Investigating the Exposure and Toxicity of UV filters to Hard Corals

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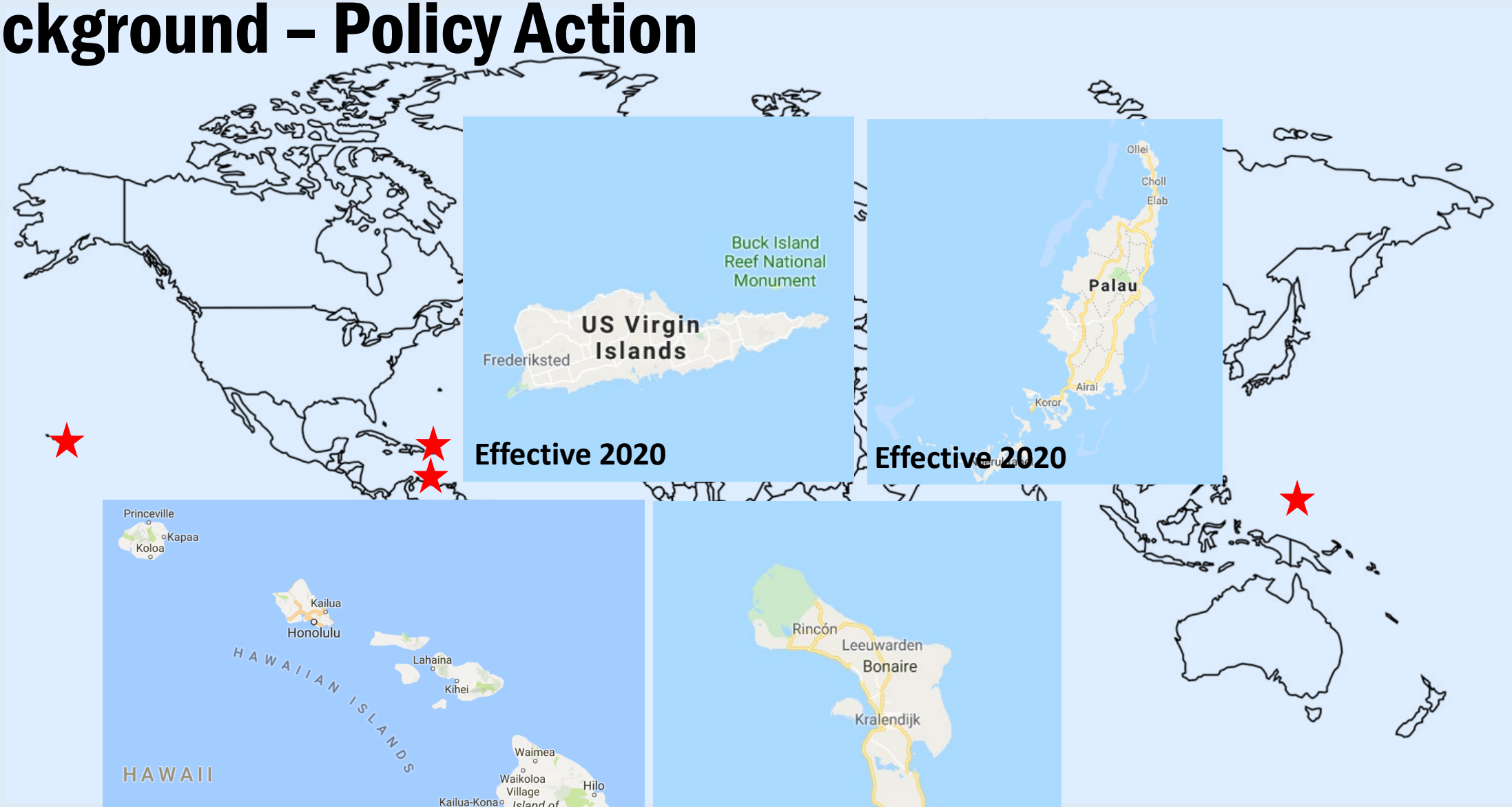
Background – Policy Action



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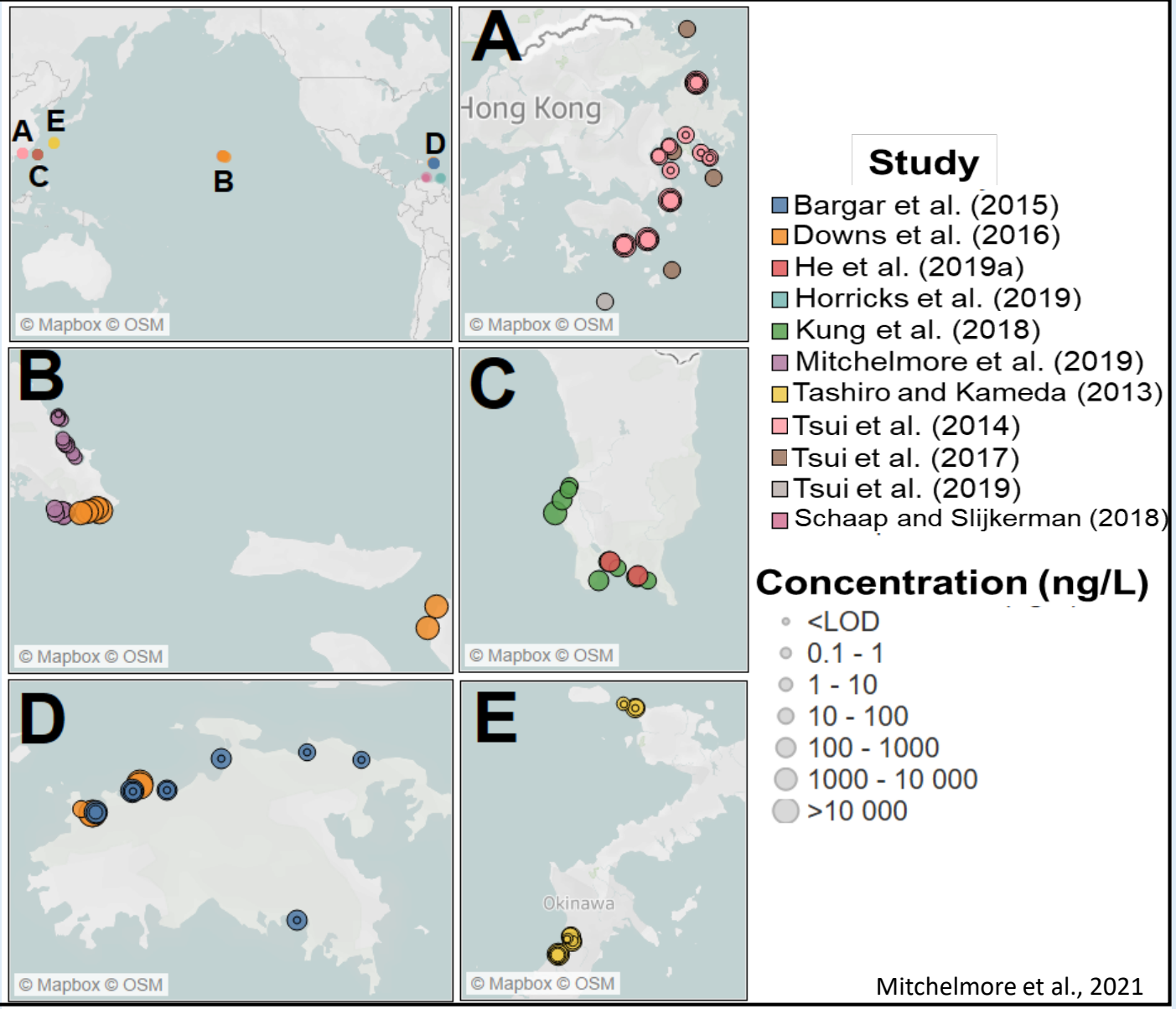
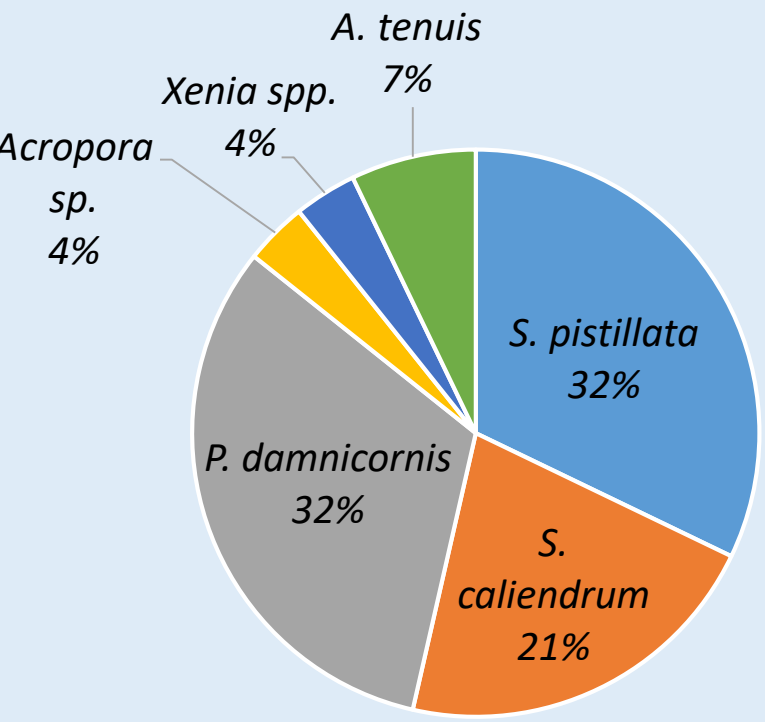
Measured Environmental Concentrations of Oxybenzone

