MISSOURI DEPARTMENT OF NATURAL RESOURCES

Ammonia criteria for aquatic life protection

Missouri Water Seminar
30 July 2024

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Ammonia criteria revisions

1999 EPA updated 304(a) criteria

- Missouri adopted in 2005

2003 USFWS requested EPA revise criteria based on new freshwater mussel data

– One of the most imperiled taxa in North America

2013 EPA updated 304(a) criteria

- added 52 species to acute dataset and six to chronic dataset
- included mollusks (16 mussel species and 2 gilled snails)

Mollusks sensitive to ammonia

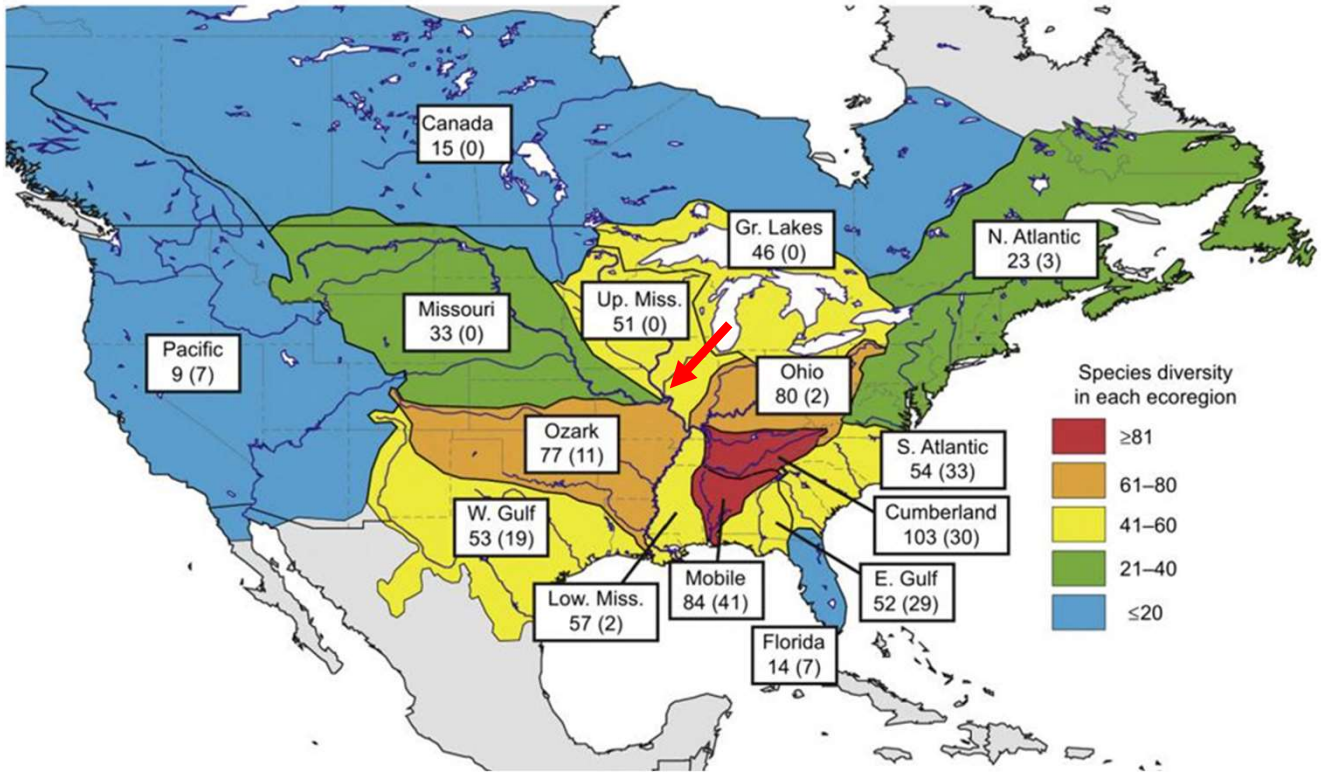
Photo by Ryan Hagerty via www.fws.gov/media/168736

- Freshwater mussels most sensitive genera in acute and chronic datasets
- Gilled snails and fingernail clams also sensitive
- 2013 criteria lower than 1999

https://goliadfarms.com/fingernail-clams-sphaerium-corneum/

https://mdc.mo.gov/discover-nature/field-guide/gilled-aquatic-snails-prosobranch-pond-snails

Mussel diversity by freshwater ecoregion

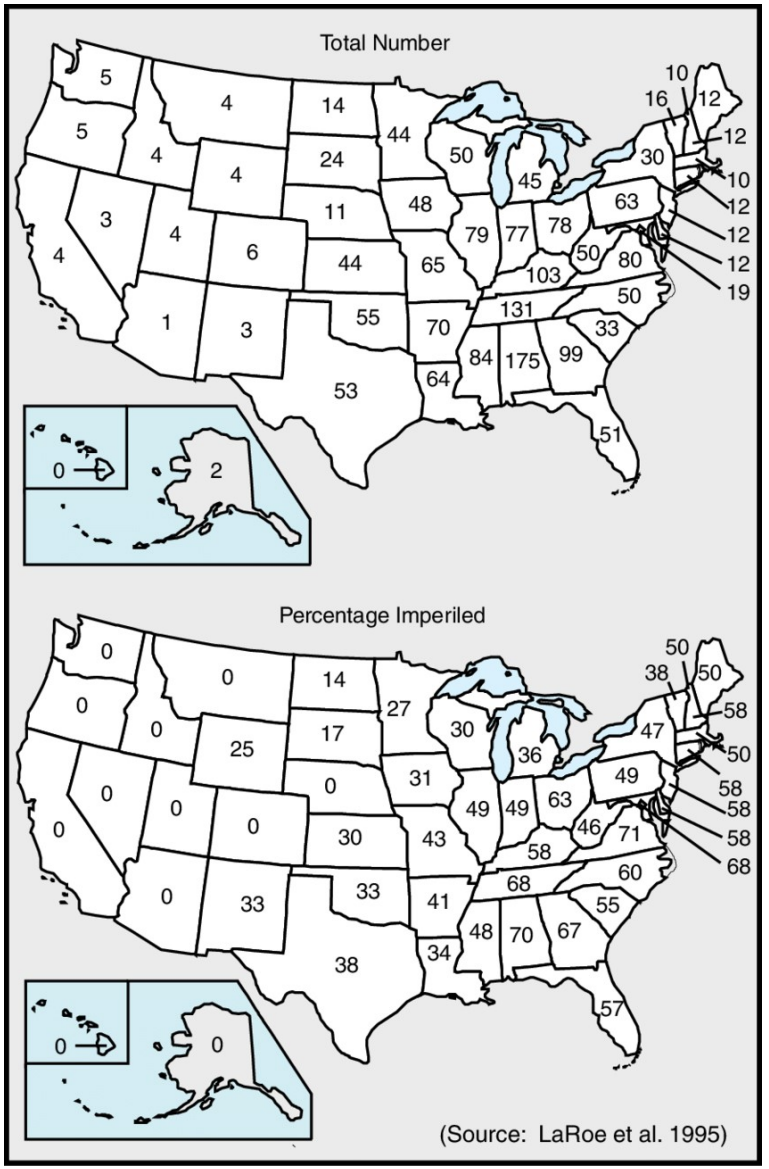


Mussel species diversity (and endemism) in North America

Map from Cummings, K.S. D.L. Graf. 2015 Mollusca: Bivalvia. [in] J.Thorp & D.C. Rogers (eds.). *Ecology and General Biology: Thorp & Covich's Freshwater Invertebrates*. Academic Press-Elsevier, New York. pp. 423-506.

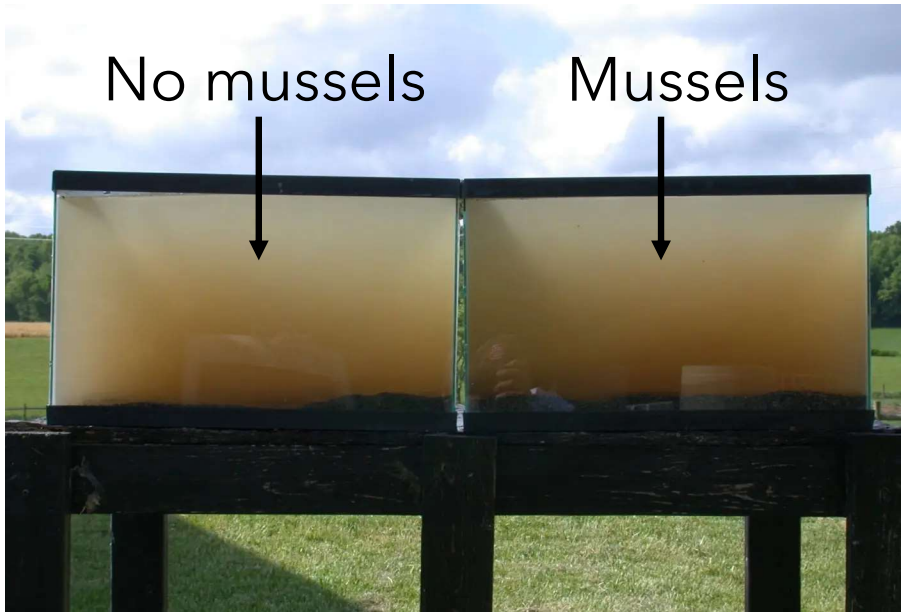
Mussels in the US

- Broadly distributed across US
- Greatest diversity in Southeast, and Mississippi and Ohio River drainages
- Highly imperiled
- Provide unique ecosystem services; ecosystem engineers

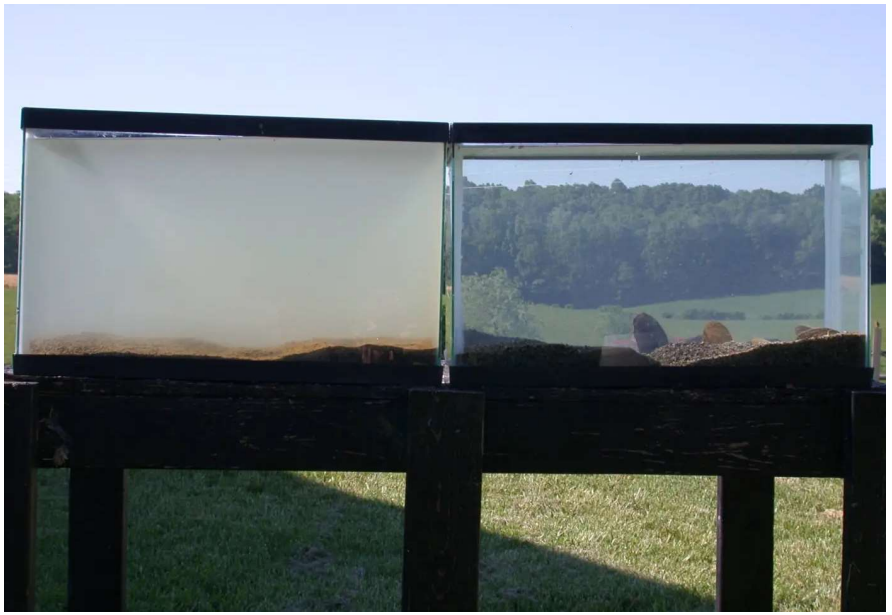


Liver of the river: nature's living water filters

Time = 0 hours



Time = 24 hours



Credit: Neves, Virgina Tech

- High diversity due to Missouri's many river systems (~70 species)
- Occur statewide in permanent bodies of water
- ~42% (29 species) are species of conservation concern
- Imperiled due to water quality degradation and habitat alteration

https://lscpagepro.mydigitalpublication.com/publication/?m=39199&i=409910&p=18&ver=html5

