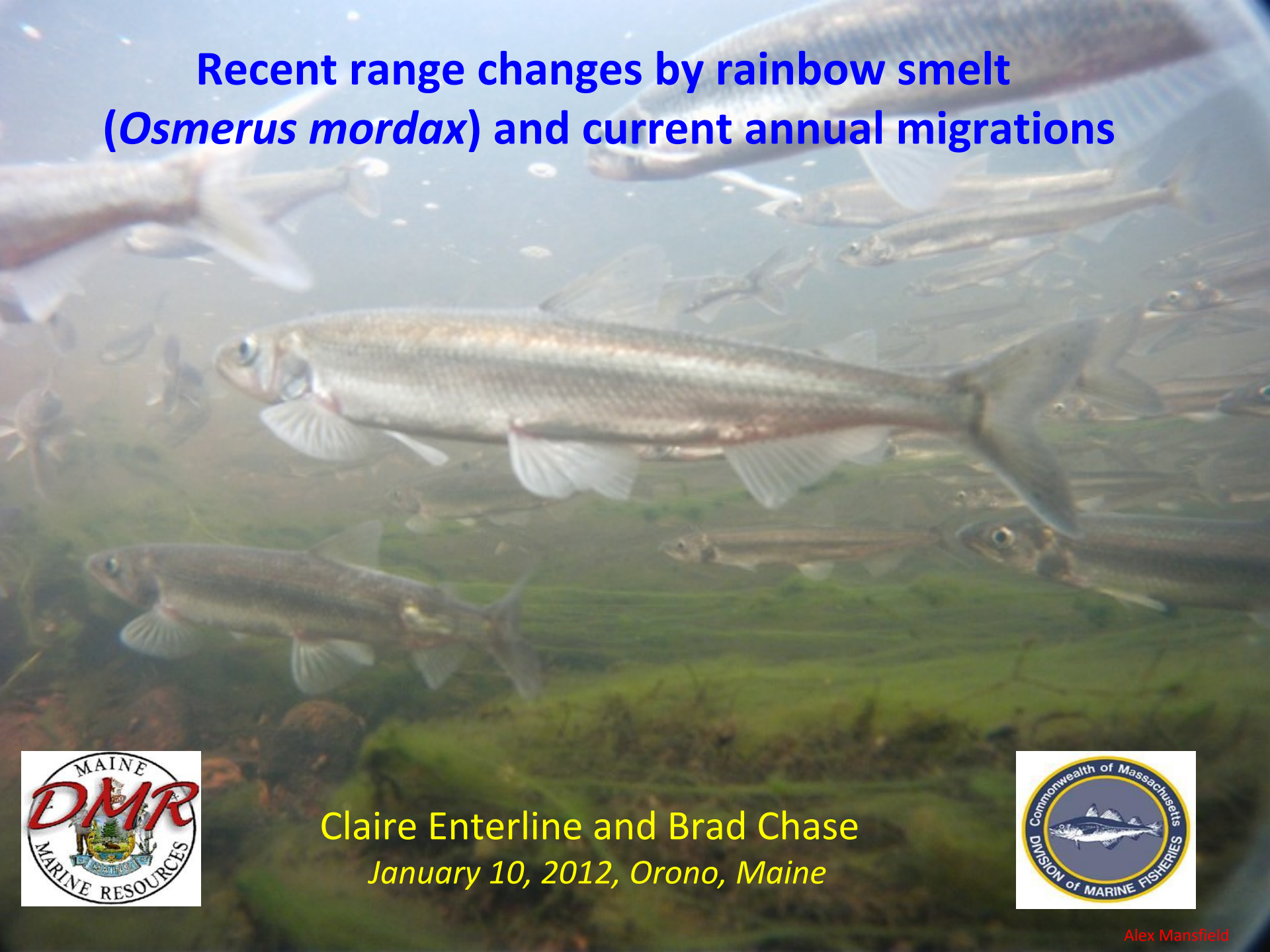
Recent range changes by rainbow smelt (*Osmerus mordax*) and current annual migrations

