Nitrogen and phosphorus on the Gallatin River near Big Sky: Implications for algae patterns and water quality modeling

Christy Meredith, Gabrielle Metzner, Troy Clift, Torrie Haraldson

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Algae blooms

Increasing in Montana Rivers

- Higher summer temperatures
- Decreased snowpack
- Reduced stream flows
- Increased nutrient inputs from septic systems, agricultural inputs, and sewage treatment facilities

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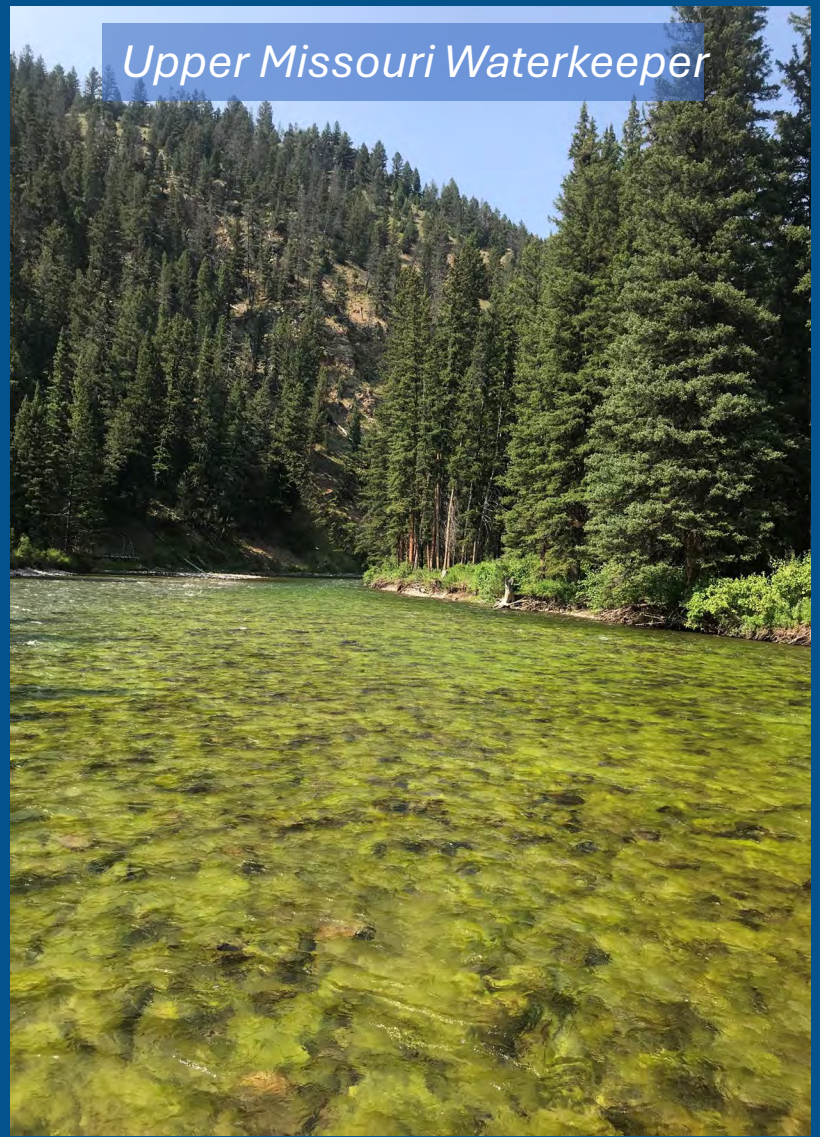
Middle Gallatin Listing Decision

- March 31st, 2022 - DEQ received petition to list
  - Upper Missouri Waterkeeper
  - Montana Trout Unlimited
  - Gallatin River Task Force
  - American Rivers
  - Greater Yellowstone Coalition



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Middle Gallatin Watershed

Park Border to Spanish Creek confluence

Sources of Nutrients

- natural geology/soils
- fertilizers
- septic systems
- animal feedlots

Town of Big Sky Experiencing Fast Growth

- doubling of population between 2010 and 2020
- increase in housing units by 20% between 2010 and 2020

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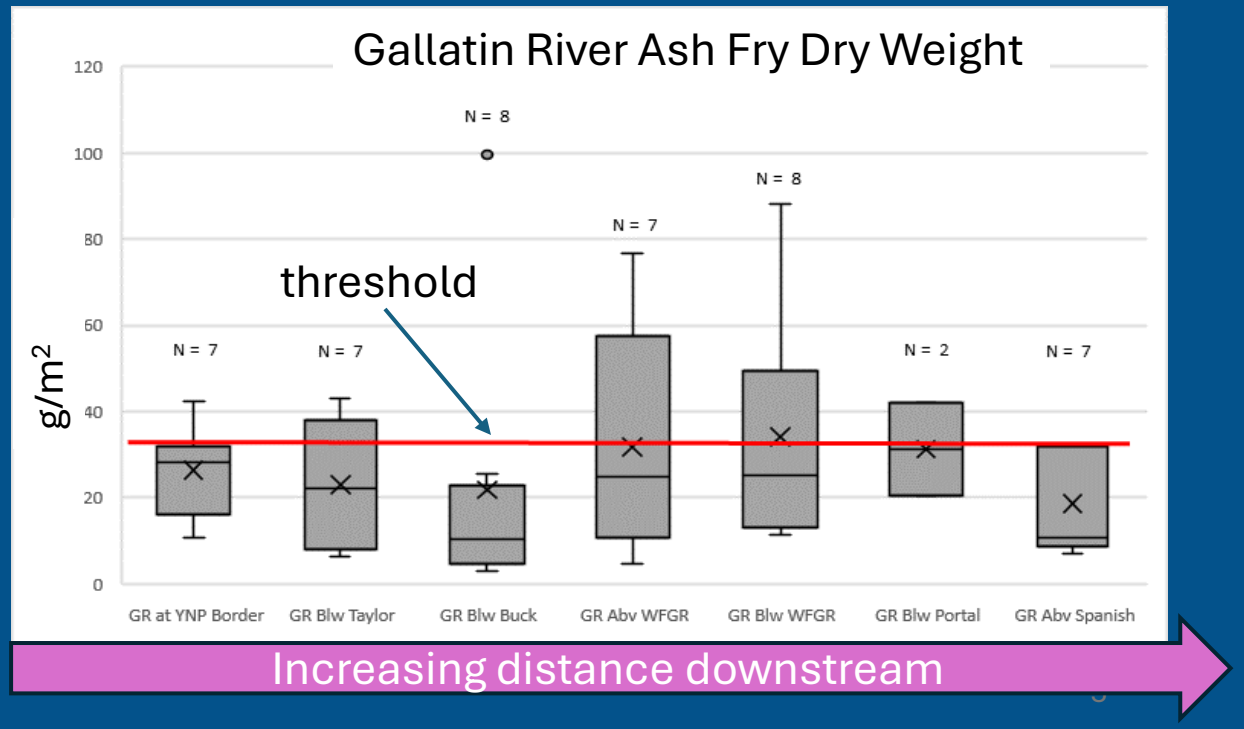
Assessment

- Evaluated data against recommended criteria (2018-2021)
- Based on distribution of values at reference sites
- High algae growth and poor bugs despite nutrients within thresholds

	Threshold	% of Samples Exceeding
Total Nitrogen (mg/L)	0.3	1.20%
Nitrate/Nitrite mg/L)	0.1	1.20%
TP (mg/L)	0.03	4%
chlorophyll a (mg/m^2)	120	0%
Dry Weight (g/m^2)	35	30%
Aquatic Bug Score (HBI)	4	81%

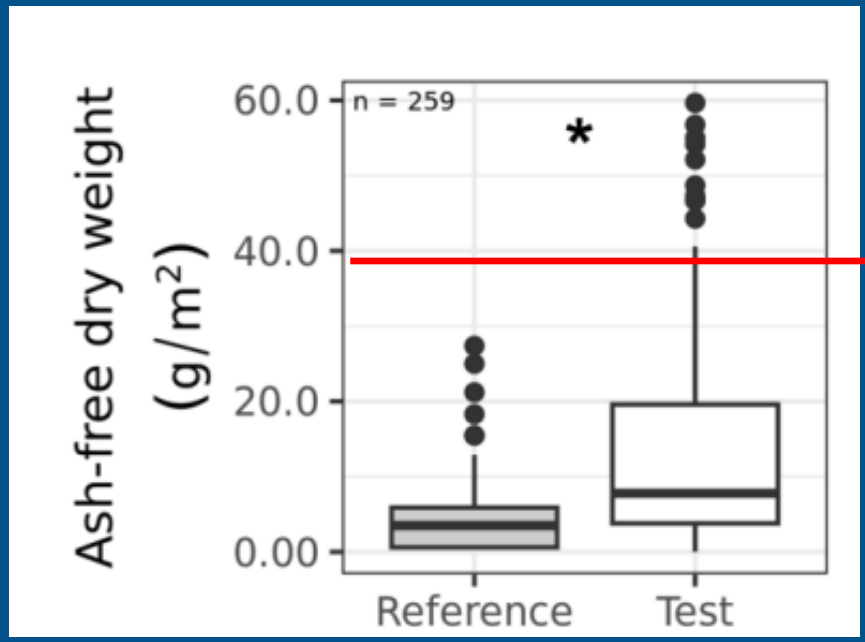


Why?

