MICROBIAL COMMUNITY RESPONSE TO SHIFTING WATER QUALITY AND QUANTITY IN AN ARID URBAN ECOSYSTEM

Jennifer Follstad Shah[1], Samantha Weintraub[2] , Rose Smith[3], Rachel Gabor[4], Yusuf Jameel[5]

[1] Environmental & Sustainability Studies / Geography, University of Utah

[2] National Ecological Observatory Network, Battelle

[3] Biology, University of Utah

[4] School of Forest Resources and Conservation, University of Florida

[5] School of Natural Resources & Environment, Ohio State University

Society for Freshwater Science Annual Meeting – May 21, 2019

S04: Novel stressors and novel ecosystems:
Ecological processes in freshwaters of the built environment

STOICHIOMETRY & MICROBIAL METABOLISM

60:7:1 C:N:P (Cleveland & Liptzin 2007 *Biogeochemistry*)

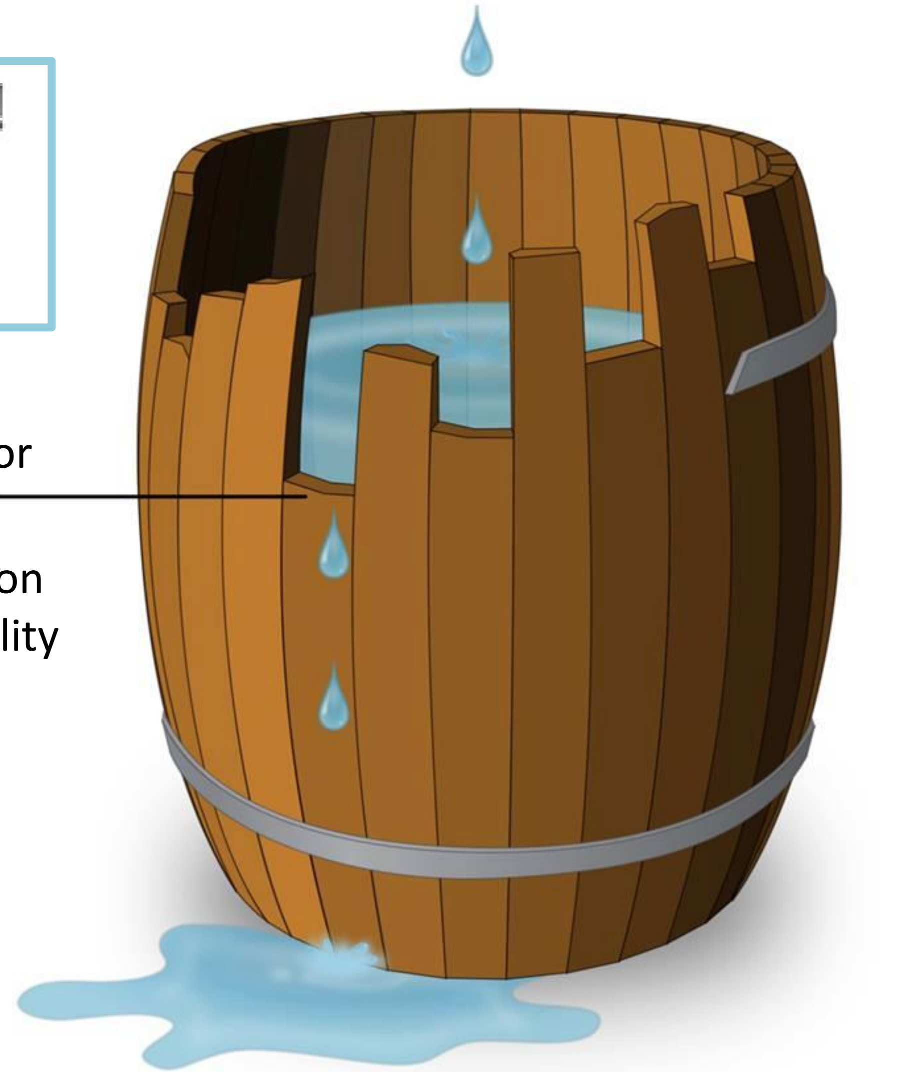
BIOGEOFEMINIST Mixer at SFS!
Tue., 21 May, 5:15-7 PM
BeerHive Pub Basement

Growth-
Limiting Factor

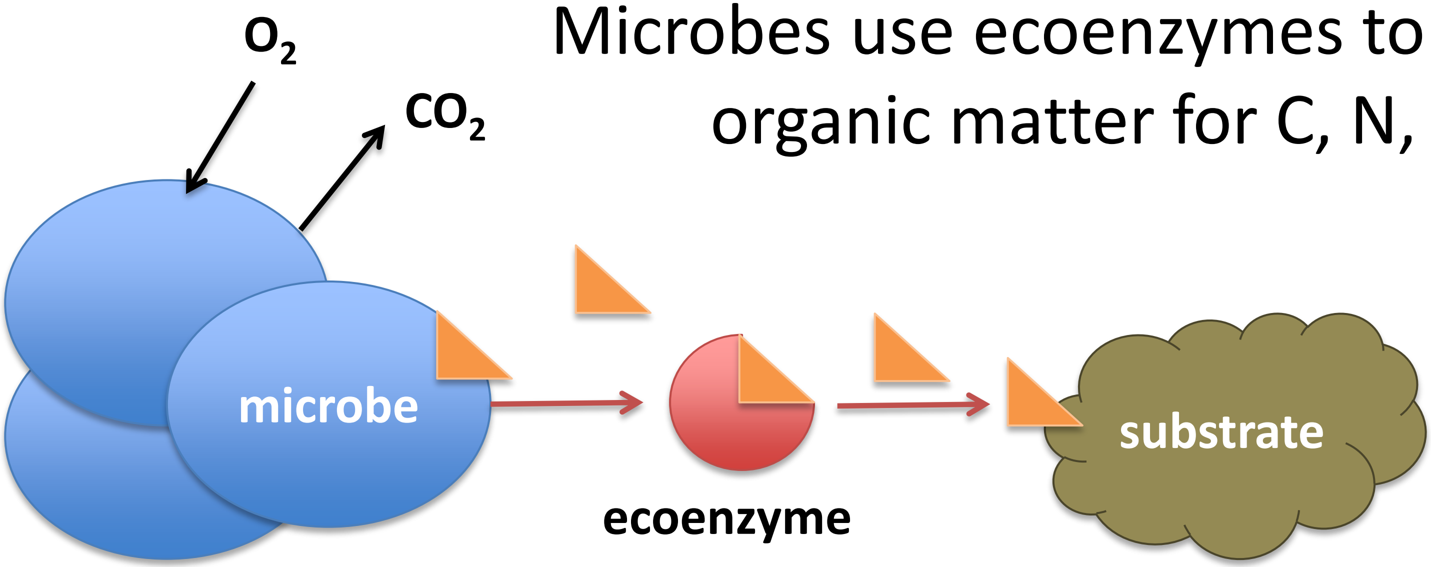
Energy: Carbon
supply & quality

AND/OR

Nutrients:
Nitrogen,
Phosphorus

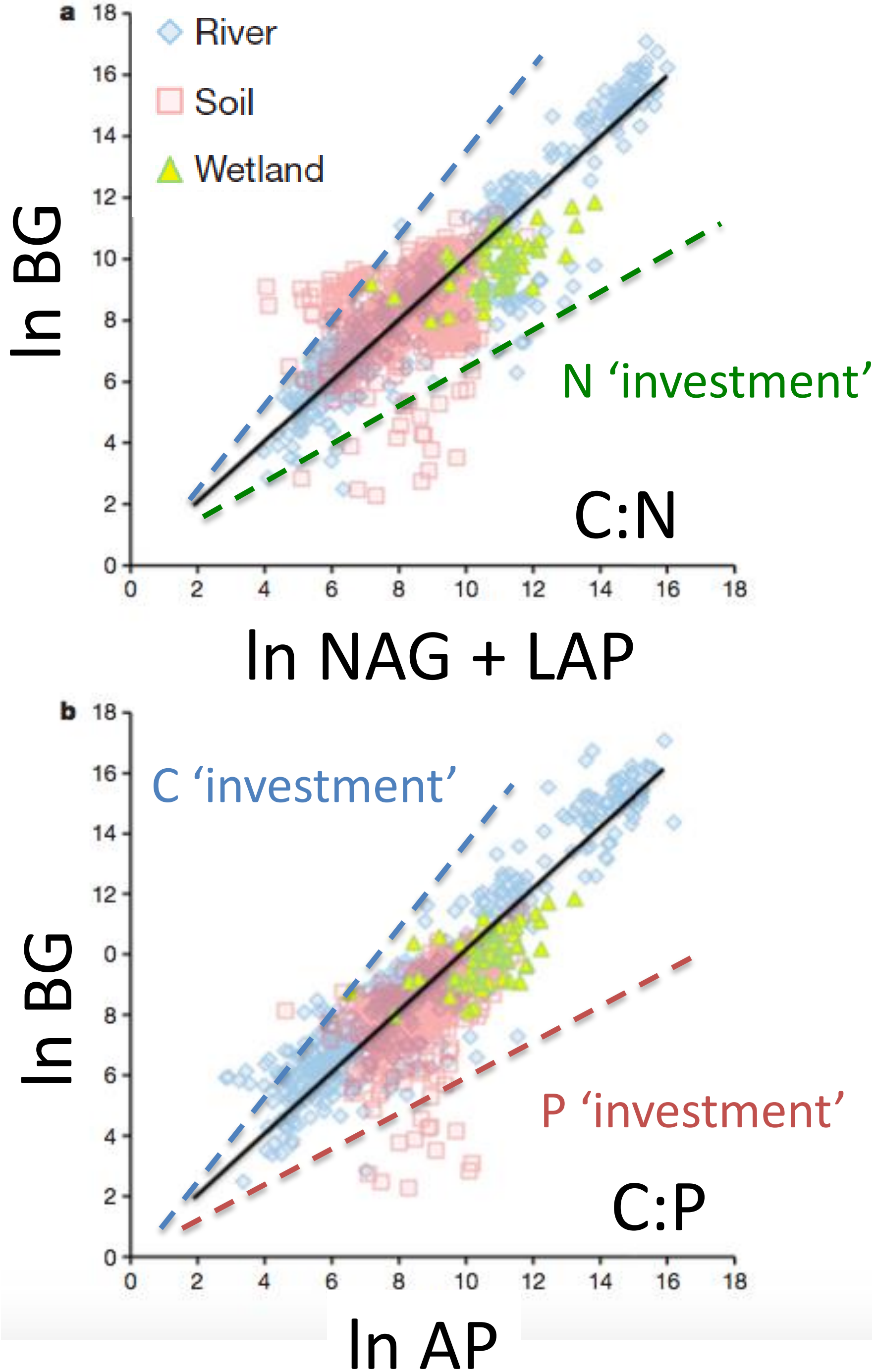


Microbes use ecoenzymes to 'mine' organic matter for C, N, P



Ecoenzyme	Code	Resource	Example Source
β-1,4-glucosidase	BG	C	cellulose
Phenol oxidase	POX	C	lignin
Leucine aminopeptidase	LAP	N	proteins, polypeptides
Alkaline phosphatase	AP	P	phospholipids, phosphosaccharides

