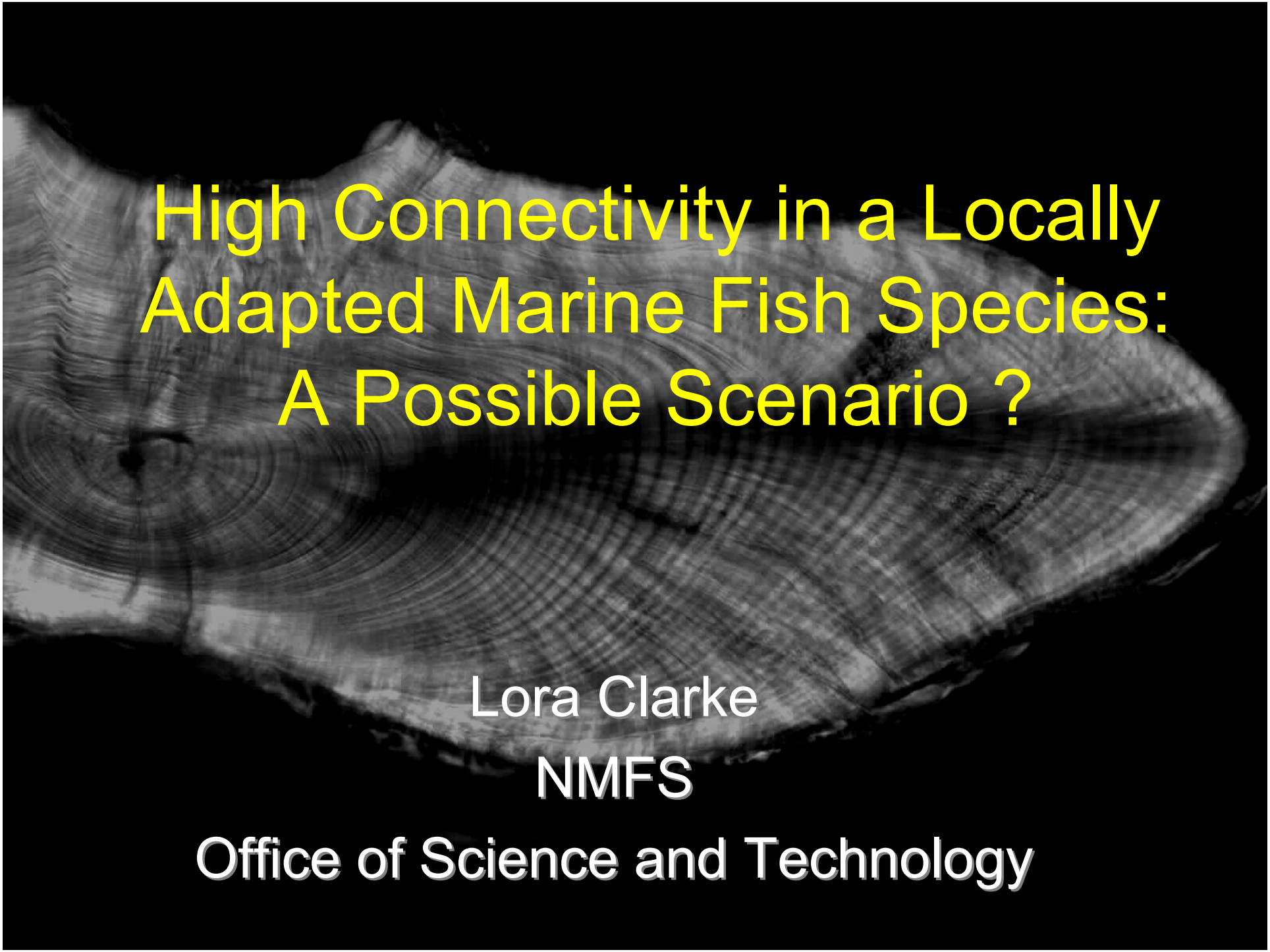


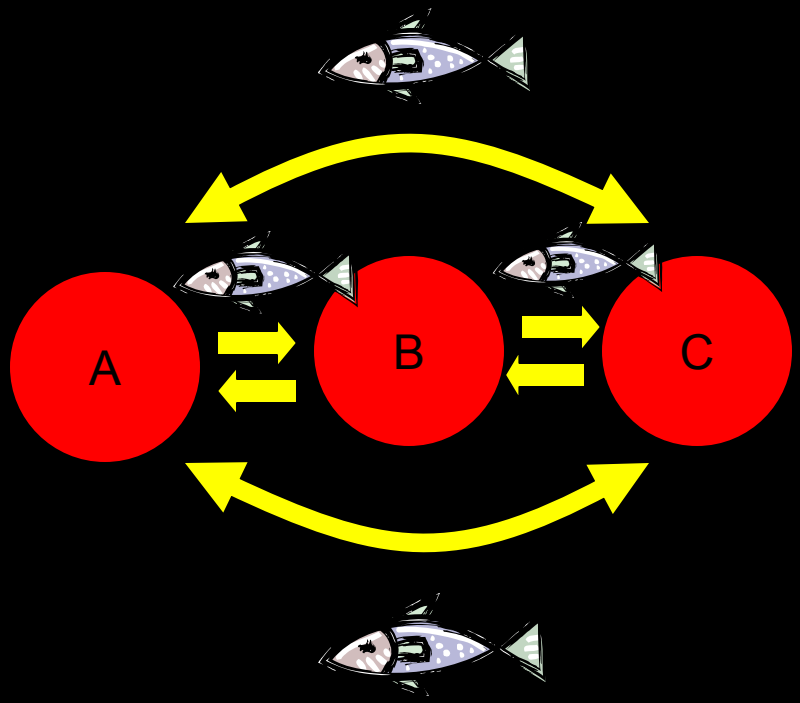
High Connectivity in a Locally Adapted Marine Fish Species: A Possible Scenario ?

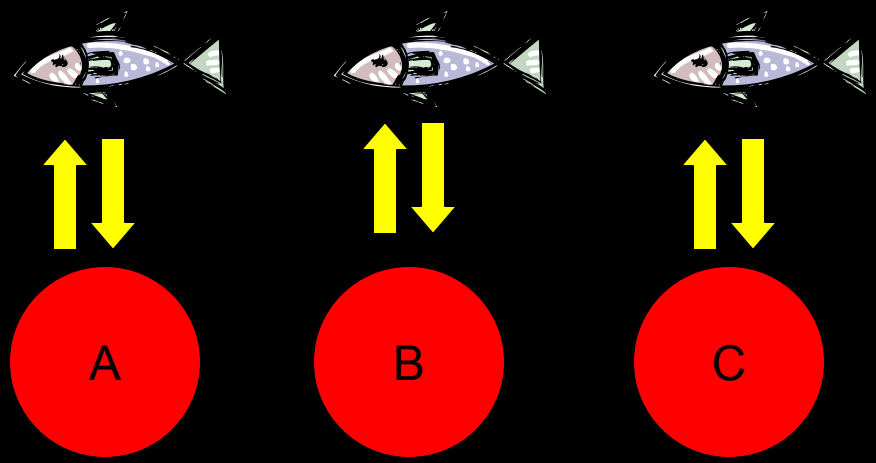
Lora Clarke
NMFS
Office of Science and Technology

Importance of Population Connectivity

- Spatially explicit management plans
- Design of marine reserves
- Colonization rates for new habitats
- Determining gene flow for understanding local adaptation

Open or Closed Populations?





Open or Closed Populations?

- Based on the life history of marine organisms, high connectivity often assumed
- Recent evidence suggests closed populations
- Patterns of connectivity are important in understanding scale of local adaptation

Understanding Local Adaptation

- Occurs when genotypes in their native habitat have higher relative fitness than genotypes originating from other habitats
- Dependent on gene flow, population size, and natural selection
- Believed to be uncommon in marine environment due to high gene flow
- Natural selection would have to be strong enough to override this gene flow

Evidence of Local Adaptation in *Menidia menidia*

- Growth rates
- Growth efficiency
- Energy allocation
- Vertebral number
- Sex determination

- Local adaptation in *Menidia menidia* suggests closed populations

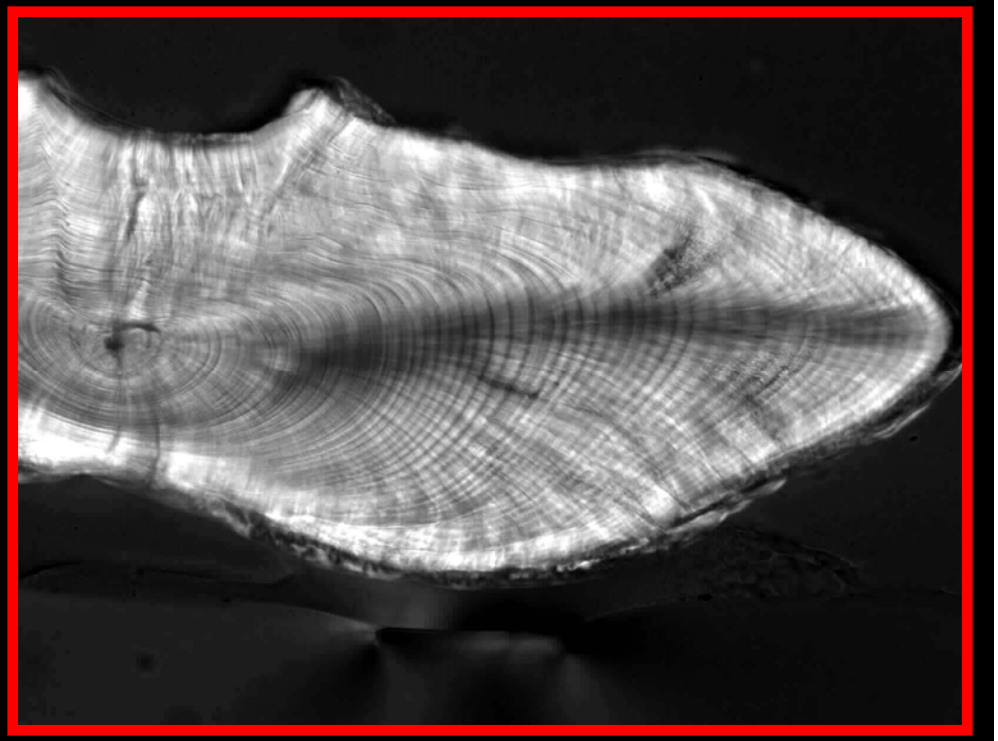
Is local adaptation maintained by limited gene flow (natal homing)?

OR

Does local adaptation exist despite high gene flow?

