Zebra Mussel: Shifting Environmental Thresholds Living on the Thermal Edge

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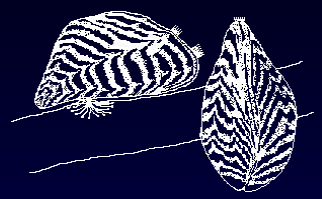


Center for Biological Macrofouling Research

WRP and GASRP Combined Fall Meeting
September 17-19 2014, Houston, Texas

Zebra Mussels in Lake Texoma, TX/OK 2011

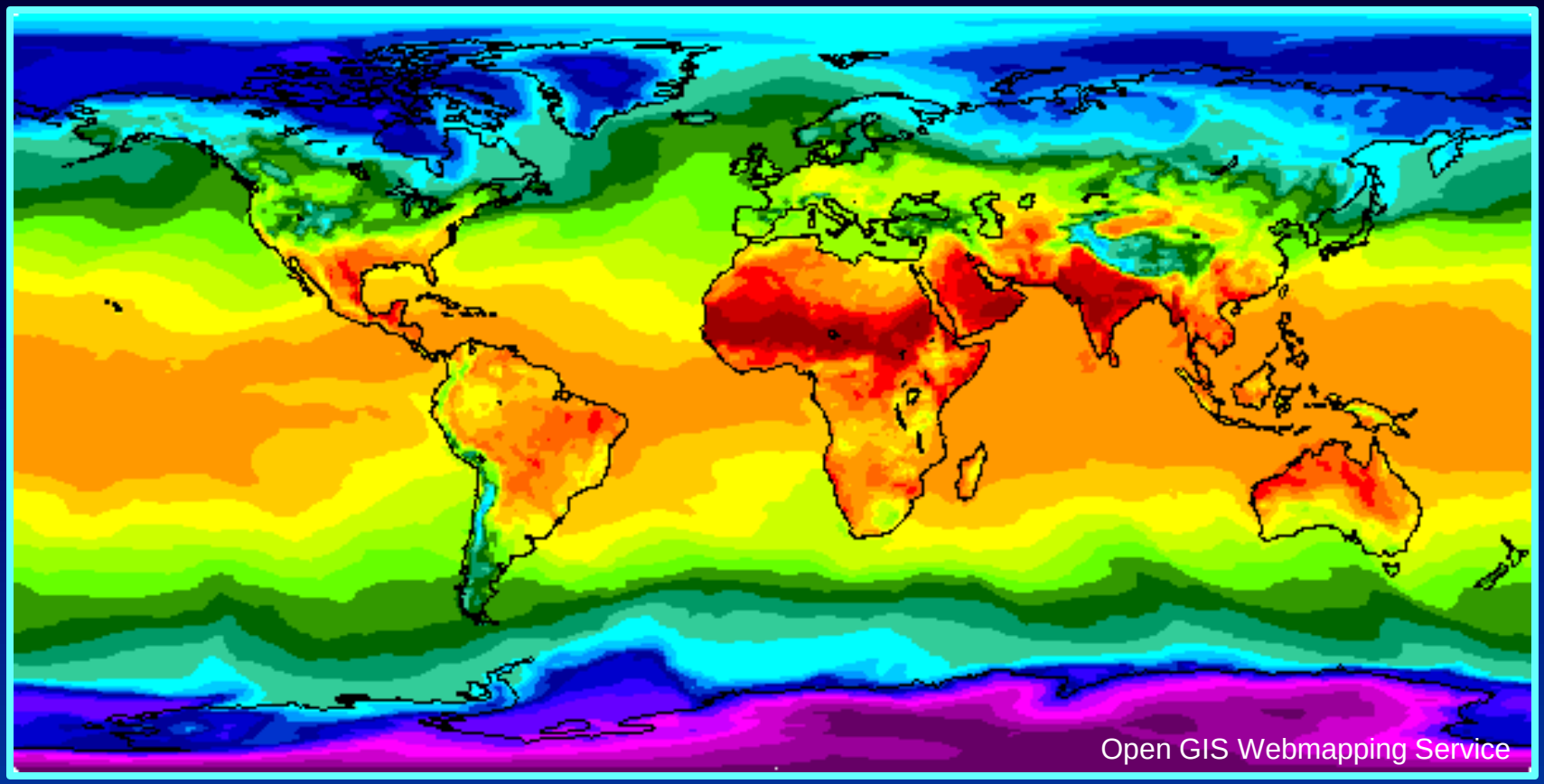
Outline

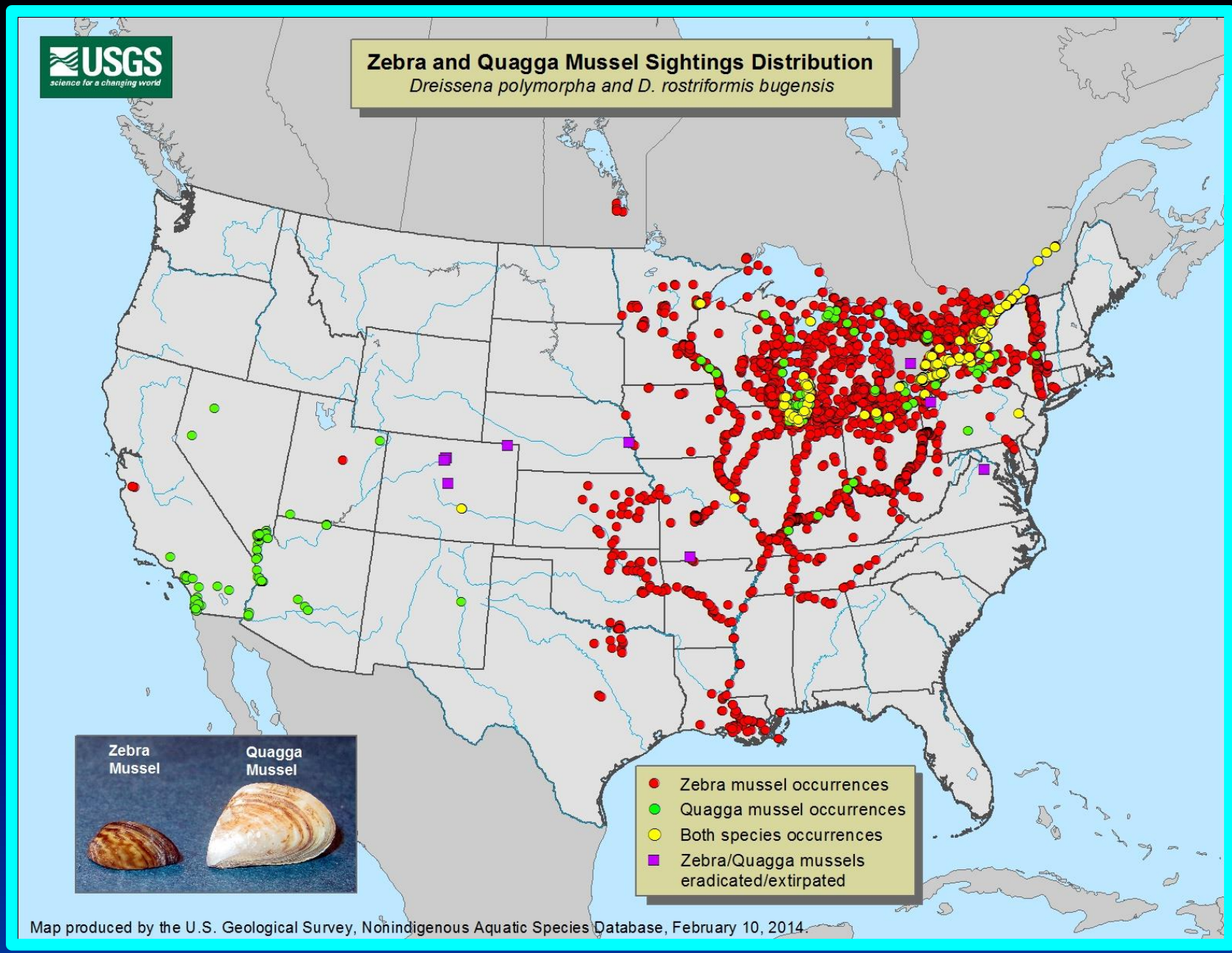
- Thermal Aspects of the Present Distribution of Zebra Mussels in North America and Europe
- Zebra Mussel Thermal Adaptation in Southwestern Water Bodies
- Zebra Mussel Population Dynamics in a Warm Texas Water Body
- Zebra Mussel Starvation at Elevated Summer Water Temperatures
- Hydrological and Thermal Characteristics of Texas Water Bodies Relative to Zebra Mussel Invasion Resistance
- Conclusions

Zebra and Quagga Mussels in North America

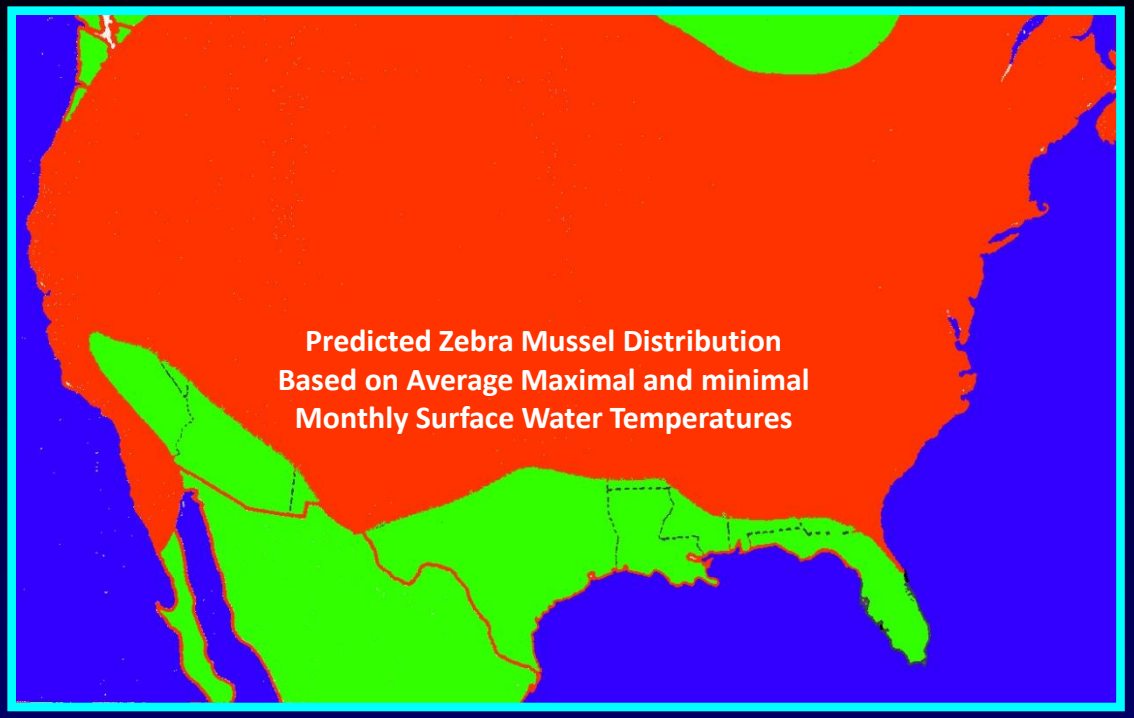
- Originally endemic to Europe
- Introduced to North America in ~ 1984-1985
- Zebra mussels found in Lake Erie in 1986
- Rapidly spread throughout major eastern US drainage systems
  - Zebra Mussels: Great Lakes, Mississippi River and eastern tributaries, lower Missouri River, Arkansas River, isolated water bodies
  - Quagga Mussels: Great Lakes, upper Mississippi and lower Ohio Rivers, lower Colorado River, reservoirs in Colorado, Arizona, southern California
  - Rapid dispersal through navigable waterways on commercial vessels and through canals and water conduits between water bodies
  - Dispersed more slowly to isolated water bodies (i.e., overland transport)
  - Zebra Mussels recently found in San Justo Reservoir Central California (2008), in Texas, Lake Texoma, (2009), Lake Ray Roberts (2012) and Lake Belton (2013), and Lake Bridgeport (2014)

Thermal Aspects of the Present Distribution of Zebra Mussels in North America and Europe




USGS
science for a changing world
Zebra and Quagga Mussel Sightings Distribution
Dreissena polymorpha and D. rostriformis bugensis
Zebra Mussel
Quagga Mussel
Zebra mussel occurrences
Quagga mussel occurrences
Both species occurrences
Zebra/Quagga mussels eradicated/extirpated
Map produced by the U.S. Geological Survey, Nonindigenous Aquatic Species Database, February 10, 2014.

