INTEGRATED ECOLOGICAL ASSESSMENT AND MONITORING OF STREAMS: THE WATERSHED AND SOCIO-ECONOMIC SHED PARADIGM

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Abstract

Although there have been tremendous advances in watershed assessment, monitoring, and planning in the last decade, there is still little integration or synthesis among statistical ecologists, process modelers, and socioeconomists. We describe our initial, awkward attempts at such an integration. We have focused initially on what we call the μ-basin, a headwater watershed of about 250-750 ha. This watershed, and its associated outflow stream, is our unit of replication in testing hypotheses about the effects of natural (e.g., basin morphometry) and human (e.g., farming practices) state variables on ecosystem health. Also associated with the μ-basin watershed is a socio-economic shed, an area not necessarily or even usually coincident with the watershed. It includes the often conflicting array of economic, spiritual, and conservation interests at many spatial scales. We will illustrate an approach to integrating the watershed and socio-economic shed assessments with examples from the Upper Thames River Basin.

Introduction

Environmental scientists assess and monitor streams to identify significant ecosystems for conservation protection, evaluate ecosystems that may have been degraded by human stressors, or see if ecosystems have recovered to some extent following rehabilitation measures. Unfortunately, there are often three very distinct approaches to assessment, even if at least putatively there are many interests and perspectives thought to be "integrated" in ecological or environmental assessment using any of the three approaches.

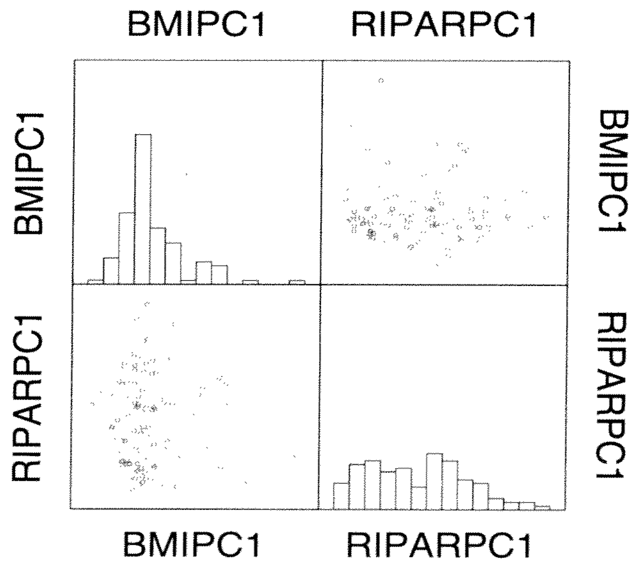
Varying Perspectives on Assessment and Monitoring of Ecosystems

Statistical Ecologists

Statistical ecologists most often carry out assessments by sampling the biota and its environment at a large number of sites, and measuring relationships between them. For example, two of us assembled data collected from sampling 104 stream sites in the Upper Thames River watershed between 1995 and 2001, and carried out a multivariate analysis of variation in the riparian vegetation (cover) and the benthic macroinvertebrate community (family percent composition) among the sites. We found major, interpretable gradients in both the riparian vegetation (open, mainly herbaceous to closed and forested) and macroinvertebrate community (simple to diverse) aspects of these ecosystems, but little correlation between the gradients (Figure 1).

Recently, in assessments of sites to see if human stressors have degraded ecosystems, the Reference Condition Approach has been used by statistical ecologists (Bailey *et al.*, 2004). The biota at "test sites" which are exposed to human stressors are compared in composition or structure to those you would expect if the site had the same environmental conditions, but not the exposure to stressors…that is, it was in "Reference Condition". Statistical ecologists commonly address large spatial scales in their studies and need many sites to adequately characterize proposed correlations. But commonly their studies are aspatial; there is no indication of the geographic proximity in the analysis shown in Figure 1. And there is usually only modest regard for causal pathways in the correlations among different elements of the ecosystem. The main goal is correlation and prediction from correlation.

