Science, Service, Stewardship

Regional hydroclimatic flood trends and relevance for river herring habitat

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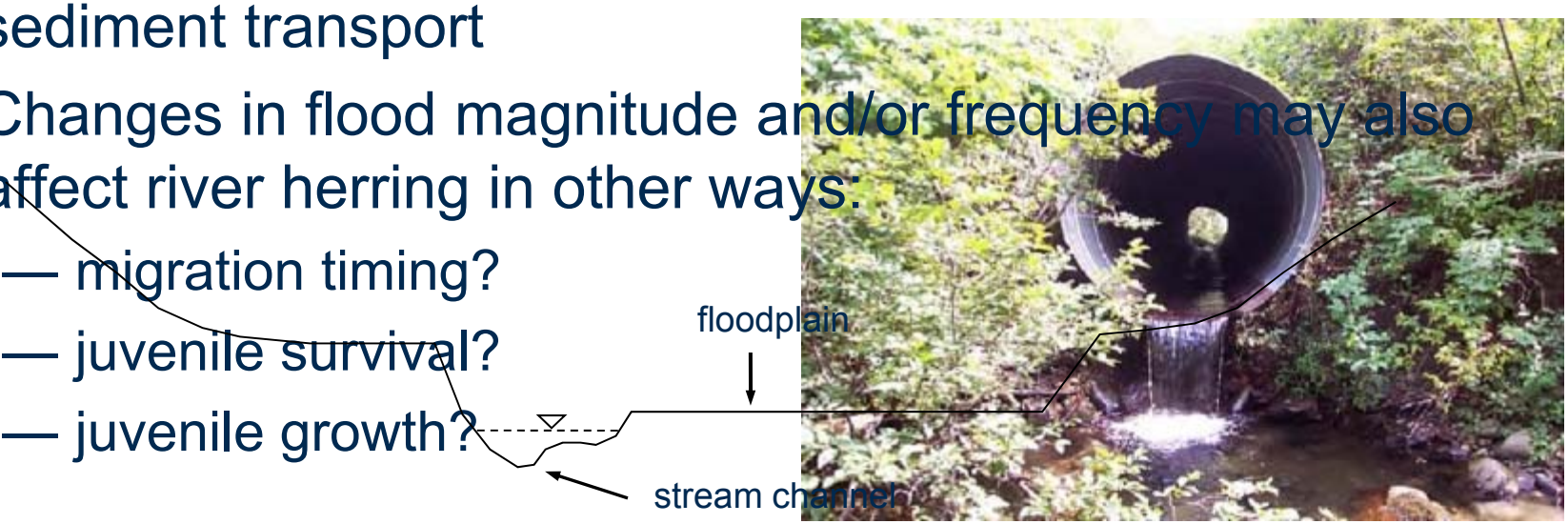
River herring and floods?

- Floods affect in-stream infrastructure and thus fish passage
- Floods also directly affect stream habitat via their influence on channel geometry (in alluvial rivers) and sediment transport
- Changes in flood magnitude and/or frequency may also affect river herring in other ways:
  - — migration timing?
  - — juvenile survival?
  - — juvenile growth?



Credit: Brian Graber

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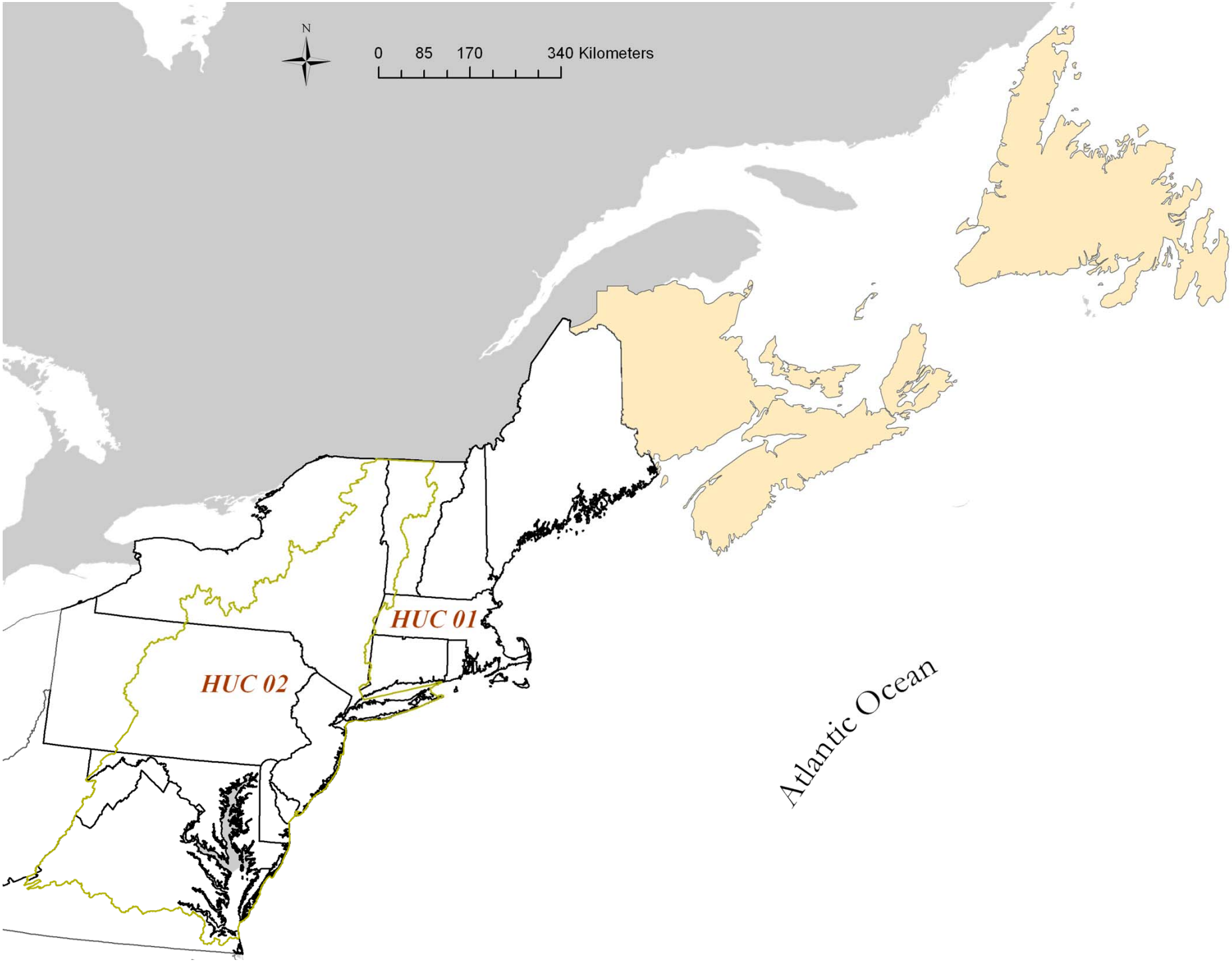
Presentation map

