Do the 29 Asian Clam-Infested Lakes and Rivers in Massachusetts from 2001 to 2016 Show any Sign of Climate Change in the Region?

David Wong

Bureau of Water Resource

Massachusetts Department of Environmental Protection

Acknowledgements

- Jane Ryder, Hana Colwell, Rachel Holland
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- Jim Straub, Tom Flannery
- Mike Lowery
- Eileen McGourty
- Ken Wagner
- Joy Trahan-Liptak
- The MassDEP Internship Program

Why *Corbicula fluminea* ?

- It is an invasive species

On a global basis... the two great destroyers of biodiversity are, first, habitat destruction and, second, invasion by exotic species.

-E.O. Wilson (1997), in Strangers in Paradise

Invasive species is now considered as one of the top threats to our planet's biodiversity (Vitousek et al. 1997 Science 277; Halpern et al. 2008 Science 319).

Clean Water Act: Aquatic Life Use

The Asian clam *Corbicula fluminea*

- It is considered to be one of the most ecologically and economically important aquatic invasive species in global aquatic ecosystems (Sousa et al. 2008)
- The native range of *C. fluminea* is Eastern Asia and Africa but it has spread to Europe, North America, South America, and other areas of the world

The Asian clam *Corbicula fluminea*

Their invasive success and dispersion mainly relies on their natural characteristics:

- Rapid growth
- Early sexual maturity
- short life span

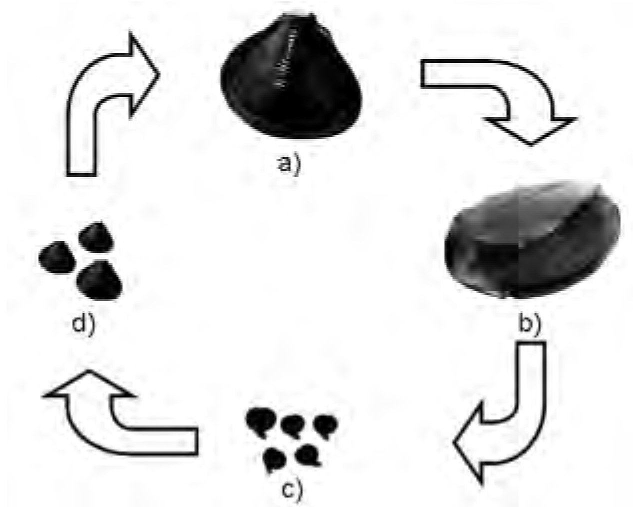


Fig. 1. Illustrative representation of the life cycle of *C. fluminea*: a) adult specimen; b) inner demibranch with larvae; c) small juveniles recently released (with a completely developed foot and with the common D-shaped configuration) and d) small adults.

Sousa et al. 2008

The Asian clam *Corbicula fluminea*

Their invasive success and dispersion mainly relies on their natural characteristics:

- Reproduction: hermaphrodites with se fertilization

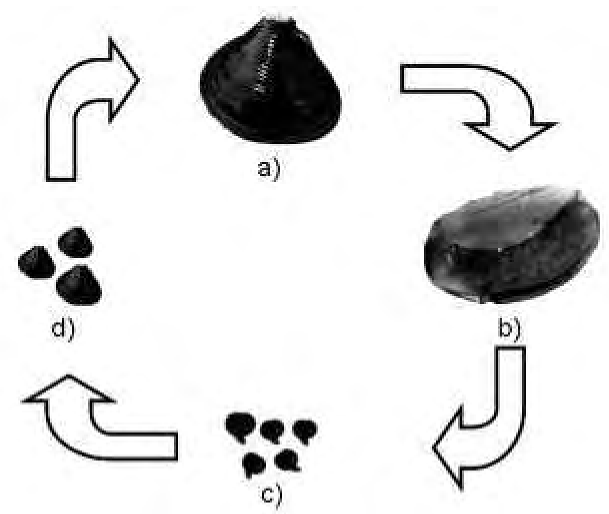


Fig. 1. Illustrative representation of the life cycle of *C. fluminea*: a) adult specimen; b) inner demibranch with larvae; c) small juveniles recently released (with a completely developed foot and with the common D-shaped configuration) and d) small adults.

Sousa et al. 2008

The Asian clam *Corbicula fluminea*

Their invasive success and dispersion mainly relies on their natural characteristics:

- High fecundity: one clam can produce as many as 400 larvae per day or up to 70,000 per year

The Asian clam *Corbicula fluminea*

Their invasive success and dispersion mainly relies on their natural characteristics:

- High fecundity: one clam can produce as many as 400 larvae per day or up to 70,000 per year
- Extensive dispersal capacities and their association with human activities (McMahon 2002)

NEANS
NORTHEAST AQUATIC NUISANCE SPECIES PANEL

Asian clam

Corbicula fluminea

Asian clam
Credit: Emily Debolt, Lake George Association

History:

- First confirmed report in North America was in 1938 in the Columbia River drainage
- Since then Asian clams have become widely distributed especially in the southern United States

Characteristics:

- Shells greenish-yellow to brown with thick concentric rings
- Thick symmetrical shell
- Up to 2 inches (5 cm) long
- Inside of shell is smooth and polished with a light purple tinge
- Three cardinal teeth in each valve

Habitat:

- Large rivers and lakes
- Clams burrow prefer sandy or silty sediments into which they burrow up to 6-8 inches

Known Distribution:

- Widely distributed in southern and western United States, in the Great Lakes and in southern New England
- Discovered in 2010 in Lake George, NY in the Champlain basin

Impacts:

- Clogging of power plant and industrial water systems, irrigation canals and pipes and drinking water supplies
- Competes with native species for limited resources
- May promote algae blooms due to localized nutrient loading from dense clam beds (observed in Lake Tahoe, CA)

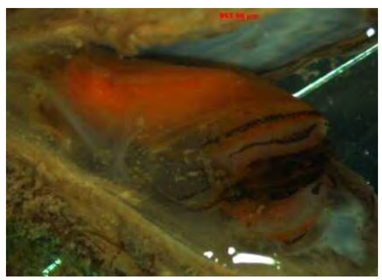
Common Vector(s):
Aquarium releaseBait releaseOverland transport (e.g. boats, equipment)

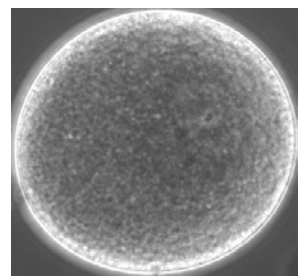
Why *Corbicula fluminea* ?

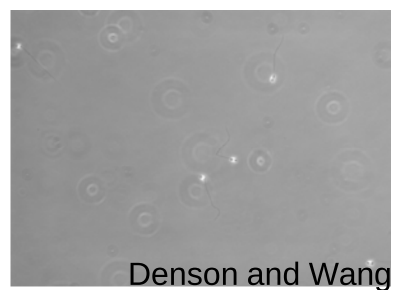
- $ 1 billion/year to control in USA (Pimentel et al. 2005)
- Ecological damage: Filter feeders and a dominant species
- Thermal sensitive species: lower thermal limit 2°C (Mattice and Dye 1976)

Asian Clam vs. Zebra Mussel

- Reproduction: Self-fertilization with less larvae vs. External-fertilization with more larvae







