Methods to Assess and Monitor Native Mussel Communities in the Upper Mississippi River

Heidi Dunn, Steve Zigler, Teresa Newton, and Jon Duyvejonck

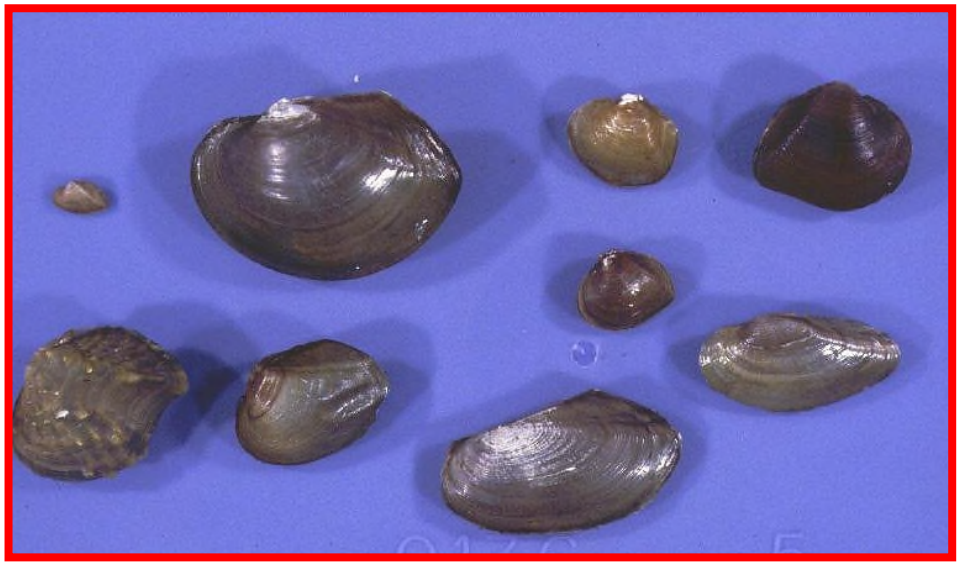
Environmental Management Program

Restoring & Monitoring ON THE UPPER MISSISSIPPI RIVER SYSTEM

U.S. Department of the Interior
U.S. Geological Survey

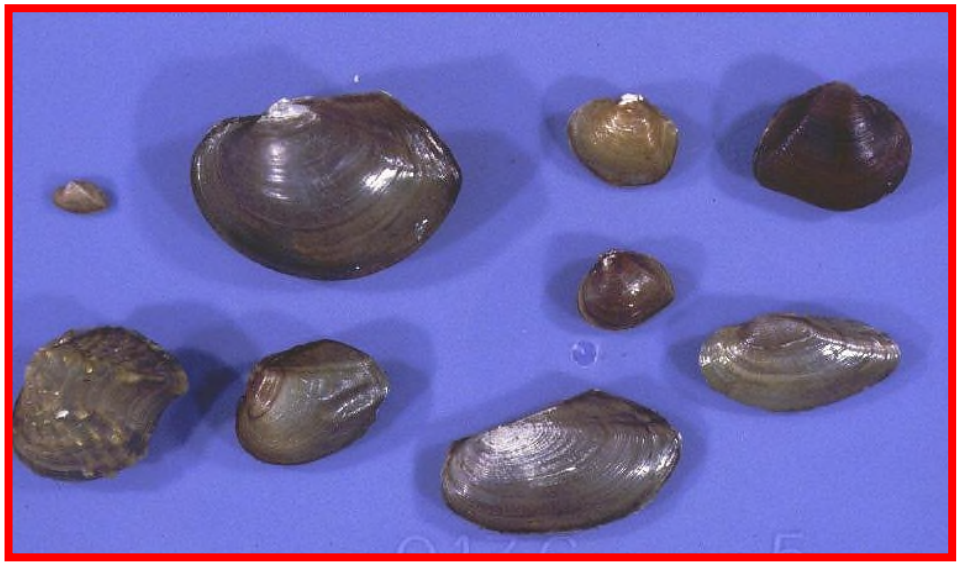
“Freshwater mussels are good indicators of water quality” but…

- Lack of tolerance data
- Tolerance differs between adults and juveniles
- Behavioral responses to disturbance varies with tribe
- Tolerance/behavior of fish host
- Lack of data on factors controlling population processes

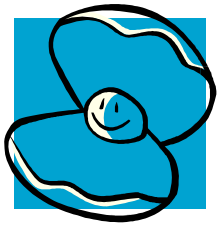


Challenges

- What is a healthy mussel community?
- How do we sample it, measure it, and compare it?
- Managers need a quantitative means of collecting, monitoring, and evaluating the relative health or value of mussel assemblages
- Need to identify and preserve mussel resources, assess impacts, and assess the success of restoration techniques



Approach



- Sequential approach
  - *Develop a series of metrics that represent community dynamics or "health"*
  - Develop a broader framework for monitoring mussels in the Upper Mississippi River System (UMRS)
- Objectives
  - *Develop and test a quantitative community assessment tool (MCAT) for native mussels that can be used to assess the health of mussel communities in the UMRS*
  - Develop and test sampling protocols that can be used by the Long Term Resource Monitoring Program (LTRMP) and others

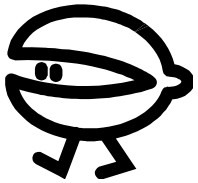
Phases of Research

- Phase I. *Gather data and explore metrics to assess mussel community health (funded by USACE)*
- Phase II. Conduct full analyses of selected metrics
- Phase III. Develop potential sampling and monitoring protocols for LTRMP
- Phase IV. Field test selected protocols

