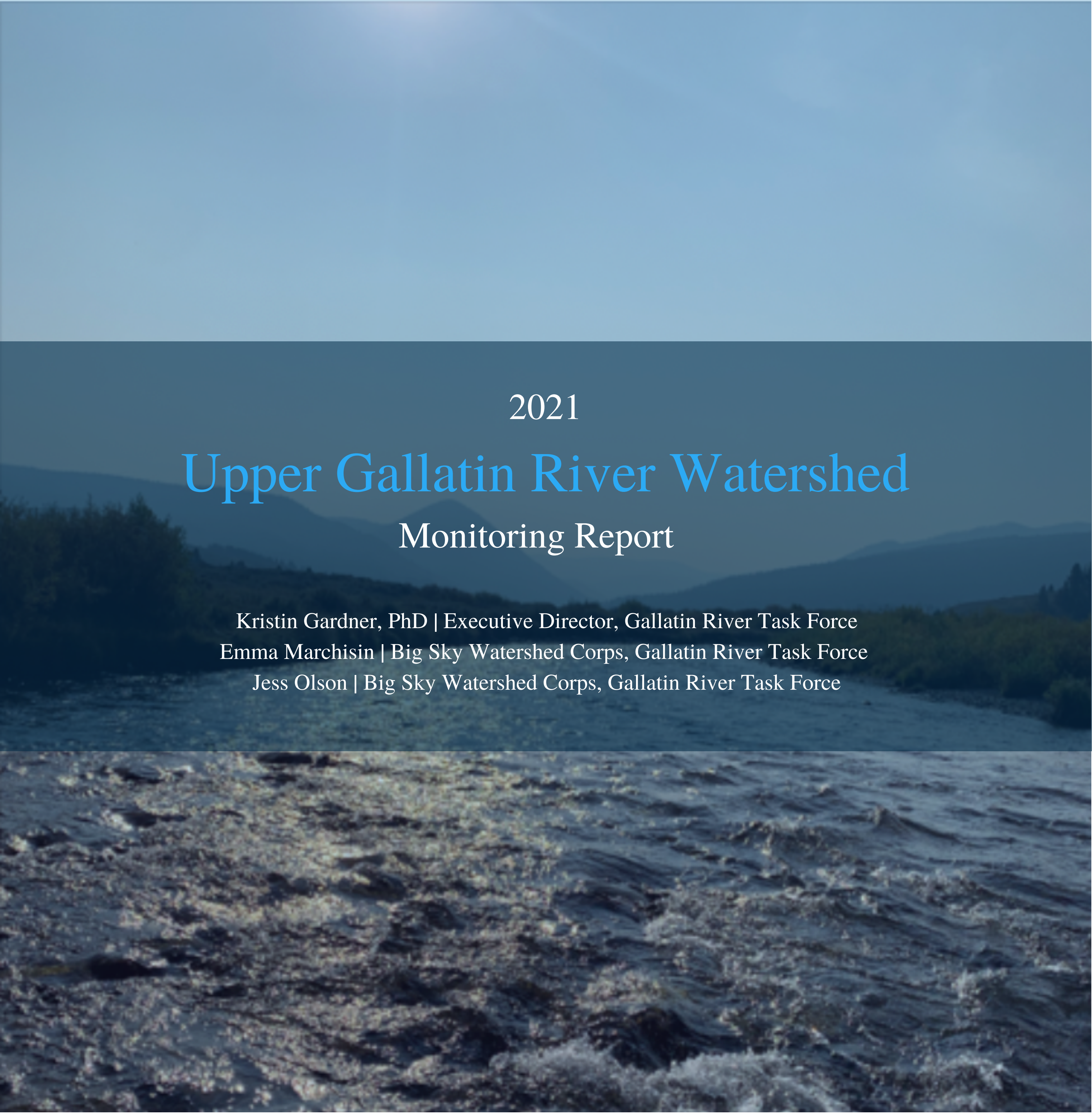

2021

Upper Gallatin River Watershed

Monitoring Report

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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.

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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, Gallatin River Task Force partnered with the Montana Department of Environmental Quality (MT DEQ) to conduct a study to determine the causes of this algae bloom. A similar nuisance bloom occurred again in 2020. Factors that can influence algae growth include nitrogen and phosphorus concentrations, water temperature, water hardness, streamflow, and sunlight.

In 2021, 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 streamflow gauges were used to collect water temperatures and streamflow in the upper West Fork, North Fork, South Fork, lower West Fork, and Deer Creek.

A large-scale algae bloom was not observed in 2021 except for on the lower Taylor Fork. Although Ash Free Dry Weight (AFDW) at six of the thirteen sites was above the Montana AFDW threshold of 35 mg/m^2, these elevated levels were likely influenced by other factors like the presence of *Didymosphenia geminate*, or Didymo. Chlorophyll a was below the Montana chlorophyll a threshold of 125 mg/m^2 for all sites in August and September.

Total nitrogen levels at two sites were above the Montana water quality standard (MT WQS) in September- one on the West Fork and the other on the mainstem Gallatin, below Portal Creek. The West Fork site has historically exhibited high nitrogen levels; however, the Portal Creek site was a new site in 2021. For all other sites on the mainstem Gallatin, nutrient levels were below Montana water quality standards 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. Nitrate and nitrite levels at three sites were elevated: two in the West Fork and one at the most downstream site in the mainstem Gallatin. Phosphorus levels were highest at the most upstream sites on the Gallatin River. Nutrient limitation experiments on the Gallatin at the Yellowstone National Park boundary and above Deer Creek indicated algae growth was limited by nitrogen.

Average air temperatures in June, July, and September of the 2021 season were higher than the corresponding monthly average temperatures in 2018-2020. Water temperatures were generally warmer in 2021 at all sites than in 2018-2020. By July, all sites were within the growing range for Cladophora with the upper West Fork, South Fork, lower West Fork, and the Gallatin above Deer Creek hitting the optimal temperature growing range. In August and September, all sites exhibited ideal hardness for Cladophora growth except for one site on the Middle Fork and one on the West Fork.

The 2021 peak streamflow, which occurred during the first week of June, was in line with the timing of the peak flows in 2018-2020. As the season progressed, the average streamflow was consistently below the historic average, reaching the greatest difference of 42% of the historical average during the beginning of July.

During July of 2018 and 2020, solar irradiance was higher than 2019 and 2021. These years of higher solar irradiance during July were the years the large-scale algae blooms were observed. This correlation alludes to the role that sunlight could play on the occurrence of algae blooms.

From the four 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 these 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 includes developing central sewer for Gallatin Canyon, restoration projects on the West Fork and Gallatin, and the Trout Friendly Landscaping program. 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 help keep the Gallatin a resilient and thriving river!

A monitoring site on the Gallatin below Buck Creek

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 crews of volunteers have been collecting watershed data since 2000 on the Upper Gallatin River and its tributaries. The collected data is used to assess water quality and health by identifying spatial and historical trends, determining impacts of unforeseen events, and guiding resource management decisions.

The Upper Gallatin River flows from its headwaters in Yellowstone National Park to the Spanish Creek confluence, just before it exits Gallatin Canyon. In 2018, an unprecedented large-scale algae bloom occurred in the Upper Gallatin at sites on the South Fork, West Fork, Taylor Fork, and mainstem Gallatin River. Blooms like these 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 showed that nitrogen levels were some of the highest on record 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. Average weekly water temperature in 2018 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 and nutrient concentration are important factors that contribute to algae growth in the Gallatin River and tributaries.

Starting in 2019, the Task Force partnered with the Montana Department of Environmental Quality (MT DEQ) 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; however, another one did occur in 2020. This data will inform MT DEQ's decision making process of whether to add the Upper Gallatin to the 303(d) list of impaired waters. This report summarizes the data collected during the 2021 season.

Mainstem Gallatin below the West Fork

Nutrient and Algae Assessment

Background

Algae

Cladophora glomerata (Cladophora) is the dominant filamentous algae species that grows in the Gallatin River and its tributaries. Excess algae growth can deplete rivers of dissolved oxygen vital for aquatic life. Factors that can contribute to these blooms 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) a water hardness of greater than 121 mg/L $CaCO_3$.

To assess algae growth, chlorophyll a and ash free dry weight (AFDW) are measured. Chlorophyll a is a green pigment found in plant cells, including algae, that facilitates photosynthesis. Chlorophyll a levels are used to quantify the amount of algae growing in a given area. AFDW determines the mass of the organic matter after algae samples are thoroughly dried. The state of Montana has determined thresholds for both measures. The threshold for chlorophyll a is 125 mg/m² and AFDW is 35 g/m². Methods of collection are detailed within the Sampling Analysis Plan (MT DEQ, 2020).