Figure 1. *Correlations between the riparian vegetation (RIPARPC1) and benthic macroinvertebrates (BMIPC1) at 104 stream sites in the Upper Thames River catchment area (Rios and Bailey, unpublished data).*

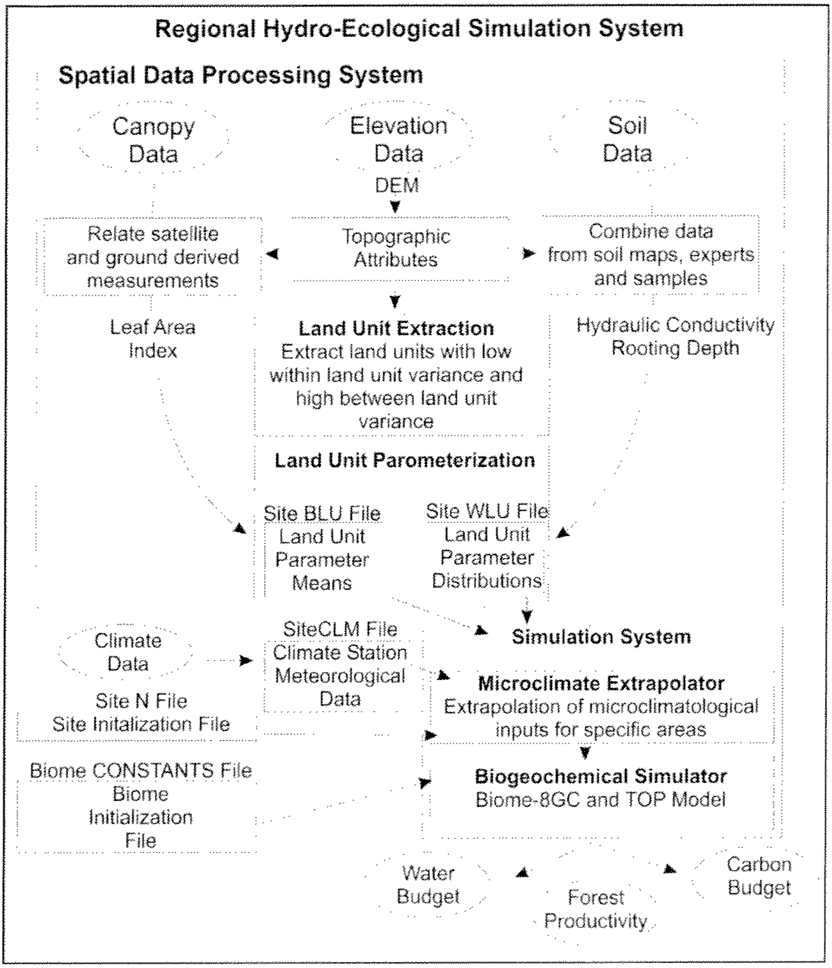


Process Modelers

Unlike statistical ecologists, the main concern of process modelers is cause and effect…building a credible model of ecosystem function. They use theoretical links between different components of a hypothetical ecosystem, and usually data from a real ecosystem, to parameterize and tune the model.

With a process model, the effect of human stressors on the ecosystem can be incorporated to see how the ecosystem responds. Band *et al.* (1996) built a hydro-ecological model of a forest stream (Figure 2).

Figure 2. *A process model of a forest stream (Band* et al.*, 1996).*



Process modelers commonly utililize a very small spacial scales, often only one or two sites, in their studies. They often explicitly consider spatial variation within the site in building their models. Although cause-effect relationships are central to the process model, there is usually only modest regard for variation among real ecosystems in these processes at a broader geographic scale. The main goal is inference of the effect of a stressor in one particular site, and extrapolation to a broader extent.

Socio-economists

Socio-economists are interested in the social and economic dimension of environmental assessment. For example, Shrubsole *et al.* (1997) evaluated the effect of floodplain management on housing values (Table 1).

Socioeconomists use both small and large spatial scales, among several "sites" (human individuals), but often concerning only one or a few ecosystems and the effect of human activity on them, and with an aspatial analysis of these individuals. There is usually an economic model behind the hypothesis tested, but the approach is perhaps best described as the application of statistical ecology to human concerns.