Phase I

- Use existing quantitative mussel data in the UMR to explore a series of metrics to assess mussel community health
- Evaluate both a multi-metric index and a series of statistically derived curves that plot the frequency distribution of various mussel metrics

Phase I Tasks



1. Gather existing data and re-format to a common dataset
2. Develop criteria for inclusion of specific datasets
3. Calculate a suite of potentially useful metrics
4. Conduct exploratory analyses (e.g., generate preliminary frequency curves, explore potential for an index value, and identify redundancy)
5. Determine data gaps
6. Determine a suitable approach for Phase II comprising detailed analyses to develop and validate an appropriate assessment tool

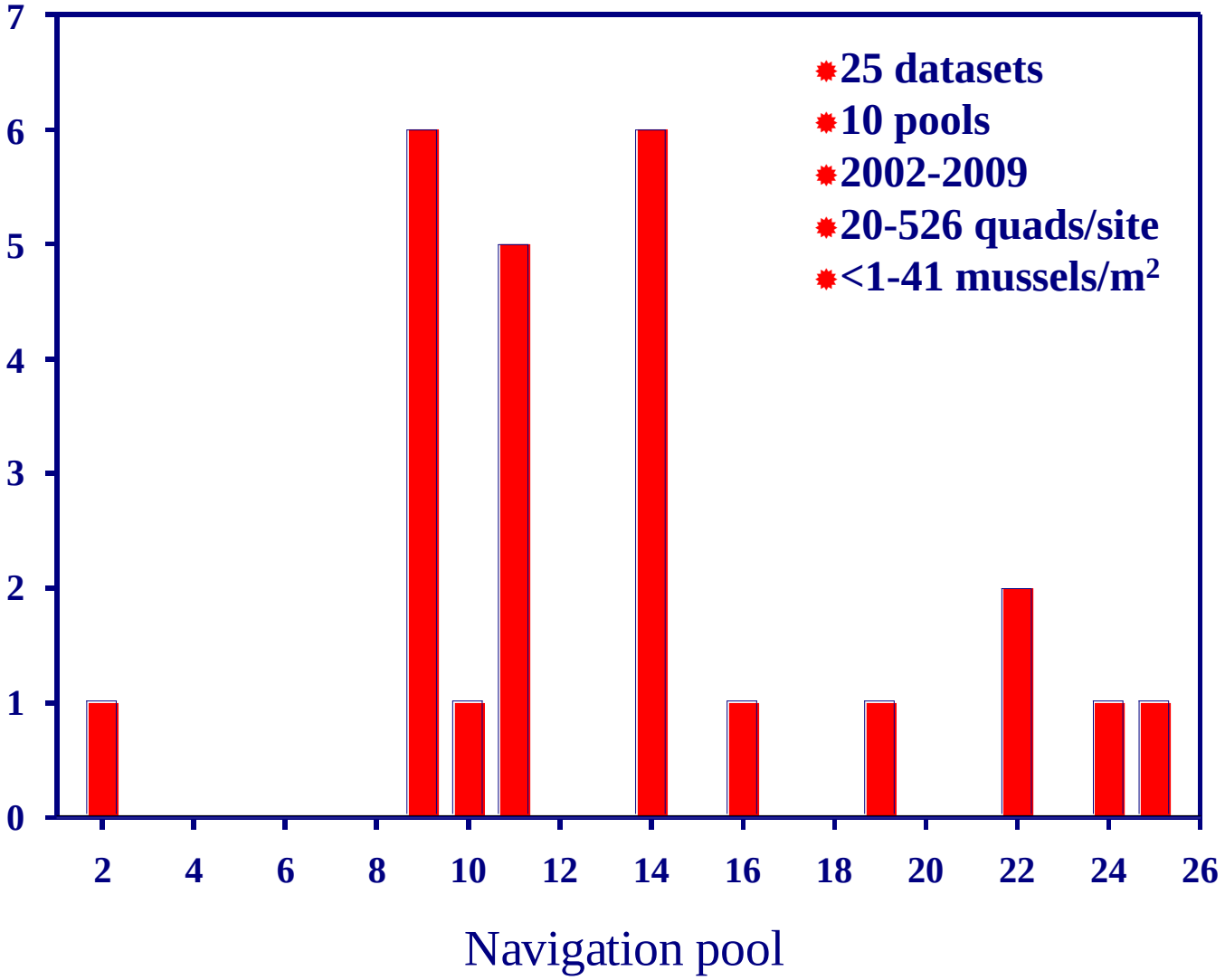
A Priori Criteria

- Quantitative data only (minimum 20 quads per site)
- Data post-2000 (post ZM, similar methods & people)
- River reach of at least 250m^2
- UMR proper (no tributaries)

Data covers a range of:

- Spatial scales (bed→reach)
- Sample densities
- River miles

Data Sets in Preliminary Analysis



Initial Metrics (~50)

