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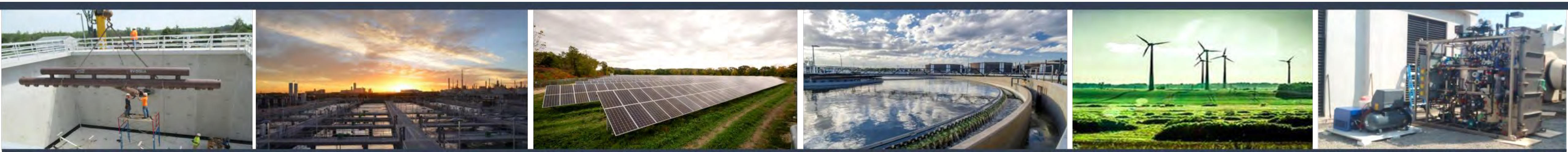
We will begin our presentation in a few minutes…



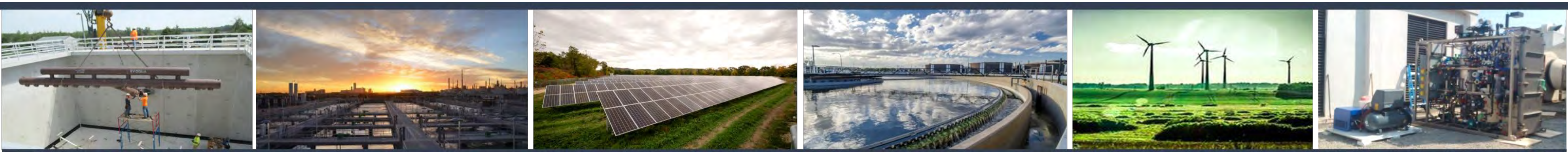
Leadership and Excellence in Environmental Engineering and Science

What exactly is a PechaKucha?

A PechaKucha celebrates people, passion and creative thoughts.

PechaKucha

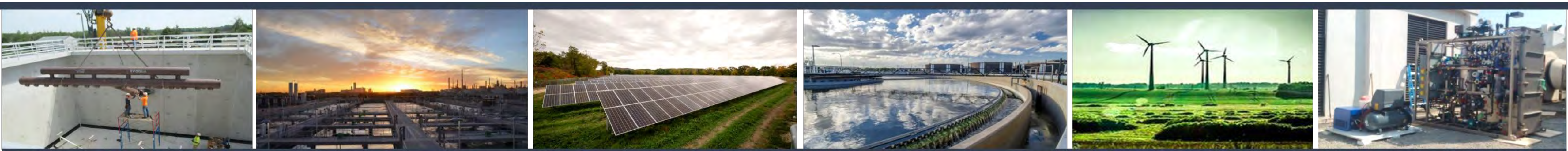
20 images X 20 seconds



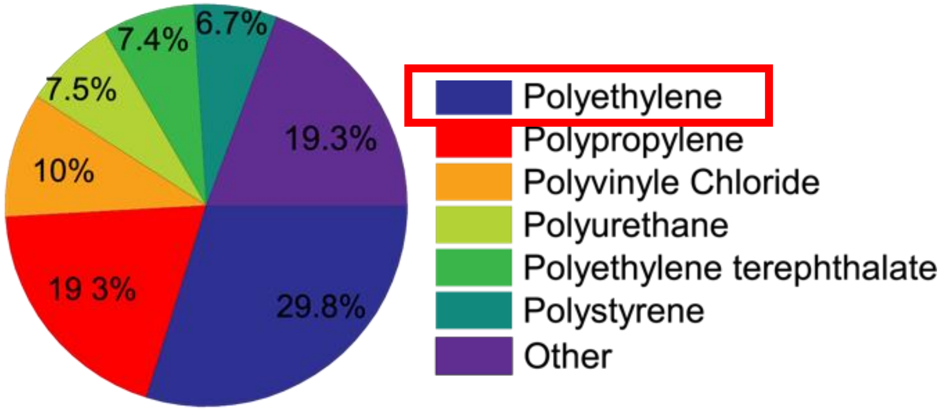
NOVEL INSIGHTS INTO NANOPLASTIC RELEASE IN NATURAL ENVIRONMENT

AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS & SCIENTISTS®

Prof. Boya Xiong
Assistant professor
University of Minnesota, Twin Cities
AAEES member

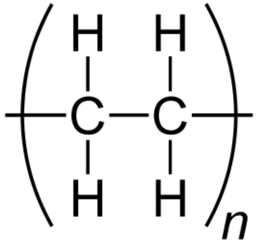


We use a lot of plastics in modern life



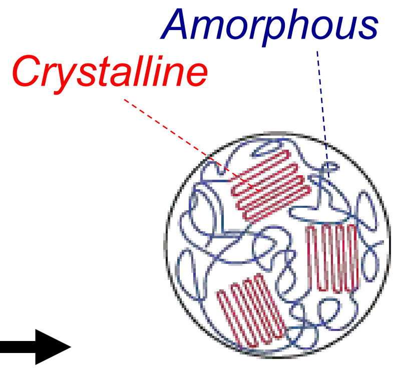
4 LDPE

2 HDPE

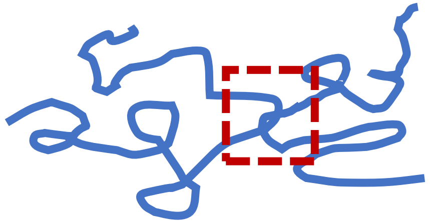


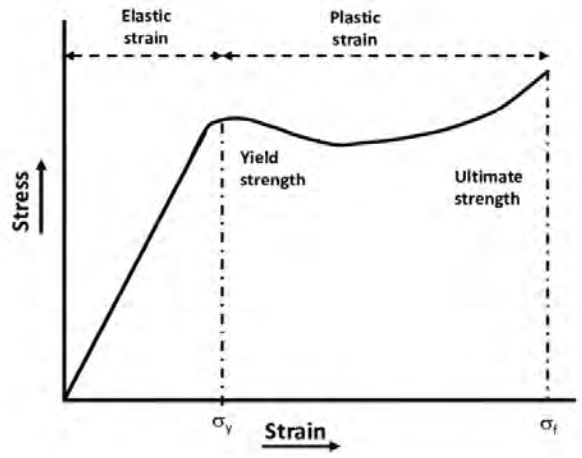
10-1000 kg/mol

Crystallization

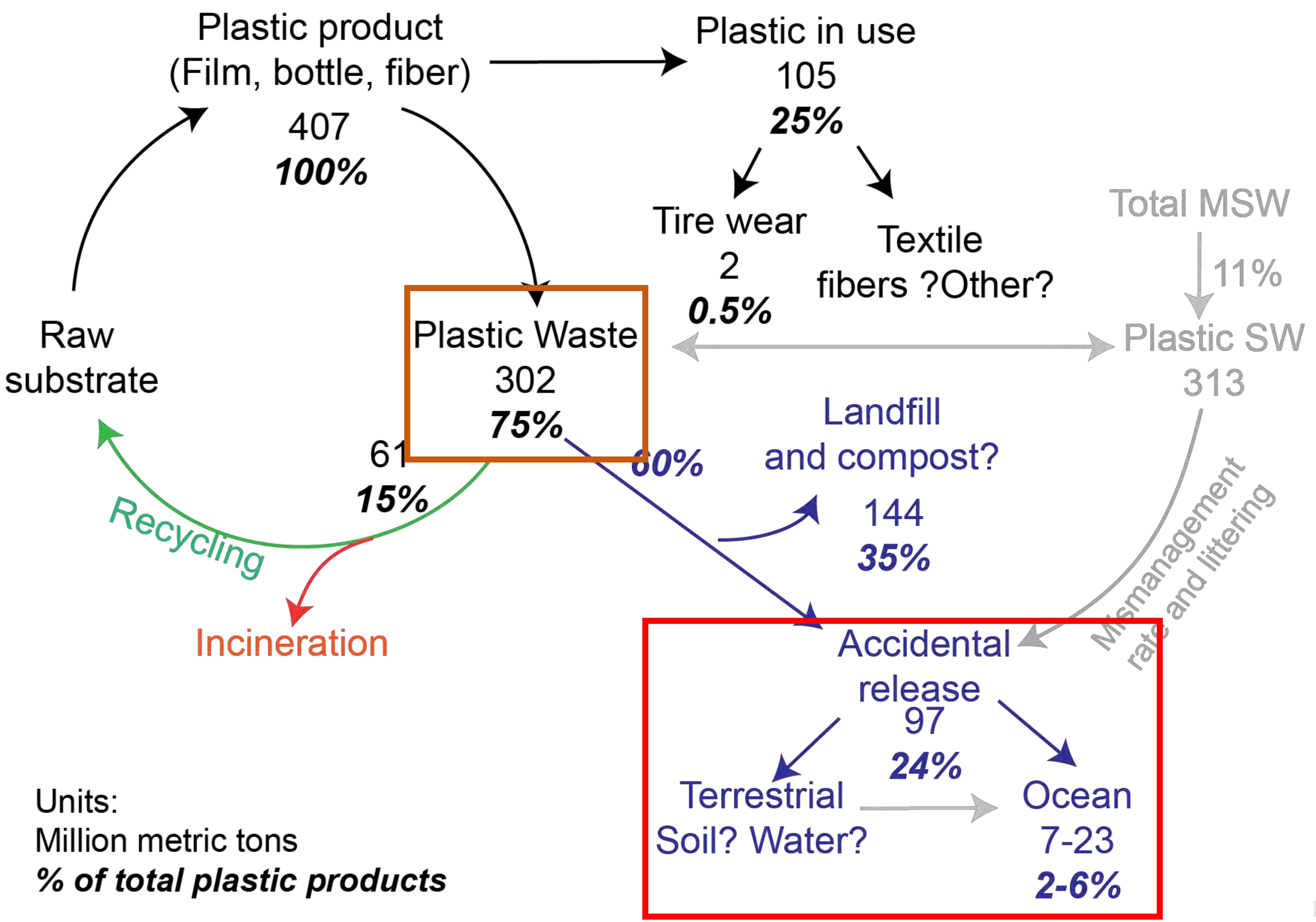


Chain entanglement



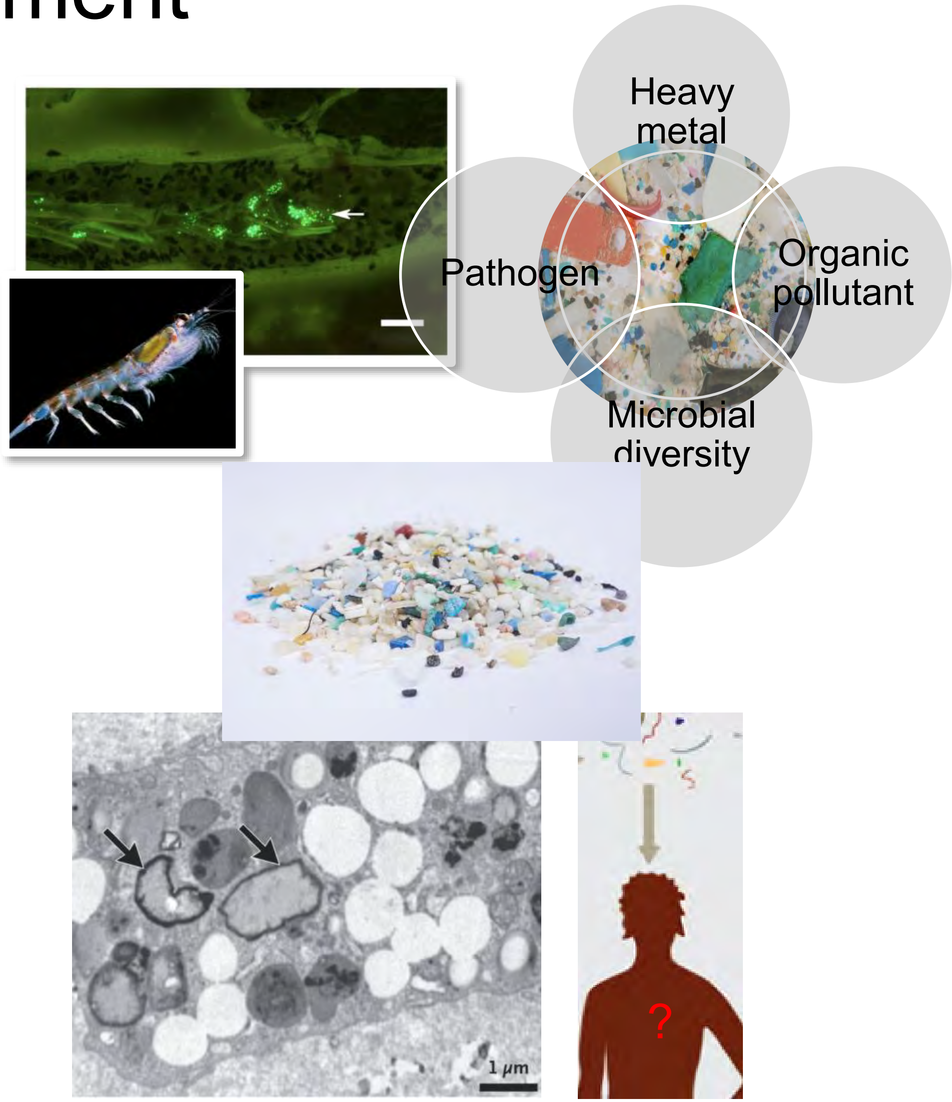


THE LINEAR AND LEAKY PLASTIC CYCLE



Units:
Million metric tons
% of total plastic products

Source and impact of plastic debris in natural environment

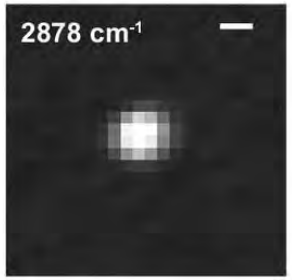


Microplastic and nanoplastics are break down products of large plastic debris

Macroplastics | **Microplastics** | **Nanoplastics found in bottled water**

50-100 mm | 20-50 mm | 10-20 mm | 5-10 mm | <5 mm | <1 μm

PP



Hard to detect

?

Mission of Xiong lab: expand method and knowledge of polymer degradation in the environment

CIRCULARITY IMPACT PROGRAM
A National Science Foundation Research Traineeship

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National Science Foundation MRSEC
MATERIALS RESEARCH SCIENCE AND ENGINEERING CENTERS

MnDRIVE
Minnesota's Discovery, Research, and InnoVation Economy

U.S. CENTERS FOR DISEASE CONTROL AND PREVENTION

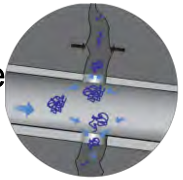
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

MN water research fund

National Science Foundation

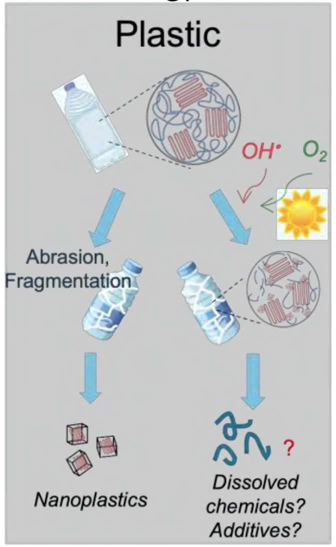
NSF Center for Sustainable Polymers

Water soluble polymers



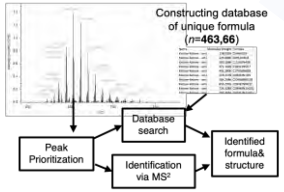
Xiong *et al.*, ES&T 2018
Xiong *et al.*, npj Clean water 2018
Xiong *et al.*, ES:WRT 2020

&

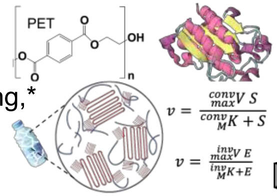


Shieh, … Xiong *et al.*, Nature 2020
Xiong *et al.*, Chem 2021
Ghafari,… Xiong* *et al.*, ES:WRT 2021

High-resolution mass spec

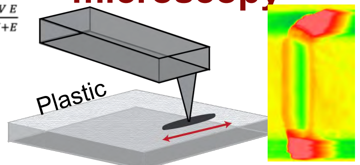


Keyes, Xiong,* ESPI 2024



Kamal, Xiong,* Submitted, 2024

Lateral force microscopy



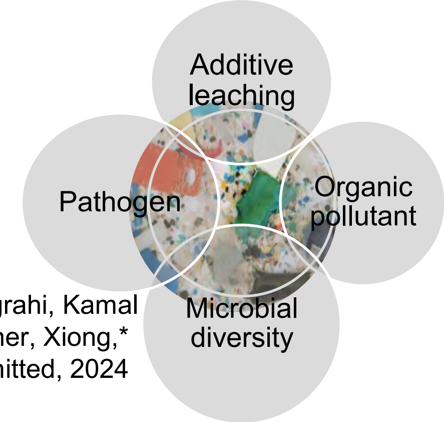
Rahman, Xiong,* ES&T, 2024
Rahman, Xiong,* In prep

Molecular scale

Nano/microscale

Macroscale

Water column/ Watershed scale

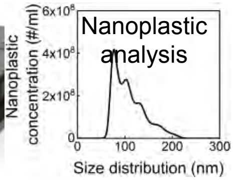


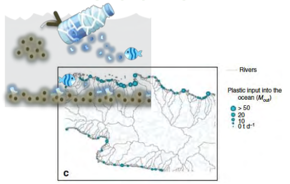
Panigrahi, Kamal Dutcher, Xiong,* Submitted, 2024

Lifetime prediction &Chemistry/property -degradability

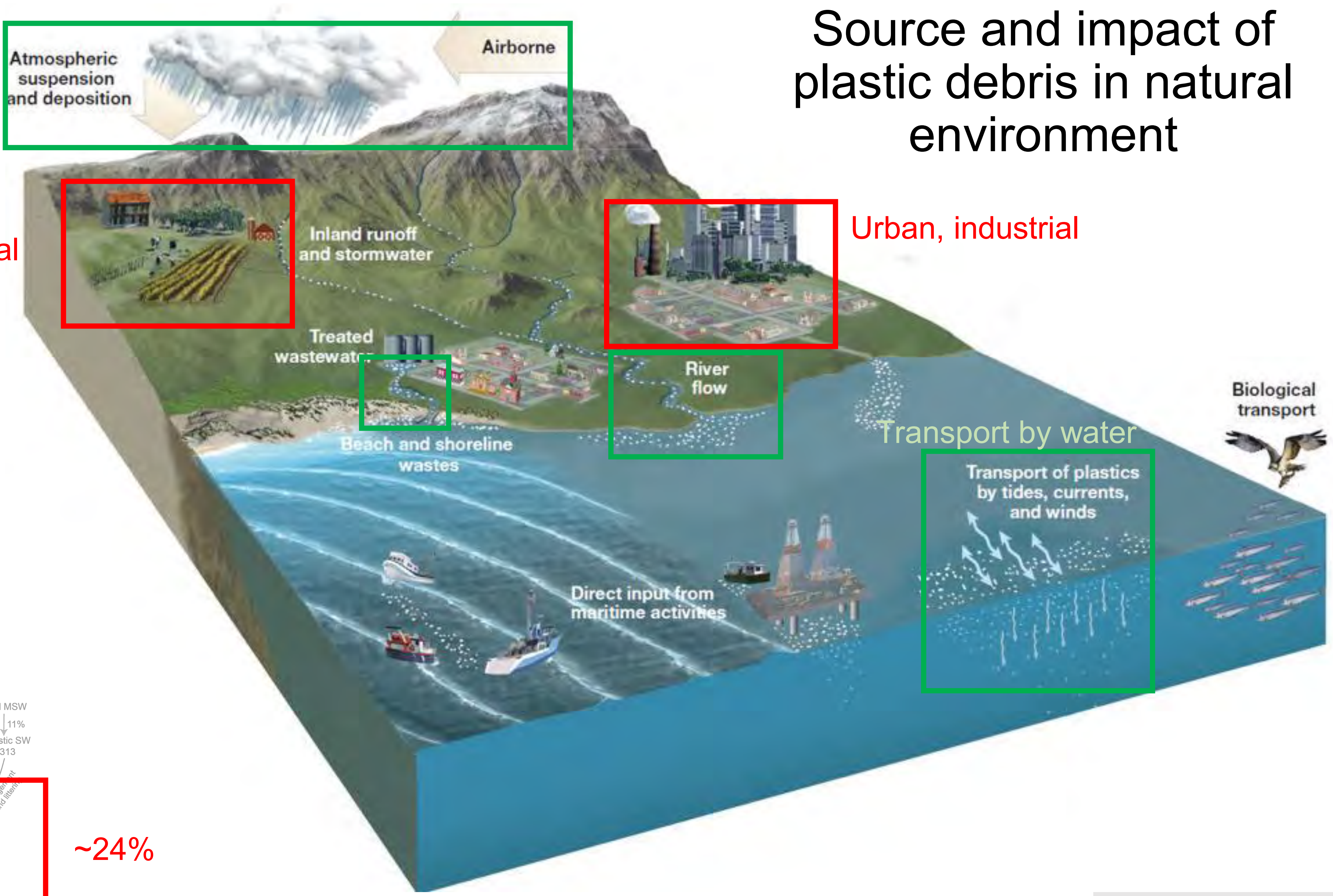
$$SSDR = \frac{1}{2}\frac{d_0}{t}\left(1 - \sqrt[a]{1 - \frac{\Delta m}{m_0}}\right)$$

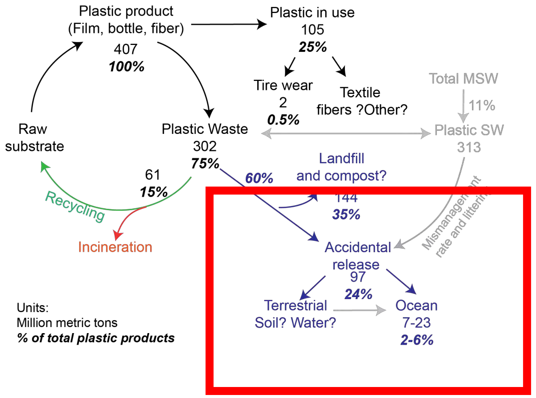
High throughput abrasion device





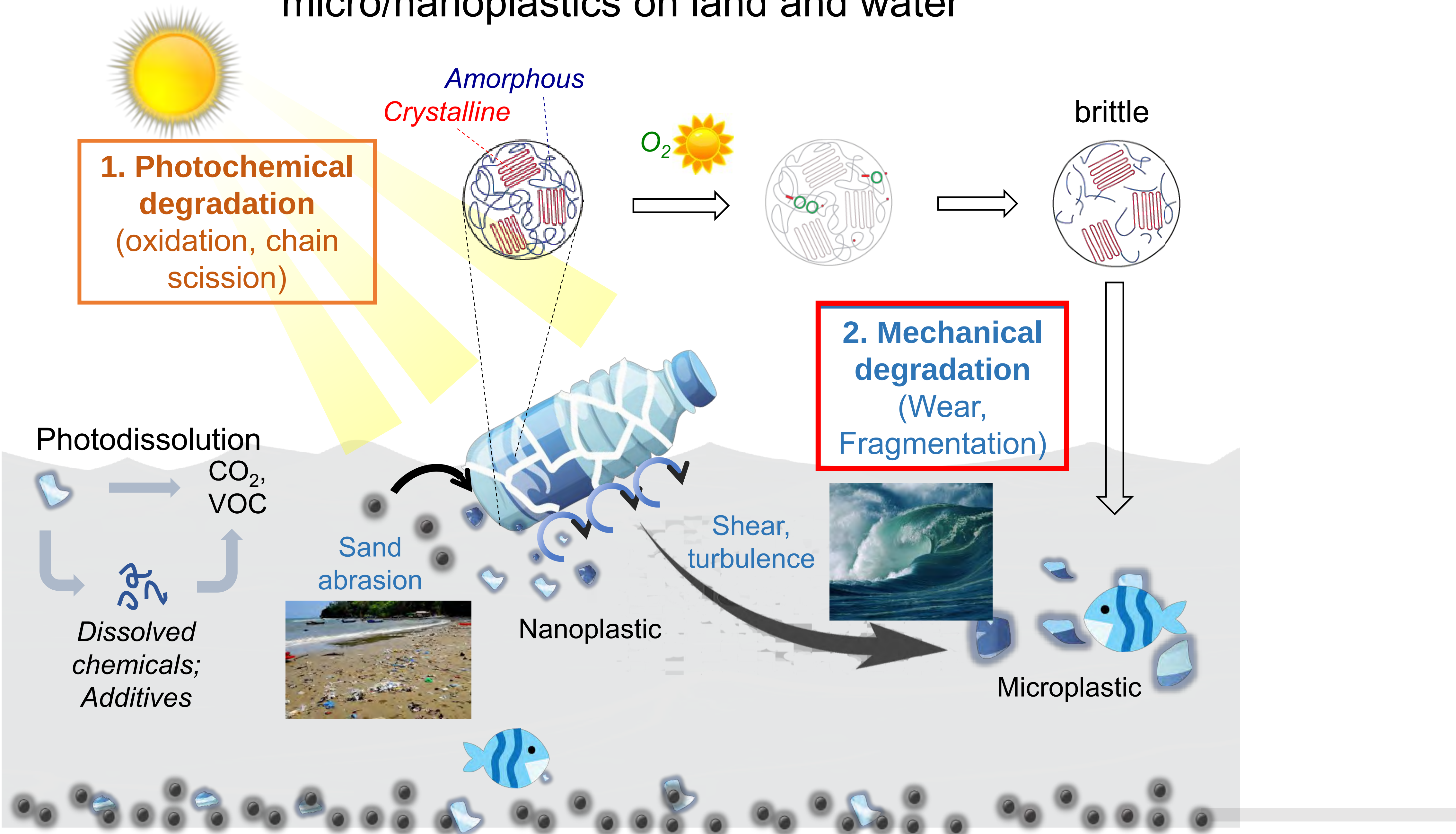
Source and impact of plastic debris in natural environment

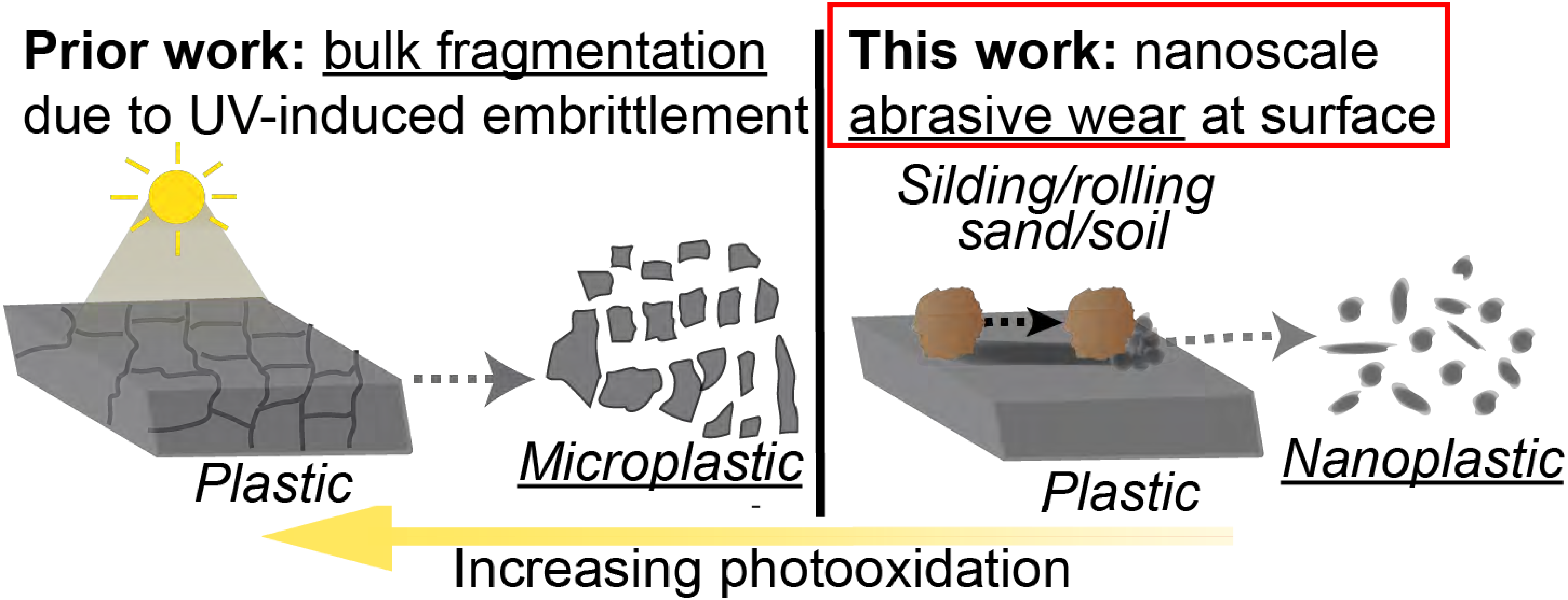




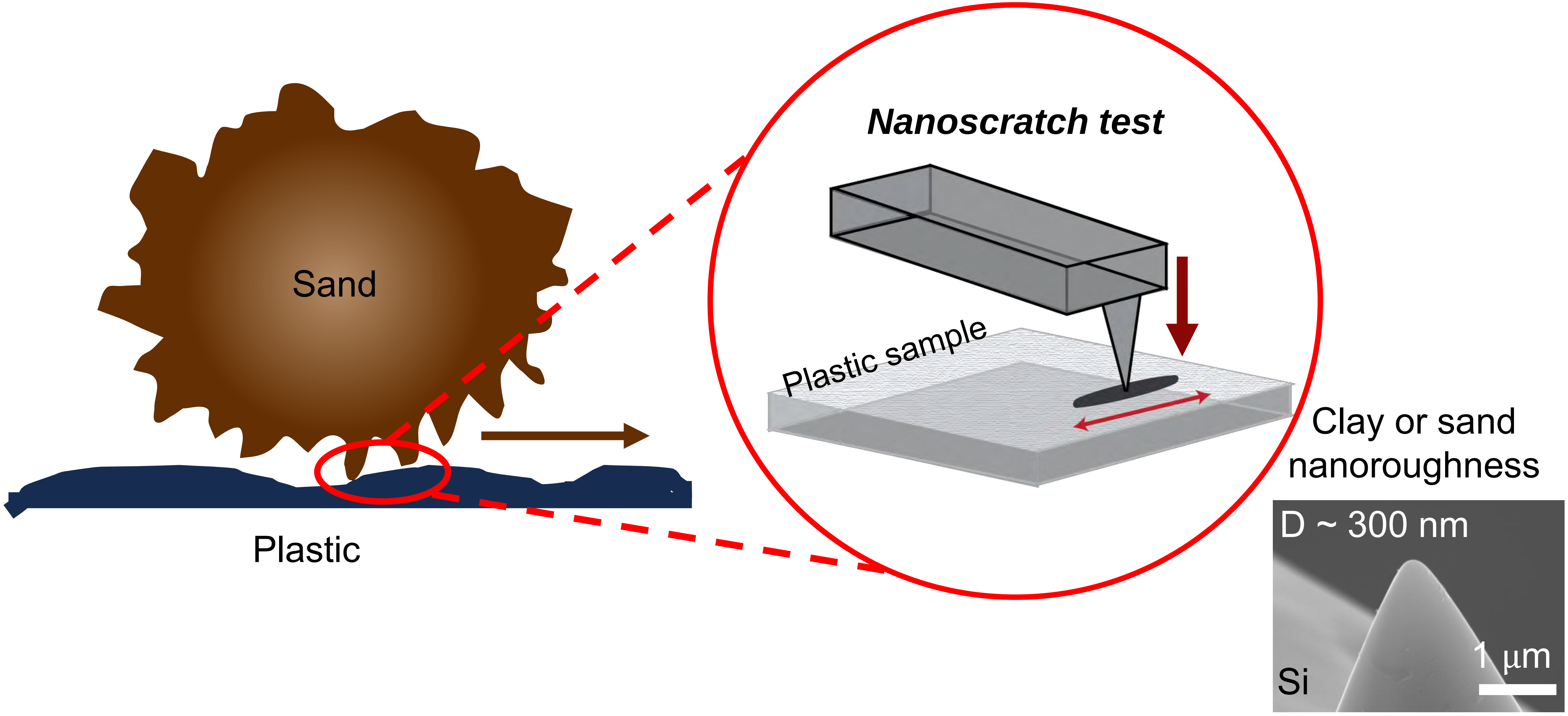
~24%

Proposed abiotic degradation pathways that generate micro/nanoplastics on land and water



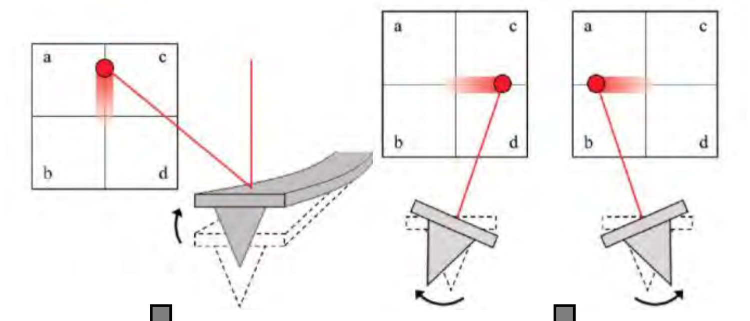

Prior work: bulk fragmentation
due to UV-induced embrittlement
Plastic
Microplastic
This work: nanoscale
abrasive wear at surface
Silding/rolling
sand/soil
Plastic
Nanoplastic
Increasing photooxidation

Abrasive wear at the initial contact is at nanoscale



Nanoscale control and measurement of abrasive wear to quantify nanoplastic release *per input force*