Sinsabaugh & Follstad Shah 2012 *Ann Rev of Ecol Evol & Syst*



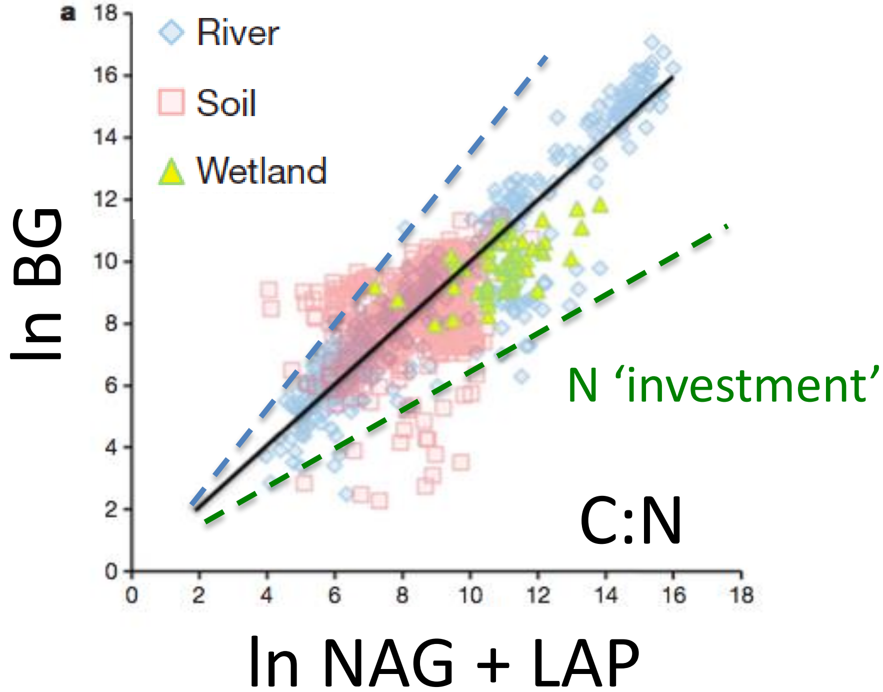
ECOENZYME SCALING RELATIONSHIPS

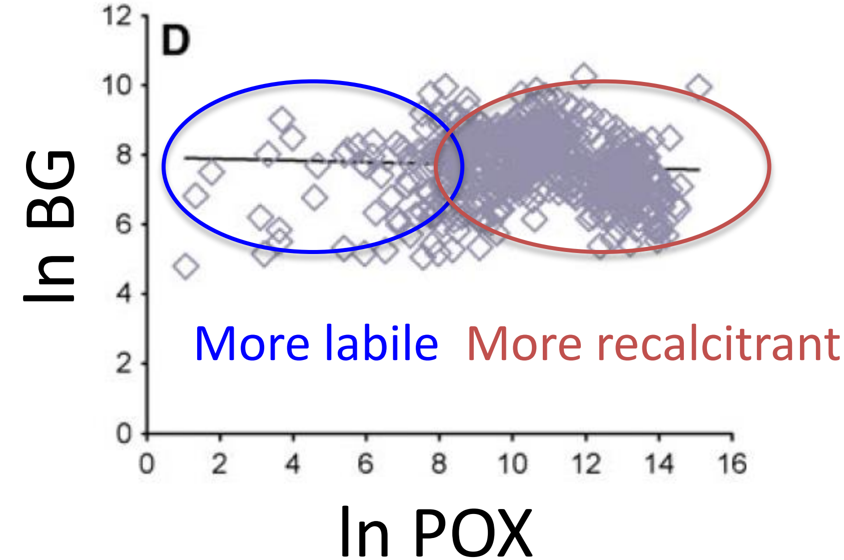
Ecoenzyme ratios are ~ 1:1 across broad scales

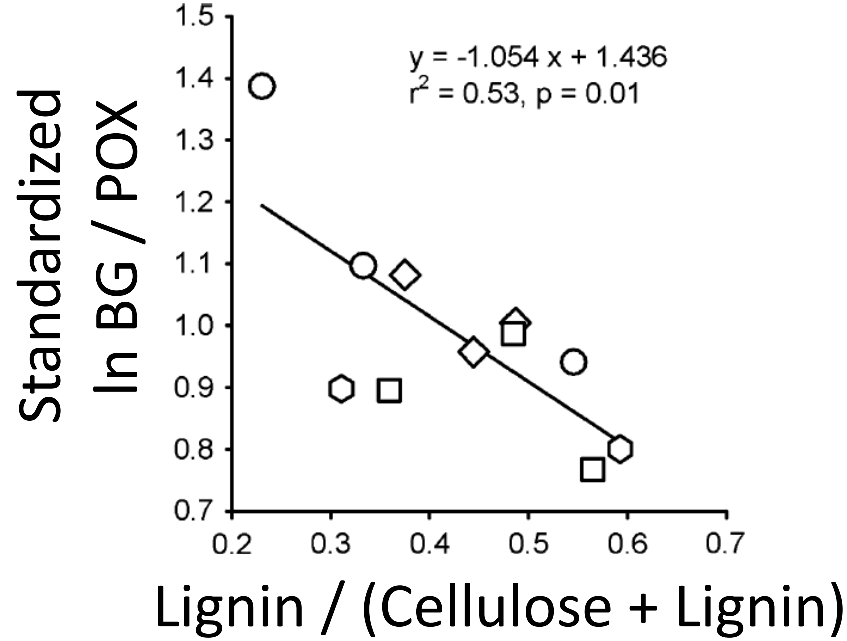
Production of ecoenzymes can be costly:

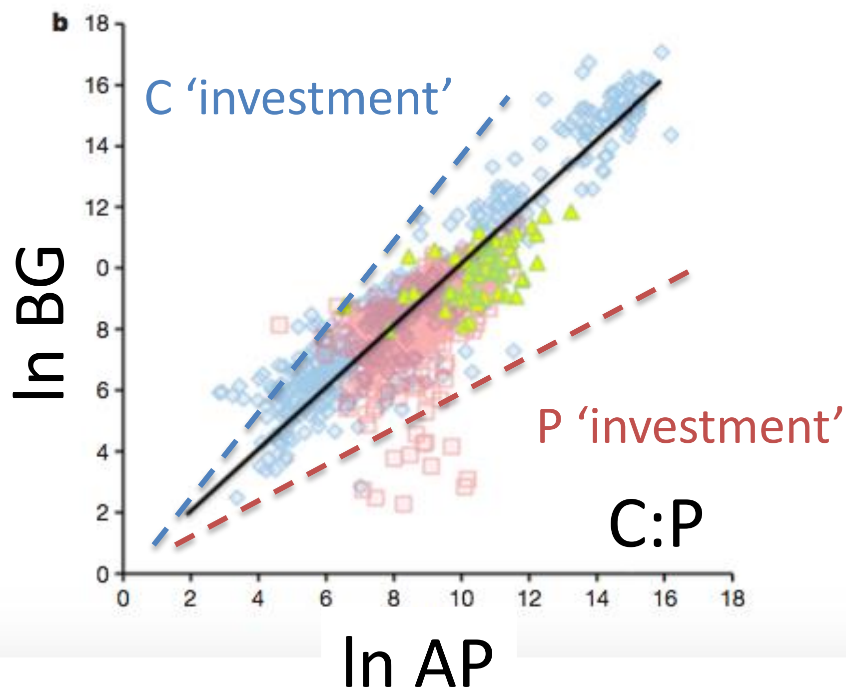
- Ratio > 1: greater C investment
- Ratio < 1: greater N or P investment

