Hydrological and biological responses to restoration of dynamic alluvial valleys at Robinson Fork, PA

Searching for indicators of water and nutrient retention

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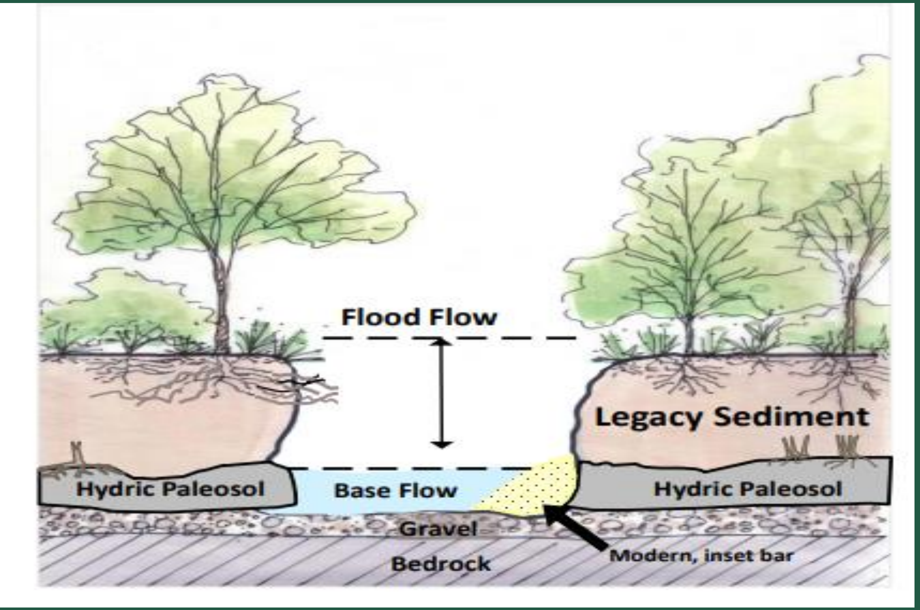
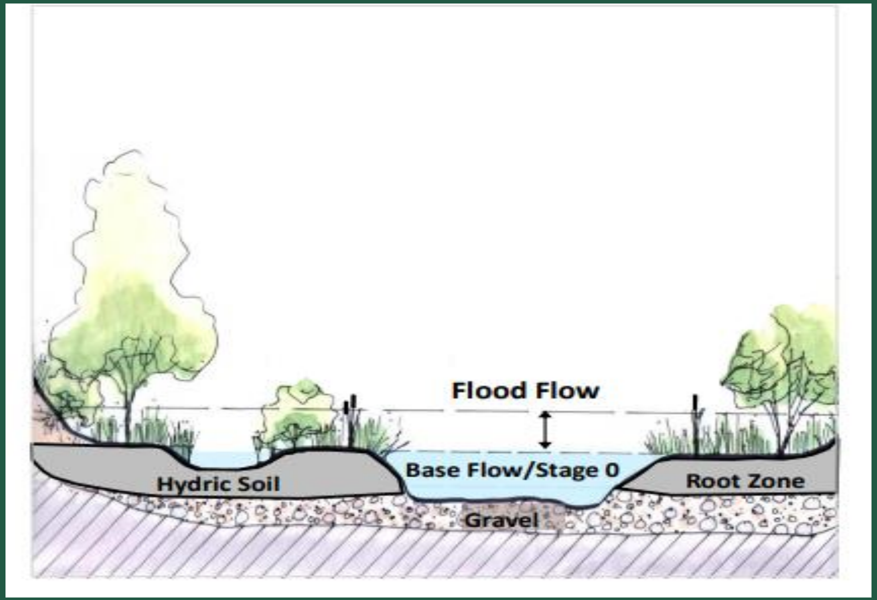
Typical stream

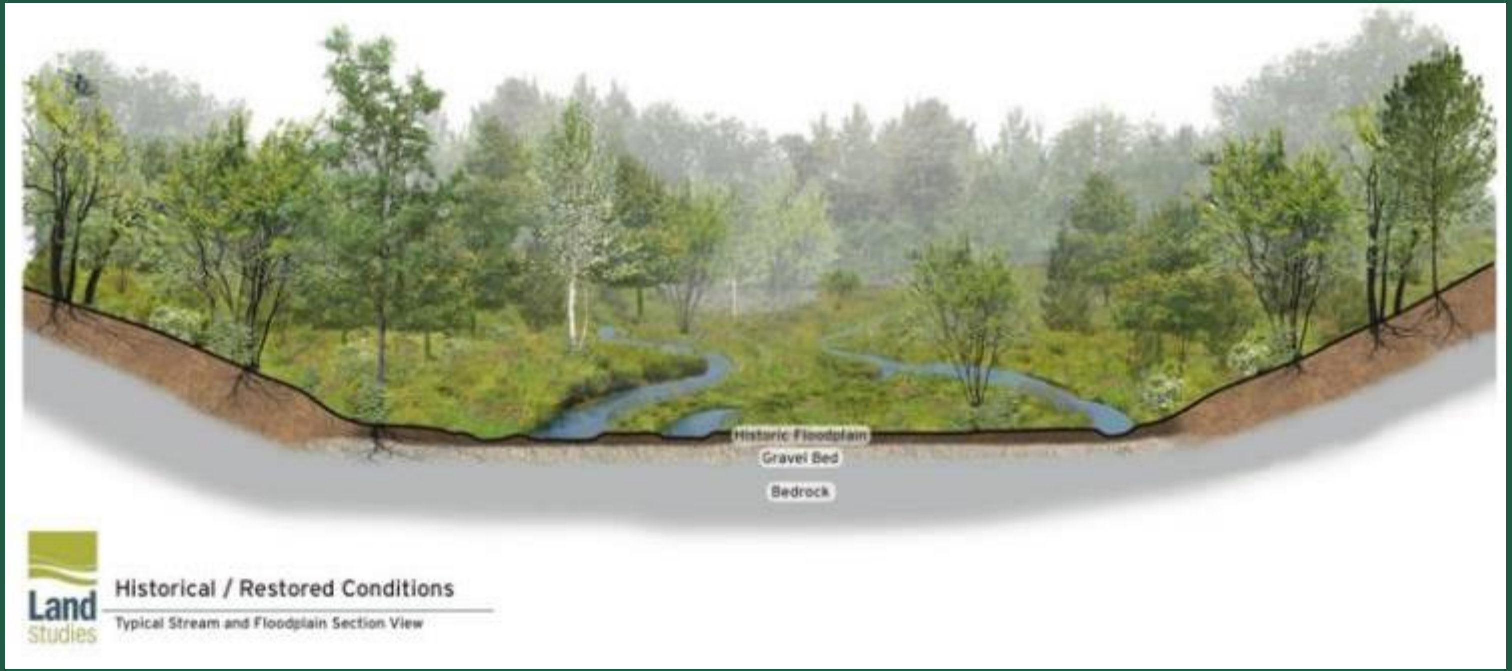
'Pre-settlement' stream wetland complex





Images from J. Hartranft PA Legacy Sediment Workgroup

Restoration of dynamic alluvial valley should



- Increase water storage during peak and low flows
- Reduce erosion/improve sediment retention
- Enhance geochemical cycling (longer inundation periods)
- Reduce nutrient export
- Mosaic of habitat types (different flows, velocity, depth) for biodiversity
- Have high secondary production, biodiversity

(Flitcroft et al. 2022, Leberg and Topping 2023, Goerman et al. 2013, Kaushal et al 2014, Parola and Hansen 2011)

Objectives

Characterize and compare functional aspects of restored and unrestored sites

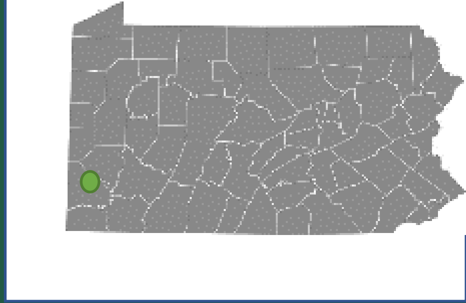
- Water storage
- Sediment retention and export
- N and P retention and export

- In-stream primary production (periphyton)
- Macroinvertebrate communities (diversity and biomass)

- Carbon accumulation and retention (soil organic content, woody debris, terrestrial litter input, decomposition rates)