- Briefly review study area and methods
- Present results of three flood magnitude trend studies
  - — Northeast U.S. (*Armstrong et al., in review*; *Collins, 2009)*;
  - — Atlantic Canada (in progress)
- Discuss implications of magnitude trends for fish passage and habitat restoration design
- Present results from two flood frequency trend studies
  - — Northeast U.S. (*Armstrong et al., 2012; Armstrong et al., in review*)
- Discuss implications for stream channel habitat


N
0 85 170 340 Kilometers
HUC 01
HUC 02
Atlantic Ocean

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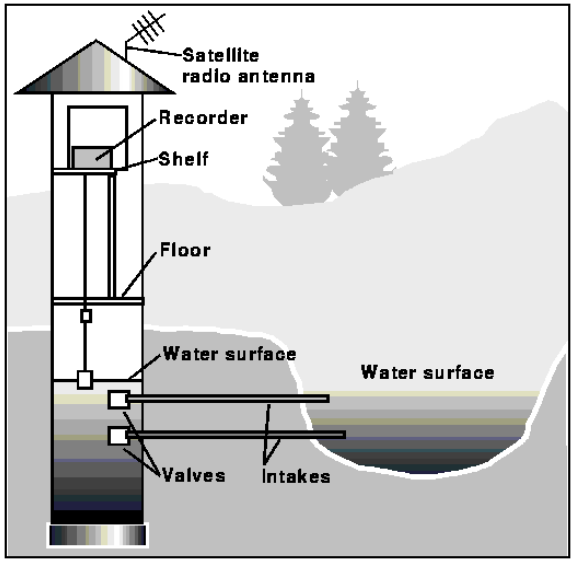
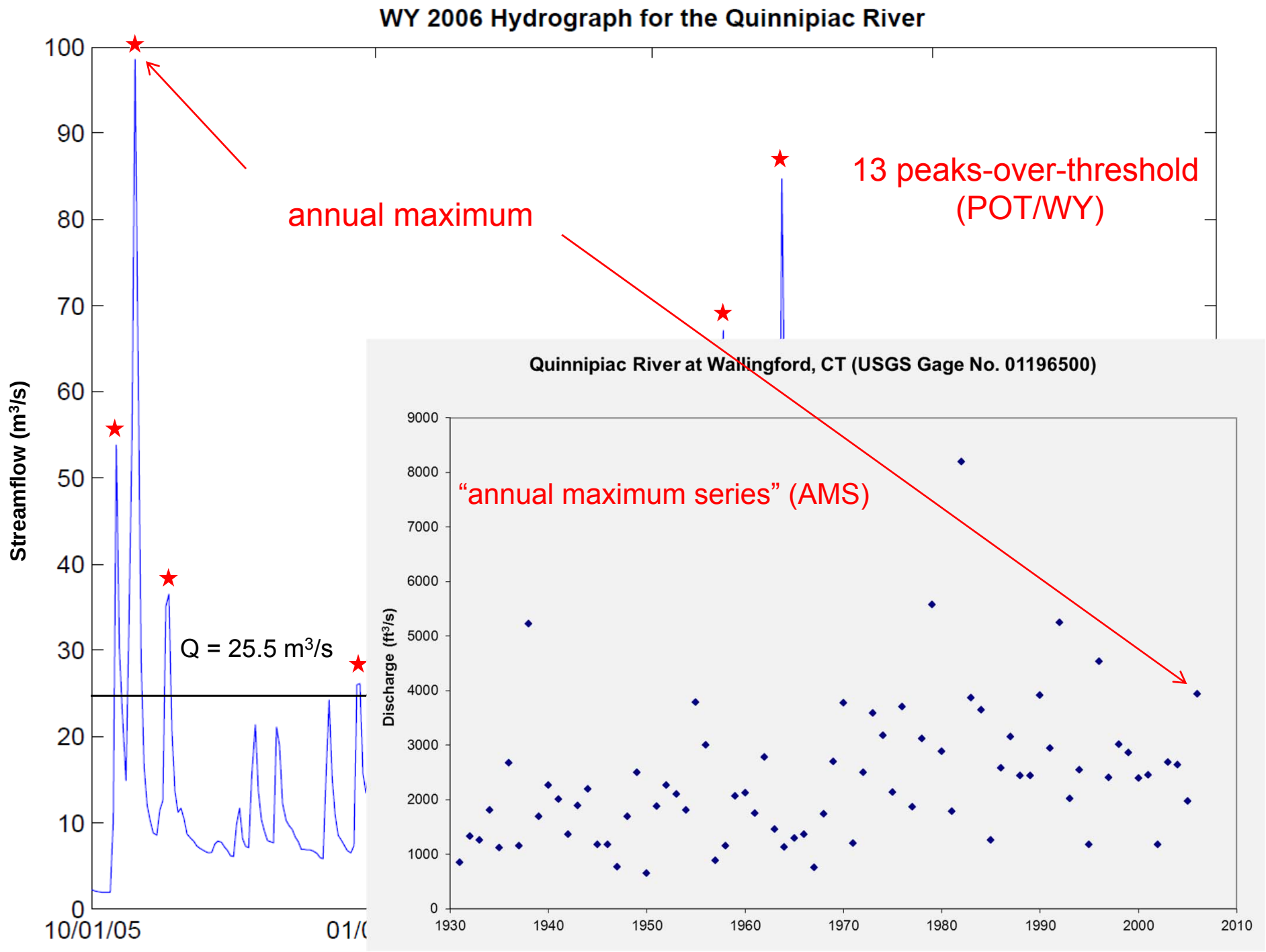
Methods



Using data from U.S. Geological Survey (USGS) and Water Survey of Canada (WSC) stream gauges:

- Annual maximum series for magnitude trend studies
- "Peaks-over-threshold" series for frequency trend studies


WY 2006 Hydrograph for the Quinnipiac River
Streamflow (m³/s)
100
90
80
70
60
50
40
30
20
10
0
10/01/05
01/(
annual maximum
13 peaks-over-threshold
(POT/WY)
Q = 25.5 m³/s
Quinnipiac River at Wallingford, CT (USGS Gage No. 01196500)
Discharge (ft³/s)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1930
1940
1950
1960
1970
1980
1990
2000
2010
"annual maximum series" (AMS)

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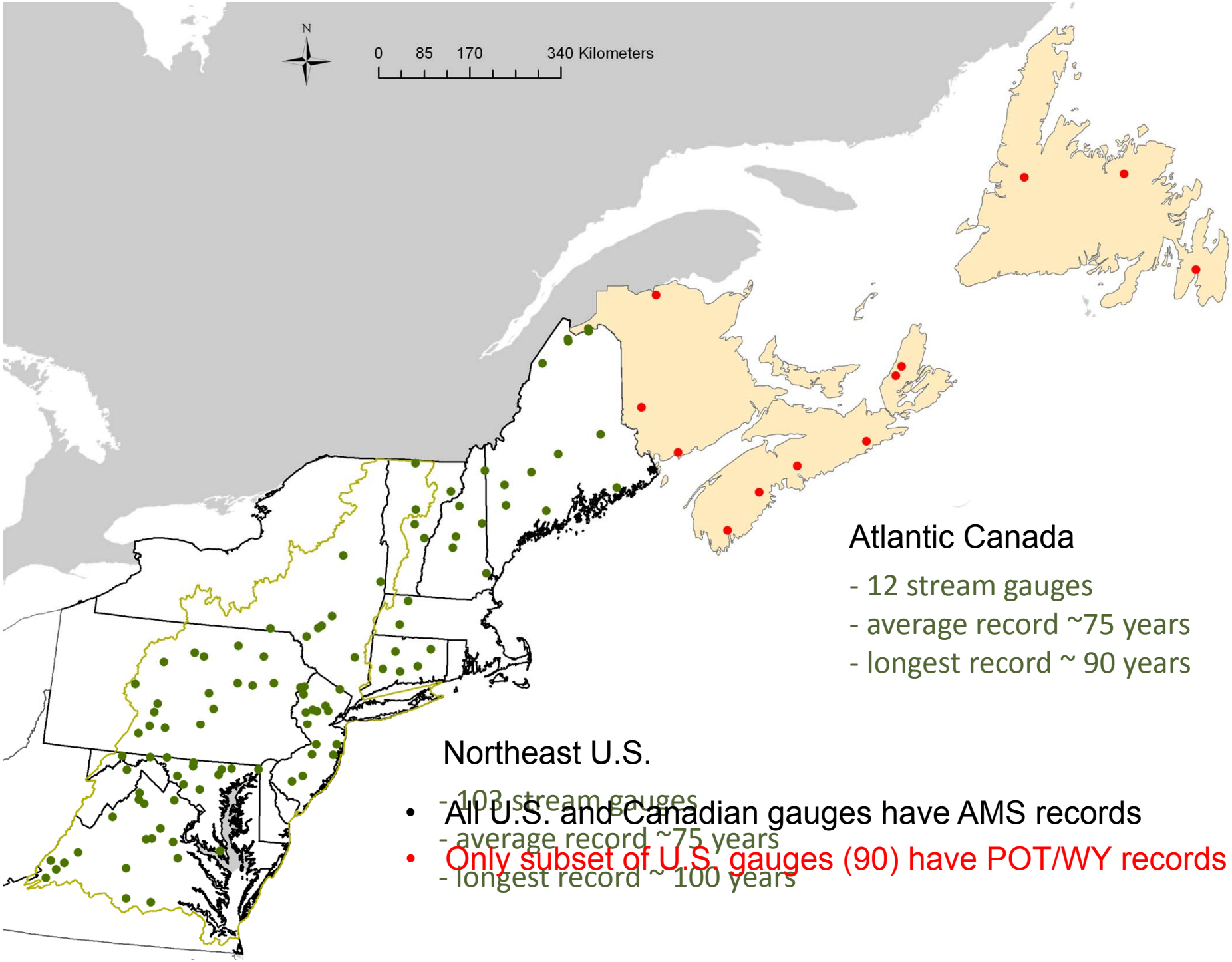
Methods

- Avoiding urbanizing watersheds
- Using watersheds “relatively free” of human influence
  - —USGS Hydro-Climatic Data Network (HCDN)
  - —WSC Reference Hydrologic Benchmark Network (RHBN)
- Our additional criteria:
  - —records beginning by at least 1951
  - —no more than 5 years of missing data
  - —no evidence of flow regulation impacting flood flows



Atlantic Canada

- 12 stream gauges
- average record ~75 years
- longest record ~ 90 years

Northeast U.S.

- 103 stream gauges
- average record ~75 years
- longest record ~ 100 years

- All U.S. and Canadian gauges have AMS records
- Only subset of U.S. gauges (90) have POT/WY records

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Methods

- Mann-Kendall non-parametric test for monotonic trends (simply ↑ or ↓ with time)
- Wilcoxon rank-sum test to investigate stepped trends
- Flood risk analyses following federal interagency guidelines (“Bulletin 17B”) (IACWD, 1981)

