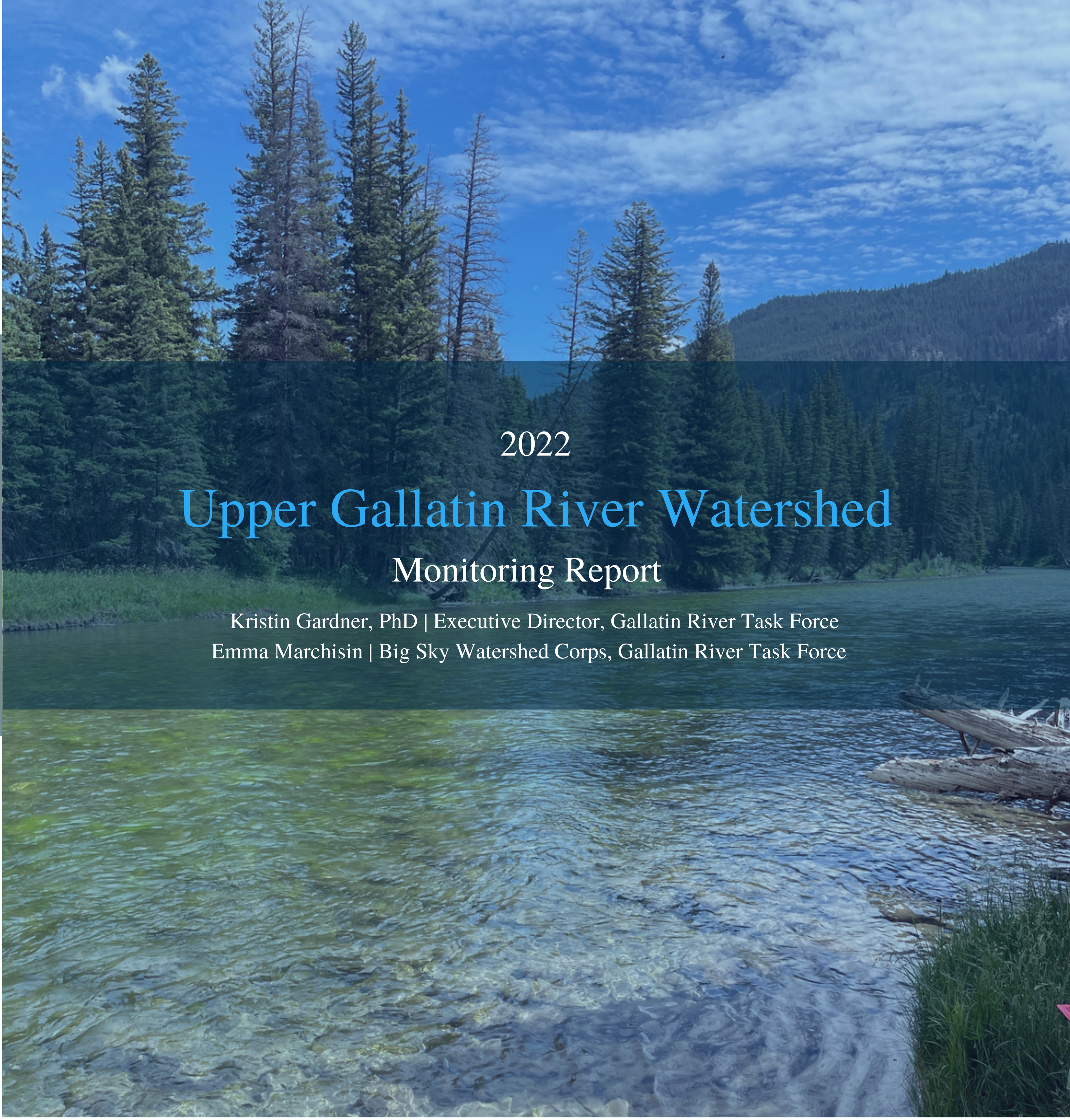


2022

Upper Gallatin River Watershed

Monitoring Report

Kristin Gardner, PhD | Executive Director, Gallatin River Task Force
Emma Marchisin | Big Sky Watershed Corps, Gallatin River Task Force

GALLATIN RIVER
TASK FORCE

The Gallatin River Task Force Community Water Quality Monitoring Program is supported by the Big Sky Resort Area Tax District, the Montana Department of Environmental Quality, Task Force donors, and volunteers. Thank you for investing in the health of the Upper Gallatin River Watershed.

Table of Contents

Tables

Figures

Executive Summary

In July of 2018, an unprecedented nuisance algae bloom occurred in the Upper Gallatin River. The dominant algae species was *Cladophora glomerata*, a filamentous algae. To investigate this, the Gallatin River Task Force is partnering with the Montana Department of Environmental Quality (MT DEQ) on a study to determine the causes of the nuisance algae growth in the Gallatin. Similar nuisance blooms occurred again in 2020 and 2022. Factors that can influence algae growth include nitrogen and phosphorus concentrations, water temperature, water hardness, streamflow, and sunlight.

In 2022, nutrient and algae data was collected at 13 sites along the Upper Gallatin and tributaries including the Taylor Fork, West Fork, Middle Fork, and South Fork. Five continuous gauges were used to collect water temperatures and streamflow in the Upper West Fork, North Fork, South Fork, lower West Fork, and Upper Deer Creek.

A large-scale algae bloom was observed in 2022. Algae data indicated that four sites were above the ash-free dry weight Montana state threshold of 35 mg/m^2 applicable from July 1st to September 30th with visually heavy cover of filamentous algae on the streambed (40-75% cover). At one site, chlorophyll A concentration was above the Montana state threshold of 125 mg/m^2.

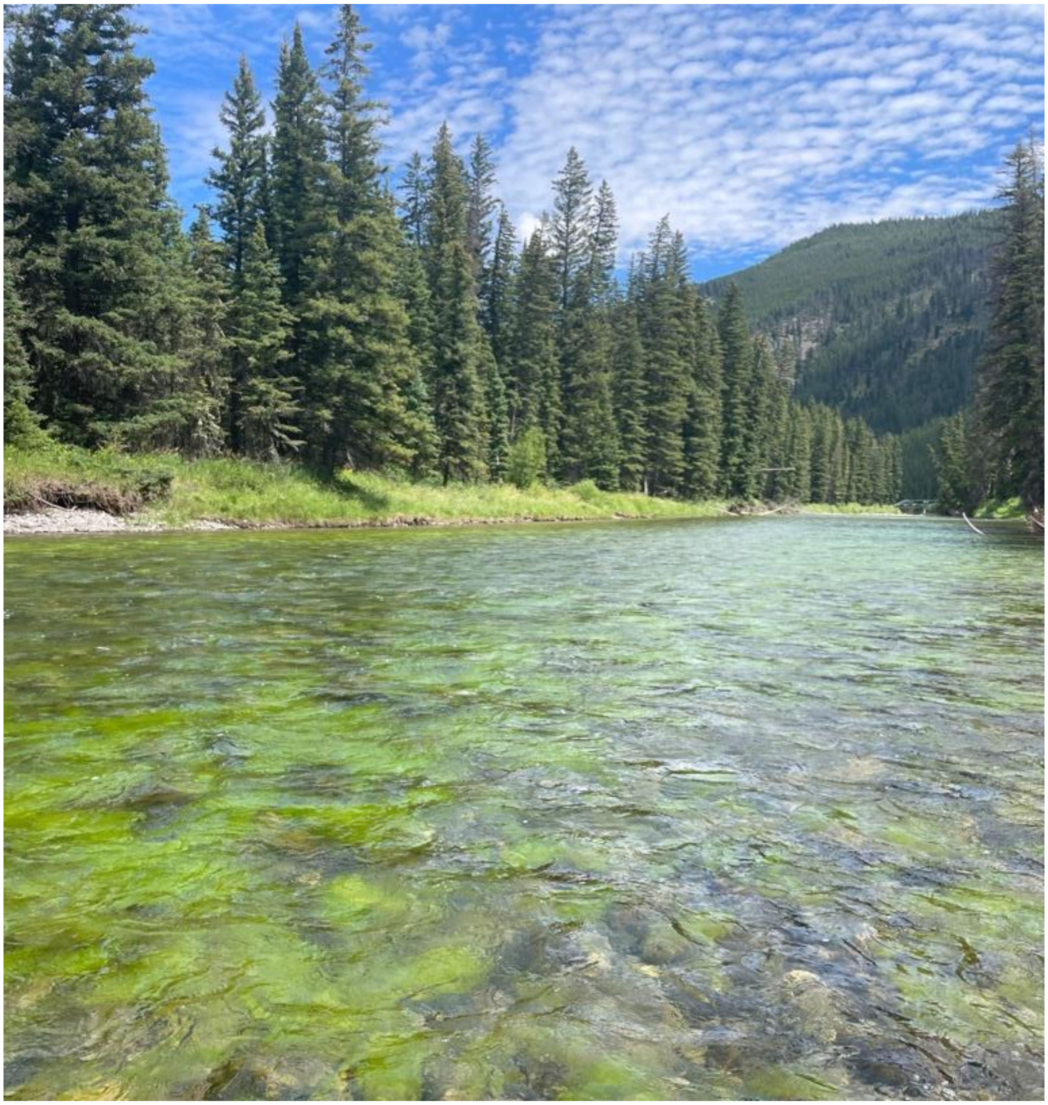
Total nitrogen at one site on the West Fork was above the Montana water quality standard (MT WQS) of 0.3 mg/L in August and September. This West Fork site has historically exhibited high nitrogen levels and is currently listed as impaired for nitrogen. At all other sites, levels of nitrogen and phosphorus were below MT WQS during the applicable time frame of July 1st to September 30th. Nitrogen and phosphorus loads were highest in June during spring runoff then dropped to lower levels for the rest of the season. Two sites on the West Fork had elevated nitrate-nitrite levels, above 0.1 mg/L. Nutrient limitation experiments at four sites three on the mainstem Gallatin and one in Taylor fork- indicate algae growth was limited by nitrogen.

