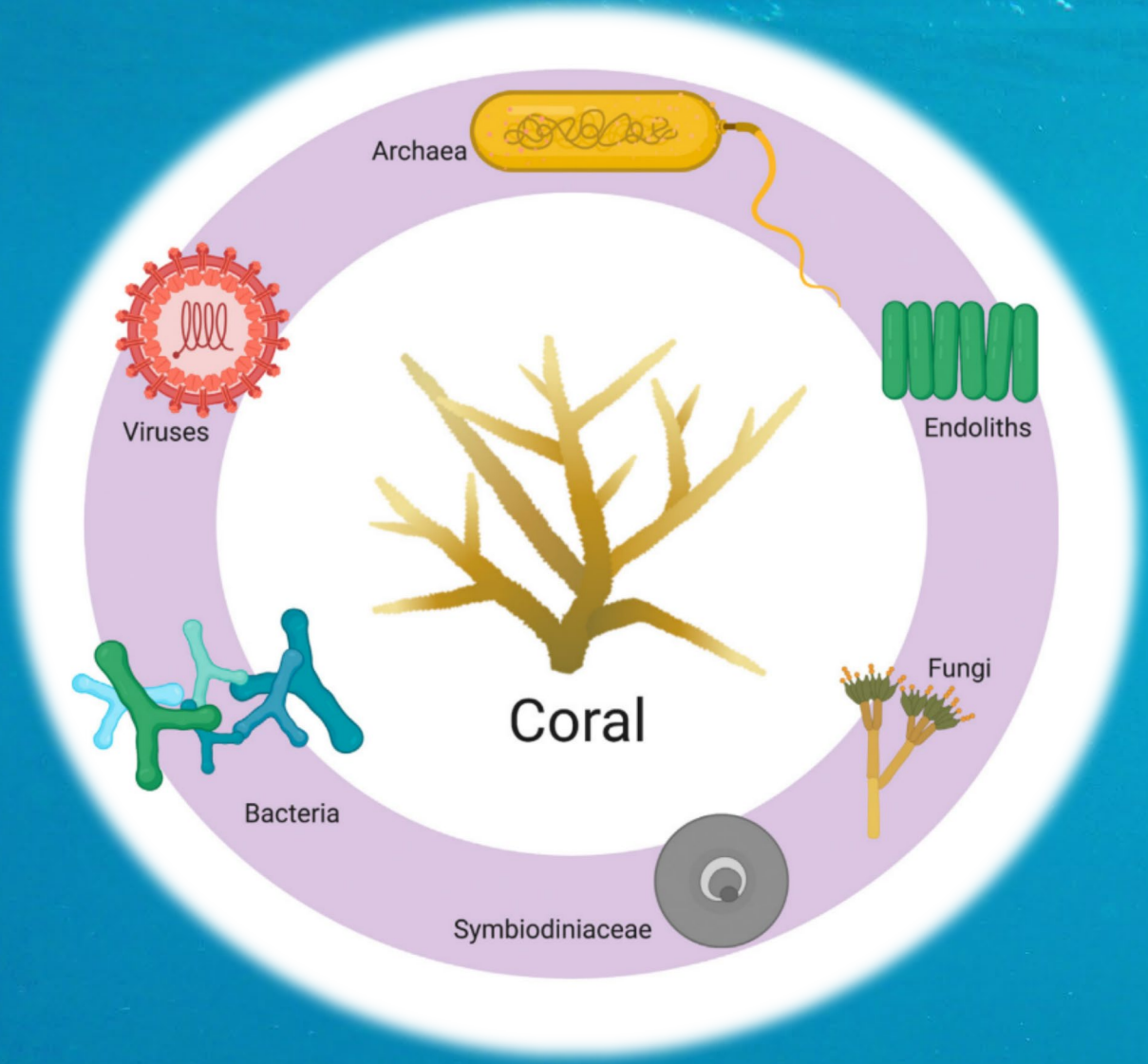
Hydrographic Connections of Inland Water to Diseased Corals and Water Quality Sites on Florida's Coral Reef

Brian K. Walker, Gareth J. Williams, Emmanuel Hanert, Thomas Dobbelaere, Greta S. Aeby, Reagan Sharkey, David R. Whitall, and Jeffrey A. Maynard

Florida's Coral Reef

- Rich biodiversity (near 25% of marine spp global)
- Thrive in oligotrophic waters (low nutrients)
- Provide vital ecosystem services
  - Coastal protection, Tourism, Sustenance

Coral Holobiont

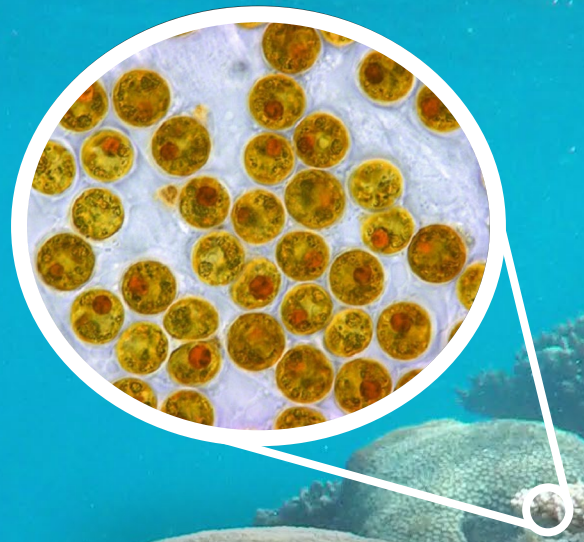


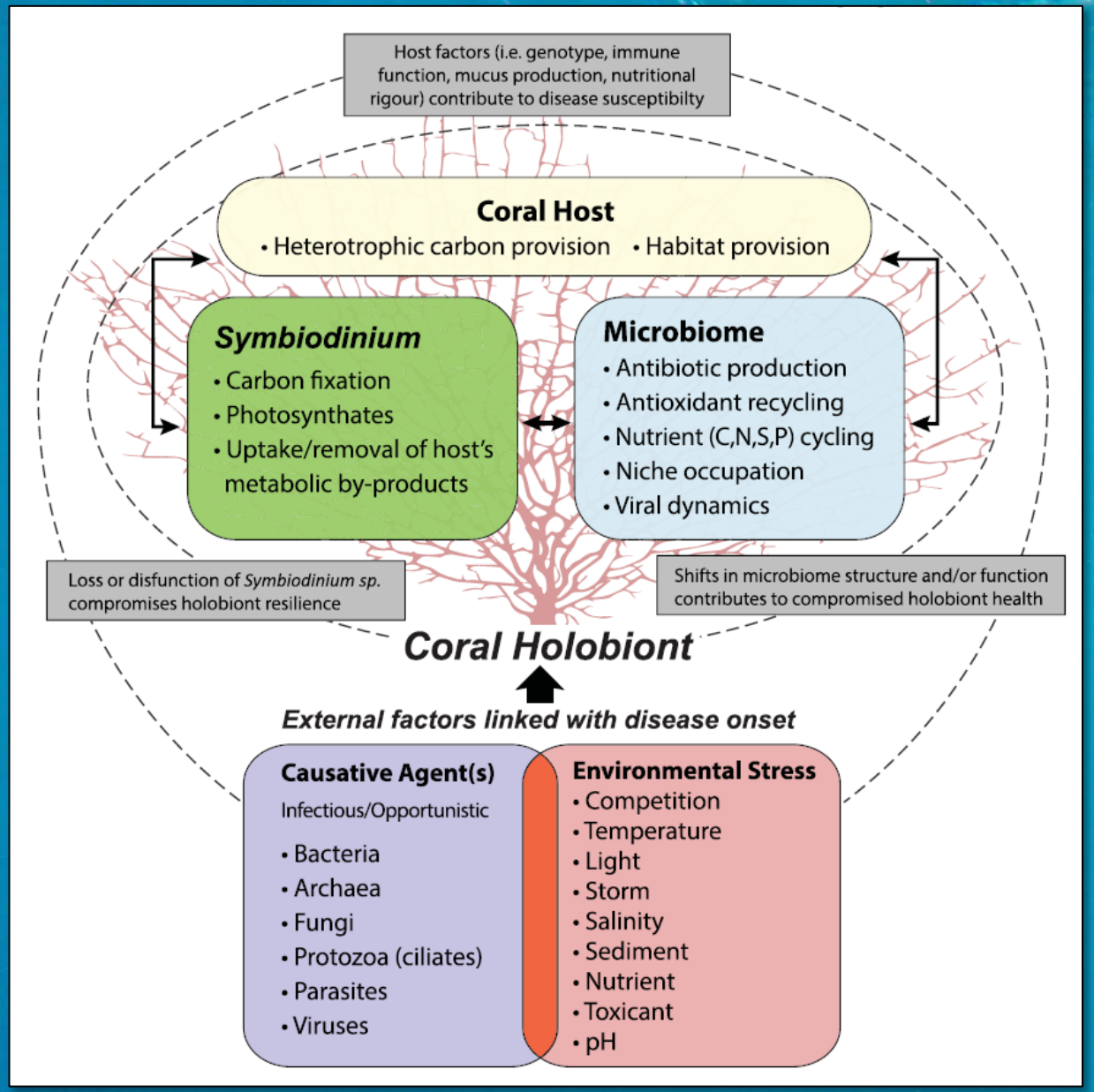
Trends in Microbiology
CellPress
REVIEWS

Review

Coral Disease Causes, Consequences, and Risk within Coral Restoration

T. Moriarty,[1] W. Leggat,[1] M.J. Huggett,[1] and T.D. Ainsworth[2,*]



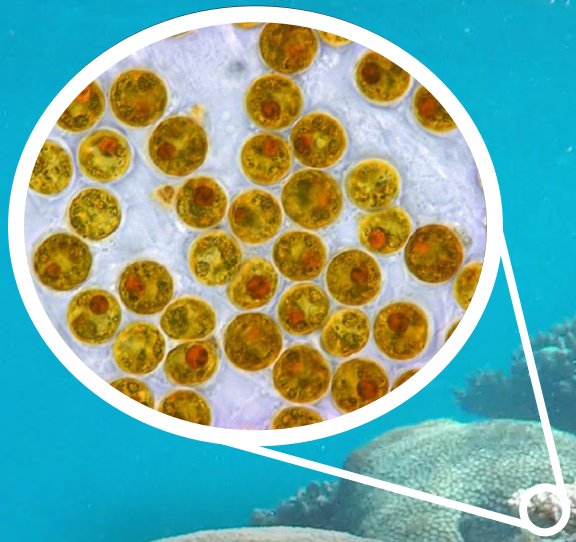


environmental microbiology
sfam society for applied microbiology
Environmental Microbiology (2018) 20(2), 431–449 doi:10.1111/1462-2920.13958

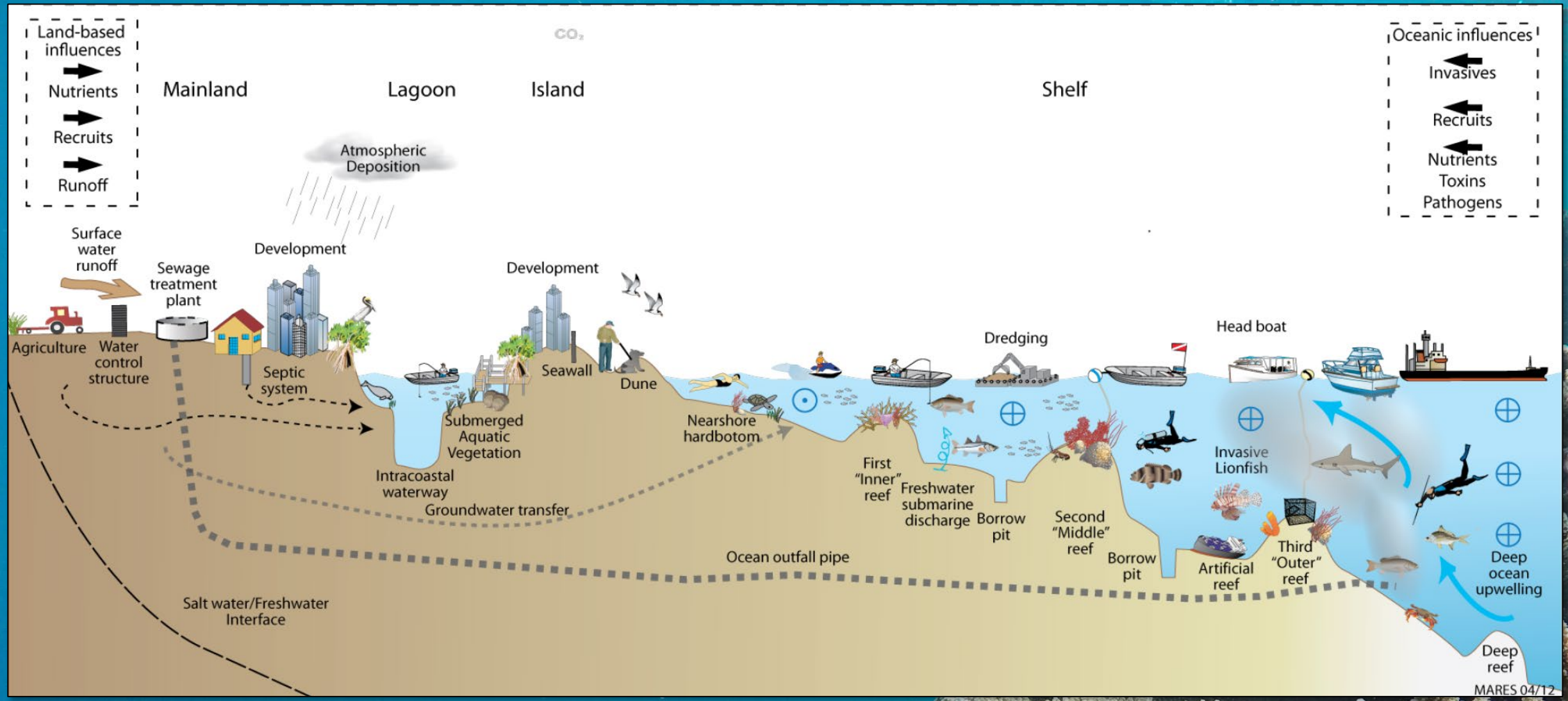
Minireview

Disentangling causation: complex roles of coral-associated microorganisms in disease

Hanaka Mera[1] and David G. Bourne[1,2*]



FCR anthropogenic threats in Southeast Florida



Coral Disease

Rising temperatures linked to increases in coral disease.

