Monitoring the Recovery of the Coal Creek Ecosystem Following the Marshall Fire

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Executive Summary: The 2021 Marshall Fire burn extent overlaps much of the Coal Creek drainage area in Boulder County, CO. Regular monitoring was initiated to assess the potential impacts on Coal Creek and associated riparian area. This study found that the areas impacted by the Marshall Fire had measurably higher values of specific conductivity, turbidity, alkalinity, dissolved organic carbon, chloride, nitrate, total nitrogen, and trace metals compared to an unburned reference location. The benthic invertebrate population at an urban, fire-affected site was found to contain more tolerant organisms and less diversity compared to historical data taken in the same month in 2019. Exceedances of the EPA aquatic life criteria for metals were noted for copper (Cu) and zinc (Zn) at the acute level and for Cu, nickel (Ni), lead (Pb), and Zn on the chronic level. There were 8 instances of acute exceedances for Cu, 30 instances for acute Zn, and 18 instances of chronic exceedances for Cu, 3 instances of chronic exceedances for Ni, 14 instances of chronic exceedances for Pb, and 21 instances of chronic exceedances for Zn. A challenge of the data set is differentiating elevated concentrations due to wildfire versus urban development. Pre-fire data, periphyton results, future sampling offer ways to separate factors.

Deliverables Summary: To date, the project has completed 34 water quality sampling events and analyzed more than 130 samples. Additionally, the project has performed 11 benthic macroinvertebrate surveys and 11 periphyton analyses. Stakeholder meetings were held over zoom on February 18th, March 4th, April 1st, May 6th, June 3rd, July 8th, and September 9th and included representatives from CU Boulder, local municipalities, watershed conservation groups, and other universities. **Potential Management Implications**: • Results will provide baseline data for a wetland restoration project planned for OSMP Superior Associates. • Results will inform protection of northern leopard frog population in the area. • Results from stormwater samples will inform protection measures for future fires.

Abstract

The effects of fire at the wildland-urban interface (WUI) on surface waters pose a serious risk to the health of stream ecosystems and the safety of nearby recreation. The December 30th, 2021, Marshall Fire burn extent overlaps much of the Coal Creek drainage area and the western trailhead of the popular Coal Creek Trail. However, few events of this magnitude have occurred at the WUI. Monitoring of water quality parameters and their effect on stream biota is valuable to identify potential risks to the public and to determine the progress of ecosystem recovery. Common water quality parameters affected by wildfires were monitored in the Coal Creek drainage area beginning directly after the fire through Fall 2022, including turbidity, alkalinity, nutrients (nitrogen species, phosphorous), specific conductivity, pH, and dissolved organic carbon, as well as major and trace metals of potential concern. Additionally, biological parameters including benthic invertebrate diversity and periphyton community composition were analyzed. This study found that total suspended solids, trace and major metal concentrations, and nutrient concentrations were higher in fire-affected reaches of Coal Creek and in a storm drain when compared to the unburned reference location. In some cases, metal concentrations exceeded the EPA aquatic habitat criteria limit at the acute and chronic level. Additionally, the benthic invertebrate population at an urban, fire-affected site was found to be lower in diversity and comprised of more tolerant taxa when compared to historical data. In the diatom communities, teratological forms are occurring at an abundance well exceeding the natural background rate in sampling sites affected by the wildfire. The results of this study may be used to inform watershed restoration projects on OSMP-managed lands including at the Superior Associates Open Space and will help with the protection of the northern leopard frog colony in

the same riparian corridor. Post-fire stormwater analyses will also provide information to assist in future post-fire protective measures for creeks in OSMP-managed areas.

Key Words: Wildfire, wildland-urban interface, water quality

Introduction

Wildfires that occur in forest and grassland landscapes are increasing in frequency and intensity (NIFC, 2021), such that the risk of fire in the WUI is escalating (Radeloff et al., 2018). The impacts of wildfires include the destruction of community infrastructure, the loss of lives, and long-term impacts to terrestrial and aquatic ecosystems (Wang et al., 2018; Fann et al., 2018). Furthermore, fires that occur in the WUI result in potential exposure risks including toxic metal contamination of surface waters (Stein et al., 2012; Burke et al., 2013). The 2021 Marshall Fire was an unprecedented WUI wildfire which destroyed more than a thousand structures in Boulder County, Colorado.

In wildland watersheds, runoff from wildfires can alter watershed processes and cause major changes in surface water quality (Smith et al., 2011). The potential for metals contamination is often a major driver of these impacts, originating from a variety of sources including burned biomass, disturbances to the underlying geology, soil structure, and fires occurring within mining and manufacturing sites (Abraham et al., 2017, Smith et al., 2011). Fire location remains a key consideration, because current and former land use can influence which contaminants are available for transport after a burning event (Odigie and Flegal, 2011). Following a wildfire, rain can mobilize ash, soil, and charred materials, causing increases in sediment loads, pH changes, and elevated dissolved, suspended, and particulate constituents within the receiving water bodies (Parise and Cannon, 2012; Smith et al., 2011). Heating can alter the speciation and therefore bioavailability of metals, often increasing the mobility in surface water systems (Wolf et al., 2011). Notably, certain metals and metallic compounds also pose acute, adverse human and ecosystem health effects (Burton et al., 2016; Stein, et al., 2012; Mendez et al., 2010; Abraham et al., 2017).

In contrast to wildland fires, fires in urban environments can release metals during the combustion of structures, vehicles, and infrastructure. Burning of these fuels creates "disaster materials", which comprise a variety of combustion byproducts, such as asbestos fibers, man-made vitreous fibers, metal-rich particles, and particle-associated persistent organic pollutants. Metals including cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn) have all been detected in combusted anthropogenic materials (Lonnermark and Blumqvist, 2006, Burke et al., 2013, Finley et al., 2009, Nriagu O. J., 1989). In particular, combusted vehicle tires have been shown to release high levels of Zn (Lonnermark and Blumqvist, 2006), which can have a toxic impact on stream biota such as periphyton and benthic invertebrates (Blanck et al., 2003; Watzin et al., 1997). These contaminants can remain local or disperse through ashfall into streambeds and surrounding soils (Hageman and Plumlee, 2008; Stec et al., 2019), thus impacting aquatic ecosystems and impairing surface water quality. Contaminants from fires in the urban fringe have been compared to levels of that in runoff from urban highways and industrial pollution (Burke et al., 2013, Nriagu et al., 1989, Finley et al., 2009), with Cu, Pb, and Zn concentrations in burned areas detected 100-700-fold higher than unburned areas (Stein et al., 2012). Additionally, with WUI fires occurring in closer proximity to residences and places of work, the risk of acute human exposure to metals is a primary concern and merits assessment (Lonnermark and Blumqvist, 2006, Stein et al., 2012, Burke et al., 2013).

In addition to the burden from excess metals, wildfires can also contribute excess nitrogen, phosphorus, and organic contaminants to surface water (Cawley et al., 2017, Johnson et al., 2007, Hauer and Spencer, 1998, Thurman et al., 2020). Nutrient inputs impact streams in both the immediate aftermath and longer-term recovery by altering stream productivity and enhancing the susceptibility of waterways to eutrophication processes and harmful algal blooms (Rhoades et al., 2019, Hauer and Spencer, 1998). The full spectrum of potential organic contaminants remains largely unexplored in terms of their chemical structure and potential human health or ecological toxicity (Thurman et al., 2020). These direct, cascading, or unknown impacts of nutrient and organic contaminants to stream health merit detailed characterization to enable both short- and long-term stream management interventions.

The December 30th, 2021, Marshall Fire was the most property-destructive fire in Colorado's history, damaging or destroying over 1,000 homes and at least 30 businesses in Superior, Louisville, and unincorporated Boulder County. In addition to residences and businesses, recreational spaces such as the popular Coal Creek Trail were impacted.

Regular monitoring was initiated to assess the potential impacts of the Marshall Fire on Coal Creek and the riparian zone along the Coal Creek Trail. The Marshall Fire burn extent overlaps with the Coal Creek drainage area at the western trailhead of the Coal Creek Trail and encompasses some of the highest density areas of burned homes, posing a potential public health risk to users of the recreational trail. It was hypothesized that changes to the landscape surrounding the creek would alter the water chemistry throughout the spring and summer, particularly due to the mobilization of material to the streambed.

Methods

This study collected one baseflow sample and up to two hydrological event (e.g., rain, snowmelt, extended drought) samples per month between January 2022 and October 2022. Six sample locations (Table 1, Figure 1) were selected to monitor multiple input sites paired with an upstream site.

Sampling locations were chosen to monitor Coal Creek above and below the impacted area and to target areas of particular interest, such as differences in land use or burn extent. The first sample site, Highway 93, is upstream of the burn area and urban areas. The intention was Highway 93 would be a reference site due to the lack of burning and presence of a healthy riparian zone. However, a water diversion structure between this site and the downstream burn area limits hydraulic connectivity. Flow at downstream locations in Coal Creek may have originated from reservoirs that are fed by sources outside the Coal Creek drainage area. Also, it has been well-established that Coal Creek is a groundwater-fed stream rather than fed by surface flow. In either case, sampling at Highway 93 is a reference point for the grassland area outside the burn area.

The second site, Superior Associates Open Space, represents a burned, non-urban riparian corridor. The third site, Highway 36, accesses Coal Creek from the Coal Creek Trail under Highway 36 and has inputs from the highway, a drainage ditch, and the overland flow from the Town of Superior next to a destroyed hotel. The fourth sample site accesses Coal Creek through the Coal Creek Trail near Dutch Creek Park, downstream of the fire perimeter. The fifth sampling location, the Mulberry Ditch, is an engineered storm drain near a burned neighborhood in Louisville, CO and returns to Coal Creek downstream of Dutch Creek Park. The sixth and final site, the Colorado Tech Center (CTC), accesses Coal Creek through the Colorado Tech Center Open Space and assesses water and habitat quality further downstream of the Marshall Fire perimeter and upstream of the Louisville Wastewater Treatment Plant. These locations were sampled once per month for baseflow measurements and immediately following precipitation events up to two times per month.

Standard water quality parameters were monitored at each site, including alkalinity, anions (e.g., chloride, nitrate-nitrite, and sulfate), dissolved organic carbon (DOC), nutrients, pH, specific conductivity, temperature, total suspended solids (TSS), metals, and turbidity. Temperature, pH, and specific conductivity were measured in the field using probes (Yellow Spring Instruments (YSI) Pro1030 pH and conductivity Meter). Grab samples were collected at each field site and transported to the University of Colorado laboratory for filtration, preservation, storage, and analysis. Samples for TSS and DOC (Shimadzu TOC-V) were analyzed using standard procedures. Bulk and trace metals were analyzed using inductively coupled plasma-mass spectrometry (Agilent 7900). Results were analyzed using EPA Aquatic Life Critera at both the acute (causing short-term effects) and chronic (causing longer term effects) levels. Anions and nitrate-nitrite samples were analyzed using ion chromatography (Thermo Fisher Scientific ICS 6000). Phosphorous and ammonia were analyzed using flow injection analysis. Metal concentrations were compared to EPA aquatic life criteria and will be compared to pre-fire historical data to assess recovery progress.

In addition to water quality parameters, this study sampled biota including benthic invertebrates and periphyton. Benthic invertebrates were collected at sites 1, 2, 3, and 6 once per month during baseflow sampling in the spring and summer months and were analyzed according to the USGS protocol (Moulton II et al., 2000). Periphyton samples were collected during baseflow sampling and chlorophyll-a was analyzed using USGS methods (Hoffman et al., 2016). A roughly fist-sized stone with a healthy standing crop of periphyton was collected from the center of each stream. The samples were put on ice for transportation back to the lab. Rocks from each site were then scrubbed clean into a known volume of DI water. Aliquots of this slurry were then filtered for chlorophyll a, and a 10 mL aliquot was preserved using lugol's solution for periphyton analysis. Periphyton samples were digested using a modified version of the methods described in Spaulding et al., 2021. Cleaned and rinsed diatom samples were then plated onto #1.5h coverslips and mounted in Naphrax.

