Ecological responses of streams to urbanization: A review of results from the U.S. Geological Survey's urban streams studies

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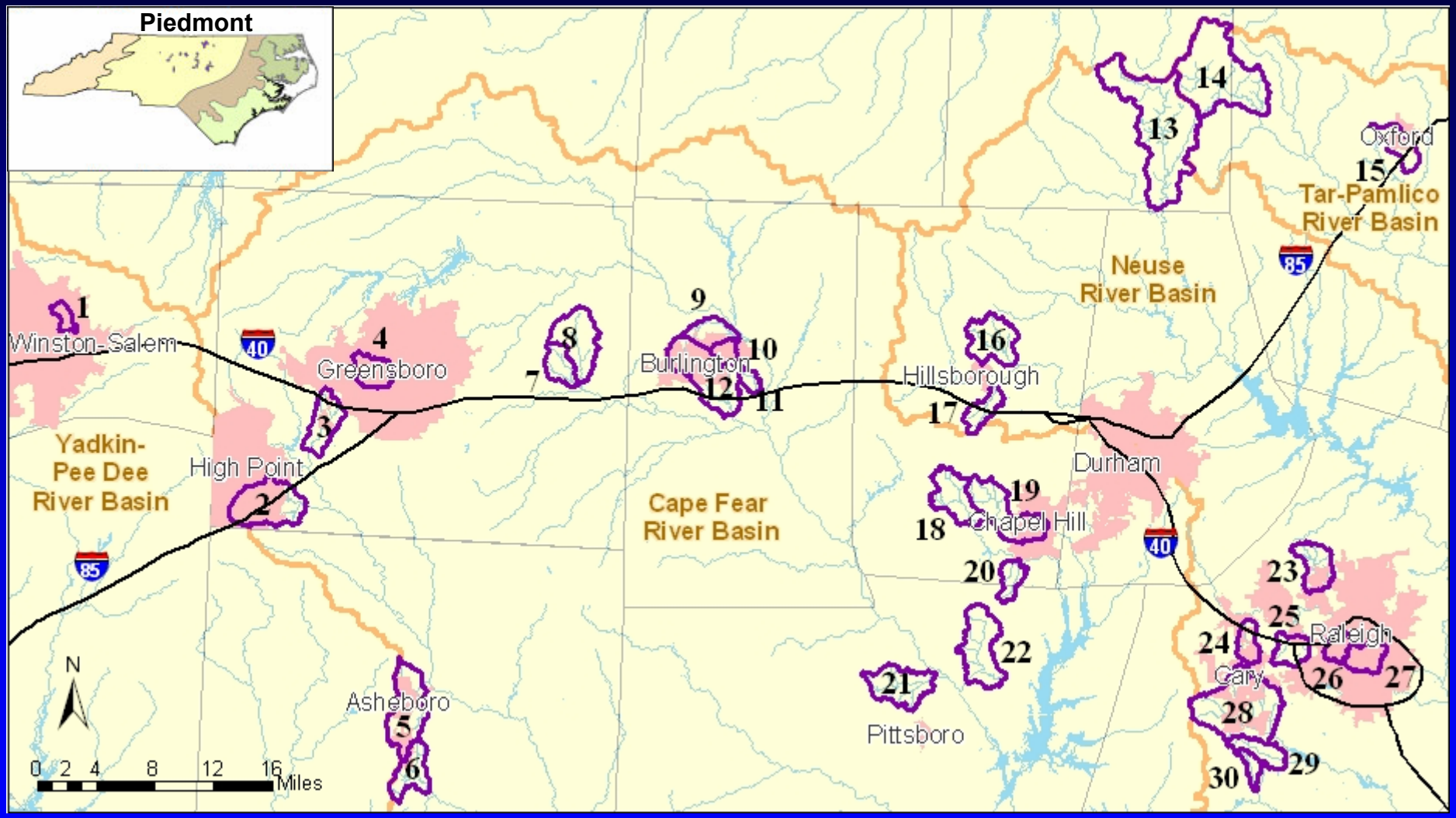
11 Urban Stream Studies

USGS

Raleigh Urban Study Area



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Objectives:

1. **Define biological, physical, and chemical responses to urbanization across conterminous US. -- *What measures best depict urban effects (monitoring)?***
2. **Identify the primary environmental factors associated with these responses. *– What factors can be changed to mitigate urban effects (planning and remediation)?***
3. **Compare how responses and driving factors change across the US. *– Can urban effects be managed using national criteria or are regional or local criteria required (management and legislation)?***

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Representing urban intensity: urban intensity index (UII)

Index based on land-cover, population, infrastructure and socioeconomic factors correlated with changes in population density

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Urban variables positively correlated with population density

	East		Central		West	
Variable	Atlanta	Raleigh	Dallas	Milwaukee	Denver	Portland
Household density	X	X	X	X	X	X
Density of housing units	X	X	X	X	X	X
Road density	X	X	X	X	X	X
Urban lands in basin (%)	X	X	X	X	X	X
Impervious surface (% basin)	X	X	X	X	X	X
Popl'n in urban areas (%)	X	X	X	X	X	X
Urban lands in riparian (%)	X	X	X	X	X	X
Impervious surface (% riparian)	X	X	X	X	X	X
Housing - utility gas (%)	X	X	X	X		X
Housing - renter occupied (%)		X				X

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Urban variables negatively correlated with population density

	East		Central		West	
Variable	Atlanta	Raleigh	Dallas	Milwaukee	Denver	Portland
Popl'n in rural area (%)	X	X	X	X	X	X
Heat with LP gas (%)	X	X	X	X	X	X
Heat with wood (%)	X	X	X	X	X	X
Forest (% basin)	X	X				X
Shrubland (% basin)	X	X	X			X
Grassland (% basin)	X	X	X		X	
Ag/pasture (% basin)		X		X	X	
Forest (% riparian)	X	X				X
Shrubland (% riparian)		X	X			X
Ag/pasture (% riparian)		X		X	X	

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Urban intensity index (UII)

Raleigh Example:

Census variables:

2000 population density

Household density

National Land-cover Data:

% of basin in developed lands

% of stream buffers in developed lands

Infrastructure:

road density

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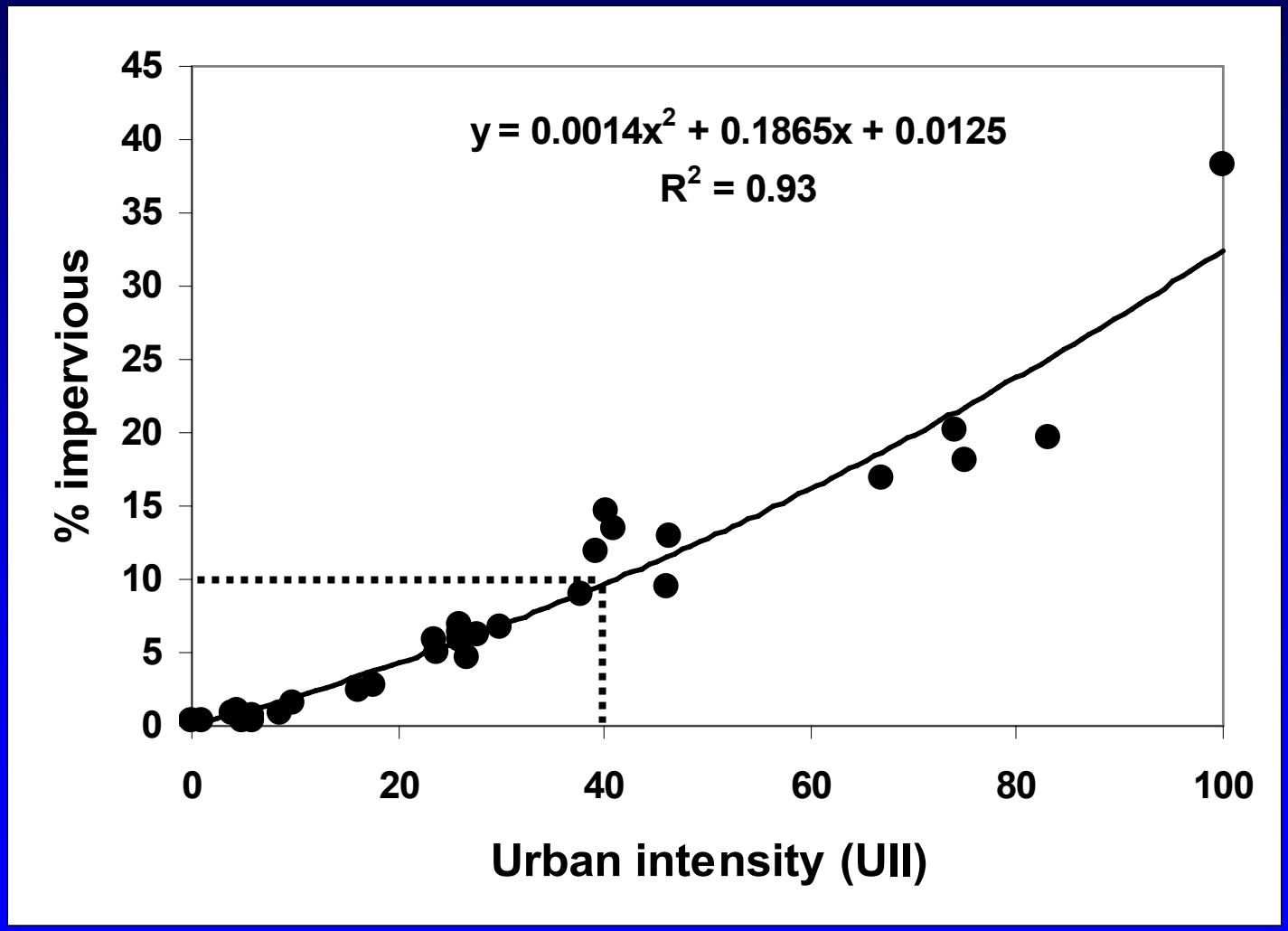
% Impervious and Urban Intensity index (UII) -- Atlanta



