LIVE INTERACTIVE LEARNING @ YOUR DESKTOP

Climate Change along Northeast Coasts and Estuaries

Presented by: Dr. John Casselman, Chris Bowser, and Cornelia Harris

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National Science Teachers Association Presents:

Climate Change along Northeast Coasts and Estuaries

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About today's web seminar….

- Focus on places and species
- Introduction to Estuaries
- Eels at the Edge
- Climate change curriculum
- Ask questions, follow-up resources

NERR: Partnerships between NOAA and local agencies

NATIONAL ESTUARINE RESEARCH RESERVES

A network of 27 protected areas

1. Wells, Maine
2. Great Bay, New Hampshire
3. Waquoit Bay, Massachusetts
4. Narragansett Bay, Rhode Island
5. Connecticut *
6. Hudson River, New York
7. Jacques Cousteau, New Jersey
8. Delaware
9. Chesapeake Bay, Maryland
10. Chesapeake Bay, Virginia
11. North Carolina
12. North Inlet-Winyah Bay, South Carolina
13. ACE Basin, South Carolina
14. Sapelo Island, Georgia
15. Guana Tolomato Matanzas, Florida
16. Rookery Bay, Florida
17. Apalachicola, Florida
18. Weeks Bay, Alabama
19. Grand Bay, Mississippi
20. Mission-Aransas, Texas
21. Tijuana River, California
22. Elkhorn Slough, California
23. San Francisco Bay, California
24. South Slough, Oregon
25. Padilla Bay, Washington
26. Wisconsin *
27. Old Woman Creek, Ohio
28. St. Lawrence River, New York *
29. Jobos Bay, Puerto Rico
30. Kachemak Bay, Alaska

** Proposed Reserve*

Use clip art to put YOURSELF on the map

What is an estuary?

- “Where rivers meet the sea”
- Mix of salt and fresh waters
- Tidal influence
- High diversity
- “Gateway” between land and sea

When society meets sea level rise

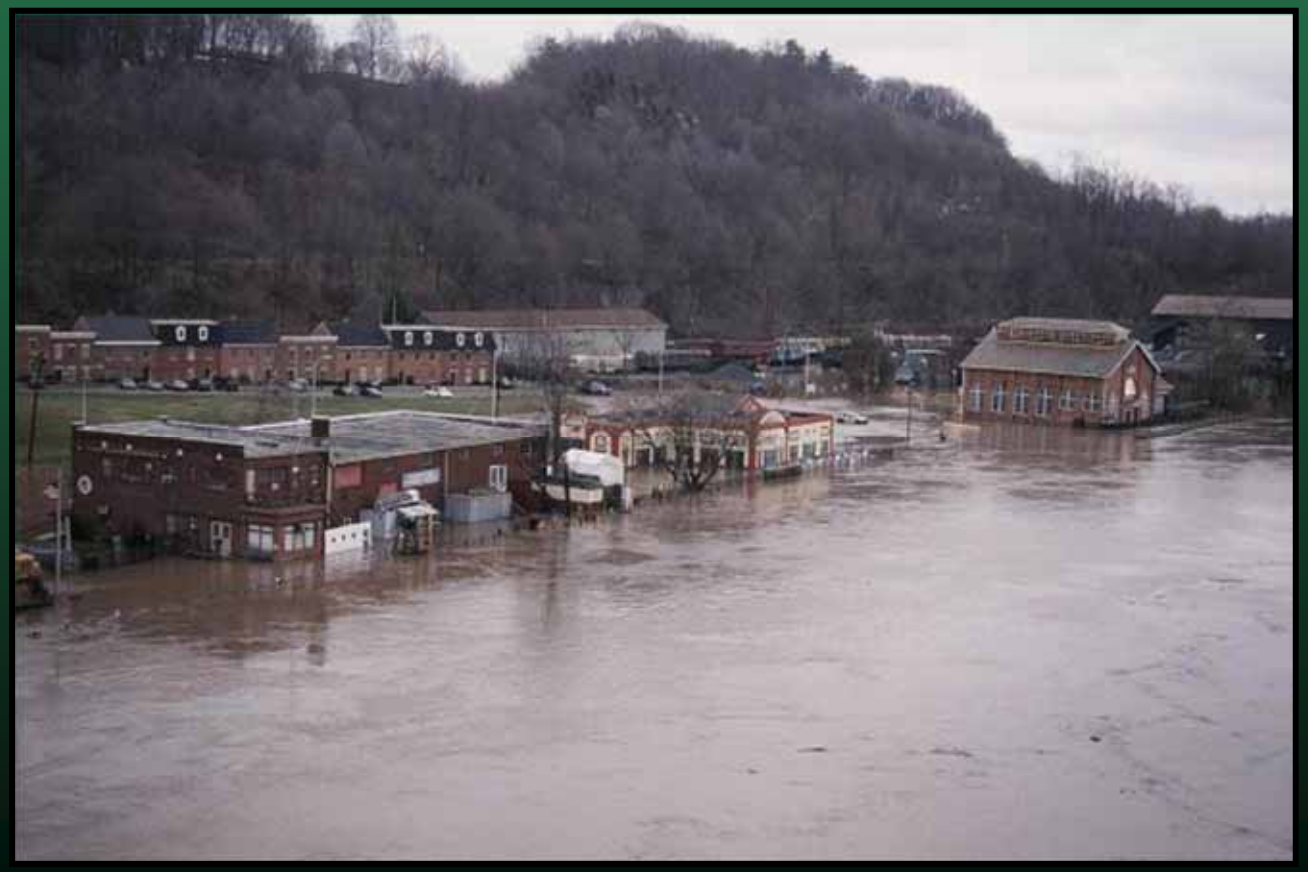
What percentage of the US population lives in coastal counties?

A: 10%

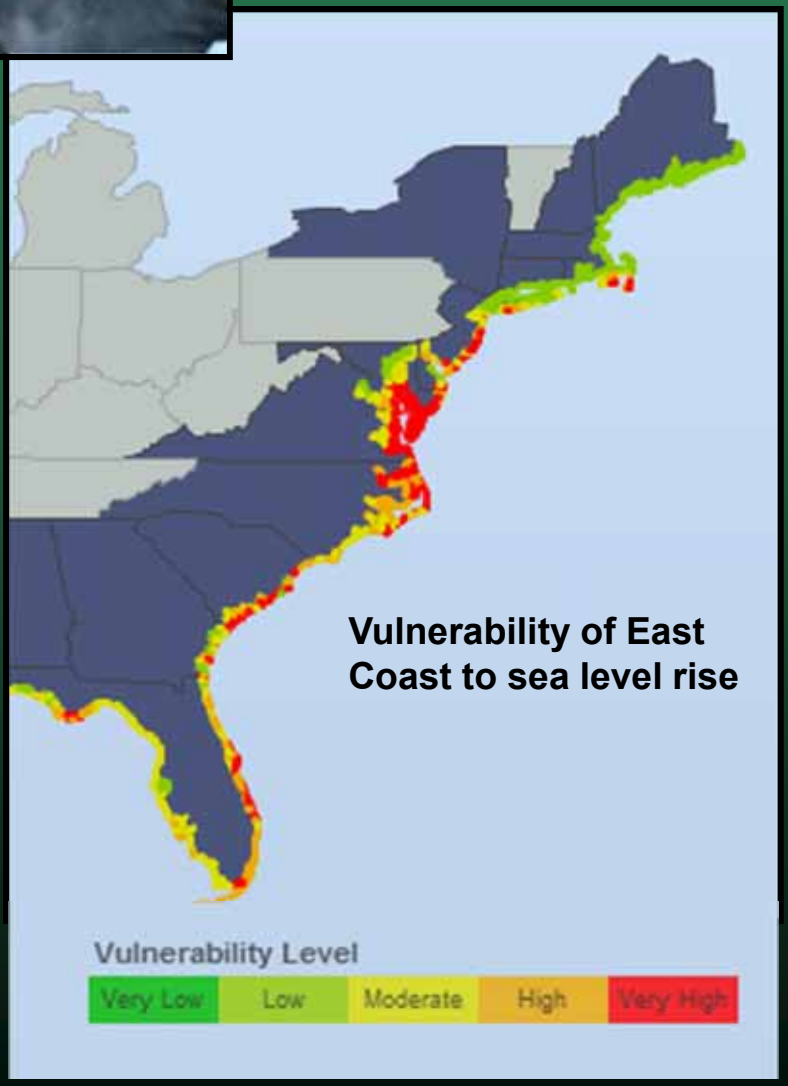
B: 25%

C: 50%

D: 75%



Societal and Economic Consequences



- **52%** of US population lives in coastal counties, which represent **17%** of US land area
- **8.5 million** people in the US live in Special Flood Hazard Areas
- **$510 billion** in assets are insured by the National Flood Insurance Program in Special Flood Hazard Areas

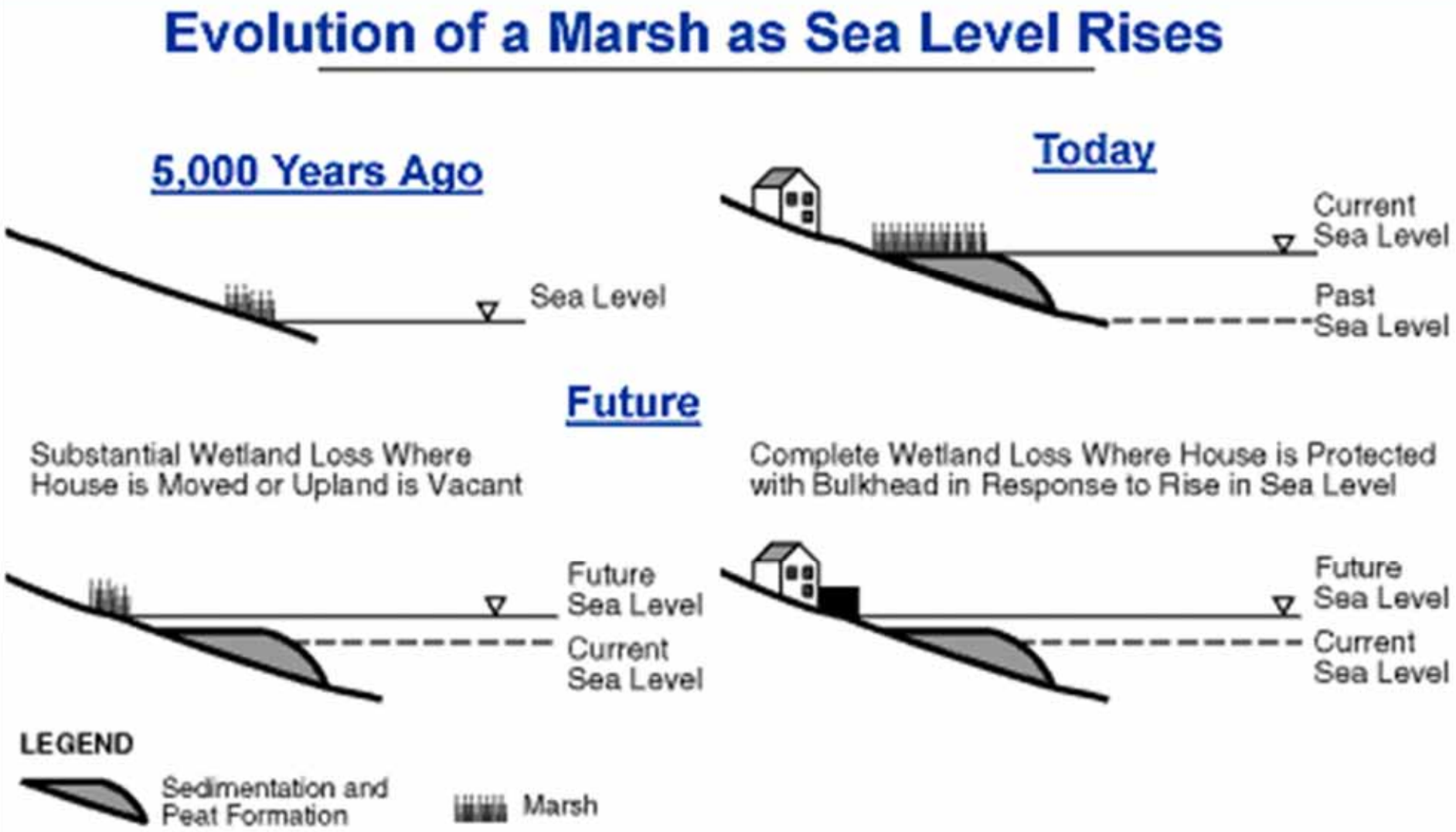
www.stateofthecoast.noaa.gov

Ecosystem Services of Tidal Shorelines

- Provide vital habitat
- Dissipate energy
- Regulate vital processes
- Serve as dispersal corridors
- Support high biodiversity and produce plants and animals

Dave Strayer. 2008. Ecology of freshwater shore zones, unpublished.

Drowning marshes….



Source: Titus, J.G. 1991. Greenhouse Effect and Coastal Wetland Policy, *Environmental Management* 15(1):39-58.

….or rising sediments?

Shifting Species

Changes in water temperature can affect range of **commercially** and **ecologically** important species

American lobster

Soft shell clam

Let's Pause for Questions?

American eels

Next: Eels on the Edge

Dr. John Casselman
Queen's University,
Ontario Canada

Eels at the Edge:

Dramatic Decline of the American Eel (*Anguilla rostrata*): An Important Indicator and Integrator of Aquatic Ecosystem Health

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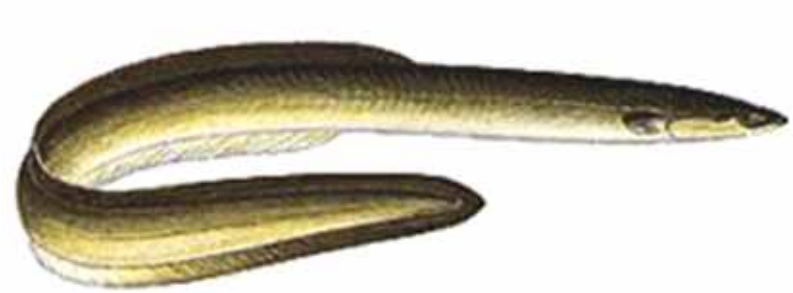
Webinar, November 2010

The unprecedented disappearance of an ancient and migratory fish from the St. Lawrence River!



American eels

are leaving the largest basin of fresh water on the planet and not returning!

Background

- American eels at the extremity of the range in St. Lawrence River watershed were once extremely abundant, highly valued, and a heavily used resource but now have declined to such a precarious state that they are officially classified as *endangered*.
- Declining abundance and loss of recruitment to the distant St. Lawrence R. stocks possibly forewarn a widespread decline of this ancient migratory species.
- The extent and causal factors of this decline need to be more thoroughly examined and better understood.

Let's explore the problem of "Eels at the Edge"

Eel Biology - 1

- American eels found from Gulf of Mexico to Labrador and lower Great Lakes
- Catadromous, spawn in Sargasso Sea (Bermuda Sea), females mature in fresh water
- Eels panmictic, one genetic stock, species is one population
- Complex life cycle; young drift in Gulf Stream (willow-leaf-like *leptocephali*)
- Go through metamorphosis, unpigmented *glass eels* swim into fresh water
- Pigmented *larval juveniles* swim to maturing grounds, reach upper St. Lawrence River-Lake Ontario 5,000 km after 4-9 yr

Eel Biology - 2

- Juveniles swimming into fresh water along the Atlantic Coast are closer to the spawning ground
- Drift of Gulf Stream makes central Atlantic states closer to source of recruitment than southern or northern states
- Atlantic provinces are farther, particularly Gulf region when compared with Fundy region
- Ottawa and St. Lawrence rivers-Lake Ontario system at extremity of the range
- Northern stocks return to spawn, and die after generation time of approximately 20 yr
- Generation time shorter in south part of range, 6-12 yr

Glass eel

Leptocephalus

Elver

Oceanic

Continental

Eggs

Yellow eel

Spawning

St. Lawrence R. system

Silver eel

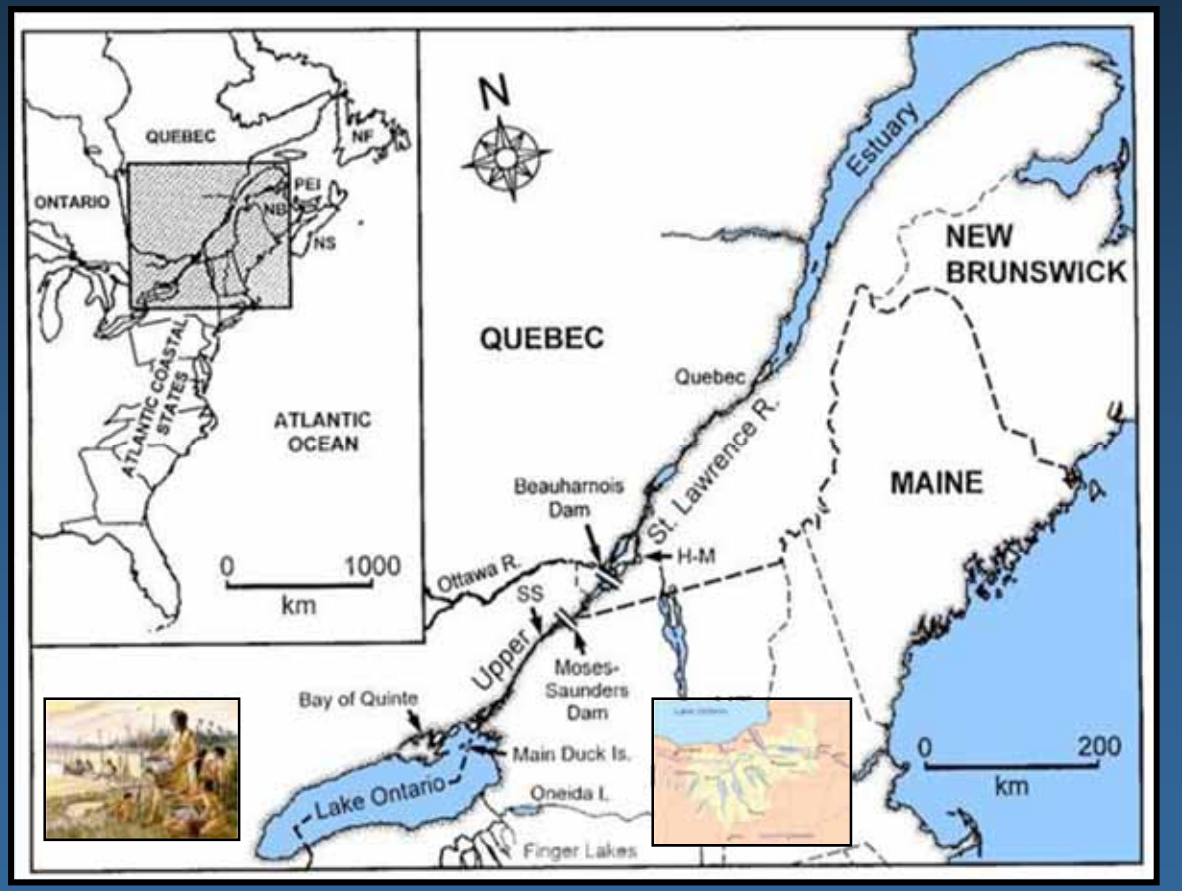
A mysterious and ancient fish with a unique life history

Life cycle of the freshwater eel


Extremity of the range
American Eel
Anguilla rostrata
Legend
Native Freshwater Range
Caribbean Near-shore Marine Range
N
600 0 600 1200 Km
Map by NatureServe, May 2006

Historic Insights – St. Lawrence River-Lake Ontario Stock

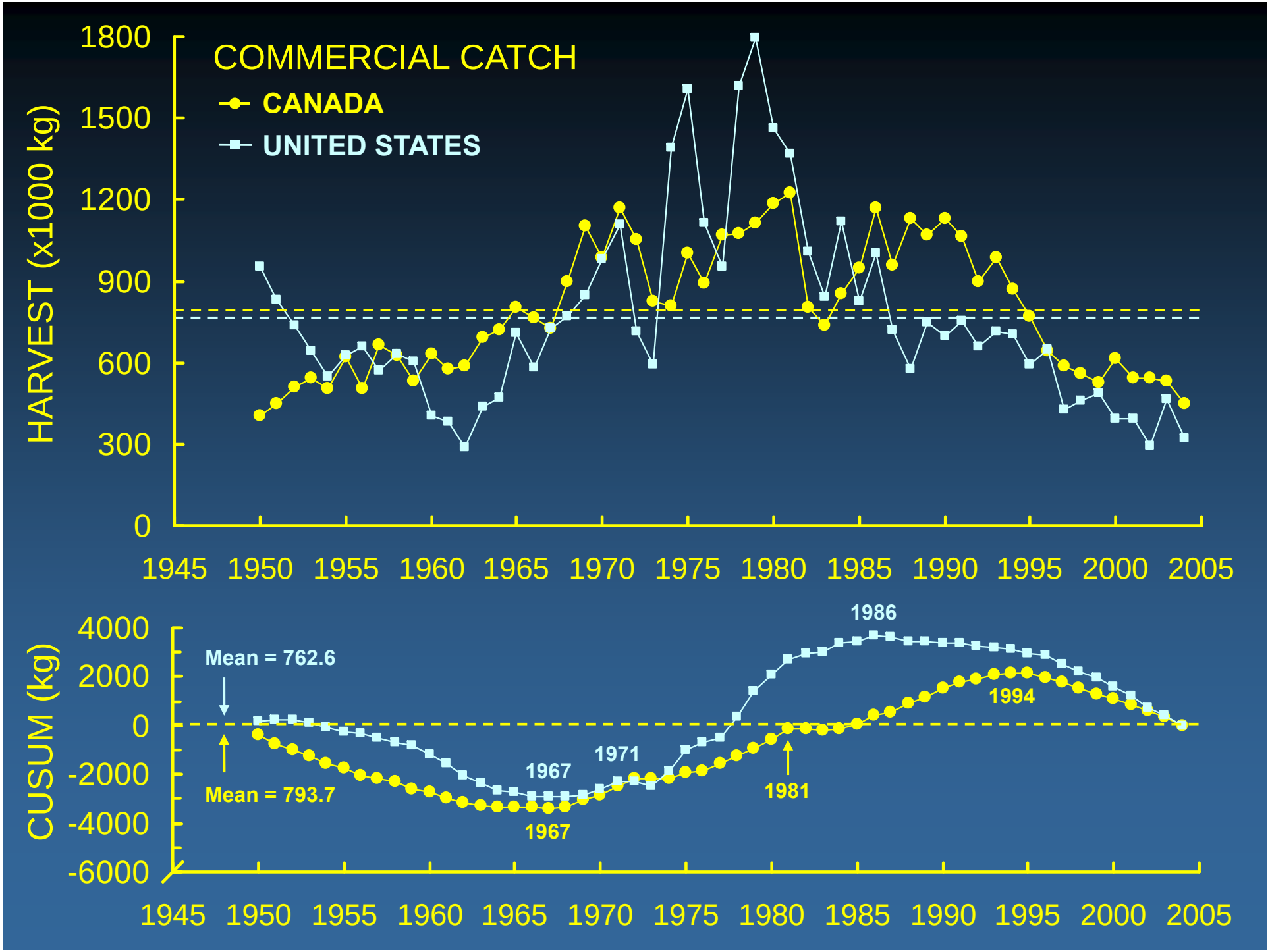
- Ottawa and St. Lawrence river stocks are at extremity of range, were historically large, producing the largest, oldest, most fecund females
- Long-term catch statistics and indices of abundance among best of any of world's three anguillid species (e.g., commercial eel catches, eel ladder)
- Prehistoric and historic evidence confirms eels were a dependable, highly valued, nutritious resource for Aboriginals and early European settlers and important winter and travelling food
- Historically half of inshore fish biomass was eels
- 1600s "celebrated eel fisheries" upper St. Lawrence River "single Onondaga eel fisherman could spear 1,000 in one night"