Results

Bulk water quality parameter results, including pH, specific conductivity, turbidity, alkalinity, and dissolved organic carbon, are shown in Figures 2, 3, and 4. Over the course of this study, the highest pH values were measured in the Mulberry Storm Drain, followed by Highway 36 and CTC Open Space (Figure 2). The highest pH values were measured during snowmelt after the fire and after rain events. Specific conductivity values were highest immediately after the fire (January-March) and were systematically higher at Mulberry and Dutch Creek Park immediately after the fire (Figure 2). The specific conductivity range was greatest at Dutch Creek Park compared to other sites, including the downstream CTC Open Space location. During January-March, turbidity was higher at Mulberry compared to Dutch Creek Park (Figure 2). During spring and summer precipitation events, high turbidity (>50 NTU) was measured at Mulberry, CTC, and EA. The storm in late August 2022 produced very high turbidity (>100 NTU) at Superior Associates and Highway 36. Between sites, Highway 36 had the biggest range in values throughout sampling. The highest alkalinity concentrations were observed immediately after the fire (January -March) at Mulberry Ditch (Figure 3). During summer precipitation events, similarly elevated alkalinity concentrations (200-300 mg/L as $CaCO_3$) were observed at both Mulberry Ditch and CTC Open space. From Superior Associates to CTC Open Space, alkalinity generally increased from upstream to downstream. Dissolved organic carbon (DOC) concentrations were typically highest at Mulberry Ditch, followed by Dutch Creek Park, CTC Open Space, and Highway 36 (Figure 4). The highest DOC concentrations were measured in the first two months after the fire (January and February), though peaks were observed as late as June 2022 (>10 mg/L) after a storm event.

The concentrations of anions (chloride, nitrate, and sulfate) and nutrients (nitrogen, ammonia, phosphate) are shown in Figure 5 and Figure 6, respectively. The highest chloride concentrations were observed at Dutch Creek Park and Mulberry Ditch in January (Figure 5), which may be due to road salt addition. Elevated concentrations were not observed after summer precipitation events. Highest nitrate, total nitrogen, ammonia, and phosphate values were observed at Mulberry Ditch in January and February. Increases in total nitrogen were also observed at Highway 36 in May after precipitation events (Figure 6). The highest sulfate concentrations were observed at Highway 93 throughout the season, which is upstream of the burn area. Highway 36 also experienced peaks in nitrogen in May during heavy storms. Data collection and analysis is ongoing.

The results of selected major (Al, Fe, Mn, and Zn) and trace (As, Ba, Cu, Li, Ni, and Pb) metals are shown in Figure 7. Highest observed concentrations of major metals (Al, Fe, Mn, and Zn) were at both fire-affected and upstream locations. Filtered As, Cu, and Li (trace metals) were consistently highest at Mulberry Ditch. Trace metal Pb peaks were measured at Superior Associates, Mulberry, and Highway 93, associated with rain events. Total Zn also increased throughout rain events at Highway 36, Highway 93, and Dutch Creek Park. This study is ongoing.

Results of benthic macroinvertebrate studies are shown in Figure 8 (community structure) and Figure 9 (Shannon Diversity index and number of organisms per meter). More detailed information on taxa and counts is available in Appendix Table 1. A generally higher number of pollution-tolerant organisms, including chironomids, leeches, blackflies, and flatworms, were observed at fire-affected sites, and in particular at Highway 36. Additionally, the benthic invertebrate population at the urban, fire-affected Highway 36 was found to contain a higher percentage of tolerant organisms when compared to historical data taken in the same month in 2019. The highest Shannon Diversity Indices were calculated at Highway 93 (reference) and at CTC (Figure 9). The lowest diversity was observed at Superior Associates and at Highway 36. The highest numbers of organisms per meter in this study were found at Highway 93 in June (>600), followed by Highway 36 in mid-April (>300). The lowest number of organisms per meter was observed in February at Superior Associates (0).

The Chlorophyll a results (Table 4, Figure 10) show a gradual increase at 93 as the season progresses, and a similar trend at Superior Associates, but with a starting baseline near or zero. At 36 and CTC there is some variability during the season. For diatom analyses (Figure 11), Highway 93 transitioned from a typical, healthy oligotrophic stream to a community dominated by taxa characteristic of anthropogenically disturbed systems such as *Rhoicosphenia abbrevata* (reference diatom figure here). Additionally, several halotolerant taxa such as *Conticribra weissflogii* were located at Highway 36 and CTC. Teratological forms occurred at a rate much higher than natural background levels at both Highway 36 and CTC.

Discussion

Higher values or concentrations of specific conductivity, turbidity, alkalinity, dissolved organic carbon, chloride, nitrate, total nitrogen, and trace metals have been observed at fire-affected sites when compared to the upstream location. It is difficult, however, to differentiate elevated concentrations due to wildfire compared to urbanization. Some parameters, including concentration of several major metals (i.e., Fe) and trace metals (i.e., Ba) were occasionally highest at the unburned reference location and likely are indicative of geological or non-fire anthropogenic influence on the watershed.

The recommended limits based on the EPA acute (causing short-term effects) and chronic (causing longer term effects) aquatic life criteria were compared to total and filtered major and trace metal concentrations throughout the study (Tables 2 and 3). Acute criteria exceedances were noted for Cu and Zn and chronic criteria exceedances were observed for Cu, Ni, Pb, and Zn. There were 8 instances of acute exceedances for Cu and 30 instances for acute Zn. Additionally, there were 18 instances of chronic exceedances for Cu, 3 instances of chronic exceedances for Ni, 14 instances of chronic exceedances for Pb, and 21 instances of chronic exceedances for Zn. Most exceedances were observed in fire-affected sections of Coal Creek (86.8% for acute and 87.9% for chronic) but a small number of exceedances also occurred at Highway 93. During one precipitation event, cloudy drainage from a culvert upstream of Highway 93 was observed, suggesting the site is impacted by some anthropogenic run-off inputs. During the first three months after the fire, acute exceedances accounted for only 13% of all exceedances as opposed to 23% of chronic exceedances.

The results of benthic macroinvertebrate studies showed that a generally higher number of pollution-tolerant organisms were observed at fire-affected sites, and in particular at Highway 36. While it is clear that many of these sites are exhibiting disturbance from what is considered a healthy stream, it is difficult to separate out the direct influence of the Marshall fire from typical urban pollution. This is due to a lack of pre-fire data and because reference site Highway 93 is notably less urban than the fire-affected sites downstream in Coal Creek. One notable exception is the historical BMI data at Highway 36. The benthic invertebrate community this site contained a higher percentage of tolerant organisms when compared to historical data taken in the same month in 2019. This could indicate a true fire affect, especially due to predicted similar levels of non-fire anthropogenic input. Other results have to be examined without access to pre-fire BMI data. The finding of no organisms at Superior Associates in early February seems to indicate a complete collapse of ecosystem after the Marshall Fire. The results were duplicated in a second sampling event two weeks after the first, with only two organisms collected. Future tests in early February of 2023 will help to confirm if this is typical of the SA site or if it is indeed a fire effect. Additionally, the highest Shannon Diversity was seen at the reference site and the site furthest downstream from the fire, which indicates that diversity is lower in fire-affected sites. Another year of monitoring will allow us to determine how much of the changes documented along Coal Creek were due to the fire and how much was due to urban runoff or seasonality.

The Chlorophyll-a results at Highway 93 and Superior Associates show a typical, seasonal gradual increase, though their differences in baseline are significant. Superior Associates started near zero but continued to increase over the season. This is likely representative of some level of rebounding after the fire event, which may have completely depleted the streambed due to significantly high combustion temperatures. Additionally, variability at Highway 36 and CTC likely reflect scouring events from storm events this summer, which were also compounded by intermittent drying of the streambed. There has been a notable shift in community composition from taxa indicating nitrogen limitation and ephemerality at Highway 93, which transitioned to a community dominated by taxa characteristic of anthropogenically disturbed systems. Additionally, the halotolerant taxa at Highway 36 and CTC indicate a level of disturbance consistent with human pollution or fire, though it is difficult to distinguish the root cause in this case. The most compelling result of the diatom analysis is that teratological forms are occurring at a higher than the natural background rate (Arini et al. 2012). Environmental stressors such as trace metal contamination, extremes in pH or salinity, and organic contaminants are all known to drive the production of teratological forms (Falasco et al. 2021). This is a rapid, sub-lethal response to environmental stimuli that may appear even if there is not a meaningful shift in the other commonly measured metrics such as biomass and community composition.

A summary of the deliverables follows: Stakeholder meetings were held over zoom on February 18th, March 4th, April 1st, May 6th, June 3rd, July 8th, and September 9th and included representatives from CU Boulder, local municipalities, watershed conservation groups, and interested faculty from other departments and universities. A public-facing data dashboard was also launched to make the water quality and invertebrate data broadly accessible to community members and other interested parties.

To date, the project has completed 34 water quality sampling events. Additionally, the project has performed 11 benthic macroinvertebrate surveys and 11 periphyton analyses.

Literature Cited

Abraham, J., K. Dowling, S. Florentine, and D. Barcelo. 2017. Risk of post-fire metal mobilization into surface water resources: A review. Science of the Total Environment 599–600:1740–1755.

Arini, A., Feurtet-Mazel, A., Maury-Brachet, R., Coste, M., & Delmas, F. (2012). Field translocation of diatom biofilms impacted by Cd and Zn to assess decontamination and community restructuring capacities. *Ecological Indicators, 18, 520–531. https://doi.org/10.1016/j.ecolind.2012.01.005*

Blanck, H., W. Admiraal, R. F. M. J. Cleven, H. Guasch, M. A. G. T. Van Den Hoop, N. Ivorra, B. Nyström, M. Paulsson, R. P. Petterson, S. Sabater, and G. M. J. Tubbing. 2003. Variability in zinc tolerance, measured as incorporation of radio-labeled carbon dioxide and thymidine, in periphyton communities sampled from 15 European river stretches. Archives of Environmental contamination and toxicology 44:17–29.

Burke, M. P., T. S. Hogue, A. M. Kinoshita, J. Barco, C. Wessel, and E. D. Stein. 2013. Pre- and post-fire pollutant loads in an urban fringe watershed in Southern California. Environmental Monitoring and Assessment 185:10131–10145.

Burton, C. A., T. M. Hoefen, G. S. Plumlee, K. L. Baumberger, A. R. Backlin, E. Gallegos, and R. N. Fisher. 2016. Trace elements in stormflow, ash, and burned soil following the 2009 station fire in southern California. PLOS One 11:1–26.

Cawley, K. M., A. K. Hohner, D. C. Podgorski, W. T. Cooper, J. A. Korak, and F. L. Rosario-Ortiz. 2017. Molecular and spectroscopic characterization of water extractable organic matter from thermally altered soils reveal insight into disinfection byproduct precursors. Environmental Science and Technology 51:771–779.

Spaulding, S., Potapova, M, Bishop, I.,Lee, S., Gasperak, T., Jovanoska, E., Furey, P., Edlund, M., 2021. Diatoms.org: supporting taxonomists, connecting communities. Website. https://diatoms.org/practitioners/how-to-clean-diatom-samples.

