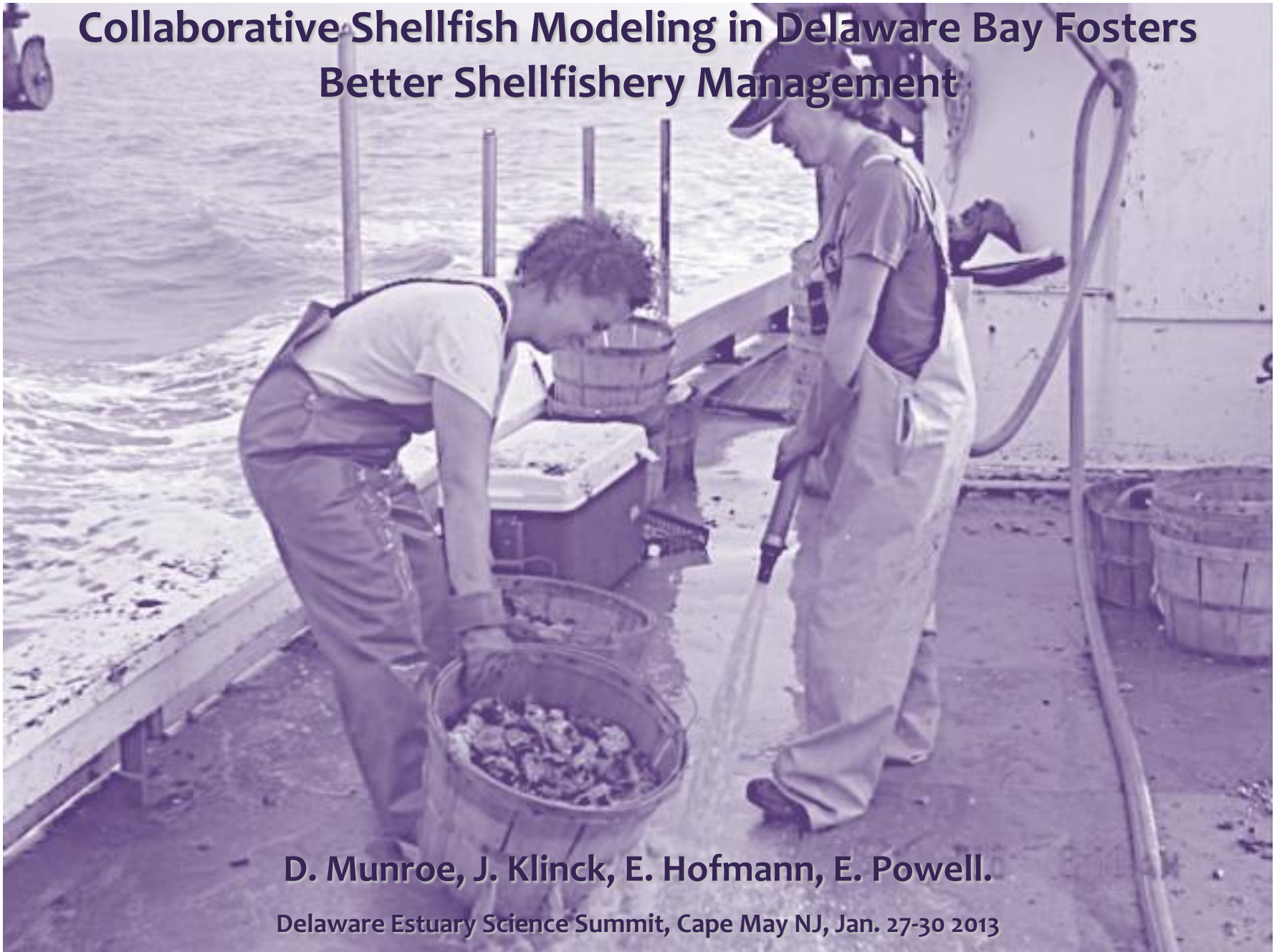


# Collaborative Shellfish Modeling in Delaware Bay Fosters Better Shellfishery Management



**D. Munroe, J. Klinck, E. Hofmann, E. Powell.**

Delaware Estuary Science Summit, Cape May NJ, Jan. 27-30 2013





# DyPoGEN

Spatially-Explicit Individual-Based Numerical Model

Multiple Linked Population Dynamics Models

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

Juvenile Mortality  
(Applied to Juveniles)

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

$$P = 1 - LarvSurv$$

Larval Mortality  
(Applied to Offspring)

Larval Dispersal  
(Exchange Rates from Particle Model)

Offspring Produced  
(Meiosis)

Spawning

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

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

DyPoGEN  
Time Step  
One Year

Increment Age

Adult Mortality  
(Age Dependent)

Functional Sex Change  
(Size Dependent)

Parents Selected

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

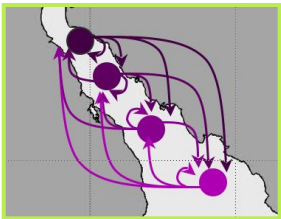
$$Ff = ae^{b\sigma(Age)}$$

$$Df = \frac{dFf}{dAge} = abge^{\frac{\sigma}{\sigma}(Age) + \frac{\sigma}{\sigma}b\sigma(Age)}$$

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

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

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



# The Model

Individual Genetics:

- Based on parental genotype
- Offspring created by meiosis



*DyPoGEn*

*Dynamic **P**opulation **G**enetics **E**ngine*

# The Model

*DyPoGEn*

*Dynamic Population Genetics Engine*

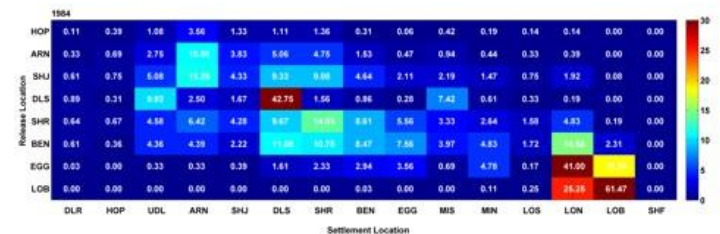
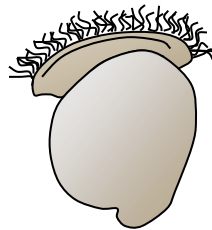
Individual Genetics:

- Based on **GENETICS**
- Offspring created by meiosis



Larvae can:

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



# The Model

*DyPoGEn*

*Dynamic Population Genetics Engine*

Individual Genetics:

## GENETICS

- Based on Mendelian genetics
- Offspring created by meiosis



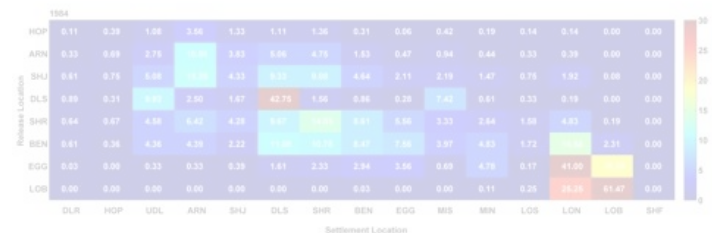
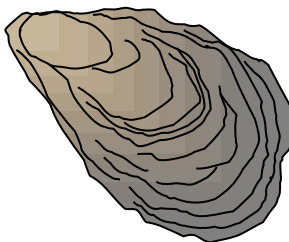
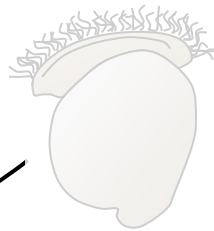
Larvae can:

## LARVAL DISPERSAL

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

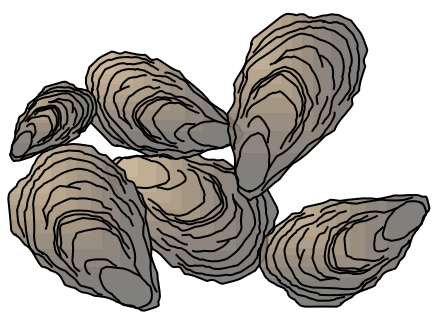
Recruits will:

- Grow
- Experience mortality or fishing
- Change sex
- Spawn

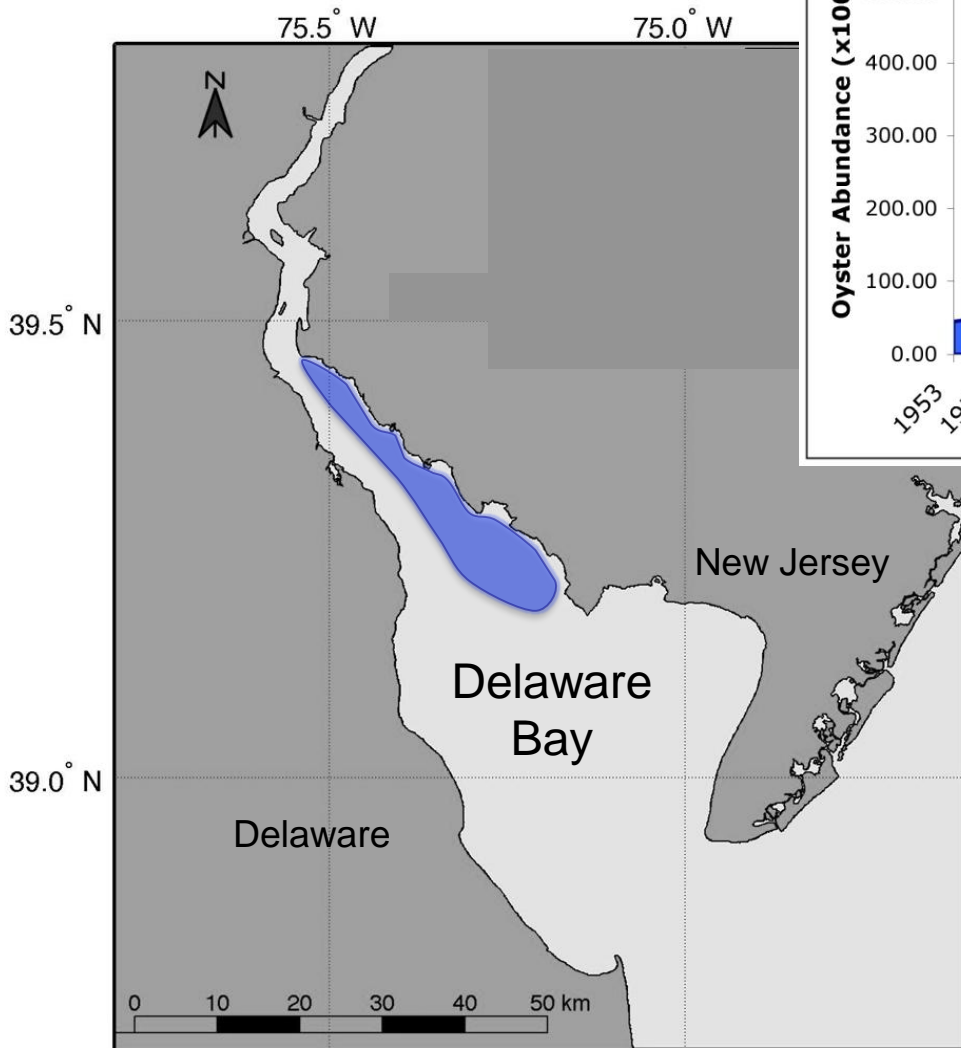
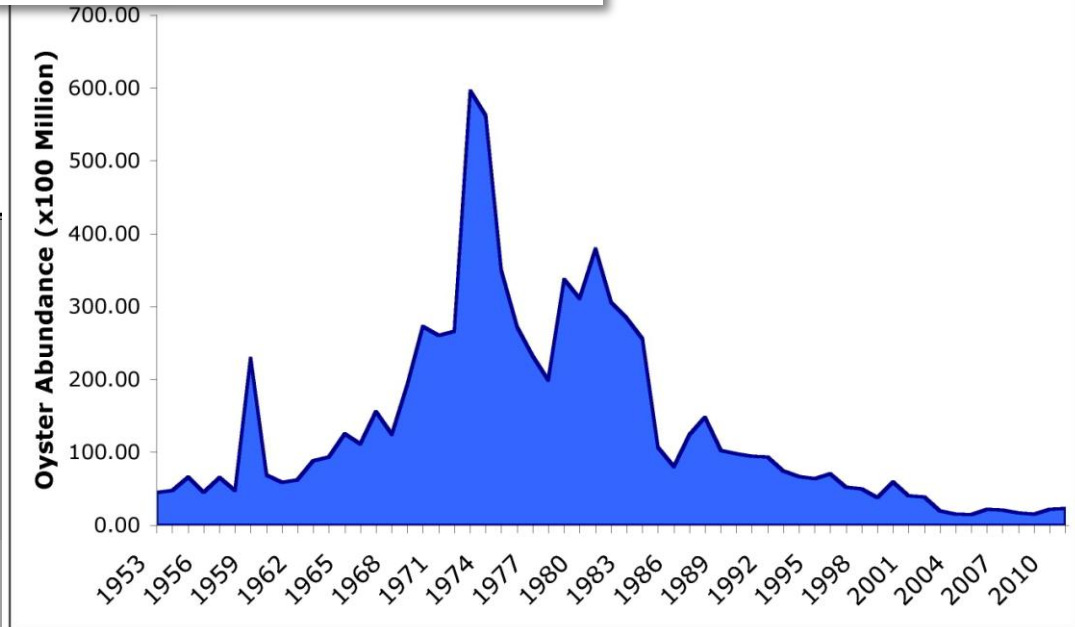








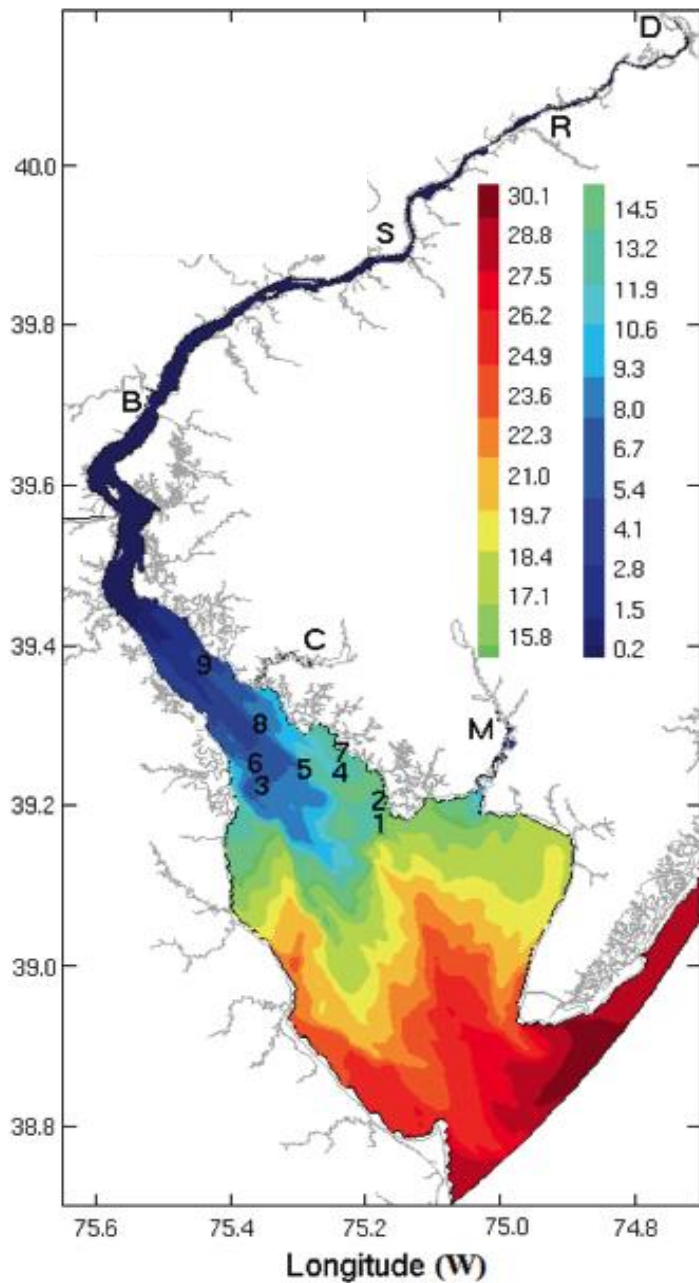
# The System



- Delaware Estuary
- Oyster Fishery
  - Eastern Oyster (*Crassostrea virginica*)
- Stock Assessment
  - oyster timeseries 1953-current

Strong salinity gradient.

