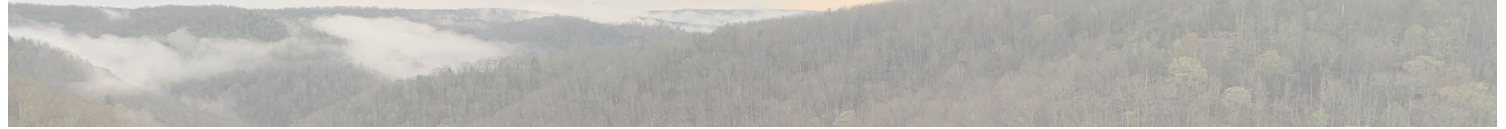




Discrete Water Quality Monitoring: Water Year 2021



Background

Water resources within Big South Fork National River and Recreation Area (BISO) include approximately 80 miles (129 kilometers) of the Big South Fork of the Cumberland River along with its two major tributaries, Clear Fork and New River. In addition, there are hundreds of miles of tributaries and headwater streams within the park's 125,000 acres (50,585 hectares).

The BISO rivers and streams sustain nationally important freshwater fauna, including 11 federally-listed mussel species and the only population in existence of the federally-endangered tuxedo darter (*Etheostoma lemniscatum*). Big South Fork National River and Recreation Area supports one of the largest concentrations and some of the most pristine examples remaining of the globally-imperiled Cumberlandian cobble bar or riverside scour prairie. These cobble bar prairies and the rare species that inhabit them thrive in the presence of frequent flood disturbance and are dependent upon natural flood regimes and unpolluted water.

Big South Fork National River and Recreation Area occupies a small, downstream portion of its large (1,120 square mile [2,901 square kilometers]) watershed, and therefore, the health of its aquatic systems is dependent to a large degree on external factors.



From left, Big South Fork of the Cumberland River, fish swimming underwater, Cumberland elktoe (*Alasmidonta atropurpurea*) mussel buried in the sand in a tributary. NPS photos / APHN staff.

Issues of Management Concern

The primary threats to water quality at Big South Fork National River and Recreation Area are related to acid mine drainage from coal mines, sedimentation associated with mining and roads and trails, and impacts from timber harvest, agriculture, water development, and oil and gas activities.

Highlights

- 32 water-quality samples were collected at 14 sites in WY2021 (28 with 4 QAQC replicates).
- All measurements of dissolved oxygen, temperature, and pH were within state and EPA water quality standards.
- 28% of samples were above reference criteria for specific conductance.
- 10 sites had ANC values indicative of streams sensitive to acidification.