Zebra/Quagga Mussel Temperature Limits for Invasion

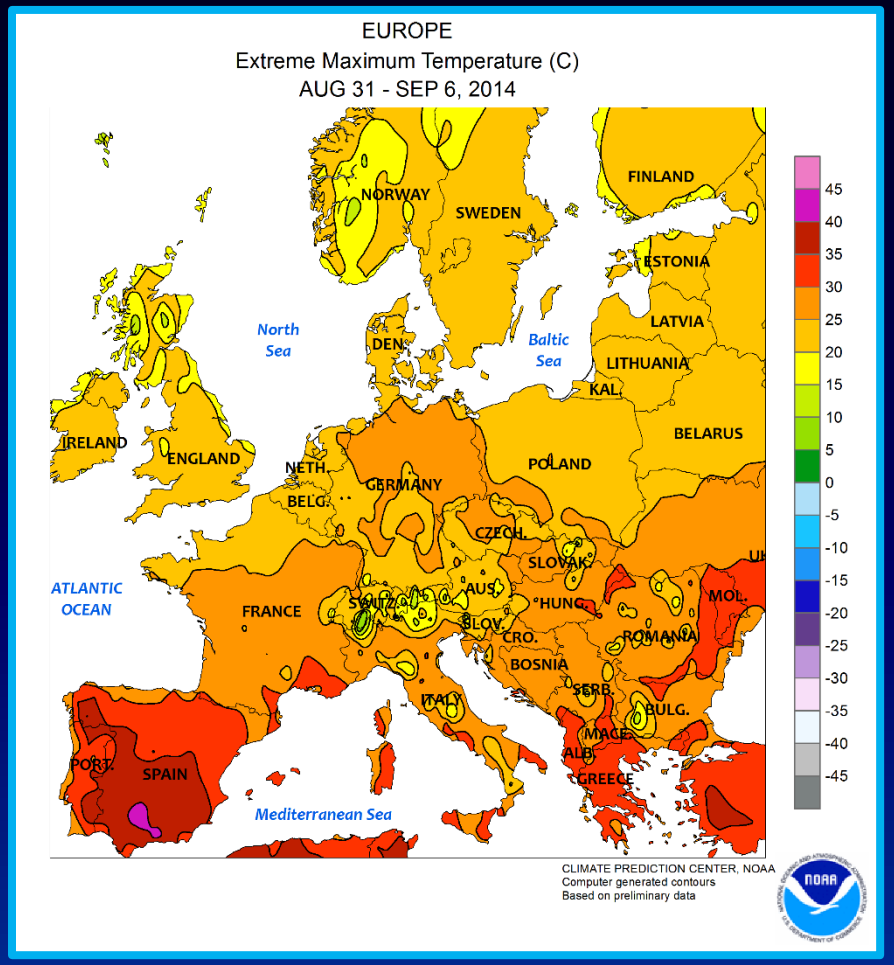


- Generally agreed long-term incipient upper thermal limit of zebra mussels was 30°C and 28°C for quagga mussels based on European and Northeastern US studies
- Generally agreed temperature for initiation of spawning was 16-18°C
- These temperature limits were used predict potential zebra mussel distribution in North America based on maximum summer surface water temperatures – similar for quagga mussels
- Recent successful establishment of zebra mussels in warm waters of Texas and quagga mussels in the warm waters of the Lower Colorado, southern California and Arizona requires a re-examination of these assumptions

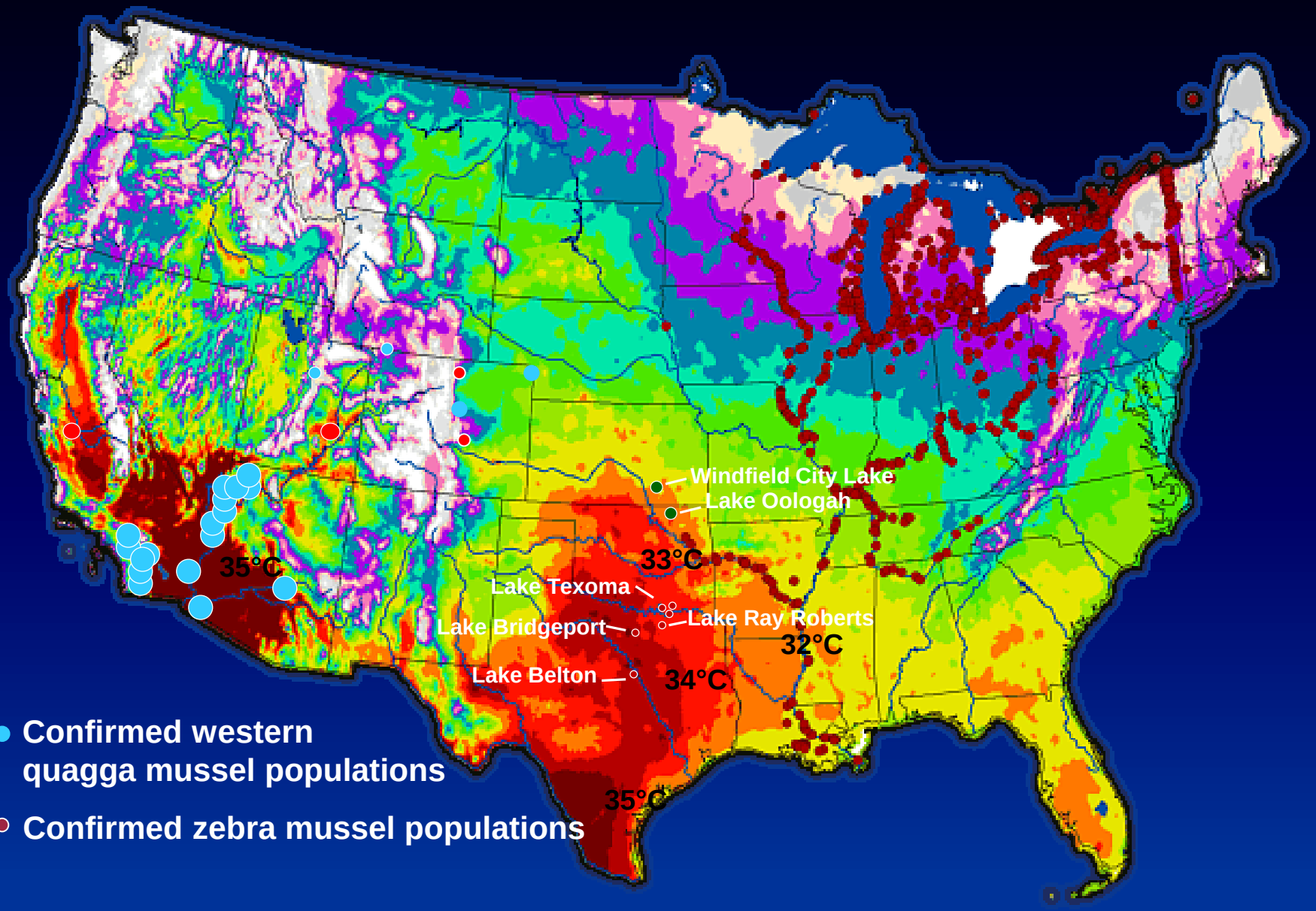
European Distribution of Dreissenid Mussels Relative to Peak Summer Temperature

Endemic Range

Invasion Range



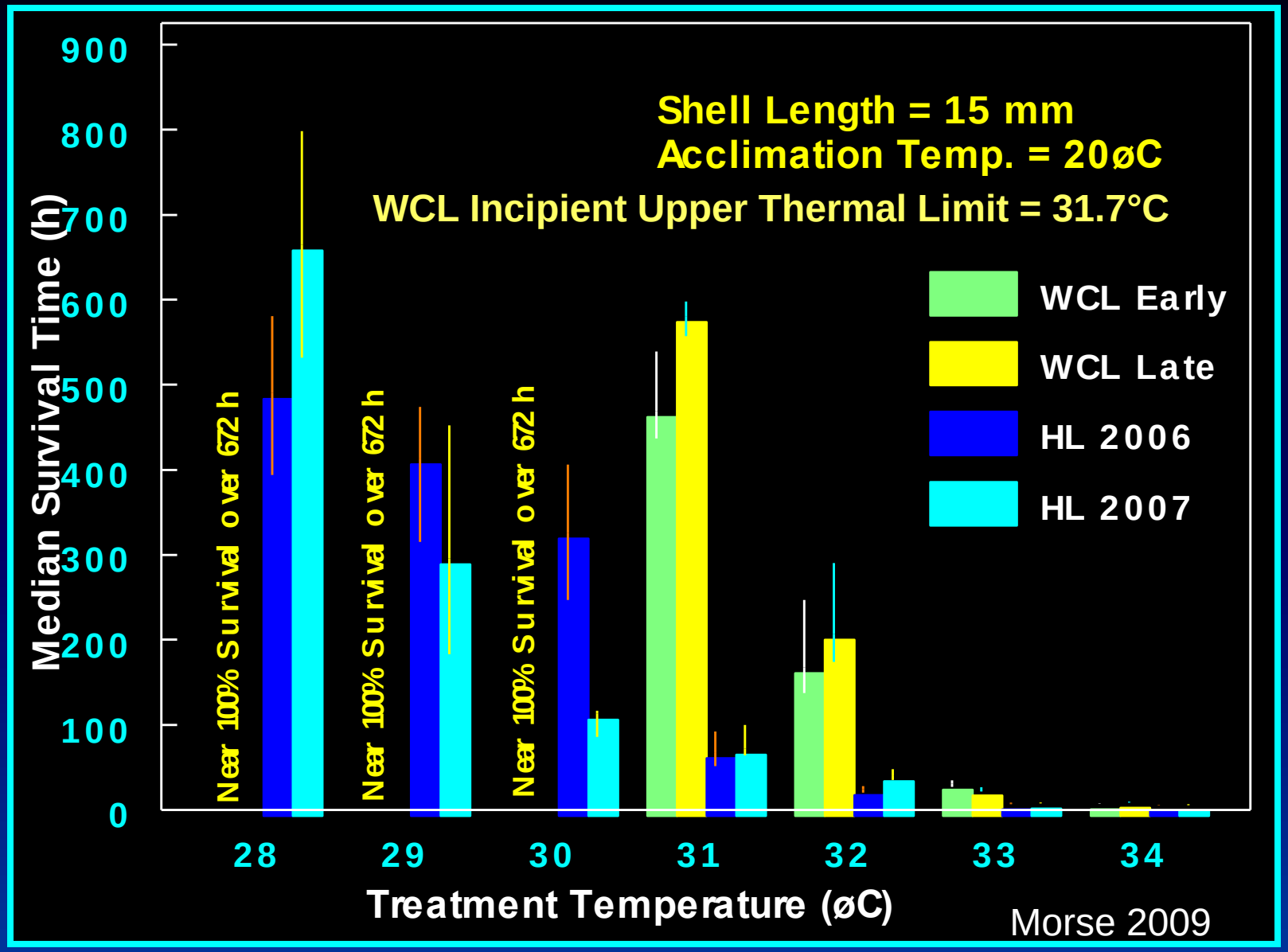
1°C Mean Maximum Air Temperature Isotherms (1961-1990)
Source: Spatial Climate Analysis Service, Oregon State University



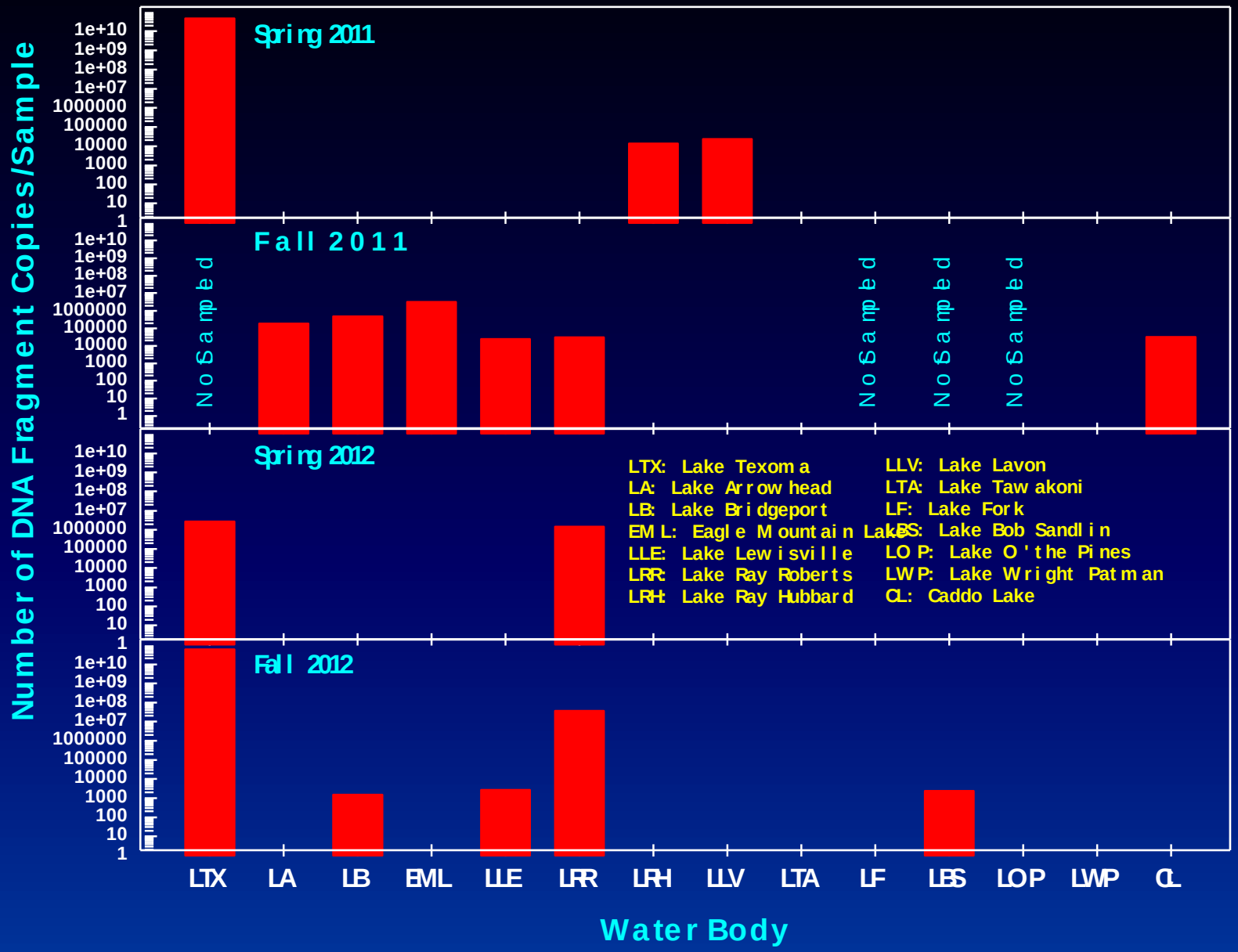
Zebra Mussel Thermal Adaptation in Southwestern Water Bodies

