Maryland Biological Stream Survey:

Improving Indicators

What is it like now?

Is it getting worse or better?

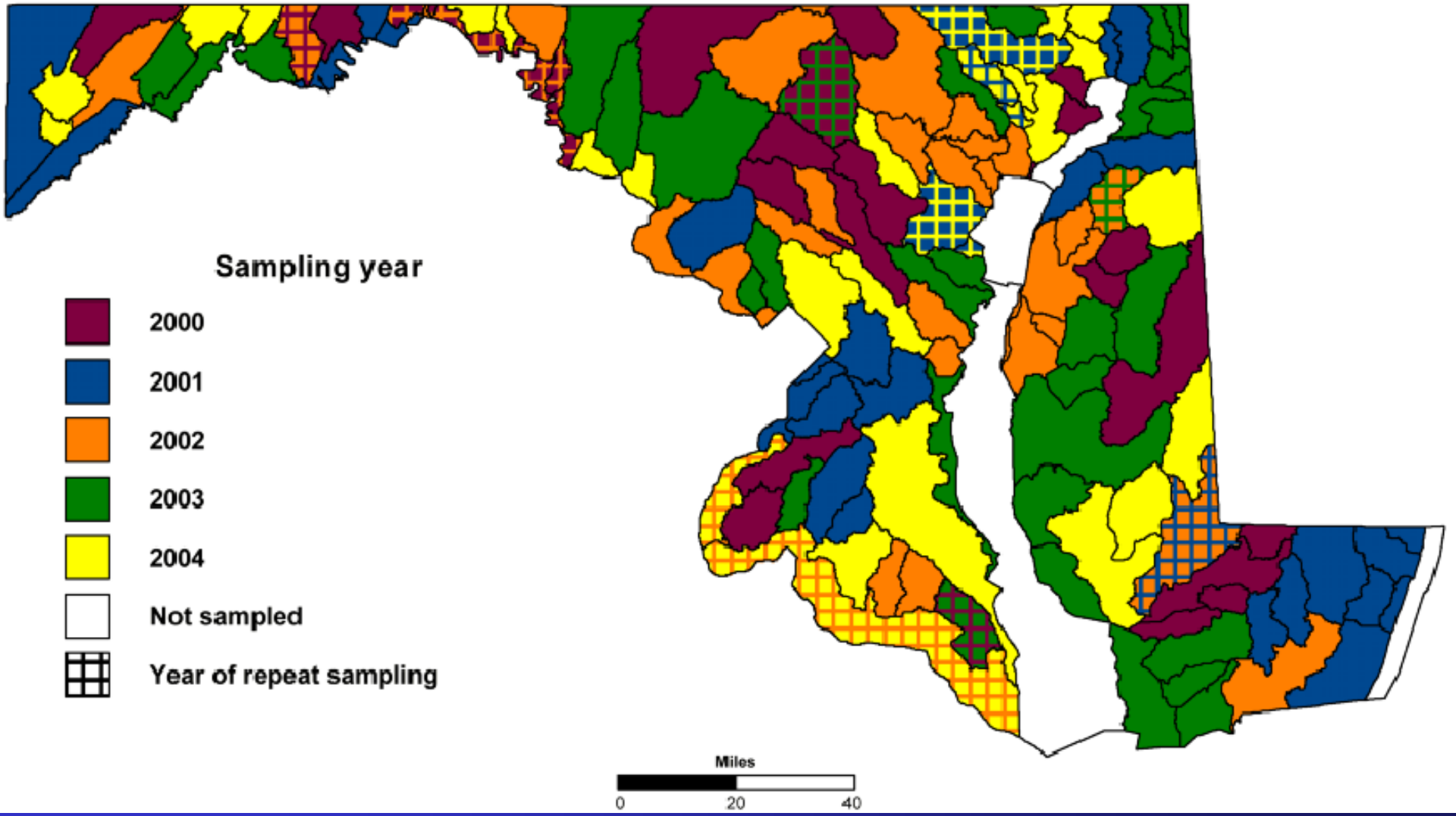
What biological resources do we have?

What areas deserve our highest protection?

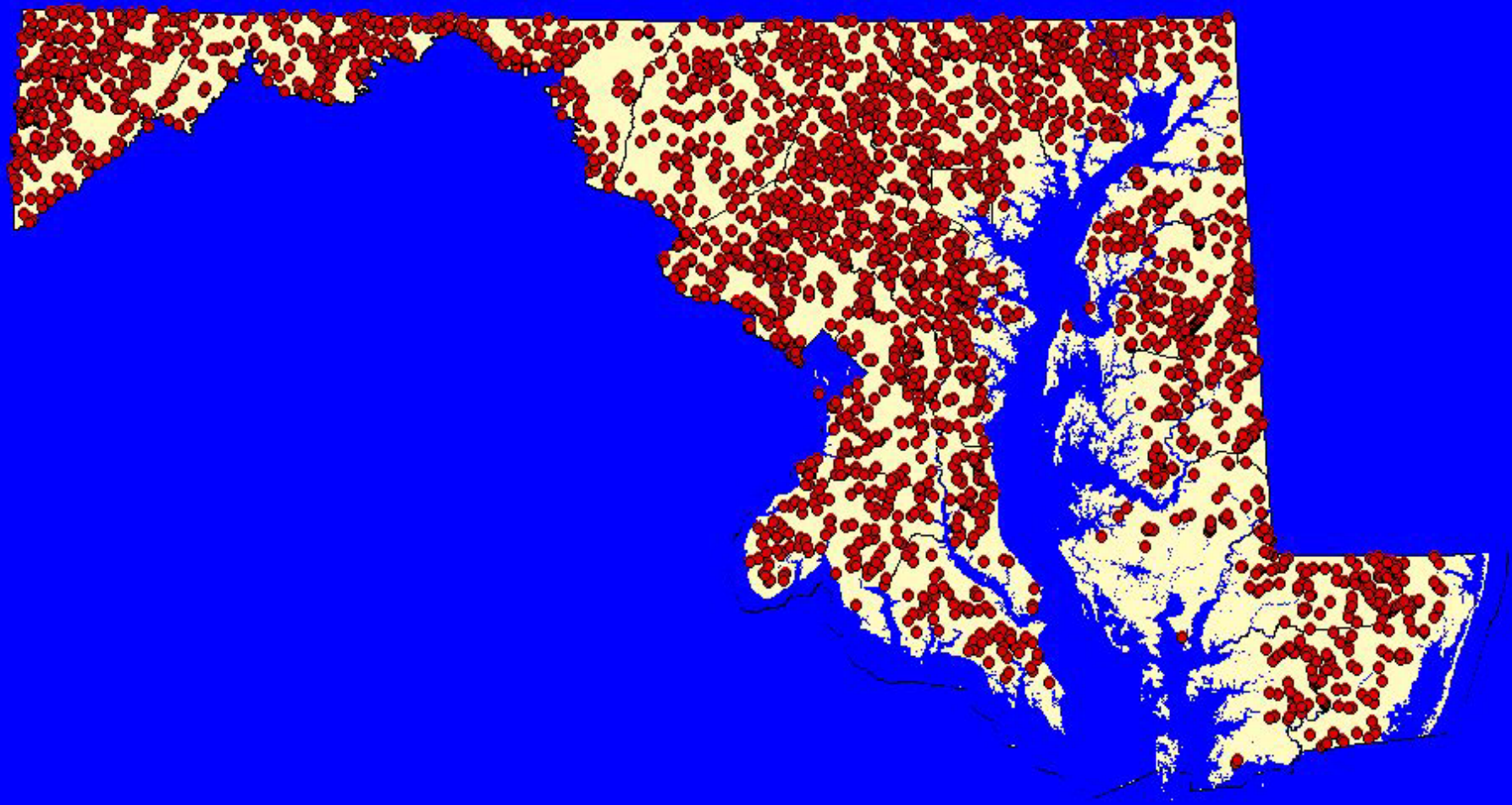
How do we keep it from getting worse?

What do we fix & Where?

How much $$$$???


Sampling year
2000
2001
2002
2003
2004
Not sampled
Year of repeat sampling
Miles
0
20
40

MBSS Sites 1994-2003



MBSS Sentinel Site Network

How much change should we expect between years?

Keep an eye on the best remaining streams

Stream Waders

STATE OF MARYLAND

DEPARTMENT OF NATURAL RESOURCES

Volunteer

Benthic Sample Collection by Trained Volunteers

Lab analysis by DNR staff

Water Quality


Physical Habitat

Benthos

Fish

Groups Using MBSS Methods:

7 of 23 Counties & Baltimore City

2 State Agencies & MNCPPC

3 Colleges

Smithsonian (SERC)

US Fish & Wildlife Service

National Park Service

US Army Corps of Engineers

Ferraro, Italy

Almost half of Maryland streams are in POOR condition

Good

Fair

Poor

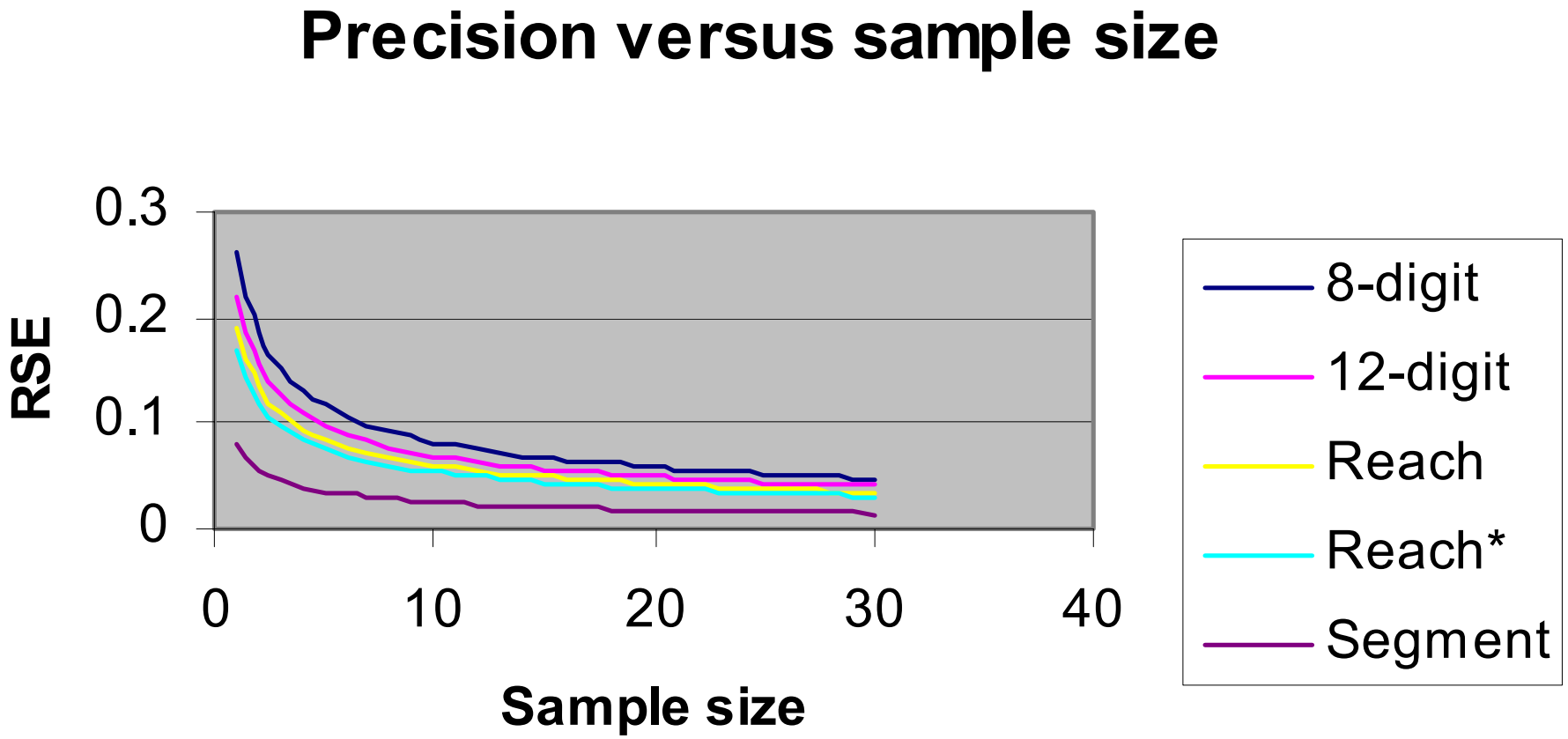
0

50

100

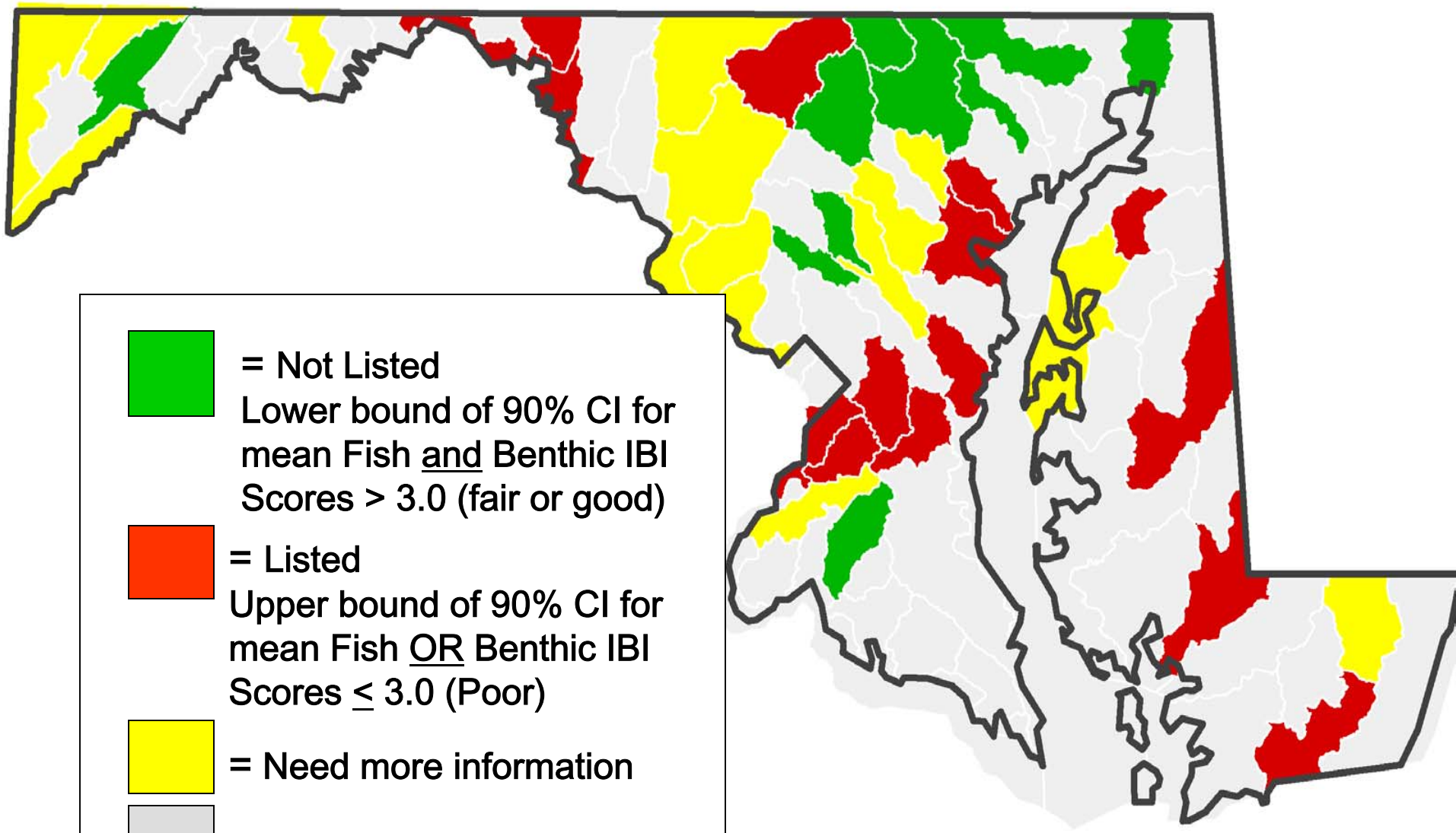
% Stream Miles

Relative standard error BIBI



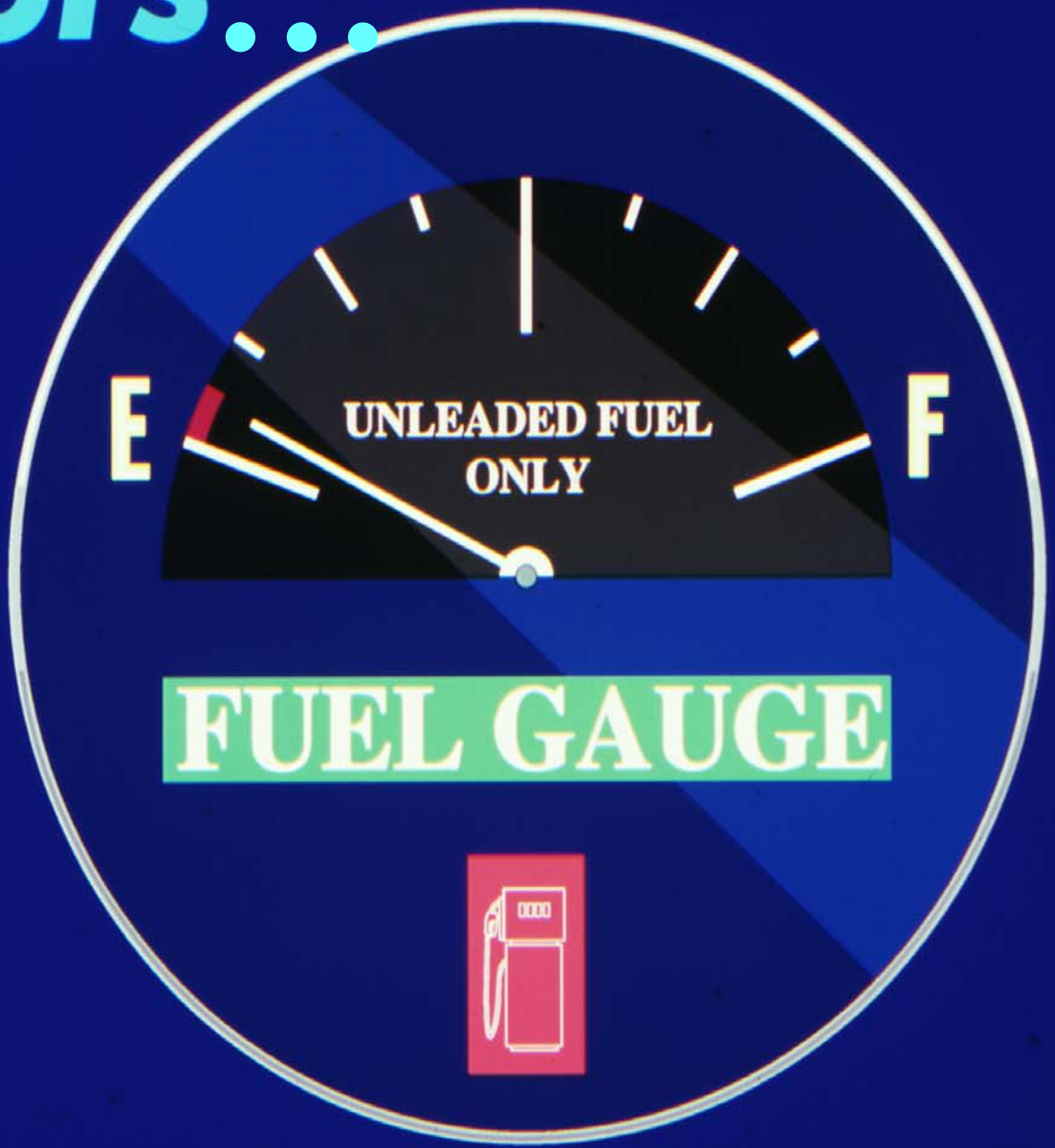
Biocriteria - 303D Listing

Watersheds sampled during 2000-2002



Indicators...

