Effects of sunscreen formulations on coral health and survival

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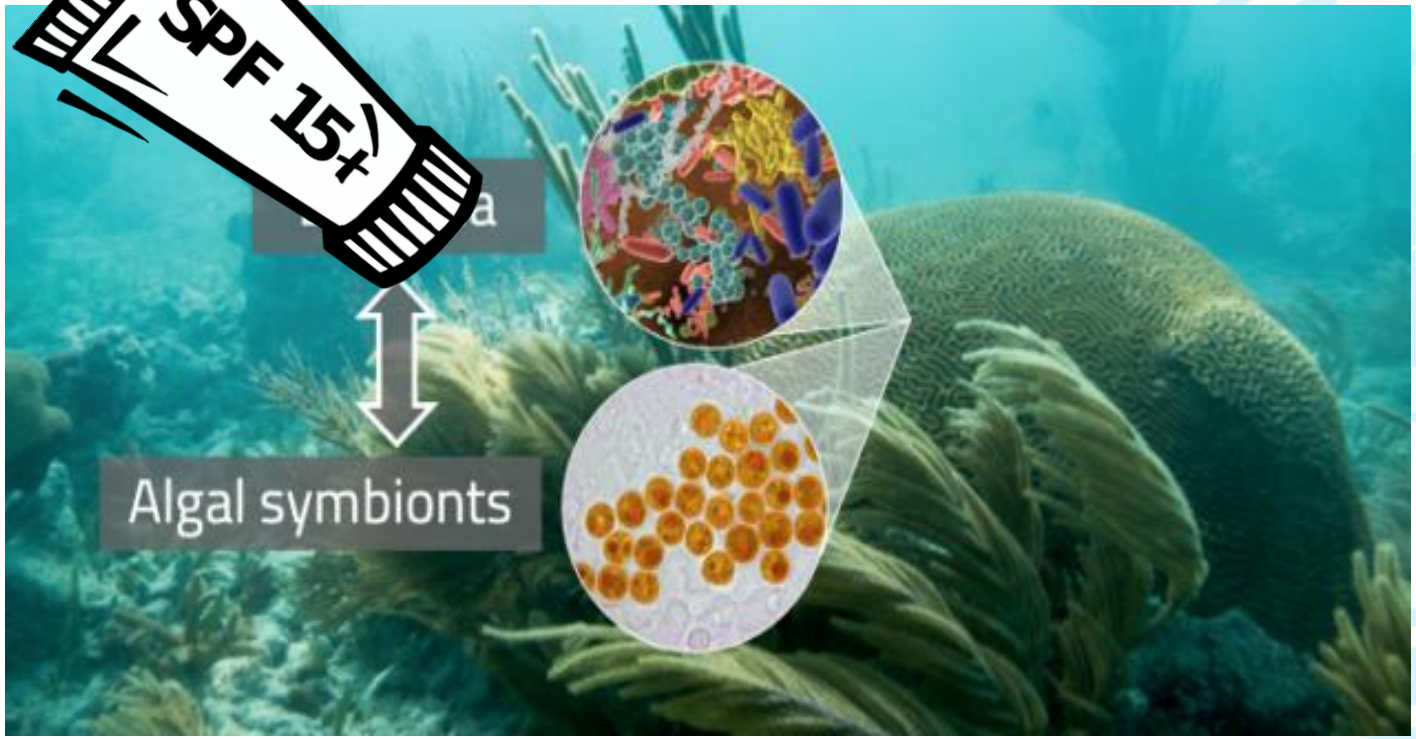
Coral Holobiont



Davies Lab, http://sites.bu.edu/davieslab/research/coral-microbiome/

Two Experiments

- **Experiment #1:** Establish effects of an oxybenzone based sunscreen formulation; 5 concentrations
  - **Endpoints:** visual health, survival, growth, and photochemical parameters, *Vibrio* spp. bacteria concentration
  - **Coral species:** *Acropora cervicornis* and *Montipora carpricornis*

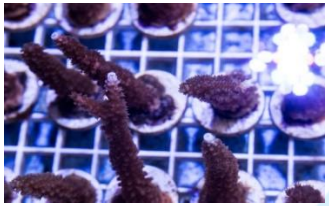
- **Experiment #2:** Compare four other sunscreen formulations to the highest concentrations of oxybenzone sunscreen
  - **Endpoints:** survival, photochemical parameters, RGB bleaching response
  - **Coral species:** *Acropora cervicornis, Orbicella faveolata,* and *Montipora carpricornis*

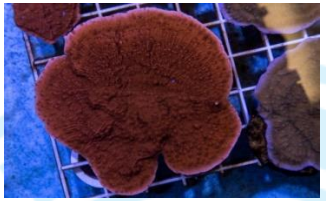
Why Sunscreen Formulation?