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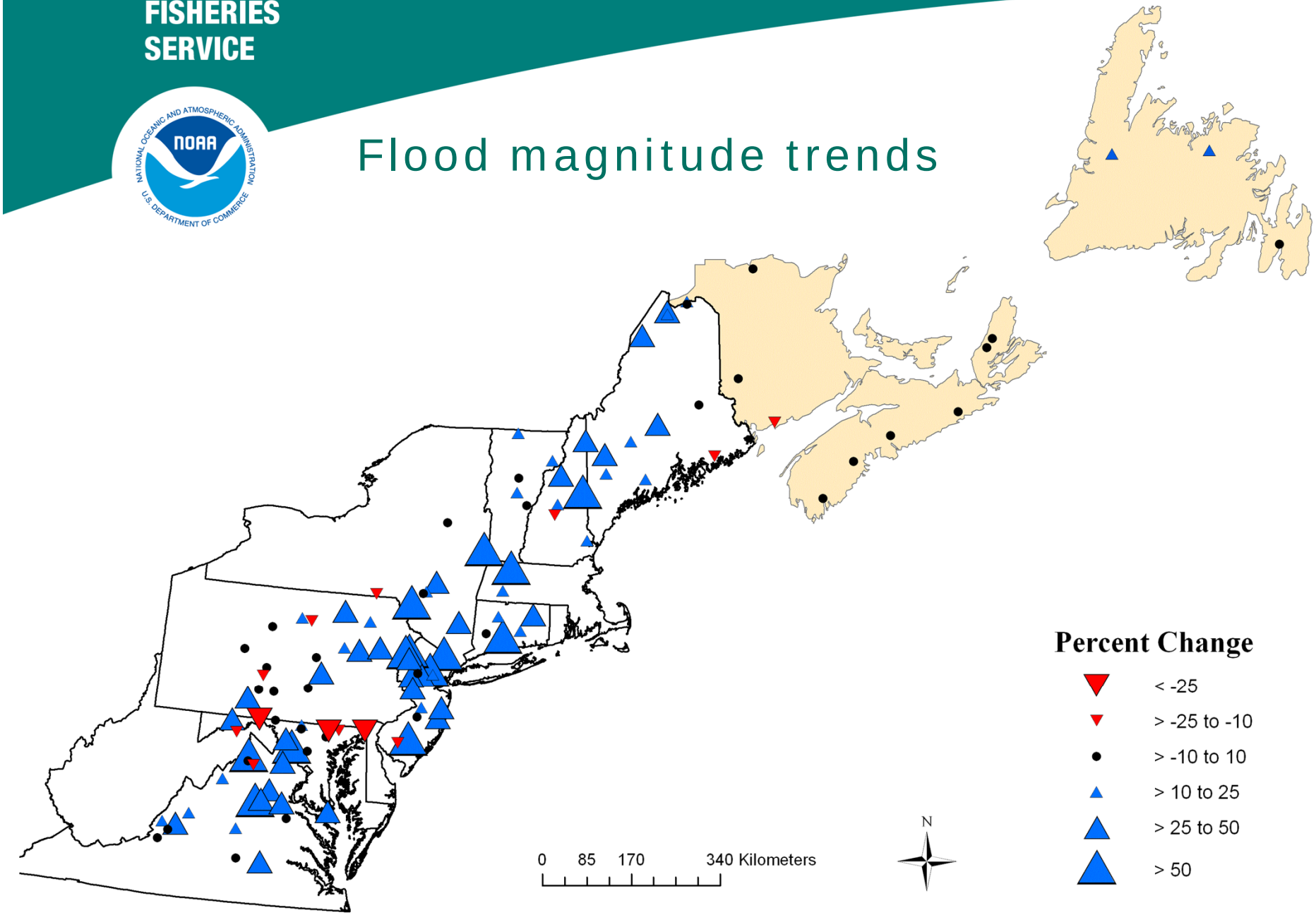
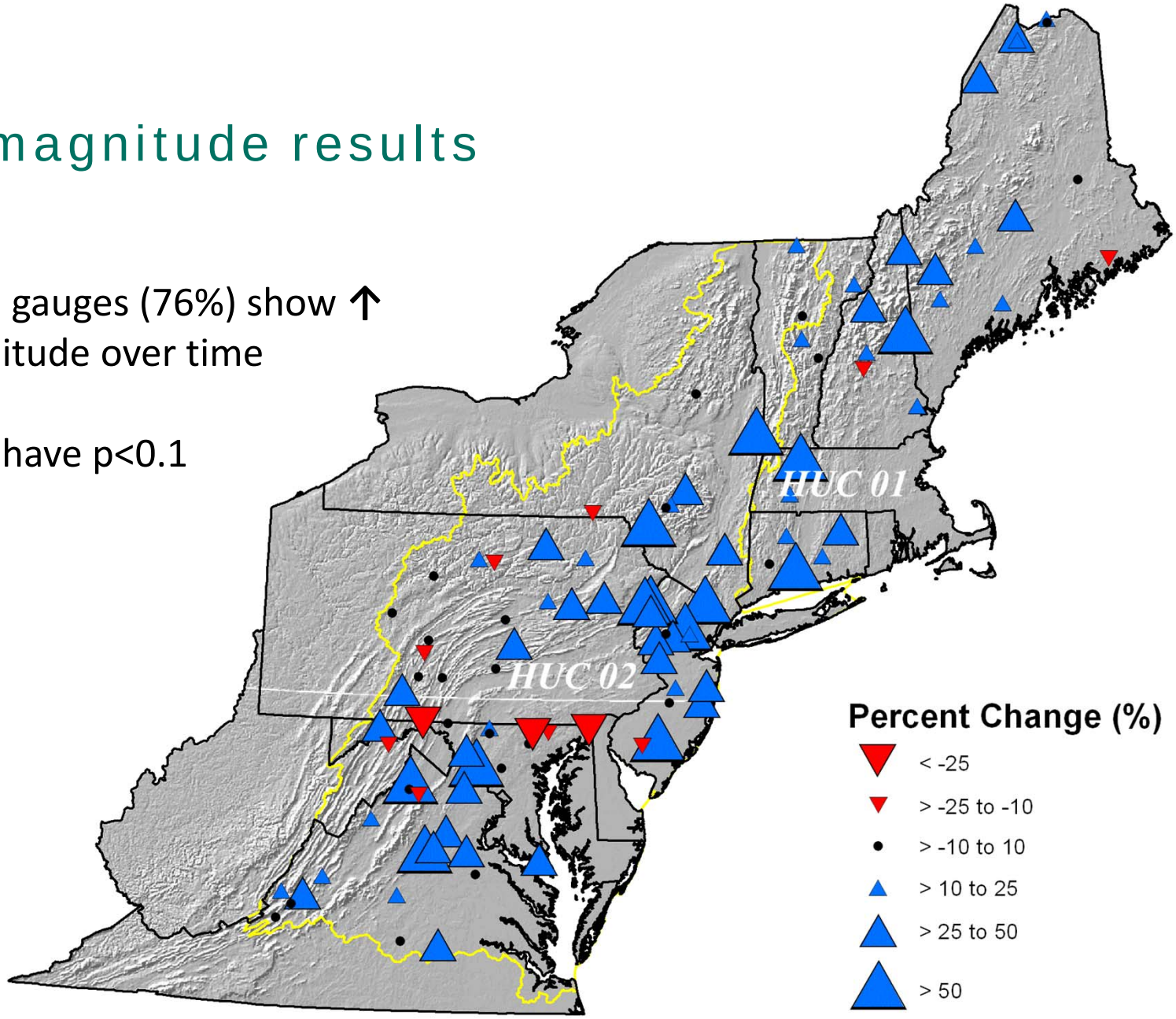
Flood magnitude trends