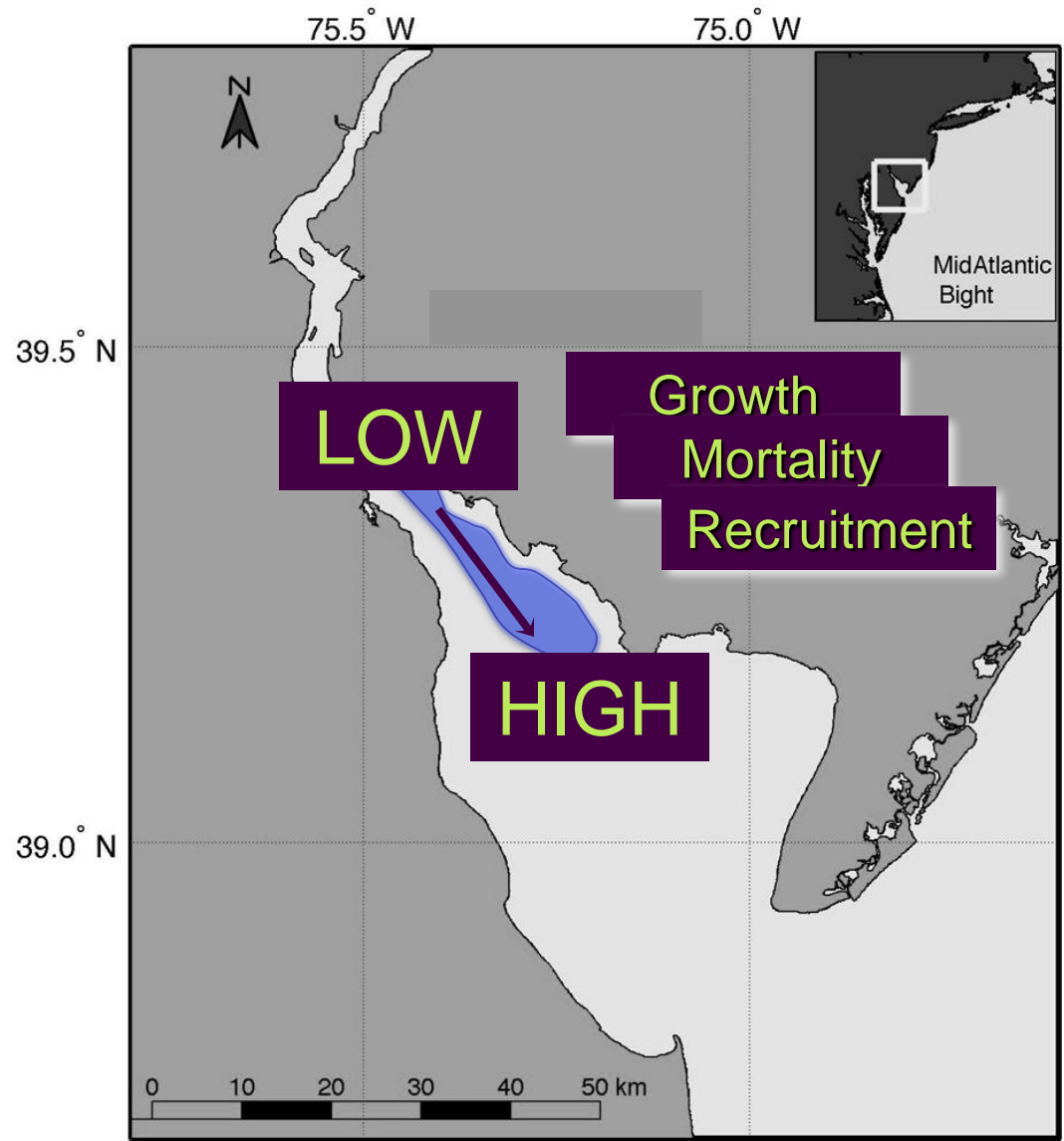
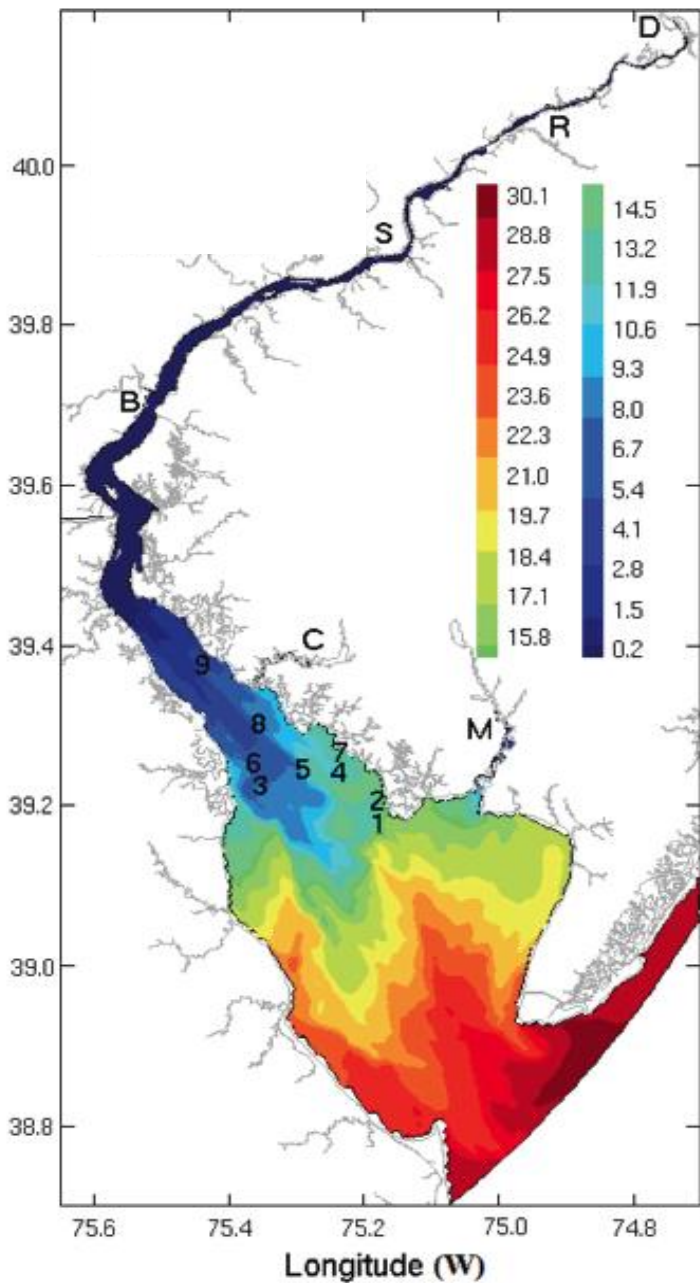
Oyster populations respond biologically.



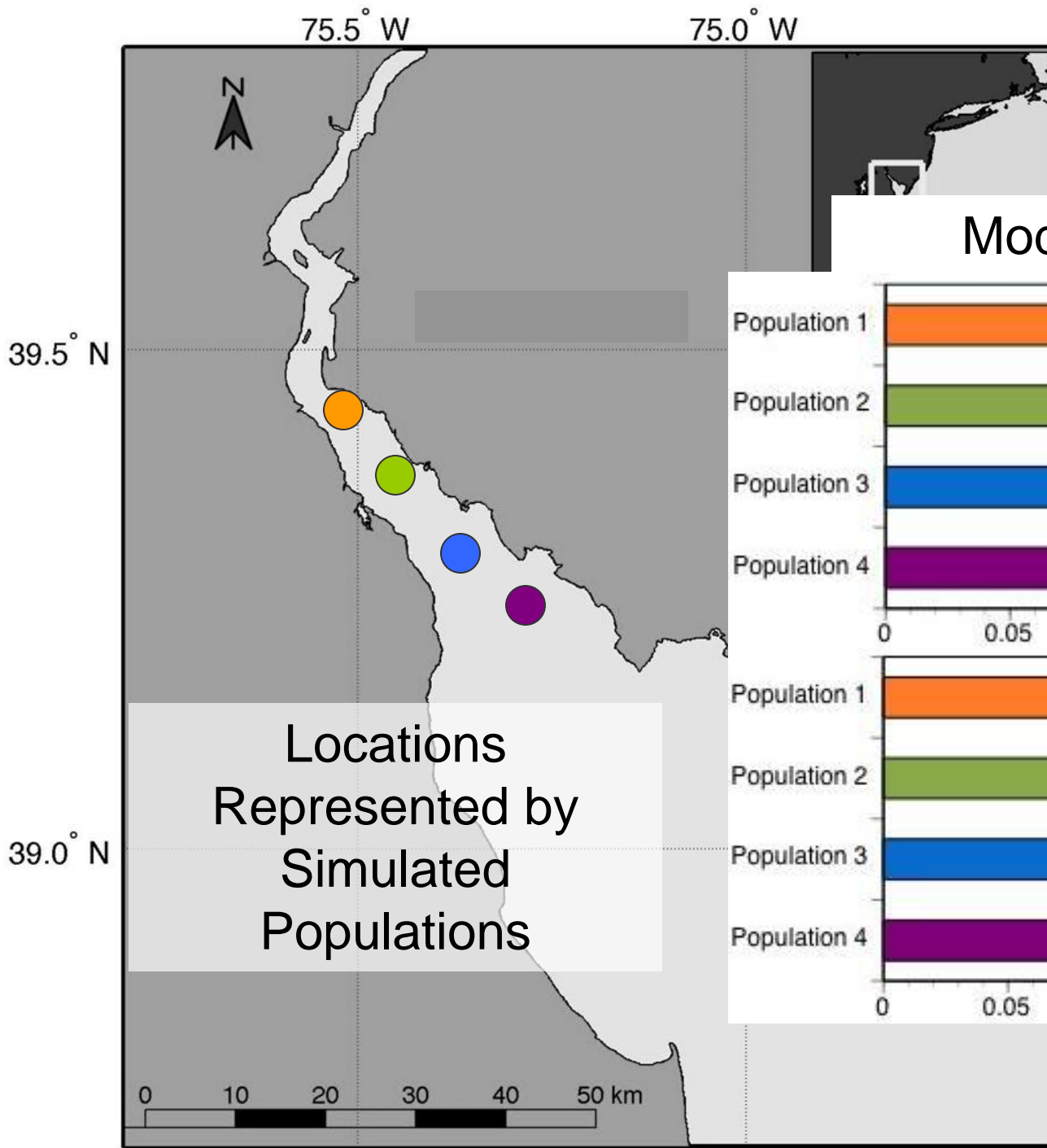
From: Hofmann *et al.*,  
Oceanography, 22: 212-231.

Strong salinity gradient.