Todd Robinson of TPWD with zebra mussel infested rock from Lake Texoma.
From *State Impact*: Energy and Environment reporting for Texas 03/19/2014

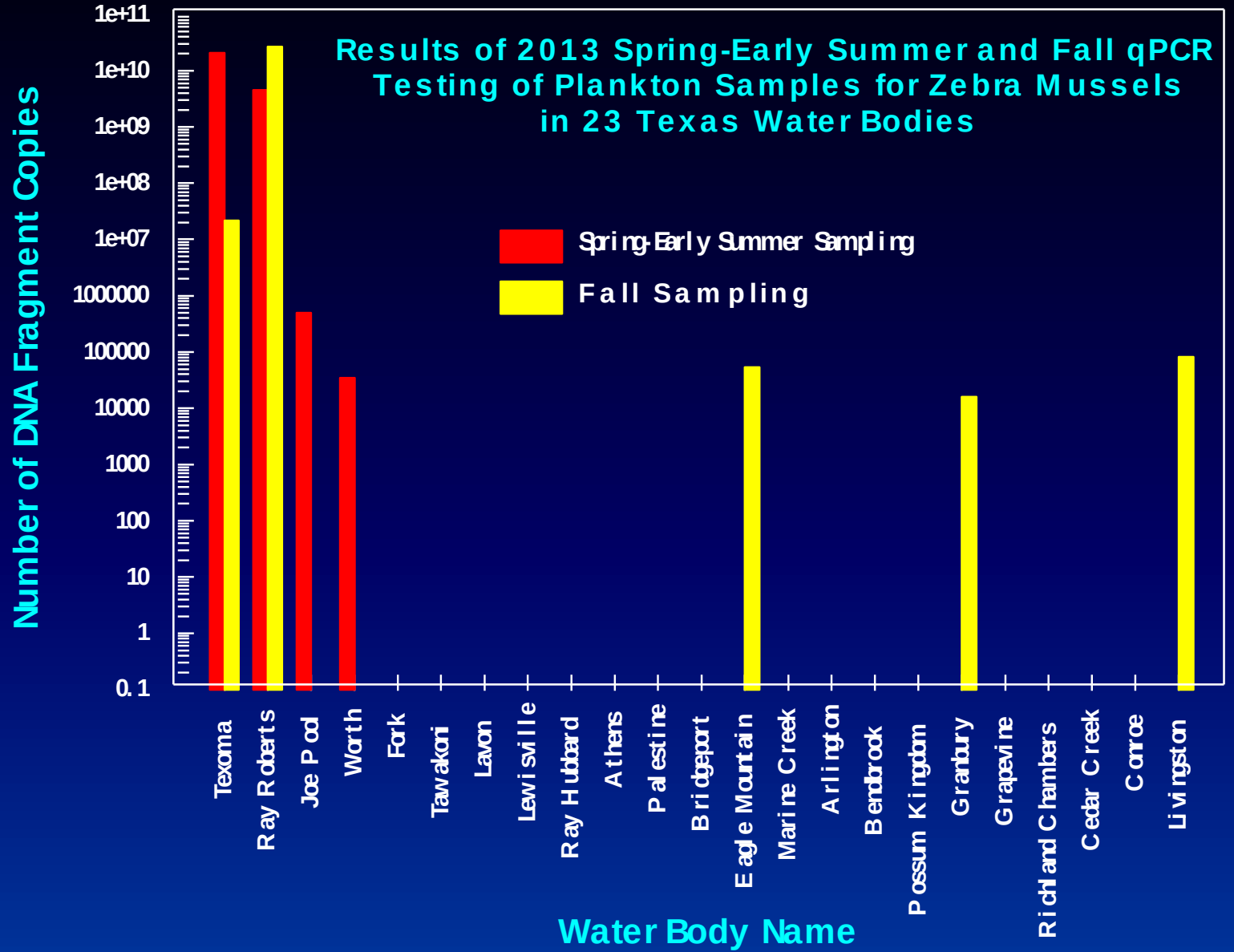
Comparison of Median Survival Times Between Zebra Mussels from Winfield City Lake (KS) and Hedges Lake (NY)



2011 and 2012 qPCR Results



2013 qPCR Results for 23 Texas Water Bodies

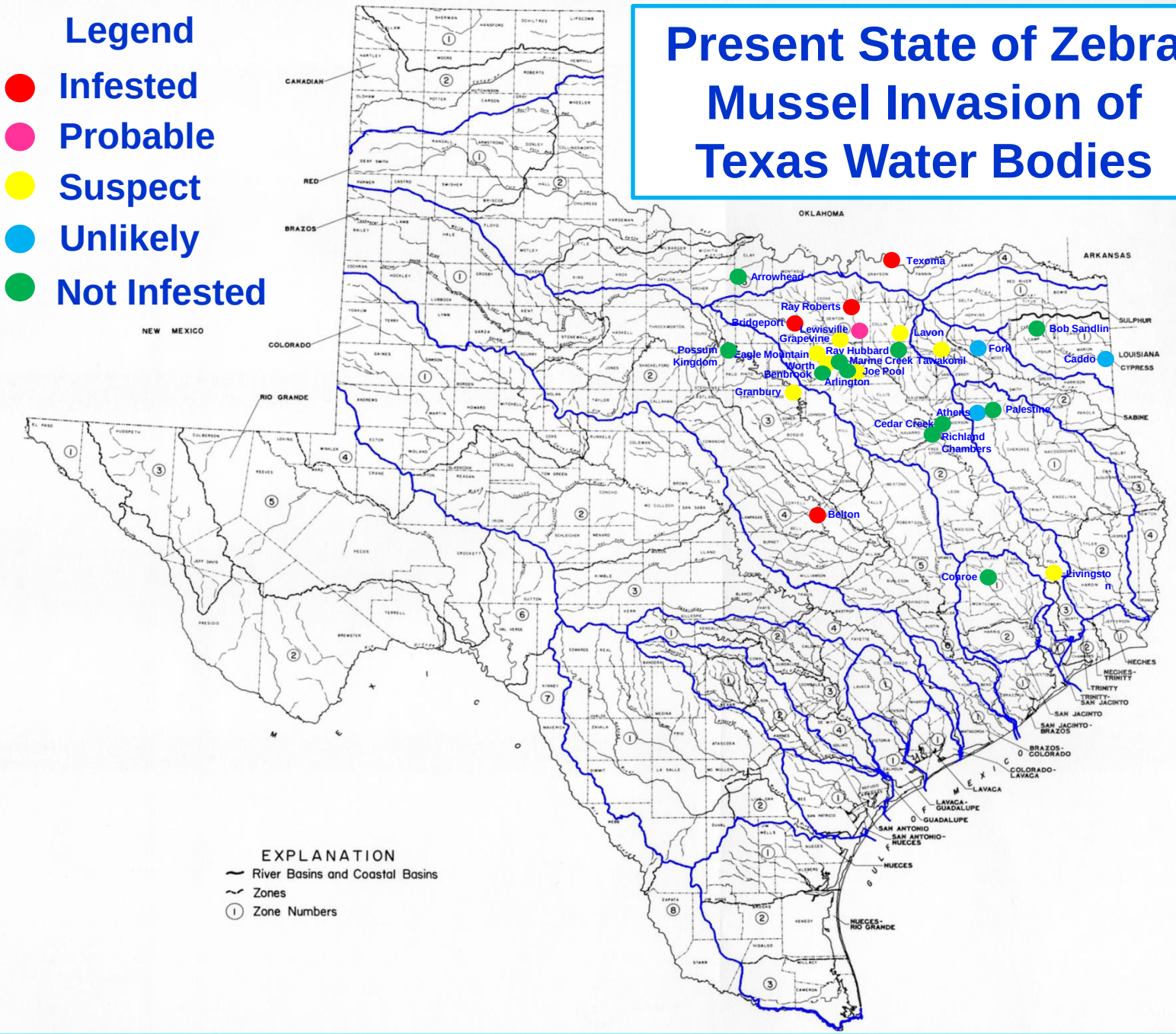


Texas Water Bodies with Known or Suspected Zebra Mussel Infestations

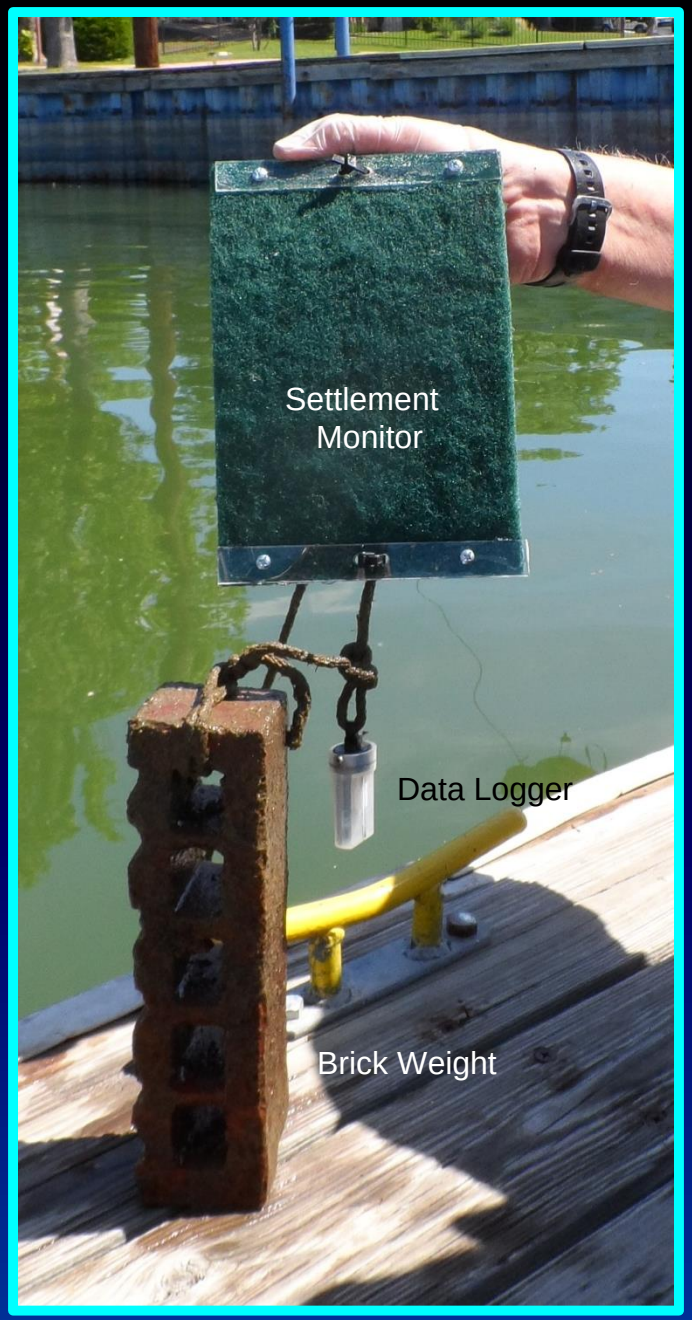
Water Body	2009				2010				2011				2012				2013			
	qPCR	Larvae	Juveniles	Adults	qPCR	Larvae	Juveniles	Adults	qPCR	Larvae	Juveniles	Adults	qPCR	Larvae	Juveniles	Adults	qPCR	Larvae	Juveniles	Adults
Texoma			✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ray Roberts									✓				✓	✓	✓		✓	✓	✓	✓
Belton																				✓
Lavon									✓			✓					✓	✓		
Ray Hubbard									✓			✓								
Arrowhead									✓											
Bridgeport									✓				✓					✓		✓
Eagle Mountain									✓								✓			
Lewisville									✓						✓			✓	✓	
Caddo Lake									✓											
Bob Sandlin													✓							
Worth																	✓			
Grapevine																	✓			
Fork																	✓			
Tawakoni																	✓			
Joe Pool																	✓			
Granbury																	✓			
Livingston																	✓			
Arlington																				
Benbrook																				
Athens																				
Palestine																				
Marine Creek																				
Possum Kingdom																				
Richland Chambers																				
Cedar Creek																				
Conroe																				
Livingston																				