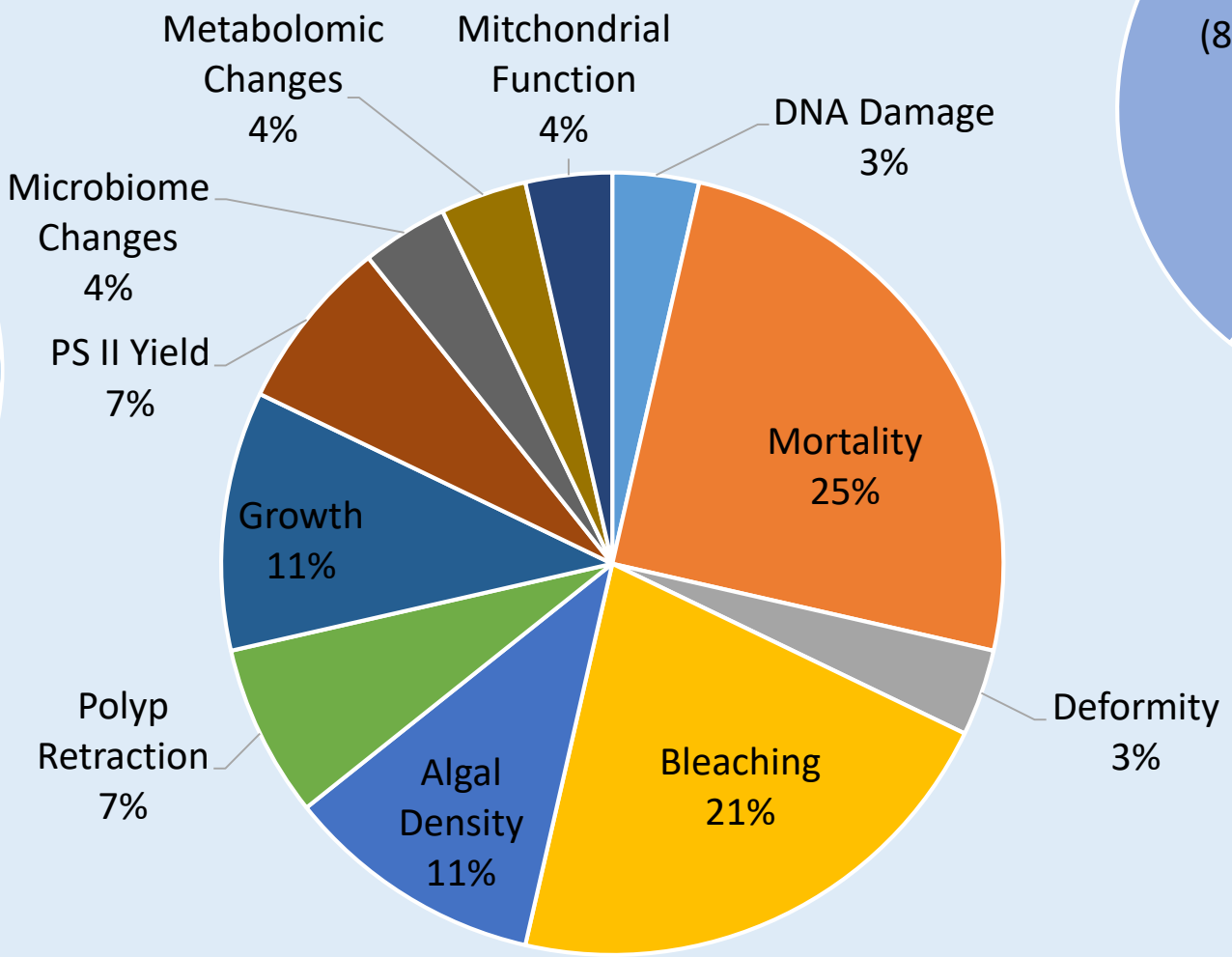


Mitchelmore et al., 2021

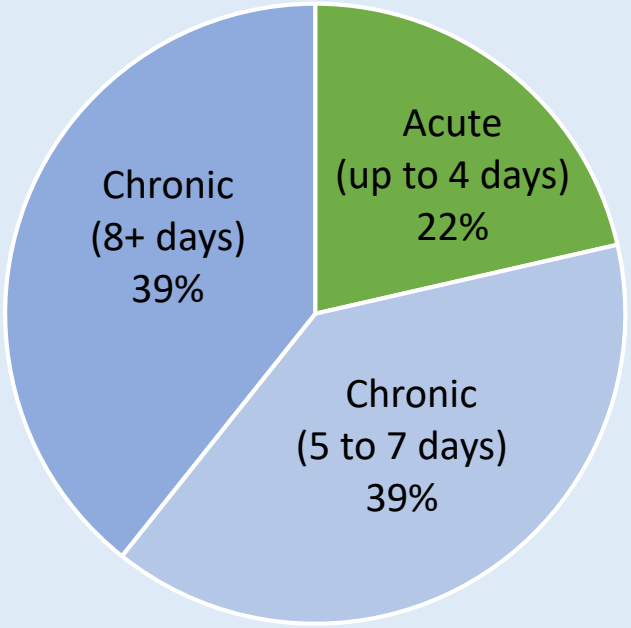
Summary of Oxybenzone Impacts in Corals



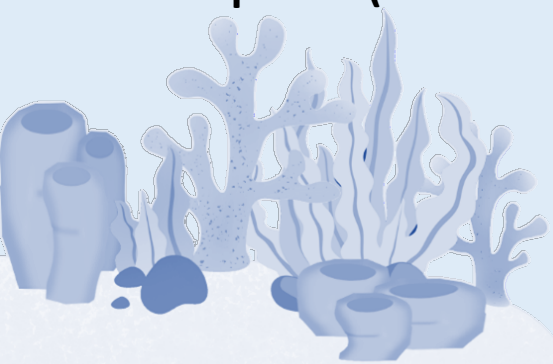
Species (whole organism)



