Sunscreens (UV-filters) in Coral Reef Environments

Dr. Carys L. Mitchelmore

Professor; University of Maryland Center for Environmental Science

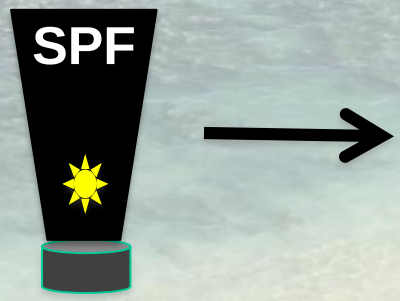
Key West City Commission Meeting, Key West, FL, January 15th, 2019

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
CHESAPEAKE BIOLOGICAL LABORATORY
Post Office Box 38
Solomons, Maryland 20688

mitchelmore@umces.edu

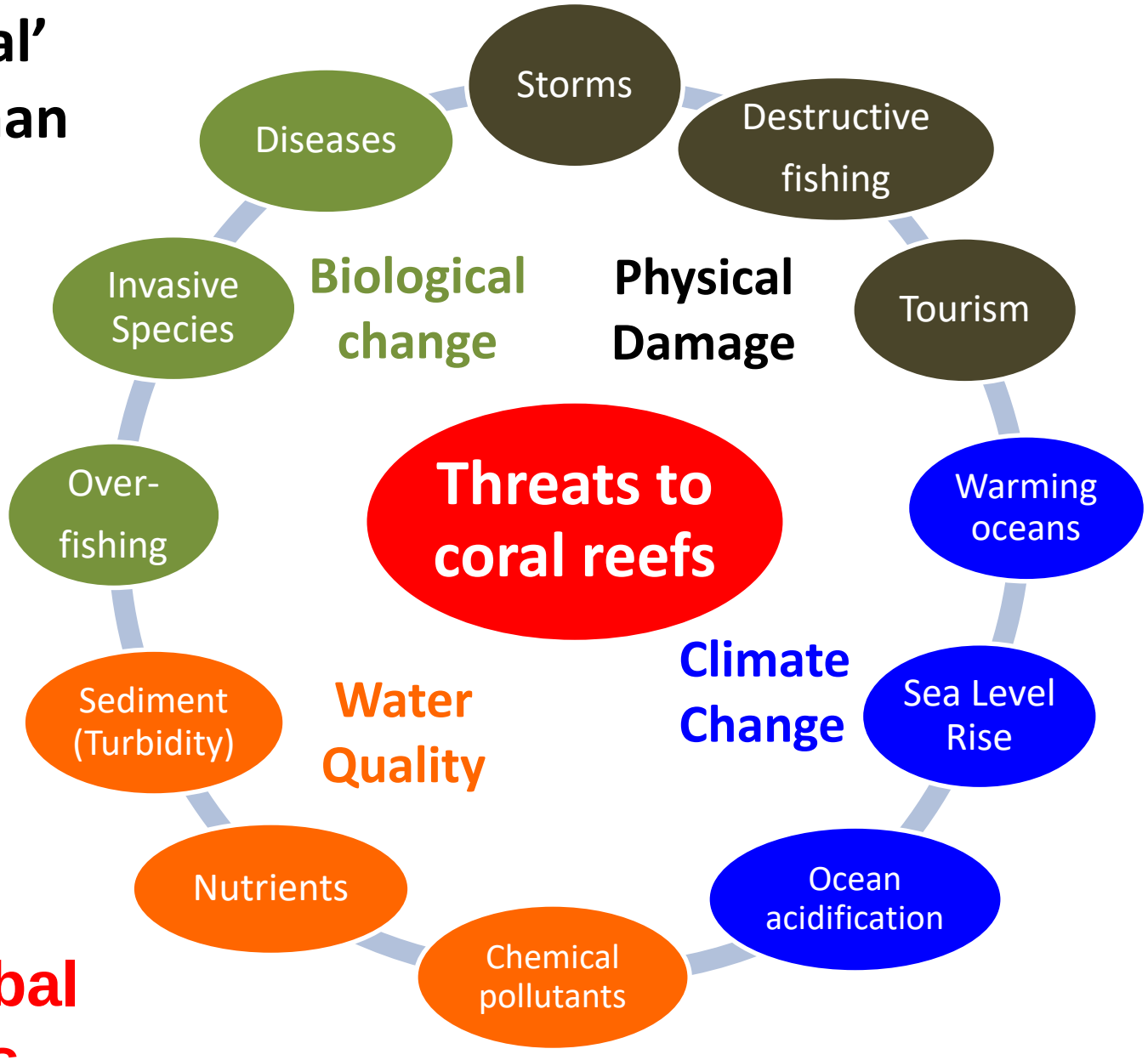
410-326-7283

www.umces.edu



Globally Coral Reefs are in Rapid Decline – WHY?

