Side-stream Enhanced Biological Phosphorus Removal (S2EBPR) - A Comparison of Performance and Microbial Ecology with Conventional EBPR.

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Brown and Caldwell

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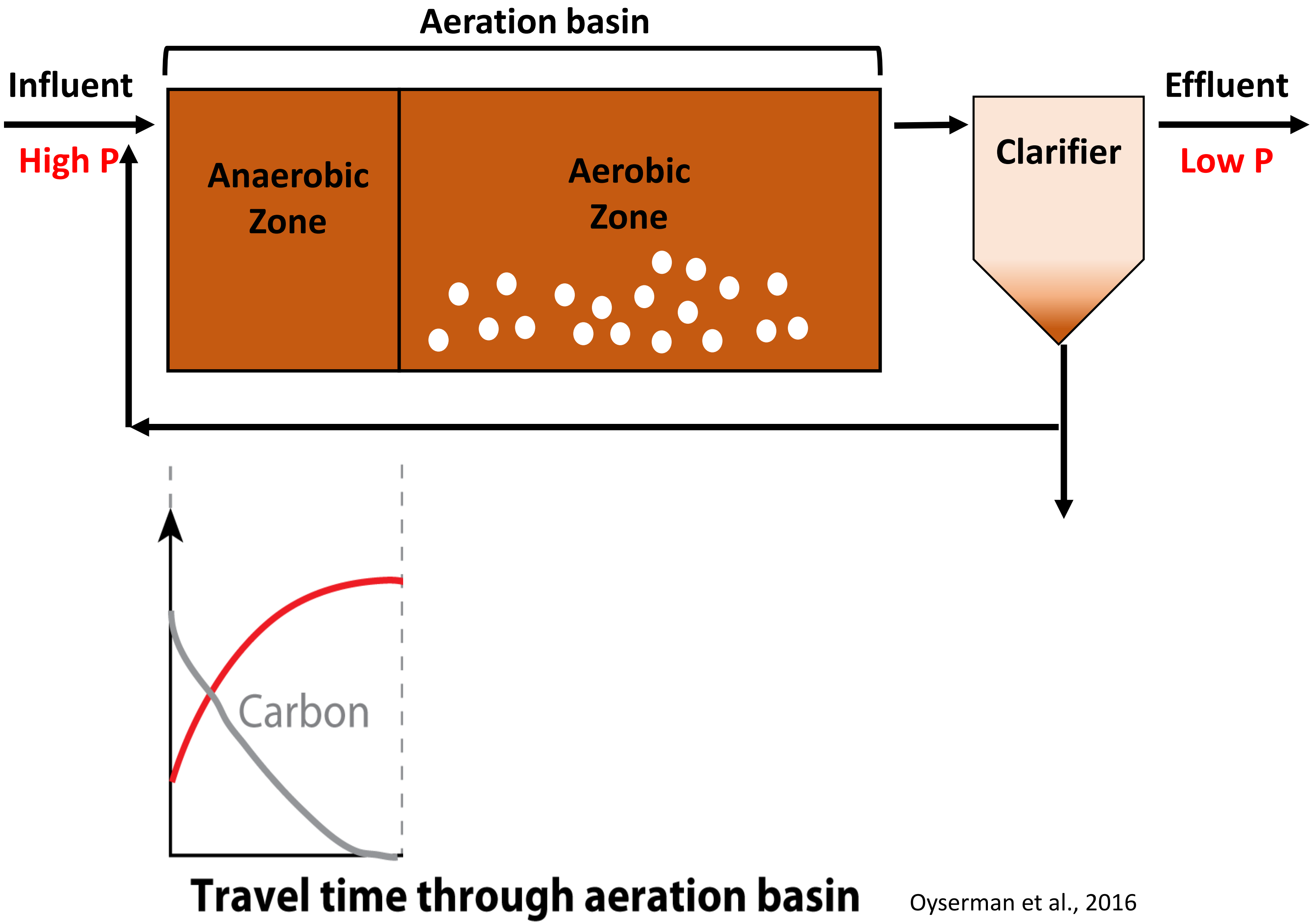
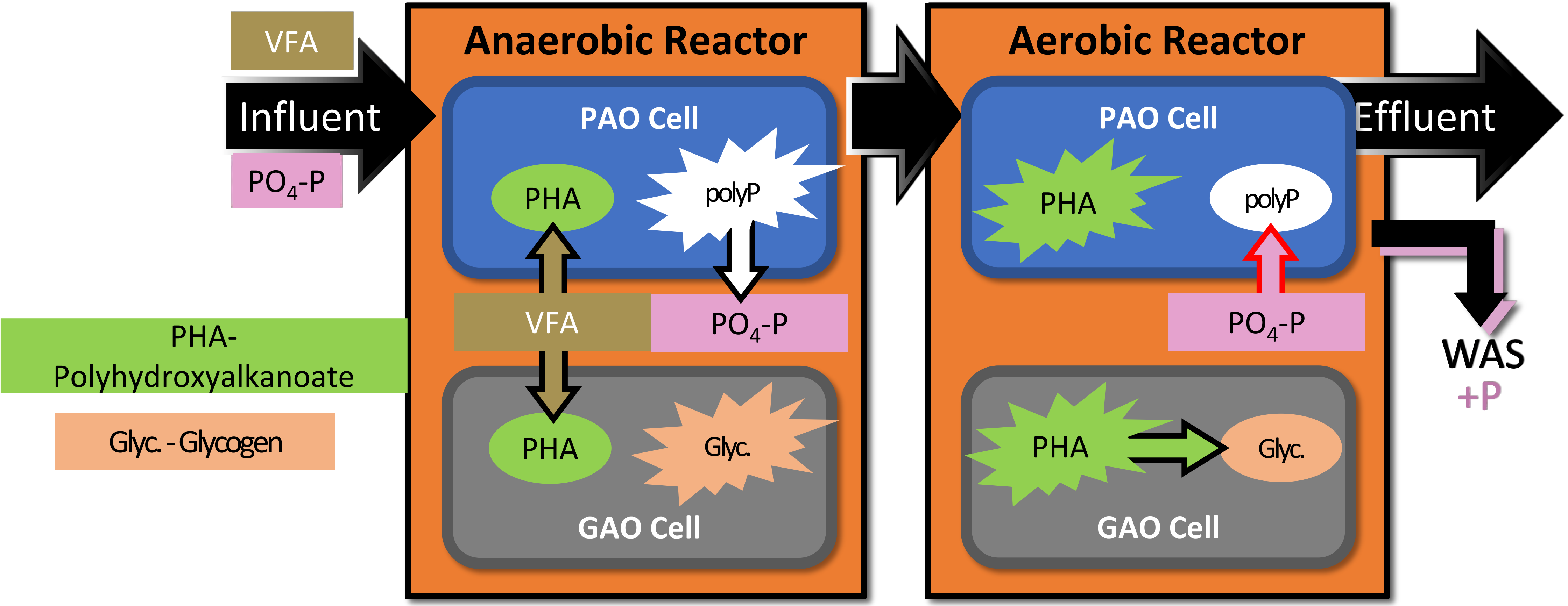
How does EBPR work?