Sinsabaugh, Hill, & Follstad Shah 2009 *Nature*



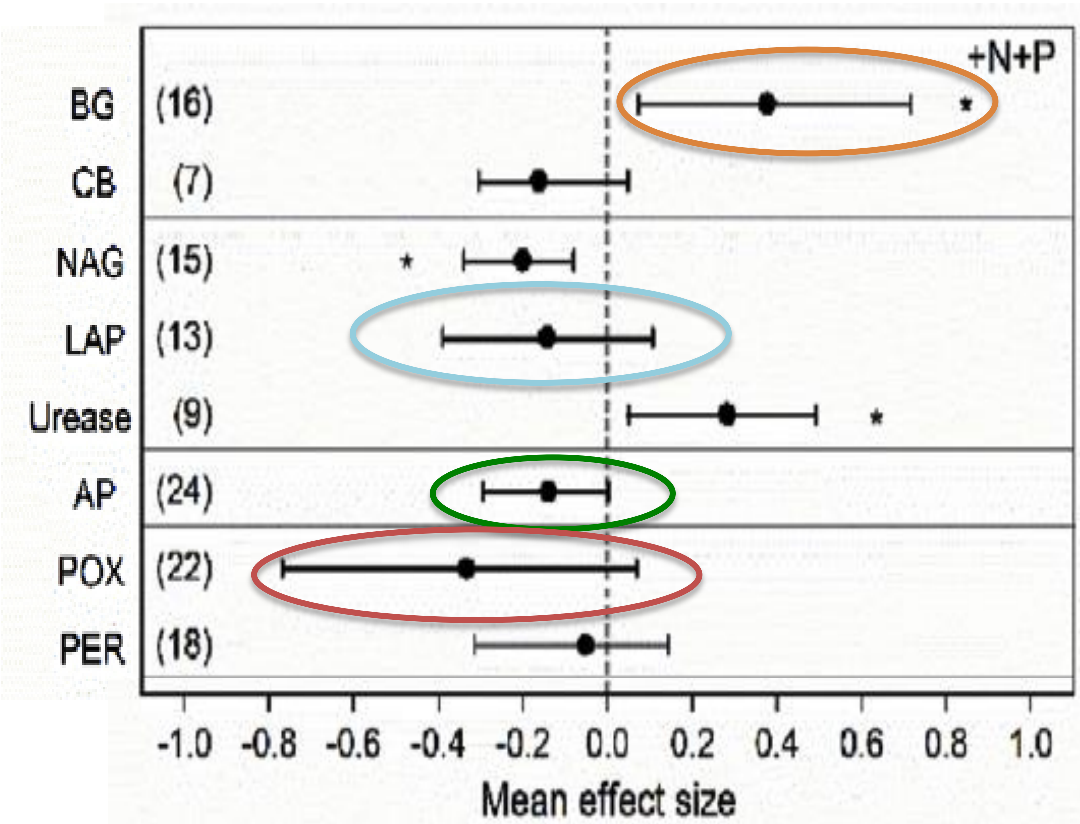


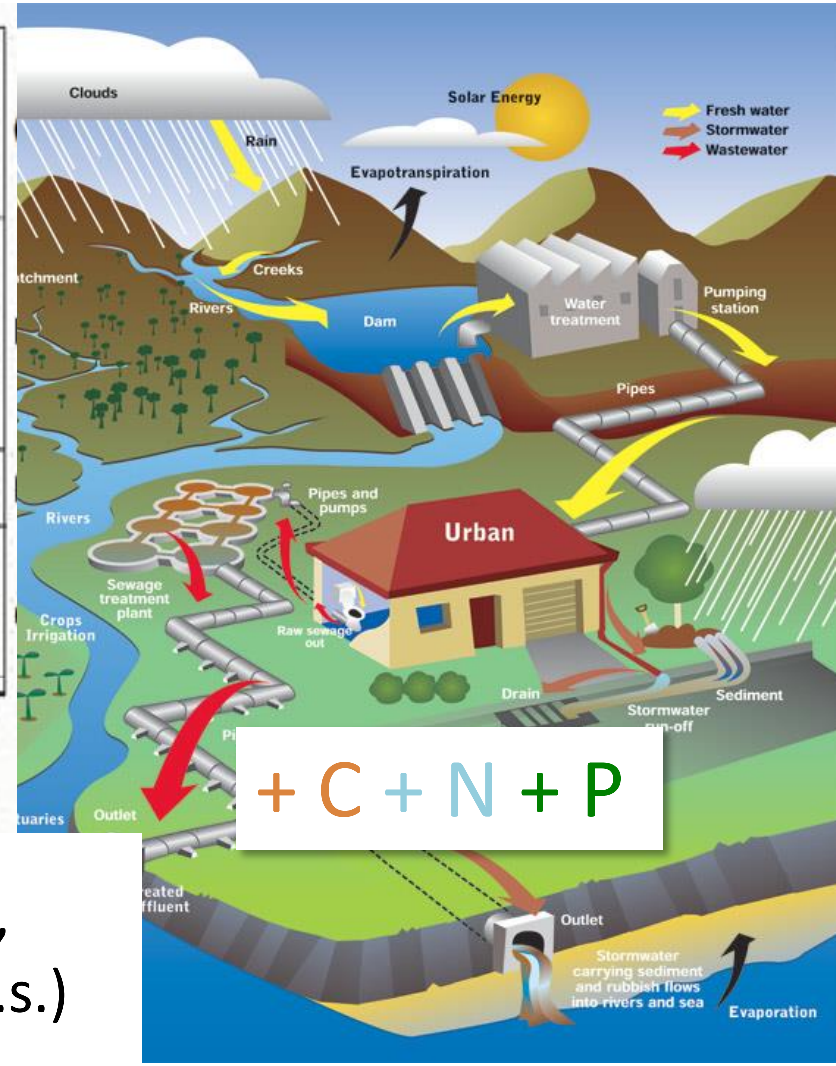




Sinsabaugh & Follstad Shah 2011 *Biogeochemistry*

URBAN WATER INFRASTRUCTURE – NOVEL STRESSORS





+ C + N + P

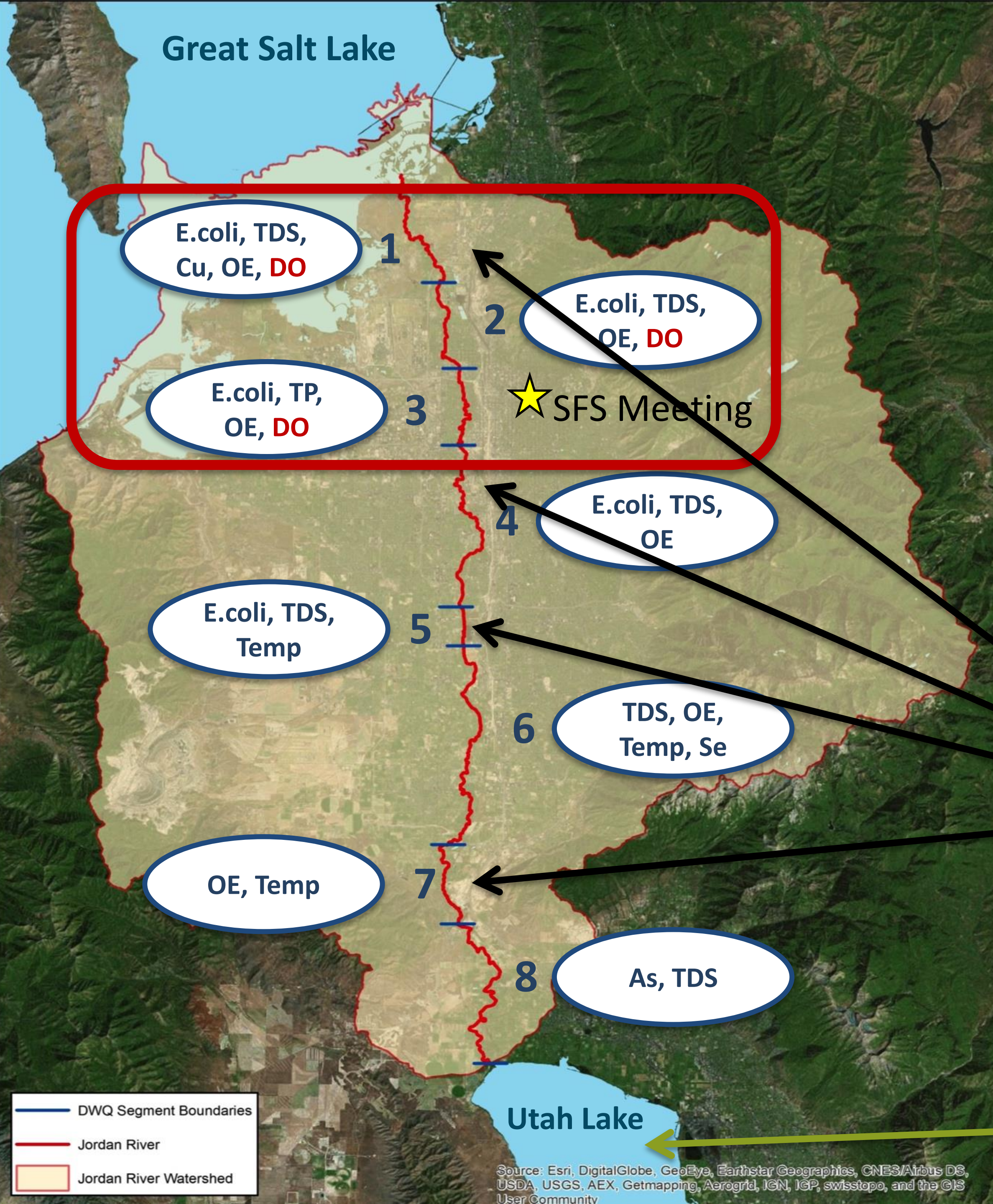
+ N, P fertilization stimulates BG activity, while LAP, AP, & POX activity declines (n.s.)

Xiao et al. 2018 *Soil Biology & Biogeochemistry*

Catchment size: 2,085 km^2
Population size: 1.12 million people
Land use: 44% urban

Are there consistent relationships between source water contributions, water quality, & ecoenzyme activity rates & ratios?

Do ecoenzyme stoichiometric relationships hold for urban river systems with chronic inputs of C, N, & P?

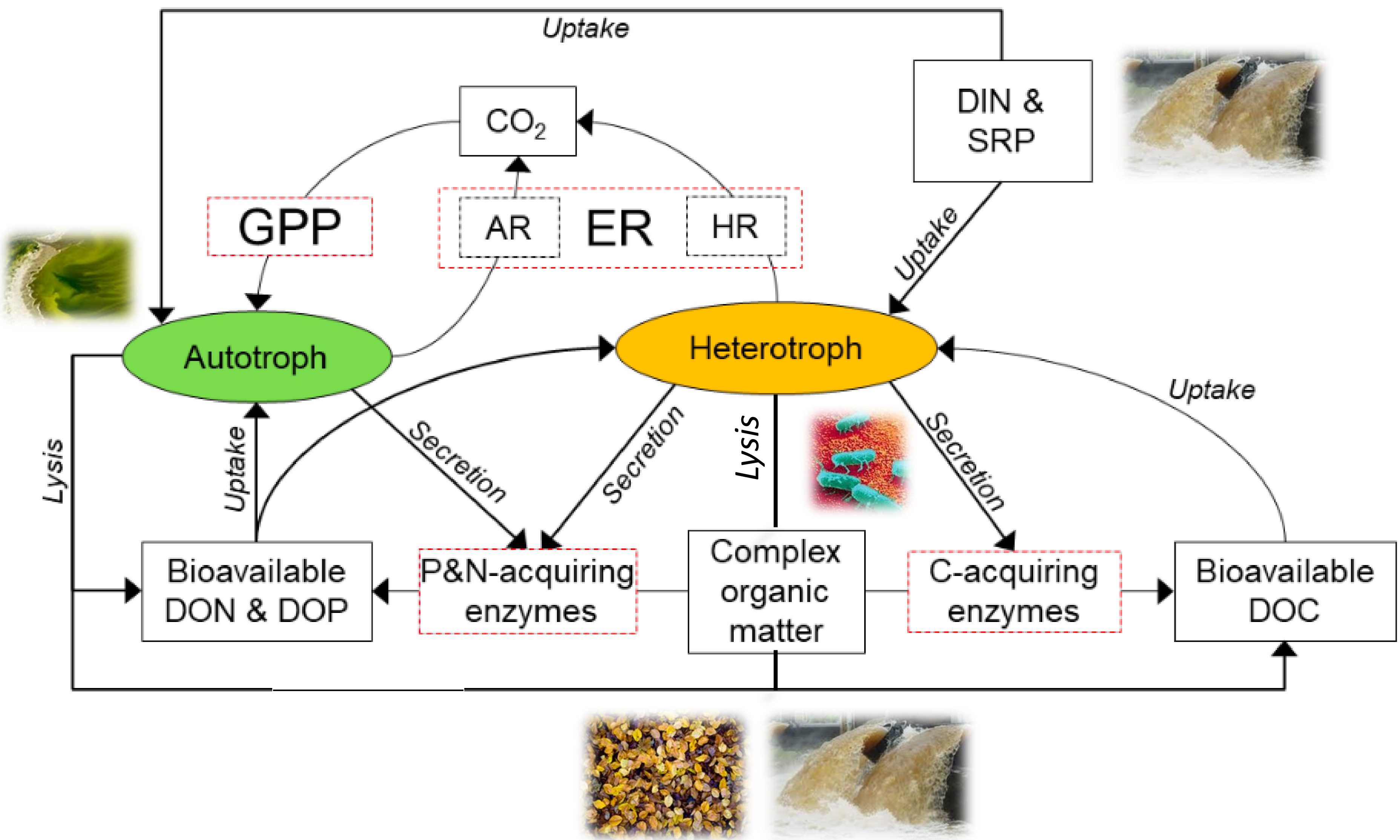


JORDAN RIVER, UT

Low dissolved oxygen (DO) in downstream reaches ➔ U.S. EPA **303d listing** ➔ TMDL process

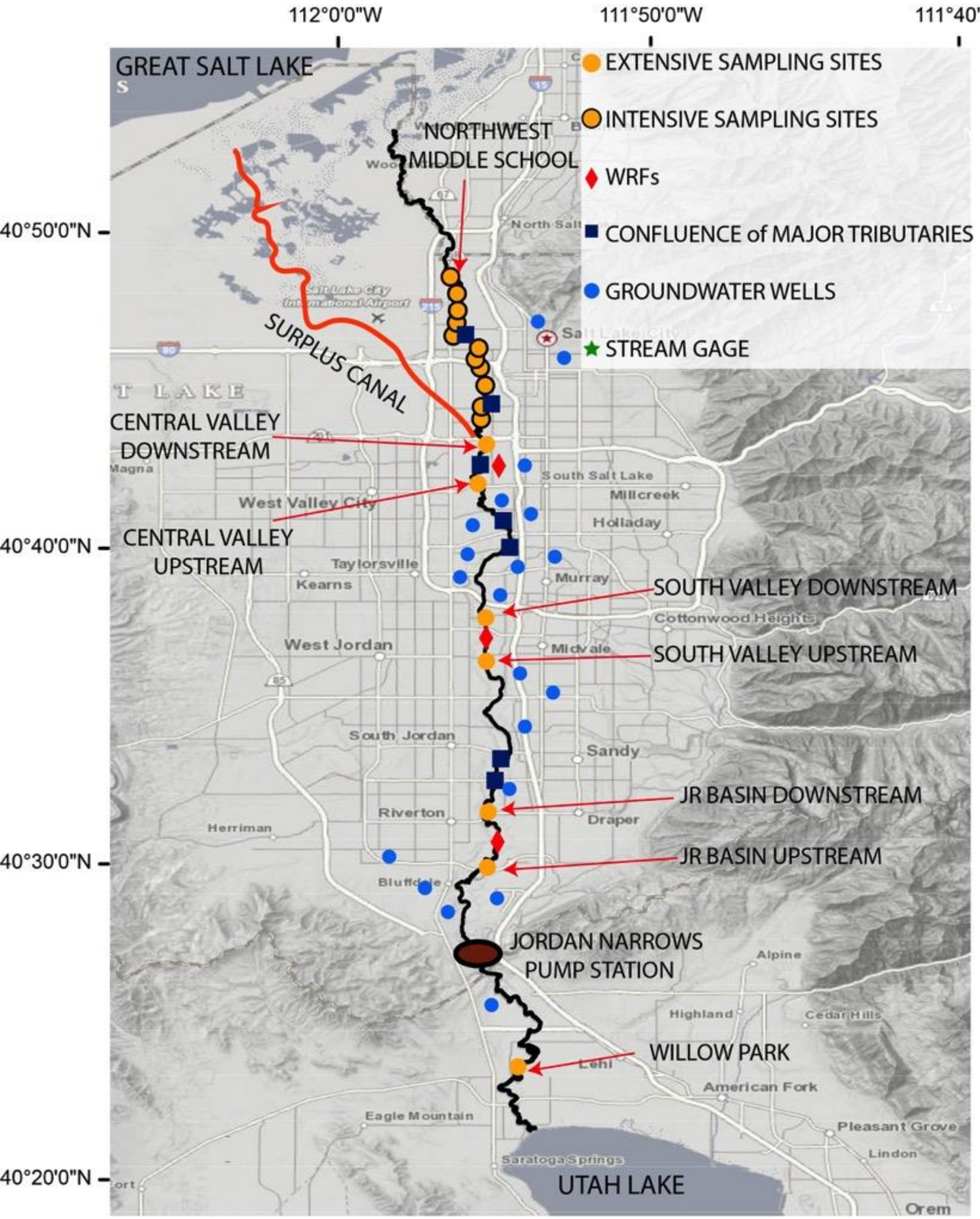
2013 DWQ report: **Too much organic matter ➔ high BOD**