Endpoint



Duration



n = 27 endpoints from 6 studies

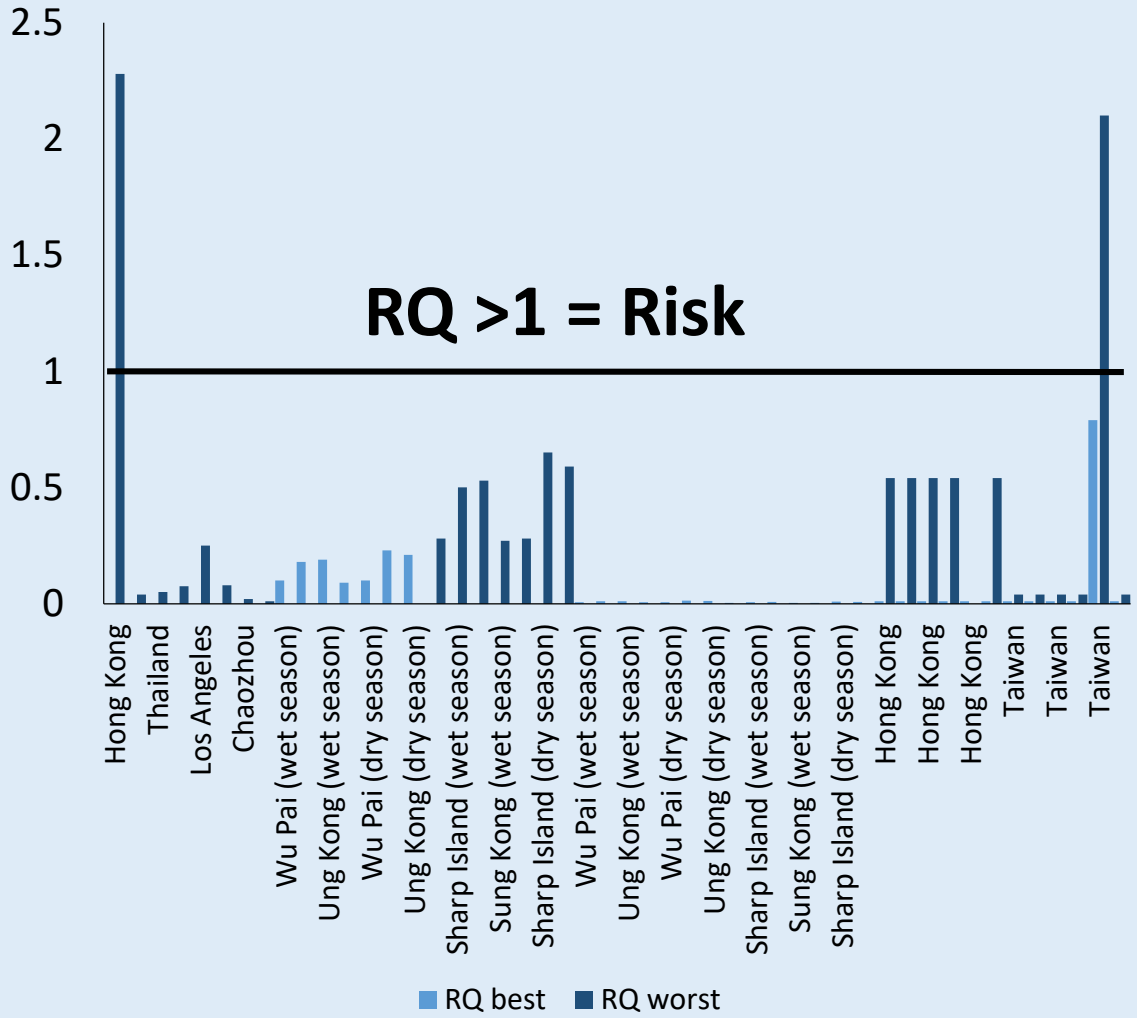
Danovaro et al, 2008; Downs et al, 2016; McCoshum et al, 2016; He et al, 2019; Stein et al, 2020; Wijgerde et al, 2020

Calculating Risk

RQ = **MEC** / **PNEC** **PNEC** = (**EC** / **AF**)

- **RQ** = Risk quotient
- **MEC** = Measured environmental concentration
- **PNEC** = Predicted no-effect concentration = **EC**/**AF**
- **EC** = Effect concentration
  - Acute Test: **LC50**
  - Chronic Test: **NOEC or EC10 (preferred)**
- **AF** = Assessment factor, accounts for uncertainty
  - Acute Test: **1000**
  - Chronic Test: **100**

Outlier: Hong Kong RQ_{worst} 31.61



Calculations by Mitchelmore et al., 2021 from Tsui et al., 2014, 2017; He et al., 2019a

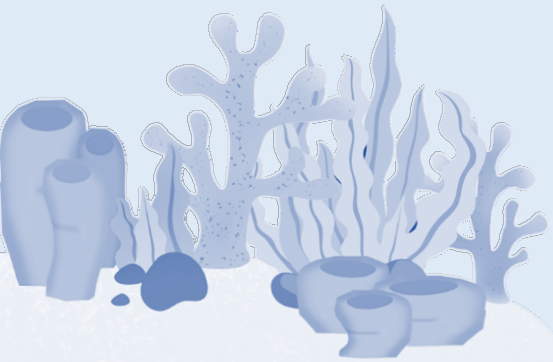
Findings and Recommendations for UV Filter Coral Toxicity Tests

- Develop a standard coral toxicity test that can generate reliable acute and chronic endpoints from dose–response relationships using appropriate test durations.
  - Evaluate UV filters to identify the most suitable biological endpoints and life stages.
  - Ensure use of appropriate solvents.
  - Proper positive and negative controls should be utilized.
  - Chronic endpoint relevant to population impacts (i.e. growth and/or reproduction) should be explored.
  - Develop a comprehensive and robust test setup that ensures consistent toxic-dose delivery.
    - A strategy to maintain UV filter concentrations throughout the exposure should be included.
    - An analytical sampling plan suitable to calculate robust time-weighted exposure concentrations should be formed.