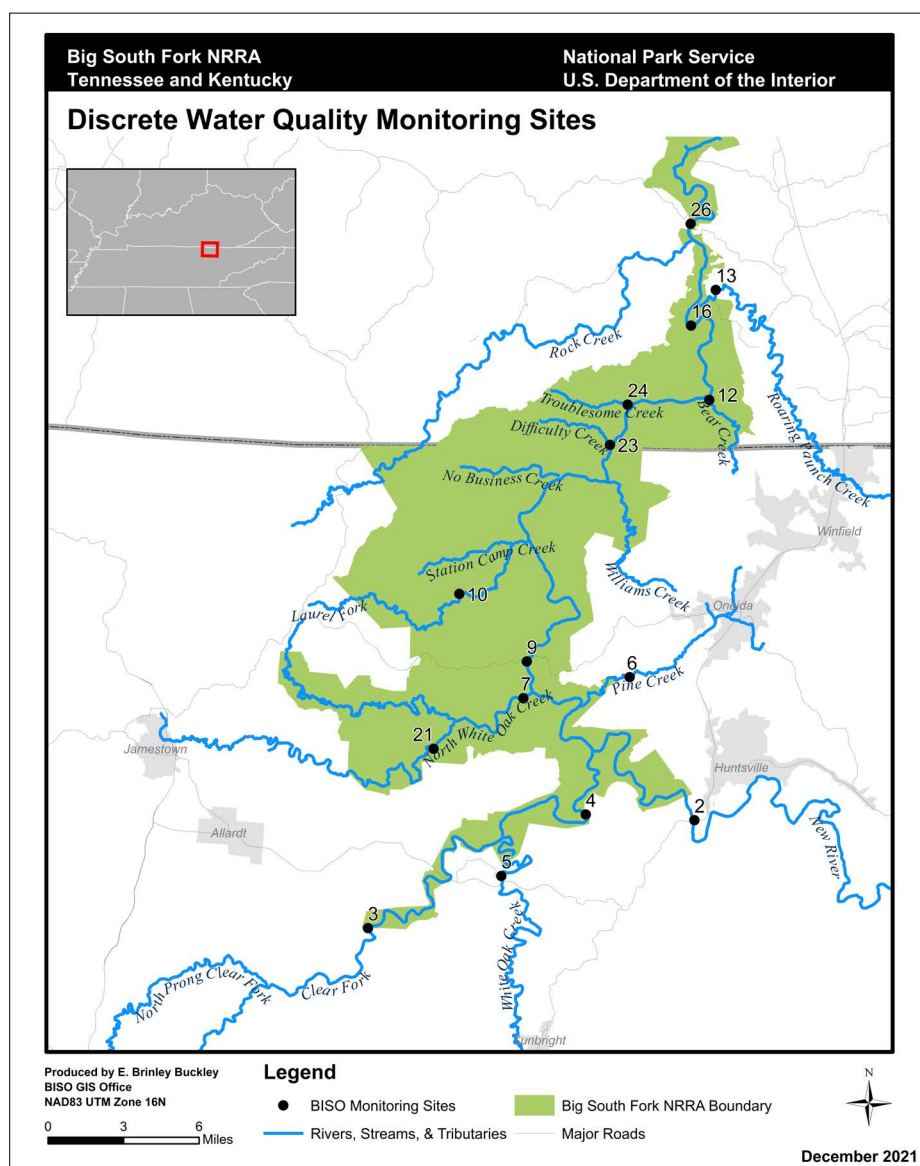
Monitoring and Objectives

The Appalachian Highlands Inventory and Monitoring Network (APHN) monitors water quality at strategic integrator sites to identify water resource conditions. The network monitors core water quality parameters including:

- Streamflow
- Water Temperature
- Dissolved Oxygen
- pH
- Specific Conductance
- ANC
- *Escherichia coli* (*E. coli*)
- Turbidity
- Metals
- Nutrients
- Major Ions

Current conditions are compared to state and federal standards (TDEC 2019), as well as natural reference conditions within Big South Fork National River and Recreation Area. (Rikard et al. 1986).

For detailed methods, see Hughes et al. 2018.



Map showing discrete water quality monitoring sites in the Big South Fork National River and Recreation Area watershed.

Table showing discrete water quality monitoring site identification numbers, site location names, the total number of samples collected from 2016–2021, and the number of samples collected in water year 2021 in Big South Fork National River and Recreation Area.

ID	Name	2016–2021	2021
02	New River at New River	44	5
03	Clear Fork at Peters Bridge	14	1
04	Clear Fork at Burnt Mill Bridge	46	6
05	White Oak Creek at Rugby	12	1
06	Pine Creek at Toomey	13	1
07	North White Oak Creek near mouth	13	1
09	Big South Fork at Leatherwood Ford	42	5
10	Laurel Fork at Station Camp Crossing	12	1
12	Bear Creek at mouth	11	1
13	Roaring Paunch at Barthell	12	1
16	Big South Fork at Blue Heron	12	1
21	North White Oak Creek at Zenith	1	1
23	Difficulty Creek	1	1
24	Troublesome Creek	2	2

Water Year 2021

Sampling during water year 2021 (WY2021) occurred from October 2020 to September 2021. Due to change in personnel, the majority of sampling took place after May of 2021. Therefore, minimal sampling was conducted from October to April, seasons characteristic of higher flows and lower temperatures in Big South Fork National River and Recreation Area. In WY2021, monitoring sites paired with USGS gaging stations were sampled five to six times, while the remaining sites were sampled one to two times. According to the Appalachian Highlands Inventory and Monitoring Network (APHN) data record, three sites were sampled by the network for the first time in WY2021, including North White Oak at Zenith (BISO_21), Difficulty Creek (BISO_23), and Troublesome Creek (BISO_24).

As most of the sampling occurred from May to September, site-specific mean streamflow was lower than the average of prior years (Figure 1). Concurrently, mean water temperature was generally higher than the average of prior years (Figure 2) and mean dissolved oxygen levels were mostly below the mean of prior years (Figure 3).

Streamflow

For WY2021, streamflow at the time of sampling ranged from a low of 0.48 cubic feet per second (cfs) at Troublesome Creek to 287 cfs at New River. Mean streamflow was 101.29 cfs for all sites. Streamflow was measured by APHN staff with an acoustic Doppler flowmeter except at three sites with USGS gaging stations (BISO_02, BISO_04, BISO_09).



Stonefly on a rock (left) and a fish (right) found in BISO streams. NPS photos / APHN staff.

Water Temperature

Water temperature ranged from a low of 13.8°C (56.8°F) to a high of 27.8°C (82.0°F) with an overall mean of 20.95°C (69.71°F). All measurements were below the Tennessee and Kentucky water quality criteria. However, five measurements from three sites were above the BISO reference standard of 25.0°C (77.0°F). These sites were the main stem and major tributaries of the Big South Fork including Clear Fork (BISO_02), New River (BISO_04), and Big South Fork at Leatherwood (BISO_09).

Dissolved Oxygen

Dissolved oxygen ranged from a low of 7.0 mg/L at New River to a high of 10.8 mg/L at Clear Fork near Robbins. Mean dissolved oxygen was 8.78 mg/L across all sites. Most aquatic life requires an average value greater than 5.0mg/L of dissolved oxygen in order to survive. All measurements surpassed this and were above state and NPS minimum standards.