- General
  - n_quads
  - n_muss_quads
  - n_muss_aged
  - p_listed
  - p_pool_list
  - p_fresh_dead
- Species Comp
  - p_Lampsilis
  - p_Quadrula
  - p_Potamilus
  - p_Amblema
  - p_Truncilla
  - p_Obliquaria
  - Amb_Lamp
- Diversity
  - richness
  - J' (evenness)
  - H'
  - N1
  - ES_39
  - ES_50
  - ES_100
  - ES_200
- Host Guild
  - p_h_gen
  - p_h_spec
- Tribes
  - p_tr_Anodontini
  - p_tr_Pleurobemini
  - p_tr_Quadrulini
  - p_tr_Lampsilini
  - p_tr_Amblemini
- Abundance
  - tot_mn
  - var_tot
  - std_tot
  - max_tot
  - med_tot
  - abun_q25
  - abun_q75
  - abun_q90
- Age Structure
  - p_juv
  - p_age6_10
  - p_age11_20
  - p_age_gr_20
  - age_10
  - all_mean_age
  - all_median_age
  - AMB_mn_age
  - AMB_med_age
  - LAMP_mn_age
  - LAMP_med_age
  - QUAD_mn_age
  - QUAD_med_age

Reduced Metrics (~20)

- Describe an important ecological facet of the mussel community
- Have sufficient spread of values to be discriminatory
- Relatively insensitive to sampling design/effort

- Conservation Status/ Sensitivity
  - % Fed/State listed
  - % tolerant
- Abundance
  - Mean density
  - Q75 Density
- Diversity
  - J' (evenness)
    - Species
    - Tribe
  - H'
  - N1
  - ES_100
  - Species count
- Taxonomic
  - % Anodontini
  - % Amblemini
  - % Pleurobemini
  - % Quadrulini
  - % Lampsilini
- Population processes
  - % fresh dead
  - % ≤5 years old
  - % species ≤5
  - % 6 to 15yrs
  - % >15yrs
  - Q_75 ≤5 yrs
  - Q_75 >5 yrs