Modified from Mitchelmore et al., 2021; Table 4

Acute Toxicity of the UV filter oxybenzone to the hard coral *Galaxea fascicularis*

Conway et al., 2021



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Science of The Total Environment

Volume 796, 20 November 2021, 148666

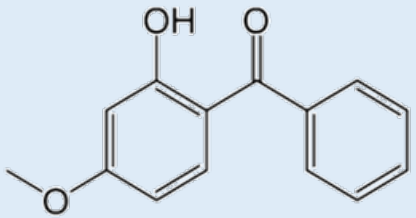
Acute toxicity of the UV filter oxybenzone to the coral *Galaxea fascicularis*

Annaleise J. Conway, Michael Gonsior, Cheryl Clark, Andrew Heyes, Carys L. Mitchelmore

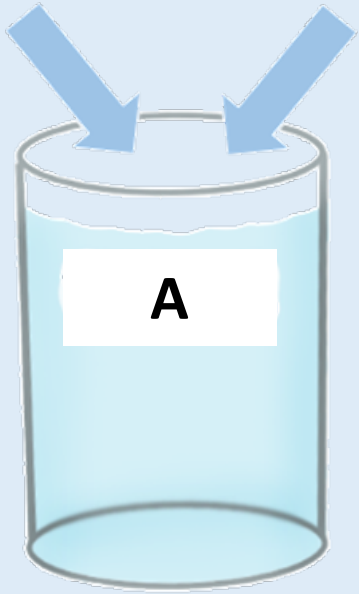
Oxybenzone Acute Exposures

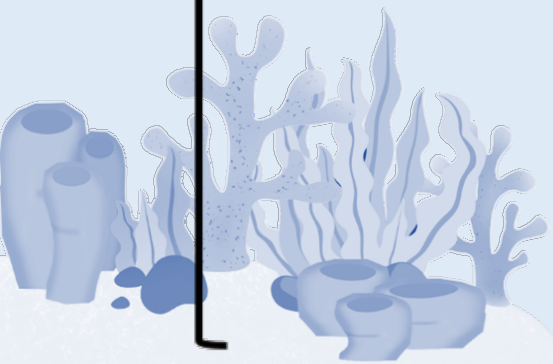
x3

G. fascicularis



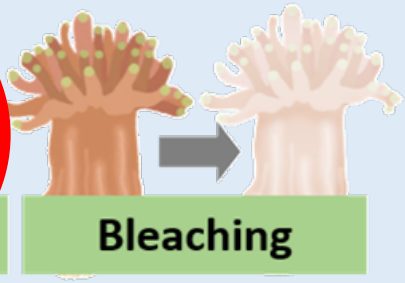
Benzophenone-3
(0.31 to 10 mg/L)
+ Negative, Solvent
and Positive Controls





