
Aggregation and Degradation of Dispersants & Oil by Microbial Exopolymers
A GoMRI Research Consortium
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Texas A&M University at Galveston
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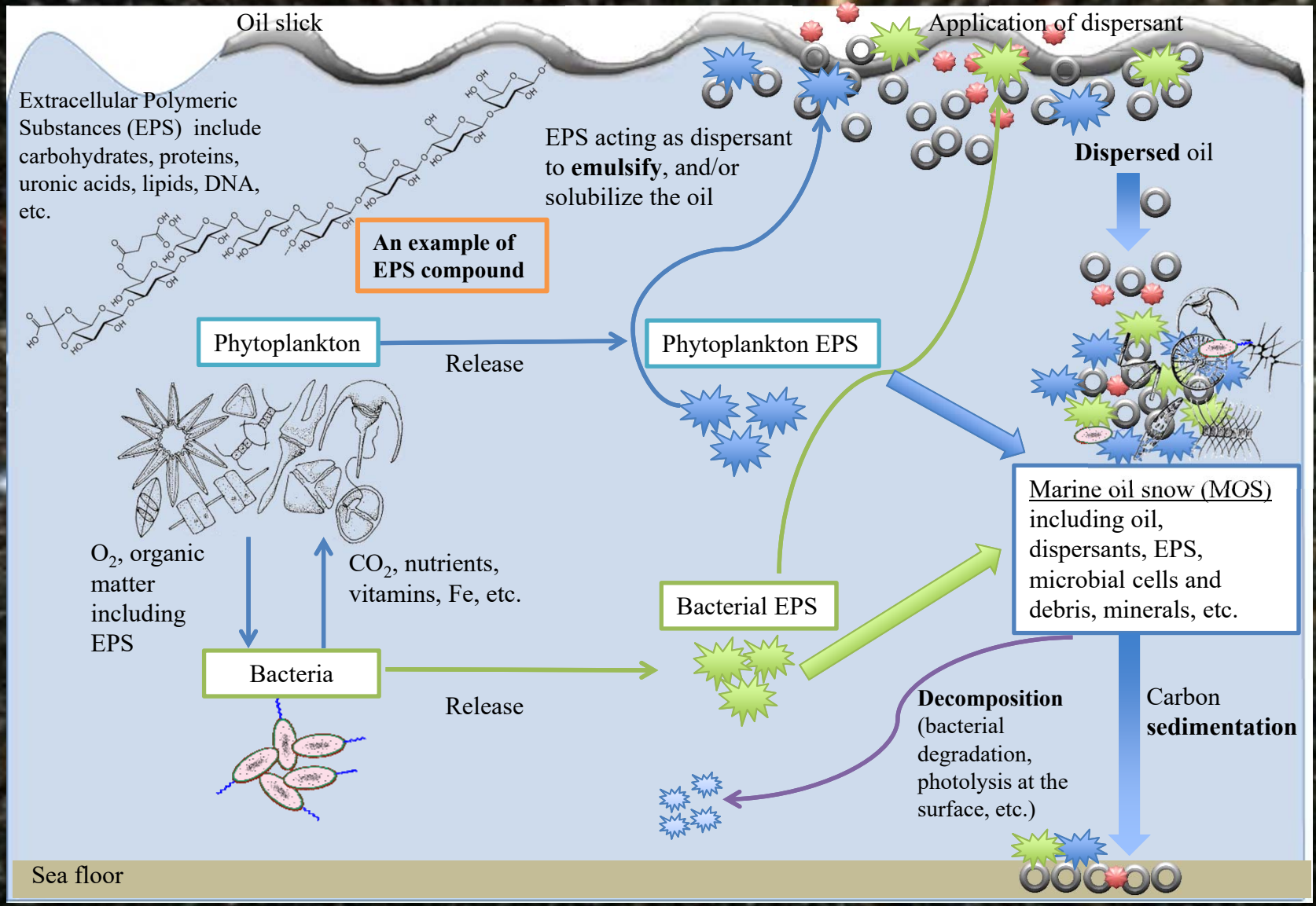
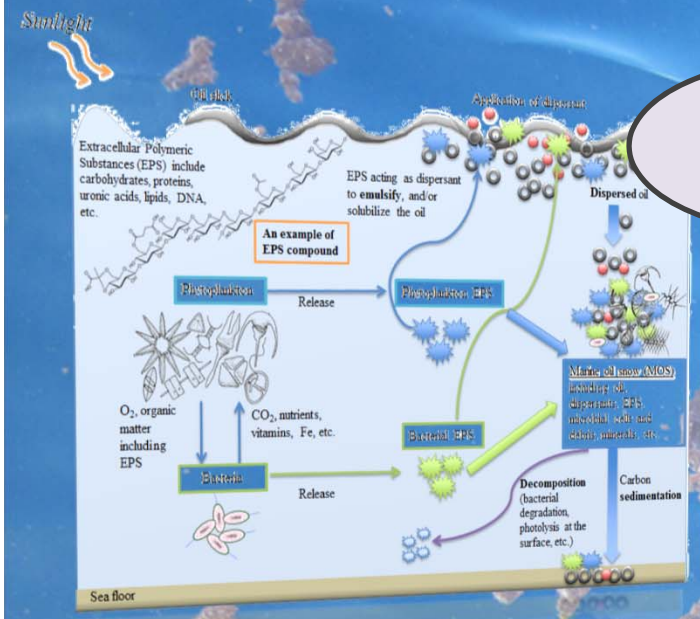
UNIVERSITY OF CALIFORNIA
Mount Allison UNIVERSITY
Department of OCEANOGRAPHY
COLLEGE OF GEOSCIENCES
Marine Macroecology and Biogeochemistry Lab
From exudates to snow: unraveling the production, and composition and relevance of aggregates to oil transport
Aggregation and Degradation of Dispersants and Oil by Microbial Exopolymers

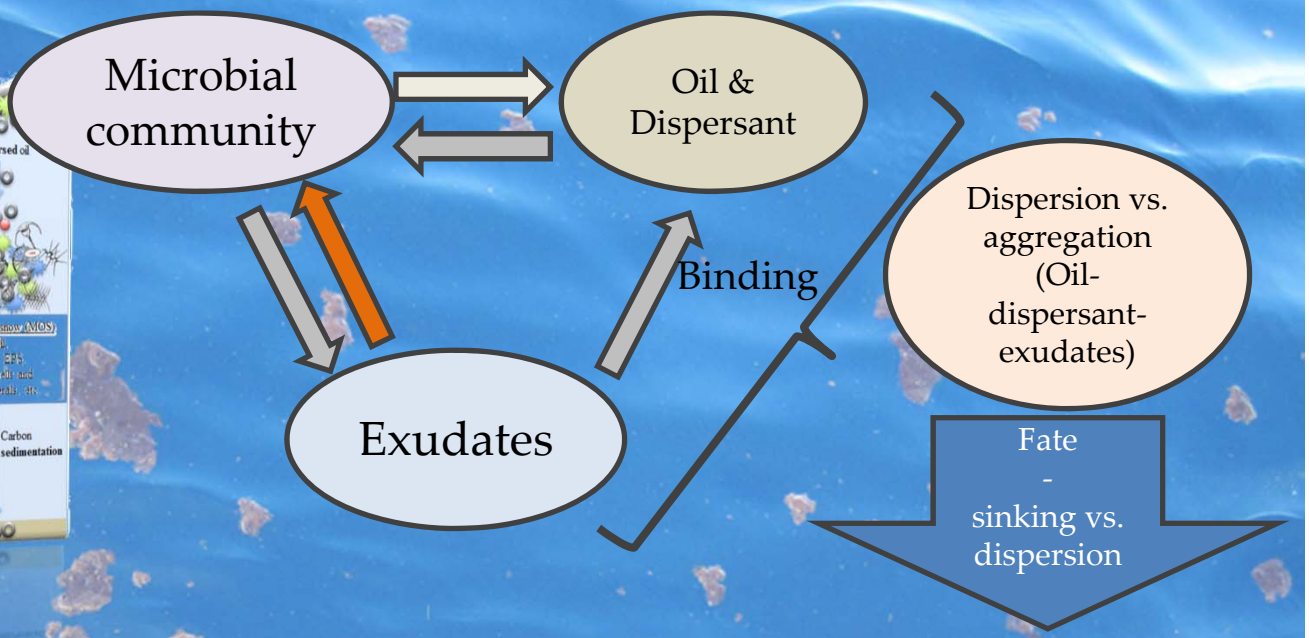
Sunlight

In the Beginning, ……



Quigg et al., *Limnol. Oceanogr. Letters*, 2016





(1) how phytoplankton and oil and non-oil-degrading microbes respond to oil and oil-dispersant mixture

(2) how MOS oil components have been modified during these processes

(3) how EPS components (carbohydrate vs. protein) aid in aggregation and/or dispersion of oil

(4) how the presence of dispersants affect the resulting ternary system (oil-dispersant-EPS) and the fate of petrocarbon

Heliyon

ELSEVIER

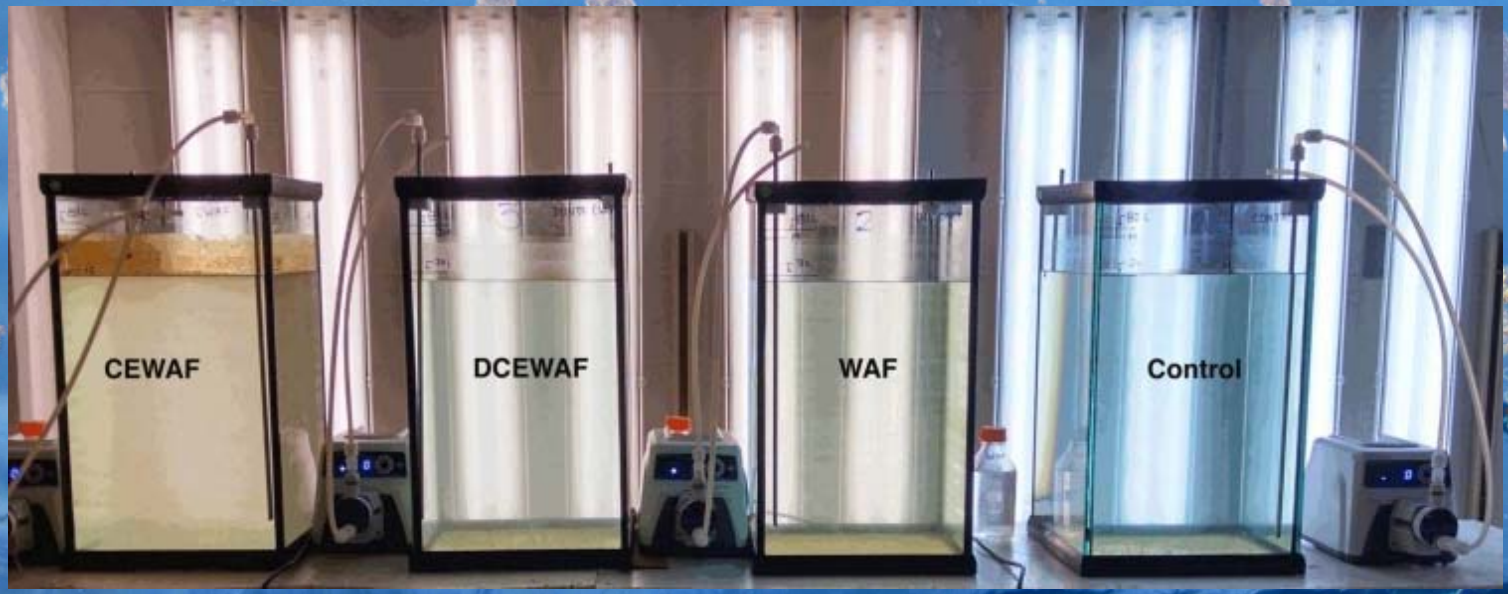
Received:
17 July 2017
Revised:
29 August 2017
Accepted:
21 September 2017

