National Park Service
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Division of Fire and Resource Management

Assessment of *Escherichia coli* Concentrations in the Surface Waters of Buffalo National River

2009 to 2012

Buffalo National River Report NPS/B-0100/2013

ON THIS PAGE
Mitch Hill Spring near Mt. Hersey, water quality meter in aperture of spring.
Photograph by: Faron Usrey

ON THE COVER
Beech Creek, Upper Boxley Valley
Photograph by: Faron Usrey

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Abstract

Buffalo National River has conducted a water quality monitoring program for nearly twenty five years and bacteria monitoring has been a major component of that program. In 2009 the monitoring program added *Escherichia coli* as a parameter to supplement the fecal coliform sampling already being conducted. *Escherichia coli* has been found to be a much better indicator of possible human pathogens in surface waters, and quantification and enumeration methods for *Escherichia coli* are much more efficient and accurate. Quarterly sampling was conducted from 2009 through 2012, and 456 samples from base-flow conditions were collected and analyzed for *Escherichia coli* concentrations. Geometric means based upon the quarterly sampling and pooled through the years were not observed to be above the state water quality standards. However fifteen samples, one river site, eleven tributaries, and one spring, exceeded the single sample maximum of 298 colonies/100ml. Maximum risk for human water based recreation was defined and based upon the state standard for *Escherichia coli* concentrations. Base-flow conditions for *Escherichia coli* concentrations were generally well below the maximum risk concentrations for river sites, but tributaries did pose a higher risk for contracting a water-borne illness during recreational activities. Springs were similar to river sites for *Escherichia coli* concentrations and were low risk for recreational uses; however, observations of public use at spring sites were for direct water consumption which poses a much greater risk of contracting water-borne pathogens.

Acknowledgments

The creation of this report would have been difficult without the continued support of the staff of Buffalo National River, especially support from Charles Bitting (Geologist), Shawn W. Hodges (Fisheries Biologist), and Barbara Wilson (former Chief of Fire and Resource Management). Also contributing to the many field collections was Shelley Baird (now Hydrologic Technician with U. S. Geological Survey, Jared James (Administrative Assistant, Buffalo National River), and Raymond Benjamin (Biological Technician, Buffalo National River). I also want to thank the reviewers of this report for their assistance and insight; Kurt Kestleloot, Pete Penoyer, and Gary Rosenlieb of the NPS.

Also, acknowledgements should also be made to those professionals that had the foresight and initiative to create the Water Quality Monitoring Program at Buffalo National River in the early 1980's; David N. Mott (Hydrologist, 1992 through 2003), Donnie Weeks (Hydrologist, 1988 through 1990), and Steve Chaney (Resource Management Specialist, 1985 through 1989).

Introduction

Buffalo National River (BNR) was established by the 92nd Congress in 1972 by Public Law 92-237 which states the park was created "*for the purposes of conserving and interpreting an area containing unique scenic and scientific features, and preserving a free-flowing stream an important segment of the Buffalo River in Arkansas for the benefit and enjoyment of the present and further generations…"*. The enjoyment of the river by the visiting public takes in a wide array of uses such as canoeing, wade fishing, and swimming. These uses are the major sources of enjoyment that the river provides to the visiting public. An important service that BNR provides to the public during water based recreation is to maintain a safe environment as practical. Ensuring that the surface water of the river system is of high quality is a major priority of the park.

Since 2009, BNR has documented several tributaries that have been contaminated by animal wastes, and upon one in particular (Mill Creek T04) water quality advisories were issued for the protection of the public, the first water quality advisory in the history of the park. Within this same time period, BNR also added *Escherichia coli* (*E. coli*) sampling to the water quality monitoring program as *E. coli* was recommended by United States Environmental Protection Agency (EPA) as a better indicator of warm-blooded animals (including human) fecal contamination than the previously used fecal coliform. Human fecal contamination in recreational water is associated with an increased risk of contracting gastrointestinal illness in humans, and less often, is identified with respiratory illness. As such, fecal contamination and its indicators are considered as pathogen indicators for human health risk assessment (EPA 2012). Therefore, sufficient data exist at this time to assess the risk to health and human safety for water based recreation in the waters of BNR, as related to animal waste pollution using *E. coli* concentrations in surface waters of BNR.

This report is an environmental review of the *E. coli* data collected from all water quality monitoring sites from 2009 through 2012. The focus of this report is to examine concentrations of *E. coli* found in the surface waters of BNR as related to human health and safety standards set in recreational waters by Arkansas Pollution Control and Ecology Commission (APCEC Regulation Number 2).

Background

In 1988 the Buffalo River was placed under special protection designation by the Arkansas Department of Environmental Quality (ADEQ) as an Outstanding National Resource Water (ONRW), with the extraordinary recreation and aesthetic values, the highest ranking of stream quality by the State. ADEQ applies specific standards to the Buffalo River under the ONRW designation, which exceed those standards applied to undesignated waters. These steps were necessary to comply with the Extraordinary Resource Waters (ERW) designation which requires no degradation of existing water quality. Despite these measures, the lower portions of the Buffalo River have been placed on the State's List of Impaired Waterbodies (303(d) List) for high water temperatures and dissolved oxygen (ADEQ 2008). None of the river sites or tributaries was listed because of high bacteria concentrations.

In the 1980s BNR began to document the high quality of the surface waters of the park in order to create a baseline of conditions to measure any future departures (Thorton and Nix 1985, Chaney 1986, Weeks 1987, Mott and Apel 1988, and Fraser 1988). In 1985 the park established the beginnings of a formal monitoring program (Chaney 1985) that established most of the sites used within this study, and most all sites have been consistently sampled quarterly since 1990. From the beginning of the monitoring, health and human safety has played a role in the selection of water quality parameters, and fecal coliform concentrations have been monitored continuously throughout the program. In recent years, guidance from the EPA has suggested that the utilization of *E. coli* was more effective in monitoring surface waters from a human health perspective than was fecal coliform. So, in 2009 the park began to make the transition from fecal coliform to that of *E. coli* for monitoring purpose, and as of now, the park collects both fecal coliform and *E. coli*.

E. coli is a commonly used indicator of fecal contamination of fresh water (EPA 1986 and 2012) because it constitutes greater that 90 percent of the bacteria found in human and animal excrement. These bacteria can become pathogenic to humans when they contact tissues outside the intestinal tract, particularly the urinary and biliary tracts, lungs, peritoneum, and meninges. *E. coli* is recommended over other indicators such as fecal coliforms and e*nterococci* because they exhibit less correlation to illness associated with swimming. Other microbial pathogens such as the protozoa cryptosporidium and *Giardia lamblia* are also sources of water-borne illness. These protozoa do not function well as monitoring devices for detection of point and non-point sources of pollution because they are difficult and expensive to process in field and laboratory settings and their detection times are too long for timely public notification process. However, many of these other pathogens are understood to be present in association with *E. coli*, and *E. coli* can generally be used to effectively represent the risk that these other pathogens may be present in water.

The Arkansas Pollution Control and Ecology Commission (APCEC) is tasked with setting the water quality standards for the State of Arkansas, while Arkansas Department of Environmental Quality (ADEQ) administers and enforces those regulations. Water quality regulations are outlined in Regulation Number 2 (2007). Within this regulation, Section 2.507 assigns "*the Arkansas Department of Health with the responsibility of approving or disapproving surface waters for public water supply and for approving or disapproving the suitability of specifically delineated outdoor bathing places for body-contact recreation, and as such has issued rules and regulations pertaining to such uses*". Section 2.507 of Arkansas Regulation 2 states that "*all streams with watersheds less than 10 square miles shall not be designated for primary contact unless and until site verification indicates that such use is attainable*". Within the Primary Contact Waters period, between May 1 and September 30, the maximum allowable *E. coli* criteria or level is calculated either as a geometric mean (no less than 5 samples within 30 days) of **126 colonies per 100ml or a single-sample maximum of 298 colonies per 100ml** in lakes, reservoirs, ERWs, and Natural and Scenic Waterbodies (NSW). Additionally the regulation states that "*During the calendar year, these criteria may be exceeded, but at no time shall these counts exceed the level necessary to support secondary contact recreation.*" Secondary Contact

Waters criteria states that the maximum allowable *E. coli* as a geometric mean of 630 colonies per 100ml and a single-sample maximum of 1490 colonies per 100ml. Regulation 2.203 further describes Outstanding Resource Waters (ORW) as "*high-quality waters which constitute an outstanding state or national resource, such as those waters designated as extraordinary resource waters, ecologically sensitive or natural and scenic waterways, those uses and water quality for which the outstanding waterbody was designated shall be protected by 1) water quality controls, 2) maintenance of natural flow regime, 3) protection of instream habitat, and 4) encouragement of land manage practices protection of the waters.*" The Buffalo River is listed as an ERW and as an ORW.