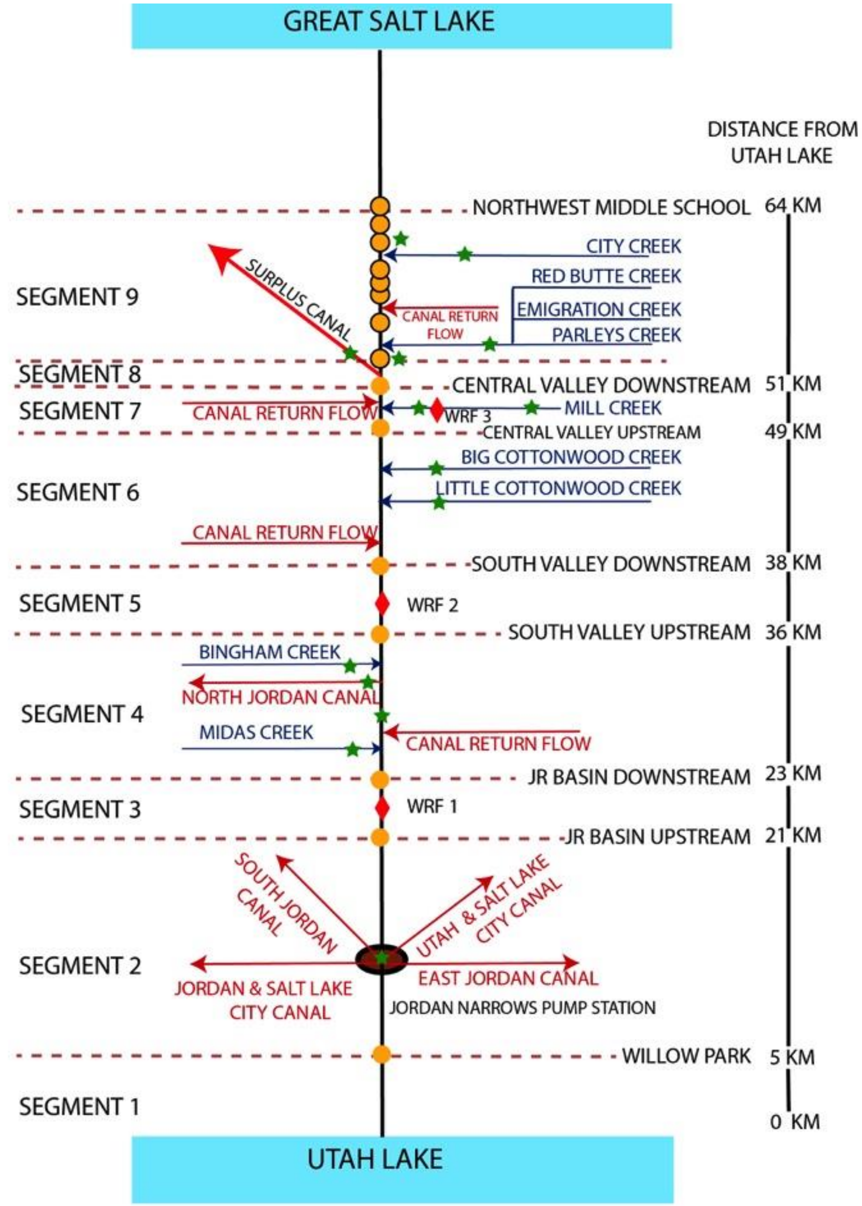
Organic substrates can be derived (& recycled) from both autochthonous & allochthonous sources

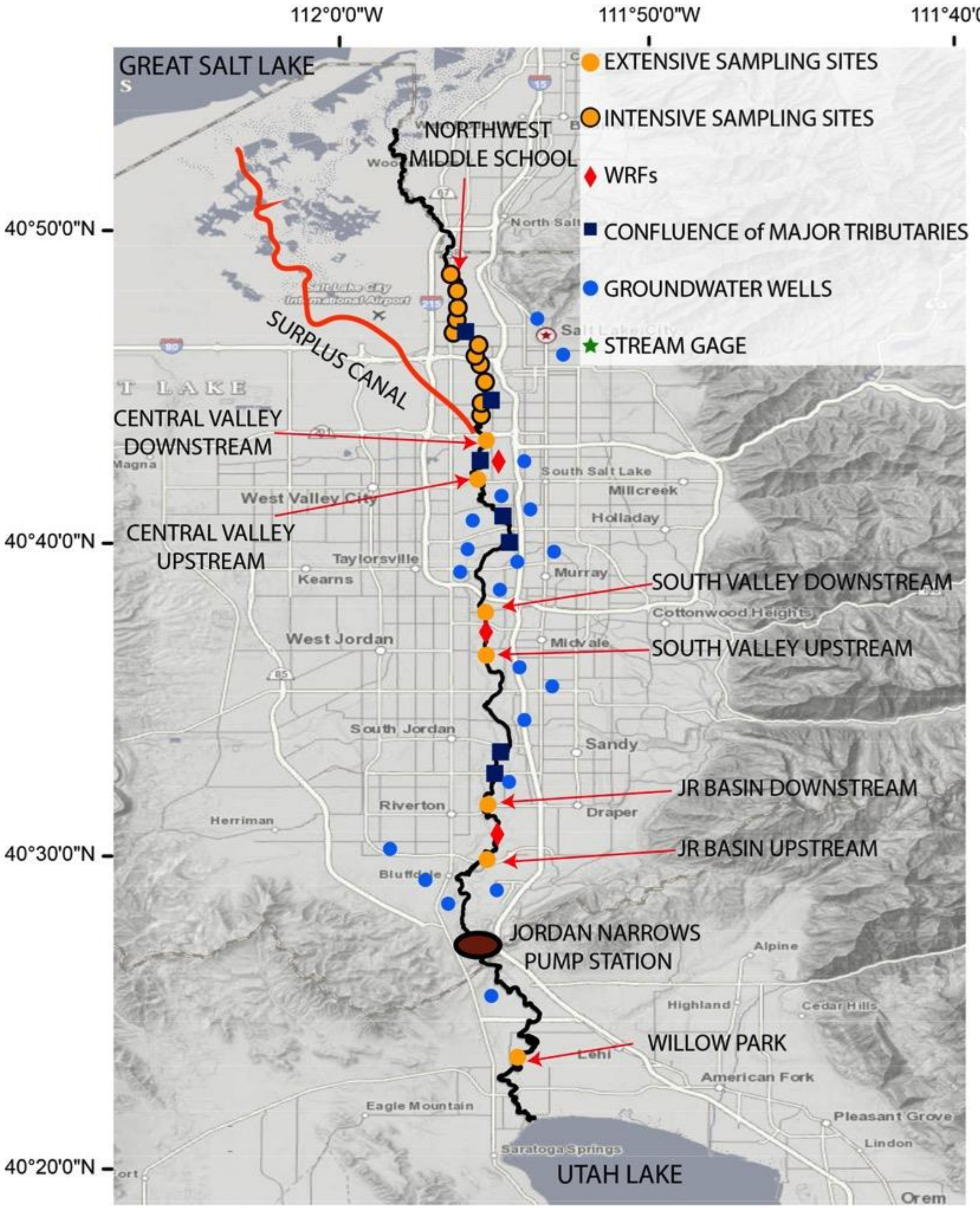


Follstad Shah et al. 2019

J. of the Amer. Water Res. Assoc.

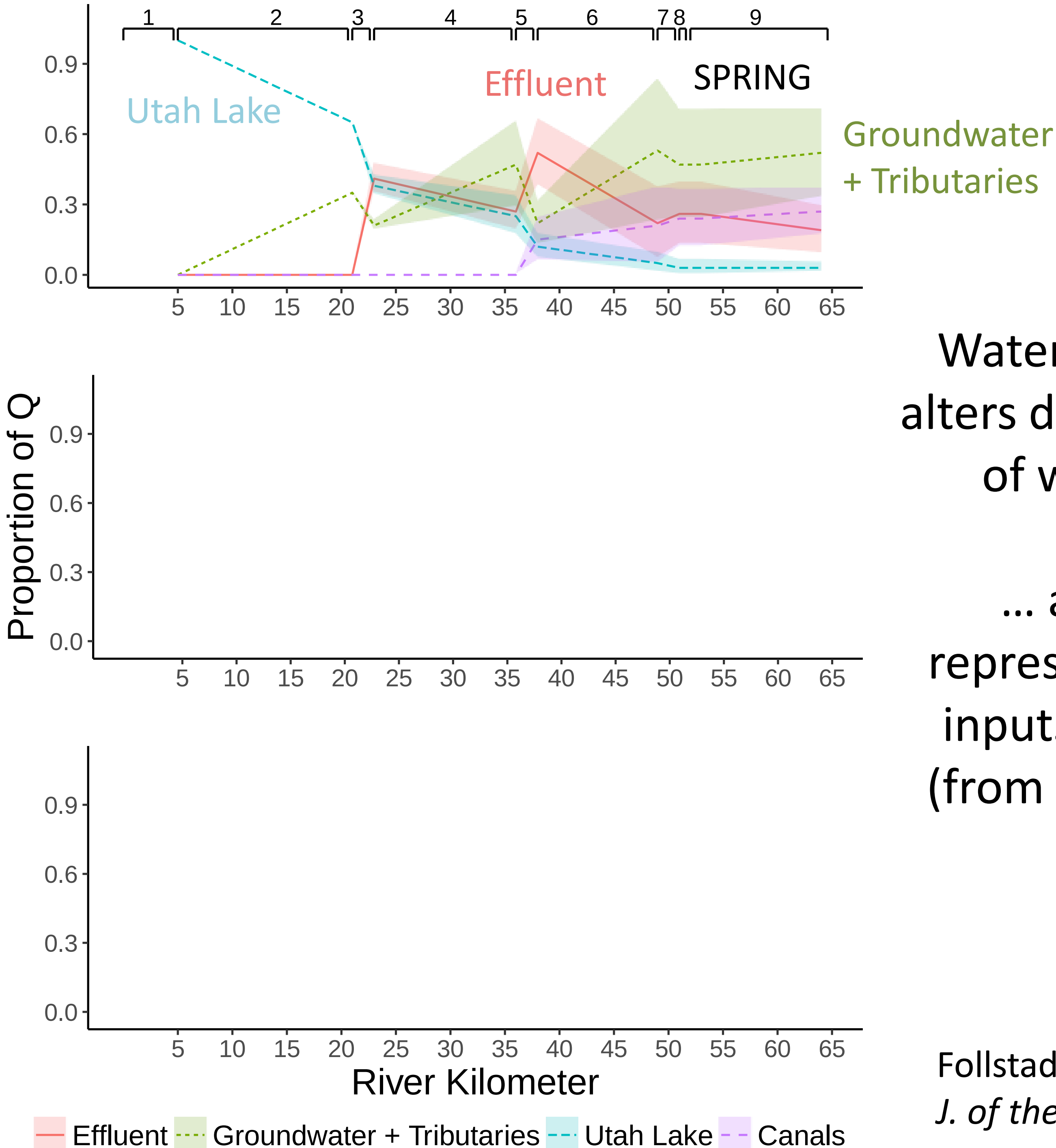






DATA COLLECTION (May, August, Nov., 2016)

