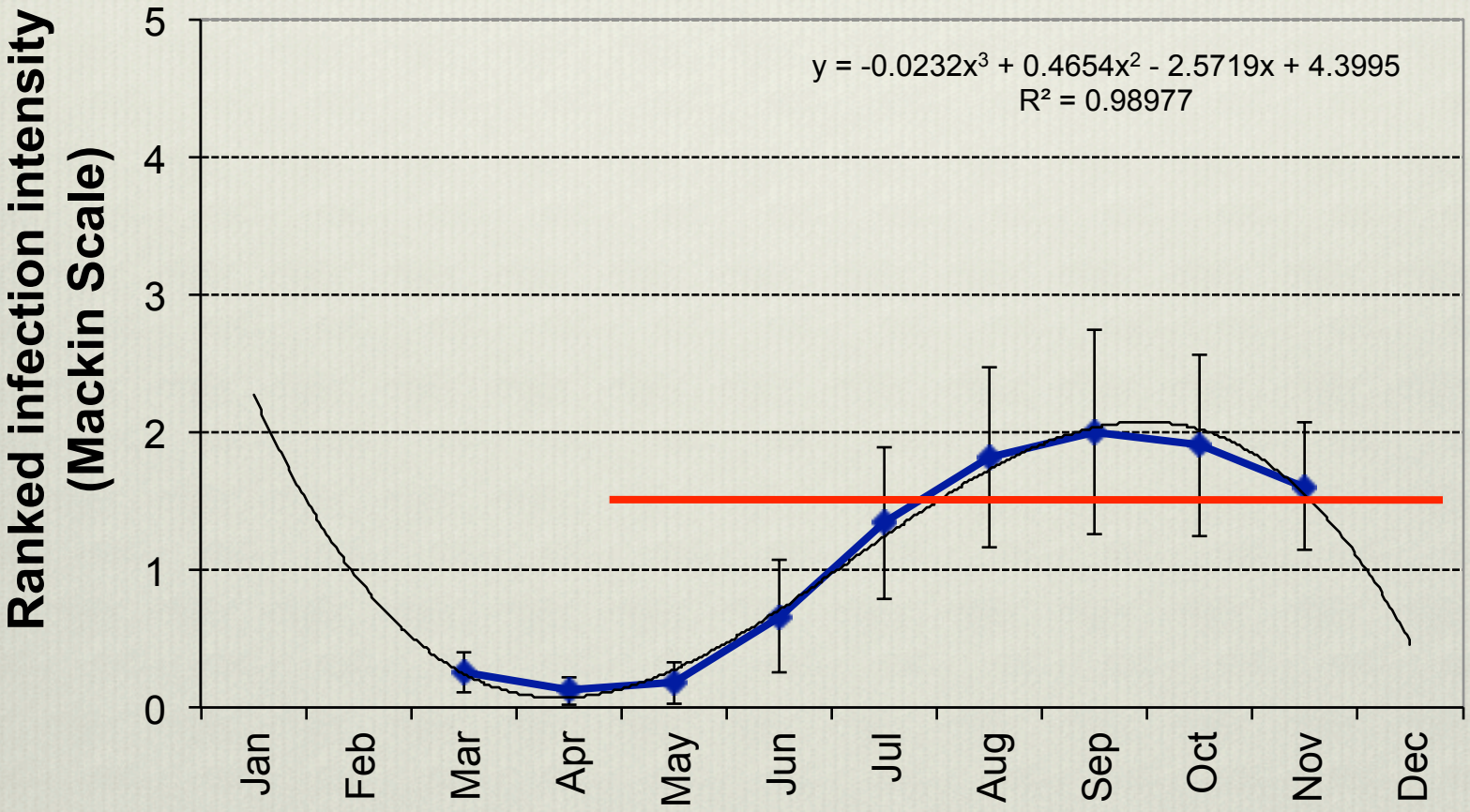
$r^2 = 0.52$, $p < 0.0001$ (prevalence)

$r^2 = 0.64$, $p < 0.0001$ (WP)

Mortality as a function of Dermo intensity



Seasonal Dermo Cycle



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Disaster's Aftermath: Assessing Hurricane Irene's Damage

Scientists from some of the areas hardest hit have now had time to evaluate the storm's dramatic geologic effects on their home states

By Andrea Mustain and OurAmazing Planet | October 14, 2011

MINNEAPOLIS — Less than two months after Hurricane Irene barreled up the eastern coastline of the United States, a group of scientists from some of the areas hardest hit presented evidence of the storm's dramatic geological effects on their home states.

Researchers from Pennsylvania, New Jersey, New York and Vermont took to the podium at a meeting of the Geological Society of America, to discuss what they've learned since the massive storm swept across the Northeast.

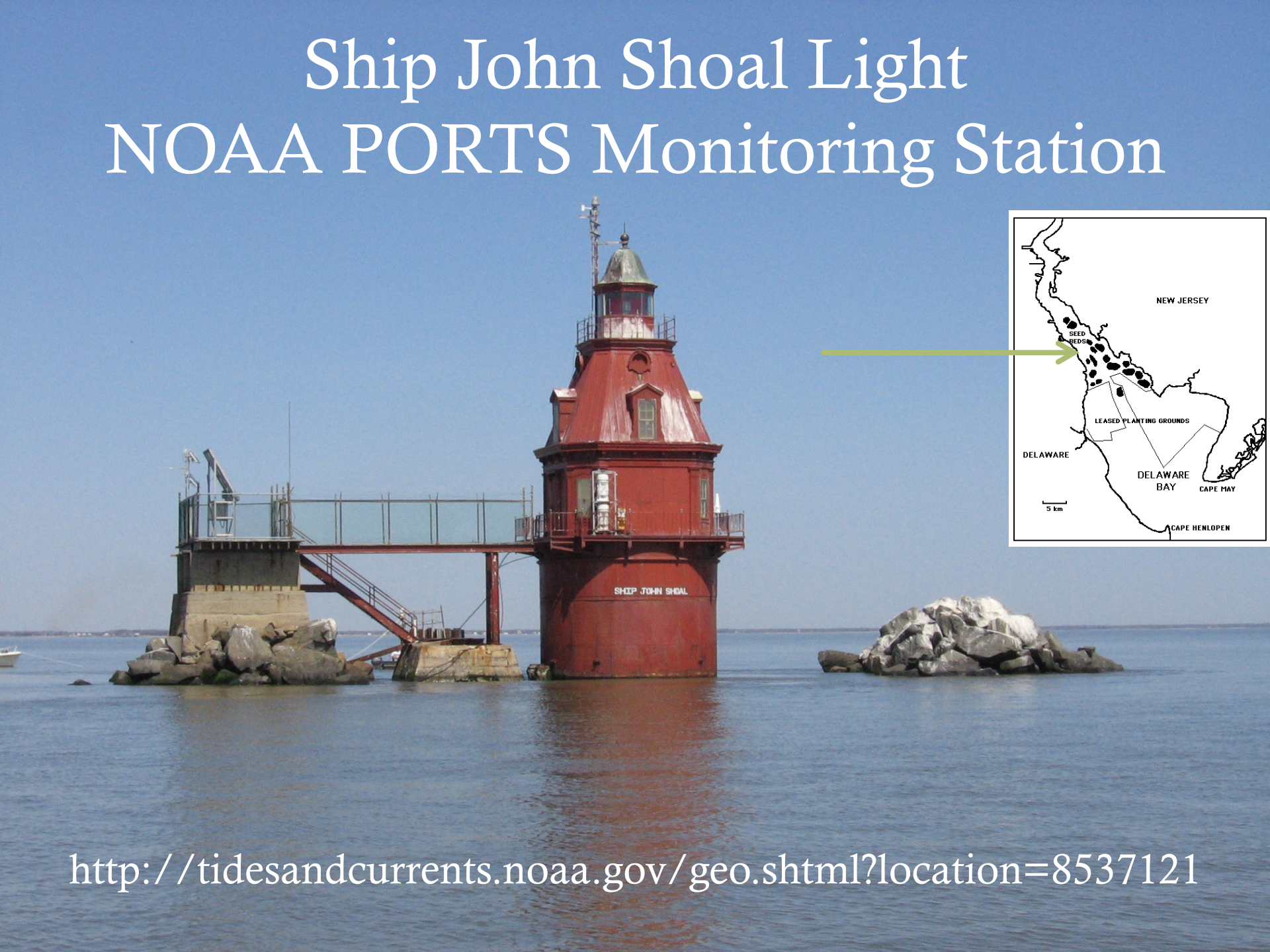
EYE FROM THE SKY: Hurricane Irene makes landfall over New York City. For much of New England, the extreme damage was still to come. *Image: NASA/NOAA GOES Project*

The numbers that are emerging, not

- "we got a year's worth of precipitation in those two months."
- "Some streams… saw peak levels that were 300% higher than high-water records"
  - Joshua Galster, Montclair State University
- "The flood was so massive it pushed all the salt water out into the ocean"
  - Douglas A. Burns, U.S. Geological Survey

