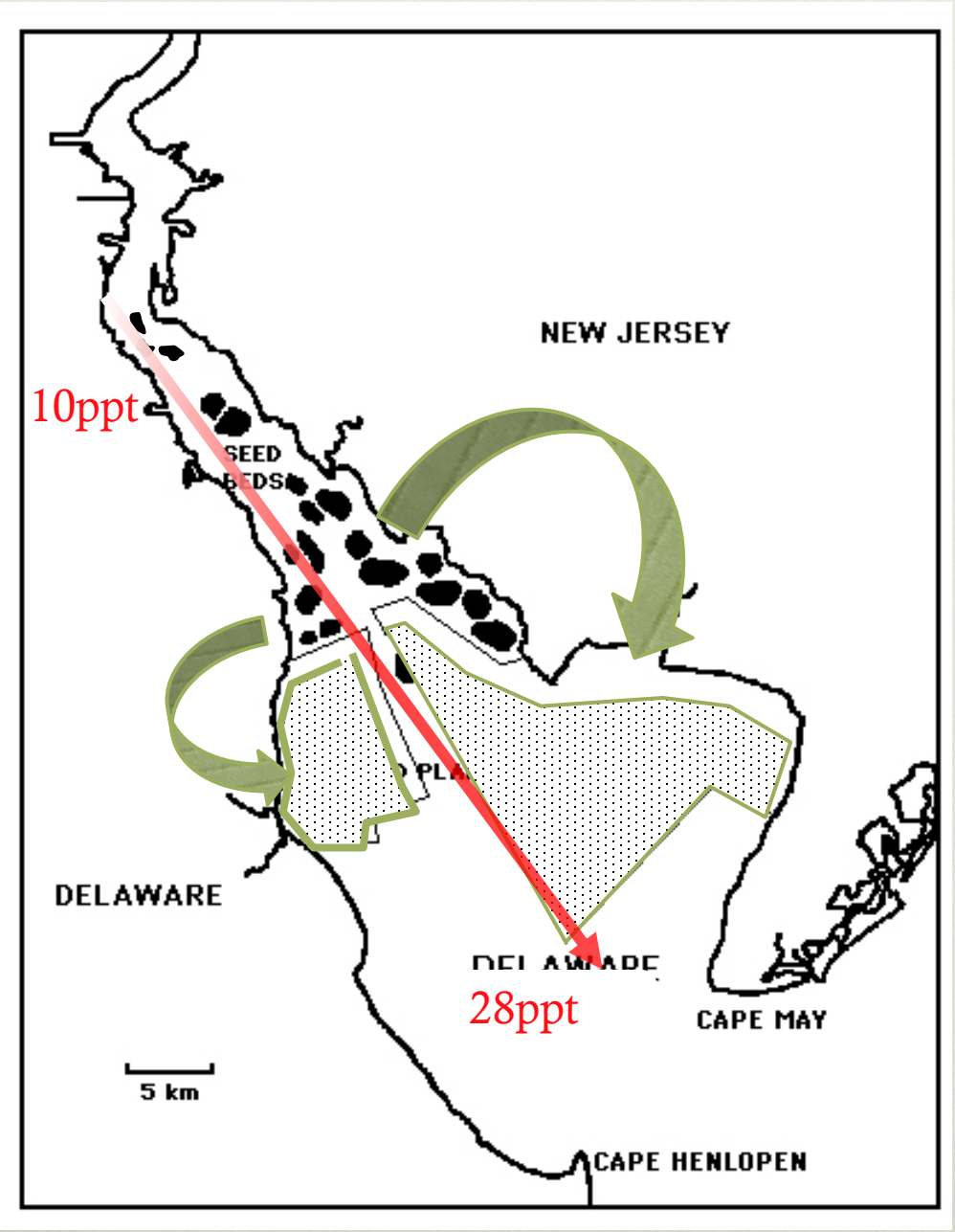
Oyster Mortality & Disease in Delaware Bay: Impact & recovery following major storms

David Bushek & Daphne Munroe

2013 Delaware Estuary Science and Environmental Summit

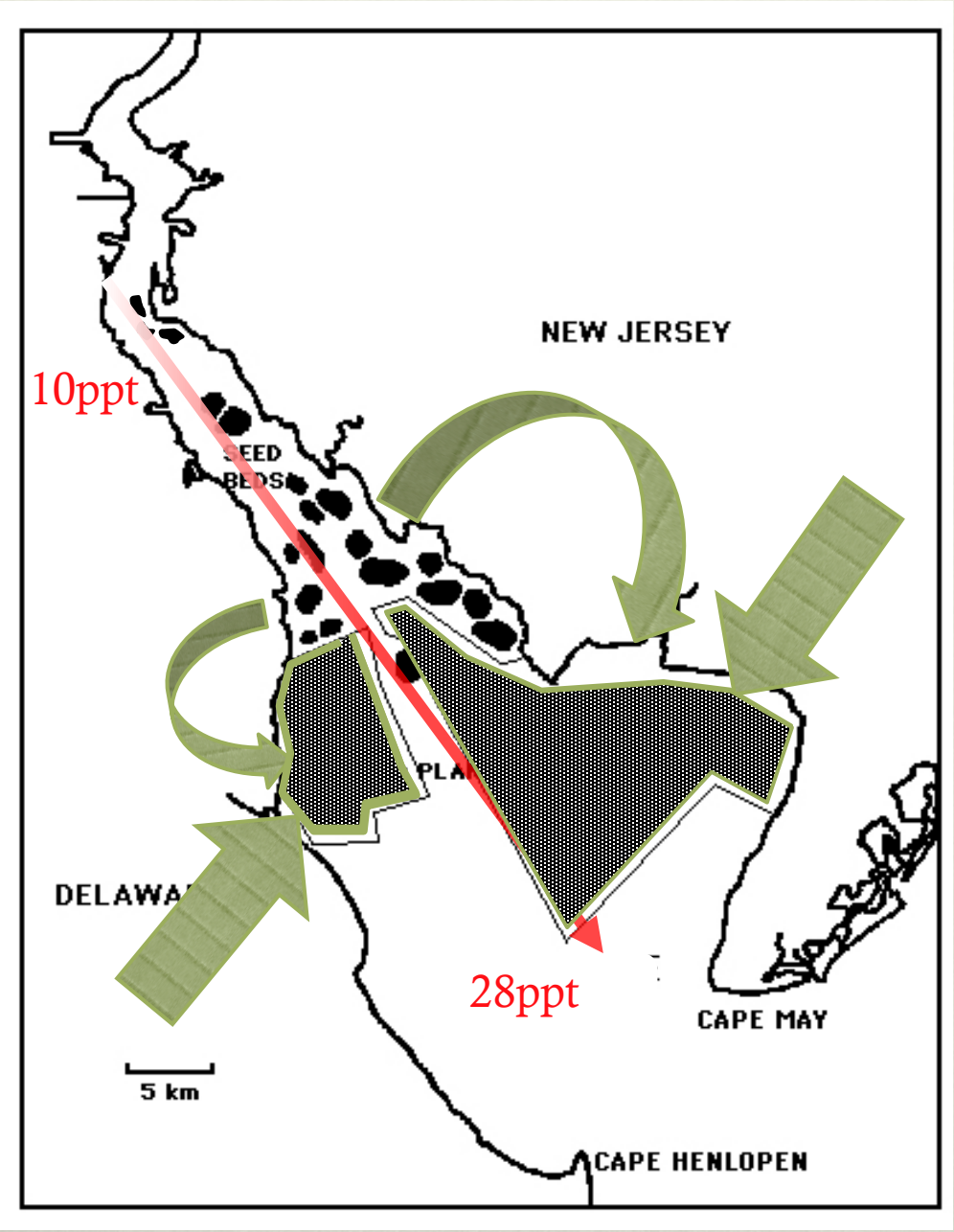
RUTGERS
Haskin Shellfish
Research Laboratory



Delaware Bay Oyster Population

- Bay divided into natural beds and planted grounds
- Oyster recruitment, growth, condition and quality all increase with salinity
- Historical fishery moved/transplanted oysters during “bay season” to improve quality for subsequent harvest

Delaware Bay Oyster Population



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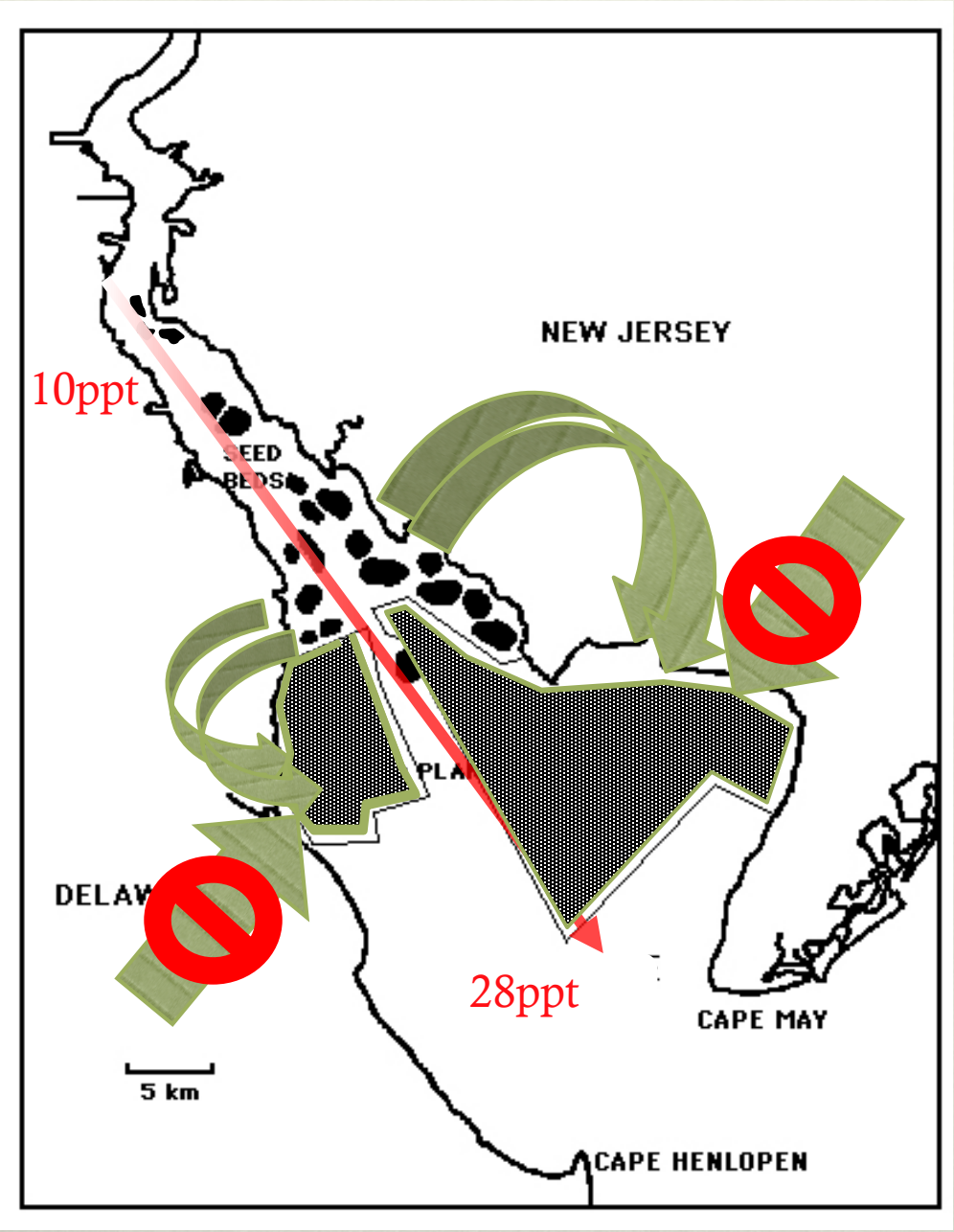

