Back from the past: Use and recovery of historic soil microbiome in contemporary restorations and implications for water quality and biodiversity

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4/15/2026

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Soil Health in Stream & Floodplain Restoration

Soil health and microbial diversity is essential to long-term effectiveness of restoration projects

Ecosystem Services provided by microbial communities:

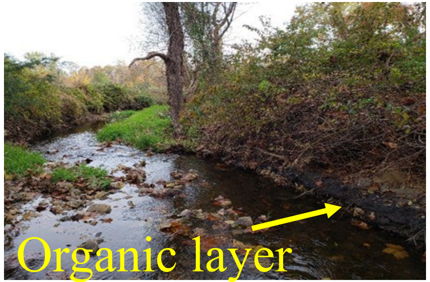
- ❖Organic matter decomposition
- ❖Nutrient cycling (C, N, P, and S)
- ❖Biomass production
- ❖Overall soil structure

Promoting Ecosystem Services in Restoration Design

- **Diversifying physical conditions:** elevation change, instream structures
- Retention of organic matter within streams
- Floodplain reconnection

(Miller & Kochel, 2013)

Pre-restoration

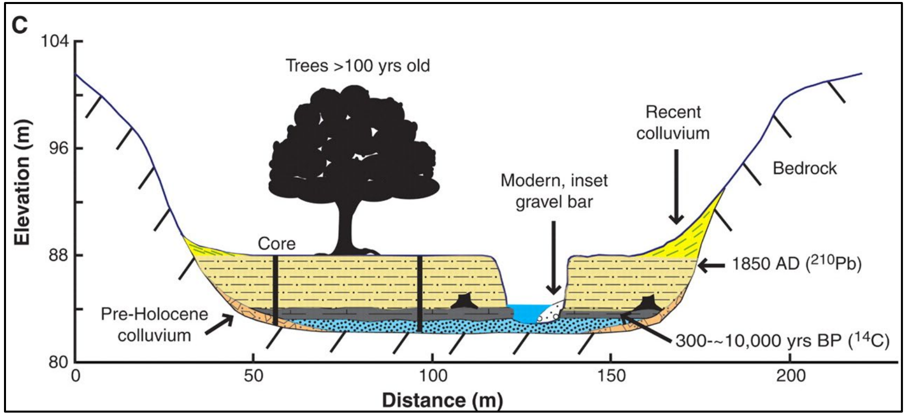


Post-restoration

Create "biogeochemical hotspots" for microbial activity

Buried Historic Hydric Soils

- Buried by legacy sediment deposits resulting from colonial era agricultural and deforestation practices.



(Walter & Merritts, 2008)

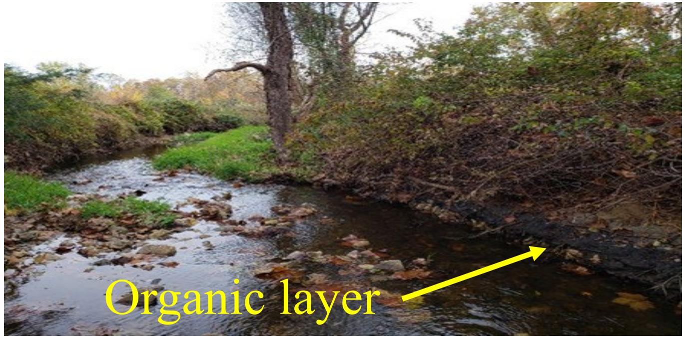
- Organic-rich (C and N) soil horizon from pre-colonial wetlands overlain by legacy sediment deposits

Buried Relict Soils – Removal During Restoration

- Buried Relict Soils are **typically removed** with overlying legacy sediment during restoration

Relict soil horizons contain historical soil microbiomes and nutrients that could be leveraged to improve water quality at restored sites

