

Development and evaluation of a multi-dimensional spatially and temporally dynamic mesohabitat classification model for stream management and water flow allocation planning in southern New England streams

Basic Information

Title:	Development and evaluation of a multi-dimensional spatially and temporally dynamic mesohabitat classification model for stream management and water flow allocation planning in southern New England streams
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Publication

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Statement of regional or state water problem: Connecticut, through recent legislation, has entered a process to evaluate the allocation of stream waters between “human” and “environmental” uses. The State is seeking a better understanding of the biological and geomorphological significance of flow regimes to protect stream biota and ecosystem functions for all streams in the state. The question of how much water stream inhabitants really need has most often been answered using hydraulic models which cover a relatively short reach of stream. Such models make assumptions that modeled reaches are representative and inference from results are typically limited in space. To use this modeling approach for all streams in the state is essentially cost prohibitive. Connecticut has begun to evaluate the flow requirements of stream biota using a newer modeling approach based on mesohabitats (Parasiewicz 2001), which are also known as channel geomorphic units and hydraulic habitat units, among other names, but represent what are commonly known as pools, riffles, glides, etc. (Figure 1). The mesohabitat modeling approach covers a longer reach of river for the same cost and because of the larger spatial scale may be more transferable among similar streams. Mesohabitats are known to be important to the stream

biota and have been shown to support distinct biotic assemblages (Rabeni and Jacobson 1993a, Peterson and Rabeni 2001b, Rabeni et al. 2002). While pools, riffles, and runs seem easy enough to identify, mesohabitats are flow dependent (i.e. they get

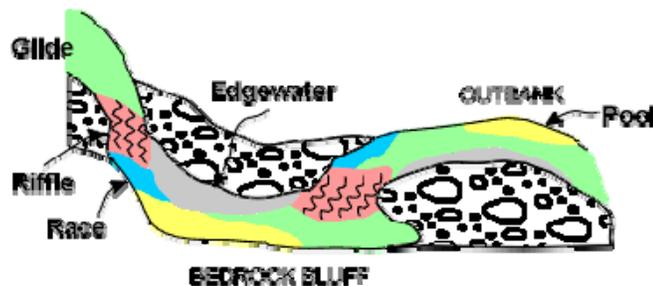


Figure 1. Sketch of a planview map of a stream reach with 5 mesohabitat types.

bigger and smaller with changes in stream stage) and are more numerous in type than one might initially suspect. Pools, riffles and runs are more correctly categories of mesohabitats, for example pools have been subdivided into obstruction, lateral, bluff, plunge, and beaver pools. Not all regions have streams with the same compliment of mesohabitats and regional variant classification schemes are numerous. Researchers in the Rocky Mountains use a scheme with different mesohabitats than those in the Ozark Plateaus region and again different than those in the southern Appalachian Mountains. **Connecticut needs a regionalized southern New England classification scheme for mesohabitats if it is to defensibly use mesohabitats to determine the effects of flow diversion on stream biota habitat quantity.** To address this need, a sound, scientific empirically-based investigation of geomorphic, hydraulic and biological mesohabitat distinctness in Connecticut should be prerequisite to the development and use of a classification system to inform management decisions. That is to say, **definitions of physically distinct mesohabitats must be created and stream biota must show**

differences in assemblage structure and composition within these mesohabitats to be a meaningful basis for decision making.

Statements of results or benefits: A physically distinct and biologically meaningful classification of mesohabitats for southern New England would result in the potential improvement of mesohabitat modeling efforts underway to quantify the effect of flow diversions on habitat quantity for stream biota. In addition, the classification scheme would serve to increase general understanding of stream ecosystems in the region. Future research and monitoring would benefit from the ability to stratify sampling among mesohabitats, increasing the quality of data and interpretations. Further, the evaluation of the classification scheme will also provide detailed information documenting the patterns of mesohabitat characteristics and size changes with varying discharge. This pattern of change is an extremely important underpinning of comparisons between high-water and low-water modeling scenarios. Furthermore, the significance of hydrogeomorphic classifications becomes more powerful when measurements are representative of the complete biologically significant variability within mesohabitats (e.g. three-dimensional vs. one dimensional velocity measurements).