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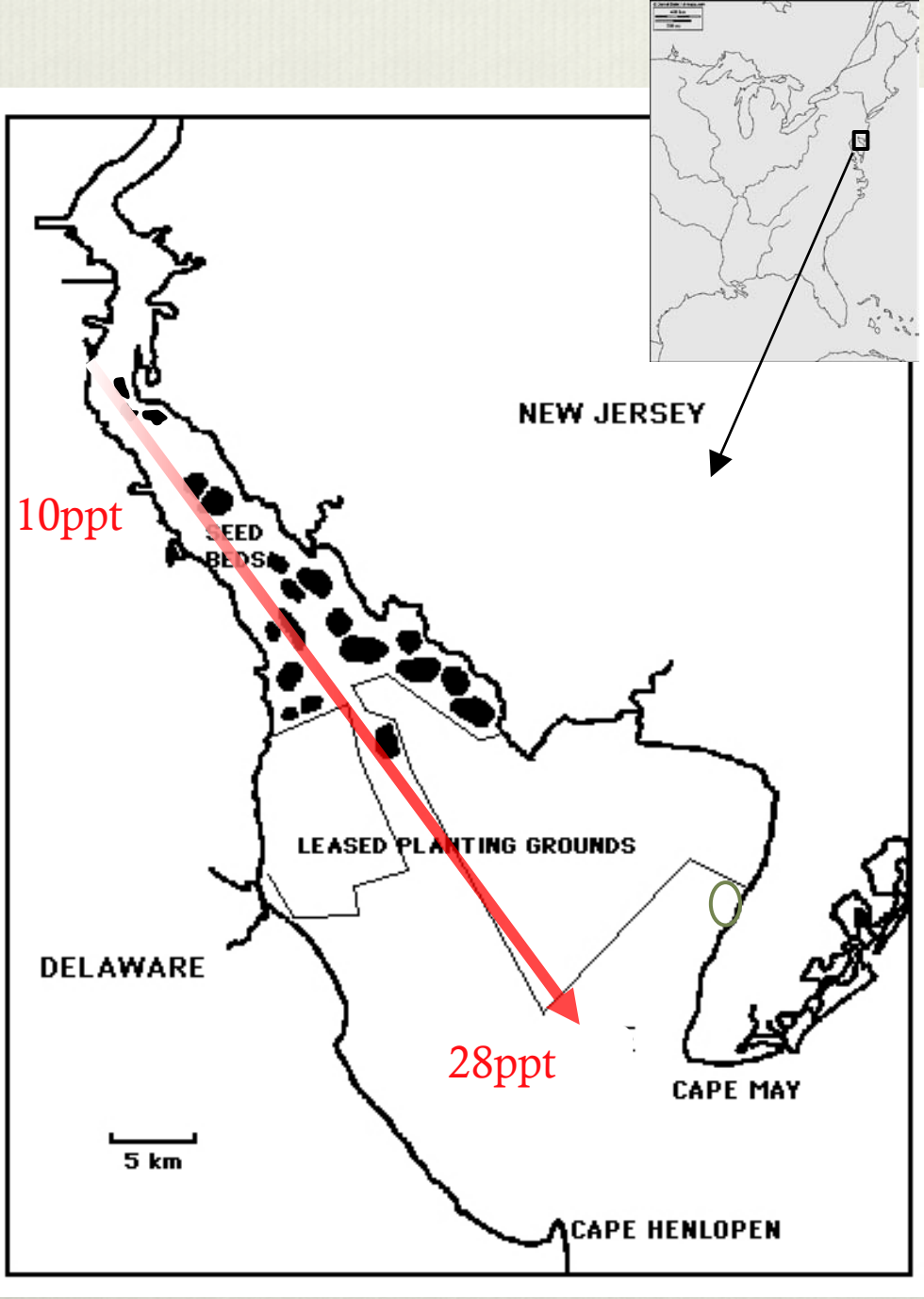
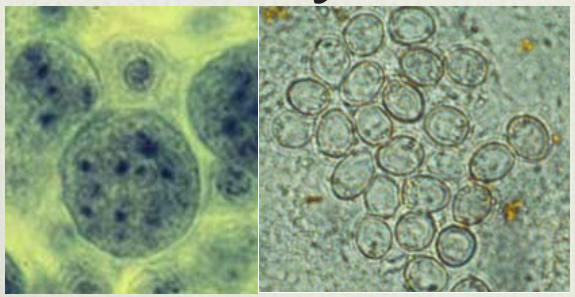
Delaware Bay Oyster Seedbeds

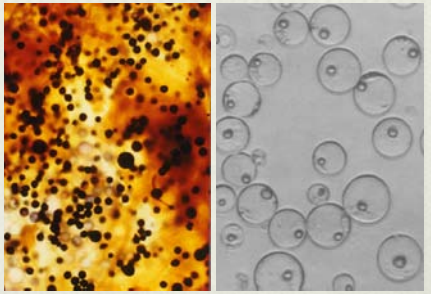


- Long-term data sets:
  - oyster abundance since 1953
  - MSX disease since 1958
  - Dermo disease since 1990
- Management changes
  - 40% rule
  - Disease impacts on leased grounds
  - Direct market fishery
- Seedbed management goal
  - Stable, sustainable production

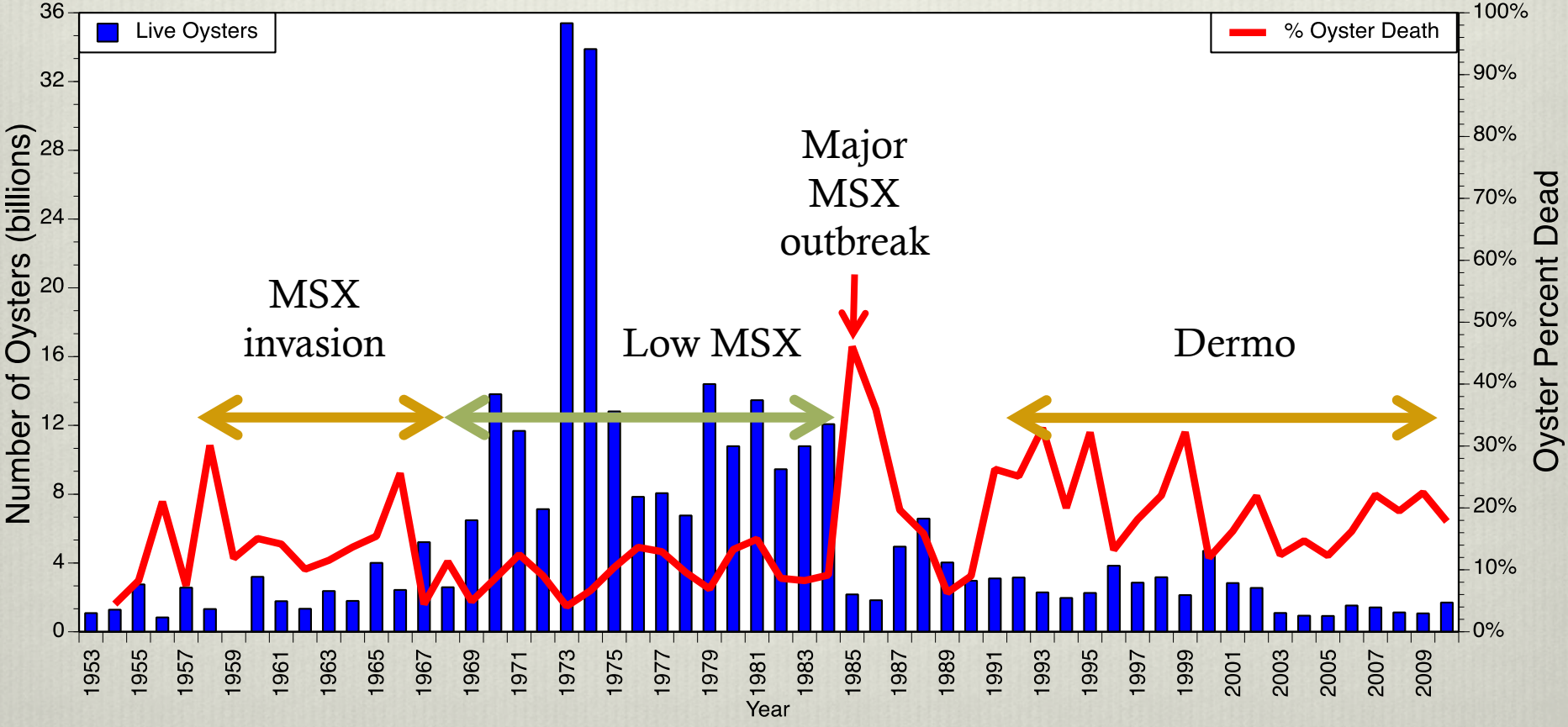
Oyster Abundance Associated with Oyster Diseases MSX and Dermo



MSX = *Haplosporidium nelsoni*



Dermo = *Perkinsus marinus*



Spatial Patterns of MSX and Dermo Associated with Salinity Gradient

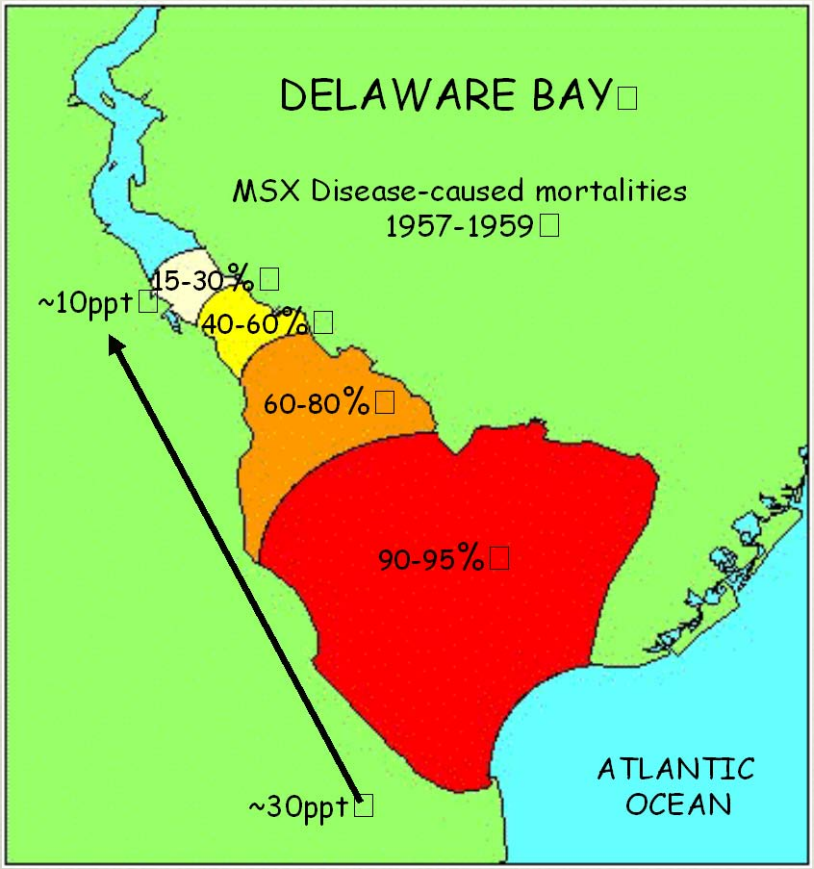
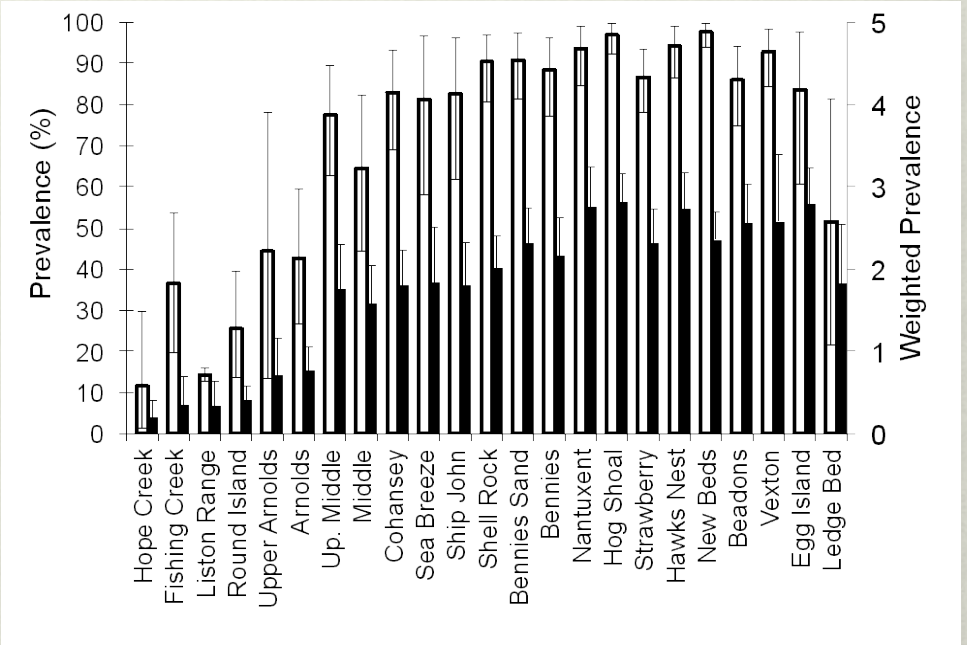


Image courtesy of SE Ford

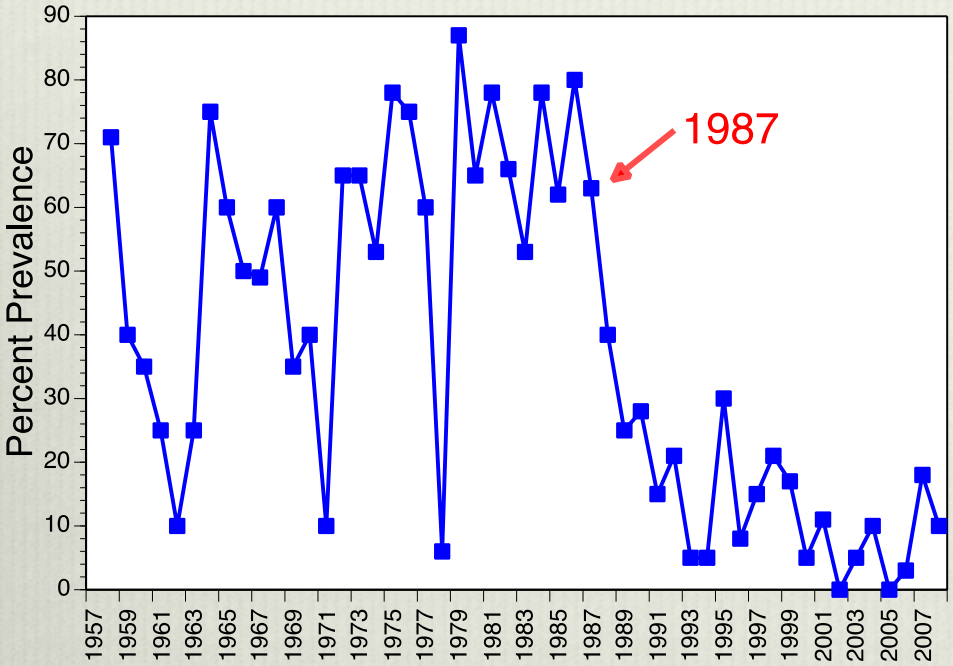
Dermo

Up bay - - - - - - - - - - - - Down bay



Bushek, D., S.E. Ford and I. Burt. 2012. Long-term patterns of an estuarine pathogen along a salinity gradient.
J. Mar. Res. 70:225-251.