What we have now

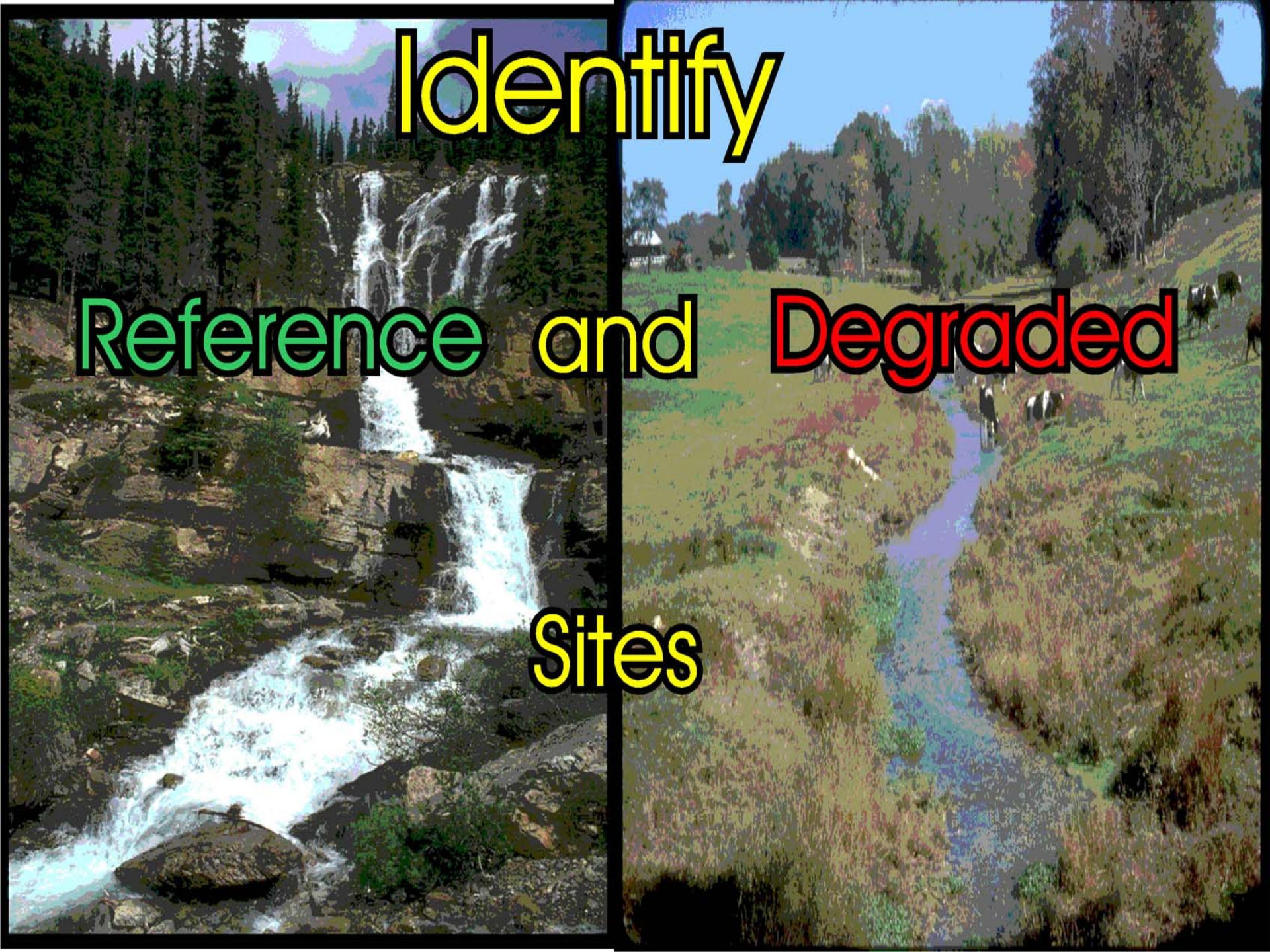


Multimetric Indicators

Fish Assemblage

Benthic Macroinvertebrate Assemblage

Physical Habitat Index


Identify
Reference and Degraded
Sites

CRITERIA FOR REFERENCE SITES

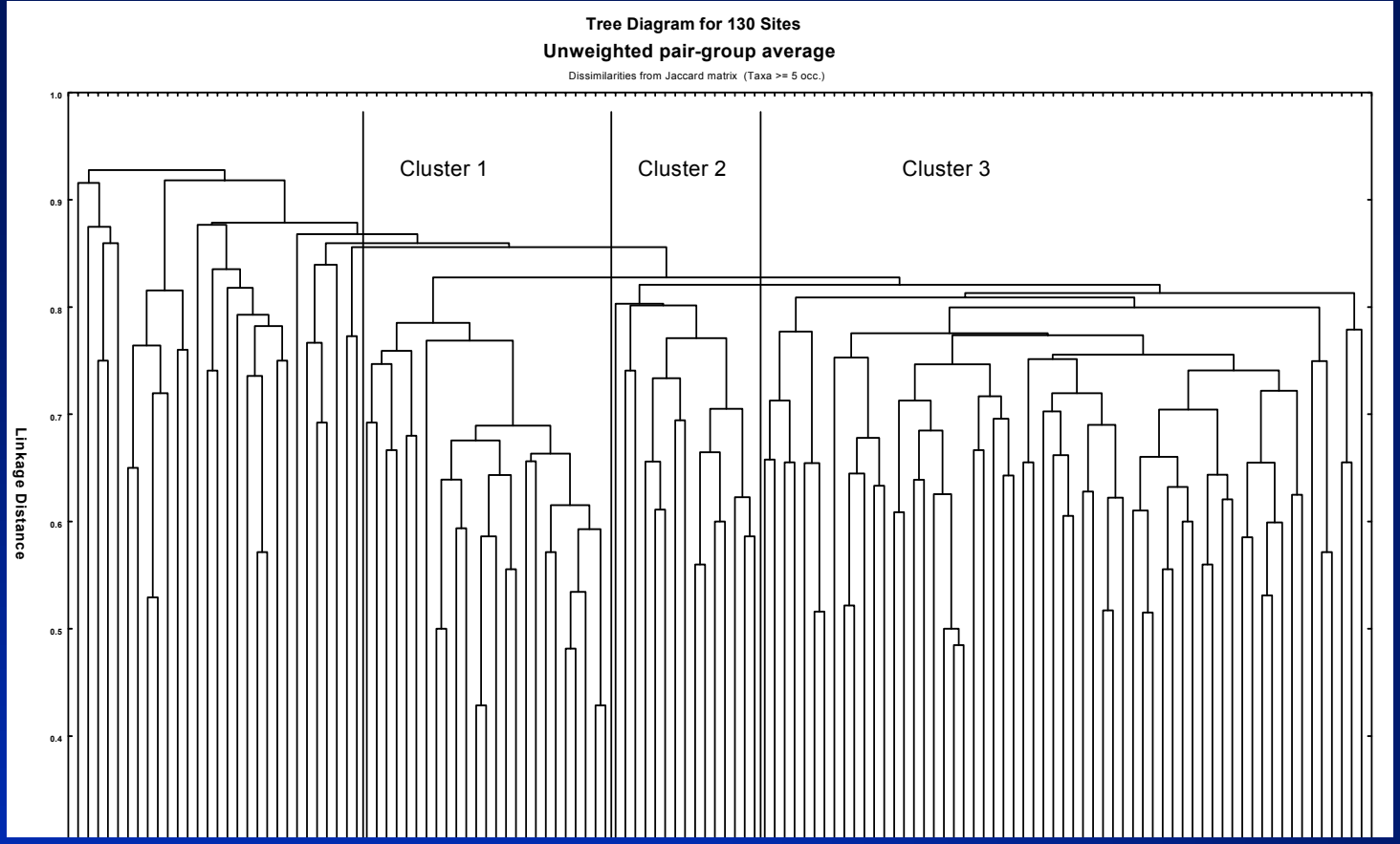
- pH > or = 6 or (DOC > or = 8 mg/L)
- ANC > or = 50 mg/L
- DO > or = 4 ppm
- NITRATE < or = 4.2 mg/L
- REMOTENESS SCORE > 10
- AESTHETICS SCORE > 10
- RIPARIAN BUFFER WIDTH > or 15 m
- INSTREAM HABITAT SCORE > 10
- NO CHANNELIZATION
- NO POINT SOURCE DISCHARGES
- URBAN LAND USE < or = 20%
- FORESTED LAND USE > or = 25%

Criteria For Degraded Sites

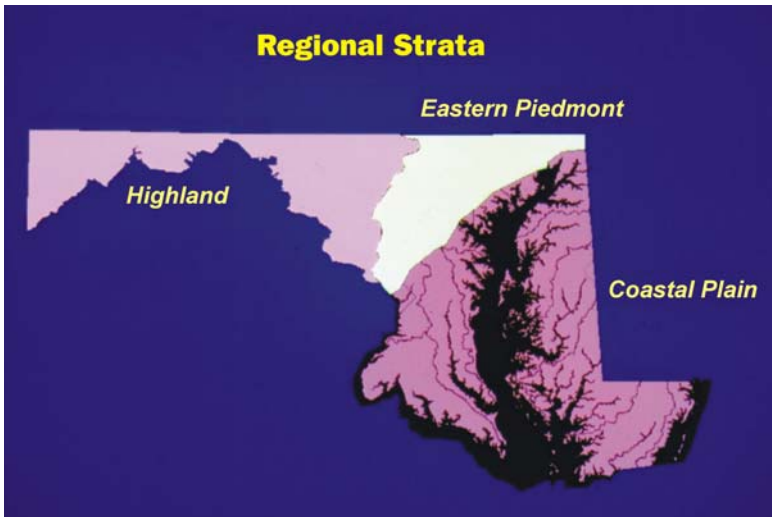
- pH < or = 5 and ANC < or = 0 and DOC < or = 8
- DO < or = 1.5 ppm
- Nitrate > 7 mg/l and DO < 3 ppm
- Instream Habitat < 6 and Bank Stability <6
- Instream Habitat < 6 and Channel Alteration < 6
- Instream Habitat < 6 and Urban Land Use > 50%

MBSS REFERENCE WATERSHEDS (1994 - 1997)

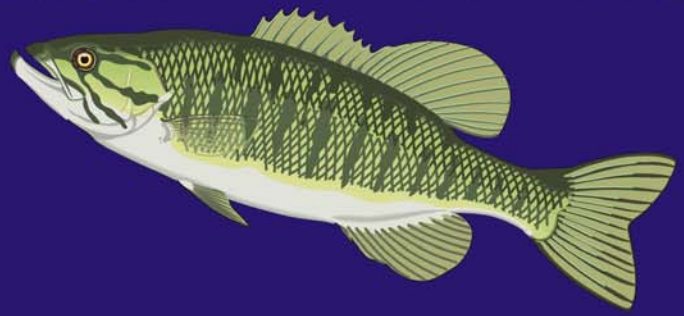
Determine stratification based on biological assemblages

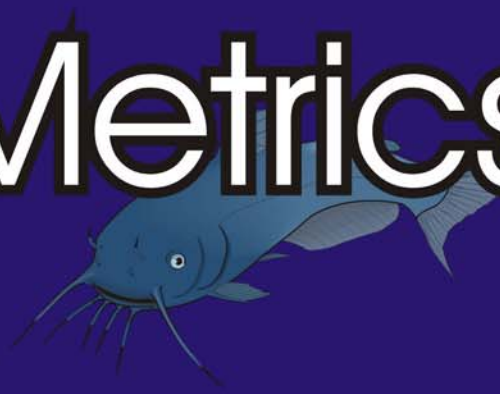


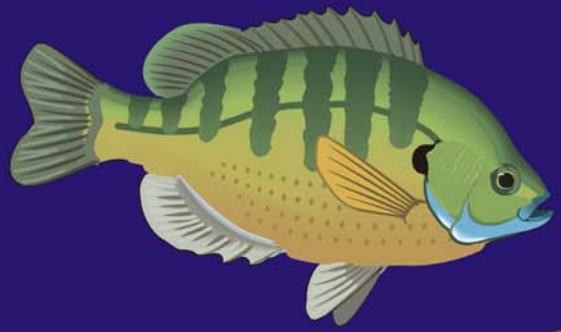
Cluster Analysis

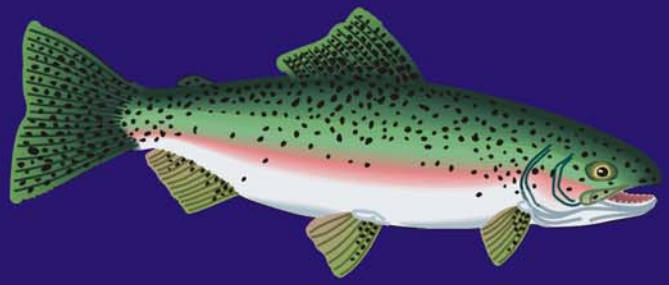


List Candidate Metrics



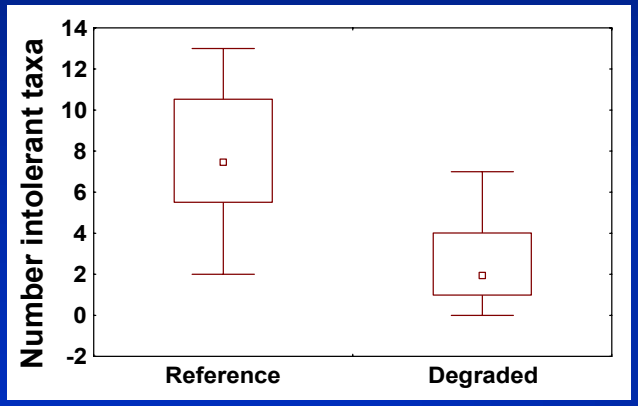




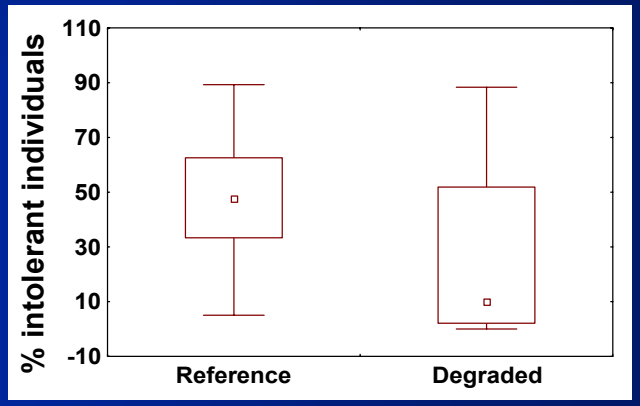


Test Candidate Metrics

Metric Responses



Strong



Weak

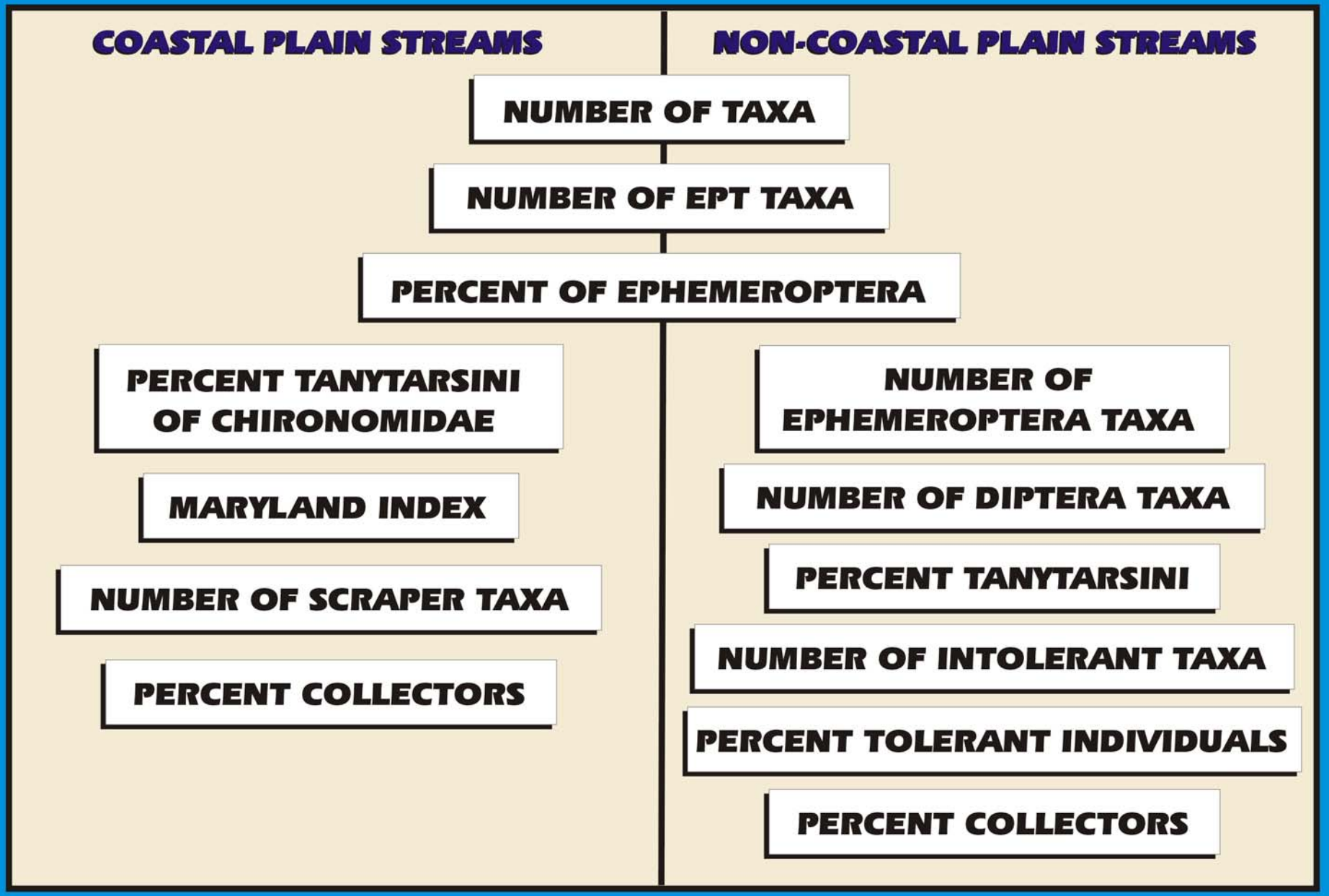
Index Validation using independent set of data

Fish IBI Metrics

	Coastal Plain	Piedmont	Highlands
# Native Spp.*	X	X	
# Benthic Spp.*	X	X	X
# Intolerant Spp.	X	X	X
% Tolerant Fish	X	X	X
% Abund. Of Dom Spp.	X	X	X
% Gen., Omni., & Invert.	X	X	X
# Indiv/m^2	X	X	
Biomass (g/m^2)	X	X	
% Lithophilic Spawners		X	
Insectivores			X

* adj. by watershed area

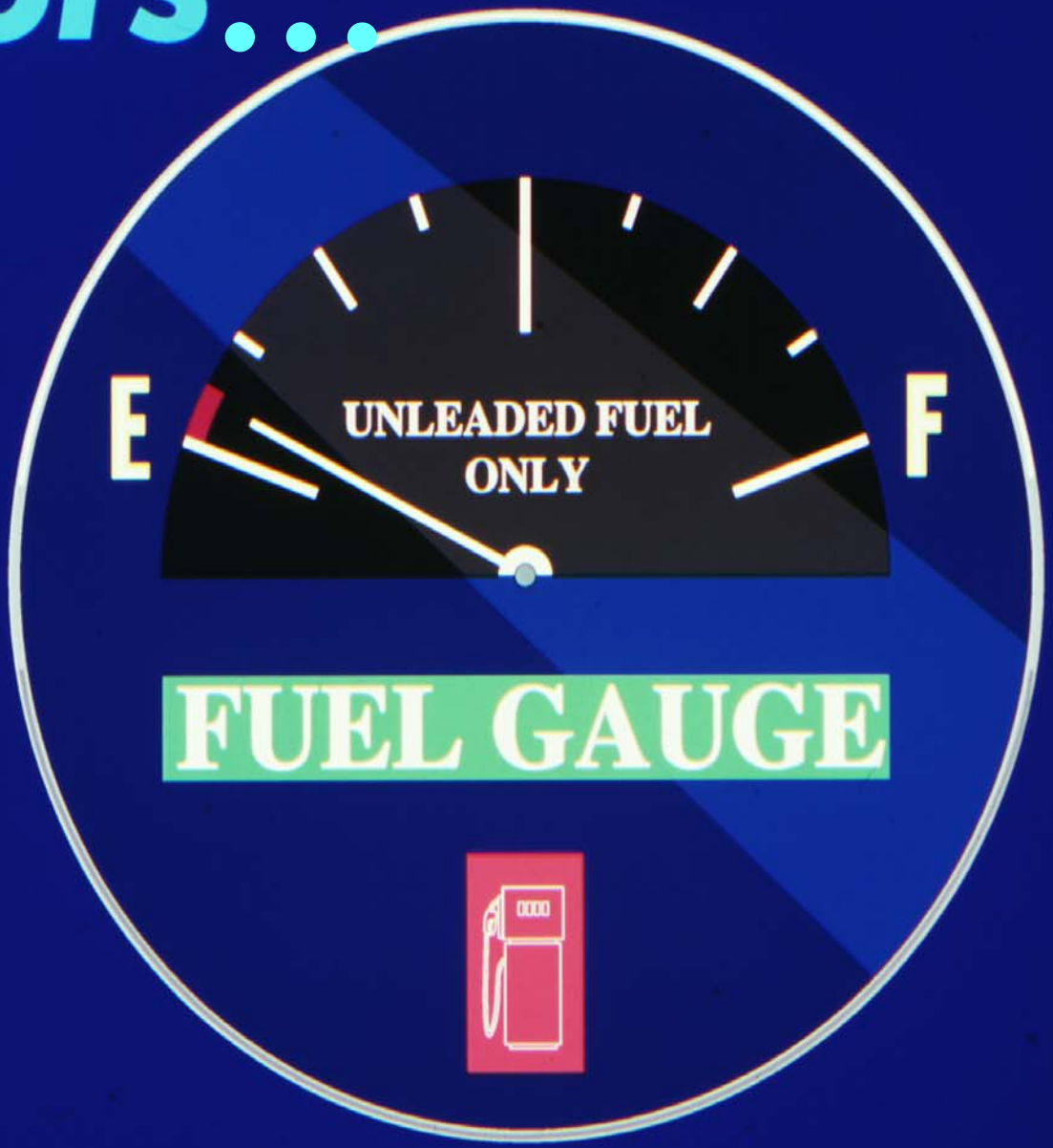
MD BENTHIC MACROINVERTEBRATE IBIs



Good	**4.0- 5**	**Comparable to reference streams**
Fair	**3.0-3.9**	**Some aspects of biological integrity may not resemble the qualities of reference streams**
Poor	**2.0-2.9**	**Significant deviation from reference**
Very Poor	**1.0-1.9**	**Strong deviation from reference indicating severe degradation.**

Indicators...

Can we improve them?



Cautions

Comparison with historical data

Usage by other programs

Death by 1000 changes

Explaining changes in condition

Issues

Reference conditions

Scale for scoring

Metric improvement

Small streams

Unique habitats & biota

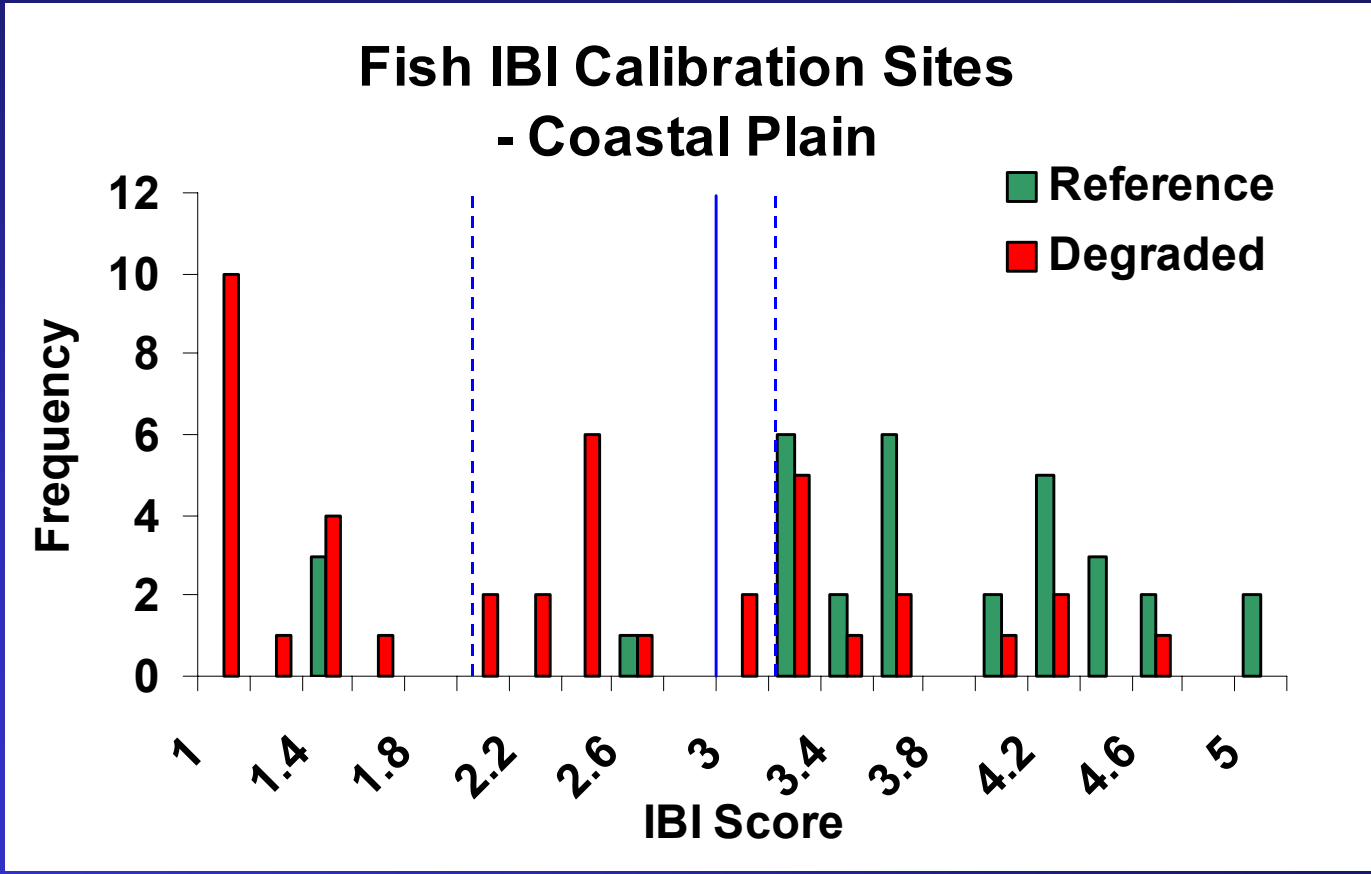
Combining assemblages

Small stream habitat evaluation

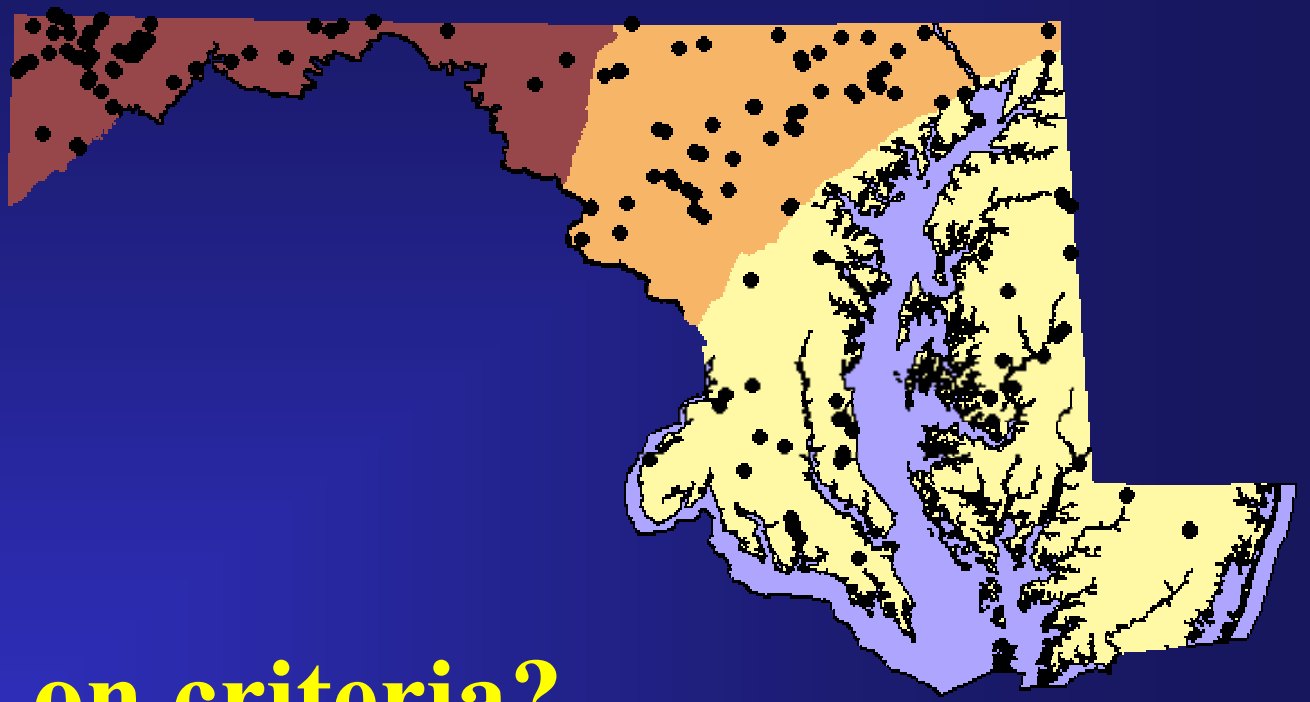
Local zoogeography

Reference Conditions

Fish IBIs at Reference and Degraded Sites – Coastal Plain



Regional modification?