Nutrients

Nitrogen and phosphorus are the primary nutrients facilitating algae growth. Three tributaries in the Upper Gallatin watershed are 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. Excess phosphorus sources are similar to those of nitrogen but include soil erosion. Historically, phosphorus concentrations in the Upper Gallatin tributaries have been below Montana state water quality standards (MT WQS). The Montana water quality standards for total nitrogen is 0.3 mg/L and total phosphorus is 0.03 mg/L, with both standards applicable only July 1st until September 30th. Algae growth is often 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 affect water temperature 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. Cladophora thrives in a hardness greater than 121 $CaCO_3$ mg/L.

Streamflow

Streamflow is the measure of the volume of water moving though 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/ meter squared (W/m^2).

<u>Study Design</u>

Water quality samples were collected over five events from June to October of 2021 (*Table 1)*. For each event, data from thirteen sites was collected 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, 2020).

Table 1: Water quality data measured at 13 sites in 2021 season

	June 6/14	**July 7/12**	**August 8/2-8/5**	**September 9/7-9/9**	**October 10/4**
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
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	

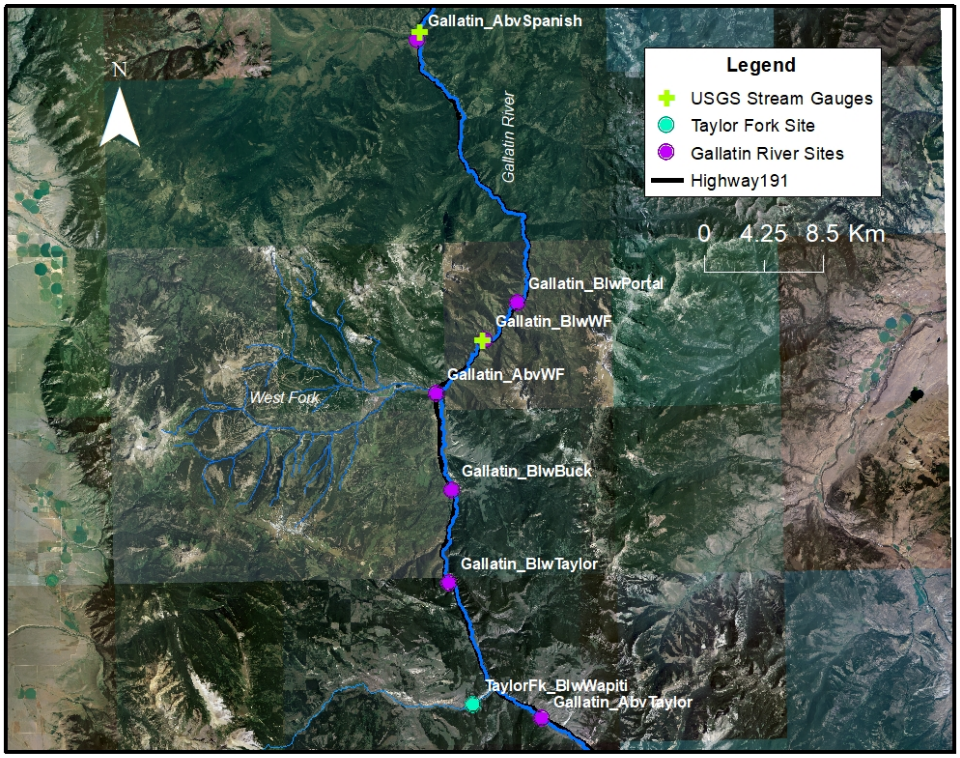

Figure 1: Map of monitoring sites along the mainstem Gallatin and Taylor Fork, and USGS stream gauges

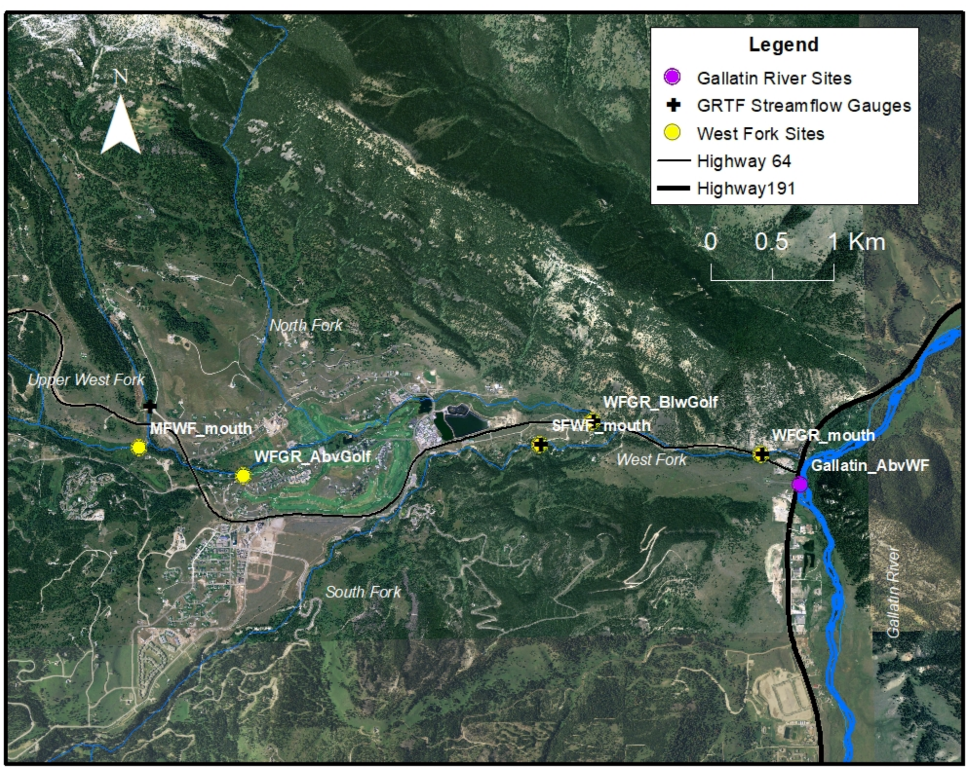

Figure 2: Map of monitoring sites and streamflow gauges in the West Fork watershed

2021 Monitoring Results

Algae

There was not a widespread algae bloom observed in 2021 except for on the lower Taylor Fork. Ash free dry weight was below the Montana threshold in August except at two sites on the Gallatin, Gallatin_AbvTaylor (42.2 mg/m^2) and Gallatin_AbvWF (35.60 mg/m^2) *(Figure 3)*. Most sites showed an increase in AFDW from August to September except for Gallatin_AbvTaylor and Gallatin_AbvSpanish. In September, AFDW measured at six of the thirteen sites was above the threshold: Gallatin_BlwBuck (99.5 mg/m^2), Gallatin_AbvWF (76.7 mg/m^2), WFGR_AbvGolf (39.81 mg/m^2), WFGR_BlwGolf (53.20 mg/m^2), Gallatin_BlwWF (88.0 mg/m^2), and Gallatin_BlwPortal (42.13 mg/m^2). Algae at these sites was sampled via template method suggesting that algae was primarily non-filamentous. The existence at some sites of Didymo may have elevated the AFDW.