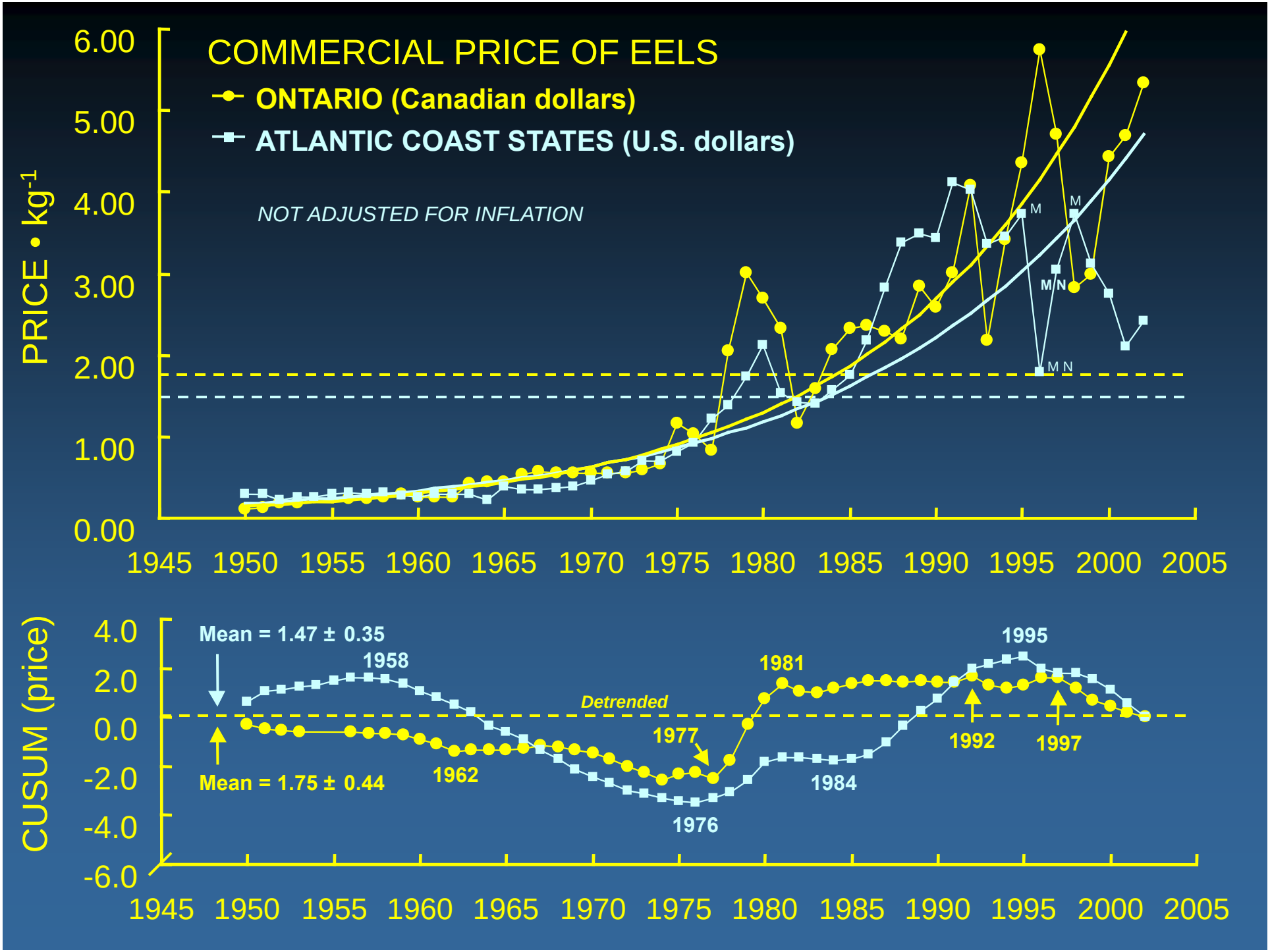


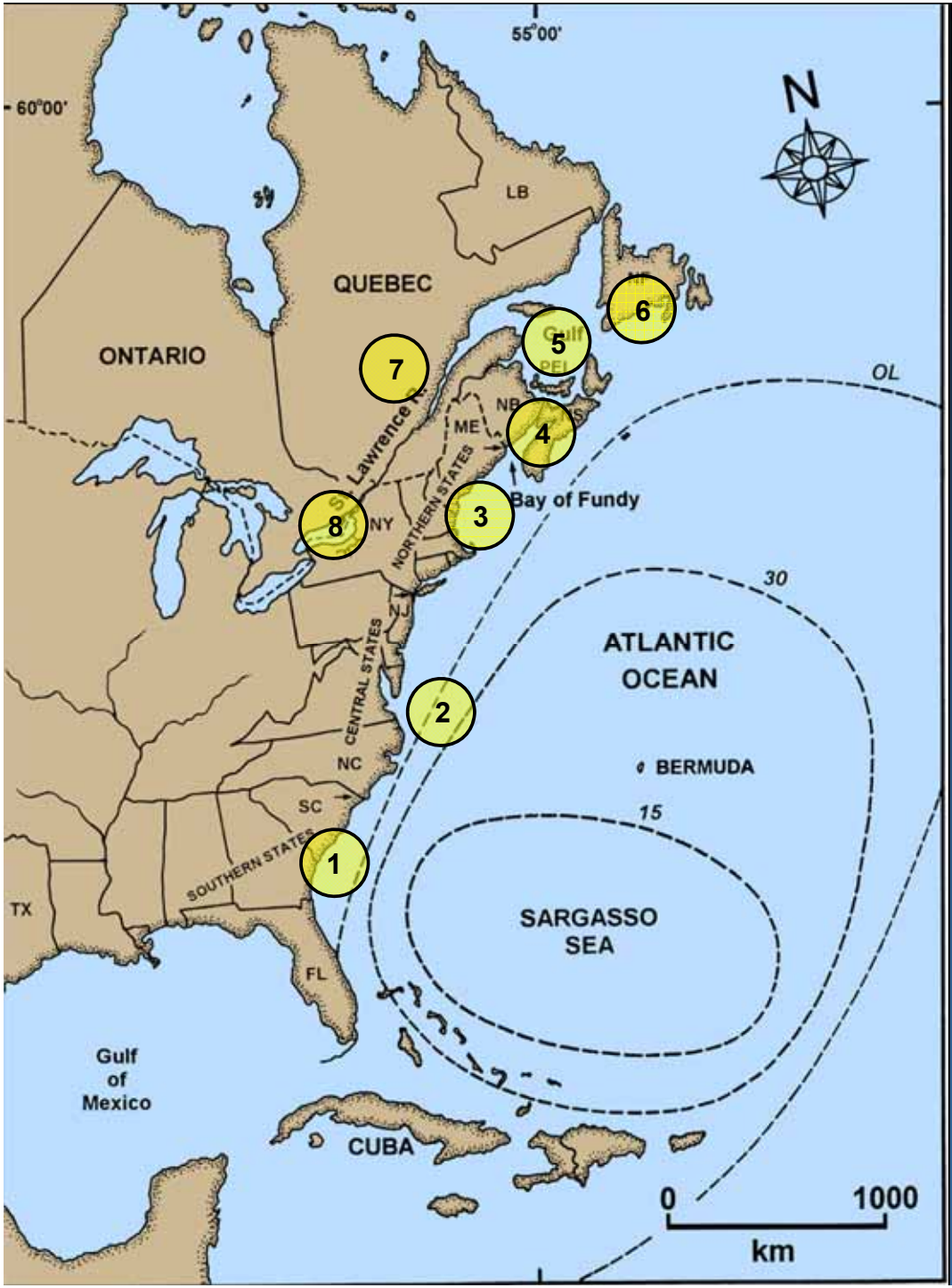
Long-Term Trends in Commercial Harvest and Price

Combined and by region in Canada and United States

Recent trends "Eels at the Edge"

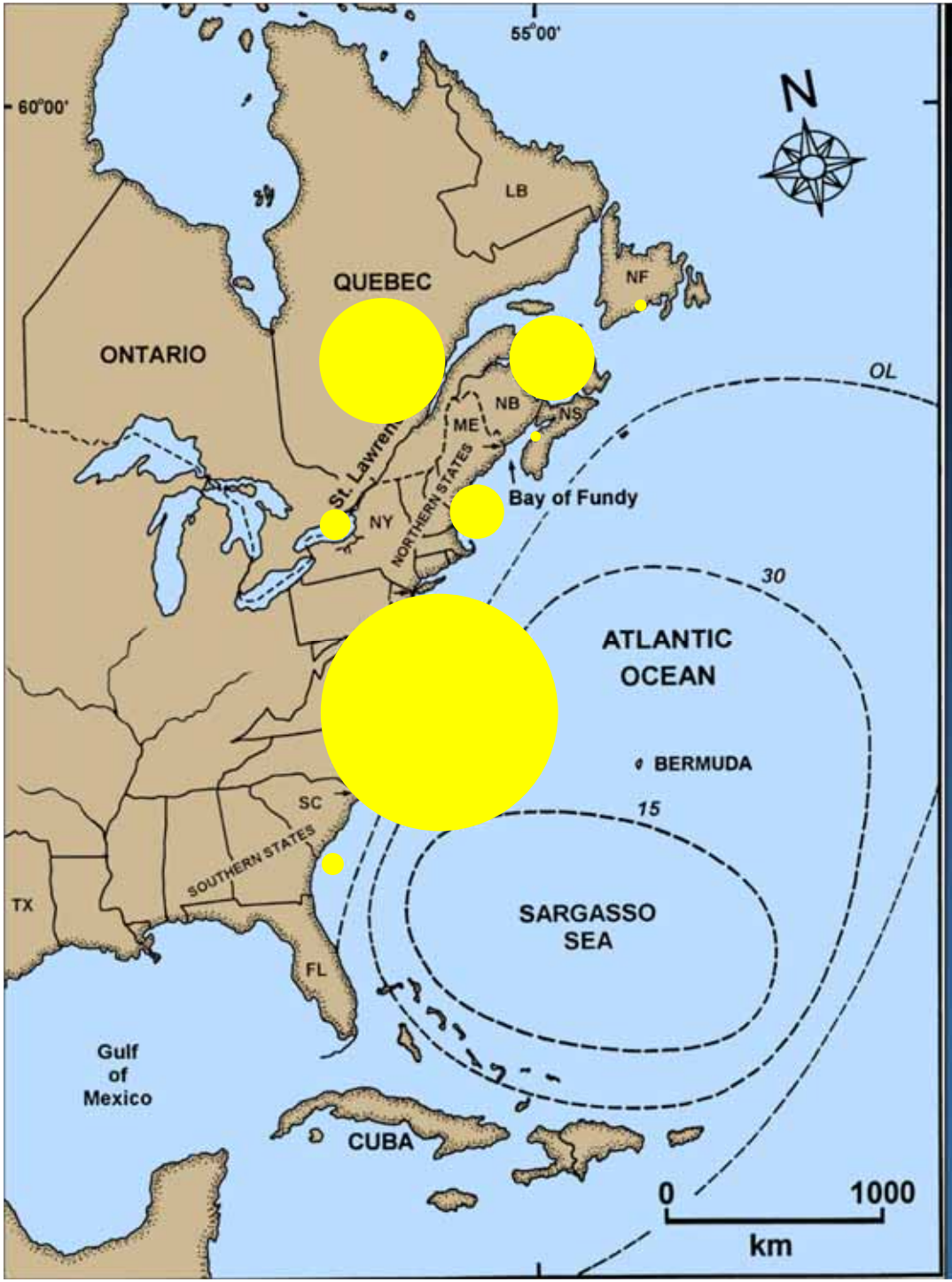

COMMERCIAL CATCH
CANADA
UNITED STATES
HARVEST (x1000 kg)
1800
1500
1200
900
600
300
0
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005
CUSUM (kg)
4000
2000
0
-2000
-4000
-6000
Mean = 762.6
Mean = 793.7
1986
1994
1971
1967
1967
1981
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005


COMMERCIAL PRICE OF EELS
ONTARIO (Canadian dollars)
ATLANTIC COAST STATES (U.S. dollars)
NOT ADJUSTED FOR INFLATION
PRICE • kg-1
6.00
5.00
4.00
3.00
2.00
1.00
0.00
M
M
M/N
M N
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005
CUSUM (price)
4.0
2.0
0.0
-2.0
-4.0
-6.0
Mean = 1.47 ± 0.35
Mean = 1.75 ± 0.44
Detrended
1958
1962
1976
1977
1981
1984
1992
1995
1997
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005



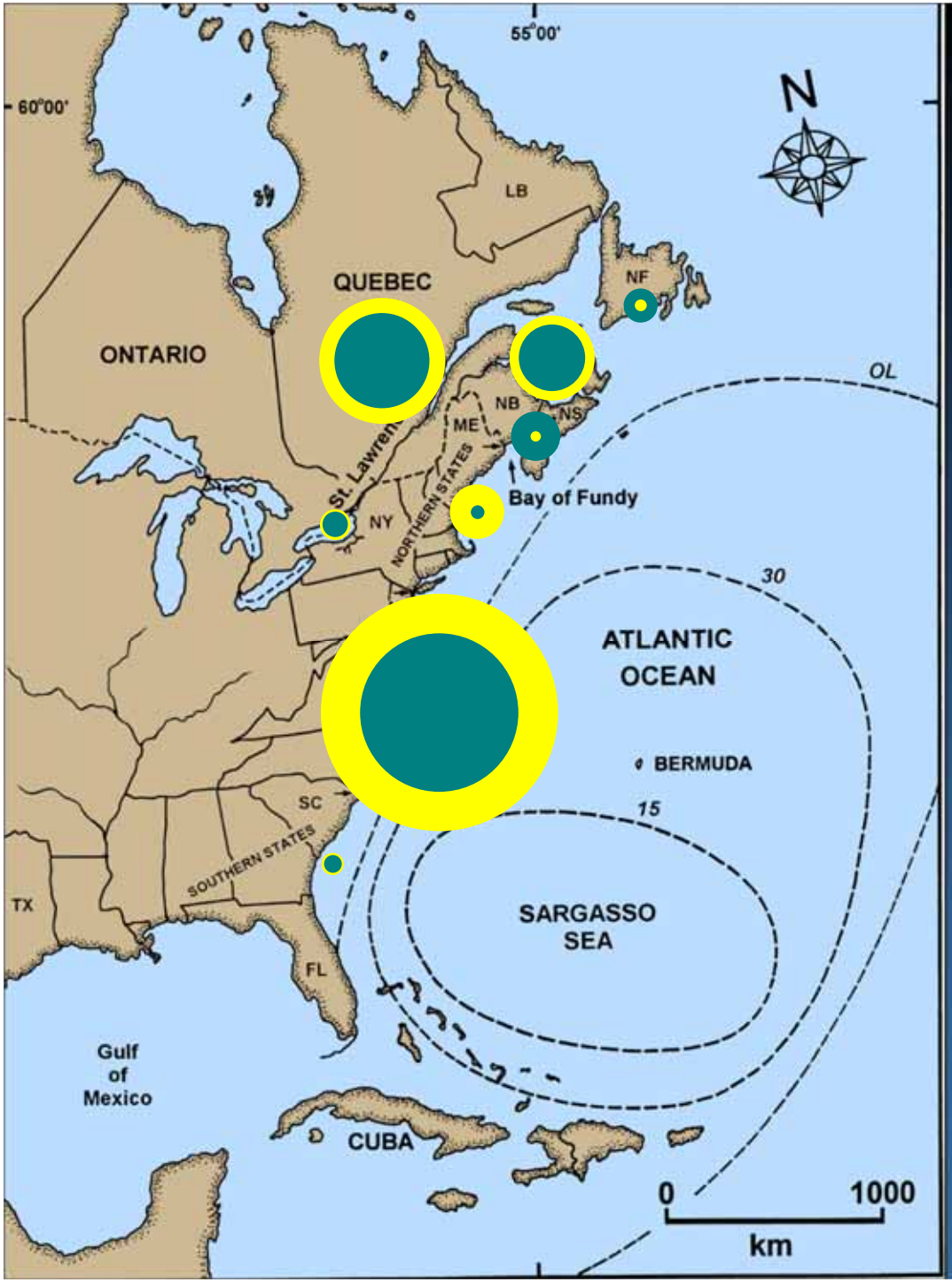
American Eel Harvest Regions

1. Southern States
2. Central States
3. Northern States
4. Scotia–Fundy Region
5. Gulf Region
6. Newfoundland Region
7. Lower St. Lawrence River
8. Upper St. Lawrence River and Lake Ontario



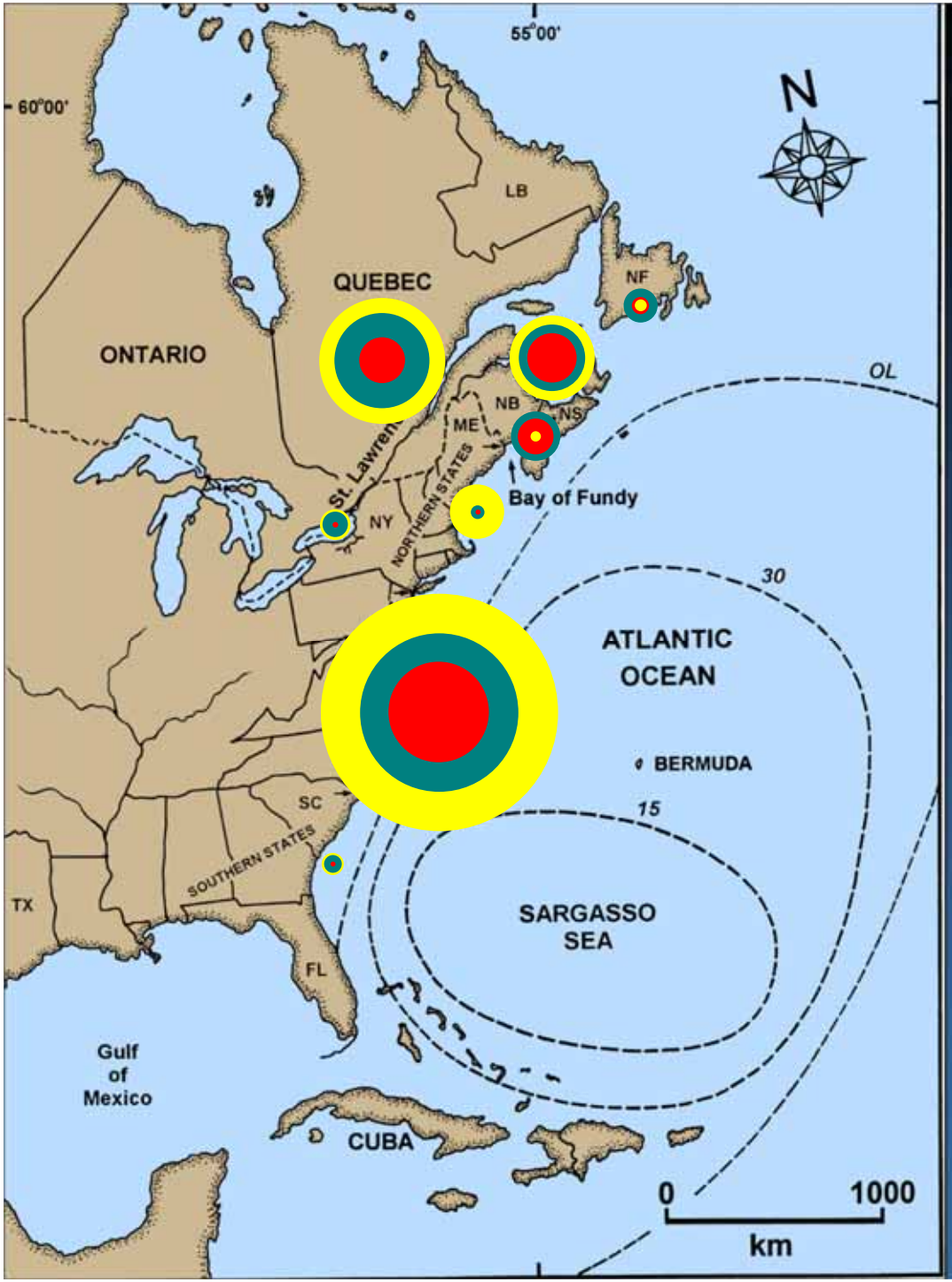
Mean Harvest 1980 to 1984 (x1000 kg)

Southern States	79.0
Central States	876.7
Northern States	202.3
Newfoundland Region	40.8
Gulf Region	318.2
Scotia–Fundy Region	31.8
Lower St. Lawrence River	461.9
Upper St. Lawrence River and Lake Ontario	117.5
Total	2,128.2



Mean Harvest 1990 to 1994 (x1000 kg)

Southern States	70.4
Central States	589.9
Northern States	51.4
Newfoundland Region	119.6
Gulf Region	244.8
Scotia–Fundy Region	153.8
Lower St. Lawrence River	347.7
Upper St. Lawrence River and Lake Ontario	109.2
Total	1,686.8



