



Assessing Impacts Due to Small Impoundments in North Carolina

North Carolina Department of the Environment and Natural Resources

Division of Water Quality

INTRODUCTION

North Carolina (NC) currently has difficulty fully assessing the effects on water quality when considering 401 Certification applications for small impoundments (surface area of 10-100 acres) of headwater streams. Results from a Tennessee study (Arnwine 2006) and from existing NC lake and impoundment monitoring programs suggested that this type of authorized activity can have negative effects on water quality and aquatic life uses in impounded streams. However, available data from small headwater impoundments specifically in NC were sparse.

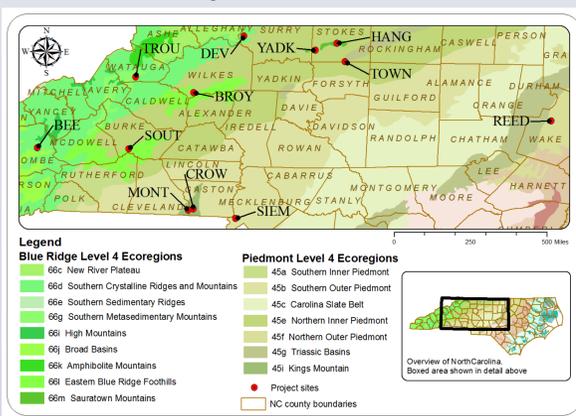
The study design was based on monitoring upstream, within, and downstream of small headwater impoundments in the Blue Ridge and Piedmont ecoregions within NC. Assessments included water chemistry, water temperature data loggers, benthic macroinvertebrate community, periphyton biomass, and instream habitat. The NC Trophic State Index (NCTSI) was calculated for impoundments. Biotic index scores were calculated from the benthic macroinvertebrate data.

OBJECTIVES

This project was intended to address a variety of these concerns resulting from impounding free-flowing waters to create small artificial reservoirs, and to determine if these impoundments are likely to cause issues with respect to complying with existing water quality standards, including the state administrative code's narrative anti-degradation standard (15A NCAC 02B .0201, Antidegradation Policy), and to gain a better understanding of the combined effects of nutrient regimes, temperature changes, dissolved oxygen levels, and habitat impacts on instream communities. Secondly, results are being compared to existing research to determine if results from these studies may be considered applicable to NC waters.

FIELD SITES

Twelve sites were identified for sampling in the Piedmont and Blue Ridge ecoregions. Four monitoring stations were established at each site: an upstream reference (station A), upper impoundment (station B), lower impoundment (station C), and downstream below the dam (station D). Station A served as a background reference station to which other downstream sites were compared.



Project ecoregion	Site Code	Site Name	Year Built	Drainage area at dam (mi ²)	Surface Area (ac.)	Dam release Type
Blue Ridge	BEE	Bee Tree Reservoir	1927	7.61	41	Top
	BROY	Lake Broyhill	2000	3.97	135	Top + bottom
	DEV	Devotion	1936	2.34	54	Top
	HANG	Hanging Rock	1938	0.73	12	Top
	SOUT	South Mountain State Park	1950	2.44	13	Top
	TROU	Trout Lake	1971	0.74	14	Top
Piedmont	CROW	Crowders Mountain State Park	1961	0.87	12	Bottom
	MONT	Lake Montonia	1933	1.01	26	Top + bottom
	REED	Reedy Creek Lake	1955	4.42	20	Top
	SIEM	Siemens	1965	0.36	12	Top
	TOWN	Town Fork Creek	1981	3.77	27	Top
	YADK	Little Yadkin River	1977	4.67	49	Top

METHODS

Water chemistry and chlorophyll-a: (3x/site during growing season 2011): Dissolved oxygen (DO), water temperature, pH, and specific conductance were taken *in situ* at all stations (surface readings only at stream stations A and D; vertical profiles at impoundment B and C). Secchi depth was also collected within impoundments (B, C). Samples for total Kjeldahl nitrogen (TKN), nitrite + nitrate (NOx), total phosphorus (TP), chlorophyll-a, and total suspended solids (TSS) were collected and analyzed by the NC DWQ Chemistry Laboratory. Results were used to calculate the NC Trophic State Index (NCTSI) for impoundment stations B and C.

