EFFECTS OF LAND-USE CHANGE ON SEDIMENT TRANSPORT AND FISH ASSEMBLAGE STRUCTURE IN SOUTHERN APPALACHIAN STREAMS

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Abstract. We examined the relationship between land use, sediment transport and fish in four Appalachian streams. There was a significant increase in suspended load, and substrate embeddedness with increasing non-forested land use. There was also a strong negative correlation between non-forested land use and relative abundance of fishes requiring clean gravel for spawning. Finally, we established a relationship between NTU and TSS for Blue Ridge streams.

INTRODUCTION

Human-induced sediment loading negatively impacts stream ecosystems by reducing habitat suitability and degrading water quality (Lemly 1982, Waters 1995). Excessive sedimentation affects over 45% of the streams in the U.S. and is considered the primary problem facing America's flowing waters (U.S. EPA 1990). Much of the research concerning sedimentation and fishes relates to salmonids, primarily in western streams. In contrast little is known about the relationship between land use and the diverse fish fauna of the southern Appalachians. With over 345 species of fish, the southern Appalachians harbors one of the most diverse fish faunas in the world (Burkhead and Jenkins 1991, Walsh et al. 1995). This is an important region for study because of the high number of imperiled fish species; of the 300 darter and minnow species in the southeast, over 21% are imperiled. The purpose of this research is to provide information that will be useful to regional policy makers and resource managers concerning the negative impacts of excessive sedimentation on fish assemblages in southern Appalachian upland streams. By attempting to link landscape disturbance with instream physical processes this study brings us closer to understanding how large scale land-use patterns may be negatively affecting the streams of the southeast. The ultimate objective of this work is to provide information that will help preserve the biotic integrity and diversity of southeastern streams. A secondary objective of this research was to determine the relationship between NTU and TSS measures in the Blue Ridge physiographic province. This is important to regulatory agencies and others monitoring stream health because NTU measurements are less costly and less time consuming than TSS measurements.

METHODS

Land Use

GIS land-use coverages were determined for 1950, 1970 and 1990 within the entire watershed, within a 100-m buffer along the drainage network (mainstem-riparian), and within a 100-m wide buffer on the reach encompassing the study site (1.2 – 1.7 km in length) (reach-riparian).

Study sites

Four study streams were chosen based on 1990 GIS coverages for the whole watershed. The two reference streams (Tellico and Coweeta creeks) had less than 5% non-forested land cover while the two disturbed streams (Watauga and Rabbit creeks) drained watersheds with between 15 – 25% non-forested land cover.

Suspended Sediment

Baseflow and stormflow suspended sediment transport was measured using grab samples and samples collected using USGS type rising-stage sediment samplers. Samples were collected from July 1997 to March 1998 at intervals ranging from 3 to 14 days. Turbidity (NTU) was measured using a Hach Model 2100P turbidimeter. Total suspended solids

(TSS) was measured using a standard protocol (Hauer and Lamberti 1996).

Benthic Habitat

Percent embeddedness of the streambed and % coverage of the substrate with fines (< 0.25 mm) were estimated in August 1997 using a Plexiglas viewbox with a 400 cm^2 viewing area. Estimates were taken at one meter intervals along 20 randomly chosen transects per site.

Fishes

Fishes were collected between late September and early October 1997 using a Smith-Root backpack electrofisher. Species were placed into spawning and feeding guilds based on behavioral descriptions in Etnier and Starnes (1993). Guild information is summarized in Table 1.

Statistical Analysis.

NTU and TSS were compared using regression analysis of log-transformed data. Because of potential instrument error, we only used NTU values < 900. Percent embeddedness and percent coverage of fines were compared using ANOVA and regression methods.

RESULTS AND CONCLUSIONS

Regression analyses results suggest that large-scale land use (whole watershed) is a good predictor of baseflow and stormflow suspended sediment transport (Table 2). The two largest land-disturbance scales (watershed and mainstem riparian) were also strongly correlated with mean percent embeddedness of the streambed (Table 2). The relationship between reach-scale land use was minimal. These results suggest that reach-scale embeddedness may result from watershed-scale erosion and sedimentation processes, rather than local- scale sediment processses. There was also a significant increase in percent embeddedness at sites with increasing non-forested land cover (Figure 1).

Percent coverage of substrate with fines (< 0.25 mm) showed no such relationship. The slopes for regressions between sediment parameters and land use were steepest and correlations highest for 1990.