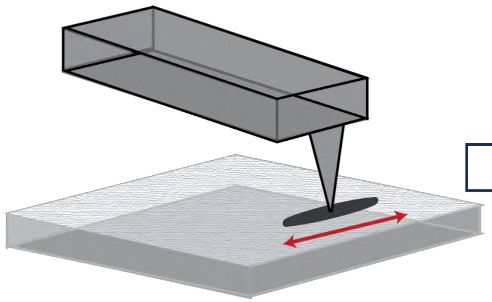
Lateral force microscopy



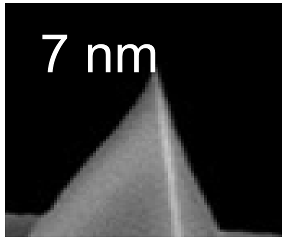
Controlled normal force

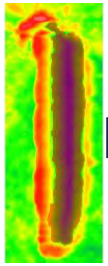
Measuring friction force

Nanoscratch test



3D high-res topography imaging



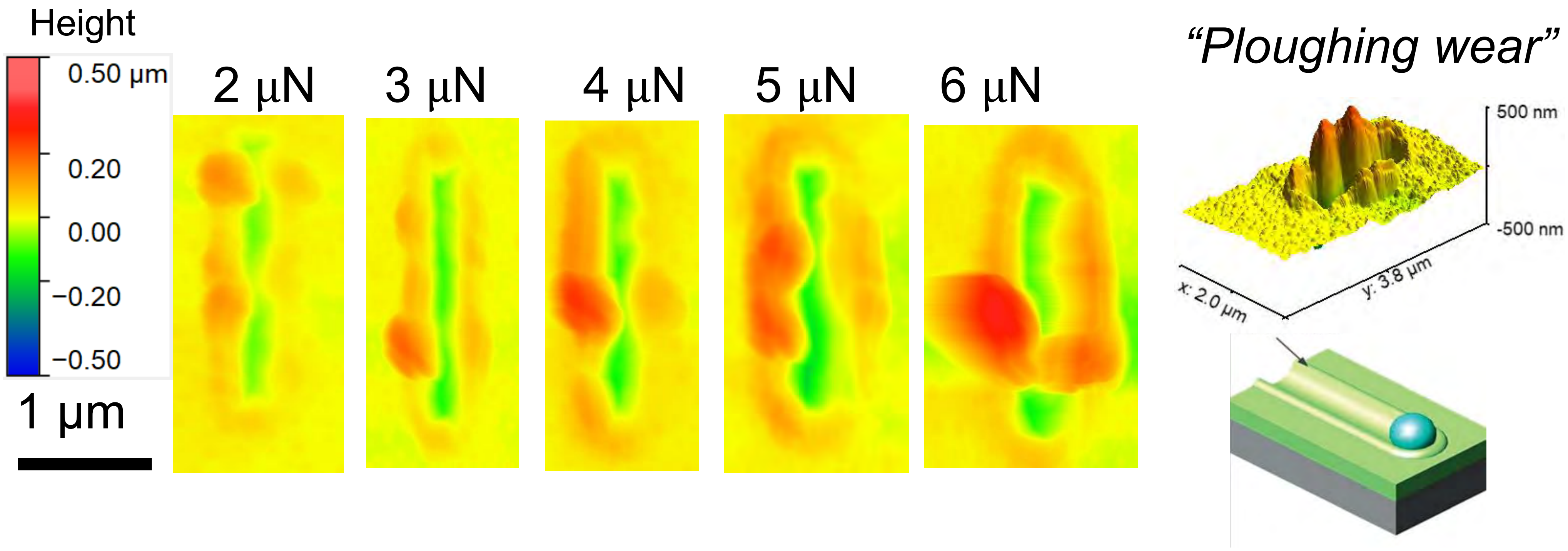


7.7 nm/pixel

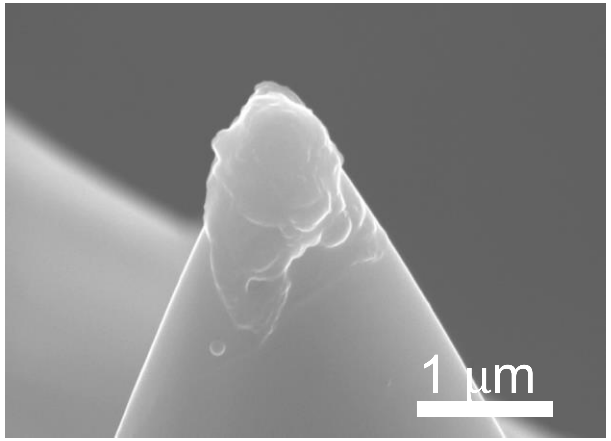
Analyze wear volume

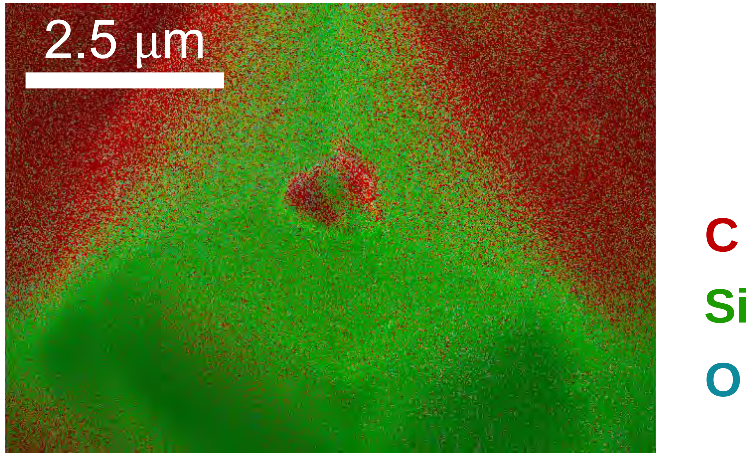
$\mu m^3/\mu m/\mu N$

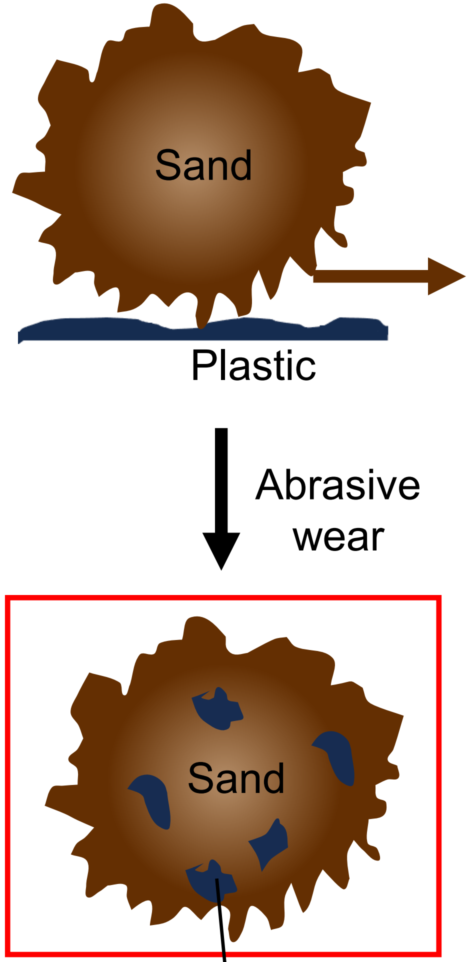
Nanoscale wear of virgin LDPE is primarily abrasive ploughing wear, release little debris



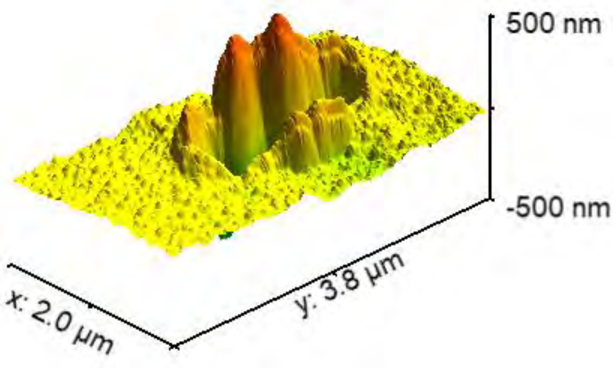
Polymer transfer to tip during nanoscratching: novel release profile of nanoplastic release

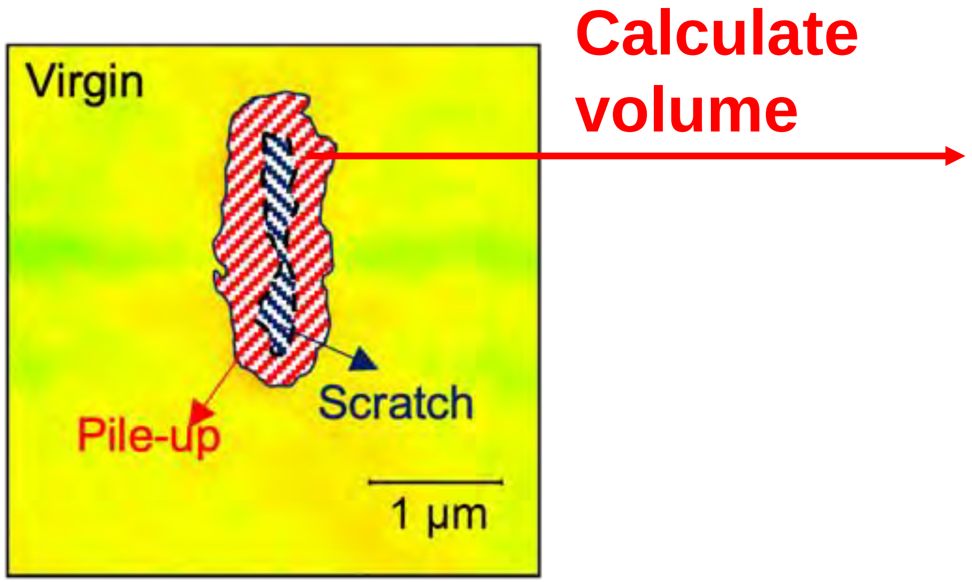


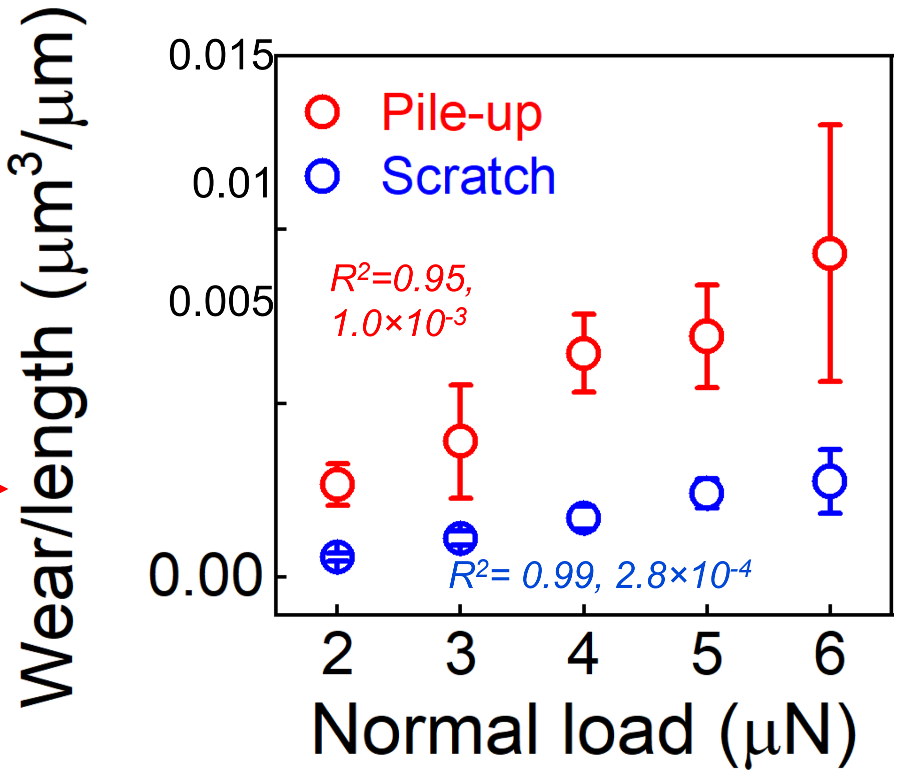




Quantifying nanoscale wear rate at single asperity level (μm³/μm·μN)





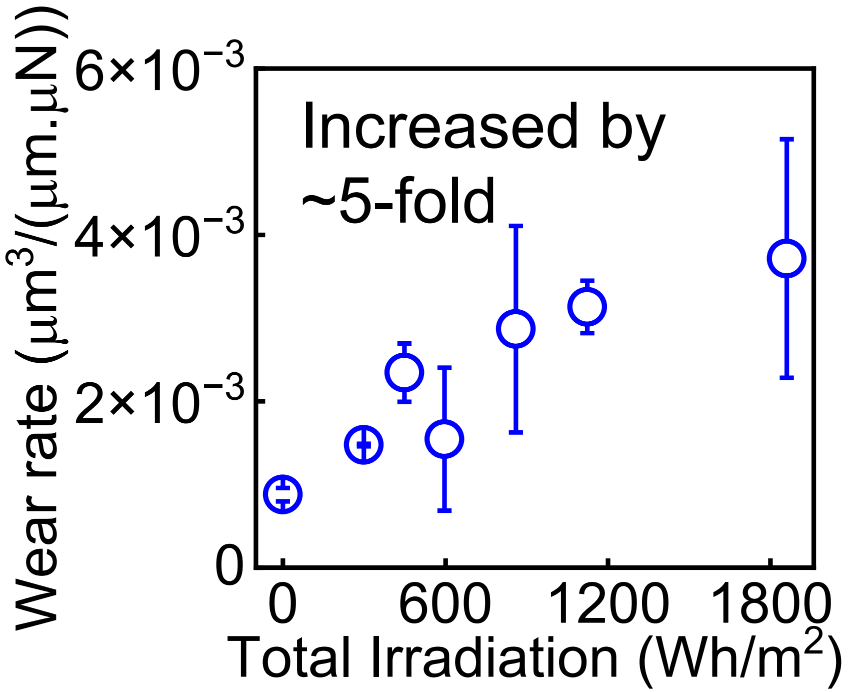


3D topography image

From pile-up: 1.0×10^{-3} μm³/μm·μN

Impact of photo-oxidation: increase in *wear rate* and shift of *wear mechanism*

Cumulative UVA energy	*Virgin*	ASTM G154, UVA 340 nm	*1860*	Wh/m^2
Weathering time under Boulder, CO weather	*0*		*20*	*Month*



⇨ Will all release as nanoplastics?

Impact of photo-oxidation: increase in *wear rate* and shift of *wear mechanism*

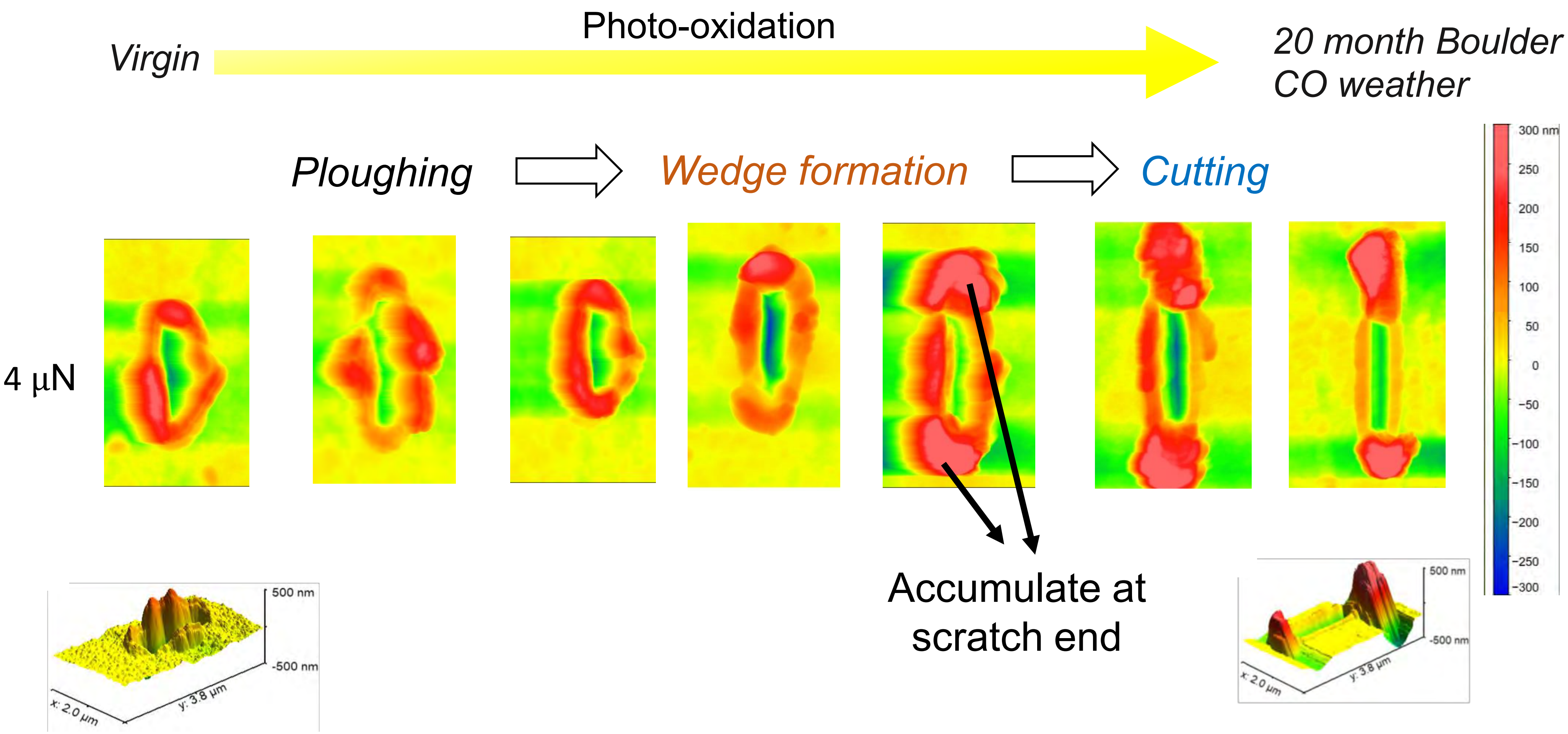
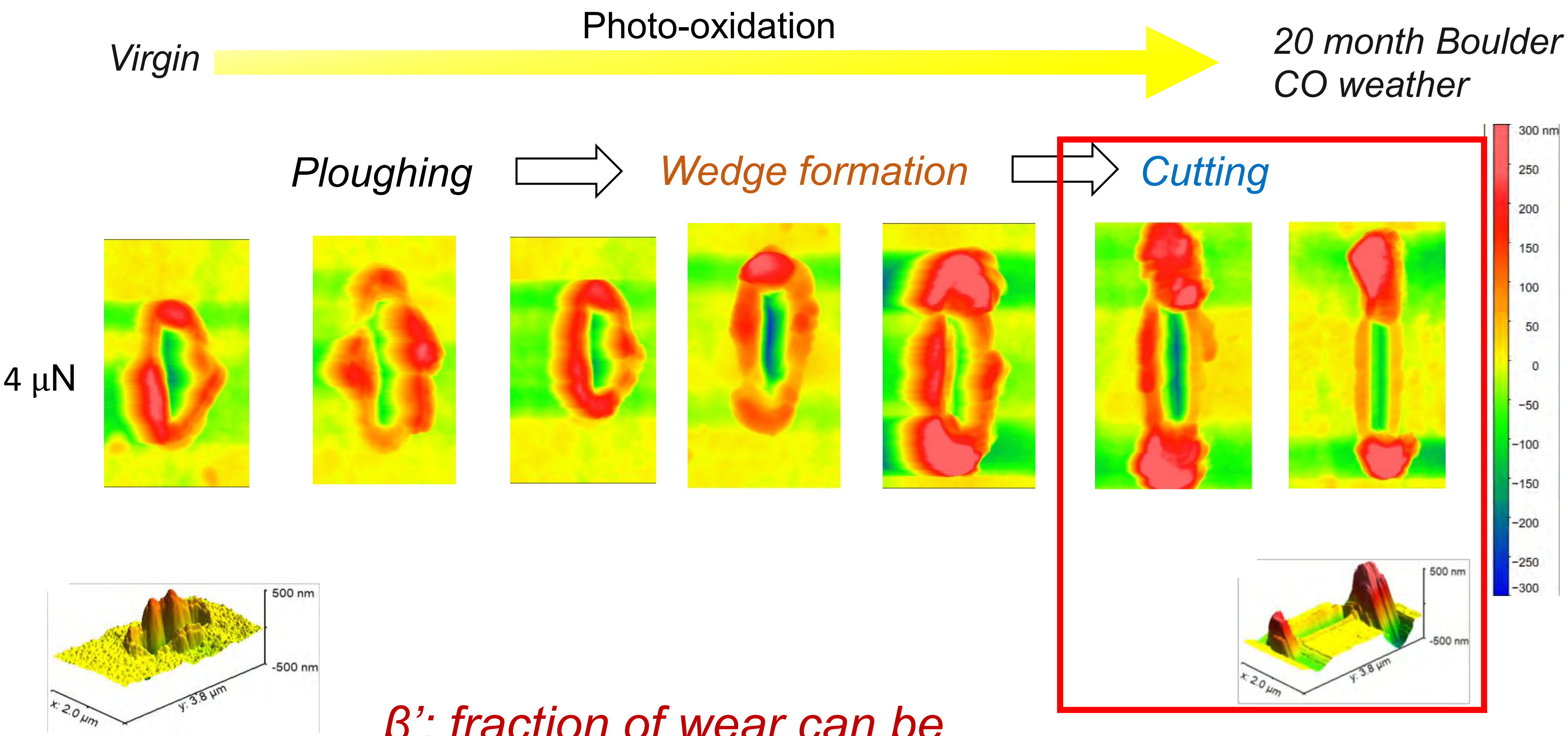
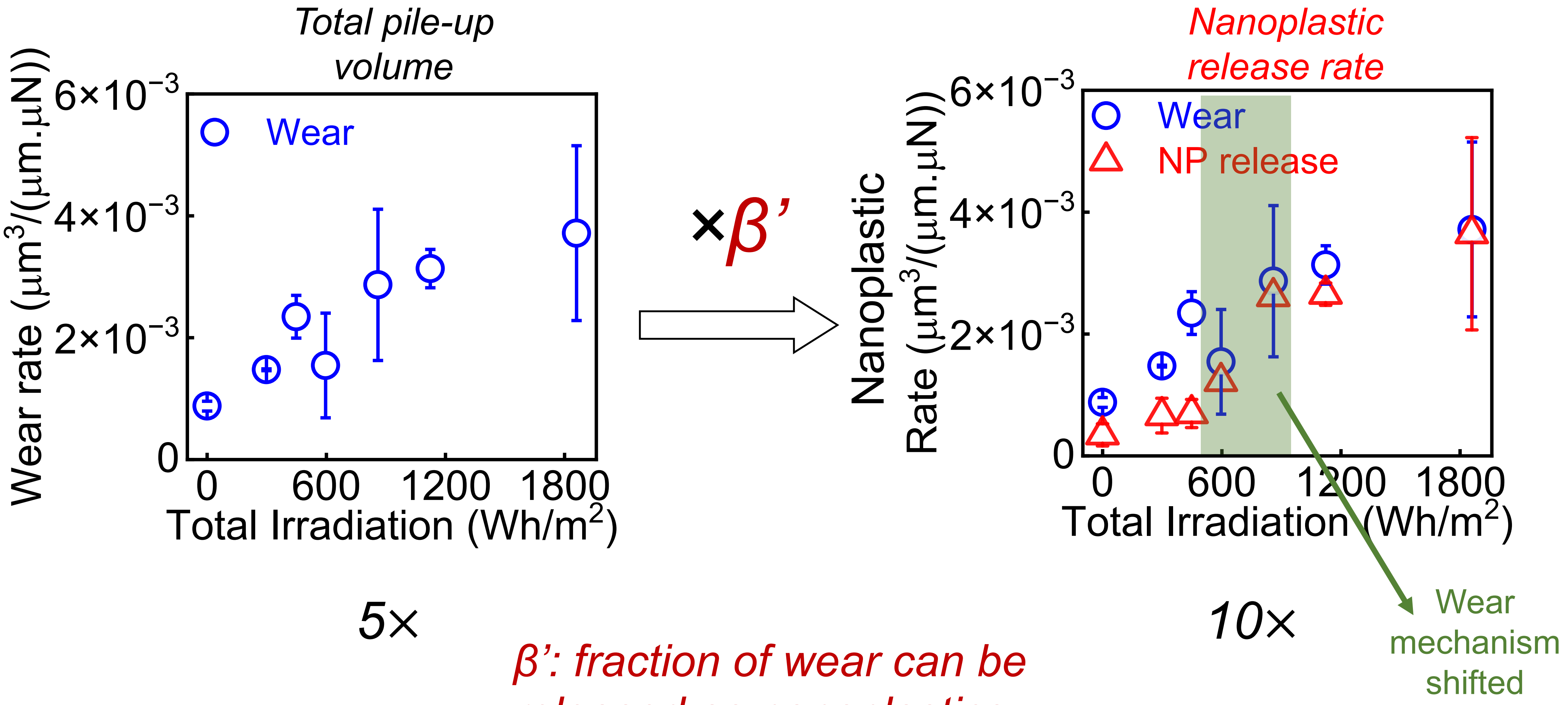


Photo-oxidation increase in *wear rate* and increase the likelihood of wear release as nanoplastics



β': fraction of wear can be released as nanoplastics

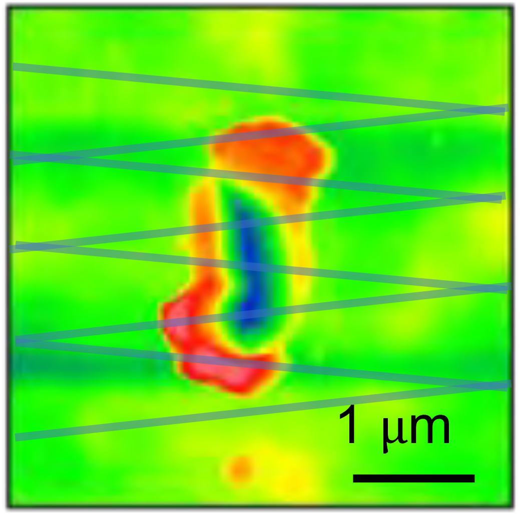
For the first time, we estimate *nanoplastic release* at single asperity level



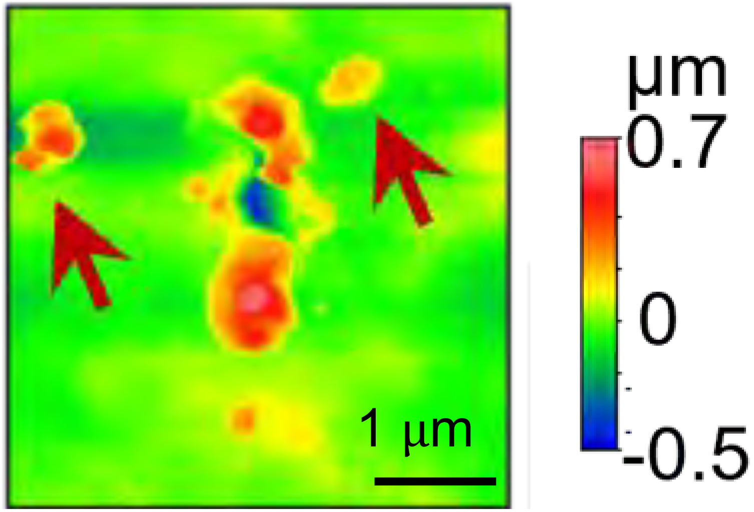
5× *10×*

β': fraction of wear can be released as nanoplastics

Measuring actual release of nanoplastics



Sliding using gentle force (~300 nN)



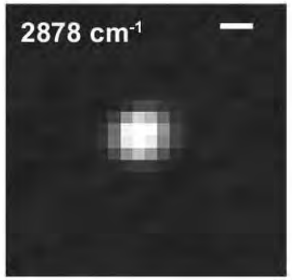
Unpublished results

Macroplastics | **Microplastics** | **Nanoplastics**

<1 μm

50-100 mm | 20-50 mm | 10-20 mm | 5-10 mm | <5 mm

PP



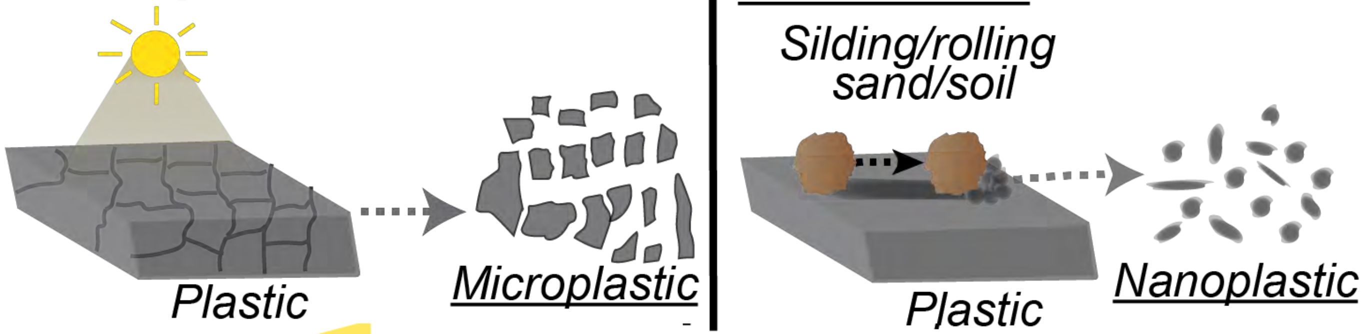
Hard to detect

?

Beach, soil erosion

Prior work: bulk fragmentation due to UV-induced embrittlement

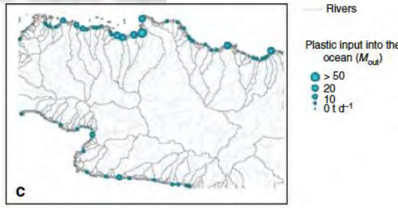
This work: nanoscale abrasive wear at surface

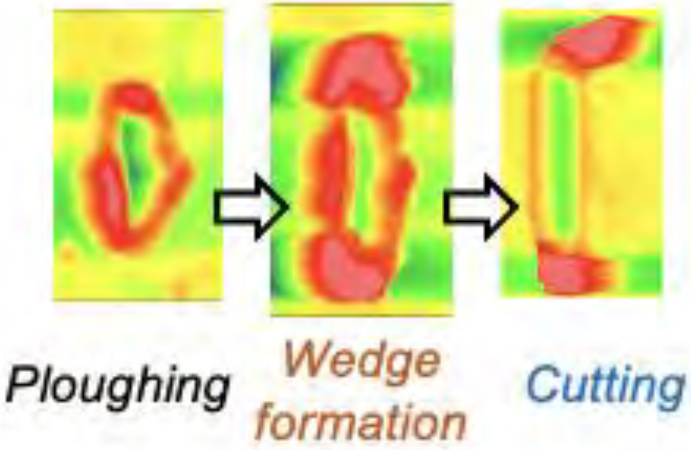


Increasing photooxidation

Water column/
Watershed
scale

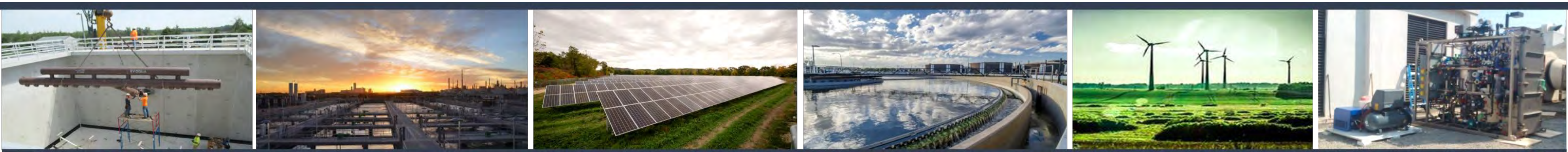
0.4-4 $\times 10^{-3}$
$\mu m^3/\mu m \cdot \mu N$



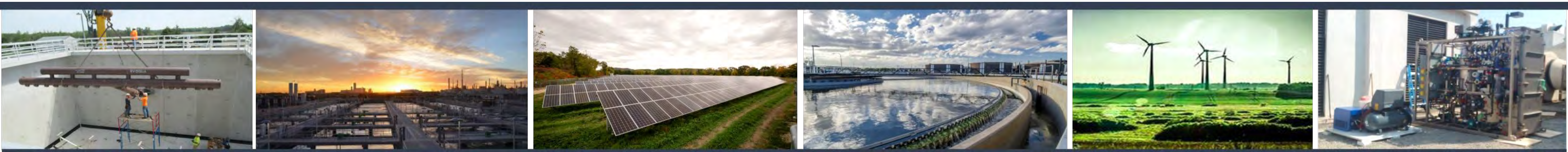


Q and A

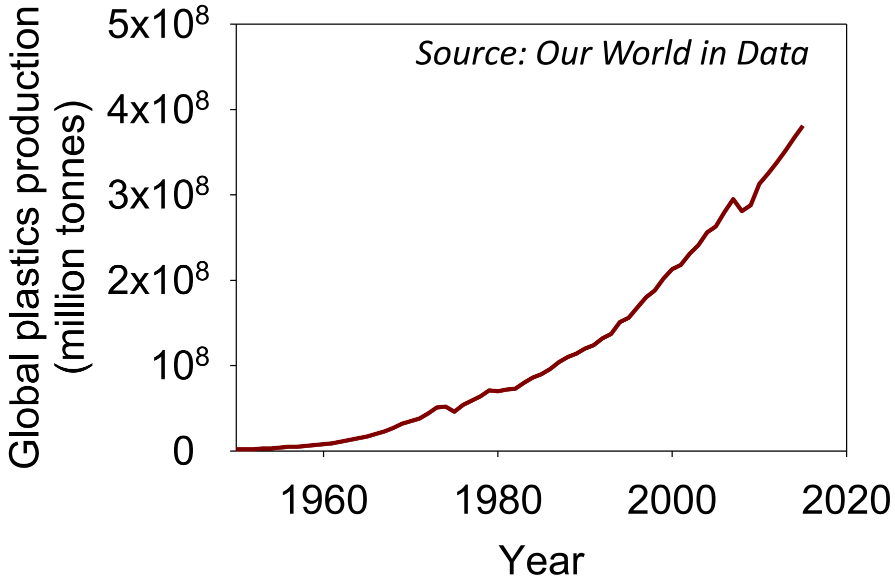
If you have a question, just click on the Q and A icon on the bottom of the screen and type it in there.



Nicole Fahrenfeld, PhD
Associate Professor
Rutgers, The State University of New Jersey
AAEES member



Plastics production continues to increase



...and is harder to ignore

TECHNOLOGY

Is This the End of Recycling?

Americans are consuming more and more stuff. Now that other countries won't take our papers and plastics, they're ending up in the trash.

By Alana Semuels

The Atlantic

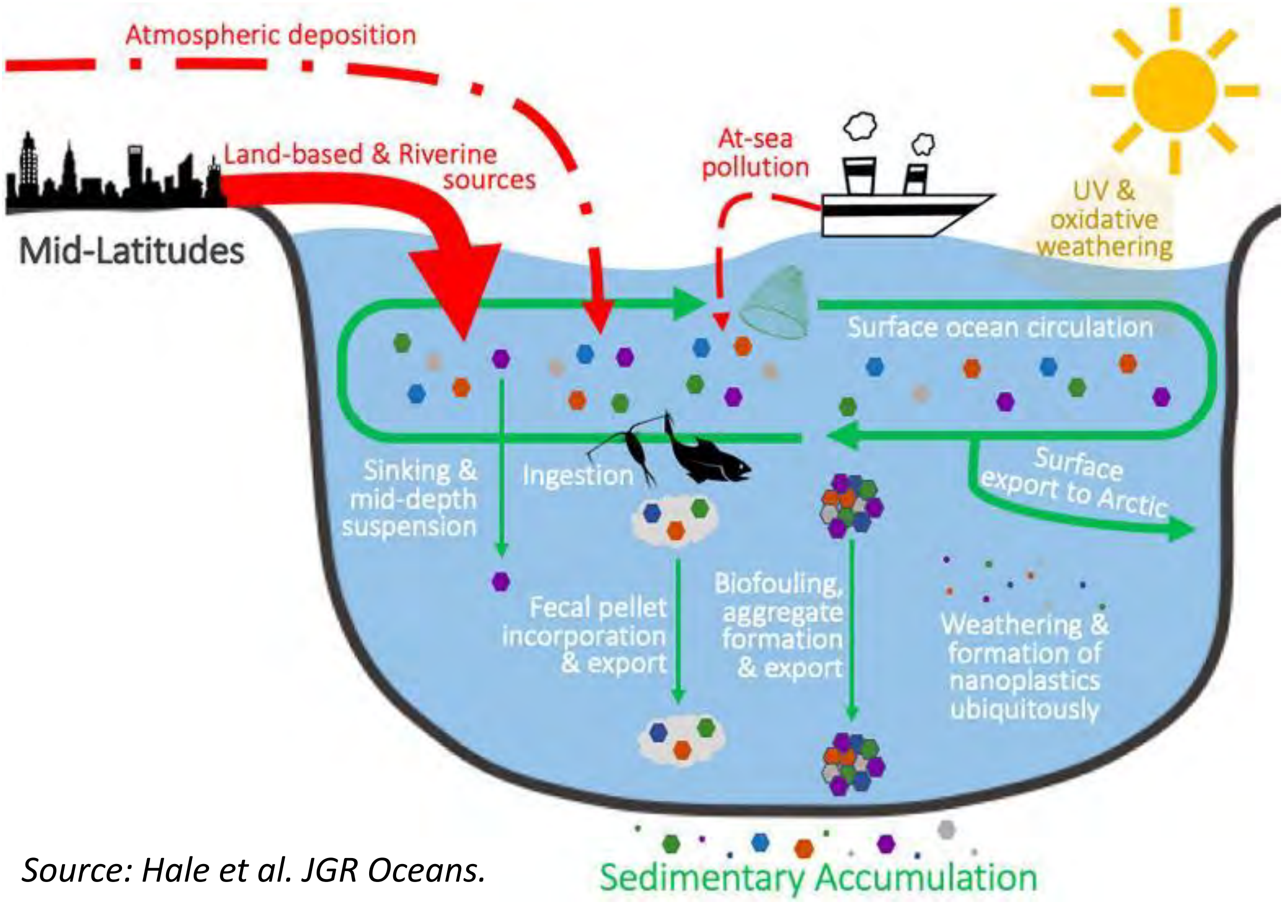
Fish mistaking plastic debris in ocean for food, study finds

Behavioural evidence suggests marine organisms are not just ingesting microplastics by accident but actively seeking them out as food

▲ Fish eat microplastics driven by their odour. Above, debris found in the stomach of a fish in Portugal. Photograph: Paulo Oliveira/Alamy

Fish may be actively seeking out plastic debris in the oceans as the tiny pieces appear to smell similar to their natural prey, new research suggests.

