

2014 Fish & Water Quality Annual VITAL SIGNS REPORT

2014 Vital Sign Selection and Implementation

VITAL SIGN AQUATIC COMMUNITY SITE SELECTION: Tentative aquatic community sites were identified in four of the six primary watersheds selected by the original watershed draw (i.e. Abrams Creek, East Prong Little River, Cataloochee Creek, Hazel Creek). The decision to initiate data collection in four of the six primary watersheds in 2014 in support of the 2014 aquatic community and water quality vital signs monitoring plan was based upon known staffing and volunteer support for 2014. Attempts were made to select the new vital signs sites along a single main stem corridor, within each 305m band (100 foot) and at access points where they could feasibly be collected. In potential sampling areas that included historic sampling sites, retaining old sites with long term data sets were given preference over creating new vital sign sites with no data. GRSM and UT staff as well as volunteers surveyed potential survey sites and selected sites that met the aforementioned criteria and were perennial streams. Two sites were dropped (ABC_4, CAT_5) due to having no consistent source of flowing water and one site was dropped because there was no safe and feasible means of collecting the data within the criteria mentioned above (CAT_5). In some cases, alternate sites were selected that met the elevation criteria but were not on the main stream corridor, however had better access. Final sites for these four watersheds are listed in Table 1.

Stream water temperature loggers were placed in four of the six primary watersheds set to collect temperature data at one hour intervals (Table 2). Temperature loggers were not placed in Cataloochee Creek (http://waterdata.usgs.gov/nc/nwis/uv/?site_no=03460000&PARAMeter_cd=00065,00060) and EP Little River (http://waterdata.usgs.gov/tn/nwis/uv/?site_no=03497300) because each had USGS stream gages, which included real-time temperature data. Stream temperature data will capture seasonal variation as well as annual mean temperatures, both of which can be analyzed for climate change effects over time (Figure 7).

HISTORIC WATER QUALITY MONITORING: Annual water quality surveys were collected bi-monthly on the third weekend of each sampling month starting in January 2014 through November 2014. Water quality data was collected at the 43 historical collection sites (Figure 1) during January, March and May of 2014 (Table 1). Starting in July 2014, water quality data collection switched to four of the six new vital sign site collections and continued bi-monthly through November 2014.

FISH COMMUNITY MONITORING: Fish community Index of Biotic Integrity (IBI) sites and trout population survey sites were completed on four primary watersheds in 2014 (Abrams Creek, EP Little River, Hazel Creek and Cataloochee Creek). Prior to sampling, GRSM biologists and field staff attempted to visit and ground truth potential survey sites in order to ensure they met the sampling design (sites longitudinally in each 305m [1,000ft] band)) and sampling techniques (IBI or 3-pass depletion). Tentative sites were paired with established water quality monitoring sites as described above. In most cases, fish sites were located at or within 50m of water quality monitoring sites. In some cases, sites were not conducive to IBI sampling due to low species diversity; therefore 3-pass depletion surveys were conducted in these areas. In some instances, access (CAT_4) and/or stream size (HAZ_2) required fish sampling sites to be moved to other locations within the watershed that met selection criteria (elevation band, access, historical data) (Figure 2). Once established (Table 1), fish communities were sampled using either IBI or 3-pass techniques according to standard methods. Field crews also evaluated some low elevation sites (<620m) in the two other primary watershed in 2014 (Deep Creek, Middle Prong Little Pigeon River). IBI samples were conducted in both Deep Creek (DPC_1) and Middle Prong Little Pigeon River (MPL_1) in order to establish baseline community data while a determination is being made with regards to resampling frequency (Table 1).

RESULTS

Fish Communities (IBI): Eight large-stream Index of Biotic Integrity (IBI) sites were sampled for fish in 2014 (Abrams Creek, Cataloochee Creek, Deep Creek, EP Little River, Hazel Creek and Middle Prong Little Pigeon River) in each of the six primary vital sign watersheds (Table 1). Most sampling was conducted by GRSM fisheries staff and volunteers, however TVA assisted with 2 sites (CAT_2 & EPLR_2) as these sites are also part of the larger Southeast Monitoring Network (SEMN) sampling design. All results were recorded on GRSM datasheets (and some data recorded on TVA field data loggers at CAT_2) and QA/QC checked once back in the office. Once data was checked, PDF copies of all IBI data sheets were sent to Dave Matthews (TVA) for entry into the TVA IBI software, scoring and upload to the TVA Oracle database. The Oracle database stores IBI data from the entire Tennessee Valley from the surrounding 10 states. Results of the analyses were then sent back to GRSM for use in reporting. Data were processed by site and scored according to the metrics developed for the upper Blue Ridge stream ecoregion (Table 3).

In general, fish communities in the six primary watersheds appear to be healthy and representative of typical low- to mid-elevation stream communities in the Blue Ridge ecoregion. There were no obvious signs of stress or disease in the species collected, other than ubiquitous and benign commensal parasites like black spot (black grub) and the occasional leech. East Prong Little River just upstream of the Townsend Wye was the most speciose site

with 17 species of fish collected (Table 4). The Middle Prong Little Pigeon River just upstream of the park boundary was the second most speciose site with 16 species of fish collected (Table 4). The Little River just upstream of Elkmont was had the lowest species diversity with only 4 species present (Table 4).

IBI scores from the six primary streams ranged from 'poor' to 'good' (Figure 3) and included 4 to 17 species per site (Table 4). Abrams Creek (ABC_1) scored the highest (52) and the Little River site at Elkmont (EPLR_2) scored the lowest (28) (Figure 3). Although the scores for the six primary watershed sites are lower than anticipated, much of the lower scoring can be attributed to the fact that these sites are in the upper range of IBI applicability in terms of elevation. GRSM sites EPLR_2 and CAT_2 represent the uppermost applicable range of Blue Ridge stream IBI metrics due because species diversity declines sharply above 700m (2,300 feet). Although sites such as EPLR_2 located just above Elkmont campground represent excellent cold water habitat, the lack of species diversity results in a low IBI score (28). Fish at the EPLR_2 site are healthy and typical of streams at that elevation, therefore the low score is accurate and not necessarily indicative of poor stream quality, rather higher elevation and coldwater habitat that is less speciose. In fact, across the primary watershed sites, elevation was inversely relate to IBI score and explained 82% of the variation in scores in each watershed ($p < 0.05$, $R^2 = 0.82$). IBI within site variation was negligible ranging from 0-4 points (Figure 1). These scores provide a good baseline for each site and indicate the scores should change very little from year to year unless major species assemblage changes occur.

The low variability of IBI scores within sites and the minimal anthropogenic impacts to these sites will allow for less frequent revisit intervals than at 3-pass sites in the upper watershed. The influence of acid deposition, drought and flood events in the upper elevations of the watershed are more severe and create greater fluctuations in year class strength than at lower elevations. The fish population drivers in GRSM watersheds suggest changes will occur more rapidly at mid- to high-elevation 3-pass sites than low elevation IBI sites. These attributes support the decision to revisit the lower elevation IBI sites on a 3-year rotation versus the mid- to high-elevation 3-pass sites on an annual basis (Table 4).