Average air temperature in August was higher than past years that the study has been conducted. By July, water temperatures at all sites were within the growing range for Cladophora. All but the North Fork hit into the optimal growing range in August then dropped but were still within the growing range in September. From August to October, all sites were within the ideal hardness levels for Cladophora growth except for one site on the Middle Fork and two on the West Fork.

2022 peak streamflow occurred during the third week of June, slightly later than past years. The peak was 168% of the historical average. As the season progressed, streamflow stayed close to the historical average and then dropped below average at the end of the summer.

During July of 2018, 2020, 2022, solar irradiance was higher than 2019 and 2021 corresponding with the years of large-scale algae blooms. Average solar irradiance in August of 2022 was the highest for that month since the study started five years ago. These correlations indicate the significant role sunlight may play on the occurrence of nuisance algae blooms.

After five years of data collection, preliminary findings suggest algae blooms are caused by a combination of sufficient nutrients, warm water temperatures, low streamflow, and an abundance of sunlight. To address some of the factors and mitigate future blooms, the Gallatin River Task Force has been working to reduce nutrient levels in the Upper Gallatin while also reducing commercial and residential water usage. Examples of this work include restoration projects on the West Fork and Gallatin, Trout Friendly Landscaping program, rebates for commercial and residential water-saving fixtures, and connecting Gallatin Canyon to a centralized sewer system. There are many actions the community can take to make a positive impact, including landscaping with native plants, regularly inspecting private septic systems, avoiding fertilizer application before storms, picking up pet waste, and much more. Every action counts in an effort to keep the Gallatin a resilient and thriving river!



Algae at Gallatin below the West Fork

Introduction

The Gallatin River Task Force (Task Force) is a non-profit organization focused on preserving the health of the Gallatin River watershed for now and future generations. With a mission *to partner with our greater community to lead conservation and inspire stewardship of the Gallatin River Watershed*, the Task Force and dedicated volunteers have been collecting watershed data since 2000 on the Upper Gallatin River and its tributaries. This data is used to assess water quality and health, identify historical trends, determine impacts of unforeseen events, and guide resource management decisions.

The Upper Gallatin River flows north from its headwaters in Yellowstone National Park to the Spanish Creek confluence, just before it exits Gallatin Canyon. In 2018, the Upper Gallatin first experienced a large-scale algae bloom at sites on the South Fork, West Fork, Taylor Fork, and mainstem Gallatin River. Large-scale algae blooms have negative impacts on water quality, aquatic life, and human recreation. Factors that can influence algae growth include phosphorus and nitrogen levels, water temperature, water hardness, streamflow, and sunlight.

Data collected in 2018 indicated that nitrogen levels were some of the highest recorded in the West Fork. Sources of anthropogenic nitrogen include fertilizer, stormwater runoff, land application of treated wastewater, effluent from private septic systems, and pet waste. Sunlight levels were higher in July 2018 than any other years recorded at the ORSL weather station in Bozeman since 2012. Average weekly water temperature during the last week of July at the West Fork streamflow station was the highest ever recorded since installing the gauge in 2009. This week aligned with the start of the 2018 algae bloom which suggests that water temperature, high sunlight, and nutrient concentration are important factors that contribute to algae growth in the Gallatin River and tributaries.

Responding to the bloom, the Task Force began partnering with the Montana Department of Environmental Quality (MT DEQ) in 2019 to conduct annual assessments on the Upper Gallatin to determine drivers of the nuisance algae blooms. There was not a widespread algae bloom in 2019 or 2021; however, blooms did occur in 2020 and 2022. This data will inform MT DEQ's establishment of a Total Maximum Daily Load for the Upper Gallatin if the EPA approves MT DEQ's preliminary determination that the Upper Gallatin is impaired by nuisance algae. This report summarizes the data collected during the 2022 season.

Sampling algae via the hoop method

Nutrient and Algae Assessment

Background

Algae

Cladophora glomerata (Cladophora) is the dominant algae species that grows in the Gallatin River and its tributaries. Excess algae growth can deplete rivers of dissolved oxygen vital for aquatic life and alter aquatic insect habitat. Factors that can contribute to these nuisance algae blooms by creating an ideal environment for growth are: 1) water flowing at a velocity of 0.4-0.7 m/sec, 2) clear water that allows sunlight to penetrate down to the algae, 3) sufficient sunlight to stimulate photosynthesis, 4) elevated nitrogen and/or phosphorus concentrations, 4) water temperatures between 10-25 degrees Celsius, 5) pH levels greater than 7.0, and 6) water hardness of greater than 121 mg/L $CaCO_3$.

To assess algae growth, chlorophyll A and ash free dry weight (AFDW) are measured to quantify the amount of algae growing in a given area. Chlorophyll A is a green pigment found in plant cells, including algae, that facilitates photosynthesis. AFDW is the mass of organic matter after algae samples have been thoroughly dried. The state of Montana has determined thresholds for both measures. The threshold for chlorophyll A is 125 mg/m^2 and ADFW is 35 mg/m^2. Microalgae is collected through the template method and filamentous algae through the hoop method. Methods of collection are detailed within the Sampling Analysis Plan (MT DEQ, 2022).

Nutrients

The primary nutrients facilitating algae growth in the Gallatin River are nitrogen and phosphorus. Three tributaries in the Upper Gallatin watershed are on the Montana 303(d) list as impaired for nitrogen- the West Fork, Middle Fork, and South Fork. Possible sources of excess nitrogen include fertilizer, land application of treated wastewater, effluent from private septic systems, pet waste, and stormwater runoff. Sources of excess phosphorus are similar to those of nitrogen with the addition of soil erosion. Historically, phosphorus concentration in the Upper Gallatin tributaries have been below Montana state water quality standards (MT WQS). The MT WQS for total nitrogen is 0.3 mg/L and total phosphorus is 0.03 mg/L, with both standards applicable annually between July 1st until September 30th. Algae growth is limited by the availability of nitrogen and/or phosphorus in the water.

Air and Water Temperature

Warm water temperatures create ideal environments for Cladophora blooms. The growing range for Cladophora is between 10-25 degrees Celsius, with an optimal growing range of 13.5-17.5 degrees Celsius. Warm water temperatures create added stress for fish populations, such as trout that may be forced to migrate or struggle to survive when they are forced out of their optimal temperature range. Air temperature does not have a direct impact on Cladophora growth, but it does impact water temperatures and the timing of snowmelt runoff.

Water Hardness

Water hardness is the amount of magnesium and calcium in the water. Both of which are essential for plant growth and needed for the formation of calcium carbonate ($CaCO_3$). Cladophora thrives in a hardness of greater than 121 $CaCO_3$ mg/L.

Streamflow

Streamflow is the measure of the volume of water moving through a given system over a specific time period and is typically measured in cubic feet per second (CFS). Lower streamflow may facilitate algae growth because water is more easily influenced by warm air temperatures and sunlight can more easily reach the streambed.

Sunlight

Sunlight is necessary for algae to undergo photosynthesis. Sunlight is measured as solar irradiance which is the power received per unit area and measured in watts per meter squared (W/m^2).

Study Design

Water quality samples were collected over five events from June to October of 2022 *(Table 1) at* thirteen sites along the Upper Gallatin and tributaries including the Taylor Fork, West Fork, Middle Fork, and South Fork *(Figure 1 and 2)*. Five continuous gauges were used to collect water and air temperatures in the upper West Fork, North Fork, South Fork, lower West Fork, and Gallatin above Deer Creek. More details on the sampling methods and lab analysis can be found in the sampling analysis plan (MT DEQ, 2022).

	June 6/2	July 7/11	August 8/1-8/3	September 8/29-8/31	October 10/17
Air Temperature	X	X	X	X	X
Water Temperature	X	X	X	X	X
Conductivity	X	X	X	X	X
Dissolved Oxygen	X	X	X	X	X
pH	X	X	X	X	X
Total Suspended Solids	X	X	X	X	X
Total Nitrogen	X	X	X	X	X
Total Phosphorus	X	X	X	X	X
Nitrite + Nitrate	X	X	X	X	X
Orthophosphate	X	X	X	X	X
Hardness	X	X	X	X	X
Calcium	X	X	X	X	X
Magnesium	X	X	X	X	X
Ash Free Dry Weight			X	X	
Chlorophyll A			X	X	

Table 1: Water quality data measured at 13 sites in 2022 season

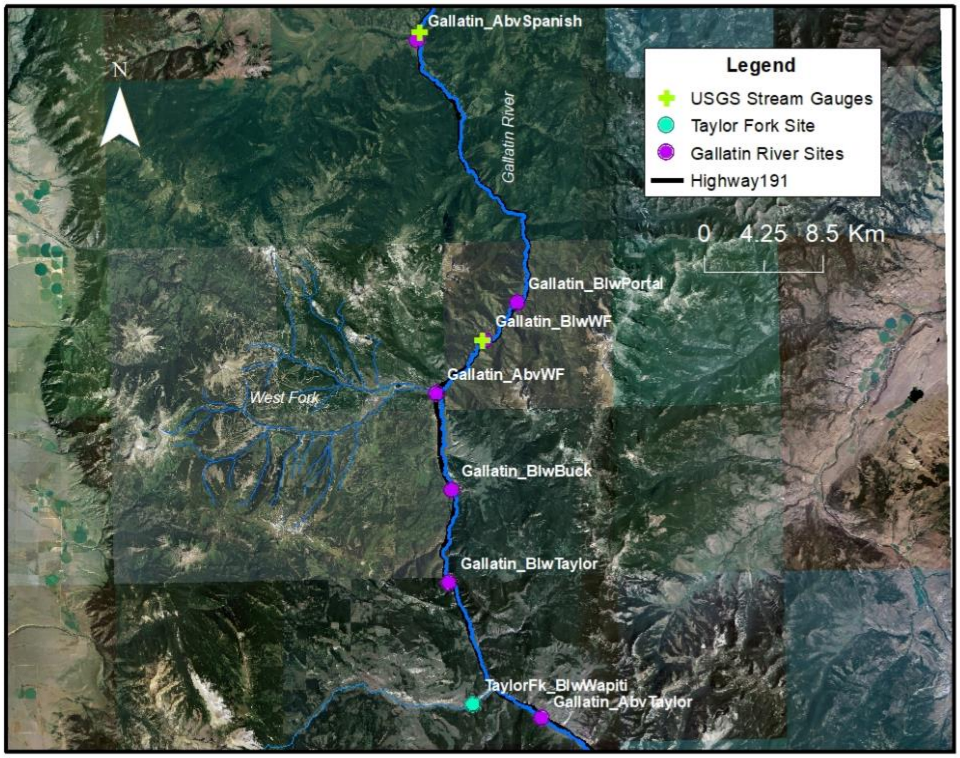


Figure 1: Map of monitoring sites along the mainstem Gallatin and Taylor Fork, and USGS stream gauges