- Discharge & water isotopes (^{18}O, ^{2}H) for water sources
  - River
  - Inputs – Utah Lake, effluent, tributaries
  - Outputs – diversions
- Water physiochemistry & enzymes (river & effluent)
  - DOC
  - NO_3-N, NH_4-H, TDN
  - PO_4-P, TDP
  - β-1,4-glucosidase (BG)
  - Leucine aminopeptidase (LAP)
  - Alkaline phosphatase (AP)
  - Phenol oxidase (POX)



Water infrastructure alters dominant sources of water to river

… and effluent represents 30-70% of inputs in all seasons (from river km 22-64)

Follstad Shah et al. 2019
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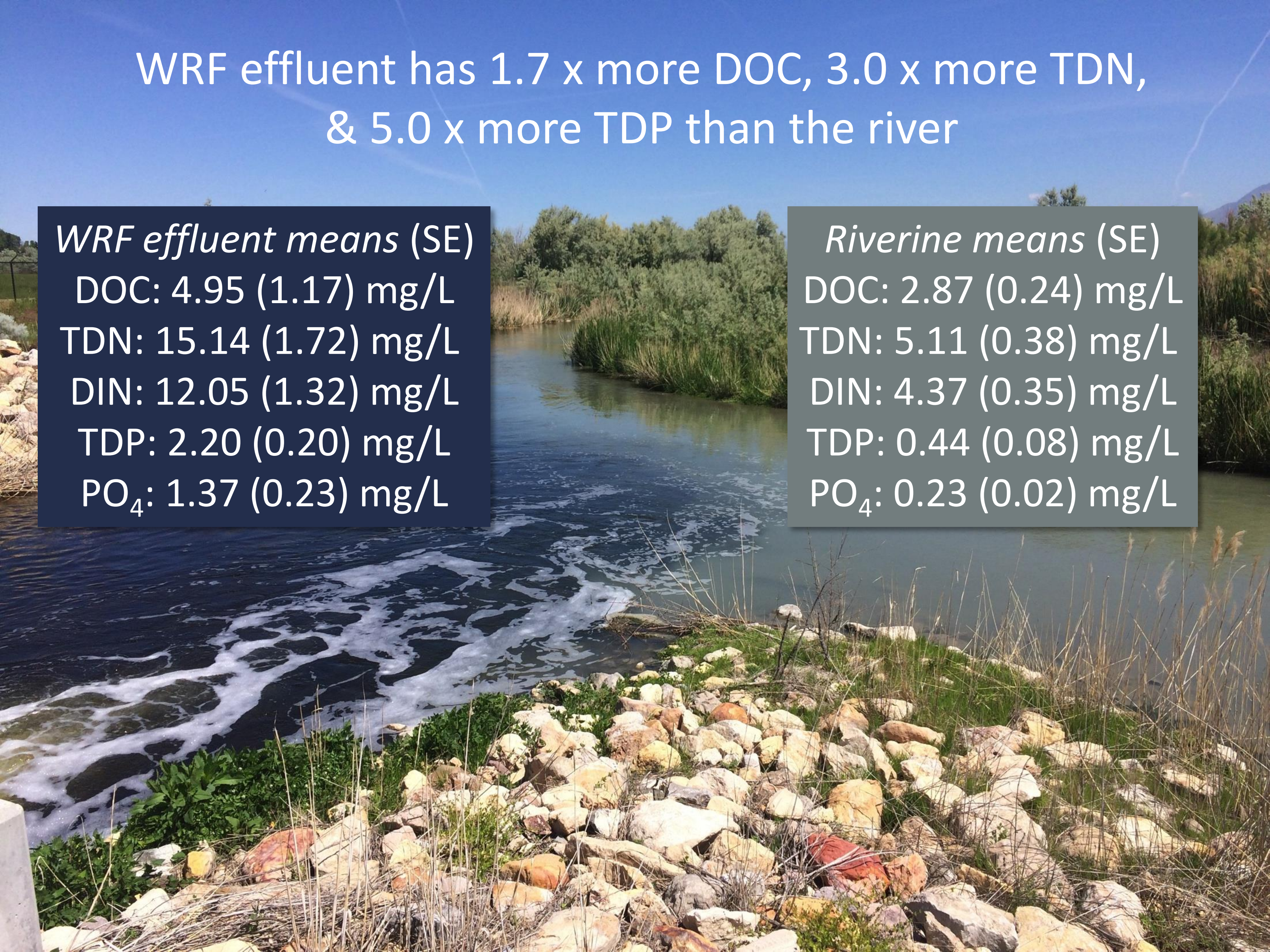
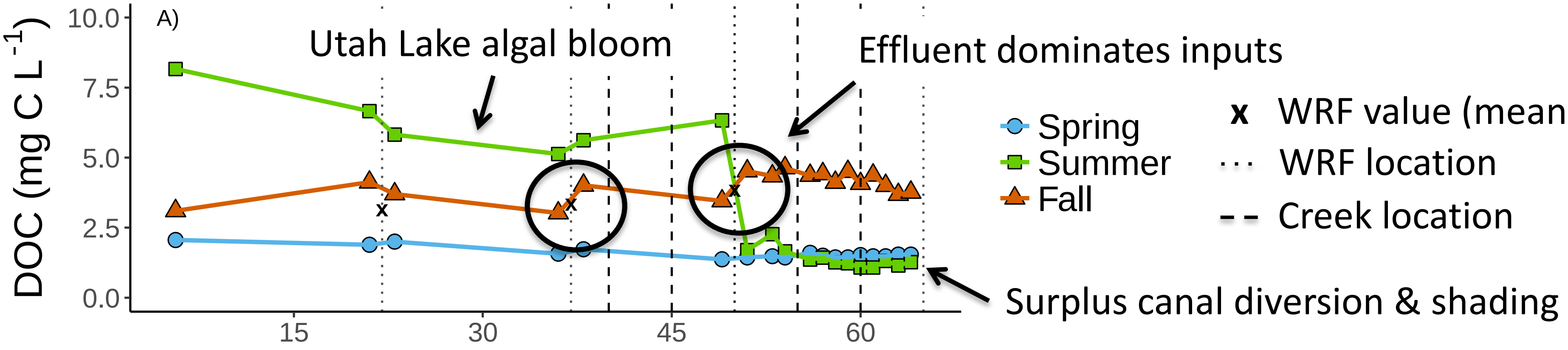
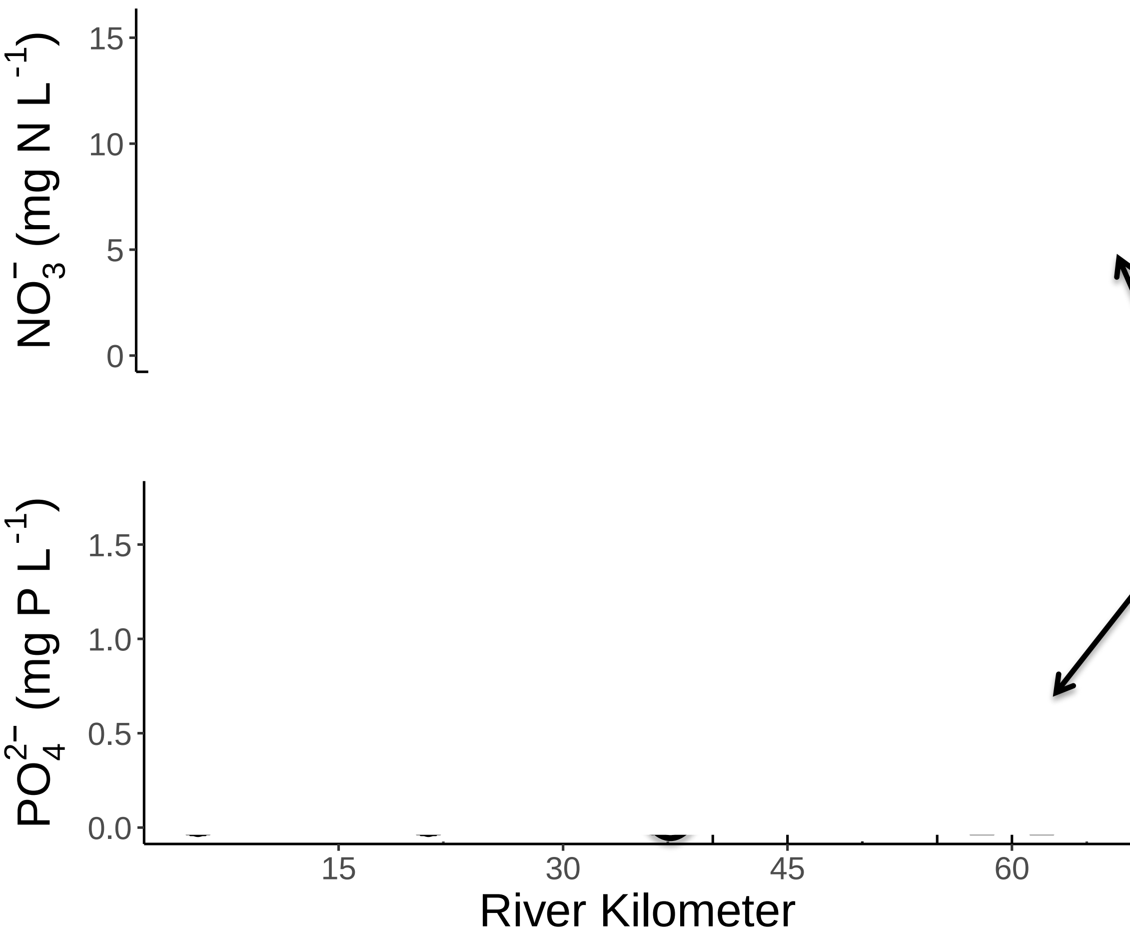
WRF effluent has 1.7 x more DOC, 3.0 x more TDN, & 5.0 x more TDP than the river



WRF effluent means (SE)	*Riverine means* (SE)
DOC: 4.95 (1.17) mg/L	DOC: 2.87 (0.24) mg/L
TDN: 15.14 (1.72) mg/L	TDN: 5.11 (0.38) mg/L
DIN: 12.05 (1.32) mg/L	DIN: 4.37 (0.35) mg/L
TDP: 2.20 (0.20) mg/L	TDP: 0.44 (0.08) mg/L
PO_4: 1.37 (0.23) mg/L	PO_4: 0.23 (0.02) mg/L



Differences in water inputs are reflected in spatial and seasonal variation in water chemistry



