A COMPARISON OF ALGAE AND FISH COMMUNITY RESPONSE TO URBANIZATION

Session C: Application of Multilevel Modeling
in Studying the Effects of Urbanization in Stream Ecosystems
Wednesday October 08 2008

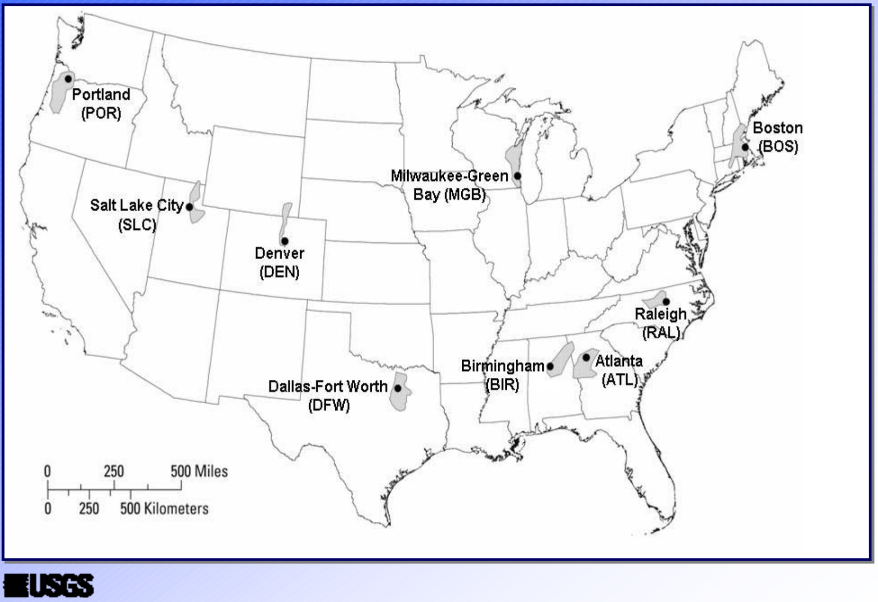
Ibrahim Almaeddine, PhD Student
Yoon Kyung Cha, PhD Student
Nicholas School of the Environment & Earth Sciences
Duke University

2008 WRRI
Raleigh, NC

Introduction to EUSE

- **Effect of Urbanization on Stream Ecosystems (EUSE)**
- **Main goal:**
  - **Identifying and understanding primary environmental factors that respond to urbanization**
- **Study site:**
  - **Nine metropolitan regions** across U.S.
  - ~30 sampling basins for each region
- **This presentation focuses on work done with algae/fish multilevel modeling**
  - Linking in-stream ecological responses of algae and fish to urbanization and environment parameters

Nine metropolitan regions

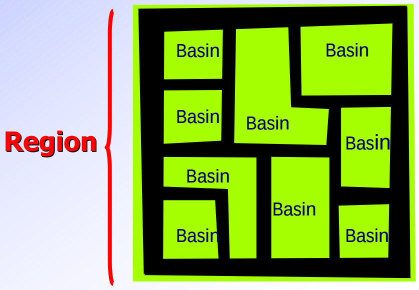


Multilevel modeling

- **Partial pooling**

  Compromise between complete and no pooling

  - **Shrinkage towards overall mean**
  - **Allowing for higher level differences**
- **Incorporate both basin and region level factors in building model structure**