Recommended adoption approach

Phase 1: Adopt 2013 ammonia criteria statewide, except for Missouri and Mississippi Rivers

- Missouri and Mississippi Rivers are unique, highly modified systems
  - modified aquatic habitat use may be appropriate for some segments
  - requires additional consideration

Phase 2: Adopt 2013 ammonia criteria for appropriate segments of Missouri and Mississippi Rivers in subsequent rulemaking

Recommended adoption approach

Phase 1: Adopt 2013 ammonia criteria statewide, except for Missouri and Mississippi Rivers

- Current focus
- Focus on flexibilities for permittees

2013 ammonia criteria framework

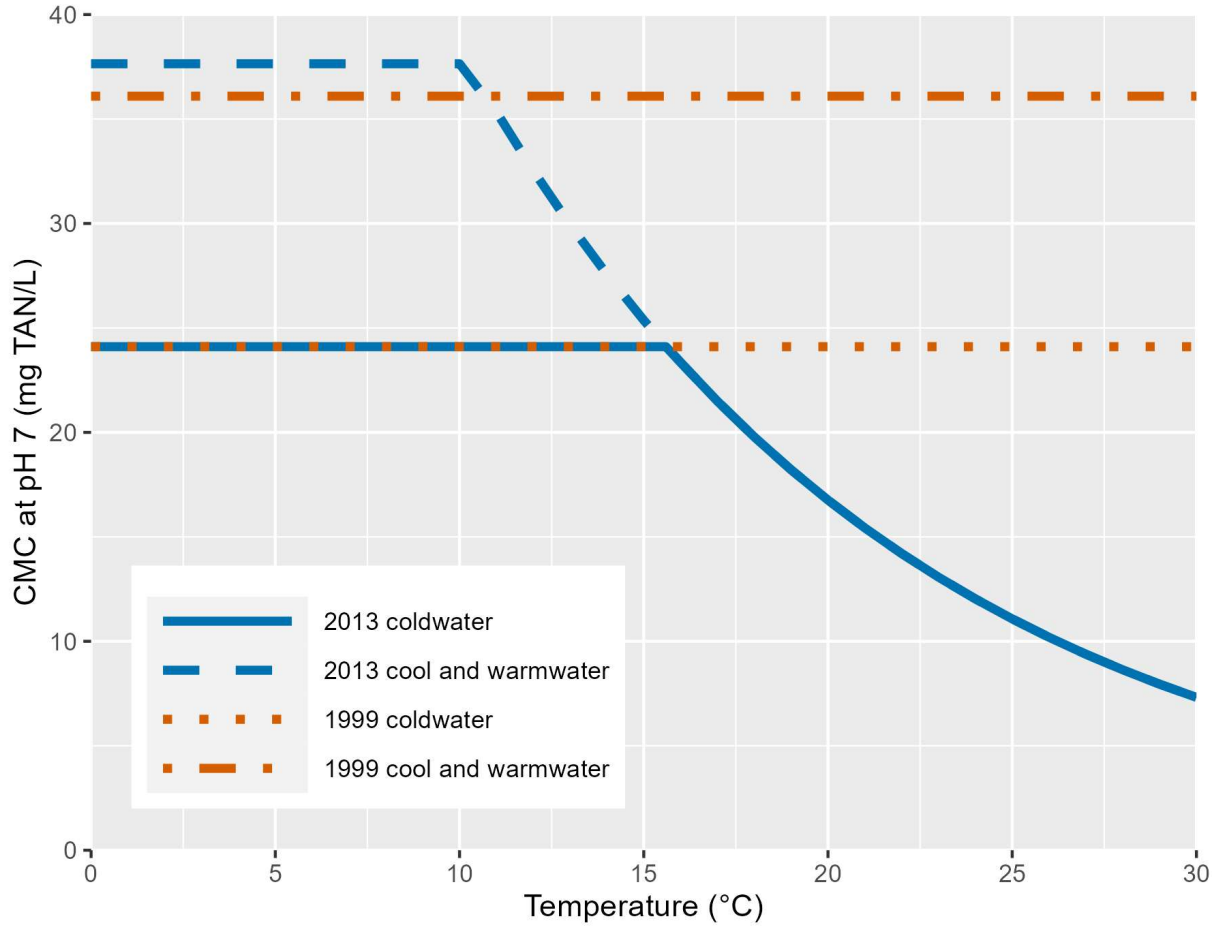
- As pH and temperature ↑, criterion ↓
  - both acute and chronic equations based on pH and temperature

- Two different equations and tables for acute criterion
  1. coldwater habitat (trout present)
  2. cool and warmwater habitat (trout absent)

- Single equation and table for chronic criterion

- Duration and exceedance frequency are the same as 1999

Acute criterion comparisons

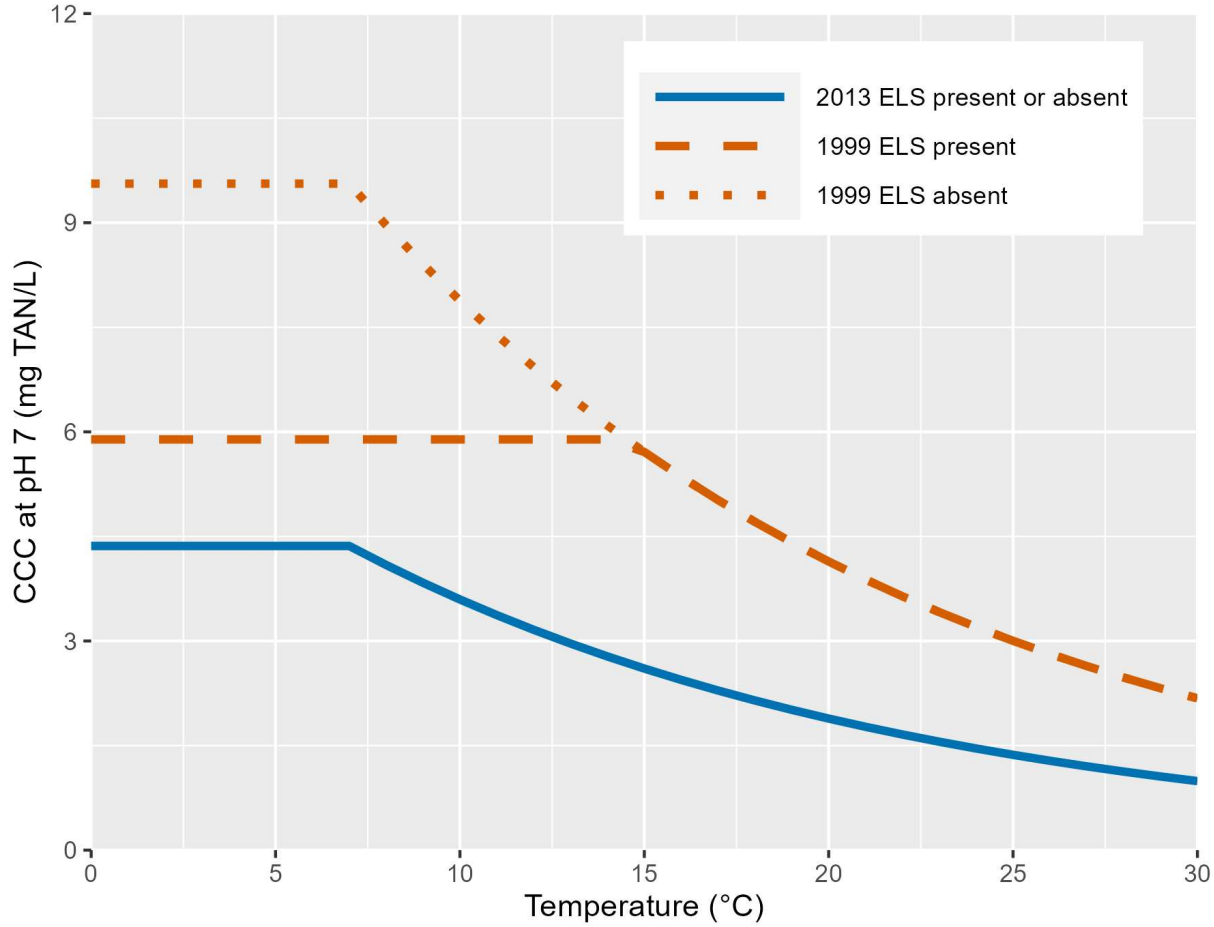


Acute criterion examples

Example criterion maximum concentrations (CMCs) for cool (CLH) and warmwater habitat (WWH)

pH and Temperature	1999 CMC	2013 CMC
pH 7.0 at 20°C	36.09	16.76
pH 7.8 at 25°C	12.14	3.72
pH 8.0 at 30°C	8.41	1.70

Chronic criterion comparisons



Chronic criterion examples

pH and Temperature	1999 CCC	2013 CCC
pH 7.0 at 20°C	4.140	1.887
pH 7.8 at 25°C	1.604	0.736
pH 8.0 at 30°C	0.895	0.408

Flexibilities

1. Option for mussels absent criteria where appropriate
   - Will require permittee to conduct study (protocol in development)

2. Staggered implementation schedule
   - Based on facility size
   - Smaller facilities get more time

3. Multiple discharger variance

4. Schedules of compliance

Photo credit: Chris Lukhaup
https://mdc.mo.gov/discover-nature/field-guide/gilled-aquatic-snails-prosobranch-pond-snails

https://molluskconservation.org/MC_GALLERY/Gallery1.html

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Questions

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Ammonia: Standards, *IMPLEMENTATION*, & Impacts

David Carani, HDR
Jay Hoskins, MSD

July 30, 2024

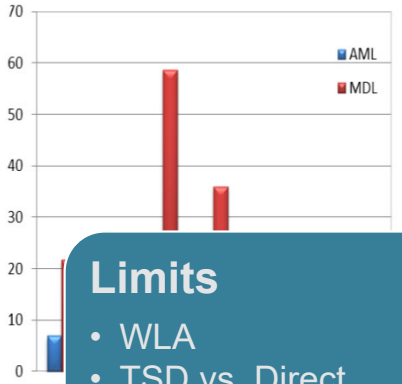
Factors driving ammonia limits

Criteria

- pH
- Temperature
- Mussels (present/absent)