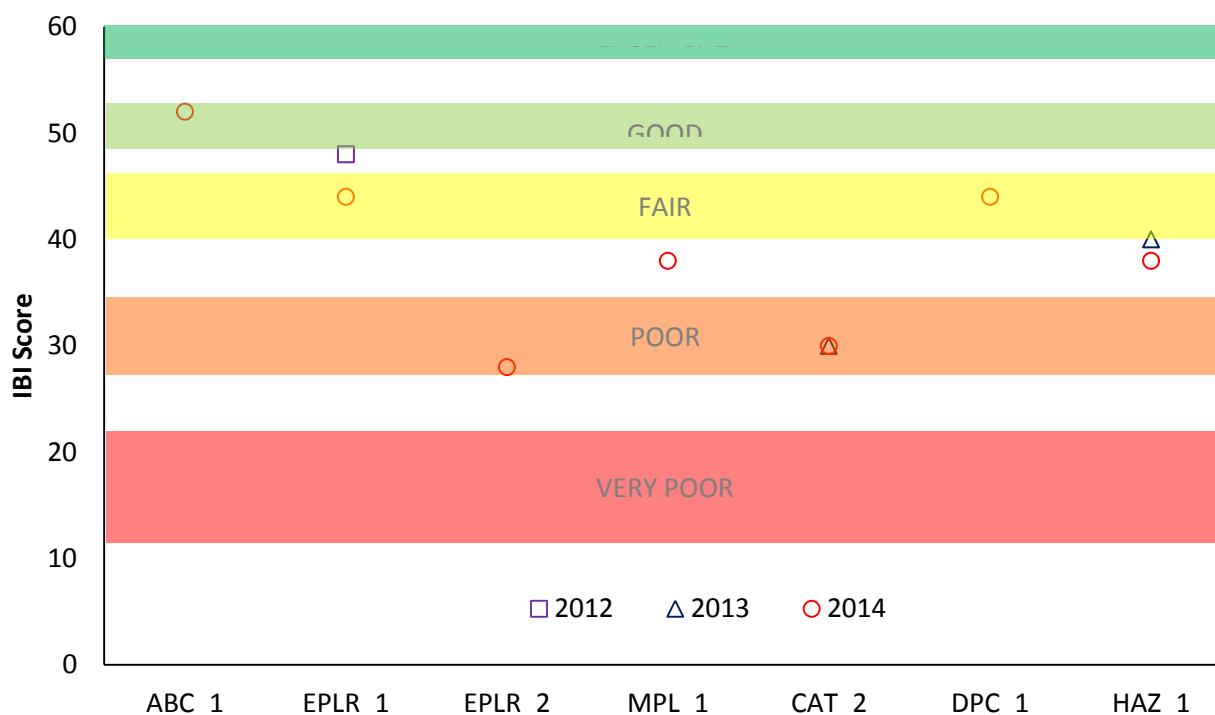


Figure 3.—Index of Biotic Integrity (IBI) scores for six streams in Great Smoky Mountains National Park. Site codes refer to Abrams Creek (ABC), East Prong Little River (EPLR), Middle Prong Little Pigeon River (MPLP), Cataloochee Creek (CAT), Deep Creek (DPC) and Hazel Creek (HAZ) (Table 1). The Blue Ridge Stream metric was used as the scoring metric for all IBI scoring (Table 3).

Fish Communities (3-Pass Depletion): Three-pass depletion monitoring was conducted at 11 sites on 8 Vital Sign streams in 2014. In three of the eleven sites, ten years of monitoring data were available, which afforded the opportunity to present the trend data using control charts. Control charts, developed for industrial applications, indicate when a system is going ‘out of control’, by plotting through time some measure of a stochastic process with reference to its expected value (e.g., Beauregard et al. 1992; Gyrya 2001; Montgomery 2001). Control charts may be univariate or multivariate, and can represent many different types of variables. Control charts have been applied to ecological data (McBean and Rovers 1998; Manly 2001), including fish communities (Pettersson 1998; Anderson and Thompson 2004) and natural resources within the Inventory and Monitoring program (Atkinson et al. 2003). Control charts contain upper and lower control limits specifying thresholds beyond which variability in the indicator reveals a biologically important change is occurring, and warns that management may need to act. Control charts present the annual abundance values (density or biomass), mean of population abundance and lower (LCL) and upper (UCL) confidence limits. Control limits can be set to any desired level, however for our data were calculated as ± 3 times the standard error (SE) of the mean. For the remaining eight sites, biomass by species will be reported annually until ten years of data are available to generate control charts.

Quantitative field surveys indicated that adult brook trout biomass ranged from 2.8-14.3 kg/ha (9.4-44.0 kg/ha total sympatric trout biomass) across sympatric populations and 12.3-37.7 kg/ha in allopatric populations (Table 5). Total carrying capacity for salmonids in most GRSM streams ranges from 10-44 kg/ha. Streams such as Cosby Creek (COS_2) with average pH of 6.30 (Std Dev=0.22) have higher carrying capacities than streams such as Rock Creek (site 137) that have mean pH of 5.86 (Std Dev=0.24). The biomass of age-0 or YOY brook trout was slightly below average in Cosby, Rock Creek and in most GRSM streams due to high flows between January and May 2014 that impacted fall spawning success (Figures 3 & 4). Species abundance patterns were similar in the eight sympatric sites as well where cumulative biomass was reported (Figures 5 & 6). Note that where found, brown trout typically represent $\leq 15\%$ of the overall population (Figures 5 & 6). Also note that timing of major flood events ($>1,000\text{ft}^3/\text{second}$) timed either during or in the three months following spawning, typically result in poor year class production in GRSM streams. These rainfall and high flow patterns do not always impact all species in sympatric equally due to differential spawning seasons (brook trout fall spawn, rainbow trout spring spawn). For example, poor brook trout year classes were observed in 2009 and 2013, whereas poor rainbow trout year classes were observed in 2008, 2009 and 2014 (Figure 6).

Figure 3. — Control chart of young-of-year (YOY) and adult brook trout biomass in Cosby Creek between 2005 and 2014. Note mean represents 10 years of data during collection period. Lower confidence limit (LCL) and upper confidence limit (UCL) are 3 standard errors (SE) below and above the mean. Values outside of the LCL (and UCL) are considered outliers and should be examined more carefully.

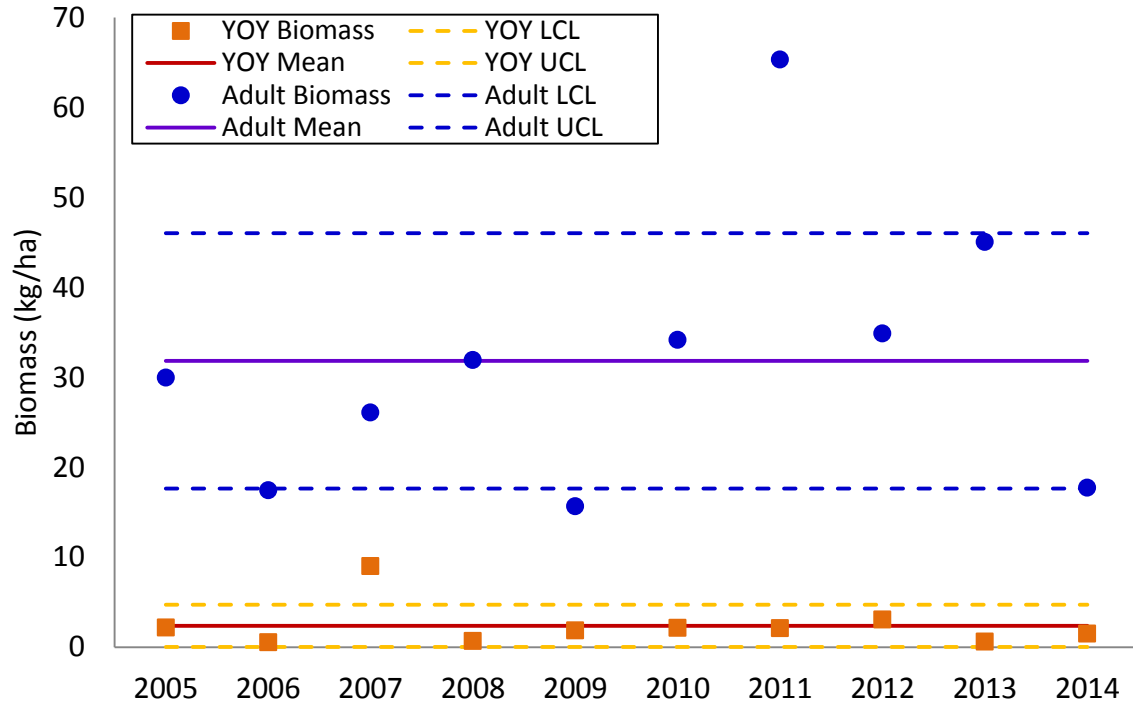


Figure 4. — Control chart of young-of-year (YOY) and adult brook trout biomass in Rock Creek between 2005 and 2014. Note mean represents 10 years of data during collection period. Lower confidence limit (LCL) and upper confidence limit (UCL) are 3 standard errors (SE) below and above the mean. Values outside of the LCL (and UCL) are considered outliers and should be examined more carefully.