Falasco, E., Ector, L., Wetzel, C. E., Badino, G., & Bona, F. (2021). Looking back, looking forward: a review of the new literature on diatom teratological forms (2010–2020). *Hydrobiologia, 848(8), 1675–1753. https://doi.org/10.1007/s10750-021-04540-x*

Fann, N., B. Alman, R. A. Broome, G. G. Morgan, F. H. Johnston, G. Pouliot, and A. G. Rappold. 2018. The health impacts and economic value of wildland fire episodes in the U.S.: 2008–2012. Science of the Total Environment 610–611:802–809.

Finley, B. D., P. C. Swartzendruber, and D. A. Jaffe. 2009. Particulate mercury emissions in regional wildfire plumes observed at the Mount Bachelor Observatory. Atmospheric Environment 43:6074–6083.

Hauer, F. R., and C. N. Spencer. 1998. Phosphorus and Nitrogen Dynamics in Streams Associated with Wildfire: A Study of Immediate and Longterm Effects. International Journal of Wildland Fire 8:183–198.

Johnson, D., J. D. Murphy, R. F. Walker, D. W. Glass, and W. W. Miller. 2007. Wildfire effects on forest carbon and nutrient budgets.

Lönnermark, A., and P. Blomqvist. 2006. Emissions from an automobile fire. Chemosphere 62:1043–1056.

Mendez, G. O. 2010. Water-quality data from storm runoff after the 2007 fires, San Diego County, California. Page Open-File Report.

Nriagu, J. O. 1989. A global assessment of natural sources of atmospheric trace metals. Letters to Nature 338:47–49.

Odigie, K. O., and A. R. Flegal. 2011. Pyrogenic Remobilization of Historic Industrial Lead Depositions. Environ. Sci. Technol 45:6290–6295.

Odigie, K. O., E. Khanis, S. A. Hibdon, P. Jana, A. Araneda, R. Urrutia, and • A Russell Flegal. 2016. Remobilization of trace elements by forest fire in Patagonia, Chile. Regional Environmental Change 16.

Parise, M., and S. H. Cannon. 2012. Wildfire impacts on the processes that generate debris flows in burned watersheds. Natural Hazards 61:217–227.

Radeloff, V. C., D. P. Helmers, H. Anu Kramer, M. H. Mockrin, P. M. Alexandre, A. Bar-Massada, V. Butsic, T. J. Hawbaker, S. Martinuzzi, A. D. Syphard, and S. I. Stewart. 2018. Rapid growth of the US wildland-urban interface raises wildfire risk. Proceedings of the National Academy of Sciences of the United States of America 115:3314–3319.

Rhoades, C. C., J. P. Nunes, U. Silins, and S. H. Doerr. 2019. The influence of wildfire on water quality and watershed processes: new insights and remaining challenges. International Journal of Wildland Fire 28:721–725.

Smith, H. G., G. J. Sheridan, P. N. J. Lane, P. Nyman, and S. Haydon. 2011. Wildfire effects on water quality in forest catchments: A review with implications for water supply. Journal of Hydrology 396:170–192.

Stein, E. D., J. S. Brown, T. S. Hogue, M. P. Burke, and A. Kinoshita. 2012. Stormwater contaminant loading following southern California wildfires. Environmental Toxicology and Chemistry 31:2625–2638.

Thurman, E. M., Y. Yu, I. Ferrer, K. A. Thorn, and F. L. Rosario-Ortiz. 2020. Molecular Identification of Water-Extractable Organic Carbon from Thermally Heated Soils: C-13

NMR and Accurate Mass Analyses Find Benzene and Pyridine Carboxylic Acids. Environmental Science and Technology 54:2994–3001.

Wang, D., D. Guan, S. Zhu, M. Mac Kinnon, G. Geng, Q. Zhang, H. Zheng, T. Lei, S. Shao, P. Gong, and S. J. Davis. 2021. Economic footprint of California wildfires in 2018. Nature Sustainability 4:252–260.

Watzin, M. C., and P. R. Roscigno. 1997. The Effects of Zinc Contamination on the Recruitment and Early Survival of Benthic Invertebrates in an Estuary. Marine Pollution Bulletin 34:443–455.

Wolf, R. E., S. A. Morman, P. L. Hageman, T. M. Hoefen, and G. S. Plumlee. 2011. Simultaneous speciation of arsenic, selenium, and chromium: Species stability, sample preservation, and analysis of ash and soil leachates. Analytical and Bioanalytical Chemistry 401:2733–2745.

Tables

Table 1. Names, descriptions, and site coordinates of study sampling locations along Coal Creek

Sample Name	Site #	Description	Sample Site Coordinates
Highway 93	1	Upstream pre-fire sample point at Highway 93/Highway 128 and Coal Creek. Just outside the Greenbelt Plateau Open Space area in unincorporated Boulder County.	39.924562” N, -105.227875” W
Superior Associates (also known as Superior Associates)	2	Fire-affected forested area between Telleen-DePoorter and Superior Associates Open Spaces in Boulder.	39°57'06.1" N, -105°10'46.2" W
Highway 36	3	Coal Creek Trail below the Element Hotel in Superior, Colorado	39.955795” N, -105.160273” W
Dutch Creek Park	4	Coal Creek in Dutch Creek Park in Louisville, CO.	39°57'57.3" N, -105°08'23.2" W
Mulberry St. Ditch	5	Storm drain between Fireside Elementary and Louisville Rec. Center in Louisville, CO.	39.9719976” N, -105.156108” W
Colorado Tech Center (CTC)	6	Coal Creek at Empire Road in the Mayhoffer Farm area. Accessed through the Colorado Tech Center Open Space in Louisville, CO.	39°58'14.4" N, -105°07'07.7" W

Table 2. EPA National Recommended Aquatic Life Criteria (Acute) Exceedances

Site	Date	Metal	Concentration (ppb)	Acute Limit	Percent Exceeded	Total vs. Filtered
Dutch Creek Park	8/16/22	Cu	7.5	6.6	114%	Total
Superior Associates	6/29/22	Cu	68.5	25.8	265%	Filtered
Highway 36	2/27/22	Cu	20.8	12.0	173%	Total
Highway 93	8/16/22	Cu	8.8	3.6	242%	Filtered
Highway 93	8/16/22	Cu	25.4	6.6	385%	Total
Mulberry	5/4/22	Cu	11.4	7.7	149%	Filtered
Mulberry	5/4/22	Cu	12.5	8.7	144%	Total
CTC Open Space	8/18/22	Zn	482	250	193%	Filtered
CTC Open Space	7/12/22	Zn	630	390	162%	Total
Dutch Creek Park	7/12/22	Zn	335	300	112%	Filtered
Dutch Creek Park	8/15/22	Zn	330	230	144%	Filtered
Dutch Creek Park	8/18/22	Zn	303	230	132%	Filtered
Dutch Creek Park	8/16/22	Zn	739	60.9	1,210%	Total
Superior Associates	8/18/22	Zn	171	170	101%	Filtered
Superior Associates	8/15/22	Zn	173	170	102%	Filtered
Superior Associates	7/12/22	Zn	496	97.0	511%	Filtered
Superior Associates	5/4/22	Zn	393	300	131%	Total
Superior Associates	8/18/22	Zn	677	160	423%	Total
Superior Associates	7/12/22	Zn	616	99.2	622%	Total
Superior Associates	8/16/22	Zn	602	88.6	680%	Total
Superior Associates	7/25/22	Zn	110	83.2	133%	Total
Highway 36	7/12/22	Zn	141	110	128%	Filtered
Highway 36	6/29/22	Zn	425	330	129%	Total
Highway 36	6/22/22	Zn	393	230	171%	Total
Highway 36	8/18/22	Zn	624	200	312%	Total
Highway 36	7/12/22	Zn	576	120	480%	Total
Highway 36	2/27/22	Zn	162	110	148%	Total
Highway 36	2/27/22	Zn	260	100	260%	Total
Highway 36	7/20/22	Zn	128	93.9	136%	Total
Highway 36	5/4/22	Zn	62.3	60.9	102%	Total
Highway 93	7/12/22	Zn	237	230	103%	Filtered
Highway 93	4/16/22	Zn	466	330	141%	Total
Highway 93	7/12/22	Zn	503	240	210%	Total
Mulberry	8/15/22	Zn	231	170	136%	Filtered
Mulberry	7/12/22	Zn	414	270	153%	Total

Table 3. EPA National Recommended Aquatic Life Criteria (Chronic) Exceedances

Site	Date	Metal	Concentration (ppb)	Chronic Limit	Percent Exceeded	Total Vs Filtered
Dutch Creek Park	1/8/22	Cu	26.5	24.8	106%	Filtered
Dutch Creek Park	8/16/22	Cu	7.5	4.7	159%	Total
Superior Associates	6/29/22	Cu	68.5	16.2	423%	Filtered
Superior Associates	8/16/22	Cu	7.7	6.9	112%	Total
Highway 36	2/27/22	Cu	18.9	8.5	221%	Total
Highway 36	2/27/22	Cu	20.8	8.1	256%	Total
Highway 36	8/16/22	Cu	9.71	4.3	228%	Total
Highway 93	8/16/22	Cu	8.8	2.7	321%	Filtered
Highway 93	8/16/22	Cu	25.4	4.7	539%	Total
Mulberry	1/29/22	Cu	19.0	15.5	123%	Filtered
Mulberry	1/29/22	Cu	18.2	14.8	123%	Filtered
Mulberry	5/4/22	Cu	11.4	5.4	212%	Filtered
Mulberry	5/21/22	Cu	14.4	9.7	148%	Filtered
Mulberry	1/3/22	Cu	23.7	19.0	125%	Total
Mulberry	1/29/22	Cu	16.7	14.7	114%	Total
Mulberry	5/4/22	Cu	12.5	6.0	207%	Total
Mulberry	8/16/22	Cu	17.3	13.2	131%	Total
Dutch Creek Park	8/16/22	Ni	67.2	24.0	280%	Filtered
Highway 36	8/16/22	Ni	39.8	21.4	186%	Filtered
Highway 93	8/16/22	Ni	64.9	16.1	403%	Filtered
CTC Open Space	8/16/22	Pb	3.7	1.5	245%	Total
Dutch Creek Park	8/16/22	Pb	4.0	1.2	349%	Total
Superior Associates	6/15/22	Pb	28.0	8.7	322%	Total
Superior Associates	6/22/22	Pb	11.9	10.7	111%	Total
Superior Associates	8/16/22	Pb	9.7	2.0	478%	Total
Highway 36	2/27/22	Pb	5.5	2.8	196%	Total
Highway 36	2/27/22	Pb	5.7	2.6	220%	Total
Highway 36	5/4/22	Pb	2.0	1.2	174%	Total
Highway 36	8/16/22	Pb	4.49	1.0	453%	Total
Highway 93	8/16/22	Pb	1.31	0.5	242%	Filtered
Highway 93	8/16/22	Pb	23.6	1.2	2,050%	Total
Mulberry	5/4/22	Pb	4.5	1.7	268%	Total
CTC Open Space	8/15/22	Zn	310	310	100%	Filtered
CTC Open Space	8/18/22	Zn	482	260	185%	Filtered
CTC Open Space	7/12/22	Zn	631	390	162%	Total