Pre-restoration

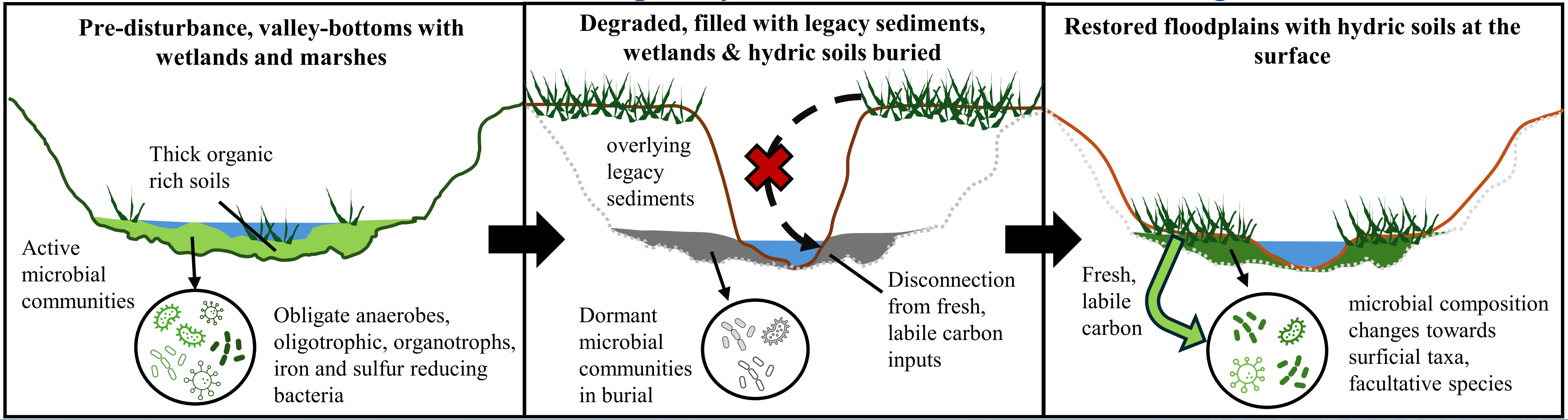


Post-restoration

Historic hydric soils could boost ecosystems services

"Daylighting" of relict soils

- Enhance ecosystem functions (denitrification, organic matter decomposition, etc…) within the floodplain
- Recovery of dormant, native, microbial communities – **increase in diversity and function**
- Colonization of active, contemporary, microbial communities in organic rich soil

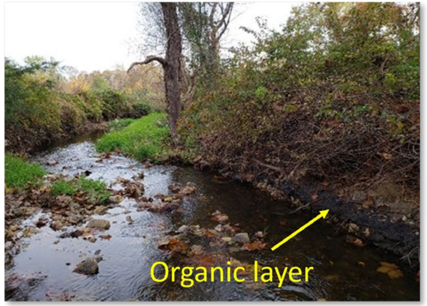


How do microbial communities in historic hydric soils change during the first three years following restoration, and how do they compare with contemporary soils?

Site Description – Gramies Run in Elkton, MD

- Floodplain restoration project completed between March 2019 and March 2020
- Removal and regrading of overlying legacy sediments
  - **Relict soil horizon was removed**
  - Raising of streambed
  - Construction of instream structures

2017, pre-restoration



March 2019, post-restoration

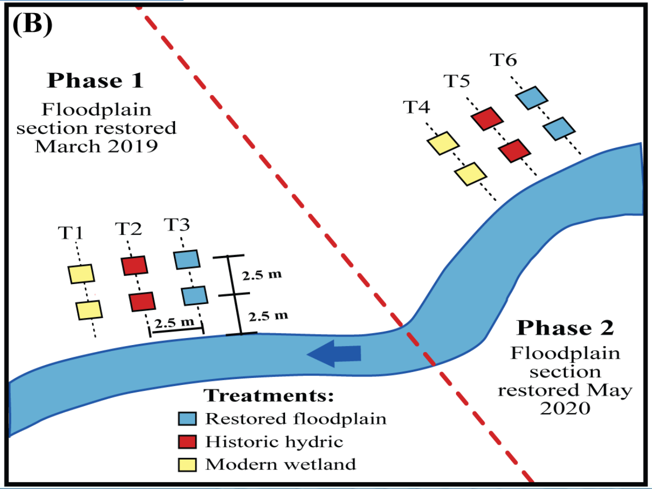
June 2019

June 2023

Soil and Porewater Analysis

- **Three – year floodplain incubation (Nov. 2020 – Nov. 2023)**
- **Soil porewater chemistry** – Monthly sampling
- **Bulk soil chemistry** – Spring and fall sampling
- **Total microbial community characterization** – high throughput sequencing of 16S rRNA (Next Generation Sequencing (NGS))
- **Active microbial community characterization** – high throughput sequencing (NGS) of 16S rRNA amplified from cDNA

