Macroinvertebrate Response to Land Use and Stream Chemistry in the Mid-Atlantic Coastal Plains

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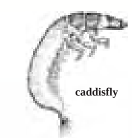
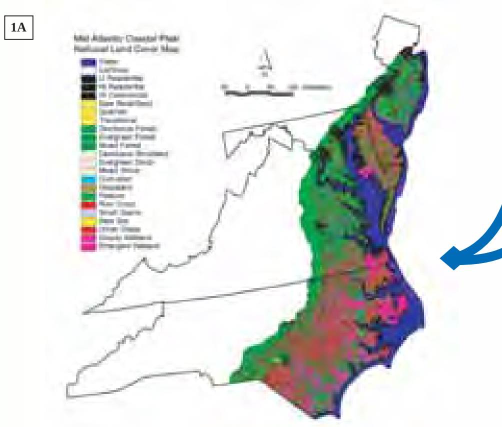


1. Purpose of Study

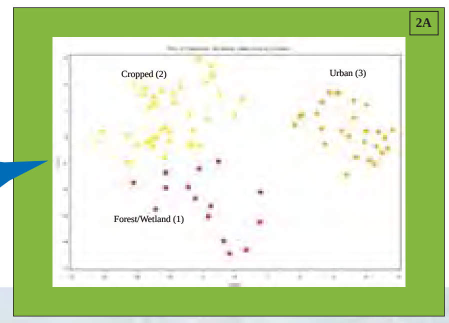
The Landscape Indicators for Pesticides Study in Mid-Atlantic Coastal Streams (LIPS-MACS) is a research collaboration between the U.S. Environmental Protection Agency's Office of Research and Development and the U.S. Geological Survey's National Water Quality Assessment Program. An objective of this research is to develop models to relate land use, geology, and other geographic variables to water quality and the biotic integrity of small streams.

Pesticides, nutrients, and other chemicals can dramatically affect water quality and biota in streams in areas with substantial agriculture, industry, or urban development. Thus, the landscape setting (i.e., the location of a stream within its valley and the relative proportions of various land uses combined with the topography and related physical features, Figure 1A) can provide crucial information about a water body's condition. The problem, however, is that measurements are not possible in every watershed because of cost and other practical constraints. We examined the applicability of potential landscape indicators to efficiently estimate the biological integrity of streams in the Mid-Atlantic Coastal Plains Region.

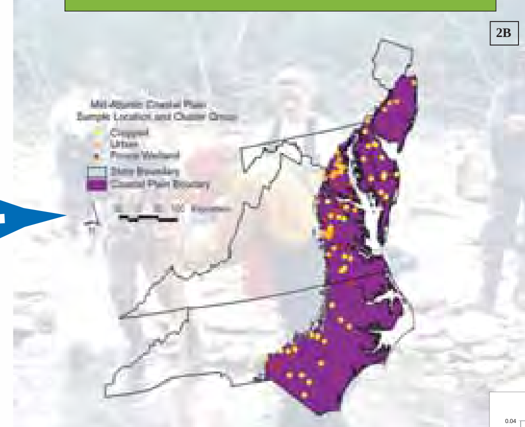
1A



2A



2B

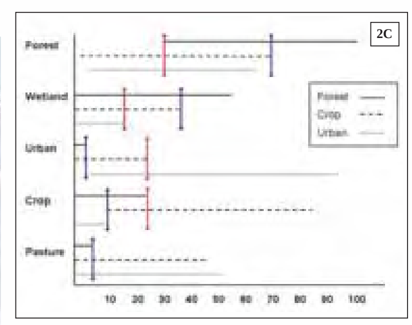


2. Design and Clustering Method

From a population of 10,144 first-order watersheds in the region, we chose 174 small (typically first-order) streams that represented the regional hydrogeologic and land use gradient. Of these 174 sites sampled during base flow in the late winter and spring of 2000, we selected a subset of 82 having benthic riffle habitat for analysis.

We used principal components and cluster analyses to group the first-order streams by land use to capture the greatest variability across the region. The analyses resulted in three distinct watershed groupings. The first group was dominated by natural cover (forest and wetland), the second by urban, and the third by crops (Figures 2 A and B).