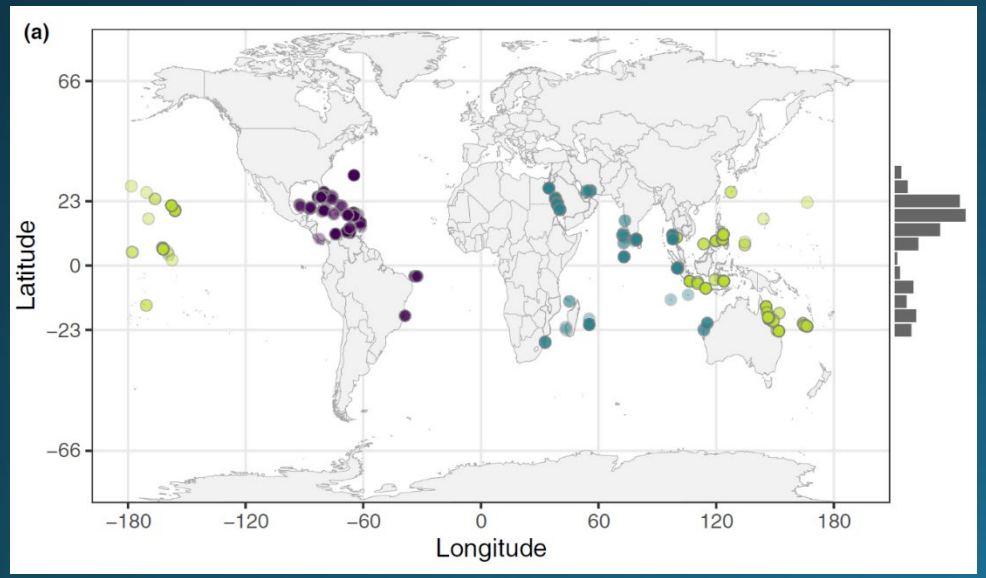
Global coral disease prevalence tripled between 1992 and 2018 reaching 9.92%.

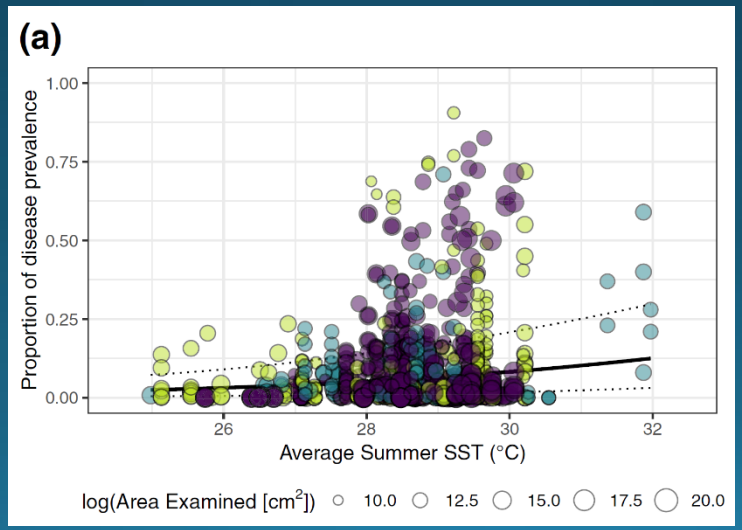
SYNTHESIS

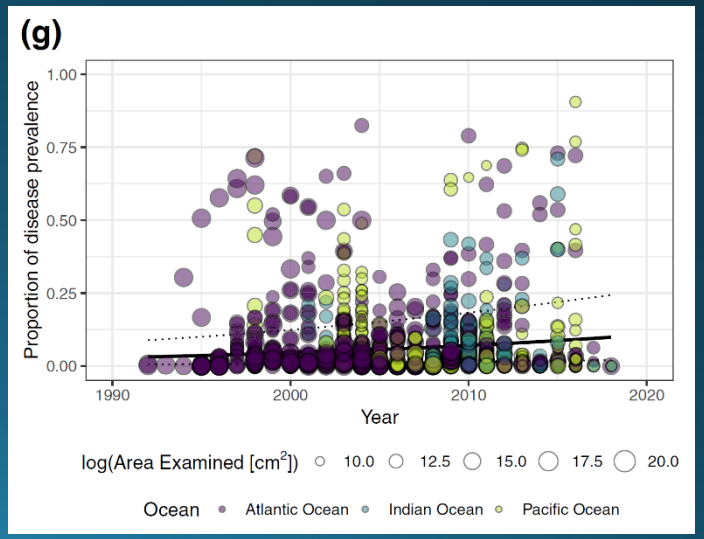
ECOLOGY LETTERS | WILEY

The impact of rising temperatures on the prevalence of coral diseases and its predictability: A global meta-analysis

Samantha Burke[1] | Patrice Pottier[1] | Malgorzata Lagisz[1] | Erin L. Macartney[1] | Tracy Ainsworth[2] | Szymon M. Drobniak[1,3] | Shinichi Nakagawa[1,4]







Variable Responses

Nutrient concentrations have beneficial and antagonistic effects dependent on many factors.

Nitrogen pollution interacts with heat stress to increase coral bleaching across the seascape

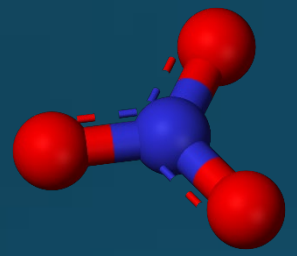
Mary K. Donovan[a,1], Thomas C. Adam[a], Andrew A. Shantz[b,c], Kelly E. Speare[b], Katrina S. Munsterman[b], Mallory M. Rice[b], Russell J. Schmitt[a,b], Sally J. Holbrook[a,b], and Deron E. Burkepile[a,b,1]

Ecosystems (2020) 23: 798–811
https://doi.org/10.1007/s10021-019-00433-2

ECOSYSTEMS

Nitrogen Identity Drives Differential Impacts of Nutrients on Coral Bleaching and Mortality

Deron E. Burkepile,[1,2]* Andrew A. Shantz,[1] Thomas C. Adam,[2] Katrina S. Munsterman,[1] Kelly E. Speare,[1] Mark C. Ladd,[1] Mallory M. Rice,[1] Leïla Ezzat,[1] Shelby McIlroy,[3] Jane C. Y. Wong,[3] David M. Baker,[3] Andrew J. Brooks,[2] Russell J. Schmitt,[1,2] and Sally J. Holbrook[1,2]



Contents lists available at ScienceDirect

Science of the Total Environment

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

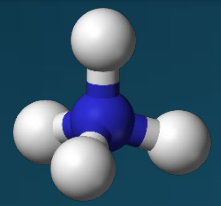
Review

Impacts of nitrogen pollution on corals in the context of global climate change and potential strategies to conserve coral reefs

Hongwei Zhao [a,c,d,**], Meile Yuan [a,b], Maryna Strokal [d], Henry C. Wu [e], Xianhua Liu [b,*], AlberTinka Murk [c], Carolien Kroeze [d], Ronald Osinga [c]

Synergistic/antagonistic effects of nitrate/ammonium enrichment on fatty acid biosynthesis and translocation in coral under heat stress

Jingjing Zhang [a,b,c,1], Zanhui Huang [b,1], Yuanchao Li [d,1], Dinghui Fu [b], Qipei Li [c], Lixin Pei [b], Yanwei Song [b], Liang Chen [b], Hongwei Zhao [a,c,*], Shuh-Ji Kao [a,e]



SCIENTIFIC REPORTS

OPEN

Limited phosphorus availability is the Achilles heel of tropical reef corals in a warming ocean

Received: 02 February 2016
Accepted: 27 July 2016

Leïla Ezzat[1], Jean-François Maguer[2], Renaud Grover[1] & Christine Ferrier-Pagès[1]

RESEARCH ARTICLE

Functional Ecology

Nutrient starvation impairs the trophic plasticity of reef-building corals under ocean warming

Leïla Ezzat[1] | Jean-François Maguer[2] | Renaud Grover[1] | Cécile Rottier[1] | Pascale Tremblay[3] | Christine Ferrier-Pagès[1]

Marine Biology (2019) 166:108
https://doi.org/10.1007/s00227-019-3538-9

HIGHLIGHT ARTICLE

Nitrogen enrichment, altered stoichiometry, and coral reef decline at Looe Key, Florida Keys, USA: a 3-decade study

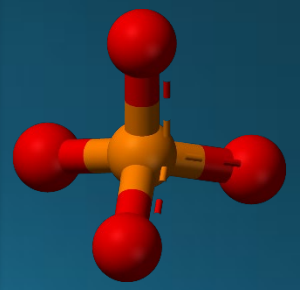
Brian E. Lapointe[1] · Rachel A. Brewton[1] · Laura W. Herren[1] · James W. Porter[2] · Chuanmin Hu[3]

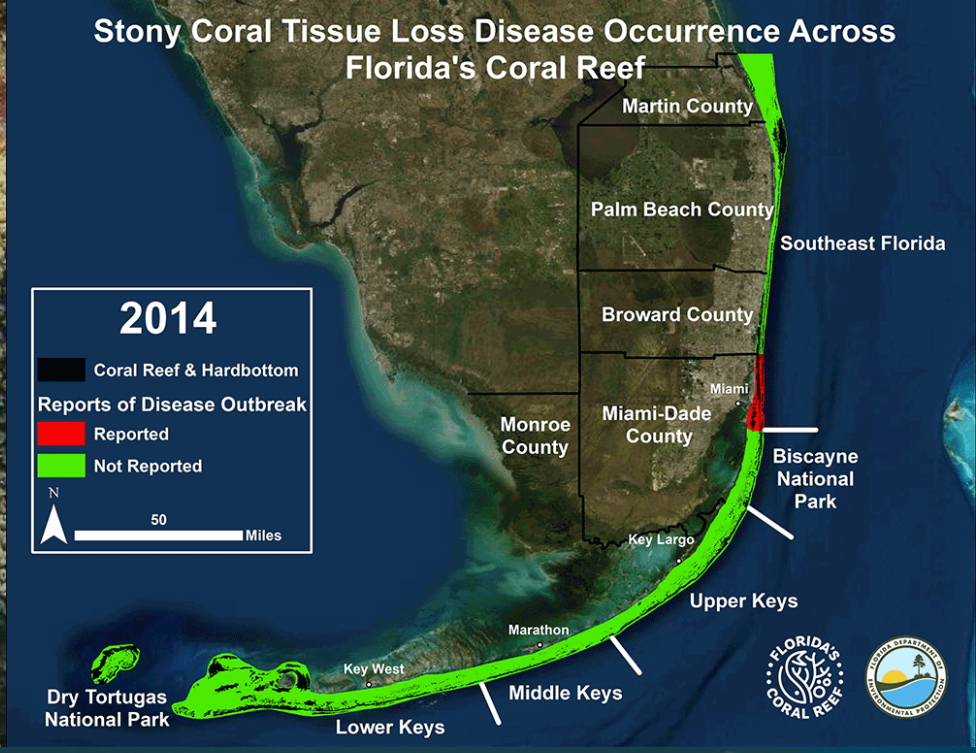
Marine Pollution Bulletin

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

Elevated ammonium reduces the negative effect of heat stress on the stony coral *Pocillopora damicornis*

Zhi Zhou [a,*,1], Guoqing Zhang [a,1], Guangmei Chen [a], Xingzhen Ni [a], Liping Guo [a,b,*], Xiaopeng Yu [a], Chunlin Xiao [a], Yanlai Xu [c], Xiaowei Shi [d], Bo Huang [a]





Stony Coral Tissue Loss Disease

- Killing millions of colonies on Florida's Coral Reef
- Originated in SE FL in 2014 spreading N & S over 6 yrs
- Currently changing the population demographics in the Dry Tortugas
- Resistant corals continue to get infected further declining populations

Use most effective DI treatment

Antibiotic paste >90% effectiveness

Disease breaks can increase effectiveness but there are trade offs with time and materials that may limit number of corals treated.

scientific reports

OPEN

Assessing the effectiveness of two intervention methods for stony coral tissue loss disease on *Montastraea cavernosa*

Erin N. Shilling, Ian R. Combs & Joshua D. Voss

Stony coral tissue loss disease (SCTLD) was first observed in Florida in 2014 and has since spread to multiple coral reefs across the wider Caribbean. The northern section of Florida's Coral Reef has

Scientific Reports | (2021) 11:8566

frontiers in Marine Science

ORIGINAL RESEARCH
published: 02 July 2021
doi: 10.3389/fmars.2021.666224

Optimizing Stony Coral Tissue Loss Disease (SCTLD) Intervention Treatments on *Montastraea cavernosa* in an Endemic Zone

Brian K. Walker*, Nicholas R. Turner, Hunter K. G. Noren, Samantha F. Buckley and Kelly A. Pitts

Geographic Information Systems (GIS) and Spatial Ecology Lab, Halmos College of Arts and Sciences, Nova Southeastern University, Dania Beach, FL, United States

Stony coral tissue loss disease (SCTLD) has persisted since 2014 in the Southeast Florida Coral Reef Ecosystem Conservation Area (Coral ECA) where it was first discovered. Most of the highly susceptible corals have perished, leaving *Montastraea*

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frontiers in Marine Science

ORIGINAL RESEARCH
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Short- and Long-Term Effectiveness of Coral Disease Treatments

Karen L. Neely*, Colin P. Shea, Kevin A. Macaulay, Emily K. Hower and Michelle A. Dobler

Halmos College of Natural Sciences and Oceanography, Nova Southeastern University, Fort Lauderdale, FL, United States, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg, FL, United States

Since 2014, stony coral tissue loss disease (SCTLD) has led to large-scale mortality of over 20 coral species throughout the Florida Reef Tract. In 2019, in-water disease intervention strategies were implemented to treat affected corals. Two treatment strategies were employed: (1) topical application of an amoxicillin paste directly to disease margins, and (2) application of a chlorinated epoxy to disease margins as well as an adjacent "disease break" trench. Effectiveness of treatments on 2,379 lesions from 725 corals representing five species was evaluated using mixed effects logistic regression models which demonstrated substantially greater effectiveness of amoxicillin compared to chlorine-treated lesions across all species up to 3 months post-treatment. As a result of the failed chlorinated epoxy treatments, any new lesions that appeared during subsequent monitoring events were treated with amoxicillin paste, and all corals were monitored and treated as needed approximately every 2 months for up to 24 months. The health status of 1664 amoxicillin-treated corals during each monitoring event was used to model the probability of a coral being uninfected over time. Models included species and geographic regions as variables. The appearance of new lesions (reinfection rates) varied by species, and offshore sites showed greater