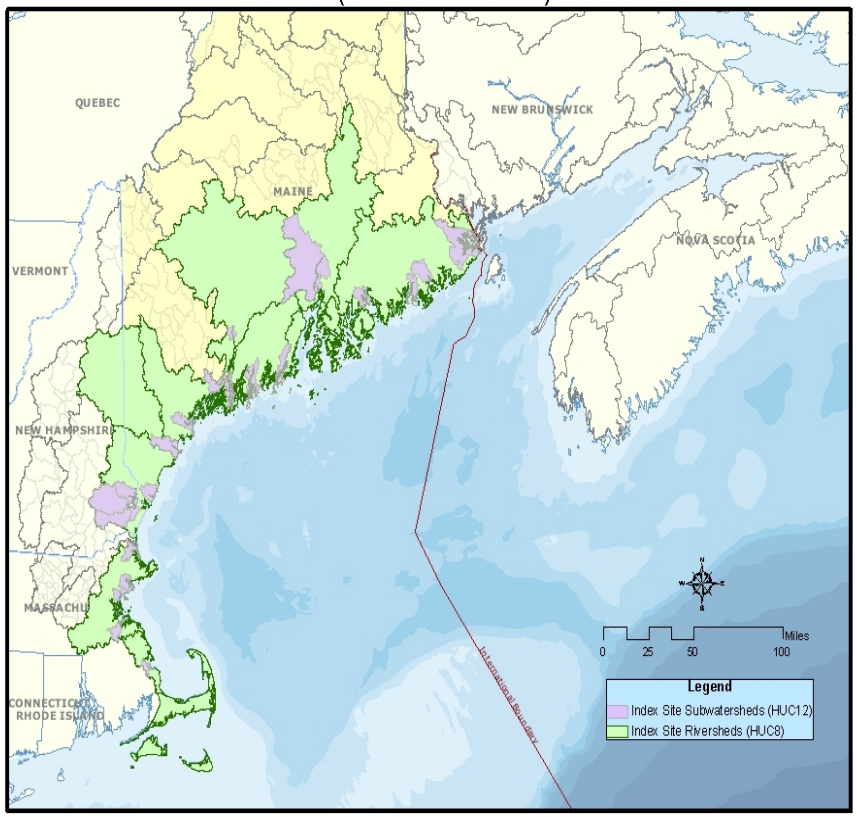


Claire Enterline and Brad Chase

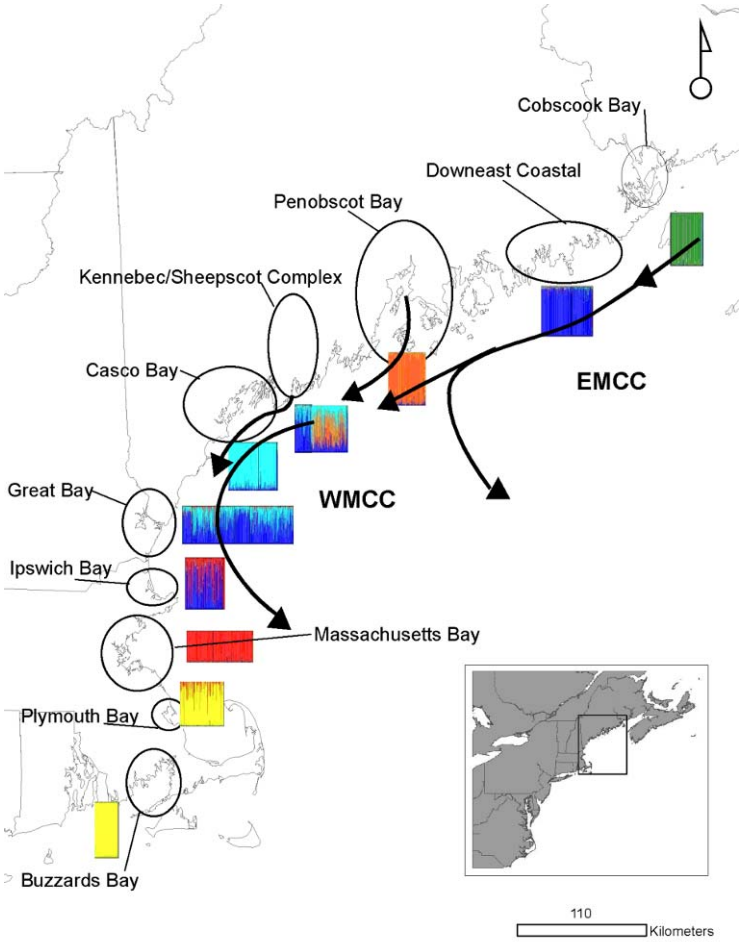
January 10, 2012, Orono, Maine

Alex Mansfield

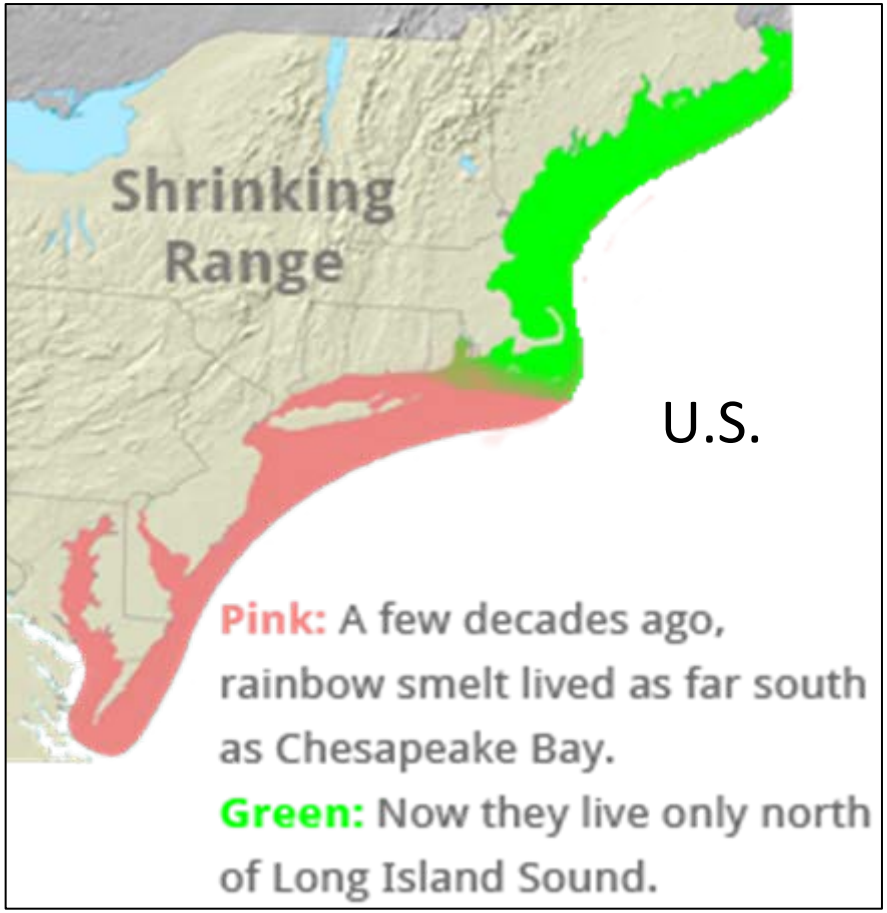
Gulf of Maine Species of Concern Grant
Rainbow Smelt (Osmerus mordax) Index Sites



Gulf of Maine Genetic Stocks



Rainbow Smelt Range

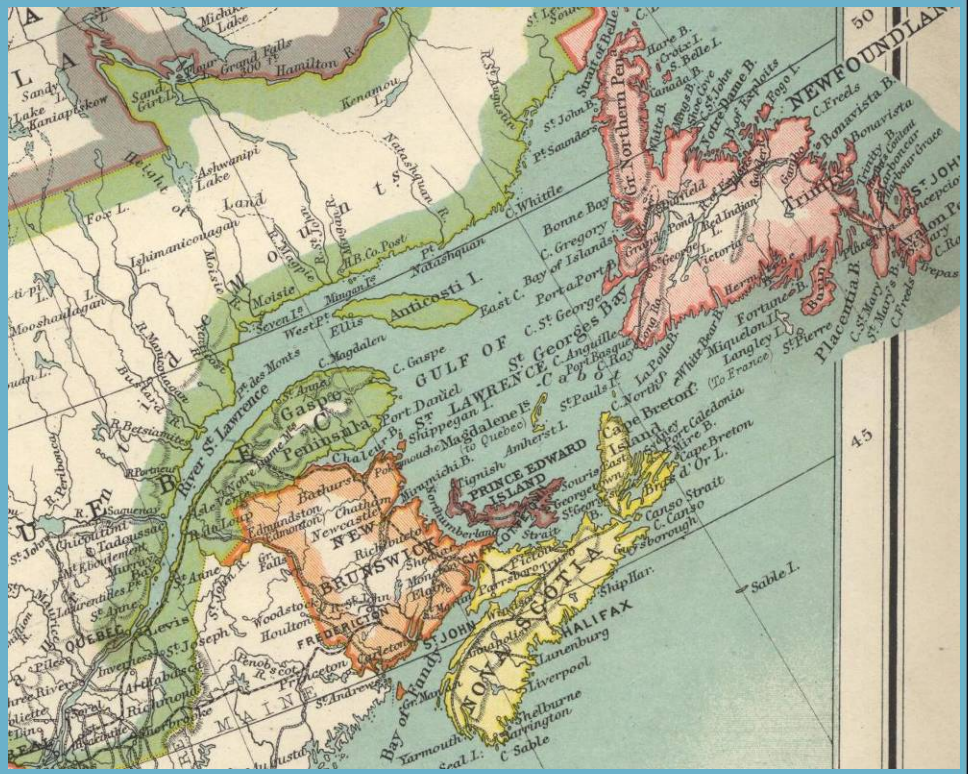


Historic Smelt Fisheries

- Important cultural feature of coastal communities
- widespread participation
- sustenance harvest expanded into commercial fisheries as coastal populations grew

Canadian Maritimes

- No alarms raised for the Maritimes
- Miramichi Bay, New Brunswick
- St. Lawrence River has similar concerns as New England



New England

- Primarily recreational fisheries
- Valuable and popular smelt shack fishery in Maine
- Gradient of decline in Gulf of Maine

Neponset River -- Boston Public Library

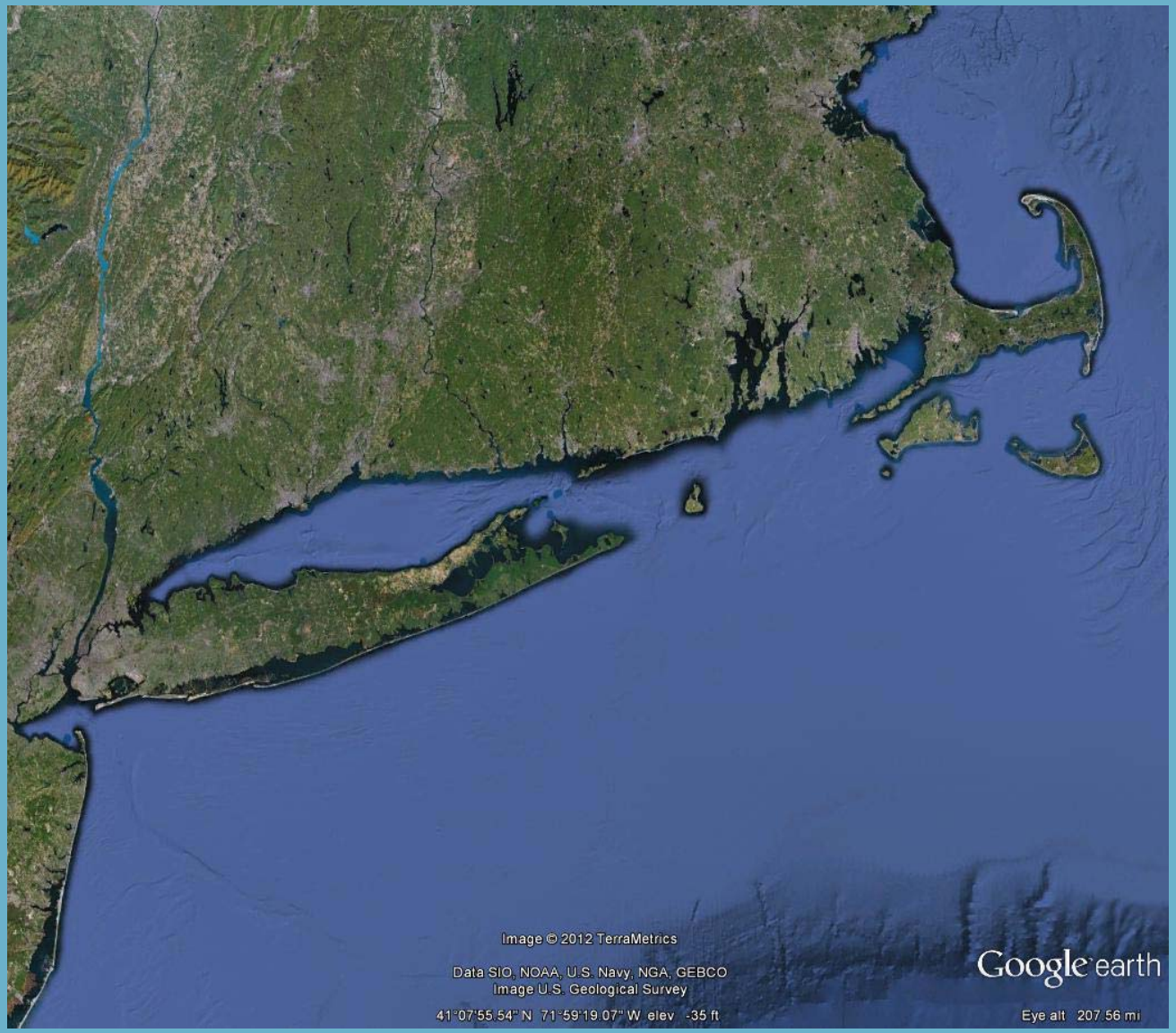
Mid-Atlantic

- Chesapeake Bay is southern boundary with poor documentation
- Delaware Bay is the southernmost region with fishery references: commercial fisheries in 1830 - 1840s , declining catches in 1850s - 1860s, and management concerns in 1870 - 1880s
- NY follows similar pattern but later. Both states assign blame on industrial pollution and stock smelt eggs for several decades
- NJ considered smelt extirpated in 1941
- Hudson River: data series from ichthyoplankton and juvenile fish surveys found smelt were common during 1970 - 1980s. Dramatic decline since mid-1990s
- NY Presently considered “extirpated or at extremely low abundance”

