Report for 2005TN17B: Impacts of watershed urbanization on longitudinal fragmentation of stream habitat quality and fish habitat use

Publications

- Dissertations:
    - Sain, Robert, Lee., 2006, Characterizing how fish communities and physical habitat structure are affected by urbanization in an East tennessee watershed, "MS Disseration", Department of Biosystem Engineering and Environmental Science, College of Agriculture, the University of Tennessee, Knoxville, TN., pp.112.
- Conference Proceedings:
    - Schwartz,John,S., 2005,Linking ecological response with the dynamics of fluvial processes, habitat maintenance, and sediment characteristics: A framework for sediment TMDL development, "in" Proceedings of the Fifteenth Tennessee Water Resources Symposium, Tennessee Section of American Water Resources Association Nashville,TN., 1A-7-10.
    - Thames,Brantley,A., John S. Schwartz, 2005, Modeling of sediment delivery and channel transport processes: Case study comparison between an urban and non-urban subwatershed, "in" Proceedings of the Fifteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN., 2A-7-12.
    - Sain, Robert,L., John S. Schwartz, 2006, Impacts of urbanization on habitat qualityand fisheries in a ridge and valley watershed: Implications for stream rehabilitation planning, "in" Proceedings of the Sixteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, TN., 2B-9-14.
    - Bennett, Shannon, E., John S. Schwartz, 2006, Use of a dynamic sediment delivery model for watershed planning in beaver creek, Knox County, Tennessee, "in" Proceedings of the Sixteenth Tennessee Water Resources Symposium, Tennessee Section of the American Water Resources Association, Nashville, Tn., 2B-18-21.

Report Follows

Water Problems Addressed:

Many waterbodies in Tennessee are identified on the 303(d) list as biological impaired from excessive sedimentation that causes physical habitat degradation, thereby reducing biological integrity. Most urban streams are listed as biological impaired from a multitude of environmental stressors, including siltation and habitat alteration. The Tennessee Department of Environment and Conservation (TDEC) is required by statute to produce total daily maximum loads (TMDLs) for these 303(d) listed urban streams. However, degradation of stream ecosystems from urbanization is poorly understood. TDEC needs better assessment techniques that can aid in the development of sediment TMDLs, and identify the limitations to ecological recovery in urbanizing watersheds. The focus of this research was to explore relationships among watershed patterns of urban land cover, physical habitat quality, and biological integrity in order to better identify critical stream reaches for conservation or restoration.

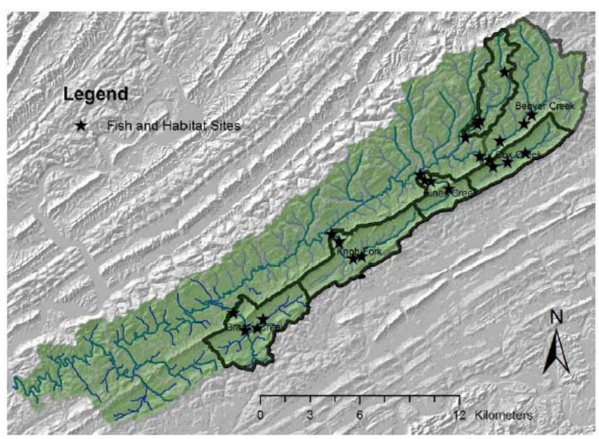
Research Objectives of Study:

The objectives of the study were: 1) determine whether physical habitat structure is altered by urbanization within the context of drainage area, and 2) determine whether fish community structure is altered by urbanization, and whether it is associated with physical habitat alteration. The research was conducted in Beaver Creek, a Tennessee Ridge and Valley stream, Knox County. By interpretation of the results, this study explored qualitatively how reach-scale fragments of poor habitat quality within drainage networks impact fish community structure.

Research Results and Findings:

The study, conducted in Beaver Creek of the Lower Clinch River lies in HUC 06010207 (Lat. 36° 04' 39"and Long. 83° 56' 09"), in which 24 study sites were selected from six subwatersheds with varying ranges of percent urban land cover (Figure 1). Within each subwatershed, four study sites were selected along the longitudinal gradient from headwaters, and downstream usually to the confluence with Beaver Creek main stem. Drainage and land cover characteristics upstream of each site were compiled by ArcGIS software using a land-use layer shape-file, manually created from 2003 KGIS aerial photos. Drainage areas per site ranged from 1.25 to 14.68 mi^2, but most sites were below 6 mi^2. The %total urban land cover ranged from 0.26% to 54.23%, and %industrial-commercial land cover ranged from 0% to 16.85%. Total urban land cover included five subcategories, which were high- and medium residential,

Figure 1. Study site locations within the Beaver Creek watershed.



