Article 24

Technical Note #94 from Watershed Protection Techniques. 2(4): 507-510

Fish Dynamics in Urban Streams Near Atlanta, Georgia

A few short decades ago, much of the landscape of the upper Chatahoochee basin was rural in character, dominated by second growth forest and pasture. The basin's close proximity to the rapidly growing Atlanta metropolitan area, however, has created intense development pressure. For example, in the last five years, the twenty county metropolitan region has added residents at a rate of 50,000 per year—roughly equivalent to the creation of a small city every year. Watershed managers are concerned about the impact of this explosive growth on 35 major warm water streams that flow through the southern Piedmont into the Chattahoochee River. To assess the impact of watershed development, Carol Couch and her colleagues at the U.S. Geological Survey (USGS) have conducted three intensive studies of the fish community in several dozen streams that drain to the Chattahoochee River (Table 1). These studies provide fresh insights on how southeastern warm water streams respond to watershed change.

The original fish community in the warm water streams of the study area was quite diverse, based on historical collections. Some 50 fish species were represented, with 42 native species and eight recent introductions (usually from bait buckets or stocking). Minnows and suckers dominate the warm water fish community, although sunfish, bass, catfish and darters are also well represented. Minnows play a critical role in the food chain as prey for larger fish, reptiles and wading birds. Suckers, which feed off the bottom of streams, often account for the most fish biomass.

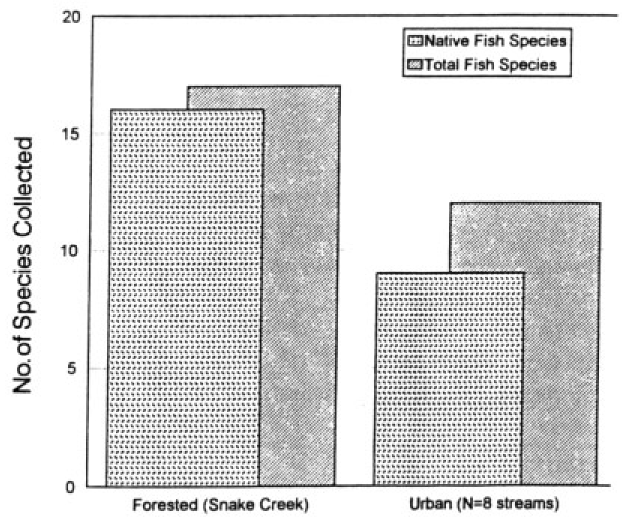
The First Fish Survey

In the first watershed study, researchers sampled fish populations at eight urban streams draining older Atlanta neighborhoods and a largely forested reference stream. The urban streams were of second to fourth order, and had watershed areas ranging from 15 to 85 square miles. Each urban watershed ranged from 70 to 90% developed (no measurements of impervious cover were available), and was primarily comprised of residential development. A single fish survey was taken in representative stream reaches within each of the nine watersheds in November 1993.

The survey confirmed that the abundance and diversity of fish declined sharply in urban streams, in comparison to the forest reference. Urban streams also had more non-native fish species than the forest stream (Figure 1). Nonnative species are often among the most

Table 1: Comparison of Three Recent Studies on Fish and Stream Ecology in Urban Watersheds of the Chattahoochee River Basin

Study Factors	Study No.1	Study No. 2	Study No. 3
Investigators/ Affiliation	Couch et al. 1995 USGS/NAWQA	DeVivo et al. 1997 USGS/NAWQA	Meyer et al. 1996 USGS/Univ. of GA
No. of watersheds sampled	9	21	8
Watershed size(square miles)	15 to 85	2 to 101	Unknown
Stream orders	2nd to 4th order	2nd to 4th order	2nd order
Watershed land use	Forest, Urban	Forest, Suburban, Urban	Forest, Suburban, Urban, Agricultural
Scope of study	Fish surveys Substrate assessment	Intensive fish survey, IBI calculation, water quality	Water quality, fish, macro invertebrates, stream ecosystem process rates.
Surveys per site	1	1 to 4	4 or more



While the number of native fish species dropped from forested to urban streams, the number of non-native fish increased slightly.

Figure 1: Comparison of Fish Species Richness and Proportion of Non-native Fish in Urban and Forested Watersheds in the Atlanta area (Couch *et al.*, 1995)

hardy and pollution tolerant members of the fish species, and include the red shiner, white sucker, black bullhead, flat bullhead, spotted bass, smallmouth bass, green sunfish and yellow perch. More sensitive native fish species that are endemic only to the Chattahoochee River basin were not collected from any of the urban streams. In addition, fewer individual fish were collected in most urban streams. One exception was a very high population of mosquito fish found in the urban Peachtree Creek. Mosquito fish are very tolerant of pollution, and recover quickly after episodes of stream disturbance. This is due in part to their ability to bear live young. Unlike other species, mosquito fish are not dependent on a stable and clean substrate for successful spawning (Couch *et al.*, 1995).