http://www.scientificamerican.com/article.cfm?id=hurricane-east-coast-damage

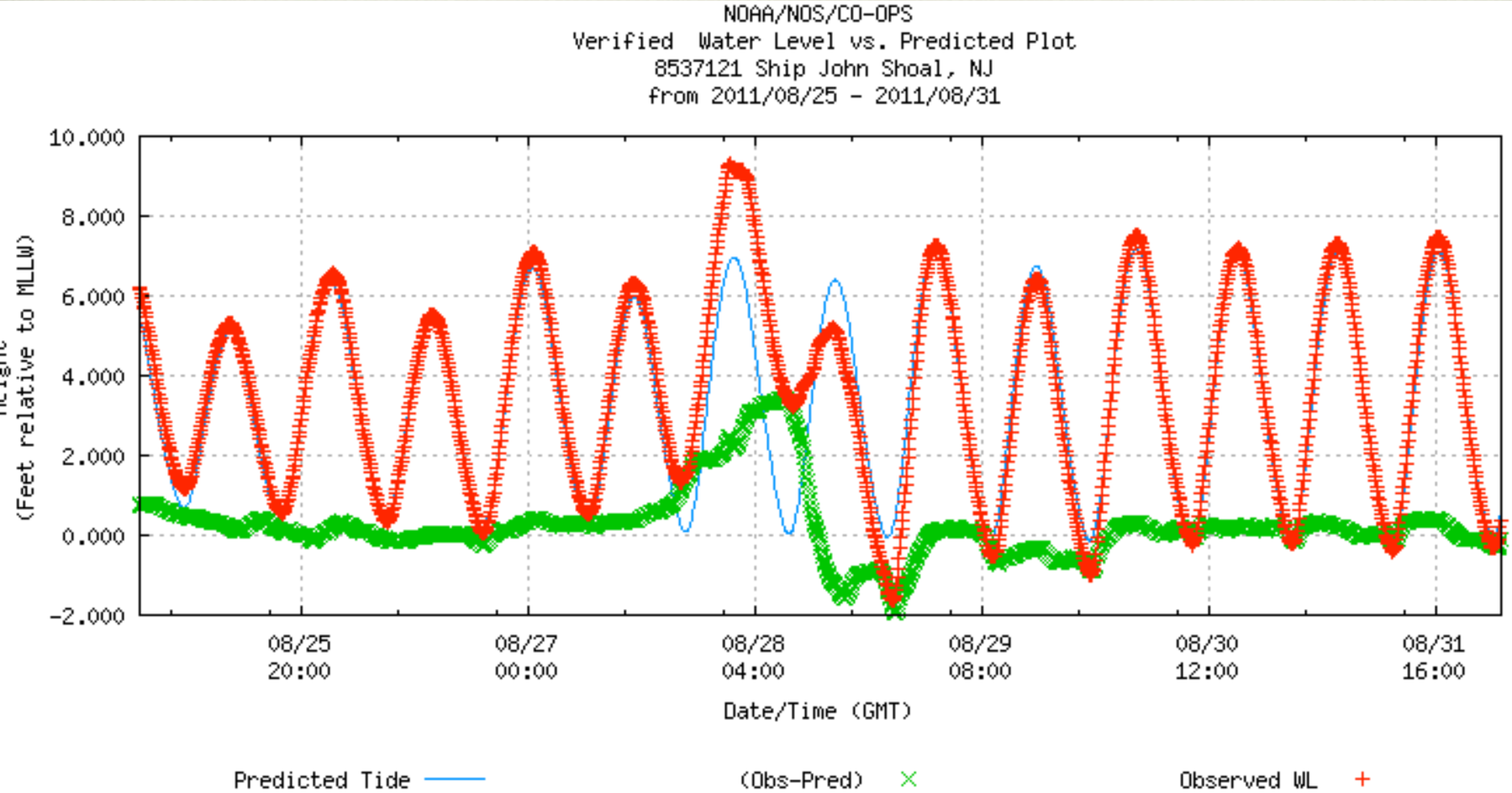
Ship John Shoal Light
NOAA PORTS Monitoring Station



http://tidesandcurrents.noaa.gov/geo.shtml?location=8537121

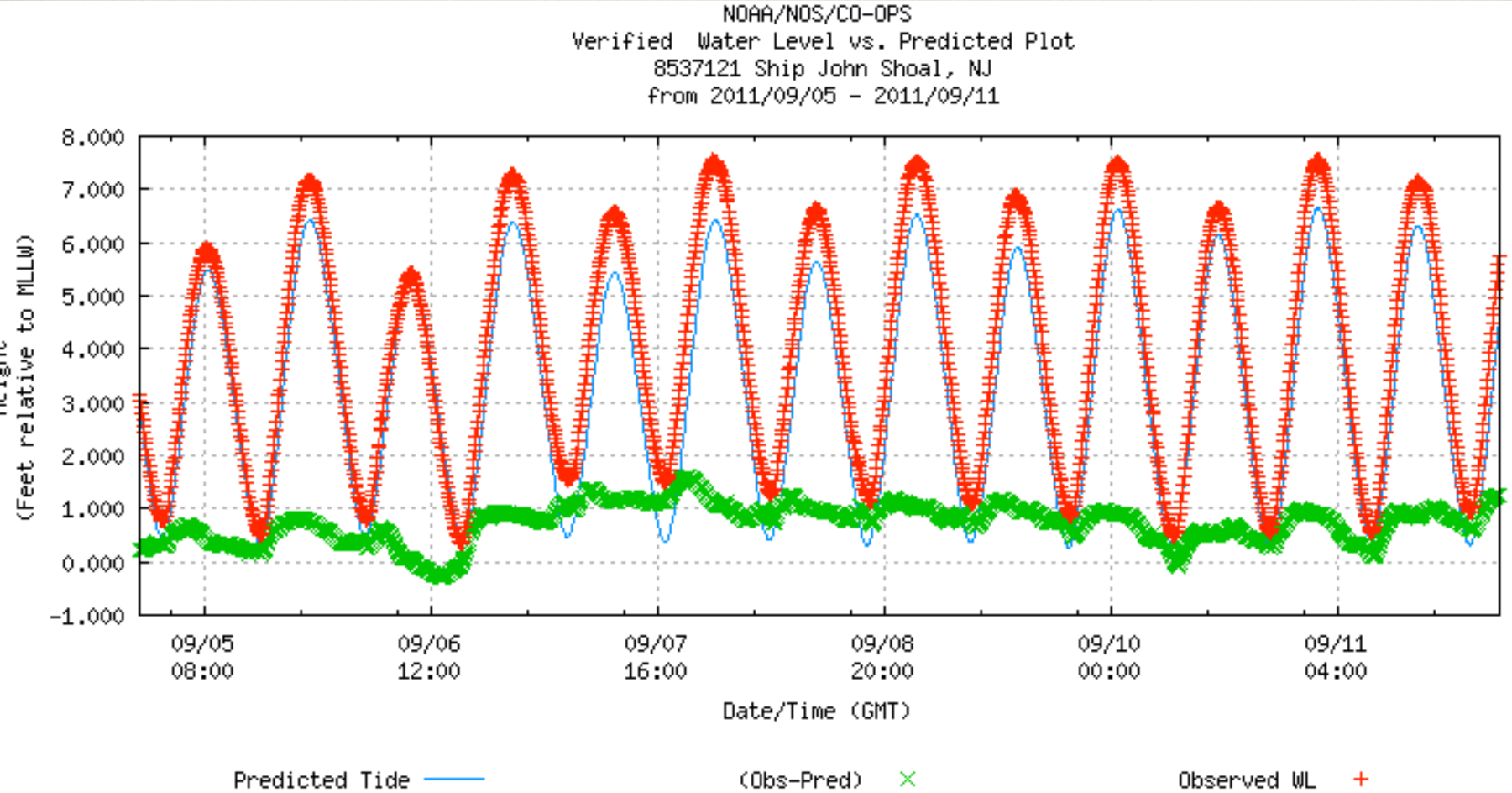
Hurricane Irene

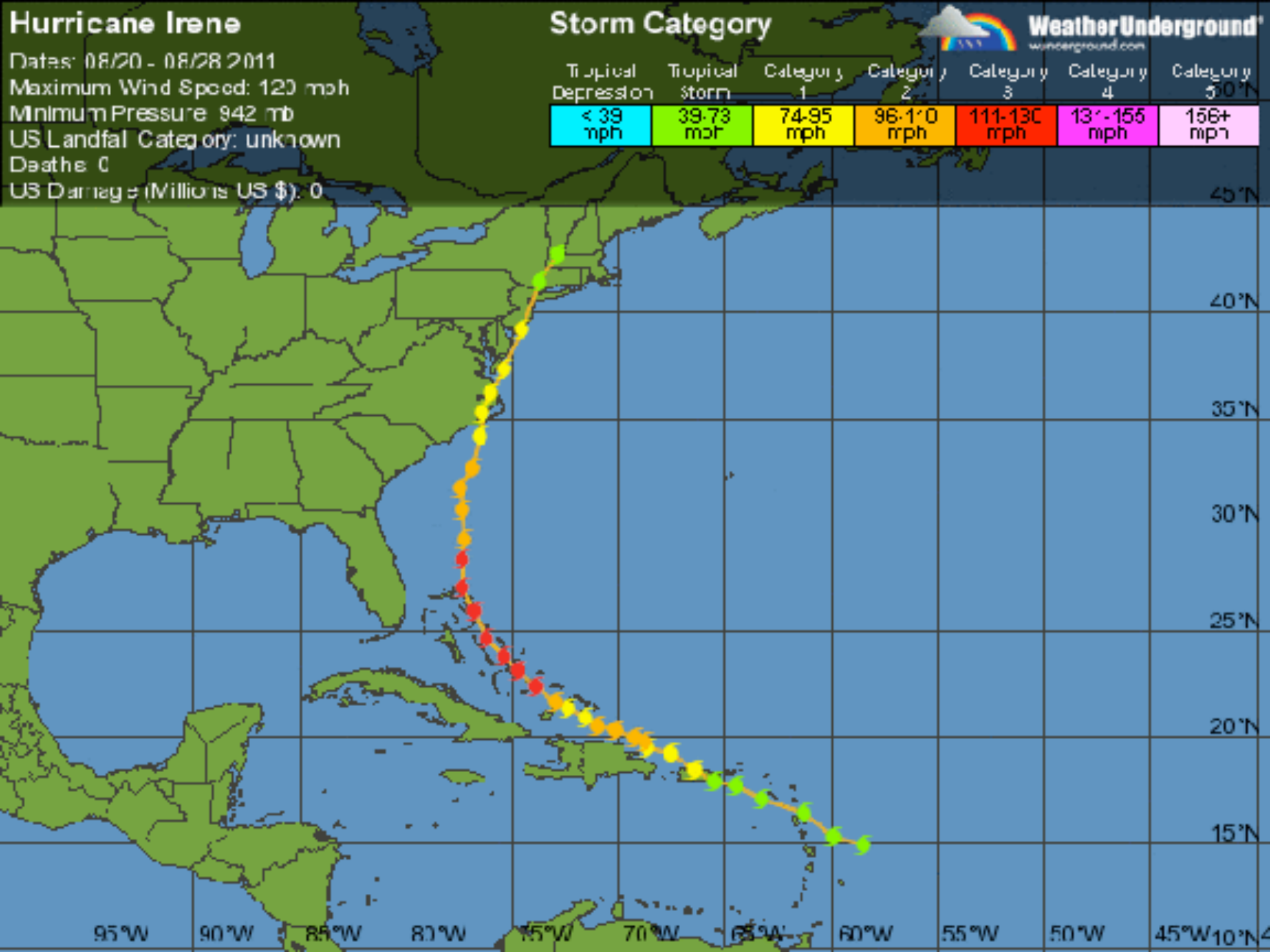
- Storm surge entered Delaware Bay on August 28, 2011