Restrictions on criteria?

Urban land use: from <20% to <5%

Forest land use: from >25% to >35%

Riparian buffer width: from 15 to 30 m

Scale for scoring

1 to 5 scores -- based on 1, 3, 5 metric scoring convention

Continuous scaling for metrics allows for greater discrimination

0 to 100 scale more familiar to public

Metric Improvement

Pollution tolerance values

Confluence effects

Physical habitat-based FIBI metric

Anomalies

Effect of watershed size on BIBI

Benthic Macroinvertebrate Stressor Tolerance Values for Maryland

- Purpose of tolerance values (TV)
  - Estimate of capacity to survive & reproduce when stressors present
- Need for revision of Maryland's TV
  - Sources often undocumented
  - Largely BPJ-based

Process

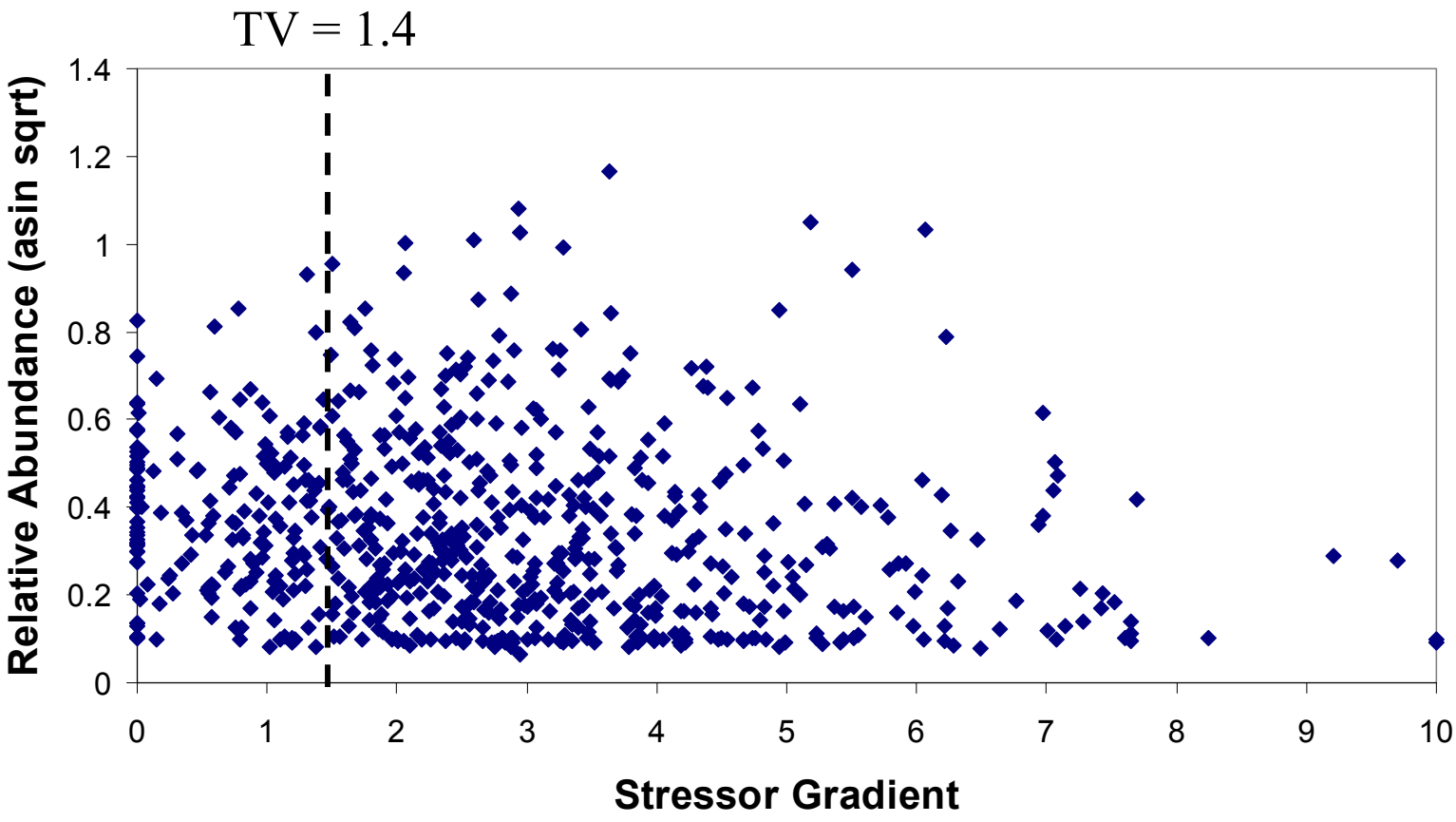
- Step 1 - principal components analysis (PCA) to identify stressors
- Step 2 - associate relative abundance of each taxon with site stressor score (PCA)
- Step 3 - calculate TV (abundance weighted average) at point along gradient of maximum relative abundance

Results

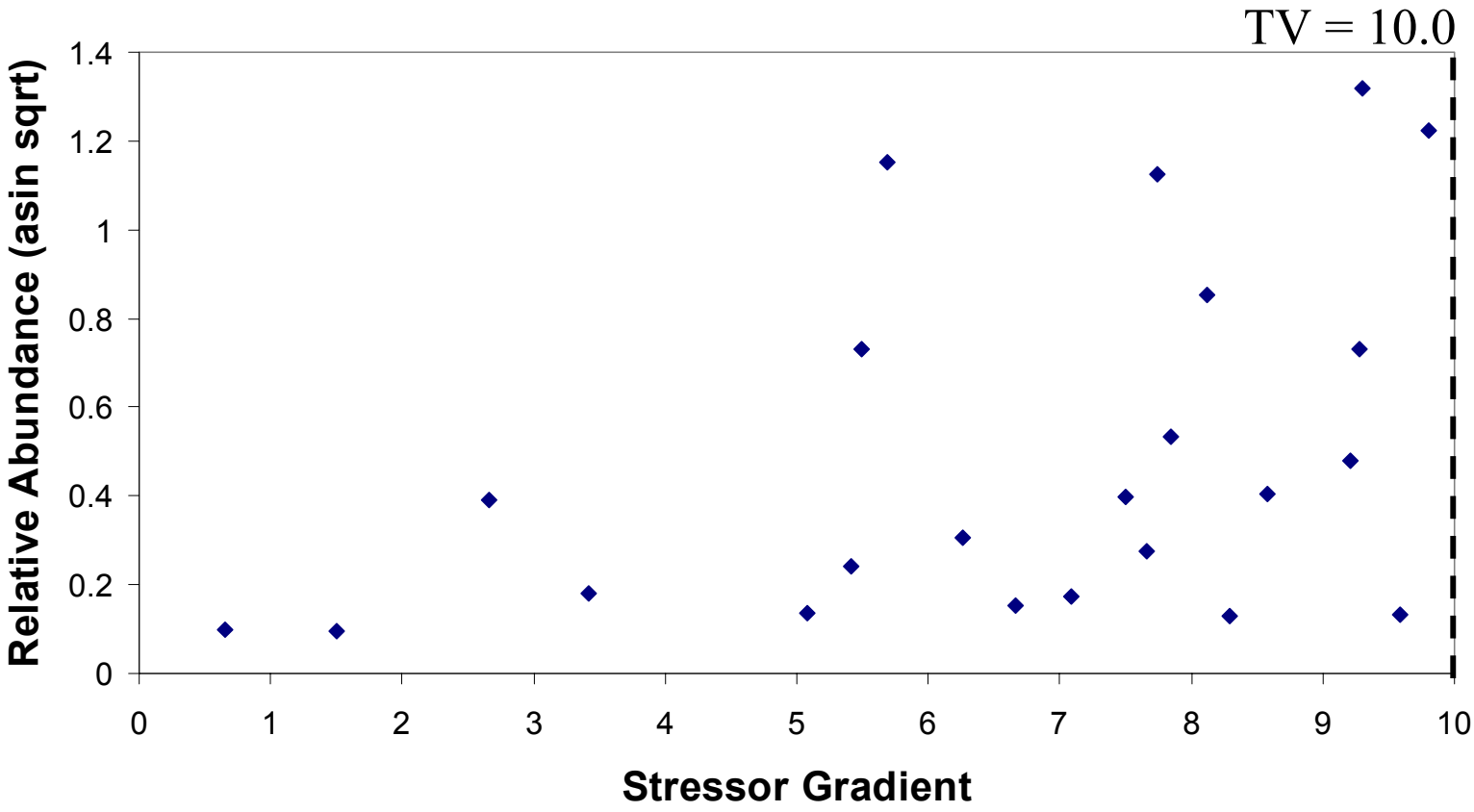
- **Stressor gradient** consists of single axis comprising
  - Instream habitat
  - Epifaunal substrate
  - Trash rating
  - % urban land use
  - Conductivity
  - Sulfate
  - pH

- TVs calculated only for taxa occurring at >10 sites
- Revised TVs developed for 336 out of 563 taxa

Ephemerella

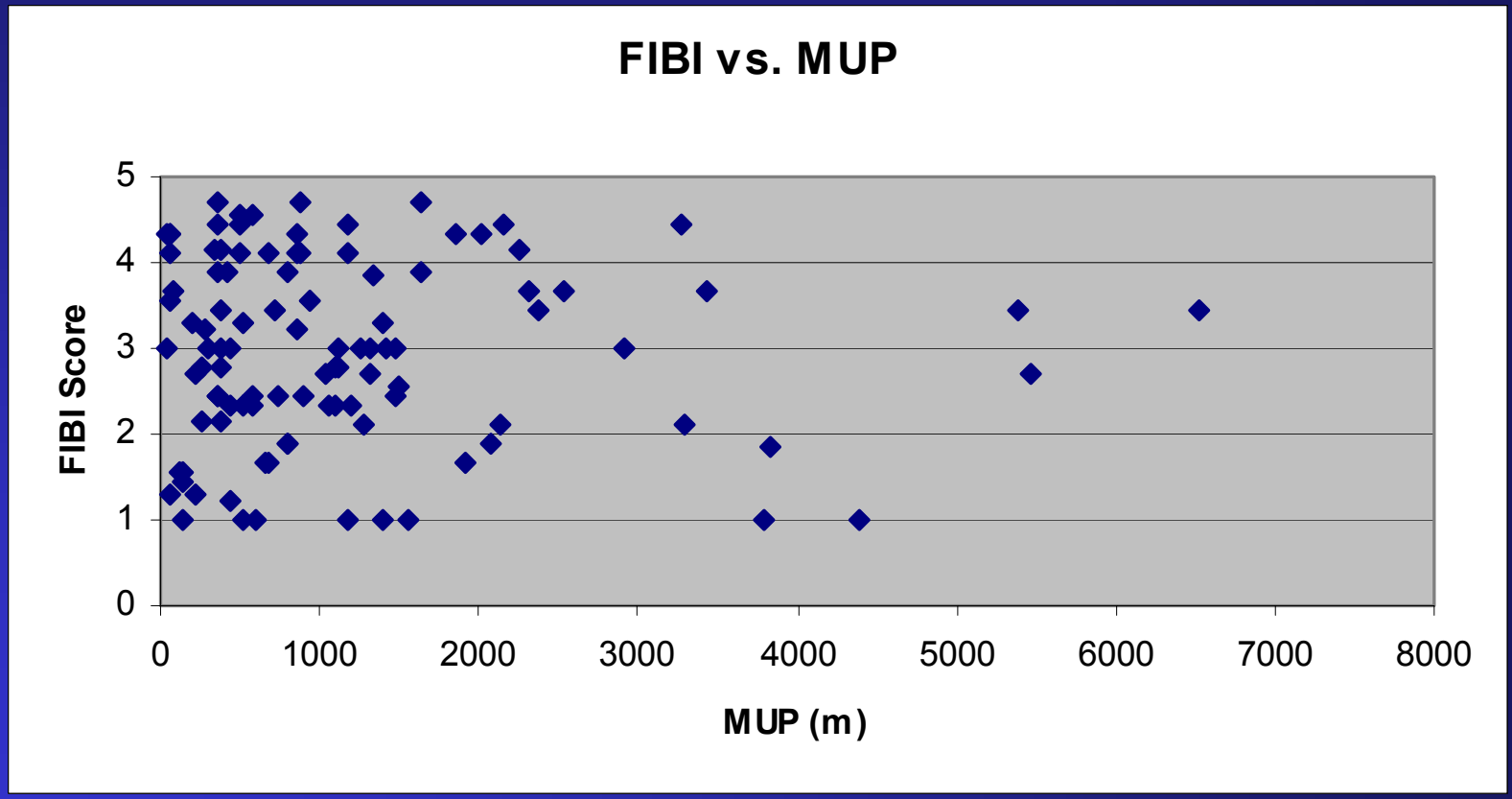


Lirceus


TV = 10.0
Relative Abundance (asin sqrt)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
8
9
10
Stressor Gradient

Confluence Effect?

Fish IBI vs Distance from Confluence



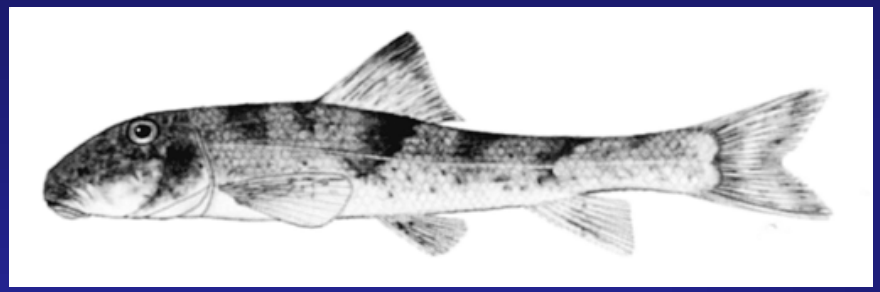
Habitat “Tolerance”

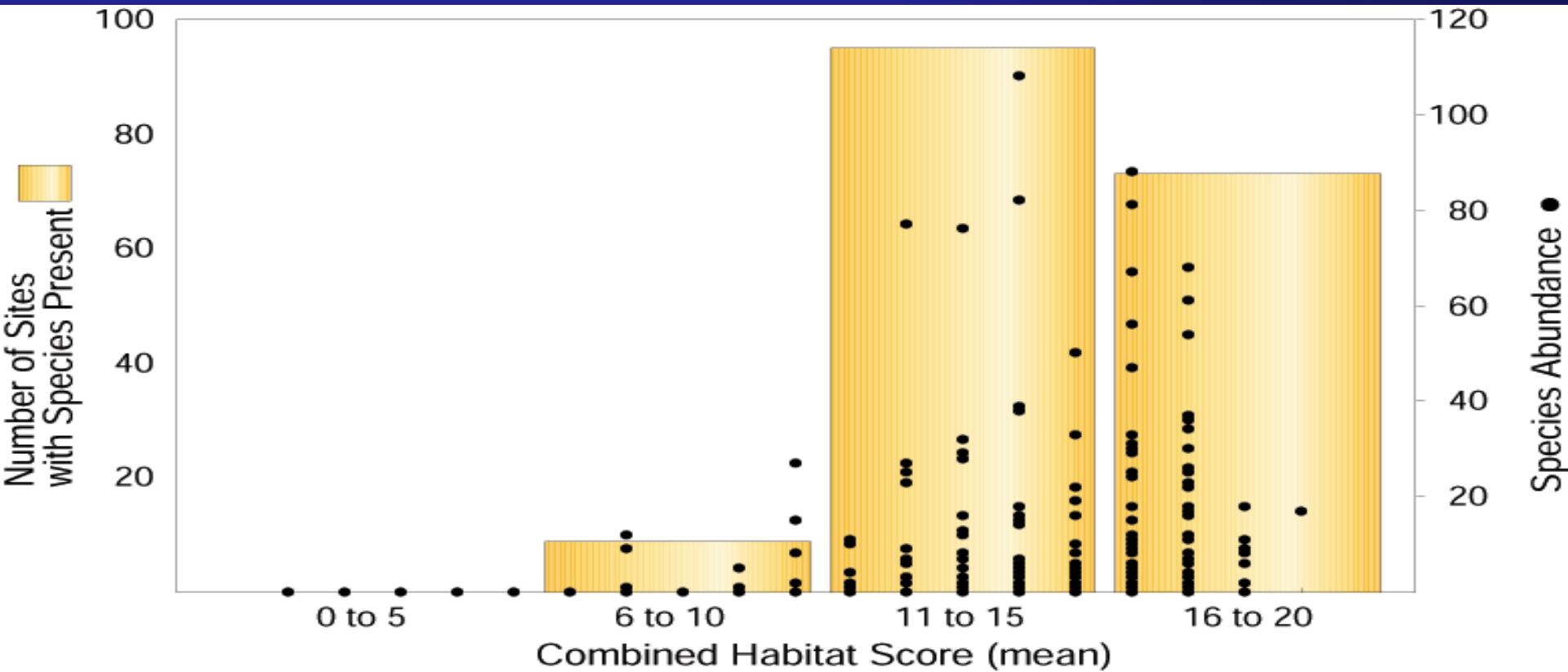
FIBI Habitat "Tolerance" Metric

- Premise- physical habitat is a primary determinant of fish abundance & diversity

- NDVI applied to abundance % occurrence fish data & 5 RBP habitat metrics

Northern hogsucker

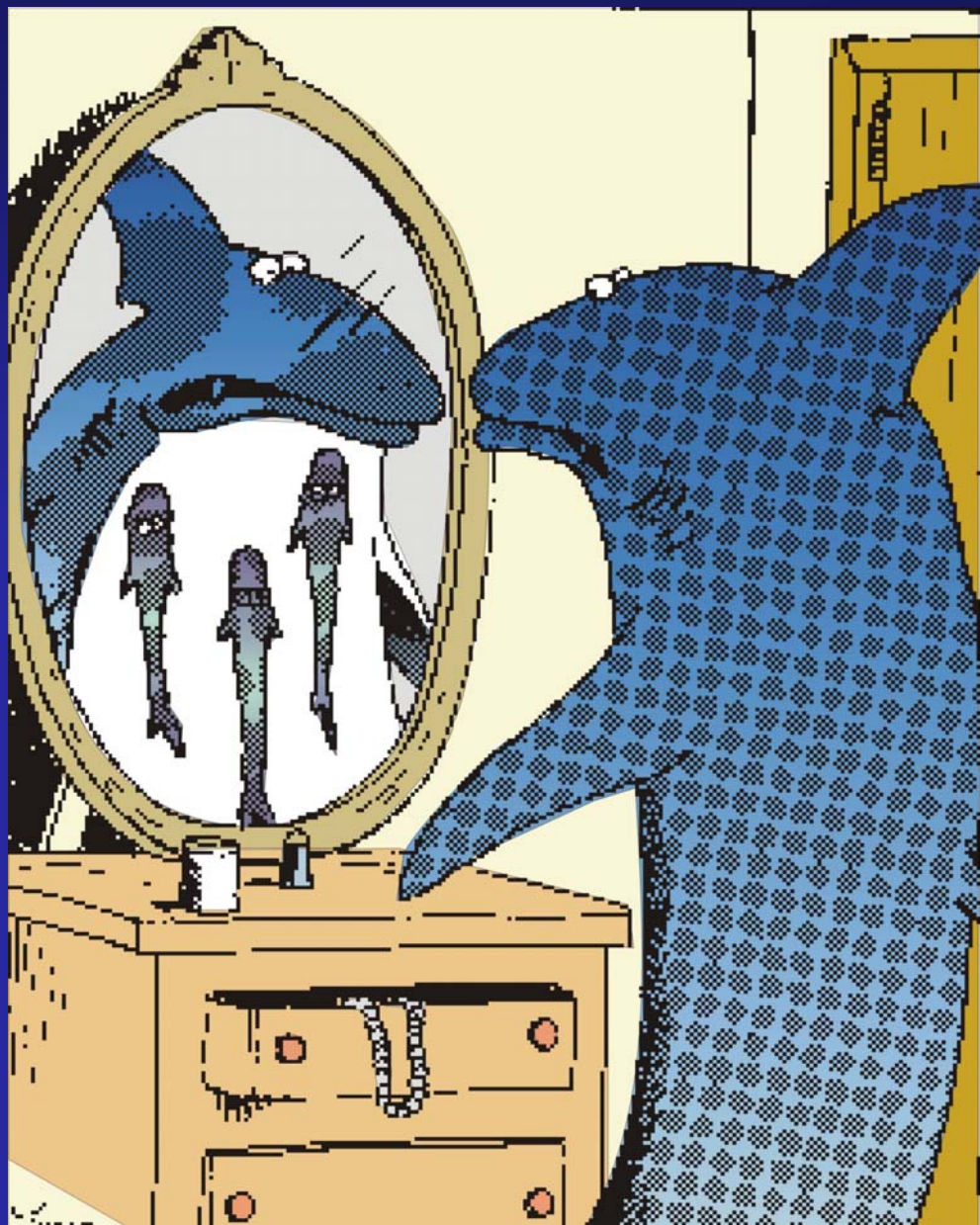




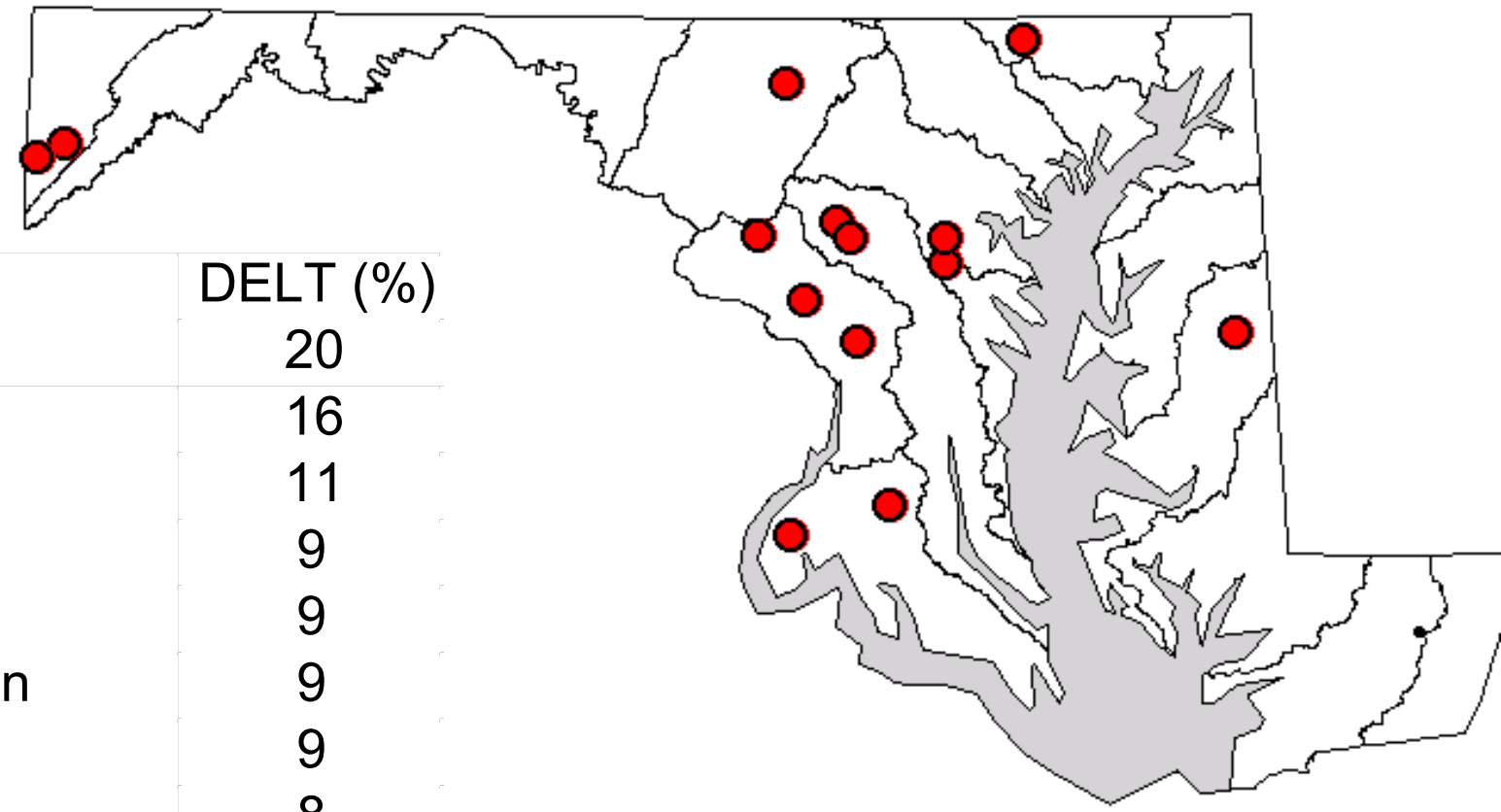
FIBI Habitat "Tolerance" Metrics

CE	Region	Best Metric
90%	Highland	Mean TV all individuals
95%	Piedmont	Mean TV all benthic spp
71%	Coastal Plain	Mean TV all indiv with NDVI >0