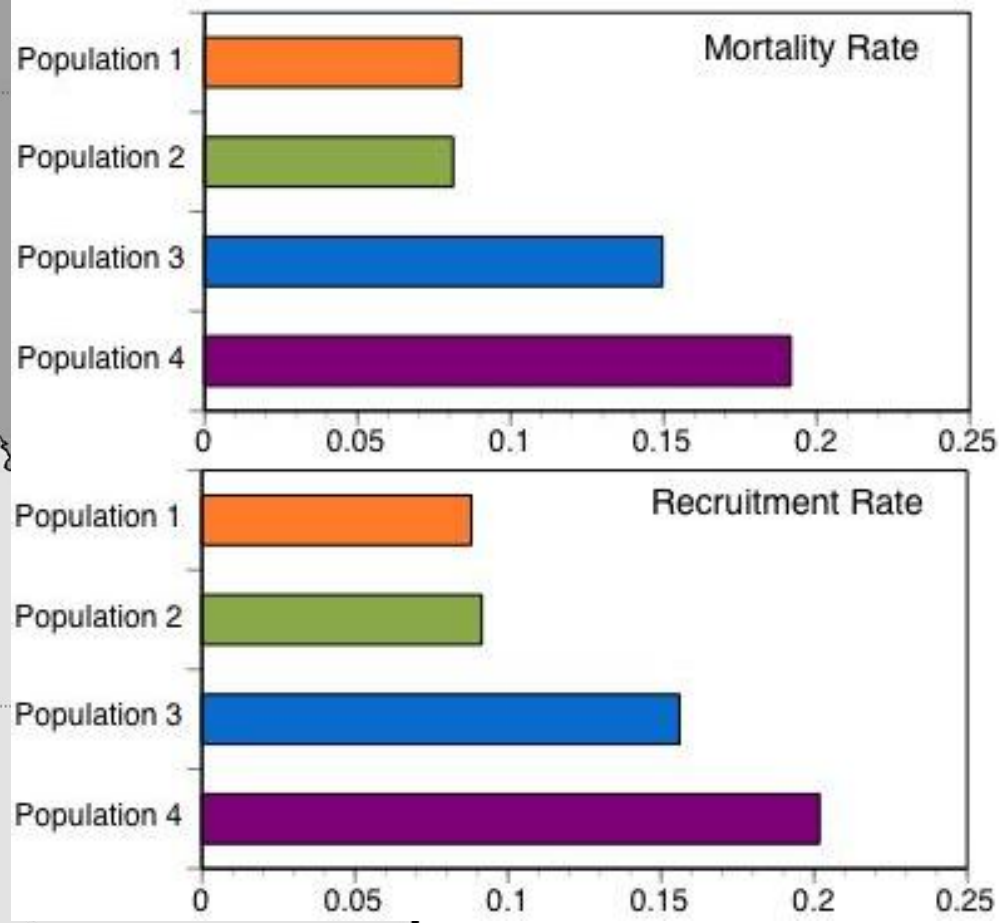
Oyster populations respond biologically

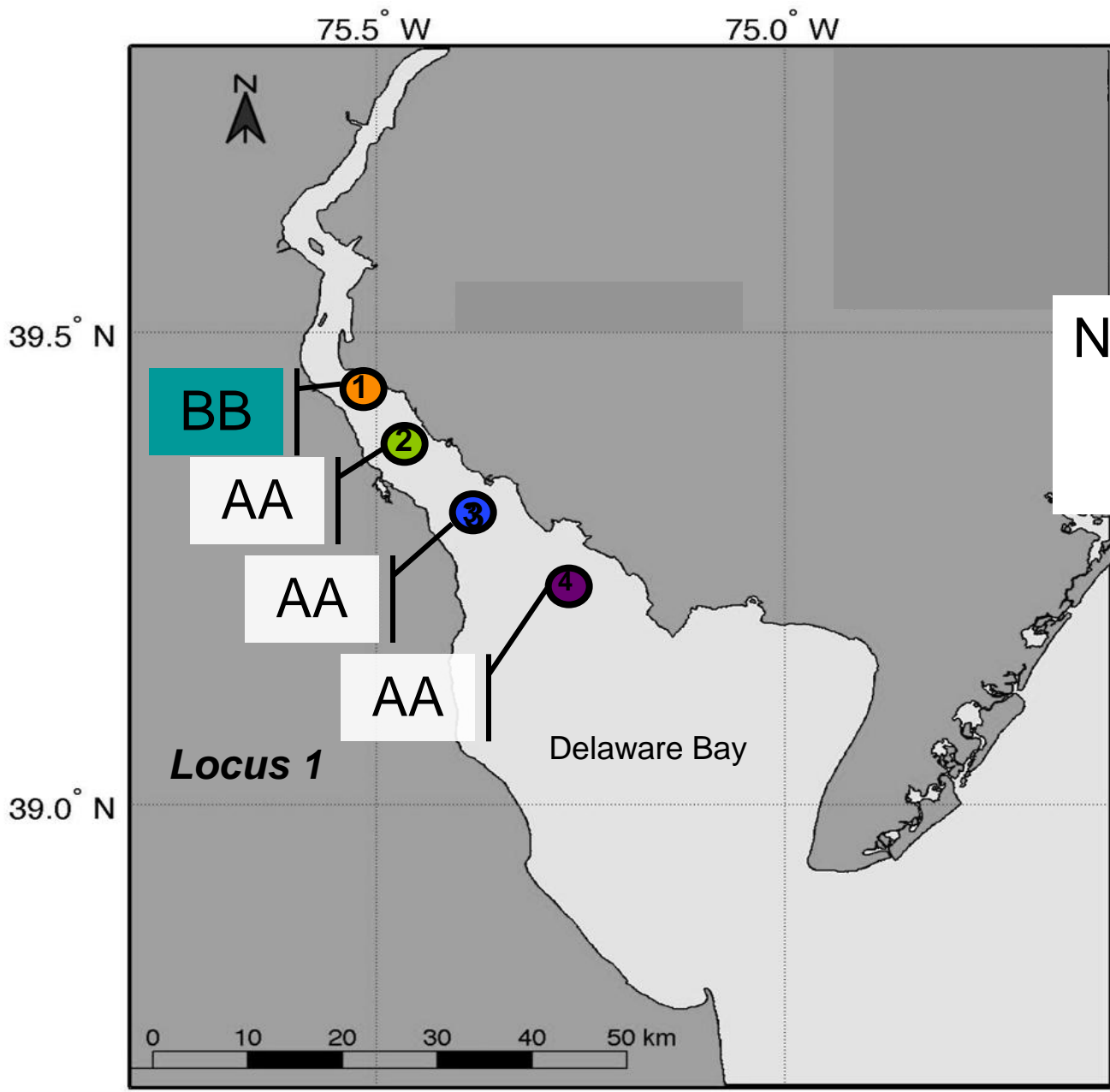


From: Hofmann *et al.*,  
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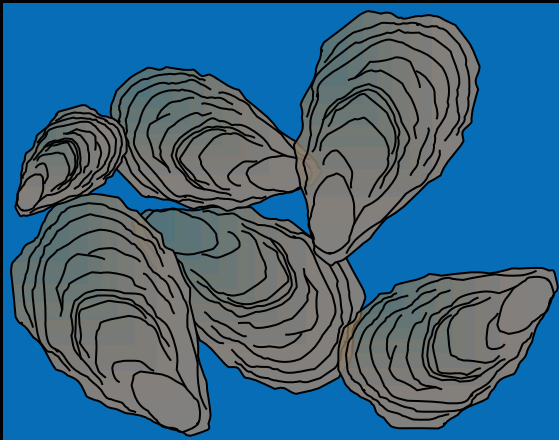


## Model Output



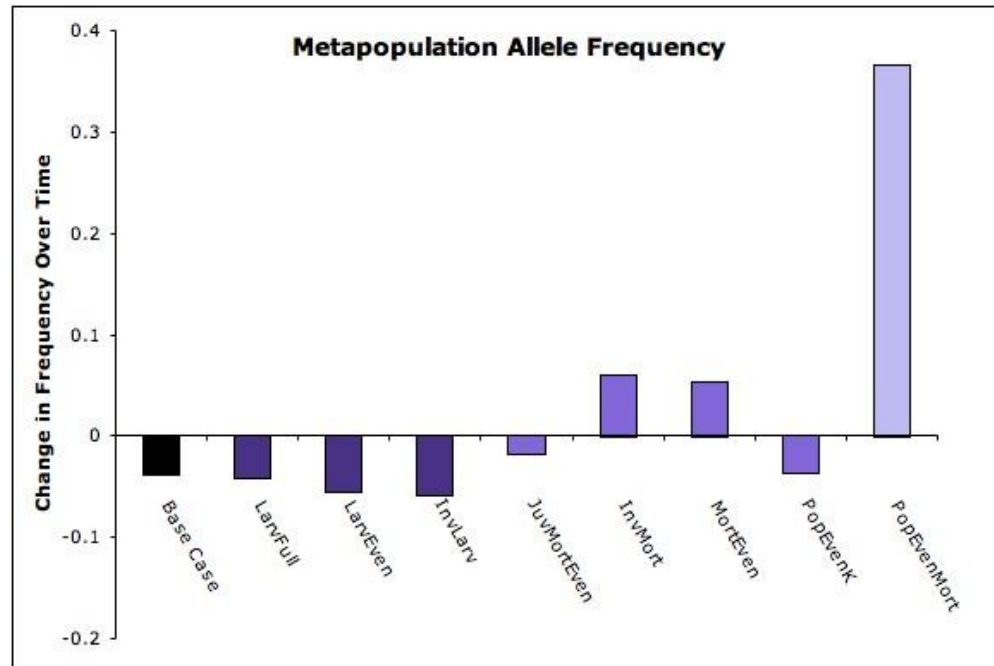


**Neutral Marker Alleles**  
Used to track genetic connectivity over time



# Is larval dispersal or post-settlement processes more important to genetic connectivity?

- Genetic connectivity is influenced by:
  - Relative mortality
  - Relative abundance

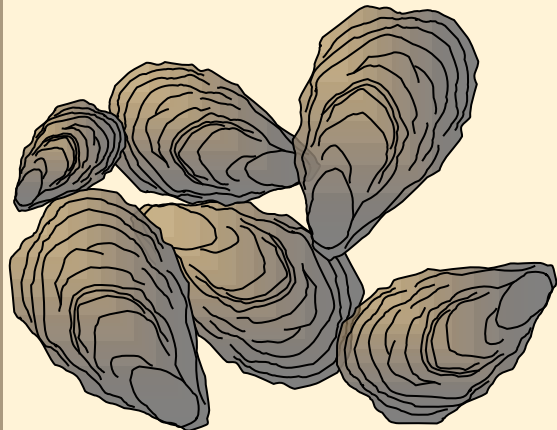


Munroe, D., J. Klinck, E. Hofmann, and E.N.P Powell. 2012. The role of larval dispersal in metapopulation gene flow: local population dynamics matter. *J. Mar. Res.* 70: 441-467.

How do fisheries influence genetic connectivity?

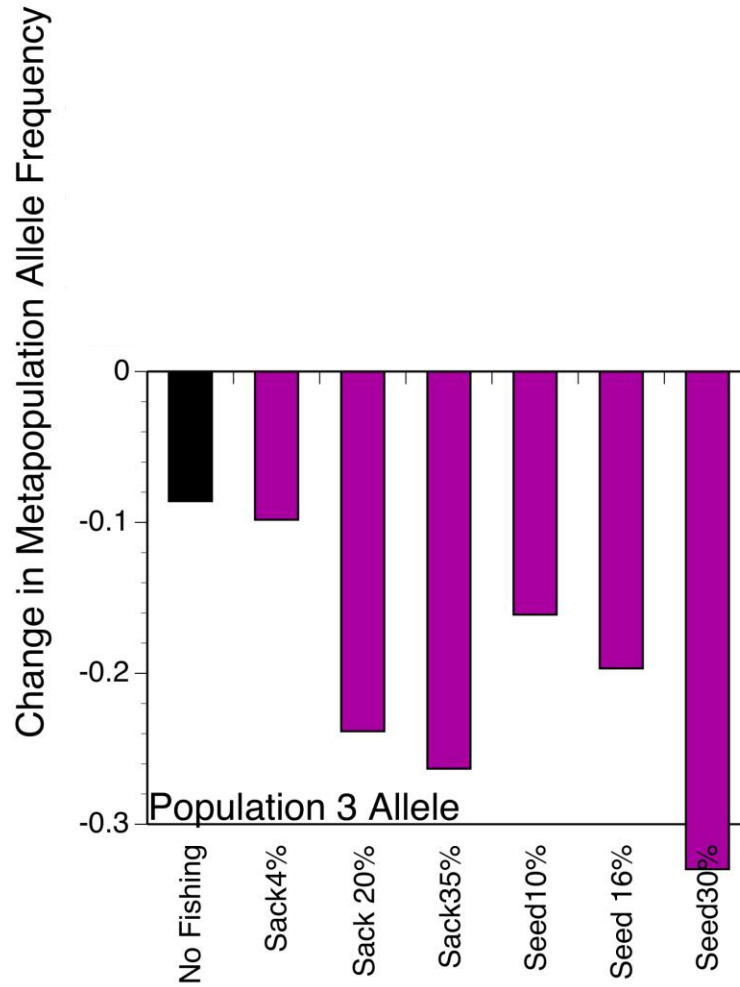


## Questions



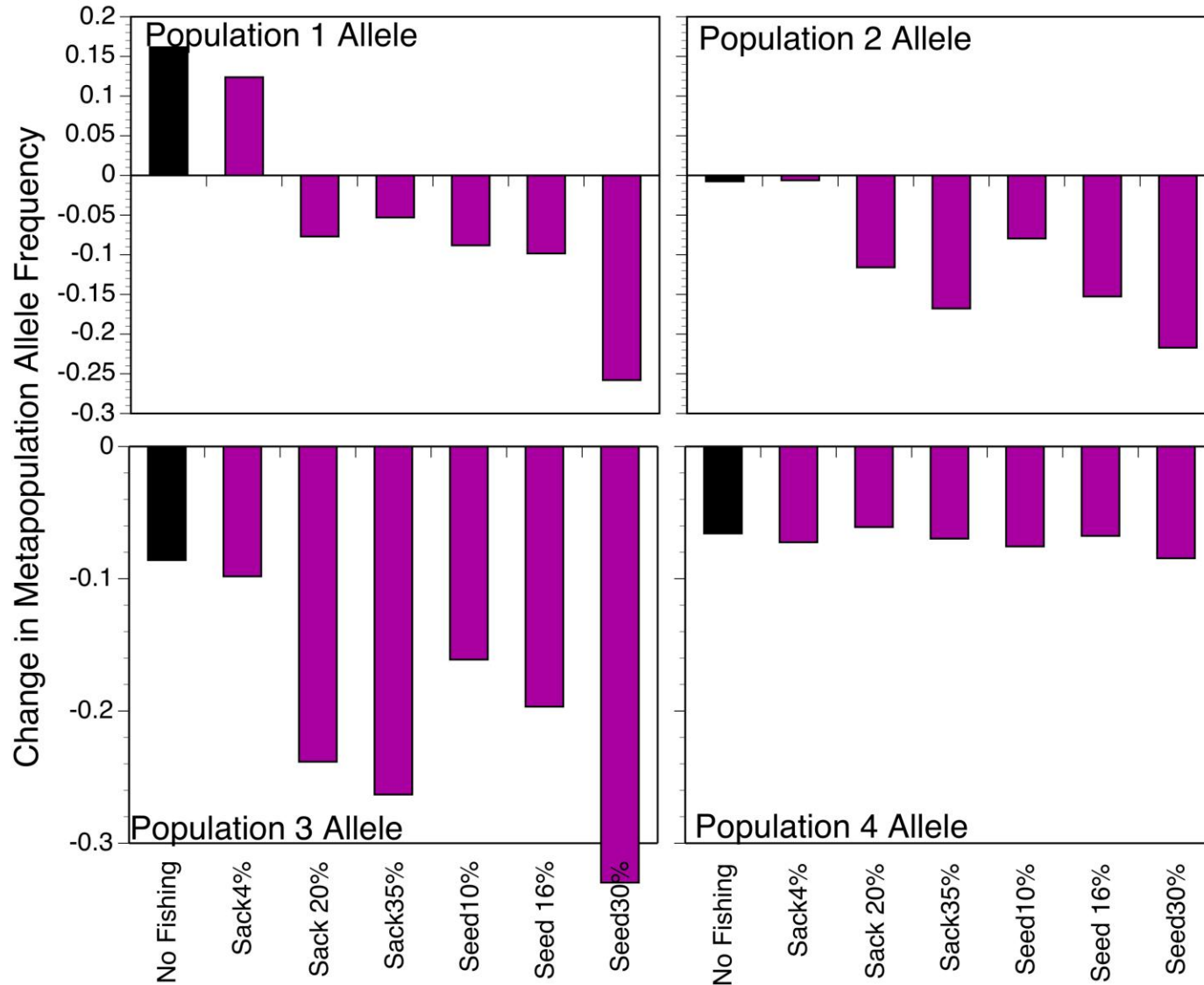
What role do MPAs play in genetic connectivity?