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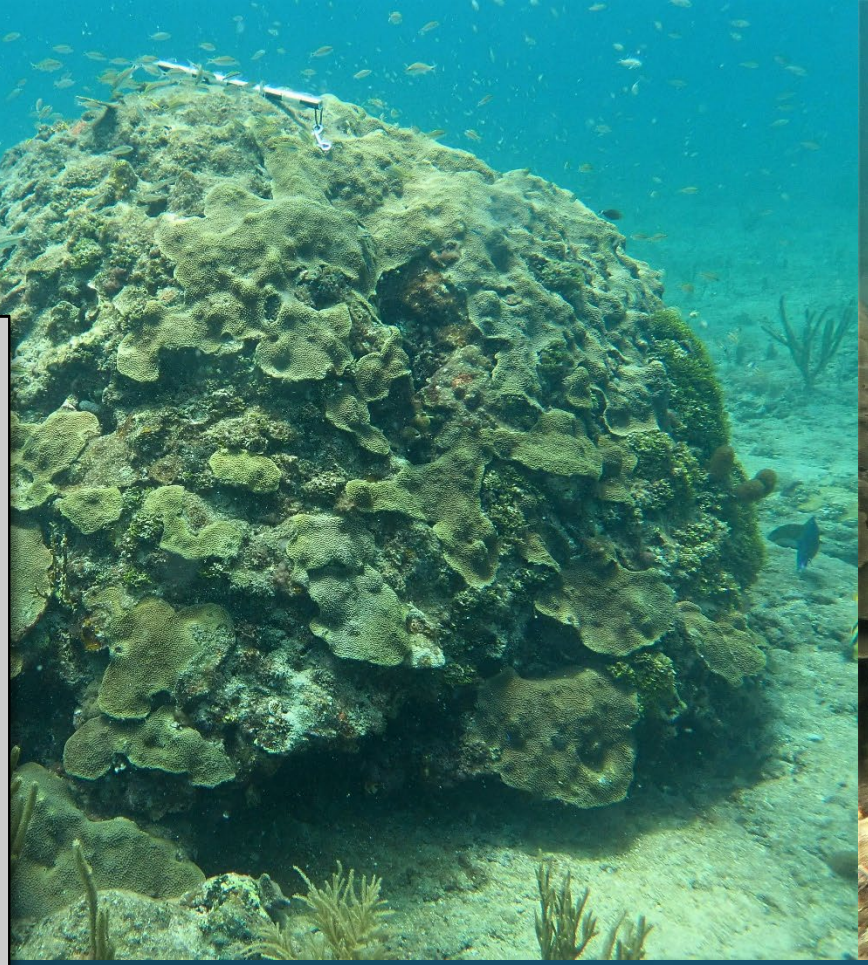
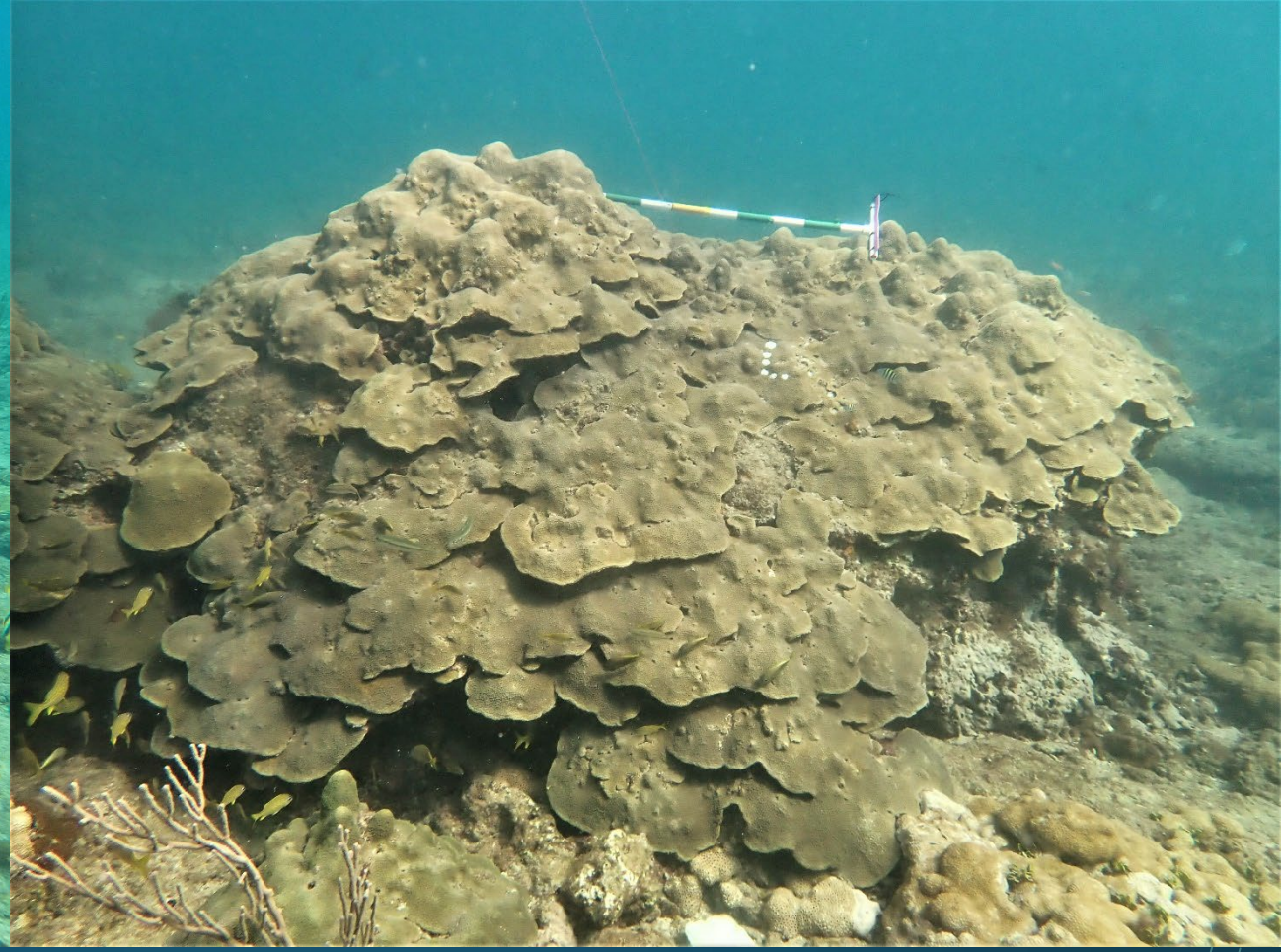
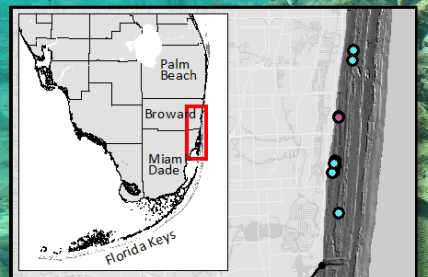




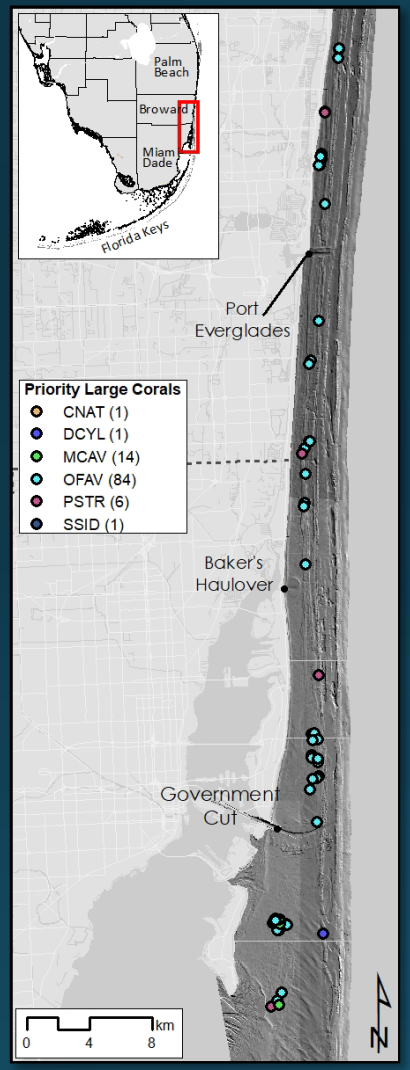


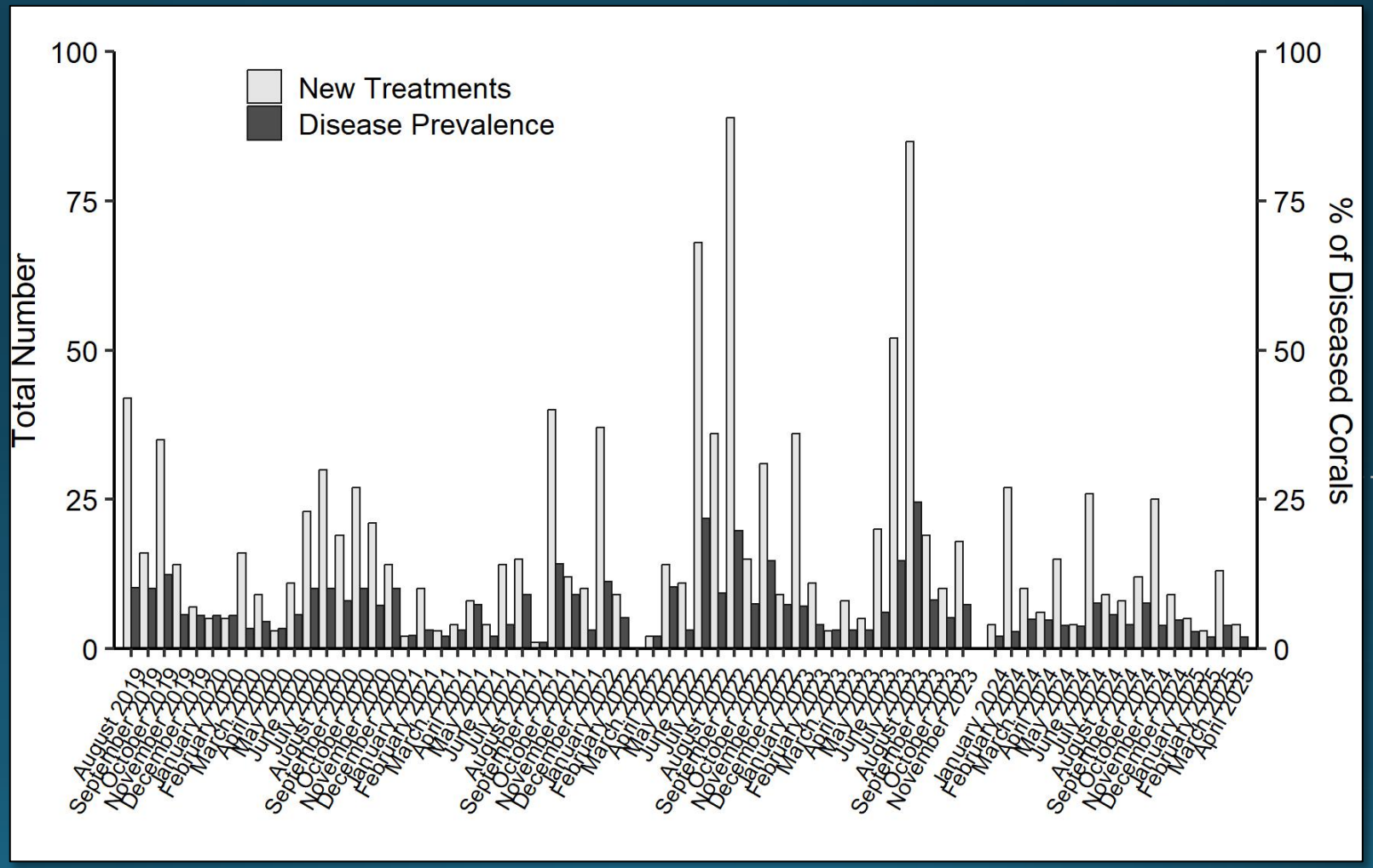
Large Coral Database & Monitoring

107 of the largest, oldest, and most resilient colonies in the KJ Coral ECA

- Monthly visits to record condition
- Disease intervention to conserve live tissue cover
- Opportunity to study frequency of new infections through time