2C



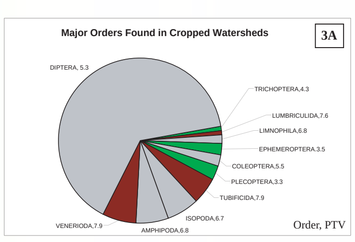
Landscape Variables

The graph to the left shows the range of percentages within each cluster group and where there is overlap (Figure 2C). The red and blue bars represent areas used for ranking all 10,144 first-order watersheds in the Mid-Atlantic Coastal Plain (Figure 6A).

3. Macroinvertebrate Distribution

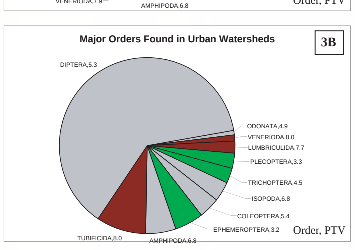
Tubificids (leeches and blood worms), Veneriods (clams and snails), and Amphipods and Isopods (crustaceans) dominated the tolerant taxa (pollution tolerance value or PTV ~ 7.0 or more). The largest portion of intolerant taxa (PTV ~ 4.0 or less) was Ephemeroptera (mayfly), Plecoptera (stonefly), and Tricoptera (caddisfly).

3A

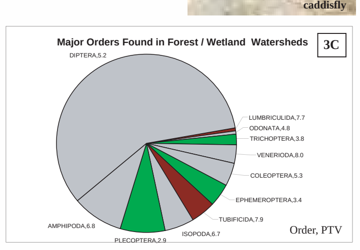


Urban streams had greater proportions of leeches and blood worms (Tubificida) (Figure 3B), versus forest/wetland streams that had greater proportions of caddisflies, stoneflies and mayflies (EPTs) (Figure 3C).

3B

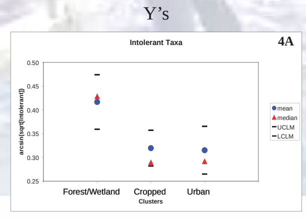


3C



Y's

4A

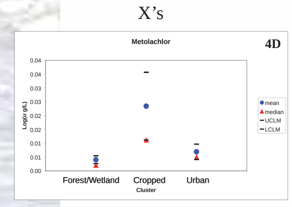


4B

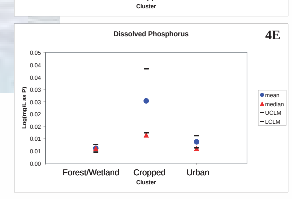
4C

X's

4D



4E



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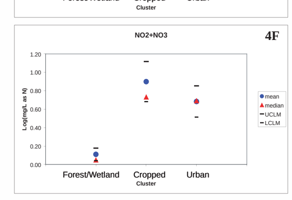
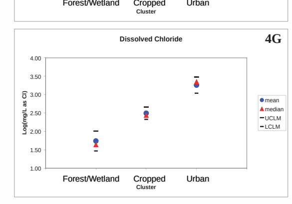


4G

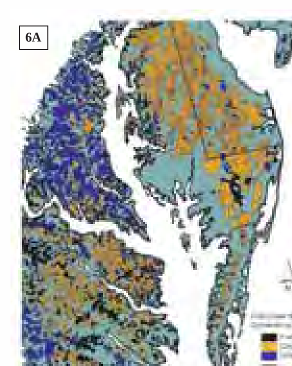


4. Benthic and Water Quality Measure Comparisons

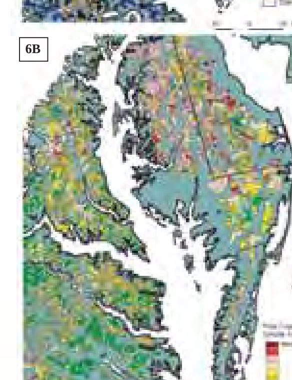
We used non-parametric analysis to test differences in benthic metrics and water chemistry data between clusters. We found that typical water chemistry measures associated with urban runoff such as specific conductance and dissolved chloride were significantly higher in the more urbanized watershed group while intolerant benthos were lowest (Figures 4D to 4G). In the highly cropped group, we found variables commonly associated with farming such as nutrients and pesticides significantly greater than the other two groups. The tolerant benthic metrics in the cropped watersheds were in the middle, while the intolerant metric values were close to that of the urban group (Figures 4A to 4C).