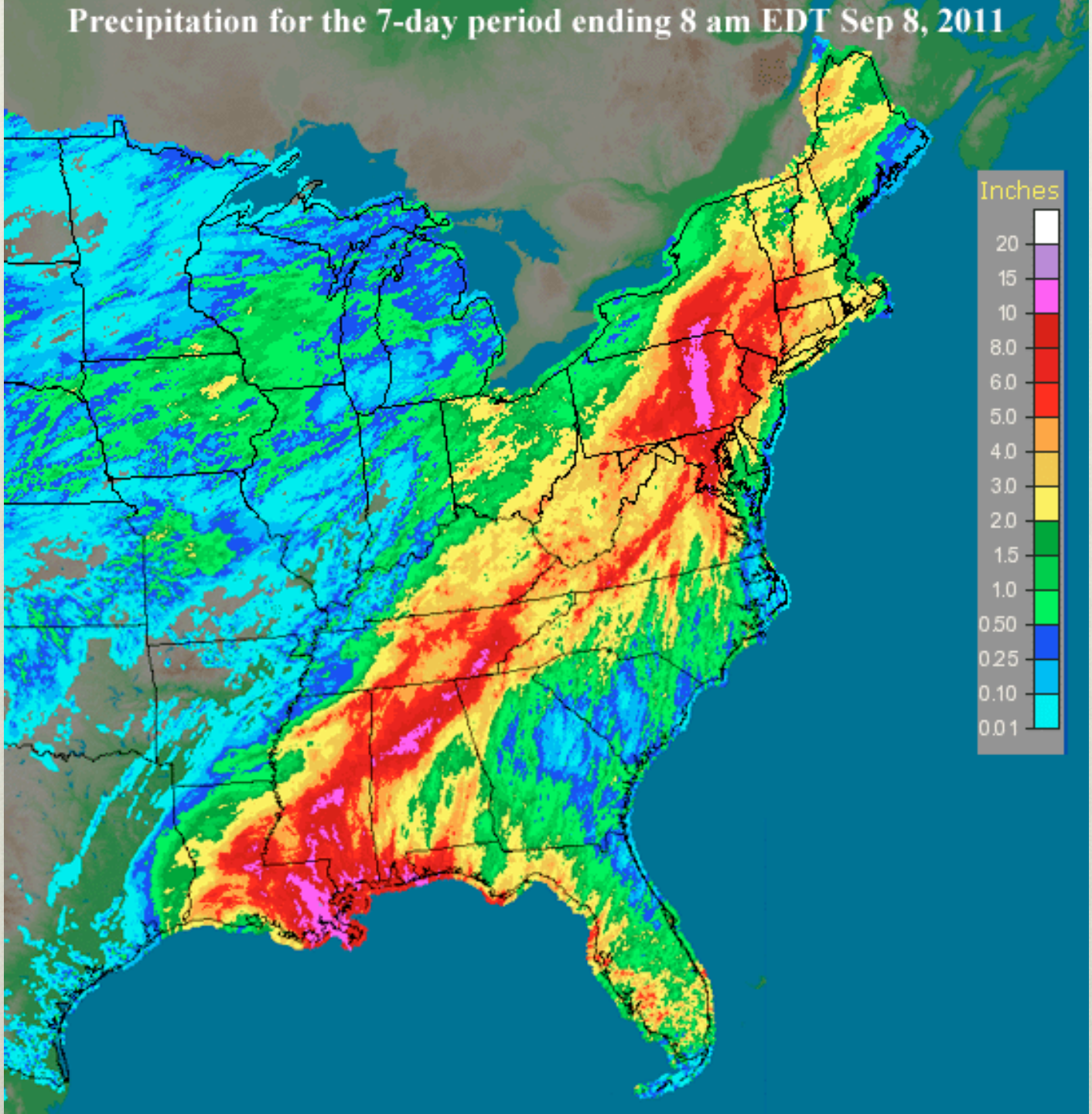


Tropical Storm Lee

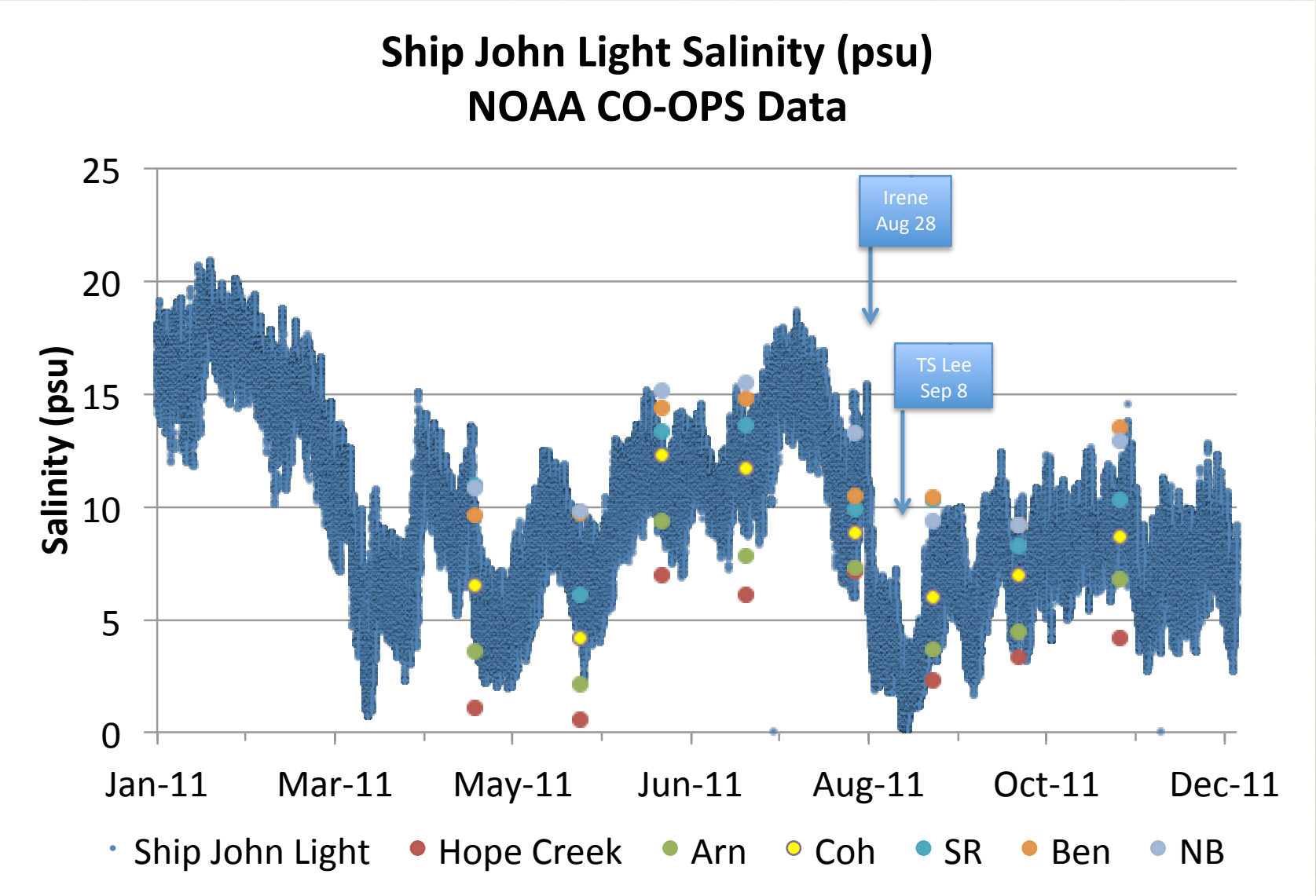
- Storm surge in Delaware Bay on September 8, 2011?




Hurricane Irene
Dates: 08/20 - 08/28 2011
Maximum Wind Speed: 120 mph
Minimum Pressure: 942 mb
US Landfall Category: unknown
Deaths: 0
US Damage (Millions US $): 0
Storm Category
Tropical Depression
< 39 mph
Tropical Storm
39-73 mph
Category 1
74-95 mph
Category 2
96-110 mph
Category 3
111-130 mph
Category 4
131-155 mph
Category 5
156+ mph
WeatherUnderground
45°N
40°N
35°N
30°N
25°N
20°N
15°N
10°N
95°W
90°W
85°W
80°W
75°W
70°W
65°W
60°W
55°W
50°W
45°W

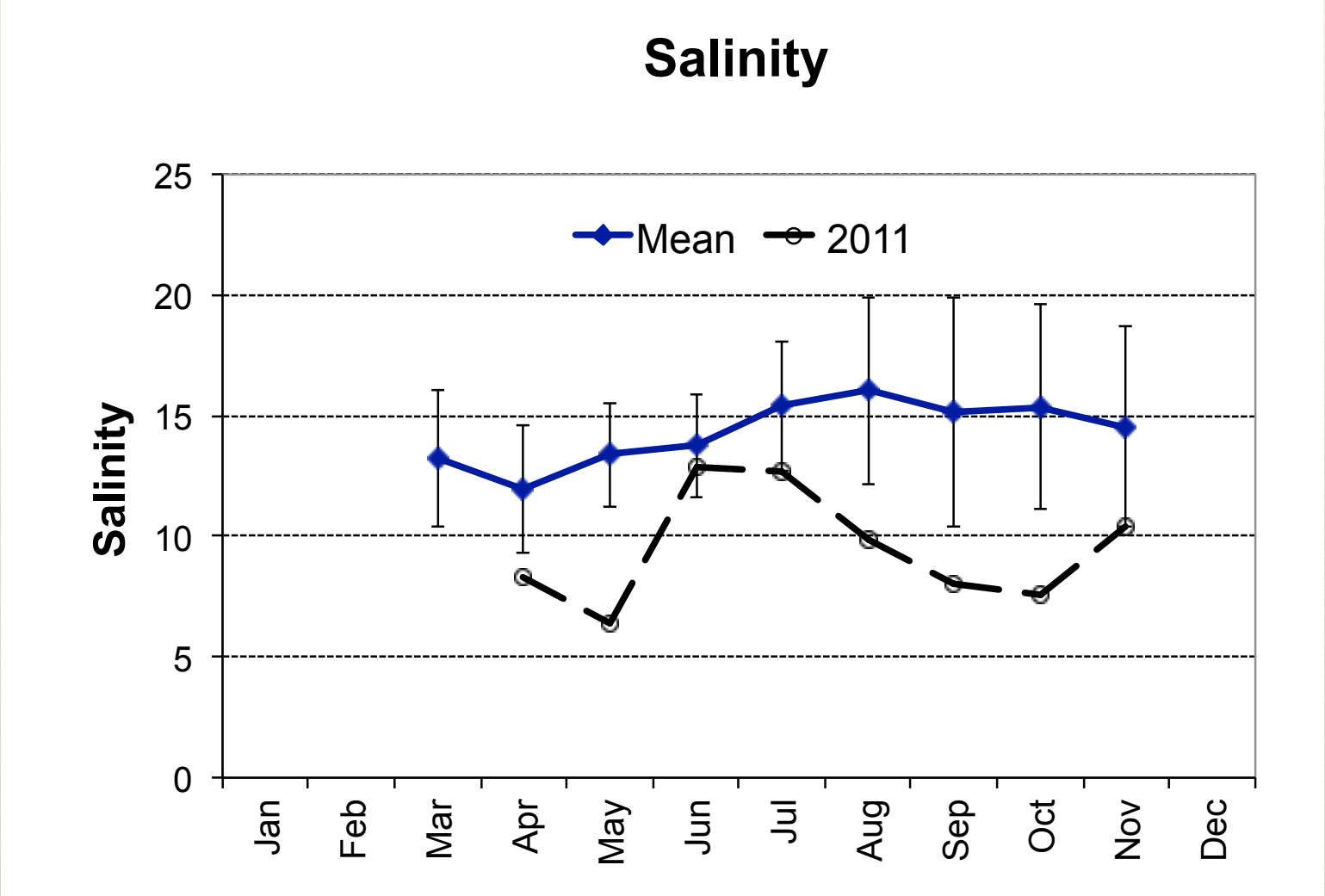

Precipitation for the 7-day period ending 8 am EDT Sep 8, 2011
Inches
20
15
10
8.0
6.0
5.0
4.0
3.0
2.0
1.5
1.0
0.50
0.25
0.10
0.01