Algae biomass high but Nutrients low

- Environmental factors at reference sites different than study area (depth, shade, stream size, geologic setting, natural nutrient inputs)
- Sampled conditions are a snapshot in time
- Different algae species may respond differently to nutrients

Gallatin 3.5 mi below West Fork 90 g/m2



Gallatin at NP Border-42 g/m2

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What controls algae growth?

shade

Filamentous Algae Growth:
Complex Interactions

Light

Air Temperature

Magnitude of spring flood

Water Temperature

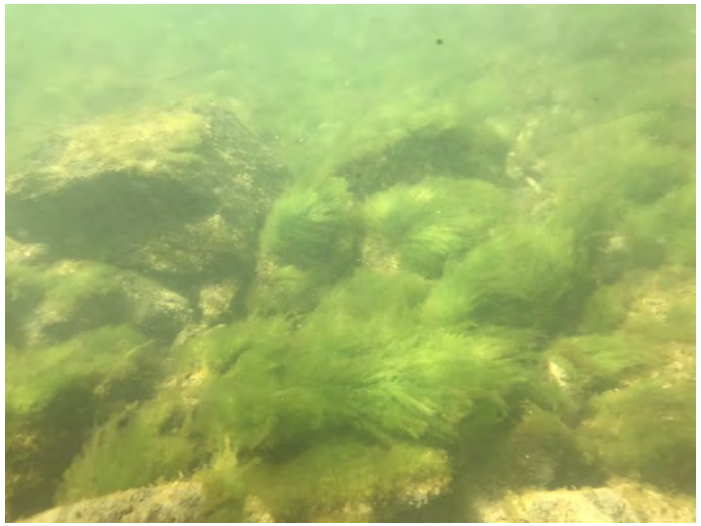
Algae Growth & Death

Water Depth

Nutrients

Phosphorus

Nitrogen

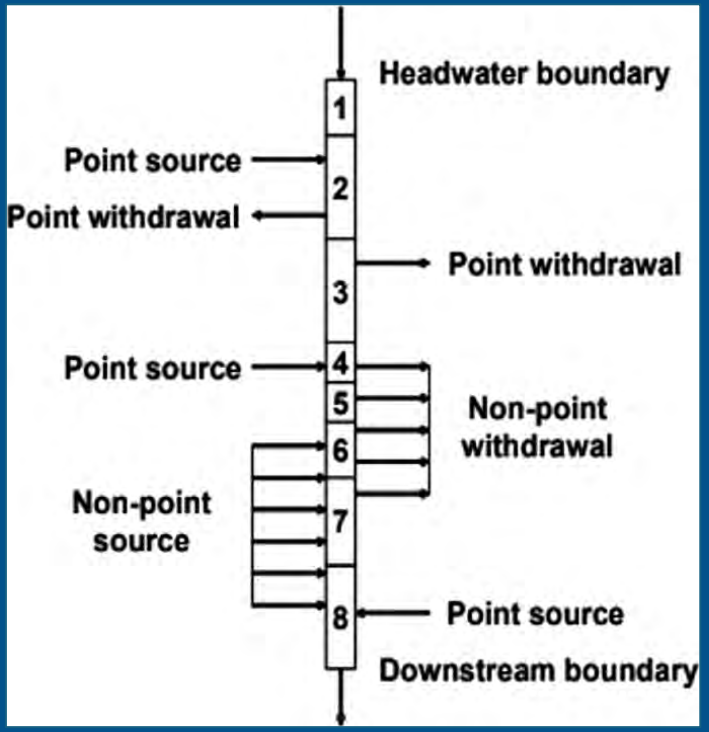


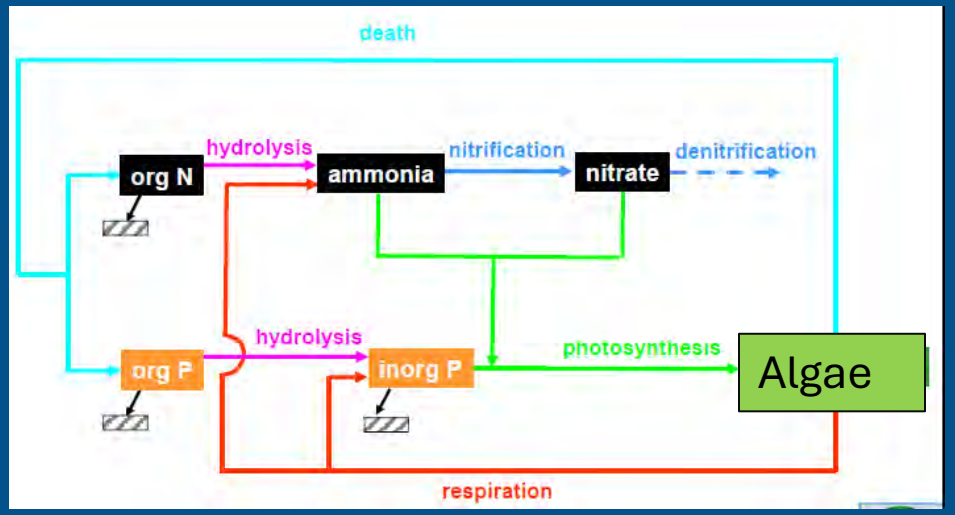
Groundwater Interactions

Biological interactions

What is a Qual 2k model?

- Break river up into sections
- Quantify inputs and outputs of
  - -water quantity
  - -light energy (temperature)
  - -nutrients
  - -algae growth
- Equations transformations in each section
- Compare your prediction to what you observed
- Do you understand the sources and how the system works?





3 year study (2023-2025)

Discrete Water Quality Sampling (seasonal, Gallatin Task Force assist)
Stream flow, total N, total P, SRP, nitrate, ammonium, total suspended solids, macroinvertebrates

Algae Monitoring (Summer)
Benthic algae visual assessment, chlorophyll *a,* ash free dry Weight

Qual2k model sampling (August 2024, 2025)
biological oxygen demand, total organic carbon, volatile suspended solids, reach slope, light extinction, shade, weather

Bioavailable phosphorus extraction from sediments (2023)

Continuous Water Quality Sampling (Summer)
dissolved oxygen, temperature, pH, turbidity, specific conductance,
Nitrate (West Fork, Russell Conti)

Aerial Imagery (Summer 2024, 2025)
UAV to obtain tiff images of benthic algae

Nutrient Limitation Experiments (August 2024, 2025)
enrich cups with N and P and examine benthic algae growth

Qual2k model development (August 2024, 2025)

How do nitrogen and phosphorus concentrations change along the Gallatin River?

Does benthic algae type and quantity change in response to nutrient changes?

What are the sources of nutrients on the Gallatin River?

How can Qual2k model help to understand algae dynamics

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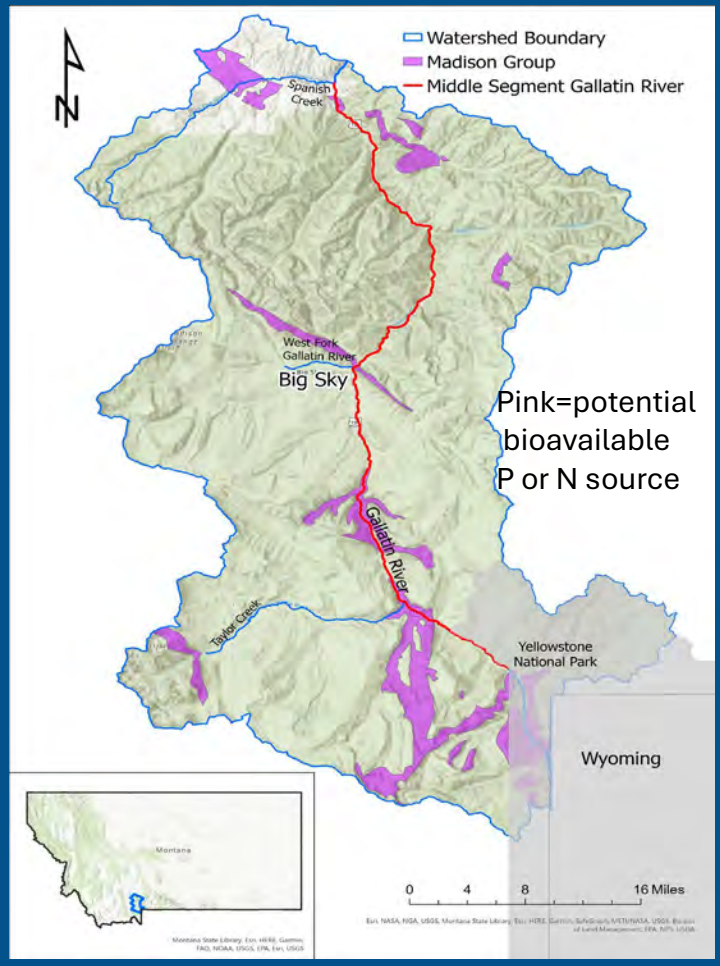
How do nitrogen and phosphorus change?

