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Effects of Landscape Characteristics on Water Quality and Fish Assemblages in the Tallapoosa River Basin, Alabama

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Abstract - To maintain and improve water quality, there is an increasing need to understand relationships between current land-use practices (e.g., agriculture, forested/silviculture, and urban) and stream ecosystems. In this study, we investigated the relationships among water quality, habitat composition, fish assemblages, and current land-use practices in the Tallapoosa River Basin in eastern Alabama. Within the six streams investigated, all fish metrics were significantly higher for forested watersheds compared to agricultural watersheds, with total nitrogen and total phosphorus being the variables most descriptive of fish biotic integrity (i.e., total nitrogen and total phosphorus were negatively related to fish biotic integrity). In addition, we found that nutrient concentrations (especially total nitrogen and total phosphorus) increased as percent agricultural land use increased. When looking at a larger scale (Tallapoosa River Basin), anthropogenic impacts such as eutrophication of Lakes Martin and Harris were related to agricultural land practices and the percentage of the basin these practices occupy. Because current land-use practices appear to be negatively impacting stream water quality and biota, it is important to decrease the amount of fertilizer, pesticides, and animal waste that runoff into streams and to protect riparian zones in order to preserve or improve biotic integrity.

Introduction

Changes in land use from watersheds dominated by forests to those dominated by agriculture or urban areas can cause structural and functional shifts in aquatic ecosystems (Allan 2004, Booth et al. 2004, Miltner et al. 2004, Paul and Meyer 2001, Roth et al. 1996, Wang et al. 2001). The resultant physical/chemical alterations to streams can restructure biological assemblages, and cause declines in diversity and productivity of invertebrates and fishes (Karr 1981, 1991; Maloney et al. 2008; Richards et al. 1996; Scott 2006; Wang et al. 2001). Agricultural runoff can deliver animal wastes, inorganic nutrients, pesticides, herbicides, and sediments to streams (Wang et al. 2002). Some of the numerous potential negative effects to stream biota caused by increases in agricultural land practices include increased nutrient loading (Carpenter et al. 1998, Karr et al. 1985, Kronvang et al. 1995, Rekolainen 1989, Shilling 2002), sedimentation (Lowrance et al. 1984, Nerbonne and Vondracek 2001, Walser and Bart 1999), and a subsequent loss of biotic diversity (Carpenter et al. 1998, Karr et al. 1986). Sediment and nutrient loading is natural within aquatic systems; however, excessive inputs associated

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with poorly managed agricultural practices have been shown to have deleterious effects on stream fishes and invertebrates (Nerbonne and Vondracek 2001, Rekolainen 1989).

Currently, one of the more discussed anthropogenic impacts of increased agricultural land use is nutrient loading. Watersheds with greater proportions of agricultural land use tend to discharge greater amounts of nitrogen and phosphorus (Buck et al. 2004, Carpenter et al. 1998, Kronvang et al. 1995, Poor and McDonnell 2007, Rekolainen 1989, Salvia-Castellvi et al. 2005, Shilling 2002). Understanding factors influencing nutrient runoff is critical to understanding the eutrophication of lakes, streams, estuaries, and coastal waters (Nixon 1995). In aquatic systems, excess nutrient enrichment (i.e., eutrophication) can cause algal blooms, a decrease in dissolved oxygen, fish kills, a decline in biodiversity, a shift in aquatic plant communities, and other problems (e.g., impaired use of water for drinking, agriculture, and recreation) (Carpenter et al. 1998).

Although numerous studies have assessed the impact of land-use practices on biotic condition and water quality, few studies have focused on the southeastern United States, where aquatic life is extremely diverse (Boschung and O'Neil 1981, Scott 2006, Walser and Bart 1999). The objective for this study was to assess the relationship between land-use practices and water quality, habitat composition, and fish assemblages within the Piedmont region of eastern Alabama.

Methods

Study area

Sampling was conducted in six headwater (first and second order) streams within the Upper and Middle Tallapoosa River sub-basins, AL, from February 2004–January 2006 (Fig. 1). All six streams lie within the Southern Inner Piedmont Subecoregion of the Piedmont Ecoregion; which, in Alabama, generally has higher elevations and more relief than the Coastal Plain to the south. Streams were classified by the dominate land use (i.e., land use with the largest area within a watershed) occupying their individual watersheds upstream from sample sites. Streams were selected based on predominance of either forest/

Table 1. Watershed area, means ($\bar{x}$), and standard errors (SE) for total alkalinity (TA), total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) for six stream sampled within the Upper and Middle Tallapoosa River sub-basins, AL 2004–2006.