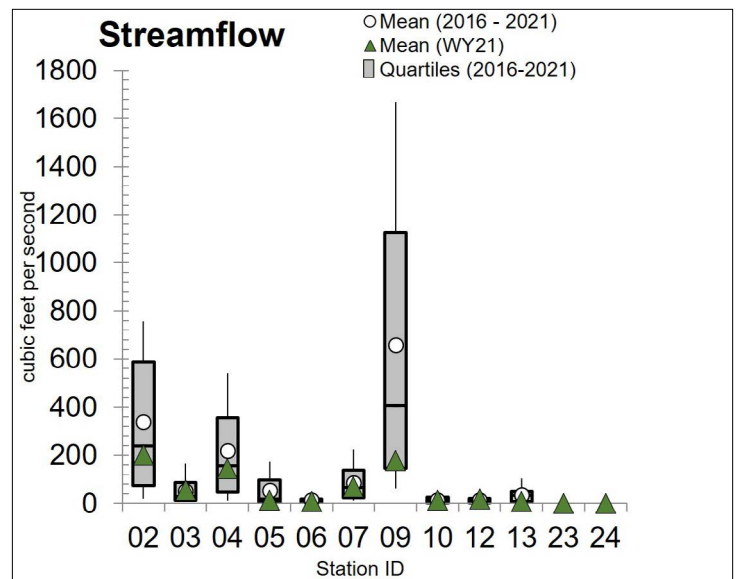


Figure 1. Streamflow at BISO monitoring sites.

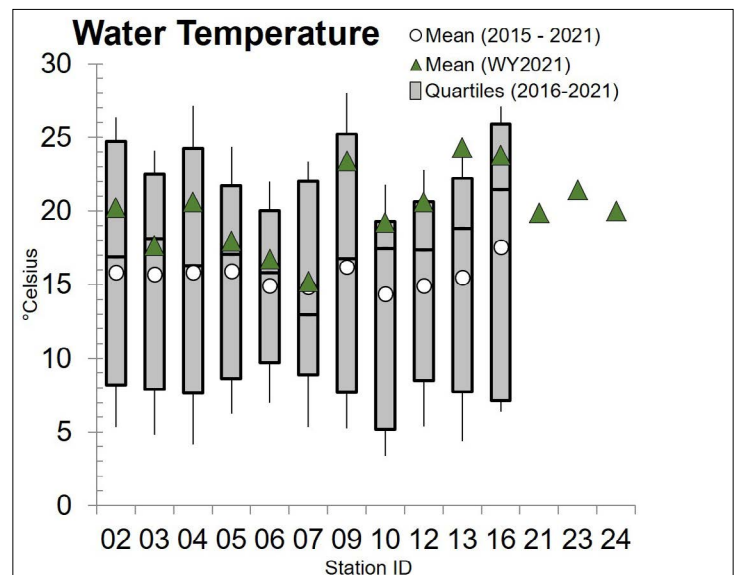


Figure 2. Water temperature at BISO monitoring sites.

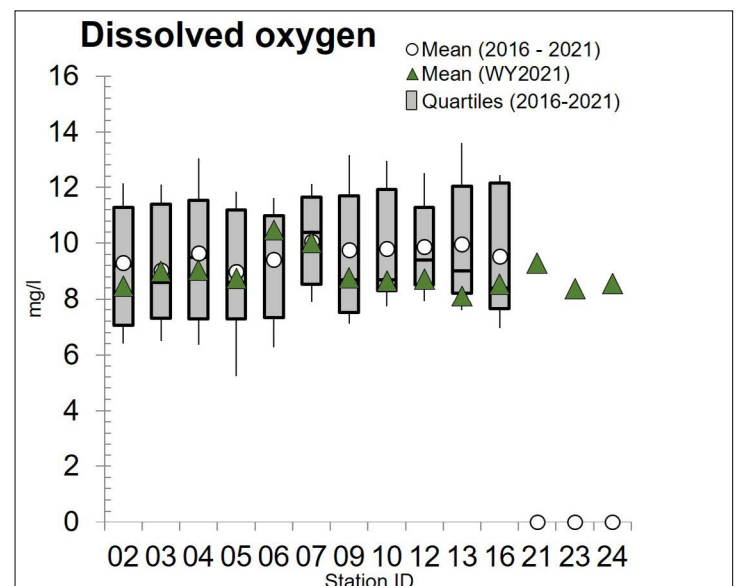
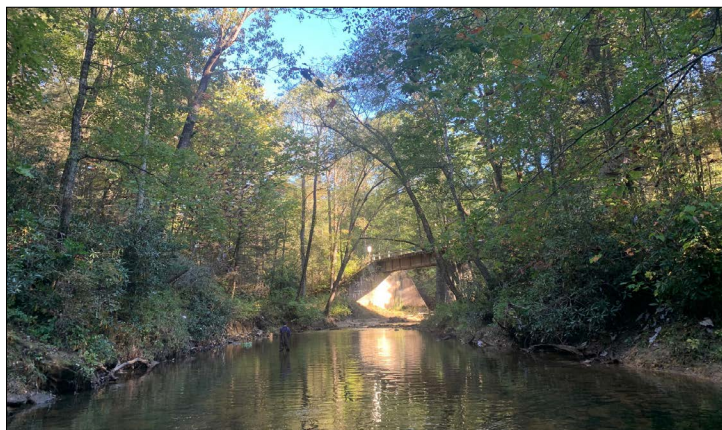


Figure 3. Dissolved oxygen levels at BISO monitoring sites.

