Smith River Nuisance Algae Study

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Montana Dept. of Environmental Quality, Water Quality Division

Public Meeting April 8, 2021

Logistics

Zoom Meeting Setup

- Welcome and thank you for participating in DEQ's Smith River Nuisance Algae and Beneficial Use Assessment Update Public Meeting. Please read the following tips about participating in this virtual meeting:
  - We are recording the meeting.
  - All participants have been automatically muted. Please remain so until called on to speak.
  - Use the "raise hand" feature in the app to indicate that you would like to speak.
  - If you are called on to speak, please identify yourself by stating your first and last name.
  - You may also use the chat box to type your questions.
  - Joining by phone?
  - Press *6 to mute/unmute yourself.
  - Press *9 to raise your hand.
  - Visit the following link for helpful tips about using Zoom software:
- https://support.zoom.us/hc/en-us/articles/201362193-Joining-a-meeting
  - *Thank you in advance for your patience, cooperation, and courtesy in this unprecedented time.*

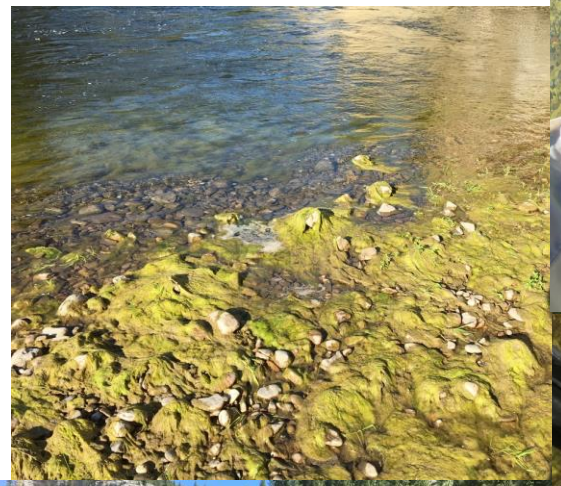
Acknowledgements

- Special Thanks
  - Landowners and stakeholders
  - Colin Maas – FWP Smith River State Parks Manager
  - Emmy Philips – DEQ Field Technician
  - Luke Fisher – DEQ Field Technician
  - Other DEQ staff – Data collection and equipment support

What prompted this project?

- Reports to FWP/DEQ began 2015 and continued through 2017

- **Historic Timeline**
  - FWP sampled a few sites for nutrients in 2016
  - DEQ sampled chlorophyll *a* and nutrients at 9 sites in 2017
  - Smith River Nuisance Algae Study started in 2018
    - **Ongoing**
    - **2020 Monitoring effected due to the Pandemic**



<u>DEQ's overarching question</u>: Why is *Cladophora* reaching nuisance levels in the Smith River, and why now?

- Air Temperature
- Water Temperature
- Nutrients

Why is this project important?

- **Recreation**
- **Aquatic life**
  - Taxa (bugs) shift river wide
  - Low DO impacts in shoreline areas

KEY TERMS:

***Cladophora glomerata* – the identified algae reaching nuisance levels in the Smith River**

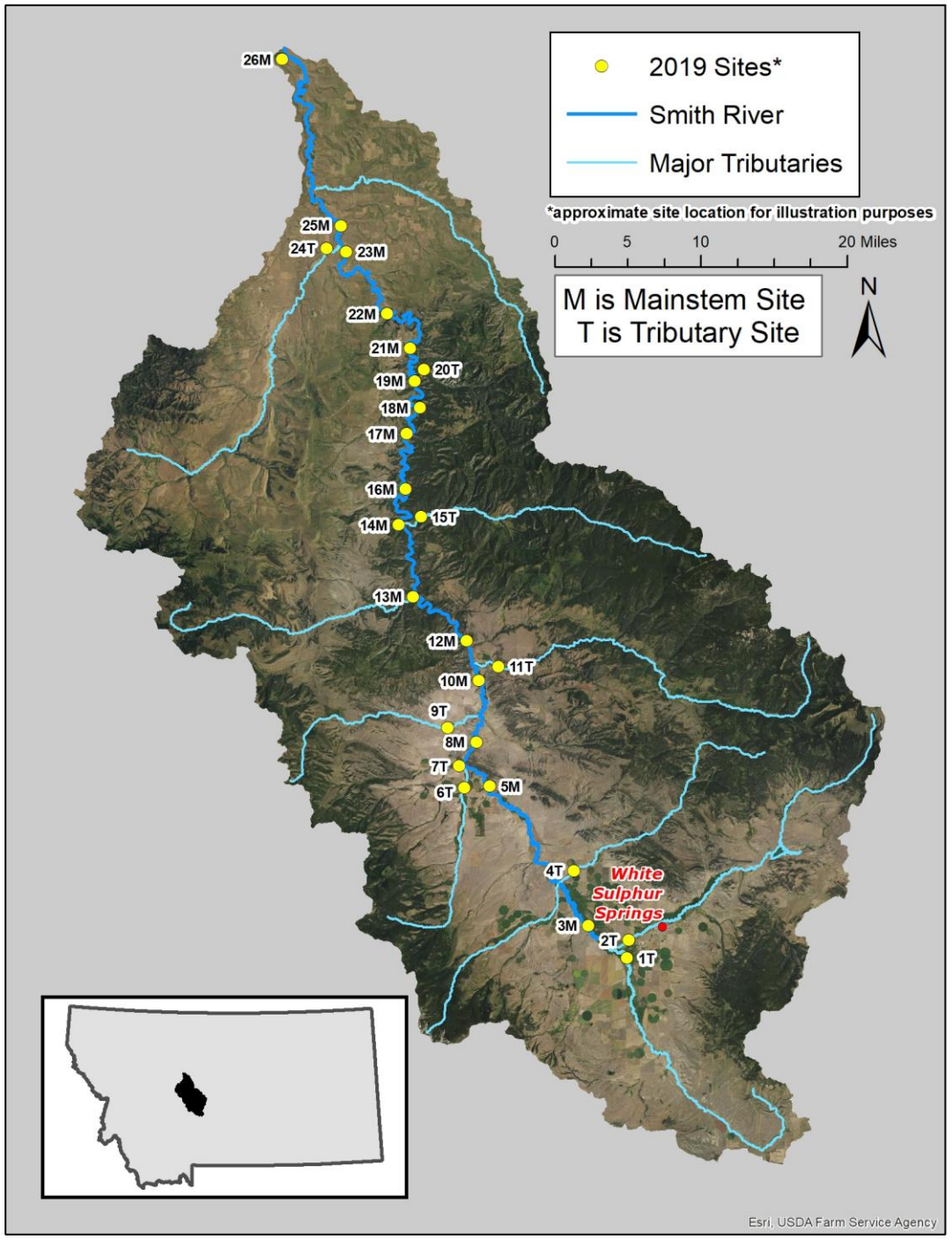
Nutrients – is in reference to nitrogen and phosphorus concentrations in the water column

P-Value – p-value of 0.1 means we are 90% certain the trend we see is really occurring

Growing Season – July 1-September 30

Water Year – October 1 to September 30

Monitoring Locations



Methods

- Trends over time: Kendall family of tests (non-parametric)
  - Developed by USGS
  - Most widely used tests for trend in environmental sciences
  - We used a significance threshold of ≤0.1 (p-values will be presented)

  - Runoff: magnitude and timing
    - Magnitude of yearly peak flow
    - Timing: center-of-mass timing (date on which 50% of Water Year flow has passed the gage)
    - Time to peak spring flow
    - Duration of peak flow (time lag between 50% of Water Year flow and 75% of Water Year flow)

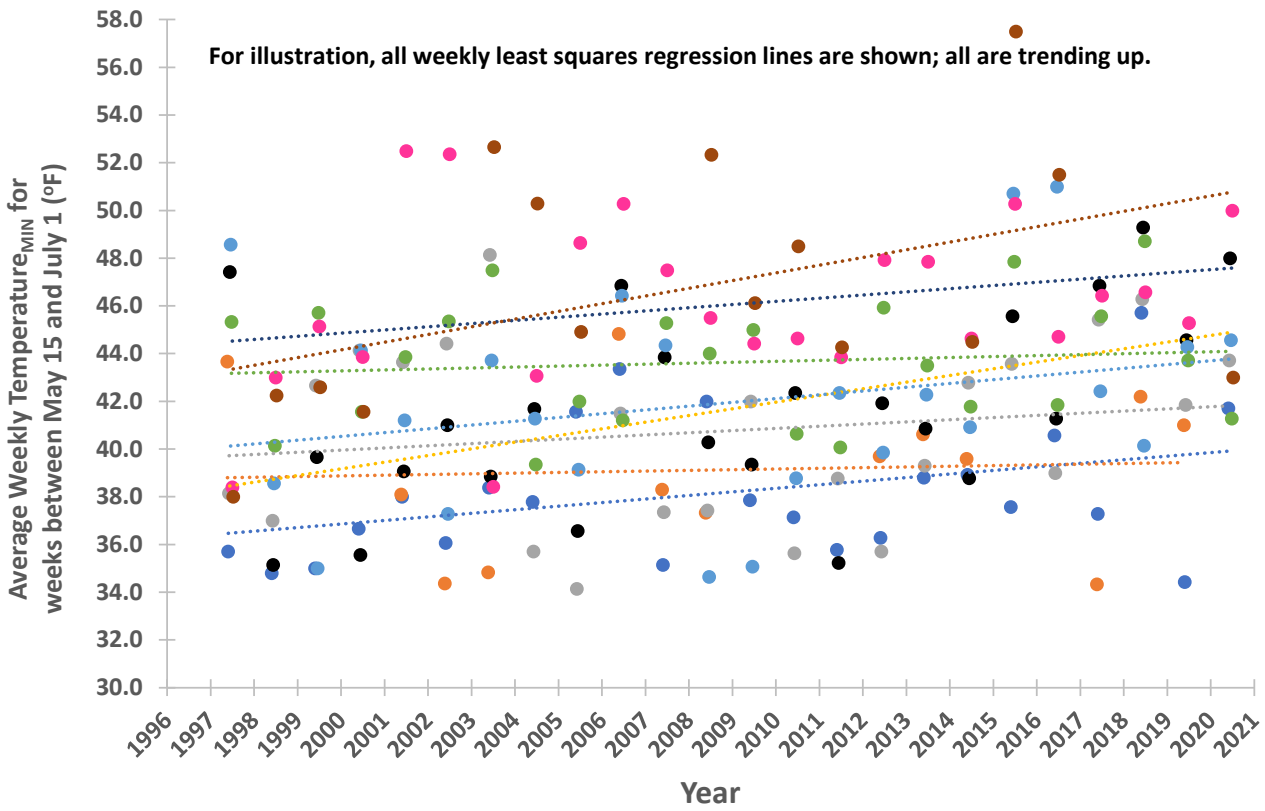
- Correlations
  - Spearman Rank Correlation (non-parametric) (e.g. flow vs. temperature)
  - Significance threshold ≤0.1 (p-values will be presented)

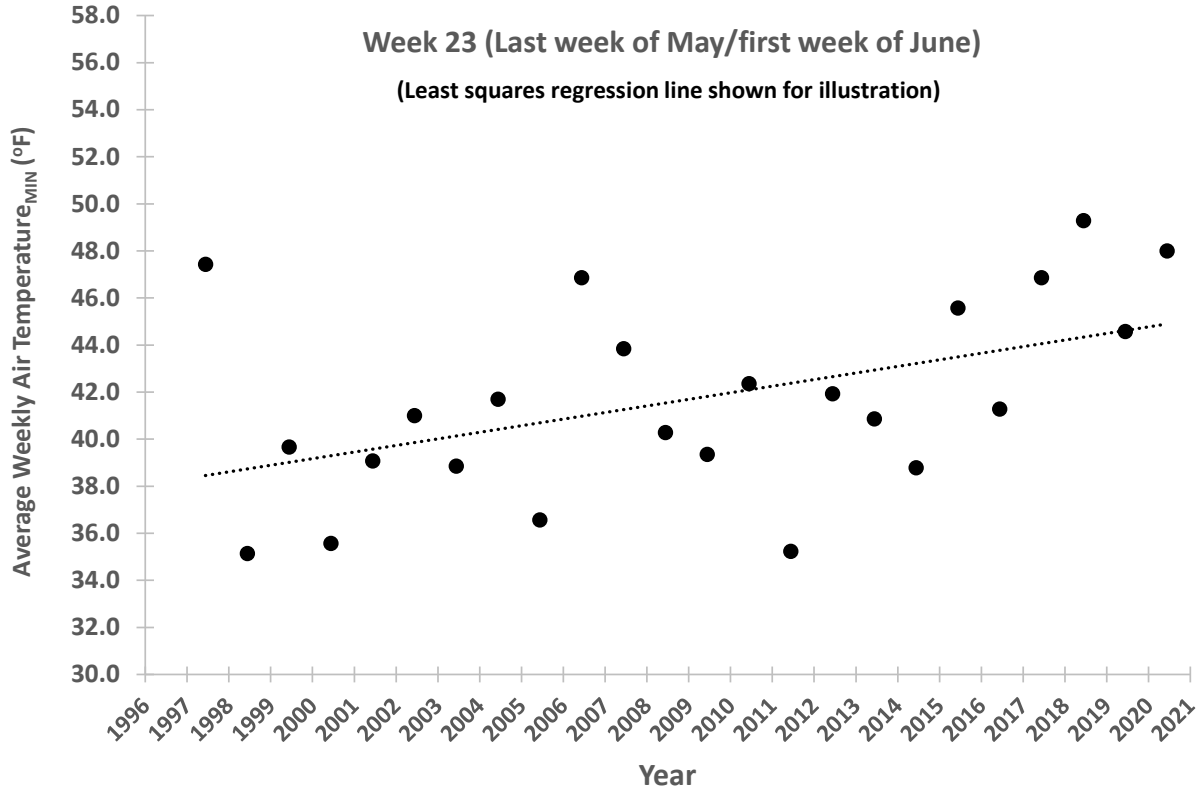
Data Analysis

- Why May 15 - July 1?
  - Smith River usually floatable
  - Captures rise and fall of hydrograph
  - Water temperatures usually rise to *Cladophora* preference during this period
  - Literature indicates this is when air temperatures are trending up

Air Temperature

White Sulphur Springs, MT, Weather Station



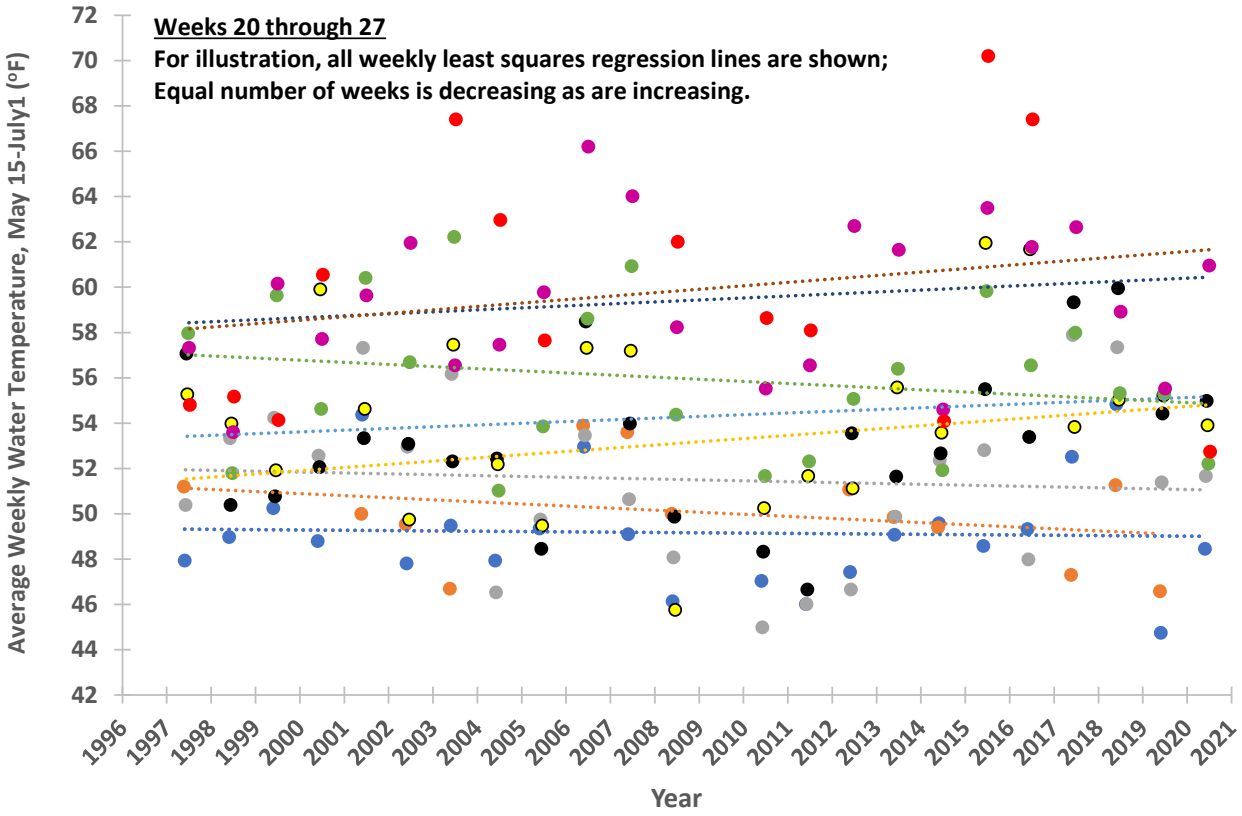


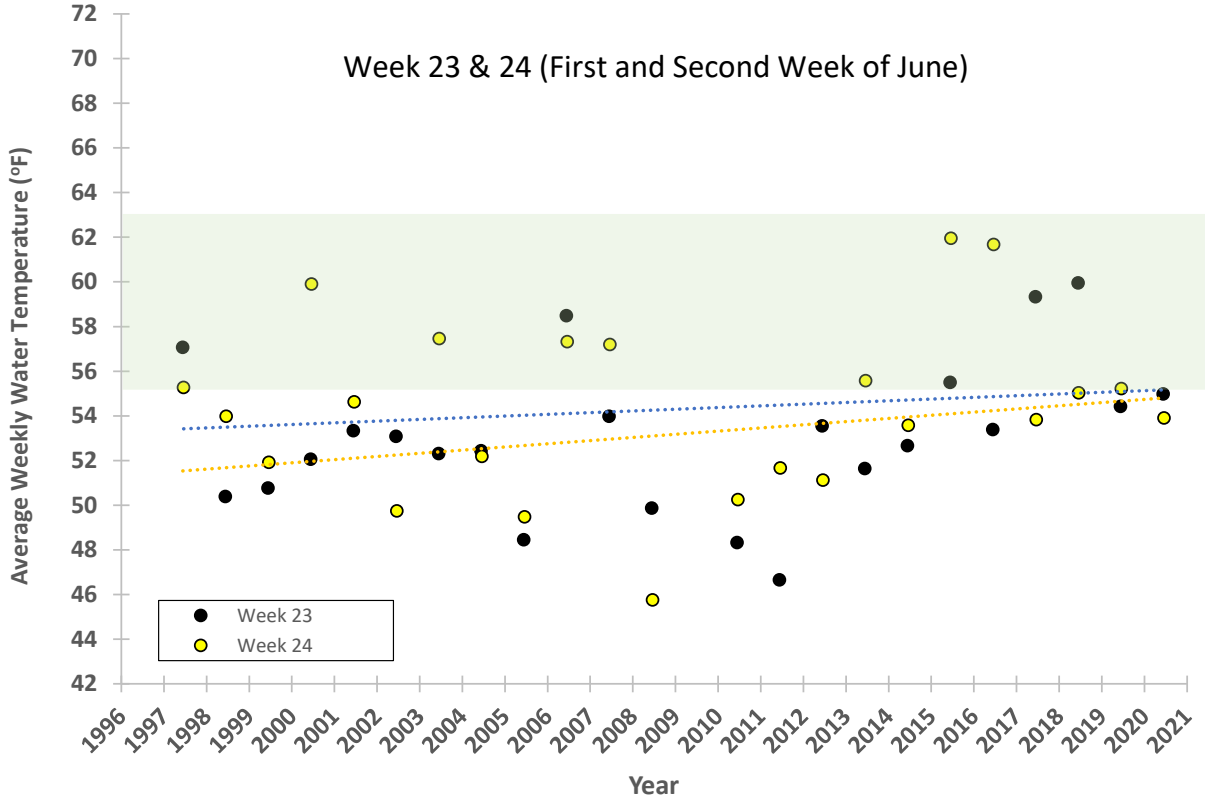
Minimum daily air temperature significantly increasing over the entire May 15 to July 1 period (p-value = <0.01; Seasonal Kendall, season=week)

+3.6 °F over the 24-year period

Water Temperature:

USGS Gage 06077200 (start of float reach)



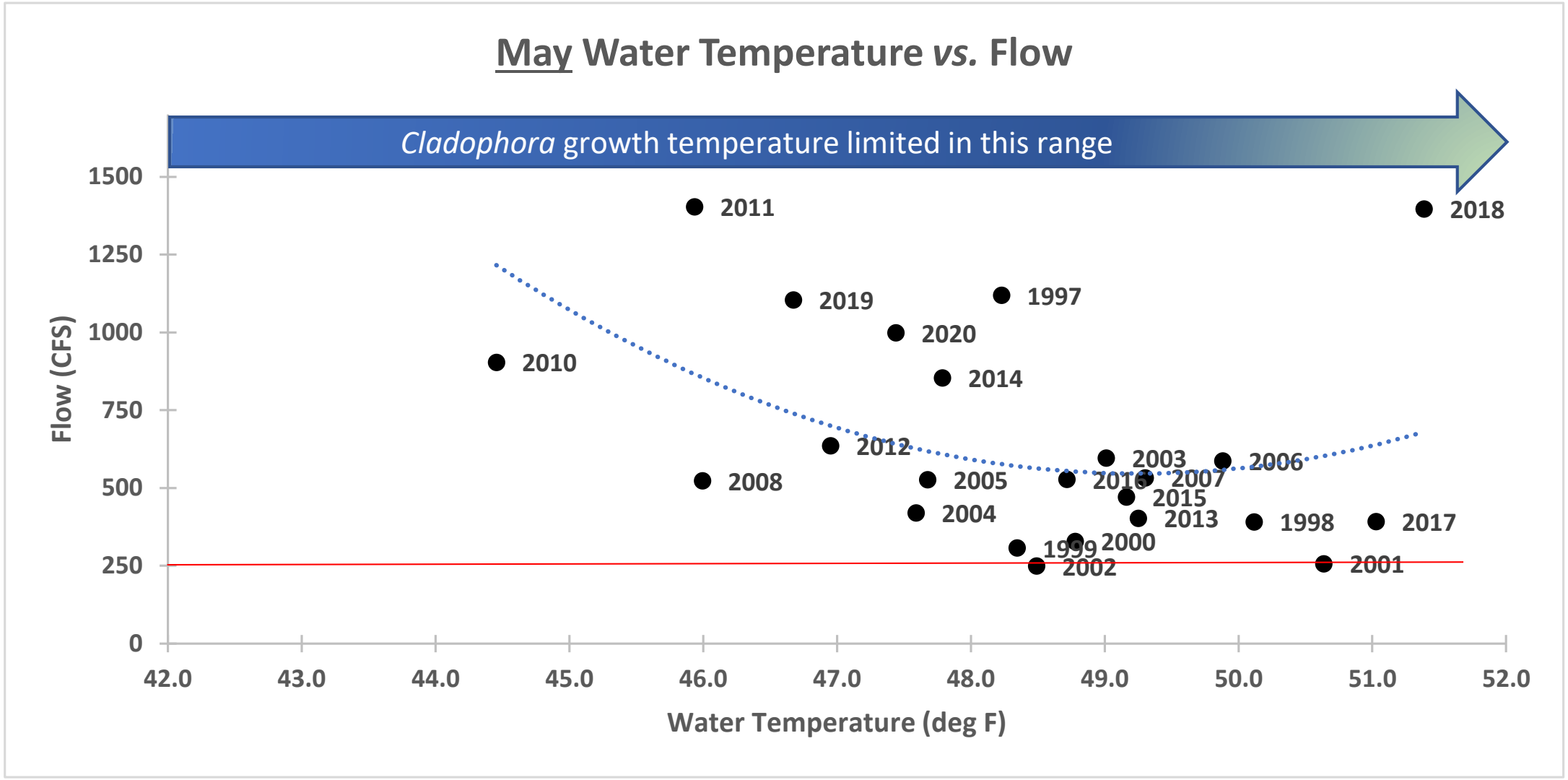


May 15 to July 1 (weeks 20-27), average and minimum water temperature are significantly trending up (p-value = 0.1).