Stream	Land use	Watershed area (ha)	TA (mEq/l) $\bar{x}$ (SE)	TN (mg/l) $\bar{x}$ (SE)	TP (mg/l) $\bar{x}$ (SE)	TSS (mg/l) $\bar{x}$ (SE)
Birdsong Creek	Forest/silviculture[A]	1386.1	6.29 (0.28)	0.25 (0.03)	0.02 (0.00)	4.38 (0.74)
Jones Creek	Forest/silviculture	1191.0	6.38 (0.25)	0.27 (0.03)	0.02 (0.00)	7.38 (1.49)
Prairie Creek	Agriculture[B]	1096.7	9.96 (0.36)	0.89 (0.05)	0.05 (0.89)	13.13 (2.21)
Rice Branch	Agriculture	322.9	6.82 (0.27)	1.53 (0.07)	0.09 (0.02)	11.85 (4.54)
Grants Branch	Agriculture	772.5	6.67 (0.25)	0.84 (0.08)	0.04 (0.01)	7.41 (1.93)
Pine Hill Creek	Agriculture	254.6	9.00 (0.41)	2.41 (0.25)	0.13 (0.04)	13.90 (4.40)

[A] Watersheds classified as forest/silviculture were >90% forested/silviculture land use, including clear cuts.

[B] Watersheds classified as agriculture were >33% agricultural land use.

silviculture or agricultural land use, because these two land-use types account for the majority of the Upper and Middle Tallapoosa River sub-basins. Overall, forest/silviculture and agricultural land uses dominated each of the six watersheds (Table 1). Forest/silviculture sites consisted of clear cuts and areas dominated by *Pinus taeda* L. (Loblolly Pine) at various stages of maturity. Agricultural sites