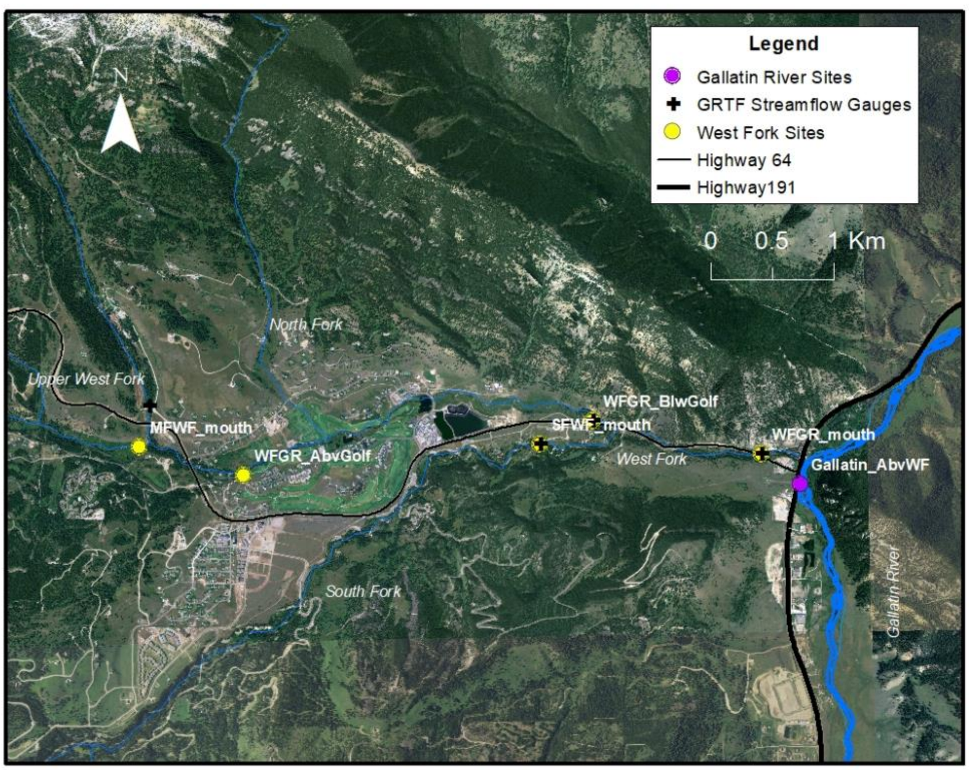


Figure 2: Map of monitoring sites and streamflow gauges in the West Fork watershed

2022 Monitoring Results

Algae

A widespread algae bloom occurred on the mainstem Gallatin, Taylor Fork, West Fork, and South Fork in 2022. All sites were below the Montana threshold for ash free dry weight (AFDW) in August *(Figure 3)* and exhibited an increase from August to September. Four sites were above the AFDW Montana state threshold in September: TaylorFk_BlwWapiti (110 mg/m^2), GallatinAbvWF (37.6 mg/m^2), SFWF_Mouth (60.9 mg/m^2), and Gallatin_BlwPortal (41.7 mg/m^2). Algae at these sites were measured primarily via template method in August and hoop method in September, showing the shift from microalgae to filamentous as the primary type of algae. Gallatin_AbvWF was completely inundated with Didymo Geminata, a diatom, which could explain the high AFDW in September despite a low percent cover of filamentous algae.

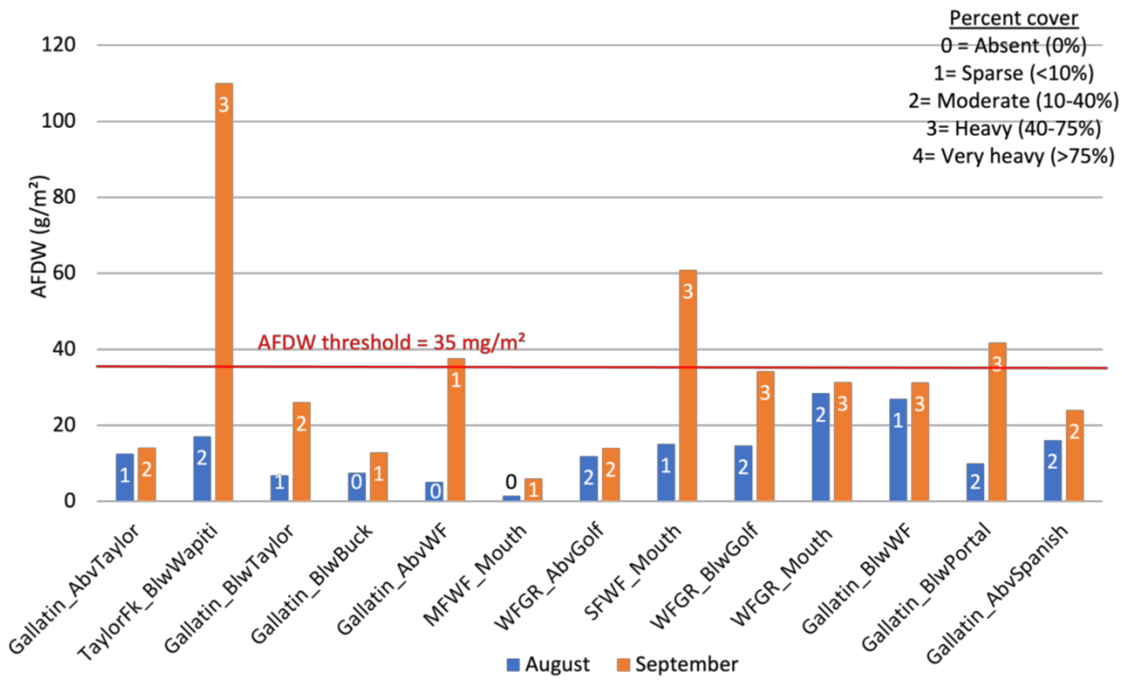


Figure 3: Ash free dry weight and percent cover of filamentous algae via visual assessment at 13 sites on the Gallatin, West Fork, South Fork, and Taylor Fork in August and September. For site locations, see Figures 1 and 2.

Chlorophyll A levels were below the Montana threshold of 125 mg/m^2 at all sites except for SFWF_Mouth in September (153.4 mg/m^2) *(Figure4)*. All sites exhibited an increase in chlorophyll A levels from August to September except for Gallatin_AbvSpanish, which decreased by 6.0 mg/m^2.

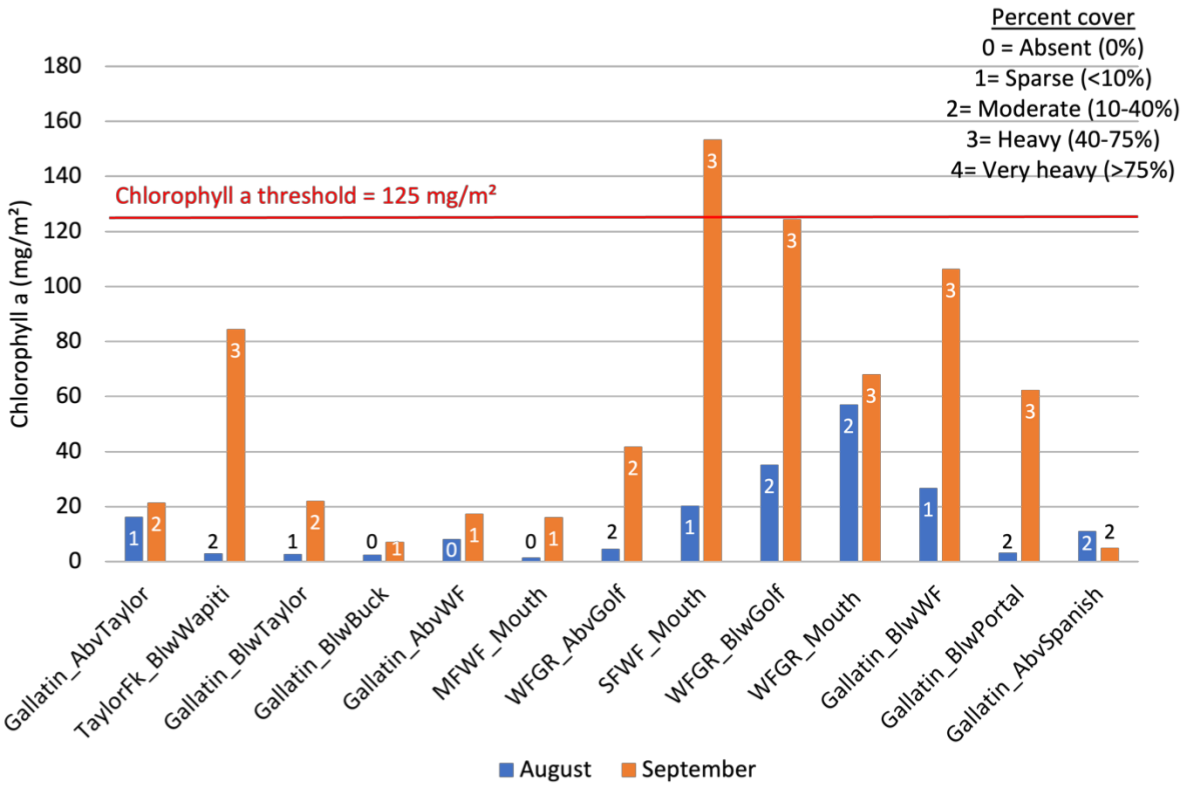


Figure 4: Chlorophyll A data and percent cover of filamentous algae via visual assessment at 13 sites on the Gallatin, West Fork, and Taylor Fork in August and September.