96 h

Mortality

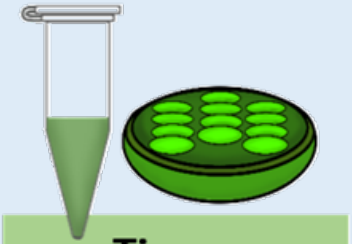


Bleaching

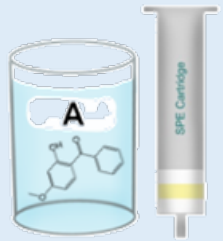
Polyp
Retraction

$\Delta F/F_m'$

Photosynthetic
Efficiency



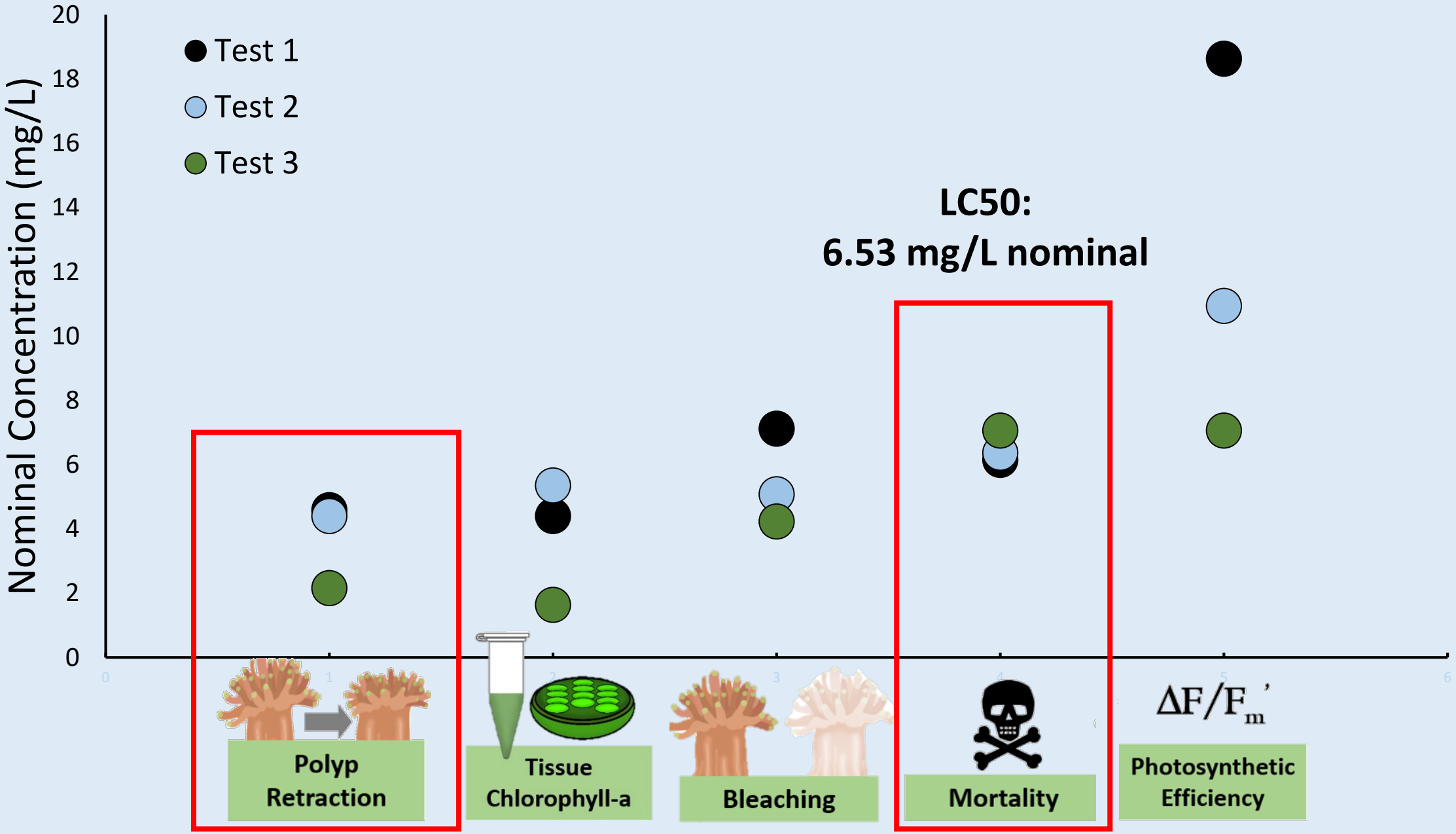
Tissue
Chlorophyll-a



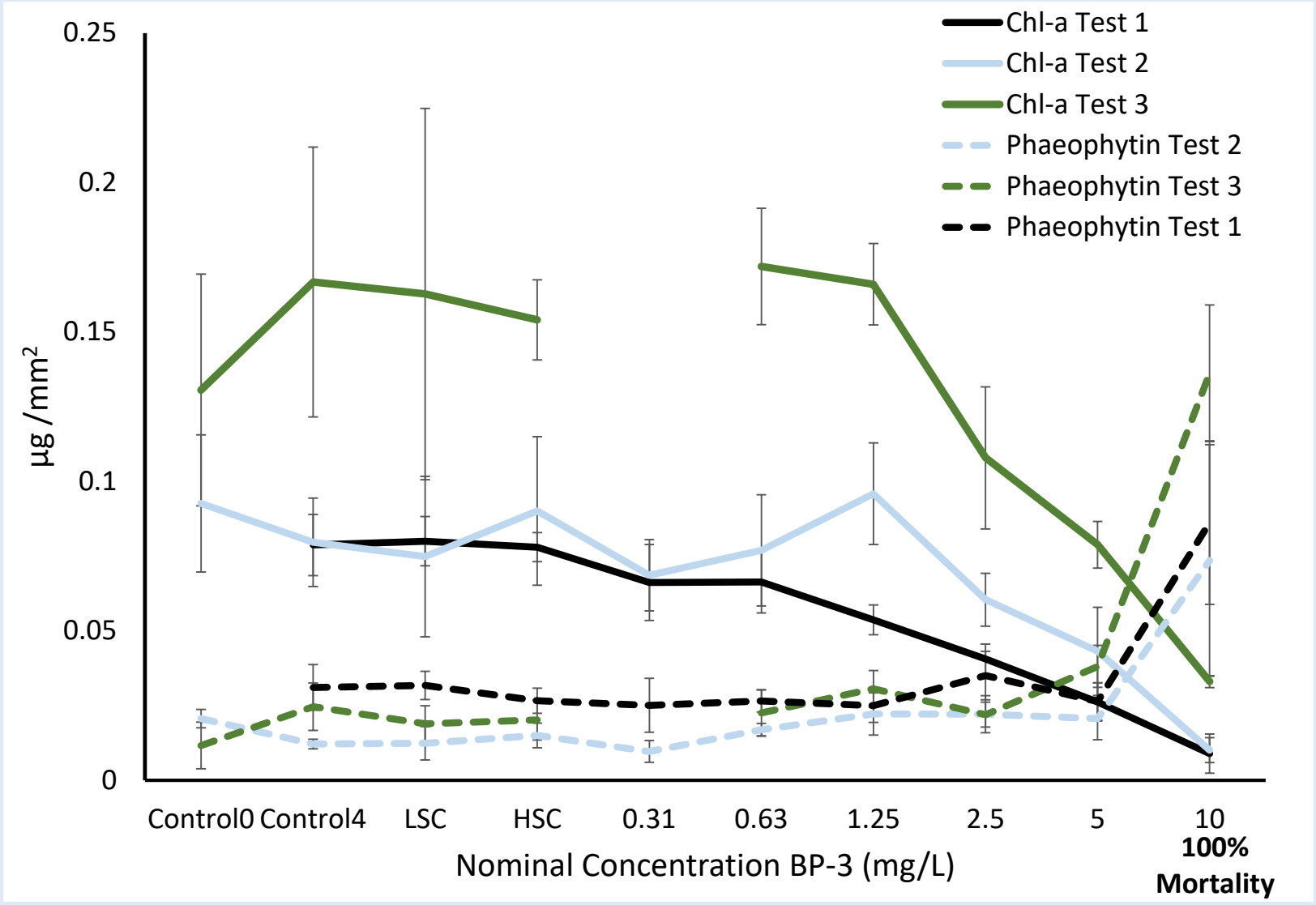
Daily Chemical
Analysis

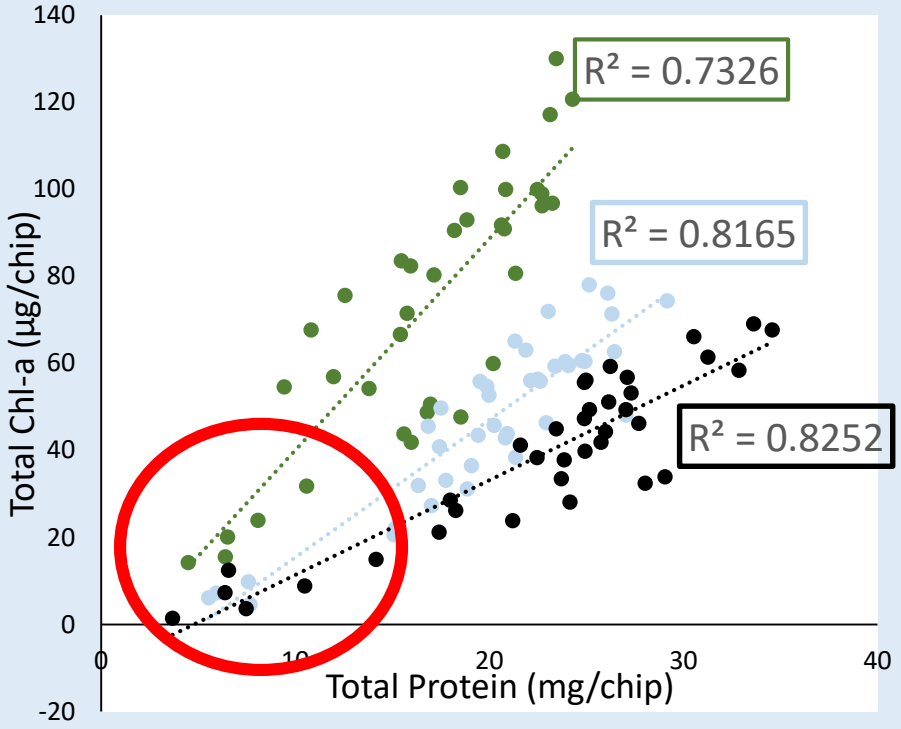
Acute Exposure LC/EC50s

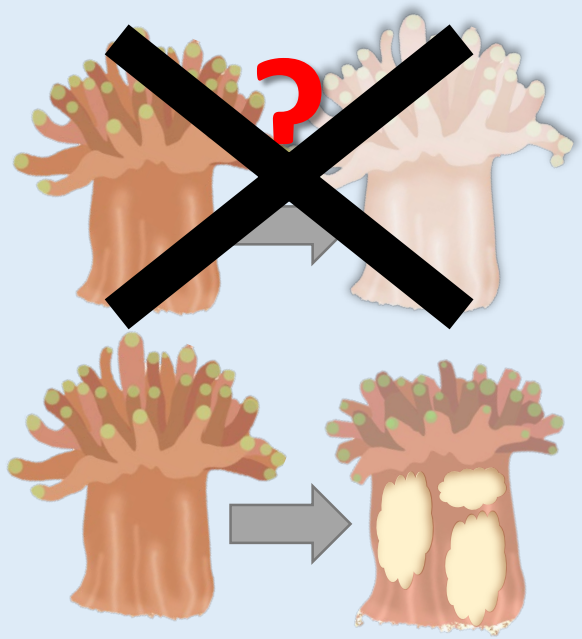
Endpoints calculated using drc package in R



Acute Tissue Pigment Results

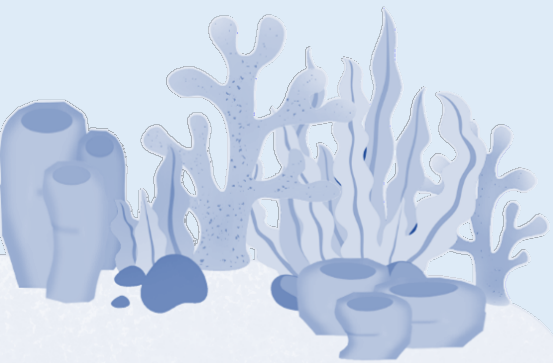






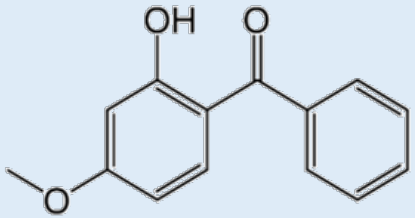
Chronic toxicity of the UV filter oxybenzone to the hard coral *Galaxea fascicularis*