SCTLD Seasonality



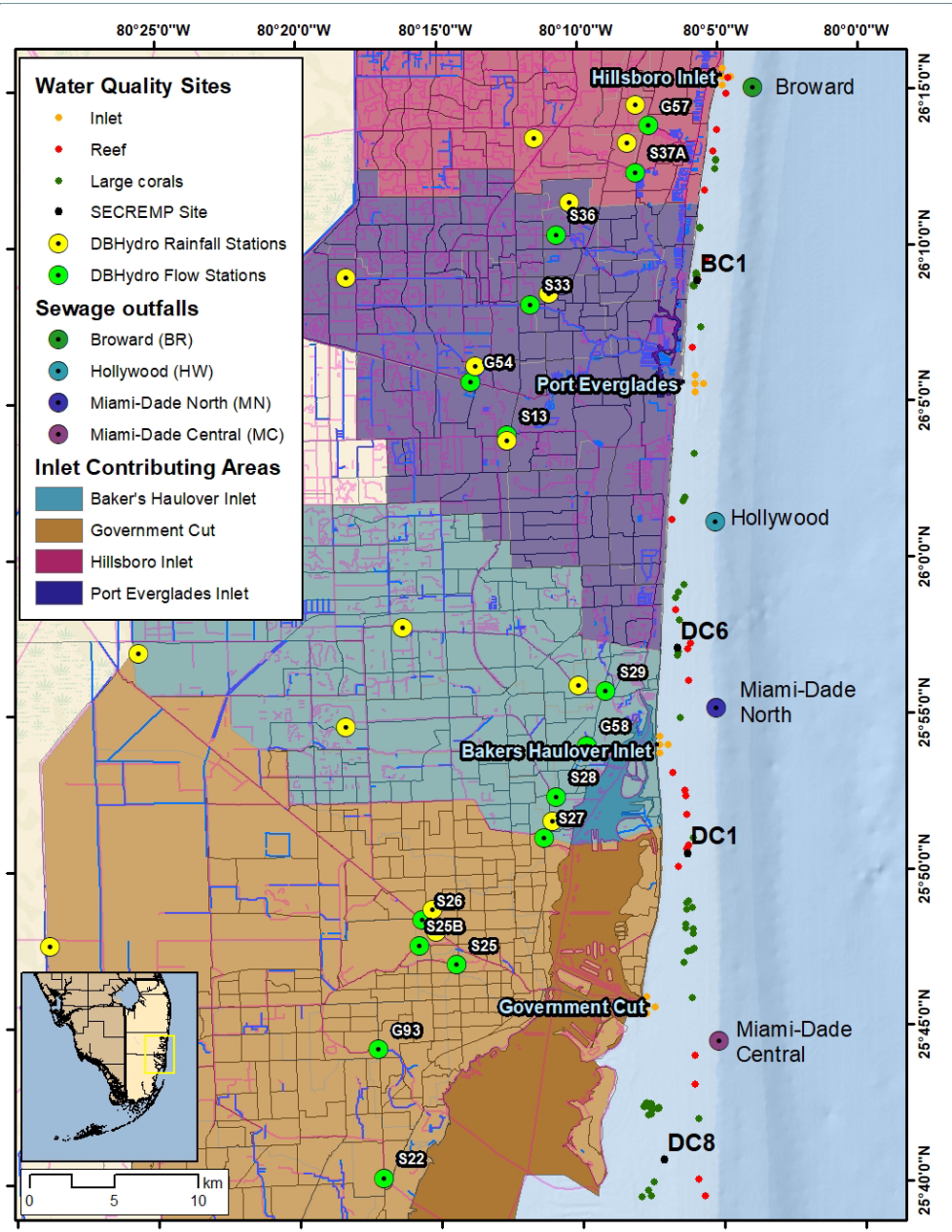


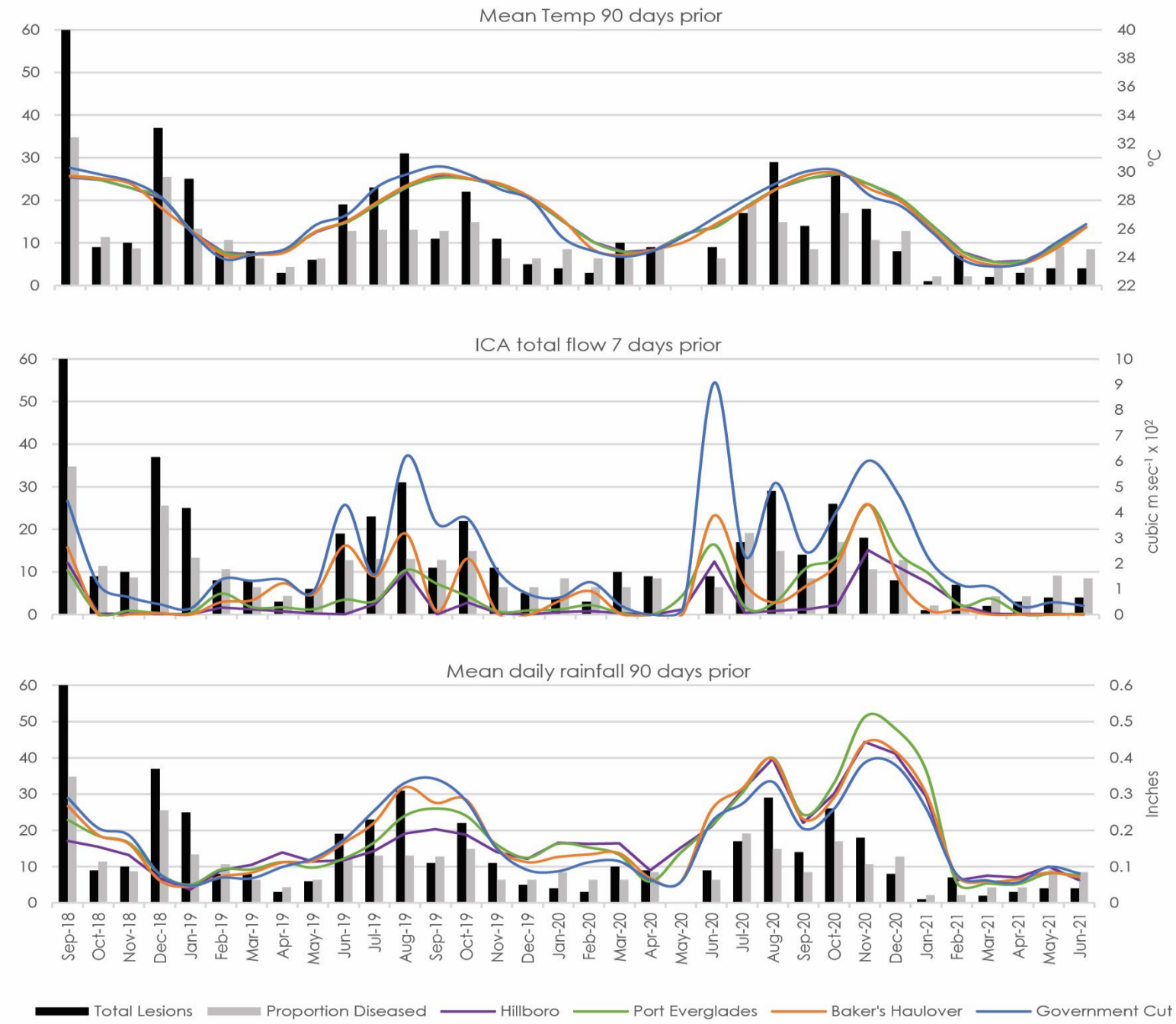
Statistical modeling

Do variations in local conditions explain patterns in SCTLD and WQ data?

- Nutrient loading (nitrate, nitrite, phosphorous, orthophosphate, TSS, silicate)
- Reef water temperature
- Inlet flow
- Rainfall
- Wind speed (including direction)

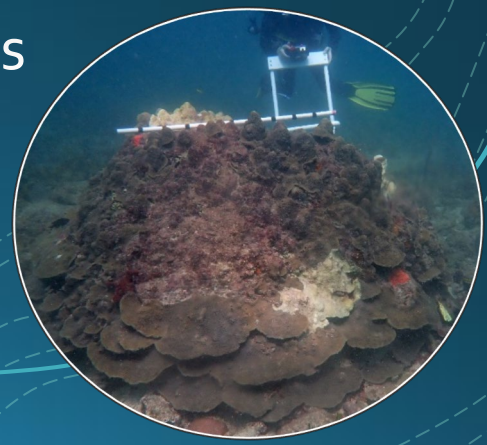
DBHYDRO





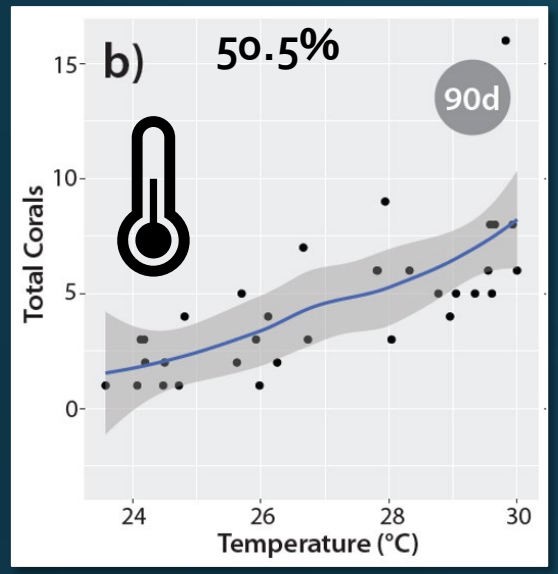
Temp, ICA, & Rainfall

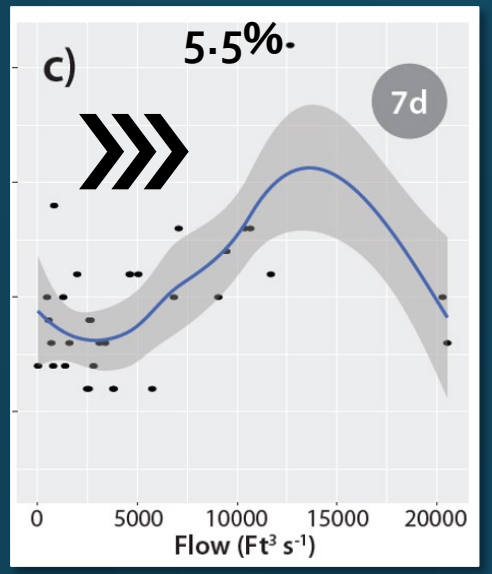
- Mean temp highly correlated with SCTLD infections
- Disease incidence exacerbated by high flow and heavy rainfall
- Can use all 3 parameters to make better predictions

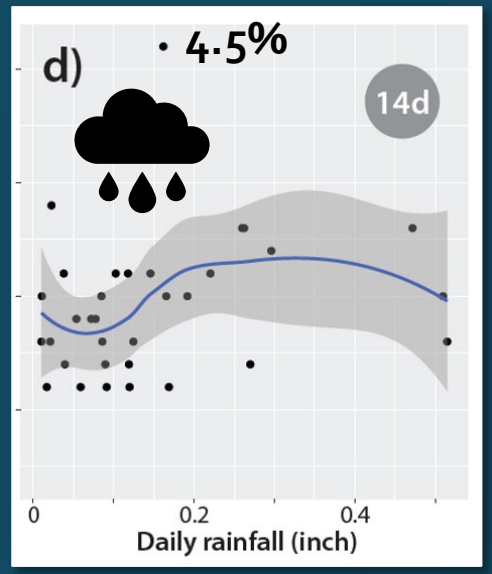


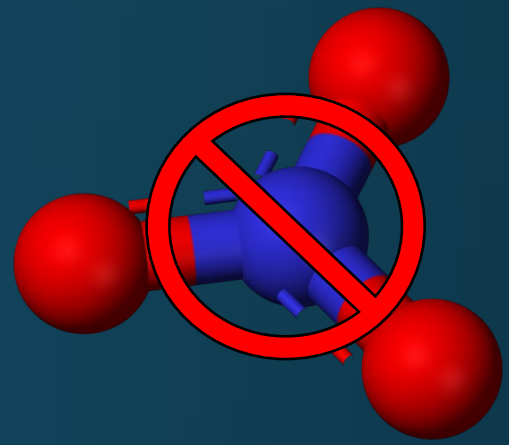
(Walker et al In prep)

66.2 % of the model variation in the number of corals with lesions could be explained by six predictors:

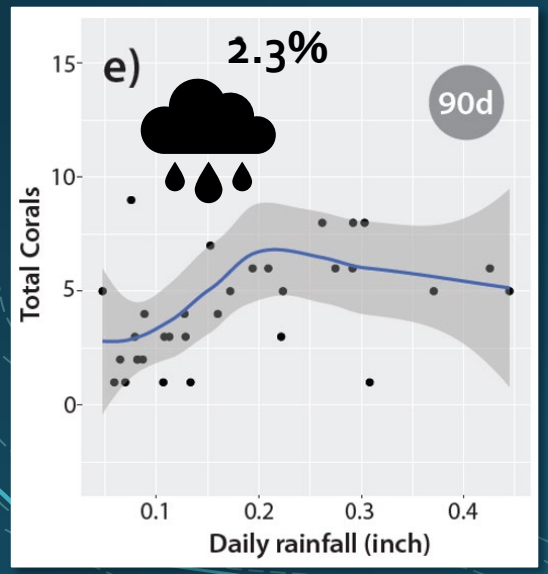


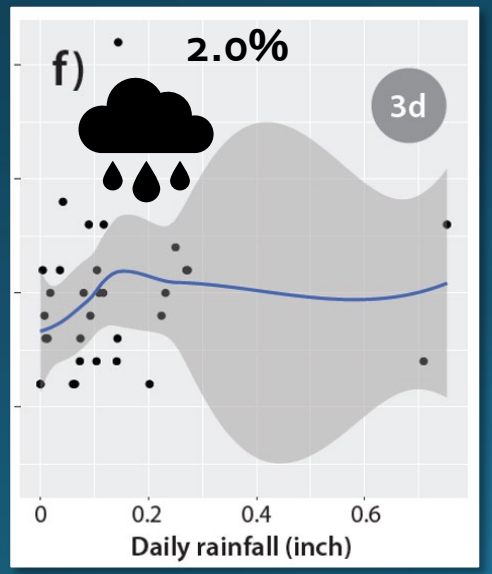


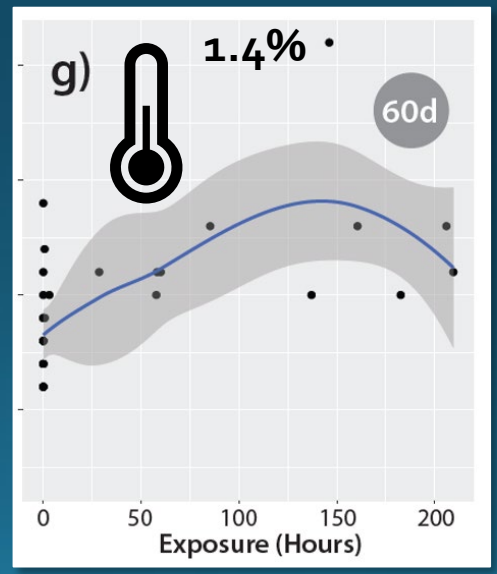


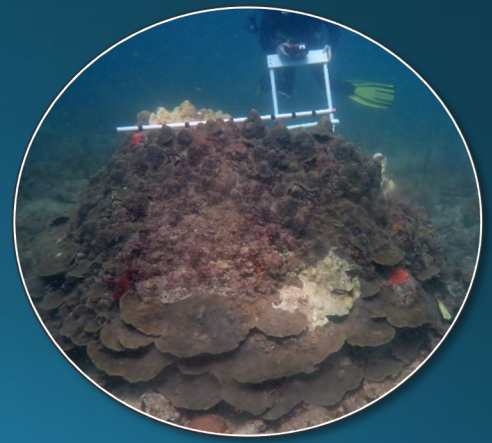


No sig WQ predictors









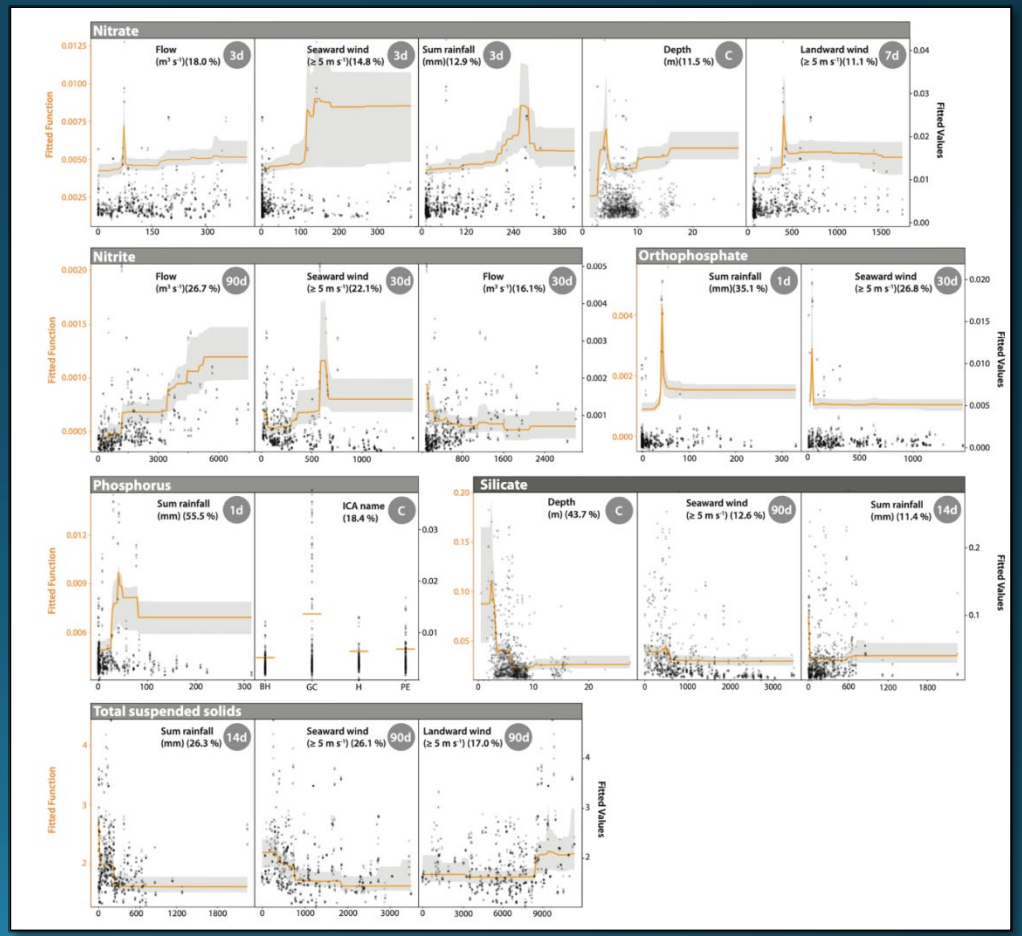
(Walker et al In prep)

Reef water quality stats models

	Nitrate	Nitrite	Orthophosphate	Phosphorous	Silicate	TSS
Model Parameters						
Tree complexity	4	5	4	3	4	2
Learning rate	0.001	0.001	0.001	0.001	0.001	0.001
Bag fraction	0.7	0.8	0.5	0.8	0.5	0.7
Number of trees	7200	6550	10750	10150	4600	5600
Model Performance						
Percentage explained (%)	55.0	60.1	79.5	57.4	46.4	20.7
cvPercentage explained (%)	32.1	37.2	64.0	40.0	21.5	7.0