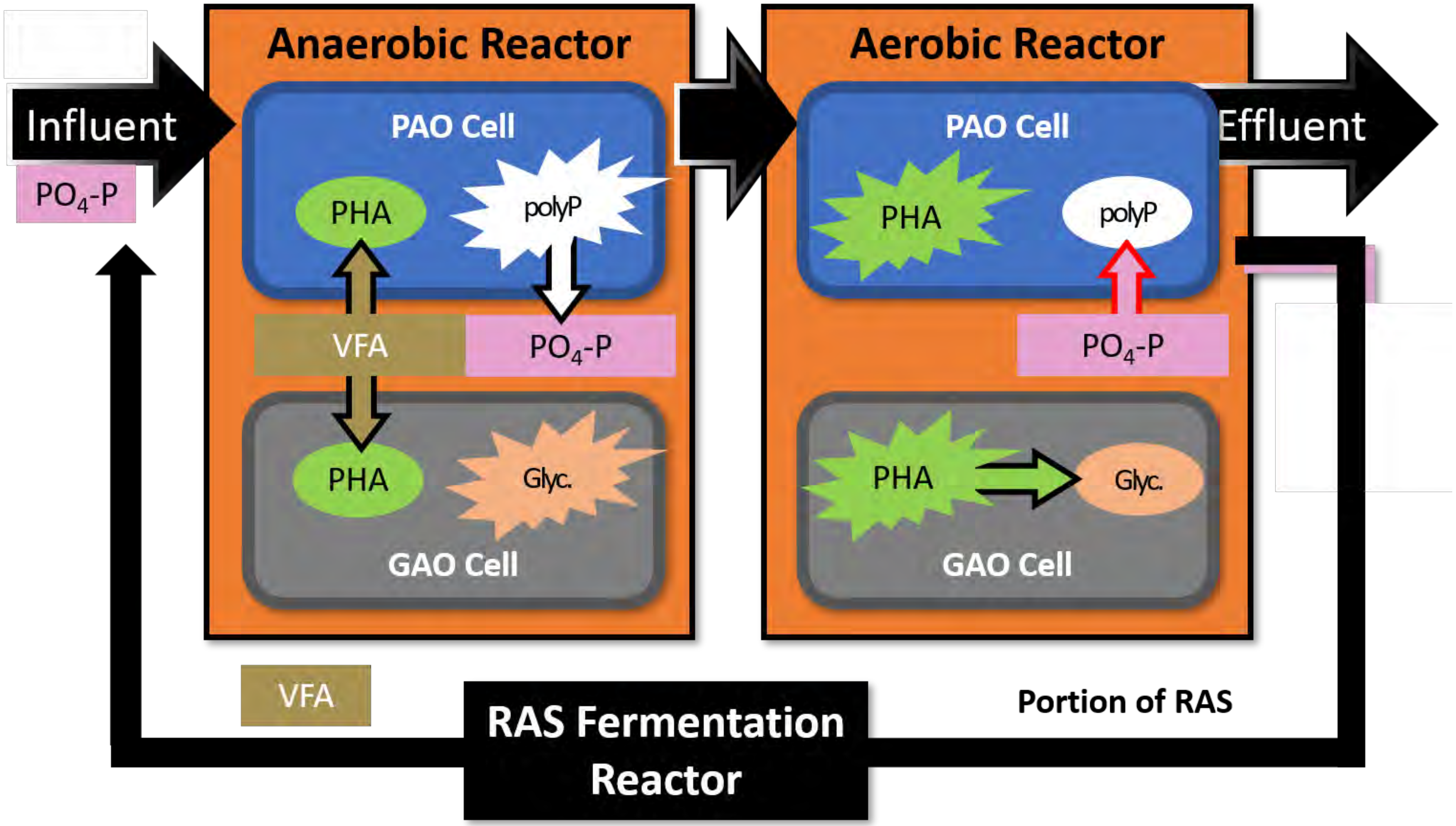


Oyserman et al., 2016

Microbial activity is the key to EBPR

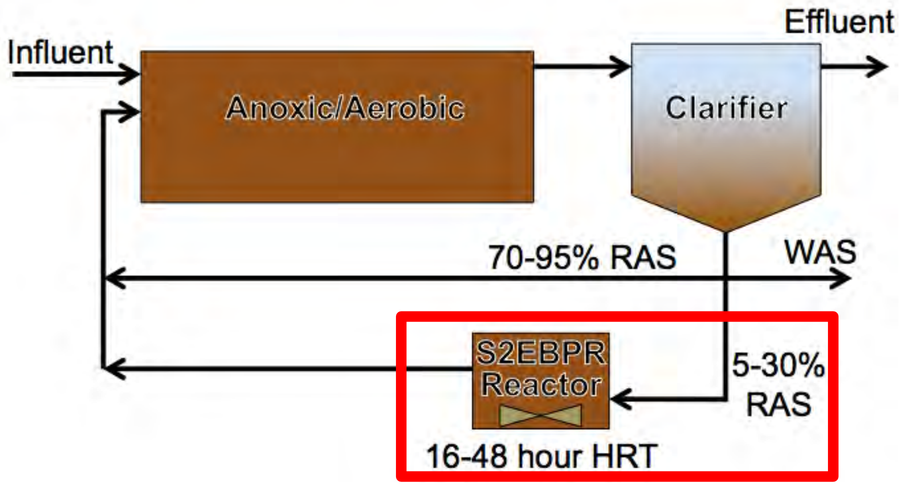


Side-stream EBPR

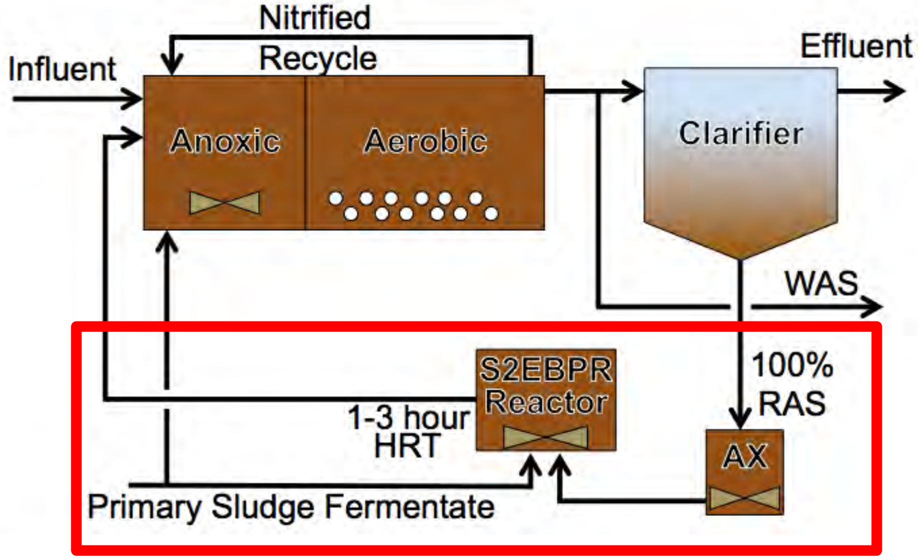


S2EBPR - Four Configurations

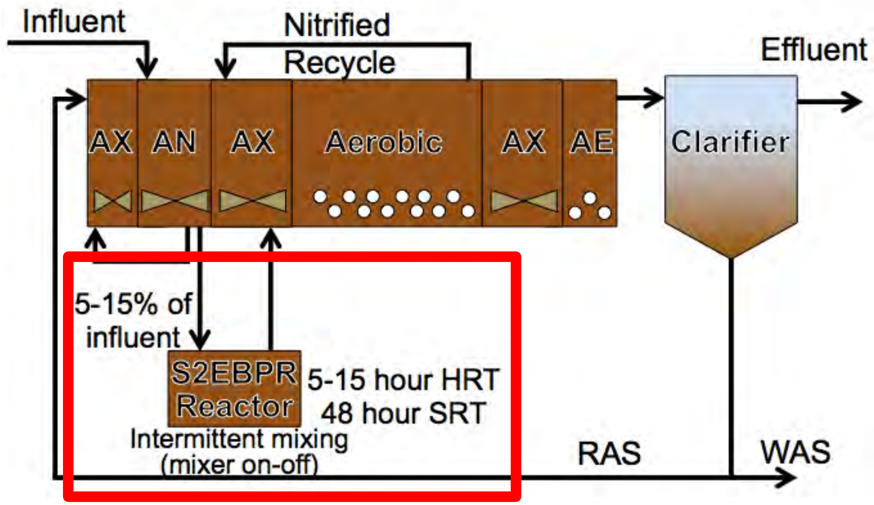
Side-Stream RAS (SSR)



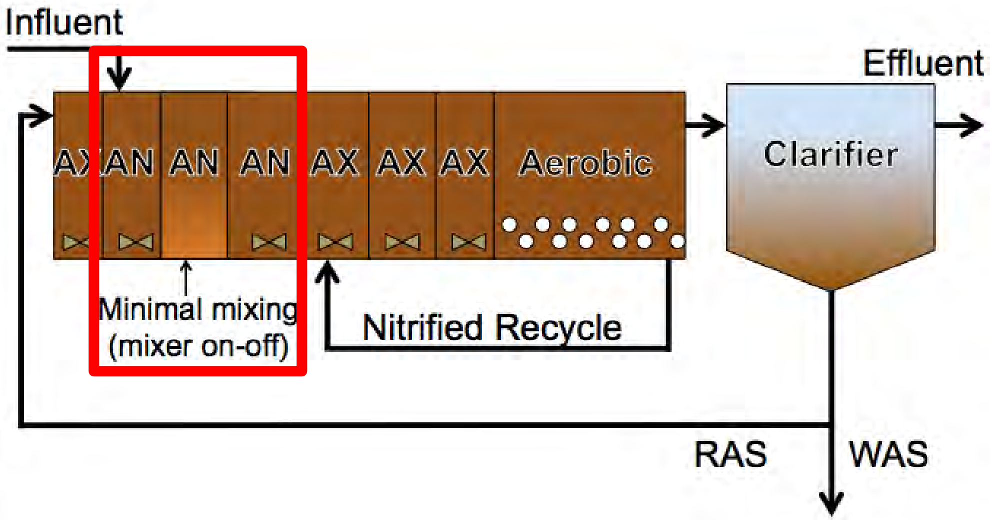
Side-Stream RAS plus Carbon (SSRC)



Side-Stream MLSS (SSM)



Unmixed In-Line Fermentation (UMIF)



S2EBPR has several advantages

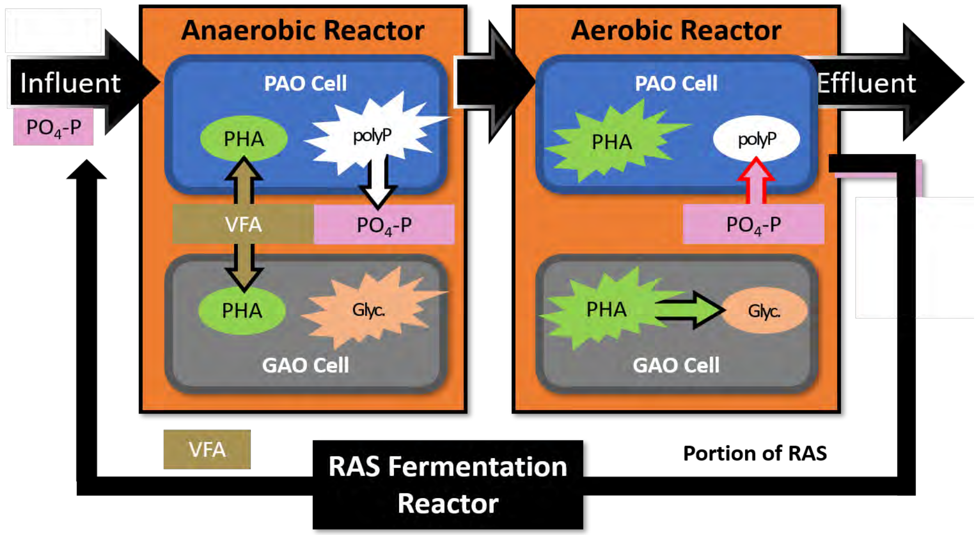
Conventional EBPR

- Dependent on influent C/P ratio
- Competition for C between N and P removal
- Typically requires chemical backup

S2EBPR

- Independent of influent C/P ratio
- Decoupled C requirement for N and P removal
- Chemical addition can be avoided due to improved performance stability

Process design can help manage microbial activity



Influent C/P Ratio

System SRT

System Configuration

Feed Composition Substrates

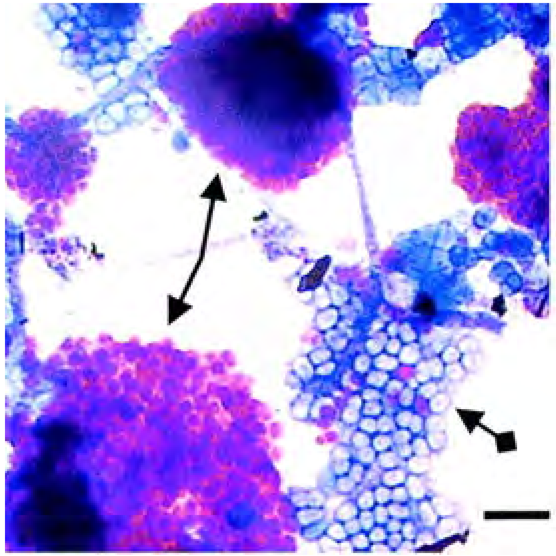
Environmental Conditions (Temp, pH)