- Vegetation
- Amphibian breeding habitat

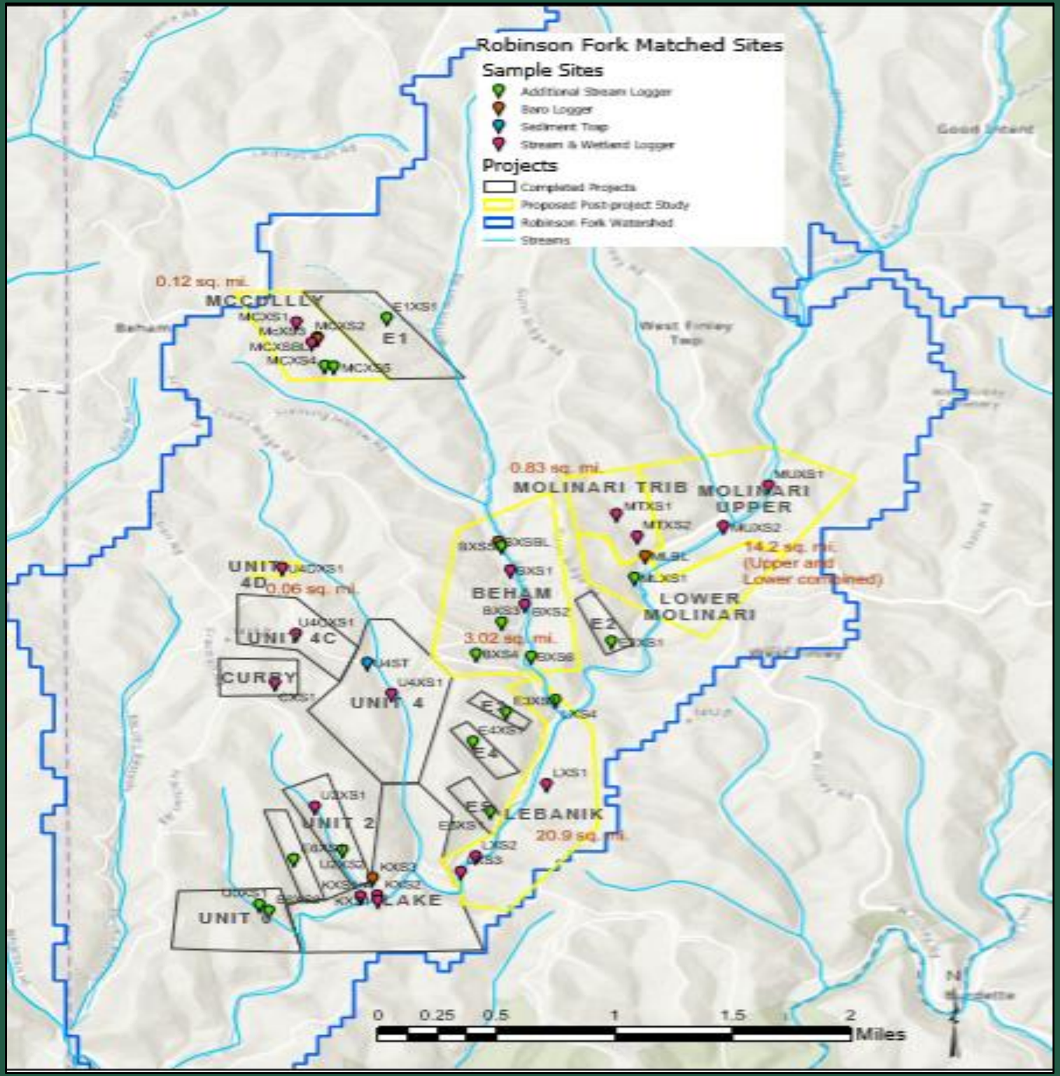
Robinson Fork Stream Mitigation area

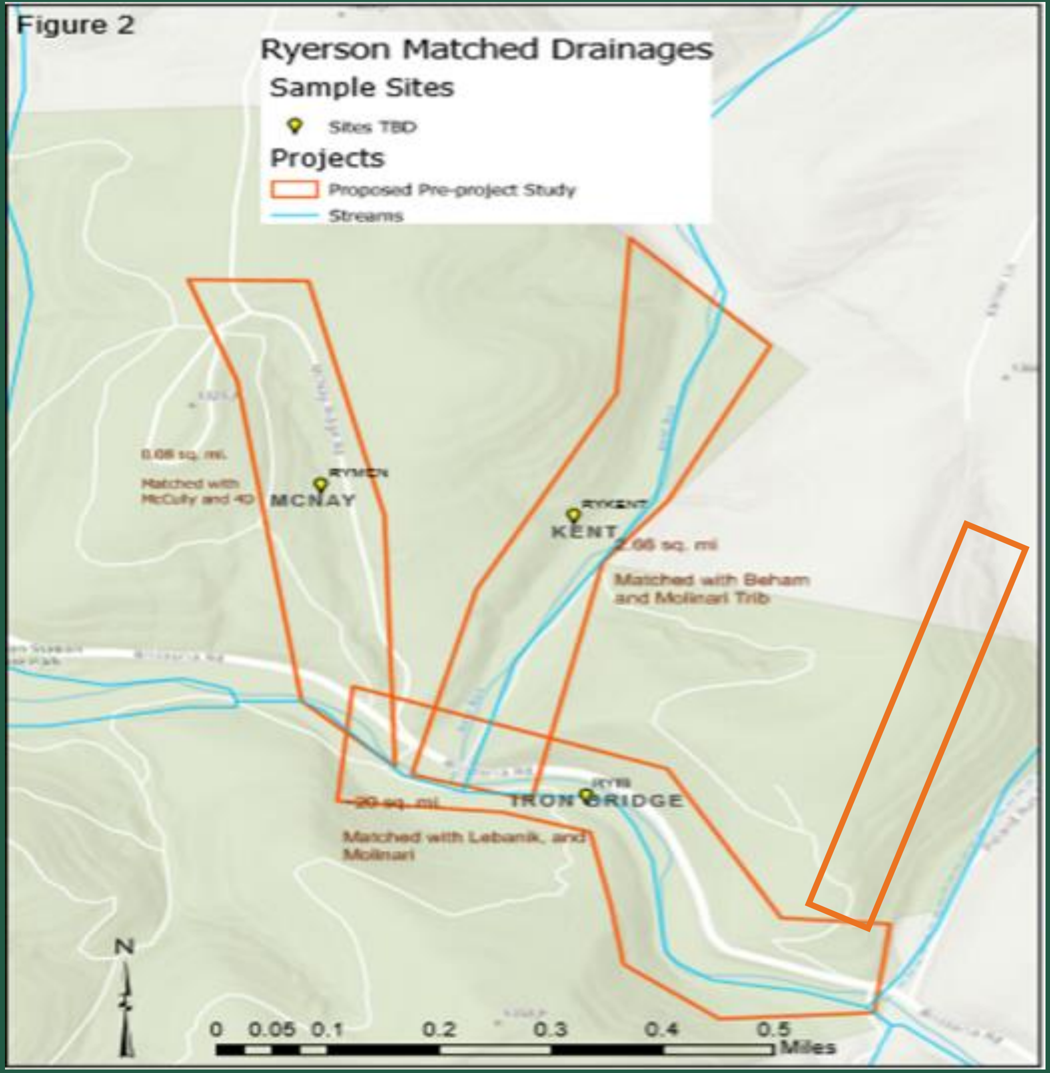


- 14.4 square miles in Western PA, Western Alleghany Plateau
- Forest cover 70%, 5.67% urban development, and 0.23% impervious surface
- Some historical agriculture, timbering and coal mining
- Designed/Implemented by LandStudies & RES
- Six sites 3-4 years post-restoration (in 2019)

6 restored sites (Robinson Fork)

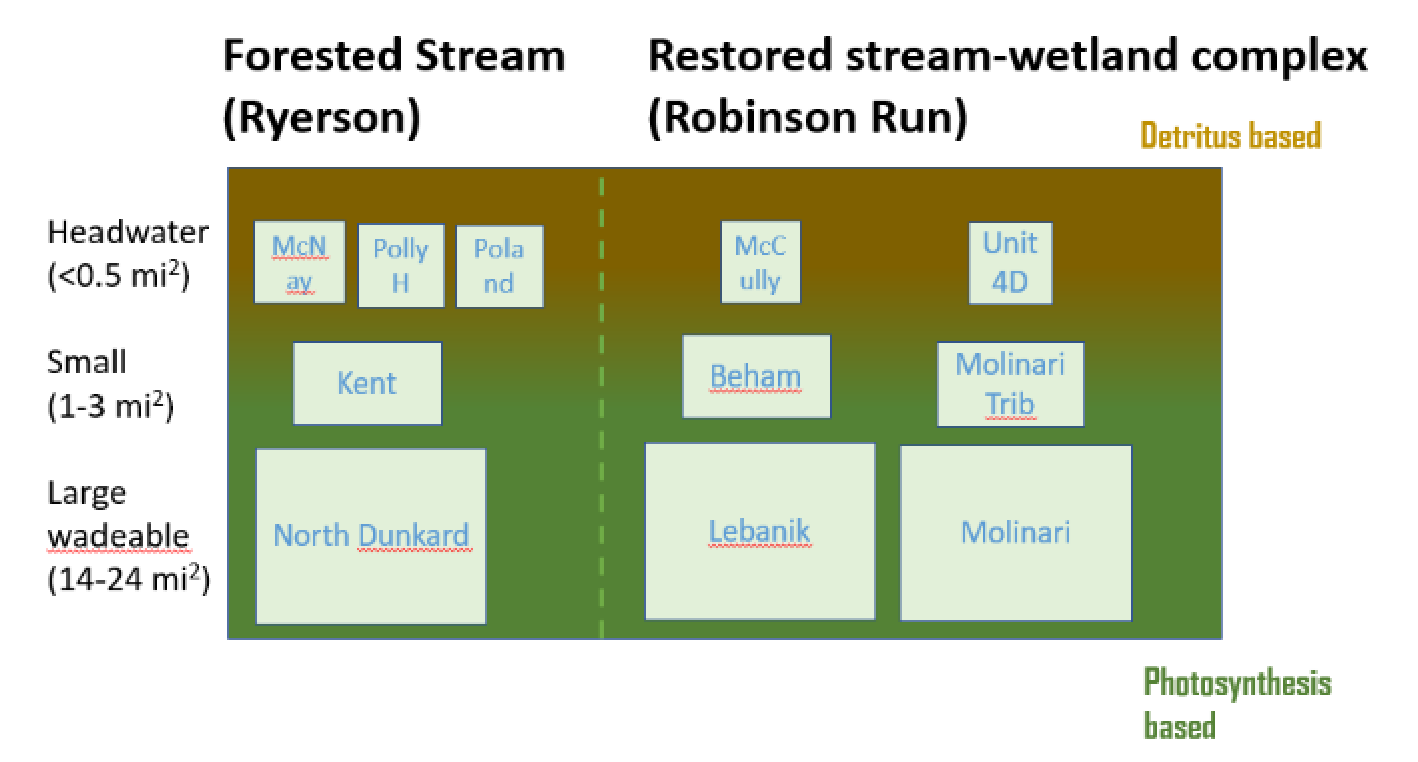
4 forested, single channel (Ryerson)





Ryerson Station State Park forested streams

- 76% forest cover, 5.74% urban development, 0.24% impervious
- Historical mining, timbering



Water Chemistry

QUARTERLY

- Samples analyzed for TSS, N, and P,
- TOC

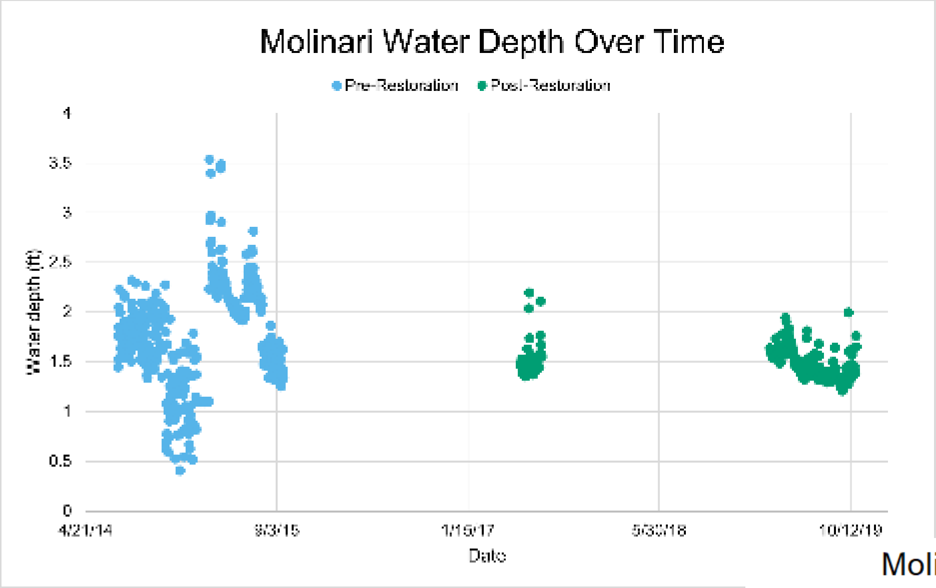
- Myron Ultrameter used for field parameters

- Hach kits total N and P used for higher frequency/field tests

Flow and Water Storage

- Channel flow with flume, SonTek, or pygmy
- Salt tracing to measure transient flow with YSI meter
- Water storage is difference between salt tracing flow (includes vadose zone) and channel flow
- Water depth monitored w/divers

Water Storage (pre- and post) estimated from historical precipitation data and water level monitoring



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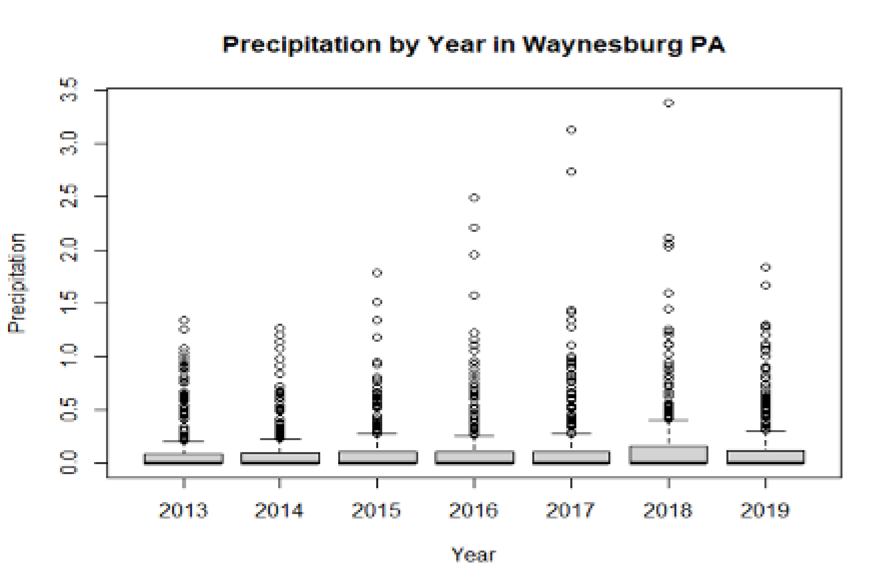
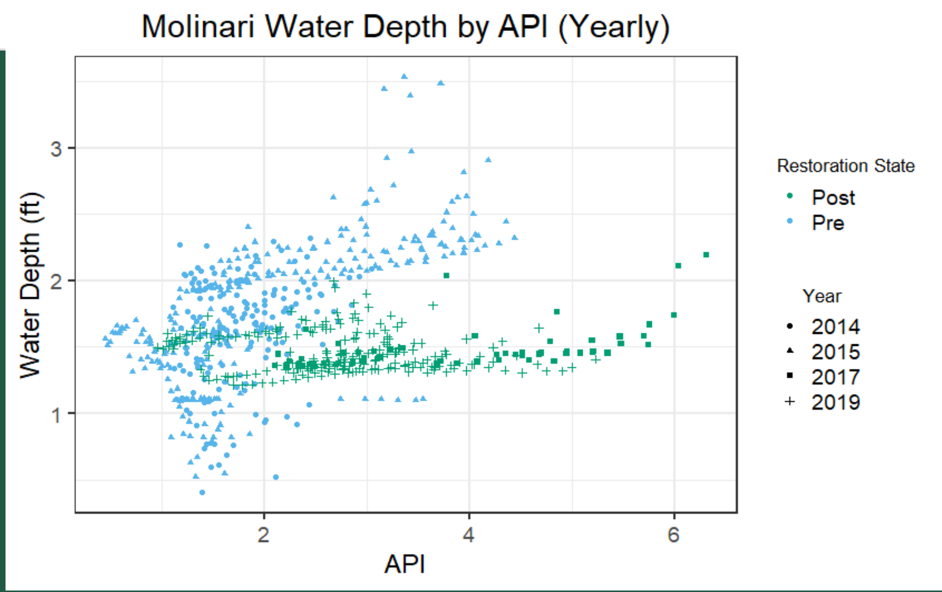
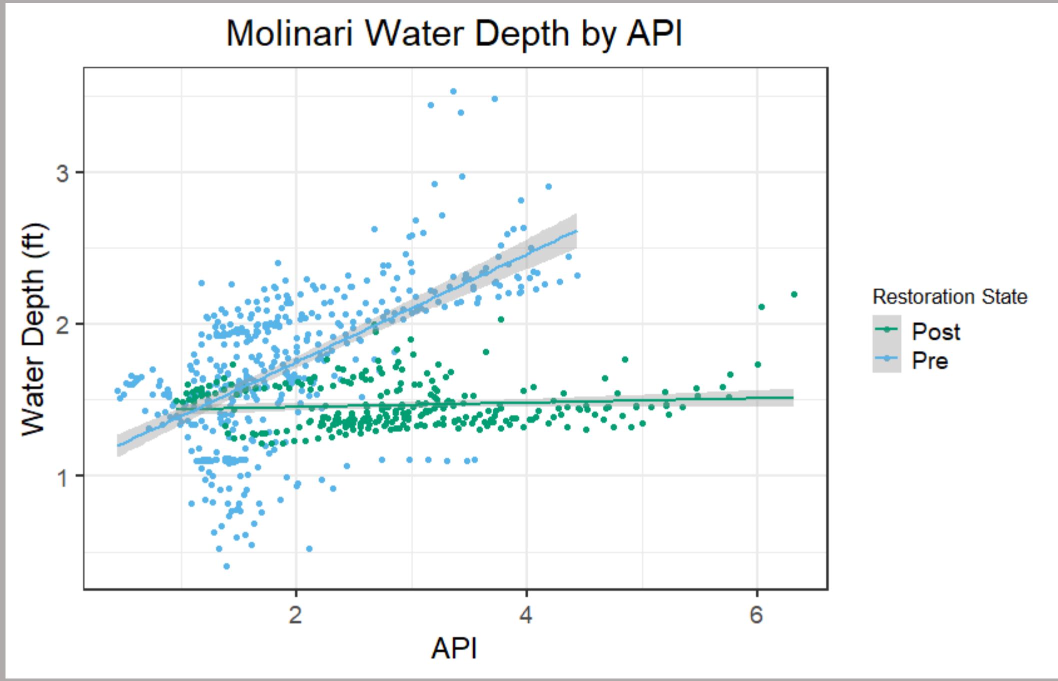
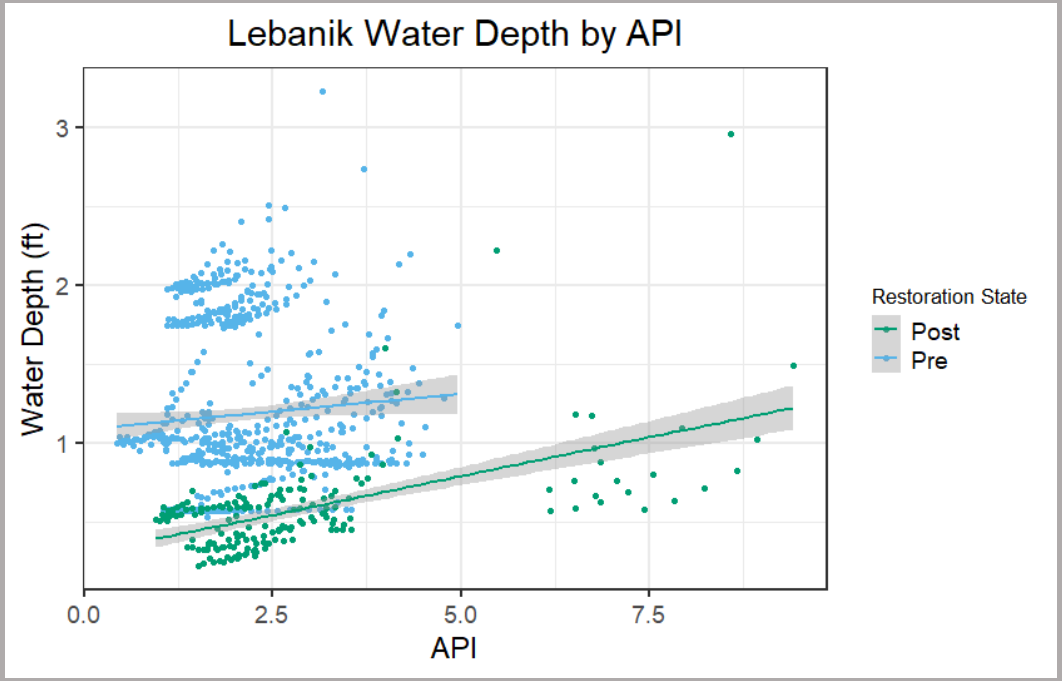