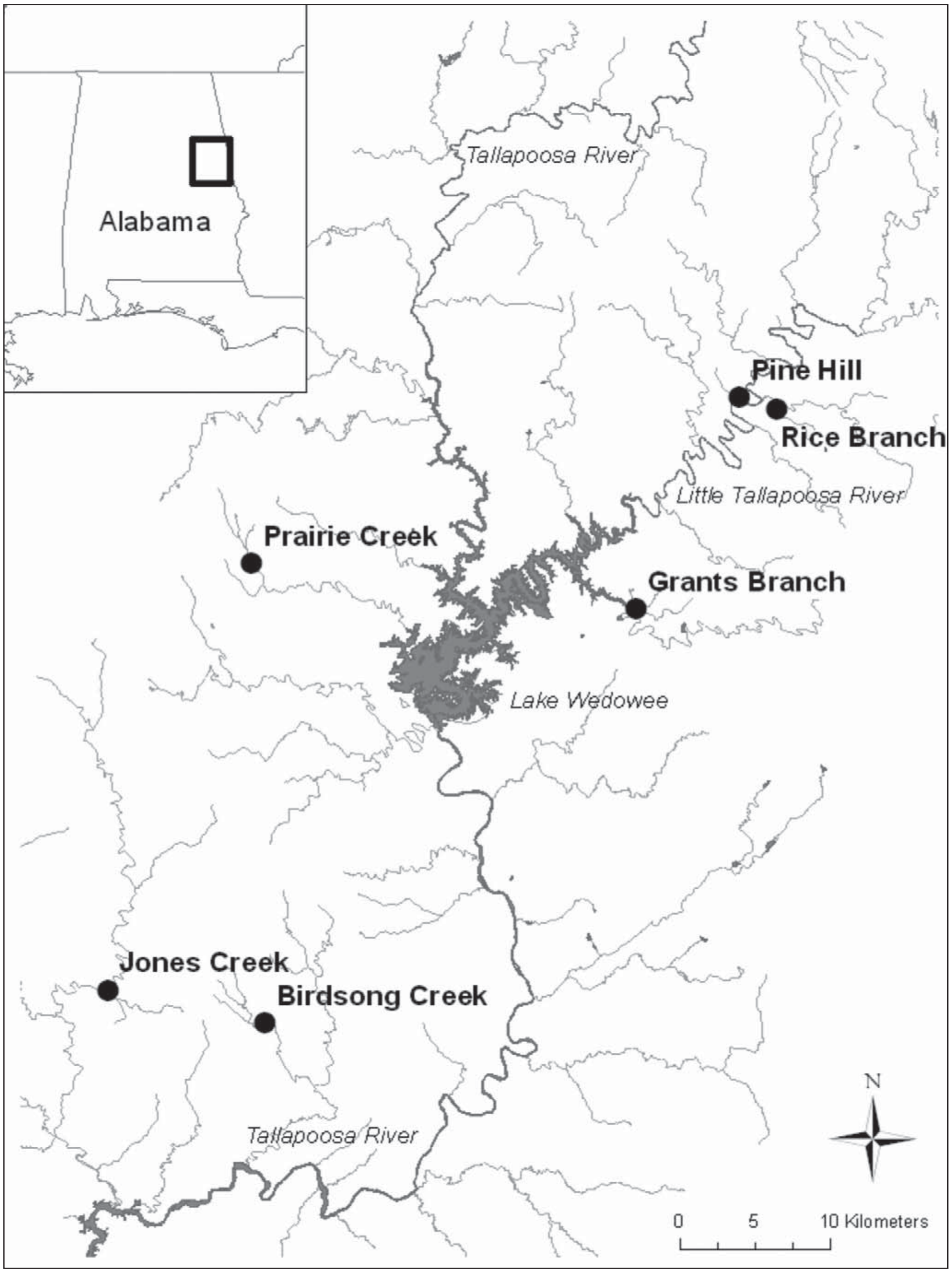

Figure 1. Location of study area streams within the Upper and Middle Tallapoosa River sub-basins, AL.

were dominated by pastureland interspersed with forested land. Poultry-rearing facilities were common throughout the agricultural watersheds, at varying densities. It should be noted that litter from these facilities is valued as a nutrient-rich fertilizer and commonly applied across pasturelands within the region, thus litter from local poultry farms contributed to the environmental impacts from pastureland (Alabama Soil and Water Conservation Committee 2007). An additional nutrient input to pasturelands resulted from livestock grazing, primarily cattle.

Land-use classification

Land-use classifications were obtained for each of the six watersheds from the Alabama GAP Analysis Program (Alabama Cooperative Fish and Wildlife Research Unit 2001). An accuracy assessment was conducted by ground-truthing numerous sites throughout the basin, resulting in an overall accuracy of 85% and a Kappa Index accuracy of 80%. For our analyses, we combined the land-cover classes into 1) forest/silviculture (combined coniferous, deciduous, and mixed classes), 2) urban, 3) agriculture/pasture, and 4) disturbed (clear-cuts, forest roads, etc.). Size of each watershed upstream from our sampling site and the amount of impervious surfaces (ha) were obtained through use of ArcHydro's Watershed Delineation Tool in ArcGIS 9.2 (Environmental Systems Research Institute, Redlands, CA). Once the size and shape of each watershed was known, this layer was added to an ArcGIS 9.2 file, where it was overlaid with the reclassified GAP land-use file. Once these two files were overlaid, percent composition for each land-use classification was obtained for all six watersheds.

Habitat sampling

Visual habitat assessments were conducted between November 2004 and January 2005 at each stream site. No seasonal differences were detected in water level or velocity, indicating habitat sampled during this time frame was representative of the whole study period (Tallapoosa Watershed Project, unpubl. data). Habitat variables were evaluated according to methods described in the United States Environmental Protection Agency (US EPA) rapid bioassessment protocols (Barbour et al. 1999, Plafkin et al. 1989). Habitat data collected within each reach included instream (bottom substrate, available cover, embeddedness of substrate material, and velocity/depth conditions), channel morphology (sediment deposition, channel flow status, channel alteration, and pool/riffle ratio), and riparian and bank structure (bank stability, bank vegetation, and riparian cover) variables. All habitat variables were scored based on the rapid bioassessment protocols, and the scores for each variable were summed to get an overall habitat score for each stream.

Stream flow sampling

We obtained discharge measurements at all stations on a monthly basis to define the stage-discharge relationship (rating) for each station. Flow measurements were conducted through use of a Marsh-McBirney Flo-Mate® portable velocity meter. Our measurements followed the two-point, six-tenths, and three-point methods, as described in the United States Geological Survey Techniques of Water Resources Investigations (Buchanan and Somers 1969). As a general rule, stream widths were divided into enough subsections so that no one subsection contained more than five percent of the overall discharge. Typically, this procedure resulted in 25–30 subsections measured at each stream transect.

Water quality sampling

A total of 36 water quality samples was collected at each stream (12 rain events and 24 normal monthly samples) during February 2004–January 2006. Temperature, dissolved oxygen, and specific conductance were measured in situ at each station. Water grab-samples were collected mid-stream and mid-depth in 2-L Nalgene bottles. Upon collection, bottles were stored on ice in a cooler until arrival at the laboratory for analysis. The following water quality variables were measured in the Auburn University Limnology Laboratory: pH, total alkalinity, total hardness, total phosphorus (TP), total nitrogen (TN), turbidity, and total suspended solids (TSS). Standard analytical methods were followed for all variables, and holding times were well within recommended limits (American Public Health Association 1998).