Table 1. *Comparison of housing value inside versus outside a legislated floodplain managed by a Conservation Authority (Shrubsole* et al., *1997).*

PAIRWISE *t*-TESTS OF HOUSING VALUE

Variable	Location	Mean	*t*-value/ significance
Selling price	Inside floodplain	49 970	0.05
	Outside floodplain	50 116	0.96
List price	Inside floodplain	53 604	-0.22
	Outside floodplain	54 262	0.82
Assessed value	Inside floodplain	3 943	-0.10
	Outside floodplain	3 944	0.92
Days on the market	Inside floodplain	14.4	0.11
	Outside floodplain	14.2	0.91

Combining Approaches: the μ-basin

In our assessment and monitoring work we are trying to combine the approaches of the statistical ecologist, the process modeler, and the socio-economist in studying patterns among what we call μ-basins ("microbasins"). Each μ-basin is defined using a Digital Elevation Model (DEM) of a region of interest. In the Upper Thames River basin, we defined over 300 such μ-basins, and then selected a subset of these with various criteria (e.g., size <1500 ha, no urban land cover). We ended up with about 150 μ-basins which we have studied in more detail.

In each μ-basin, we have been gathering information that would be relevant to a statistical ecologist. We have collected biota, water quality, and habitat information at the outflow of the basin. But beyond this, we are gathering information about the basin that would be of interest to a process modeler, including the morphometry and land cover of the basin, and the spatial configuration of the land cover (Figure 3). Finally, we have assembled information that the socio-economist would be interested in. Within each μ-basin, we have catalogued landowner participation in programs for environmental protection and rehabilitation (Figure 4). Thus, we will eventually be able to build statistical models that relate all three of these perspectives. We can test hypotheses such as, *"Does greater participation of landowners in more BMP programs cause a more diverse, "healthy" ecosystem in the outflow stream of the μ-basin?"*

One aspect of this new μ-basin paradigm that is challenging is the precise definition of what we call its "socio-economic shed". It is easy to define the watershed of a site; all of the land mass that drains away from its topographical high toward that point. It is more challenging to define all of the sources of socio-economic influence on the point. A transportation corridor nearby, a share cropping farmer whose operation is based far outside of the μ-basin where some farming activities occur, or a suburban housing development whose stressors are affected by the economy in the city its residents work in, are all examples of a non-contiguous socio-economic shed (Figure 5). We are currently exploring ways of incorporating these non-contiguous sheds into our assessment and monitoring of stream ecosystems.

Figure 3. *μ-basins in a watershed showing forest patches (dark shading) in each μ-basin.*

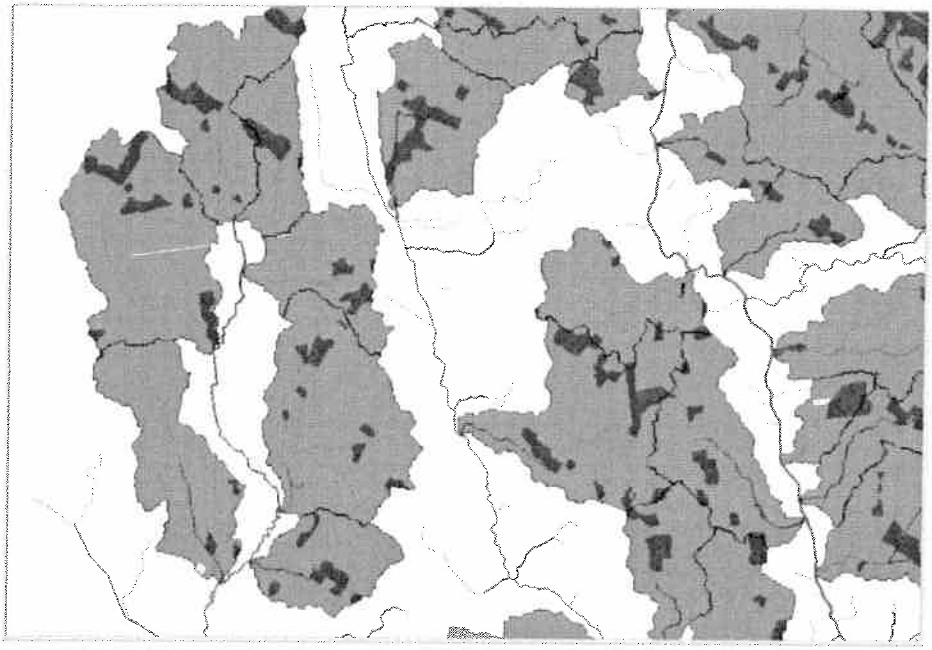


Figure 4. μ-basins in a watershed showing the number of "Best Management Practice" projects funded in each μ-basin.