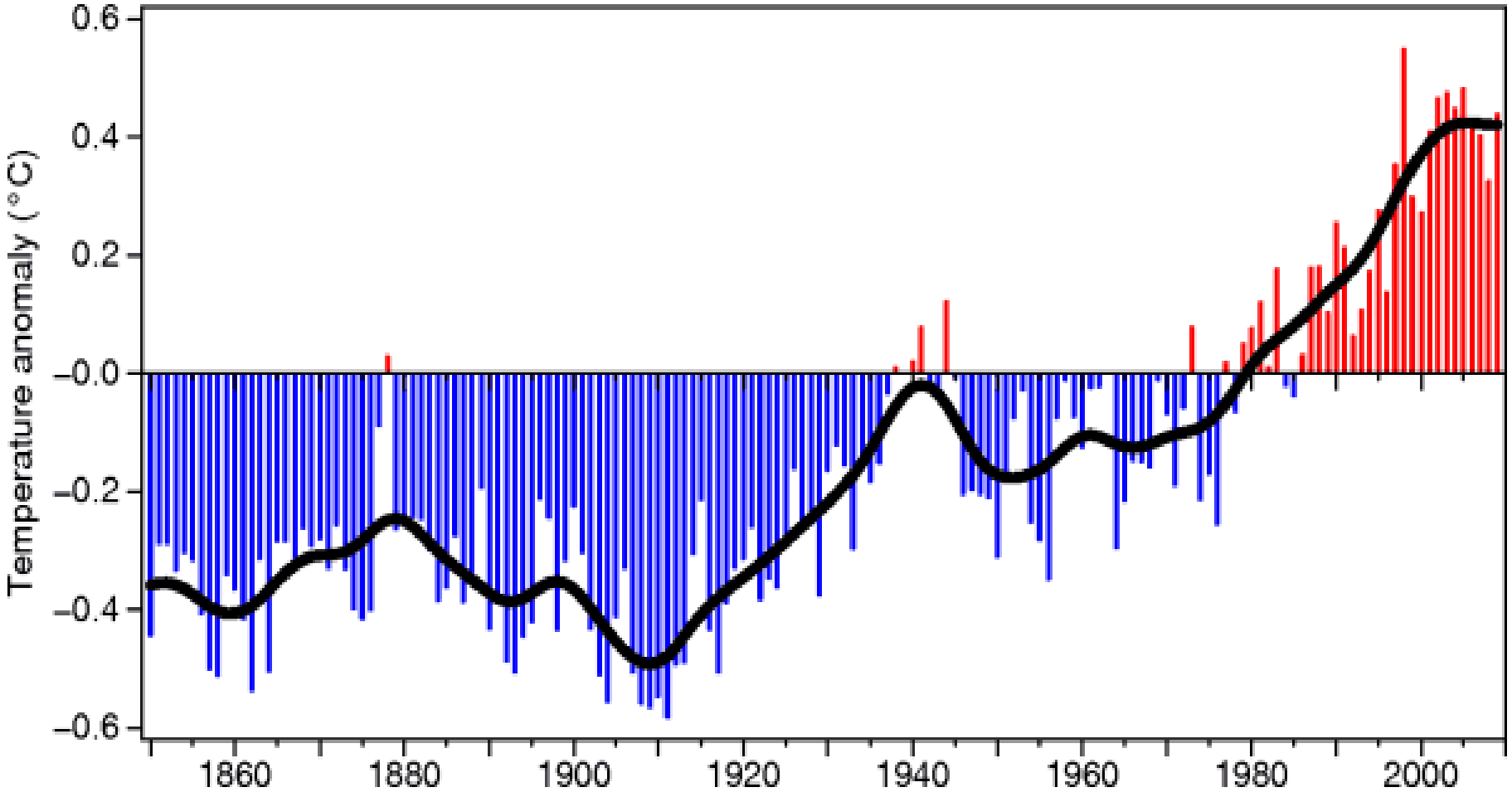
Southern New England

- Important 19th century fisheries in CT, RI and southern MA; Catches fade in late 19th century similar to NJ and NY
- A rebound occurs in the 1960s and both CT and RI. No concerns noted yet in southern MA
- Sharp decline in presence starting in 1980s
- Presently considered “extirpated with a chance of trace populations” in CT and RI