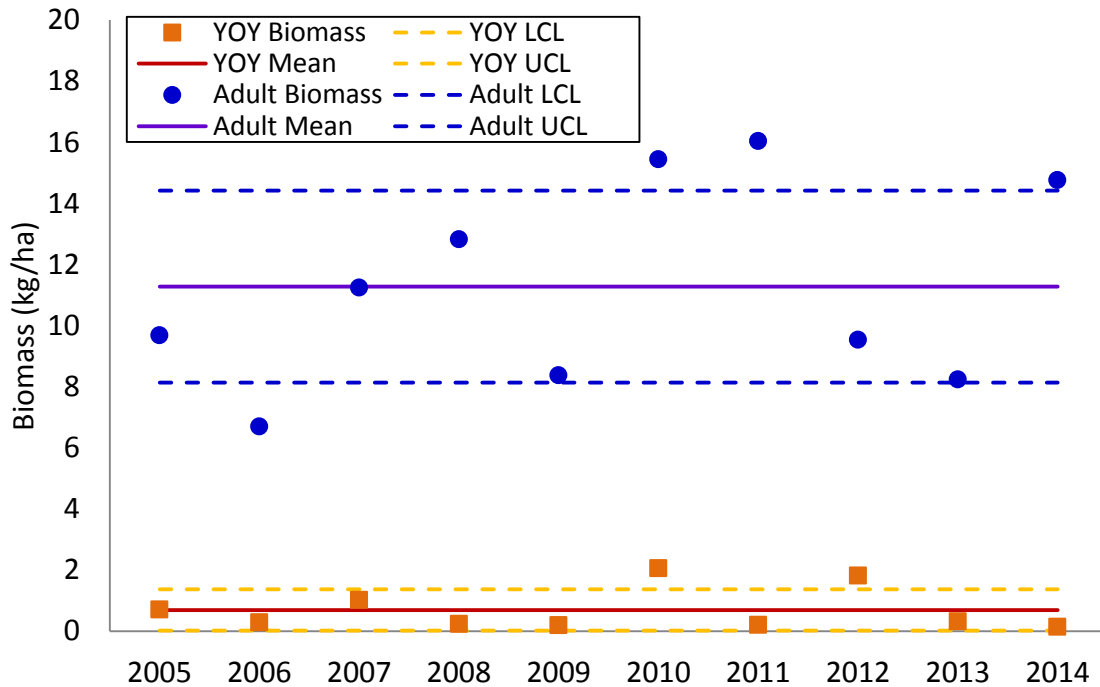


Figure 5.—Annual biomass of four fish species sampled in Bone Valley Creek in 2010, 2013 and 2014 within Great Smoky Mountains National Park. Note that blacknose and longnose dace biomass represents total biomass of all individuals.

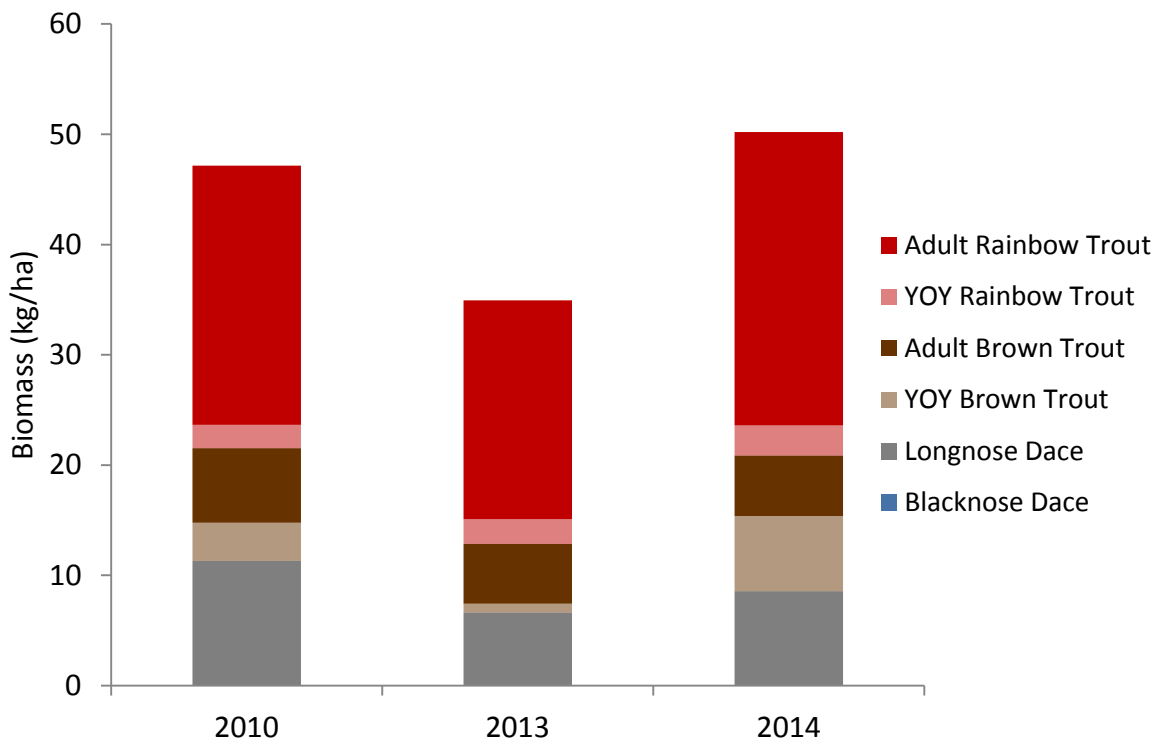
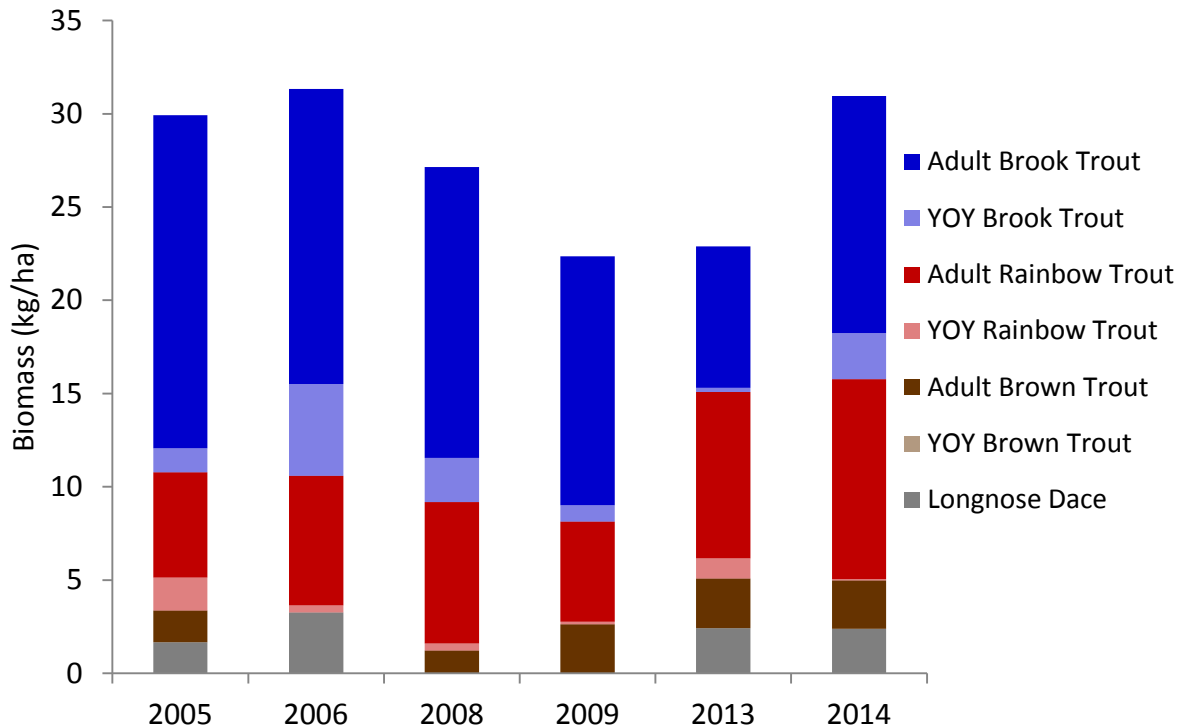


Figure 6.—Annual biomass of four fish species sampled various years in Hazel Creek between 2005 and 2014 within Great Smoky Mountains National Park. Note that longnose dace biomass represents total biomass of all individuals.



