Historic and Contemporary Migrations of Striped Bass in the Northwest Atlantic

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Diadromous Species Restoration Science 2013:
Migration, Habitat, Species Interactions, and Management
10-11 January 2013
University of Maine - Orono

Presentation Overview

- Acknowledgments
- Background
- Large Scale Migratory Patterns
  - Winter Offshore Distribution
  - Distribution of Recaptures
- Multiple Methods for Small Scale Movements
  - Food habits, PUFA, otoliths, genetics, habitat fingerprinting
- Conclusions and Recommendations

Acknowledgements

- **Administrative and logistical support:**
  - Edith Bullock, John Ellis, Eric Gowdy, Stephen Jackson, Aubrey Onley, Sam Pollock, Stephen Taylor, Ronnie Smith, and Sara Winslow
- **Coordination and support:**
  - NOAA Fisheries, Dr. Bill Hogarth, Dr. John Boreman, Dr. Steve Brown, Dr. Dave Detlor, Jeff Gearhart, Kendall Falana, Steve Meyers, Wendy Taylor, Perry Thompson,
- **Data management:**
  - Maryland Department of Natural Resources (special thanks to Carol McCollough, Cynthia Goshorn and Beth Rodgers); U.S. Fish and Wildlife Service, Maryland Fisheries Resources Office (Tina McCrobie, Matthew Breece, Sheila Eyler, Ian Park)

Acknowledgements

- **Funding:** ASMFC; NOAA Fisheries, headquarters, NE and SE Fishery Science Centers; USFWS, Maryland Fisheries Resources Office; NC Sea Grant; NC CRFL grant program; NC Division of Marine Fisheries; USFWS South Atlantic Fisheries Coordination Office

- **GIS maps:** NOAA Fisheries, Jodi Marcus and Keith Bickers; U.S. Fish and Wildlife Service, Ecological Services-Raleigh, Doug Newcomb

- **Sampling platforms:** NOAA Research Vessels and Crews, ALBATROSS IV (1992), CHAPMAN, OREGON II (especially Captain Jim Rowe, Todd Wilson Roger Zirlatt and the OREGON II crew); NSF R/V CAPE HATTERAS (2004, 2009, 2010, 2013)

- **Scientific Party staff:** All partnering agencies, but especially the Atlantic States Marine Fisheries Commission, East Carolina University, Maryland DNR-Fisheries Service, North Carolina Division of Marine Fisheries, and the US Fish and Wildlife Service.

Large Scale Migration

Tagging programs for striped bass have been conducted since the 1930s (see Boreman and Lewis 1987)

Boreman and Lewis (1987) concluded from prior studies (ALS*):

1) Coastal migration -- north in the spring, south in the fall.

2) Populations south of Cape Hatteras are “endemic and riverine”.

3) The majority of striped bass caught in northern waters are of Chesapeake Bay origin, with a lesser contribution by striped bass originating in the Hudson River and the Roanoke River.

4) Striped bass < two years old do not participate in coast-wide migrations

5) Most coastal migrants are female.

6) the contribution of the Hudson River stock to coastal fisheries is essentially northeastward from the river mouth.

*ALS= American Littoral Society, 1964-1985

Large Scale Tagging Studies

- The coordinated coastwide tagging program concept originated in the ASMFC Striped Bass Technical Committee in 1986-1987.
- The program was established with eight components: four programs in “producer” areas; and four in coastal areas.
- Four coastal components: MA hook and line; NY ocean haul seine (recently changed to trawl); NJ trawl; and VA/NC Cooperative Winter Tagging Cruise.
- Other state striped bass tagging programs also were initiated and continue to the present (e.g., NCDMF and NCWRC began in 1991).

Cooperative Winter Tagging Cruises

- The Cooperative Winter Tagging Cruise (Cruise) was initiated in 1988 and has continued through 2013.
- Data from the Cruise are maintained at MDDNR, and the USFWS Maryland Fishery Resource Office in Annapolis, MD.
- The USFWS produced a summary report after the first five years of the Cruise, and is working on a second summary report which will cover the 22 years from 1988 through 2009.

Vessels Used

NOAA R/V Albatross IV

NOAA R/V Chapman

Vessels Used

NOAA R/V Oregon II

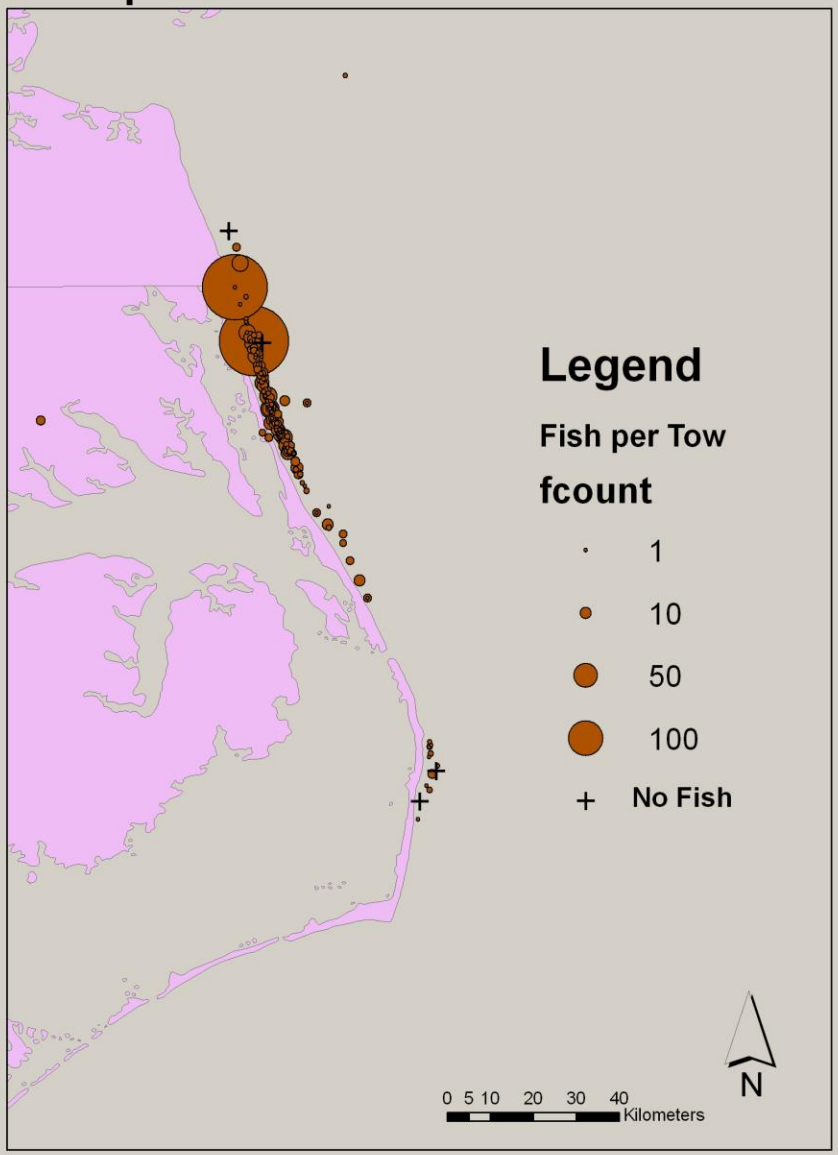
NSF Cape Hatteras

CWTC 1988-2009

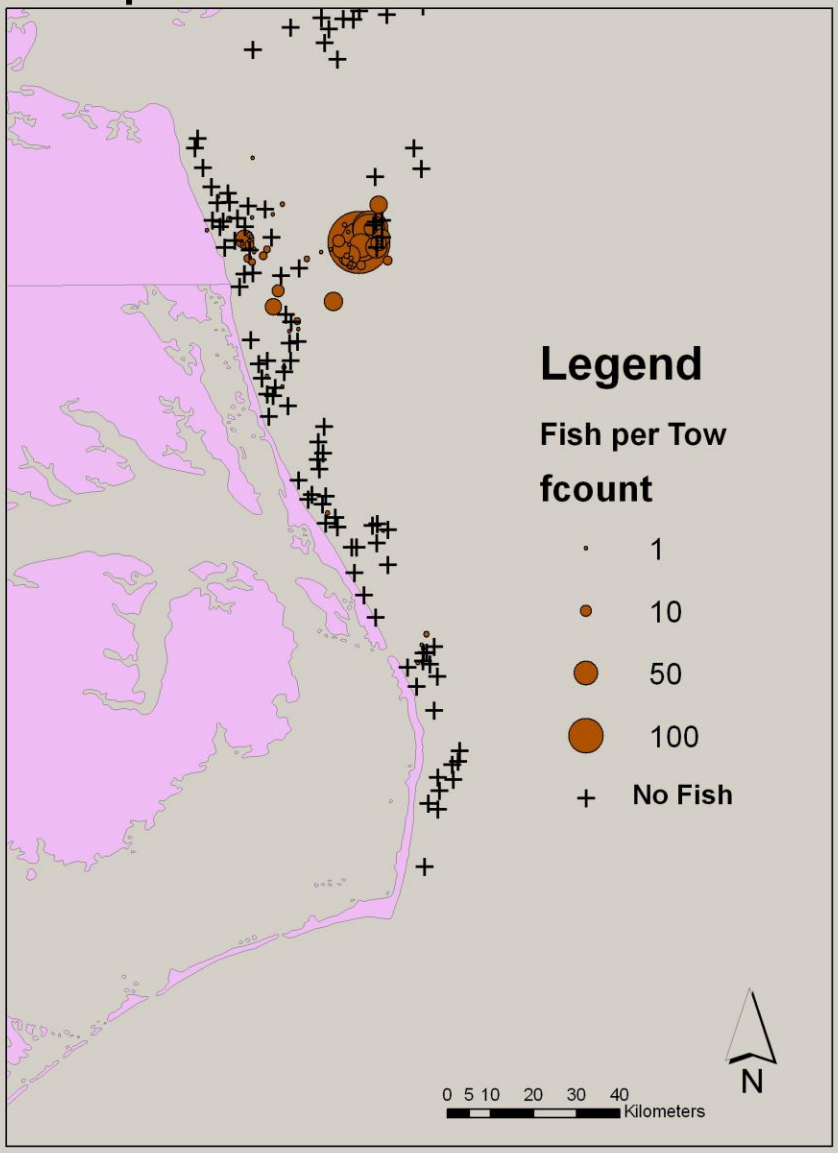
- For 1988-2009, the total released was 43,558
- Range for annual number tagged was 146 to 6,236
- Average annual number tagged was 1,980

Changes in Annual Winter Distribution of "Coastal Migratory Stock" based on the CWTC, 1988-2009

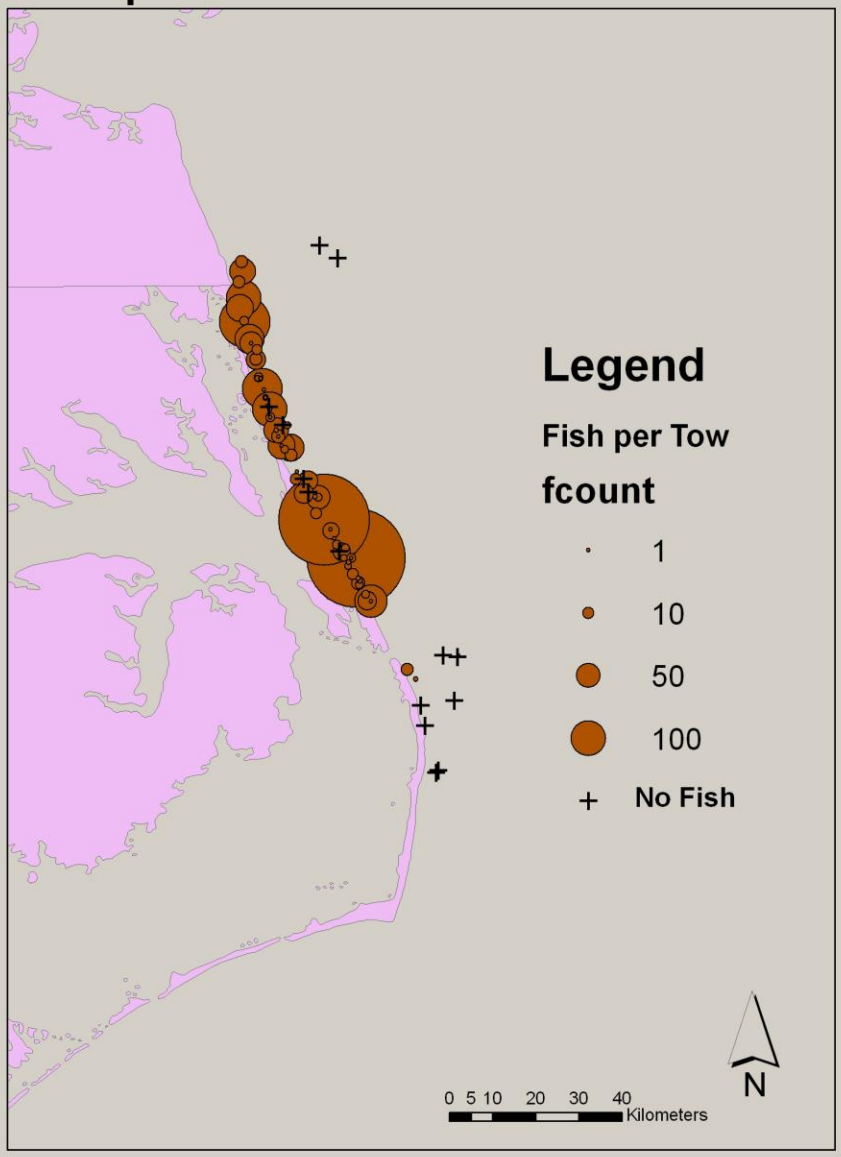
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1988



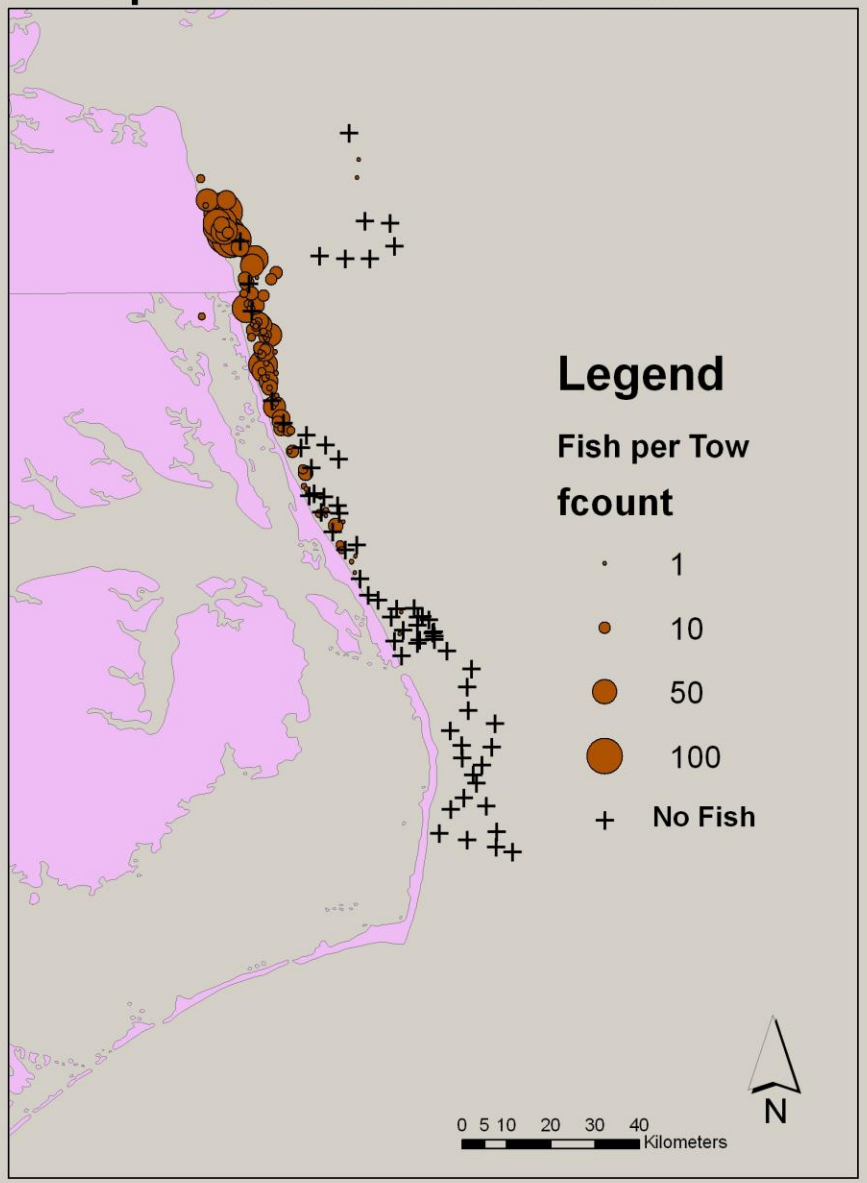
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1989



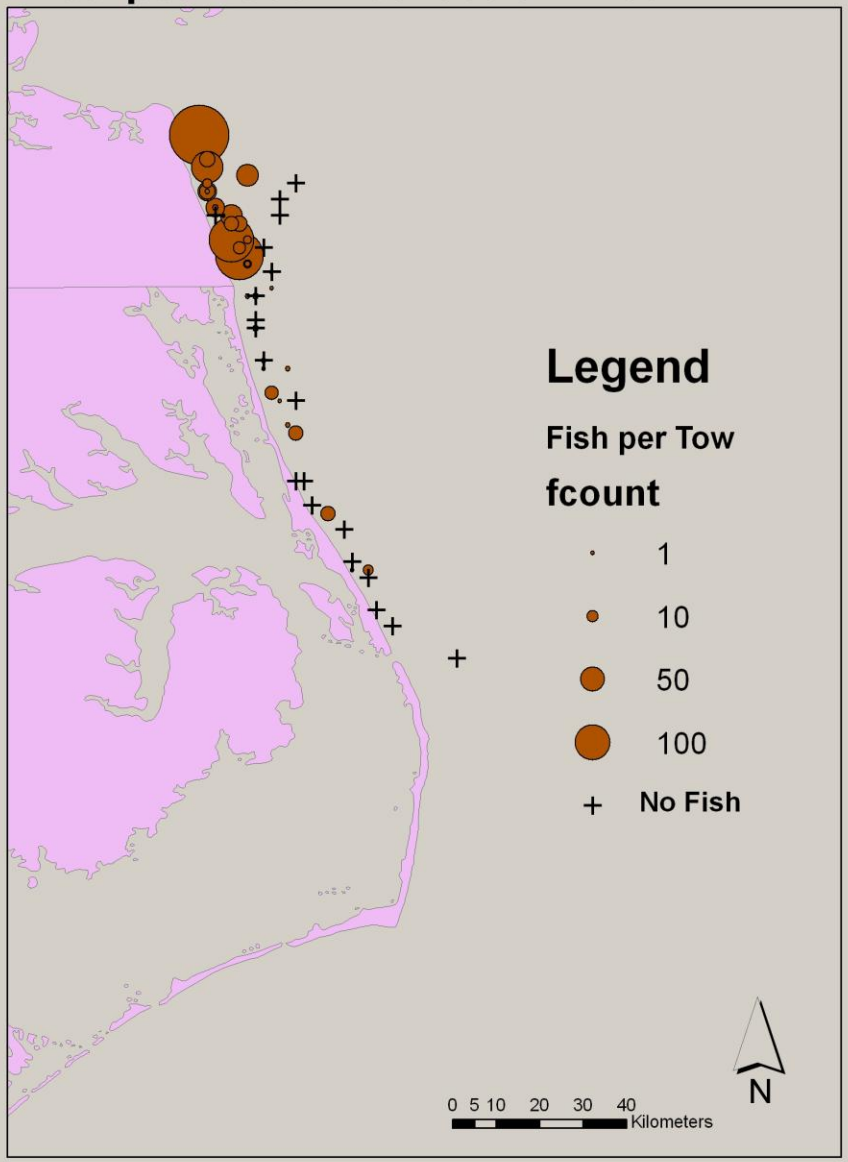
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1990



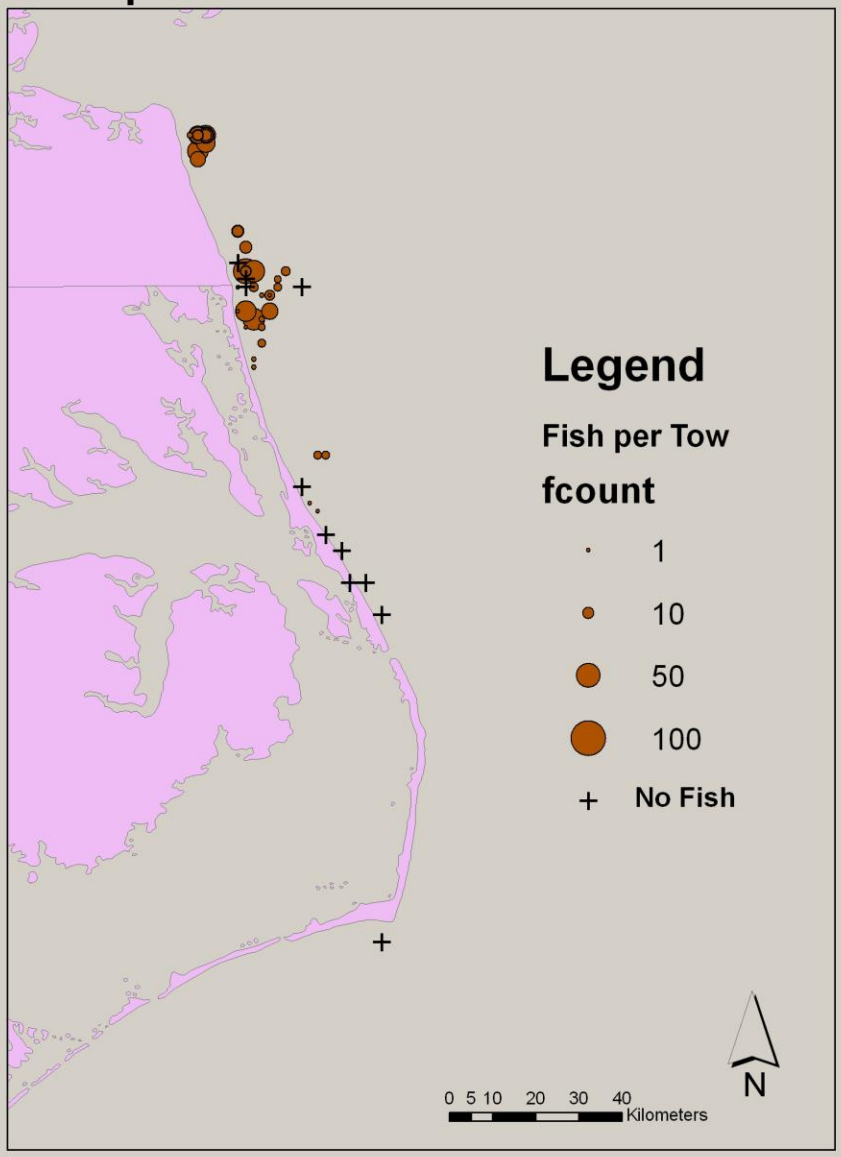
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1991