The Guardian Weekly



Source: Hale et al. JGR Oceans.

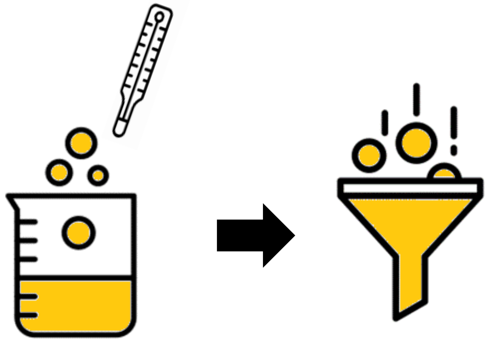
Improve our ability to measure environmental microplastics

Characterize MP in stormwater

Understand estuarine distribution and entry into food web

Improve our ability to measure environmental microplastics


Laboratory Methods for the Analysis of Microplastics in the Marine Environment:
Recommendations for quantifying synthetic particles in waters and sediments
NOAA Marine Debris Program
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Technical Memorandum NOS-OR&R-48
July 2015



Density separation

- Losses due to heating?
- Losses of dense polymers?

Designation: D8333 – 20

Standard Practice for
Preparation of Water Samples with High, Medium, or Low Suspended Solids for Identification and Quantification of Microplastic Particles and Fibers Using Raman Spectroscopy, IR Spectroscopy, or Pyrolysis-GC/MS[1]

Peroxide

Cellulose digestion

Lipid and protein digestion

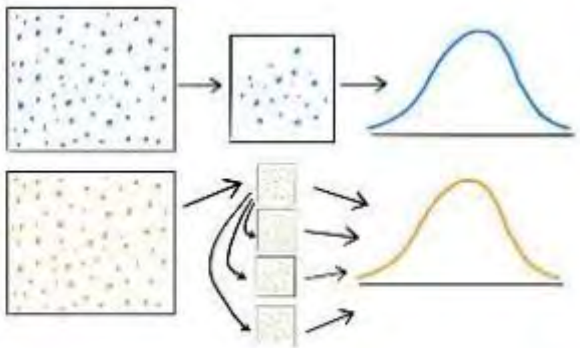
- Limited adoption in the literature to date

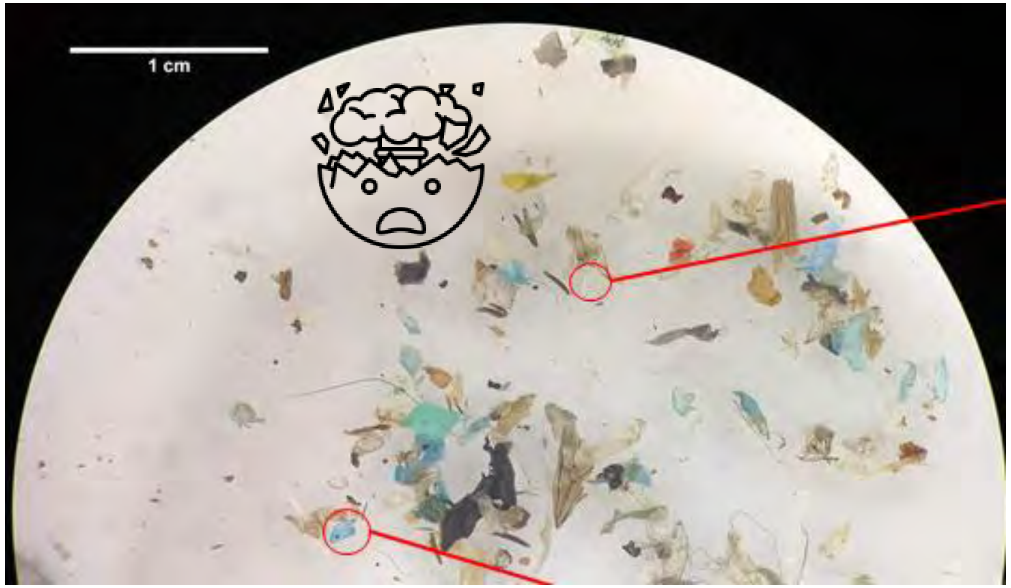
Improve our ability to measure environmental microplastics

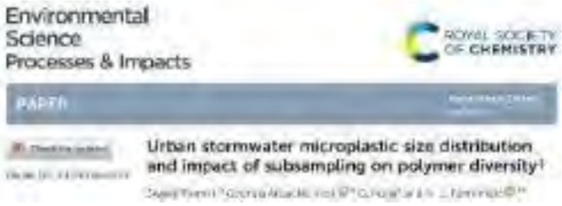
Subsampling strategies

…beware of those based on visual ID only!

Impact of subsampling on polymer diversity and MP concentrations ?






Environmental Science Processes & Impacts

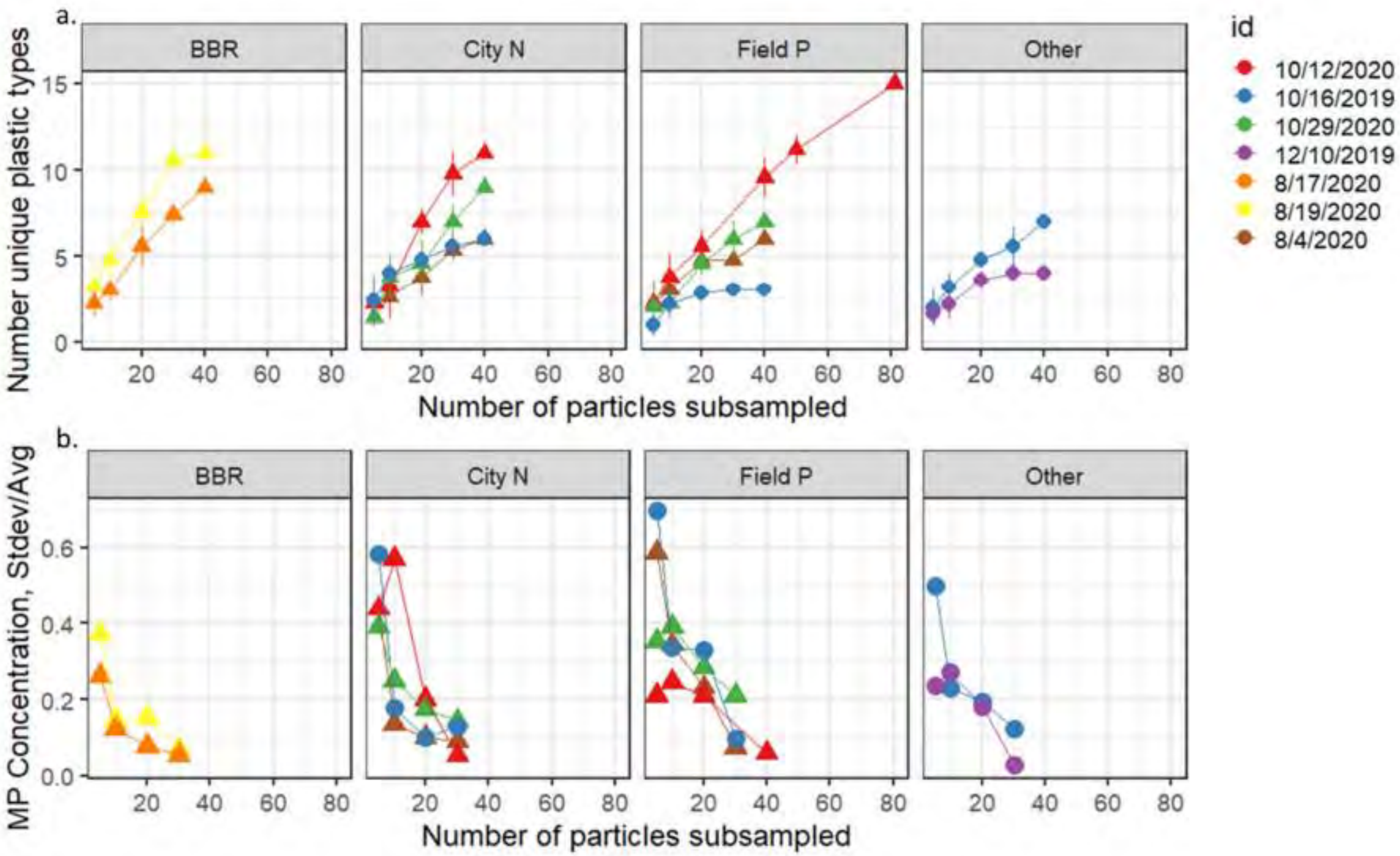
ROYAL SOCIETY OF CHEMISTRY

PAPER

Urban stormwater microplastic size distribution and impact of subsampling on polymer diversity

Improve our ability to measure environmental microplastics

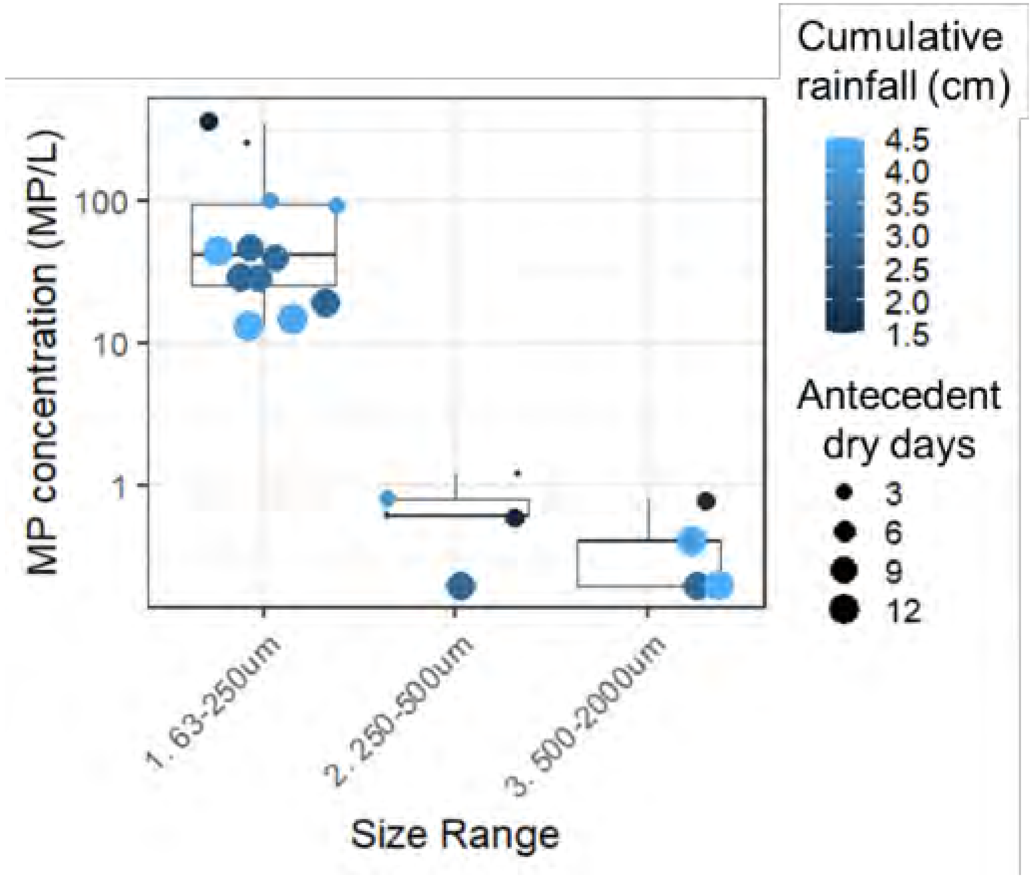
Subsampling impacts on polymer diversity and concentration

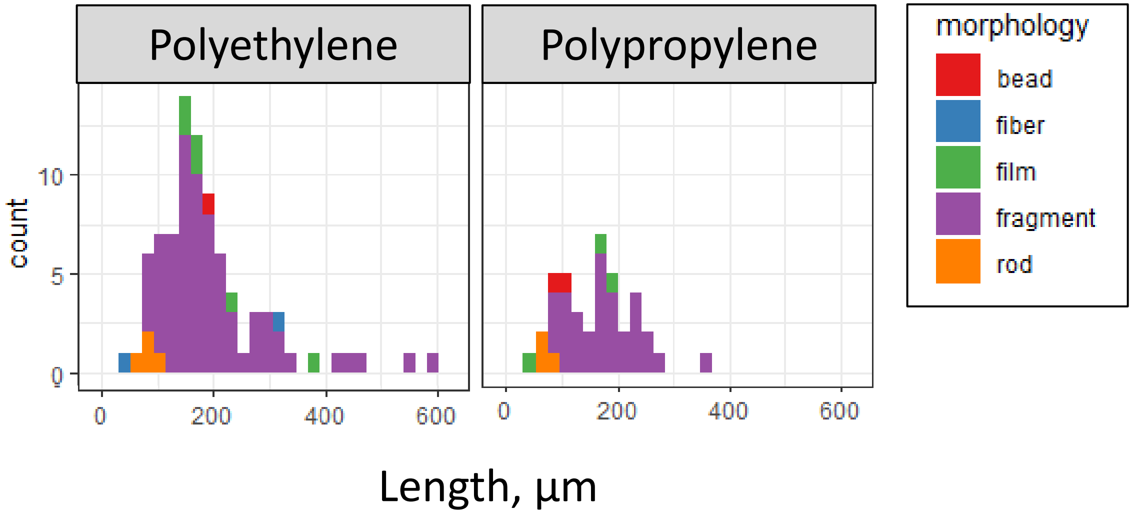


Urban stormwater microplastic size distribution and impact of subsampling on polymer diversity†

Swaraj Parmar,[a] Georgia Arbuckle-Keil,[a] G. Kumi[a] and N. L. Fahrenfeld*[b]

Characterize MP in stormwater





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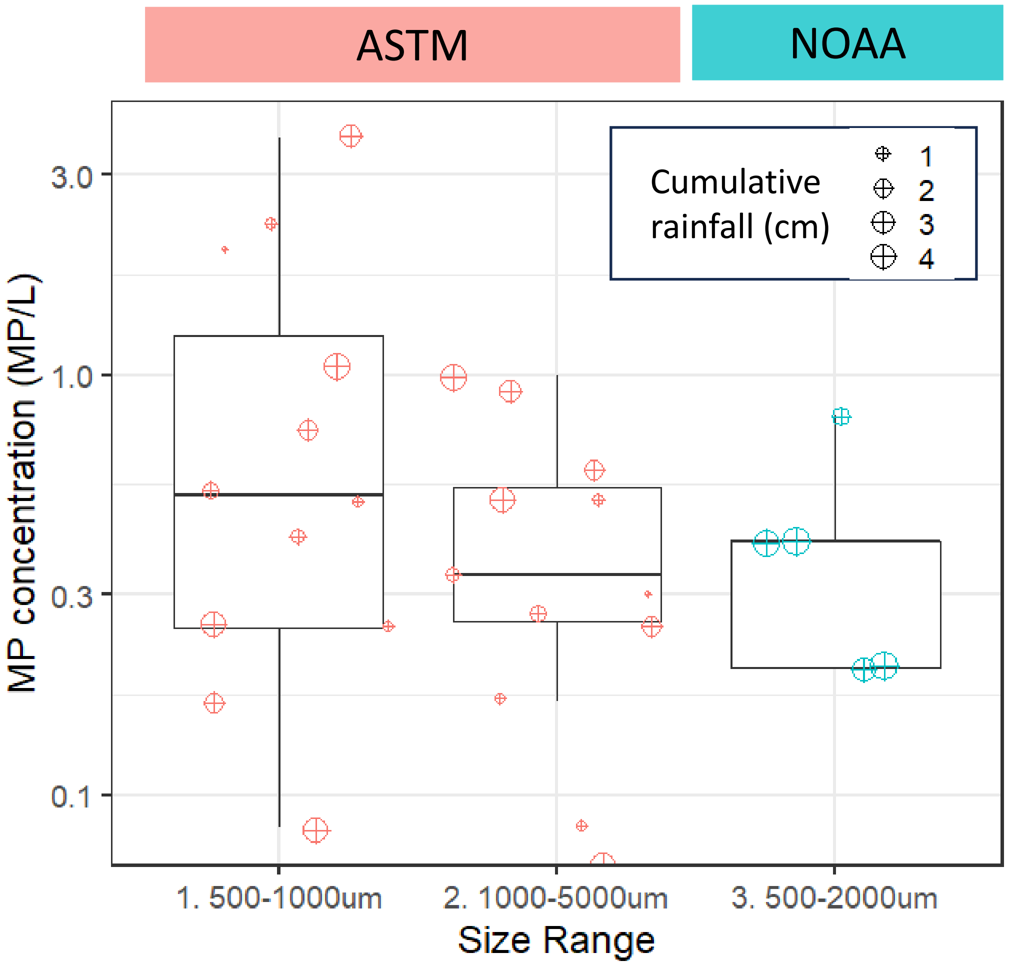
Characterize MP in stormwater



Urban stormwater microplastic size distribution and impact of subsampling on polymer diversity†

Swaraj Parmar,[a] Georgia Arbuckle-Keil,[a] G. Kumi[a] and N. L. Fahrenfeld*[b]

Science of The Total Environment
Volume 929, 15 June 2024, 172485

Stormwater runoff microplastics: Polymer types, particle size, and factors controlling loading rates

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Lilia Ochoa [a], Julianne Chan [a], Caitlyn Auguste [b], Georgia Arbuckle-Keil [b], N.L. Fahrenfeld [a]

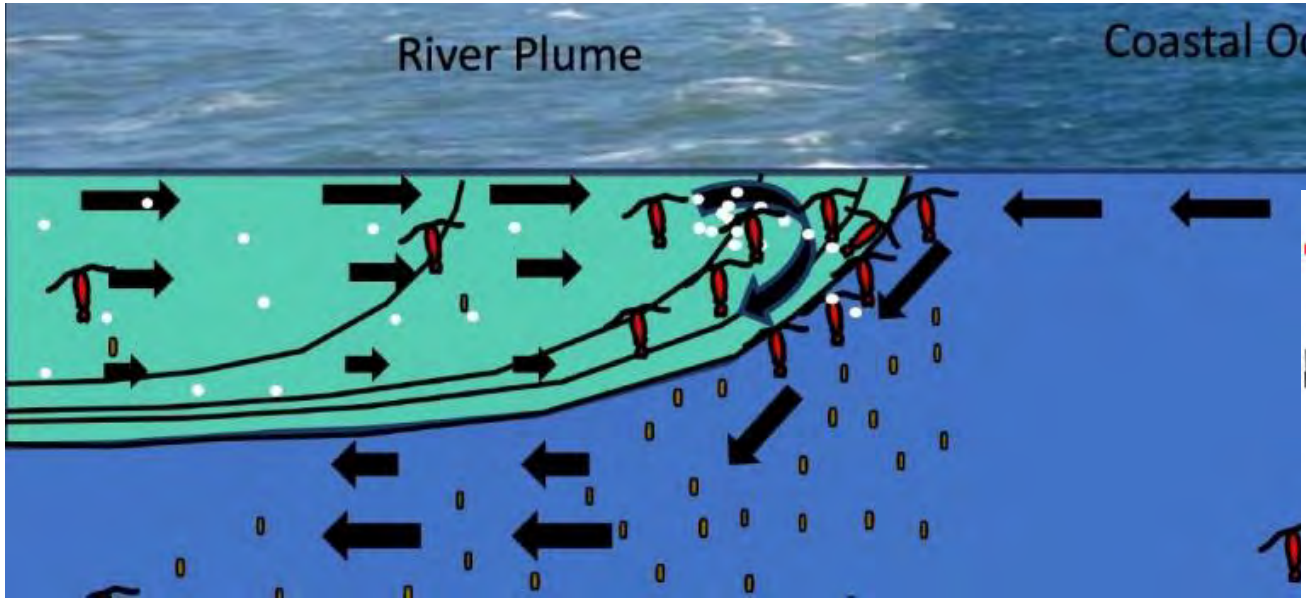
Buoyant

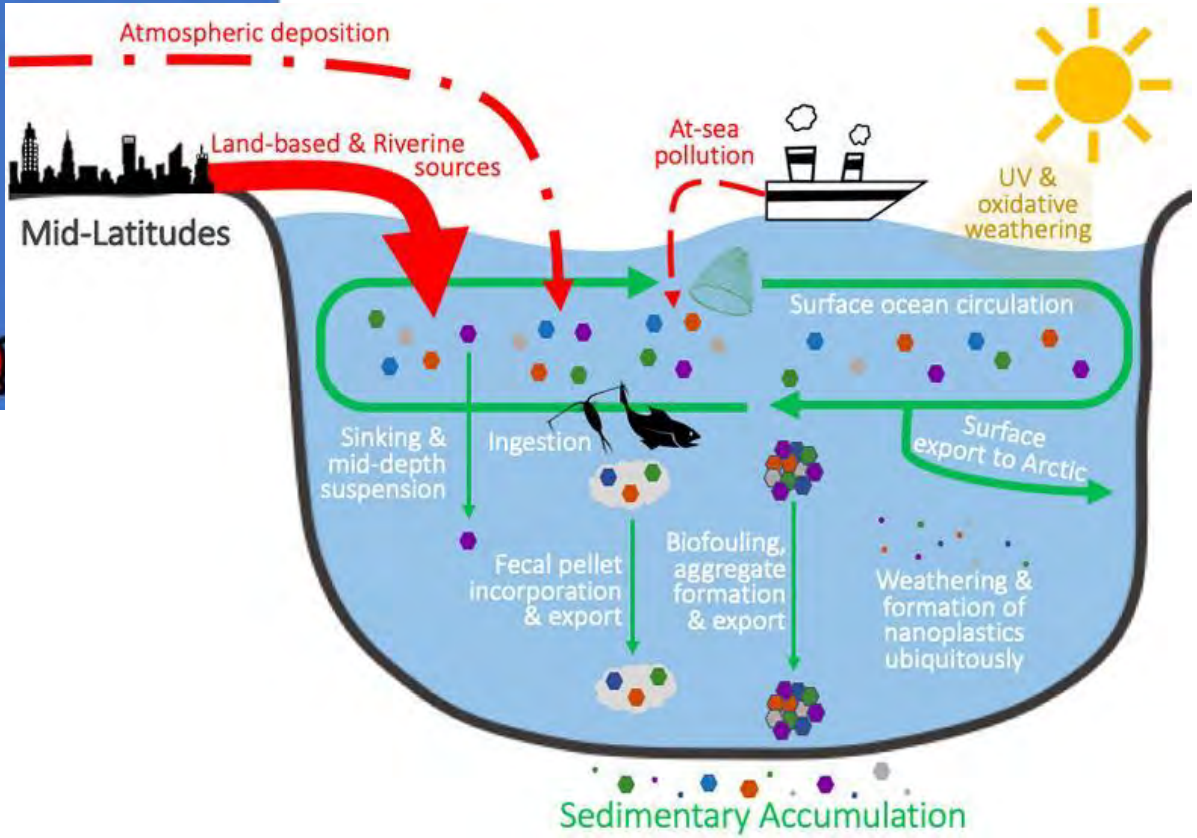
- **Polyethylene (N=75 PE)**
- **Polypropylene (N=20 PP)**
- **Polystyrene (N=20 PS)**
- Polydimethylsiloxane (PDMS)
- Resin dispersión
- Ethylene propylene rubber (EPM)

Non-buoyant

- **Polyurethane (N=14 PU)**
- **Polyvinyl chloride (N= 12 PVC)**
- **Polyacrylamide (N=11 PAM)**
- Aramid
- Polyamide (PA)
- Polychloroprene (CR)
- Polyethylene terephthalate (PET)
- Alkyd varnish
- Polymethyl methacrylate (PMMA)
- Polyvinyl alcohol (PVA)
- Polysulfone (PSU)

Understand estuarine distribution and entry into food web





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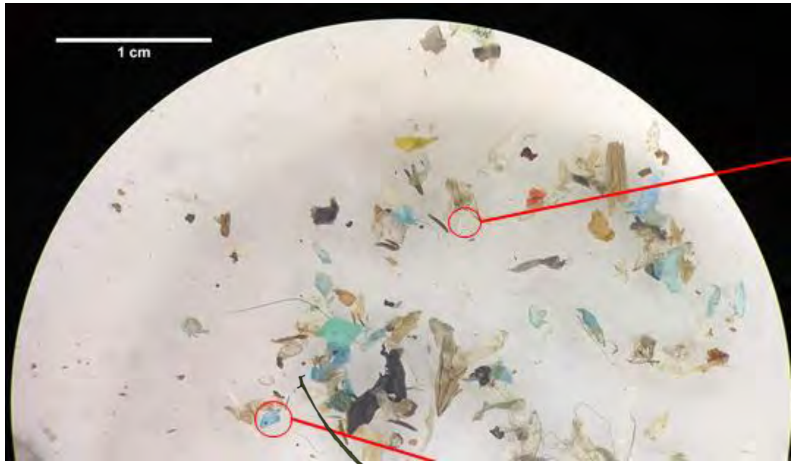
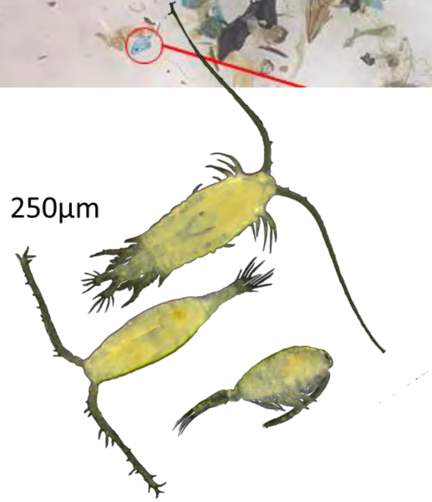




Understand estuarine distribution and entry into food web

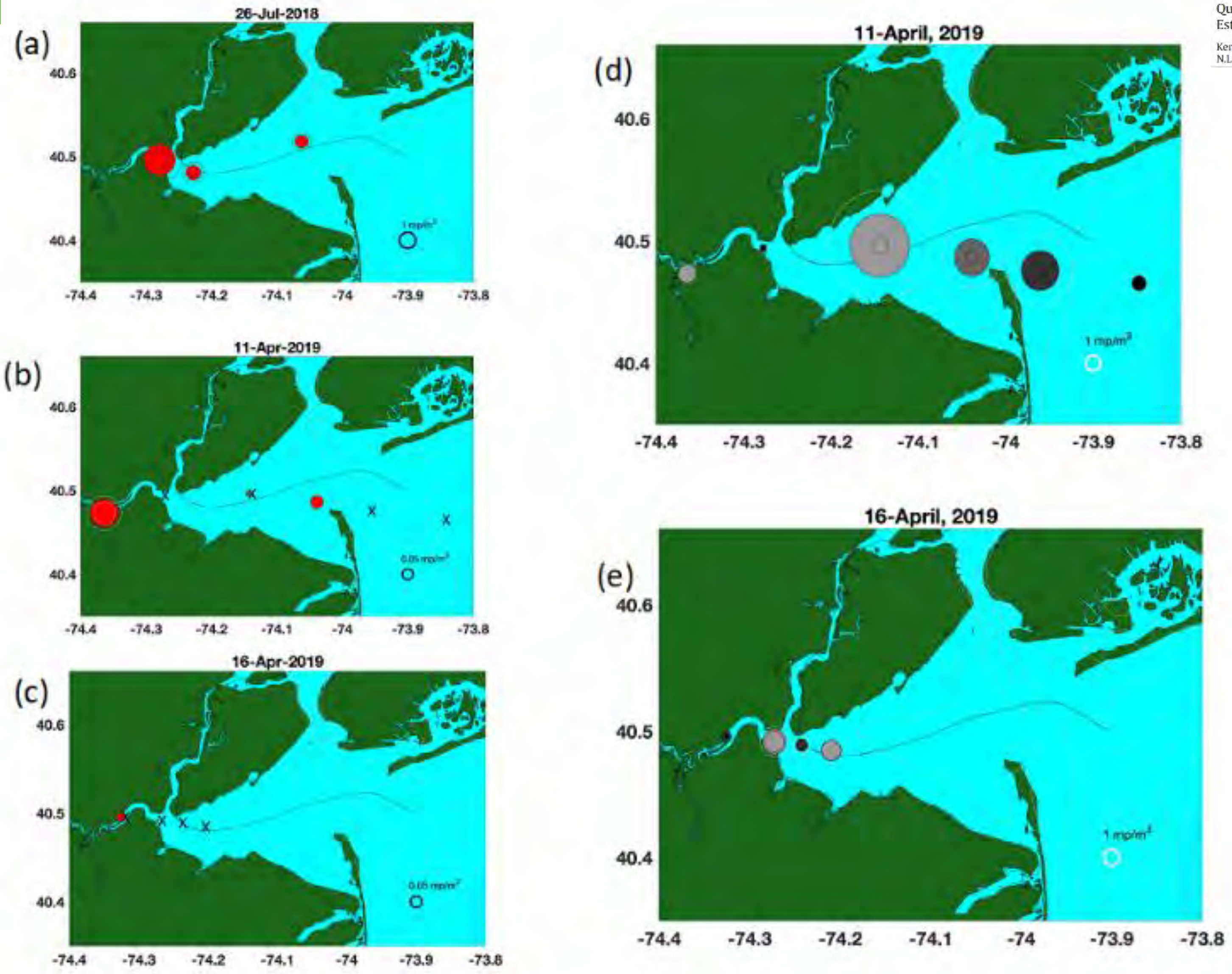
500-2000 µm

250-500 µm

Low Flow

Low Flow

High Flow

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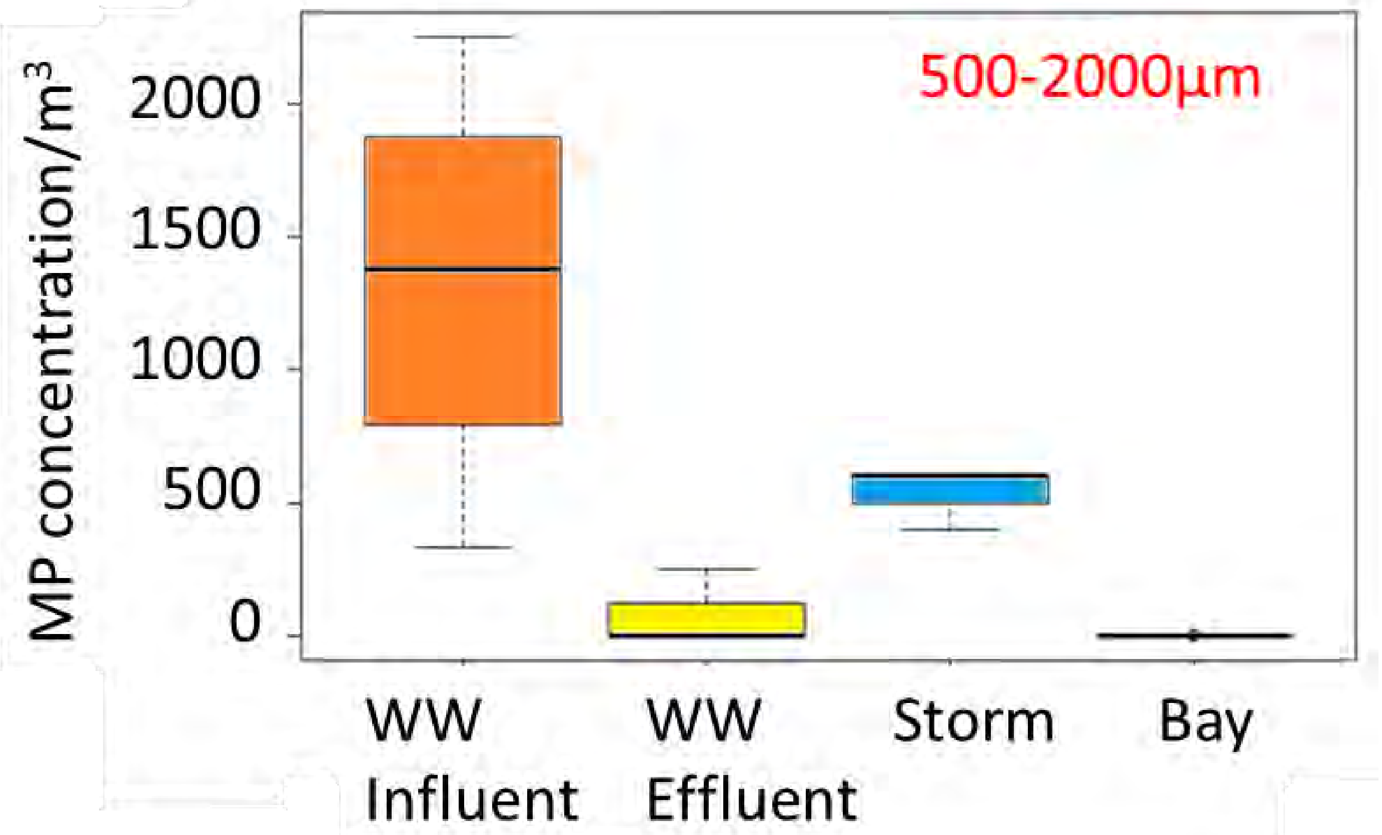
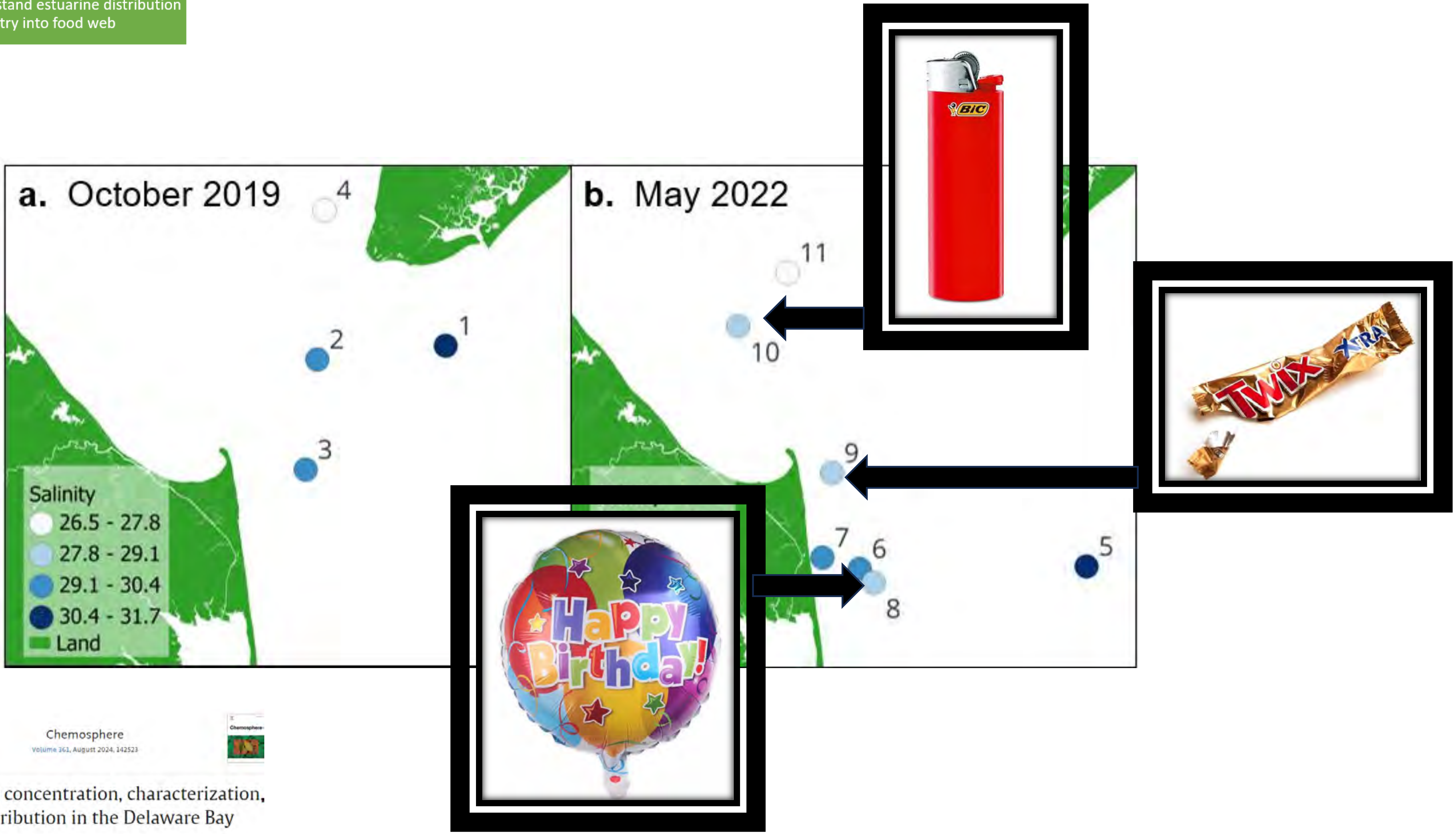