Water Year 2021 (Continued)

pH

In WY2021, pH ranged from a minimum of 6.51 SU (standard units) at Difficulty Creek to 8.43 SU at Pine Creek. Mean pH across all sites was 7.39 SU (Figure 4). All measurements fell within state and NPS standards.



Pine Creek (BISO_06) near Toomey, Tennessee. NPS photo / APHN staff.

Specific Conductance

Specific conductance (SpC) ranged from 20.4 $\mu\text{S}/\text{cm}$ at Difficulty Creek to 298 $\mu\text{S}/\text{cm}$ at New River. Reference values for SpC at Big South Fork National River and Recreation Area are 50 $\mu\text{S}/\text{cm}$ for sandstone-dominant streams and 100 $\mu\text{S}/\text{cm}$ for limestone. Provisional target criteria for Big South Fork NRRA is 200 $\mu\text{S}/\text{cm}$ in the main stem of Big South Fork (BISO_09, BISO_16), and 100 $\mu\text{S}/\text{cm}$ in the tributaries. Big South Fork was below 200 $\mu\text{S}/\text{cm}$ for all SpC measurements in WY2021 and averaged 114.2 $\mu\text{S}/\text{cm}$. In the tributaries, eight sampling events exceeded 100 $\mu\text{S}/\text{cm}$ at four sites including New River (BISO_02), Pine Creek (BISO_06), Bear Creek (BISO_12) and Roaring Paunch (BISO_13). New River had the highest mean SpC measurements at 181.35 $\mu\text{S}/\text{cm}$; however all SpC measurements were below the EPA benchmark for biological impairment of 300 $\mu\text{S}/\text{cm}$ (EPA 2011). Mean SpC across all sites for WY2021 was 93.97 $\mu\text{S}/\text{cm}$ (Figure 5).

Acid Neutralizing Capacity

Acid neutralizing capacity (ANC) is a measure of a stream's capacity to buffer the effects of acid inputs. Many BISO streams are sandstone-influenced and are susceptible to acid contamination because of their very low alkalinity. This lack of buffering capacity, with low ANC values below 20 mg/L as CaCO_3 , renders park waters highly susceptible to degradation by acidic input, such as the acid mine drainage that has adversely affected many streams on the Plateau. The EPA specifies less than 4 mg/L as CaCO_3 (50 $\mu\text{eq}/\text{L}$) as highly sensitive to acidification. ANC ranged from a minimum of 3.5 to 71.6 mg/L as CaCO_3 . One site, Troublesome (BISO_24), was below this threshold. In addition, nine sites had mean ANC values below 20 mg/L as CaCO_3 , indicating sensitivity to acidification, including North White Oak Creek at the mouth (BISO_07) and at Zenith (BISO_21), Laurel Fork (BISO_10), and Difficulty Creek (BISO_23; Figure 6).

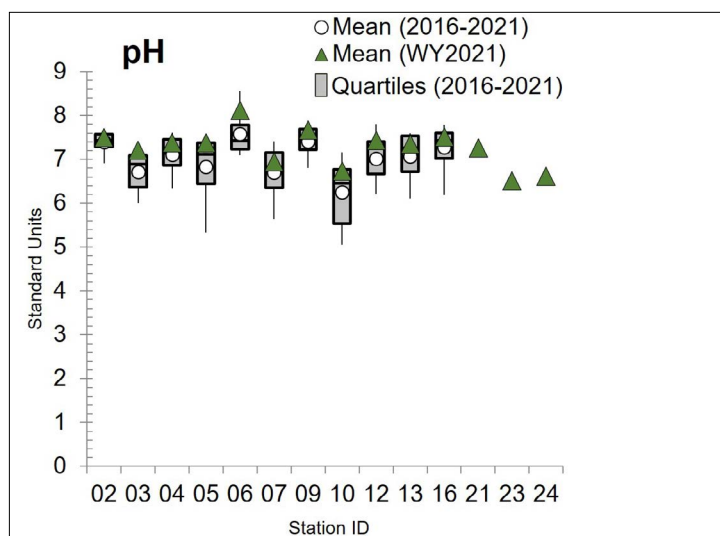


Figure 4. pH levels at BISO monitoring sites.