The first study also found that the bottoms of many of urban streams had a higher percentage of sand than the forested stream, which can be an indicator of poor habitat quality. The researchers, however, could not find a direct relationship between substrate quality and the urban fish diversity or abundance.

The Second Fish Survey

Fish surveys were expanded in the second study to include 21 watersheds in the Upper Chattahoochee Basin using a stream bioassessment tool known as the Index of Biotic Integrity (or IBI). The warmwater streams ranged from second to fourth order, and were surveyed to develop a regionally appropriate IBI for Atlanta (DeVivo *et al.*, 1997). Two forested streams were sampled to represent reference conditions.

The IBI, developed by James Karr for Midwestern streams, compares a given fish assemblage to an undisturbed stream benchmark, based on its species composition, diversity and functional organization. In the original IBI, twelve fish community metrics are measured and scored to arrive at an index of overall stream quality. It was necessary to adapt and modify the IBI for the Atlanta region to account for the unique regional differences in the warmwater fish community of the urbanizing southern Piedmont. The research team modified the IBI by conducting a statistical analysis of key variables to explain data variances in the fish community at the 21 stream sites. Based on this analysis, DiVivo and colleagues concluded that human population density was the best variable to represent watershed disturbance in the study area. (It is interesting to note that another commonly used development index—watershed impervious cover—did not provide as good of fit. Available estimates of impervious cover were not thought to be very accurate, and the research team is now using infrared satellite data to obtain better estimates). The final metrics used in the modified IBI for the Atlanta metropolitan area are profiled in Table 2

The relationship between population density and mean IBI scores in Atlanta streams is portrayed in Figure 2. As expected, the forest reference had the highest overall IBI score of any stream. They did not, however, receive an “excellent” rating, as they lacked certain sucker and minnow species that indicate high quality conditions. It is speculated that few if any “excellent” reference streams exist in the Upper Chattahoochee basin due to prior land use change. This is not surprising when it is considered that the region has experienced three cycles of cultivation and land abandonment since the Civil War, severely eroding much of the original topsoil over the landscape (DeVivo *et al.*, 1997). Two lightly populated agricultural streams were analyzed in the study, and their IBI scores fell into the fair/good range (29 and 30). This finding is generally consistent with findings from an agricultural stream in North Carolina (see article 22) that agricultural streams have slightly lower IBI scores than forest streams, but still score higher than urban streams.

No urban stream scored higher than “fair” in the IBI analysis. In general, urban stream IBI scores were inversely related to watershed population density. Once watershed population density exceeded four persons per acre, urban streams consistently were rated as “very poor” according to the modified IBI. The relationship between population density and urban stream IBI scores, however, was not without variation, with up to 10 points of IBI variation noted for streams of similar population density, and from two to four points of IBI variation observed at individual stream sites. The variation in IBI scores witnessed at urban streams appears to reflect the frequency and intensity of watershed disturbance that creates temporal instability in the fish community

Table 2: IBI Metric Selection for Atlanta Region
(DeVivo *et al.*, 1997)

IBI Metric Category	Response to Increasing Population Density
Assemblage	
1. Diversity Index Score for native species	Decrease
2. Number of native sucker species	Decrease
3. Number of native cyprinid (minnow) species	Decrease
4. Proportion of non-native individuals	Increase
5. Proportion of gravel-dwelling fish	Decrease
Assemblage Function	
6. Proportion of generalized feeders	
7. Proportion of benthic insect eaters	Decrease
8. Dominant nest-building fish	Faunal Shift [a]
Fish Abundance and Condition	
9. Proportion of tolerant individuals	Increase
No. of native taxa, no. of individuals, and fish with lesions or parasites	No discernable trend, dropped from regional IBI

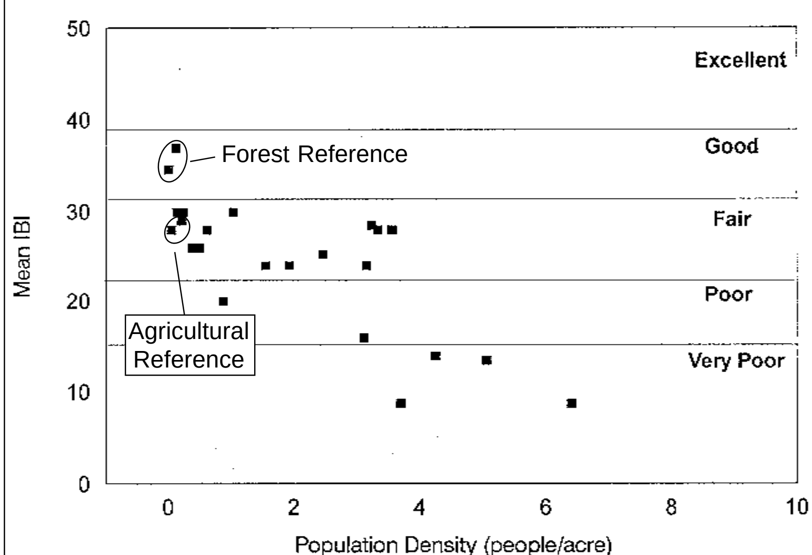
[a] The type of dominant nest-building fish did not just decrease but shifted from one taxa to another. In least-developed watersheds, the endemic bandfin shiner was dominant; in intermediate developed watersheds the yellowfin shiner dominated; and in the most human modified watersheds the introduced red shiner was dominant (or nest associated fish were altogether absent).