Fish sampling

Fish assemblages were sampled at all stream sites during the winter of 2005 using a Coffelt Mark-10 portable backpack electrofishing unit powered by a Honda EX350 generator. The backpack shocker consisted of a separate anode connected to a pole held by the operator and a trailing rattail cathode. A maximum of 4 to 5 amps was applied to stun and collect fish. Sampling occurred between November and December, coincident with low stream flow, allowing for more effective sampling (O'Neil et al. 2006). Electrofishing sites were selected based on type and availability of habitat in each stream. Sections containing at least three riffle-pool sequences were preferred. A 100-m section was cordoned off using a 3-m seine with 3-mm mesh prior to electrofishing. Fish were captured, enumerated, identified to species (using Boschung and Mayden 2004 and Mettee et al. 1996), weighed (g), and measured (cm). Areas within the 100-m section that were difficult to access with an electrofishing unit (e.g., undercut banks) were additionally sampled with a 3-m kick seine (3-mm mesh) in order to alleviate bias associated with preferential sampling.

Fish assemblages were compared using traditional structural indices including species richness, species evenness (relative abundance), and Shannon-Wiener diversity index (H'). In addition, a modified index of biotic integrity (IBI) developed by O'Neil et al. (2006) for the Coosa and Tallapoosa Rivers, AL, was used to further discern variations within and among fish assemblages in each stream. The use of IBIs is well documented for detecting changes or status of fish assemblages associated with human disturbances to aquatic ecosystems (Angermeier and Karr 1986, Karr 1981, Karr et al. 1986).

Data analysis

Analysis of variance (ANOVA, PROC GLM; SAS Institute 2002) was used to determine any differences in fish assemblages and water quality (total alkalinity, TSS, TP, and TN) between dominant land-use classifications (forest/silviculture and agriculture). An alpha level of 0.05 was used for these analyses, and least squared means separation was used to examine differences. As no differences were detected among years, water quality data were pooled in all analyses. Additionally, simple linear regression (PROC REG; SAS Institute 2002) was used to determine which water quality and habitat variable(s) were most strongly related to fish assemblages. Fish IBI scores were used as the response variable because they incorporate several biotic metrics into one value. For our candidate set of models, we included all variables (percent land-use composition, discharge, impervious surfaces, stream habitat, and water quality) individually, where correlated variables were not permitted in the same model. To account for the multi-colinearity among predictor variables, water quality (TP, TA, TSS, and TP) and land-use variables (% forested/silviculture, % agriculture, % disturbed, and % urban) were reduced into a smaller set of unrelated variables using principal component analysis (PROC PRINCOMP; SAS Institute 2002). In addition, simple linear regression models (PROC REG; SAS Institute 2002) were used to determine which variables were most strongly related to water quality (TP, TN, and TSS). For our candidate set of models, we included the following variables individually: percent land-use composition, discharge, impervious surfaces, and stream habitat. Akaike's information criterion corrected for small sample size (AICc) was used to rank the model(s), where models were considered plausible if ΔAICc < 2 (Burnham and Anderson 2002).

Results

Mean concentrations of TN, TP, TSS, and total alkalinity were significantly lower ($P < 0.05$) in forested/silviculture-dominated watersheds as compared with watersheds dominated by agricultural land uses (Tables 1 and 2). Among the population of 8 models developed for TP, the top-ranked model (AIC_w =

Table 2. Means ($\bar{x}$), standard errors (SE), and *P*-values resulting from analysis of variance of water quality and fish variables for forest/silviculture ($n = 2$ streams) and agriculture streams ($n = 4$ streams) located in the Upper and Middle Tallapoosa River sub-basins, AL, 2004–2006.

	Forest/silviculture		Agriculture		
Variable	$\bar{x}$	SE	$\bar{x}$	SE	*P*-value
Water quality					
Total phosphorus	0.02	0.00	0.08	0.01	<0.001*
Total nitrogen	0.26	0.02	1.42	0.09	<0.001*
Total suspended solids	5.88	0.85	11.57	1.73	0.024*
Total alkalinity	6.33	0.19	8.11	0.20	<0.001*
Fish					
IBI	44.00	2.00	31.00	2.52	0.031*
Species richness	16.25	0.75	16.33	2.43	0.983
Species evenness	0.75	0.09	0.71	0.07	0.787
Shannon-Wiener	2.03	0.24	1.92	0.22	0.775

*Significant *P*-value.