Storms severely depressed salinity

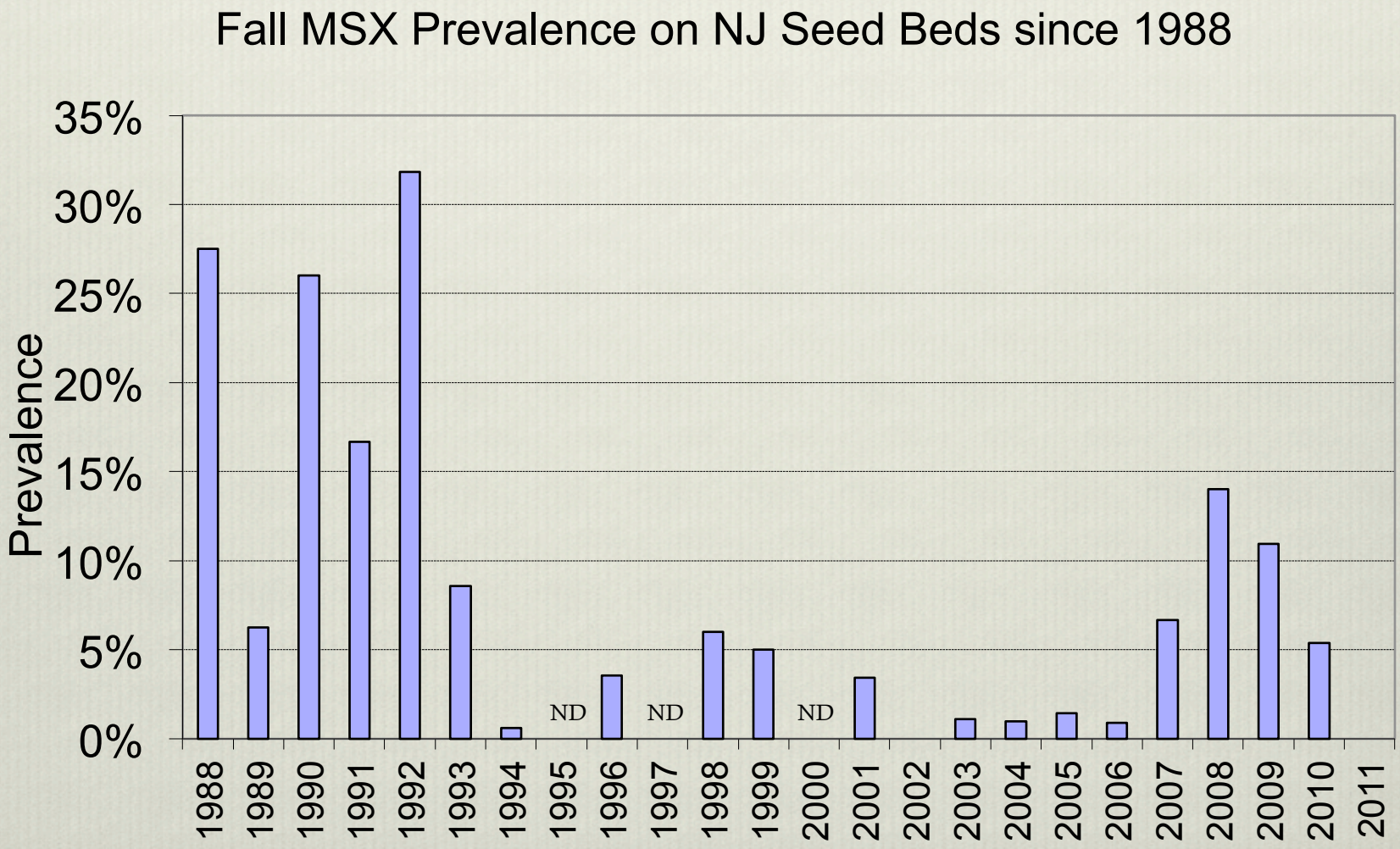


Normal spatial pattern, but high spring runoff and tropical storms depressed salinity