Relative abundance of crevice and gravel spawning fishes (BC+G) was inversely related to both mean NTU and % embeddedness of the streambed. BC + G fishes are of interest because they require spawning substrate that is free of excessive fine sediment (Table 1). They are therefore a good indicator of the impacts

Table 1. Spawning Guild Classifications

Guild	Spawning Description
Benthic Crevice and Gravel Spawners	spawn over or under clean gravel/cobble or within boulder/bedrock crevices
Benthic Nest Builders	create and spawn on gravel mounds
Benthic Nest Associates	spawn on benthic nest builder mounds
Benthic Excavators	create and spawn in depressions in soft substrates

Table 2. Correlation Coefficients (r) for Regressions of Land Use vs. Sediment Measures and Fish Guilds

Sediment Measure	Whole Watershed	Watershed Riparian	Reach Riparian
Baseflow NTU	0.97*	0.69	0.04
Stormflow NTU	0.99*	0.82	0.02
% Embeddendess	0.99*	0.94*	0.00

Fish Guild	Whole Watershed	Watershed Riparian	Reach Riparian
Gravel Spawners	-0.99*	-0.95*	0.00
Mound Builders	0.10	0.24	0.84
Sand Excavators	0.85	0.97*	0.40

* denotes a significant correlation ($p < 0.05$).

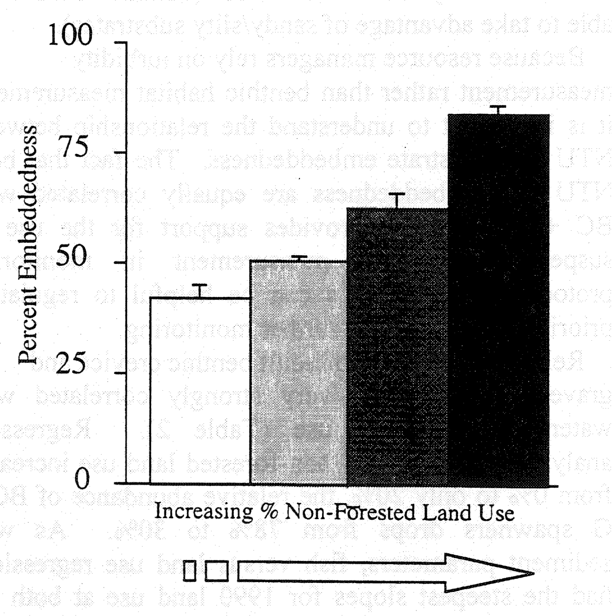
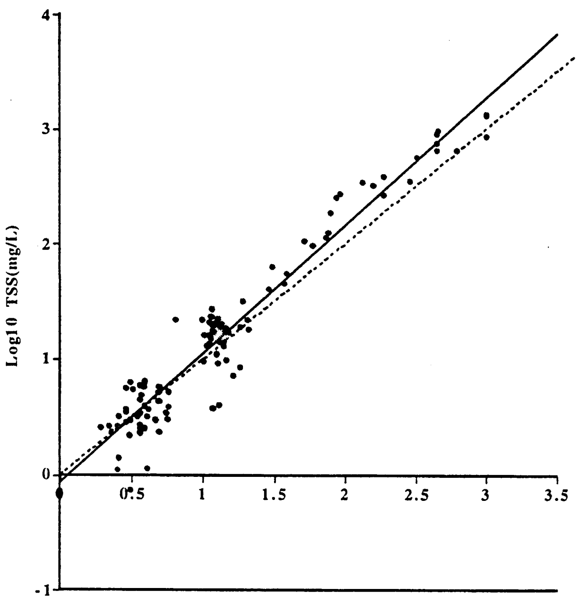


Figure 1. Mean Percent Embeddeness of Substrate at Little Tennessee Study Sites



* The regression equation is Log_{10} TSS = -0.059 + 1.118 Log_{10} NTU ($r^2 = 0.93$, n = 106). The dashed line represents the 1:1 line.

Figure 2. Regression of Log_{10} NTU versus Log_{10} TSS at all Little Tennessee River Sites Combined for NTU Values < 900*.

of human-induced sedimentation. There was no correlation between these physical parameters and any other spawning guild (Table 1). However, at the study site with the highest sediment transport and embeddedness levels, the fish fauna was composed almost entirely of centrarchids (benthic excavators able to take advantage of sandy/silty substrates).

Because resource managers rely on turbidity measurement rather than benthic habitat measurement, it is important to understand the relationship between NTU and substrate embeddedness. The fact that both NTU and embeddedness are equally correlated with BC + G spawners provides support for the use of suspended sediment measurement in monitoring protocols. NTU levels can be helpful to regulators prioritizing streams for further monitoring.

Relative abundance of adult benthic crevice and gravel spawners was very strongly correlated with watershed-level land use (Table 2). Regression analysis reveals that as non-forested land use increases from 0% to only 20%, the relative abundance of BC + G spawners drops from 78% to 30%. As with sediment parameters, fish versus land use regressions had the steepest slopes for 1990 land use at both the watershed and mainstem-riparian levels. Current rather than historic land use is a better predictor of current fish assemblage structure in these streams.

This study suggests that there is a positive relationship between increasing watershed disturbance and increasing sediment transport and substrate homogenization. These results also suggest that increasing land disturbance negatively influences those fishes requiring clean gravel and cobble for spawning.

Regression analyses suggest that there is a strong correlation between NTU and TSS measures for NTU values < 900 (Figure 2). These results suggest that NTU is a good indicator of suspended sediment levels and could replace TSS as standard monitoring protocol. The regression equation developed can be used to convert from NTU to equivalent TSS units in the Blue Ridge physiographic province.

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