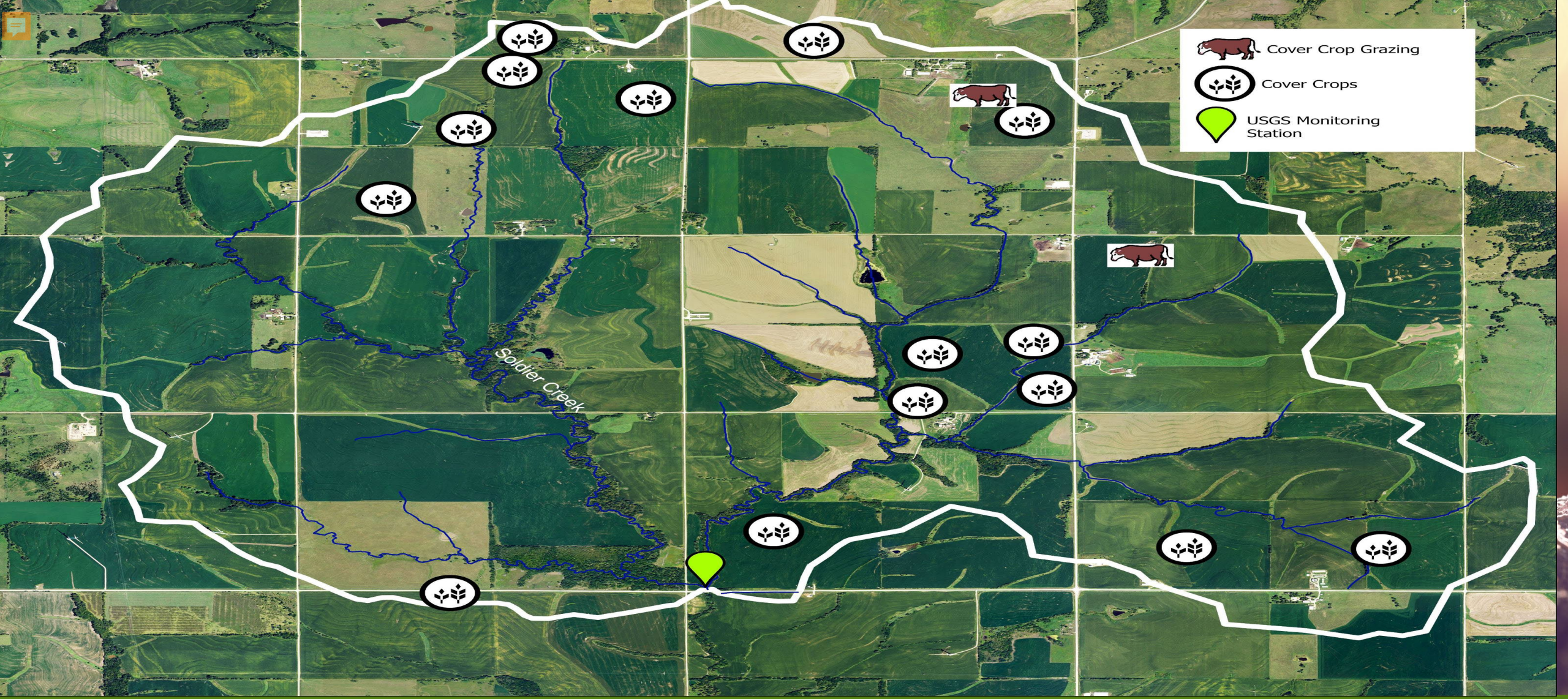


Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 1- It's Origin.

Kansas Department of Health and Environment
Division of Environment

Scott Satterthwaite November 10, 2026

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 1- It's Origin.

Even the cows are interested in learning about healthy soil!

(I am guessing one is fixated on a morsel in someone's back pocket.)



There is a PDF of the entire 4-part presentation on the back table.

Soil Health workshop exercise in field near Hays, KS

Source KDHE WMS

THANKS TO THE TAG TEAM FOR HELPING PUTTING THIS PRESENTATION TOGETHER.

Scott Satterthwaite- KDHE Watershed Management Section (WMS)

Jonathan (Jon) Wedel- Kansas Hydrologist for the USGS

Jack Lapin- Stream Scientist for KDHE Bureau of Water

Maija Weaver- Graduate Research Assistant for Dr. Gido at K State

I haven't seen any study in Kansas looking at a watershed in this holistic manner, if you have, please let us know.

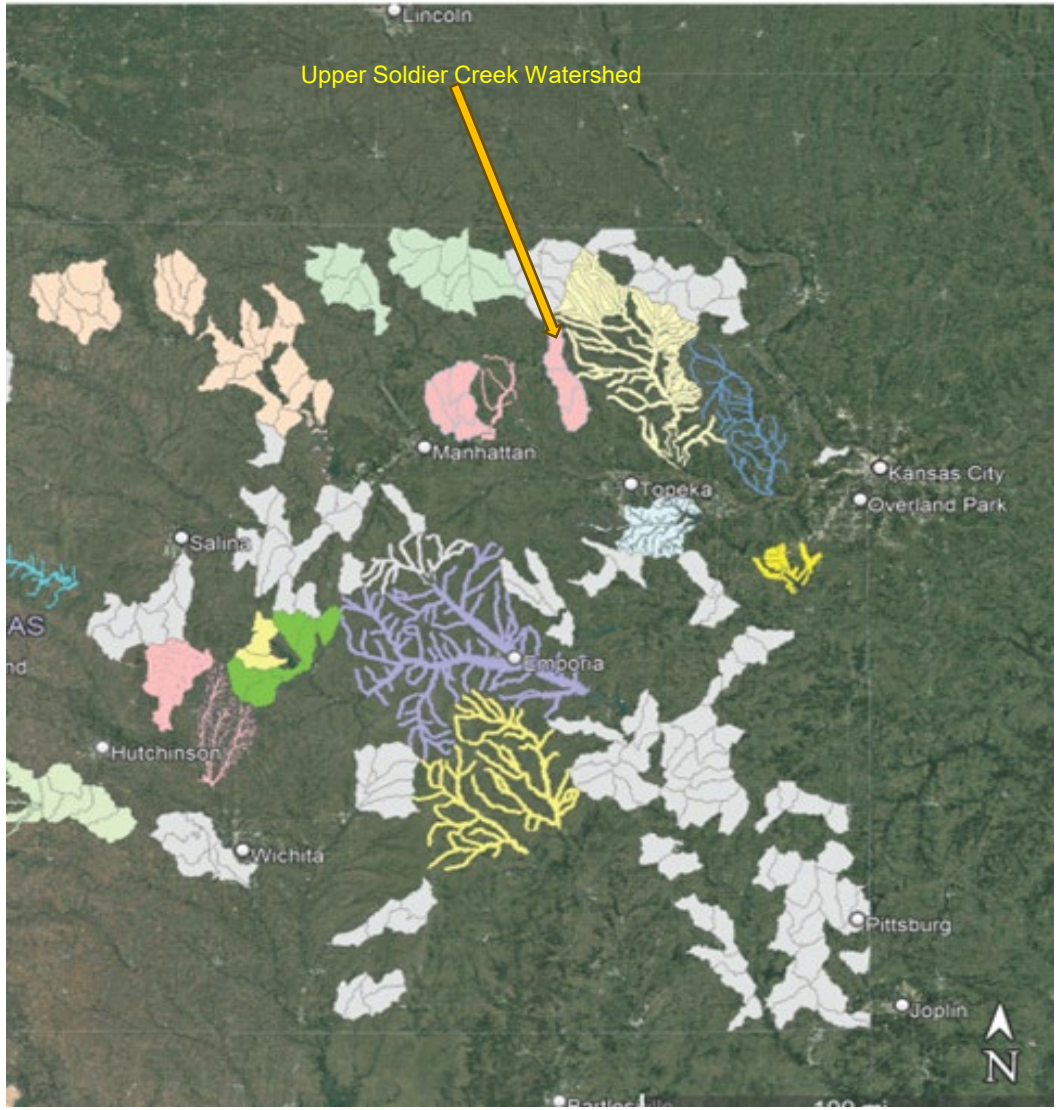
Watershed Management Section

- Through Environmental Protection Agency (EPA) Section 319 and State Water Plan Funds.
    - Develops and Implements the Kansas Nonpoint Source Pollution Management Plan.
        - Watershed Restoration and Protection Strategy (WRAPS)
        - Drinking Water Protection
        - Local Environmental Protection Program
        - Water quality certification of state and federal actions not necessarily requiring a National Pollutant Discharge Permit (NPDES).

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 1- It's Origin.

A Collaborative Solution – Watershed Restoration and Protection Strategy- WRAPS

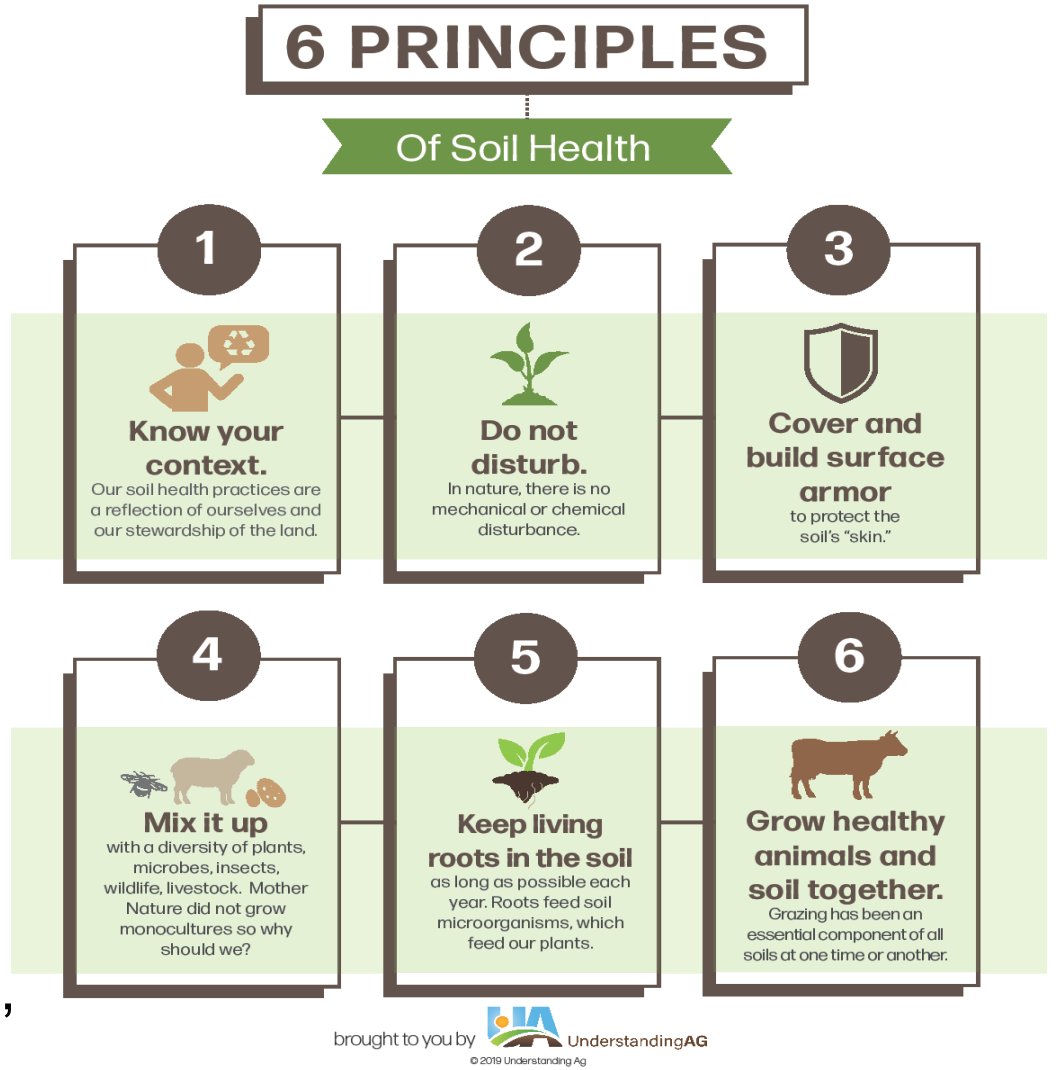
Kswraps.org



Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 1- It's Origin.

Mechanisms for Most Water Quality Protection Nonpoint Source Pollution Control and Agriculture Pollutants They Address

- **Cover:** living- nutrients, sediment, pesticides; non-living- sediment, nutrients **(2 and 3)**
- **Keep living roots in the ground:** year around **(5).**
- **Avoidance:** physically or alternatives to tillage **(2)**
- **Natural predation/plant and livestock diversity**: pesticides, nutrients **(2) (6)**
- **Transform:** nutrients for crop availability **(4 and 5)**
- **Neutralize:** pesticides/bacteria
- **Minimize:** nutrients, sediment, bacteria, pesticides
- **Product/practice:** Alternatives-nutrients, sediment, bacteria, pesticides **(1)** and **(2)**
- **Filter:** nutrients, sediment **(2) (3) (4)**
- **Infiltrate and percolate**: Can reduce runoff, nutrients, sediment, bacteria, pesticides if managed right **1-6**



Identifying willing participants through workshop and door to door methods

KAWS Middle Kanas River WRAPS Coordinator already helping with 319 funding, just found farmers wanting to try something different.

Outcomes from KAWS/partners sponsored soil health workshops?