Multilevel modeling

Level 1: Basin level

$Y = a + b \cdot X$,   X = Basin-level predictor

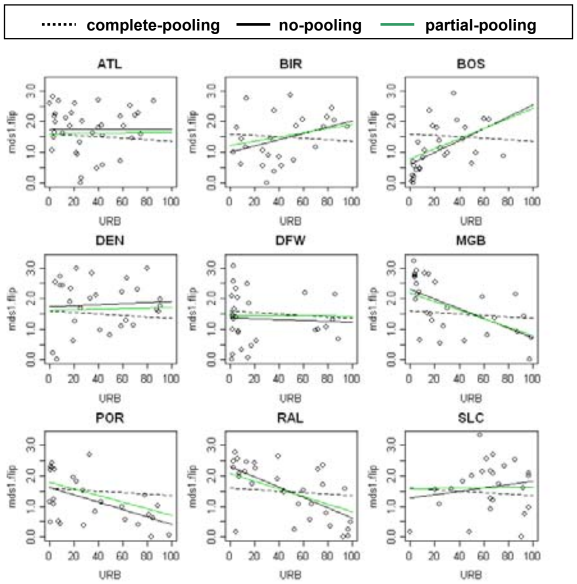
Level 2: Region level

$a = \alpha_0 + \beta_0 \cdot R$ $b = \alpha_1 + \beta_1 \cdot R$

R = Region-level predictor

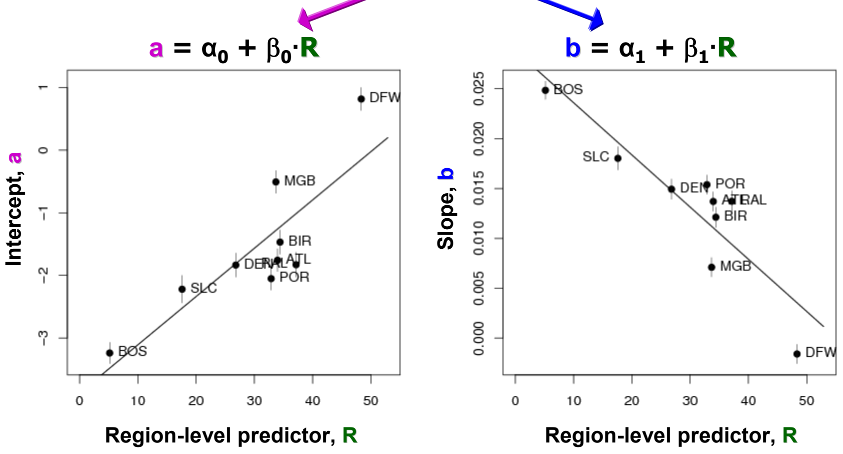
e.g.) background agriculture, temperature, or precipitation

Partial pooling



Region-level regression (a,b)

$$Y = a + b \cdot X$$



$$a = \alpha_0 + \beta_0 \cdot R$$

$$b = \alpha_1 + \beta_1 \cdot R$$

[Average ECO value when %URB=0]

[Average change in ECO per unit %URB]

Variables explored with respect to algae

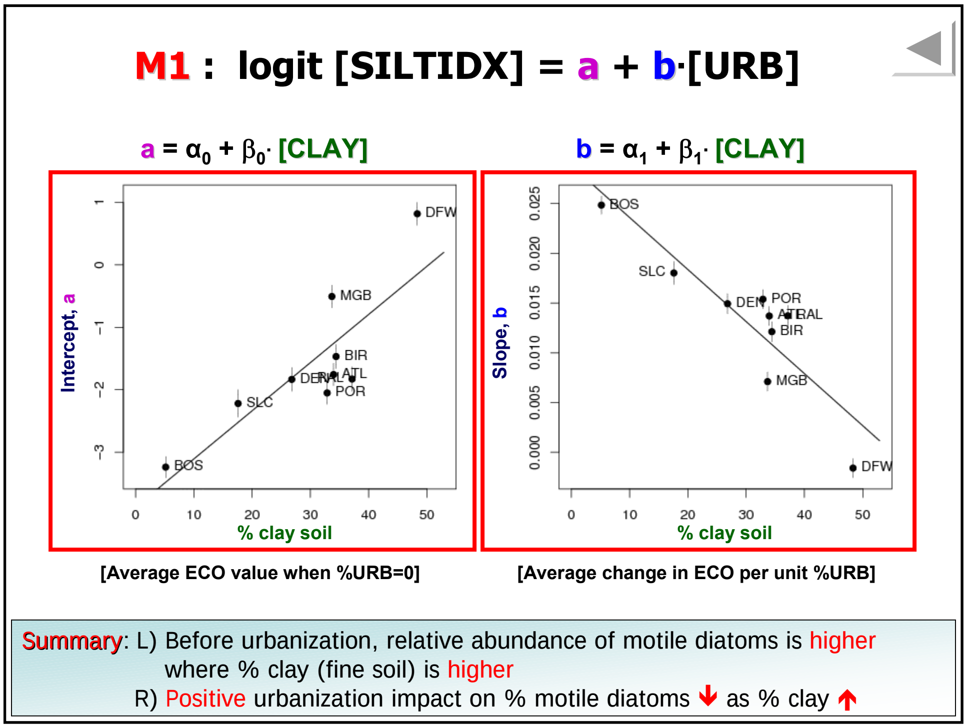
Basin-level response	*Basin-level predictor*	*Region-level predictor*
mds1 (“flip” to increase with URB)	P.NLCD2	Temperature
mds2 (“flip” to increase with URB)	(% urban land cover)	Precipitation
Taxa richness	P.NLCD8	Background Ag
QQ richness	P.NLCD78	Conductivity
SL_HB_DP (halobiontic diatoms)	Conductivity	% Clay soil
TR_E_DP (eutraphentic diatoms)	Total nitrogen	Erodibility
PC_SN_DP (pollution sensitive)	Total phosphorus	Snow
SILTIDX (diatoms motile in silt)	Inorganic nitrogen	
Chl-a	Inorganic phosphorus	

List of models for predicting algae (diatom) responses

Basin-level response	*Basin-level predictor*	*Region-level predictor*	*Model*
% diatoms motile in silt [SILTIDX]	**% urban land-use [URB]**	**% clay soil [CLAY]**	**M1**
% eutraphentic diatoms [TR_E_DP]		**% background agriculture [AG]**	**M2**
% salt-loving diatoms [SL_HB_DP]		**Temperature [TEMP]**	**M3.1**
		% background agriculture [AG]	**M3.2**
		TEMP + AG (categorical)	**M3.3**

Since all responses are reported in %
➔ *logit transformation* is used in all responses in all models