'Natural' & Human Causes



Local & Global Scales

Take Home Messages

Major drivers in Florida:

- **Temperature** (extent & duration)
- **Disease**

Consequences:

- Bleaching and **death**
- Breakdown of reef ecosystem

Management approach:

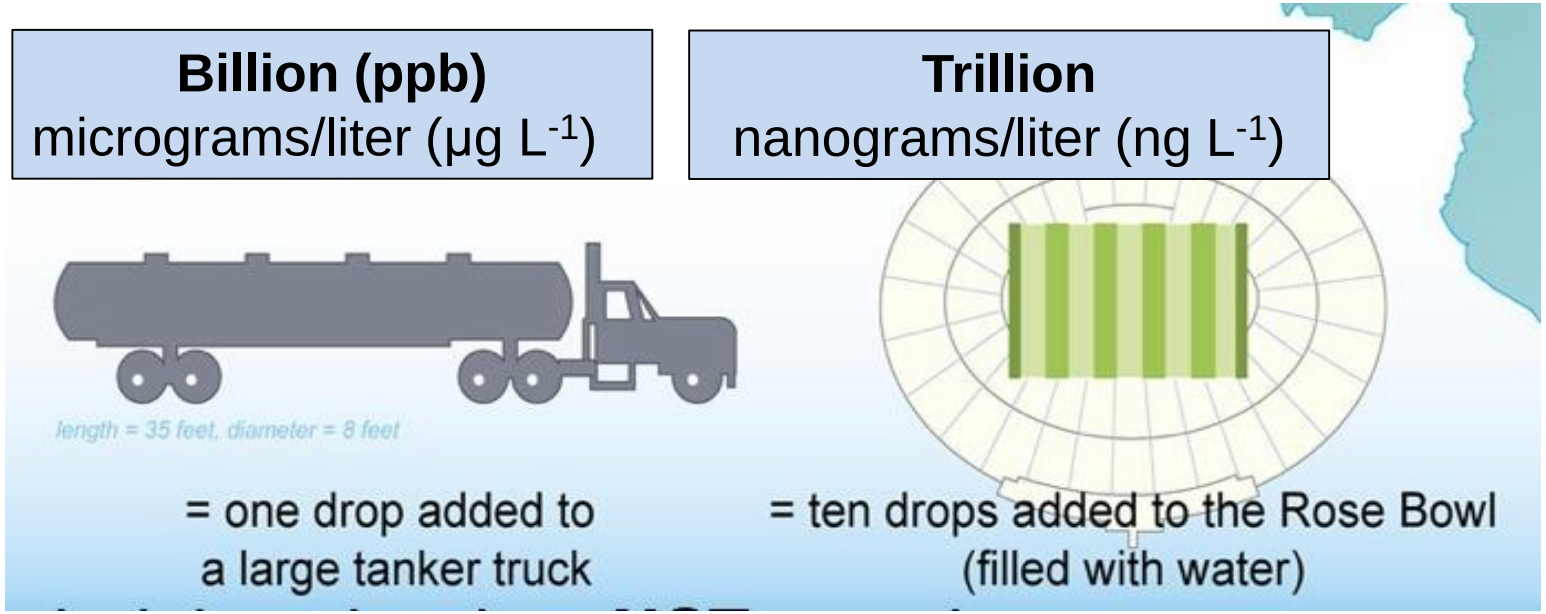
- Conduct risk assessments to identify priority problems

Some Background Terminology

Environmental <u>Exposure</u>: How much is one part per….

Billion (ppb)
micrograms/liter (μg L^{-1})

Trillion
nanograms/liter (ng L^{-1})



Take Home Messages:

- Detection does **<u>NOT</u>** mean harm
- <u>Concentration</u> and <u>time (duration)</u> of exposure is critical
- **<u>Everything</u>** is **TOXIC** at some concentration/dose
- So the question is does the organism get exposed to a chemical at a toxic concentration?

Toxicology (<u>Hazard</u>):

“Father of toxicology” 1493-1541

Paracelsus stated, “What is there that is not poison? All things are poison and there is nothing without poison. Solely the dose determines that a thing is not a poison.”

