How Streams Work and the Role of Streamside Forests
To advance knowledge and stewardship of freshwater systems through global research, education, and watershed restoration.
What Are Your Goals?

How Do You Achieve Them?
What Are Your Goals?

• Reduce:
  • Sediment
  • Pathogens
  • Nitrogen and Phosphorous Pollution
  • Flooding & Excessive Runoff
• Removal of Impaired Status – Clean Water Act
• Wild Trout
Wild Brook Trout?
Forest Buffers as Filters
STREAMSIDE FOREST BUFFER WIDTH NEEDED TO PROTECT STREAM WATER QUALITY, HABITAT, AND ORGANISMS: A LITERATURE REVIEW

Bernard W. Sweeney and J. Denis Newbold
Stroud Water Research Center
Avondale, PA
64% for first 33 ft…… 84% for 100 ft

Buffer Width (m)

Sediment Trapping Efficiency

Equation (3)

Liu et al. 2008
64% for first 33 ft...... 84% for 100 ft

The 20% more @ 100 ft are the fine silts and clays!!!
Cryptosporidium spores
(“Crypto”)
Pesticides (e.g., Atrazine)
Questions on the Role of Forest Buffers

1. Should we focus forest buffers based on landscape position, i.e., in flowpaths?

2. What if concentrated flows move directly through a buffer?

3. What if we do an outstanding job managing the upland? Why bother with a buffer? The potential of a Soil Health focus?
The Rest of The Story
Small streams matter

- Are “capillaries” of watersheds
- >80% of stream miles
- Often disregarded
- Determine health downstream
Stream organisms...

- Are highly specialized
- Are adapted to forested conditions
Forest Buffers provide In-Stream services

- forested streams...
- remove 2 to 9x more nitrogen pollution
- have 2 to 5x more biological activity
• 2-4x more stream bottom area
• better conditions for biofilm
• more and preferred foods
• shading provides cooler temperatures
The Difference Forests Make

Study by Stroud Water Research Center

- 16 streams in eastern Pennsylvania
- adjoining sections w/ and w/o forest
Riparian deforestation, stream narrowing, and loss of stream ecosystem services

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A study of 16 streams in eastern North America shows that riparian deforestation causes channel narrowing, which reduces the total amount of stream habitat and ecosystem per unit channel length and compromises in-stream processing of pollutants. Wild forest reaches had more macroinvertebrates, total ecosystem processing of organic matter, and nitrogen uptake per unit channel length than contiguous narrow deforested reaches. Stream narrowing nullifies any potential advantages of deforestation regarding abundance of fish, quality of dissolved organic matter, and pesticide degradation. These findings show that forested stream reaches have a wider and more natural configuration, which significantly affects the total in-stream amount and activity of the ecosystem, including the processing of pollutants. The results reinforce both current policy of the United States that endorses riparian forest buffers as best management practice and federal and state programs that subsidize riparian reforestation for stream restoration and water quality. Not only do forest buffers prevent nonpoint source pollutants from entering small streams, they also enhance the in-stream processing of both nonpoint and point source pollutants, thereby reducing their impact on downstream rivers and estuaries.

Deforestation, which annually averaged ~14.6 million hectares (ha) worldwide between 1990 and 2000 (1), will continue as long as humans assign a higher value to food and agriculture than to “ecosystem services” (2) provided by the forests, such as watered protection, wildlife conservation, and carbon sequestration (3). The deforestation of riparian areas not only reduces wildlife habitat and corridors but also directly impacts the stream itself by lowering water and habitat quality due to (a) loss of woody debris, fine litter, and dissolved organic carbon inputs (4); (b) lack of shading, which causes very high levels of photosynthetically active radiation (5), solar UV radiation (6), and temperature (7); and (c) less buffering against nonpoint source pollutants (8). Although the deforestation that denuded most of eastern North America in the 19th century was reversed in upland areas decades ago, debate continues about whether riparian areas of that region and elsewhere should remain treeless (9, 10). Although recent U.S. legislation (11) has emphasized the use of forested buffers to keep nonpoint source pollutants out of streams (8), grass buffers can also intercept pollutants (12). Ultimately, the debate turns on how buffers affect the structure and function of the stream itself and especially its ability to impede the downstream transport of pollutants to larger rivers, estuaries, and oceans. Here we test the hypothesis that the narrowing of small streams caused by riparian deforestation leads to a significant decline in (i) the amount and functional quality of stream ecosystem and (ii) the ability of that ecosystem to process water pollutants.