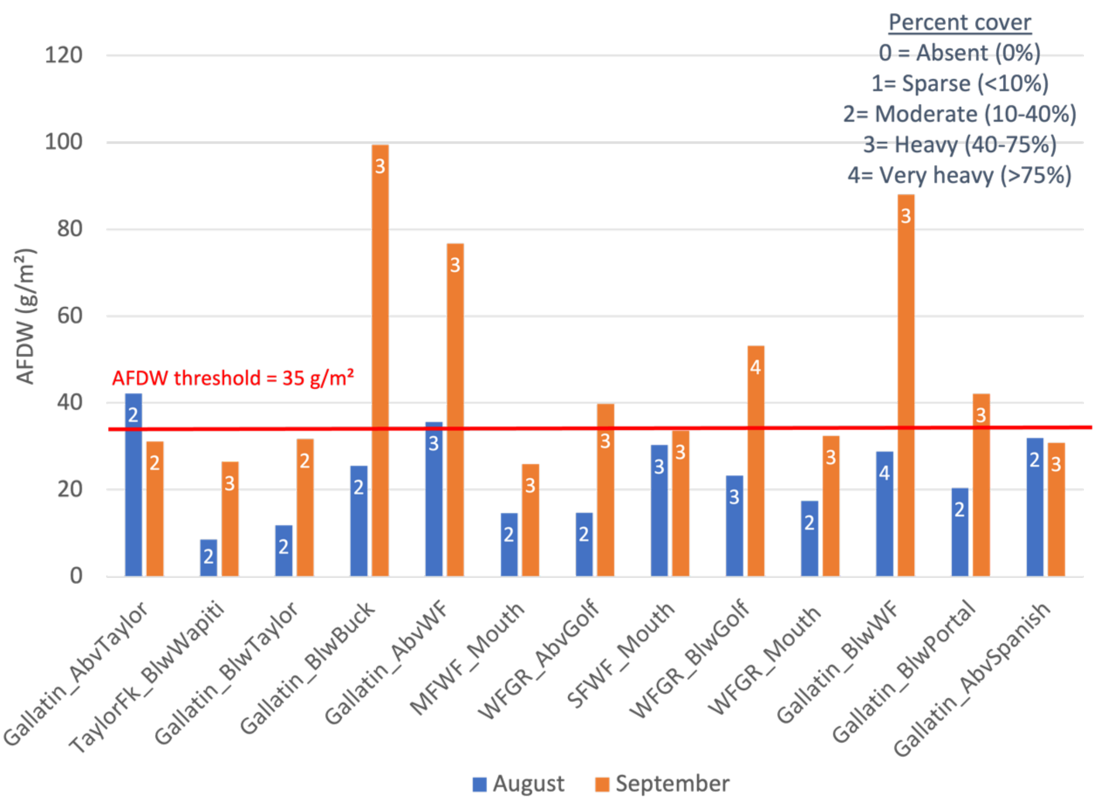

Figure 3: Ash free dry weight and percent cover via visual assessment at 13 sites on Gallatin, West Fork, South Fork, and Taylor Fork in August and September. For site locations, see Figures 1 and 2.

Hoop method gathering algae on the West Fork in August

Chlorophyll a was below the Montana threshold of 125 mg/m^2 at all sites in August and September *(Figure 4)*. Ten sites showed an increase in chlorophyll a and three showed a decrease from August to September.

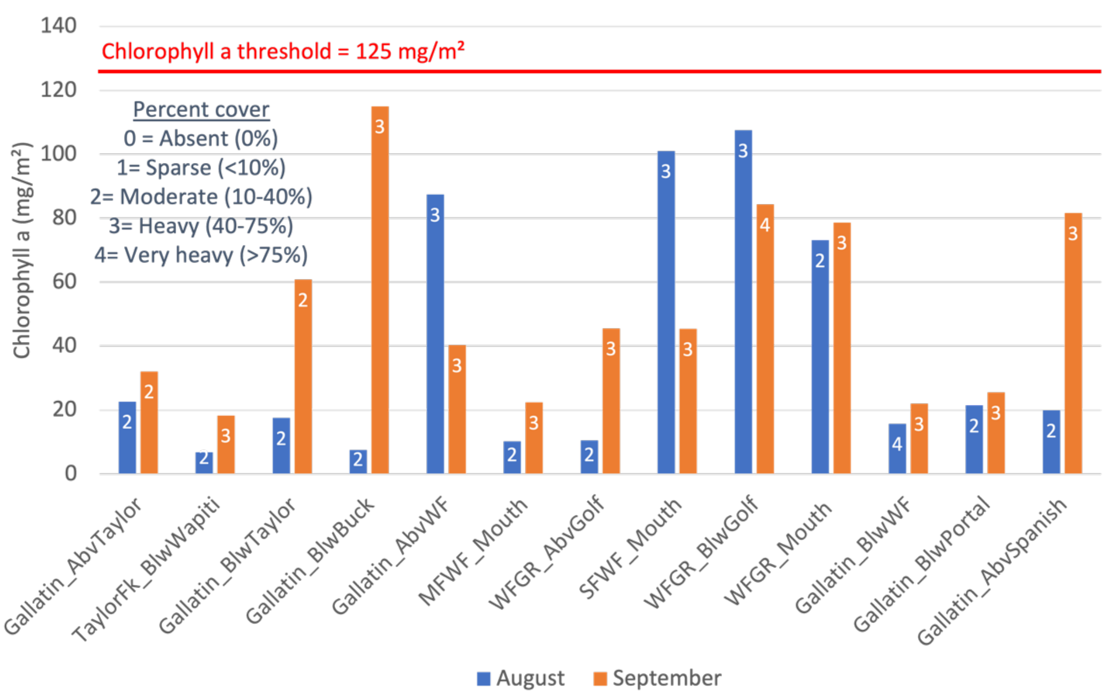

Figure 4: Chlorophyll a and percent cover via visual assessment at 13 sites on Gallatin, West Fork, South Fork, and Taylor Fork in August and September.

Nutrients

Total nitrogen (TN) levels at two sites were above the Montana water quality standard of 0.3 mg/L in September: WFGR_BlwGolf (0.46 mg/L) and Gallatin_BlwPortal (0.8 mg/L) *(Figure 5)*. Gallatin_BlwPortal had a very large jump in TN concentration from August to September. This may indicate an anomaly and will be looked at closely in upcoming assessments.

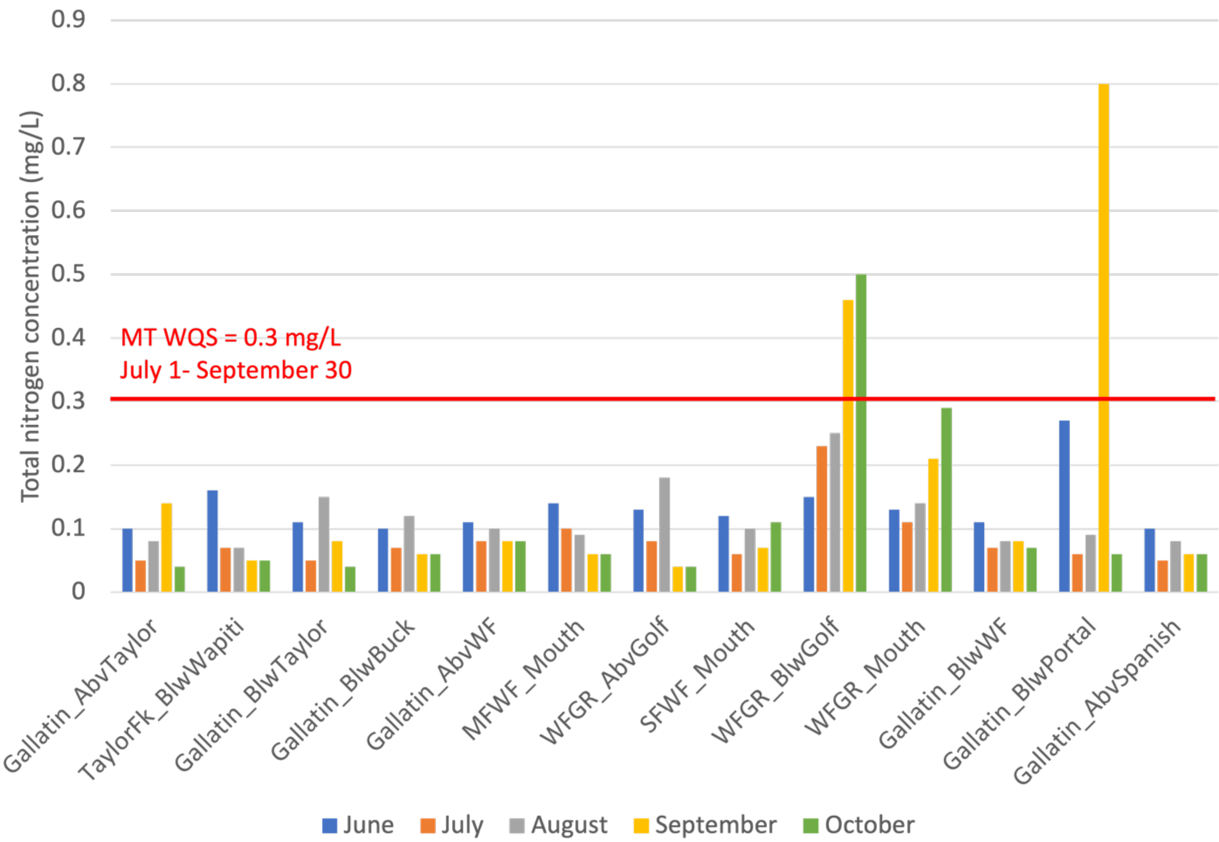

Figure 5: Total nitrogen concentrations across 13 sites for each month of 2021 season