Water Quality Monitoring: The Great Smoky Mountains (GRSM) National Park annual Water Quality (WQ) Monitoring Program consists of: 1) detailed hydrologic and WQ monitoring at Noland Divide, a high-elevation forested site, and 2) Park-wide stream survey monitoring. This report gives a summary of all data collected for the GRSM monitoring program, from 1991 through the current year 2013. The annual mean pH of precipitation samples collected at the Noland Divide site was 5.34 for throughfall (TF) and 5.27 for Open Site (OS) wet deposition only. Precipitation pH at these two sites has been trending upward since 2007; prior to that year TF pH remained below 4.4 and OS pH below 4.0. Annual sulfate deposition loads at Noland Divide in post-2008 years (< 700 eq/ha/yr) have been consistently less than in pre-2008 years (>1,100 eq/ha/yr) (Figure 6). In 2013, TF sulfate deposition was 695 eq/ha/yr. Evidence indicates that reduction in sulfate deposition likely has resulted from emission reductions at two coal-fired power plants within 100 miles of the GRSM. The 2013 TF data represented a continuation of a generally decreasing trend since 2008 in deposited total inorganic nitrogen (T.I.N.) below 900 eq/ha/yr (Figure 7). In 2013 T.I.N. for TF was measured at 344 eq/ha/yr. In general during this period since 2008, ammonium represented a greater portion of T.I.N, which is converted by soil microbes to nitrate through mineralization and nitrification resulting in increased acidity. However, soil pH in the upper horizon for 2013 was observed to generally be higher than long-term measurements. Soil water chemistry data is highly variable over time and needs additional analysis. Overall in 2013, sulfate, nitrate, and base cations were lower in soil water

concentrations than historic measurements. Streams at Noland Divide had an average pH of 5.81 and 6.01 for the NE and SW streamlets, respectively, and remain in an acidified condition with acid neutralizing capacity (ANC) averaging 11.4 and 20.3 $\mu\text{eq/L}$ for the NE and SW streamlets, respectively. Among the Park-wide stream survey sites, 21 of the 197 samples collected during 2013 had a pH of less than 6.0, and eleven samples had a pH less than 5.5 (a toxic threshold impairing trout growth). Seven samples had dissolved aluminum concentrations greater than or equal to 0.2 mg/L, a known toxic threshold for that metal. The locations where these exceedances occur appear to be associated with alumino-silicate mineral weathering from soils, resulting in leaching of dissolved metals into adjacent streams. In 2013, the mean pH was > 6.0 in all monitored streams Park-wide; however, each watershed has unique factors (i.e., bedrock geology, soil, and vegetation) that greatly influence biogeochemistry processes, thus the fate of acid pollutants entering the GRSM and transport to the streams. Park-wide data from both monitoring programs provide critical information to assess aquatic resource health. It also supports BGC-Pn-ET model calibration and verification for estimating critical acid deposition loads, and predicting possible recovery trends.

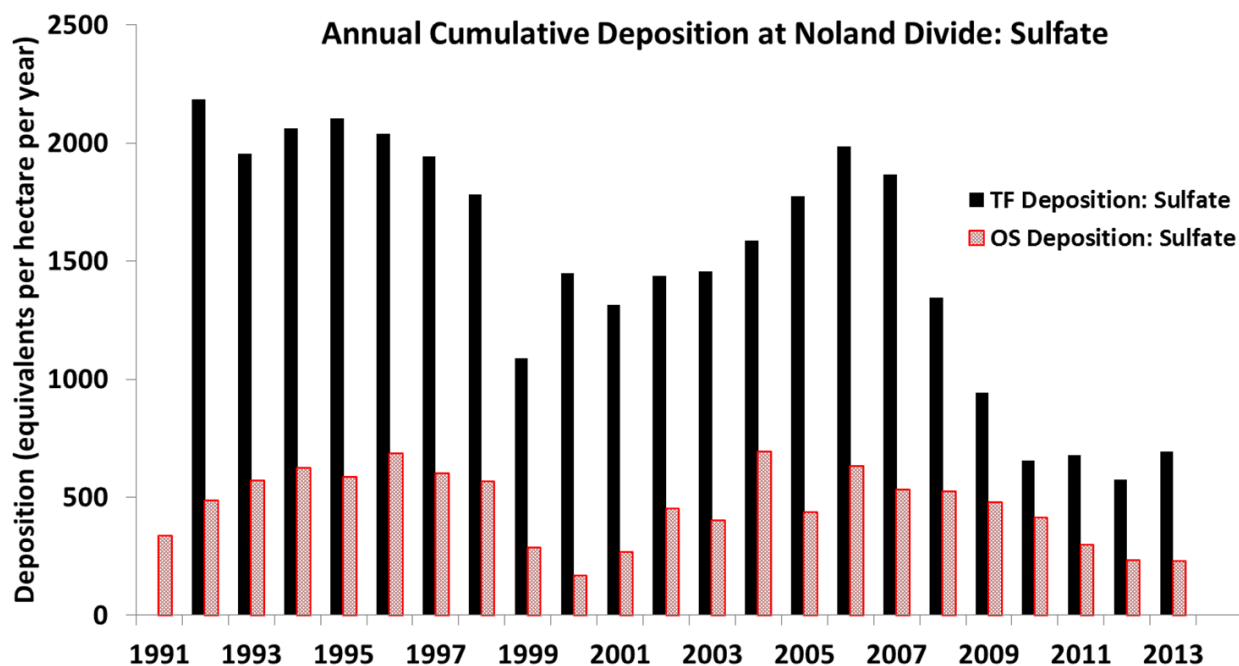


Figure 6. — Total sulfate (in equivalents per hectare per year; eq/ha/yr) entering NDW via precipitation measured at TF and OS. Sampling in 1991 began mid-year; those data do not represent the entire year.

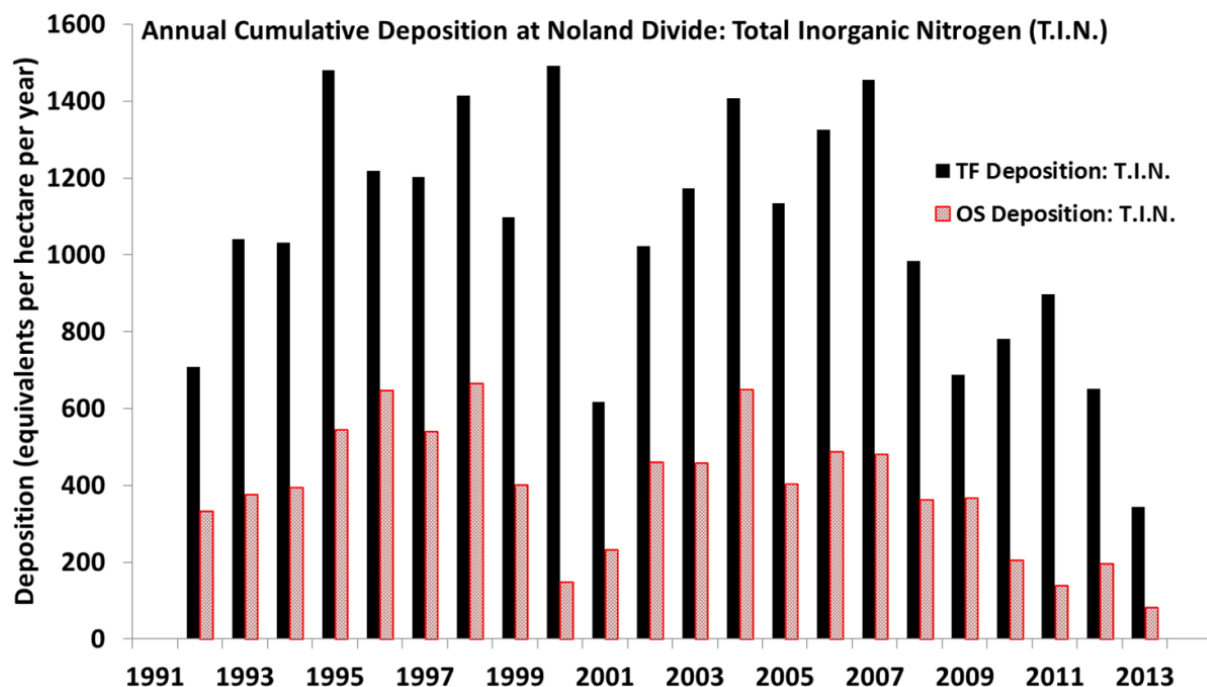


Figure 7. — Total inorganic nitrogen (nitrate + ammonium; eq/ha/yr) entering NDW via precipitation measured at TF and OS. Sampling in 1991 began mid-year; those data do not represent the entire year.

REPORTING

- Freshwater Communities:** Two reports were submitted and accepted for the Natural Resource Technical Report Series. One was an annual summary report of water quality monitoring results from the high elevation Noland Divide watershed input/output budget and park wide base flow water quality monitoring (<https://irma.nps.gov/App/Reference/Profile/2216084>). The second report was a summary of the first phase of critical load determinations for 12 streams in GRSM based upon the PnET-BGC model (<https://irma.nps.gov/App/Reference/Profile/2214370>).