Proximity to Sources
-natural deposits
-West Fork and other major tributaries
-sediment inputs (total suspended solids)
-groundwater inputs

Seasonality and Diurnal
-winter
-spring run-off
-summer storms
-night

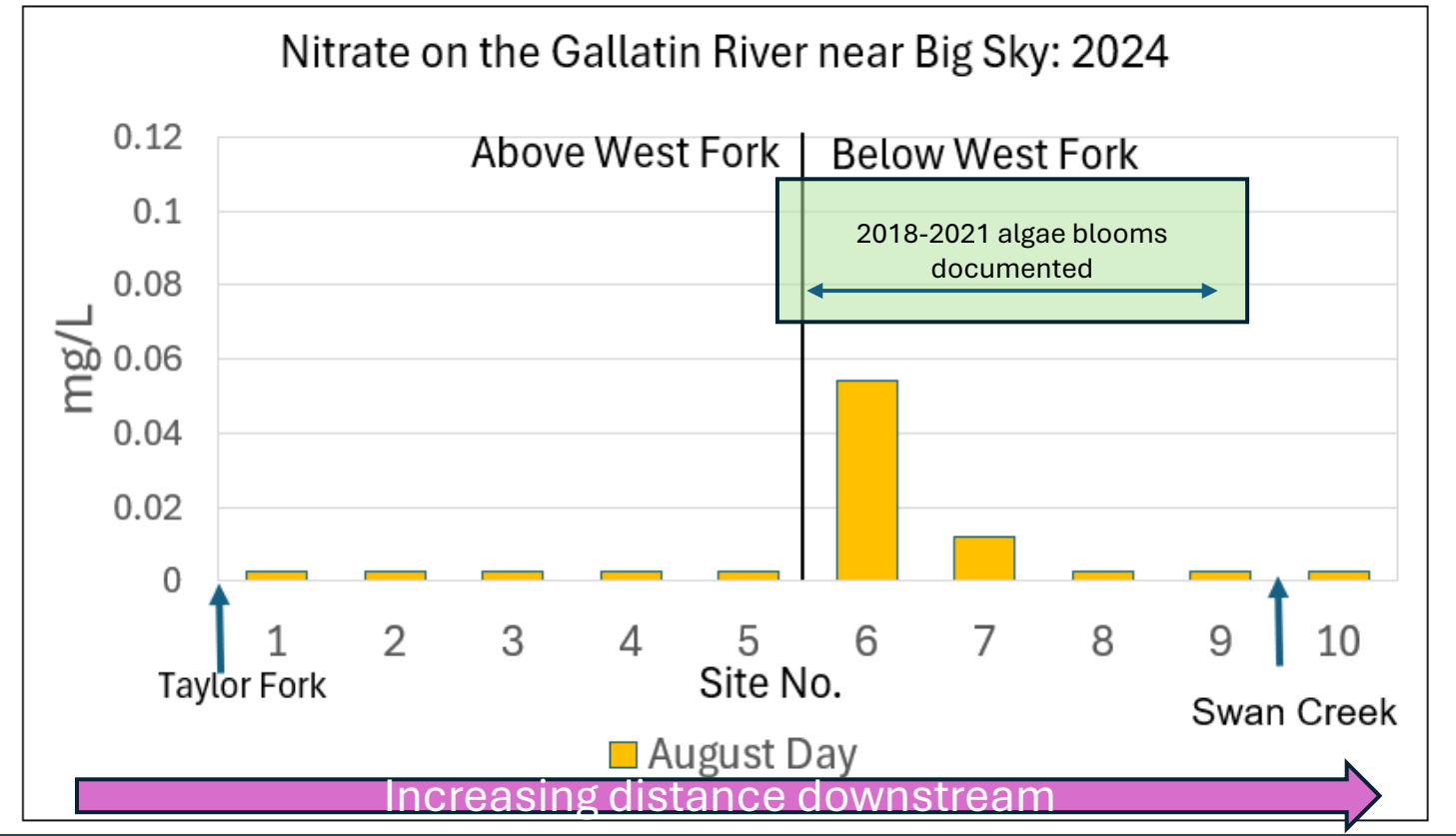
Form
-total
-bioavailable (nitrate and SRP)
-sediment bound