Microbial Population Composition and Their Competition

System Function and

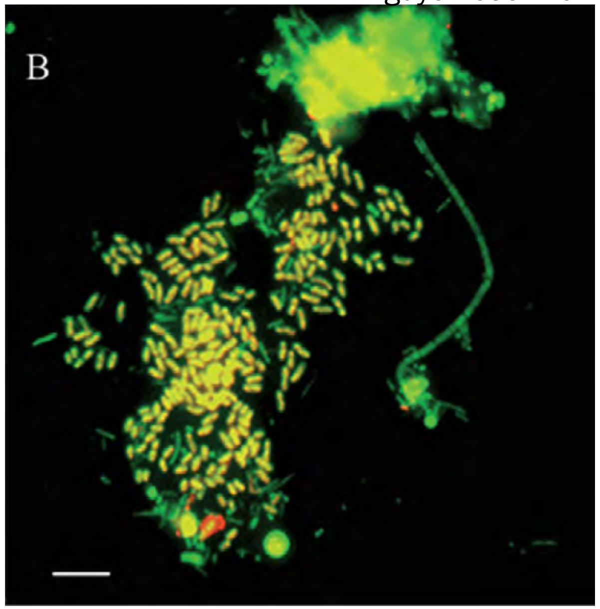
Microbial Players

Crocetti et al., 2000

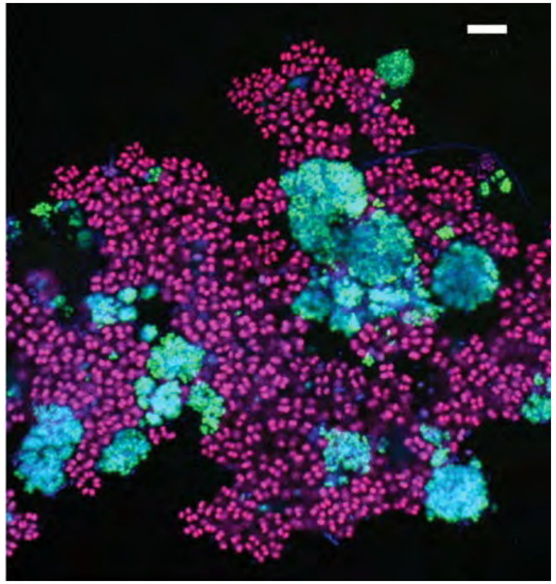


Ca. Accumulibacter

Nguyen et al 2012

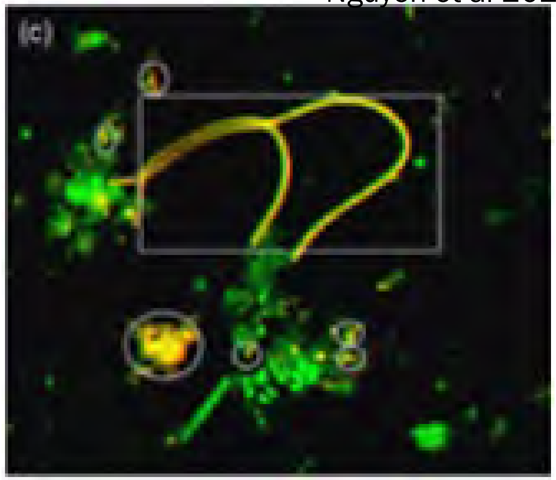


Ca. Accumulimonas



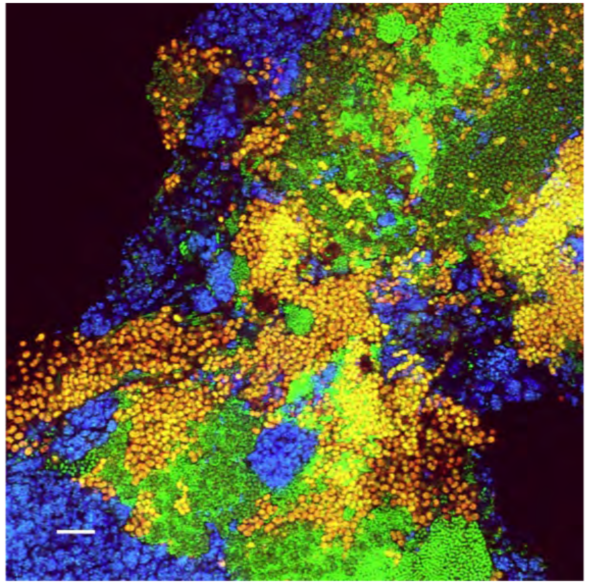
Defluviicoccus

Nguyen et al 2011



Tetrasphaera

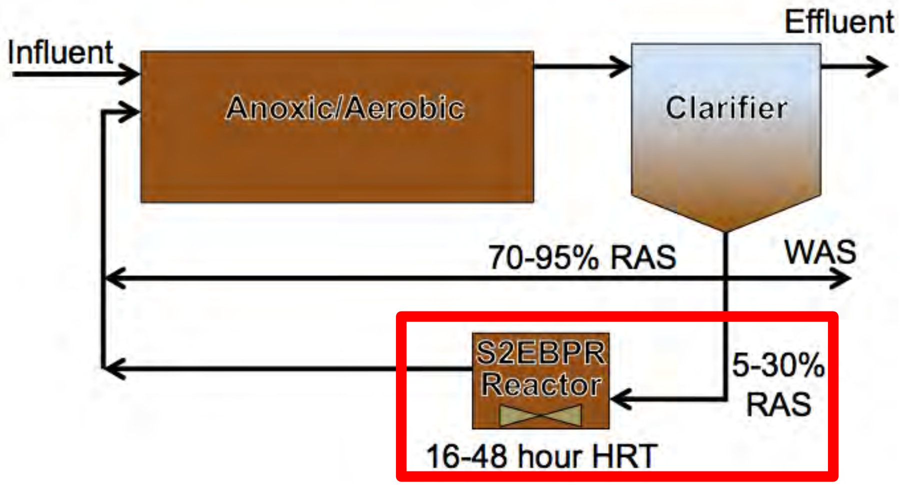
McIlroy 2010



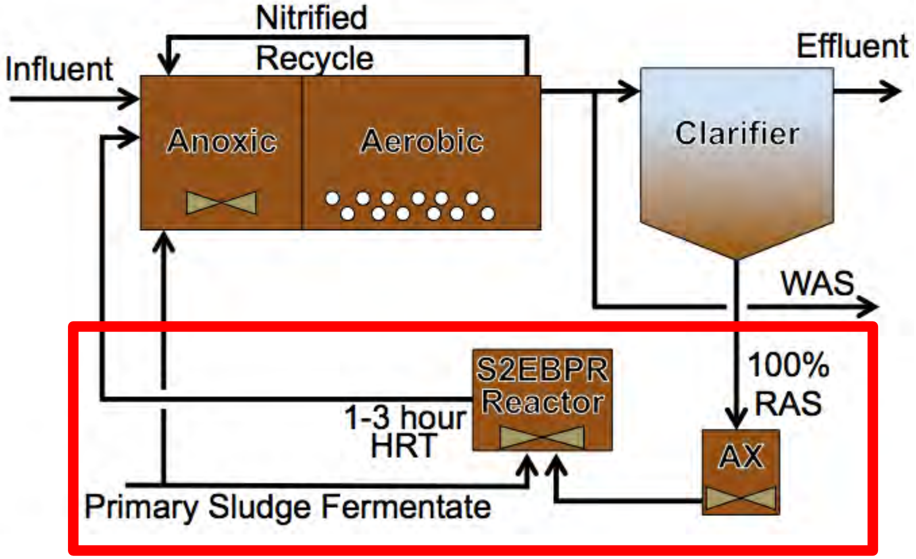