Recreational uses have traditionally been divided by the United States Environmental Protection Agency (EPA) into two levels of exposure for humans; primary contact and secondary contact. The primary contact classification seeks to protect people from illness during recreational activities where there is a potential for ingestion of water. Primary contact recreation typically includes swimming, water-skiing, skin-diving, surfing, and other activities where immersion is likely to occur. The secondary contact classification is protective during recreational activities when immersion is unlikely. Examples are boating, canoeing, kayaking, fishing, wading, etc. (EPA 2012).

The EPA's 1986 numeric criteria recommendations for *E. coli* concentrations in recreational waters corresponded to a level of water quality that is associated with an estimated illness rate expressed in terms of the number of highly credible gastrointestinal illnesses (HCGI) per 1,000 primary contacts of people recreating in polluted waters. In the 1986 criteria, the numerical criteria (value) recommended as a standard was a geometric mean of 126 colony forming units (cfu) per 100ml of surface water with a minimum of 5 samples over a 30-day period. This concentration equated to 36 illnesses per 1,000 people recreating in polluted waters, or 3.6% of the people in direct recreational contact with waters at this threshold concentration may become ill. ADPCE adopted this approach in Regulation 2, Section 2.507. Further review and research of that criteria recommendation by the National Epidemiological and Environmental Assessment of Recreational Water (NEEAR) group recommended that further work by the states is needed to minimize risk of susceptible groups. The numerical standard could be reduced to a geometric mean of 100 cfu per 100ml, which would reduce the percentage of people potential affected down to 3.2 percent (EPA, 2012). Within the scope of this study, we adopt the 1986 criteria as the minimal risk allowable in recreational waters of BNR in order to set a standard for discussion of managing the risk associated with water pollution from animal wastes. This criterion is the same as used by the State of Arkansas and directly relates to the water quality criteria for *E. coli*.

Methods

Water quality monitoring sites used in this report were sites originally selected in 1985 for long-term monitoring (Table 1, Figure 1), with a couple of original sites being dropped because of redundancies and a perceived duplication of effort. Water quality monitoring sites were selected based upon stream nodes, time of assimilation of pollutants into the river's ecology, river use patterns, and site access. Site locations were developed in cooperation with hydrologists from the NPS's Water Resources Division and researchers from Ouachita Baptist University (Thorton and Nix, 1985). Sites listed herein have been consistently sampled for fecal coliform since 1990, and for *E. coli*, since 2009.

Sampling was conducted quarterly at all sites during the period of study; therefore, sample size and effort should be near equal. Sites not having all samples collected were due to base-flow conditions not being present at time of sampling, dry channels, or accidental sample loss. All samples used in analysis were from base-flow conditions (normal seasonal flows) or the lower end of a falling hydrograph (near the end of a flood). All rising hydrograph conditions (flooding) were eliminated from analysis due to the higher concentrations of water pollution during those hydrologic events and the less likelihood of recreational contact by the general public.

E. coli sample collections and all physicochemical measurements follow the guidelines found in *Standard Methods for the Examination of Water and Wastewater* (2005) for surface water collection in streams and rivers. *E. coli* samples are collected in the center flow of the stream using collection bottles from the IDEXX Colilert-18 system (http://www.idexx.com). Samples are taken just below the surface of the river by holding the bottle near its base with a gloved hand and plunging it, neck downward, below the surface. Turning the bottle until neck points slightly upward and mouth is directed toward the current. Once sufficiently filled to 100-ml, the bottles are tightly capped. Samples were marked with site ID, date, and time of arrival at the sampling site. Bacteria samples were placed on ice (below 10^{o}C) and transported to the lab for processing within a maximum 6-hour holding time. Sample processing strictly follows the IDEXX Coliert-18 methodology in its entirety, using only provided equipment and supplies. The IDEXX Coliert-18 method is EPA approved and is widely accepted as a reliable *E. coli* enumeration procedure for the 0157:H7 strain. The IDEXX system produces an estimate of the number of colonies present per 100ml by using a probability index. IDEXX results are reported as most probable number of colony forming units (cfu) and are directly equated to the number of colonies present in the sample. More details on procedures can be found on the IDEXX website listed above. See Appendix A for general IDEXX procedures.

Discharge was measured using the mid-sector method at all tributary and spring locations by park staff. Discharge on all river sites were estimated using the U. S. Geological Survey's (USGS) National Water Information System. On tributaries and springs, discharge was measured using a Marsh-McBirney model 2000 flow meter. A cross-section at each of the water quality monitoring sites was measured with the cross-section being relatively uniform in depth and flow. The cross-section width was divided into equal width increments (1-foot intervals or at 2-intervals, depending upon width) and depth and velocity were measured at each interval. An engineered, metered, depth rod was used to measure velocity at 60% depth; depth at average vertical flow. Flow rates were calculated using the conversion formula; $Q = \Sigma w_n * d_n * v_n$; where

W_n = mean width at a particular station, D_n = mean depth at a particular station, and V_n = mean velocity at a particular station. Calculations resulted in discharge (Q) being reported in cubic feet per second (cfs).

Quality assurance and control was conducted with each sampling and processing event. Duplicates (side by side sample collection), trip blanks, replicates (sequential collections), and positive control indicator samples were obtained at a 1 to 10 ratio; 1 quality assurance sample to 10 environmental sample was collected. Although the BNR water quality laboratory was not an EPA certified laboratory, the lab adhered to *Standard Methods for the Examination of Water and Wastewater* (2005). Controlled samples were purchased from IDEXX at quantification levels expected from site conditions and at levels near the contact threshold (http://www.idexx.com). Results from the QA/QC analysis can be seen in Appendix B.

Geometric mean is understood as the average of the logarithmic value of a data set, converted back to a base 10 number. Geometric means, unlike arithmetic means, tends to dampen the effect of very high or low values, which might otherwise bias the mean of a arithmetic value. For this reason, geometric means are valuable in presenting bacteria concentrations which are naturally variable. Geometric means were calculated from no less than 12 samples over the period of study. Means were used to characterize *E. coli* concentrations, and geometric means are specified by ADEQ and EPA as five samples over a thirty day period. The sampling regime utilized in the BNR's Water Quality Monitoring program does not fall within this definition. Sampling was conducted over a 4-year period with samples collected quarterly. Sample sizes from all sites ranged from 9 to 17 samples per site with the average being 14. The experimental design of the monitoring program does not comply with this requirement; therefore the span of time is much greater than the required 30 days. However, for the purpose of site characterizations and an estimation of recreational risk, the geometric mean calculations are a useful tool to characterize the chronic conditions of recreational risk. By performing the analysis in this way, the chance of missing individual samples that are highly concentrated has increased. The result is that the geometric means calculated in this study might be an underrepresentation of actual conditions, and this must not be discounted in considering which sites pose more risk for water based recreation.

Trend analysis completed for each site was kept as simple as possible using data plots through time. Upon these plots a linear trend line was created in MS Excel™ with an associated coefficient of determination (R^2). Due to the limited number of the sample sizes, the strength of the linear relationships could be questionable, but the intent of the R^2 was to give evidence to the validity of the trend prediction whether or not sites were decreasing or increasing through time in *E. coli* concentrations. R^2 is generated as a number between 0 and 1.0 and is used to describe how well a regression line fits the data. A 1.0 value indicates a regression (trend) line fits the data completely and the prediction is more valid. Values closer to 0 indicate that the regression line does not fit the data well and its prediction may not be as valid. Given the limited size of the data set for each site, a regression value near 1.0 would not be expected even if the trend were known to be real. None the less, regression values were considered as a useful tool to evaluate trend validity and were included in the data analysis.