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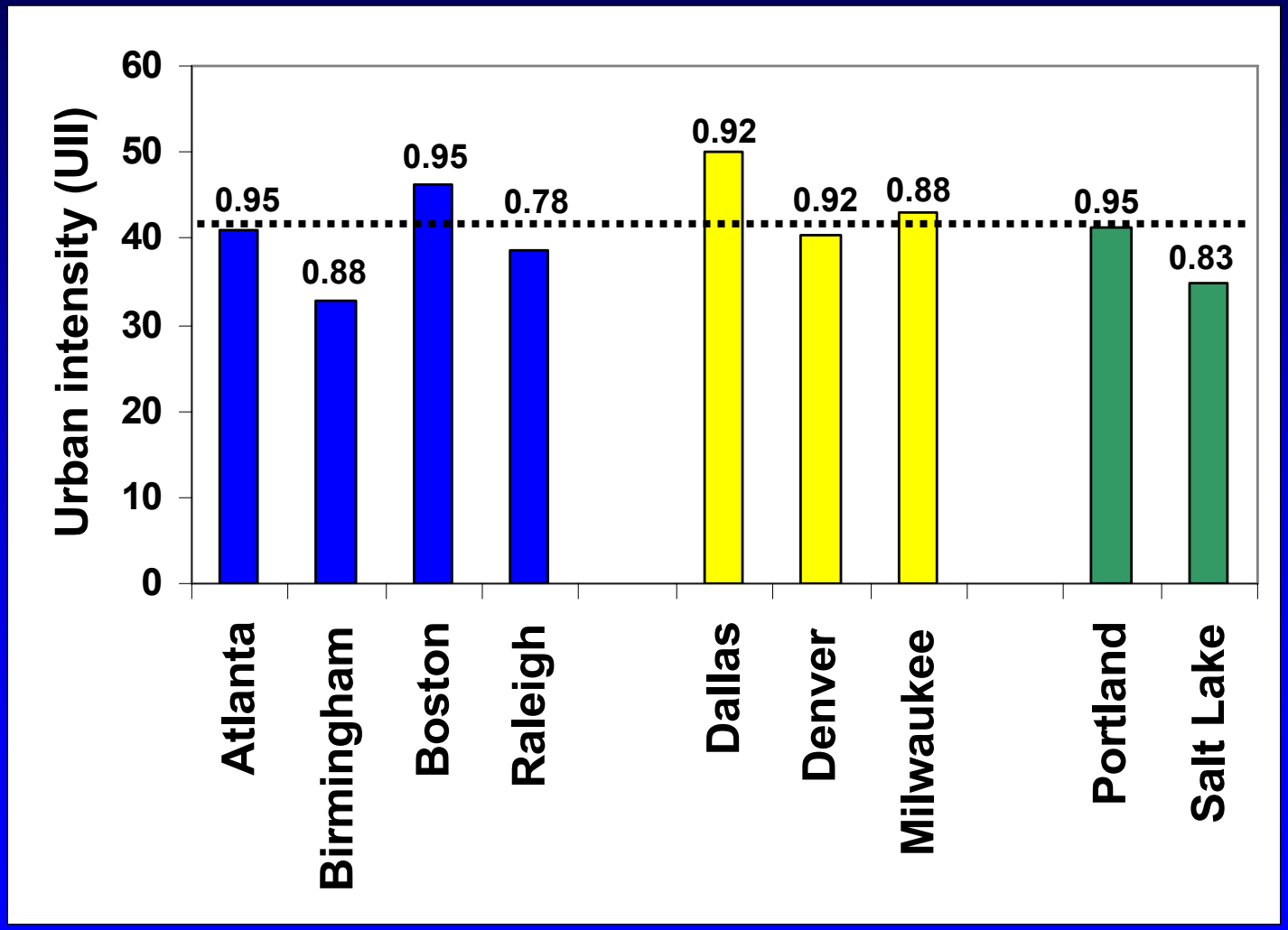
Urban intensity (UII) at 10% impervious surface