Dutch Creek Park	7/12/22	Zn	335	300	112%	Filtered
Dutch Creek Park	8/15/22	Zn	331	230	144%	Filtered
Dutch Creek Park	8/18/22	Zn	303	230.	132%	Filtered
Dutch Creek Park	8/16/22	Zn	739	60.9	1,210%	Total
Superior Associates	7/12/22	Zn	496	97.8	507%	Filtered
Superior Associates	8/15/22	Zn	173	170	102%	Filtered
Superior Associates	5/4/22	Zn	393	300	131%	Total
Superior Associates	7/12/22	Zn	616	99.2	622%	Total
Superior Associates	7/25/22	Zn	110	83.2	133%	Total
Superior Associates	8/16/22	Zn	602	88.6	680%	Total
Superior Associates	8/18/22	Zn	677	160	423%	Total
Highway 36	7/12/22	Zn	141	110	128%	Filtered
Highway 36	2/27/22	Zn	162	110	148%	Total
Highway 36	2/27/22	Zn	260	100	260%	Total
Highway 36	5/4/22	Zn	62.3	60.9	102%	Total
Highway 36	6/22/22	Zn	394	230	171%	Total
Highway 36	6/29/22	Zn	426	330	129%	Total
Highway 36	7/12/22	Zn	576	12	480%	Total
Highway 36	7/20/22	Zn	128	93.9	136%	Total
Highway 36	8/18/22	Zn	624	200	312%	Total
Highway 93	7/12/22	Zn	237	230	103%	Filtered
Highway 93	4/16/22	Zn	466	330	141%	Total
Highway 93	7/12/22	Zn	503	240.	210%	Total
Mulberry	8/15/22	Zn	231	180	128%	Filtered
Mulberry	7/12/22	Zn	414	270	153%	Total

Table 4. Chlorophyll-A Results, Spring and Summer 2022, units are (µg chl a/cm^2)

Site	**3-Apr**	**16-Apr**	**22-Jun**	**12-Jul**
Highway 93	11.43	3.42	51.87	75.12
Superior Associates	1.78	0.23	2.65	17.28
Highway36	20.33	26.06	57.6	25.91
CTC	56.73	31.63	45.19	52.72

Figures

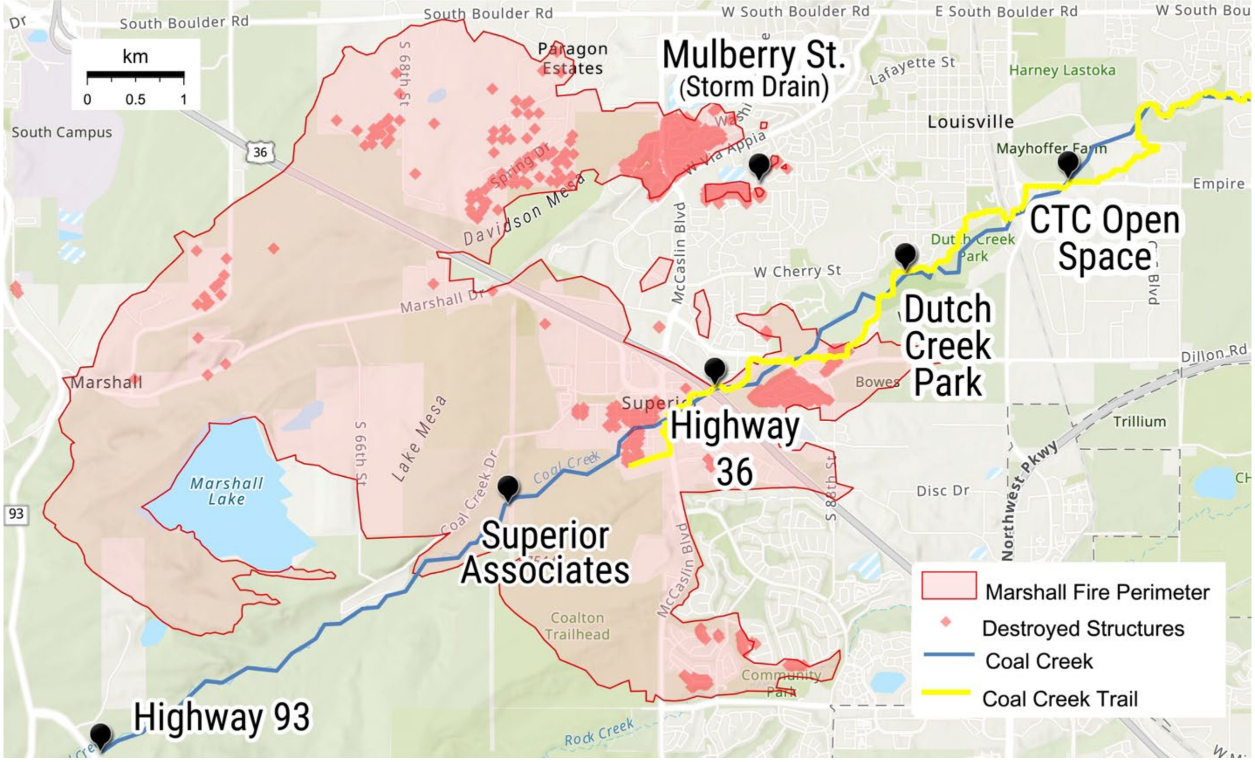


Figure 1. The Marshall Fire perimeter and structures destroyed in the fire, Coal Creek, the Coal Creek Trail, and study sampling locations Highway 93, Superior Associates (also referred to as Erin Arsenault in some figures), Highway 36, Dutch Creek Park, Mulberry St., and CTC Open Space.

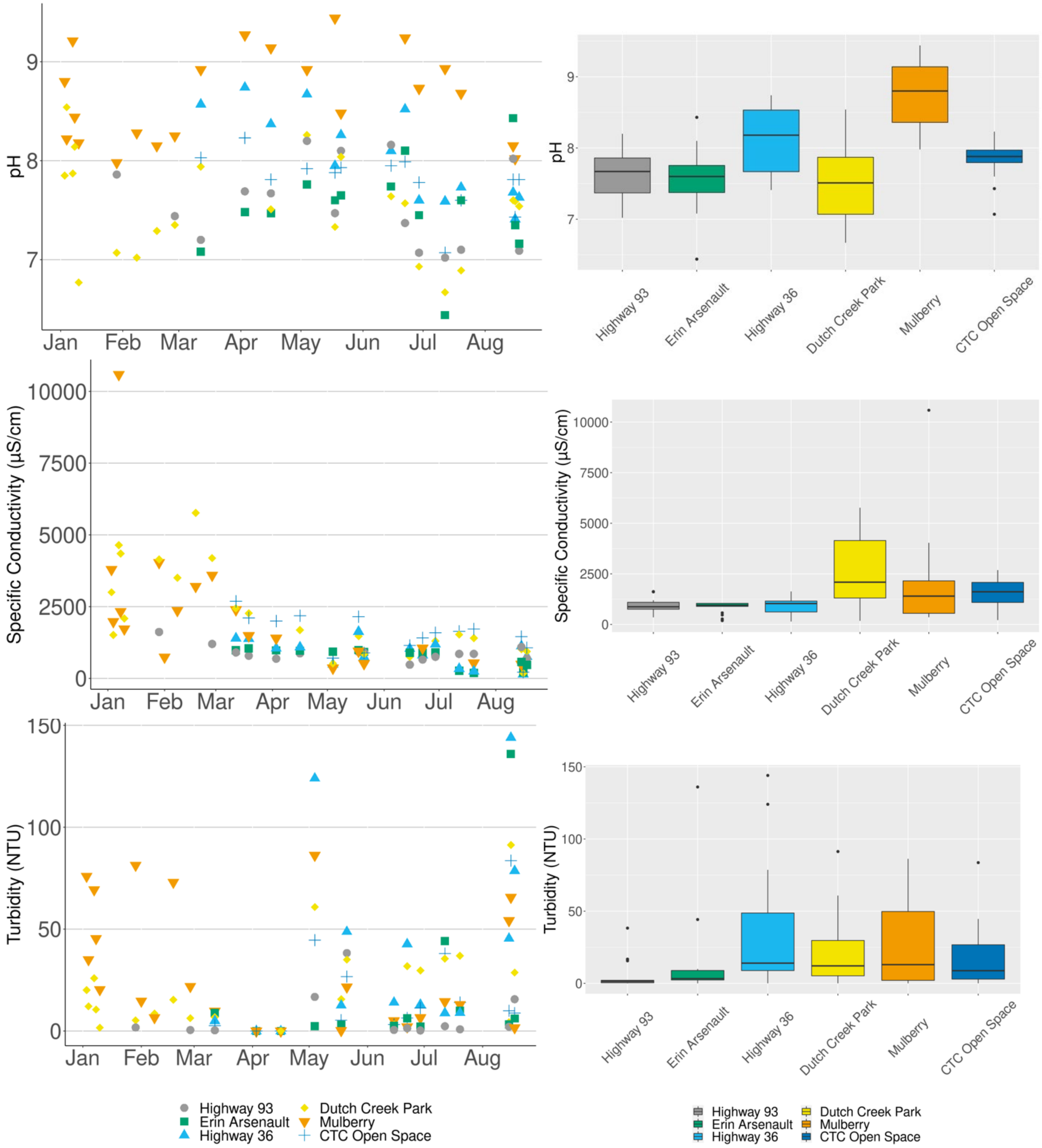


Figure 2. Bulk water quality parameters: pH, specific conductivity, and turbidity results. Please note, Erin Arsenault refers to the OSMP-managed Superior Associates Open Space. Left plots show results over time while right plots show box plots. Boxes show 25% and 75% quartiles with the center line at the median of the dataset. The whiskers extend to 5% and 95%, and outliers extend outside of the whiskers.

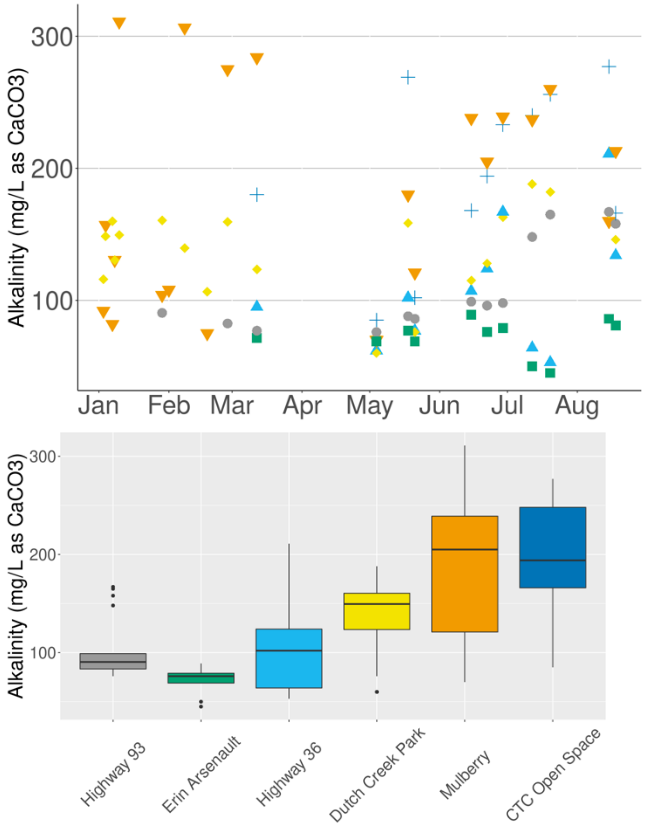


Figure 3. Alkalinity results. Please note, Erin Arsenault refers to the OSMP-managed Superior Associates Open Space. Above plot shows changes from January to August, below plot shows box plots. Boxes show 25% and 75% quartiles with the center line at the median of the dataset. The whiskers extend to 5% and 95%, and outliers extend outside of the whiskers.