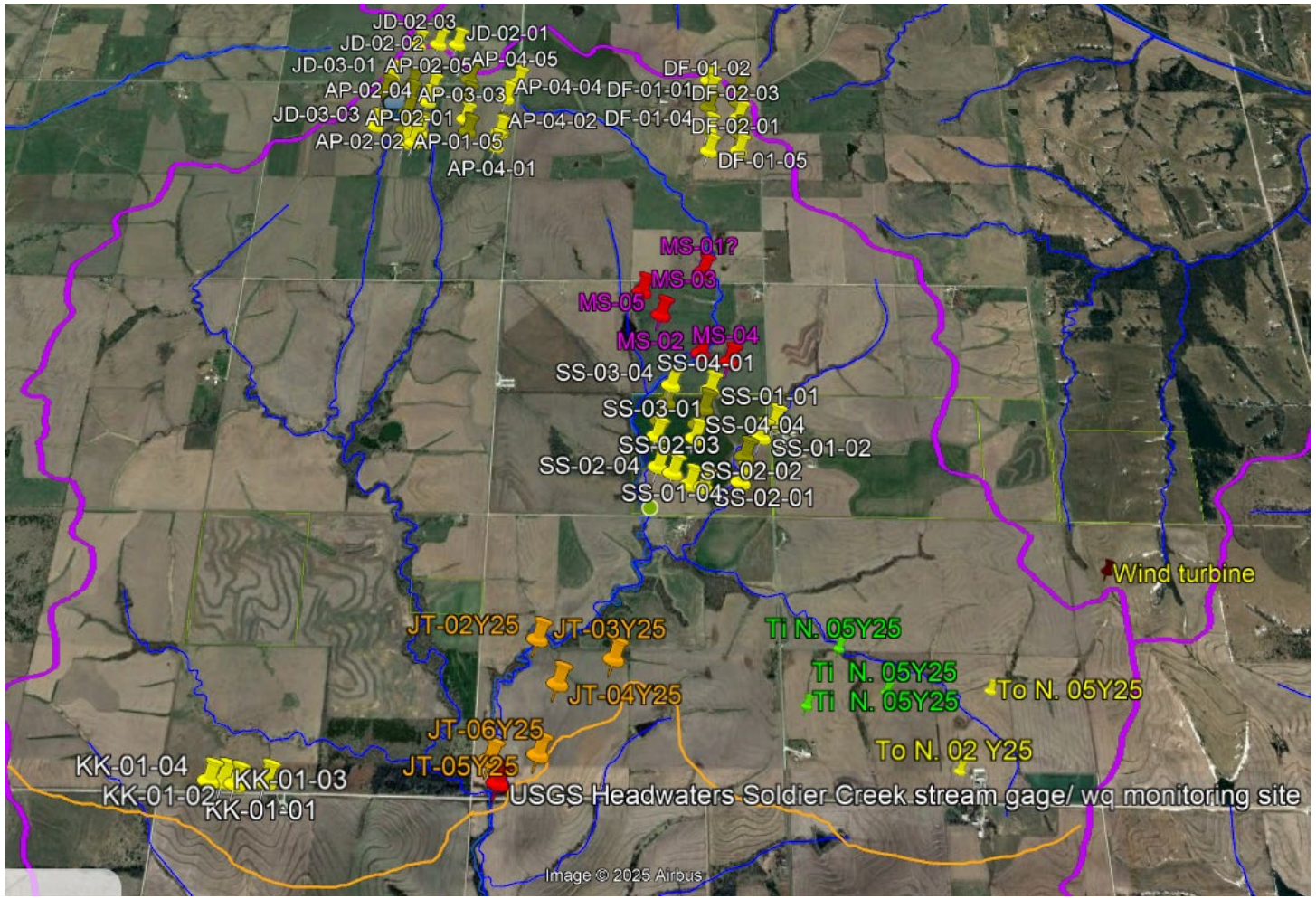
- Soil Health Coaching for workshop participants
- Understanding Ag Soil Health coaching for watershed participants

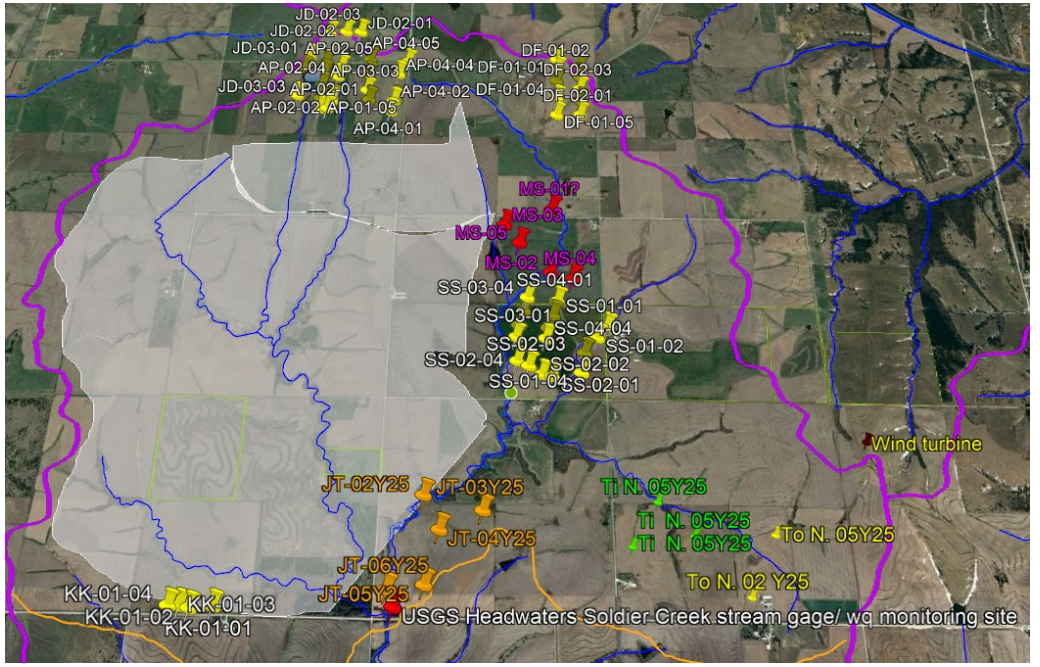


Source KDHE WMS

Upper Soldier Creek Watershed-Wide Soil Health Impacts on the Water Quality Hydrograph Ecology – Part 1- It's Origin.

We have three seasons of soil health data from each participating field.



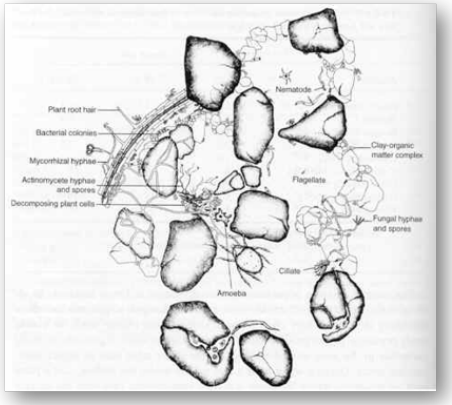


Out of an estimated 5,500 acres with landowners/operators contacted, 9 landowners/operators with approximately 1,000 acres participated

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 1- It's Origin.

SOIL HEALTH DATA COLLECTED FROM EACH FIELD BY A SOIL HEALTH COLLECTION AND ANALYSIS PLAN

Aggregate Stability, Bulk Density- Shows soil hydrologic function, water holding capacity, infiltration etc.



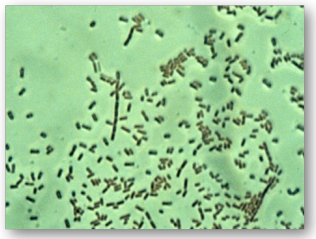
Source: KDHE-WMS Living Soil PPT. "Soil Organisms Living Within a Soil Aggregate"

Haney Test- pH, % Soil Organic Carbon and Matter also nitrogen and phosphorus and other nutrients available to the crop. Used for nutrient management recommendations and sometimes cover crop mixes.

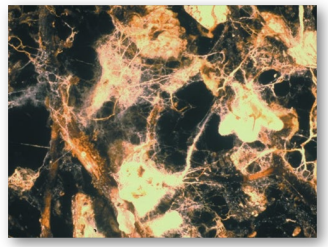
Nitrogen Phosphorus Potassium

PLFA- Phospholipid Fatty Acid Test- measures respiration and biomass of bacteria, fungi and their ratios, protozoa, other biology.

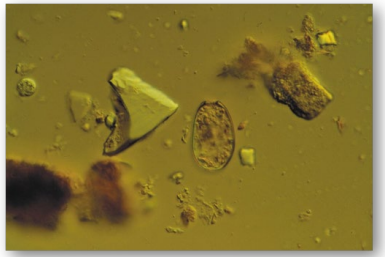
Total soil samples processed= approximately 500



Credit: Michael T. Holmes, Oregon State University, Corvallis



https://www.istockphoto.com/photo/mycorrhiza-gm526595591-52831392



https://www.istockphoto.com/photo/paramecium-bursaria-micrograph-gm117333415-7498383



View looking downstream at Soldier Creek near Corning, KS (06889110) Source USGS

Upper Soldier Creek Watershed Wide Soil Health Impacts on the Water Quality Hydrograph

- **Background on Best Management Practices**
  - Implementation of soil health principles (SHP) or best management practices (BMPs) may help improve soil properties by reducing soil disturbance, increasing biodiversity, maintaining soil cover, maintaining living roots all year, resulting in increasing water infiltration and soil moisture, and reducing soil temperature and reducing runoff (USDA-NRCS, 2023b).
  - Monitoring soil health BMPs (reduced tillage, prevention of overgrazing, maintaining soil cover, and crop rotation) in conjunction with continuous water-quality and soil moisture within the study area basin over the long term (10 years or more) will help to increase the scientific knowledge and enable future study design for similar research.
  - Some landowners will implement soil health BMPs even if it means their yield is less because they are committed to improving the soil health.
    - Return-on-investment may be higher in the long run since some of the BMPs involve reducing cost of inputs such as fertilizer applications, etc.

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 1- It's Origin.



Integrating livestock and minimal disturbance are also soil health principles



Source KDHE WMS

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 1- It's Origin.







Biodiversity, keeping the ground covered and with living roots year around are key soil health principles.

KDHE WMS

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 1- It's Origin.

AVERAGE, MINUMUM MAXIMUM and RANGE FOR SOIL HEALTH METRICS

Spring 2023

Comparison	AGGREGATE STABILITY % (indicator of infiltration and porosity)	HANEY TEST (biological respiration nutrient cycling for crop availability)	Organic Matter%	Phospholipid Fatty Acids (PLFA) Signatures (% of Total Biomass)			
				Bacteria	Fungi/Bacteria Ratio	String Fungi	Protozoa
Average	81.7	93.01	3.25	35.75	0.122	2.228	0.0596
Minimum	70.8	34.35	2.70	0	0.077	1.540	0.0014
Maximum	87.7	198.0	3.90	55.00	0.197	3.440	0.0101

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 1- It's Origin

AVERAGE, MINUMUM MAXIMUM and RANGE FOR SOIL HEALTH METRICS

Spring 2024

Comparison	AGGREGATE STABILITY % (indicator of infiltration and porosity)	HANEY TEST (biological respiration nutrient cycling for crop availability)	Organic Matter%	Phospholipid Fatty Acids (PLFA) Signatures (Count and % of Total Biomass)			
				Bacteria	Fungi/Bacteria Ratio	String Fungi	Protozoa
Average	81.7	82.24	4.1	54.70	0.190	2.422	0.170
Minimum	46.6	28.05	2.8	45.78	0.228	0	0
Maximum	90.9	87.52	6.8	62.66	0.300	4.41	1.83

Upper Soldier Creek Watershed-Wide Soil Health Impacts on the Water Quality Hydrograph Ecology – Part 1- It's Origin

AVERAGE, MINUMUM MAXIMUM and RANGE FOR SOIL HEALTH METRICS

Summer 2024

Comparison	AGGREGATE STABILITY % (indicator of infiltration and porosity)	HANEY TEST (biological respiration nutrient cycling for crop availability)	Organic Matter%	Phospholipid Fatty Acids (PLFA) Signatures (% of Total Biomass)			
				Bacteria	Fungi/Bacteria Ratio	String Fungi	Protozoa
Average	71.3	62.9	3.3	44.824	0.162	2.77	0.009
Minimum	46.1	28.05	2.1	32.100	0.121	2.28	0
Maximum	84.3	151.24	4.6	55.420	0.233	3.36	0.013

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 1- It's Origin



Take Aways from Todays Presentation



- A cost-share approach may get producers in the door, however, building relationships, providing coaching or mentoring and paying them for their data will result in more trust and better end results.
    - Reimbursing them to help them change toward improving soil health may increase likelihood of being able to do more studies in the same watershed.
- A concern is there is usually insufficient time to work these multi-disciplined/partner projects dependent on weather.
- U.S. Geological Survey Central Plains Water Science Center is developing a model for tracking hydrograph change and nutrient flow.
- Much more work needs to be done to connect improved soil health to watershed hydrograph, macro-invertebrate and intermediate stream fish communities.
    - A current study on nutrient (nitrogen) and sediment sourcing (stream bank or land) in the same watershed at the KU Geological Survey; going into the upper tributaries.

"BE GREAT INFILTRATE…WITH HEALTHY SOILS!!"

Scott L. Satterthwaite
Phone: 785-296-5573
Cell: 785-480-9837
Email: Scott.Satterthwaite@ks.gov

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 2- Realtime and On-site Water Quality Hydrograph Weather and Soil Moisture.

Soldier Creek Water Quality and Soil Health BMP Study

- Cooperative study between Kansas Department of Health and Environment and the U.S. Geological Survey Central Plains Water Science Center.
- Initial study period went from October 2020 through June 2025.
- A rescope to the study in June 2023 added soil moisture and weather, extending the study period through June 2028.