commercial, industrial, and disturbed (exposed soil from human activities). Physical habitat and fish surveys were conducted at each site from June to August 2005. Physical habitat surveys were done according to standard USFS protocols (Overton *et al*. 1997), delineating mesohabitat units in sequence (pool, glide, run, riffle), and characterizing microhabitat quality (unit dimensions depth and width, woody debris, root wads, and bed substrate characteristics) and adjacent riparian cover (contiguous extend, and tree density) recorded per mesohabitat unit. Fish surveys followed standard IBI protocols for the southern Appalachian region (TVA 2005), using a Smith-Root LR-24 backpack shocker and a team of dip netters. Pearson correlations were used to statistical analyze relationships among the study variables. Six major comparisons were evaluated: 1) habitat metrics to drainage area, 2) habitat metrics to %urban land cover, 3) habitat metrics to riparian corridor and in-channel wood metrics, 4) fish metrics to drainage area, 5) fish metrics to %urban land cover, and 6) fish metrics to habitat metrics.

The study found significant positive correlations ($p < 0.05$) between drainage area and average habitat unit width ($r = 0.57$), average habitat unit depth ($r = 0.64$), average pool depth ($r = 0.71$), average riffle depth ($r = 0.43$), and crest to maximum depth ratio ($r = 0.39$). As one would expect, results indicated that habitat unit dimensions increased proportionally with drainage area. However, %length of the different habitat unit types did not correlate with drainage area, which indicates sequence scale is independent of drainage area. These findings are consistent with current geomorphic-habitat literature.

The study found significant negative correlations ($p < 0.05$) between %industrial-commercial land cover and average riffle width ($r = -0.45$) and crest to maximum depth ratio ($r = 0.47$); and ($p < 0.1$) between %industrial-commercial land cover and average habitat unit width ($r = -0.38$) and %length of run ($r = -0.37$). Industrial-commercial land cover represents the greatest degree of imperviousness (CN > 98) compared to residential and disturbed lands (CN < 90). It appears that some habitat alteration from hydromodification can be inferred from the results. Other researchers have found a loss of mesohabitat structure associated with greater impervious land cover, which typically causes increased peak flows, channel instability, and sedimentation. The relationship between %industrial-commercial land cover and crest to maximum depth ratio would indicate a minor loss of pool-riffle habitat structure possibly from sediment-rich flood waters. However, the negative correlation with this land cover to %length of run is contrary to this finding and current literature when considering impacts from increased peak flows. When considering hydromodification by baseflow degradation rather than increased peak flows this correlation is explainable. It requires evaluating how habitat units are field delineated, in that each unit must be al least equal to the channel width. Runs are typically transitional habitat units between riffles and pools. When baseflow are low relative to normal channel dimensions, field delineation of runs possibly were lumped into pools or riffles because morphologically they lacked sufficient unit length. This possible explanation is supported by the fact that average habitat unit width and average riffle width also decreased with increased %ind.-com. land cover.

The study found significant positive correlations ($p < 0.05$) between the number of riparian trees and %length of riffle ($r = 0.63$) and %occurrence of point bars ($r = 0.63$); and a significant negative correlation ($p < 0.05$) between the number of riparian trees and %length of pool ($r = -0.46$). In addition, significant positive correlations ($p < 0.05$) were found between in-channel average wood volume and average pool depth ($r = 0.64$), average riffle depth ($r = 0.65$), average riffle width ($r = 0.57$), crest to maximum depth ratio ($r = 0.48$), average habitat unit depth ($r = 0.54$), and average habitat unit width ($r = 0.\ 46$). As with average wood volume, similar positive correlations were found between in-channel number of wood pieces and habitat metrics. A significant positive correlation ($p < 0.1$) was found between %intact riparian cover and in-channel number of wood pieces ($r = 0.39$), but not with the number of riparian trees and in-channel number of wood pieces. Overall, it appears in-channel wood plays an important role in the maintenance of mesohabitat structure, which is consistent with findings by other researchers. This study indicated that the structural role of in-channel wood with mesohabitat heterogeneity is more important to these urban streams, and the larger streams surveyed. Wood recruitment from the riparian corridor appears to be dependent on presence or absence of vegetation rather than the density of trees when a forested corridor exists.

The study found significant positive correlations ($p < 0.05$) between drainage area and fish metrics (percent site abundance of blueside darters, greenside darters, snubnose darters, total darters, mountain shiners, centrarchids, suckers, and specialized insectivores). These correlations between stream size and fish community structure has been recognized by other researchers, in fact are they are accounted for in fish IBI computations.