# How do fisheries influence genetic connectivity?

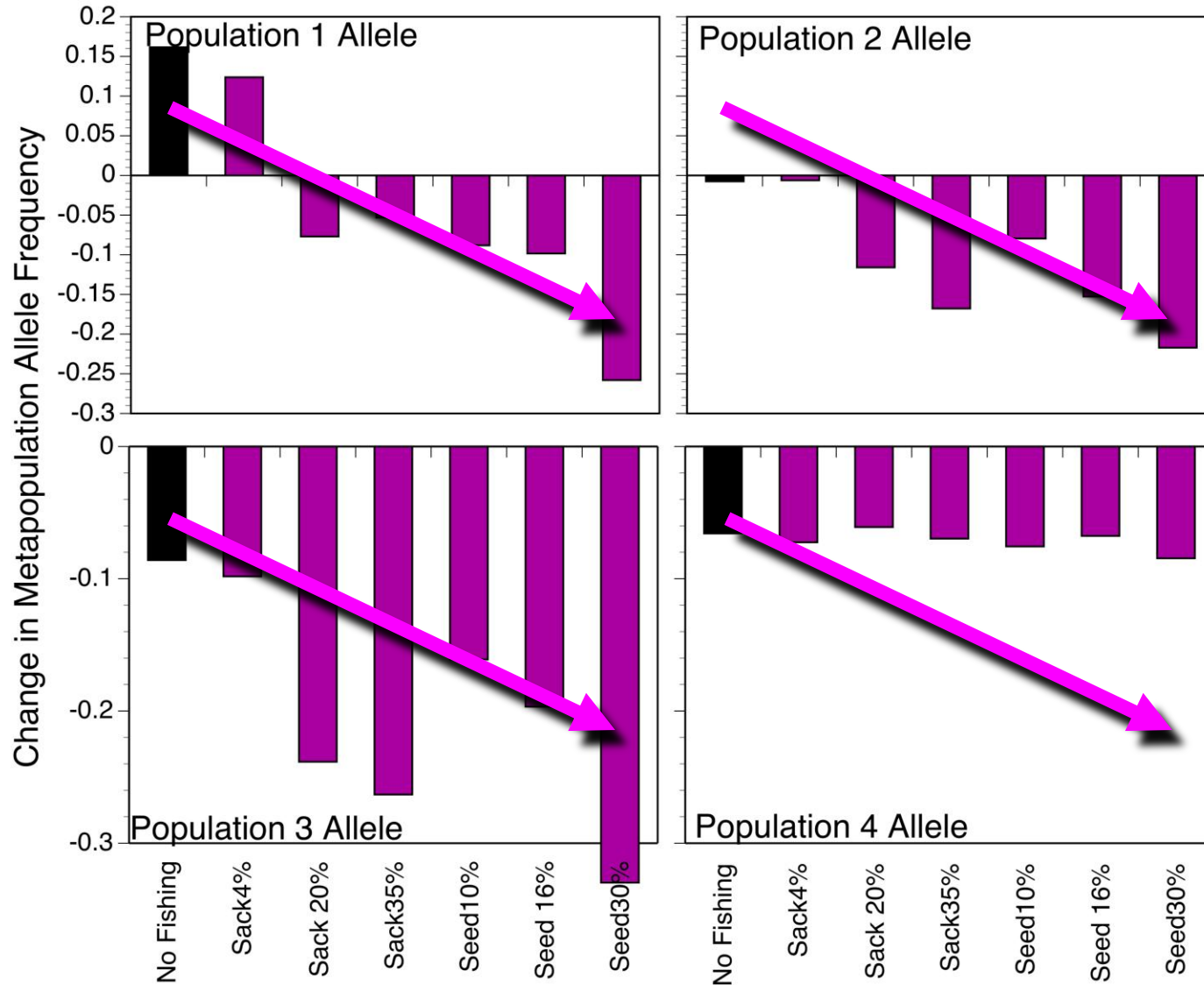




# How do fisheries influence genetic connectivity?



# How do fisheries influence genetic connectivity?



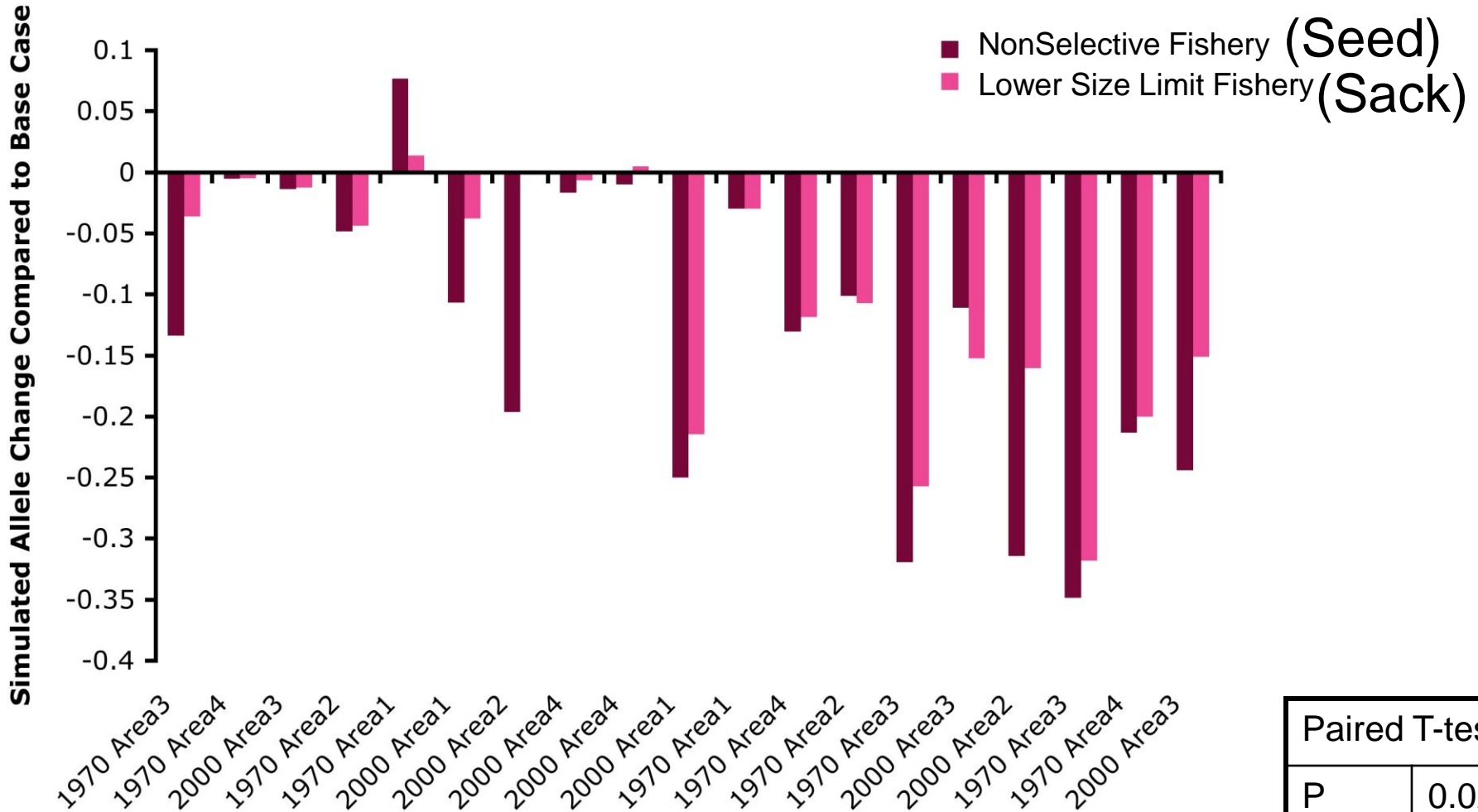
# Seed And Sack Fishery

- Seed fishery - no lower size limit
- Sack fishery - lower size limit
  - 63.5 mm (2.5 inch)



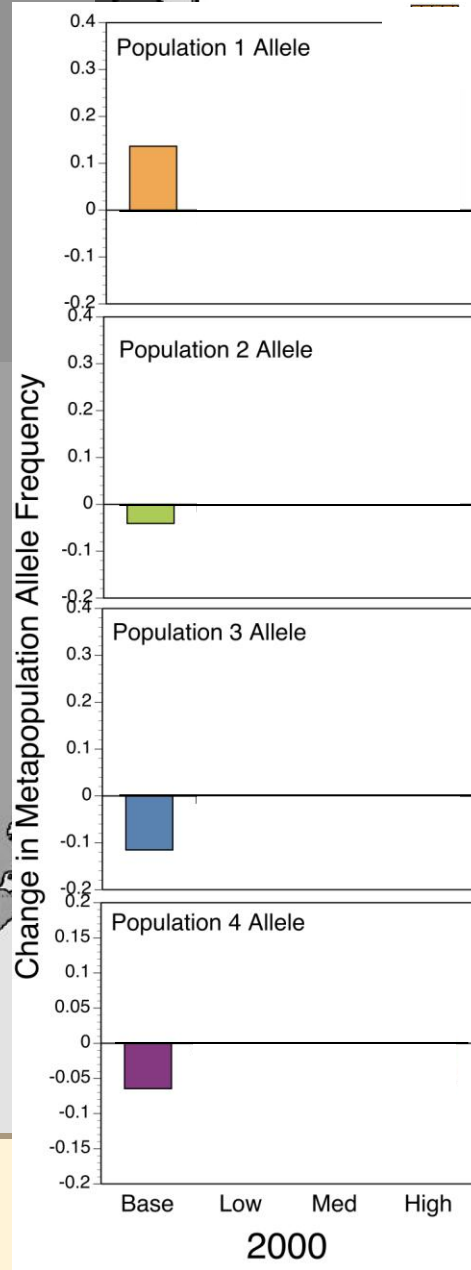
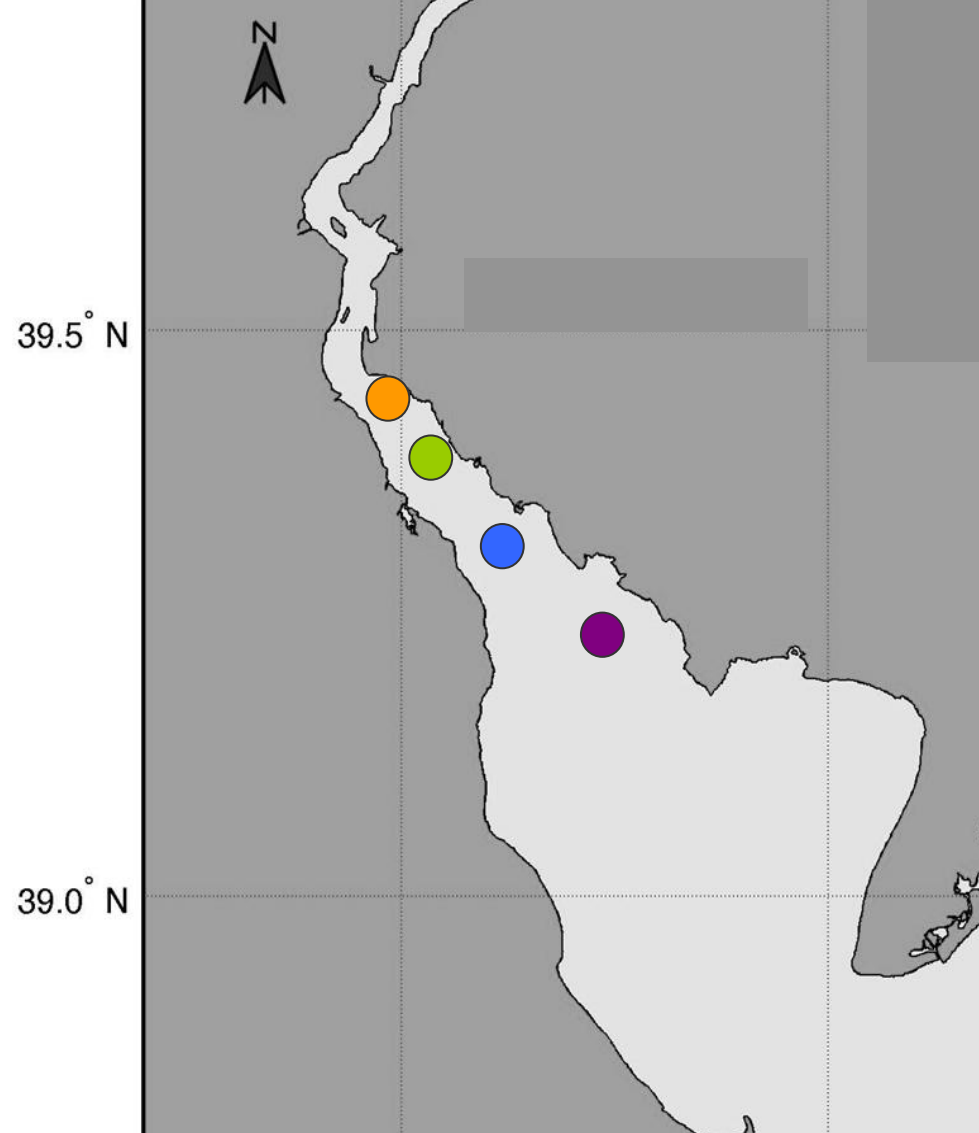
Photo Credit: Louisiana Department of Wildlife & Fisheries

# How do fisheries influence genetic connectivity?



NonSelective < Size Selective Fishery  
 allele change versus Base Case  
 on average 3.5 % lower allele frequency