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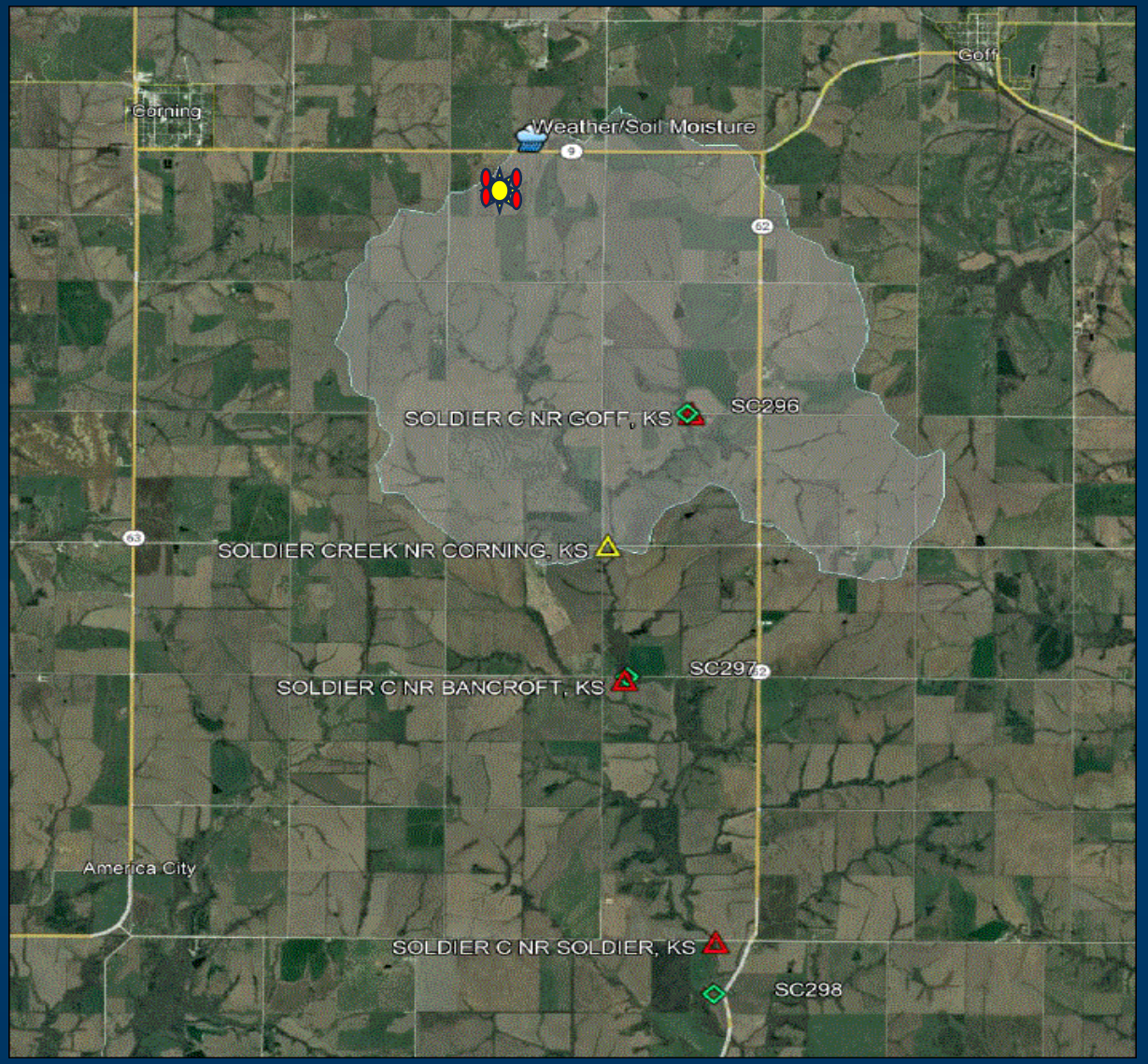


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Study Objectives

- Overarching aim of the study is to assess streamflow and water-quality at the downstream edge of a 5,915-acre basin at the headwaters of Soldier Creek on a watershed scale.
- Evaluate trends and changes over time in nutrient and sediment concentrations, as well as pesticides.
- Examine trends and changes over time in soil moisture and weather data.
- KDHE is monitoring bacteria levels and assessing annual changes in macroinvertebrates.
- Locations of fields adjacent to each other collecting soil moisture and weather data.
- Red shapes indicate soil moisture sites and yellow sun indicates meteorological station.
- Study sites were selected based on knowledge regarding the high probability that soil health BMPs would be implemented by the landowners.
- Limitations in spatial extent of soil moisture.

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Headwater Basin of Soldier Creek showing streamflow gage Soldier Creek nr Corning (includes water-quality monitor and water quality sampling, yellow triangle), KDHE historical water quality sample sites (green diamonds), historical USGS streamflow gages (red triangles), and weather/soil-moisture sites.

Soil Moisture

- Operate and maintain continuous soil moisture sensors at soil moisture station 1 near Corning, KS, and soil moisture station 2 near Corning KS.
- Have been collecting real-time continuous soil moisture and soil temperature data since May of 2024.
- Sensors are located at 5, 10, 20, 50, and 100cm depths.
  - Designed to stay in ground permanently
  - Low maintenance
- Data transmits hourly via data logger and displayed on Water Data for the Nation website.

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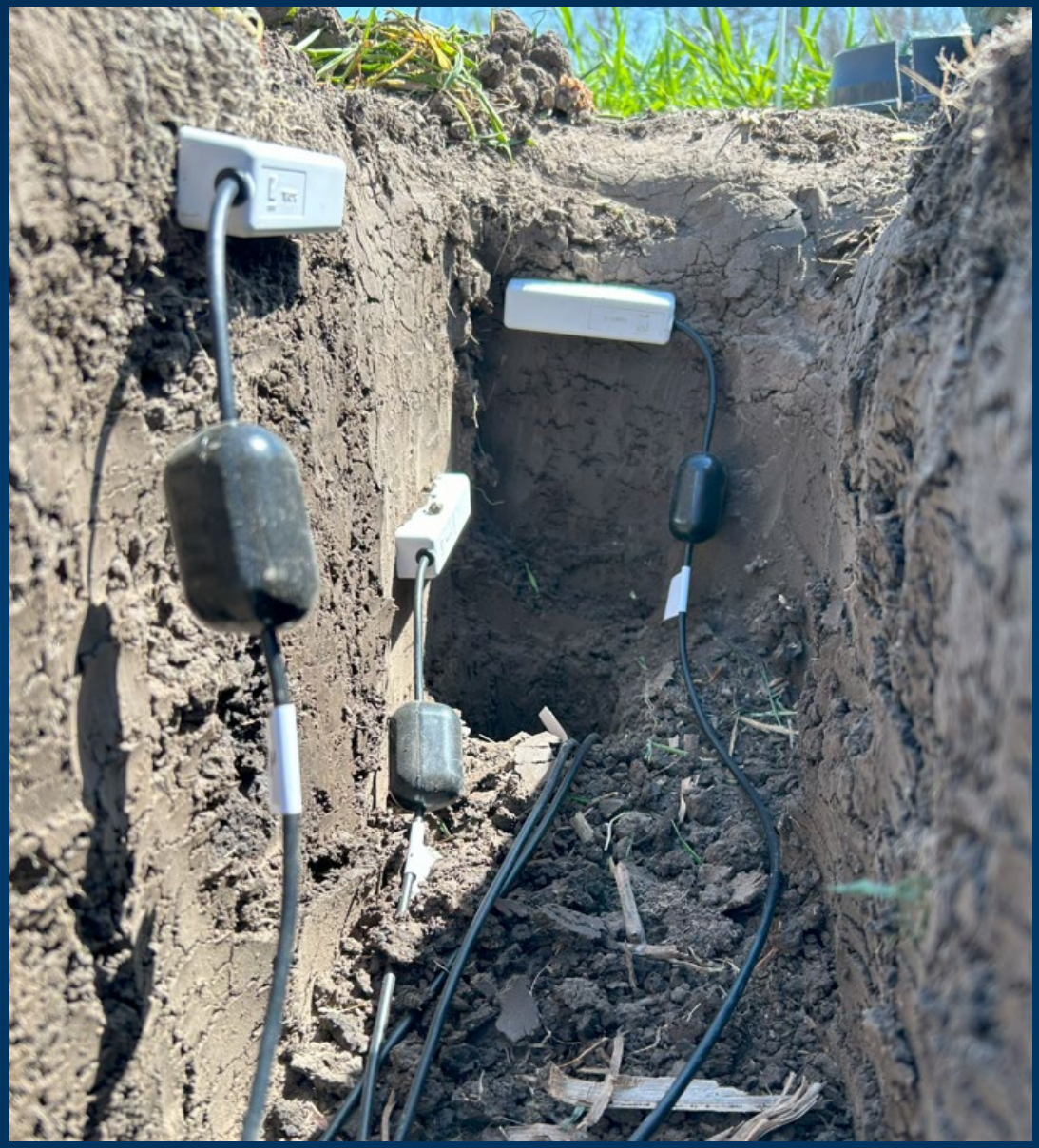
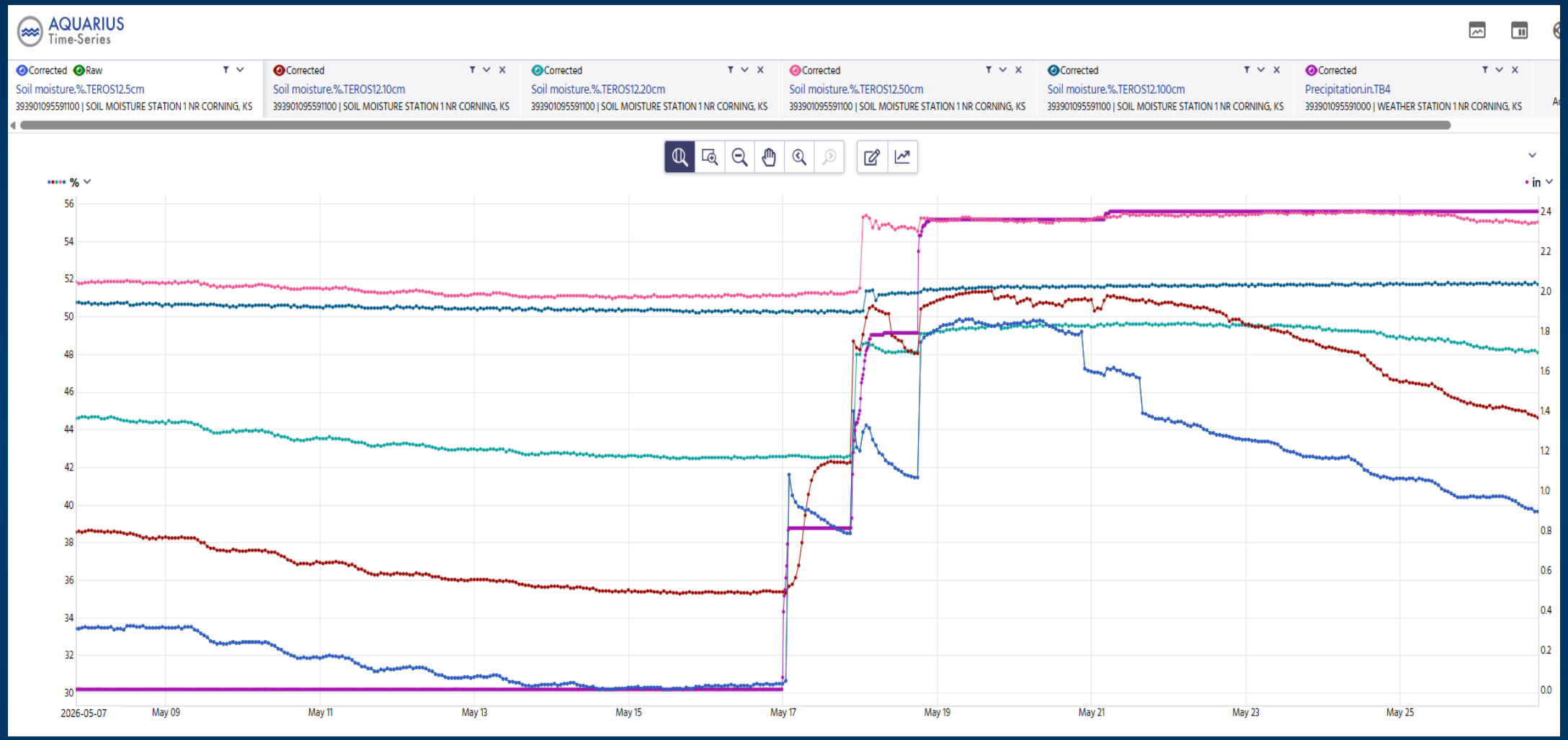


Image of Teros 12 Soil Moisture sensor setup during installation near Corning, KS

Soil Moisture and Precipitation near Corning, KS



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- ✓ Allows landowners to see how their soil moisture is responding to precipitation.
- ✓ May help assess infiltration and decreasing runoff.

Meteorological Station

- Operate and maintain continuous weather equipment at weather station 1 near Corning, KS.
- Have been collecting real-time continuous weather data since May of 2024.
- Parameters include air temperature, air pressure, relative humidity, wind speed, wind direction, total precipitation, solar radiation, and evapotranspiration.
    - Requires site visits to ensure equipment is functioning properly and quality control verification readings are collected using NIST traceable Kestrel.
- Data transmits hourly via data logger and displayed on Water Data for the Nation website.

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Meteorological Station near Corning, KS

Water-Quality Monitoring

- Operate and maintain continuous water-quality monitor at Soldier Creek near Corning, KS.
- Have been collecting real-time continuous water-quality data since July of 2021.
    - Water Temperature
    - Specific Conductance
    - Turbidity
    - Dissolved Oxygen
    - pH
    - Nitrate
- Continuous water-quality monitor housed in a 6-foot long, 4-inch diameter aluminum pipe suspended by aircraft cable from bridge.



Continuous water-quality monitor at Soldier Creek near Corning (06889110)

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Water Quality Monitoring (Continued)

- Sensors can be susceptible to sediment and biological buildup affecting data at times.
- Requires data collectors to service and clean the site monitor to ensure the sensors are functioning properly and transmitting representative data.
- During cleaning visits, a calibrated field monitor is used as part of the quality control process.
- Data transmits every 15 minutes via data logger and displayed on Water Data for the Nation website.