Otolith Geochemistry

- Otoliths can act as a natural tag
- Continual growth, not subject to resorption
- Often better markers for migration and exchange



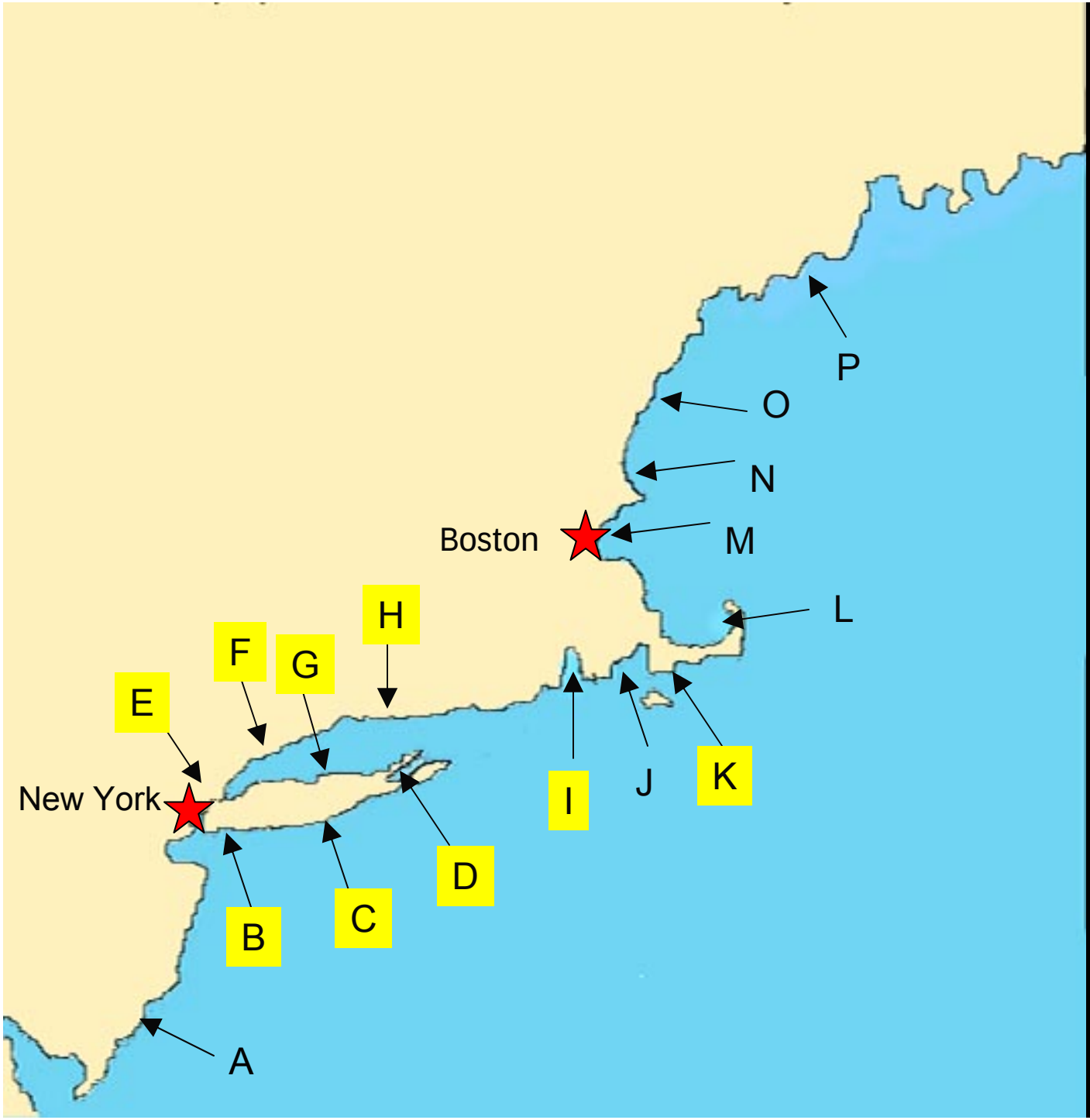
Objectives

1. Quantify the geochemical signatures of juvenile otoliths collected in estuaries from New Jersey to Maine

2. Using these geochemical signatures, determine patterns of dispersal in adults returning the following spring to the same locations

Menidia menidia

- Common from FL to Canadian Maritimes
- Annual species
- Demersal eggs, attach to vegetation
- Juveniles remain in natal estuaries



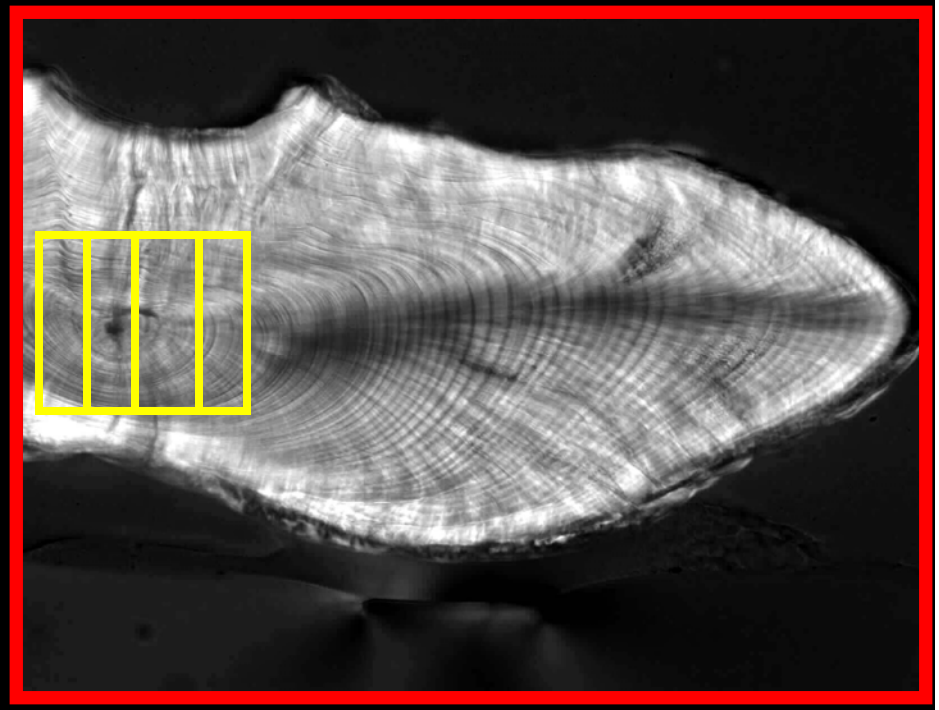
Study Sites:

A – Little Egg Inlet, NJ
B – Jamaica Bay, NY
C – Great South Bay, NY
D – Peconic Bay, NY
E – Hudson River, NY
F – New Haven, CT
G – Flax Pond, NY
H – Conn. River, CT
I – Narragansett Bay, RI
J – New Bedford, MA
K – Waquoit, MA
L – Welfleet, MA
M – Boston, MA
N – Plum Island, MA
O – York, ME
P – Muscongus, ME

30 juvenile *M. menidia* were collected in Summer 2003 and 2004 from each location

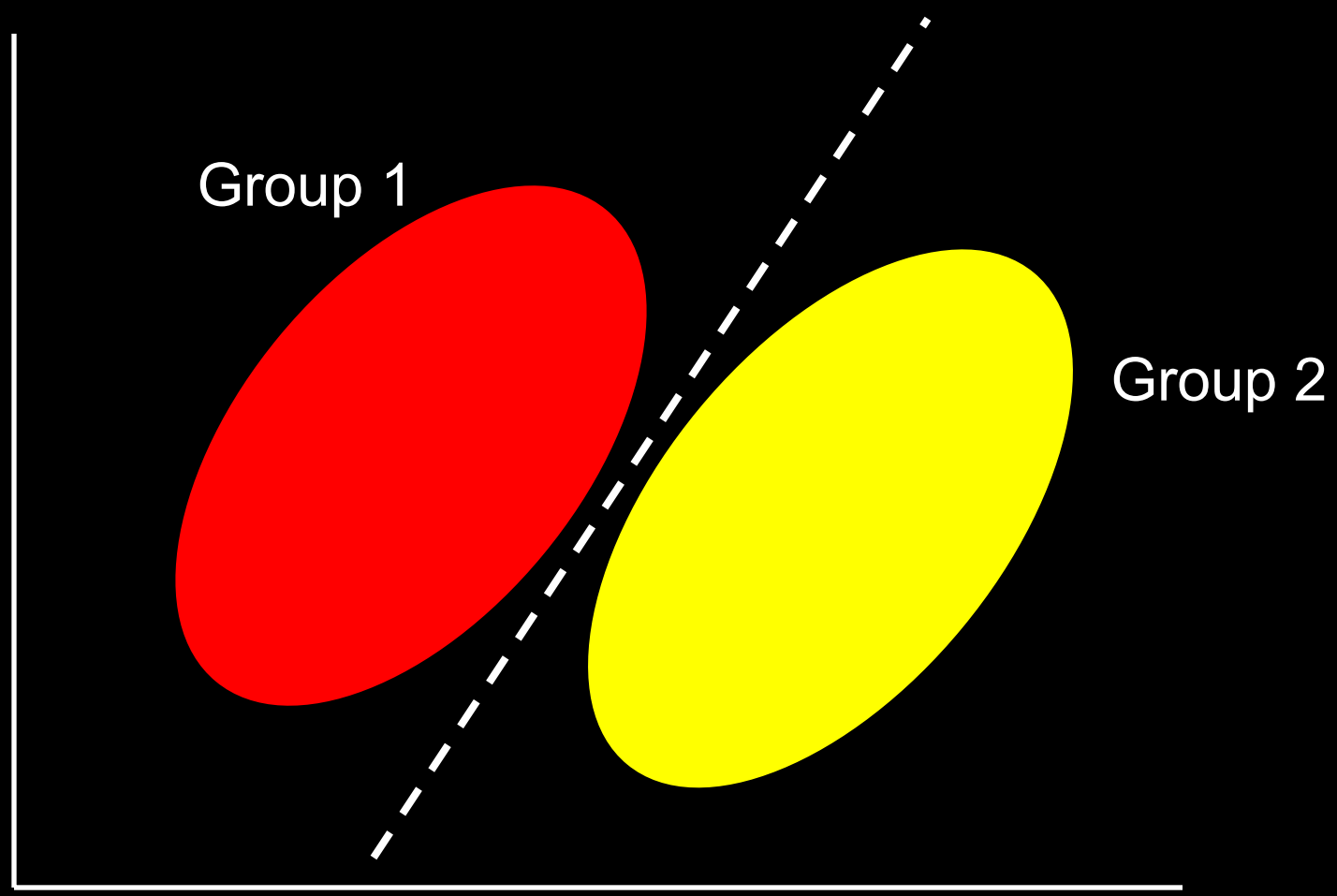
Otolith Analysis

- Otoliths were removed, ground to the core, and prepared for analysis in a class 100 clean bench
- Trace element analysis:
  Sr/Ca, Mg/Ca, Ba/Ca, Mn/Ca, Cu/Ca, and Pb/Ca ratios were analyzed using LA-ICPMS
- Stable Isotope: $\delta^{13}C$ and $\delta^{18}O$ signatures were analyzed on an isotope ratio mass spectrometer
- Juvenile section of the otolith was isolated for analysis