---



M1 : logit [SILTIDX] = a + b·[URB]

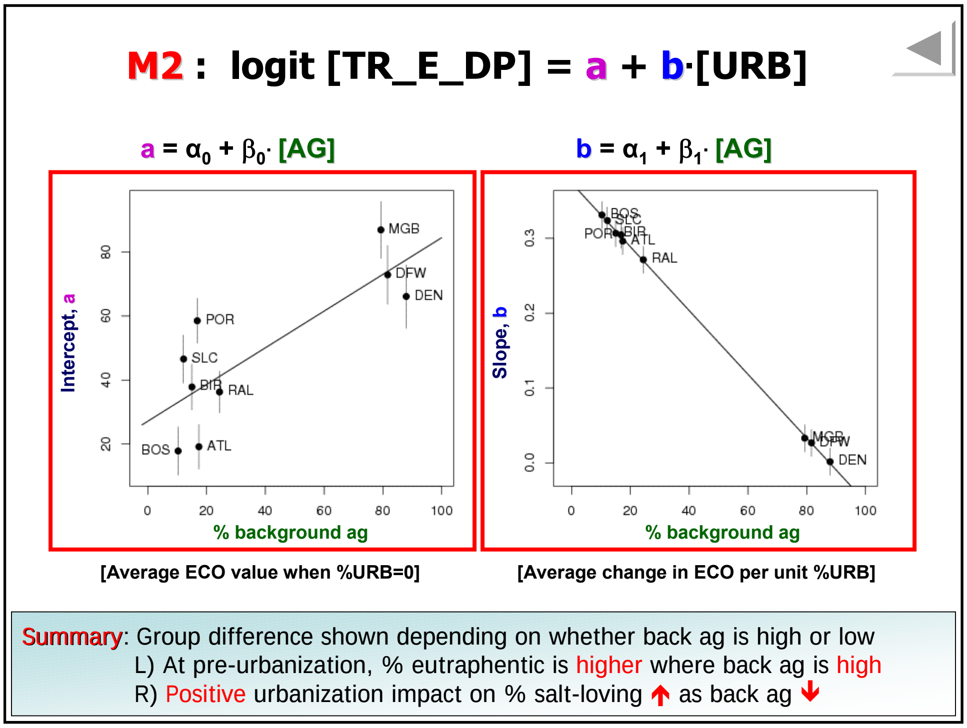
$a = \alpha_0 + \beta_0 \cdot$ [CLAY]

$b = \alpha_1 + \beta_1 \cdot$ [CLAY]

[Average ECO value when %URB=0]

[Average change in ECO per unit %URB]

Summary: L) Before urbanization, relative abundance of motile diatoms is higher where % clay (fine soil) is higher
R) Positive urbanization impact on % motile diatoms ↓ as % clay ↑



M2 : logit [TR_E_DP] = a + b·[URB]

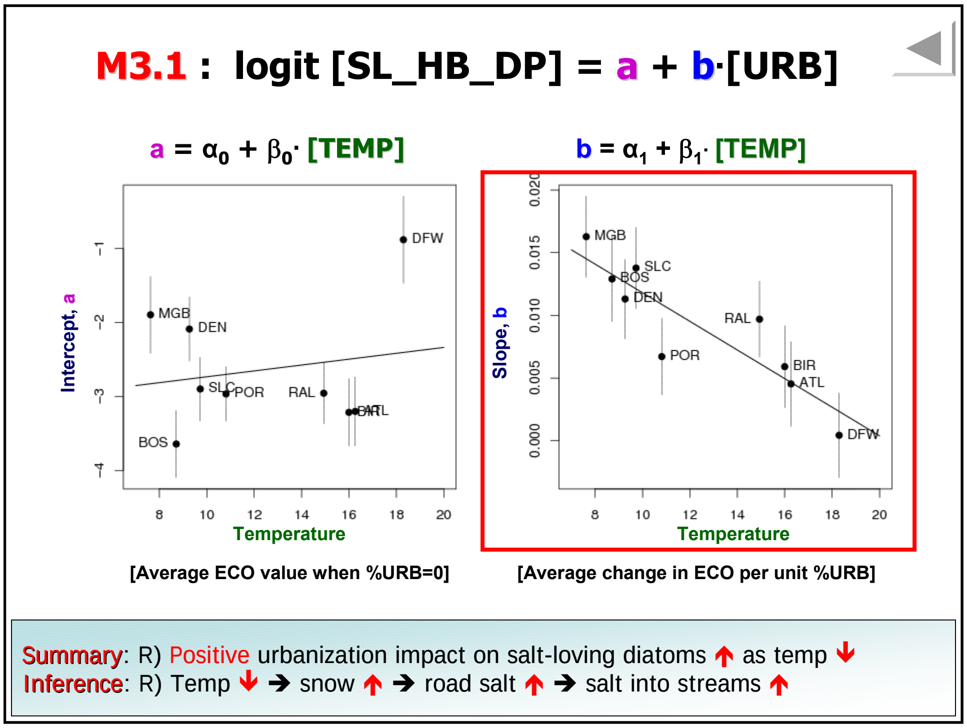
$a = \alpha_0 + \beta_0 \cdot$ **[AG]**

$b = \alpha_1 + \beta_1 \cdot$ **[AG]**

[Average ECO value when %URB=0]