Manuscript in preparation – Data not finalized



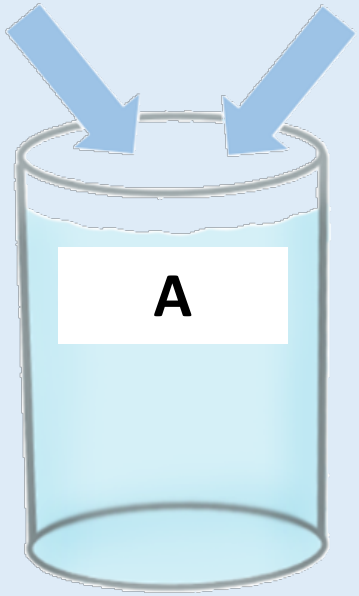
Oxybenzone Chronic Exposure

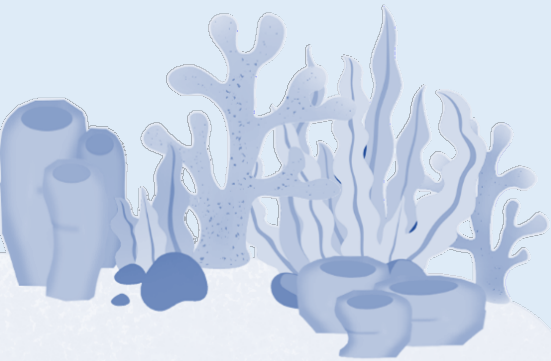
G. fascicularis



Benzophenone-3

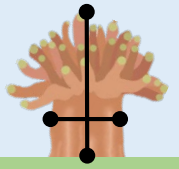
0.009 to 0.30 mg/L
+ Negative, Solvent
and Positive Controls





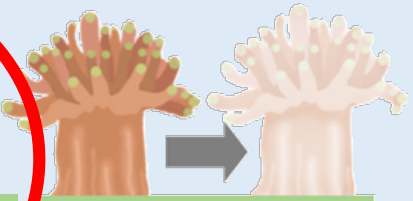
28 days

Newly emerged polyps

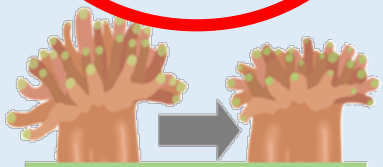


Polyp width/length

Buoyant weight



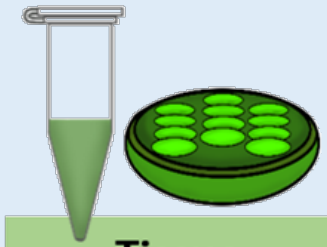
Bleaching



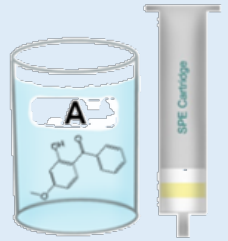
Polyp Retraction

$\Delta F/F_m'$

Photosynthetic Efficiency



Tissue Chlorophyll-a

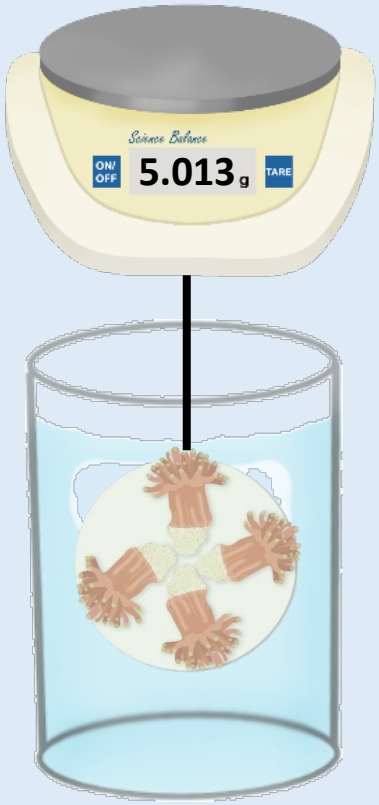


Biweekly chemical analysis

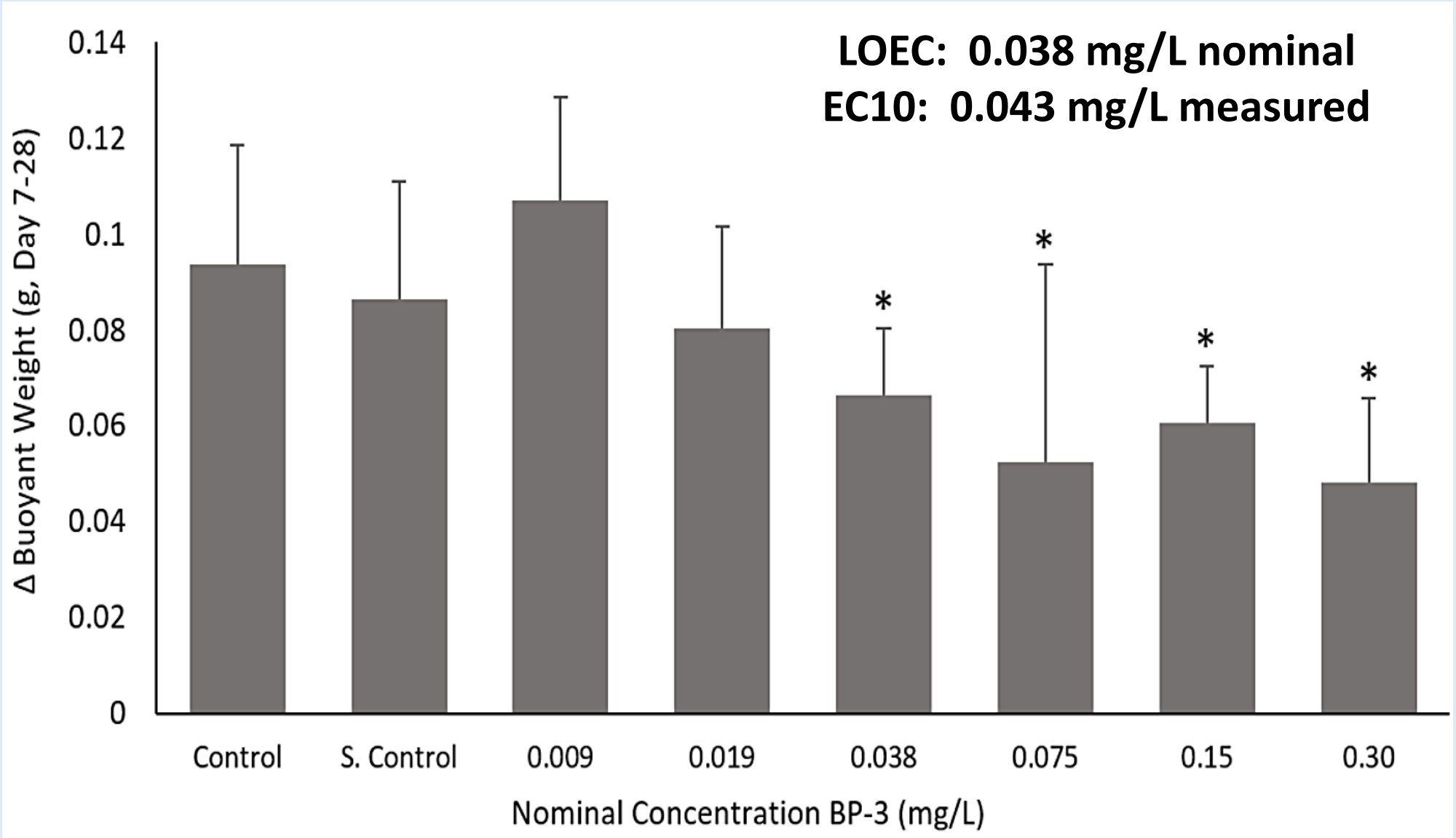
Manuscript in preparation – Data not finalized