Anomalies




SITE
P A X M
BASIN
P X
(see back for codes)
DATE
Year
0 1
Month
0 6
Day
1 1
TIME
1 3 1 5
(Military)
CREW:
COMMENTS:
Electrofishing
Habitat Assessment
Water Quality
1 = Dry Stream
2 = Too Deep
8 = Unsafe
Beaver
Potential sign of stress
prior to population decline

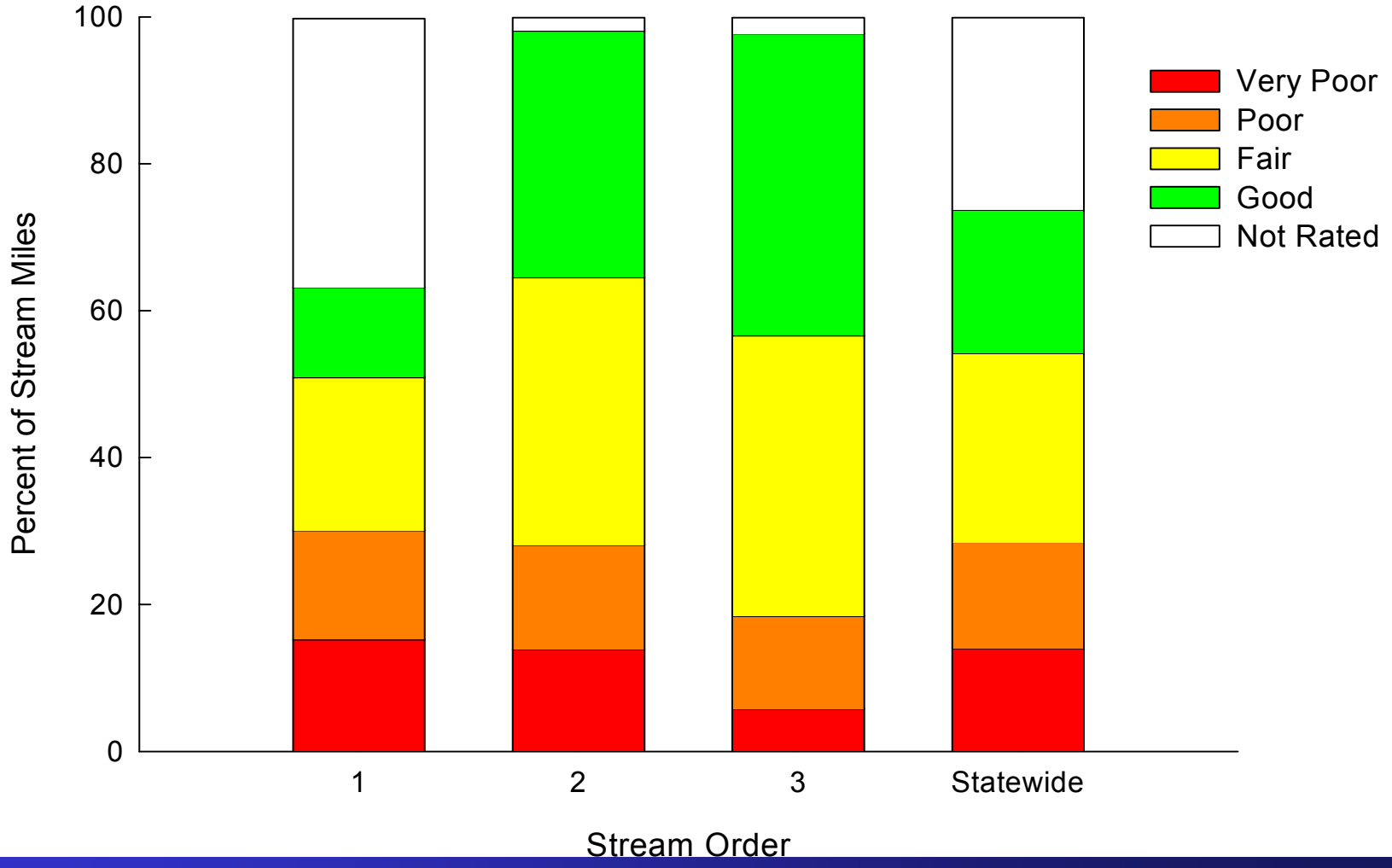


Name	DELT (%)
Little Yough	20
Little Seneca	16
Piney Branch	11
Ut Tridelphia	9
UT Tridelphia	9
UT Cabin John	9
Cherry Creek	9
Stony Run	8
Sams Creek	6
Ut Janes Berry	5
Deep Run	5
NW Branch Anacostia	5
UT Forge Branch	5
Little Deer Creek	5

Sites with ≥ 5% DELTs (Poor IBI Threshold) (Karr et al.1986)

Small Streams

Fish IBI by Stream Order

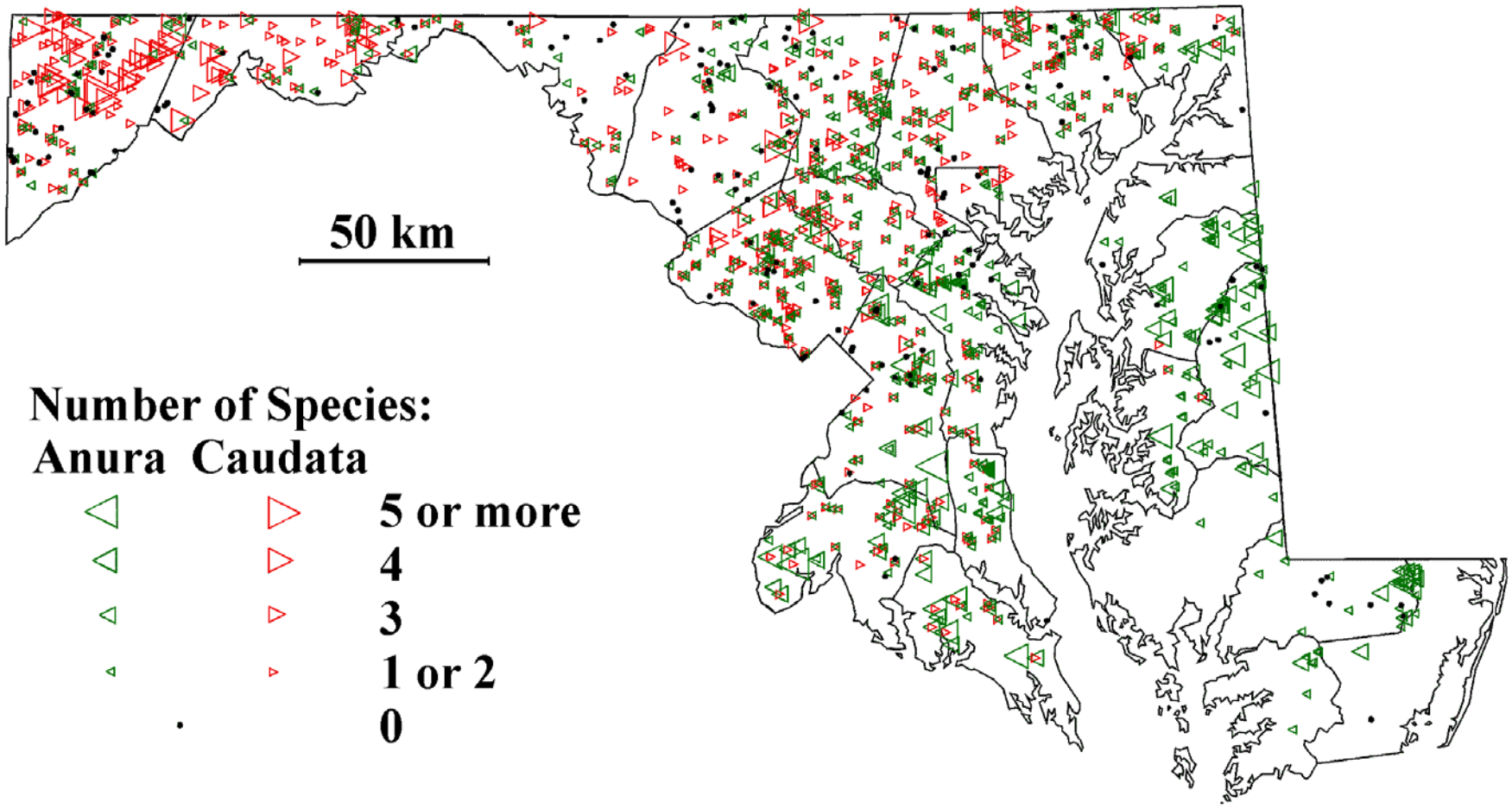


Stream Salamanders as Indicators

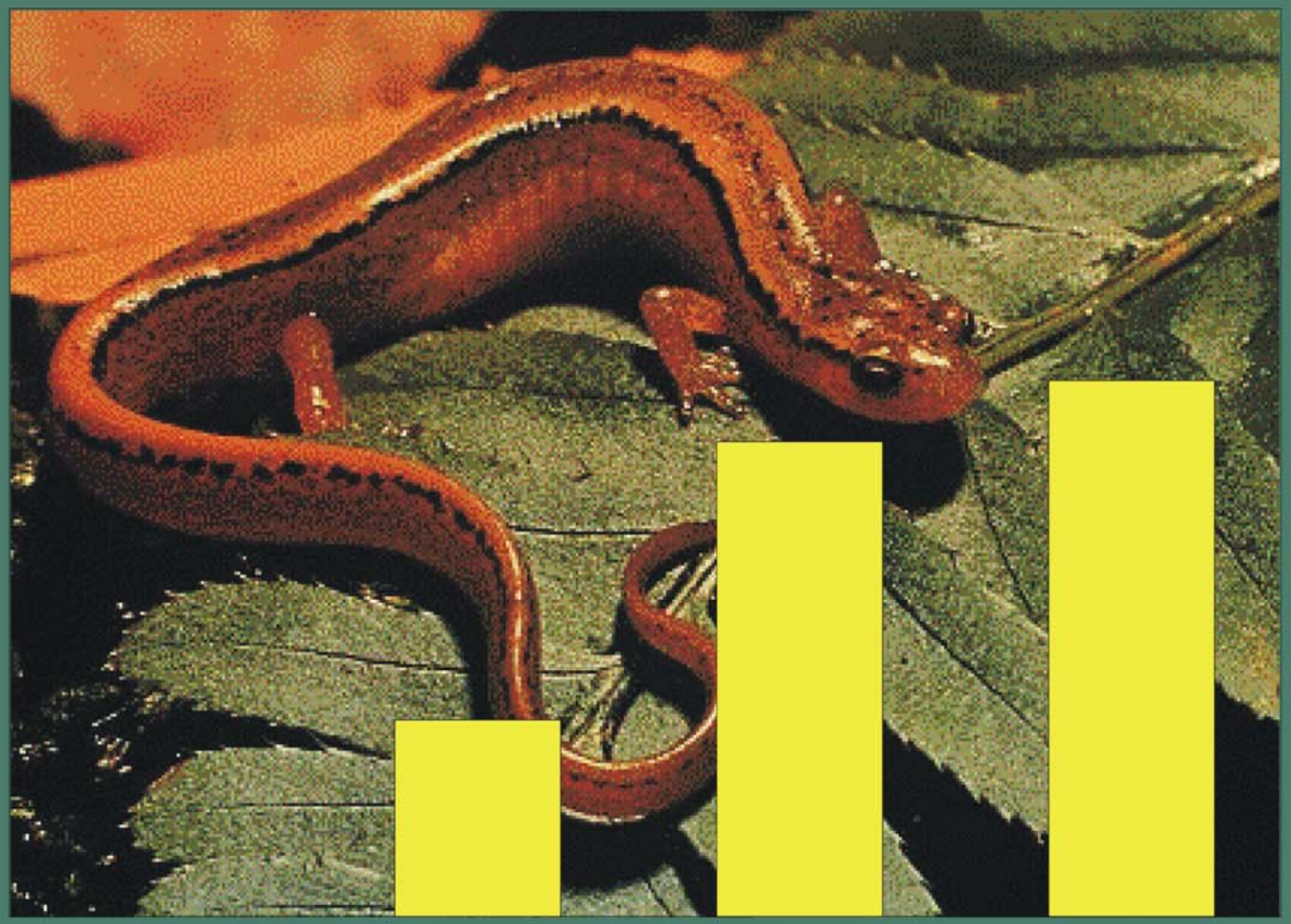
- Widely distributed
- Abundant
- Life history
- Physiology (moist, permeable skin required for respiration)
- Respond to multiple stressors

➢ Good indicators of environmental health

Species Richness Distribution



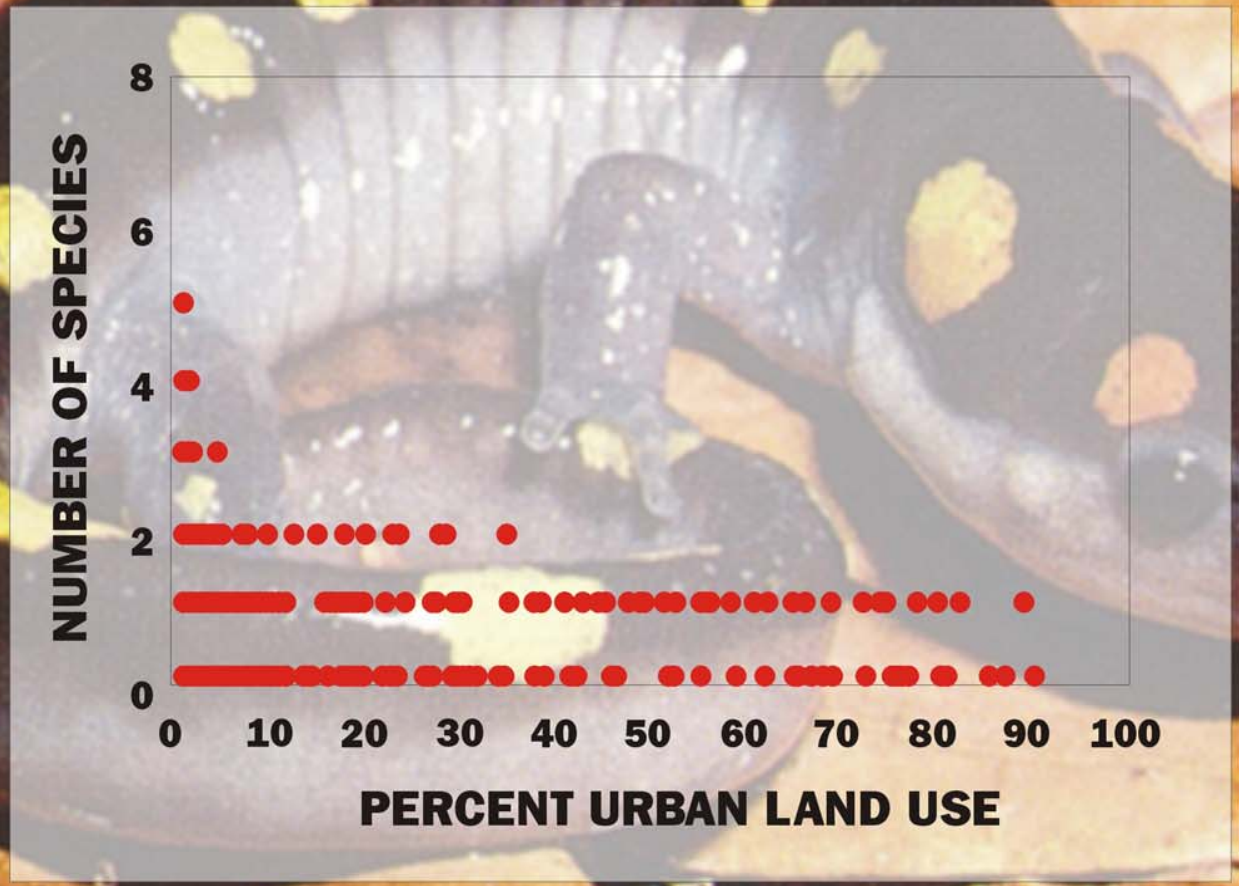
NORTHERN TWO-LINED SALAMANDER AND ACID BUFFERING



MBSS 1995-1

AQUATIC SALAMANDER SPECIES vs. URBAN LAND USE

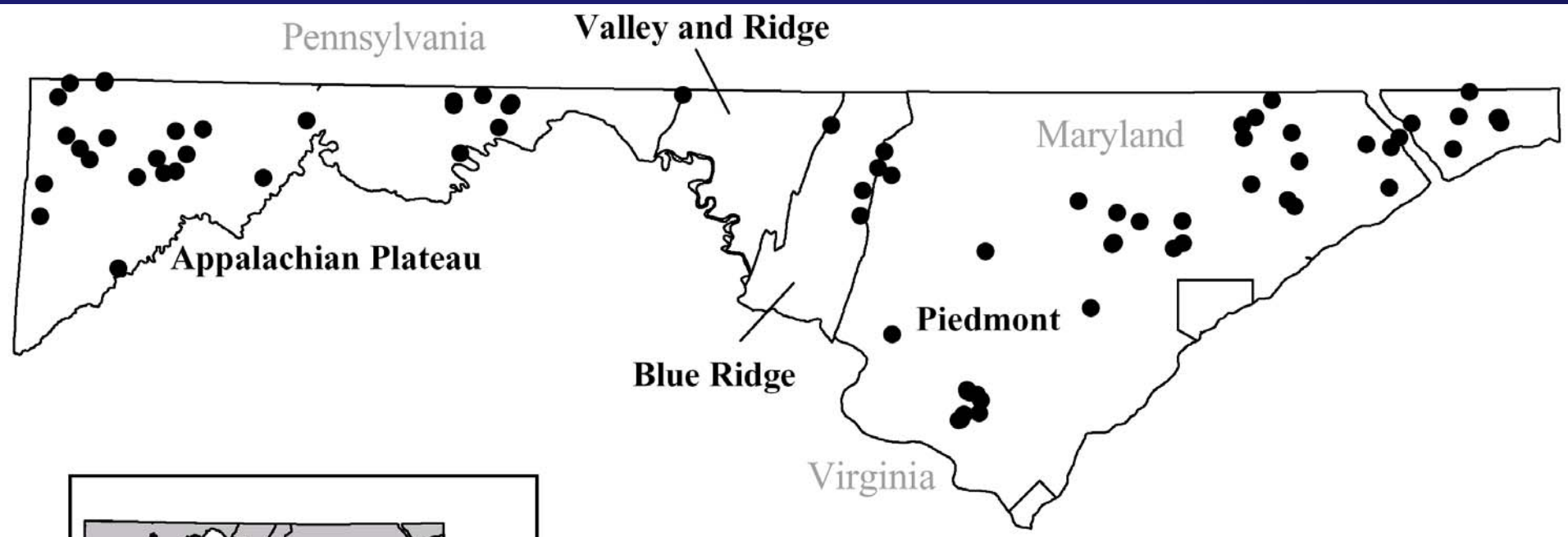
ALL BASINS

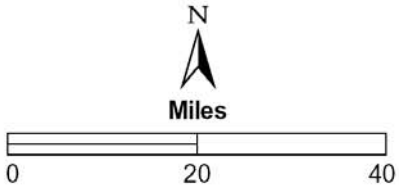


STATE OF MARYLAND
DEPARTMENT OF NATURAL RESOURCES

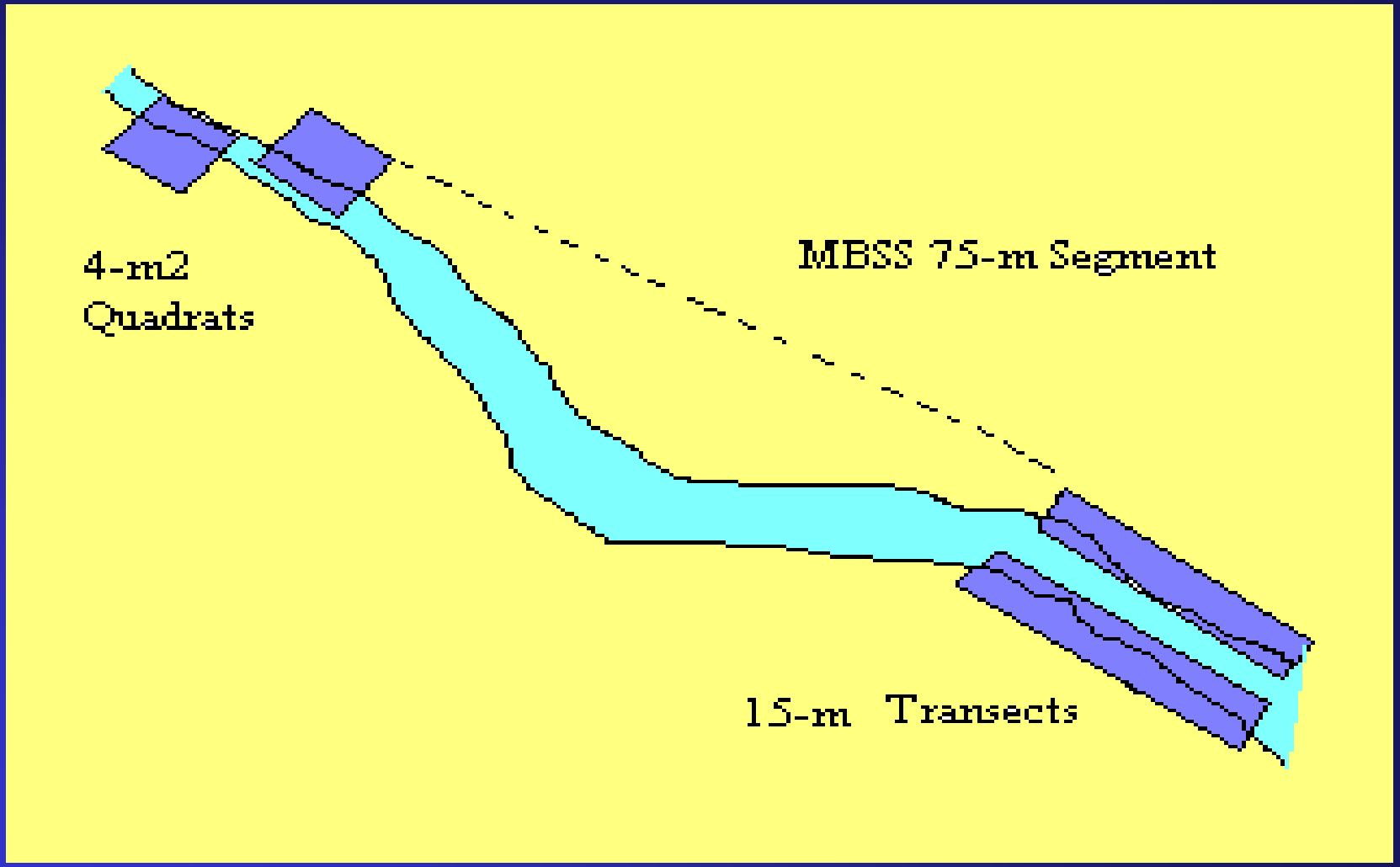
1995-1997 MBSS

Salamander Sampling Sites





Salamander Sampling Methods



Metrics

Number of species

Total abundance

Number of intolerant salamanders

Number of adults

SS-IBI Classification Efficiencies

- Highland 88%
- Piedmont 87%

Effect of watershed size on BIBI– Issue in smallest streams?