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Biological responses to urbanization

Fish, Invertebrates, and Algae

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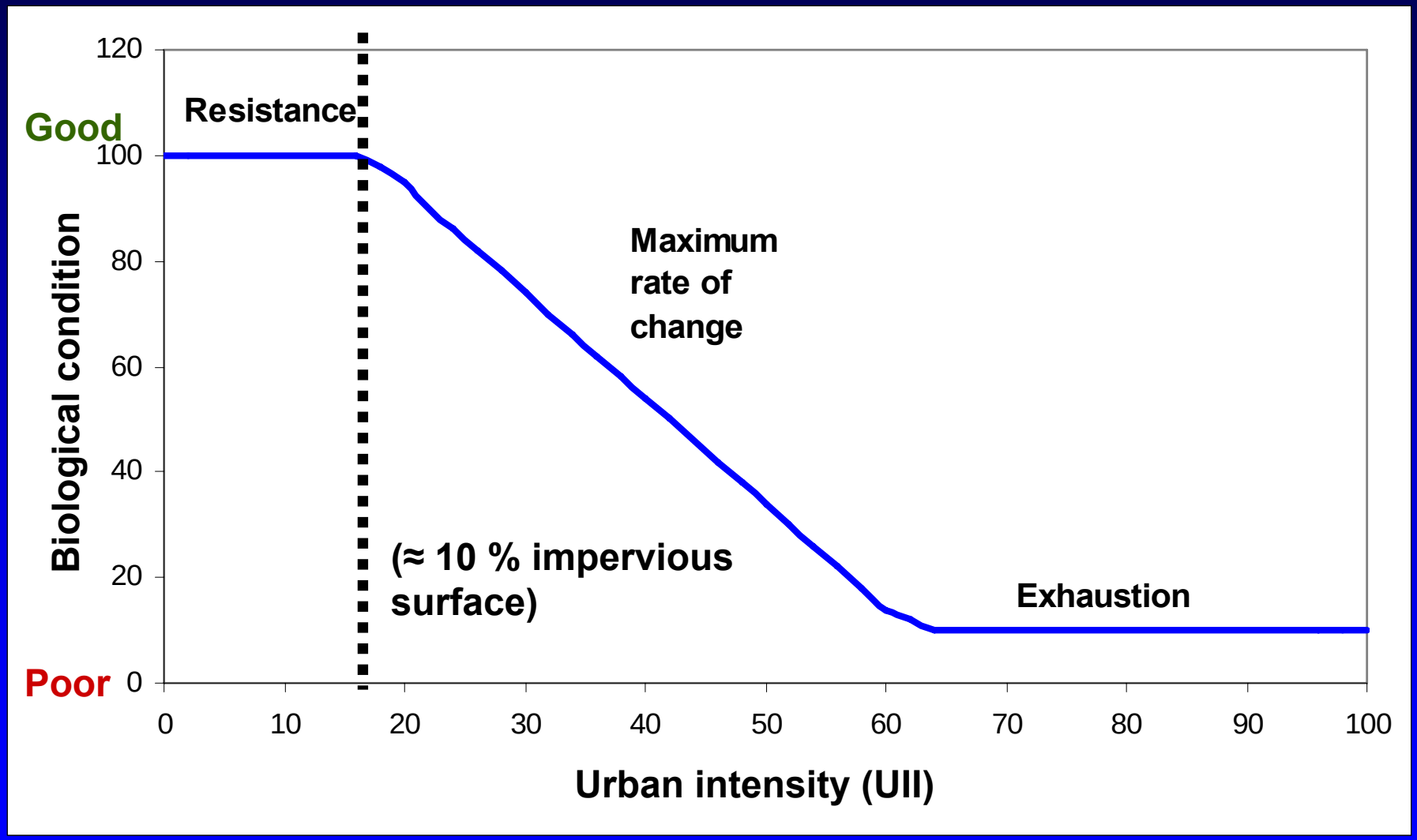
Expected response