Resistance to MSX in Delaware Bay

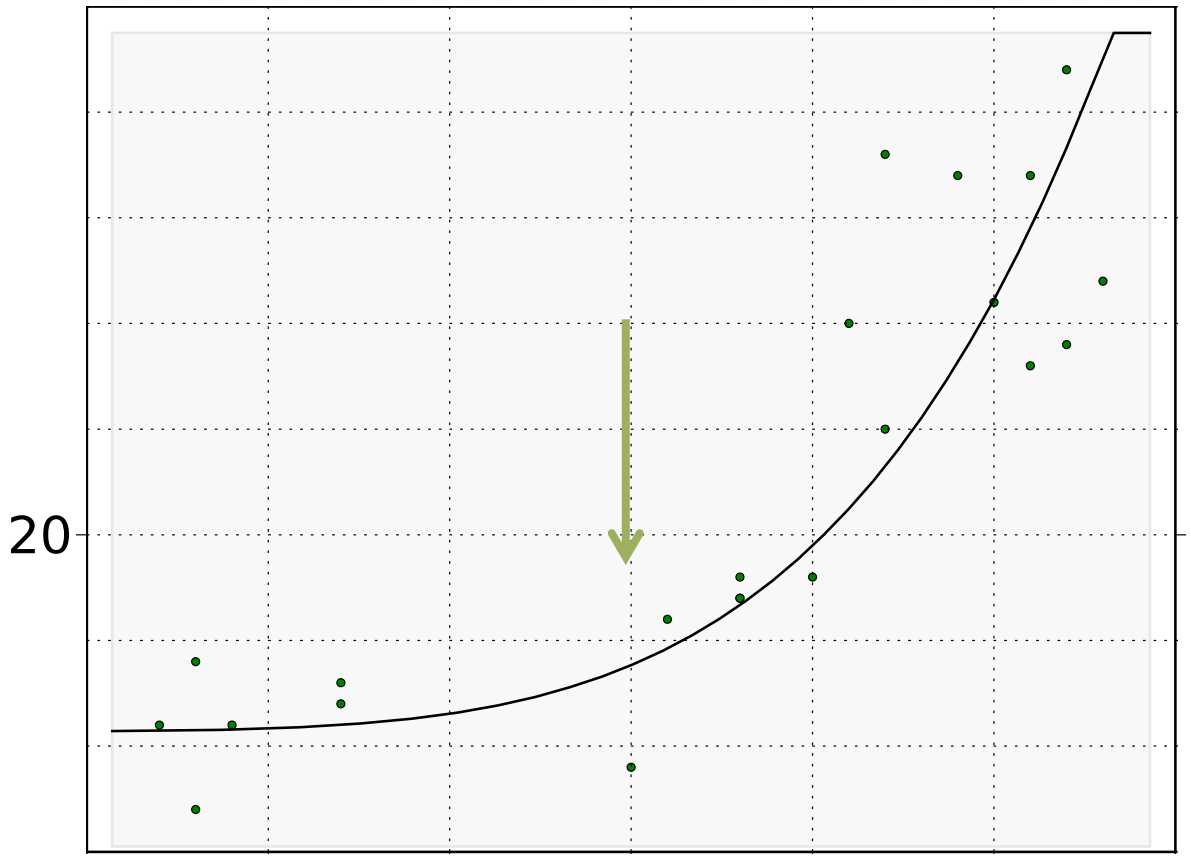


After several cycle of MSX: Delaware Bay natives resistant, naïve stocks susceptible

Ford, S.E. and D. Bushek. 2012. Development of resistance to an introduced marine pathogen by a native host. J. Mar. Res. 70:205-223.

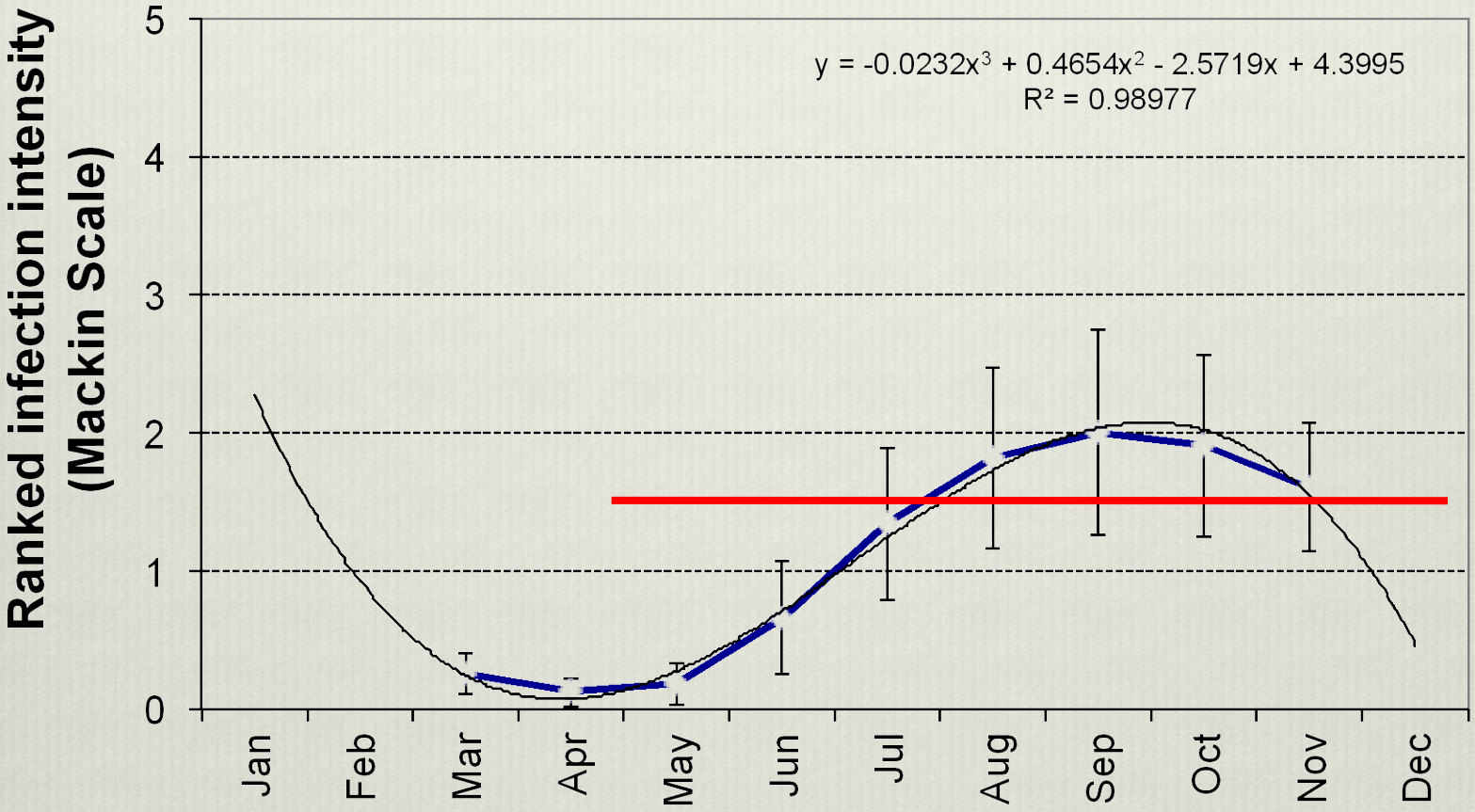
	Naïve	Natives
1964	70	75
1965	65	55
1998	70	ND
2000	100	5
2001	53	0
2002	26	0
2003	4	0
2004	81	0
2005	90	0
2006	75	5
2007	55	0
2008	55	0
2009	90	5

Mortality as a function of Dermo intensity

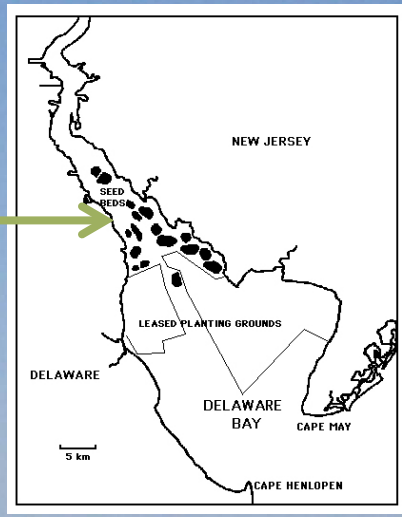


Seasonal Dermo Cycle

Seedbed mean since 1998



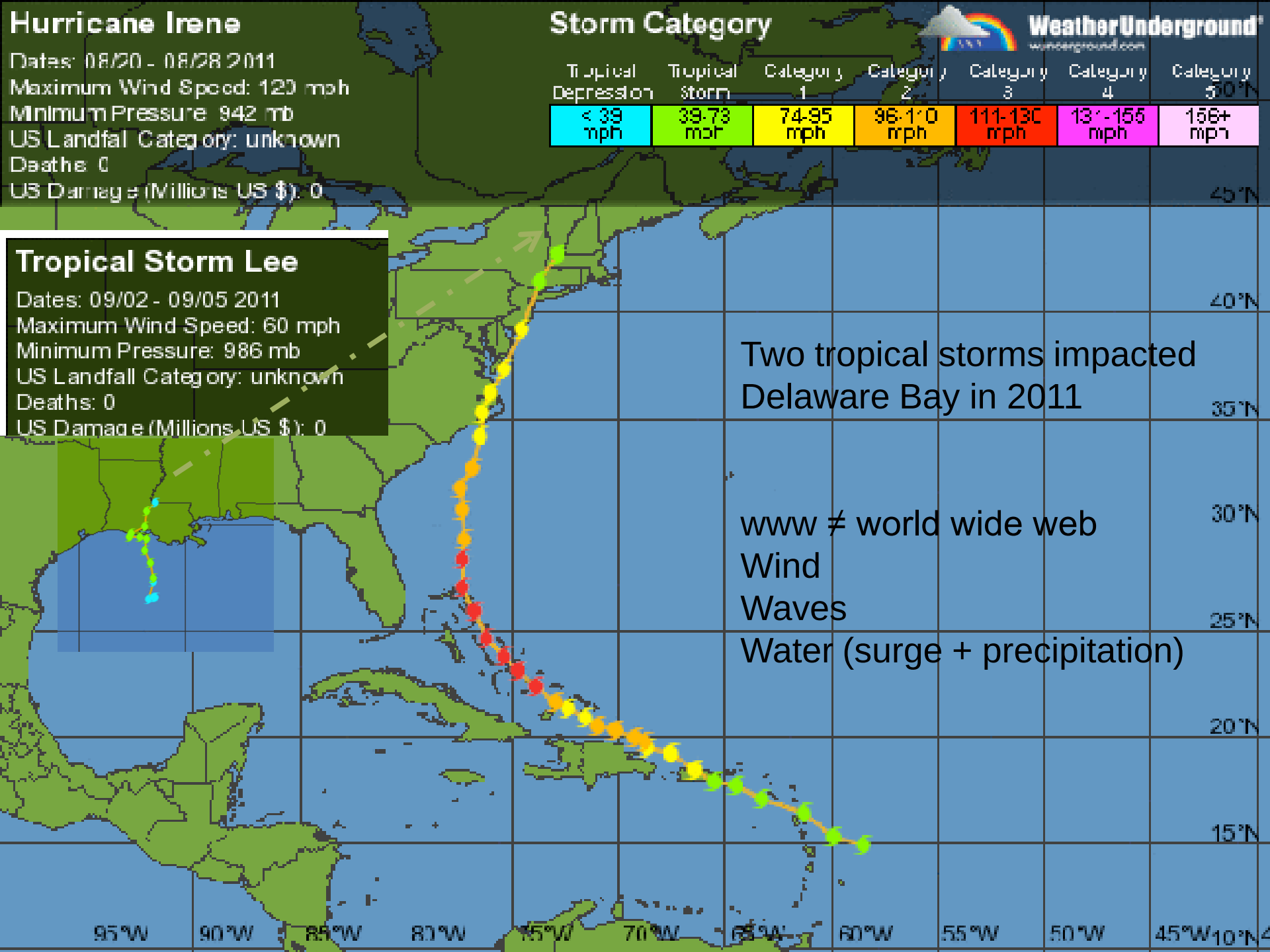
How do major storms affect oyster disease and mortality?

