Technical Note #93 from Watershed Protection Techniques 2(4): 507-510

Historical Change in a Warmwater Fish Community in an Urbanizing Watershed

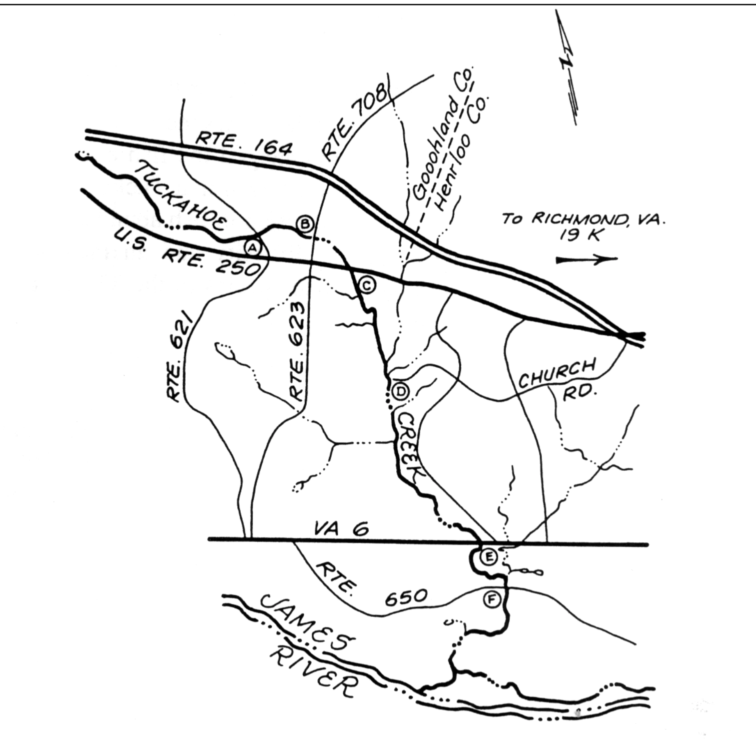
Most investigators exploring the link between urbanization and stream quality sample stream indicators from a large population of urban watersheds. An alternative approach is to sample a single watershed at two points in time (i.e., take a historical snapshot of stream indicators before and after the watershed develops). Alan Weaver and Greg Garman recently applied this method to track changes in the fish community of Tuckahoe Creek, a watershed that has been shifting from rural to suburban land use over the last three decades. The study provides several interesting insights into how a warmwater fish community can change over time in response to watershed development.

Tuckahoe Creek is the last major tributary to the James River above the Fall Line in Virginia (Figure 1). The creek is 17 miles long and drains a watershed of over 40,000 acres. On average, the creek is 12 feet wide and two feet deep. Its upper reaches have a moderate gradient, and possess a substrate of sand and impacted cobble. As the creek descends toward its confluence with the James River, however, it begins to interact with a large wetland complex and wide floodplain. At this point, the creek's substrate changes to silt and detritus.

Situated only a dozen miles west of Richmond, Virginia, the Tuckahoe watershed has experienced considerable development pressure over recent decades. Several indicators of the rapid watershed change that has occurred are profiled in Table 1. In the late 1950s, for example, the watershed was dominated by forest and crops, and had a population density of only one person to every two acres. Over the next 30 years, however, population in the watershed nearly tripled, reaching an average density of 1.5 people per acre. The length of roads, water crossings and amount riparian development also increased dramatically over this period. Although Garman and Weaver did not estimate impervious cover as part of their study, a ballpark estimate can be derived using the Stankowski population density/impervious cover equation. The equation projects that impervious cover was 5% in 1958 and grew to 12% by 1990.

The fish community of Tuckahoe Creek was extensively sampled in 1958, when the watershed was still in a rural condition. While the stream conditions reported in the 1958 survey by Flemer and Woolcott were certainly not representative of "pre-settlement conditions," they did not appear to have changed much from the late 1800s. Indeed, remarkably little change was observed in the Tuckahoe Creek fish community from 1958 to as far back as 1869, according to historical records.

In 1990, Weaver and Garman replicated the fish sampling methods on the same stream that had been surveyed 32 years earlier by Flemer and Woolcott. The research team pinpointed the location of six stream reaches sampled in 1958 from site landmarks, and employed identical seining methods and sampling effort used in the earlier study. The researchers quantified changes in watershed variables between the two surveys by analyzing census data, quad maps, documents and selected aerial photography. As a further indicator of watershed change, Weaver and Garman computed the Index of Biotic Integrity (IBI) for Tuckahoe Creek during the 1990 survey, and compared it with IBI scores for Byrd Creek, a nearby reference stream in a largely



Six stations in Tuckahoe Creek were sampled in both 1958 and 1990. (Designated A-F.)

