Water Quality Assessment of Linville River Watershed for Long Term Monitoring of Human Development Impacts

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ABSTRACT

Increasing population growth, development and the impending largescale NC DOT widening project for NC HWY 105 from Boone to Linville, are expected to have negative impacts on the Linville River watershed and downstream in the impounded waters of Lake James. Environmental degradation is a major concern for the lake due to an increase in human activity, residential development, industrial discharge and unprotected banks within the Linville River watershed. Riparian habitat assessment, kick net aquatic benthic macroinvertebrate sampling (to determine family level richness and NC biotic index), water chemistry, and bank erosion assessment were executed at four sites along the Linville River from the headwaters to just upstream of the inflow to Lake James. Water samples were collected from all four sites, plus Lake James itself, for ion chromatography and Inductively Coupled Plasma – Optical Emission Spectroscopy analysis. We found that habitat quality and bank erosion potential were of suitable condition at all four sites. Biotic integrity of each site was reported as “excellent”, and there were no trace elements or anions of concern detected at any sample locations. We have concluded that the current water quality conditions in the Linville River are not of immediate concern.

INTRODUCTION

Decreasing biodiversity and ecosystem health has become a major problem within freshwater ecosystems (Strayer and Dudgeon 2010). Most of these threats to the environment are anthropogenic, due to our constantly increasing and spreading populations (Saunders et al. 2002, Strayer and Dudgeon 2010). There are many factors impacting the environment, but it has been suggested that residential development and increased human activities have the greatest impact on aquatic systems (Strayer and Dudgeon 2010, Merriam et al. 2011). As we increase the amount of impervious surfaces and construction sites, we increase erosion and sedimentation in freshwater streams (Roy et al. 2003). Along with increased sedimentation, residential development has been shown to significantly lower water quality and biotic integrity and can even increase the severity of other environmental threats, such as power plant effluent (Roy et al. 2003, Merriam et al. 2011).

Lake James, located northeast of Marion, NC in Burke and McDowell counties is one of the many freshwater systems possibly affected by anthropogenic activities. This lake, filled by North Fork, Catawba, and Linville Rivers is a popular community recreational area used for a variety of purposes such as fishing, boating, swimming, camping, educational outreach, etc. An organization by the name of Lake James Environmental Association (LJEA) has been preserving the integrity of this lake and its watershed since 1973 by maintaining industrial permit policies, organizing community upkeep events, and working with scientific researchers to ensure water quality standards (LJEA 2015).

The purpose of this following research was to assess habitat and water quality of the Linville River upstream of the impounded waters of Lake James. We tested water chemistry, habitat quality, biotic integrity and trace toxin levels at four sites in the Linville River watershed. This is part of a long-term study conducted by the Lake James Environmental Association (LJEA) which monitors the water quality of Lake James and its tributaries. I hypothesized that negative impacts, such as sedimentation, erosion or trace toxins, would be present at some of the Linville River sites due to increased human activity within the Linville River watershed.

MATERIALS AND METHODS

Site descriptions

Four sites in the Linville River watershed were evaluated in terms of habitat and water quality to determine potential measurable impacts of anthropogenic activity. Water samples were taken from a fifth site; Lake James itself. These sites, following Linville River from the town of Linville down to the northern tip of Lake James, display the variation in environmental disruption and stream characterization.

Site 1, furthest upstream from Lake James, is located off the side of Newland Highway in Avery county, North Carolina (36.07135 N, 81.87590 W) at an elevation of 3,615 feet. Visible land use of the region consists mostly of forest and residential areas. The stream is of varying width averaging around 22 meters, with an average depth of 0.2 meters. Bottom substrate consists of mostly gravel, cobbles and boulders. The stream has frequent riffles and has a riparian zone consisting of mostly mature trees.

Site 2 is White Pine Creek, a small tributary of the Linville River. This site is located at Crossnore of Avery county, North Carolina (36.02172 N, 81.91989 W) with an elevation of 3,374 feet. Visible land use consists of forest, residential areas and active pastures. This site represents a poor-quality stream, due to nutrient runoff from cow pastures and a deteriorating building alongside the creek. This creek is relatively small with a width of 5 meters and an average depth of 0.2 meters. Bottom substrate consists of embedded gravel, cobble and boulders. Bank vegetation is dominated by grasses with sparse mature trees as well.