Ca. Competibacter

S2EBPR - A Tale of Four Facilities

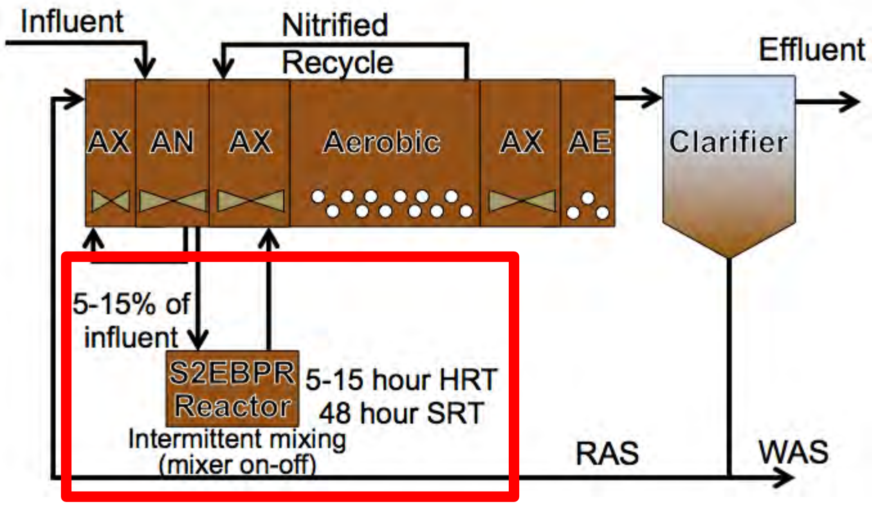
SSR – South Cary



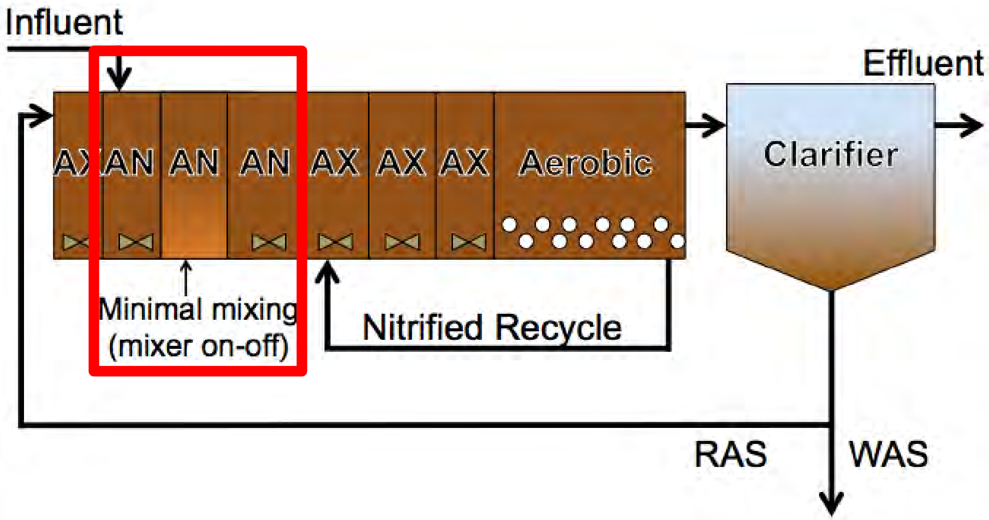
SSRC – Westside Regional



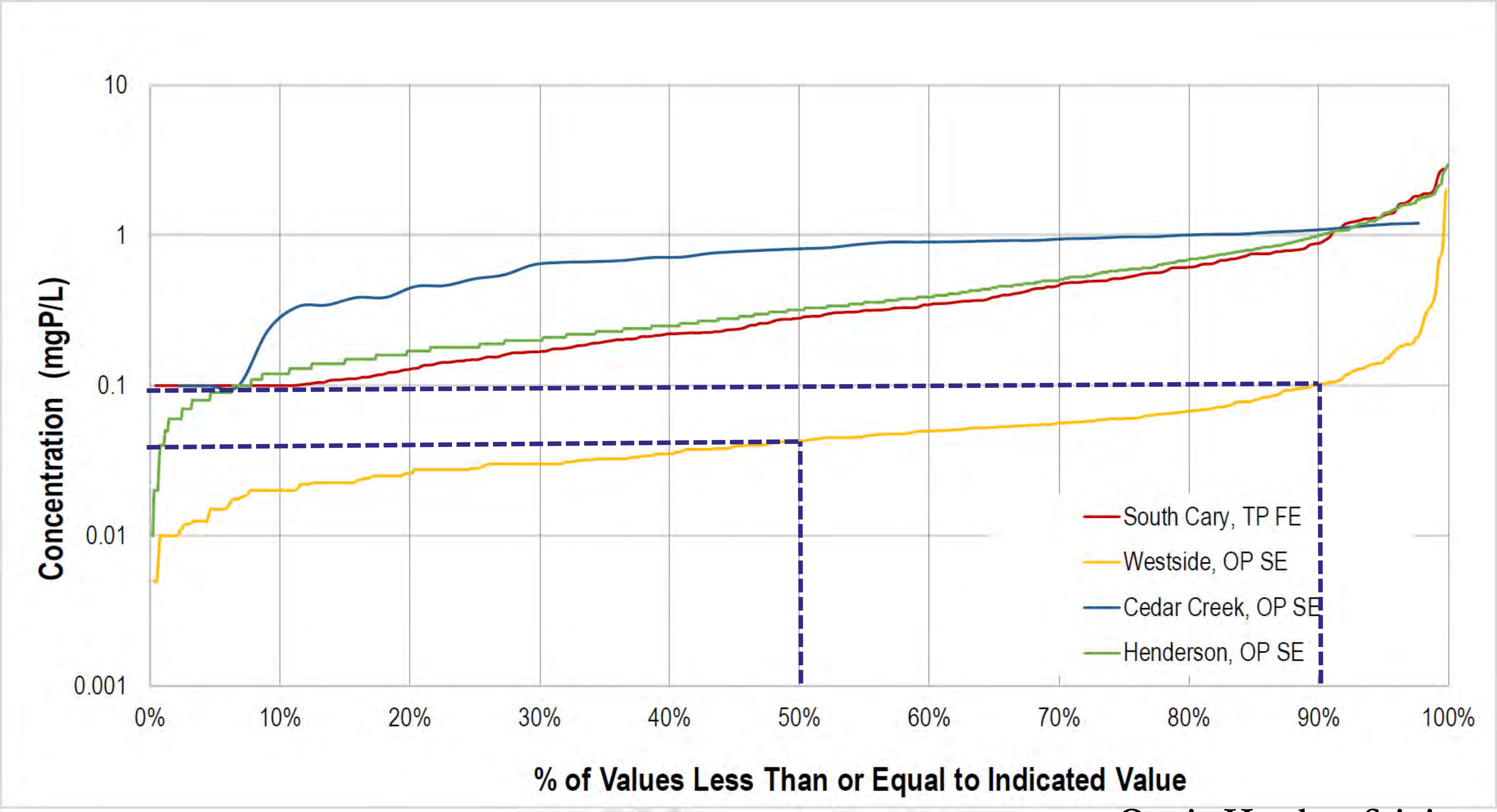
SSM – Cedar Creek



UMIF - Henderson

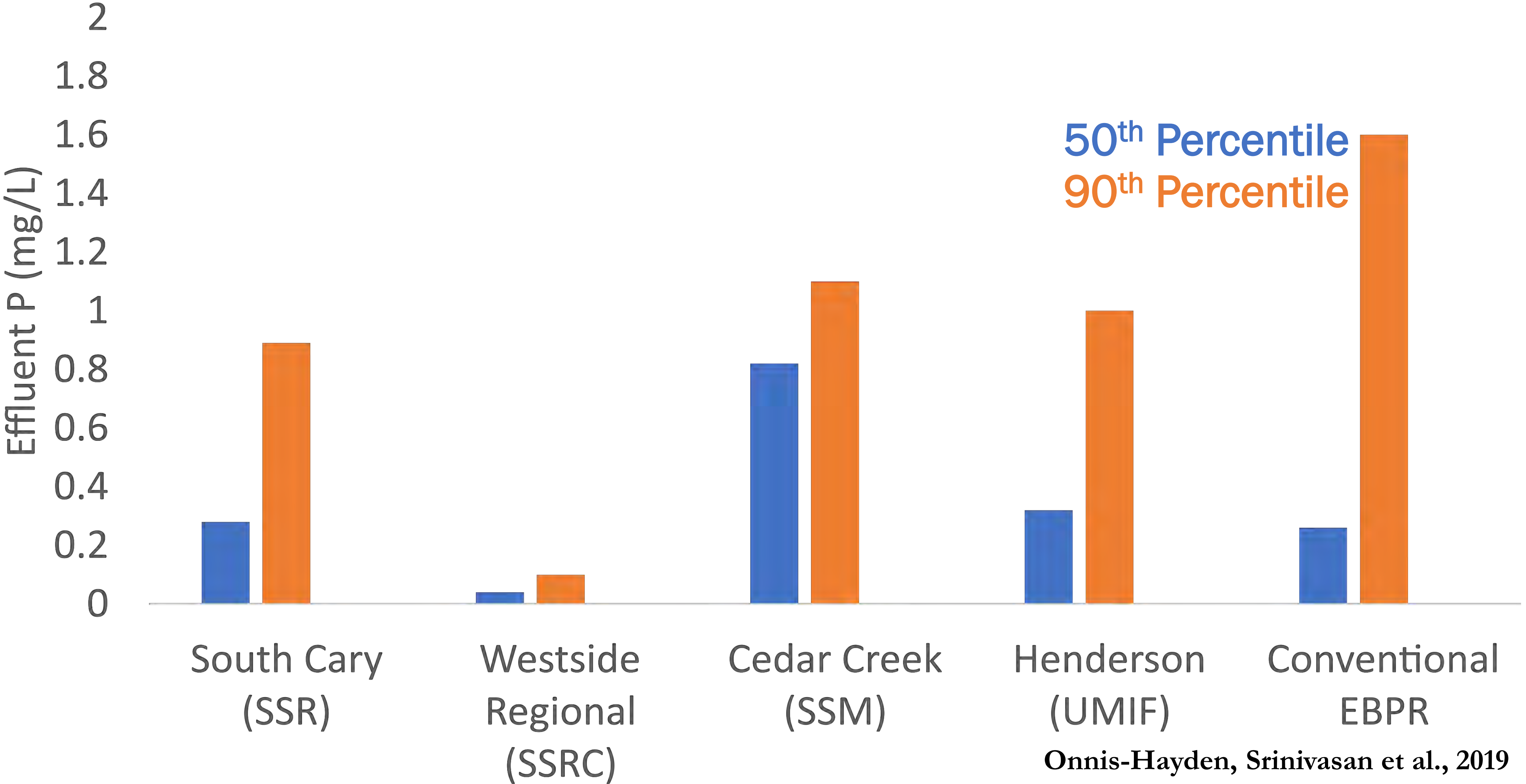


Performance of S2EBPR Plants



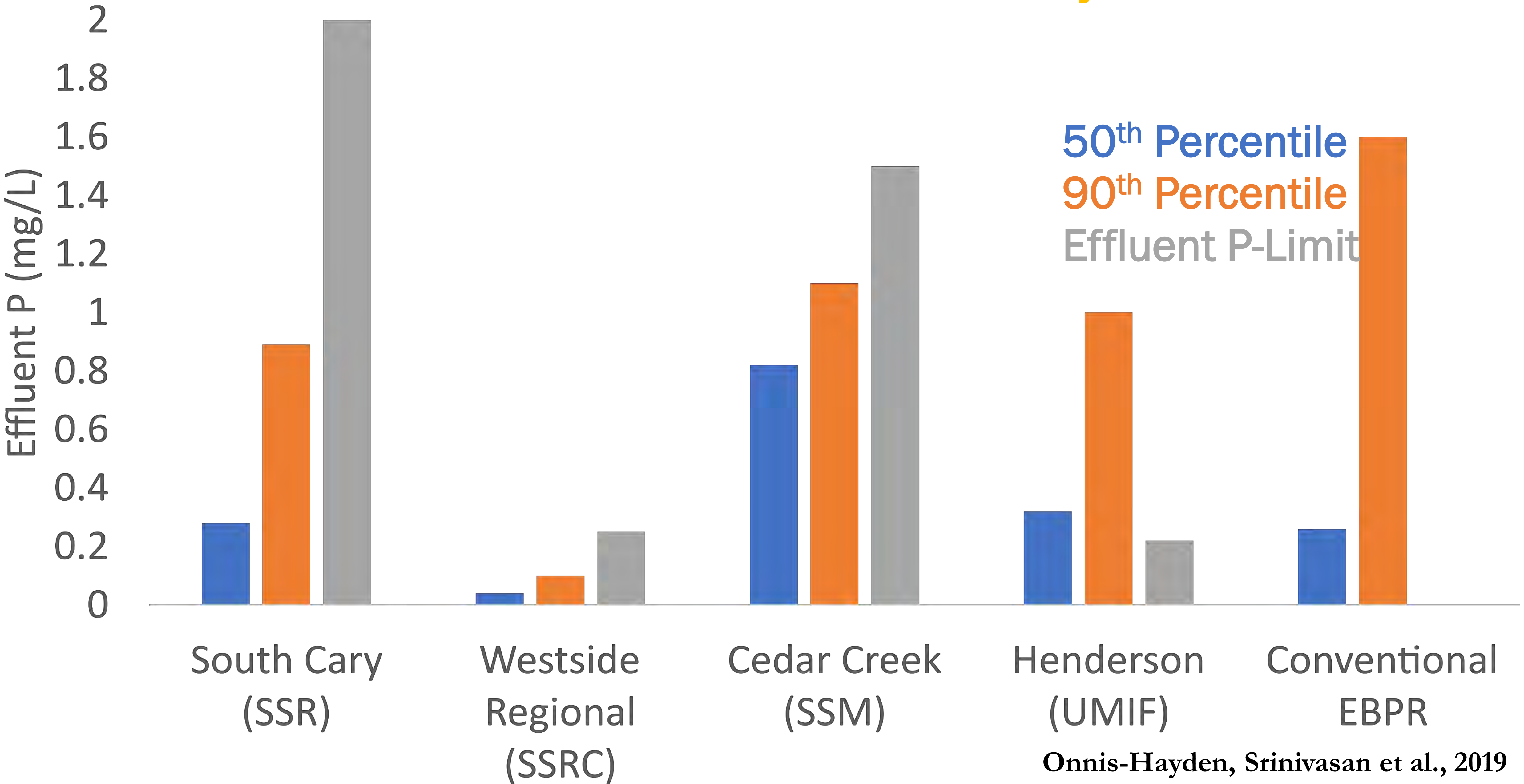
Onnis-Hayden, Srinivasan et al., 2019

Performance differences



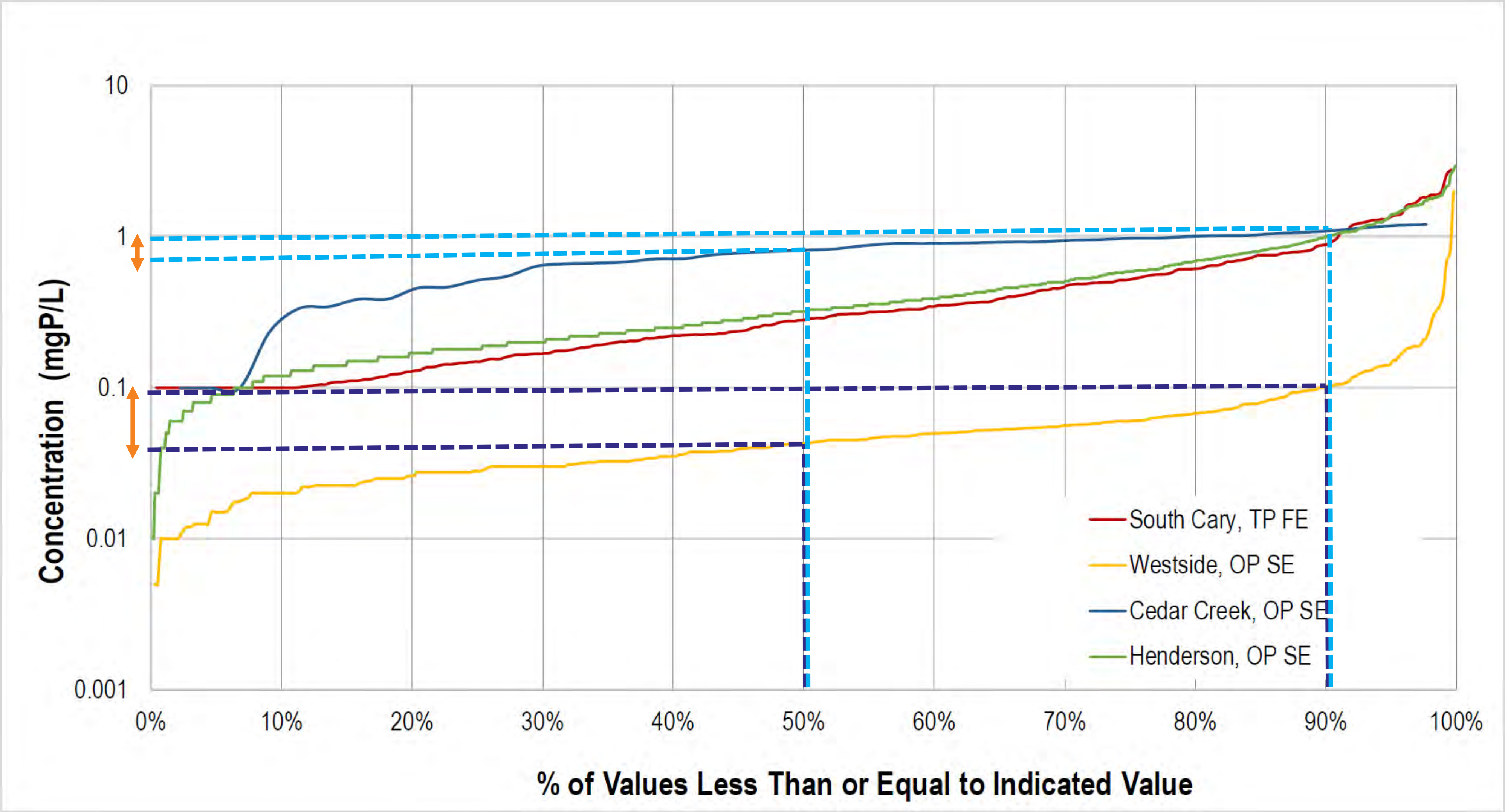