Instream habitat classification has multiple management implications that require an ability to predict both the trajectory of the habitats themselves and the biota that live within the habitats. Classifications systems will have more utility if they have been verified biologically. It could be that a dozen or so physically distinct mesohabitats can be statistically defined in southern New England, but biologically only half of those may house distinct biotic assemblages. This information would inform managers that a collapsed set of mesohabitats may be important to conservation. Research has emphasized applications of minimum instream flow determination on regulated rivers (Newson and Newson 2000, Parasiewicz 2001), routine biological sampling (Poole et al. 1997, Rabeni 2002), and river rehabilitation and restoration (Sear 1994, Kemp et al. 1999). Our proposed empirical research would greatly improve the capability of mesohabitat models to contribute to these important management challenges.

Current mesohabitat delineation techniques in southern New England have to date been based on visual identification and limited (in both number and complexity) quantitative field measurements. Our proposed research will enable an unbiased, statistical delineation of mesohabitats based on objective hydrogeomorphological criteria. This refinement of mesohabitat classification will provide foundational background and definitions that will be helpful to the modeling efforts that are already in place.

Nature, scope, and objectives of the project, including a timeline: The proposed research is an integrated empirical field data collection and modeling study that will produce both a biologically meaningful classification of mesohabitats for southern New England streams and a model to predict spatio-temporal changes in these mesohabitats under variable streamflow conditions. The specific objectives of this research are to:

- 1) Collect hydraulic characterizations of mesohabitat channel units from three streams and use statistical classification to create a scheme of physically distinct mesohabitats based on channel morphology, flow depth and Froude number, and three-dimensional flow variability with stage

- 2) Develop a hydraulic model which demonstrates the spatio-temporal patterns of channel units as they vary with discharge
- 3) Collect macroinvertebrate and fishes (abundance, size classes, and species identity) from mesohabitats and statistically determine biological distinctness among channel units

The proposed research project began with intensive geomorphologic and hydraulic field data collection during summer 2006. Macroinvertebrate and fish sampling occurred during the summer and fall of 2006. Field work is complete. Data analysis of fish communities is complete. Data analysis of macroinvertebrates and hydraulic model development have become problematic as cooperating personnel have left the University with task left to be completed.

Methods, procedures, and progress: Three streams in southern New England were used for data collection, both physical and biological. Study reaches, one per stream, were 1-2 km in length and chosen to encompass heterogeneous habitat conditions. Streams sampled were the Willimantic River, the Still River (Farmington watershed) and Elldredge Brook.

Though mesohabitat spacing varies widely in nature, we attempted to sample 25 mesohabitat units within each study system. The geomorphology of each study reach was surveyed in detail using electronic total station surveying, sediment substrate characterization, and micro-habitat unit mapping. Hydraulic flow fields were characterized at low and moderate flows using a YSI FlowTracker acoustic doppler velocimeter (ADV). The combined geomorphic and hydraulic data will be used to generate a two-dimensional model of the study reaches using a well-established pre-packaged modeling program (River2D). This modeling software, when combined with our statistically-generated mesohabitat definitions (criteria) will enable



Figure 2. Sampling crew at the Still River electrofishing within a mesohabitat.

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quantification of mesohabitat aerial change with changing flow stage, as well as permit quantification of hydraulic variability in different mesohabitat units at multiple stages.

Macroinvertebrates and fish were collected from geo-referenced locations in the study reaches and will be later delineated to specific mesohabitats to generate species assemblage data for particular mesohabitats. Macroinvertebrates were sampled using a kick-net stream benthos sampler and fish with backpack and push-barge electrofishing gear. Fish species assemblages were compared among mesohabitat samples using

principal component analysis and hierarchical cluster analysis (Peterson and Rabeni 2001b).