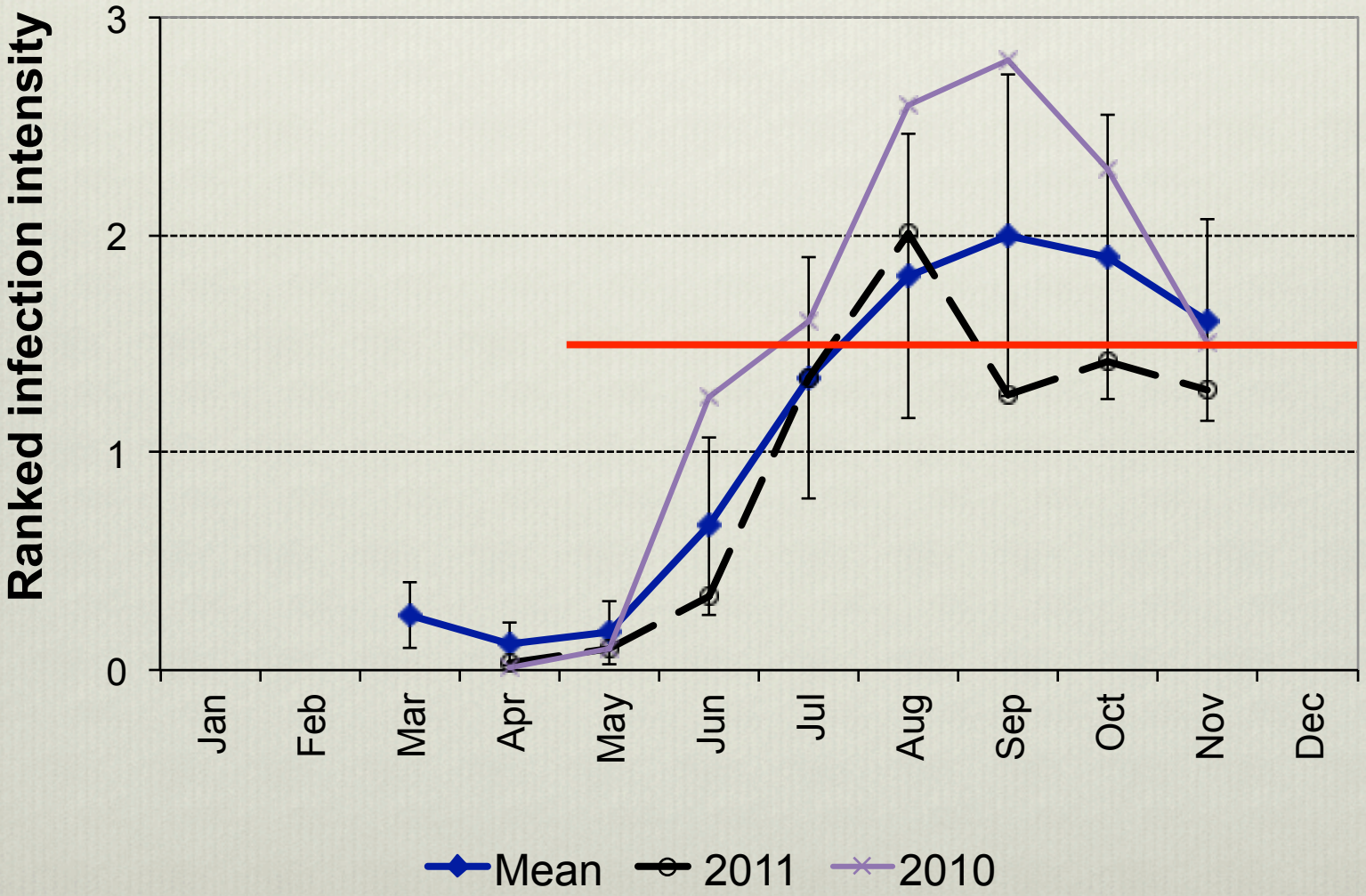
Unusually low Salinity

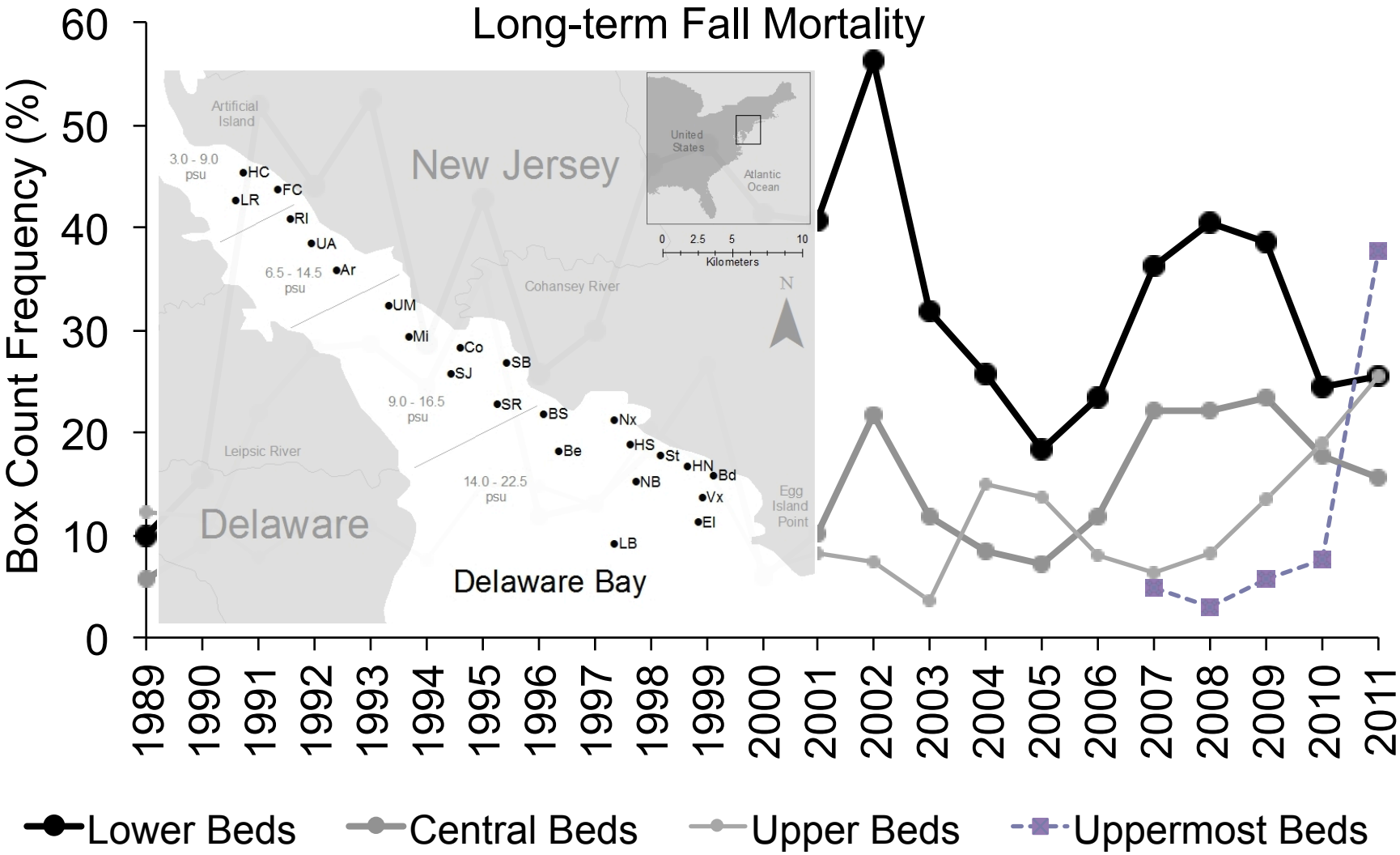


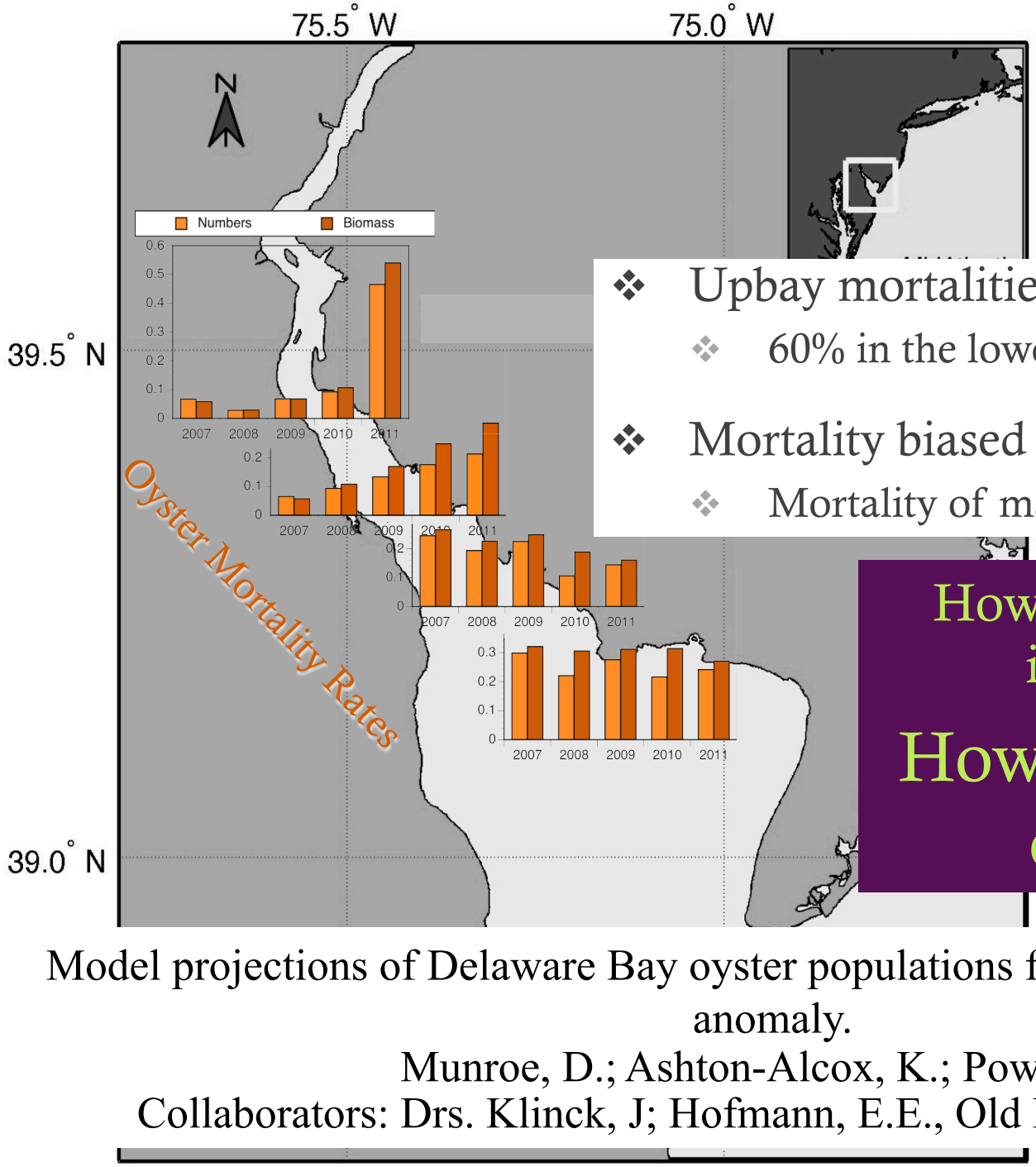
No MSX following 2011 floods



Seasonal Dermo Cycle




Long-term Fall Mortality
Box Count Frequency (%)
60
50
40
30
20
10
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Artificial Island
New Jersey
United States
Atlantic Ocean
0 2.5 5 10
Kilometers
N
3.0 - 9.0 psu
HC
FC
LR
RI
UA
6.5 - 14.5 psu
Ar
UM
Mi
Co
SB
SJ
9.0 - 16.5 psu
SR
BS
Nx
Cohansey River
Leipsic River
Be
HS
St
HN
Bd
14.0 - 22.5 psu
NB
Vx
El
Egg Island Point
Delaware
LB
Delaware Bay
Lower Beds
Central Beds
Upper Beds
Uppermost Beds



- Upbay mortalities extremely high
  - 60% in the lowest recruitment area
- Mortality biased to large animals
  - Mortality of market-size oysters ~ 76%

How will these changes impact oysters?

How long will these effects last?

Model projections of Delaware Bay oyster populations following the 2011 salinity anomaly.

Munroe, D.; Ashton-Alcox, K.; Powell, E.

Collaborators: Drs. Klinck, J; Hofmann, E.E., Old Dominion University

Spatially-Explicit Individual-Based Numerical Model

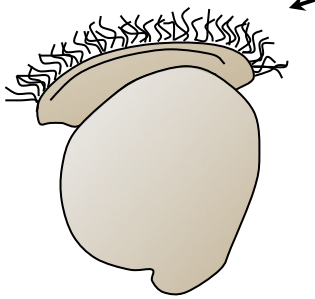
Multiple Linked Population Dynamics Models

DyPoGEn

***Dy**namic **Po**pulation **G**enetics **En**gine*

Individual Genetics:

- 10 chromosomes
- 4 genes per chromosome
- Offspring created by meiosis

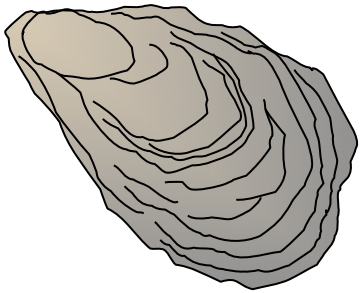


Larvae can:

- Experience mortality
- Remain within source population
- Disperse
  - Informed by coupled particle model (larval growth-behaviour & ROMS)

Recruits will:

- Grow
- Experience mortality
- Change sex
- Spawn



HASKIN SHELLFISH RESEARCH LABORATORY

RUTGERS MARINE & COASTAL SCIENCES

CENTER FOR COASTAL PHYSICAL OCEANOGRAPHY
OLD DOMINION UNIVERSITY

THE TOOLBOX

Spatially-Explicit Individual-Based Numerical Model

Multiple Linked Population Dynamics Models

$$P_{mort} = 0.5\left(1 + \tanh\left(\frac{Age - AveAgeMort}{AveSpreadMort}\right)\right)$$

$$LarvSurv = (0.5 + 1.5R)\frac{K}{nOff\ \ nParents}$$

$$P = 1 - LarvSurv$$

Juvenile Mortality
(Applied to Juveniles)

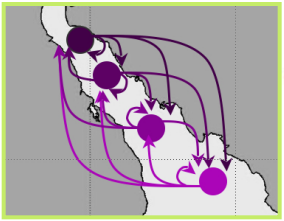
Larval Mortality
(Applied to Offspring)

Increment Age

$$P_{mort} = 0.5\left(1 + \tanh\left(\frac{Age - AveAgeMort}{AveSpreadMort}\right)\right)$$

DyPoGEn

Time Step
One Year



Larval Dispersal
(Exchange Rates from Particle Model)

Adult Mortality
(Age Dependent)

Functional Sex Change
(Size Dependent)

$$Ff = \alpha e^{\beta e^{(\gamma \cdot Age)}}$$

$$Df = \frac{dFf}{dAge} = \alpha\beta\gamma e^{\left((\gamma \cdot Age) + \left(\beta e^{(\gamma \cdot Age)}\right)\right)}$$

$$P_{sex\Delta} = \min\left(1, \frac{Df}{1 - Ff}\right)$$

Offspring Produced
(Meiosis)