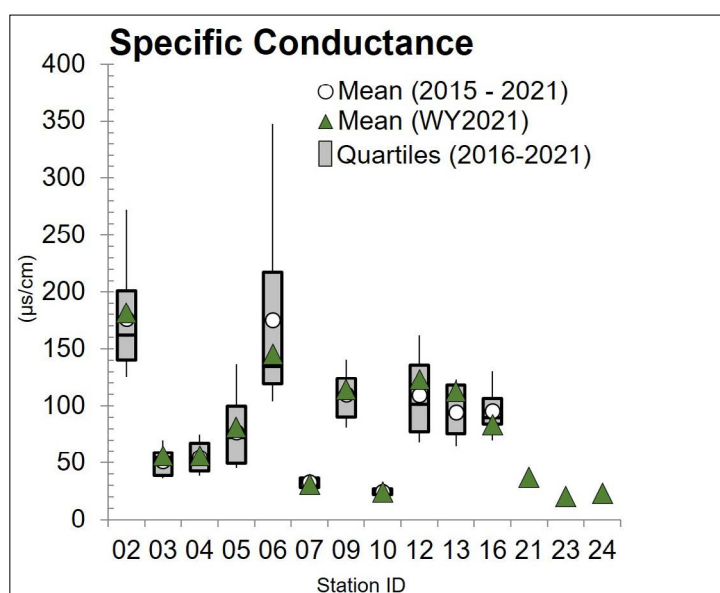


Figure 5. Specific conductance levels at BISO monitoring sites.

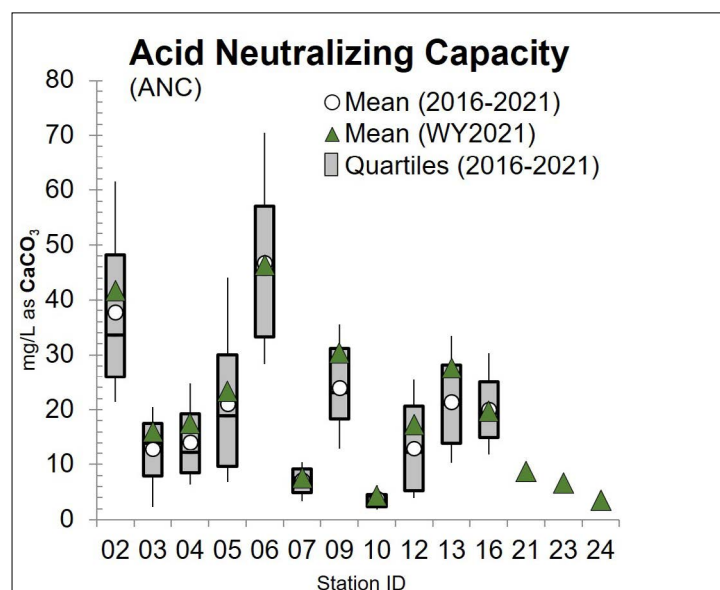


Figure 6. Acid Neutralizing Capacity levels at BISO monitoring sites.

Water Year 2021 (Continued)

E. Coli

E. coli (*Escherichia coli*) ranged from less than 1 to 517.2 MPN/100mL with a mean of 88.5 MPN/100mL across all sites during WY2021 (Figure 7). Most probable number or MPN, is an estimate of the number of organisms in a sample using statistical probability tables. Six samples exceeded 100 MPN/100 mL, the reference condition for BISO (Rikard et al. 1986). The measurement, 100 MPN/100 mL, is the standard for Tennessee, Kentucky, and NPS water quality criteria. However, these standards require a geometric mean based on five samples within 30 days (NPS Recreational Water Quality Criteria 2018), a sampling metric not achievable with APHN's sampling design. *E. coli* criteria for a single sample under state and NPS standards is 320 cfu/100 mL. Two samples exceeded this metric, one at Laurel Fork (BISO_10) and one at New River (BISO_02).

Turbidity

Turbidity ranged from 0 FNU (Formazin Nephelometric Unit) at Troublesome (BISO_24) to 39.6 FNU at Bear Creek (BISO_12), with a mean of 5.35 FNU across all sites (Figure 8). State regulatory standards do not provide numeric water quality criteria for turbidity; however, the following is the narrative criteria from the Tennessee Department of Environment and Conservation: "There shall be no turbidity, total suspended solids, or color in such amounts or of such character that will materially affect fish and aquatic life. In wadeable streams, suspended solid levels over time should not be substantially different than conditions found in reference streams." For BISO streams, undisturbed reference values of turbidity are 10 FNU. Based on this reference, five measurements at four sites were above the criteria including New River (BISO_02), Big South Fork at Leatherwood (BISO_09), Bear Creek (BISO_12), and Clear Fork near Robbins (BISO_04). However, mean site-specific turbidity was below the reference for all sites except Bear Creek (BISO_12) and Big South Fork at Blue Heron (BISO_16).

