Distinguishing the effects of point source from those caused by upstream nonpoint source (NPS) inputs: Refinement of a watershed development index for New England

Detenbeck, N.E.[1], L. Hayes[2], C. Rosiu[3], J. Legros[4,5], D. Parsley[5], and A. Sherman[4]

[1]US EPA Atlantic Ecology Division, [2]USGS NH-VT Water Science Center, [3]US EPA Region 1, [4]Univ of Mass-Amherst,[5]former student services contractor, US EPA-AED

NEAEB 2010

March 17-19, 2010

Newport, RI

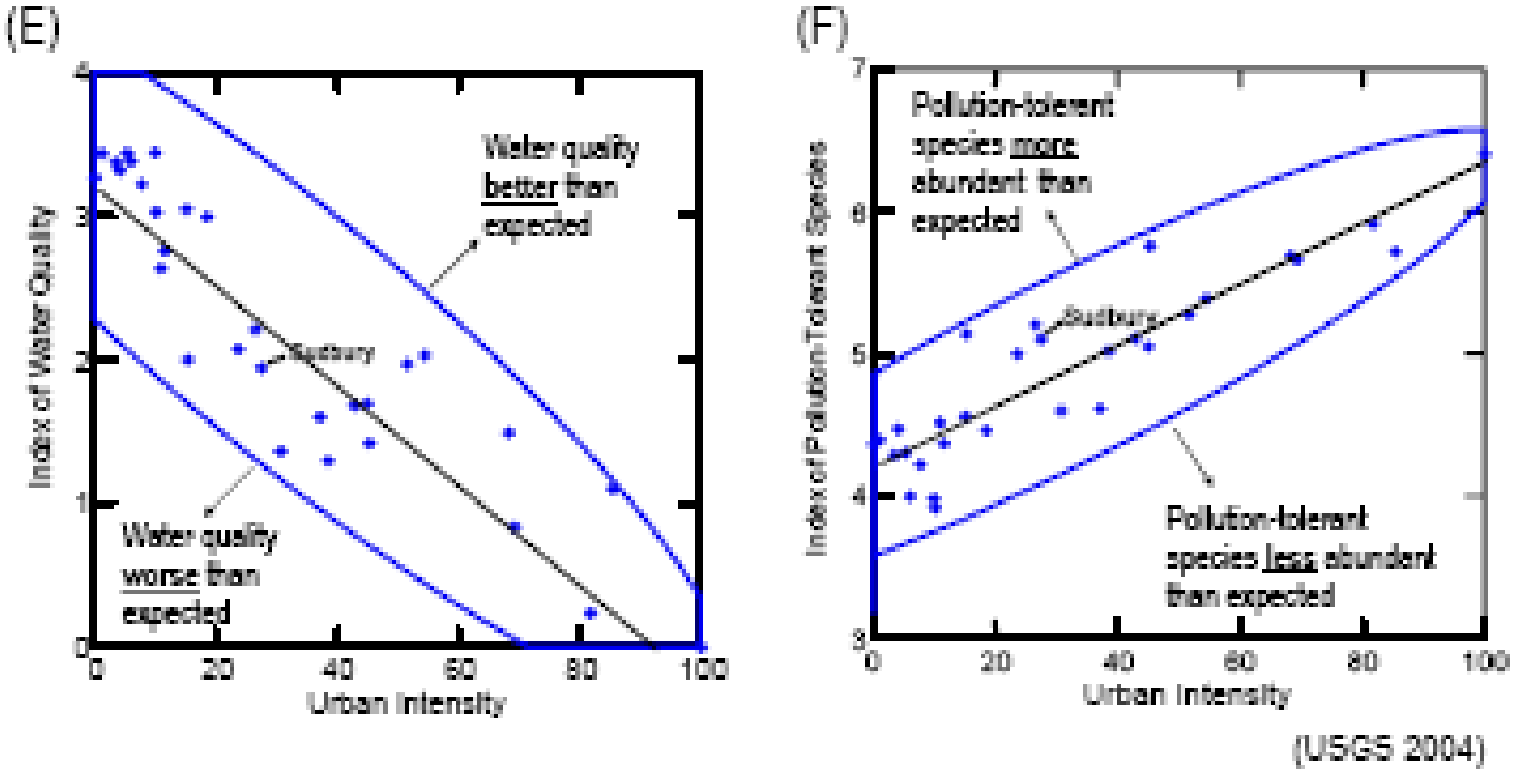
RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

Objectives

- Refine an index of watershed development for New England (building off of USGS work on index of urban intensity (Coles et al 2004))
- Develop watershed development – biological or water quality condition relationships as a tool to predict diffuse watershed effects (nonpoint source) and separate these from local impacts (point source)
- Test the utility of the watershed development index tool for evaluation of Superfund site recovery potential, evaluation of stormwater permits, and partitioning cause-effect relationships in TMDL applications

The Basic Concept



(USGS 2004)

Risks can be attributed to contaminants to the extent that responses deviate from expected on the basis of the stressor-response model

Rosiu, C. and J. Coles. 2005. Standardizing Sediment Risk Characterization on the Basis of Urban Intensity of the Watershed***. US EPA Science Forum, Washington, DC.***

RESEARCH & DEVELOPMENT

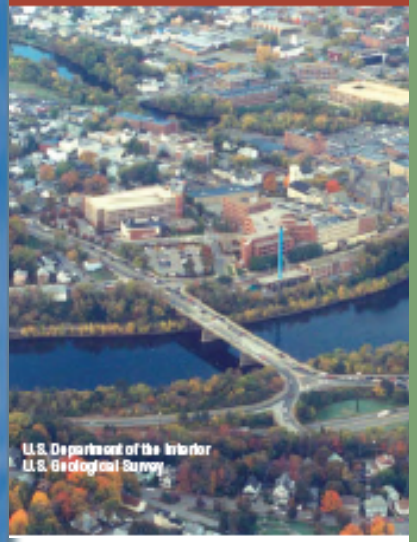
Building a scientific foundation for sound environmental decisions

USGS science for a changing world

NATIONAL WATER-QUALITY ASSESSMENT PR

The Effects of Urbanizatic Biological, Physical, and Characteristics of Coasta England Streams

Professional Paper 1695



USGS science for a changing world

Cuffney and Falcone 2008

National Water-Quality Assessment Program

Derivation of Nationally Consistent Indices Representing Urban Intensity within and across Nine Metropolitan Areas of the Conterminous United States

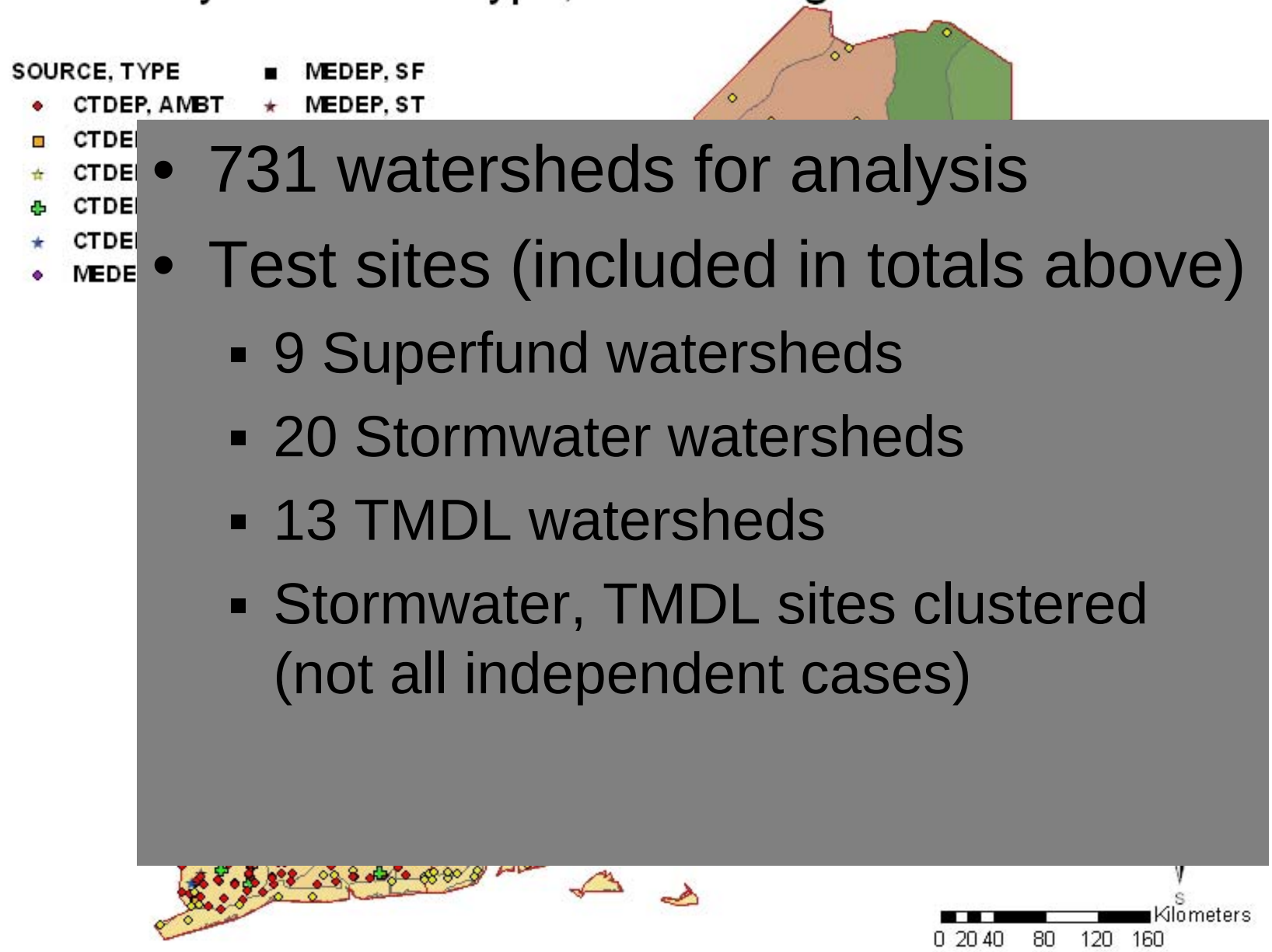
Final National UII components

- Housing Unit density
- Road density
- % developed land

Proposed additions (Falcone et al. 2007)