Cite as: Terry L. Wade, Maya Morales-McDevitt, Gopal Bera, Dawai Shi, Stephen Sweet, Binbin Wang, Gerado Gold-Bouchot, Antonietta Quigg, Anthony H. Knap. A method for the production of large volumes of WAF and CEWAF for dosing mesocosms to understand marine oil snow formation.
Heliyon 3 (2017) e00419.
doi: 10.1016/j.heliyon.2017.e00419

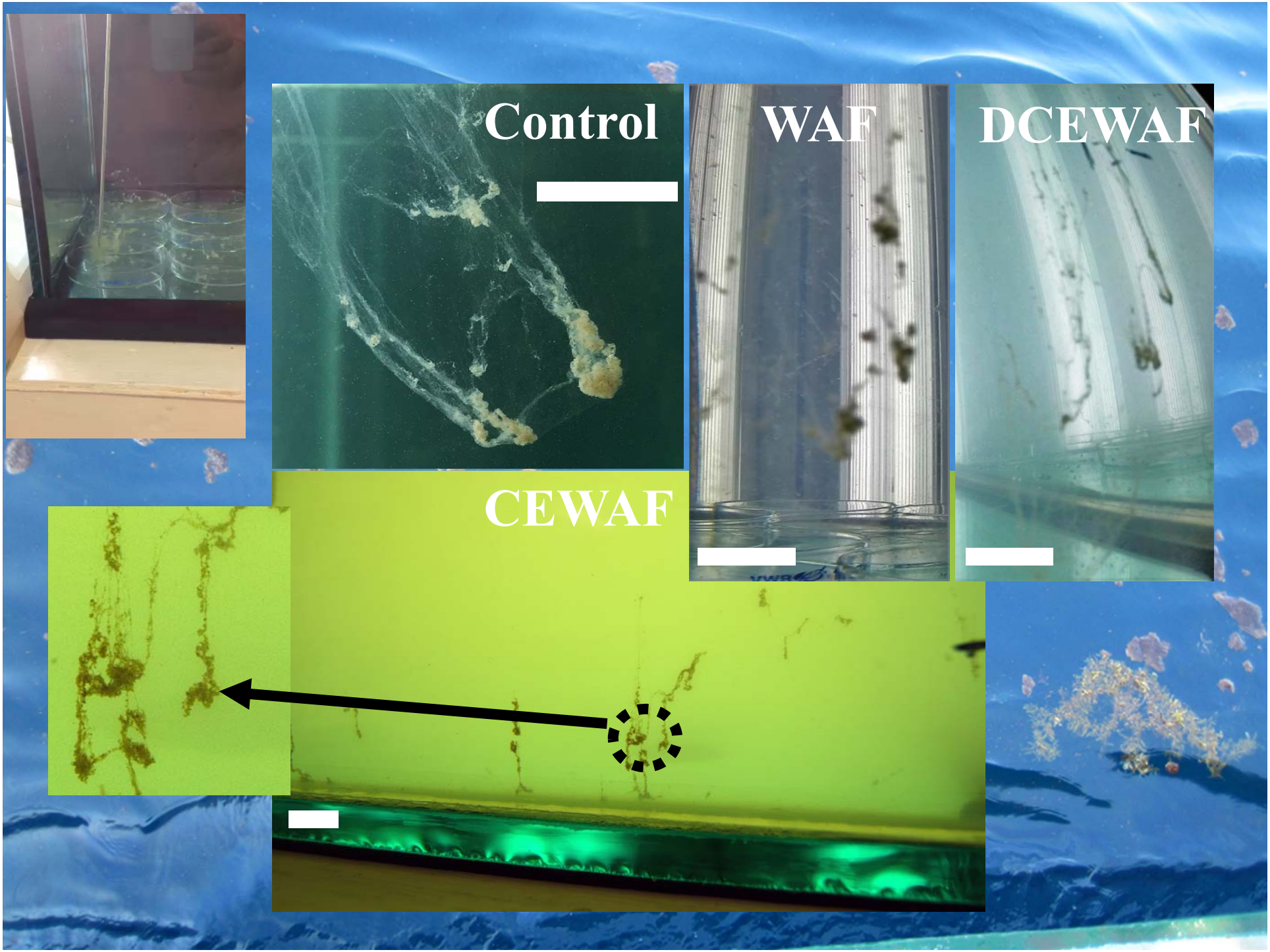
A method for the production of large volumes of WAF and CEWAF for dosing mesocosms to understand marine oil snow formation

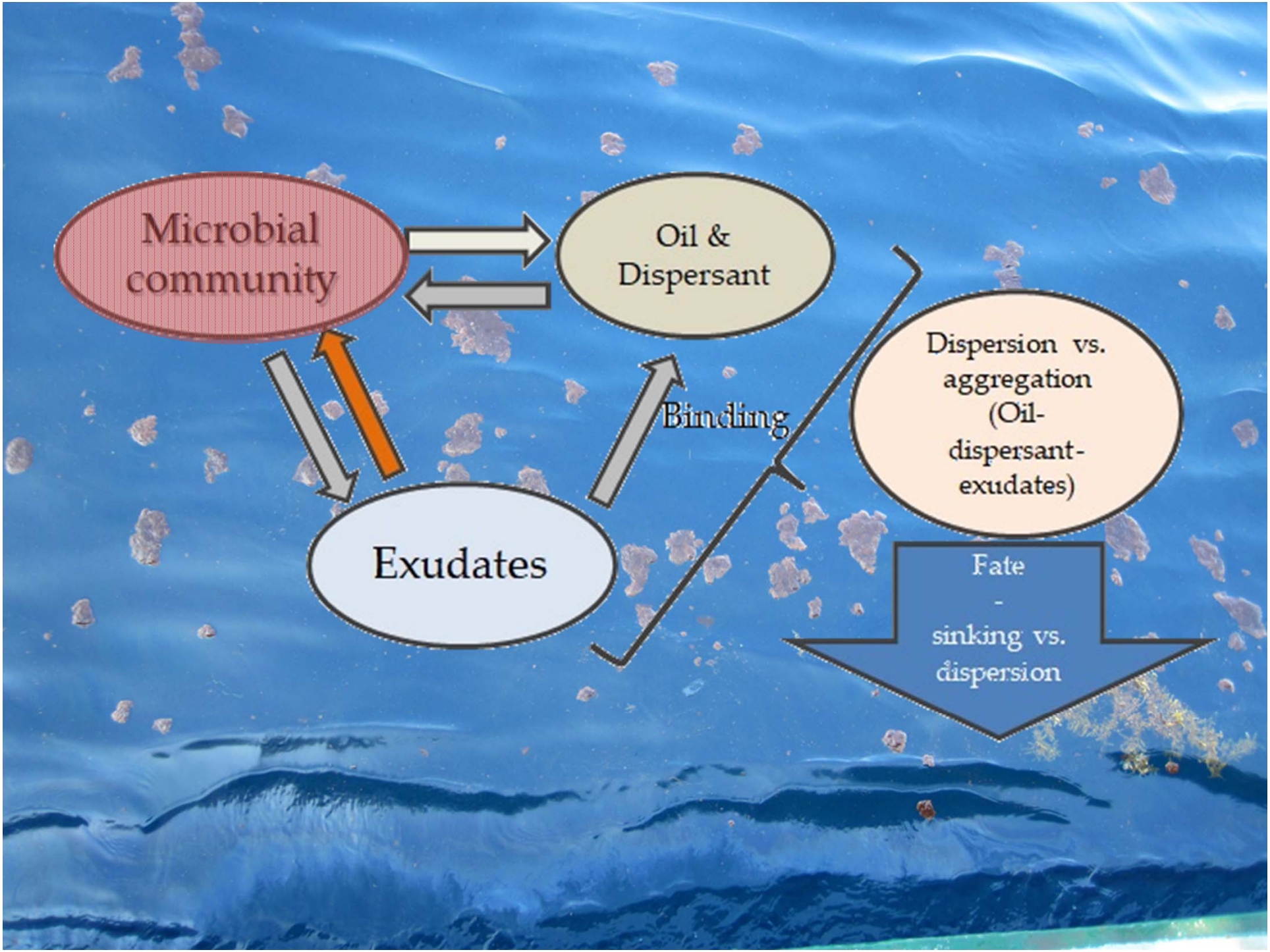
Terry L. Wade [a], Maya Morales-McDevitt [a], Gopal Bera [a], Dawai Shi [a], Stephen Sweet [a], Binbin Wang [a], Gerado Gold-Bouchot [a], Antonietta Quigg [b], Anthony H. Knap [a,*]

Baffled recirculating tanks (BRT)



Wade et al., *Heliyon*, 2017


Control
WAF
DCEWAF
CEWAF


Microbial community
Oil & Dispersant
Binding
Exudates
Dispersion vs. aggregation (Oil-dispersant-exudates)
Fate
-
sinking vs. dispersion