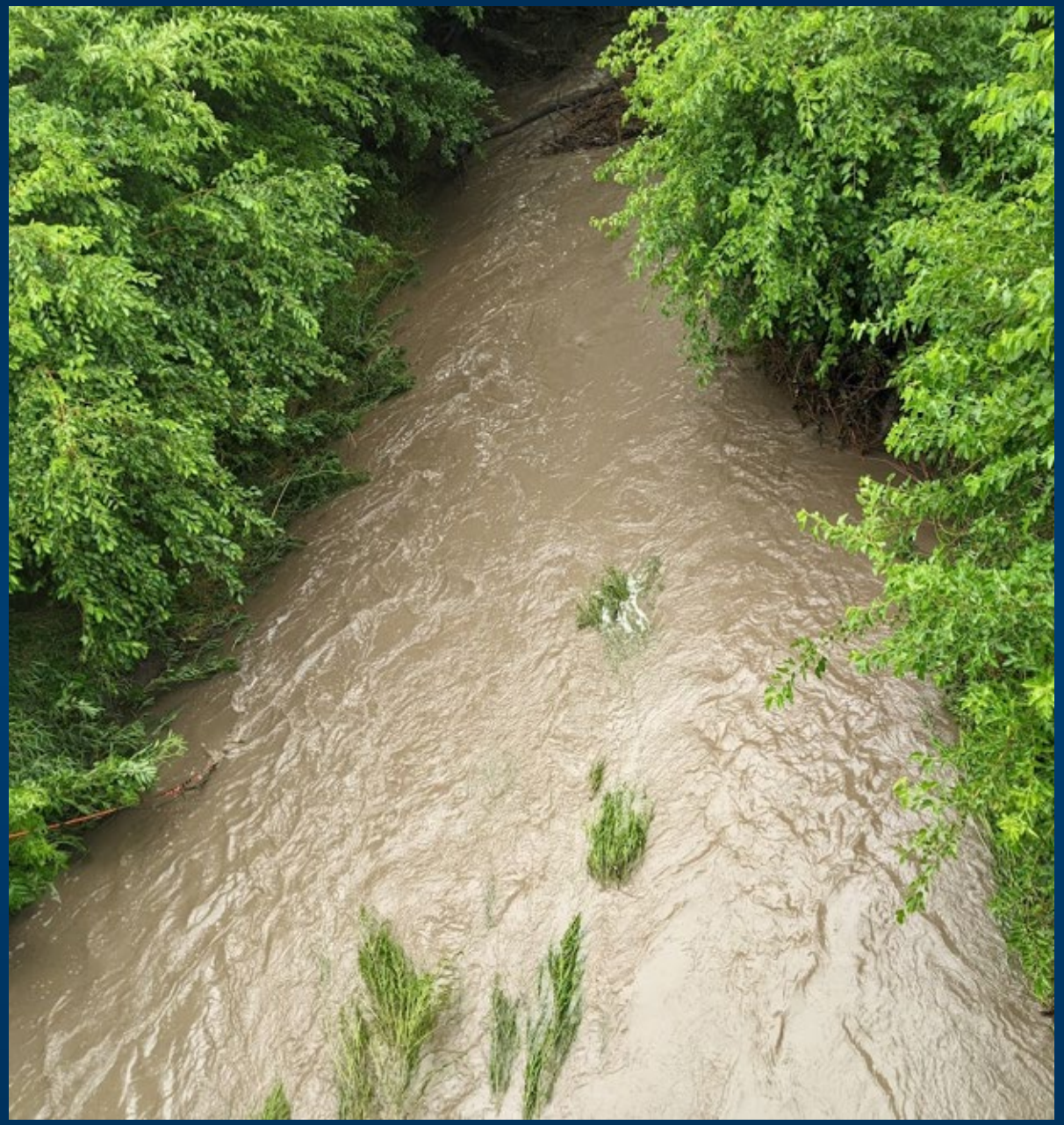
Close up view of water-quality monitor and associated sensors at Soldier Creek near Corning (06889110)

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Discrete Water-Quality

- Collection of discrete water-quality samples at Soldier Creek near Corning, KS.
  - Types of sampling methods include grab, multiple vertical, and autosampler.
- Have been collecting discrete water-quality samples since August of 2021.
  - Nutrient Analytes (Nitrogen and Phosphorus species)
  - TSS (Total Suspended Solids)
  - SSC (Suspended Sediment Concentration)
  - Turbidity
  - Bacteria (E-Coli & Total Coliforms)
  - Pesticides

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Discrete water-quality sample collection occurred on this day (July 7, 2022) at Soldier Creek near Corning, KS

Synthesizing continuous and discrete data

- **The discrete samples for nutrients and sediment are strongly related to the continuously measured parameters.**
- **This allows us to develop a relationship (called a surrogate model) between the lab data and the continuous data so that we can use data from the continuous monitor to provide a continuous estimate of nutrient and sediment concentration.**
- **Combined with the streamflow data, this allows us to estimate loads for nutrients and sediments on time scales from near instantaneous to annual.**
- **These load estimates allow us to investigate trends over time. Is less of the constituent being transported over time?**
- **Flow (Q) * Concentration (SSC) = Load (L)**

Q (ft^3/s) * *28.3169 (L/ft^3)* * *86400 (s/day)* * **SSC** (mg/L) * *1/453592 (lb/mg)* = **L (lb/day)**

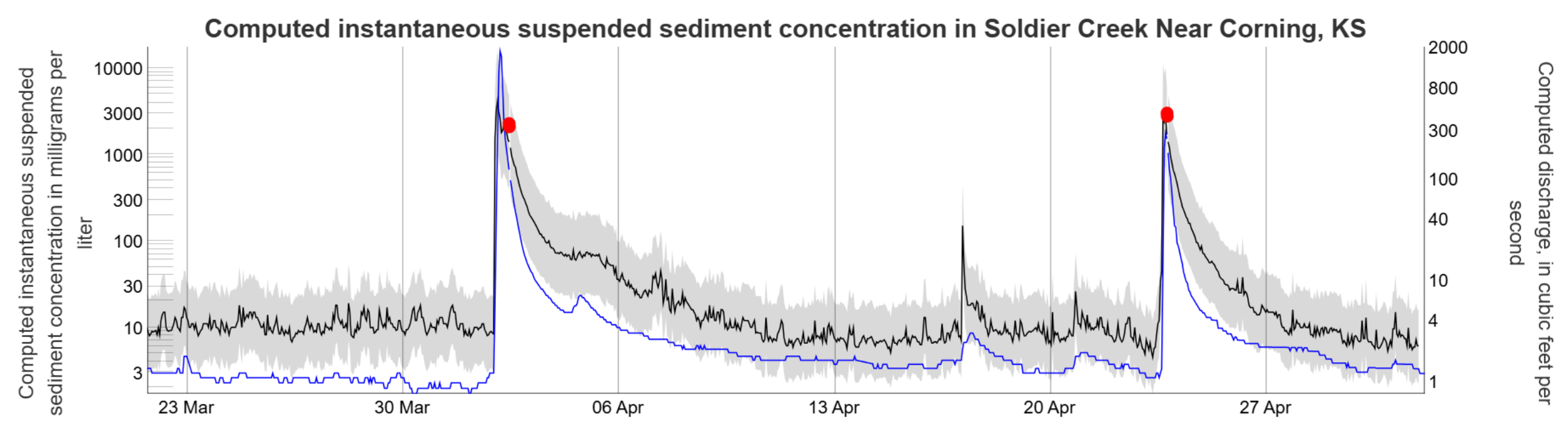
Mean daily streamflow from gage

Mean daily concentration of sediment/ nutrient, derived from surrogate model

Total mass of constituent transported

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Model Computed Suspended Sediment Concentration at Soldier Creek



- This image demonstrates why the models are useful.
- Without the model we only get the red discrete data points at a moment in time.
- With the model we can fill everything in between for a continuous estimate.

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Kansas Department of Health and Environment
Division of Environment

Upper Soldier Creek Watershed-Wide Soil Health Impacts on the Water Quality Hydrograph – Part 3 – Biological Monitoring

Jack Lapin | November 10, 2026

Upper Soldier Creek Watershed-Wide Soil Health Impacts on the Water Quality Hydrograph Ecology – Part 3- Biological Monitoring.



- Stream Biological Monitoring Program: Established by KS Department of Health in 1972 to support the Clean Water Act (CWA)
- In support of CWA: restore and maintain the chemical, physical, and *biological integrity* of the nation's waters.
- How do we assess biological integrity and aquatic life support?

Upper Soldier Creek Watershed-Wide Soil Health Impacts on the Water Quality Hydrograph Ecology – Part 3- Biological Monitoring.

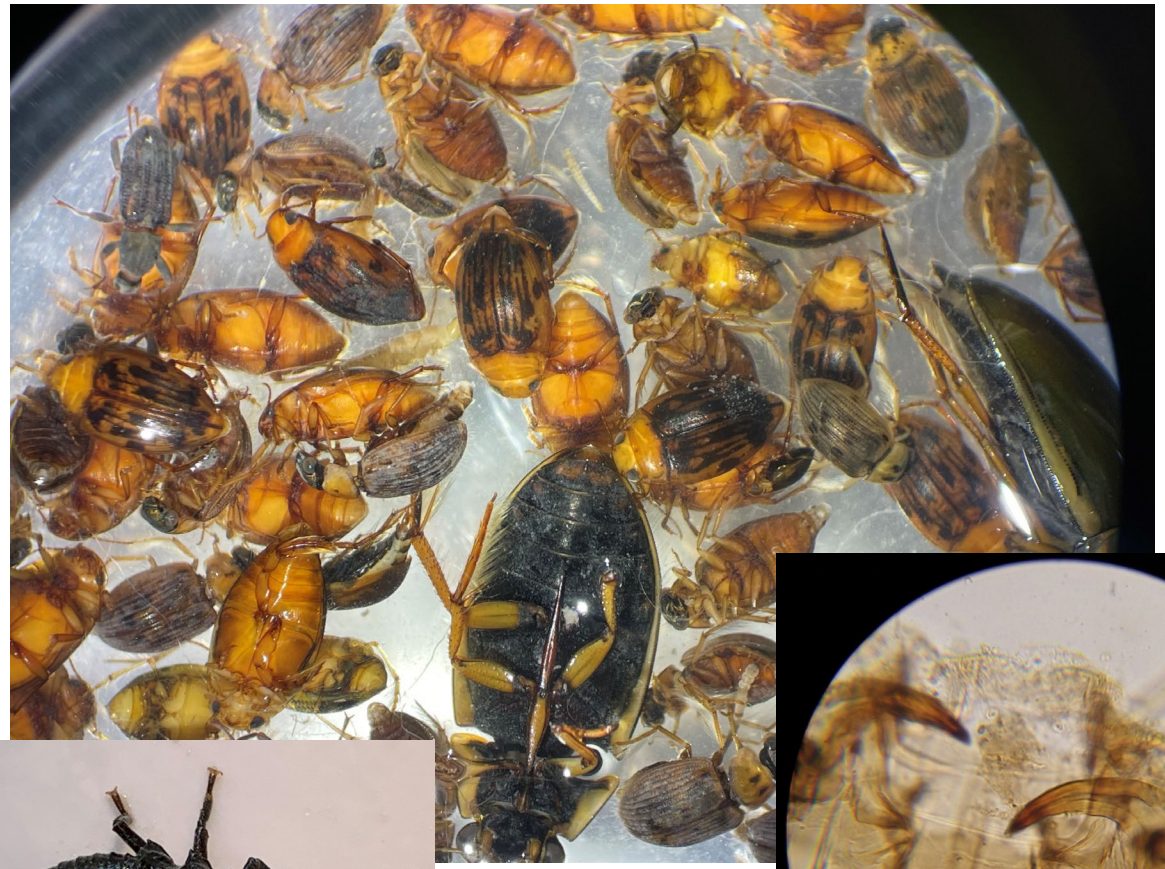






- Assessing biological integrity requires biomonitoring: usually fish, diatoms, benthic macroinvertebrates (or BMI, aquatic bugs and mussels).
- Over 200 sampling locations statewide
- BMI's sampled by hand using D-frame net and forceps in prescribed time frame, targeting all available habitats in given reach length
- Riffles, bank roots, leaf packs, filamentous algae, macrophytes, woody debris
- Organisms are collected and preserved in jar of ethanol, brought back to lab for ID and counting
- Organized into database of statewide insect community samples – about 50 years of data across the state

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 3- Biological Monitoring.







- These bug samples can tell us a lot about the environment in which they were collected.
- All organisms have range of physical and chemical conditions in which they can exist.
- Different species have different known tolerances to variety of stressors.
- As stressors increase, number and relative abundance of intolerant/sensitive species will decrease.
- Repeated samples over time reflect these changes and create a valuable timeline of biological integrity.

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph – Part 3 – Biological Monitoring



- Over 200 distinct insect species to date

- 16 species of mussels, only 4 found alive: Creeper, Giant Floater, Fragile Papershell, Pondhorn
- Remaining 11 only found as weathered and relic valves. Mussel community used to be more diverse.

- 25 species of fish: 1 sp darter, 9 spp shiners & minnows, 4 spp sunfishes, 5 spp catfishes, 3 spp suckers, Largemouth Bass, Common Carp, Logperch







Upper Soldier Creek Watershed-Wide Soil Health Impacts on the Water Quality Hydrograph Ecology – Part 3- Biological Monitoring.

- These 3 orders of insects (collectively called EPT) are generally considered more sensitive. Their numbers and relative abundance are useful when assessing BMI response to environmental stressors. May be familiar if you are a fly fisher!

Ephemeroptera (mayflies)



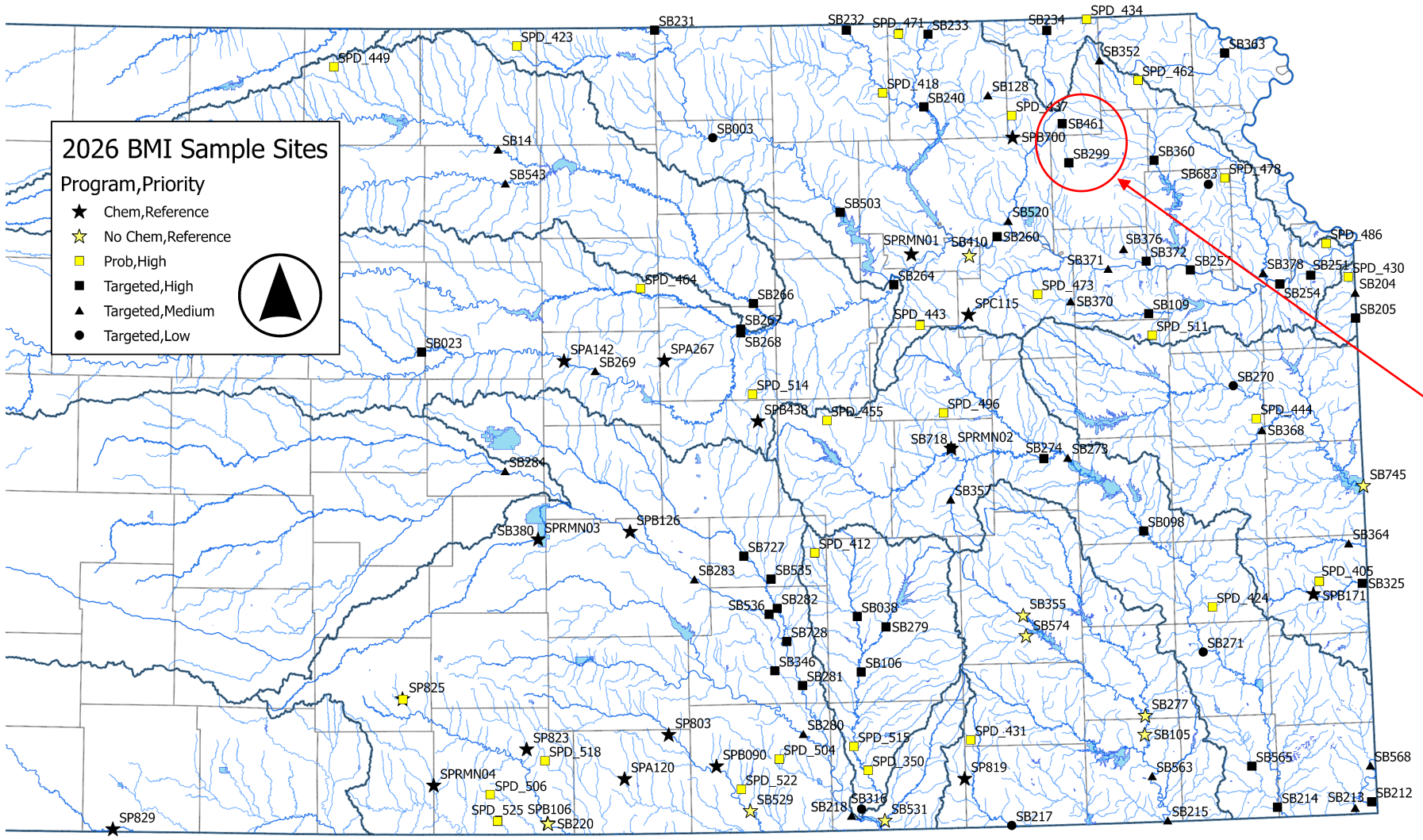
Plecoptera (stoneflies)