Understand estuarine distribution and entry into food web



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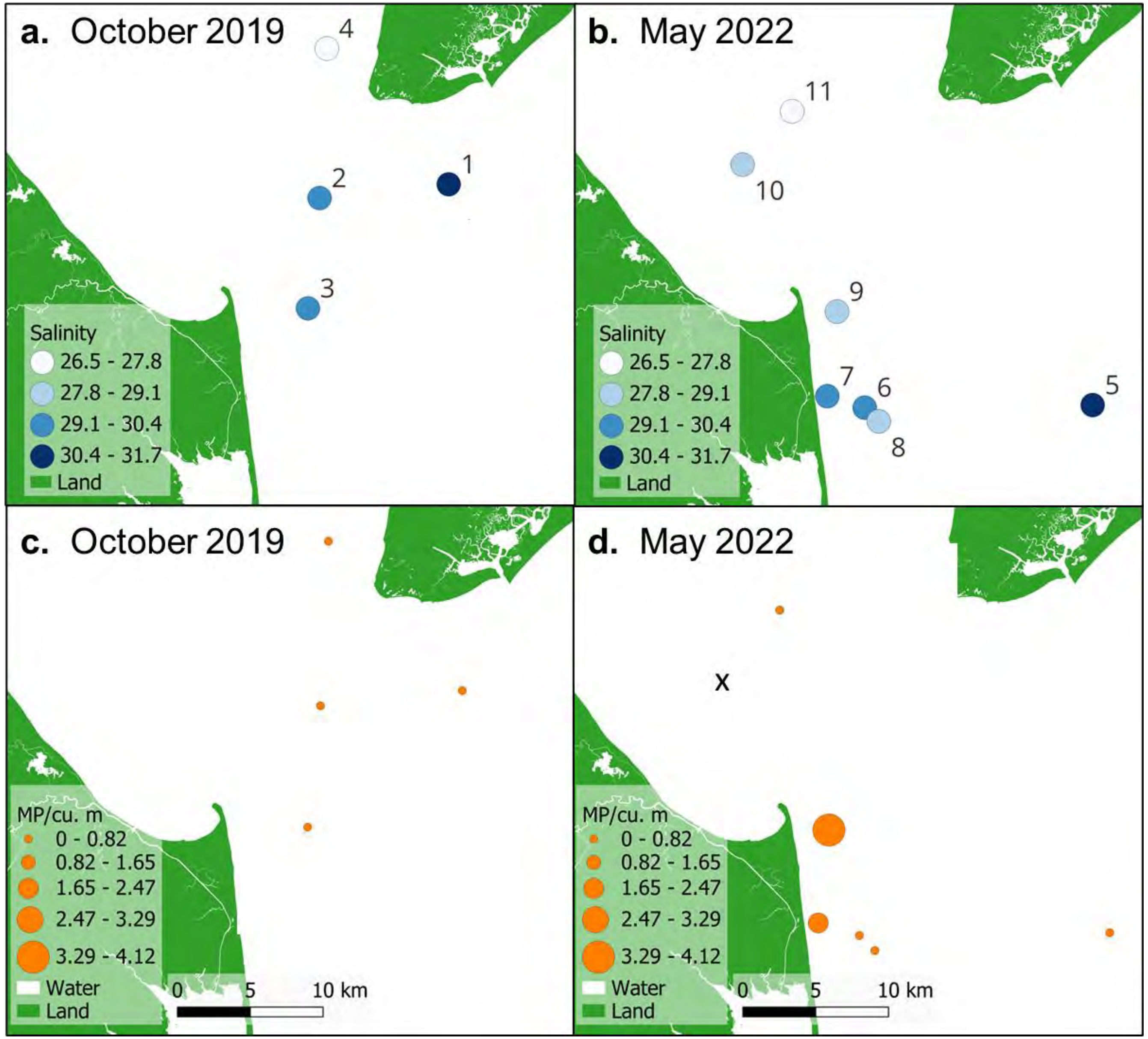
Erik J. Nitzberg [a], Swaraj Parmar [b], Georgia Arbuckle-Keil [b], Grace K. Saba [c], Robert J. Chant [c], N.L. Fahrenfeld [a]



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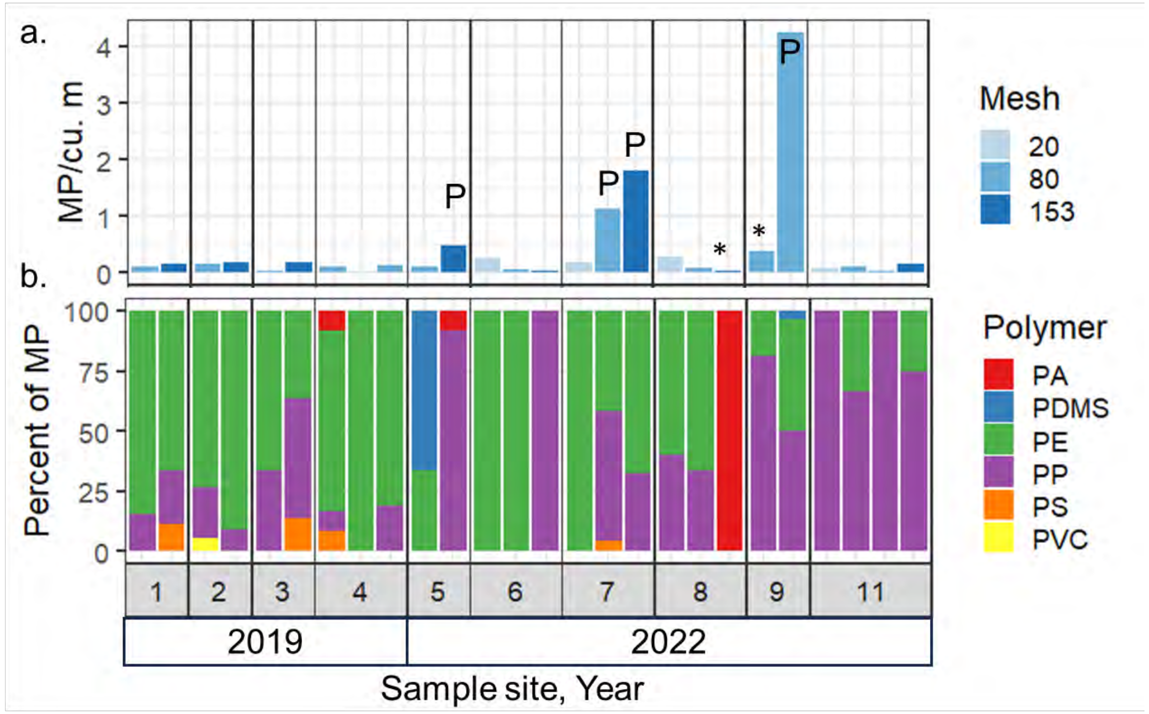

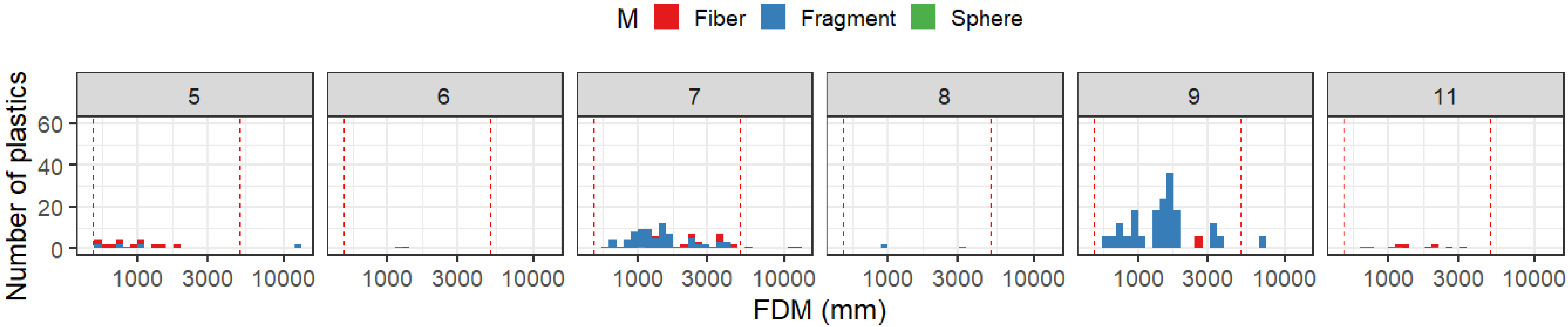

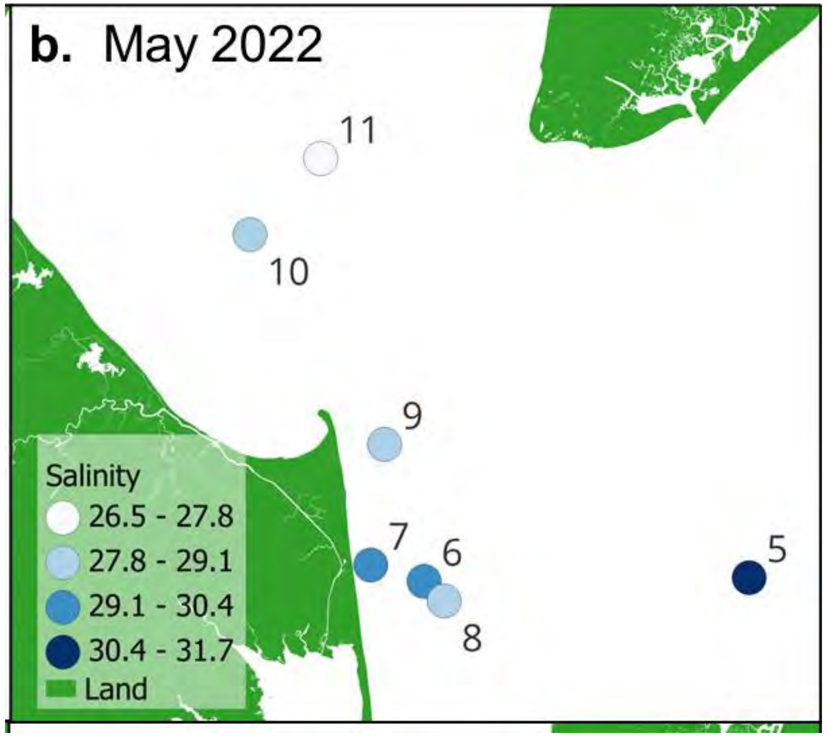

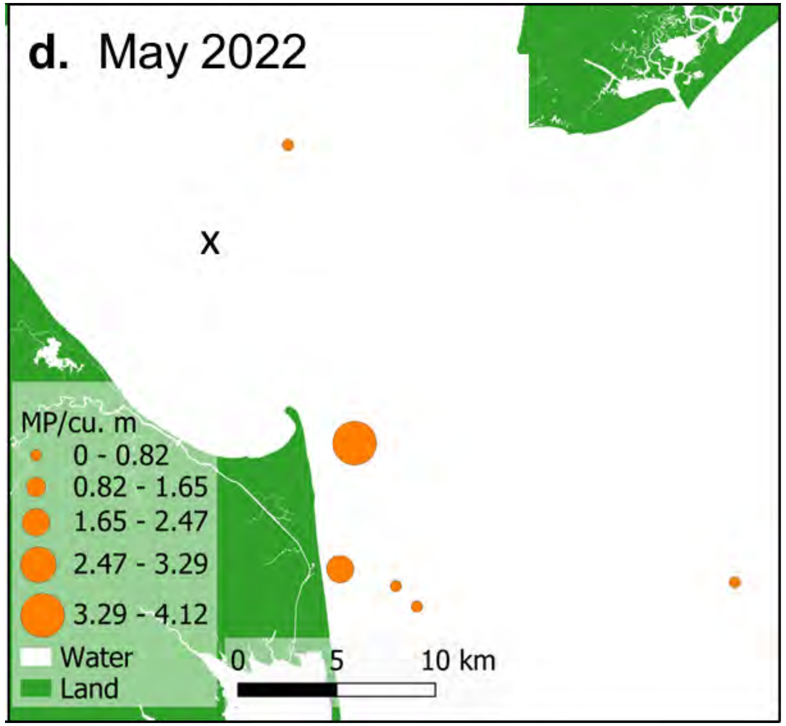

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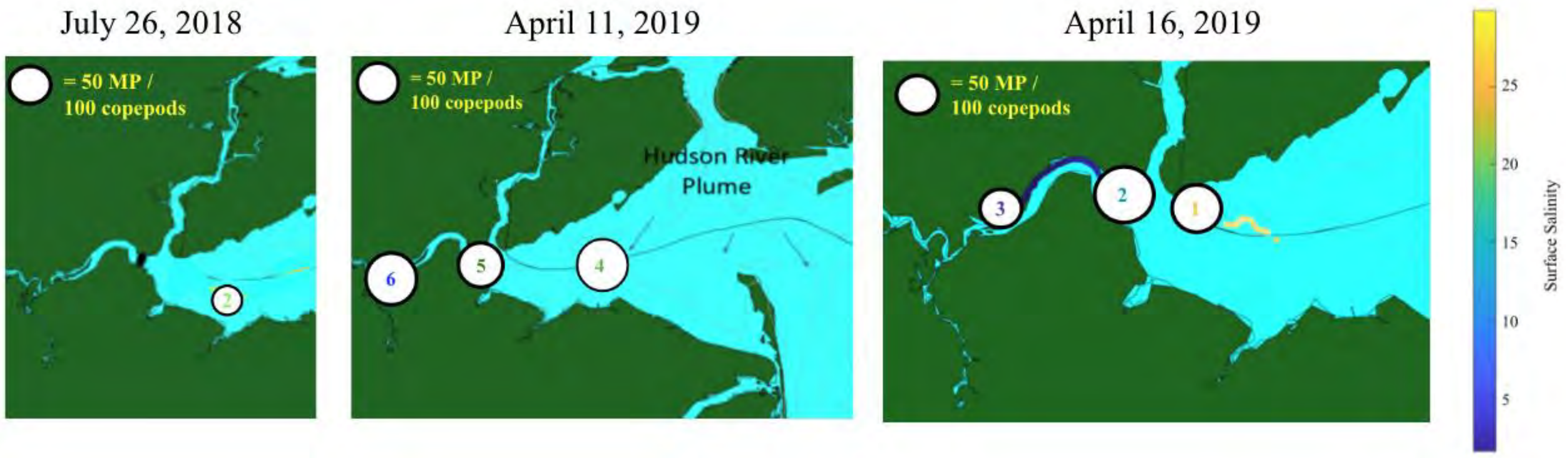
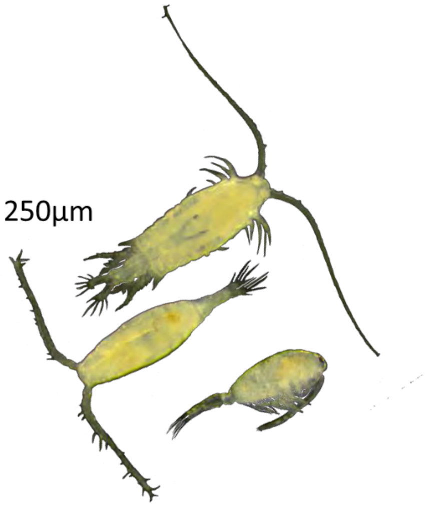


Sampling Date and Site	Zooplankton Species	Ingestion Incidence (MP individual^{-1}) Average ± SD
7/26/2018 Site 2	*A. tonsa*	0.30 ± 0.07
4/11/2019 Site 4	*A. tonsa*	0.73 ± 0.09
Site 5	*P. crassirostris*	0.60 ± 0.08
Site 6	*P. crassirostris*	0.74 ± 0.14
4/16/2019 Site 1	*A. tonsa*	0.69 ± 0.13
Site 2	*C. typicus*	0.82 ± 0.48
Site 3	*A. tonsa*	0.51 ± 0.14



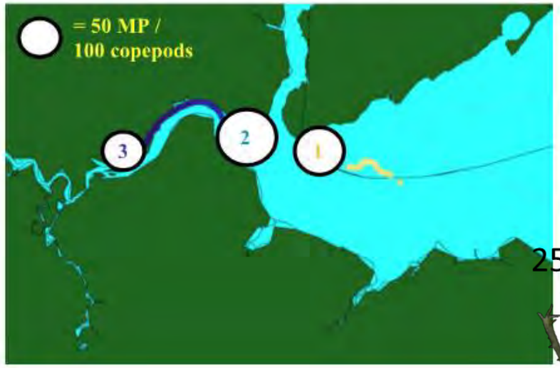
Pervasive occurrence of microplastics in Hudson-Raritan estuary zooplankton

Karli Sipps [a], Georgia Arbuckle-Keil [a], Robert Chant [b], Nicole Fahrenfeld [c], Lori Garzio [b], Kasey Walsh [b], Grace Saba [b,*]

Improve our ability to measure environmental microplastics

Impact of nitric acid digestion on ability to accurately ID polymers extracted from biota?

April 16, 2019




Science of the Total Environment 817 (2022) 152812

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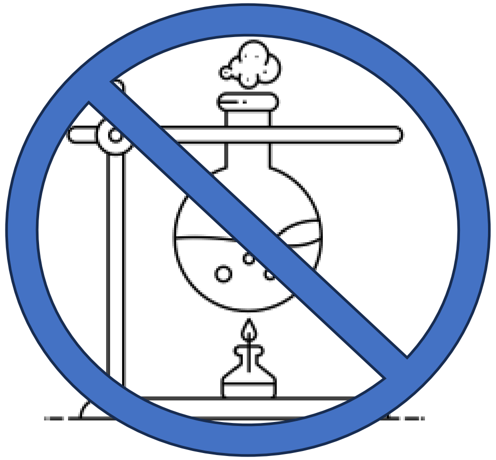
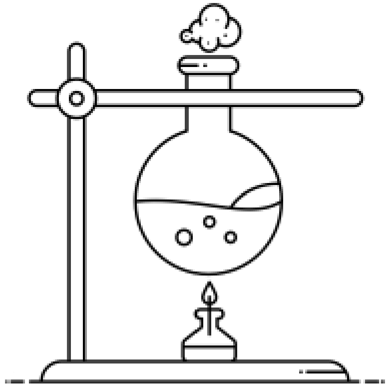
[a] Department of Chemistry, Rutgers, The State University of New Jersey, Camden, NJ 08102, USA
[b] Department of Marine and Coastal Sciences, Rutgers, The State University of New Jersey, New Brunswick, NJ 08901, USA

Treatment





Analysis

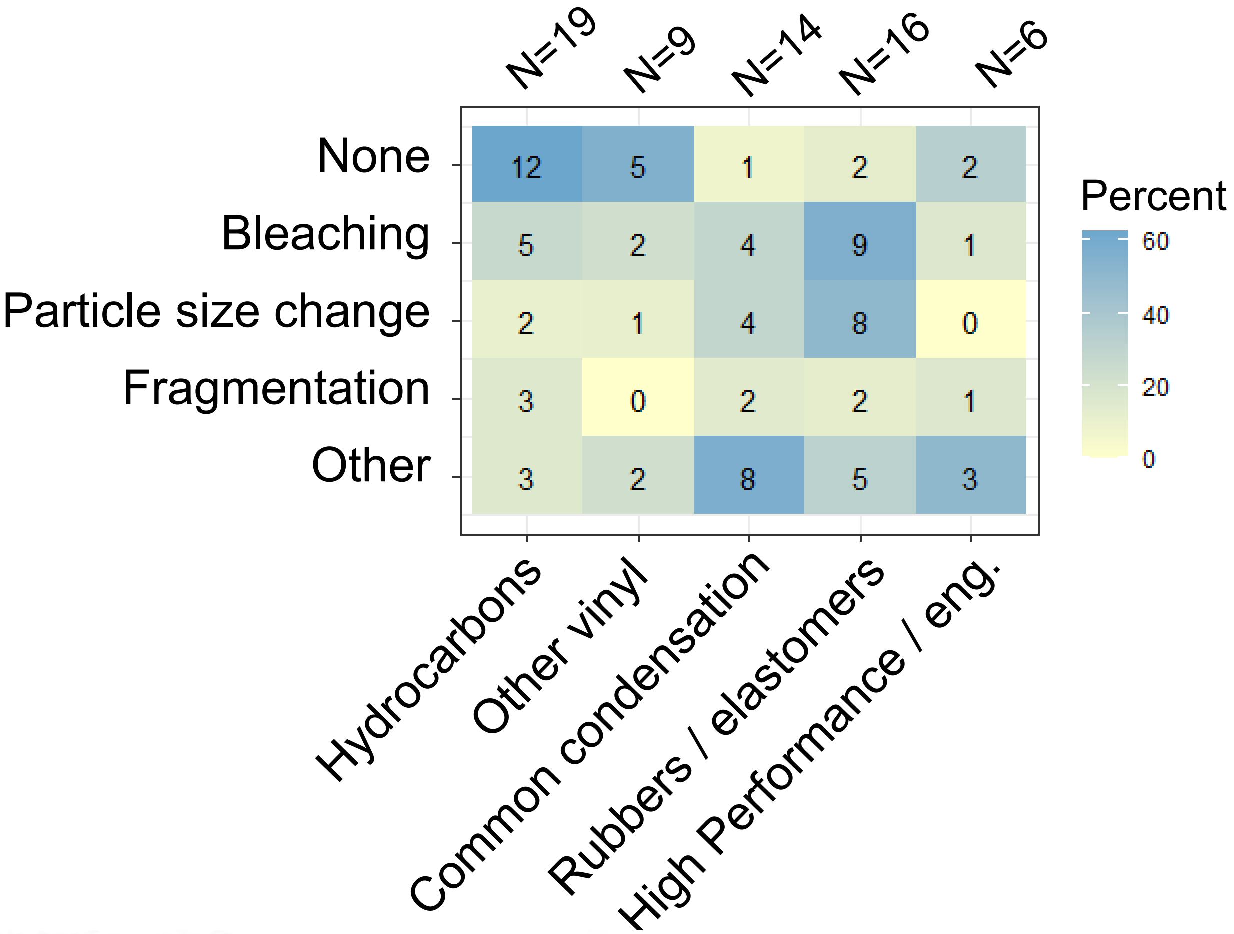
Interpretation

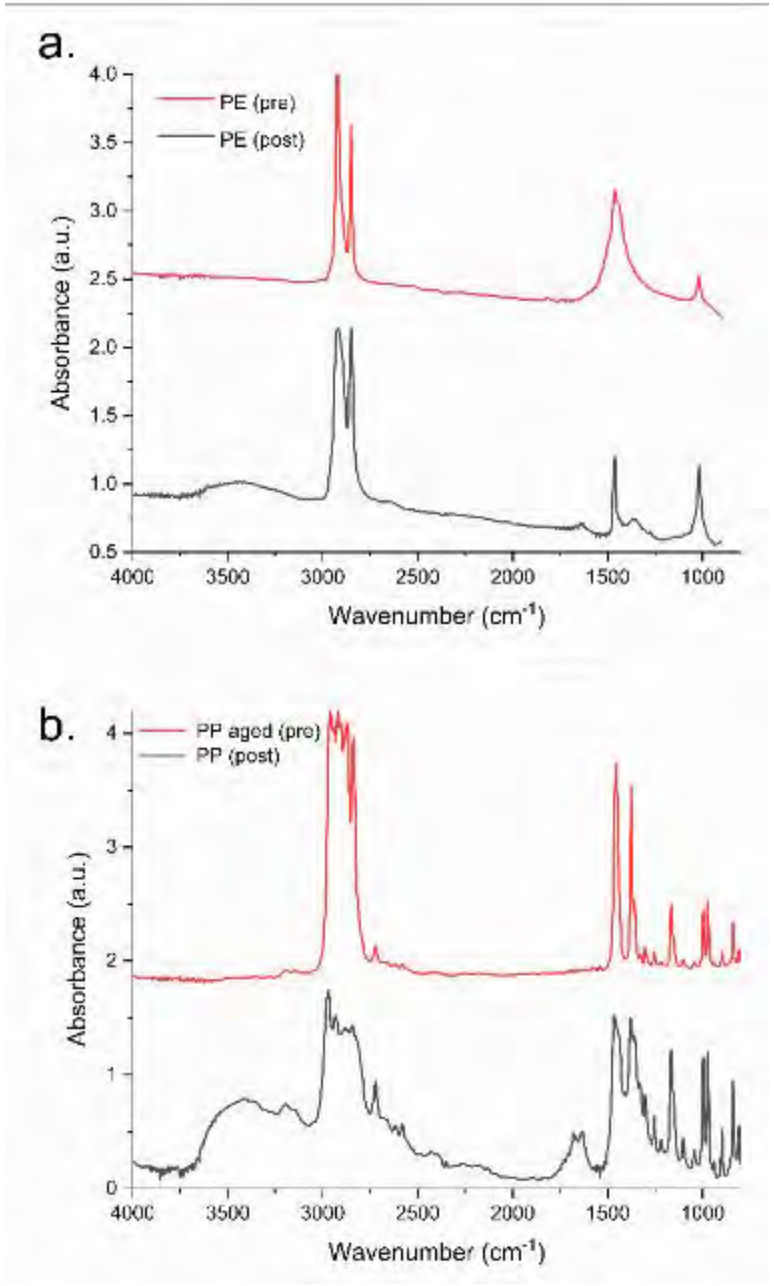
siMPle

Systematic Identification of MicroPLastics in the Environment

Developed by Aalborg University, Denmark and Alfred Wegener Institute, Germany

OPEN SPECY





Analytical and Bioanalytical Chemistry (2023) 415:6809–6823
https://doi.org/10.1007/s00216-023-04960-9

RESEARCH PAPER

Quantitative and qualitative impacts of nitric acid digestion on microplastic identification via FTIR and Raman spectroscopy, implications for environmental samples

Karli Sipps[1,2] · Shreya Patil[3,4] · Lilia Ochoa[3] · Julianne Chan[3] · Caitlyn Auguste[1] · Georgia Arbuckle-Keil[1] · N. L. Fahrenfeld[3]

Improve our ability to measure environmental microplastics

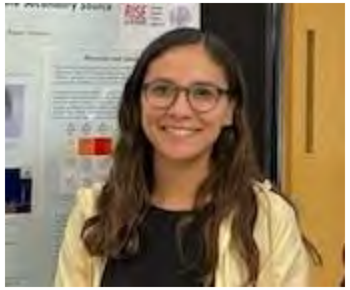
Consider subsampling strategy to capture MP concentration and polymer diversity, biases introduced by acid digestions

Characterize MP in stormwater

Stormwater is an important pathway of entry with a diverse range of polymer types, buoyant and non-buoyant

Understand estuarine distribution and entry into food web

Frontal zones can concentration microplastics, particle size distribution varies spatially

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Urban stormwater microplastic size distribution and impact of subsampling on polymer diversity†

Swaraj Parmar,[a] Georgia Arbuckle-Keil,[a] G. Kumi[a] and N. L. Fahrenfeld[*b]

ELSEVIER
Science of The Total Environment
Volume 809, 25 February 2022, 151104

Inter-storm variation in microplastic concentration and polymer type at stormwater outfalls and a bioretention basin

William Boni [a], Georgia Arbuckle-Keil [b], N.L. Fahrenfeld [a]

Aresty Research Center
Division of Undergraduate Academic Affairs

NSF

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THE Water Research FOUNDATION



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Karli Sipps [a], Georgia Arbuckle-Keil [a], Robert Chant [b], Nicole Fahrenfeld [c], Lori Garzio [b], Kasey Walsh [b], Grace Saba [b,*]
[a] Department of Chemistry, Rutgers, The State University of New Jersey, Camden, NJ 08102, USA
[b] Department of Marine and Coastal Sciences, Rutgers, The State University of New Jersey, New Brunswick, NJ 08901, USA


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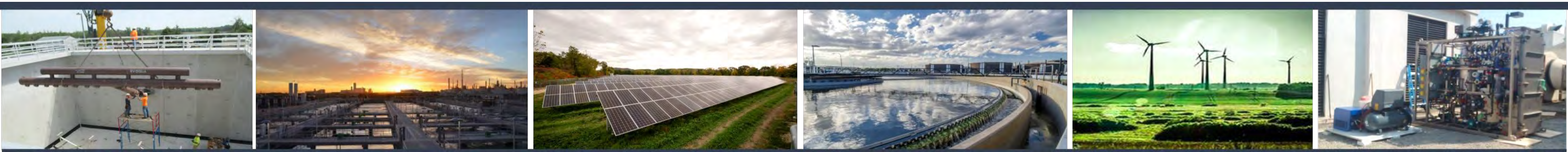
RUTGERS
Douglass Residential College

Sea Grant
NJ Sea Grant Consortium

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Q and A

If you have a question, just click on the Q and A icon on the bottom of the screen and type it in there.



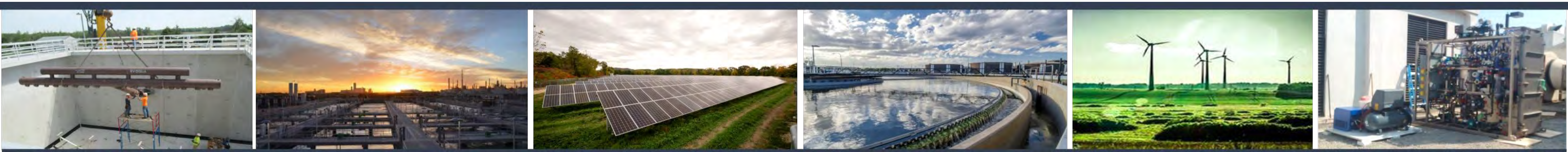
Using Low Dissolved Oxygen for Energy-Efficient Biological Nitrogen Removal

AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS & SCIENTISTS®

Fabrizio Sabba, PhD, ENV SP

Process Engineering Associate
Black & Veatch

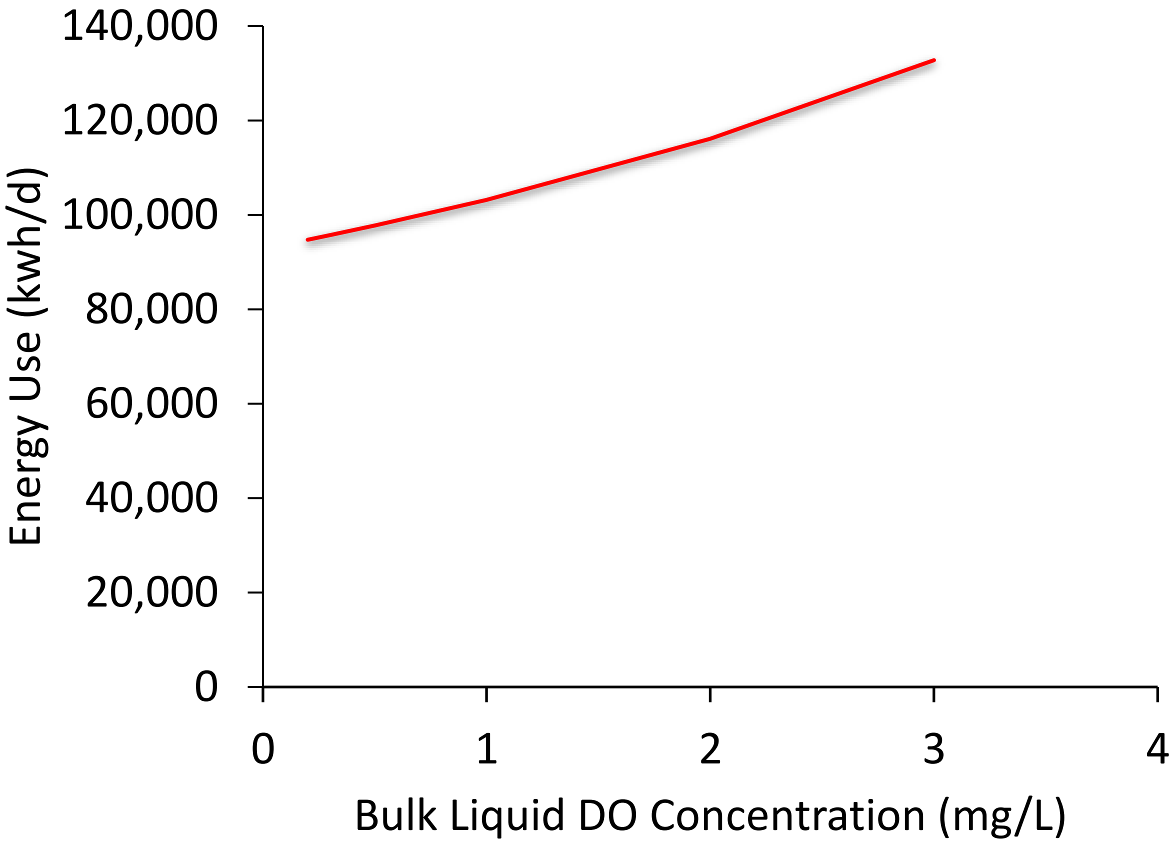
BLACK & VEATCH



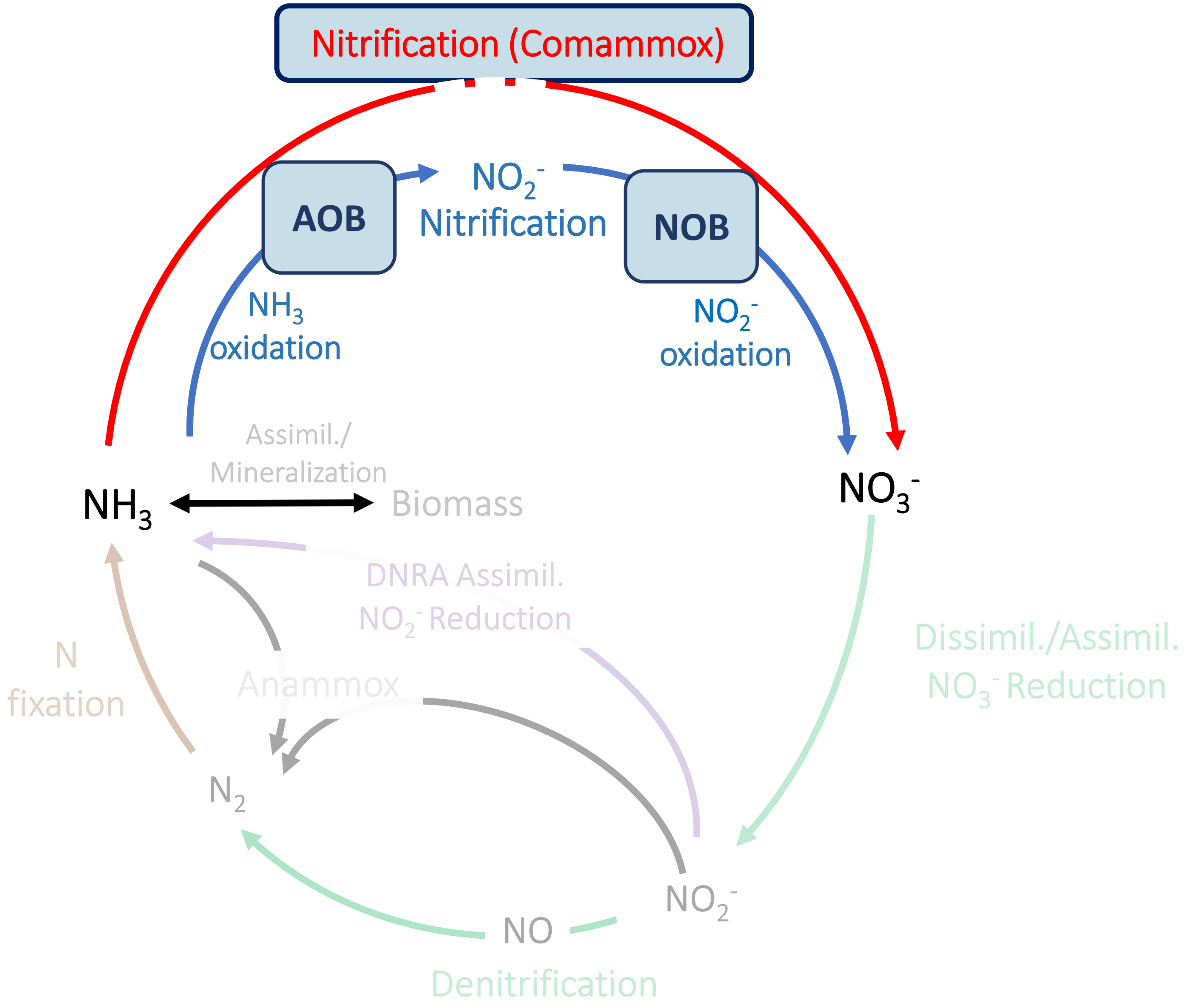
Leadership and Excellence in Environmental Engineering and Science

Why are we concerned with oxygen concentrations in wastewater?