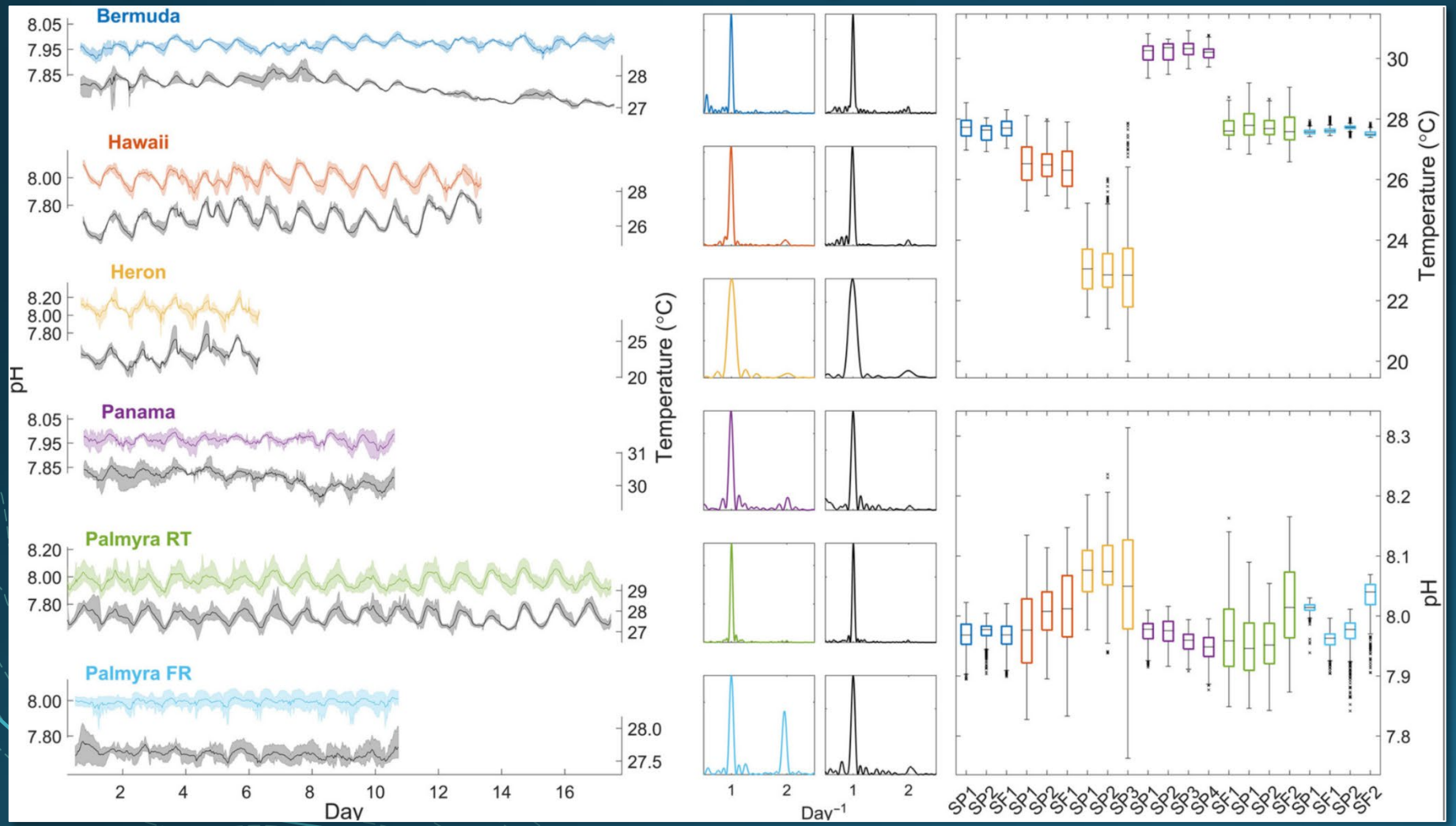
(Whitall et al, In revision)

Analyte	Predictor	Rel Influence (%)	Cumul Influence (%)
Nitrate	Flow (prior 3 days)	18.0	18.0
	Seaward wind (prior 3 days)	14.8	32.8
	Rain (prior 3 days)	12.9	45.7
	Depth	11.5	57.2
	Landward wind (prior 7 days)	11.1	68.3
Nitrite	Flow (prior 90 days)	26.7	26.7
	Seaward wind (prior 30 days)	22.1	48.8
	Flow (30 days prior)	16.1	64.9
Orthophosphate	Rain (prior 1 day)	35.1	35.1
	Seaward wind (prior 30 days)	26.8	61.9
Phosphorous	Rain (prior 1 day)	55.5	55.5
	ICA	18.4	73.9
Silicate	Depth	43.7	43.7
	Seaward wind (prior 90 days)	12.6	56.3
	Rain (prior 14 days)	11.4	67.7
TSS	Rain (prior 14 days)	26.3	26.3
	Seaward wind (prior 90 days)	26.1	52.4
	Landward wind (prior 90 days)	17.0	69.4

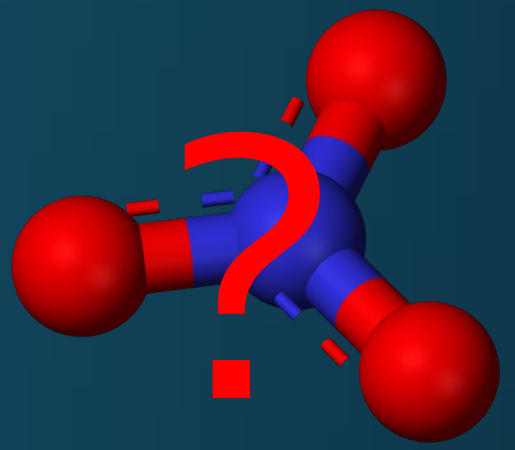


Why no sig WQ predictors?

Likely from a mismatch in WQ sampling vs response variables

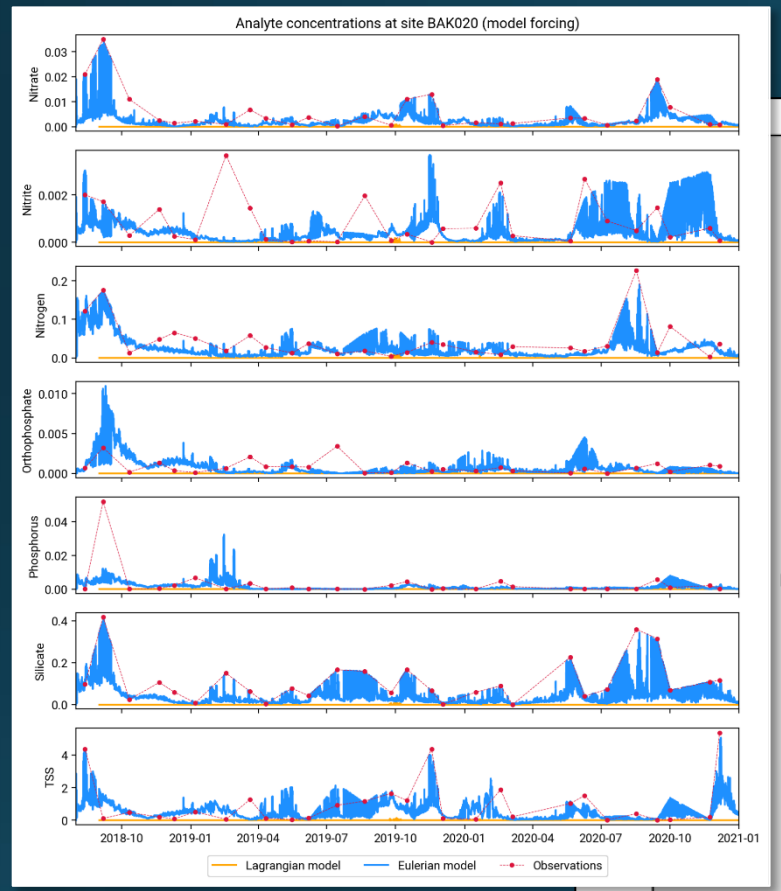


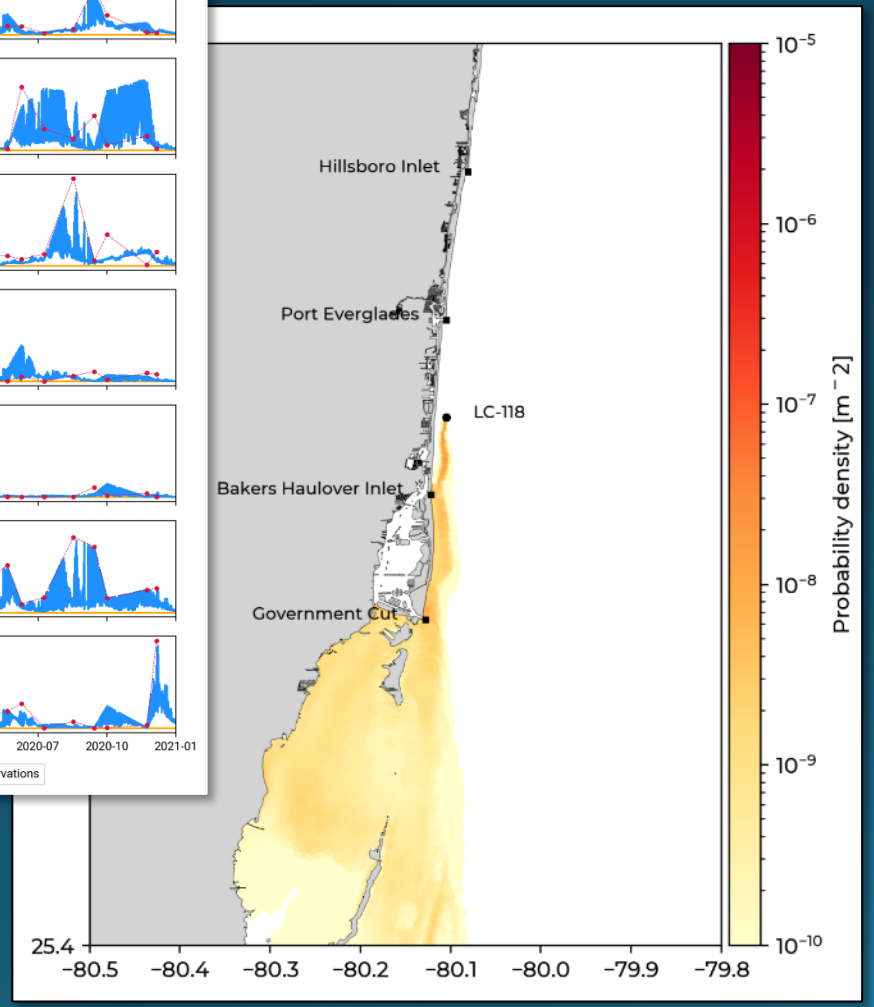
(Cyronak et al 2019)

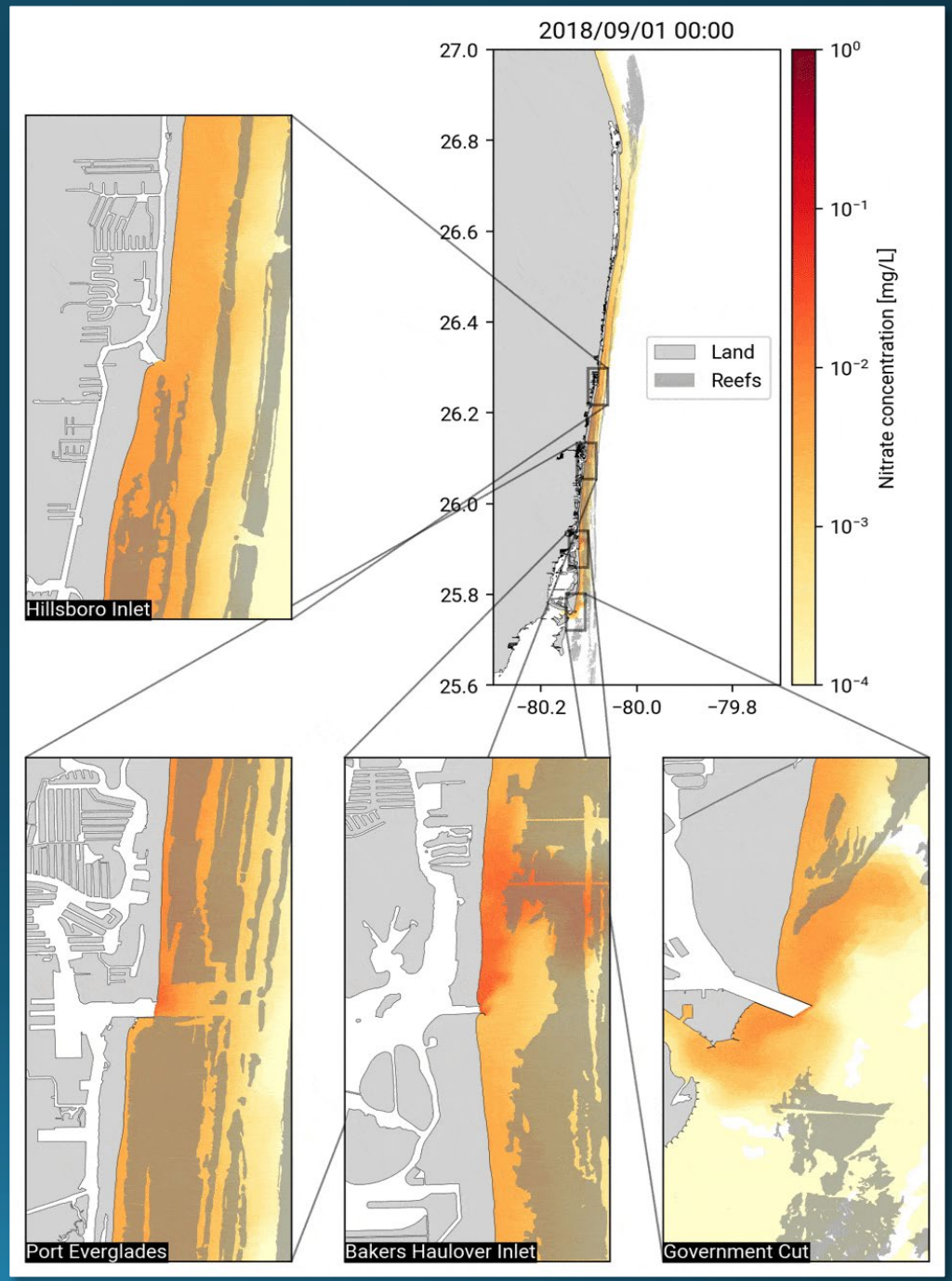


Monthly WQ samples aren't capturing the variability needed to relate to biological responses.