Figure 1: Location of the Tuckahoe Creek Watershed (Weaver, 1991)

Table 1: Indicators of Watershed Change in Tuckahoe Creek: 1958 to 1990 (Weaver and Garman, 1994)		
Watershed Indicator	**1958**	**1990**
Dominant Land Uses	crops and mixed pine/ hardwood forest	suburban land use
Dwellings	7,789	27,692
Population Density	0.54 persons/acre	1.5 persons/ acre
Road Crossings	43	85
Road Length in Basin	96 miles	227 miles
Riparian Zone Development	7%	28%
Estimated Impervious Cover [a]	5%	12%

[a] Center estimate using the Stankowski equation which computes % impervious cover based on population density.

undeveloped watershed (sampling methods used in 1958 did not allow for the calculation of the IBI, so a surrogate stream was needed as a reference). In addition, Weaver and Garman also performed feeding ecology studies to determine if the diet of four dominant fish species had changed (bluegill, common shiner, bluehead chub, and johnny darter).

Weaver and Garman predicted that the 1990 fish survey would show that the watershed's gradual development over time had changed the fish community. Specifically, they hypothesized that Tuckahoe Creek would experience a reduction in fish abundance, species richness, species diversity and an increase in exotic or non-native fish species in the 32 years between surveys.

Results

Weaver and Garman did find that the Tuckahoe Creek fish community had significantly changed from 1958 to 1990 (Table 2). For example, only 412 fish were collected in the 1990 survey compared to 2,056 in the 1958 study, despite the same sampling effort. Fish abundance declined at every site, with the greatest drop seen in the upstream reaches. Species richness also declined in the three decades between surveys. Thirty-two species representing 10 families were collected in 1958; whereas only 23 species representing nine families were collected in 1990. The most dominant species in 1990 were the bluegill and common shiner, together representing 67% of the catch. The fact that these two species fared reasonably well is not surprising since both are habitat and trophic "generalists." This means that the bluegill and common shiner can exploit a wide range of habitats and food sources, allowing them to respond to changing stream conditions over time. Still, the populations of these hardy fish dropped from 1958 to 1990.

Populations of two other historically dominant species, the johnny darter and bluehead chub, declined by more than 55% between 1958 and 1990. Six fish species collected in 1958 were not present in 1990 (e.g., eastern silverjaw minnow, rosyface shiner, satinfin shiner, fallfish, stripeback darter and yellow bullhead), and populations of several other species plummeted (e.g., chain pickerel, and mountain redbelly dace). Species that favor benthic habitats or depend on quality stream substrates also dropped sharply in abundance (johnny darter, pirate perch, torrent sucker, and eastern mud minnow). It was thought that greater sediment deposition and siltation that has occurred along the stream bottom in recent decades may have smothered the bottom habitats where benthic prey live. Overall, Tuckahoe Creek was scored as "fair" according to the Index of Biological Integrity, compared to a "good" rating for the reference stream (Byrd Creek, Table 3).

A disadvantage of historical fish community analysis is that other factors or events can be responsible for producing the observed change (such as floods, drought or toxic spills). While these factors can never be entirely discounted, the researchers presented indirect evidence that watershed development was a key factor. They found fish species diversity to be negatively correlated with an index of development near each sampling site. (The index was defined as the percentage of developed area in a two square kilometer riparian zone upstream of each sampling site—see Figure 2.)

Although the analysis clearly showed that the Tuckahoe creek fish community had simplified over the years, two predicted changes in the fish community did not happen. First, the predicted invasion of non-native

fish into Tuckahoe Creek did not occur during the study period. Second, fish diet analysis demonstrated no wholesale change occurred in the trophic structure of the fish community over three decades. Other researchers have noted that the foodweb of disturbed streams are restructured, with omnivorous fish species replacing insectivores and piscivores. As Figure 3 illustrates, however, this pattern was not followed in Tuckahoe Creek. The proportion of fish species within each of the four different feeding guilds remained about the same over time during the study.

It was concluded that the cumulative impact of gradual watershed development can, over time, rival that of shorter but more intense disturbances such as clear cutting and extreme floods. In this sense, the frequency of disturbance can be as important as its

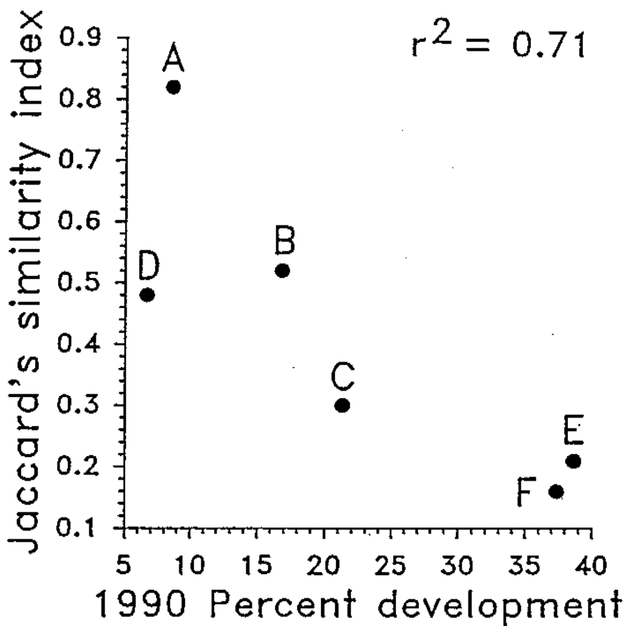
Table 2: Changes in Fish Community Observed from 1958 to 1990 (Weaver, 1991)