For April, May, June, and July: only the month of **June** is significantly warming (p-value = 0.07)

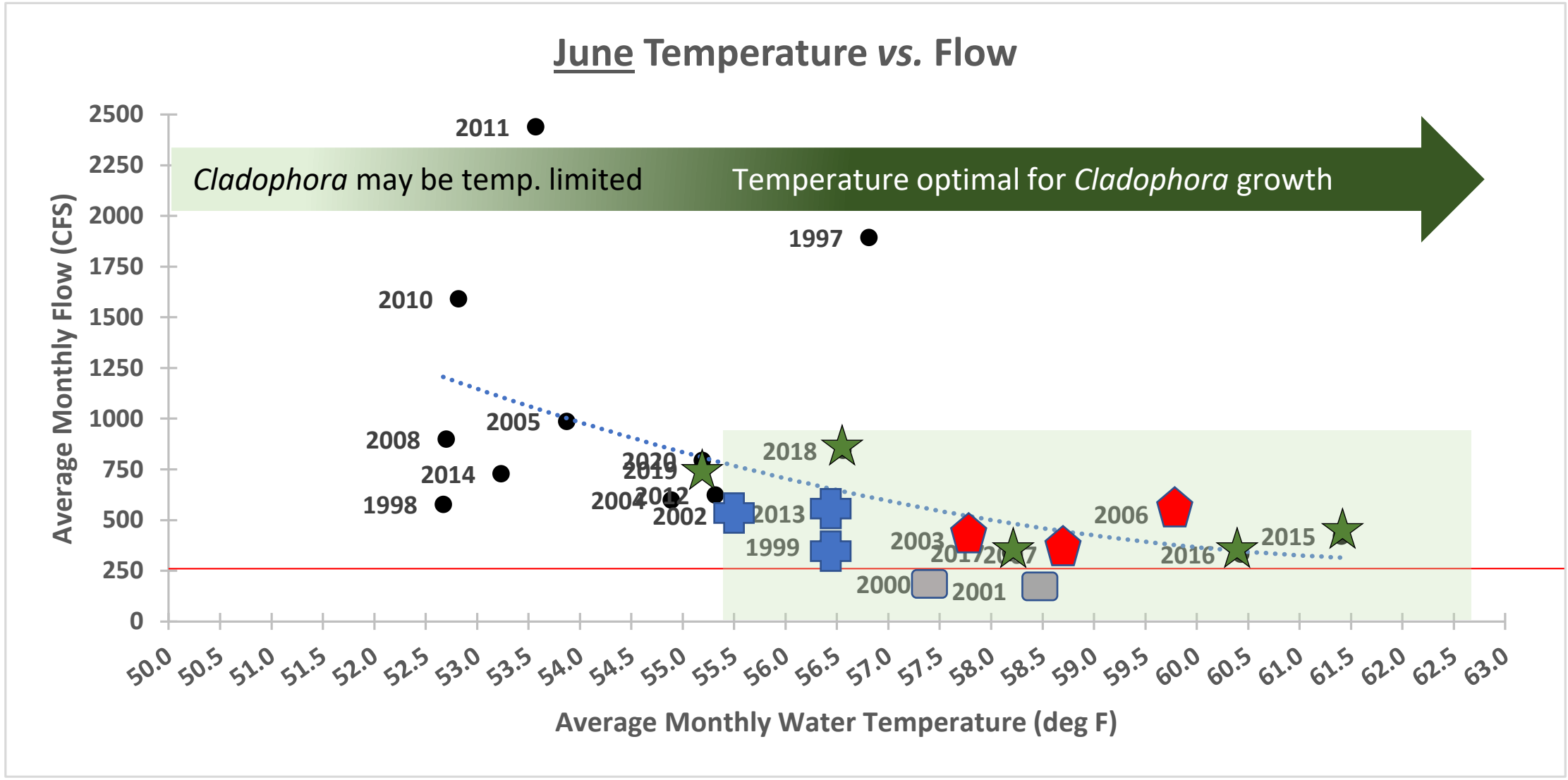
Water temperature is significantly increasing during the first two weeks of June (right graph) (p-value = 0.05)

Smith River USGS Gage 06077200 (1997-2020)



Note: Optimal *Cladophora* temperature is ~55.4 to ~62.6° F.

Smith River USGS Gage 06077200 (1997-2020)



With a few exceptions, nuisance algae occurred during years when average water temperature during the first half of June was in the optimal range (~55.4 to ~62.6°F) and flows were not too high.

Runoff Patterns

- USGS Gage (06077200), start of float reach (1997-2018)
- USGS Gage (06077500), end of float reach (1951-1969, 2006-2019)

- No significant trends over time for magnitude or timing of flow at either gage
- No significant trend over time for duration of peak flow at 06077200

- Literature suggests spring runoff timing has changed (earlier now), but change occurred mid-1980s (Pederson *et al.* 2011)
  - Our datasets would have missed this

Hydrology

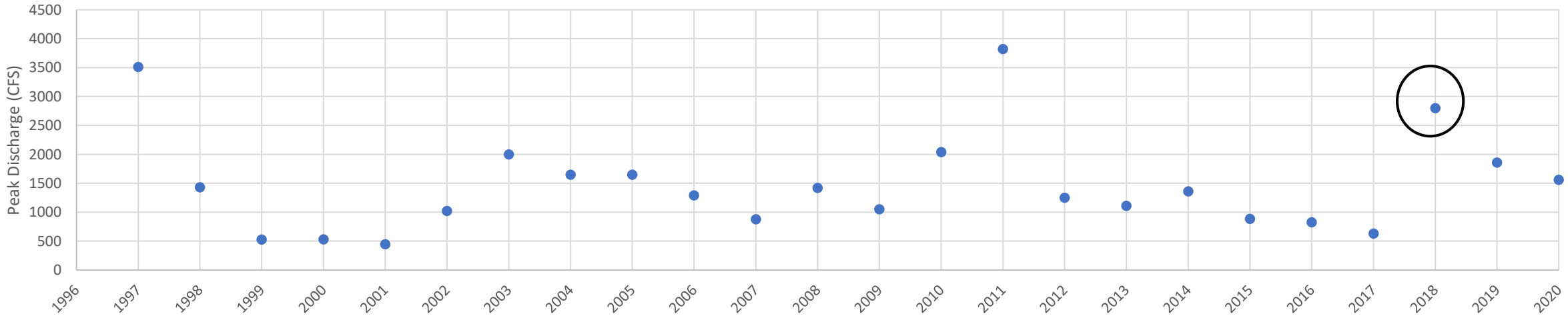
- **2018 was 3rd highest peak flow on record**
- **Natural experiment**
- **Nuisance algae still occurred**

June 17, 2018

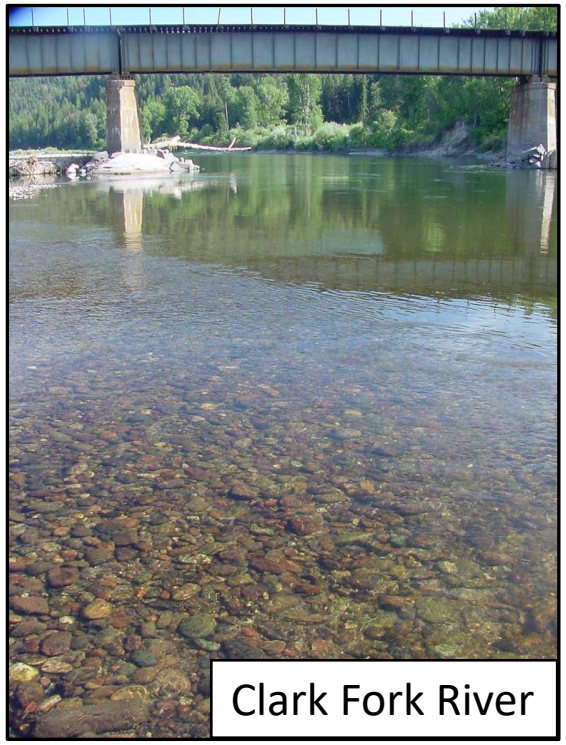
July 16, 2018

July 1, 2019

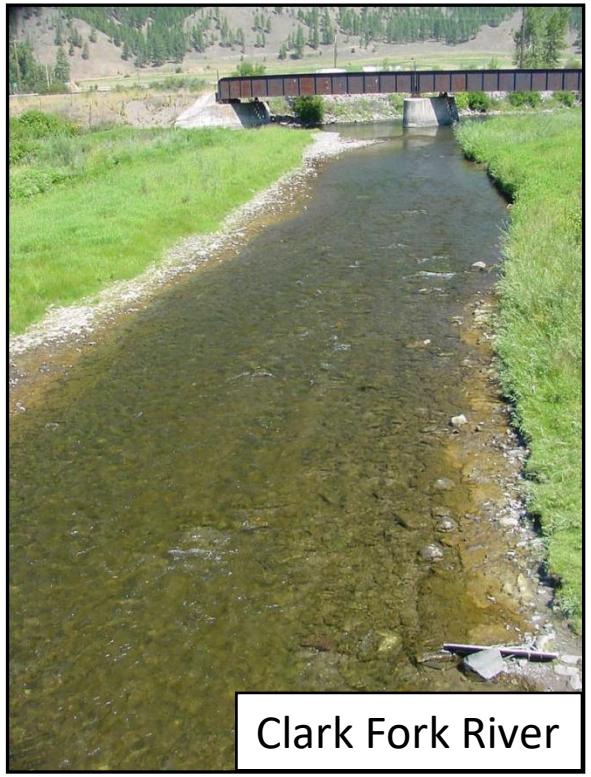
Smith River Peak Discharge (1997-2020)
USGS Gage (06077500)



Attached algae quantified as milligrams of chlorophyll a per square meter of streambed (Chl*a*/m²), or by eye, as % cover

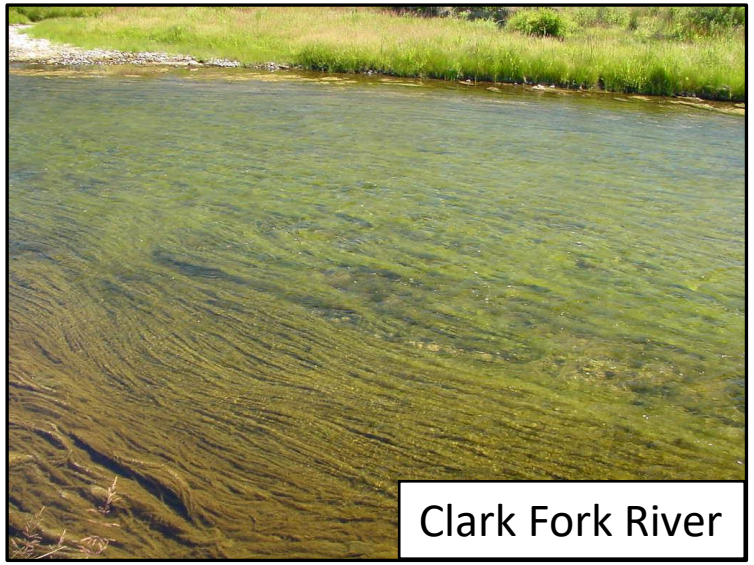


40 mg Chl*a*/m²
(~5% bottom cover)



120 mg Chl*a*/m²
(~30% cover)

*≤ 150 mg Chla/m² preferred by MT public for recreation**



300 mg Chl*a*/m² (~60%+ cover)

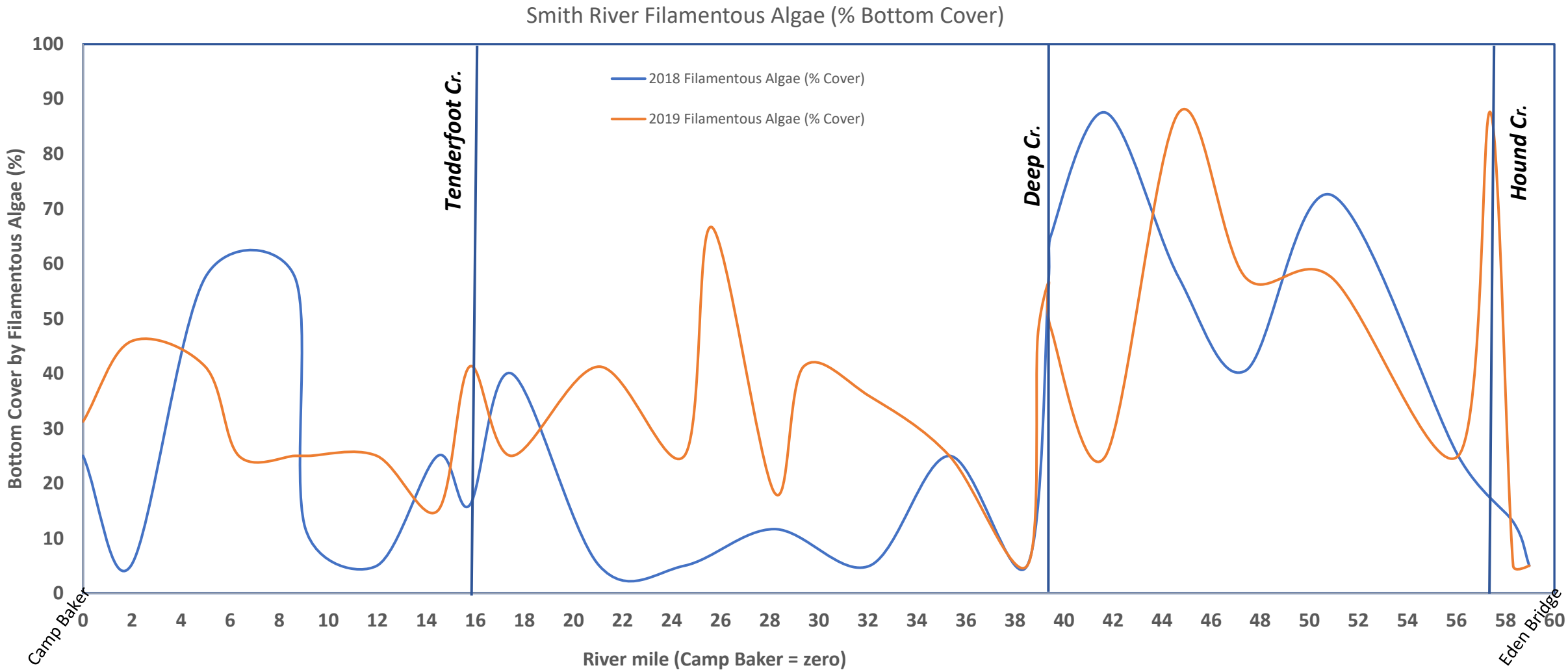
*Suplee, M.W, et al. (2009). How Green is too Green? Public Opinion of what Constitutes Nuisance Algae Levels in Streams. *Journal of the American Water Resources Association*, 45, 123-140.

Methods

- Visual Assessment of Algal Biomass
  - 2018 & 2019 Floats – Systematic visual assessments roughly every two river miles.
  - Additional visual assessments downstream of where tributary effects were noted.

  - DEQ was unable to float during the 2020 season.

2018 & 2019 Float Trip Observations

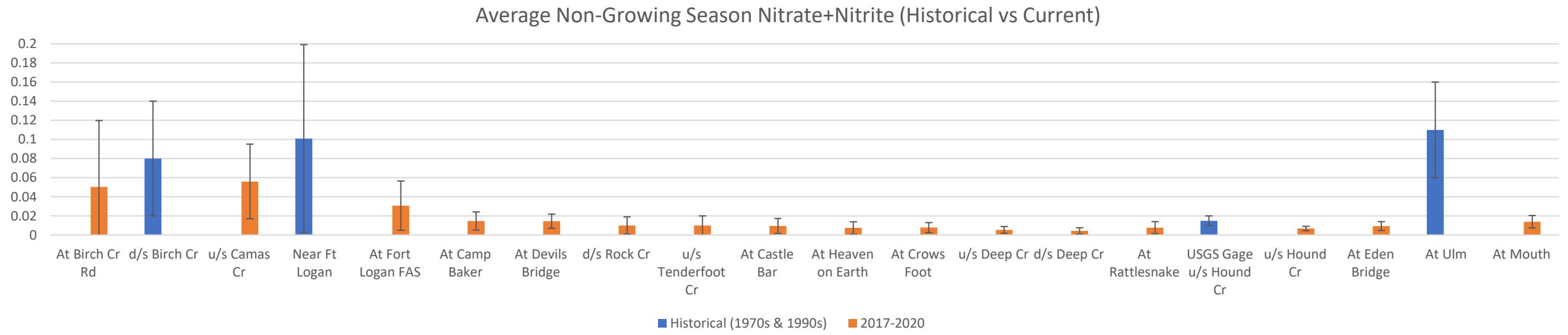


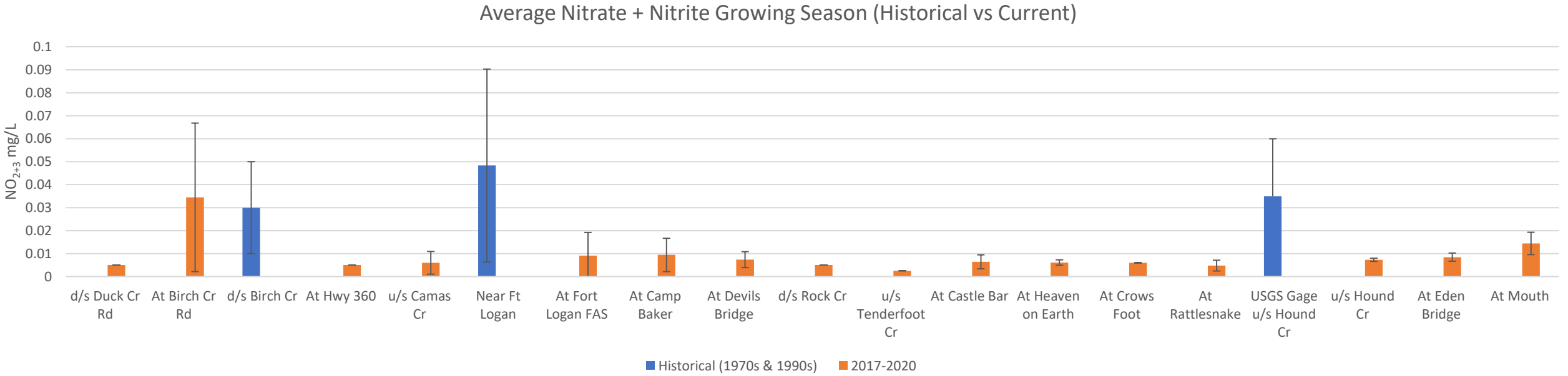
Methods

- Nutrient Concentrations
  - Historical vs. Current
  - 2018 & 2019 patterns – space and time