Denson and Wang 1994

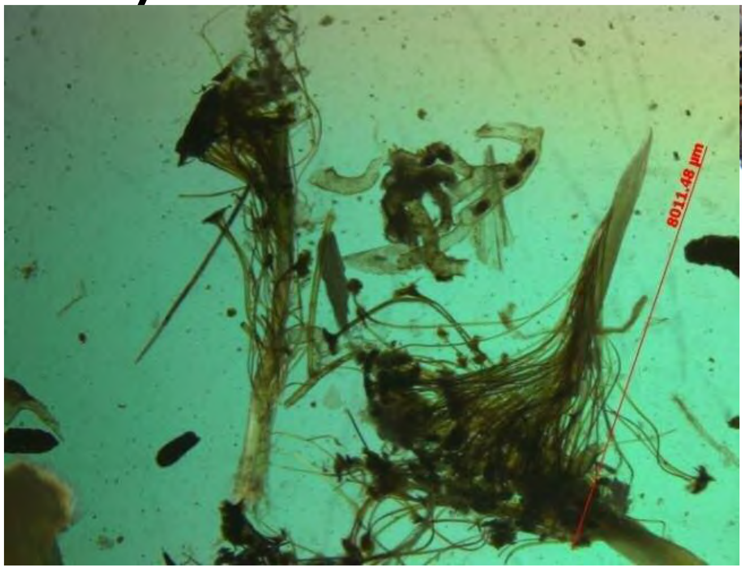
Asian Clam vs. Zebra Mussel

- Byssal Thread: One vs. Many

Photos by Dan Minchin

Asian Clam vs. Zebra Mussel

- Byssal Thread: One vs. Many



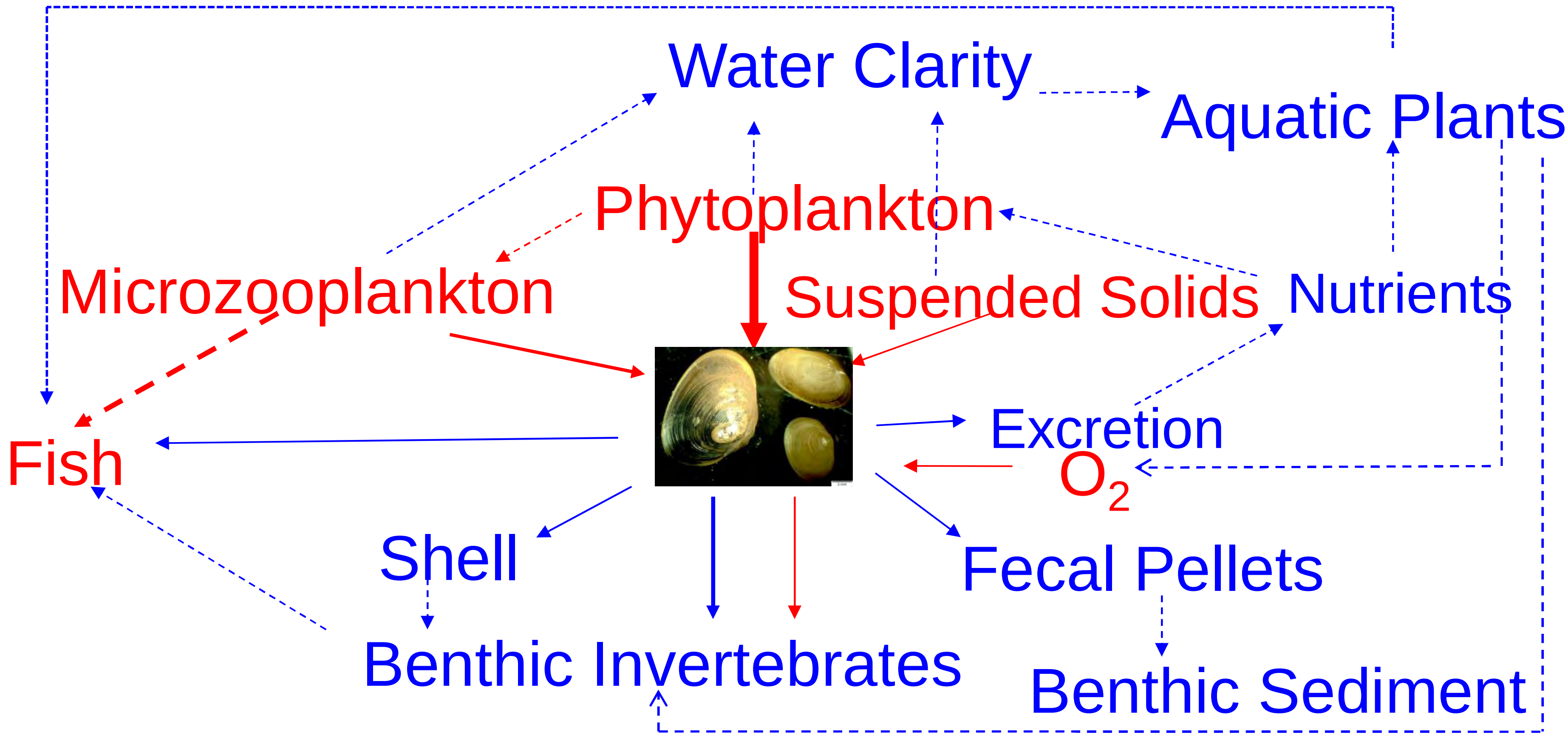
Photos by David Wong

Asian Clam vs. Zebra Mussel

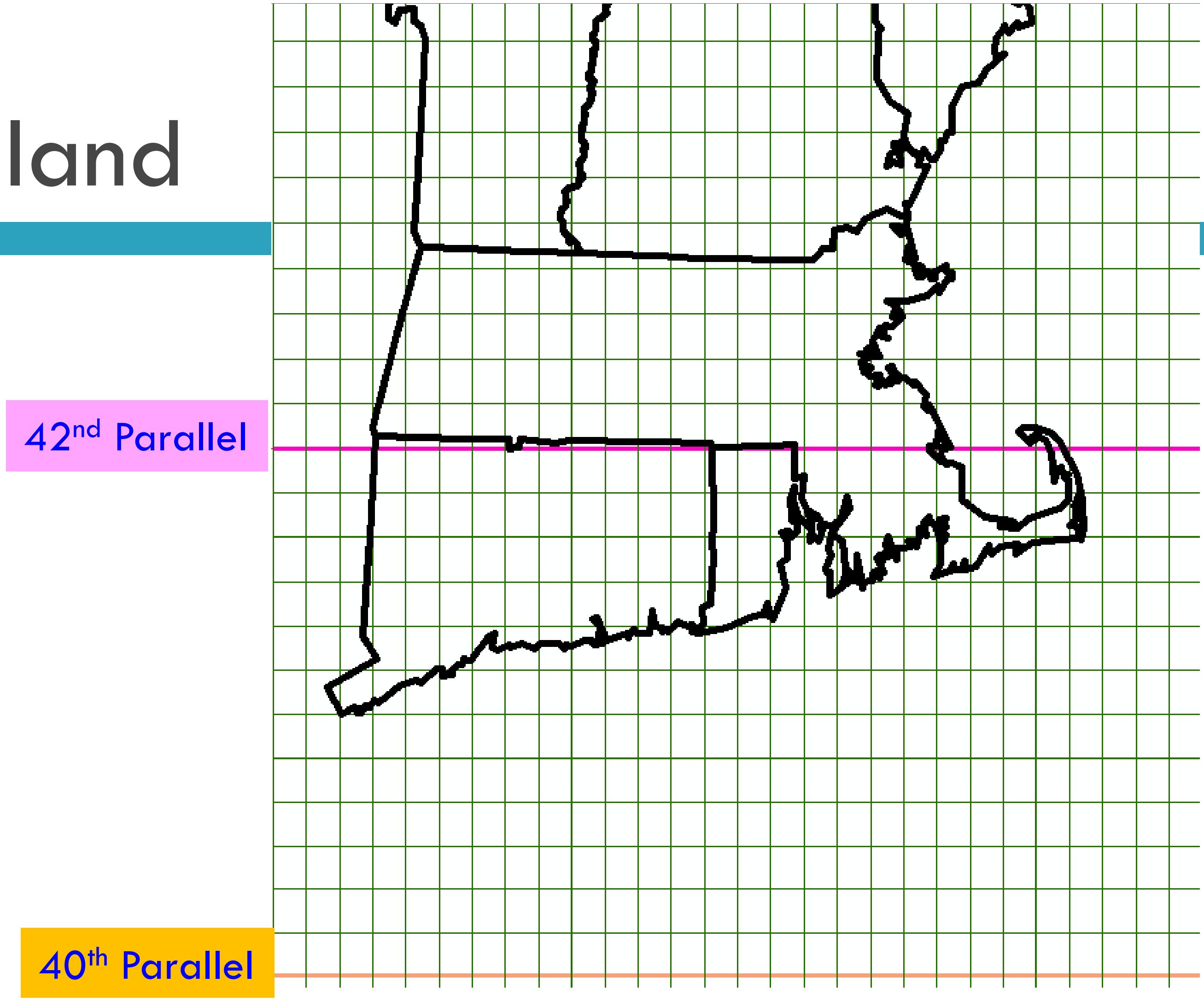
- Asian clams are food while zebra mussels are not for human beings

Ecosystem Engineers

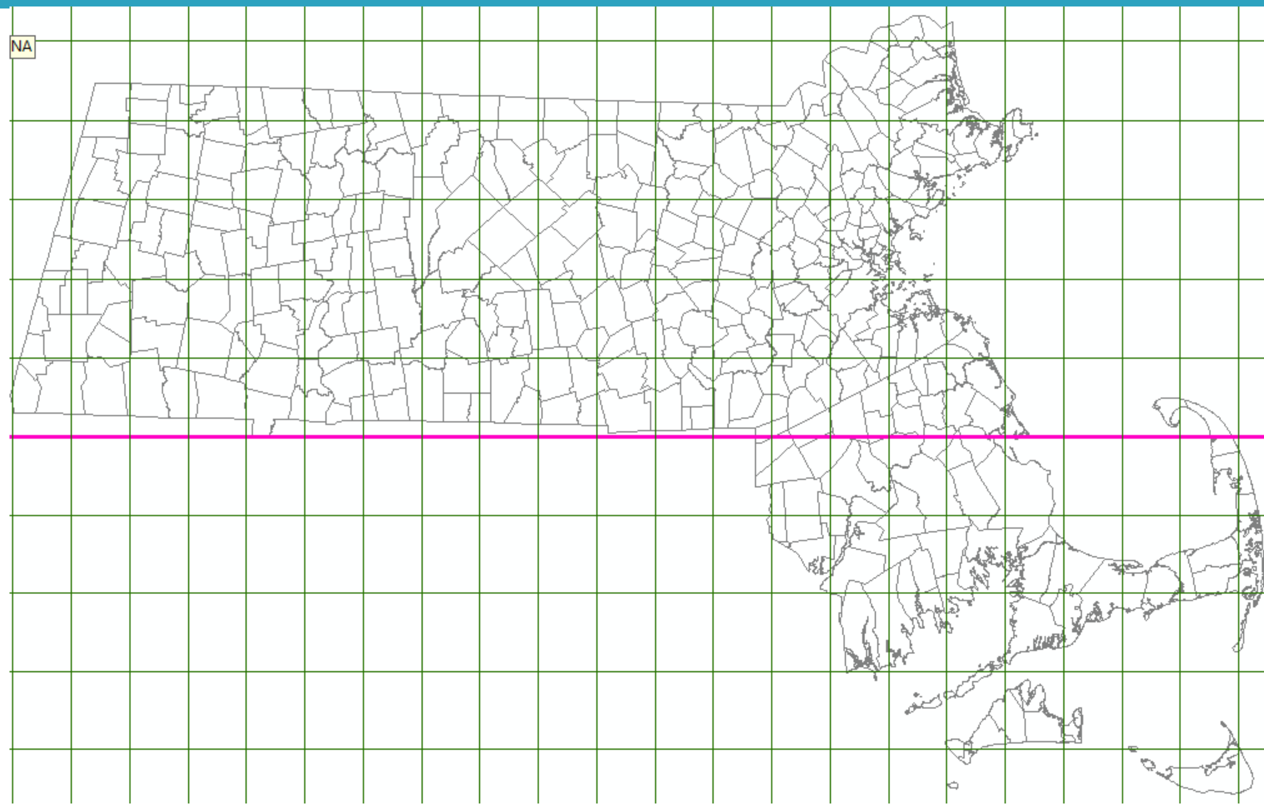
(Wong et al. 2011)



New England

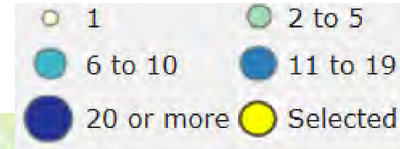


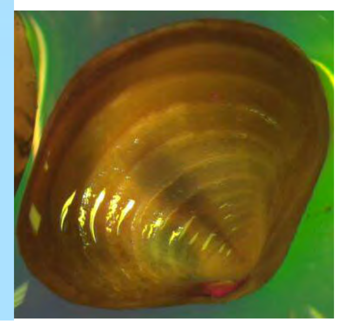
Massachusetts



42nd Parallel

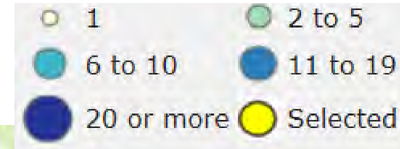
Cobicula fluminea: 1938 to 1970 in North America

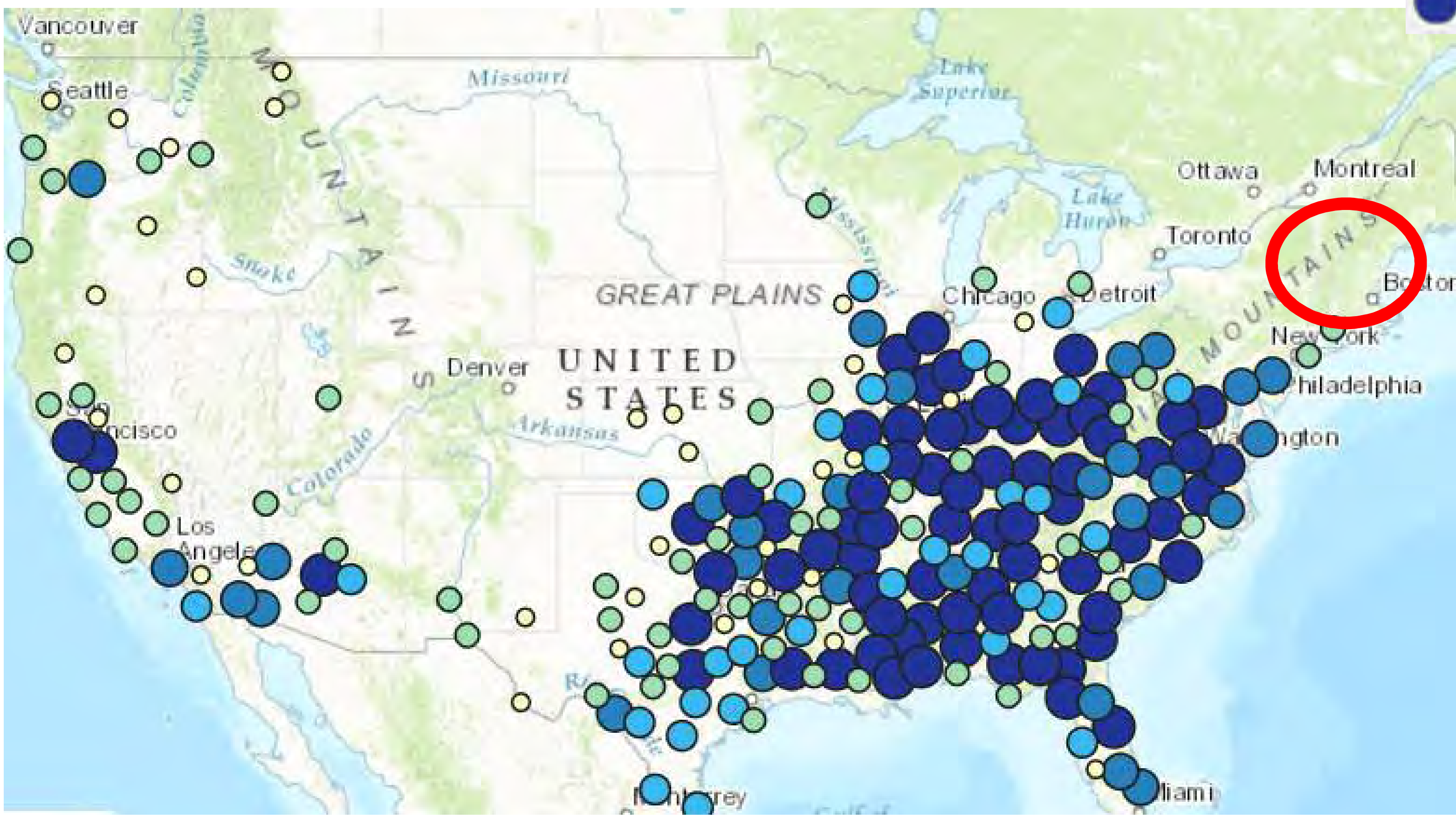




U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [3/9/2017].

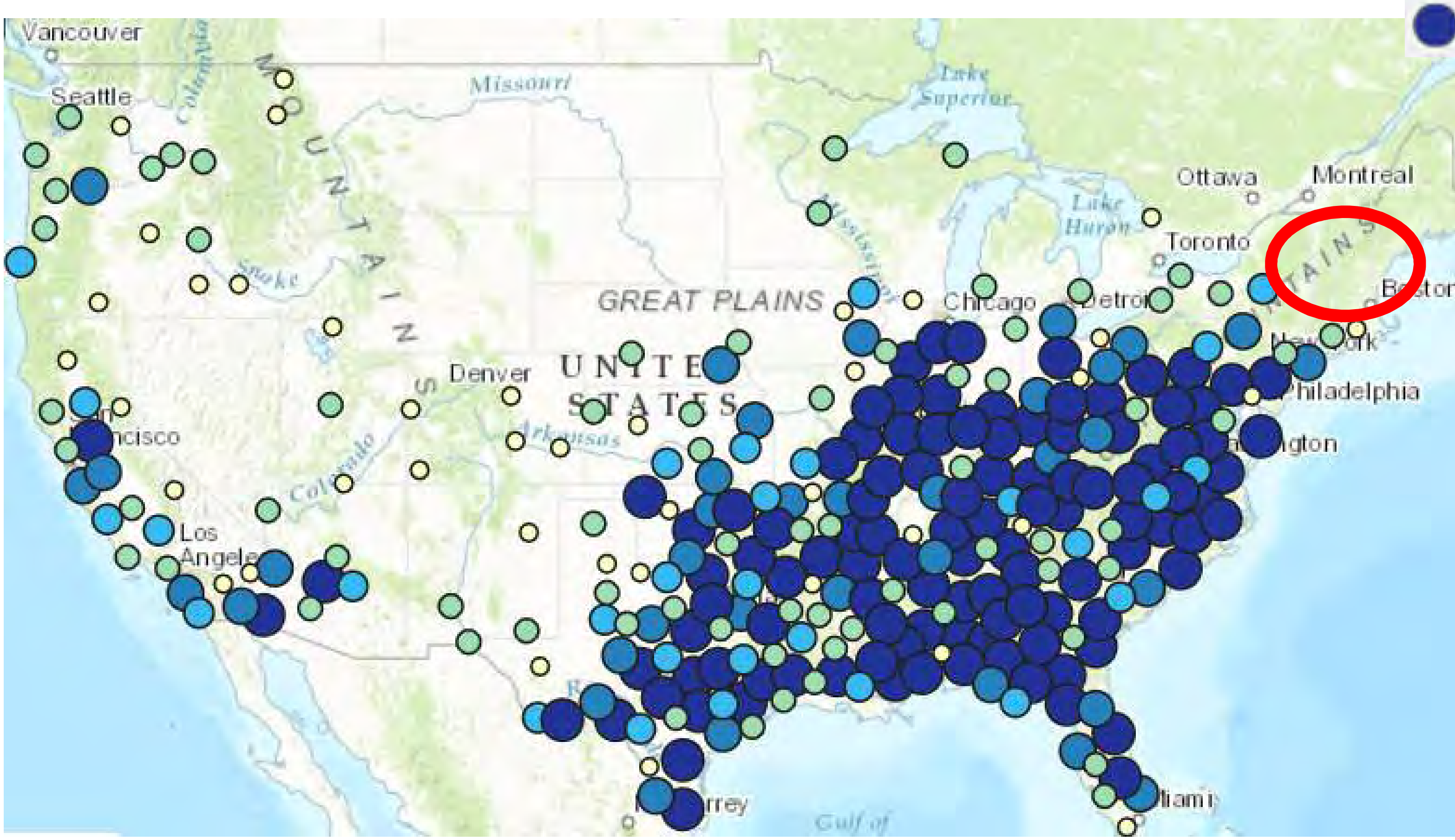
Cobicula fluminea in North America: 1990

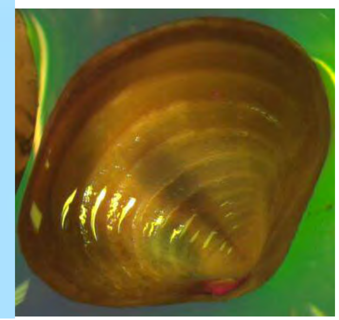




U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [3/9/2017].