DOC, NO_3-N, NH_4-N, Total C & N



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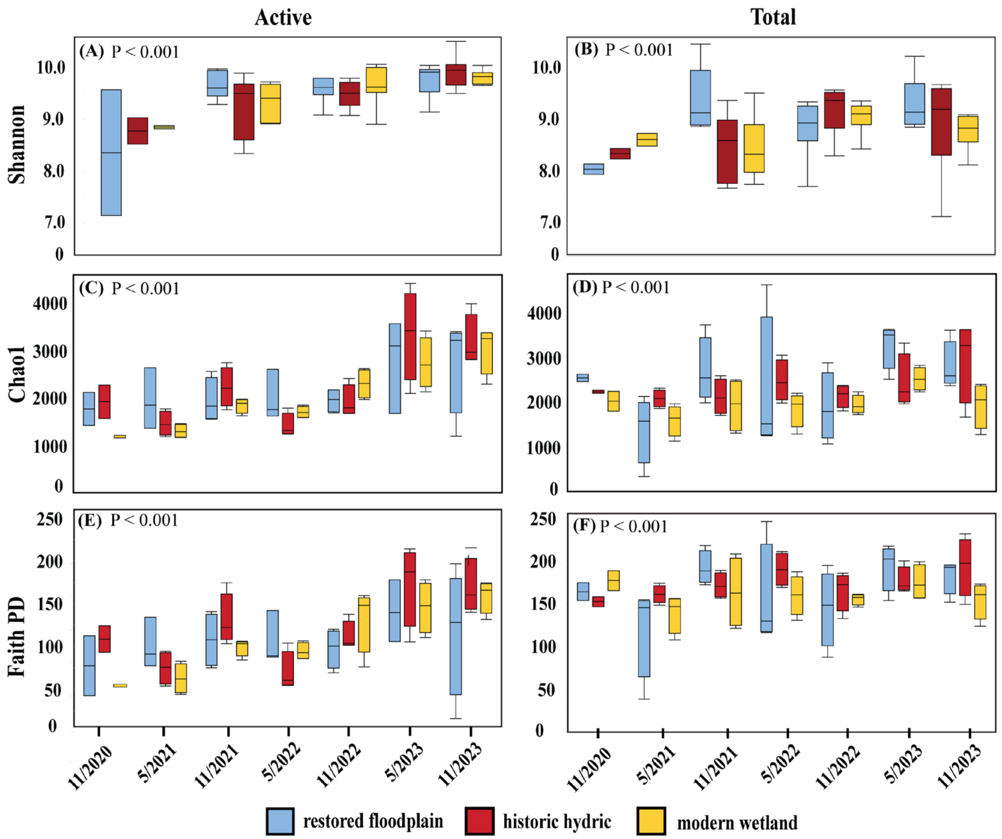
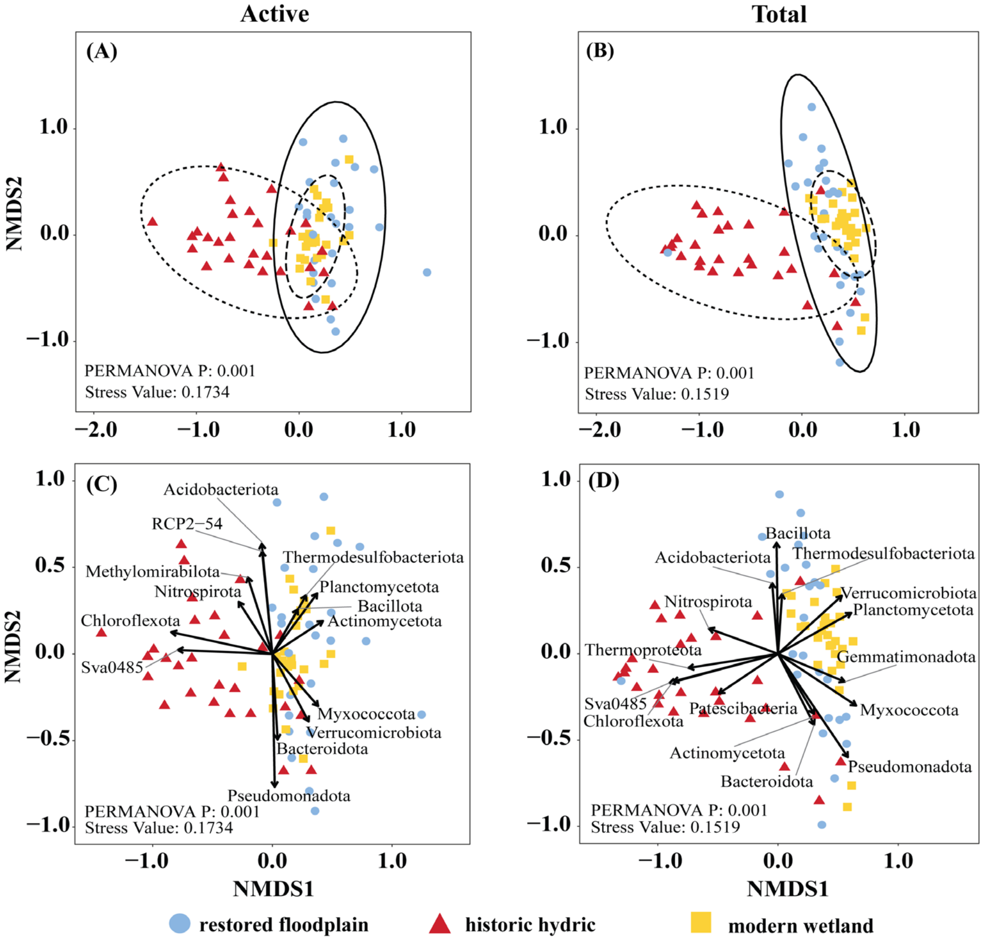
Microbial Soil Diversity Significantly Increased Over Time