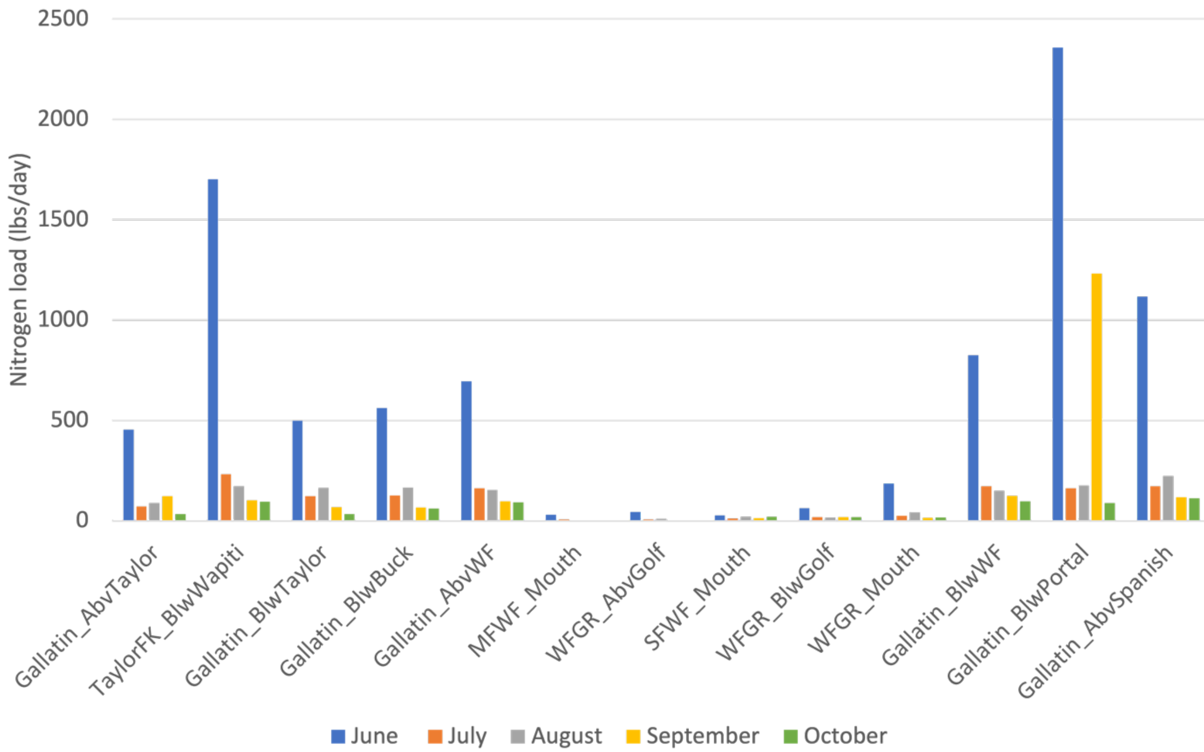

Figure 6: Nitrogen loads calculated for 13 sites in 2021 season

Nitrogen load was highest during spring runoff *(Figure 6)* in Taylor Creek and the mainstem Gallatin. Values in the West Fork were relatively low. In the months following June, nitrogen loads dropped. A spike in nitrogen load occurred in September at Gallatin_BlwPortal.

Sampling site at the South Fork mouth in October

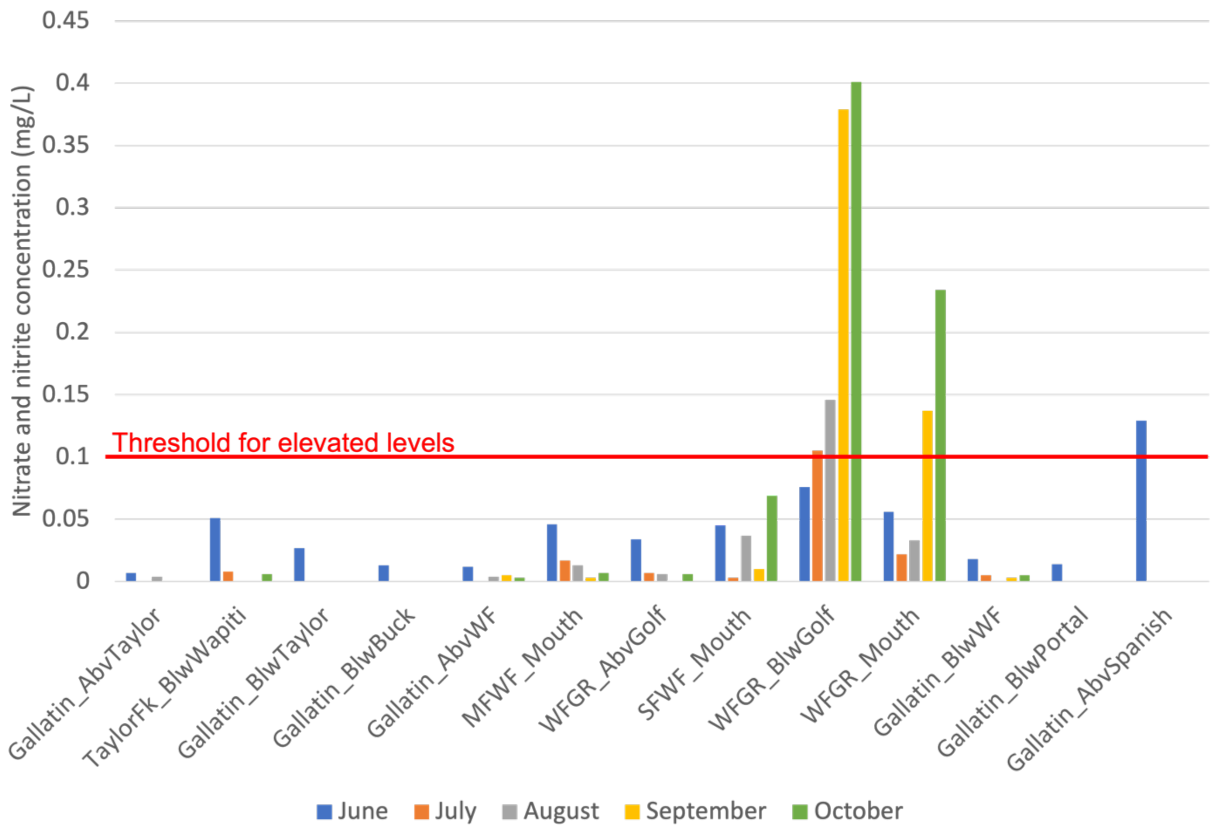

Figure 7: Nitrate-nitrite concentrations across sites throughout 2021 season

Nitrate-nitrite concentrations July through September at WFGR_BlwGolf, September at WFGR_Mouth and June at Gallatin_AbvSpanish were elevated (>0.1 mg/L) *(Figure 7)*. Concentrations at WFGR_BlwGolf and WFGR_Mouth increased across the time streamflow decreased suggesting a groundwater source of nitrate. After June, concentrations at many sites were very low to non-detect (ND) shown by the absence of bars in *Figure 7*.

A volunteer collecting samples on the Gallatin above Spanish Creek

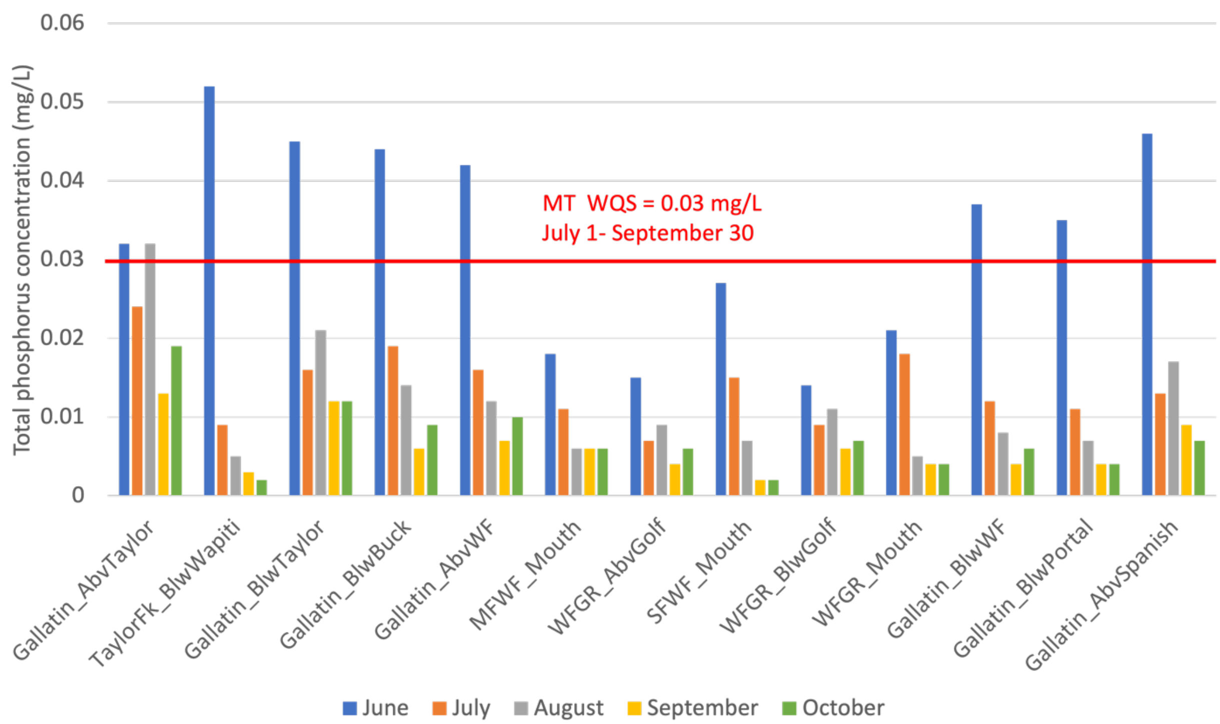

Figure 8: Total phosphorus concentrations across sites recorded monthly for 2021 season