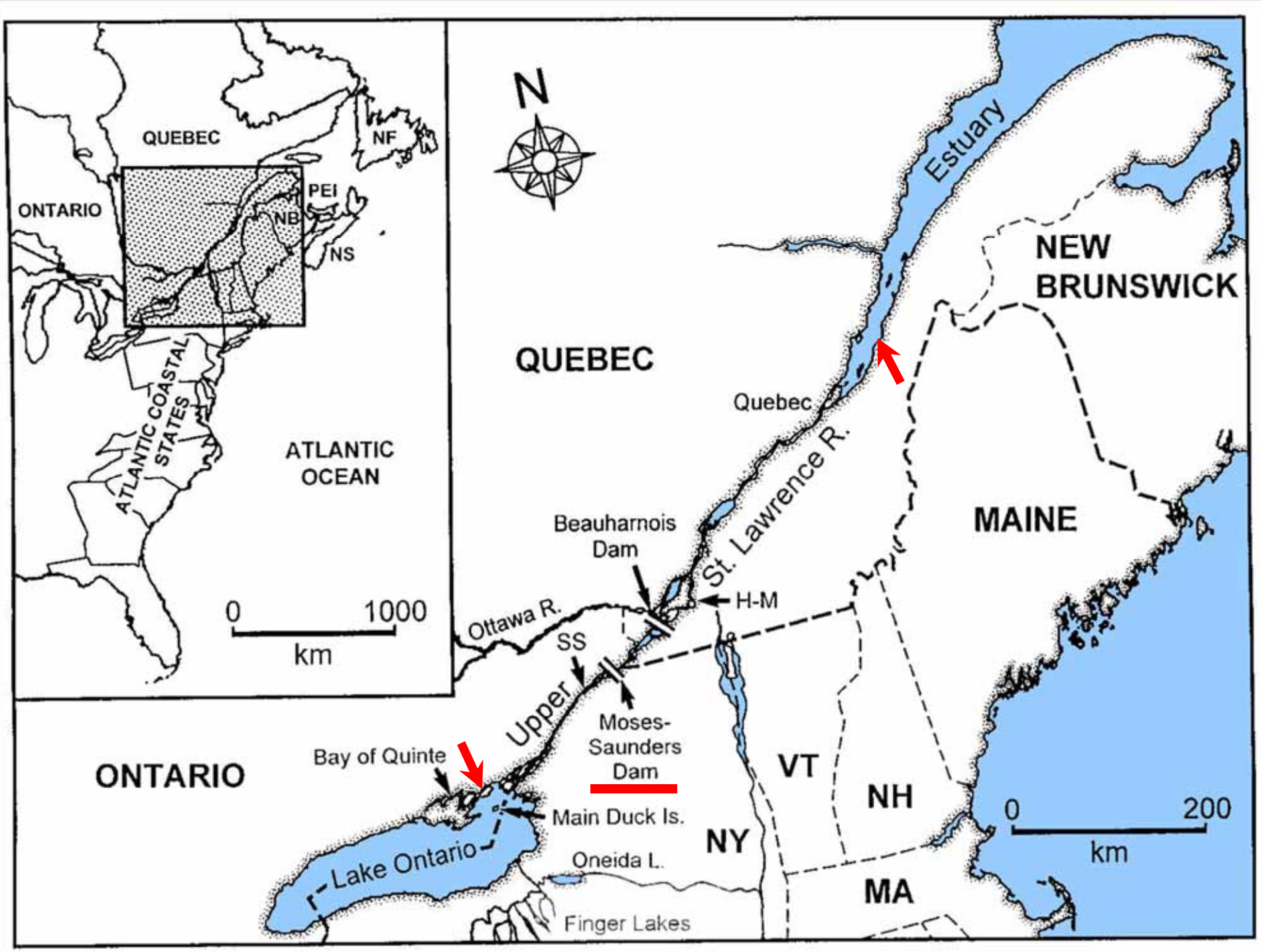
Mean Harvest 2000 to 2004 (x1000 kg)

Southern States	4.2
Central States	369.9
Northern States	11.0
Newfoundland Region	56.0
Gulf Region	180.0
Scotia–Fundy Region	111.8
Lower St. Lawrence River	168.4
Upper St. Lawrence River and Lake Ontario	20.8
Total	922.1

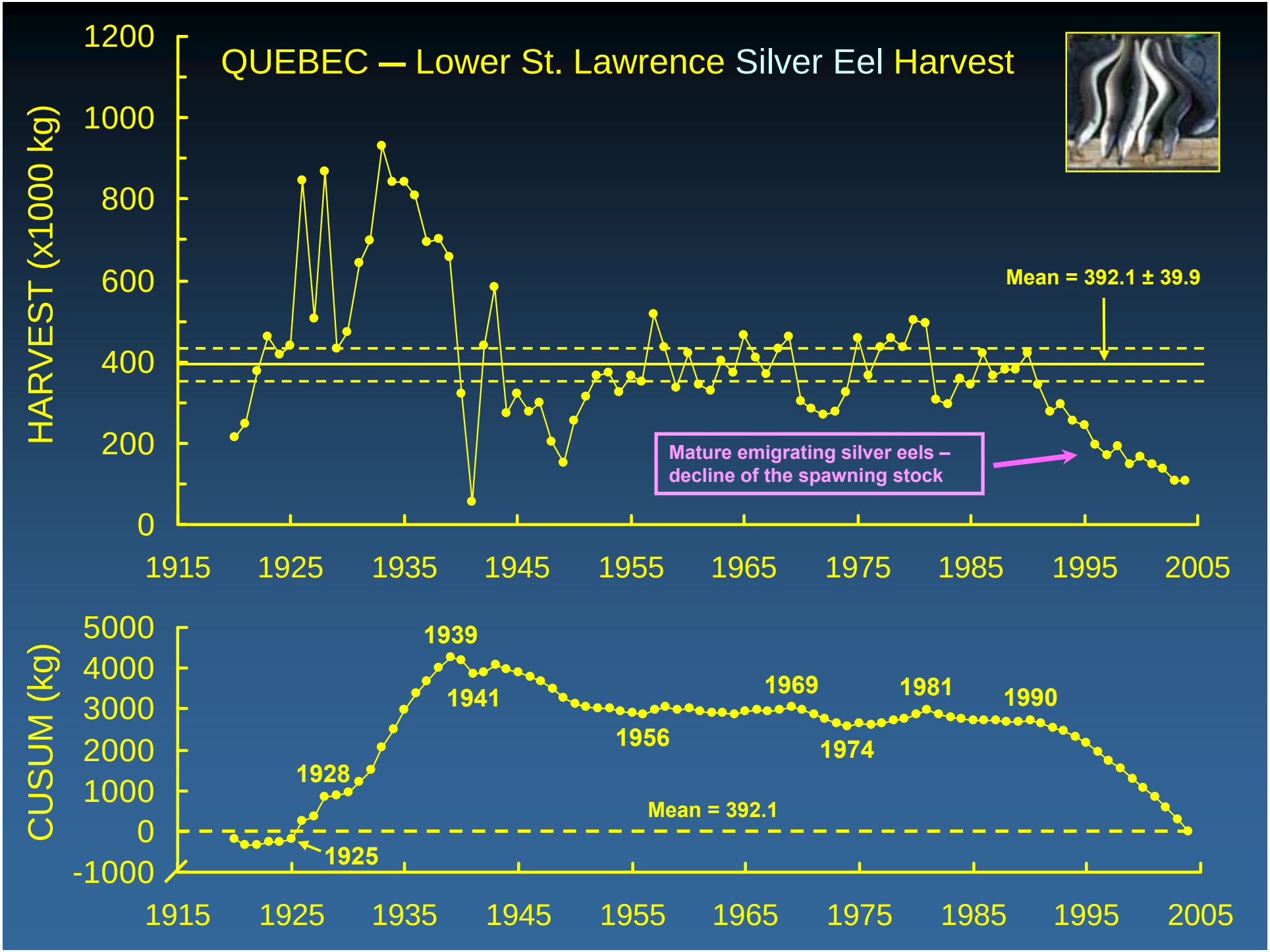
Long-Term Indices of Declining Abundance

St. Lawrence River – Lake Ontario system

Dramatic disappearance of a once abundant fish !

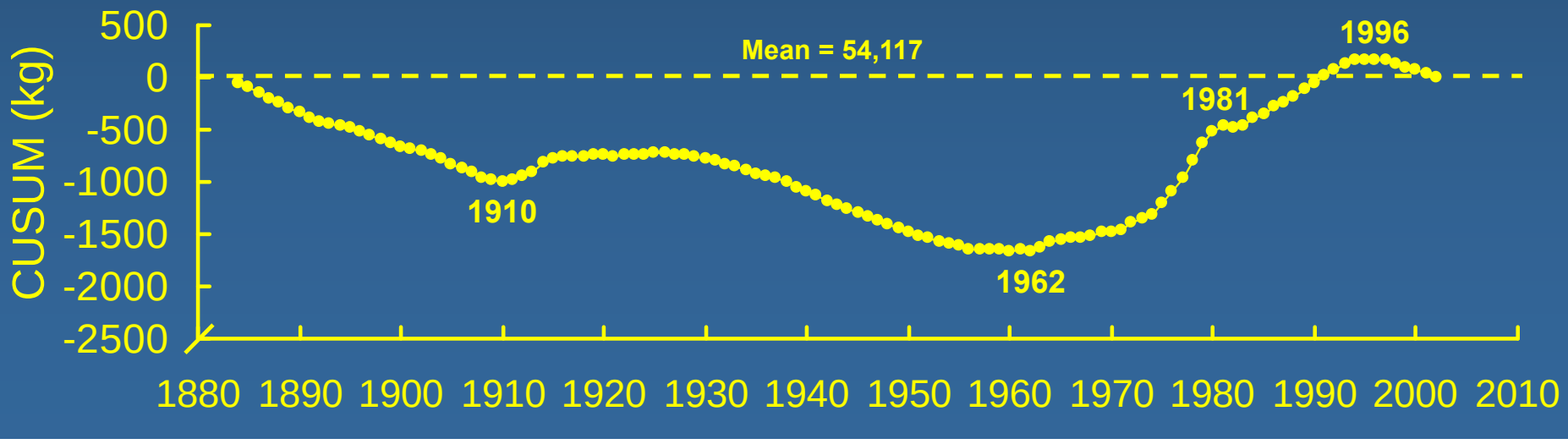

QUEBEC
NF
PEI
ONTARIO
NB
NS
ATLANTIC COASTAL STATES
ATLANTIC OCEAN
0
1000
km
N
QUEBEC
Estuary
NEW BRUNSWICK
Quebec
St. Lawrence R.
MAINE
Beauharnois Dam
H-M
Ottawa R.
SS
Upper
Moses-Saunders Dam
Bay of Quinte
ONTARIO
VT
NH
Main Duck Is.
NY
Lake Ontario
Oneida L.
MA
Finger Lakes
0
200
km

Tidal Eel Weir
Lower St. Lawrence River


QUEBEC — Lower St. Lawrence Silver Eel Harvest
HARVEST (x1000 kg)
1200
1000
800
600
400
200
0
Mean = 392.1 ± 39.9
Mature emigrating silver eels –
decline of the spawning stock
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
CUSUM (kg)
5000
4000
3000
2000
1000
0
-1000
1939
1941
1928
1925
1956
1969
1974
1981
1990
Mean = 392.1
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005

COMMERCIAL CATCH

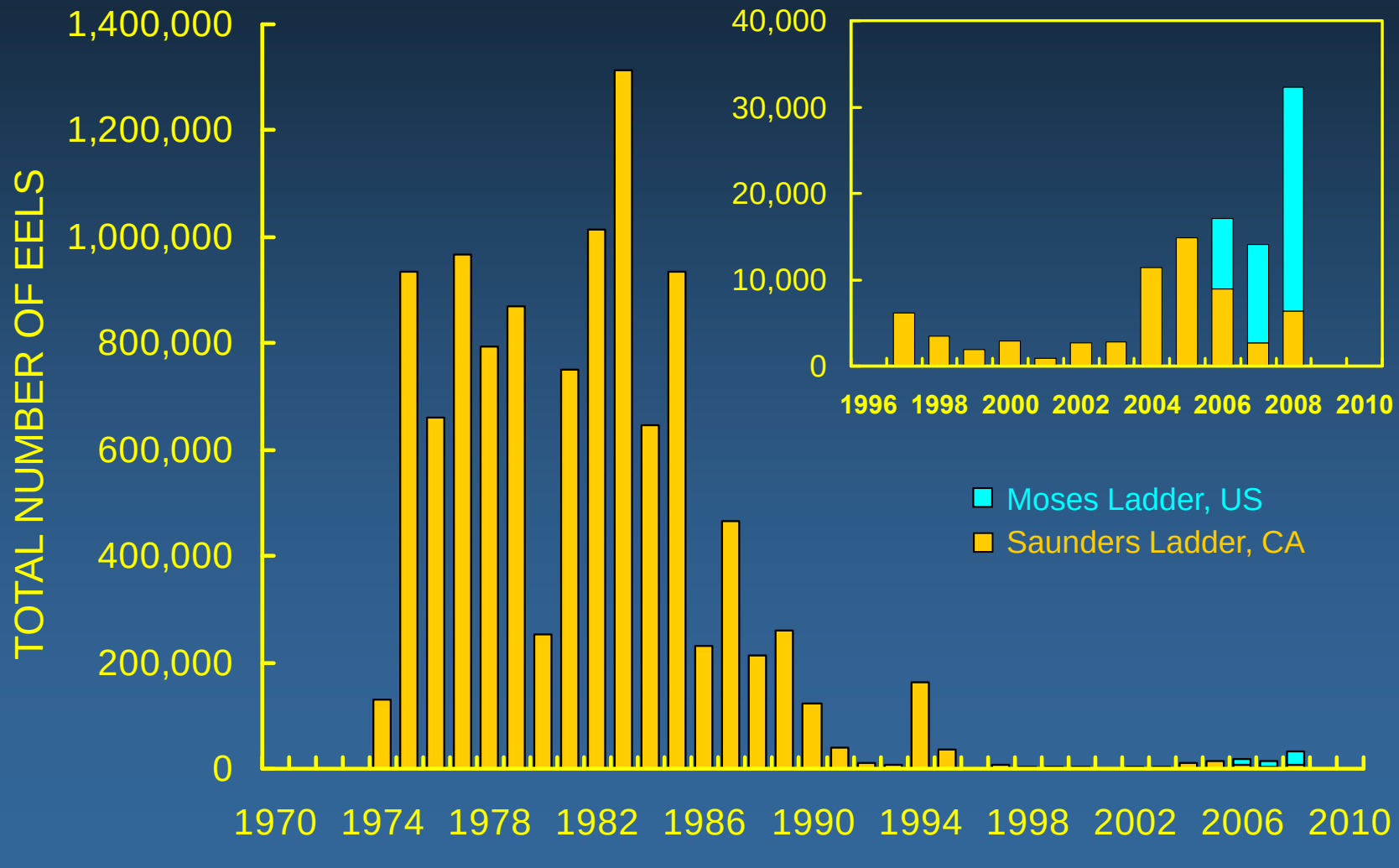
1 1970 – fishery closed east of long. 76° 50’ due to mercury contamination
2 1972 – harvest increased because export markets approved
3 1982 – closure of European market due to contaminants
4 1985 to 1988 – commercial licence buyout by OMNR
5 1998 to 1999 – reduced effort, size limits and some zone closures due to contaminants
6 2004 to 2008 – fishery closed

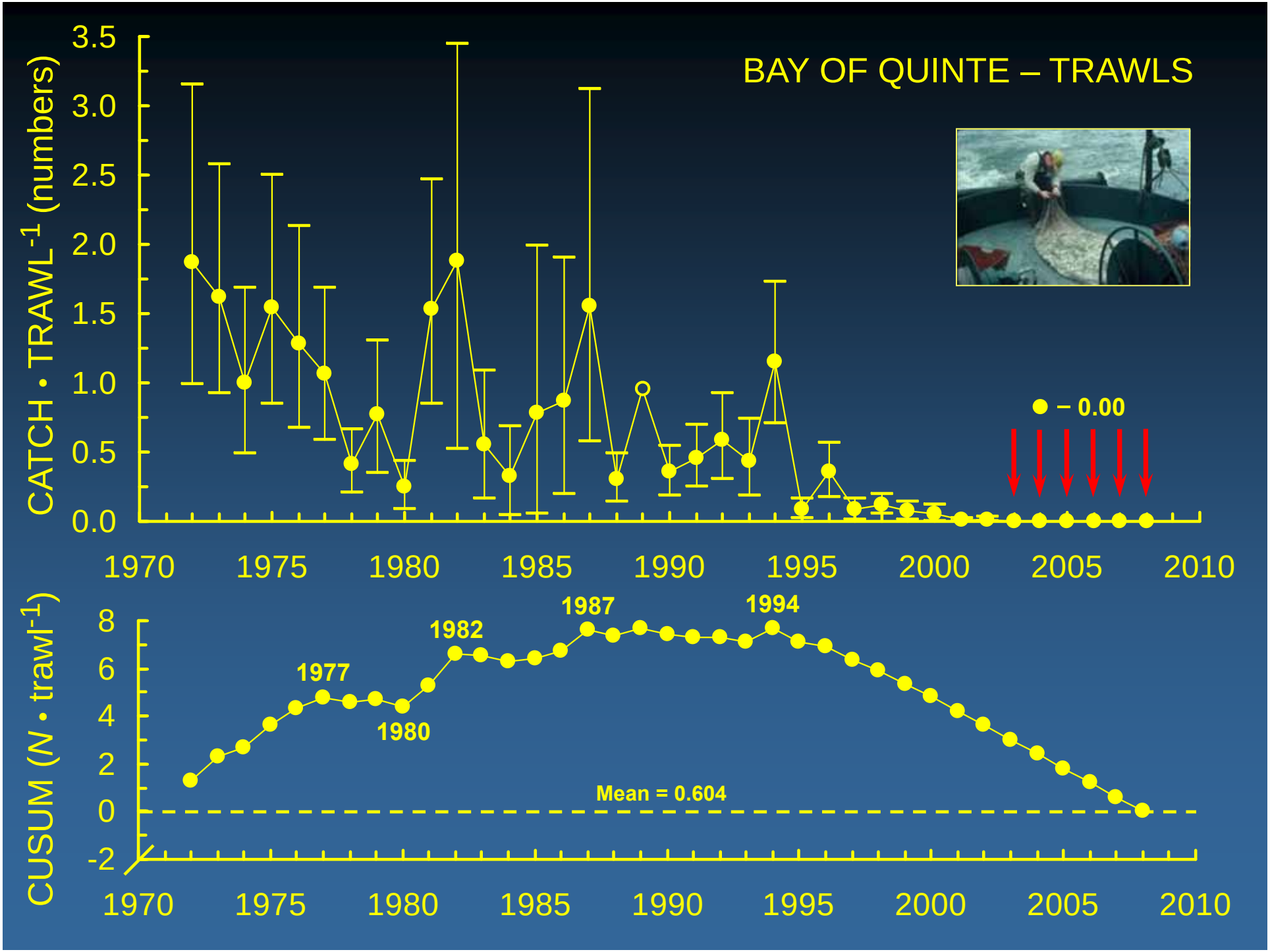


Moses-Saunders Dam and Eel Ladder, Upper St. Lawrence River

TOTAL ANNUAL UPSTREAM EEL PASSAGE

Upper St. Lawrence R., Moses-Saunders dam, 1974-2008

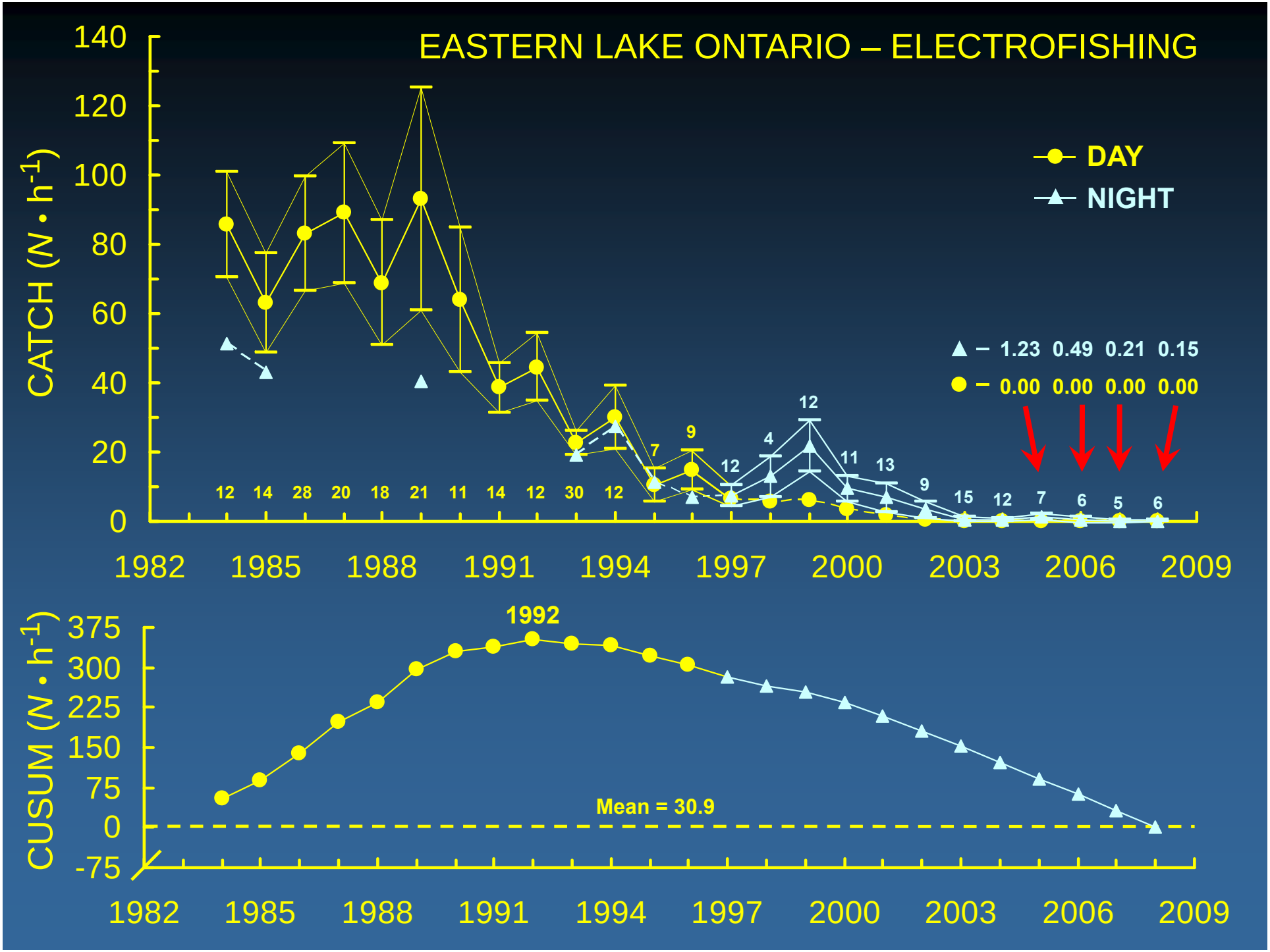


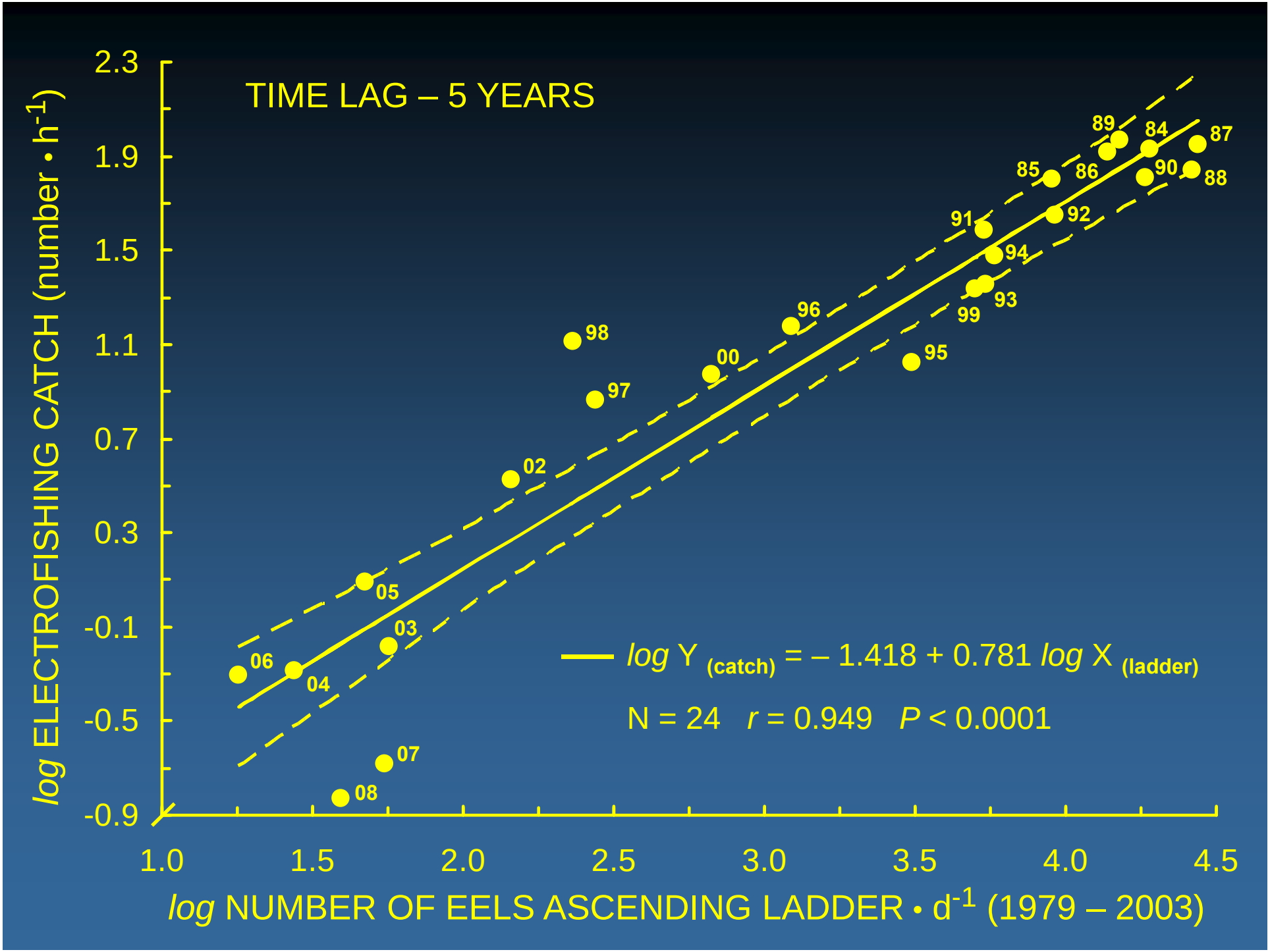

BAY OF QUINTE – TRAWLS
CATCH • TRAWL-1 (numbers)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
– 0.00
1970
1975
1980
1985
1990
1995
2000
2005
2010
CUSUM (N • trawl-1)
8
6
4
2
0
-2
1977
1980
1982
1987
1994
Mean = 0.604
1970
1975
1980
1985
1990
1995
2000
2005
2010