Typically 50% of energy costs!



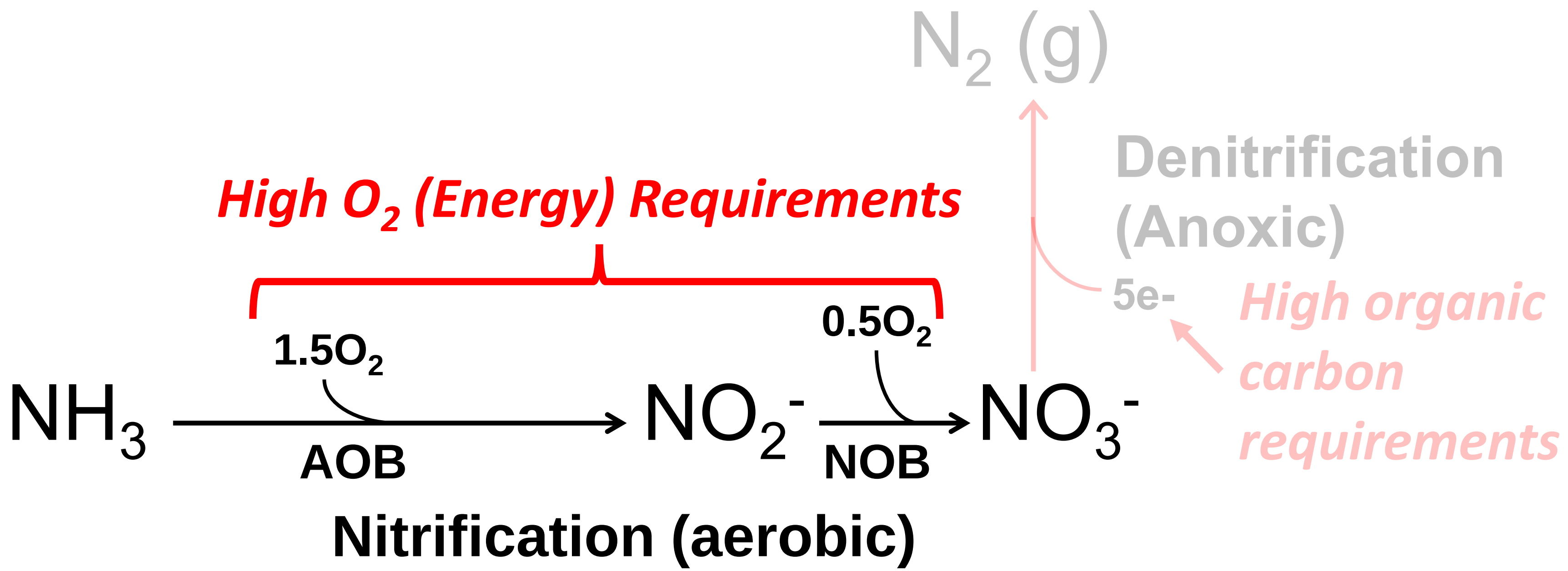
The solution is in the nitrogen cycle



*Sabba et al., Applied Microbiology and Biotechnology 2018

Leveraging Metabolic Versatility in the Microbial N Cycle for Sustainable Nutrient Removal

Conventional Biological N Removal: Nitrification/ Denitrification



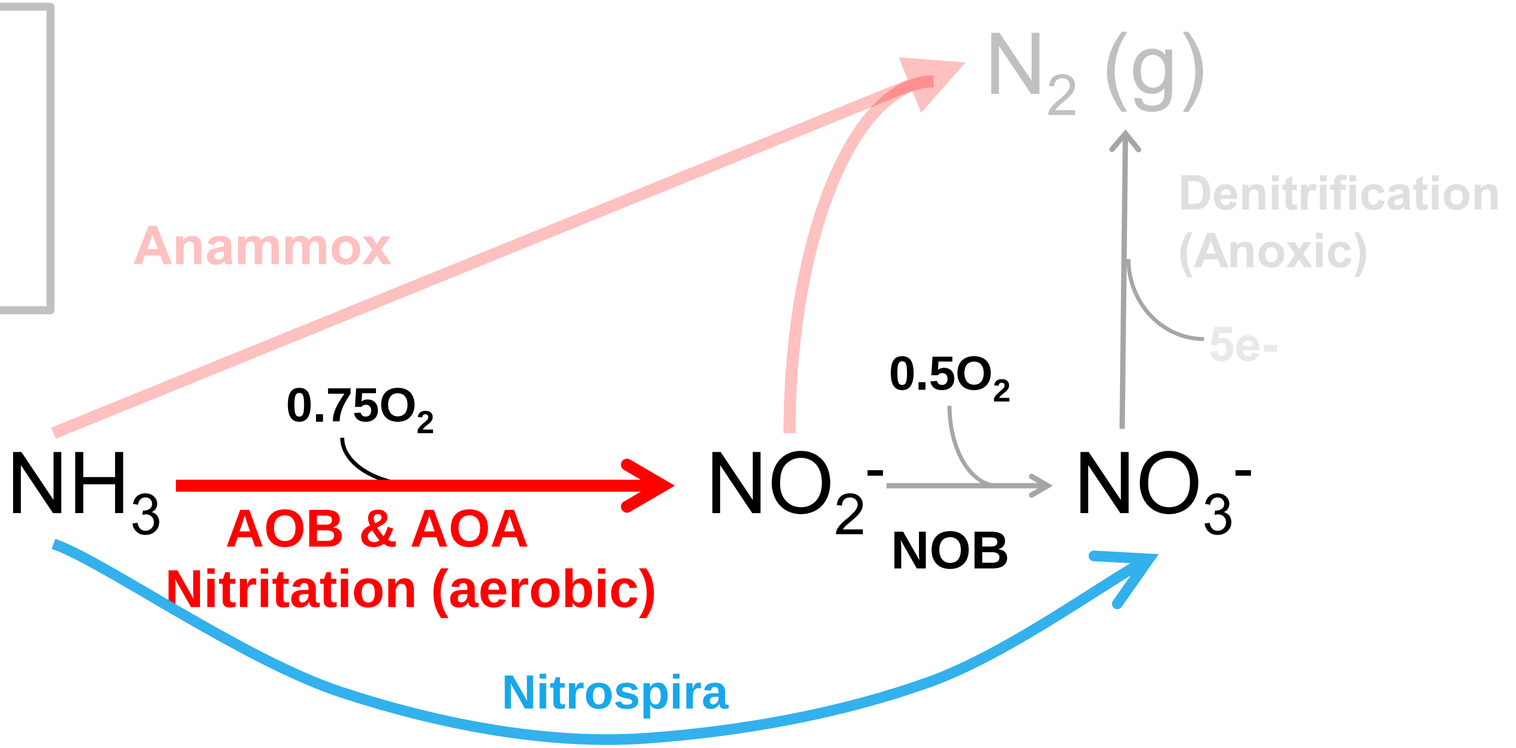
Highly energy intensive due to <u>high dissolved oxygen</u> concentrations (>3 mg/L), and required high levels of organic carbon

Leveraging Metabolic Versatility in the Microbial N Cycle for Sustainable Nutrient Removal

Shortcut N removal: Deammonification

(or Partial Nitritation/Anammox [PNA])

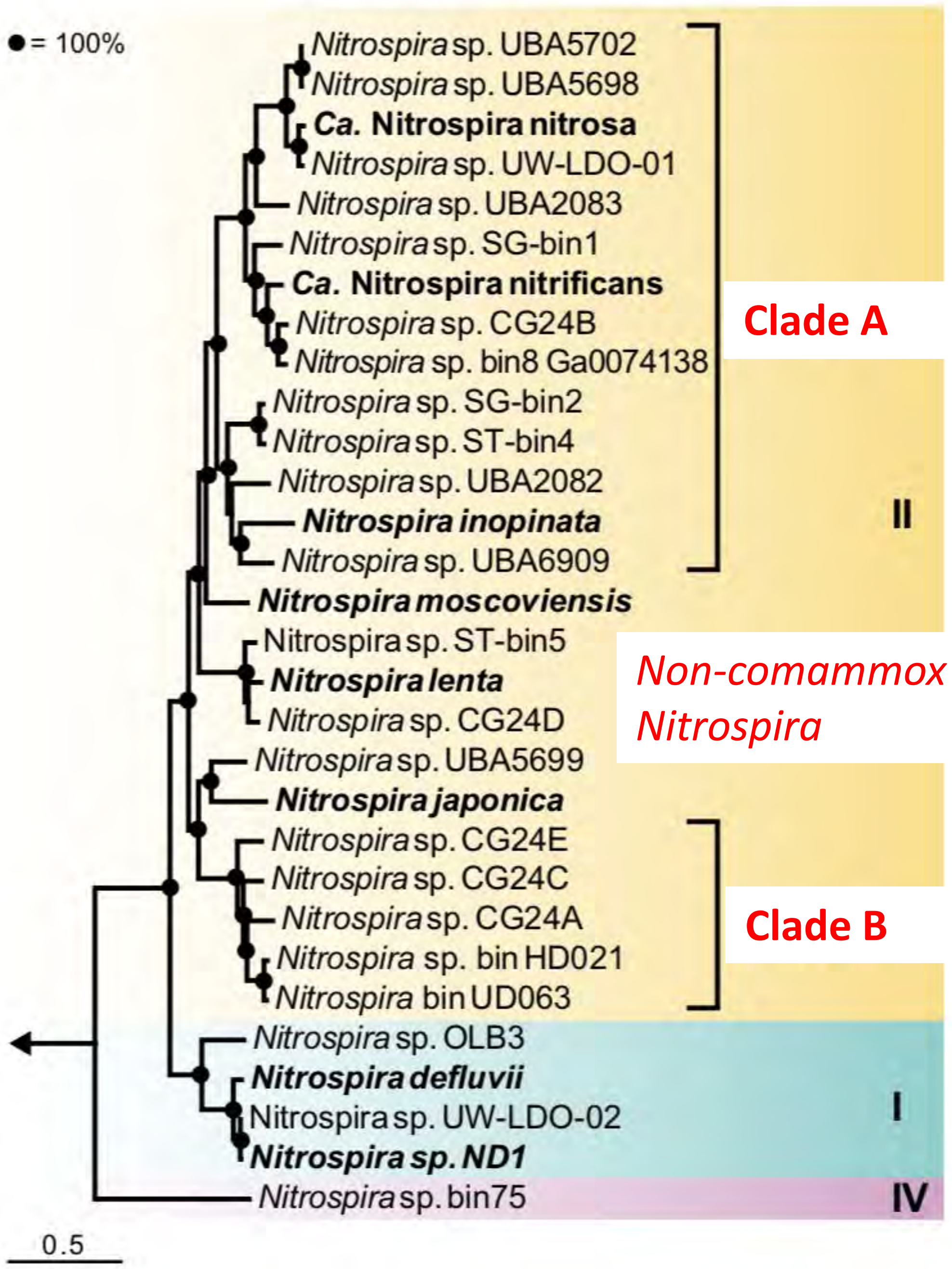
Deammonification processes **decrease O_2 requirement for N removal** by ~60%



Comammox
COMplete AMMonia OXidation

Comammox Diversity, Putative Niche, and Relevance to Practice

- Comammox form two distinct clades within the genus *Nitrospira*[1]
- Comammox *Nitrospira* appear to be adapted to an oligotrophic lifestyle with low NH_4^+, and possibly also low dissolved oxygen[2]



Koch et al. 2018 *AMAB* (doi.org/10.10

1. Daims et al. 2015 *Nature* 428: 504-509
2. Kits et al. 2017 *Nature* 549: 269-272.

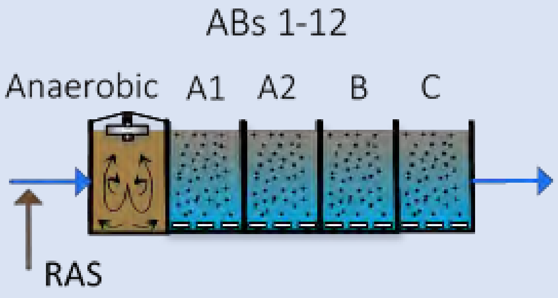
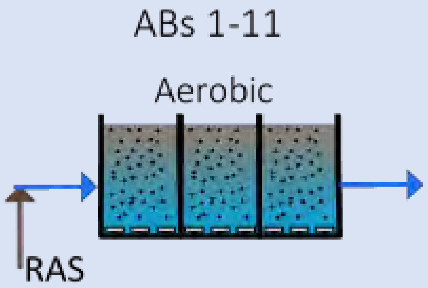
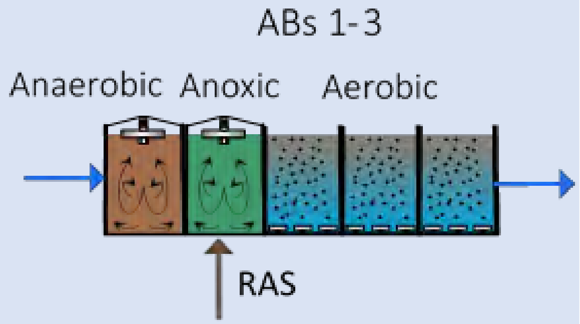
Research Objectives

1. Elucidate the impacts of DO on different nitrifying communities

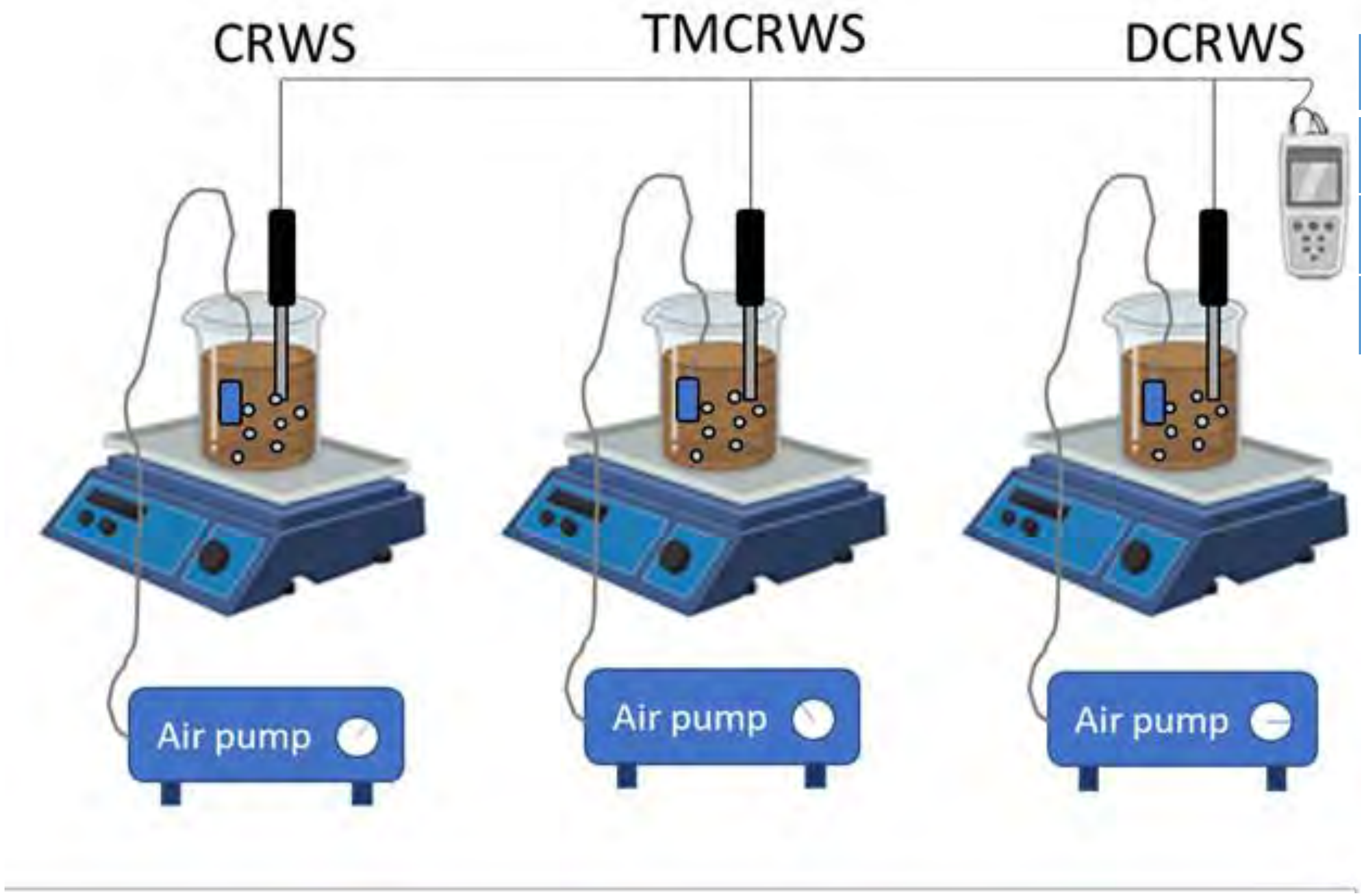
2. Use bench scale data to estimate kinetic rates via model data fitting across the facilities

3. Determine key microbial players via 16S rRNA amplicon sequencing and qPCR

Tested Facilities

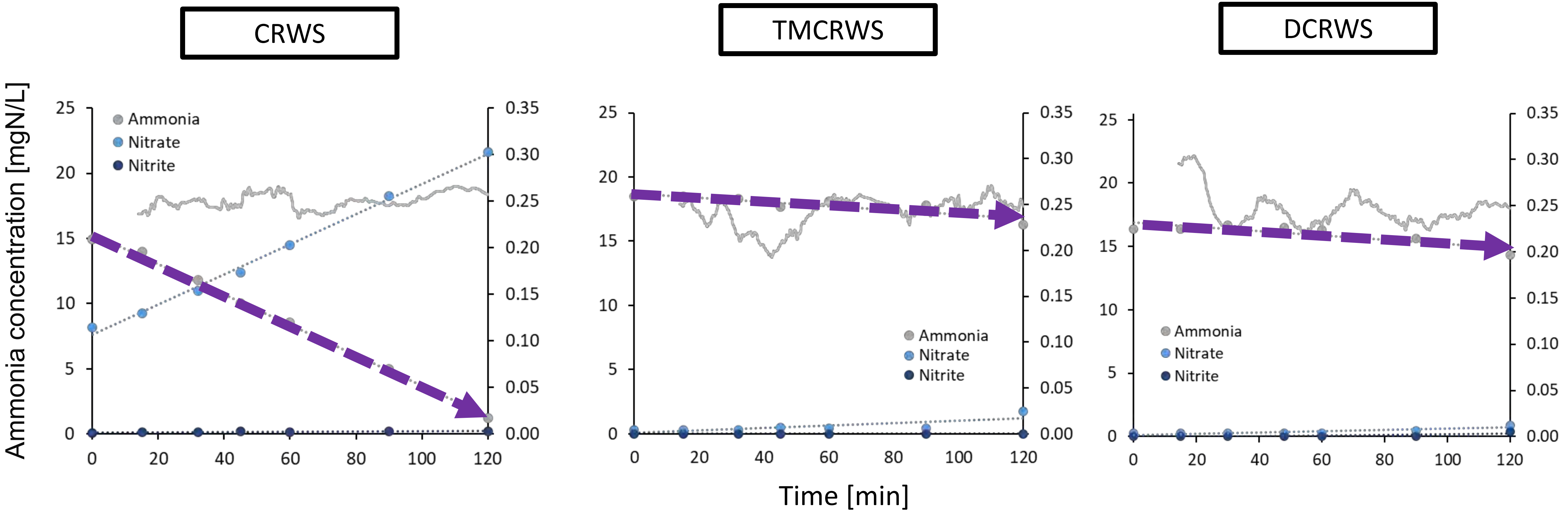
Parameter	CRWS plant	TMCRWS plant	DCRWS plant
Total SRT	10-12 d	12-14 d	8.5 d
MLSS (average)	6,000 mg L^{-1}	5,800 mg L^{-1}	3,800 mg L^{-1}
DO (average)	Based on DO setpoints	5.0 mg L^{-1}	2.33 mg L^{-1}
Aeration strategy	ABAC System	N/A	N/A
Bio-P	Yes	No	Yes
Settleability	Avg SVI= 55 mL g^{-1}	Avg SVI= 85 mL g^{-1}	Avg SVI= 85 mL g^{-1}
BNR configuration	A/O Process 	CAS 	A2/O Process 

Experimental Setup

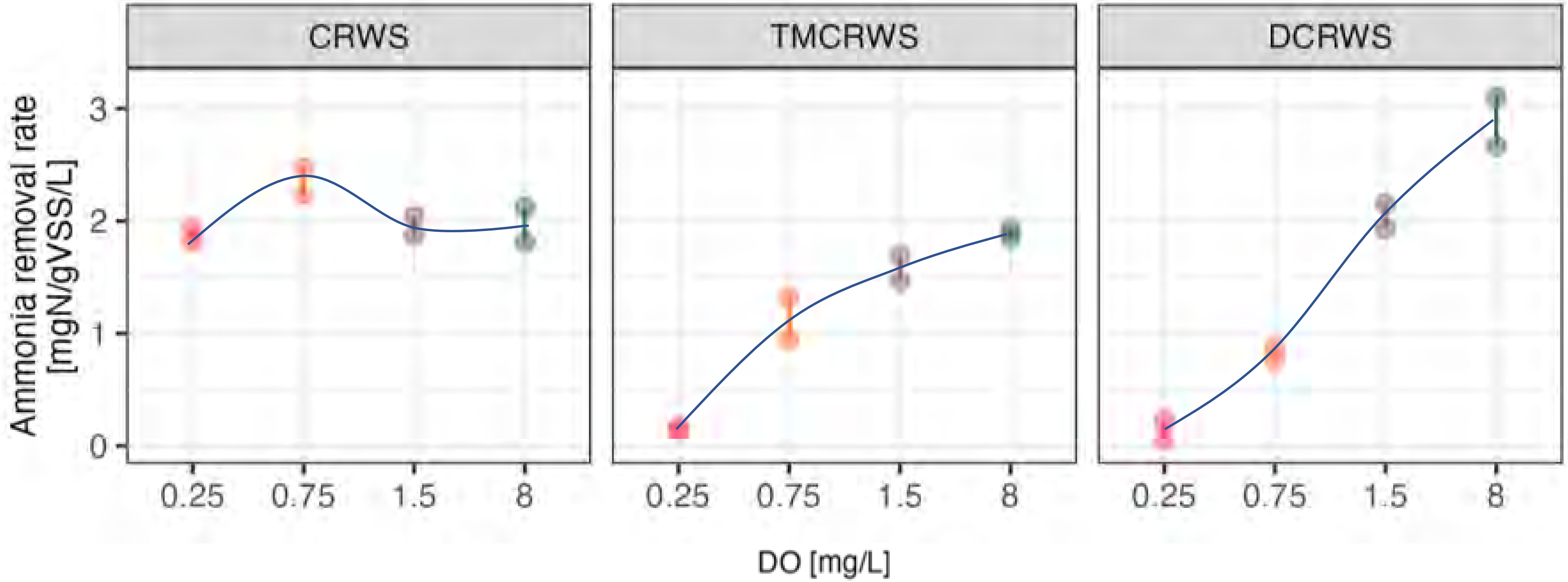


Plant	DO tested (mgDO L^{-1})
CRWS	0.25, 0.75, 1.5 and 8.0 mg L^{-1}
TMCRWS	0.25, 0.75, 1.5 and 8.0 mg L^{-1}
DCRWS	0.25, 0.75, 1.5 and 8.0 mg L^{-1}

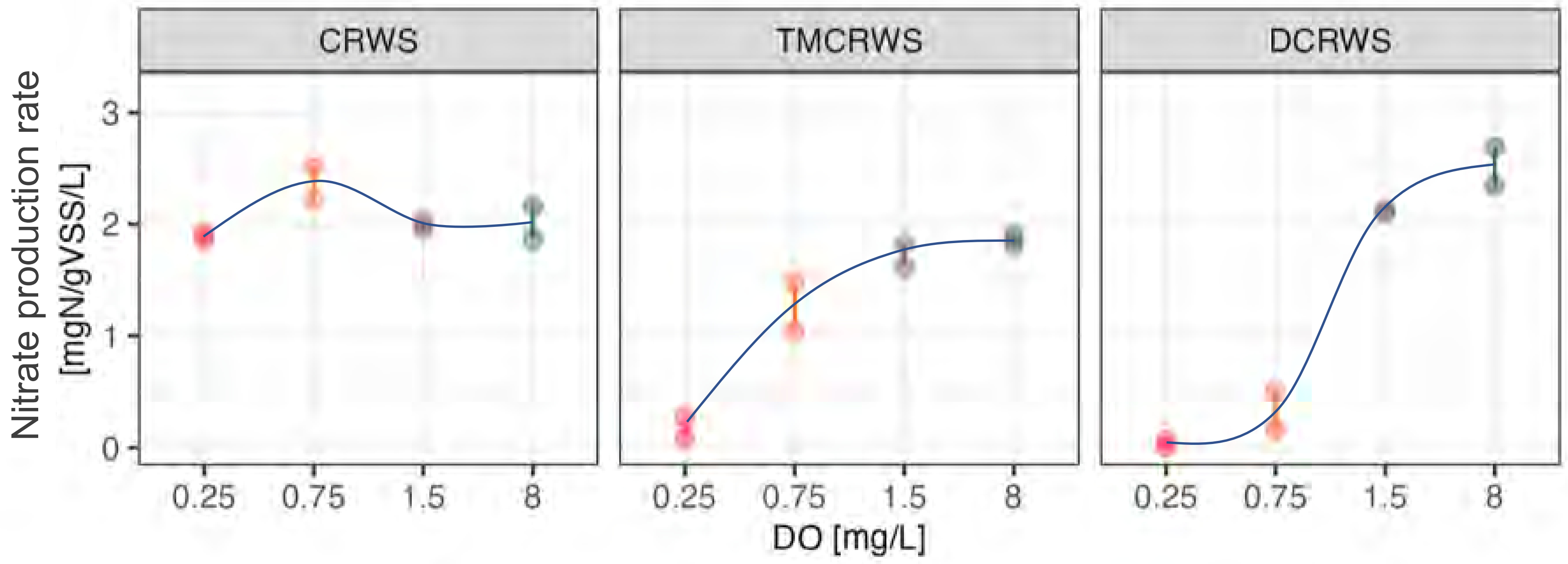
Ammonia Removal at low DO



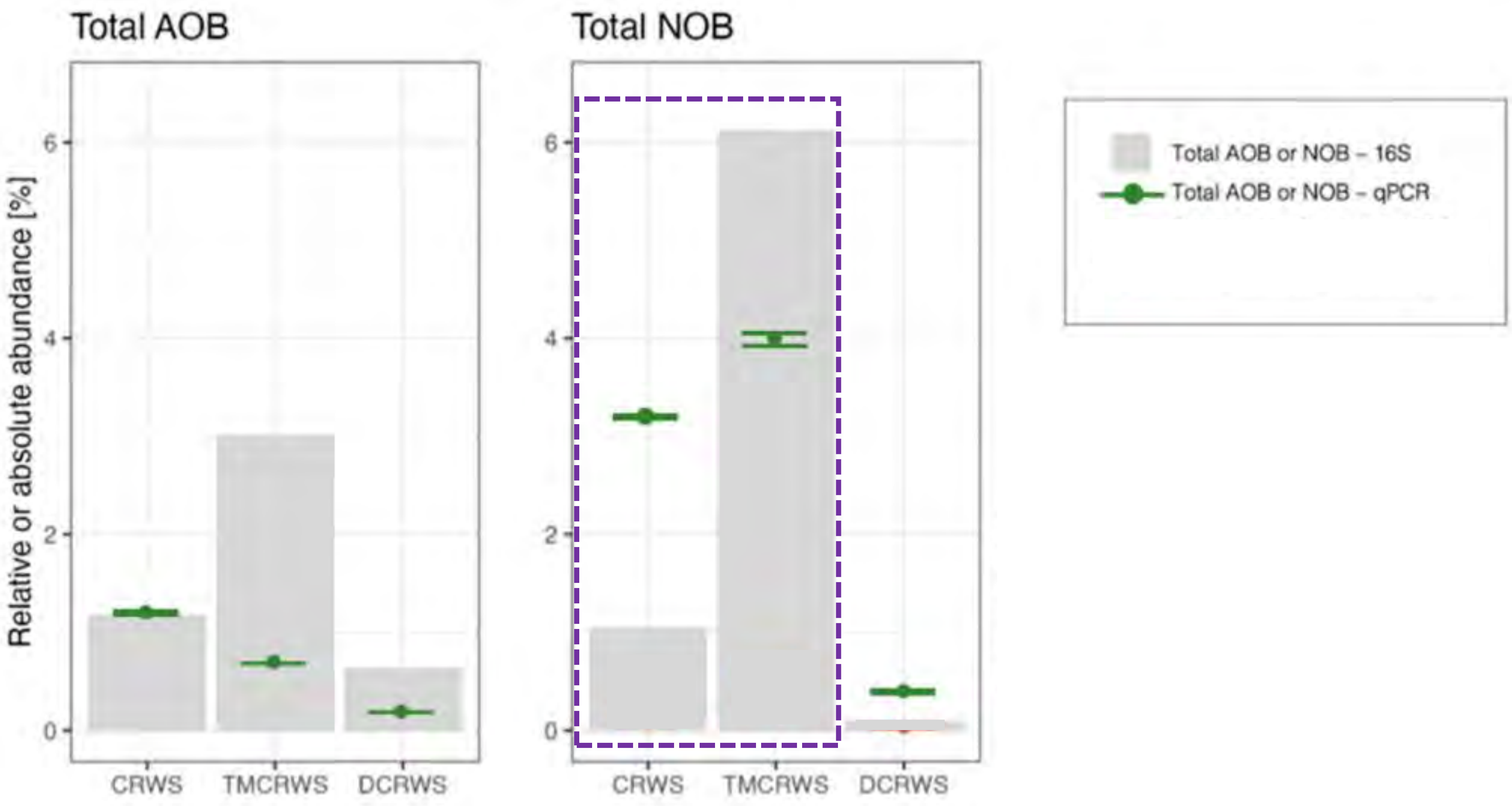
Ammonia Removal Rates



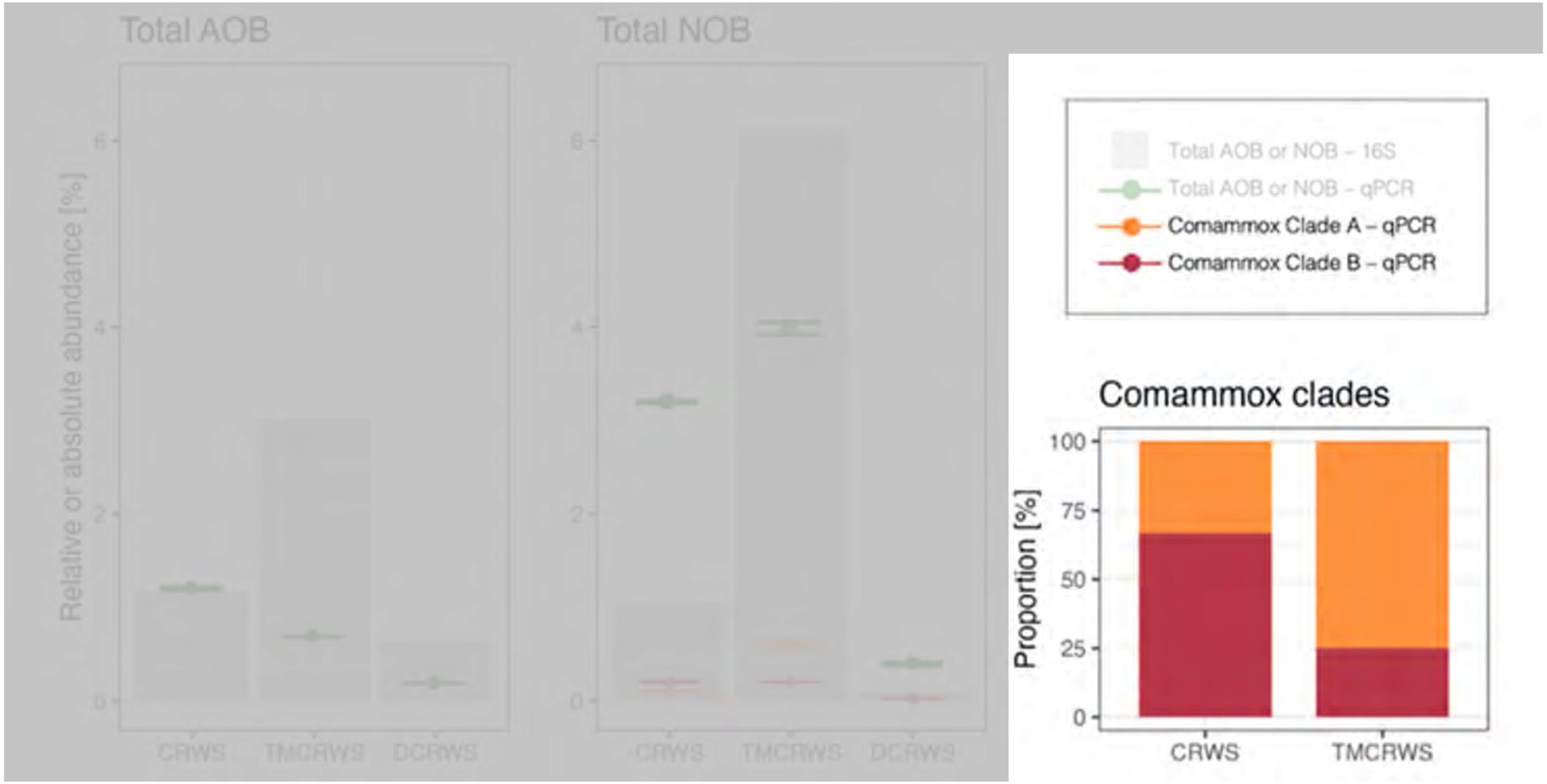
Nitrate Production Rates



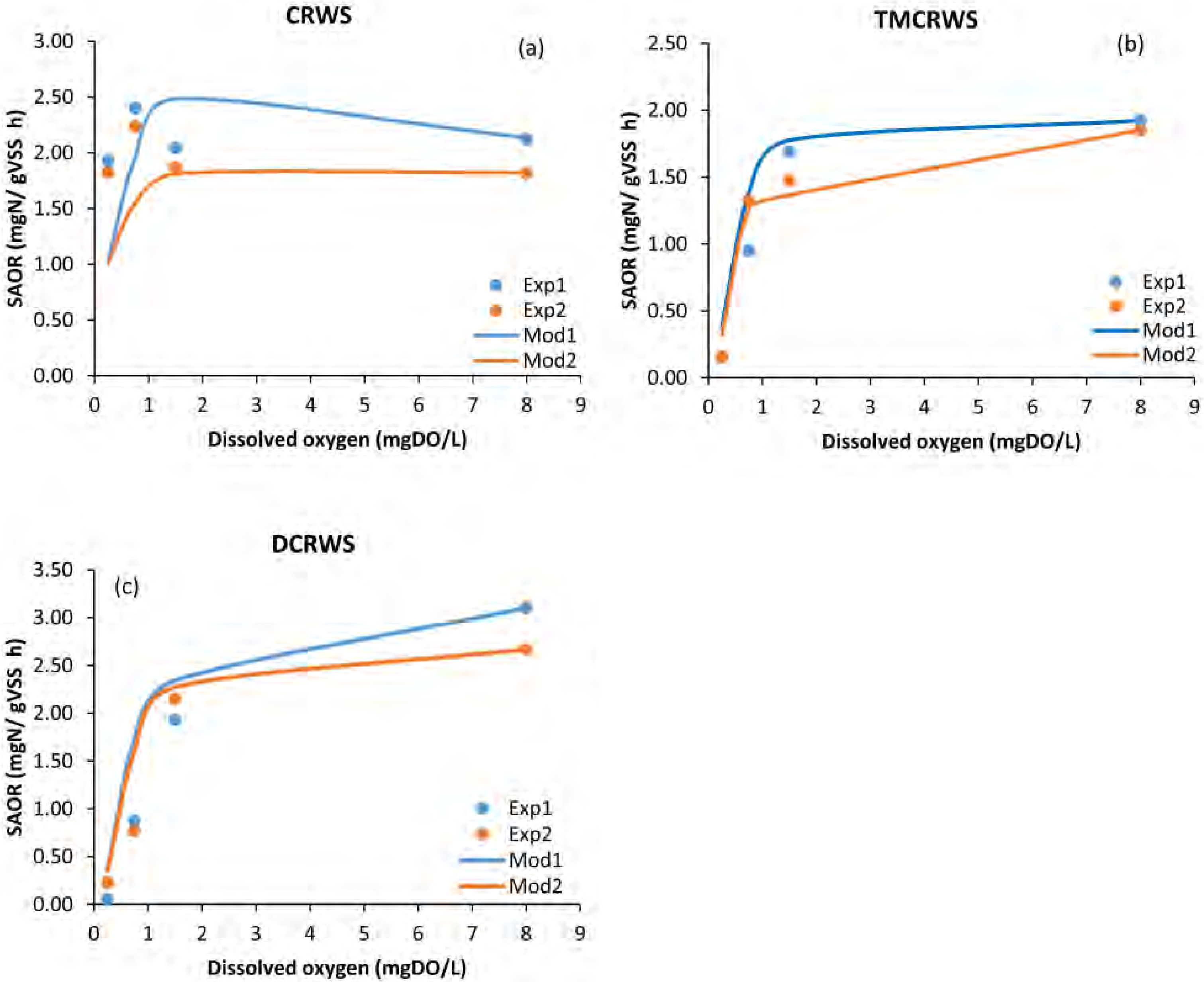
16 and qPCR analysis shows significant presence of NOB