Significant increases in species diversity and richness across all soils, regardless of treatment



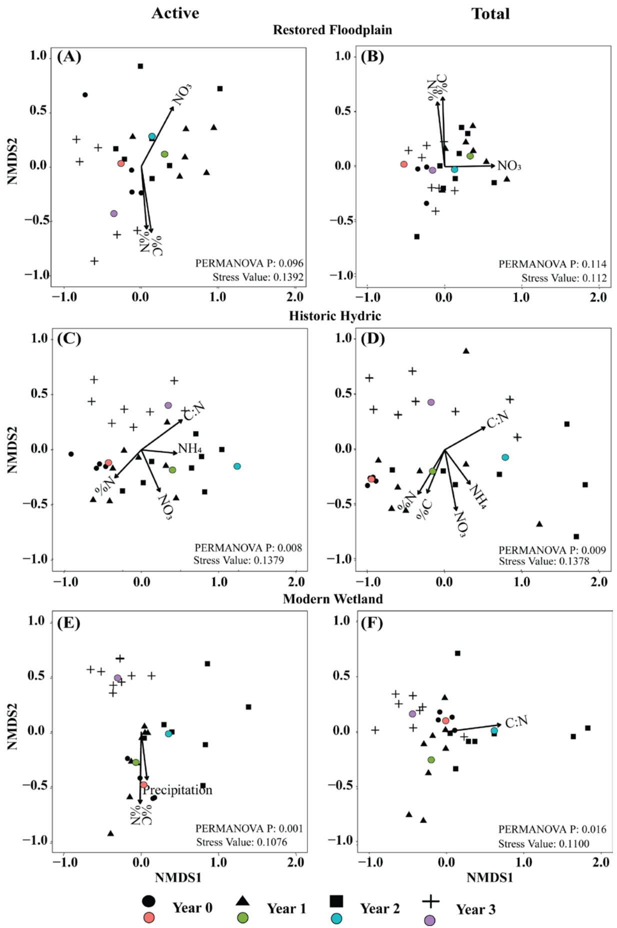
Historic Hydric Soil Microbiome is Distinct From Contemporary Soils