Table 1. List of Water Quality Monitoring sites on Buffalo National River.

Sites	Description	Type	County
R01	Buffalo River at Upper Buffalo Wilderness NPS Boundary	River	Newton
R02	Buffalo River at Ponca Access above Ponca Bridge	River	Newton
R03	Buffalo River at Pruitt Access	River	Newton
R04	Buffalo River at Hasty Bridge	River	Newton
R05	Buffalo River at Woolum Access Above Richland Creek Confluence	River	Searcy
R06	Buffalo River at Gilbert Access	River	Searcy
R07	Buffalo River at Highway 14	River	Marion
R08	Buffalo River at Rush Access Above Rush Creek	River	Marion
R09	Buffalo River above Confluence with Whiter River	River	Marion
T01	Beech Creek At Highway 21 Crossing	Tributary	Newton
T02	Ponca Creek At Highway 74 Above Confluence With Buffalo River	Tributary	Newton
T03	Cecil Creek Above Confluence With Buffalo River	Tributary	Newton
T04	Mill Creek At County Road Crossing Near Pruitt Access	Tributary	Newton
T05	Little Buffalo River above Confluence with Buffalo River	Tributary	Newton
T06	Big Creek near Carver at Gene Rush Road Crossing	Tributary	Newton
T07	Davis Creek at Mount Hershey above Confluence with Buffalo River	Tributary	Newton
T08	Cave Creek near Gene Rush WMU	Tributary	Newton
T09	Richland Creek upstream from Woolum Access	Tributary	Searcy
T10	Calf Creek above confluence with Buffalo River	Tributary	Searcy
T11	Mill Creek above Confluence with Buffalo River at Tyler Bend Campground	Tributary	Searcy
T12	Bear Creek above Confluence with Buffalo River	Tributary	Searcy
T13	Brush Creek above Confluence with Buffalo River	Tributary	Searcy
T14	Tomahawk Creek at Searcy County Road 82 Crossing	Tributary	Searcy
T15	Water Creek 1.5 Miles above Confluence with Buffalo River	Tributary	Searcy
T16	Rush Creek above Confluence with Buffalo River	Tributary	Marion
T17	Clabber Creek above Confluence with Buffalo River	Tributary	Marion
T18	Big Creek in the Lower Wilderness above Confluence with Buffalo River	Tributary	Marion
T19	Cedar Creek in the Lower Wilderness above Confluence with Buffalo River	Tributary	Marion
T23	Middle Creek in the Lower Wilderness above confluence with Buffalo River	Tributary	Marion
T24	Leatherwood Creek in the Lower Wilderness above Confluence with Buffalo River	Tributary	Marion
T25	Little Buffalo River above Jasper, Arkansas (Cow Creek)	Tributary	Newton
T26	Little Buffalo River below Jasper, Arkansas (Stewart Creek)	Tributary	Newton
S02	Luallen Spring at Source	Spring	Newton
S33	Mitch Hill Spring At Source Near Mt. Hershey	Spring	Newton
S41	Gilbert Spring at Source	Spring	Searcy

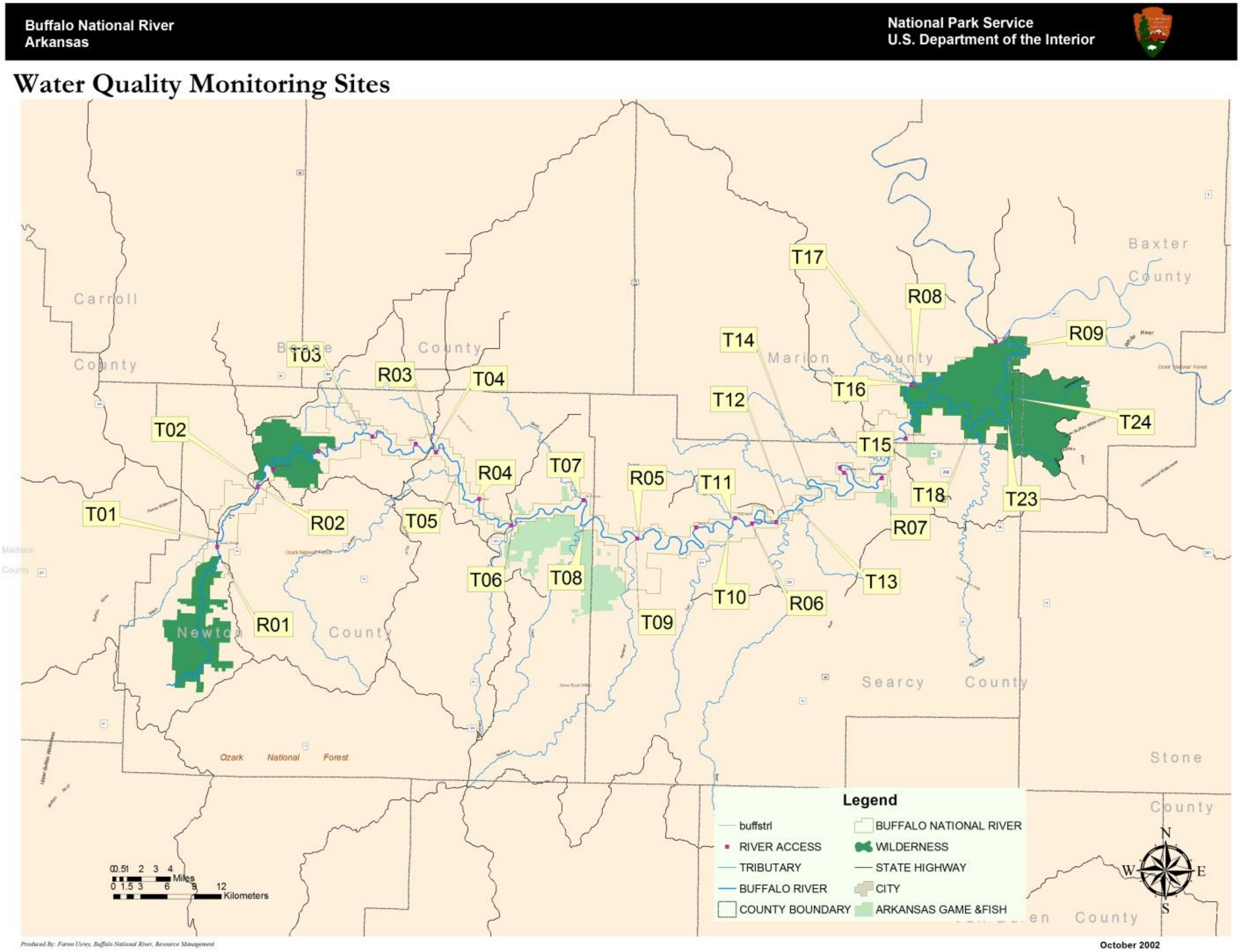

Figure 1 Area map of the Buffalo National River area with water quality sites labeled along the river's channel. Upper areas of the river have lower site number and increase downstream.

Results

Geometric means for river sites during the period of study did not reach the 126 cfu/100ml concentrations set in the ADEQ standards. The geometric means for river sites ranged from three to nineteen colony forming units, (Figure 2, Table 2). The highest mean concentration was observed at Ponca Access (R02) at 19 cfu/100ml. The lower mean concentrations were observed at the Woolum Access (R05) and the Lower River site (R09) at 3 cfu/100ml. The longitudinal trend in river sites was that concentrations of *E. coli* in Buffalo River were declining downstream. Comparison of the geometric means and average discharge at river sites found that lower discharge sites had higher *E. coli* concentrations (Figure 3). Comparison of average discharge and the watershed area for each river monitoring site was observed as an increasing trend line with data appearing to fit well along the trend line (Figure 4). Comparison of these observations supports the result that *E. coli* are in greater concentrations near input sources, the upper portions of the river are more susceptible to animal waste contamination, and *E. coli* concentrations decline with distance from sources.