Evaluate Redundant Metrics

	p_ambl	p_tr_anod	p_tr_pleur	p_tr_quad	p_tr_lamp	p_pol_tol	p_pool_list	perc_FD	perc_juv	p_age6_15	p_agegr15	agels5_q75	agegr5_q75	tot_mn	abun_q75	spec_count	perc_spec_juv	J_even	ES_100	H_shannon	N1
p_ambl	1.00	-0.34	0.03	-0.19	-0.40	0.60	0.08	0.04	-0.44	0.40	0.25	-0.23	0.08	-0.04	0.13	-0.03	-0.06	-0.59	-0.28	-0.33	-0.33
		0.10	*0.88*	*0.38*	*0.05*	*0.00*	*0.71*	*0.85*	*0.05*	*0.08*	*0.28*	*0.31*	*0.74*	*0.86*	*0.53*	*0.88*	*0.80*	*0.00*	*0.24*	*0.11*	*0.11*
p_tr_anod	-0.34	1.00	0.04	-0.47	0.26	-0.45	0.31	0.17	0.40	-0.31	-0.29	0.31	-0.08	0.04	-0.09	0.15	0.10	0.28	0.48	0.31	0.31
	0.10		*0.83*	*0.02*	*0.21*	*0.03*	*0.14*	*0.41*	*0.07*	*0.18*	*0.20*	*0.18*	*0.75*	*0.86*	*0.66*	*0.48*	*0.65*	*0.18*	*0.04*	*0.13*	*0.14*
p_tr_pleur	0.03	0.04	1.00	-0.16	-0.25	-0.23	0.51	-0.27	-0.17	0.32	-0.50	0.11	0.42	0.33	0.25	0.26	0.00	0.13	-0.03	0.15	0.17
	0.88	*0.83*		*0.45*	*0.23*	*0.28*	*0.01*	*0.19*	*0.46*	*0.16*	*0.02*	*0.63*	*0.06*	*0.11*	*0.23*	*0.20*	*1.00*	*0.55*	*0.91*	*0.46*	*0.43*
p_tr_quad	-0.19	-0.47	-0.16	1.00	-0.53	0.38	-0.33	-0.20	-0.18	0.16	0.05	-0.24	-0.22	-0.21	-0.26	-0.26	0.15	-0.01	-0.27	-0.01	-0.01
	0.38	*0.02*	*0.45*		*0.01*	*0.06*	*0.10*	*0.33*	*0.44*	*0.48*	*0.84*	*0.29*	*0.34*	*0.32*	*0.21*	*0.21*	*0.50*	*0.97*	*0.26*	*0.96*	*0.97*
p_tr_lamp	-0.40	0.26	-0.25	-0.53	1.00	-0.49	0.12	0.41	0.52	-0.54	0.06	0.32	0.08	0.23	0.26	0.19	0.01	0.31	0.48	0.24	0.23
	0.05	*0.21*	*0.23*	*0.01*		*0.01*	*0.57*	*0.04*	*0.01*	*0.01*	*0.78*	*0.16*	*0.74*	*0.28*	*0.21*	*0.37*	*0.96*	*0.14*	*0.04*	*0.25*	*0.28*
p_pol_tol	0.60	-0.45	-0.23	0.38	-0.49	1.00	-0.39	0.03	-0.54	0.49	0.39	-0.53	-0.27	-0.32	-0.20	-0.45	-0.09	-0.51	-0.53	-0.53	-0.54
	0.00	*0.03*	*0.28*	*0.06*	*0.01*		*0.06*	*0.91*	*0.01*	*0.03*	*0.08*	*0.01*	*0.24*	*0.11*	*0.33*	*0.02*	*0.70*	*0.01*	*0.02*	*0.01*	*0.01*
p_pool_list	0.08	0.31	0.51	-0.33	0.12	-0.39	1.00	-0.03	0.19	-0.10	-0.44	0.25	0.08	0.35	0.28	0.40	0.30	0.07	0.68	0.52	0.52
	0.71	*0.14*	*0.01*	*0.10*	*0.57*	*0.06*		*0.88*	*0.40*	*0.67*	*0.05*	*0.28*	*0.73*	*0.09*	*0.17*	*0.05*	*0.17*	*0.74*	*0.00*	*0.01*	*0.01*
perc_FD	0.04	0.17	-0.27	-0.20	0.41	0.03	-0.03	1.00	0.41	-0.42	0.12	0.24	-0.02	-0.05	0.03	-0.18	0.03	-0.06	0.22	-0.12	-0.12
	0.85	*0.41*	*0.19*	*0.33*	*0.04*	*0.91*	*0.88*		*0.07*	*0.06*	*0.59*	*0.29*	*0.92*	*0.80*	*0.89*	*0.40*	*0.90*	*0.77*	*0.37*	*0.57*	*0.58*
perc_juv	-0.44	0.40	-0.17	-0.18	0.52	-0.54	0.19	0.41	1.00	-0.95	-0.31	0.68	-0.13	0.34	0.28	0.48	0.70	0.22	0.75	0.62	0.62
	0.05	*0.07*	*0.46*	*0.44*	*0.01*	*0.01*	*0.40*	*0.07*		*<.0001*	*0.17*	*0.00*	*0.58*	*0.13*	*0.23*	*0.03*	*0.00*	*0.33*	*0.00*	*0.00*	*0.00*
p_age6_15	0.40	-0.31	0.32	0.16	-0.54	0.49	-0.10	-0.42	-0.95	1.00	0.06	-0.68	0.12	-0.34	-0.30	-0.45	-0.65	-0.14	-0.71	-0.60	-0.59
	0.08	*0.18*	*0.16*	*0.48*	*0.01*	*0.03*	*0.67*	*0.06*	*<.0001*		*0.79*	*0.00*	*0.60*	*0.14*	*0.18*	*0.04*	*0.00*	*0.54*	*0.00*	*0.00*	*0.00*
p_agegr15	0.25	-0.29	-0.50	0.05	0.06	0.39	-0.44	0.12	-0.31	0.06	1.00	-0.25	0.05	-0.09	0.01	-0.23	-0.38	-0.25	-0.46	-0.19	-0.20
	0.28	*0.20*	*0.02*	*0.84*	*0.78*	*0.08*	*0.05*	*0.59*	*0.17*	*0.79*		*0.27*	*0.85*	*0.69*	*0.98*	*0.31*	*0.09*	*0.28*	*0.07*	*0.40*	*0.40*
agels5_q75	-0.23	0.31	0.11	-0.24	0.32	-0.53	0.25	0.24	0.68	-0.68	-0.25	1.00	0.47	0.77	0.78	0.77	0.59	-0.09	0.56	0.61	0.62
	0.31	*0.18*	*0.63*	*0.29*	*0.16*	*0.01*	*0.28*	*0.29*	*0.00*	*0.00*	*0.27*		*0.03*	*<.0001*	*<.0001*	*<.0001*	*0.00*	*0.71*	*0.02*	*0.00*	*0.00*
agegr5_q75	0.08	-0.08	0.42	-0.22	0.08	-0.27	0.08	-0.02	-0.13	0.12	0.05	0.47	1.00	0.79	0.84	0.58	-0.21	-0.11	-0.07	0.24	0.25
	0.74	*0.75*	*0.06*	*0.34*	*0.74*	*0.24*	*0.73*	*0.92*	*0.58*	*0.60*	*0.85*	*0.03*		*<.0001*	*<.0001*	*0.01*	*0.37*	*0.64*	*0.80*	*0.29*	*0.27*
tot_mn	-0.04	0.04	0.33	-0.21	0.23	-0.32	0.35	-0.05	0.34	-0.34	-0.09	0.77	0.79	1.00	0.94	0.83	0.33	-0.10	0.37	0.56	0.57
	0.86	*0.86*	*0.11*	*0.32*	*0.28*	*0.11*	*0.09*	*0.80*	*0.13*	*0.14*	*0.69*	*<.0001*	*<.0001*		*<.0001*	*<.0001*	*0.14*	*0.62*	*0.12*	*0.00*	*0.00*
abun_q75	0.13	-0.09	0.25	-0.26	0.26	-0.20	0.28	0.03	0.28	-0.30	0.01	0.78	0.84	0.94	1.00	0.78	0.29	-0.24	0.26	0.42	0.42
	0.53	*0.66*	*0.23*	*0.21*	*0.21*	*0.33*	*0.17*	*0.89*	*0.23*	*0.18*	*0.98*	*<.0001*	*<.0001*	*<.0001*		*<.0001*	*0.20*	*0.24*	*0.27*	*0.04*	*0.04*
spec_count	-0.03	0.15	0.26	-0.26	0.19	-0.45	0.40	-0.18	0.48	-0.45	-0.23	0.77	0.58	0.83	0.78	1.00	0.49	0.15	0.65	0.72	0.72
	0.88	*0.48*	*0.20*	*0.21*	*0.37*	*0.02*	*0.05*	*0.40*	*0.03*	*0.04*	*0.31*	*<.0001*	*0.01*	*<.0001*	*<.0001*		*0.02*	*0.46*	*0.00*	*<.0001*	*<.0001*
perc_spec_juv	-0.06	0.10	0.00	0.15	0.01	-0.09	0.30	0.03	0.70	-0.65	-0.38	0.59	-0.21	0.33	0.29	0.49	1.00	-0.13	0.70	0.58	0.59
	0.80	*0.65*	*1.00*	*0.50*	*0.96*	*0.70*	*0.17*	*0.90*	*0.00*	*0.00*	*0.09*	*0.00*	*0.37*	*0.14*	*0.20*	*0.02*		*0.57*	*0.00*	*0.00*	*0.00*
J_even	-0.59	0.28	0.13	-0.01	0.31	-0.51	0.07	-0.06	0.22	-0.14	-0.25	-0.09	-0.11	-0.10	-0.24	0.15	-0.13	1.00	0.43	0.32	0.31
	0.00	*0.18*	*0.55*	*0.97*	*0.14*	*0.01*	*0.74*	*0.77*	*0.33*	*0.54*	*0.28*	*0.71*	*0.64*	*0.62*	*0.24*	*0.46*	*0.57*		*0.07*	*0.12*	*0.13*
ES_100	-0.28	0.48	-0.03	-0.27	0.48	-0.53	0.68	0.22	0.75	-0.71	-0.46	0.56	-0.07	0.37	0.26	0.65	0.70	0.43	1.00	0.74	0.74
	0.24	*0.04*	*0.91*	*0.26*	*0.04*	*0.02*	*0.00*	*0.37*	*0.00*	*0.00*	*0.07*	*0.02*	*0.80*	*0.12*	*0.27*	*0.00*	*0.00*	*0.07*		*0.00*	*0.00*
H_shannon	-0.33	0.31	0.15	-0.01	0.24	-0.53	0.52	-0.12	0.62	-0.60	-0.19	0.61	0.24	0.56	0.42	0.72	0.58	0.32	0.74	1.00	1.00
	0.11	*0.13*	*0.46*	*0.96*	*0.25*	*0.01*	*0.01*	*0.57*	*0.00*	*0.00*	*0.40*	*0.00*	*0.29*	*0.00*	*0.04*	*<.0001*	*0.00*	*0.12*	*0.00*		*<.0001*
N1	-0.33	0.31	0.17	-0.01	0.23	-0.54	0.52	-0.12	0.62	-0.59	-0.20	0.62	0.25	0.57	0.42	0.72	0.59	0.31	0.74	1.00	1.00
	0.11	*0.14*	*0.43*	*0.97*	*0.28*	*0.01*	*0.01*	*0.58*	*0.00*	*0.00*	*0.40*	*0.00*	*0.27*	*0.00*	*0.04*	*<.0001*	*0.00*	*0.13*	*0.00*	*<.0001*	