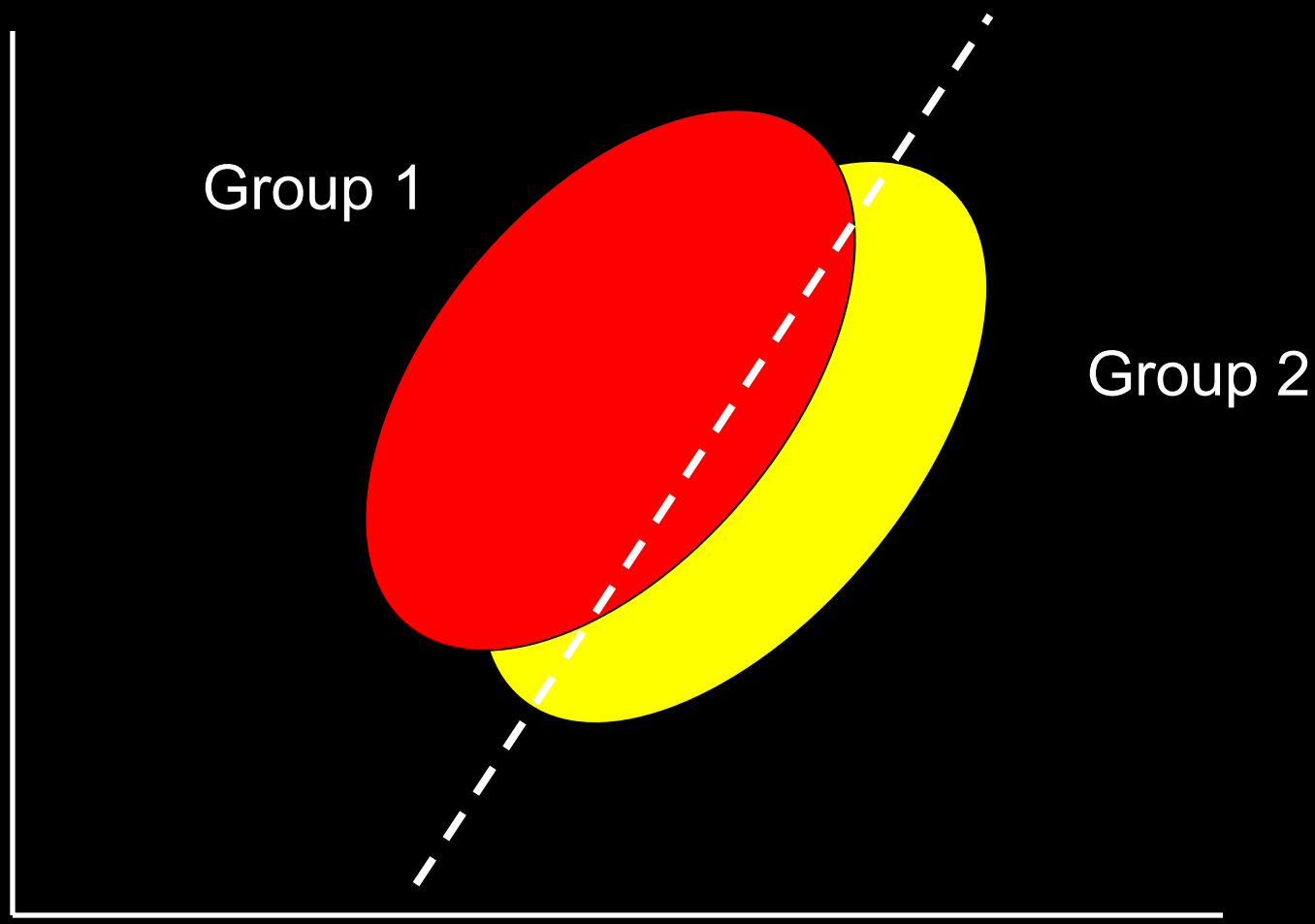


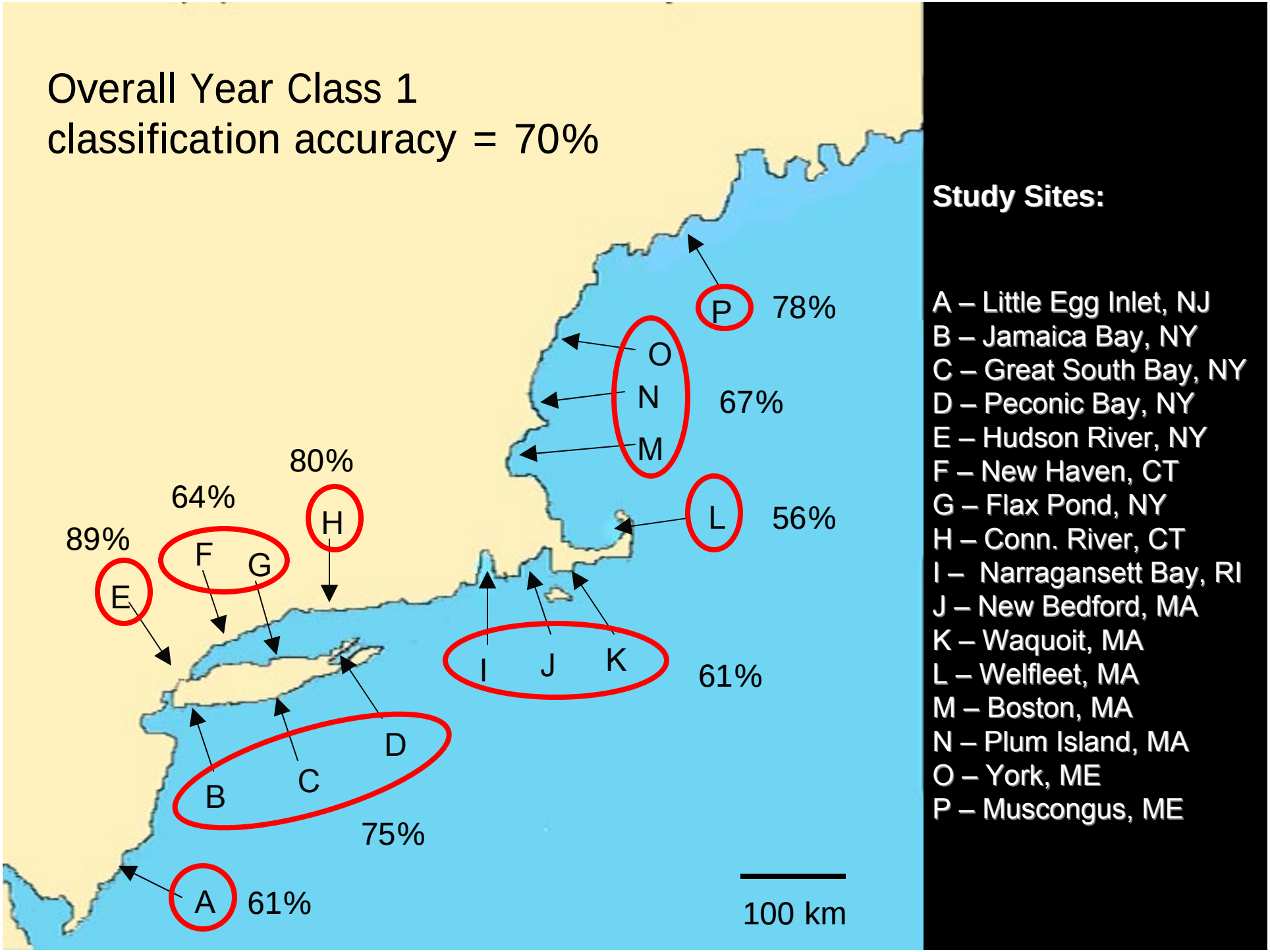
Results – Objective 1

Quadratic Discriminant Analysis



Quadratic Discriminant Analysis




Overall Year Class 1
classification accuracy = 70%
Study Sites:
A – Little Egg Inlet, NJ
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F – New Haven, CT
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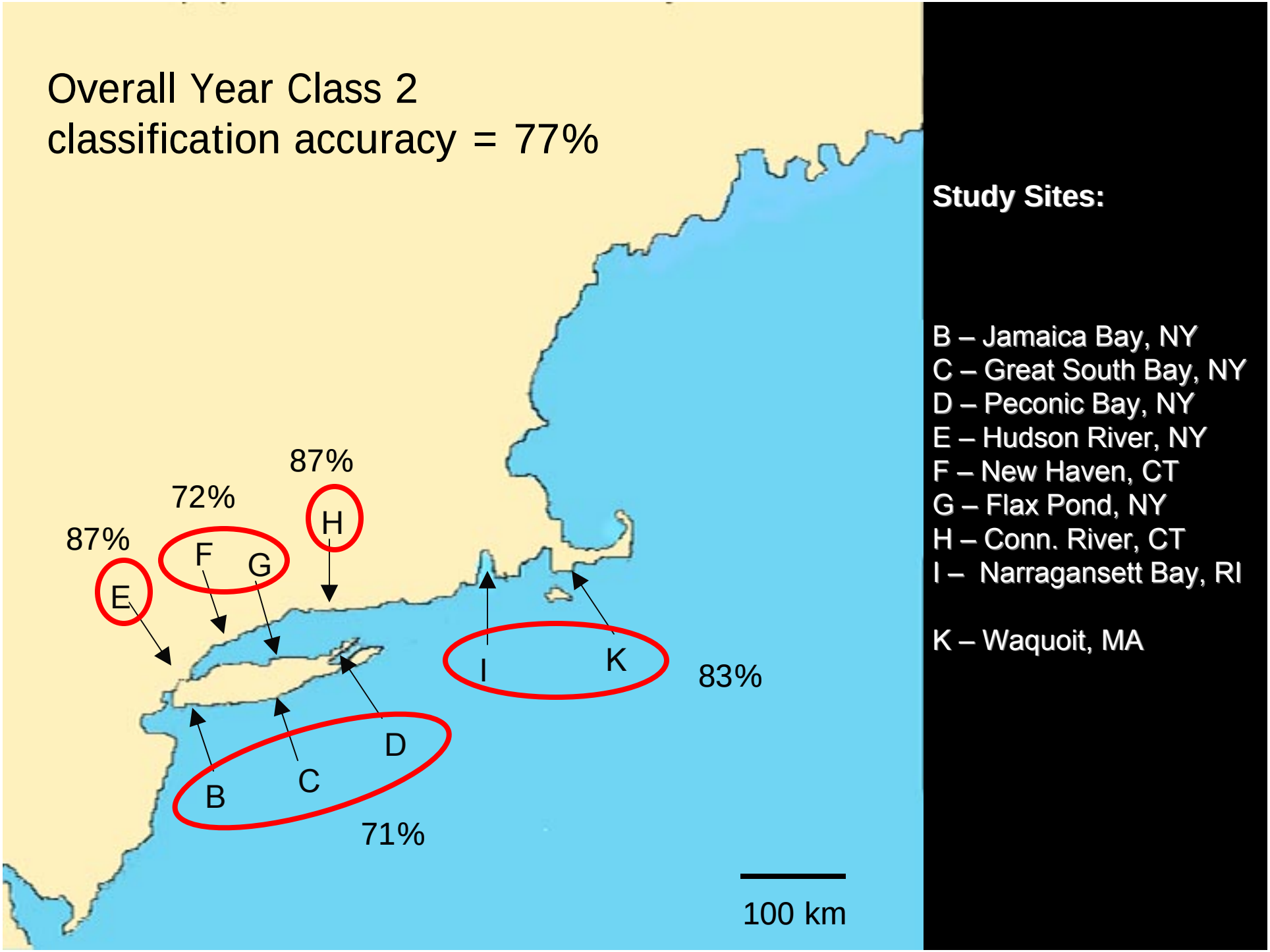
K – Waquoit, MA
L – Welfleet, MA
M – Boston, MA
N – Plum Island, MA
O – York, ME
P – Muscongus, ME
P
78%
O
N
M
67%
80%
64%
89%
H
F
G
E
L
56%
I
J
K
61%
D
B
C
75%
A
61%
100 km