The study found significant negative correlations between fish IBI scores and %total urban land cover ($p = 0.006$, $r = 0.29$), and %industrial-commercial land cover ($p = 0.0004$, $r = 0.53$). IBI scores ranged from 28 to 50 out of a possible range of 12 to 60 (Figure 2). Significant negative correlations ($p < 0.05$) were found between %industrial-commercial land cover and total% darters (r =-0.44) and %specialized insectivores (r = -0.45). Similarly, %urban land cover was negatively correlated ($p < 0.1$) with total% darters (r =-0.37) and %specialized insectivores (r = -0.36). Darters and specialized insectivores are 2 of 12 metrics used in generating an IBI score, and undoubtedly influenced the study's IBI scores. Ecologically, darters and specialized insectivores rely on quality riffle habitat. It appears urbanization impacts riffle quality; however the evidence from the mesohabitat correlations would indicate it is not from total number of riffle per unit length of stream. It is possible that riffle surface area is reduced by urbanization, as observed by the decreased riffle widths in more urban sites. Another possibility is that some quality metric for the riffle habitat unit was not measured.

Several significant correlations were found between fish and habitat metrics ($p < 0.05$, $p < 0.1$ levels). Greenside darters and blueside darters were positively correlated with average riffle width ($r = 0.52$; $r = 0.38$). Greenside darters were also positively correlated with average pool depth ($r = 0.37$), average riffle depth ($r = 0.50$), crest to maximum depth ratio (r =0.49), average habitat unit depth ($r = 0.49$), and average habitat unit width ($r = 0.45$). Blueside darters were also positively correlated with average pool depth ($r = 0.43$), and average habitat unit depth ($r = 0.38$). Because darters were correlated with both pool and riffle structure, but typically occupy riffles, it appears there is some interdependence of riffle quality with pool structure and elevation differences between juxtaposition units. Omnivores were positively correlated with %length of pools ($r = 0.43$), average pool depth ($r = 0.49$), and average habitat unit depth ($r = 0.42$). Suckers were positively correlated with average pool depth ($r = 0.36$), and average habitat unit depth ($r = 0.37$). Omnivores and suckers appear to prefer deeper pools. Because omnivore and suckers were not correlated with %urban land cover, but darters were correlated, it appears riffle quality degrades initially from the impacts of urbanization.

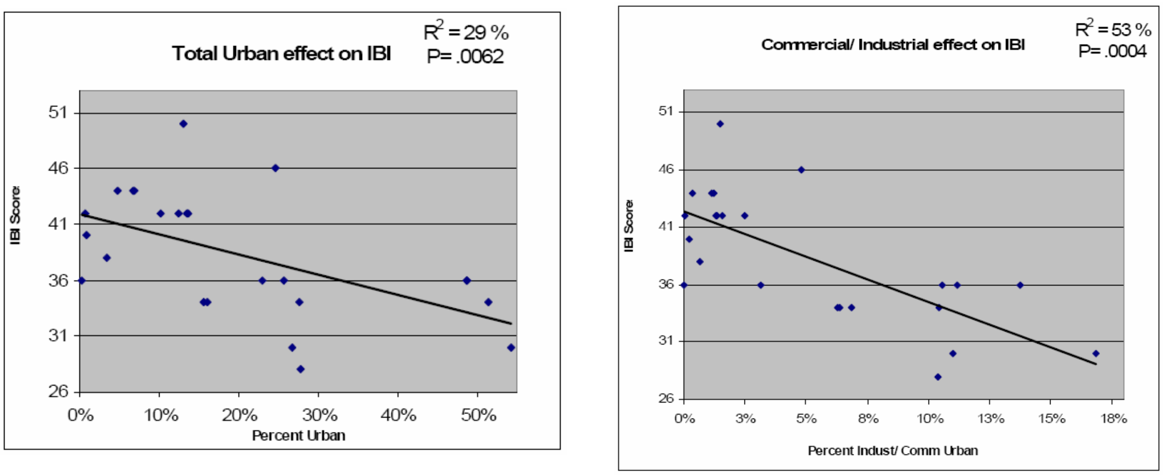


Figure 2. Fish IBI scores versus %urban land cover and %industrial-commercial land cover.

Summary

This research found %urban land cover significantly altered physical habitat and fish community structure. It appears modified fluvial processes from urbanization initially degrade riffle quality before pool quality when riparian vegetation supplies the channel with large woody debris (LWD). In general, LWD appears to maintain pools by promoting localized scour. Fish community structure was more severely impacted from urbanization in larger streams (drainage areas greater than 2-3 mi^2) because they naturally support more biodiversity. Additional analyses to support the summary statement can be found in Robert Sain's MS thesis. Stream restoration potential appears to be best by enhancing riffle quality, and hydraulically promoting a heterogonous bed structure provided by pool-riffle structures.