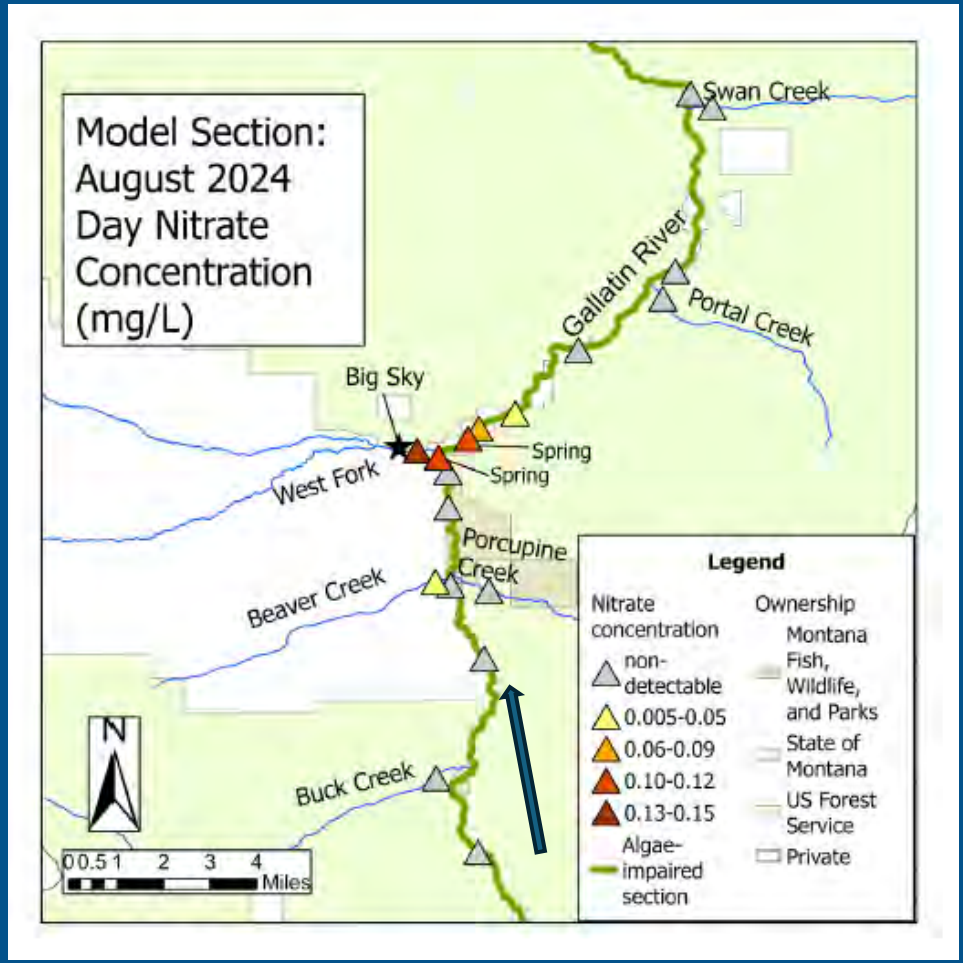


Pink=potential bioavailable P or N source

Nitrate

- Main predictor: Proximity to West Fork





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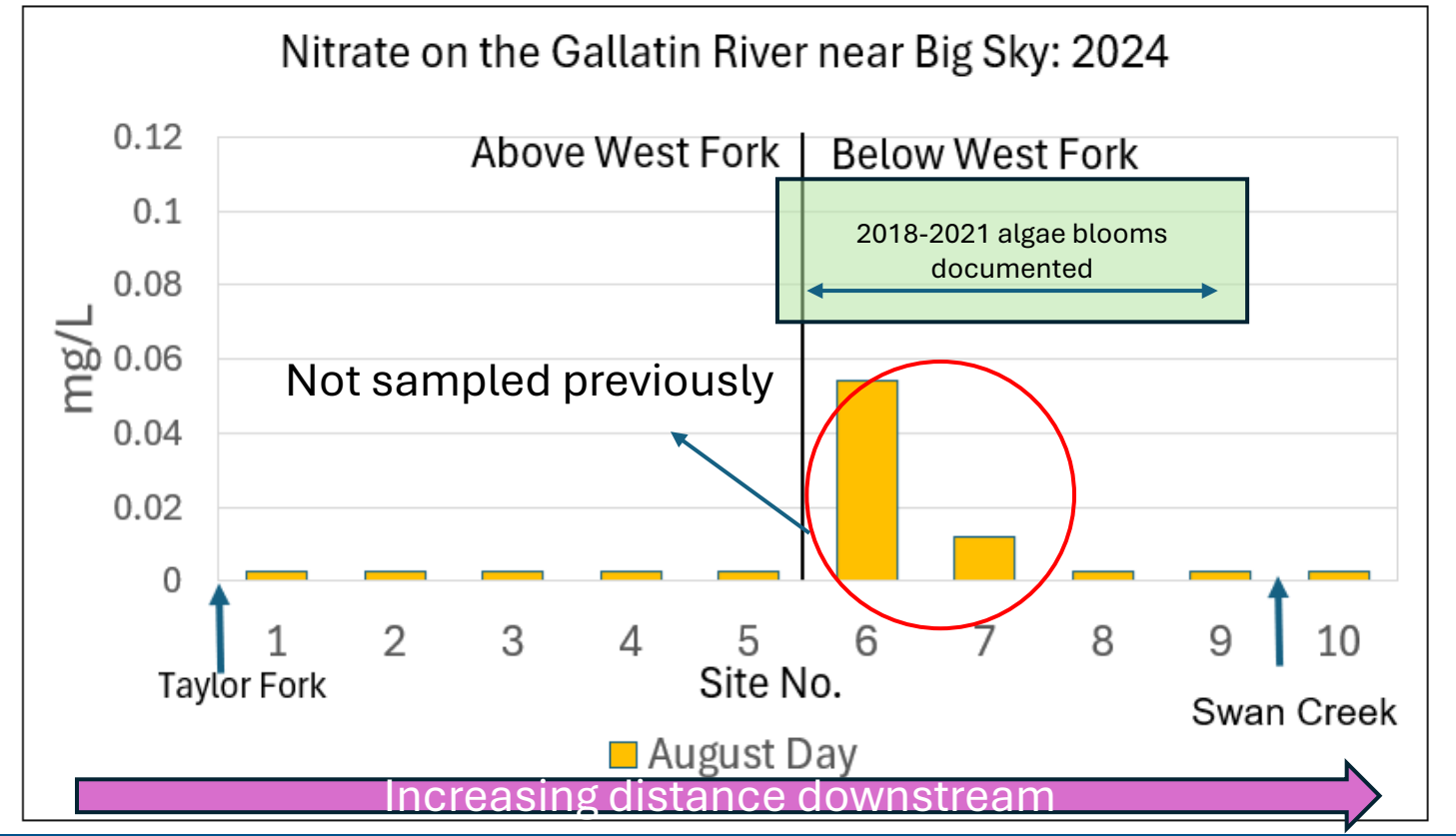