Overall Year Class 2
classification accuracy = 77%
87%
72%
87%
H
F
G
E
I
K
83%
D
B
C
71%
100 km
Study Sites:
B – Jamaica Bay, NY
C – Great South Bay, NY
D – Peconic Bay, NY
E – Hudson River, NY
F – New Haven, CT
G – Flax Pond, NY
H – Conn. River, CT
I – Narragansett Bay, RI
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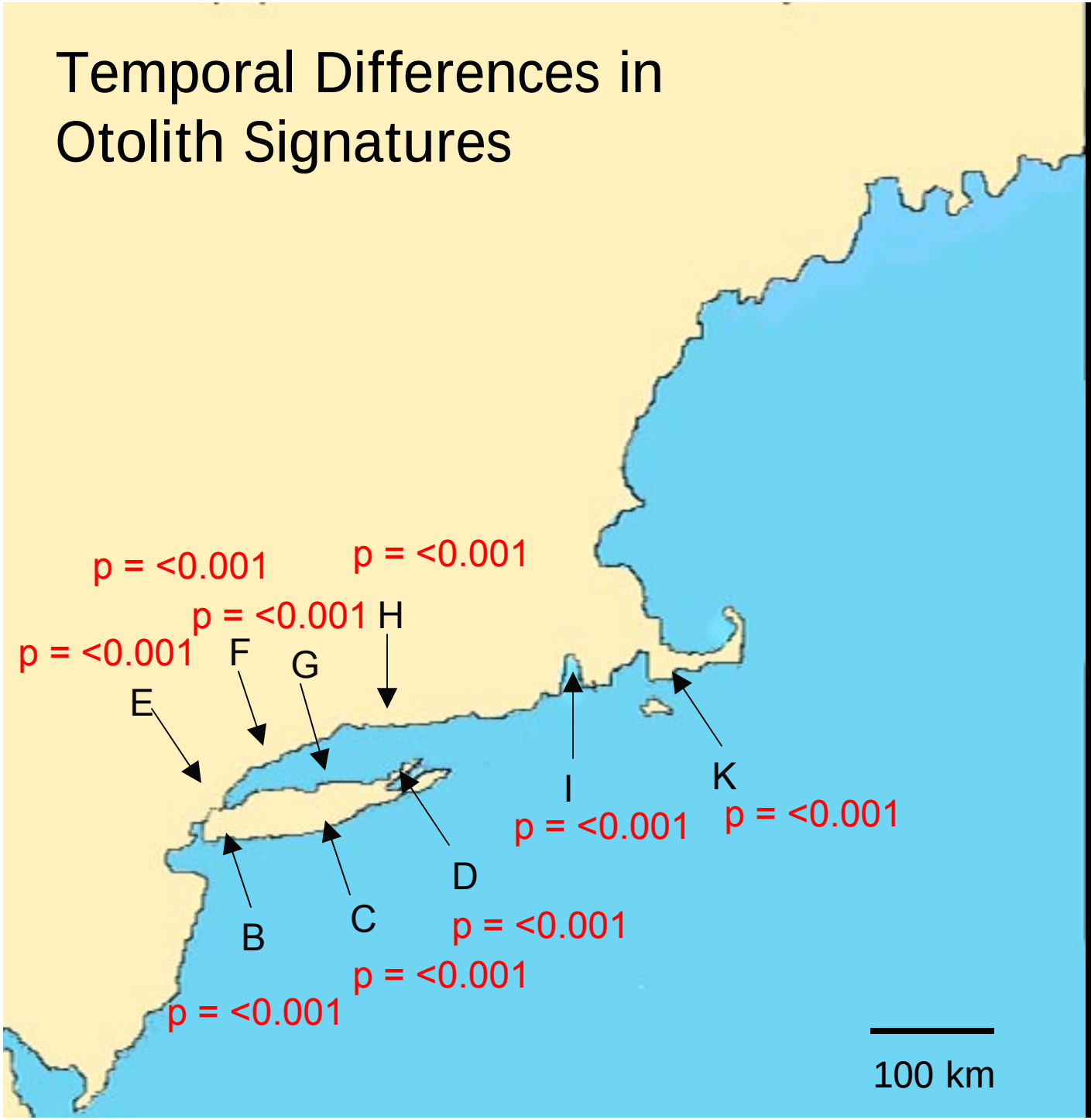
Temporal Differences in Otolith Signatures



Study Sites:

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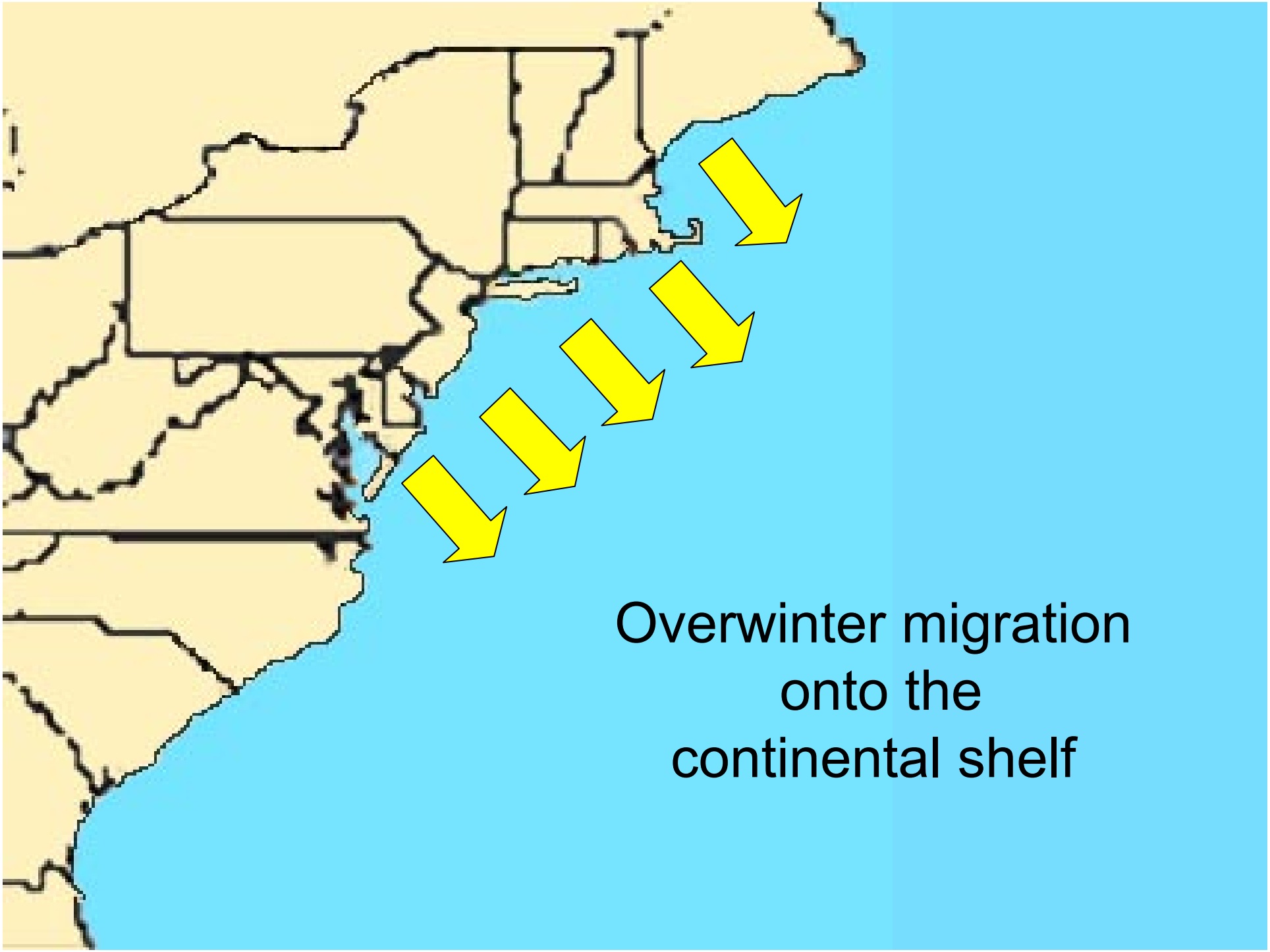
Objective 2

Using these geochemical signatures, determine patterns of dispersal in adults returning the following spring to the same locations