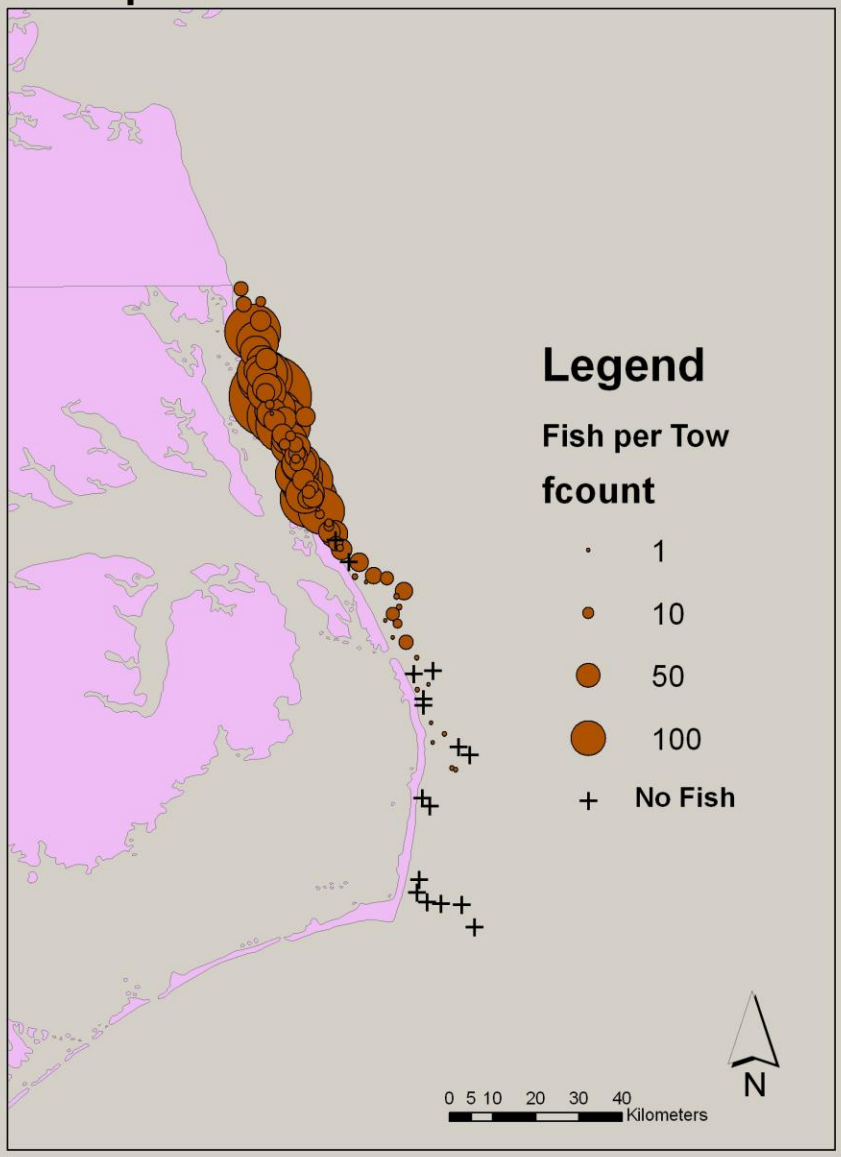
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1992



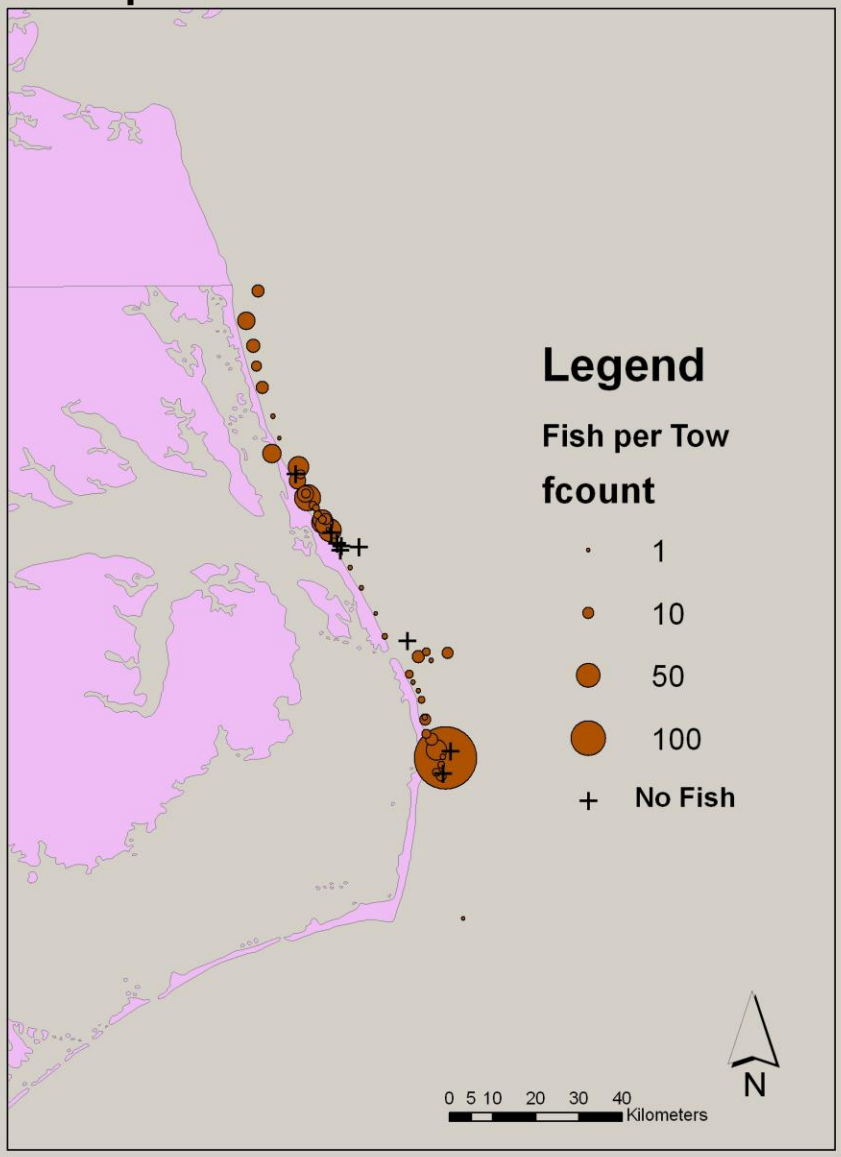
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1993



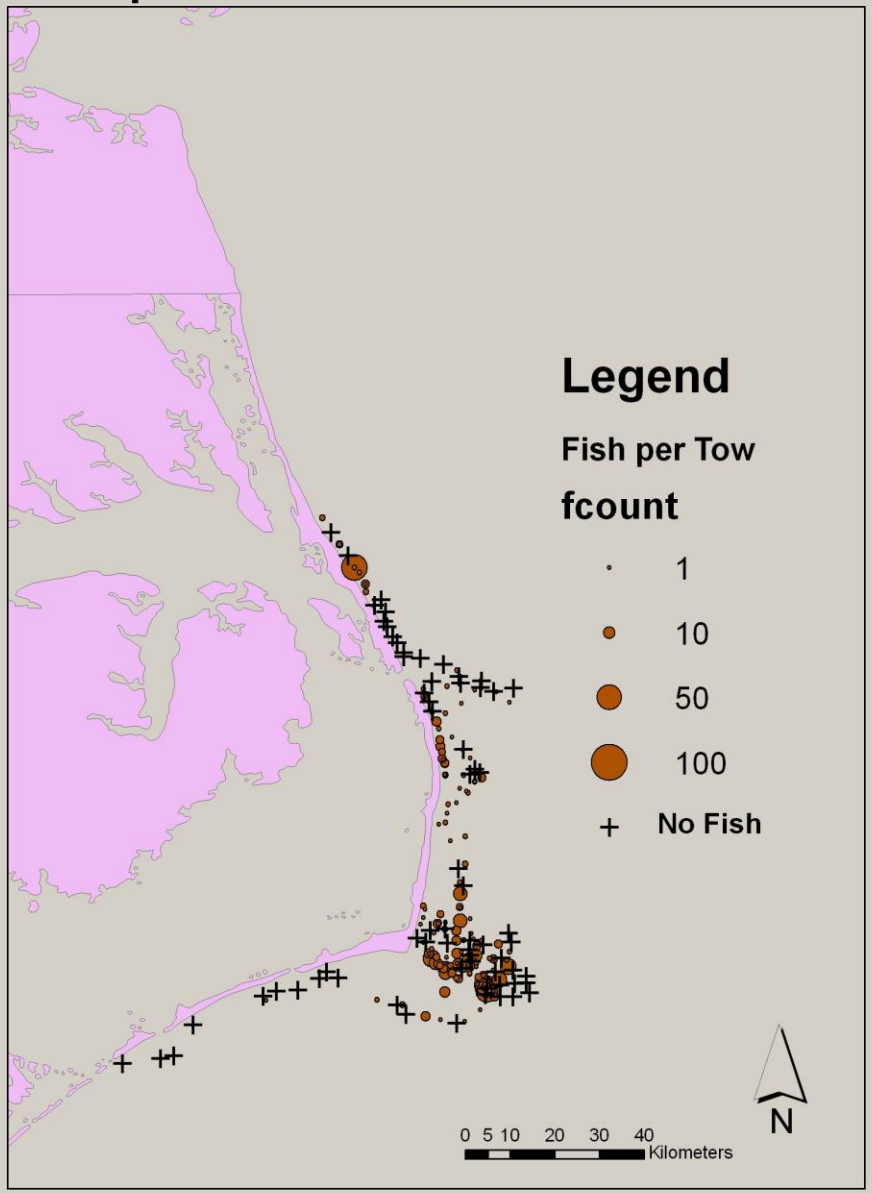
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1994



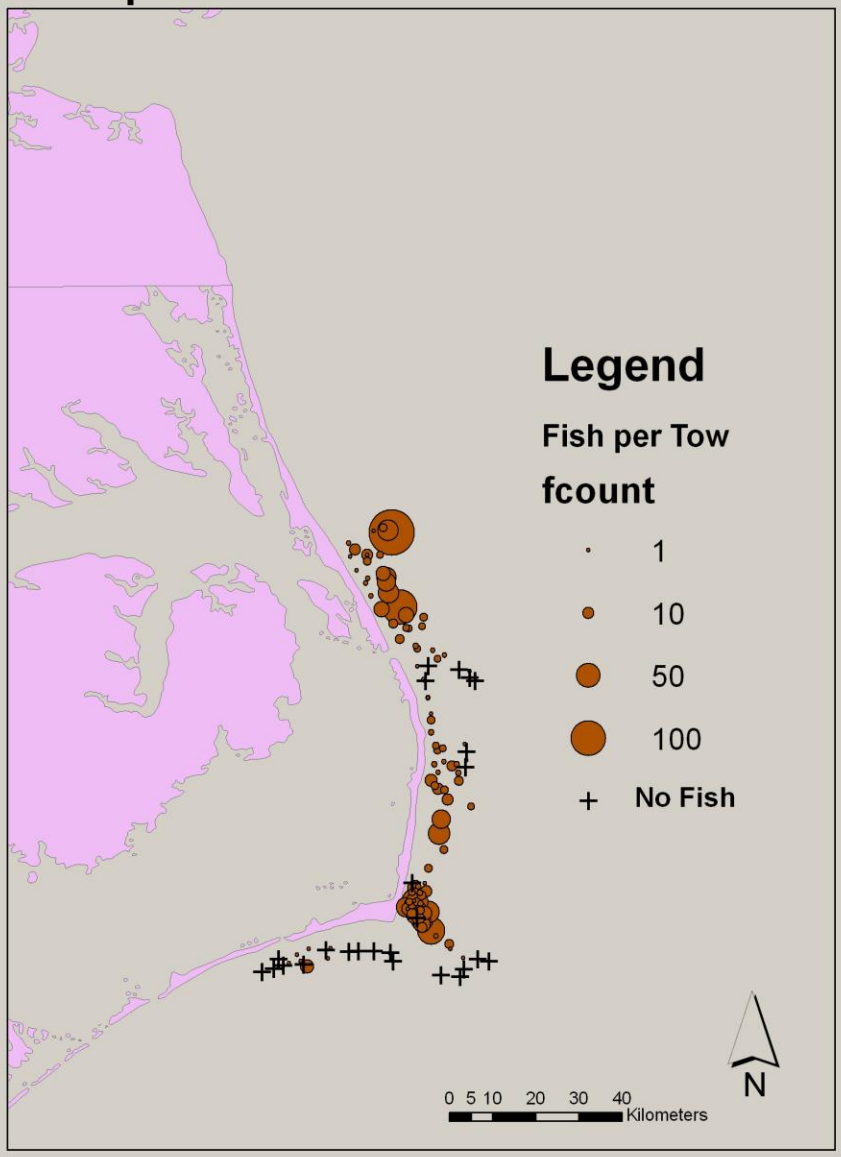
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1995



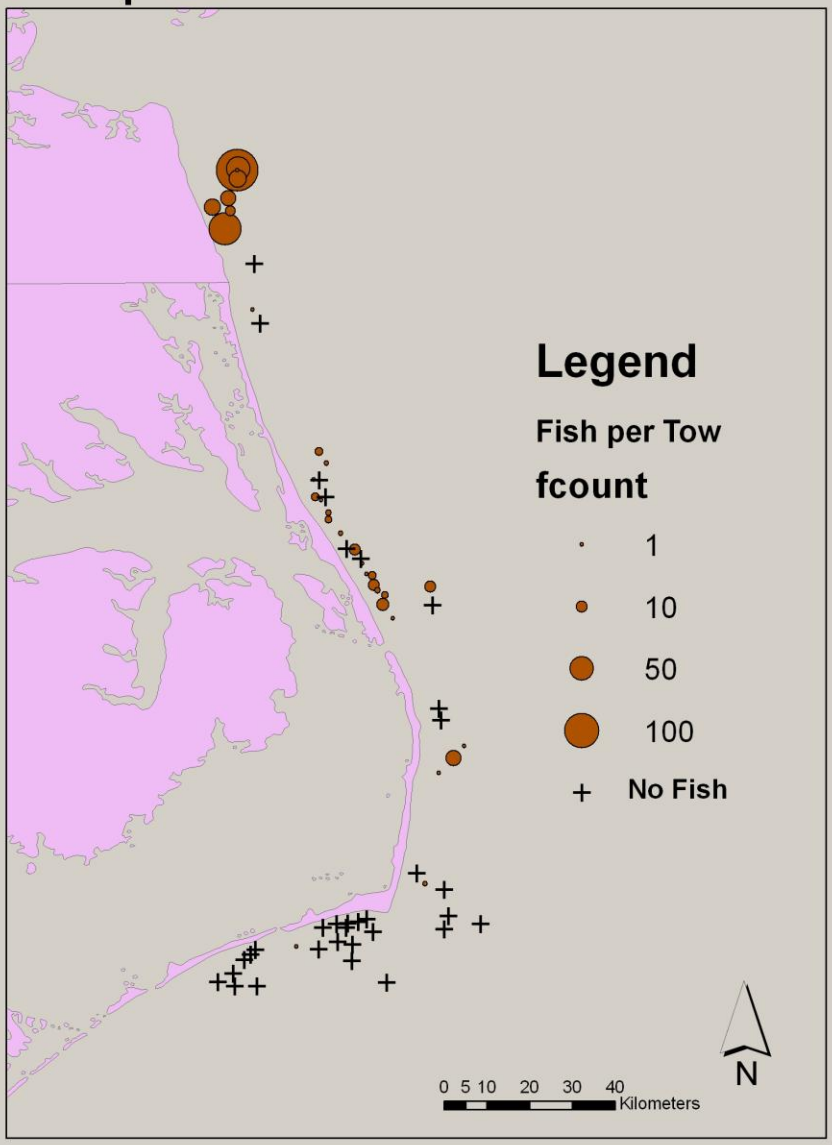
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1996



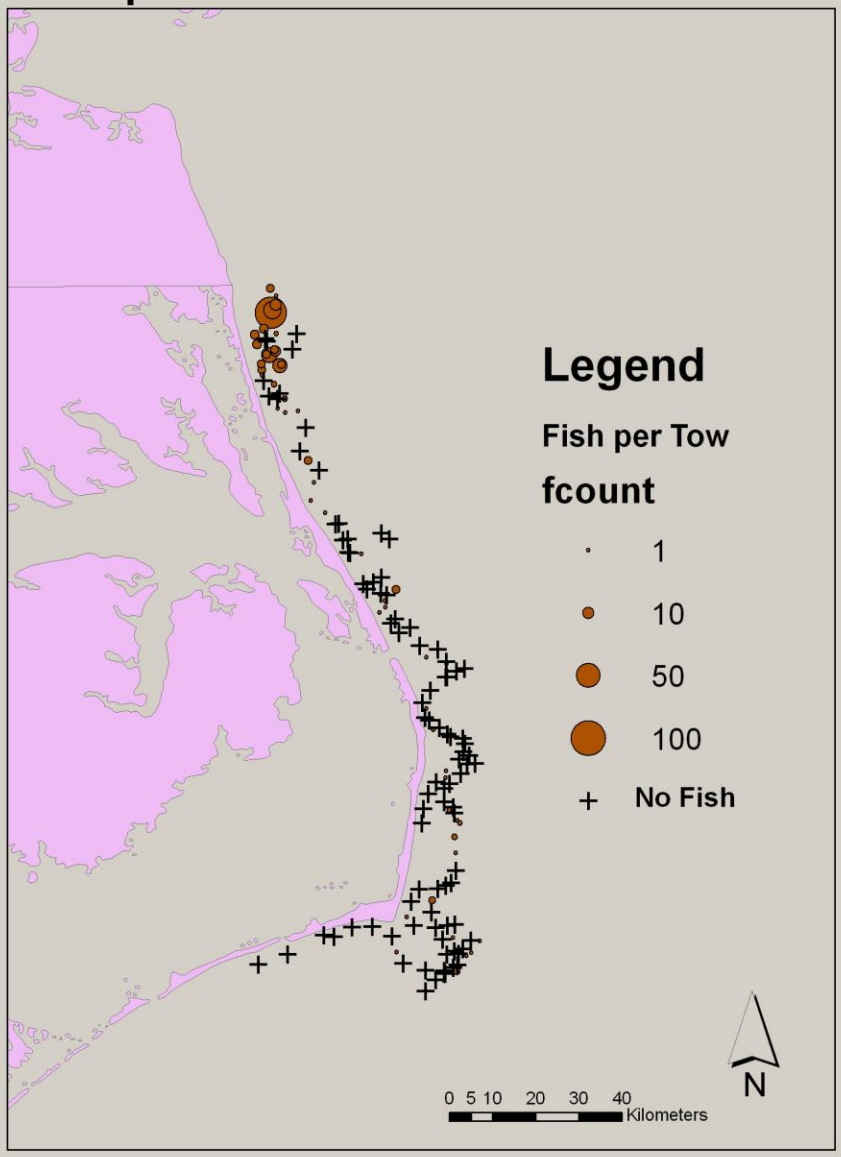
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1997



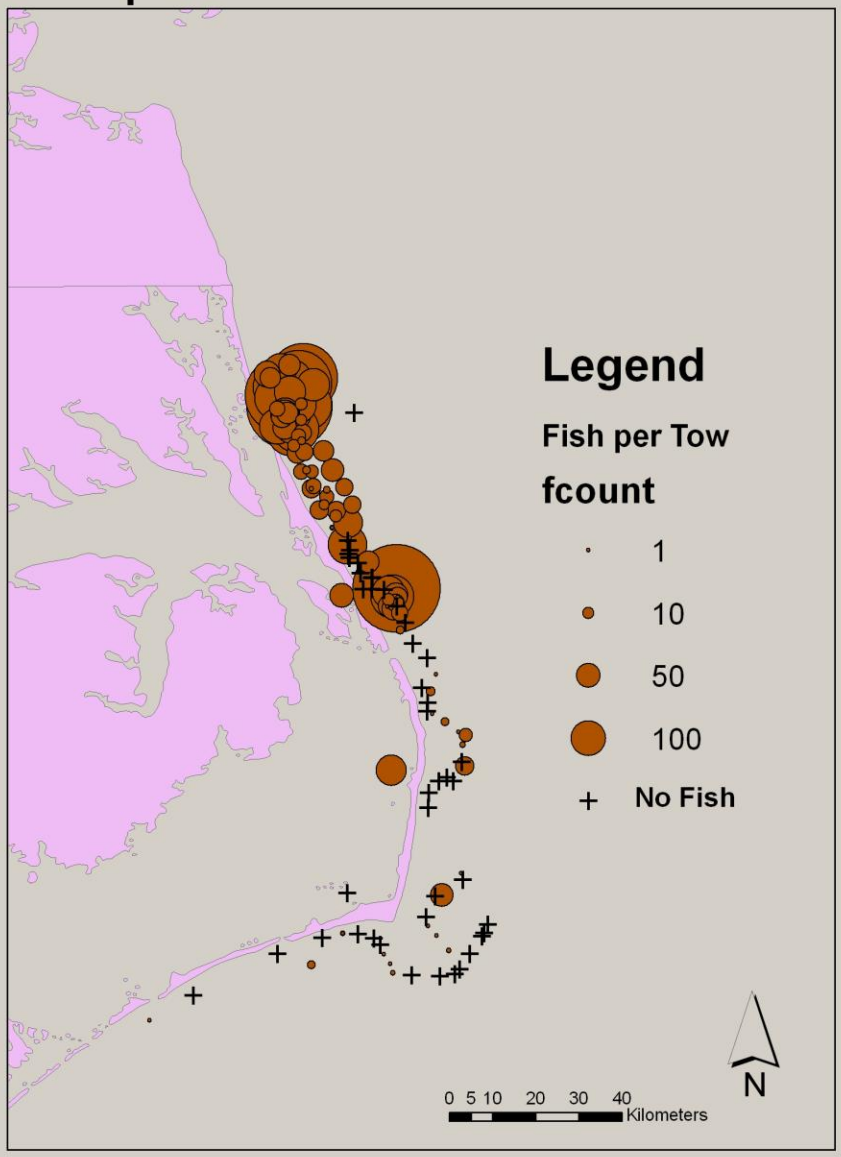
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1998



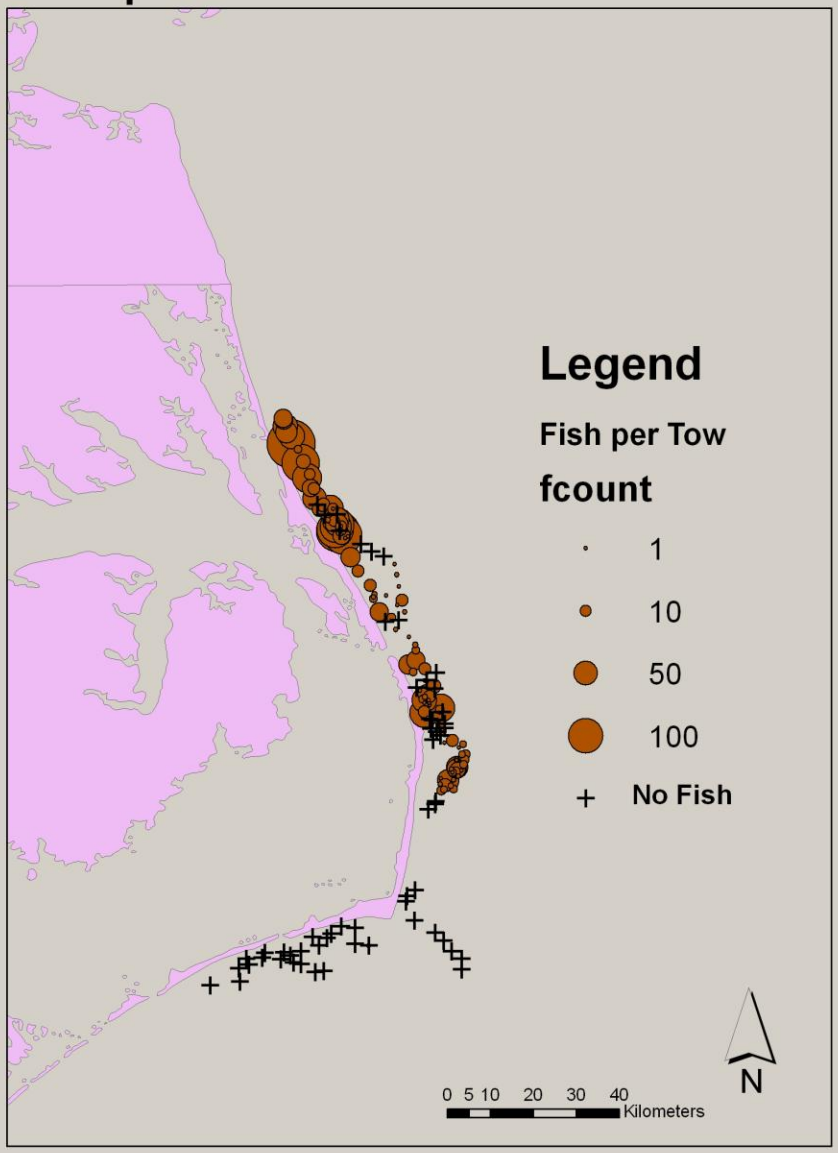
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 1999