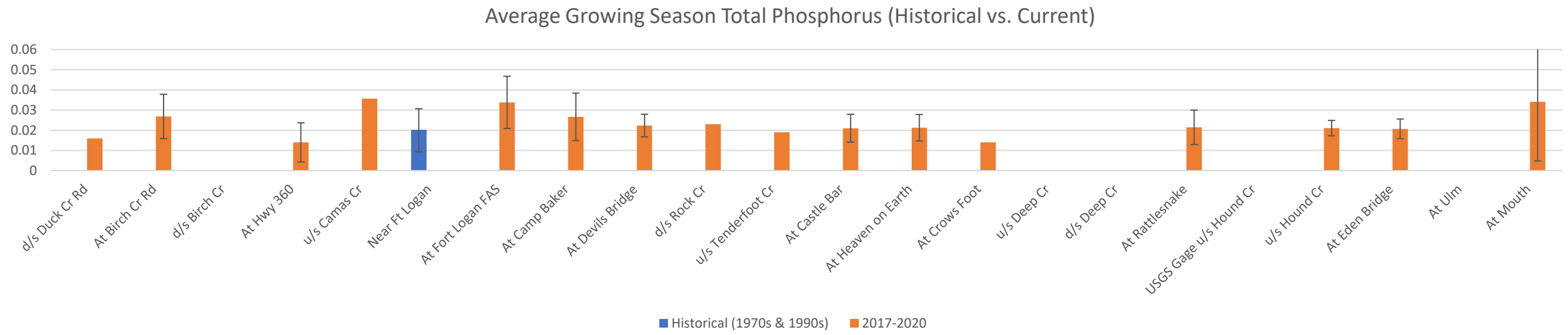
- Nutrient Limitation
  - Diffusing Substrates
    - Two deployments (early summer, late summer)
  - *Cladophora* Tissue Analysis (Carbon, Nitrogen, Phosphorus)

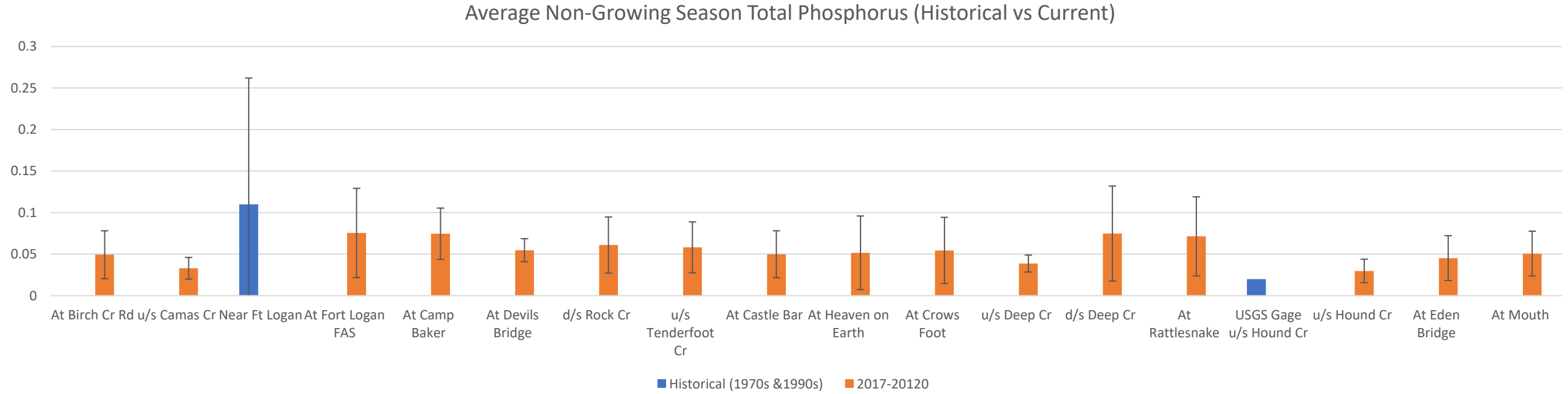
Nitrate+Nitrite Historical vs. Current



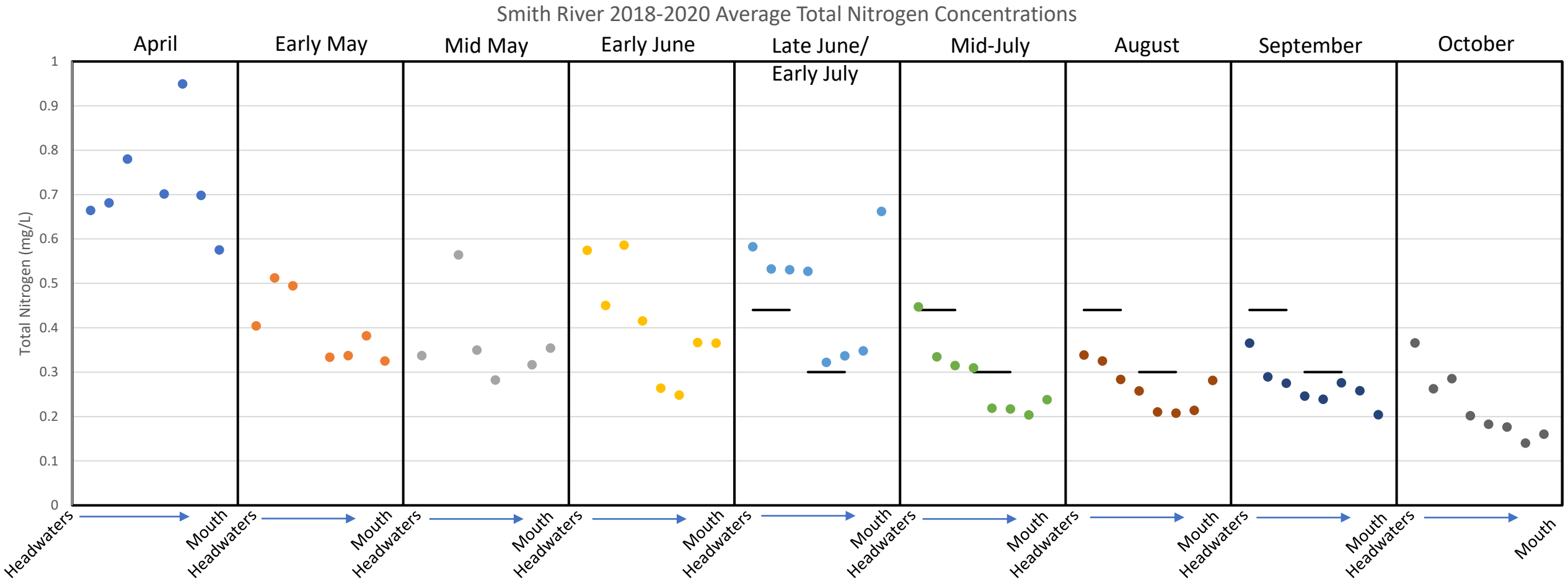


Total Phosphorus Historical vs. Current

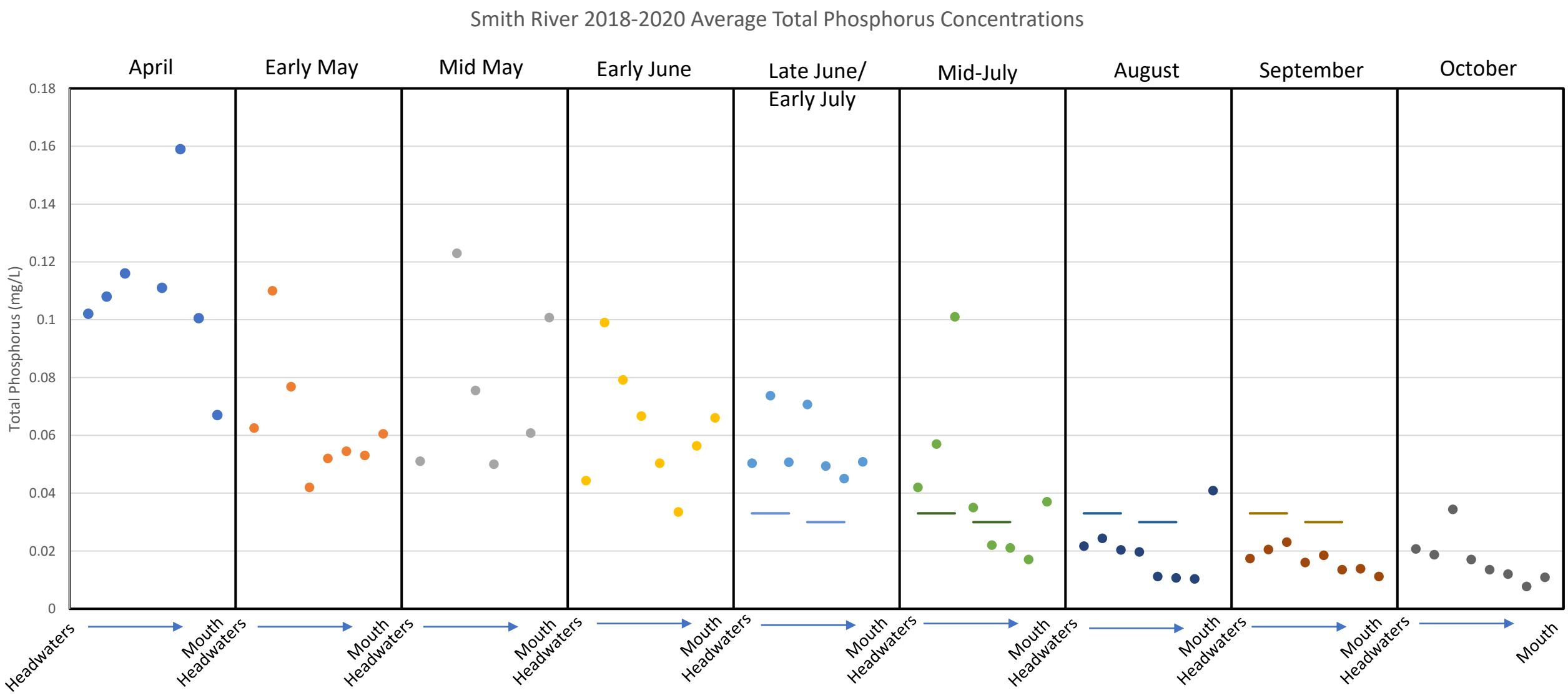




2018 – 2020 Total Nitrogen

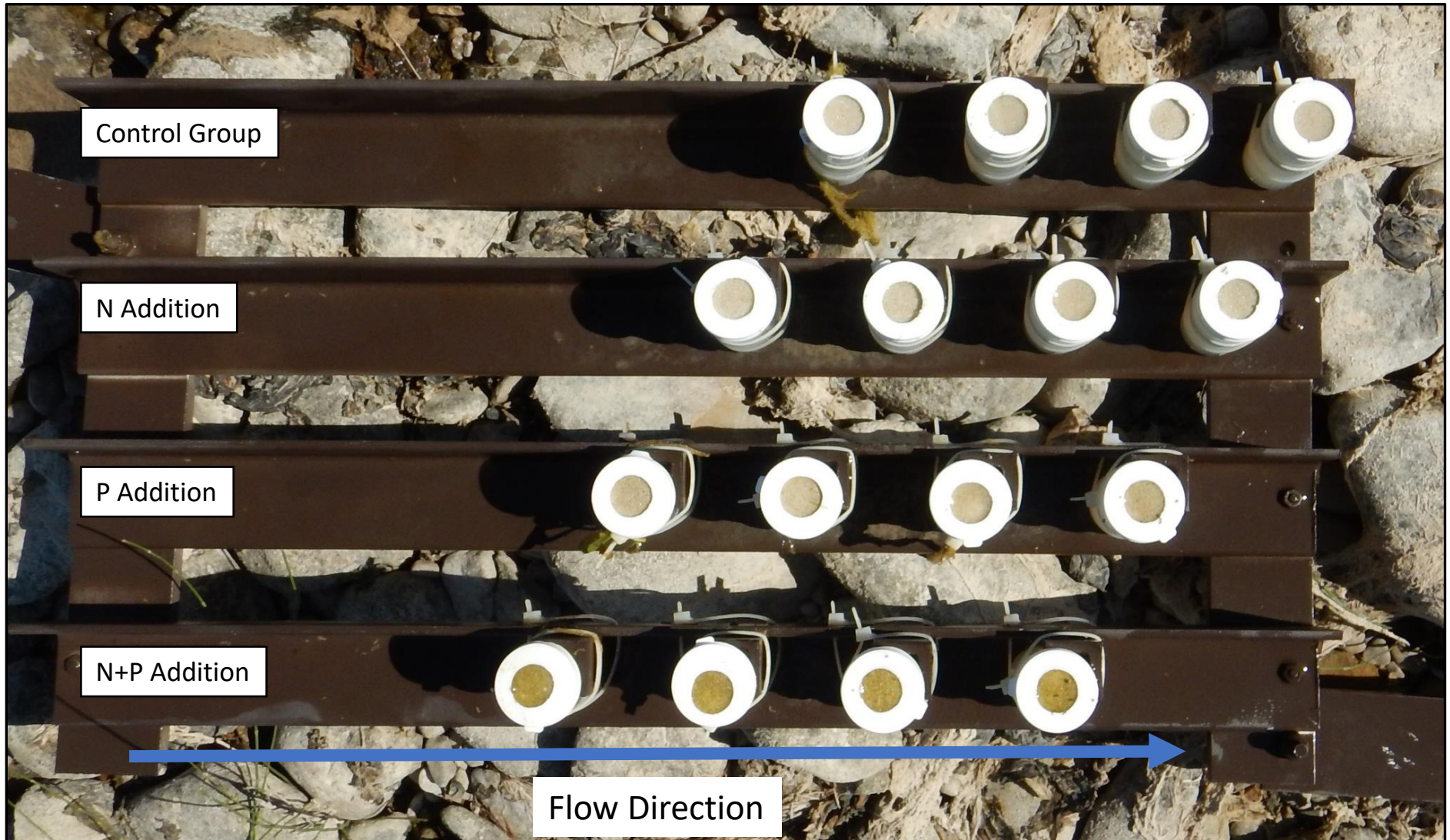


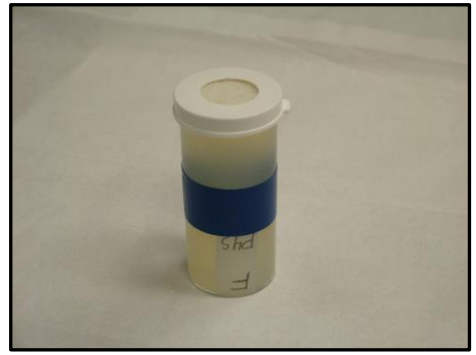
2018-2020 Total Phosphorus



Nutrient Limitation – 2018 & 2019

- **We add nutrients to see which one is limiting**
- **Nutrient limitation indicates which nutrient is <u>NOT</u> sufficiently available in the water for the algae.**



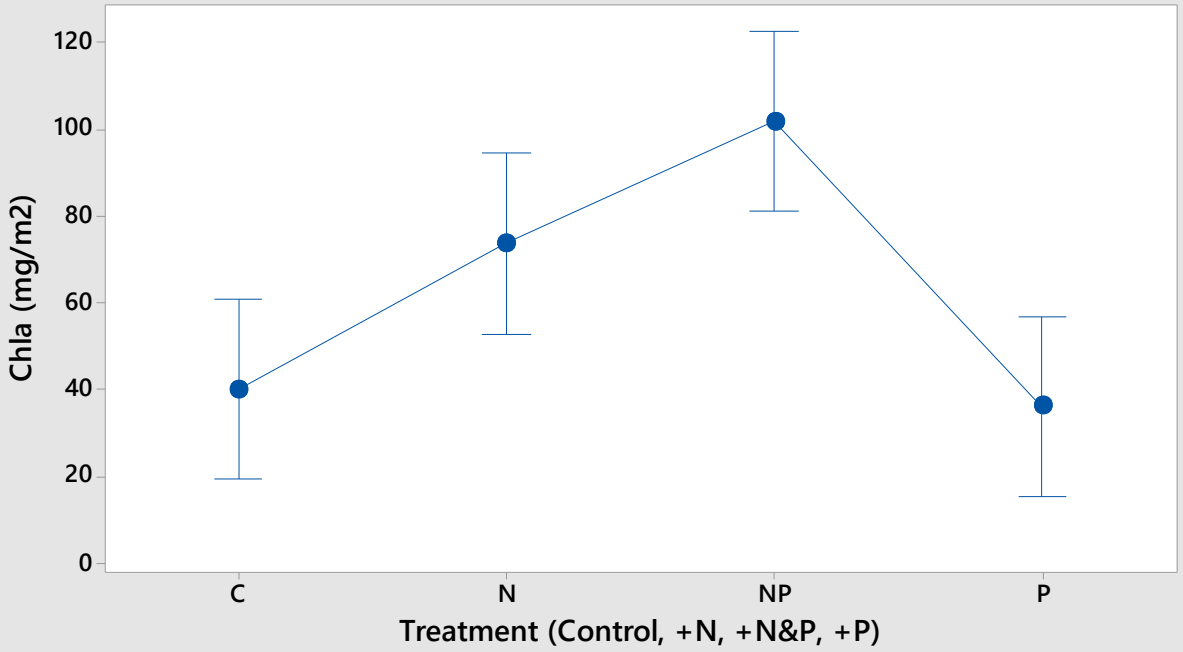


Nutrient Limitation

Nutrient limitation indicates which nutrient is <u>NOT</u> sufficiently available in the water for the algae

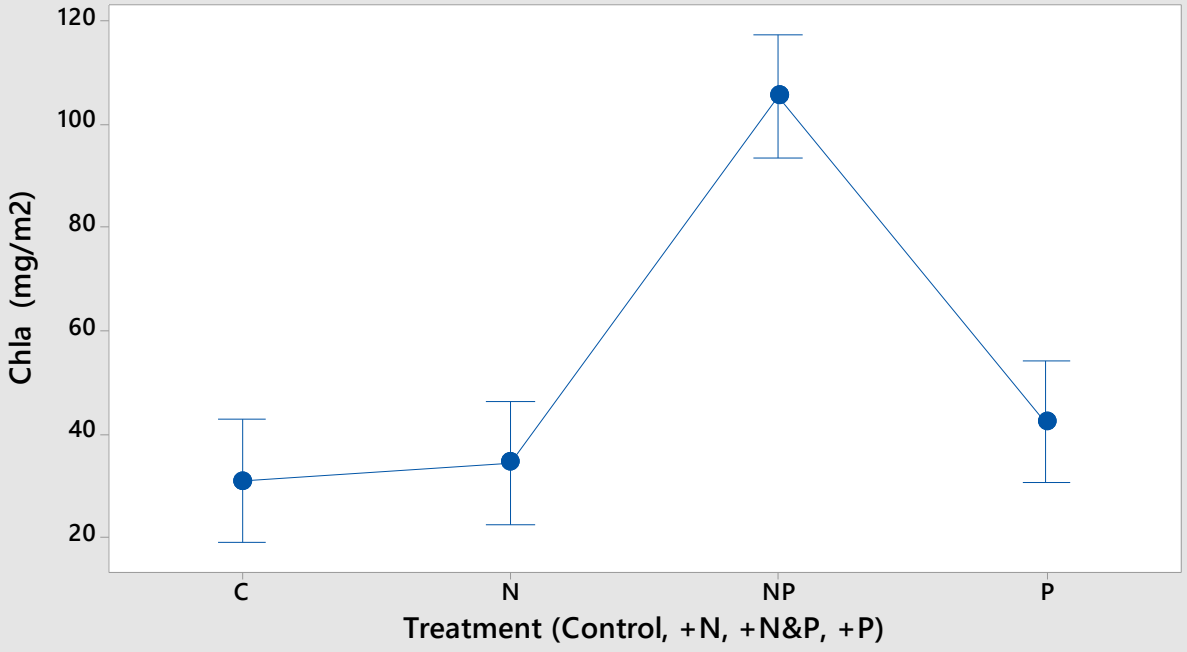
- <u>Nutrient Diffusers July</u> – algae was never limited by P, weakly limited by N or co-limited by N&P
- <u>*Cladophora* Tissue July</u> – in upper river algae was not strongly limited by N or P; downriver, algae showed more N limitation
- <u>Nutrient Diffusers August-September</u>— Similar to 2018, N & P co-limitation was the norm throughout the river reach

<u>Smith River@ Castle Bar Road: June to early July 2019</u>
(Error bar = 95% CI for the mean)



The pooled standard deviation is used to calculate the intervals.

<u>Smith River @ Castle Bar Road: Aug-Sept 2019</u>
(Error bar = 95% CI for the mean)



The pooled standard deviation is used to calculate the intervals.

Recap of Findings

- Over the past 23-24 years, from late spring to early summer:
  - Local air temperature has significantly increased 3.6 ^{o}F
  - Smith River water temperature has also significantly increased
    - June, and particularly the first half of June, is significantly warmer
  - No significant changes in runoff patterns (magnitude, duration, timing)

- Smith River water temperature:
  - May—too cold to support robust *Cladophora* growth
  - June often optimal for *Cladophora* growth during lower flows
  - Junes in 2015-2019 conducive to *Cladophora;* nuisance growth occurred
    - June 2020 was too cold during first half, heavy growth not observed
  - Other Junes conducive to growth (2003, 2006, 2007) but no known reports
    - Reasons unclear

Recap of Findings, Cont.

- Smith River Nitrogen and Phosphorus (Nutrient) Concentrations:
  - Historical nutrient concentrations are not notably different than today
    - If anything nitrate appears to be lower now than in past decades
  - Today, concentrations are high enough in late spring/early summer for algal growth
  - Nutrient concentrations mostly fall below numeric limits later in summer

- Nutrient Limitation:
  - June-July 2019: Algae was not limited by P, weakly limited by N or co-limited by N&P
  - August 2019: N&P limitation was the most common result throughout floatable reach

- Sources of Bioavailable Phosphorus:
  - In 2019, DEQ found that some tributaries are substantial sources of P during June runoff
  - DEQ is exploring whether better P control could help address nuisance algae, especially in June
    - Much more detailed discussion of tributary runoff from 2020 coming up (DEQ and USGS)

- Scouring of Algae by Spring Runoff:
  - 2018 runoff was one of the highest peak flows of dataset; nuisance *Cladophora* still developed
    - Probably not important factor

Conclusions to date (2018-2020)

- For *Cladophora* growth, June appears to be undergoing change
  - Water temperatures now often warm enough to support rapid growth, trending warmer
    - Warm first half of June may be important to commence *Cladophora* growth
  - June 2018 - 2020 nutrient concentrations high enough to support *Cladophora* growth
    - Orthophosphate abundant

- Later in summer, strong nutrient limitation by N and P generally develops
  - Probably limits *Cladophora* growth

Why is *Cladophora* reaching nuisance levels in the Smith River, and why now?