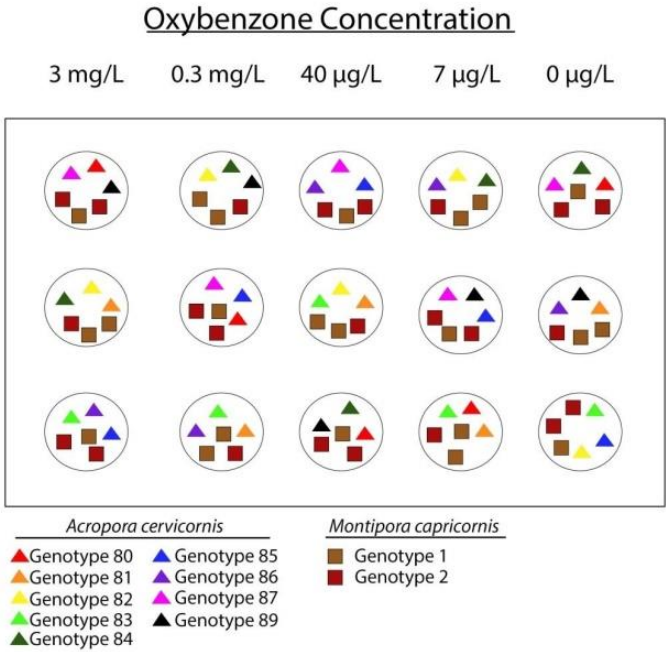
- Corals are not exposed to single ingredients, they are exposed to the formulation
- Some companies have suggested that the formulation can make potential contaminants less toxic
- Marketing strategies suggest mineral based sunscreens are ‘reef safe’…how do they compare to those with oxybenzone?

https://www.fasthorseinc.com/blog/2015/02/hawaii-is-fantastic-but-you-should-never-go-to-waikiki/

Methods







- 90 coral
  - 45 *Acropora cervicornis* (9 genotypes)
  - 45 *Montipora capricornis* (2 genotypes)
- Dosing occurred every 48 hours
- 17 day exposure
- Each tank contained powerhead for flow
- Daily measurements of temperature, salinity, pH, and dissolved oxygen

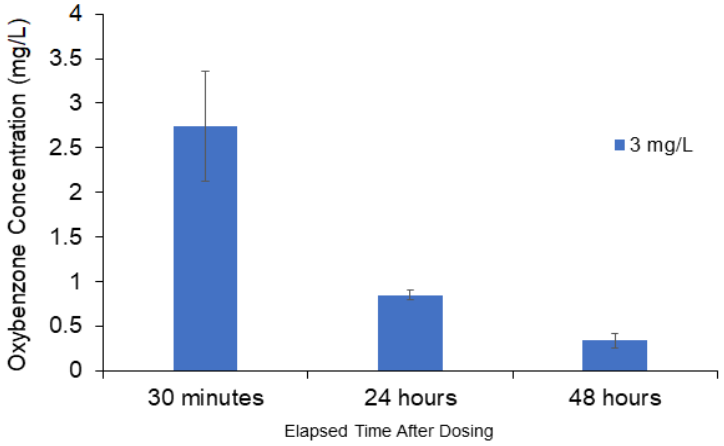
Physiological Impacts

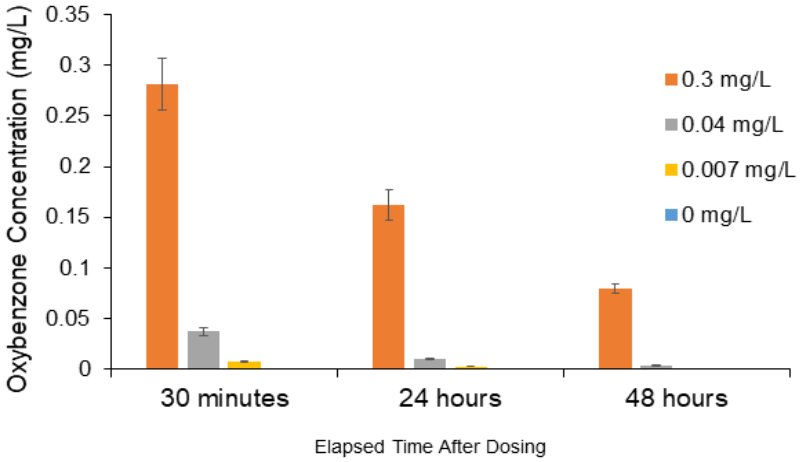
- Visual Health
- Survival
- Growth rates of *M. capricornis*
- Photochemical efficiency

Bacterial Concentration - *Vibrio* sp.