Algae below West Fork by Dave Pecunies

Nutrients

Total nitrogen (TN) levels at WFGR_BlwGolf were above the Montana water quality standard of 0.3 mg/L in August (0.34 mg/L) and September (0.4 mg/L) *(Figure 5)*.

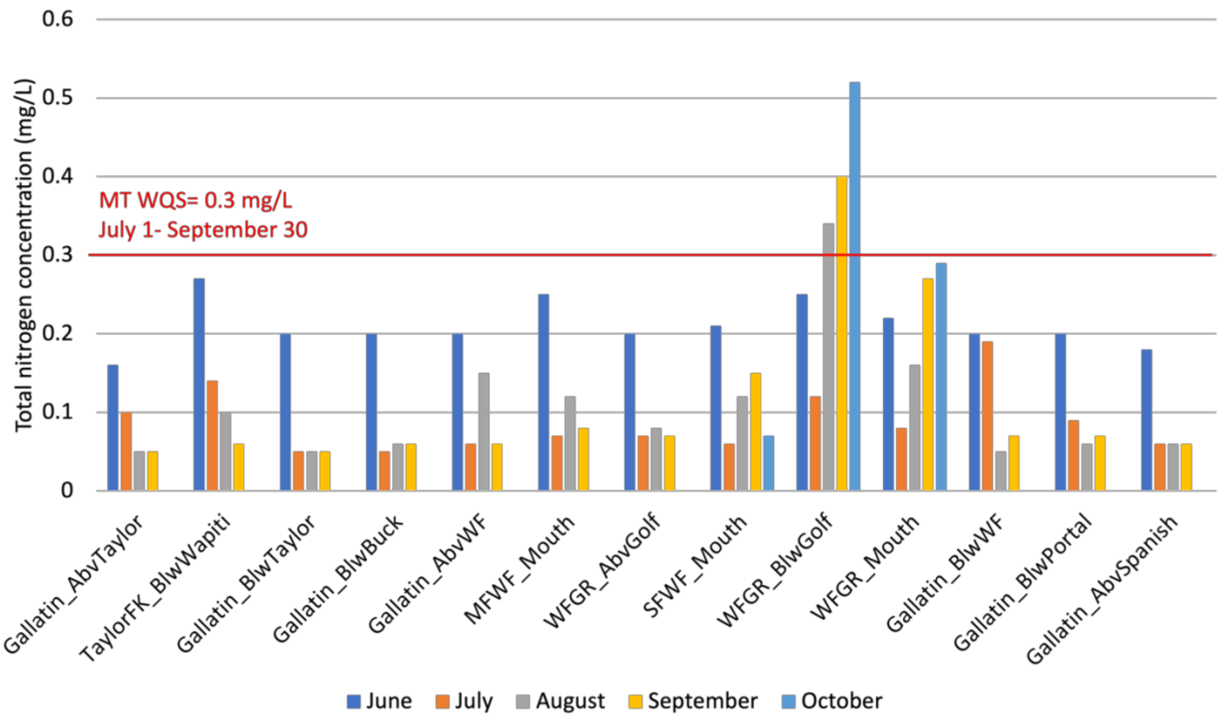


Figure 5: Total nitrogen concentrations across 13 sites for each month of 2022 season

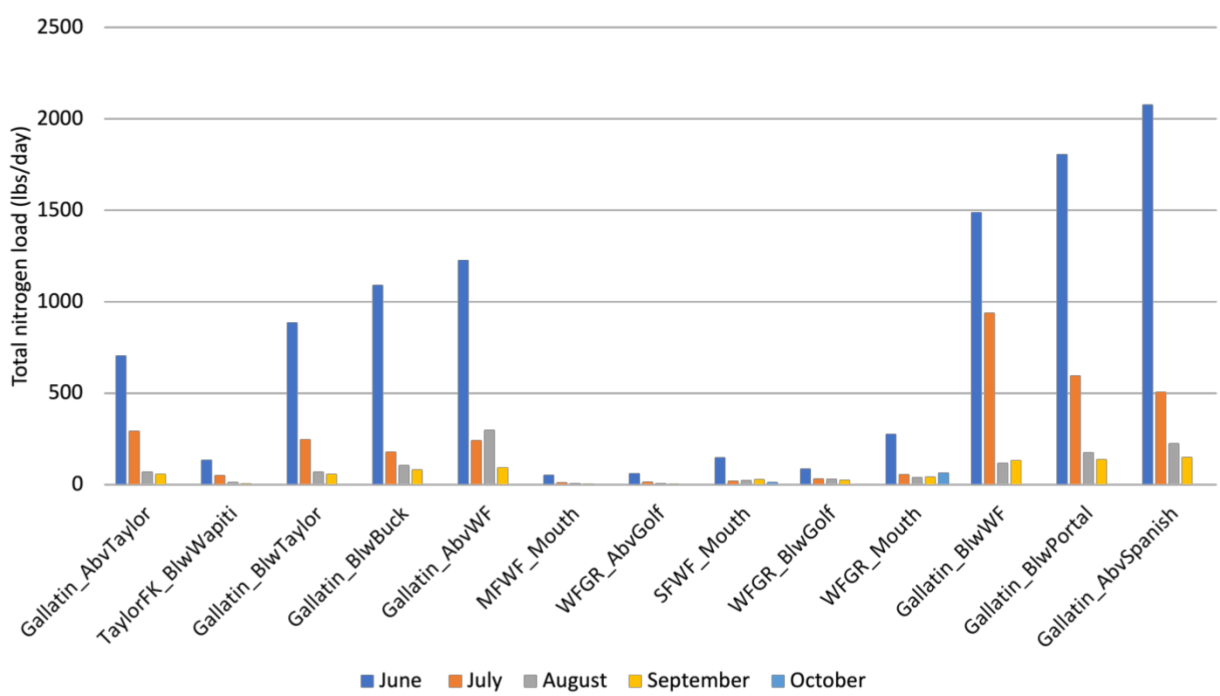


Figure 6: Total nitrogen loads calculated for 13 sites in 2022 season

Total nitrogen load, the amount of nitrogen in the water at a given time, was highest during spring runoff in June *(Figure 6)*. Loads were highest in the mainstem Gallatin compared to loads in the West Fork watershed and Taylor Fork. Following spring runoff, nitrogen loads dropped.

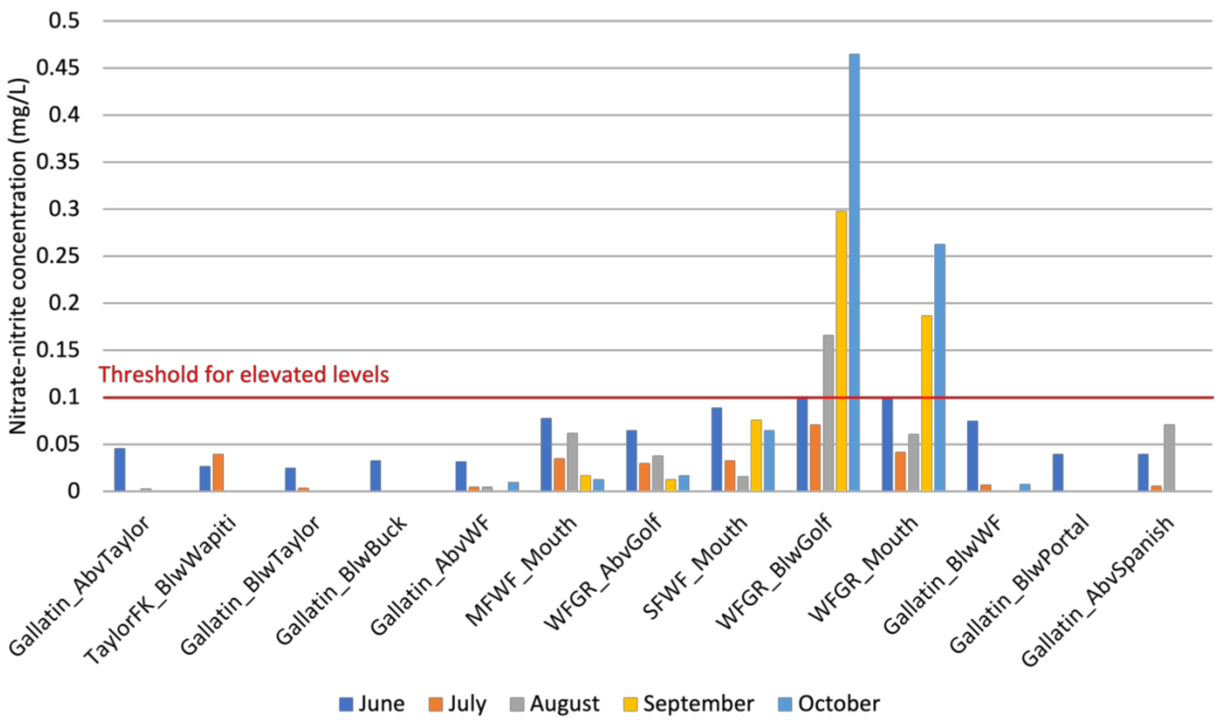


Figure 7: Nitrate-nitrite concentrations on the Gallatin and tributaries throughout 2022 season

Nitrate-nitrite, the form of nitrogen most readily assumed by plants, concentrations in August through October at WFGR_BlwGolf and September through October at WFGR_Mouth were elevated (>0.1 mg/L) *(Figure 7)*. Concentrations at both sites increased during a time when streamflow decreased suggesting a groundwater source of nitrate impacting surface water concentrations. After June, concentrations at many sites were very low to non-detectable shown by the absence of bars in *Figure 7*.