Flatter slope post-restoration (green) indicates water level is not influenced by periods of high precipitation as much as it was pre-restoration (blue)





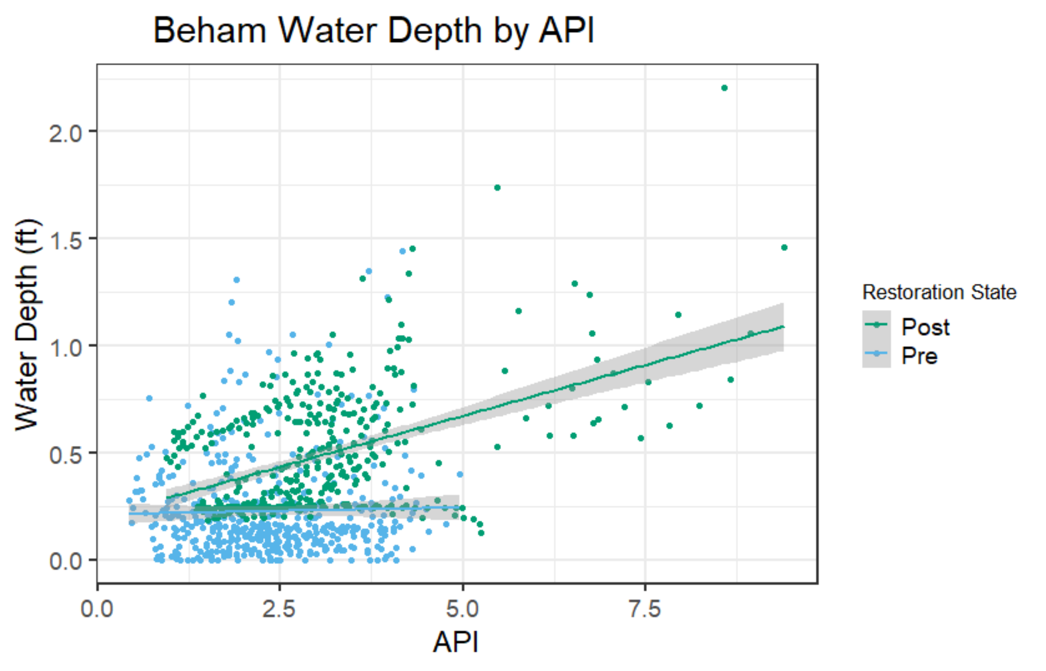
Wadeable (larger) streams

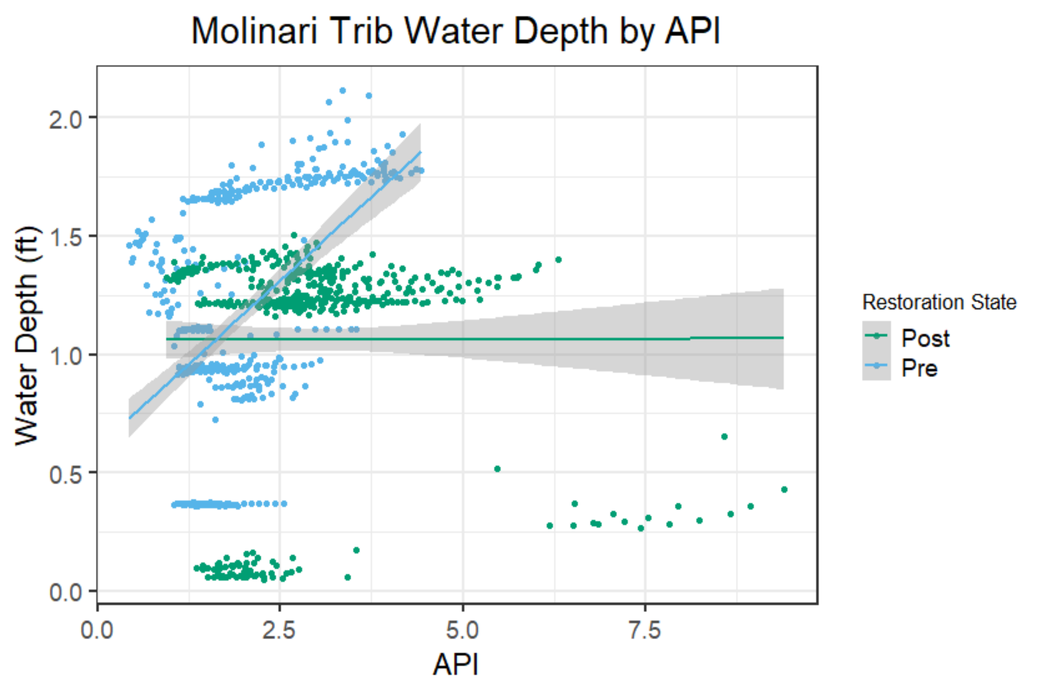
Molinari – 14.2 mi^2 - Slope decreased post-restoration. Water level stays consistent over a wide range of wetness and is not influenced by periods of high precipitation as much as it was pre-restoration.

Less flashy

Lebanik – 20.9 mi^2 - Water level was lower post-restoration. Contrary to expectation, it behaves oppositely Molinari and the slope increases post-restoration. Water level was more influenced by periods of high precipitation after restoration

More flashy





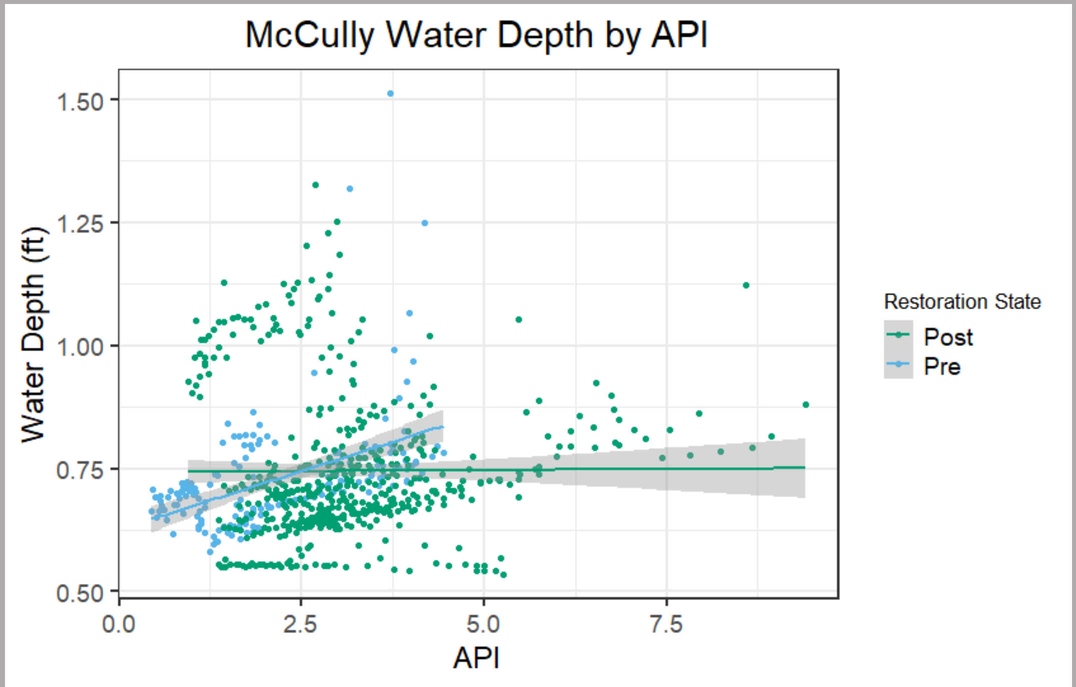
Midsized headwater streams

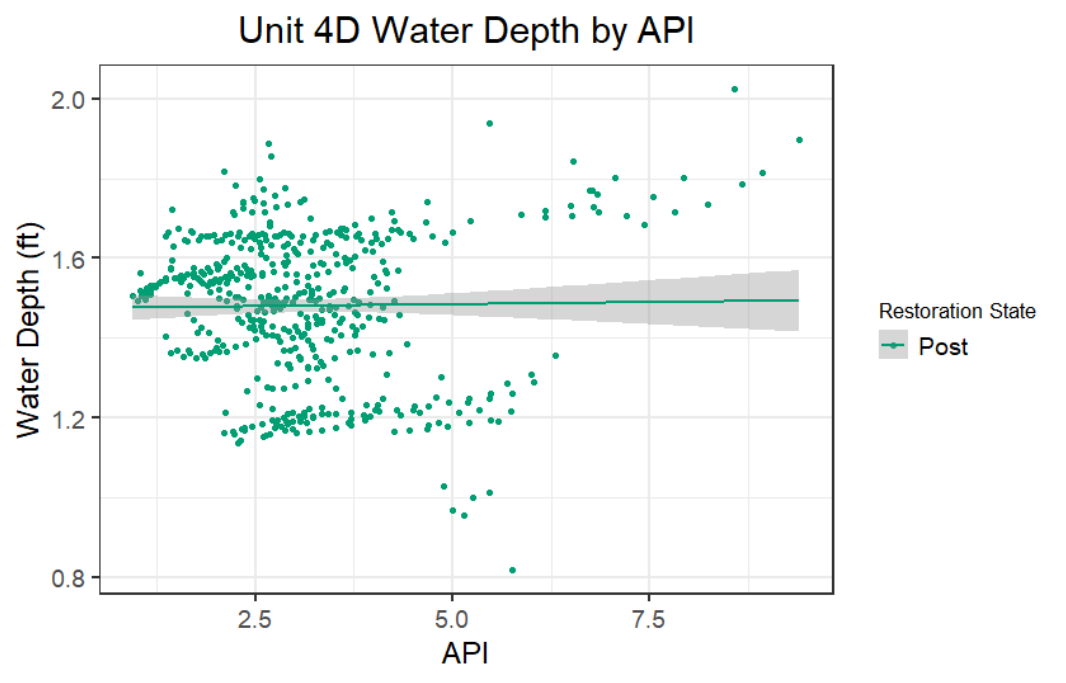
Beham – 3.0 mi ^{2} -Water level was higher post-restoration. Slope increased post-restoration.

More flashy

Molinari Trib – 0.83 mi ^{2} - Slope decreased post-restoration. Water level is not influenced by periods of high precipitation as much as it was pre-restoration.