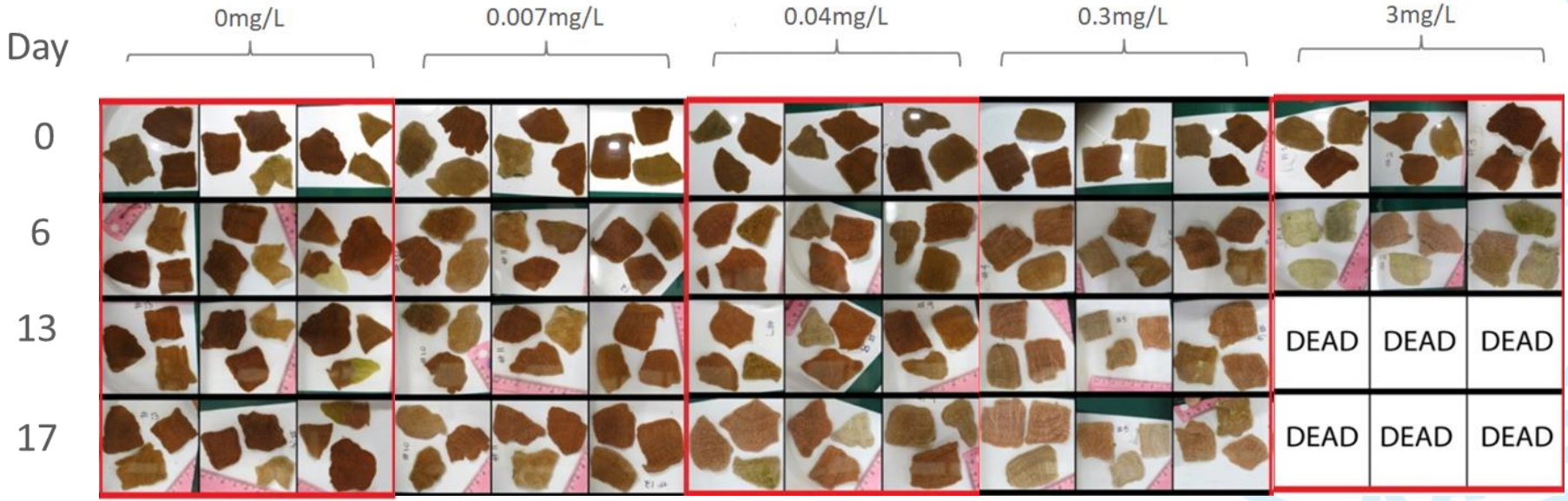
- Water Column vs *Acropora cervicornis* tissue
- Pre dose, first sign of visible bleaching, and post exposure