Geometric means from tributary sources were much higher than those observed in the main river (Figure 5, Table 2). The lowest mean concentration was found in Rush Creek (T16) at 8 cfu/100ml. The highest mean concentration was found in Tomahawk Creek (T14) at 63 cfu/100ml, and the second highest was observed in Mill Creek (T04) at 47 cfu/100ml. Observations of individual sample concentration through time at Tomahawk Creek was declining and the strength of this trend was at 0.17 R^2 value. Mill Creek's individual sample concentration through time was increasing with a 0.10 R^2 value. The strength of these predictive relationships is relatively weak.

Geometric means from monitored springs for *E. coli* were highest at Mitch Hill Spring (S33) at 16 cfu/100ml. Next was Gilbert Spring (S41) at 11 cfu/100ml, and last was Lu Allen Spring (S02) at 6 cfu/100ml. Lu Allen had the strongest relationship with an increasing trend line and a R^2 of 0.1. All means produced within springs were well below ADEQ standards as recommended for recreational contact.

Single grab sample maximums and percentage of samples exceeding state standards for all sites are listed in Table 2. Only one river site had a single grab maximum over the state standard of 298 colonies/100ml and that was Buffalo River at Highway 14 (R07). R07 had a concentration of 361 cfu/100ml. All other sites were well below the single maximum allowable. Single grab maximum E. coli concentrations in tributaries were nearly three times as high as river sites, and several sites had concentrations above the state standard. Tomahawk (T14) had two events over the limit, and 13% of the time sampled, the waters had elevated risk for human recreation. Little Buffalo River (T05) had the highest single grab maximum at 2420 cfu/100ml but only exceeded the maximum one time during the period of study. Gilbert Spring had the highest single grab maximum at 2419 cfu/100ml and exceeded the maximum two times during the period of study.

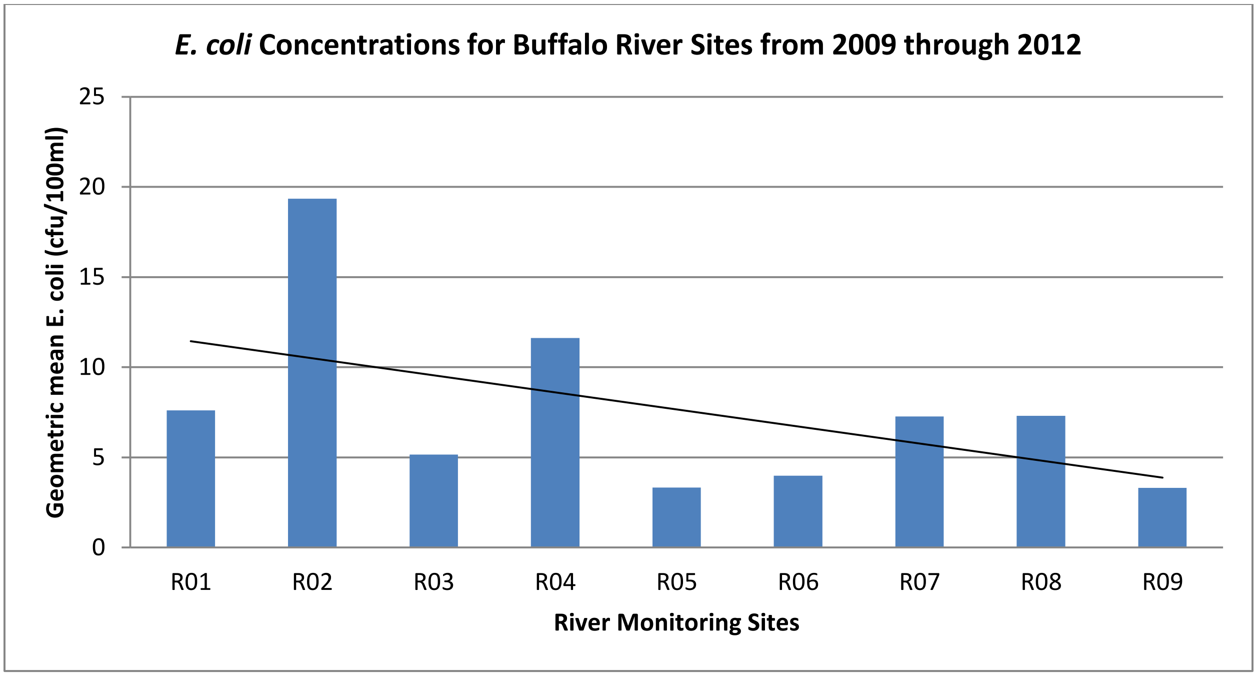

Figure 2. Graph illustrates the geometric means of concentrations of *E. coli* for Buffalo River monitoring sites for data from 2009 through 2012.

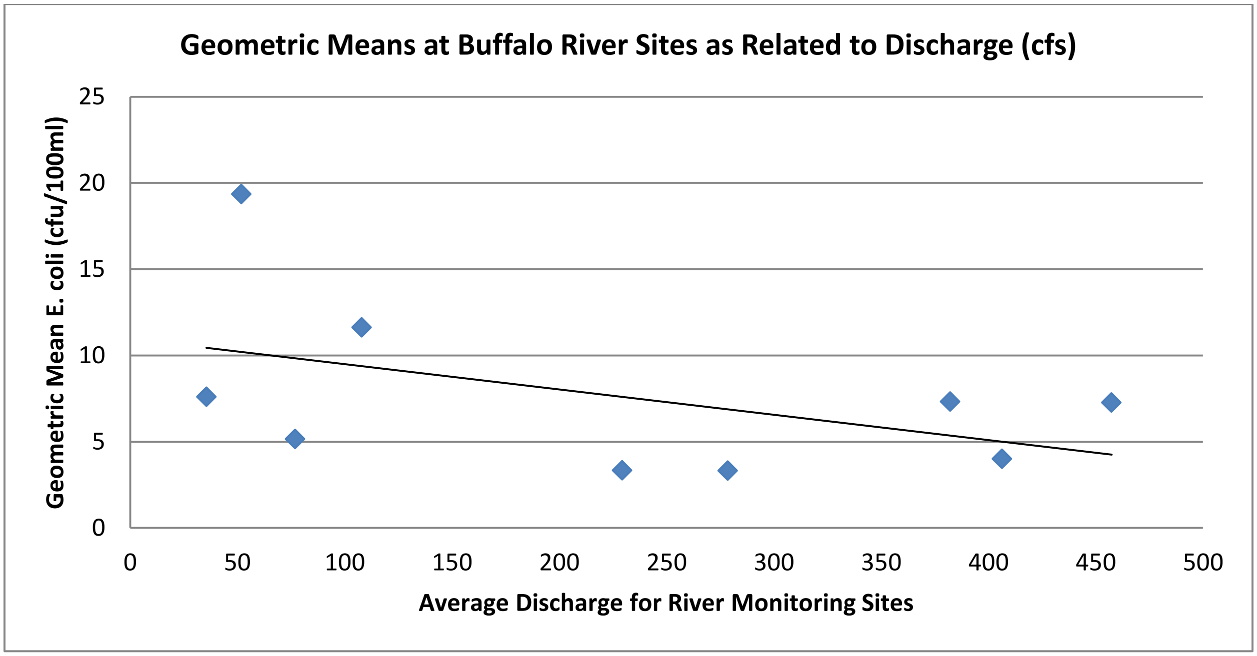

Figure 3. Geometric mean of *E. coli* concentrations as related to the average discharge (cfs) for Buffalo River monitoring sites.