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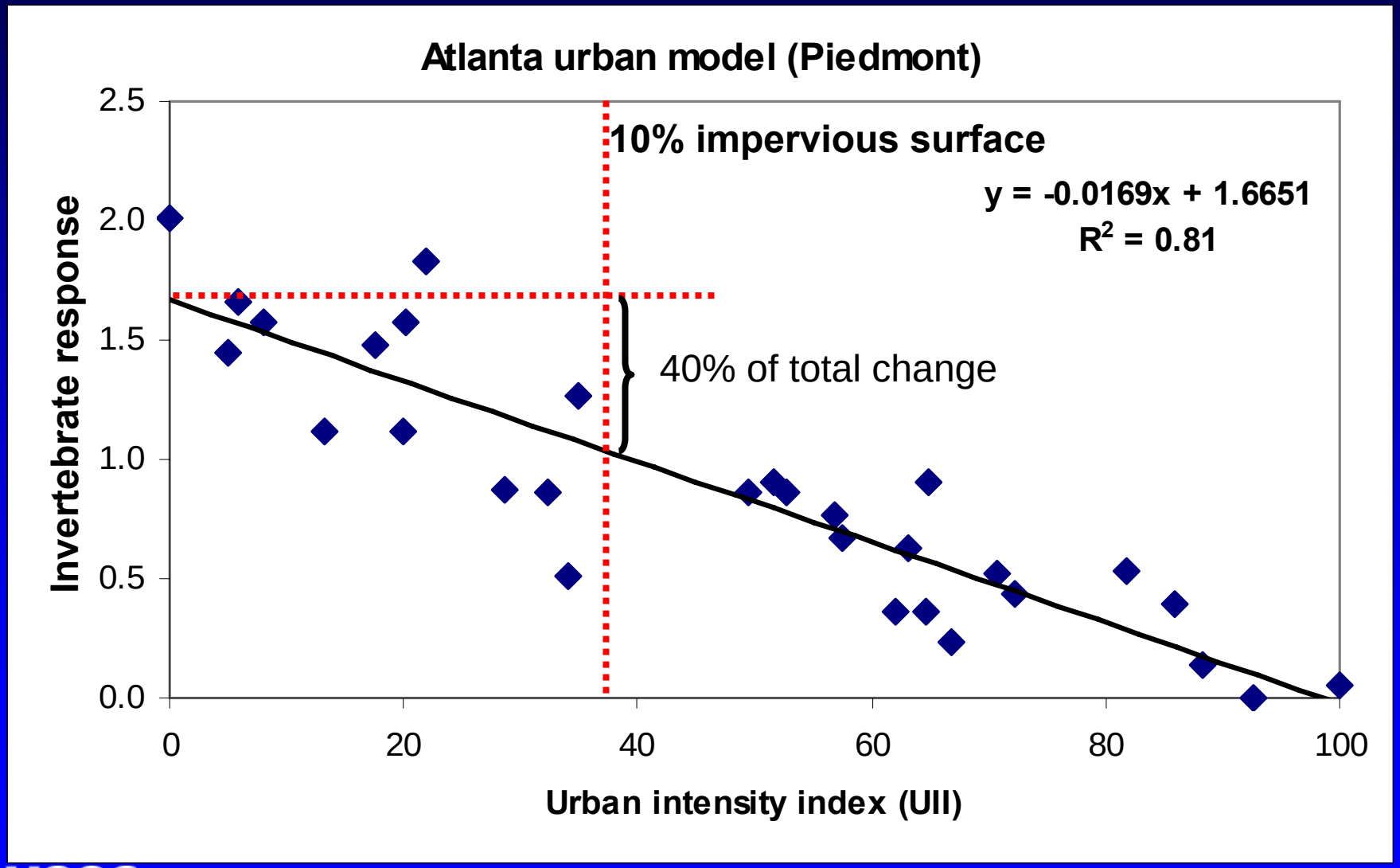
Typical response (Inverts Atlanta)