- % impervious area
- urban patch metrics
- indices of sprawl

1: EPA & USGS Priority Sites
By source and type, over ecoregion subsections



- 731 watersheds for analysis
- Test sites (included in totals above)
  - 9 Superfund watersheds
  - 20 Stormwater watersheds
  - 13 TMDL watersheds
  - Stormwater, TMDL sites clustered (not all independent cases)

RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

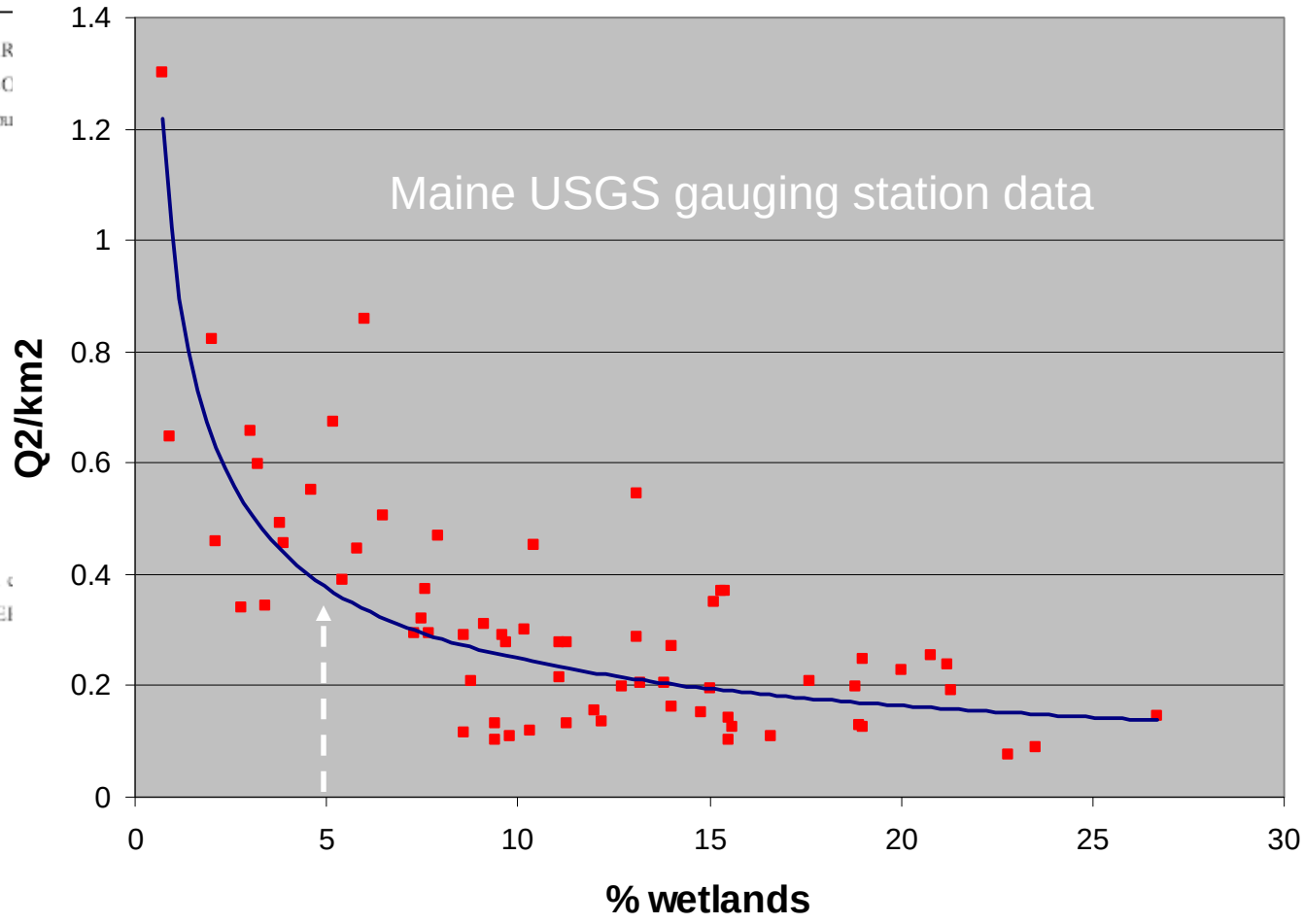
Estimating the Magnitude of Peak Flows for Streams in Maine for Selected Recurrence Intervals

by Glenn F

U.S. DEPAR
U.S. GEOLO
Water-Resou

Prepared in c
MAINE DEI

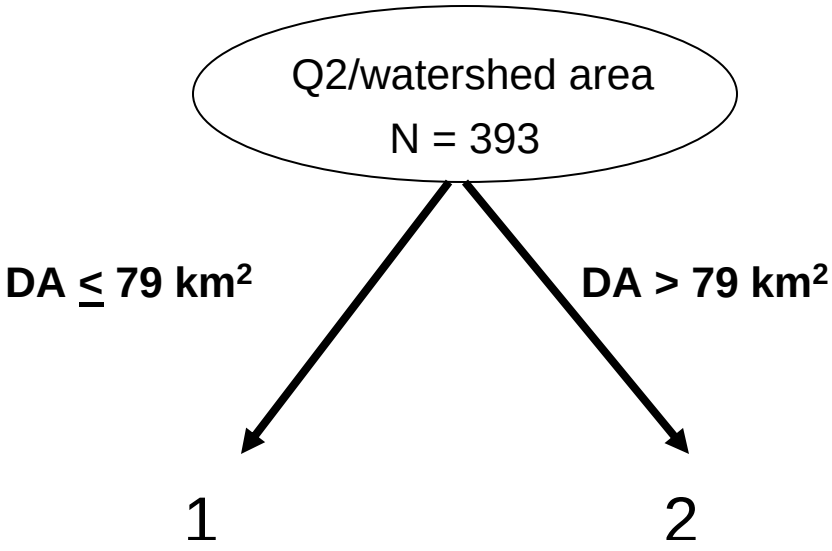
Flow responsiveness vs % storage



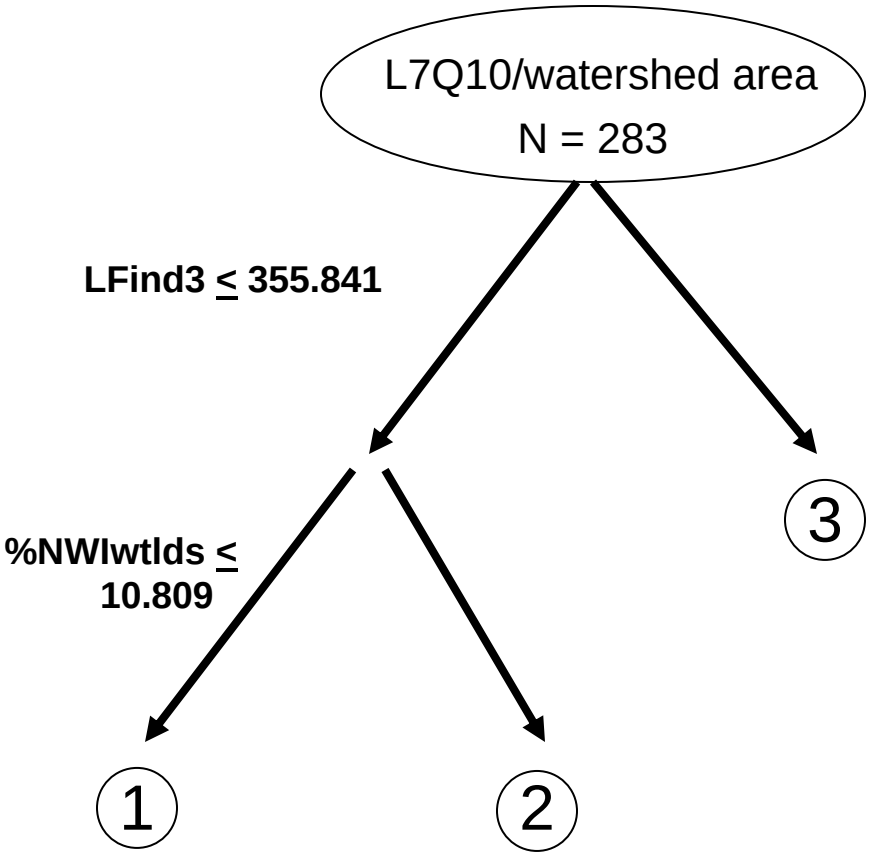
NE basin characteristics related to peak or low flow

- Watershed area
- Main channel length
- Main channel slope
- Lake + pond area (high resolution NHD)
- % wetland area (palustrine emergent + open water classes based on National Wetlands Inventory coverages but not including lake + pond area from high-resolution NHD)
- Percent impervious area
- Percent coarse glacial till, outwash, and stratified drift
- 2-year 24-hour rainfall depth
- % forested (NLCD92 and NLCD01)
- Mean elevation, % area with elevation > 1200 ft
- Annual, spring, and winter precipitation averages (PRISM)
- Annual mean temperature (PRISM)

Bayesian Classification and Regression Tree analysis (BCART)



Which variables discriminate watershed classes with different peak flow prediction equations?