0.16) was the model containing percent agricultural land use (estimate = 0.04, SE = 0.00; Table 3); however, the model containing percent forested/silviculture land use (estimate = -0.08, *SE* = 0.00) was also considered plausible (ΔAIC_c = 1.40, AIC_w = 0.15; Table 3). Among the population of 8 models developed for TN, the top-ranked model (AIC_w = 0.15) was the model containing percent agricultural land use (estimate = 0.04, SE = 0.00; Table 3). Additionally, from the suite of models tested for TN, the models containing percent forested/silviculture land use (estimate = -0.07, SE = 0.00), percent disturbed land use (estimate = 0.07, SE = 0.00), and percent impervious surfaces within watershed (estimate = 7.63, SE = 0.13) were considered plausible ($\Delta AIC_c < 2.00$; Table 3). Among the population of 8 models developed for TSS, the top-ranked model (AIC_w = 0.15) was the model containing stream habitat scores (estimate = -0.13, SE = 0.65; Table 3); however, the model containing percent

Table 3. Model results for the linear regression models for estimating the influence of habitat variables on water quality for six streams located within the Upper and Middle Tallapoosa River sub-basins, AL, 2004–2006.

Model	# of parameters	ΔAIC_c[A]	AIC_w[B]	R^2
Total phosphorus				
% agriculture land use	2	0.00	0.16	0.884
% forest/silviculture land use	2	1.40	0.15	0.854
% disturbed land use	2	2.25	0.14	0.832
% impervious surfaces	2	4.91	0.13	0.738
Stream discharge	2	6.38	0.12	0.666
Intercept[C]	1	7.95	0.11	-
Stream habitat scores	2	10.35	0.10	0.352
% urban land use	2	11.50	0.09	0.212
Total nitrogen				
% agriculture land use	2	0.00	0.15	0.832
% forest/silviculture land use	2	0.77	0.14	0.808
% impervious surfaces	2	1.32	0.14	0.790
% disturbed land use	2	1.62	0.14	0.780
Stream discharge	2	3.82	0.12	0.682
Intercept[C]	1	5.69	0.11	-
Stream habitat scores	2	7.92	0.10	0.369
% urban land use	2	9.39	0.09	0.195
Total suspended solids				
Stream habitat scores	2	0.00	0.15	0.800
% forest/silviculture land use	2	0.09	0.15	0.797
% agriculture land use	2	2.45	0.14	0.699
Intercept[C]	1	4.65	0.12	-
% disturbed land use	2	5.10	0.12	0.532
% impervious surfaces	2	6.93	0.11	0.365
Stream discharge	2	7.64	0.10	0.285
% urban land use	2	7.67	0.10	0.281

[A] Difference between model's Akaike's information criterion corrected for small sample size and the lowest AIC_c value.

[B] AIC_c relative weight attributed to model.

[C] Model with no effects added.

Table 4. Relative abundance of fish species collected from six streams located within the Upper and Middle Tallapoosa River sub-basins, AL, 2004–2006.