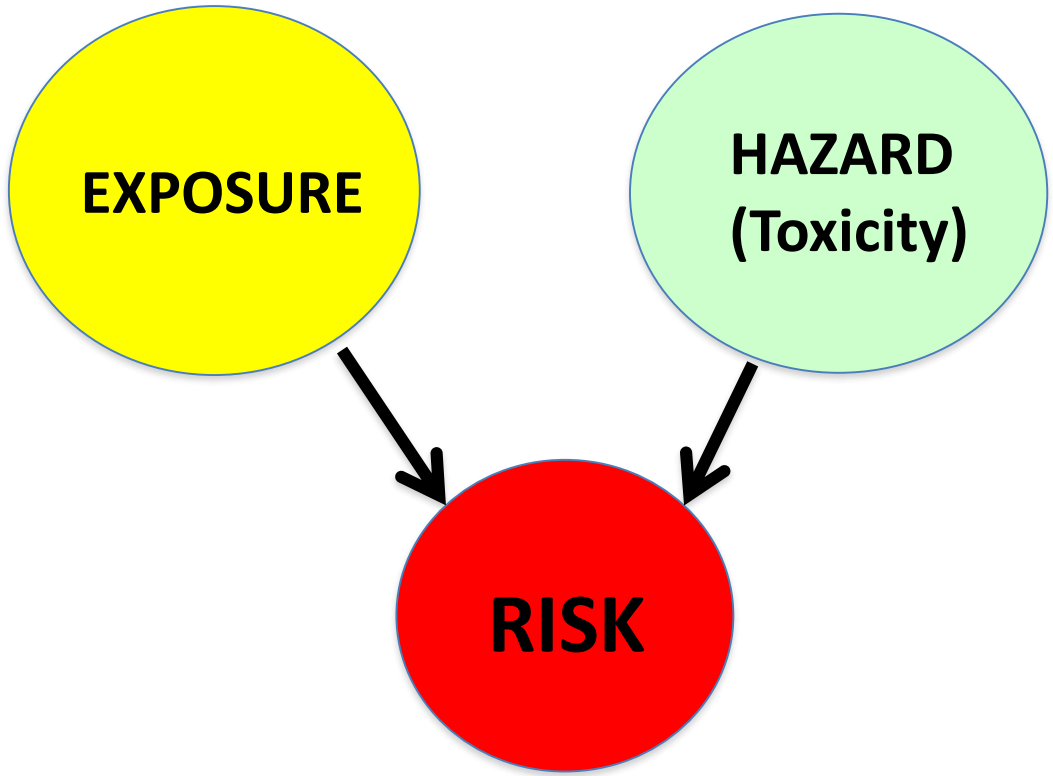
Ecological Risk Assessments (ERAs)

Requires two sets of data:

(1) **EXPOSURE:** concentration (levels detected) of the chemical in seawater

(2) **HAZARD:** Toxicity test endpoints

Requires numerous, rigorous scientific studies



Take Home Messages

- Estimates the concentration of a chemical associated with harm
- Identifies the most toxic chemical(s)
- Help guide management / regulatory decisions

Sunscreens and UV-filters: What are they?

- Sunscreens are mixtures of one or usually more active ingredients and also inactive ingredients

- Two main types: (1) Organic (can be biodegradable); UV absorbers
  (2) Inorganic (**not biodegradable**; metal element); physical barriers to UV light

COMMON ORGANIC UV ABSORBERS

UVB

- Homosalate
- Octocrylene
- Octinoxate
- Octisalate
- Phenylbenzimidazole sulfonic acid

UVA

- Avobenzone
- Oxybenzone

ABSORBANCE PROTECTION

COMMON INORGANIC UV PHYSICAL BARRIERS

- Titanium dioxide
- Zinc oxide

PHYSICAL PROTECTION

Sunscreens and UV-filters: Sources to the Environment

(Environmental Exposure Routes of UV filters)

Waste Water treatment in Florida Keys is different

WWTP water treated & injected into deep wells; NOT released to surface waters

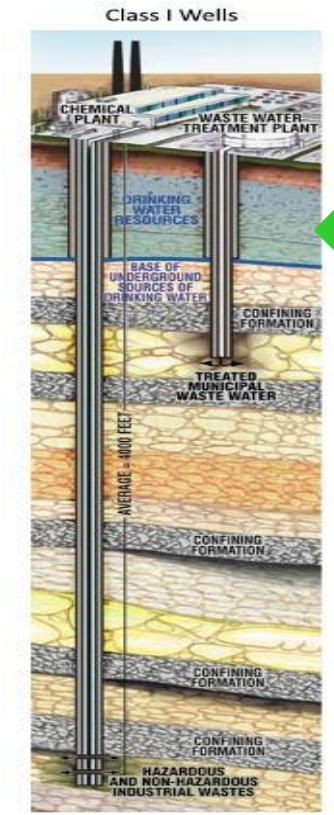
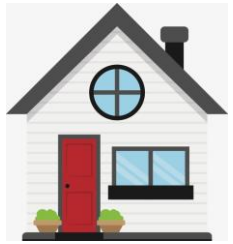
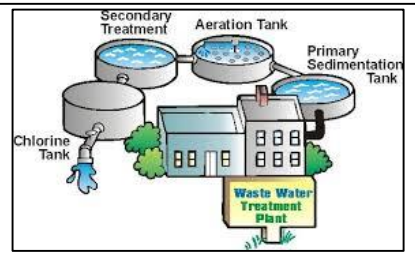