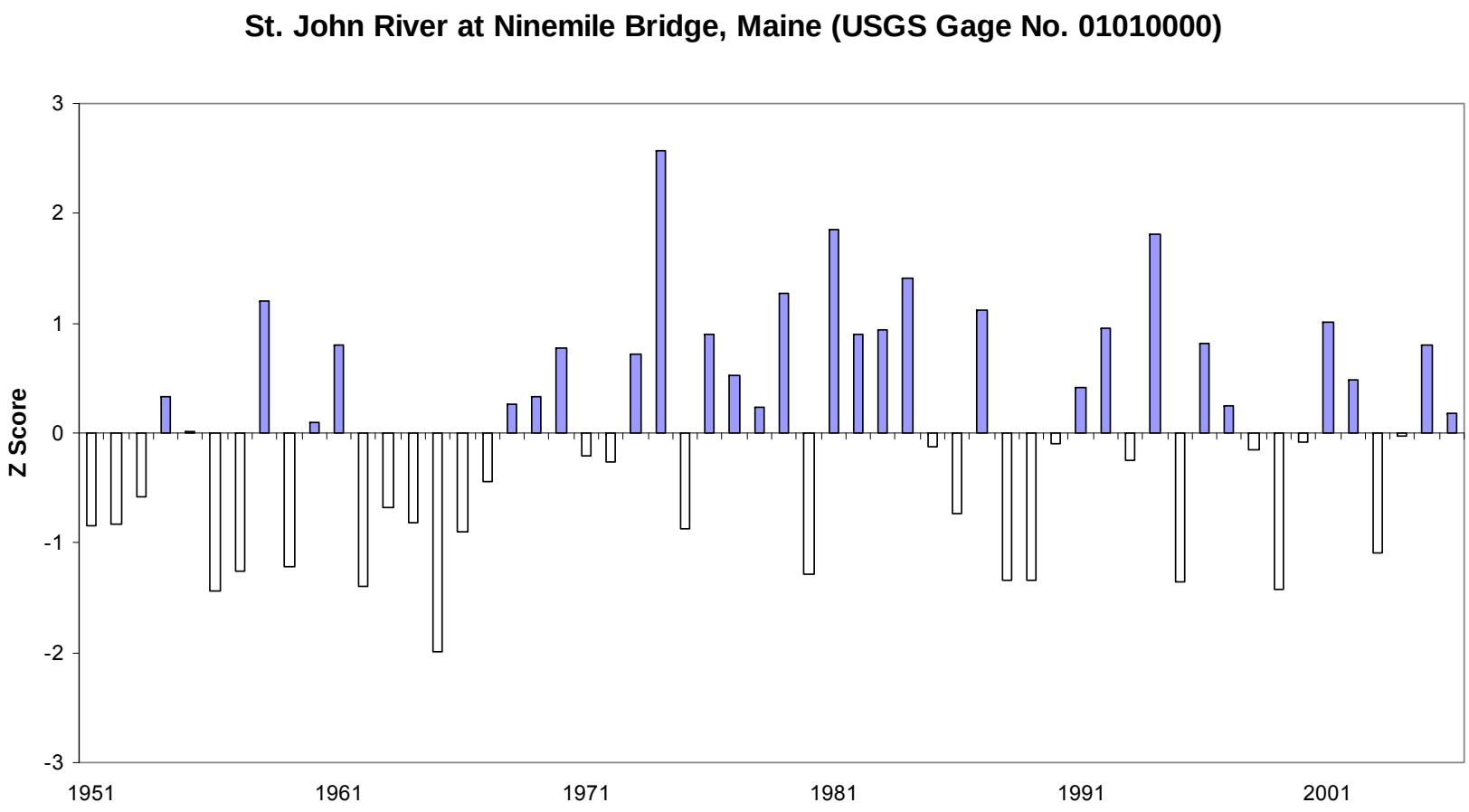
Flood magnitude results

- 78 of 103 gauges (76%) show ↑ flood magnitude over time
- 25 (24%) have p<0.1



after Collins (2009) and Armstrong et al. (in review)

Step changes in magnitude?



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Step changes in flood magnitude?

<u>Wilcoxon rank-sum test</u>

- Comparison groups:
  - —post-1970 Z scores
  - —pre-1970 Z scores
- 90 of 103 (87%) U.S. gauges have post-1970 > pre-1970
- 40 of 103 (39%) have $p<0.1$