Reduced Metrics to 10

- Discarded redundant (highly correlated) metrics
- Goal of 1-3 metrics in each category
- Plotted, scored in Quartiles (25% good, 25% poor)

Sensitivity/Tolerance

% Listed Individuals

% Tolerant Individuals

Taxonomic Composition

% Tribe Lampsilini

Community Processes

% Freshly dead (mortality)

% ≤5 yrs old (recruitment)

% ≥15 yrs old

Abundance

75th Quartile abundance

Diversity

ES_100

Tribe Evenness

Species Evenness

Top 10 List

Conservation Status/Sensitivity

Metric	Description	Significance
% Listed species	Percent of individuals listed by federal or adjacent state (IL, IA, MN, MO, WI) regulations as endangered, threatened or of special concern	Measure of the abundance of rare and sensitive species
% Tolerant	Percent of individuals classified as tolerant (A. plicata, Q. quadrula, and O. reflexa)	Index of species that are relatively tolerant to human-induced changes to habitat or water quality

Top 10 List

Taxonomic composition

% Tribe Lampsilini	Percent of mussels in the tribe Lampsilini	Index of balance in taxonomic composition (behavior, life history characteristics)

Community Processes

% Fresh Dead	Percent of fresh dead mussels	Index of recent mortality
% juveniles	Percent of aged mussels ≤5 years old	Index of recent recruitment to the community
% ≥15 years old	Percent of aged mussels ≥15 years old	Index of balanced age distribution