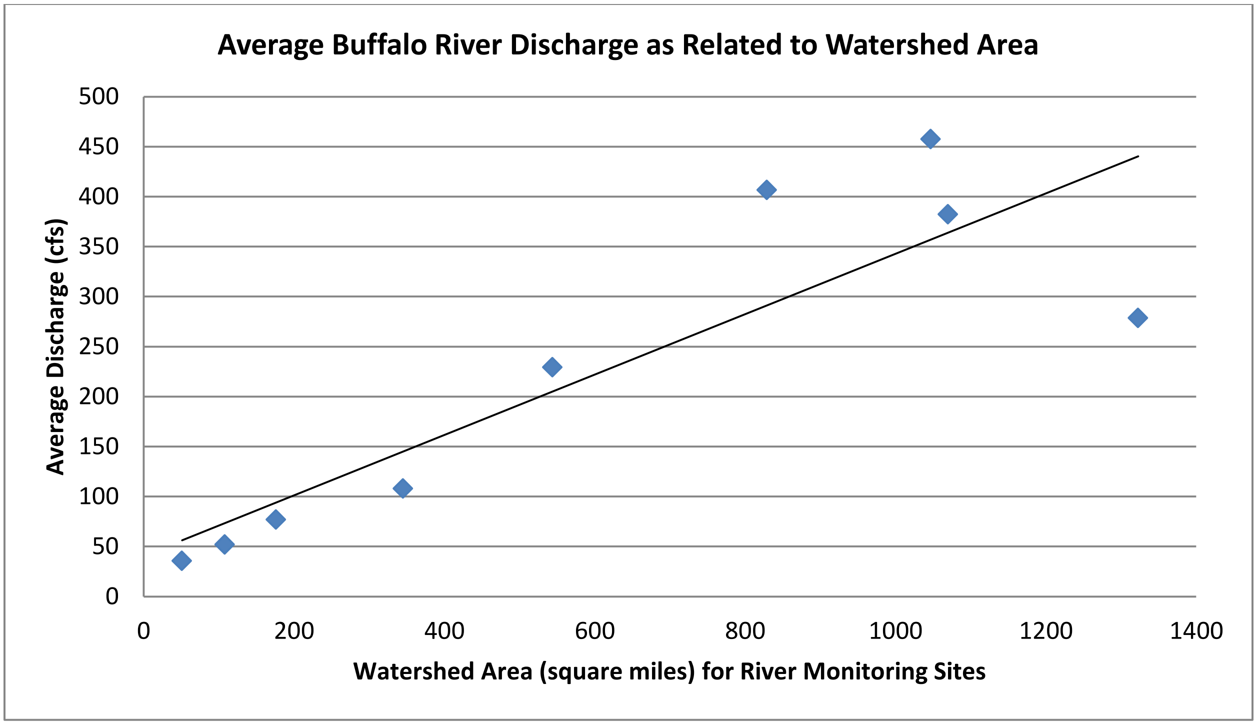

Figure 4. Average discharge measurements of Buffalo River monitoring sites as related to watershed area.

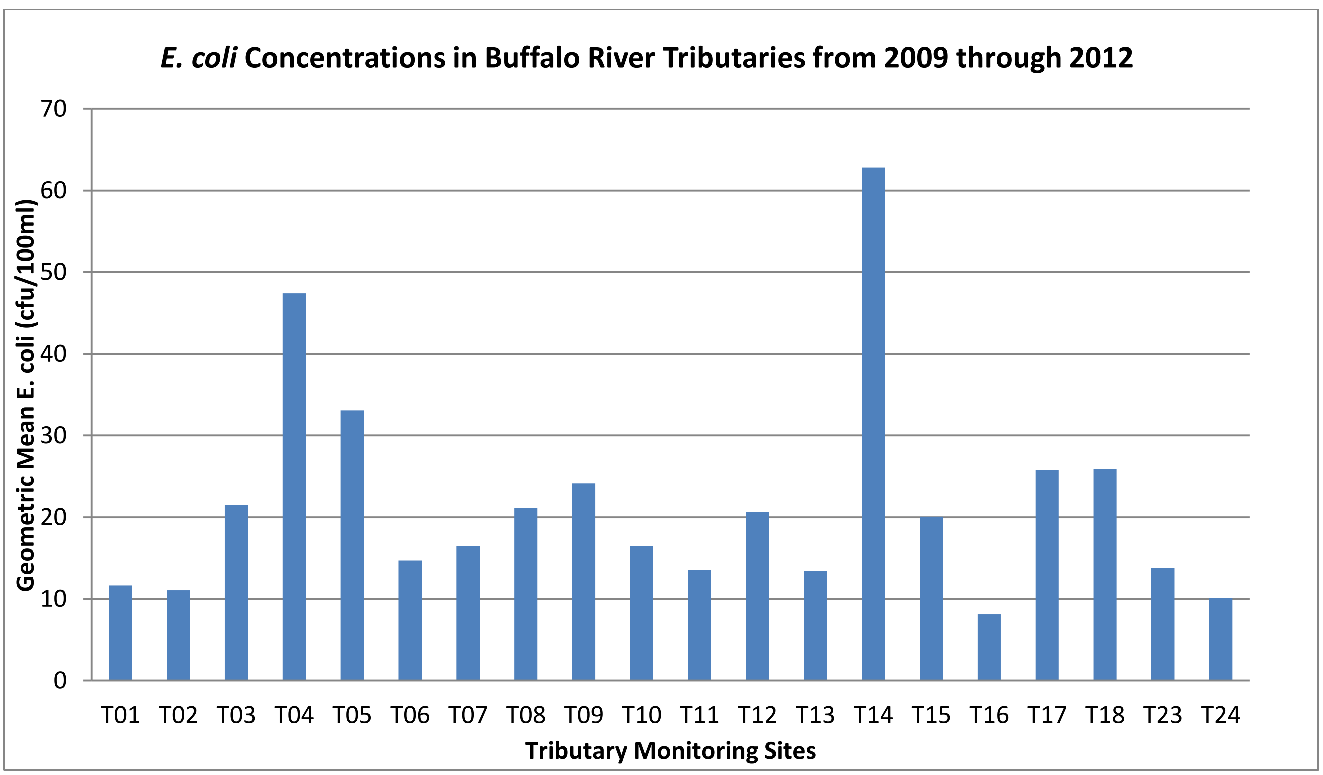

Figure 5. Geometric mean of *E. coli* concentrations from Buffalo River tributaries.

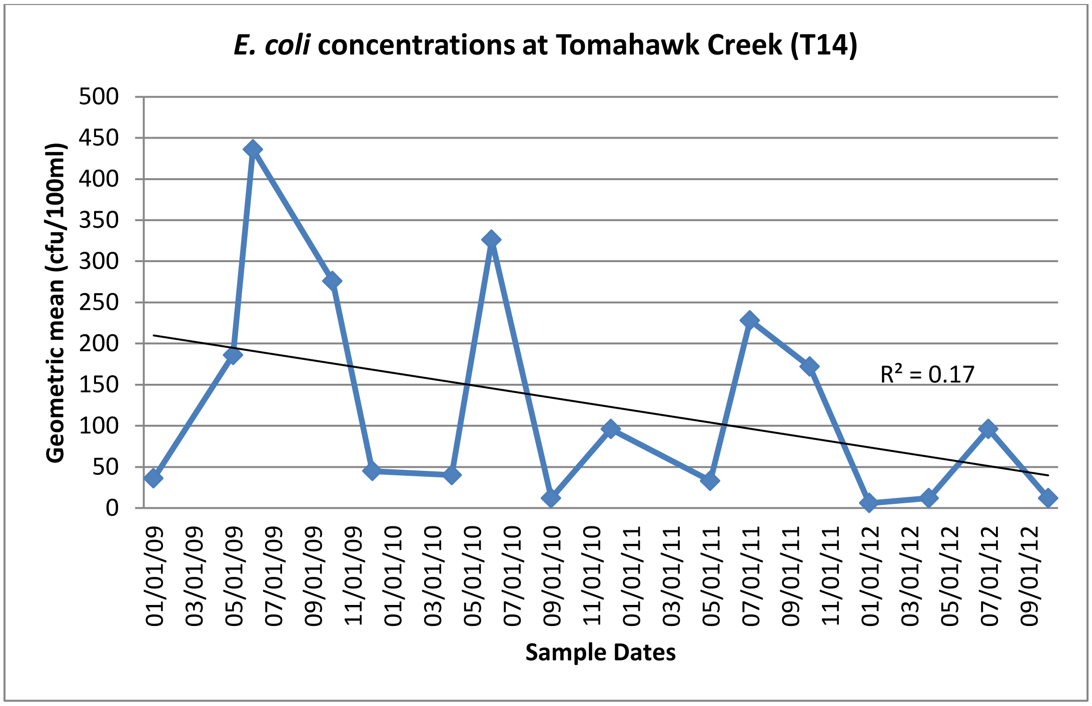

Figure 6. Single sample concentrations of *E. coli* through time, 2009 through 2012.