Oxybenzone Concentration After Dosing



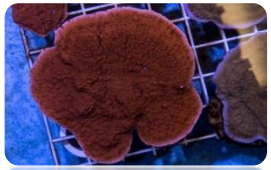


Visual Health Assessments

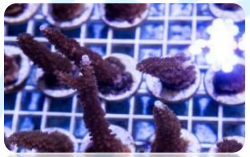


Visual Health Assessments/Survival

M. capricornis

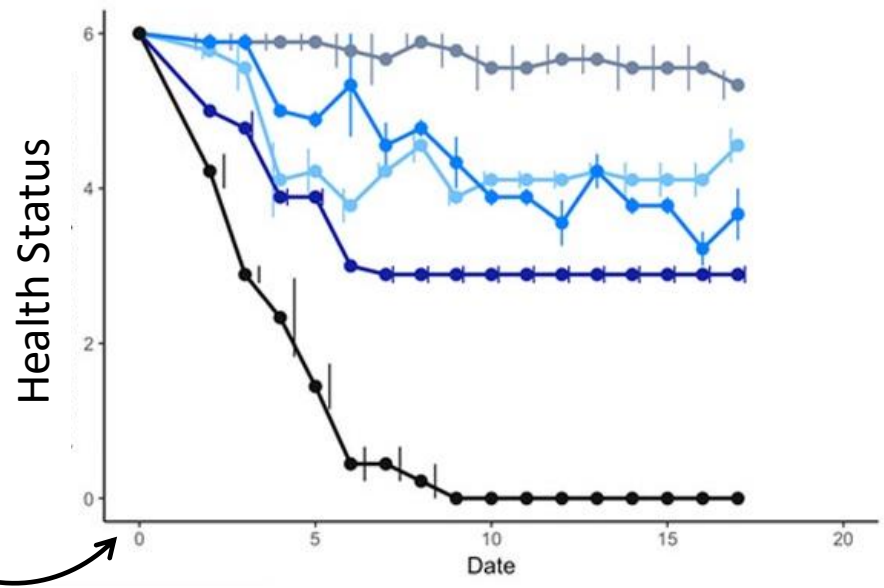


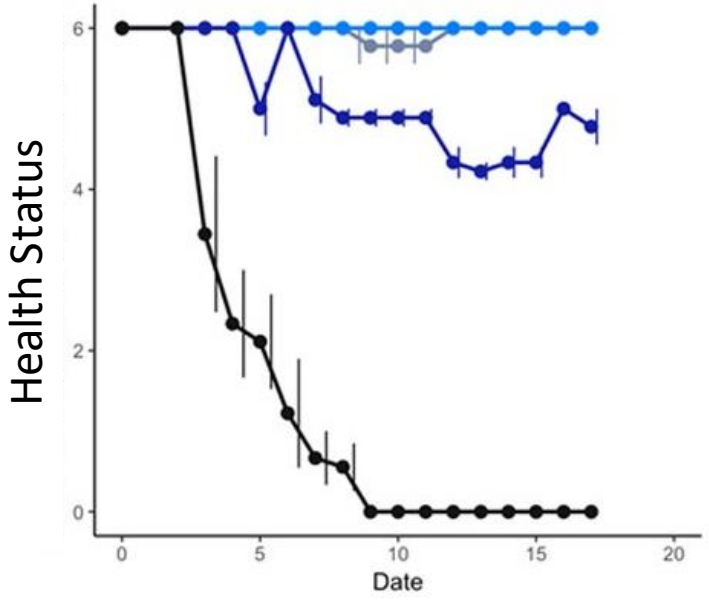
A. cervicornis



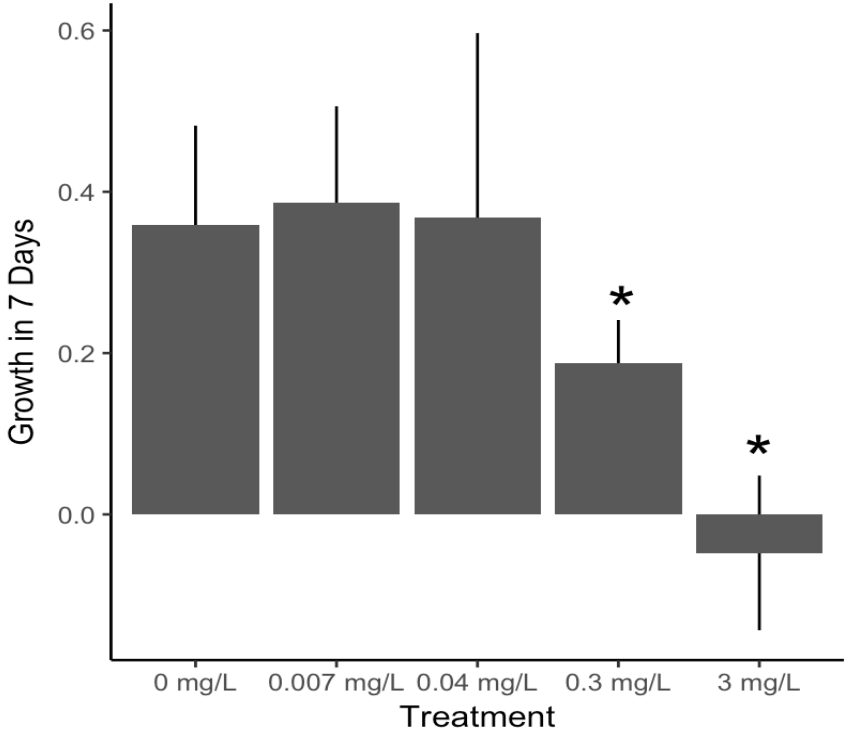
Healthy

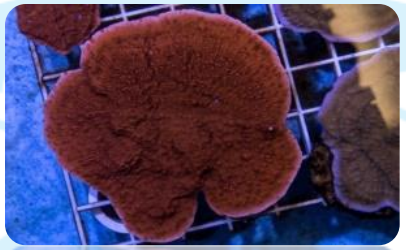