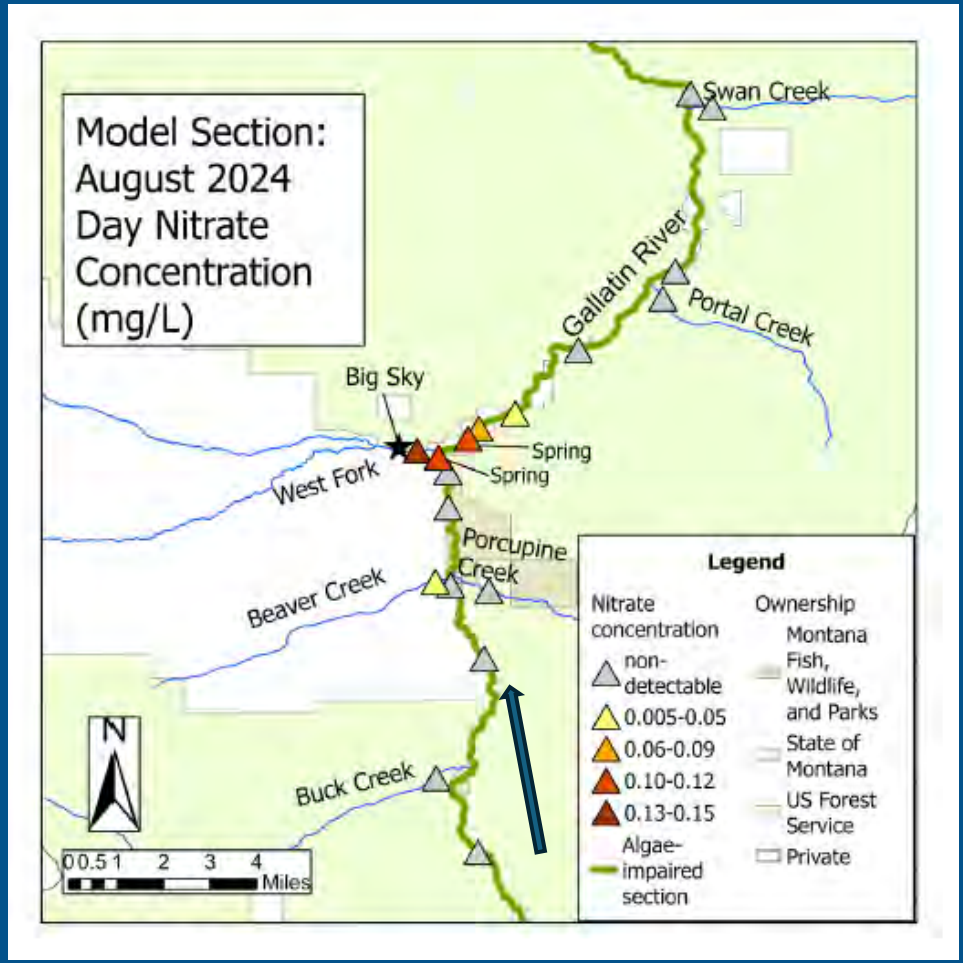

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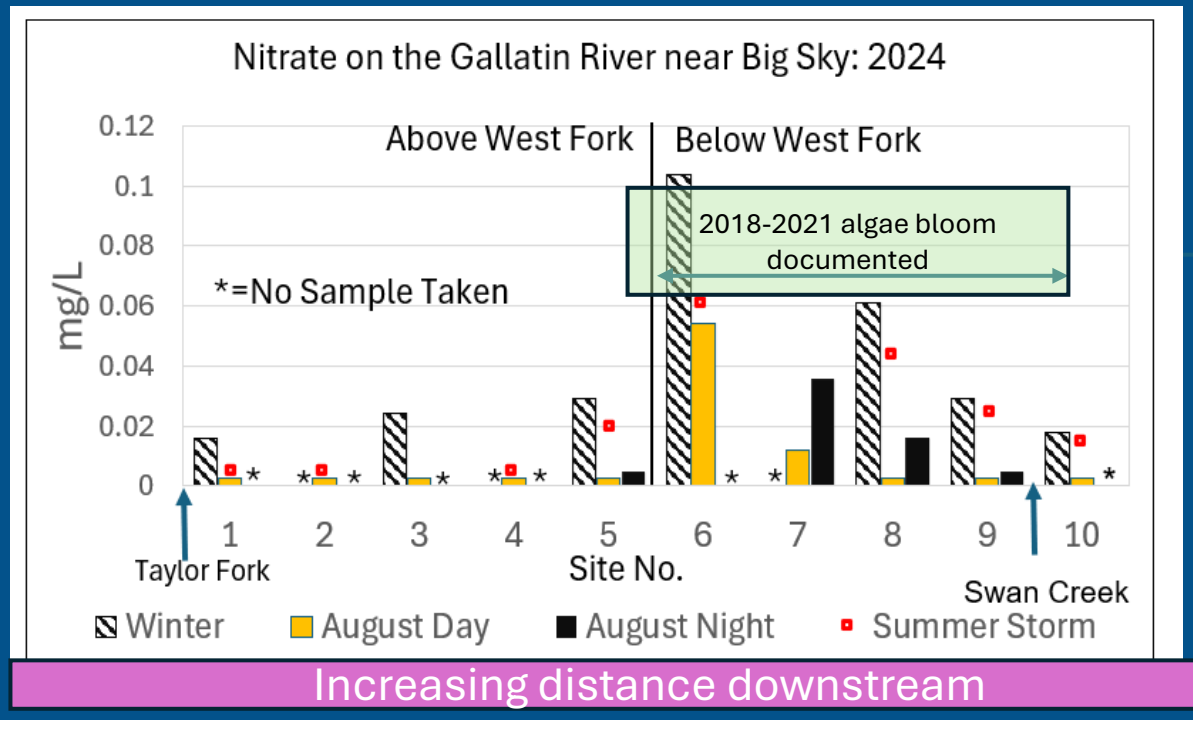
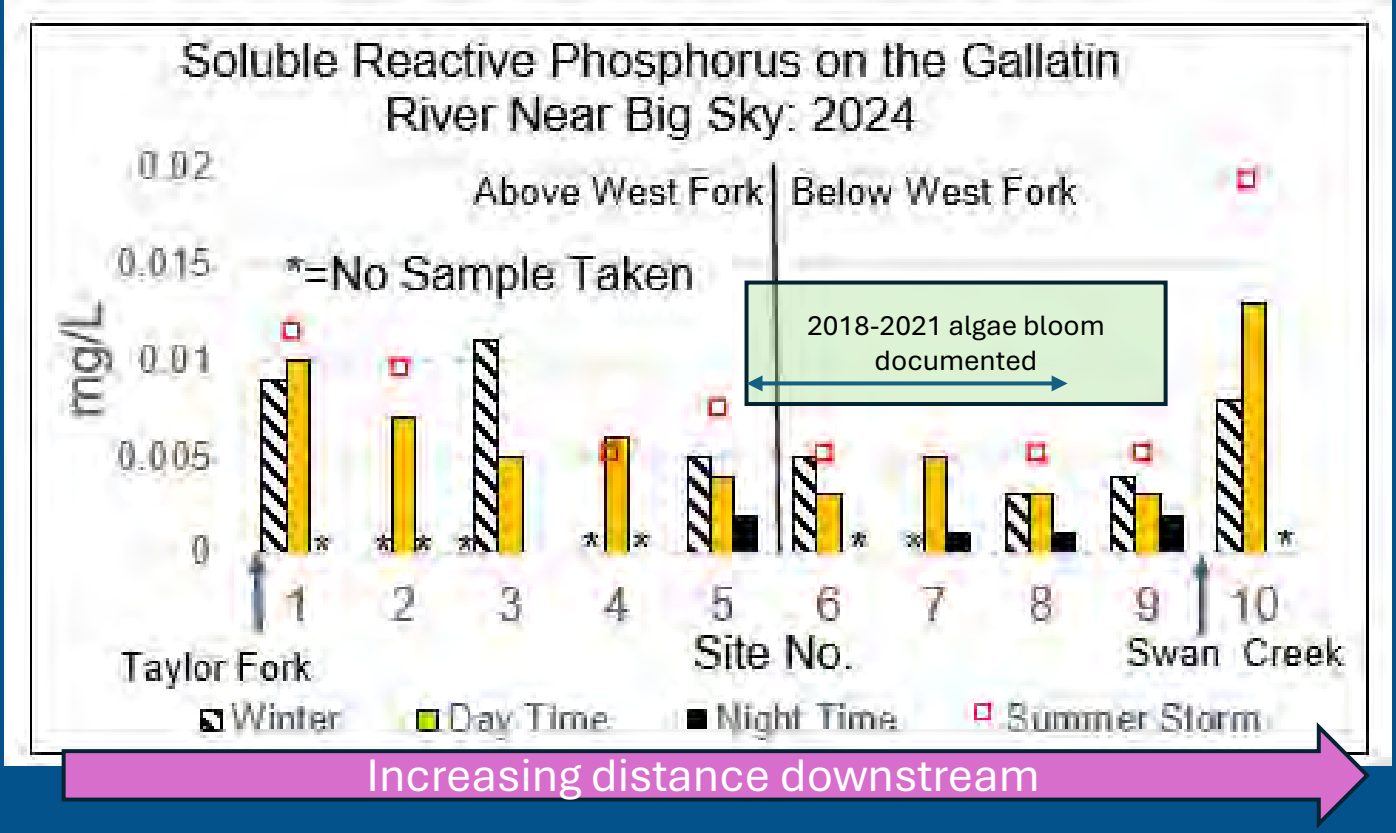
Nitrate

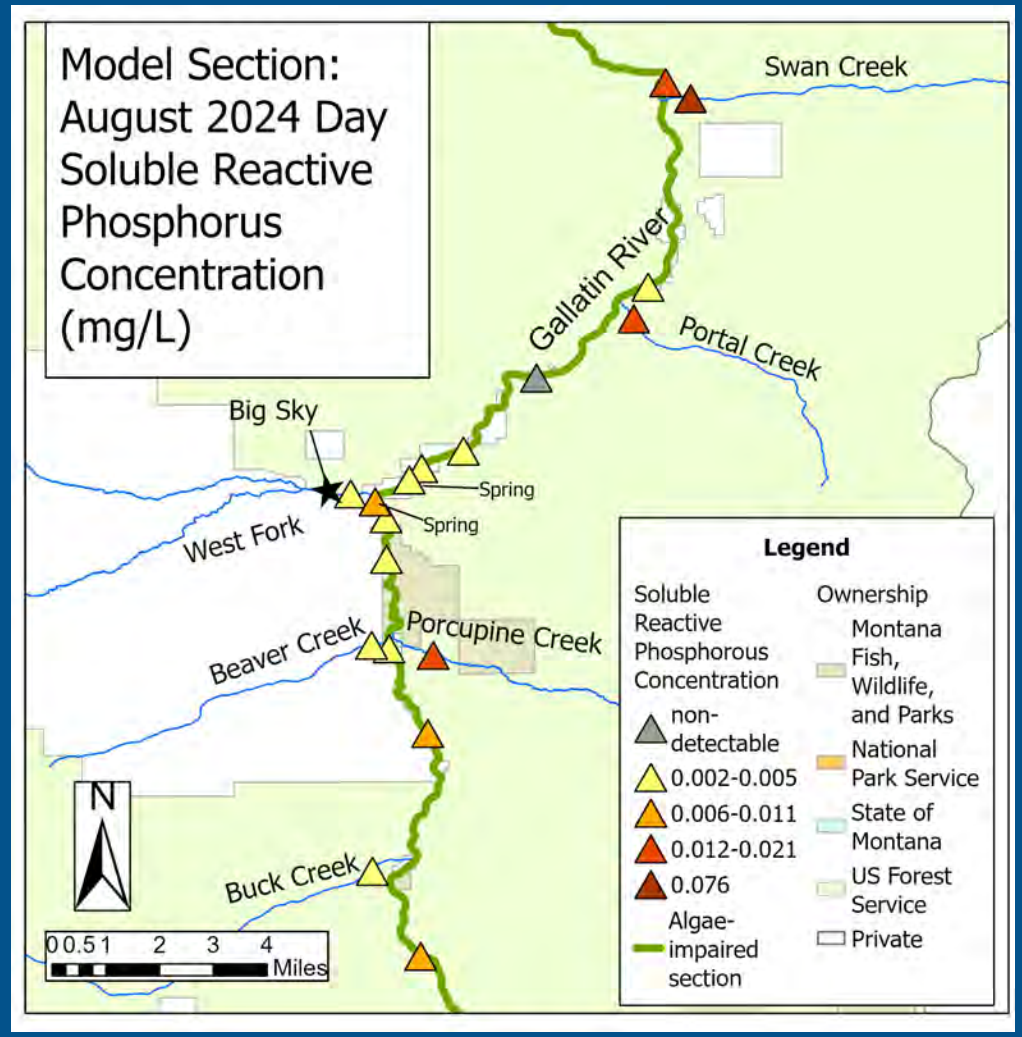
- Main predictor: Proximity to West Fork
- Increases during storm events
- Night and winter sampling improves source assessment



Soluble Reactive Phosphorus

- Main predictor: Proximity to high P tributaries
- Increases during storm events