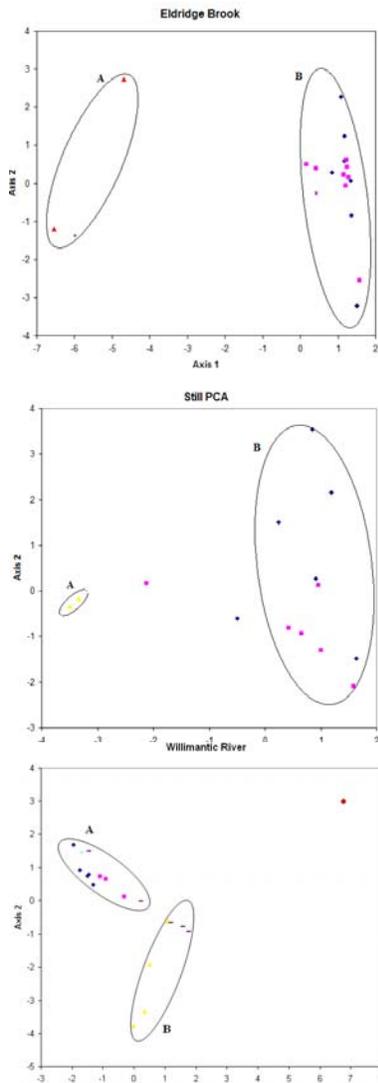


Figure 3. Pricipal components analyses of fish assemblage data collected in 2006

Results from the fish assemblage data analyses suggest that perhaps as few as two assemblages of fish occur in reaches of Connecticut streams. These two assemblages appear to relate to “fast-water” and “slow-water” habitats (Figure 3). While only part of the ecosystem, this may foretell that mesohabitat-level instream assessments using fish may be able to use a much simpler classification than those recently employed. Identification of invertebrates is a current priority. The hydrodynamic modeling portion was not completed and remains a work item. To date, only one of the stream reaches has been completed in Program River2D. Alignment of fish sampling enclosures to River2D model outputs for this reach will be attempted, hopefully setting a procedure that can be replicated by student workers.

Personnel status: One senior personnel continues to work on the project, the project CO-PI has left the University of Connecticut and is less involved at present. This departure has left the PI without needed expertise close at hand. The research assistant that lead the biotic sampling during summer 2006 ended employment after six months as planned and is in now enrolled in graduate school at Tennessee Technological University studying a crayfish species of conservation concern. A PhD student in Geopgraphy/fluyial geomorphology had taken up work on the hydrodynamic modeling but did not complete it. New personnel will be needed to complete this portion of the project. A crew member from the field crew of summer 2006 worked on the macroinvertebrate sorting and analyses as an indepent study project during the fall 2007 and spring 2008 semester. In total to date, nine different students have participated in project-related data collection activities.

References

- Bisson, P.A., Nielsen, J.L., Palmason, R.A., and Grove, L.E. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62-73 *in* Armantrout, N.B., Ed., Acquisition and Utilization of Aquatic Habitat Inventory Information. American Fisheries Society, Bethesda, Maryland.
- Frissel, C.A., Liss, W.J., Warren, C.E., and Hurley, M.D. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management*: 10:199-214.
- Goodwin, C.N. 1999. Fluvial classification: neanderthal necessity or needless normalcy. Pages 229-236 *in* Olson, D.S. and Potyondy, J.P., eds. Wildland Hydrology Symposium Proceedings. American Water Resources Association, Middleburg, Virginia.
- Harper, D., Smith, C., Barham, P. and Howell, R. 1995. The ecological basis for the management of the natural river environment. Pages 219-238 *in* Harper, D.M. and Ferguson, A.J.D., eds. The Ecological Basis for River Management. John Wiley, Chichester.
- Hawkins, C.P. and ten co-authors. 1993. A hierarchical approach to classifying stream habitat features. *Fisheries* 18:3-12.
- Jowett, I.G. 1993. A method for objectively identifying pool, run, and riffle habitats from physical measurements. *New Zealand Journal of Marine and Freshwater Research* 27:241-248.
- Kemp, J.L., Harper, D.M. and G.A. Crosa. 1999. Use of 'functional habitats' to link ecology with morphology and hydrology in river rehabilitation. *Aquatic Conservation: Marine and Freshwater Ecosystems* 9:159-178.
- Leopold, L.B. and Maddock, T.M., Jr. 1953. The hydraulic geometry of stream channels and some physiographic implications. U.S. Geological Survey Professional Paper 252.
- Malavoi, J.R. 1989. Typologie des facies d'ecoulement ou unites morpho-dynamiques d'un cours d'eau a haute energie. *Bulletin Francais de la Peche et de la Pisciculture* 315:189-210.
- McCain, M.D., Fuller, D., Decker, L. and Overton, K. 1990. Stream habitat classification and inventory procedures for northern California. U.S. Forest Service, Fish Habitat Relationships Technical Bulletin 1, Vallejo, California.
- McKenney, R. 1997. Formation and maintenance of hydraulic habitat units in streams of the Ozark Plateaus, Missouri and Arkansas. PhD Dissertation. Pennsylvania State University, State College.
- McKenney, R. 2001. Channel changes and habitat diversity in a warm-water, gravel-bed stream. Pages 57-71 *in* Dorava, J.M., Montgomery, D.R., Palcsak, B.B. and Fitzpatrick, F.A., eds. Geomorphic Processes and Riverine Habitat, Water Science and Application Volume 4. American Geophysical Union, Washington DC.
- Newson, M.D. and Newson, C.L. 2000. Geomorphology, ecology and river channel habitat: mesoscale approaches to basin-scale challenges. *Progress in Physical Geography* 24:195-217.