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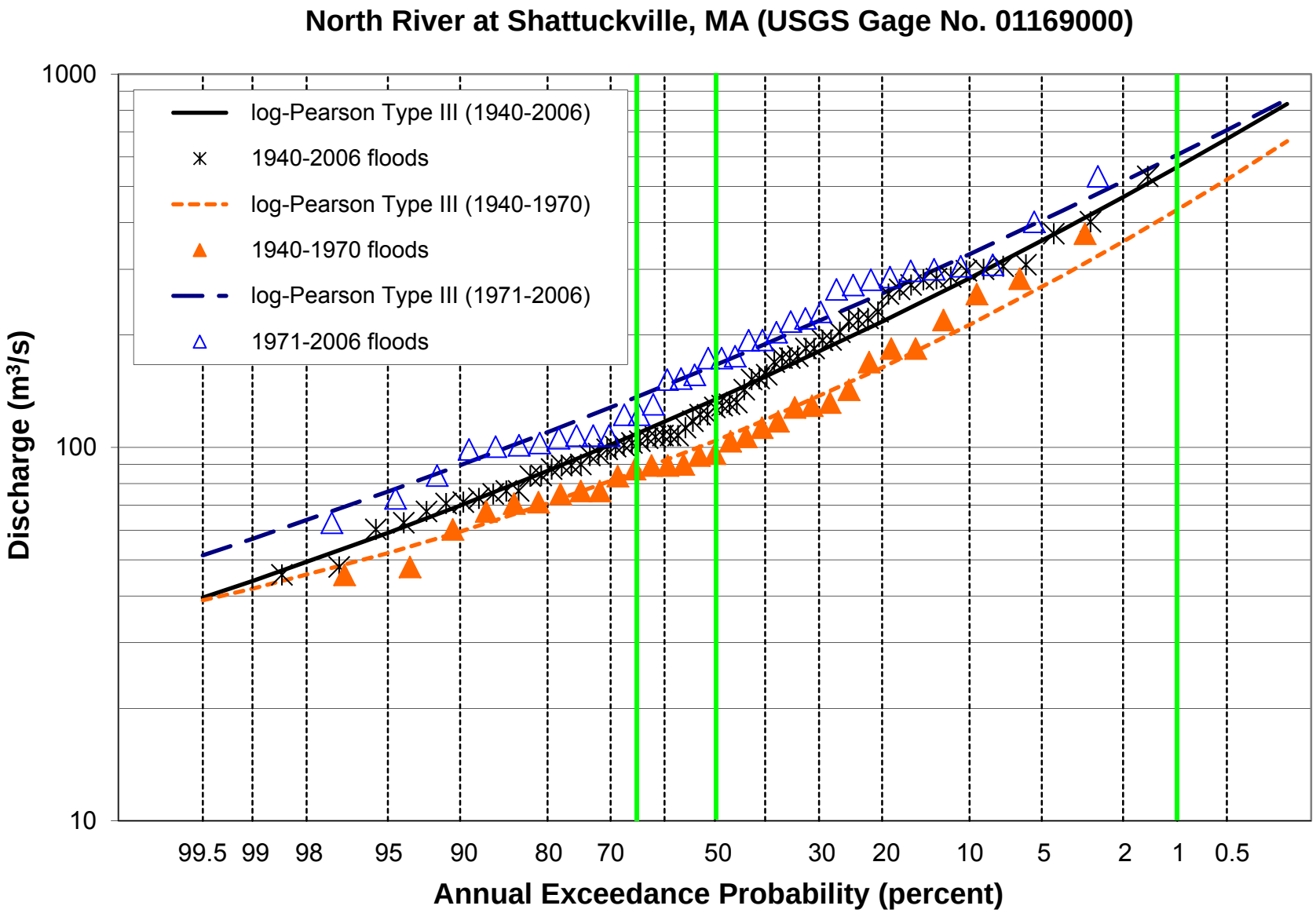
Implications of magnitude trends for fish passage and habitat

- AMS used to compute flood risk estimates for designing culverts and fish passage infrastructure (e.g. spillways)
- What happens to flood risk estimates when there are stepped, upward trends in the AMS?
  - In Northeast U.S., dated estimates will usually be <u>underestimates</u> (e.g. older FEMA Flood Insurance Studies);
  - Yet older estimates still frequently used for design!

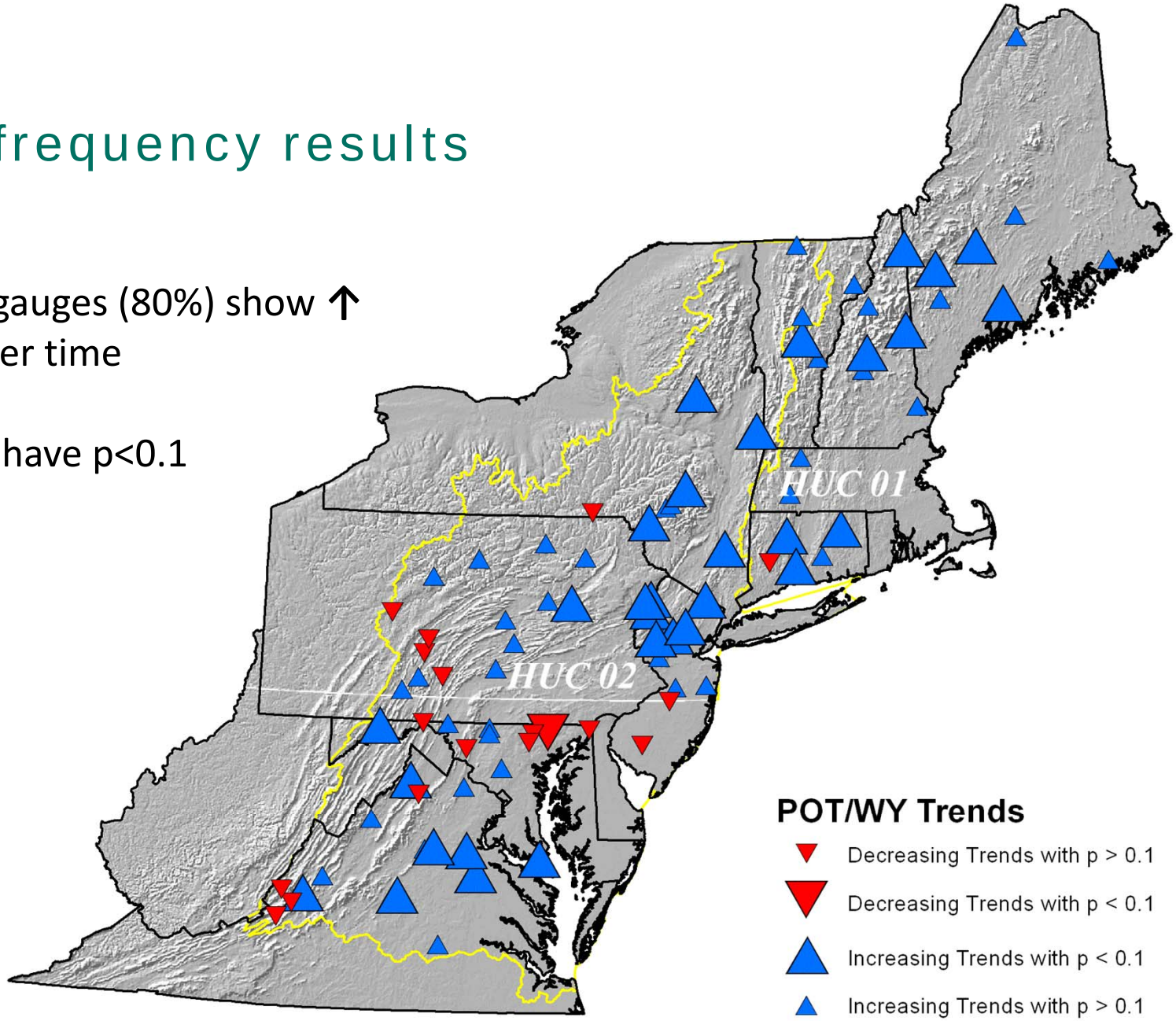

North River at Shattuckville, MA (USGS Gage No. 01169000)
log-Pearson Type III (1940-2006)
1940-2006 floods
log-Pearson Type III (1940-1970)
1940-1970 floods
log-Pearson Type III (1971-2006)
1971-2006 floods
Discharge (m³/s)
1000
100
10
99.5
99
98
95
90
80
70
50
30
20
10
5
2
1
0.5
Annual Exceedance Probability (percent)