As of March 2021:

The Causal Variables:

- Air Temperature changes over time
- Water Temperature changes over time
- ~~Discharge patterns (timing, magnitude, duration)~~
- ~~Hydrology/Scour~~
- Recent changes in nutrient concentrations
- pH
- Water Hardness

Nutrients, pH and Hardness are all playing a role in algae growth but have not notably changed over time.

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Future Predictions

- June will likely manifest nuisance *Cladophora* growth going forward because:
  - Water temperatures favorable, water and air temperatures trending up
    - First half of June may be important as a growth trigger
  - 2018, 2019 & 2020 data show nutrients are generally sufficiently available to support algal growth
    - Potential to reduce phosphorus to sufficiently low levels in June to affect *Cladophora* was investigated in 2020 (***up next…)***

Preliminary Analysis of Phosphorus Loading to the Smith River During Runoff 2020

A Cooperative Study with the United States Geological Survey

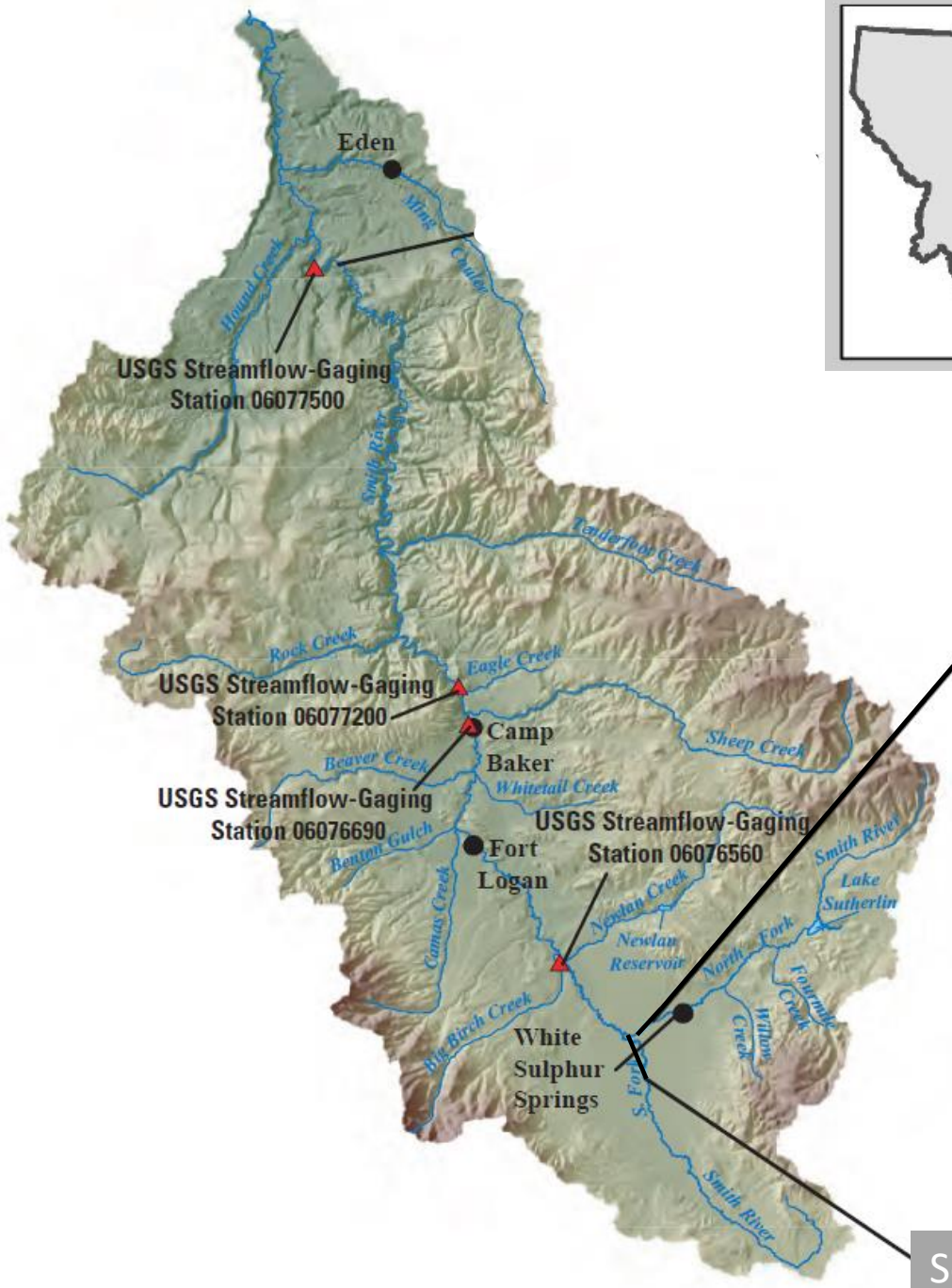
DEQ
Montana Department
of Environmental Quality

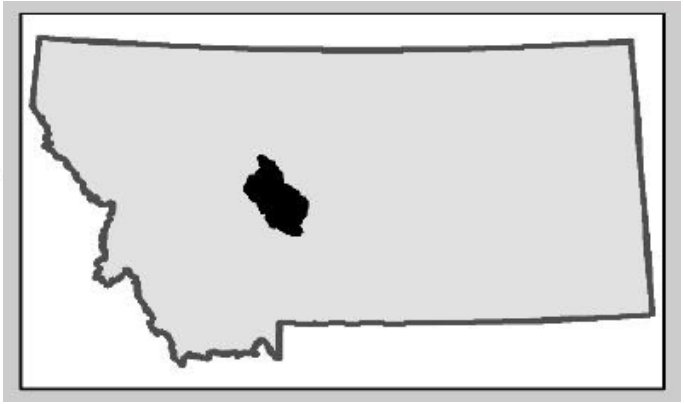
USGS
science for a changing world

Acknowledgements

- **USGS**
  - Chris Ellison, Rod Caldwell, Tom Cleasby, Hannah Nilges, and other USGS staff

- **MT DEQ**
  - Rosie Sada, Kylee Hughes





North Fork Smith River

South Fork Smith River

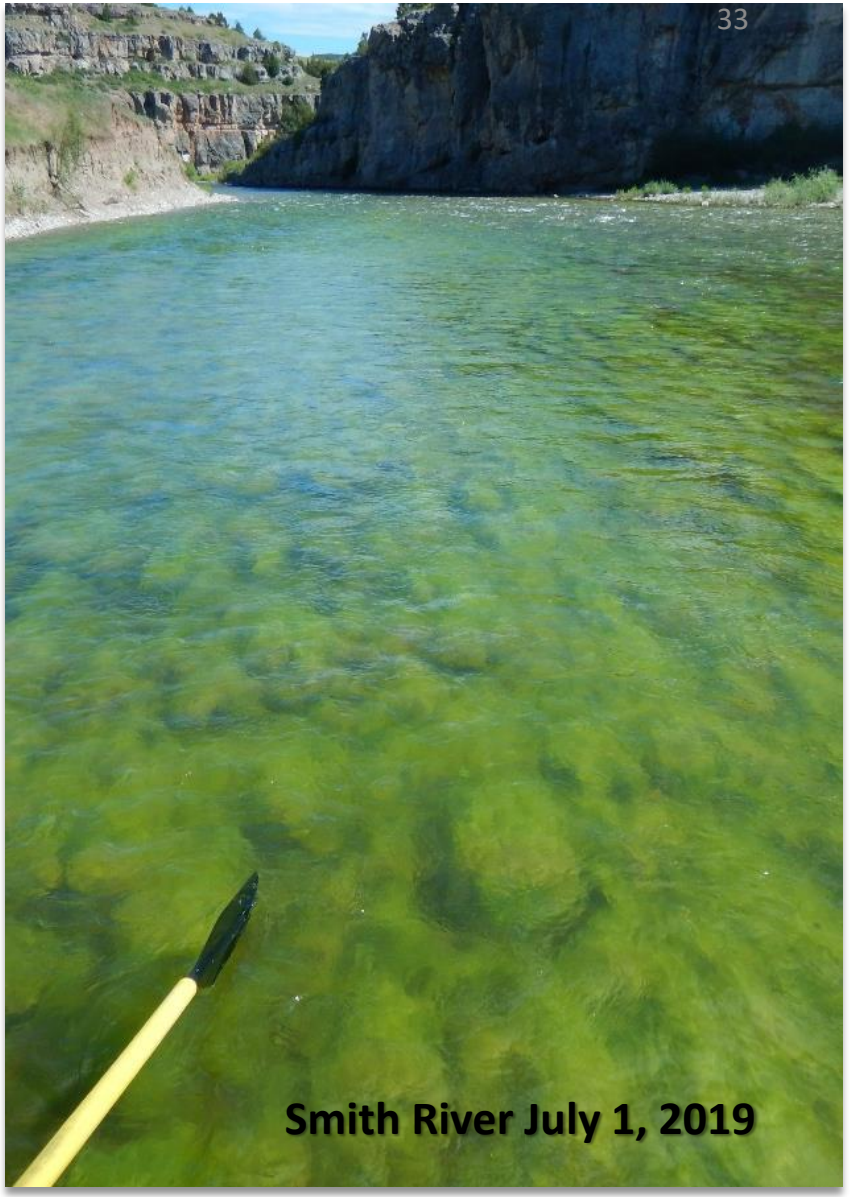
The Smith River Watershed

Study Motivation

- Soluble phosphorus (SRP) in the Smith River is high
  - Runoff and baseflow
  - Unusual

- P in rivers is closely associated with suspended sediment
  - More suspended sediment, more available P

If P could be better controlled during runoff by reducing runoff suspended sediment, could June *Cladophora* blooms be reduced by inducing P-limitation?



2019 Pilot Results Pointed to Two Tributaries

Tributary	Tributary P Load (%) to Smith R. at Camp Baker	
	June 10, 2019	June 25, 2019
North Fork Smith River	10.7%	17.1%
South Fork Smith River	5.2%	2.1%
Newlan Creek	1.1%	1.8%
Camas Creek	19.4%	25.2%
Benton Gulch	4.4%	5.3%
Beaver Creek	*no flow data*	0.7%

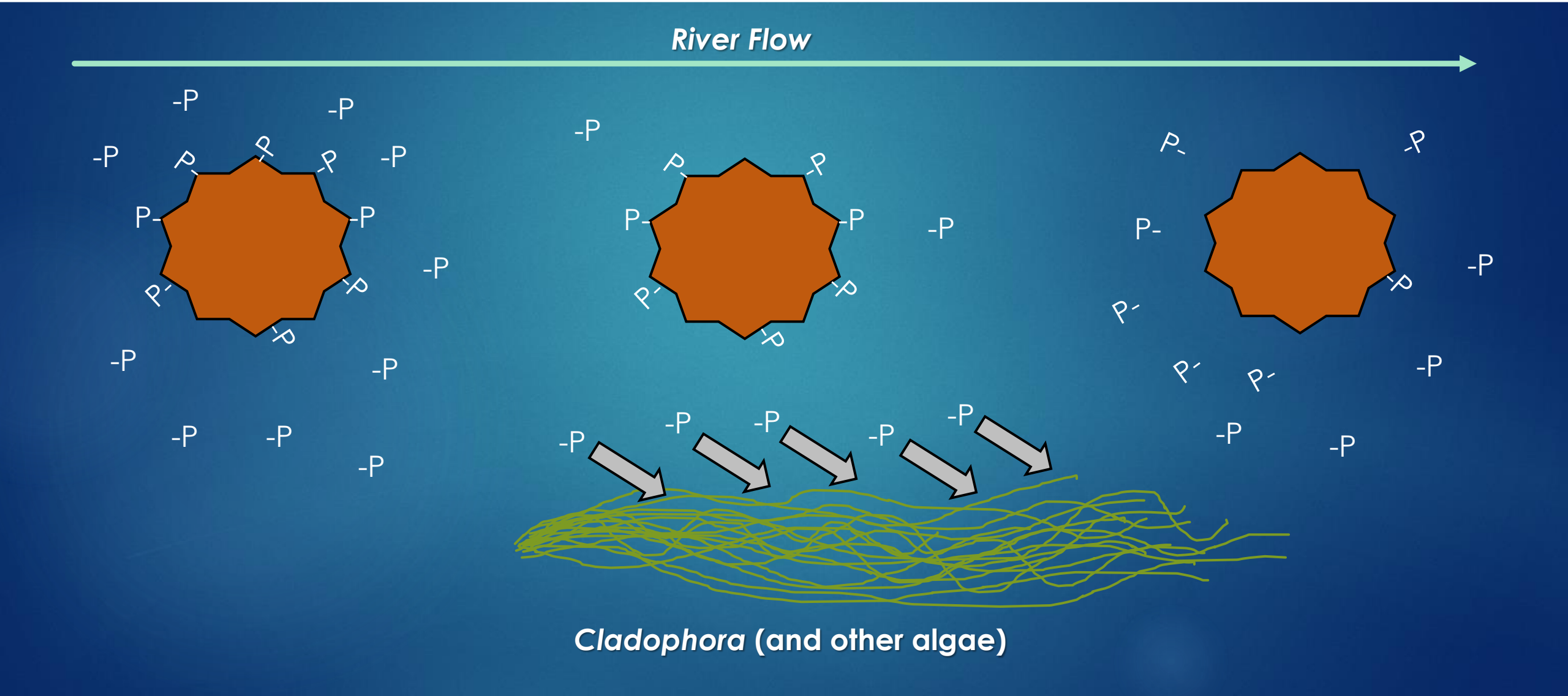
Phosphorus: Different Types

- Total P: All phosphorus in the sample
- Soluble P: Dissolved P in the sample ("SRP")
- Bioavailable P: SRP plus P easily extracted off suspended sediment in the sample
  - Method modified from Uusitalo *et al*., 2000 (Suplee 2021, *in press*)

Concentration in streams:

TP ≥ Bioavailable P ≥ SRP

Bioavailable P in Rivers: How it Becomes Available



2020 Spring Runoff

- Deployed YSI sondes, ISCO samplers, and flow gages on targeted streams
  - Camas Creek
  - North Fork Smith River

- YSI sondes: turbidity every 15 min
  - Smith River @ Camp Baker (at USGS gage *06076690*)
  - NF Smith River and Camas Cr

- Collected event-driven (ISCO) and routine (grab) samples for TP, SRP, Bioavailable P

- Collected bi-weekly flow and grab samples (TP, SRP) at four other major tributaries (4 events)

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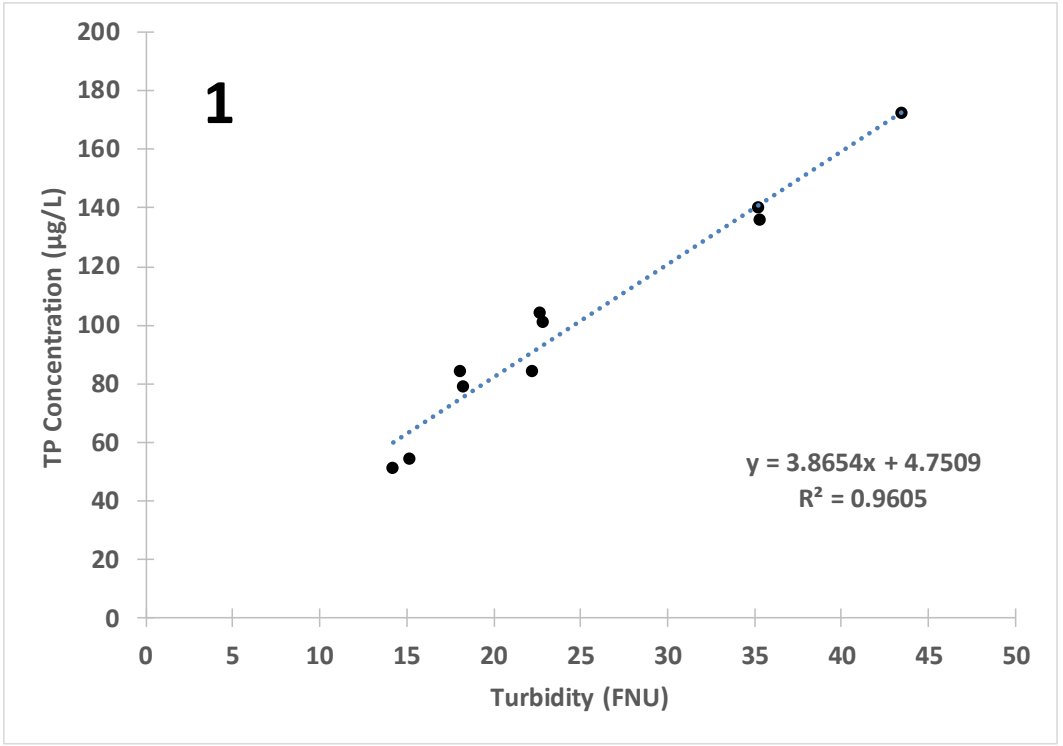
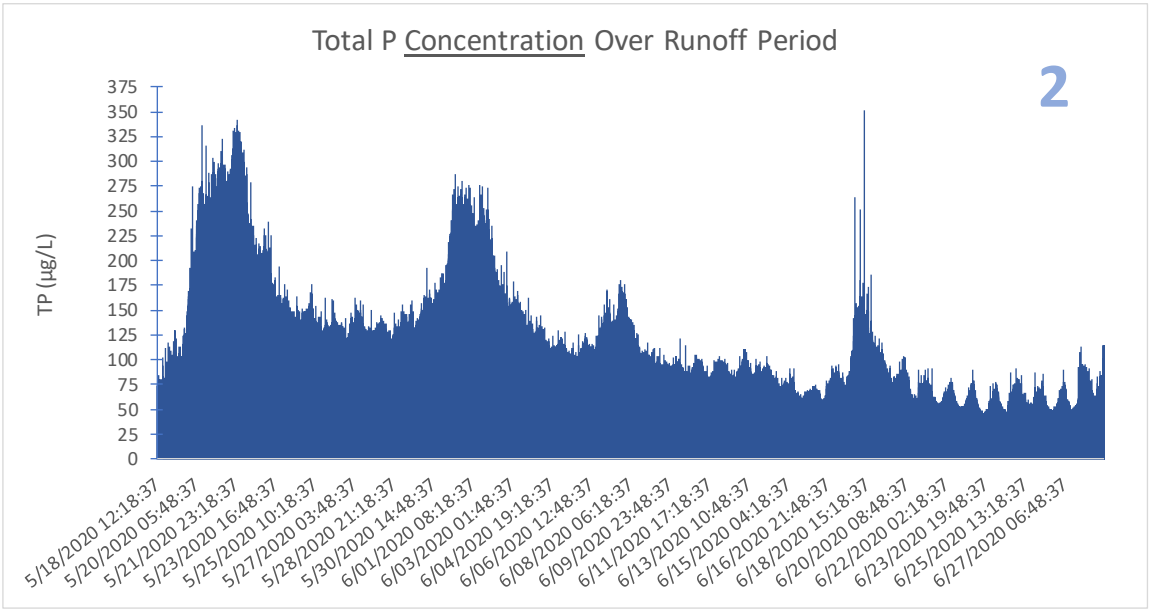
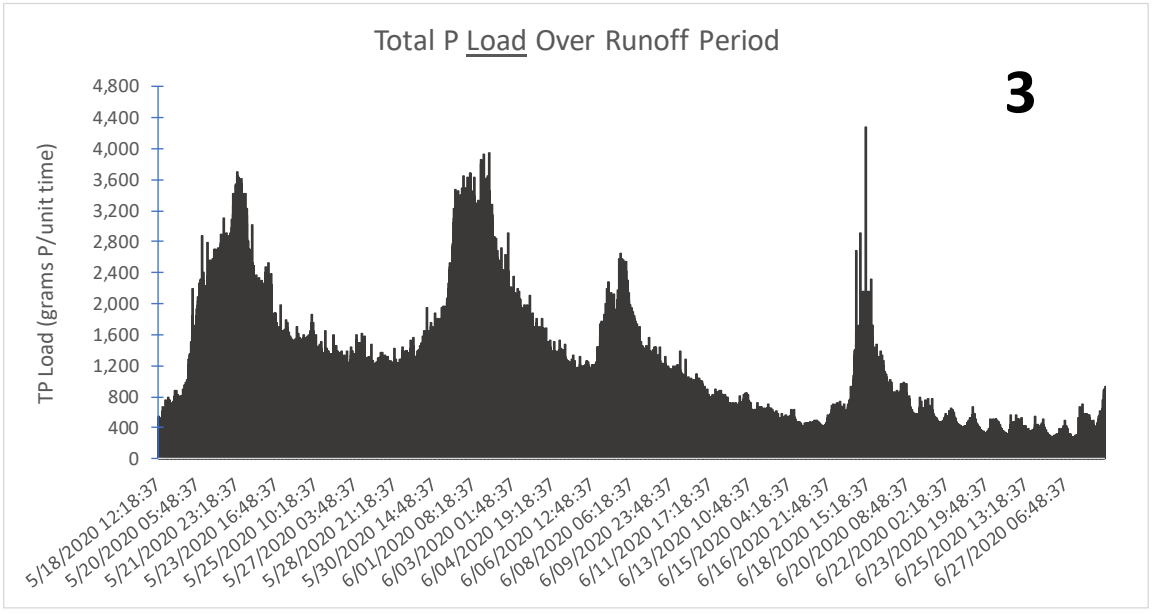
Photos provided by USGS