Less flashy





Smallest (Primary) headwaters

McCulley – 0.05 mi ^{2} - Slope decreased post-restoration

Less flashy

Unit 4D – 0.05 mi ^{2} - no pre-restoration data, but the trendline is flat like most of the other sites post-restoration, so likely a decrease

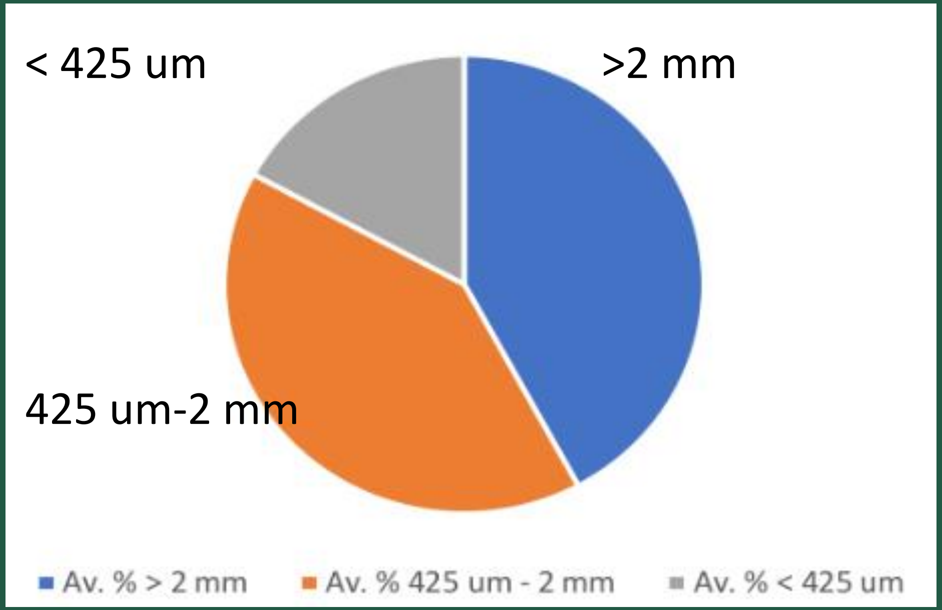
Likely less flashy

Sediment Dynamics

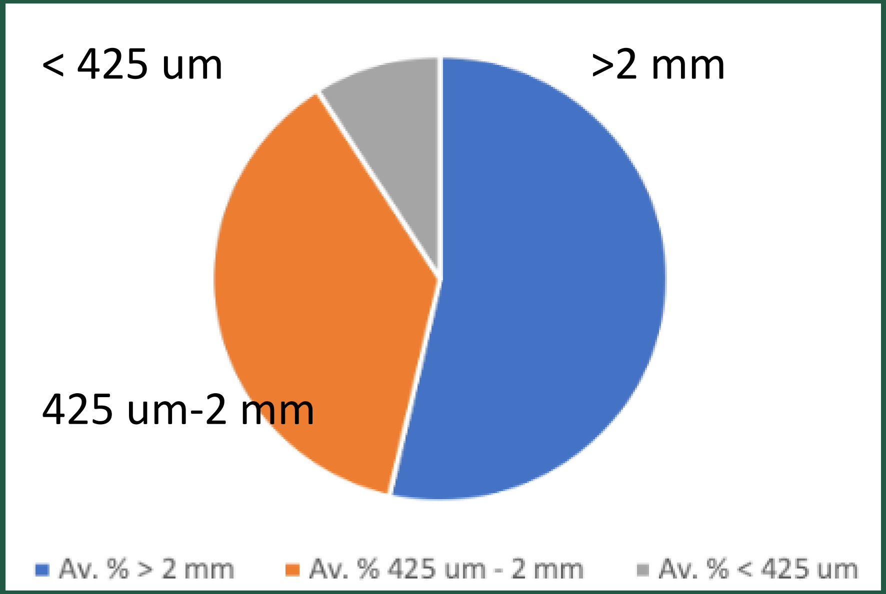
- Sediment pit traps at all downstream sites
- Grain size distribution
- TN and TP concentrations
- Trowel method when needed

Sediment retention

Restored stream complexes retained more fine-grained sediment

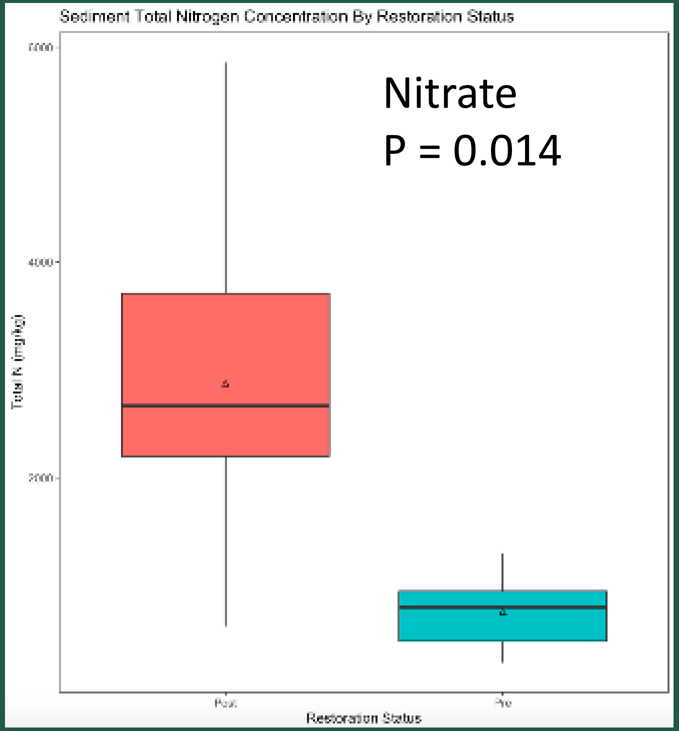


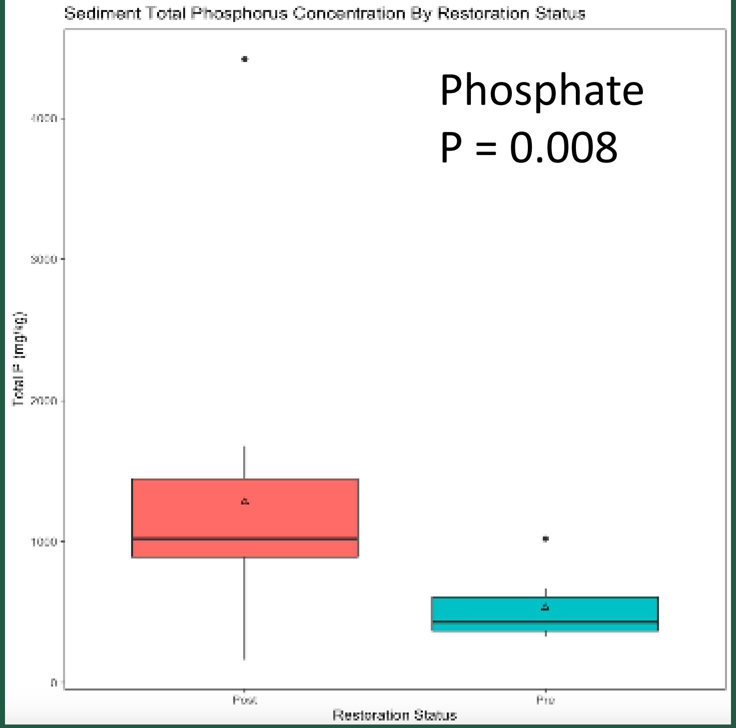
Unrestored (Forested channel)



Sediment Nutrients

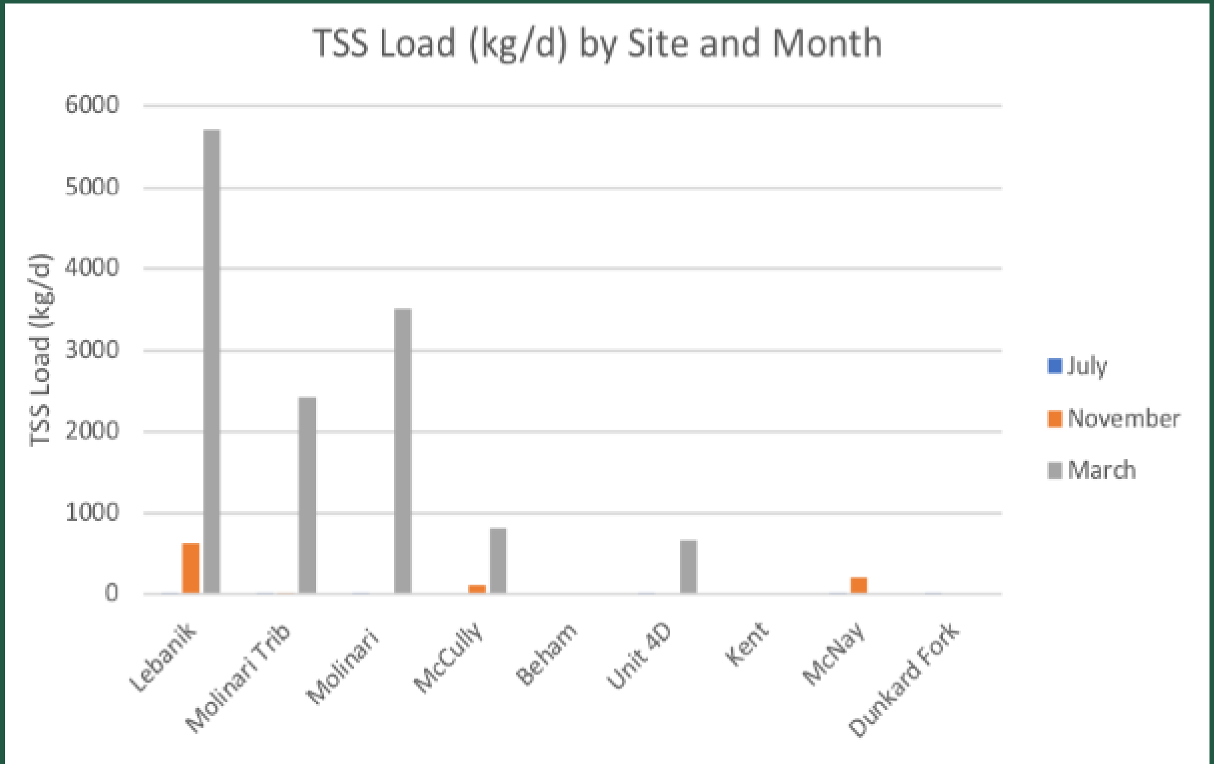
- Higher nutrients in restored sites

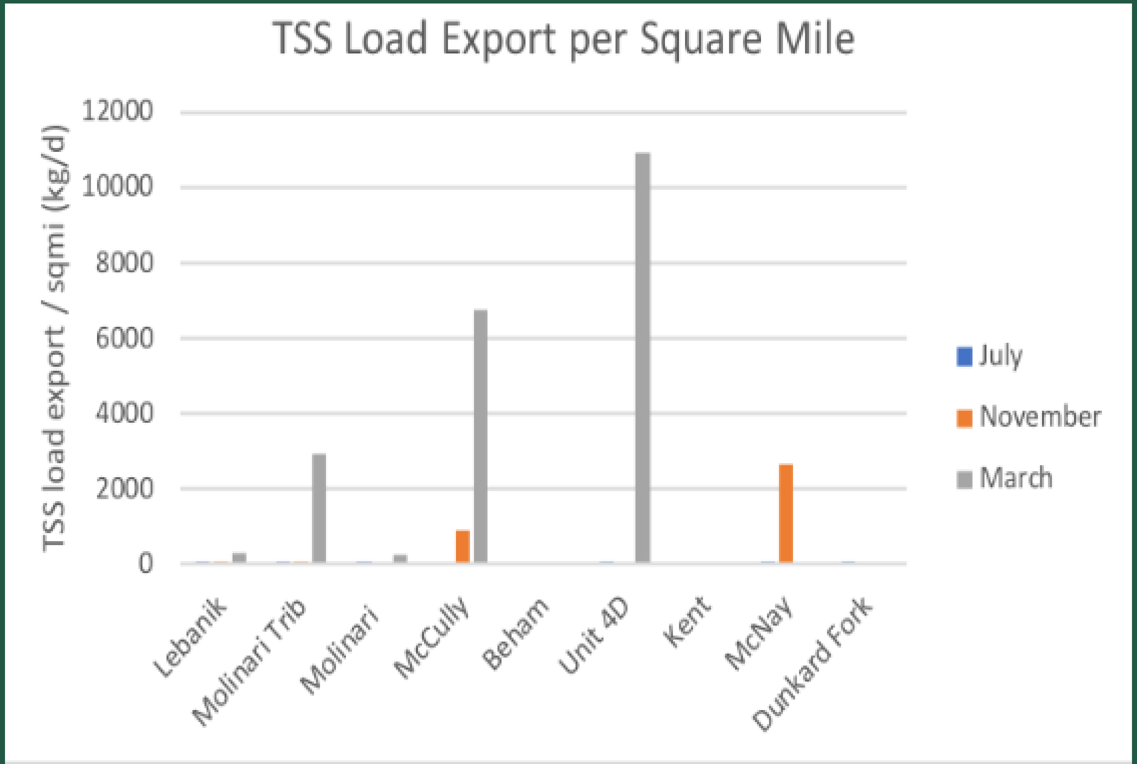




Sediment Dynamics - still in process

- TSS load export/sq mi was highest in high flow, lowest during low flow months (July)