Spawning

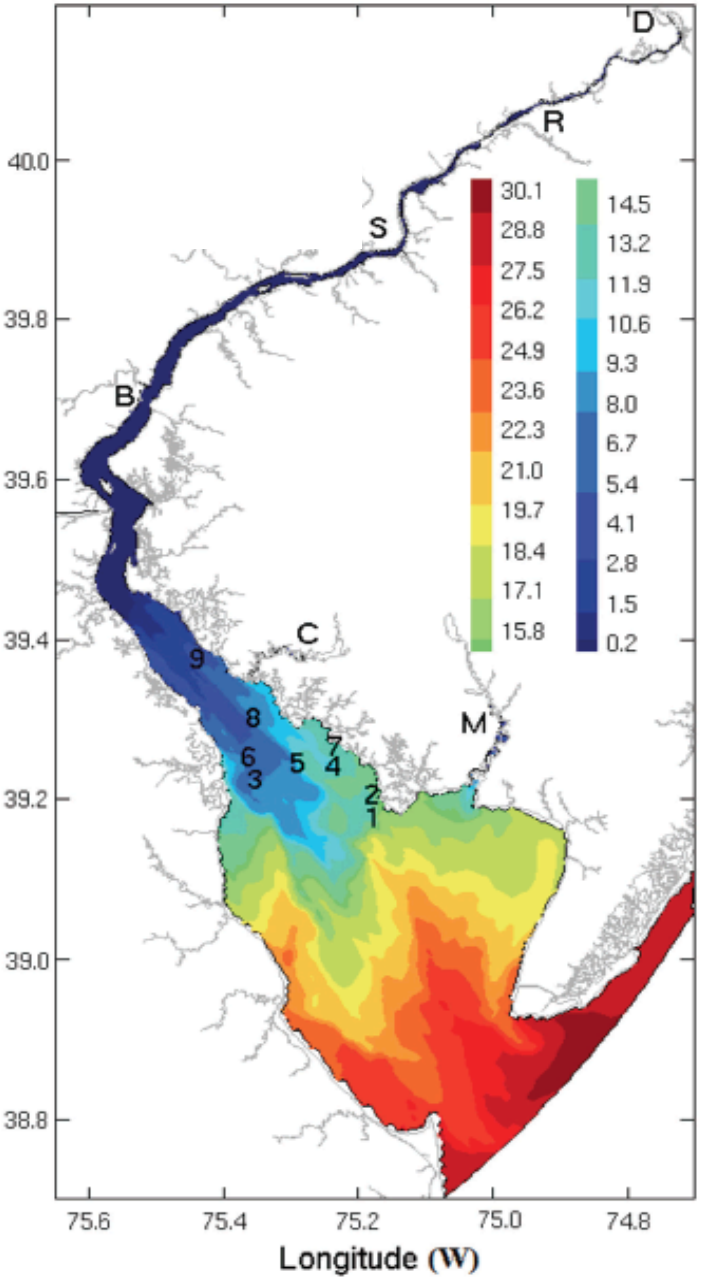
$$W = W_{\infty}\left(1 - e^{-k(Age - Age_{\infty})}\right)^{b}$$

$$nOff = \frac{W_{\infty}}{W_{76}}\left(1 - e^{-k(Age - Age_{0})}\right)^{b} MaxOff$$

Parents Selected

$$FrParents = FracParents \cdot 10^{(N \cdot FracParentsVar)}$$

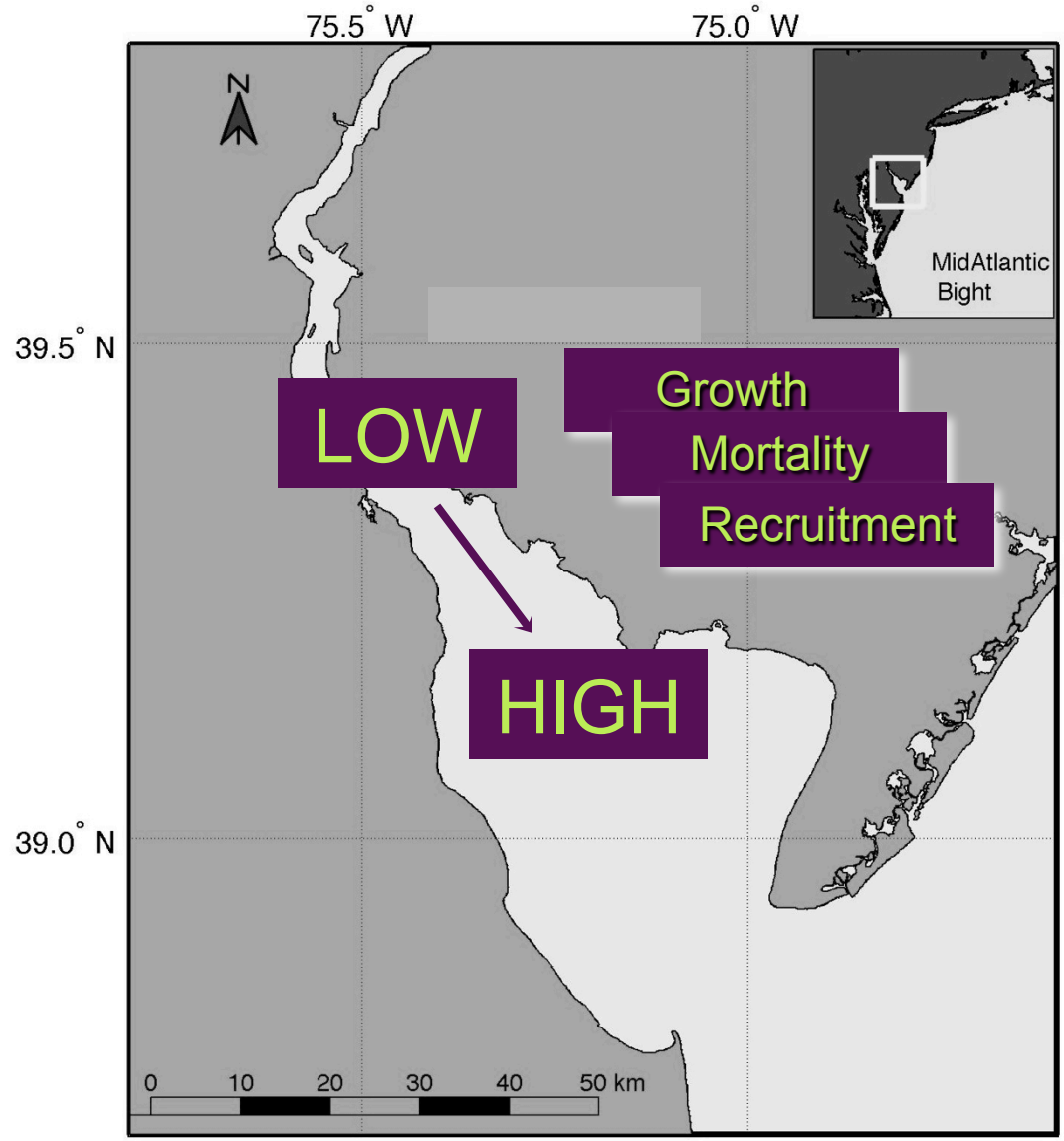
$$nParents = \max(0.5 \cdot FrParents \cdot LastAnimal,\ minParent)$$