Correlated data: If you know one, you can predict the other

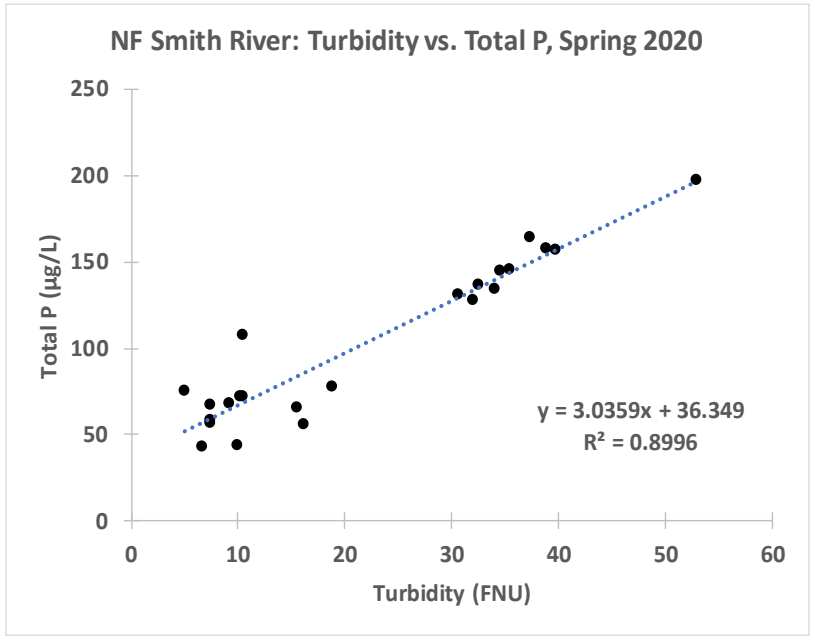


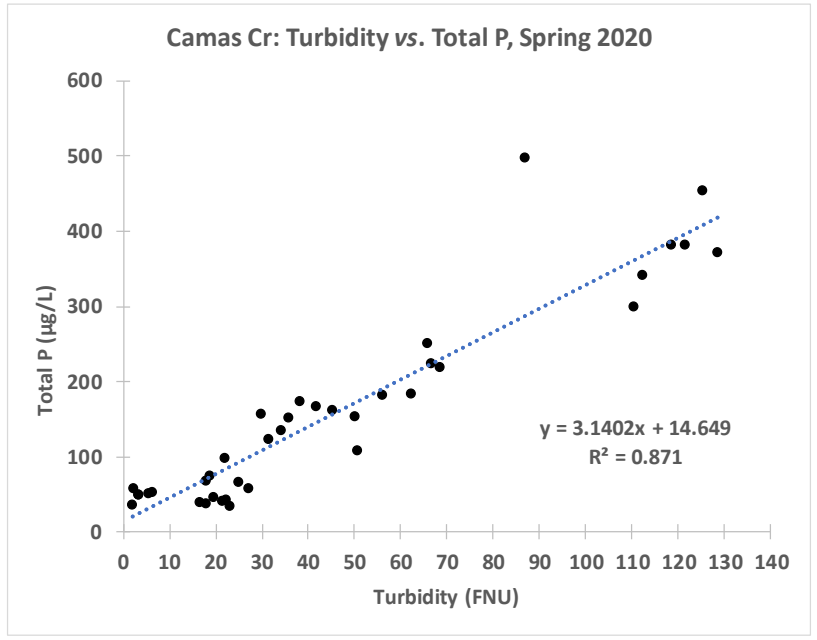


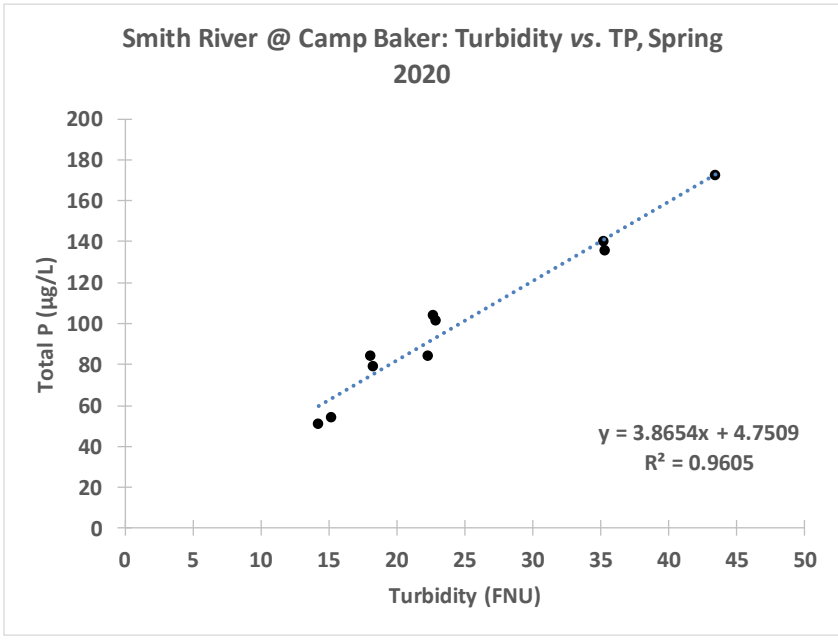


1. **Develop Turbidity-P regression;**
2. **Derive P concentration during runoff;**
3. **Derive P load (integrate area under the curve)**

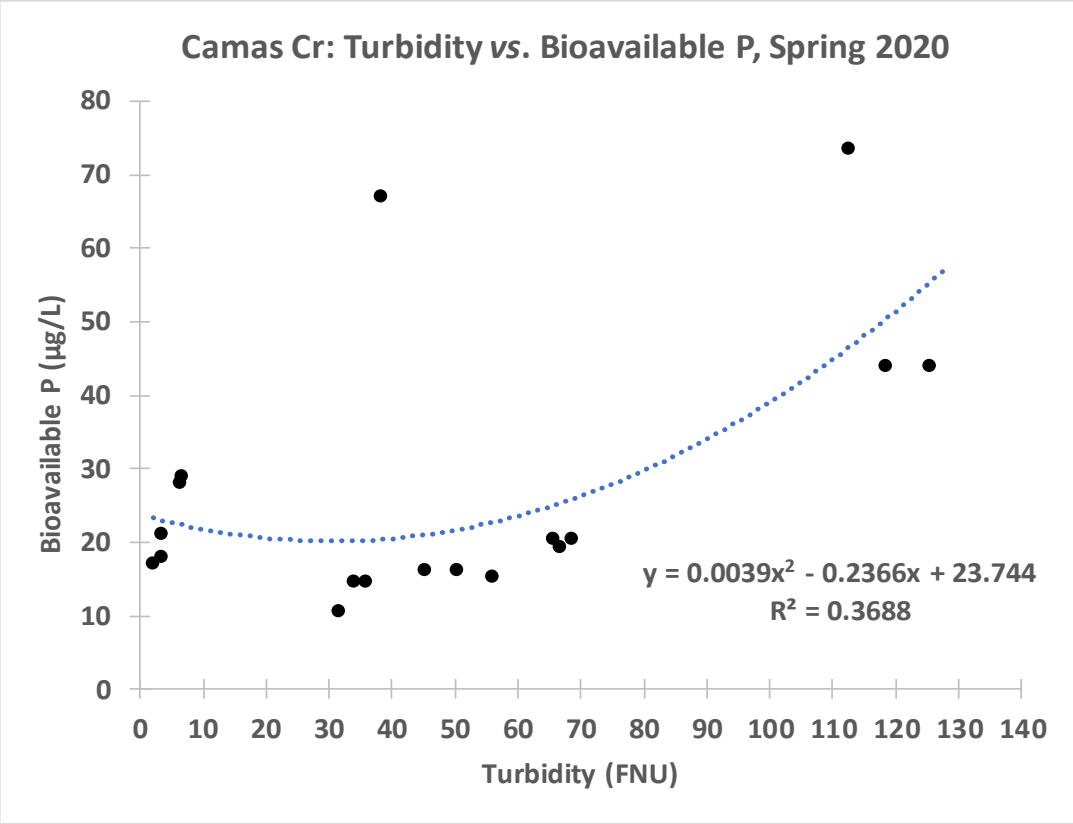
Correlation between Turbidity and Total P Concentrations

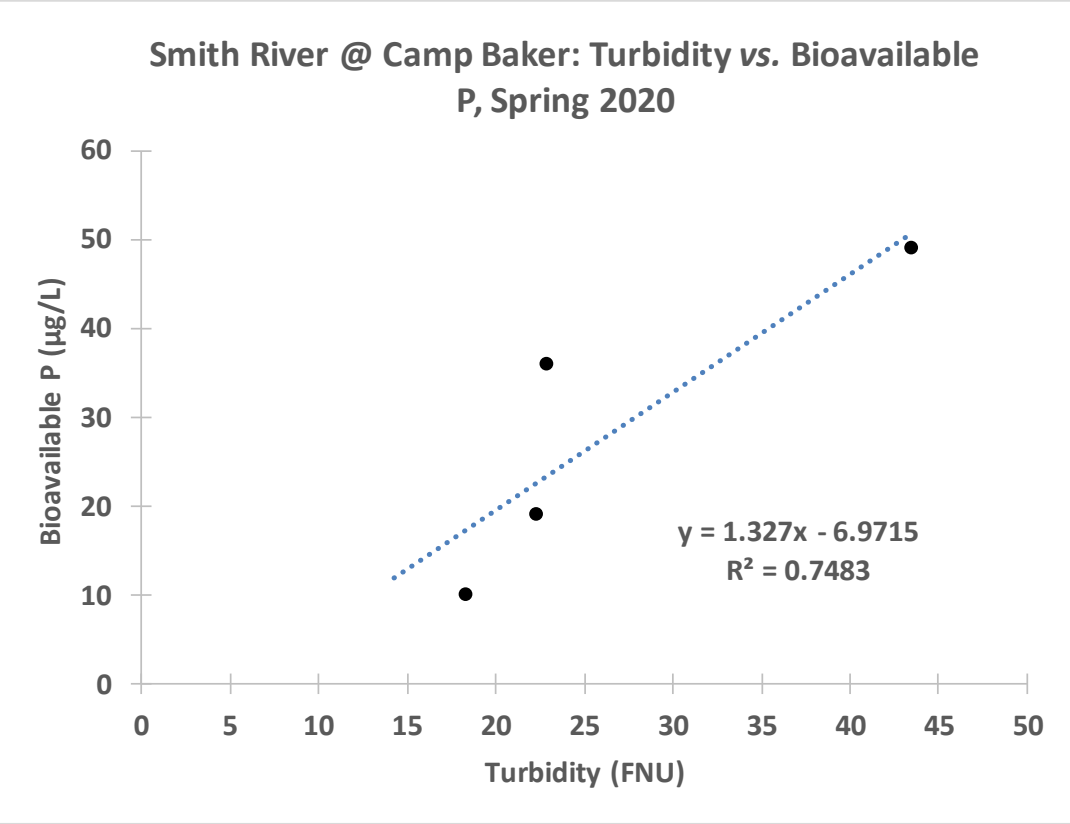






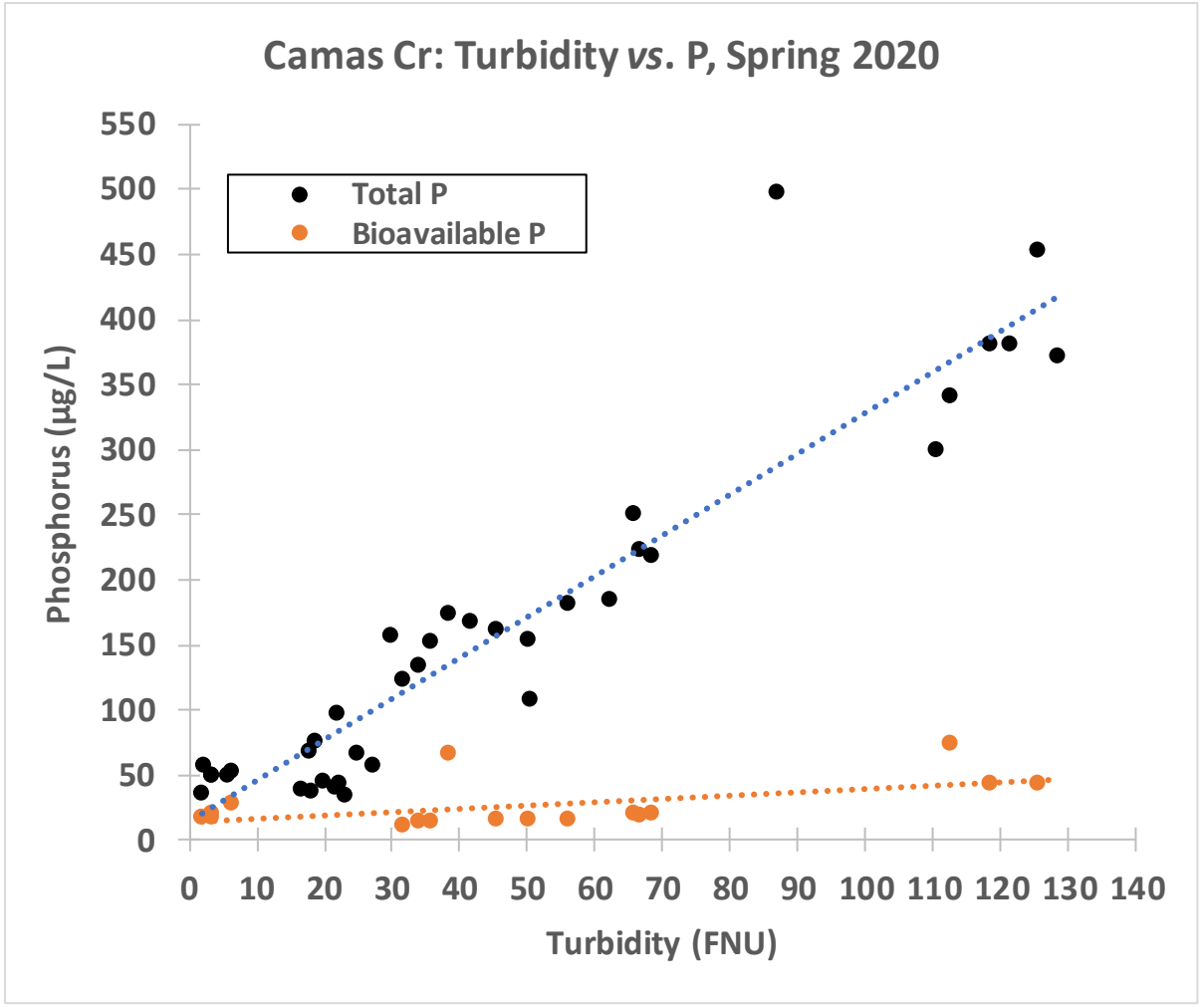
Correlation between Turbidity and Bioavailable P Concentration

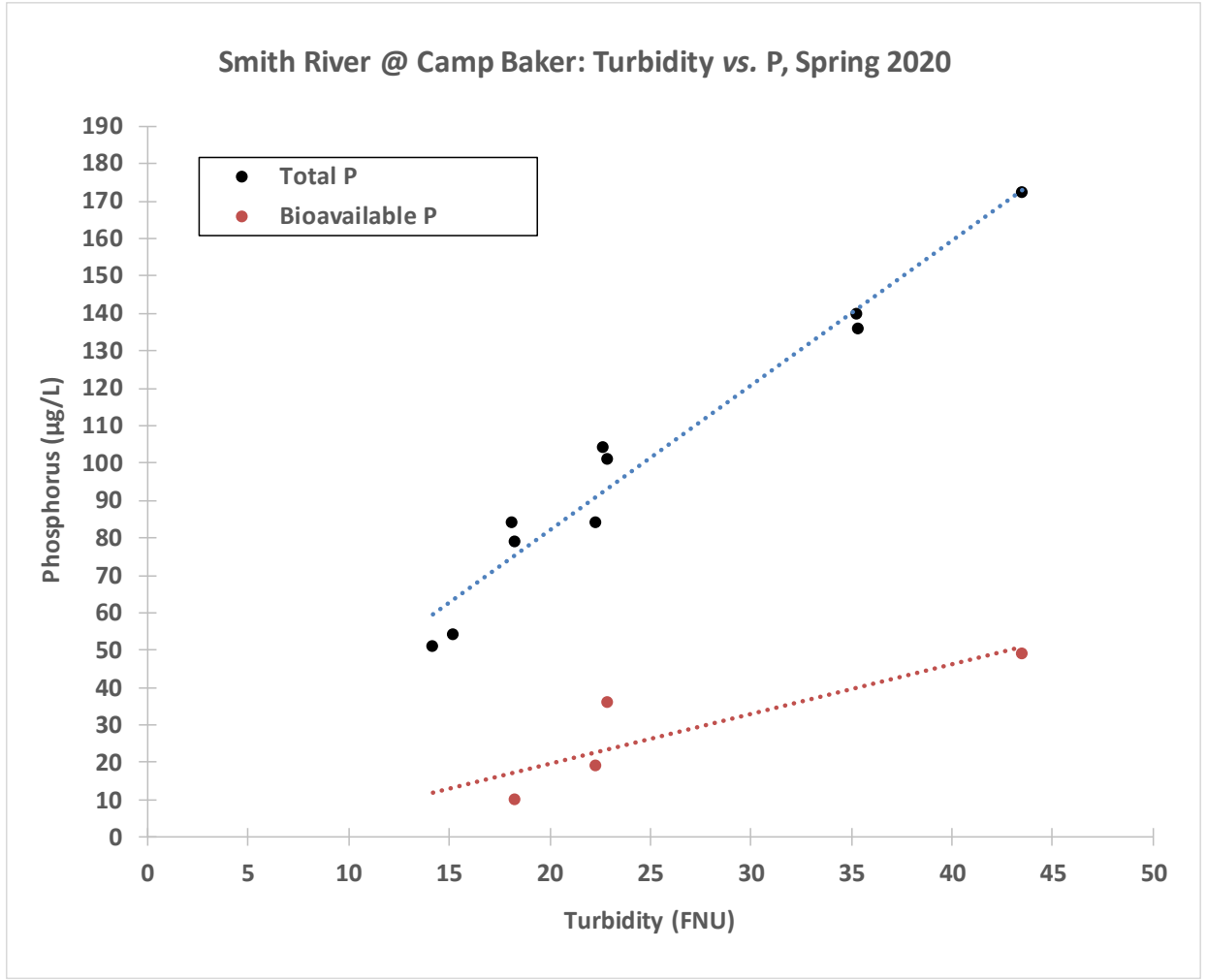




Note: No correlation for NF Smith River.

Most Total P During High Runoff is Not Bioavailable

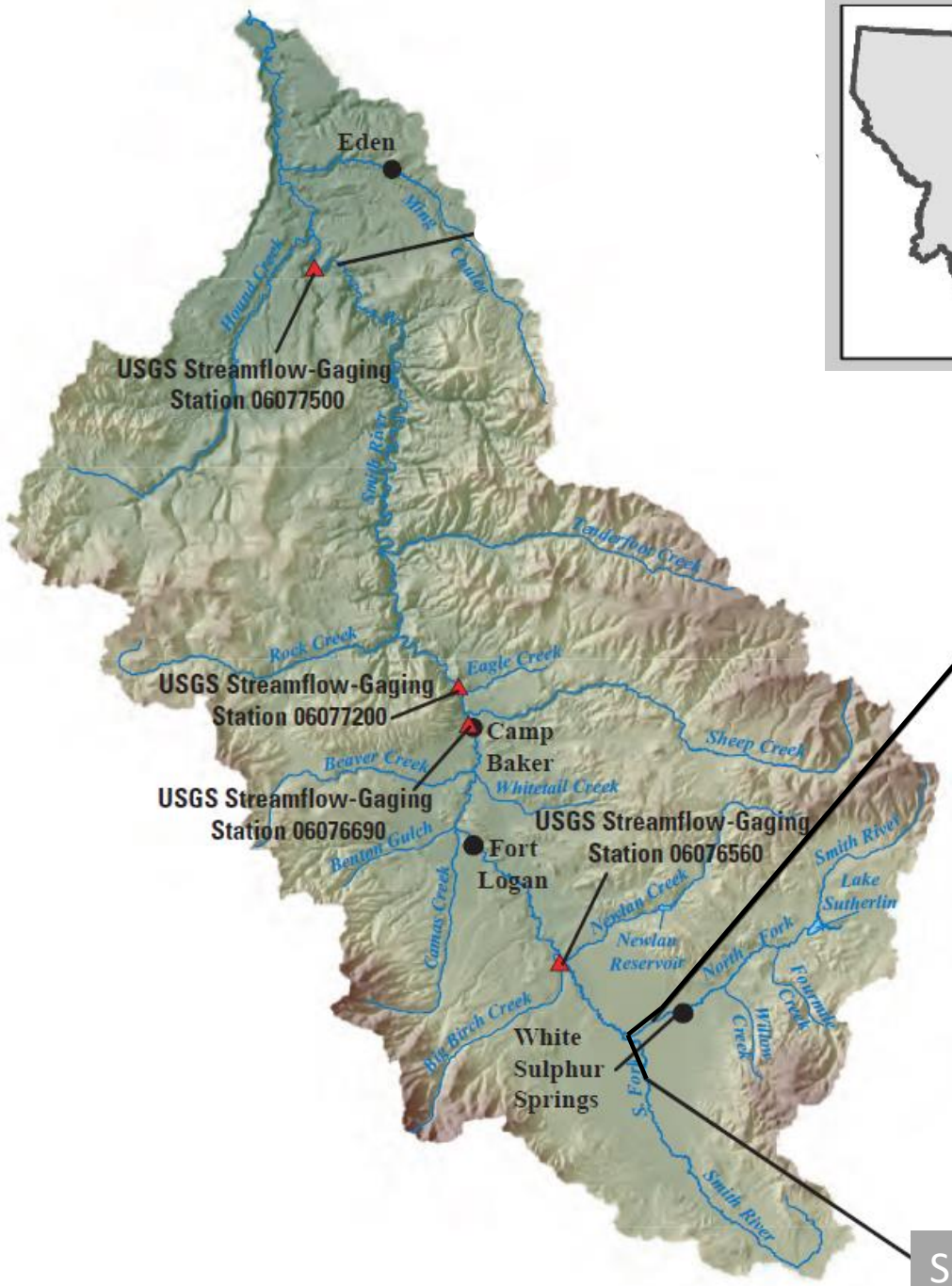


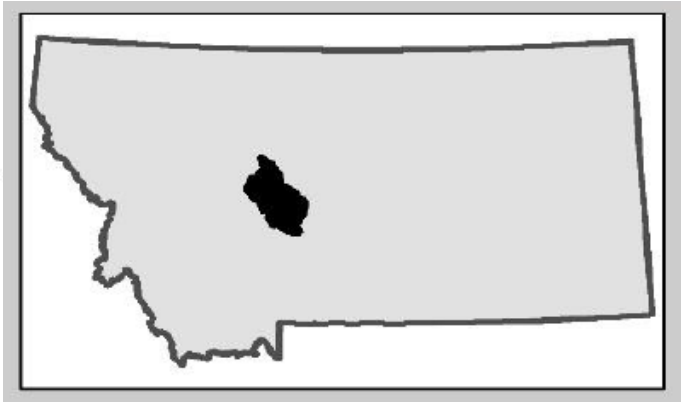


Smith River @ Camp Baker (06076690)