Commercial Electrofishing

Main Duck Island

Eastern Lake Ontario


EASTERN LAKE ONTARIO – ELECTROFISHING
CATCH (N • h-1)
140
120
100
80
60
40
20
0
DAY
NIGHT
1.23 0.49 0.21 0.15
0.00 0.00 0.00 0.00
12 14 28 20 18 21 11 14 12 30 12 7 9 12 4 12 11 13 9 15 12 7 6 5 6
1982 1985 1988 1991 1994 1997 2000 2003 2006 2009
CUSUM (N • h-1)
375
300
225
150
75
0
-75
1992
Mean = 30.9
1982 1985 1988 1991 1994 1997 2000 2003 2006 2009

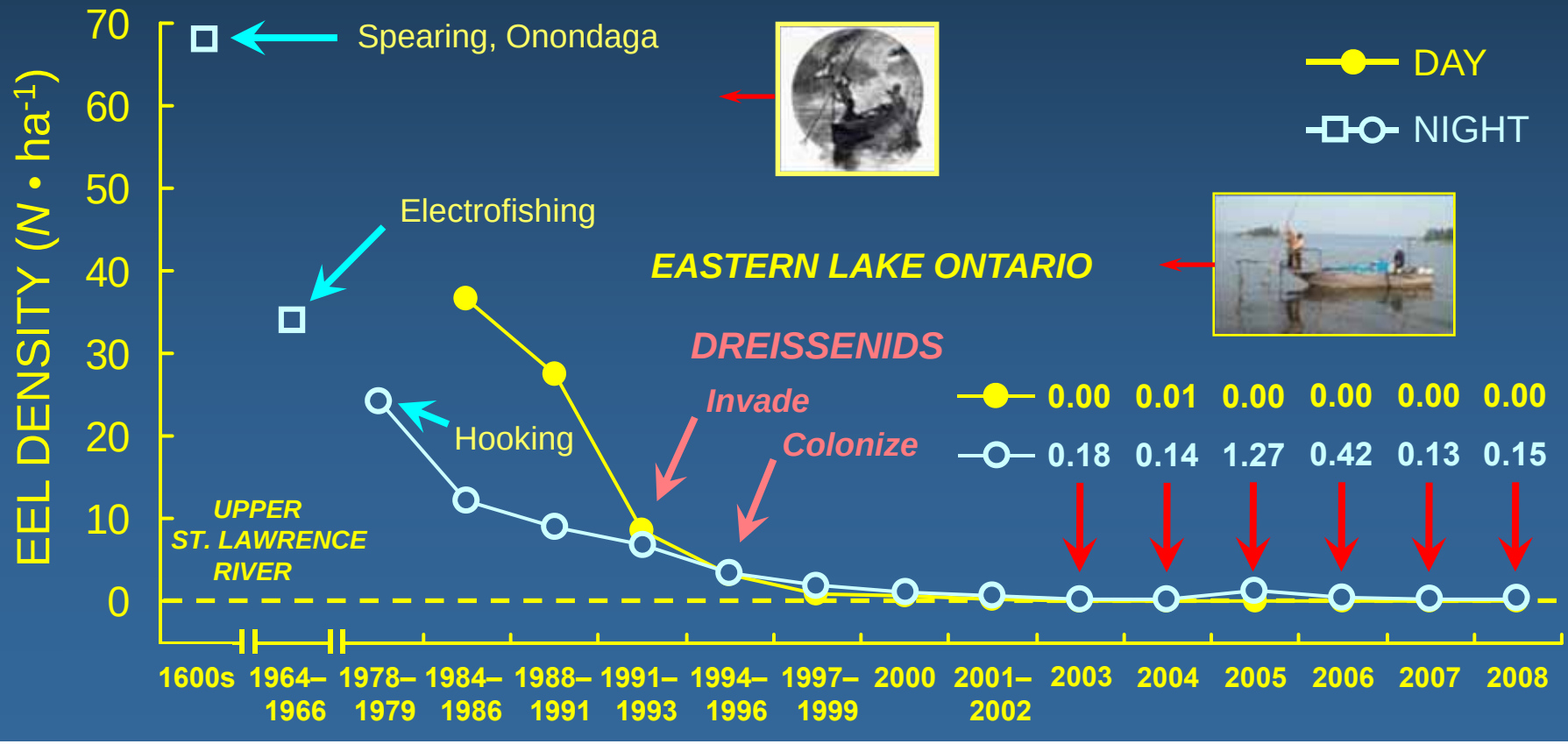

TIME LAG – 5 YEARS
log ELECTROFISHING CATCH (number • h-1)
2.3
1.9
1.5
1.1
0.7
0.3
-0.1
-0.5
-0.9
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
log NUMBER OF EELS ASCENDING LADDER • d-1 (1979 – 2003)
89
84
87
85
86
90
88
91
92
94
93
99
96
98
00
95
97
02
05
03
06
04
07
08
log Y (catch) = – 1.418 + 0.781 log X (ladder)
N = 24 r = 0.949 P < 0.0001

Modelling Eel Abundance and Migrations in St. Lawrence River System

Four recruitment and age-based models were developed, calibrated, and validated

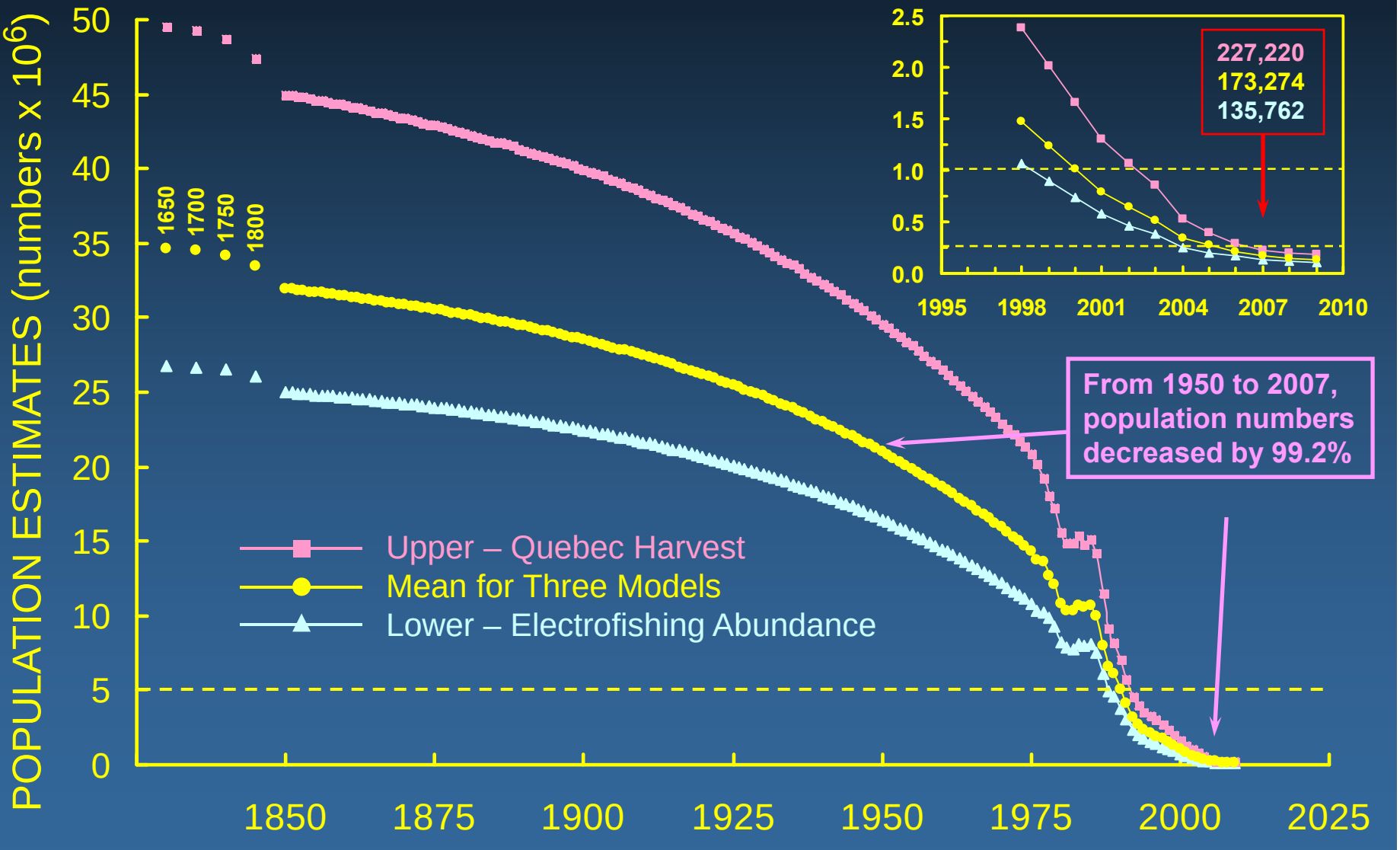
Abundance in Upper St. Lawrence River – Lake Ontario

- **Absolute declines in eel abundance in inshore waters of upper St. Lawrence River – Lake Ontario are well documented with scientific evidence**
- **Eels have left inshore waters in daytime and are rarely seen at night (one in 5.6 ha)**
- **Current decreases in abundance are primarily related to emigration of mature eels and loss of recruitment (annual rate of exploitation in 1990s – 5-8%)**



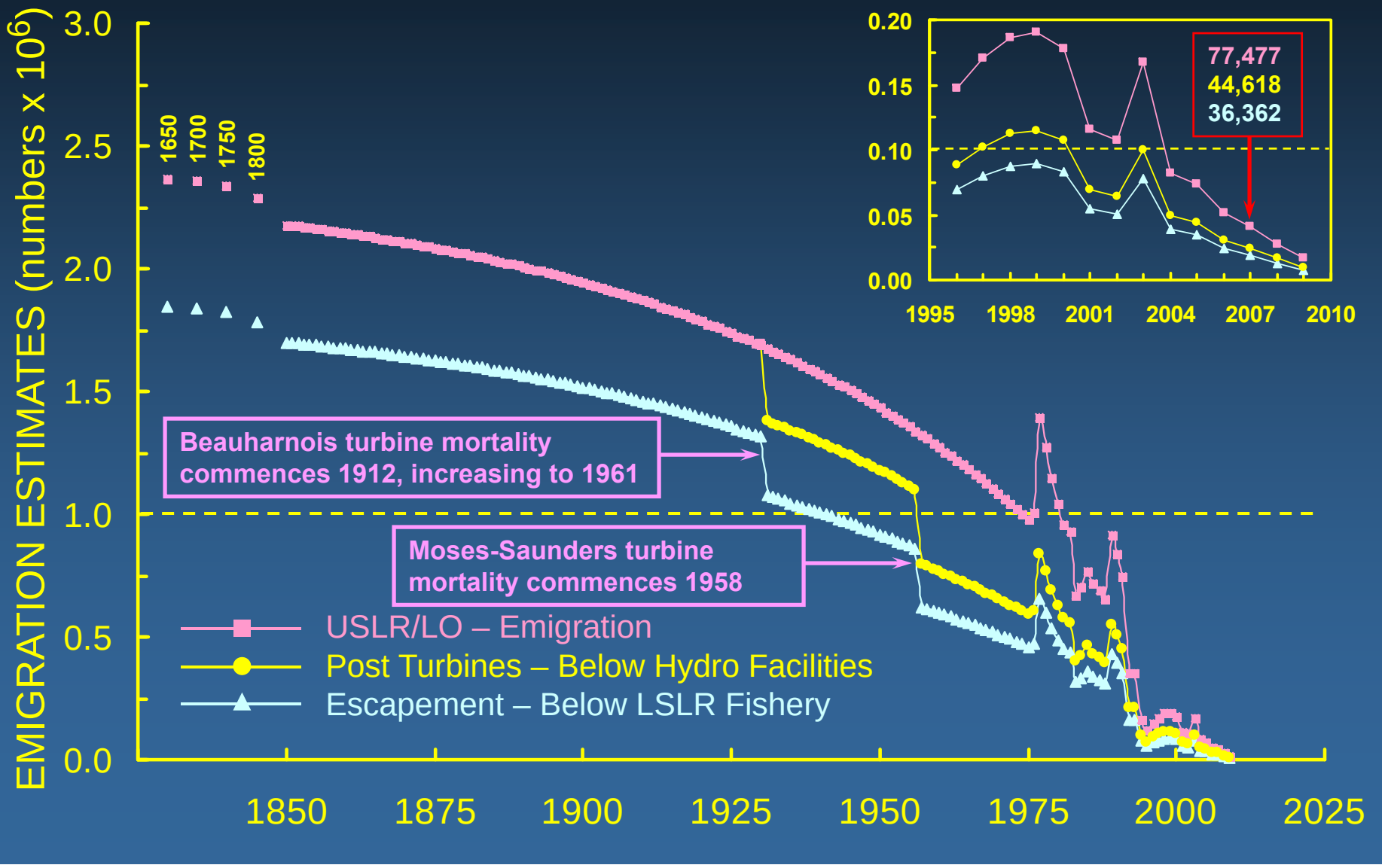
MODEL ESTIMATES – POPULATION NUMBER

Lake Ontario – Upper St. Lawrence River



MODEL ESTIMATES – EMIGRANT NUMBERS

St. Lawrence River System



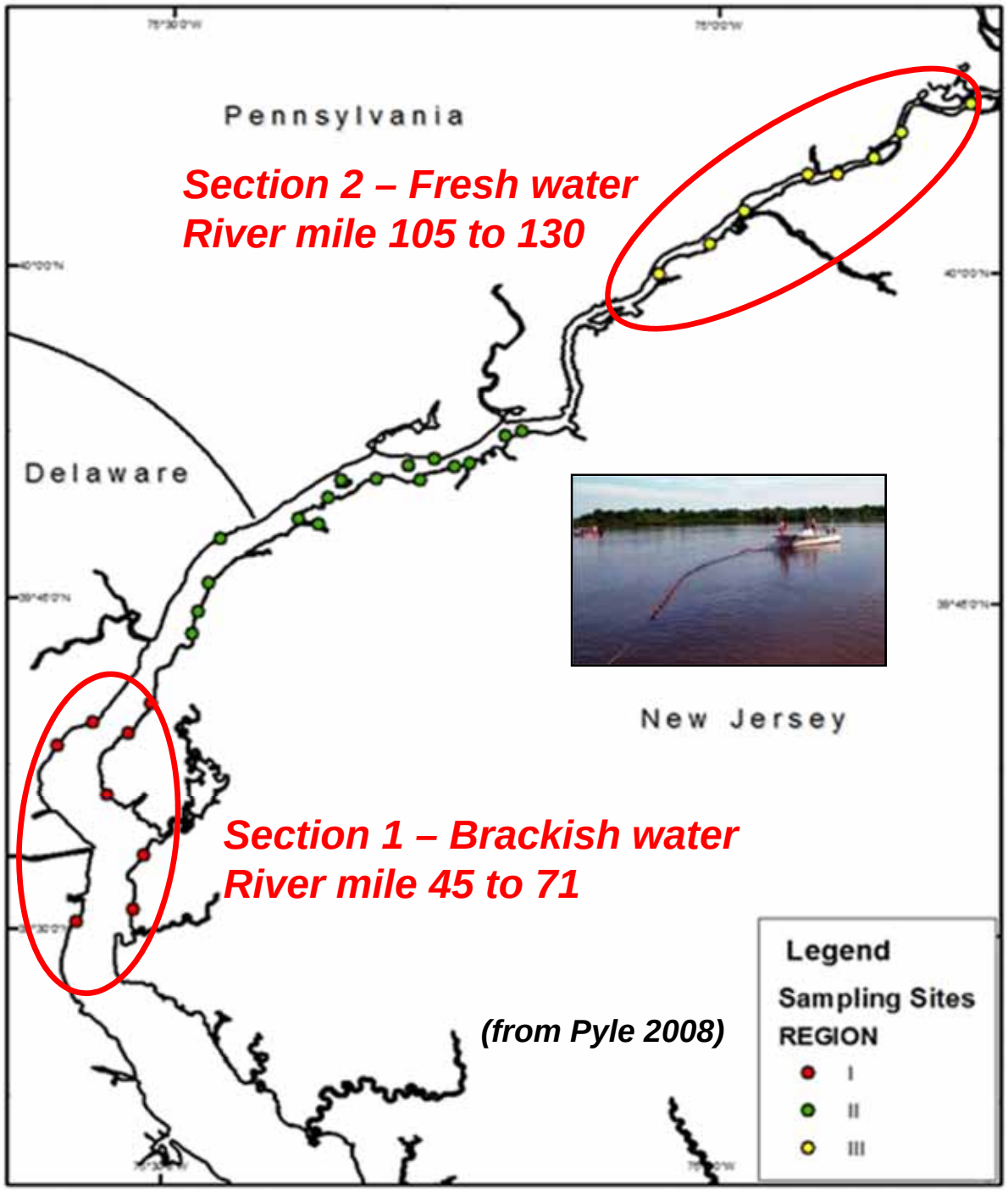
Let’s Pause for Questions?