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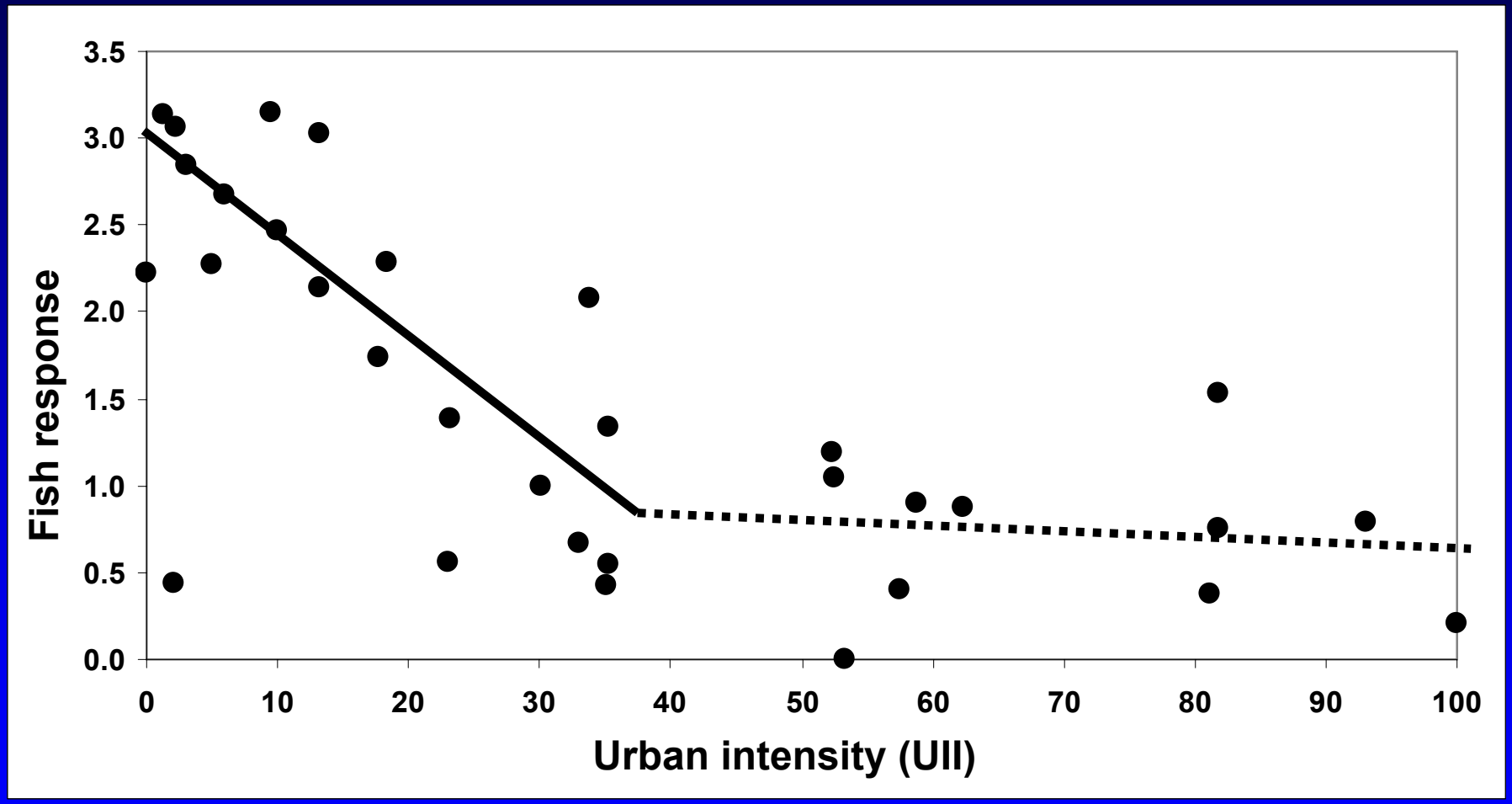
Boston Fish: Exhaustion