Nitrate

Nitrate (NO_3) ranged from 0.04 mg/l to 2.34 mg/l with an average of 0.42 mg/l across all sites. Pine Creek (BISO_06) had the highest mean nitrate levels in WY2021. However, site-specific means for NO_3 in 2021 were generally lower than prior site-specific means (Figure 10). Tennessee recommended $\text{NO}_3 + \text{NO}_2$ nutrient criteria for the BISO region is less than 0.27 mg/l (TDEC 2001). Ten sites had levels above this, including Clear Fork at Peters Bridge (BISO_03) and Pine Creek (BISO_06) with $\text{NO}_3 + \text{NO}_2$ levels above 1 mg/l (Figure 9).



Hydrology intern, Isabel Ahlstrom, sampling at Bear Creek (BISO_12). NPS photo / APHN staff.

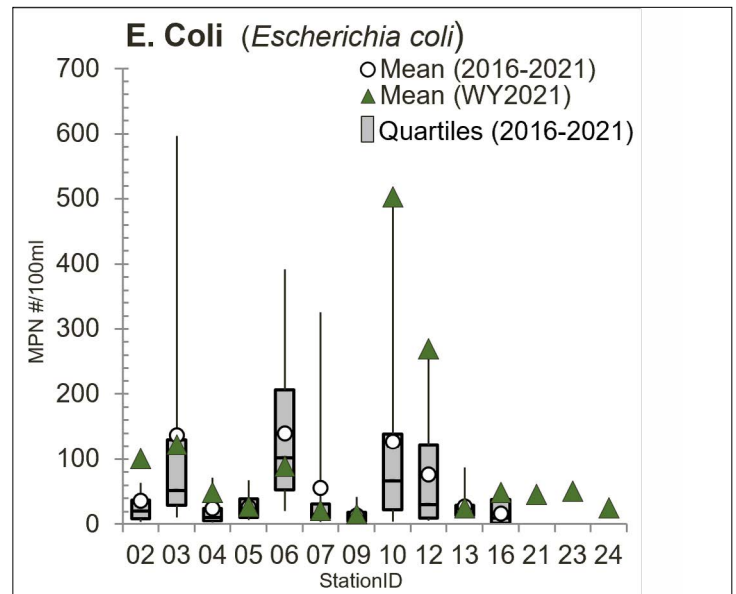


Figure 7. *E. coli* levels at BISO monitoring sites.

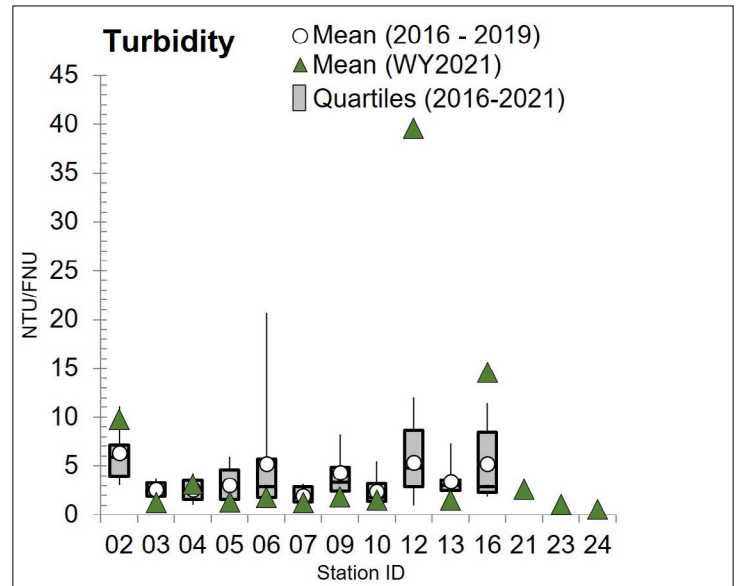


Figure 8. Turbidity levels at BISO monitoring sites.

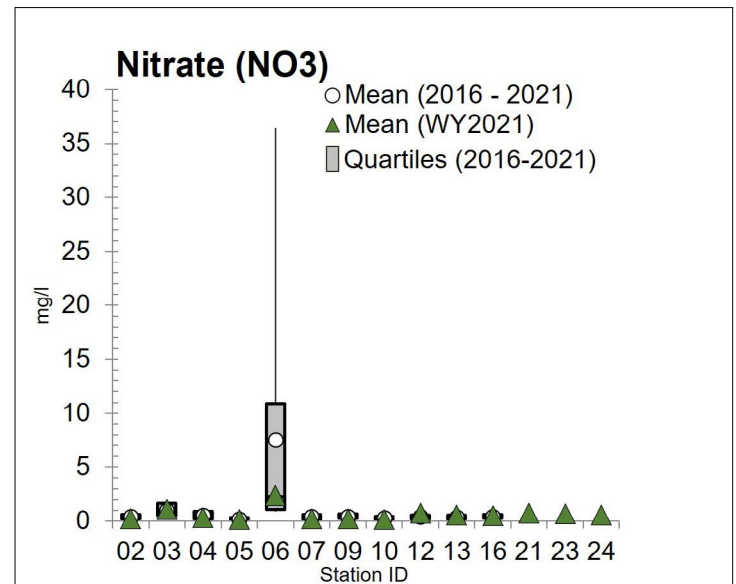


Figure 9. Nitrate levels at BISO monitoring sites.