Not Infested | Unlikely | Suspect | Probable | Infested

Present State of Zebra Mussel Invasion of Texas Water Bodies

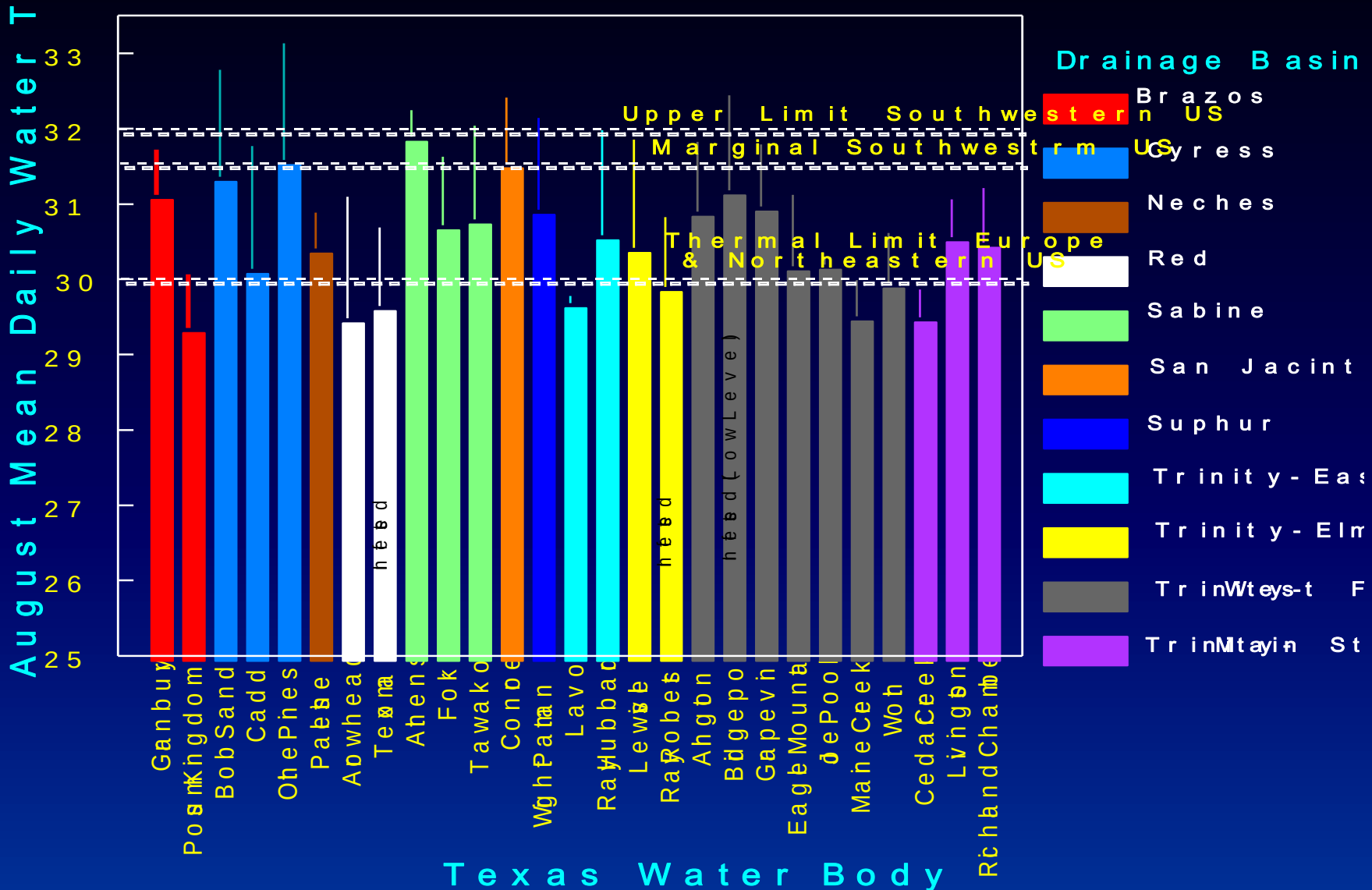


Zebra Mussel Population Dynamics in a Warm Texas Water Body (Lake Texoma)



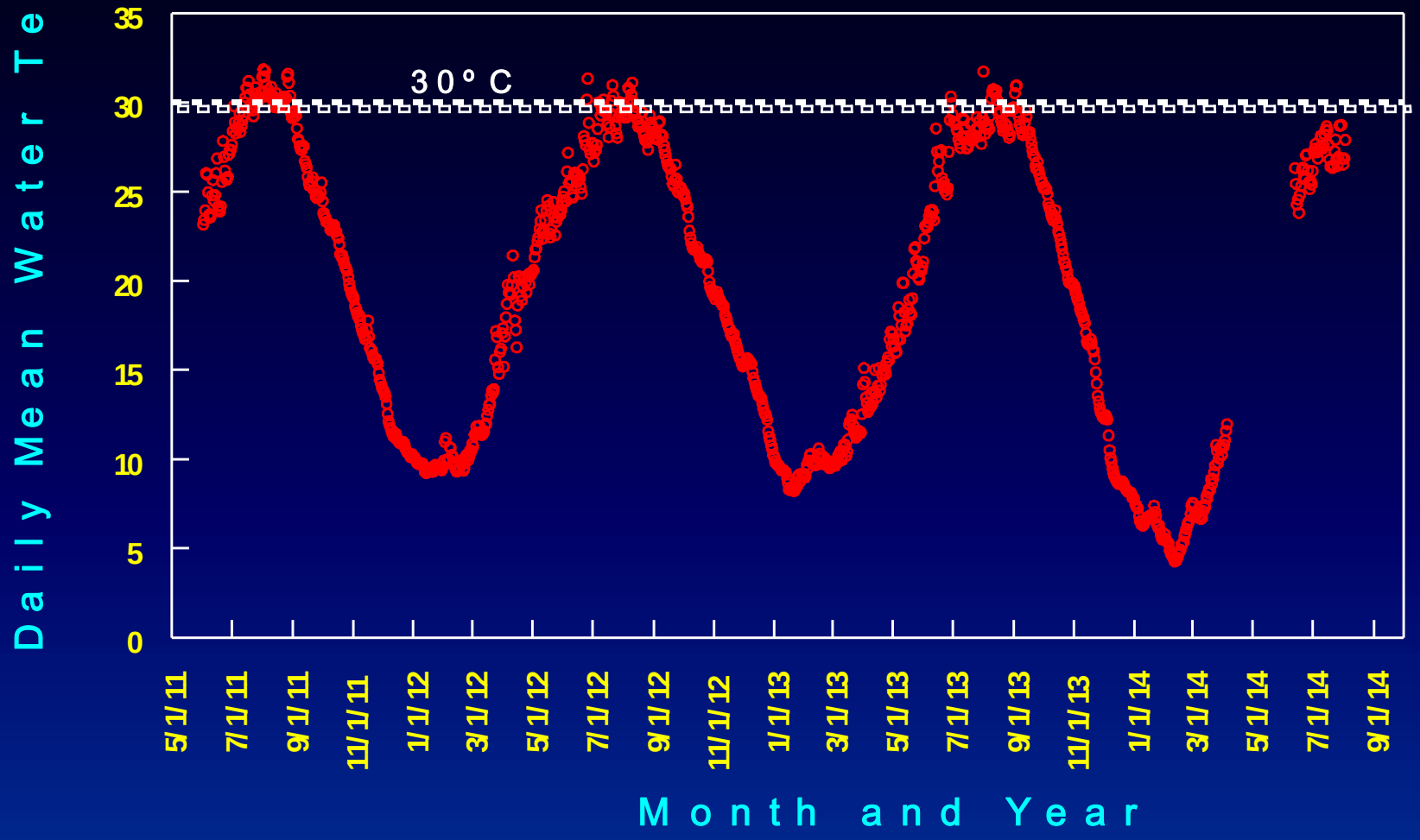
- **Hobo data loggers recorded surface water temperatures continuously at one hour intervals**
- **Daily mean surface water temperatures computed from hourly data**

Mean August Surface Water Temperature in Texas Water Bodies

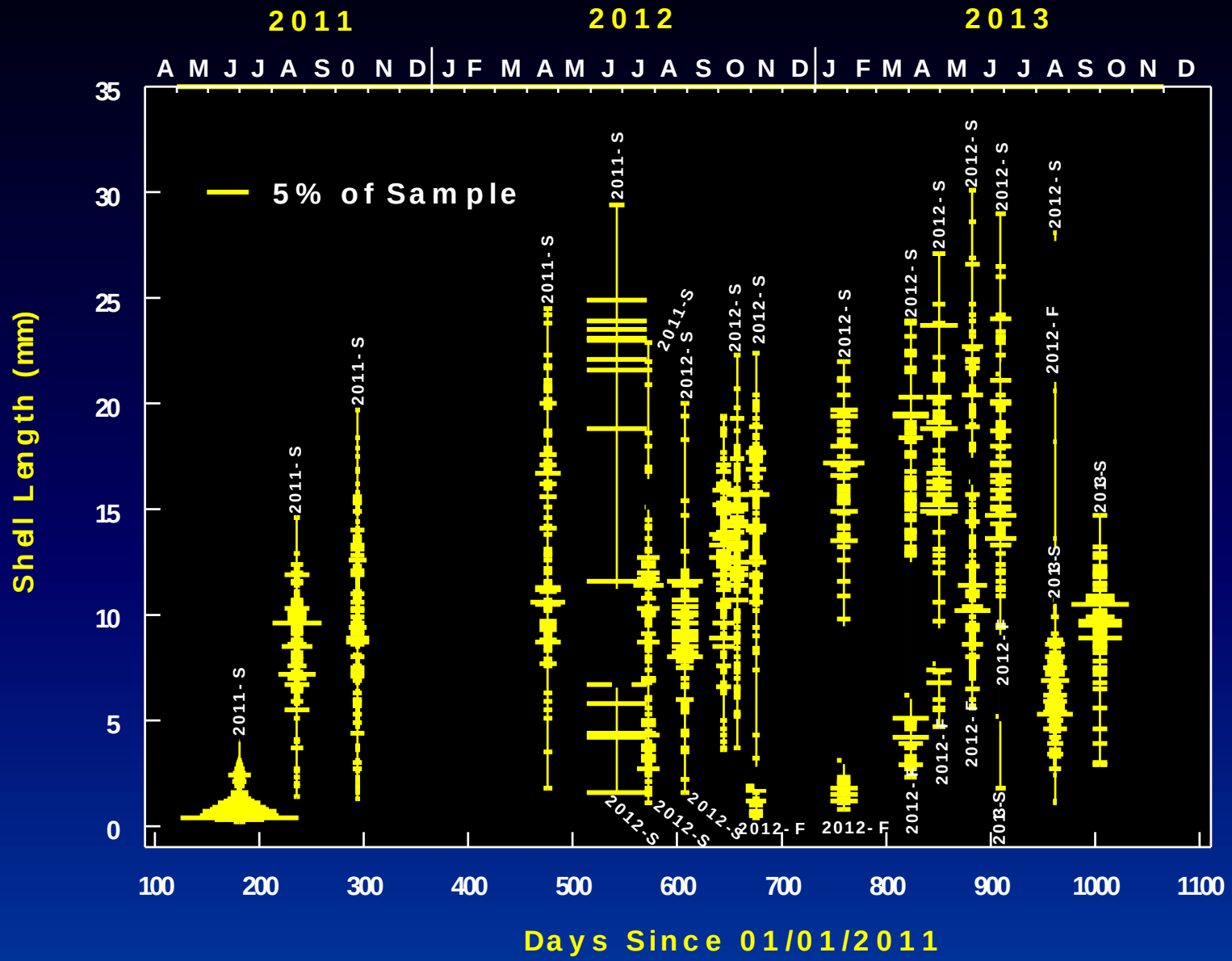


Zebra Mussel Distribution in Lake Texoma (TK/OK)