Seining Surveys in the Delaware River

Temporal and spatial extremity changes

Data from and analyzed in cooperation with Heather Corbett, Div. F&W, NJ

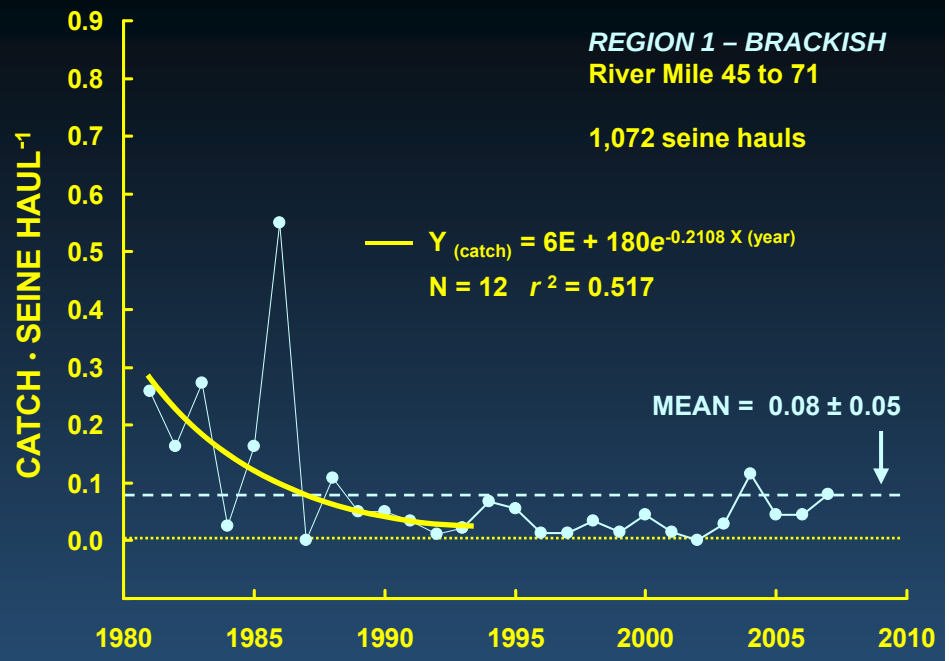
DELAWARE RIVER STRIPED BASS RECRUITMENT SEINING SURVEY

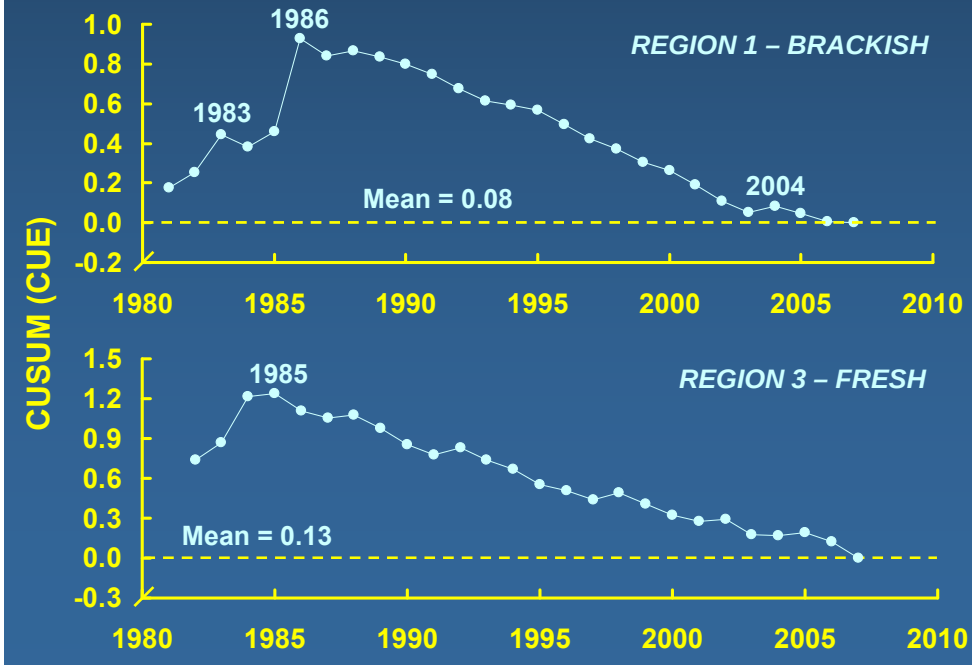


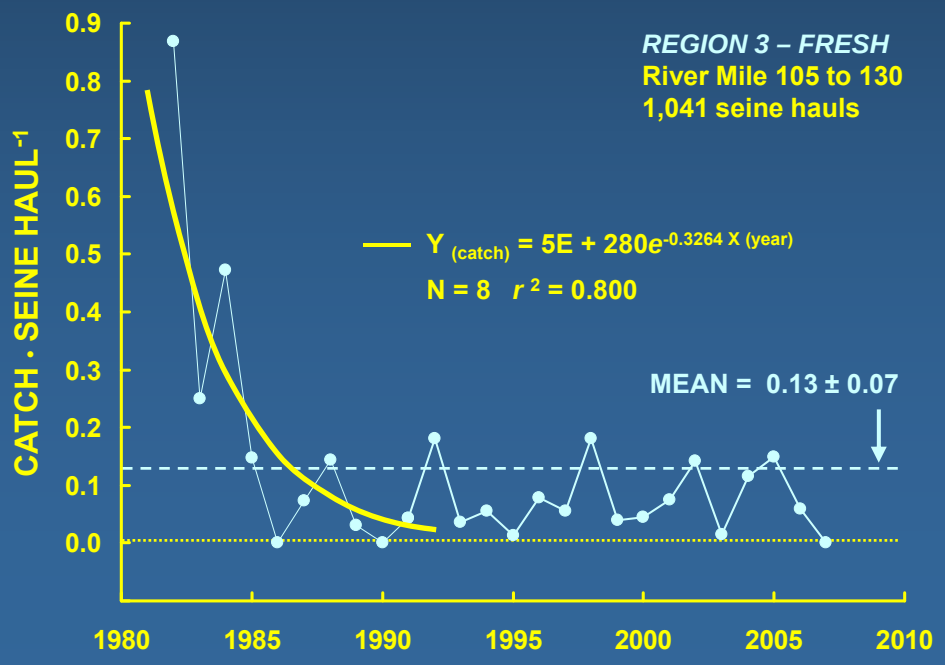
DELAWARE RIVER SEINING SURVEY

For two regions – region 1 in brackish water and region 3 in fresh water

Catch is geometric monthly mean for Aug, Sep, and Oct for 26 and 27 years, 1981 to 2007







Possible Factors Causing Recent Eel Declines

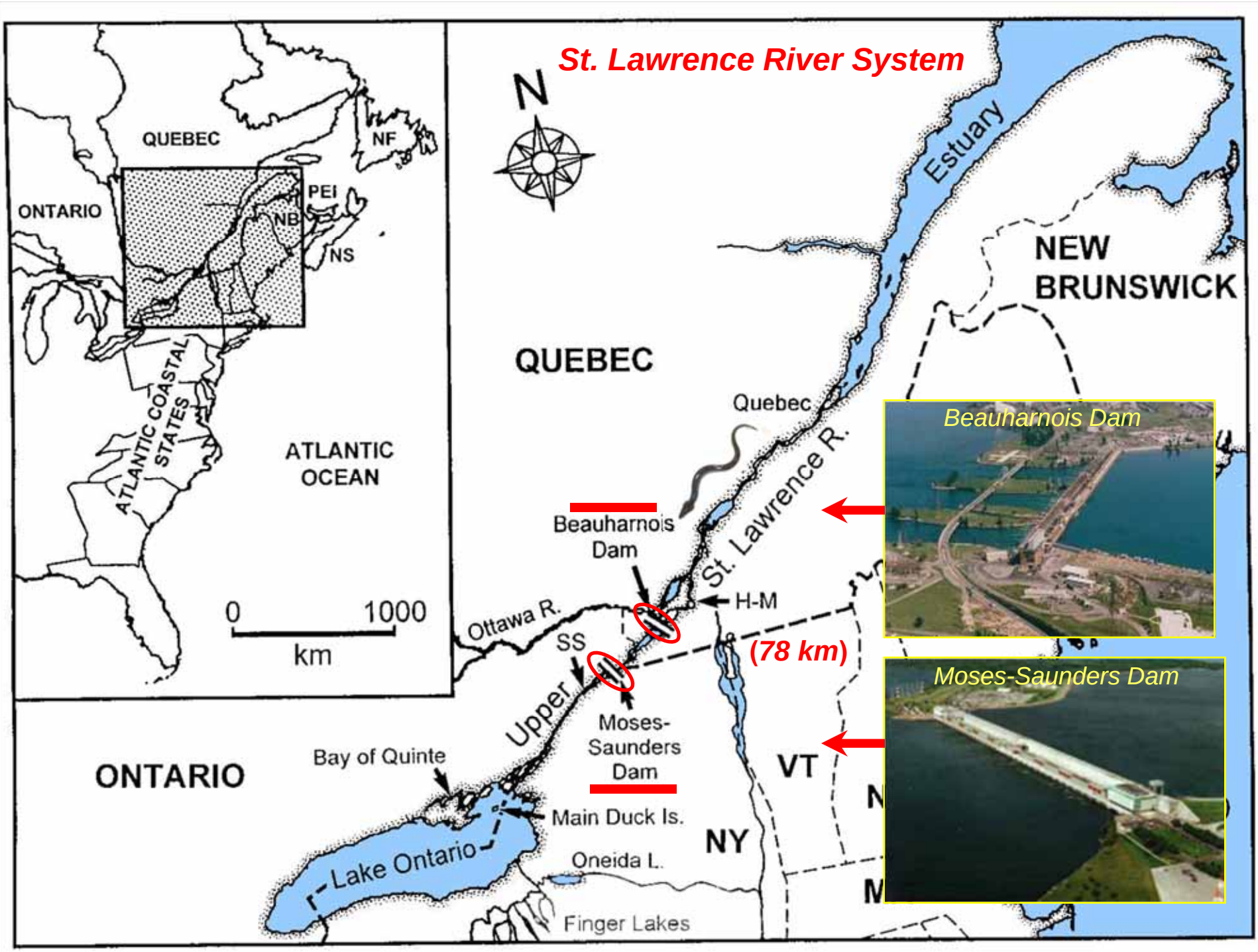
Historic order of impact:

1. Alteration and loss of habitat
2. Barriers to migration
3. Toxicity of contaminants
4. Exploitation of all life stages
5. Hydroelectric turbine mortality
6. Changes in oceanic conditions
7. Productivity and food web changes
8. Parasitism
9. Sargasso weed harvest

American eels and Climate Change

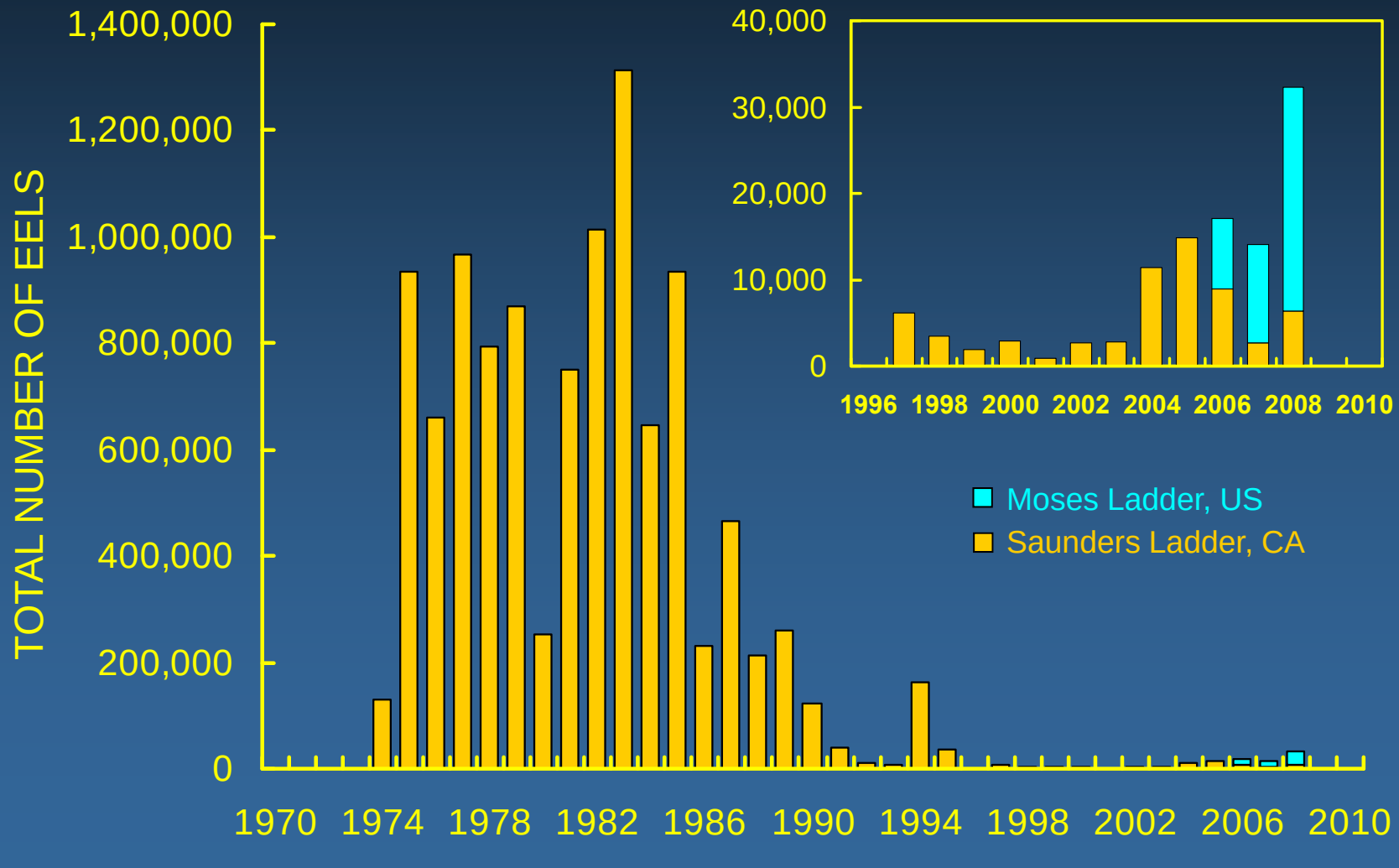
Eel Immigration in the Upper St. Lawrence River and Oceanic Influences

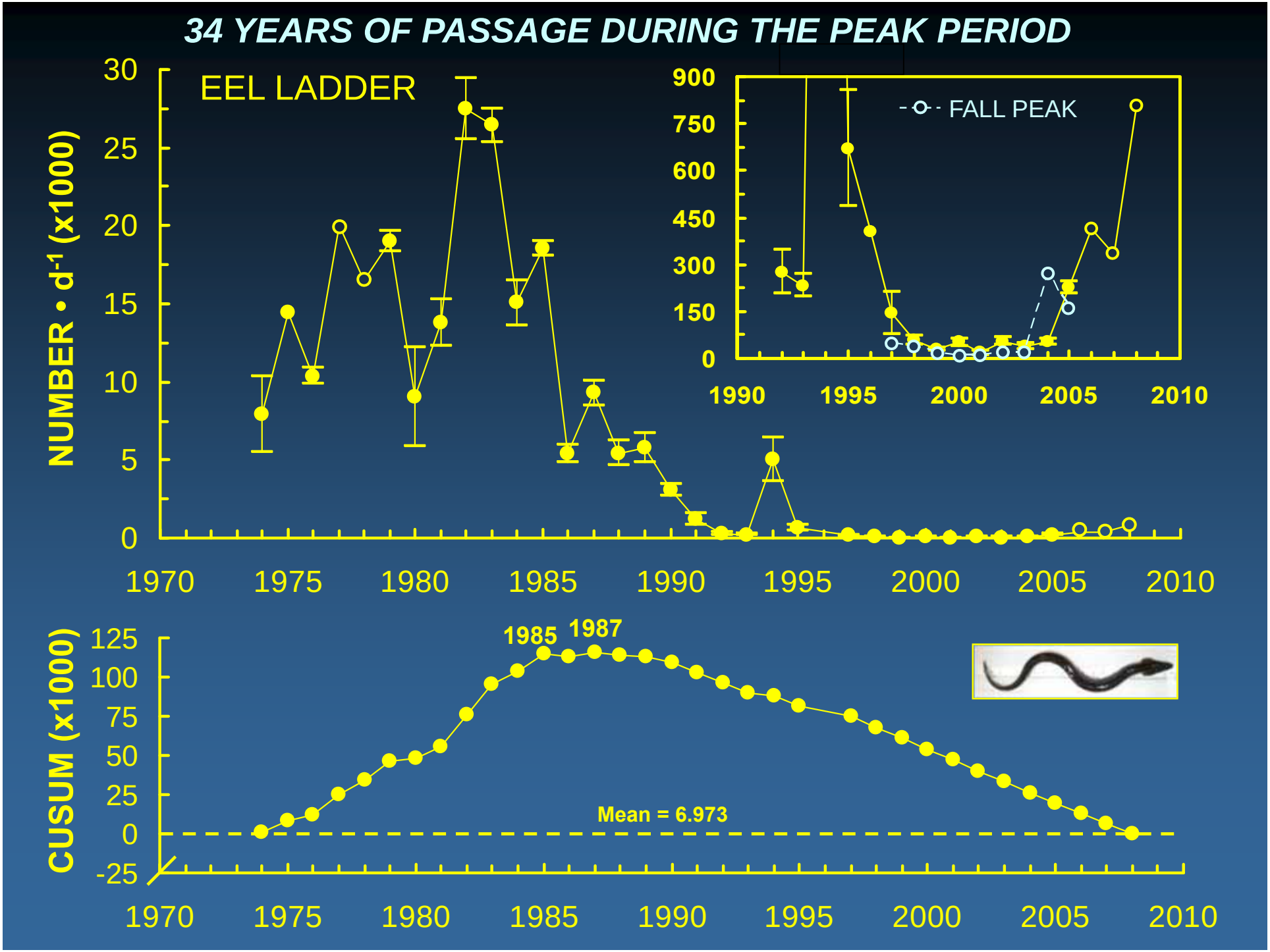
Eel recruitment at the northern extremity of the range and the North Atlantic Oscillation Index

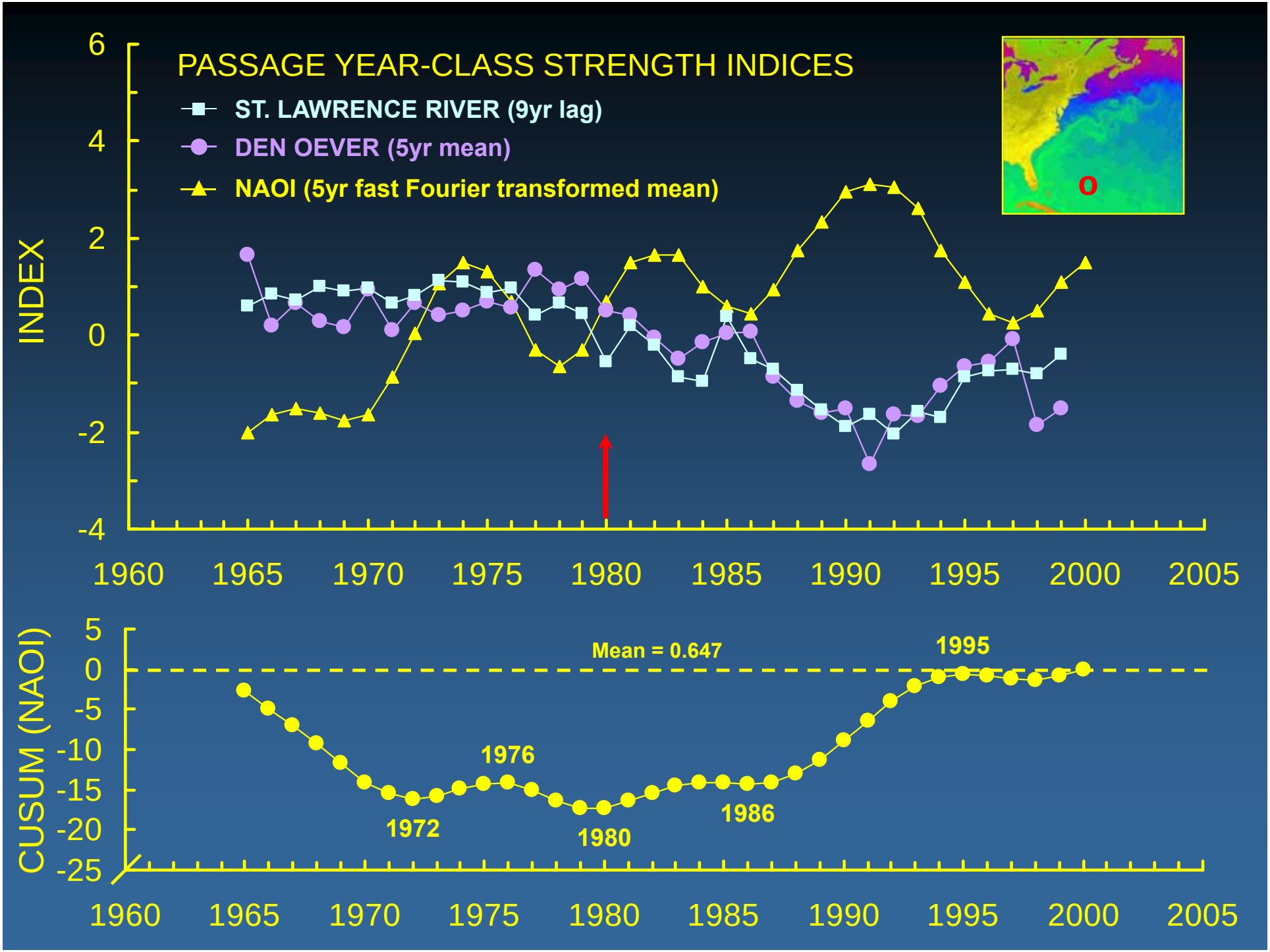

St. Lawrence River System
N
QUEBEC
NF
PEI
ONTARIO
NB
NS
ATLANTIC COASTAL STATES
ATLANTIC OCEAN
0
1000
km
QUEBEC
Estuary
NEW BRUNSWICK
Quebec
St. Lawrence R.
Beauharnois Dam
H-M
(78 km)
Ottawa R.
SS
Upper
Moses-Saunders Dam
Bay of Quinte
ONTARIO
Main Duck Is.
Lake Ontario
Oneida L.
Finger Lakes
NY
VT
Beauharnois Dam
Moses-Saunders Dam

TOTAL ANNUAL UPSTREAM EEL PASSAGE

Upper St. Lawrence R., Moses-Saunders dam, 1974 - 2008




34 YEARS OF PASSAGE DURING THE PEAK PERIOD
EEL LADDER
NUMBER • d-1 (x1000)
30
25
20
15
10
5
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
FALL PEAK
900
750
600
450
300
150
0
1990
1995
2000
2005
2010
CUSUM (x1000)
125
100
75
50
25
0
-25
1985
1987
Mean = 6.973
1970
1975
1980
1985
1990
1995
2000
2005
2010


PASSAGE YEAR-CLASS STRENGTH INDICES
ST. LAWRENCE RIVER (9yr lag)
DEN OEVER (5yr mean)
NAOI (5yr fast Fourier transformed mean)
INDEX
6
4
2
0
-2
-4
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
CUSUM (NAOI)
Mean = 0.647
5
0
-5
-10
-15
-20
-25
1976
1972
1980
1986
1995

Long-Term Dynamics in Relative Year-Class Strength

TL – 440mm TW – 103g
Date – 20060830 – 4
CSA – 6o NCA – 5
Year class – 2001

Age assessment of 4,041 eel ladder eels subsampled from 9 years from 1976 to 2007