Species	Birdsong	Jones	Prairie	Branch	Rice Branch	Grants Pine Hill
Ichthyomyzon gagei Hubbs and Trautman (Southern Brook Lamprey)	6.3	.	.	.	.	.
Campostoma oligolepis Hubbs and Greene (Largescale Stoneroller)	3.1	4.0	6.2	16.9	17.6	61.3
Cyprinella gibbsi Howell and Williams (Tallapoosa Shiner)	32.8	54.9	11.3	6.9	0.5	.
Cyprinella venusta Girard (Blacktail Shiner)	.	3.5	.	1.3	1.0	.
Hybopsis lineapunctata Clemmer and Suttkus (Lined Chub)	8.9	2.5	.	.	.	.
Luxilus chrysocephalus Rafinesque (Striped Shiner)	2.6	9.1	.	.	.	.
Luxilus zonistius Jordan (Bandfin Shiner)	.	.	16.5	3.1	0.5	.
Nocomis leptocephalus Girard (Bluehead Chub)	8.9	6.1	7.2	5.0	2.0	2.7
Notropis baileyi Suttkus and Raney (Rough Shiner)	14.6	.	.	.	0.5	.
Notropis texanus Girard (Weed Shiner)	.	.	.	.	3.0	.
Semotilus atromaculatus Mitchill (Common Creek Chub)	.	2.52	9.3	6.3	0.5	19.6
Hypentelium etowanum Jordan (Alabama Hog Sucker)	4.2	2.5	24.7	3.1	1.5	4.6
Ameiurus natalis Lesueur (Yellow Bullhead)	.	.	.	.	.	0.2
Noturus funebris Gilbert and Swain (Black Madtom)	1.0	1.3	.	0.6	.	0.7
Fundulus bifax Cashner and Rogers (Stippled Studfish)	0.5	.	.	.	.	.
Fundulus olivaceus Storer (Blackspotted Topminnow)	.	.	.	1.3	4.5	.
Ambloplites ariommus Viosca (Shadow Bass)	.	.	.	.	.	0.2
Lepomis auritus L. (Redbreast Sunfish)	2.6	.	4.1	0.6	2.0	.
Lepomis cyanellus Rafinesque (Green Sunfish)	.	.	2.1	2.5	3.0	1.1
Lepomis macrochirus Rafinesque (Bluegill)	.	1.0	2.1	0.6	32.2	0.9
Lepomis megalotis Rafinesque (Longear Sunfish)	.	0.1	.	.	.	0.2
Micropterus coosae Hubbs and Bailey (Redeye Bass)	3.1	0.5	.	.	.	.
Micropterus punctulatus Rafinesque (Spotted Bass)	.	.	1.0	.	.	.
Micropterus salmoides Lacepéde (Largemouth Bass)	.	.	.	.	2.5	.
Etheostoma tallapoosae Suttkus and Etnier (Tallapoosa Darter)	3.1	5.0	12.4	14.4	9.1	1.1
Percina kathae Thompson (Mobile Logperch)	.	.	.	.	2.0	.
Percina palmaris Bailey (Bronze Darter)	.	1.5	.	.	1.0	.
Percina smithvanizi Williams and Walsh (Muscadine Darter)	0.5	0.3	2.1	0.6	1.0	.
Cottus bairdii Girard (Mottled Sculpin)	7.8	5.3	1.0	36.9	15.6	7.3

forested/silviculture land use (estimate = -0.32, SE = 0.08) was also considered plausible ($\Delta AIC_c = 0.08$, $AIC_w = 0.15$; Table 3).

A total of 1484 fish representing 30 species was collected (see Table 4 for summary of species collected by stream and Table 5 for summary of metrics [i.e., IBI, species richness, species evenness, and Shannon-Wiener diversity index] by stream). IBI scores for forested/silviculture streams were significantly higher than those for agricultural streams ($F_{1,5} = 10.73$, $P = 0.031$; Fig. 2, Table 2). Species richness, evenness, and Shannon-Wiener diversity index were similar among forested/silviculture and agricultural streams ($P > 0.05$; Table 2). The first principal component was retained for both water quality and land use, explaining > 81% of the variation. TP, TN, and TSS highly loaded on the first water-quality principal component (eigenvector > 0.52 for all three variables), while % forested/silviculture, % agriculture, and % disturbed highly loaded on the first land-use principal component (eigenvector > 0.52 for all three variables). Among the population of 23 models for fish IBI scores, the top-ranked model ($AIC_w = 0.10$) was the model containing the first principal component of water quality variables (estimate = -2.51, SE = 0.45; Table 6). From the suite of models tested, the models containing TP (estimate = -7.76, SE = 0.86), TN (estimate = -8.94, SE = 1.67), percent forested/silviculture land use (estimate = 0.69, *SE* = 0.38), TSS (estimate = -1.92, SE = 0.13), principal component of land use (estimate = 0.32, *SE* = 0.07), and percent agricultural land use (estimate = -0.34, SE = 0.76) were also considered plausible ($\Delta AIC_c < 2$; Table 6).

Discussion

Numerous studies have documented declines in water quality, habitat, and biological assemblages as the extent of agricultural land increases within a watershed (Delong and Brusven 1998, Richards et al. 1996, Roth et al. 1996, Sponseller et al. 2001). Among sampled watersheds, we found that streams with a high percentage of agricultural land use consistently yielded lower IBI scores for fish assemblages than forested/silviculture-dominated streams. These lower scores were attributable to having fewer lithophilic spawners, fewer invertivores, a greater percentage of omnivores, and a higher diversity of tolerant species. A decline in lithophilic spawners is typical in streams affected by siltation as

Table 5. Fish metrics (IBI, species evenness, species richness, Shannon-Weiner diversity index, and total number of fish collected) for six streams sampled within the Upper and Middle Tallapoosa River sub-basins, AL, 2004–2006.