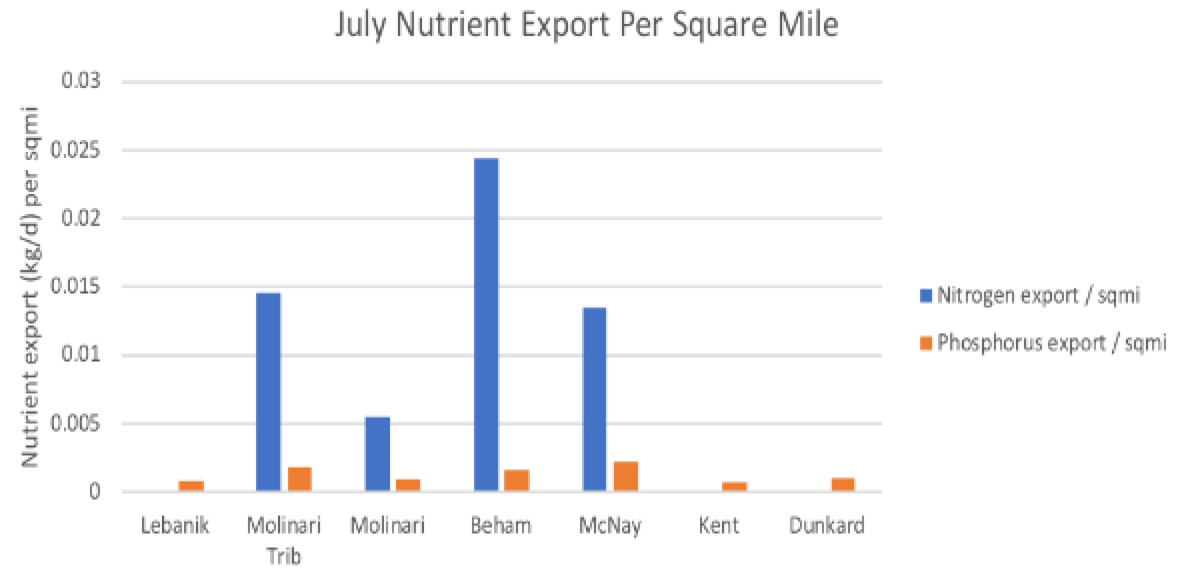


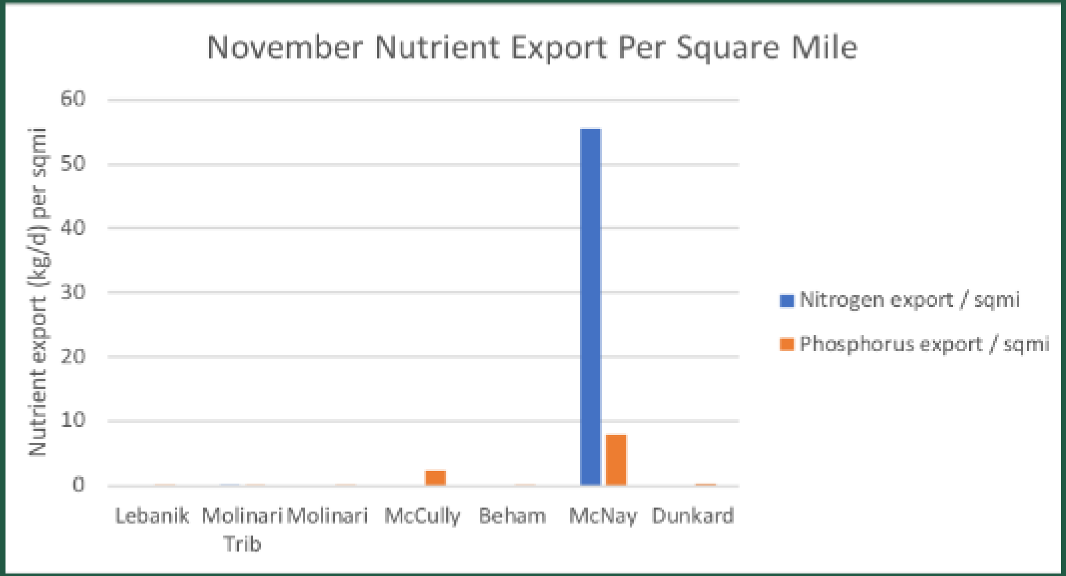


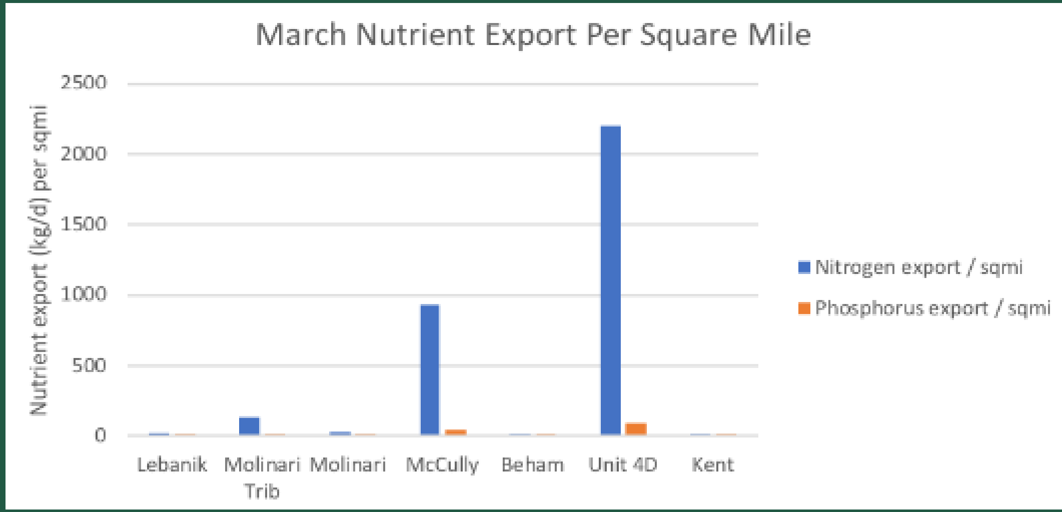
Nutrient Flux – still in progress

Varies with flow (season)

Lowest export in July







Macroinvertebrates

SAMPLING METHODS

Quant: Riffle – kicknet (n=3)

Depositional – ‘bucket’ (n=5)

Qual: Edges, woody debris, pools – 20 jabs with D-ring dipnet

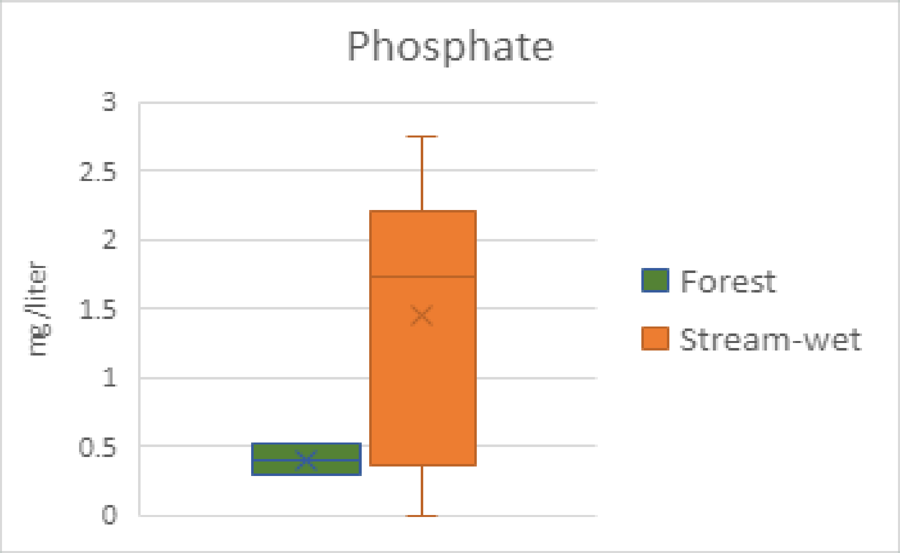
METRICS

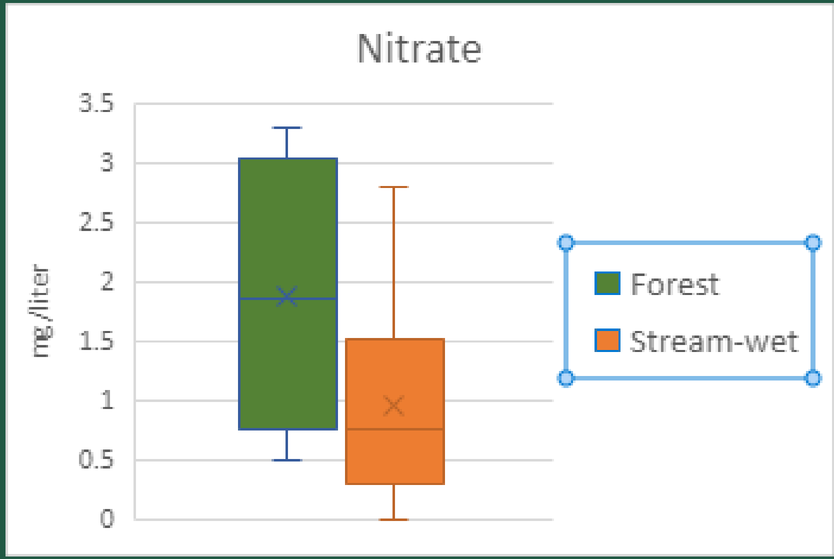
- Total biomass, abundance, richness, diversity, %EPT
- Biomass of Elmidae, Heptageniidae, Hydropsychidae and Chironomidae

Periphyton

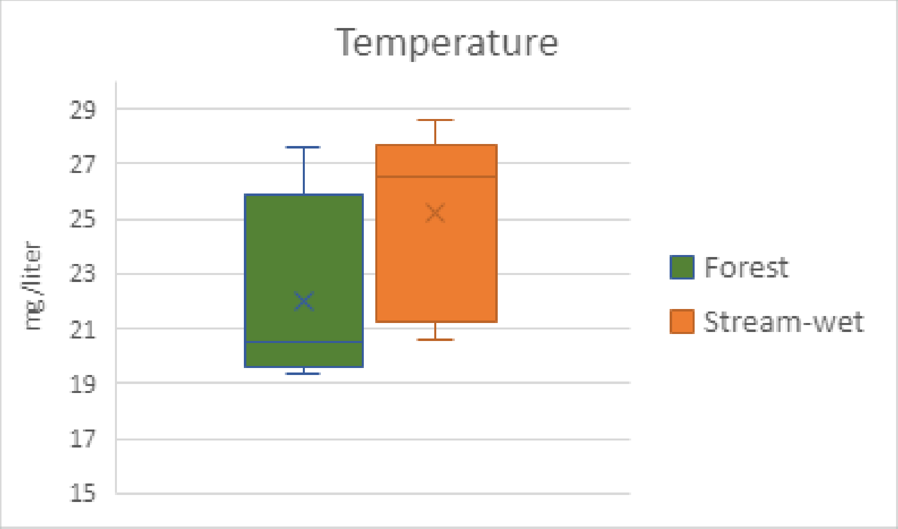
- July 2019
- 10 rock scrubs
- Lyophilized
  - AFDM
  - Chlorophyll *a*