Credit: USFWS-GOMCP and Kennebec Estuary Land Trust.

Credit: Alden Research Laboratory, Inc.

Flood frequency results

- 72 of 90 gauges (80%) show ↑ POT/WY over time
- 32 (36%) have p<0.1



after Armstrong et al. (2012) and Armstrong et al. (in review)

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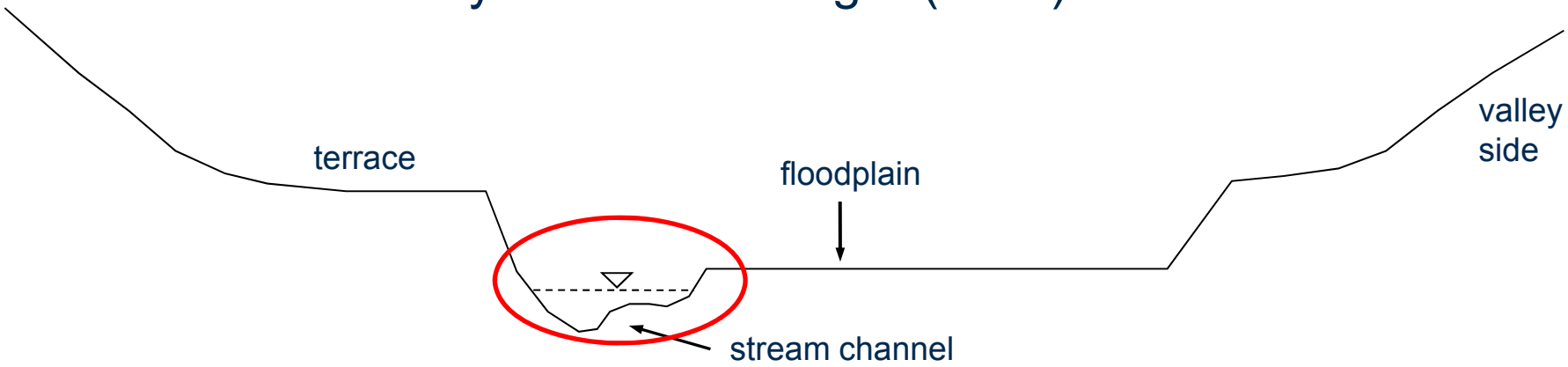
Implications for stream habitat

- Alluvial channel size is determined by small, frequent floods—1 to 2 yr recurrence intervals (Wolman and Miller, 1960)
- Our data show that small floods are increasing in magnitude AND frequency
- This suggests alluvial channels in the NE U.S. should be actively enlarging
- Recent work by Slater and Singer (2011) corroborates this



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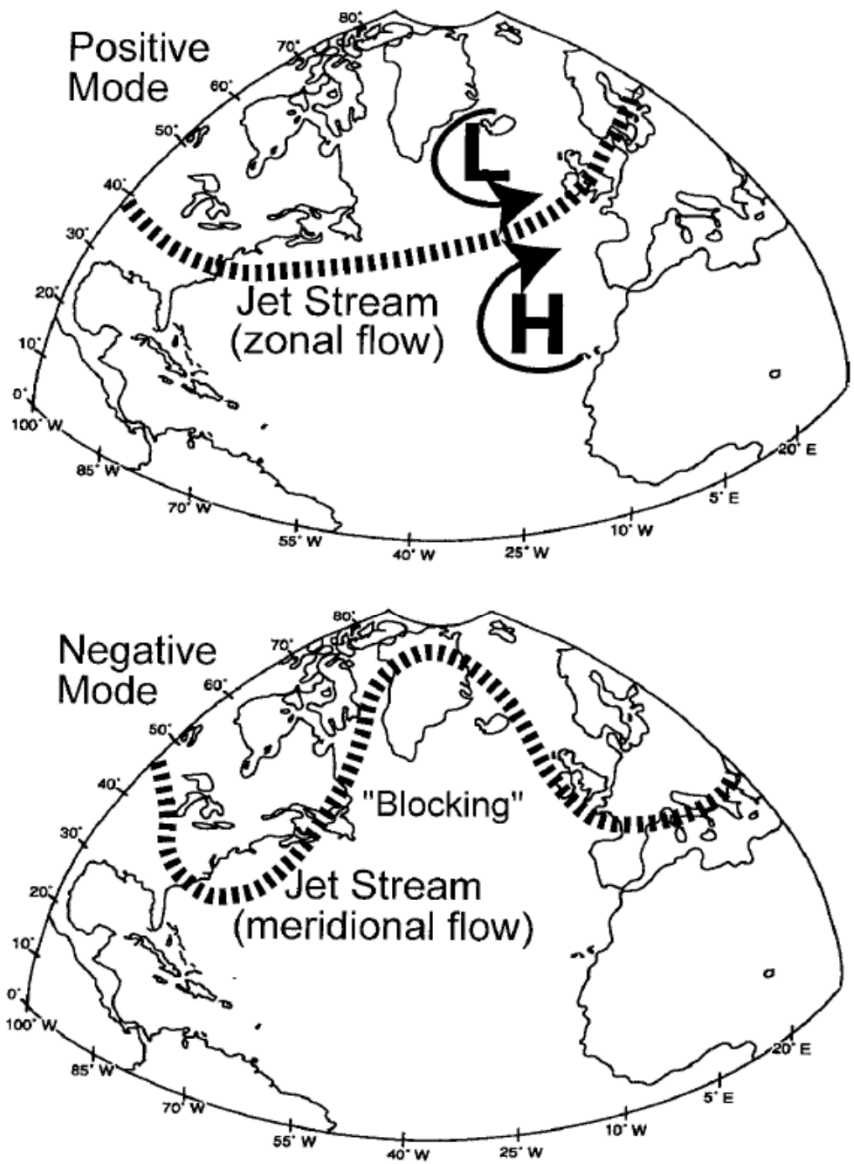
Summary

- Larger and more frequent floods over last decade appear to be part of a hydroclimatic step increase that began around 1970
- Trends especially compelling given rural NE land cover trends over last 100 years
- Trends have implications for fish passage infrastructure and for stream channel habitat
- Trends may have other implications for river herring?
- Climatically-induced changes are superimposed on, and enhance, similar changes brought about by watershed urbanization

Questions?

