A SCIENTIFIC BASIS FOR EROSION AND SEDIMENTATION STANDARDS IN THE BLUE RIDGE PHYSIOGRAPHIC PROVINCE

Judy Meyer, Andrew Sutherland, Kevin Barnes, David Walters and Byron Freeman

AUTHORS: Institute of Ecology, University of Georgia, Athens, Georgia 30602.

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Abstract. Excessive sedimentation is a threat to riverine ecosystems in the southern Appalachians. We sampled fish and suspended sediments in ten tributaries of the Etowah and Little Tennessee rivers. Sampling sites varied in the extent of sedimentation and could be separated into low and high turbidity streams. Based on differences in fish assemblages in these two stream types, the following standards would protect fishes in the Blue Ridge physiographic province: Turbidity values in stream water sampled during base flow conditions should not exceed 15 NTU, and turbidity should exceed 10 NTU in only one out of five stream water samples collected during base flow conditions. Base flow turbidity values in excess of these indicate excess sedimentation that threatens the integrity of southern Appalachian fish assemblages.

INTRODUCTION

Land-disturbing activities such as agriculture, road construction, and urban development can result in erosion and excessive sedimentation in rivers and streams. Excessive sedimentation is responsible for degradation of more stream miles in the U.S. than any other factor (Waters 1995). Sediments fill the interstices of gravel and cobble stream bottoms, reducing spawning habitat for fishes and degrading the habitat of their prey (Wood and Armitage 1997). Suspended sediments increase stream turbidity, which can impair fish feeding (Barrett et al. 1992).

Georgia has a diverse freshwater fish fauna; for example, the Etowah River has 91 native species (Burkhead et al. 1997). Yet adequate data addressing the effects of sedimentation on fishes native to Georgia are not available (Ga. Bd. Regents Scientific Panel 1995). Recommending science-based erosion and sedimentation standards requires comparisons of native fishes and levels of sedimentation at the same sites; few such data are available for Georgia (Barnes et al. 1996). Hence the objective of this research was to compare stream fish assemblages with measures of sedimentation at several sites to determine the sensitivity of native fishes to sedimentation. Our goal was to provide a scientific basis for recommending suspended sediment standards that are protective of fishes in the Blue Ridge physiographic province.

METHODS

We collected data on fishes and sediments in two river systems that are representative of rivers in the Blue Ridge province. These data were collected from paired tributaries (with less vs. more land-disturbing activity in their watersheds) in the Etowah River system and two reference and two disturbed tributaries in the Little Tennessee River system. The streams sampled are listed in Table 1 with detailed site descriptions in Barnes (1998) and Sutherland (1998).

Turbidity and total suspended sediment (TSS) concentrations were determined on samples collected from January - September 1997 in the Etowah River tributaries and from July 1997 - March 1998 in the Little Tennessee River tributaries. Grab samples were collected during base flow, and a rising stage sampler was used to collect storm samples (Sutherland et al. 1998). Turbidity was measured in nephelometric turbidity units (NTU) in the field with a Hach model 2100P turbidimeter, and TSS was measured using standard protocols (Hauer and Lamberti 1996).

Fishes were sampled by electro-shocking a 100-m stream reach during June and November 1997 in the Etowah River tributaries and during September and October 1997 in the Little Tennessee River tributaries. Fishes were counted and identified to species, and species were assigned to spawning and feeding guilds (Table 2; Etnier and Starnes 1993, Jenkins and Burkhead 1994). Benthic crevice spawners (BC) spawn in crevices within the gravel/cobble matrix of riffles, whereas gravel spawners (G) do not use crevices, but spawn directly over or in gravel substrates. We distinguished benthic nest builders (BNB) from benthic excavators (BE), those species that spawn by excavating depressions and then fanning currents of water over the eggs, which removes fine sediments. Benthic nest associates (BNA) are fishes which spawn over the gravel nests made by BNB species, but which do not actively build the nest. The five feeding guilds recognized were: (1) benthic invertivores (BI) whose sole food source is benthic invertebrates such as stoneflies and caddisflies; (2) general invertivores (I) that are opportunistic predators on invertebrates in the water column and in the benthos; (3) detritivores (D) that feed on detritus;

Table 1. Study streams included in each turbidity group from either the Little Tennessee River (LTR) or Etowah River (ER) basins and % of base flow samples exceeding 10 or 15 NTU out of n samples collected from each stream and for all streams in each turbidity group. Median base flow and median storm flow NTU values are also indicated for each stream and for all streams in each turbidity group.