WLA

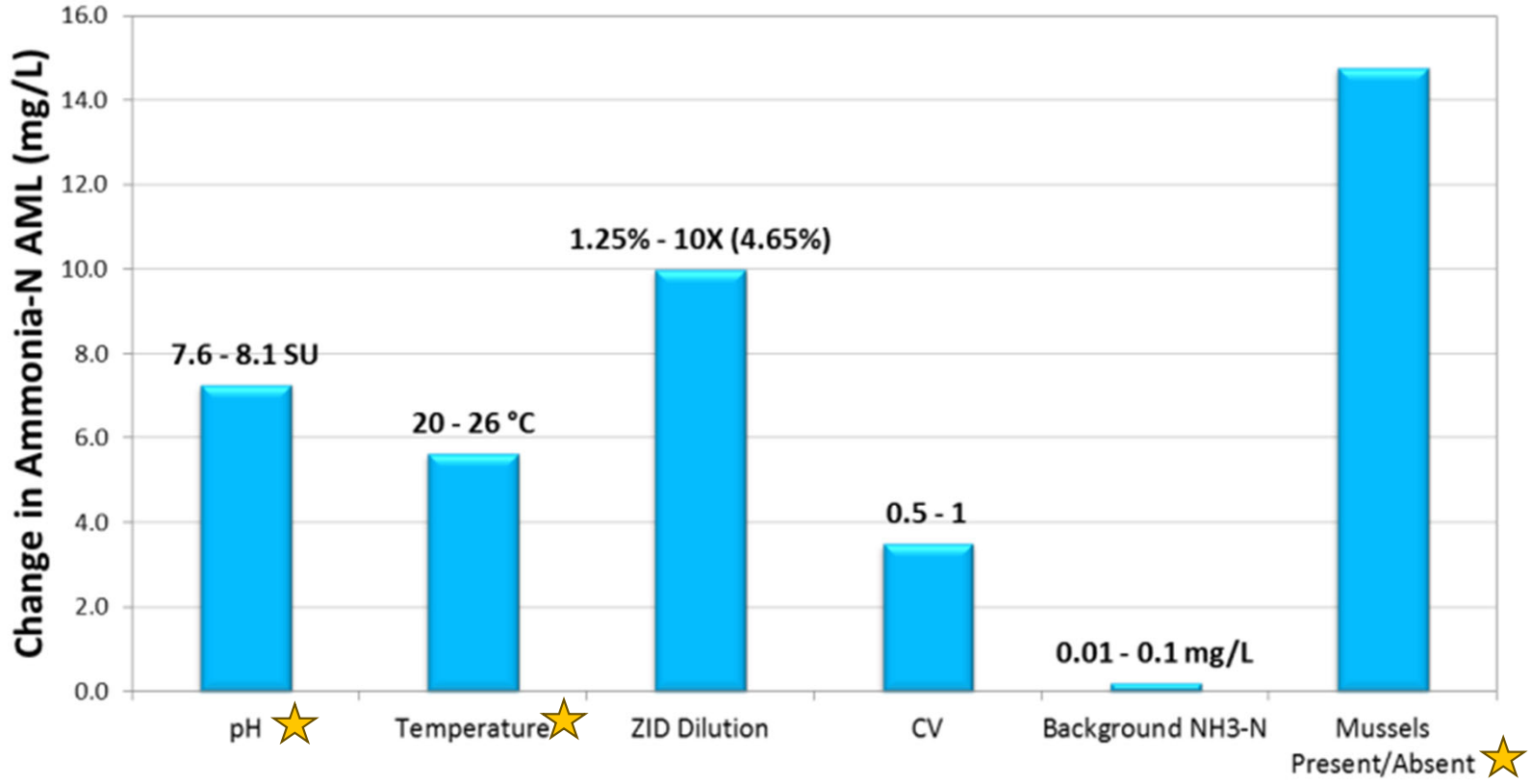
- Criteria
- Design Flow
- MZ Flow
- ZID Flow
- Background Concentration



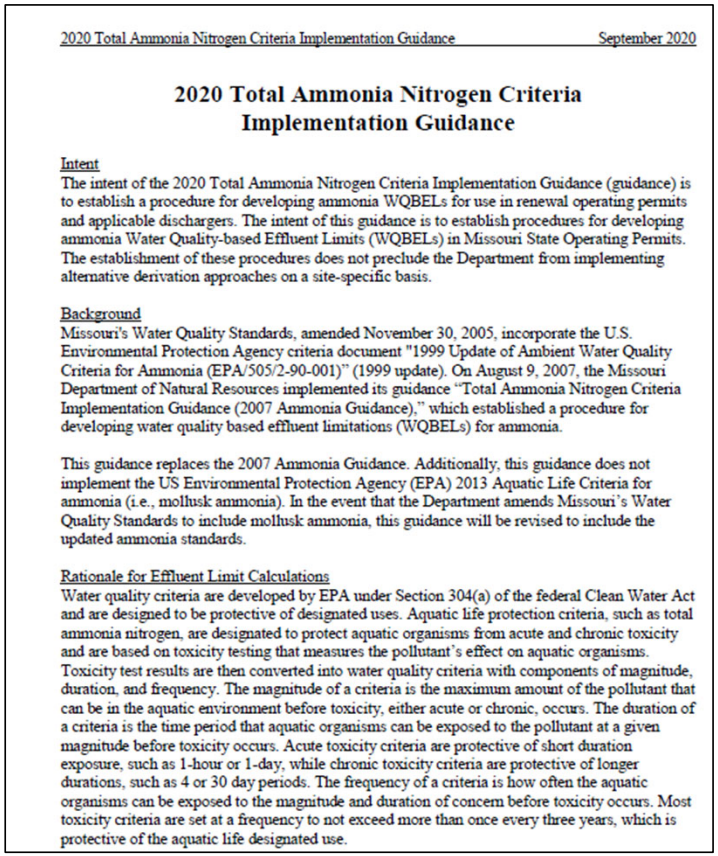
Limits

- WLA
- TSD vs. Direct Translation

Implementation policies will significantly impact effluent limits and compliance rates



MDNR's 2020 Implementation Guidance Document includes reasonable input assumptions



2020 Total Ammonia Nitrogen Criteria Implementation Guidance September 2020

2020 Total Ammonia Nitrogen Criteria Implementation Guidance

Intent

The intent of the 2020 Total Ammonia Nitrogen Criteria Implementation Guidance (guidance) is to establish a procedure for developing ammonia WQBELs for use in renewal operating permits and applicable dischargers. The intent of this guidance is to establish procedures for developing ammonia Water Quality-based Effluent Limits (WQBELs) in Missouri State Operating Permits. The establishment of these procedures does not preclude the Department from implementing alternative derivation approaches on a site-specific basis.

Background

Missouri's Water Quality Standards, amended November 30, 2005, incorporate the U.S. Environmental Protection Agency criteria document "1999 Update of Ambient Water Quality Criteria for Ammonia (EPA/505/2-90-001)" (1999 update). On August 9, 2007, the Missouri Department of Natural Resources implemented its guidance "Total Ammonia Nitrogen Criteria Implementation Guidance (2007 Ammonia Guidance)," which established a procedure for developing water quality based effluent limitations (WQBELs) for ammonia.

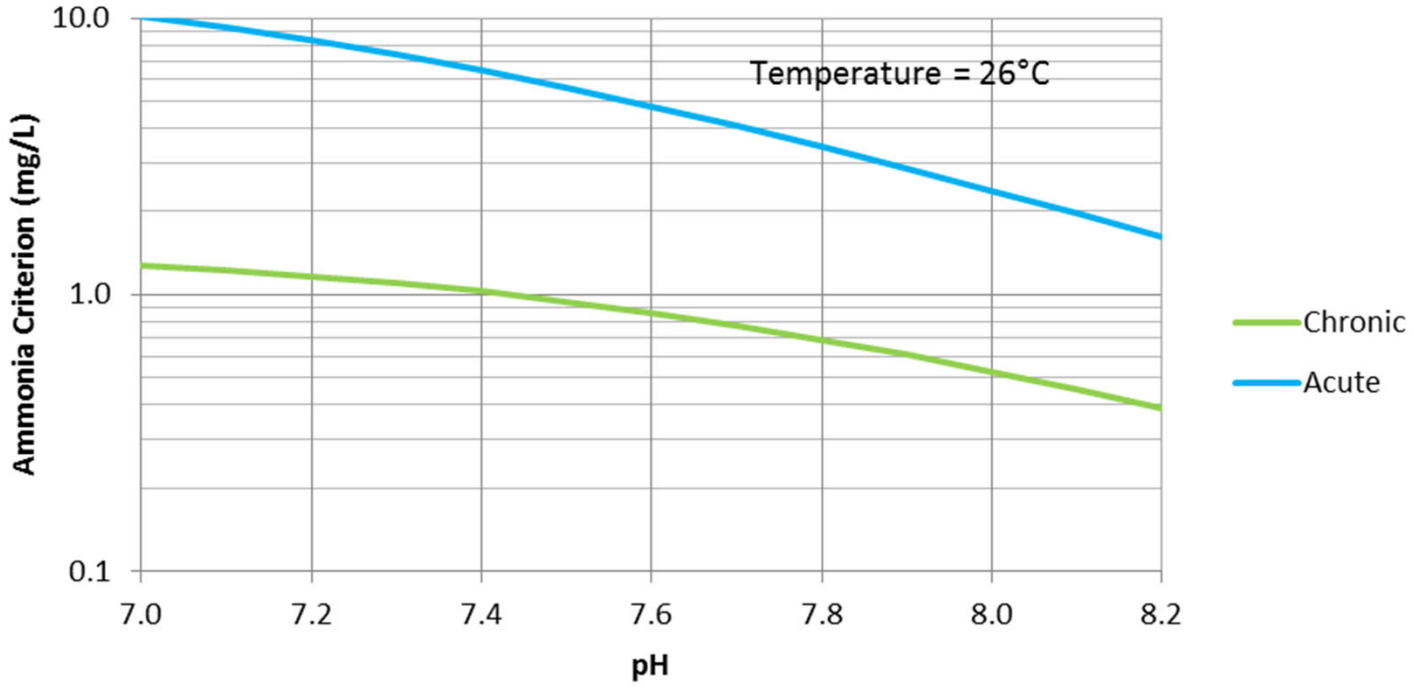
This guidance replaces the 2007 Ammonia Guidance. Additionally, this guidance does not implement the US Environmental Protection Agency (EPA) 2013 Aquatic Life Criteria for ammonia (i.e., mollusk ammonia). In the event that the Department amends Missouri's Water Quality Standards to include mollusk ammonia, this guidance will be revised to include the updated ammonia standards.

Rationale for Effluent Limit Calculations

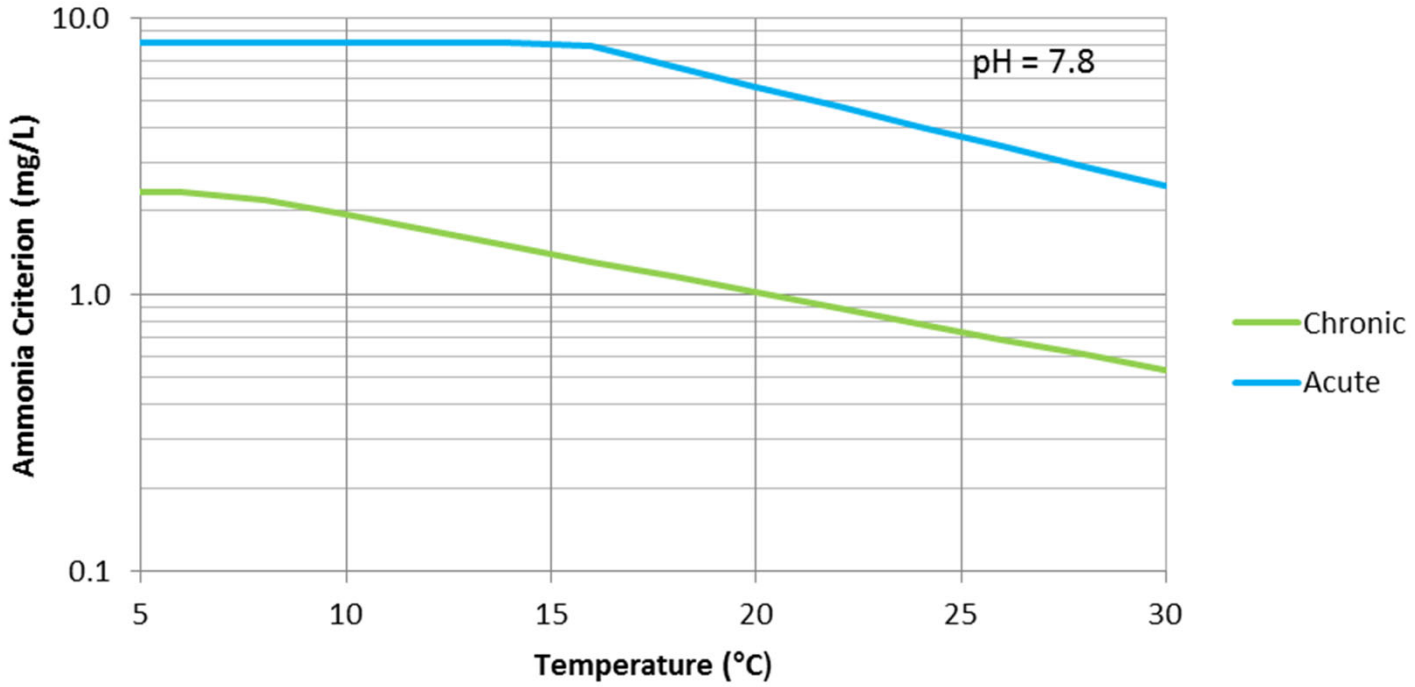
Water quality criteria are developed by EPA under Section 304(a) of the federal Clean Water Act and are designed to be protective of designated uses. Aquatic life protection criteria, such as total ammonia nitrogen, are designated to protect aquatic organisms from acute and chronic toxicity and are based on toxicity testing that measures the pollutant's effect on aquatic organisms. Toxicity test results are then converted into water quality criteria with components of magnitude, duration, and frequency. The magnitude of a criteria is the maximum amount of the pollutant that can be in the aquatic environment before toxicity, either acute or chronic, occurs. The duration of a criteria is the time period that aquatic organisms can be exposed to the pollutant at a given magnitude before toxicity occurs. Acute toxicity criteria are protective of short duration exposure, such as 1-hour or 1-day, while chronic toxicity criteria are protective of longer durations, such as 4 or 30 day periods. The frequency of a criteria is how often the aquatic organisms can be exposed to the magnitude and duration of concern before toxicity occurs. Most toxicity criteria are set at a frequency to not exceed more than once every three years, which is protective of the aquatic life designated use.