Revised physical habitat indicator (PHI)

Reference Criteria

Highlands

Ref: >95% Forest, <0.5% Urban (n=36)
Deg: <25% Forest, >30% Urban, >75% Ag (n=28)

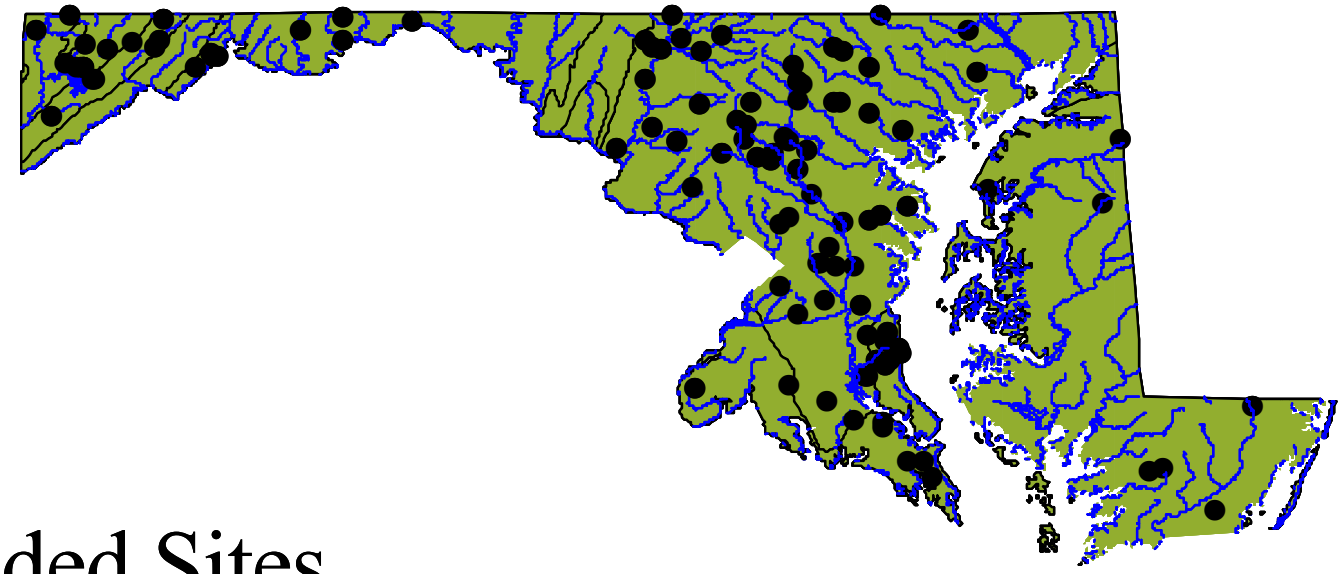
Piedmont

Ref: >55% Forest, <2% Urban (n=30)
Deg: <10% Forest, >70% Urban, >85% Ag (n=66)

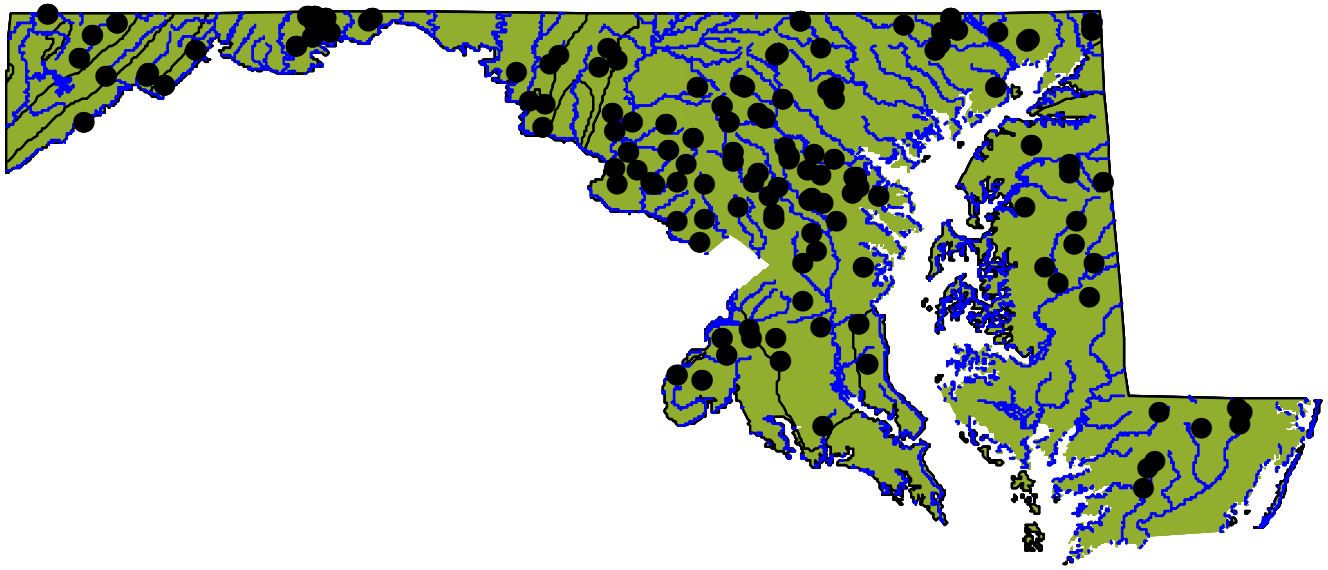
Coastal Plain

Ref: >70% Forest, <3% Urban (n=40)
Deg: <15% Forest, >50% Urban, >85% Ag (n=49)

Reference Sites

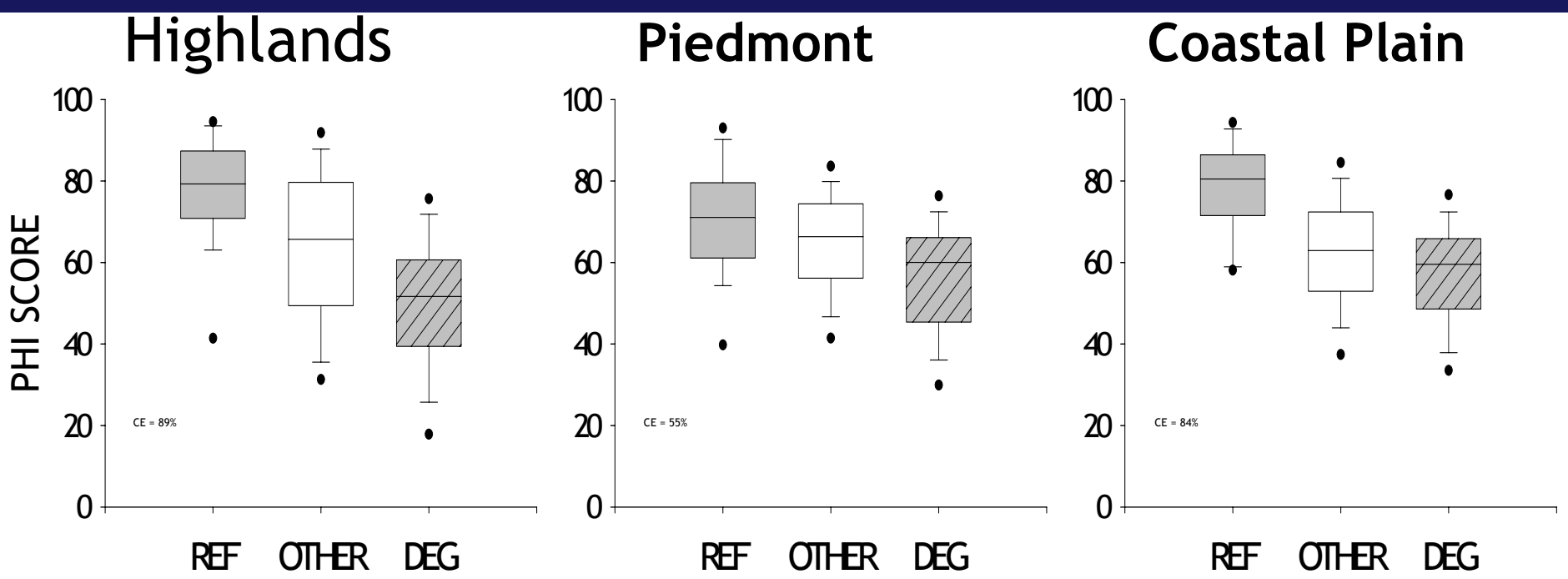


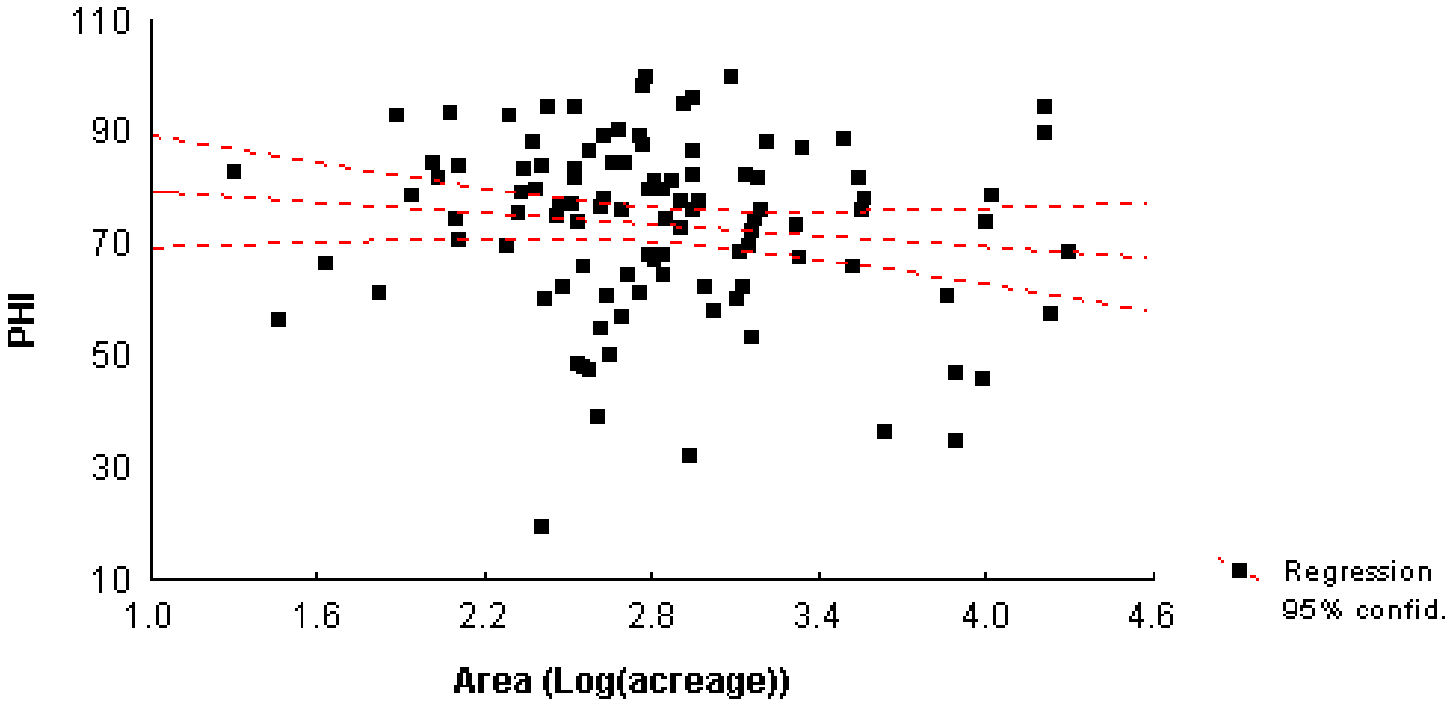
Degraded Sites



PHI Metrics

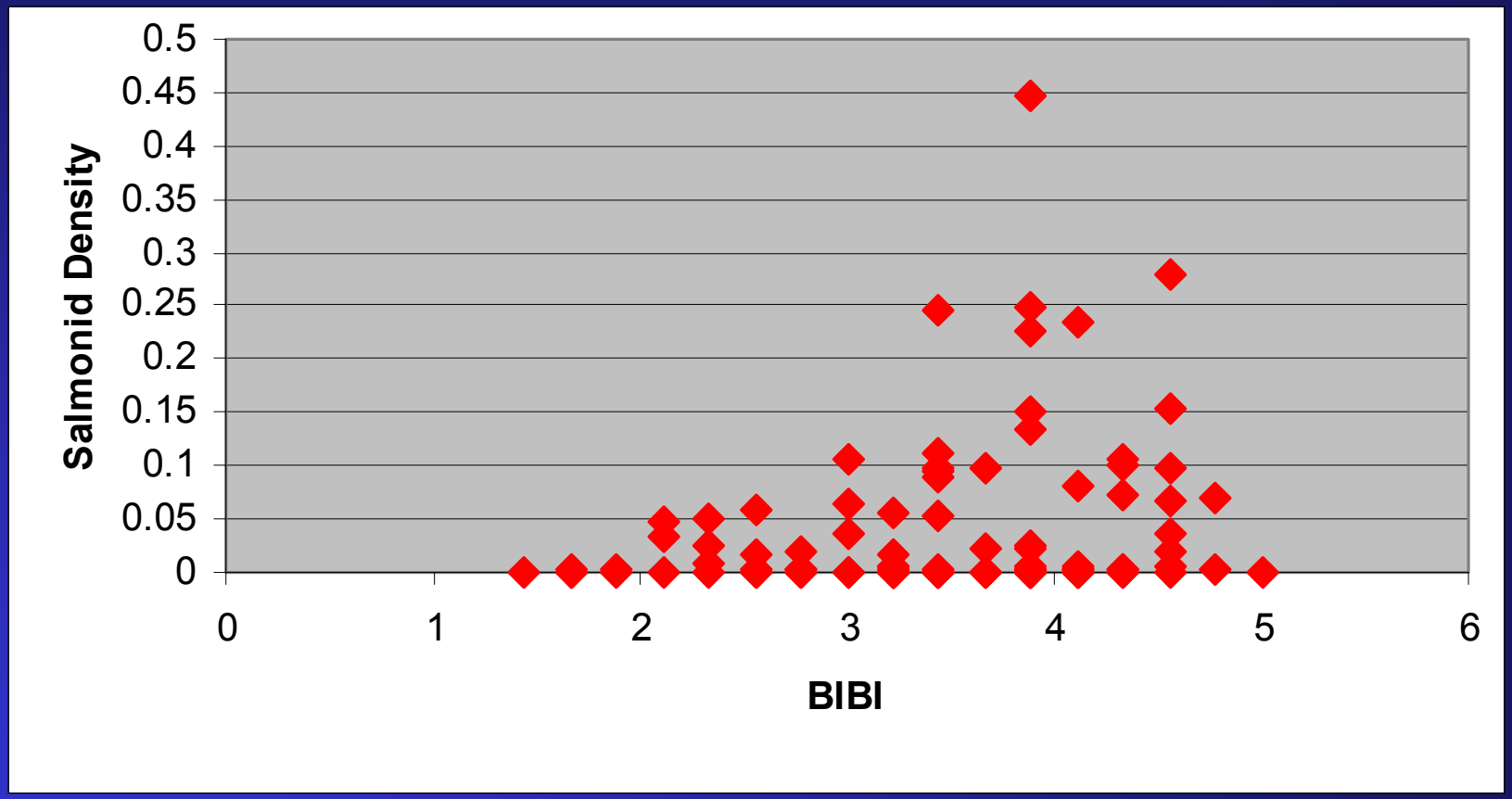
	Coastal Plain	Piedmont	Highlands
Remoteness	X	X	X
Shading	X	X	X
Epibenthic substrate	X	X	X
Instream habitat	X	X	
Wood	X	X	
Bank stability	X	X	X
Embeddedness	X	X	
Riparian Width			X
CE	84%	55%	89%


Highlands
Piedmont
Coastal Plain
PHI SCORE
100
80
60
40
20
0
CE = 89%
CE = 55%
CE = 84%
REF
OTHER
DEG

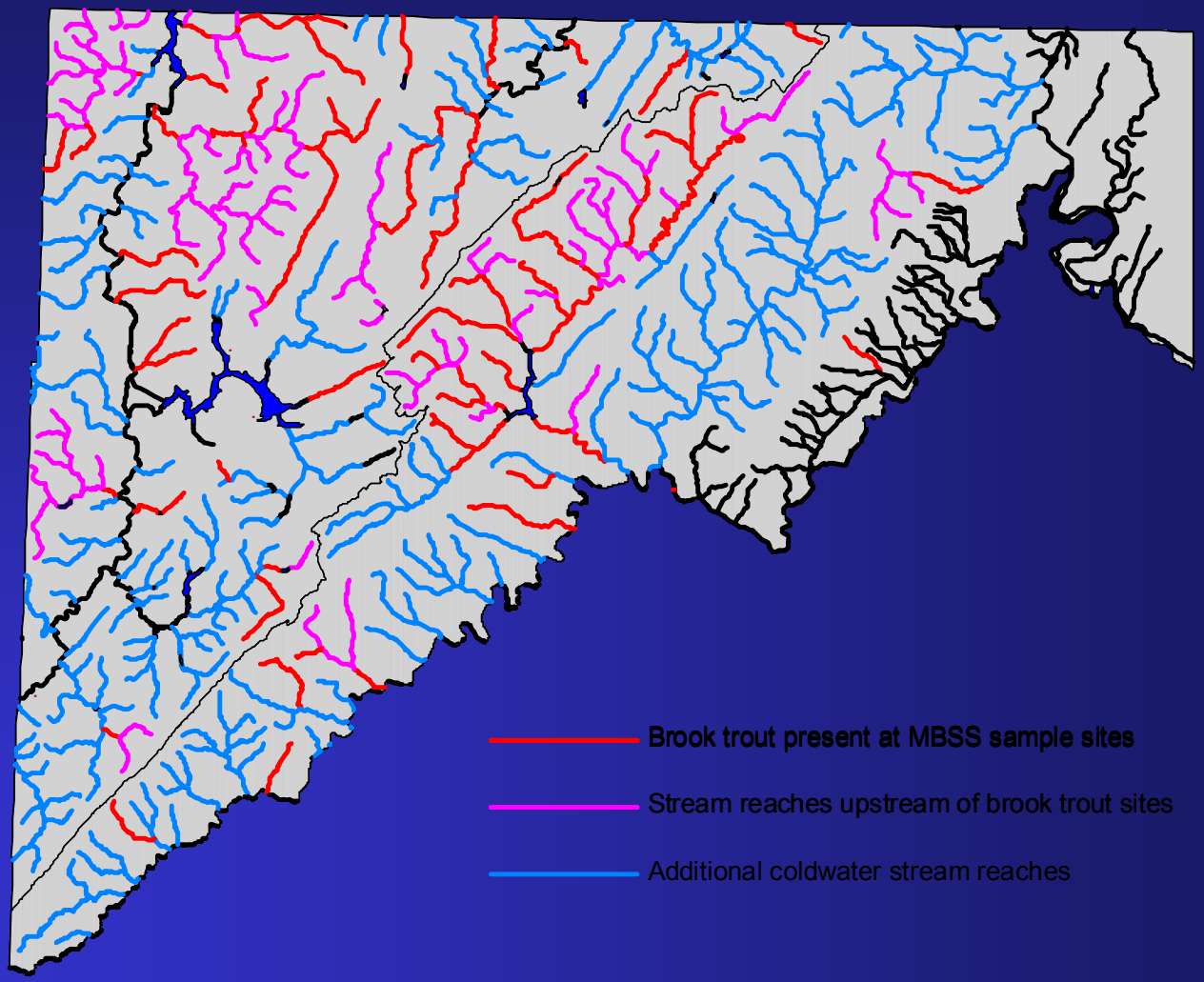

PHI
110
90
70
50
30
10
1.0
1.6
2.2
2.8
3.4
4.0
4.6
Area (Log(acreage))
Regression
95% confid.