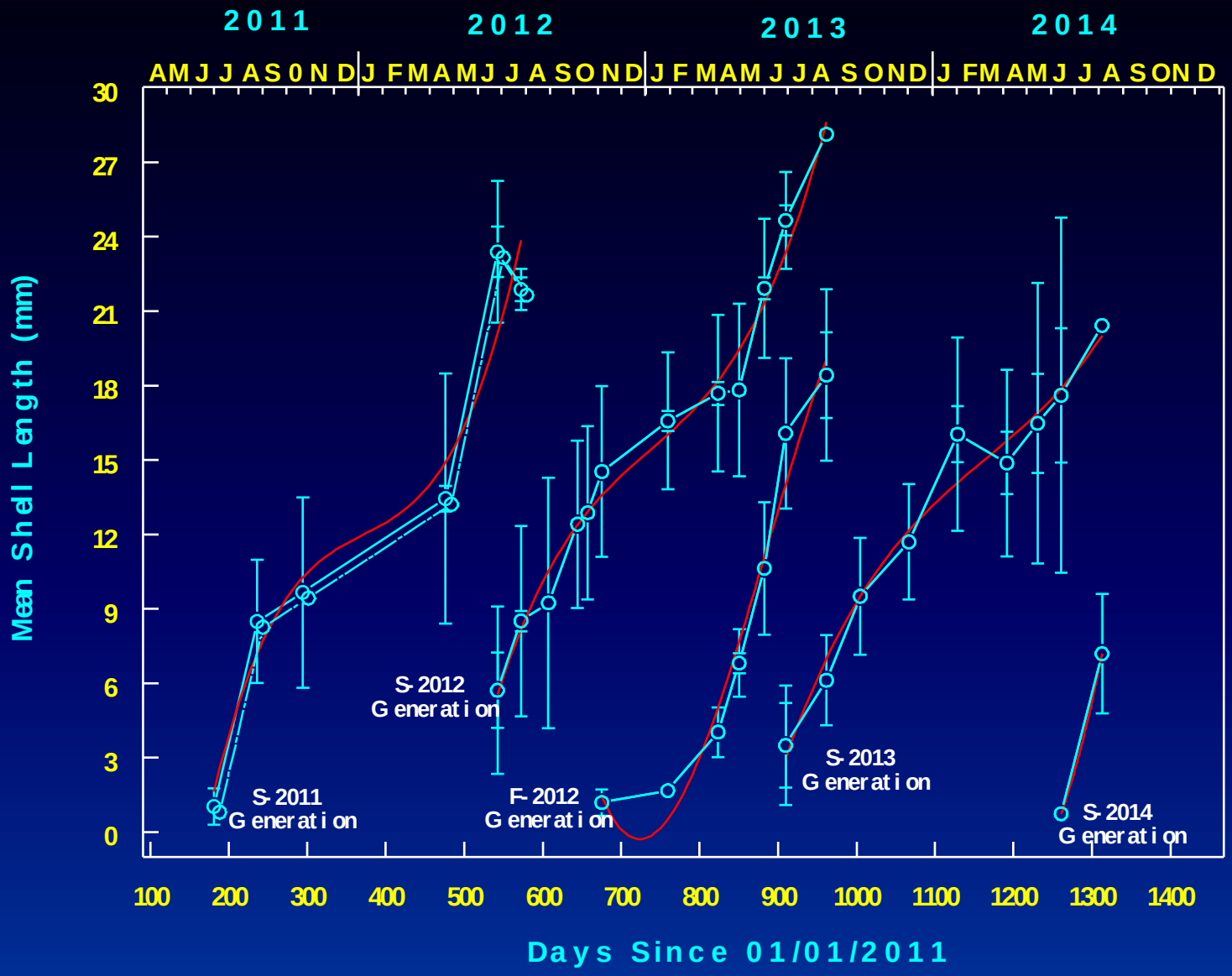
Lake Texoma Daily Mean Water Temperature



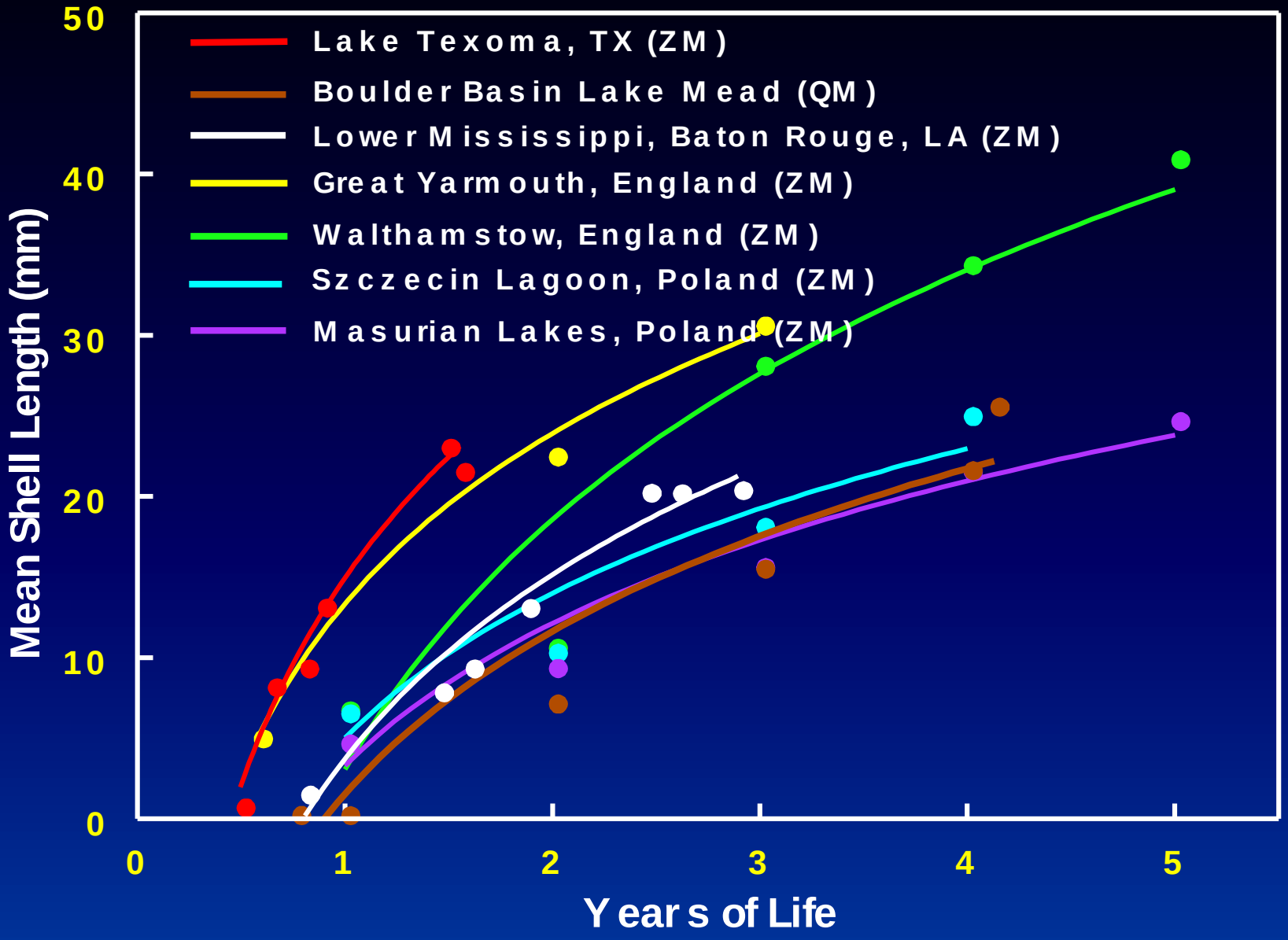
Zebra Mussel Size Distributions in Lake Texoma



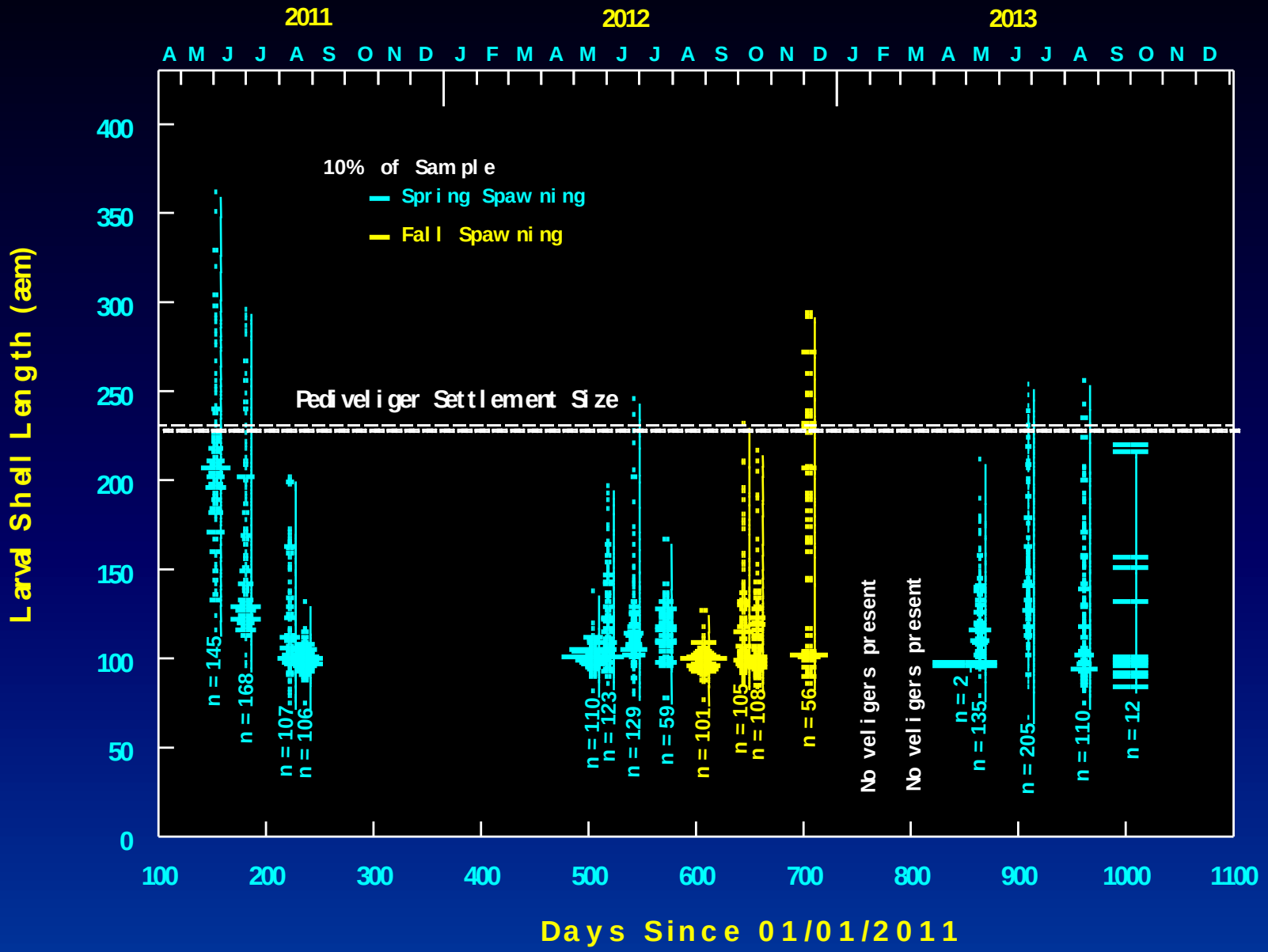
Zebra Mussel Growth Rate & Life Spans in Lake Texoma