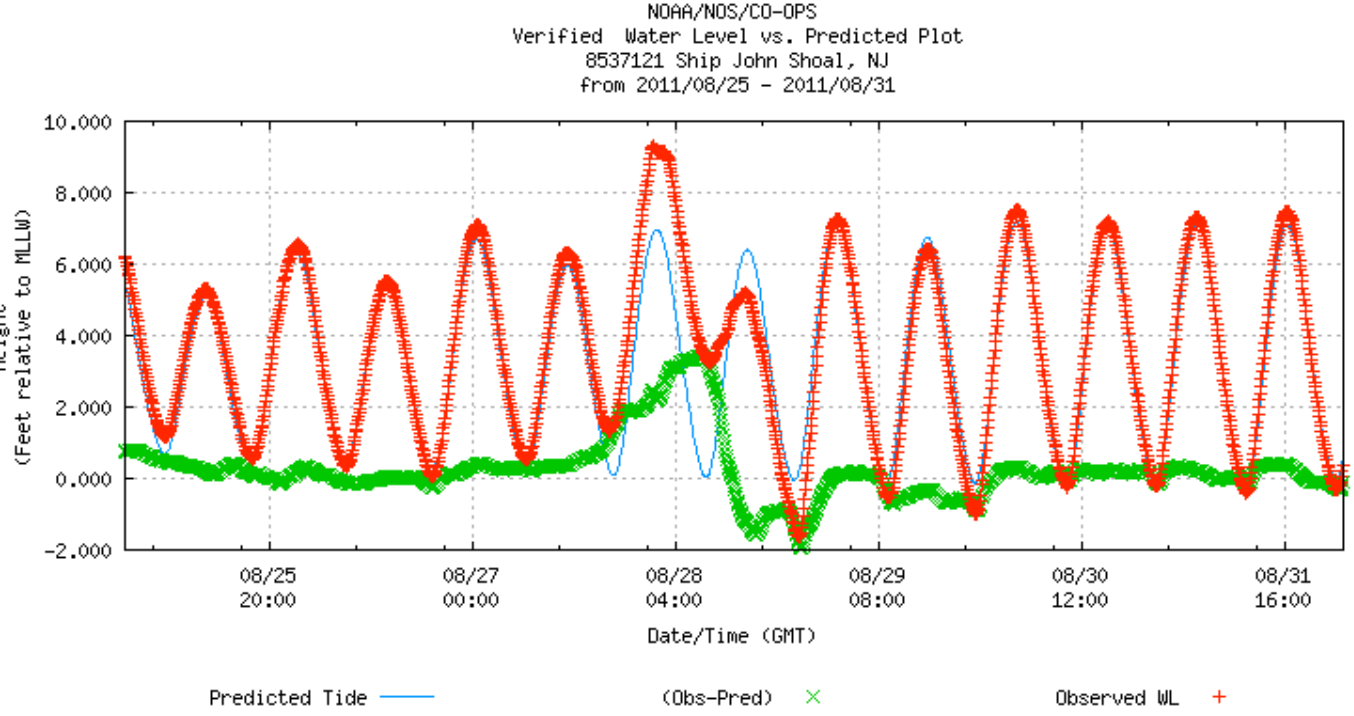


Ship John Shoal Light

NOAA PORTS Monitoring Station

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


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
Tropical Storm
Category 1
Category 2
Category 3
Category 4
Category 5
< 39 mph
39-73 mph
74-95 mph
96-110 mph
111-130 mph
131-155 mph
156+ mph
WeatherUnderground
Tropical Storm Lee
Dates: 09/02 - 09/05 2011
Maximum Wind Speed: 60 mph
Minimum Pressure: 986 mb
US Landfall Category: unknown
Deaths: 0
US Damage (Millions US $): 0
Two tropical storms impacted Delaware Bay in 2011
www ≠ world wide web
Wind
Waves
Water (surge + precipitation)
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

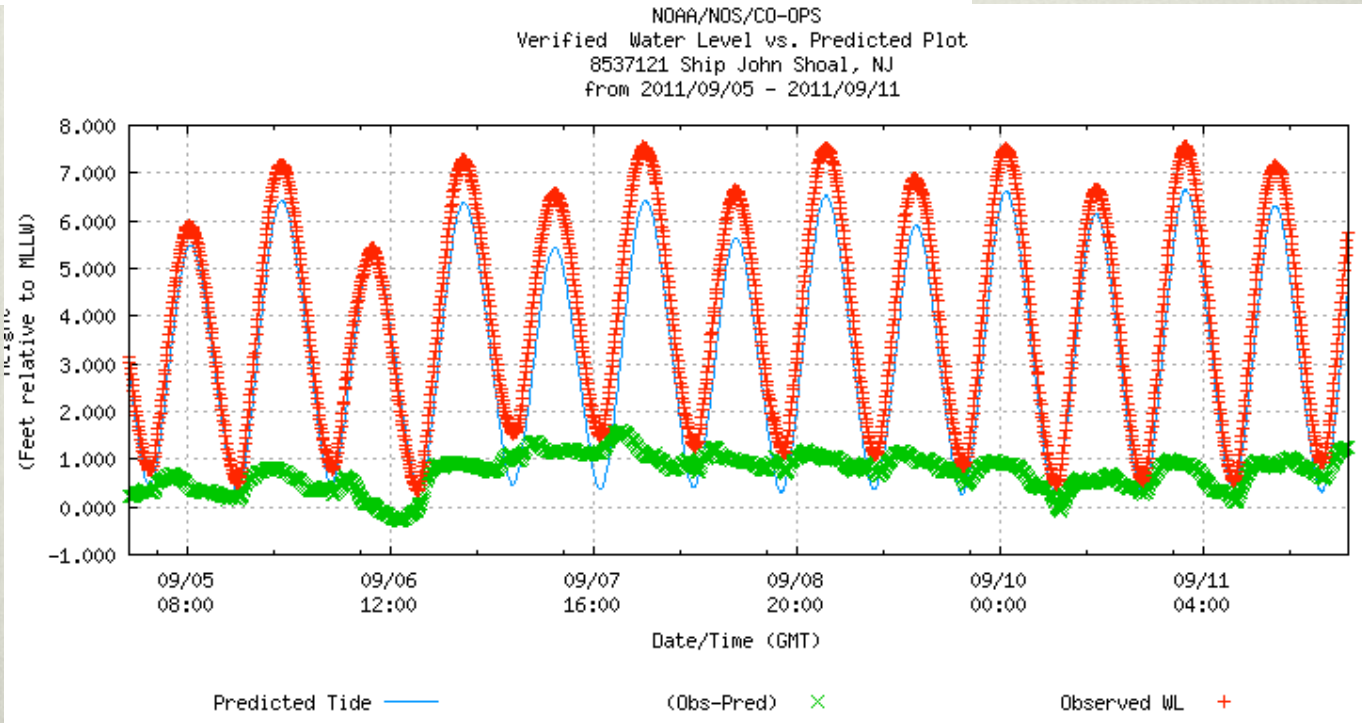


Irene storm surge
August 28, 2011

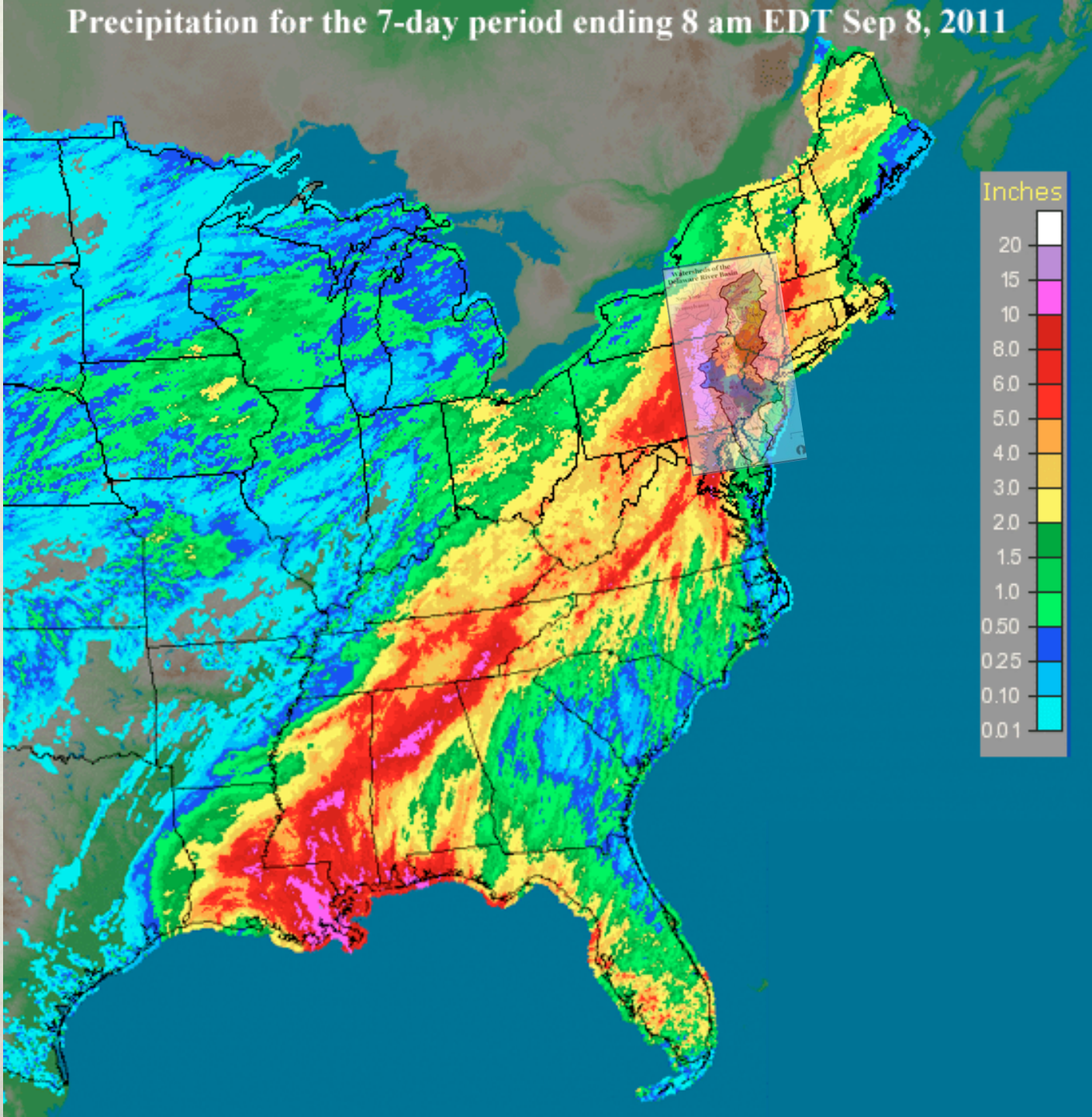
Peak at low tide

TS Lee
Sept 8, 2011

No storm surge



Rainfall after Irene and Lee in 2011



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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