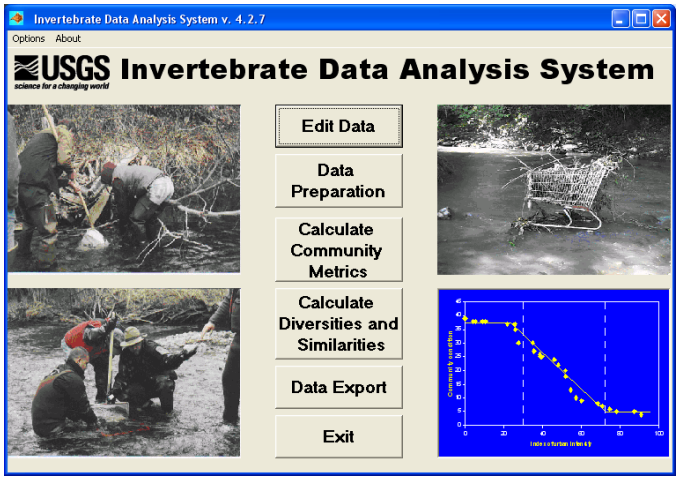
CART

Which variables discriminate watershed subclasses with different low flow levels?

LFind3 = precwntr*tempannav / (precspr*(fr_coarsedep+0.01))

Macroinvertebrate data processing

- ITIS taxonomy codes
- Adjustment to common taxonomy resolution (CTXH)
- Ambiguous taxa corrections and calculation of metrics using combination of USGS IDAS software and MS Access queries
  - % abundance and richness
    - Taxonomic groups
    - Trophic guilds[1]
    - Habit guilds[1]
  - Abundance- and taxa-weighted tolerance values
    - Fine substrate[2]
    - Suspended sediments[2]
    - DO/temperature[2]
    - Nutrients[2,3]
    - Ionic strength[2]
  - Diversity indices



[1] Updated for New England from RBP tables w Vieira et al. 2006
[2] Carlisle et al. 2007
[3] Smith et al. 2007 TP, NO_3 optima (NY state)

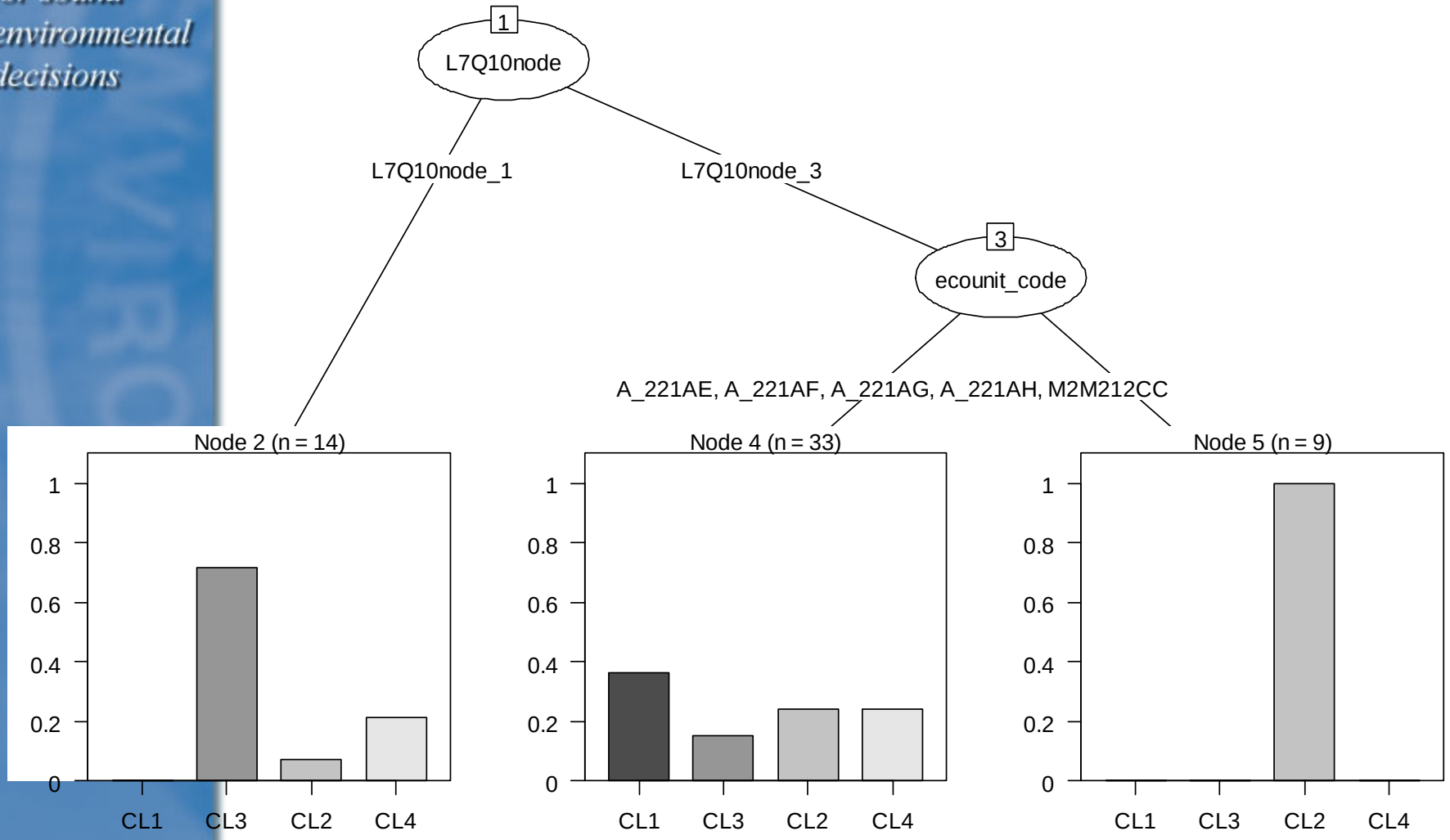
Metrics of taxa loss

- Taxa richness
- Observed/Expected (O/E)
  - Cluster analysis of taxa P/A for ref sites
  - Classification of sites to predict cluster membership and expected n taxa (E)
    - CHAID= classification tree w multiway splits possible
    - Factors =Julian day, NEGEOCL, NESZCL, NESLPCL, NETEMPCL, ecoreg, ecounit, low flow class, peak flow class
- Modified for regional scale
  - Bray-Curtis index of dissimilarity (BC)
  - Coefficient of Community Loss (CCL)

RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

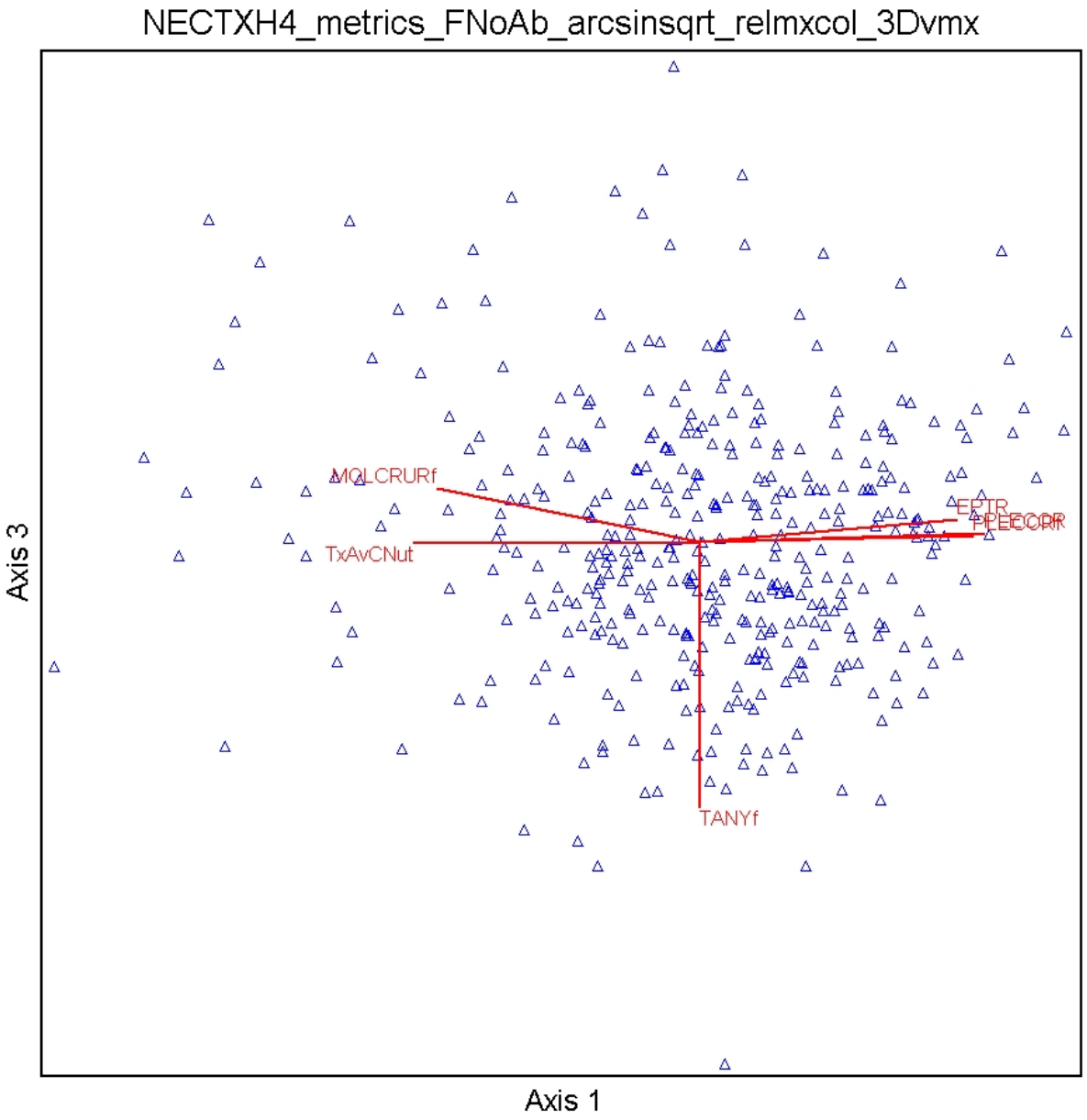
CHAID prediction model for CT 4 taxa clusters



RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

NMDS ordinations



Metrics chosen to represent axes of major variation

- NEWS data set
  - EPTRf, MOLCRURf, WtAvSNO3
- CTDEP data set
  - EPTR, MOLCRURf, bu_rich
- MEDEP data set
  - EPTR, EPT_CHR, ORTHORf
- Combined CTXH
  - EPTR, DIPR,DIPRf, EPTf,TANYf

EPT = Ephemeroptera/Plecoptera/Trichoptera,CHR = Chironomids, DIP = Diptera, ORTHO = Orthocladinae midges, TANY = Tanytarsini midges, bu = burrower guild

RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

NEWS Indicator Analysis

Lo-imperv (<1%)	Hi-imperv (>10%)	p-value
Climbers		0.0486
Sprawlers		0.0300
Mayflies		0.0078
Stoneflies		0.0006
Orthocladinae midges		0.0168
	Gastropods	0.0112
	Isopods	0.0022
Predators		0.0464
	Omnivores	(0.0538)
Scrapers		0.0366
Shredders		0.0036

Dufrene, M. and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecol. Monogr. 67:345-366.

RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

CTDEP Indicator Analysis

Lo-imperv	Hi-imperv	p-value
Climbers		0.0066
Swimmers		0.0004
Mayflies (E)		0.0018
Stoneflies (P)		0.0002
	Caddisflies (T)	0.0006
Dragonflies		0.0002
Aq beetles		0.0002
Predators		0.0002
	Omnivores	0.0296
	Filterer-collectors	0.0008
Scrapers		0.0002
Shredders		0.0046

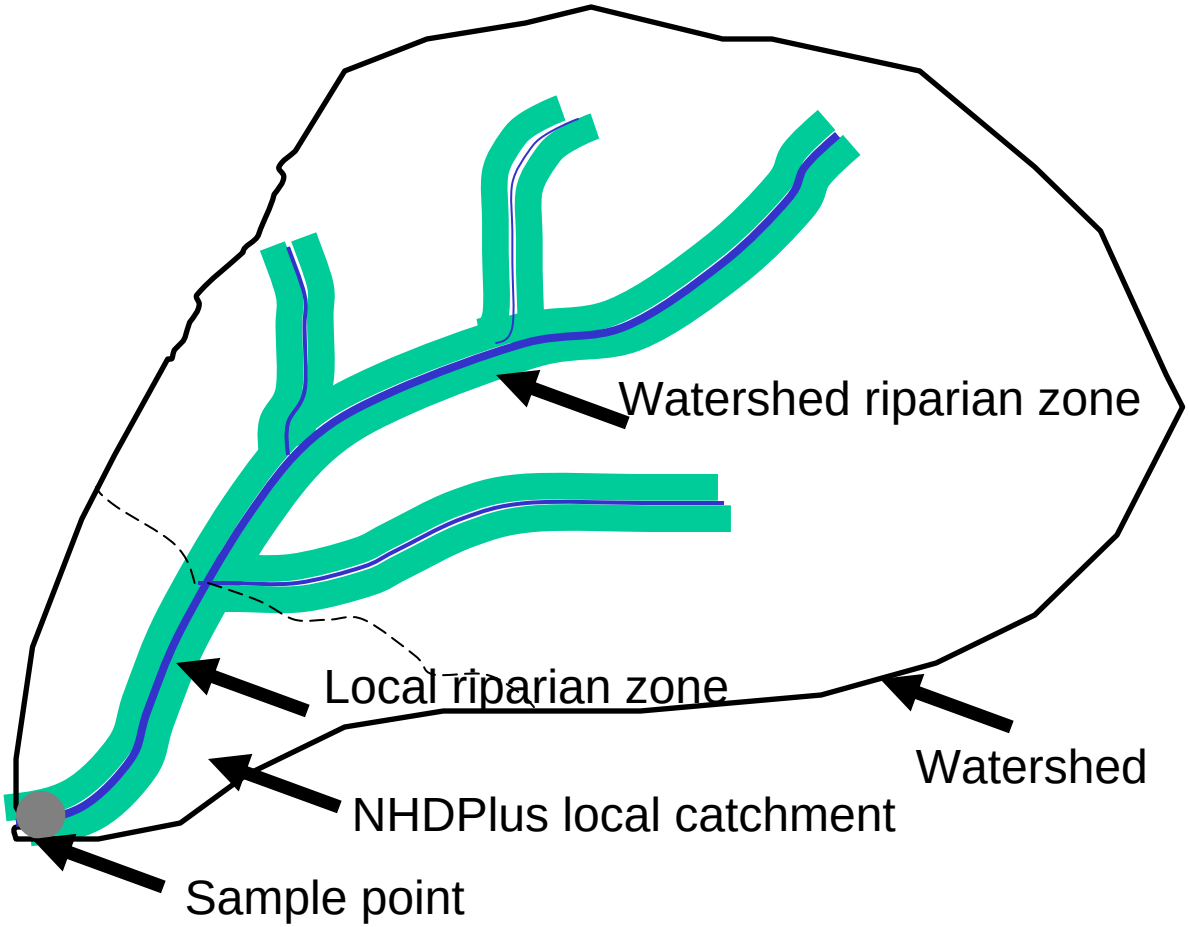
RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

MEDEP Indicator Analysis

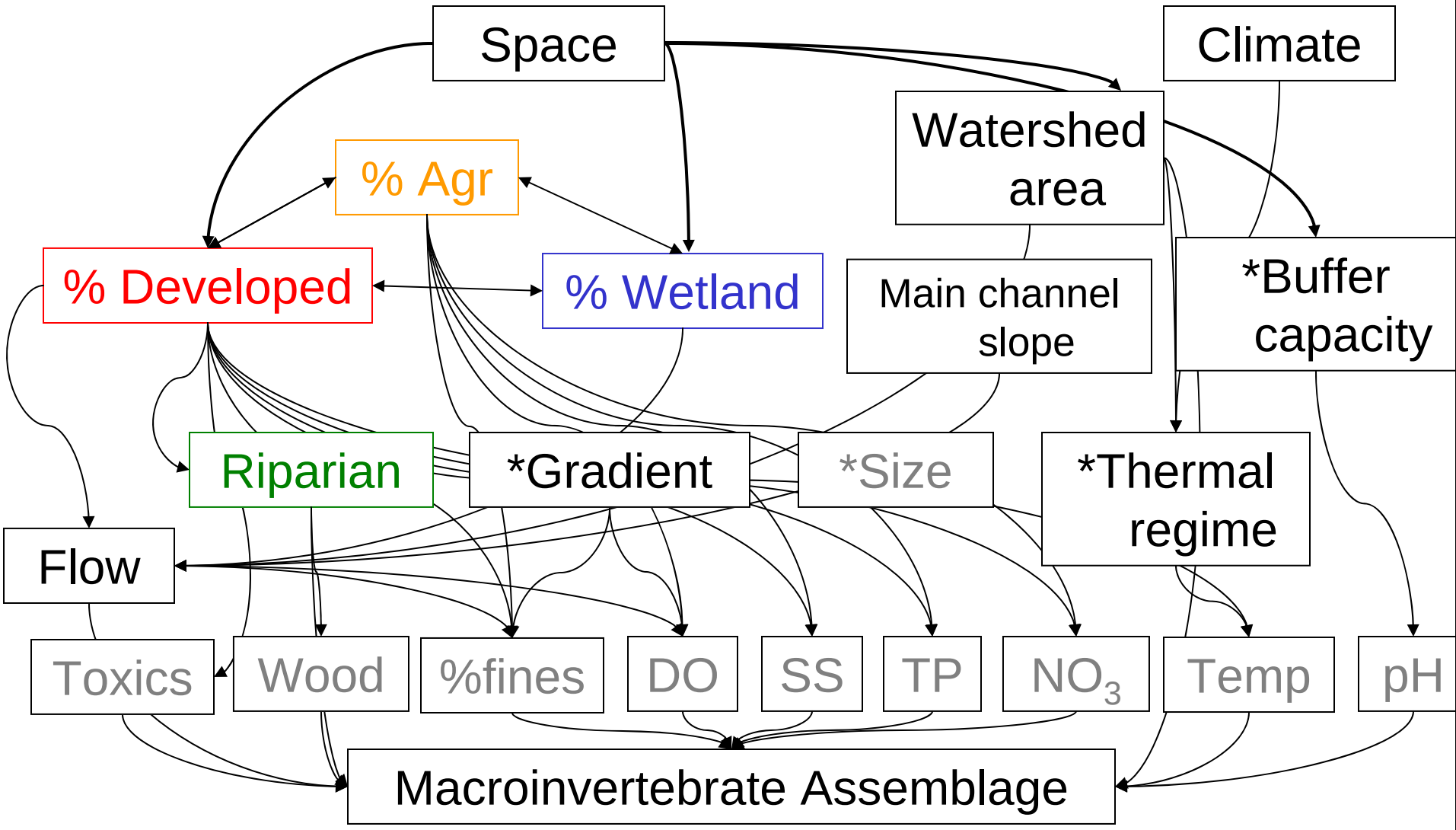
Lo-imperv	Hi-imperv	p-value
Clingers		0.0250
Sprawlers		0.0104
Swimmers		0.0274
EPT		0.0002
Mayflies (E)		0.0002
Stoneflies (P)		0.0012
Caddisflies (T)		0.0026
Pteronarcys		0.0258
Aquatic beetles		0.0302
	Amphipods	0.0232
	Isopods	0.002
Predators		0.0002
Filterer-collectors		0.0008
Scrapers		0.0094
Shredders		0.0004