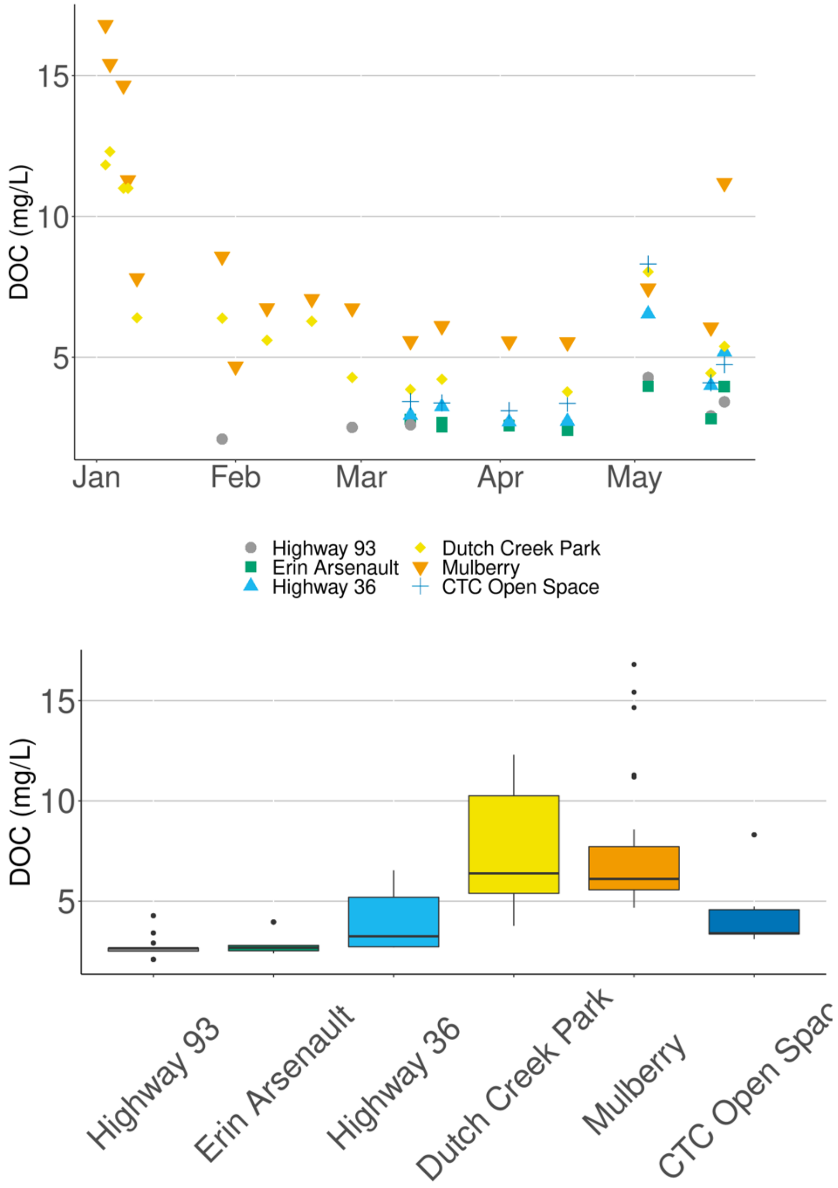


Figure 4. Dissolved organic carbon (DOC) results. Please note, Erin Arsenault refers to the OSMP-managed Superior Associates Open Space. Above plot shows changes from January to August, below plot shows box plots. Boxes show 25% and 75% quartiles with the center line at the median of the dataset. The whiskers extend to 5% and 95%, and outliers extend outside of the whiskers.

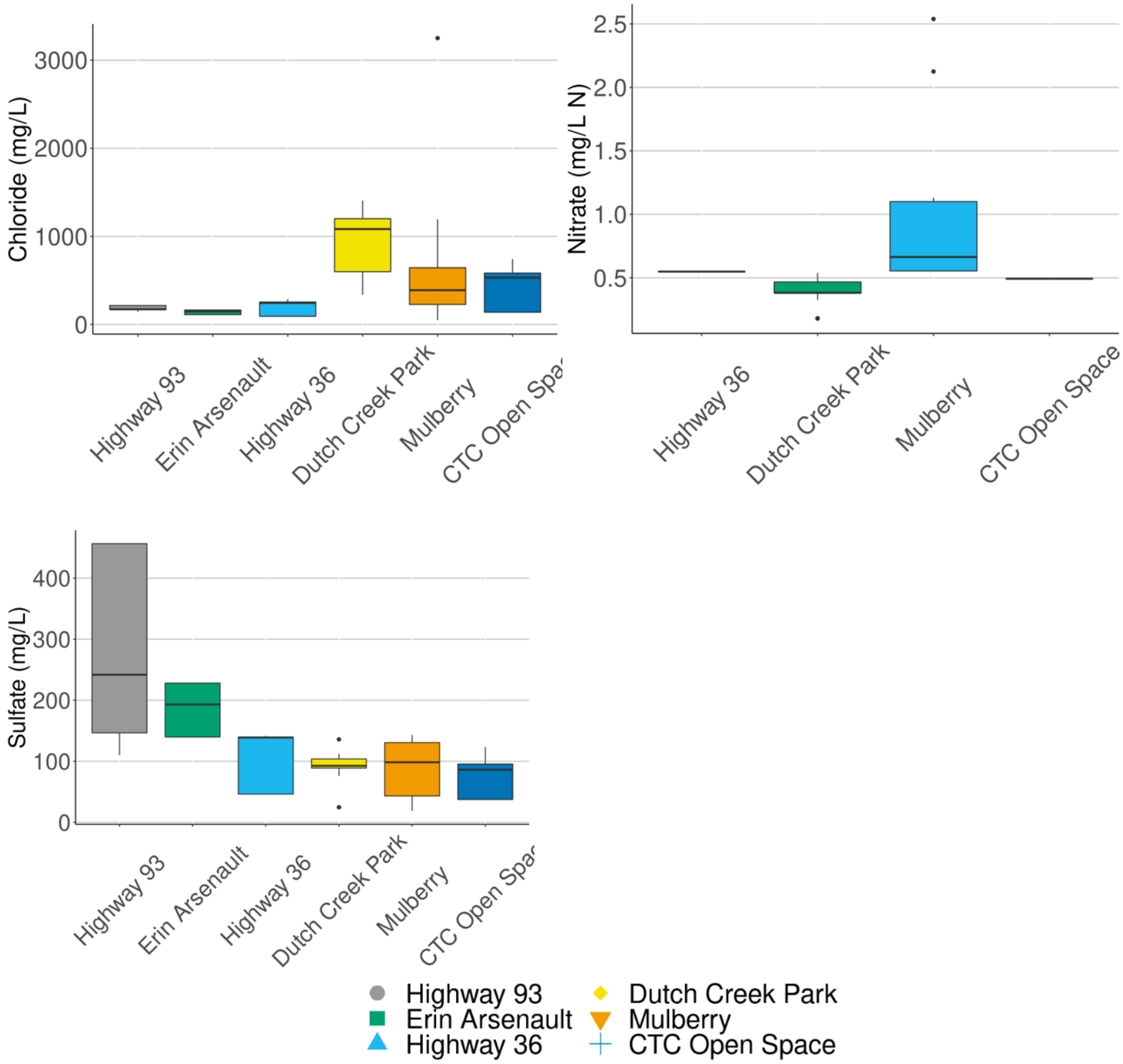


Figure 5. Anions results: chloride, nitrate, and sulfate. Please note, Erin Arsenault refers to the OSMP-managed Superior Associates Open Space. . Boxes show 25% and 75% quartiles with the center line at the median of the dataset. The whiskers extend to 5% and 95%, and outliers extend outside of the whiskers.

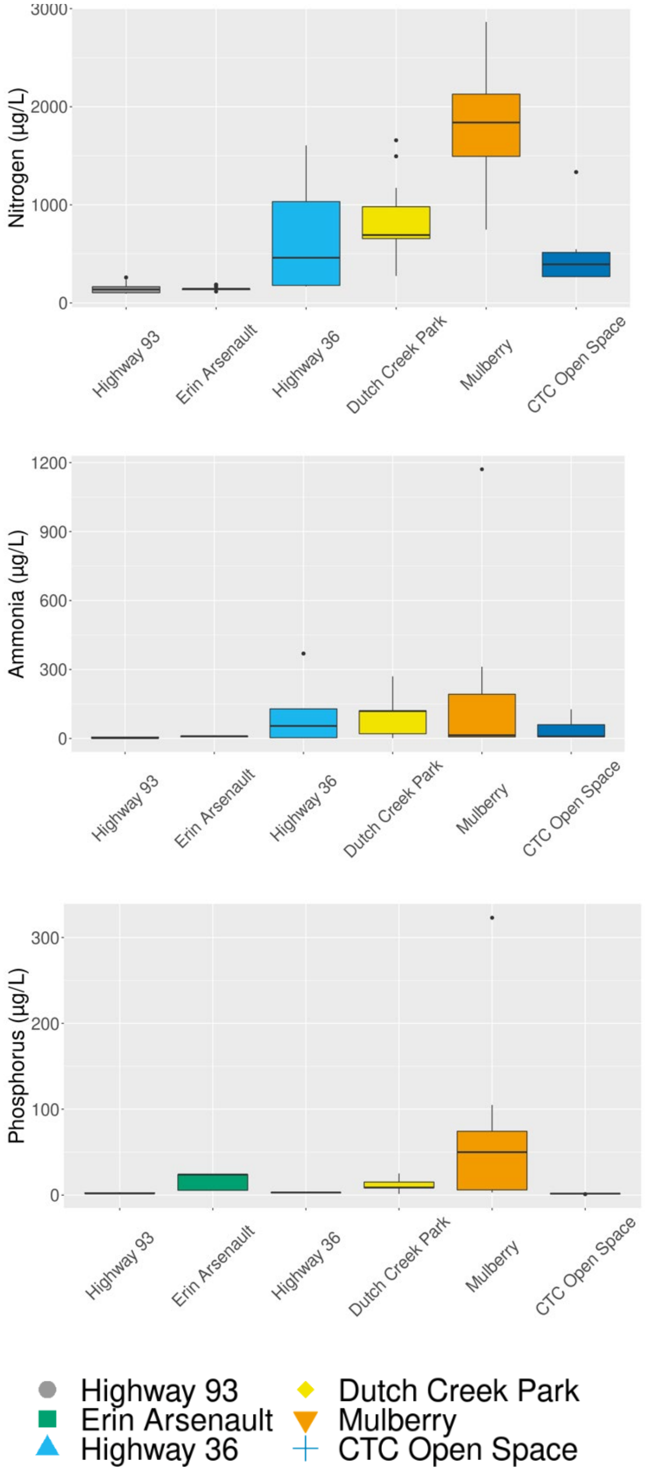
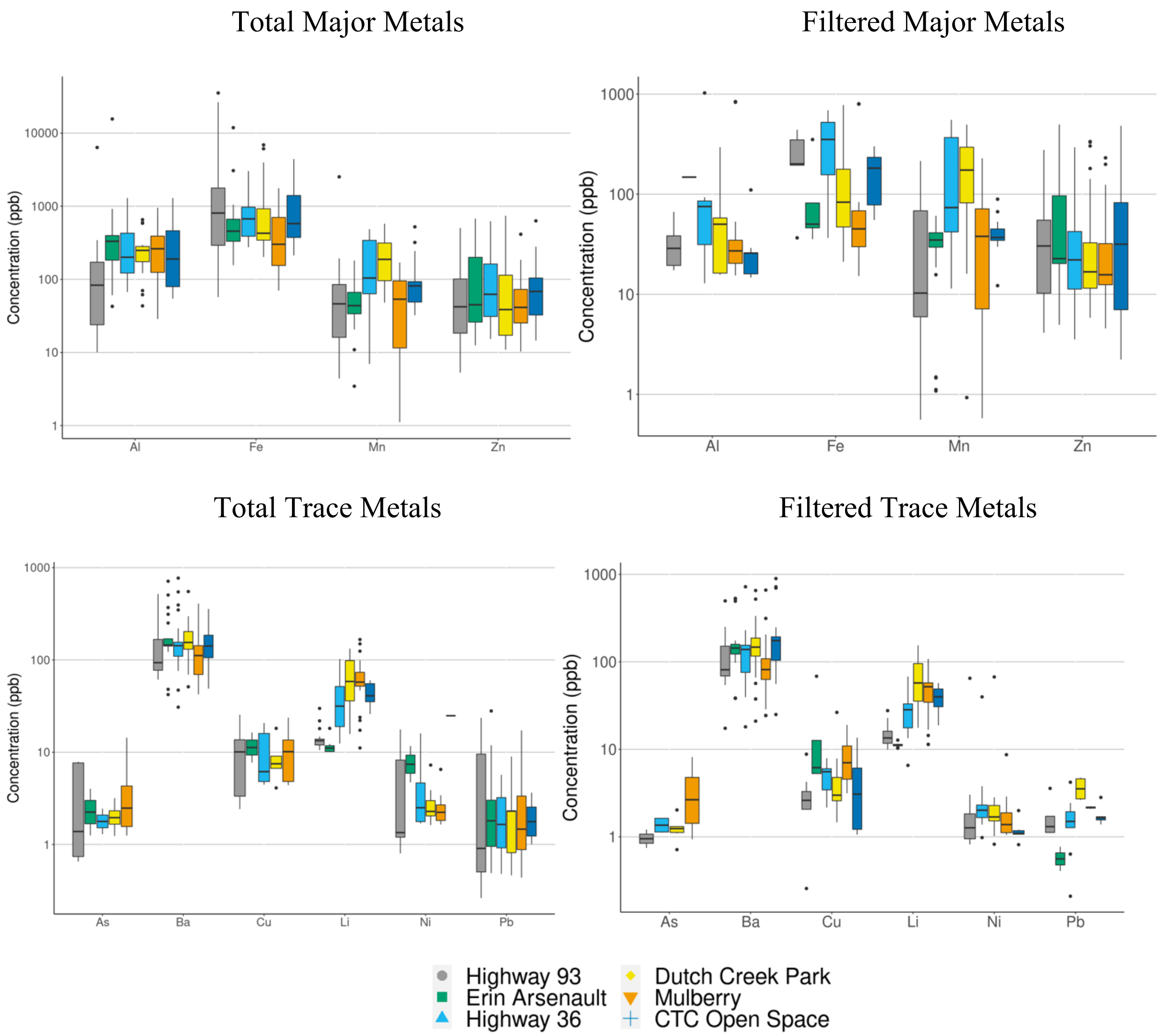