Unique habitats & biota

Salmonid Density vs. BIBI

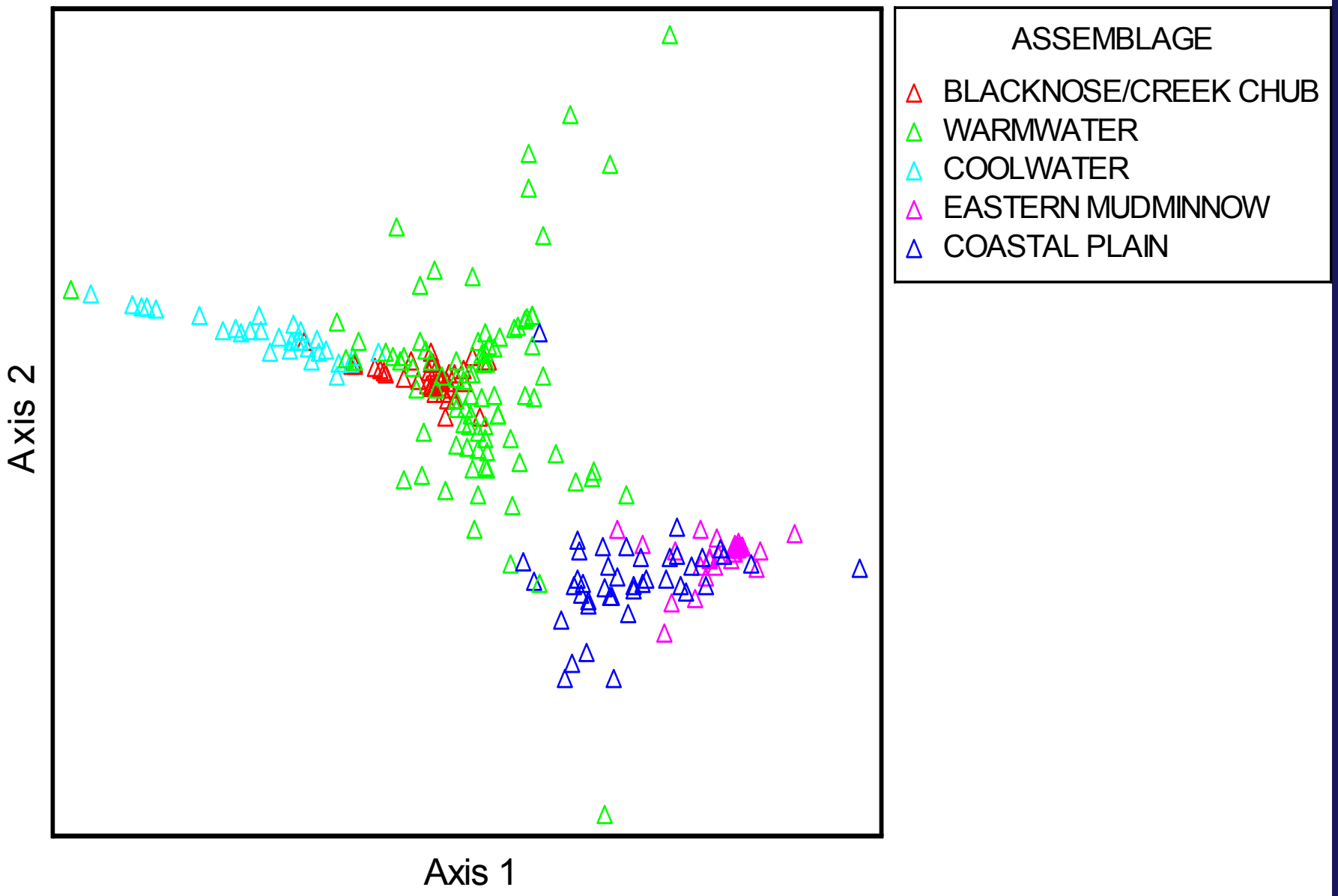


Western Maryland's Brook Trout Streams

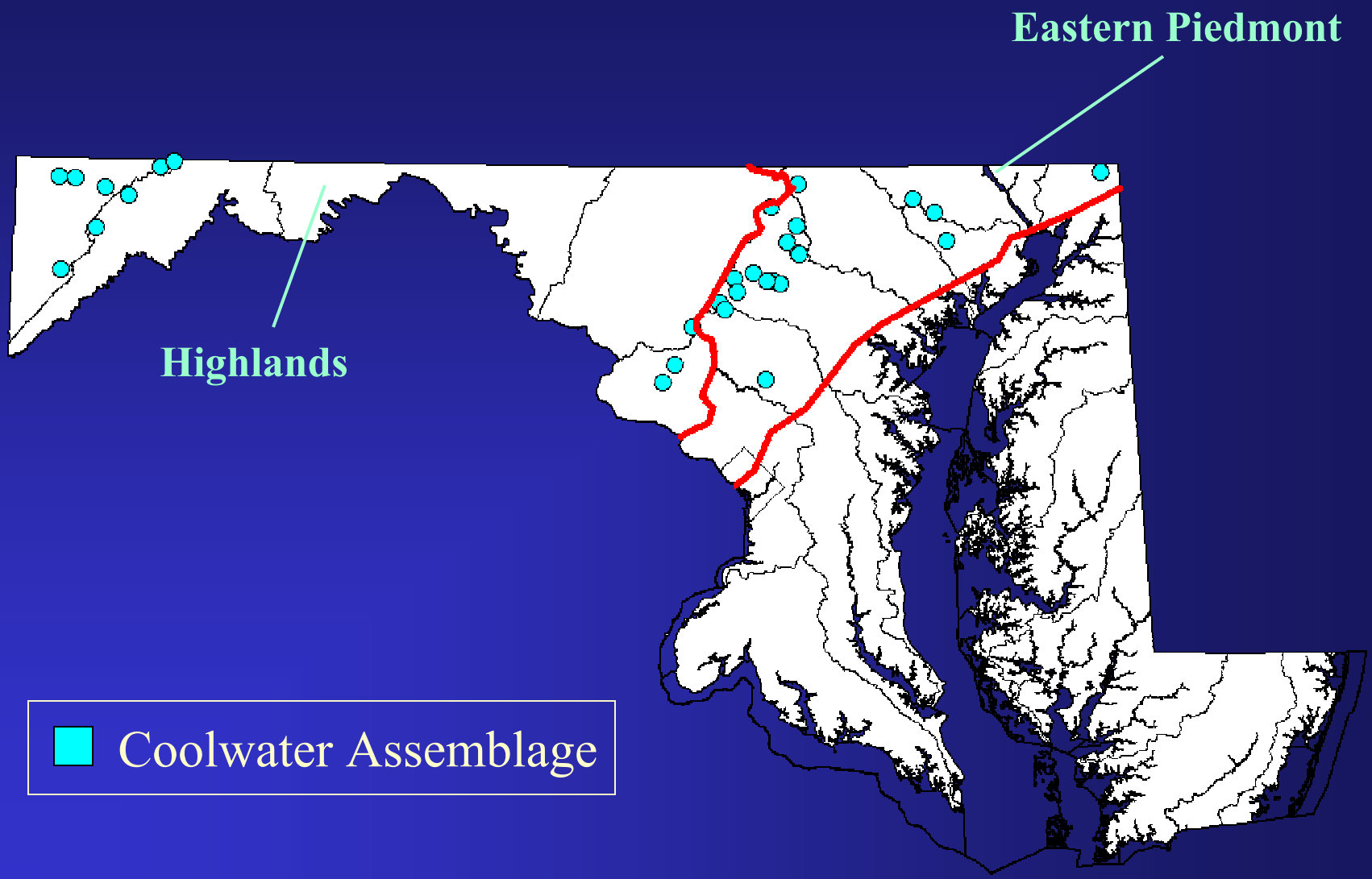


Spatial Variability of Stream Fish Assemblages: Implications for the Index of Biotic Integrity

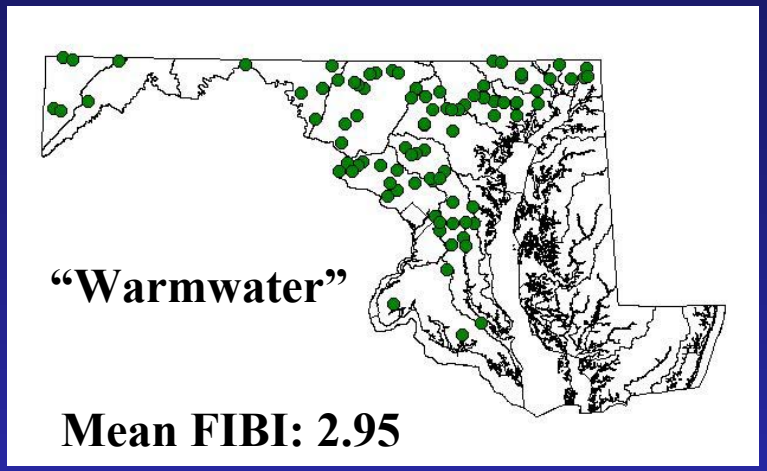
1st Order Assemblages: Ordination Results

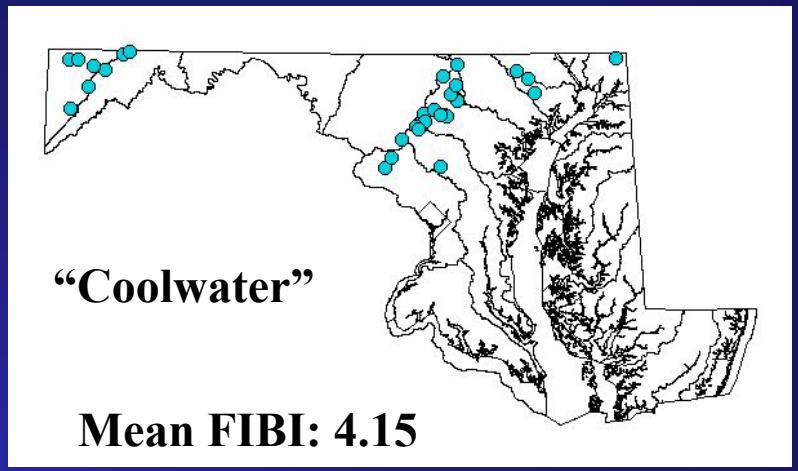


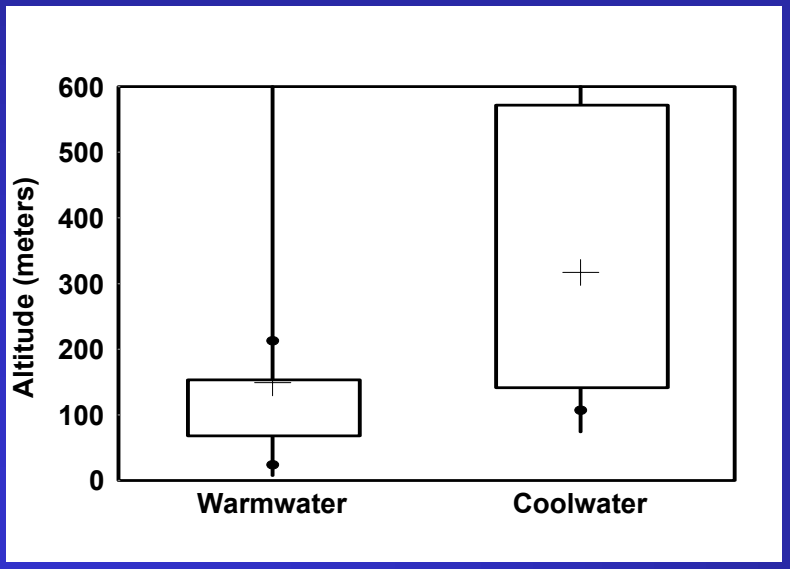
Inter-Strata Variation

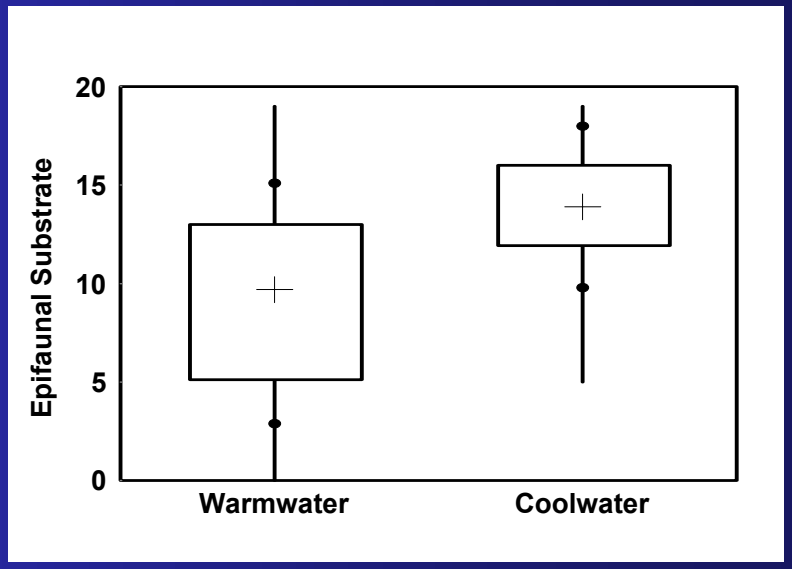


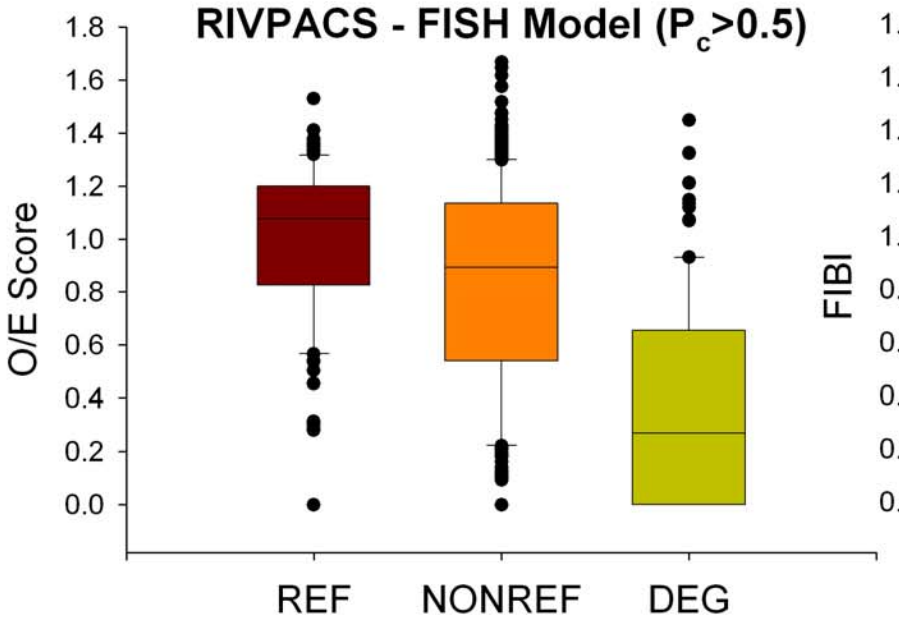
Implications on the Fish Index of Biotic Integrity





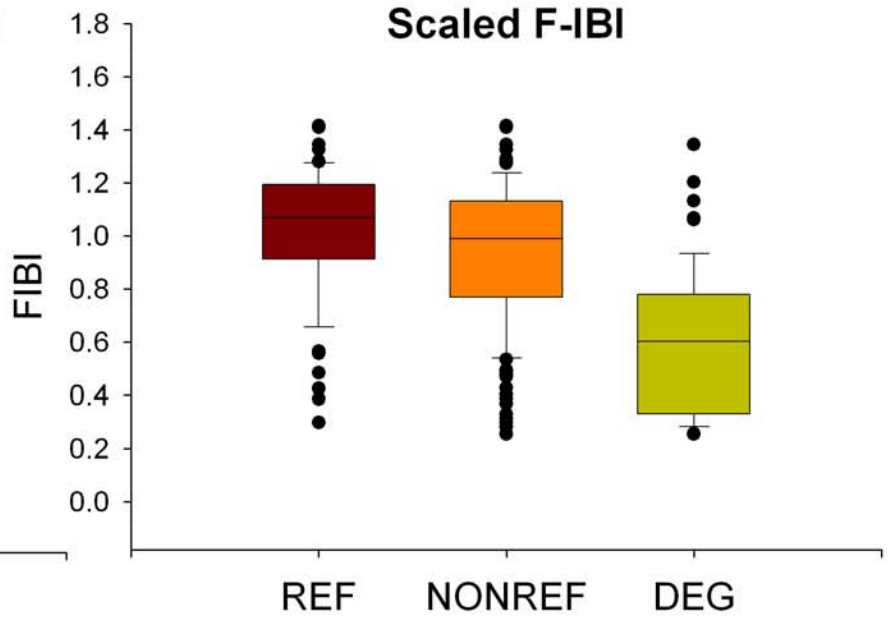






Discrimination Efficiency = 88%

Classification Efficiency = 83%



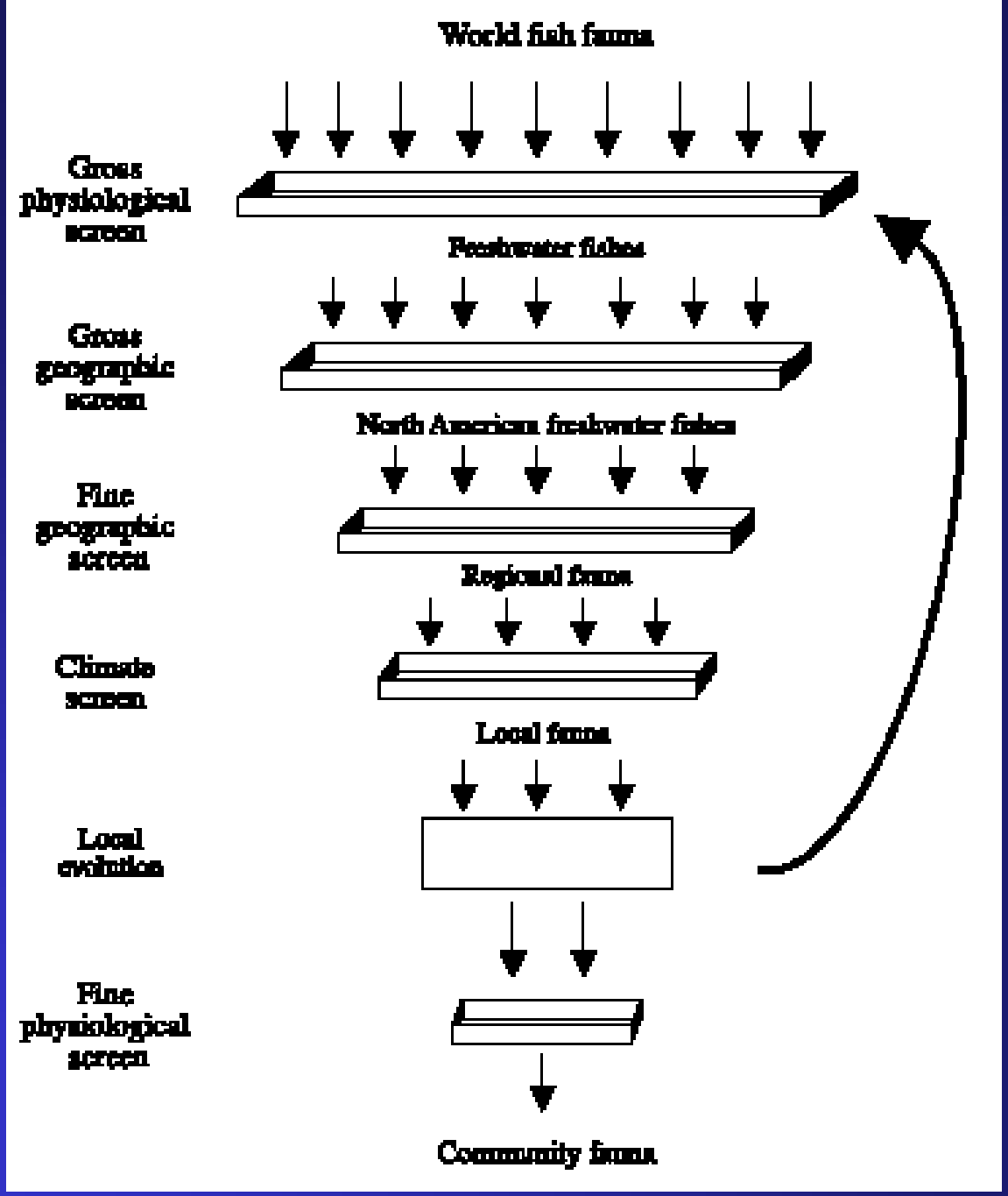
Discrimination Efficiency = 82%

Classification Efficiency = 82%

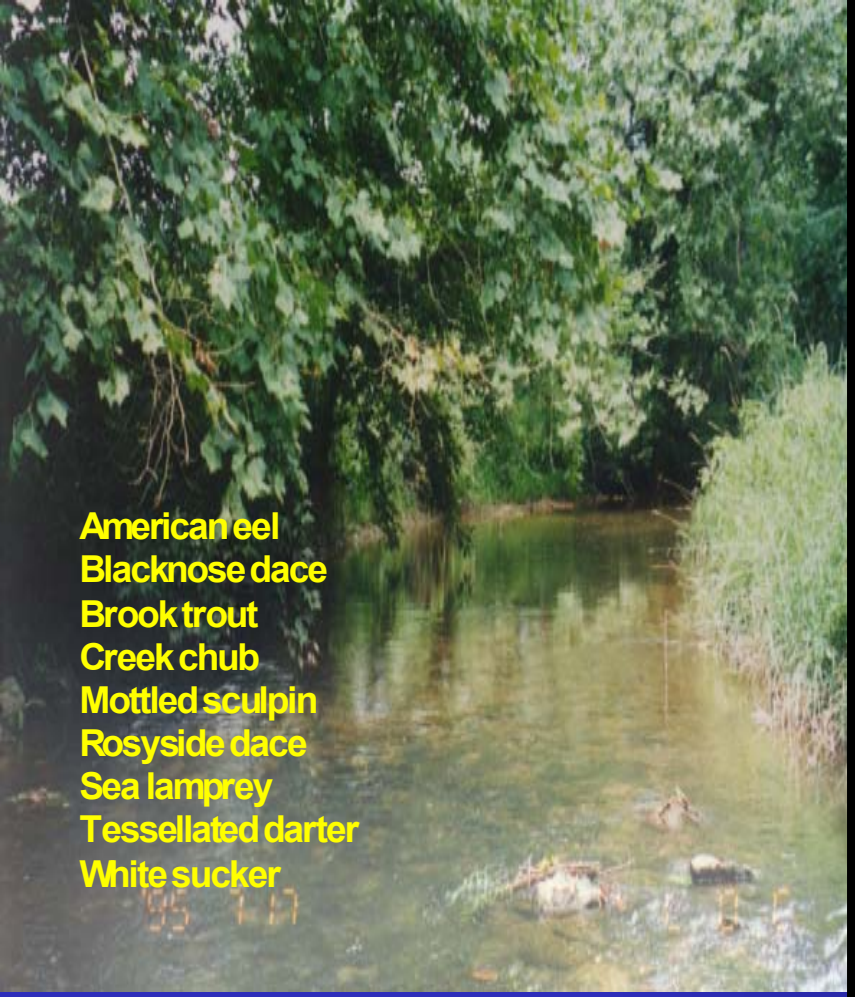
Prediction and Diagnosis Approach (PDA)

Goals:

1. Predict the stream fish assemblage
2. Diagnose probable stressors to fishes
3. Provide thresholds for restoration and protection



From Jackson et al. 2001



Good stream

85% forested catchment
1% impervious
Good habitat

Bad stream

9% Forested
85% urban
25% impervious
D.O. 4.4 ppm

9 species
3 tolerant
4 intolerant
1 filter feeder
3 generalists
2 invertivores
1 insectivores
2 omnivores
2 benthic species
5 lithophilic spawners
725 individuals
2,344 grams biomass

2 species
2 tolerant
1 omnivore
1 insectivore
64 individuals
23 grams biomass

IBI = 4.5 (Good)

IBI = 1.5 (Poor)

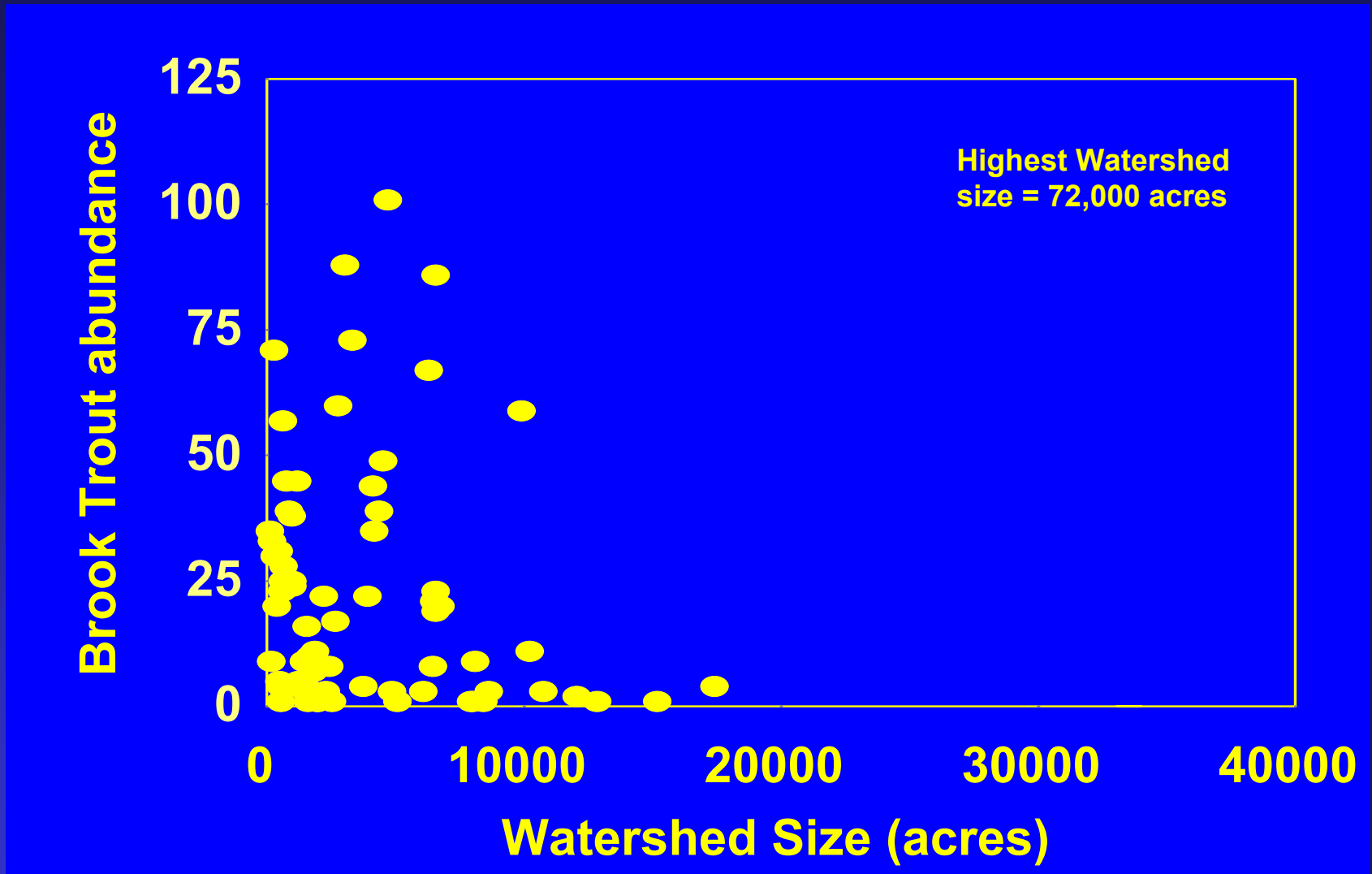
Step One

Generate a list of the fish species expected to occur at a site in the absence of major anthropogenic stress

Separated variables into predictor variables and stressor variables

List of Predictor Variables

Physiography
Drainage basin
Wetted width
Average depth
Maximum depth
Strahler stream order
Gradient
Discharge
Average current velocity
Watershed size
Dissolved organic carbon
Altitude


Brook Trout abundance
125
100
75
50
25
0
0
10000
20000
30000
40000
Watershed Size (acres)
Highest Watershed size = 72,000 acres