MDNR should retain these flexibilities in future revisions to the Permit Implementation Guidance (PIG)

pH impacts on Criteria



Temperature Impacts on Criteria



Water Quality Criteria: Temperature and pH Assumptions

- Site Specific (Receiving) Water Data
- Ecoregional (Default) Values
  - pH: 50th percentile (median)
  - Temperature: 75th percentile
  - Applied to both acute and chronic criteria
  - Monthly or quarterly values provided
- Comparison to other States
  - Virginia: 90th percentile temperature, 75th-90th percentile pH (depends on water)
  - Kansas: Average monthly temperature, median monthly pH or default=8
  - Nebraska:
    - Temp: 50th percentile (chronic), 90th percentile of effluent (acute)
    - pH: 50th percentile (chronic), 90th percentile of effluent (acute)

Seasonal, Quarterly, or Monthly Limits

- Water Temperature Affect on Treatment Operations
  - Lower temperatures → Slower Ammonia Removal
  - Slower Ammonia Removal → Higher Ammonia in Effluent
- Water Temperature Affect on Limits
  - Lower temperatures → Lower Ammonia Toxicity
  - Lower Ammonia Toxicity → Higher Ammonia Effluent Limits
- One-size fits all approach may not be best…
  - Take higher limits in winter months (when treatment is more difficult)
  - Trade off is lower limits in summer months (when treatment is more achievable)

Ammonia Concentrations in Municipal Wastewater: Example of Variability

Summer Data

Period of Record	2011-2015		2018-2023
Statistic	95th	Max	Max
Bissell	9.56	11.80	8.4
Lemay	10.60	16.80	10
Lower Meramec	4.50	15.70	6.6
Missouri R.	6.26	--	17.4
Coldwater	16.35	17.90	14
Grand Glaize	0.70	12.80	1.92

Winter Data

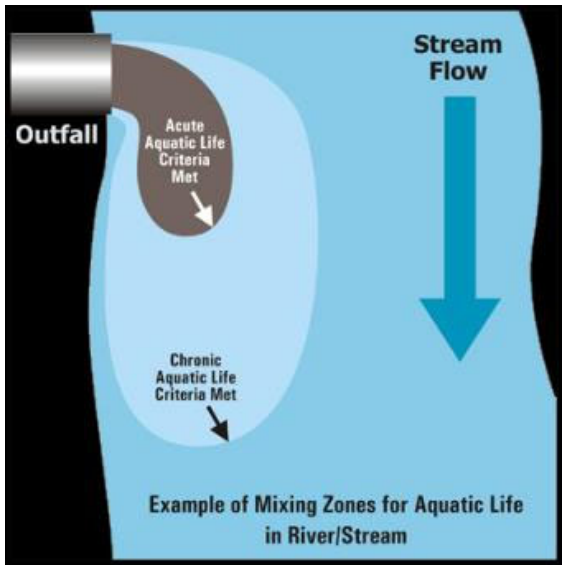
Period of Record	2011-2015		2018-2023
Statistic	95th	Max	Max
Bissell	11.80	15.10	7.8
Lemay	22.10	47.00	10.6
Lower Meramec	8.13	12.30	7.3
Missouri R.	10.69	--	20.2
Coldwater	17.40	20.20	16.2
Grand Glaize	0.18	4.90	1.18

Wasteload allocation and mixing flexibilities are equally critical to implementation

$$WLA = \frac{WQC\left(Q_{eff} + Q_{up}\right) - Q_{up}(WQ_{up})}{Q_{eff}}$$

Where:
WQC = water quality criterion
Q_{eff} = effluent design flow
Q_{up} = upstream flow available for mixing (i.e., mixing allowance)
WQ_{up} = background water quality

MDNR Default Mixing:
Mixing Zone = 25% of 30Q10
Zone of Initial Dilution = Max of 2.5% of 1Q10 or 10X DAF



Affordability Framework

- RSMO 644.145: Will require Affordability Finding to Implement 2013 Ammonia WQC, for POTWs
- DNR is not proposing to revise procedures/guidance used
- POTWs need to review and comment on the DNR's finding (permit fact sheet)
- Possible Regulatory Relief for POTWs
  - Extended Compliance Schedules
  - Variance (?)

WLA vs TSD Method

- Missouri's 2020 Ammonia Implementation Procedures
  - Acute WLA = Max Daily Limit
  - Chronic WLA = Average Monthly Limit
- EPA's 1991 Technical Support Document (TSD)
  - WLA converted to limits based on coefficient of variation (CV)
  - LTAa vs LTAc
- TSD method results in more stringent monthly average and daily max limits fi chronic limited

Chronic
(4-day average)

$LTA_c = WLA_c \bullet e^{[0.5\ \sigma_4^2 - z\ \sigma_4]}$

where $\sigma_4^2 = ln[CV^2/4 + 1]$,
z = 1.645 for 95th percentile occurrence probability, and
z = 2.326 for 99th percentile occurrence probability

CV	WLA Multipliers $e^{[0.5\ \sigma_4^2 - z\ \sigma_4]}$	
	95th Percentile	99th Percentile
0.1	0.922	0.891
0.2	0.853	0.797
0.3	0.791	0.715
0.4	0.736	0.643
0.5	0.687	0.581
0.6	0.644	0.527
0.7	0.606	0.481
0.8	0.571	0.440
0.9	0.541	0.404
1.0	0.514	0.373
1.1	0.490	0.345
1.2	0.468	0.321
1.3	0.449	0.300
1.4	0.432	0.281
1.5	0.417	0.264
1.6	0.403	0.249
1.7	0.390	0.236
1.8	0.379	0.224
1.9	0.369	0.214
2.0	0.360	0.204

Average Monthly Limit

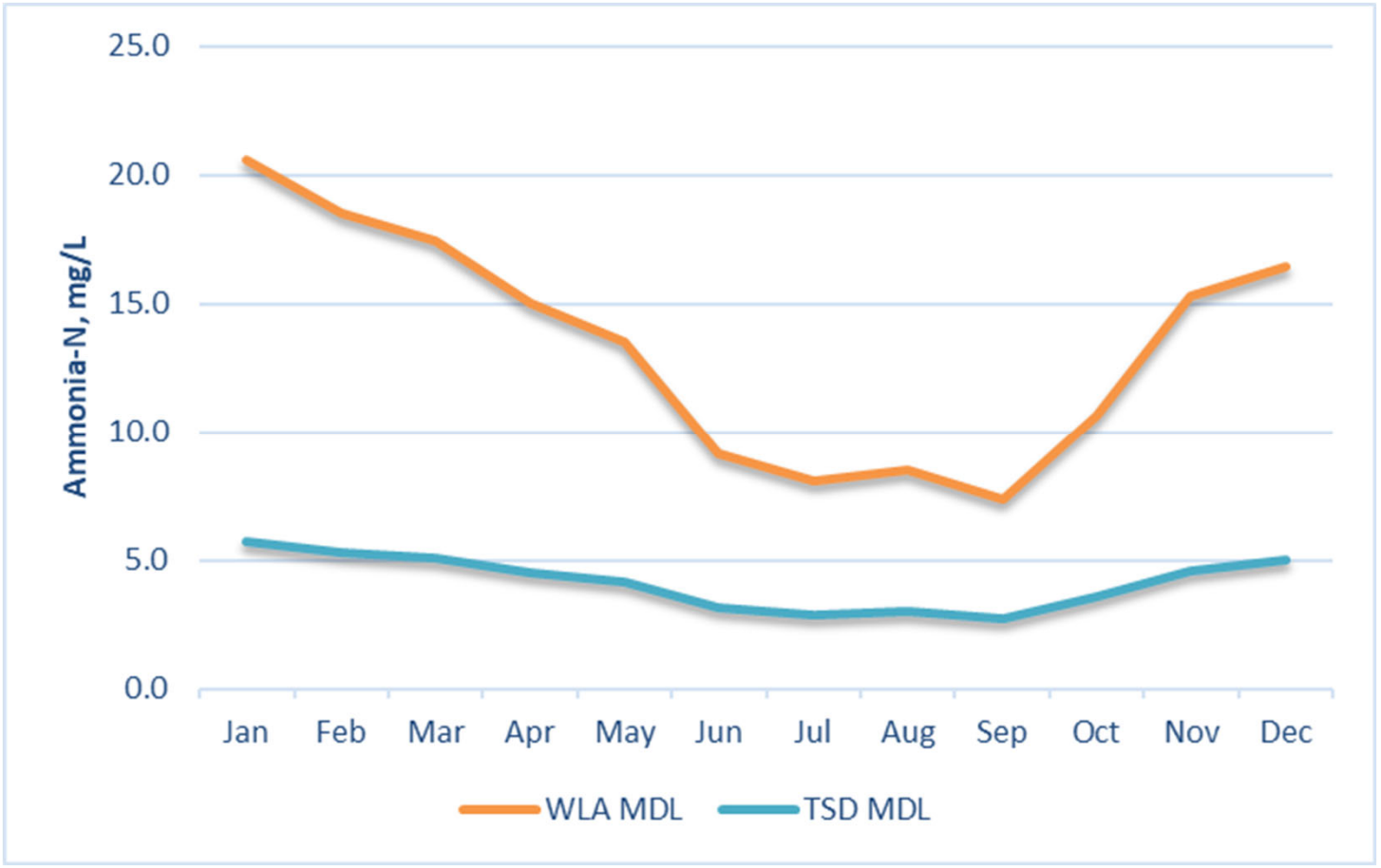
$AML = LTA \bullet e^{[z\ \sigma_n - 0.5\ \sigma_n^2]}$

where $\sigma_n^2 = ln[CV^2/n + 1]$,
z = 1.645 for 95th percentile,
z = 2.326 for 99th percentile, and
n = number of samples/month