Chronic Growth Results

Endpoints calculated using drc and mixtox packages in R



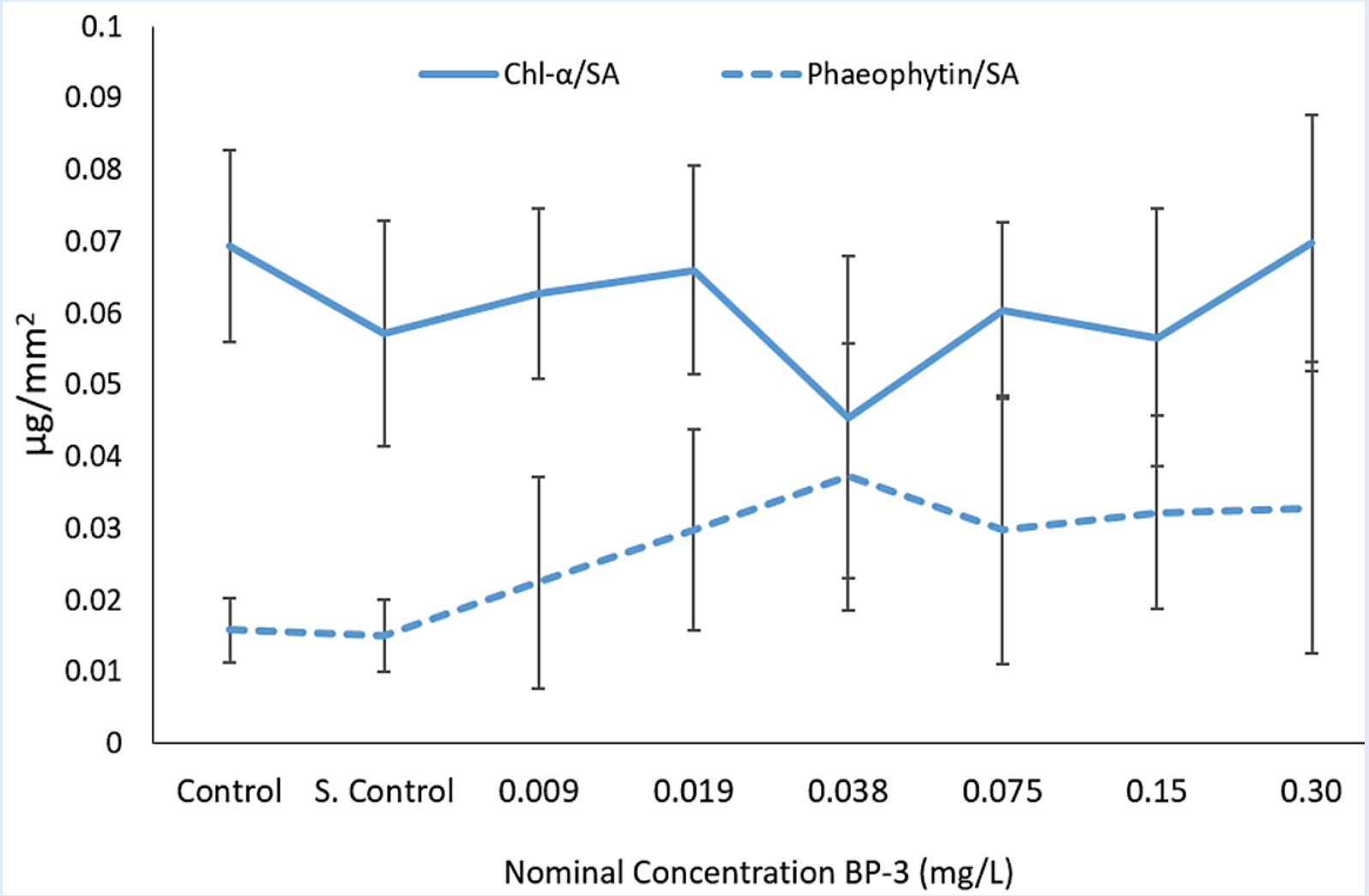
LOEC: 0.038 mg/L nominal
EC10: 0.043 mg/L measured



Manuscript in preparation – Data not finalized

*; significantly different from controls

Chronic Bleaching Results



No significant chl-α loss

Manuscript in preparation – Data not finalized

Analytical Chemistry Considerations

- Solid-phase extraction with LCqqq-MS analysis
- Oxybenzone sticks to surfaces (especially plastics) leading to losses
  - Each UV filter will behave differently depending on their chemistry which should be taken into account during analytical method development
- Little oxybenzone was found partitioned to particulate matter
  - This was expected due to a log Kow of 3.79
- Overall ended up with better percent nominal concentrations than some previous studies even without method recovery correction
  - Significant loss overnight (expected under UV light exposure, adsorption, coral and biofilm uptake)
- Chronic concentrations increased during the first week then plateaued
- Accurate analytical chemistry is necessary
  - Proper QA/QC is essential (i.e. spikes, blanks, analytical replicates, etc.)
  - Losses during processing may lead to underestimation of toxicity

Analytical considerations discussed at length in Conway et al., 2021 (10.1016/j.scitotenv.2021.148666)

Calculating Risk

RQ = MEC / PNEC **PNEC = (EC / AF)**

- **RQ** = Risk quotient
- **MEC** = Measured environmental concentration
  - Both tests: 142.7 mg/L or 0.0001427 mg/L
- **PNEC** = Predicted no-effect concentration = EC/AF
- **EC = Effect concentration**
  - Acute Test: 6.53 mg/L BP-3 (nominal)
  - Chronic Test: 0.043 mg/L BP-3 (measured)
- **AF = Assessment factor** = Accounts for uncertainty
  - Acute Test: 1000
  - Chronic Test: 100