Share Email Print 1 2 Next >

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*

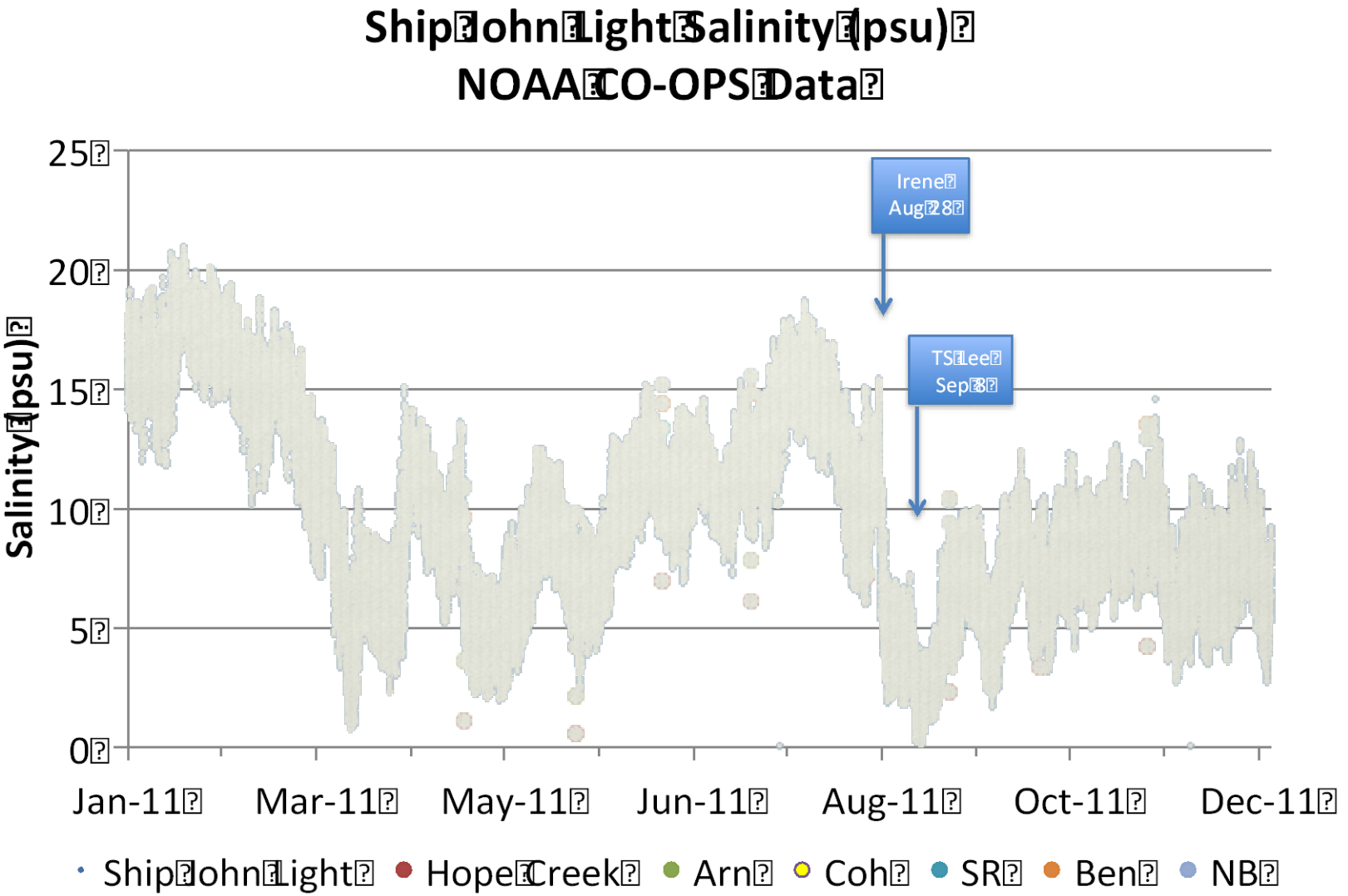
The numbers that are emerging, not

Tropical Storms Irene and Lee

- "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

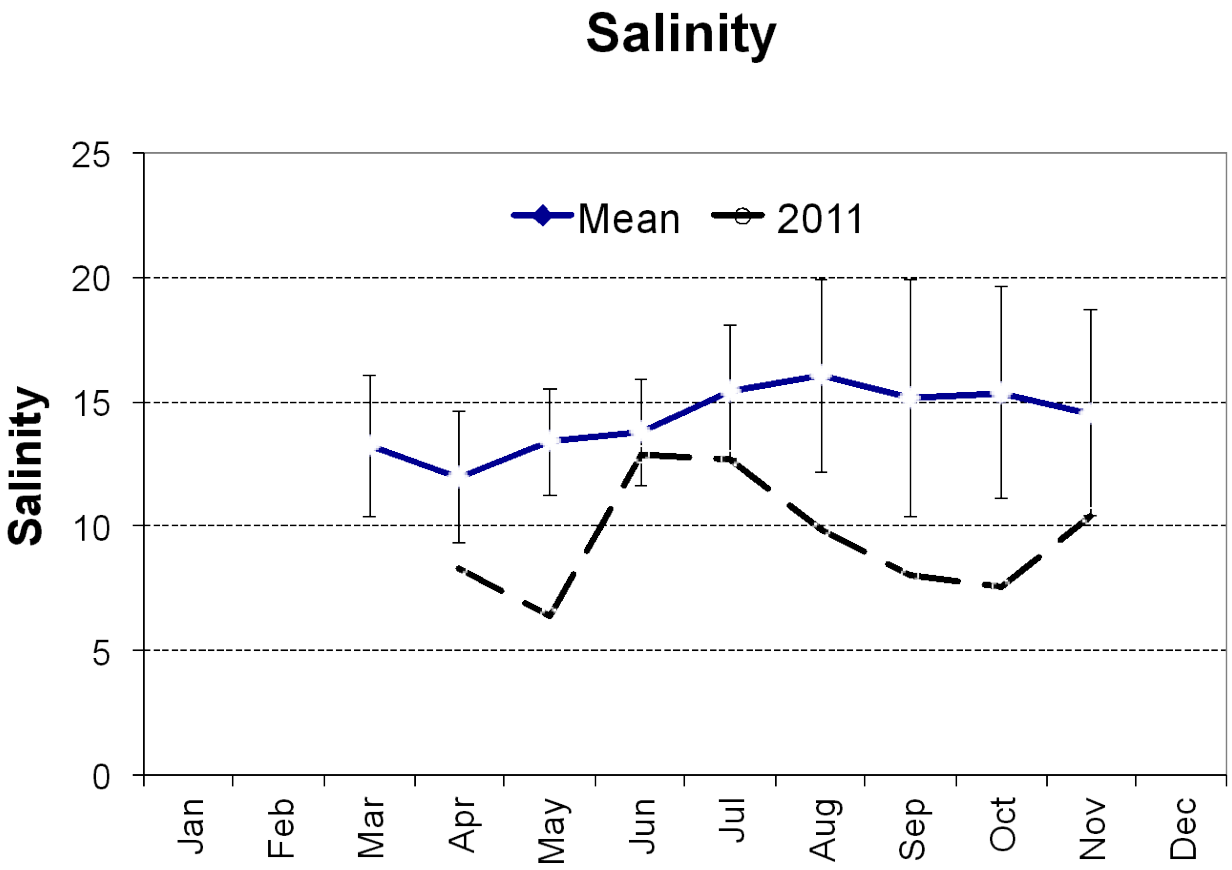
http://www.scientificamerican.com/article.cfm?id=hurricane-east-coast-damage

Runnoff depressed salinity

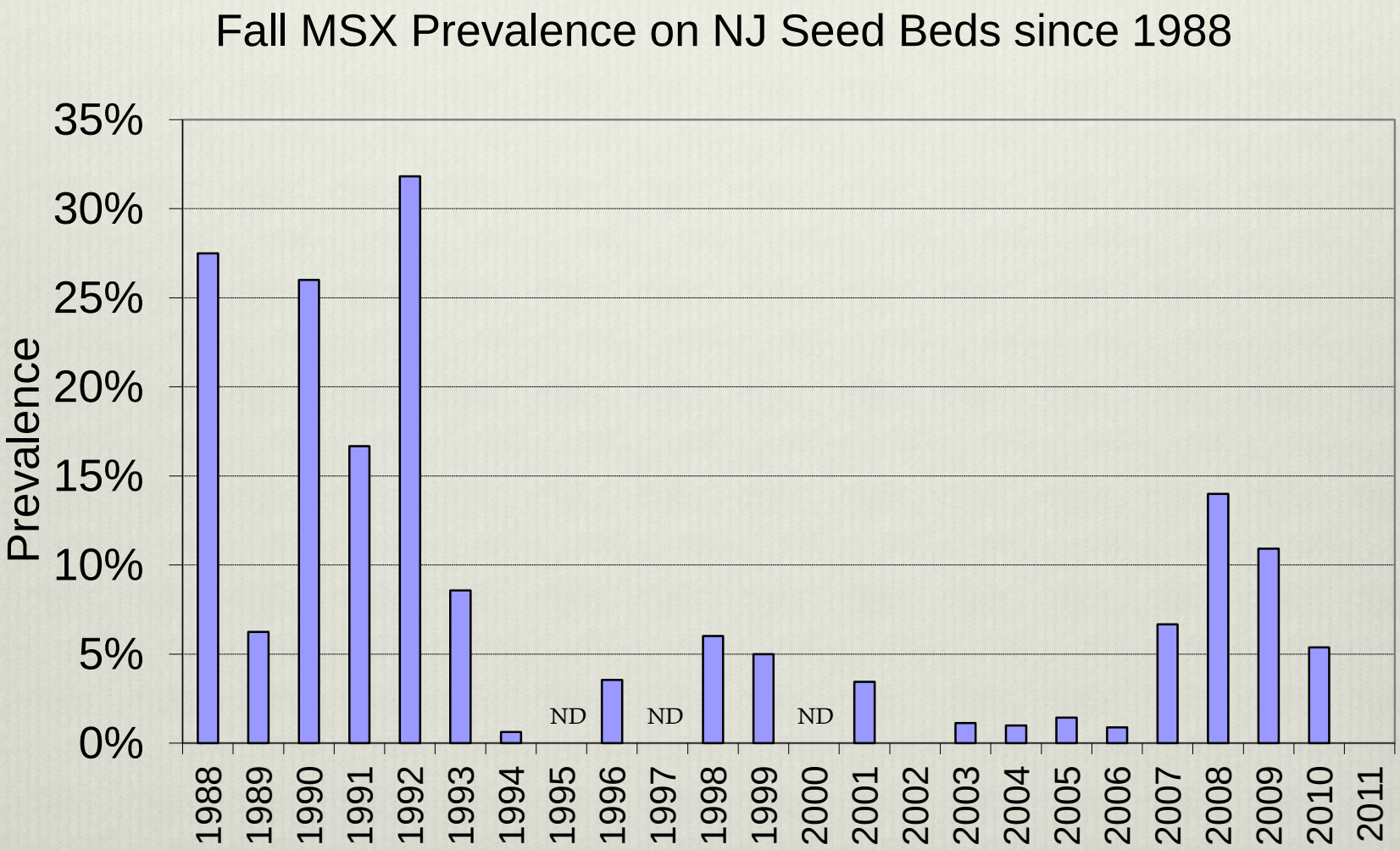


Normal spatial pattern, but high spring runoff and tropical storms depressed salinity