2015 Vital Sign Implementation

In 2015, IBI and three-pass depletion sample sites will be established in MP Little Pigeon River and Deep Creek. All fish vital sign sites will be established and sampled in MP Little Pigeon River and Deep Creek watersheds in 2015. Bi-monthly water quality monitoring will continue in the initial four watersheds and will begin in the MP Little Pigeon River and Deep Creek watersheds in July 2015.

References

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- Pettersson, M. 1998. Monitoring a freshwater fish population: Statistical surveillance of biodiversity. *Environmetrics* 9:139-150.

Figure 1. — Historic water quality monitoring sites sampled bi-monthly between January and May 2014. Historic water quality monitoring sites are shown in green and new vital sign primary (pink) and secondary (light blue) watersheds are shown for reference.

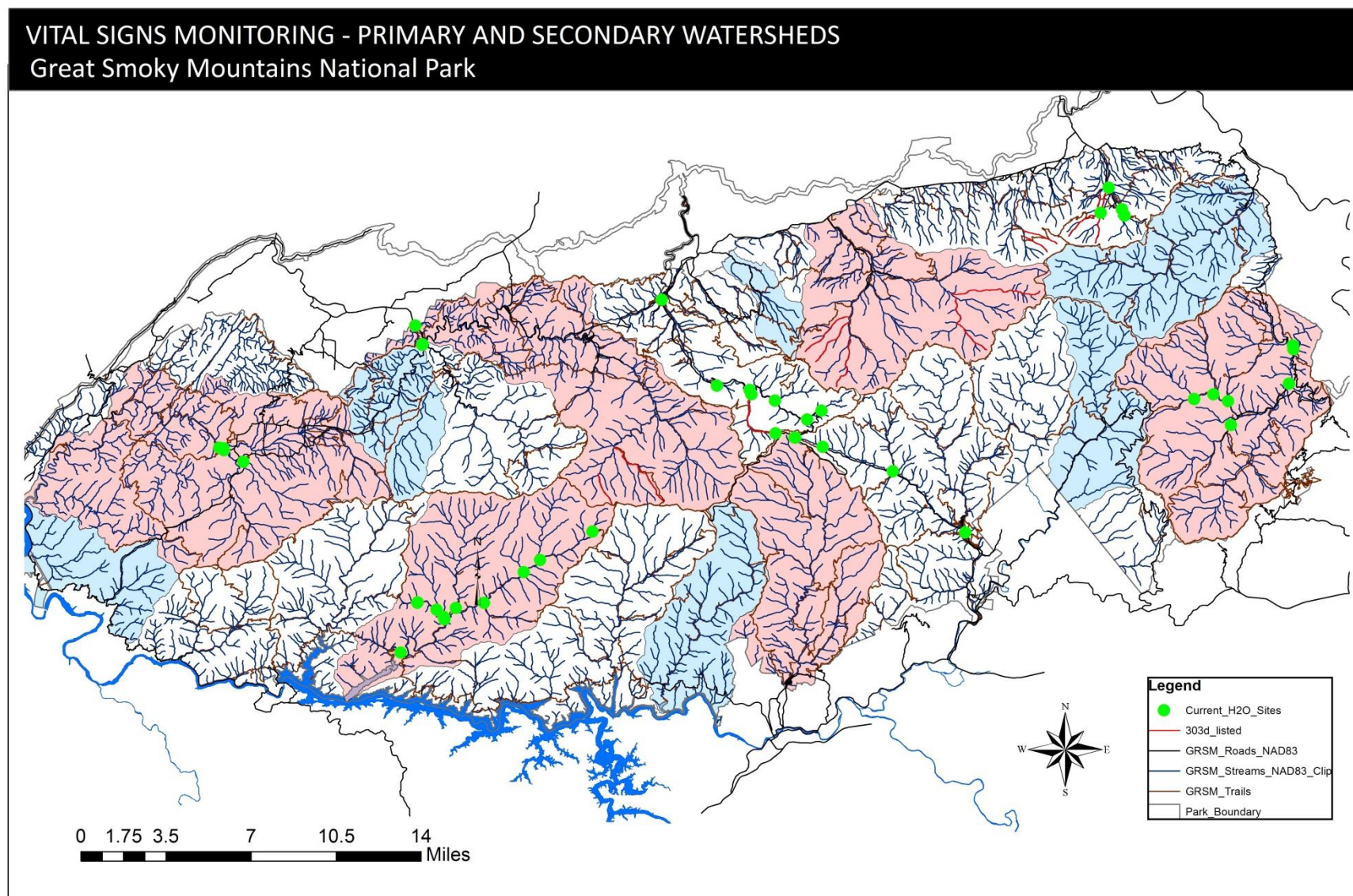


Figure 2. — New vital sign water quality monitoring sites sampled bi-monthly between July November 2014. Water quality in the primary watersheds (pink) were sampled in 2014, however Middle Prong and Deep Creek watersheds (orange) were not sampled in 2014. Note that water quality sample sites shown in two orange watersheds are tentative until ground-truthed.

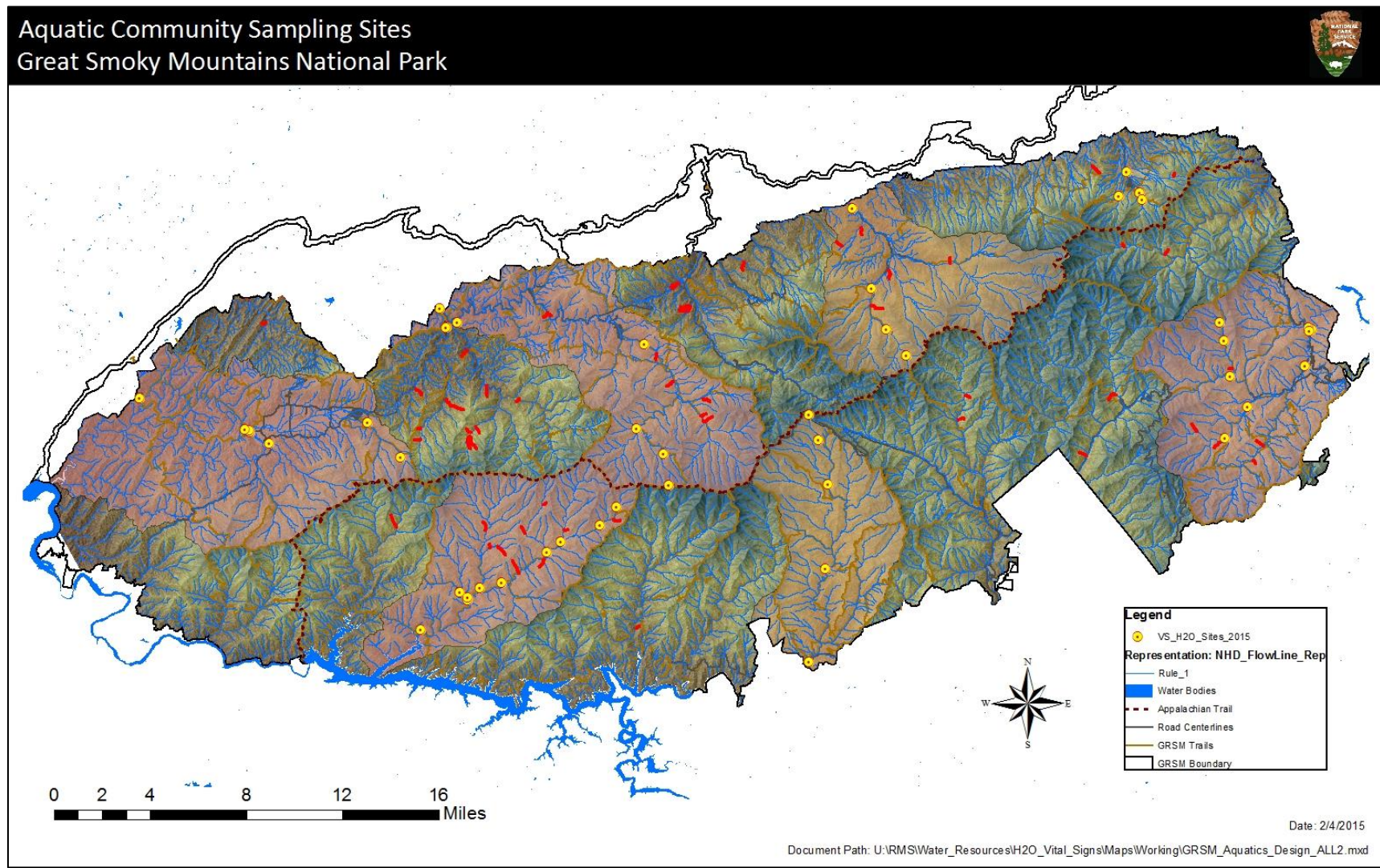


Figure 7.— Stream water temperature data collected between 1 March 2012 and 10 February 2015 at the Little River USGS gaging station (http://waterdata.usgs.gov/tn/nwis/uv/?site_no=03497300) located at the Park boundary within Great Smoky Mountains National Park (GRSM). Data represented are 15-minute data over the study period.