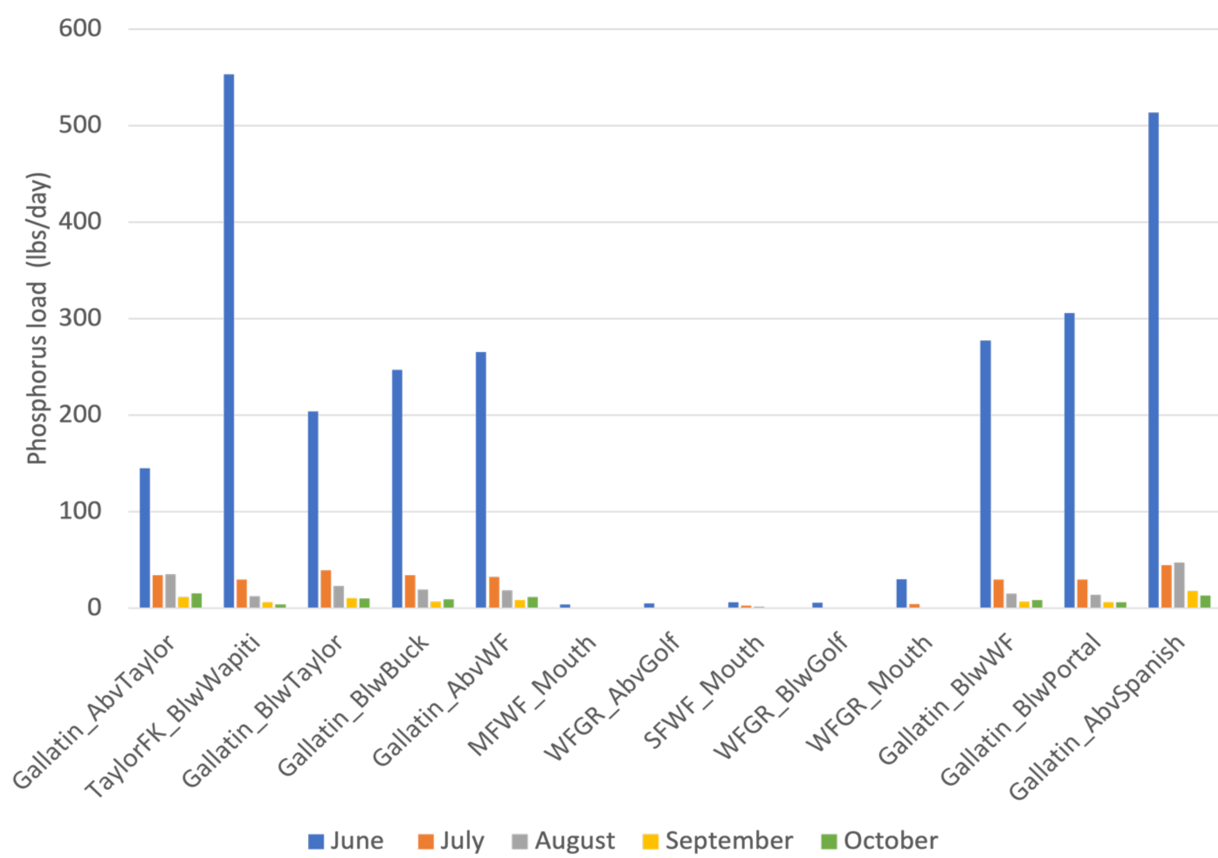

Figure 9: Phosphorus loads across each month in 2021 season

Total phosphorus (TP) concentrations were highest at every site during spring runoff in June than other months *(Figure 8)*. TP concentration at Gallatin_AbvTaylor surpassed the Montana water quality standard of 0.03 mg/L in August. Gallatin_AbvTaylor is downstream from the Yellowstone National Park boundary and typically exhibits elevated phosphorus concentrations, which suggests a phosphorus source coming from the park. All the West Fork watershed sites were below the standard throughout the season and had low phosphorus loads *(Figure 9)*.

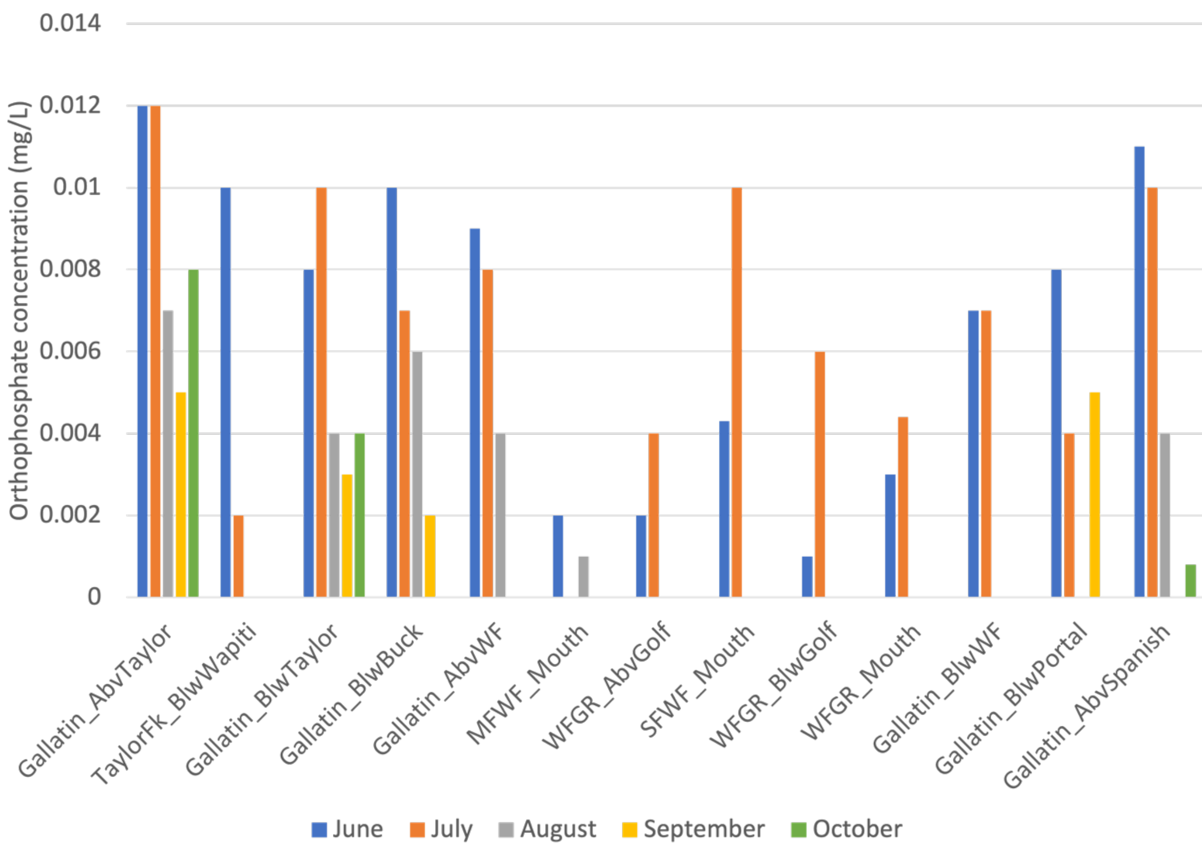

Figure 10: Orthophosphate concentrations through 2021 season

Orthophosphate levels were highest at the most upstream sites on the Gallatin River (*Figure 10)*. Concentrations in the mainstream Gallatin were consistently higher than those in the tributaries, where orthophosphate was not detected, shown by the absence of a bar. Similar to total phosphorus, orthophosphate was highest at Gallatin_AbvTaylor.