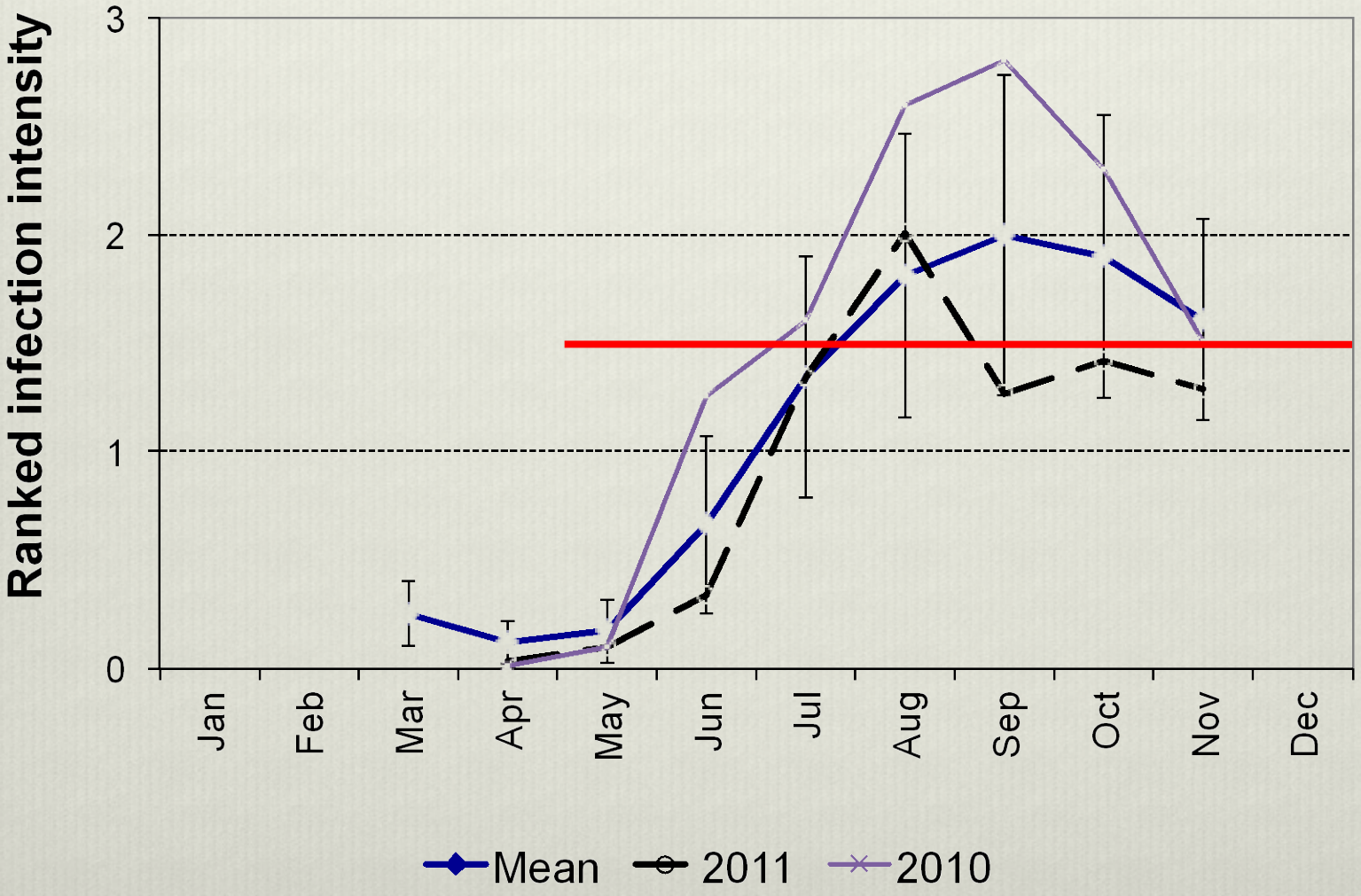
Unusually low salinity year

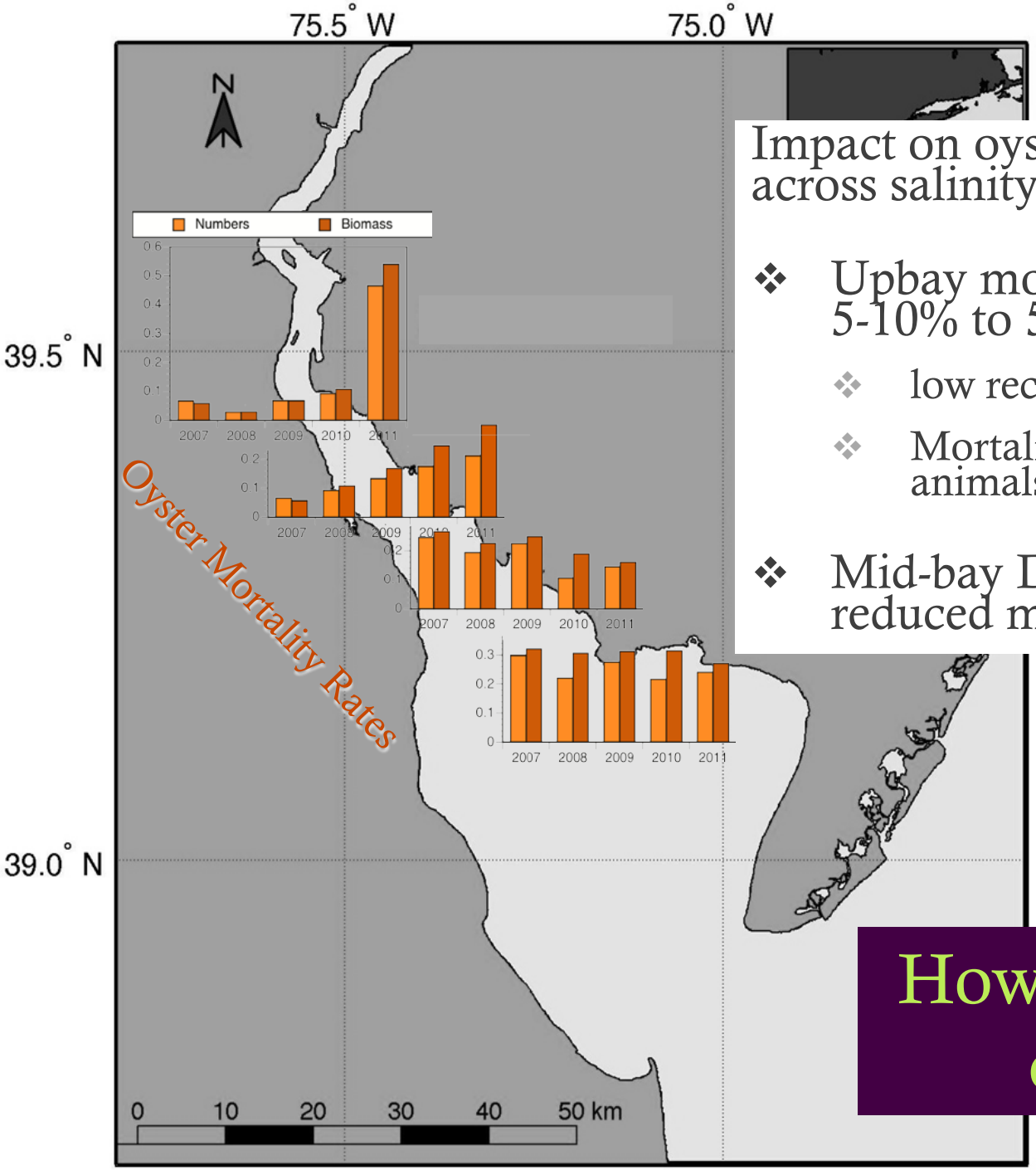


No MSX following 2011 floods



Seasonal Dermo Cycle





Impact on oyster mortality varied across salinity gradient:

- Upbay mortality increased from 5-10% to 50%-70%
  - low recruitment area
  - Mortality biased toward large animals
- Mid-bay Dermo decrease reduced mortality

How long will these effects last?

Spatially-Explicit Individual-Based Numerical Model

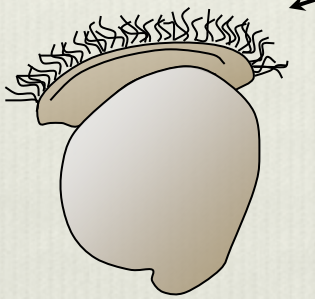
Multiple Linked Population Dynamics Models

DyPoGEn

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

Individual Genetics:

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

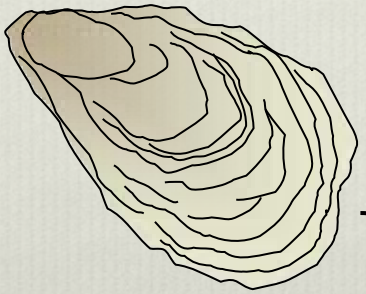


Larvae can:

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

Recruits will:

- Grow
- Experience mortality
- Change sex
- Spawn



DYOPOGEN GEAR BOX

Spatially-Explicit Individual-Based Numerical Model

Multiple Linked Population Dynamics Models

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

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

$$P = 1 - LarvSurv$$

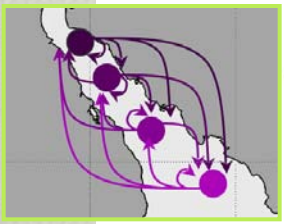
Juvenile Mortality
(Applied to Juveniles)

Larval Mortality
(Applied to Offspring)

Increment Age

Adult Mortality
(Age Dependent)

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



Larval Dispersal
(Exchange Rates from
Particle Model)

DyPoGEn

Time Step
One Year

Functional Sex Change
(Size Dependent)

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

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

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

Offspring Produced
(Meiosis)

Parents Selected

Spawning

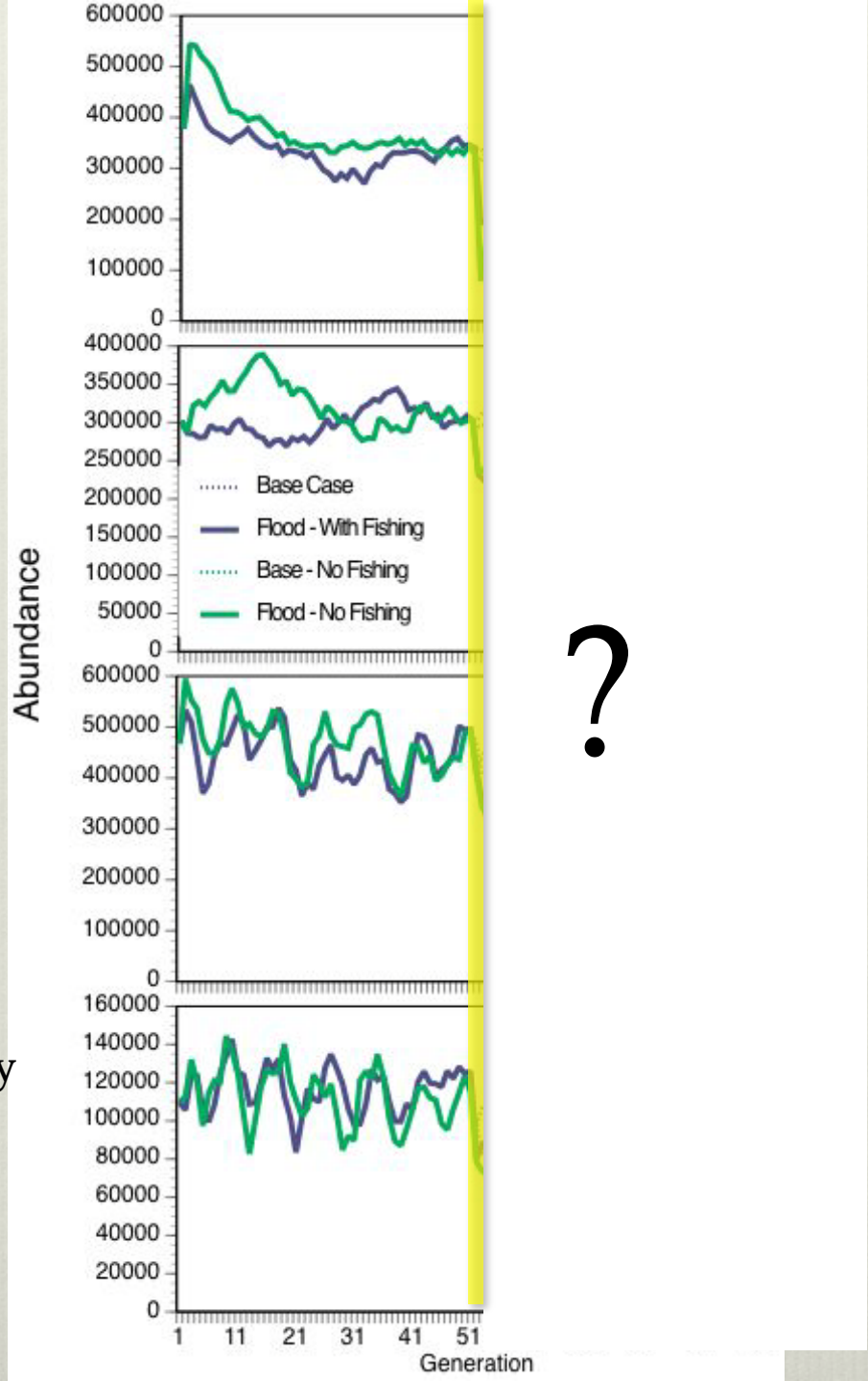
$$W = W_\infty\left(1 - e^{-k(Age - Age_0)}\right)^b$$

$$nOff = \frac{W_\infty}{W_{76}}\left(1 - e^{-k(Age - Age_0)}\right)^b MaxOff$$

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

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

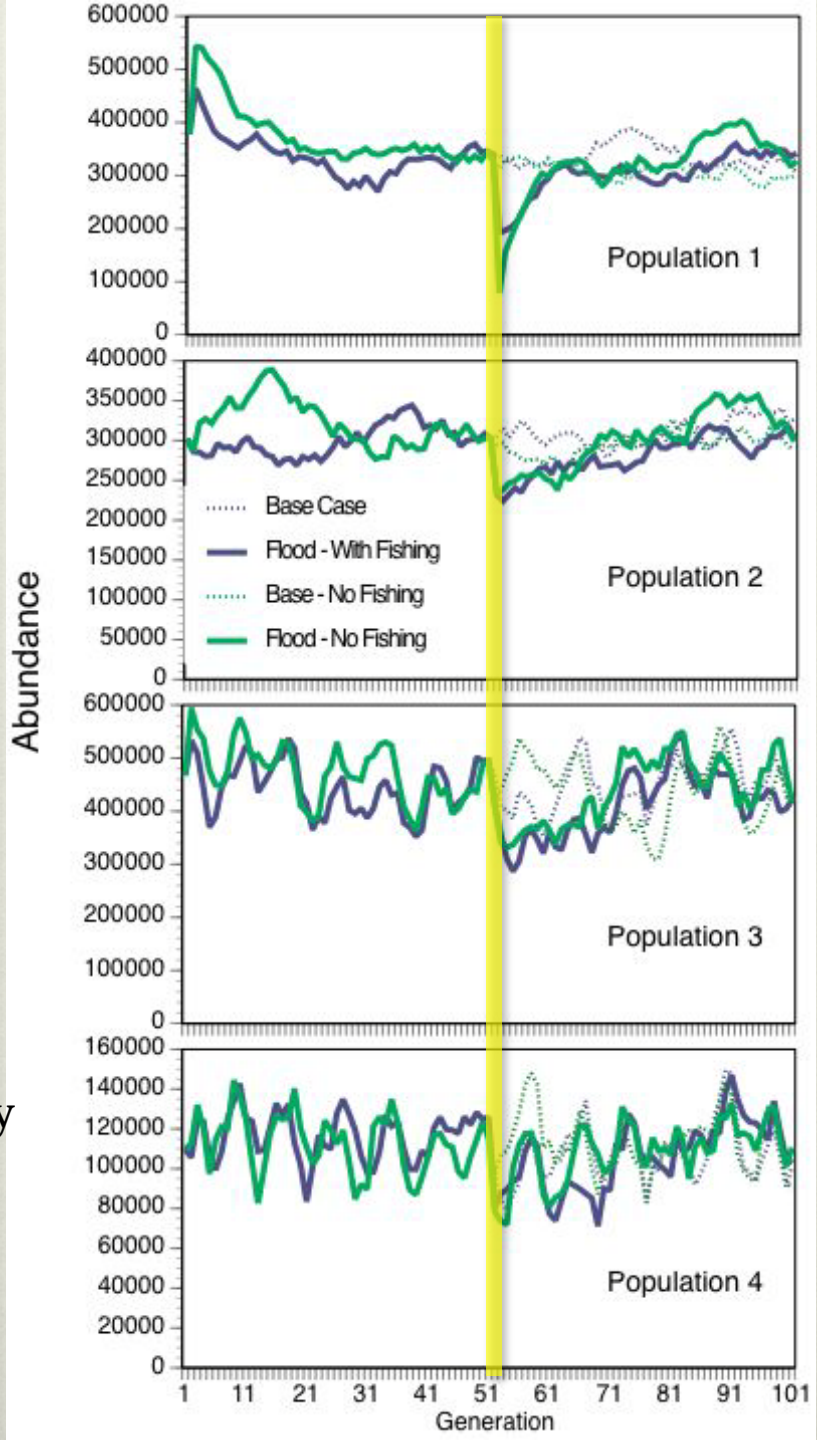
Upbay



?