FLOW

Beaver Cr
Benton Gulch
Camas Cr
Newlan Cr
NF Smith River
SF Smith River





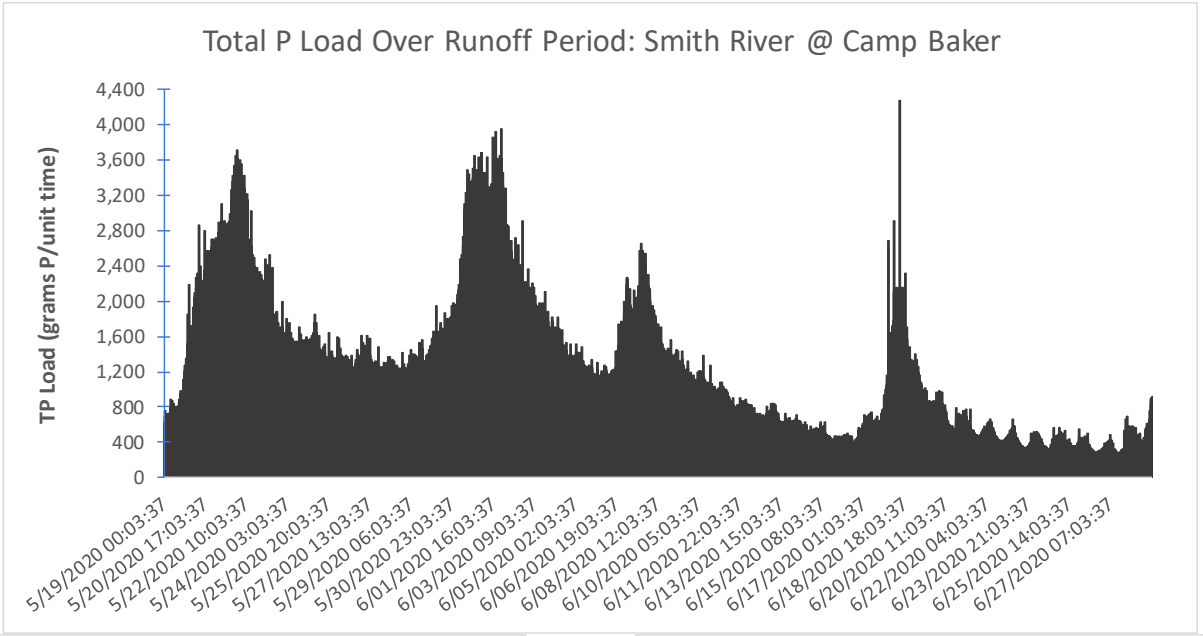
North Fork Smith River

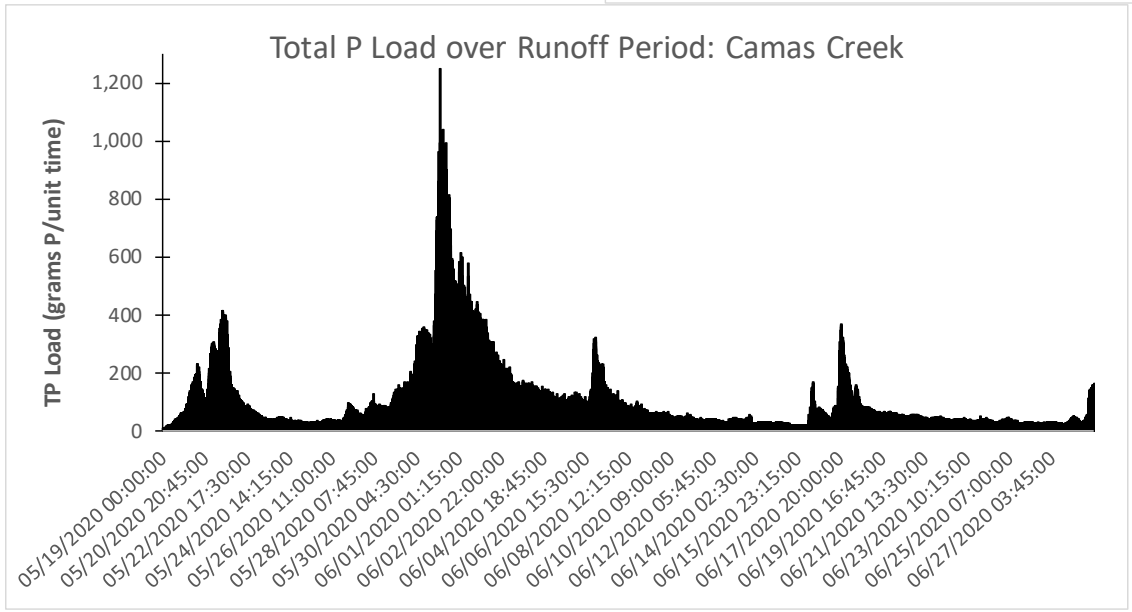
South Fork Smith River

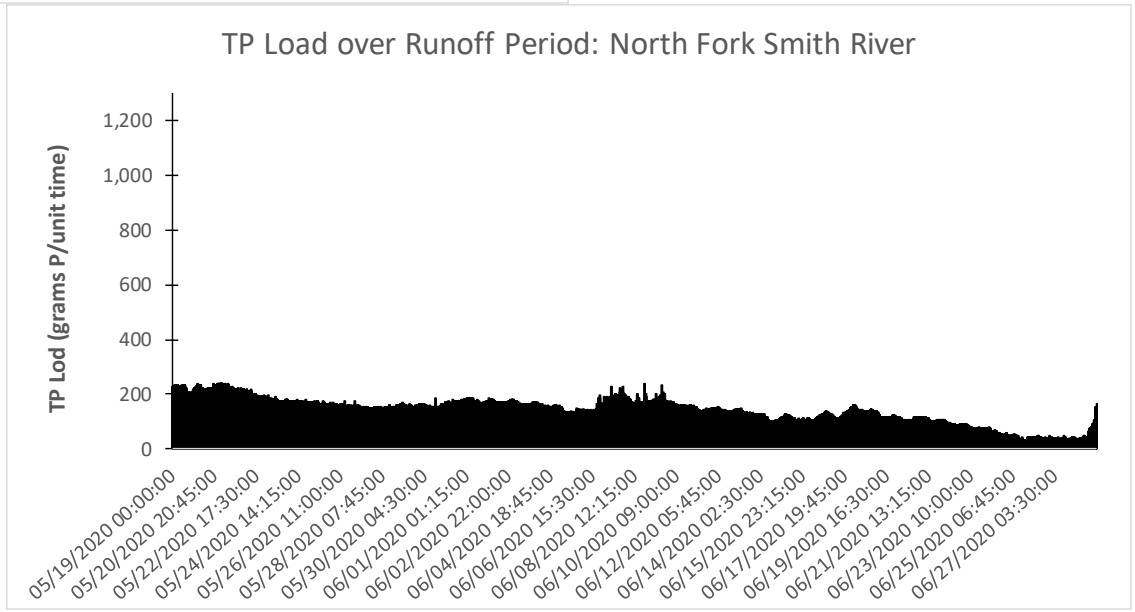
Phosphorus (P) loads for the six tributary sites were compared to the P load in Smith River @ Camp Baker

Travel time from tributaries to Smith River @ Camp Baker was accounted for

Total P Loads Observed

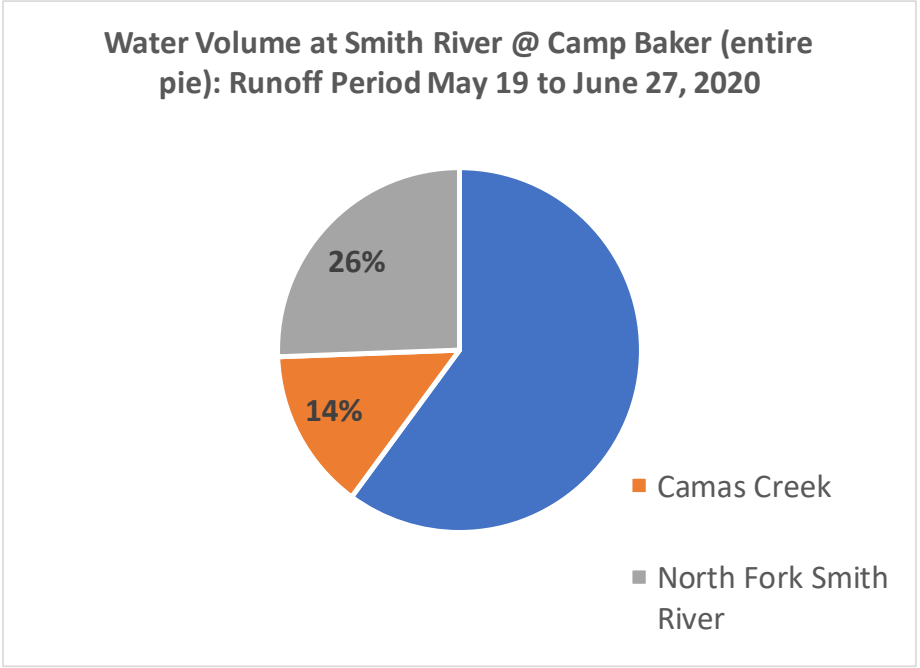


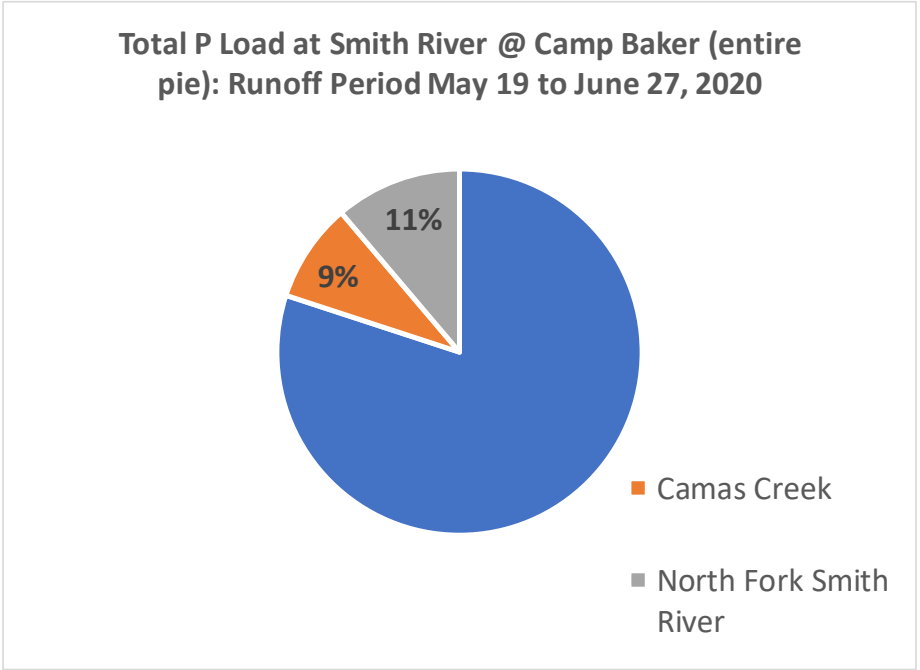




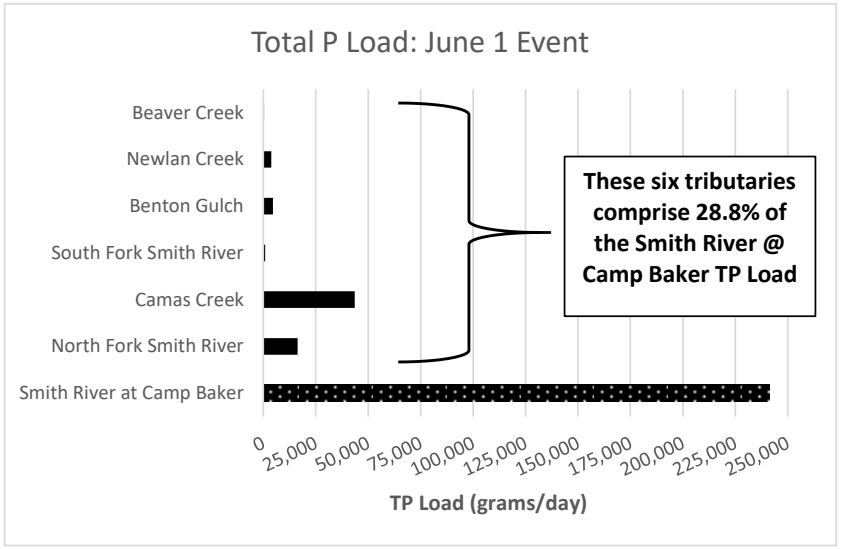
Volume and Load During Runoff

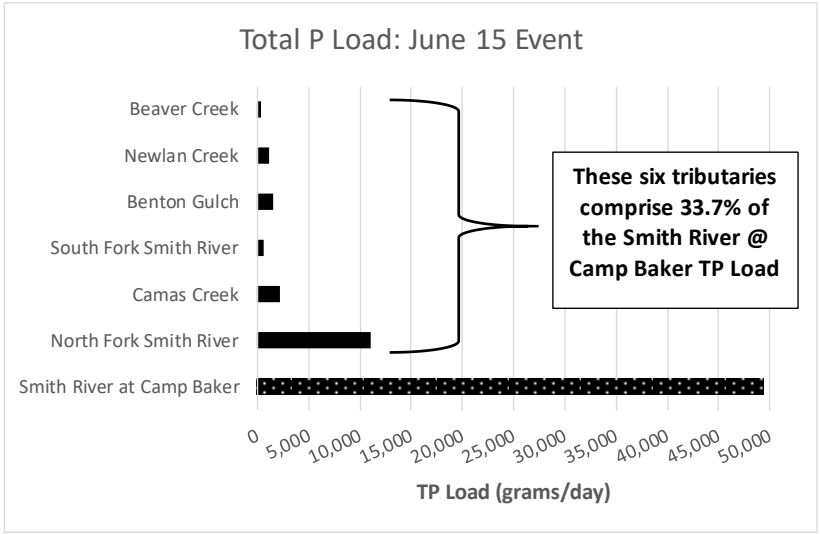
Continuously Measured Data
May 19 to June 27, 2020

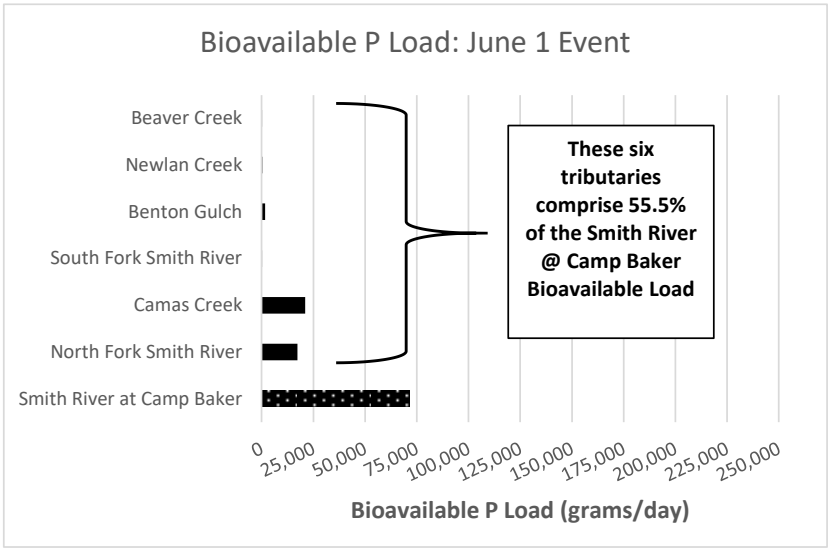


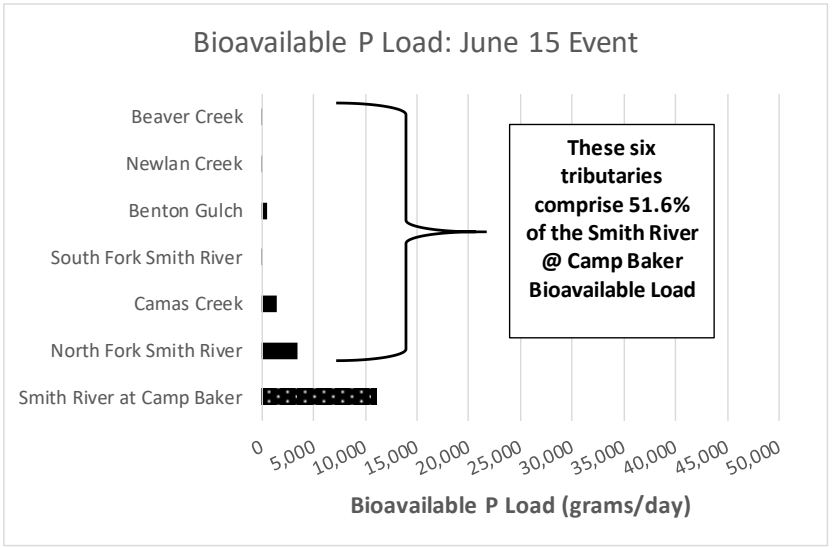


Tributary P Contributions to Smith R. @ Camp Baker









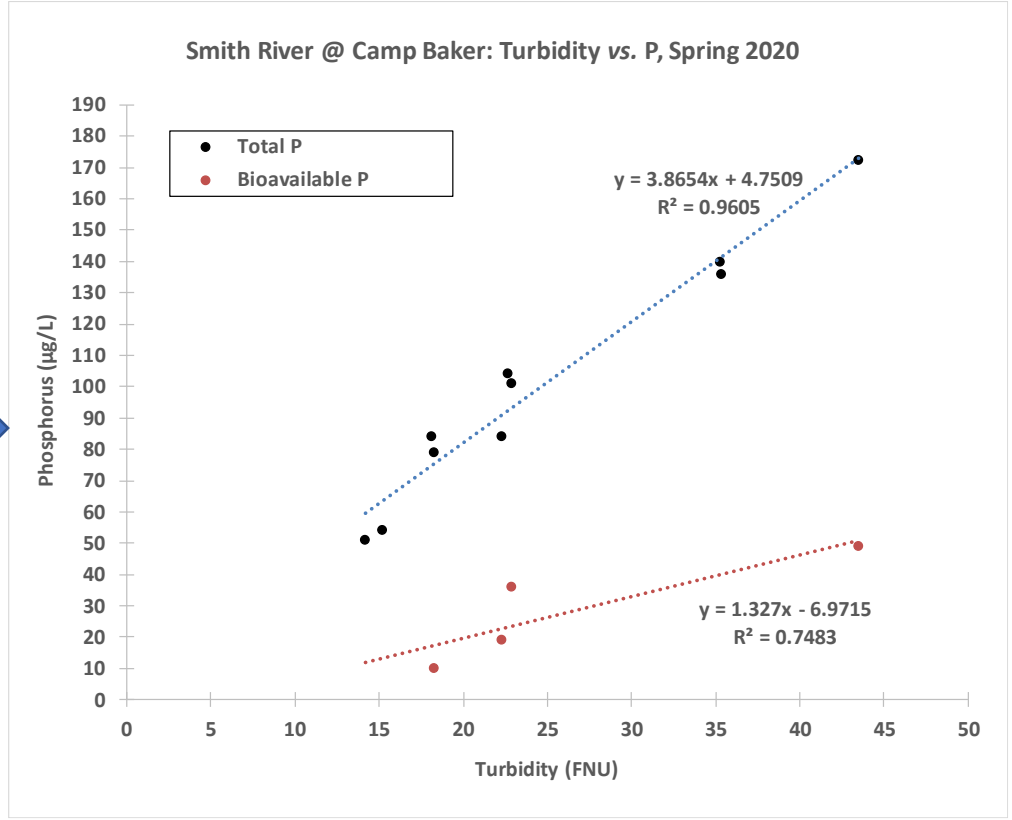
***Tributaries: % of Camp Baker Flow*:** **54%** **43%**

Preliminary Estimates of Reducing Bioavailable P During Runoff

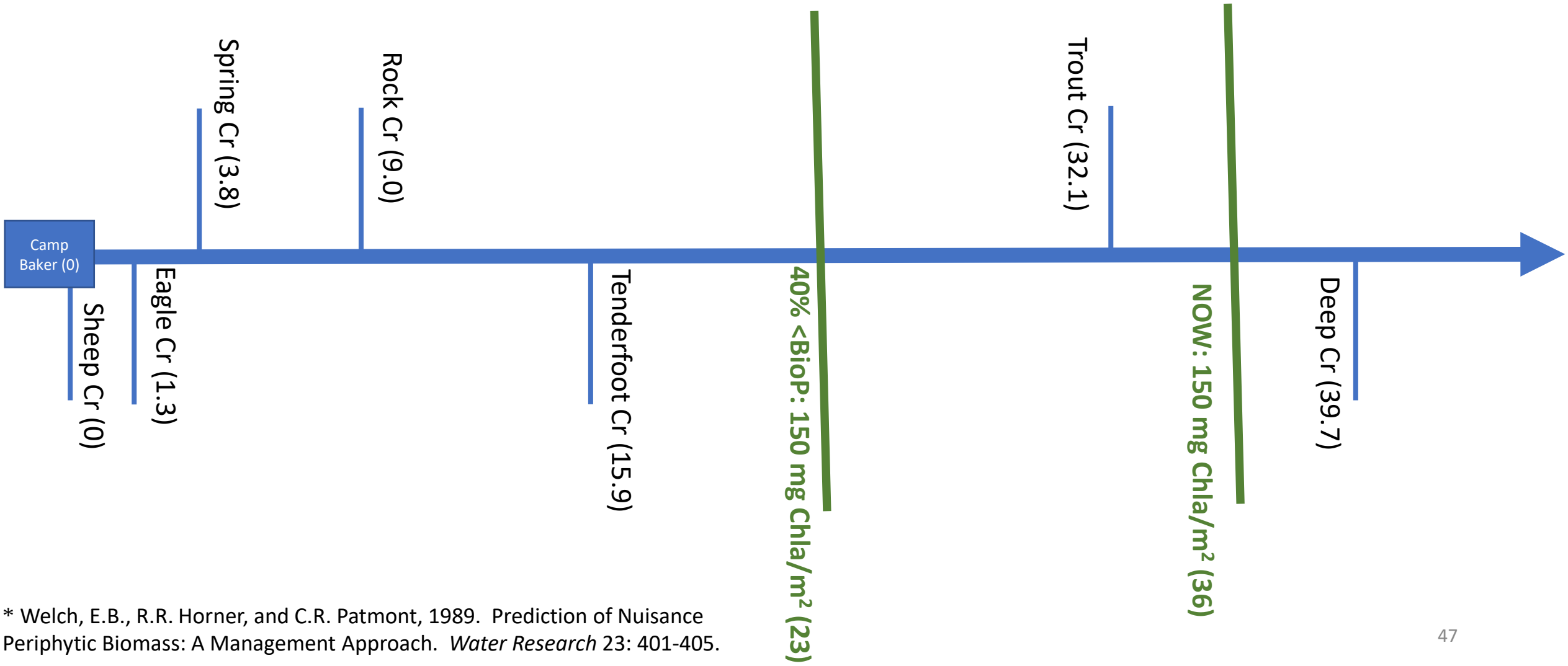
- ***Assume***: Reduce TP load from all six tributaries during runoff period by 40%
  - This is a large BMP reduction
  - Compute current and new TP concentrations
  - Use regressions to compute bioavailable P

- If a 40% reduction in TP from all six tributaries occurred:
  - Bioavailable P concentration at Smith River @ Camp Baker would drop, on average, from **39** µg P/L to about **29** µg P/L

- SRP threshold is <30 µg/L, most likely 5-10 µg/L



Preliminary Estimate* of Reducing Runoff Bioavailable P to Benthic Algae (*river miles*)



* Welch, E.B., R.R. Horner, and C.R. Patmont, 1989. Prediction of Nuisance Periphytic Biomass: A Management Approach. *Water Research* 23: 401-405.