Hudson River to Buzzards Bay



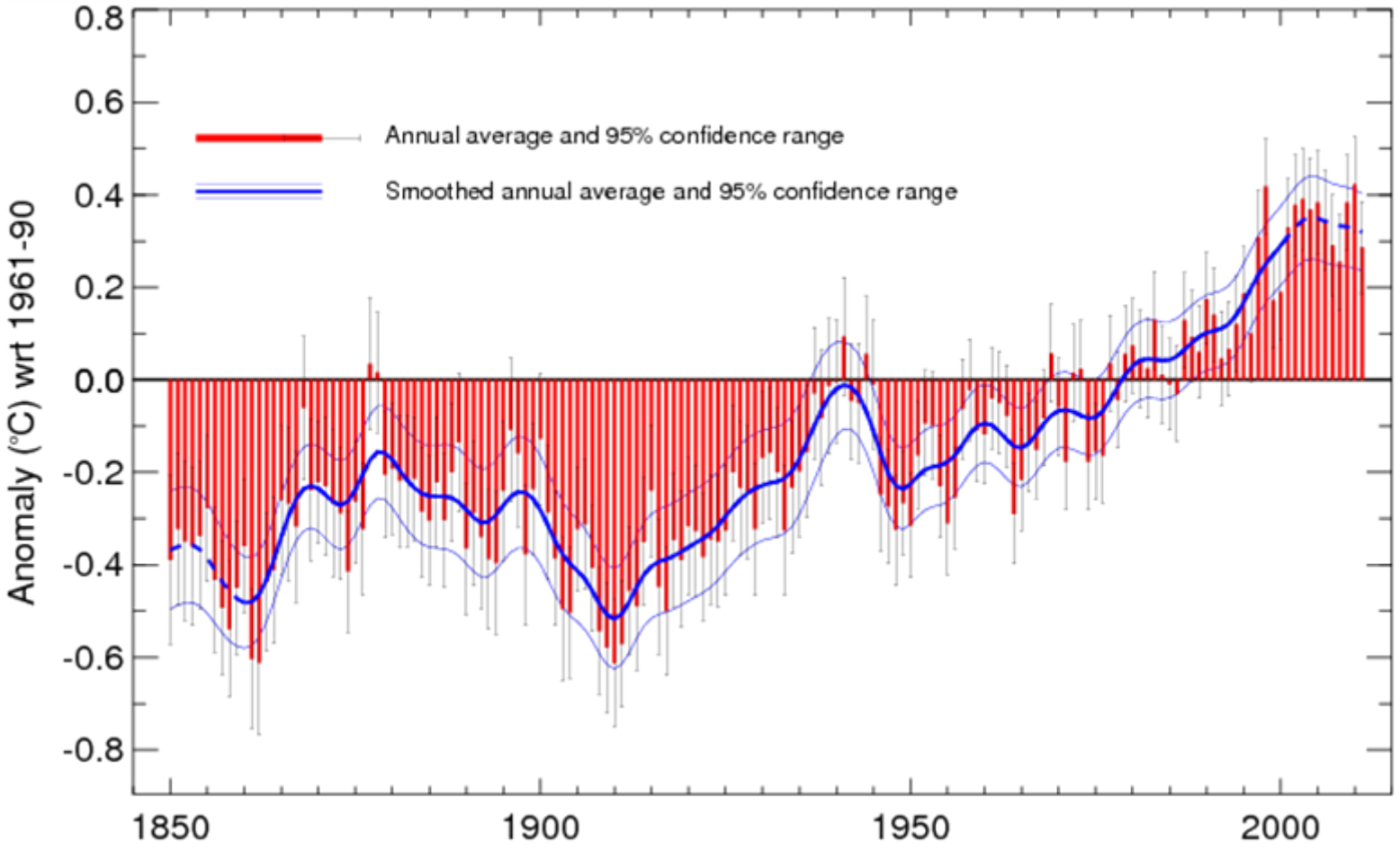
Global Mean Air Temperature



Source: NCDC/NESDIS/NOAA

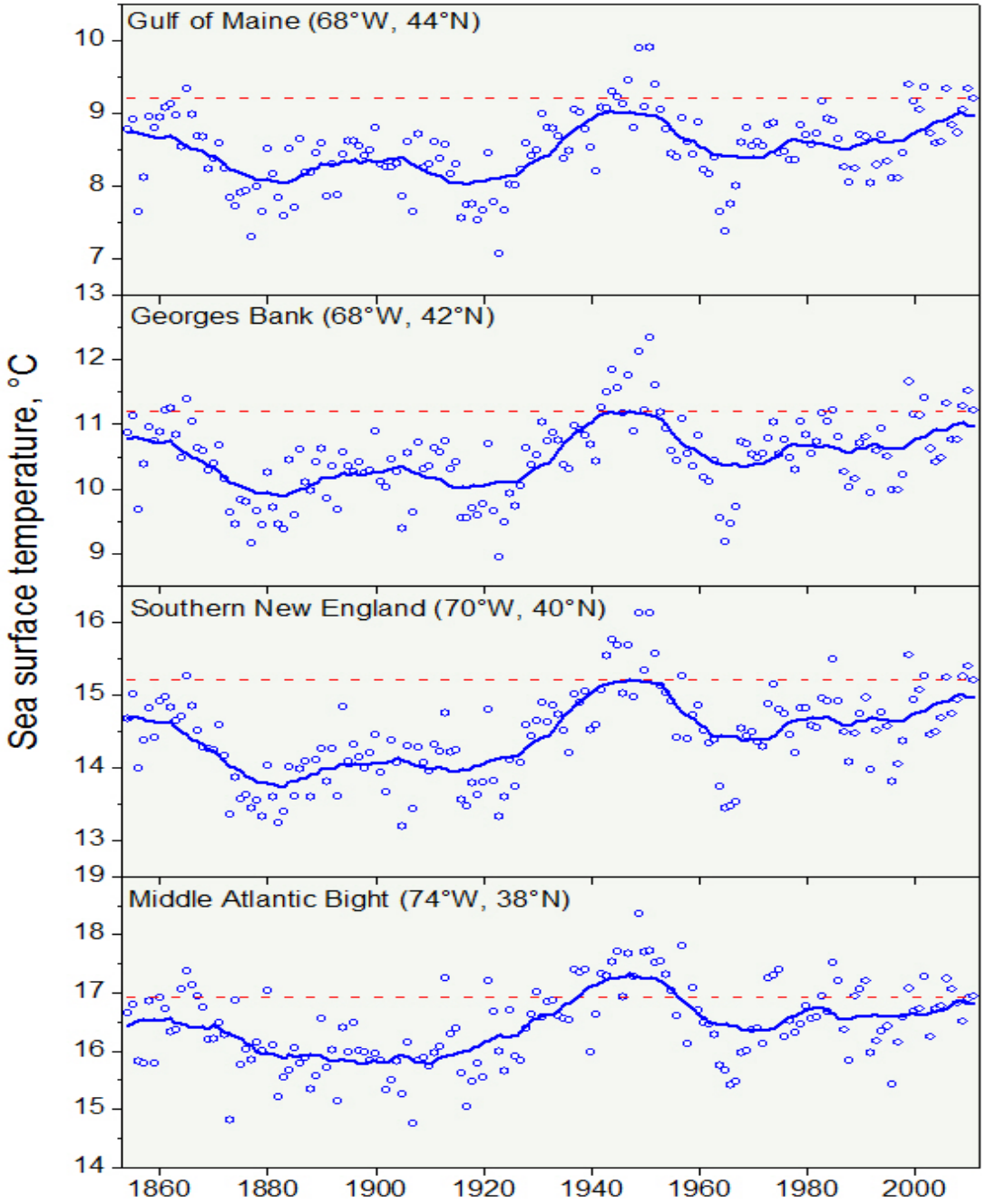
Global average sea-surface temperature 1850-2011

Based on Rayner et al. 2006



Met Office Hadley Centre

Source: www.metoffice.gov.uk/hadobs



Annual Mean Sea-Surface Water Temperature (°C)

Source:
NOAA NEFSC

How might warming impact smelt?

- **Environmental**

1. Changes in snow melt
2. Reduced summer base flow to estuaries
3. Reduced estuarine ice
4. Sea Level Rise

- **Biological Responses**

1. Changes in migrations and growth
2. Reduced benefit of anti-freeze biochemistry
3. Eutrophication impacts on spawning and nursery habitat

Smelt Anti-Freeze

--Smelt produce antifreeze proteins and seasonally regulate glycerol that allows them to remain active in winter

--low temperatures (3–5 □C) activate the glycerol production and continued feeding is needed to survive

--Without the cold temperature challenge, glycerol remains low. Are these fish at a disadvantage with reduced winter activity?

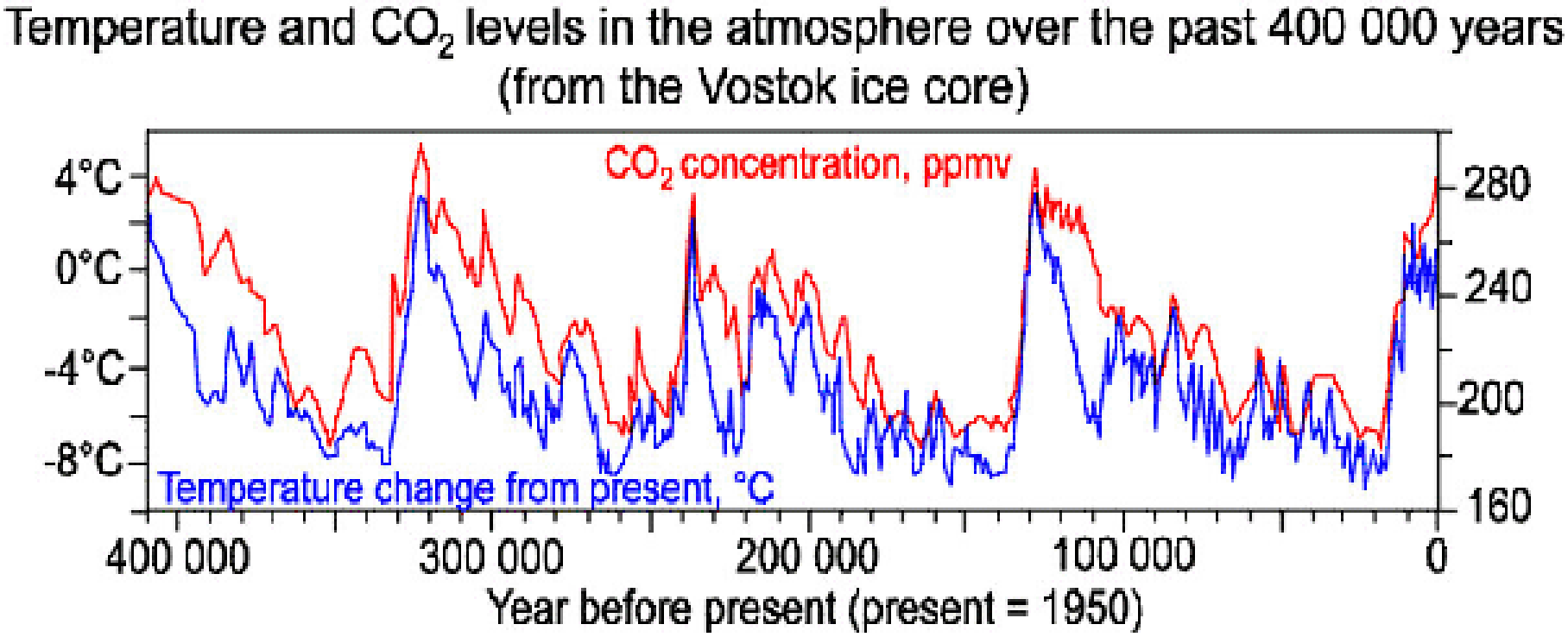
Restoration Outlook at Southern Extent

- Decades of egg transfers had little impact
- Clean Water Act responses had little impact
- Landscape and Hydrologic changes could be important
- Long-term warming trend may be most important
- How do we manage for range contraction and extirpation of genetic stocks?