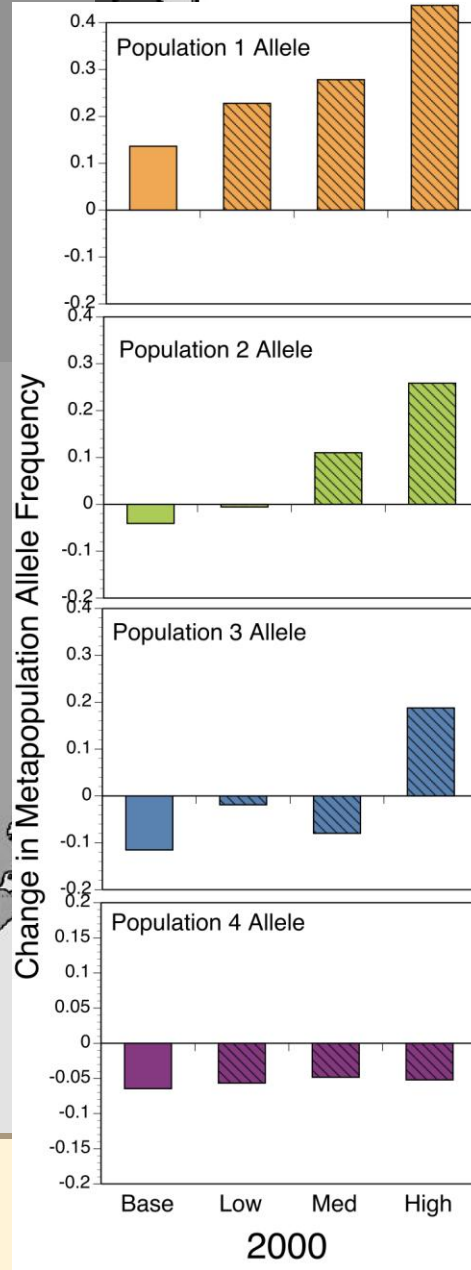
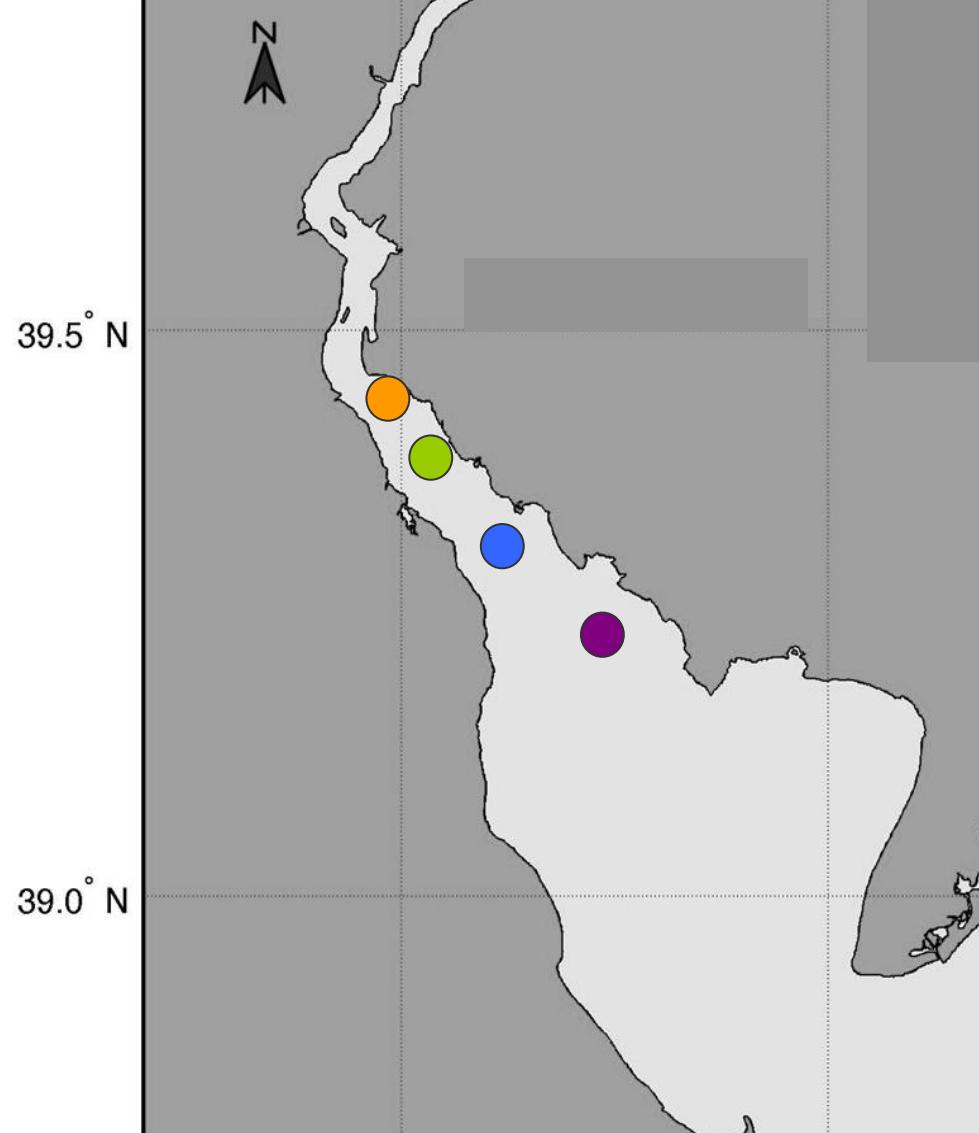
Paired T-test	
P	0.025
T	-2.09
df	18



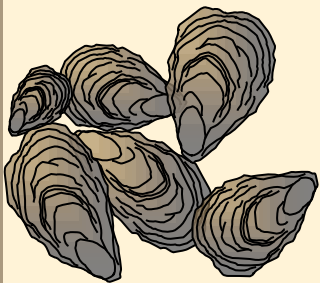
Shifts in source:sink dynamics



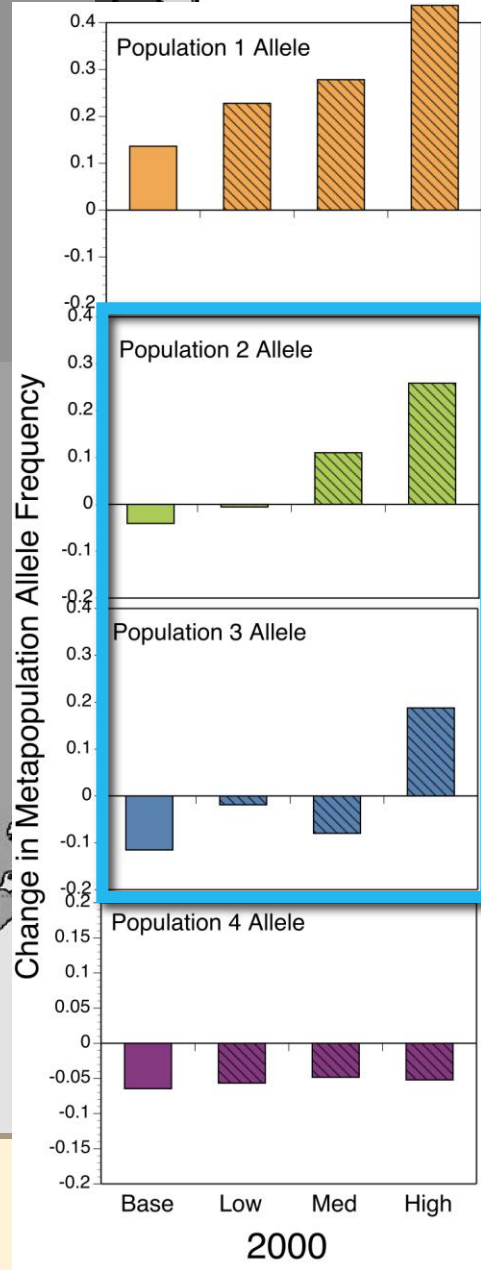
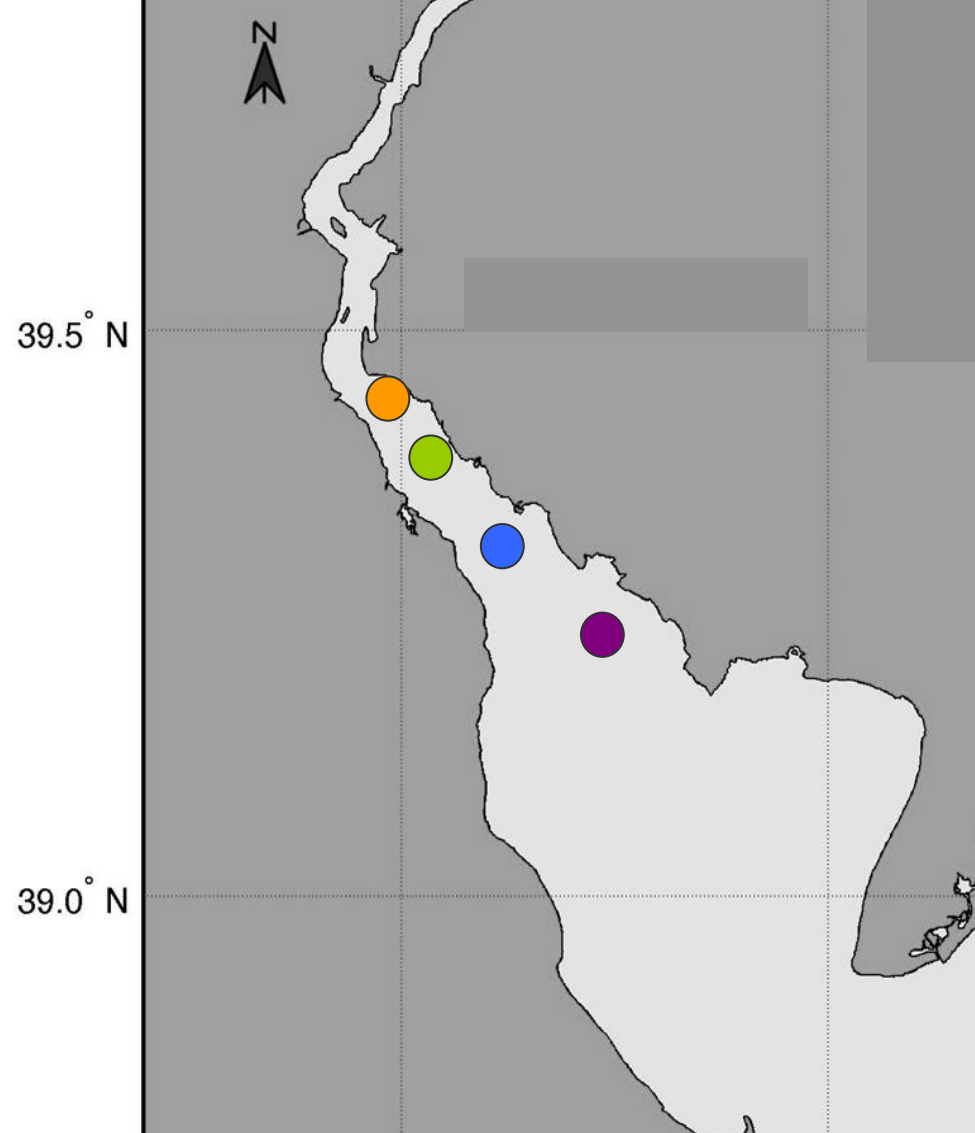
What role do MPAs play in genetic connectivity?



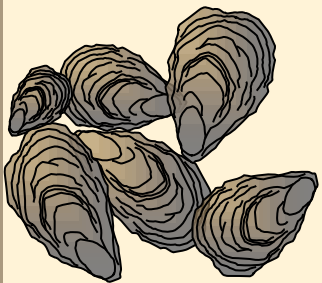
MPAs:  
Increasing  
export of  
allele with  
surrounding  
fishing  
pressure



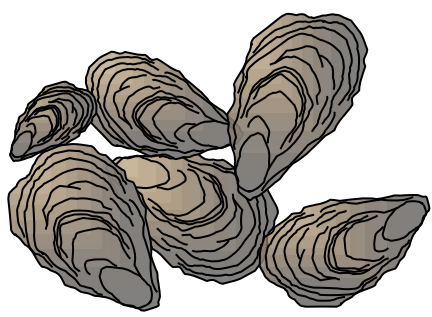
What role do MPAs play in genetic connectivity?



MPAs:  
Can alter  
source:sink  
locations



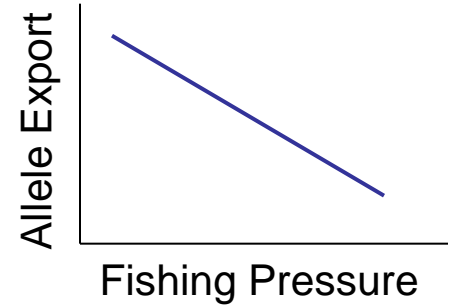
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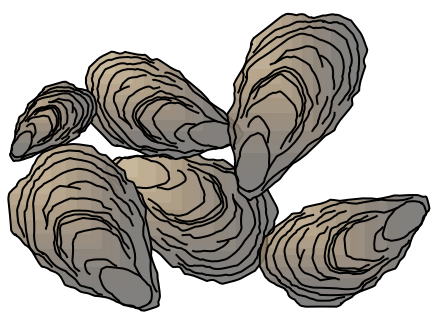
# Summary

## Fishing:

- Increasing fishing decreases allele export
  - True for both fishery types



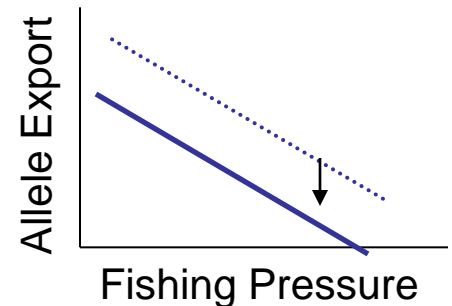
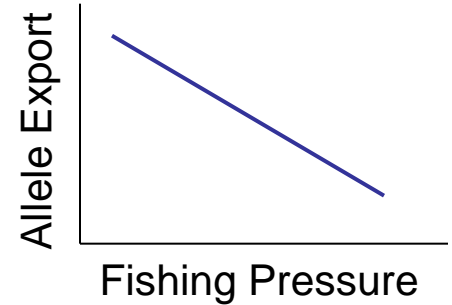


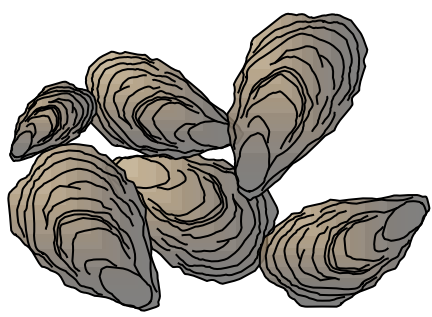


# Summary

## Fishing:

- Increasing fishing decreases allele export
  - True for both fishery types
- For a given regime/area, and keeping fishing rate constant, non-selective fisheries lead to a greater decrease in allele export
  - On average, 3.5% lower





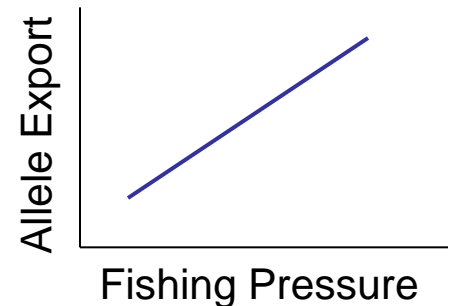
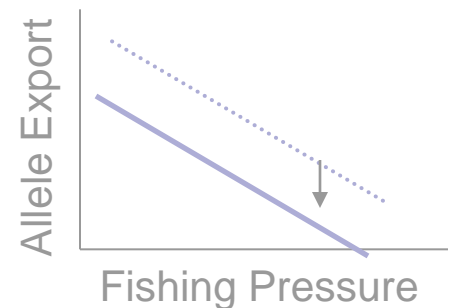
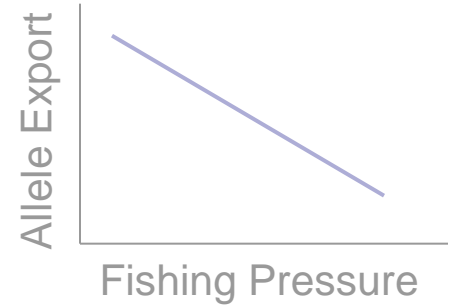
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## Fishing:

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  - On average, 3.5% lower

## MPAs:

- MPAs can enhance protected area genotypes
  - Especially with high surrounding fishing pressure



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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

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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.