Stream	River Basin	n	% > 10 NTU	% > 15 NTU	Base flow NTU	Storm flow NTU
LOW TURBIDITY						
Tellico	LTR	21	0	0	3.1	70
Coweeta	LTR	20	0	0	3.6	84
Ward	ER	18	6	0	4.5	493
Jones	ER	13	7	0	4.4	208
Nimblewill	ER	13	15	0	6.0	356
ALL low turbidity		85	5	0	3.9	182
HIGH TURBIDITY						
Watauga	LTR	20	95	10	13	449
Rabbit	LTR	22	91	23	12	533
Two Run	ER	18	33	17	7.3	432
Mill	ER	14	71	57	16	151
Hurricane	ER	14	50	36	7.9	546
ALL high turbidity		88	70	27	12	429

(4) algivores (A) that utilize periphyton scraped from stones; and (5) invertivore/piscivores (IP) that eat both invertebrates and vertebrates.

Suspended sediment measures and fish assemblages were compared in groups of streams using the non-parametric Mann-Whitney U test.

RESULTS

An examination of base flow turbidities from these Blue Ridge streams revealed two groups of streams (Table 1): (1) "low turbidity" streams in which turbidity at base flow never exceeds 15 NTU and in which turbidity exceeds 10 NTU in less than 20% of base flow samples; and (2) "high turbidity" streams in which turbidity at base flow occasionally exceeds 15 NTU and in which turbidity exceeds 10 NTU in more than 20% of base flow samples. Five streams are in each turbidity group, each of which has two Little Tennessee tributaries and three Etowah tributaries. Median NTU at base flow ($p < 0.001$) and storm flow ($p < 0.02$) are significantly higher in the high turbidity streams (Table 1).

Table 2. Reproductive and feeding guilds assigned to fishes in the Little Tennessee and Etowah River tributaries in this study. Abbreviations for guilds are defined in the text.

Species	Reproductive Guild	Feeding Guild
LITTLE TENNESSEE RIVER FISHES		
Ichthyomyzon greeleyi	G	D
Campostoma anomalum	BNB	A
Clinostomus funduloides	BNA	I
Cyprinella monacha	BC	I
C. galactura	BC	I
Luxilus coccogenis	BNA	I
Nocomis micropogon	BNB	IP
Notropis leuciodus	BNA	I
Phenacobius crassilabrum	BNA	I
Rhinichthys atratulus	G	I
R. cataractae	G	I
Semotilus atromaculatus	BNB	IP
Catostomus commersoni	G	BI
Hypentelium nigricans	G	BI
Oncorhynchus mykiss	BNB	IP
Salmo trutta	BNB	IP
Cottus bairdi	BC	BI
Ambloplites rupestris	BE	IP
Lepomis auritus	BE	I
L. cyanellus	BE	I
L. macrochirus	BE	I
Micropterus dolomieu	BE	IP
M. punctulatus	BE	IP
Etheostoma blennioides	G	BI
E. chlorobranchium	G	BI
Percina evides	G	BI
ETOWAH RIVER FISHES		
Ichthyomyzon gagei	G	D
Campostoma oligolepis	BNB	A
Semotilus atromaculatus	BNB	IP
Nocomis leptocephalus	BNB	IP
Notropis chrosomus	BNA	I
N. lutipinnis	BNA	I
Hypentelium etowanum	G	BI
Oncorhynchus mykiss	BNB	IP
Salmo trutta	BNB	IP
Cottus sp. cf. carolinae	BC	BI
Lepomis auritus	BE	I
L. macrochirus	BE	I
Micropterus coosae	BE	IP
M. salmoides	BE	IP
Percina nigrofasciata	G	BI
P. palmaris	G	BI

Although the fish assemblages of the Etowah and Little Tennessee tributaries contained many of the same guilds and genera, they shared few of the same species.

Only five of the 16 species collected in the Etowah tributaries were included among the 26 species collected in the Little Tennessee tributaries, and three of those were introduced species. By combining data from both river basins, recommendations for erosion and sedimentation standards are based on distributional information for 37 fish species. Species lists and abundances in each stream can be found in Sutherland et al. (1998).

Low and high turbidity streams differed in their fish assemblages (Table 3). Because streams differ in channel width and amount of time spent electroshocking (25 - 60 min), all abundance data were expressed as individuals /100 m^2 for 10 minutes of electro-shocking to account for these differences. Fish assemblages in low turbidity streams have more adult rainbow trout, sculpins, and darters (Table 3). Low turbidity streams also have more obligate benthic invertivores, benthic crevice and gravel spawners, but fewer benthic excavators. There was little difference in abundance of benthic nest builders and nest associates or generalized invertivores in low vs. high turbidity streams. Although brown trout abundance also did not differ in the two stream groups, adult rainbow trout were ten times more abundant in low turbidity streams.