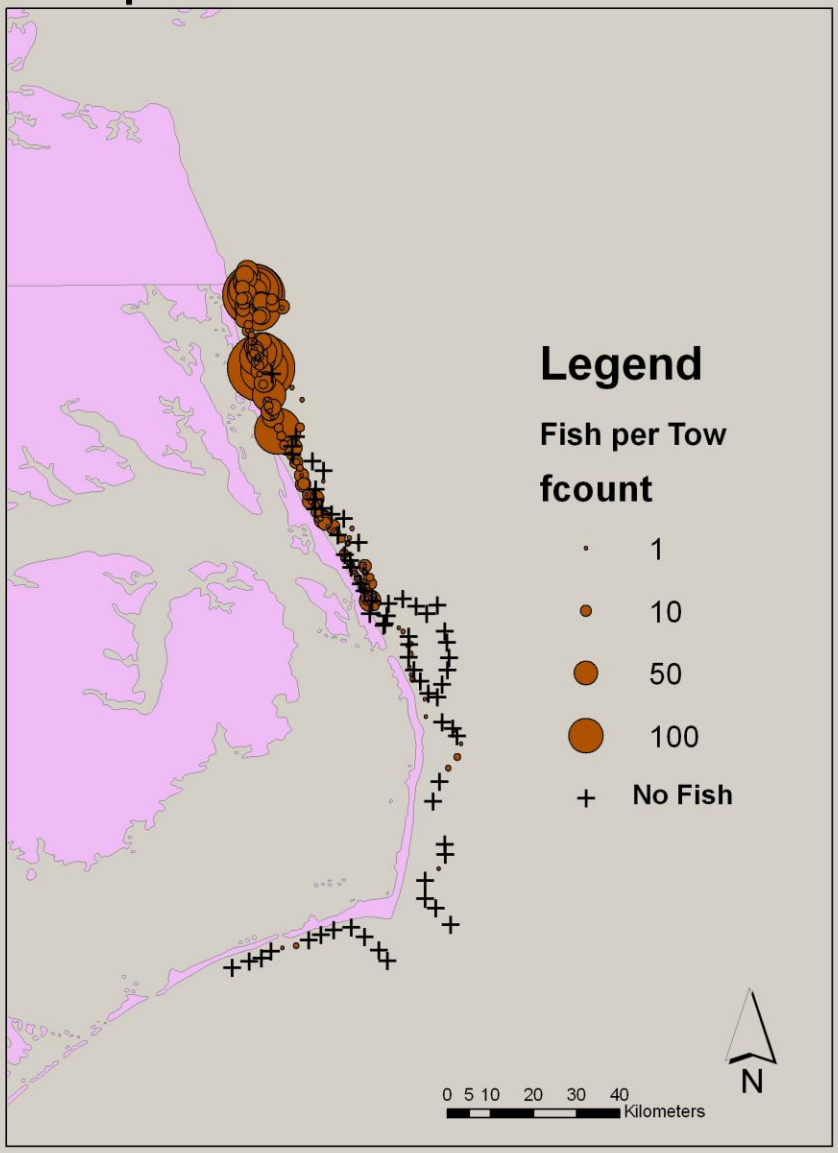
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 2000



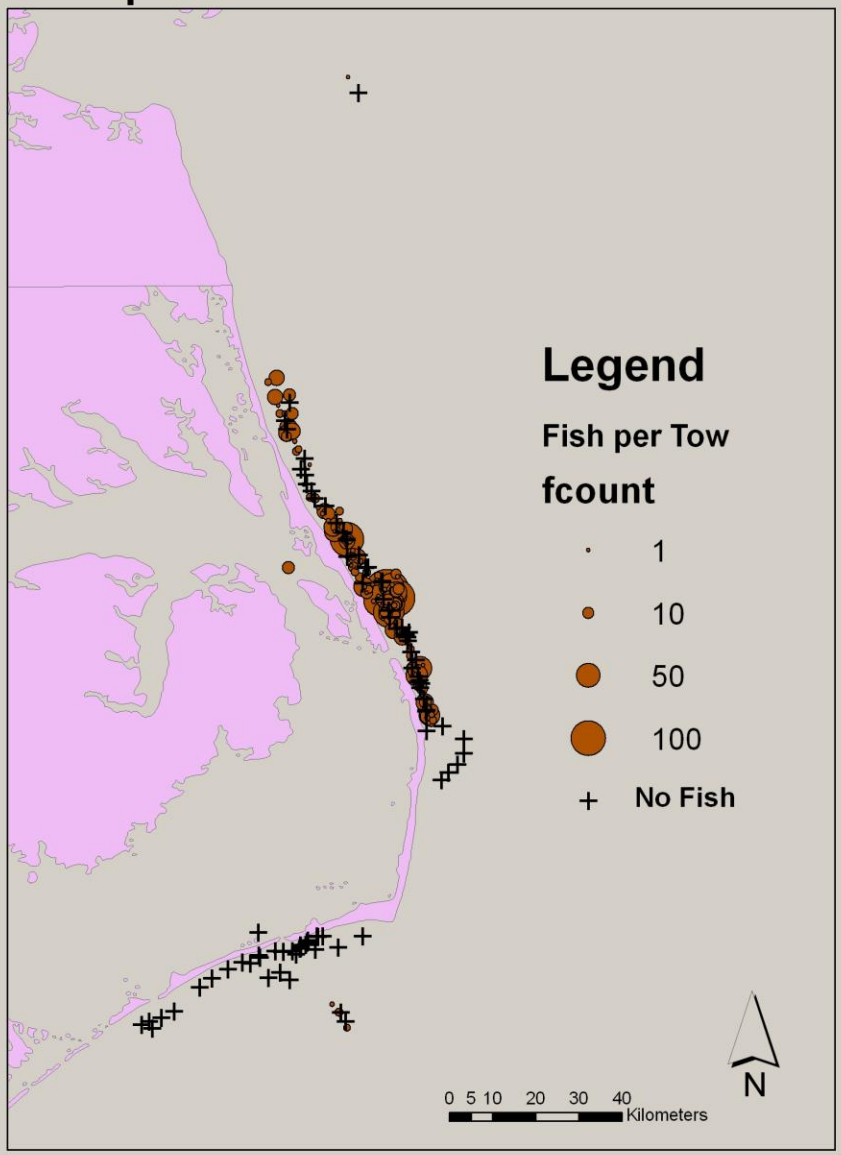
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 2001



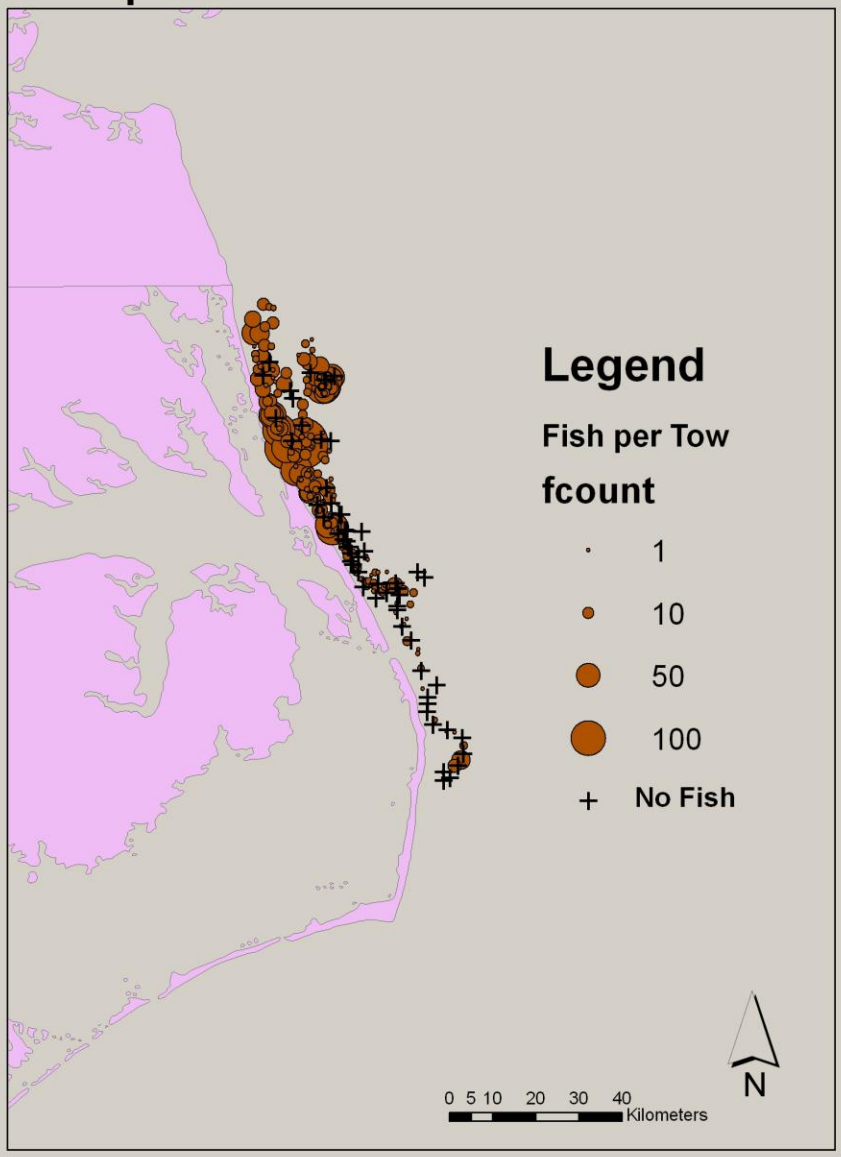
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 2002



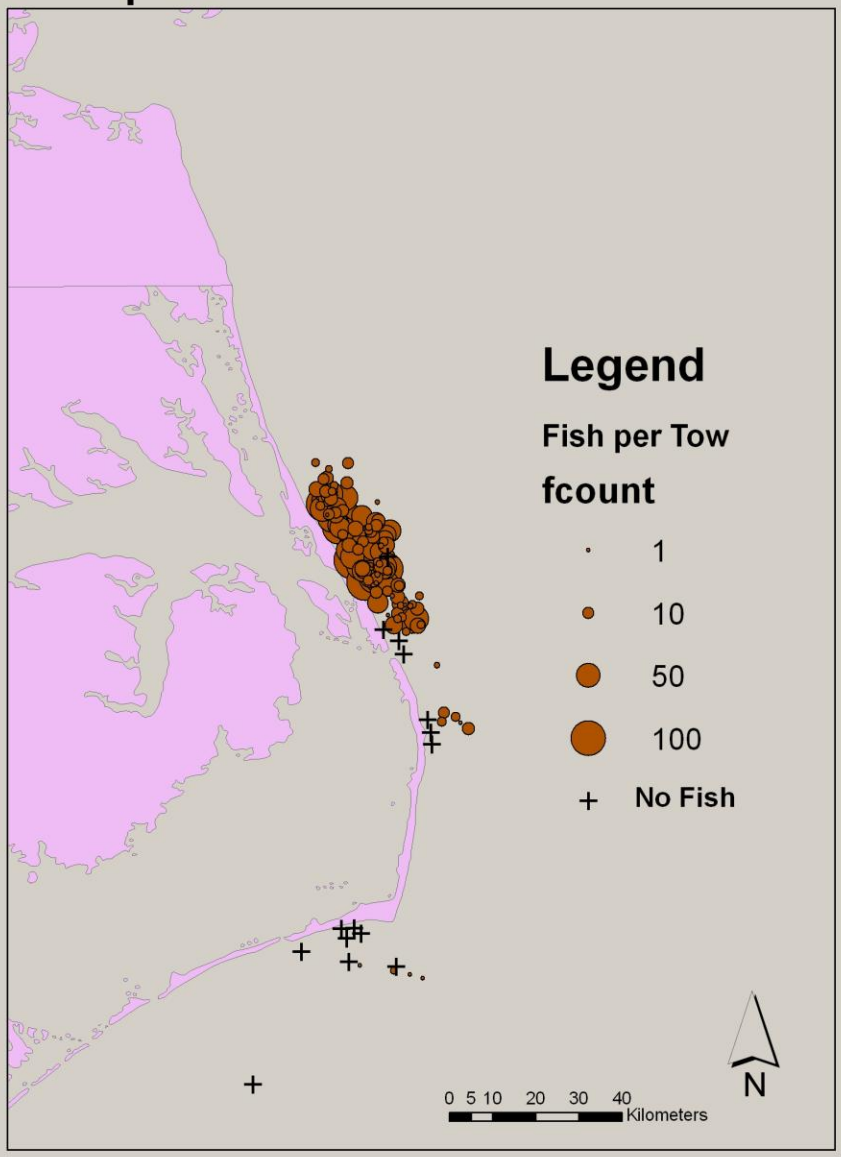
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 2003



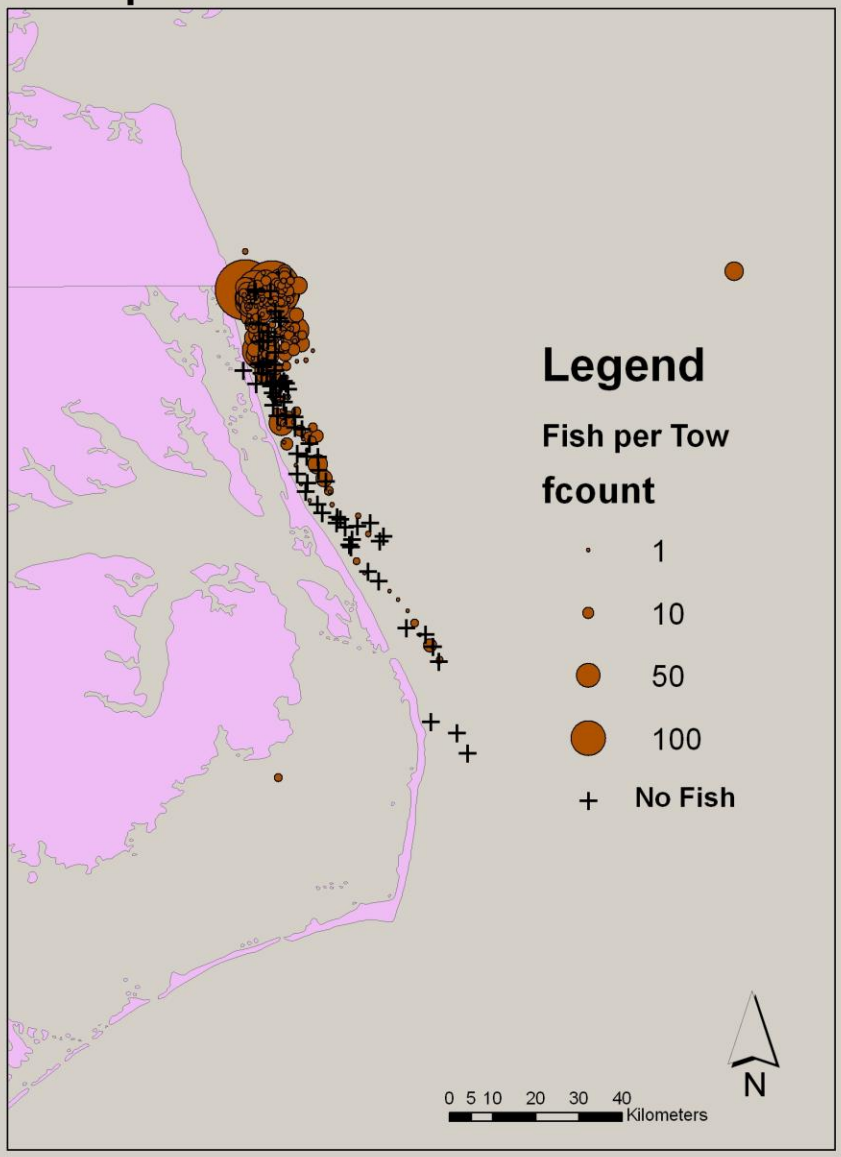
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 2004



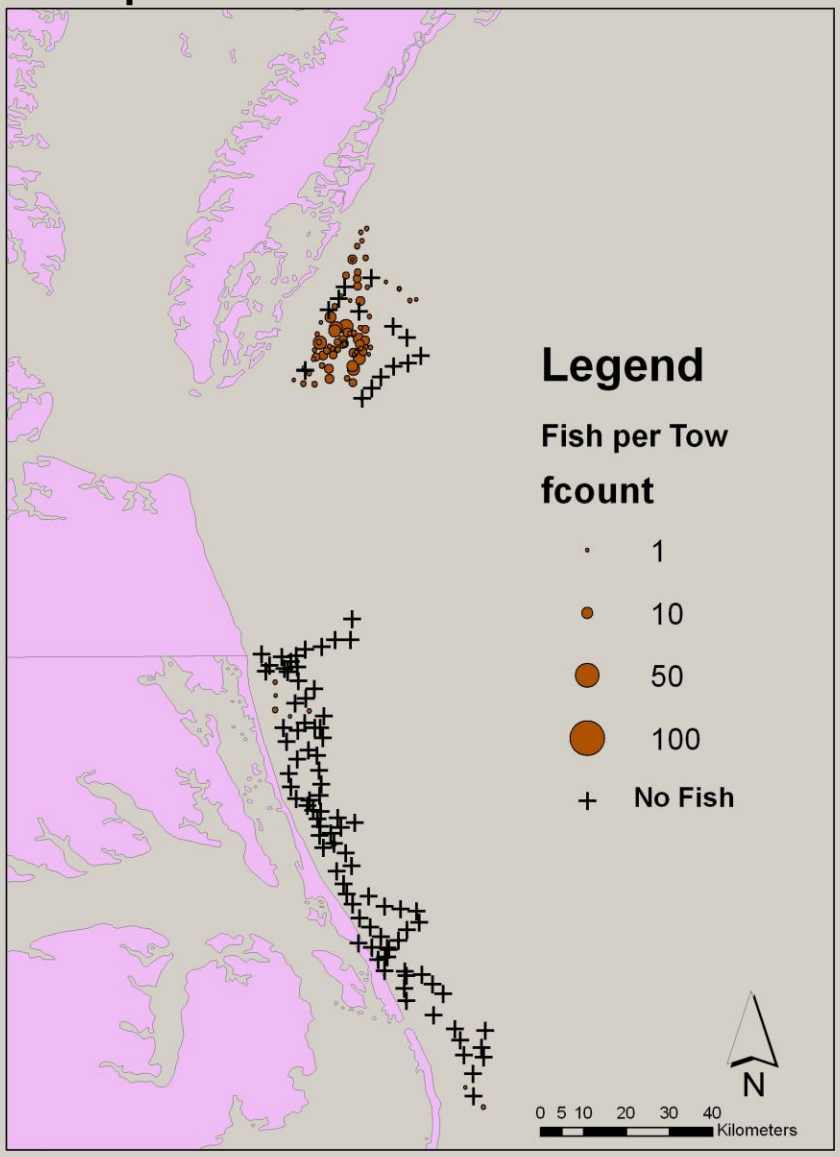
Cooperative Winter Tagging Cruise: Striped Bass Distribution - 2005



Cooperative Winter Tagging Cruise: Striped Bass Distribution - 2006



Cooperative Winter Tagging Cruise: Striped Bass Distribution - 2007

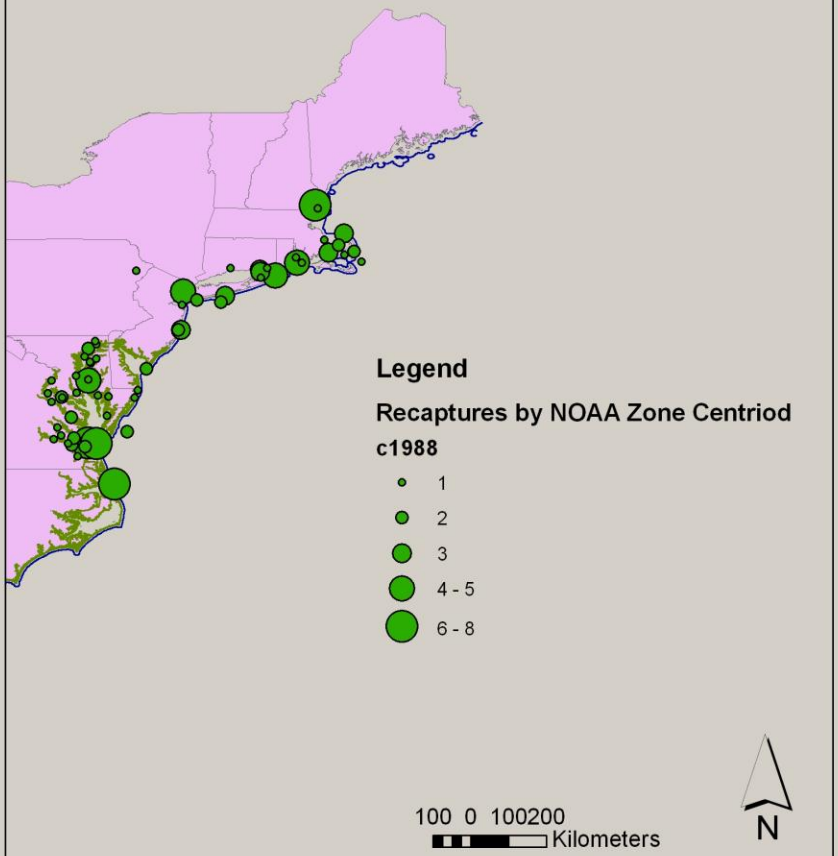


Recapture Results for CWTC, 1988-2009

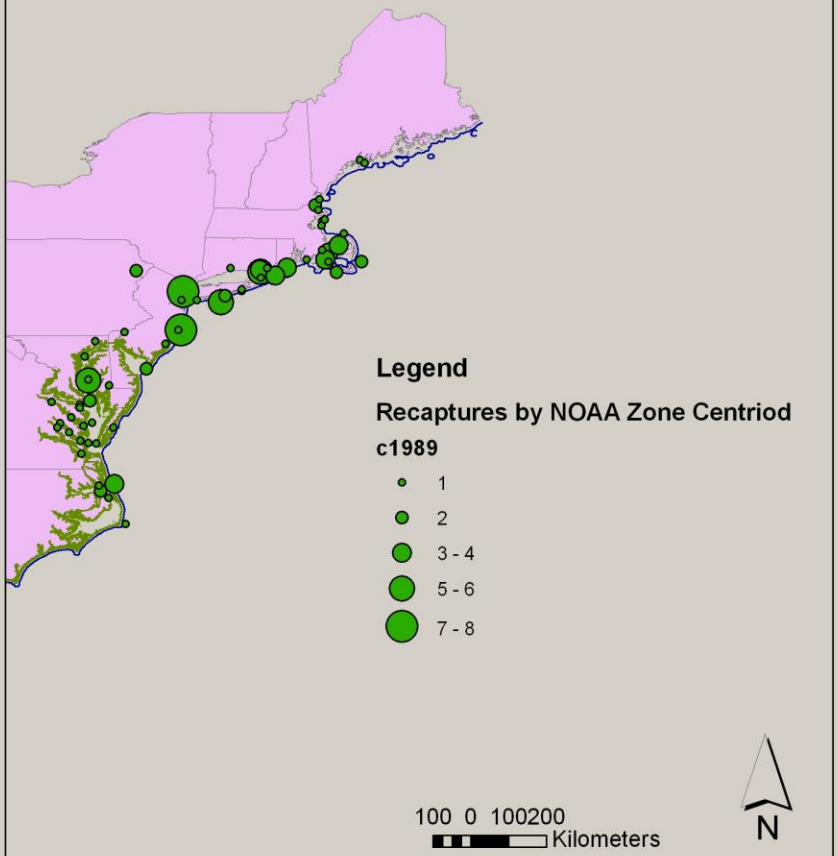
- For 1988-2009, total recaptures = 7,504 (17.2 %)
- Range for number recaptured after one year was 5-411 (3.4-13.2 %)
- Total percentage recaptured to date = 3.4 % (2009) to 32.2 % (1992)