CV	LTA Multipliers $e^{[z\ \sigma_n - 0.5\ \sigma_n^2]}$									
	95th Percentile					99th Percentile				
	n=1	n=2	n=4	n=10	n=30	n=1	n=2	n=4	n=10	n=30
0.1	1.17	1.12	1.08	1.06	1.03	1.25	1.18	1.12	1.08	1.04
0.2	1.36	1.25	1.17	1.12	1.06	1.55	1.37	1.25	1.16	1.09
0.3	1.55	1.38	1.26	1.18	1.09	1.90	1.59	1.40	1.24	1.13
0.4	1.75	1.52	1.36	1.25	1.12	2.27	1.83	1.55	1.33	1.18
0.5	1.95	1.66	1.45	1.31	1.16	2.68	2.09	1.72	1.42	1.23
0.6	2.13	1.80	1.55	1.38	1.19	3.11	2.37	1.90	1.52	1.26
0.7	2.31	1.94	1.65	1.45	1.22	3.56	2.66	2.08	1.62	1.33
0.8	2.48	2.07	1.75	1.52	1.26	4.01	2.96	2.27	1.73	1.39
0.9	2.64	2.20	1.85	1.59	1.29	4.46	3.28	2.48	1.84	1.44
1.0	2.78	2.33	1.95	1.66	1.33	4.90	3.59	2.68	1.96	1.50
1.1	2.91	2.45	2.04	1.73	1.36	5.34	3.91	2.90	2.07	1.56
1.2	3.03	2.56	2.13	1.80	1.39	5.76	4.23	3.11	2.19	1.62
1.3	3.13	2.67	2.23	1.87	1.43	6.17	4.55	3.34	2.32	1.68
1.4	3.23	2.77	2.31	1.94	1.47	6.56	4.86	3.56	2.45	1.74
1.5	3.31	2.86	2.40	2.00	1.50	6.93	5.17	3.78	2.58	1.80
1.6	3.38	2.95	2.48	2.07	1.54	7.29	5.47	4.01	2.71	1.87
1.7	3.45	3.03	2.56	2.14	1.57	7.63	5.77	4.23	2.84	1.93
1.8	3.51	3.10	2.64	2.20	1.61	7.95	6.06	4.46	2.98	2.00
1.9	3.56	3.17	2.71	2.27	1.64	8.26	6.34	4.68	3.12	2.07
2.0	3.60	3.23	2.78	2.33	1.68	8.55	6.61	4.90	3.26	2.14

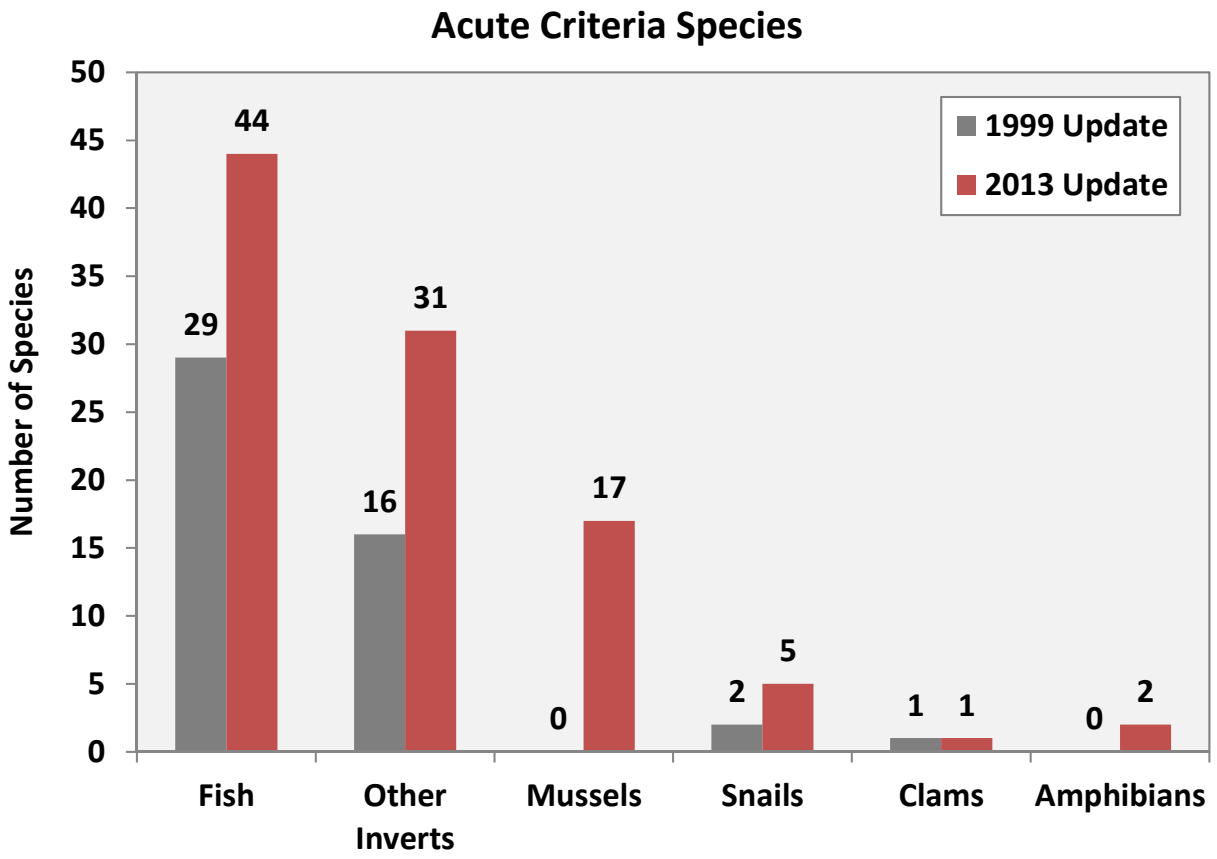
EPA's 1991 Technical Support Document for Water Quality-based Toxics Control