Figure 6. Nutrients results. Please note, Erin Arsenault refers to the OSMP-managed Superior Associates Open Space. . Boxes show 25% and 75% quartiles with the center line at the median of the dataset. The whiskers extend to 5% and 95%, and outliers extend outside of the whiskers.



Total Major Metals

Filtered Major Metals

Total Trace Metals

Filtered Trace Metals

Figure 7. Selected major and trace metals filtered and total results**.** Please note, Erin Arsenault refers to the OSMP-managed Superior Associates Open Space. Also, note log scale on y-axis. Left plots show total major and total trace metals of interest, right plots show filtered major metals and filtered trace metals of interest. Boxes show 25% and 75% quartiles with the center line at the median of the dataset. The whiskers extend to 5% and 95%, and outliers extend outside of the whiskers.

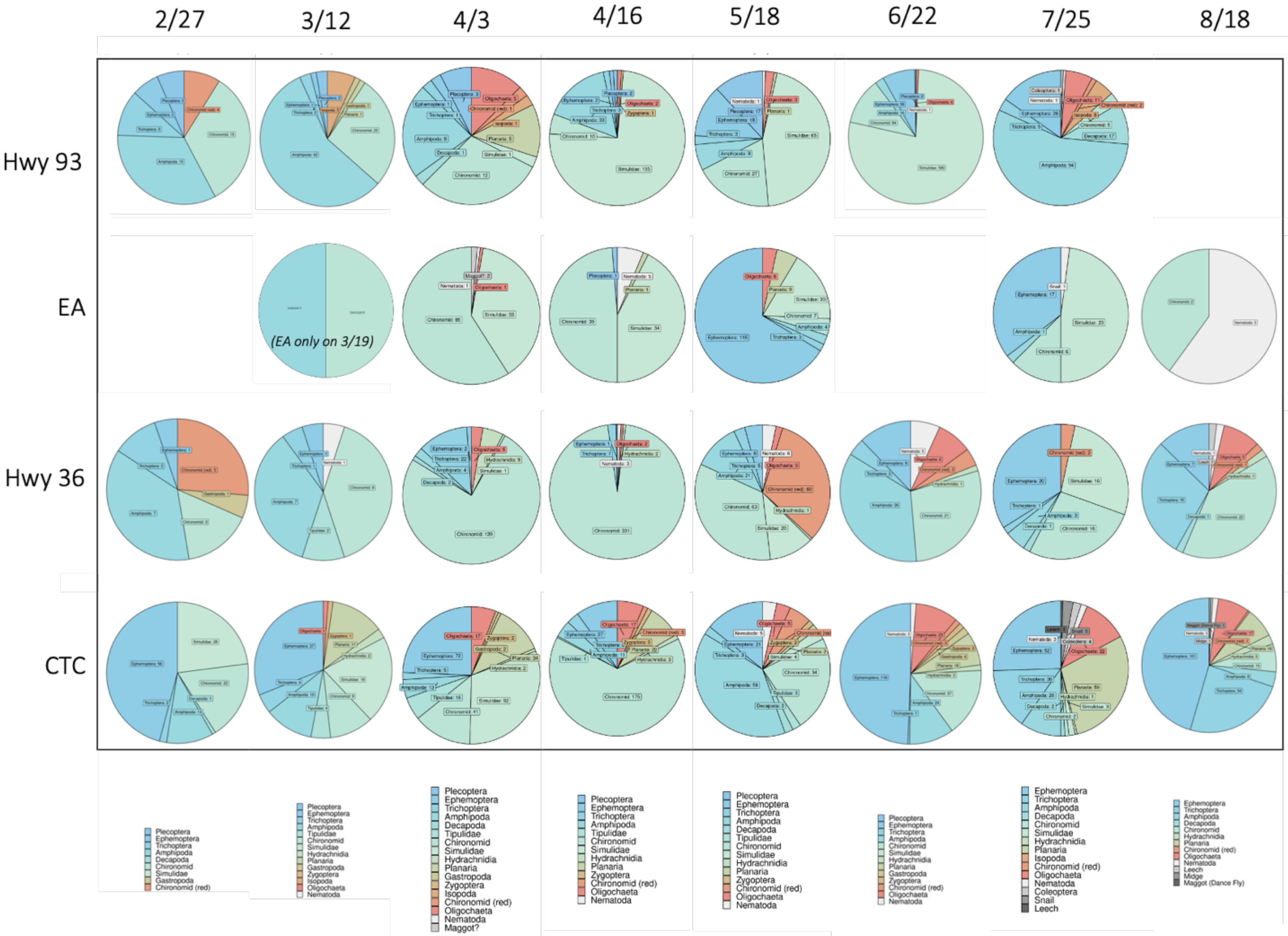


Figure 8. Benthic macroinvertebrates community structures and diversity results. No entry means no benthic invertebrates observed (EA 2/27) or not enough flow to sample (all others).Please note, Erin Arsenault refers to the OSMP-managed Superior Associates Open Space.

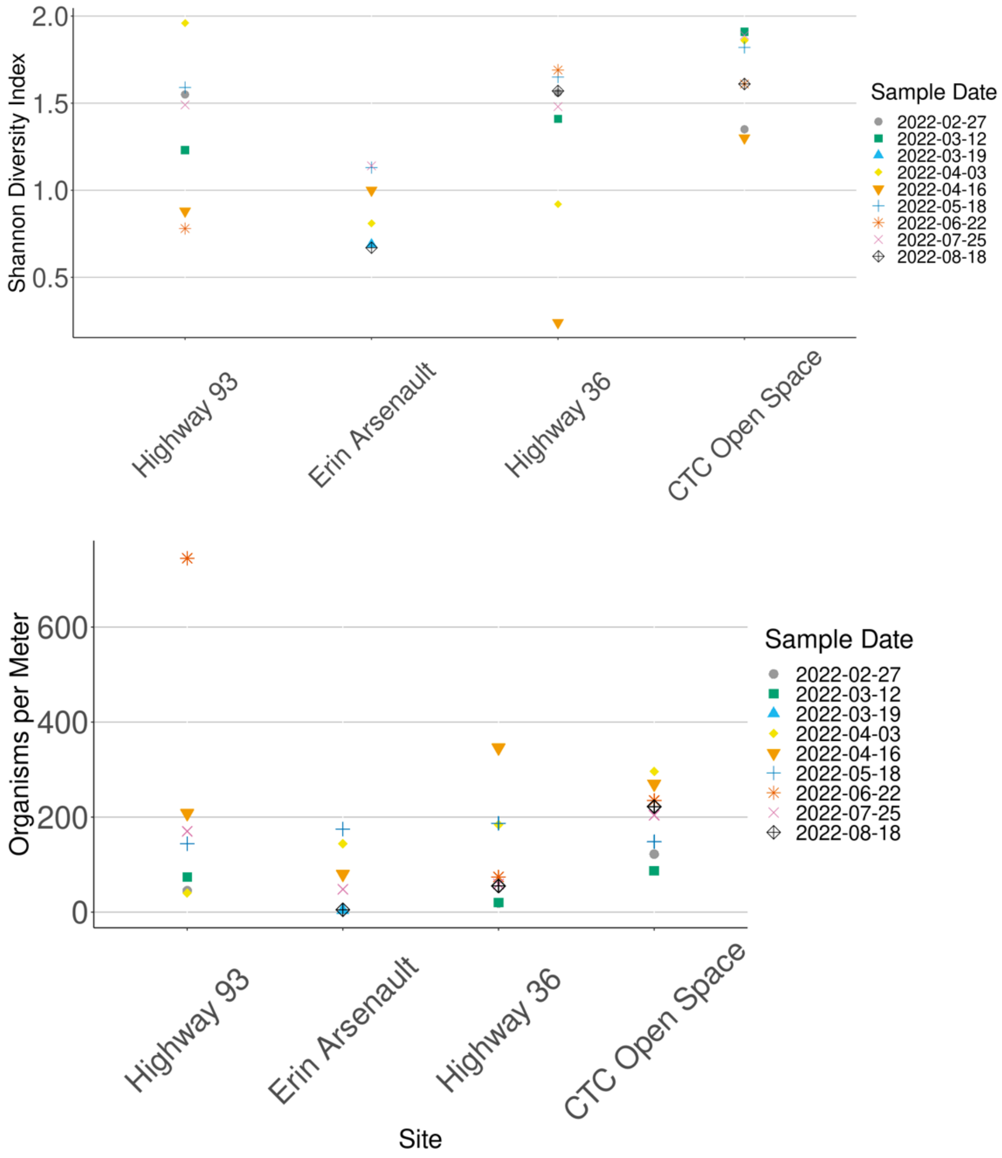


Figure 9. Benthic macroinvertebrate Shannon diversity and organisms per meter. Please note, Erin Arsenault refers to the OSMP-managed Superior Associates Open Space. Sample dates range from February to August 2022.