Preliminary Findings—Runoff 2020

- Turbidity is a useful surrogate for phosphorus concentration
  - r^2 for TP ranged from 0.87 to 0.96—very good to excellent correlations
  - r^2 for bioavailable P weaker, but good at Smith River @ Camp Baker (r^2 = 0.75)

- ≥50% of the P load at the Smith River @ Camp Baker is not yet accounted for
  - *More work needed in 2021*

- If a 40% reduction in tributary total P load during runoff occurred, bioavailable P would probably still be above saturation for *Cladophora*
  - Initial projections show 12 fewer river miles would exceed 150 mg Chla/m^2
  - *More work needed in 2021*

Thank You for Participating

Questions?

- Discussion about 2020 Field Season findings

- 2021 Field Season sampling strategy up next…

Runoff 2021 Plan: Data Collection

- Fill data gaps in runoff loading mass balance
  - Collect grab samples from large upstream tributaries (Big Birch and Whitetail creeks)
  - Collect grab samples from Eagle, Spring, and Rock creeks
  - Add near-river groundwater SRP concentrations (well data)

- Collect grab-sample data (4 events) from 2020 sites, same frequency
  - No ISCO sampling

DEQ Montana Department of Environmental Quality

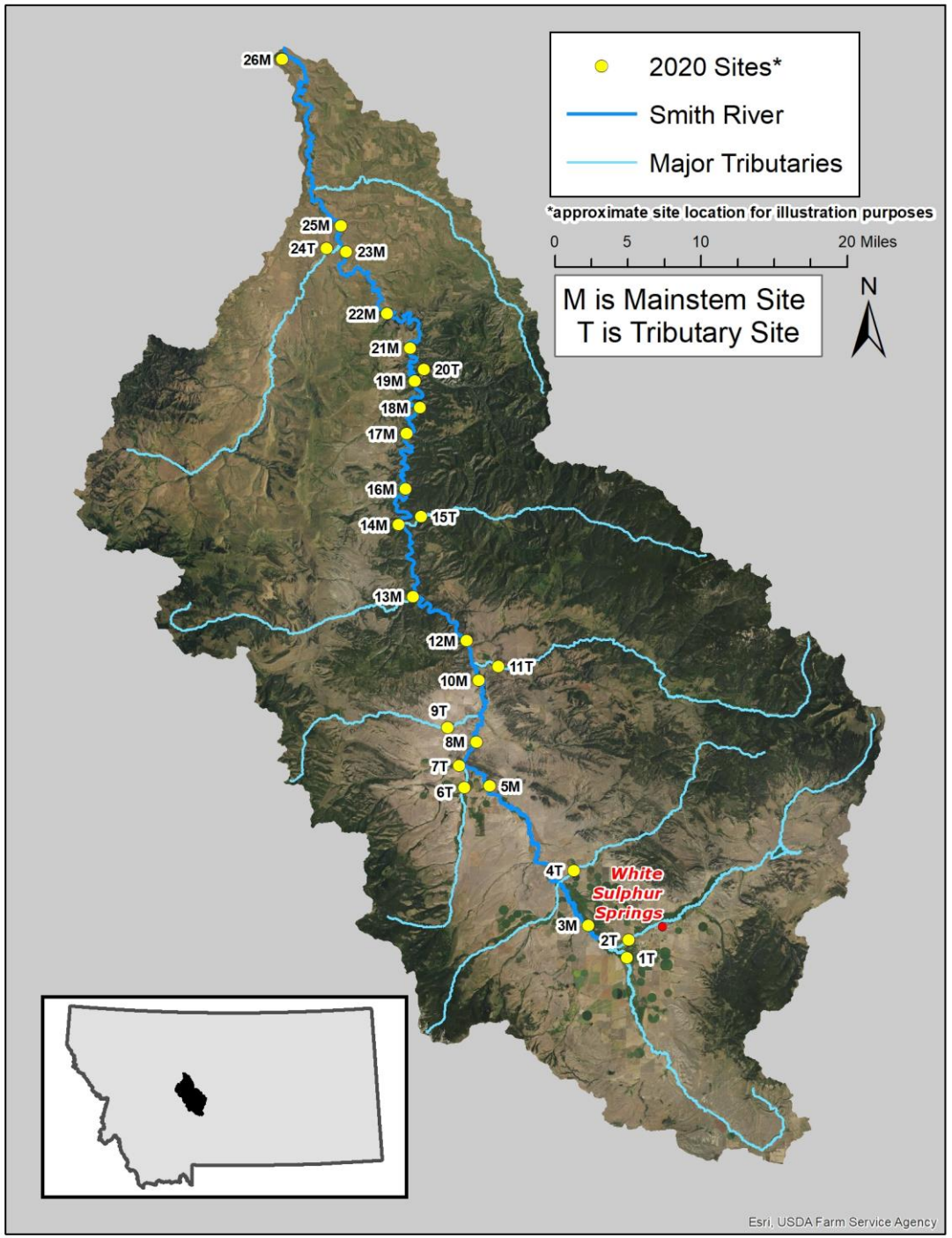
USGS science for a changing world

2021 Monitoring and sampling strategy

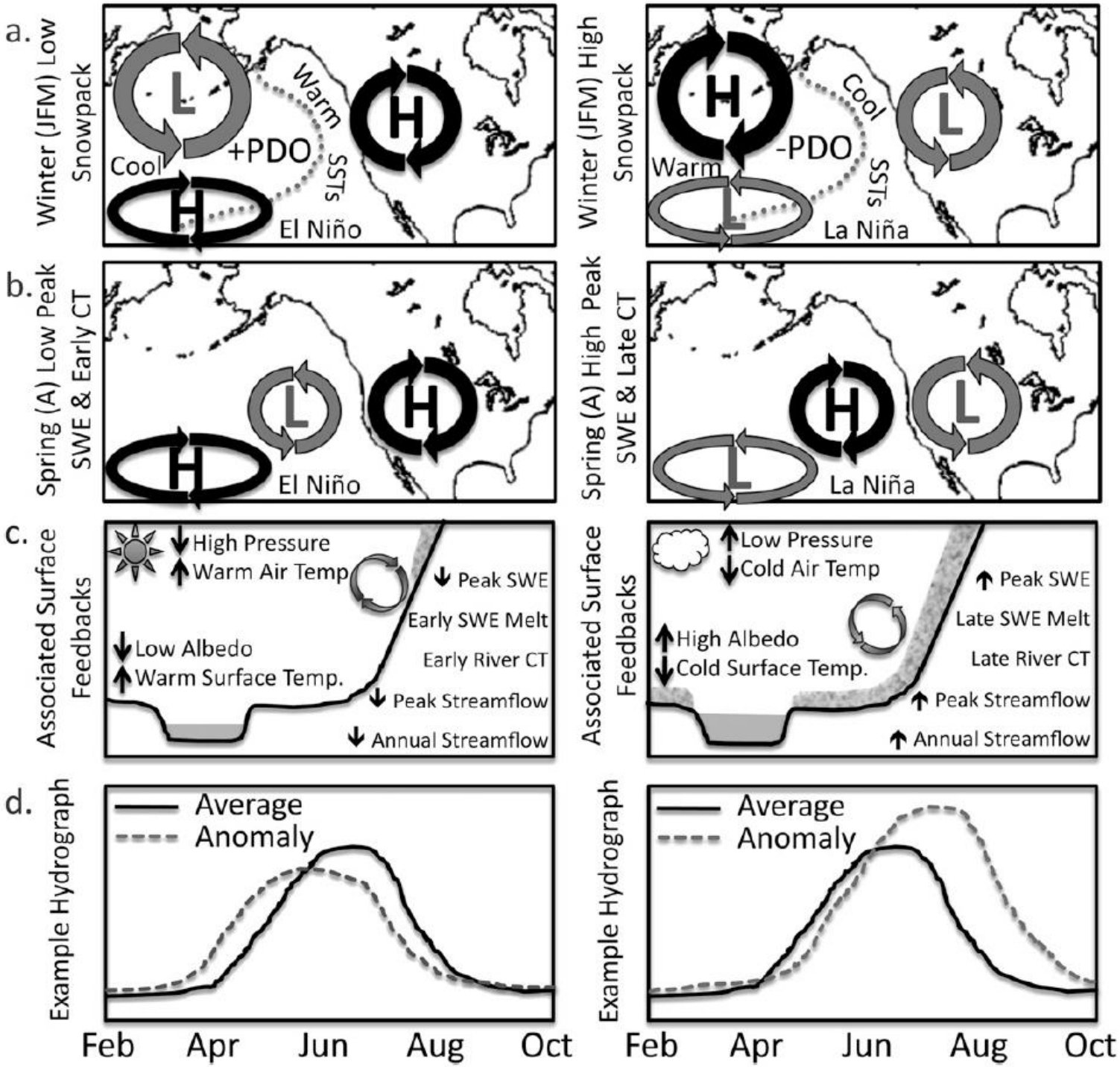
Characterize current conditions

- Upstream to downstream
- Timing of algae growth
- Focus in on tributaries identified in 2019 and 2020 where:
  - Add sites in the headwaters to account for missing P loads at Camp Baker
- Continue trend analysis
- Nutrient Limitation

Continue comparing new data to historical data



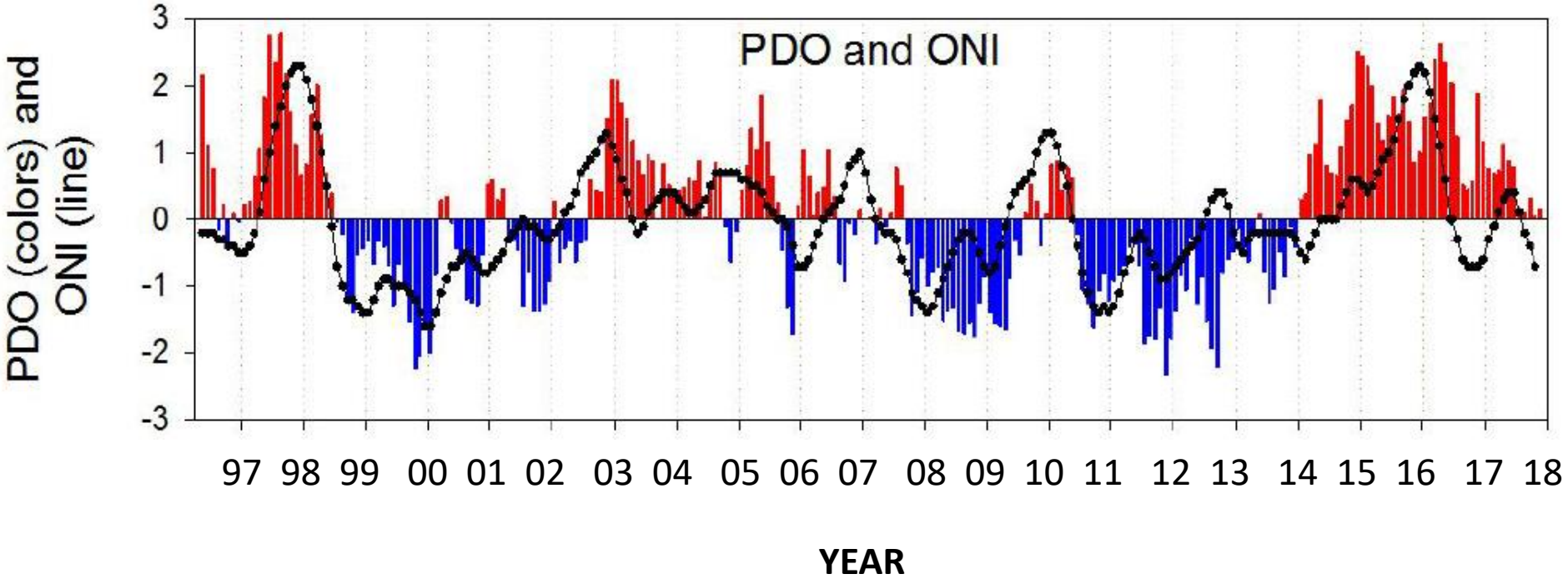
Final Discussion



Idealized relationship between Northern Rocky Mountain snowpack/streamflow and the Pacific decadal oscillation (PDO) and El Niño/La Niña climate drivers.

From Pederson *et al.* (2011) "*Climate Controls on The Snowmelt Hydrology of the Northern Rocky Mountains*."

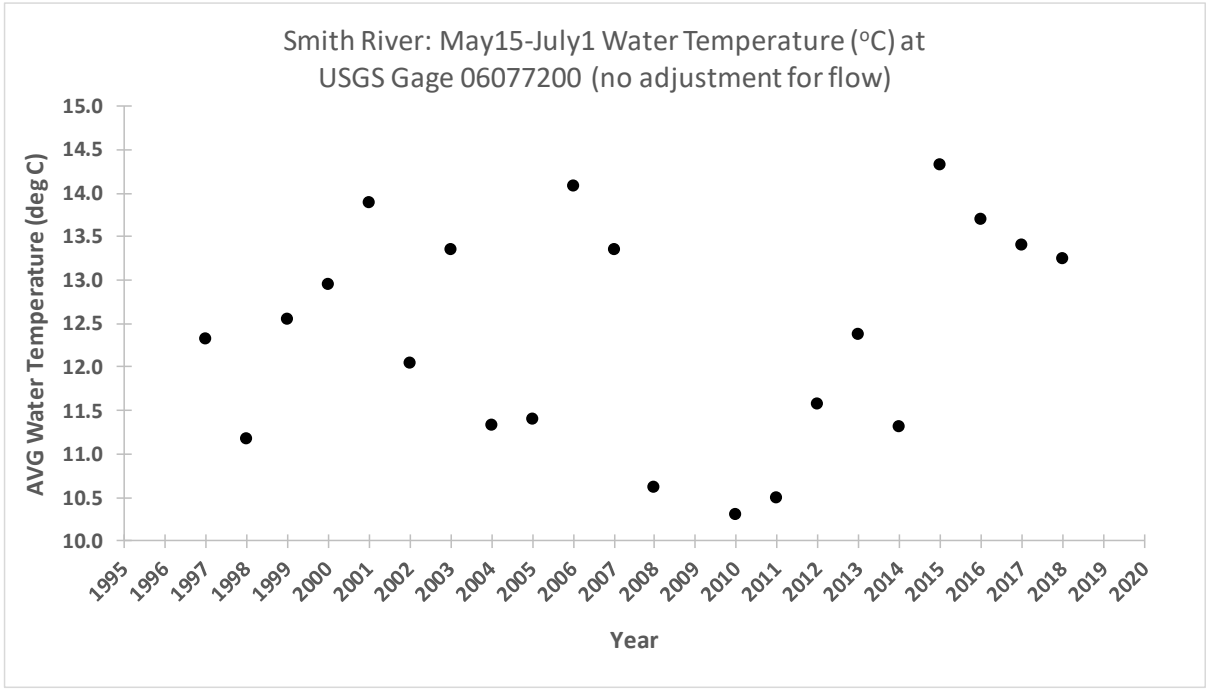
The PDO and Oceanic El Niño (ONI) Sea Surface Temperature Anomalies (1997-2017)

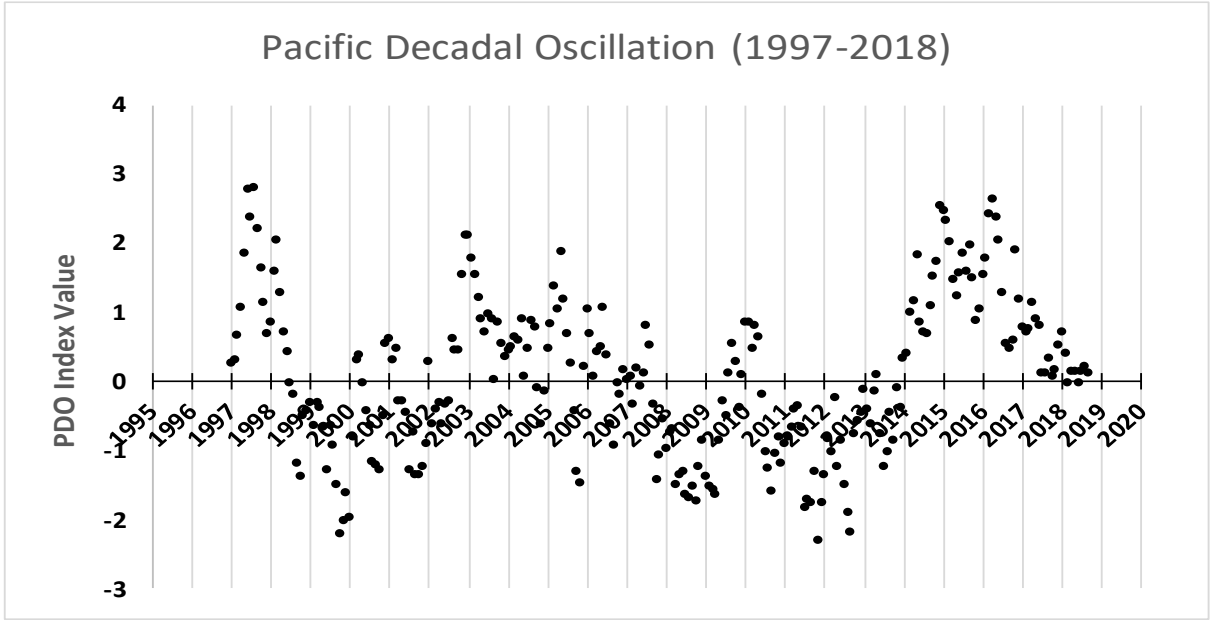


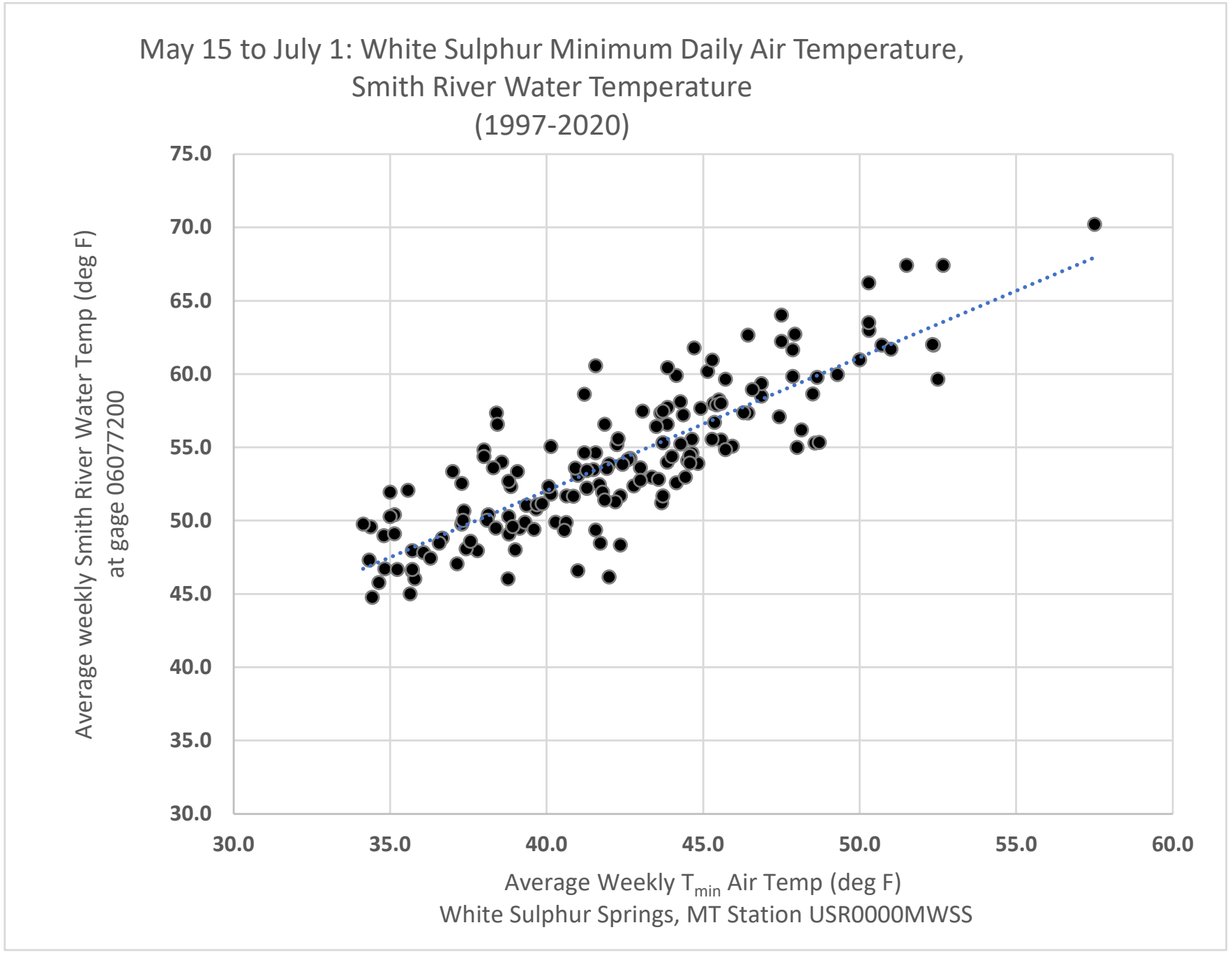
PDO and El Niño can be viewed as "leading Indicators" of oceanic conditions, which in turn influence the climate of the Northern Rockies

From Peterson et al. (2017) "*Oceanic Ecosystem Indicators of Salmon Marine Survival in the Northern California Current*."