Three Strikes:

1. Overfishing
2. Habitat Degradation
3. Global Warming

Antarctic Ice Core




MAR 9 2006

Annual Migrations & Habitat Use: What do we know?

Annual movements and habitat use by rainbow smelt historically based on patterns in recreational and commercial fishing

Fishing independent surveys focus on distinct phases of the life cycle

- Juvenile Abundance Index (Beach Seine Surveys)
- Near-Shore Trawl Survey
- Spawning and habitat use studies

Hydroacoustic Tagging: large scale movements

Generalized Life Cycle

Movements directed by life cycle (spawning) and water temperature

Spring

Adults are inshore and in streams/rivers
Spawn at head of tide

Summer

Young of the year in estuaries
Adults in coastal waters
No surveys targeting adults in summer

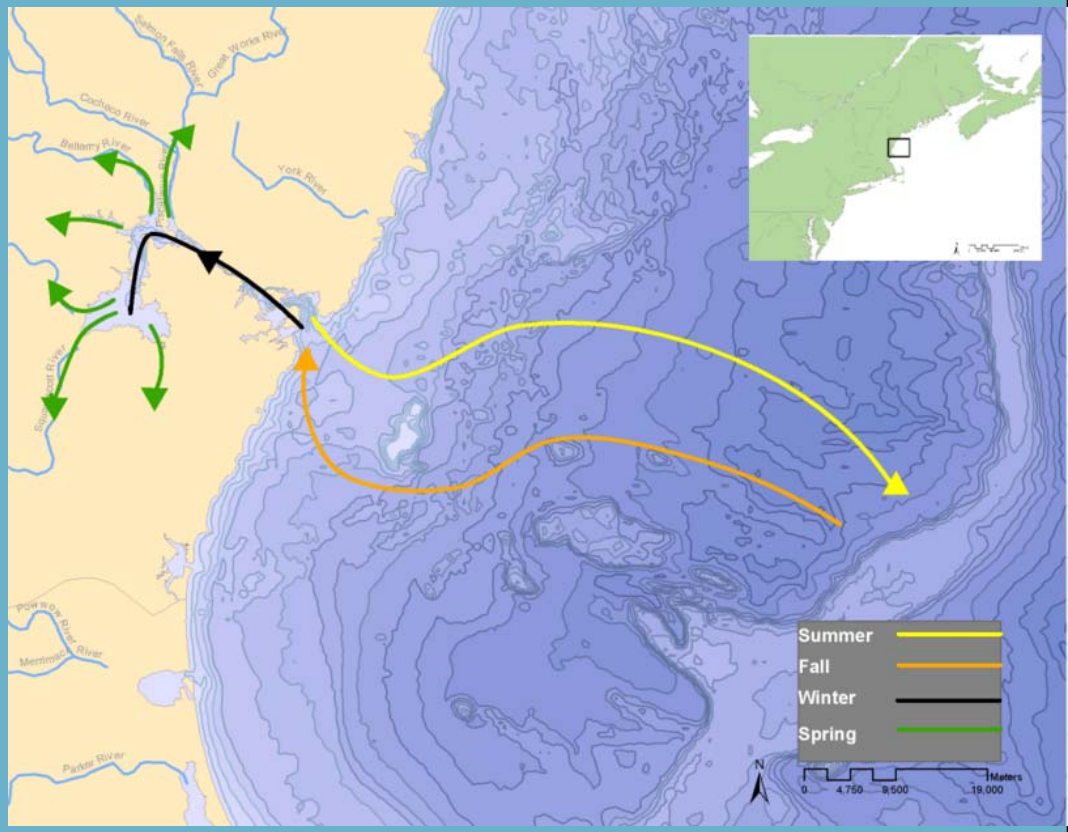
Fall

Moving towards shore
Bays and mouths of rivers

Winter

Sheltered bays, large tidal rivers

(Buckley 1989, Kendall 1926, Murawski et al. 1980)



Near-Shore Trawl Survey – Do Catches Differ Between Seasons?

Comparing Catch Between Seasons		
	Fall	Spring
MEAN (Number of Smelt Caught)	129*	31
Q90 (90% of Recorded Catches Less Than)	384	37
MAX (Number of Smelt Caught)	2615	3257

*Significantly larger, $p < 0.0001$, Wilcoxon ranked sign test

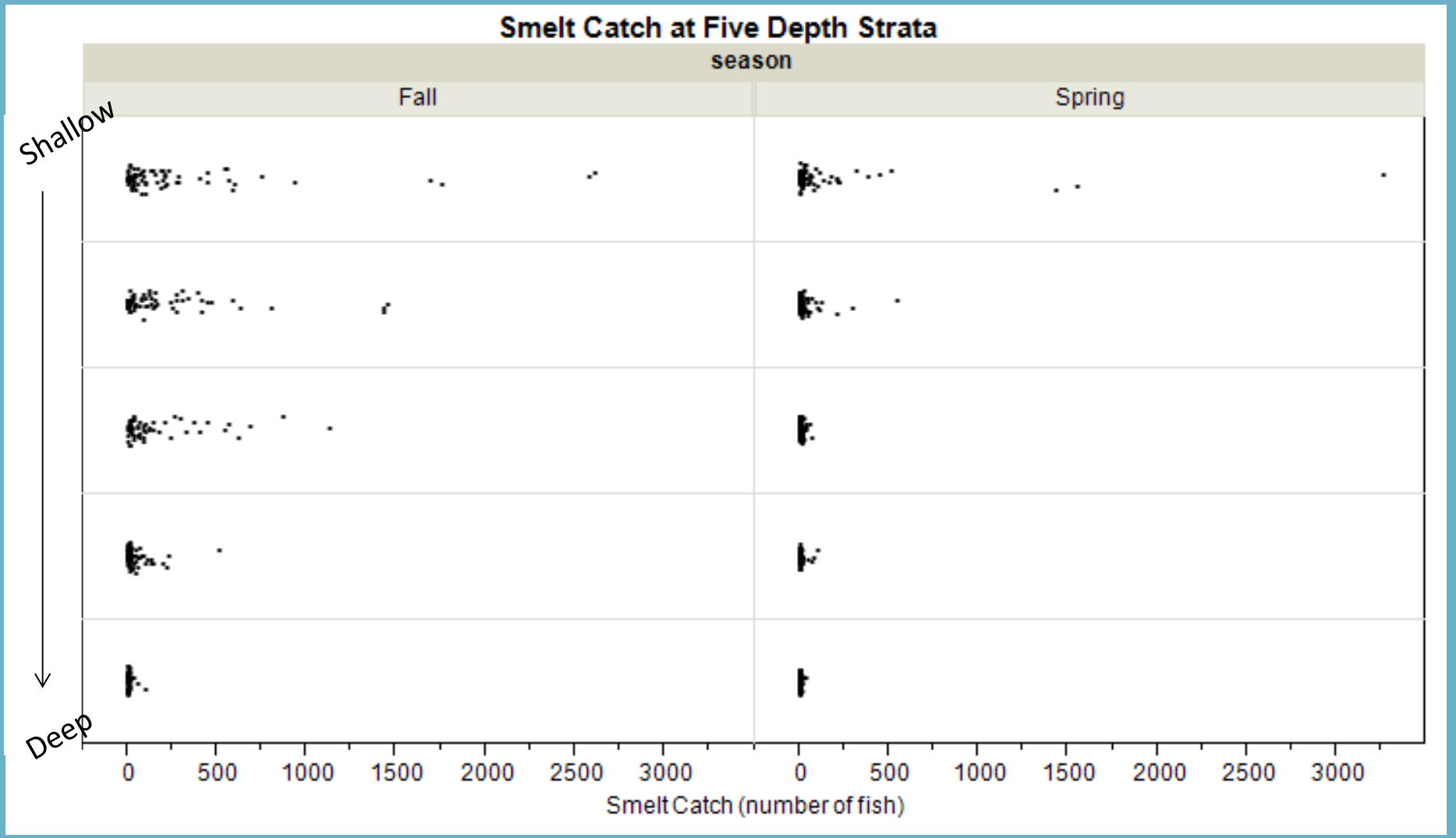
Fall:

- Caught Deeper
- Higher Catches

Spring:

- Caught Shallower
- Smaller Catches, depending on timing

Trawl Survey: Does catch and location of catch differ between seasons?