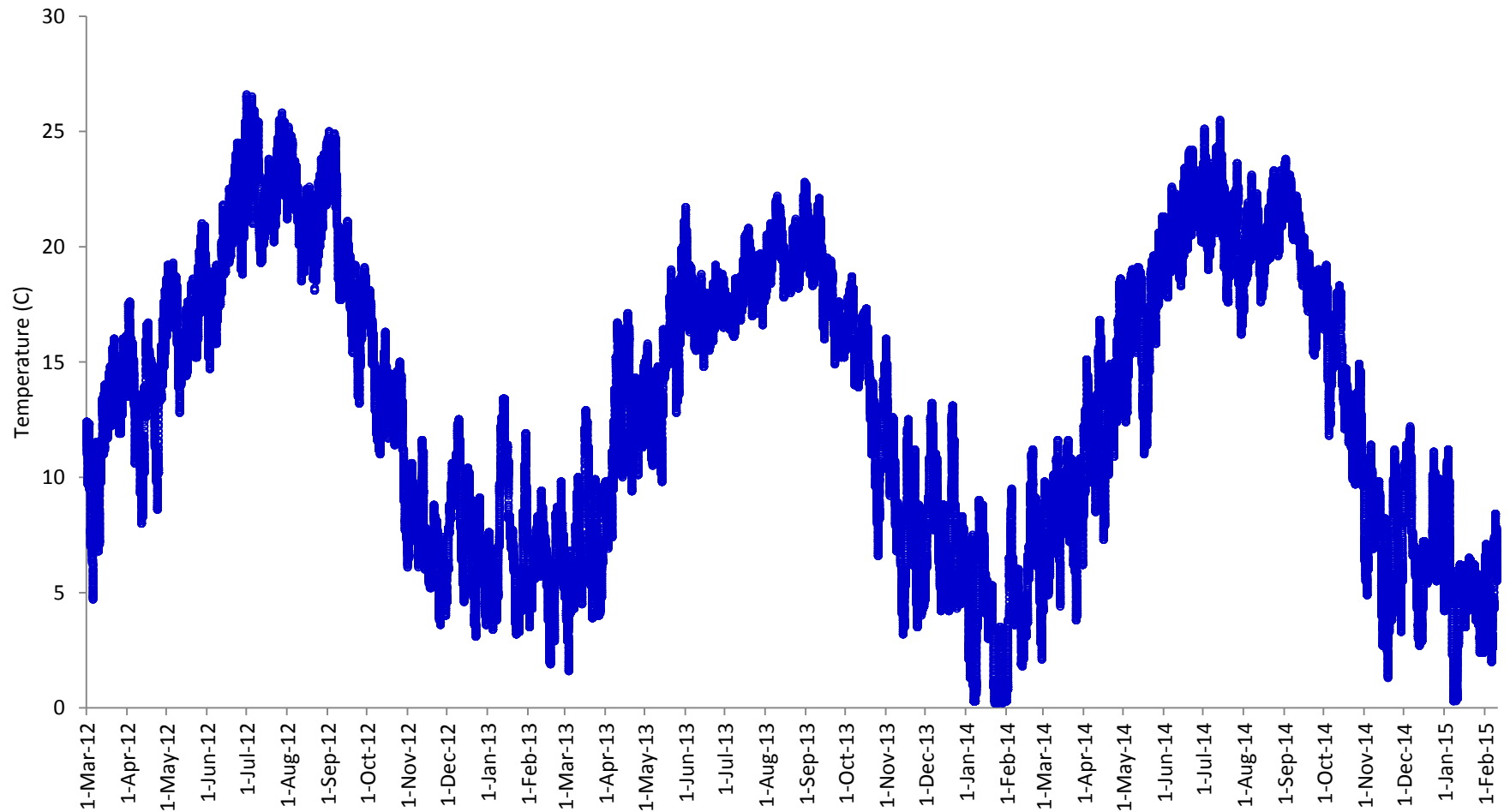


Table 1. — List of water quality sites where water quality samples were collected during 2014.

Watershed	Site Number	Stream Name	Elevation (feet)	UTM-E	UTM-N	Fish Sampling	Jan	Mar	May	Jul	Sep	Nov
Abrams Creek	ABC_1 (156)	Abrams Creek	1,095	234145.1	3944546.3	IBI				X	X	X
	173	Mill Creek	1,702	241449.0	3942139.0		X	X	X	X	X	X
	174	Abrams Creek	1,702	241490.0	3942219.0		X	X	X	X	X	X
	488	Mill Creek	1,791	243151.0	3941241.0		X	X	X	X	X	X
	489	Abrams Creek	1,709	241408.0	3942175.0		X	X	X	X	X	X
	ABC_2 (423)	Anthony Creek	2,096	249424.7	3942882.4	3-Pass				X	X	X
	ABC_3 (200)	Anthony Creek	3,307	251618.9	3940581.9	3-Pass				X	X	X
Little River	13	Little River	1,099	254281.0	3950270.0		X	X	X	X	X	X
	EPLR_1 (14)	East Prong Little River	1,147	255391.3	3949598.1	IBI				X	X	X
	23	Middle Prong Little River	1,148	254669.0	3949114.0		X	X	X	X	X	X
	24	West Prong Little River	1,148	254624.0	3949021.0		X	X	X	X	X	X
	EPLR_2 (40)	East Prong Little River	2,307	267886.7	3948163.1	IBI				X	X	X
	EPLR_3 (213)	East Prong Little River	3,316	267414.7	3942469.4	3-Pass				X	X	X
	EPLR_4	East Prong Little River	4,158	269203.3	3940819.8	3-Pass				X	X	X
	EPLR_5 (220)	East Prong Little River	5,496	269573.2	3938739.9	No Fish				X	X	X
Hazel Creek	221	Hazel Creek	3,998	265848.0	3936490.0			X				
	224	Hazel Creek	2,998	261476.0	3934250.0			X			X	
	HAZ_2 (310)	Bone Valley Creek	2,287	256885.0	3931580.0	3-Pass		X			X	
	311	Hazel Creek	2,188	256076.0	3930780.0			X			X	
	HAZ_1 (479)	Hazel Creek	1,738	253245.0	3928614.0	IBI		X			X	
	480	Sugar Fork	2,184	256090.0	3931024.0			X			X	
	481	Little Fork	2,380	254333.0	3931940.0			X				
	482	Sugar Fork	2,539	254311.0	3931919.0			X				
	483	Sugar Fork	2,319	255541.0	3931564.0			X			X	
	484	Hazel Creek	2,473	258786.0	3931903.0			X				
	485	Walker Creek	2,860	261409.0	3933962.0			X			X	
	HAZ_3 (222)	Hazel Creek	3,622	264972.9	3936058.0	3-Pass					X	