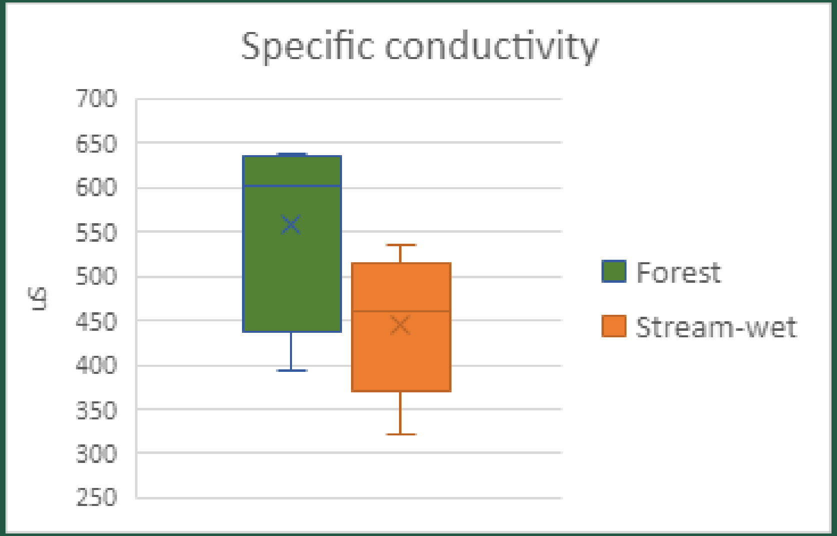
Water quality in July 2019





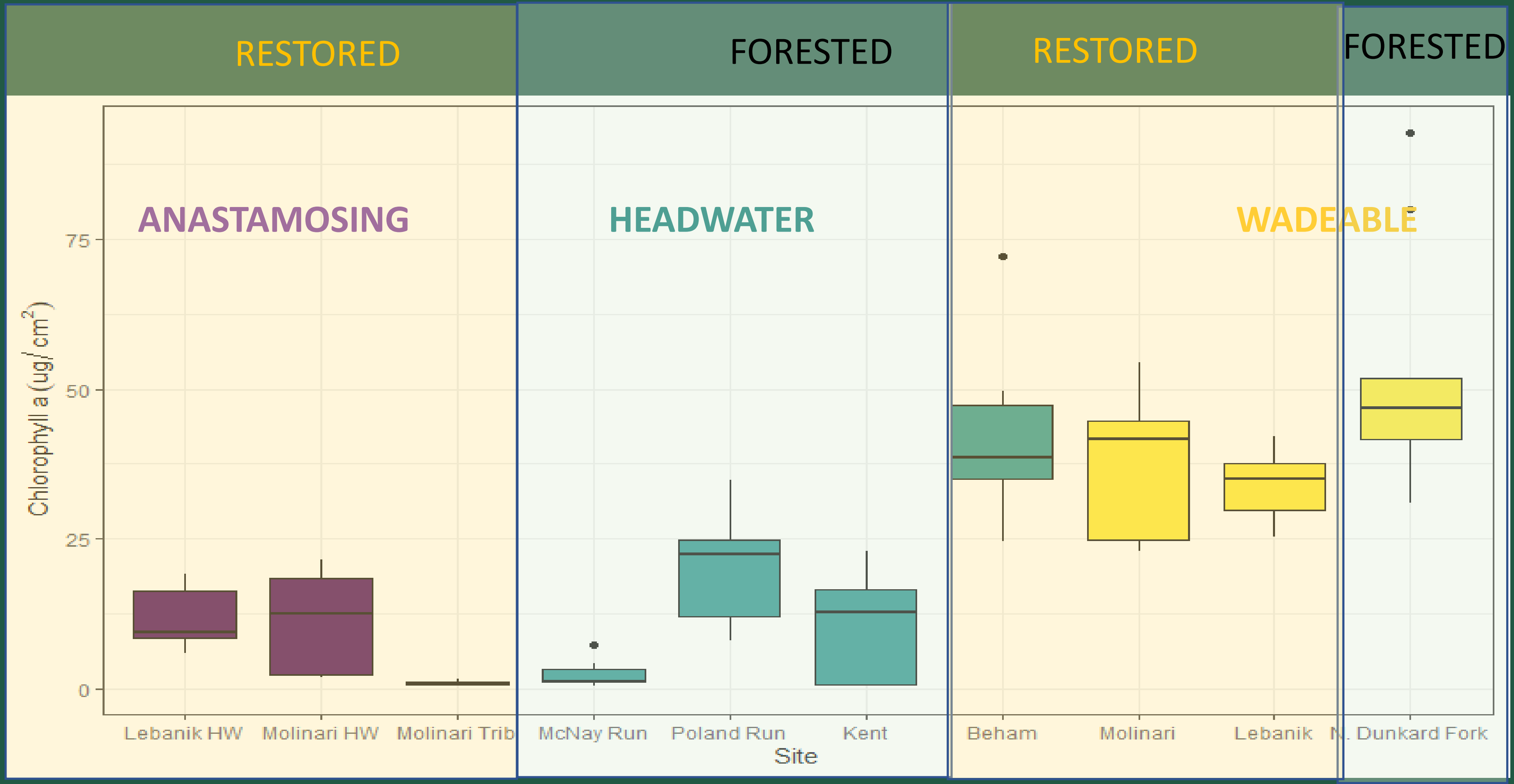
Nitrate levels did not differ between restored sites and forested ($F_{1,8}$ = 1.7971, p = 0.22)

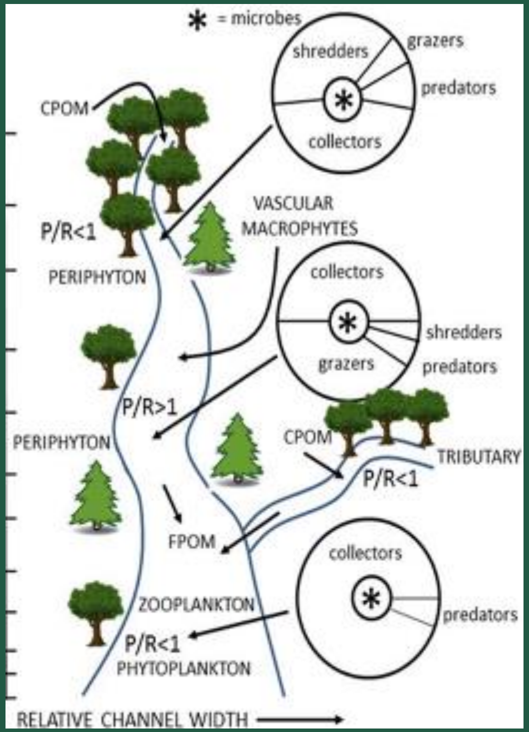




Phosphate levels did not differ ($F_{1,8}$ = 3.892, p = 0.084)

Periphyton influenced by stream size, not restoration status

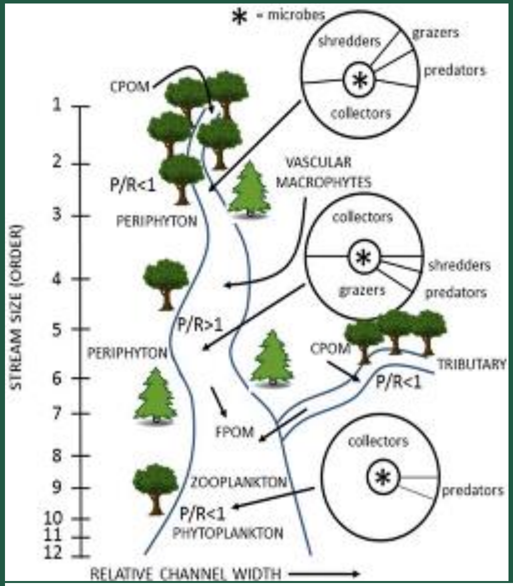


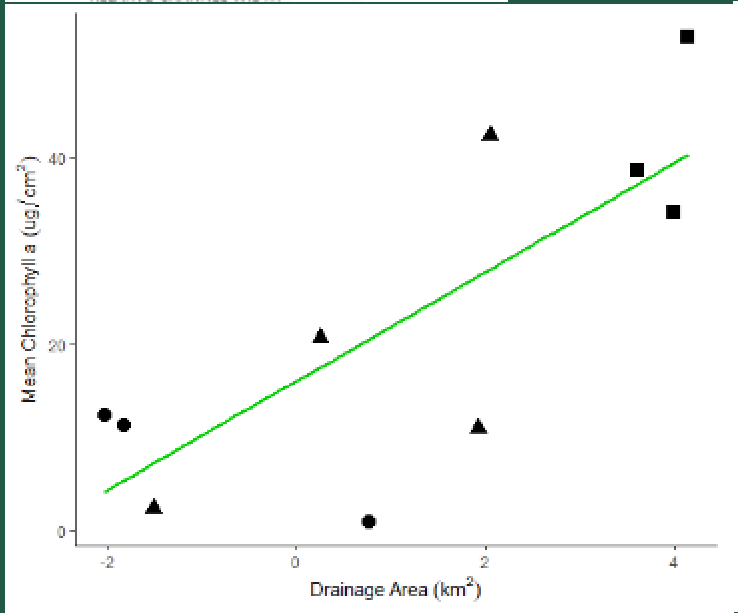


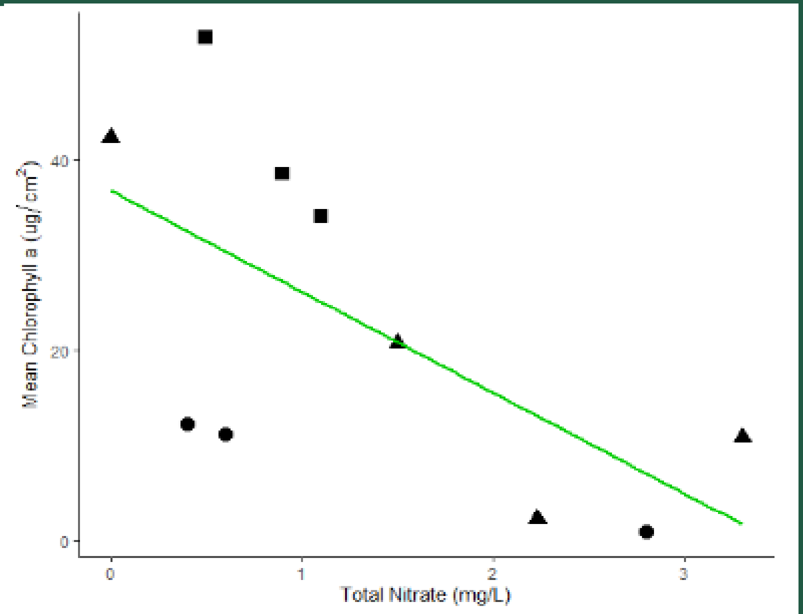
Mean chlorophyll a differed between sites ($F_{9,79}$ = 28.74, $p < 0.0001$) and stream size ($F_{2,86}$ = 37.02, $p < 0.0001$) but not between forested and restored sites ($F_{1,87}$ = 0.1642, $p = 0.6863$).

Mean AFDM (g) did not differ among stream size ($F_{2,27}$ = 0.4608, $p = 0.6356$), or between forested and restored sites ($F_{1,28}$ = 0.0257, $p = 0.8738$)

- Chlorophyll a increased with drainage area
- Negative correlation with nitrate

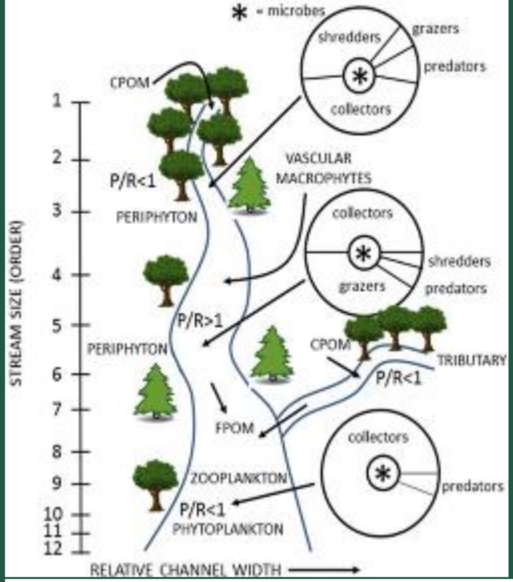




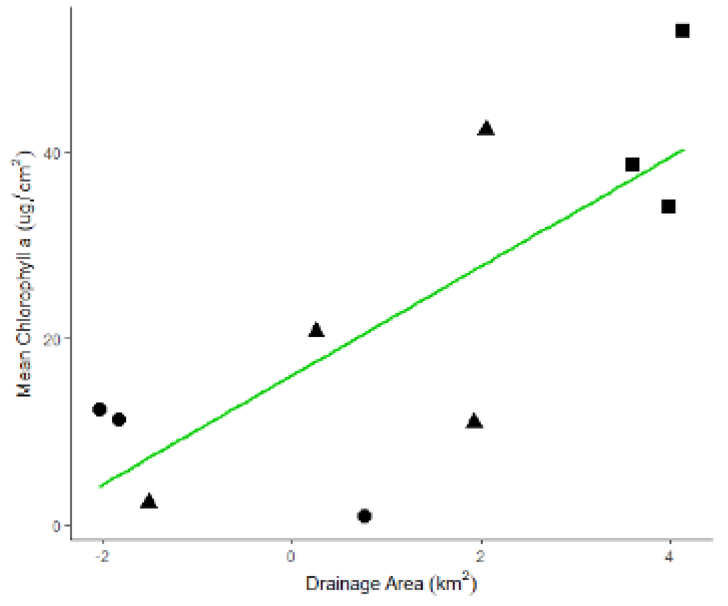


Drainage Area and Mean Chlorophyll a
Linear: R^2=0.60, $F_{1,8}$ = 11.9, p = 0.0087

Total Nitrate and Mean Chlorophyll a
Linear: R^2 = 0.42, $F_{1,8}$ = 5.79, p = 0.043



- Chlorophyll a increased with drainage area
- Negative correlation with nitrate
- Periphyton predicted macro biomass, abundance



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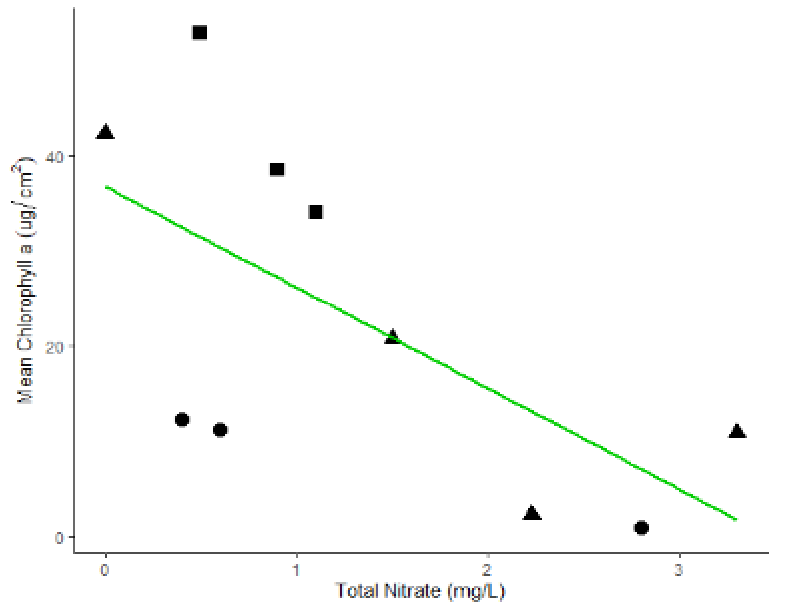