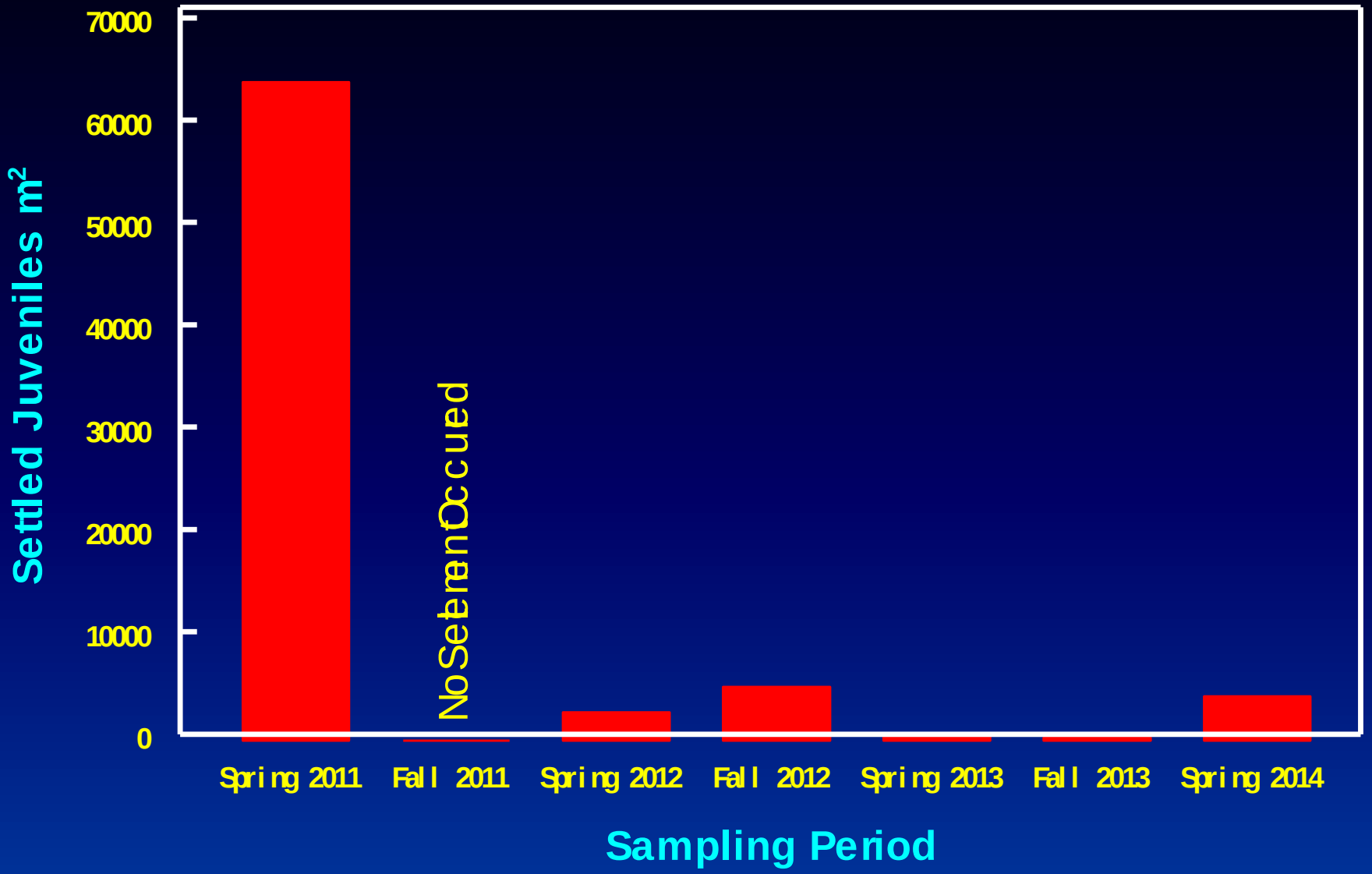
Dreissenid Growth Rates – US and Europe



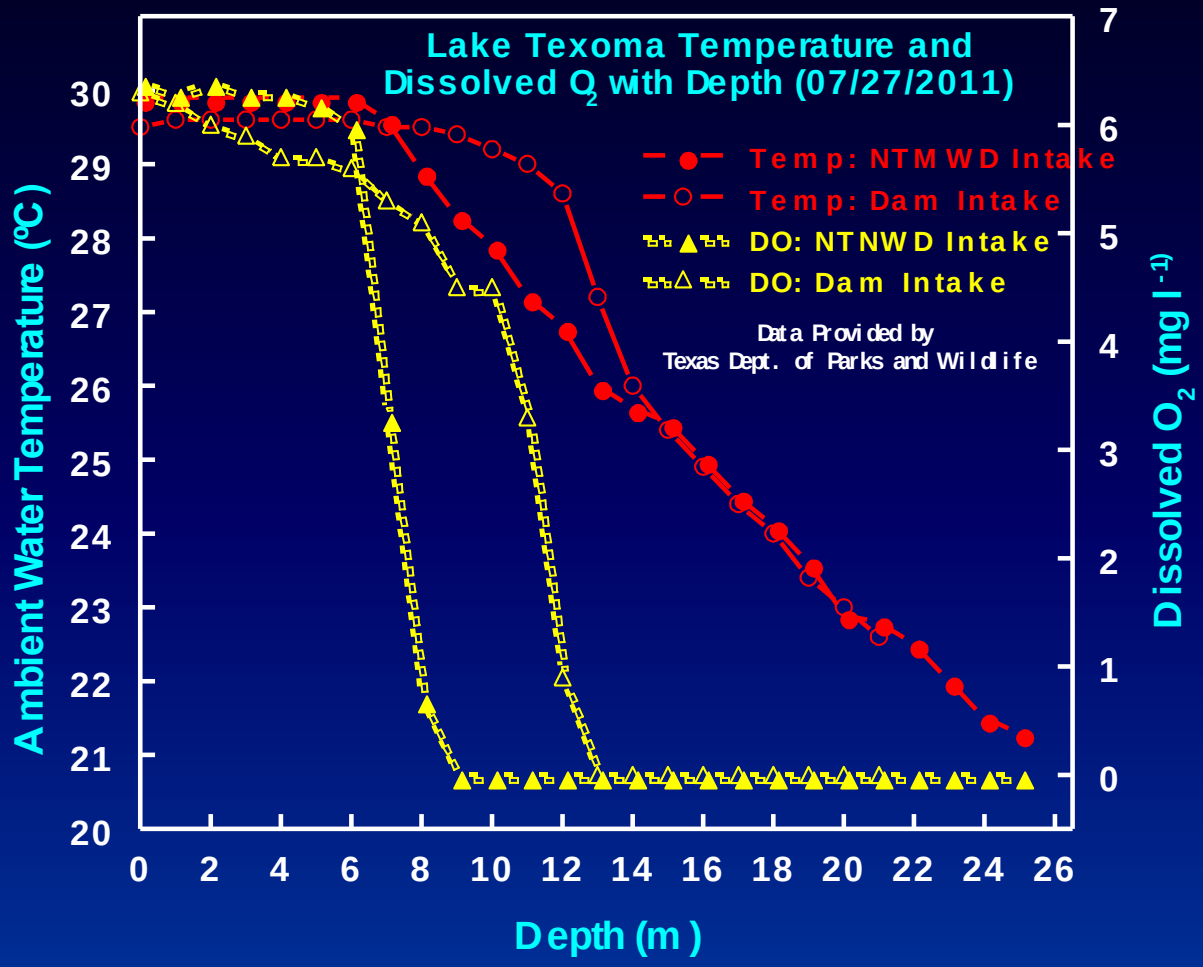
Zebra Mussel Veliger Size Distributions in Lake Texoma

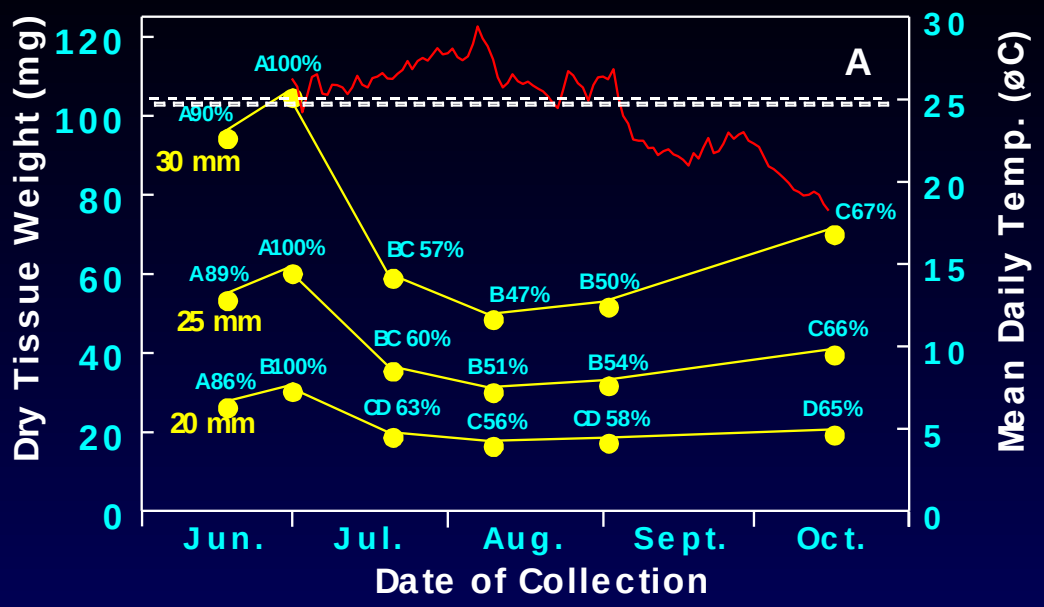


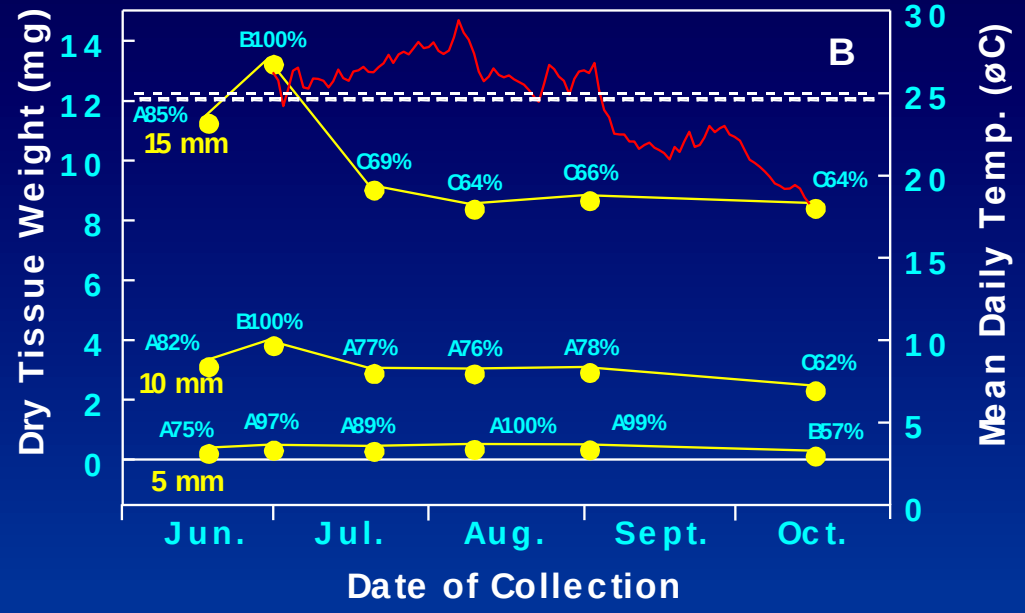
Zebra Mussel Settlement in Lake Texoma



Zebra Mussel Starvation at Elevated Summer Water Temperatures





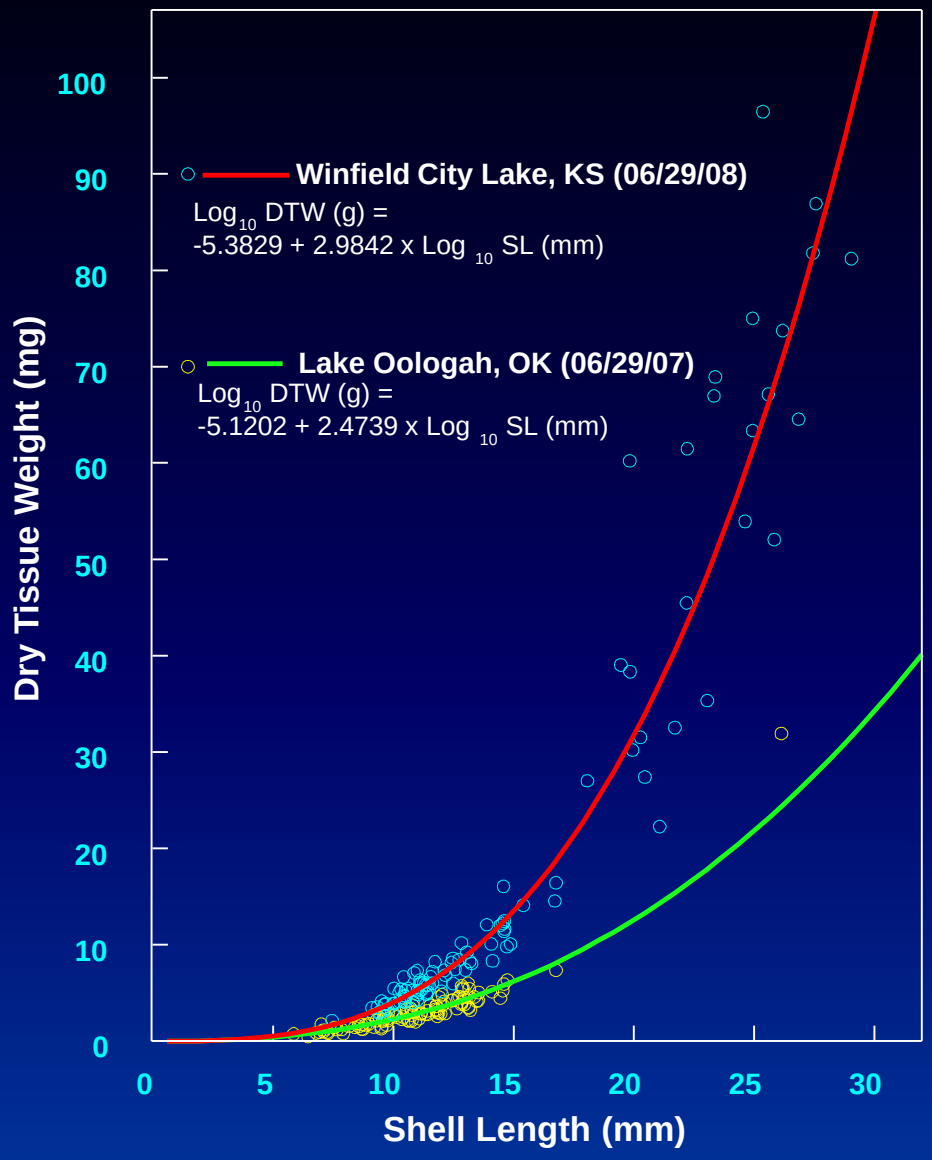


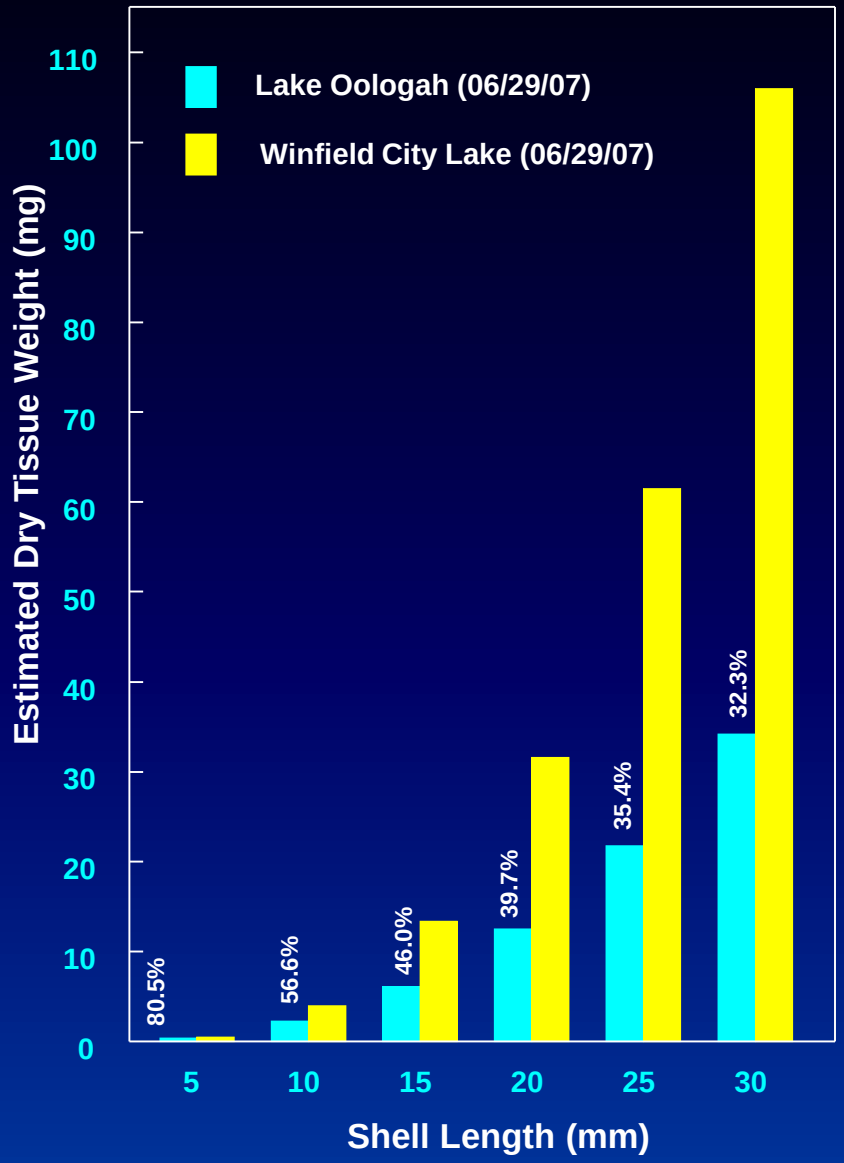
Zebra Mussel Dry Tissue Weight Variation in Winfield City Lake, KS