Determining scale of influence



Challenges: Spatial autocorrelation, spurious effects

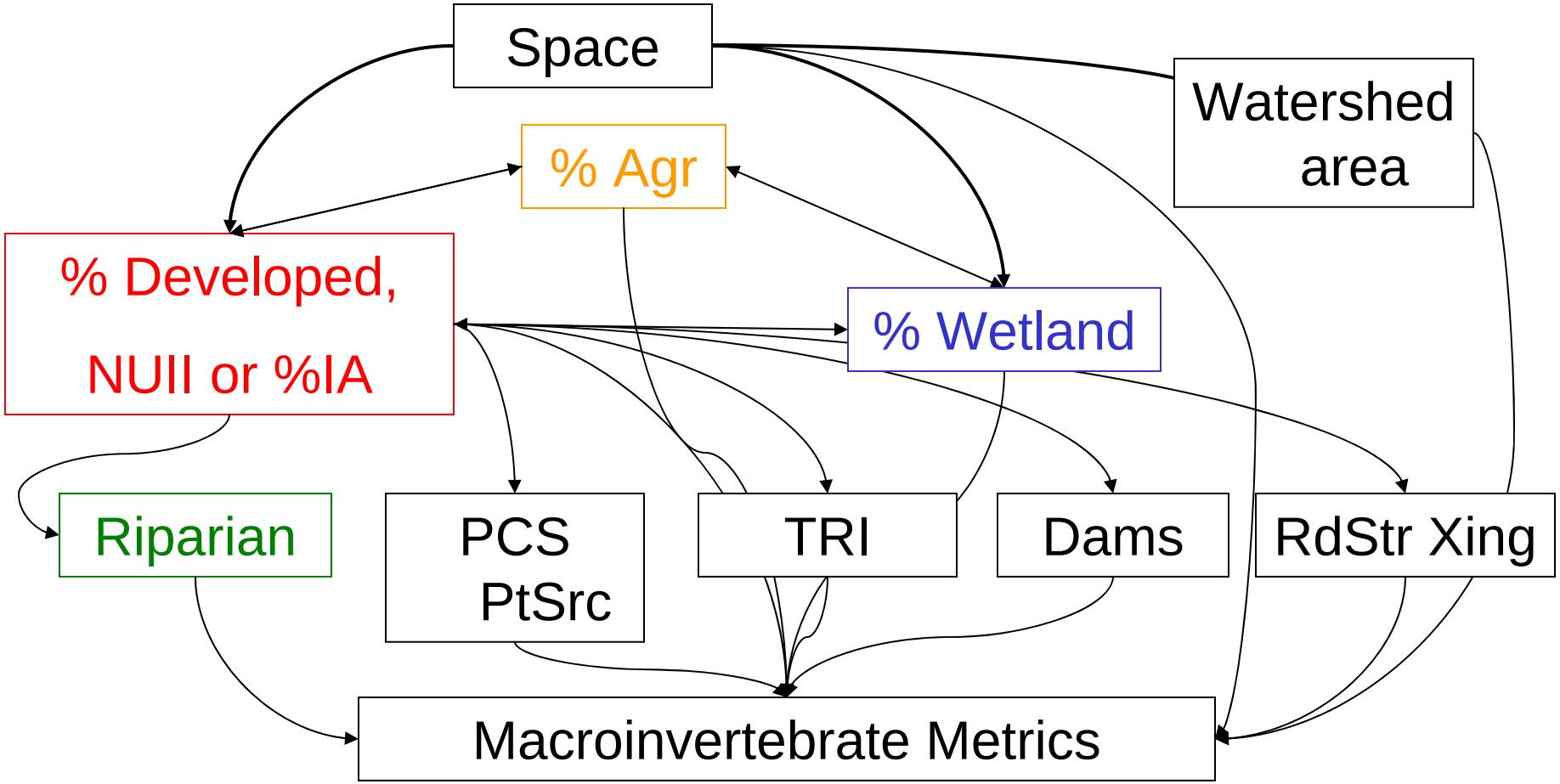
Ideal partial Mantel path diagram



* TNC NE Aquatic habitat classes

Modified from King et al. 2005. Ecol. Appl. 15:137-53.

Applied partial Mantel tests

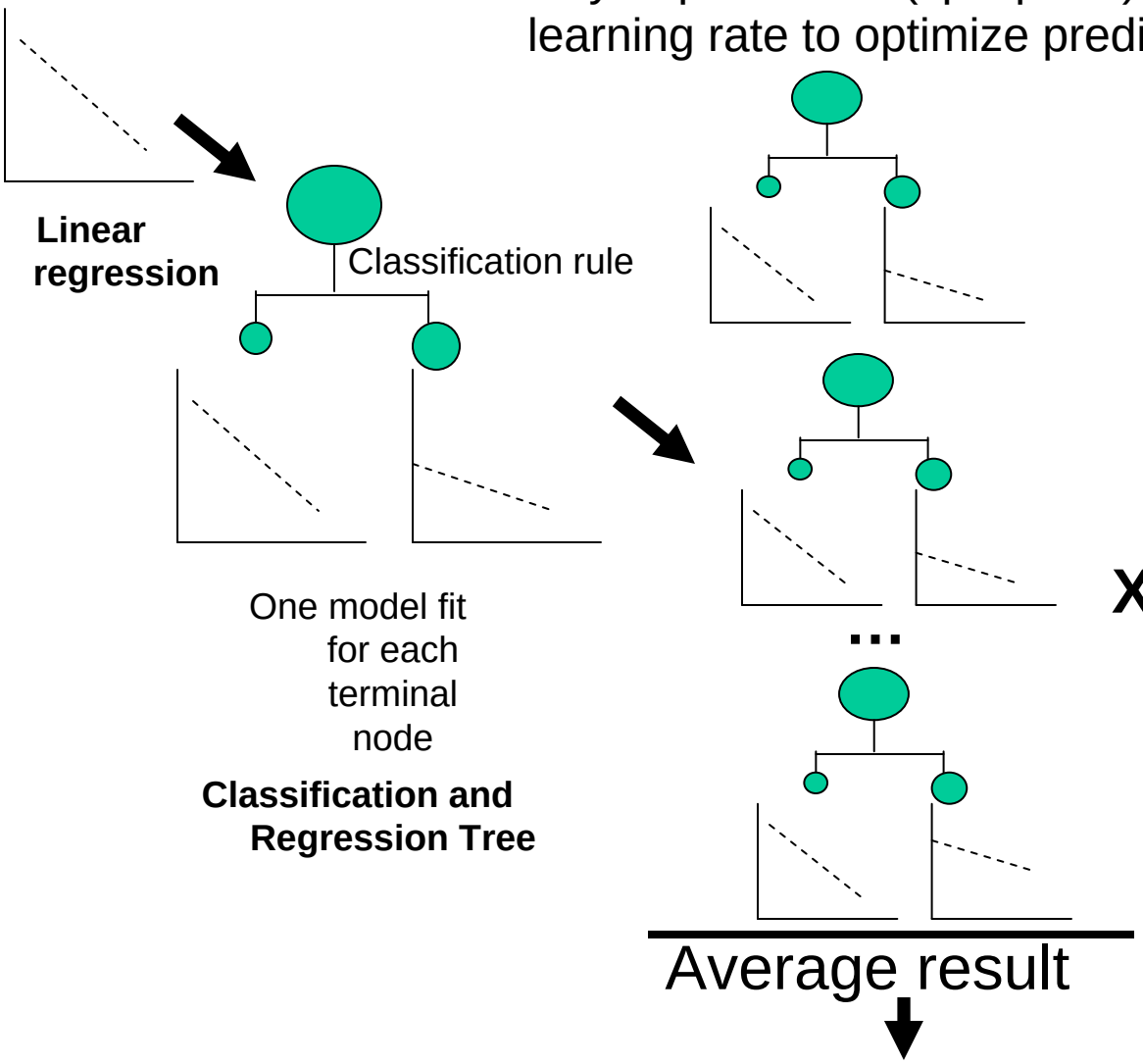


Which land-use/land-cover scale is most strongly associated with macroinvertebrate community response?

Can we discriminate between whole watershed/catchment effects and mediating effects of wetlands or riparian zone?

Boosted regression trees

Modify depth of tree (split prob.) and learning rate to optimize prediction



X 10 = 10-fold cross validation (c.v.)

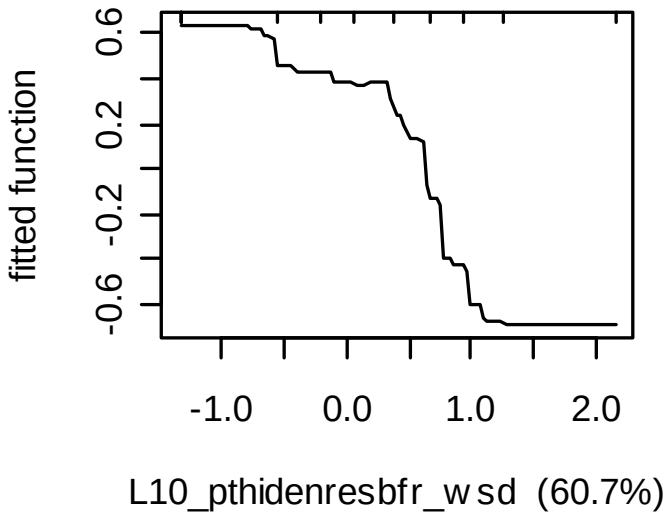
Test predicted vs. observed on withheld 10% of data