Onnis-Hayden, Srinivasan et al., 2019

Performance differences are obscured by effluent limits



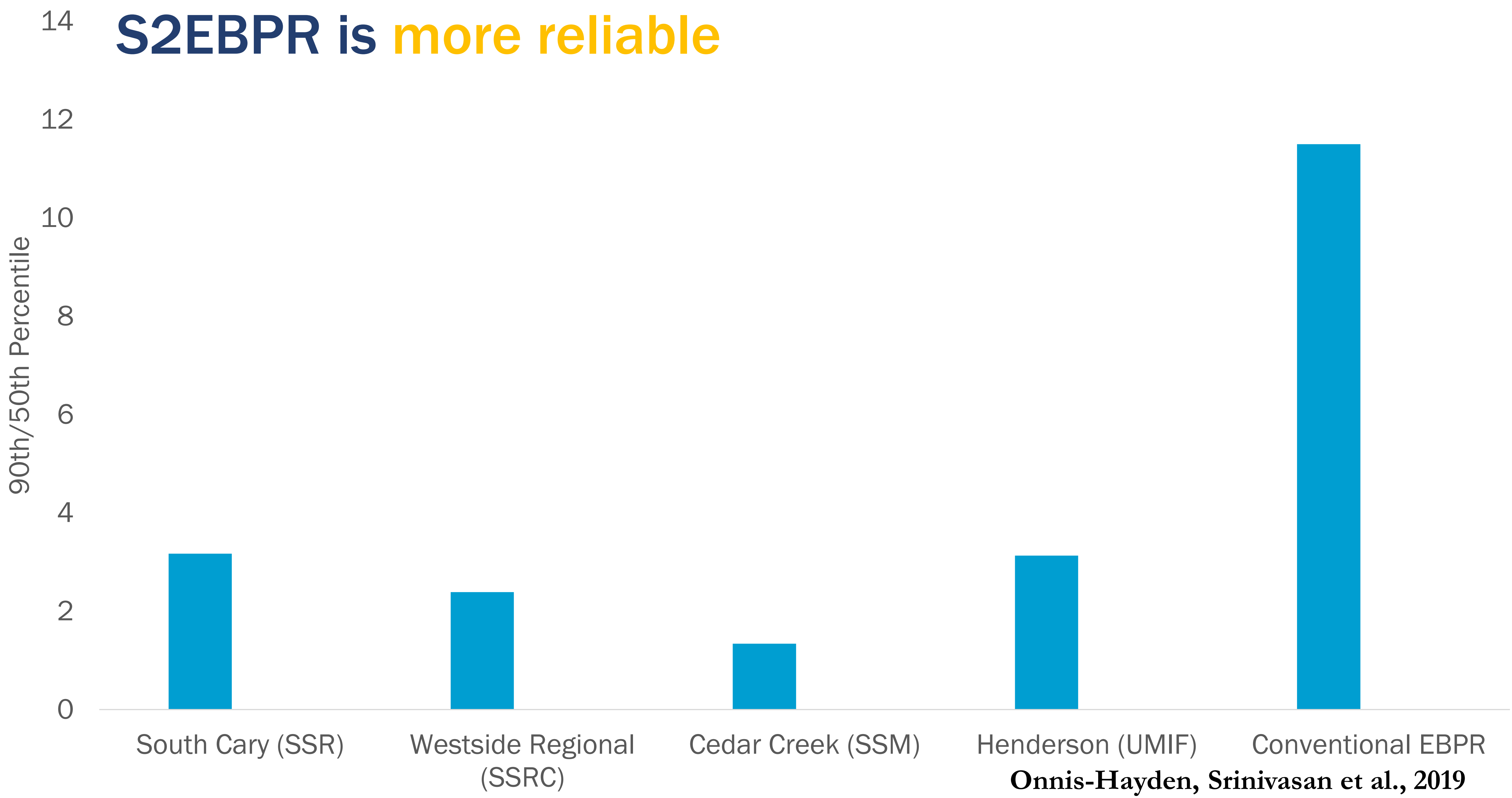
Onnis-Hayden, Srinivasan et al., 2019

Performance of S2EBPR Plants



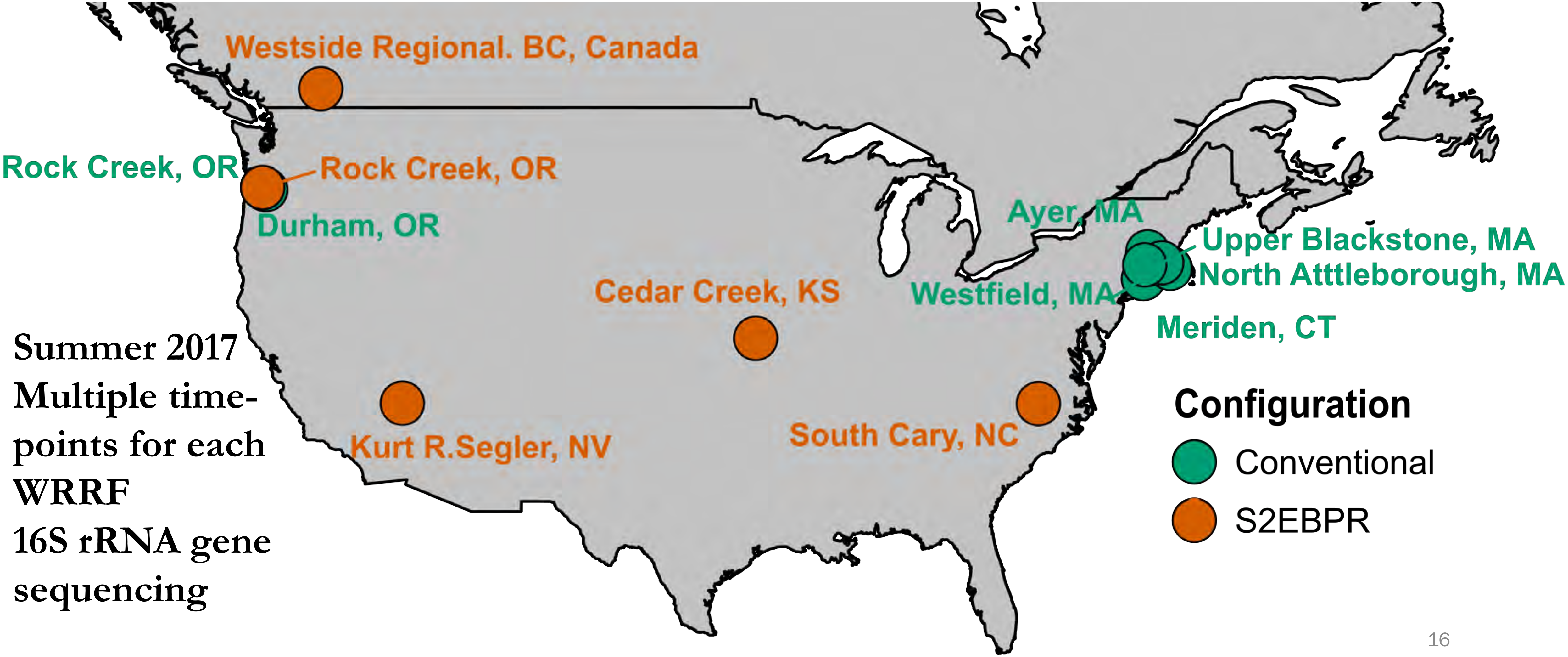
Onnis-Hayden, Srinivasan et al., 2019

S2EBPR is more reliable



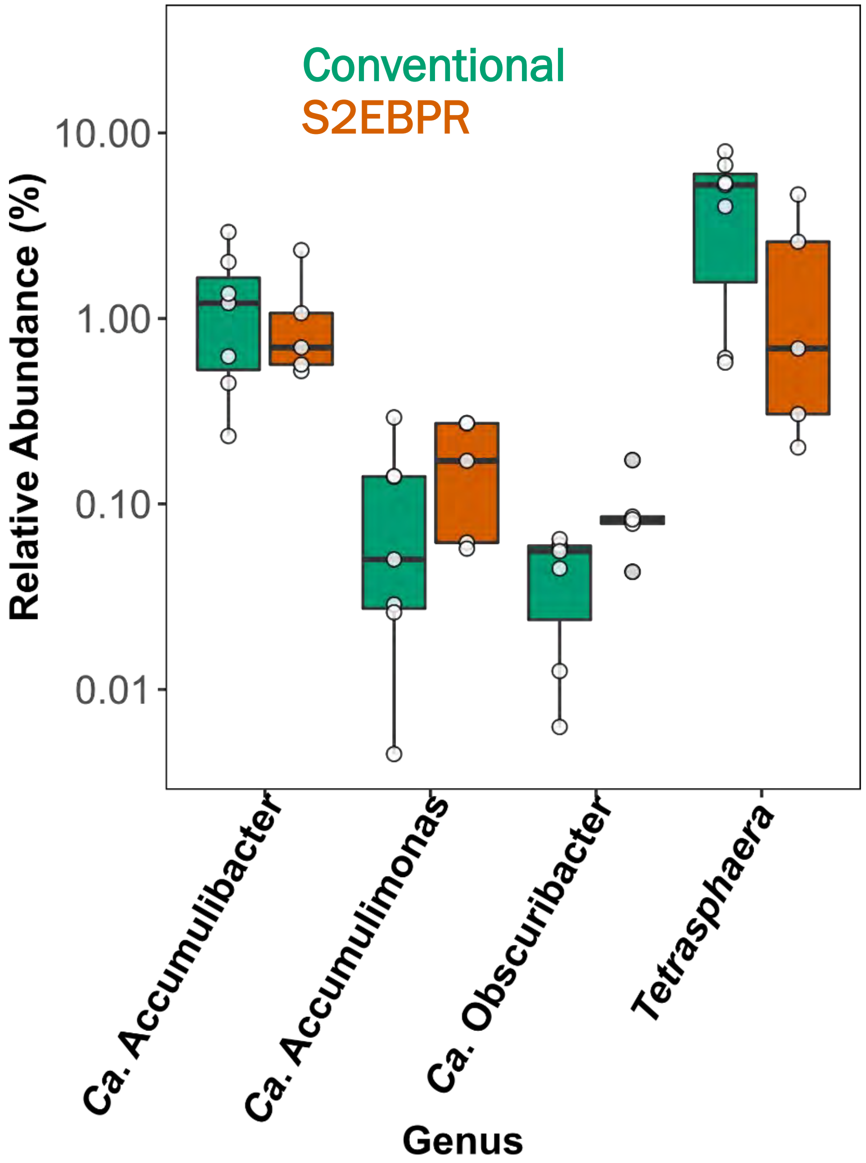
Onnis-Hayden, Srinivasan et al., 2019

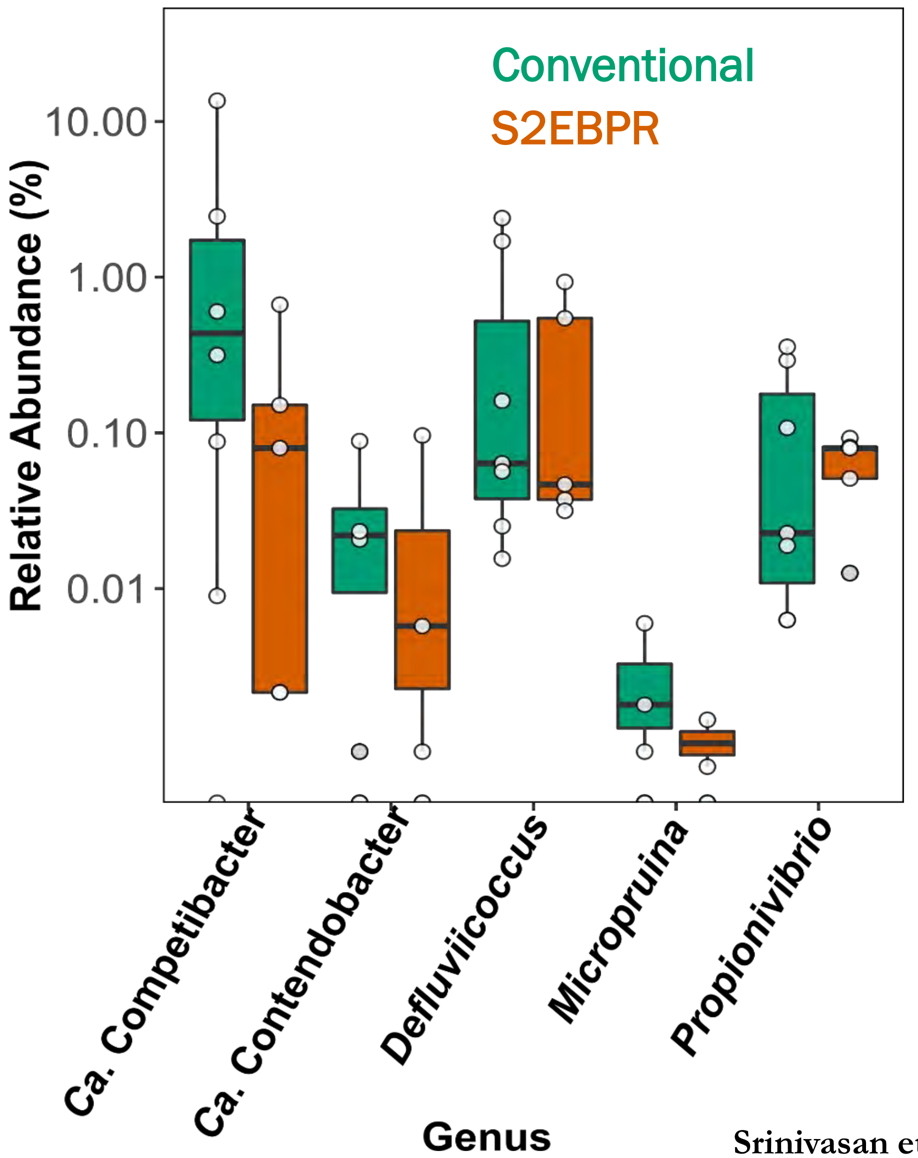
Survey of 12 Facilities – 5 S2EBPR, 7 Conventional