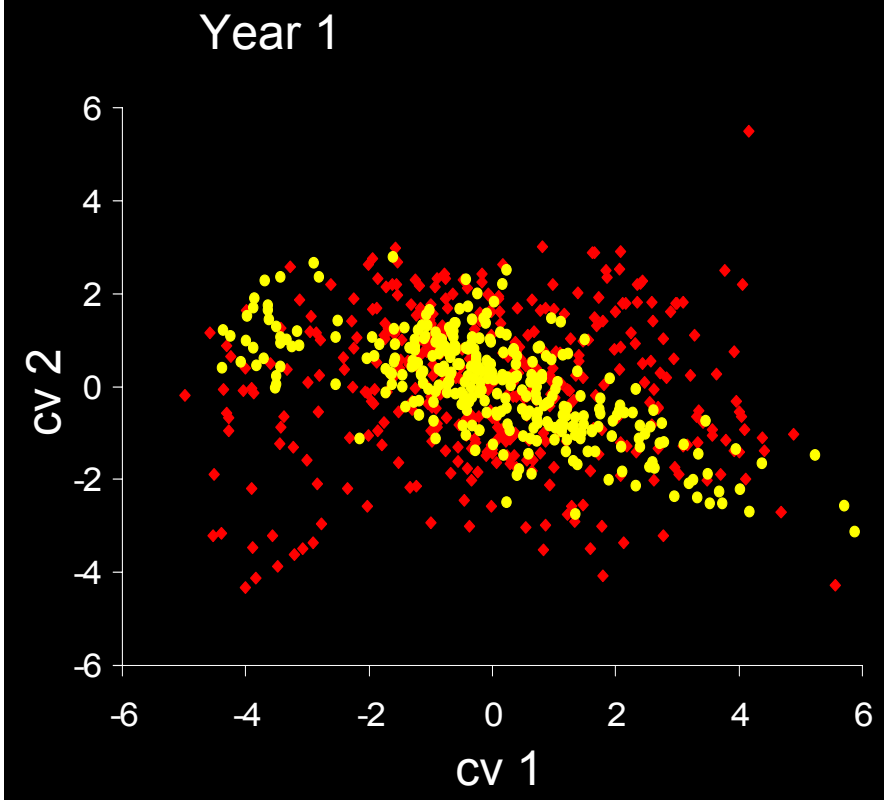

Overwinter migration
onto the
continental shelf

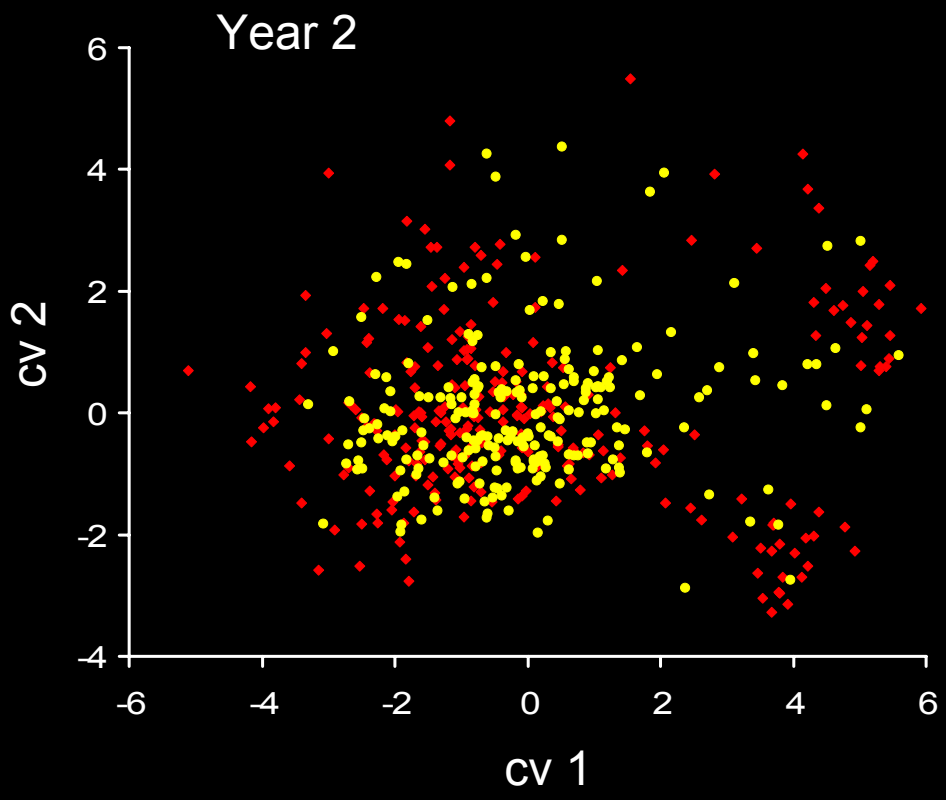

?
Where do they go?


30 adult *M. menidia* were collected from
the same locations in the Spring 2004 and 2005