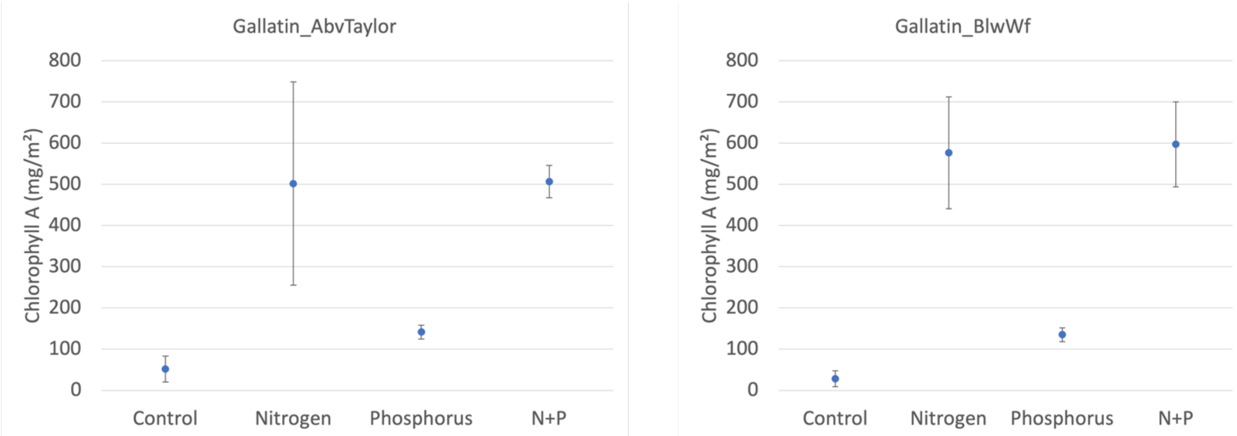

Figure 11: Chlorophyll a levels measured from nutrient limitation experiments at two sites on the Gallatin

Chlorophyll a levels measured from nutrient-diffusing substrate experiments at Gallatin_AbvTaylor and Gallatin_BlwWF suggest that algae growth in the Upper Gallatin was limited by nitrogen *(Figure 11)*. Both sites show a small increase in algae growth when phosphorus was added. Significantly more algae growth occurred when nitrogen was added. Algae growth at both sites was approximately 450 mg/m^2 higher than the control. The addition of both nitrogen and phosphorus promoted approximately the same amount of algae growth as addition of only nitrogen. This experiment was conducted on the Taylor Fork, but some samples were lost due to uncontrollable circumstances leading to an incomplete data set.

Air and Water Temperatures

Average monthly air temperatures were higher in June, July, and September in 2021 than past years *(Figure 12)*. Average June temperatures in 2021 measured 15 °C compared to a temperature of 10.7 °C from the year prior. July of 2021 (17.1 °C) average temperatures were slightly above that of July 2018 (16.7 °C) when the first large algae bloom was reported.

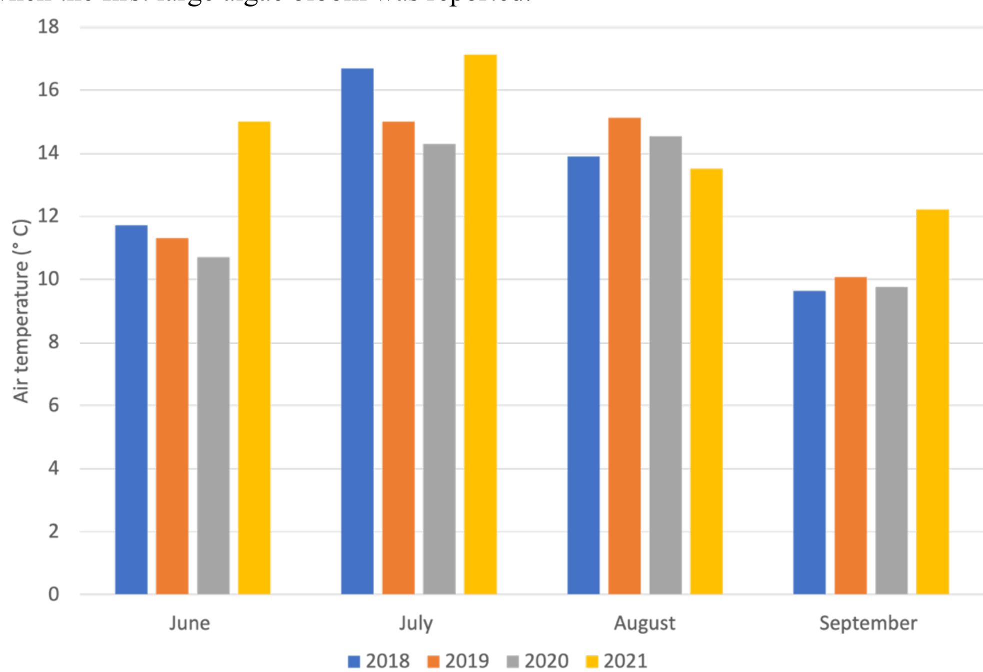

Figure 12: Average monthly air temperatures across monitoring season from 2018-2021