The numbers that are emerging, not

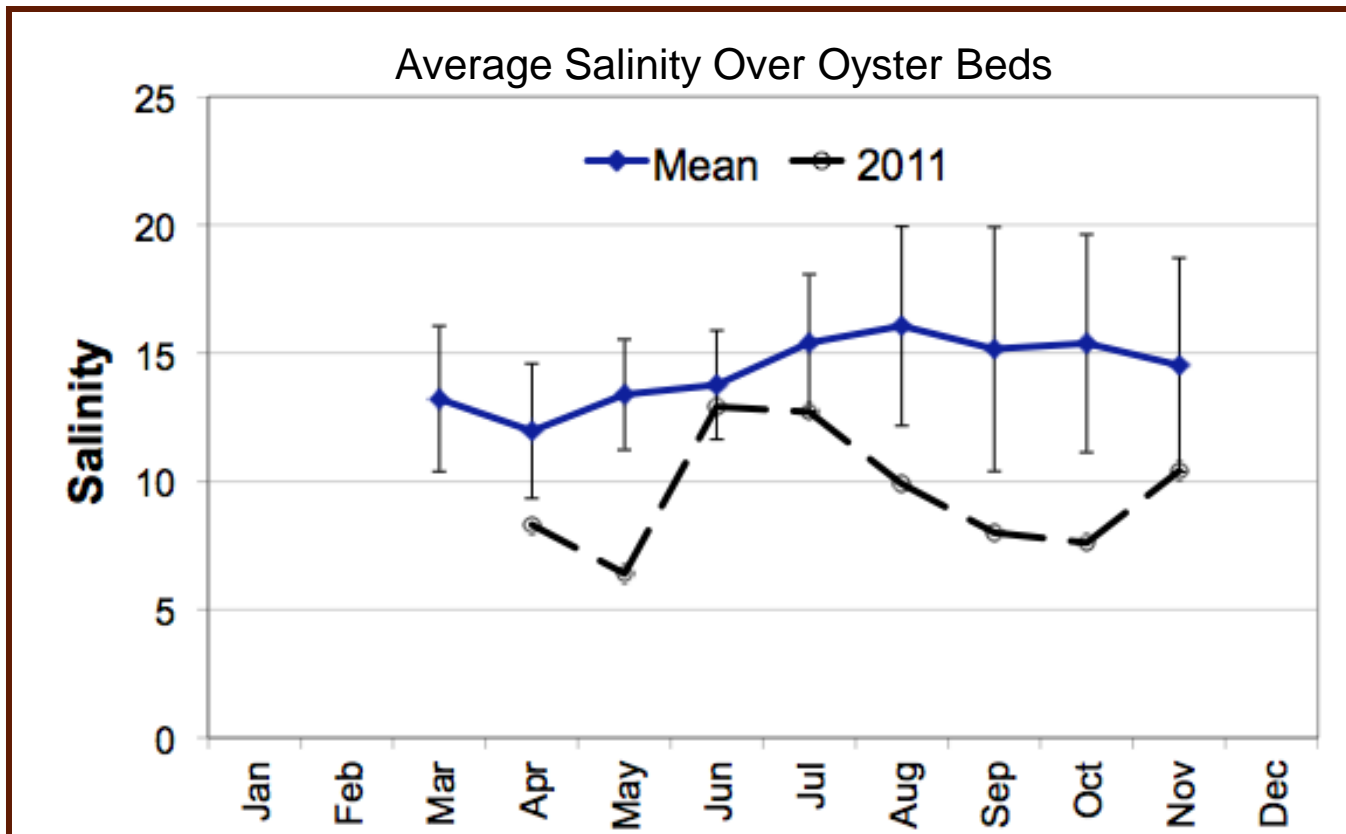


**EYE FROM THE SKY:** Hurricane Irene makes landfall over New York City. For much of New England, the extreme damage was still to come.  
*Image: NASA/NOAA GOES Project*

- “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

# Low Salinity Anomaly 2011

- High snow melt in spring
- Hurricane Irene
- Tropical Storm Lee



75.5° W

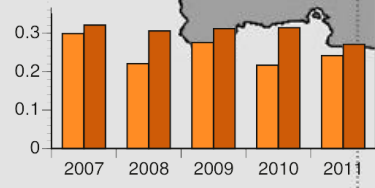
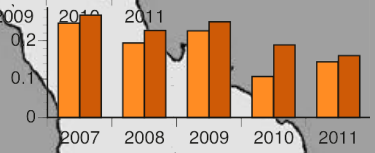
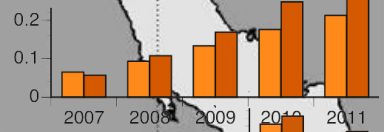
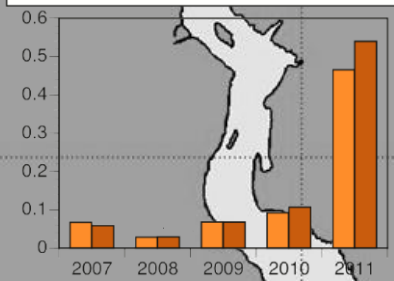
75.0° W



# Impacts on Oysters

- Upbay mortalities extremely high
  - 60%\*
- Mortality biased to large animals
  - Mortality of market-size oysters ~ 76%\*

■ Numbers
 ■ Biomass

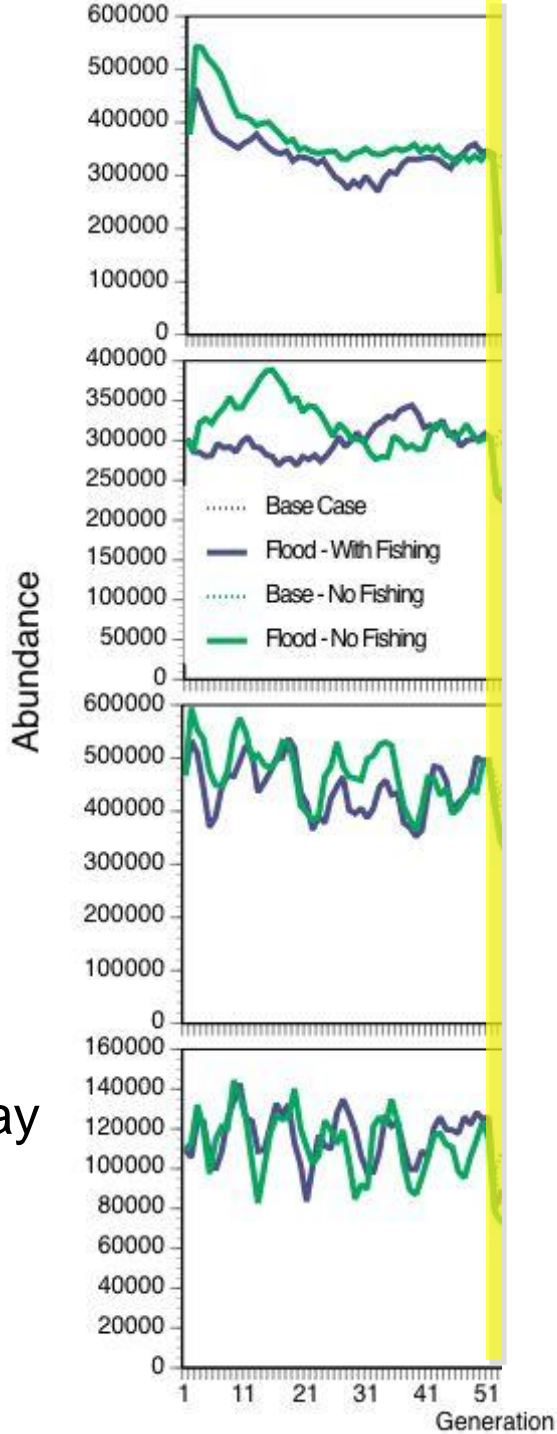


Oyster Mortality Rates

How will these changes impact oysters?  
 How long will these effects last?

\*Powell EN, et al. 2012. Report of the 2012 Stock Assessment Workshop (14th SAW) for the New Jersey Delaware Bay oyster beds. Port Norris, NJ: Haskin Shellfish Research Laboratory Report.

Upbay



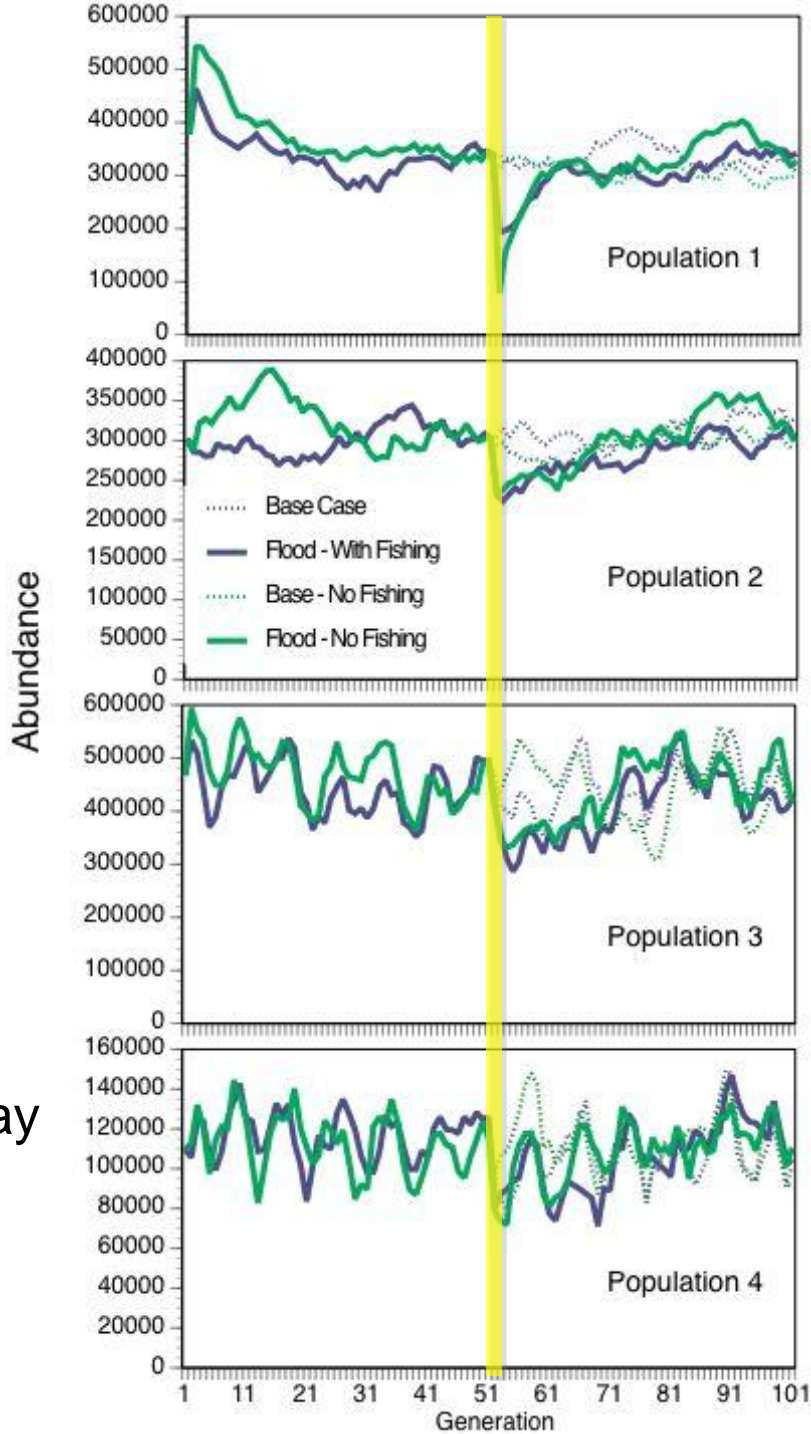
?