Downbay

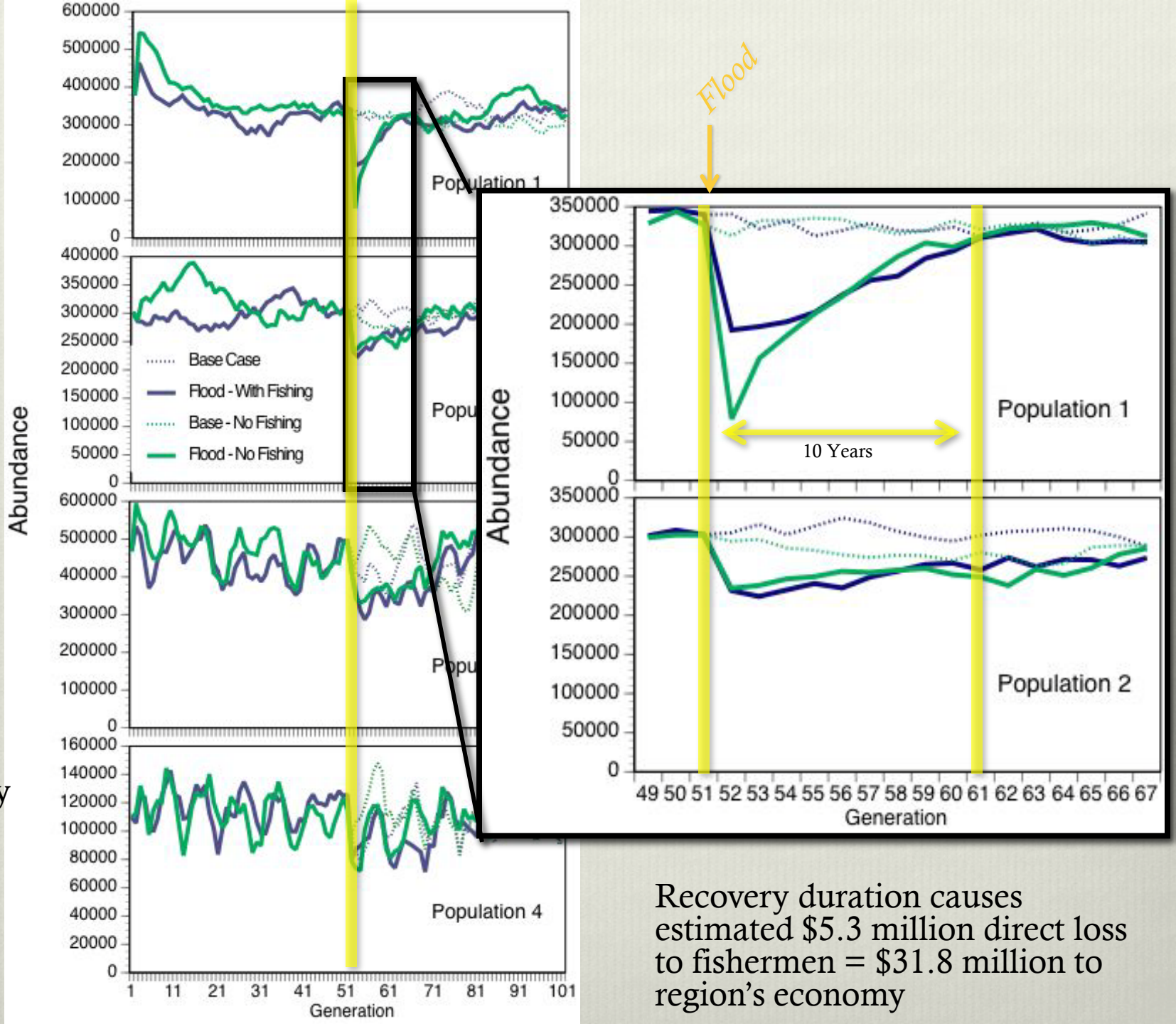
Upbay



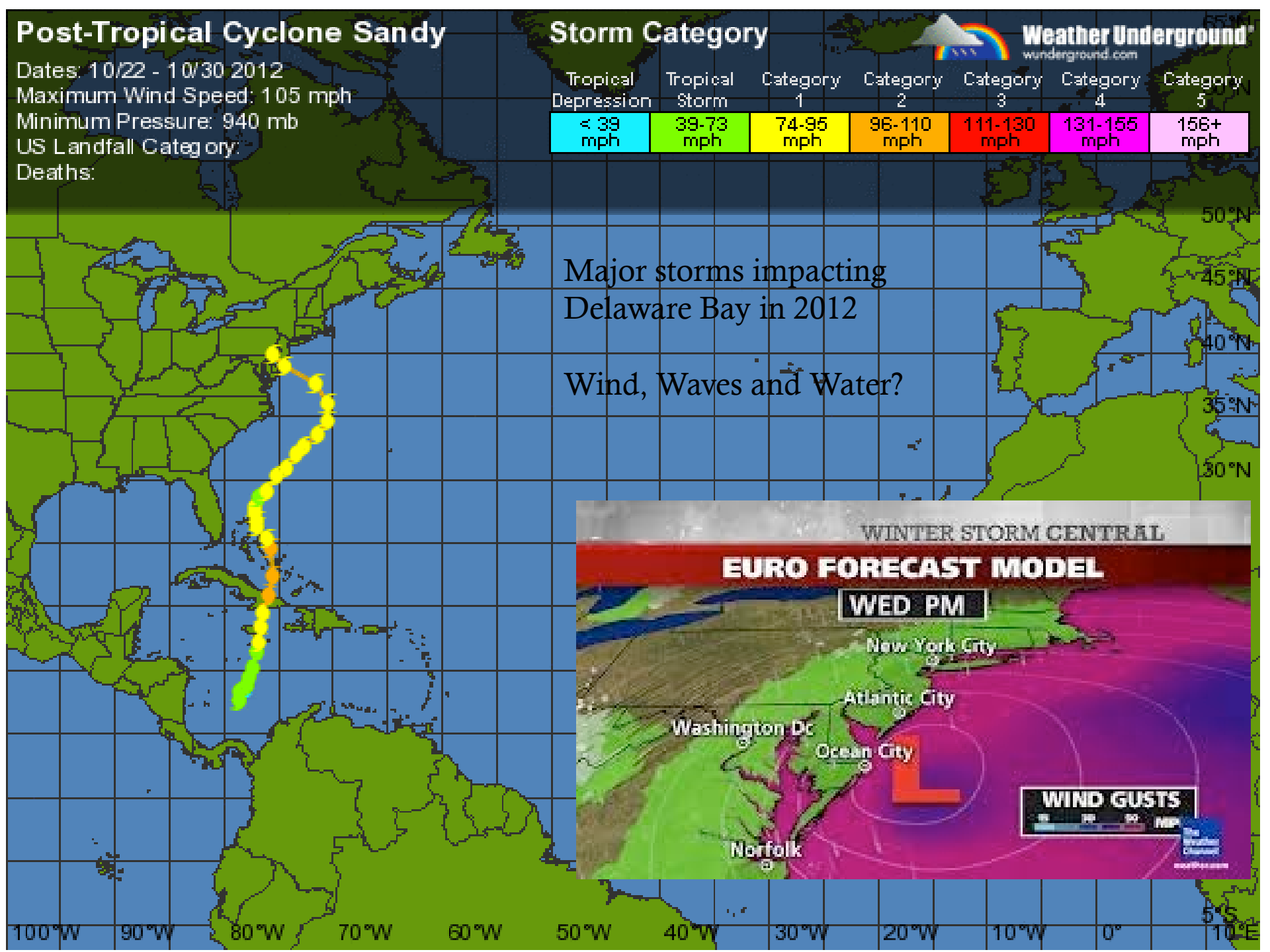
Downbay

Upbay

Downbay



Recovery duration causes estimated $5.3 million direct loss to fishermen = $31.8 million to region's economy

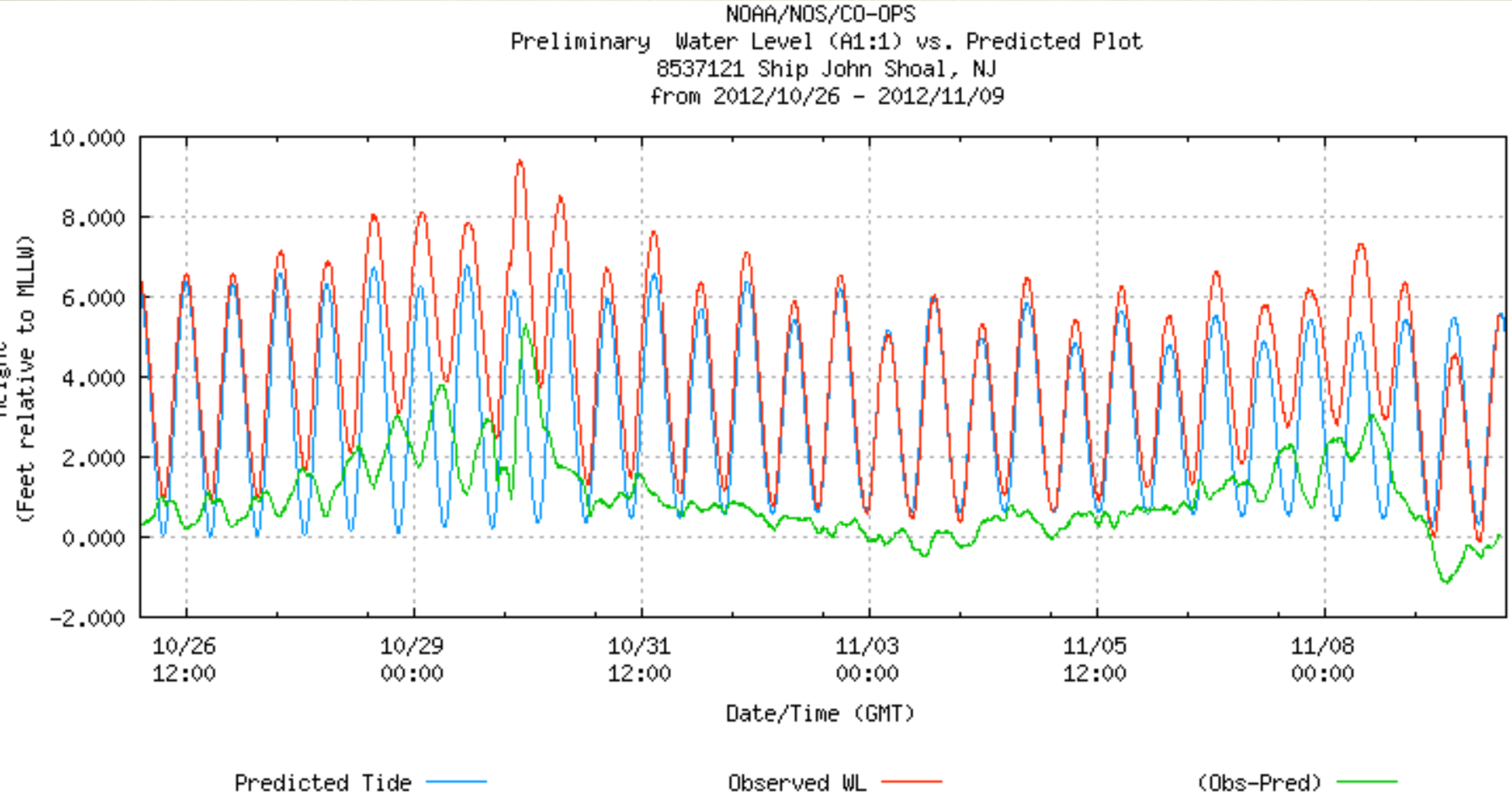

Post-Tropical Cyclone Sandy
Dates: 10/22 - 10/30 2012
Maximum Wind Speed: 105 mph
Minimum Pressure: 940 mb
US Landfall Category:
Deaths:
Storm Category
Weather Underground
wunderground.com
Tropical Depression
< 39 mph
Tropical Storm
39-73 mph
Category 1
74-95 mph
Category 2
96-110 mph
Category 3
111-130 mph
Category 4
131-155 mph
Category 5
156+ mph
Major storms impacting Delaware Bay in 2012
Wind, Waves and Water?
WINTER STORM CENTRAL
EURO FORECAST MODEL
WED PM
New York City
Atlantic City
Washington Dc
Ocean City
Norfolk
WIND GUSTS
50°N
45°N
40°N
35°N
30°N
100°W
90°W
80°W
70°W
60°W
50°W
40°W
30°W
20°W
10°W
0°
10°E