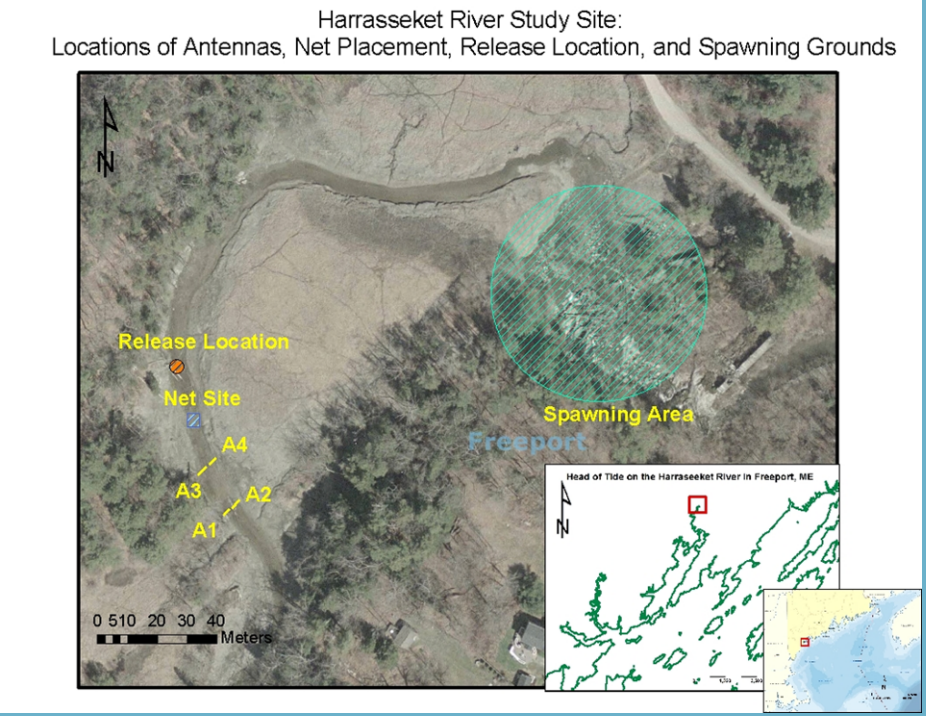
Movements Associated with Spawning Activity

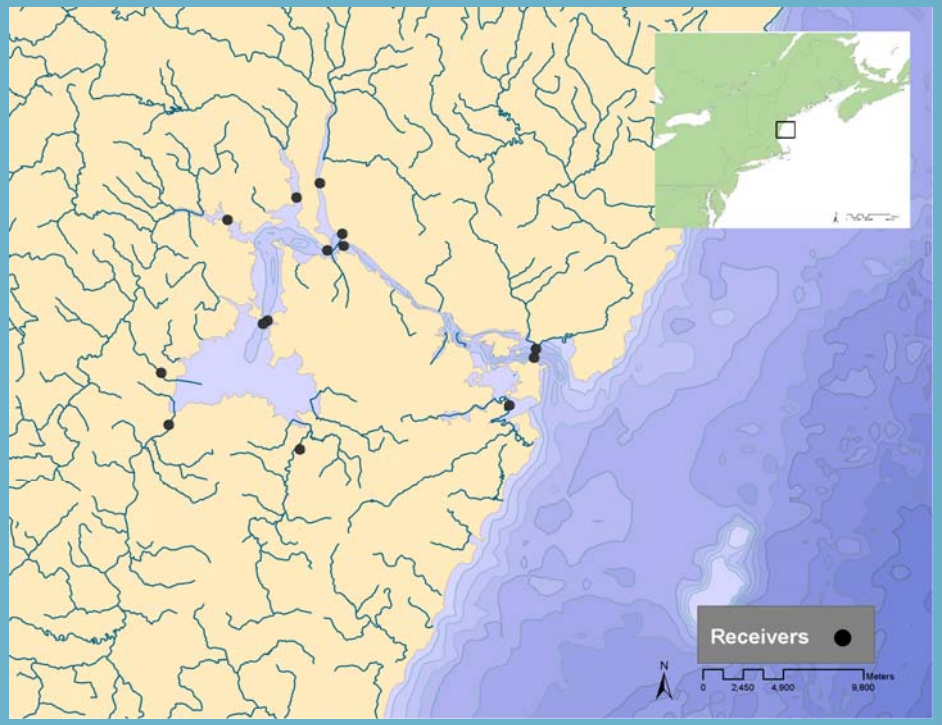
Small-scale movements at the spawning grounds

- **Within-season repeat spawning behavior**

Large-scale movements between rivers and within large bay systems

- **Habitat use during and after the spawning season**



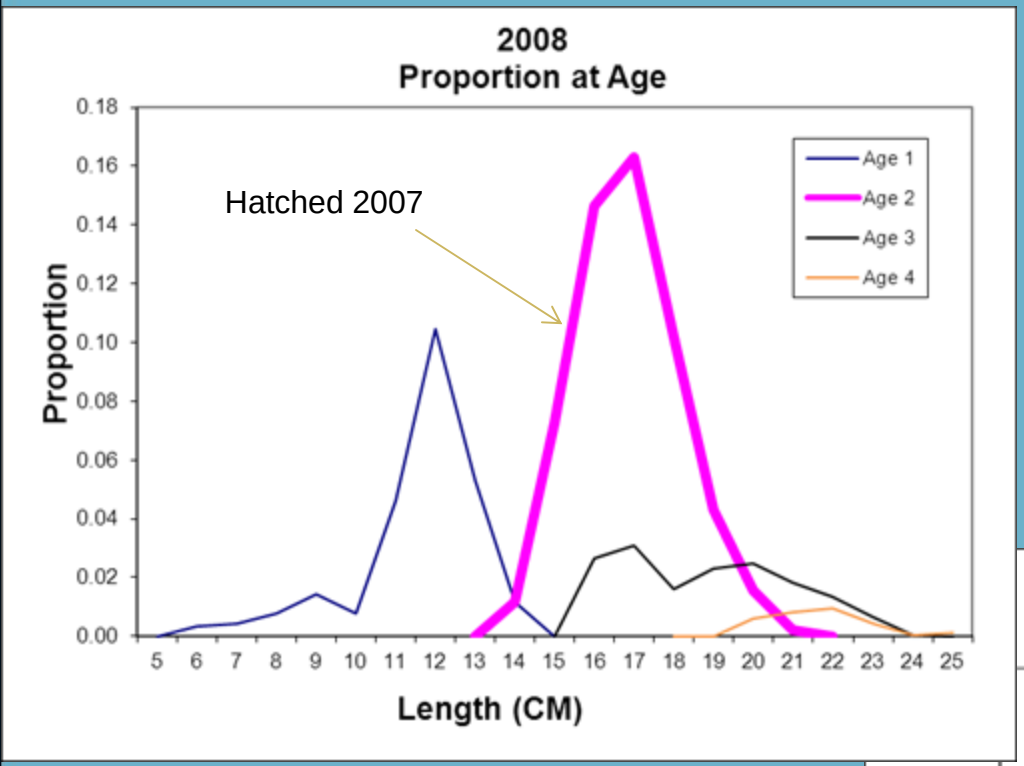


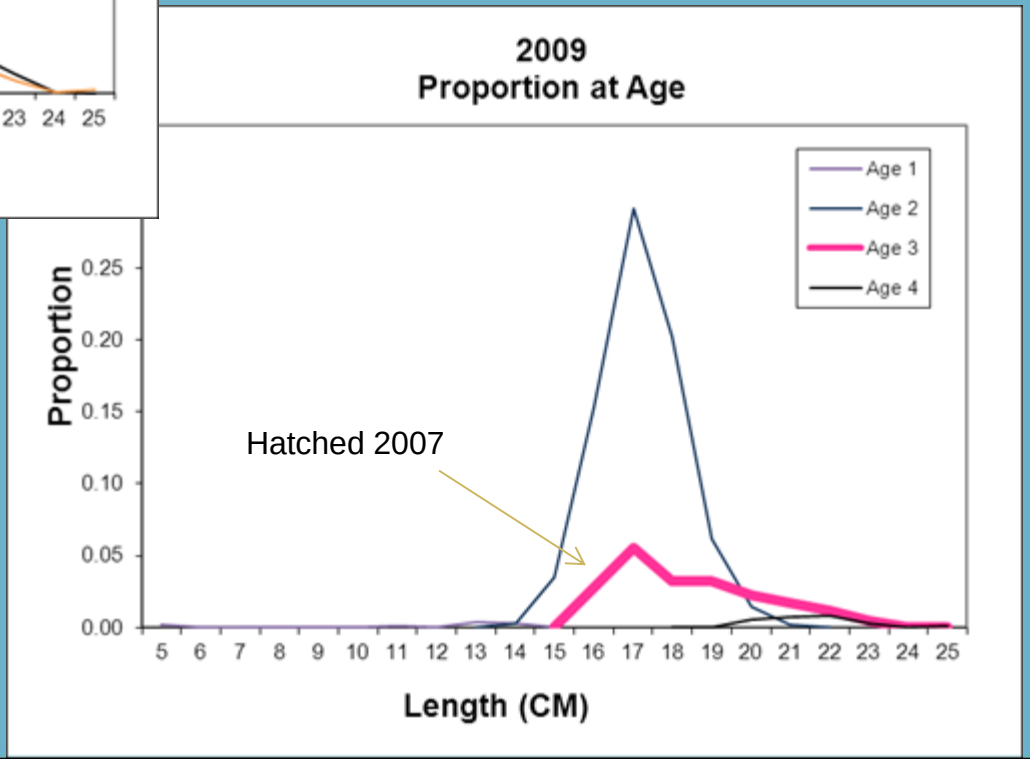
Small Scale: Within-Season Repeat Spawning in Smelt

- Males have a longer physiological spawning period
- Multiple males attending to one female increases fertility success
- Historical mark and recapture studies found same male at the same and different spawning sites within a given year

Clayton 1976; Langlois 1935; Marcotte and Tremblay 1948; Murawski et al. 1980; Purchase et al. 2007; Rupp 1968

Is Within-Season Repeat Spawning Age Dependent?