[Average change in ECO per unit %URB]

Summary: Group difference shown depending on whether back ag is high or low
L) At pre-urbanization, % eutraphentic is higher where back ag is high
R) Positive urbanization impact on % salt-loving ↑ as back ag ↓



M3.1 : logit [SL_HB_DP] = a + b·[URB]

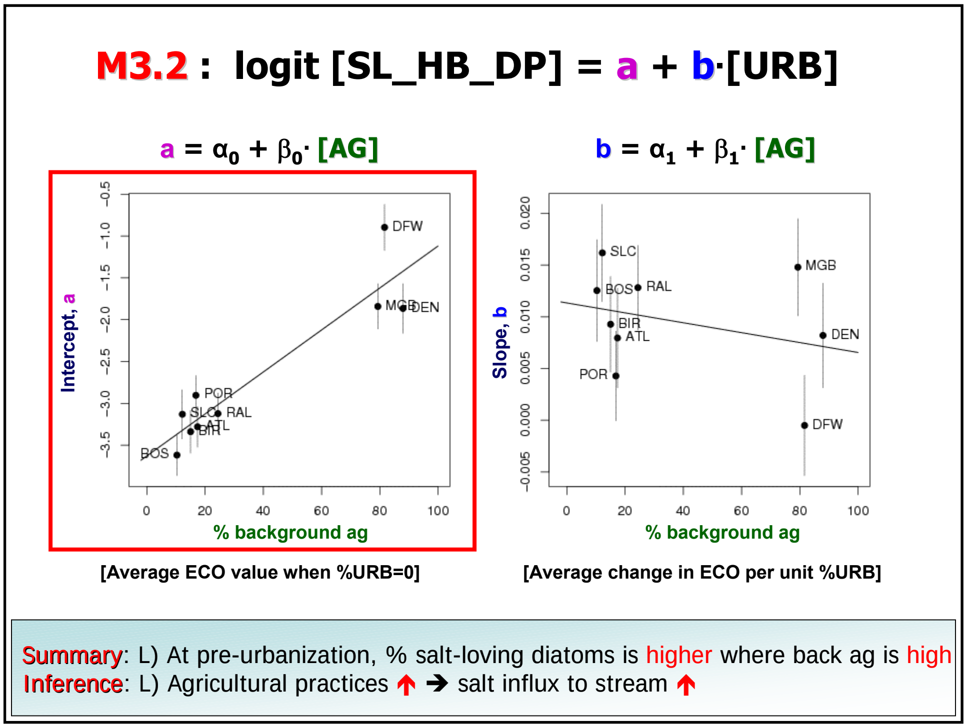
$a = \alpha_0 + \beta_0 \cdot$ **[TEMP]**

$b = \alpha_1 + \beta_1 \cdot$ **[TEMP]**

[Average ECO value when %URB=0]

[Average change in ECO per unit %URB]

Summary: R) Positive urbanization impact on salt-loving diatoms ↑ as temp ↓
Inference: R) Temp ↓ ➔ snow ↑ ➔ road salt ↑ ➔ salt into streams ↑



M3.2 : logit [SL_HB_DP] = a + b·[URB]

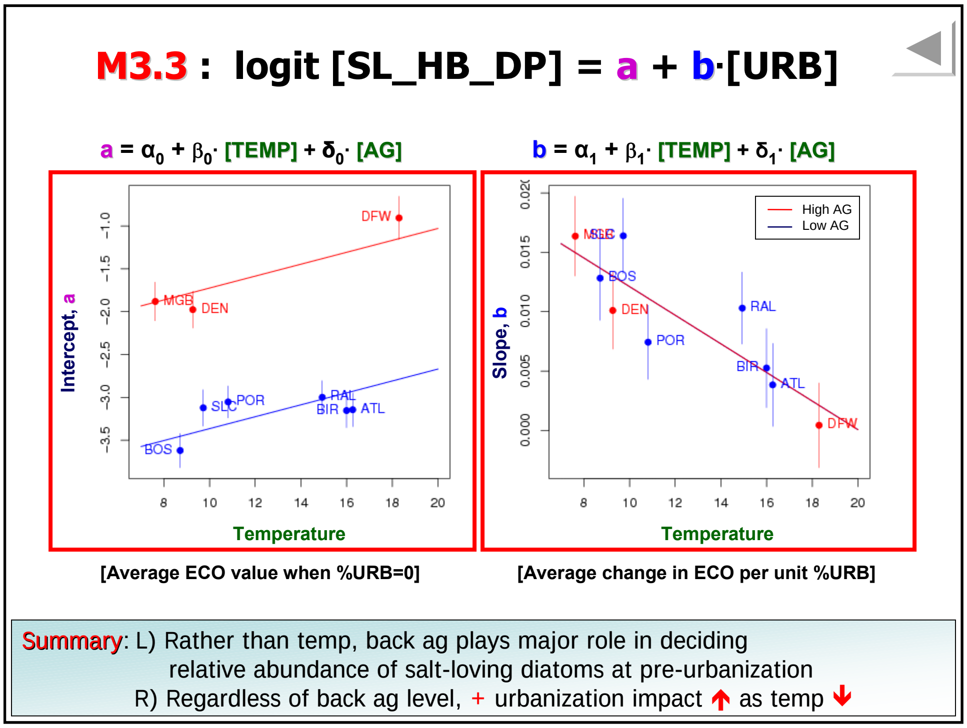
$a = \alpha_0 + \beta_0 \cdot$ [AG]