Trichoptera



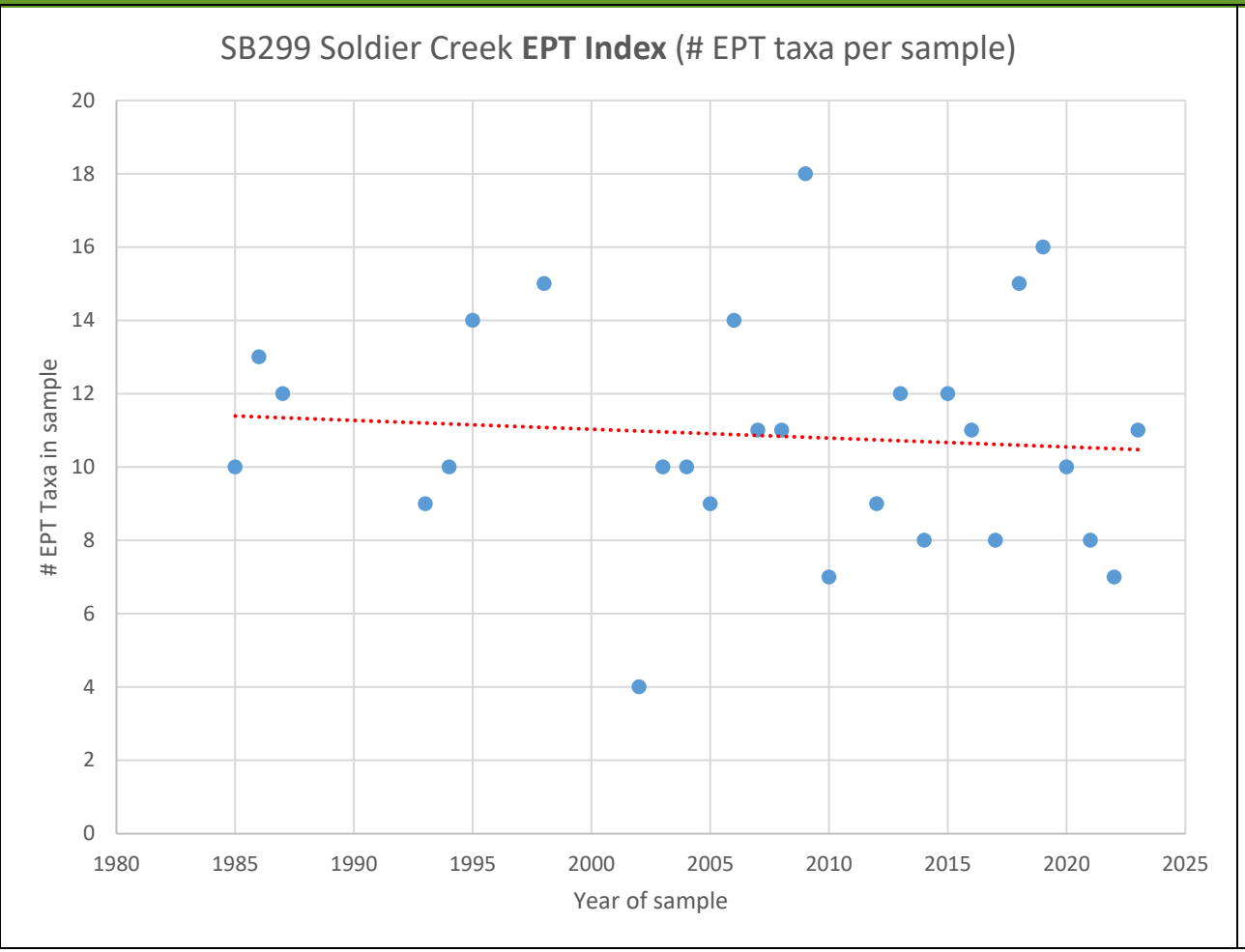
Upper Soldier Creek Watershed-Wide Soil Health Impacts on the Water Quality Hydrograph Ecology – Part 3- Biological Monitoring.

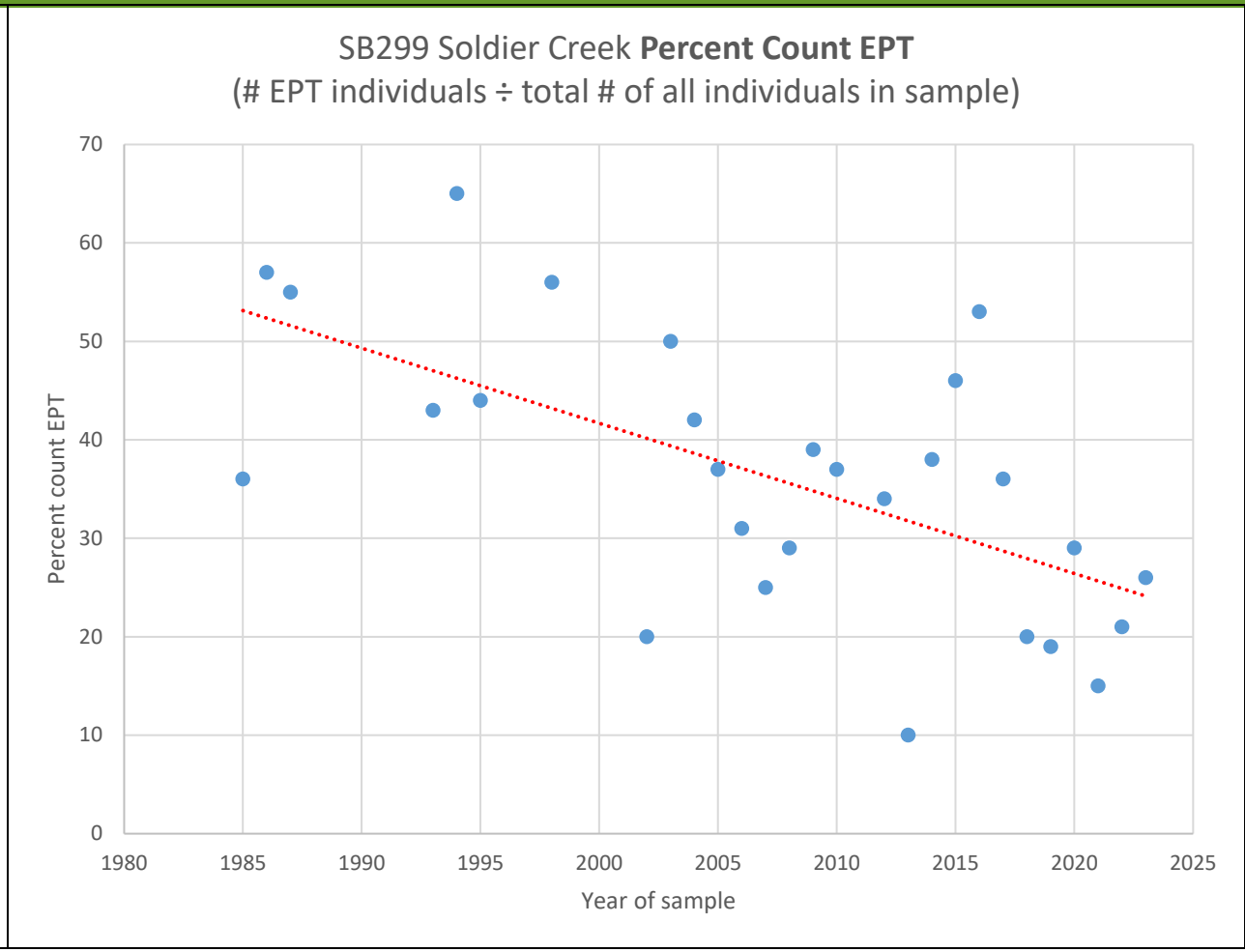


- Over 200 sampling locations statewide. About 50-70 samples collected each year.

Two Soldier Creek macroinvertebrate monitoring sites

Upper Soldier Creek Watershed-Wide Soil Health Impacts on the Water Quality Hydrograph Ecology – Part 3- Biological Monitoring.





- Lack of trend here suggests EPT taxa richness has not deteriorated significantly since 1985.

- Downward trend here suggests relative abundance of EPT individuals has dropped since 1985.

Upper Soldier Creek Watershed-Wide Soil Health Impacts on the Water Quality Hydrograph Ecology – Part 3- Biological Monitoring.

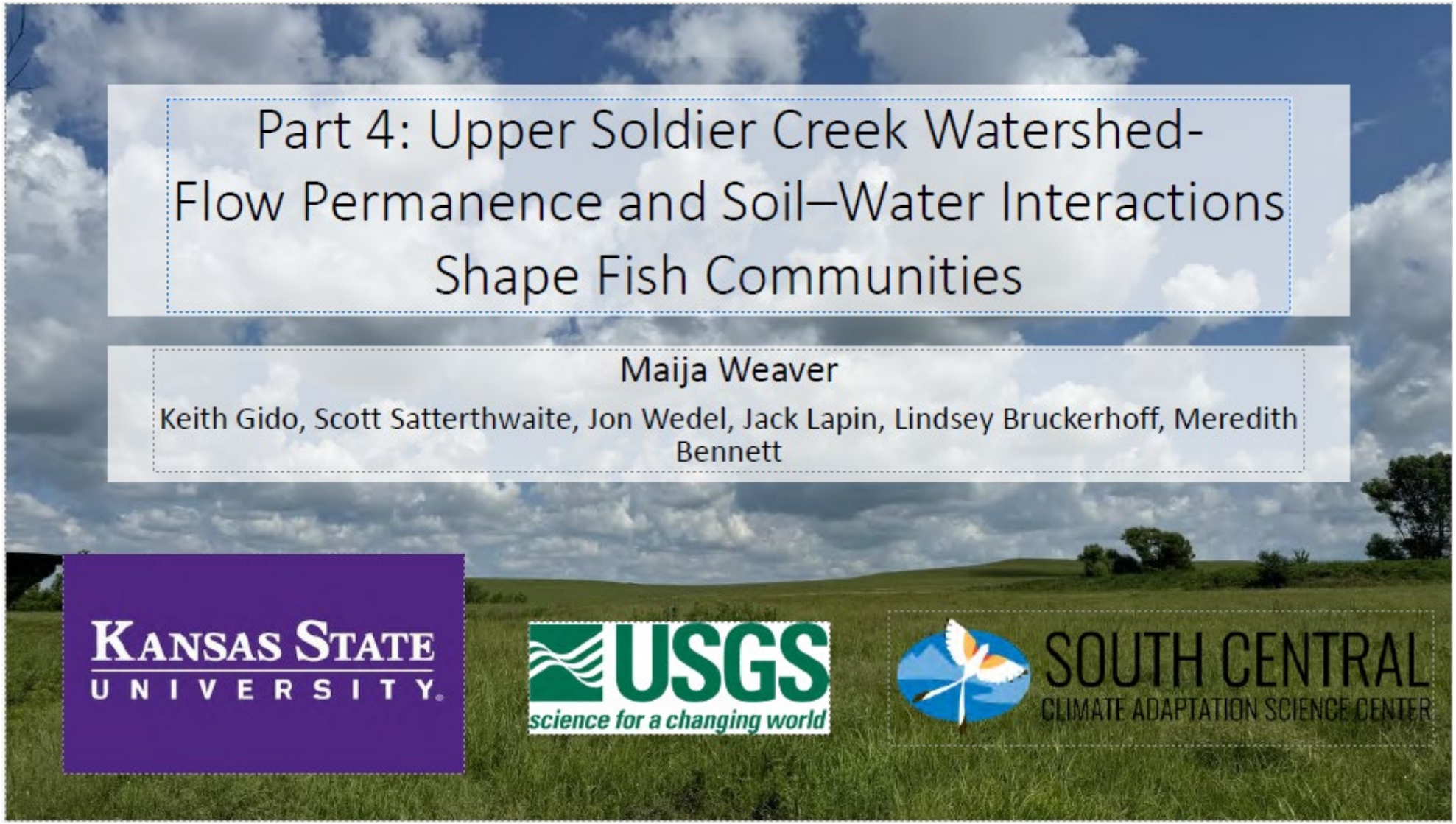


- Soldier Creek delisted from CWA section 303(d) for total suspended solids (TSS) impairment in 2022 thanks to reduced sediment in the water column. Still listed impaired for biology.
- Much of the excess sediment formerly in the water column remains settled in substrate.
- Many of the intolerant/sensitive insect species require habitat with coarse substrate, i.e. open, rocky bottoms.
- Will take time to flush out and re-expose this habitat for aquatic life use.
- With continued improvements in water quality, continued biomonitoring should reflect those improvements in the benthic macroinvertebrate community!

Thank you!

Jack Lapin – Stream Monitoring Scientist
Jack.Lapin@ks.gov – 785-213-4674

Upper Soldier Creek Watershed-Wide Soil Health Impacts on Water Quality Hydrograph Ecology – Part 4- Stream Flow and Fish Communities.