- ❖ HHS microbial community composition significantly different from contemporary soils, both active and total
- ❖ Significant correlations of soil treatments with top abundant phyla (relative abundance > 1%)



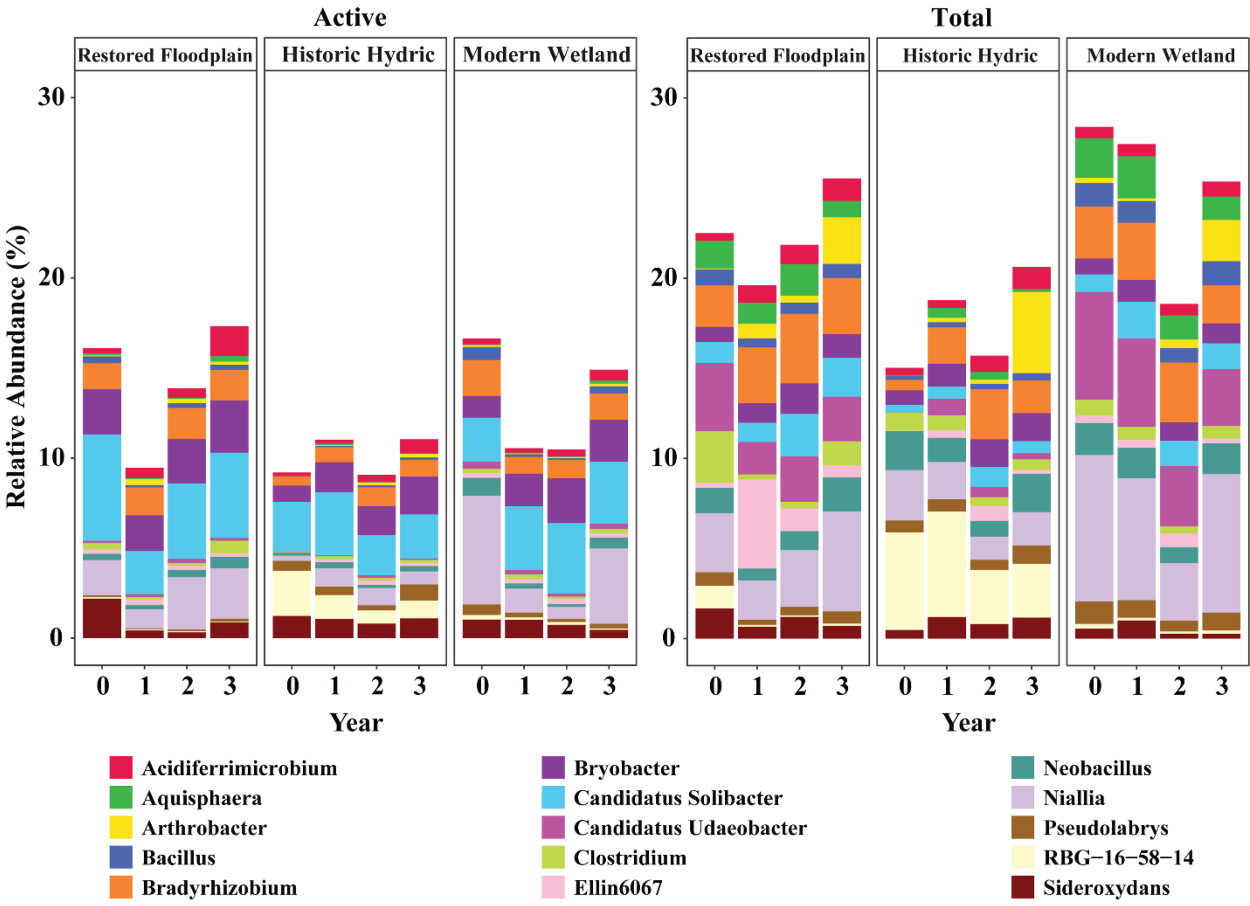
Shifts in Microbial Community Composition Associated with Soil Chemistry