Top 10 List

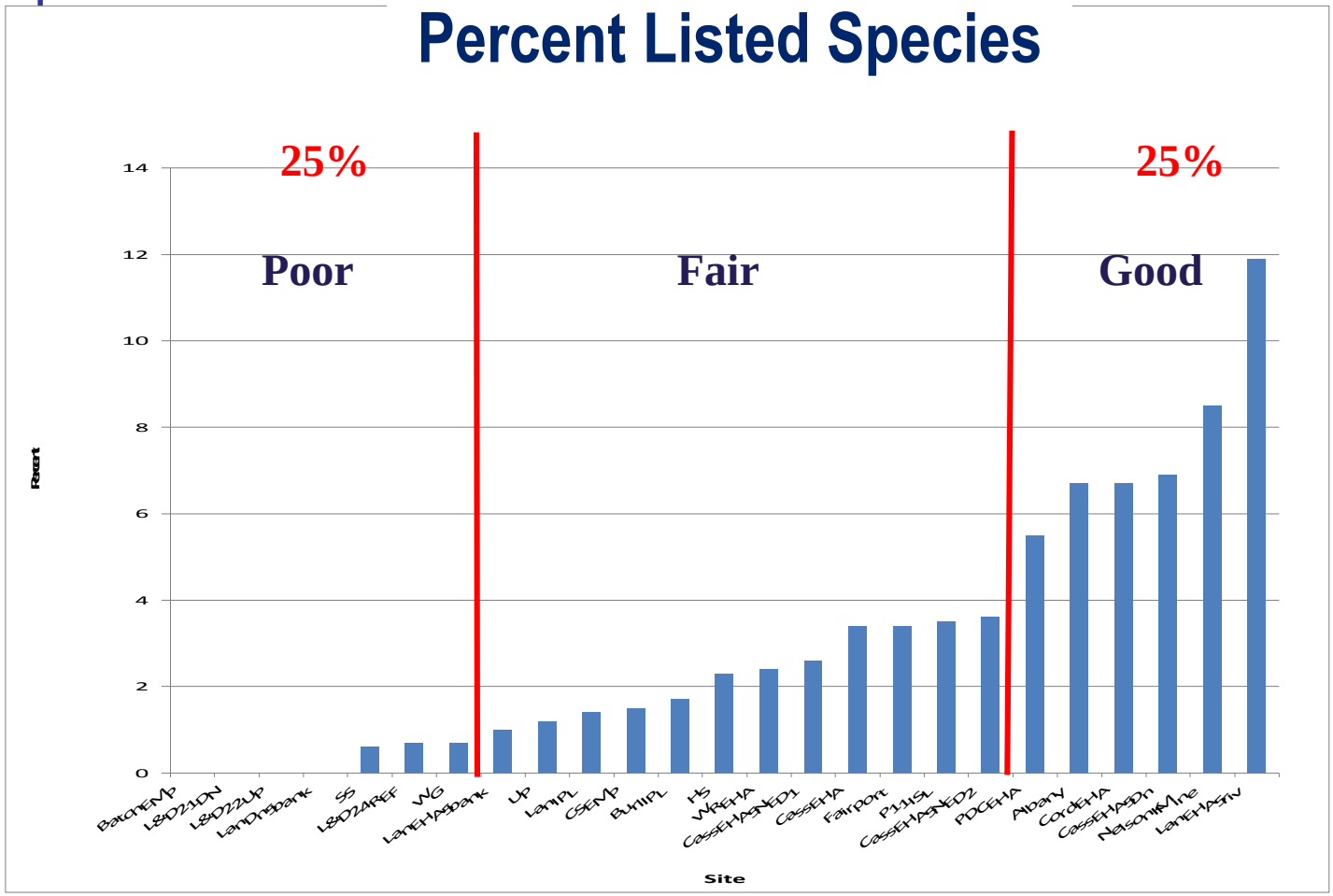
Abundance

Abundance at 75th Quartile	Density in the quadrats at the 3rd quartile	Identifies abundance in high quality areas; may identify patches or if sampling occurs on the edge of a bed

Diversity

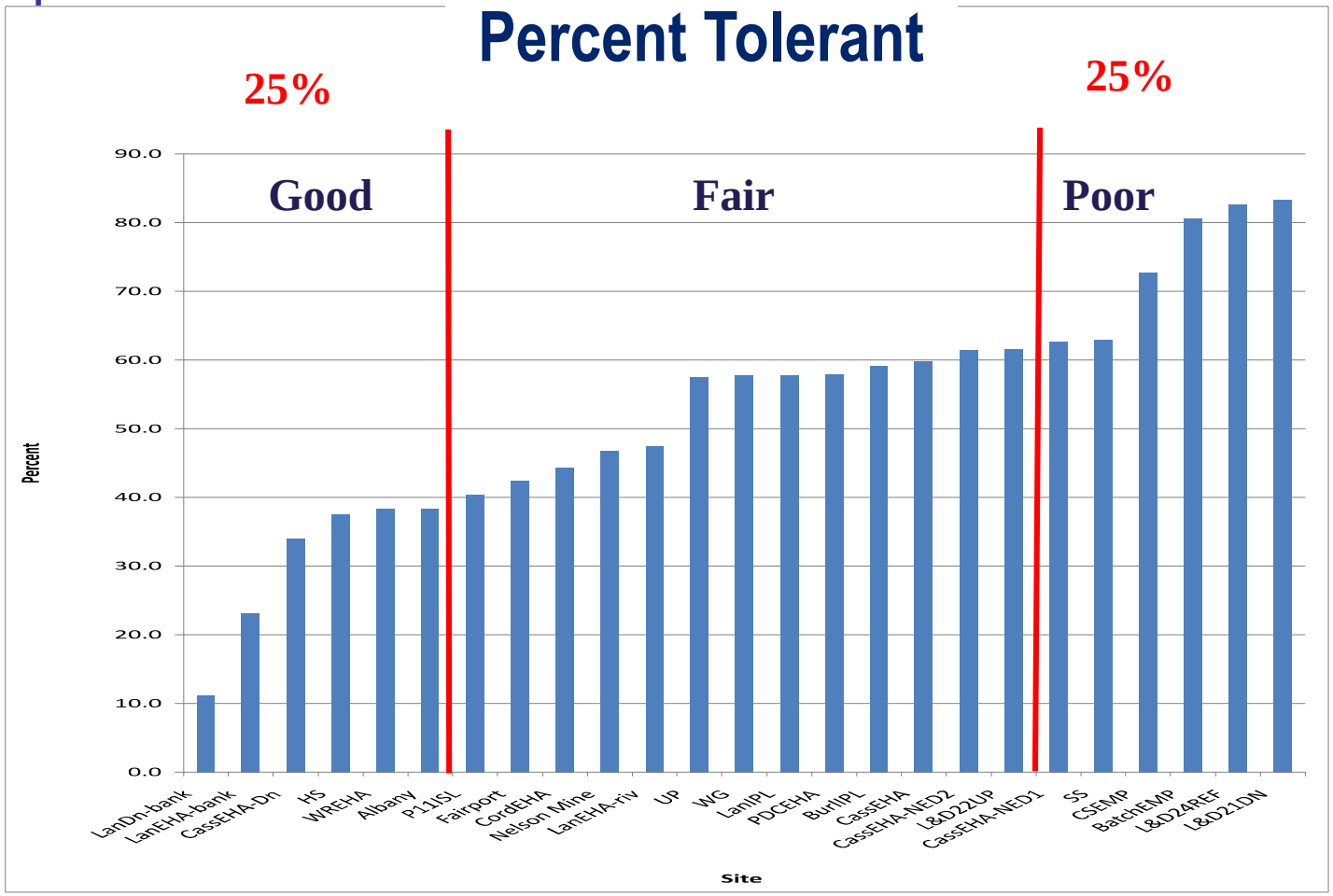
Species Evenness	Pielou's evenness index (J') estimated at the species level	Estimate of the dominance of the community by a few species
Tribe level Evenness	Pielou's evenness index (J') estimated at the tribe level	Estimate of the dominance of the community by a tribe
ES_100	Expected number of species at a sample size of 100 mussels estimated via rarefaction	Estimate of species richness with equal sample sizes