WLA vs TSD Ammonia Limits with New Criteria



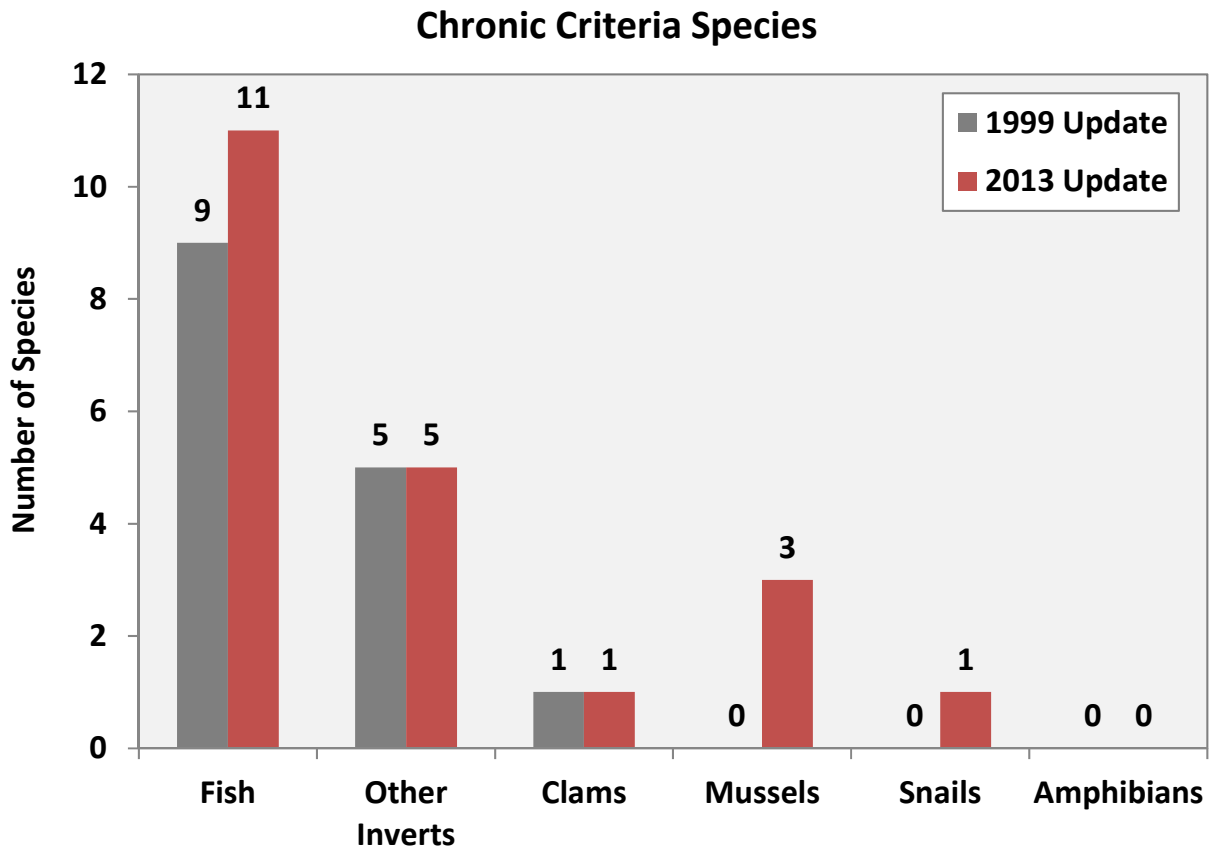
1999 vs. 2013 Criteria Update

Acute Criteria Species Comparison



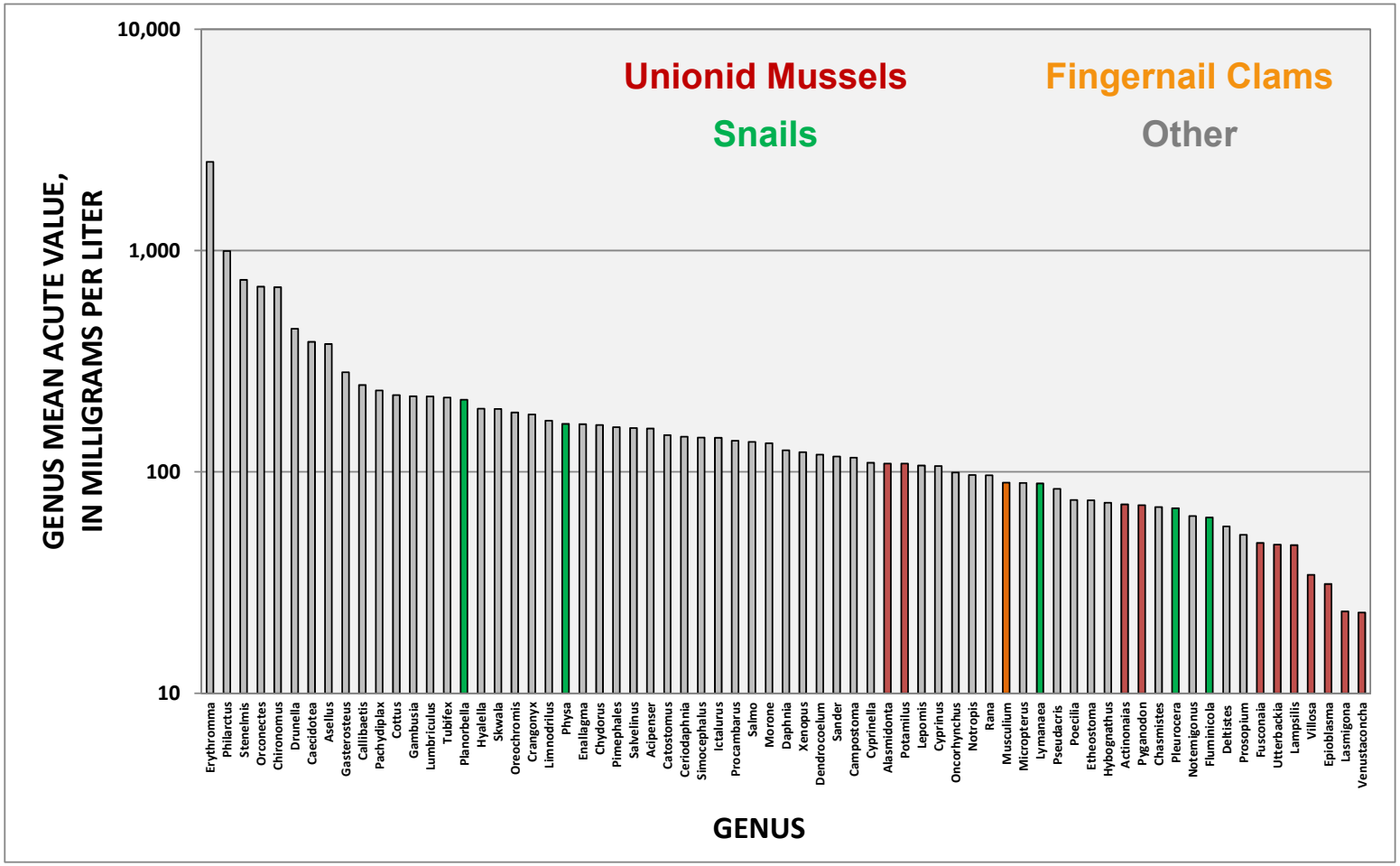
1999 vs. 2013 Criteria Update

Chronic Criteria Species Comparison



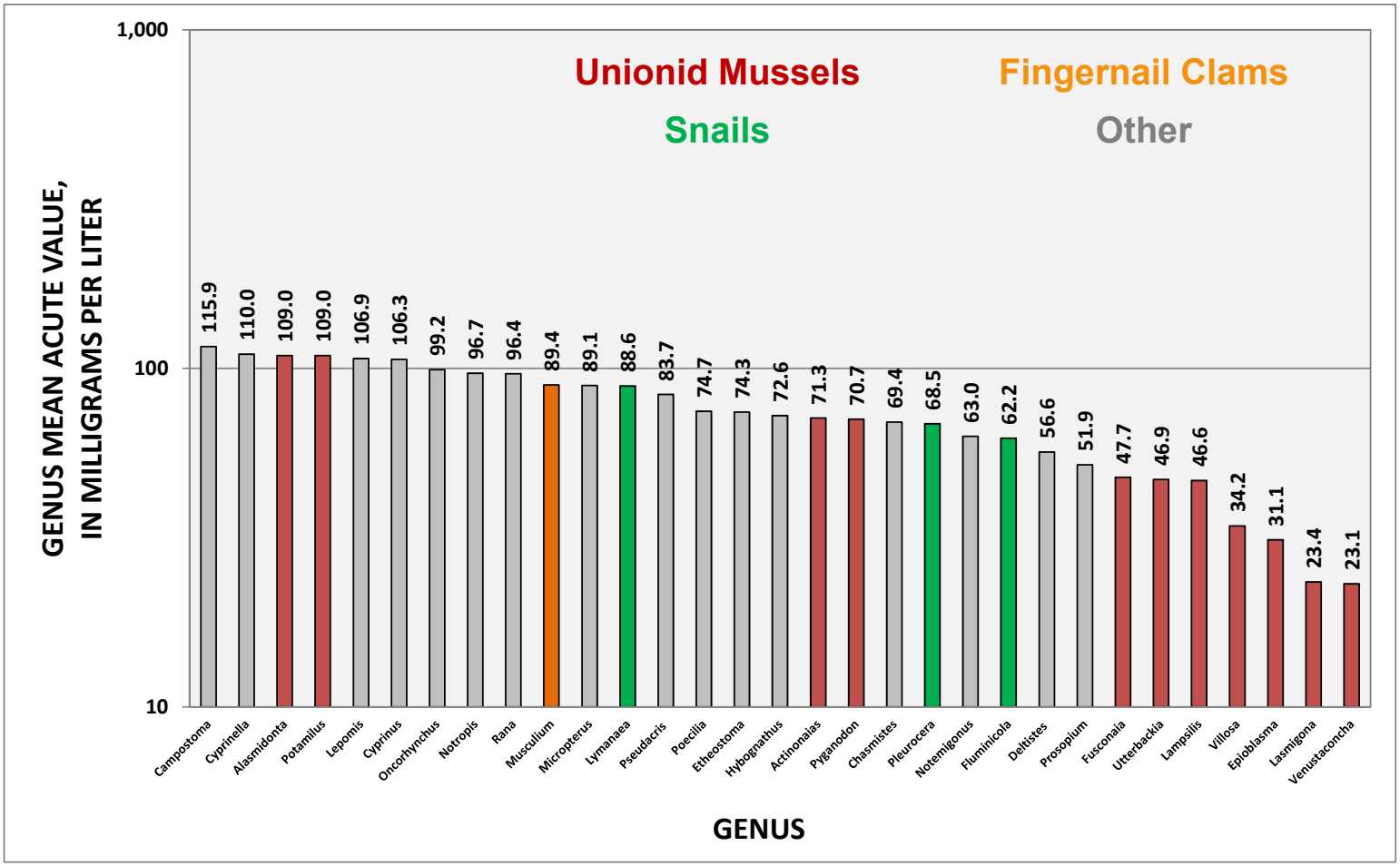
Species Sensitivity Distribution

Acute Ammonia Toxicity



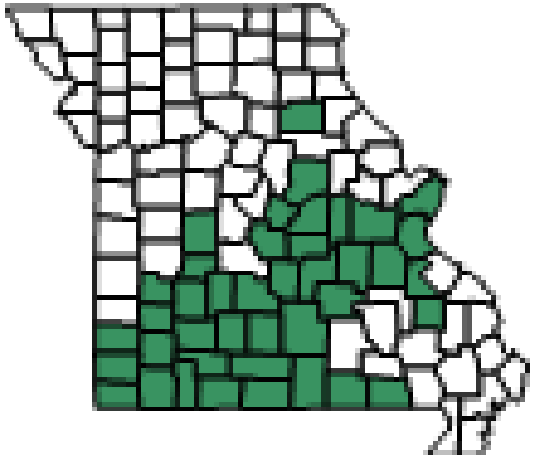
Species Sensitivity Distribution

Acute Ammonia Toxicity

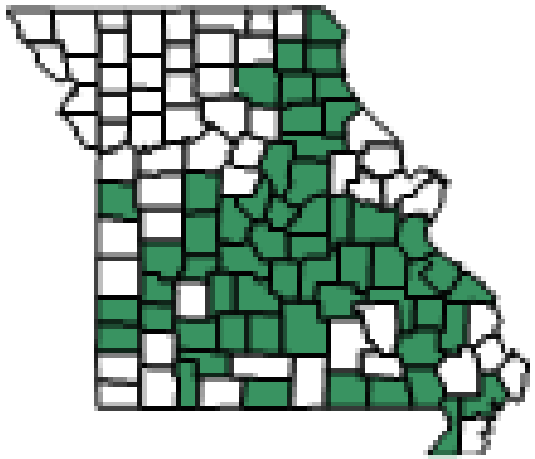


What does mussels “absent” even mean?

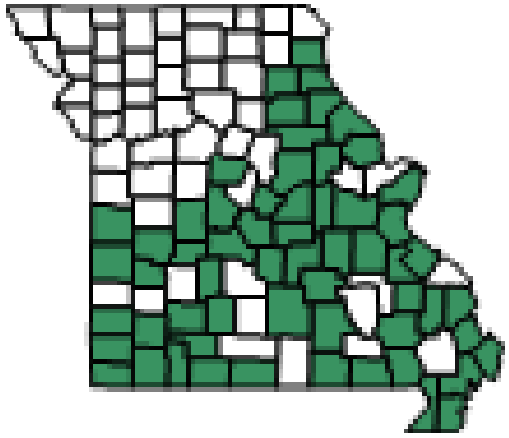
Ellipse and Bleedingtooth
Venustaconcha ellipsiformis and V. pleasii



Fatmucket
Lampsilis siliquoidea



Plain Pocketbook
Lampsilis cardium



Species Recalculation Procedure to demonstrate mussels are absent or present

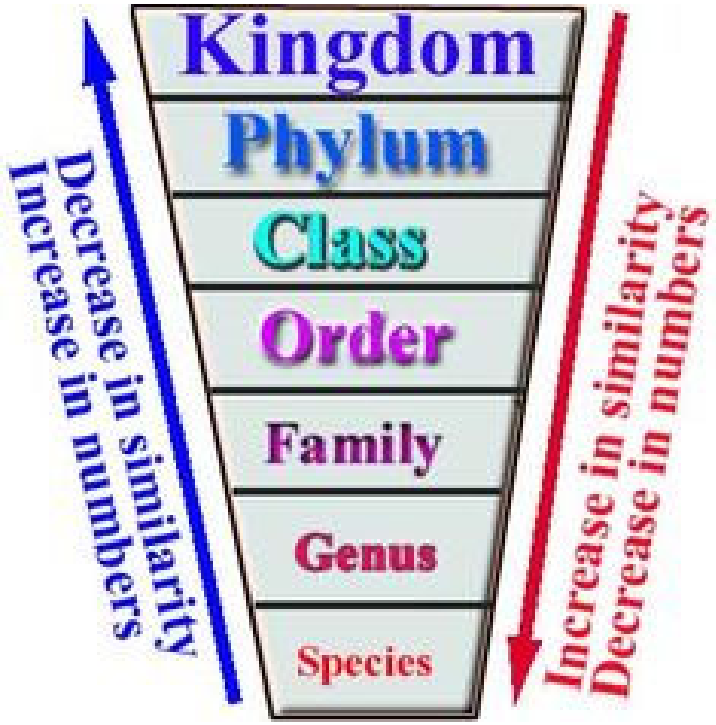
What are resident species?