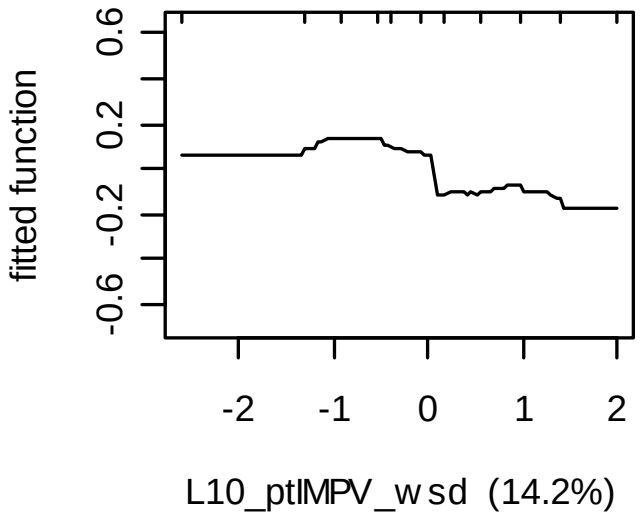
Predictive power of boosted regression tree models: Predicted vs observed

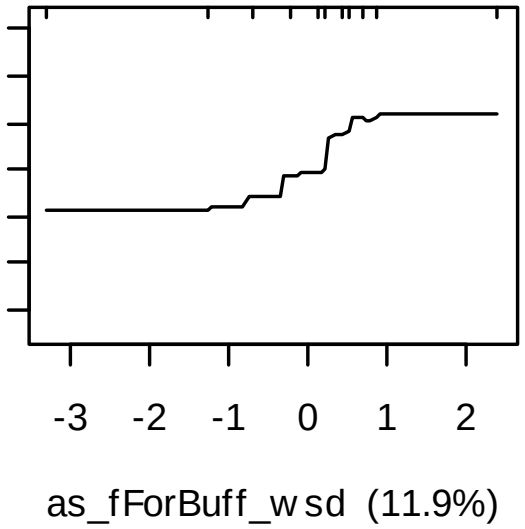
Training data set vs. 10-fold cross-validation results

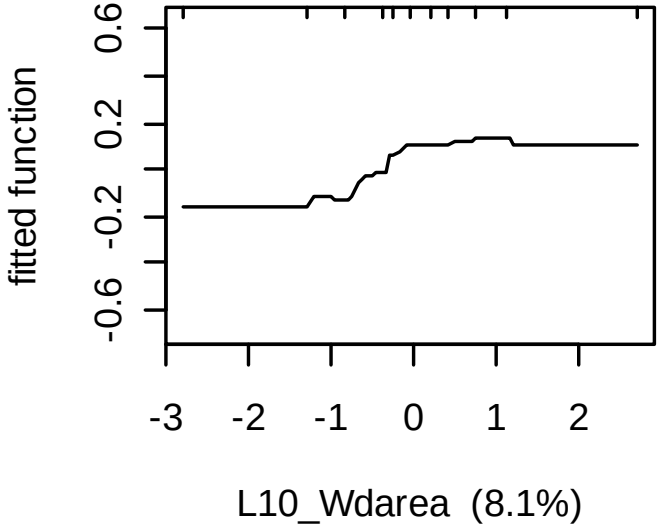
	ME		NEWS		CT	
	Training corr'n	CV corr'n	Training corr'n	CV corr'n	Training corr'n	CV corr'n
Sensitive taxa	---	---	0.82	0.599	---	---
Overall richness	0.714	0.572			0.75-0.89	0.63-0.67
Group Richness	0.49-0.82	0.39-0.67	0.72-0.81	0.58-0.60	0.64-0.85	0.57-0.73
Relative richness	---	---	0.79-0.80	0.52-0.73	---	---
Relative abundance	0.63-0.63	0.21-0.53	0.56-0.64	0.28-0.52	0.47-0.76	0.34-0.55
Trophic guild relative abundance	---	---	0.56-0.73	0.17-0.44	0.65-0.83	0.52-0.61
Habitat guild relative abundance	0.48	0.36	0.65	0.34	0.30-0.75	0.25-0.46
Summary	0.48-0.82	0.21-0.67	0.56-0.82	0.15-0.73	0.39-0.89	0.25-0.73

Partial effects on EPT richness (CT DEP)



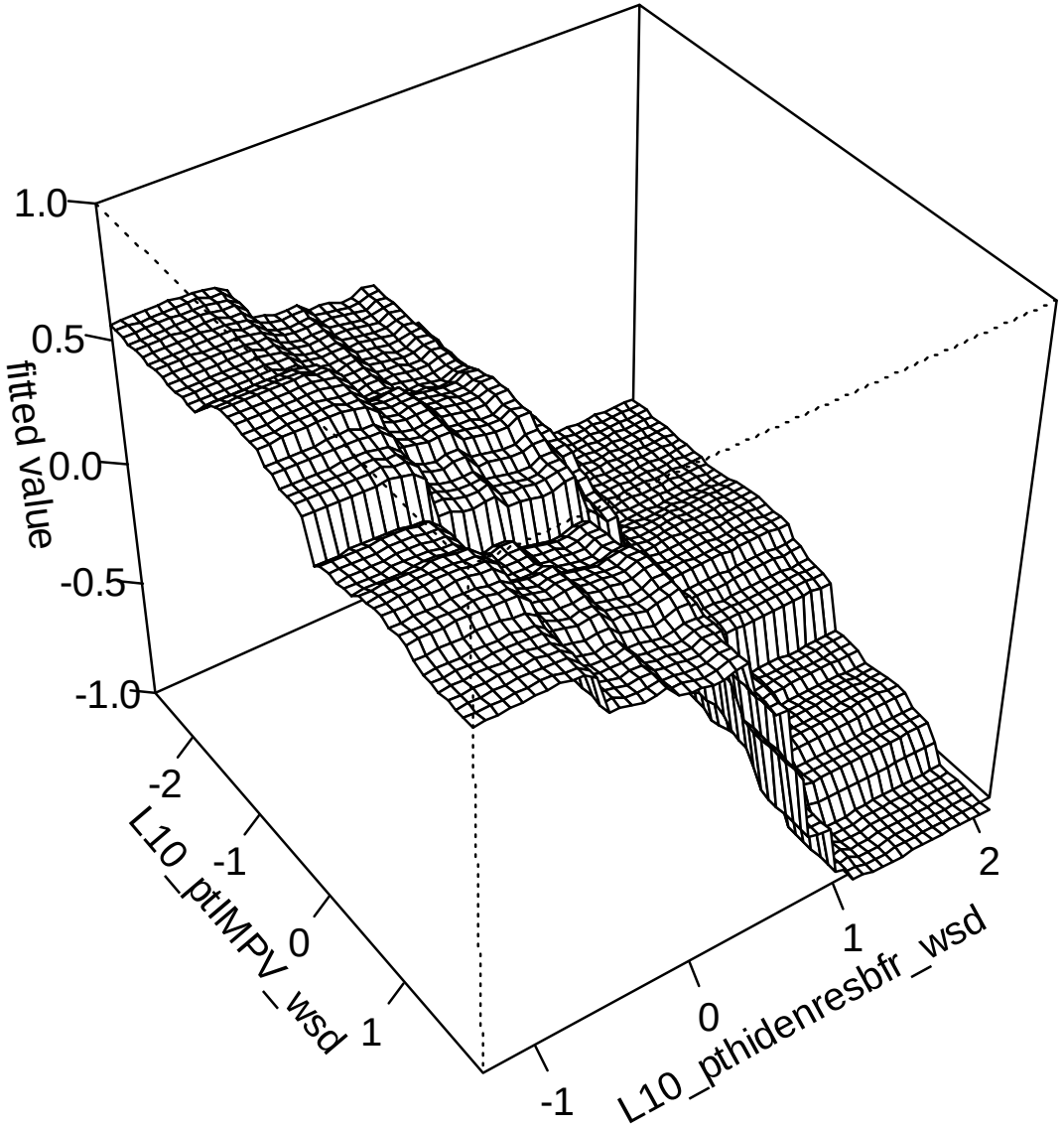






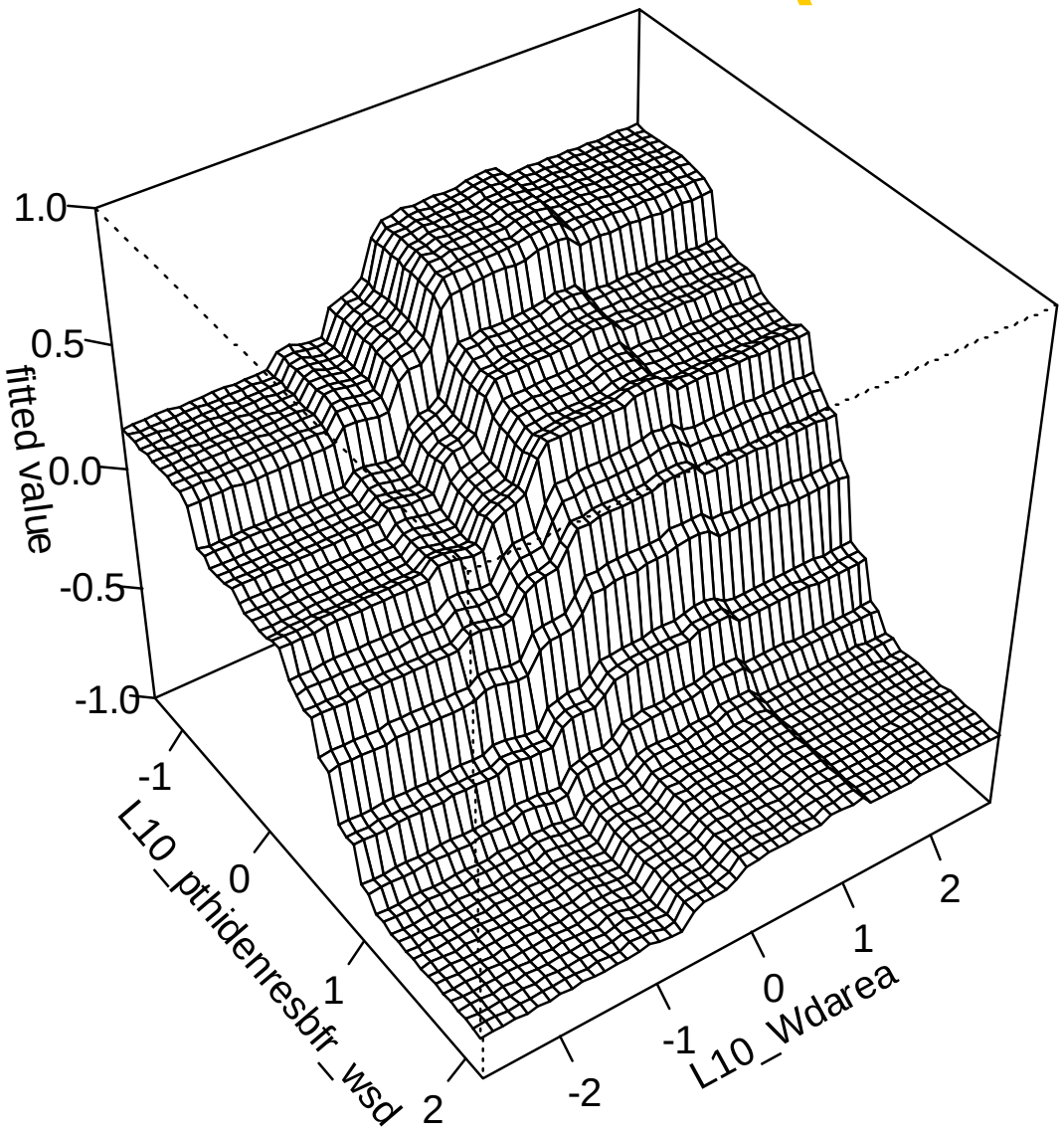
Note: All units standardized to z-scores for comparability