Start with 44 native species:

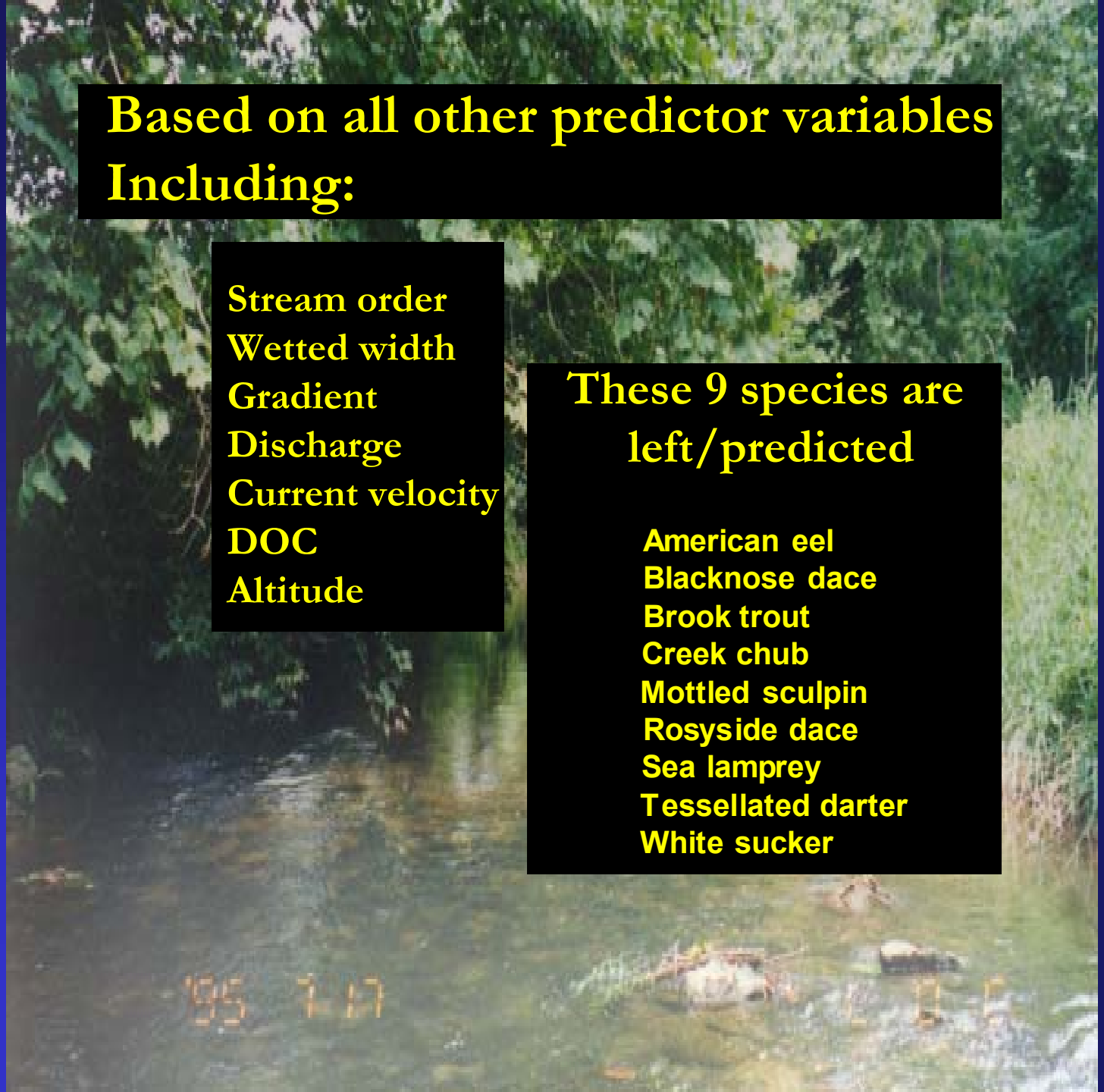
- American eel
- Banded sunfish
- Blacknose dace
- Bluespotted sunfish
- Bluntnose minnow
- Brook trout
- Central stoneroller
- Chain pickerel
- Checkered sculpin
- Common shiner
- Creek chub
- Creek chubsucker
- Cutlips minnow
- Eastern mudminnow
- Fallfish
- Fantail darter
- Golden shiner
- Greenside darter
- Least brook lamprey
- Longnose dace
- Margined madtom
- Mottled sculpin
- Mud sunfish
- Northern hogsucker
- Pearl dace
- Pirate perch
- Potomac sculpin
- Pumpkinseed
- Redbreast sunfish
- Redfin pickerel
- River chub
- Rosyface shiner
- Rosyside dace
- Satinfin shiner
- Sea lamprey
- Shield darter
- Silverjaw minnow
- Spotfin shiner
- Spottail shiner
- Swallowtail shiner
- Swamp darter
- Tadpole madtom
- Tessellated darter
- White sucker

Then-
Eliminate species from this list based on the values for the prediction variables at the site


Site is in Piedmont so…
American eel
Blacknose dace
Bluntnose minnow
Brook trout
Central stoneroller
Common shiner
Creek chub
Cutlips minnow
Fallfish
Golden shiner
Longnose dace
Margined madtom
Mottled sculpin
Northern hogsucker
Pumpkinseed
Redbreast sunfish
River chub
Rosyface shiner
Rosyside dace
Satinfin shiner
Sea lamprey
Shield darter
Silverjaw minnow
Spotfin shiner
Spottail shiner
Swallowtail shiner
Tessellated darter
White sucker
Eliminate species not found in Piedmont
Now 28 species


Site is in Susquehanna Basin so…
American eel
Blacknose dace
Bluntnose minnow
Brook trout
Central stoneroller
Common shiner
Creek chub
Cutlips minnow
Fallfish
Longnose dace
Margined madtom
Mottled sculpin
Northern hogsucker
Redbreast sunfish
River chub
Rosyface shiner
Rosyside dace
Satinfin shiner
Sea lamprey
Shield darter
Spotfin shiner
Spottail shiner
Swallowtail shiner
Tessellated darter
White sucker
Eliminate species
not found
in Susquehanna Basin
Now 26 species


Site watershed area is 870 acres so…
American eel
Blacknose dace
Bluntnose minnow
Brook trout
Central stoneroller
Common shiner
Creek chub
Cutlips minnow
Fallfish
Longnose dace
Margined madtom
Mottled sculpin
Redbreast sunfish
Rosyside dace
Sea lamprey
Shield darter
Spottail shiner
Swallowtail shiner
Tessellated darter
White sucker
Eliminate species not found at sites smaller than 870 acres
Now 20 species



Based on all other predictor variables Including:

Stream order
Wetted width
Gradient
Discharge
Current velocity
DOC
Altitude

These 9 species are left/predicted

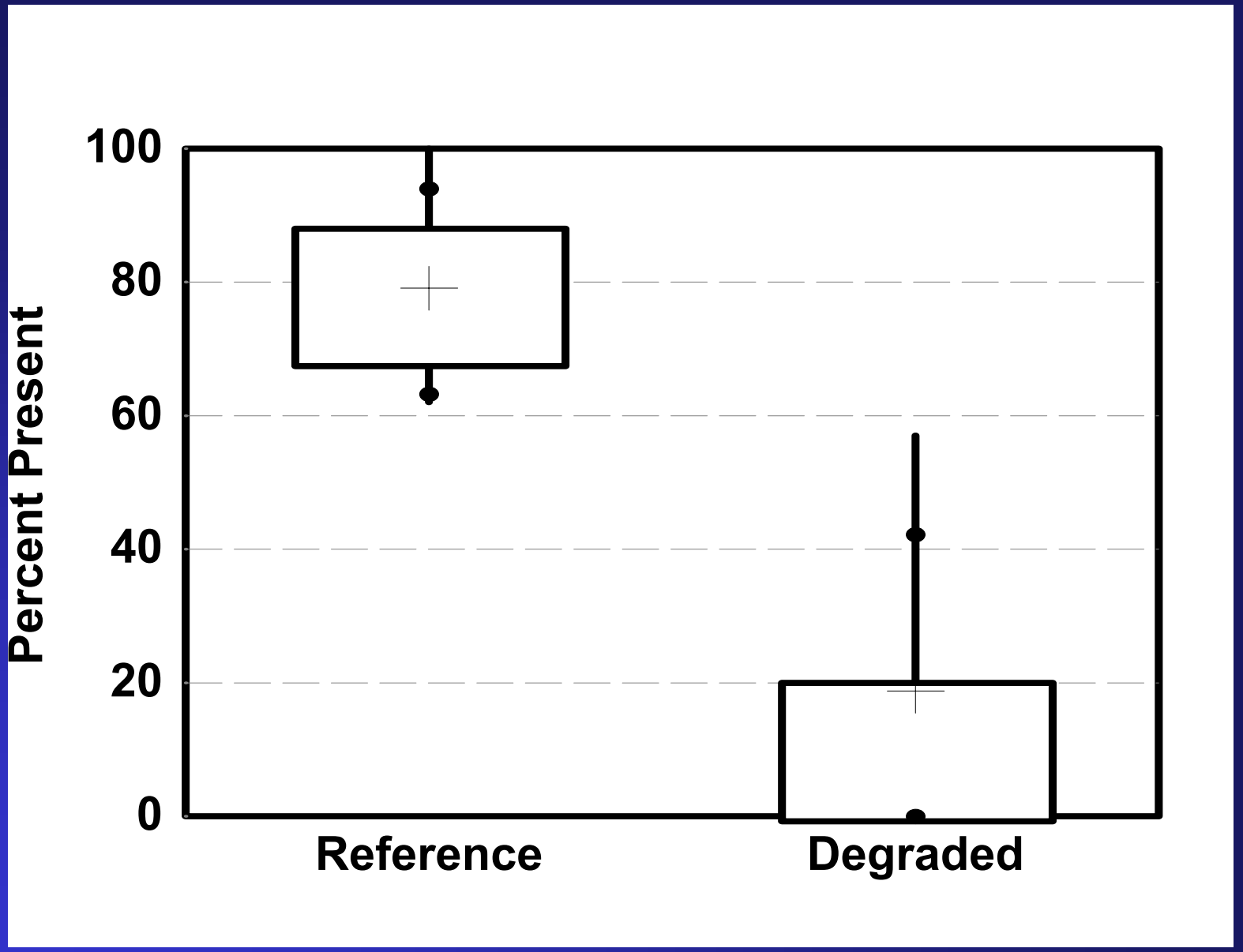
American eel
Blacknose dace
Brook trout
Creek chub
Mottled sculpin
Rosyside dace
Sea lamprey
Tessellated darter
White sucker

100% expected collected

Predicted	Collected
American eel	
Cutlips minnow	
Fallfish	
Redbreast sunfish	
Tessellated darter	
White sucker	
Swallowtail shiner	Swallowtail shiner
Blacknose dace	Blacknose dace

25% expected collected

Predicted	Collected
American eel	American eel
Blacknose dace	Blacknose dace
Brook trout	Brook trout
Creek chub	Creek chub
Mottled sculpin	Mottled sculpin
Rosyside dace	Rosyside dace
Sea lamprey	Sea lamprey
Tessellated darter	Tessellated darter
White sucker	White sucker

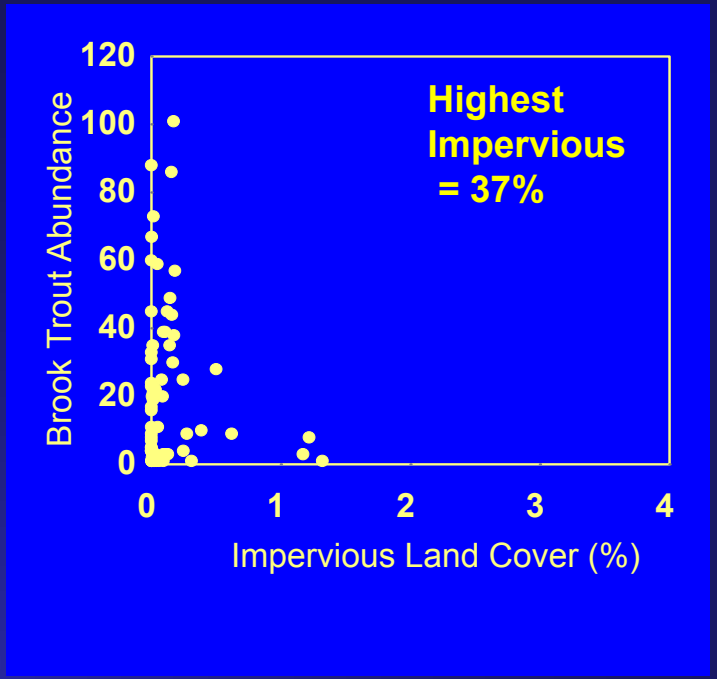

Percent Present
100
80
60
40
20
0
Reference
Degraded

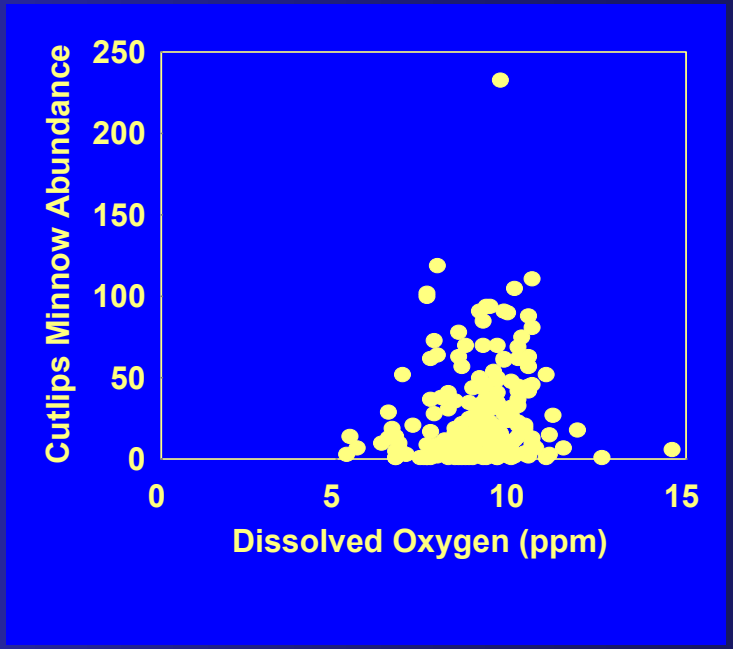
Step 2 - Stressor Diagnosis

Use species relationships to stressor variables
["biological response signature" (Yoder and Rankin 1995)]
to determine probable stressors to fishes

Stressor Variables

- Dissolved oxygen
- pH
- Temperature
- Nitrate nitrogen
- Specific conductance
- Acid neutralizing capacity
- Sulfate
- Instream habitat
- Epifaunal substrate
- Velocity depth diversity
- Pool quality
- Riffle quality
- Channelization
- Stream bank erosion
- Percent riffle embeddedness
- Percent canopy shading
- Trash index
- Percent urban land cover
- Percent imperviousness
- Percent agriculture land cover
- Percent forested land cover
- Percent coal mine
- Number of non-native Salmonids
- Percent riffle embeddedness



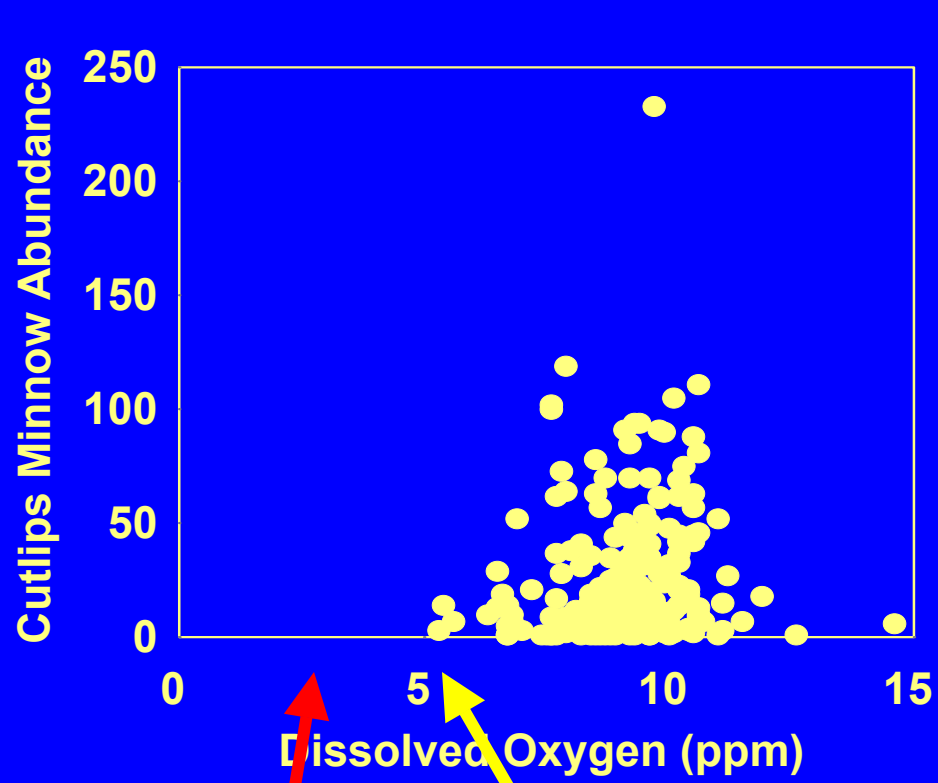


Predicted

American eel
Cutlips minnow
Fallfish
Redbreast sunfish
Tessellated darter
White sucker
Swallowtail shiner
Blacknose dace

Collected

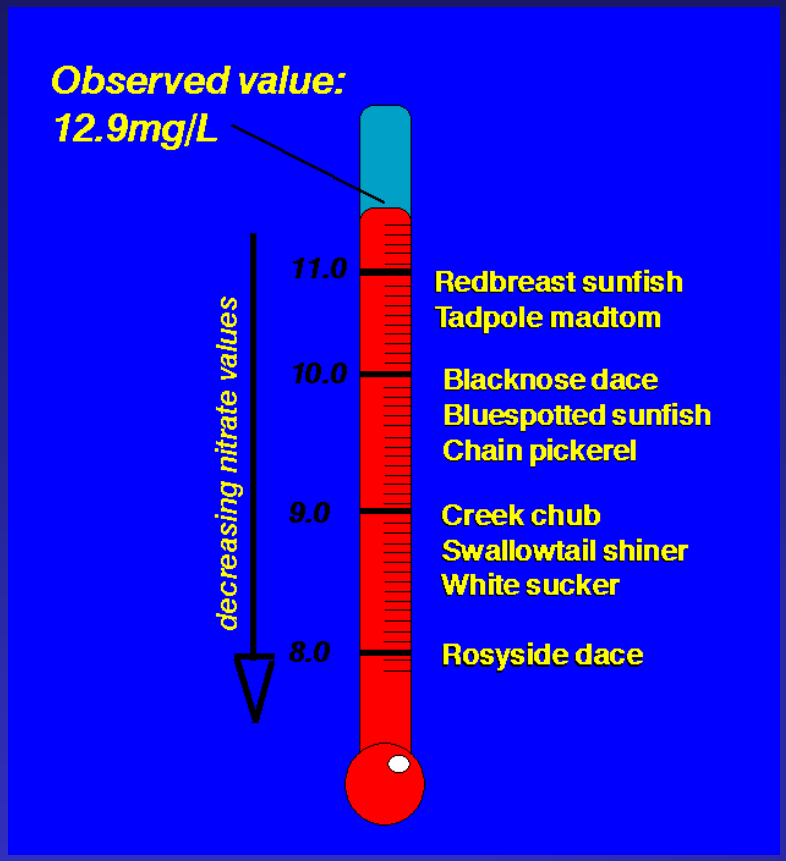
Swallowtail shiner
Blacknose dace



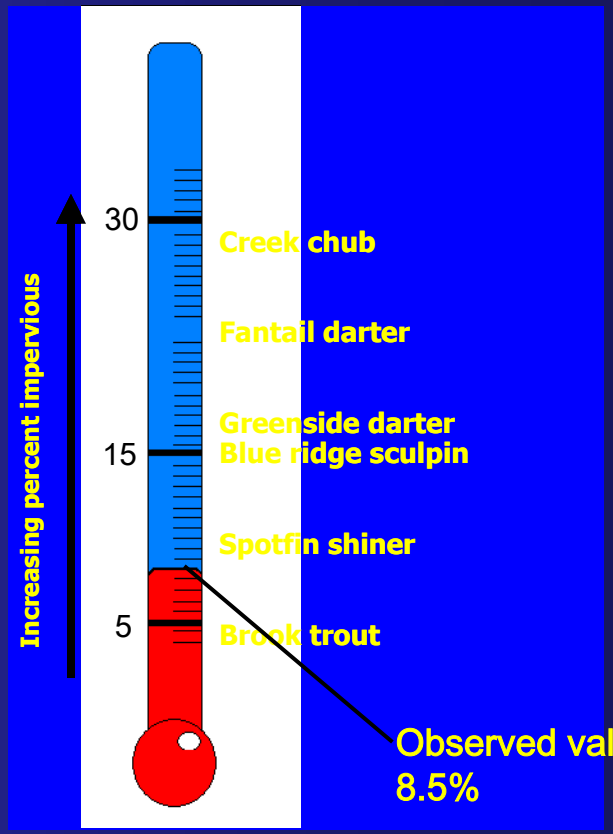
Dissolved oxygen at this site = 4.3

Cutlips minnow Not found at any Site with DO less Than 5.1

Expected but Absent	Probable Stressors
Culips minnow	Dissolved oxygen, Urban/impervious
Fallfish	Instream habitat, Urban/impervious
Redbreast sunfish	Pool quality, Urban/impervious
Tessellated darter	Urban/impervious
White sucker	Urban/impervious
American eel	

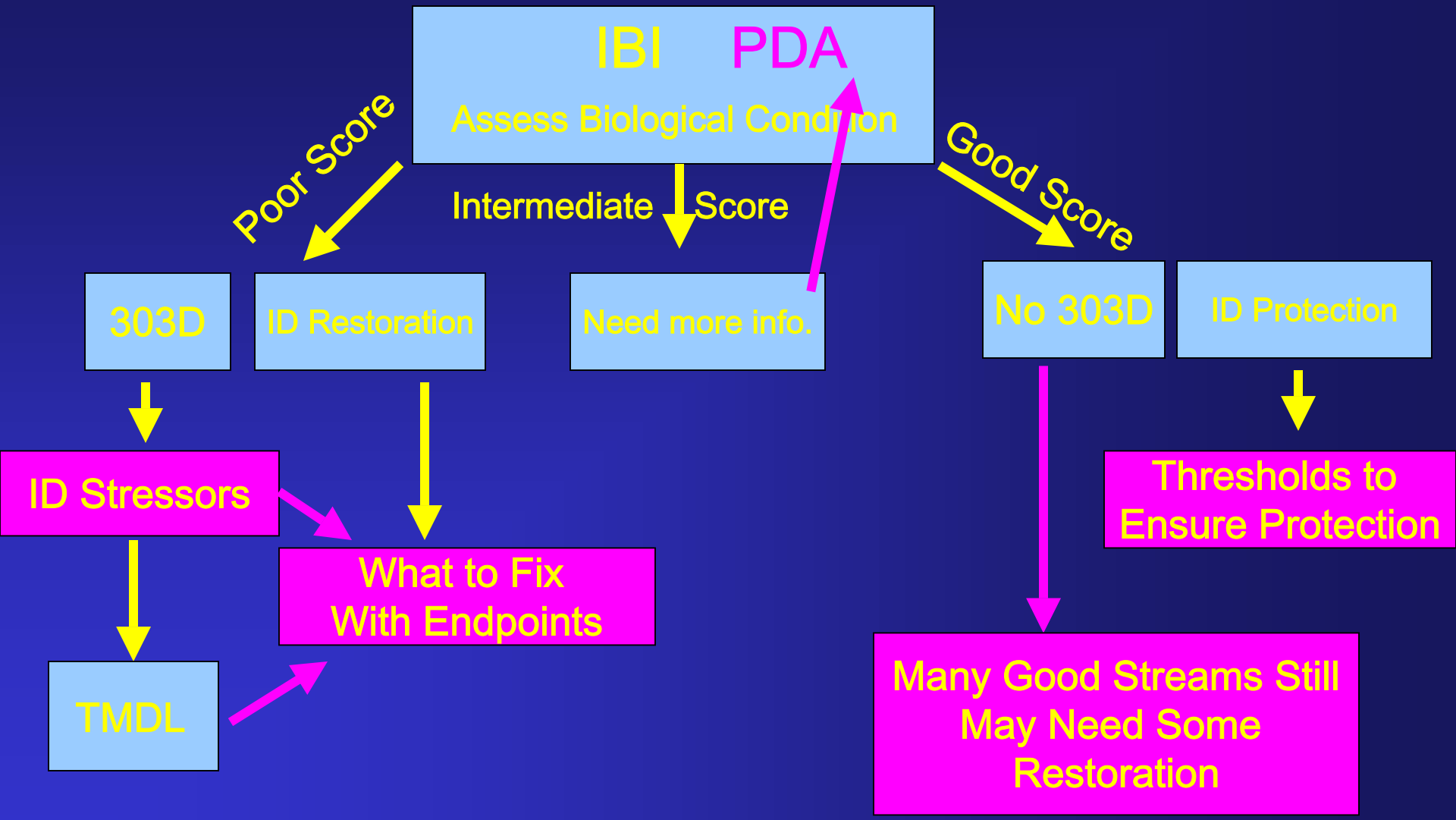


Stream Restoration (what needs to be fixed)