- Summer 2017
- Multiple time-points for each WRRF
- 16S rRNA gene sequencing

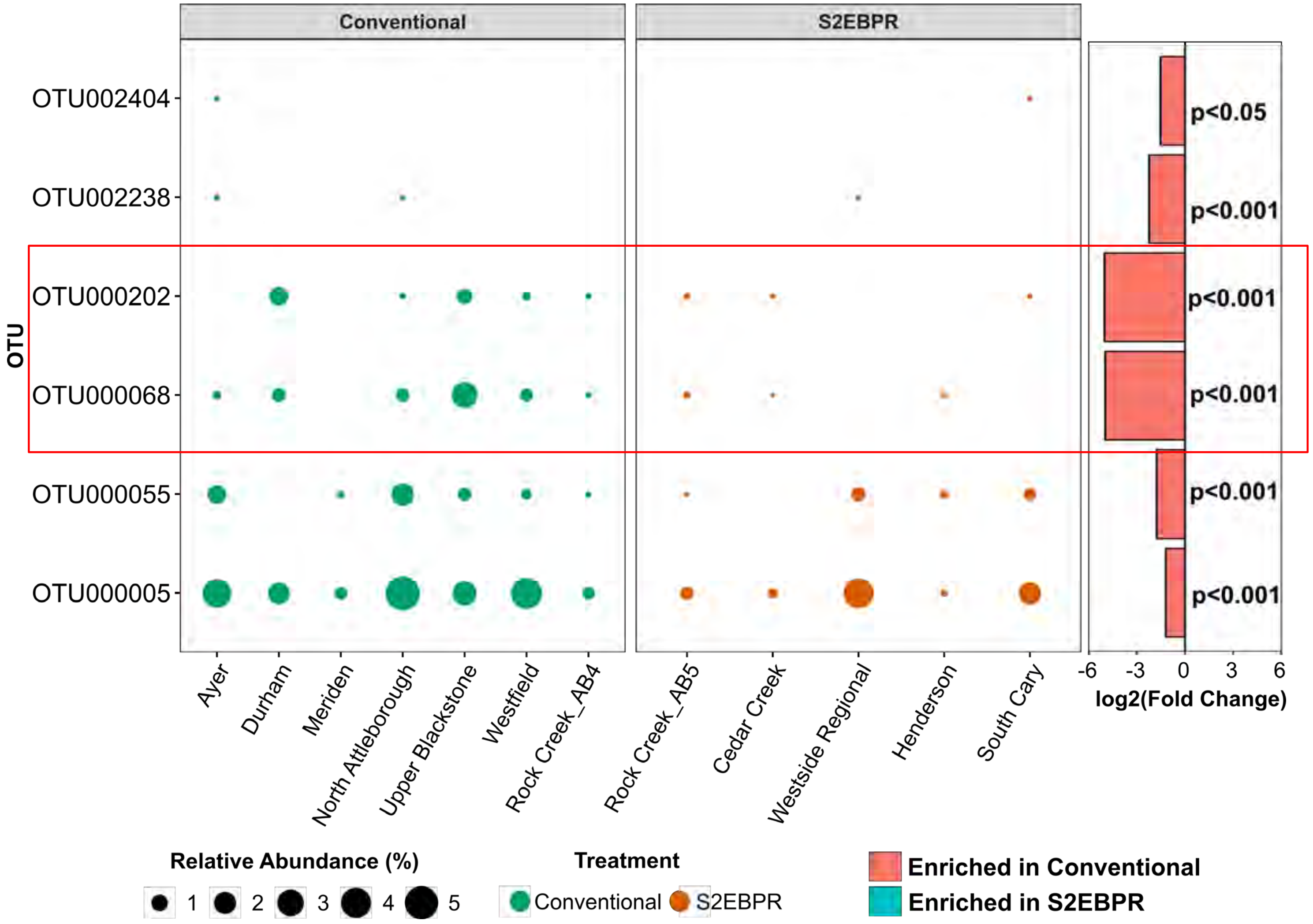
At Genus level – no significant difference found for known PAOs and GAOs





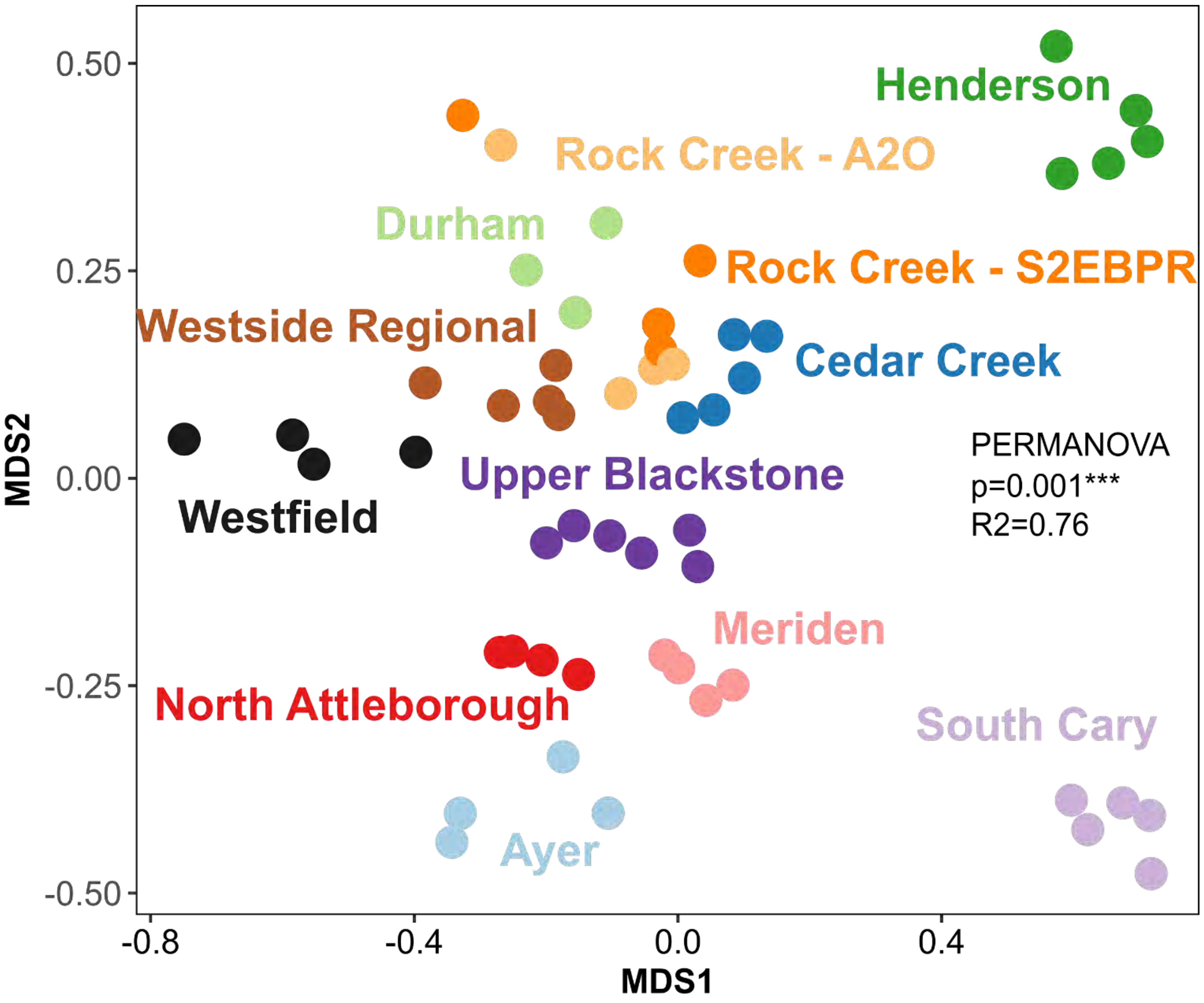
Srinivasan et al., (in prep)

Specific OTUs of *Tetrasphaera* are significantly affected by conditions in S2EBPR



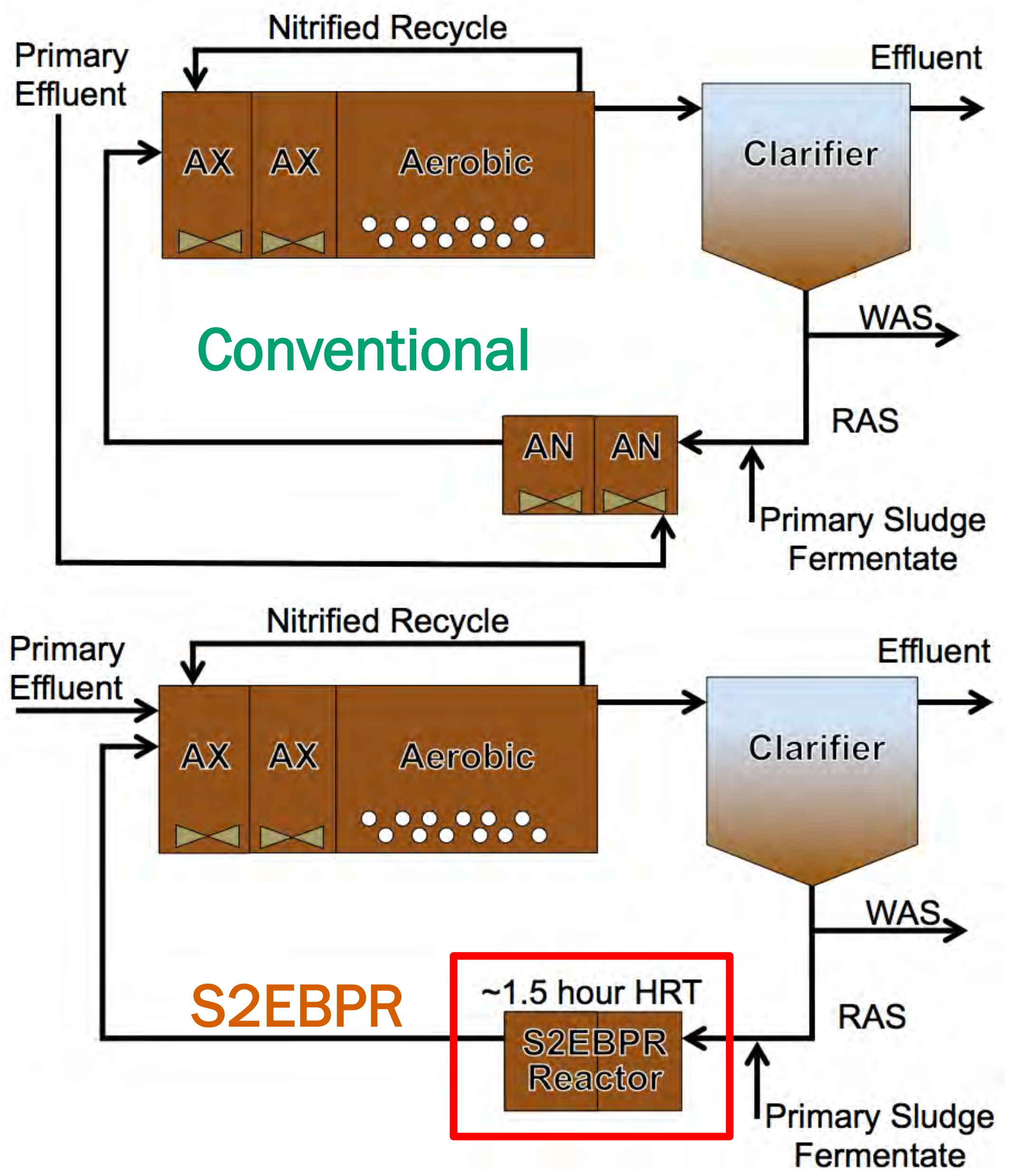
Srinivasan et al., (in prep)