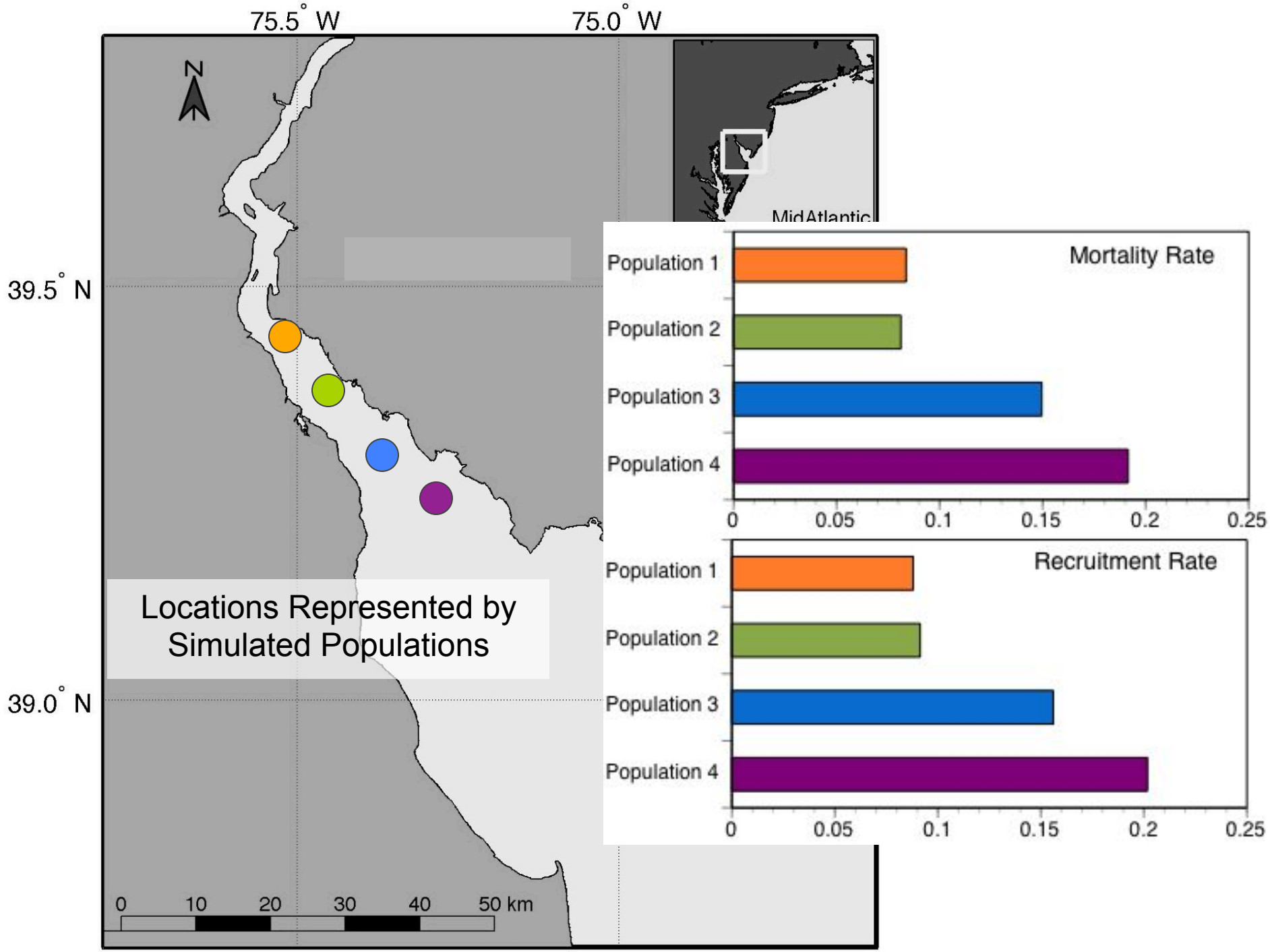


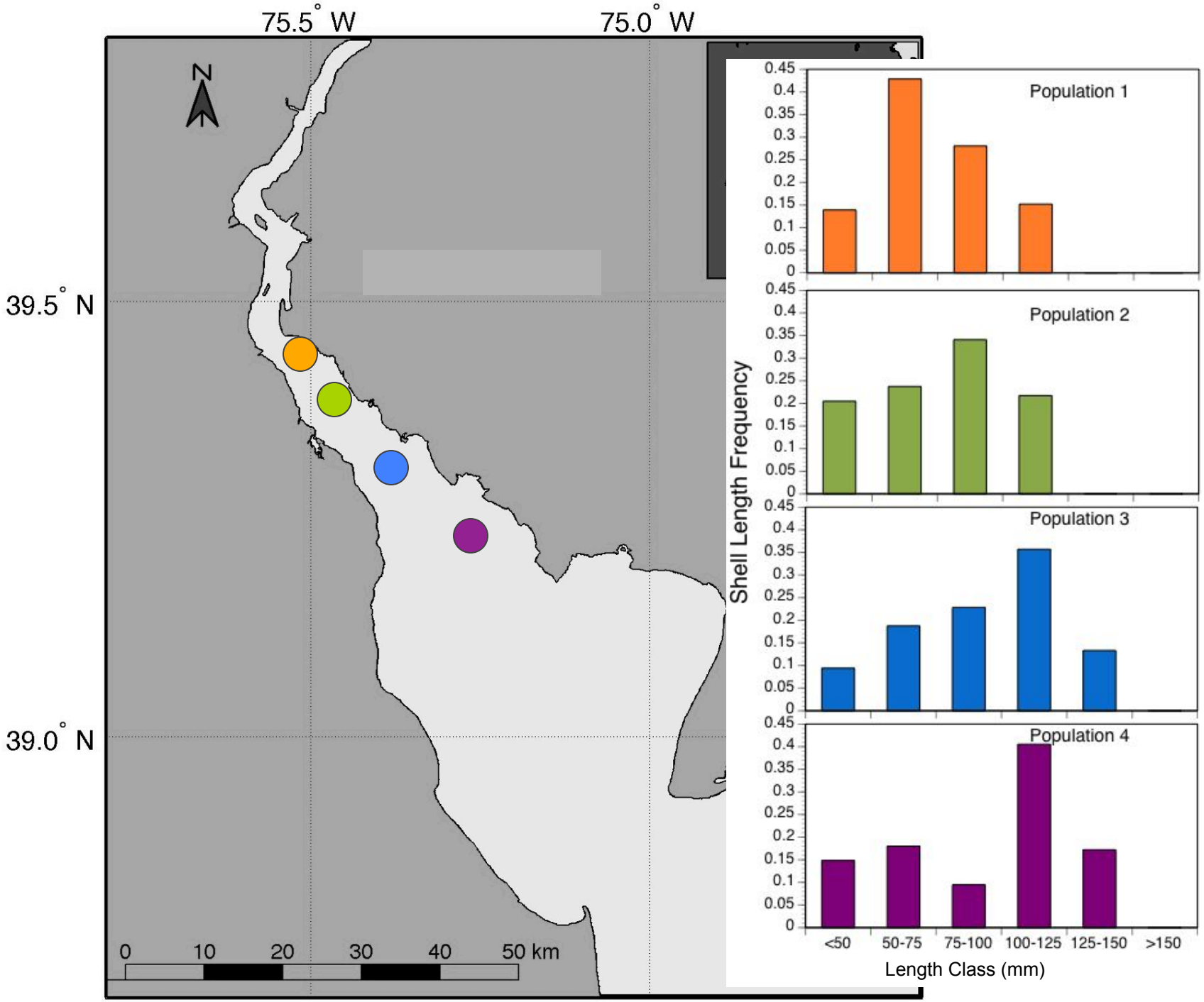
From: Hofmann *et al.*, Oceanography, 22: 212-231.

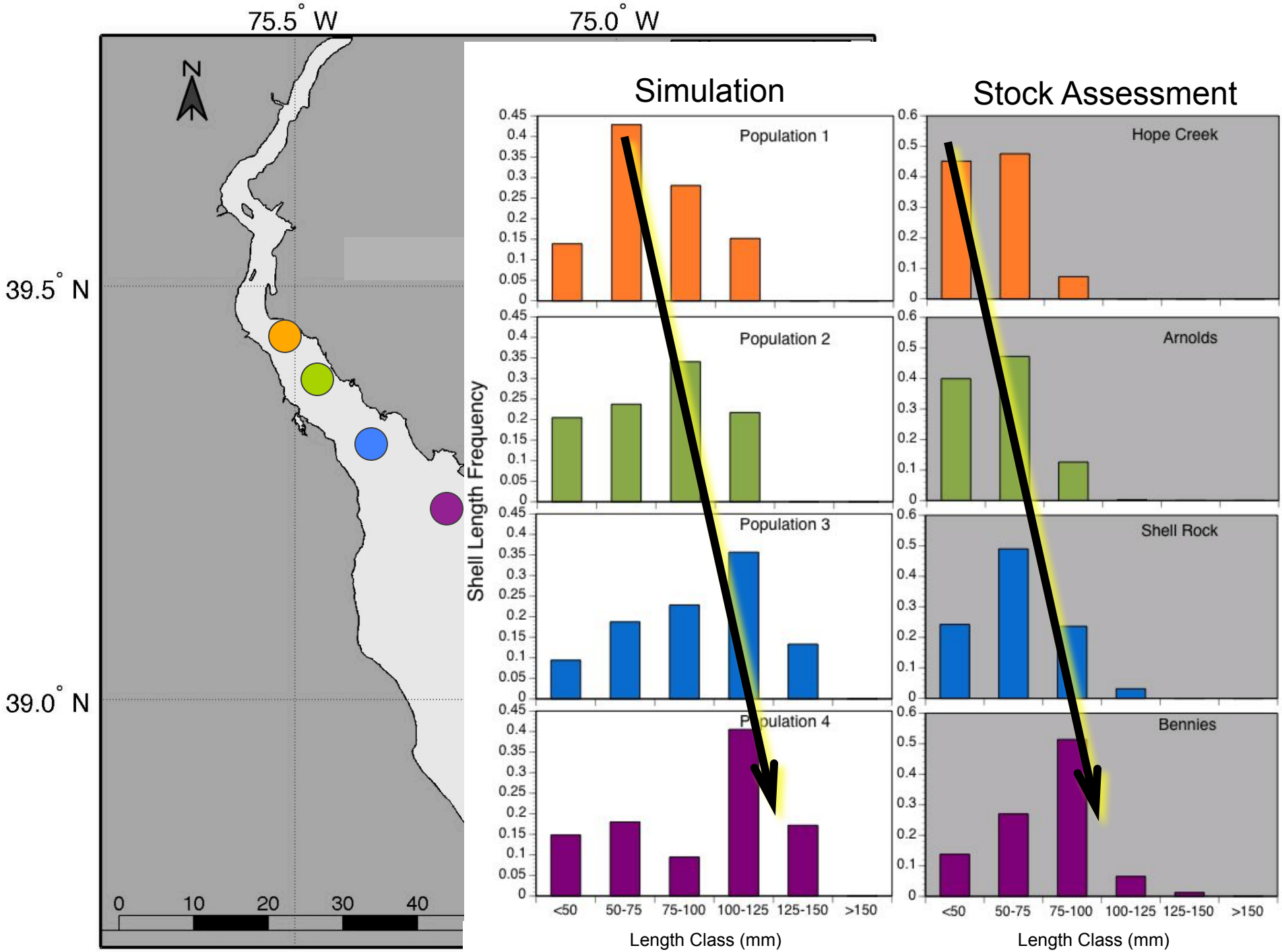
Strong salinity gradient.

Oyster populations respond biologically

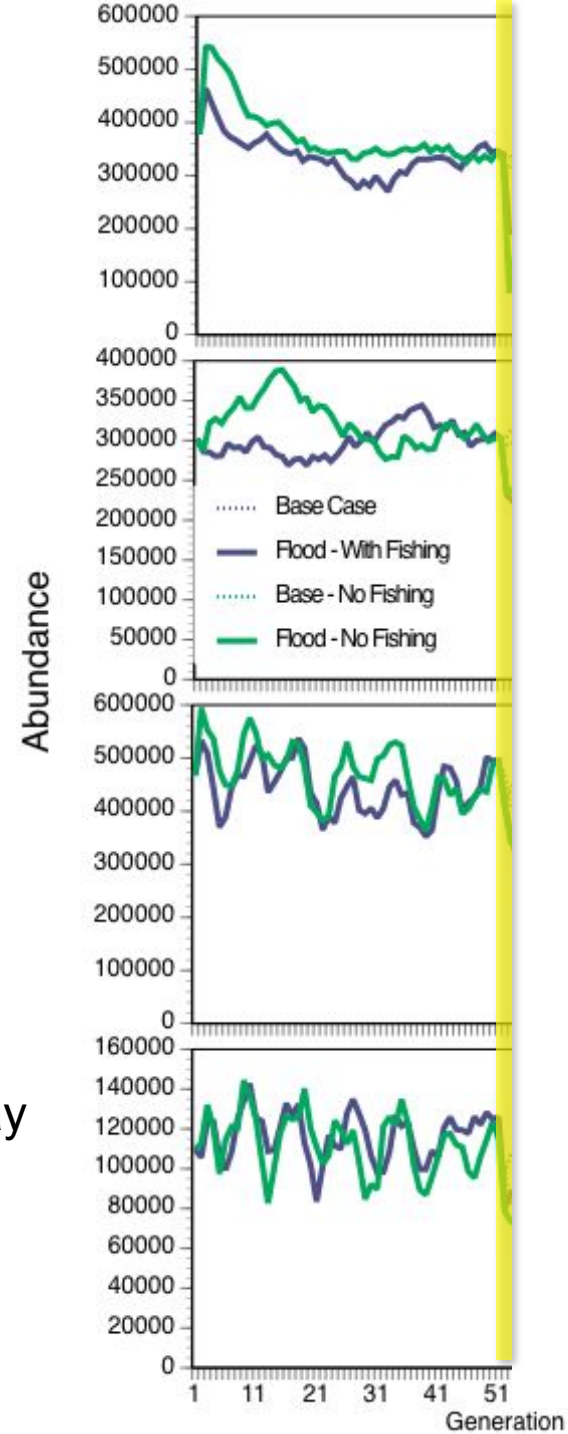



75.5° W
75.0° W
39.5° N
39.0° N
N
MidAtlantic
Locations Represented by Simulated Populations
0 10 20 30 40 50 km
Mortality Rate
Population 1
Population 2
Population 3
Population 4
0 0.05 0.1 0.15 0.2 0.25
Recruitment Rate
Population 1
Population 2
Population 3
Population 4
0 0.05 0.1 0.15 0.2 0.25