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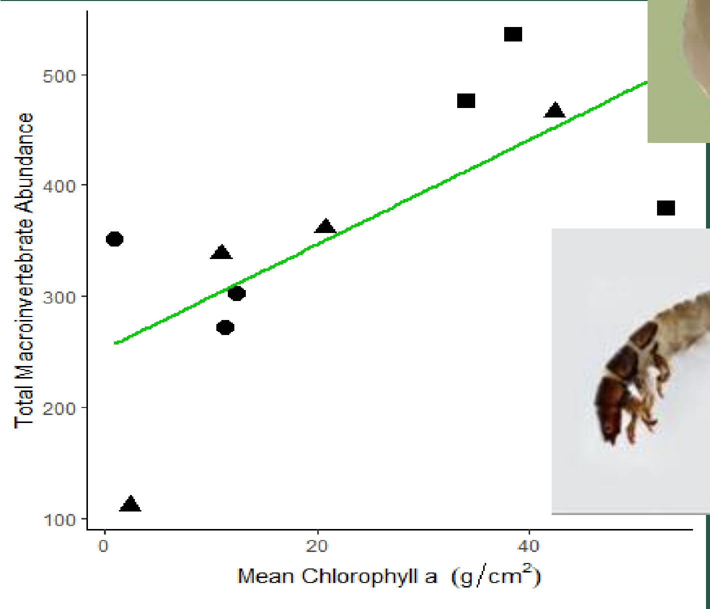
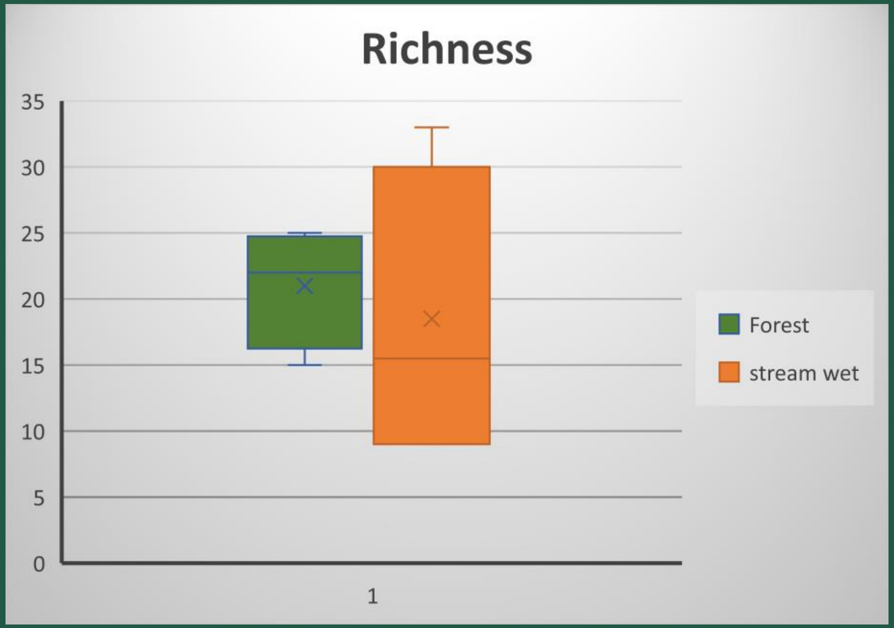
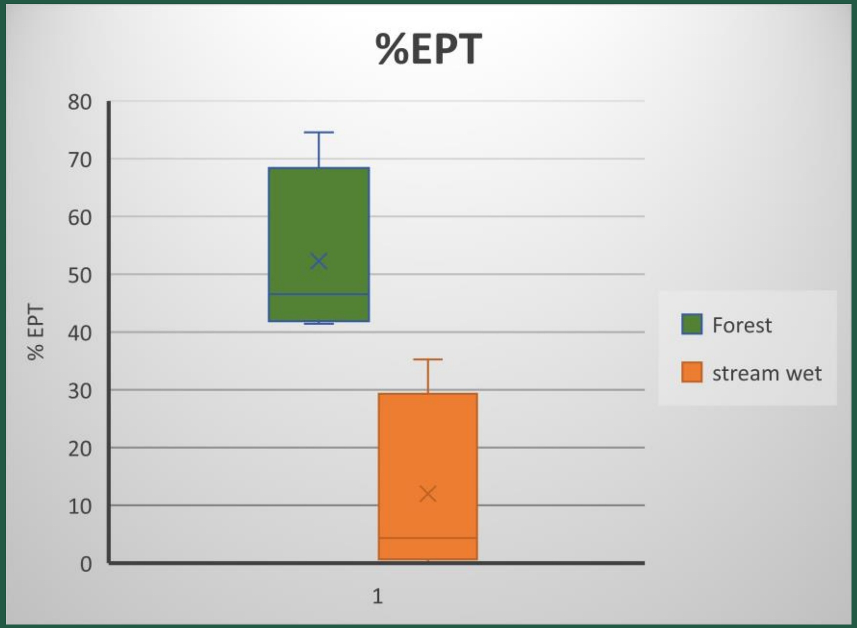


Macroinvertebrate abundance correlated with chl a biomass R^2 = 0.50, $F_{1,8}$ = 8.15, p = 0.021

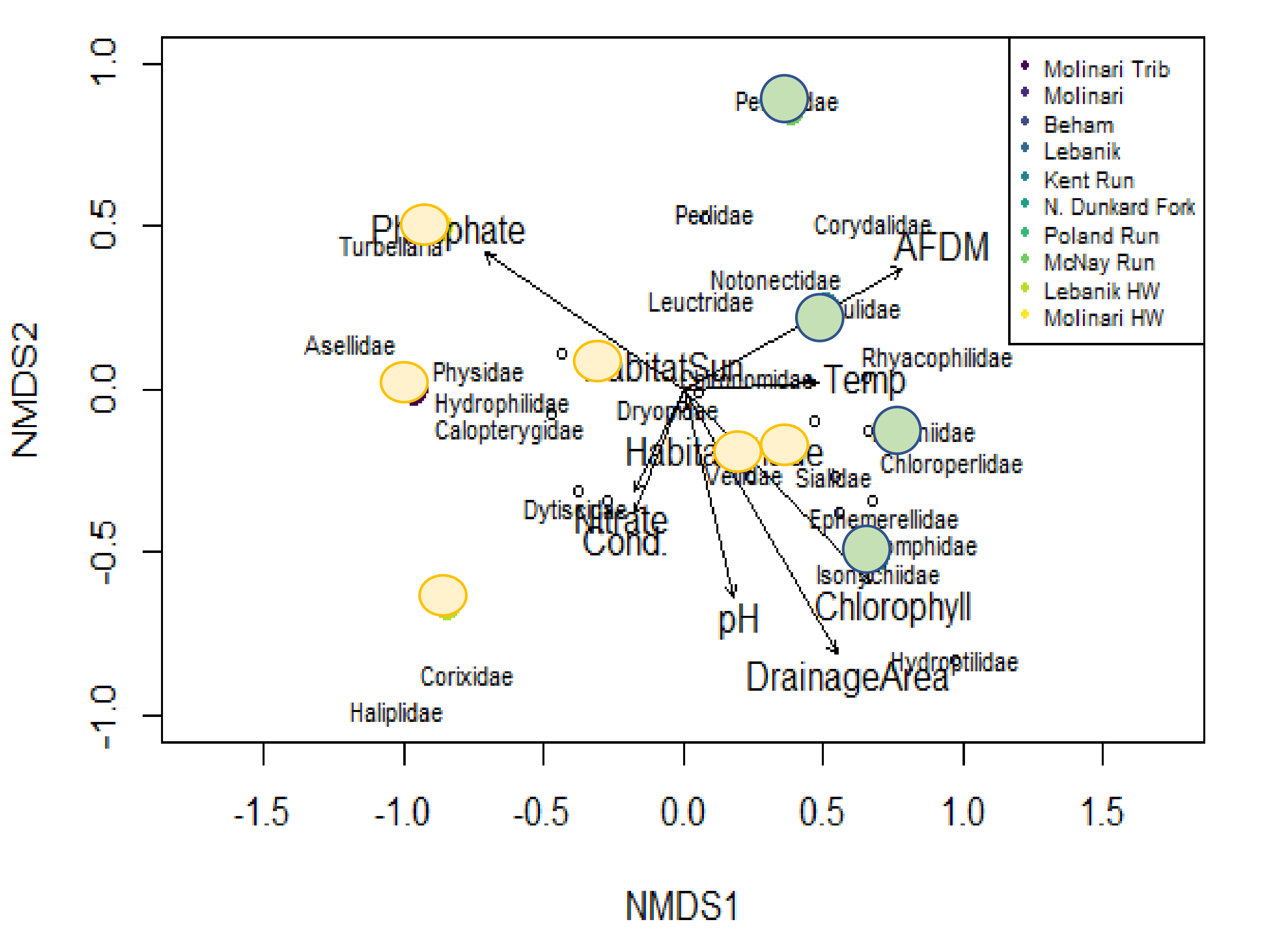
Restored sites (stream-wetland complexes) had similar taxa richness but fewer EPT taxa





% EPT Taxa not affected by drainage area ($F_{1,8}$ = 0.8086, p = 0.395) but did differ between forested and post-restoration stream complexes ($F_{1,8}$ = 16.681, p = 0.003)

Macroinvertebrate community composition differed between restored and unrestored sites



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Family composition differed between restored stream-complexes and unrestored forested sites ($F_{1,8} = 2.7969$, $p = 0.033$) and stream size ($F_{2,7} = 3.0251$, $p = 0.012$)

Functional links between nutrients > periphyton > macroinvertebrate biomass (Braccia et al. 2023)

Organic matter too?

- inputs
- breakdown
  - (shredders)
- retention/export

Litter bags, water TOC, woody debris inventory, terrestrial litter traps, soil organic content (SOC)

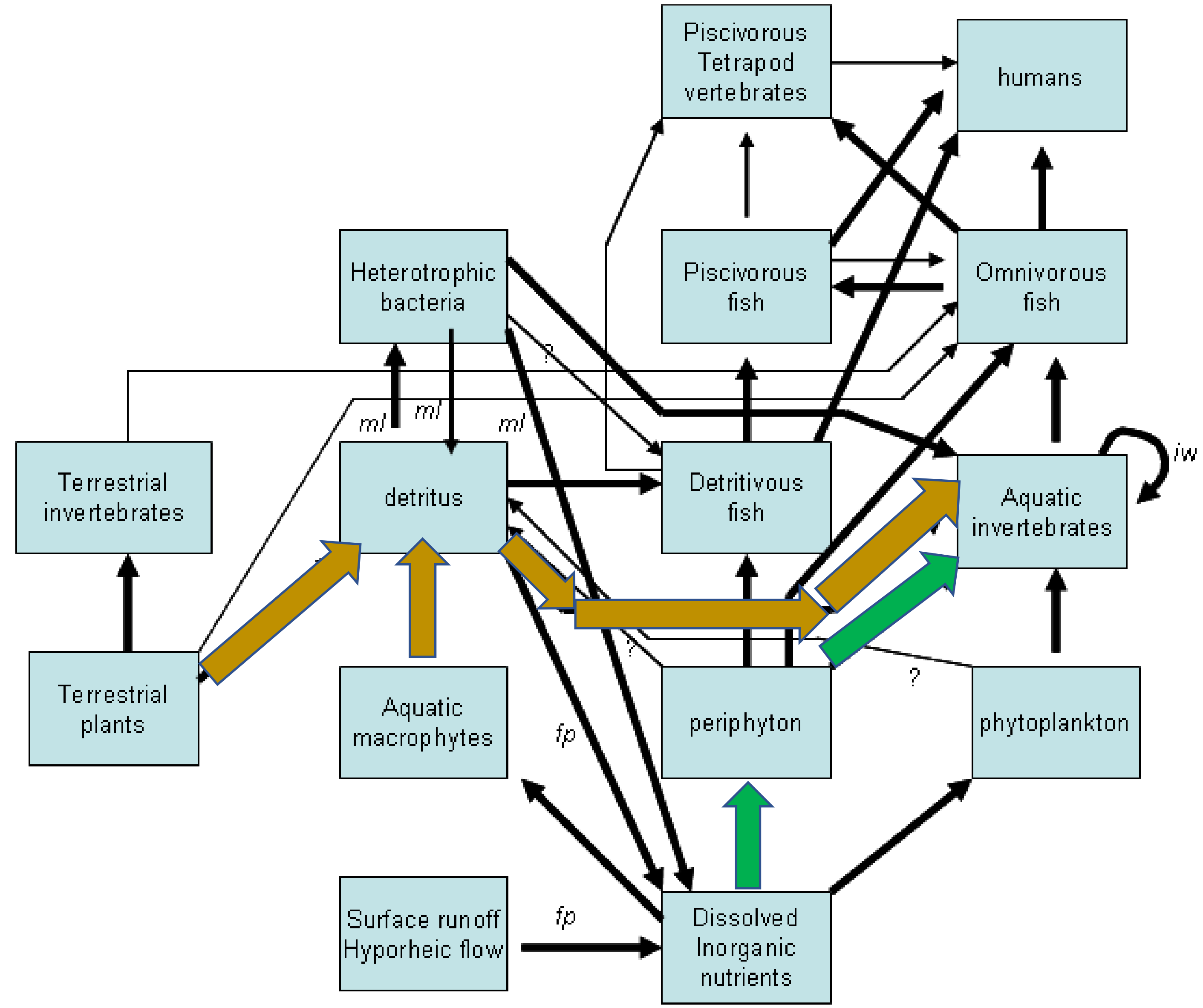


Figure 1: Generalised food web for floodplain-river ecosystems (adapted from Winemiller 2003)
Boxes are aggregate material pools and vectors represent consumer resource interactions with thick arrows representing dominant pathways (ml= microbial loop path, fp = nutrient pathways enhanced by flood pulses, iw = invertebrate web having complex trophic structure involving invertebrates and ? = poorly quantified pathways).