Water temperature data loggers (every 15 min., May 2011-May 2012): Continuous data loggers were deployed at A, C, and D.

Benthic macroinvertebrates (once/station, growing season 2011): Known areas of substrate were sampled using a Surber or Ponar at A, B, and D. Taxa were identified to the lowest practical taxonomic level and the number of individuals per taxa was normalized as number/m² for analysis.

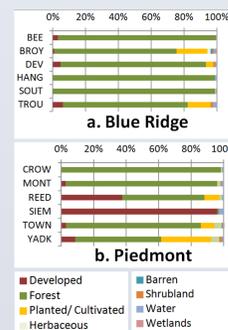
Habitat assessments (once/station, growing season 2011): NC DWQ standard instream habitat assessments completed at A and D at the time of benthic macroinvertebrate sampling.

Periphyton biomass (once/station growing season 2011): Artificial substrates deployed at A, C, and D and retrieved 2-3 weeks later. Periphyton growth removed and analyzed for ash-free biomass.

RESULTS

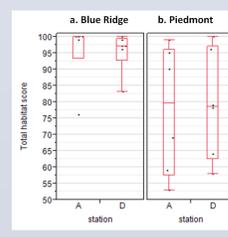
Site land use

Blue Ridge watersheds were predominantly forested with small amounts of planted/cultivated and developed land use in some watersheds. Piedmont watersheds showed a greater variety of land use, including two sites (REED, SIEM) with significant amounts of development. Minimal changes in percent contribution of major land uses between upstream and downstream stations suggest that land use was not responsible for differences in water quality between stations.



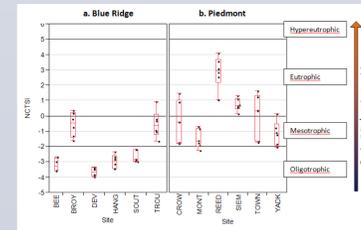
Instream habitat

Differences in upstream and downstream habitat were very variable with no significant overall differences, suggesting that any differences in other parameters (biologic communities, temperature) were not attributable to changes in habitat. Piedmont sites had overall lower ratings than Blue Ridge sites.



NC Trophic State Index

Most Blue Ridge impoundments were rated oligotrophic for each sampling visit based on the NCTSI score. Almost all Piedmont sites were mesotrophic or eutrophic during sampling visits. There was a significant increase in NCTSI between upper and lower impoundment stations in both ecoregions.



RESULTS

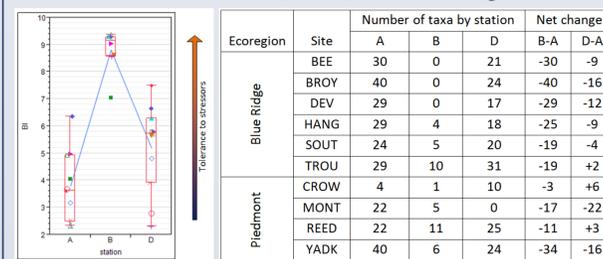
Water chemistry and chlorophyll-a

Matched pairs analysis (Wilcoxon signed rank test) was used to compare results from individual stations at each site and to determine if a significant overall increase or decrease occurred. The figure below shows the stations being compared (A, B, C, and D) and the arrows indicate that a significant change was detected and the direction of that change. Red arrows indicate that the change was in an unfavorable direction, green was in a favorable direction, and black was a neutral change. No arrow indicates no significant change.