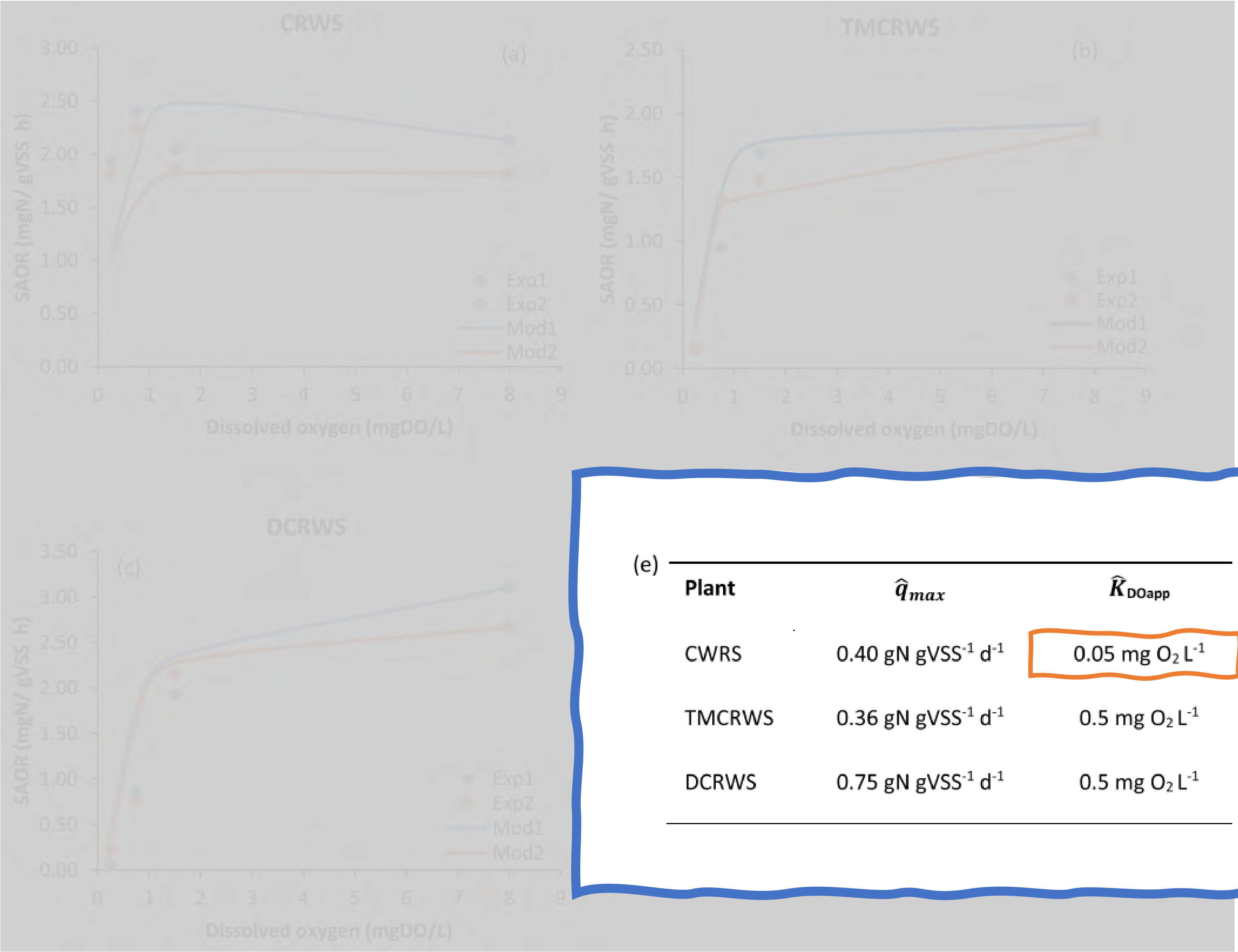
Targeted qPCR shows presence of comammox



Kinetics Parameters Estimation



Kinetics Parameters Estimation

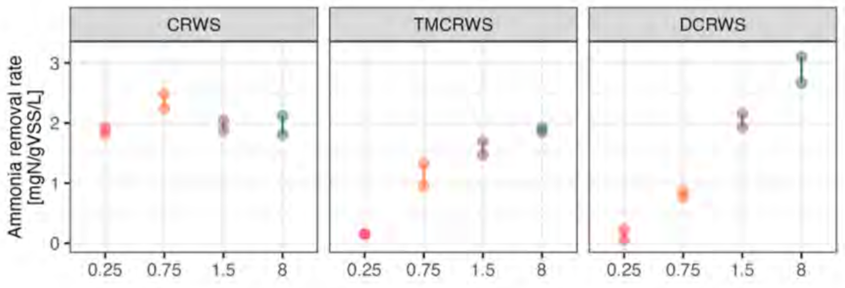


(e)

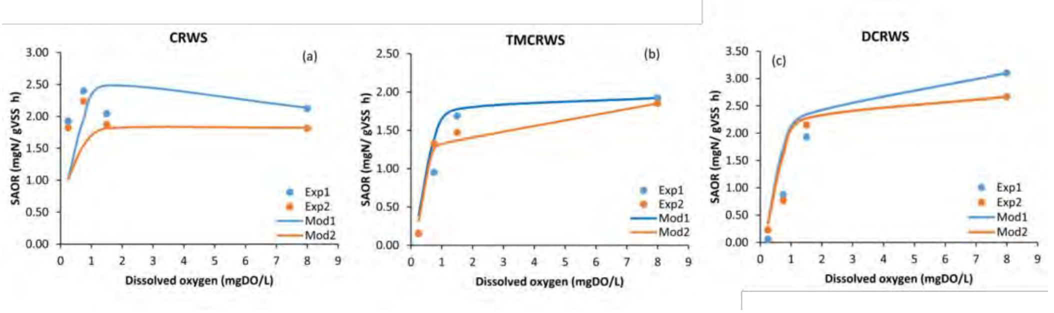
Plant	$\hat{q}_{max}$	$\hat{K}_{DOapp}$
CWRS	0.40 gN $gVSS^{-1}$ d^{-1}	0.05 mg O_2 L^{-1}
TMCRWS	0.36 gN $gVSS^{-1}$ d^{-1}	0.5 mg O_2 L^{-1}
DCRWS	0.75 gN $gVSS^{-1}$ d^{-1}	0.5 mg O_2 L^{-1}

Key Takeaways – Strategies for energy and resource efficient N removal

1) Low DO-adapted biomass achieve **highest removal rate** and maxes out at lowest DO → higher DO would be a waste of energy



2) Comammox Nitrospira was found in both plants with **longer SRT → crucial parameter for selection**

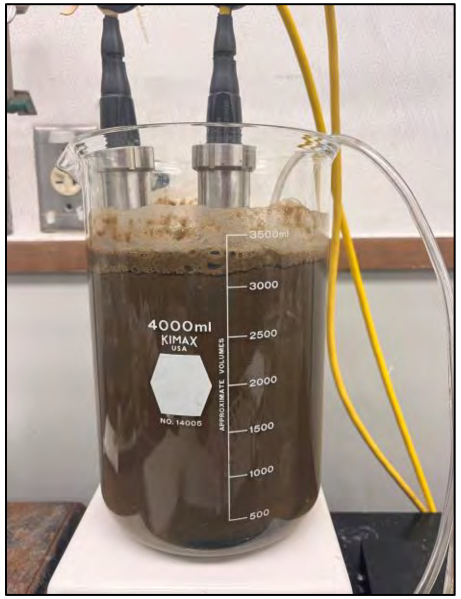


3) Two strains with **different affinity** for oxygen were found in comammox Nitrospira was found in both plants with long SRT

From (near) Zero to Hero

How Microbes Thrive in Low Dissolved Oxygen Water Resource Recovery Facilities

BREAKING NEWS



- Apparent resiliency of microbial populations adapted to low DO
- High nitrification rates at different DO concentrations

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Article

Exploring Community and Kinetic Shifts in Nitrifying Microbial Communities in Low Dissolved Oxygen Activated Sludge Facilities for Energy-Efficient Biological Nitrogen Removal

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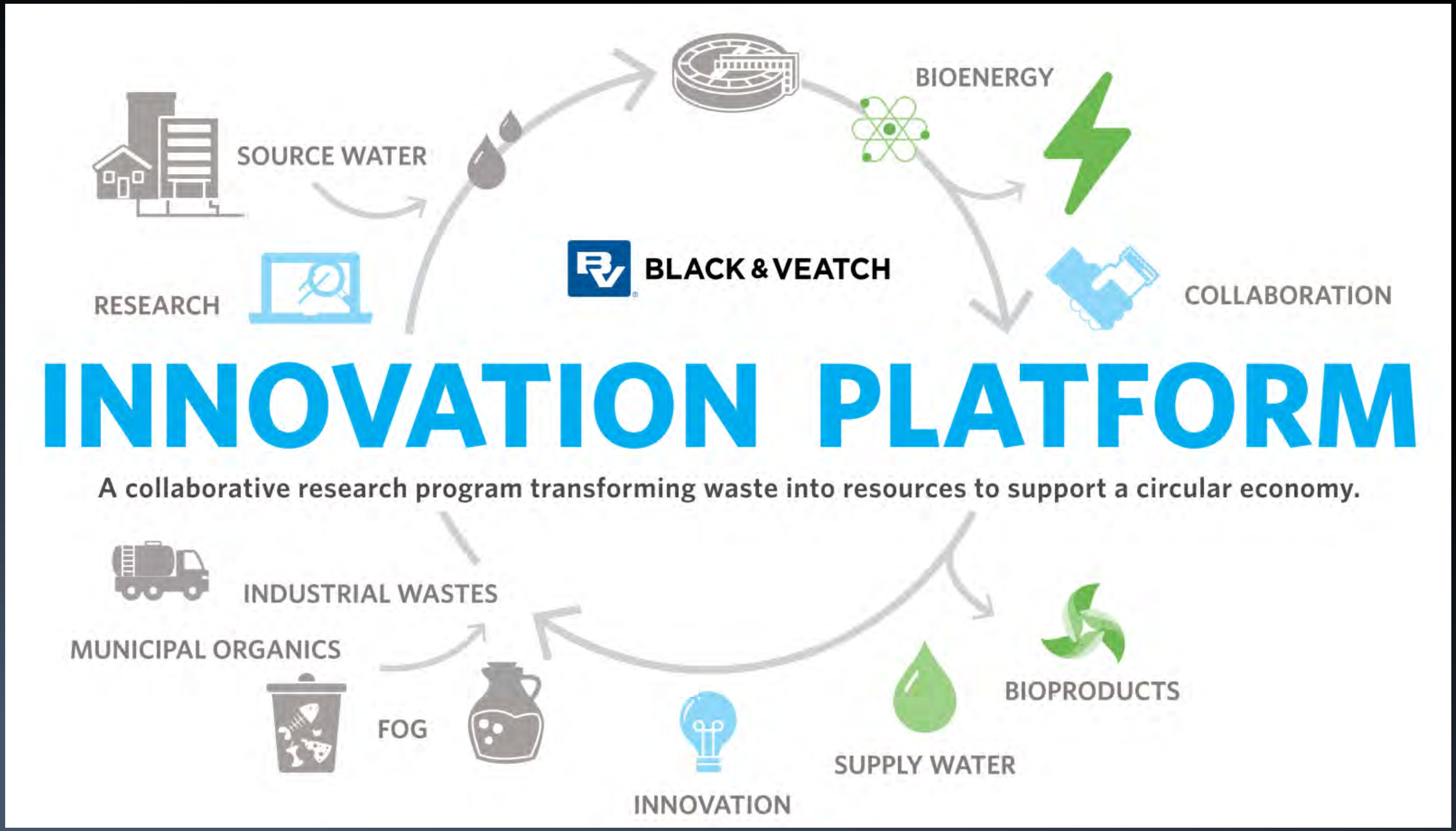
ABSTRACT: The discovery of the complete ammonia oxidation process (comammox) has challenged conventional nitrification theory, showing microbial adaption to very low dissolved oxygen (DO) concentrations. This study aimed at investigating the effects of different DO concentrations using a series of bioreactors inoculated with biomass from three operationally diverse water resource recovery facilities. Results show that microbial populations adapted to low DO environments can maintain high rates across a range of DO concentrations, indicating their ability to function well even at high DO concentrations. Additionally, long solids retention times (>10 days) can encourage the persistence of comammox populations adapted to different DO concentrations. Molecular analyses revealed that the low DO-facility had a nitrifying population with similar ratios of comammox clades A and B, while the high DO facility was dominated by clade A. Modeling results suggest that the nitrifying population including comammox bacteria from the low DO facility has a different half-saturation coefficient for DO (e.g., 0.05 mg L⁻¹) and possible intrapopulation diversity within clades A and B. This study highlights that a changing nitrification community can enable the activated sludge process to operate effectively at low DO concentrations, leading to low-energy biological nitrogen removal.

BLACK & VEATCH

tra Trinity River Authority of Texas

Enriching the Trinity basin as a resource for Texans

BUILDING A WORLD OF DIFFERENCE



Q and A

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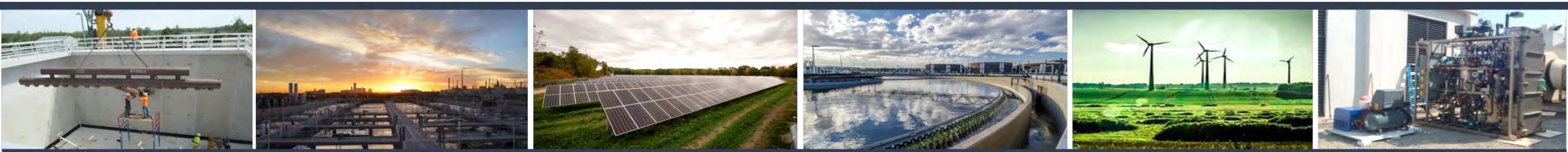
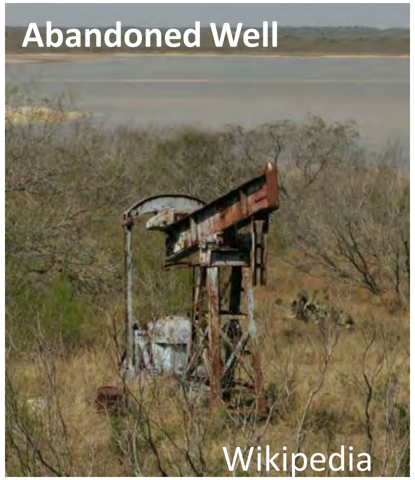
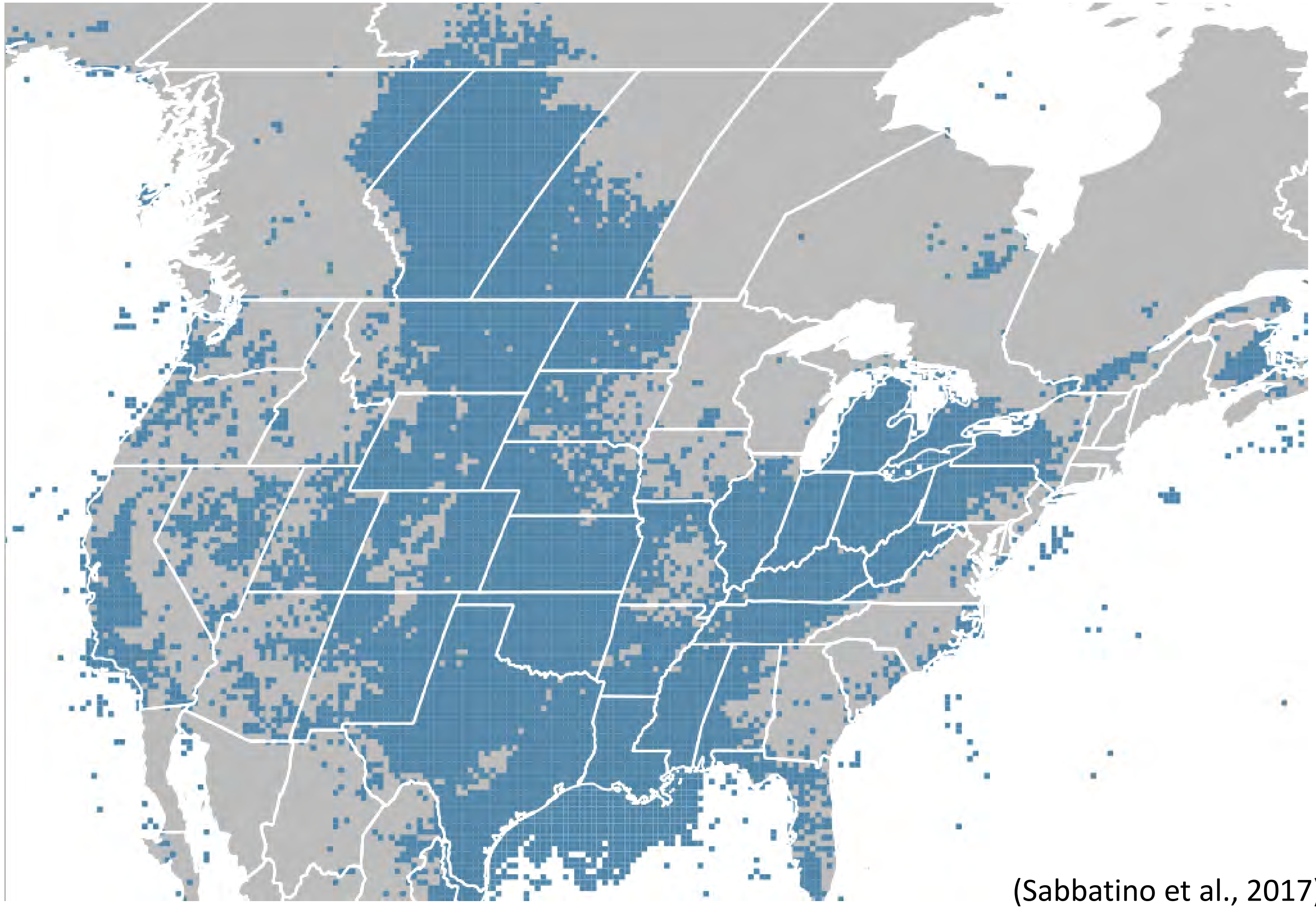
Greg Lackey, Ph.D.
Research Engineer
National Energy Technology Laboratory
AAEES Member



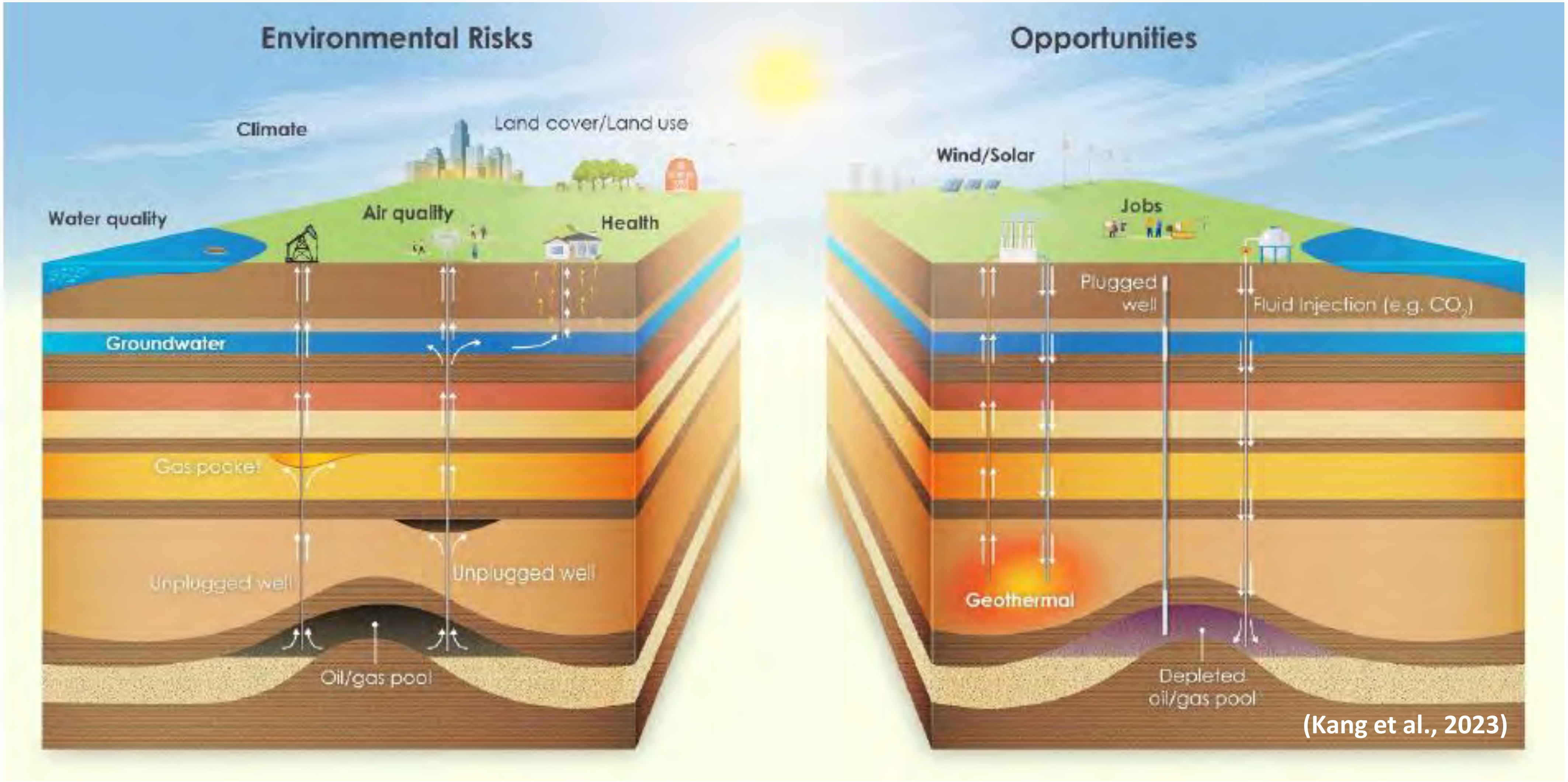
There are millions of oil and gas wells in the United States





(Sabbatino et al., 2017)

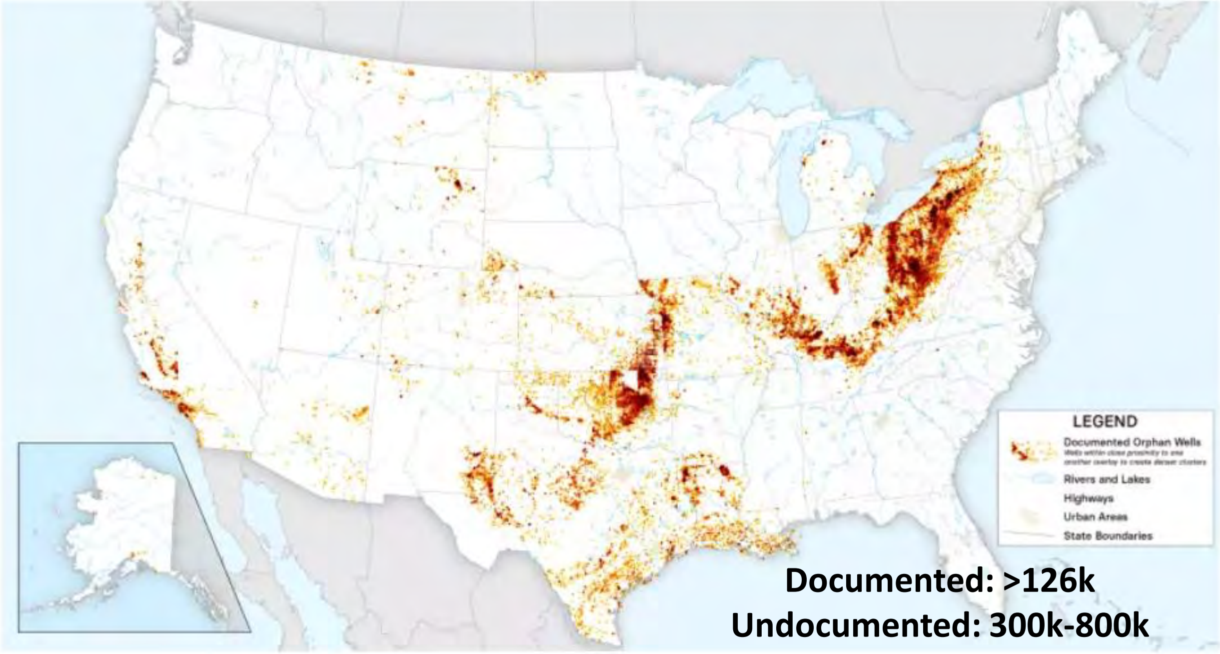
Wells that leak pose an environmental risk



However, intact wells present opportunities as well

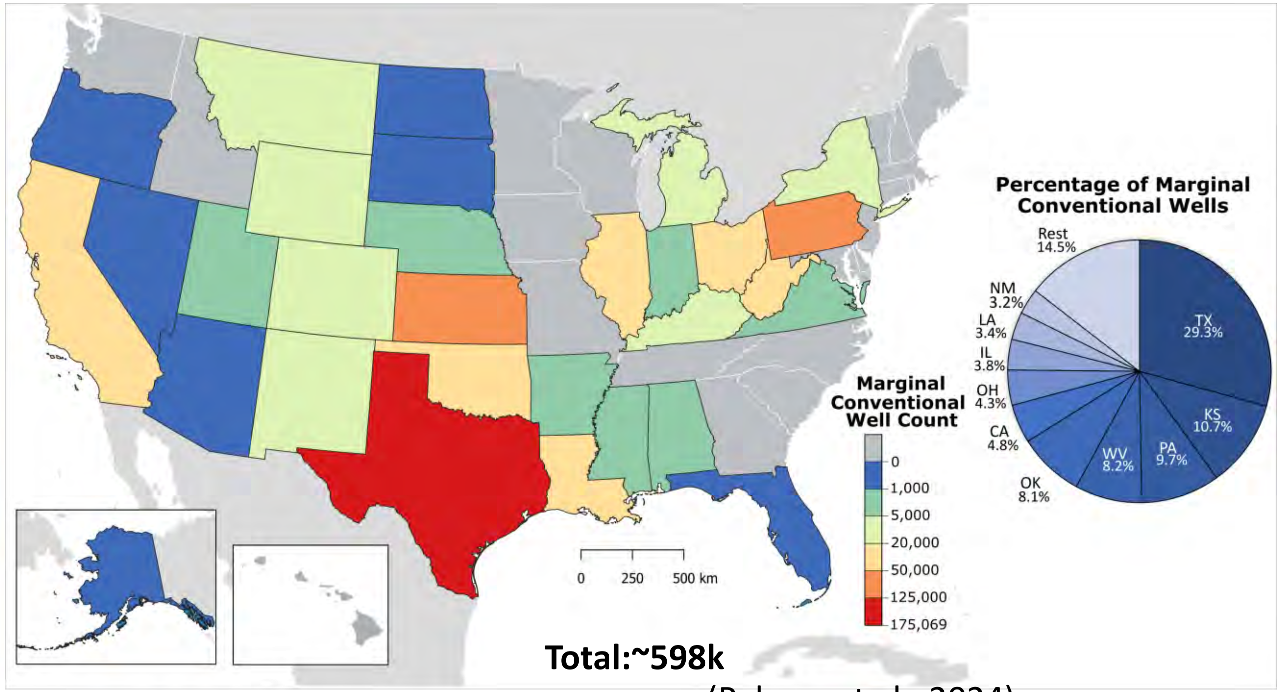
Historic levels of funding are currently available for plugging orphaned and marginally productive wells

Orphaned Wells



(Boutot et al., 2022)

Marginal Wells



(Pekney et al., 2024)

Bipartisan Infrastructure Law: $4.7 billion
Inflation Reduction Act: $350 million

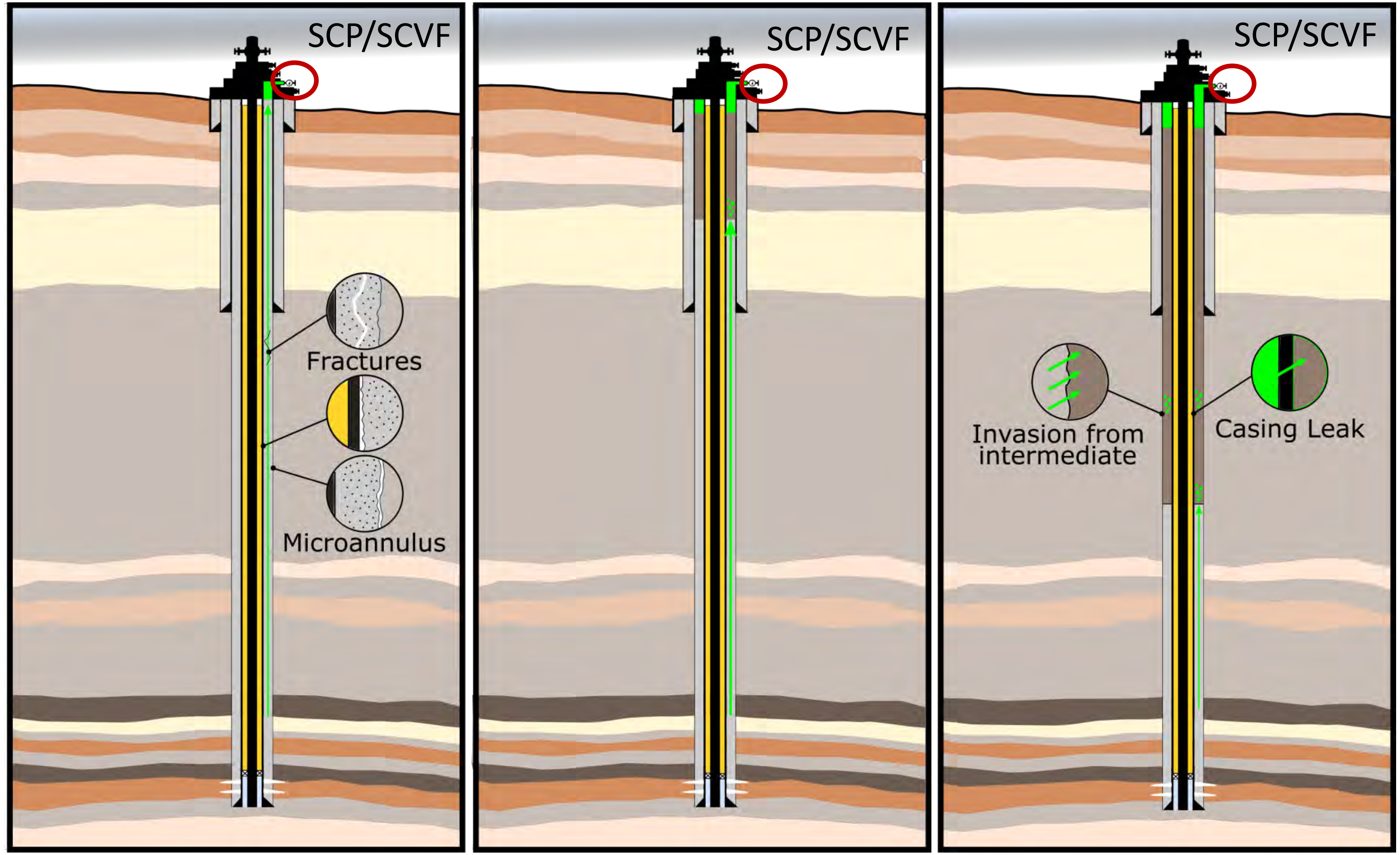
Most states prioritize leaking wells for plugging

	DSR	Leak	Safety	Well	Log.	Geo.	Surf.	Econ.	EJ
California	1	4		2	5	6	7		3
Federal	1	2	2		4				4
Indiana	2	1	5	3		6	4	7	
Louisiana	3	1	2	6	4	4	7	8	
Michigan	2	1	6	3	7	4	8		5
Montana	1	3	5	2			4	6	
Nebraska	2			1				3	
New Mexico	3	1	4	2	5	5		7	
New York	1	3	2	4	5	6	7	8	
Ohio	1	2	3	6	4	5	7	8	
Pennsylvania	2	1	3	5	5	4	7		
Texas	3	1	1	4	6	5		7	

Iyer et al., In Review

Leaking wells also a priority for other subsurface energy operations

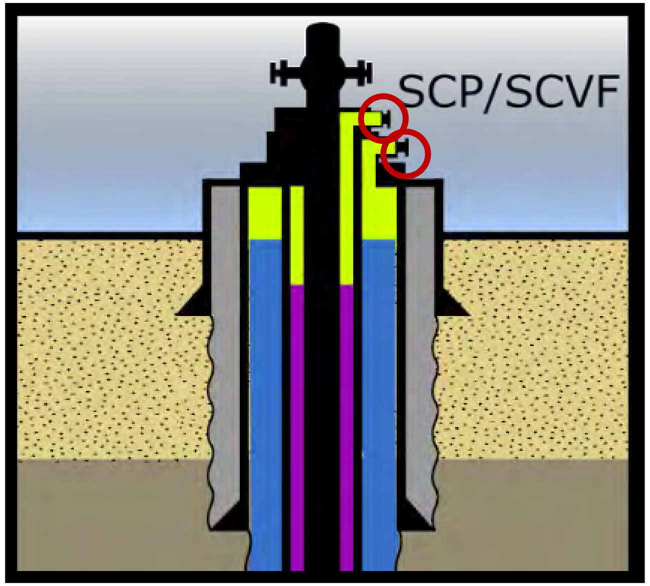
Well leaks require both a source and a pathway

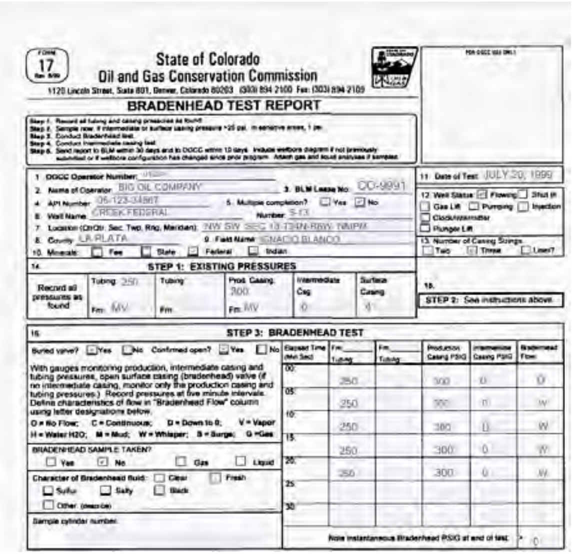


(Modified from Lackey & Rajaram, 2019)

Sources: producing/intermediate zones; Pathways: annuli, barrier flaws

Well integrity data are only available in a few U.S. states





FORM 17

State of Colorado
Oil and Gas Conservation Commission
1120 Lincoln Street, Suite 801, Denver, Colorado 80203 (303) 894 2100 Fax: (303) 894 2109

BRADENHEAD TEST REPORT

1. OGCC Operator Number:
2. Name of Operator: BIG OIL COMPANY
3. BLM Lease No: CO-9991
4. API Number: 05-123-34867
5. Multiple completion? Yes / No
6. Well Name: CREEK FEDERAL Number: 5-13
7. Location (QtrQtr, Sec, Twp, Rng, Meridian): NW SW SEC 13 T34N-R8W NMPM
8. County: LA PLATA
9. Field Name: IGNACIO BLANCO
10. Minerals: Fee / State / Federal / Indian
11. Date of Test: JULY 20, 1999
12. Well Status: Flowing / Shut in / Gas Lift / Pumping / Injection / Clock/Intermitter / Plunger Lift
13. Number of Casing Strings: Two / Three / Liner?