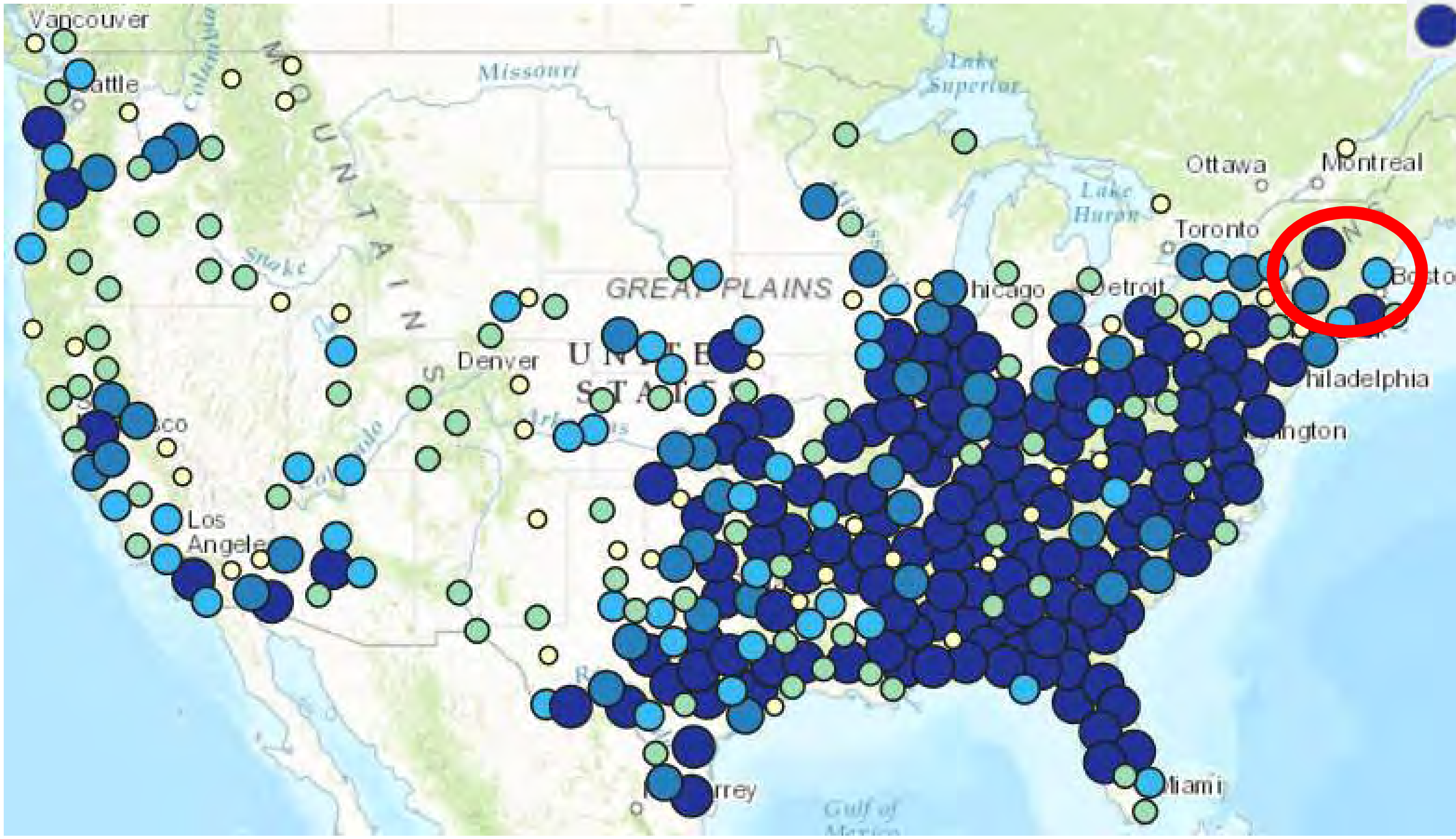
Cobicula fluminea in North America: 2000





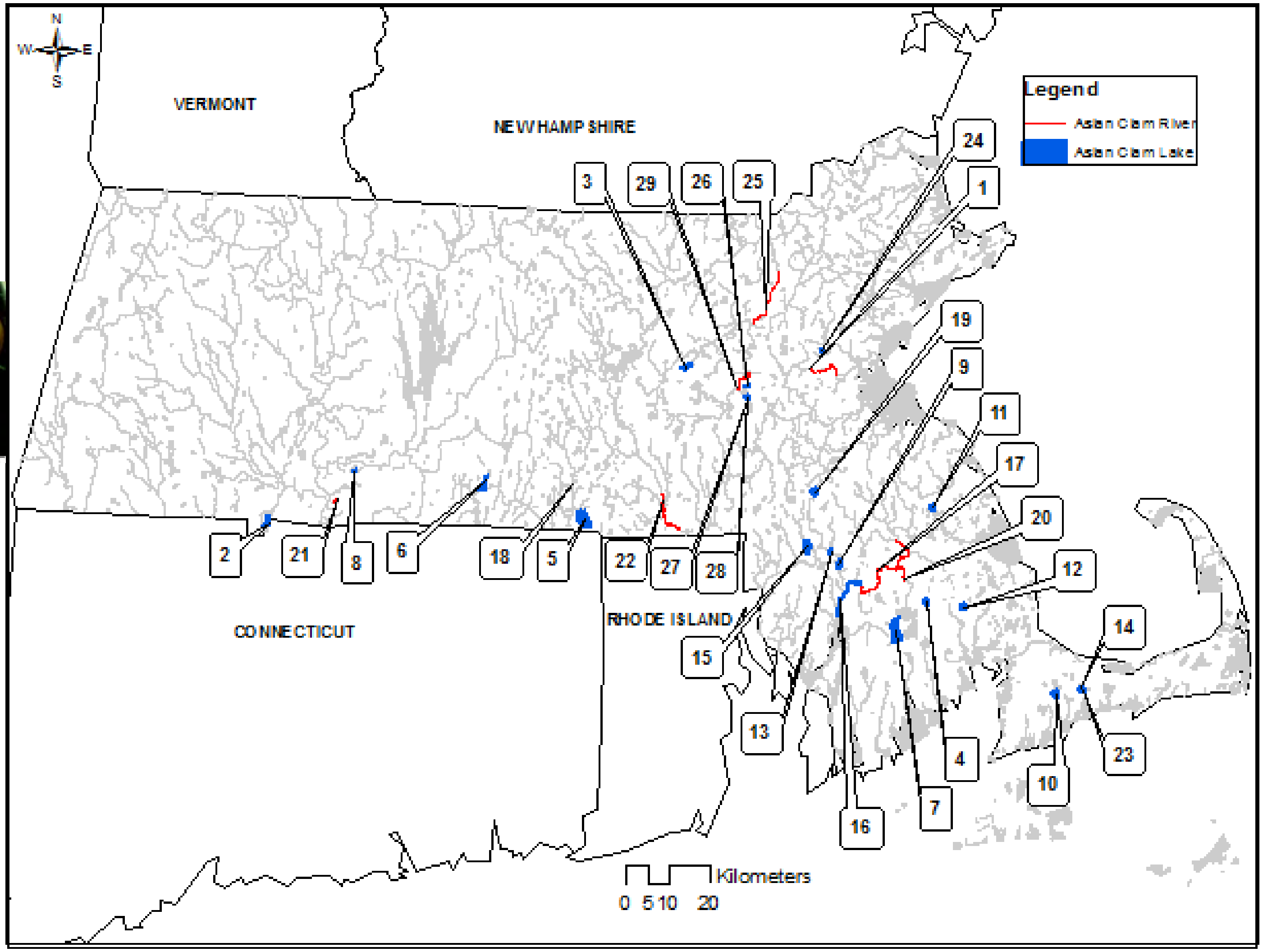
U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [3/9/2017].

Distributions of Cobicula fluminea in North America 2017

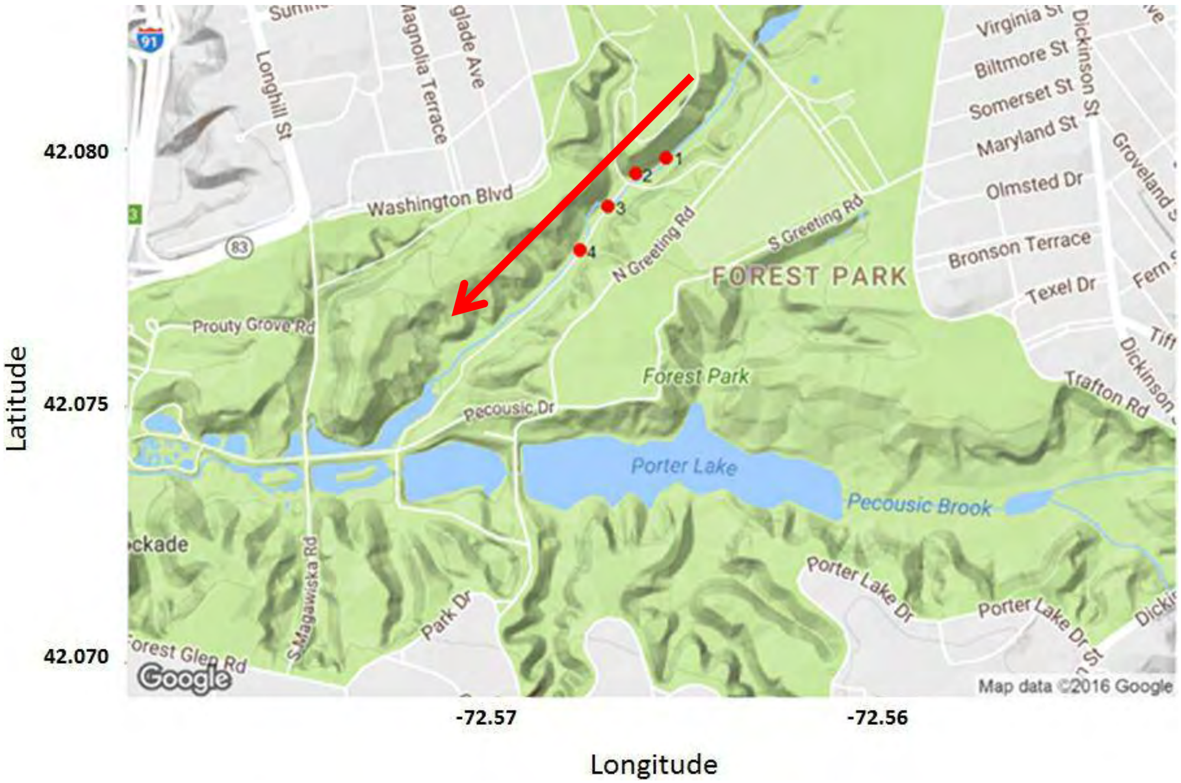


U.S. Geological Survey. [2017]. Nonindigenous Aquatic Species Database. Gainesville, Florida. Accessed [3/9/2017].