Interactive effects on EPT richness (CT DEP)



Combined effects of % impervious watershed area and % high density residential buffer zone are more than additive

Interactive effects on EPT richness (CT DEP)

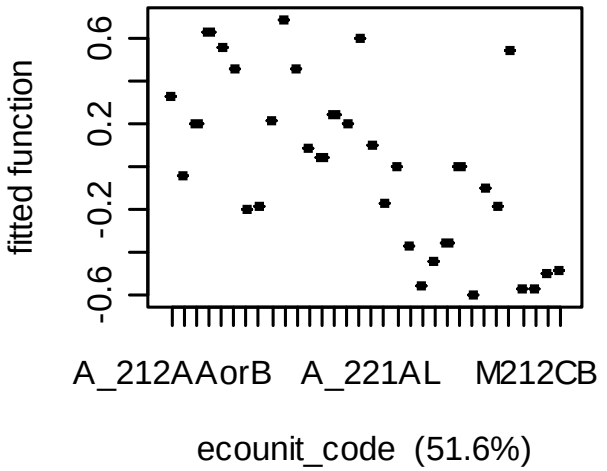


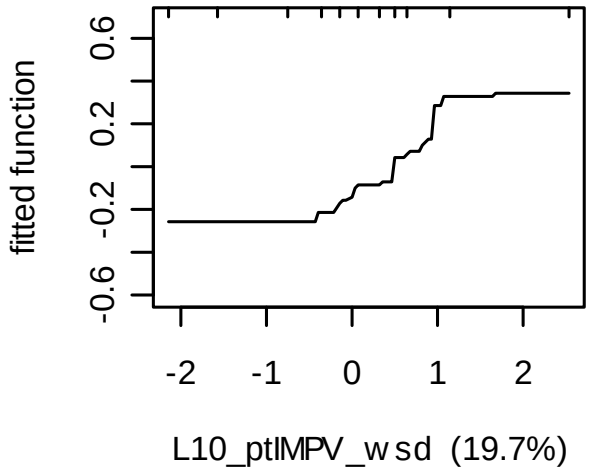
Greater loss of taxa along gradient of high-density residential buffer zone in larger watersheds

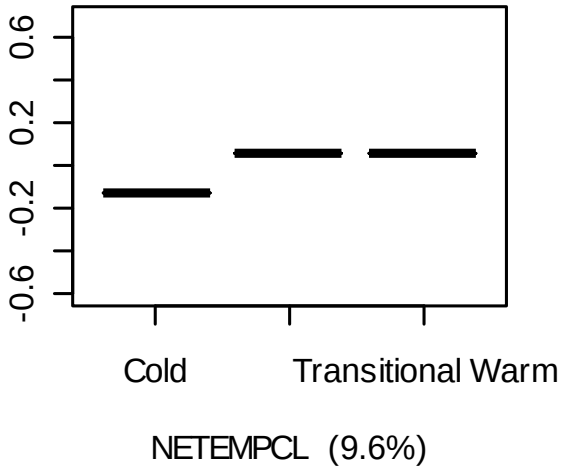
RESEARCH & DEVELOPMENT

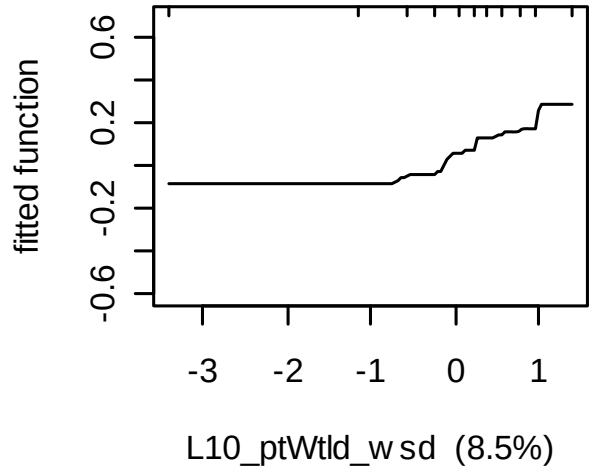
Building a scientific foundation for sound environmental decisions

Partial effects on relative richness of molluscs + crustaceans (NEWS)







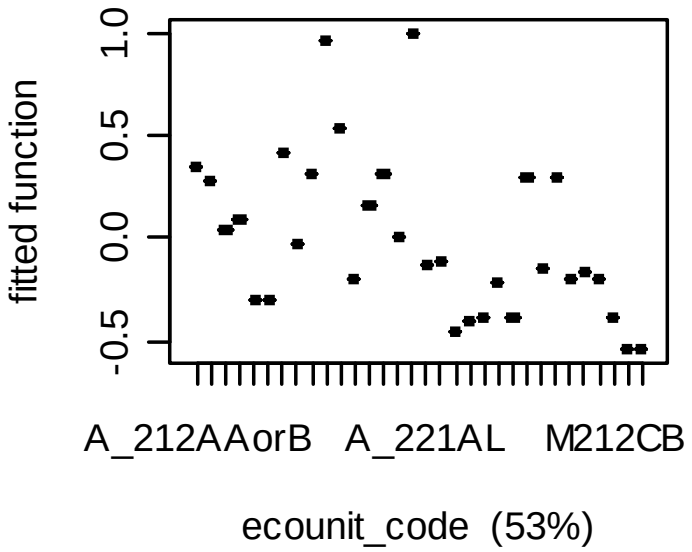


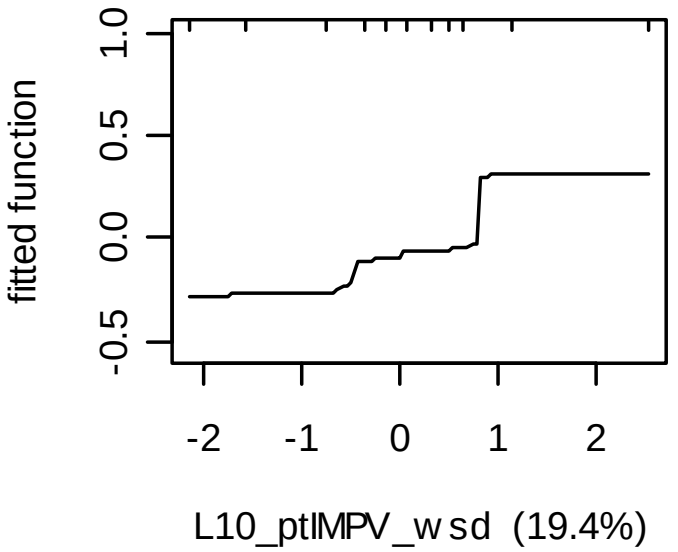
RESEARCH & DEVELOPMENT

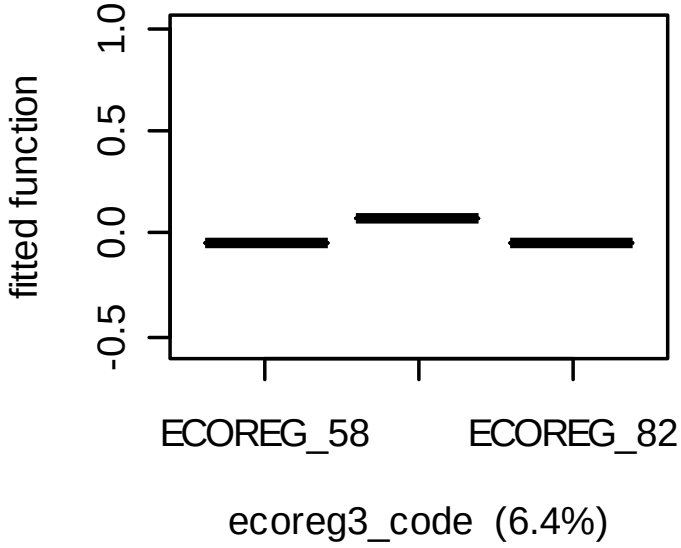
Building the scientific foundation for sound environmental decisions

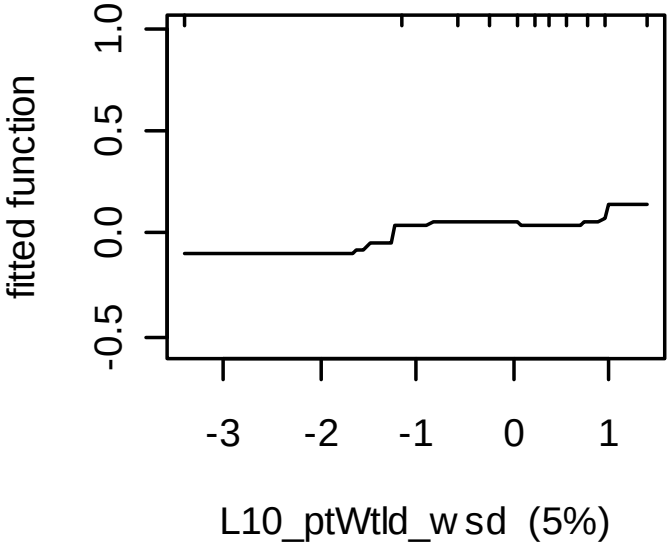
Partial effects on NO3 score (NEWS)

Atmospheric loading gradient?