14. STEP 1: EXISTING PRESSURES

Record all pressures as found	Tubing	Tubing	Prod. Casing	Intermediate Csg	Surface Casing
	250 Fm: MV	Fm:	300 Fm: MV	0	0

15. STEP 2: See instructions above.

16. STEP 3: BRADENHEAD TEST

Buried valve? Yes / No Confirmed open? Yes / No

With gauges monitoring production, intermediate casing and tubing pressures, open surface casing (bradenhead) valve (if no intermediate casing, monitor only the production casing and tubing pressures.) Record pressures at five minute intervals. Define characteristics of flow in "Bradenhead Flow" column using letter designations below.
0 = No Flow; C = Continuous; D = Down to 0; V = Vapor
H = Water H2O; M = Mud; W = Whisper; S = Surge; G = Gas

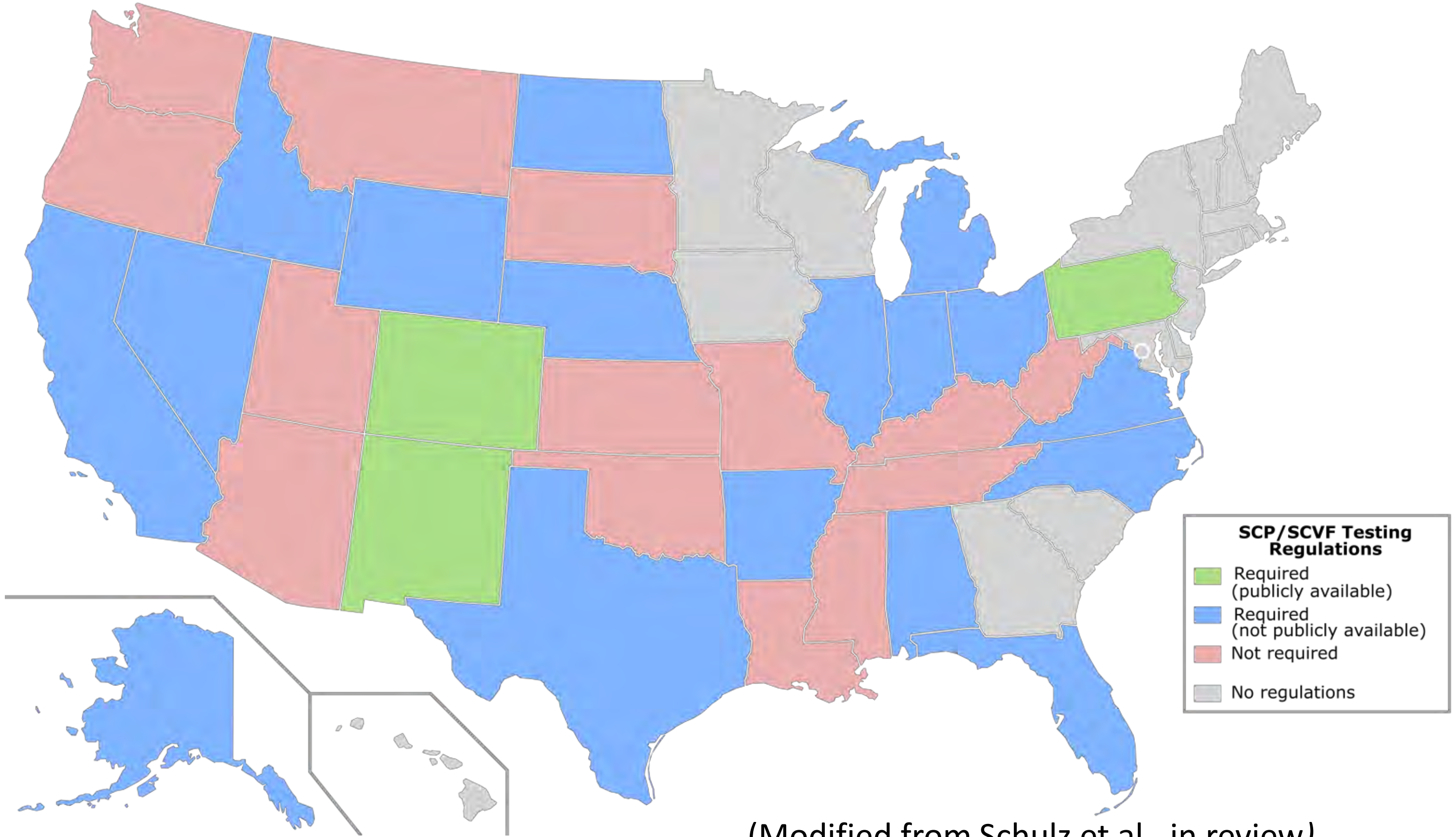
BRADENHEAD SAMPLE TAKEN? Yes / No / Gas / Liquid

Character of Bradenhead fluid: Clear / Fresh / Sulfur / Salty / Black / Other (describe)

Sample cylinder number:

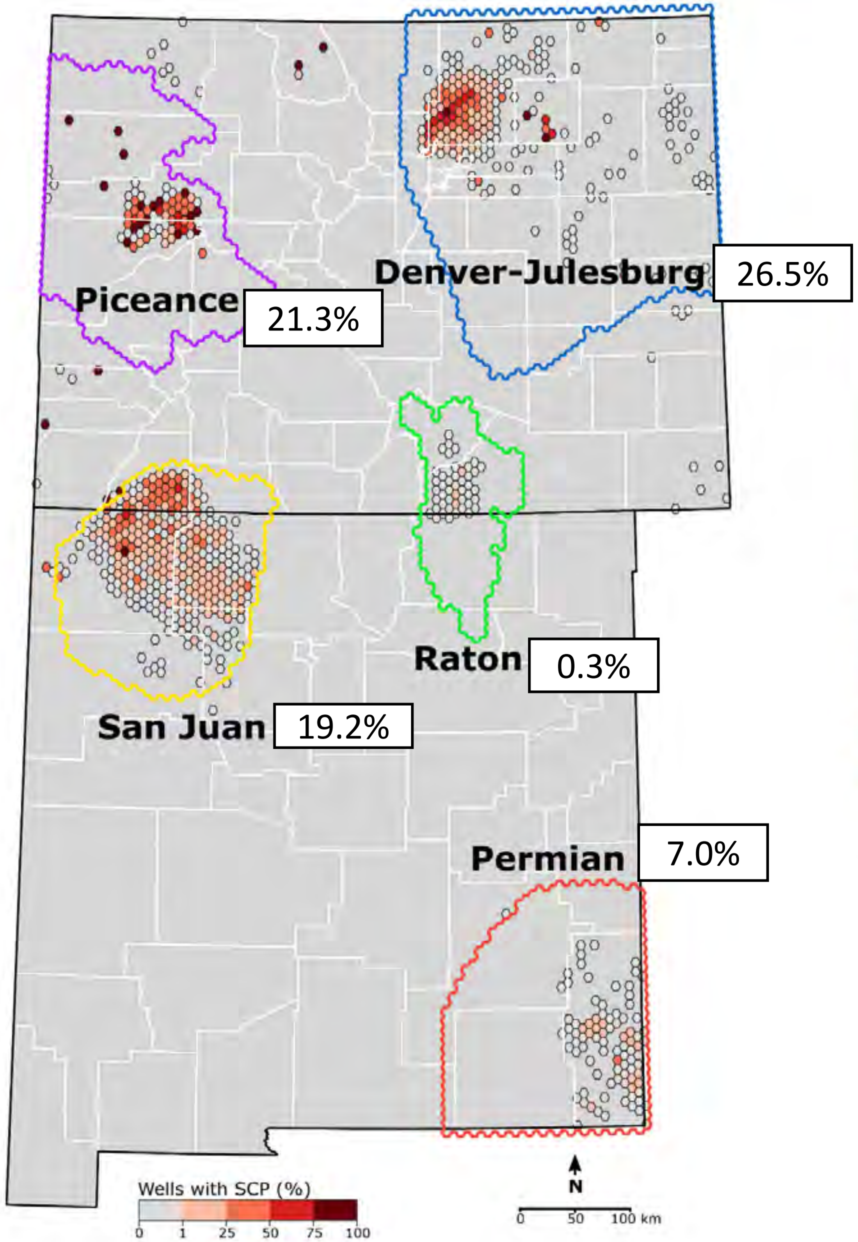
Elapsed Time (Min Sec)	Fm Tubing	Fm Tubing	Production Casing PSIG	Intermediate Casing PSIG	Bradenhead Flow
00	250		300	0	0
05	250		300	0	W
10	250		300	0	W
15	250		300	0	W
20	250		300	0	W
25					
30					

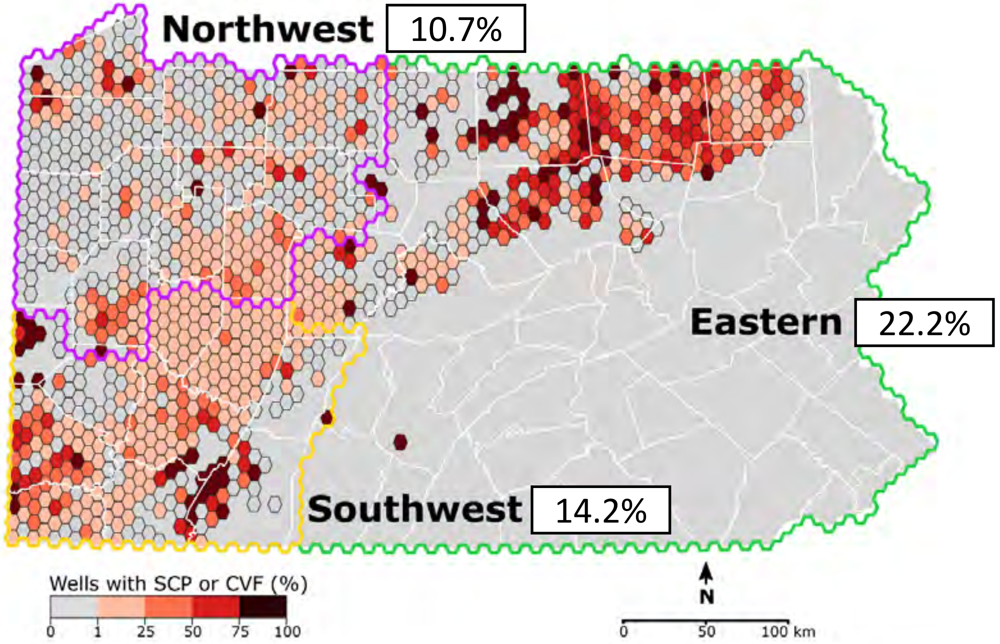
Note instantaneous Bradenhead PSIG at end of test: 0



(Modified from Schulz et al., in review)

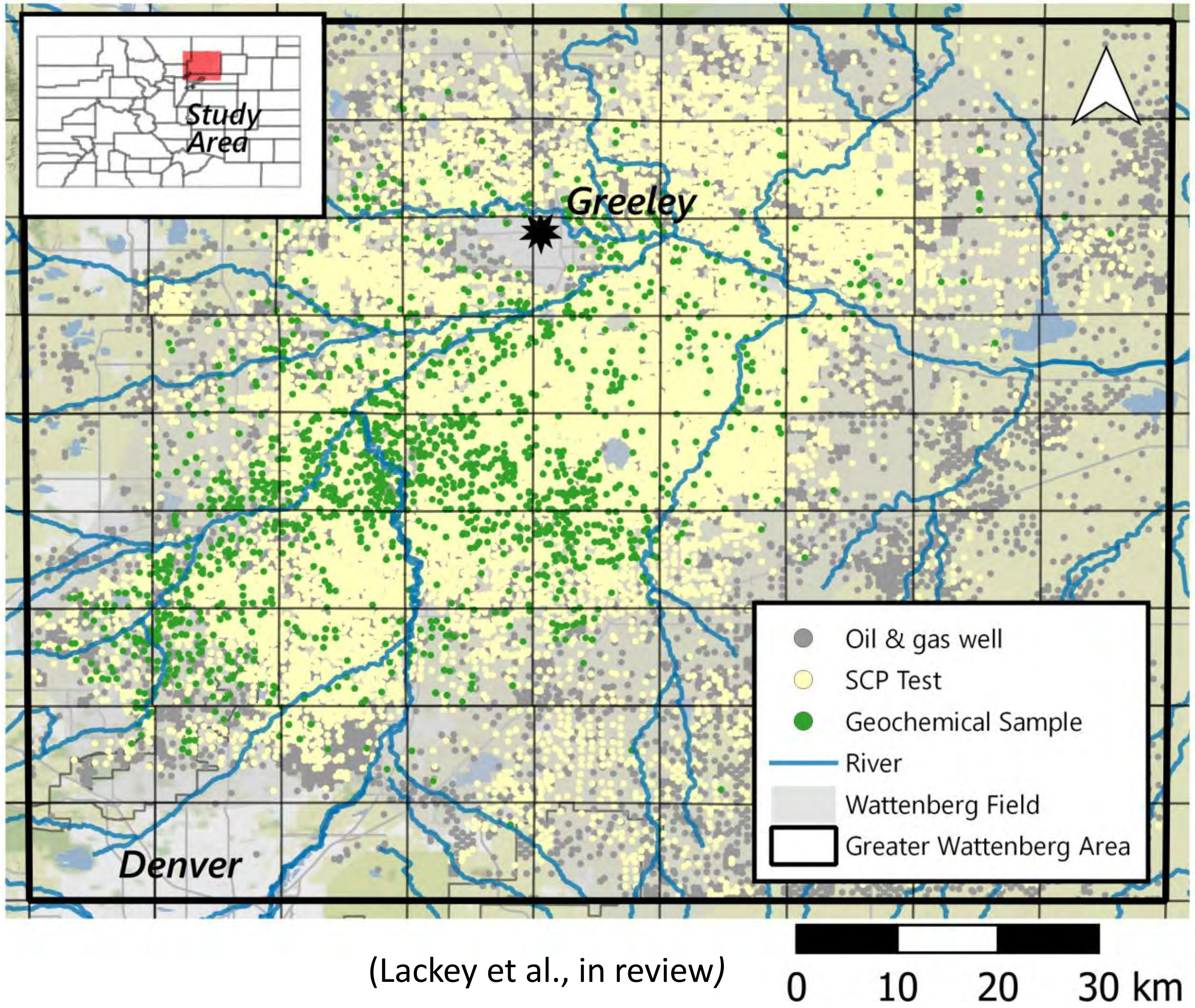
The frequency of integrity issues varies widely across regions





(Lackey et al., 2021)

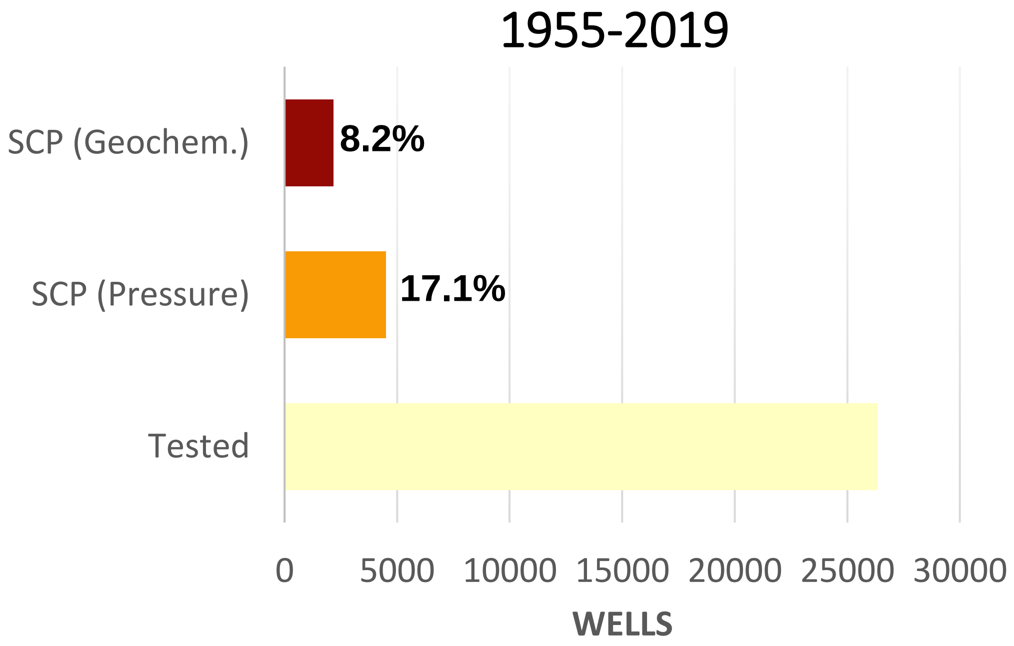
The Greater Wattenberg Area is an excellent case study

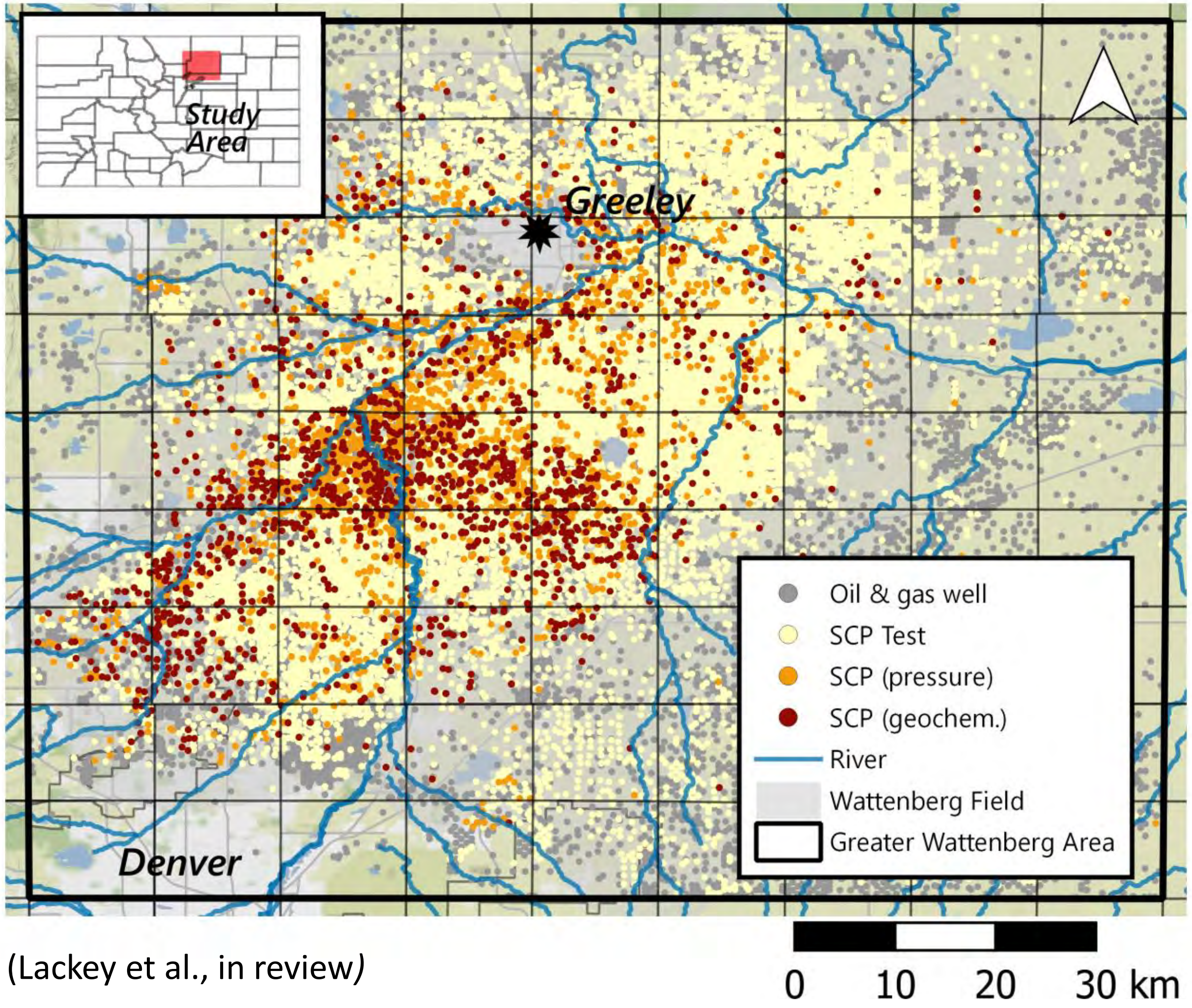


(Lackey et al., in review)

What drives well integrity issues?

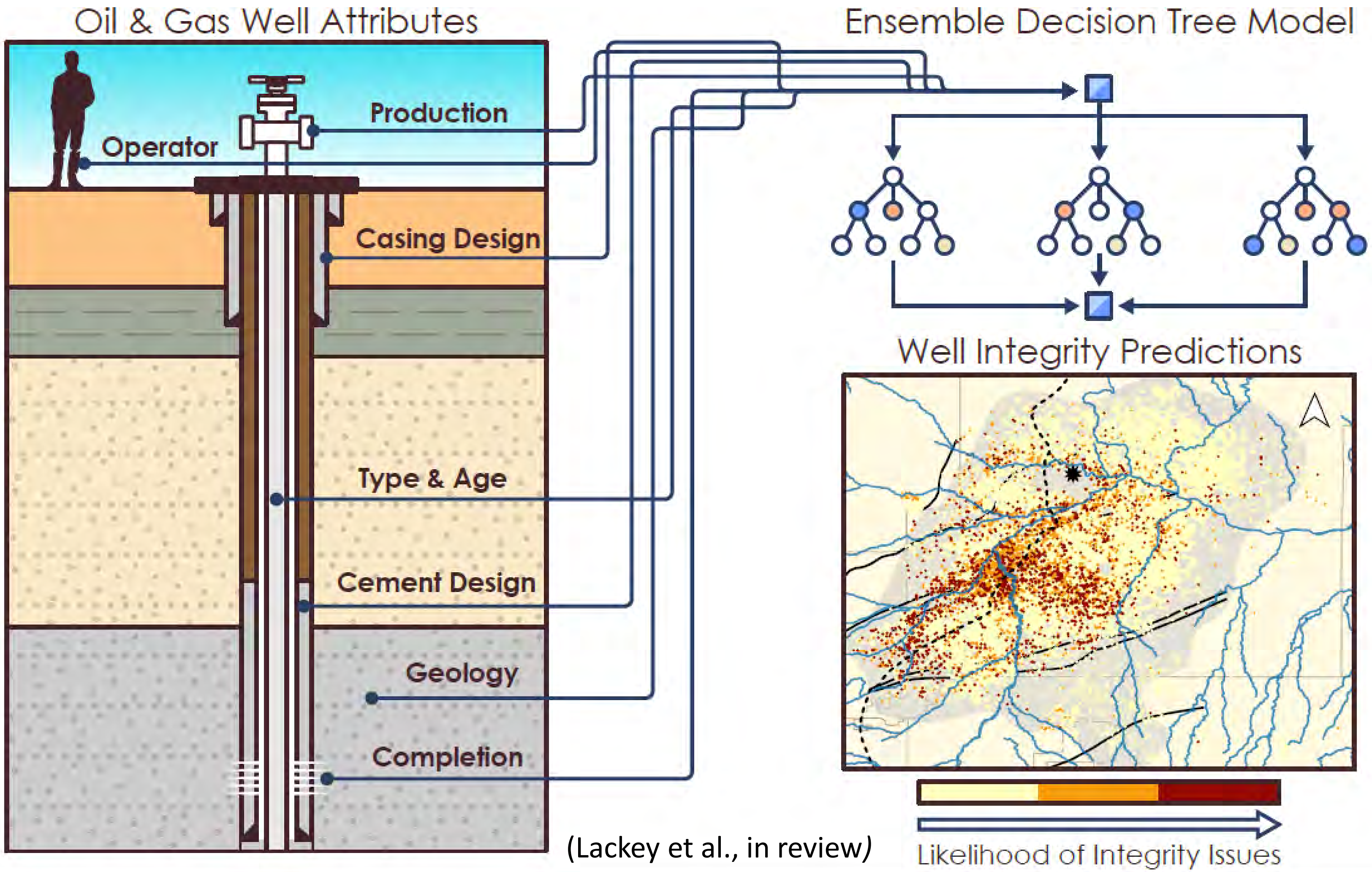
A relatively high percentage of GWA wells have experienced integrity issues





(Lackey et al., in review)

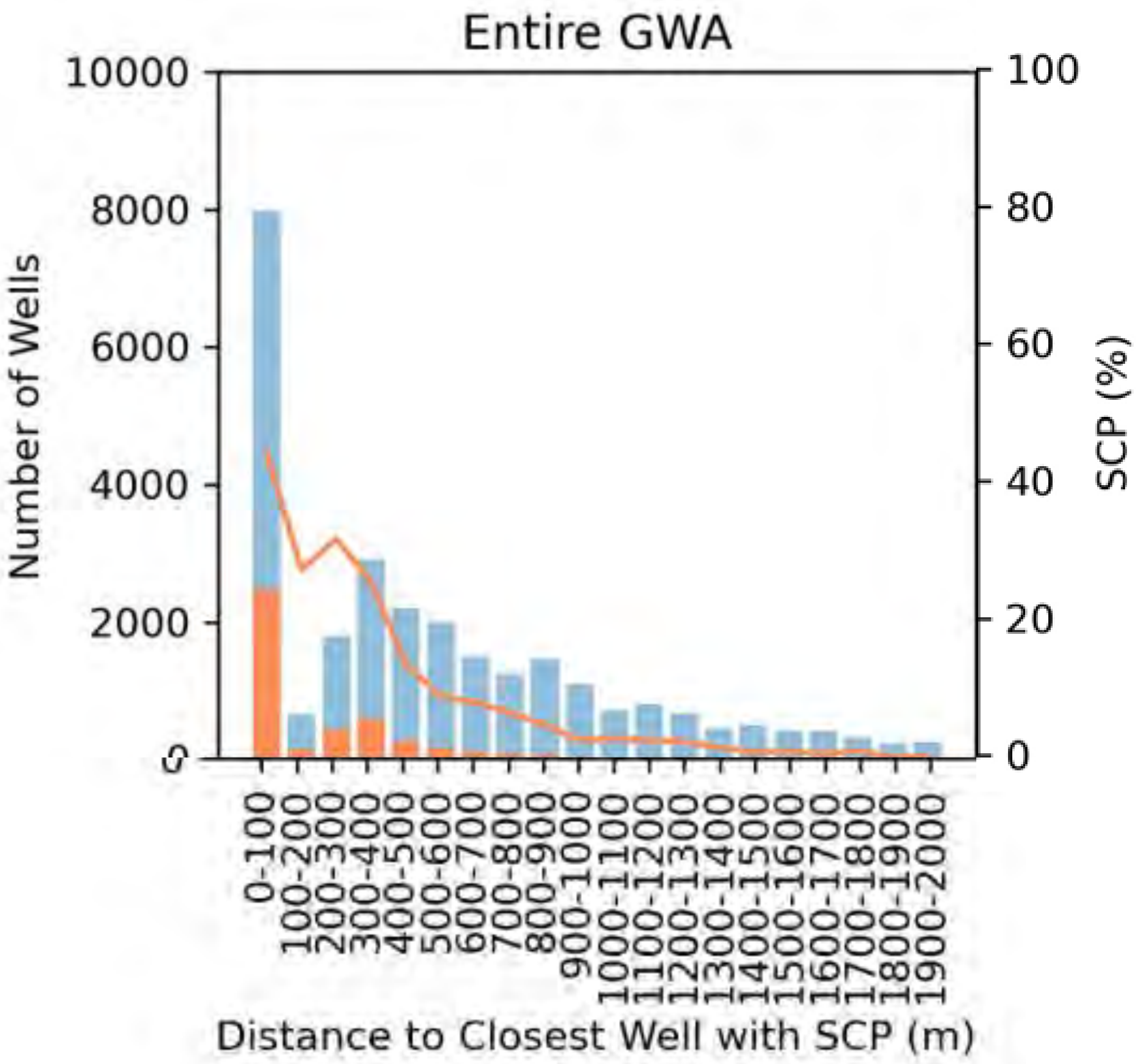
Machine learning models make useful predictions about integrity issues and provide insight into drivers



(Lackey et al., in review)

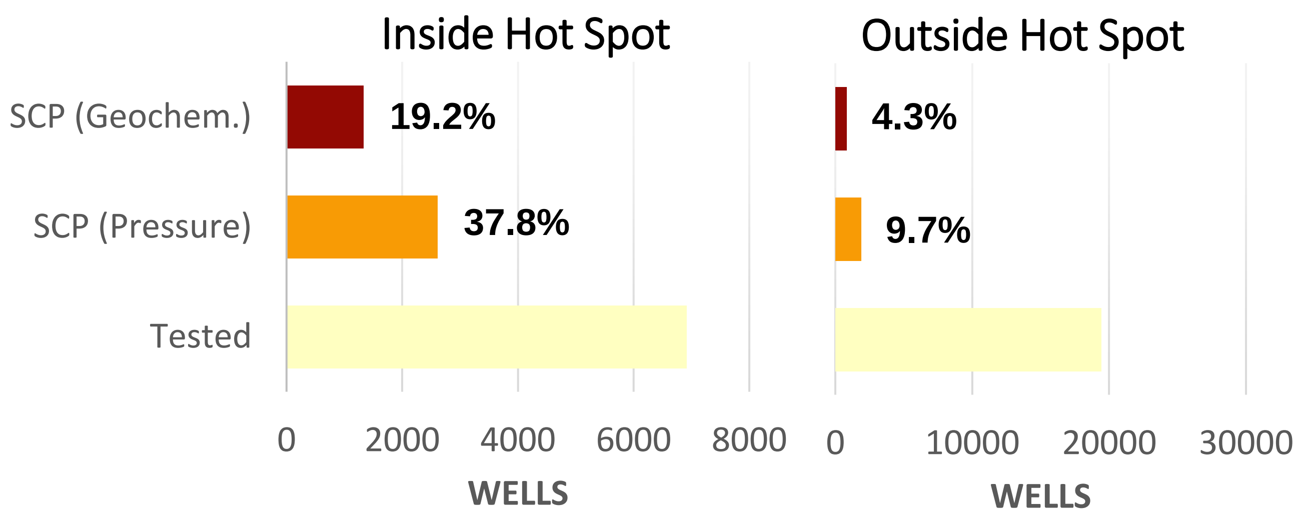
Models predict probability (not magnitude) of integrity issue

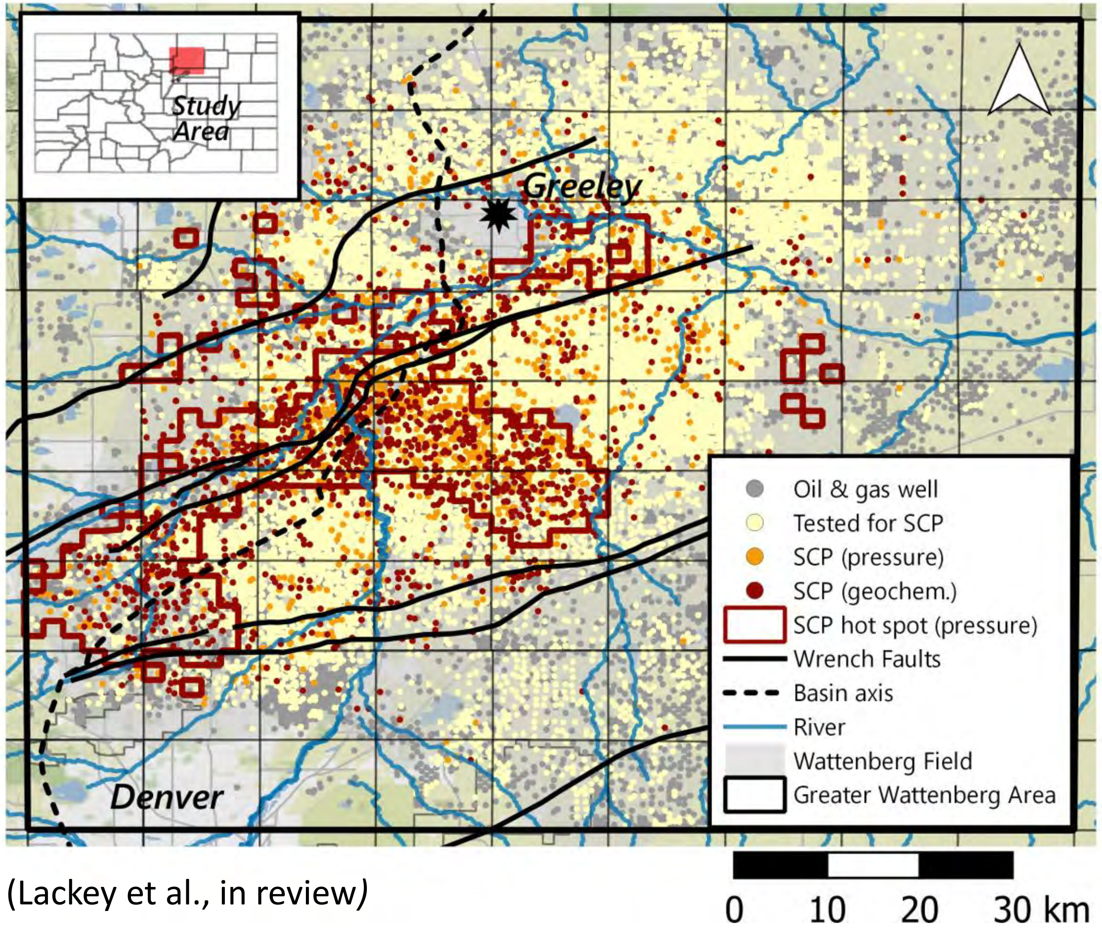
Integrity issues are spatially clustered



(Lackey et al., in review)