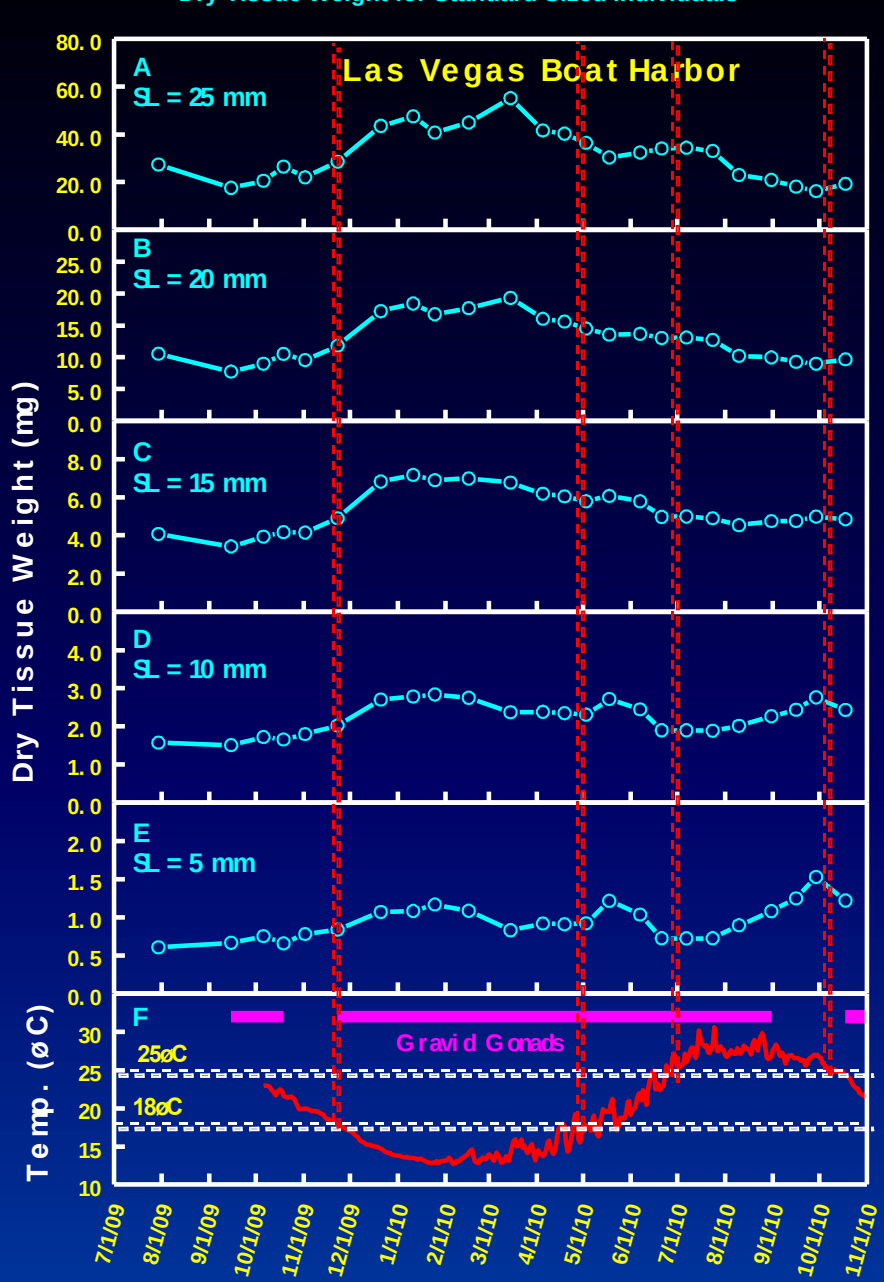
- Estimated DTW from regression equations for specific sized mussels
- SL = 5, 10, 15, 20, 25, and 30 mm
- DTW declined at water temperatures >25°C
- Most pronounced in larger mussels
- Suggests starvation above 25°C
- Most pronounced in larger individuals

McMahon, Leung and Morse

Comparison of Mussel DTW of Lake Oologah and Winfield City Lake

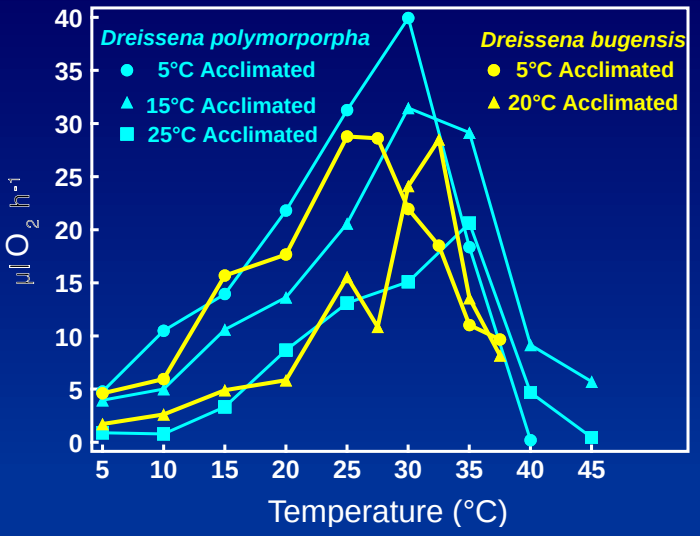






Annual Dry Tissue Weight Variation

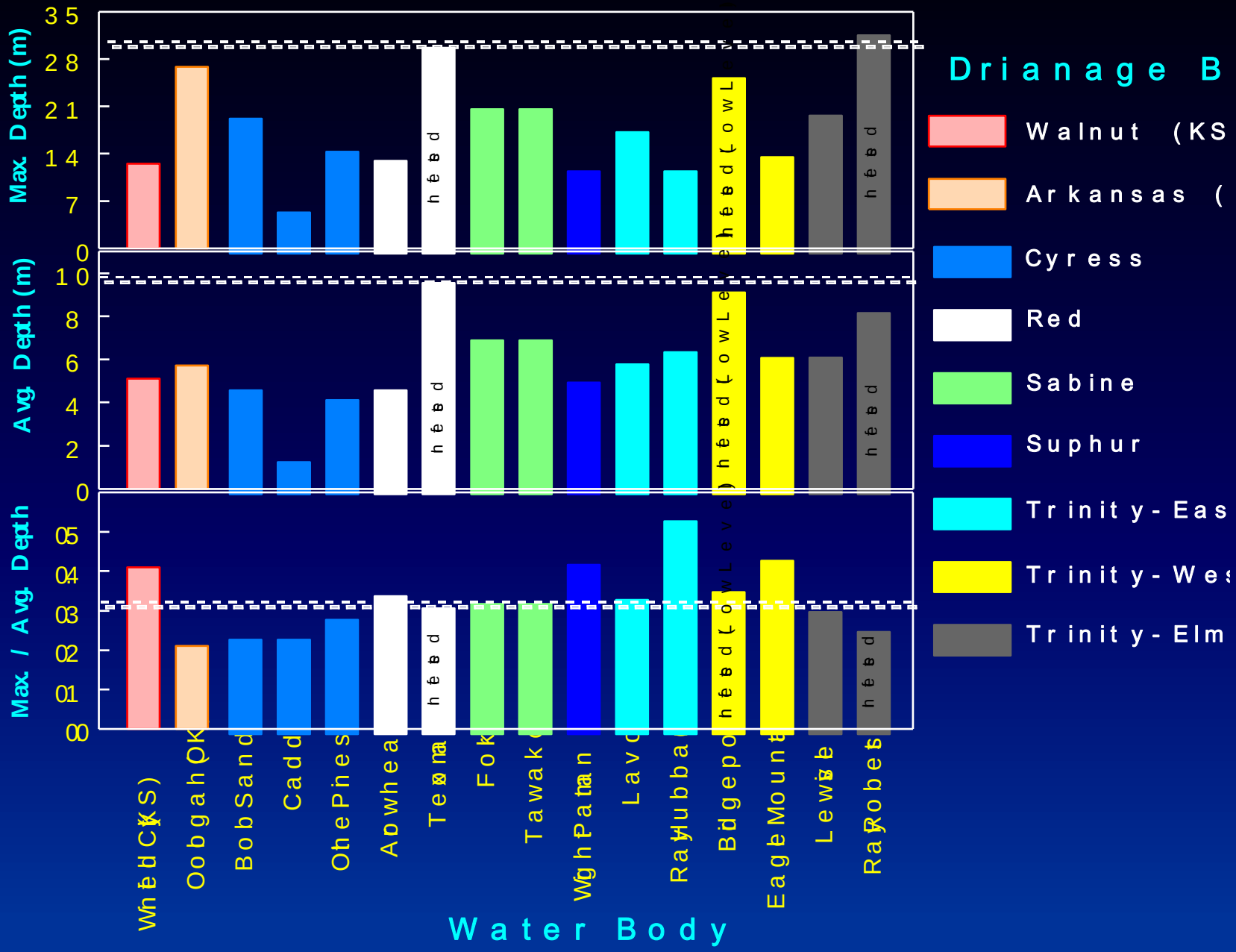
- In all examined standard sized mussels a tendency to loss DTW occurred when water temperatures rose above 25°C
  - More pronounced in larger individuals
  - Indicative of summer starvation
  - Maintenance energy demands > energy assimilation
    - Negative scope for growth
- Larger individuals gain tissue mass when water temperatures are <18°C
  - Maintenance energy demands < energy assimilation
    - Positive scope for growth
  - Not spawning
  - Reduced maintenance energy due to low water temperatures



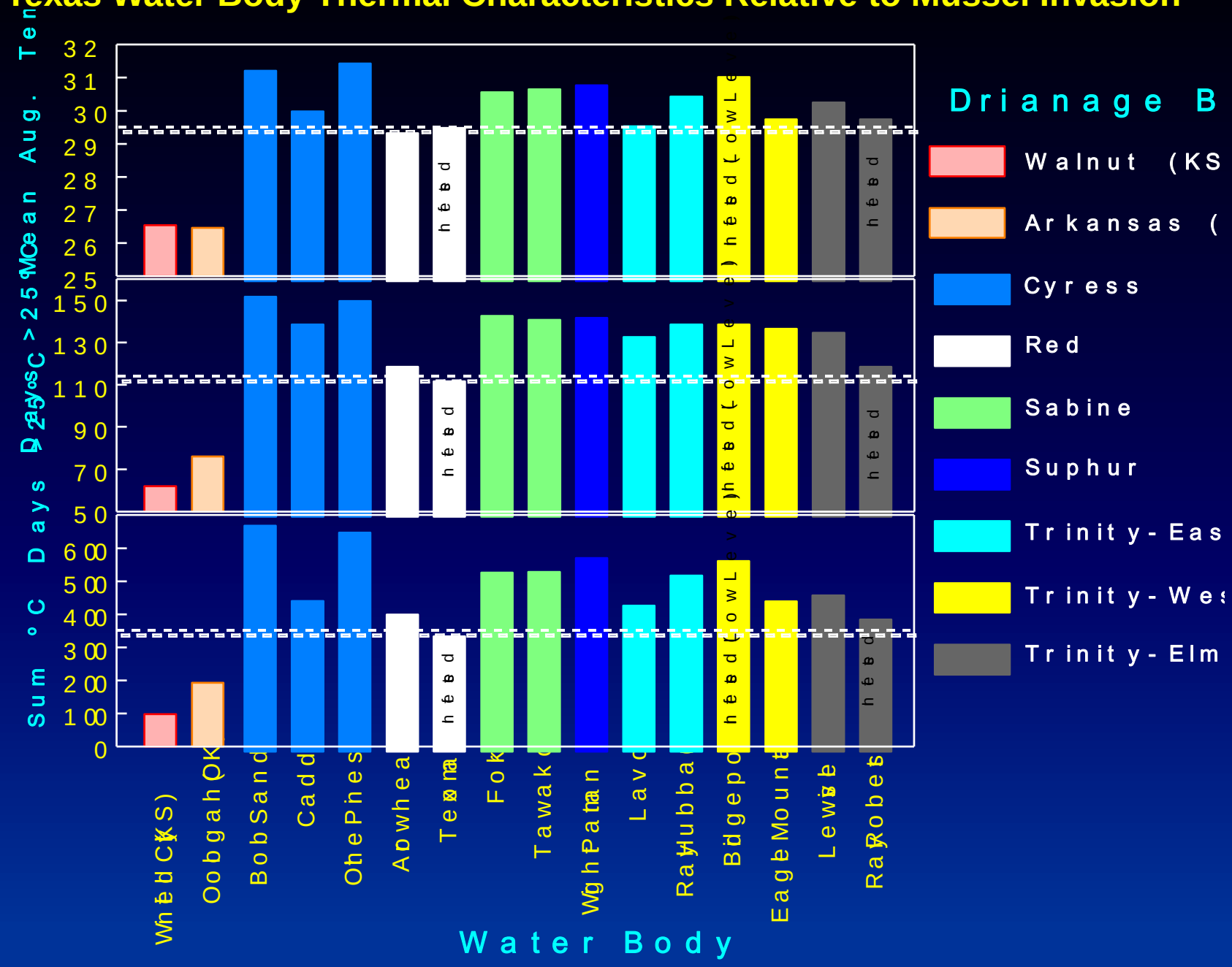
Hydrological and Thermal Characteristics of Texas Water Bodies Relative to Resistance to Zebra Mussel Invasion