Community fingerprints are plant-specific

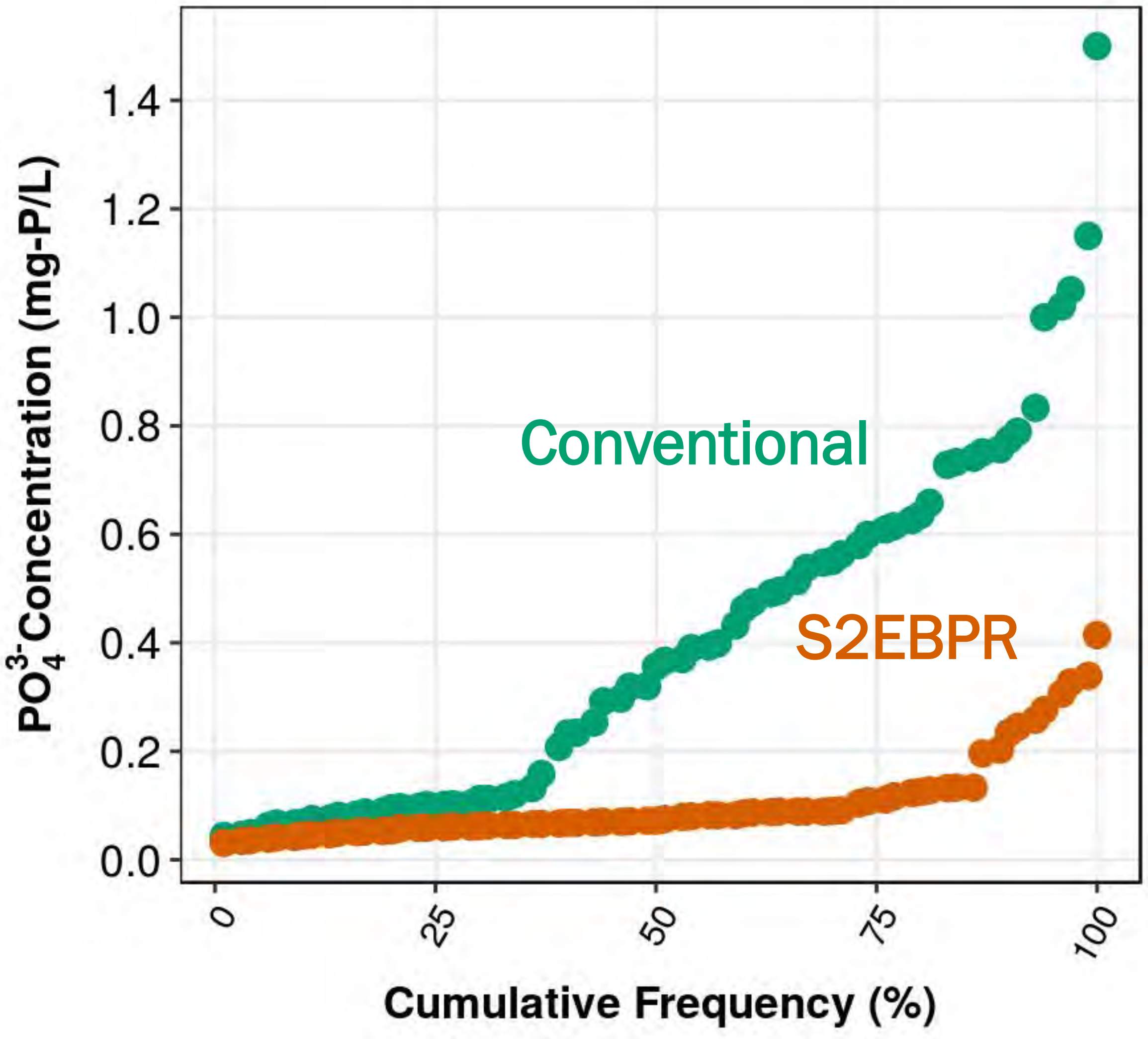


Srinivasan et al., (in prep)

Side-by-Side Full Scale Pilot

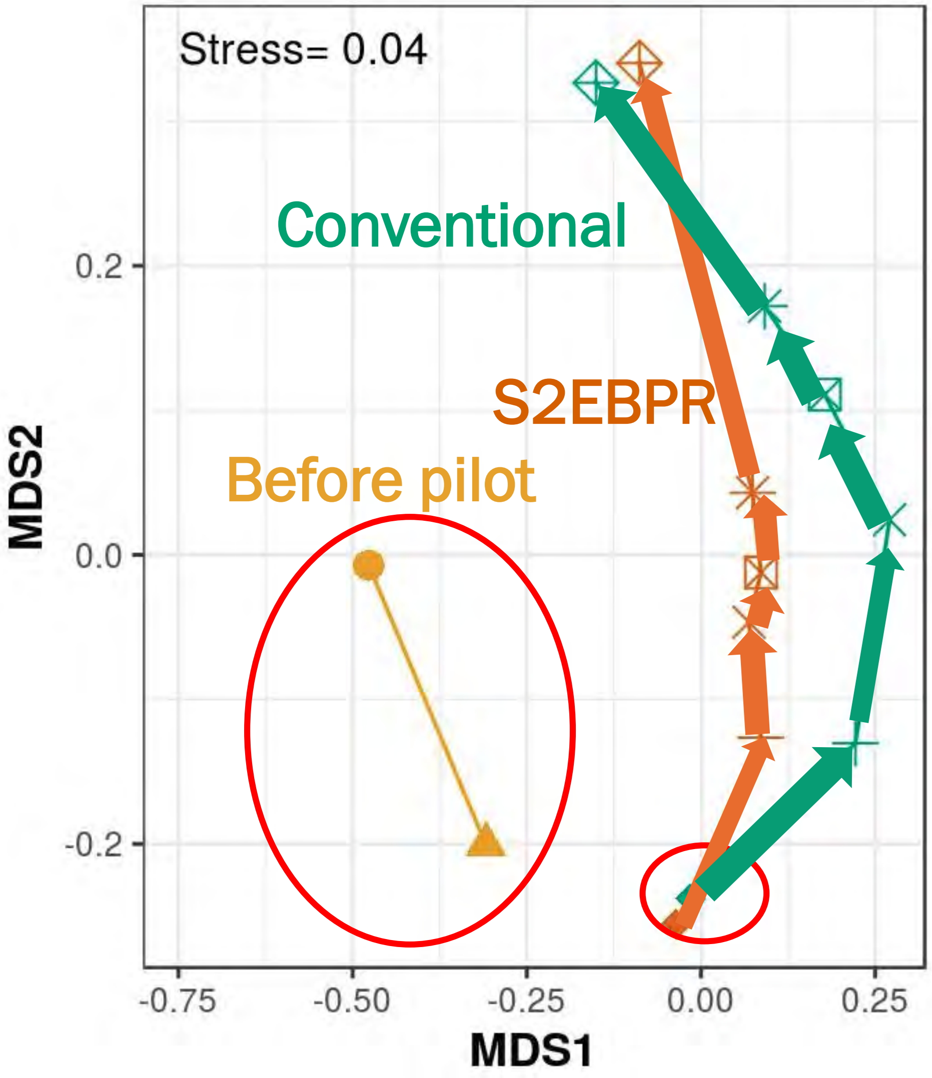


P-removal was more consistent and higher in S2EBPR



Wang , Tooker, Srinivasan et al., 2019

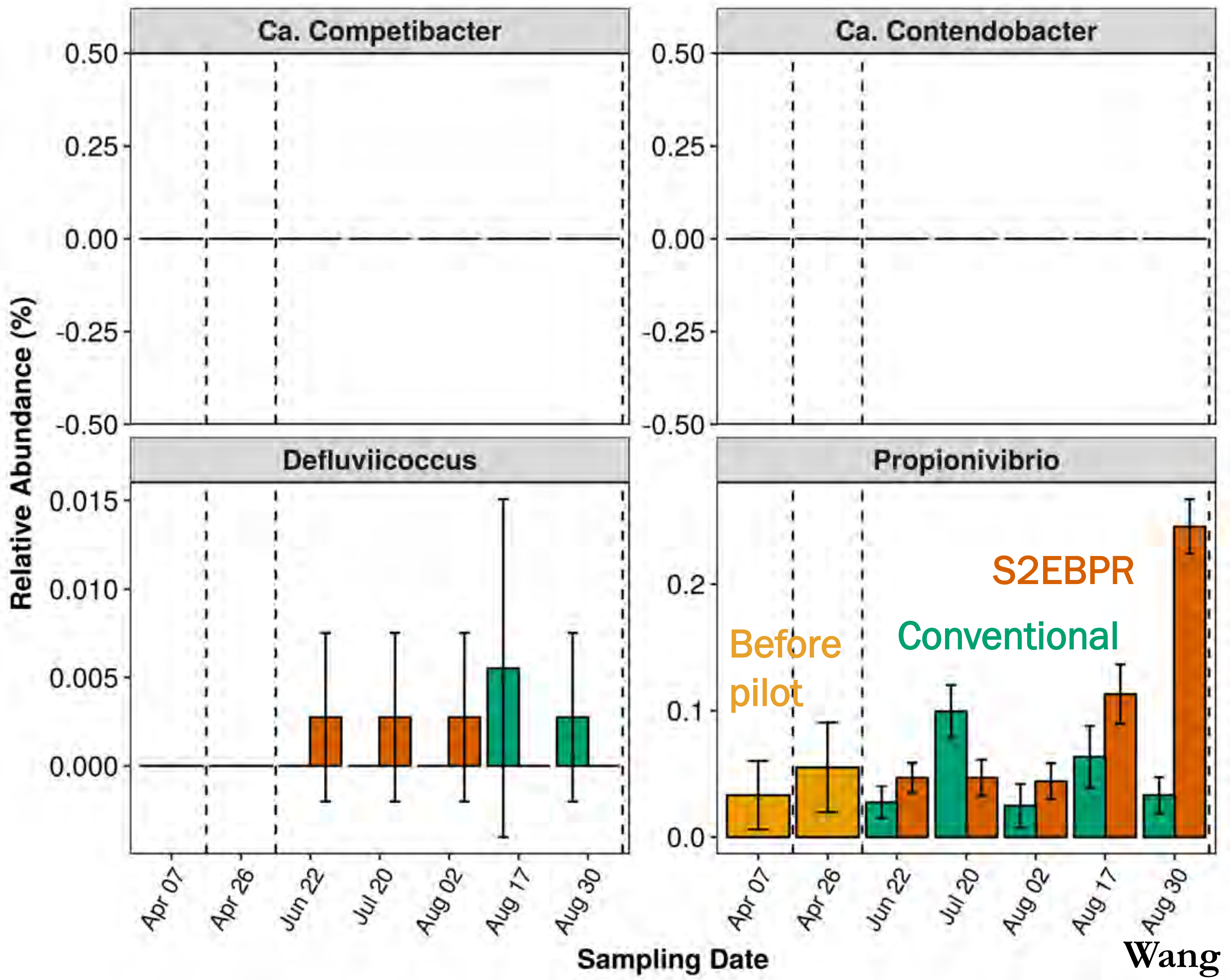
Community fingerprints indicate different community structures