Dead



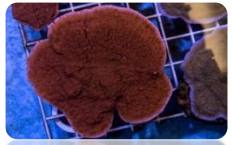


Growth rates of *M. capricornis* declined

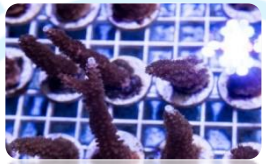


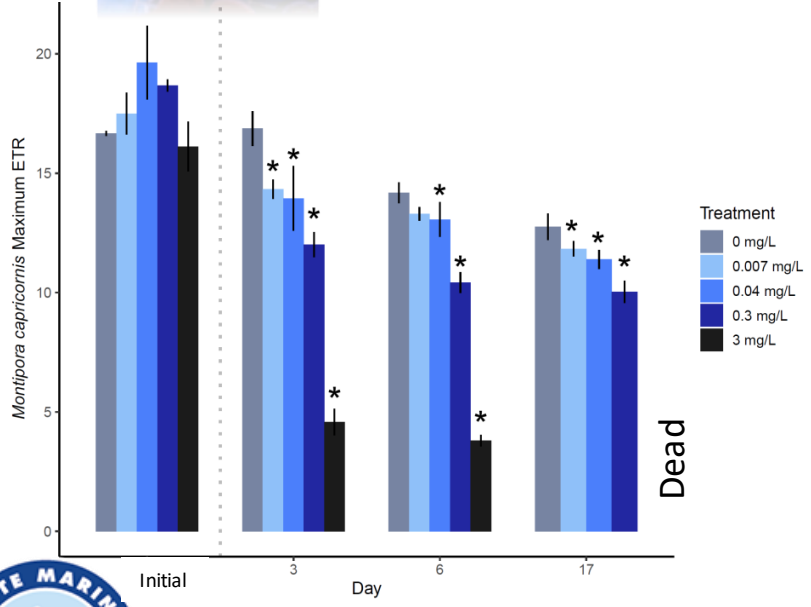


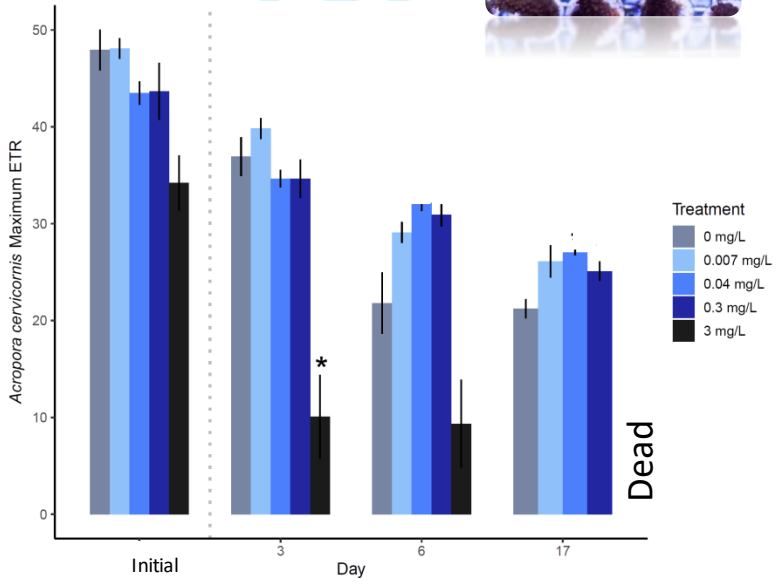
Maximum Electron Transport Rate was reduced



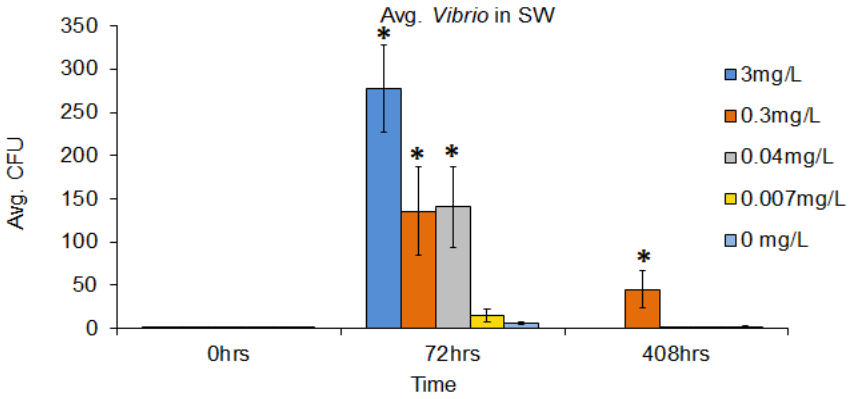
- Maximum rate an organism can move electrons through photosystem II.