Results – Objective 2

Canonical Variates of Juvenile and Adult Otolith Signatures

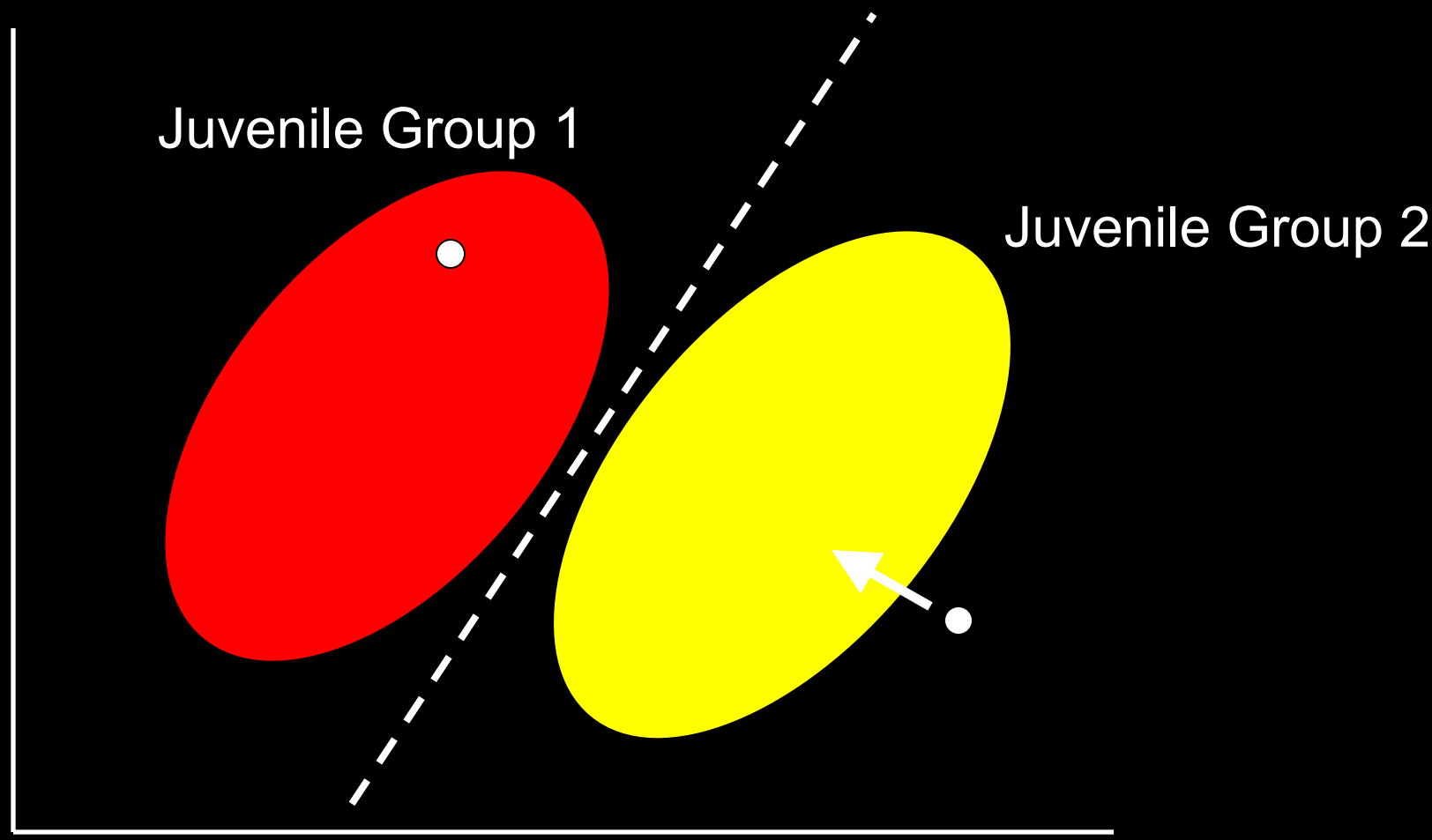




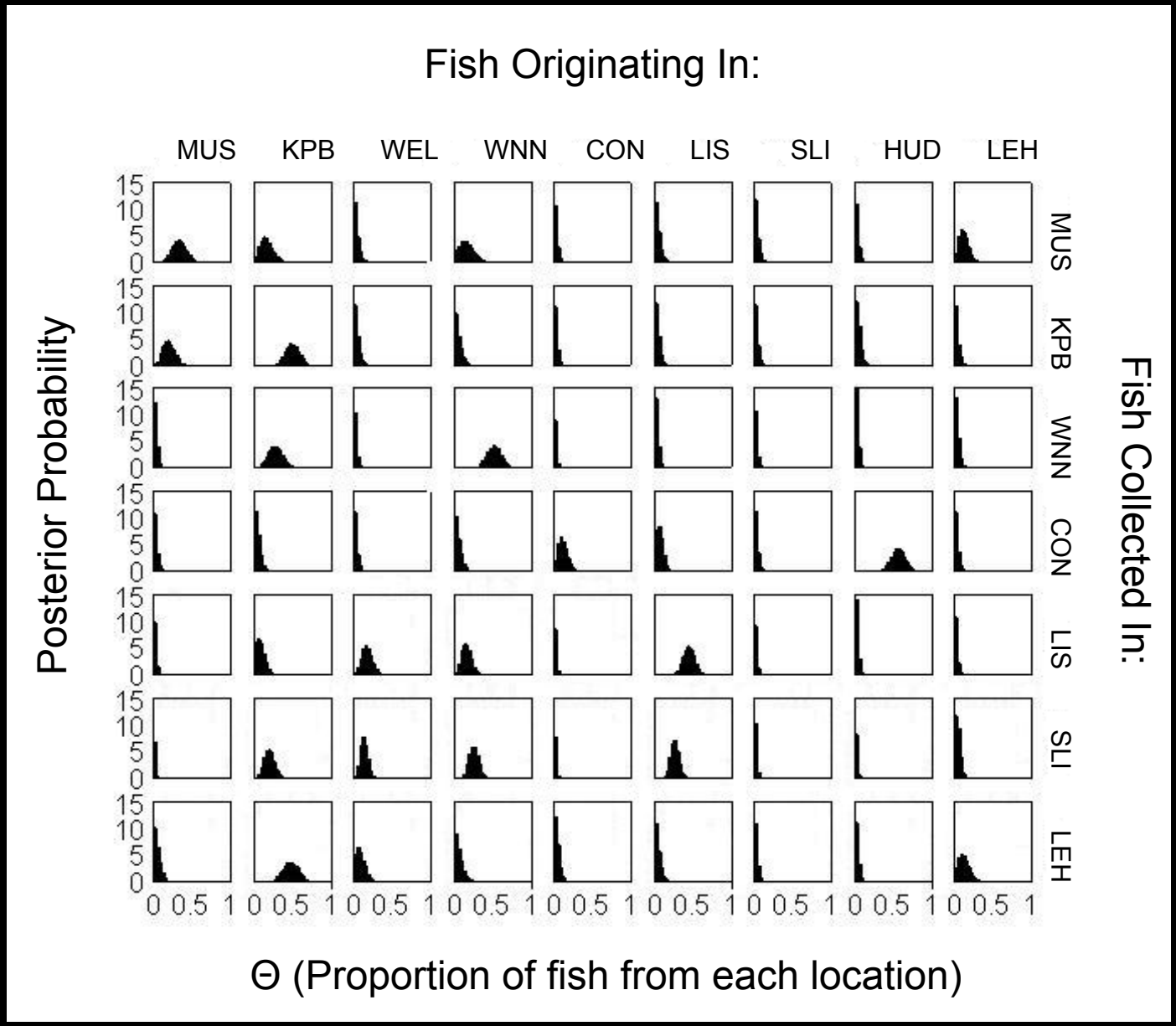
Juvenile Signatures

Adult Signatures

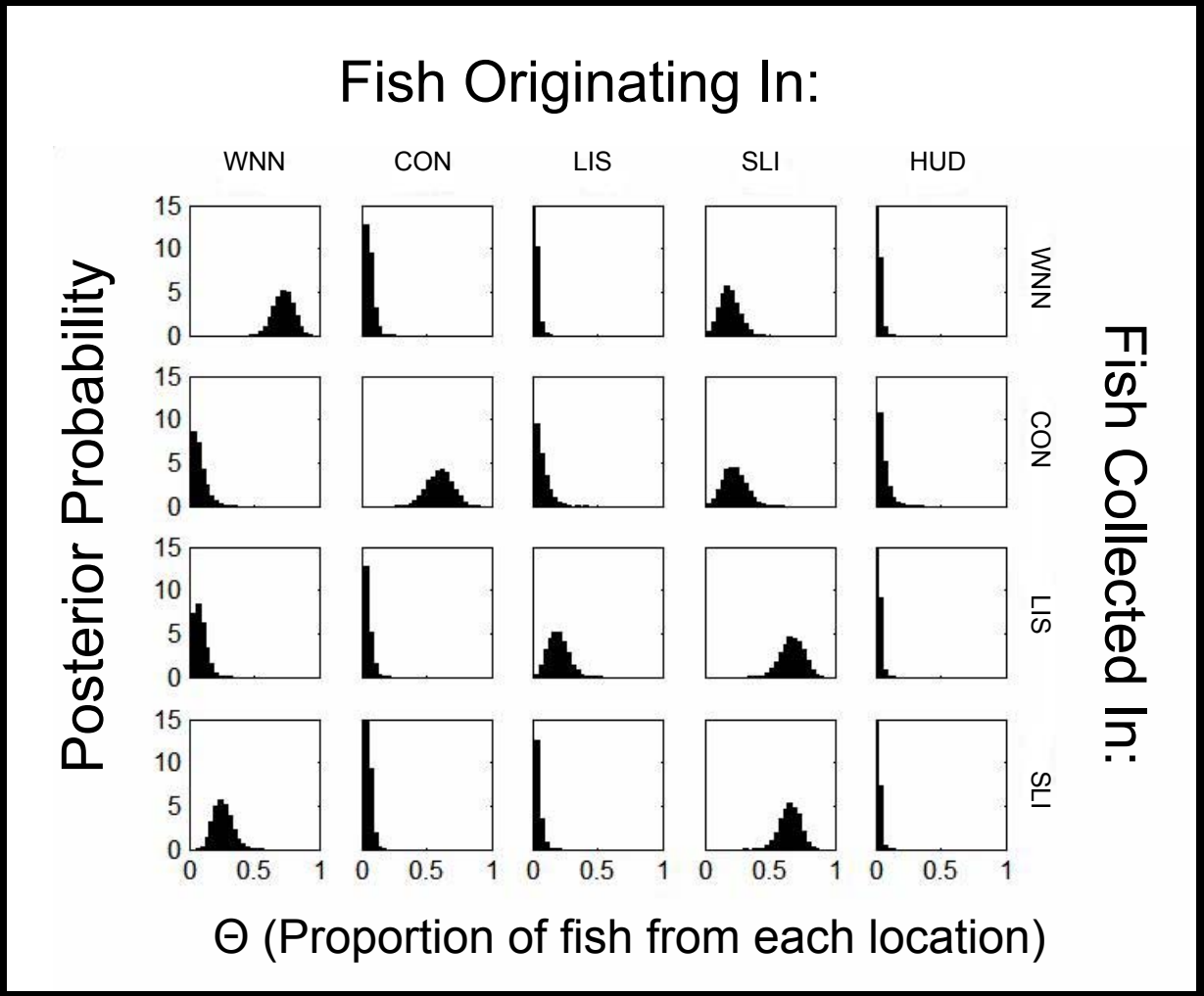
Adult Classifications



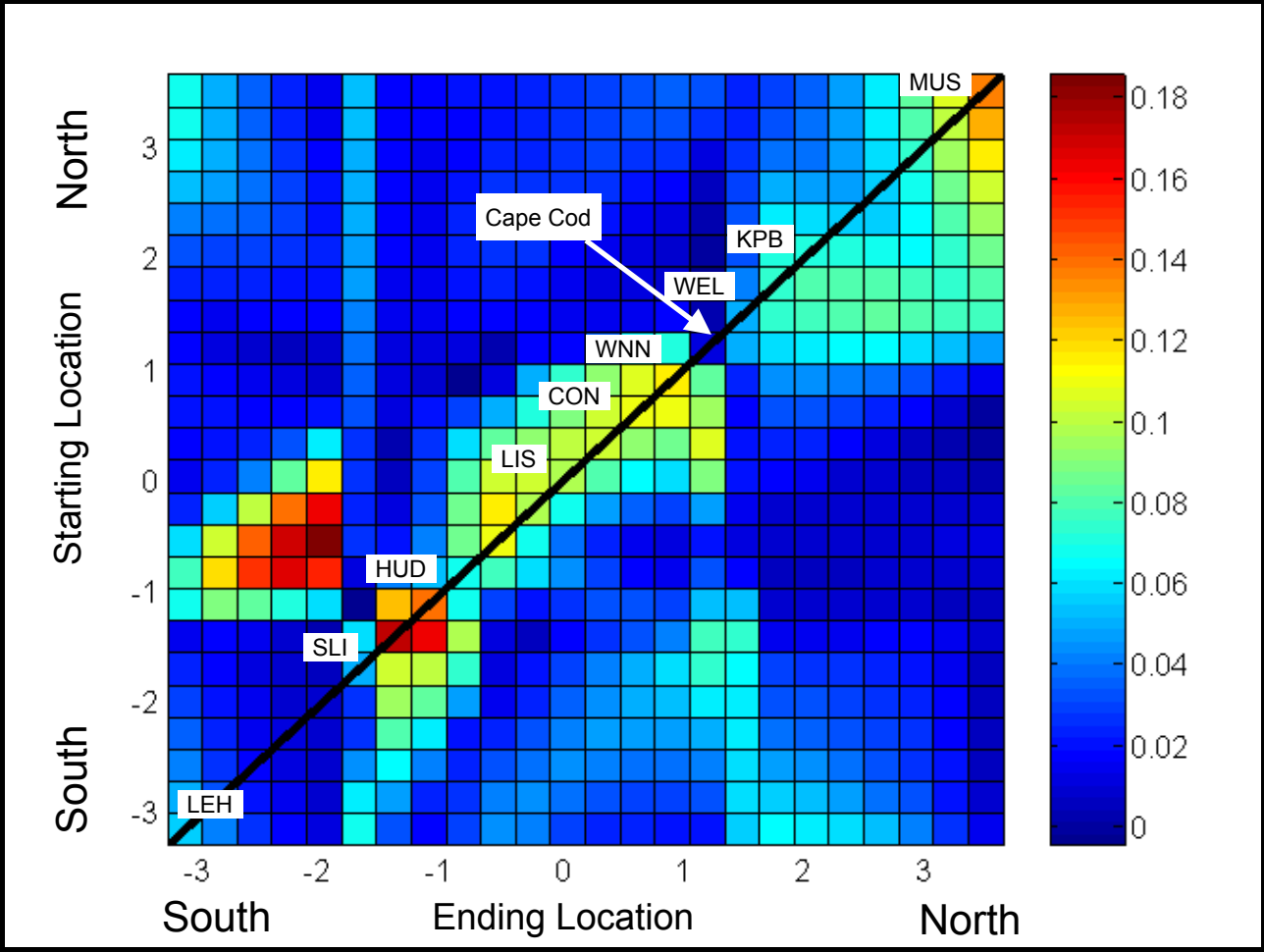
Mixed Stock Composition of Year Class 1



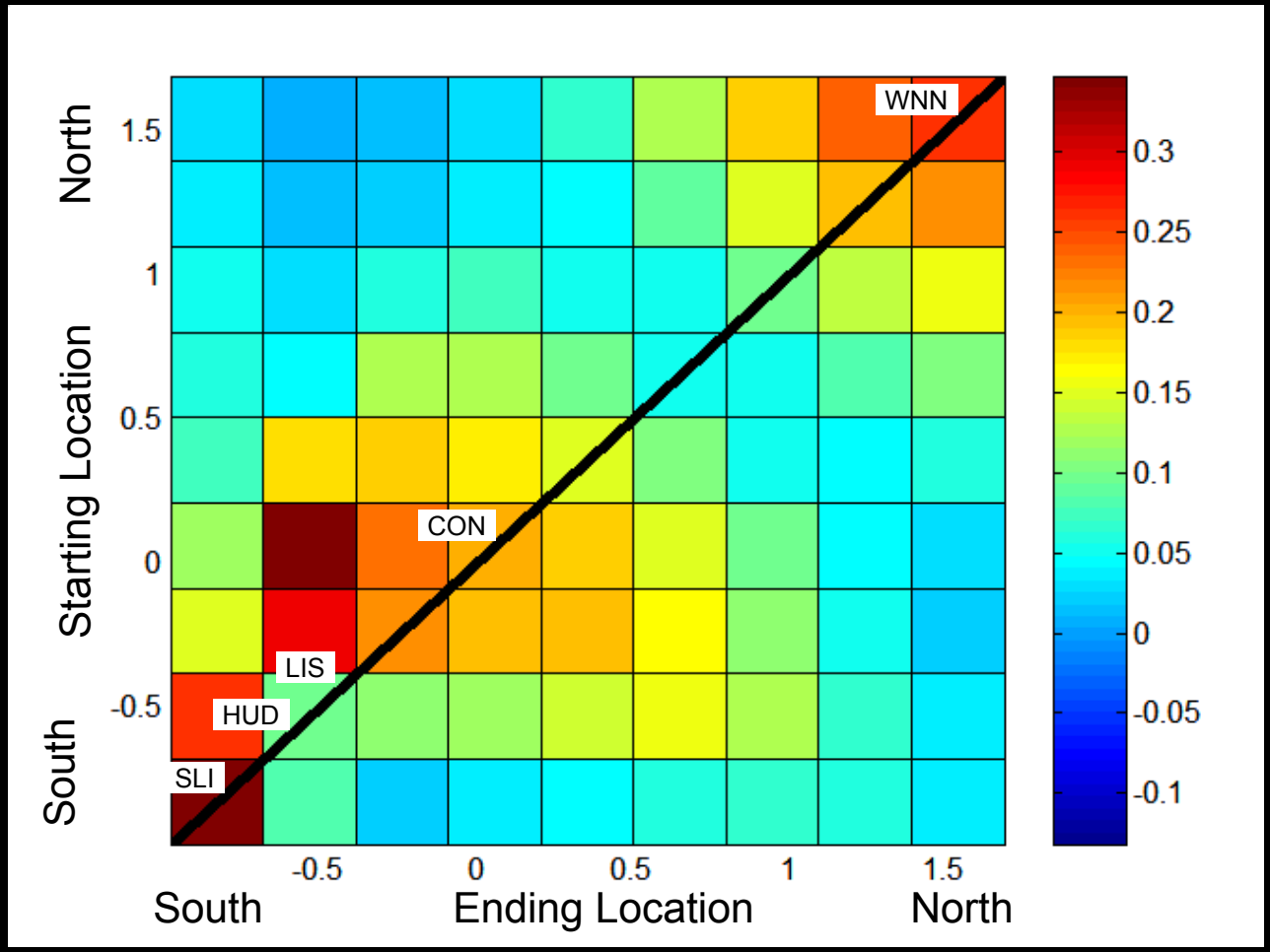