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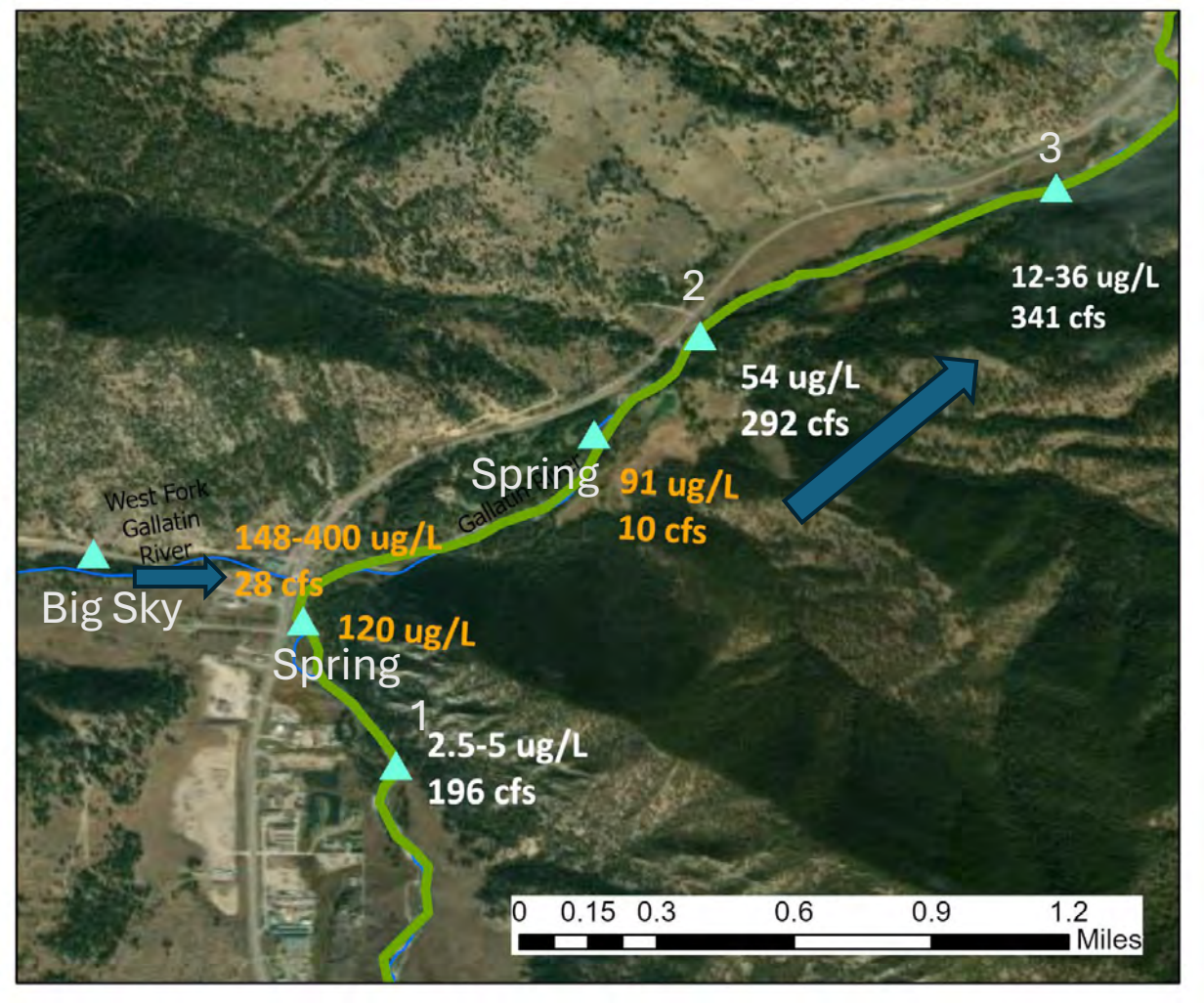
What is the relative contribution of Nitrate-N from sources near the canyon section?



- 42% from West Fork
- 6% from Gallatin upstream of West Fork
- 52% groundwater/other

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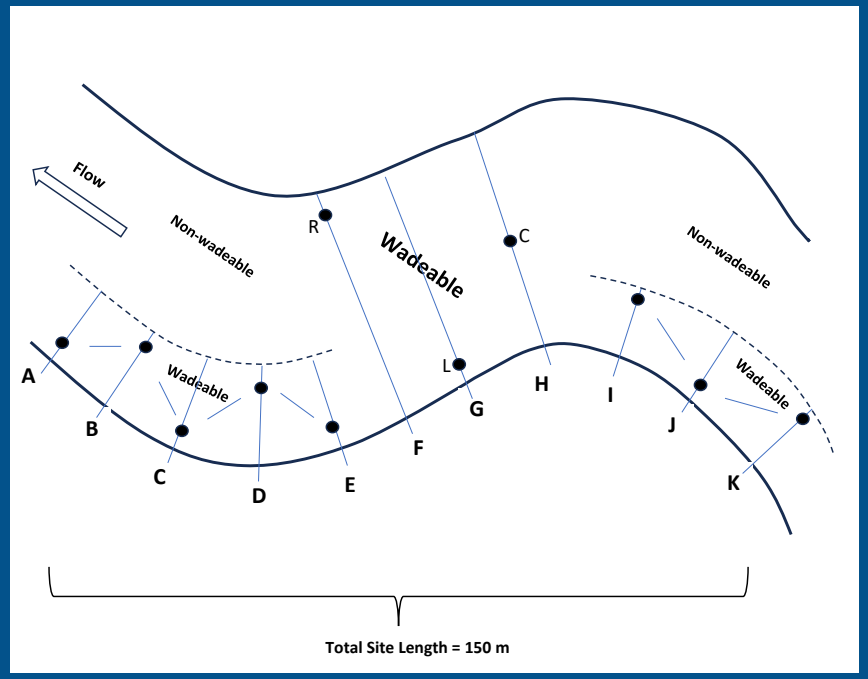


DEQ Algae Sampling

Standard Operating Procedure

Visual Assessment: percent of reach covered in which type of algae?

Sample Collection-11 transects (alternating sides)

- Chlorophyll *a* content
- Ash Free Dry Weight
- Composite sample

Does chlorophyll a exceed 120 mg/m^2?