$b = \alpha_1 + \beta_1 \cdot$ [AG]

[Average ECO value when %URB=0]

[Average change in ECO per unit %URB]

Summary: L) At pre-urbanization, % salt-loving diatoms is higher where back ag is high
Inference: L) Agricultural practices ↑ ➔ salt influx to stream ↑



M3.3 : logit [SL_HB_DP] = a + b·[URB]

$a = \alpha_0 + \beta_0 \cdot$ [TEMP] $+ \delta_0 \cdot$ [AG]

$b = \alpha_1 + \beta_1 \cdot$ [TEMP] $+ \delta_1 \cdot$ [AG]

[Average ECO value when %URB=0]

[Average change in ECO per unit %URB]

Summary: L) Rather than temp, back ag plays major role in deciding
relative abundance of salt-loving diatoms at pre-urbanization
R) Regardless of back ag level, + urbanization impact ↑ as temp ↓

EUSE & Stream Fish Communities

- The study has focused on assessing the **relative abundance** of fish species
- In this presentation: we are presenting work that has been done on fish assemblages based on **substrate preference** ▶

Fish assemblages according to substrate preference

◀

Original

- Bedrock
- Boulder
- Cobble–rubble
- Gravel
- Sand
- Mud
- Vegetation
- Variable

Grouping

Coarse

Fine

Variables Explored with Respect to Fish

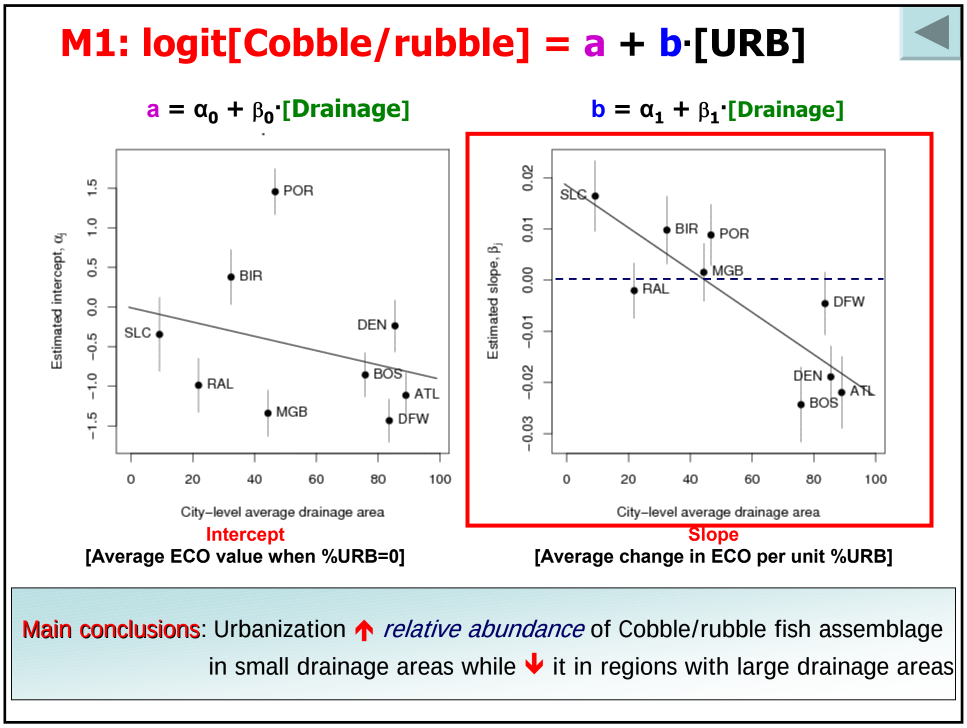
Basin-level response	*Basin-level predictor*	*Region-level predictor*
All substrate preference fish assemblages (original and compressed)	% Urban land cover	Temperature Precipitation Erodibility
	% NUII	
Geomorphic habitat preference	% Impervious surfaces	Background Ag Conductivity
	Road density	% Clay soil Drainage basin Snow Dam density Man made channels

---

Some Initial Results on the Impacts of Urbanization on Stream Fish Communities

Basin-level response	*Basin-level predictor*	*Region-level predictor*	*Model*
Cobble/rubble %	Urban land cover (%)	Drainage basin area	M1
Sand %		Precipitation	M2
Coarse %		Precipitation + background Ag	M3
		Erodibility	M4