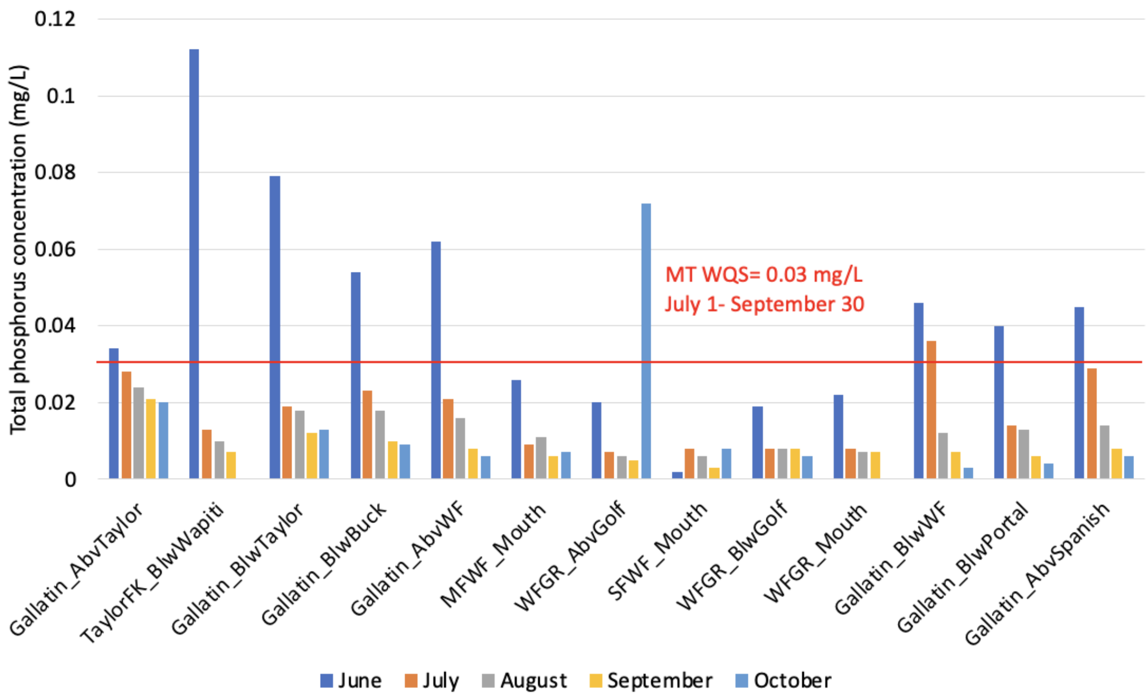


Figure 8: Total phosphorus concentrations across all sites June through October

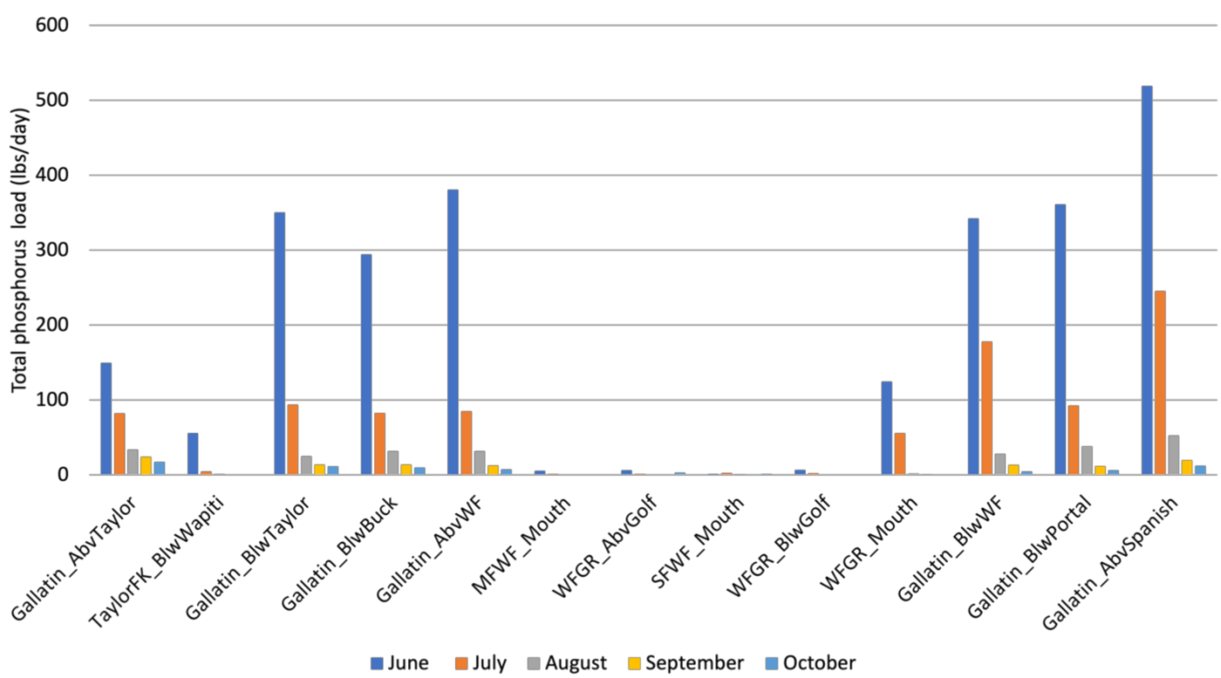


Figure 9: Total phosphorus load from 2022 field season

Total phosphorus (TP) concentrations were highest during spring runoff in June at all sites except the South Fork *(Figure 8)*. One site on the Gallatin was above the MT WQS of 0.03 mg/L: Gallatin_BlwWF in July (0.036 mg/L). WFGR_AbvGolf experienced a large jump from September (0.005 mg/L) to

October (0.072 mg/L) indicating an anomaly that will be looked at closely in upcoming assessments. All the West Fork watershed sites had very low phosphorus loads through the entire2022 field season *(Figure 9)*.

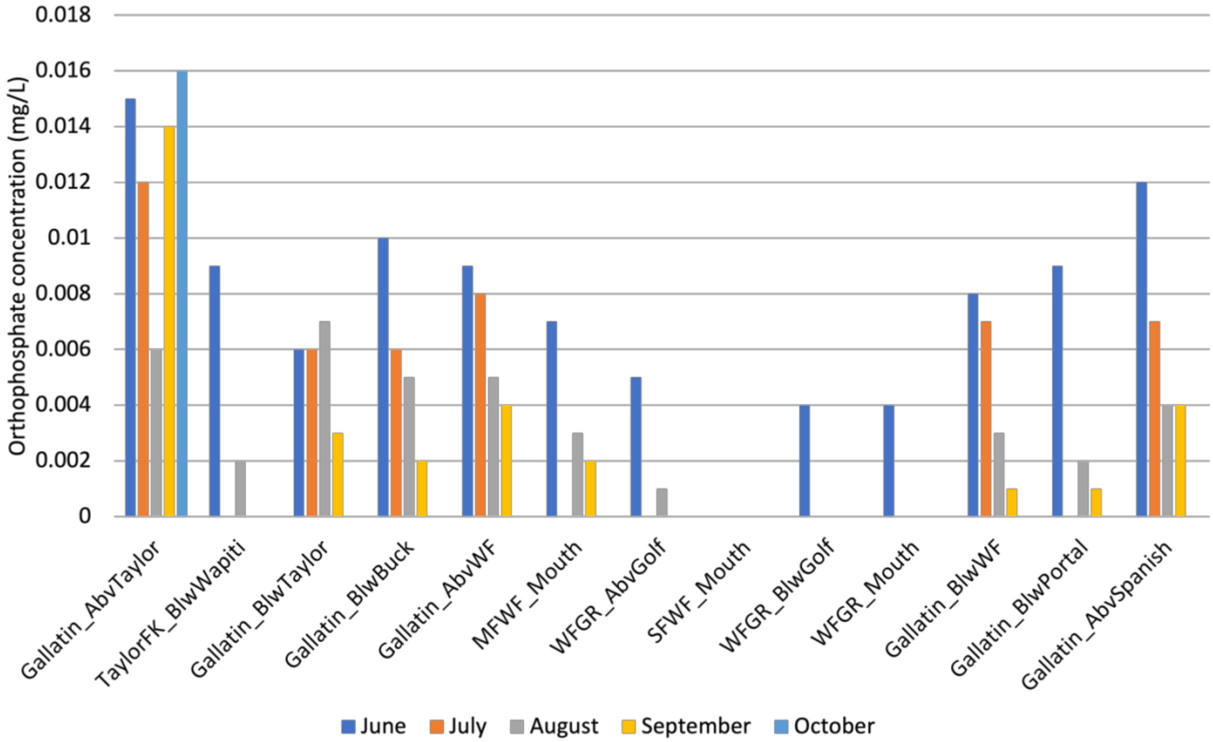


Figure 10: Orthophosphate concentrations through 2022 season

Orthophosphate, the form of phosphorus most readily taken up in plant cells, was higher on the mainstem Gallatin than in the tributaries, where concentrations were frequently non-detect, shown by the absence of bars *(Figure 10)*. Gallatin_AbvTaylor generally had the highest orthophosphate concentrations throughout the field season. Gallatin_AbvTaylor is just downstream from Yellowstone National Park boundary and typically exhibits elevated phosphorus levels, suggesting a phosphorus source coming from the park.