Site 3 is directly off the side of Highway 221 near the town of Pineola in Avery county, North Carolina (35.99957 N, 81.93827 W). This site on the Linville River, sitting at an elevation of 3,280 feet, is located directly upstream of the Linville Gorge Wilderness Area. Some level of human disturbances can be expected due to the presence of a highway directly uphill of this location. Riparian zone is narrow, consisting solely of grasses and shrubs providing a lack of canopy above this location. The stream has a width of around 14 meters and an average depth of 0.4 meters.

Site 4 is located downstream of the Linville Gorge Wilderness Area, right before the Linville River flows into Lake James. This site is adjacent to a bridge on Highway 126 in Burke County, North Carolina at an elevation of 1,225 feet. This reach of the River was relatively wide, deep and did not contain a high number of riffles. The riparian zone was well developed and consisted mainly of mature trees. The visible land use in this area is described as a mixture of residential and forested. Recreational fishing appeared to be prevalent in this area.

The fifth site is located at Lake James itself. Water samples were taken from the Lake adjacent to the boat launch parking lot.

Field/Lab Methods

All sampling took place on April 8, 2018 in low temperature conditions. All methods were completed according to the LJEA January 2017 Water Quality Site Assessment Procedure. Images were taken of sampling areas beginning with a view of upstream, and then downstream, and then towards the left bank of the river, and finals to the right bank. Detailed information about each individual site were recorded in the Field Evaluation Worksheet. The DWR Habitat Evaluation was used to measure various aspects of habitat quality such as visible land use, stream measurements, flow conditions, channel patterns, instream habitat, bottom substrate, pool and riffle presence and quality, canopy cover, bank stability and vegetation, and riparian zone quality. A Bank Erosion Hazard Index (BEHI) variable worksheet was used to record bank height and max depth bankfull, root depth and bank height, weighted root density, bank angle, and surface protection.

Water chemistry was tested at each site using a YSI Water Quality Multi-Meter. Measurements of dissolved oxygen (mg/l), temperature (° C), conductivity (µS/cm), specific conductivity (µS/cm), pH, chloride and turbidity were recorded. A Global Water meter and tape measure were used to determine discharge at each location.

Macroinvertebrate sampling was conducted at all four sites using a kick-seine in a 1m x 3m reach. A standard of two people kicking per sample was kept. After removing the kick-seine from the water, all four crew members worked to pick out any visible macroinvertebrates using micro-forceps. Picking was performed until macroinvertebrates were no longer detectable. The specimens were preserved immediately in ethyl alcohol and taken back to the lab for identification. All macroinvertebrates were identified to the family level to determine Biotic Index values and ratings using the NC DWQ Macroinvertebrate Biotic Index. Family level richness was also calculated using the macroinvertebrate samples.

A water sample was collected from each study site, including a fifth water sample from Lake James itself, to test water quality. Inductively Coupled Plasma- Optical Emission Spectrophotometry (ICP-OES) was performed to analyze potential toxic elements in the water samples (20 elements). Ion Chromatography (IC) was used to quantify the amount of anions present (Cl, Br, SO_4, NO_3, PO_4). Concentrations were then analyzed to detect any possible abnormalities that may be occurring in the water of our sample sites.

RESULTS

Bank Erosion Hazard Index (BEHI) values were calculated for all four sites: Newland Highway, White Pine Creek, Highway 221, and Highway 126 (see Table 1). The BEHI rating values were reported as 7.3, 14.3, 10.3, and 6.25, respectfully. Newland Highway and Highway 126 had BEHI ratings that fall into the category of “very low” bank erosion potential. White Pine Creek and Highway 221 had BEHI ratings that fall into the category of “low” bank erosion potential. BEHI rating categories are defined as following: very low (5-9.5), low (10-19.5), moderate (20-29.5), high (30-39.5), very high (40-45) and extreme (46-50).

Table 1. Bank Erosion Hazard Index (BEHI) values of four sites in the Linville River watershed.