Distribution of Recaptures from the CWTC, 1988-2009

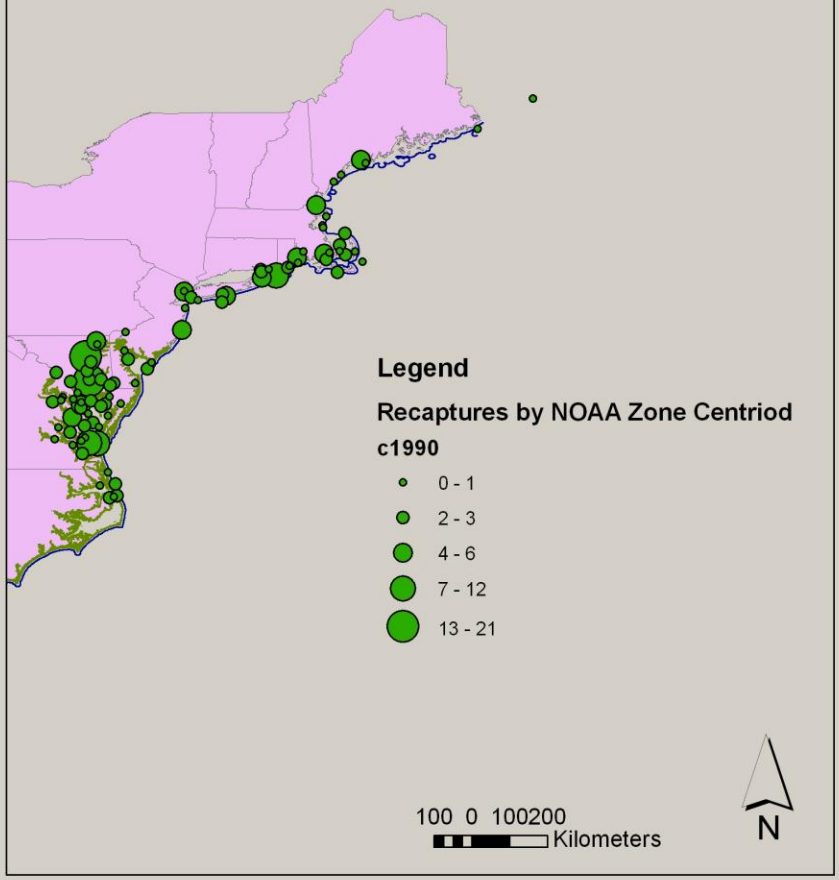
Recapures by NOAA Zone Centriods 2/1/1988 -1/31/1989



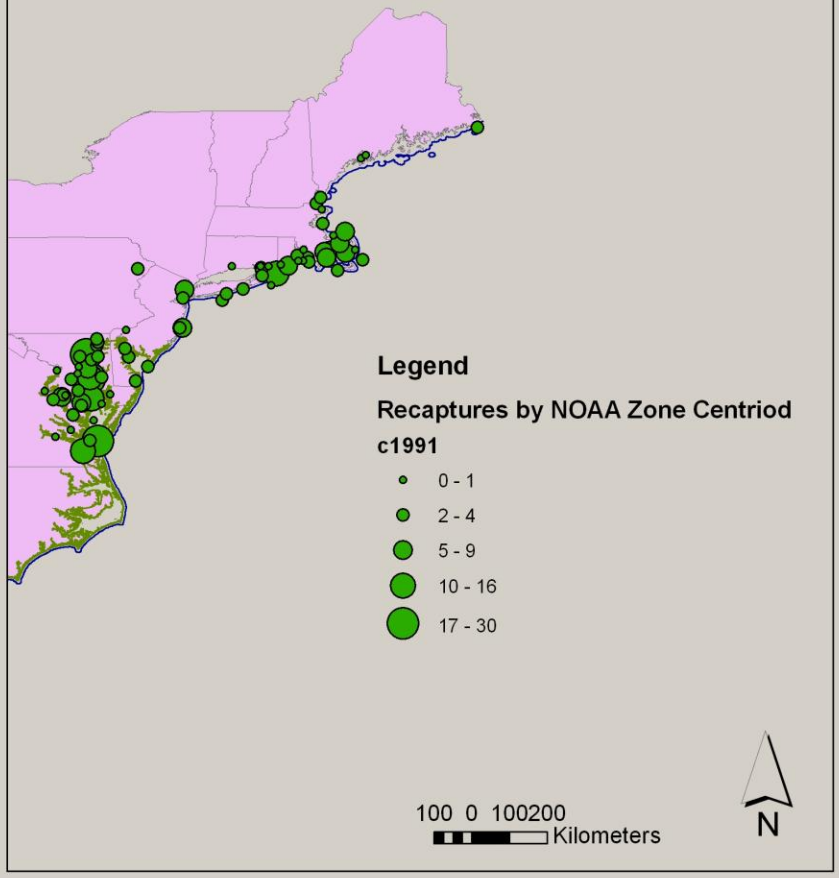
Recapures by NOAA Zone Centriods 2/1/1989 -1/31/1990



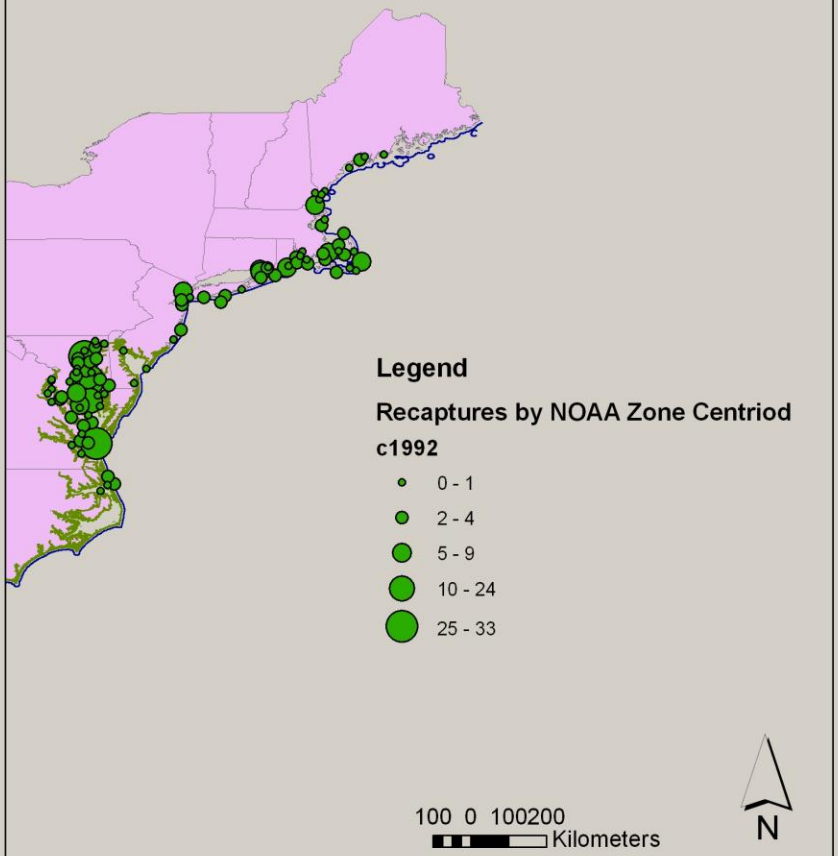
Recapures by NOAA Zone Centriods 2/1/1990 -1/31/1991



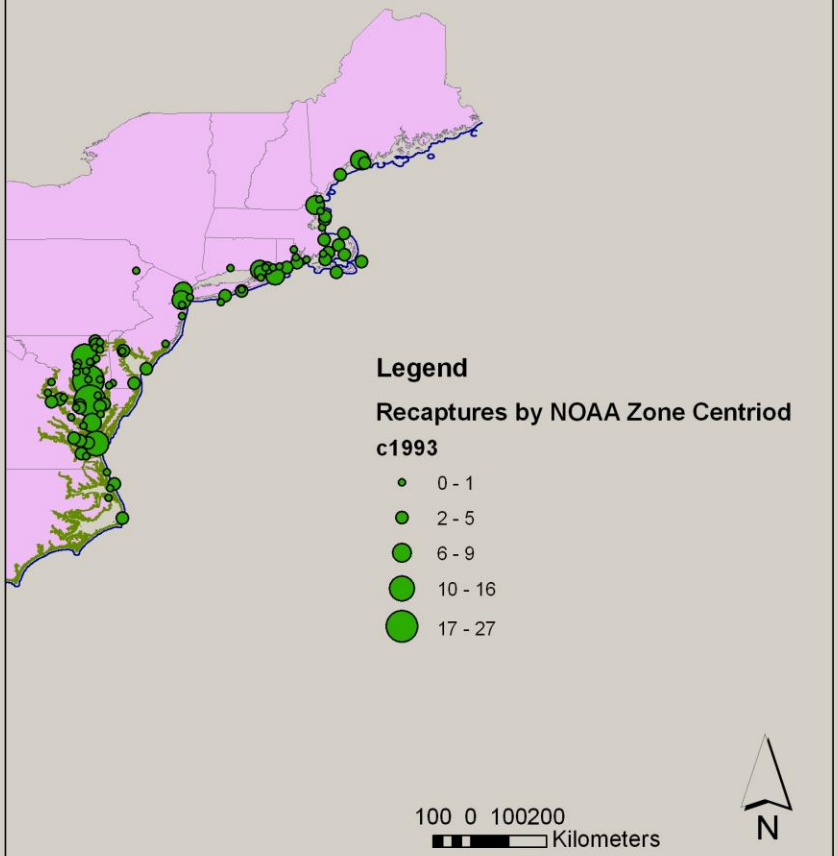
Recapures by NOAA Zone Centriods 2/1/1991 -1/31/1992



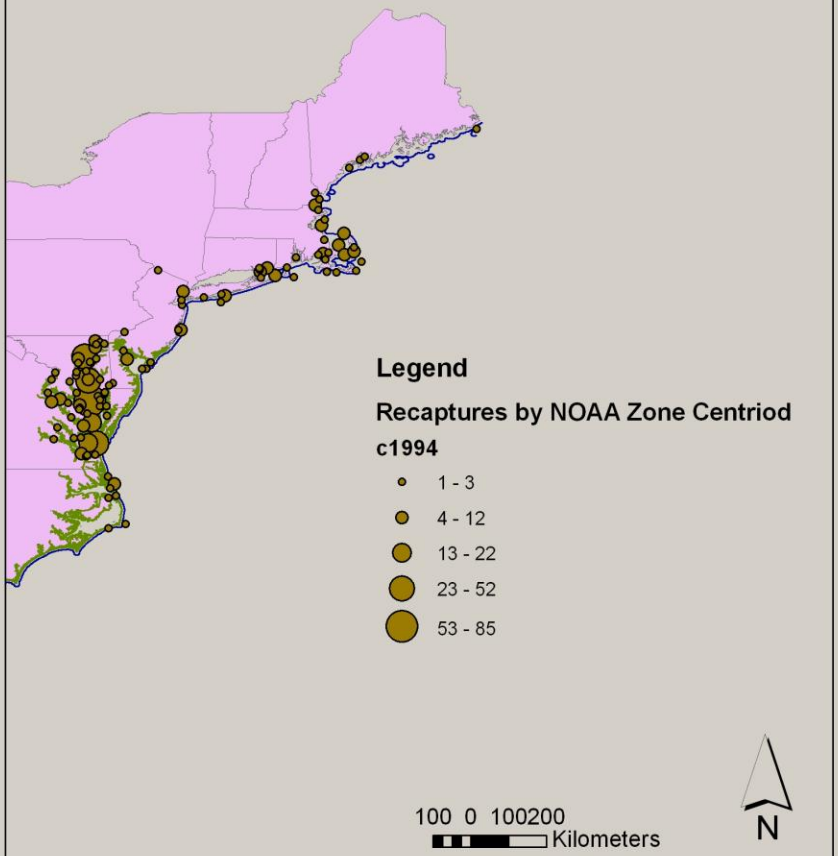
Recapures by NOAA Zone Centriods 3/1/1992 -2/28/1993



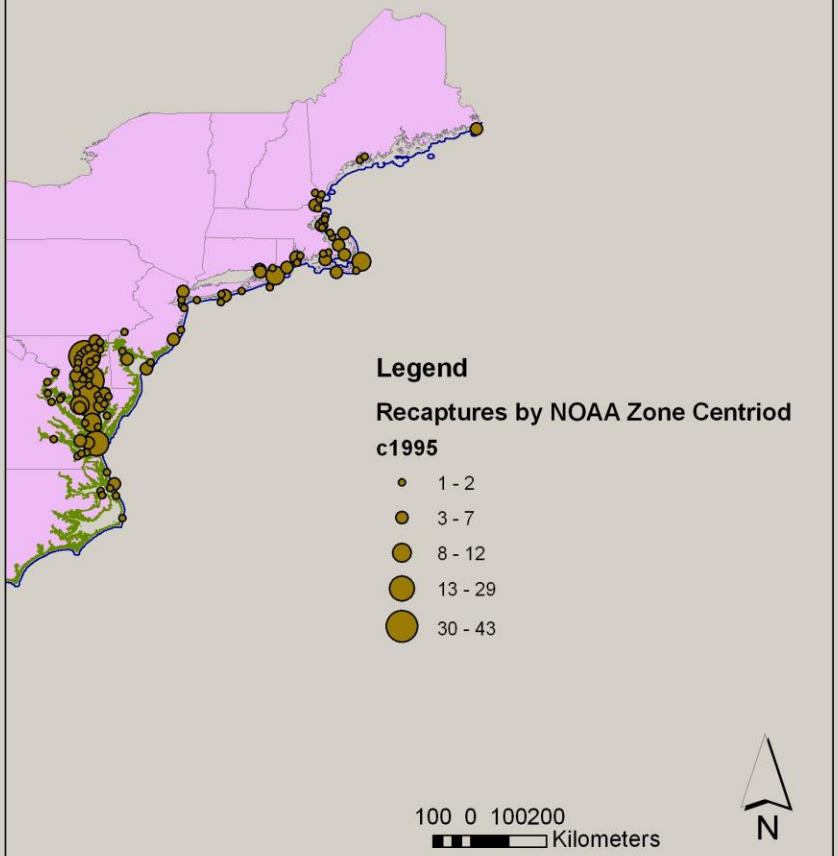
Recapures by NOAA Zone Centriods 3/1/1993 -2/28/1994



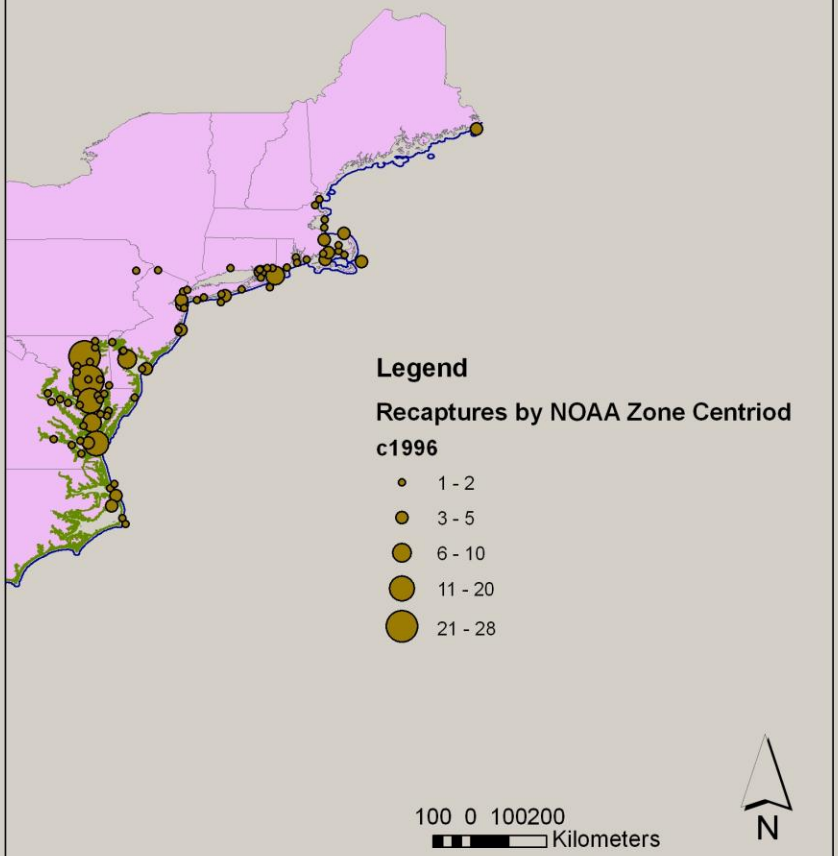
Recapures by NOAA Zone Centriods 2/1/1994 -1/31/1995



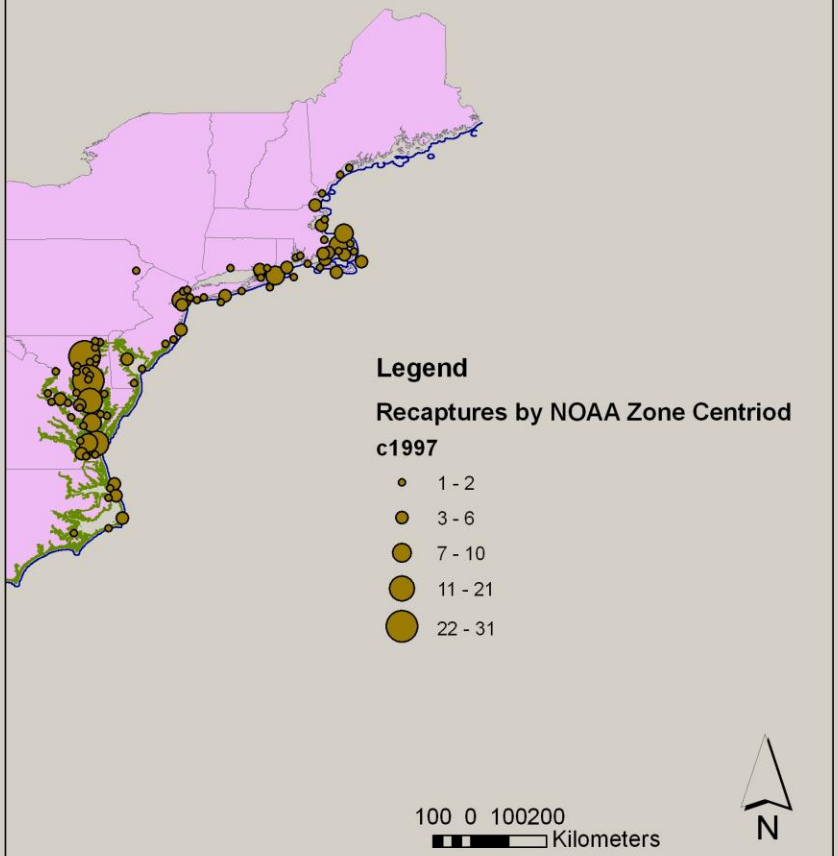
Recapures by NOAA Zone Centriods 2/1/1995 -1/31/1996



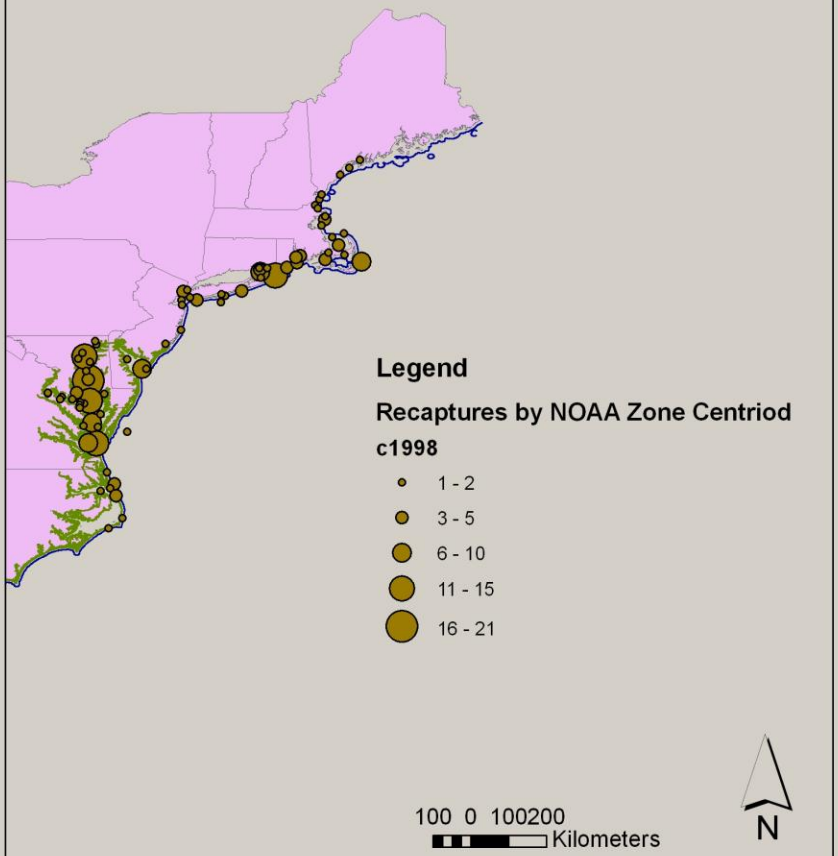
Recapures by NOAA Zone Centriods 3/1/1996 -2/28/1997