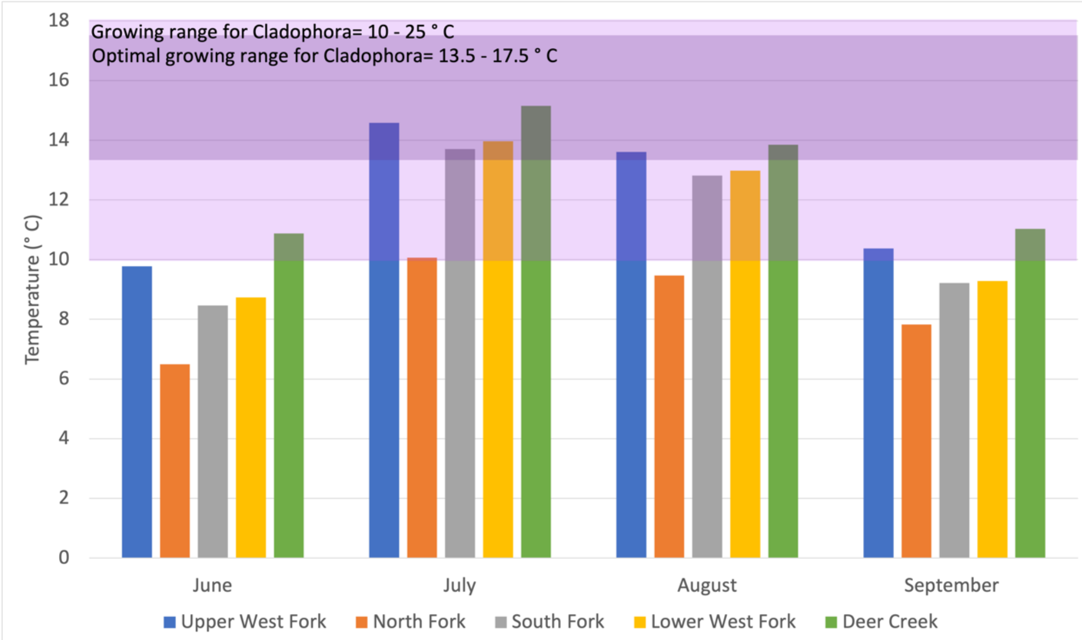

Figure 13: Average monthly water temperature over 2021 season

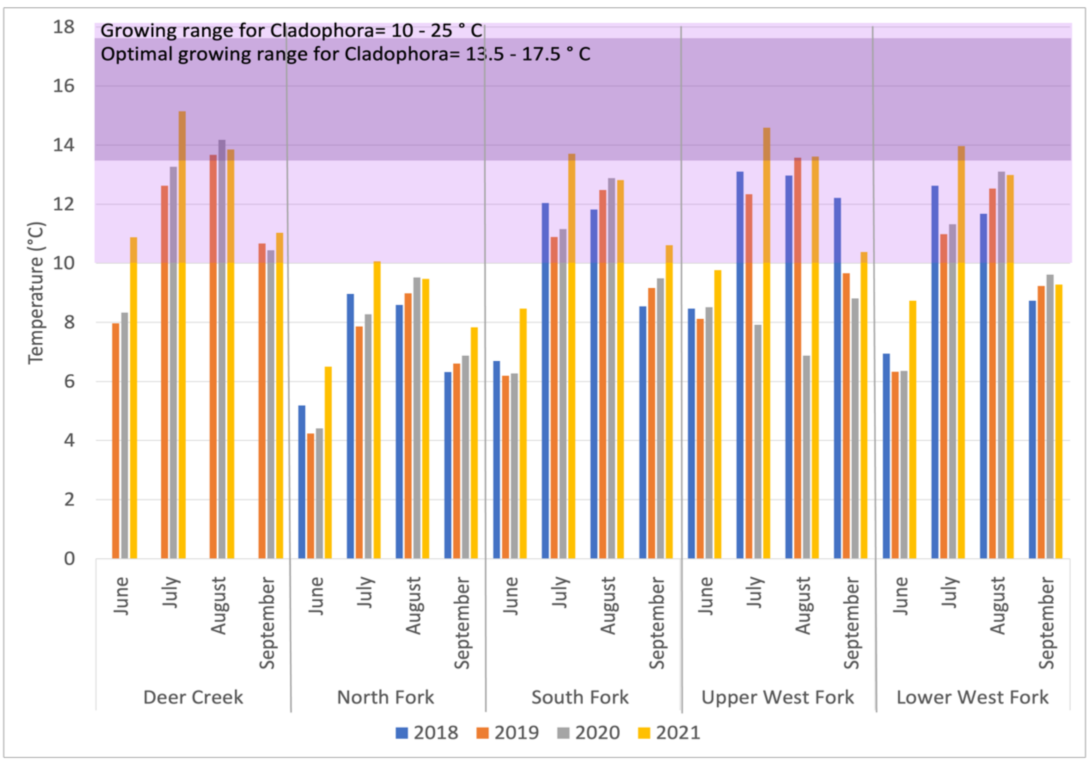

Figure 14: Average monthly water temperature across monitoring season from 2018-2021

Water temperatures in June of 2021 in the Gallatin above Deer Creek were the only average temperatures to be within the growing range for Cladophora at 10.9 °C *(Figure 13)*. By July, all sites were within the growing range for Cladophora with upper West Fork (14.6 °C), South Fork (13.7 °C), lower West Fork

(14.0 °C), and the Gallatin above Deer Creek (15.2 °C) hitting the optimal temperature growing range. By August, the upper West Fork and the Gallatin above Deer Creek were still within the optimal growing range with the South Fork and lower West Fork still within the standard growing range. In September, the upper West Fork (10.4 °C) and Deer Creek (11.0 °C) were the only sites still within the growing range for Cladophora. Water temperatures were generally warmer in 2021 at all sites than previous years *(Figure 14)*. July temperatures were the warmest of all the months at all locations. The South Fork, upper West Fork, and lower West Fork have reached the growing temperature range in July and August for all years between 2018-2021. The Gallatin above Deer Creek has also reached the growing temperature range for Cladophora over 2019-2021. The USGS Gallatin above Deer Creek gauge was installed in 2019.

Hardness

Site	June	July	August	September
Gallatin_AbvTaylor	102	**122**	**139**	**136**
TaylorFk_BlwWapiti	89	118	**143**	**152**
Gallatin_AbvSpanish	84	116	**142**	**157**
Gallatin_BlwTaylor	97	**126**	**128**	**150**
Gallatin_BlwBuck	99	**131**	**149**	**143**
Gallatain_AbvWF	102	**133**	**148**	**146**
MFWF_Mouth	55	84	102	108
WFGR_AbvGolf	49	76	97	105
SFWF_Mouth	82	**129**	**156**	**158**
WFGR_BlwGolf	55	94	**126**	**155**
WFGR_Mouth	72	118	**142**	**161**
Gallatin_BlwWF	102	**154**	**183**	**178**
Gallatin_BlwPortal	90	**138**	**172**	**172**

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

Hardness at each site increased over the season. Highest levels were in the mainstream Gallatin and at sites downstream from WFGR_AbvGolf. In August and September, all sites were in the ideal growing hardness for Cladophora except for MFWF_Mouth and WFGR_AbvGolf.

Streamflow

At the USGS Gallatin above Deer Creek gauge, peak streamflow was 3,540 cubic feet per second (CFS) at 23:15 on 6/5/21 *(Figure 15)*. Peak streamflow at the USGS Gallatin Gateway gauge was 5,230 cubic feet per second (CFS) reached 30 minutes later at 23:45 on 6/5/21 *(Figure 16)*. Peak flows were in line with the timing of the peak flows from 2018-2021 which occurred during the week of May 31-June 6 *(Figure 17)*. After peak flow, average streamflow was consistently below the historic average. The greatest difference from historical average occurred during the week of June 28-July 4th at 42% of the average. Weekly streamflow in 2018, 2020, and 2021 were all below the historic average after June 14th until September 5th.