Site	BEHI Rating
Newland Highway	7.3
White Pine Creek	14.3
Highway 221	10.3
Highway 126	6.25

Water chemistry values were measured and recorded using a YSI Water Quality Multi-Meter at all four sites (see Table 2). Percent of dissolved oxygen values were within a relatively tight range for all four sites. The values ranged from 91% DO (Highway 221), 99% DO (Highway 126), 103% DO (Newland Highway), to 110% DO (White Pine Creek). Water temperatures of all sites were within the range of 9.4 °C- 10.8 °C, except for the Newland Highway site which had the lowest temperature at 4.7°C. Conductivity values were 36 µS/cm at Highway 126, 39 µS/cm at Newland Highway, 40 µS/cm at Highway 221, and 60 µS/cm at White Pine Creek. Specific conductivity values followed the same trend, with Highway 126, Highway 221, and Newland Highway sites having values of 49, 58, and 64 µS/cm; and White Pine Creek having specific conductivity of 85 µS/cm. pH values were 7.16 (Newland Highway), 7.43 (Highway 126), 7.70 (Highway 221), and 8.44 (White Pine Creek). Chloride levels in units of mg/L were detected at 3.8, 4.8, 8.3 and 9.1 for Highway 221, Highway 126, Newland Highway, and White Pine Creek. Turbidity values were recorded as follows: 0.8 (Highway 126), 1.5 (Highway 221), 2 (White Pine Creek), and 3 (Newland Highway). All of this data can be seen in Table 2.

Table 2. Water chemistry values of four sites in the Linville River watershed, taken using a YSI Water Quality Multi-Meter.

Site	Dissolved Oxygen (%)	Temperature (° C)	Conductivity (µS/cm)	Specific Conductivity (µS/cm)	pH	Chloride (mg/l)	Turbidity (NTU)
Newland Highway	103	4.7	39	64	7.16	8.3	3
White Pine Creek	110	9.4	60	85	8.44	9.1	2
Highway 221	91	9.2	40	58	7.70	3.8	1.5
Highway 126	99	10.8	36	49	7.43	4.8	0.8

Family level biotic index calculations, using the NC DWQ Macroinvertebrate BI, resulted in “excellent” BI ratings at all four study sites (see Table 3). The BI values ranged from 3.15 at the Newland Highway site to 3.49 at the White Pine Creek site. Family level richness values were generally very close, with the exception of White Pine Creek. White Pine Creek had a family level richness of 8, Newland Highway site had a value of 14, while Highway 221 and Highway 126 sites had a richness value of 15.

Table 3. Family level biotic index values, ratings, and richness calculated using the NC DWQ Macroinvertebrate BI of four sites in the Linville River watershed.

Site	**Overall BI Value**	**BI Rating**	**Richness (Family Level)**
Newland Highway	3.15	Excellent	14
White Pine Creek	3.49	Excellent	8
Highway 221	3.19	Excellent	15
Highway 126	3.15	Excellent	15

Inductively Coupled Plasma- Optical Emission Spectrophotometry (ICP-OES) tests resulted in the concentrations of fifteen different elements which could have potentially been found at each of the sample sites (see Figure 1). The elements tested for include Aluminum, Arsenic, Barium, Cadmium, Cobalt, Chromium, Copper, Iron, Manganese, Molybdeum, Nickel, Lead, Tin, Selenium, and Strontium. Detectable levels of all elements remained below 0.100 ppm, excluding Lead at the Highway 221 site, and Aluminum and Iron at all five sites. Lead was measured at levels above 0.300 ppm in the water at the Highway 221 site. Aluminum and Iron had the highest values at the Highway 221 site as well, with Aluminum being above 0.700 ppm and Iron being above 0.800 ppm.