2016

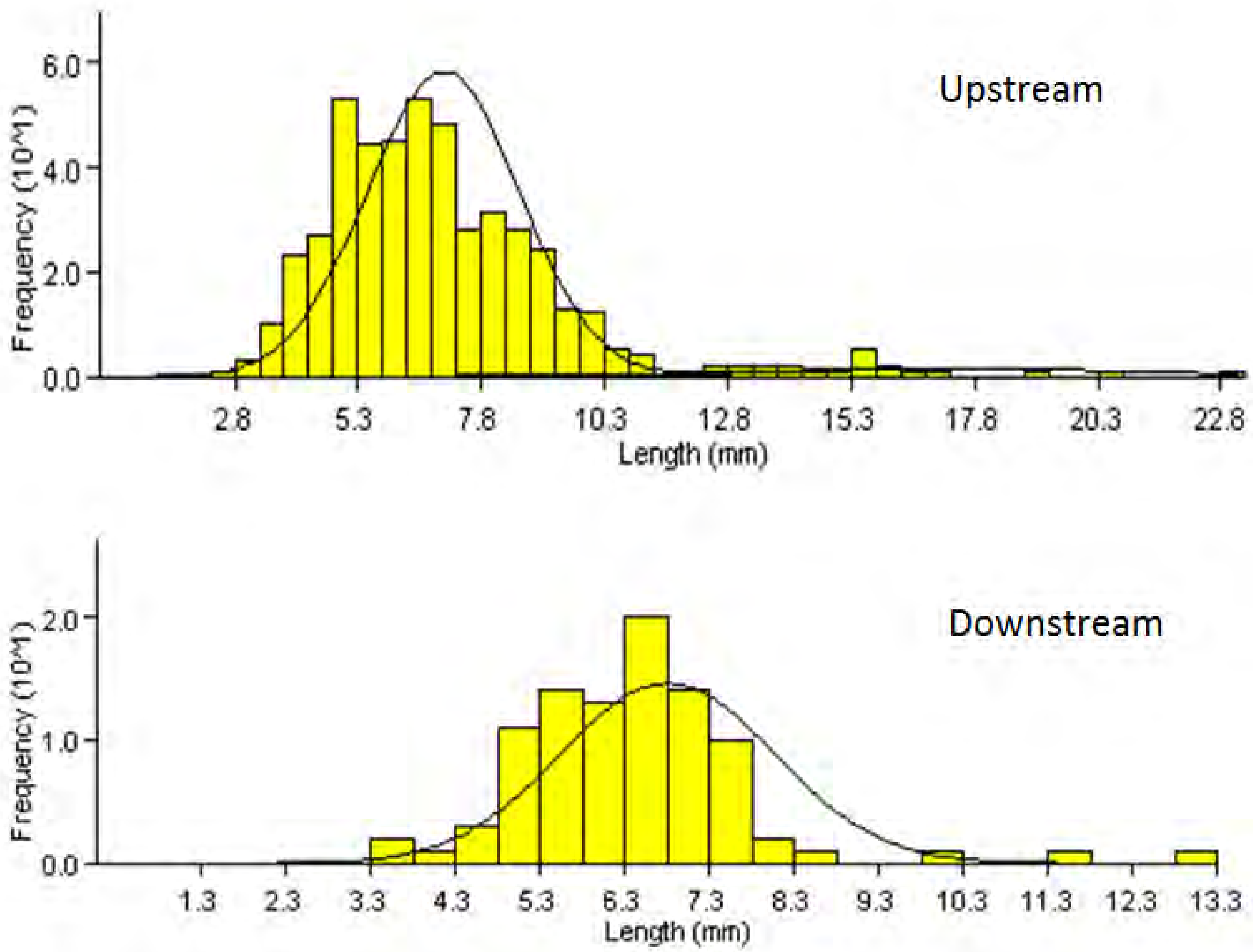

N
W
E
S
VERMONT
NEW HAMPSHIRE
CONNECTICUT
RHODE ISLAND
Legend
Asian Clam River
Asian Clam Lake
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
Kilometers
0 5 10 20

They are abundant, too

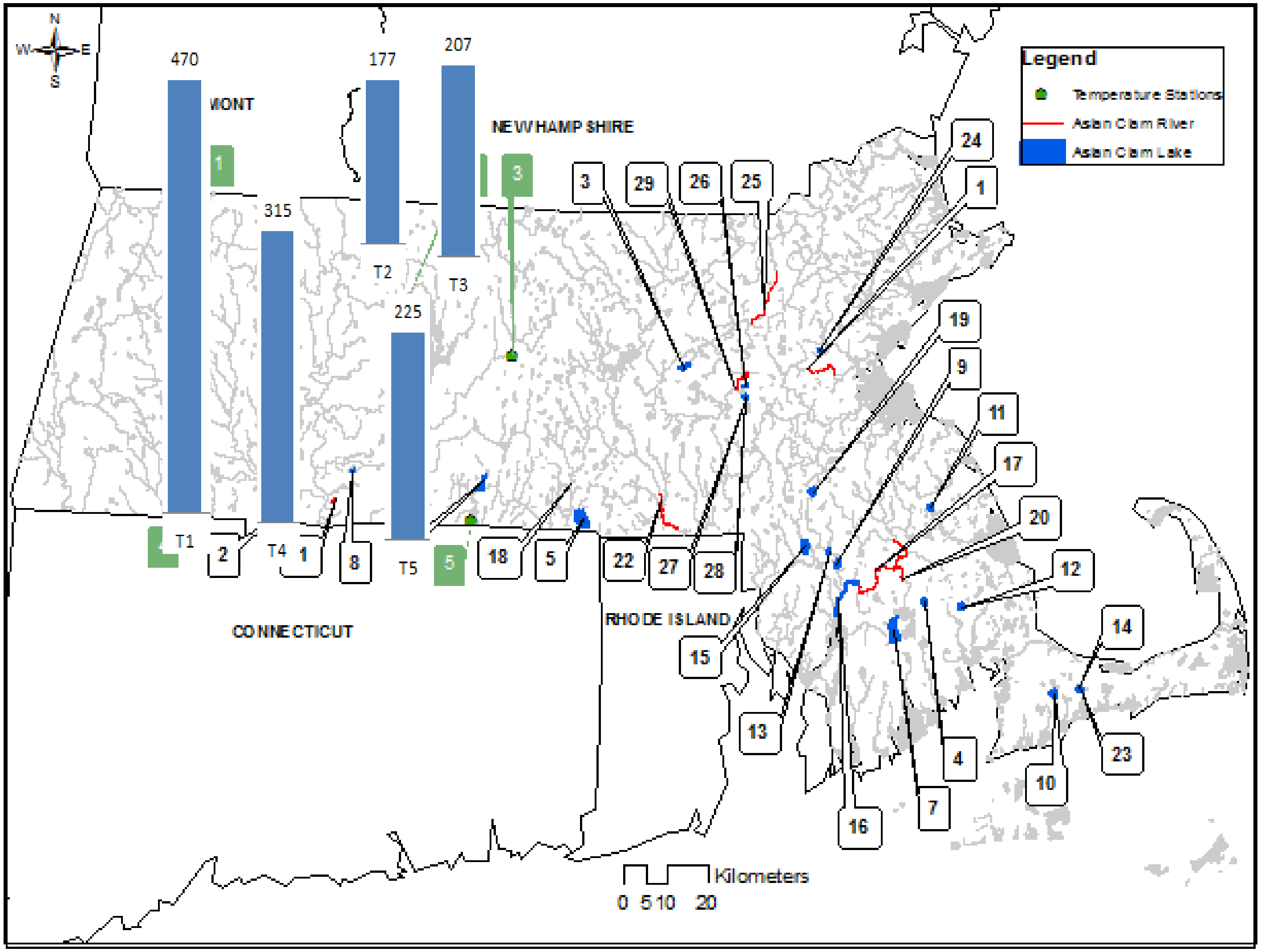


Sampling along an unnamed tributary to Porter Lake in Springfield, Massachusetts

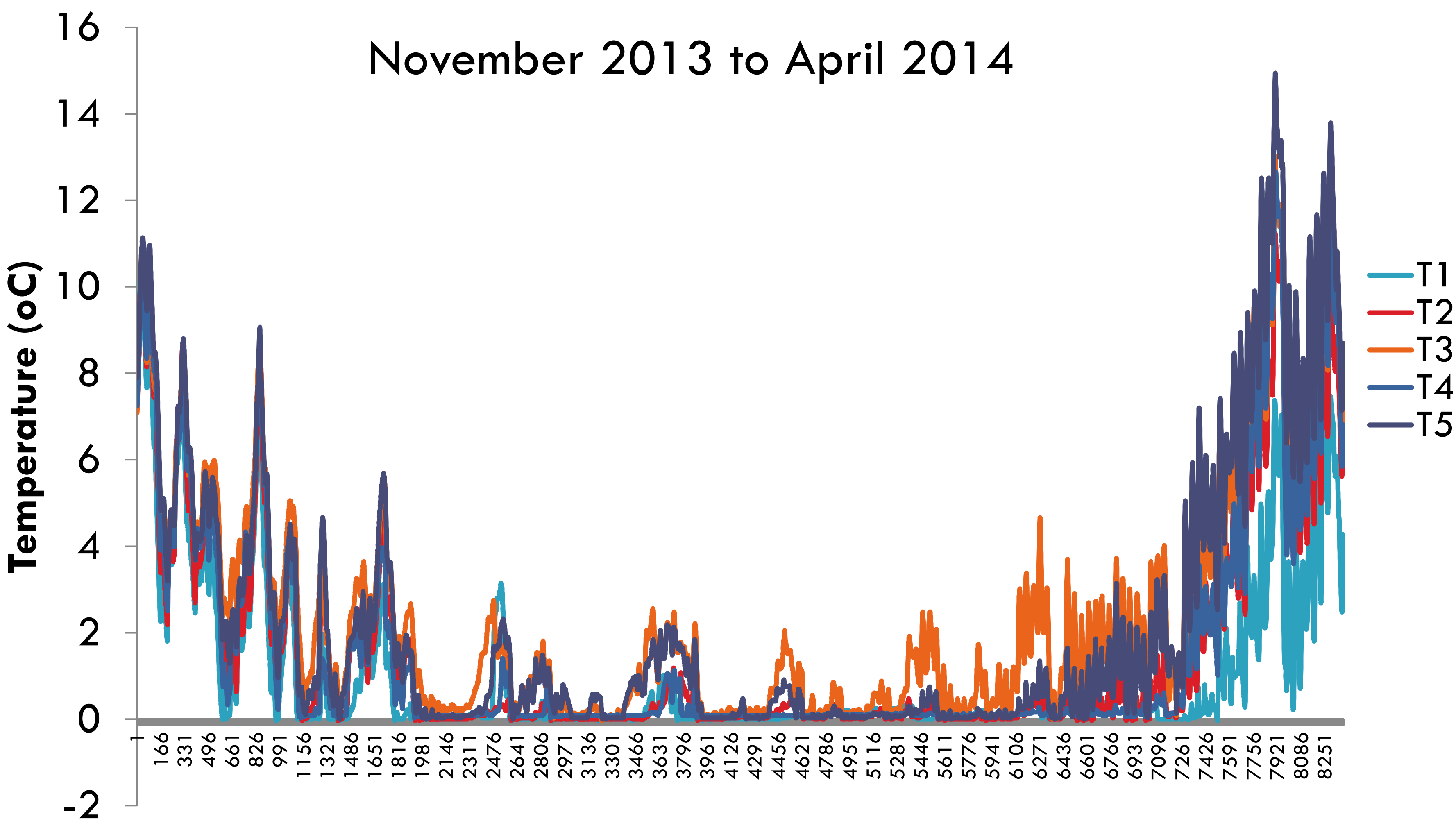
Station	Station 1	Station 2	Station 3	Station 4
Density (Ind/m2)	7,104	6,932	6,416	4,047
Dry Dead Shell Weight (g/m2)	512.3	159.3	51.7	4.3



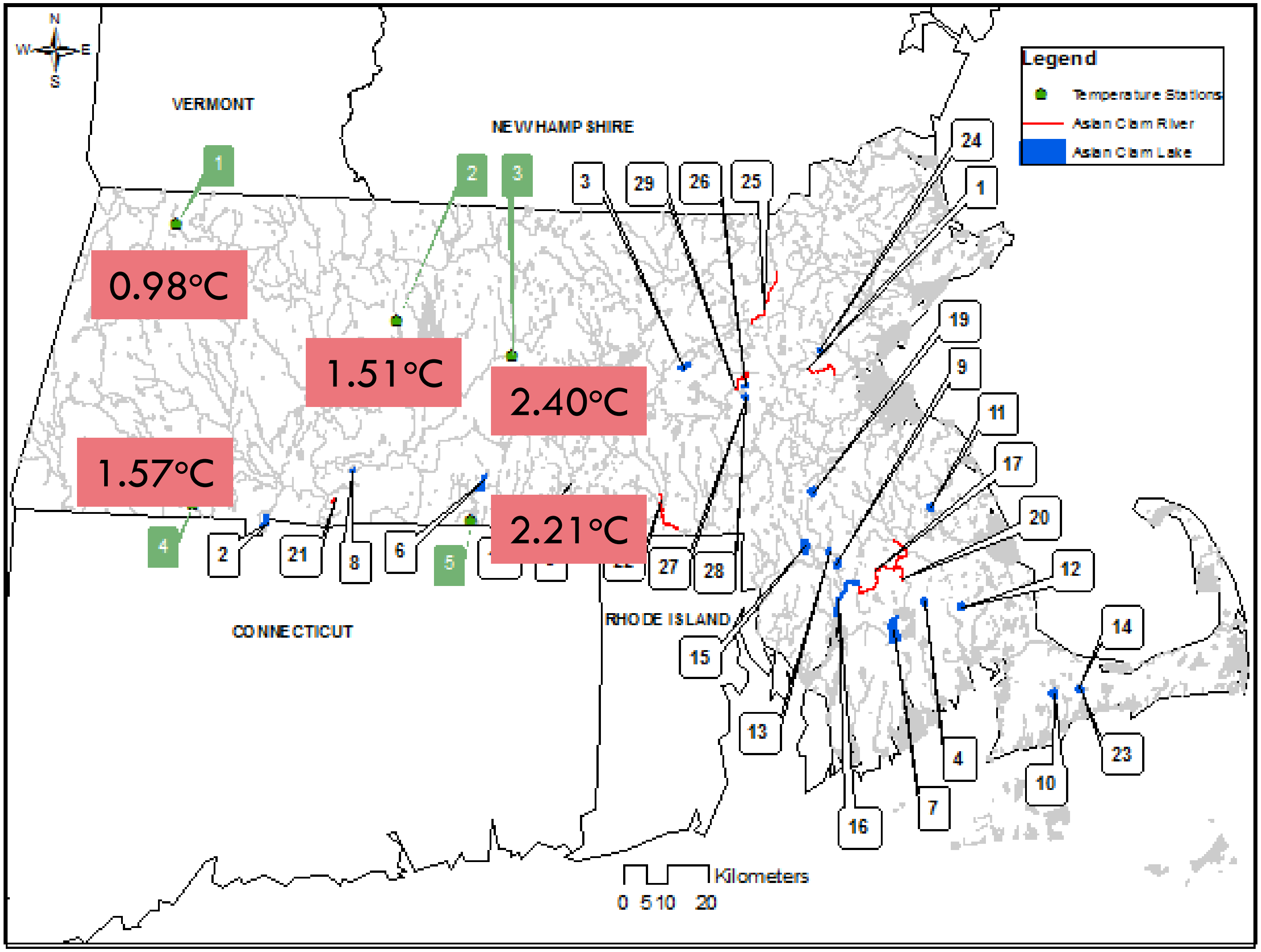
Frequency of *Corbicula fluminea* in upstream and downstream stations of an unnamed tributary inside of Forest Park, Springfield, Massachusetts