Note: Smith River water temperature significantly increasing over time (p = 0.097)

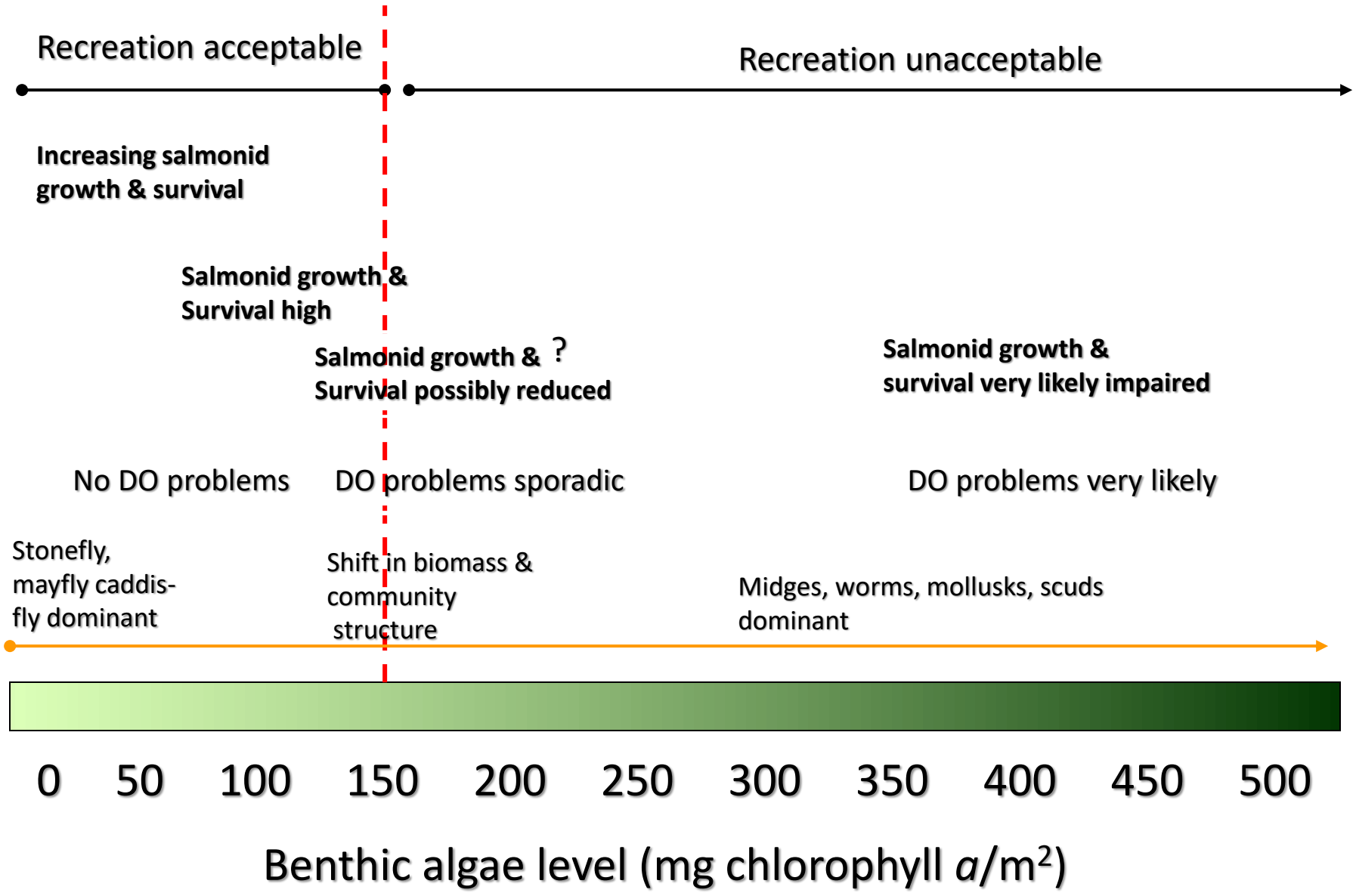






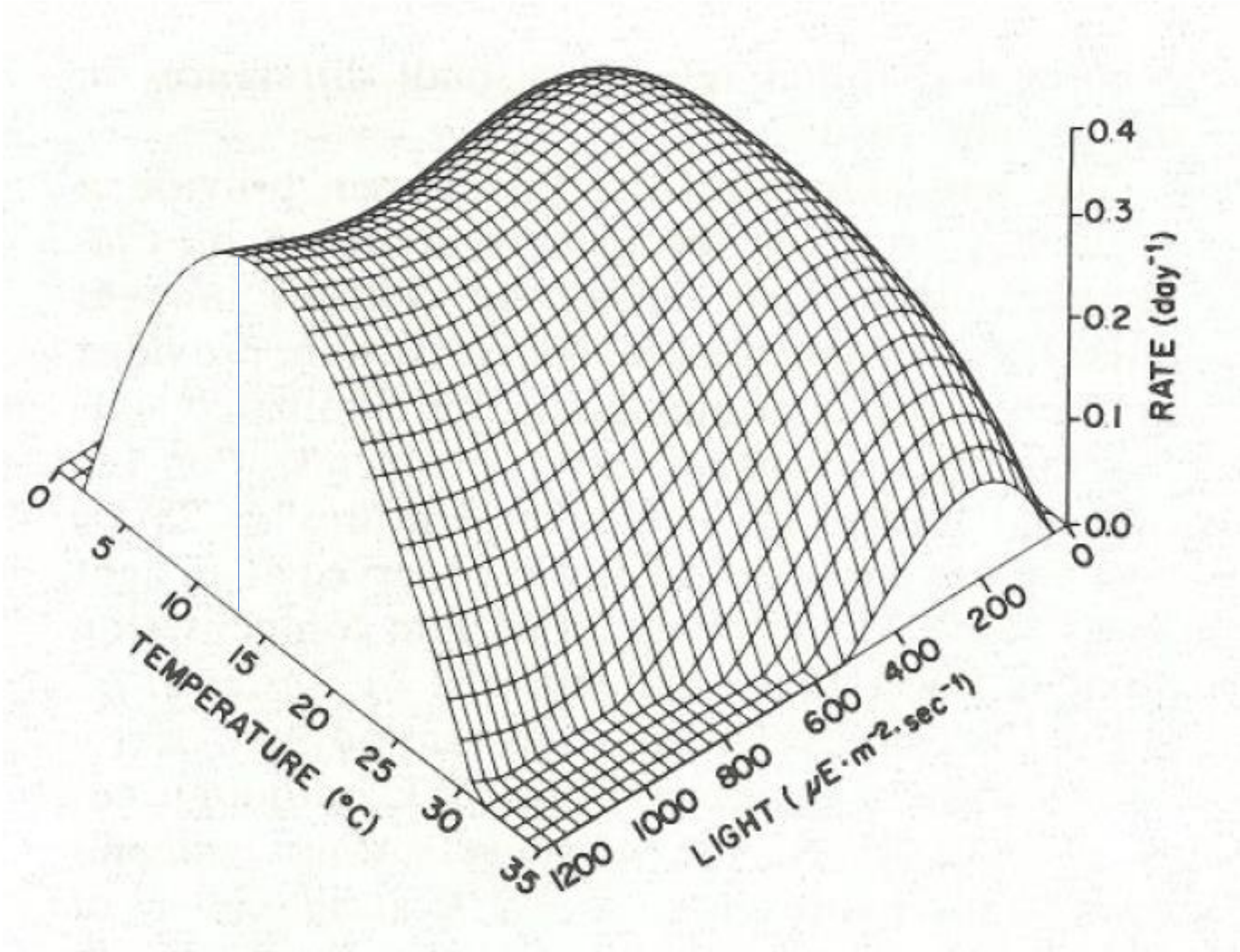
Spearman Rho= 0.83
P-value <0.001

Known/likely effects on wadeable-streams at different algae levels (western MT)



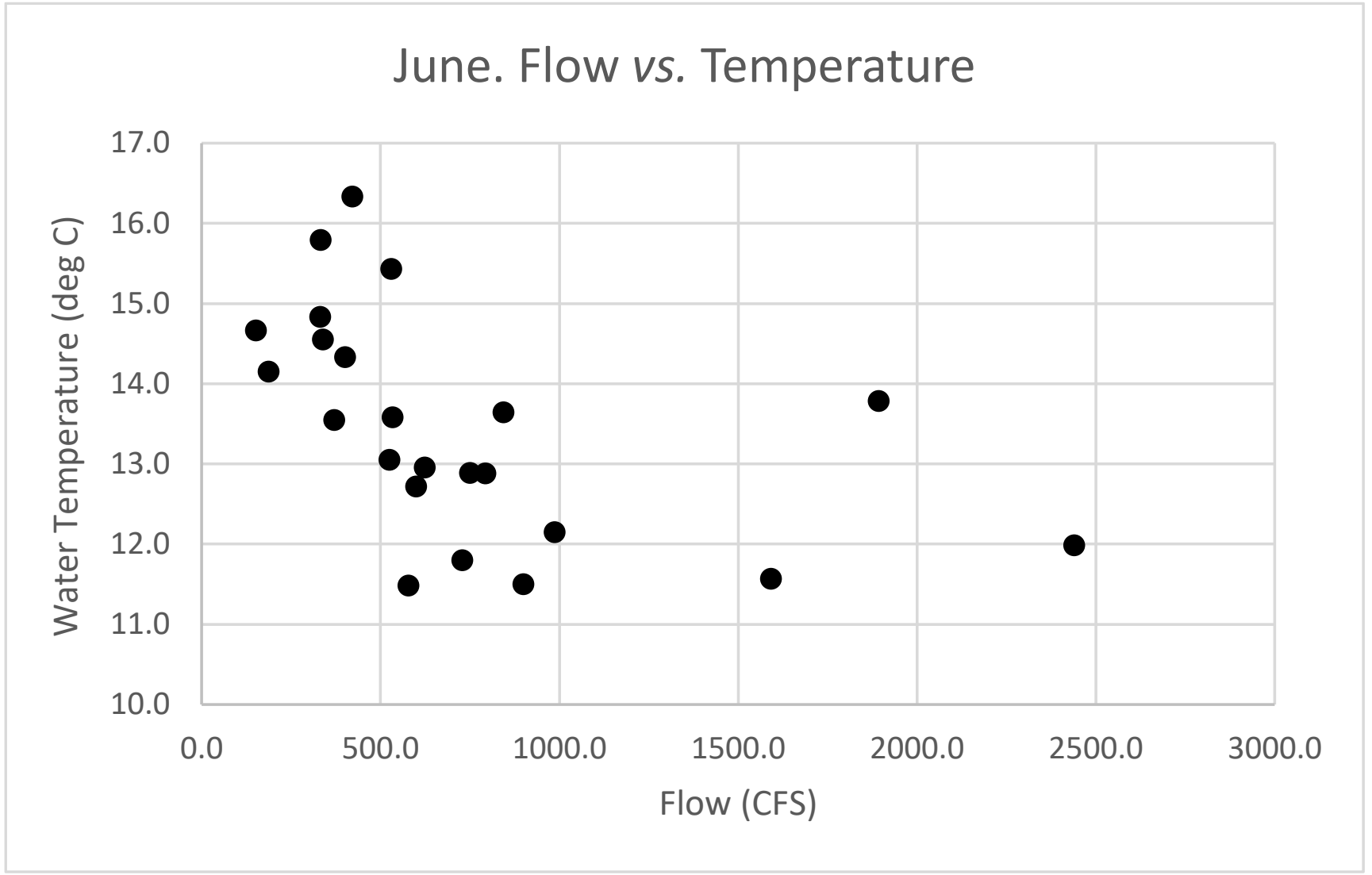
Cladophora glomerata:
Laboratory-controlled measurement of photosynthesis in response to temperature and light (nutrients unlimited)

From Graham *et al.* (1982)



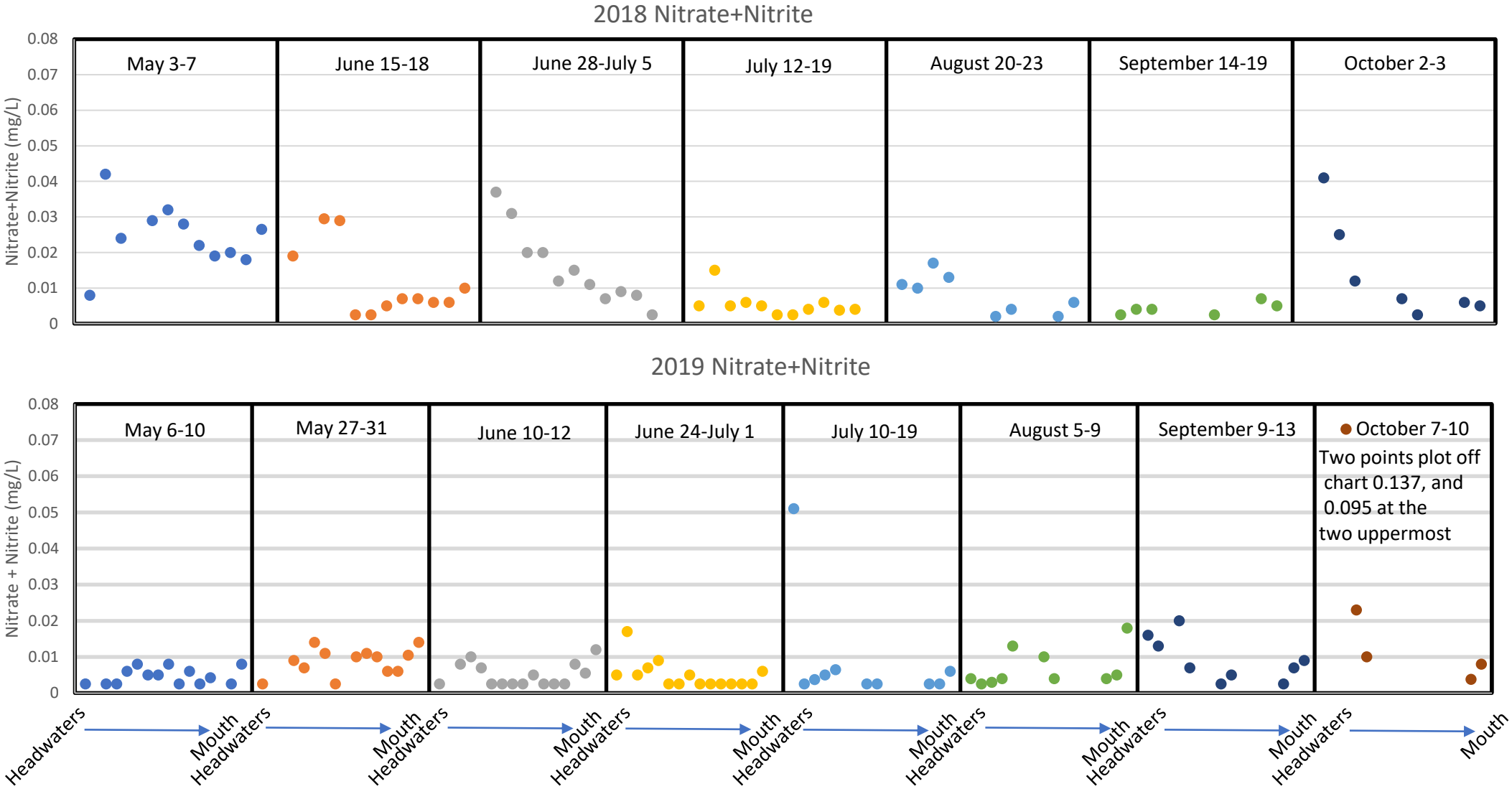
Other Studies:
No growth at 5 °C, only slight growth at 10 °C.

Smith River
USGS Gage
06077200
(1997-2020)

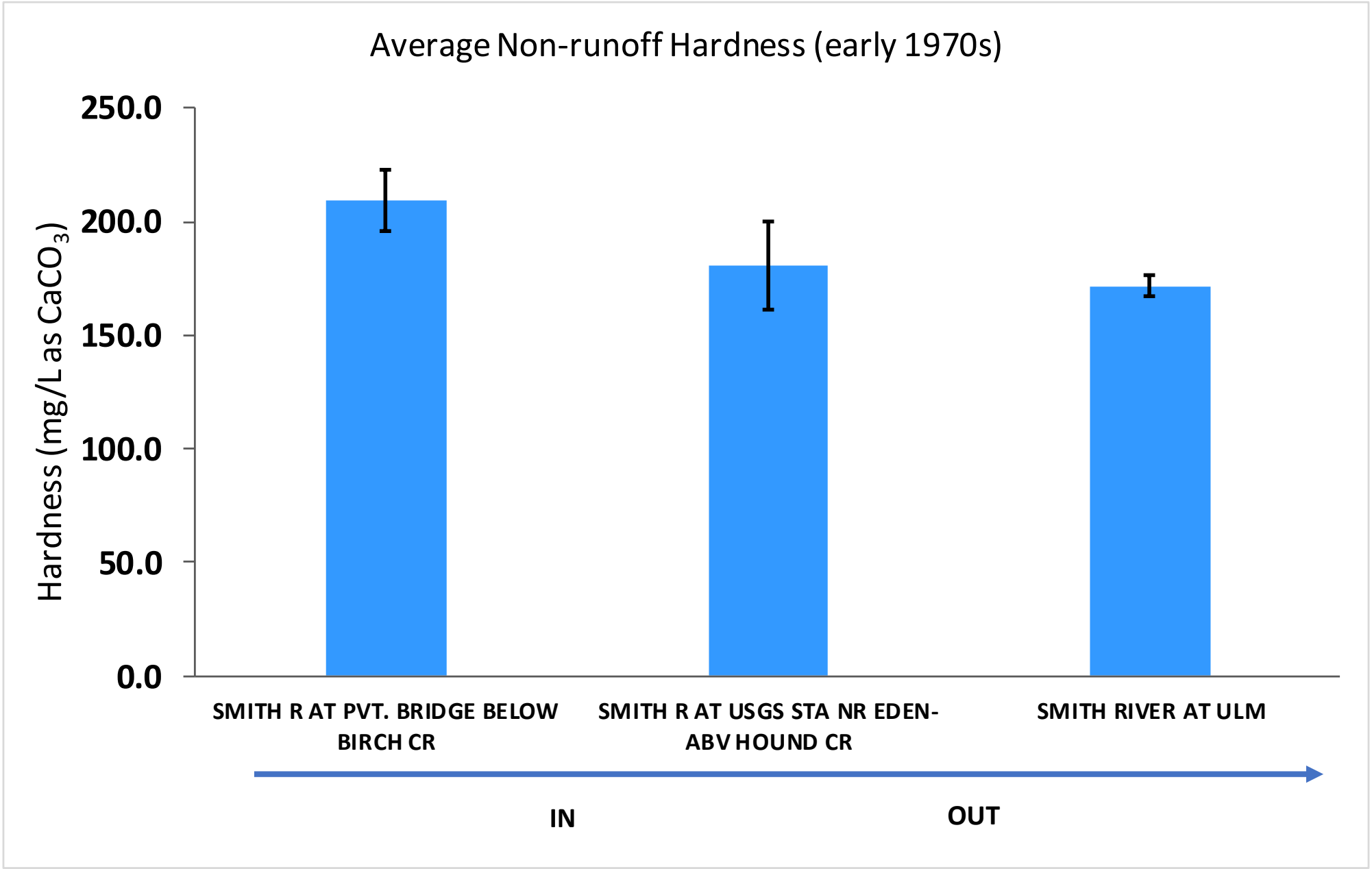


Spearman Rho = -0.69, p-value = <0.001

Nutrients (Nitrate+Nitrite) 2019



Historic Conditions - Hardness



Mid-July Float Trip Observations