- ❖ Historic hydric soil had more significant temporal changes in active versus total microbial community composition (compared to contemporary soil)
- ❖ Systematic change over time (counterclockwise trend)
- ❖ Largest compositional changes in historic hydric soil between year 0 and Year 1 correlated with increase in porewater DOC, bulk soil NO_3, NH_4 during same time-period



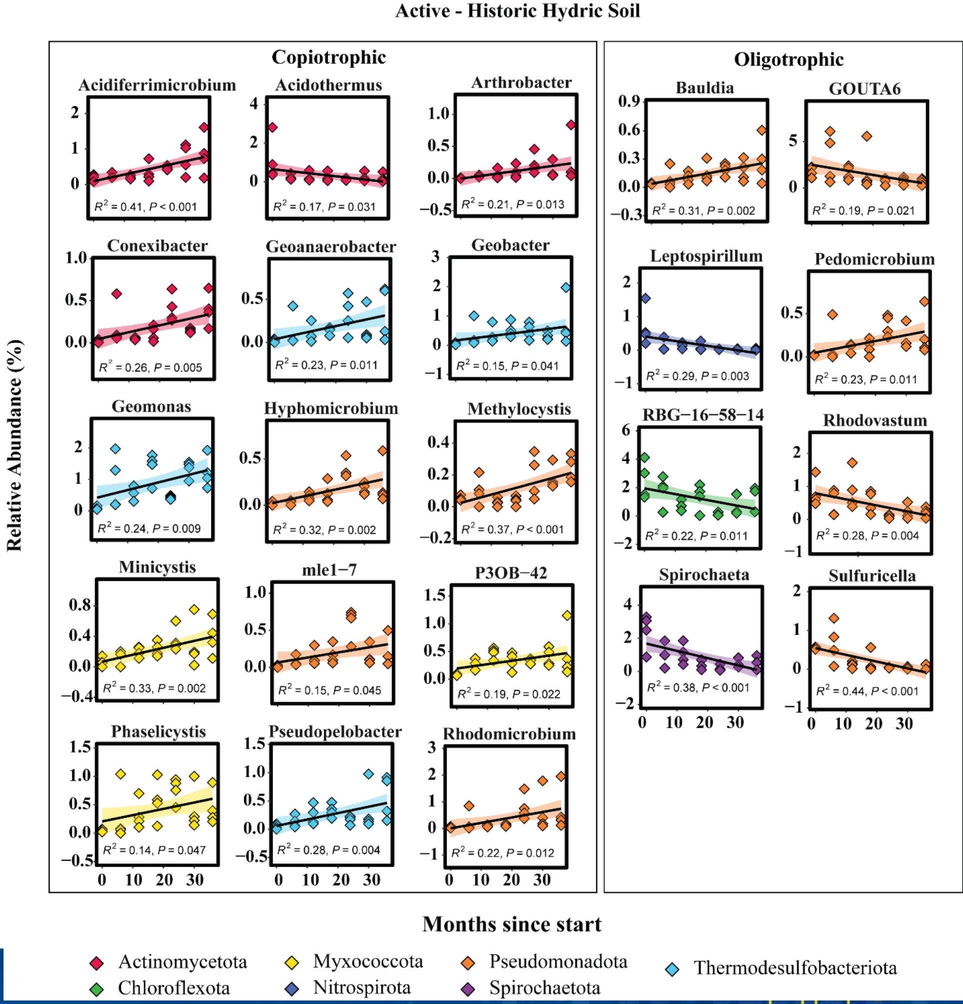
Historic Hydric Soil Significantly Differed in Top Genera Abundance & Rank

- Greater shifts in abundance of active community in historic soils versus contemporary
- Historic:
  - Increases: *Acidiferrimicrobium, Arthrobacter, Bacillus, Bryobacter*
  - Decrease: RGB-16-58-14



Indicator Taxa Abundance Shifted with Nutrient Availability

- Increasing trends over time in copiotrophic (nutrient rich) taxa
- Decreasing trends over time in oligotrophic (nutrient poor) taxa
- Indicate potential shift in microbial community composition based on changing nutrient availability -> increased labile carbon, N species, etc…