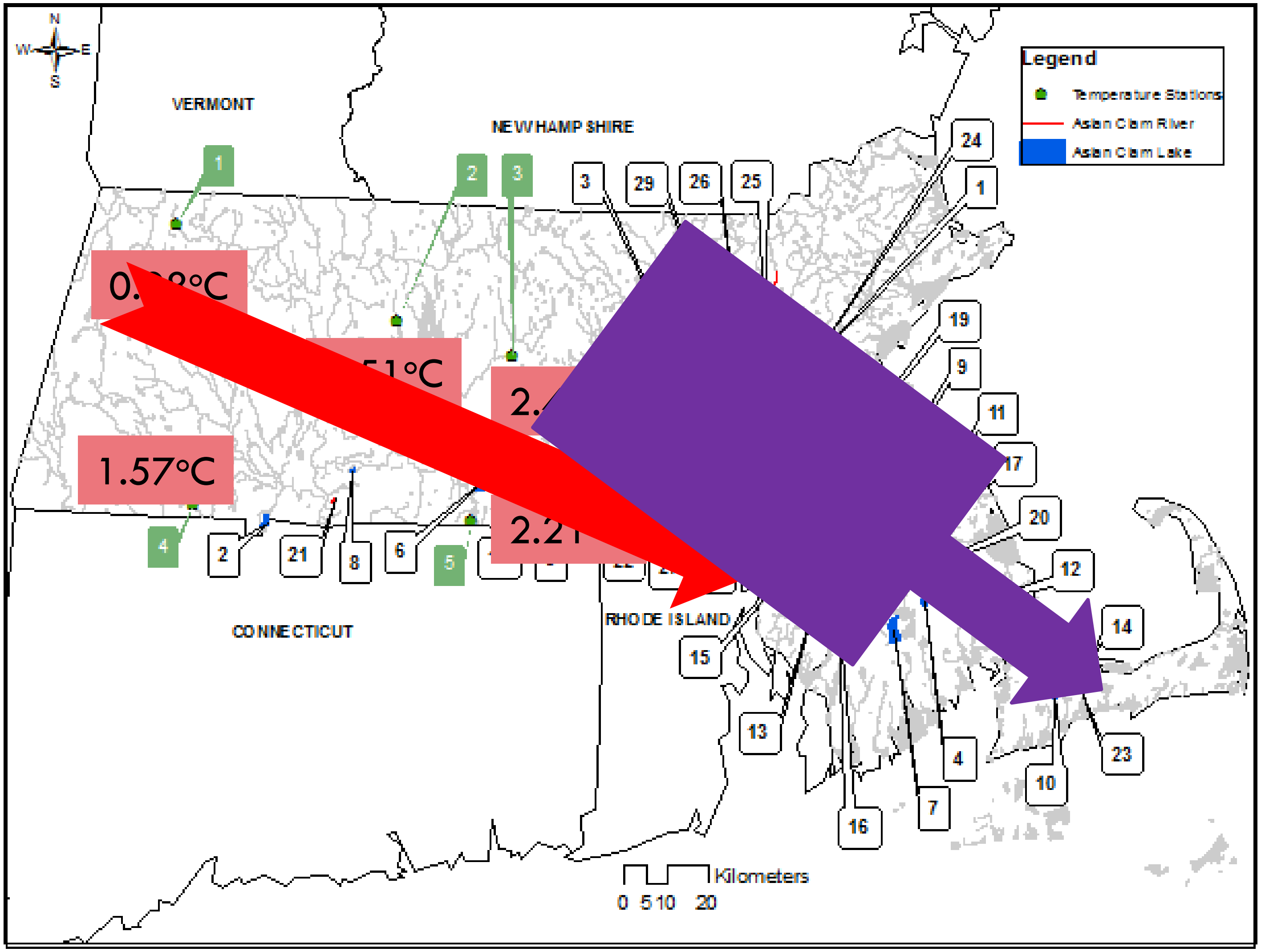
N
W
E
S
470
177
207
315
225
MONT
NEW HAMPSHIRE
CONNECTICUT
RHODE ISLAND
T1
T2
T3
T4
T5
Legend
Temperature Stations
Asian Clam River
Asian Clam Lake
Kilometers
0 5 10 20



November 2013 to April 2014
Temperature (oC)
16
14
12
10
8
6
4
2
0
-2
1
166
331
496
661
826
991
1156
1321
1486
1651
1816
1981
2146
2311
2476
2641
2806
2971
3136
3301
3466
3631
3796
3961
4126
4291
4456
4621
4786
4951
5116
5281
5446
5611
5776
5941
6106
6271
6436
6601
6766
6931
7096
7261
7426
7591
7756
7921
8086
8251
T1
T2
T3
T4
T5



Legend
Temperature Stations
Asian Clam River
Asian Clam Lake
VERMONT
NEW HAMPSHIRE
CONNECTICUT
RHODE ISLAND
0.98°C
1.51°C
2.40°C
1.57°C
2.21°C
Kilometers
0 5 10 20



N
W
E
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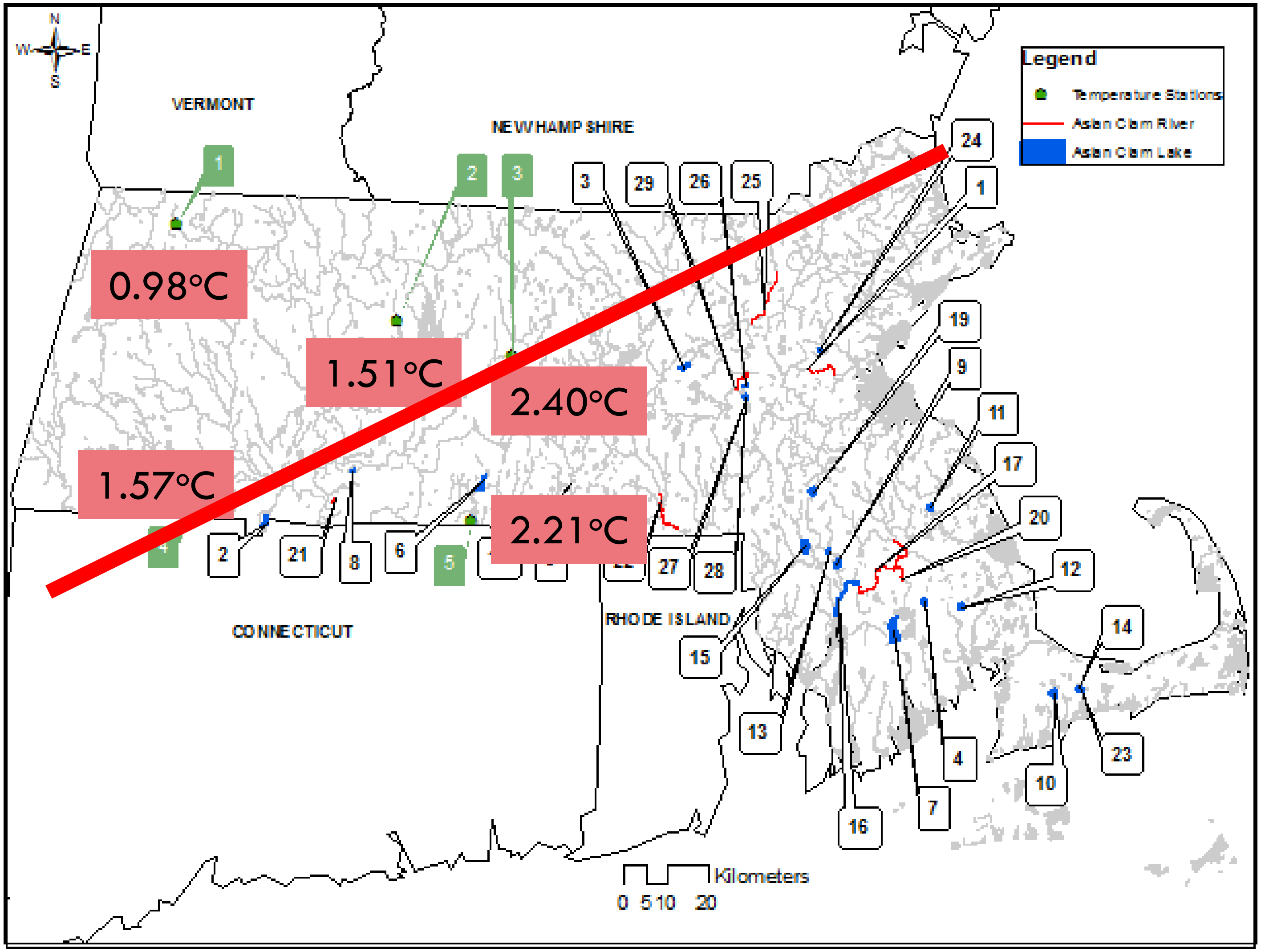
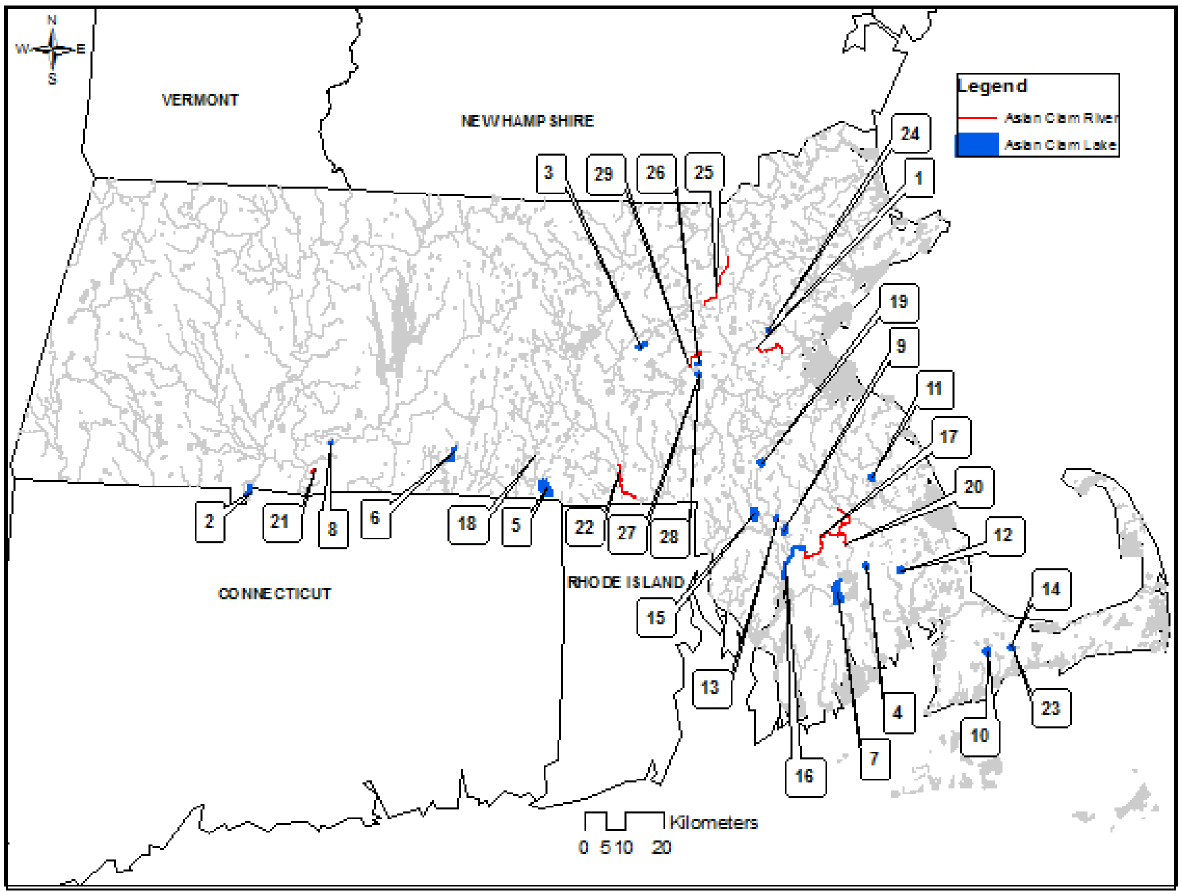
VERMONT
NEW HAMPSHIRE
CONNECTICUT
RHODE ISLAND
Legend
Temperature Stations
Asian Clam River
Asian Clam Lake
1.57°C
2.21
Kilometers
0 5 10 20