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Invertebrates responses to urbanization (Y = a + b*UII) across US

Region	City	b	R^2	P
East				
	Atlanta	-0.017	0.70	< 0.001
	Birmingham	-0.017	0.63	< 0.001
	Boston	-0.017	0.82	< 0.001
	Raleigh	-0.016	0.73	< 0.001
Central				
	Dallas/Fort Worth	-0.007	0.16	0.023
	Milwaukee	-0.009	0.20	0.007
West				
	Denver	-0.007	0.22	0.008
	Salt Lake City	-0.015	0.47	< 0.001
	Portland	-0.016	0.57	< 0.001

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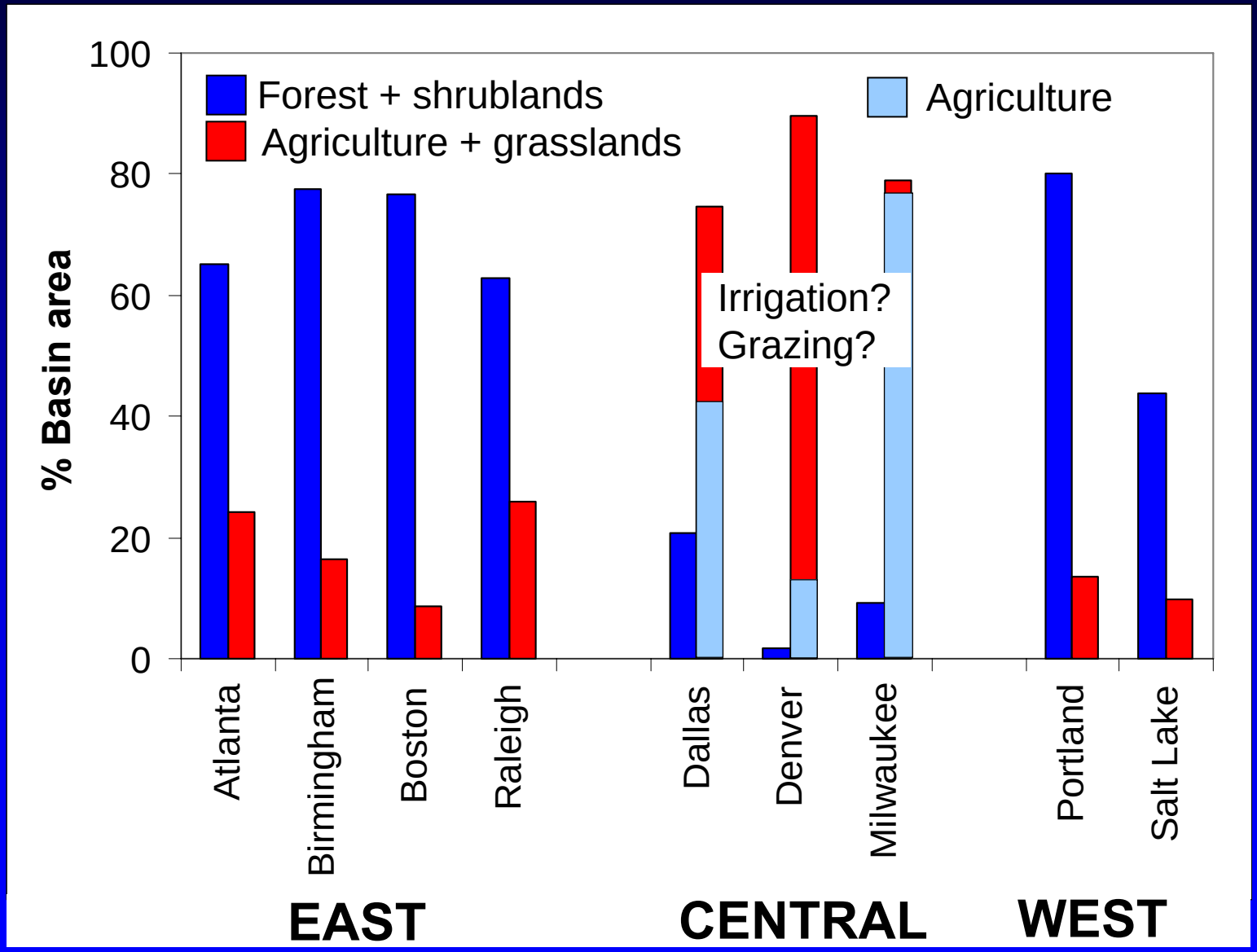
Land cover at “background” sites: UII < 20