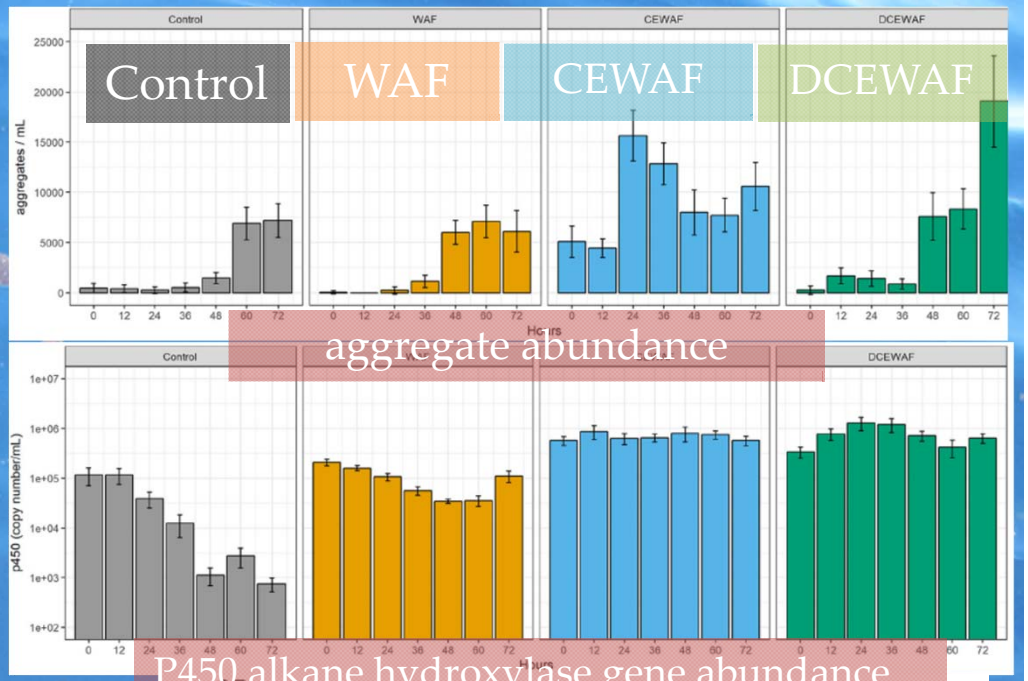
Doyle et al., *Frontiers in Microbiology*, 2018

frontiers in Microbiology

ORIGINAL RESEARCH
published: 11 April 2018
doi: 10.3389/fmicb.2018.00689

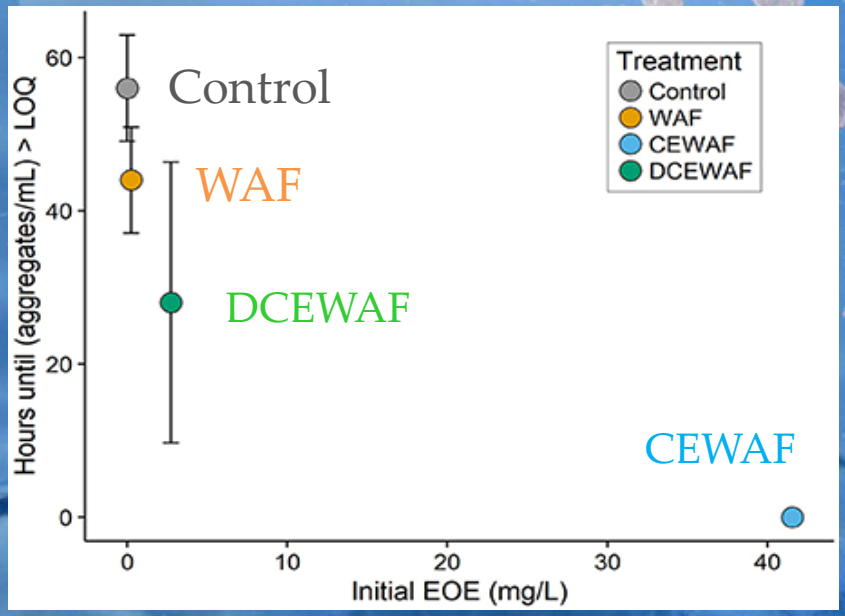
Rapid Formation of Microbe-Oil Aggregates and Changes in Community Composition in Coastal Surface Water Following Exposure to Oil and the Dispersant Corexit

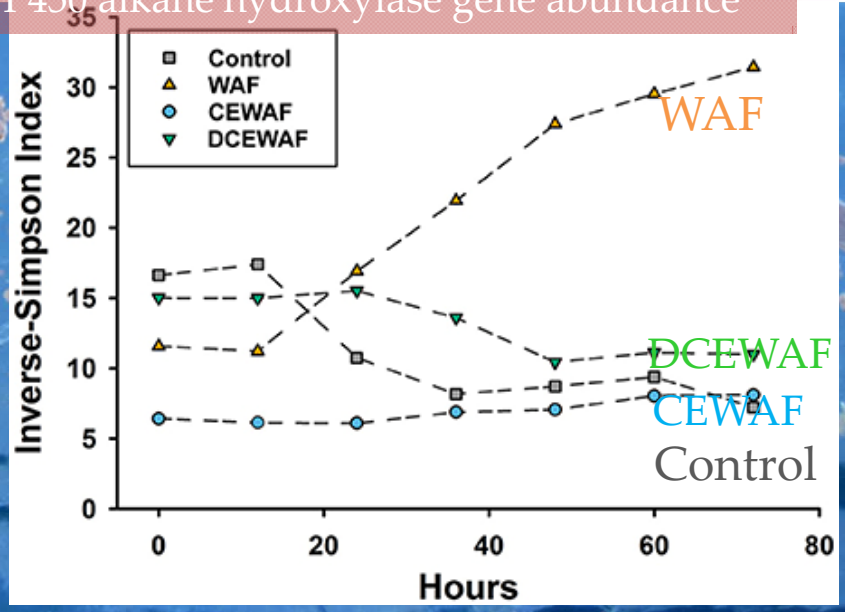
Shawn M. Doyle[1], Emily A. Whitaker[1], Veronica De Pascuale[1], Terry L. Wade[1,2], Anthony H. Knap[1,2], Peter H. Santschi[1,3], Antonietta Quigg[1,4] and Jason B. Sylvan[1]*



aggregate abundance

P450 alkane hydroxylase gene abundance





Phytoplankton responses are species-specific, some are tolerant or grow better in oil/dispersant

J. Phycol. 54, 317–328 (2018)

DOI: 10.1111/jpy.12625

PHYSIOLOGICAL RESPONSE OF 10 PHYTOPLANKTON SPECIES EXPOSED TO MACONDO OIL AND THE DISPERSANT, COREXIT[1]

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Alicia Williams
Department of Marine Sciences, University of New England, Biddeford, Maine 04005, USA
Jennifer Genzer, Jessica Hillhouse, Manoj Kamalanathan
Department of Marine Biology, Texas A&M University at Galveston, Galveston, Texas 77553, USA
Zoe V. Finkel
Environmental Science, Mount Allison University, Sackville, New Brunswick, Canada E4L 1E4
and Antonietta Quigg
Department of Marine Biology, Texas A&M University at Galveston, Galveston, Texas 77553, USA
Department of Oceanography, Texas A&M University, College Station, Texas 77843, USA

Bretherton et al., *J. Phycol.*, 2018a

- Exposure to WAF did not cause a significant change in the photophysiology of the phytoplankton community, but CEWAF inhibited photosynthetic rates and quantum yield.

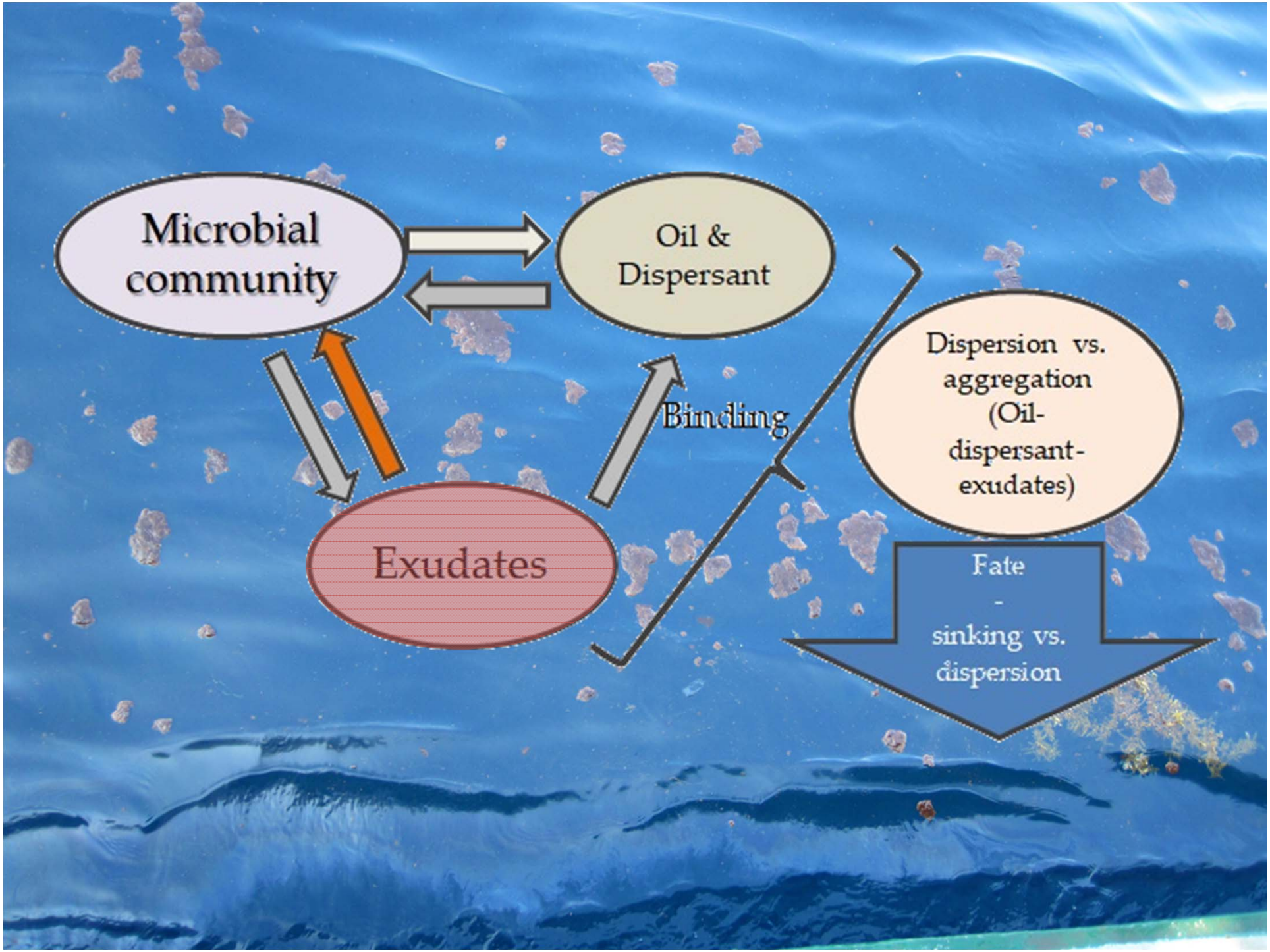
Accepted Manuscript

Title: Response of natural phytoplankton communities exposed to crude oil and chemical dispersants during a mesocosm experiment

Authors: Laura Bretherton, Manoj Kamalanathan, Jennifer Genzer, Jessica Hillhouse, Samantha Setta, Yue Liang, Chris M. Brown, Chen Xu, Julia Sweet, Uta Passow, Zoe V. Finkel, Andrew J. Irwin, Peter H. Santschi, Antonietta Quigg