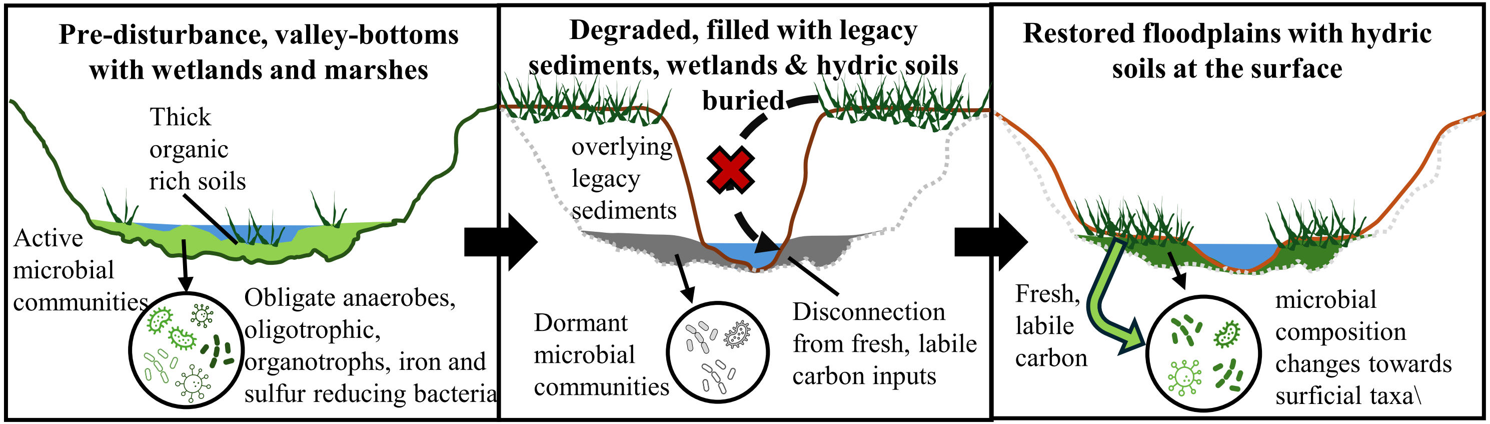


Conclusions

- Historic hydric soils exhibited distinct microbial communities compared to contemporary soils
- Historic hydric soil microbial community gradually shifted from anaerobic, oligotrophic dominated taxa to more aerobic and copiotrophic communities
- Active and Total communities of historic soils displayed more clear, progressive change over time than contemporary soils -> strong indication for reactivation and revival of dormant communities
- Significant temporal change in composition of active microbial community -> potential for strong recovery in soil functions

Incorporation in Restoration

- Allow historic hydric soils to remain *in-situ* at original elevation in floodplain where possible
- Achieving microbial community structures and functional capacities comparable to natural floodplains or reference sites is likely a long-term process



Next Steps – Mesocosm Experiments

What is driving changes in microbial community composition of historic hydric soil?

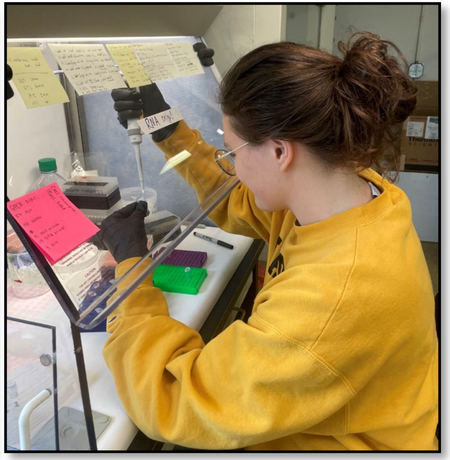
Anoxic (glovebox) experiment

- ❖ One year incubation experiment of relict soil at anaerobic conditions

Aerobic (greenhouse) experiment

- ❖ One year incubation experiment of relict soil at anaerobic conditions

- ❖ Assessing chemical and biological controls on microbial community recovery in historic hydric soils



Thank You!

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References

Miller, J. R., & Craig Kochel, R. (2013). Use and performance of in-stream structures for river restoration: a case study from North Carolina. Environmental earth sciences, 68, 1563-1574.

Walter, R. C., & Merritts, D. J. (2008). Natural streams and the legacy of water-powered mills. *Science*, *319*(5861), 299-304.