Downbay

Upbay



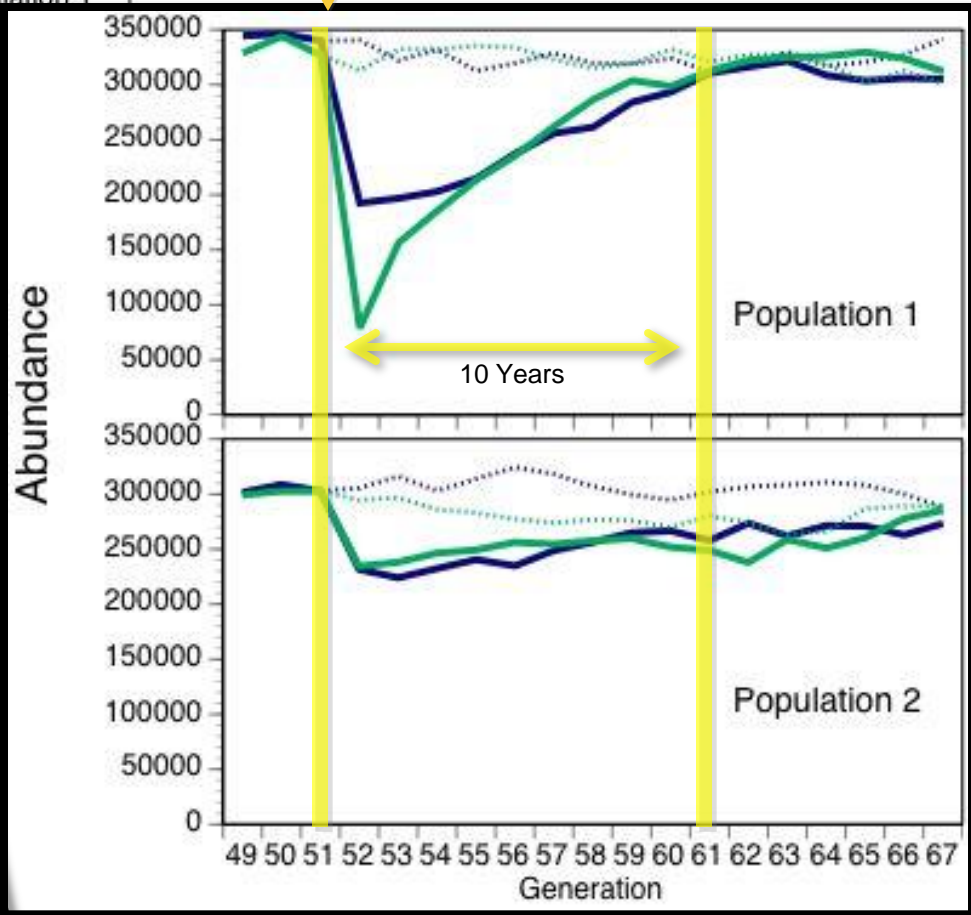
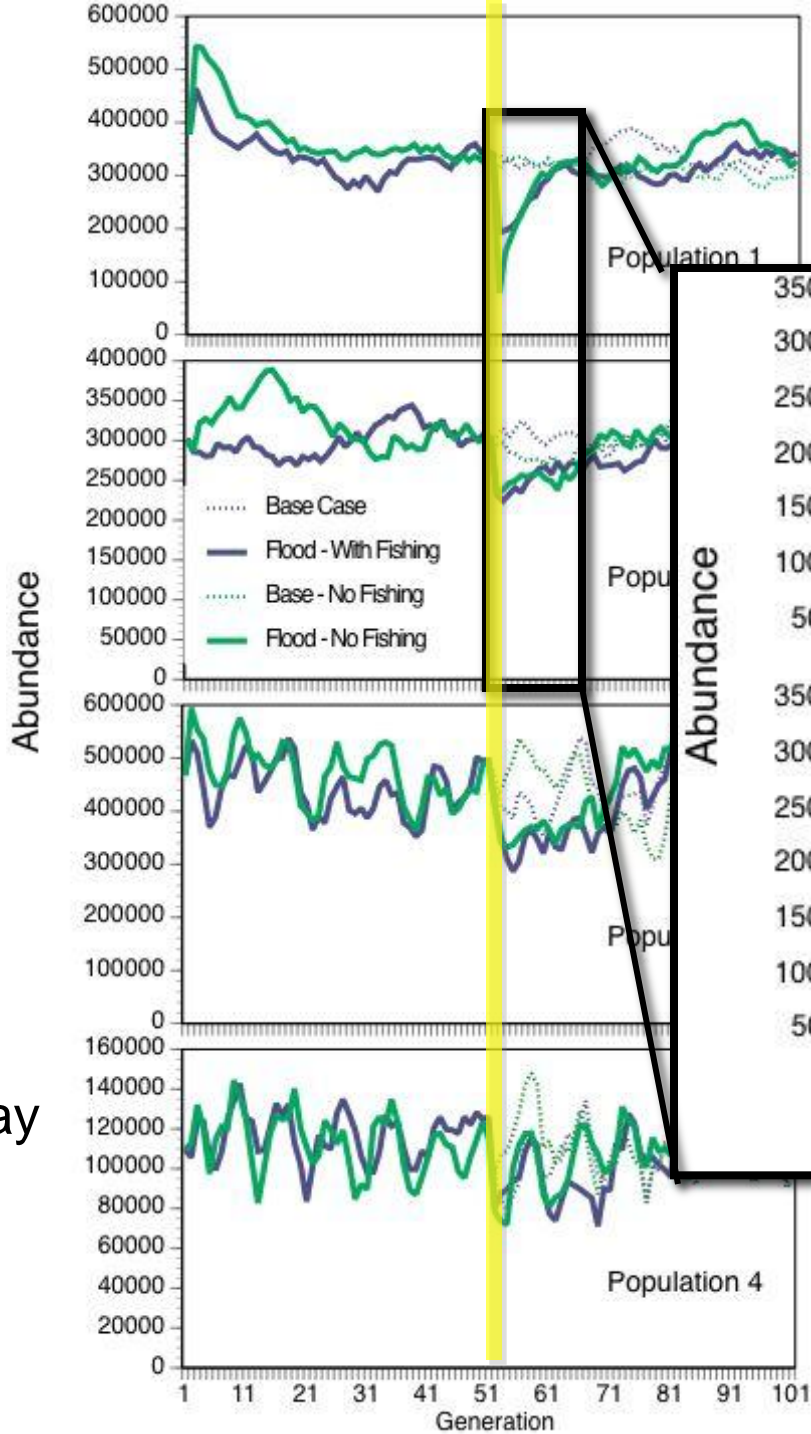
Downbay



Upbay

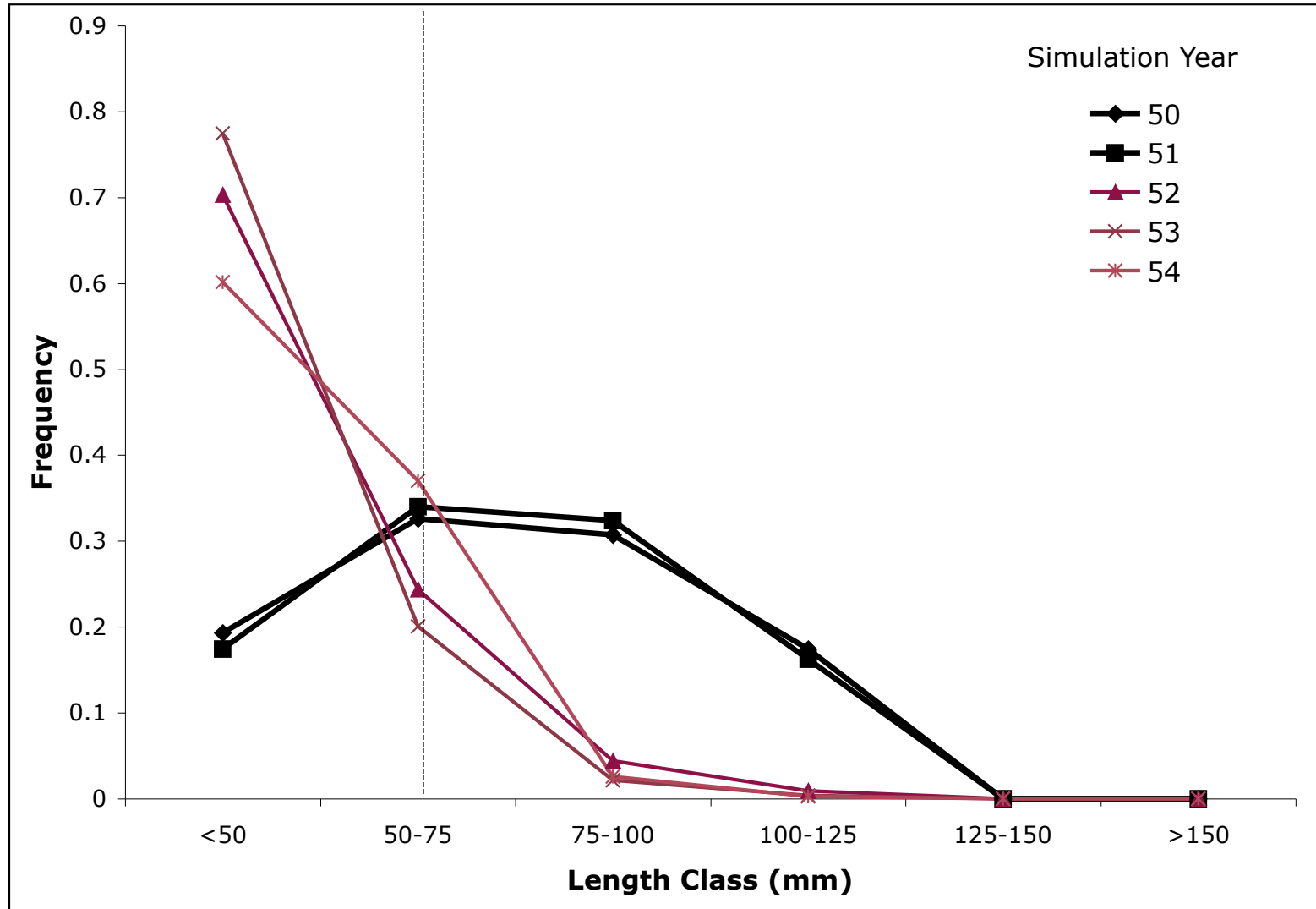


Downbay



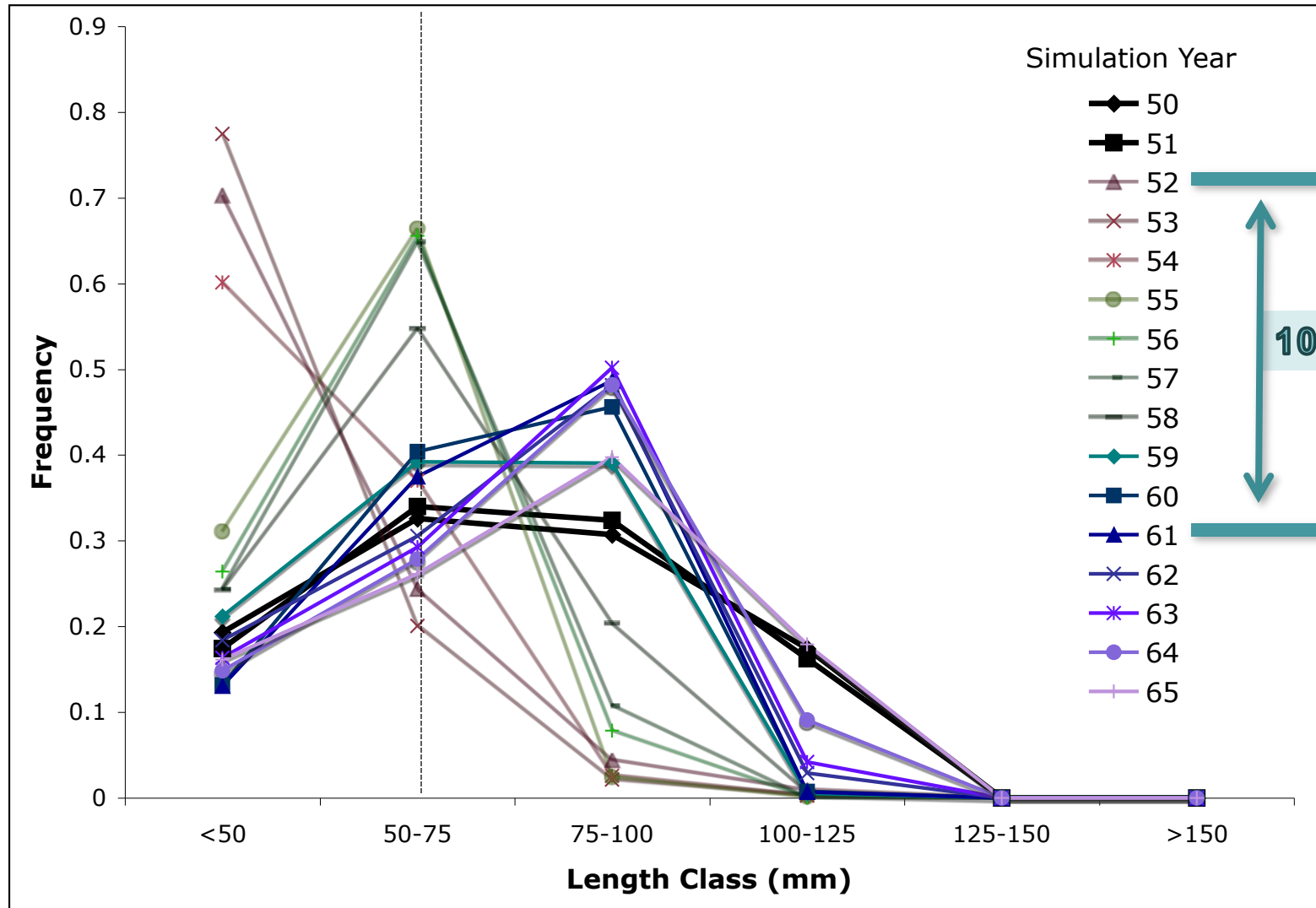


# Population 1 - Post-Flood Simulated Length Frequencies





# Population 1 - Post-Flood Simulated Length Frequencies



## 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*

# Thanks to

## *Stock Assessment Team:*

Haskin Shellfish Research Lab,  
NJDEP,  
Oystermen of Delaware Bay

## *CoAuthors:*

Eileen Hofmann  
John Klinck  
Eric Powell

Funding for this research provided by NSF Grant #  
OCE-6022642  
OCE-0622672

[Dmunroe@hsrl.rutgers.edu](mailto:Dmunroe@hsrl.rutgers.edu)