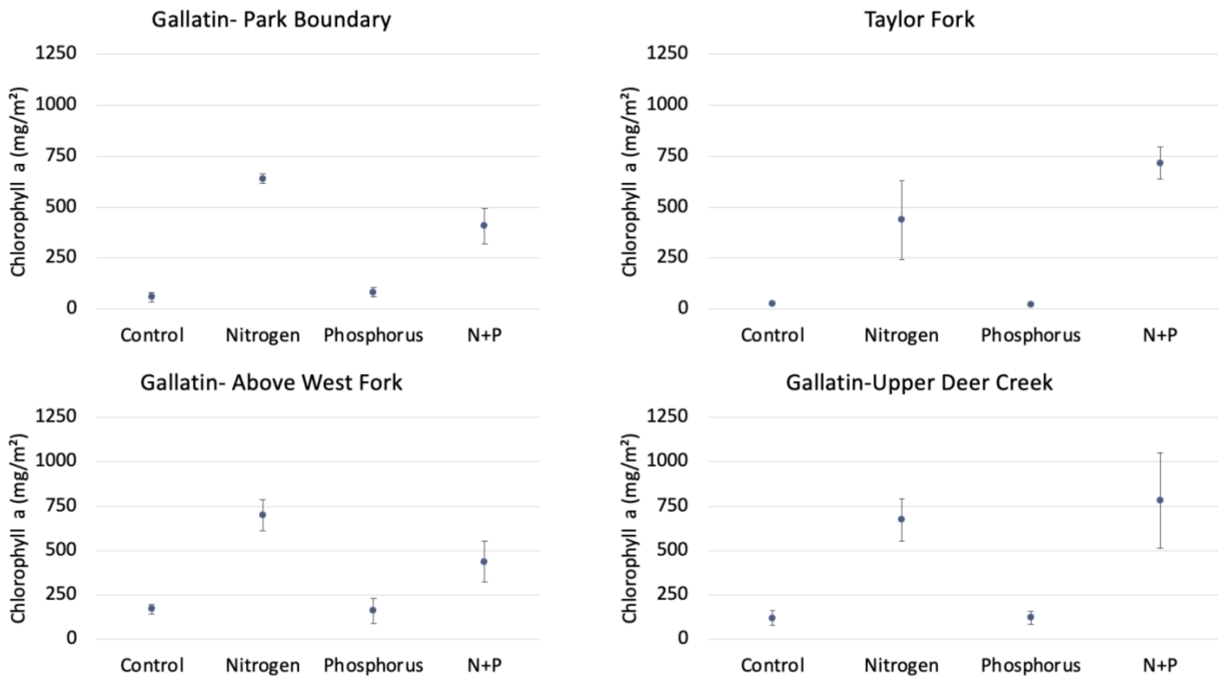


Figure 11: Results from nutrient limitation experiments at three sites on the Gallatin and one on the Taylor Fork

Chlorophyll A levels measured from nutrient-diffusing substrata experiments on the mainstem Gallatin and Taylor Fork suggest that algae growth was limited by nitrogen *(Figure 11).* When phosphorus was added at all sites, algae growth stayed similar to the control. Noticeably more algae growth occurred when nitrogen was added. Samples with added nitrogen exhibited an average of 518 mg/m^2 more algae growth than the control. Experiments with both nitrogen and phosphorus exhibited an increase in algae growth compared to the control. Averages of both nutrients added at Taylor Fork and Gallatin- Upper Deer Creek were similar to those of nitrogen only. Gallatin- Park Boundary and Gallatin- Above West Fork had higher chlorophyll A levels on only nitrogen added compared to both nutrients.

Nutrient limitation experiment setup before deployment

Air and Water Temperatures

July was the warmest month during the 2022 field season *(Figure 12)*. Average monthly air temperatures were higher in August 2022 than in 2018-2021.

