

SUMMARY OF STUDIES CONCERNING THE EFFECT OF WATERSHED DEVELOPMENT UPON AQUATIC COMMUNITIES

Geographic Area of Study	Aquatic Systems Studied	Organisms Studied	Nature of Effect of Increasing Watershed Development	Impact Threshold (% Impervious)	Reference
Connecticut	wetlands	aquatic insects and other macroinvertebrates	A decline in various indicators of aquatic macroinvertebrate community health was observed in wetlands draining watersheds more than 3% impervious. The degradation became significant in most wetlands at an imperviousness of 8%-9%. This degradation was thought to result from physical alterations of the wetlands, sedimentation, nutrients, elevated water temperature, reduced night time dissolved oxygen, elevated pH, and de-icing salts.	8%-9%	Hicks and Larson. 1997
Delaware	streams	aquatic insects and other macroinvertebrates	Dramatic drop in various indices of health of macroinvertebrate community health which are combined into an index of Biologic Integrity	8% - 15%	Shaver et al. 1994
Georgia	streams	aquatic insects and other macroinvertebrates	As watershed development increased the number of macroinvertebrates species declined.		Benke et al. 1981
Maryland	streams rivers	fish, aquatic insects and other macroinvertebrates, and stream baseflow	Fish community Species Diversity Index and stream baseflow declines as watershed imperviousness increases. Most fish species are eliminated when watershed imperviousness reaches 20%.	10% - 12%	Klein 1979
	streams	brook trout	Brook trout were almost never found in watersheds where impervious land cover exceeded 4%, as assessed from the 2001 National Land Cover Dataset (2001 NLCD); the single exception was in a stream that displayed consistently low water temperatures. Landscapescale analyses indicated that increases in water temperature and erosion were associated with increasing percentages of urbanization and imperviousness and decreasing percentage of forested land cover. Three of six brook trout populations that were followed over time were extirpated between 1996 and 2005, coinciding with increases in urbanization and impervious land cover. At these sites, water temperatures were substantially greater than at the three sites with extant brook trout.	<4%	Stranko et al. 2008
	streams	brook trout brown trout	Brook trout only occur in watersheds that are less than 2% impervious. Brown trout disappear when watershed imperviousness exceeds 8% and do best when imperviousness is less than 3%.	<2% <8% <3%	Roth et al. 1999
	streams	aquatic insects and other macroinvertebrates and fish	Combined indexes of macroinvertebrate and fish community health showed decline as watershed development increased.		Kazyak et al. 1992
	streams	aquatic insects and other macroinvertebrates	As percent urban land use increased indicators of macroinvertebrate community health declined.	15%	Boward and Hurd 1996

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	streams	aquatic insects and other macroinvertebrates and fish	Fish and macroinvertebrate diversity declined as watershed imperviousness increased.	10% - 12%	Schueler and Galli, 1992
	tidal creeks	fish	Fish assemblages were less diverse in tidal creeks with watersheds dominated by urban land uses when compared to forest and wetland dominated watersheds; dissolved oxygen was lower in creeks draining urban watersheds when compared to forest-wetland dominated watersheds.		Carmichael et al. 1992
	tidal rivers	fish, macroinvertebrates, and plants	In general, the authors found that tidal tributaries draining more intensely developed watersheds exhibited greater toxicity to fish, benthic macroinvertebrates, and plants. Toxic effects were greatest where developed land uses occupied 25% to 36% of the watershed		Hartwell et al. 1995
Maryland and Virginia	tidal rivers	benthic macroinvertebrates and water quality	As watershed urbanization increased the health of benthic communities declined; as the proportion of the watershed in forest increased, so did the condition of benthic communities.		Ranasinghe et al. 1994
Minnesota	streams	aquatic insects and other macroinvertebrates	As watershed development increased, macroinvertebrate community diversity decreased.		Richards and Host 1994
New York	nontidal and tidal streams	fish	Alewife herring egg and larval densities decreased as the extent of watershed development increased; dissolved oxygen was more variable in streams draining urbanized vs. undeveloped watersheds.		Limburg and Schmidt 1990
New Jersey	wetlands	plants	As watershed development increased indigenous plant species declined due to water quality changes and invasion by upland and exotic species.		Ehrenfeld and Schneider 1991
	wetlands	plants	Runoff from developed land killed sphagnum moss in two wetlands.		Vedagiri and Ehrenfeld 1991
	stream	aquatic insects and other macroinvertebrates	Diversity and abundance declined dramatically as a stream flowed through a heavily developed area.		Garie and McIntosh 1986
Ontario, Canada	streams	fish	Index of macroinvertebrate community health and brook trout declined as the degree of watershed development increased. Using data presented in Steedman 1988, Booth and Reinelt (1993) calculated that brook trout begin declining when watershed imperviousness reaches 7% - 10%.	7% - 10%	Steedman 1988 Booth & Reinelt 1993