Part 4: Upper Soldier Creek Watershed- Flow Permanence and Soil–Water Interactions Shape Fish Communities

Maija Weaver

Keith Gido, Scott Satterthwaite, Jon Wedel, Jack Lapin, Lindsey Bruckerhoff, Meredith Bennett

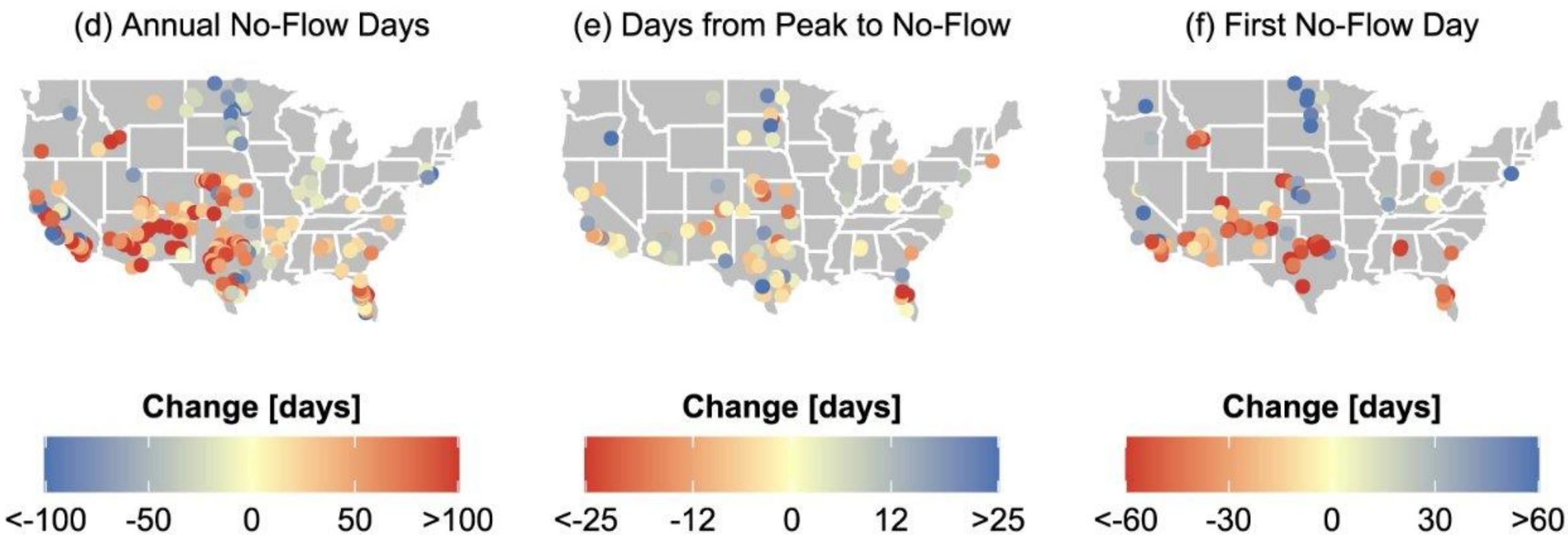






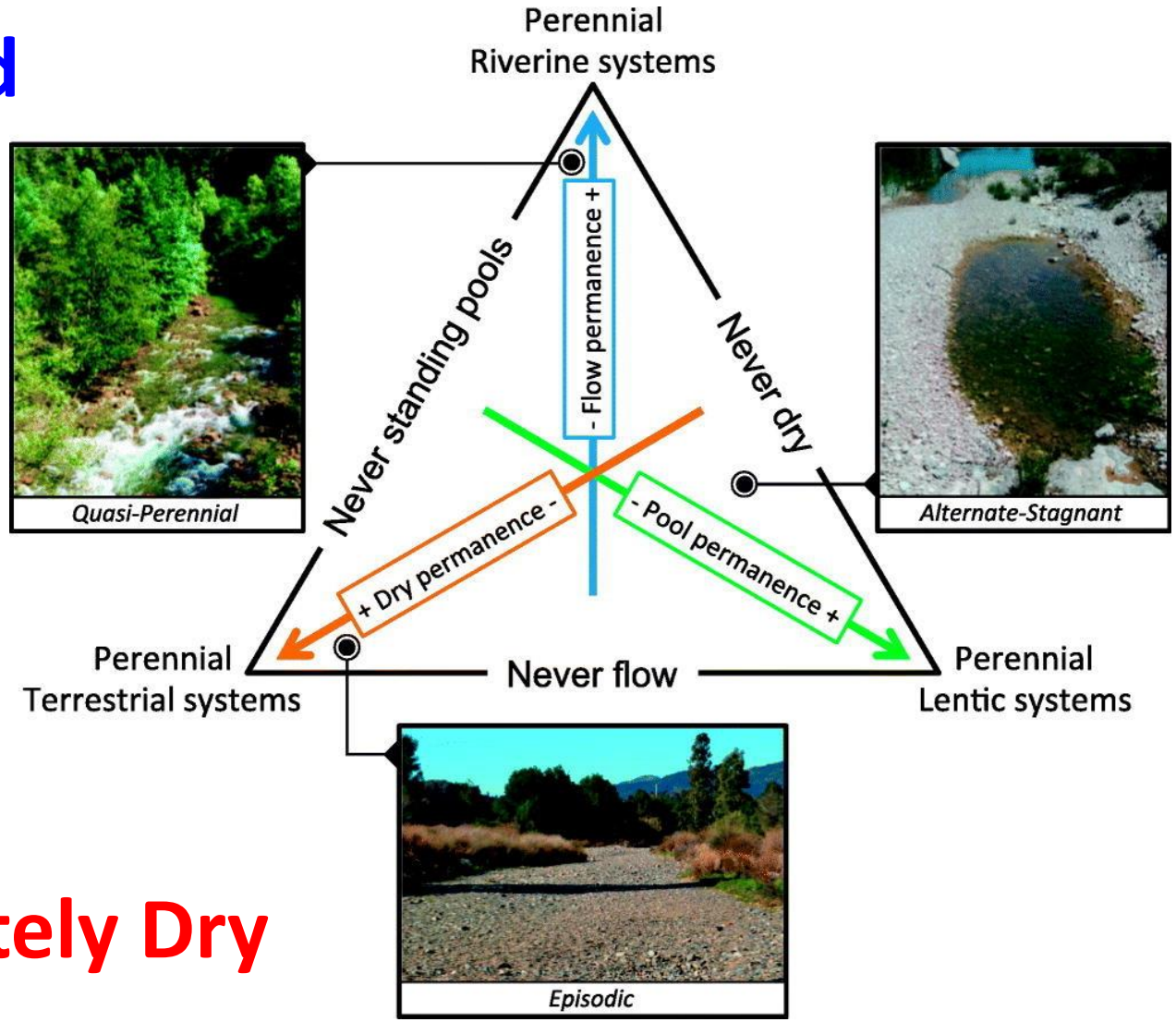
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CLIMATE ADAPTATION SCIENCE CENTER

Stream drying is becoming more prevalent.



Stream drying states fluctuate among three stages.

Connected



Isolated Pools

Completely Dry

Gallart et al. 2017

How do stream organisms deal with extreme variation in rivers?

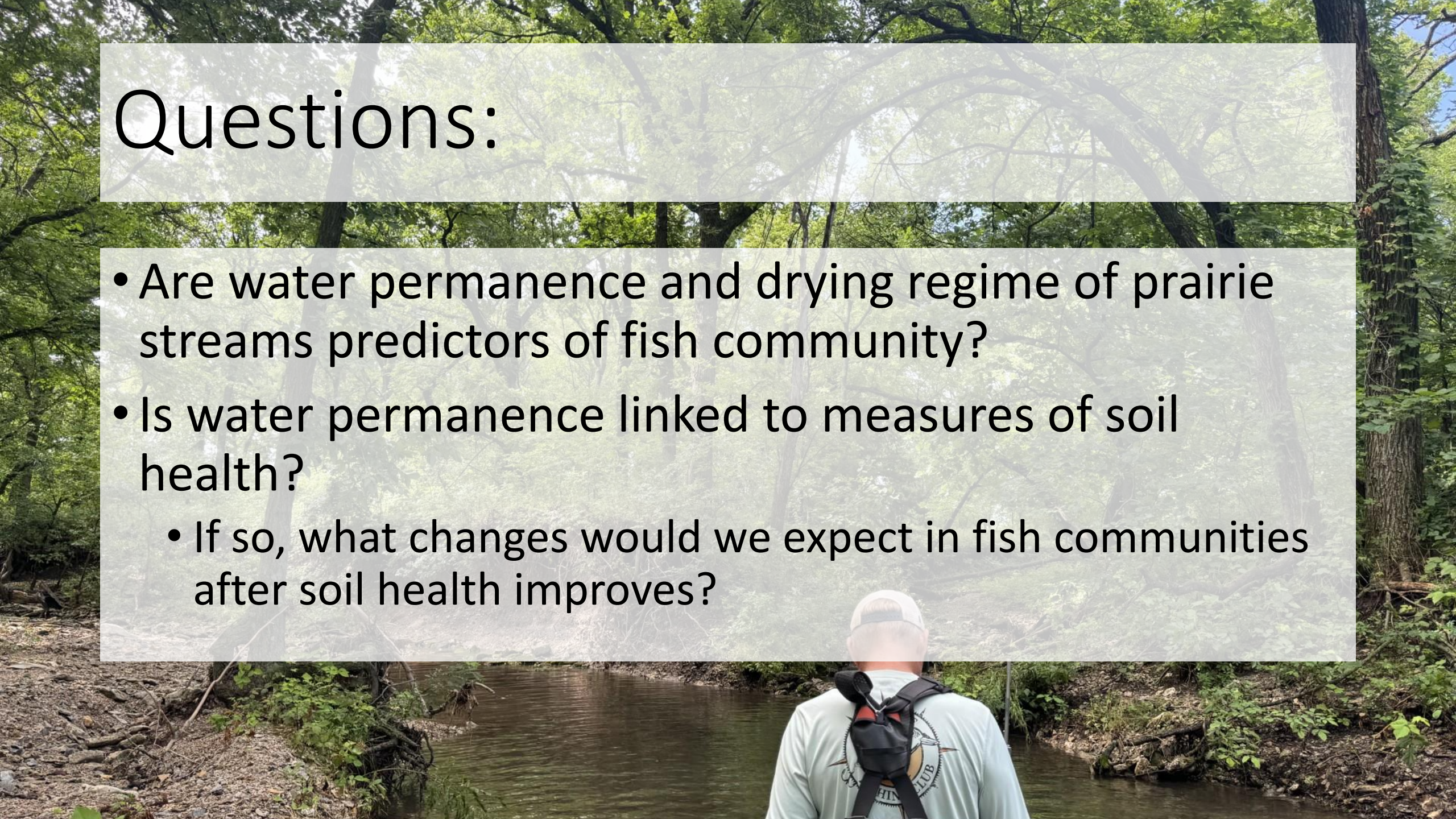


- Physiological and ecological traits
- Thermal tolerances
- DO tolerance
- Resource acquisition
- Reproduce here?
- Predators and competitors?

- Dispersal/colonization traits
- Swimming ability
- Behavior
- Reproduce there?
- Predators and competitors?

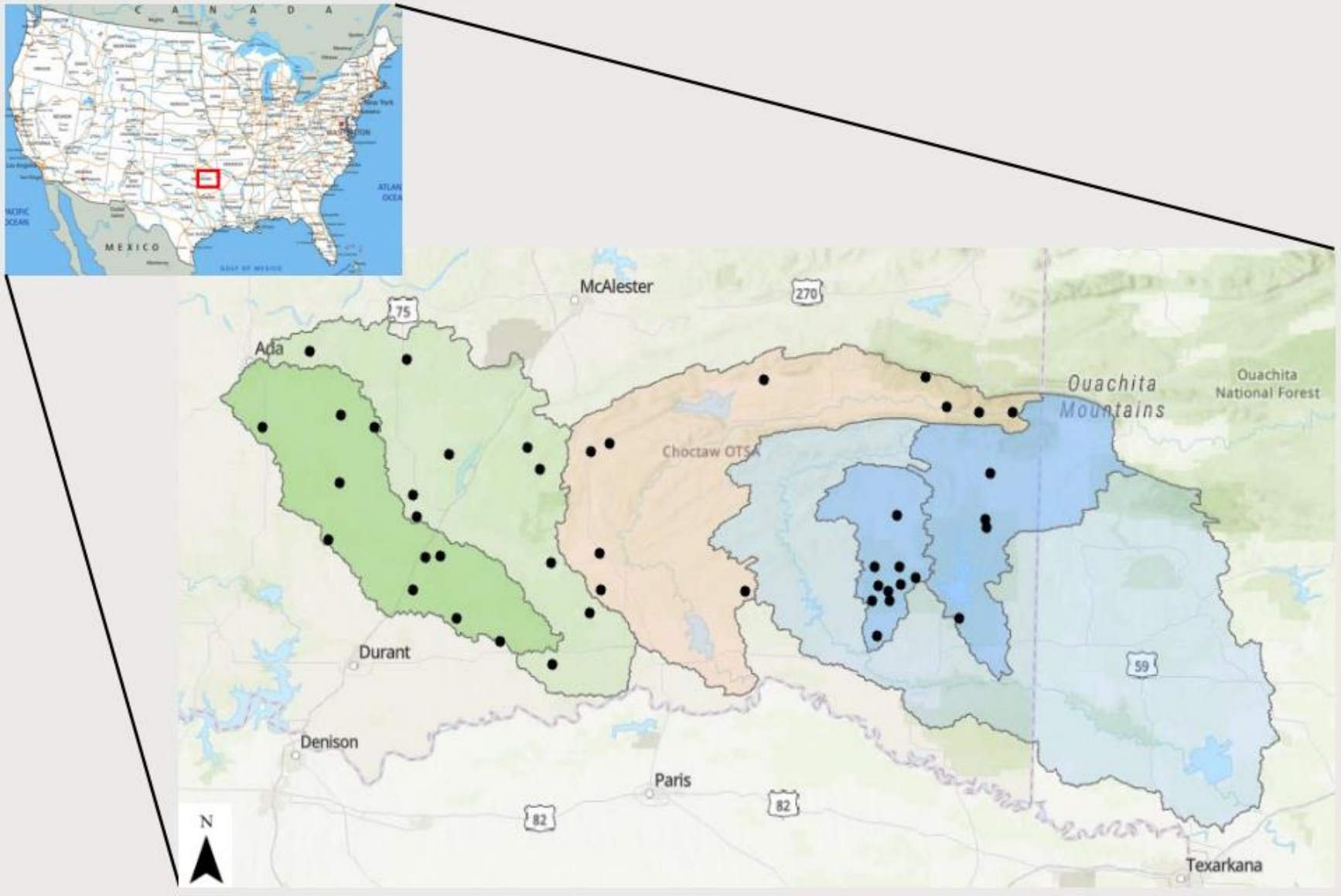
Questions:

- Are water permanence and drying regime of prairie streams predictors of fish community?
- Is water permanence linked to measures of soil health?
  - If so, what changes would we expect in fish communities after soil health improves?