Acknowledgement: The authors thank the U.S. EPA's Ecological Exposure Research Division for collecting and analyzing the benthic macroinvertebrate samples and the U.S. Geological Survey for performing the water quality sampling and analysis for this study.

6A



6B



5. Within Cluster Step-Wise Linear Regressions

Forested/Wetland watersheds were less polluted and had more intolerant species, probably due to better water quality. Tolerant benthos in urban and cropped watersheds did not show measurable response to differences in pollutants, while intolerant benthos decreased in abundance with increasing pollutant concentration. We hypothesize that the proportion of tolerant taxa increases rapidly in less polluted sites as pollution increases (i.e., ag. chemicals, urban runoff, sediment, nutrients, etc.) and begins to enter the stream, making these metrics sensitive indicators of changes in the landscape detrimental to water quality. In sites with more human disturbance, however, metrics of intolerant taxa might provide a better means of monitoring continued water quality degradation.

		Water Variable (partial R²)									Model	
Cluster	Biota	Discharge	Sp.Cond	Dissolved Oxygen	pH	Humic/ Humic - H	Total P	Dissolved P	Dissolved Chloride	Metolachlor	R²	P > F
Forest	Tricoptera					0.28(-)					0.28	0.0406
Wetland	Diptera	0.31(-)				0.33(+)					0.64	0.0023
(n = 15)	Mollusk						0.51(+)			0.23(+)	0.74	0.0003
	Insects					0.17(-)		0.59(-)			0.76	0.0002
	Crustaceans	0.19(+)			0.40(-)	0.11(-)					0.70	0.0006
	Oligochaeta	0.46(+)									0.46	0.0018
	Non-insects					0.17(-)		0.59(+)			0.76	0.0002
	Tolerant			0.2(-)				0.42(+)			0.62	0.0031
	Sprawlers				0.27(+)			0.30(-)			0.57	0.0017
	Scavengers							0.40(+)			0.40	0.0041
Urban	EPT		0.17(-)								0.17	0.04
(n = 25)	Intolerant		0.31(-)			0.15(-)					0.46	0.0011
	Tricoptera		0.17(-)		0.24(+)						0.41	0.003
	Mollusk				0.14(+)						0.14	0.05
	Facultative	0.15(+)									0.15	0.04
	Sprawlers					0.24(-)					0.24	0.014
	Collector/ Gatherers					0.30(-)					0.30	0.0043
	Scavengers											
Cropped	EPT	0.09(-)							0.15(-)	0.13(-)	0.37	0.035
(n = 40)	Intolerant			0.13(+)					0.16(-)		0.29	0.0017
	Plecoptera	0.16(-)							0.21(-)	0.08(-)	0.41	
	Tricoptera			0.12(+)					0.17(-)		0.29	0.0013
	Mollusk			0.10(+)					0.20(+)		0.30	0.004
	Sprawlers					0.24(-)					0.24	0.0141

6. Expanding Methods to all First-Order Watersheds in the Mid-Atlantic Coastal Plains

We used the ranges of land cover/land use from the cluster analysis to categorize the 10,144 first-order watersheds delineated for the Mid-Atlantic Coastal Plains. Cropped watersheds dominated the Delaware and North Carolina regions and likely have the highest nutrient and pesticide levels (Figure 6A). The western most ridge areas, particularly in Maryland, tended to have a larger number of urbanized watersheds where runoff and dissolved chloride would be expected to be greater.

From data collected in this study, we ranked all watersheds based on land use so that estimates of regional stream biological integrity could be made. We used cluster overlap areas to define cutoffs (Figure 2C); those watersheds with percentages above the blue line for forest and wetland were given the highest rank and those below the red line the lowest, while for human use ranking was reversed. The final rank for each watershed was determined by summing the ranks given to each land use (see Figure 6B). Using this method, we can identify a range of conditions from reference to at-risk watersheds. Furthermore, using the major land use group and ranking maps together provides a way to relate land use type to major pollutants and those pollutants likely to have a continued effect on biotic integrity. We demonstrate with this study the applicability of using landscape models for efficiently estimating the biological integrity of small streams in the Mid-Atlantic Coastal Plains Region.