Since all responses are reported in % ➔ *logit transformation* was used on all response variables in all multilevel hierarchical models that have been developed



M1: logit[Cobble/rubble] = a + b·[URB]

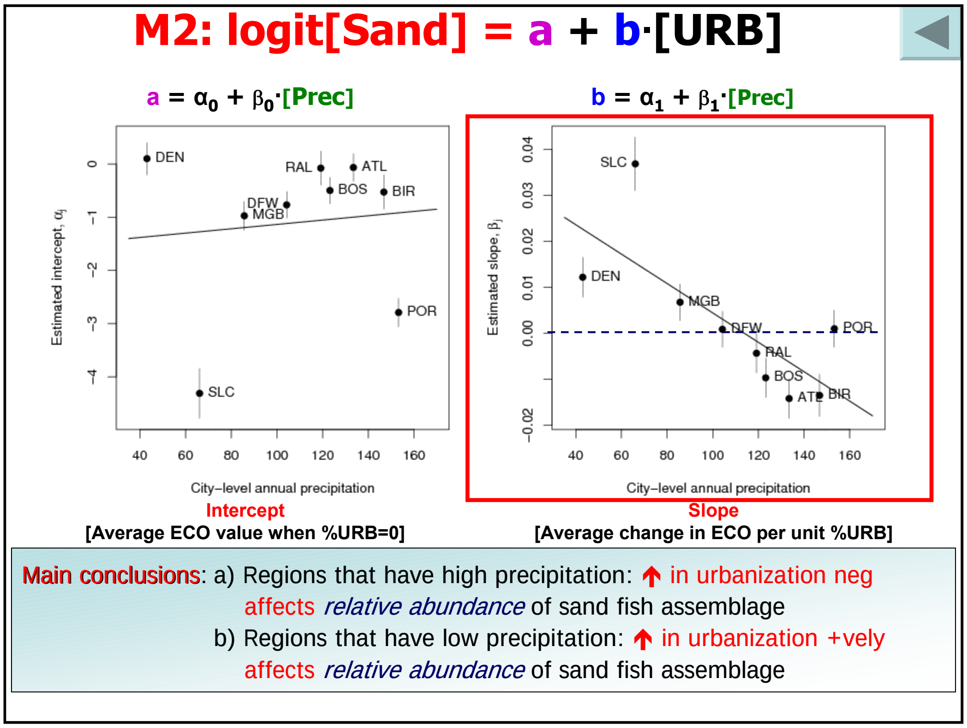
$a = \alpha_0 + \beta_0 \cdot$[Drainage]

$b = \alpha_1 + \beta_1 \cdot$[Drainage]

Intercept
[Average ECO value when %URB=0]

Slope
[Average change in ECO per unit %URB]

Main conclusions: Urbanization ↑ *relative abundance* of Cobble/rubble fish assemblage in small drainage areas while ↓ it in regions with large drainage areas



M2: logit[Sand] = a + b·[URB]

$a = \alpha_0 + \beta_0 \cdot$[Prec]

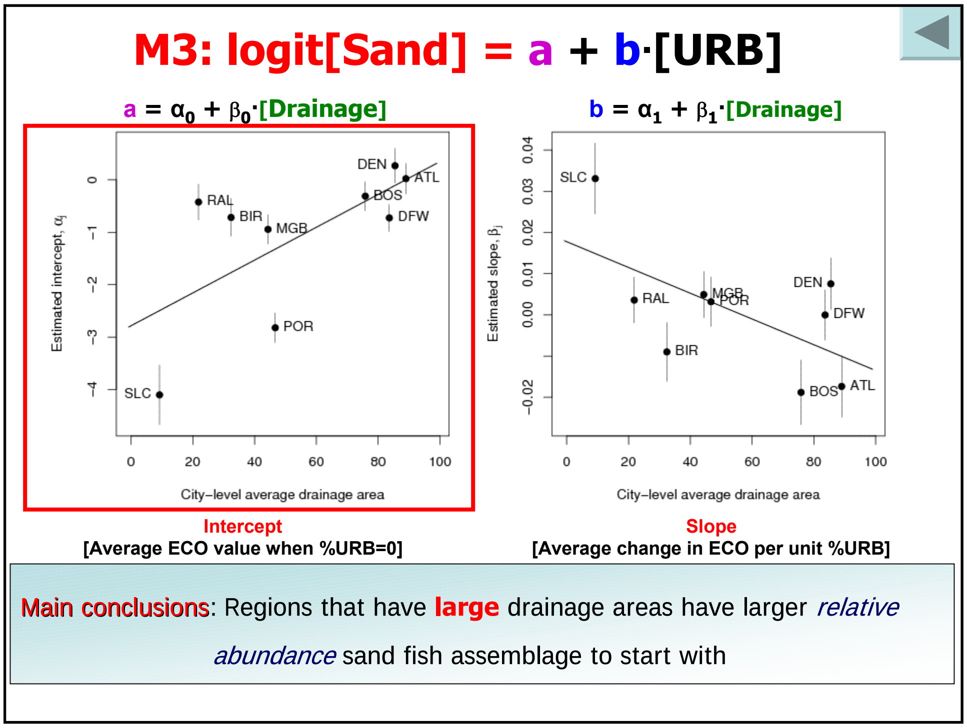
$b = \alpha_1 + \beta_1 \cdot$[Prec]