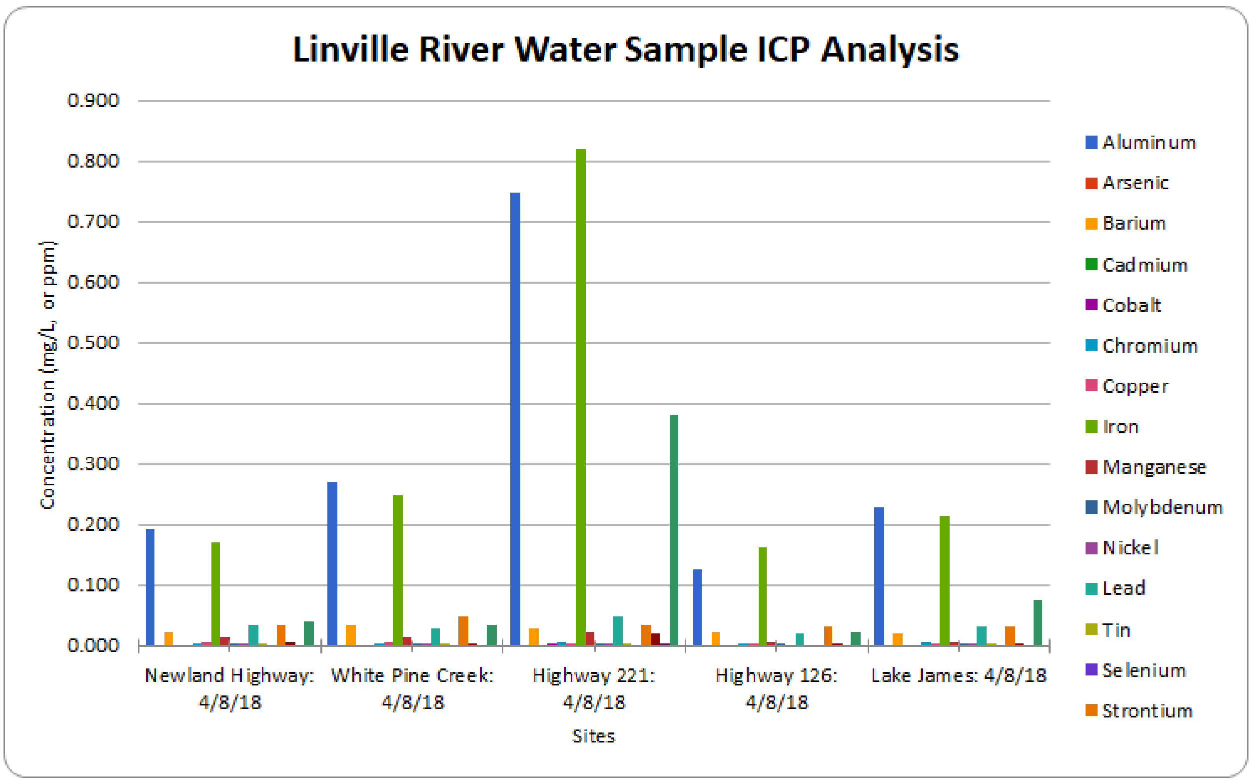

Figure 1. Concentration of elements (mg/L or ppm) detected at five sites in the Linville River Watershed using Inductively Coupled Plasma- Optical Emission Spectrophotometry (ICP-OES).

Ion Chromatography was used to detect levels of anions of concern at all five sample sites (see Table 4). Levels were reported for Chloride, Fluoride, Sulfate, Bromide, Nitrate and Phosphate. Chloride levels were below the NC Water Criteria level at all our sample sites.

Fluoride levels were also below NC Water Criteria standards, with Newland Highway site, White Pine Creek and Lake James having levels below detection. Sulfates were found present at all five of our sample sites. Bromide was below detection levels at all sites except for the Highway 126 site, which had 0.024 ppm. Nitrates were at detectable levels in White Pine Creek, Lake James, and at the Highway 126 site. Phosphate was detected in all five of our sites, excluding White Pine Creek.

Table 4. Ion Chromatography (IC) results of five sites in the Linville River watershed measured in ppm.

Sample Site	**Chloride**	**Fluoride**	**Sulfate**	**Bromide**	**Nitrate**	**Phosphate**
NC Water Criteria	230.00	1.80	(LD)	n.a.	n.a.	n.a.
Newland Highway	13.50	BDL	2.21	BDL	BDL	0.10
White Pine Creek	18.55	BDL	1.79	BDL	3.69	BDL
Highway 221	10.58	0.02	1.85	BDL	BDL	0.10
Highway 126	14.28	1.56	2.39	0.02	0.42	0.13
Lake James	7.19	BDL	3.01	BDL	0.32	0.12

DISCUSSION

Habitat quality was deemed to be of acceptable quality at all four of our sites, although the White Pine Creek site was of much lower quality than the rest of the sites. Visible land use at all sites was mainly a mix of residential and forested areas. While mostly forested land use is great for stream health, presence of residential areas can have a negative impact on freshwater systems(Line et al. 2002). Urbanized areas have high amounts of impervious surfaces which can increase sediment transport into streams by ~25% (Line et al. 2002, Roy et al. 2003). White Pine Creek was located in a region characterized by cow pastures, which are known to cause increases of nutrient flows into streams(Line et al. 2002). Along with this, the White Pine Creek site had a deteriorating abandoned building on its banks, indicating that no upkeep whatsoever is provided at this site.