Low end of Scale "Poor"



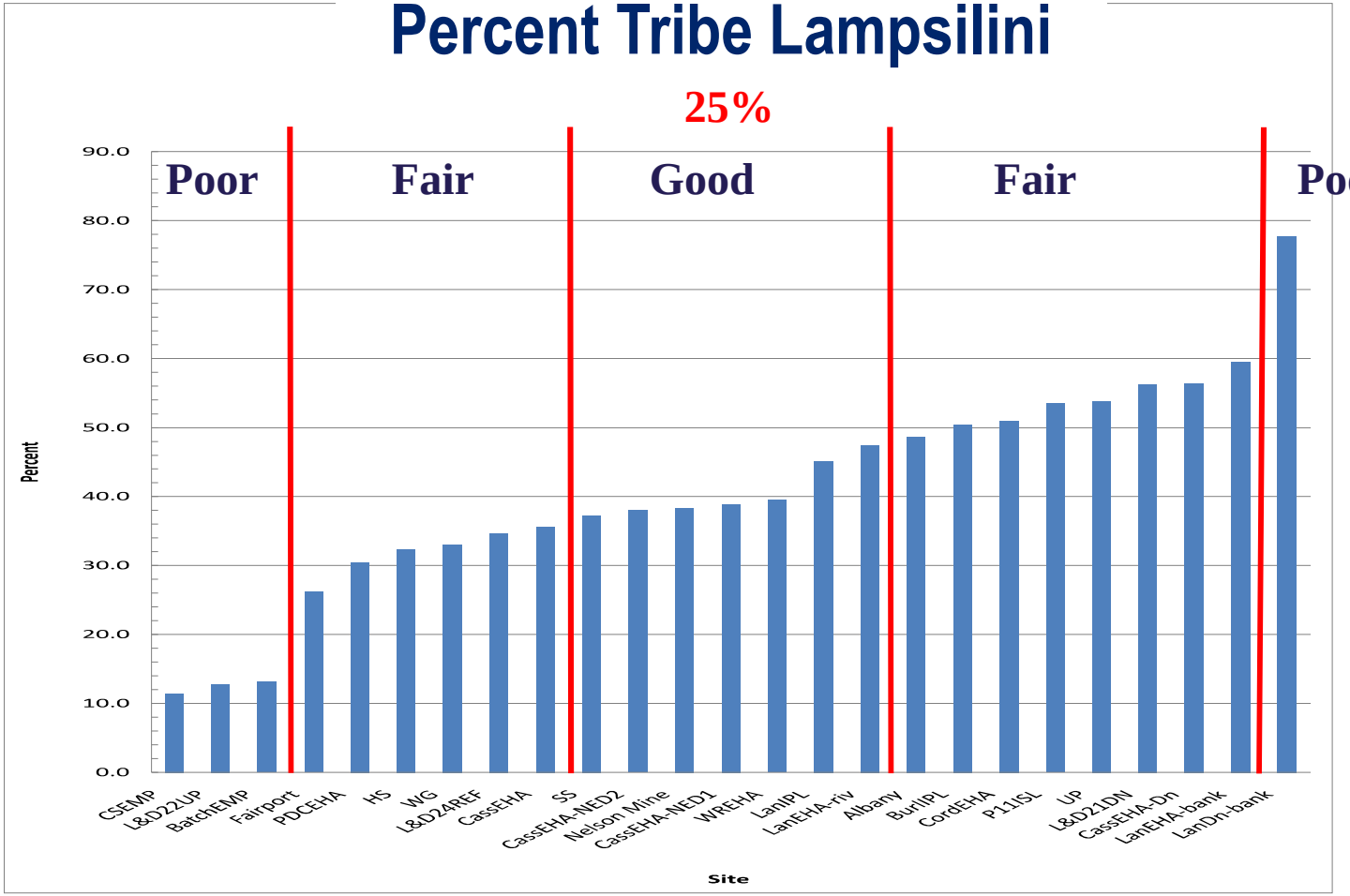
% Listed Species
% Juveniles
75th Q. Density
Species Evenness
Tribe Evenness
ES_100

Low end of scale "Good"



% Tolerant
% Fresh dead

Middle "Good", Extremes "Poor"