75.5° W
75.0° W
39.5° N
39.0° N
N
0 10 20 30 40 50 km
Population 1
Population 2
Population 3
Population 4
Shell Length Frequency
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45
<50
50-75
75-100
100-125
125-150
>150
Length Class (mm)

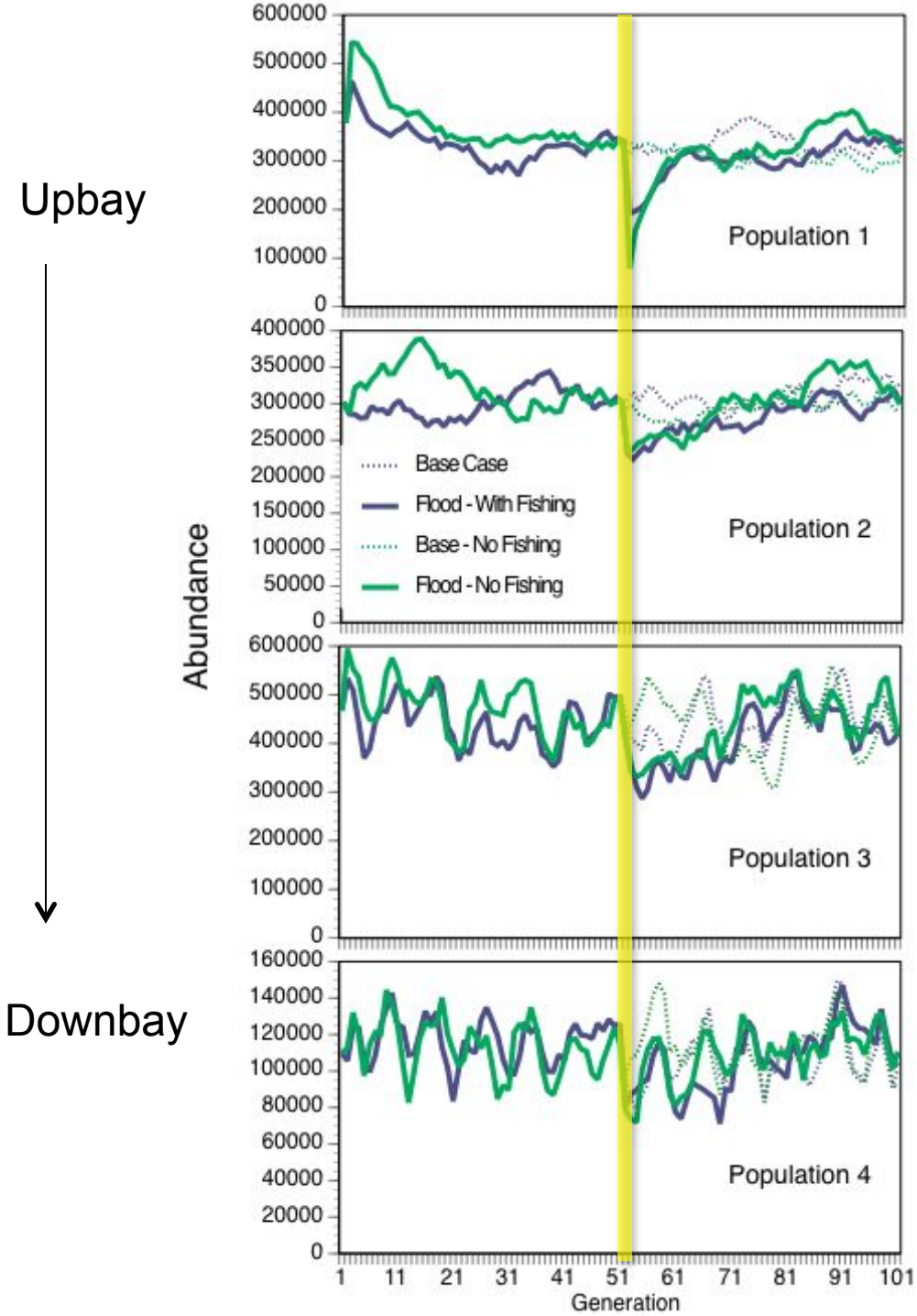

75.5° W
75.0° W
39.5° N
39.0° N
N
0
10
20
30
40
Simulation
Stock Assessment
Population 1
Population 2
Population 3
Population 4
Hope Creek
Arnolds
Shell Rock
Bennies
Shell Length Frequency
<50
50-75
75-100
100-125
125-150
>150
Length Class (mm)
Length Class (mm)

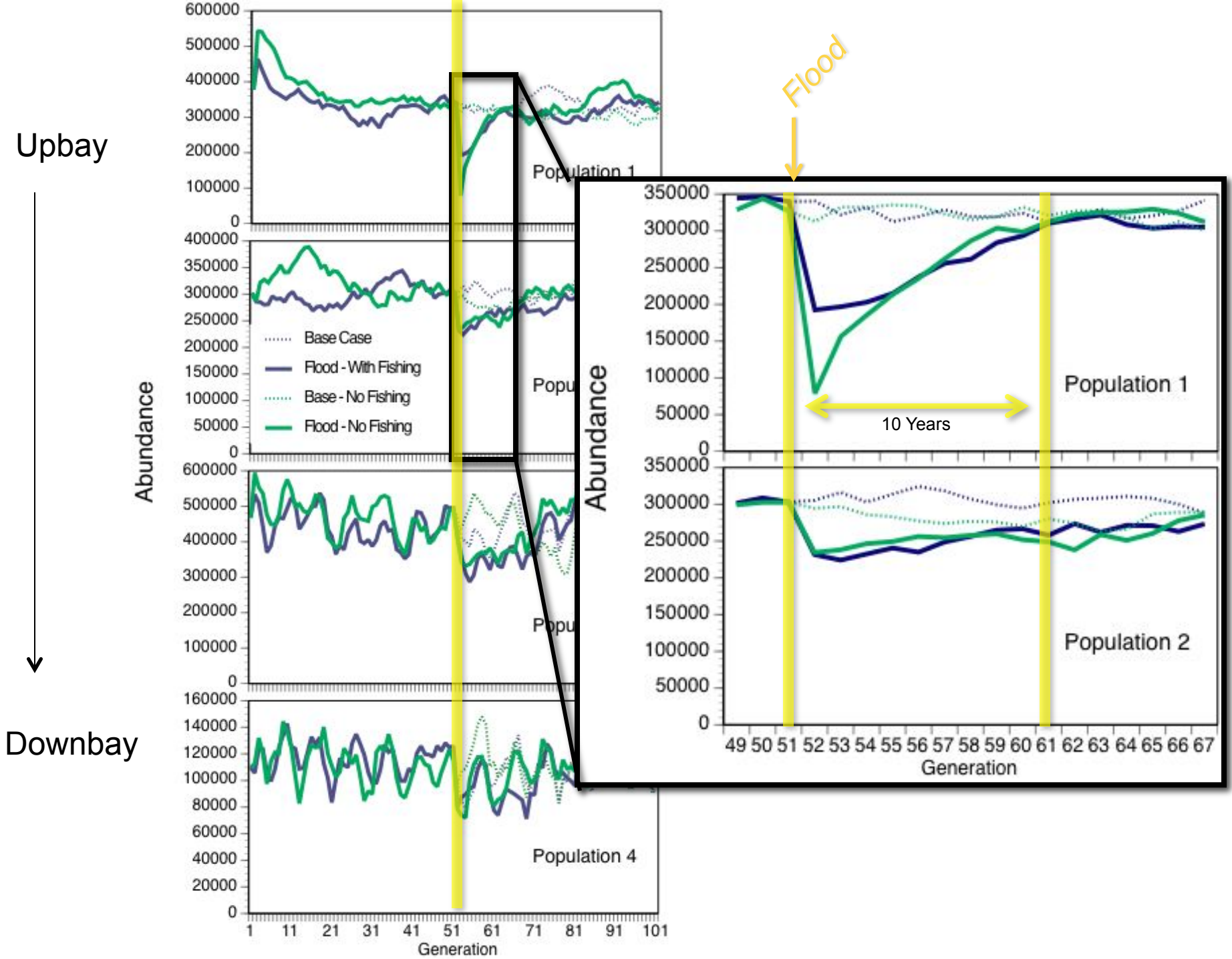
Upbay



Downbay

?


Upbay
Downbay
Abundance
Population 1
Population 2
Population 3
Population 4
Base Case
Flood - With Fishing
Base - No Fishing
Flood - No Fishing
Generation
600000
500000
400000
300000
200000
100000
0
400000
350000
300000
250000
200000
150000
100000
50000
0
600000
500000
400000
300000
200000
100000
0
160000
140000
120000
100000
80000
60000
40000
20000
0
1
11
21
31
41
51
61
71
81
91
101


Upbay
Downbay
Abundance
Base Case
Flood - With Fishing
Base - No Fishing
Flood - No Fishing
Population 1
Population 4
Generation
Flood
10 Years
Population 2

Post-Flood - What we might expect:

- Reduced length frequencies & abundance upbay ~10 years
- No change to gene flow (neutral alleles only)

Economic Projections*:

- Estimated $5.3 million direct loss to fishermen

*These projections do not account for loss of production downbay deriving from transplanted oysters

Summary

- Storm effects varied spatially
  - Low salinity push disease down bay, but killed oysters on the upper beds
    - Mortality reduced 2012 oyster quota and closed the uppermost beds to the fishery, possibly for a decade
  - Oysters entered winter with low Dermo levels
    - Over winter survival may be higher than normal on lower beds
  - Oysters entered winter in lowest recorded condition on central to uppermost beds
    - Overwinter mortality expected to be high on these beds
- Current warm winter and lack of precipitation may allow Dermo to increase quickly, eliminating the lower bay benefits

Questions?