Elevated inorganic nutrient supply should suppress ecoenzyme activity

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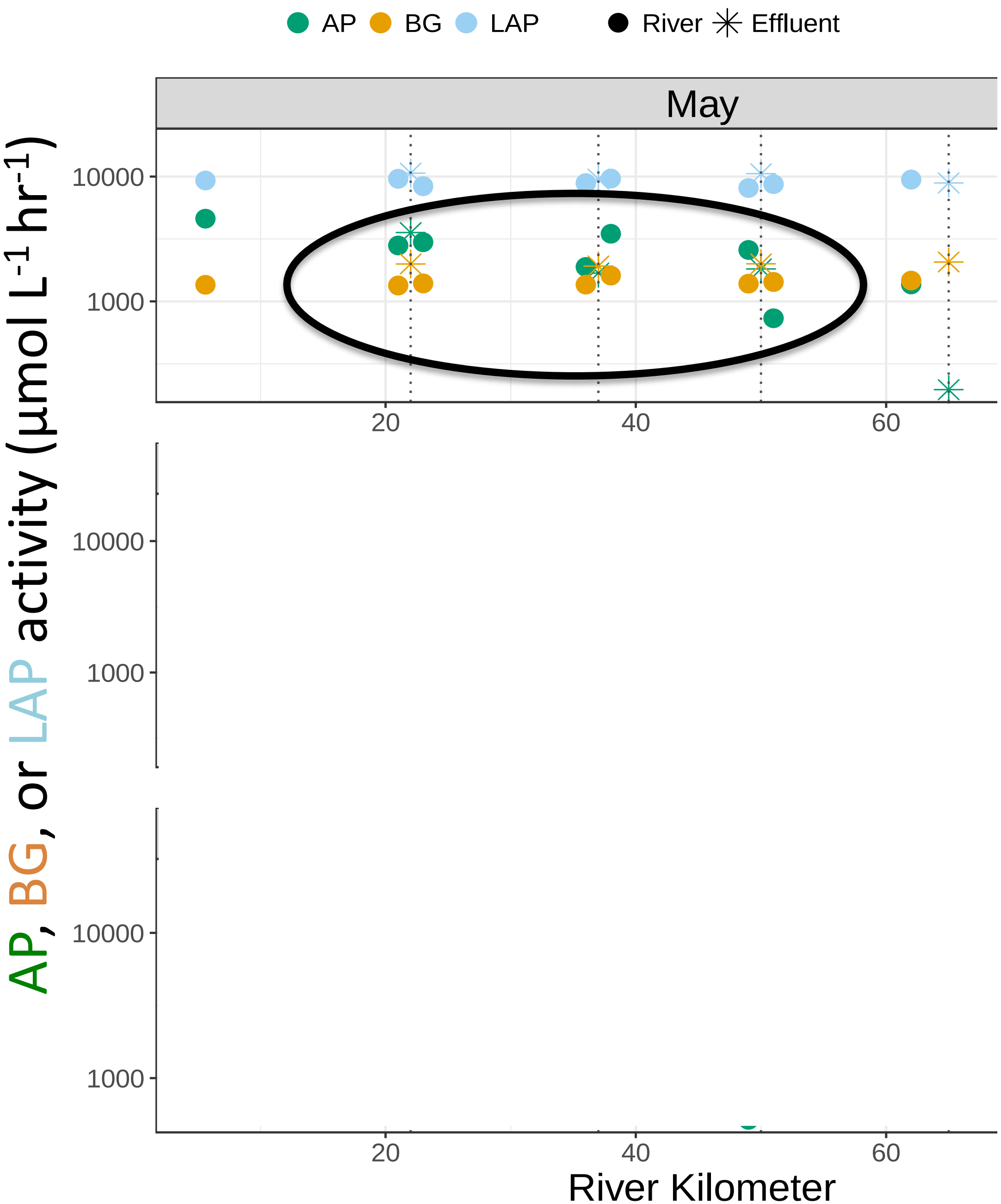
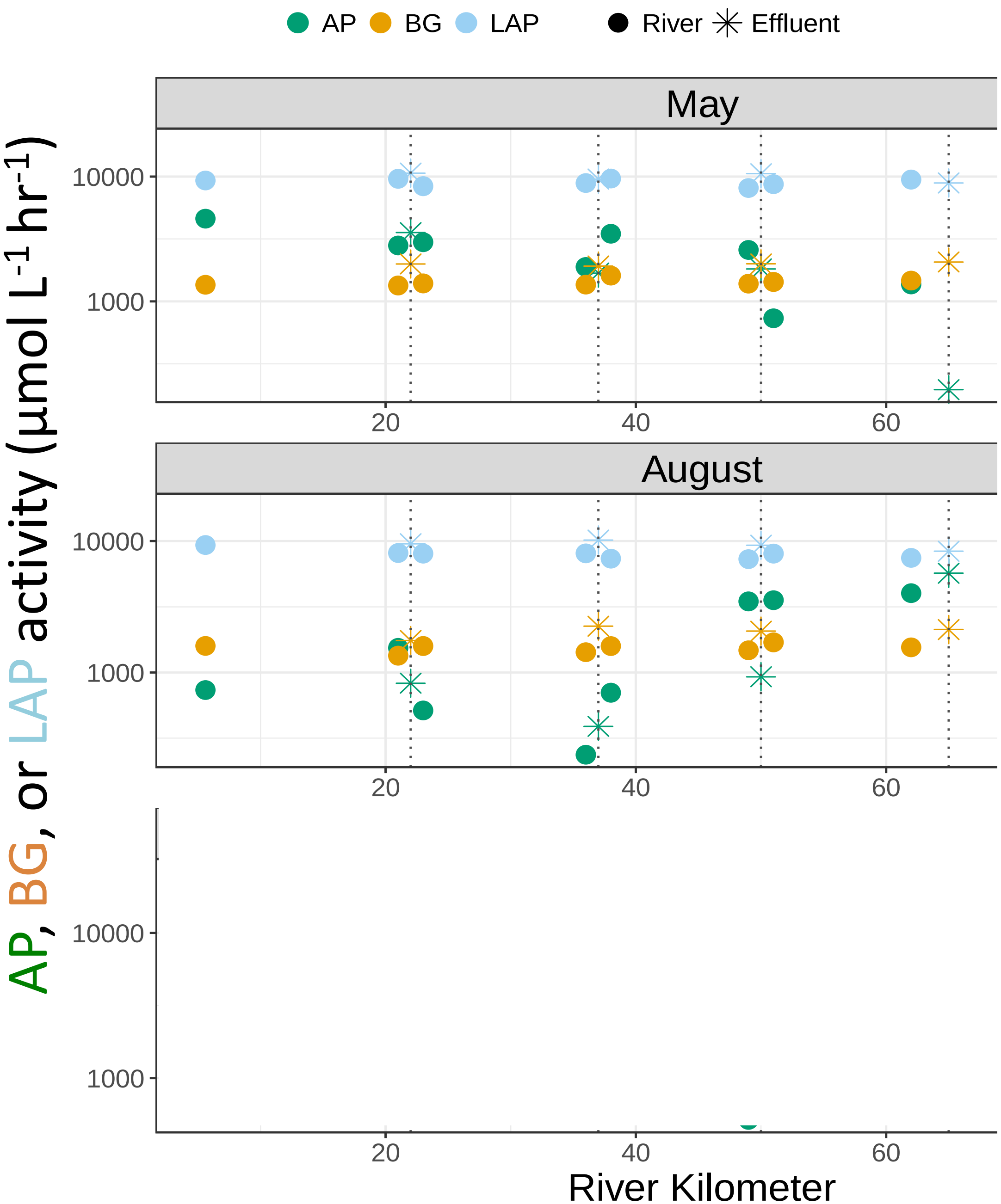


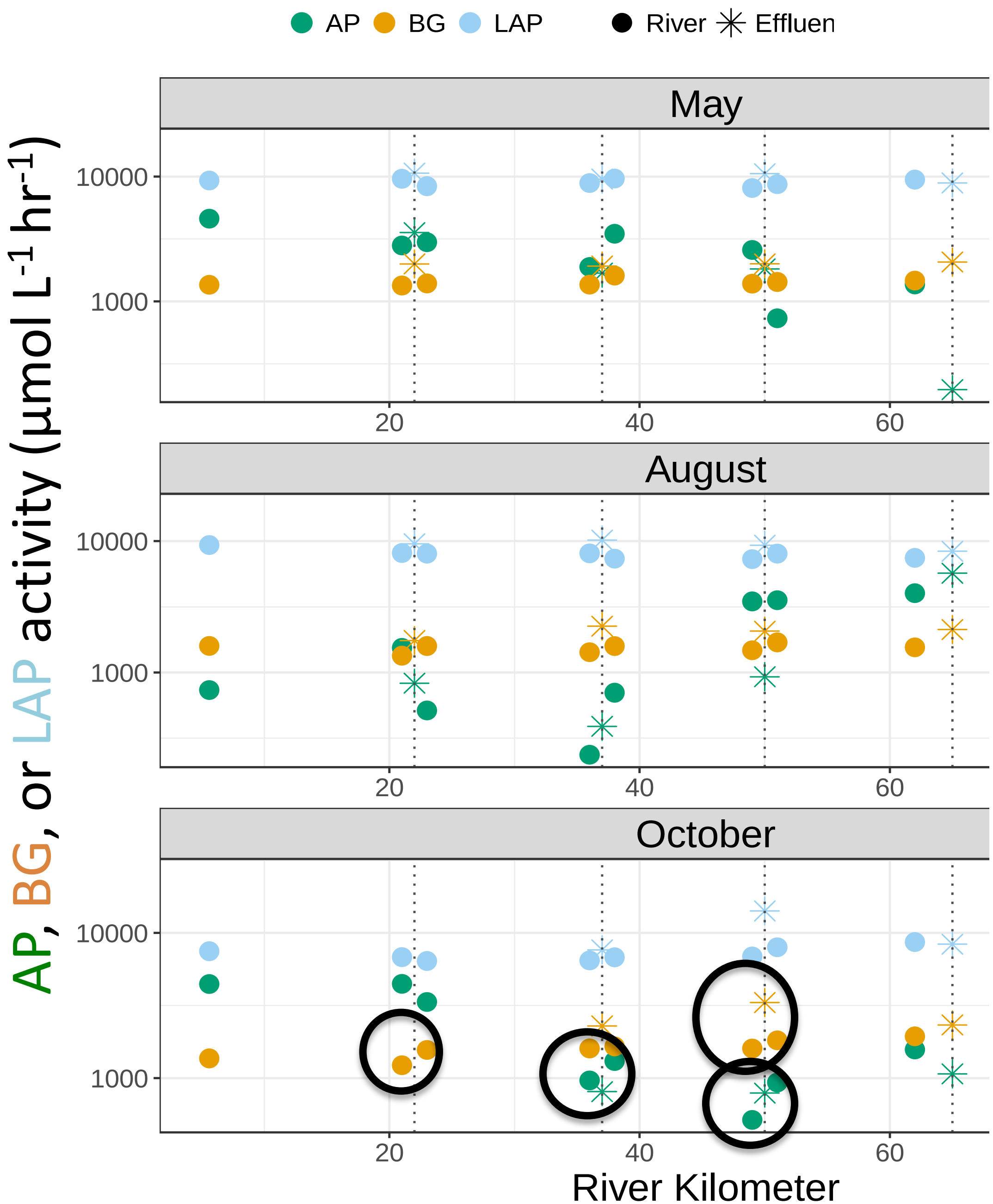
SPRING:

- BG (& DOC) is stable
- LAP is stable & high
- AP is most variable (no consistent response to effluent inputs)



SUMMER:

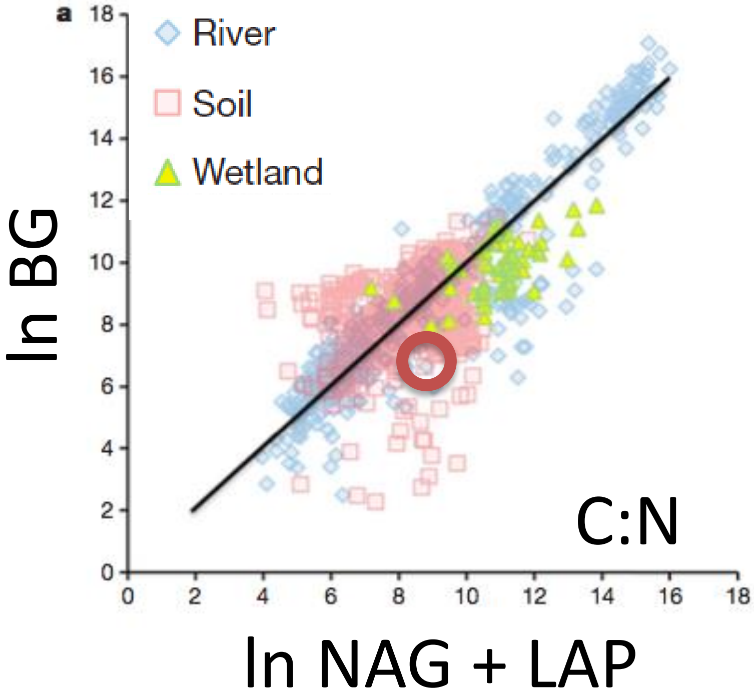
- BG increases along the flowpath (with decline in DOC)
- LAP is stable & high (despite elevated NO_3)
- AP switches to higher rates downstream (despite elevated PO_4); still no consistent response to effluent input