Recapures by NOAA Zone Centriods 3/1/1997 -2/28/1998



Recapures by NOAA Zone Centriods 2/1/1998 -1/31/1999



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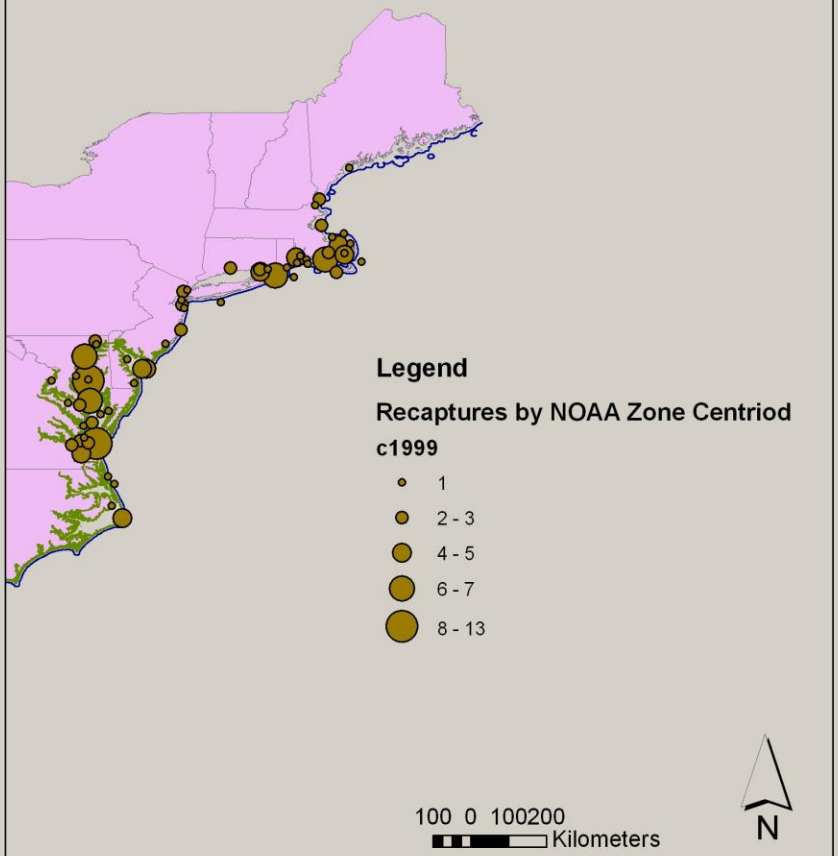
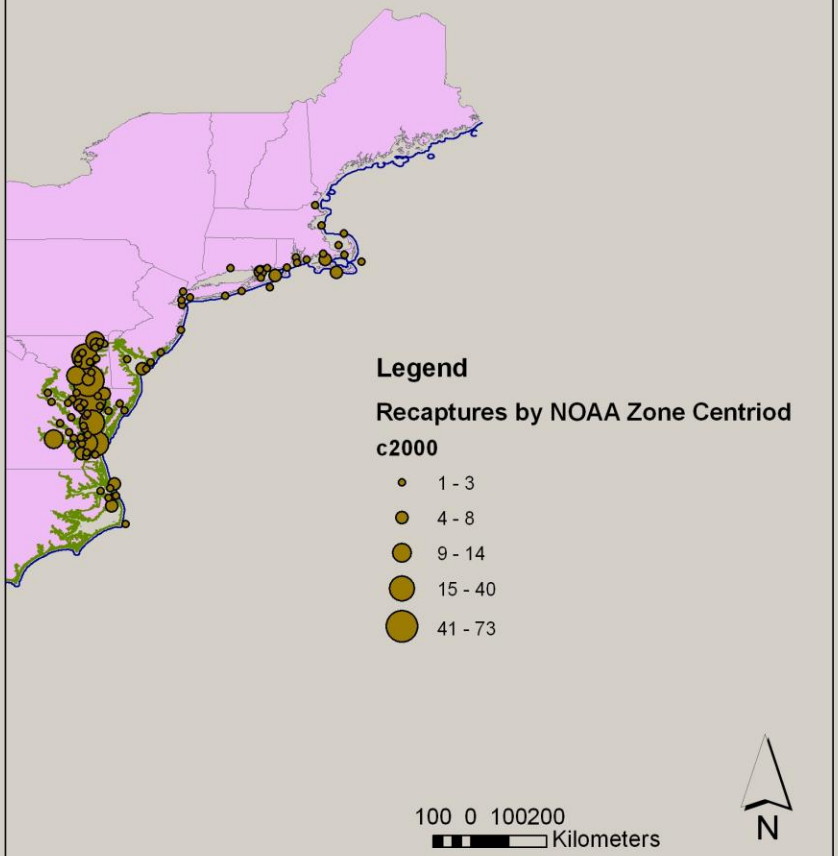
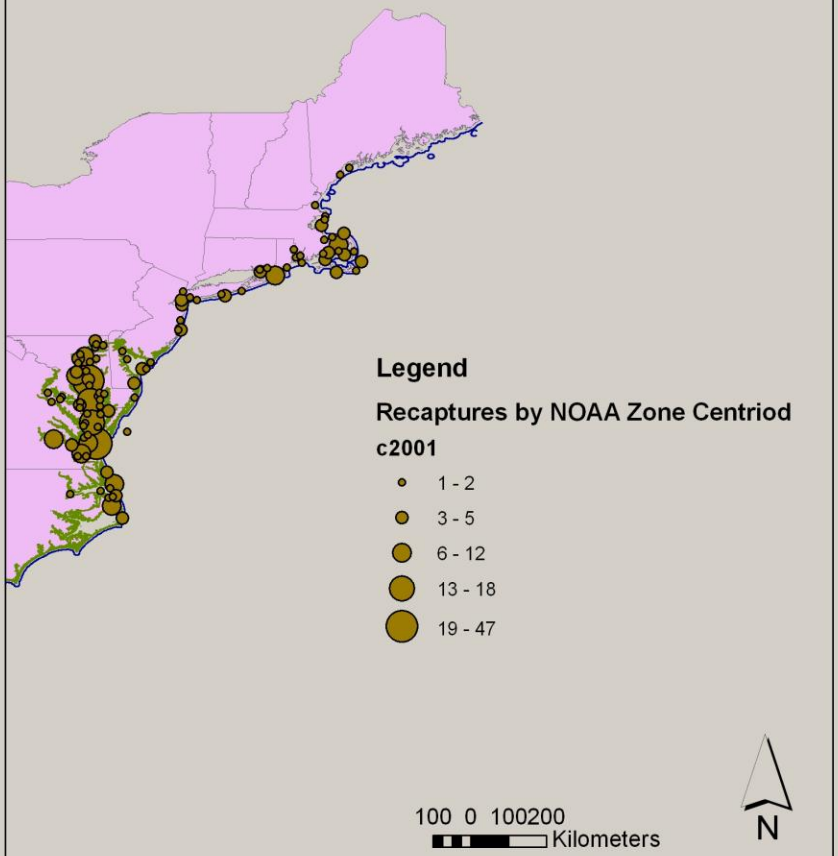


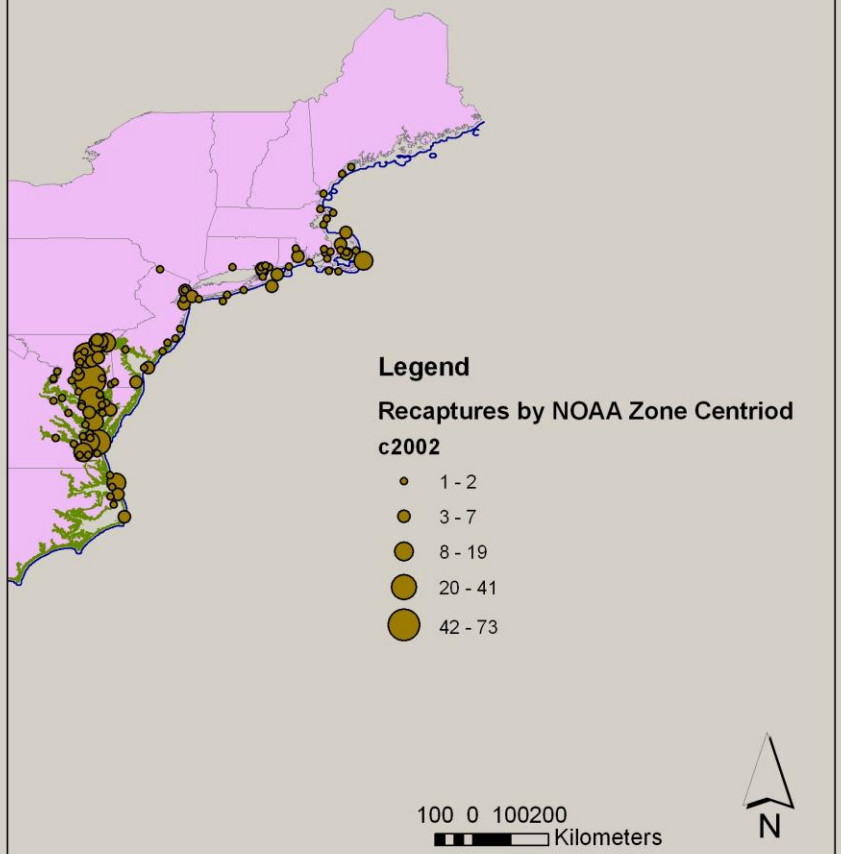
Recapures by NOAA Zone Centriods 3/1/2000 -2/28/2001



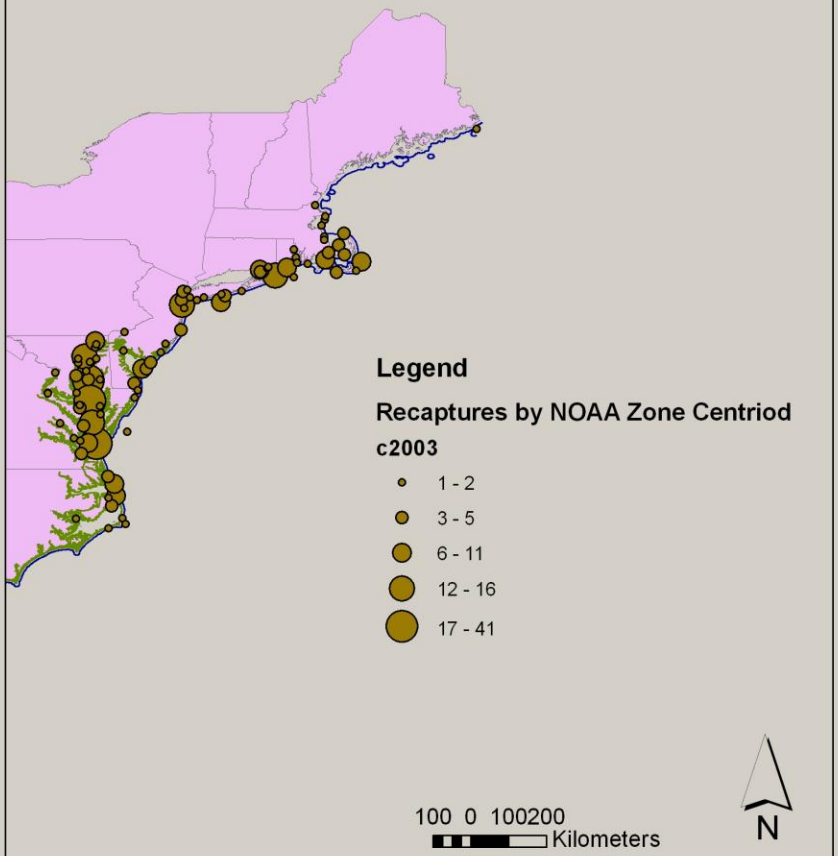
Recapures by NOAA Zone Centriods 2/1/2001 -1/31/2002



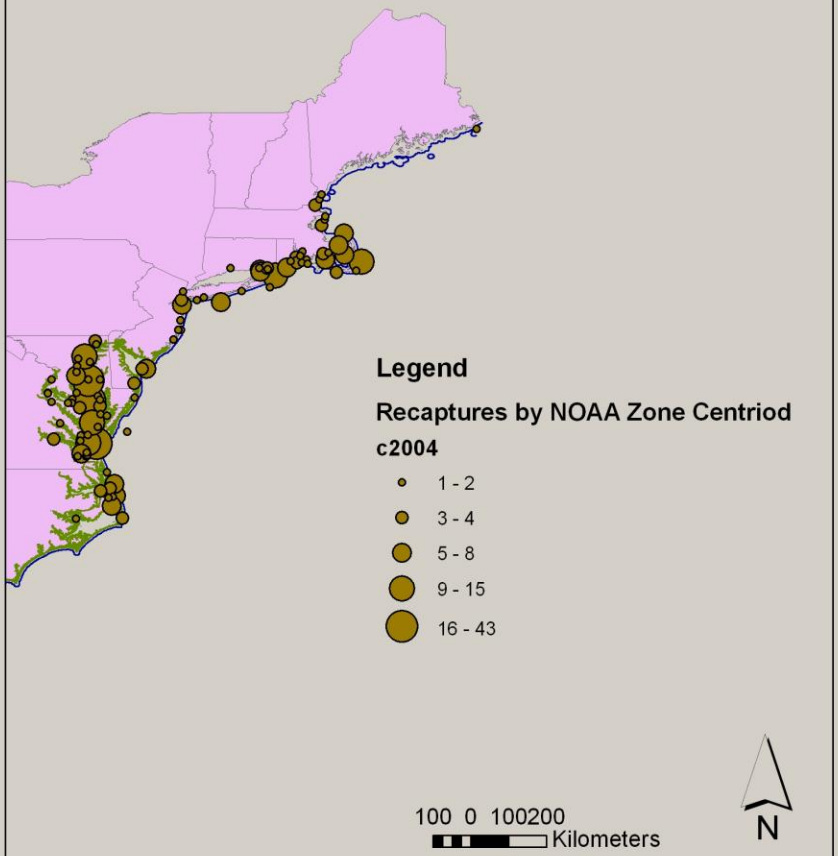
Recapures by NOAA Zone Centriods 2/1/2002 -1/31/2003



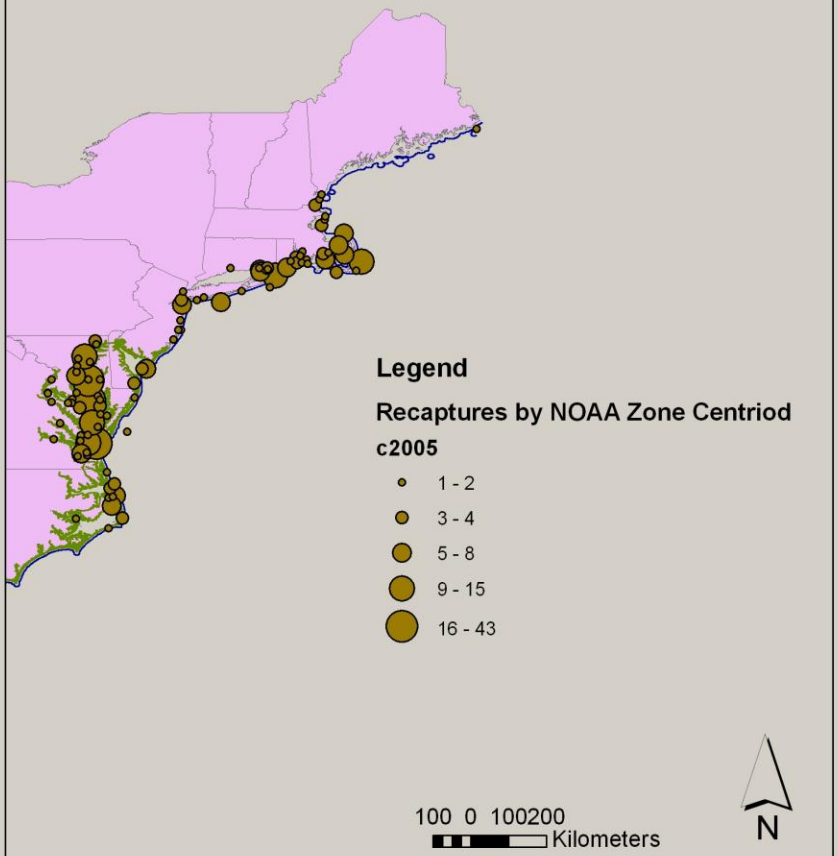
Recapures by NOAA Zone Centriods 2/1/2003 -1/31/2004



Recapures by NOAA Zone Centriods 2/1/2004 -1/31/2005



Recapures by NOAA Zone Centriods 3/1/2005 -2/28/2006



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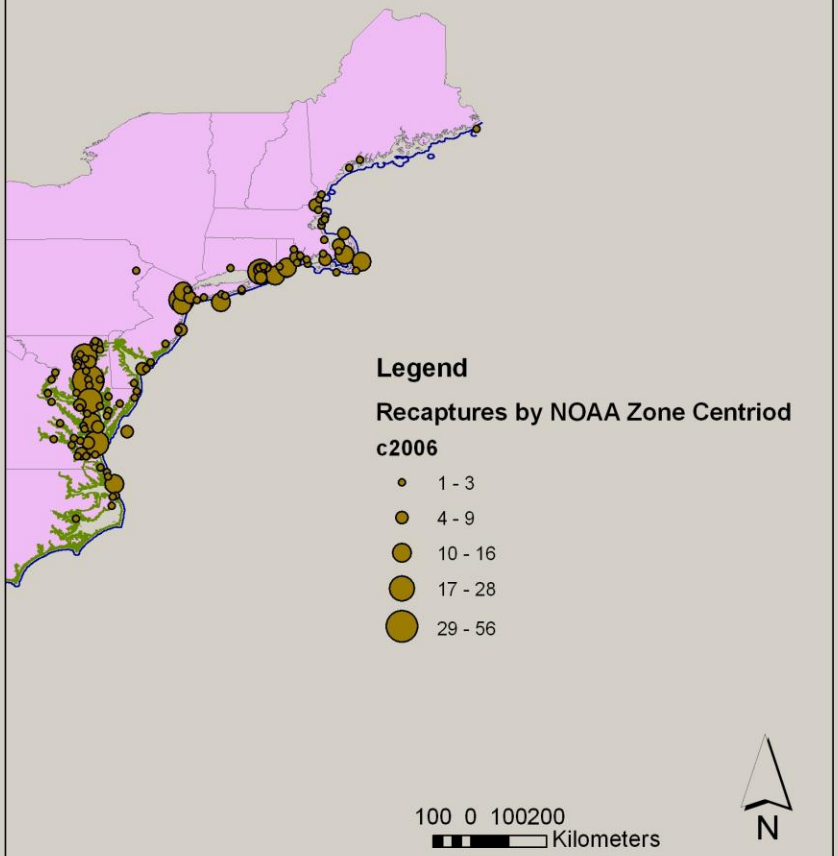
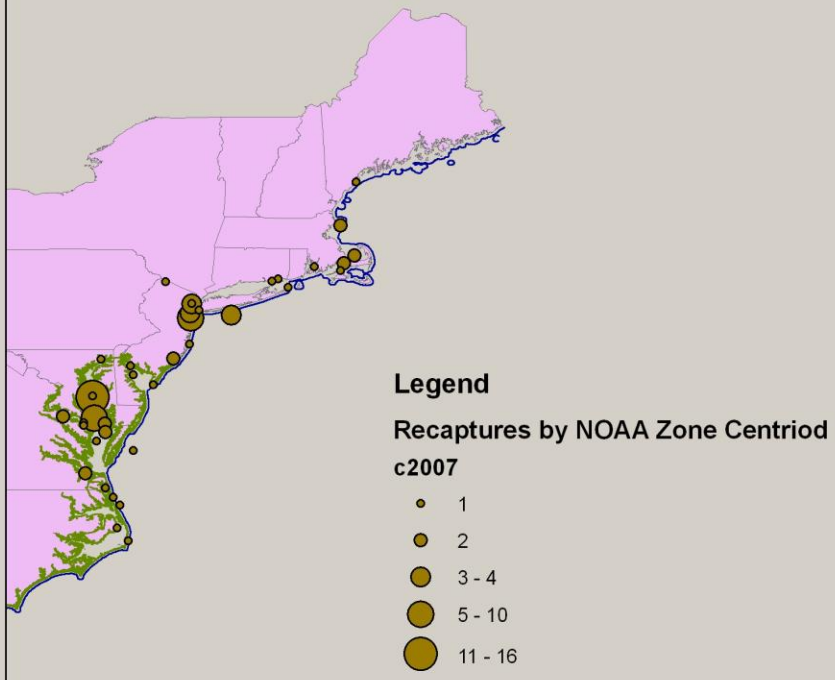


Recapures by NOAA Zone Centriods 2/1/2007 -1/31/2008



Conclusions/Observations for "Atlantic Coastal Migratory Stock"

- Offshore overwintering habitat varies, some years further south, other years more north, and distance offshore varies
- In recent years (2007-2013) fish have stayed further north, and further offshore (e.g., 12-20 nm offshore, versus inside 3 nm in many past years)
- Recapture patterns observed by Boreman and Lewis (1987) seem to persist (i.e., north in spring, south in winter)
- Some fish from southern populations do migrate (Cape Fear R., Savannah R.)
- A majority of the fish caught during the VA/NC winter fishery are likely from Chesapeake Bay
- Some Hudson River fish are caught to the south

Caveats to Large Scale Migration Analyses

- The Cruise (CWTC) does NOT give a complete picture of winter distribution:
  - Cannot sample shallow [less than 25 feet] water
  - Cannot sample over hard bottom
  - Samples narrow temporal window
  - Targets relatively small area in the southern part of species range)
  - Striped bass numbers captured do NOT correlate with population abundance (at least we don't believe they do)

Searching on the Small Scale for Migratory Patterns

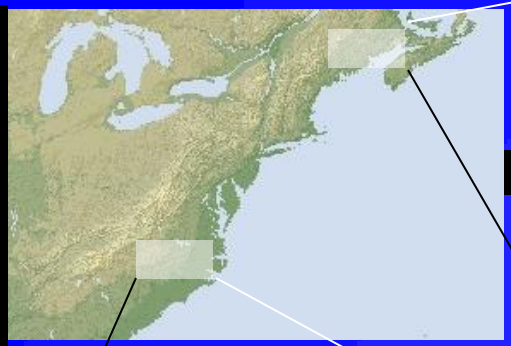
- Should we look at the population level for small movements, or at the individual level?
- All students leaving a classroom, vs individuals within that class.
- What should we use as "criteria" to determine markers as measuring "the common" as opposed to "the unique"?