Adult Zebra Mussels on Settlement Monitor in Lake Ray Roberts, August 4, 2014

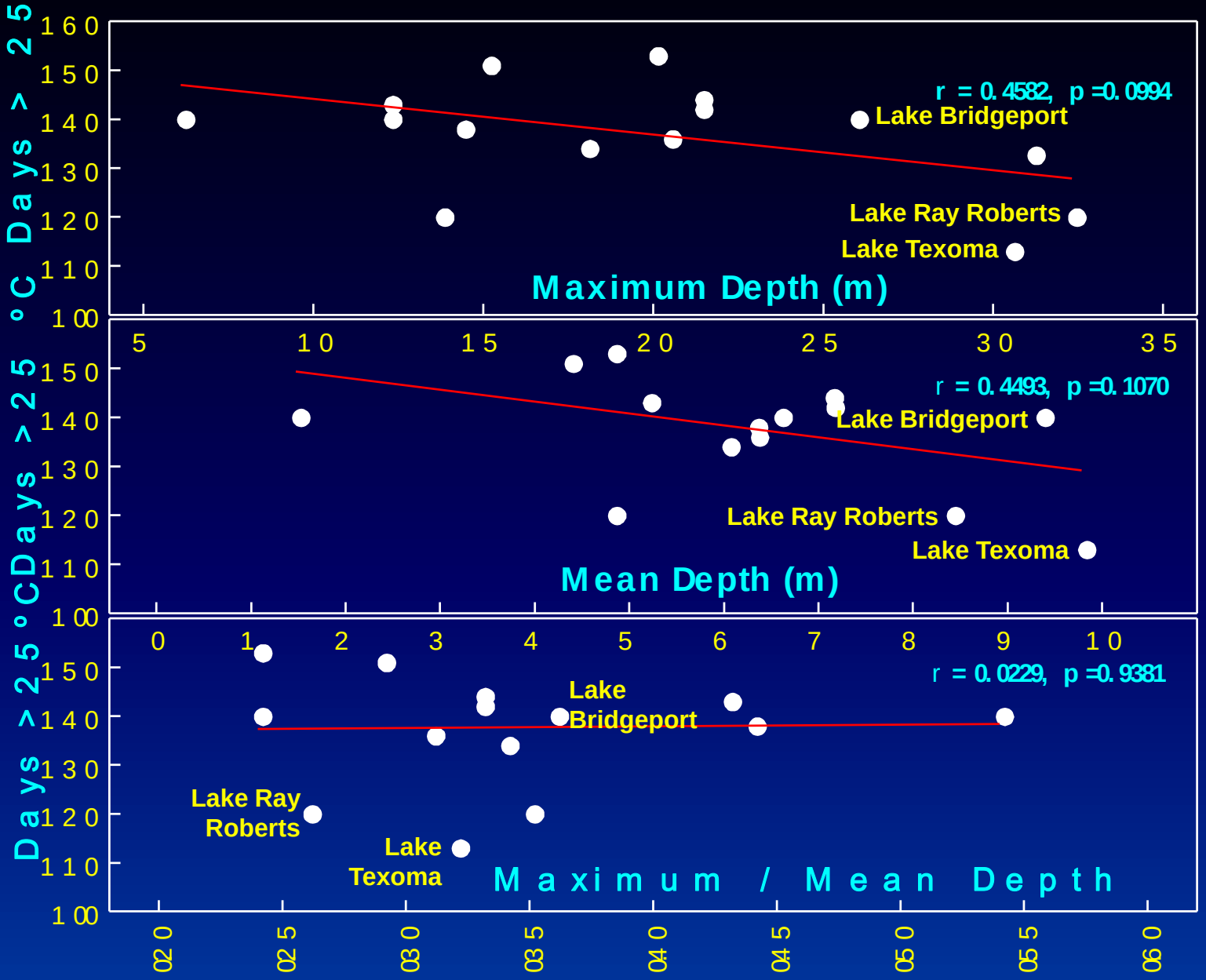
Texas Water Body Hydrological Characteristics Relative to Mussel Invasion

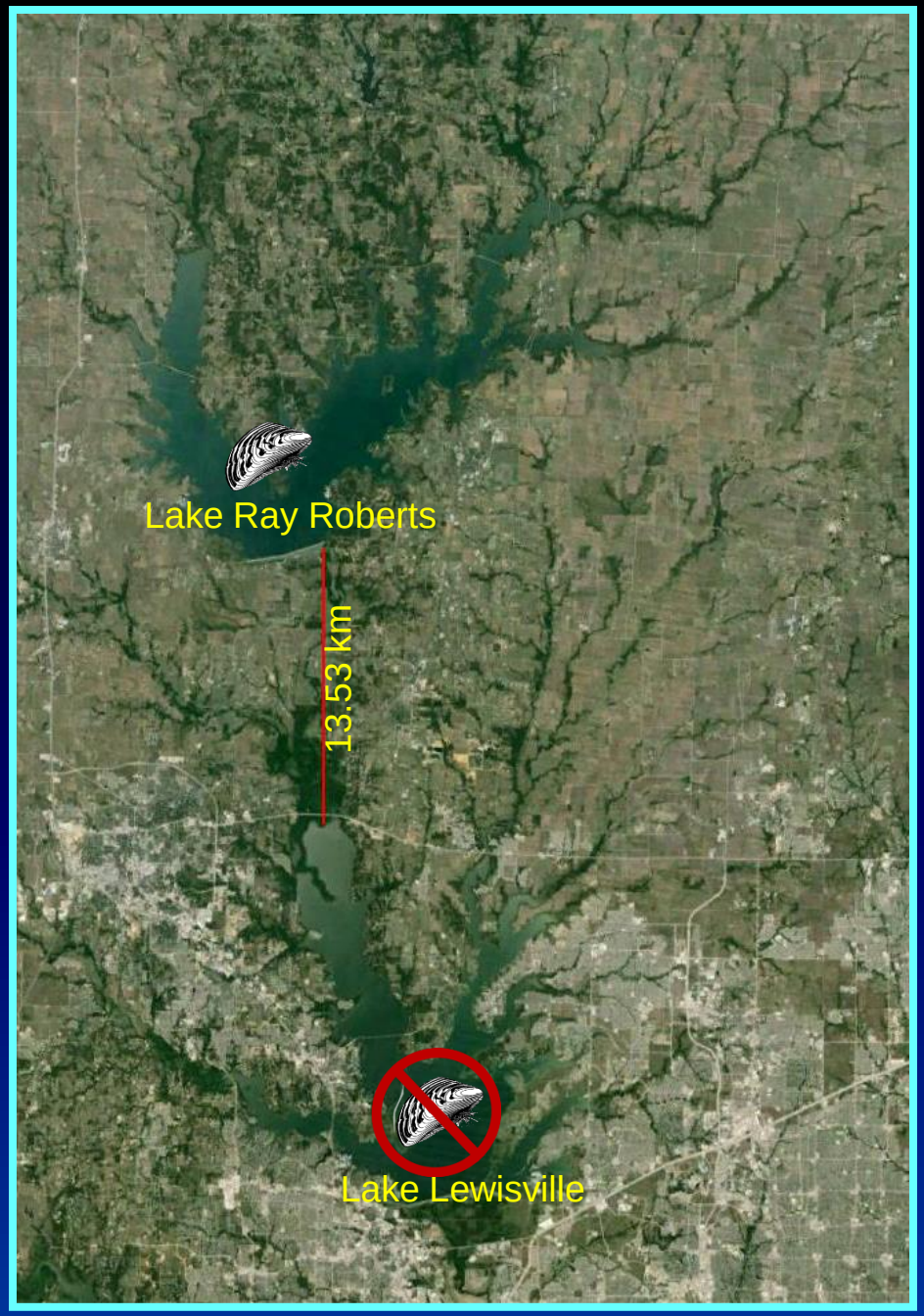


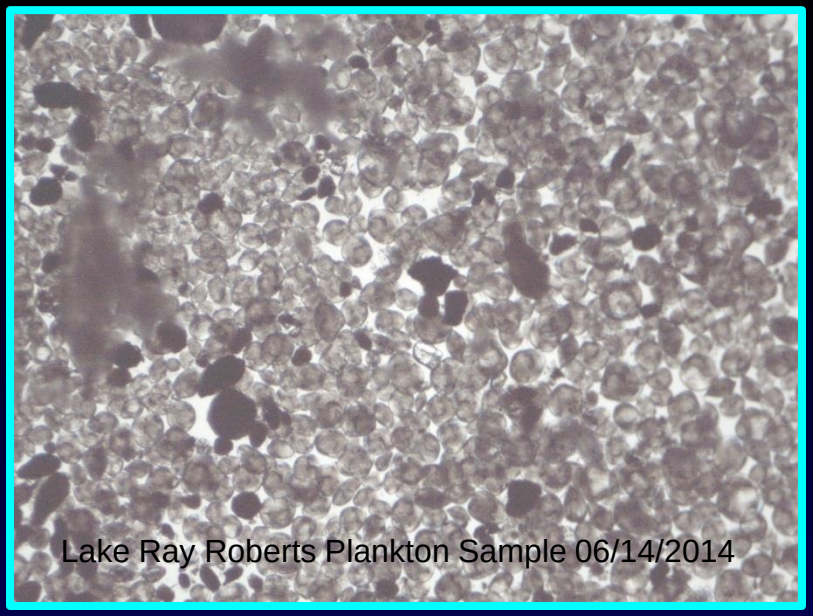
Texas Water Body Thermal Characteristics Relative to Mussel Invasion



Correlation of Texas Water Body Hydrological and Thermal Characteristics






Lake Ray Roberts Plankton Sample 06/14/2014

Lake Ray Roberts

- Maximum depth = 32.3 m
- Average depth = 8.39 m
- Mean August Temperature = 29.9°C
- Number of days >25°C = 121
- Sum °days >25°C = 399.5

Lake Lewisville

- Maximum depth = 14.33 m
- Average depth = 6.32 m
- Mean August Temperature = 30.4°C
- Number of days >25°C = 137
- Sum °days >25°C = 473.178

Lake Lewisville may be thermally resistant to zebra mussel invasion

Conclusions

- Zebra mussels appear to have evolved increased thermal resistance in warm southwestern water bodies
  - Increased thermal tolerance (31°C)
  - Continue to spawn up to 30°C (>25°C upper limit in European and Northeastern US)
  - Veliger larvae tolerate temperatures up to 30°C (<25°C in Europe and Northeastern US)

- Impacts of elevated water temperatures on zebra mussel biology and ecology
  - Increased growth rates and shorter life spans in Texas water bodies
  - Elevated summer water temperatures (>25°C) lead to starvation and loss of tissue mass
    - Nutrient removal – reduction in phyto-bacterioplankton food availability
    - Most prominent in adult mussels
    - May result in life spans being reduced to 1-1.5 years
    - May eventually lead to population density reduction or extirpation

- Some southwestern water bodies may be thermally resistant to zebra mussel invasion
  - Surface water temperatures tend to increase with decreased water body depth
    - Increases the number of days when water temperature is >25°C
    - Increases the number of °days >25°C experienced by mussels during summer months
    - Increased heat stress in shallow water bodies may lead to mussel starvation and extirpation
  - Highest at-risk water bodies may be characterized by:
    - Elevated maximum and mean depths
    - Reduced surface water temperatures (<31°C) during summer months
  - May be a potential parameter for zebra mussel invasion risk assessment for southwestern water bodies
  - May be the basis for lack of successful zebra mussel invasion of Lake Lewisville even though it is receiving mussel larvae from the highly mussel infested Lake Ray Roberts 13.5 km upstream

Acknowledgements

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US Fish and Wildlife Service (USFWS)

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The many marina owners who allowed mussel veliger larvae sampling to be conducted and settlement monitors deployed at their facilities

Thanks For Your Attention