- Padmore, C.L. 1997. Physical biotopes in representative river channels: identification, hydraulic characterisation and application. Ph.D. Dissertation. University of Newcastle, Newcastle upon Tyne.
- Panfil, M.S. and Jacobson, R.B. 1999. Hydraulic modeling of inchannel habitats in the Ozark Highlands of Missouri: assessment of physical habitat sensitivity to environmental change. U.S. Geological Survey, Columbia Environmental Research Center, Columbia, Missouri. (<http://www.cerc.usgs.gov/model/>)
- Parasiewicz, P. 2001. MesoHABSIM: a concept for application of instream flow models in river restoration planning. *Fisheries* 26:6-13.
- Peterson J.T. and Rabeni, C.F. 1995. Optimizing sampling effort for sampling warmwater stream fish communities. *North American Journal of Fisheries Management* 15:528-541.
- Pflieger, W.L. 1997. *The Fishes of Missouri*. Missouri Department of Conservation, Jefferson City.
- Poole, G.C., Frissell, C.A. and Ralph, S.C. 1997. In-stream habitat unit classification: inadequacies for monitoring and some consequences for management. *Journal of the American Water Resources Association* 33:879-896.
- Rabeni, C.F., Doisy, K.E. and Galat, D.L. 2002. Testing the biological basis of a stream habitat classification using benthic invertebrates. *Ecological Applications* 12:782-796.
- Rabeni, C.F. and Jaconson, R.B. 1993a. Geomorphic and hydraulic influences on the abundance and distribution of stream Centrarchids in Ozark USA streams. *Polskie Archiwum Hydrobiologii* 40:87-99.
- Rabeni, C.F. and Jacobson, R.B. 1993b. The importance of fluvial hydraulics to fish-habitat restoration in low-gradient alluvial streams. *Freshwater Biology* 29:211-220.
- Rahel, F.J. and Hubert, W.A. 1991. Fish assemblages and habitat gradients in a Rocky Mountain-Great Plains stream: biotic zonation and additive patterns of community change. *Transaction of the American Fisheries Society* 120:319-332.
- Sear, D.A. 1994. River restoration and geomorphology. *Aquatic Conservation* 4:169-177.
- Sheldon, A.L. 1968. Species diversity and longitudinal succession in stream fishes. *Ecology* 49:193-198.
- Thomson, J.R., Taylor, M.P., Fryirs, K.A. and Brierley, G.J. 2001. A geomorphological framework for river characterization and habitat assessment. *Aquatic Conservation: Marine and Freshwater Ecosystems* 11:373-389.
- Vadas, R.L. and D.J. Orth. 1998. Use of physical variables to discriminate visually determined mesohabitat types in North American streams. *Rivers* 6:143-159.
- Wadson, R.A. 1994. A geomorphological approach to the identification and classification of instream flow environments. *South African Journal of Aquatic Sciences* 20:1-24.