Modeling reef exposure to inland water flows





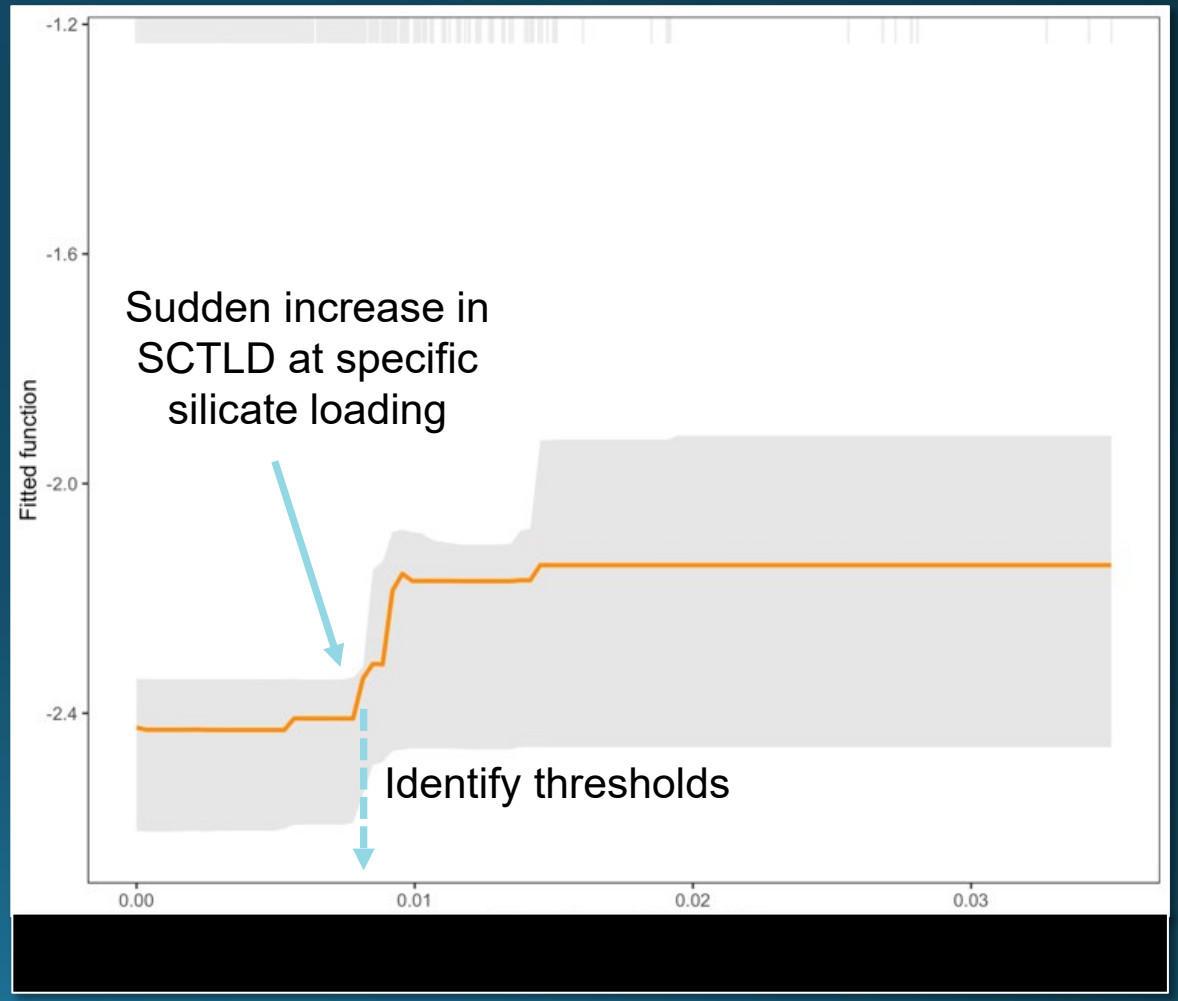


UCLouvain

Statistical modeling

Silica and coral disease

- Water passing through or over the earth dissolves silica from sands, rocks, and minerals
- The relationship of modeled silica values shows a spike in coral disease
- Perhaps captures exposure to freshwater sources of pollution more accurately?
- Does silicate reflect something else in the inlet water?



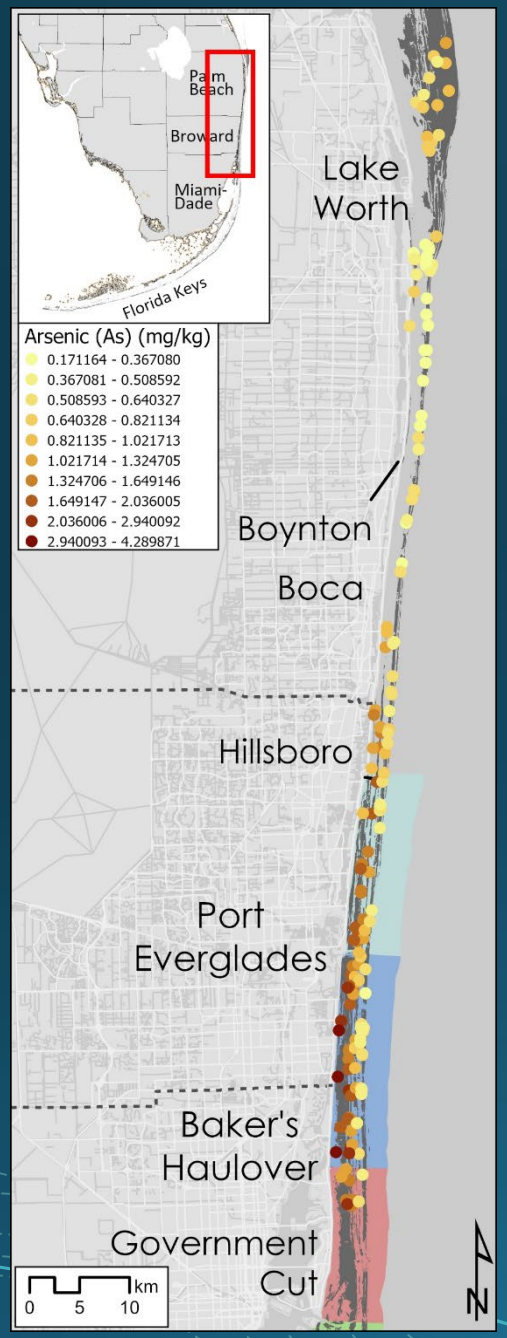
(Walker et al In prep)

Significant interaction between inlet exposure & depth on heavy metals

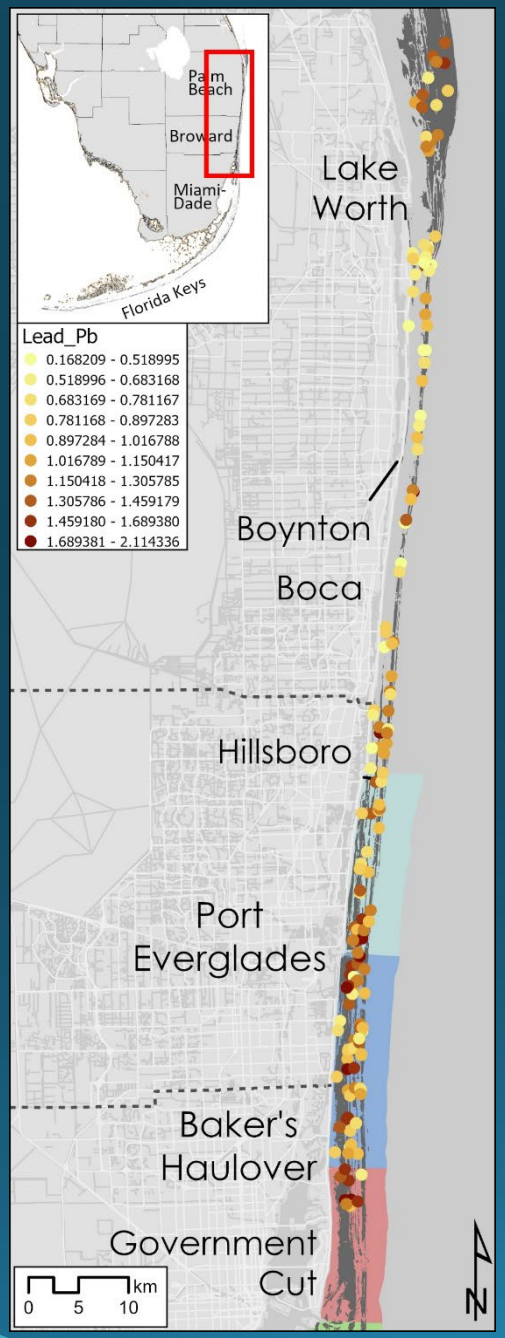
159 random reef sediment samples

(Lopez et al In prep)

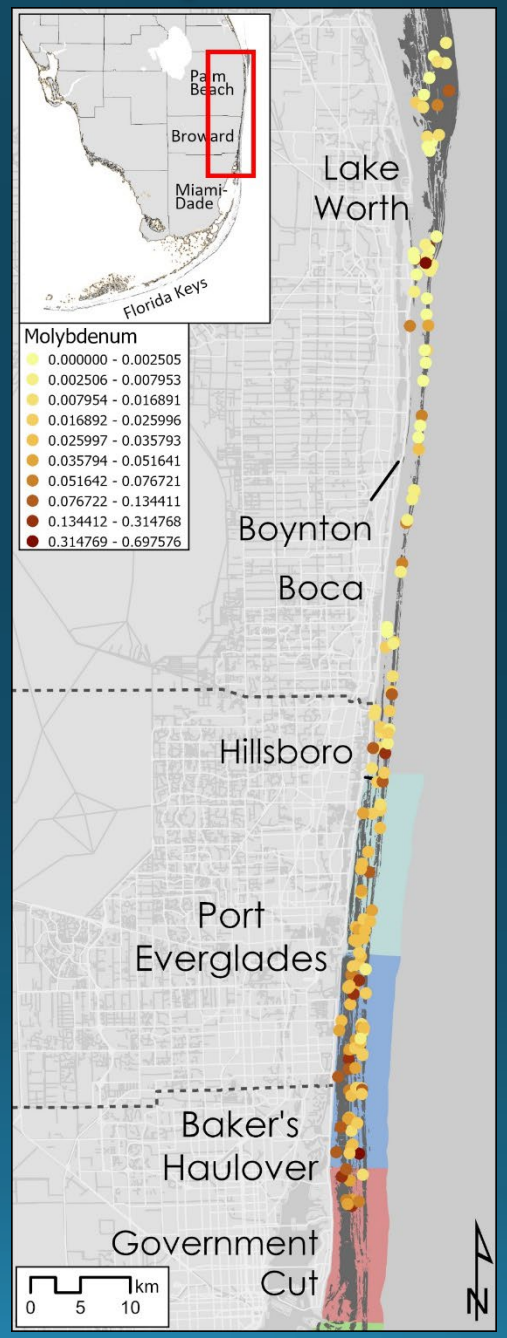
Arsenic



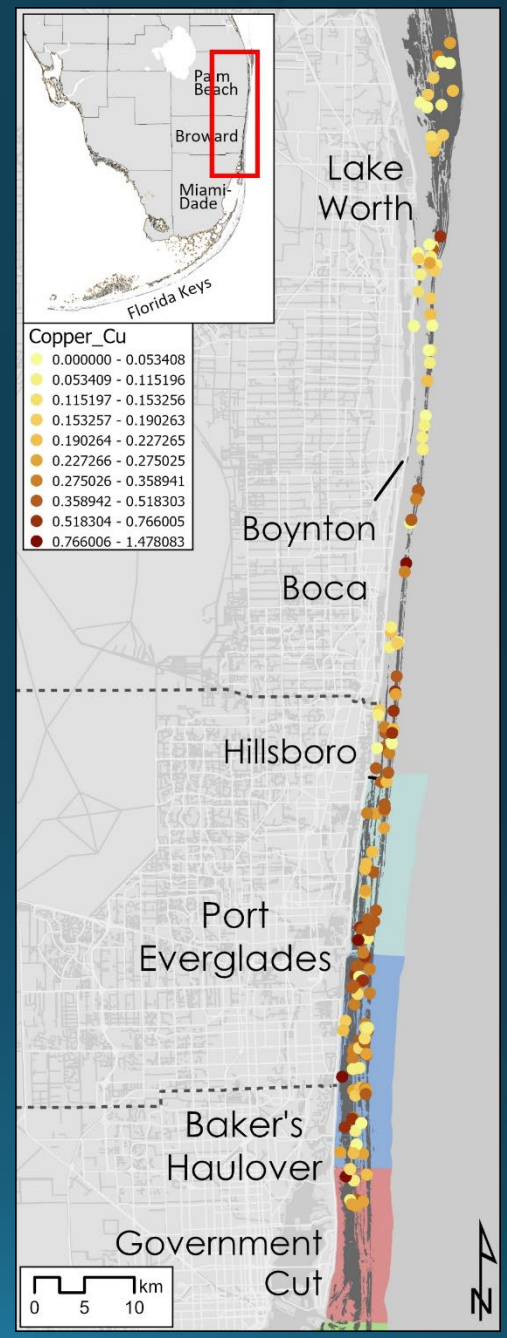
Lead



Molybdenum



Copper



Significance and Future Implicati

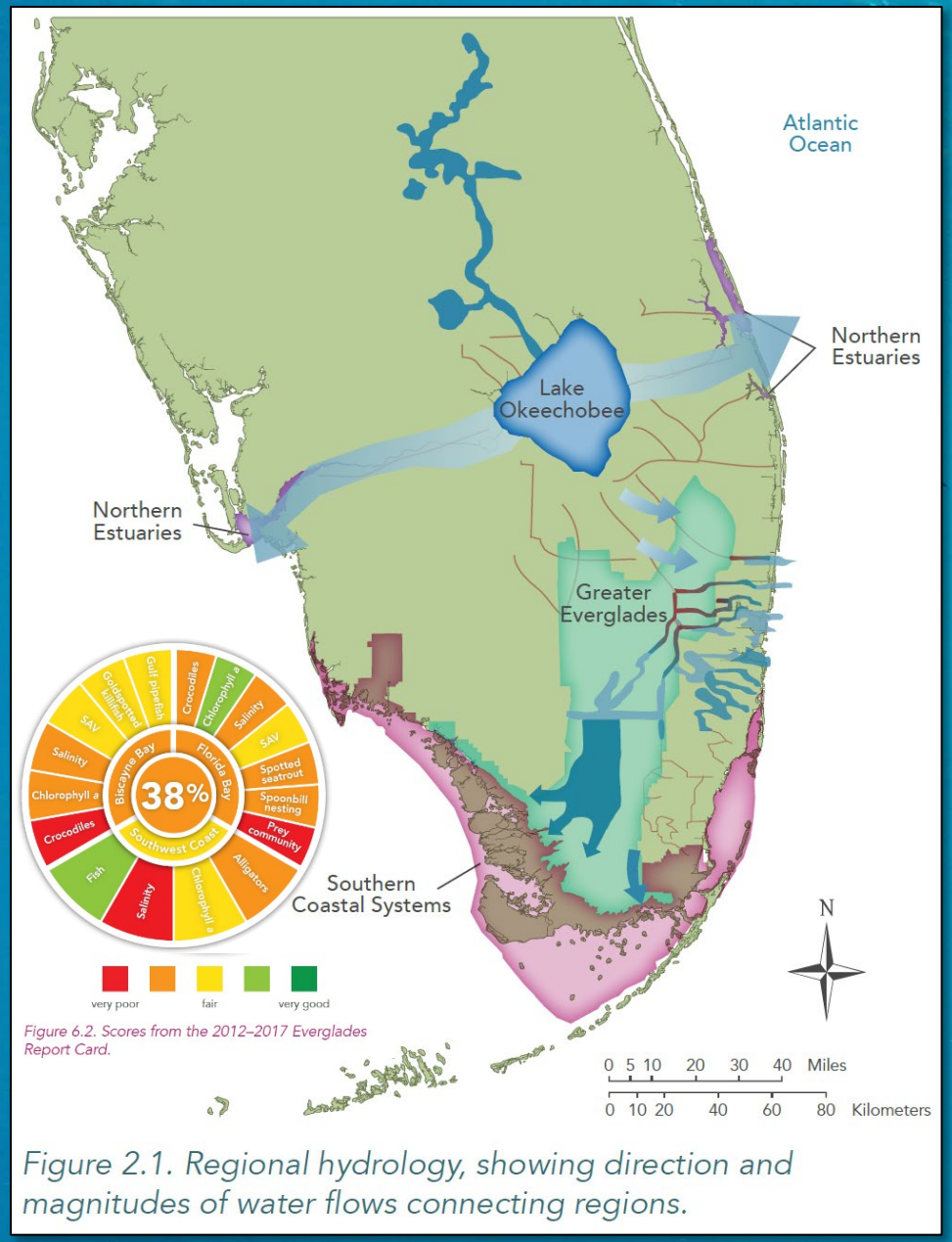
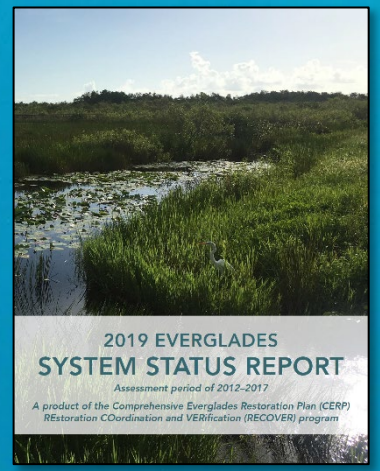


Figure 6.2. Scores from the 2012–2017 Everglades Report Card.