	HAZ_4	Hazel Creek	4,200	266050.2	3937281.6	3-Pass				X		
Cataloochee Creek	CAT_4 (130)	Onion Bed Branch	4,157	306400.0	3949585.0	3-Pass				X	X	X
	142	Beech Creek	3,337	305724.0	3945480.0		X	X	X			
	143	Lost Bottom Creek	3,323	305748.0	3945540.0		X	X	X			
	144	Palmer Creek	3,008	307133.0	3945972.0		X	X	X	X	X	X
	CAT_2 (147)	Cataloochee Creek	2,454	312396.0	3949005.0	IBI	X	X	X	X	X	X
	148	Little Cataloochee Creek	2,473	312374.0	3949020.0		X	X	X	X	X	X
	149	Cataloochee Creek	2,549	312075.0	3946490.0		X	X	X	X	X	X
	CAT_3 (286)	Bear Branch	3,068	306743.3	3941839.0	3-Pass				X	X	X
	293	Rough Fork	3,068	306743.3	3941839.0		X	X	X	X	X	X
	493	Palmer Creek	2,840	308073.0	3945282.0		X	X	X			
	PTH-1	Pretty Hollow	3,560	306712.0	3948353.0					X	X	X
West Prong Little Pigeon River	30	West Prong Little Pigeon River	1,430	270435.0	3952120.0		X	X	X			
	66	West Prong Little Pigeon River	2,680	274082.0	3946370.0		X	X	X			
	71	Road Prong	3,480	276295.0	3946000.0		X	X	X			
	73	Walker Camp Prong	3,360	276235.0	3946180.0		X	X	X			
	74	Walker Camp Prong	3,820	278028.0	3945370.0		X	X	X			
	233	Walker Camp Prong	4,240	278939.0	3944640.0		X	X	X			
	234	Road Prong	5,000	278028.0	3943220.0		X	X	X			
	237	Walker Camp Prong	4,510	281138.0	3944790.0		X	X	X			
Oconaluftee River	268	Oconaluftee River	2,170	290458.0	3936860.0		X	X	X			
	270	Beech Flats Prong	2,800	286292.0	3940370.0		X	X	X			
	251	Beech Flats Prong	4,010	281187.0	3942310.0		X	X	X			
	252	Beech Flats Prong	4,760	279516.0	3942840.0		X	X	X			
	253	Beech Flats Prong	4,840	279409.0	3942860.0		X	X	X			
Cosby Creek	4	Rock Creek	1,679	300164.1	3959698.8		X	X	X	X	X	X
	114	Cosby Creek	2,509	301041.3	3958266.4		X	X	X	X	X	X
	137	Rock Creek	2,749	299625.9	3958027.2		X	X	X	X	X	X
	492	Camel Hump Creek	2,729	301214.3	3957833.2		X	X	X	X	X	X
Deep Creek	DPC_1	Deep Creek	1,802	278933.0	3926880.0	IBI						

Middle Prong Little Pigeon River	MPL_1	Middle Prong Little Pigeon River	1,373	281805.9	3957230.0	IBI
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Table 2. — Locations of HOBO temperature loggers placed in four of the six vital signs monitoring watersheds.

Unit Number	Type	Model Number	Elevation (ft)	UTM-E	UTM-N	Location
2	HOBO Water Temp Pro V2	U22-001		234178.898	3944227.59	Abrams Creek- Located approx. 30m upstream of horse crossing on Rabbit Creek Trail on large sycamore rootball cable is wrapped around base of tree
3	HOBO Water Temp Pro V2	U22-001		271714.319	3957374.86	MPLPR- Is located approx. 50m down from lower end of second parking lot is on a large sycamore that has a hollow center on far side of stream.
4	HOBO Water Temp Pro V2	U22-001		279544.220	3928251.782	Deep Creek- is located at base of bridge just above Indian Creek confluence. Cable is wrapped around rocks on the upstream side of the bridge
5	HOBO Water Temp Pro V2	U22-001		253035.382	3928986.872	Hazel Creek- is located on the upstream side of center pillar of the bridge at the Calhoun house

Table 3.— Biotic integrity classes for Blue Ridge streams used in assessing fish communities along with general descriptions of their attributes (Karr et al. 1986).

Class	Attributes	IBI Range
Excellent	Comparable to the best situations without influence of man; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.	58-60
Good	Species richness somewhat below expectation, especially due to loss of most intolerant forms; some species with less than optimal abundances or size distribution; trophic structure shows some signs of stress.	48-52
Fair	Signs of additional deterioration include fewer intolerant forms, more skewed trophic structure (e.g., increasing frequency of omnivores); older age classes of top predators may be rare.	40-44
Poor	Dominated by omnivores, pollution-tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.	28-34
Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.	12-22
No fish	Repetitive sampling fails to turn up any fish.	

Table 4. — Fish species collected during annual fish Index of Biotic Integrity (IBI) surveys within Great Smoky Mountains National Park in 2014. Note for each site, the total number of collected for each species is listed in the table.

FAMILY	COMMON NAME	SCIENTIFIC NAME	ABC_1 2014	CAT_2 2013	CAT_2 2014	DPC_1 2014	HAZ_1 2013	HAZ_1 2014	LRV_2 2014	LRV_1 2012	LRV_1 2014	MPLR_1 2014
Percidae	Banded Darter	<i>Etheostoma zonale</i>	19								2	
Percidae	Greenfin Darter	<i>Etheostoma chlorobranchium</i>	63			14	3	6				9
Percidae	Redline Darter	<i>Etheostoma rufilineatum</i>	144							39	19	3
Percidae	Tennessee Darter	<i>Etheostoma tennesseense</i>	11							5	3	6
Percidae	Tuckasegee Darter	<i>Etheostoma gutselli</i>				1	11	14				
Percidae	Olive Darter	<i>Percina squamata</i>						1				
Percidae	Greenside Darter	<i>Etheostoma blennioides</i>								3	6	
Percidae	Tangerine Darter	<i>Percina aurantiaca</i>								3		
Percidae	Wounded Darter	<i>Etheostoma vulneratum</i>								1	5	
Percidae	Gilt Darter	<i>Percina evides</i>									1	
Percidae	Fantail Darter	<i>Etheostoma flabellare</i>										9
Percidae	Swannanoa Darter	<i>Etheostoma swannanoa</i>										9
Cyprinidae	Bigeye Chub	<i>Hybopsis amblops</i>	12							1	28	
Cyprinidae	Central Stoneroller	<i>Camptostoma anomalum</i>	41	8	4	6	4	3		8	26	76
Cyprinidae	River Chub	<i>Nocomis micropogon</i>	18				46	28		10	25	1

Cyprinidae	Telescope Shiner	<i>Notropis telescopus</i>	102				16			21	1	2
Cyprinidae	Tennessee Shiner	<i>Notropis leuciodus</i>	29				42	63		83	91	86
Cyprinidae	Warpaint Shiner	<i>Luxilus coccogenis</i>	9				16	23		35	44	
Cyprinidae	Whitetail Shiner	<i>Cyprinella galactura</i>	24								3	
Cyprinidae	Longnose Dace	<i>Rhinichthys cataractae</i>		75	68	38	7	15	12			11
Cyprinidae	Blacknose Dace	<i>Rhinichthys atratulus</i>				8						
Cyprinidae	Rosyside Dace	<i>Clinostomus funduloides</i>				5	4					
Cyprinidae	Saffron Shiner	<i>Notropis rubricroceus</i>										21
Catastomidae	Golden Redhorse	<i>Moxostoma erythrurum</i>	7									
Catastomidae	Northern Hogsucker	<i>Hypentelium nigricans</i>	14	4	7	21	4	6		2	1	2
Catastomidae	White Sucker	<i>Catostomus commersonii</i>				1						
Catastomidae	Unidentified Redhorse spp.	<i>Moxostoma sp.</i>								1		
Centrarchidae	Rock Bass	<i>Ambloplites rupestris</i>	6									
Centrarchidae	Smallmouth Bass	<i>Micropterus dolomieu</i>	13				1	1		5	2	
Centrarchidae	Largemouth Bass	<i>Micropterus salmoides</i>					2					
Centrarchidae	Bluegill	<i>Lepomis macrochirus</i>				5	2					
Salmonidae	Brown trout	<i>Salmo trutta</i>		9	10	22			2			3
Salmonidae	Rainbow trout	<i>Oncorhynchus mykiss</i>		13	14	41			32	1		

Salmonidae	Brook trout	<i>Salvelinus fontinalis</i>			1							
Cottidae	Mottled sculpin	<i>Cottus bairdii</i>				137	78	103	49	20	22	
Cottidae	Banded sculpin	<i>Cottus carolinae</i>								9	12	70
Petromyzontidae	Mountain brook lamprey	<i>Ichthyomyzon greeleyi</i>				5						

Table 5. — Fish sampling sites included in the Great Smoky Mountains National Park (GRSM) vital signs monitoring program. Sites are listed by watershed and include fish sampling technique and sampling schedule from 2012-2020. Note sites with an ‘*’ are sampled annually as part of the Southeast Monitoring Network (SEMN) sampling program. Sites with ‘**’ will be ground truthed in 2015, 2016 and 2017 as these watersheds are added to the sampling design.