(DeVivo *et al.*, 1997). More research is underway to resolve this issue.

The Third Fish Study

A third intensive research study is now comparing stream ecosystem function in four pairs of watersheds that span a gradient of land uses: forest, agricultural, suburban and urban. The joint monitoring study is being conducted by the University of Georgia and the USGS, and will relate watershed conditions to stream ecology. Traditional chemical and biological indicators are being supplemented by rate measurements of stream ecosystem functions, such as the input, storage and transport of carbon, nutrient transport and uptake, and community production and respiration (Meyer *et al.*, 1996). Although the stream ecosystem study is in its preliminary stages, some initial watershed comparisons are provided in Table 3.

For example, the nutrient-rich agricultural stream appears to be the most biologically productive of the four stream types. It has a surprisingly diverse fish and macro invertebrate community, high leaf decay rates, short nutrient uptake lengths, and a rapid metabolism. Algal production appears to be stimulated by the nutrients in the agricultural stream. By contrast, both the suburban and urban streams had lower biotic diversity, more exotic species, and lower nutrient levels. Early measurements of ecosystem rates indicate that primary



Modified IBI scores decline once watershed population density exceeds four persons/acre in 21 urban streams. Forest and agricultural IBI scores are shown for reference.

Figure 2: Relationship Between Watershed Population Density and Stream IBI scores
(DeVivo *et al.*, 1997 and Couch, personal communication)

Table 3: Preliminary Comparison of Stream Attributes for Four Types of Watersheds in the Chattahoochee River Basin (Meyer *et al.*, 1997)

Stream Attributes	Forested	Agricultural	Suburban	Urban
Name	Snake Creek	West Fork	Sope Creek	Peachtree Ck.
Impervious Cover (%)	<1%	<1%	30%	47%
Pop. Density (people/acre)	0.75	1.37	21	33
Total Phosphorus (mg/l)	0.17	0.64	0.15	0.20
Ammonia-N (mg/l)	0.04	0.24	0.07	0.16
EPT Index [a]	4	6	3	2
Benthic Organic Matter [b]	559	151	160	3,350
Net Daily Metabolism [c]	-1.6	-0.8	-2.3	-4.0
Leaf Decay Rate [d]	-0.0078	-0.0293	-0.0146	-0.0334
Ammonia Uptake Length [e]	intermediate	shortest	longest	longest

[a] EPT index, which is a macro invertebrate metric contained in EPA's Rapid Bioassessment Procedure, ranges from 0 to 6, with a higher score indicating greater diversity.

[b] Grams ash free dry weight per square meter of fine and coarse organic matter on stream bottom.

[c] Grams of oxygen produced (consumed) per square meter per day; negative value indicates community respiration exceeds gross primary production.

[d] Decay rate of leaf pack in the stream, per day.

[e] Distance needed for uptake of soluble nitrogen in stream which is an index of nutrient spiraling.

production in the urban and suburban streams is much lower. The reference forest stream was very retentive of the carbon and nutrients that are delivered to it from its watershed, and had high fish and macroinvertebrate diversity. A better picture of dynamics of these four stream ecosystems will be developed by further monitoring over the next several years.

In summary, the three studies clearly show that watershed development has a negative impact on urban warm water streams in the southern Piedmont. This is manifested in reduced fish abundance, lower species richness, increased nonnative fish species, lower IBI scores, reduced macro invertebrate diversity and lower community metabolism. The severity of many of these impacts can generally be related to the intensity of watershed development, as measured by watershed population density. The Atlanta studies provide the first documentation in the Southeast of the strong negative relationship between urbanization and stream quality that has been observed in other eco-regions.

—TRS

References

Couch, C.A., J.C. DeVivo and B.J. Freeman. 1995. *USGS/NAWQA Program: What Fish Live in the Streams of Metropolitan Atlanta?* Fact Sheet: FS-091-95. (February 1995).

Couch, C.A., E Hopkins, and P. Hardy. 1996. *Influence of Environmental Settings on Aquatic Ecosystems in the Apalachicola-Chattahoochee-Flint River Basin.* USGS Water-Resources Investigations Report 95-4278. 58 pp.

DeVivo, J.C., C.A. Couch and B.J. Freeman 1997. "Use of Preliminary Index of Biotic Integrity in Urban Streams Around Atlanta, Georgia." pp. 40-43. In: *1997 Georgia Water Resources Conference*.

Meyer, J.L., E.A. Kramer, M.J. Paul, W.K. Taulbee, and C.A. Couch. 1996. *Influences of Watershed Land Use on Stream Structure and Function*. EPA/NSF Water and Watersheds Symposium. (November 1996).