Water Total Organic Carbon (TOC): a useful measure?

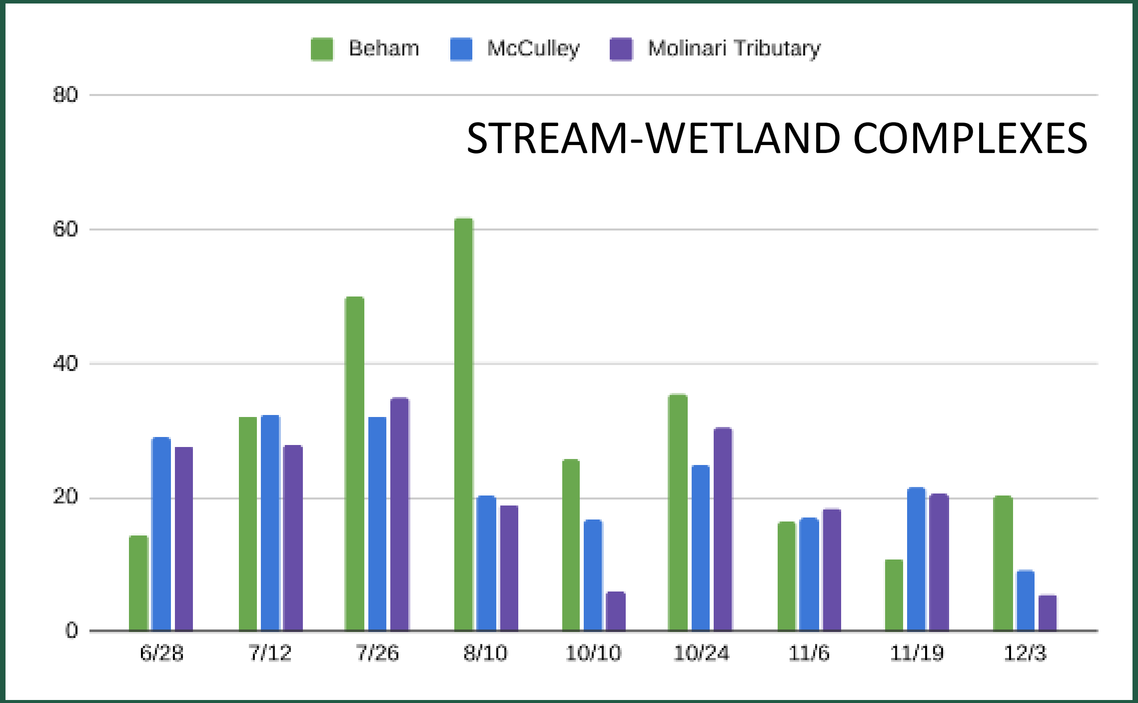
bog	33 ppm
marsh	17
Eutrophic lake	12
Oligotrophic lake	2
River	7

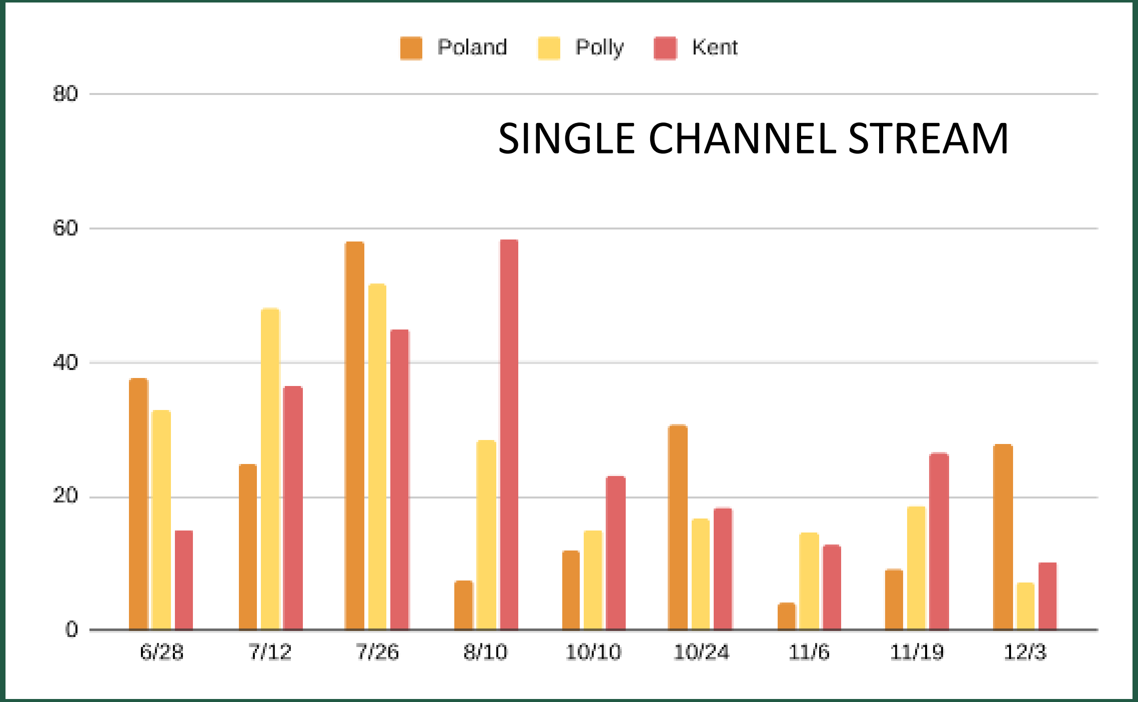
Hach Test 'n Tube method

TOC measured using DR2800 spectrophotometer

TOC and Season $p < 0.05$

No effect of restoration status

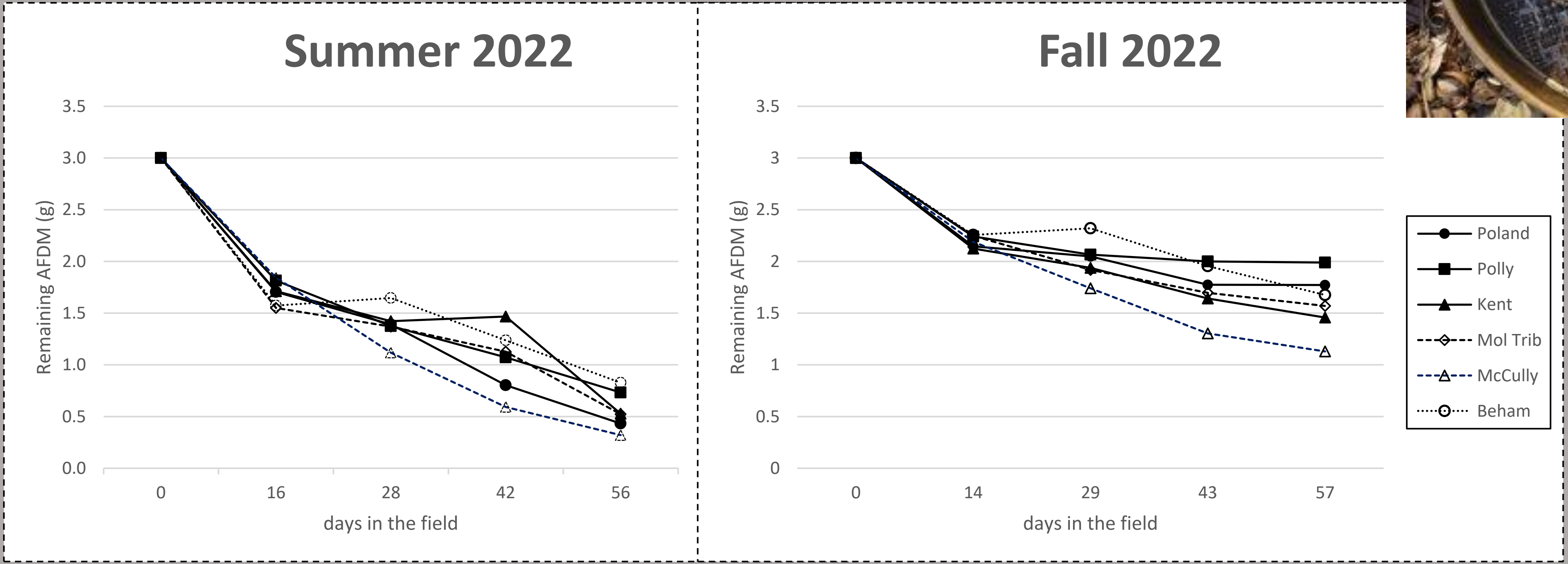


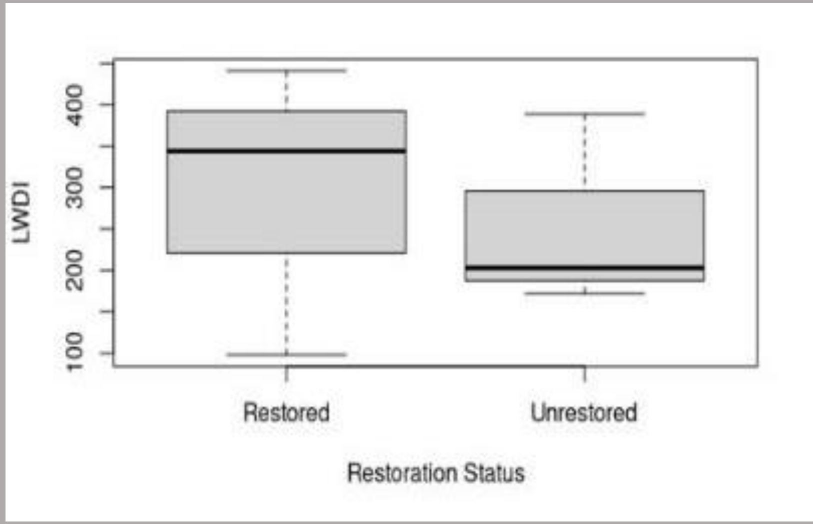


Leaf litter breakdown

Predicted faster decomposition in stream-wetland complexes

- not supported





Large Woody Debris Index (LWDI)

- 100 m reach
- Dead wood >10 cm diameter and > one-m long
- More than 3 pieces together is a ‘debris dam’

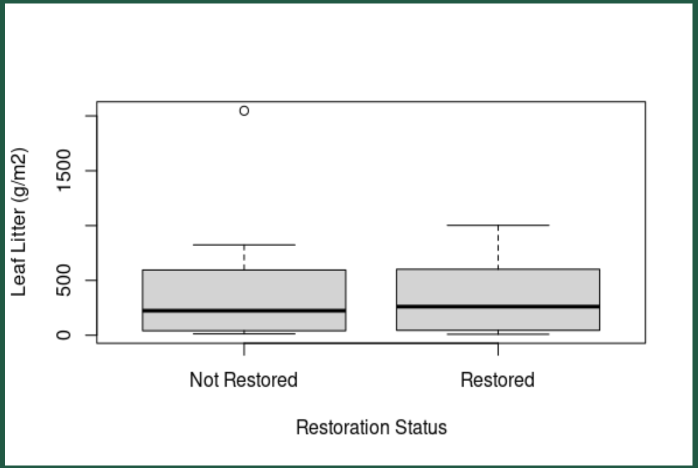
For each piece of wood:

Length/Diameter (cm)
Type (bridge, ramp, buried, and submerged)
Structure (amount of branches/roots attached)
Stability (potential mobility)
Orientation (degrees), Bankfull width

No relationship between large woody debris and TOC or Restoration Status

Leaf Litter Inputs

- 5 baskets per site
- Random placement with in the 100m stretch of stream with a 3m buffer on each side of the stream
- Collected every 2 weeks (10/10, 10/24, 11/6, 11/19 and 12/3)
- Leaf litter dried and weighed



No statistical relationship between leaf litter input and TOC or Restoration Status

Soil Organic Matter (SOC)

- Twenty cores per sample reach
- Within 3 m of stream channel
- Pooled and oven dried
- Ground and sieved (500g of fine soil)
- 3 reps of 50g of soil per site
- Ashed at 400° C for 3 hours
- Mass Loss on Ignition = Soil Organic Content

No effect of soil organic matter on TOC.

Soil organic matter higher at restored sites $p<0.05$

Conclusions

Water storage

- Increased at four of six restored sites
-

Sediment

- Higher proportion of fine-grained sediment at restored sites

Nutrients

- Sediment: Higher N and P in restored site sediments
- Dissolved N and P variable

Periphyton biomass follows stream size/light and nitrate, not restoration status

- Predicts macroinvertebrate biomass (esp. scraper-grazer and collector-filterers)

Macroinvertebrate

-Restored sites had similar taxa richness and diversity, high biomasses, but fewer EPT taxa

Organic matter

-Carbon Inputs (woody debris, leaf litterfall) and litterbag decomposition not different

-Total organic carbon (TOC) varied by season, not restoration status

-Soil organic content (SOC) higher at restored sites

Acknowledgements

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  - Pennsylvania Department of Environmental Protection
  - Land Studies and RES
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    Nichole Kirchner, Nicole Mazzone,
    Sebastian Teas

Western Pennsylvania Conservancy

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