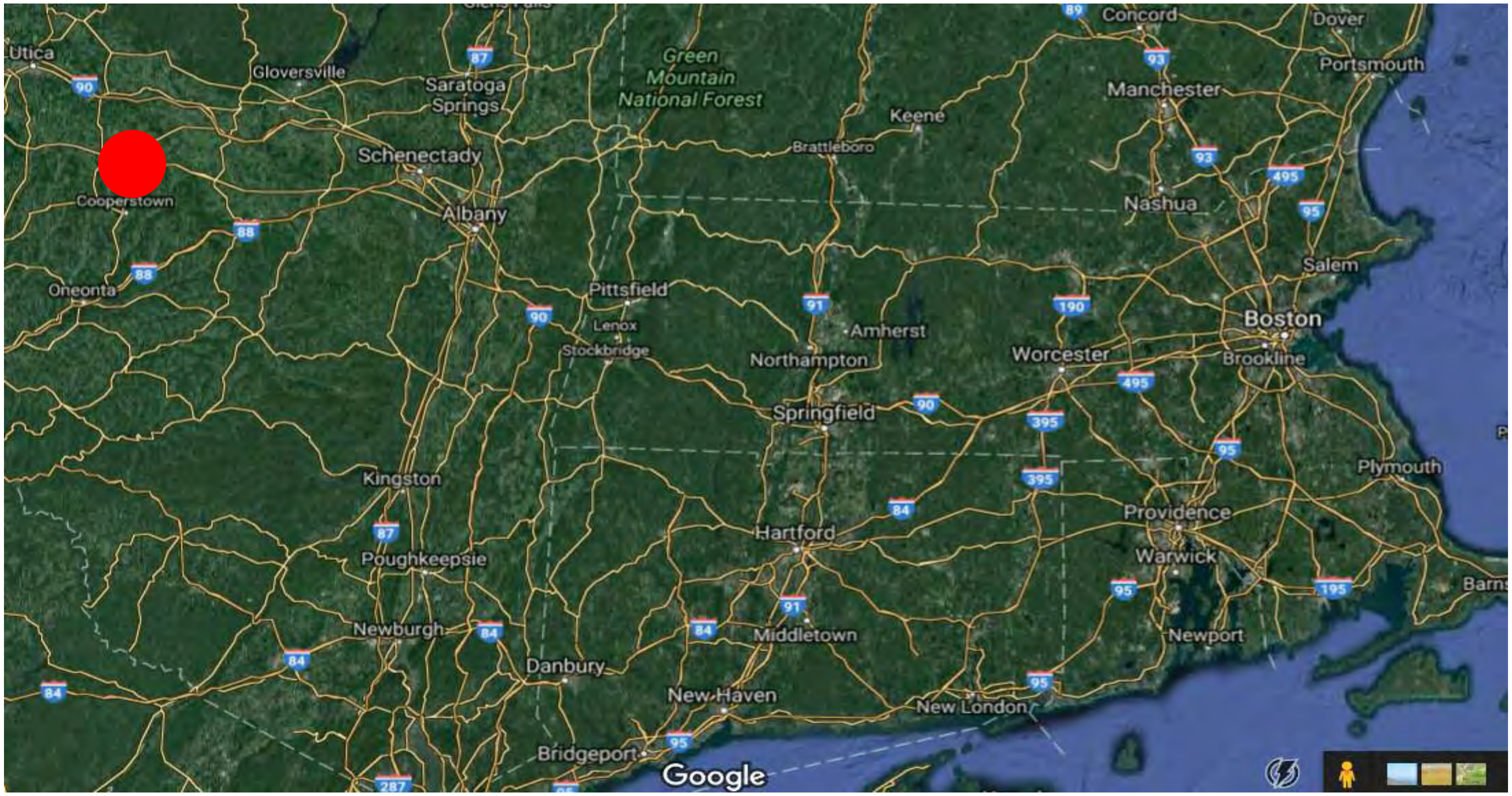


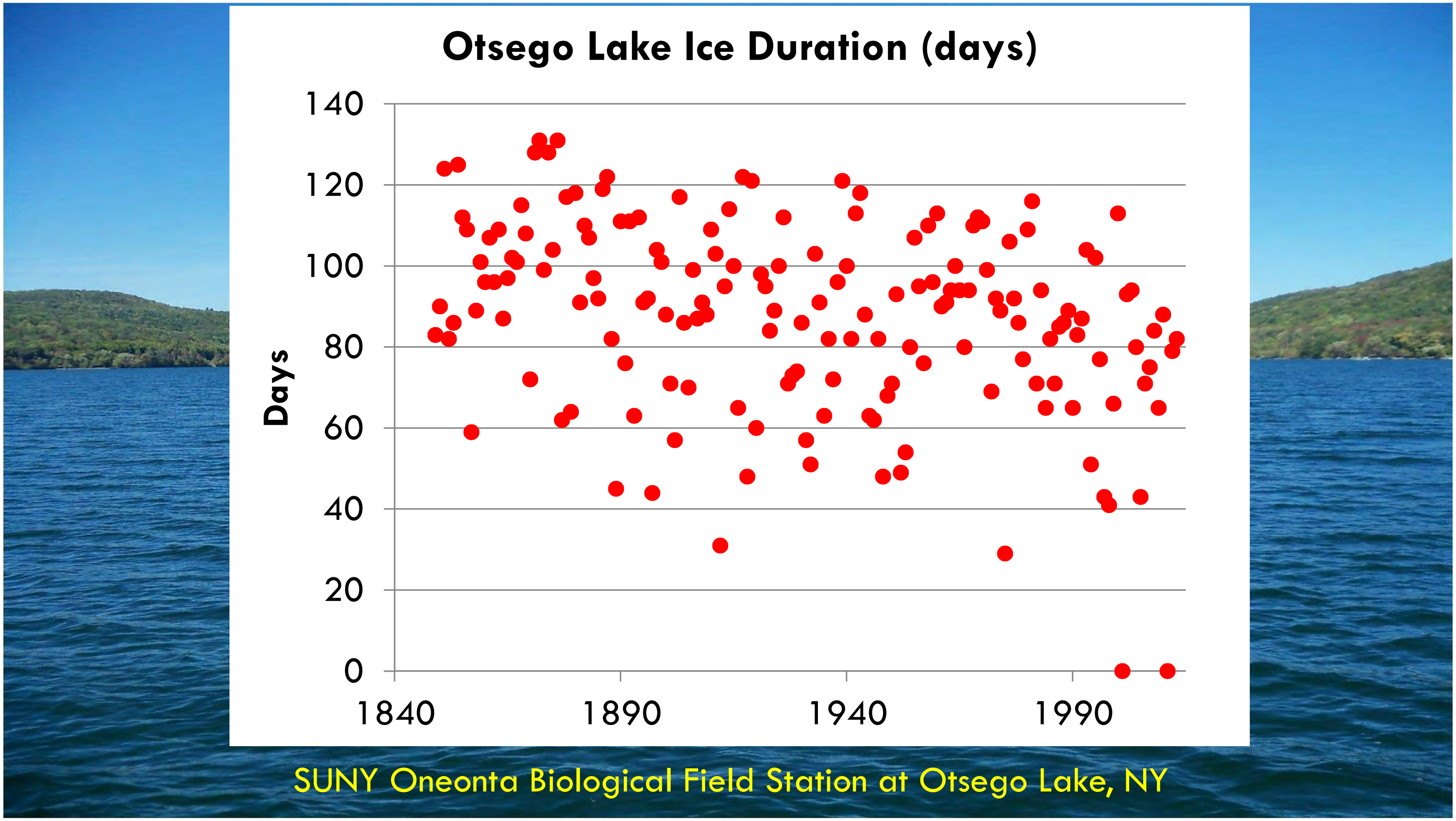
Legend
Temperature Stations
Asian Clam River
Asian Clam Lake
VERMONT
NEW HAMPSHIRE
CONNECTICUT
RHODE ISLAND
0.98°C
1.51°C
2.40°C
1.57°C
2.21°C
Kilometers
0 5 10 20