Watershed	Site Number	Stream Name	Elev. (feet)	UTM-E	UTM-N	Fish Sampling	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cataloochee Creek	CAT_2 (147)*	Cataloochee Creek	2,454	312396	3949005	IBI		X	X	X	X	X	X	X	X
Cataloochee Creek	CAT_3 (286)	Rough Fork	3,068	306743	3941839	3-Pass			X	X	X	X	X	X	X
Cataloochee Creek	PTH-1	Pretty Hollow	3,560	306712	3948353	3-Pass				X	X	X	X	X	X
Cataloochee Creek	CAT_4 (130)	Onion Bed Branch	4,157	306400	3949585	3-Pass				X	X	X	X	X	X
Deep Creek	DPC_1	Deep Creek	1,780	278933	3926880	IBI			X	X			X		
Deep Creek	DPC_2 (DPC-16)	Deep Creek	2,000	280000	3930033	IBI				X			X		
Deep Creek	DPC_3 (DPC 1D)	Deep Creek	3,870	279884	3941111	3-Pass				X	X	X	X	X	X
Deep Creek	DPC_4 (DPC 3D)	Deep Creek	4,050	279589	3941530	3-Pass				X	X	X	X	X	X
Hazel Creek	HAZ_1 (479)	Hazel Creek	1,738	253245	3928614	IBI		X	X		X			X	
Hazel Creek	HAZ_2 (310)	Bone Valley Creek	2,287	256885	3931580	3-Pass		X	X	X	X	X	X	X	X
Hazel Creek	HAZ_3 (222)	Hazel Creek	3,622	264973	3936058	3-Pass		X	X	X	X	X	X	X	X
Hazel Creek	HAZ_4	Hazel Creek	4,200	266050	3937282	3-Pass			X	X	X	X	X	X	X
Abrams Creek	ABC_1 (156)	Abrams Creek	1,095	234145	3944546	IBI			X			X			X
Abrams Creek	ABC_2 (423)	Anthony Creek	2,096	249425	3942882	3-Pass			X	X	X	X	X	X	X
Abrams Creek	ABC_3 (200)	Anthony Creek	3,307	251619	3940582	3-Pass				X	X	X	X	X	X

East Prong Little River	EPLR_1 (14)	East Prong Little River	1,147	255391	3949598	IBI	X		X		X			X	
East Prong Little River	EPLR_2 (40)*	East Prong Little River	2,307	267887	3948163	IBI	X		X	X	X	X	X	X	X
East Prong Little River	EPLR_3 (213)	Goshen Prong	3,316	267415	3942469	3-Pass			X	X	X	X	X	X	X
East Prong Little River	EPLR_4	Goshen Prong	4,158	269203	3940820	3-Pass			X	X	X	X	X	X	X
Middle Prong Little Pigeon River	MPL_1	Middle Prong Little Pigeon River	1,373	281806	3957230	IBI			X	X			X		
Middle Prong Little Pigeon River	MPL_2 (CAN 1D)	Cannon Creek	2,420	282893	3951119	3-Pass	X		X	X	X	X	X	X	X
Middle Prong Little Pigeon River	MPL_3	Buck Fork	3,010	289820	3952660	3-Pass				X	X	X	X	X	X
Cosby Creek	4	Rock Creek	1,679	300164	3959699	3-Pass	X	X	X	X	X	X	X	X	X
Cosby Creek	114	Cosby Creek	2,509	301041	3958266	3-Pass	X	X	X	X	X	X	X	X	X
Cosby Creek	137	Rock Creek	2,749	299626	3958027	3-Pass	X	X	X	X	X	X	X	X	X
Big Creek	BIG_1**	Big Creek	1,558	309739	3959479	IBI				X			X		
Noland Creek	NOL_1**	Noland Creek	1,776	270615	3926366	IBI					X			X	
Straight Fork Creek	STR_1**	Straight Fork Creek				IBI						X			X
Roaring Fork Creek	RFC_1**	Roaring Fork Creek				3-Pass	X			X	X	X	X	X	X
Tabcat Creek	TAB_1**	Tabcat Creek				IBI					X			X	
West Prong Little River	24**	West Prong Little River	1,148	254624	3949021	IBI						X			X

Table 6. — Results of 3-pass depletion fish sampling at eleven sites in the Great Smoky Mountains National Park (GRSM) vital signs monitoring program.

Stream	Species	Date	Site	Area	Population Estimate			Density (# fish/100m ²)			Mean Weight (g)			Biomass (kg/ha)		
					YOY	Adult	Total	YOY	Adult	Total	YOY	Adult	Total	YOY	Adult	Total
Anthony Creek	Rainbow Trout	6/16/2014	2	554.3	54	45	76	9.7	8.1	13.7	1.4	52.0	32.3	1.4	42.2	44.3
Bone Valley	Blacknose Dace	9/8/2014	3	1188.6			2	0.0	0.0	0.2			1.4	0.0	0.0	0.0
Bone Valley	Brown Trout	9/8/2014	3	1188.6	81	5	85	6.8	0.4	7.2	10.0	130.0	18.3	6.8	5.5	13.1
Bone Valley	Longnose Dace	9/8/2014	3	1188.6			108	0.0	0.0	9.1			9.4	0.0	0.0	8.5
Bone Valley	Rainbow Trout	9/8/2014	3	1188.6	54	42	95	4.5	3.5	8.0	6.0	75.4	38.7	2.7	26.6	30.9
Cannon Creek	Rainbow Trout	6/11/2014	1	577.6	8	6	14	1.4	1.0	2.4	0.5	57.7	29.1	0.1	6.0	7.1
Cosby Creek	Brook Trout	6/3/2014	2	692.8	62	34	92	8.9	4.9	13.3	1.7	36.1	15.3	1.5	17.7	20.3
Goshen Prong	Brook Trout	7/14/2014	3	518.6	20	4	24	3.9	0.8	4.6	2.9	20.4	6.0	1.1	1.6	2.8
Goshen Prong	Longnose Dace	7/15/2014	3	518.6			52	0.0	0.0	10.0			8.2	0.0	0.0	8.2
Goshen Prong	Rainbow Trout	7/16/2014	3	518.6	15	10	25	2.9	1.9	4.8	1.3	32.1	13.6	0.4	6.2	6.6
Goshen Prong	Brook Trout	7/15/2014	4	743.9	19	35	54	2.6	4.7	7.3	2.0	25.2	17.0	0.5	11.9	12.3
Hazel Creek	Brook Trout	9/9/2014	4	464.9	90	49	139	19.4	10.5	29.9	3.2	29.7	12.6	6.2	31.3	37.7
Hazel Creek	Brook Trout	9/9/2014	3N	485.5	21	16	39	4.3	3.3	8.0	5.7	38.6	17.8	2.5	12.7	14.3
Hazel Creek	Brown Trout	9/9/2014	3N	485.5		1	1	0.0	0.2	0.2		125.6	125.6	0.0	2.6	2.6
Hazel Creek	Longnose Dace	9/9/2014	3N	485.5			3	0.0	0.0	0.6			38.7	0.0	0.0	2.4
Hazel Creek	Rainbow Trout	9/9/2014	3N	485.5	1	10	11	0.2	2.1	2.3	3.1	52.1	47.6	0.1	10.7	10.8
Rock Creek	Blacknose Dace	6/9/2014	3	404.9			9	0.0	0.0	2.2			6.3	0.0	0.0	1.4
Rock Creek	Brook Trout	6/9/2014	3	404.9	9	20	29	2.2	4.9	7.2	1.9	21.7	15.6	0.4	10.7	11.2
Rock Creek	Longnose Dace	6/9/2014	3	404.9			32	0.0	0.0	7.9			6.8	0.0	0.0	5.4
Rock Creek	Mottled Sculpin	6/9/2014	3	404.9			17	0.0	0.0	4.2			11.9	0.0	0.0	5.0
Rock Creek	Rainbow Trout	6/9/2014	3	404.9	6	1	7	1.5	0.2	1.7	0.3	67.2	9.8	0.0	1.7	1.7
Rock Creek	Brook Trout	6/3/2014	7	634.1	8	37	44	1.3	5.8	6.9	1.1	25.3	22.7	0.1	14.8	15.8

Rough Fork	Brook Trout	7/23/2014	3	589.9	40	9	48	6.8	1.5	0.0	4.0	42.1	11.5	2.7	6.4	0.0
Rough Fork	Brown Trout	7/23/2014	3	589.9	10		10	1.7	0.0	1.7	3.9		3.9	0.7	0.0	0.7
Rough Fork	Longnose Dace	7/23/2014	3	589.9			41	0.0	0.0	7.0			10.9	0.0	0.0	7.6
Rough Fork	Rainbow Trout	7/23/2014	3	589.9	15	16	30	2.5	2.7	5.1	2.5	42.2	26.9	0.6	11.4	13.7