The conceptual basis of our hypothesis is that unnatural channel narrowing caused by riparian deforestation results in less watered bottom (i.e., benthic) habitat per unit of channel length, increased water velocity, and lower bed roughness. By reducing the total amount of benthic stream ecosystem per unit of channel length, these physical changes compromise in-stream ecosystem function and the processing of pollutants. Our idea builds on an earlier hypothesis that riparian deforestation lowers water and habitat quality in streams (13) and on scientific research that has demonstrated more biological and biogeochemical activity on or in the bottoms of small streams than in their water columns (14). We show that, when averaged across many small, important ecosystem services and both structural and functional ecosystem parameters (e.g., levels of nitrogen and phosphorus processing, dissolved organic matter processing, pesticide degradation, stream metabolism, and the abundance of macroinvertebrates and fish) in forested reaches equaled or exceeded those in deforested reaches per unit of length of stream.

Methods

We studied contiguous (paired) forested and deforested reaches of 16 temperate streams in rural Piedmont watersheds in eastern North America (Fig. 1). Streams ranged from first to fifth order, with watershed areas of 0.1–123 km². The forested reaches were upsteam from the deforested reach at 11 sites and downstream at 5. Similar topographic gradients and riparian soils and lack of urbanization characterized nearly all pairs of reaches. To avoid factors that might confound the primary study variable (presence/absence of forest), all deforested reaches lacked the typical anthropogenic disturbance common in the region (e.g., disturbance from roads, buildings, or row crop agriculture or urbanization). We measured geomorphology, biodegradable dissolved organic matter (BDOM), macroinvertebrates, and fish in all 16 streams. Because of time and budget constraints, we studied gross primary production (GPP), community respiration (CR), nutrient processing, and pesticide degradation in 8–14 streams. We sampled macroinvertebrates five times a year and BDOM, GPP, CR, nutrient processing, and pesticide degradation twice (summer and winter, with multiple measurements per season for GPP and CR). We measured all other parameters once and used quantitative methods (see below) to study most parameters.

Geomorphology

A global positioning system with differential correction was used to locate the top and bottom of each of the experimental reaches, which were ~100–200 m in length. A laser level was used to quantify the longitudinal profile of each reach. Along this profile, we measured bankfull elevation, channel bottom width, and water elevations, width of the water surface, and width and depth at 10-m intervals as well as at important features, such as top of riffle, top of pool, and deepest point in pool. At every third equal interval (i.e., 30, 60, 90 m, etc., from the top of the reach), we used a laser level to survey a detailed channel cross-section orthogonal to the flow. Stream substrata

Acknowledgments.

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All abbreviations used: ha, hectare; DCM, dissolved organic carbon; BDOM, biodegradable dissolved organic carbon; GPP, gross primary production; DOC, dissolved organic carbon; CR, community respiration; NDM, net daily metabolism.
The Hidden Energy of Streams
Filamentous algae
Diatoms

- Need shady conditions to thrive
- A preferred food for scrapers
- Small % of food energy in stream
Tree leaves feed streams

- Leaves, twigs, pollen: solid carbon
- Streams collect ~5x more than other areas
- Only ~1/3 of stream’s energy
Without Trees ....these are missing
Watershed Tea

DISSOLVED ORGANIC CARBON

OTHER

(leaves, twigs, pollen,
seeds, animals, etc.)
“Watershed Tea”

- dissolved organic carbon
- ~ 2/3 of a stream’s food supply
Fish grow on trees
In-Stream Services

Portions of streams with forest...

• Had 3-5x more biological activity
• Removed 2-8x more nitrogen pollution

...than stream areas with healthy grass buffers
Why? BETTER Habitat!