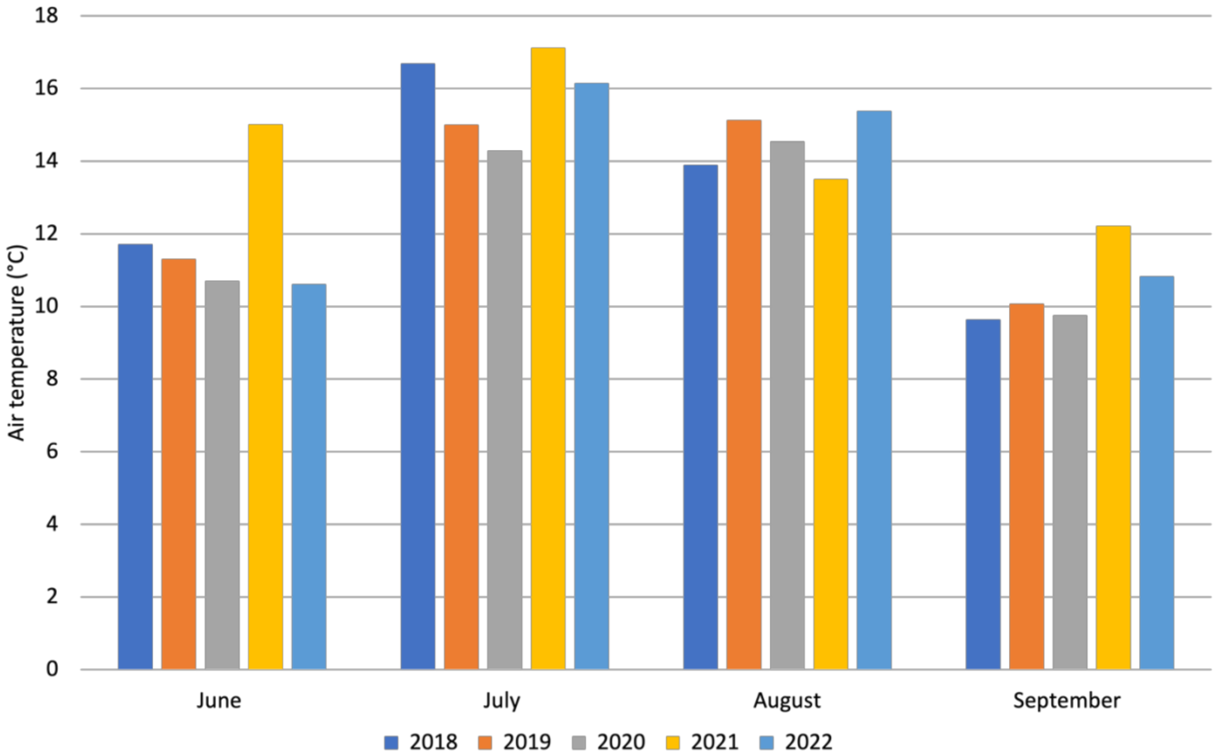


Figure 12: Average monthly air temperatures from 2018-2022

BSWC member and water quality intern deploying nutrient limitation experiments

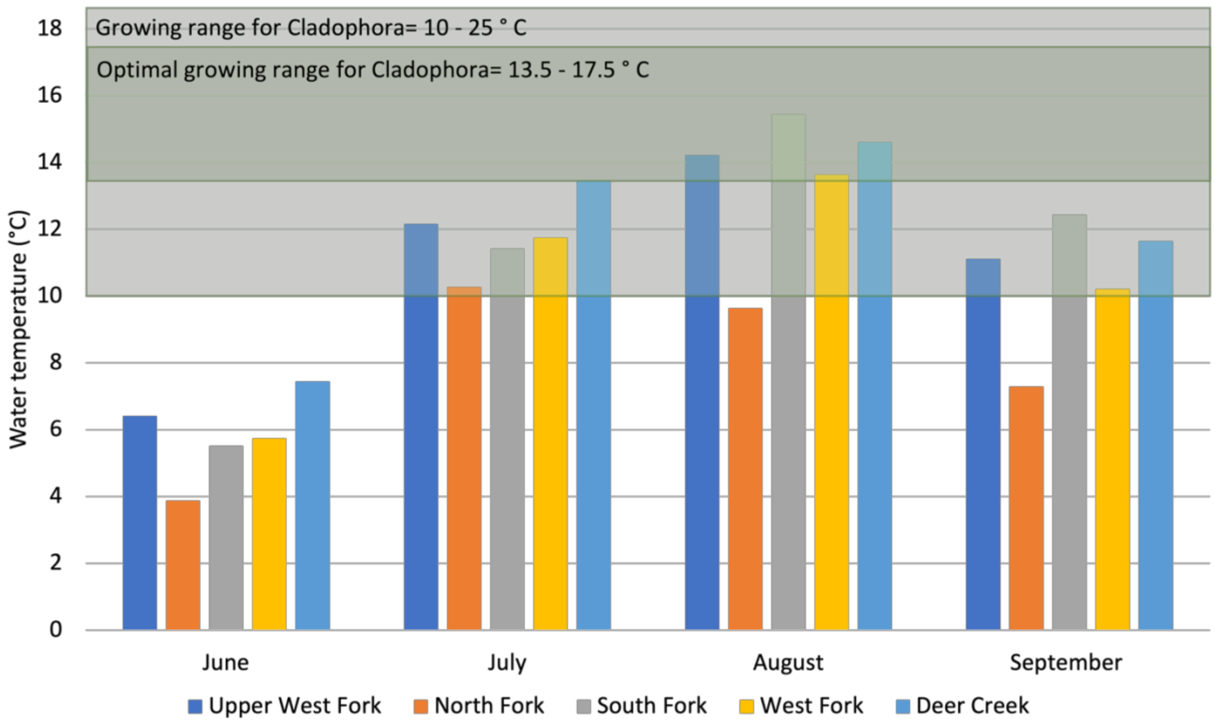


Figure 13: Average monthly water temperature over 2022 season

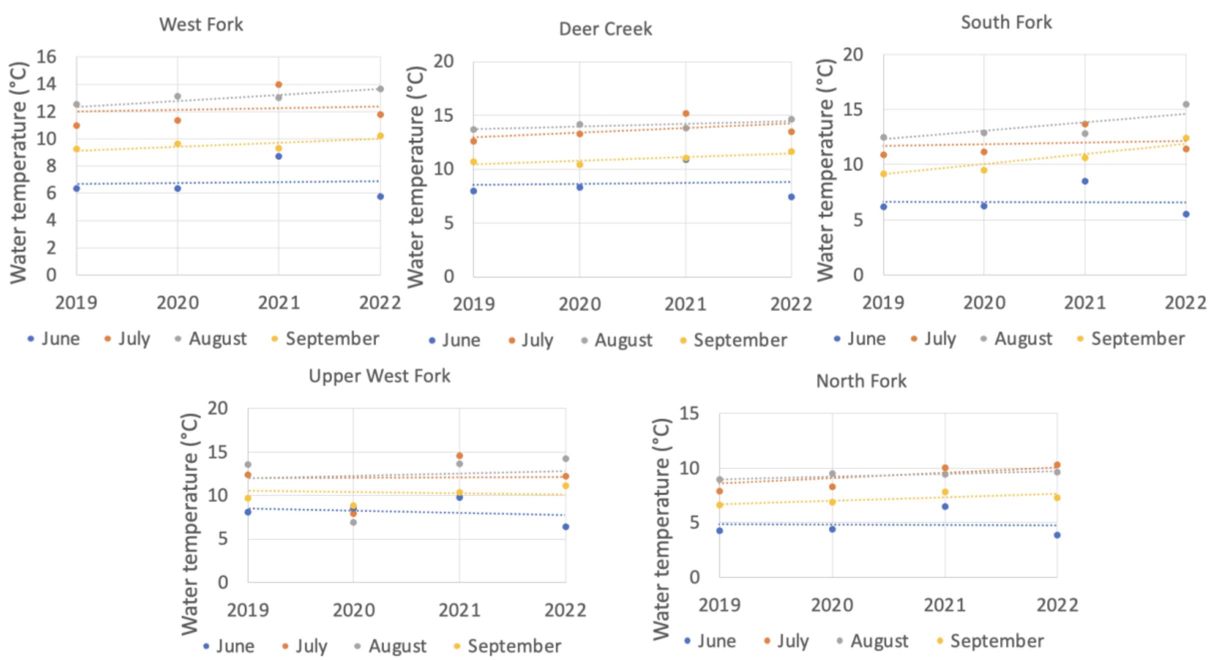


Figure 14: Average monthly water temperatures across monitoring season from 2018-2022

Average water temperatures at all sites were within the growing range for Cladophora in July: Upper West Fork (12.2°C), North Fork (10.3°C), South Fork (11.4°C), West Fork (11.8°C), and Deer Creek (13.5°C) *(Figure 13)*. In August, all sites were within the optimal growing range, except for the North Fork which decreased in temperature by 0.6°C. In September, water temperatures decreased and stayed within the growing range, except for North Fork. There appears to be an increasing trend in water temperatures on the Gallatin and West Fork tributary between 2018-2022 *(Figure 14)*. The West Fork and Deer Creek have a positive correlation for every month from 2018-2022, showing an increase in water temperatures over the years. The North Fork and South Fork have a positive correlation for all months, except for June, while the Upper West Work is positive for July and August and negative for June and September. Water temperatures in the South Fork, Upper West Fork and West Fork have been within the growing range for Cladophora (above 10°C) each year in July and August from 2018-2022. The Gallatin above Deer Creek has reached growing ranges for Cladophora July through September from 2019-2022. The USGS Gallatin above Deer Creek gauge was installed in 2019.

Hardness

Site	June	July	August	September	October
Gallatin_AbvTaylor	104	126	129	138	136
TaylorFk_BlwWapiti	135	96	127	150	157
Gallatin_BlwTaylor	123	114	134	148	152
Gallatin_BlwBuck	118	123	133	145	151
Gallatin_AbvWF	118	123	133	145	155
MFWF_Mouth	63	56	85	104	114
WFGR_AbvGolf	66	51	82	99	110
SFWF_Mouth	95	108	137	153	163
WFGR_BlwGolf	71	62	104	134	155
WFGR_Mouth	89	88	124	147	162
Gallatin_BlwWF	120	128	159	173	196
Gallatin_BlwPortal	109	113	149	171	184
Gallatin_AbvSpanish	102	98	130	145	160

Table 2: Hardness measurements over the 2022 season measured in mg/L $CaCO_3$. Shaded boxes indicate ideal conditions for algae over 121 mg/L $CaCO_3$.

Hardness typically increased over the course of the 2022 monitoring season due to the increasing influence of groundwater on streamflow. By September all but two sites (MFWF_Mouth and WFGR_AbvGolf) were within optimal hardness levels for Cladophora growth.

Streamflow

In June of 2022, peak streamflow on the Gallatin was the third highest on record due to late snowfall and a quick prolonged rise in temperatures. The USGS Gauge above Deer Creek recorded peak streamflow at 6,370 CFS at 15:30 on 6/13/22 *(Figure 15)*, while the USGS Gallatin Gateway gauge recorded peak streamflow at 8,640 CFS at 17:00 *(Figure 16)*. Streamflow was above average at the beginning of the summer moving to below average in the latter half of the summer (*Figure 17*).