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Virginia	streams	aquatic insects and other macroinvertebrates	As watershed development increased pollution sensitive macroinvertebrates became less abundant.	14%	Jones and Clark 1987
		fish	Comparisons of fish communities in a stream over a 32-year period showed that watershed development resulted in a significant decline in species diversity.		Weaver and Garman 1994
		aquatic insects and other macroinvertebrates and algae	Macroinvertebrate diversity s and algal species decrease as watershed development increased.		Mangun 1988-89
Washington (state)	streams	fish habitat	Quality of fish habitat declines with increasing watershed development.	8% - 10%	Booth and Jackson 1994
	streams	fish and aquatic insects and other macroinvertebrates	As watershed development increases indices of salmonid health declines, zinc concentrations increase, 2-year peak discharge increases, stream baseflow decreases along with dissolved oxygen. This investigation also documented that stormwater management measures - mostly ponds - did not significantly reduce the adverse impacts of watershed development.	5%	May et al. 1997
	streams	aquatic insects and other macroinvertebrates	Macroinvertebrate community in a rural stream was twice as diverse when compared to a stream draining an urbanized watershed.		Pederson and Perkins 1986
	wetlands	amphibians, water-level fluctuations, and water quality	Significant decline in the number of amphibian species as the degree of watershed development increased; significant increase in water-level fluctuations; conductivity, suspended solids, and fecal coliform bacteria were higher in wetlands draining most developed watersheds.	4% - 14%	Azous and Horner 1997

References

Benke, A.C., G.E. Willeke, F.K. Parrish, and D.L. Stites, 1981. Effects of urbanization on stream ecosystems. Environmental Resources Center, Georgia Institute of Technology, Atlanta, GA 30332.

Booth D.B. and C.R. Jackson. 1994. Urbanization of aquatic systems - degradation thresholds and the limits of mitigation. Proceedings Annual Summer Symposium of the American Water Resources Association - Effects of Human-Induced Changes on Hydrologic Systems, pp 425-434.

- Booth D.B. and L.E. Reinelt. 1993 Consequences of urbanization on aquatic systems - measured effects, degradation thresholds, and corrective strategies. *Proceedings Watershed 93 - A National Conference on Watershed Management*, pp. 545-550.
- Boward, D. and M. Hurd. 1996. DRAFT Evaluation of Maryland's benthic rapid bioassessment program: Relationships between cumulative land use impacts and non-tidal stream ecological conditions. Resource Assessment Service, Maryland Department of Natural Resources, Tawes State Office Building, Annapolis, MD 21401.
- Boward, D., P. Kayzak, S. Stanko, M. Hurd, and A. Prochaska, 1999. From the mountains to the Sea: The state of Maryland's freshwater streams. Maryland Department of Natural Resources, Tawes State Office Building, Annapolis, MD 21401.
- Carmichael, J.T., B.M. Richardson, M. Roberts, and S.J. Jordan, 1992. Fish assemblages and dissolved oxygen trends in eight Chesapeake Bay tributaries during the summers of 1989 - 1991: A data report. Chesapeake Bay Research and Monitoring Division, Maryland Department of Natural Resources, Tawes State Officer Building, Annapolis, MD 21401.
- Ehrenfeld, J.G. and J.P. Schneider, 1991. *Chamaecypris thyoidea* wetlands and suburbanization effects on hydrology, water quality and plant community composition. *Journal of Applied Ecology* 28:467-490.
- Garie, H.L. and A. McIntosh, 1986. Distribution of benthic macroinvertebrates in a stream exposed to urban runoff. *Water Resources Bulletin* 22(3):447-455.
- Hartwell, S.I., C.E. Dawson, E.Q. Durell, D.H. Jordahl, S.J. Jordan, M.R. McGinty, A.S. Ives, D.A. Randle, B.S. Rodney, R.W. Alden, P.C. Adolphson, D.A. Wright, G.M. Coelho, J.A. McGee, M.S. Illstock, and C.M. Norman, 1995. Integrated measures of ambient toxicity and fish community diversity. Chesapeake Bay Research and Monitoring Division, Maryland Department of Natural Resources, Tawes State Officer Building, Annapolis, MD 21401.
- Hicks, A.L. and J.S. Larson. 1997. Aquatic invertebrates as an index for estimating the impacts of urbanization on freshwater wetlands. The Environmental Institute, University of Amherst, MA. Report submitted to U.S. Environmental Protection Agency, Corvallis, OR.
- Jones, R.C. and C.C. Clark, 1987. Impact of watershed urbanization on stream insect communities. *Water Resources Bulletin* 23(6):1047-1055.
- Kazyak, P.F., 1992. Assessment of the relationship between land use patterns and biotic indices in the Gwynns Falls watershed. Maryland Save Our Streams, 258 Scotts Manor Drive, Glen Burnie, MD 21061.
- Klein, R.D., 1979. Urbanization and stream quality impairment. *Water Resources Bulletin* 15(4):948-963.