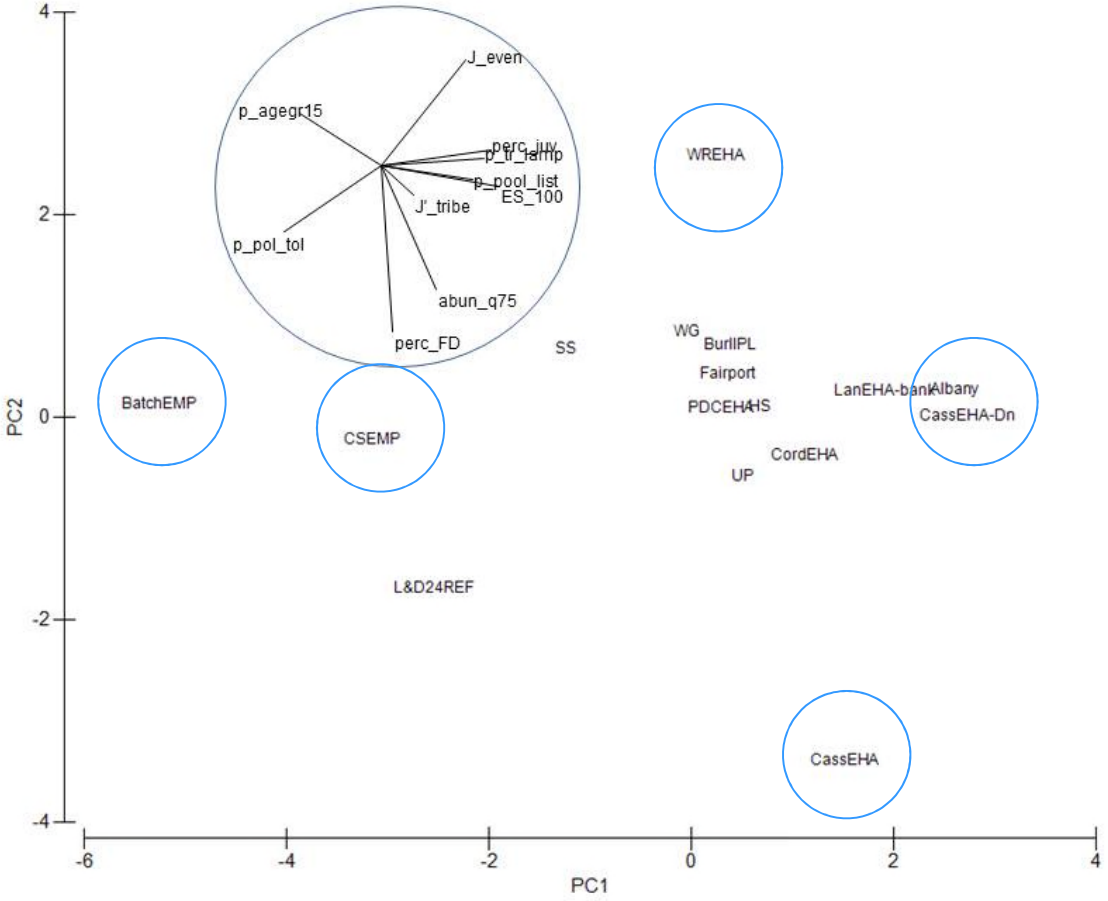


% Lampsilini
% ≥15 years old

Robust UMR Mussel Community

Metric	Good
Listed Species	>5%
Tolerant Species	<40%
Lampsilini	37 to 48%
Fresh Dead Shells	≤10%
Juveniles (≤5 yrs)	49 to 55%
≥15 years old	2 to 5.5%
Q75 Density	>15/m^2
Species Evenness	>0.80
Tribe Evenness	>0.81
ES_100	>16 species

PCA Separated High/Low Quality Sites



Use of metrics to evaluate sites - Example

Metric	Batchtown EMP (Pool 25) (Low PCA 1)	Capoli Slough EMP (Pool 9) (Low PCA 1)	Albany (Pool 14) (High PCA 1)	Whiskey Rock EHA (Pool 9) (High PCA 1&2)	Cassville EHA (Pool 11) (High 1& Low 2
% Listed Species	*Poor*	Fair	**Good**	Fair	Fair
% Tolerant	*Poor*	*Poor*	**Good**	**Good**	Fair
% Lampsilini	*Poor*	*Poor*	Fair	**Good**	Fair
% FD	**Good**	*Poor*	**Good**	**Good**	Fair
% Juveniles	*Poor*	*Poor*	**Good**	*Poor*	Fair
% ≤15 years	*Poor*	**Good**	Fair	Fair	Fair
75th Q Density	Fair	*Poor*	Fair	Fair	**Good**
Species J'	*Poor*	*Poor*	**Good**	**Good**	*Poor*
Tribe J'	*Poor*	*Poor*	Fair	**Good**	**Good**
ES_100	*Poor*	*Poor*	**Good**	Fair	**Good**

Data Gaps/Questions?

- Lacking low quality sites
- Definition of what is too low
- Would distributions change with additional data
- How would same site rate over time (temporal variation)
- How would multiple sites within a similar area score (spatial variation)

Next Steps - PHASE II

Conduct full analyses of selected metrics

- Test discrimination power
  - Identify additional data sets
  - Test *a priori* classification of sites
- Evaluate temporal and spatial variation in metrics
- Refine the MCAT

Research Funded By

- U.S. Army Corps of Engineers

Environmental Management Program

USGS

Restoring & Monitoring
ON THE
UPPER MISSISSIPPI RIVER SYSTEM