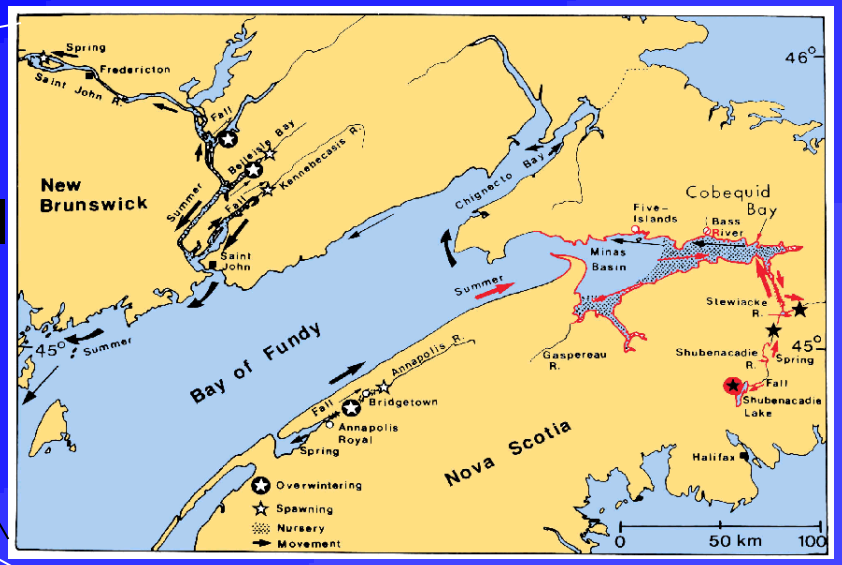
Mint Museum, Charlotte

Use Multiple Methods to Increase Power of Population Discrimination

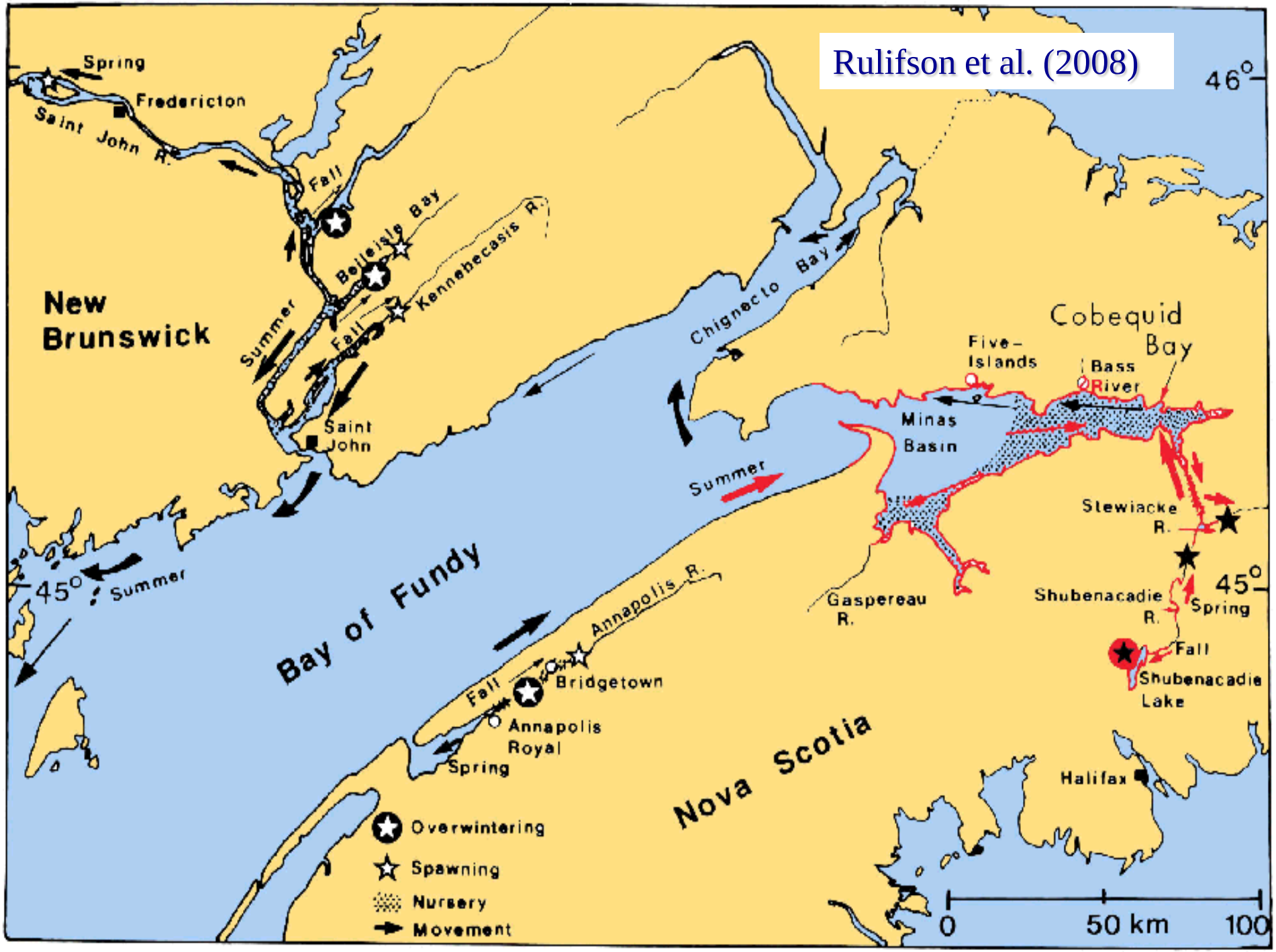
Multiple methods can corroborate evidence of migration from different angles.

- Food habits (short term, hours to a day)
- Tissue fatty acids (months)
- Genetics (differences within/among populations)
- Trace element deposition in otoliths (lifetime)

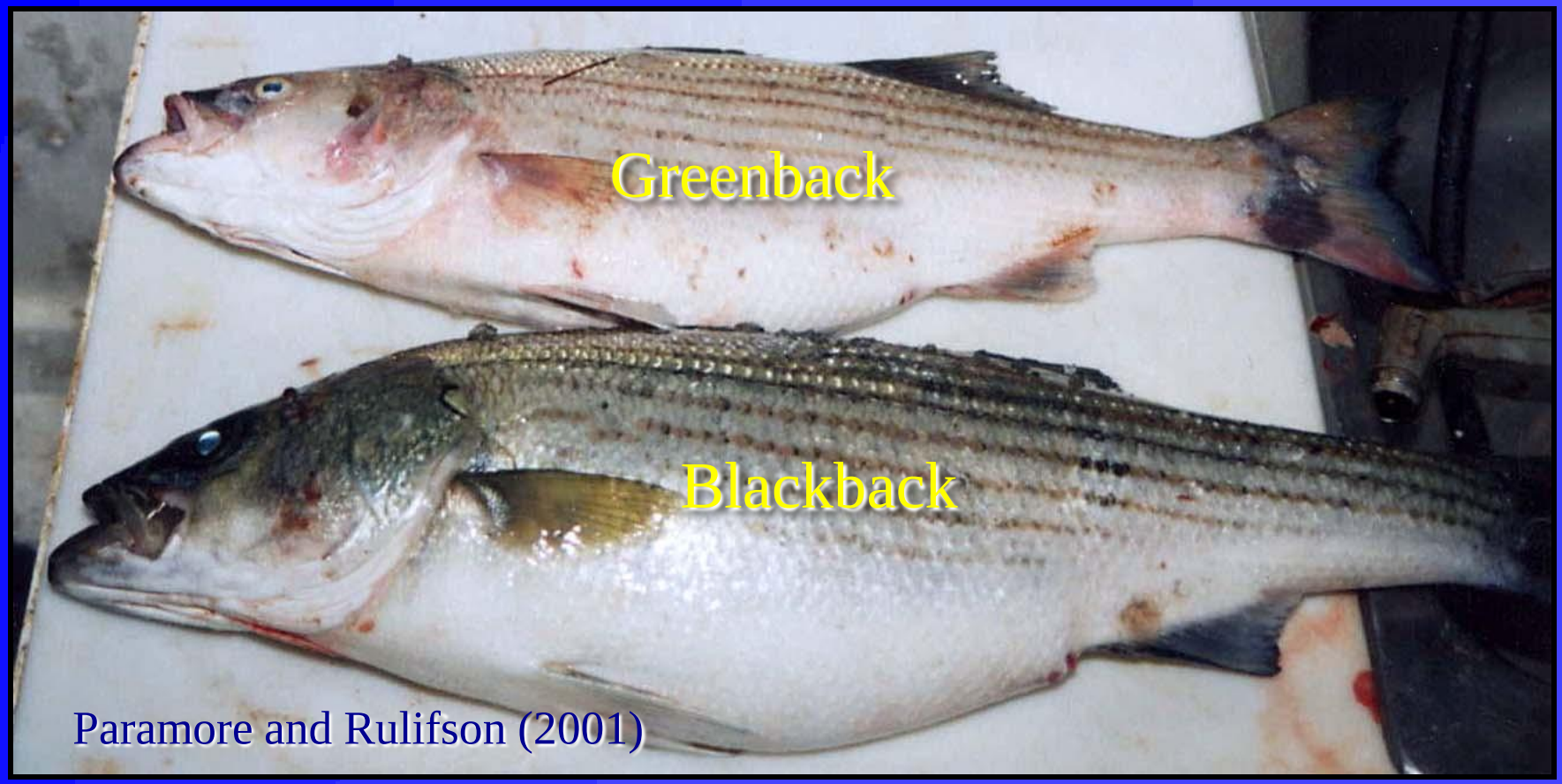




- Juvenile striped bass habitat
  - Neuse- Pamlico Sound
  - Roanoke- western Albemarle Sound
  - Stewiacke- Unknown- Hypothesized to be the upper Bay of Fundy


Rulifson et al. (2008)
Spring
Fredericton
Saint John R.
Fall
Belleisle Bay
Kennebecasis R.
New Brunswick
Summer
Fall
Saint John
Chignecto Bay
Cobequid Bay
Five-Islands
Bass River
Minas Basin
Summer
Stewiacke R.
Gaspereau R.
Shubenacadie R.
Spring
Fall
Shubenacadie Lake
45°
Summer
Bay of Fundy
Annapolis R.
Fall
Bridgetown
Annapolis Royal
Spring
Nova Scotia
Halifax
46°
Overwintering
Spawning
Nursery
Movement
0
50 km
100

Shubenacadie/Stewiacke Population has Two Phenotypes



This “Greenback/Blackback phenomenon” was also reported to me in the Miramichi and other Gulf of St. Lawrence watersheds by commercial fishermen

Paramore and Rulifson (2001)

Stomach Contents of Striped Bass

	Combined		Black		Green		Mottled*	
Food item	A	B	A	B	A	B	A	B
Cod sp.	30.0	18.3	71.4	61.9	33.3	6.2	75.0	28.3
Alewife	13.3	63.6	0.0	0.0	66.6	91.1	50.0	17.6
Blueback herring	3.3	10.0	0.0	0.0	0.0	0.0	25.0	51.7
Stickleback sp.	6.7	2.2	28.6	19.6	0.0	0.0	0.0	0.0
Anchovy sp.	6.7	0.5	28.6	12.5	0.0	0.0	0.0	0.0
American eel	6.7	0.5	28.6	3.1	0.0	0.0	0.0	0.0
Flounder sp.	3.3	0.5	0.0	0.0	33.3	1.5	0.0	0.0
Fish parts	30.0	4.4	85.7	2.9	33.3	1.2	25.0	2.4

A = % occurrence **B = % by weight**

*External color patterns must be ephemeral; rate of change unknown.

Fatty Acids in Tissues from Two Phenotypes

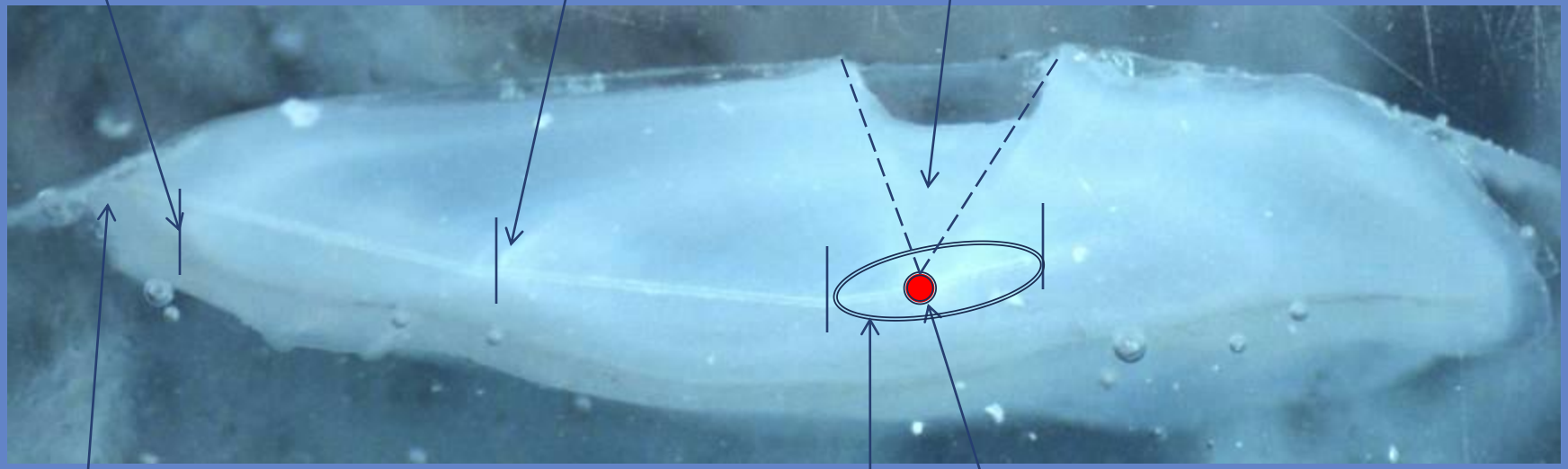
Fatty Acids that were significantly different based on independent t-test with $p<0.05$. SE in ( ).

Phospholipids:	Blackbacks (n=4)	Greenbacks (n=4)
• 20:4n6	6.1%	2.8%
(FW food web)	(1.1)	(0.2)
• 20:5n3	10.5%	14.0%
(Marine food web)	(0.6)	(1.2)

Neutral lipids: No significant differences detected.

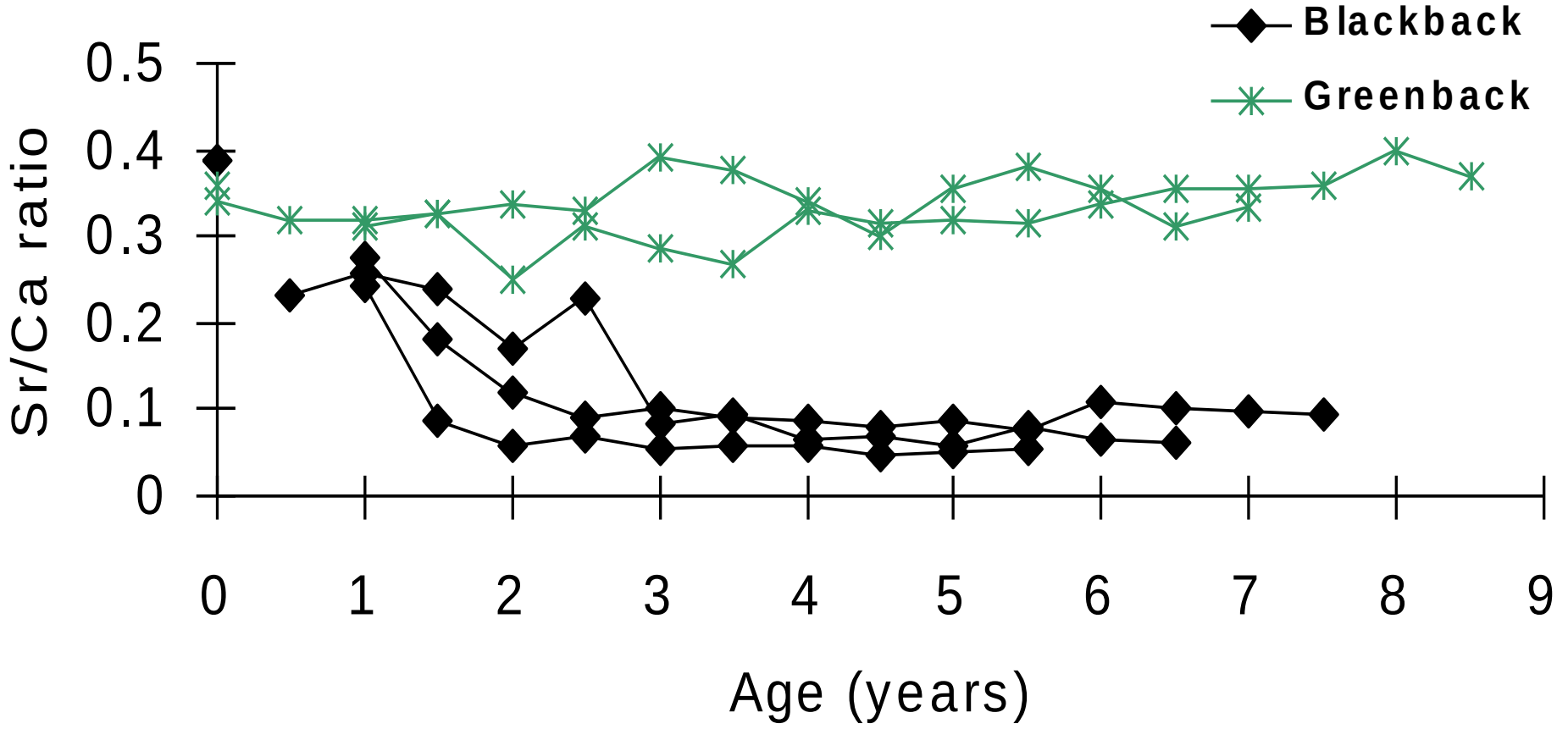
Gallagher et al. (1998); Paramore and Rulifson (2001)

Parts of the Otolith



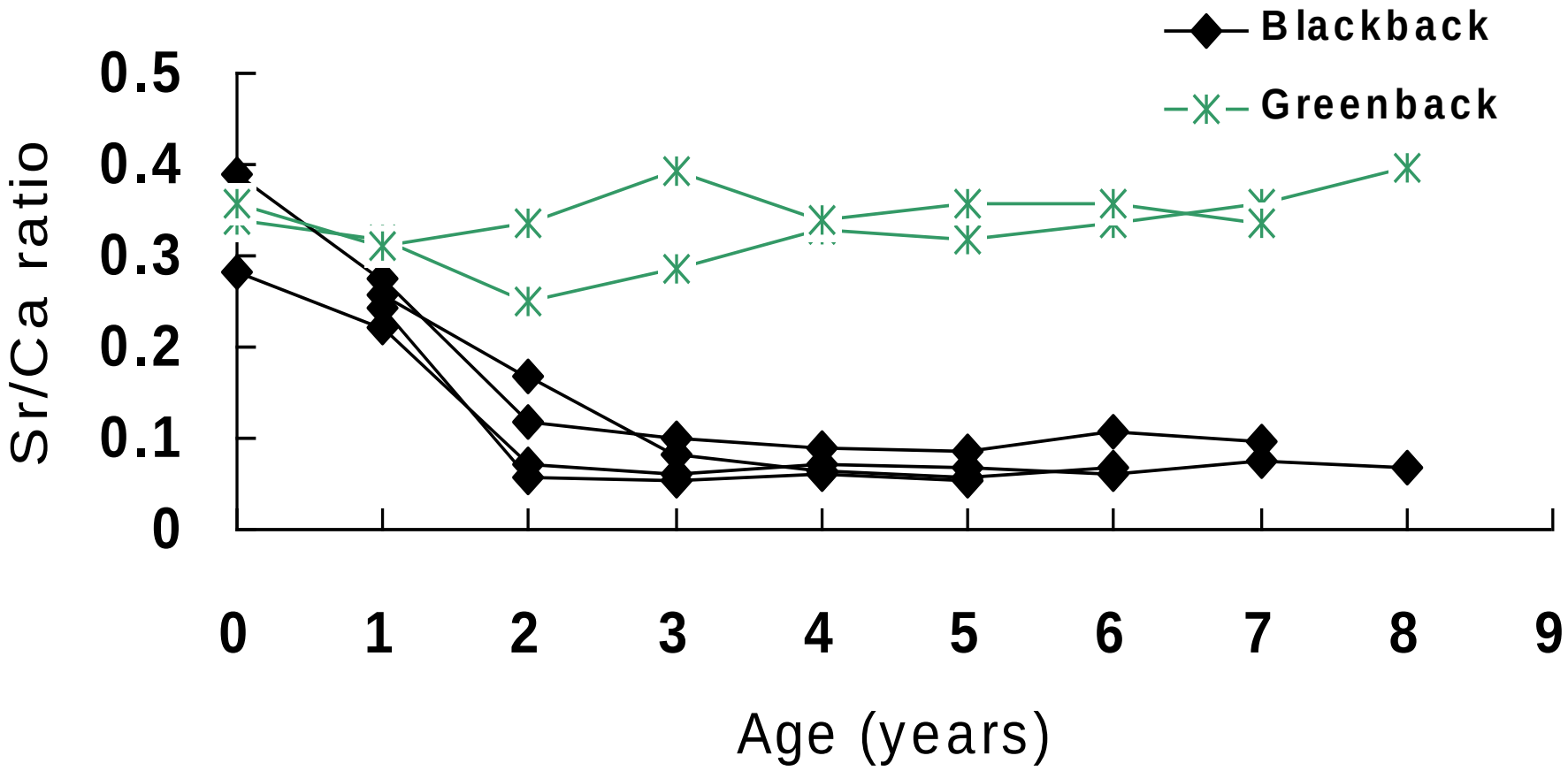
•Plot of $^{86}Sr/^{48}Ca$ Ratio vs. Fish Age

•All Regions



Paramore and Rulifson (2001)

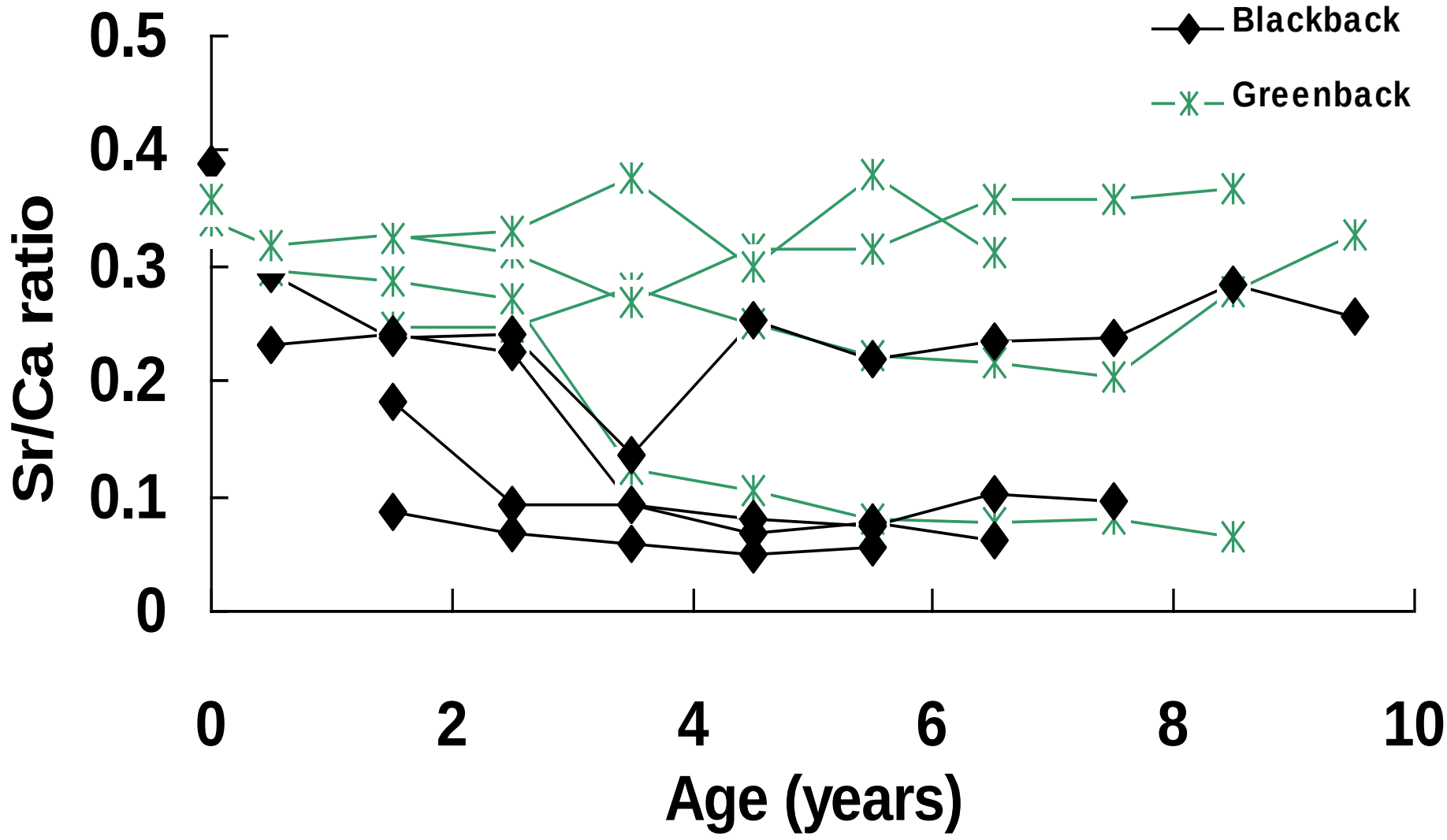
- Plot of $^{86}Sr/^{48}Ca$ Ratio vs. Fish Age
- Opaque Regions



Paramore and Rulifson (2001)