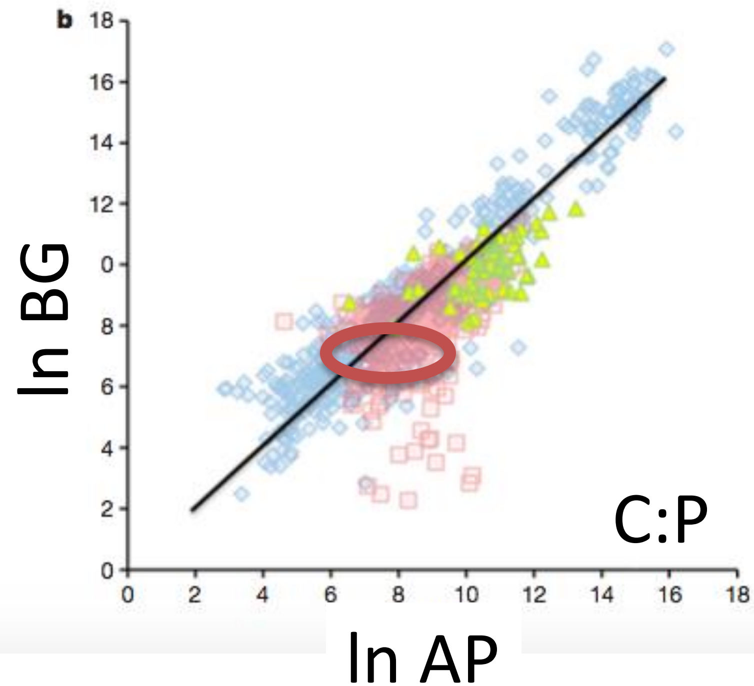


Ecoenzyme responses do not clearly follow the ‘economics of ecoenzyme allocation’

FALL:

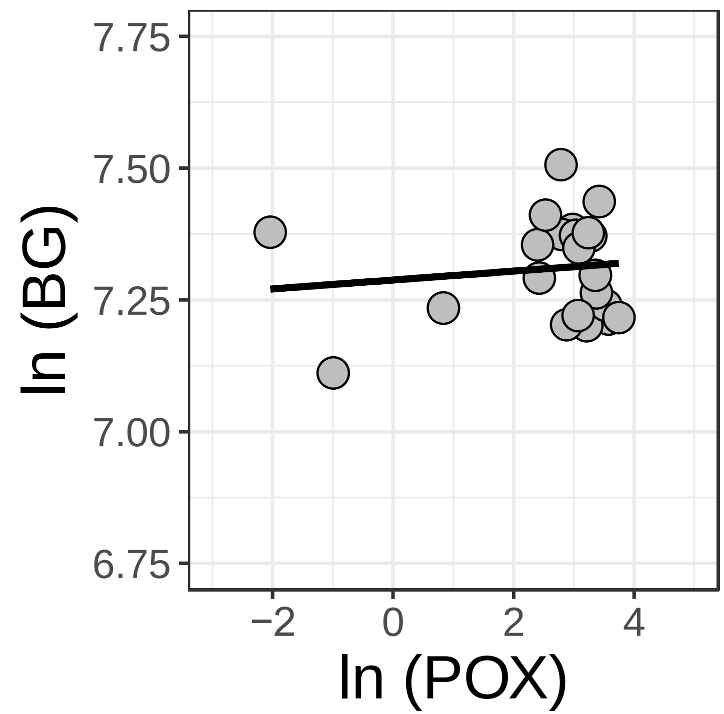
- BG increases along flowpath (with elevated DOC)
- LAP is stable & high (despite elevated NO_3)
- AP switches back to higher rates upstream (despite elevated PO_4); higher rates in response to effluent from older WRFs





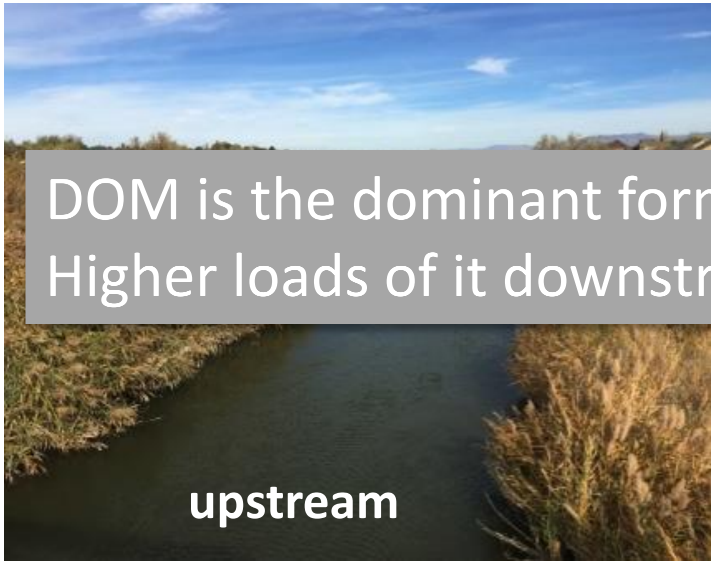
JORDAN RIVER:

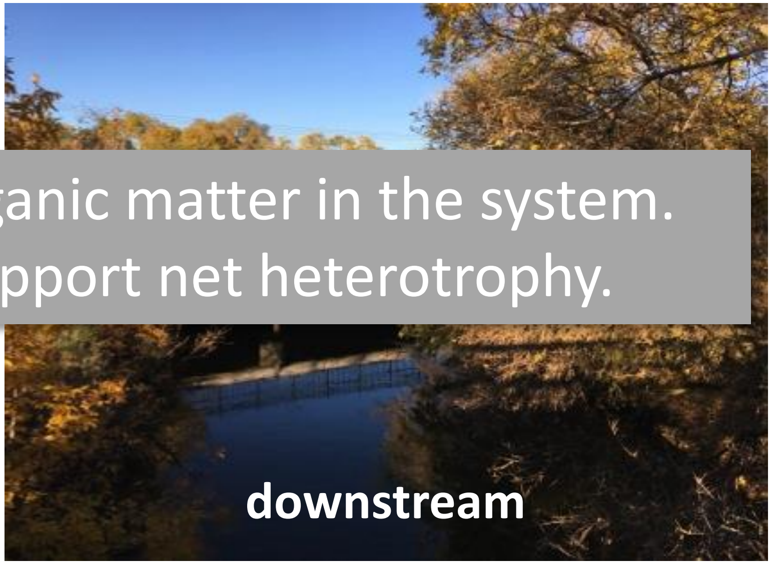
- Ratios are within range of observed river values
- Ratios indicate imbalance in N & sometimes P relative to C
- BG is 2 orders of magnitude greater than POX ➔ labile C substrates

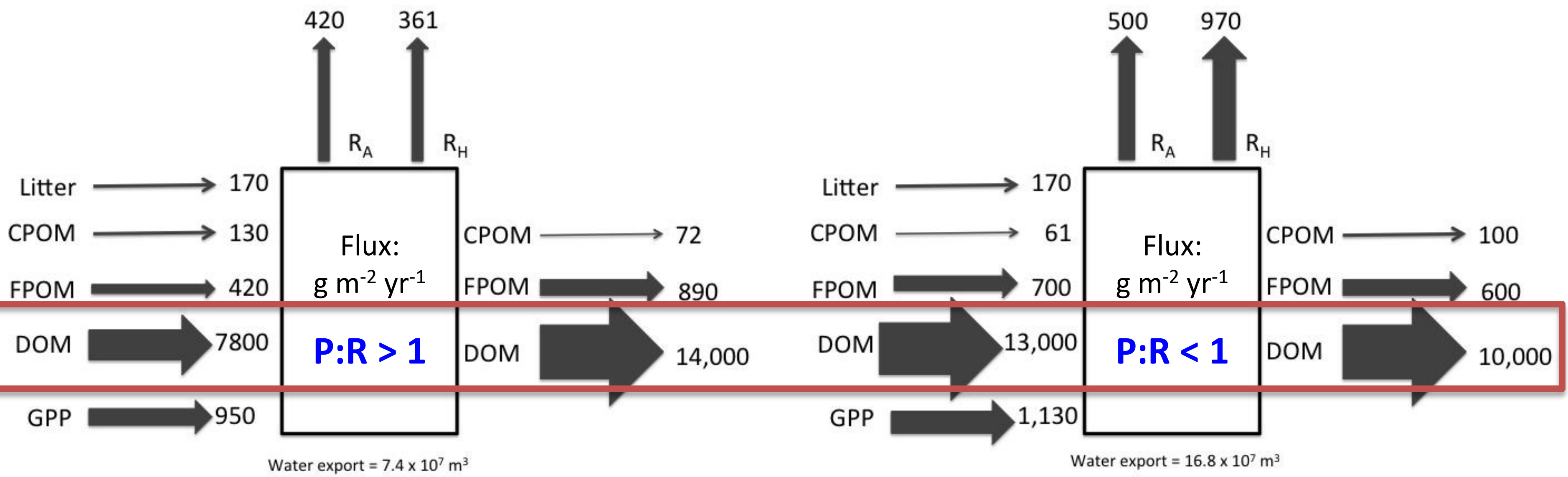


Sinsabaugh, Hill, Follstad Shah 2009 *Nature*

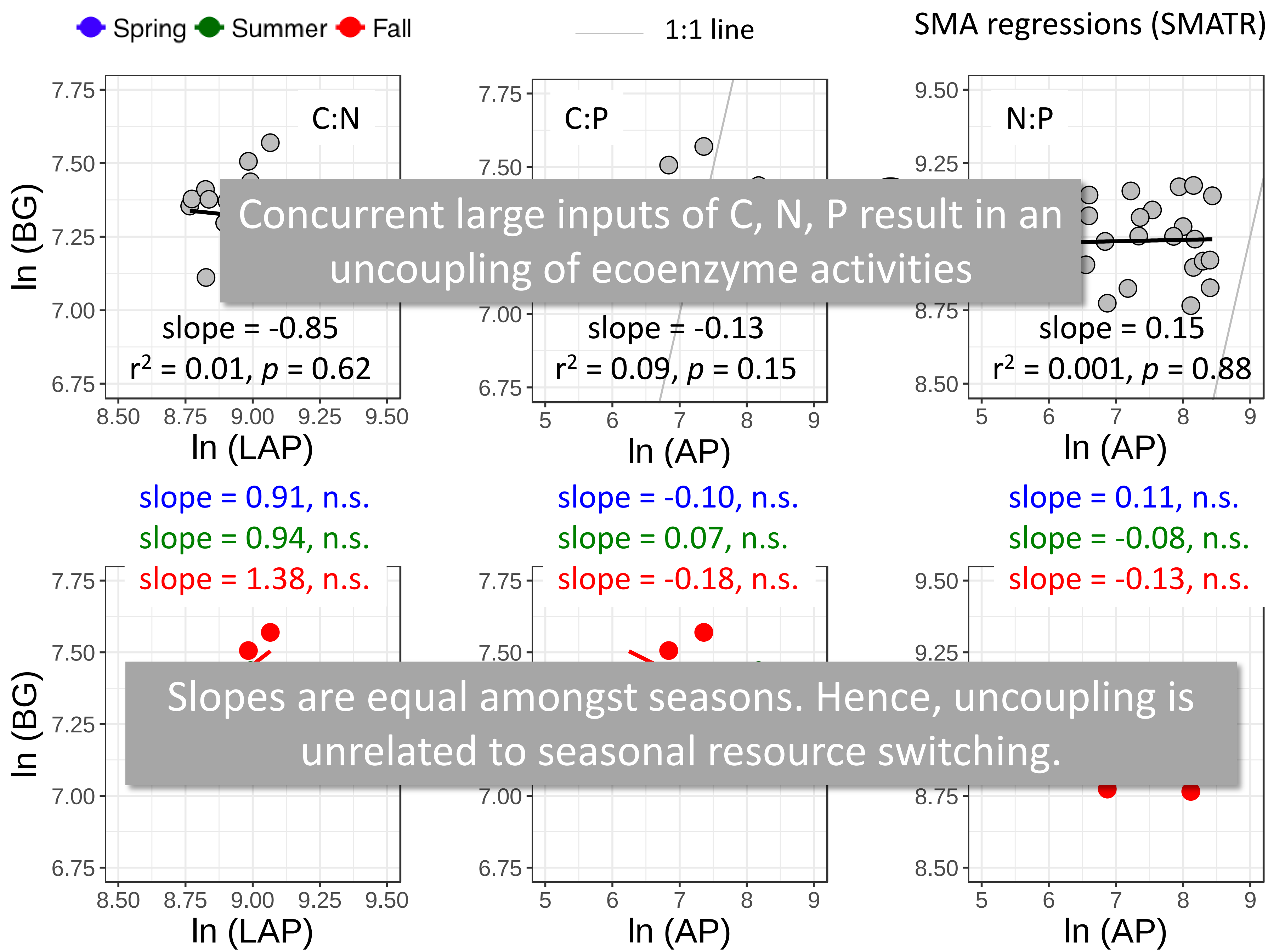
DOM is the dominant form of organic matter in the system. Higher loads of it downstream support net heterotrophy.