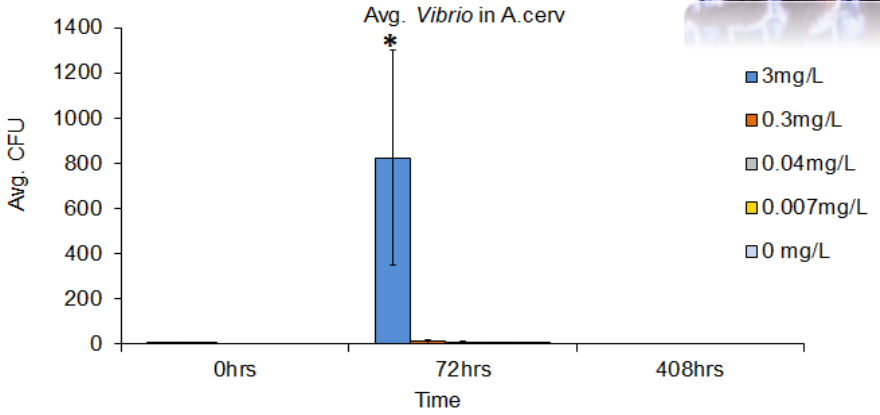






Concentration of *Vibrio* sp.bacteria increased





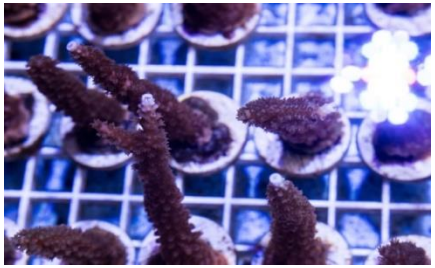
Summary

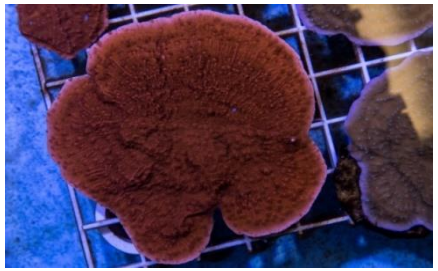
- One sunscreen formulation (6% oxybenzone) caused significantly:
  - Reduced coral survivorship (3.0 mg/L)
  - Reduced growth rate (*M. capricornis*: 3.0 mg/L and 0.3 mg/L)
  - Reduced photochemical function of electron transport rate
    - *M. capricornis* (0.007 mg/L)
    - *A. cervicornis* (3.0 mg/L)
  - Increased *Vibrio* spp. abundance (*A. cervicornis* 3 mg/L)

Experiment #2: How do other sunscreen formulations compare?

Pound for Pound Study?

Sunscreen Active Ingredients	% Oxybenzone	% Octinoxate	% Titanium Dioxide	% Zinc Oxide
Oxybenzone (Experiment #1)	6	0	0	0



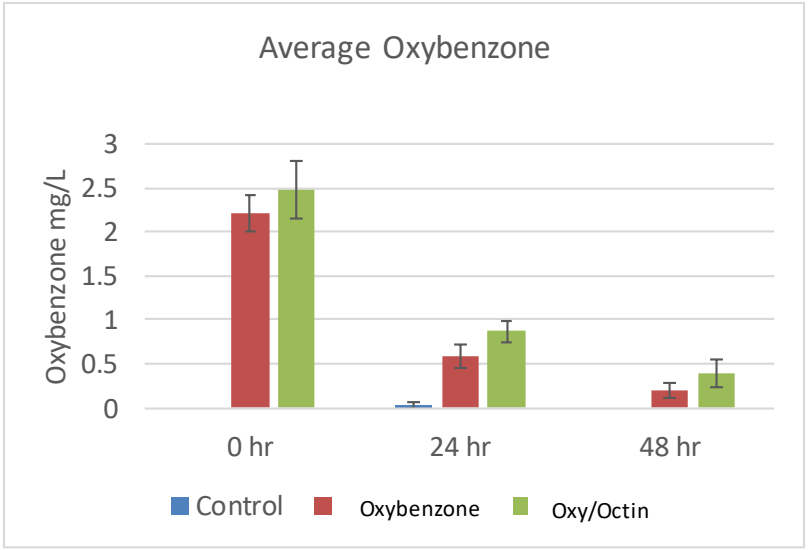


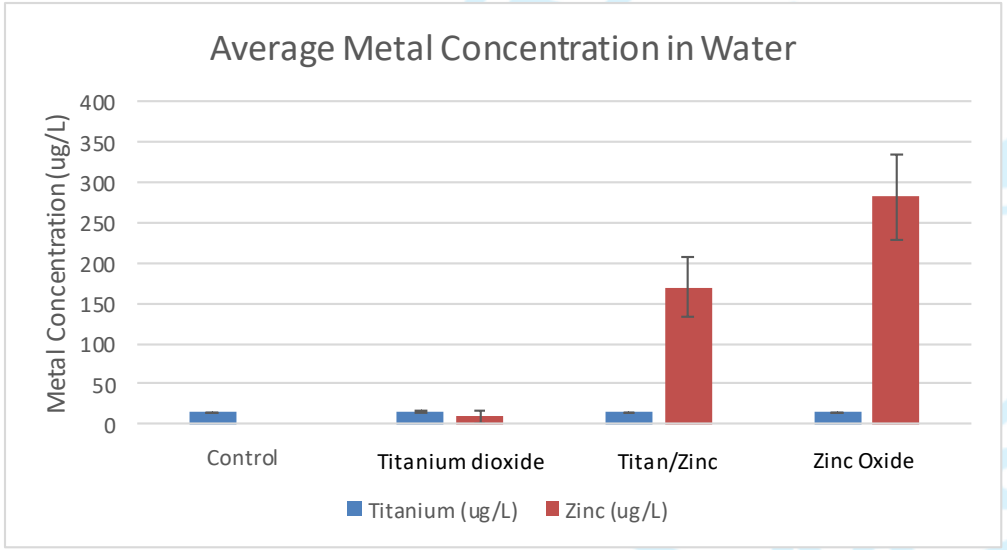
Methods

- Three coral species
  - *Acropora cervicornis* (n=4 per treatment)
  - *Montipora capricornis* (n=4 per treatment)
  - *Orbicella faveolata* (n=4 per treatment)
- 1 concentration per sunscreen formulation
  - 329 mg of sunscreen formulation per dose
  - 5 formulations (see previous table)
- Dosing occurred every 48 hours (100% exchange)
- 4 weeks of repeated exposure