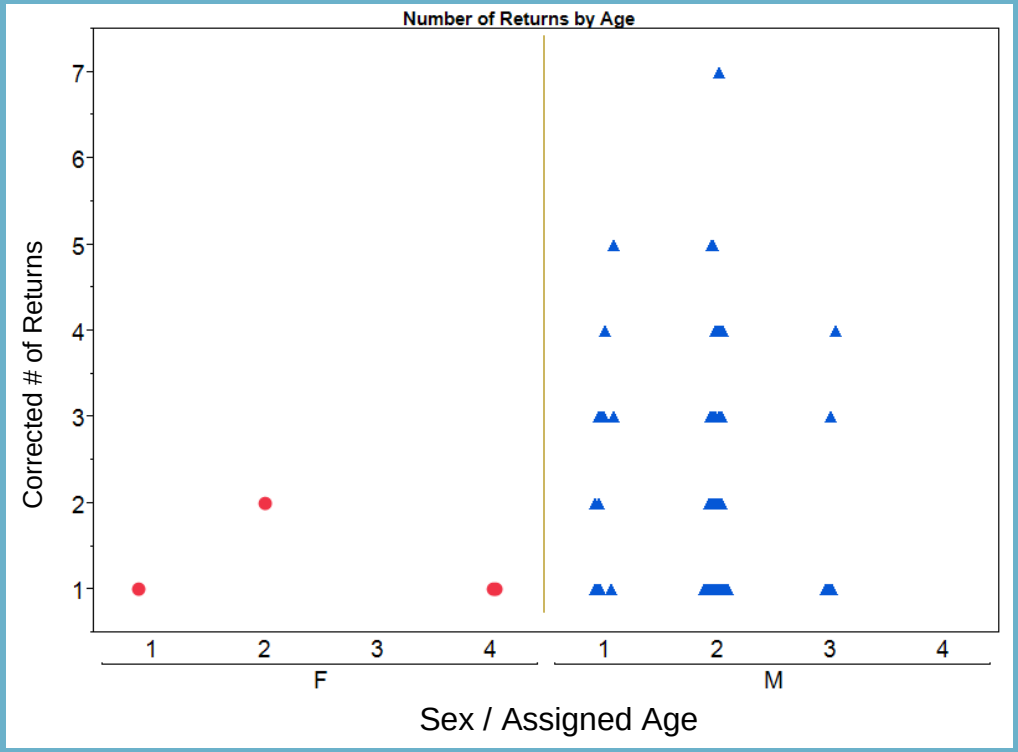
Quantifying Repeat Spawning Behavior in the Harraseeket River

Passive Integrated Transponder (PIT) systems using solar power monitor movement into and out of the spawning grounds 24/7 for 10 weeks March – May fully encompassing the spawning season

Average system efficiency 2009-2011 ~82%

Repeat spawning behavior differs by age and sex

	Average # of Returns	
	F	M
Age-1	1 (n=1)	2.12 (n=17)
Age-2	2 (n=1)	2.03 (n=71)
Age-3	0	1.63 (n=8)
Age-4	1 (n=2)	0



- Age-1 and Age-2 males return at a higher rate than older males
- Males return significantly more than females
- **Evidence of batch spawning by males**

Large Scale Movements During and After Spawning

1. **Are all movements to the spawning grounds made at night-time high tide?**
2. **Do smelt visit different rivers within the same year?**
3. **How long do they remain in near-shore habitats?**

Implications for habitat protection, connectivity and construction of permanent or semi-permanent in-water structures (tidal gates, turbines)

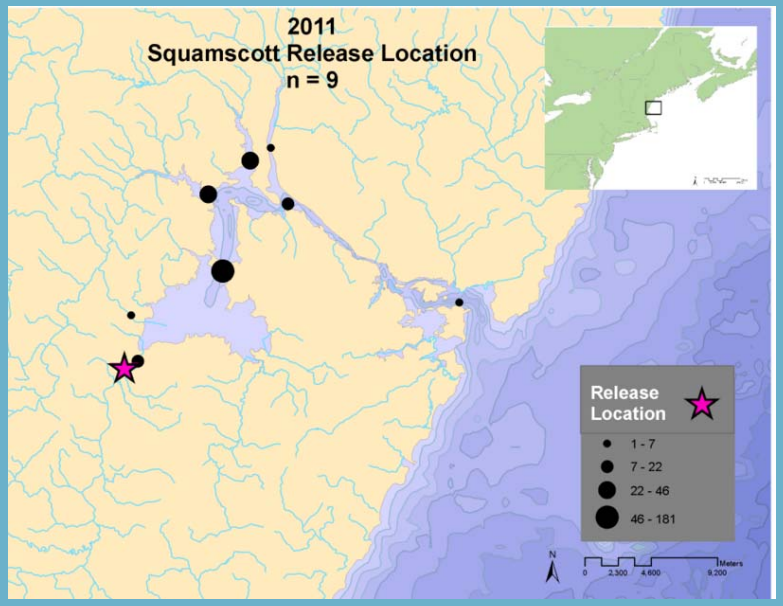
1. Are all movements to the spawning grounds made at night-time high tide?

NO!

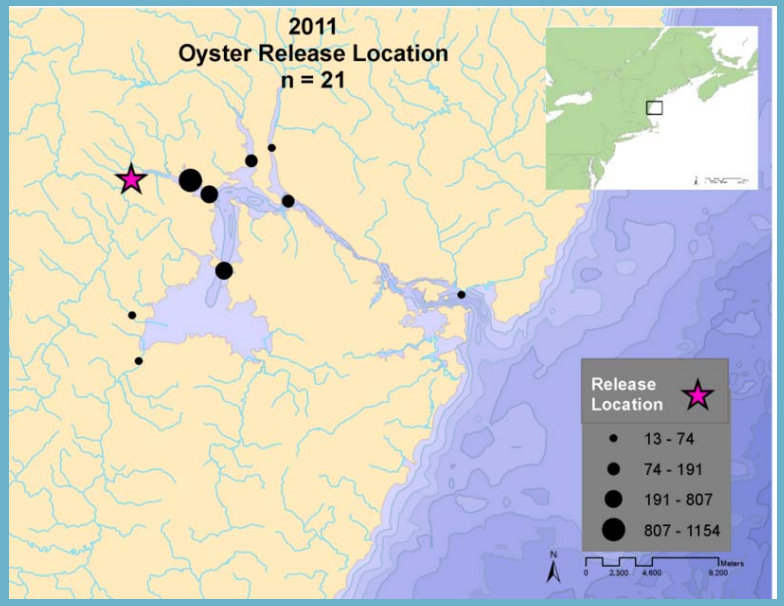
•Tide cycle shifts during spawning season – high tide might not coincide with darkest hours (midnight – 4 A.M.)