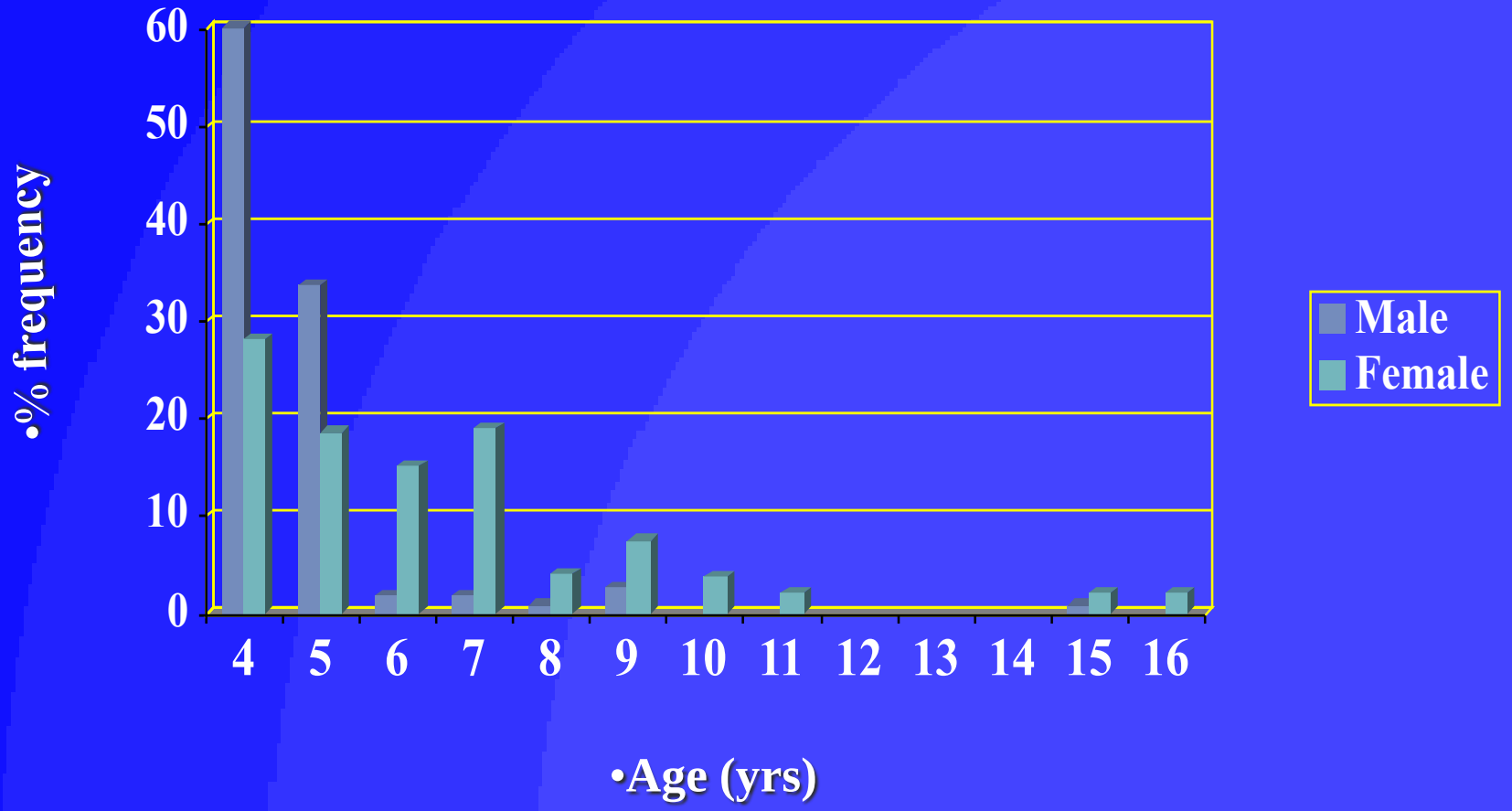
•Plot of $^{86}Sr/^{48}Ca$ Ratio vs. Fish Age

•Translucent Regions



Paramore and Rulifson (2001)

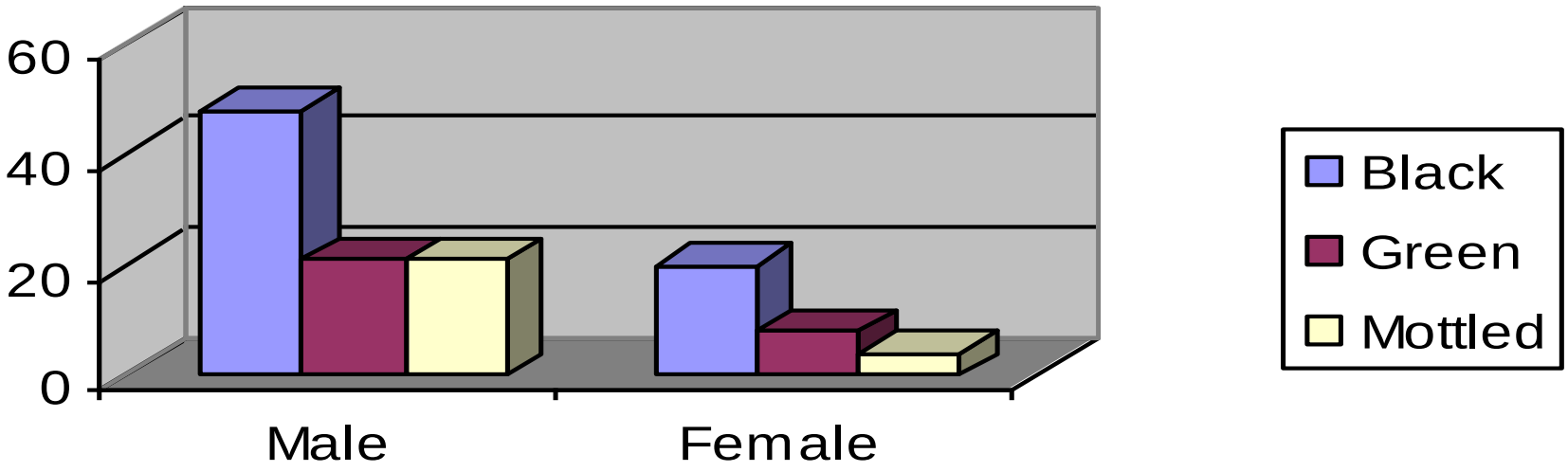
Age Frequency Distribution Does not Tell Us Contingents Based on Length



Paramore and Rulifson (2001)

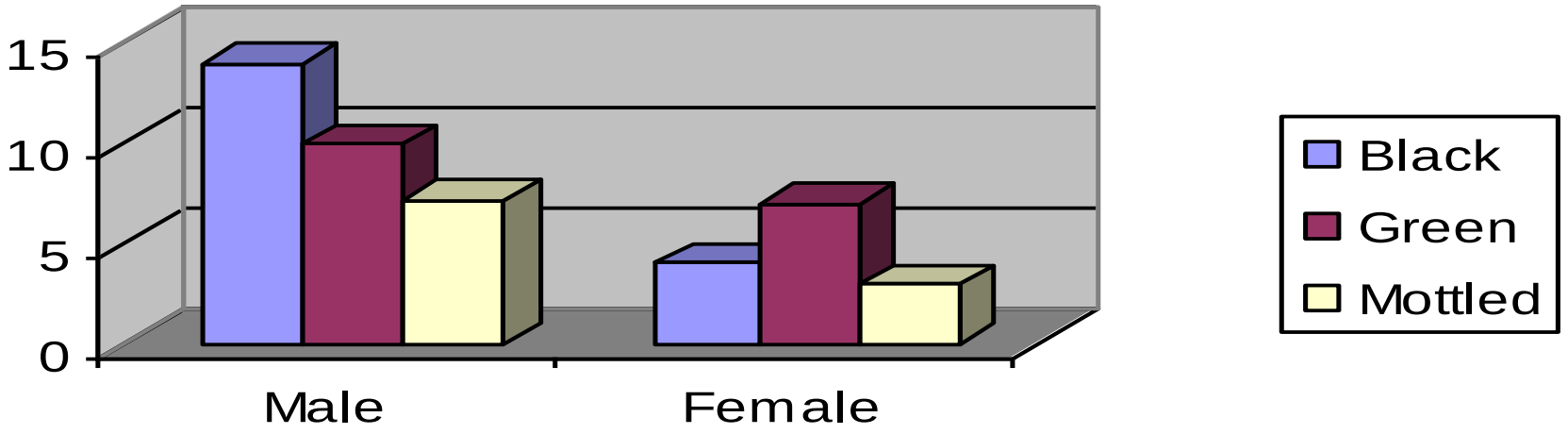
Period 1

May 11-24



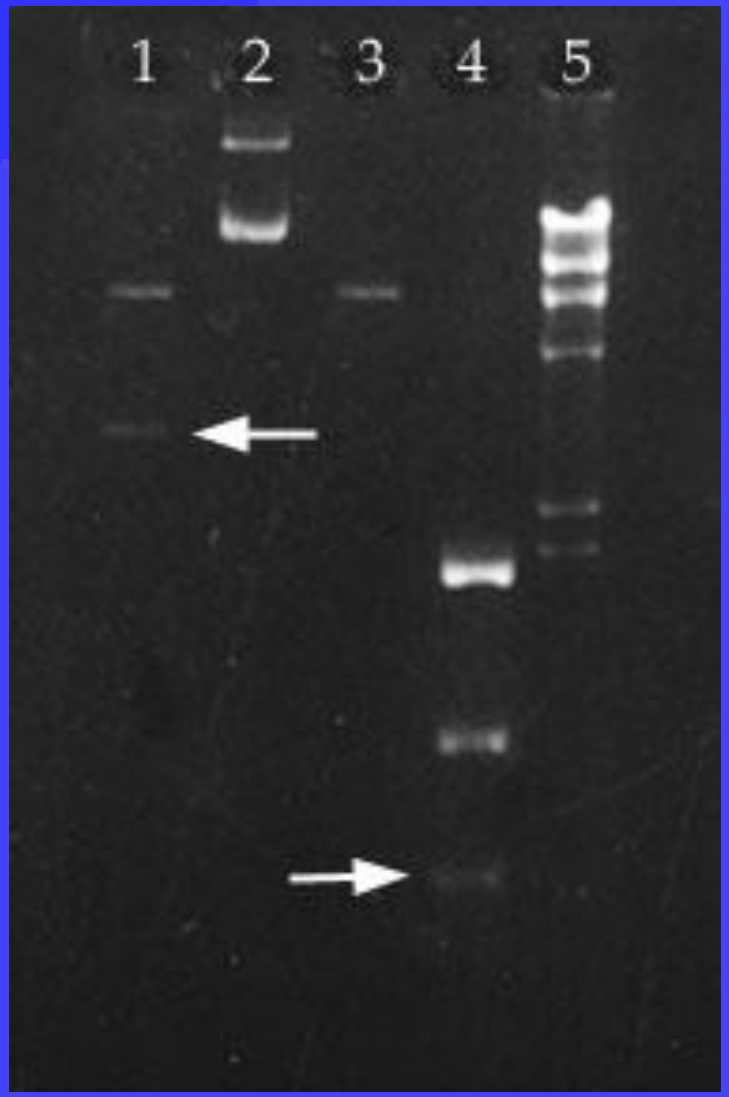
Period 2

May 25-June 7

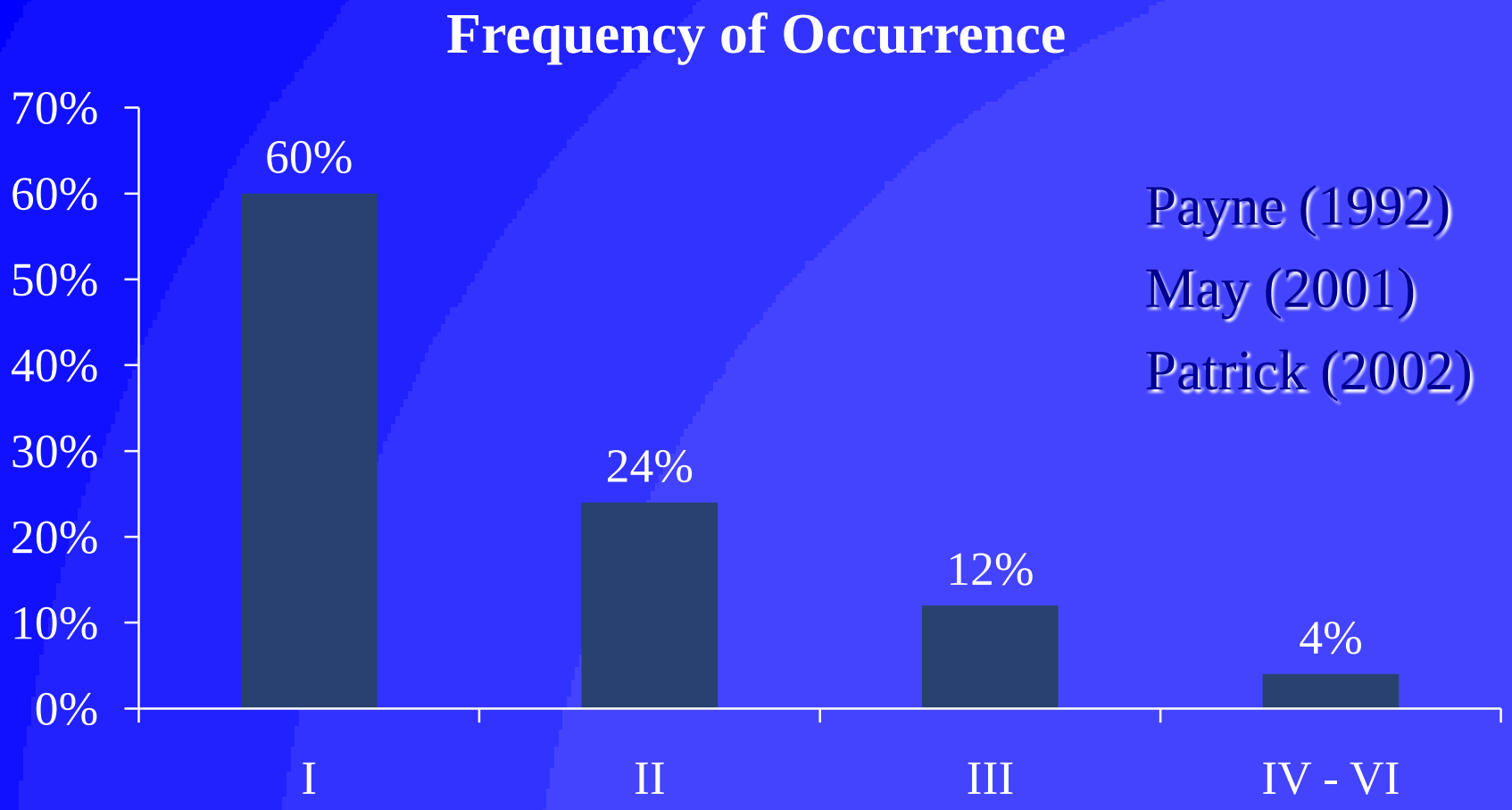


What Will Genetics Tell Us?

- Our studies in the 1990s and early 2000s used specific cutters on mtDNA.
- Results differed based on which cutters were used.
- Wirgin – sampled Roanoke River, got homogeneity
- Stellwag and Rulifson – sampled same season and year as Wirgin, used different cutters and got heterogeneity.



Genotypes from mtDNA Sequencing = Roanoke River Heterogeneity*



*Three different studies and two different techniques gave the same results. This is the distribution from Patrick (2002).

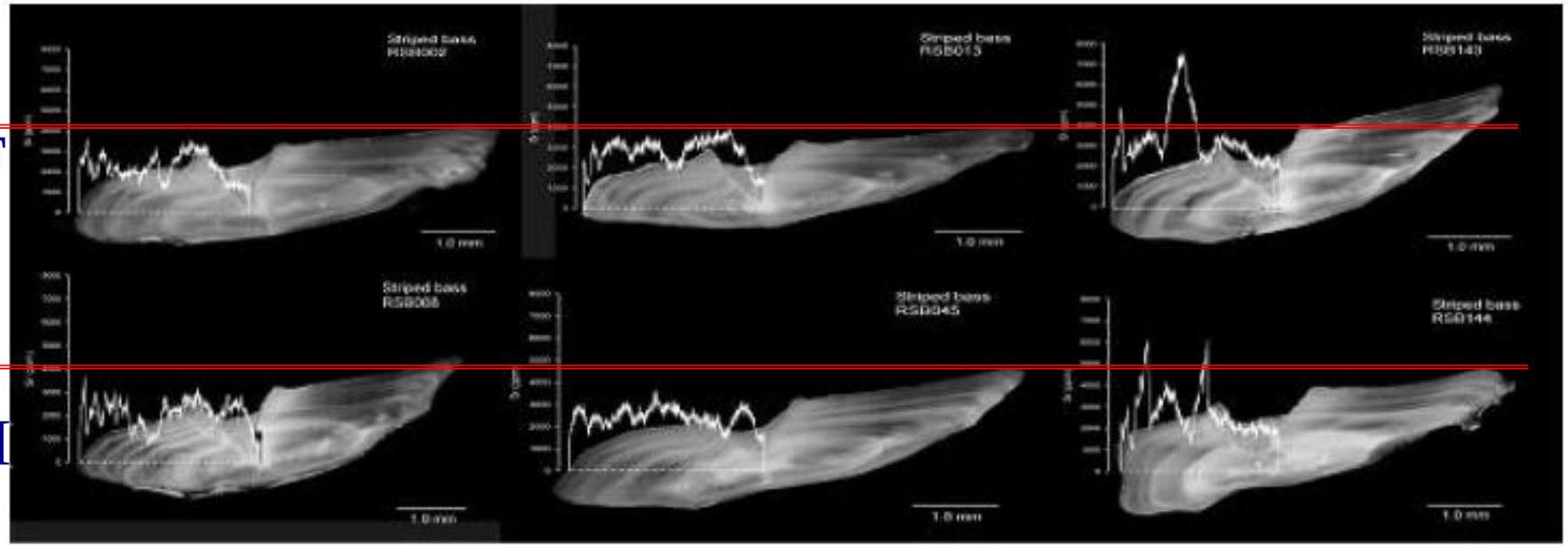
Combining Genetics with Otolith Microchemistry

- Morris et al. (2005)
  - Genotypes I, II, and III
  - Sr concentrations proxy for marine migration

I II III

F

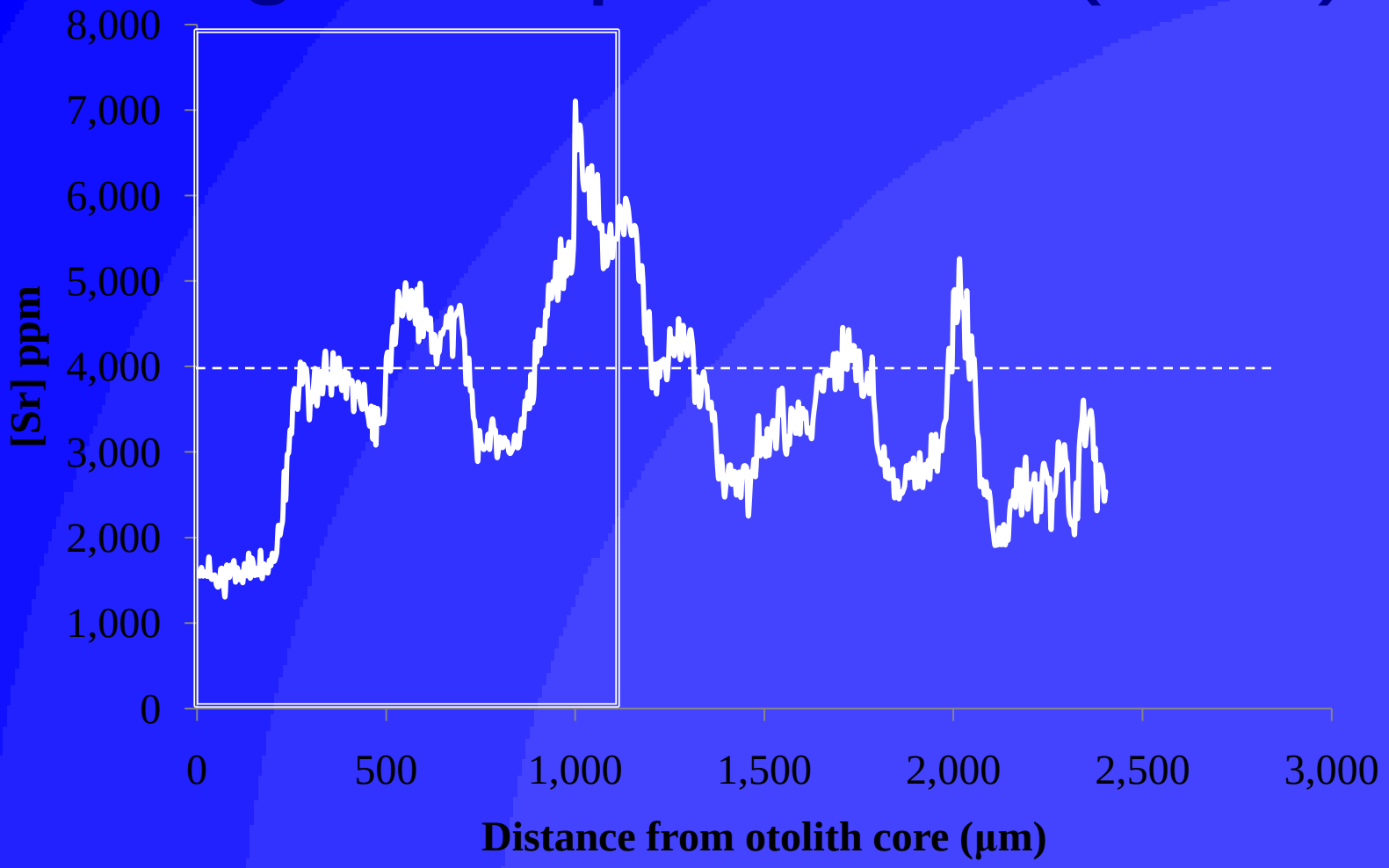
M



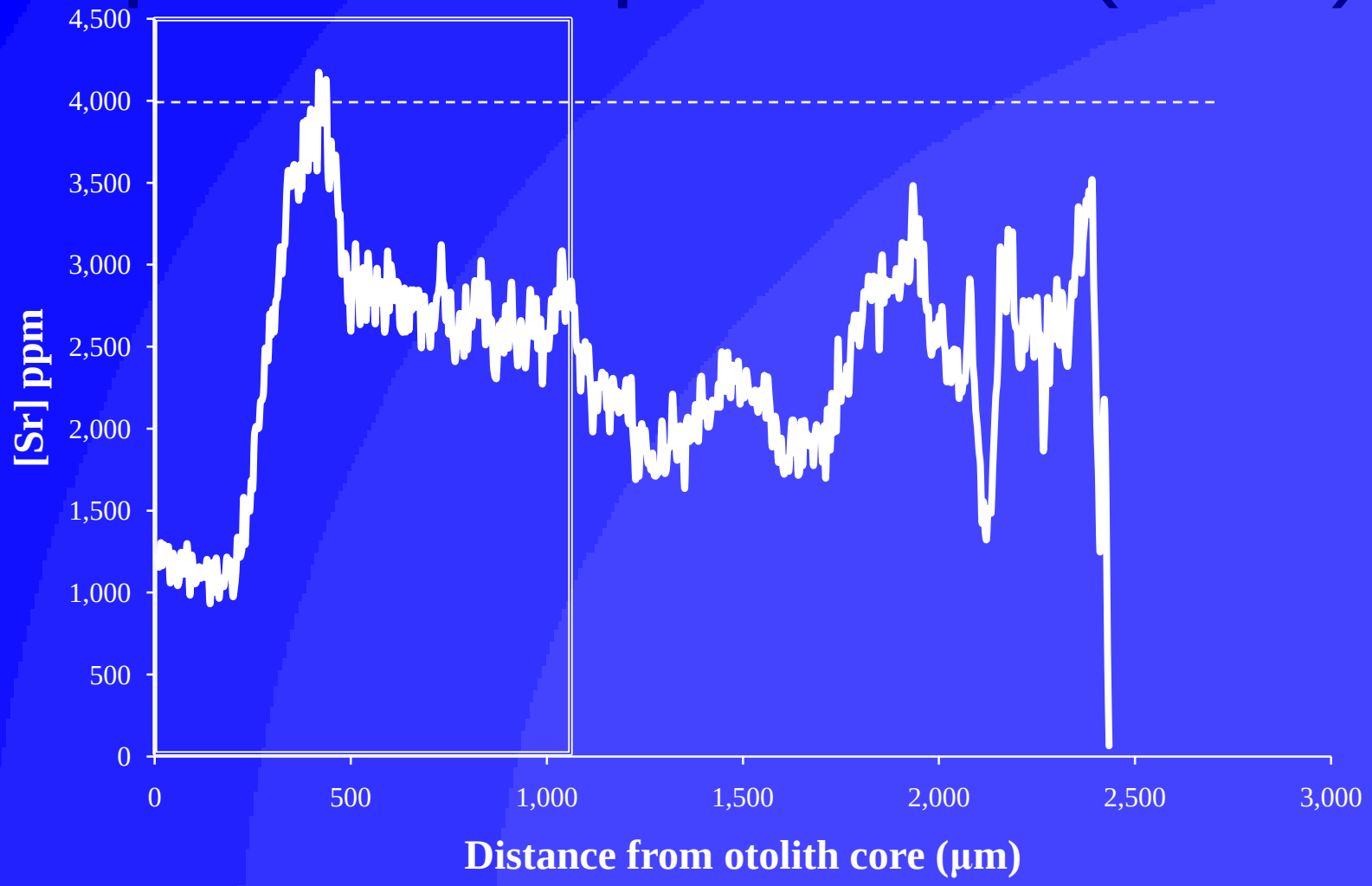
Significance of Preliminary Findings (Morris et al. 2005)

- Suggests linkage between marine migration and genotype III striped bass
- Management applications
  - Allocation – Marine migration 12% vs 3% of time.
  - Spatially adjust fishing effort.
  - Restoration of striped bass watersheds with sub-optimal estuarine habitat.
- Patrick (2010) found no evidence of genetic-based diadromy with the genetic markers used.