- lots of preferred foods
- better stream bed habitat
- Key: Biofilm on stream bottom
Better Habitat

Preferred light levels
• More diatoms

Preferred temperatures
• Cooler in summer
• Warmer in winter
Forested streams have more natural temperature regime

“cooler in summer, warmer in winter”
Mayfly: *Eurylophella verisimilis*
Eurylophella verisimilis

Growth Rate (mg/mg/d)

- 10 °C: 0.02
- 15 °C: 0.04
- 20 °C: 0.06

Temperature:
- 50 F
- 59 F
- 68 F
Cold Water Species

“live on the edge”
For 1000’s of years .... most small streams were shaded and never went above 68 F
A stream’s “ecosystem” is on the bottom.

- Microorganisms (e.g., hyphomycete fungi) 
- Course particulate organic matter 
- Larger plants (mosses, red algae) 
- Light 
- Epilithic algae 
- Dissolved organic matter 
- Flocculation 
- Fine particulate organic matter 
- Microorganisms 
- Invertebrate shredders 
- Invertebrate collectors 
- Invertebrate scrapers 
- Vertebrate predators 

These components interact within the stream ecosystem, illustrating the flow of energy and nutrients.
Forested Streams:

- remove 2 to 9x more nitrogen pollution
- have 2 to 5x more biological activity
- 2-4x more stream bottom area
- better conditions for biofilm
Wider streams have more bottom (ecosystem) per unit length

Forest

Deforested (grass)
Lititz Run - 18 Year Old Forest Buffer
Thoughts on Successful Buffer Establishment
Plant for Success
four-year old trees:
herbicide strips + mowing = “clean culture”

Photo: Chesapeake Bay Foundation
Herbicide v 12” Stone Mulch

3’ herbicide spot

93% survival @ 4 yrs

~$7.70/tree

“2A modified” stone mulch (no herbicide)

76% survival @ 4 years

~$2.50/tree
Center Hole Net Method

- Nets protect birds
- If neglected, nets tangle trees

Photos: Matt Gisondi
Center Hole Net Method (Cont.)

- Sweeney: ~75% less tree tangling
  - intentionally neglected nets
  - limited sample size

- But, do birds go in center hole?
Center Hole Net Method (Cont.)

~10,000 tubes checked 2016-17
- One dead bird found, but net was improperly installed
- Seems ready for adoption

Center hole nets also blow off tube less often than tassel method

Not a recc. to neglect nets
Results (by weight of competing veg):

Single shake (Feb/March):
- 42% reduction vs. no Snapshot

Two shakes: (Feb/March):
- 45% reduction vs. no Snapshot

**But some oriental bittersweet came through!**
Snapshot works for ~ 3 months

Next Tests: Other Options:
- A **second** application in May
- Use of additional active ingredients
Rout ™: additional active ingredients

What a typical application looks like
Results in 18 months for silky dogwood:

control – no fence  
mean height: 26 cm

“biodegradable” fence:  
wooden stakes + bailer twine  
mean height: 37 cm

welded wire fencing  
mean height 91 cm
Watershed Restoration

Aims to re-establish normal rates and magnitudes of physical, chemical, and biological processes that create and sustain river and floodplain ecosystems
Streams are dynamic systems.

Streams are not static in place, time, hydrology or ecosystem function.
RIVER CORRIDOR PLANNING

A goal of the Vermont Rivers Program is to manage toward, protect, and restore the fluvial geomorphic equilibrium condition of Vermont rivers by resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner. River corridor planning is conducted in Vermont to remediate the river instability that is largely responsible for erosion conflicts, increased sediment and nutrient loading, and a reduction in river habitat.

The Rivers Program has developed a technical corridor planning guide that provides the:

- river science and societal benefits of managing streams toward equilibrium conditions;
Vermont Agency of Natural Resources
River Corridor Planning Guide

to Identify and Develop
River Corridor Protection and Restoration Projects

River Management Program
April 1, 2010
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<th>BMP Number</th>
<th>Default Rate Estimated in TMDL Plan at 115 lb/ft² (tons/yr)</th>
<th>BANCS Method (tons/yr)</th>
<th>Watershed DEM Differencing Erosion ± Error (tons/yr)</th>
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*Net Deposition*
Large Woody Debris

- Slow Stormwater Flow
- Improve In-stream Habitat
- Alter Channel Shape