Study Area

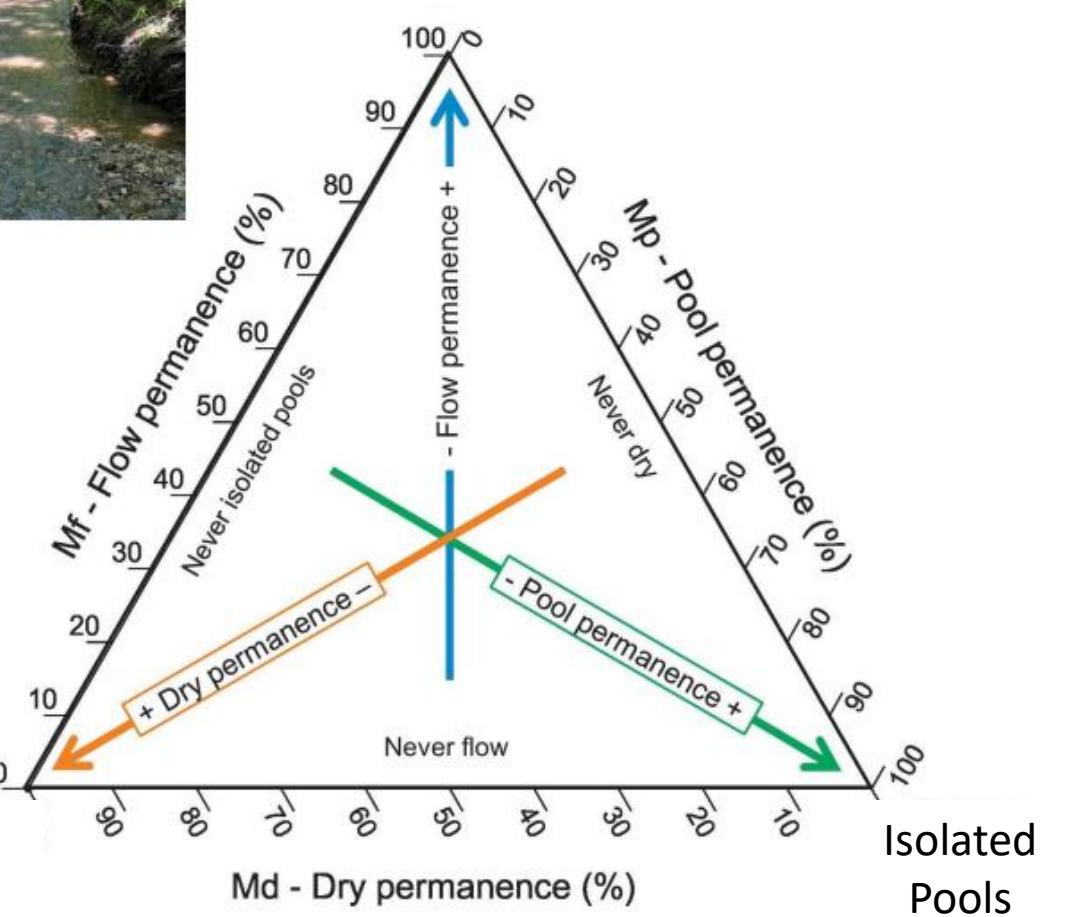
- Five drainage basins across southeastern Oklahoma
  - Glover
  - Mountain Fork
  - Kiamichi
  - Muddy Boggy
  - Clear Boggy
- Data collected at 44 sites during Summer and Fall 2024





Can streams be clustered into meaningful groups based on drying patterns?

Flowing



Dry

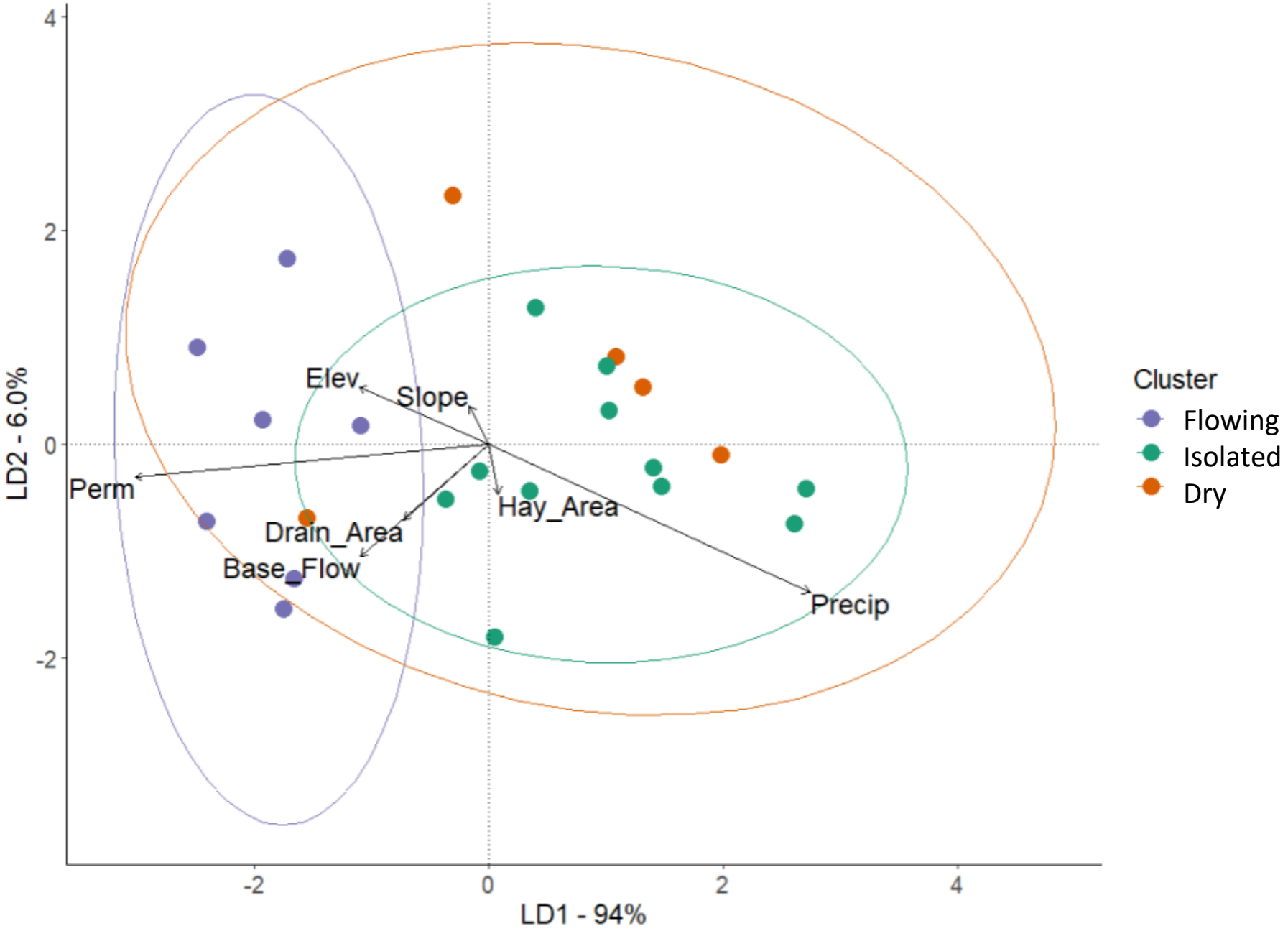
Isolated Pools

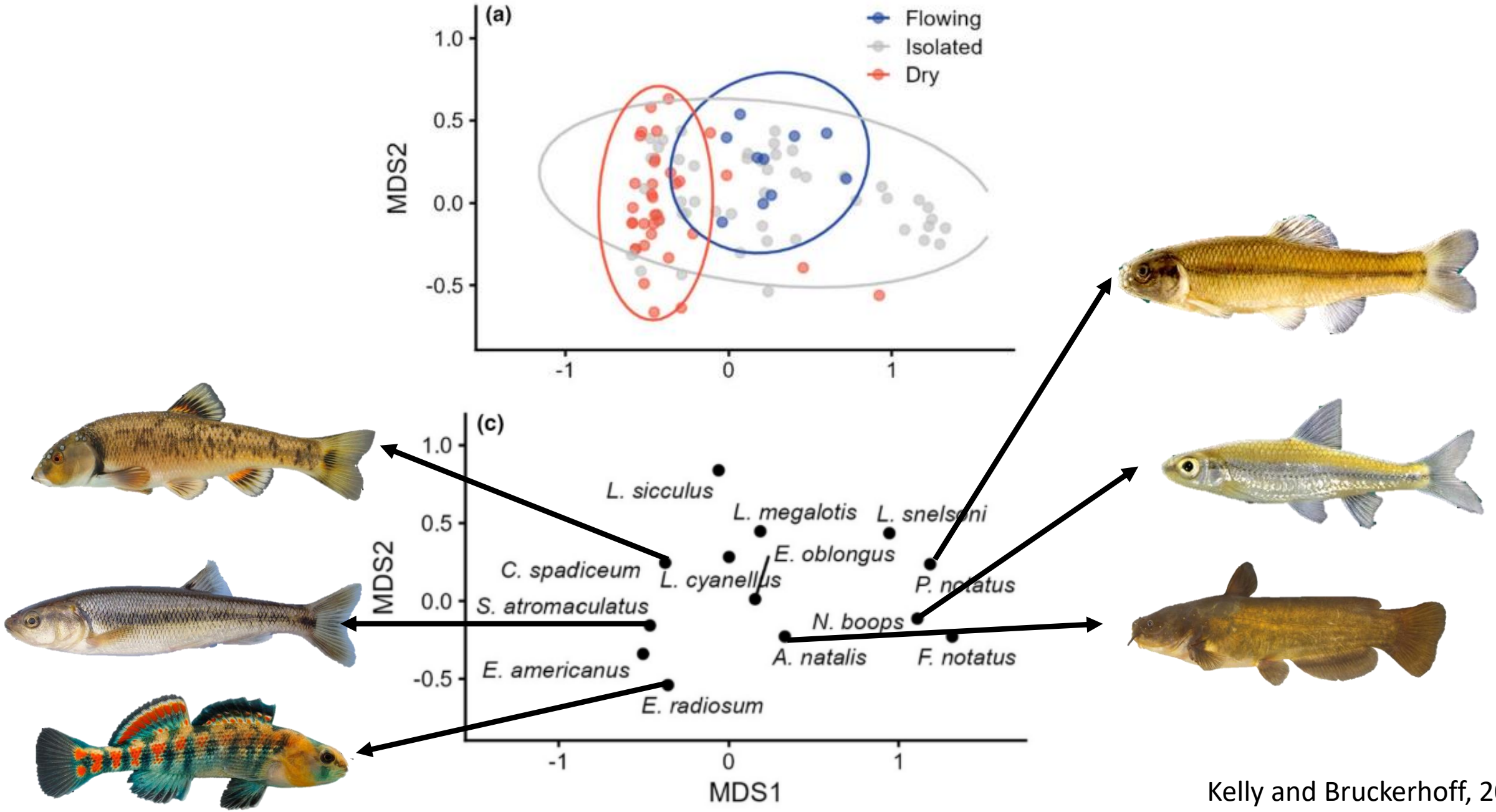
(Gallart et al. 2017)





Do environmental variables differ between the clusters?



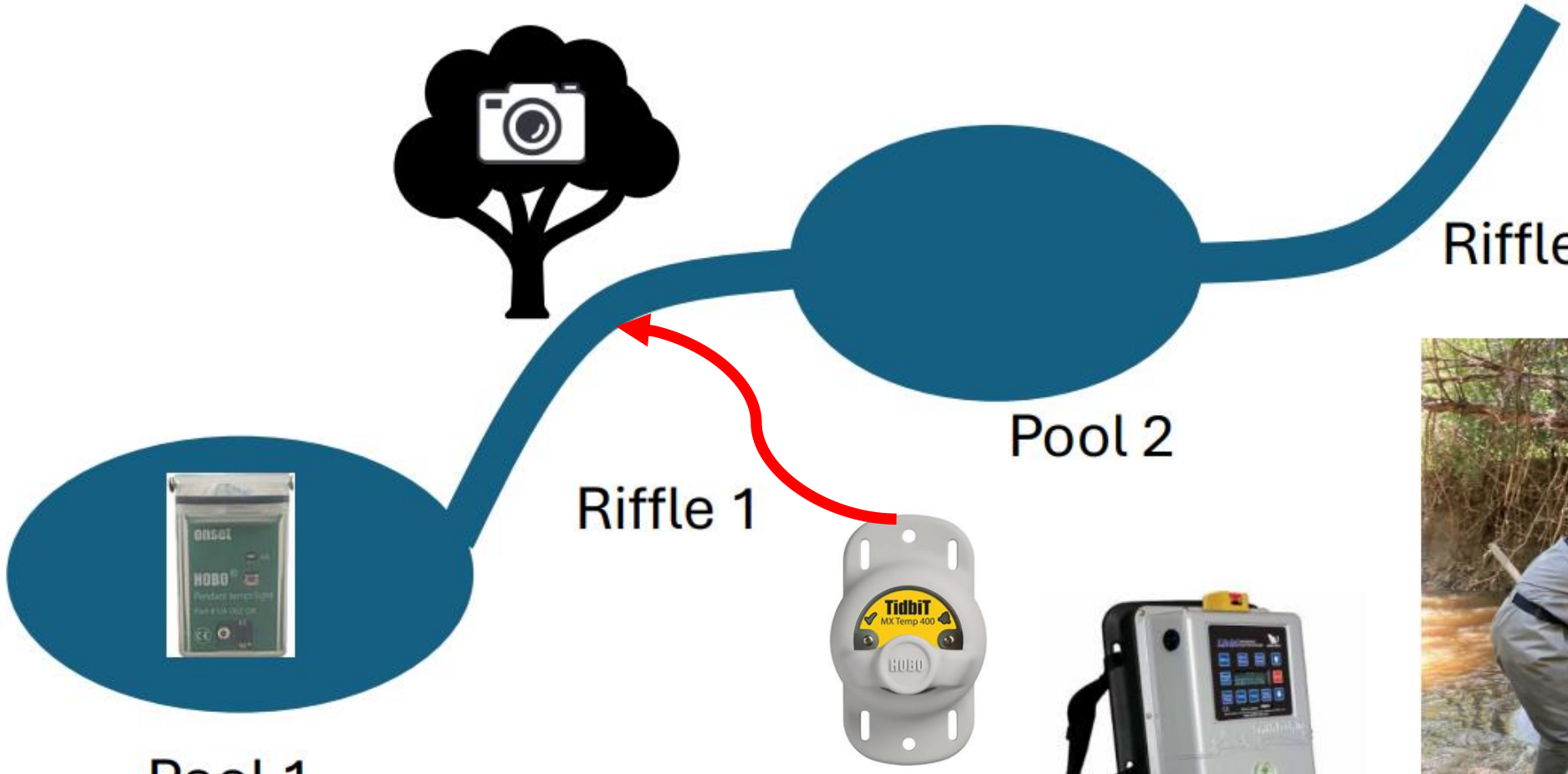


Kelly and Bruckerhoff, 2024

Kansas Sites

- 21 total sites across Kansas
  - 20 more added in 2025-data not collected yet
- 4 sites in Solider Creek
  - 2 permanent and 2 intermittent
  - Avg 14.5 species vs. 4 intermittent
- Separated into 3 groups for analysis
  - Dries completely, dries partially (isolated), and permanent