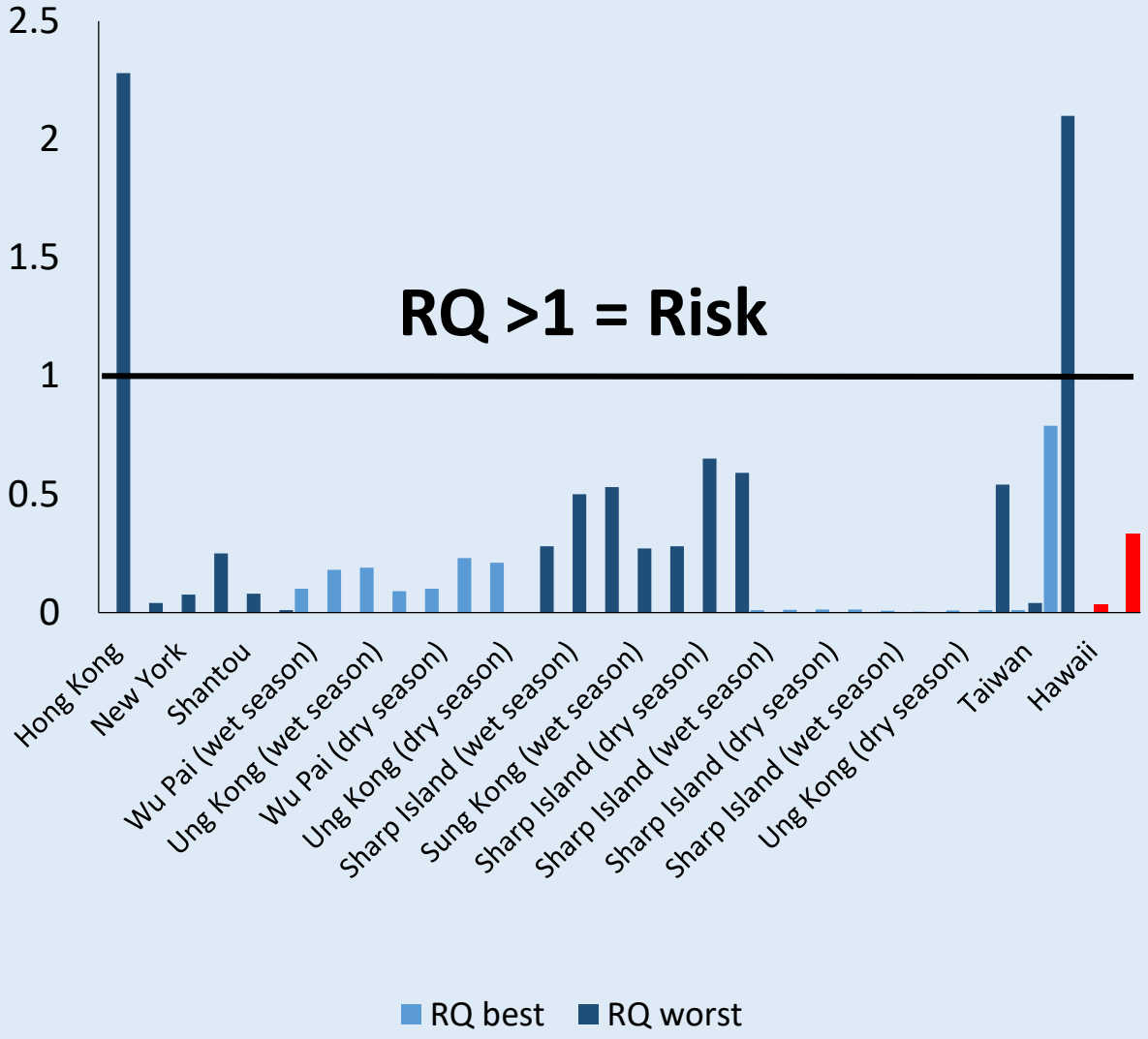
$RQ_{acute} = 0.0001427 / (6.53 / 1000)$

$RQ_{acute} = 0.032$

$RQ_{chronic} = 0.0001427 / (0.043 / 100)$

$RQ_{chronic} = 0.332$

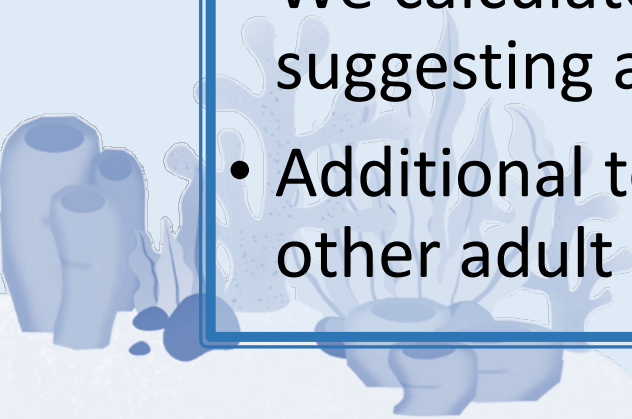
Outlier: Hong Kong RQ_{worst} 31.61



Calculations by Mitchelmore et al., 2021 from Tsui et al., 2014, 2017; He et al., 2019a

Takeaways & Recommendations

- There is limited oxybenzone toxicity data in corals and they have varied methodology
- We designed a repeatable standard toxicity test using G. fascicularis, and used it to find:
  - An adult hard-coral acute LC50
  - An adult hard-coral EC10 for growth
- We calculated RQs using both acute and chronic endpoints, neither suggesting a risk of oxybenzone to G. fascicularis
- Additional toxicity studies using standardized testing are needed for other adult hard coral species to explore species variability



Thank you!

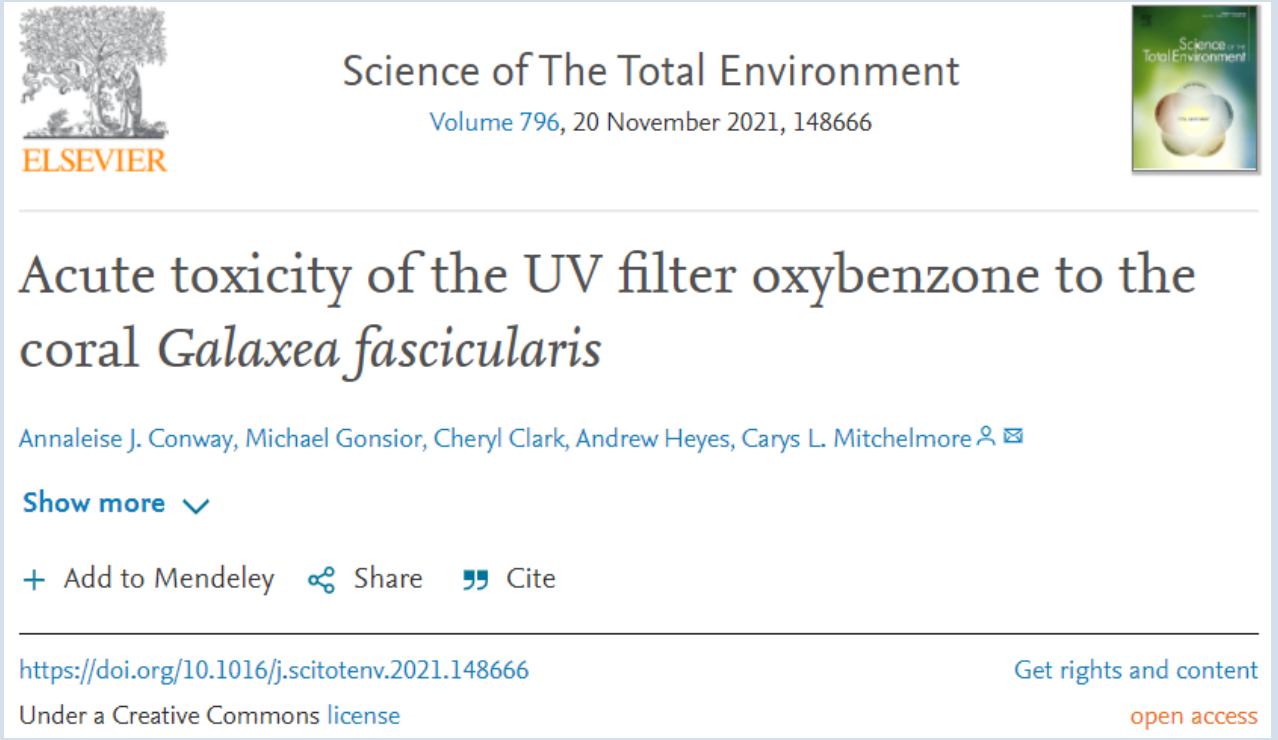
Project Acknowledgments:

Dr. Carys Mitchelmore,
Dr. Michael Gonsior,
Dr. Andrew Heyes,
Cheryl Clark,
& Cynthia Ross

St Mary's College of Maryland

Dr. Emily Brownlee
Dr. Elaine Szymkowiak
Thomas Brewer
Wet Lab Staff – Nhu, Ava, Rustin, Tanner

University of Maryland
Center for Environmental Science
Chesapeake Biological Laboratory



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Research was supported by Johnson & Johnson Consumer, Inc.

Additional Funding:

Chesapeake Biological Laboratory GEC Fellowship