Bretherton et al., *Aquatic Toxicoloty*, 2018b

- Diatom dominated communities in both control and WAF tanks, while other heterotrophic and mixotrophic eukaryotes dominated in the CEWAF and DCEWAF


Microbial community
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sinking vs. dispersion

Kamalanathan et al., *Frontiers in Microbiology*, 2018

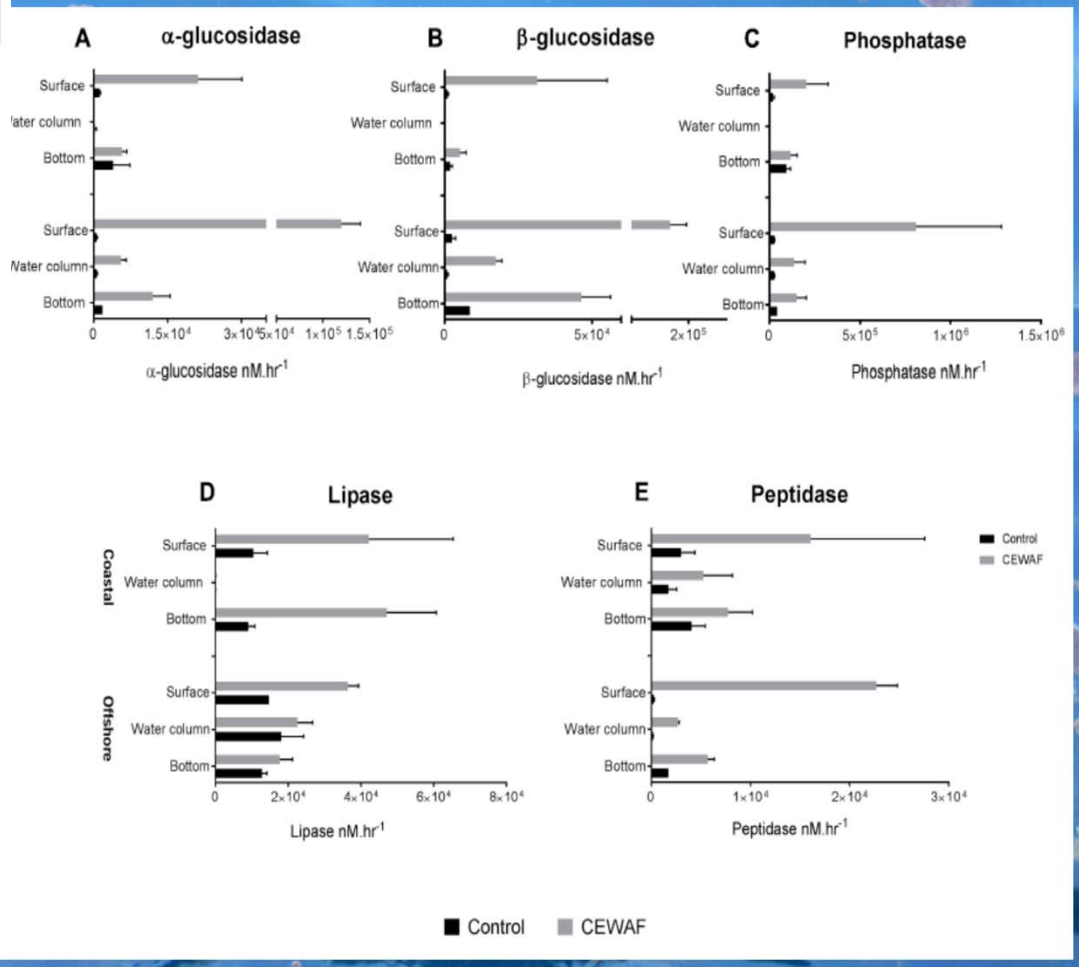
frontiers in Microbiology

ORIGINAL RESEARCH
published: 24 April 2018
doi: 10.3389/fmicb.2018.00798

Check for updates

Extracellular Enzyme Activity Profile in a Chemically Enhanced Water Accommodated Fraction of Surrogate Oil: Toward Understanding Microbial Activities After the Deepwater Horizon Oil Spill

Manoj Kamalanathan[1], Chen Xu[2], Kathy Schwehr[2], Laura Bretherton[1], Morgan Beaver[2], Shawn M. Doyle[3], Jennifer Genzer[1], Jessica Hillhouse[1], Jason B. Sylvan[3], Peter Santschi[2,3] and Antonietta Quigg[1,3]*



Higher extracellular enzymatic activity and EPS production were observed in CEWAF relative to Control, concurrent with

1) higher bacterial cell and
2) micro-aggregate abundances

Xu et al., *Marine Chemistry*, 2018

Marine Chemistry 206 (2018) 52–61

Contents lists available at ScienceDirect

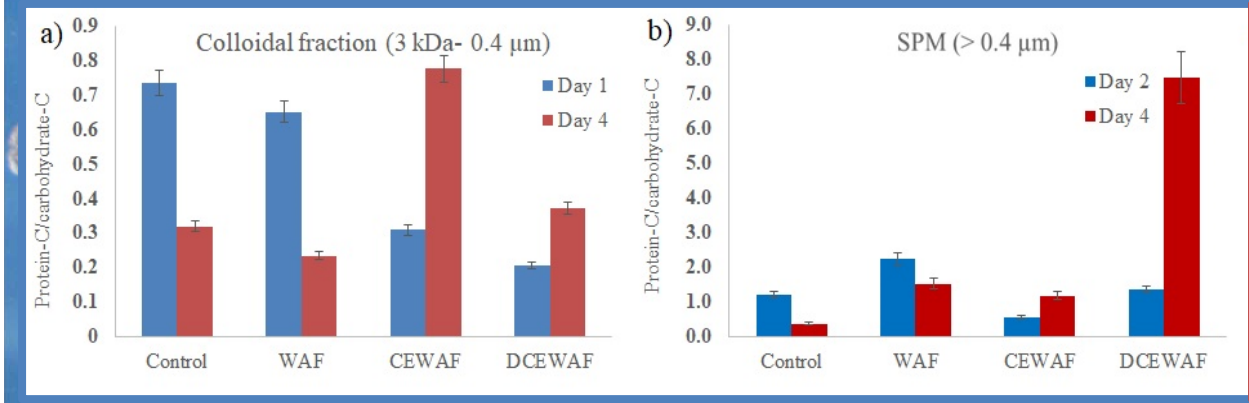
Marine Chemistry

journal homepage: www.elsevier.com/locate/marchem

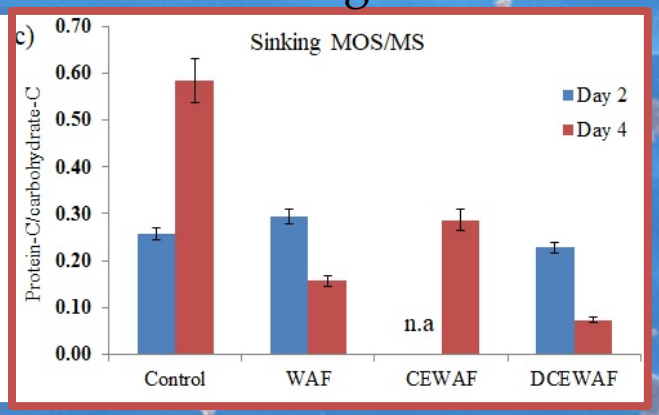
The role of microbially-mediated exopolymeric substances (EPS) in regulating Macondo oil transport in a mesocosm experiment

Chen Xu[a,*,1], Saijin Zhang[a,1], Morgan Beaver[a], Peng Lin[a], Luni Sun[a], Shawn M. Doyle[b], Jason B. Sylvan[b], Andrew Wozniak[c], Patrick G. Hatcher[d], Karl Kaiser[a], Ge Yan[a], Kathleen A. Schwehr[a], Youmin Lin[a], Terry L. Wade[b], Wei-Chun Chin[e], Meng-Hsuen Chiu[e], Antonietta Quigg[b,f], Peter H. Santschi[a,b]

Water column



Sinking MOS



- WAF stimulated extracellular polysaccharide production
- CEWAF stimulated overall EPS production but more protein production
- Corexit also promoted the association between oil and the hydrophobic components of EPS, mainly protein, resulting in a higher protein-C/carbohydrate-C ratio in the water column (colloid+ SPM) and a lower protein-C/carbohydrate-C in the sinking MOS.

Contents lists available at ScienceDirect

Marine Chemistry

journal homepage: www.elsevier.com/locate/marchem

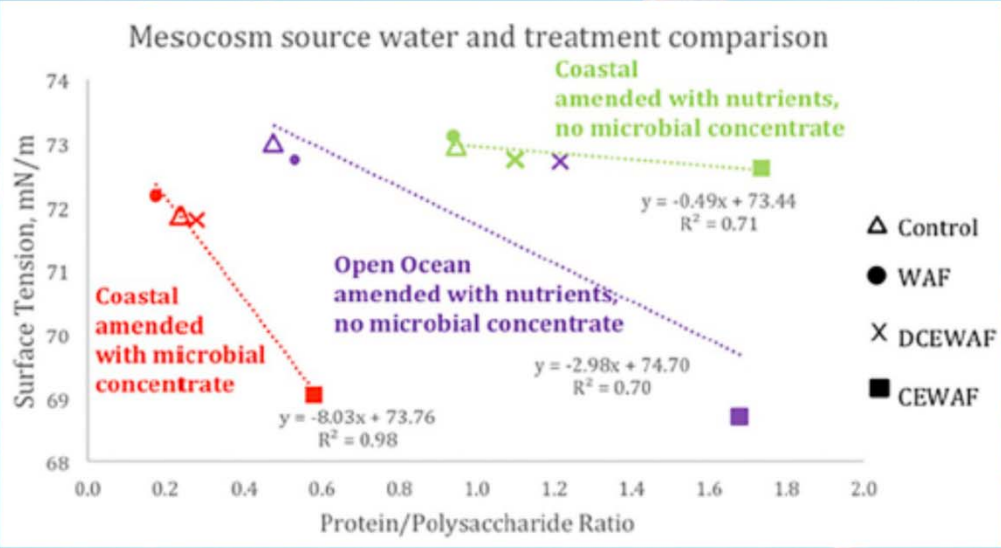
ELSEVIER

Review article

Protein: Polysaccharide ratio in exopolymeric substances controlling the surface tension of seawater in the presence or absence of surrogate Macondo oil with and without Corexit

Kathleen A. Schwehr[a,*], Chen Xu[a], Meng-Hsuen Chiu[b], Saijin Zhang[a], Luni Sun[a], Peng Lin[a], Morgan Beaver[a], Cameron Jackson[c], Oscar Agueda[a], Charles Bergen[a], Wei-Chun Chin[b],