Intercept
[Average ECO value when %URB=0]

Slope
[Average change in ECO per unit %URB]

Main conclusions: a) Regions that have high precipitation: ↑ in urbanization neg affects *relative abundance* of sand fish assemblage

b) Regions that have low precipitation: ↑ in urbanization +vely affects *relative abundance* of sand fish assemblage



M3: logit[Sand] = a + b·[URB]

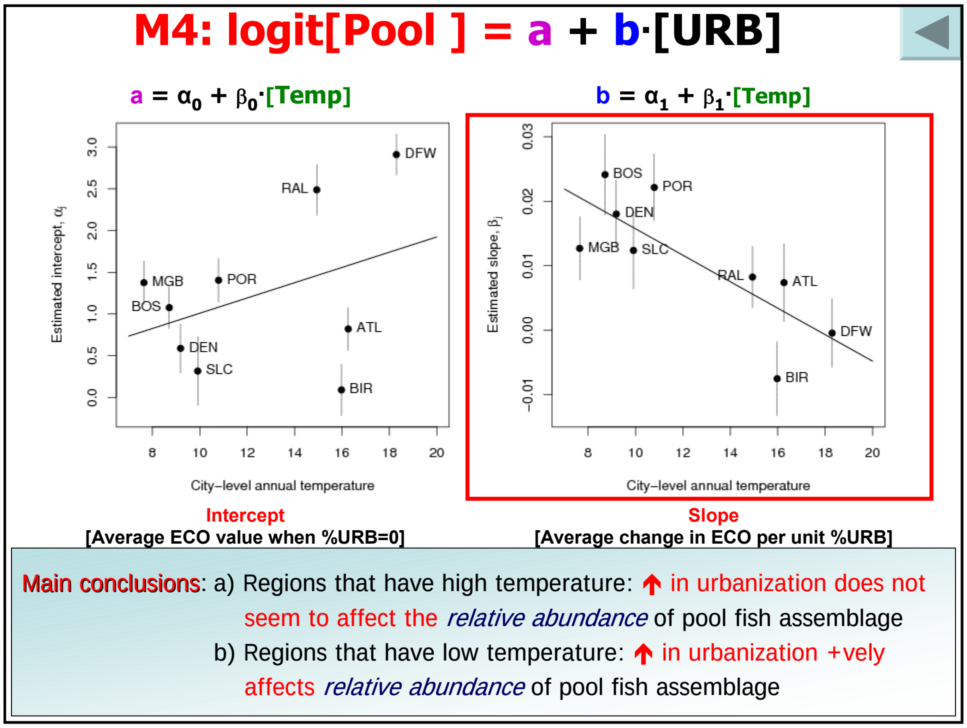
$a = \alpha_0 + \beta_0 \cdot$**[Drainage]**

$b = \alpha_1 + \beta_1 \cdot$**[Drainage]**

Intercept
[Average ECO value when %URB=0]

Slope
[Average change in ECO per unit %URB]

Main conclusions: Regions that have **large** drainage areas have larger *relative abundance* sand fish assemblage to start with



M4: logit[Pool] = a + b·[URB]

$a = \alpha_0 + \beta_0 \cdot$**[Temp]**

$b = \alpha_1 + \beta_1 \cdot$**[Temp]**

Intercept
[Average ECO value when %URB=0]

Slope
[Average change in ECO per unit %URB]

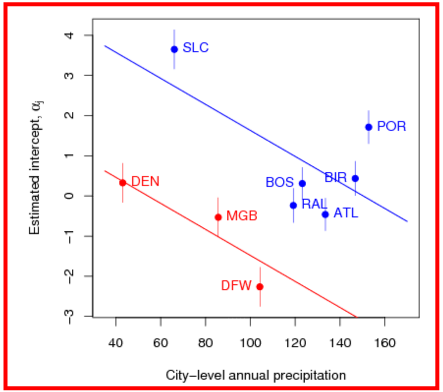
Main conclusions: a) Regions that have high temperature: ↑ in urbanization does not seem to affect the *relative abundance* of pool fish assemblage

b) Regions that have low temperature: ↑ in urbanization +vely affects *relative abundance* of pool fish assemblage

M3: logit[Coarse] = a + b·[URB]

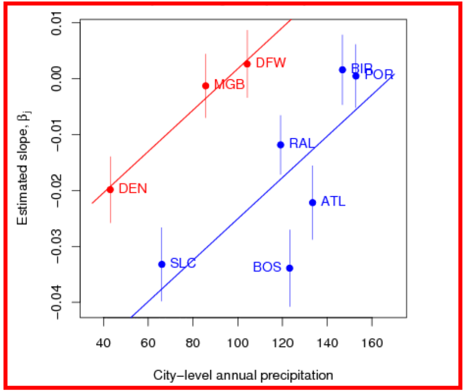
$a = \alpha_0 + \beta_0 \cdot [Prec] + \delta_0 \cdot [AG]$