Because three of the five streams in each group were stocked with trout, it is important to also consider juvenile trout abundance since this indicates reproductive success. Abundance of juvenile trout in the two groups of streams showed the same pattern as adults (Table 3): higher abundance of all trout and of rainbow trout in low turbidity streams and no difference in brown trout abundance between streams.

DISCUSSION

Most sediment transport occurs at high flow, and turbidities are usually much higher and more variable during storms than during base flow conditions in most streams, including those studied here (Table 1). Yet designing a monitoring regime that samples adequately during storms is more difficult than designing one that focuses on base flow sampling. Hence it is important to note that the turbidity differences we observed between streams are detectable at base flow and that streams are grouped according to base flow turbidity values. Although high turbidity values indicate potentially stressful conditions for the biota, further analyses are necessary to assess actual sediment impact in a particular stream. Because the embedding of riffles may take years to occur, turbidity measures alone cannot measure degree of impact. To better assess the impact of sedimentation, it is necessary to measure habitat parameters such as embeddedness and coverage with fine sediments, which are ecologically significant for fish and invertebrates. In the streams sampled here, embeddedness, coverage with fine sediments, and bedload transport were higher in the high turbidity streams, and TSS and NTU were well correlated ($r^2 = 0.87$) (Sutherland et al. 1998). Hence NTU appears to be a useful indicator of potential habitat degradation, and high base flow NTU values are cause for concern.

Table 3. Mean number of fish / 100 m^2 captured for 10 minutes of shocking. p values are for non-parametric comparisons between low and high turbidity streams.

	Low Turbidity Streams	High Turbidity Streams	P
All adult trout	1.6	0.6	0.04
Adult rainbow trout	1.1	0.1	0.07
Adult brown trout	0.52	0.46	0.5
All juvenile trout	1.5	0.4	0.06
Juvenile rainbow trout	1.2	0.02	0.17
Juvenile brown trout	0.2	0.3	0.9
Adult sculpin	25.1	14.1	0.17
Adult darters*	1.0	0.3	0.11
Benthic invertivores	31.8	18.5	0.17
Benthic crevice & gravel spawners	31.8	19.0	0.17
Benthic excavators	0.1	3.3	0.06
Invertivore & invertivore/piscivore	16.8	29.3	0.9
Benthic nest builders and associates	19.7	28.6	0.6

* Except *Percina nigrofasciata*, which appears to be a more sediment-tolerant species.

Many factors in addition to excessive sedimentation regulate the abundance of fishes in a stream. Hence it is not surprising that fish abundance was highly variable within turbidity groups. As a consequence of high variability and low sample size (5), statistical tests had limited power. Because we are particularly concerned with falsely accepting a null hypothesis of no difference between the two groups (Type II error) and because the differences we observe are consistent with what has been reported by others (e.g. Harding et al. 1998, Jones et al. in press), we report differences between stream groups when probabilities are < 0.17. Additional fish sampling in more streams in each turbidity group would increase the statistical confidence levels of these conclusions.

Low and high turbidity streams differed in measures of sedimentation and in fish assemblages. In high turbidity streams the fish assemblages have fewer juvenile and adult rainbow trout, sculpins, and darters. These streams also have fewer obligate benthic invertivores, and benthic crevice and gravel spawners. but more benthic excavators. Some high turbidity streams have more benthic nest-builders and their associates. These changes in fish assemblages are consistent with those observed in more detailed comparisons of less vs. more disturbed streams within a river system (Barnes 1998, Sutherland 1998) and parallel findings on the relationship of fish distribution to sedimentation in other Little Tennessee and French Broad river locales (Harding et al. 1998, Jones et al. in press). The changes indicate a reduction in abundance of sediment-sensitive fishes and an increase in abundance of sediment-tolerant fishes.

Given the desirability of trout to anglers, the ten-fold higher abundance of adult rainbow trout in low turbidity streams is particularly striking. Brown trout appear to be more tolerant to sedimentation than are rainbow trout .

These differences in fish assemblages are apparent in streams grouped by the extent to which base flow turbidity exceeds 10 or 15 NTU. The fact that these Southern Appalachian fish assemblages respond to such low levels of turbidity is an indication of the sensitivity of this fauna to increased sedimentation.

RECOMMENDATIONS

On the basis of differences observed in fish assemblages in streams with low vs. high base flow turbidity, the following standards would be protective of fishes in the Blue Ridge physiographic province: Turbidity values in samples of stream water collected during base flow conditions should not exceed 15 NTU; turbidity should exceed 10 NTU in only one out of five stream water samples collected during base flow conditions. Base flow turbidity values in excess of these indicate excess sedimentation that threatens the integrity of southern Appalachian fish assemblages.

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