Schwehr et al., *Marine Chemistry*, 2018



	Effectiveness, SFT mN/m	Efficiency, CMC concentration mg/L
Corexit	~32	23
Corexit	41.5	22.2
BSA protein	~68	1.4 < CMC > 10
Glucuronic acid	~75	0.24 < CMC > 1
Carrageenan, lambda	73	1

- The presence of oil and/Corexit enhanced the Protein-C/Carbohydrate-C ratio of colloidal EPS yet lowered the surface tension.
- EPS is more efficient than Corexit in causing the self-assembly of micelles in the seawater (i.e., a lower critical micelle concentration)

The effect of sunlight on aggregation

Contents lists available at ScienceDirect

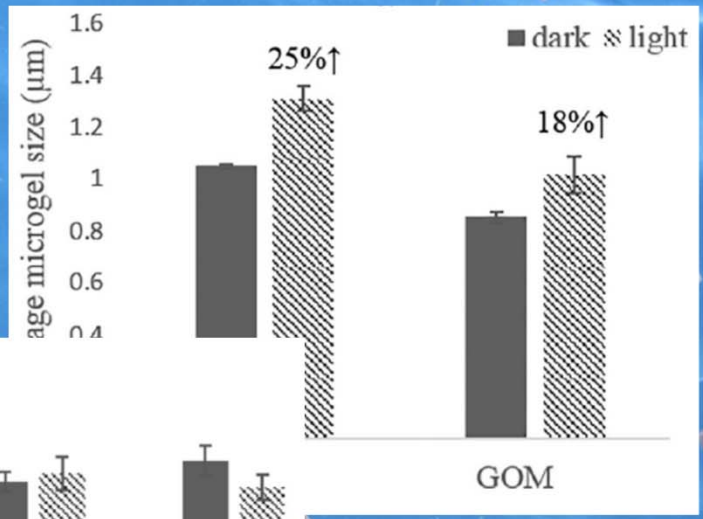
Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Light-induced aggregation of microbial exopolymeric substances

Luni Sun [a,*], Chen Xu [a], Saijin Zhang [a], Peng Lin [a], Kathleen A. Schwehr [a], Antonietta Quigg [b], Meng-Hsuen Chiu [c], Wei-Chun Chin [c], Peter H. Santschi [a]

[a] Department of Marine Science, Texas A&M University Galveston campus, Galveston, TX 77553, USA
[b] Department of Marine Biology, Texas A&M University Galveston campus, Galveston, TX 77553, USA
[c] Bioengineering Program, School of Engineering, University of California at Merced, Merced, CA 95343, USA



Contents lists available at ScienceDirect

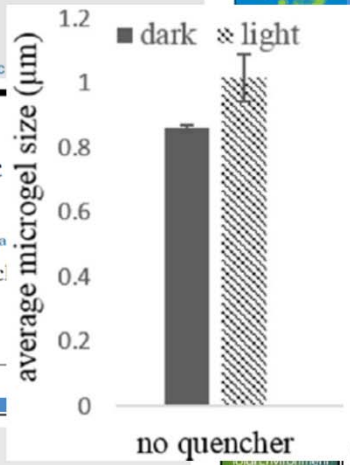
Marine Chemistry

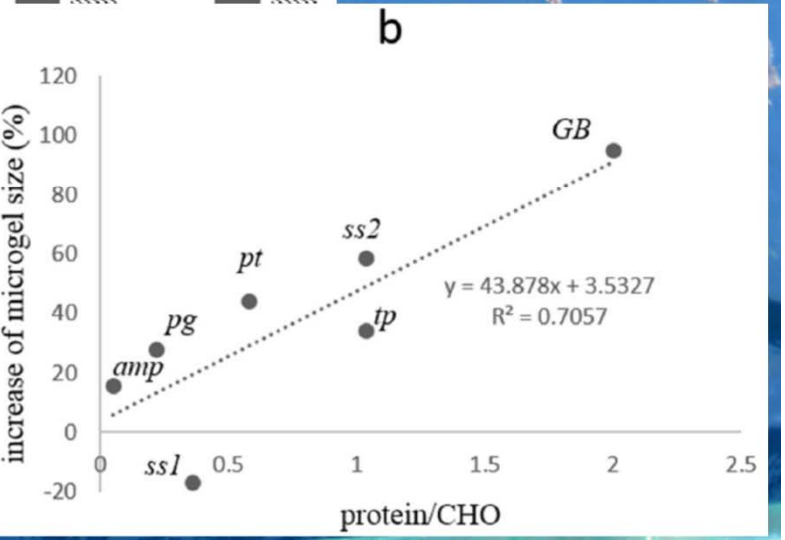
journal homepage: www.elsevier.com/locate/marc

The effects of sunlight on the composition of exopolymeric subsequent aggregate formation during oil spills

Luni Sun[a,*], Meng-Hsuen Chiu[b], Chen Xu[a], Peng Lin[a], Kathleen A. Schwehr[a], Manoj Kamalanathan[c], Antonietta Quigg[c], Wei-Chun Chin[b], Peter H. Santschi

[a] Department of Marine Sciences, Texas A&M University at Galveston, Galveston, TX 77553, USA
[b] Bioengineering, School of Engineering, University of California at Merced, Merced, CA 95343, USA
[c] Department of Marine Biology, Texas A&M University at Galveston, Galveston, TX 77553, USA





Contents lists available at ScienceDirect

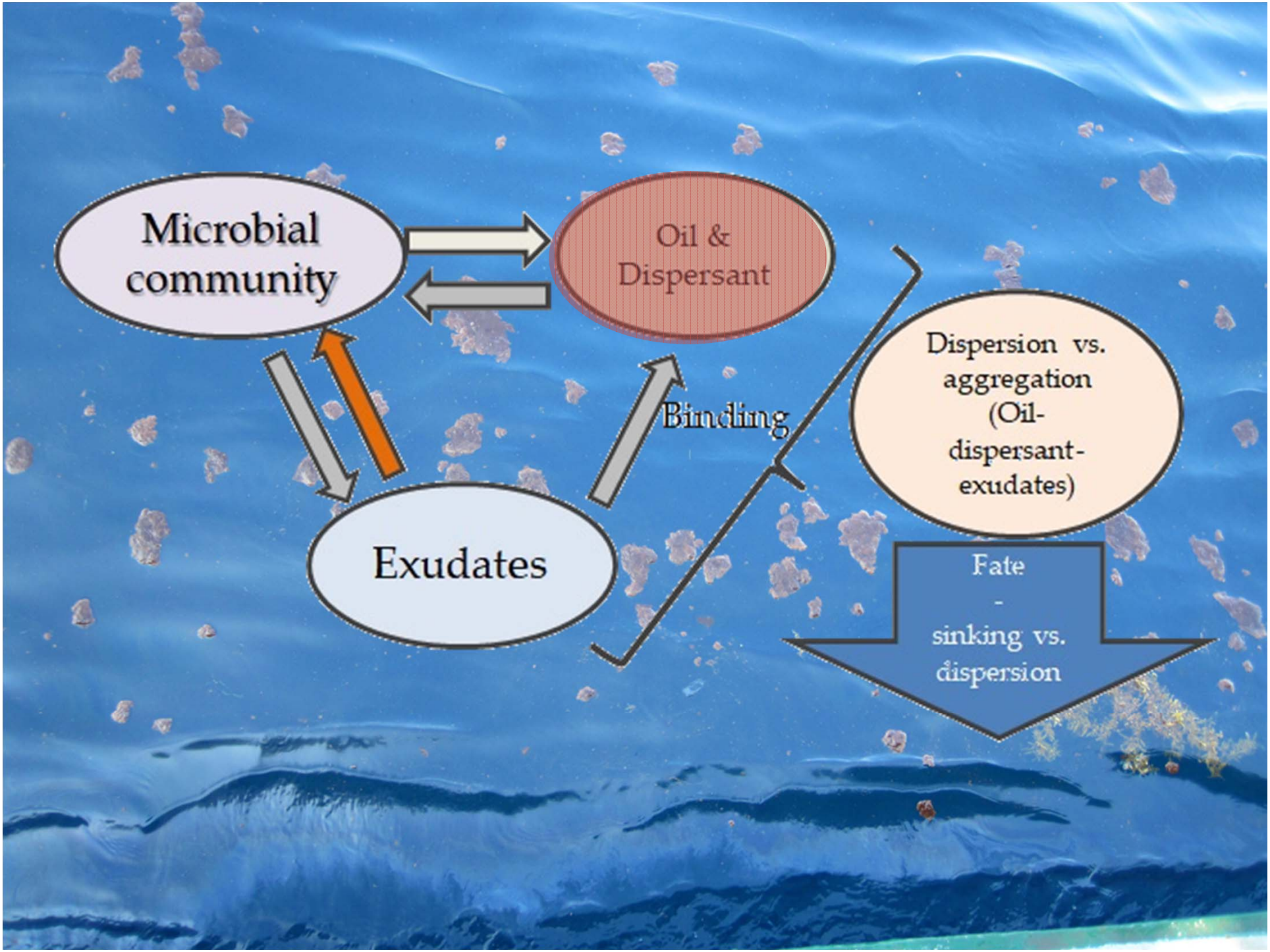
Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Sunlight induced aggregation of dissolved organic matter: Role of proteins in linking organic carbon and nitrogen cycling in seawater

Luni Sun [a,*], Wei-Chun Chin [b], Meng-Hsuen Chiu [b], Chen Xu [a], Peng Lin [a], Kathleen A. Schwehr [a], Antonietta Quigg [c], Peter H. Santschi [a]