Stream	IBI	Species evenness	Species richness	Shannon-Wiener	Total individual
Birdsong	46	0.83	17	2.26	192
Jones	42	0.66	16	1.79	397
Prairie	32	0.86	14	2.20	97
Rice Branch	32	0.74	19	2.00	160
Grants Branch	36	0.74	22	2.19	199
Pine Hill	24	0.51	12	1.27	439

increased sediment from the watershed smothers necessary reproductive habitat (e.g., cobble, gravel) leading to a reduction in habitat complexity (Allan et al. 1997, Walser and Bart 1999). The lack of invertivore diversity, and associated increase in omnivory, are also consistent with substrate depreciation, as benthic foragers are replaced by more generalized feeders. Similarly, our results showed that total suspended solids were nearly twice as high, on average, in the agricultural streams compared to the forested/silviculture streams.

With the decrease in stone substrate associated with increased siltation, fish diversity could also be influenced by the invasion of cosmopolitan species (i.e., fishes in the Family Centrarchidae). This trend is consistent with the higher percentage of omnivores collected in the agriculture streams relative to species composition of the reference stream (Birdsong Creek), where fish species composition consisted mostly of invertivores and carnivores. Additionally, because

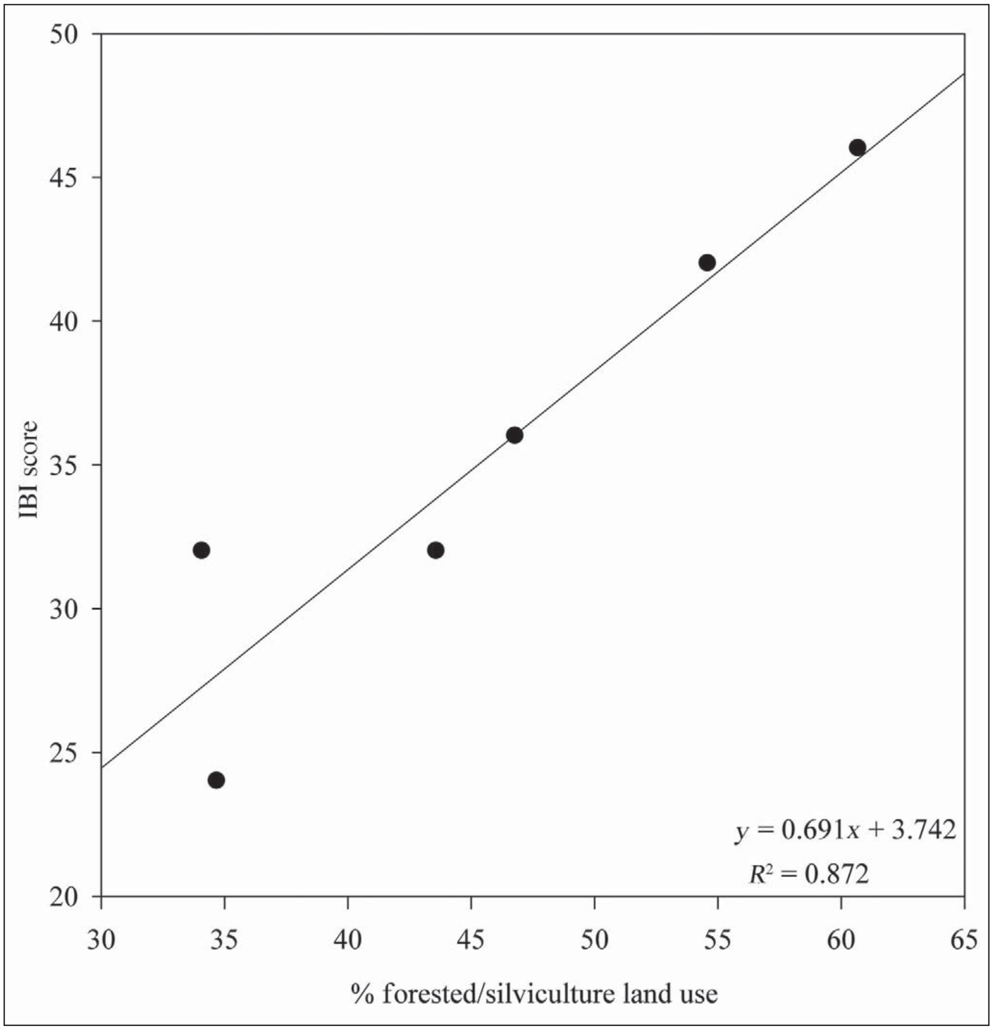

Figure 2. Index of Biotic Integrity (IBI) score for fish by percentage of forested land cover within each stream's watershed contained by the Upper and Middle Tallapoosa River sub-basins, AL, 2004–2006.

of significantly higher nutrient levels in the agriculture streams, eutrophication may be contributing to the colonization of more cosmopolitan species and the reduction in IBI scores for these streams.