Water Year 2021 (Continued)

Chloride

Chloride ranged from a low of 0.57 mg/l at Troublesome Creek (BISO_24) to a high of 10.84 mg/l at Pine Creek (BISO_06; Figure 10). Across all sites, chloride measurements averaged 2.78 mg/l. Although chloride is naturally derived from geologic formations, elevated levels can indicate pollution associated with sewage treatment, road salt, or brine water from drilling. The reference condition for chloride in undisturbed BISO streams is less than 5 mg/l. Two samples at two sites had chloride levels above reference condition, Pine Creek (BISO_06) and Roaring Paunch at Barthell (BISO_13).

Iron

Iron ranged from a minimum of 0.045 mg/l at New River (BISO_02) to 0.44 mg/l at White Oak Creek at Rugby (BISO_05; Figure 11). Iron levels across all sites averaged 0.12 mg/l. Water quality criteria for iron are 1.0 mg/l for aquatic-life and 0.3 mg/l for domestic water supply (EPA 1986). Reference streams in Big South Fork National River and Recreation Area generally have iron levels less than 0.2 mg/l. Two samples at two sites had iron levels greater than reference conditions, including White Oak Creek at Rugby (BISO_05) and Clear Fork at Peters Bridge (BISO_03). However, iron levels were below the criteria for aquatic life for all measurements.



Hydrology intern, Ross Shipley, collecting a water sample at New River. NPS photo / APHN staff.

Sulfate

Sulfate ranged from 0.03 mg/l to 58.80 mg/l with an average of 11.80 mg/l across all sites (Figure 12). Sulfate is naturally distributed in soils, sediments, and rocks and occurs naturally in freshwater systems with values ranging from a few to several thousand milligrams per liter. Mine drainage waste may increase sulfate levels through pyrite oxidation. Reference conditions in undisturbed streams at Big South Fork National River and Recreation Area have sulfate levels below 10 mg/l, while the EPA Secondary Maximum Level Contaminant Goal is 250 mg/l for drinking water (EPA 1990). Twelve samples from five sites were higher than the BISO reference condition, including Big South Fork at Blue Heron (BISO_16) and Leatherwood Ford (BISO_09), Bear Creek (BISO_12), Roaring Paunch (BISO_13), and New River (BISO_02).

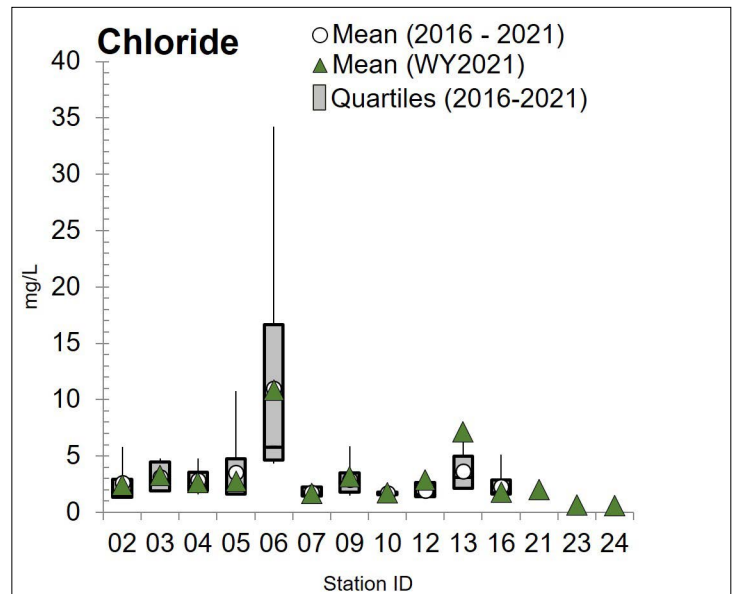


Figure 10. Chloride levels at BISO monitoring sites.

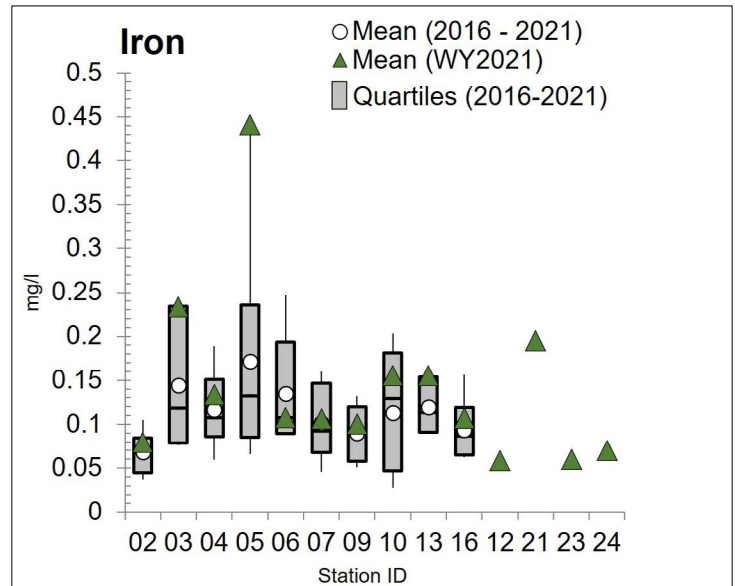


Figure 11. Iron levels at BISO monitoring sites.