Mixed Stock Composition of Year Class 2



Probability of Migrating a Certain Distance and Direction – Year Class 1

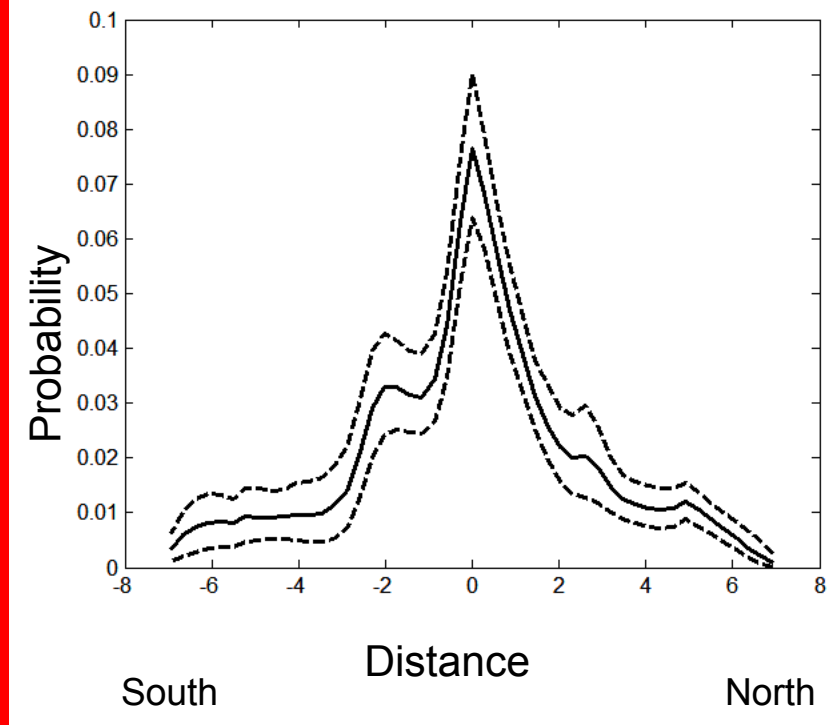


Probability of Migrating a Certain Distance and Direction – Year Class 2

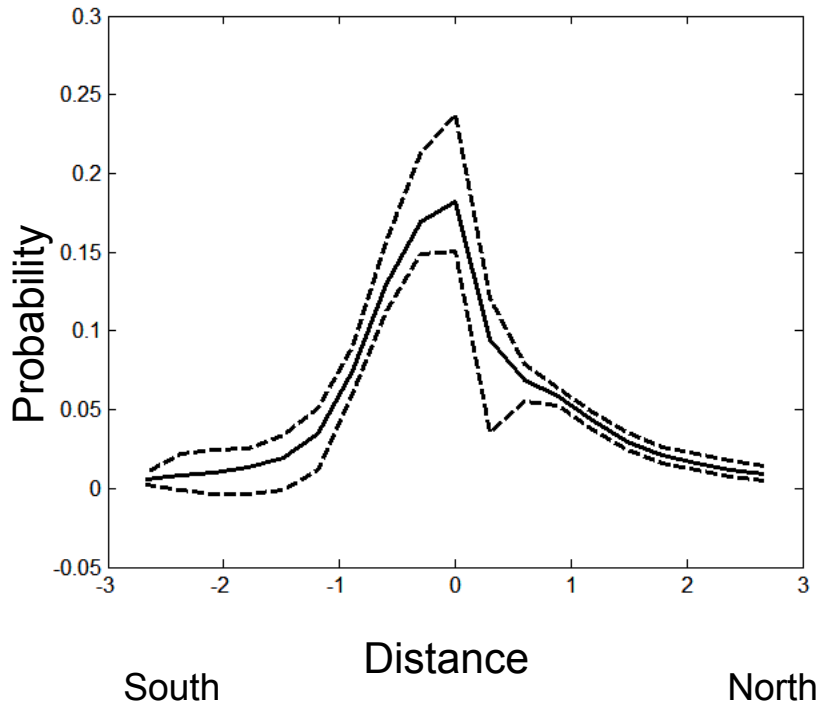


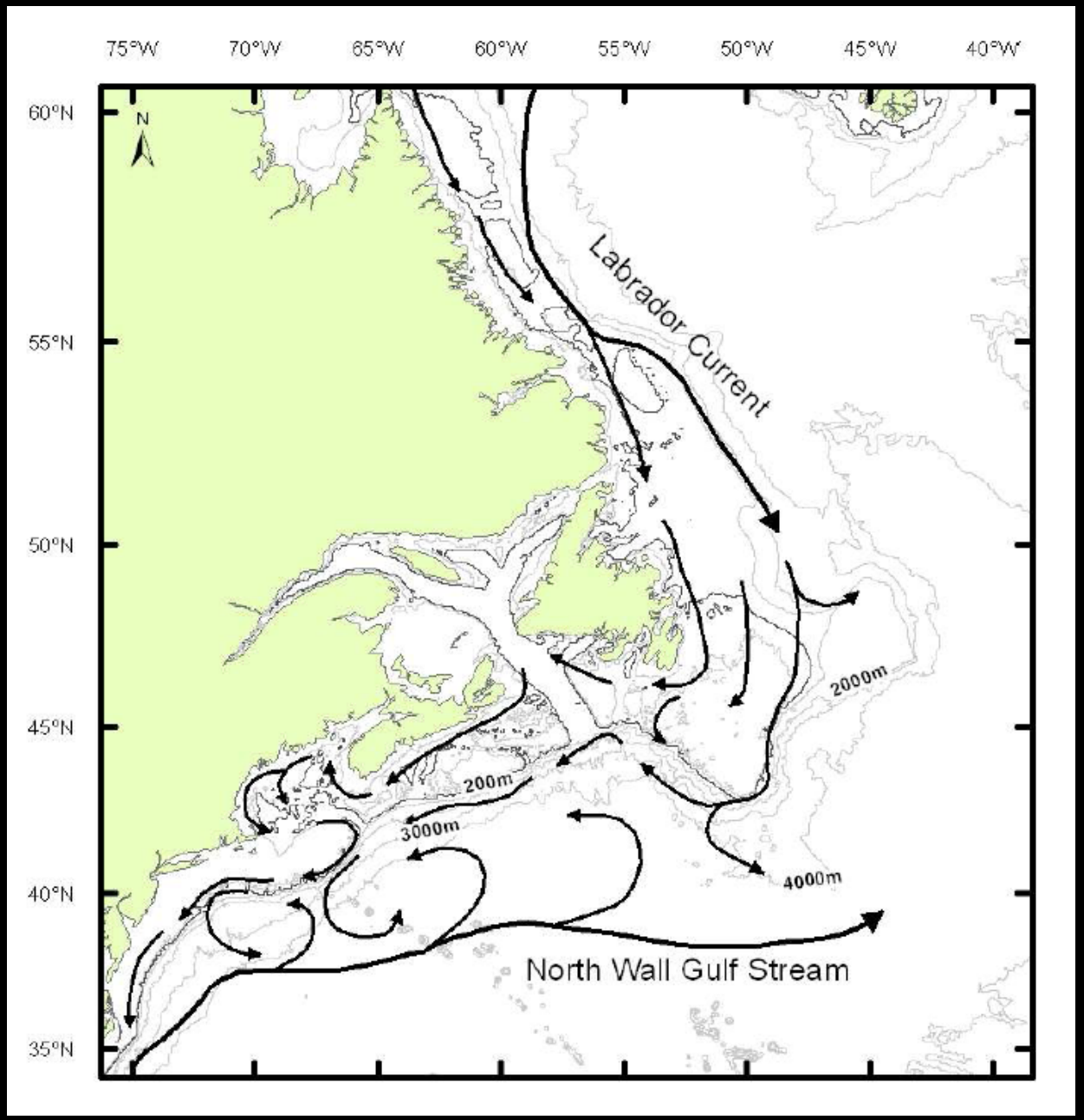
Probability of Migrating a Certain Distance and Direction