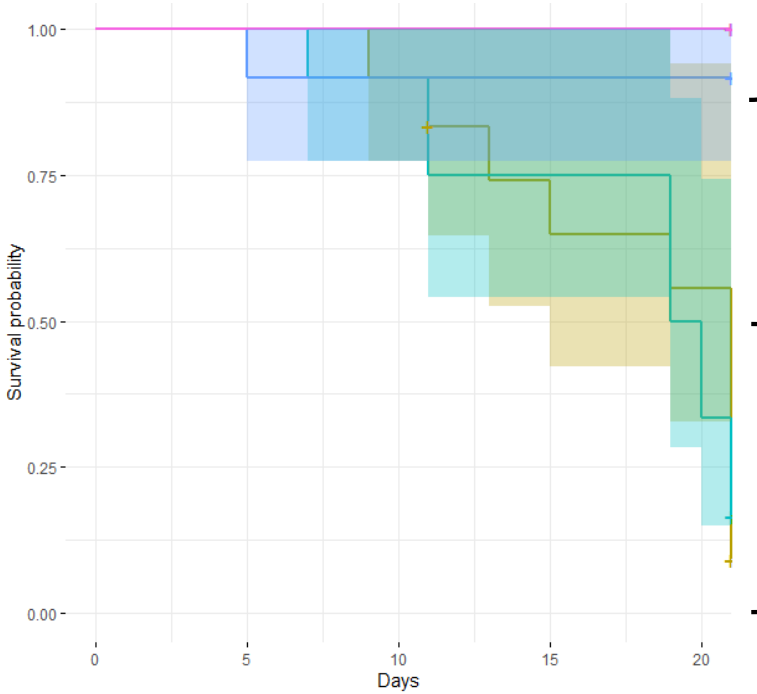
Active Ingredient Concentrations

Where is the Titanium Dioxide?