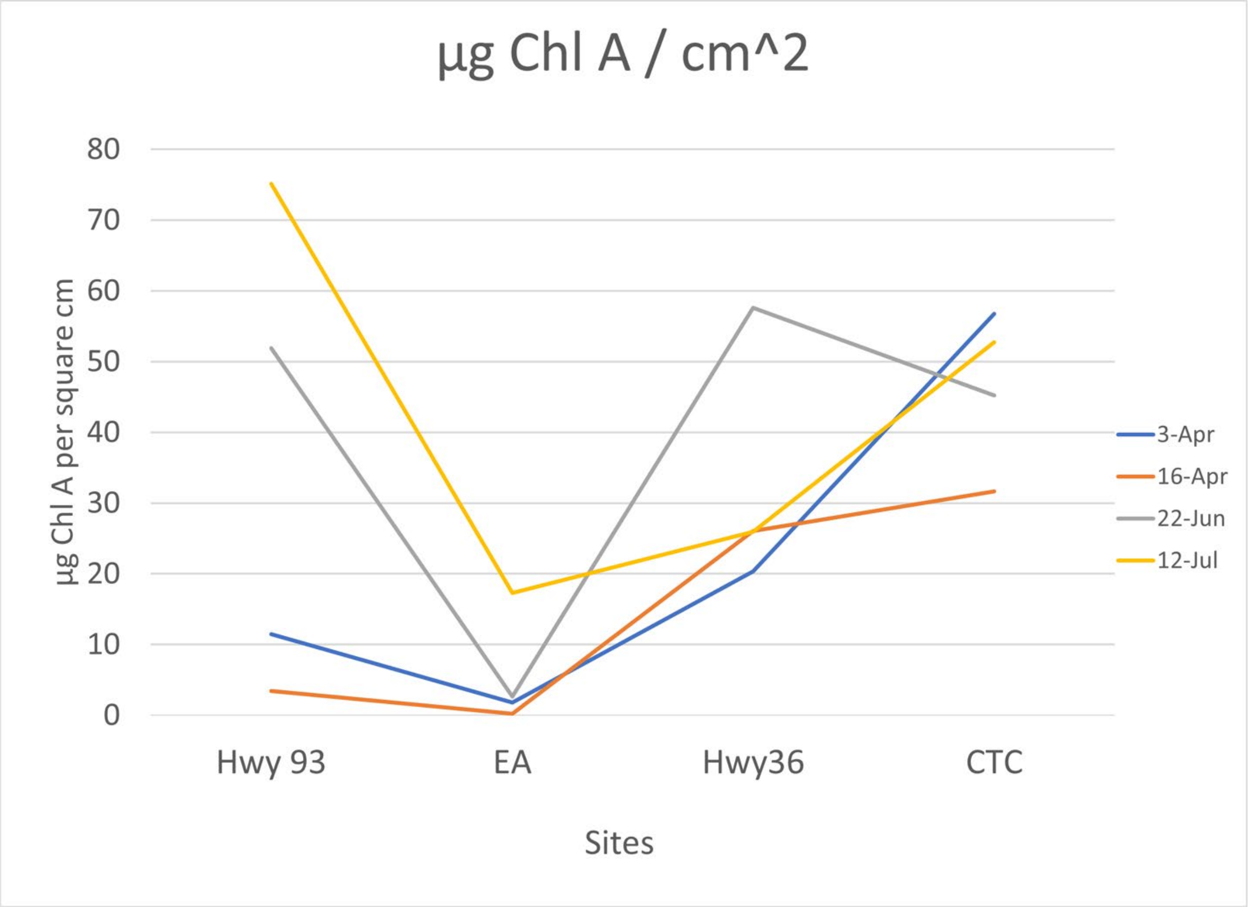


Figure 10. Chlorophyll a data from spring and summer 2022 at Highway 93, Superior Associates (EA), Highway 36, and Colorado Tech Center (ug Chl A/cm^2).

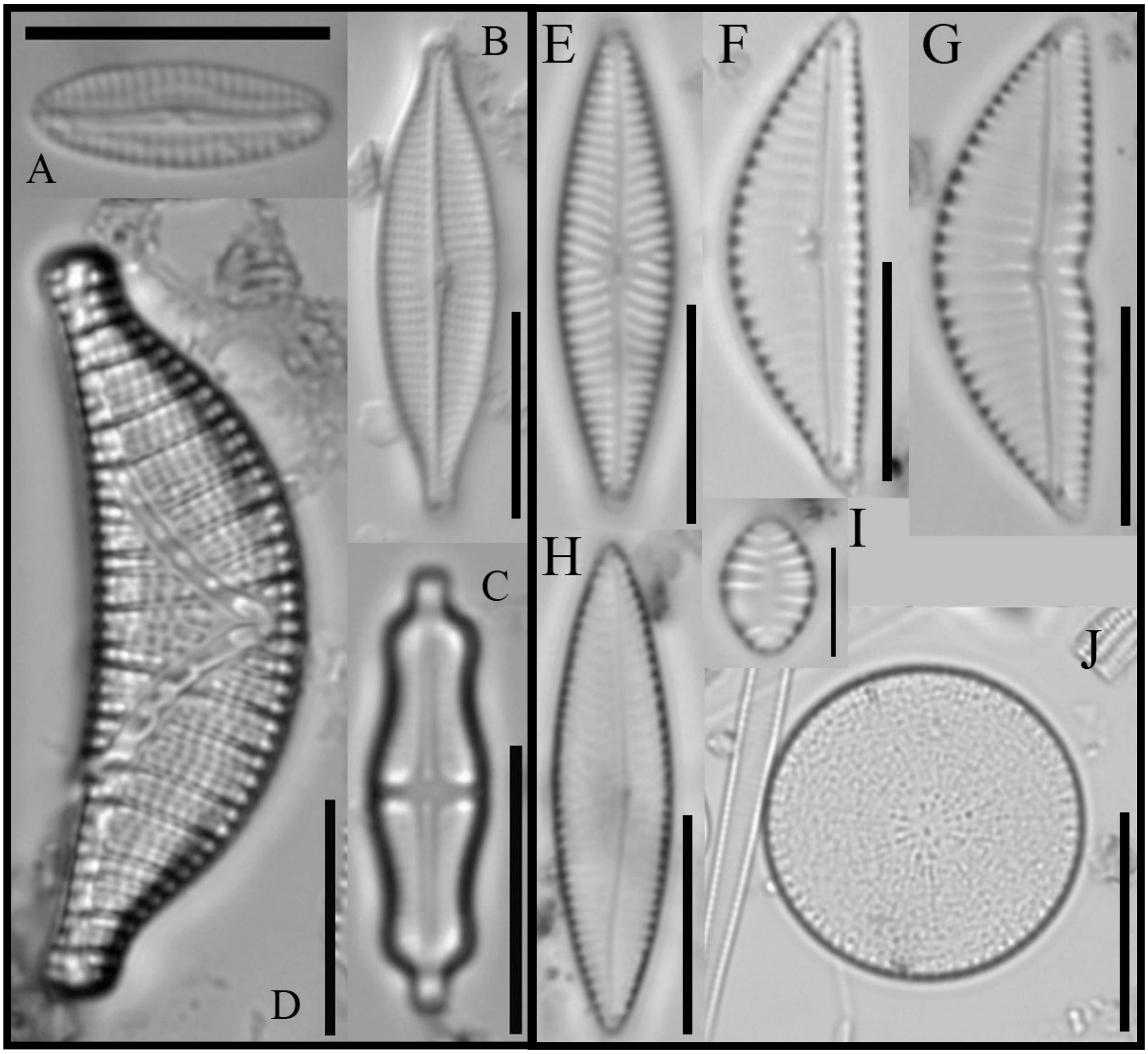


Figure 11. *Plate #3*
Left: A selection of diatoms found at the reference site (Highway 93). A, Microcostatus, a genus common in aerophilic habitats. B, Navicula gregaria, a cosmopolitan taxon known to also occur in the MDV. C, Stauroneis separanda, a taxon common in headwater streams. D, Epithemia sorex, one of several taxa in the genus Epithemia that are abundant at this site, all of which are known to be capable of nitrogen fixation.
Right: A selection of diatoms from the sampling site at Highway 36. E, Navicula sp. healthy specimen, H, teratological form of the same species of Navicula. F, healthy specimen of Encyonema sp., G, teratological Encyonema sp. I, Teratological form of Fragilaria sp. (Scale bar = 5 µm). J, Conticribra weissflogii, a marine taxon indicative of very high conductivity*, formerly placed in the genus Thallasiosira (Stachura-Suchoples & Williams, 2009).*
All scale bars = 10 µm unless noted otherwise.

Appendices

Appendix Table 1. Preliminary Benthic Macroinvertebrate Identifications and Counts

Date	Site	Voucher ID	Voucher	ID#	Name	Count
3/12/22	1	1-1	001	1	Amphipoda	42
3/12/22	1	1-2	002	2	Chironomidae	20
3/12/22	1	1-3	003	3	Isopoda	5
3/12/22	1	1-4	004	4	Plecoptera	2
3/12/22	1	1-5	005	24	Hydropsychidae	2
3/12/22	1	1-6	006	18	Leptophlebia	1
3/12/22	1	1-8	007	7	Planaria	1
3/12/22	1	1-9	NC	8	Gastropoda	1
3/12/22	3	3-1	009	9	Tipulidae	2
3/12/22	3	3-2	010	1	Amphipoda	7
3/12/22	3	3-3	011	22	Baetis	1
3/12/22	3	3-4	012	5	Trichoptera	1
3/12/22	3	3-5	013	2	Chironomidae	8
3/12/22	3	3-6	014	10	Nematoda	1
3/12/22	4	4-1	015	11	Zygoptera	1
3/12/22	4	4-2	016	9	Tipulidae	4
3/12/22	4	4-3	017	19	Tricorythodes	1
3/12/22	4	4-4	018	22	Baetis	2
3/12/22	4	4-5	019		Ephemoptera #3	24
3/12/22	4	4-6	020	12	Simulidae	18
3/12/22	4	4-7.1	NC	24	Hydropsychidae	3
3/12/22	4	4-7.2	NC	25	Limnephilidae	1
3/12/22	4	4-8	023	1	Amphipoda	10
3/12/22	4	4-9	024	2	Chironomidae	9
3/12/22	4	4-10	025	7	Planaria	11
3/12/22	4	4-11	026	13	Hydrachnidia	2
3/12/22	4	4-12	NC	14	Oligochaeta	1
4/3/22	1	1-1	028	4	Plecoptera	3
4/3/22	1	1-2	029	17	Chironomidae (red)	1
4/3/22	1	1-3	030	1	Amphipoda	9
4/3/22	1	1-4	031	15	Annelid	5
4/3/22	1	1-5	032	7	Planarian	5