- Usually present at the site
- Are only present intermittently or seasonally
- Were present historically, are not currently due to degraded conditions, and would return if conditions improved
- Are present in nearby bodies of water, are not currently due to degraded conditions, and would return if conditions improved
- Does not include those that were present historically but cannot exist due to permanent alterations at the site

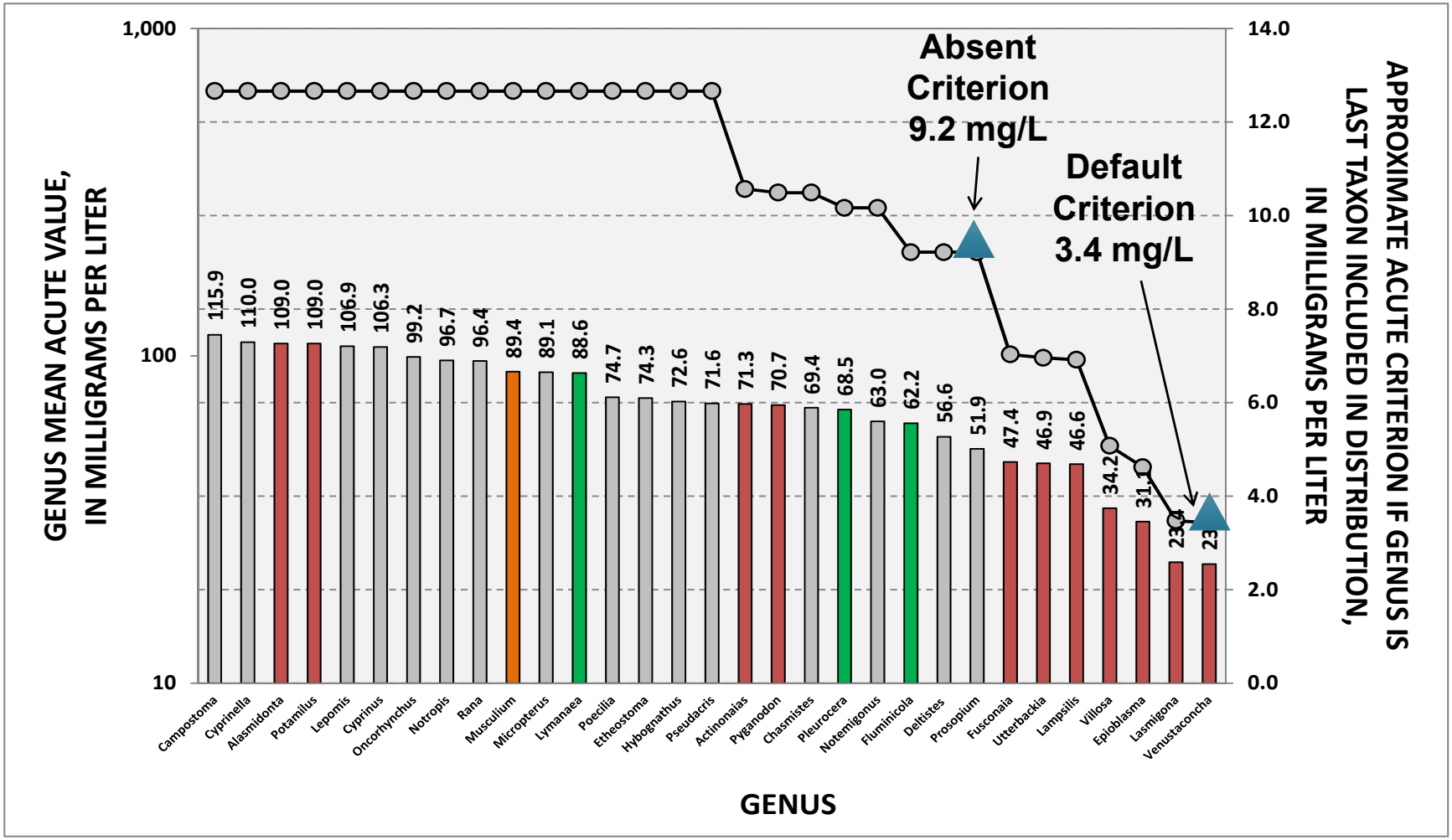
King Philip Came Over for Good Soup!

Species deletion process

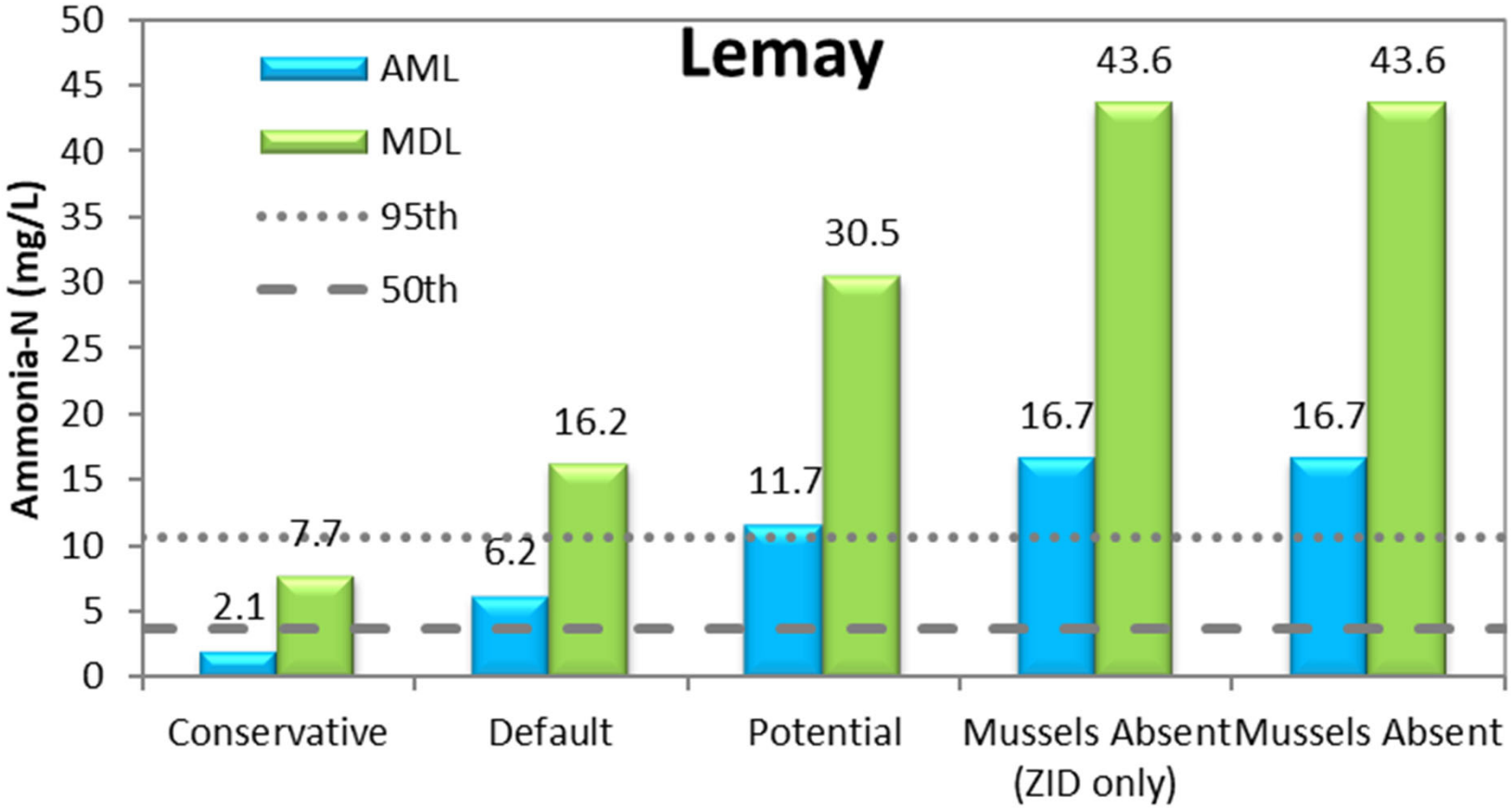
- Based on taxonomy
- Intended to ensure that each species, genus, family, etc. that occurs at the site is either
  - INCLUDED in the toxicity dataset, or
  - REPRESENTED by taxa in the toxicity dataset