Two oxybenzone sunscreen formulations led to high mortality

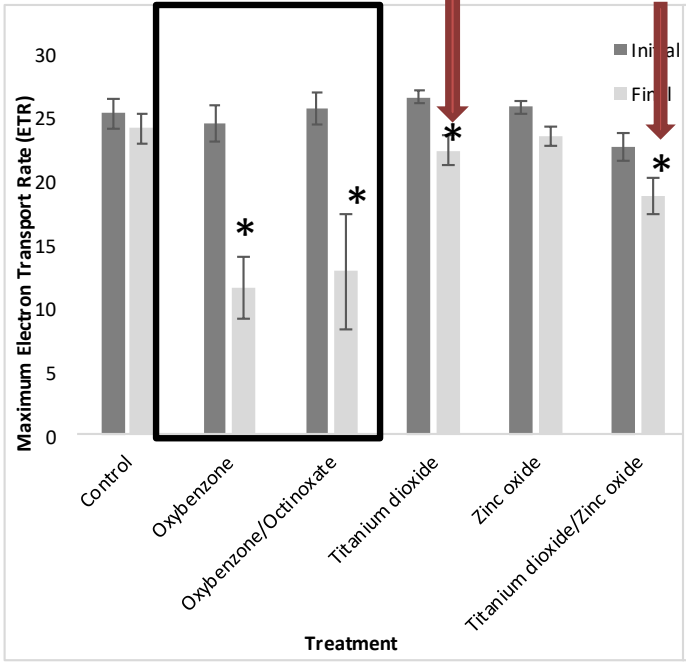


Controls, Titanium & Zinc formulations

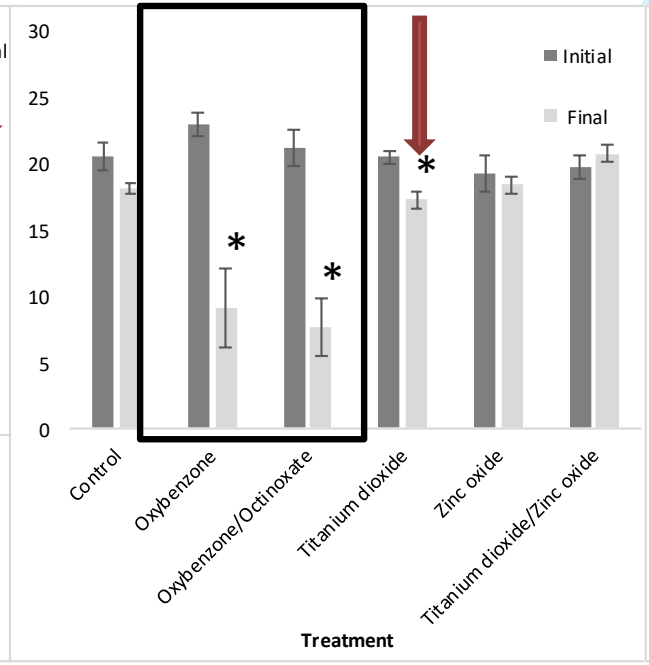
Oxybenzone formulations

Reduced ETRm was observed for several sunscreens

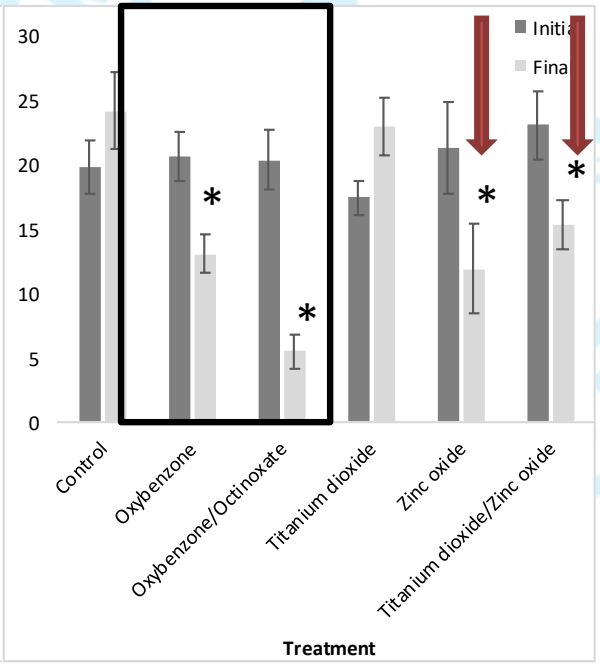
Orbicella faveolata



Montipora capricornis

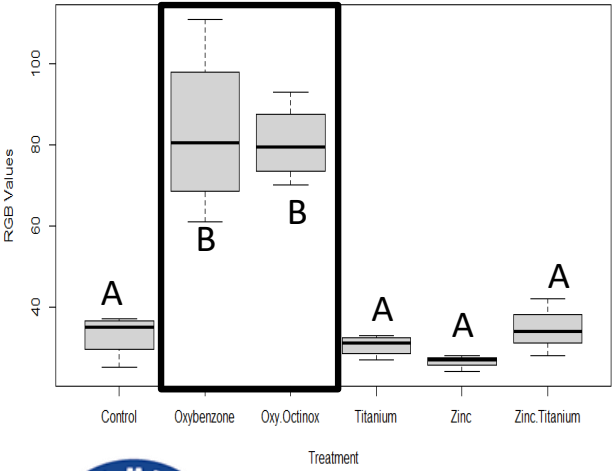


Acropora cervicornis

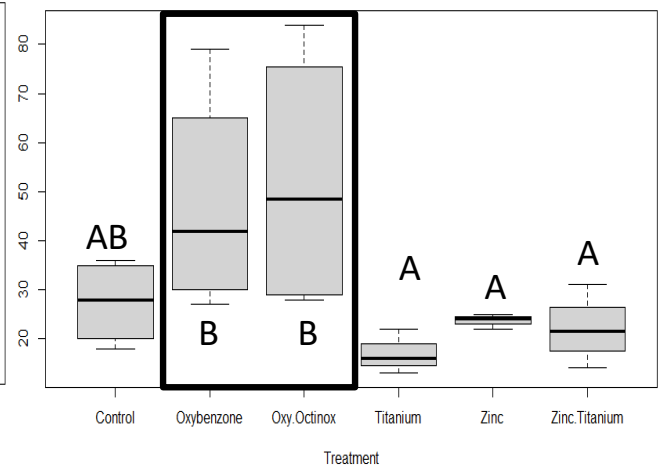


Bleaching was observed primarily within oxybenzone containing sunscreens

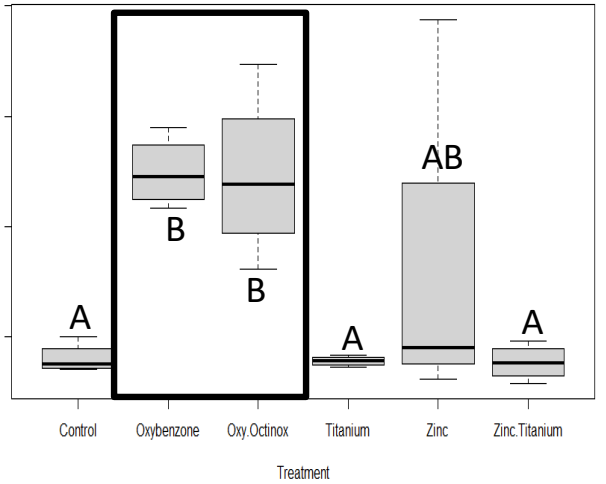
Orbicella faveolata



Montipora capricornis



Acropora cervicornis



Summary

- Comparatively high doses of titanium dioxide and/or zinc (pound for pound) showed much less toxicity to corals than oxybenzone containing formulation
- Still some negative effects of ‘mineral-based’ sunscreens especially on *Acropora cervicornis*
- Species specific responses observed, some more sensitive than others
- Recommend more studies on ‘mineral-based’ sunscreens to determine sub-colony level effects, different life stages

Acknowledgments

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