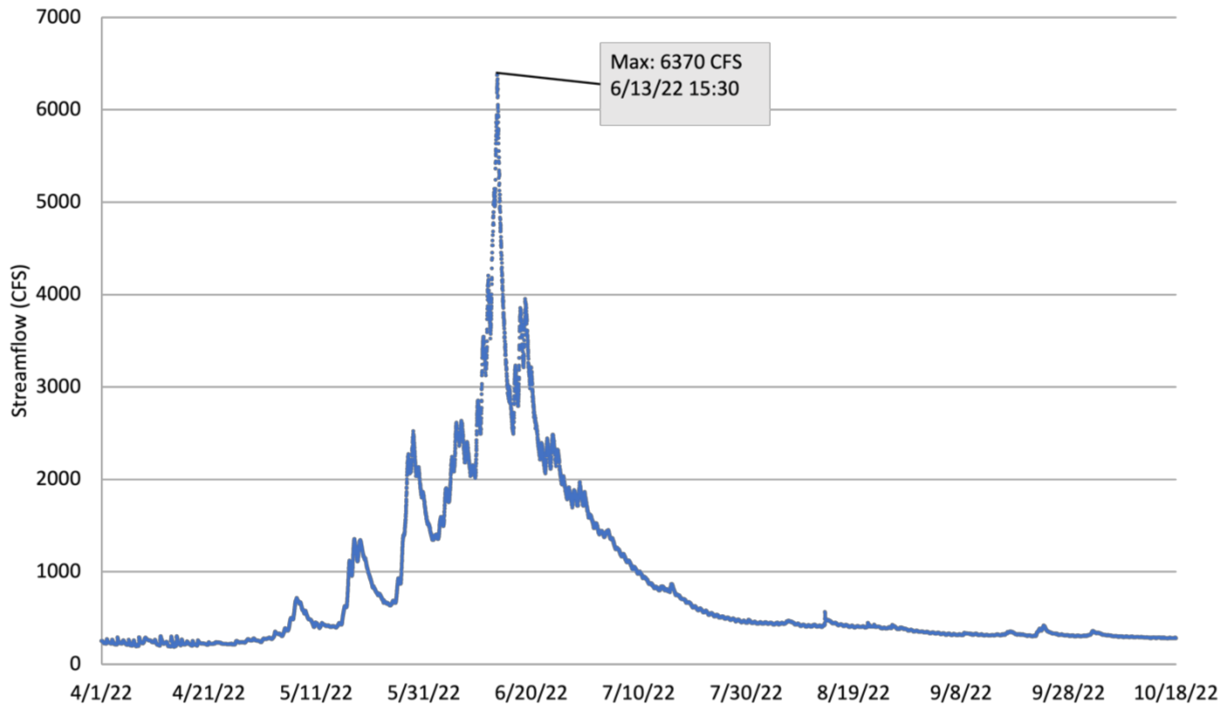


Figure 15: Streamflow at USGS Gallatin above Deer Creek gauge

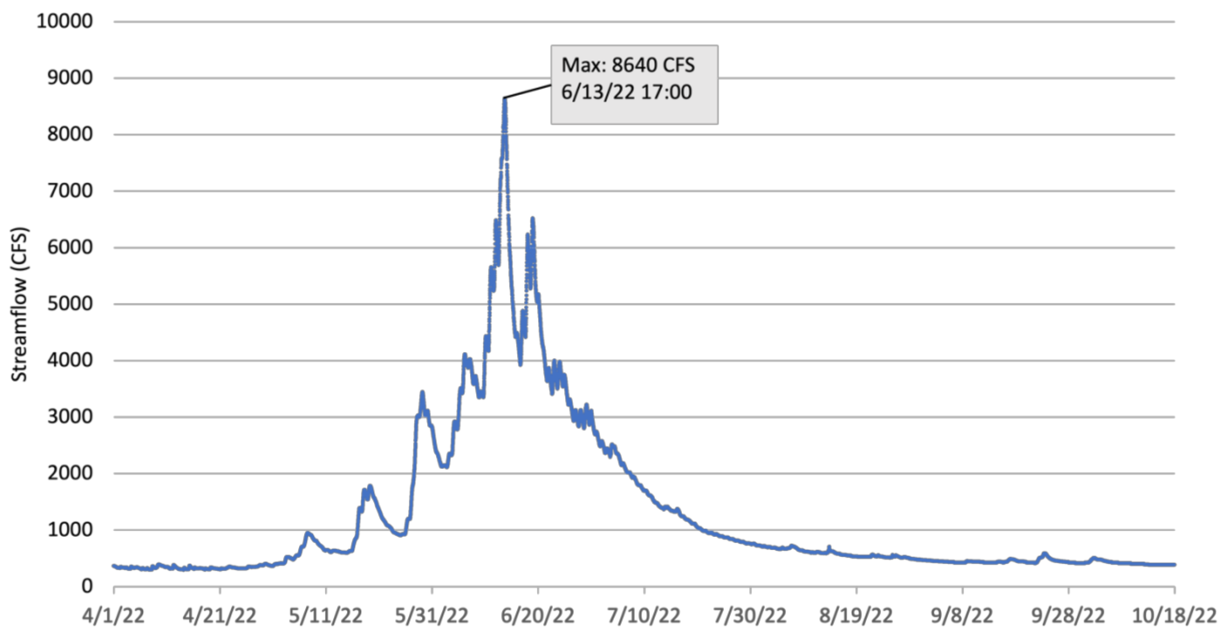


Figure 16: Streamflow at USGS Gallatin Gateway Gauge

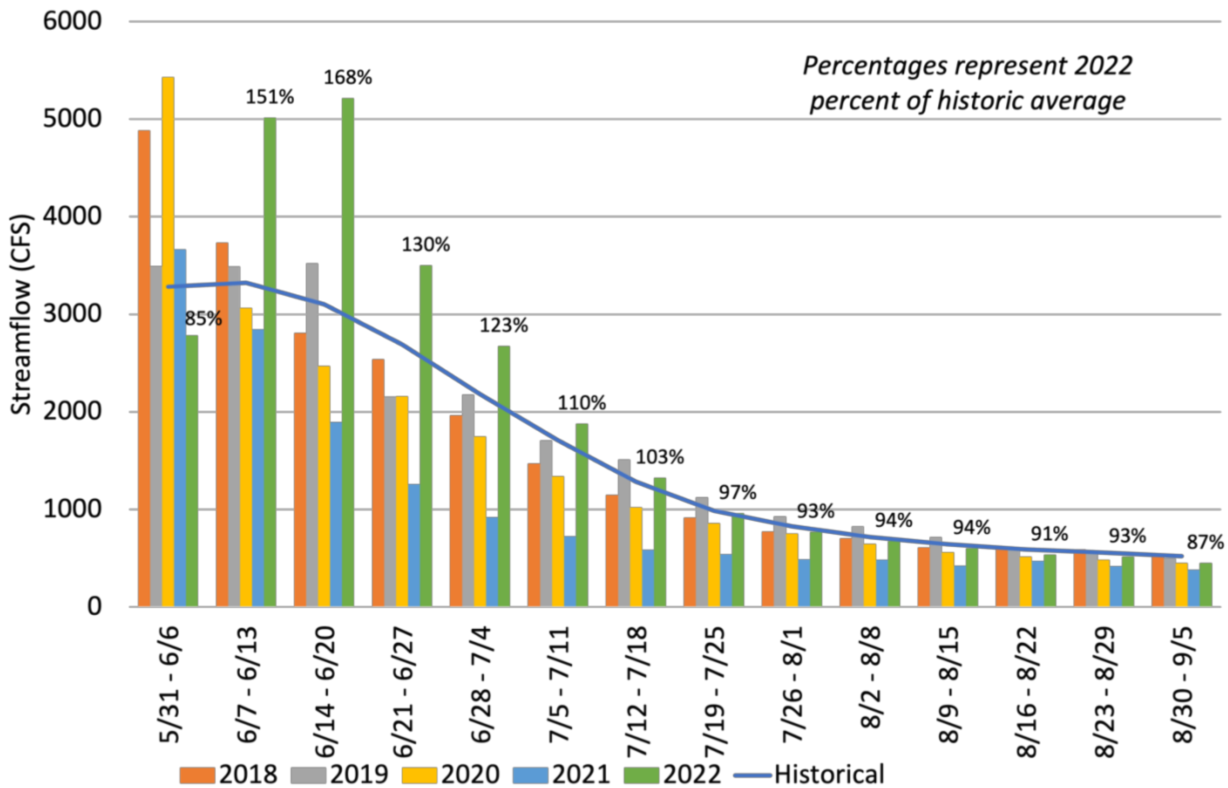


Figure 17: Average weekly streamflow compared to historical averages at USGS Gallatin Gateway gauge

Sunlight

Average solar irradiance during July of 2018, 2020, and 2022 was higher than the averages of 2019 and 2021 *(Figure 18)*. These years of higher solar irradiance correspond with the years of widespread nuisance algae blooms. Average solar irradiance in August of 2022 at 272 W/m^2, was the highest August value since the study has begun in 2018.

Two BSWC members taking streamflow measurements on the South Fork

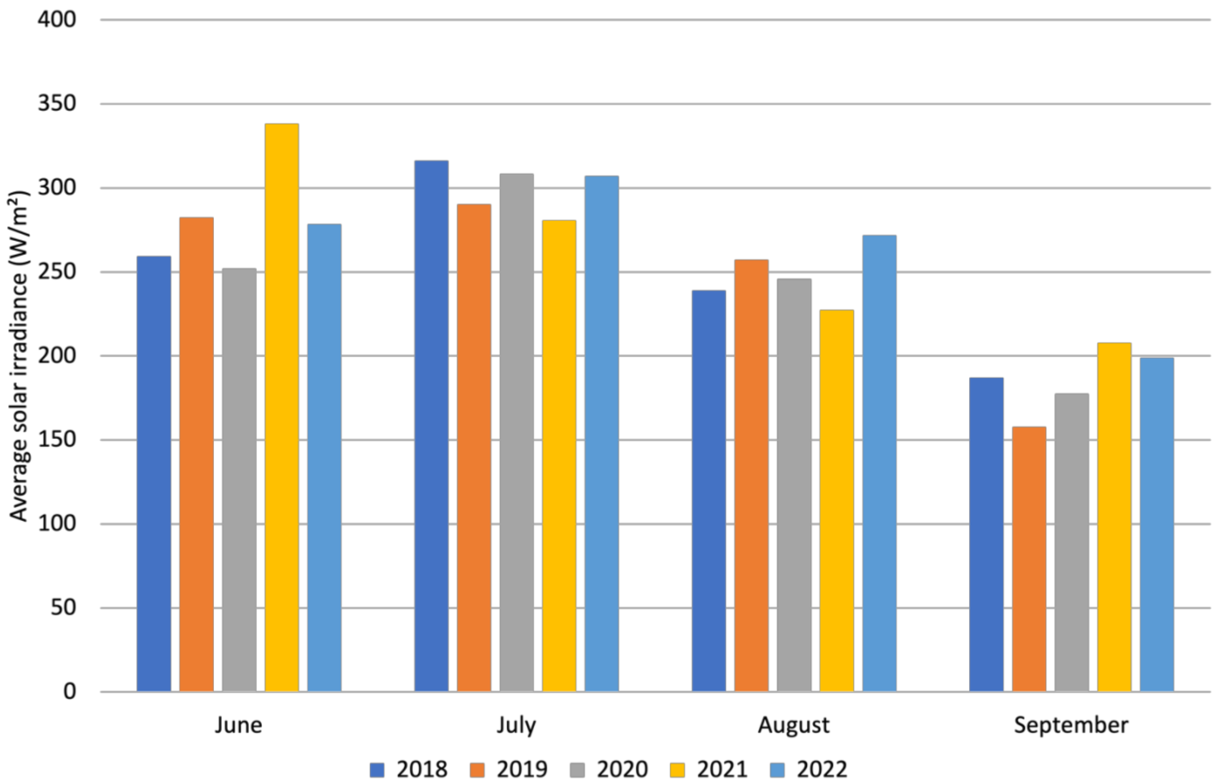


Figure 18: Average monthly solar irradiance from 2018-2022 measured at ORSL Weather Station in Bozeman

BSWC member and conservation intern collecting water quality samples on the mainstem Gallatin

Nutrient Reduction Strategies

To mitigate future algae blooms, the Gallatin River Task Force is prioritizing projects to reduce nutrient levels in the Gallatin and its tributaries and commercial and residential water usage. Strategies to reduce nutrient pollution are outlined in the Upper Gallatin Nutrient Assessment and Reduction Plan (Allen and Howell, 2020) and the West Fork Nitrogen Reduction Plan (Blue Water Task Force, 2014).

Projects completed since the development of the West Fork Nitrogen Reduction Plan in 2014 include:

1. Two restoration projects on the upper West Fork and the two on the Gallatin to reduce nutrient loading and sediment pollution
2. Annual Runoff Clean-off event: a community wide annual dog waste pickup
3. Annual Gallatin River Cleanup to remove trash along the upper and lower Gallatin River and tributaries
4. Septic system & well outreach and education events such as Fix-a-Leak Week
5. Installation of dog waste stations and signage across Big Sky Community
6. Education workshops for golf course managers, realtors, and builders
7. Creation of a new water and sewer district in Gallatin Canyon

Projects in progress:

1. Trout Friendly Landscaping initiative to conserve water and reduce nutrients through native, drought-tolerant landscaping
2. Rebates for installation of commercial and residential fixtures that conserve water
3. Restoration projects on the Gallatin at Porcupine and Beaver Creek and numerous parking areas to create sustainable access and repair current damage to native ecosystem
4. Big Sky Water and Sewer District wastewater treatment plan upgrade
5. Expansion of a central sewer system in Gallatin Canyon
6. Advocating for state and federal protections, including a 303(d) listing for the Upper Gallatin and a Wild and Scenic River designation for the Upper Gallatin and Taylor Fork.

As an individual, there are many actions you can take to help make a positive impact. These include committing to a trout friendly landscape, inspecting private septic tanks for leaks, avoiding fertilizer application before storms, picking up pet waste, and much more! Every action counts in an effort to help keep the Gallatin a resilient and thriving river.

Learn more about what you can do at gallatinrivertaskforce.org.

References

Allen, C., S. Howell. (2020). *Upper Gallatin Nutrient Assessment and Reduction Plan*. Available at gallatinrivertaskforce.org

Blue Water Task Force (2014). *West Fork Nutrient Reduction Plan.* Available at gallatinrivertaskforce.org.

Francoeur, S.N. (2001). Meta-analysis of lotic nutrient amendment experiments: detecting and quantifying subtle responses. Journal of the North American Benthological Society 20: 358-368.

MT DEQ (2014). *Department Circular DEQ-12A: Montana Base Numeric Nutrient Standards.* Available at http://deq.mt.gov/Water/Resources/circulars.

MT DEQ (2018). Smith River Nuisance Algae and Nutrient Assessment: 2018 Sampling and Analysis Plan.

MT DEQ (2022). Sampling and Analysis Plan: Nutrient and Algae Monitoring in the Upper Gallatin Watershed, 2021-2022.

RESPEC & Karen Filipovich (2018). *Big Sky Area Sustainable Watershed Stewardship Plan* Final report prepared for the Gallatin River Task Force. Available at gallatinrivertaskforce.org

1700 Lone Mountain Trail
PO Box 160513 | Big Sky, Montana 59716
Gallatinrivertaskforce.org | (406) 993-2519
headwaters@gallatinrivertaskforce.org