[a] Department of Marine Science, Texas A&M University at Galveston, Galveston, TX 77553, USA
[b] Bioengineering, School of Engineering, University of California at Merced, Merced, CA 95343, USA
[c] Department of Marine Biology, Texas A&M University at Galveston, Galveston, TX 77553, USA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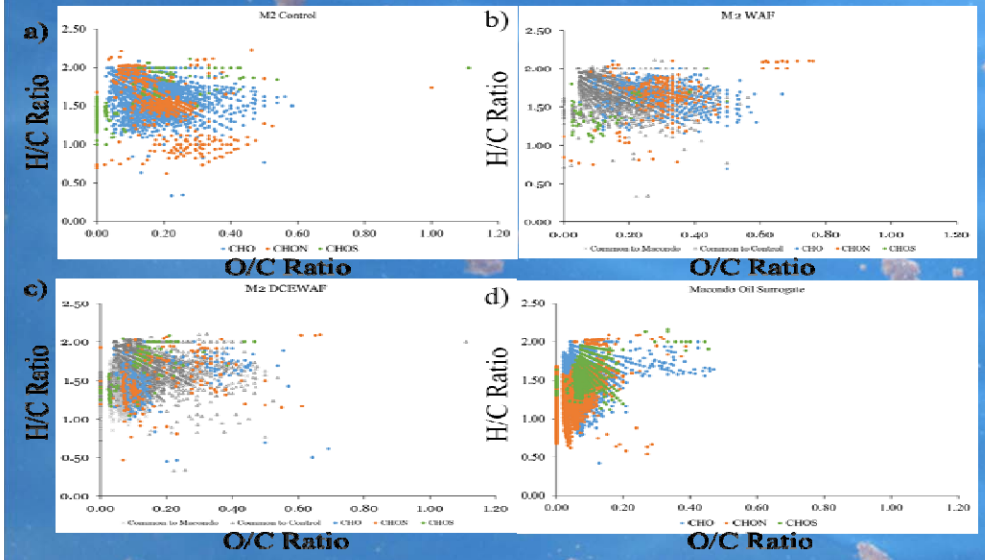
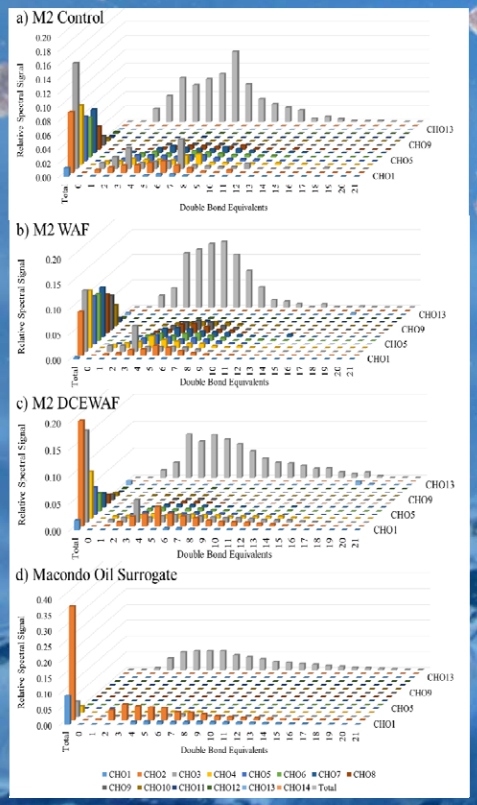
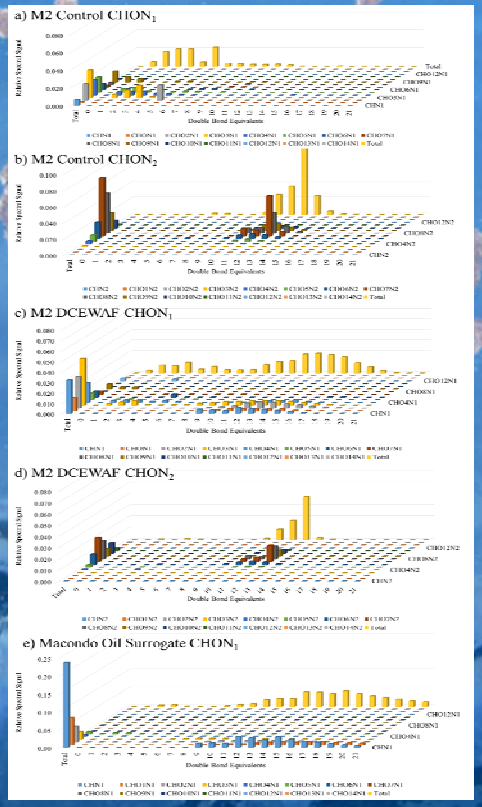


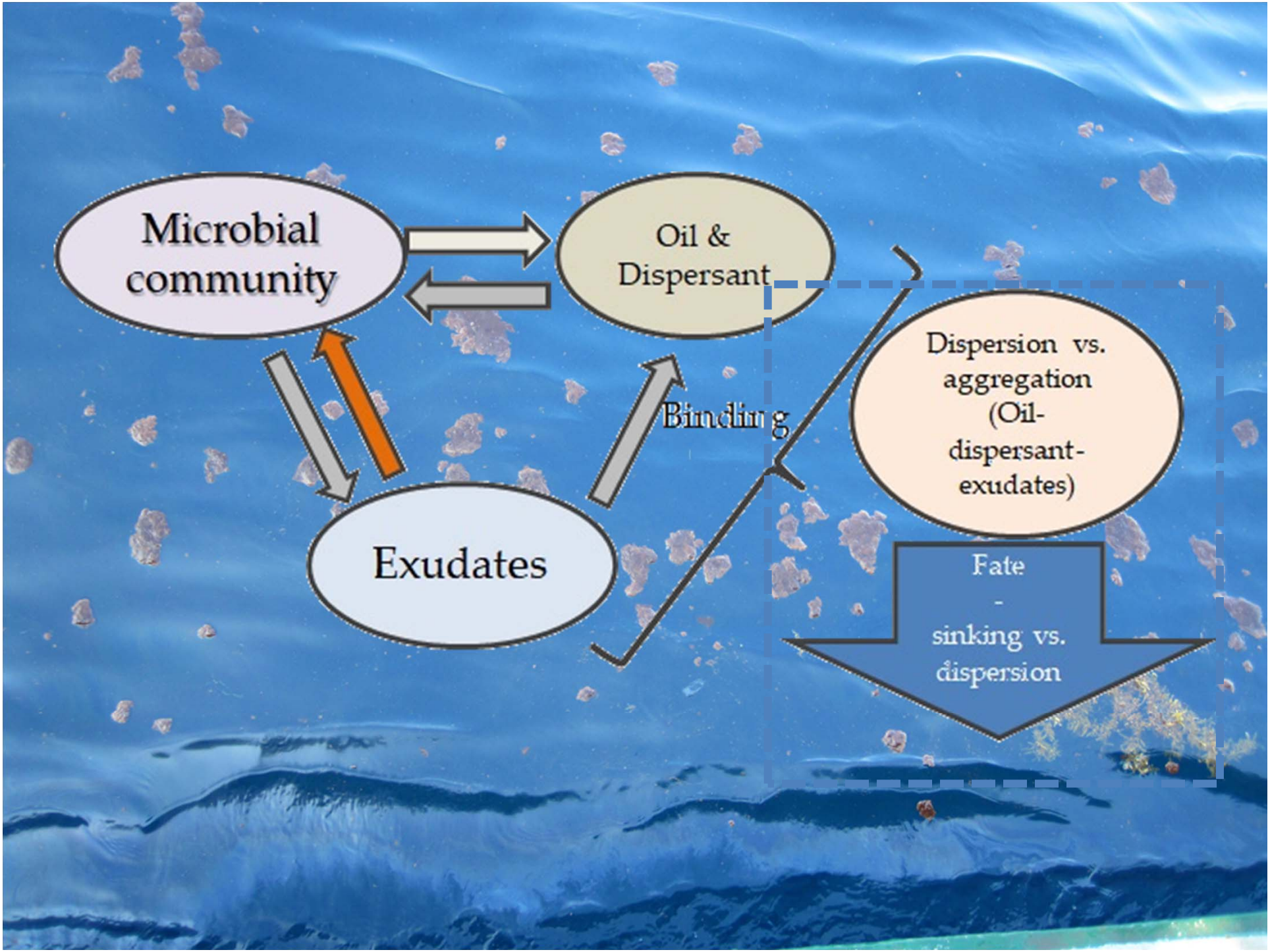




Wozniak et al. re-submitted to *ES&T*, 2018

Rapid degradation of oil in mesocosm simulations of marine oil snow events

- Similar iso-abundance distributions to those found in degraded oil.
- Biological degradation processes was responsible for the oil degradation over the short timescale (< 4 days) of the experiments.
- Oil degradation occurs within MOS during transit below the euphotic zone to the sediments, the majority of MOS lifetime.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Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

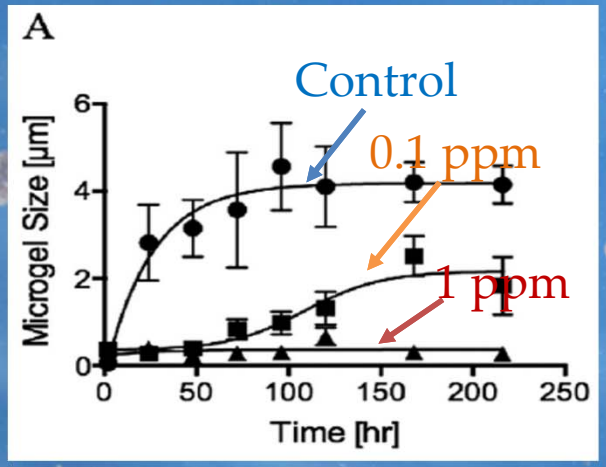
Chiu et al., *MPB*, 2017

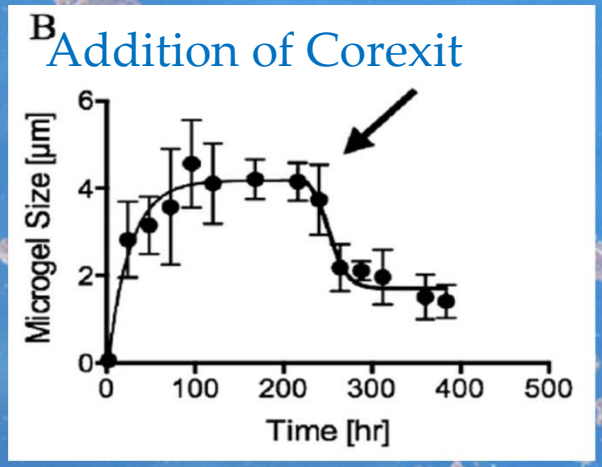
Note

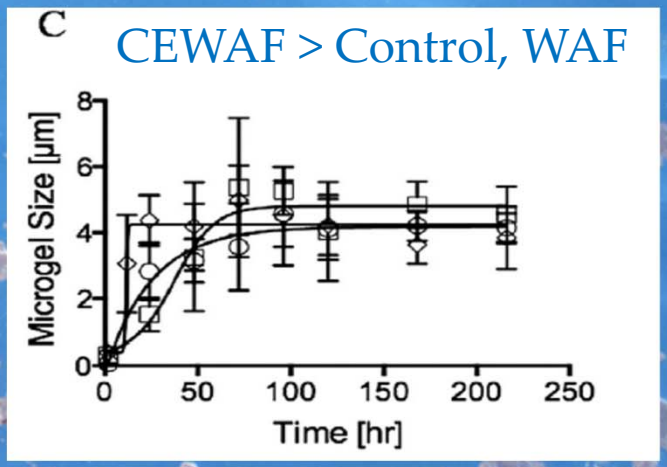
Corexit, oil and marine microgels

Meng-Hsuen Chiu[a], Santiago G. Garcia[a], Benjamin Hwang[a], Devon Claiche[a], Gabriela Sanchez[a], Reef Aldayafleh[a], Shih-Ming Tsai[a], Peter H. Santschi[b], Antonietta Quigg[c], Wei-Chun Chin[a,*]