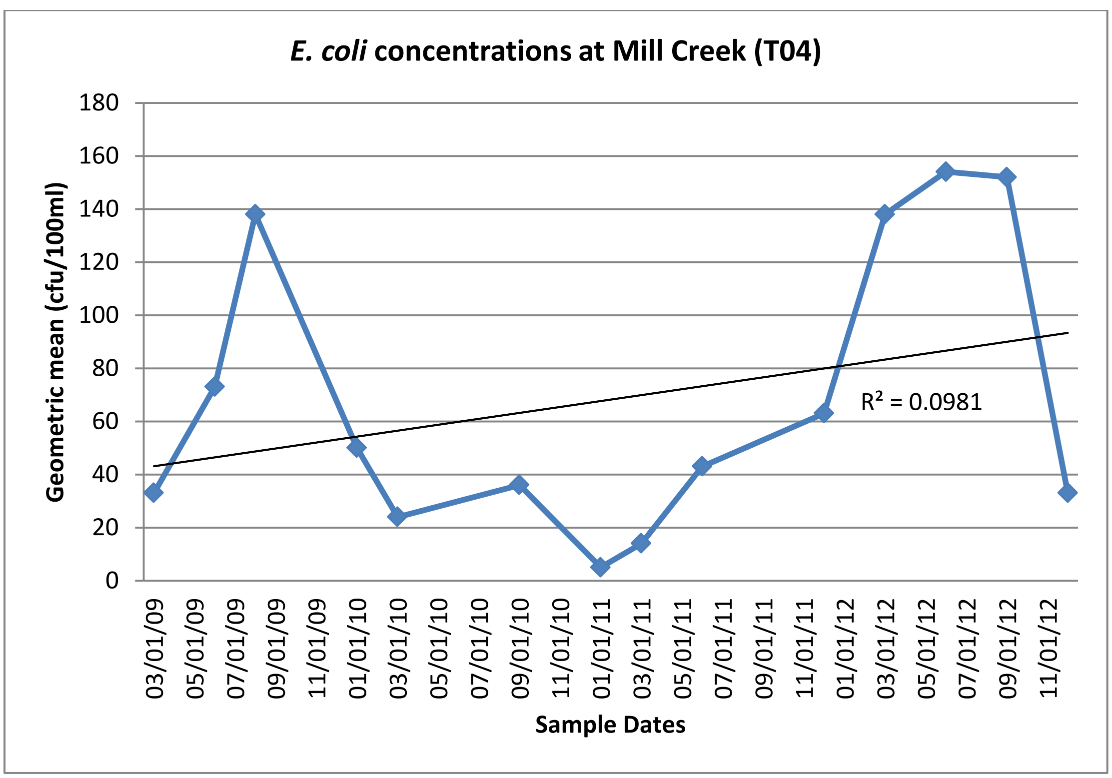

Figure 7. Single sample concentrations of *E. coli* through time, 2009 through 2012.

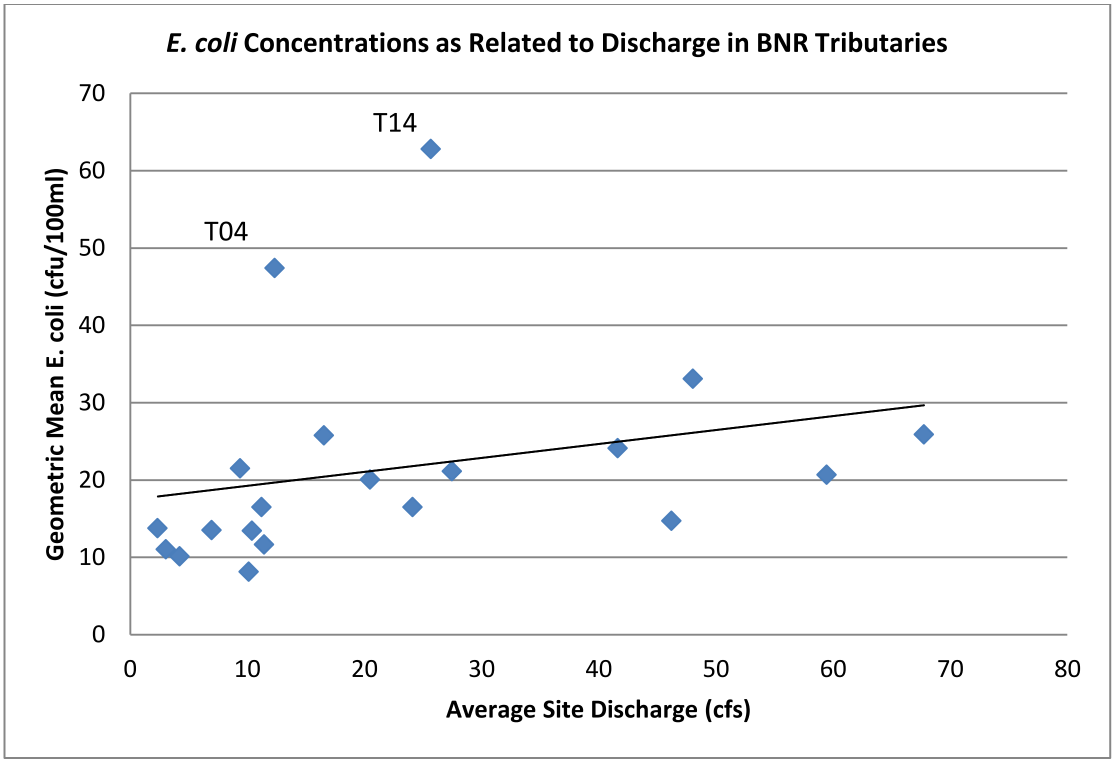

Figure 8. Geometric means of *E. coli* concentrations as related to average discharge in tributaries of Buffalo River for data from 2009 through 2012.

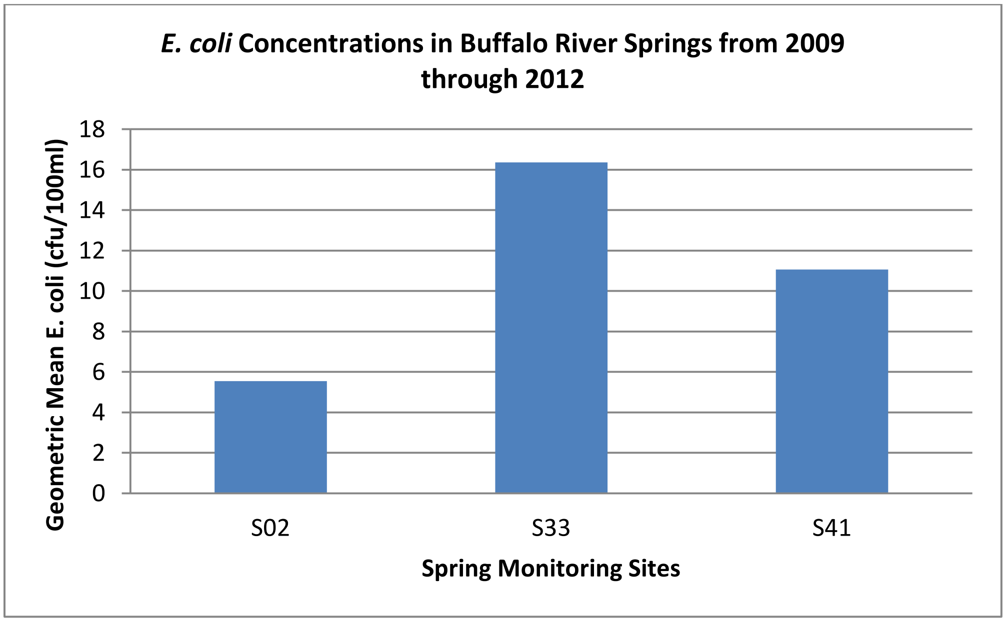

Figure 9. Geometric means from monitored springs from 2009 through 2012.