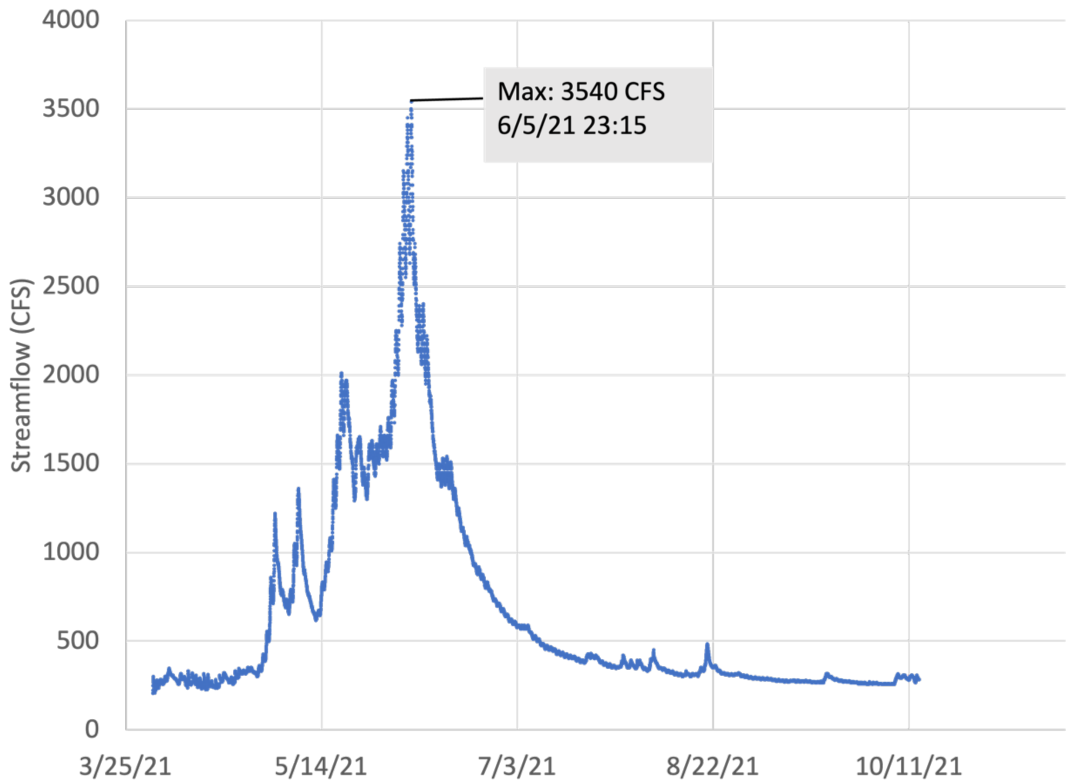

Figure 15: Discharge measured at the USGS Gallatin above Deer Creek gauge

Gallatin River above West Fork

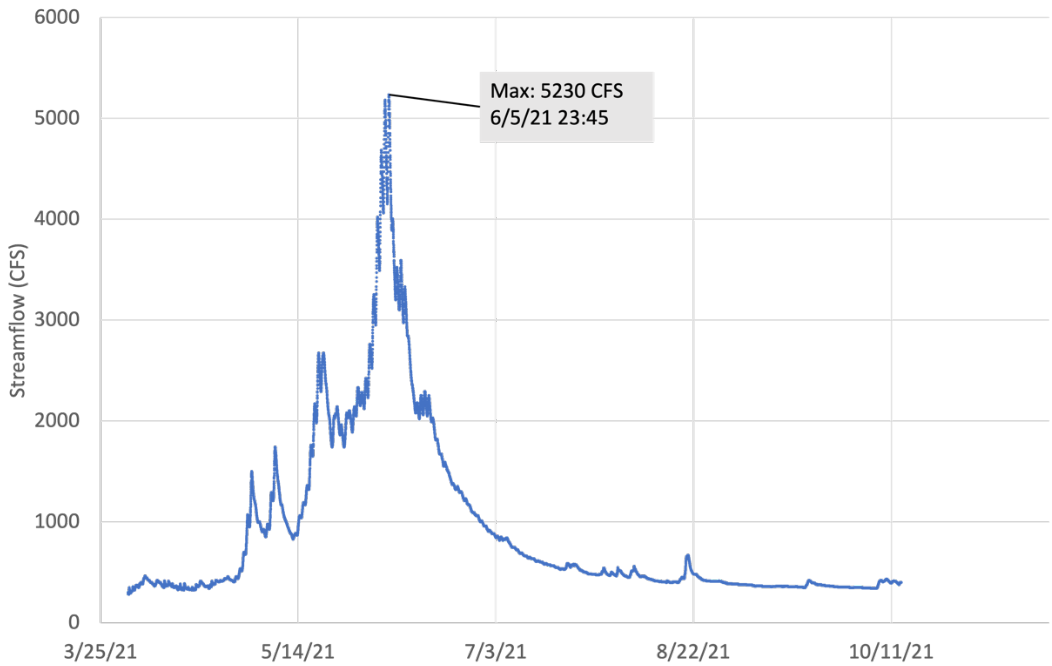

Figure 16: Discharge measured at USGS Gallatin Gateway gauge

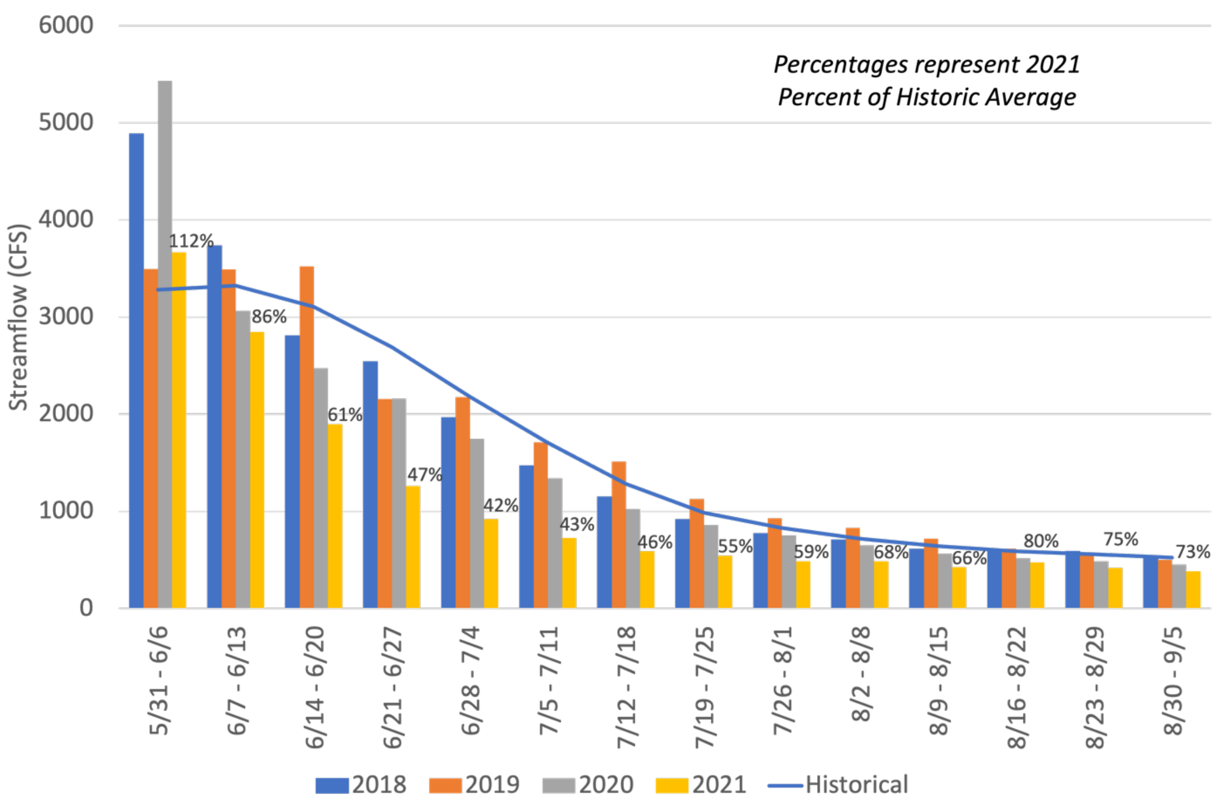

Figure 17: Average weekly streamflow compared to historic averages at USGS Gallatin Gateway gauge

Sunlight

During July of 2018 and 2020, average solar irradiance was higher than 2019 and 2021 *(Figure 18)*. These years with higher solar irradiance correspond to the years of the large algae blooms. Average irradiance in July of 2018 measured 316 W/m^2 and 2020 measured 308 W/m^2, compared to values of 290 W/m^2 in 2019 and 281 W/m^2 in 2021. The lower solar irradiance in 2021 could explain why when there were warmer water temperatures, lower streamflow, and similar nutrient concentrations as other years there was not an algae bloom.

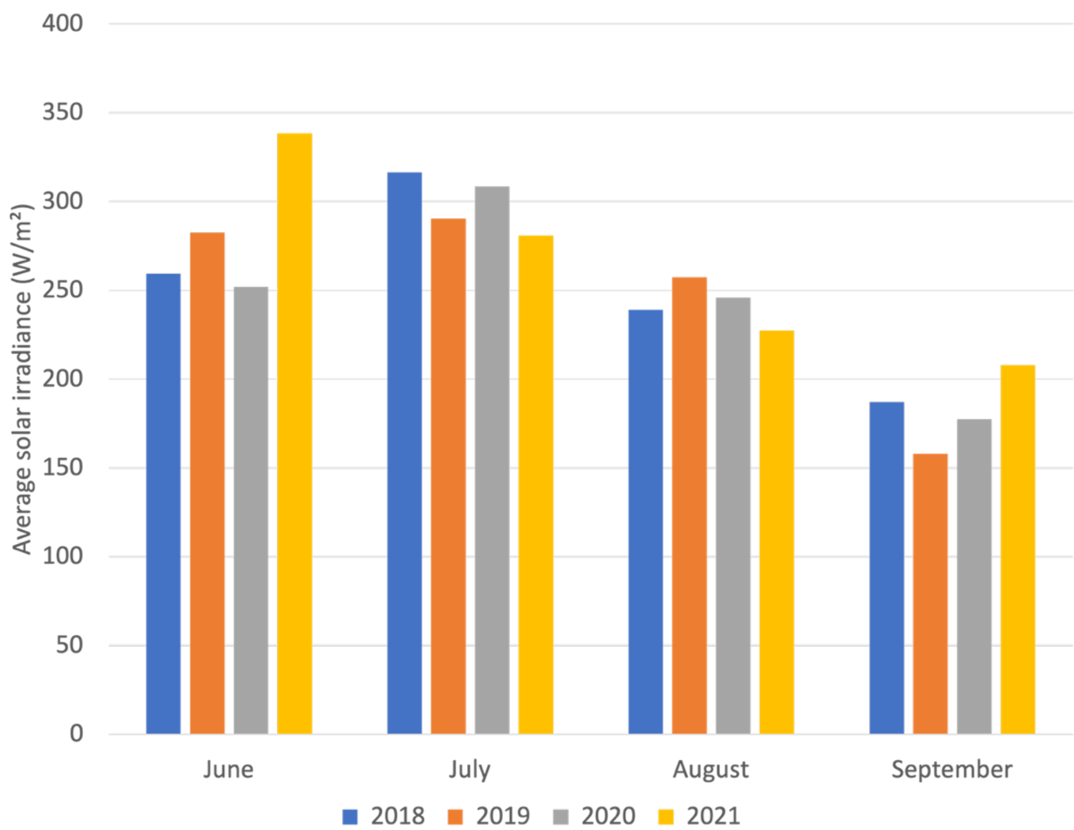

Figure 18: Average solar irradiance by month from 2018-2021 measured at Optic Remote Sensory Lab Weather Station in Bozeman

Nutrient Reduction Strategies

The Gallatin River Task Force has been working to reduce nutrient levels in the Upper Gallatin, while also reducing commercial and residential water usage to mitigate future algae blooms. Strategies to reduce nutrient pollution are outlined in Upper Gallatin Nutrient Assessment and Reduction Plan (Allen & Howell, 2020).

Projects completed to date include:

1. Restoration projects on the upper West Fork to reduce nutrient loading and sediment pollution
2. Sustainable river access and streamside vegetation enhancement at the Upper Deer Creek site
3. Annual Runoff Clean-off event: a community wide annual dog waste pickup
4. Septic system 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

Projects in progress

1. Trout Friendly Landscaping initiative to conserve water and reduce nutrients through native, drought-tolerant landscaping
2. Rebates for installation of indoor and outdoor fixtures that conserve water
3. Porcupine and Beaver Creek restoration project to create sustainable access and repair current damage to native ecosystem
4. Big Sky Water and Sewer District wastewater treatment plant upgrade
5. Central sewer to Gallatin Canyon

As an individual, there are many actions you can take to help make a positive impact. These include trout friendly landscaping, 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.

Volunteers collecting data along the South Fork

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