[a] School of Engineering, University of California at Merced, Merced, CA, USA
[b] Department of Marine Science, Texas A & M University at Galveston, Galveston, TX, USA
[c] Department of Marine Biology, Texas A & M University at Galveston, Galveston, TX, USA







- Corexit alone can inhibit EPS aggregation and disperse pre-existing microgels.
- CEWAF can facilitate EPS aggregation
- EPS aggregates with higher protein-C/carbohydrate-C ratios (i.e., more hydrophobic) showed high resistance to Corexit dispersion, while EPS with lower protein-C/carbohydrate-C ratios (i.e., more hydrophilic) were more less resistant (Chiu et al., *STOTEN*, 2018)

Xu et al., *Marine Chemistry*, 2018b

Marine Chemistry 206 (2018) 34–43

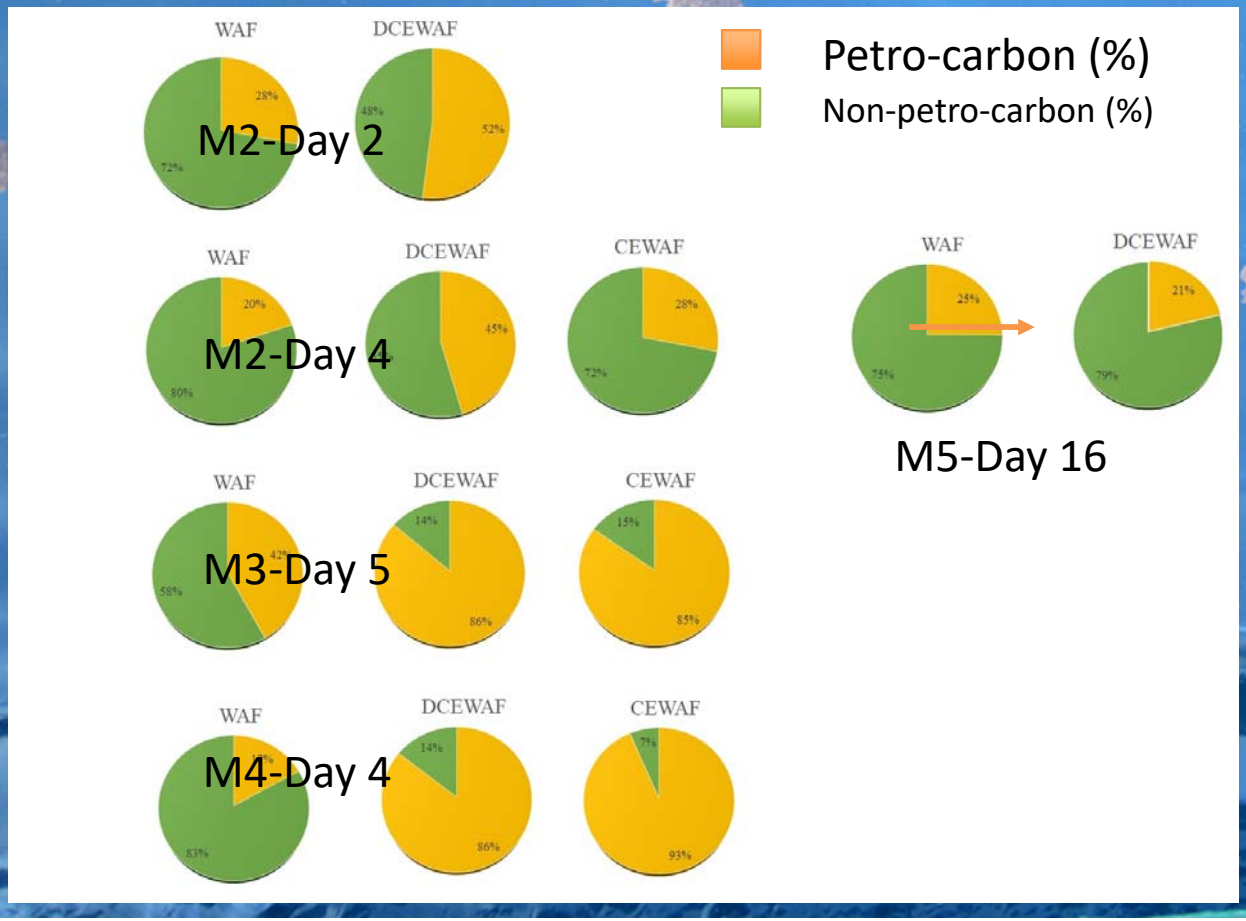
Contents lists available at ScienceDirect

Marine Chemistry

journal homepage: www.elsevier.com/locate/marchem

Decreased sedimentation efficiency of petro- and non-petro-carbon caused by a dispersant for Macondo surrogate oil in a mesocosm simulating a coastal microbial community

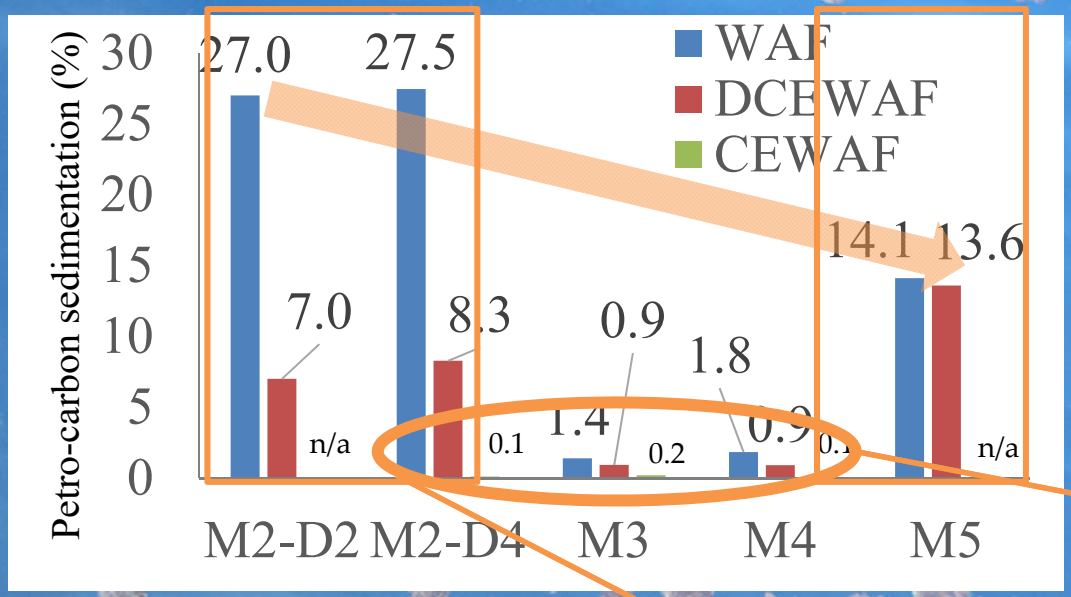
Chen Xu[a,*,1], Saijin Zhang[a,1], Morgan Beaver[a], Andrew Wozniak[b], Wassim Obeid[c], Youmin Lin[a], Terry L. Wade[d], Kathleen A. Schwehr[a], Peng Lin[a], Luni Sun[a], Patrick G. Hatcher[c], Wei-Chun Chin[e], Meng-Hsuen Chiu[e], Anthony H. Knap[d], Kendra Dean[a], Antonietta Quigg[d,f], Peter H. Santschi[a,d]



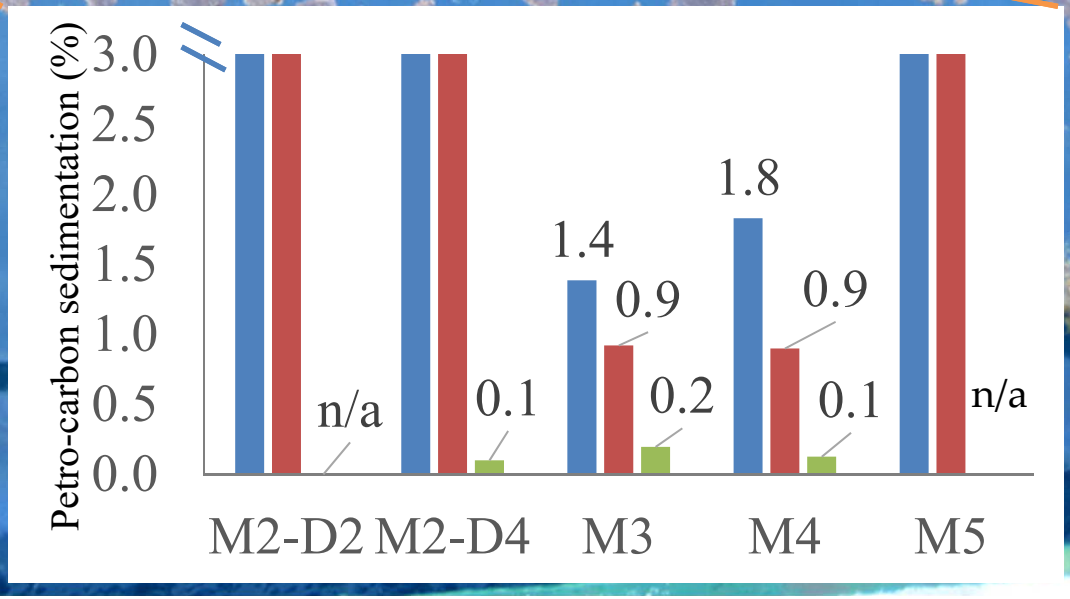
- Corexit enhanced the oil incorporation into sinking MOS in the short term.
- Petro-carbon % in MOS decrease with time (M2-D2, D4 vs. M5 D16).
- In short term, CEWAF or DCEWAF has higher % petro-carbon than WAF; in the longer term, such carbon composition is less influenced by the presence of Corexit.

Petro-carbon sedimentation efficiency

Xu et al., *in preparation*



- Within a week, coastal phytoplankton-seeded (M2) has the highest petro-carbon sedimentation efficiency in WAF and DCEWAF compared to other open ocean or coastal water w/t seeding.
- No significant difference between open ocean and coastal water (M3 vs. M4).



- In short term, WAF has higher petro-carbon sedimentation efficiency than DCEWAF and CEWAF (M2, M3 and M4). In the longer term (D16), petro-carbon sedimentation efficiency of WAF decreased and that of DCEWAF increased and close to each other.