Acute summer criterion recalculation

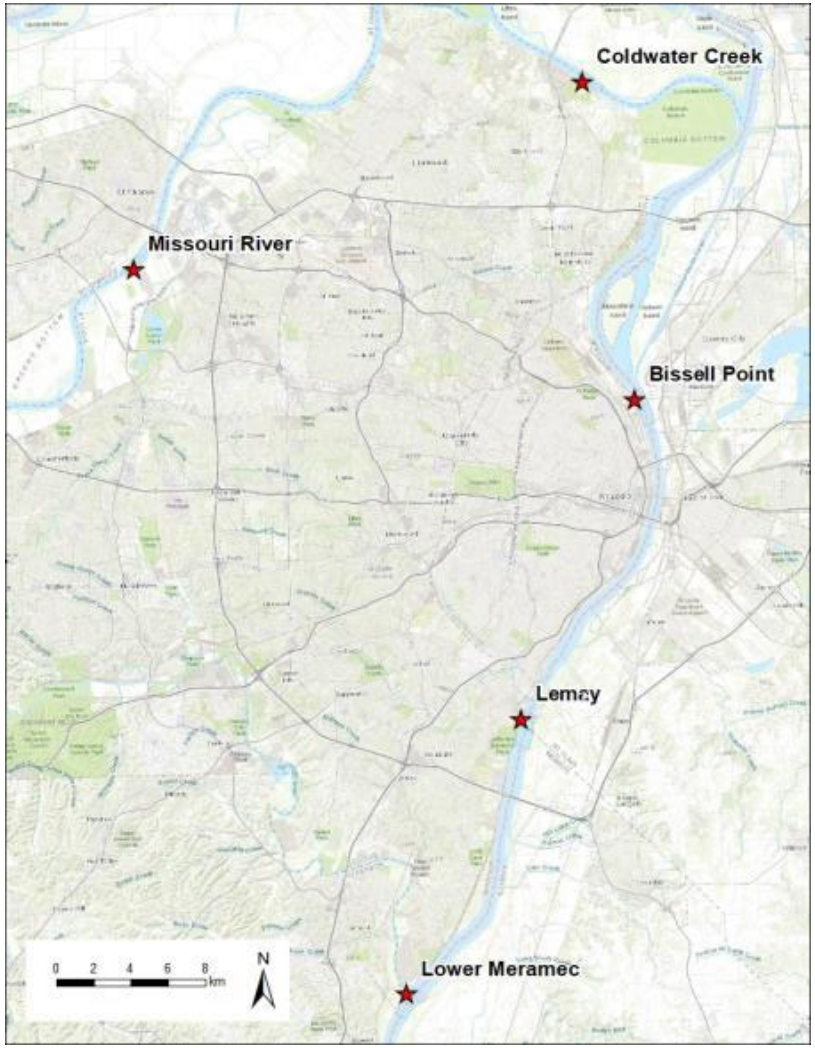


Compounding permit assumptions result in wide range of potential limits

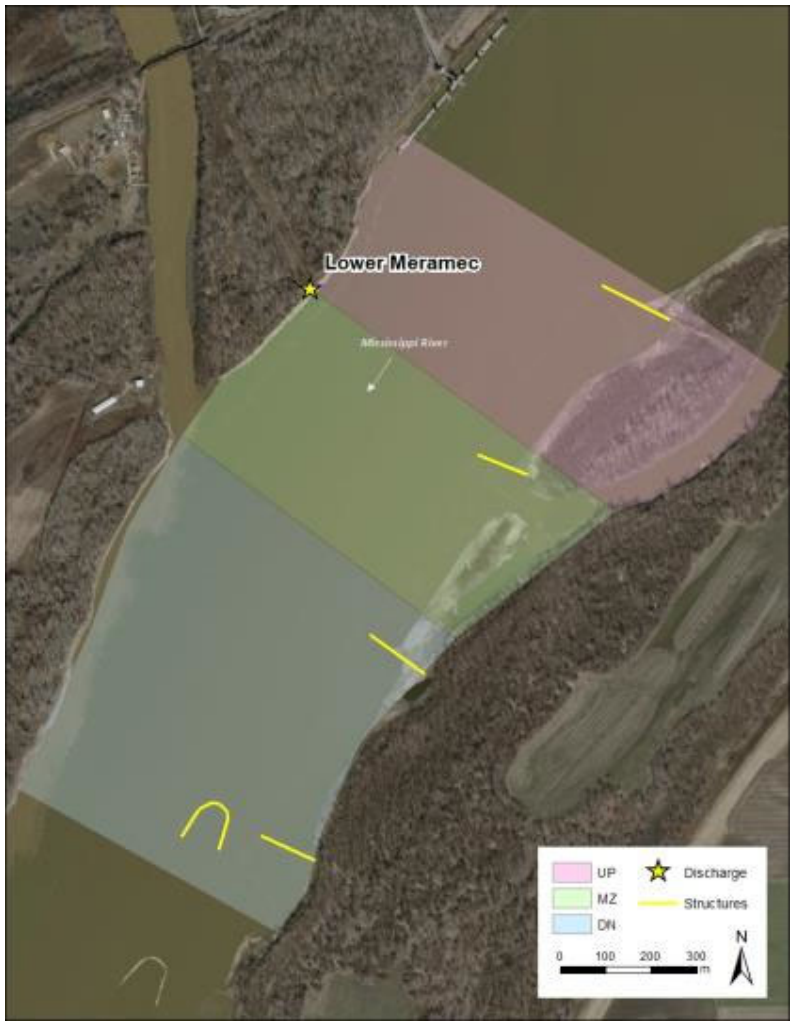


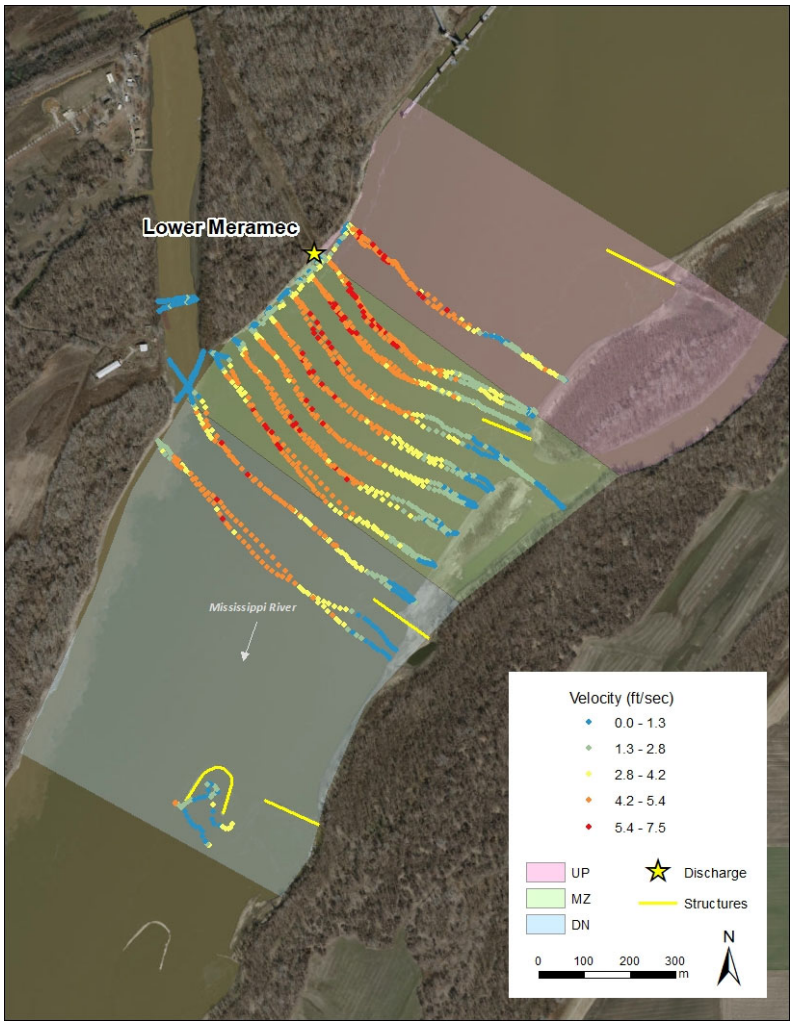
Big River Study Objectives

- MSD undertaking long-term effort to manage discharge of nutrients and ammonia
- Middle Mississippi River and Missouri River generally poor habitat for mollusks
- Do mussels and snails occur near MSD discharges?



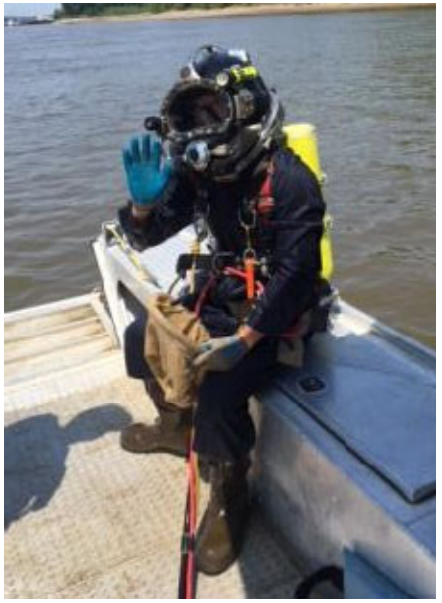
Methods


Lower Meramec
Mississippi River
UP
MZ
DN
Discharge
Structures
0 100 200 300
m
N


Lower Meramec
Mississippi River
Velocity (ft/sec)
0.0 - 1.3
1.3 - 2.8
2.8 - 4.2
4.2 - 5.4
5.4 - 7.5
UP
MZ
DN
Discharge
Structures
0 100 200 300
m
N

Methods

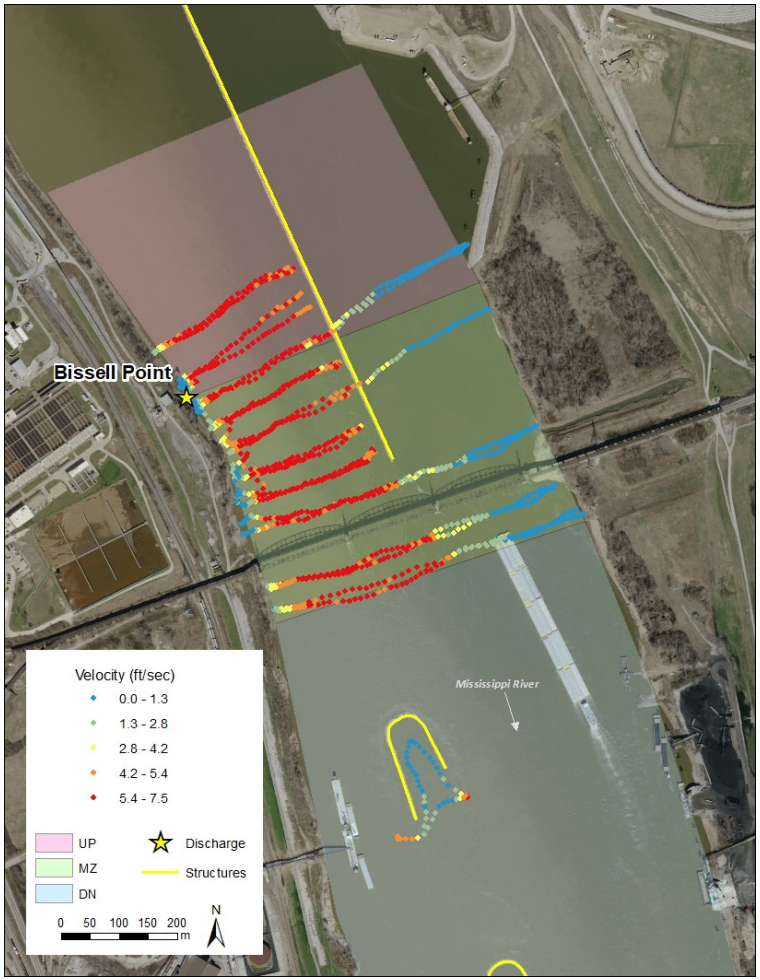
- Qualitative searches
  - 10-min increments
  - Collect all live/dead mollusks encountered by hand
  - Depth and substrate composition
  - 550 – 820 min (9 – 13 hr) per site
- Quantitative samples
  - Added to increase likelihood of collecting snails, if present
  - Excavate all substrate within 0.25 m^2 quadrat frame
  - Depth and substrate composition
  - 15 – 20 samples per site

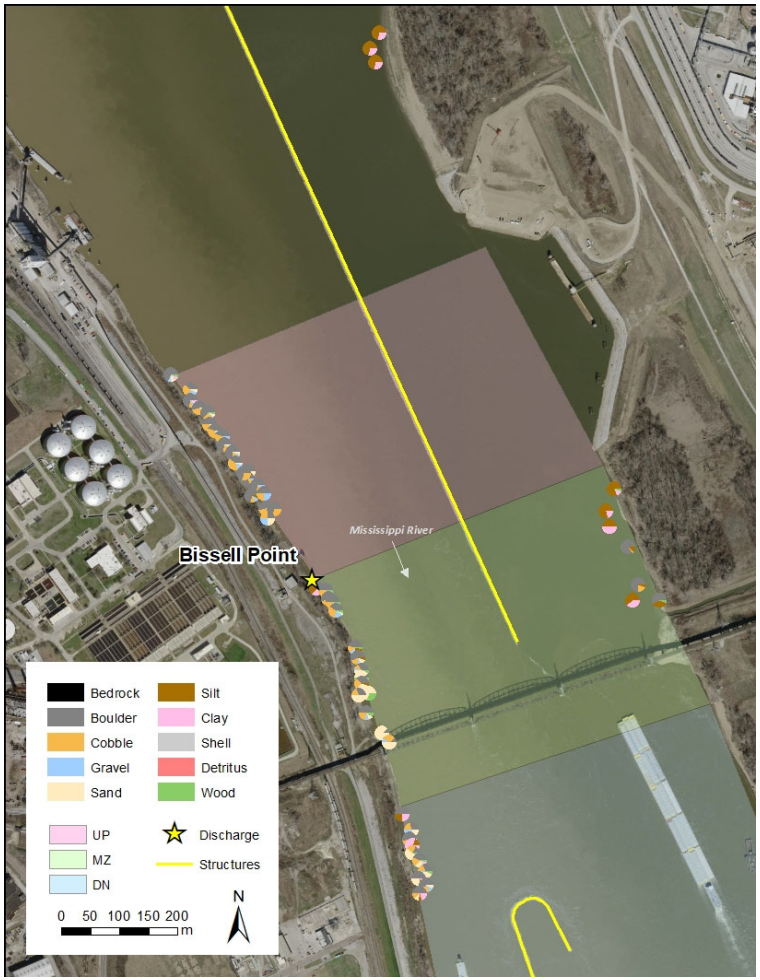


Methods

- Focus on areas with best habitat
  - Lower depth/velocity
  - Adjacent to banks (particularly protected areas)
  - Within dike fields; adjacent to/behind/downstream of dikes
  - Side channels (Lower Meramec site)

Results: Bissell Point





Results: Bissell Point

- RDB - Missouri
  - Riprap along most of bank
  - Swift current
  - UP primarily boulder, some cobble/gravel/sand
  - MZ and DN boulder near bank, some sand/silt/clay
- LDB - Illinois
  - MZ and UP behind parallel dike; mostly silt/clay (Chain of Rocks Canal)
  - DN not searched (storms); previous survey (2013) found mostly sand

Results: Bissell Point

- Mussels
  - 22 live individuals, 5 species on LDB
    - *Quadrula quadrula, Lampsilis teres, Obliquaria reflexa, P. ohiensis, Lasmigona complanata*
    - Silt/clay substrate
  - 1 dead *L. fragilis* on RDB
- Snails
  - Dead *Pleurocera acuta* shells on RDB

Discussion

- Low mollusk abundance at all sites
- Suitable habitat is limited
  - Many mussels in silt/clay – small pockets detected by depth/flow patterns
  - Coarse substrate in high velocity areas – nowhere to burrow
  - Loose sand in lower velocity areas – not stable
- Generally – if mussels were present, they were present throughout areas (i.e. they do not appear to be absent from mixing zone at current ammonia levels)

Thank you