AMERICAN EEL OTOLITH AGE ASSESSMENT

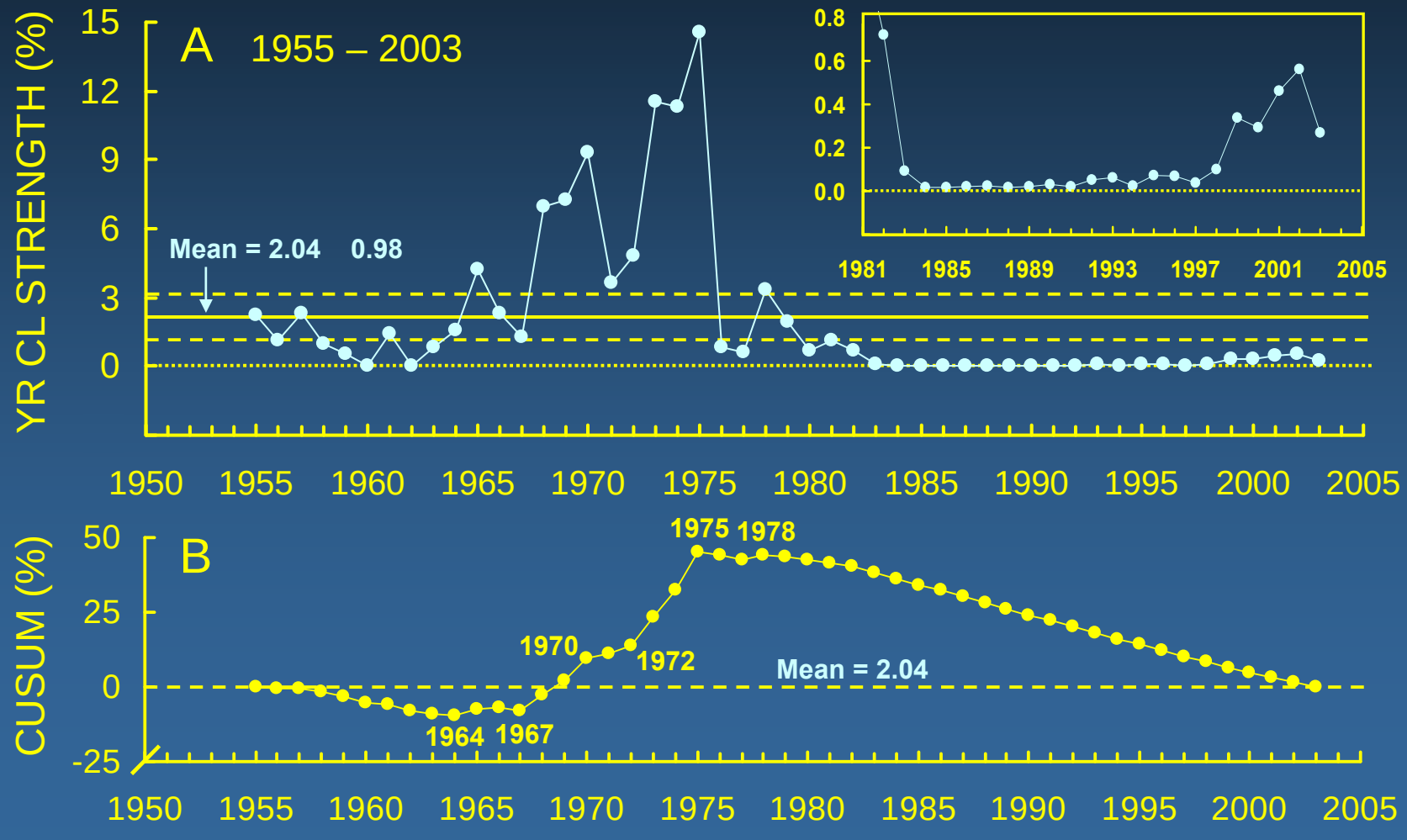
Transverse thin section

Acetate replica of section

Eel ladder otolith age – year-class strength assessment

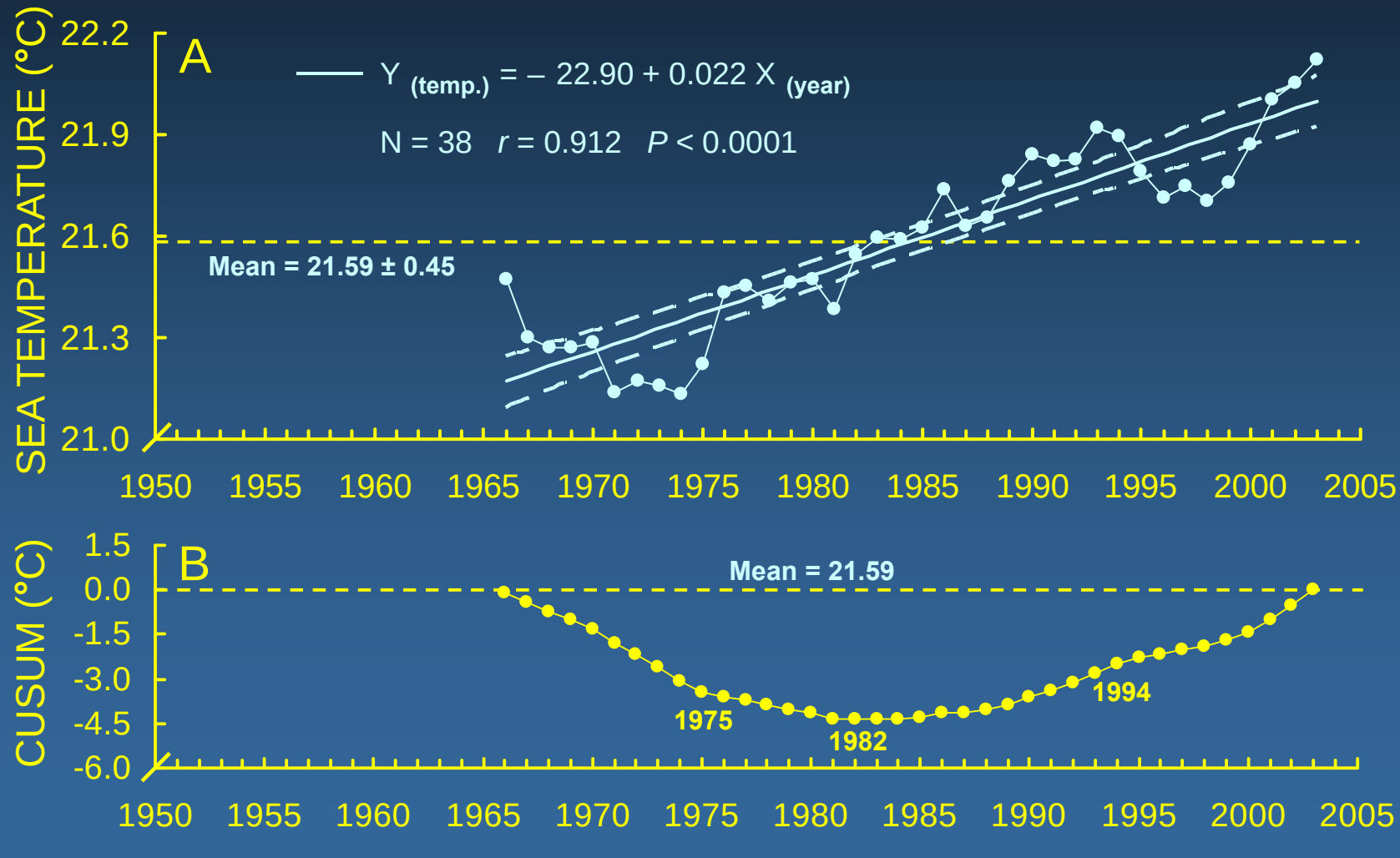
RELATIVE YEAR-CLASS STRENGTH

Upper St. Lawrence R. eel ladder, 1955 – 2003



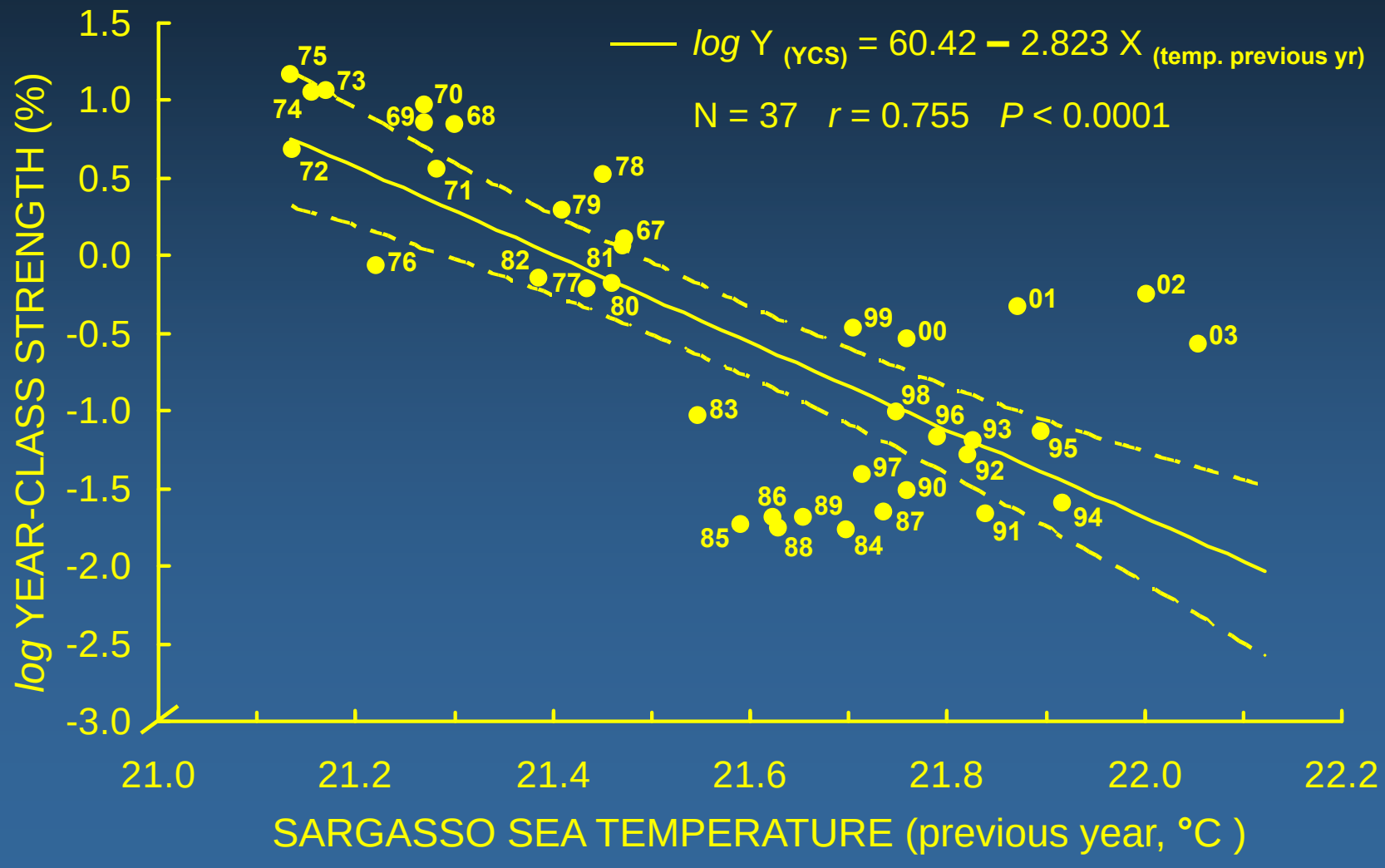
SARGASSO SEA SURFACE TEMPERATURE

Bermuda Biological Station, Hydrostation S, 38-yr period



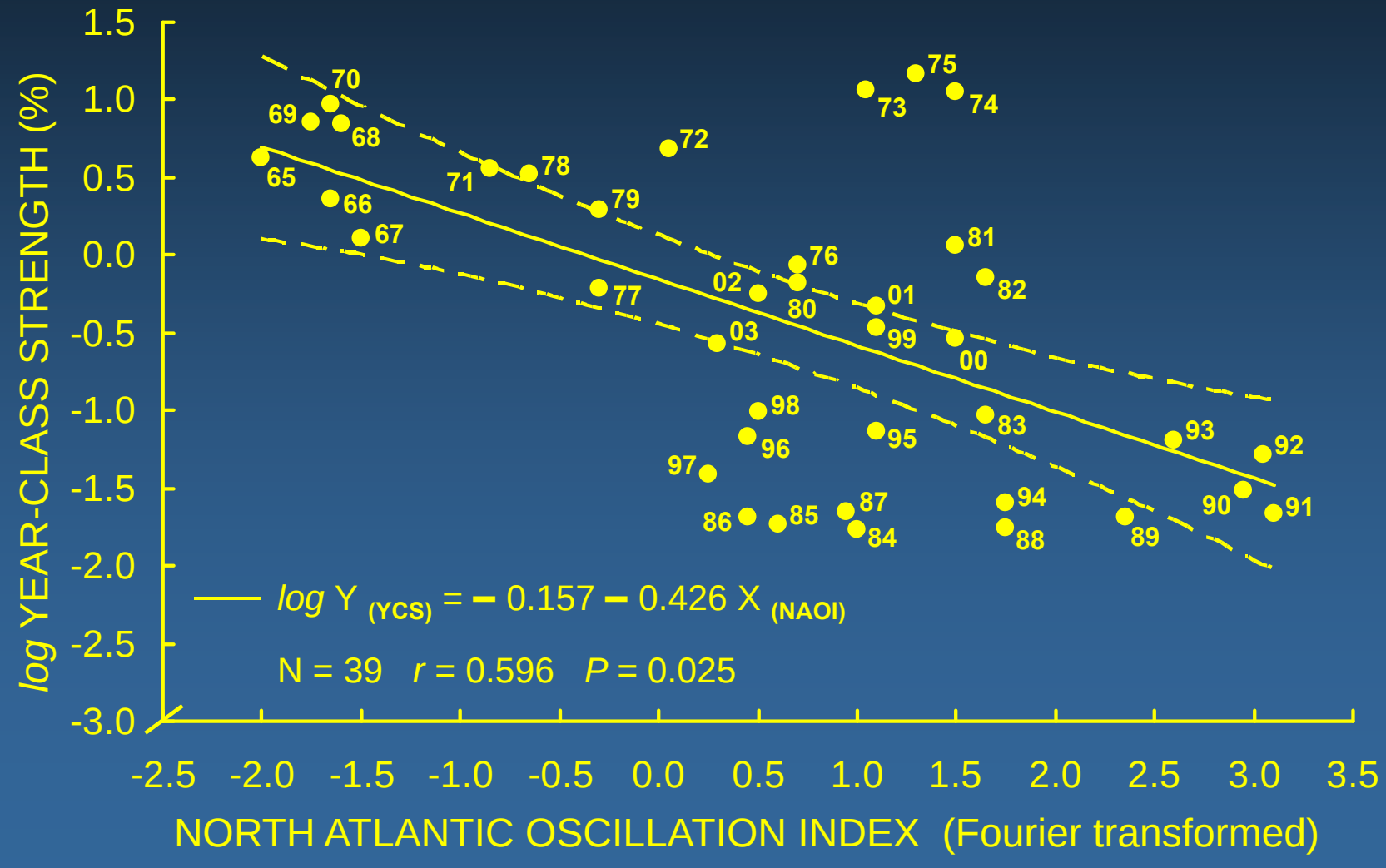
YEAR-CLASS STRENGTH AND SEA TEMPERATURE

Temperature in previous year, for 37 years, 1967 to 2003



YEAR-CLASS STRENGTH AND NAOI

North Atlantic Oscillation Index for 39 years, 1965 – 2003



Summary

- Eels are disappearing, most rapidly at the extremities of the range, and in many water bodies, the species is on the verge of extirpation.
- Numerous factors combine and interact to put this ancient panmictic migratory species in their present precarious state; nevertheless, human-induced fishing and emigration mortality must be reduced.
- Cooperative action is urgently needed. Functional recovery plans are needed across the range, given the universal decrease in abundance. The species should be considered "*Threatened*" and the resource "*Endangered* ".

“The eel-fishery is highly productive and enables people to live when all else fails” (Jesuit Relations,Thwaites 1896-1901:40:11-12)

The concern is that we may lose our association with this ancient and long-valued migratory fish

Eels could disappear from our consciousness unless we act now !

Eels are . . .

universal integrators

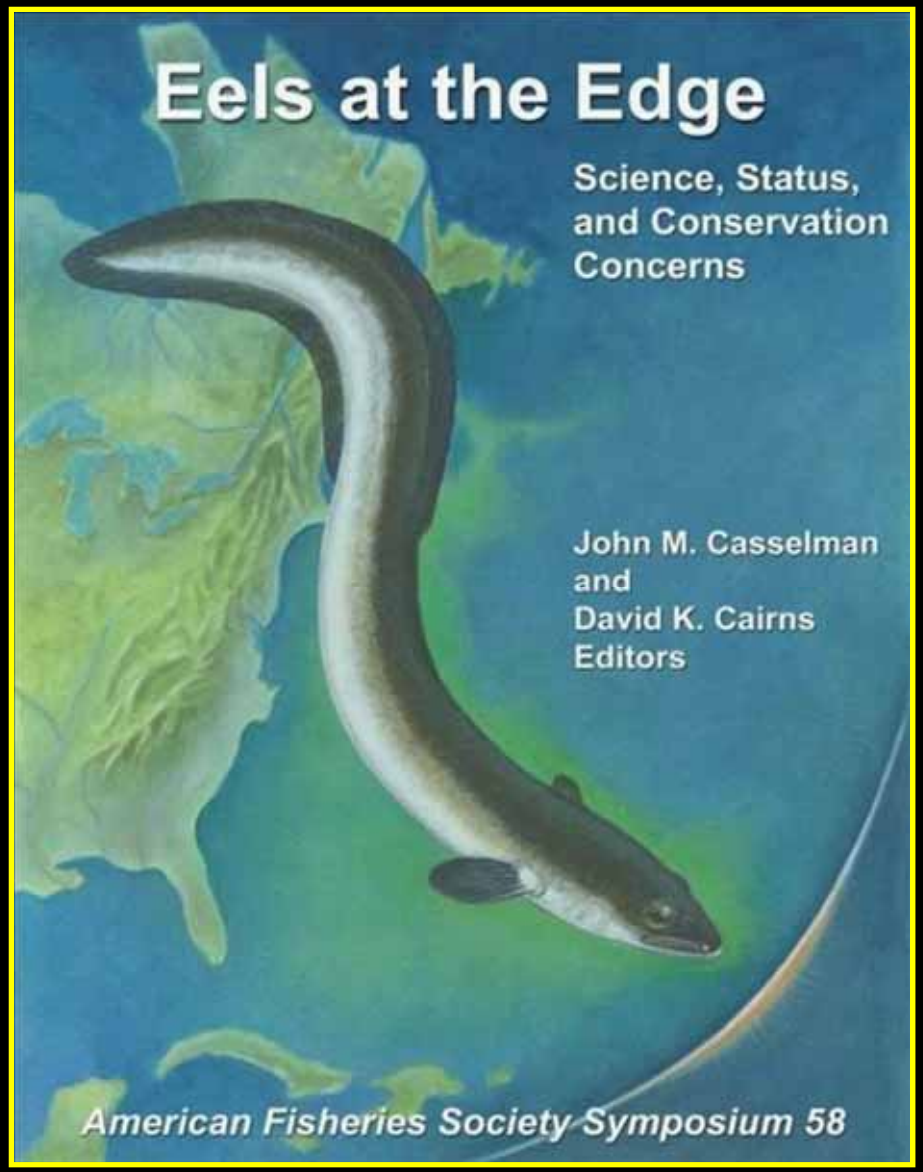
important indicators

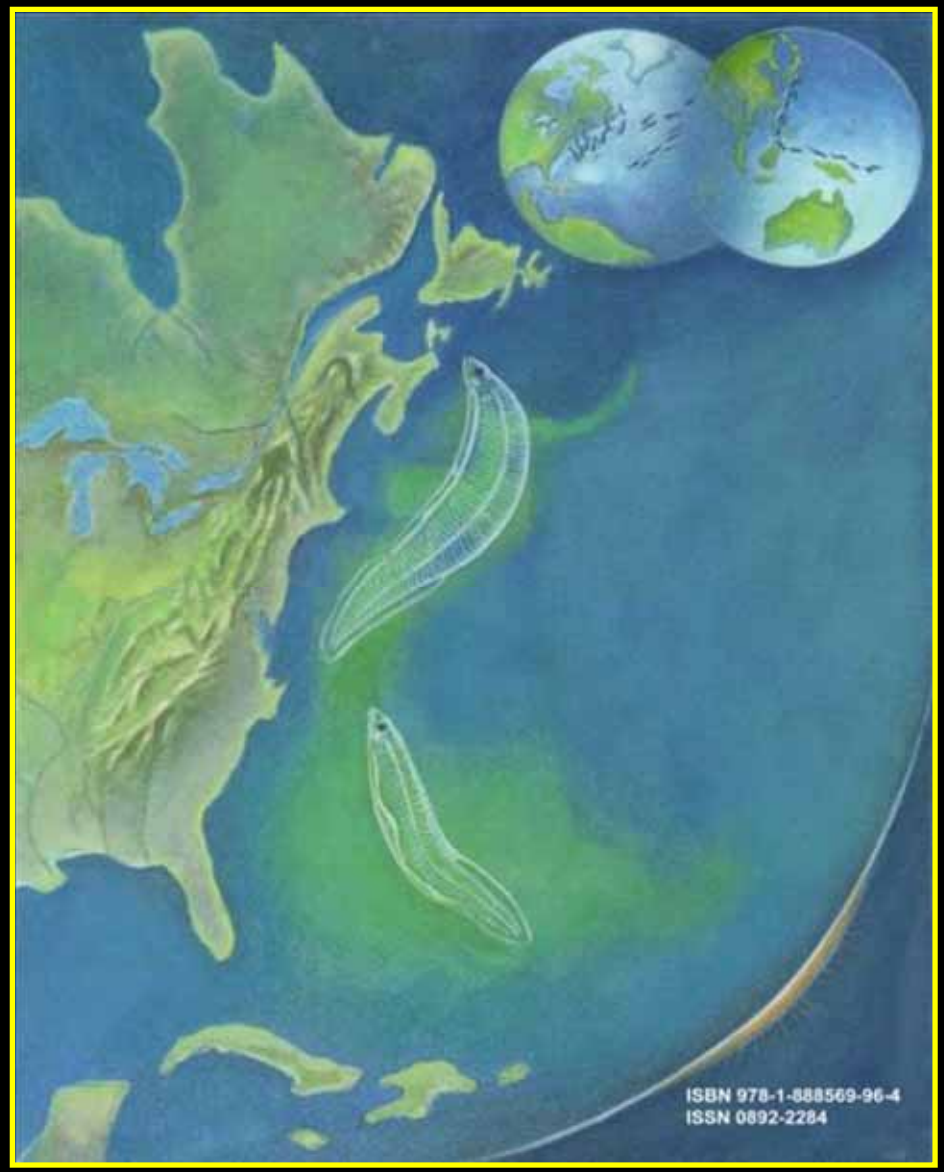
an ancient bellwether fish

Eels are sending us a message

Are we heeding it ?

ADDITIONAL REFERENCE READING






Thank you !

Let's Pause for Questions?