—***the presence of Corexit slow down the sedimentation of the MOS***

Marine Pollution Bulletin 126 (2018) 159–165

Contents lists available at ScienceDirect

Marine Pollution Bulletin

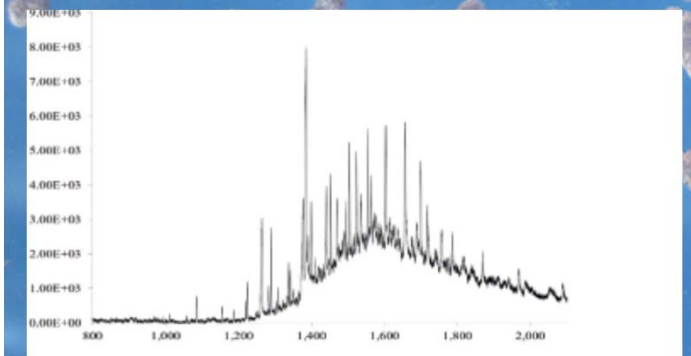
journal homepage: www.elsevier.com/locate/marpolbul

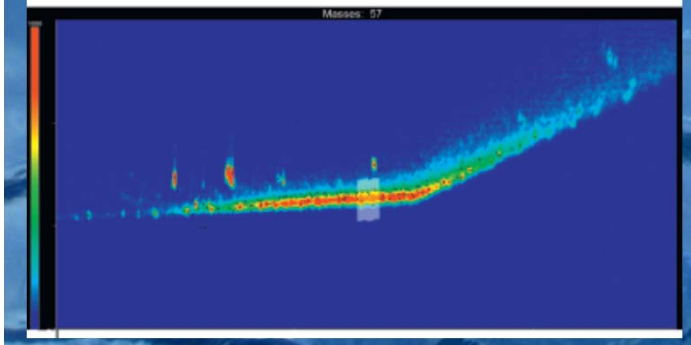
Hatcher et al., *MPB*, 2018

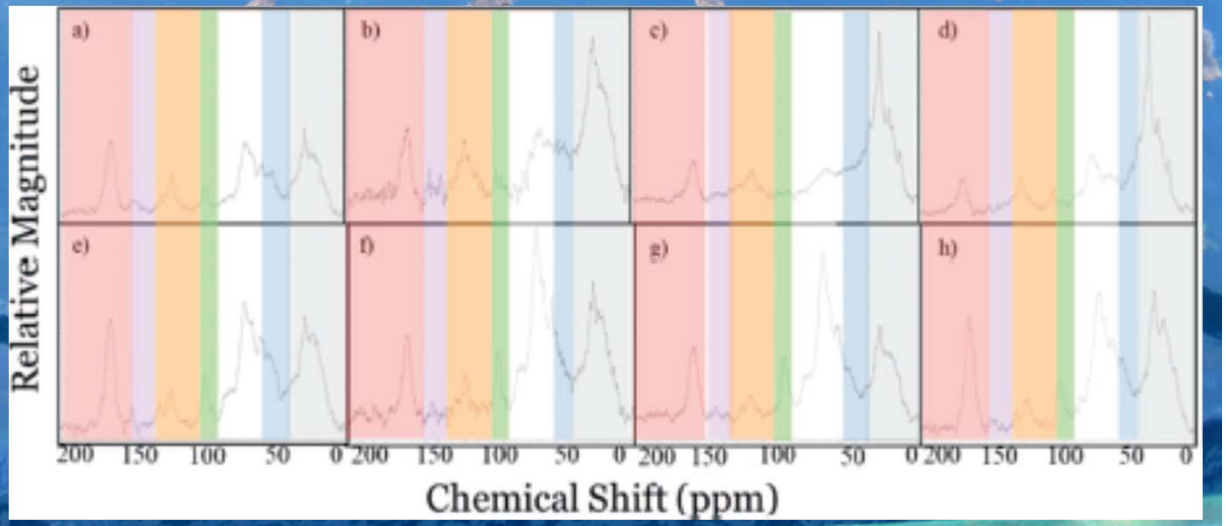
Identifying oil/marine snow associations in mesocosm simulations of the Deepwater Horizon oil spill event using solid-state ^{13}C NMR spectroscopy

Patrick G. Hatcher[a,*], Wassim Obeid[a], Andrew S. Wozniak[a], Chen Xu[b], Saijin Zhang[b], Peter H. Santschi[b,c], Antonietta Quigg[c,d]

[a] Department of Chemistry and Biochemistry, Old Dominion University, Norfolk, VA 23529, United States
[b] Department of Marine Sciences, Texas A&M University at Galveston, Galveston, TX 77553, USA
[c] Department of Oceanography, Texas A&M University, College Station, TX 77843, USA
[d] Department of Marine Biology, Texas A&M University at Galveston, Galveston, TX 77553, USA

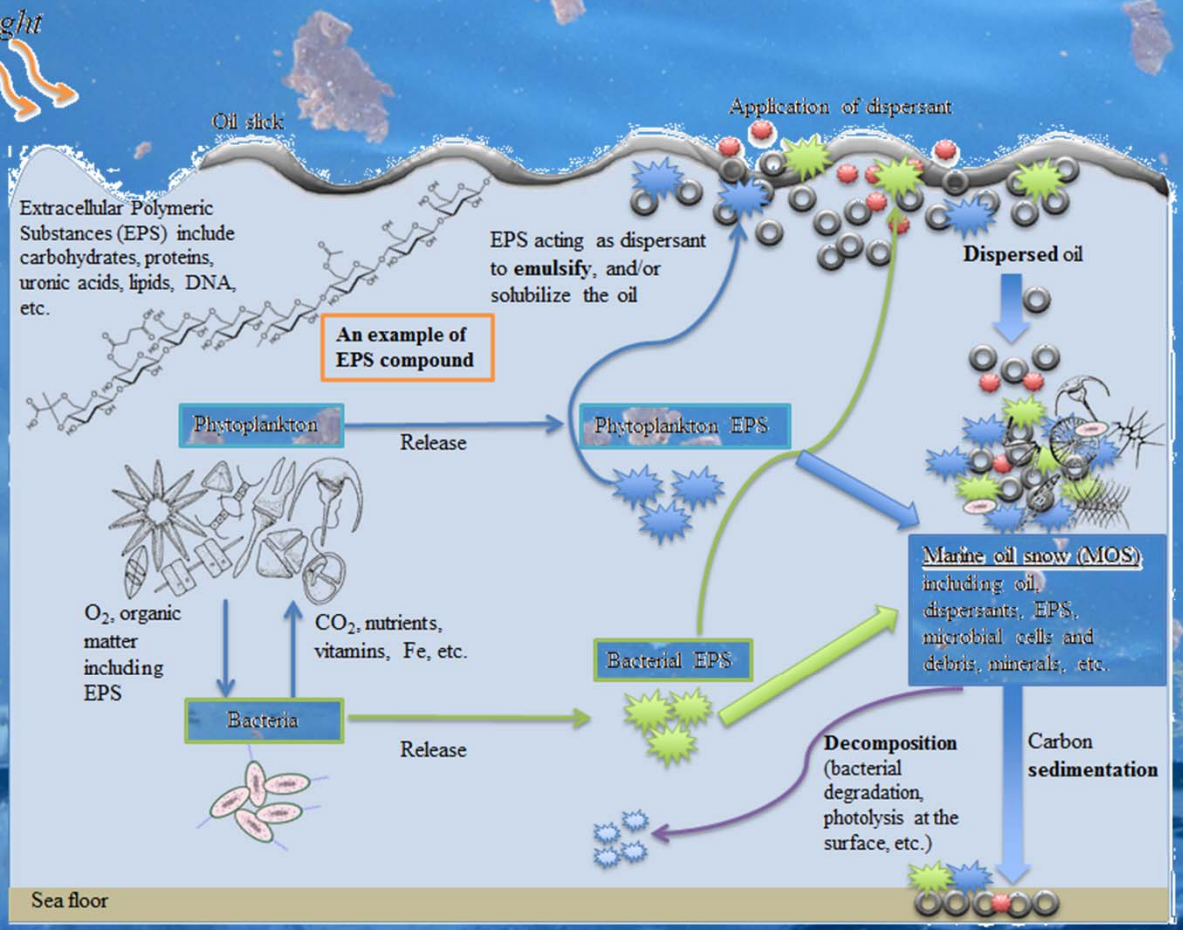






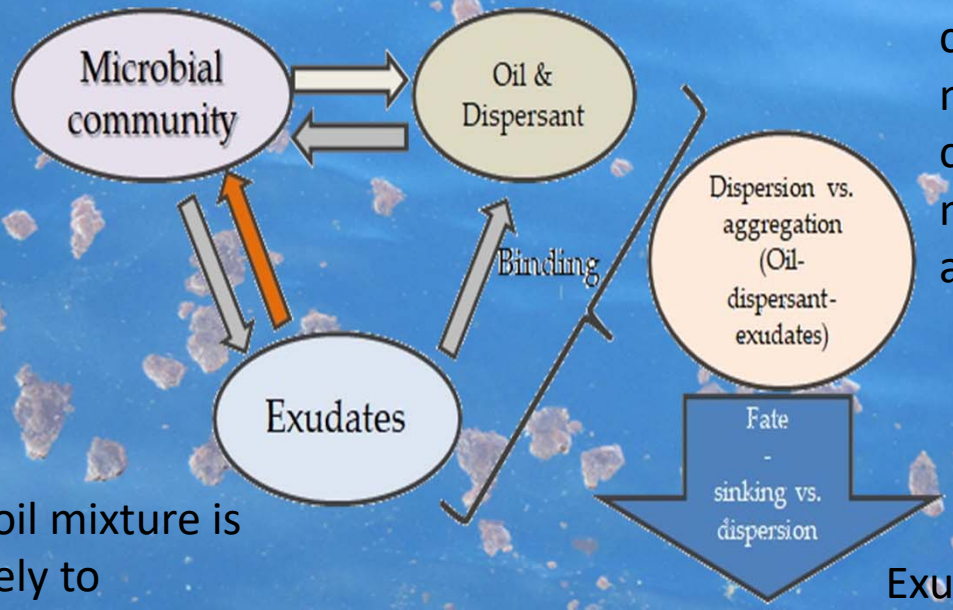
CONCLUSIONS

In the beginning…..



CONCLUSIONS

Responses are species-specific and differ depending on if oil or oil plus dispersant is present

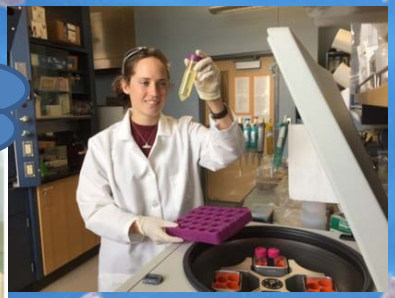


Oil-dispersant exudates have a different composition than natural exudates; they contain oxidized oil at much higher abundance

Corexit/oil mixture is more likely to induce exudate production, faster and more abundant slow-sinking aggregates

Exudates combined with oil enhance the sinking of MOS; but if dispersant is present, more oil stays dispersed in non-sinking colloids/SPM

Acknowledgements



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THANK YOU!