Cobicula likes warmer area **Is Massachusetts becoming warmer?**

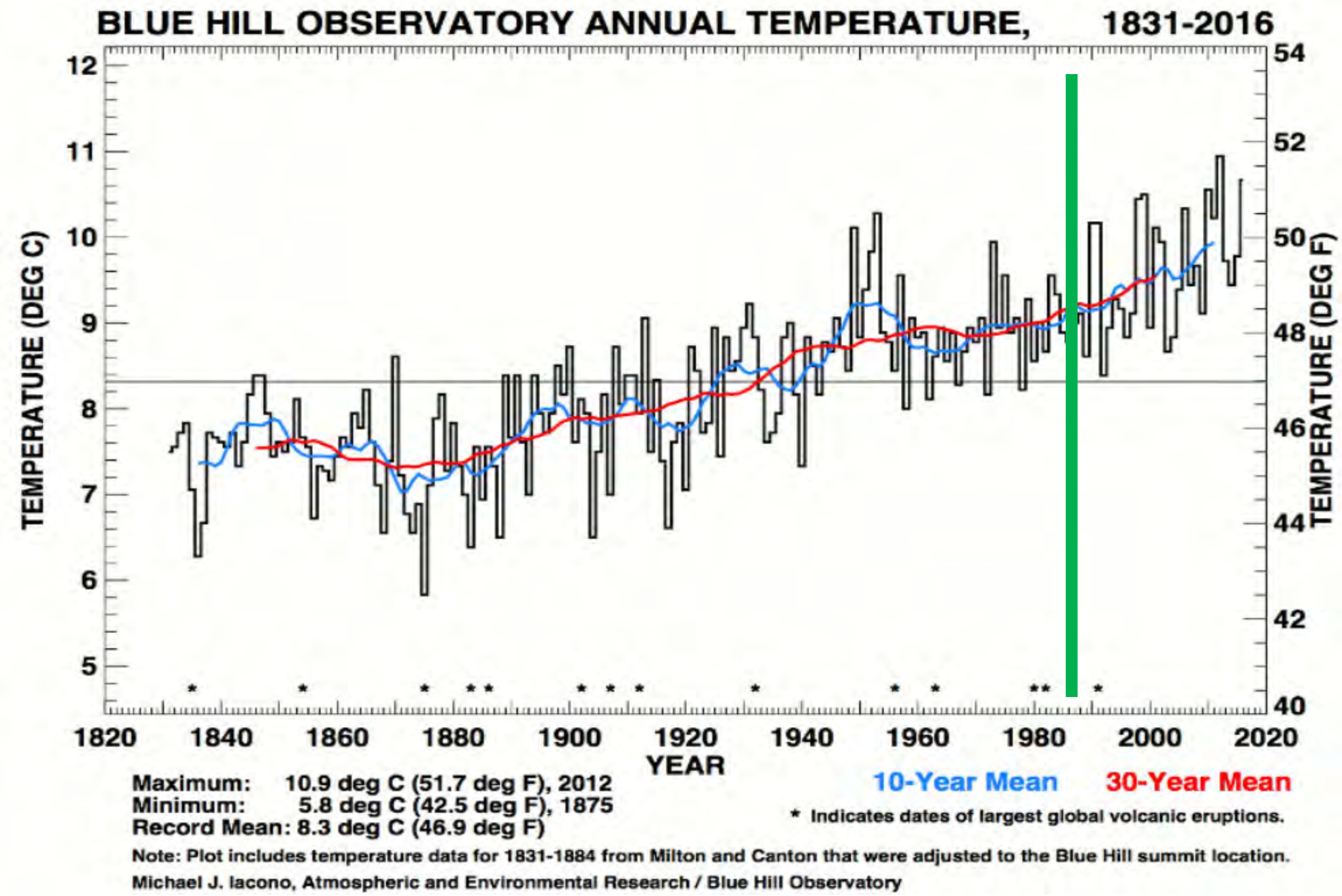


Climate Change: Ice Coverage

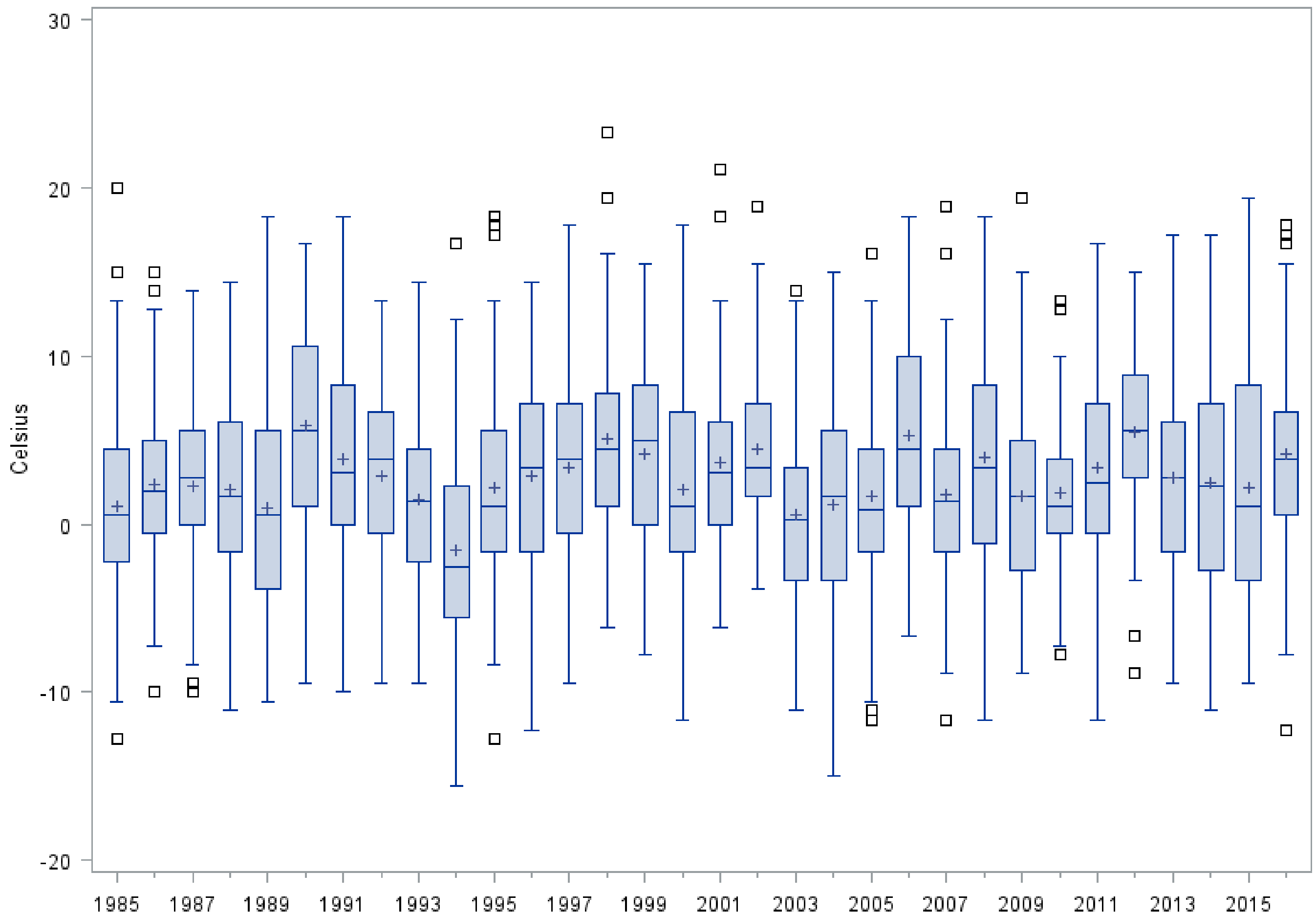



Otsego Lake Ice Duration (days)
Days
140
120
100
80
60
40
20
0
1840
1890
1940
1990
SUNY Oneonta Biological Field Station at Otsego Lake, NY

Blue Hill Observatory: Home of the Oldest Climate Record

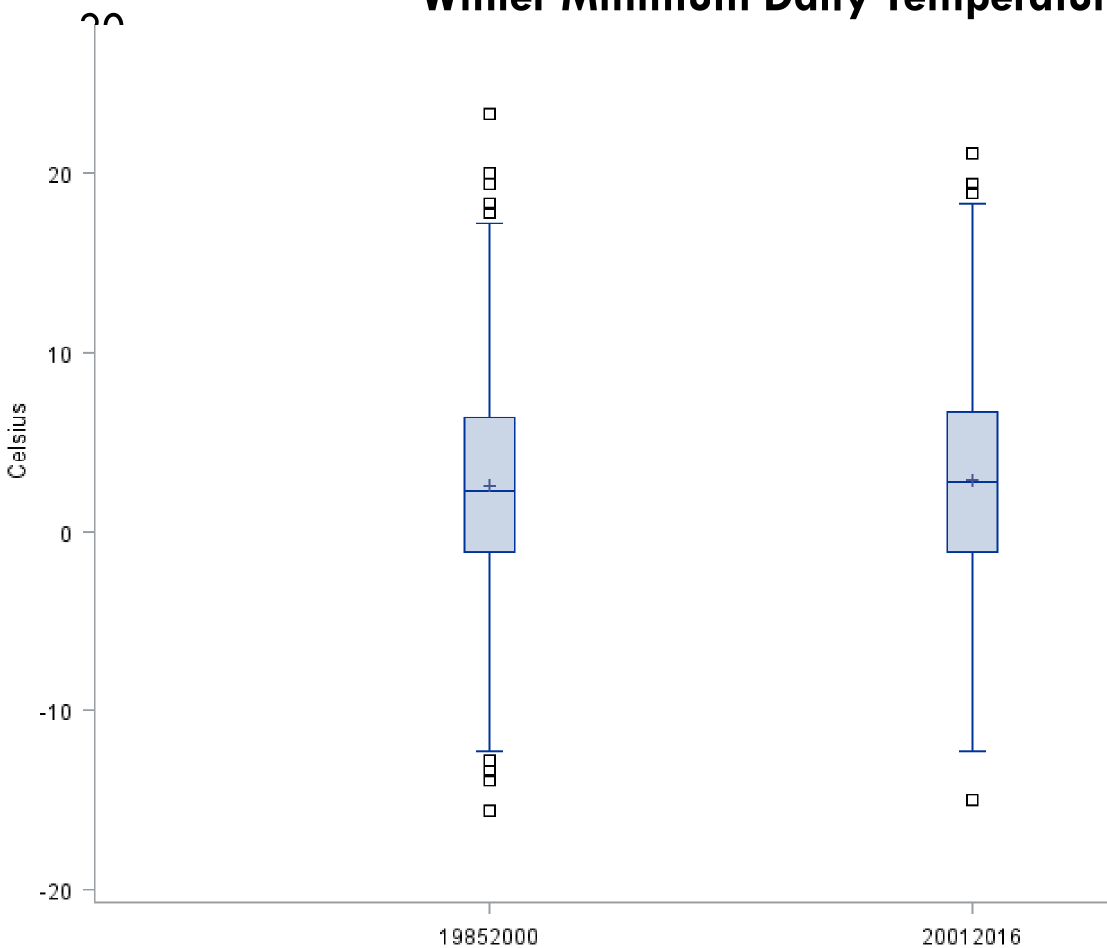


Blue Hill Observatory: Winter Daily Minimum Temperature (1985-2016)



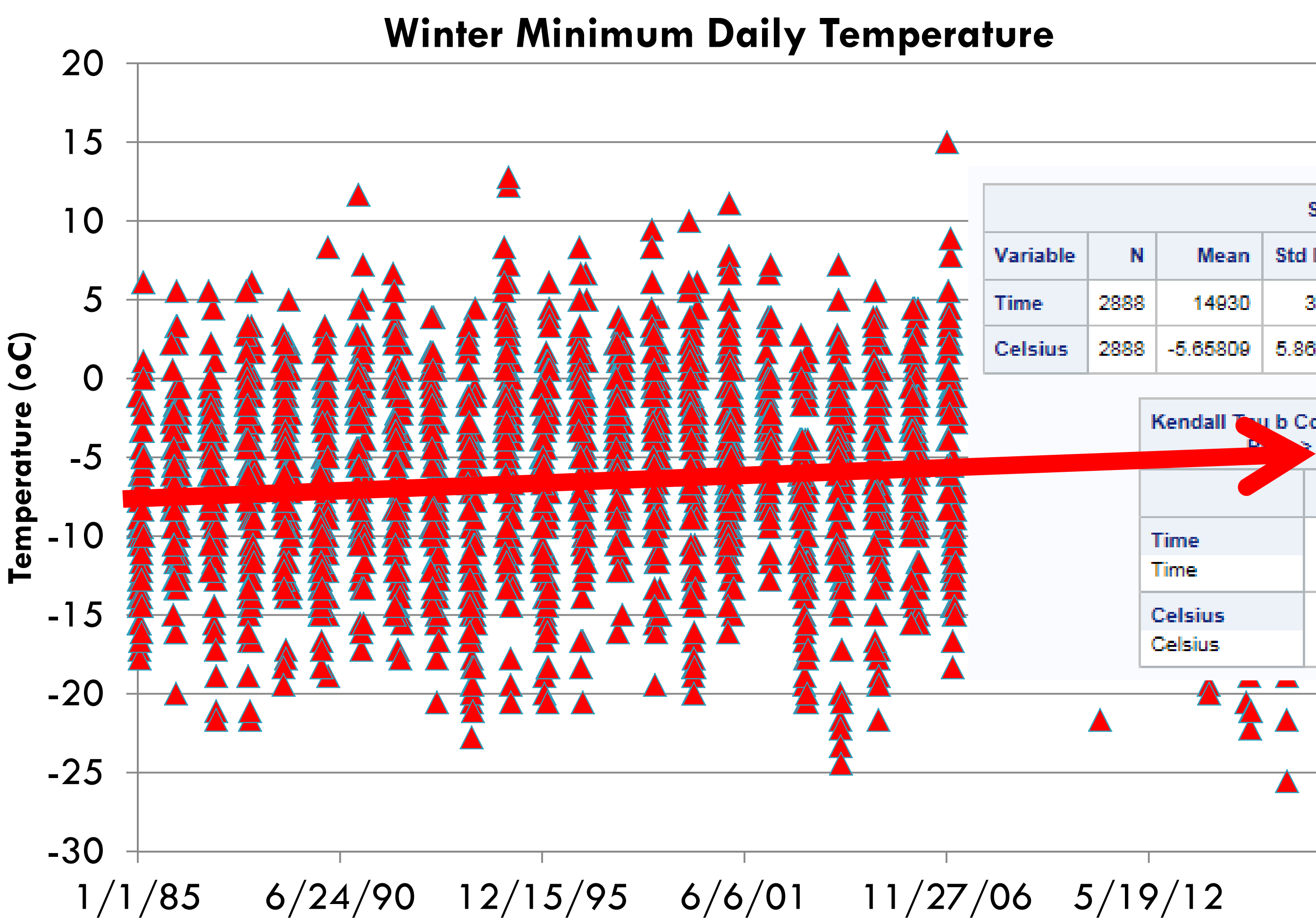
Mike Iacono

Winter Minimum Daily Temperature



Wilcoxon Scores (Rank Sums) for Variable Celsius Classified by Variable period					
period	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
19852000	1444	2035509.50	2085858.0	22395.7121	1409.63262
20012016	1444	2136206.50	2085858.0	22395.7121	1479.36738
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	2035509.5000
Normal Approximation	
Z	-2.2481
One-Sided Pr < Z	0.0123
Two-Sided Pr > |Z|	0.0246
t Approximation	
One-Sided Pr < Z	0.0123
Two-Sided Pr > |Z|	0.0246



Simple Statistics							
Variable	N	Mean	Std Dev	Median	Minimum	Maximum	Label
Time	2888	14930	3376	14976	9132	20819	Time
Celsius	2888	-5.65809	5.86286	-5.55556	-25.55556	15.00000	Celsius

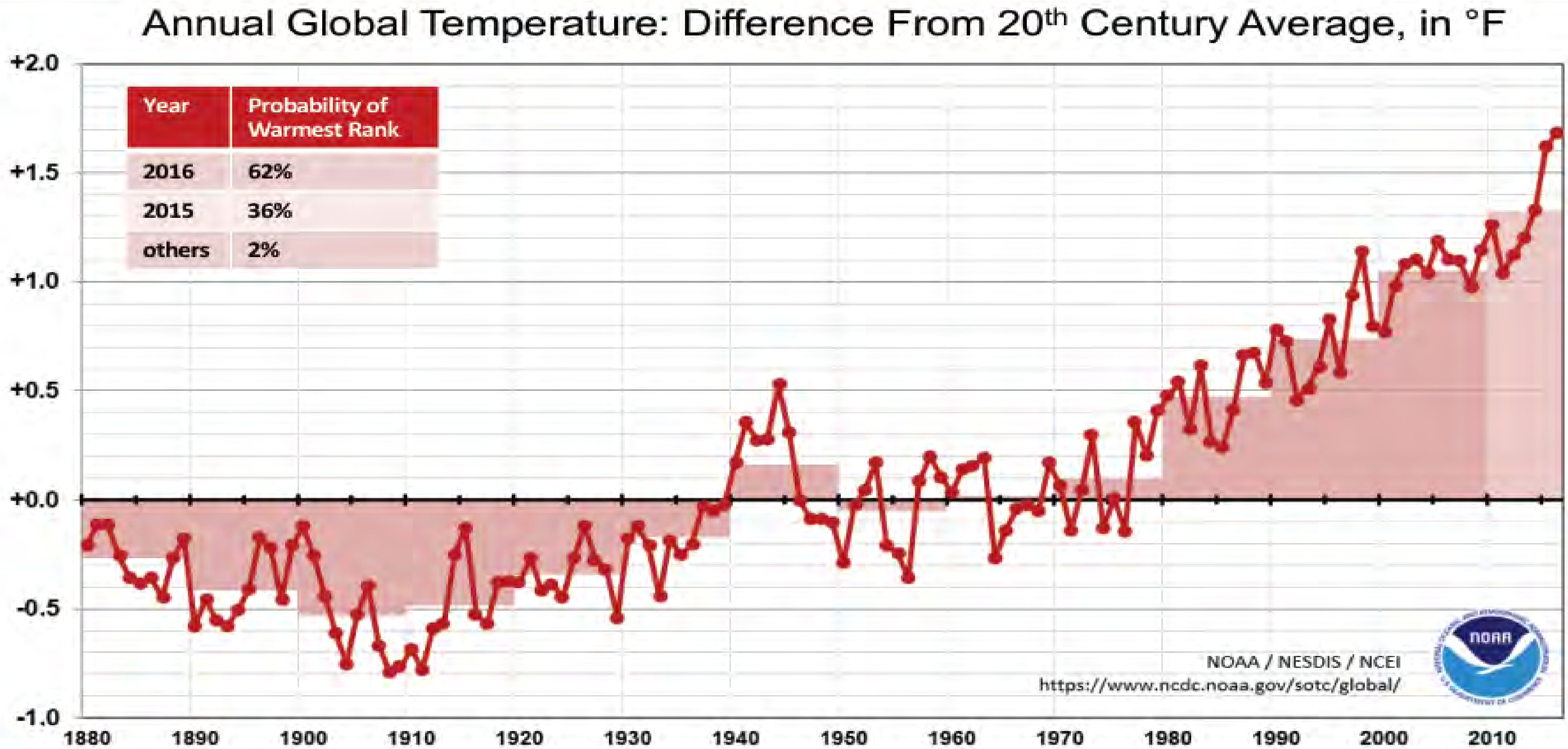
Kendall Tau b Correlation Coefficients, N = 2888
Prob > |tau| under H0: Tau=0