Sampling Date	Conventional	S2EBPR
Apr 7	Before Pilot	
Apr 26	Before Pilot	
Jun 22	A2O	SSRC- mixed
Jul 20	A2O	SSRC- Inter. mixed
Aug 02	A2O	SSRC- Inter. mixed
Aug 17	A2O	SSRC- Inter. mixed
Aug 30	A2O	SSRC- Inter. mixed
Oct 26	Washout	

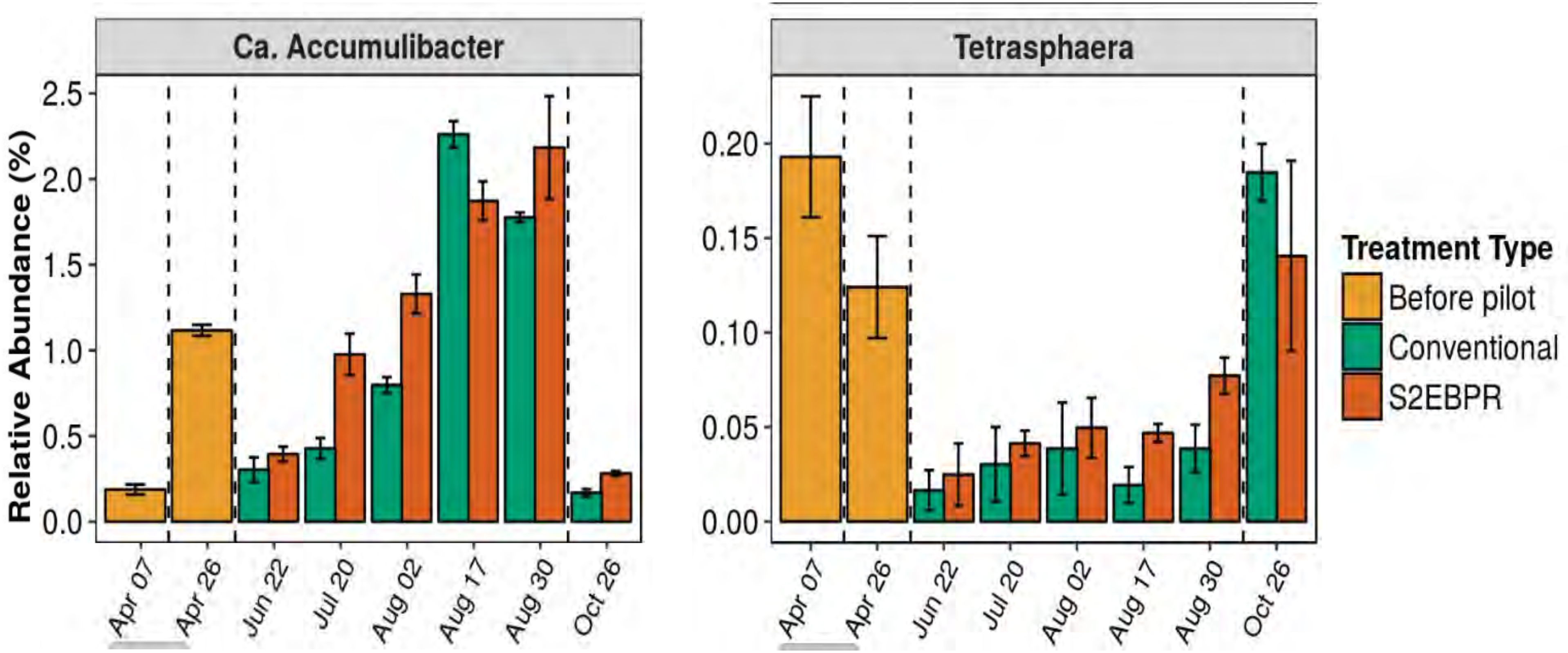
Wang , Tooker, Srinivasan et al., 2019

GAOs were low in abundance



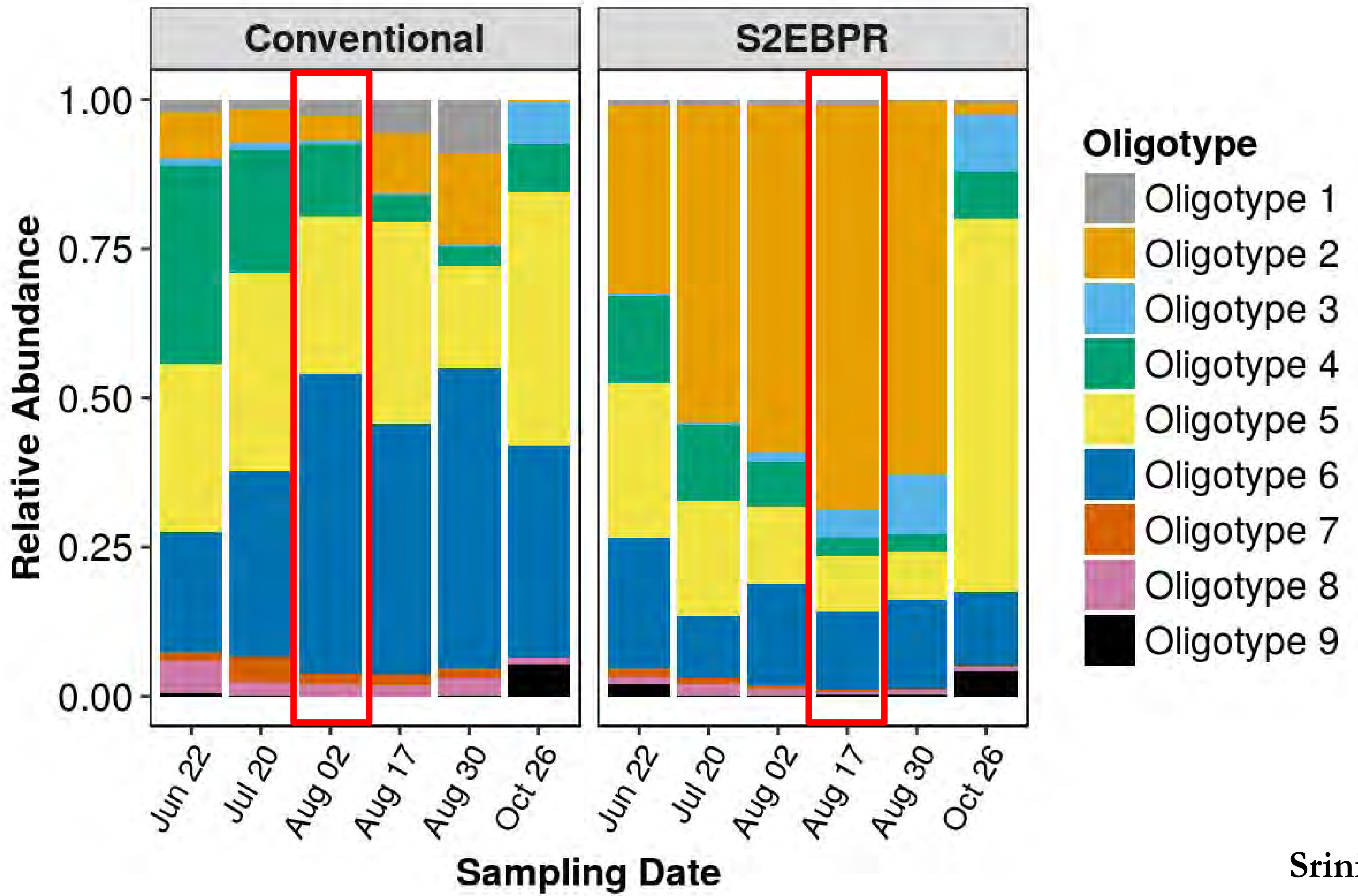
Wang , Tooker, Srinivasan et al., 2019

Accumulibacter was the most abundant PAO



Srinivasan et al., 2019 (BioRxiv)

Oligotyping reveals differences in Accumulibacter sequences



Srinivasan et al., 2019 (BioRxiv)

Conclusions

- S2EBPR
  - leads to more reliable P-removal.
  - has multiple flexible configurations
  - lowers reliability on influent VFA concentrations
- Microbial ecological differences between S2EBPR and conventional EBPR are seen only through higher-resolution methods.
  - Impact on process design and modeling?
- Oligotyping is a cost-effective and high-throughput method for profiling Accumulibacter communities at a higher-resolution.

Implications and applications

- Oligotyping could potentially be used to elucidate clade-level differences.
- This could enable
  - identification of key PAO/GAO types associated with good/bad performance.
  - Understand how operational changes impact Accumulibacter population
- Knowing the identity and abundance of PAOs and GAOs
  - can help calibrate models with appropriate kinetic parameters
  - update existing model structures

Aerobic MLSS

Can be done by partner

DNA Extraction

16S rRNA gene sequencing – V4 Region

Oligotyping Analysis

- Community Structure and Changes with Operation
- Identities Functional Group Types – PAOs/GAOs
- Higher-resolution profiling of Accumulibacter Communities

Thank You!

Questions?

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Brown AND Caldwell

Operational Conditions

Facility	South Cary [SC]	Westside Regional [WR]	Cedar Creek [CC]	Henderson [Hen]
System Configuration Information				
S2EBPR Configuration	SSR	SSRC	SSM	UMIF
Mainstream Configuration	4-stage Bardenpho	MLE	Modified Johannesburg	Johannesburg
Chemical addition	No	Yes	No	Yes
VFA addition	No	Yes, PFO[1]	No	No
Primary Sedimentation	No	Yes	No	No
Tertiary Filtration	Yes	Yes	No	Yes
TP Permit Limit (mg/L)	2.0	0.25	1.5	0.22 (seasonal)[2]
System Operating Parameters				
Wastewater temperature (°C)	21.8	17.2	16.2	24.4
Mainstream Sludge age (days)	7.3	10	13	6.4
Mainstream HRTn (hours)	23	12	19	16
Sidestream Sludge age (hours)	36	1.3	47	NA
Sidestream HRTn (hours)	2.9	0.9	0.9	0.4
Sidestream HRTa (hours)	36	1.3	13.5	NA
Mainstream MLSS (g/L)	3.4	3.2	2.1	2.0
Sidestream MLSS (g/L)	6.6	8.0	4.5-14.5[3]	N/A
Influent[4] Parameters				
Influent Flow (MGD)	5.2±0.8	2.6±0.2	3.0±0.9	20.9±1.9
TSS (mg/L)	330±115	94.3±21	246±116	274±50
BOD (mg/L)	284.4±69	240±53	236±92	263±38
TKN (mg/L)	48.2±6.8	44.1±4.8	29.4±11	43.7±5.4
TP (mg/L)	7.1±0.1	6.8±1	2.7±5.4	5.7±0.8
BOD/P (mg/mg)	39±6.6	38.4±23	102±88	46.5±4.2
VFA/P (mg/mg)	NA	NA	1.75±	NA
Alkalinity	140	NA	261	268
pH	7.3	7.3	7.4	7.4
Effluent Parameters				
TSS (mg/L)	5.7±7	2.8±11.4	6.1±3.3	5.2±1.9
BOD (mg/L)	2.8±0.5	NA	8.4±3.9	5.4±2.2
TN (mg/L)	2.1±0.7	5.8±4.3	7.6±3.1	16.4±2.3
TP (mg/L)	0.4±0.4	0.2±0.1	0.9±0.3	0.48±0.3