Well location impacted likelihood of leakage

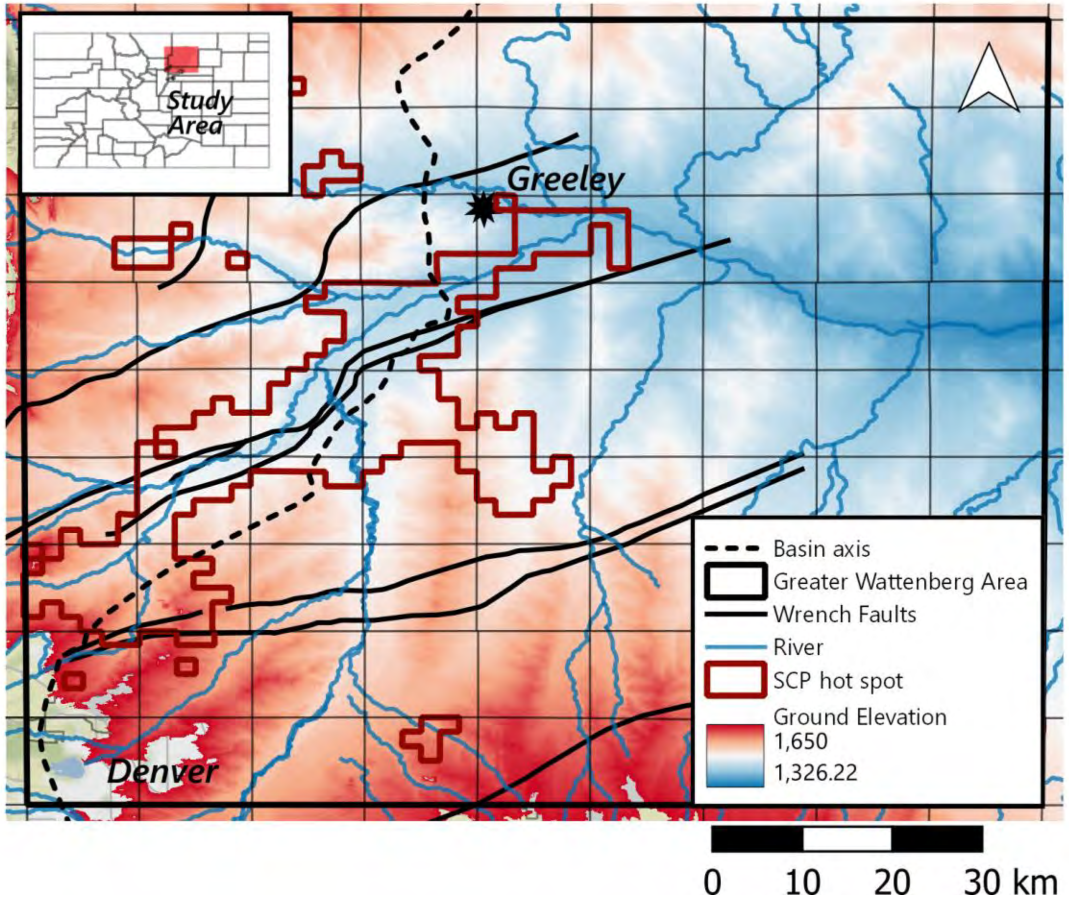


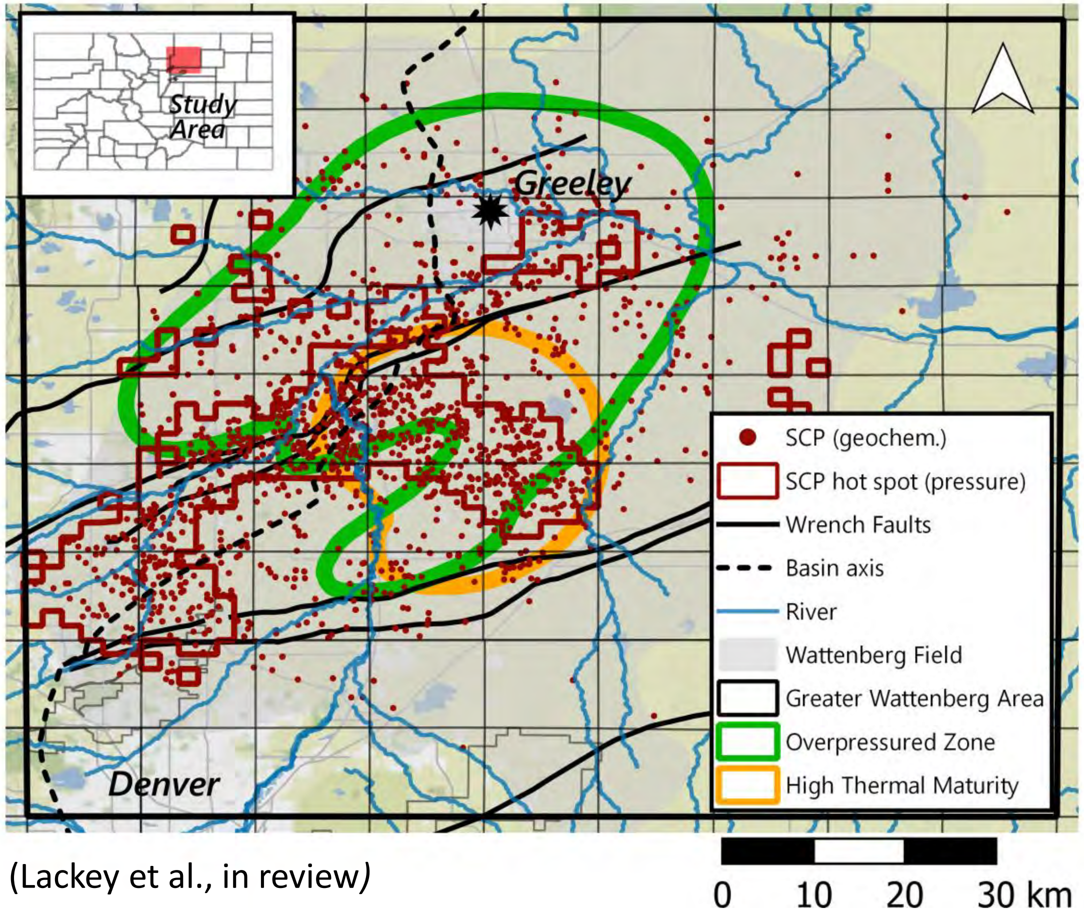


Percentage of wells with integrity issues was ~4x greater inside hot spot

(Lackey et al., in review)

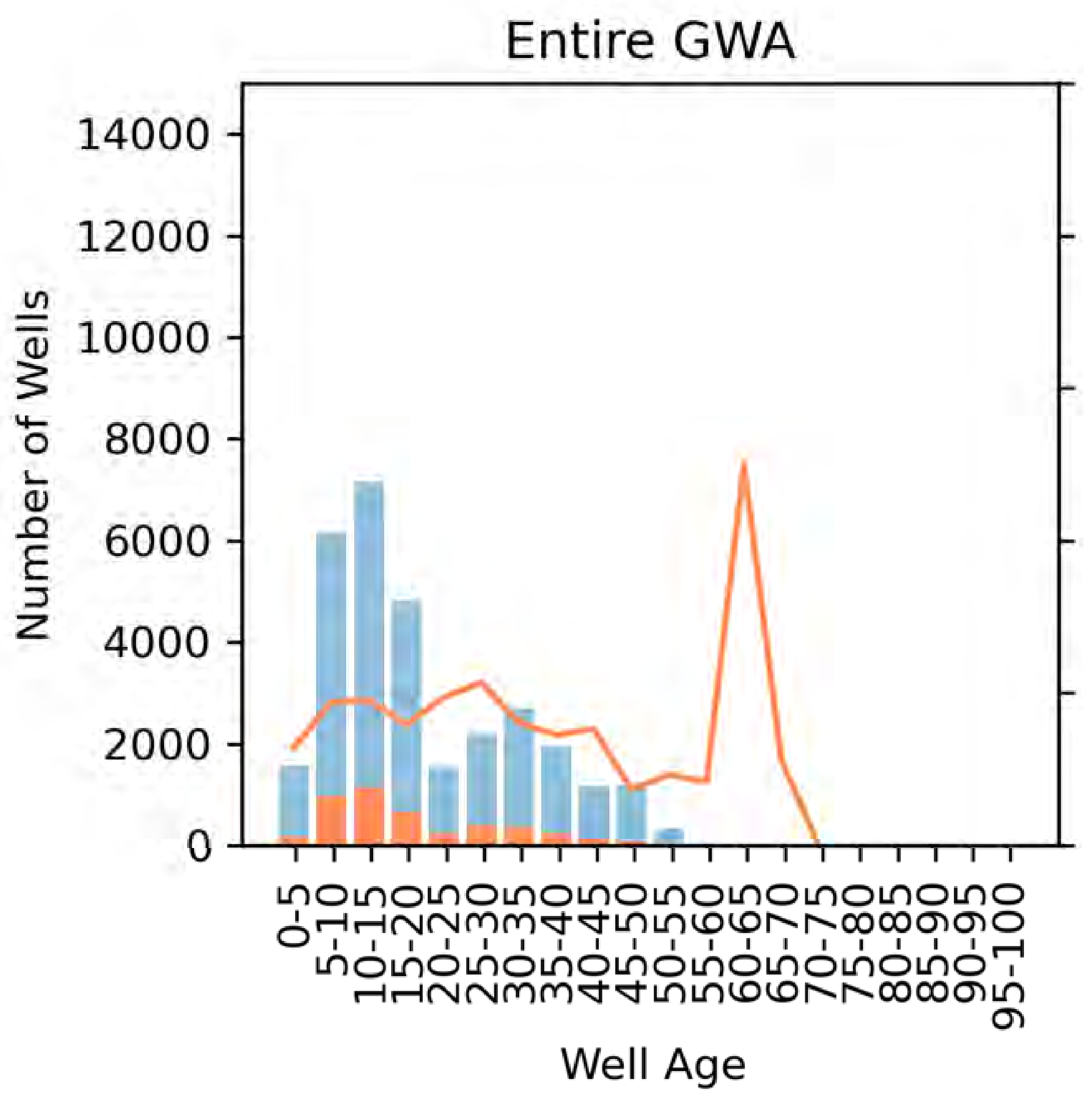
Integrity issues spatially align with geologic features





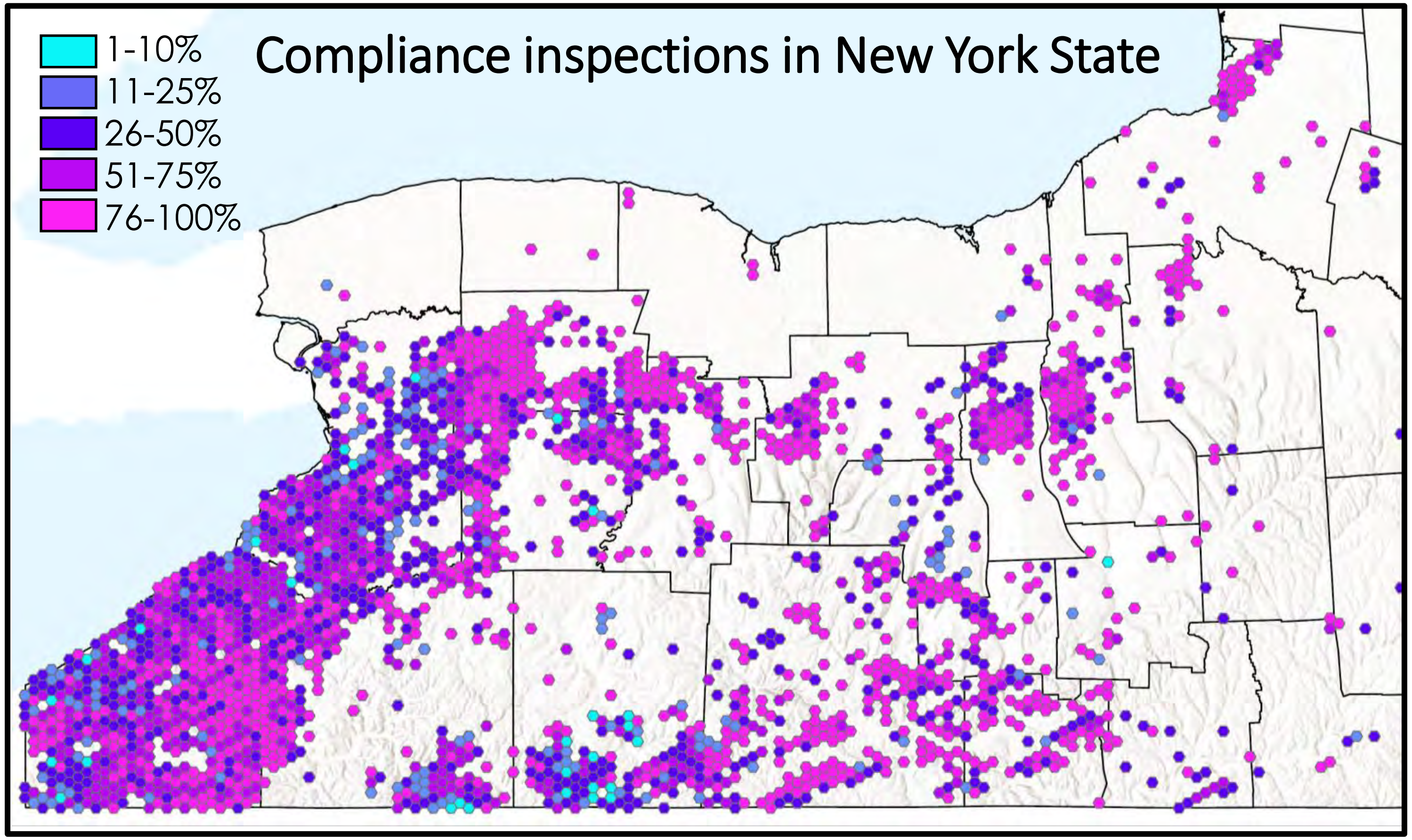
(Lackey et al., in review)

Older wells were not more likely to experience integrity issues



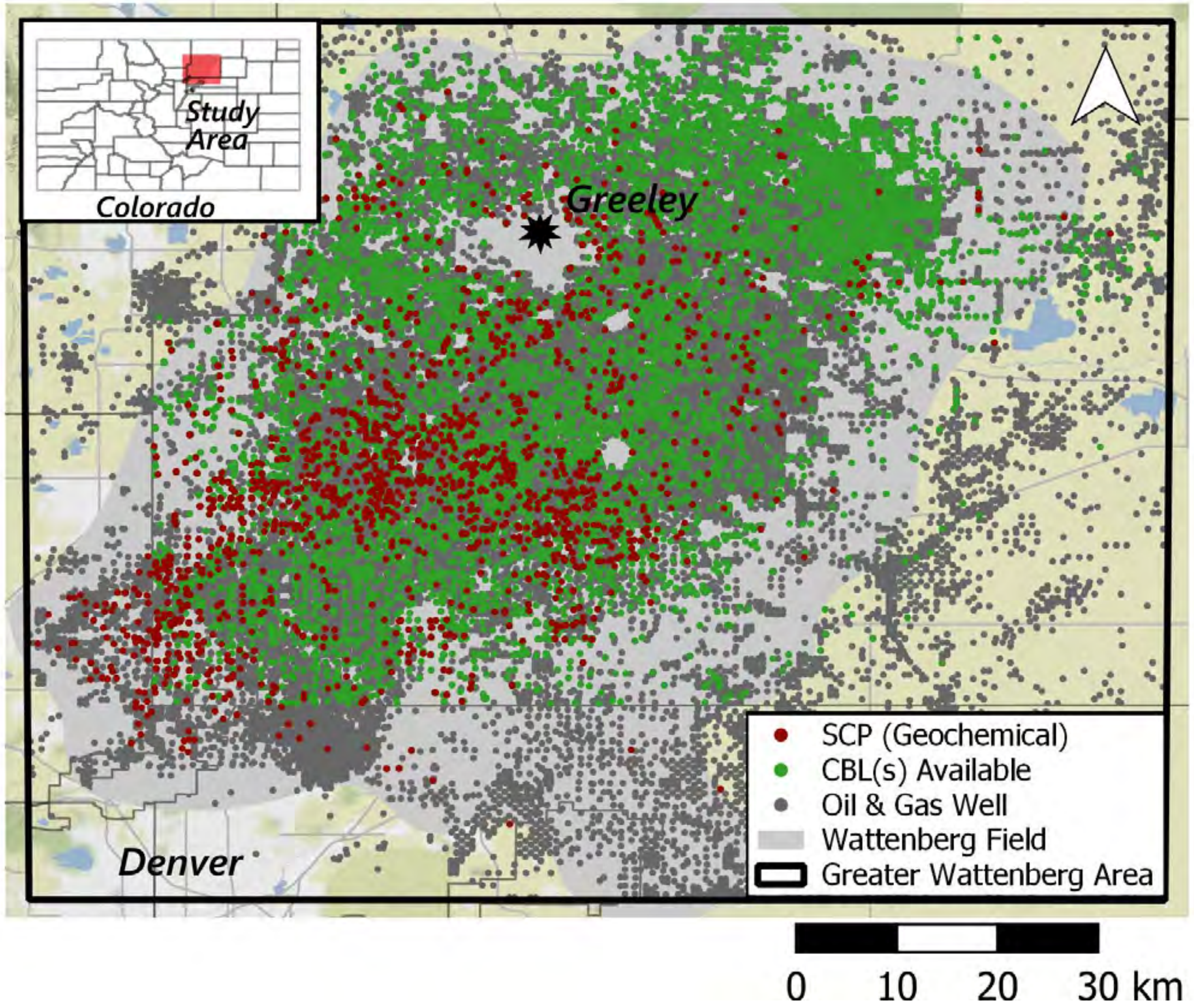
(Lackey et al., in review)

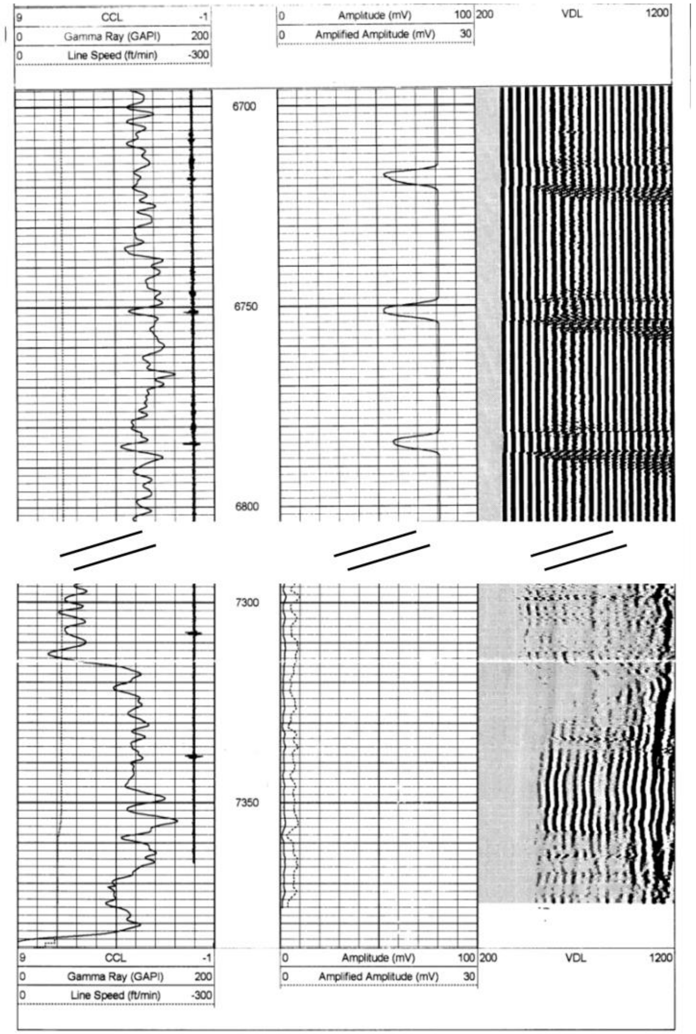
Identifying clusters of integrity issues is practicable



Most states have compliance inspection programs that could be extended with similar models

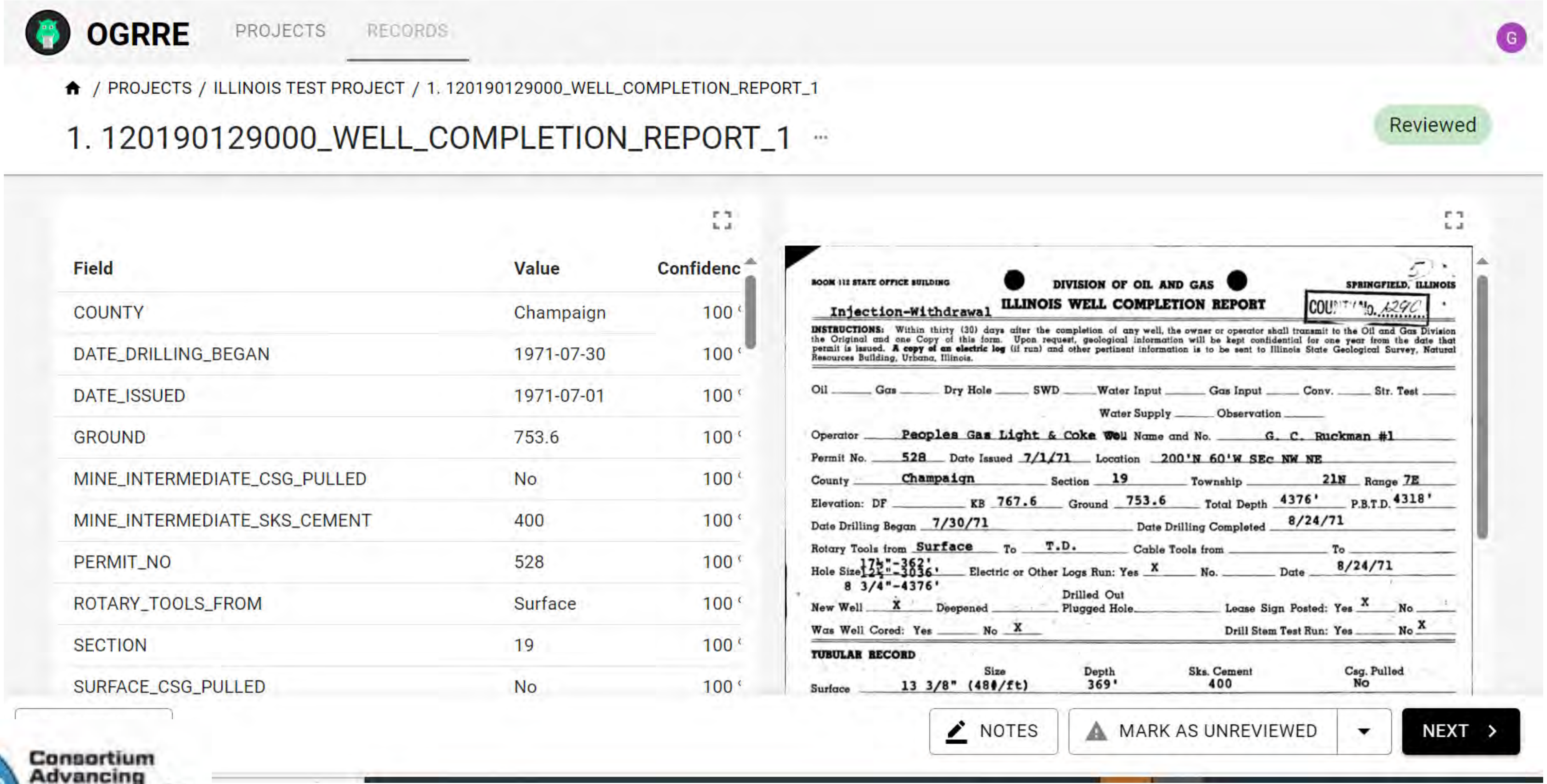
Working to incorporate other valuable information into models





API 512308297 CBL Example

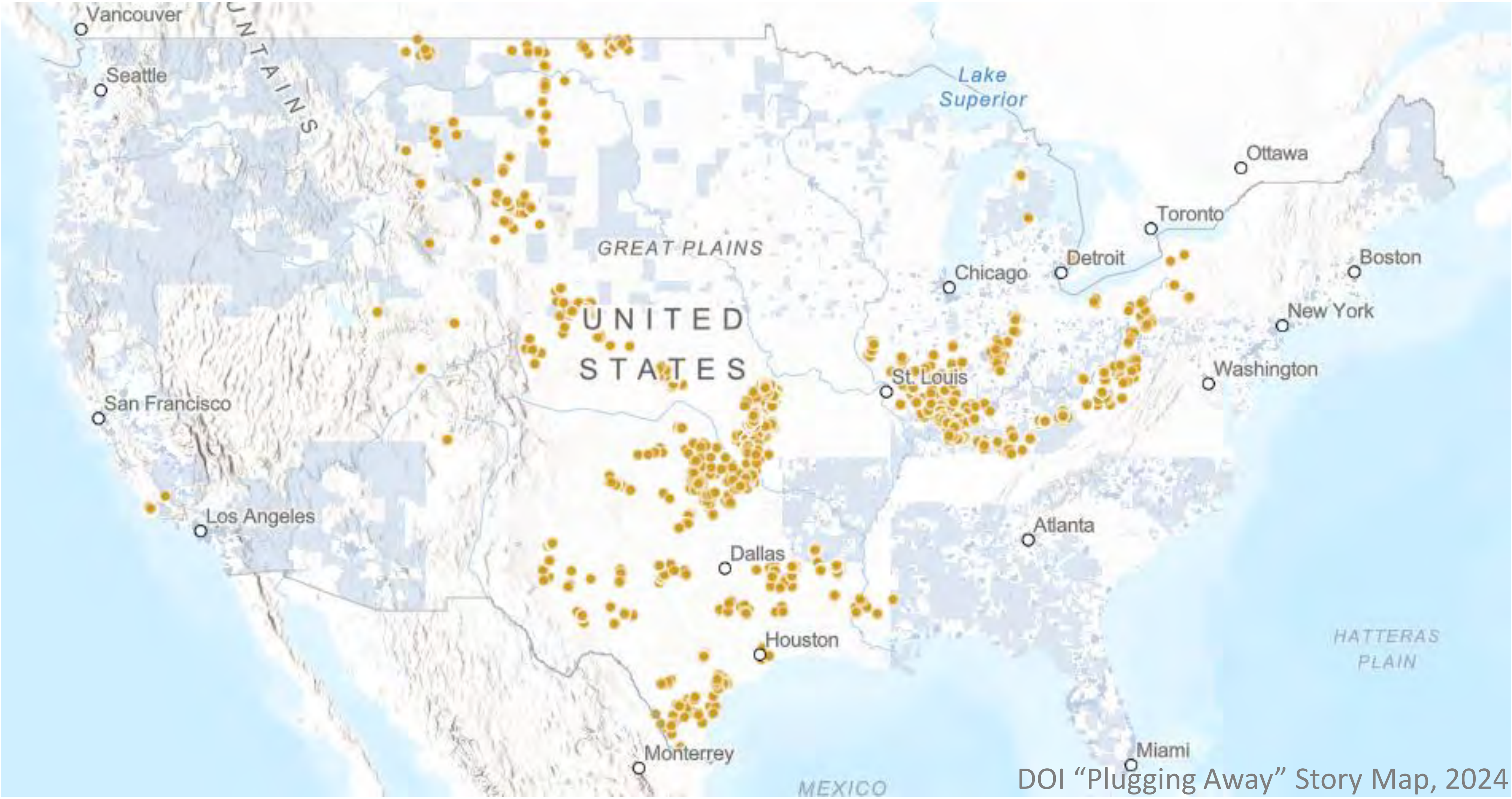
Data availability is a challenge



Consortium Advancing Technology for Assessment of Lost Oil & Gas Wells.

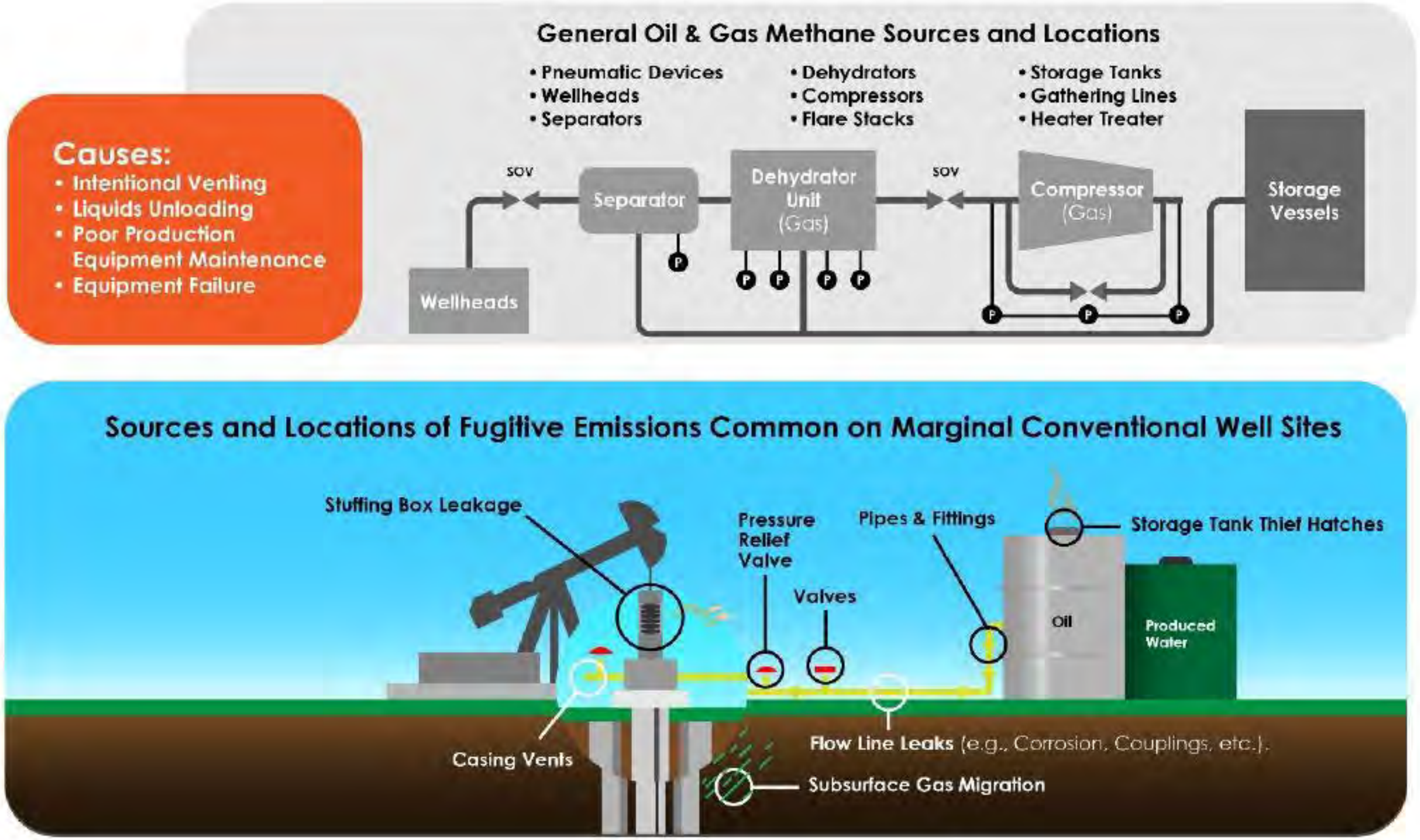
Building tools to help states digitize their data

Tremendous opportunities to gather information on older wells

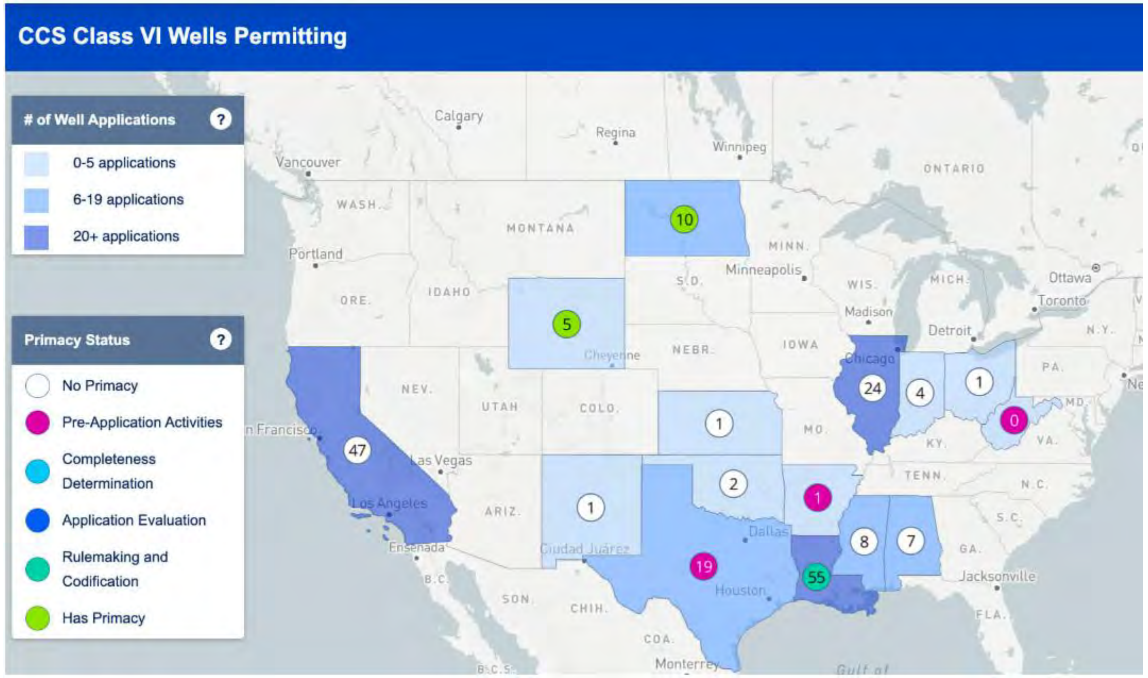


DOI "Plugging Away" Story Map, 2024

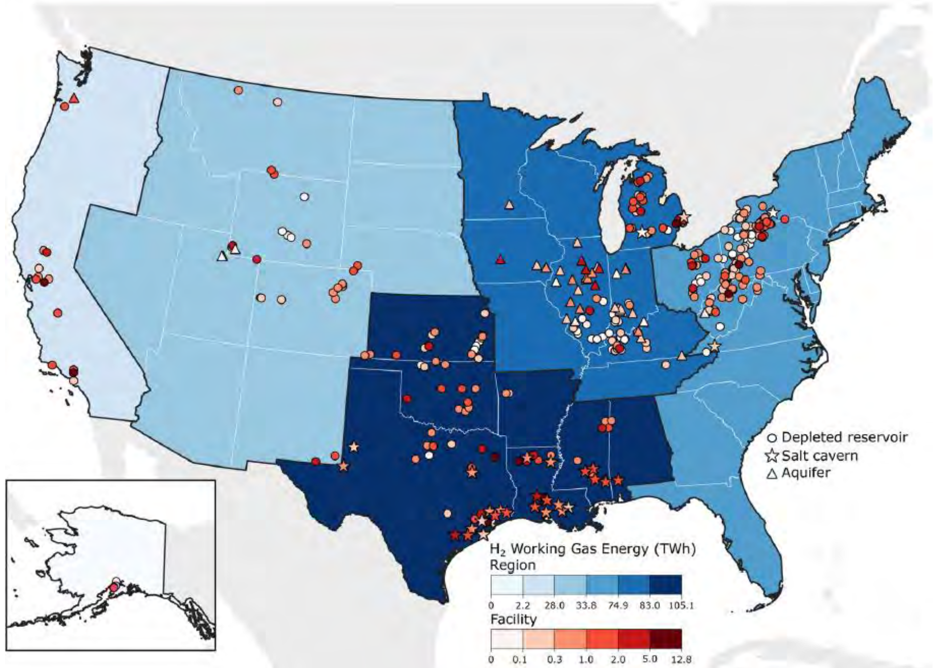
New EPA GHG reporting rules will fundamentally alter availability of well leakage data



Well integrity is important to monitor and maintain to preserve the subsurface as a resource



Clean Air Task Force, Class VI Map



Lackey et al., 2023

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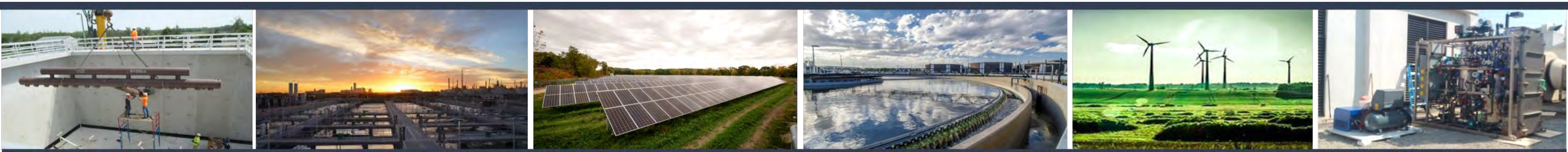

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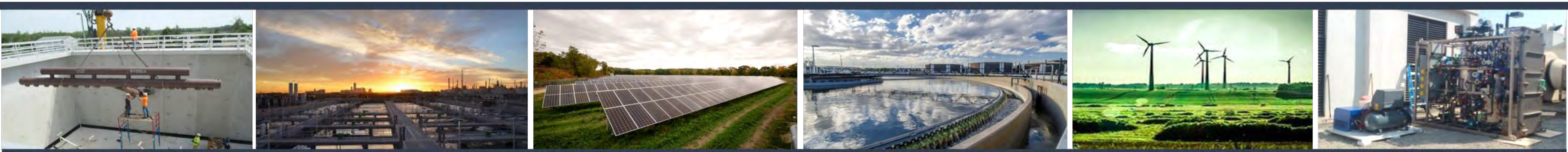

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