75.5° W

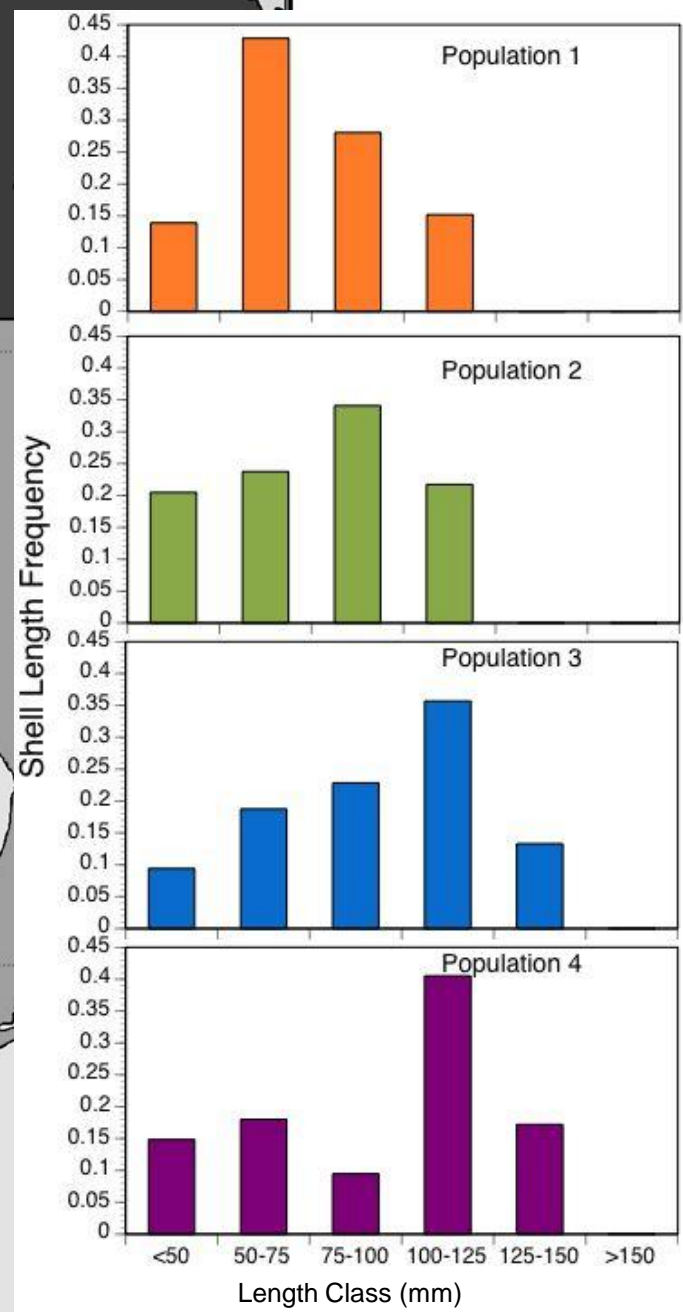
75.0° W



39.5° N

39.0° N

0 10 20 30 40 50 km



75.5° W

75.0° W

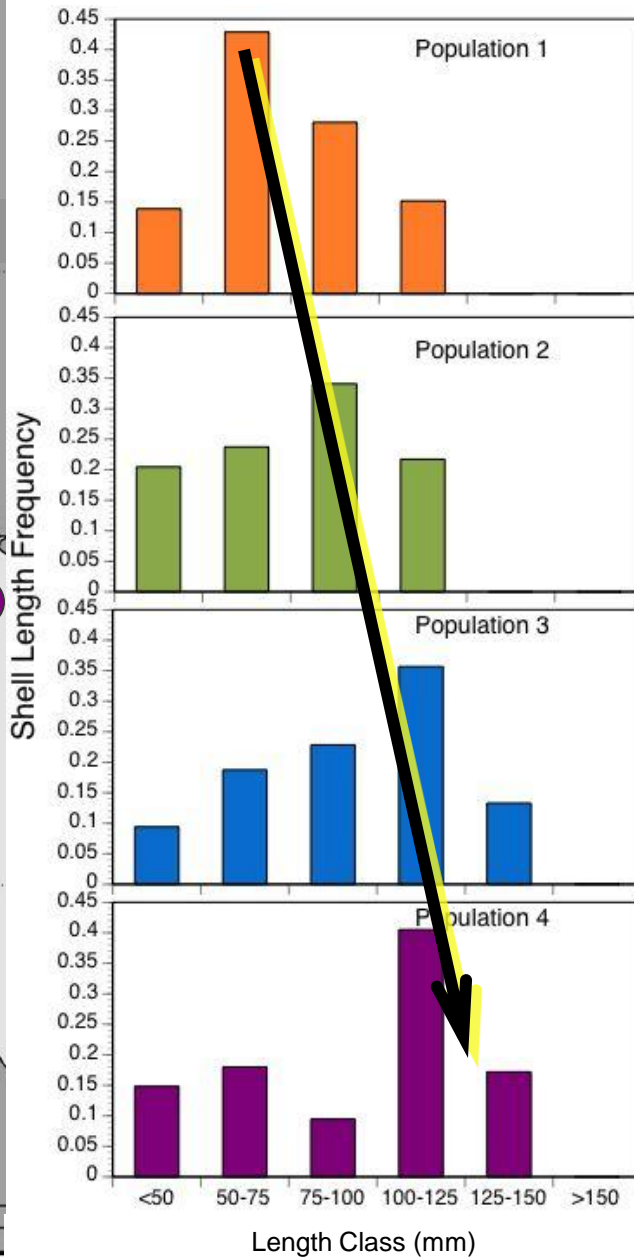


39.5° N

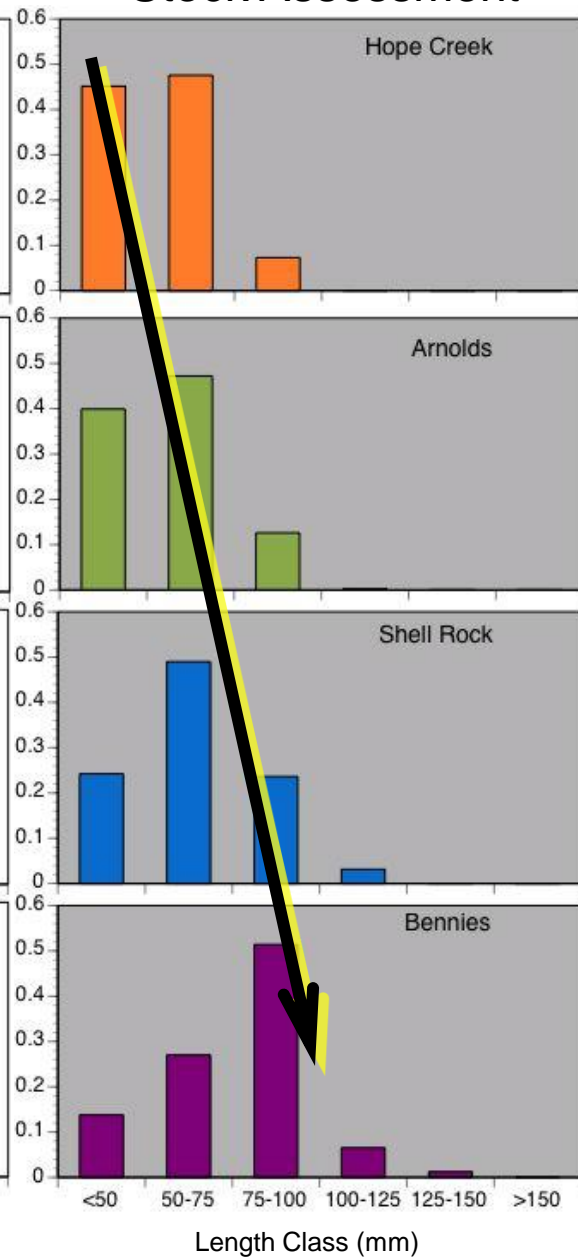
39.0° N

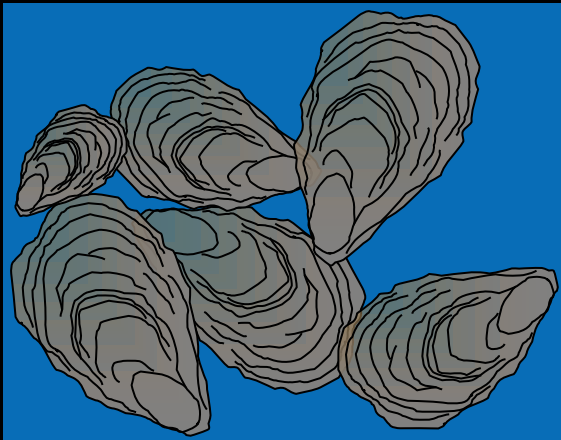
0 10 20 30 40

### Simulation



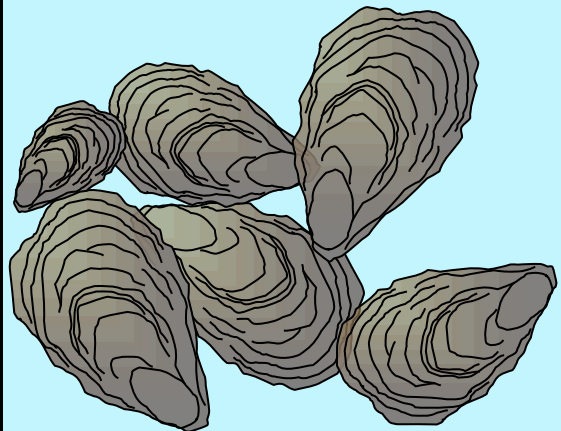
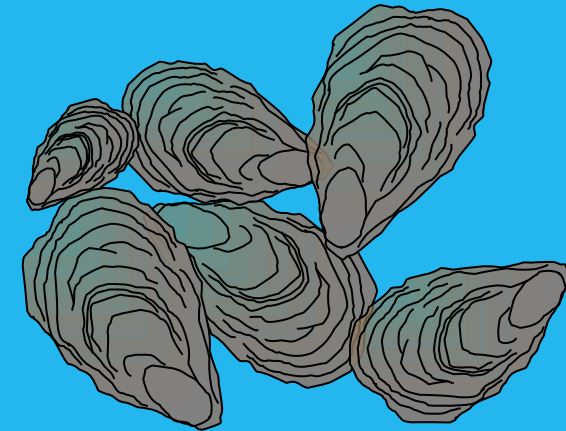
### Stock Assessment





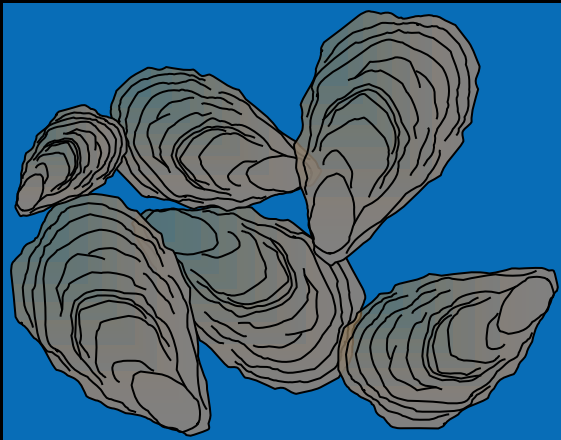
Is larval dispersal or post-settlement processes more important to genetic connectivity?

How do fisheries influence genetic connectivity?



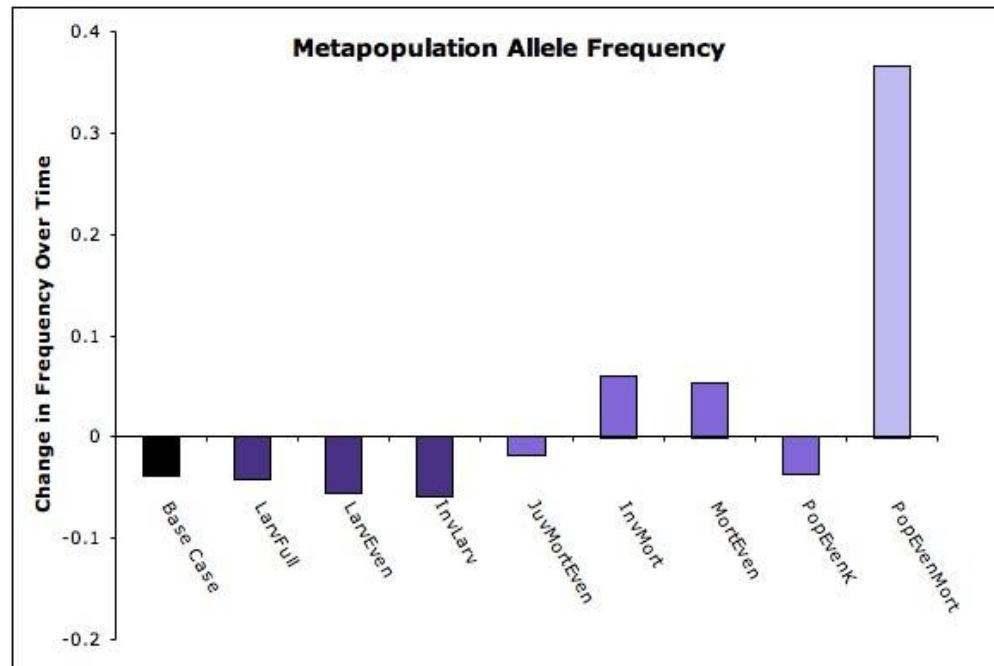
What role do MPAs play in genetic connectivity?





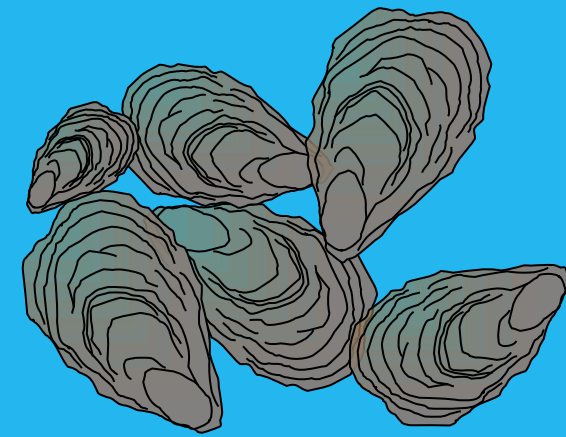
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  - Relative abundance



\*Munroe, D., et al. 2012. The role of larval dispersal in metapopulation gene flow: local population dynamics matter. *Journal of Marine Research*. 70: 441-467

# How do fisheries influence genetic connectivity?

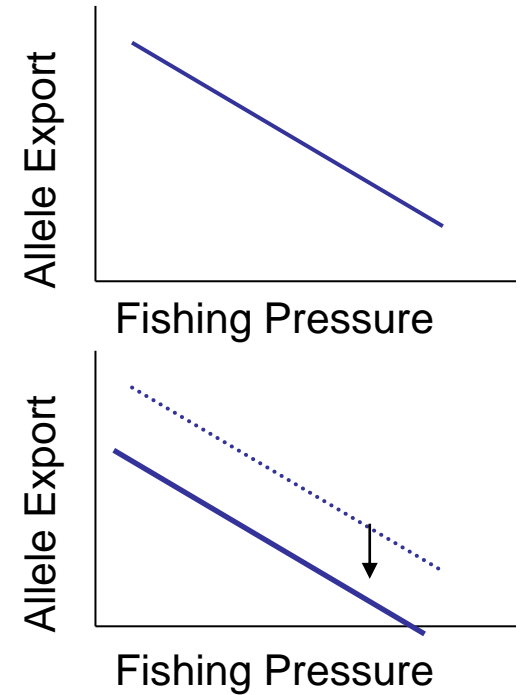


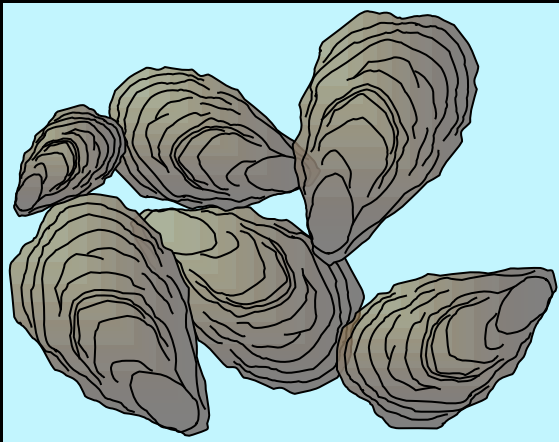
Increasing fishing decreases allele export

- True for both fishery types

Non-selective fisheries lead to a greater decrease in allele export

- On average, 3.5% lower





# What role do MPAs play in genetic connectivity?

MPAs can enhance protected genotypes

- Especially with high surrounding fishing