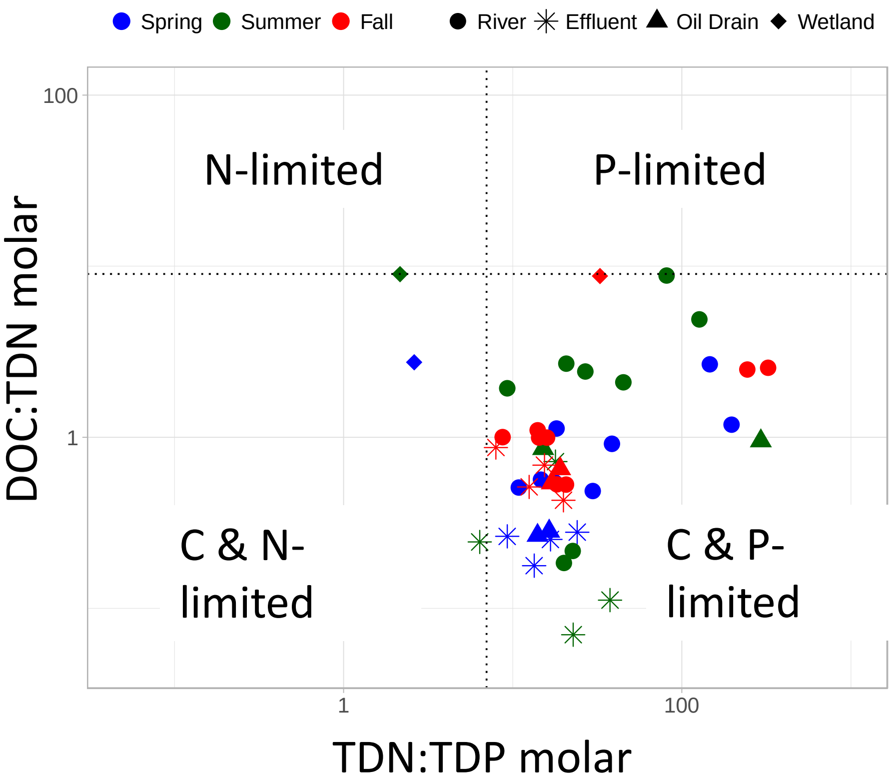
Epstein et al. 2016 *Urban Ecosystems*



Spring
Summer
Fall
1:1 line
SMA regressions (SMATR)
C:N
C:P
N:P
ln (BG)
ln (LAP)
ln (AP)
slope = -0.85
r2 = 0.01, p = 0.62
slope = -0.13
r2 = 0.09, p = 0.15
slope = 0.15
r2 = 0.001, p = 0.88
Concurrent large inputs of C, N, P result in an uncoupling of ecoenzyme activities
slope = 0.91, n.s.
slope = 0.94, n.s.
slope = 1.38, n.s.
slope = -0.10, n.s.
slope = 0.07, n.s.
slope = -0.18, n.s.
slope = 0.11, n.s.
slope = -0.08, n.s.
slope = -0.13, n.s.
Slopes are equal amongst seasons. Hence, uncoupling is unrelated to seasonal resource switching.

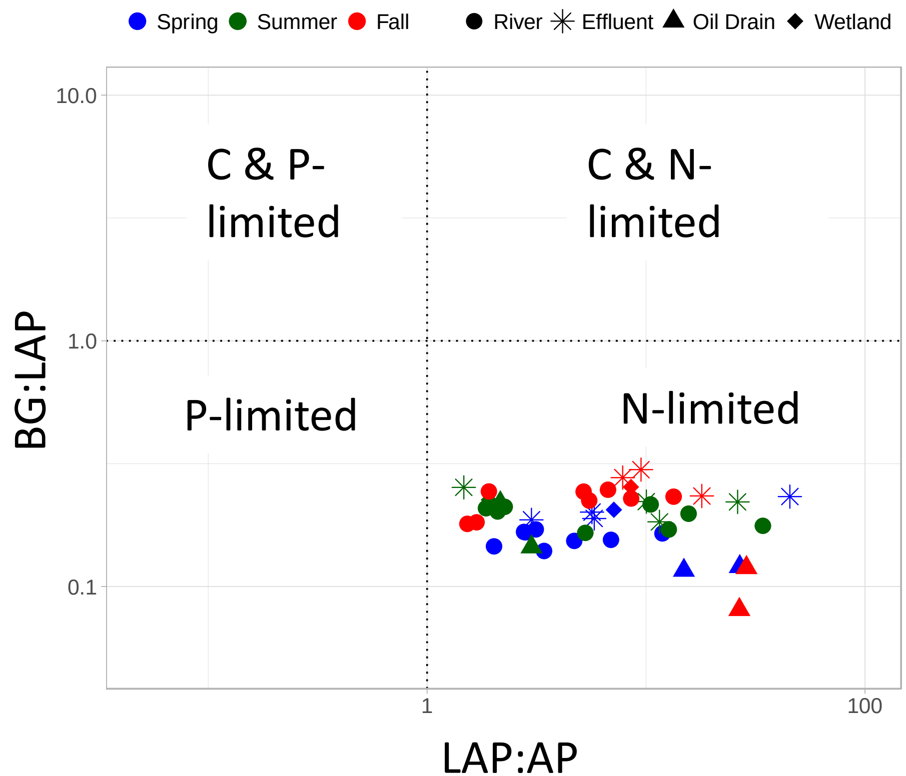
PARADOX: Water column resource supply suggests microbes may be co-limited by C & P due to high N inputs, yet ecoenzyme data suggest microbes are ‘N-limited’.

WATER CHEMISTRY STOICHIOMETRY



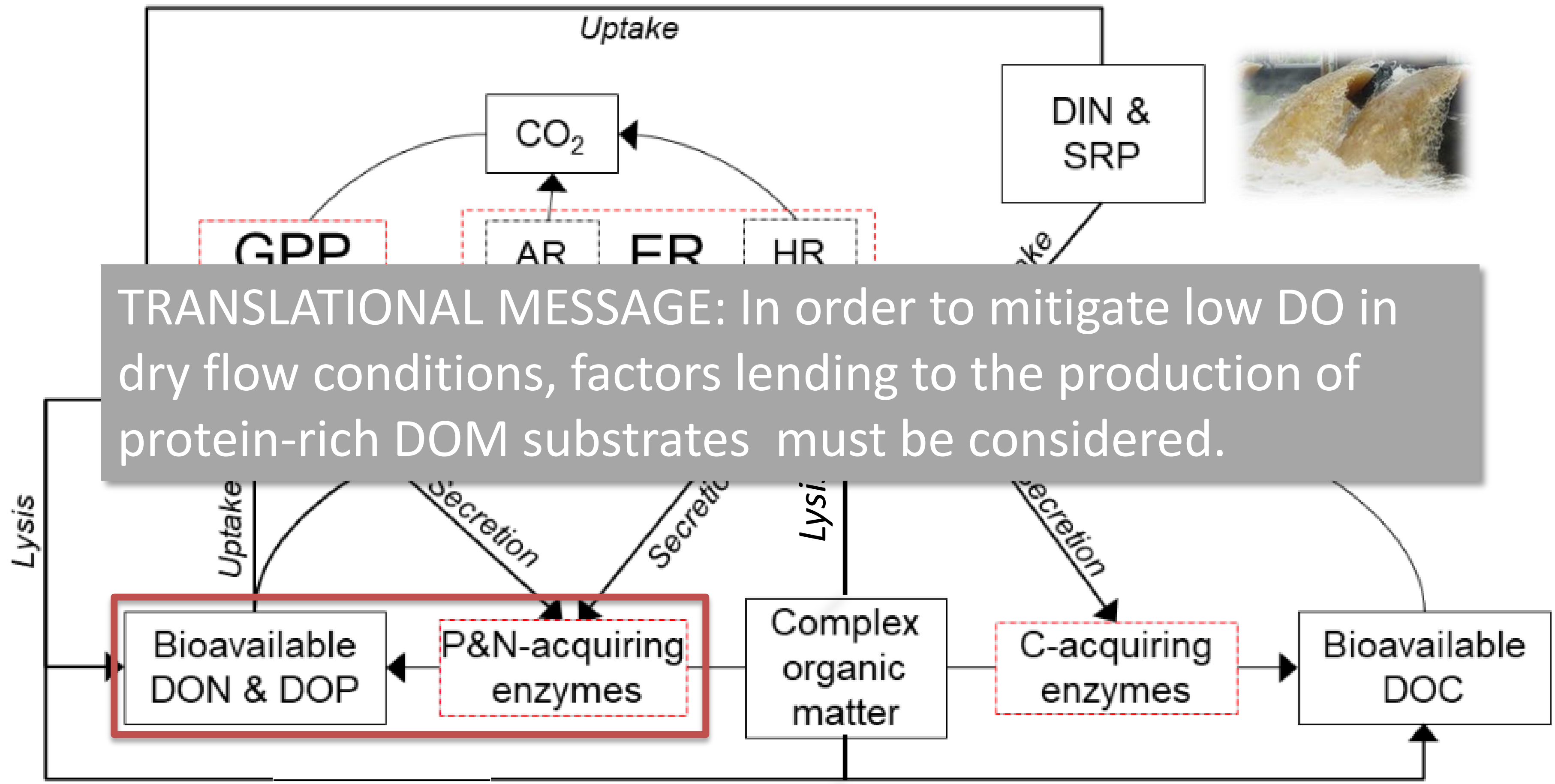
Thresholds based on microbial C:N:P (60:7:1)

ECOENZYME STOICHIOMETRY



Thresholds based on global ecoenzyme ratios related to C, N, & P acquisition (1:1:1)

The microbial community relies upon a DOM pool comprised of labile DOC and protein-rich substrates (algae, effluent by-products, lysed bacteria)



TRANSLATIONAL MESSAGE: In order to mitigate low DO in dry flow conditions, factors lending to the production of protein-rich DOM substrates must be considered.

PROTEINS & PEPTIDES

THANK YOU. QUESTIONS?

Jordan River Farmington Bay
Water Quality Council

Advisors:
Dr. Theron Miller
Prof. Jim Ehleringer
Prof. Michelle Baker
Prof. Diane Pataki
Prof. Paul Brooks
Prof. Gabe Bowen

Students:
Mickey Navidomskis
Lily Wetterlin
Alex Anderson
Calah Worthen
La'Shaye Ervin Cobley
Kendra Chritz
Nick Storey

Water Reclamation Facility Operators:
Jordan Valley
South Davis
Central Valley
Salt Lake City

Utah Division of Water Quality Scientists:
Sandy Wingert
Lucy Parnham

jennifer.shah@envst.utah.edu