4/3/22	1	1-7	034	2	Chironomidae (white)	12
4/3/22	1	1-8	035	6	Ephemoptera	1
4/3/22	1	1-9	NC	12	Simulidae	1
4/3/22	1	1-10	NC	16	Decapoda	1
4/3/22	1	1-11	NC	3	Isopoda	1
4/3/22	1	X(found on rock)	NC	24	Trichoptera (Green)	1
4/3/22	2	2-1	040	2	Chironomidae (white)	84
4/3/22	2	2-2	041		Maggot?	2
4/3/22	2	2-3	042	2	Chironomidae #2	1
4/3/22	2	2-4	043	12	Simulidae	55
4/3/22	2	2-5	NC	15	Annelid	1
4/3/22	2	2-6	NC	10	Nematode	1
4/3/22	3	3-1	046	13	Hydrachnidae	9
4/3/22	3	3-2	047	1	Amphipoda	4
4/3/22	3	3-3	048	2	Chironomidae (White)	139
4/3/22	3	3-5	050	24	Hydropsychidae	12
4/3/22	3	3-6	051	24	Hydropsychidae	10
4/3/22	3	3-7	052	19	Tricorythodes	2
4/3/22	3	3-8	NC	12	Simulidae	1
4/3/22	3	3-9	NC	16	Decapoda	2
4/3/22	3	3-10	NC	15	Annelid	5
4/3/22	4	4-1	NC	12	Simulidae	92
4/3/22	4	4-2	057	11	Zygoptera	2
4/3/22	4	4-3	NC	2	Chironomidae (white)	41
4/3/22	4	4-4	059		Ephemoptera #1	28
4/3/22	4	4-5	060	22	Baetis	41
4/3/22	4	4-6	061	19	Tricorythodes	3
4/3/22	4	4-7	NC	9	Tipulidae	16
4/3/22	4	4-8	NC	7	Planaria	34
4/3/22	4	4-9	NC	24	Hydropsychidae	3
4/3/22	4	4-10	NC	25	Limnephilidae	2
4/3/22	4	4-11	NC	15	Annelid	17
4/3/22	4	4-12	NC	13	Hydrachnidae	2
4/3/22	4	4-13	NC	1	Amphipoda	13
4/3/22	4	4-14	069	8	Gastropoda	2

4/16/22	1	1-1	070	4	Plecoptera	2
4/16/22	1	1-2	071	11	Zygoptera	1
4/16/22	1	1-3	072	24	Hydropsychidae	3
4/16/22	1	1-4	073	22	Baetis	2
4/16/22	1	1-5	074	2	Chironomidae	10
4/16/22	1	1-6	075	1	Amphipoda	33
4/16/22	1	1-7	NC	12	Simulidae	155
4/16/22	1	1-8	NC	15	Annelida	2
4/16/22	2	2-1	NC	12	Simulidae	34
4/16/22	2	2-2	NC	2	Chironomids	39
4/16/22	2	2-3	NC	10	Nematode	5
4/16/22	2	2-4	NC	7	Flatworm	1
4/16/22	2	2-5	085	4	Stonefly	1
4/16/22	3	3-1	NC	2	Chironomids	331
4/16/22	3	3-2	086	24	Hydropsychidae	3
4/16/22	3	3-3	087	24	Hydropsychidae	4
4/16/22	3	3-4	NC	15	Annelid	2
4/16/22	3	3-5	NC	10	Nematode	3
4/16/22	3	3-6	090	19	Mayfly	1
4/16/22	3	3-7	NC	13	Water mite	2
4/16/22	4		NC	2	Chironomids	175
4/16/22	4	4-1	091	22	Baetis	12
4/16/22	4	4-2	092	19	Tricorythodes	9
4/16/22	4	4-3	093	11	Zygoptera	3
4/16/22	4	4-4	094	20	Crangonyx	6
4/16/22	4	4-5	095	21	Hyalella	5
4/16/22	4	4-6	096	9	Cranefly	1
4/16/22	4	4-7	097	24	Hydropsychidae	5
4/16/22	4		NC	7	Flatworm	22
4/16/22	4	4-8	098	6	Mayfly #3	6
4/16/22	4		NC	15	Annelid	17
4/16/22	4		NC	13	Water mite	3
4/16/22	4	4-9	099	5	Green caddis	1
4/16/22	4		NC	17	Chironomid (red)	3
4/16/22	4	4-10	100	25	Limnephilidae	2
5/18/22	1		NC	15	Annelids	3
5/18/22	1	1-1	101	4	Plecoptera	17
5/18/22	1	1-2	102	20	Crangonyx	8
5/18/22	1	1-3	103	21	Hyalella	1

5/18/22	1		NC	12	Simulidae	65
5/18/22	1		NC	10	Nematoda	1
5/18/22	1		NC	7	Planaria	1
5/18/22	1	1-4	104	19	Tricorythodes	1
5/18/22	1	1-5	105	22	Baetis	17
5/18/22	1	1-6	106	5	Trichoptera (green)	1
5/18/22	1	1-6	106	24	Hydropsychidae	2
5/18/22	1		NC	2	Chironomids	27
5/18/22	2	2-1	107	5	Unknown Trichoptera	3
5/18/22	2	2-2	108	22	Baetis	108
5/18/22	2	2-3	109	18	Ephemoptera (prong gilled)	8
5/18/22	2		NC	7	Planaria	9
5/18/22	2		NC	15	Annelid	6
5/18/22	2	2-4	110	20	Crangonyx	4
5/18/22	2		NC	2	Chironomids	7
5/18/22	2		NC	12	Simulidae	30
5/18/22	3	3-1	111	19	Tricorythodes	2
5/18/22	3	3-2	112	5	Unknown Trichoptera	3
5/18/22	3	3-3	113	5	Trichoptera (brown)	2
5/18/22	3		NC	10	Nematoda	6
5/18/22	3		NC	13	Hydrachnida	1
5/18/22	3	3-4	114	17	Chironomids (red)	60
5/18/22	3		NC	15	Annelids	3
5/18/22	3		NC	2	Chironomids (white)	63
5/18/22	3	3-5	115	22	Baetis	6
5/18/22	3		NC	12	Simulidae	20
5/18/22	3	3-6	116	20	Crangonyx	17
5/18/22	3	3-7	117	21	Hyalella	4
5/18/22	4	4-5	118	19	Tricorythodes	9
5/18/22	4		NC	7	Planaria	2
5/18/22	4	4-1	119	5	Trichoptera (green)	1
5/18/22	4	4-1	119	5	Trichoptera (cased)	1

5/18/22	4	4-2	120	11	Zygoptera	2
5/18/22	4		NC	9	Tipulidae	3
5/18/22	4		NC	16	Decapoda	3
5/18/22	4		NC	15	Annelids	5
5/18/22	4		NC	12	Simulidae	4
5/18/22	4		NC	2	Chironomids (white)	34
5/18/22	4		NC	10	Nematoda	5
5/18/22	4		NC	17	Chironomids (red)	8
5/18/22	4	4-3	121	22	Baetis	12
5/18/22	4	4-4	122	5	Unknown Trichoptera	1
5/18/22	4	4-5	123	20	Crangonyx	50
5/18/22	4	4-6	124	21	Hyalella	8
6/22/22	1	NC	NC	15	Annelid	4
6/22/22	1	1-1	125	23	Ephemoptera #1 (long tailed)	1
6/22/22	1	1-2	126	22	Baetis	57
6/22/22	1		NC	12	Simulidae	580
6/22/22	1	1-3	127	4	Stoneflies	2
6/22/22	1	1-4	128	20	Crangonyx	14
6/22/22	1	1-5	129	21	Hyalella	2
6/22/22	1		NC	2	Chironomids (wh)	84
6/22/22	1		NC	10	nematode	1
6/22/22	3		NC	2	Chiron (wh)	21
6/22/22	3		NC	17	Chiron (r)	3
6/22/22	3	3-1	130		Mayflies (#1)	8
6/22/22	3	3-2	131	19	Tricorythodes	1
6/22/22	3	3-3	132	5	Caddis	3
6/22/22	3		NC	15	Annelid	5
6/22/22	3		NC	13	Hydrachnidia	1
6/22/22	3		NC	10	Nematode	5
6/22/22	3	3-4	133	26	Clitellata	1
6/22/22	3	3-5	134	20	Crangonyx	23
6/22/22	3	3-6	135	21	Hyalella	3
6/22/22	4	4-1	136	8	Gastropod	4
6/22/22	4		NC	17	Chiron (r)	3
6/22/22	4		NC	2	Chiron (wh)	37

6/22/22	4		NC	15	Annelids	22
6/22/22	4		NC	7	Flat worms	18
6/22/22	4		NC	10	Nematodes	3
6/22/22	4		NC	13	Hydrachnidia	3
6/22/22	4	4-2	137	20	Crangonyx	20
6/22/22	4	4-3	138	21	Hyalella	4
6/22/22	4	4-4	139		Mayflies (#1)	51
6/22/22	4	4-5	140	19	Tricorythodes	65
6/22/22	4	4-6	141	11	Zygoptera	3
6/22/22	4	4-7	142	26	Clitellata	1
6/22/22	4	4-8	143	5	Caddis	1
7/25/22	1		144	27	Mayfly #1	1
7/25/22	1		145	20	Scuds (C)	22
7/25/22	1	1-1	146	21	Scuds (H)	72
7/25/22	1		147	22	Mayfly #2 (Baetis)	25
7/25/22	2		148	22	Mayflies (Baetis)	17
7/25/22	5		149	22	Mayflies (Baetis)	46
7/25/22	5		150	19	Mayfly (Tricory)	1
7/25/22	5		151	24	Caddis	2
7/25/22	5		152	13	Water mite	1
7/25/22	5		153	20	Scuds (C)	13
7/25/22	5		154	21	Scuds (H)	7
7/25/22	3		155	22	Mayfly (Baetis)	16
7/25/22	3		156	2	Chironomid (White)	1
7/25/22	3		157	20	Scuds (C)	1
7/25/22	3		158	21	Scuds (H)	2
7/25/22	2		159	21	Scud (H)	1
7/25/22	5		160	24	Caddis	27
7/25/22	5		161	19	Mayfly (Trico)	5
7/25/22	3		162	19	Mayfly (Trico)	4
7/25/22	3		163	24	Caddis (G)	1
7/25/22	1		164	28	Diving Beetle	1
7/25/22	5		165	24	Cased Caddis	1
7/25/22	1		166	24	B. Caddis	5
7/25/22	1		167	3	Isopod (Asellidae)	8
7/25/22	5		168	29	Coleoptera (Gyrinidae?)	4

7/25/22	5		169	8	Snail	5
7/25/22	1			16	Crawfish	17
7/25/22	1			10	Nematode	1
7/25/22	1			15	Annelids	11
7/25/22	1			2	White Chironomid	5
7/25/22	1			17	Red Chironomid	2
7/25/22	2			30	Blackflies	23
7/25/22	2			2	Chironomids (White)	6
7/25/22	2			8	Snail	1
7/25/22	3			17	Red Chironomid	2
7/25/22	3			30	Blackflies	16
7/25/22	3			2	White Chironomid	15
7/25/22	3			16	Crawfish	1
7/25/22	5			15	Annelid	22
7/25/22	5			7	Flatworms	59
7/25/22	5			26	Leech	1
7/25/22	5			10	Nematode	3
7/25/22	5			30	Blackflies	3
7/25/22	5			2	Chironomids (White?)	2
7/25/22	5			16	Crawfish	2
8/18/22	2			10	Nematode	3
8/18/22	2			2	White Chironomid	2
8/18/22	3			16	Crawfish	1
8/18/22	3			26	Leech	1
8/18/22	3			2	White Chironomid	13
8/18/22	3			17	Red Chironomid	1
8/18/22	3			13	Water mite	1
8/18/22	3			15	Annelids	5
8/18/22	3			10	Nematode	1
8/18/22	5		170	20	Scuds (C)	8
8/18/22	5		171	22	Baetis	84
8/18/22	5		172	19	Tricorythodes	17
8/18/22	5		173	13	Water Mite	5
8/18/22	5			30	Midge	1

8/18/22	5		174	31	Maggot (Dance Fly)	1
8/18/22	5		175	24	Caddisfly	54
8/18/22	5			17	Red Chironomid	1
8/18/22	5			15	Annelid	17
8/18/22	5			7	Flatworms	16
8/18/22	5			10	Nematode	3
8/18/22	5			2	White Chironomid	15
8/18/22	3		176	22	Mayfly (Baetis)	6
8/18/22	3		177	19	Mayfly (Trico)	1
8/18/22	3		178	24	Caddis	1
8/18/22	3		179	24	Caddis	15
8/18/22	3		180	2	Chironomid (white)	9