- Limburg, K.E. and R.E. Schmidt, 1990. Patterns of fish spawning in Hudson River tributaries: Response to an urban gradient. *Ecology* 71(4):1238-1245.
- Mangun, W.R., 1989. A comparison of five northern Virginia watersheds in contrasting land use patterns. *Journal of Environmental Systems* 18(2):133-151.
- May, C. R. Horner, J. Karr, B. Mar, and E. Welch. 1997. Effects of Urbanization on Small Streams In the Puget Sound Lowland Ecoregion. *Watershed Protection Techniques*, 2(4): 483-494.
- Pedersen, E.R. and M.A. Perkins, 1986. The use of benthic invertebrate data for evaluating impacts of urban runoff. *Hydrobiologica* 139:13-22.
- Ranasinghe, J.A., S.B. Weisburg, J. Gerritsen, and D.M. Dauer, 1994. Assessment of Chesapeake Bay benthic macroinvertebrate resource condition in relation to water quality and watershed stressors. Tidewater Administration, Maryland Department of Natural Resources, Annapolis, MD 21401.
- Reinelt, L.E. and R.R. Horner, 1991. Urban storm water impacts on the hydrology and water quality of palustrine wetlands in the Puget Sound region. In: *Puget Sound Research '91 Proceedings*, Puget Sound Water Quality Authority, Vol. 1, pp. 33-42.
- Richards, C. And G. Host, 1994. Examining land use influences on stream habitats and macroinvertebrates: A GIS approach. *Water Resources Bulletin* 30(4):729-738.
- Roth, N.E., M.T. Southerland, G. Mercurio, J.C. Chaillou, P.F. Kazyak, S.S. Stranko, A.P. Prochaska, D.G. Heimbuch, and J.C. Seibel, 1999. State of the Streams: 1995-1997 Maryland Biological Stream Survey Results. Maryland Biological Stream Survey, Department of Natural Resources, Tawes State Office Building, 580 Taylor Avenue, Annapolis, Md 21401 Available for download at: <http://www.dnr.state.md.us/streams/pubs/ea-99-6.pdf>
- Schueler, T.R. and J. Galli, 1992. Environmental impacts of stormwater ponds. In *Watershed Restoration Sourcebook*, Metropolitan Washington Council of Governments, 777 North Capitol Street, N.E., Washington, D.C. 20002.
- Shaver, E., J. Maxted, G. Curtis, and D. Carter. 1994. Watershed protection using an integrated approach. Delaware Department of Natural Resources and Environmental Control.
- Steedman, R.J. 1988. Modification and assessment of an index of biotic integrity to quantify stream quality in southern Ontario. *Canadian Journal of Fisheries & Aquatic Sciences* 45:492-501.

Stranko, S. A., R.H. Hilderbrand, R.P. Morgan, II, M.W. Staley, A.J. Becker, A.Roseberry-Lincoln, E.S. Perry, and P.T. Jacobson, 2008. [Brook trout declines with changes to land cover and temperature in Maryland](#). North American Journal of Fisheries Management. Volume 28, Issue 4 (August 2008), pp. 1223–1232/

Vedagiri, U. 1989. Behaviour of lead in pristine and urbanized acid wetlands in the New Jersey Pinelands with special reference to the role of Sphagnum moss. Doctoral thesis. Graduate School - New Brunswick, Rutgers, The State University of New Jersey.

Weaver, L.A. and G.C. Garman, 1994. Urbanization of a watershed and historical changes in a stream fish assemblage. Transactions of the American Fisheries Society 123:162-172.