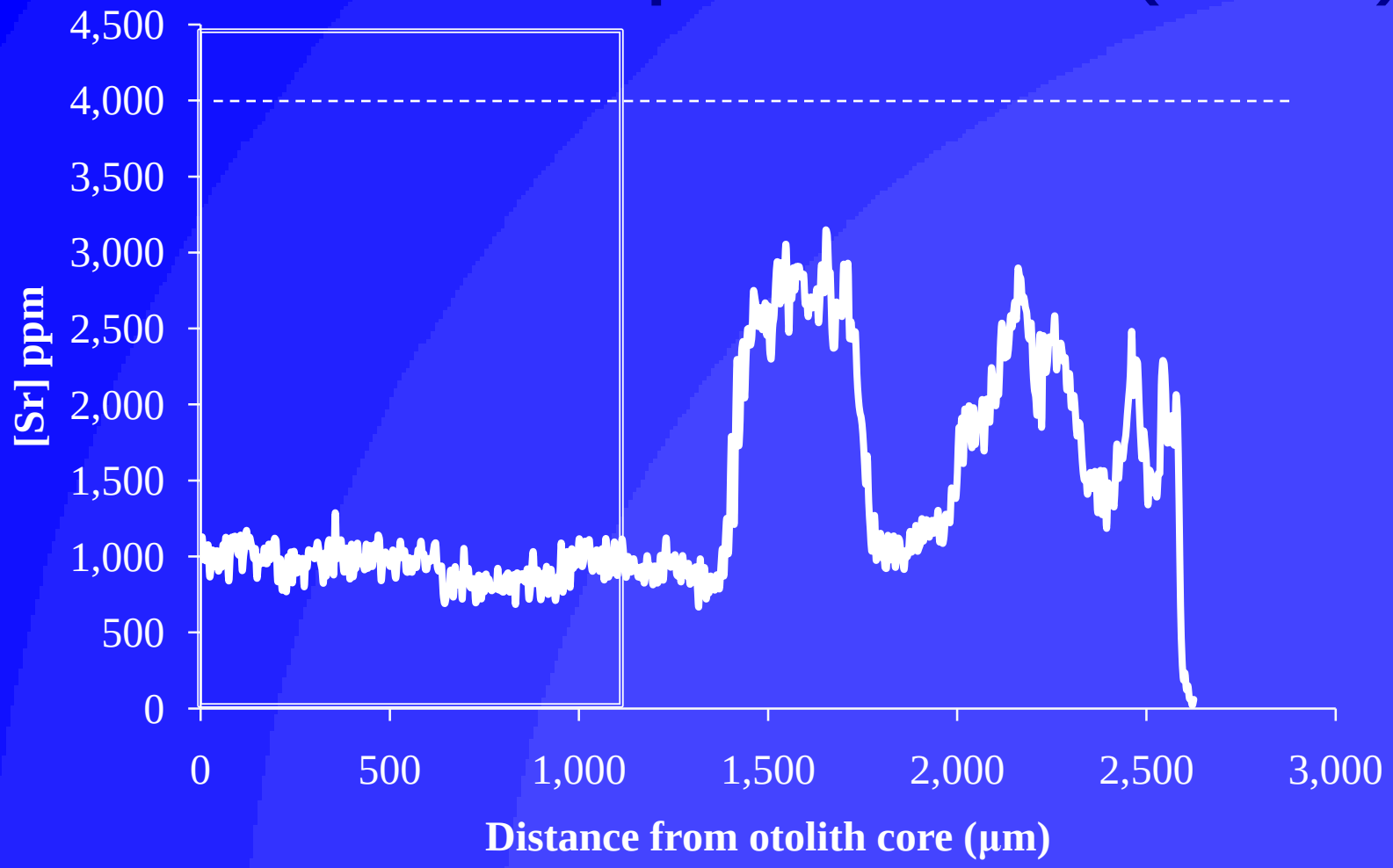
Stager Striped Bass (27%)



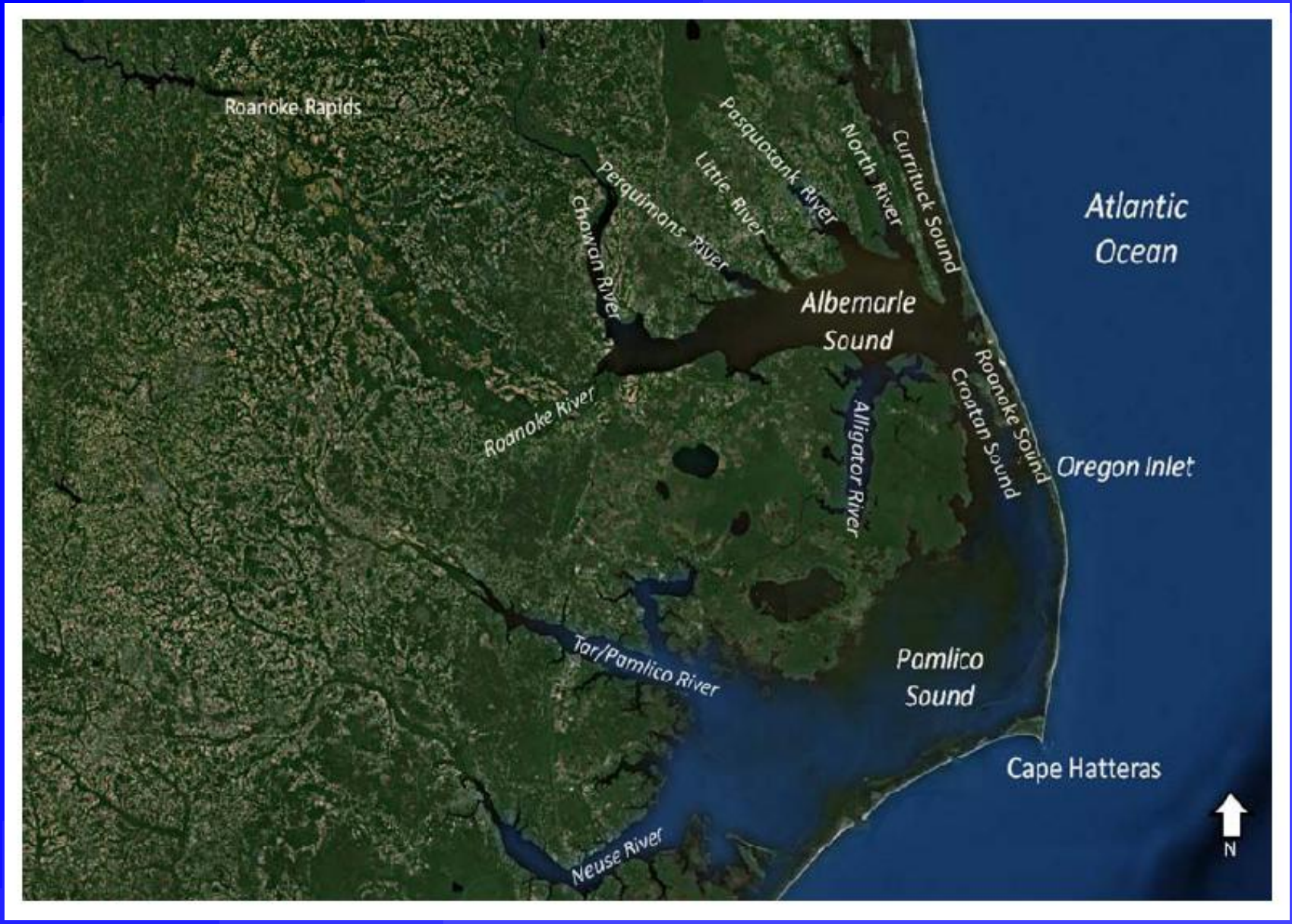
Sprinter Striped Bass (18%)



Resident Striped Bass (55%)



Watershed Fingerprinting for Trace Elements



Schoolies (Subadults) Possibly Migrate in Ocean Waters

- Acoustic tagging study by Martha Mather and Linda Deegan.
- Schoolies (Age 2-5) spend winter in southern NE estuaries, predominately Delaware Bay, Chesapeake Bay, and Hudson River.
- Springtime northward migration to concentrate in New England and Nova Scotia estuaries to feed.
- The buzz word is “BIOTIC TELECONNECTIVITY”
- Results countermand the traditional paradigm for striped bass migration.

Deegan, L. 2011. Biotic Telconnectivity: Patterns and Consequences of the Migration of Striped Bass. Ecosystems Center Report: 6-7.

Striped Bass Production in SE Hatcheries, 1878-2008

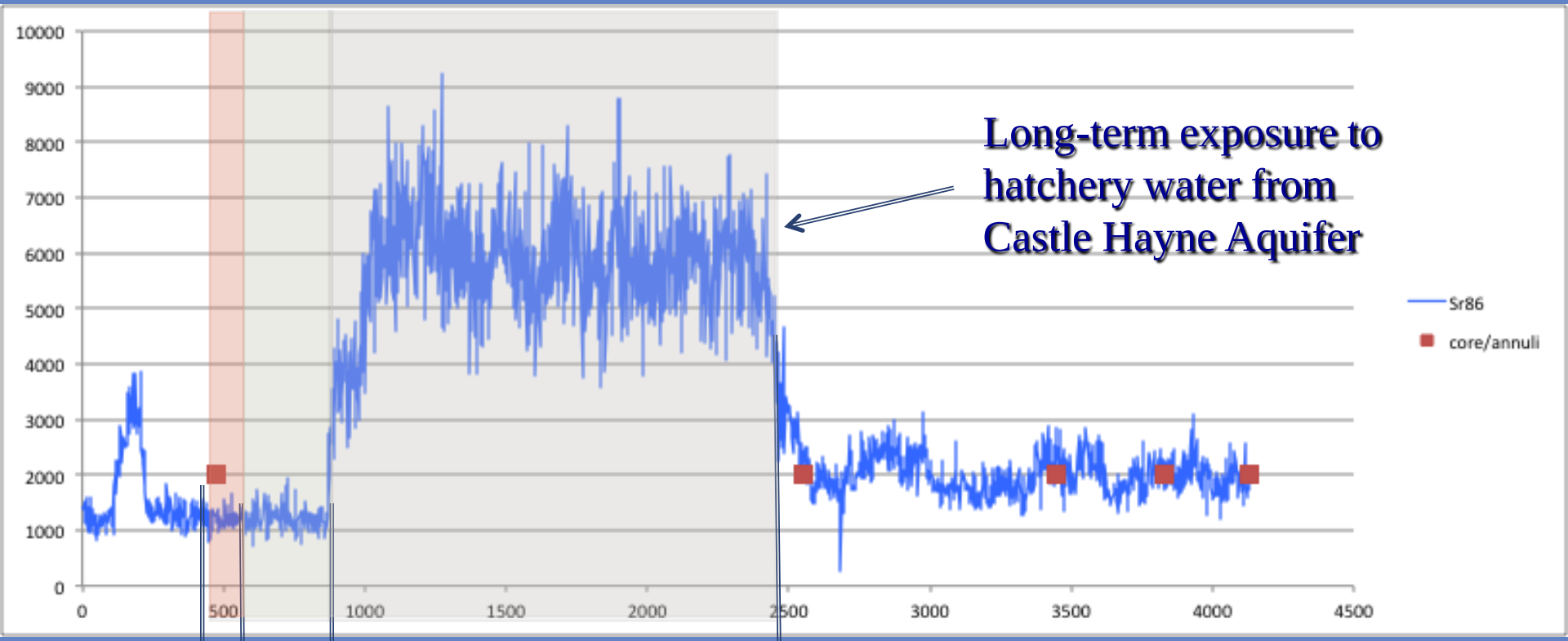
Table 8. Striped bass strains used at each hatchery for production 1873-2008.

	Appalachicola	Blackwater River	Chesapeake Bay	Gulf	Hudson River	Maryland	Roanoke River/Albemarle Sound	St. Johns River	Santee-Cooper	Savannah River
Blackwater (FL)	X	X	X	X	X	X	X	X	X	X
Bowens Mill (GA)				X					X	X
Buller (SC)							X		X	
Cheraw (SC)							X		X	
Cohen Campbell (VA)			X				X			
Cordele (GA)				X					X	X
Dawson (GA)				X			X		X	X
Edenton NFH (NC)			X		X	X	X			
Fayetteville (NC)							X			
Front Royal (VA)			X				X			
Harrison Lake NFH (VA)			X				X			
Dennis Wildlife Center (SC)				X			X		X	X
King & Queen (VA)			X				X			
Marion (NC)							X			
McKinney Lake NFH (NC)			X				X			
McDuffie (GA)				X						X
Orangeburg NFH (SC)			X				X		X	X
Richloam (FL)	X	X	X			X	X	X	X	X
Richmond Hill (GA)				X						X
Spring Stevens (SC)							X		X	
Table Rock (NC)							X			
Vic Thomas (VA)			X				X			
Walton (GA)			X							X
Warm Springs NFH (GA)				X						
Watha (NC)							X			
Welaka NFH (FL)	X	X	X	X		X	X	X	X	X
Weldon (NC)							X			

Conclusions and Recommendations

- Coastwide stocking since 1878 pretty much precludes using genetics as a valuable marker for population and migration studies. (Woodroffe 2011).
- Multiple methods can confirm hypotheses by coming at the problem from different angles – food habits, PUFA, otoliths, and possibly genetics combined.
- Large scale patterns mask real patterns of sub-populations, contingents, aggregations.
- Traditional mark and recapture studies should now be combined with other methods to enable detail at the smaller scale (e.g., acoustic telemetry)

Typical Hatchery Fish Signature*



Long-term exposure to hatchery water from Castle Hayne Aquifer

•Phase II Period

Dobbs and Rulifson, unpublished

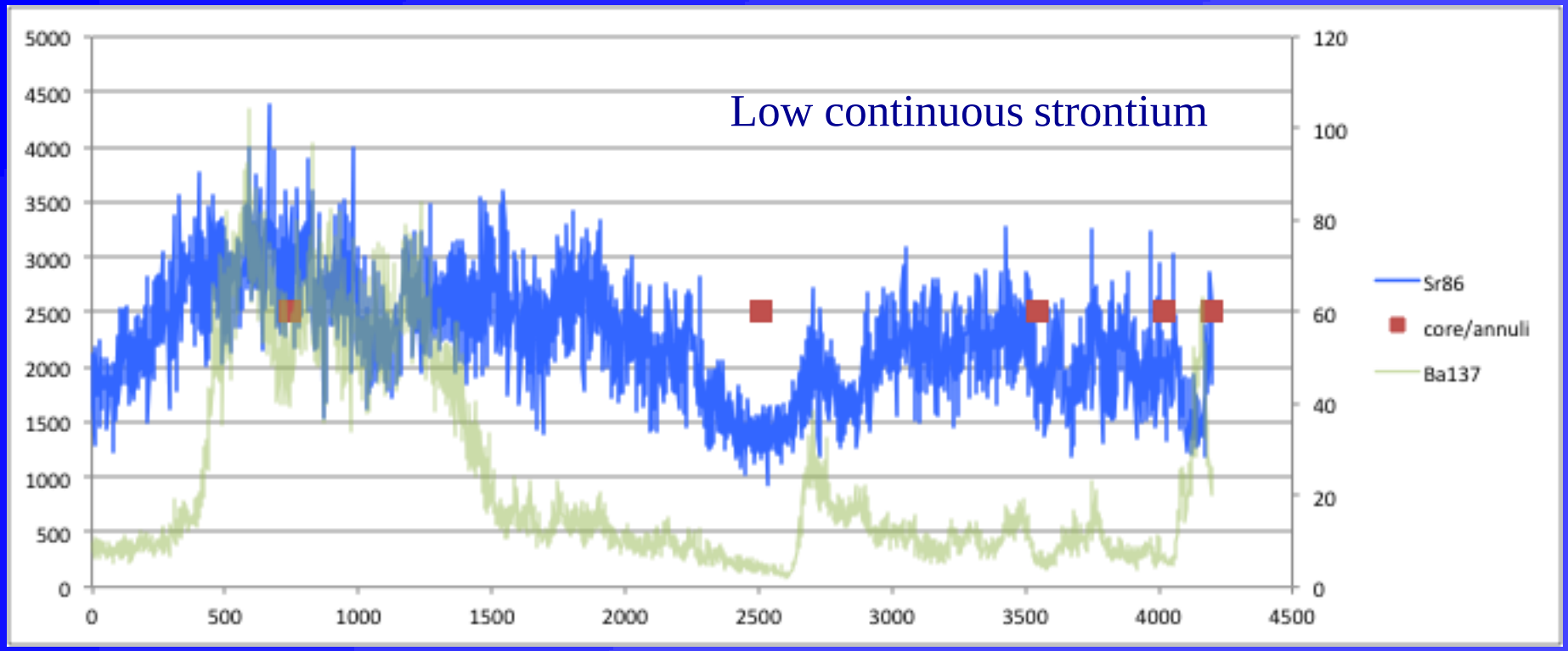
•Maternal Contribution

•Phase I Period

•Stocked into Neuse River at Bridgeton Boat Launch

*OTC marks are often missing!

Wild Fish from Neuse River

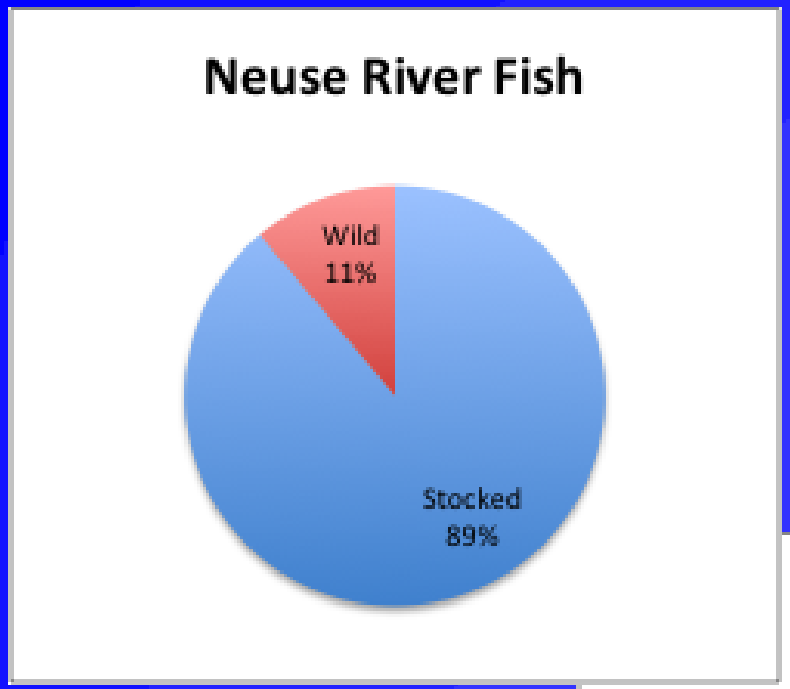


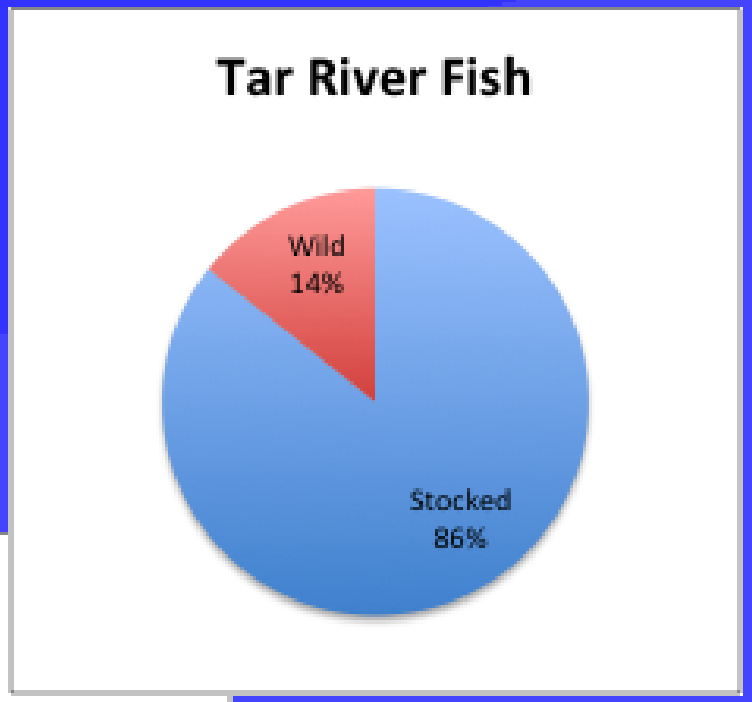
- High Barium at year 4 suggests spawning run to freshwater upstream section of river?

Dobbs and Rulifson, unpublished

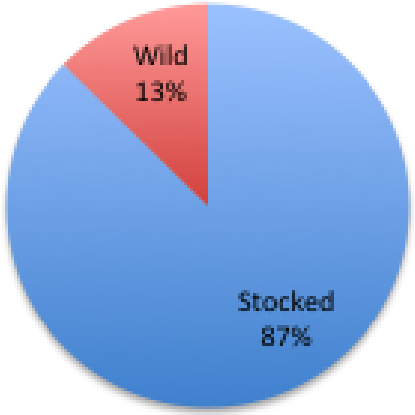
- What does high peak after year 1 indicate?

Proportions of Fish by Origin in Pamlico Sound, NC





All Fish



Dobbs and Rulifson, unpublished