Table 2. Basic statistical results for all Buffalo National River monitoring sites.

Sites	Geomean	Maximum	Average Discharge	Watershed Size (miles^2)	Number of Samples	Single Exceedance	Percent Exceedance	Trend	Trend R-square
R01	8	137	35.6	51	12	0	0	Up	0.34
R02	19	155	51.8	108	13	0	0	Up	0.14
R03	5	71	77.0	176	16	0	0	Up	0.08
R04	12	82	108.0	345	14	0	0	Up	0.01
R05	3	14	229.4	544	14	0	0	Up	0.09
R06	4	25	406.4	829	14	0	0	Up	0.04
R07	7	**361**	457.5	1047	13	1	8	Down	0.26
R08	7	25	382.2	1070	13	0	0	Up	0.14
R09	3	46	278.6	1323	13	0	0	Down	0.19
T01	12	150	11.4	18.8	9	0	0	Up	0.12
T02	11	**920**	3.1	4.2	14	1	7	Up	0.10
T03	21	**614**	9.4	19.9	16	1	6	Down	0.06
T04	**47**	154	12.3	19.4	14	0	0	Up	0.10
T05	33	**2420**	48.0	128.1	17	1	6	Down	0.01
T06	15	**687**	46.2	83.5	15	1	7	Up	0.00
T07	16	121	11.2	26.2	16	0	0	Down	0.01
T08	21	**517**	27.5	47.5	16	1	6	Same	0.00
T09	24	**345**	41.6	125.7	13	1	8	Same	0.00
T10	16	**345**	24.1	47.4	16	1	6	Down	0.01
T11	13	47	7.0	15.2	15	0	0	Up	0.17
T12	21	**629**	59.5	88.4	14	1	7	Down	0.19
T13	13	178	10.4	18	10	0	0	Down	0.08
T14	**63**	**436**	25.7	33.3	16	2	**13**	Down	0.17
T15	20	140	20.5	35.5	15	0	0	Down	0.02
T16	8	72	10.1	14.9	15	0	0	Up	0.05
T17	26	**387**	16.5	24.4	16	1	6	Same	0.00
T18	26	**727**	67.8	124.6	14	1	7	Up	0.01
T23	14	261	2.3	9.8	13	0	0	Up	0.27
T24	10	58	4.2	12.2	14	0	0	Up	0.06
S02	6	77	0.1	unknown	15	0	0	Up	0.13
S33	16	104	7.8	unknown	15	0	0	UP	0.04
S41	11	**2419**	3.0	unknown	16	2	**13**	Same	0.00

Discussion

Visitor safety is a high priority of the management of Buffalo National River. Within the language of the park's enabling legislation, "*for the benefit and enjoyment of present and future generations*", a safe environment in which to recreate is accepted as a mandate. Therefore, a high standard of water quality, free from elevated animal waste contamination was a condition intended by Congress for the country's first National River. Water-based recreation is the focal point of the park, and visitors reasonably expect safe water in which to recreate. For these purposes, good water quality is and will remain a high priority at BNR. However, reducing water-borne illness risk for the visiting public during recreational activities, such as swimming, canoeing, and wade fishing, is a difficult goal to obtain for a river park that does not manage the watershed. Not all risk can be eliminated from recreating in park waters, especially in a river system where the watershed's land-use is relatively unregulated and the production and impact of animal wastes as pollutants are difficult and expensive to monitor.

Contraction of a gastrointestinal water-borne illness by someone recreating in river water will be the result of many factors such as the concentrations of pollutants within the waters, the frequency at which a person recreates within polluted waters, the type of recreation occurring within polluted waters, and the condition or stage of life of the individual participating in the water based recreation, i.e. children inadvertently consume more water during swimming than adults and contract water-borne illnesses at a higher rate (EPA 2012). In the 1980s when the epidemiological researchers first derived the recommended numerical criteria for *E. coli* concentrations in recreational waters, they based those recommendations on the number of individuals recreating in waters that became ill. The Arkansas Pollution Control and Ecology Commission then adopted those recommendations as ADEQs water quality standards Regulation 2. Those numbers were originally based on the 1986 EPA recommended criteria that related those numeric criteria to an estimated gastrointestinal illness rate of 36 per 1000 primary contacts of people recreating in polluted waters. This equates to having a 3.6% chance of contracting a water-borne illness in waters with *E. coli* concentrations of a geometric mean of 126 or 298 for single sample maximum. That percent chance would be for an assumed one time exposure. Multiple exposures, higher concentrations of animal wastes, the type of water based recreation, and condition and stage of life will all increase risk of contracting illness.

Using the ADEQ's numerical regulation standards for *E. coli* concentrations as a minimal risk assessment tool, chronic or multiple exposures to the waters of Buffalo River are at levels far below the 3.6% chance of contracting a water-borne illness. Therefore, at base-flows, water based recreation could be considered as safe as any natural waters can be expected. Risk by acute or one time exposure, represented by the single sample maximum was only exceeded by one event during the entire period of study and that occurred during winter at base-flow at the Highway 14 Access, a time when little to no water based activity would likely have occurred. However, these observations were only conducted under base-flow conditions, and a flood event would have much greater concentrations *E. coli* loading into the river system. Personal risk of recreating during high flow conditions would be much higher than base-flows, and thus, exceeds the scope of this study.

Buffalo River at Ponca Access was chronically the highest river site for *E. coli*. Known as an easy access point for swimming and fishing, Ponca receives a higher rate of water based recreation than most upper river access points. Although 5 times below the geometric mean concentration standard for *E. coli* (R02 with geometric mean of 19 cfu/100ml) individuals, especially children frequenting this site may have an increased risk of contracting water-borne illness during recreation. Keeping this in perspective, Buffalo River coming out of the Upper Buffalo River Wilderness had a geometric mean concentration of 8 cfu/100ml and that watershed is 80 percent forested and could be considered as base line for what is assumed to be natural in the Ozark physiographic region.

Tributaries to Buffalo River are typically, volumetrically, much smaller than the main river and are much more susceptible to pollution as they interface more directly with the watershed and land-use development. This fact is reflected in the observed geometric mean concentrations of *E. coli* being nearly 3 times as high in tributaries as observed in the main river. This increase in *E. coli* also translates into increased risk during water based activities. Mill Creek near Pruitt Access and Tomahawk Creek down river from Gilbert, Arkansas were the chronically highest tributaries for *E. coli* and pose the most risk for high frequency water based recreation. However, with tributaries in general, single sample concentrations exceeding the maximum were more than 5 times likely to occur in tributaries than in the main river. This lack of assimilation capacity by tributaries, the higher likelihood of single and chronic high *E. coli* concentrations, increase the risk of contracting water-borne illnesses if recreating in tributaries to Buffalo River. Again, keeping perspective, Buffalo River at the Upper Wilderness boundary is as large as many of the larger tributaries. If 126 cfu/100ml is considered as the lower threshold of acceptable risk, then Mill and Tomahawk Creeks are relatively half way along the continuum between what is natural (wilderness) and what is the perceived threshold of acceptable risk for water based recreation.

The three springs monitored within this study were comparable to the concentrations of *E. coli* observed in the river. However, one single sample maximum at Gilbert Spring (S41) was nearly 8 times higher than the state standard. Of the springs monitored, only one spring, Mitch Hill Spring is large enough for water based recreation such as swimming. However, the likelihood of people swimming in these waters is low due to the cold water and the availability of better swimming within the river adjacent to the spring's confluence. However, the greatest risk posed by these springs to the visiting public is not through direct contact during recreation but by direct oral consumption. Lu Allen Spring is commonly known to be an unofficial drinking water source by local residents that do not have access to a municipal water source and for the visiting public that know of the spring's location. At Mitch Hill Spring, an access point for vehicles on the adjacent road has been unofficially maintained by general public so as to access the spring for the collection of spring water. Direct consumption of these waters, even at the lowest concentrations observed within this study pose a greatly elevated risk of contracting a water-borne illness.