	Time	Celsius
Time Time	1.00000	0.04759 0.0002
Celsius Celsius	0.04759 0.0002	1.00000

Warming Rate (1979-2012)

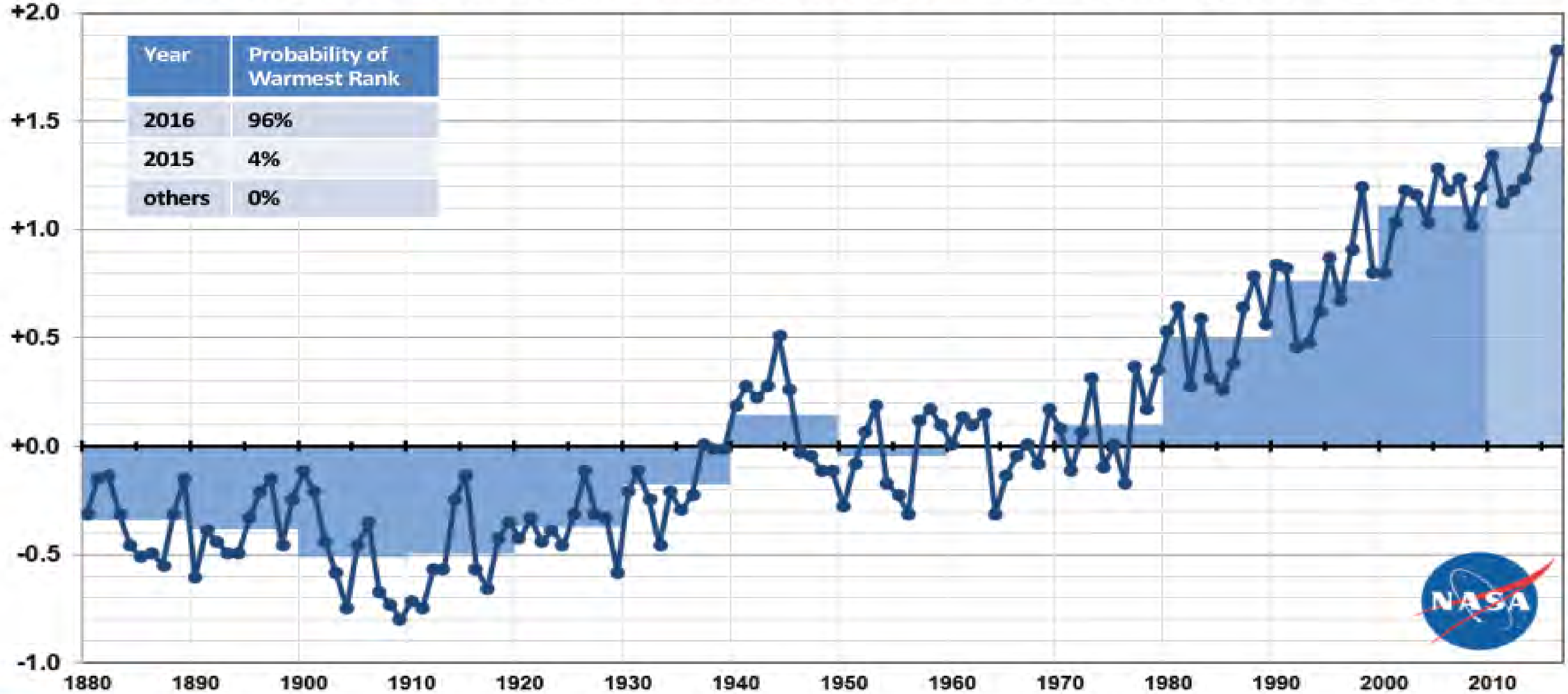
- Air Temperatures: 0.25°C per decade
- Ocean Surface Temperatures: 0.12°C per decade
- Lake Surface Temperatures: 0.34°C per decade
- Hartmann et al. 2013; O'Reilly et al. 2015

NOAA GlobalTemp



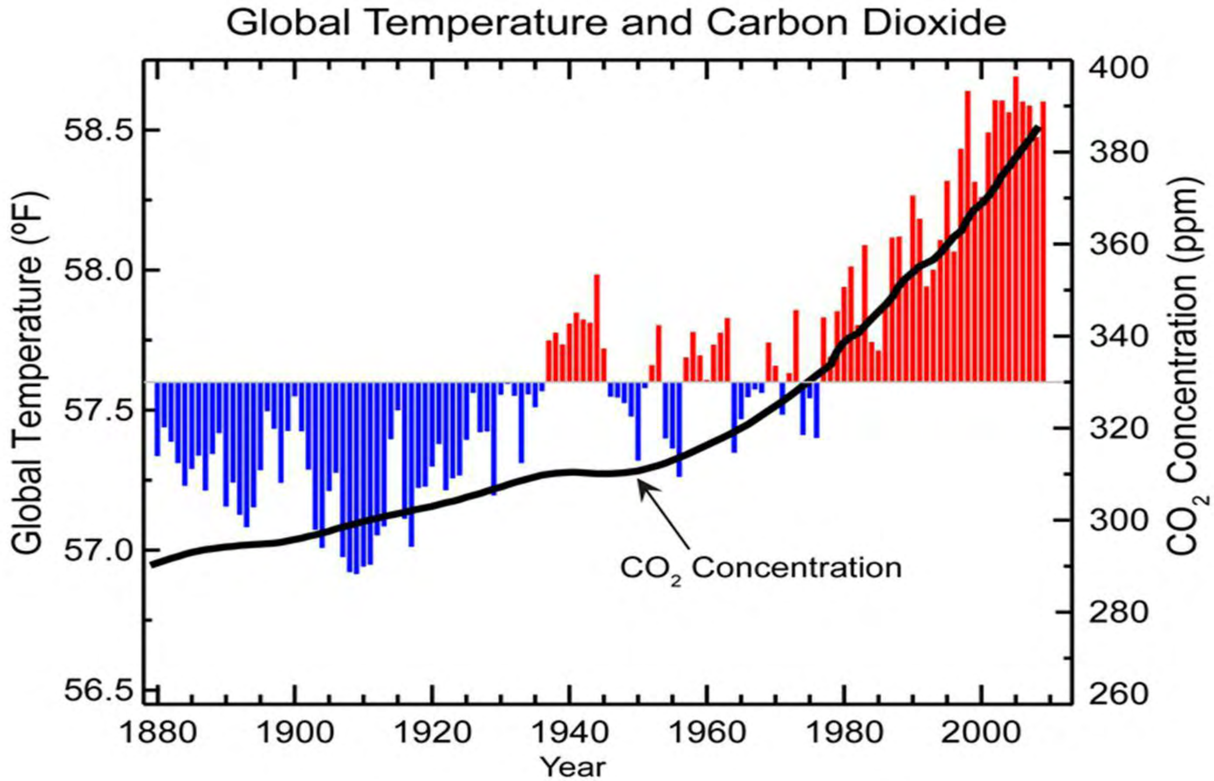
NASA GISTEMP

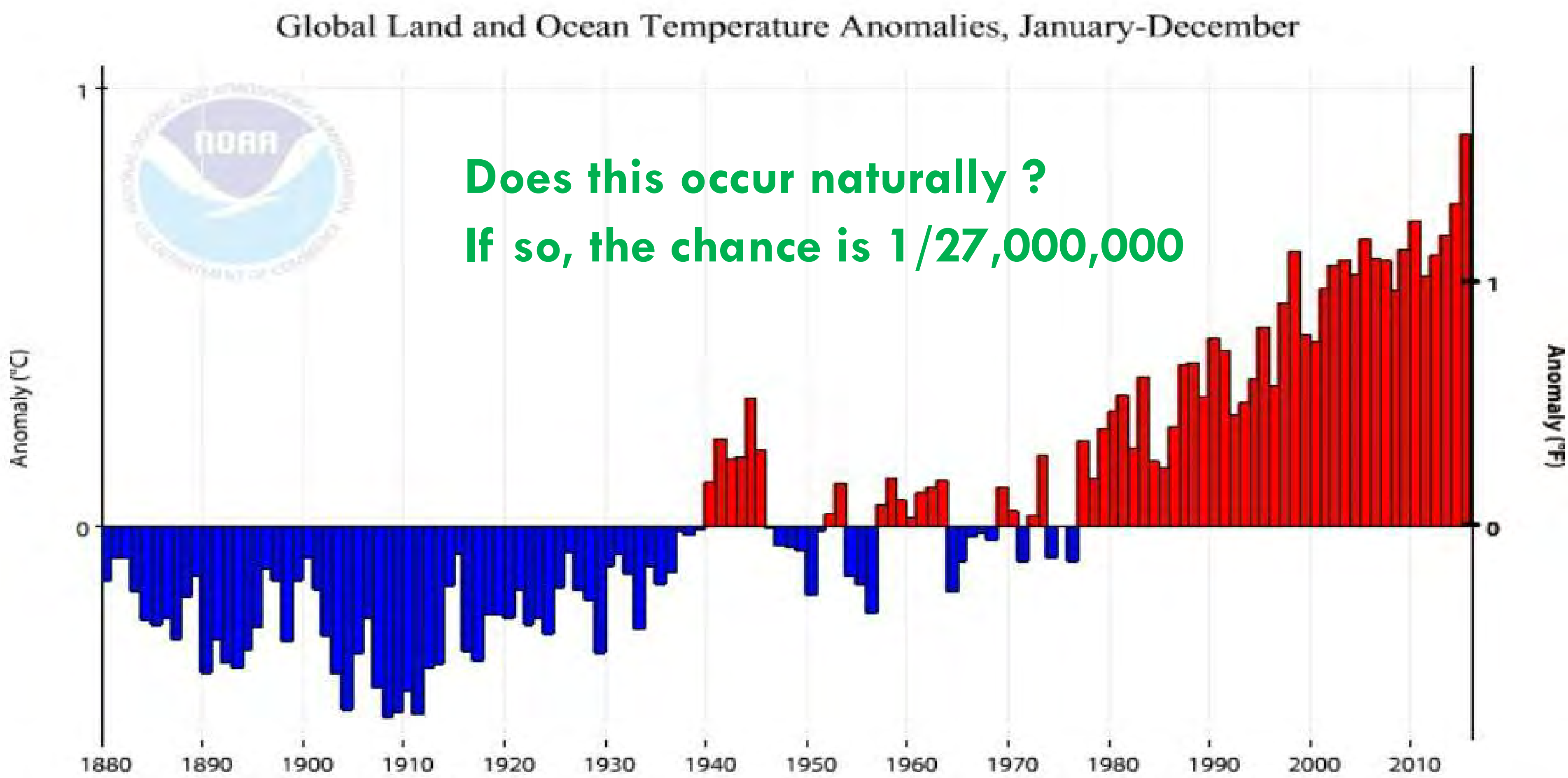
Annual Global Temperature: Difference From 20th Century Average, in °F



Year	Probability of Warmest Rank
2016	96%
2015	4%
others	0%

Correlation does not imply causation




Global Land and Ocean Temperature Anomalies, January-December
Does this occur naturally ?
If so, the chance is 1/27,000,000
Anomaly (°C)
Anomaly (°F)
1
0
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Received: 8 May 2017 | Revised: 11 October 2017 | Accepted: 26 October 2017
DOI: 10.1002/ece3.3652

ORIGINAL RESEARCH

WILEY Ecology and Evolution Open Access

Ecological consequences of invasion across the freshwater–marine transition in a warming world

Dependent variable	Significant terms	*df*	L-ratio	*p*
Bioturbation				
SBR	Size × temperature	5	17.323	.0039
$^{f\text{-}SPI}L_{mean}$	Size × salinity	5	24.593	<.001
	Temperature	1	7.118	.0076
$^{f\text{-}SPI}L_{median}$	Size × temperature	5	19.761	.0014
$^{f\text{-}SPI}L_{max}$	Size	2	12.392	.002
Nutrients				
$[NH_3\text{-}N]$	Size × salinity	3	29.392	<.001
	Size × temperature	3	11.715	.0084
$[NO_3\text{-}N]$	Size	3	49.921	<.0001
	Salinity × temperature	3	18.854	<.001
$[PO_4\text{-}P]$	Size × temperature	3	15.499	.0014
	Size × salinity	3	14.541	.0023

Ecosystem Shift and Ecosystem Service Change

Ecosystem Shift and Ecosystem Service Change: Clam Feast

Thank you!