$b = \alpha_1 + \beta_1 \cdot [Prec] + \delta_1 \cdot [AG]$



Intercept

[Average ECO value when %URB=0]



Slope

[Average change in ECO per unit %URB]

Main conclusions: L) **Ag background** regions: Lower *relative abundance* of coarse fish

L) Low precip regions have higher *relative abundance* of coarse fish assemblage

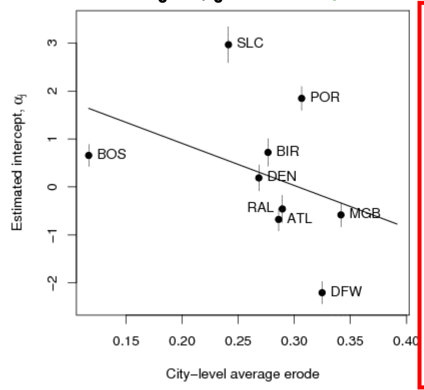
R) The **neg** impact of urbanization on coarse assemblage ↓ as precip ↑

R) Yet the impact is **more pronounces in non-Ag regions**

M4: logit[Coarse] = a + b·[URB]

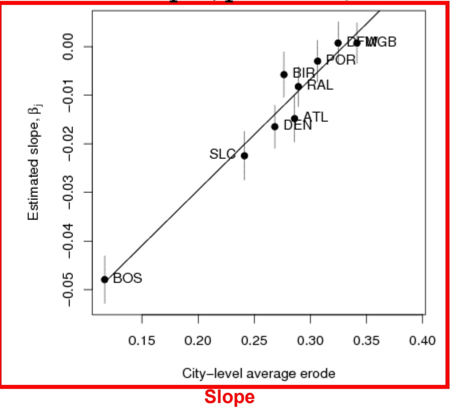
$a = \alpha_0 + \beta_0 \cdot [Erodibility]$

$b = \alpha_1 + \beta_1 \cdot [Erodibility]$



Intercept

[Average ECO value when %URB=0]



Slope

[Average change in ECO per unit %URB]

Main conclusions: With ↑ erodibility the neg impact of urbanization on coarse fish assemblages ↓ (with almost no impact at high levels)

Something "Fishy" with the Fish?

- **Hard to interpret results since:**
  - **All responses are in relative abundance**
    - **A decrease in the relative abundance of one parameter can only be explained relative to all the other (≠ Net Decrease)**
    - **Hard to define *"bad" versus "good"* assemblages**
  - **Fish are mobile with relatively long life spans**
  - **Collecting fish from streams is challenging**
  - **Too much intra-region variability:**
    - **Issues with connectivity**
    - **Introduced species**
- **Collapsing the initial substrate preferences into two groups (coarse vs fine) helped in providing some ecological explanations to the differences in responses between the regions**

Comparing the Results

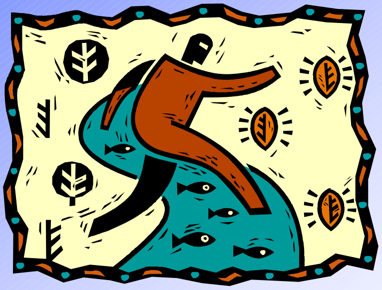
	Invertebrates	**Algae**	**Fish**
Main factors affecting variations in intercept	Precipitation Background Ag Erodibility	Temperature Background Ag % clay	Precipitation Background Ag Drainage basin area
Main factors affecting variations in slope			Precipitation Background Ag Drainage basin area Erodibility
The response of variables to urbanization	Good response	Moderate response	Weak response
Added value of multilevel models as compared to non-pooled regressions	Multilevel models helped explain patterns that were observed in no-pooling models	Multilevel models helped explain patterns that were observed in no-pooling models as well as the absence of patterns in some regions	Multilevel models helped in identifying interesting patterns that were not observed in no-pooling models. Yet the interpretation is hard

Conclusion & Future Work

- Invertebrate and algal responses to urbanization are clearer than fish
- **Hierarchical models** helped to explain differences in behavior across the US (the 9 study sites) by the inclusion of an additional regional level model ➔ better understanding of the impacts of urbanization and its interaction with background environmental parameters as well as pre-existing human induced disturbances
- Adoption of bio-monitoring programs are adequate to capture the impacts of urbanization on stream ecosystems

- **Validate** models by predicting ecological effects for regions where we have region-level predictor measures (Chicago, Anchorage, and Seattle)
- Incorporate additional variables and interactions; particularly taxa richness data for fish
- Use hierarchical multilevel models and Bayes nets to parameterize Biological Condition Gradient

THANK YOU



Research supported by United States Geological Survey.
Team members include: Gerald McMahon, Thomas Cuffney, Ken Reckhow, Song Qian, Roxolana Kashuba, Boknam Lee, Ibrahim Alameddine, Yoon Kyung Cha