Does Dry Weight exceed 35 g/m$^{2?}$

~Time involved: up to 8 hours per reach

Visual: use glass bottom tube or bucket

template method: short algae

hoop method: long filamentous algae

Types of Algae on the Gallatin River

didymo

microalgae

short filamentous algae

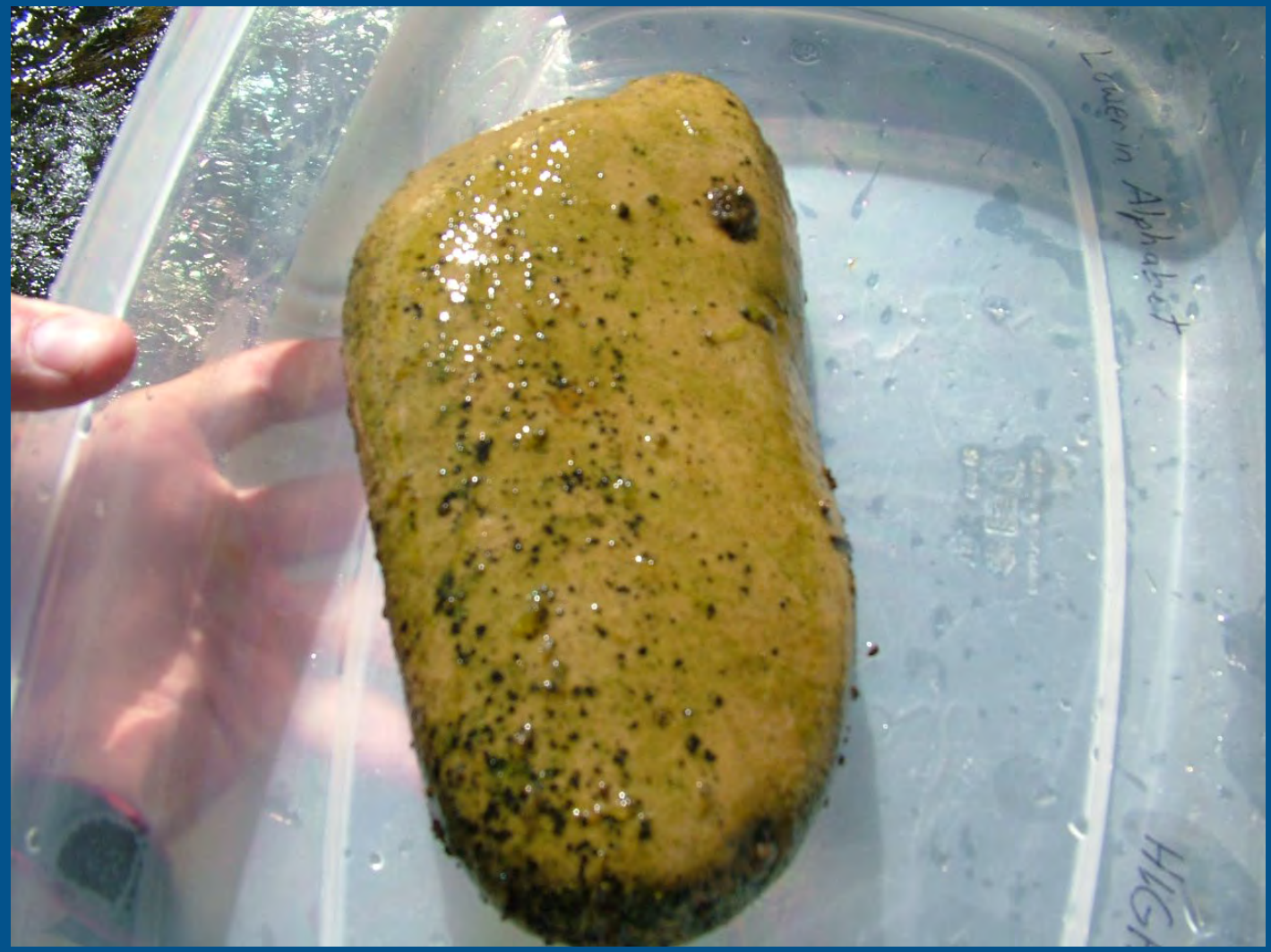
long filamentous algae

Didymo
~0.5 miles upstream
West Fork

Didymo/filamentous
3.5 mi below
West Fork

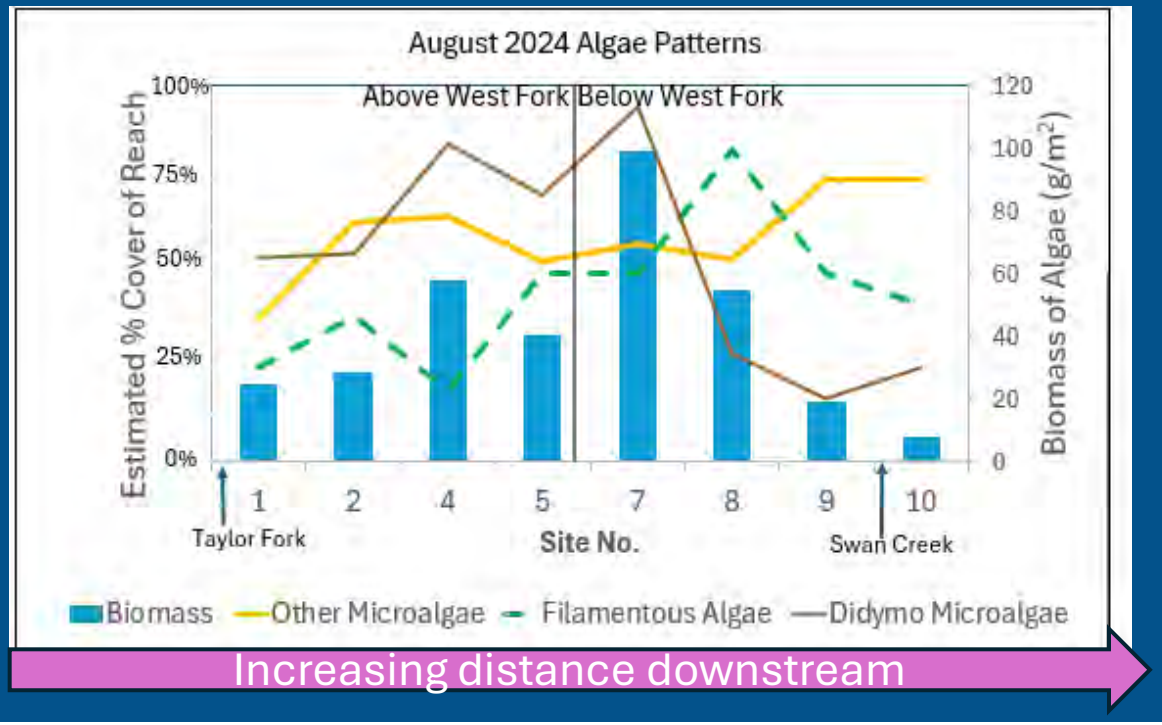
Thick microalgae
Algae 3.5 mi below
West Fork

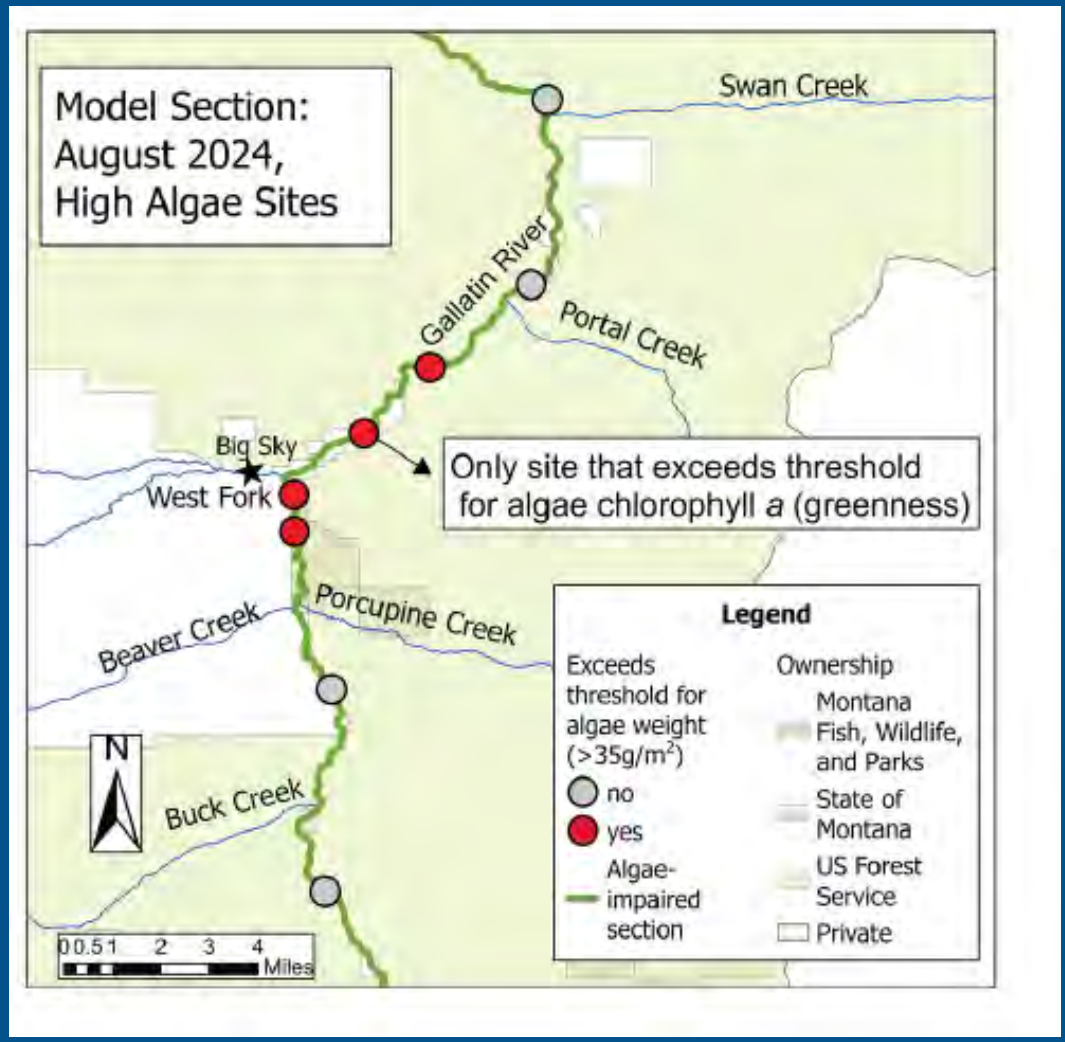
Microalgae
~ 7 miles below
West Fork



Algae Patterns

- Shift in species as well as Ash Free Dry Weight/Biomass of algae both occur as nutrients change