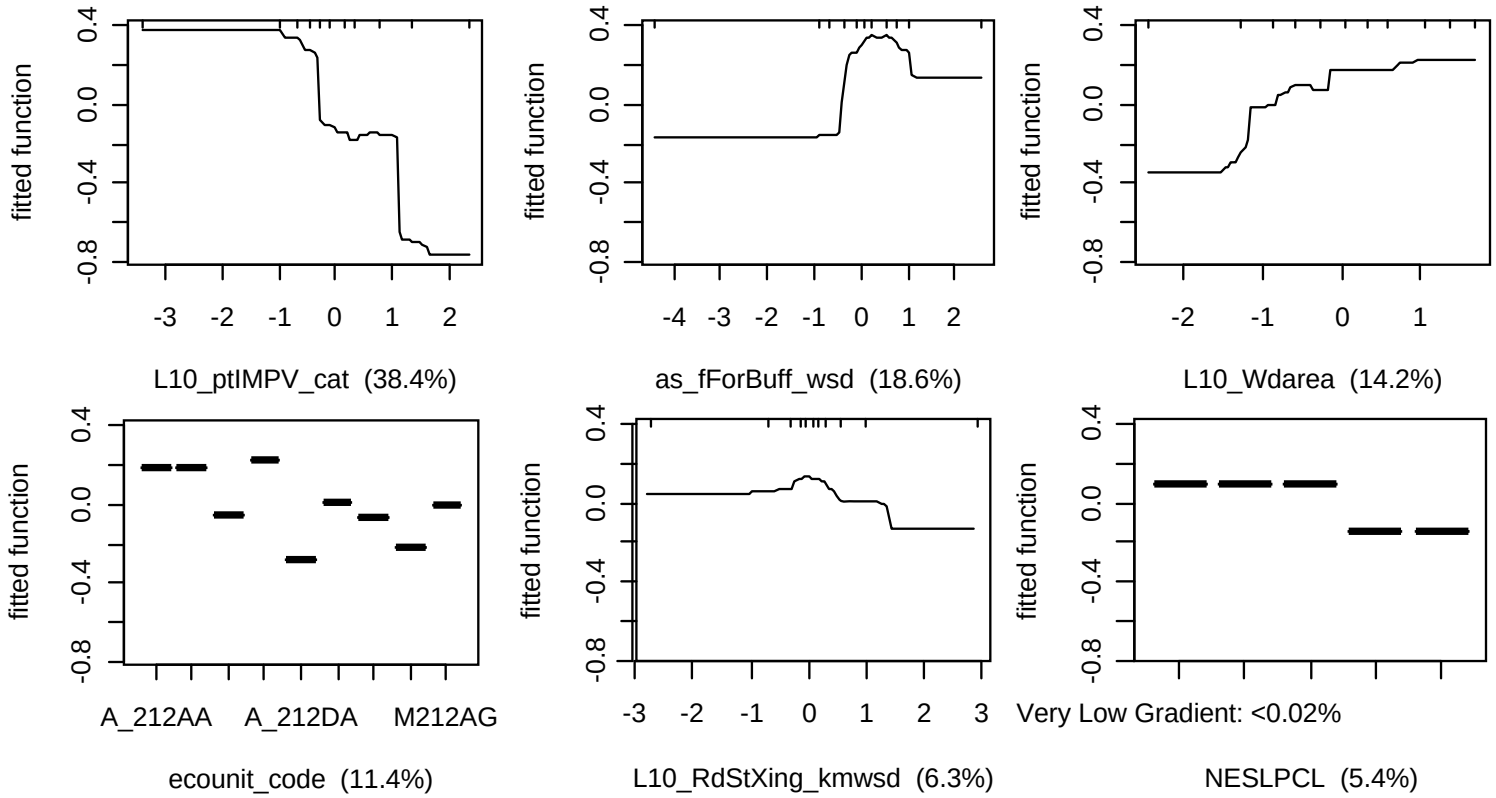








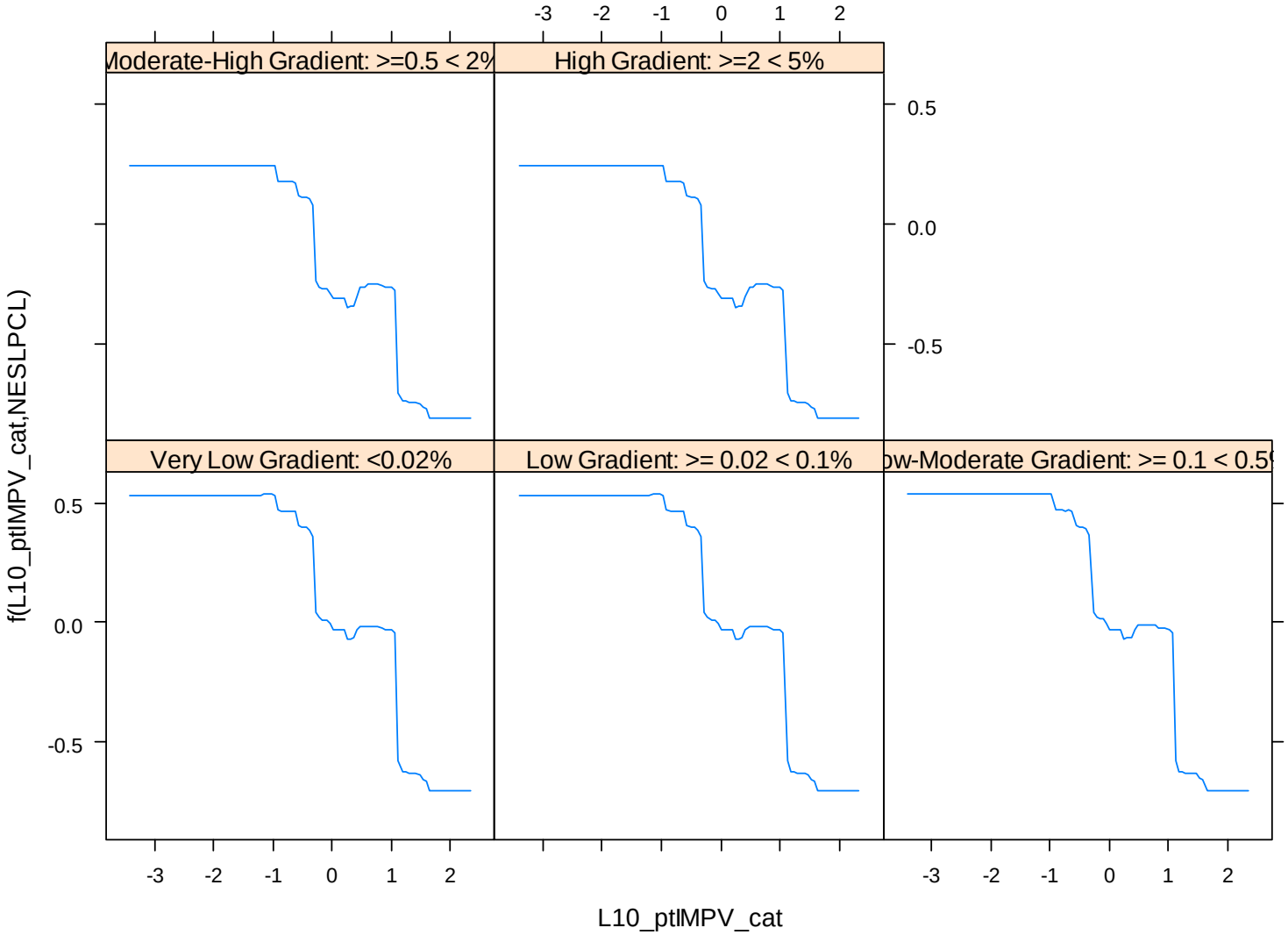
Partial effects on Ephemeroptera richness (MEDEP)



RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

Partial interactive effects on Ephemeroptera richness (MEDEP)



Conclusions: methods

- Data source effect diminished our ability to construct good predictive models for macroinvertebrate metrics for combined data => better to separate by data source
- Partial Mantel tests were useful in teasing out scale of influence of land-use/land-cover variables but are problematical in dealing with categorical variables, interactions, and nonlinearities
- Boosted regression trees proved useful in simultaneously teasing out interactions among variables and threshold effects

Conclusions: predictors

- Best predictors of watershed development impacts: % impervious area at watershed (NEWS, CT) or local (ME) scale,% high density residential area in stream buffer
- Moderating influences: % forested riparian buffer, % wetlands (local catchment)
- Most significant modifying factors: watershed area, slope class, ecounit (NEWS), low flow class
- Best predictions: Richness > Rel abund > Trophic guild > Habitat guild
- Ongoing work to identify a macroinvertebrate metric to better distinguish between urbanization effects and local contaminated sediments