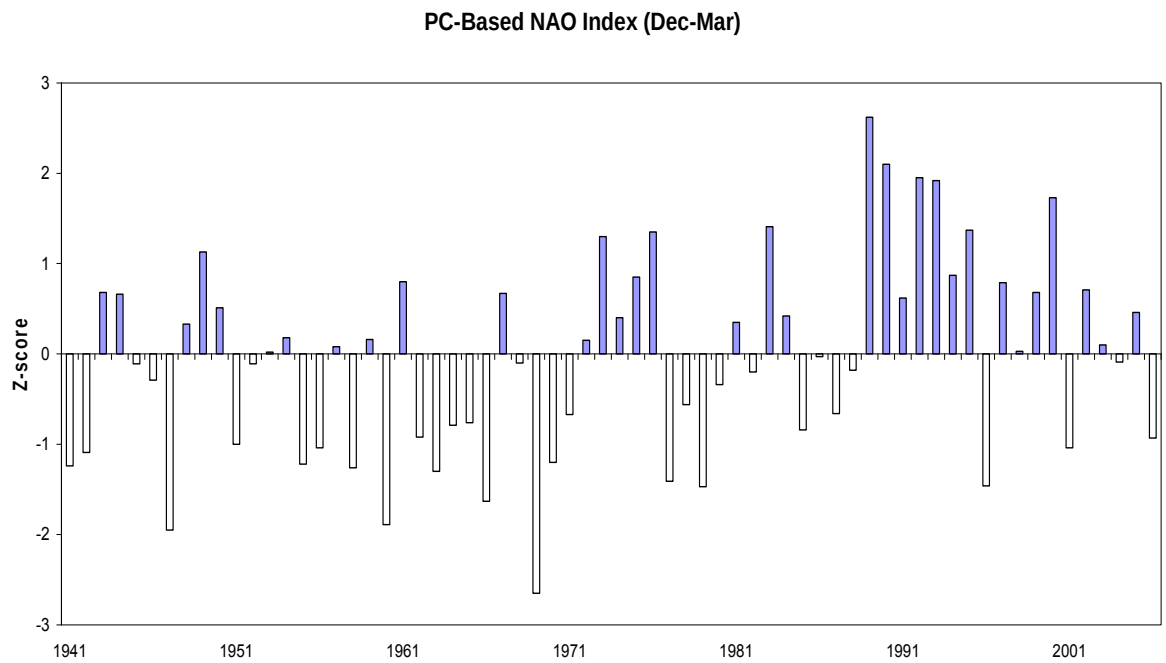


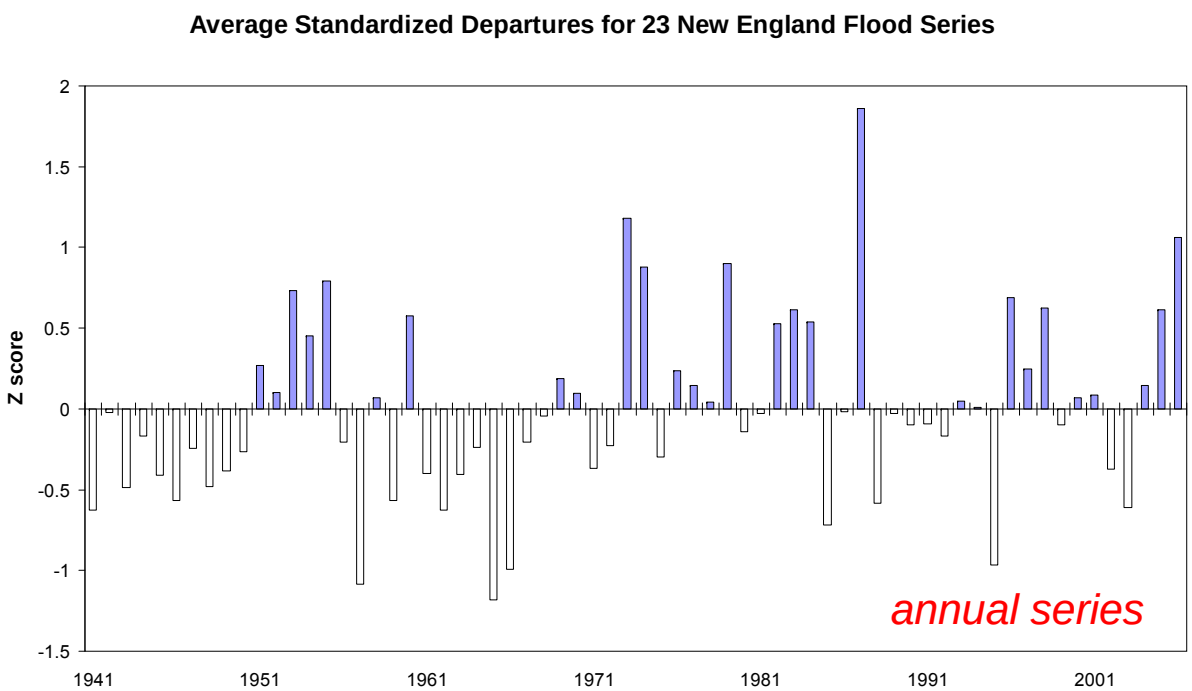
Bradbury et al. (2002)

NAO

- Positive NAO – warmer, wetter NE winters
- Negative NAO – colder, drier NE winters

NAO and NE Floods





- No correlation annually
- Significant correlation if floods lagged by 1 year ($p<0.1$)
- Substantial decadal correspondence