IRENE 08272011

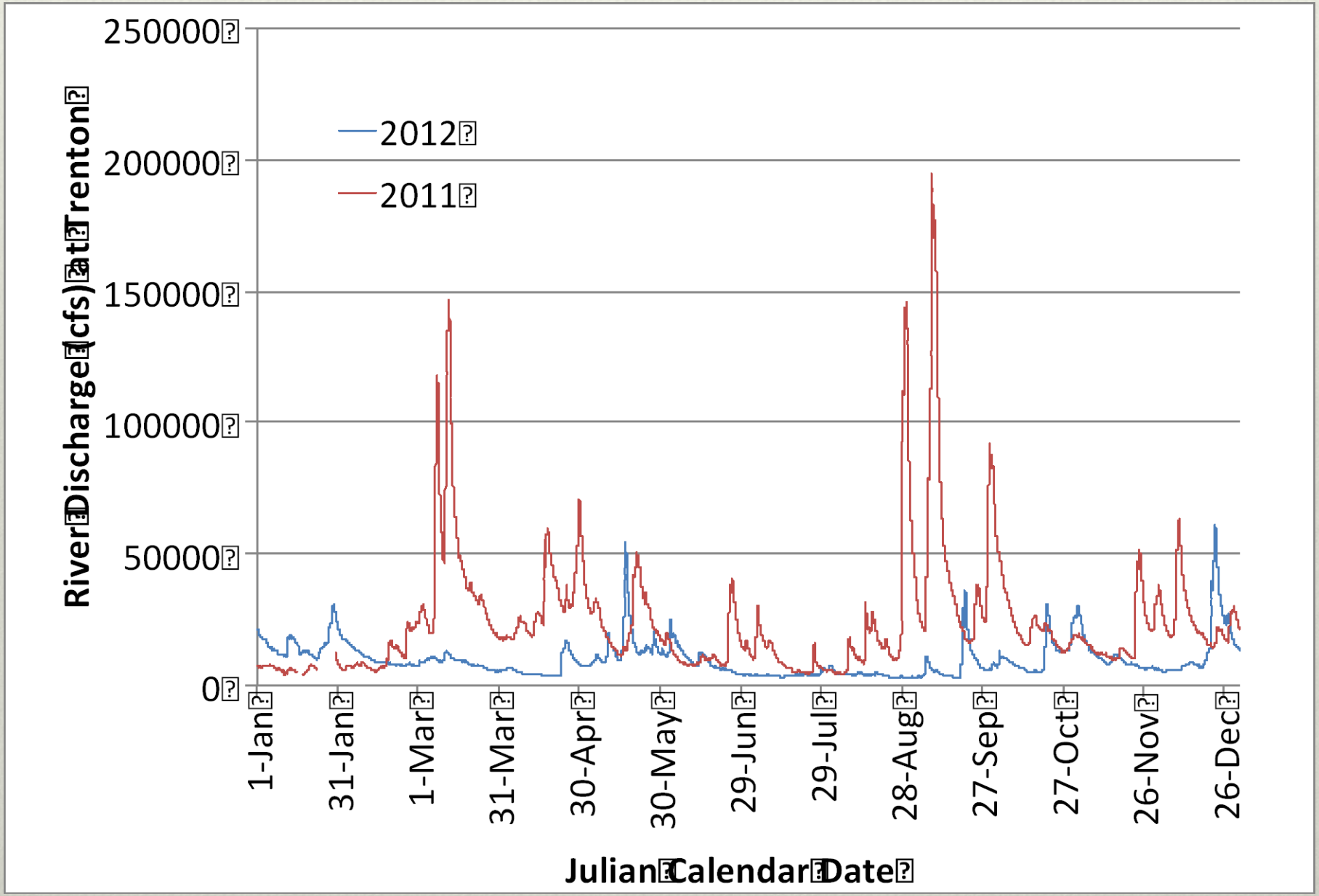

SANDY 10282012

Hurricane Sandy & Nor'easter

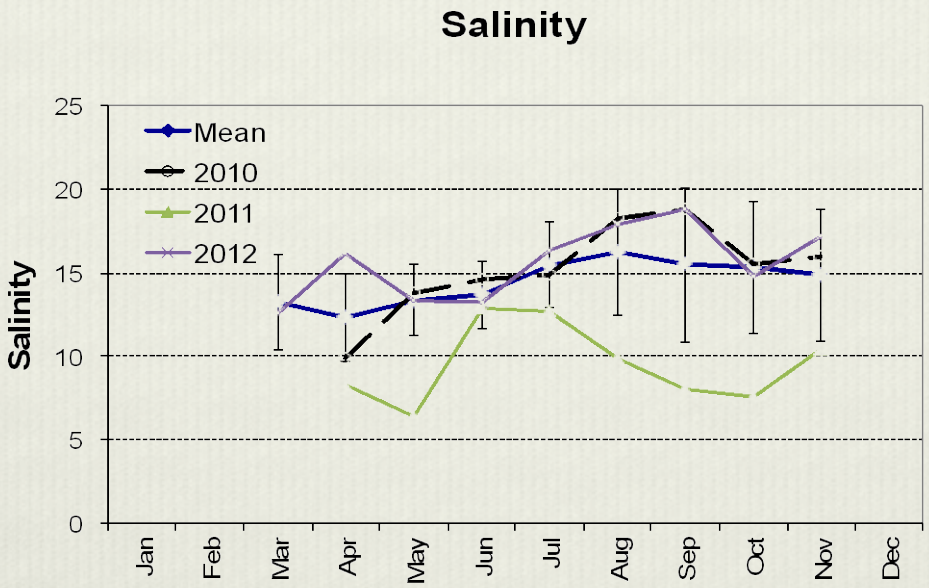
- Storm surges in Delaware Bay Oct/Nov 2011



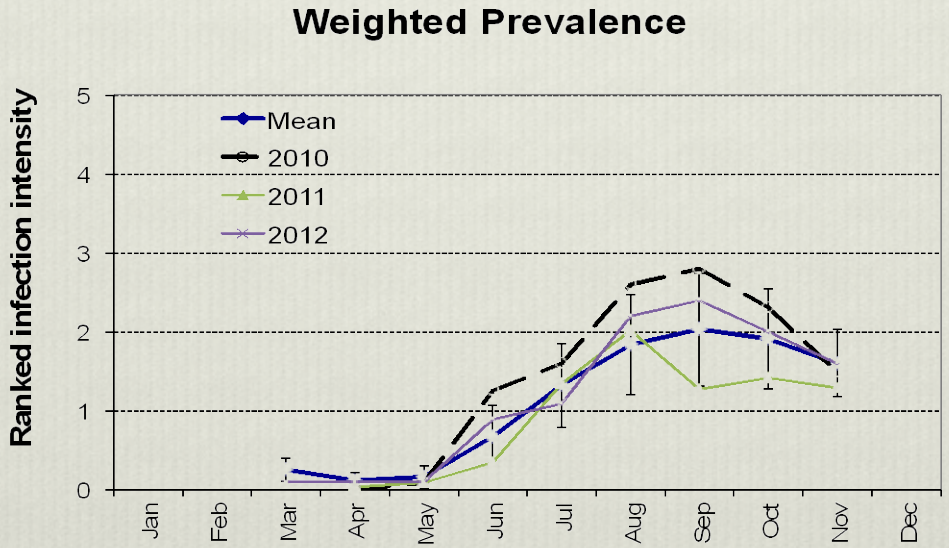
2011 vs 2012 River Discharge at Trenton



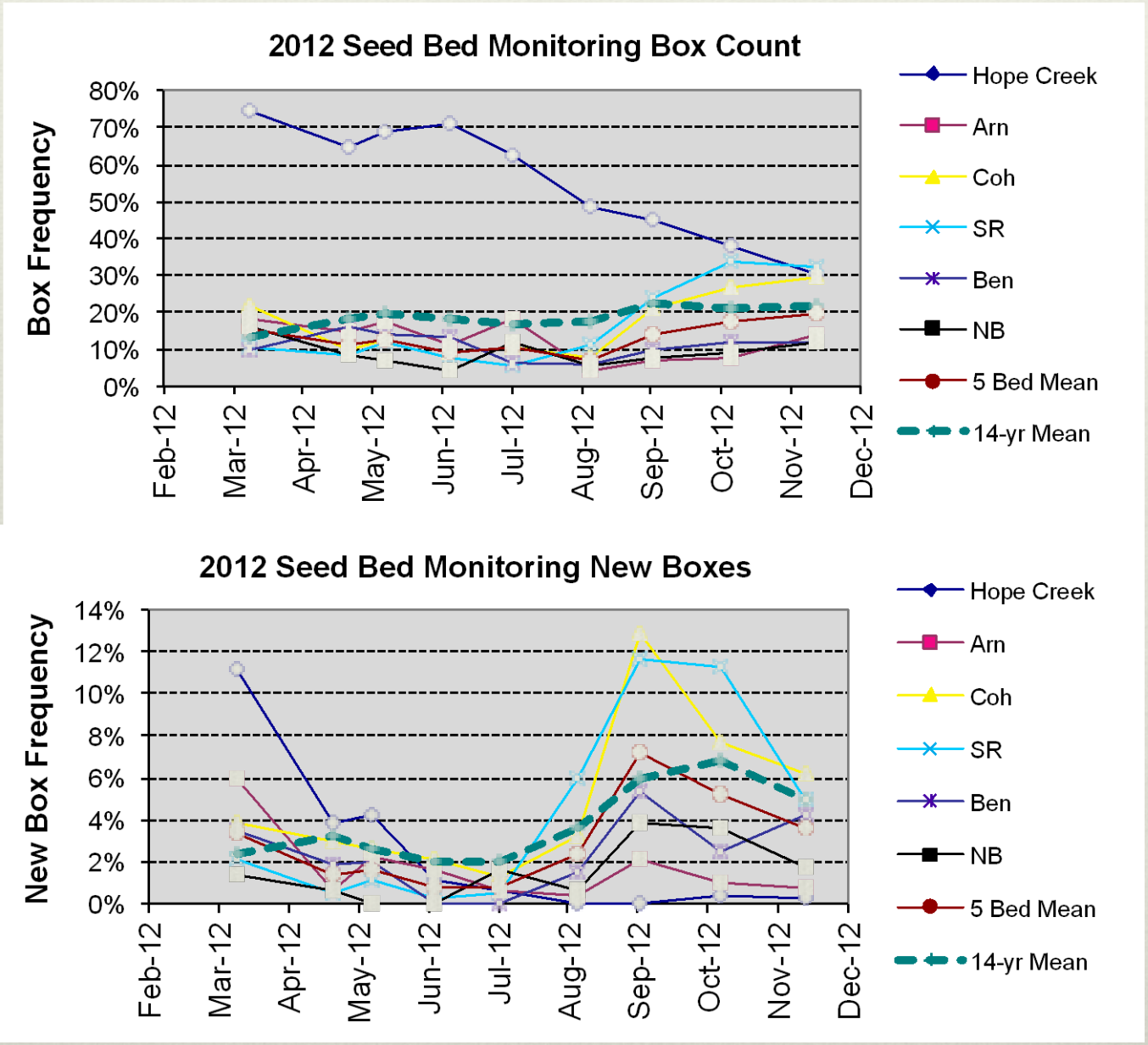
Salinity high in 2012



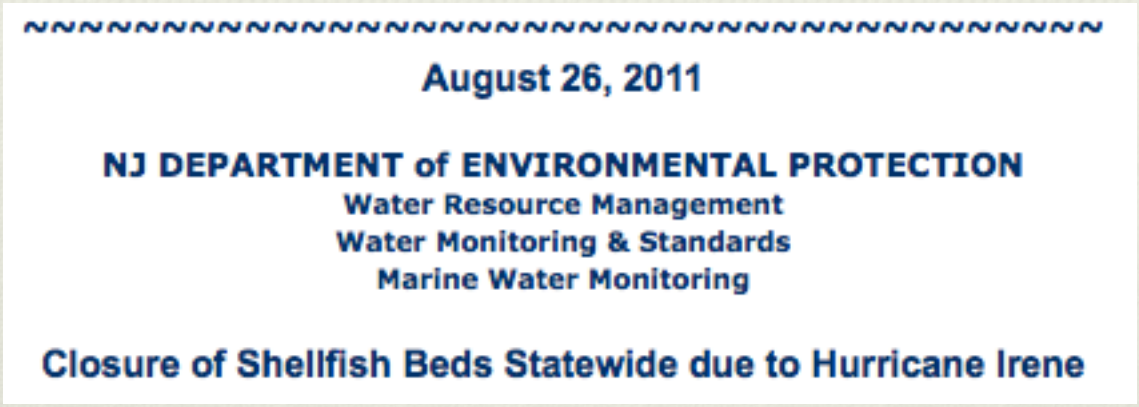
Dermo levels have returned



Oyster mortality



Management impacts from closures

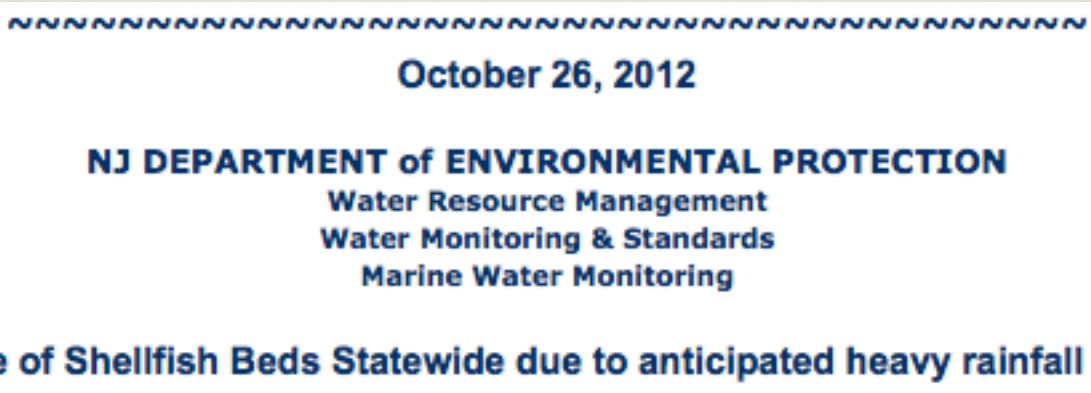


August 26, 2011

NJ DEPARTMENT of ENVIRONMENTAL PROTECTION
Water Resource Management
Water Monitoring & Standards
Marine Water Monitoring

Closure of Shellfish Beds Statewide due to Hurricane Irene

Lower Bay opened September 29th, entire Bay opened October 4th.



October 26, 2012

NJ DEPARTMENT of ENVIRONMENTAL PROTECTION
Water Resource Management
Water Monitoring & Standards
Marine Water Monitoring

Precautionary Closure of Shellfish Beds Statewide due to anticipated heavy rainfall from Hurricane Sandy

Tests were good, but state held waters closed due to approaching Nor'easter.
Closure occurred during peak market season and near end of harvest.
Season extended to allow quota to be caught and lessen economic impact

Summary

- Storm effects varied
  - 2011 flooding reduced salinity push diseases down bay, but killed oysters on the upper beds
    - reduced 2012 oyster quota and closed the uppermost beds to the fishery, possibly for a decade
  - 2012 conditions, assisted in part by Sandy, increased salinity and disease moved back up the Bay increasing disease-related mortality
  - Mandatory harvest closures had economic impacts in both years
- Future uncertainties
  - Will oysters move up bay to more restricted region if salinity moves up bay?
  - Will future storms cause widespread mortality from flooding in this region?

Questions?