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Summary of biological responses to urbanization (UII)

- **Significant relation between urban intensity and biological degradation.**
  - **Invertebrates are the strongest and most consistent indicators.**
  - **Algae and fish responses are more variable.**
  - **Relations were strongest when urbanization involved conversion of forest or shrub lands.**
  - **Relations were weakest when urbanization involved conversion of agricultural or grass lands.**
- **Little evidence for resistance to urbanization (no initial threshold).**

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Changes in water chemistry associated with urbanization and biological responses

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Chemical trends with urbanization

- **Conductivity** ↑↓
- **Pesticides:**
  - **Number detected** ↑↓
  - **Total concentration** ↑↓
  - **Pesticide index** ↑↓
- **Nutrients:** ↑↓ ↓

↑ **Chemistry** ↑ **Invertebrates**

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Chemical trends with urbanization (continued)

- **Polycyclic aromatic hydrocarbons (PAH):**
  - **Number detected** ↑ ↓
  - **Total concentration** ↑ ↓
- **Very few instances where human or aquatic life standards were exceeded.**
- **Relations with urbanization were also affected by presence of agriculture and grasslands (Central: Dallas, Denver, Milwaukee).**

↑ **Chemistry** ↑ **Invertebrates**

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Hydrologic changes associated with urbanization and biological responses

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Hydrologic change	Relations with Invertebrate condition	Relations with Increasing urbanization
↑ Flow variability	↓	↑
↑ Duration of high flows	↑	↓↑

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Key Findings from Urban Studies

1. **Degrades biological communities:**
   a. **Invertebrates are "best" biological indicator.**
   b. **No level of urbanization without an effect.**
2. **Increases chemical contamination:**
   a. **Number and conc. of pesticides.**
   b. **Number and conc. of PAH's.**
3. **Modifies hydrology**
   a. **Increases flashiness.**
   b. **Decreases duration of peak flows in many urban areas, but not all.**

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Key Findings (continued)

4. **Factors associated with urban degradation that may be useful for mitigation:**
   a. **Decrease effects of road density in basin.**
   b. **Decrease effects housing density in basin.**
   c. **Restore forest and shrub lands (basins and buffers).**
   d. **Restore connection between precipitation, ground water, and surface water (restore normal hydrology).**

5. **Responses vary geographically:**
   a. **East = West in biological (invertebrate) responses.**
   b. **≠ Central (agriculture + grasslands).**
   c. **Extent of "background" degradation affects how biology and chemistry respond to urbanization.**
   d. **Regional approaches to management and legislation may be required.**

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