Sources of *E. coli* contamination of surface waters can be generally divided into three main categories; human, domestic livestock and fowl, and wildlife (Guan et al. 2002). Upstream of the Buffalo River access in Ponca all three sources are present. Past water quality reports (Thorton 1985, Weeks 1987 and 1991, and Mott 1997) all observed elevated fecal coliform concentrations at the Ponca Access, and the source of that contamination was related to domesticated livestock. However, in recent years, the elk herd (*Cervus canadensis*) has grown considerably. As elk are much more likely to inhabit the riparian corridor, closer to the river's edge, there may be an increasing likelihood that their fecal wastes are entering the surface water of the river. Sources of contamination at Gilbert Spring, given past studies (Mott, 2002), have been primarily human, but in the last couple of years a roosting site for great blue herons (*Ardea herodias*) has developed, and fecal droppings in the spring and around the traditional water collection site has been notable. The process in separating human and domestic animal waste pollution and what is naturally occurring can be difficult (Carson et al. 2001, Guan et al. 2002), but new methods have been developed that are effective and definitive and further work to source type *E. coli* should be performed in future monitoring efforts. Buffalo River at the Wilderness Boundary is the most useful model to characterize what is natural. The single sample maximum observed during this study was 137 cfu/100. It is unknown the source of that *E. coli* load into the river system, but if recreation occurs at high rate, even in the most natural portion of the river, some susceptibility of contracting a water-borne illness still exists.

The most common source of animal wastes originating outside the park has been strongly correlated to an increase land-use conversion from a forest to agricultural, especially confined animal feeding operations. An increased concentration of agriculture in watersheds have been linked with declines in water quality and increases in bacteria concentrations in surface waters (Thorton and Nix 1985; Weeks 1987; Moore et al 1988; McCalisters 1990; Steel et al. 1990; Mott and Steel 1991; Weeks 1991; Daniel et al. 1991; Scott and Smith 1995; Davis et al. 1998; Wall 1996). In general, nutrients, suspended sediments, and bacterial loads reach surface waters during heavy rains and high flow events. During these events within Buffalo River, bacteria concentrations can exceed the State's standard by orders of magnitude (Mott 1997), and the risk for people participating in water based recreation can be quite high. The samples collected during this study only reflect the base-flow condition or a falling hydrograph near base-flow; therefore, the models created within this report reflect only the best of the water quality conditions. The portion of the water year spent at base-flow conditions in Buffalo River have been estimated at 80 to 85 percent (Mott 1997); however, due to the drought conditions occurring within the Ozark physiographic region during the last few years, a much larger percentage of the time per year is at base-flow conditions, further reducing risk of water-borne illness contraction.

The BNR Water Quality Monitoring Program was designed to detect general, long-term trends within the river system and can be a useful tool to assess risk associated with water based recreation; however, it has limitations. Setting the sampling frequency at the quarterly, 3 month period, it is the lowest and most cost efficient sampling framework from which BNR could detect water quality problems and illustrate long-term trends. The resulting resolution is such that many poor water quality events could occur during the three month period when no samples were collected and this could lead to an unknown bias in data analysis and a false assumption. Therefore, caution should be taken during the interpretation of the data, and the low risk results of this study should be recognized that, due to low sample frequency, sites might be higher risk than what was presented herein.

Conclusions

E. coli concentrations within all river sites were generally well below ADEQ Regulation 2 standards with only one sample out of 122 exceeding the single sample maximum. Tributaries were also below State standards for the geometric mean, but tributaries were twice as high as observed in the main river. Single sample maximums were also more frequently exceeded in tributaries than in the main river. More than half of the tributaries exceeded single sample maximums (11 out of 20 tributaries) with one tributary exceeding the maximum 2 times. Geometric means of the monitored springs were similar to the concentrations observed in the main river. Only one spring exceeded single sample maximum and that was exceeded 2 out of 16 samples. All samples were collected from base-flow condition or at the lower end of the falling hydrograph. Base-flow represents the best of the range of possible water quality conditions and is present for most of year conducive to water based recreation.

Maximum acceptable risk was based upon the State's numerical concentration standard, which was originally based upon the number of people expected to contract water-borne illnesses at a low frequency of exposure (36 illnesses per 1000 water based recreational events). Using that as a definition of the maximum acceptable risk, then during the period of this study, the surface waters of the Buffalo River generally exhibited very low risk to people participating in water based recreational activities. However, it should be recognized that this assessment only reflects conditions at base-flow. Surface waters experiencing storm-water runoff have much higher concentrations of bacteria and pose a much greater risk to the water based, recreating public.

E. coli concentrations observed in springs were seldom at high risk for humans participating in recreational activities. However, there is a great concern about the public using the springs as sources of drinking water. Lu Allen Spring is commonly used to provide local residents with drinking water for residential use. The risk involved in directly consuming spring water is much higher than the level associated with direct human contact for recreation. Other water-borne pathogens may be present, with *E. coli* being the lesser pathogen of concern. Direct consumption of water by the visiting public is a personal decision, but an advisory or education system needs to be instituted where surface waters are known to be directly consumed by the public.

The design of the water quality monitoring program at BNR was intended to detect broad, long-term changes in the conditions of the water quality. Quarterly sampling, as performed within this study, may be inadequate when quantifying the concentrations of *E. coli* when pollution sources are acute in duration. Therefore, tributaries and springs known to be chronically high or associated with high risk activities by the public (drinking from springs), may need more intensive sampling regimes. Intensive sampling in these systems will also create more accurate geometric means and capture more single sample maximums that were undoubtedly missed during this study.

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Appendix A

Introduction

Colilert-18 either simultaneously detects total coliforms and *E. coli*; or fecal coliforms in water. It is based on IDEXX's patented Defined Substrate Technology* (DST*). When total or fecal coliforms metabolize Colilert-18's nutrient-indicator, ONPG, the sample turns yellow. When *E. coli* metabolize Colilert-18's nutrient-indicator, MUG, the sample also fluoresces. Colilert-18 can simultaneously detect these bacteria at 1 cfu/100 mL within 18 hours even with as many as 2 million heterotrophic bacteria per 100 mL present.

Storage

Store at 2-25°C away from light.

Presence/Absence (P/A) Procedure

1. Add contents of one pack to a 100 mL sample in a sterile, transparent, nonfluorescing vessel.
2. Cap vessel and shake.
3. If sample is not already at 33–38°C, then place vessel in a 35°C waterbath for 20 minutes or, alternatively, a 44.5°C waterbath for 7–10 minutes.
4. Incubate at 35±0.5°C for the remainder of the 18 hours.
5. Read results according to Result Interpretation table below.

Quanti-Tray* Enumeration Procedure

1. Add contents of one pack to a 100 mL room temperature water sample in a sterile vessel.
2. Cap vessel and shake until dissolved.
3. Pour sample/reagent mixture into a Quanti-Tray or Quanti-Tray/2000 and seal in an IDEXX Quanti-Tray Sealer.
4. Place the sealed tray in a 35±0.5°C (or 44.5±0.2°C for fecal coliforms) incubator for 18 hours (prewarming to 35°C is not required). For incubation in a water bath, submerge the Quanti-Tray, as is, below the water level using a weighted ring.
5. Read results according to the Result Interpretation table below. Count the number of positive wells and referto the MPN table provided with the trays to obtain a Most Probable Number.

Result Interpretation

Appearance	Result
Less yellow than the comparator1 when incubated at 35±0.5°C or 44.5±0.2°C	Negative for total coliforms and *E. coli;* Negative for fecal coliforms
Yellow equal to or greater than the comparator when incubated at 35±0.5°C	Positive for total coliforms
Yellow equal to or greater than the comparator when incubated at 44.5±0.2°C	Positive for fecal coliforms
Yellow and fluorescence equal to or greater than the comparator when incubated at 35±0.5°C	Positive for *E. coli*

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