Protection - setting limits on anthropogenic activities (criteria)

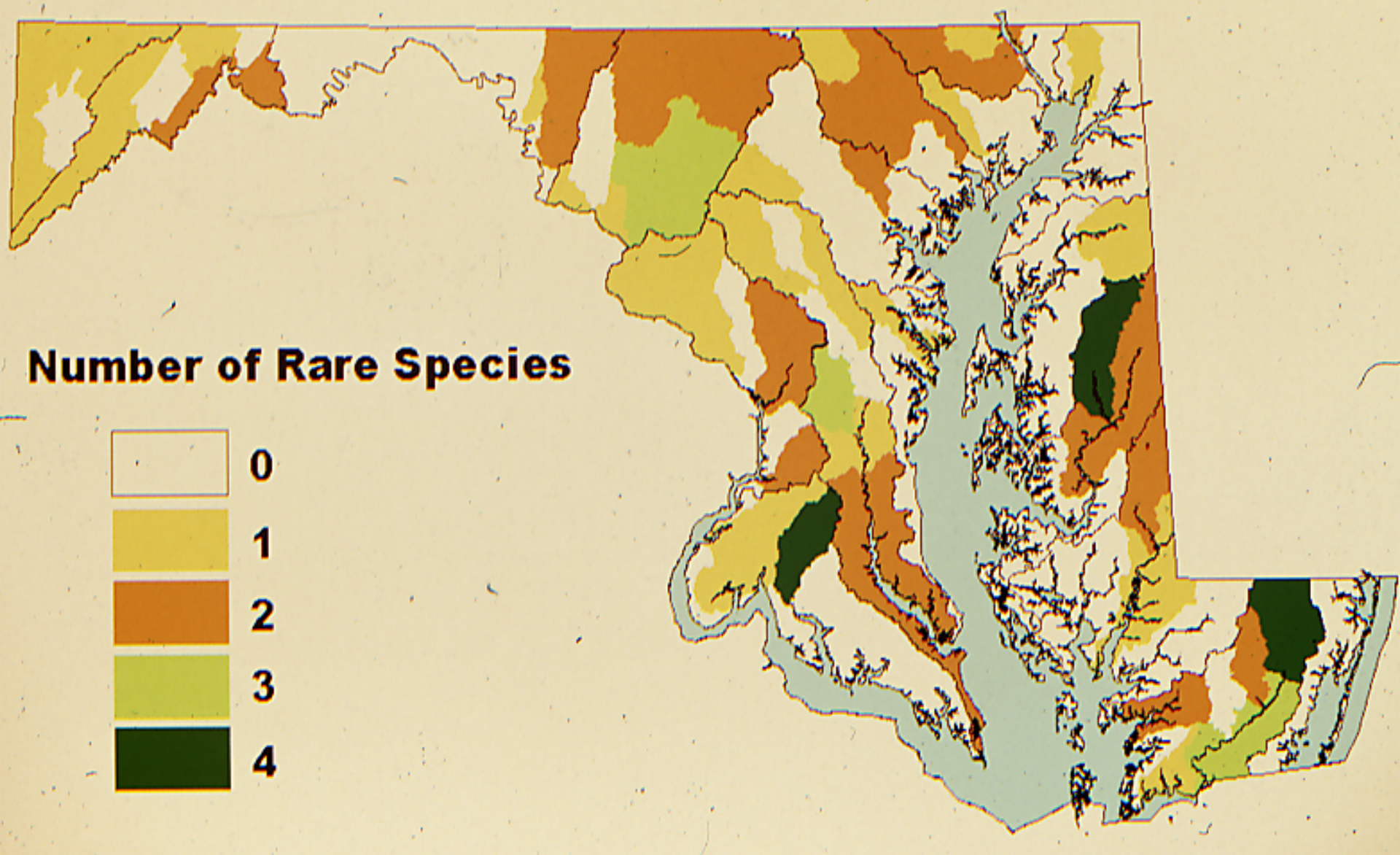
Suggested Integration

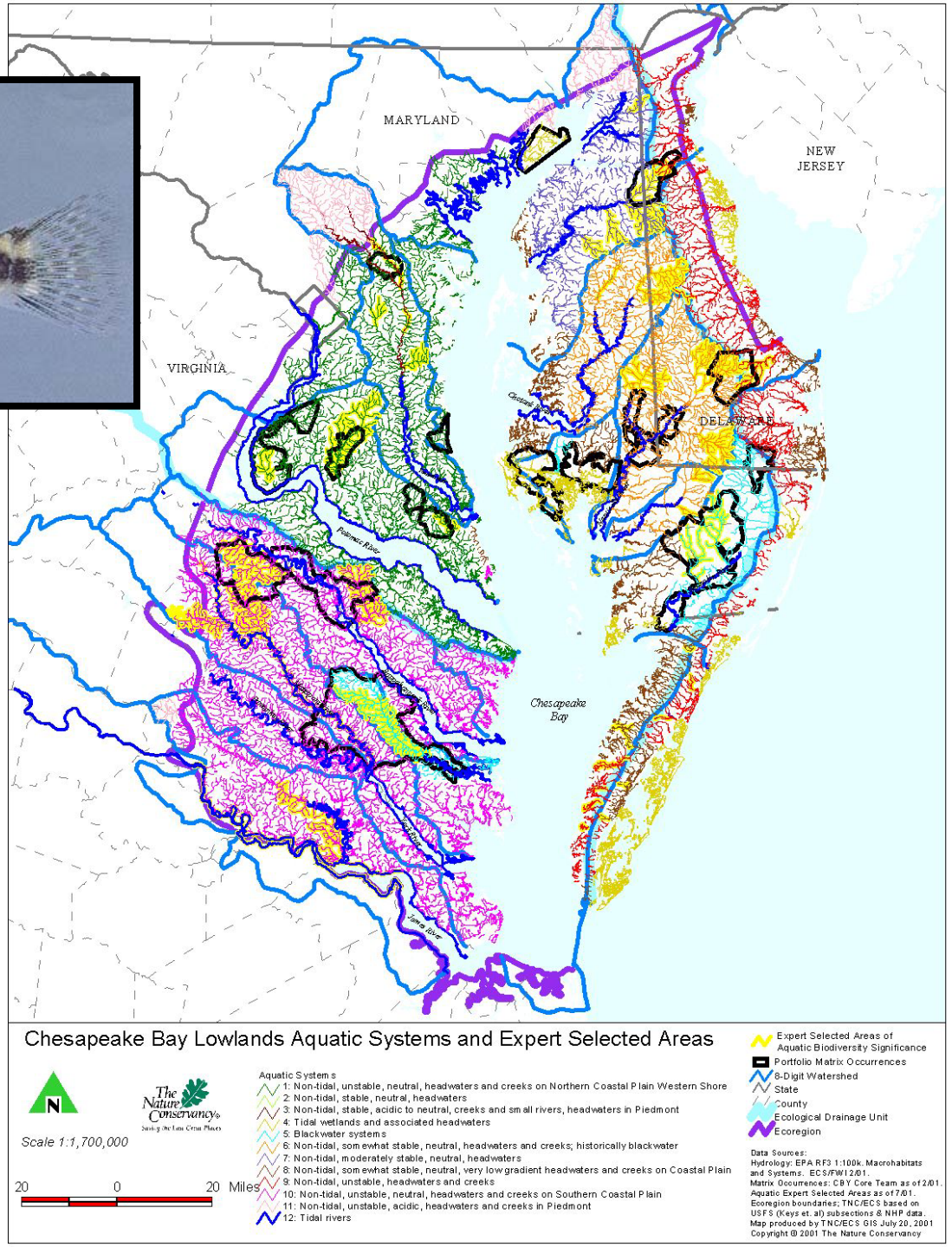


PDA

- Only need a list of fish species present and values for the predictor variables
- Can use data collected by different groups
- Widely applicable

MARYLAND WATERSHEDS WITH AT RISK FISH POPULATIONS





Chesapeake Bay Lowlands Aquatic Systems and Expert Selected Areas

N

The Nature Conservancy

Scale 1:1,700,000

20 0 20 Miles

Aquatic Systems
1: Non-tidal, unstable, neutral, headwaters and creeks on Northern Coastal Plain Western Shore
2: Non-tidal, stable, neutral, headwaters
3: Non-tidal, stable, acidic to neutral, creeks and small rivers, headwaters in Piedmont
4: Tidal wetlands and associated headwaters
5: Blackwater systems
6: Non-tidal, somewhat stable, neutral, headwaters and creeks; historically blackwater
7: Non-tidal, moderately stable, neutral, headwaters
8: Non-tidal, somewhat stable, neutral, very low gradient headwaters and creeks on Coastal Plain
9: Non-tidal, unstable, headwaters and creeks
10: Non-tidal, unstable, neutral, headwaters and creeks on Southern Coastal Plain
11: Non-tidal, unstable, acidic, headwaters and creeks in Piedmont
12: Tidal rivers

Expert Selected Areas of Aquatic Biodiversity Significance
Portfolio Matrix Occurrences
8-Digit Watershed
State
County
Ecological Drainage Unit
Ecoregion

Data Sources:
Hydrology: EPA RF3 1:100k. Macrohabitats and Systems. ECS/FWI 2/01.
Matrix Occurrences: CBY Core Team as of 2/01.
Aquatic Expert Selected Areas as of 7/01.
Ecoregion boundaries; TNC/ECS based on USFS (Keys et. al) subsections & NHP data.
Map produced by TNC/ECS GIS July 20, 2001

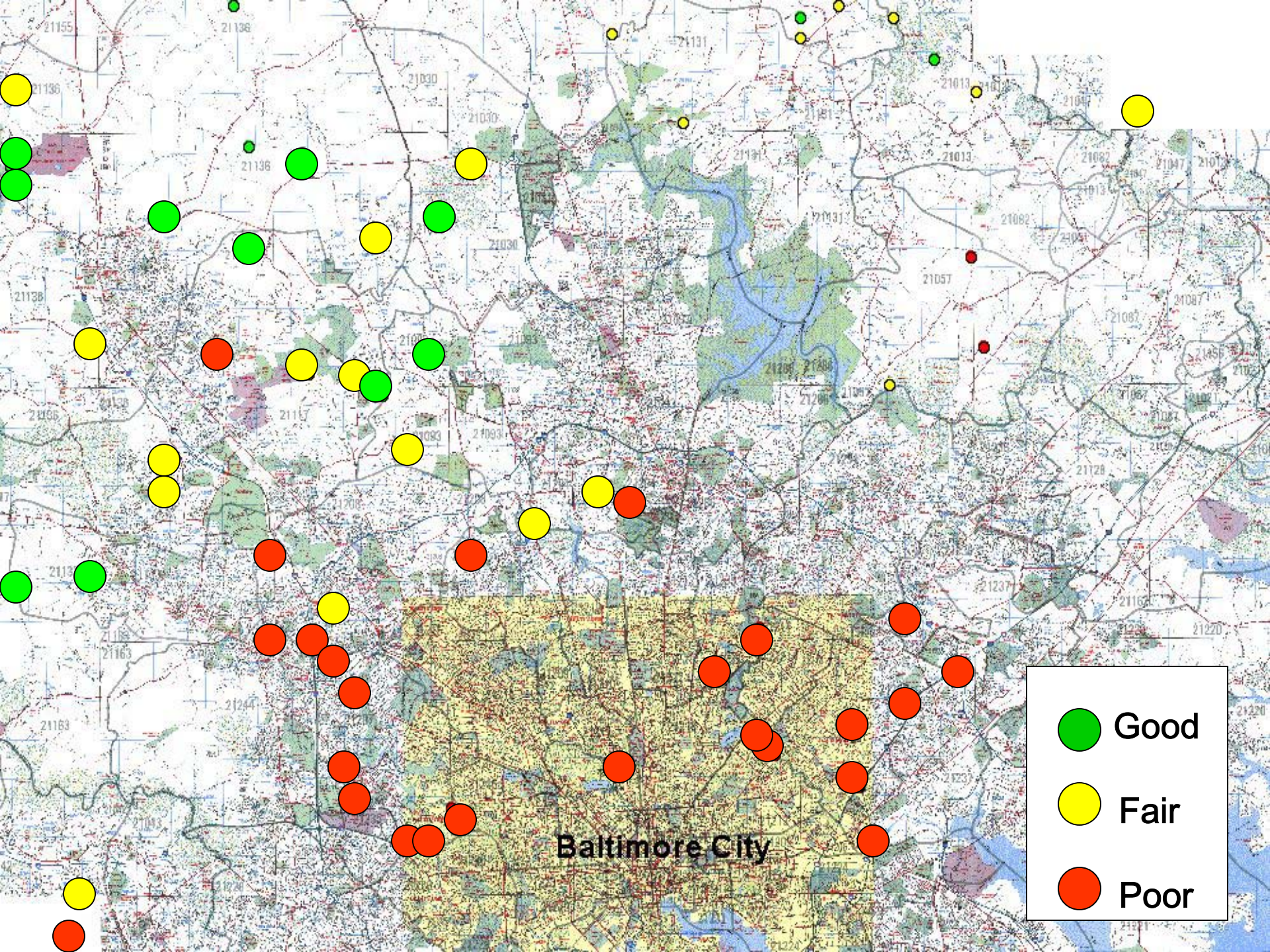

Baltimore City
Good
Fair
Poor

Table B26-1. Relationships between northern hogsucker presence, abundance, and physical habitat condition in Maryland streams. Values for a) and b) are grouped according to physical habitat scoring category reflecting various states of stream habitat: poor (0-5), marginal (6-10), sub-optimal (11-15), and optimal (16-20). Values for a) include the number of sites within that scoring category where atleast one individual was sampled and b) includes the mean species abundance in that scoring category, for only those sites listed in a).

	a) Species Presence (Number of Sites) Scoring Category				*b)* Species Abundance (Mean) Scoring Category			
Habitat Condition	0–5	6–10	11–15	16–20	0–5	6–10	11–15	16–20
Instream Habitat	0	10	68	99	0	22	14	14
Epifaual Substrate	11	25	70	71	6	13	17	13
Velocity/Depth Diversity	0	22	70	85	0	6	14	17
Pool/Glide/ Eddy Quality	0	12	71	94	0	6	17	14
Riffle Quality	11	11	66	89	15	5	11	18
Combined Habitat Score (Mean)	0	9	95	73	0	9	12	18

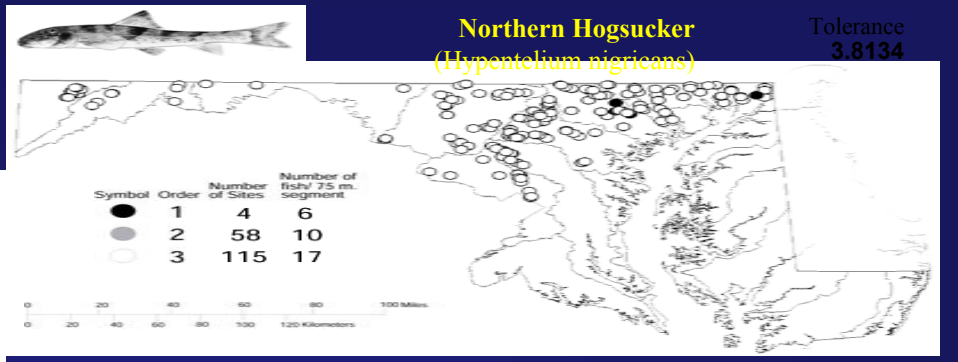


Figure B26-1. Distribution of species throughout the 17 major drainage basins in Maryland. Symbols indicate sites where at least one individual was sampled in the 1995-1997 MBSS. Symbol color indicates 1st through 3rd order streams*.

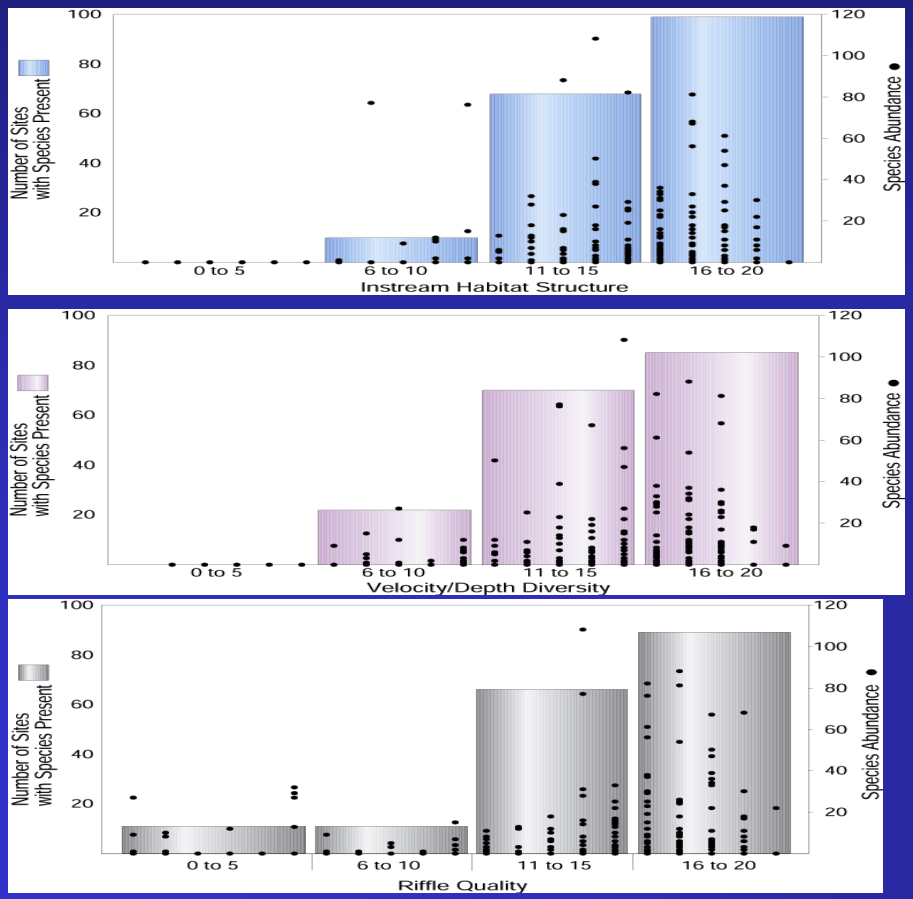


Figure B26-2. Detailed relationships between species presence, abundance, and five qualitatively assessed physical habitat parameters. Species presence and abundance values are grouped according to habitat scoring category. A combined habitat score is included as the mean of the five parameter scores for each scoring category.

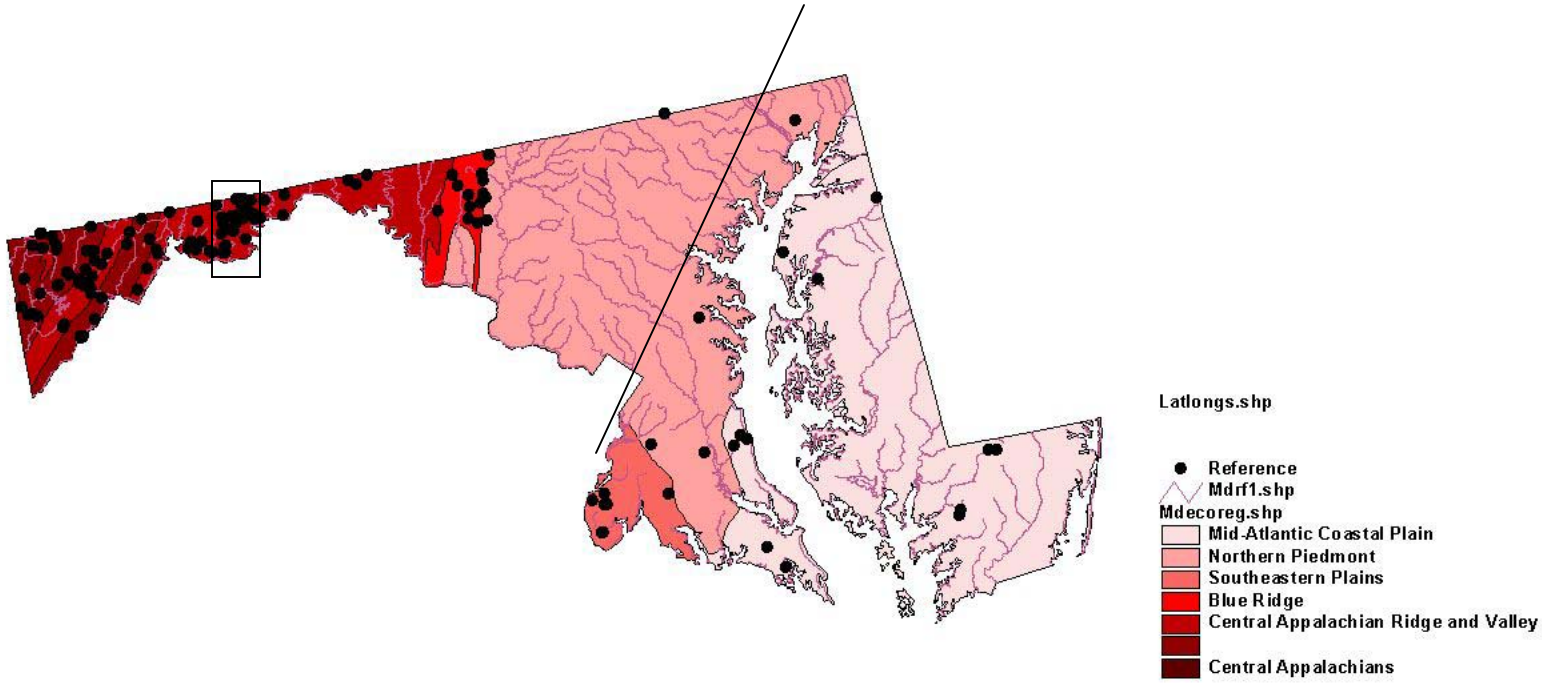
Species Scientific Name	Species Common Name	% Streams Occupied	Total Number	% Total Salamanders Captured
Desmognathus fuscus	northern dusky salamander	43.42	188	11.87
Desmognathus monticola	mountain dusky salamander	7.89	11	0.69
Desmognathus ochrophaeus	seal salamander	21.05	142	8.96
Eurycea bislineata	northern two-lined salamander	88.16	1182	74.62
Eurycea longicauda	long-tailed salamander	9.21	25	1.58
Gyrinophilus porphyriticus	northern spring salamander	13.16	21	1.33
Pseudotriton montanus	eastern mud salamander	2.63	2	0.13
Pseudotriton ruber	northern red salamander	5.26	13	0.82
TOTAL			**1584**	**100**

MBSS History:

1992	Design phase
1993	Pilot
1994	Demo
1995-97	Statewide #1
1998-99	Tidal Pilot +
2000-04	Statewide #2

Multivariable Analyses Results

- Land Use – Percent forest (+), percent impervious surface (-), percent urban (-)
- Physical Habitat – shading (+), gravel (-), riffle extent (+), riparian buffer width (+), aesthetic rating (+), total rocks (+), maximum depth (+), average thalweg depth (-)
- Water Quality – ANC (-), DOC (+)
- Biology – B-IBI (+), predator fish abundance (-)


Latlongs.shp
Reference
Mdrf1.shp
Mdecoreg.shp
Mid-Atlantic Coastal Plain
Northern Piedmont
Southeastern Plains
Blue Ridge
Central Appalachian Ridge and Valley
Central Appalachians