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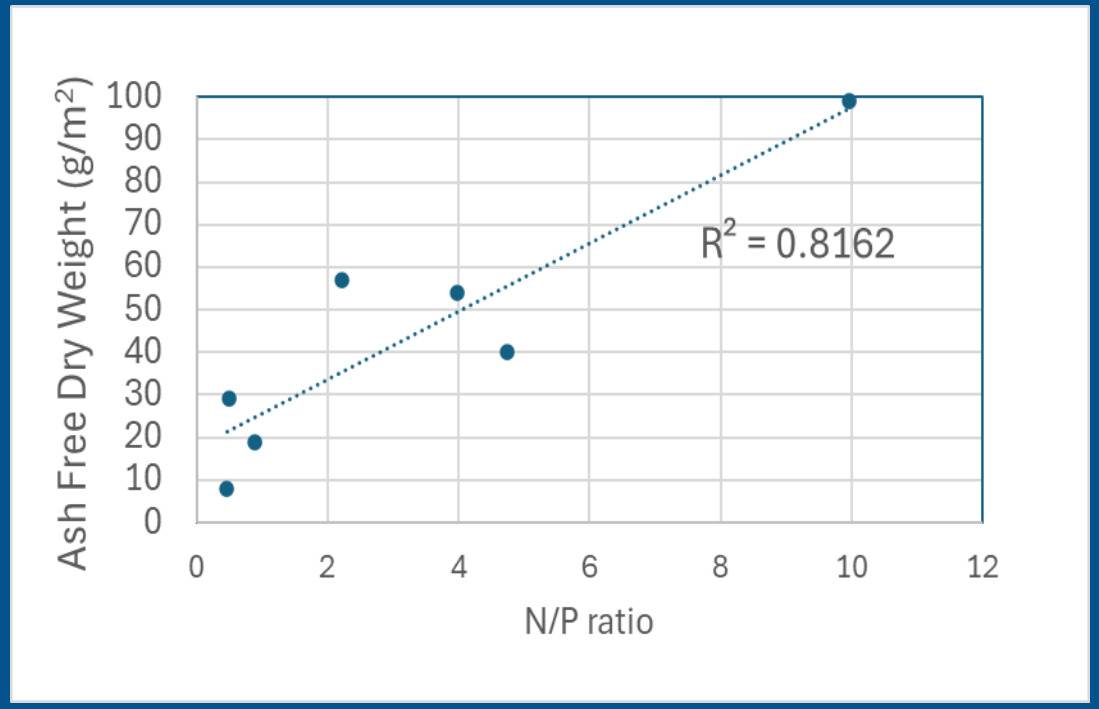
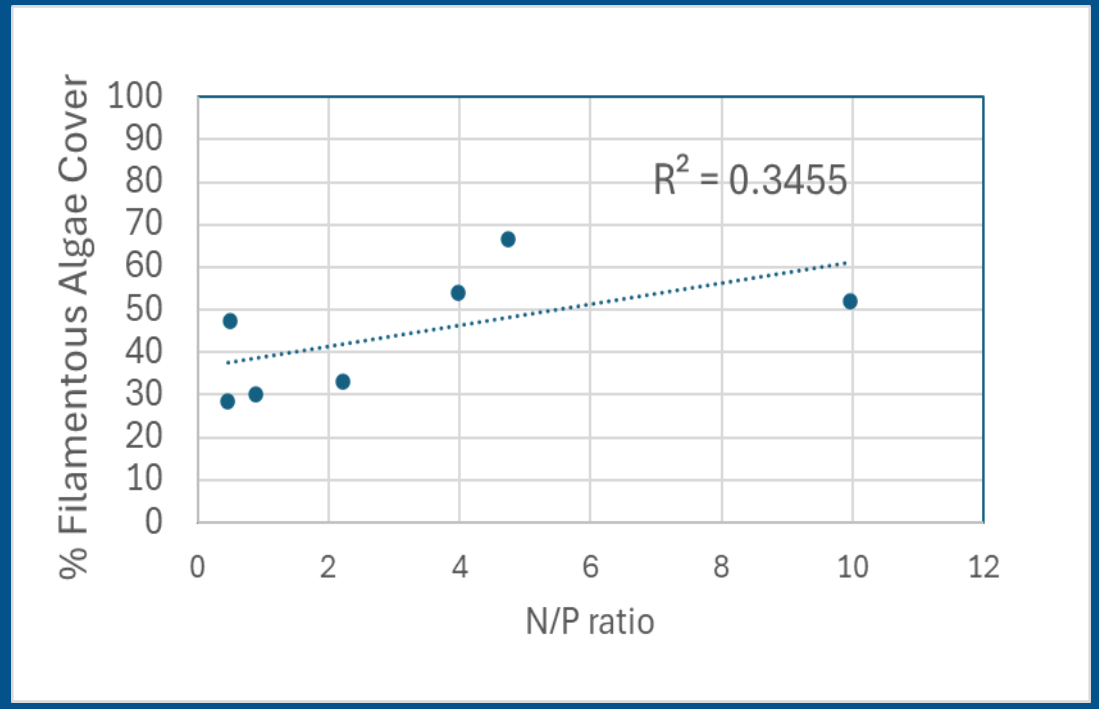
What is causing the changes in algae composition and growth?

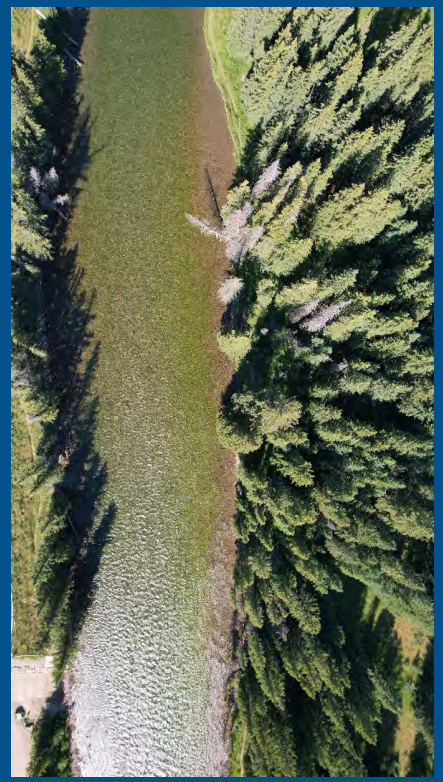




- Using Night Nitrate and Summer Storm SRP

How did conditions during 2023-2025 compare to previous years?: less filamentous algae

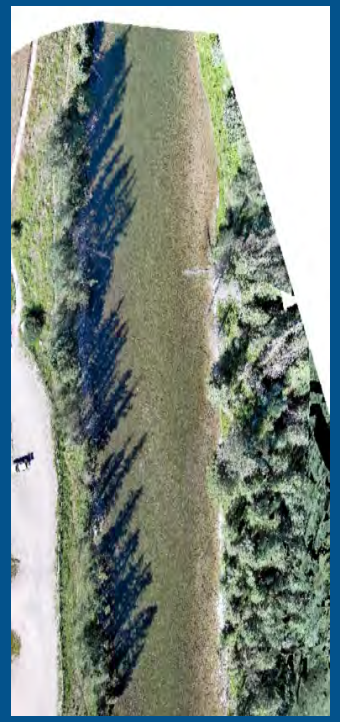
2018: Upper Missouri Water Keeper



~90 g/m^2 from samples

Other Photos Indicate: > 100 g/m^2

2024: DEQ



~50 g/m2

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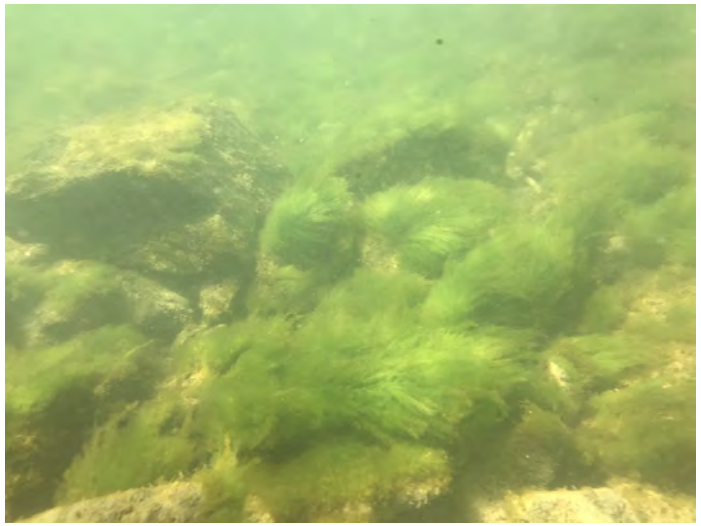
Nutrients

Phosphorus

Nitrogen



Groundwater Interactions

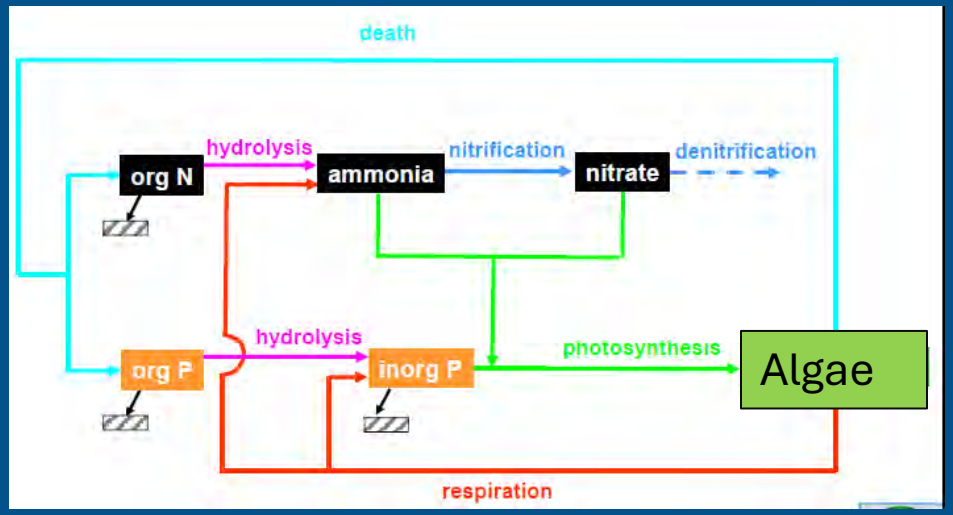
Biological interactions

How can Qual2k model help to understand algae dynamics?

- Do modeled conditions predict algae observed (dry weight, chlorophyll *a*)
- -including night data and species composition

- What nutrient or environmental conditions might have caused algae observed in problem years?

- Would a reduction in nutrients have a significant impact on algae growth?



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Acknowledgements

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