Figure 2.1. Regional hydrology, showing direction and magnitudes of water flows connecting regions.

- Land-based pollution is degrading FCR water quality and maybe contributing to coral disease
- WQ mitigation is critical to improve reef health
- Planned CERP actions may not help
- Corals would be red on the report card



Acknowledgements

Thank you to all of the funders, partners, and graduate students.

Instagram

CSELAB_NSU

Thank you to:

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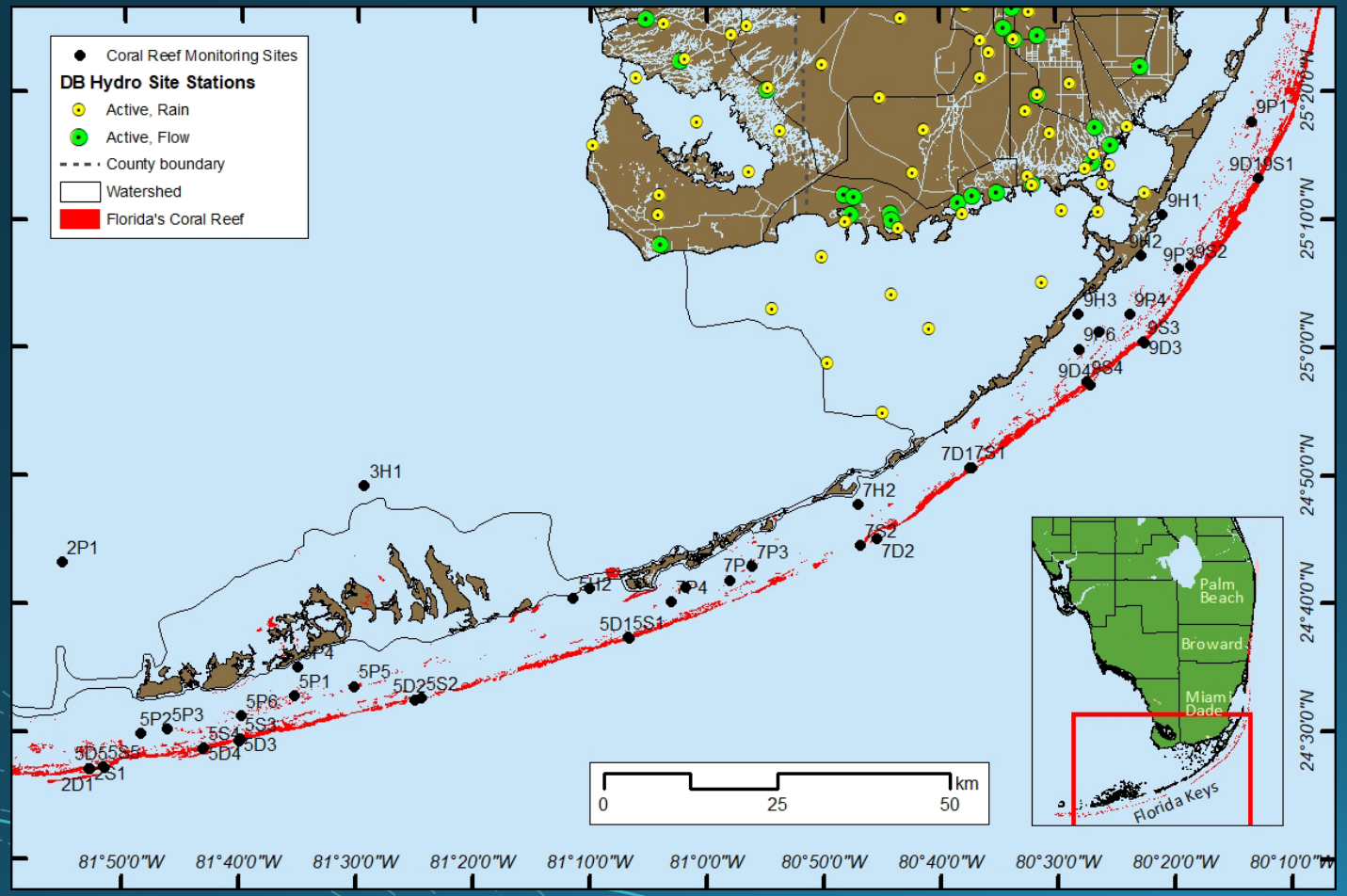
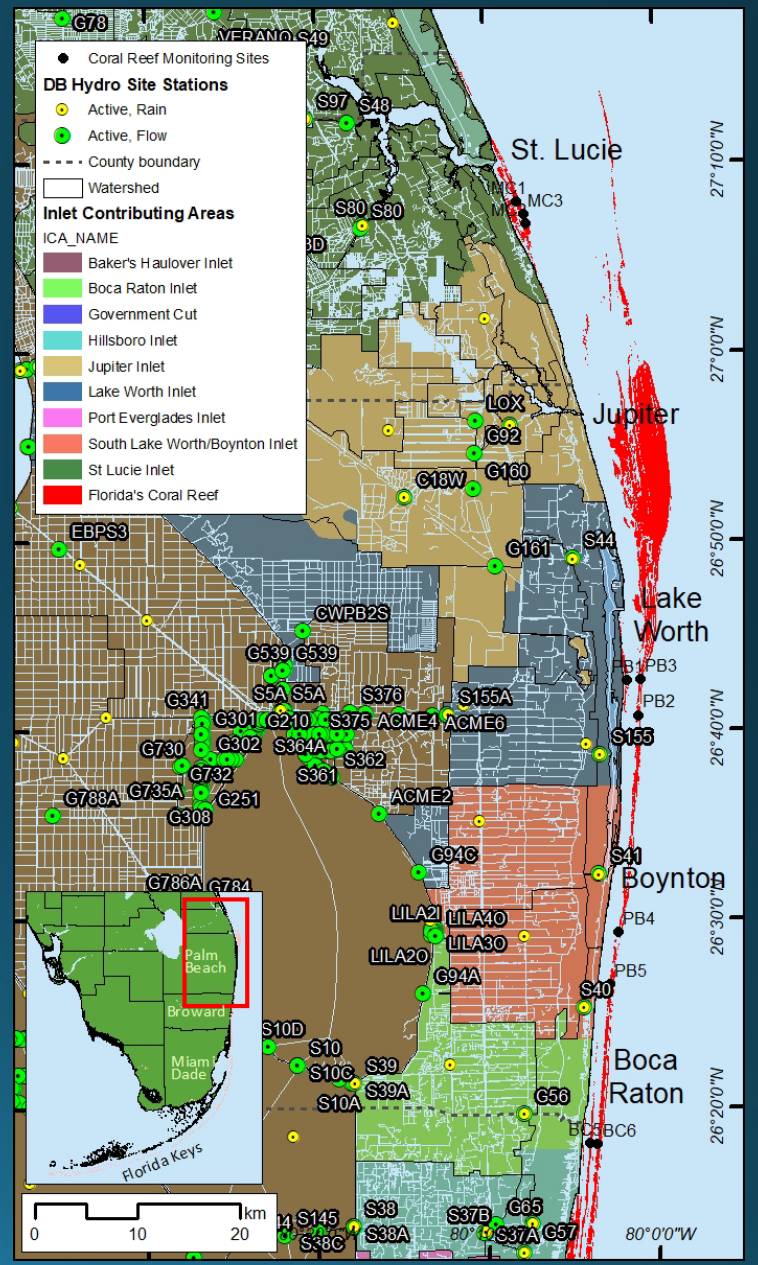
Field Ops Teams

The NSU GIS and Spatial Ecology lab members: Hunter Noren, Reagan Sharkey, Samantha Buckley, Katy Toth, Sasha Wheeler, Zach Graff, Allie Kozachuk, Amanda Zummo, Alex Wagner, Kristin Anderson, Alysha Brunelle, Elizabeth Fromuth, Tommy Ingalls, and Brooke Enright.

Next steps (pre-proposal under review)

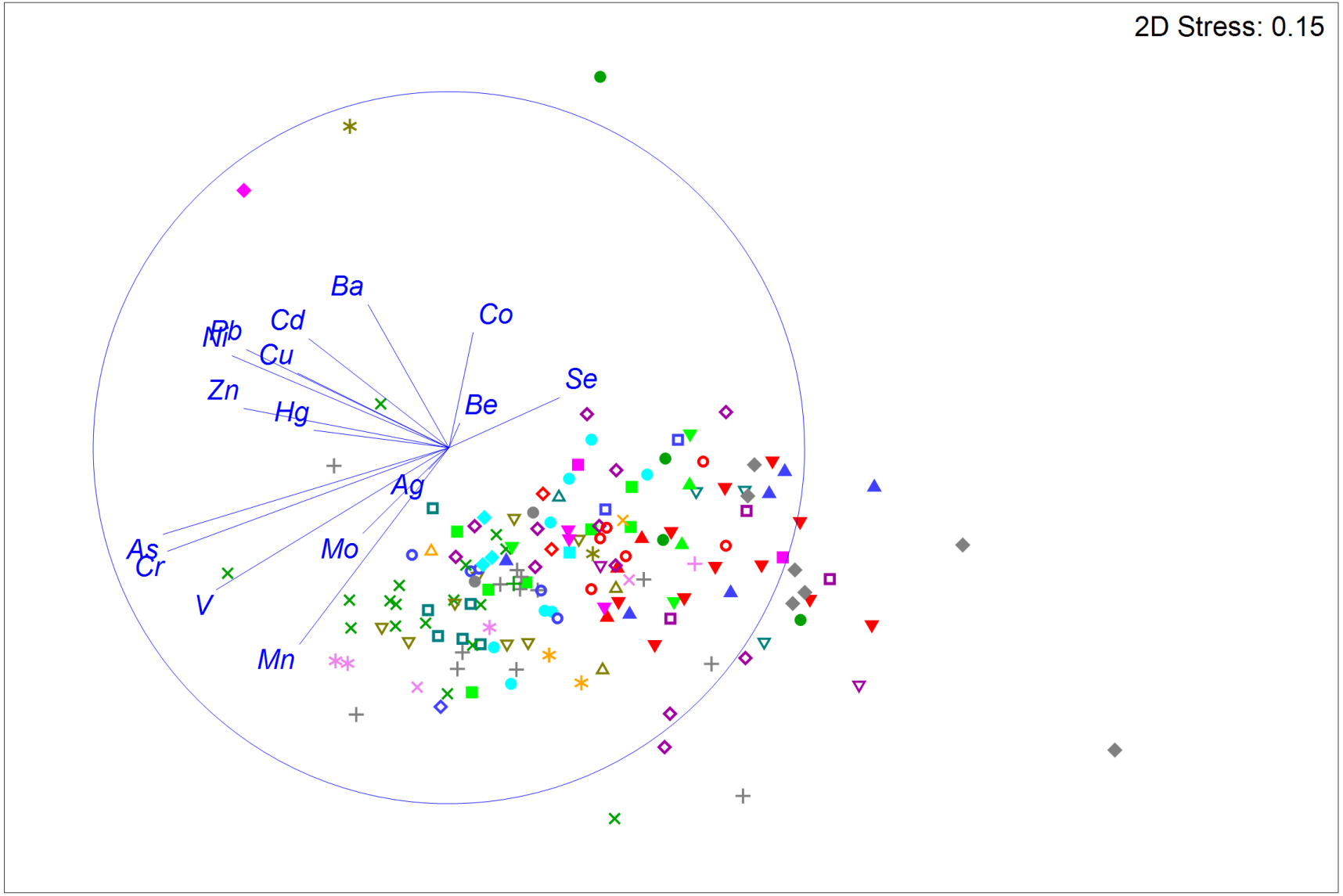
- Expand this modeling to the entire FCR.
- Partner with EPA, FWC, USGS, and others
- Use statistical modeling to associate biological and geological responses to modeled data at annual CREMP monitoring stations as far back as possible.