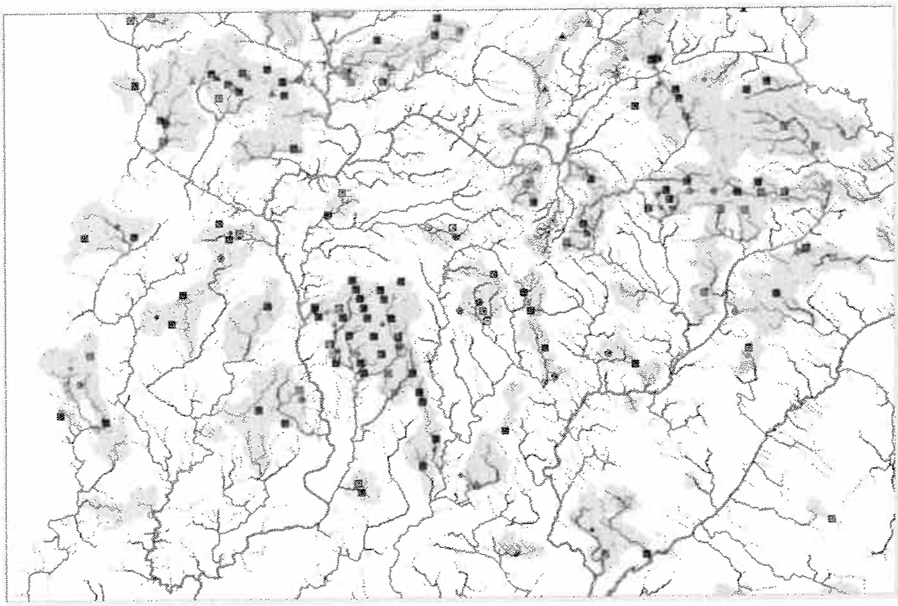
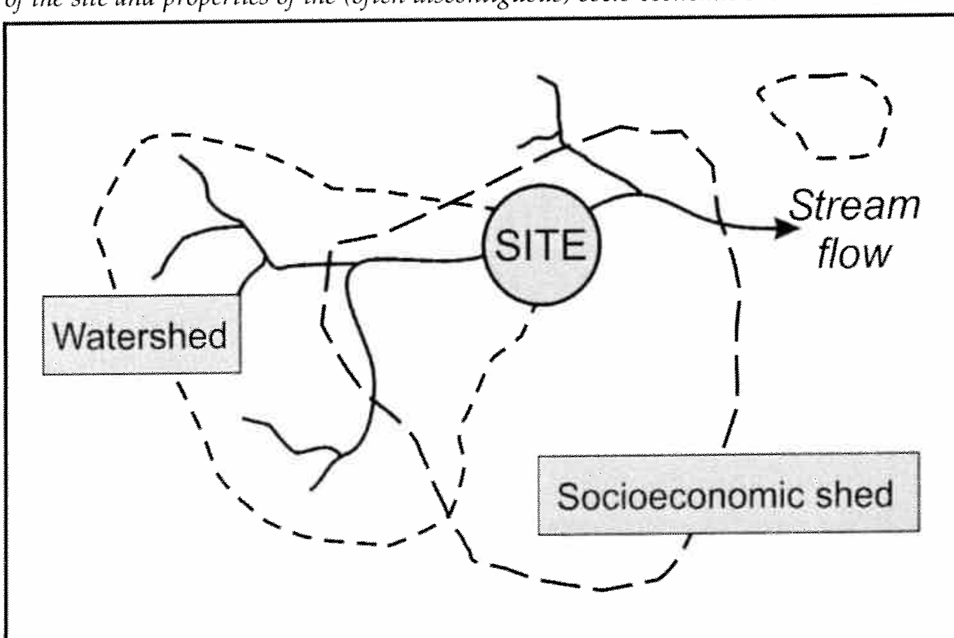


Figure 5. Properties of each μ-basin should consider both properties within the watershed of the site and properties of the (often discontiguous) socio-economic shed.



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Shrubsole, D., M. Green and J. Scherer. 1997. The actual and perceived effects of floodplain land-use regulations on residential property values in London, Ontario. *Canadian Geographer,* 41(2): 166-178.