Flow conditions, channel patterns, stream measurements, pool and riffle presence and quality and canopy cover were recorded to be on little concern at all sites. Bottom substrate was mostly gravel, cobble and boulders at all sites, but was poorly embedded at the White Pine Creek location. Bottom substrate type is important because different sediment sizes have varying abilities to accumulate detritus and nutrients (Parker 1989, Roy et al. 2003). Dominant substrate of gravel, cobble and boulders indicate healthy conditions for macroinvertebrates(Parker 1989). Riparian zone extent and quality varied between all of the sites. The Newland Highway site and the Highway 126 site had relatively wide riparian zones composed of mostly mature trees. The stream location along Highway 221 had a very narrow riparian zone consisting of mostly grasses, due to the fact that it was directly adjacent to the Highway. The White Pine Creek site had a very thin riparian zone consisting of mostly grasses and shrubs, with a few mature trees present.

Bank Erosion Hazard Index (BEHI) values were all categorized as having “low” or “very low” erosion potential. The site which was categorized as “low” was the White Pine Creek site, which had a large amount of root mass exposed, and numerous undercut banks. The rest of the sites had wide buffer zones and were well protected from erosion due to their very low bank angles, and low bankfull heights(Florsheim et al. 2008). Low bank angles, low bankfull heights, and healthy riparian vegetation are all indicators of healthy stream systems, preventing flood waters from overflowing and further eroding undercut banks (Florsheim et al. 2008). Measuring erosion potential is very critical for determining water quality because it leads to sedimentation which reduces habitat or makes it unsuitable for use (Roy et al. 2003). Habitat is reduced for aquatic macroinvertebrates when small sediments settle in between larger sediments, reducing feeding and living space (Roy et al. 2003).

Water chemistry measurements were not of great concern at our sites but did have some values that stood out. For example, the temperature at the Newland Highway site was much lower than the other sites. This may seem abnormal, but we sampled this site early in the morning before temperatures had time to rise. Specific conductivity as well as conductivity both had relatively high values at the White Pine Creek site. One possible explanation for these increased levels could be urban development, which is known to increase specific conductivity levels (Merriam et al. 2011).

Biotic index values were categorized with an “excellent” rating at all four sites. Family level richness was lowest at the White Pine Creek site, which is not surprising because this site had the lowest overall counts of macroinvertebrates. Increases in sedimentation caused by erosion along with changes in water chemistry are both shown to have negative impacts on biotic integrity (Parker 1989, Roy et al. 2003, Merriam et al. 2011). White Pine Creek was the only site that showed significant signs of erosion, which suggests that sedimentation may be at play in determining family level richness (Parker 1989). Differences in family level richness may also be impacted by residential development, which can cause significant decreases in sensitive taxa but also cause proliferation of more tolerant taxa(Merriam et al. 2011).

Inductively Coupled Plasma- Optical Emission Spectrophotometry (ICP-OES) results showed very low concentrations of all target elements, except for lead, aluminum and iron.

Aluminum and iron levels far exceed levels of any other element in all our sites. However, these elements are not of concern for water quality parameters. These concentrations of aluminum and iron can be considered as background levels for the region, due to the geological composition of the region. The high lead levels at the site along Highway 221 do spark concern for negative impacts on water quality, although they are not considered to be dangerously high. Levels are most likely elevated in the water at this site because the Linville River runs directly adjacent to the Highway for this stretch. Ion Chromatography (IC) results indicate that levels of potentially toxins are not of concern at any of our sample sites.

Overall, the water quality of sampled sites within the Linville River watershed do not indicate immediate risk for impounded water downstream at Lake James. The majority of our sample sites showed healthy habitat parameters, water chemistry, and biotic integrity. Only one site, White Pine Creek, showed evidence of erosion, low macroinvertebrate richness, and irregular water chemistry measurements.

In the future, it will be important to continue frequent monitoring of water quality in all tributaries of Lake James. Identifying new potential sources of toxins is critical to the health of our streams because the residential development that is occurring has the ability to worsen the effects of any future environmental disturbances(Merriam et al. 2011). Human activity will continue contributing to environmental degradation unless the correct management tactics are used(Strayer and Dudgeon 2010, Merriam et al. 2011). The records of habitat and water quality data from years of monitoring will be important for contributing to environmental policy making and management strategies(Merriam et al. 2011).

Useful additions to this research include looking at fish community composition, sampling of additional sites, and increasing the taxonomic level of identification used for calculating BI. Although family level analysis has proven to be efficient, genus and species level identification can show more subtle changes in biotic integrity (Jonathan 2005, Chessman et al. 2007). Research also stresses the importance of analyzing vegetation, substrate, geological information, water chemistry, and potential point sources in relation to biotic integrity, to get a broader view of ecosystem processes (Resh and Unzicker 1975, Strayer and Dudgeon 2010).

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