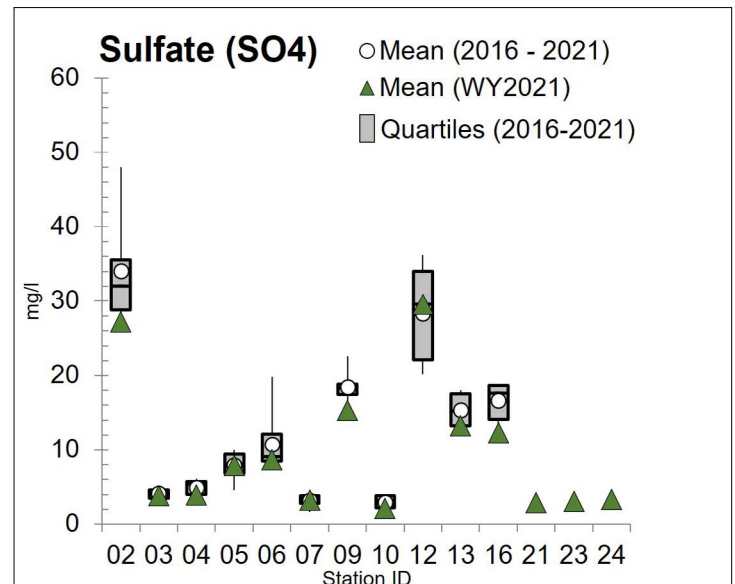


Figure 12. Sulfate levels at BISO monitoring sites.

Conclusions

Overall, water quality at monitoring locations in Big South Fork NRRA for WY2021 remained relatively stable and of high quality with a few considerations. Several tributaries sampled in WY2021 remain on the 2020 Tennessee and Kentucky list of impaired streams including Pine Creek (BISO_06), Bear Creek (BISO_12), and Roaring Paunch Creek (BISO_13). Concerns over Pine Creek (BISO_06) include *E. coli*, dissolved oxygen, nutrients, and sedimentation due to sanitary sewer overflows and municipal point source discharges. Bear Creek (BISO_12) remains 303(d) listed for pH, siltation, and elevated iron concentrations due to abandoned mining impacts. Roaring Paunch Creek (BISO_13) is listed for *E. coli* contamination. North White Oak Creek (BISO_07 and BISO_21) was on the TN 303(d) list of impaired waters from 1996 to 2002 for abandoned surface mining impacts including siltation and pH. Elevated levels of pH, turbidity, sulfate, and iron can indicate impacts from acid mining drainage, however sampling in WY2021 at N. White Oak Creek near mouth (BISO_07) and N. White Oak Creek near Zenith (BISO_21) fell within the state criteria for these parameters and no additional parameters were of concern.

Troublesome Creek (BISO_24) and Difficulty Creek (BISO_23) are two of the most secluded and near pristine streams in the park. Due to the low buffering capacity of the soils and underlying bedrock, they are highly susceptible to acidification. Draining only NPS land, and thus less influenced by external contaminants, these tributaries are high quality streams representative of natural reference conditions.

Literature Cited

- Rikard, M., S. Kunkle, and J. Wilson. 1986. Big South Fork NRRA Water Quality Report, 1982–1984. NPS Water Resources Report No. 86-7. 65pp.
- Tennessee Department of Environment and Conservation (TDEC). 2019. Revised General Water Quality Criteria.
- Tennessee Department of Environment and Conservation (TDEC). 2001. Development of Regionally-Based Interpretations of Tennessee's Narrative Nutrient Criterion.
- U.S. Environmental Protection Agency (EPA). 1986. Quality Criteria for Water. Available at: <https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table> (last accessed August 2022).
- U.S. Environmental Protection Agency (EPA). 1990. National Primary and Secondary Drinking Water Regulations; Synthetic Organic Chemicals and Inorganic Chemicals. Federal Register. Vol. 55. No. 143. 30370.
- U.S. Environmental Protection Agency (EPA). 2011. A Field-Based Aquatic Life Benchmark For Conductivity In Central Appalachian Streams. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-10/023F

Protocol Citation

- Hughes, J., R. Emmott, E. Raskin, and B. Witcher. 2018. Long-term discrete water-quality monitoring at Big South Fork National River and Recreation Area, Blue Ridge Parkway, and Obed Wild and Scenic River: Protocol narrative. Natural Resource Report NPS/APHN/NRR—2018/1840. National Park Service, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2258269> (last accessed August 2022).

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