The Hudson River eel project:
Fish conservation through citizen science

Using students, interns, and community volunteers to MONITOR American eel migrations and RESTORE them to habitats

Study design and materials

- Fyke nets installed at mouths of tributaries
- Daily collections in April-May
- Release above first barrier
- Project expands NY contribution to eel data

Internet Videos:

http://www.youtube.com/watch?v=j-tik6Y9ztA

http://www.dec.ny.gov/dectv/dectv76.html

http://www.youtube.com/watch?v=laHMR0dT-1s

Lesson #1:

Building partners

Photo courtesy of Brenda Timm, TogetherGreen

Let's Pause for Questions?

long live Anguilla rostrata

Eels for Experiencing and Learning Science

Next: Climate Change & the Hudson River

Cornelia Harris

Cary Institute of Ecosystem Studies, Millbrook NY

Cary Institute
of Ecosystem Studies

Research & Education based on Ecosystem Ecology



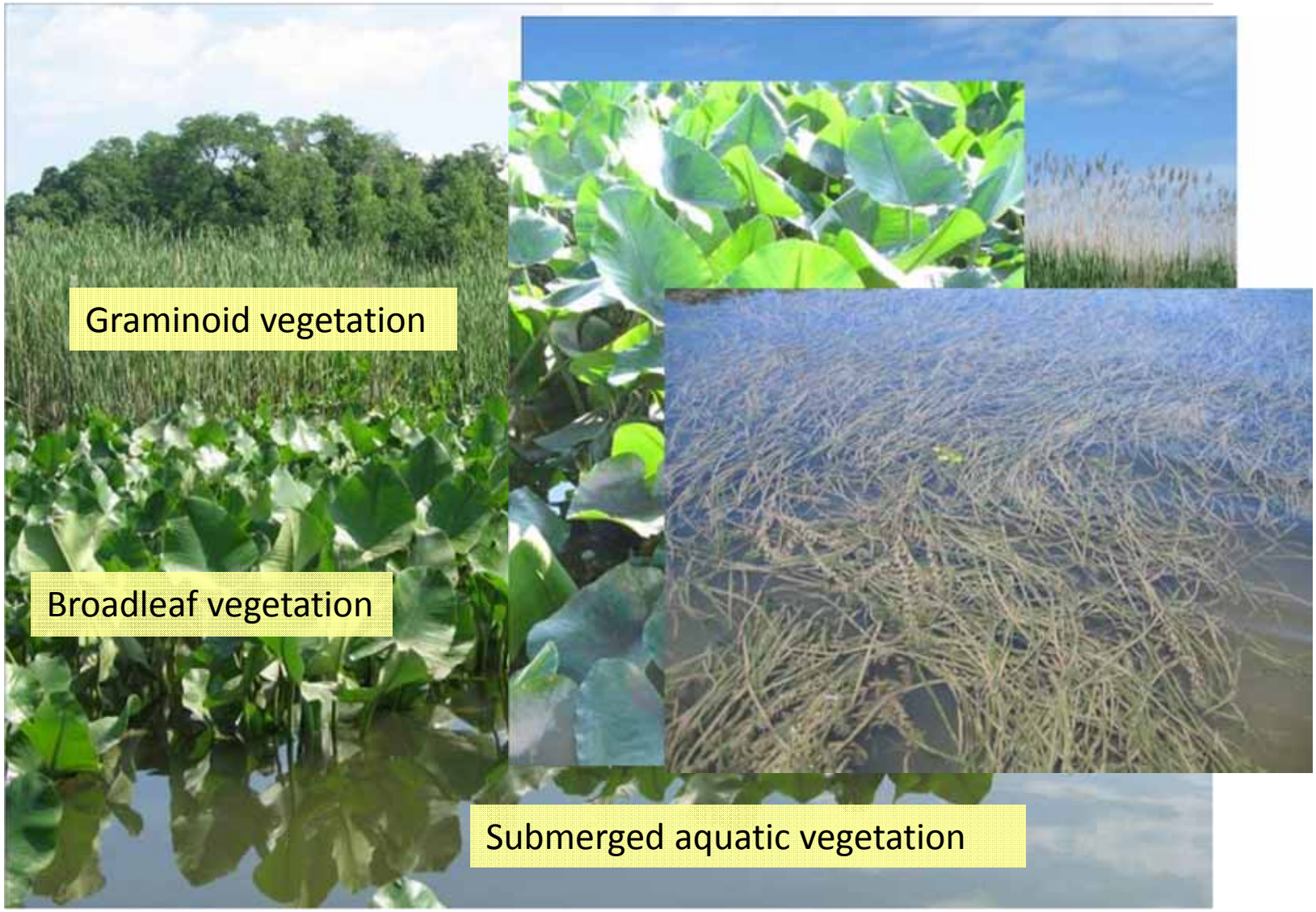
hat will happen to the tidal wetlands along the Hudson River?

A: They will migrate upland as sea level increases

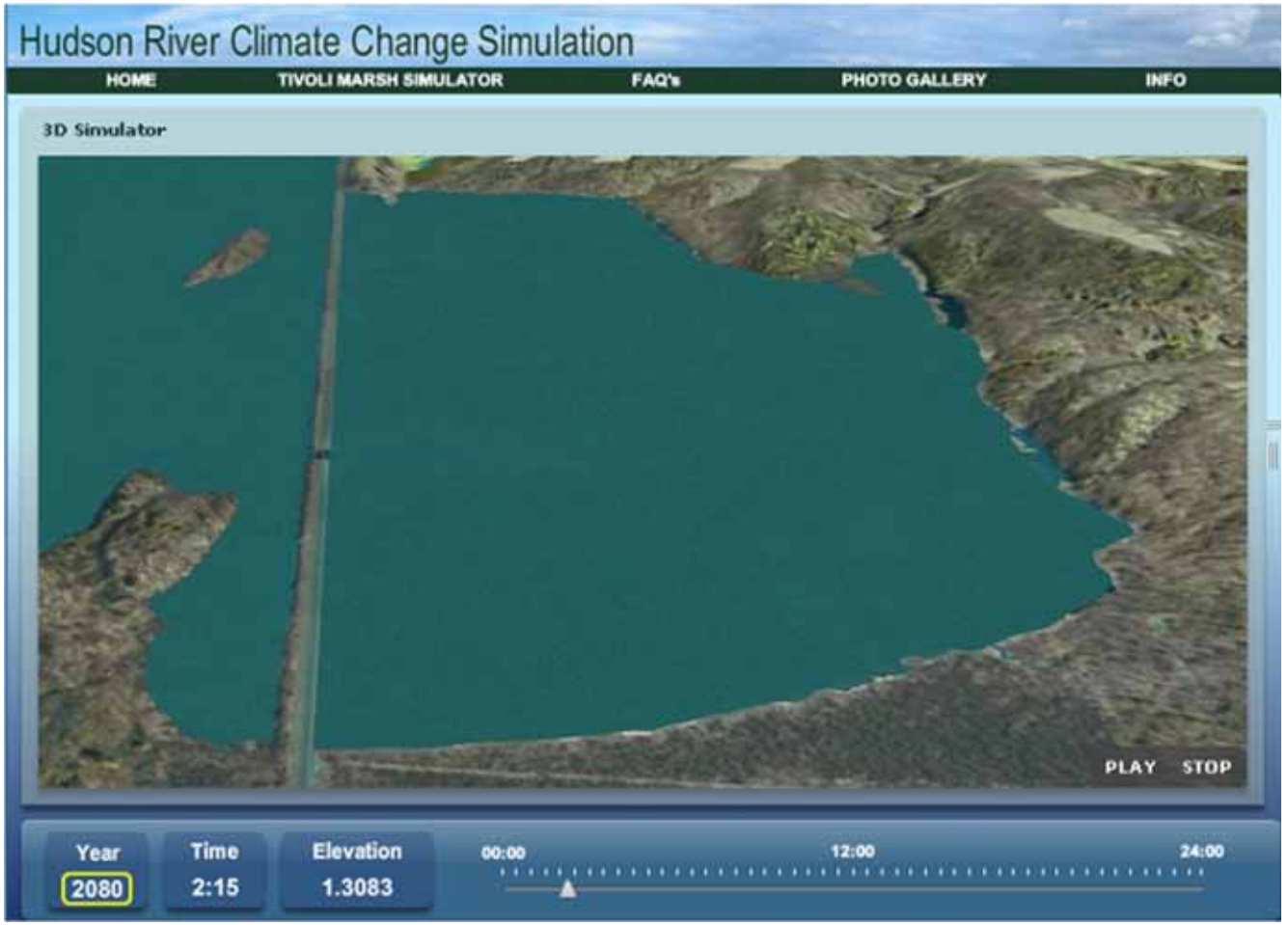
B: They will disappear because sedimentation will not be able to keep up with sea level rise

C: Sedimentation will increase, but wetlands will be 'built' along with sea level rise and thus no net loss will occur

D: I don't know!


Graminoid vegetation
Broadleaf vegetation
Submerged aquatic vegetation

Tivoli Marsh 2009

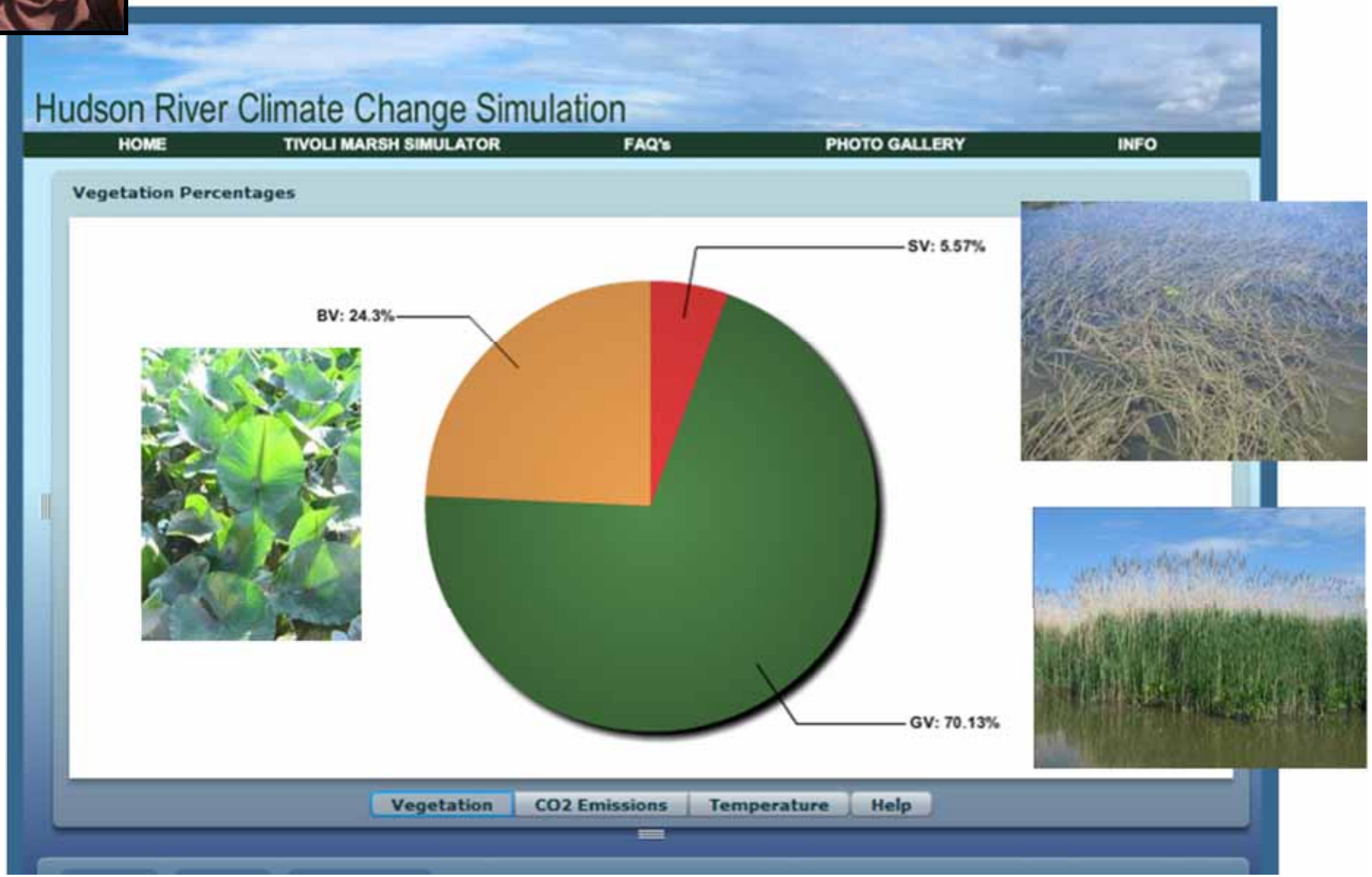


the model accurate? Is it extreme?

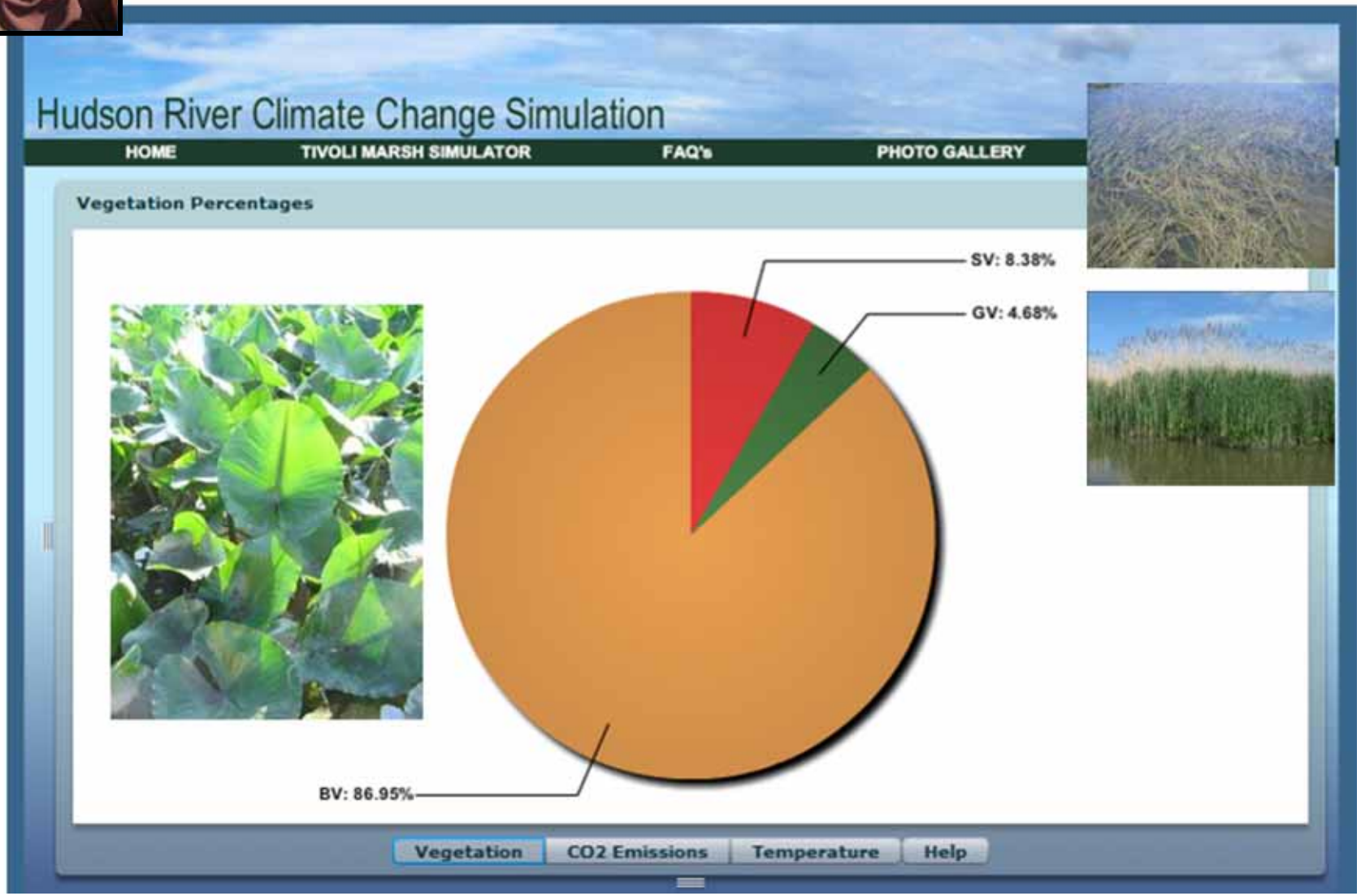
- Sedimentation rates along the Hudson River: 0.05-2.9 cm per year (Kiviat et al., 2006)
- Sea level rise in the Hudson will be anywhere between 0.1 cm/year to 1.1 cm/year over the next century (Northeast Climate Assessment, 2007; Rosenzweig & Solecki, 2001).
- The model used the IPCC forecasts for AIB, which is an "average" scenario that assumes:
  - Rapid economic growth
  - Population growth until 2050 and then decline
  - Rapid introduction of new, more efficient technologies that are not fossil-fuel based

How will wetland vegetation change?

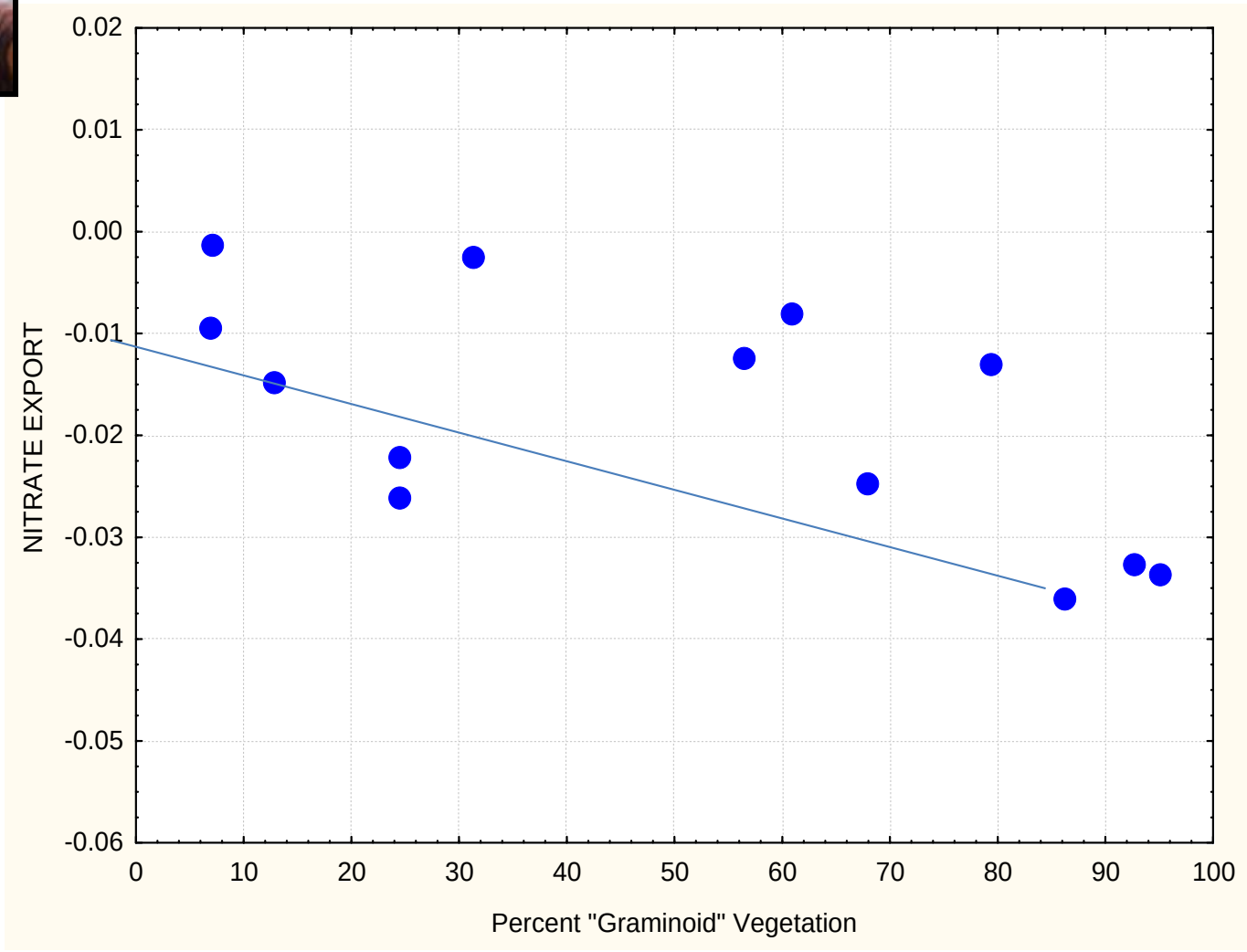
Vegetation in 2009



Vegetation in 2080



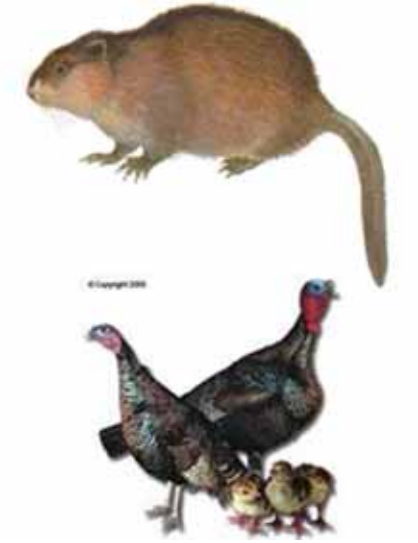
What does this mean?