TN and TP concentrations were also appreciably higher in the agricultural streams than in the forested/silviculture systems, and were strongly related to fish IBI scores. This finding may have been attributable to increased periphyton biomass often associated with high levels of nitrogen and phosphorus. Periphyton biomass was not examined during this study, but may offer a link between increased nutrients (nitrogen and phosphorus) and lower IBI scores, particularly with respect to feeding guilds. Whether from animal manure or fertilizer applications, agricultural watersheds are typified by having increased inputs of nutrients (Allan 2004). In our study, nutrient inputs to agricultural watersheds were primarily from grazing livestock (manure) and poultry houses (litter spread on pastureland). The high levels of TN, TP, and TSS documented in agricultural streams may also be attributed to the lack of adequate riparian cover, which allows for increased runoff to enter unimpeded and unassimilated.

Table 6. Linear regression models for water quality and habitat variables predicting fish IBI scores from six streams located within the Upper and Middle Tallapoosa River sub-basins, AL, 2004–2006.

Model	# of parameters	ΔAIC_c[A]	AIC_w[B]	R^2
Water quality PC1[C]	2	0.00	0.10	0.888
Total phosphorus	2	0.02	0.10	0.888
Total nitrogen	2	0.53	0.06	0.878
% forest/silviculture land use	2	0.83	0.06	0.871
Total suspended solids	2	1.00	0.06	0.868
Land use PC1	2	1.58	0.06	0.854
% agriculture land use	2	1.75	0.06	0.850
% disturbed land use	2	4.43	0.05	0.765
Water quality PC1 + % impervious surfaces	3	5.34	0.05	0.948
% impervious surfaces	2	5.58	0.05	0.646
Stream habitat scores	2	7.86	0.04	0.585
Water quality PC1 + stream discharge	3	7.93	0.04	0.921
Land use PC1 + % impervious surfaces	3	7.97	0.04	0.920
Intercept[D]	1	8.14	0.04	-
Land use PC1 + stream habitat scores	3	8.23	0.04	0.917
Total alkalinity	2	8.84	0.04	0.511
Stream discharge	2	10.08	0.03	0.399
Land use PC1 + stream discharge	3	11.58	0.03	0.854
% urban land use	2	12.18	0.03	0.148
Land use PC1 + % impervious surfaces + stream habitat scores	4	32.25	0.00	0.935
Water quality PC1 + % impervious surfaces + stream discharge	4	34.99	0.00	0.951
Land use PC1 + % impervious surfaces + stream discharge	4	36.71	0.00	0.935
Land use PC1 + stream discharge + stream habitat scores	4	37.65	0.00	0.924

[A] Difference between model's Akaike's information criterion corrected for small sample size and the lowest AIC_c value.

[B] AIC_c relative weight attributed to model.

[C] PC1 = first principal component

[D] Model with no effects added.

Within the six streams/watersheds that we sampled, increases in nutrients measured (TP and TN), sedimentation (TSS), and percentage of agricultural land were associated with decreases in fish biotic integrity. Many studies have shown similar results, but few have looked at a watershed with as diverse a biotic community as the Tallapoosa River Basin. In order to reduce anthropogenic influences on streams, it is necessary to decrease sedimentation and nutrient loading from urban and agriculture land uses. There exist a myriad of best management practices (BMPs) aimed at reducing such pollutants. Generally silviculture operations are under more pressure, both legally and publicly, to incorporate BMPs than are small to medium-sized farms, though there are many government incentive programs that exist to aid farmers in managing their land more responsibly. One example of an effective BMP is the creation of forested riparian buffer zones (or streamside management zones). We observed that these zones were intact in the forested/silviculture watersheds and degraded or absent in the agricultural watersheds, where cattle had access to riparian areas. Un-impacted riparian vegetation reduces the amount of nitrogen, phosphorus, and sediment that reaches the stream. At a larger scale (Tallapoosa River Basin), anthropogenic impacts from agricultural lands that lack proper BMPs may be manifested as eutrophication of downstream reservoirs. Decreasing the amount of manure fertilizer, pesticides, and grazing that occurs in proximity to streams (especially on pasturelands with significant slopes) and preserving stream riparian zones should improve biotic integrity in agricultural streams, which will translate to less nutrient impacts in the Lower Tallapoosa sub-basin.

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