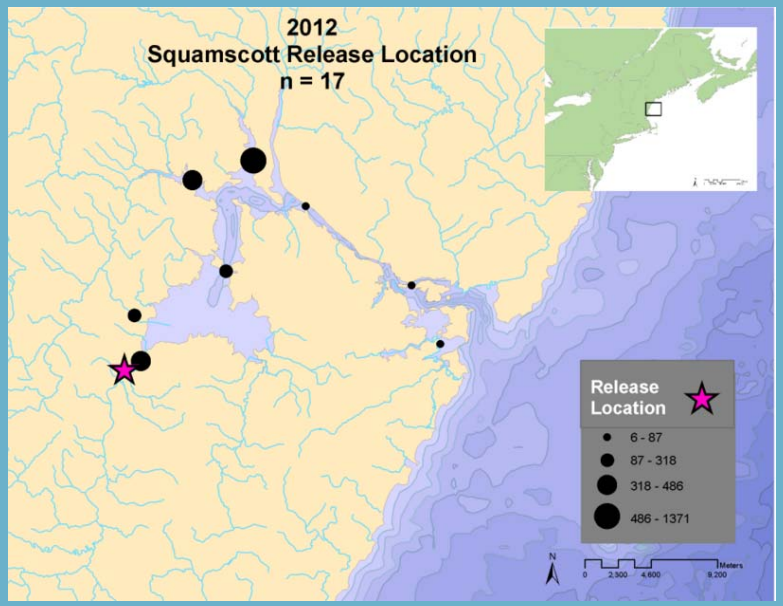
• ~13-15% of all returning smelt (PIT project) made movements against the tide to be at the spawning grounds during darkness

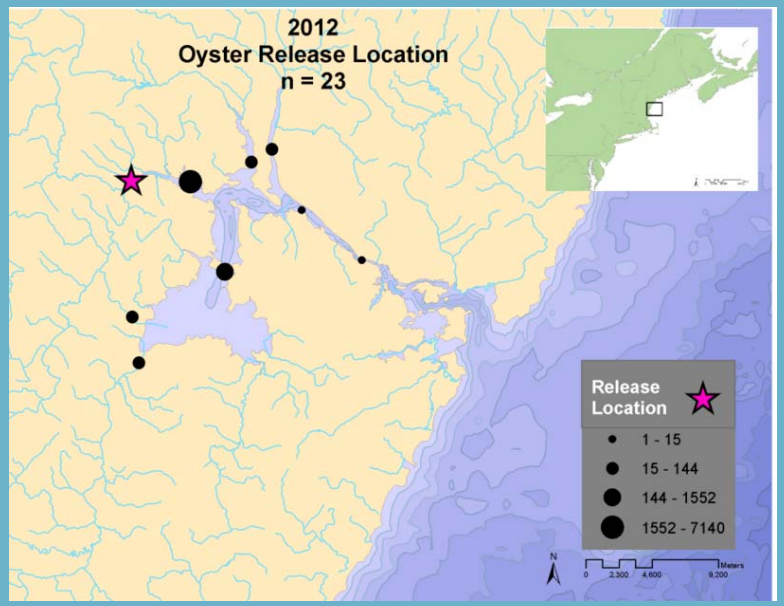
2. Do smelt visit different rivers with the same year?



Yes!



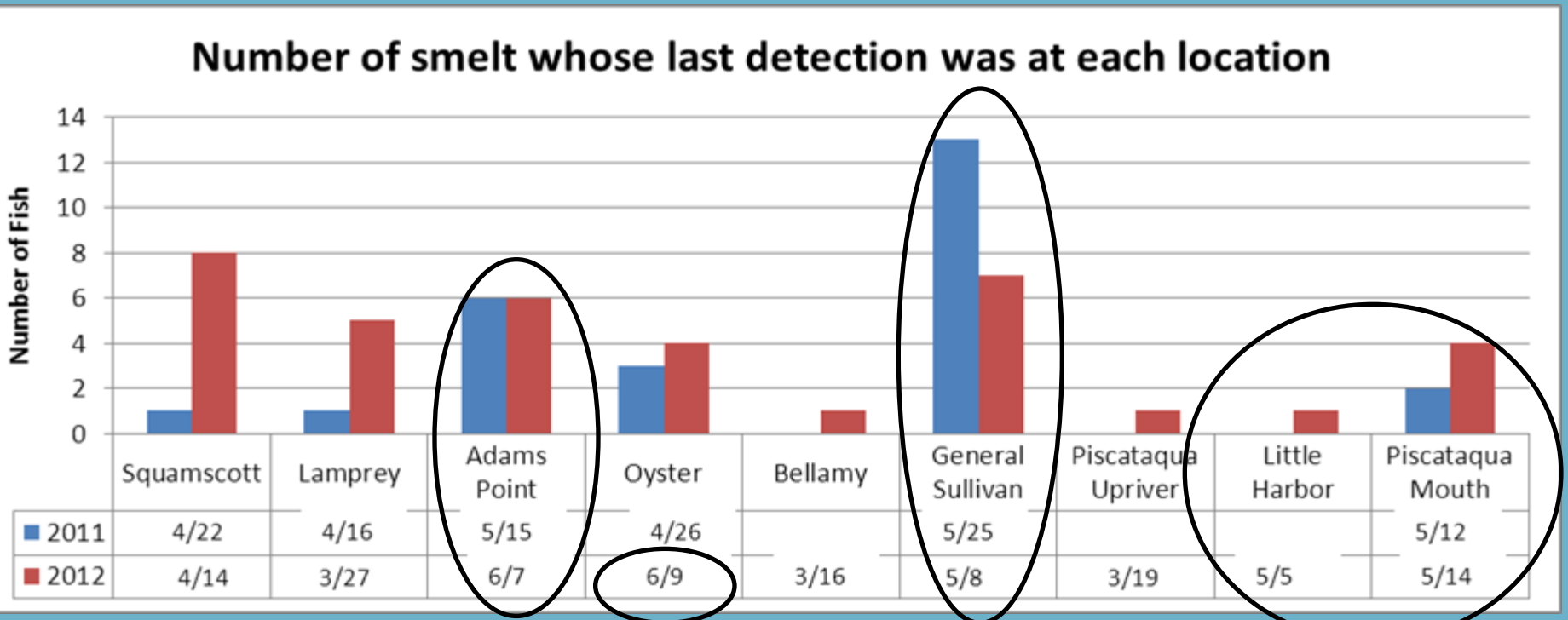




3. How long do they remain in near-shore habitats?

Not all smelt observed to leave the system

Possible factors: predation, tag mortality, lost receivers, receiver efficiency



Date is last detection date at each location for each year

UPDATED Life Cycle

Movements (still) directed by life cycle (spawning) and water temperature

Spring

Adults are inshore and in streams/rivers

Spawn at head of tide

- ✓ Within-season repeat spawning by males
- ✓ Movement between multiple rivers
- ✓ May stay in estuaries and embayments after end of spawning

UPDATED Life Cycle

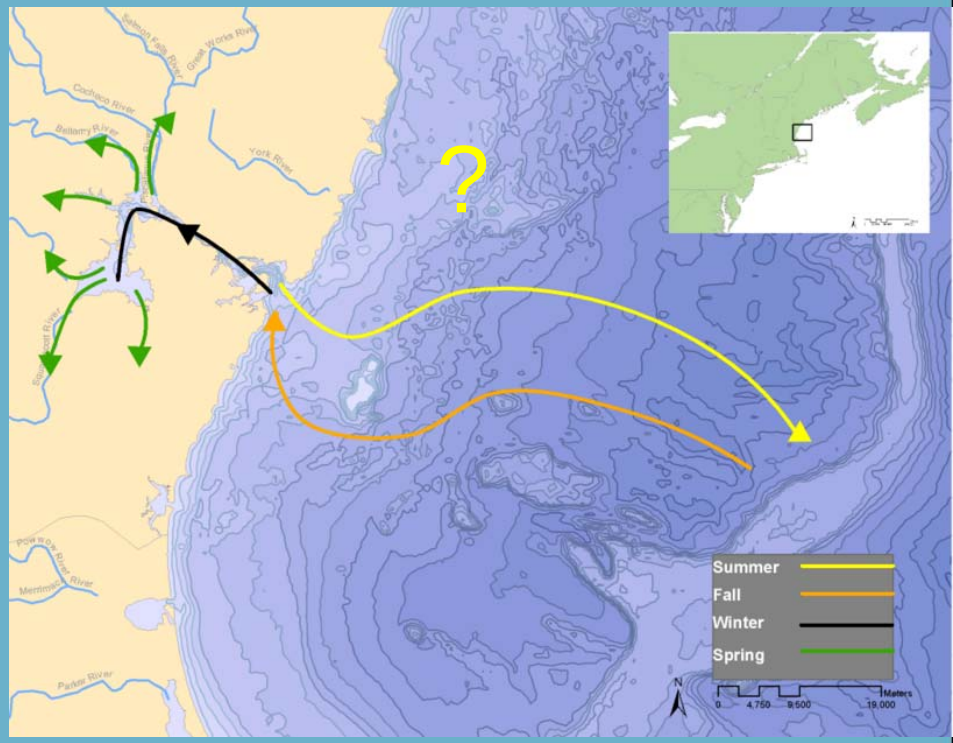
Summer

Young of the year in estuaries

Adults in coastal waters

Or remaining in embayments?

No surveys targeting adults in summer



UPDATED Life Cycle

Fall

Moving towards shore

Bays and mouths of rivers and further offshore?

Winter

Sheltered bays, large tidal rivers

Project Partners

Maine Department of Marine Resources

New Hampshire Department of Fish and Game

Great Bay National Estuarine Research Reserve

Massachusetts Division of Marine Fisheries

University of New Hampshire

USGS Conte Anadromous Fish Research Laboratory

Funding through National Marine Fisheries Services, Office of Protected Species, Species of Concern Grant Program

Citations:

Buckley, J.L. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic); Rainbow Smelt. U.S. Fish and Wildlife Service Biological Report 82(11.106). U.S. Army Corps of Engineers, TR EL-82-4. 11pp.

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