Non-metric MDS

Transform: Square root
Resemblance: S17 Bray-Curtis similarity



InletExpDepthCat_m

- Boynton26-30
- Boynton21-25
- Lake Worth26-30
- Lake Worth31-33
- Lake Worth21-25
- Haulover11-15
- Haulover6-10
- PortEv6-10
- Gov Cut11-15
- PortEv11-15
- Gov Cut6-10
- Haulover16-20
- PortEv16-20
- Boca6-10
- PortEv21-25
- Gov Cut16-20
- Hillsboro16-20
- Hillsboro21-25
- Hillsboro11-15
- PortEv0-5
- Hillsboro0-5
- Hillsboro6-10
- Boynton0-5
- Boynton6-10
- Haulover0-5
- Haulover26-30
- PortEv31-33
- Hillsboro31-33
- Boca31-33
- Boynton16-20
- Boca16-20
- Boynton31-33
- Haulover21-25
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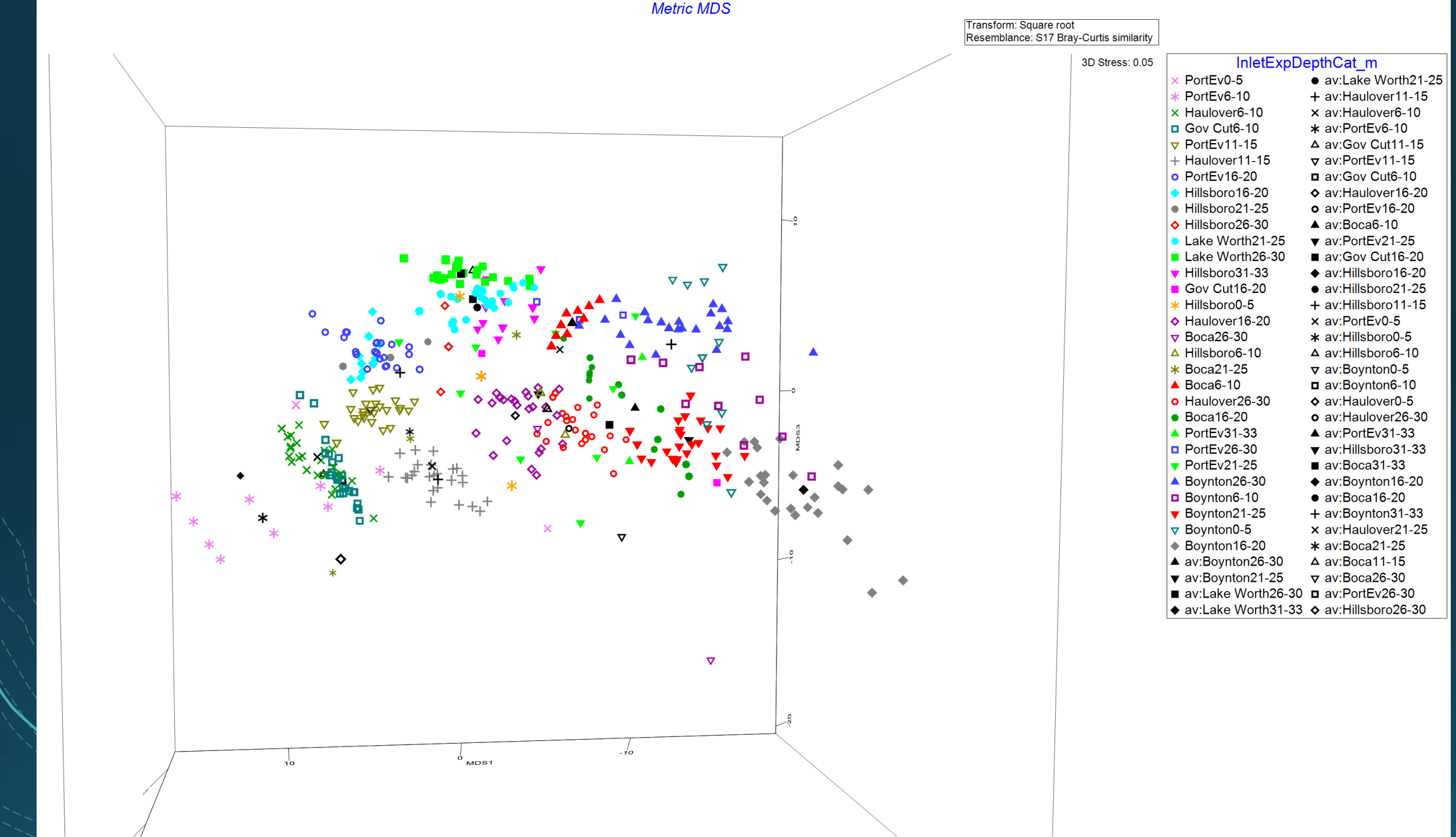
- Boca11-15
- Boca26-30
- PortEv26-30
- Hillsboro26-30


Metric MDS
Transform: Square root
Resemblance: S17 Bray-Curtis similarity
3D Stress: 0.05
InletExpDepthCat_m
PortEv0-5
PortEv6-10
Haulover6-10
Gov Cut6-10
PortEv11-15
Haulover11-15
PortEv16-20
Hillsboro16-20
Hillsboro21-25
Hillsboro26-30
Lake Worth21-25
Lake Worth26-30
Hillsboro31-33
Gov Cut16-20
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Boynton16-20
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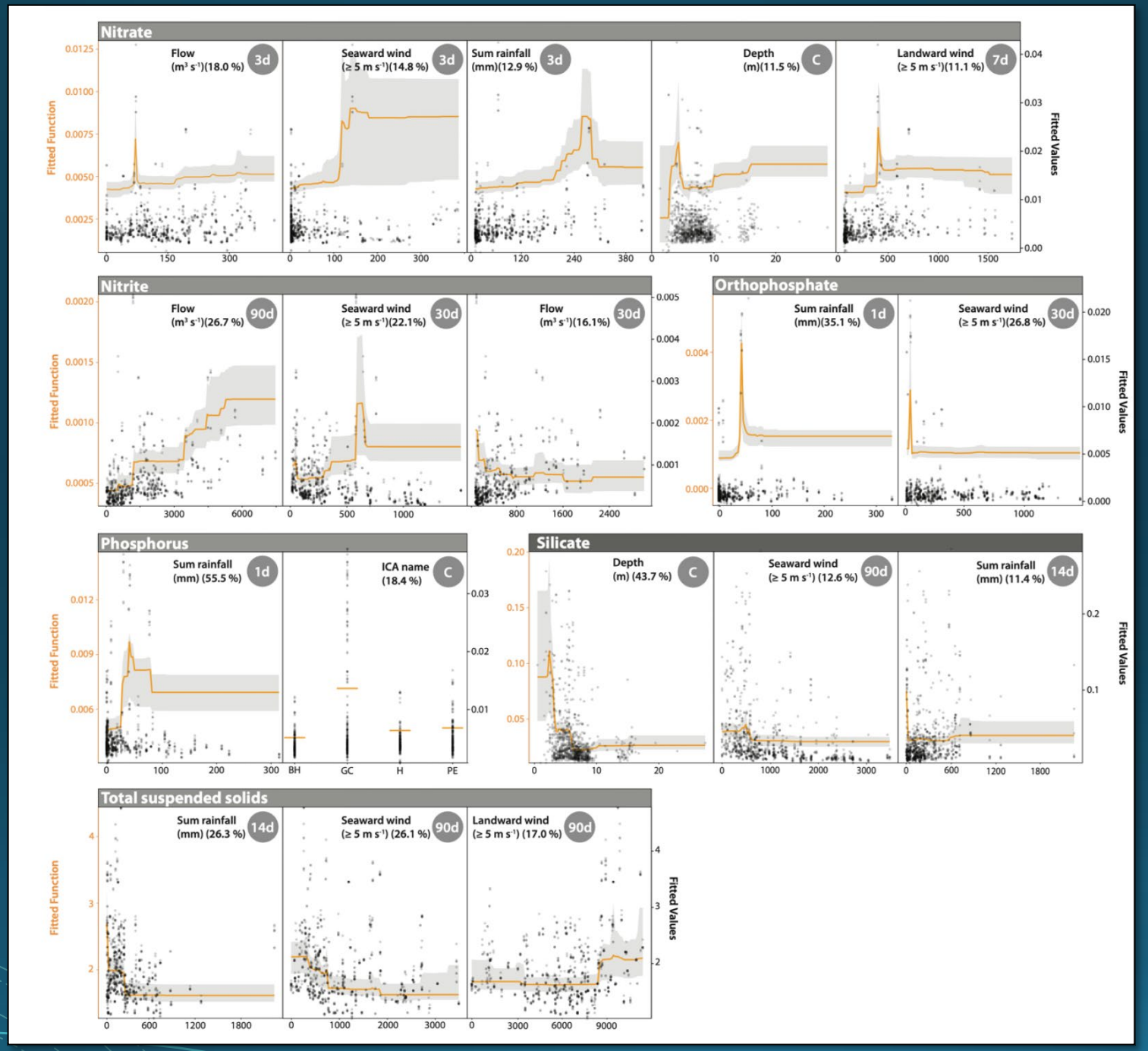
MDS1
MDS3


Nitrate
Flow (m³ s⁻¹)(18.0 %) 3d
Seaward wind (≥ 5 m s⁻¹)(14.8 %) 3d
Sum rainfall (mm)(12.9 %) 3d
Depth (m)(11.5 %) C
Landward wind (≥ 5 m s⁻¹)(11.1 %) 7d
Nitrite
Flow (m³ s⁻¹)(26.7 %) 90d
Seaward wind (≥ 5 m s⁻¹)(22.1%) 30d
Flow (m³ s⁻¹)(16.1%) 30d
Orthophosphate
Sum rainfall (mm)(35.1 %) 1d
Seaward wind (≥ 5 m s⁻¹)(26.8 %) 30d
Phosphorus
Sum rainfall (mm) (55.5 %) 1d
ICA name (18.4 %) C
BH
GC
H
PE
Silicate
Depth (m) (43.7 %) C
Seaward wind (≥ 5 m s⁻¹) (12.6 %) 90d
Sum rainfall (mm) (11.4 %) 14d
Total suspended solids
Sum rainfall (mm) (26.3 %) 14d
Seaward wind (≥ 5 m s⁻¹) (26.1 %) 90d
Landward wind (≥ 5 m s⁻¹) (17.0 %) 90d
Fitted Function
Fitted Values

SCTLD Interventions

https://www.arcgis.com/apps/dashboards/55a759f02f3c486eb1d29a95f80fba0a

Coral Disease Intervention Dashboard updated 3/25/2025

Filter Results

Filter by data provider*
All data providers

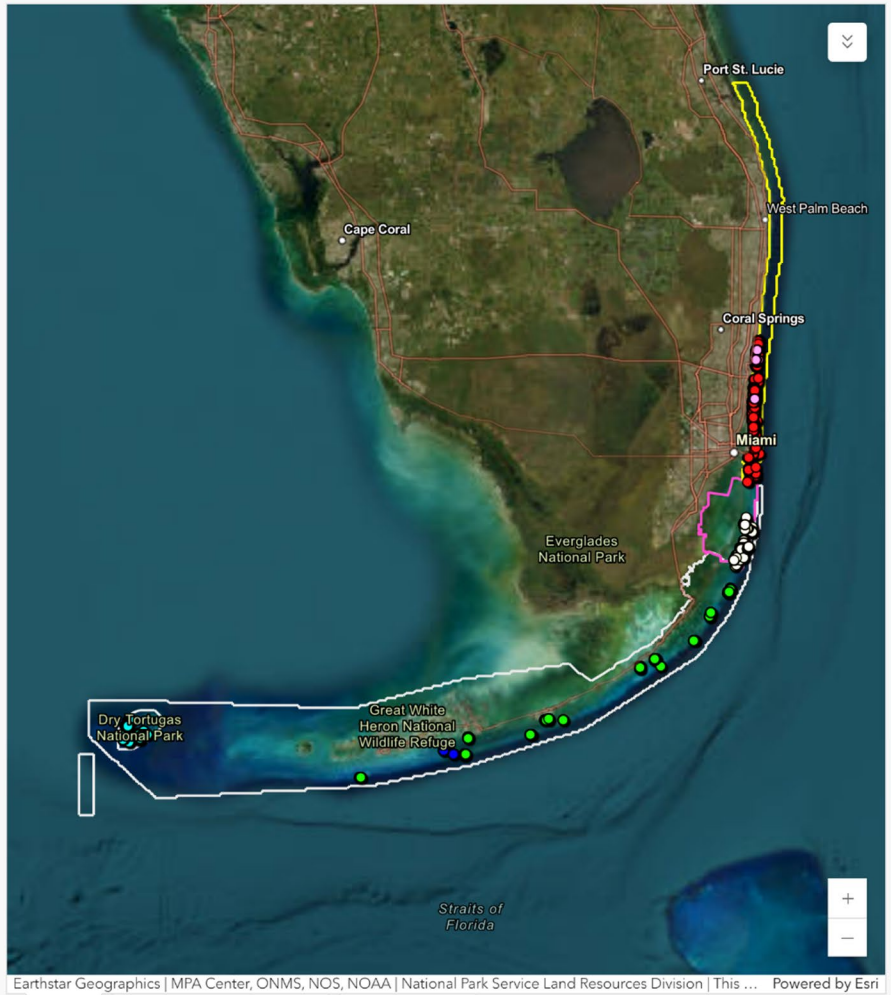
Filter by species
All species

Filter by treatment type
All treatment types

Legend*

- Biscayne National Park (NPS)
- Dry Tortugas Emergency Coral Mission #1, Nova Southeastern University, Karen Neely & Florida Atlantic University, Joshua Voss (NFWF & NOAA-CRCP)
- Dry Tortugas Emergency Coral Mission #2, Nova Southeastern University, FAU - Harbor Branch, University of the Virgin Islands (NFWF & NOAA-CRCP)
- Dry Tortugas National Park (NPS & DEP)
- Fish & Wildlife Research Institute & Mote (DEP & SWG)
- Florida Atlantic University, Joshua Voss (DEP & HBOI)
- Nova Southeastern University, Brian Walker & Miami-Dade RER, Rebecca Ross (DEP & NOAA)
- Nova Southeastern University, Karen Neely (DEP & NFWF)
- Smithsonian Marine Station, Valerie Paul (DEP)

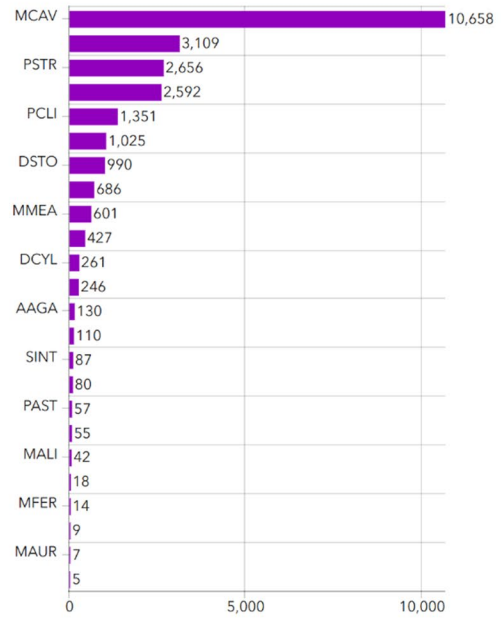
Funding partners for each data set are shown in parenthesis.



Map | Additional Information | Data Credits

25,231
Total # of Treated Corals

of Corals Treated by Species



Species not included in graph (<5 treated): ACER, HCUC, MANG, MARE, ODIF, ORBSP, PPOR, SCOL

Chart | Species Codes

of Corals Treated by Treatment Type

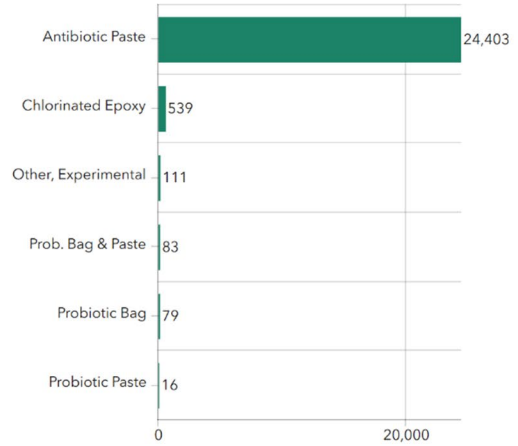


Chart | Treatment Descriptions

of Corals Treated per Year