Year Class 1



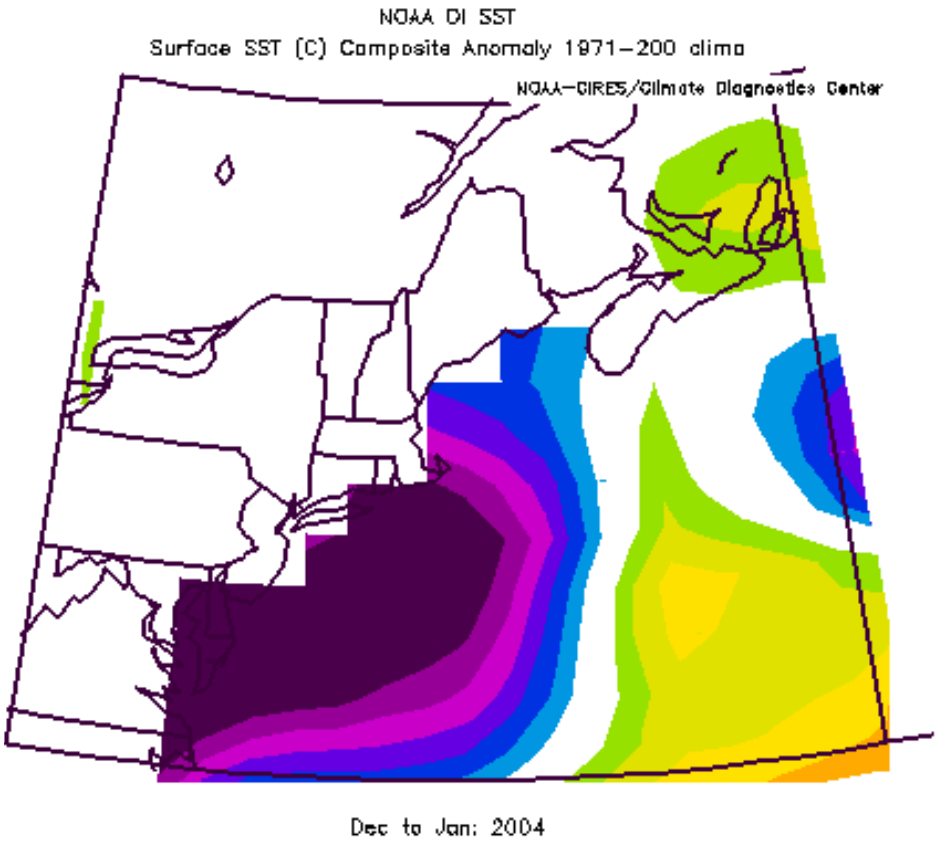
Year Class 2





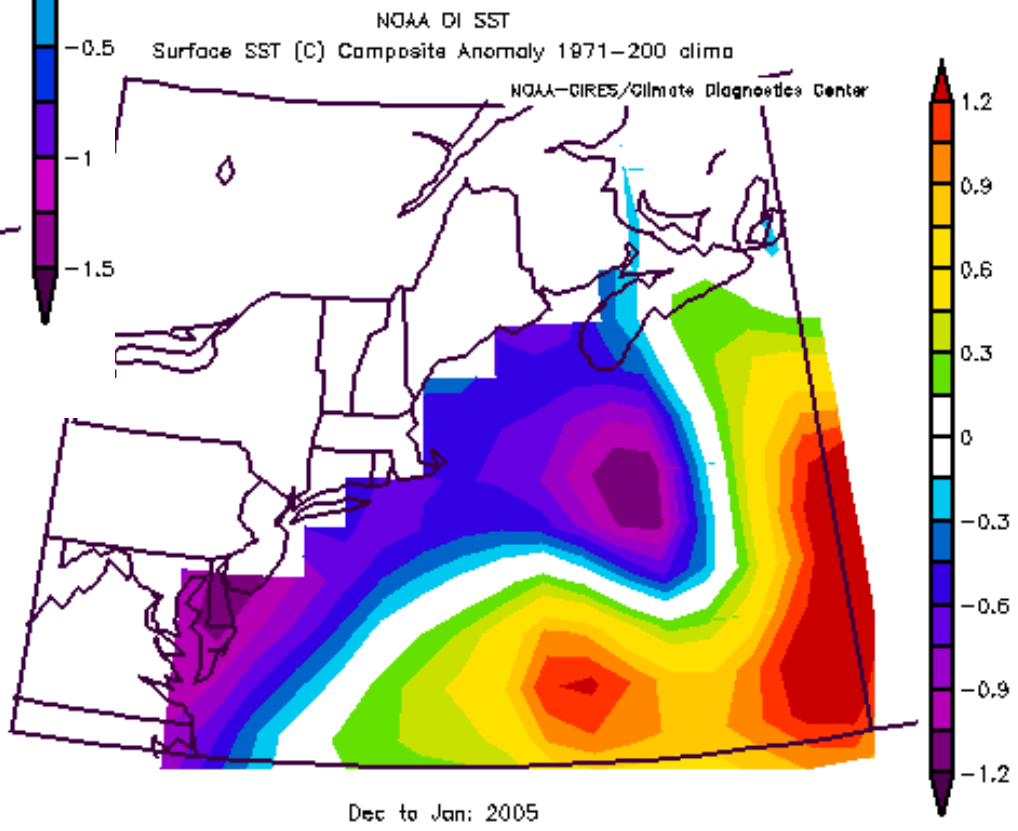
Map taken from Fogarty et al 2007

Winter Sea Surface Temperatures



Winter experienced by Year Class 1

Feb 2004: 2.8°C
Feb 2005: 4.5°C



Winter experienced by Year Class 2

Genetic Data

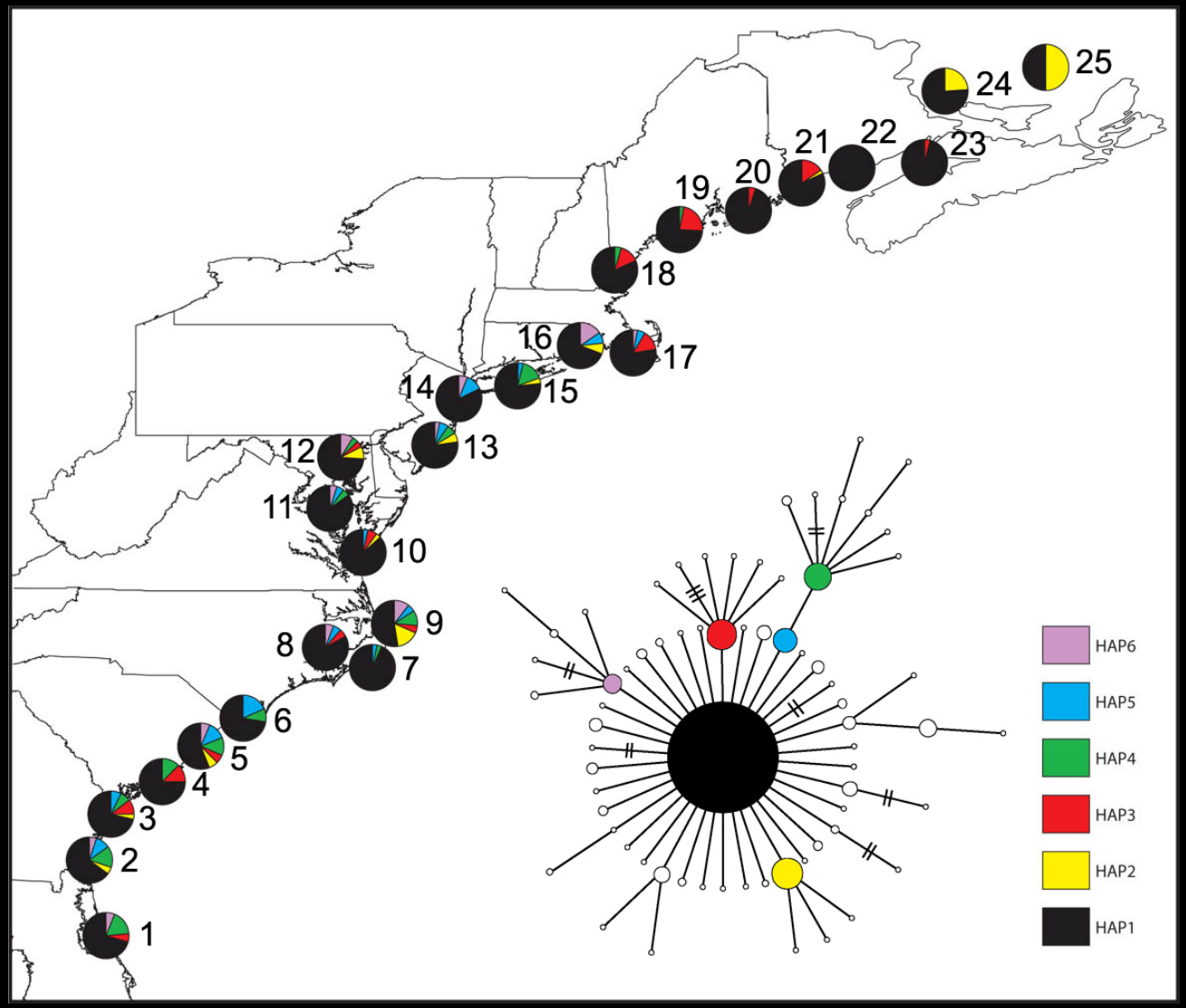


Figure taken from Megan Mach's 2007 thesis

Conclusions

- Using QDA, wild-caught juveniles can be classified with >70% cross-validated accuracy
- Adults have the highest probability of returning back to their site of origin, but evidence of high mixing exists
- Return rates are highly variable from year to year
- Local adaptation occurs despite high apparent gene flow
- Scale of local adaptation and scale of connectivity are not always equivalent
  - In the case of *Menidia menidia*, natural selection must be strong enough to maintain differences

Acknowledgements

- My advisor: Dave Conover
- My committee: Steve Munch, Bob Cerrato, Glenn Lopez, and Simon Thorrold
- Funding: NYSDEC, NSF (Thorrold), and HRF
- WHOI ICPMS Facility and Paleontology Lab – Scot Birdwhistell and Rindy Ostermann
- Julia Socrates (NYSDEC)
- Ken Able and Stacy Hagan (Rutgers)
- Benjamin Walther (WHOI)
- Many, many, many lab mates

My Fellowship Year

- Comparative Analysis of Marine Ecosystem Organization (CAMEO)
- MSA Section 406 Report to Congress
- Integrated Ecosystem Assessment (IEA) PATT