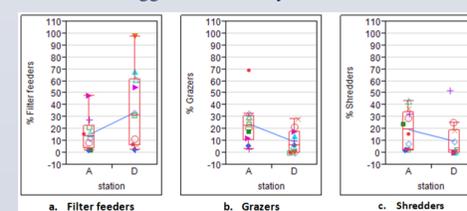
	BLUE RIDGE						PIEDMONT					
	B-A	C-A	C-B	D-A	D-B	D-C	B-A	C-A	C-B	D-A	D-B	D-C
DO % saturation												
DO concentration	↓	↓		↓	↓	↓	↑	↑			↓	↓
pH												
SC												
Temperature	↑	↓		↑	↓	↓	↑	↓	↑	↑	↑	↓
NOx	↓	↓		↑	↑	↑	↓	↓	↓	↓	↓	↓
TKN							↑	↑		↑	↑	
TN	↓	↓		↑	↑	↑				↑	↑	
TP	↓										↑	
TN:TP							↑	↑				
Chlorophyll	↑	↑	↑	↑	↓	↓	↑	↑	↑	↑		

Benthic macroinvertebrate communities

Benthic communities below the dams (station D) exhibited a significant increase in tolerance (indicated by a higher biotic index [BI] score) and number of taxa as compared to upstream (station A). Several samples from within impoundments BEE, BROU, and DEV and at one downstream station (MONT) contained no organisms.



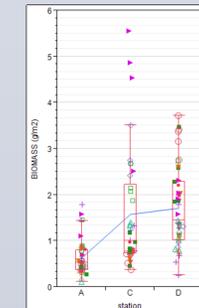
Shifts in functional feeding groups were seen between the upstream and downstream stations. While these were not statistically significant, it does suggest a trend may exist.



Periphyton biomass

Periphyton biomass showed a significant increase below the dam (station D) as compared to upstream/background levels (station A). There was no statistical difference between downstream and the impoundments (station C).

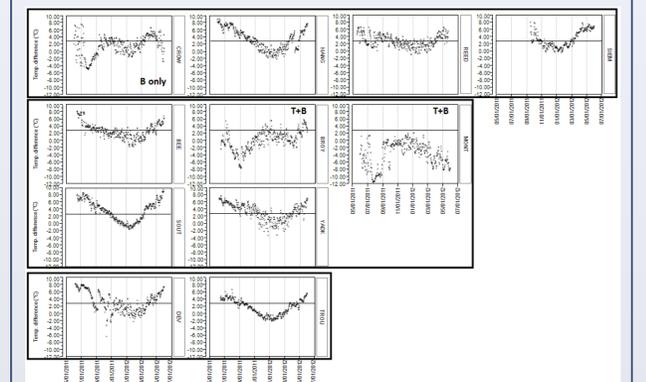
Based on the lack of statistically significant differences in habitat scores, differences in canopy/shading were not responsible for the increase in periphyton growth downstream.



RESULTS

Water temperature

A 2.8°C increase in temperature (based on NC water quality standards) was used as a screening value for comparing downstream (station D) to upstream (station A). Increases in temperature above this value occurred year-round. The bottom (B only) dam release and one combined top/bottom (T+B; BROU) dam release showed exceedences in the winter. The other T+B site (MONT) showed temperatures up to 12°C colder downstream as compared to upstream, which could also have ecological impacts on instream biota.



The NC water quality temperature standards also stipulate maximum allowable water temperatures for surface water, based on the area of the state:

- Lower Piedmont: 32°C
- Mountain/Upper Piedmont: 29°C
- Trout: 20°C

The graphs on the left present daily mean temperature for upstream (blue), impoundment (red), and downstream (green) and the max temperatures (grey lines).

Exceedence of the standard for designated Trout waters was common during the summers within the impoundment and also downstream.

REFERENCE

Arnwine D, Sparks K, James R. 2006. Probabilistic monitoring of streams below small impoundments in Tennessee. Nashville, TN: Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Available from: http://tn.gov/environment/wpc/publications/pdf/isp_report.pdf.

FUNDING

This project was funded through a Wetland Program Development Grant from the U.S. Environmental Protection Agency, Region 4 (Cooperative agreement CD 95471111).

REPORT AVAILABILITY

The full report is available from the NC Division of Water Quality website at <http://ncdenr.gov/web/wq/swp/ws/pdu>.