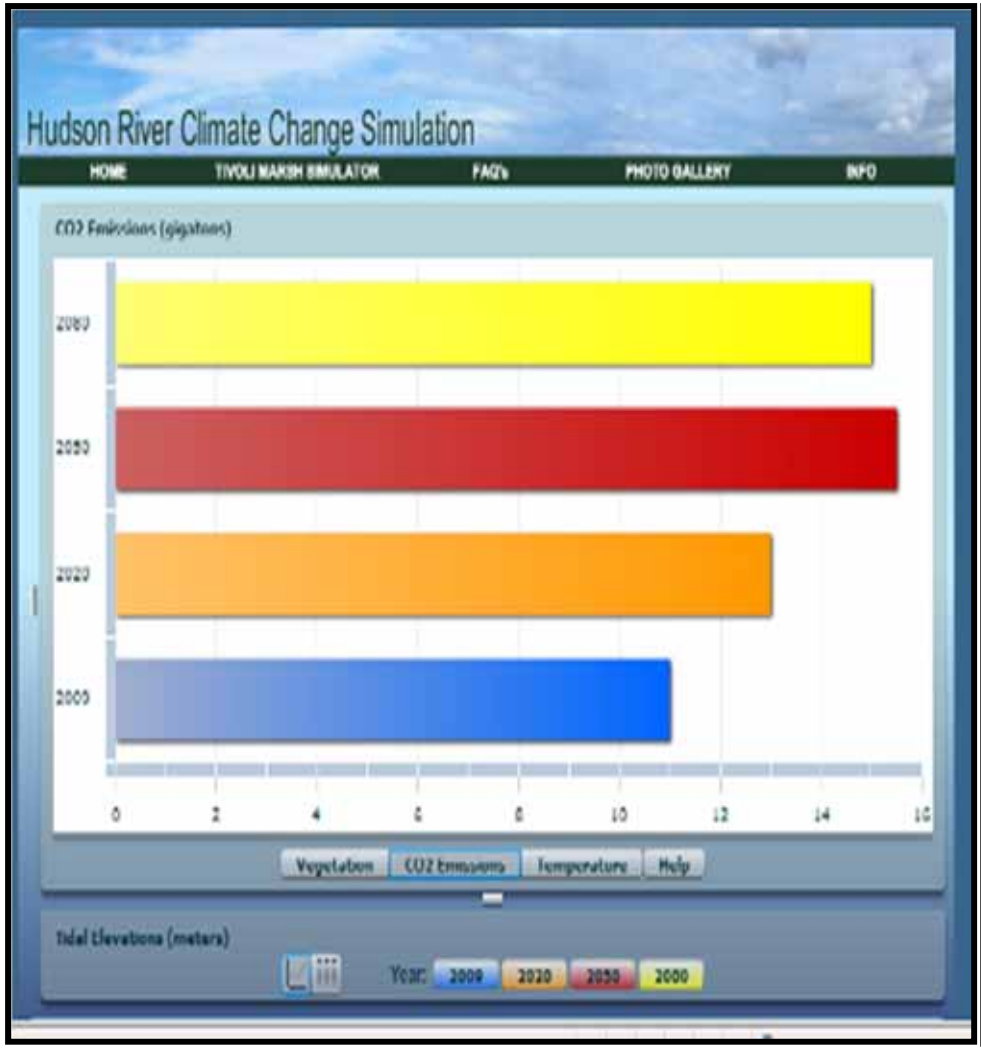
Reducing graminoid vegetation means increasing the amount of nitrate that enters the river

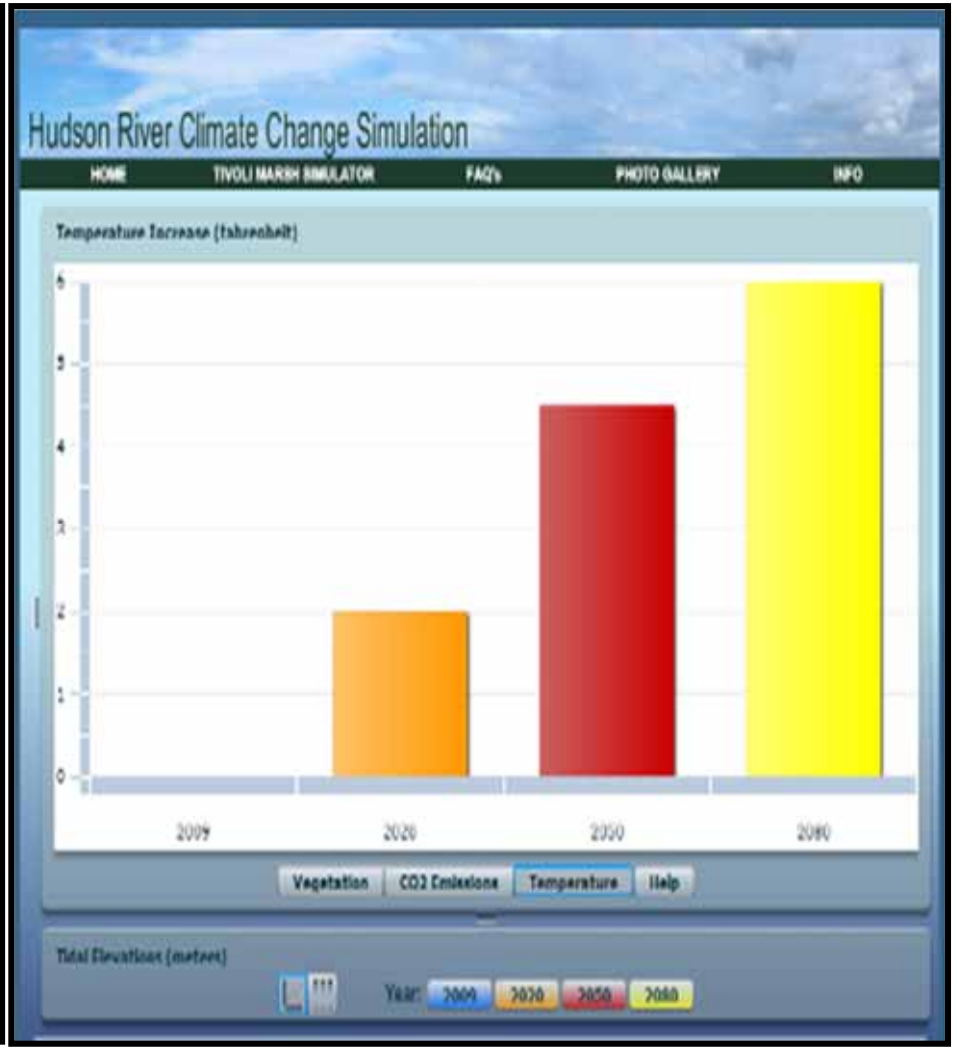
What are some other possible consequences?

Graminoid vegetation tends to harbor more diversity (plant and invertebrate; possibly avian)



Temperature & Carbon Dioxide





Why does temperature continue to increase even after carbon dioxide levels stabilize and then decline?

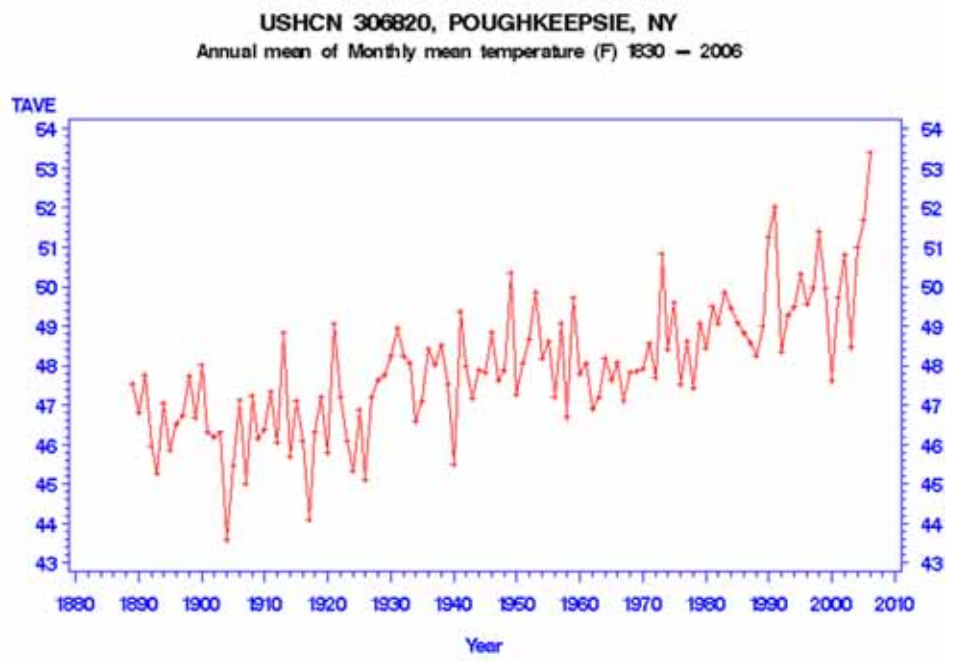
A: Temperature continues to increase because carbon dioxide has a long residence time in the atmosphere and will continue to influence temperatures for decades

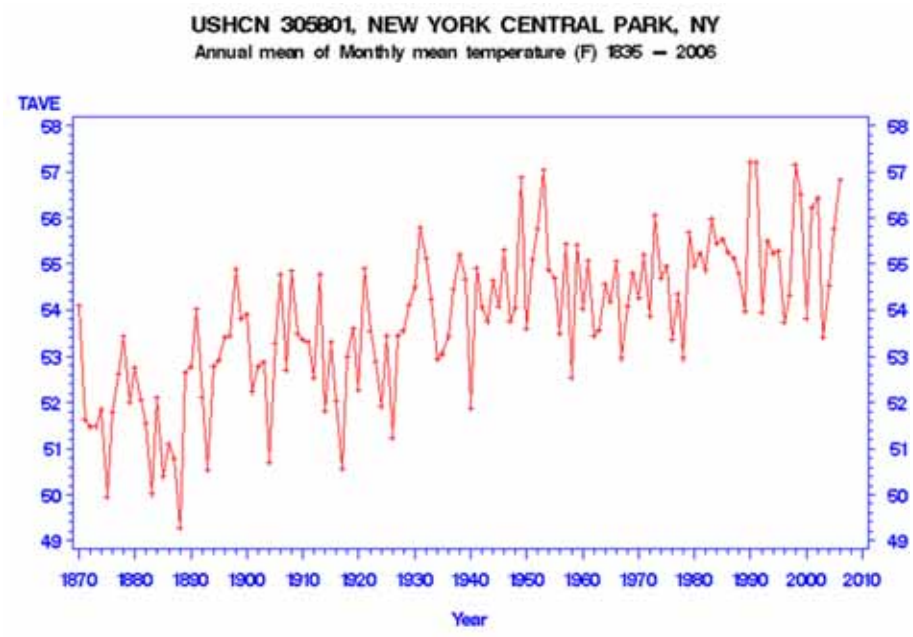
B: Temperature continues to increase because the model is inaccurate

C: Temperature continues to increase because carbon dioxide has not decreased very much, and therefore can't have a large impact on temperature

D: I don't know

Other Examples for the Classroom: Using local data

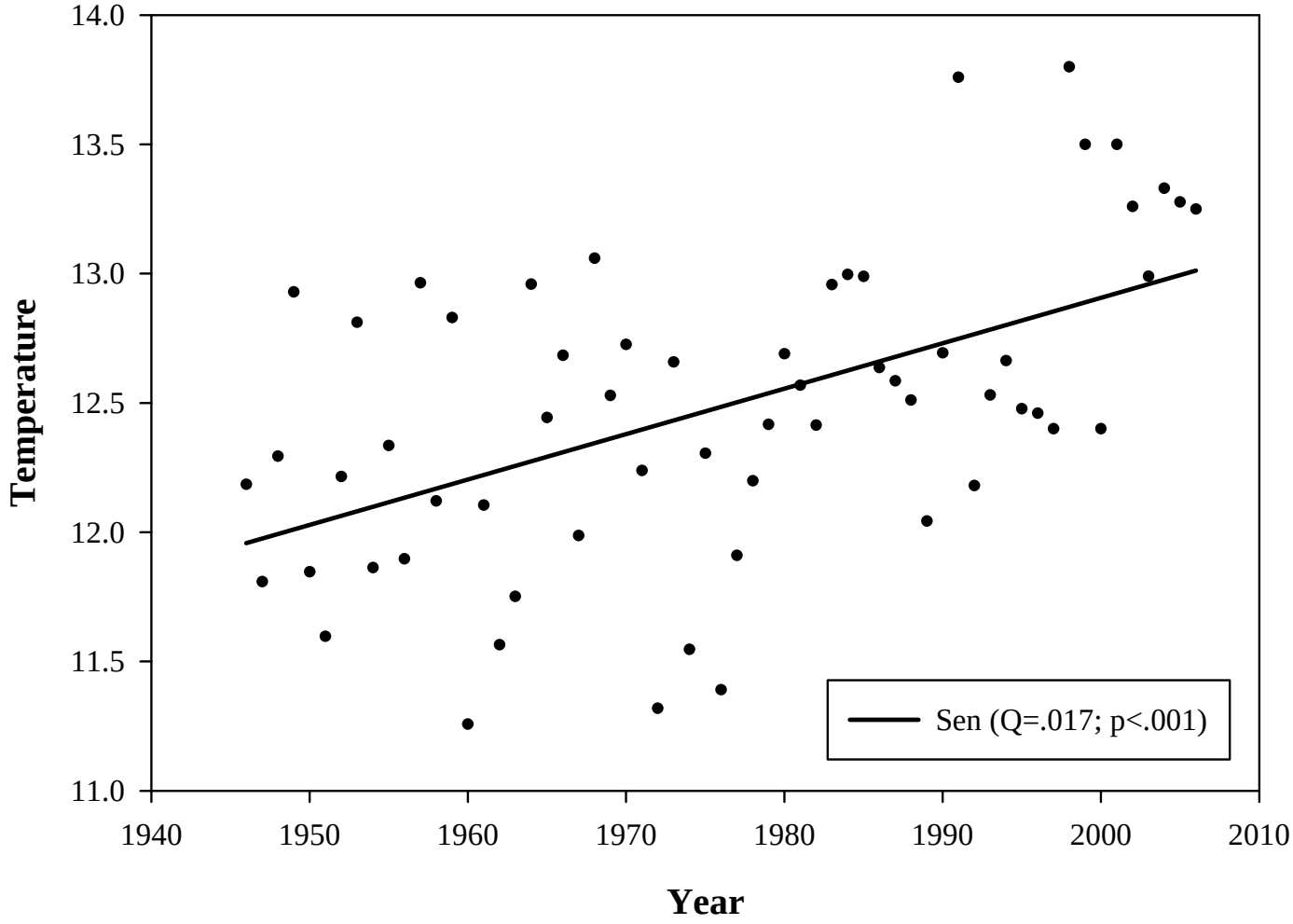




Source: CN Williams Jr., MJ Menne, RS Vose, DR Easterling, NOAA, National Climatic Data Center, Asheville, NC

Source: CN Williams Jr., MJ Menne, RS Vose, DR Easterling, NOAA, National Climatic Data Center, Asheville, NC

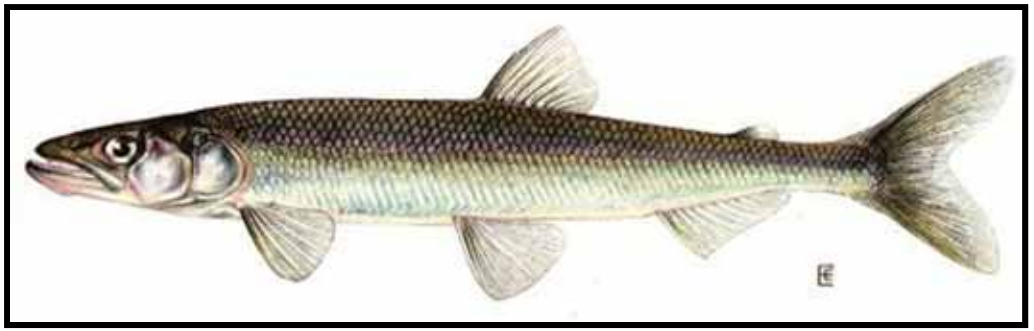
What is happening in the Hudson river?

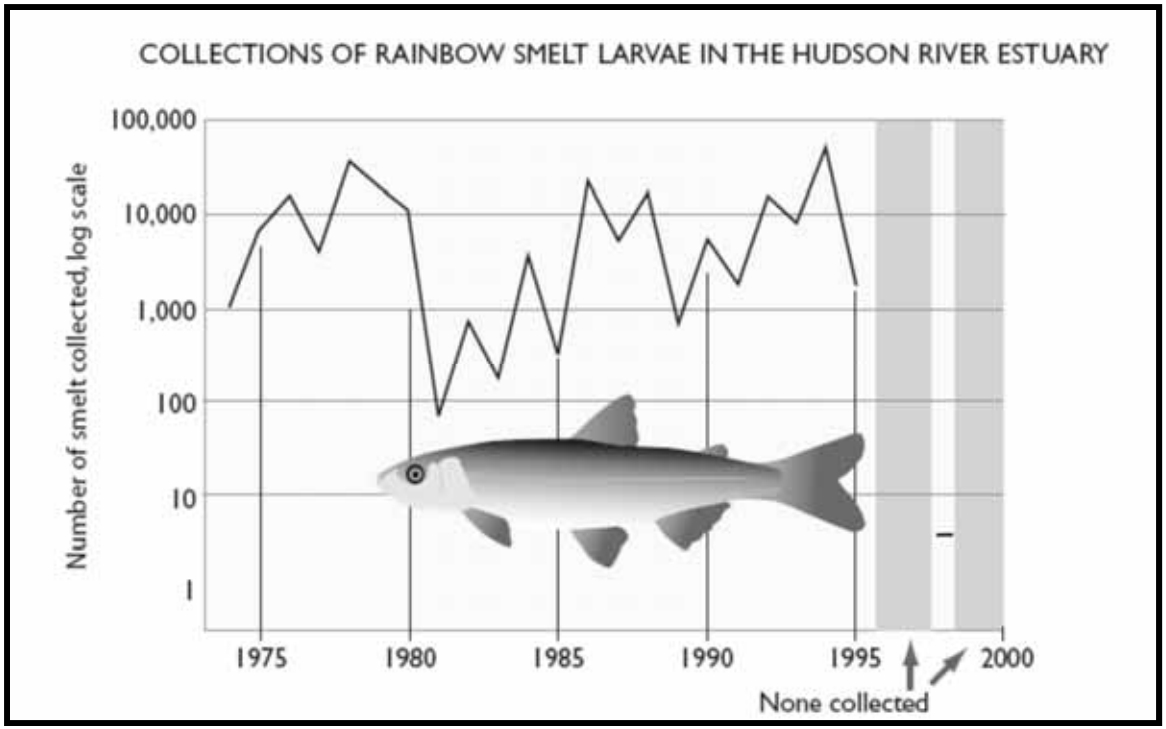


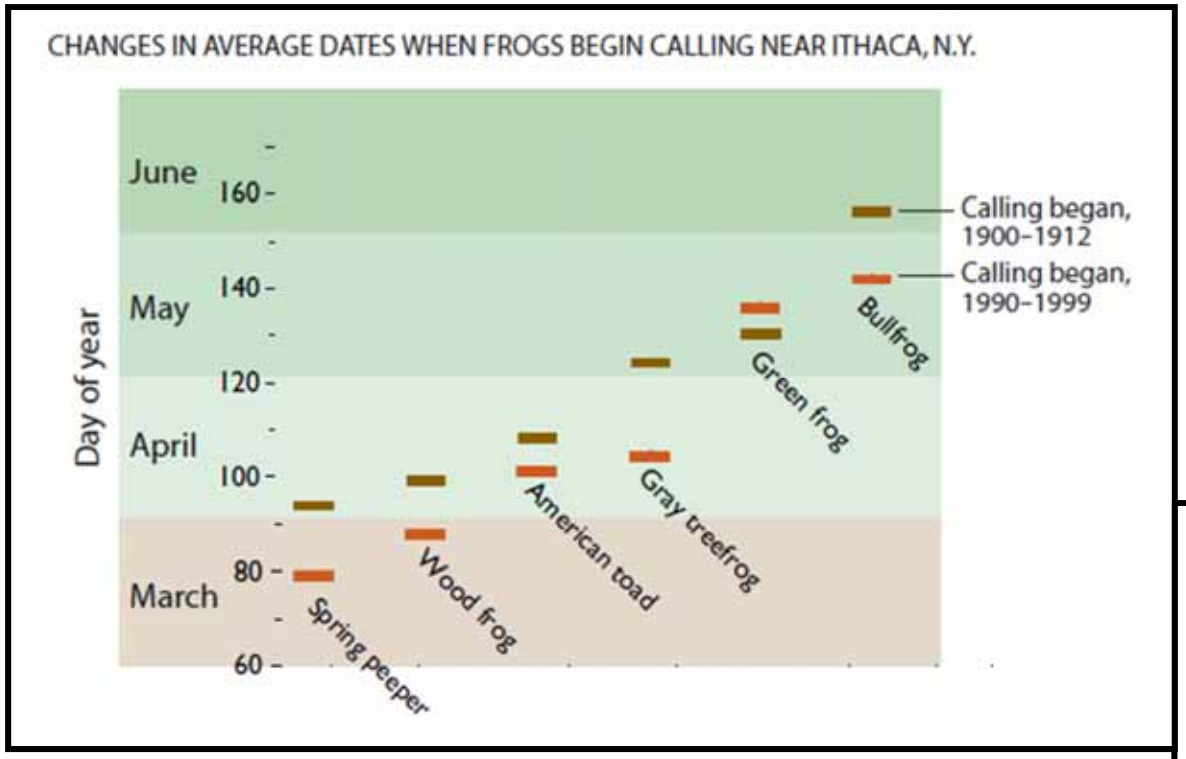
Increase of 0.017 degrees C per year

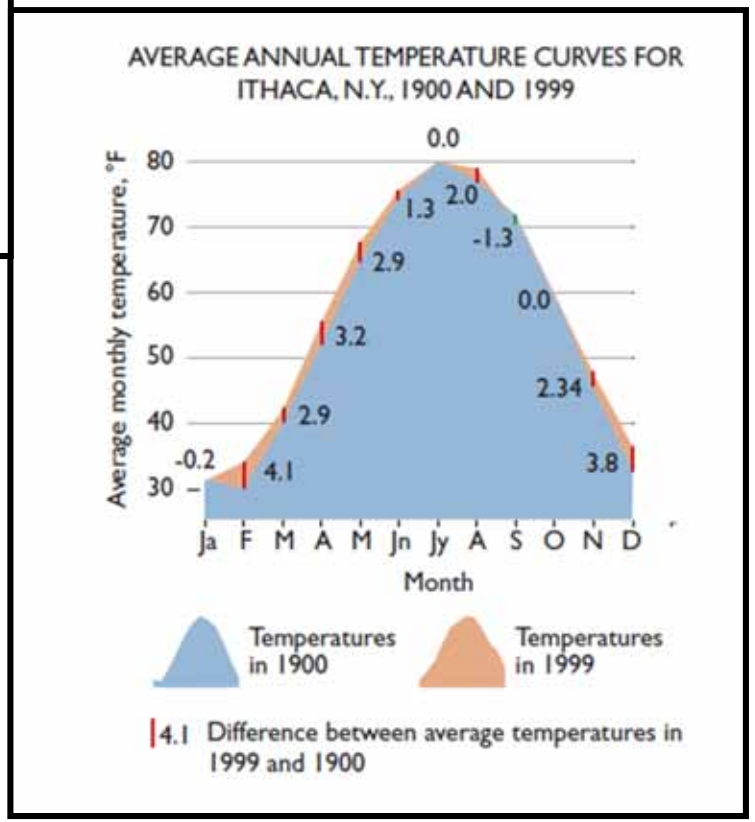
Seekel & Pace, 2008

What might this mean for the organisms that live in the Hudson River watershed?



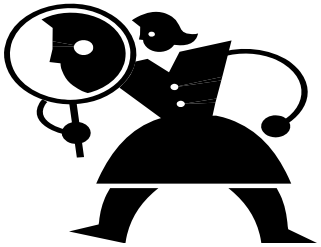


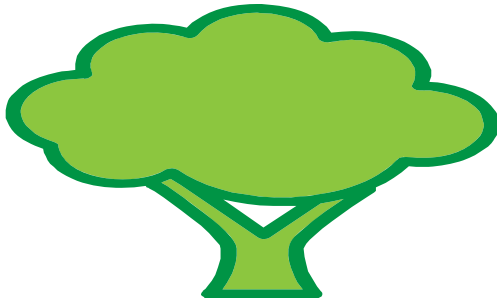




This lesson is available at the Cary Institute website; search for Hudson River Temperature.

Paleoclimate: Climate Detectives

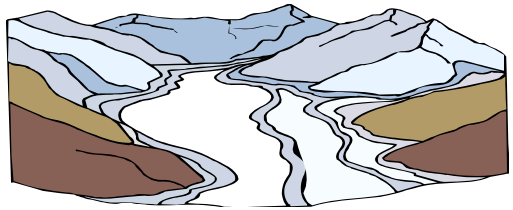




What kinds of “pollen” did you find?

“Pollen”	How many of this “pollen” did you find?	Plant

What does this tell you about the climate of your soil sample? What was it like for the plants and animals who lived during that time?



Climate Change Lessons

- What about carbon dioxide? (investigation)
- Effects of temperature on organisms (investigation)
- Hudson River temperature changes (data)
- Climate Summit (debate)
- Carbon footprint
- Paleoclimate of the Hudson Valley (investigation)

Let's Pause for Questions?

Additional Resources

National Estuarine Research Reserve

http://www.nerrs.noaa.gov/

National Oceanic and Atmospheric Association

http://www.noaa.gov/

Cary Institute of Ecosystem Studies

http://www.ecostudies.org/

American Fisheries Society

http://www.fisheries.org/afs/index.html

Hudson River Estuary Program

http://www.dec.ny.gov/lands/4920.html

Cornell Water Resource Institute

http://wri.eas.cornell.edu/

THANK YOU

Climate Change along Northeast Coasts and Estuaries

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National Estuarine Research Reserve, NYSDEC Hudson River Estuary Program
Water Resource Institute at Cornell University
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