Data Collection








STEALTH CAM®
TL 09:00AM 06/28/2025 71°F
STEALTH CAM

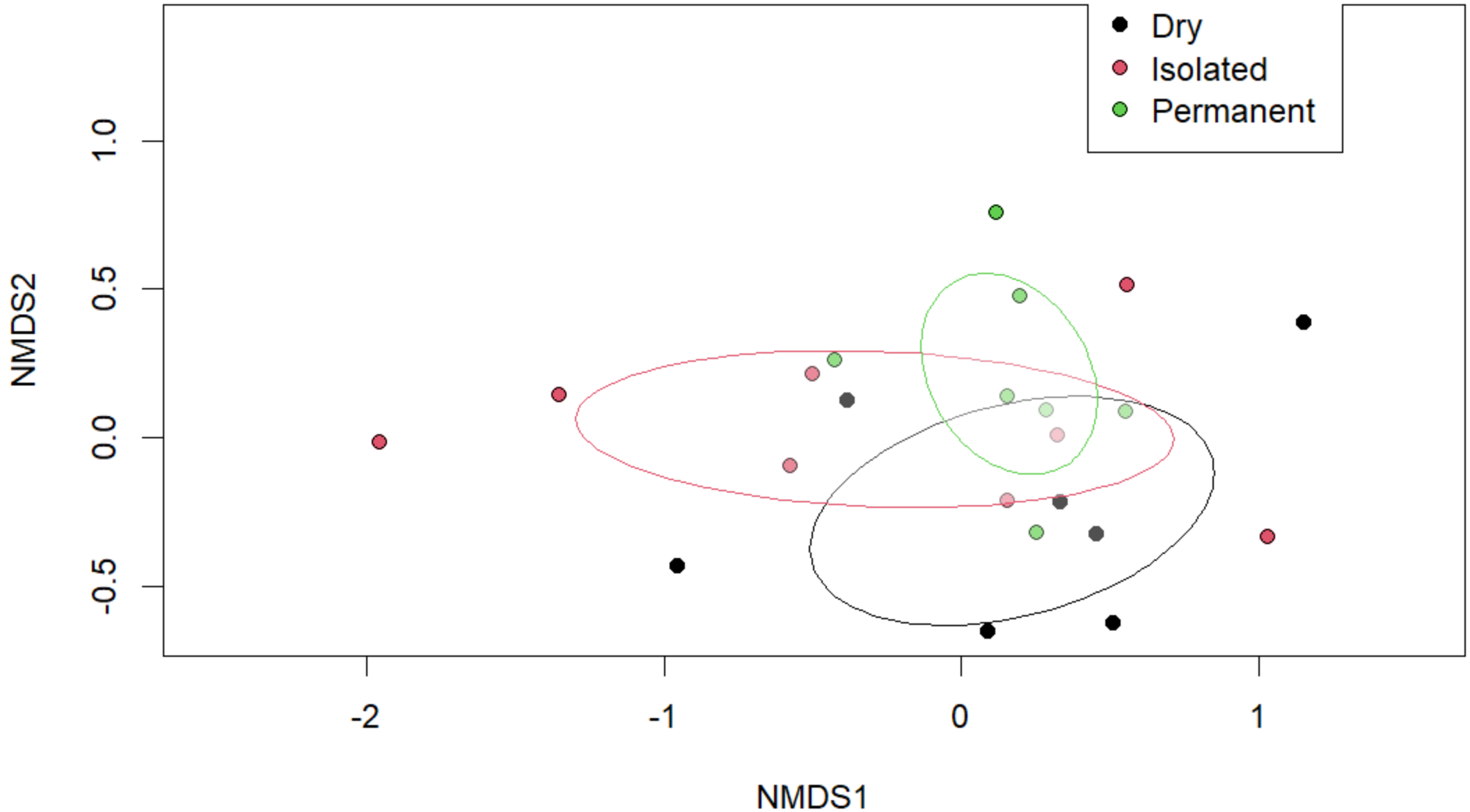


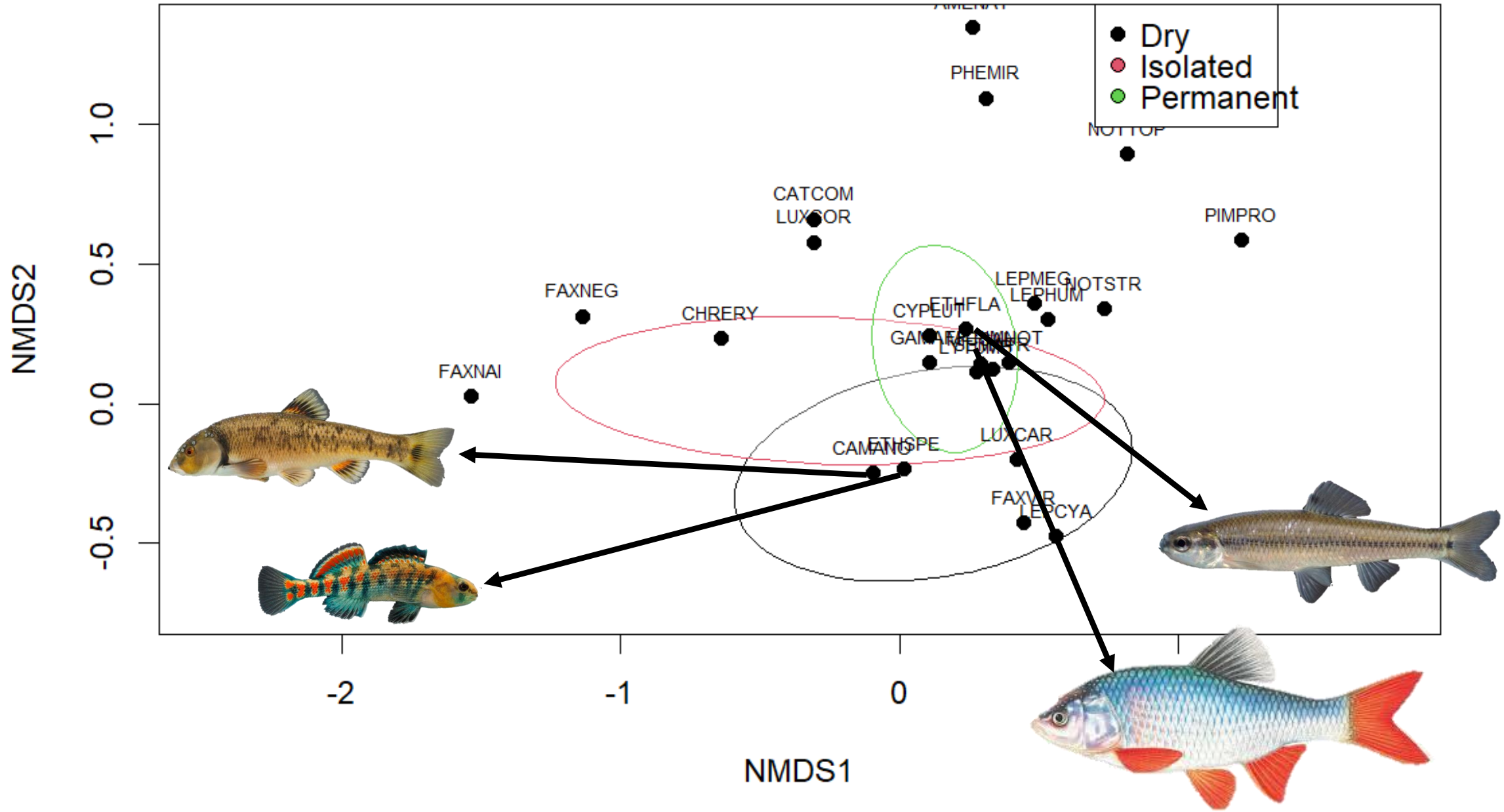









Dry
Isolated
Permanent
NMDS2
1.0
0.5
0.0
-0.5
-2
-1
0
1
NMDS1


Dry
Isolated
Permanent
PHEMIR
CATCOM
LUXCOR
PIMPRO
FAXNEG
CHRERY
LEPMEG
LEPHUM
NOTSTR
CYPEUT
ETHFLA
FAXNAI
CAMANO
ETHSPE
LUXCAR
FAXVAR
LEPCYA
NMDS1
NMDS2
-2
-1
0
1.0
0.5
0.0
-0.5

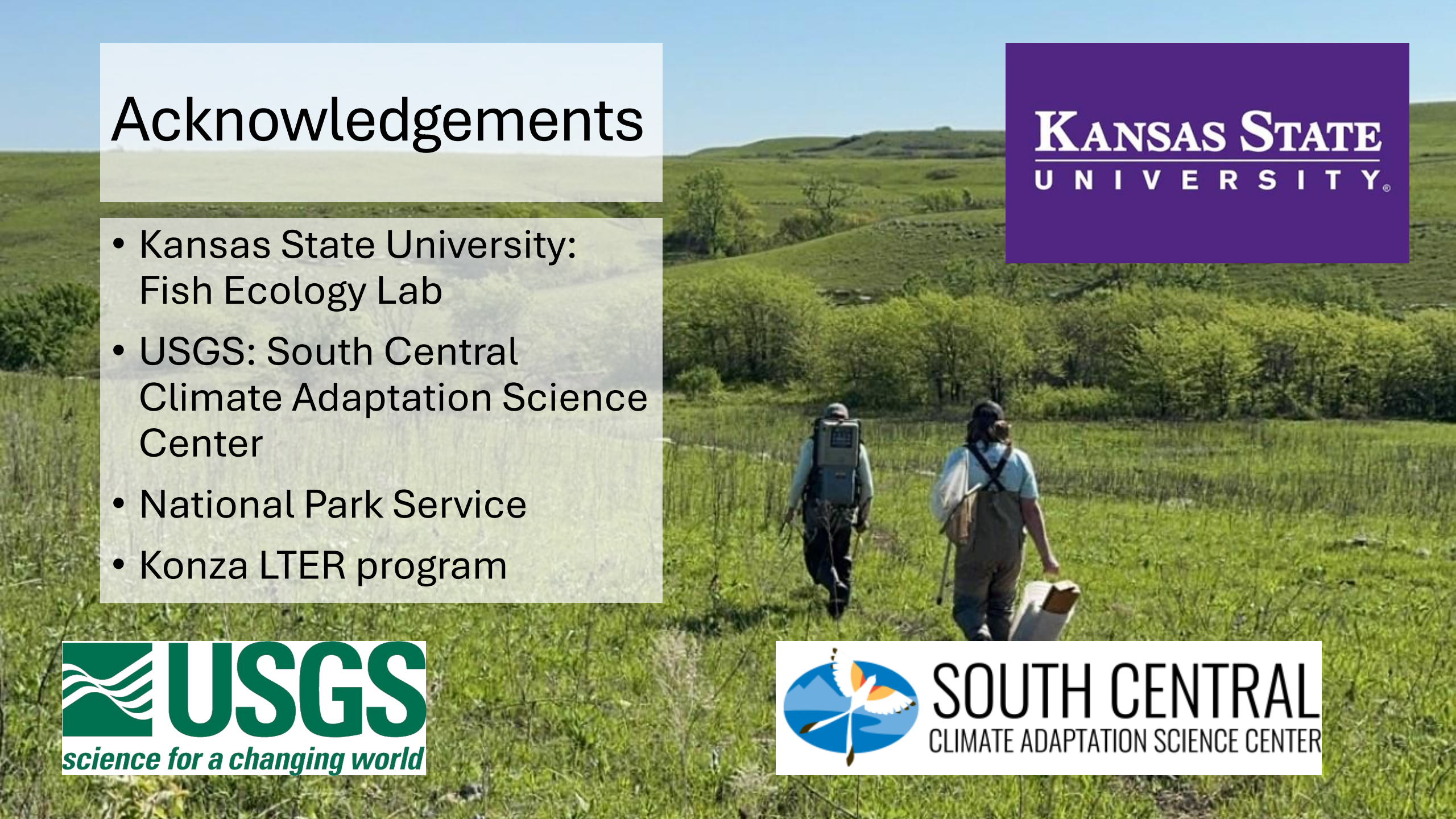

Cover Crops & Healthy Soils
More Infiltration & Groundwater Recharge
More Permanent Stream Flow
Stronger Fish Communities

Conclusions

- Previous studies show that fish diversity increases in more permanent waters
- There is a relationship between more permanent flows and soil permeability/base flow – Oklahoma data
- If soil remediation continues, we could expect to see an improvement in fish assemblages in the Soldier Creek basin

Acknowledgements

- Kansas State University: Fish Ecology Lab
- USGS: South Central Climate Adaptation Science Center
- National Park Service
- Konza LTER program




Questions?