Fish Community Indicator	1958	1990
Species Richness	32	24
Abundance	2,056	417
Exotic Fish Species	1 (bluegill sunfish)	1 (bluegill sunfish)
IBI Score	48 (good) [a]	40 (fair)
Most Dominant Species	Johnny darter	Bluegill sunfish
Trophic Guilds (proportion in each feeding category)	invertivores 60% omnivores 30% piscivores/herbivores 10%	invertivores 55%, omnivores 40% no herbivores

[a] As measured at a contemporary reference stream (Byrd Creek).

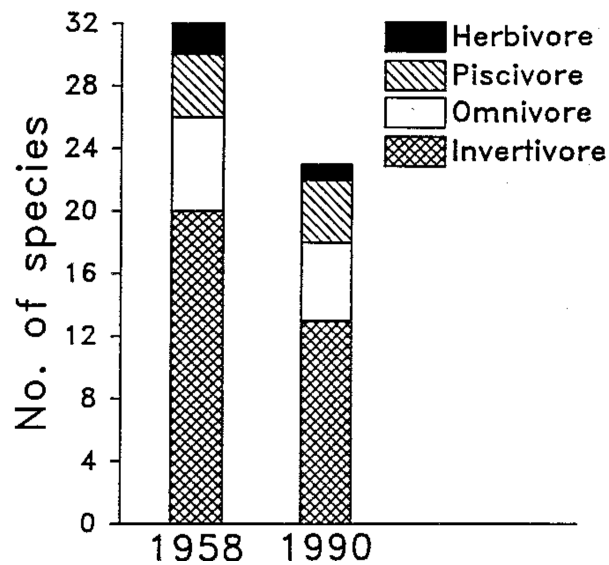
Table 3: IBI Comparison for Tuckahoe Creek and a Reference Stream

Index of Biotic Integrity (IBI) Metric	Tuckahoe Creek (Study Reach B)	Reference Stream (Byrd Creek)
1. Species Richness	17	22
2. Number of darter species	1	4
3. Number of sunfish species	4	2
4. Number of sucker species	3	4
5. Number of intolerant species	2	5
6. Proportion of creek chubsuckers	4.4%	0 %
7. Proportion of omnivores	48 %	18 %
8. Proportion of insectivorous cyprinids	3.9 %	19 %
9. Proportion of piscivores	4.4%	7.6 %
10. Number of individuals collected	24	11
11. Proportion as hybrids	0	0
12. Proportion with parasites	22.5%	11.4%
TOTAL IBI SCORE	40 points	48 points
IBI INTEGRITY CLASSIFICATION	Fair	Good



Fish diversity is measured using Jaccard's community similarity coefficient. It quantifies the presence or absence of fish species in relationship to the development index, and is used to quantify the relative degree of taxonomic similarity between faunal communities based on a cumulative listing of species' presence or absence.

Figure 2: Relationship of a Local Development Index and Fish Diversity in Tuckahoe Creek (Weaver, 1991)



Fish species can be grouped according to their feeding habitats (or guild structure). No change in the relative proportion of species in each feeding group was observed from 1958 to 1990.

Figure 3: Feeding Guild Structure in Tuckahoe Creek: 1958 and 1990

intensity, as both allow little opportunity for ecological recovery. The study provides further evidence of the value of biological indicators, as they respond to and integrate all the various factors that affect a stream.

Multiple stream indicators are needed to fully understand a watershed's dynamics over time. For example, fish may be a good indicator of broad habitat change, but may not always capture subtle changes in water chemistry, flow frequency or site modifications. Other indicators, such as aquatic macroinvertebrate surveys and direct habitat measurements, are often important pieces to complete the watershed "puzzle."

The findings from the Tuckahoe Creek study are consistent with other stream ecology research that have discovered that a relatively small degree of watershed development can produce a dramatic change in the biological diversity of streams.

—JSB

References

Weaver, L.A. 1991. *Low-Intensity Watershed Alteration Effects on Fish Assemblage Structure and Function in a Virginia Piedmont Stream*. Unpublished Masters Thesis. Virginia Commonwealth University. 77 pp.

Weaver, L.A., and G. C. Garman. 1994. Urbanization of a Watershed and Historical Change in a Stream Fish Assemblage. *Transactions of the American Fisheries Society* 123:162-172.