Figure Ref: Deep well: US EPA

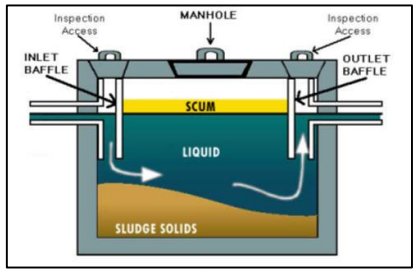


Wastewater

Sewage / Wastewater Treatment Plant (WWTP) *



Septic Tank



Groundwater

SURFACE WATERS

Sediment

OTHER KNOWN SOURCES:

- Industry (production numerous products)
- Landfill (additional products to sunscreens)
- Natural (plants and fungi)

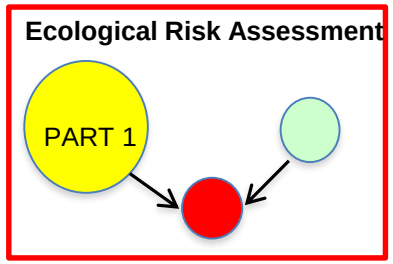
Point exposure from anthropogenic sources (e.g. bathers) is an important exposure pathway of UV filters

POINT EXPOSURE

*; Many scientific studies have shown a large % of oxybenzone and octinoxate is removed after treatment through WWTP

State of the Science – Exposure

QUESTION: What are the concentrations of oxybenzone and octinoxate in seawater near coral reefs?



Studies 1&2: Seawater from Hong Kong
(Tsui et al. 2014, 2017)

Study 3: Seawater from Japan
(Tashiro & Kameda, 2013)

Study 4: Seawater from the US Virgin Islands
(Bargar et al. 2015)

Study 5: Seawater from the Gran Canaria
(Sanchez Rodriguez et al. 2015)

Study 6: Seawater in Hawaii & US Virgin Islands (Downs et al. 2016)

Take Home Messages:

- Most concentrations in the ng L^{-1} (**parts per trillion**), some µg L^{-1} (parts per billion; ppb) (except Study 6)
- **Variable concentrations** with;
  - Location
  - Season (time of year)
  - Distance from shoreline
  - Depth (e.g. 30 times lower at coral dept than surface measurements)
- Study 6: Sites are single samples; 6/7 Hawaii samples below level of quantitation; USVI concentration 1.395 mg L^{-1} questionable

2017 Hawaii Monitoring Project: Study Design and Methods

Environmental Monitoring Overview

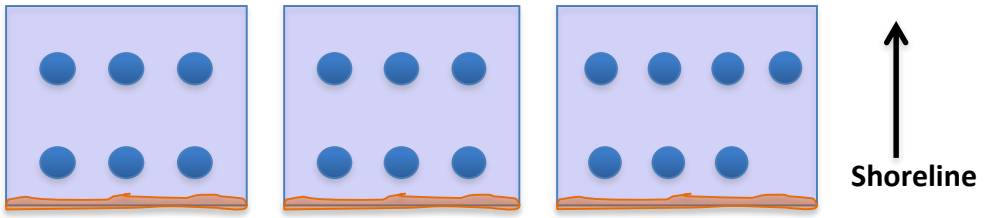
Collection Site Identification In Oahu Hawaii

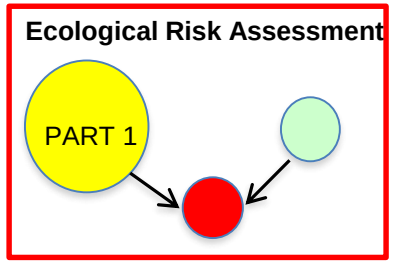
Sampling Grid – total **19 sites**

Location 1
Ka'a'awa

Location 2
Waikiki Beach

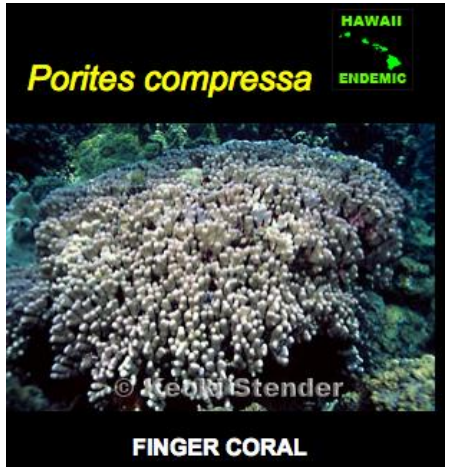
Location 3
Kaneohe Bay





Matched samples of:

- Surface water
- Sediment
- Corals: *Porites* spp.



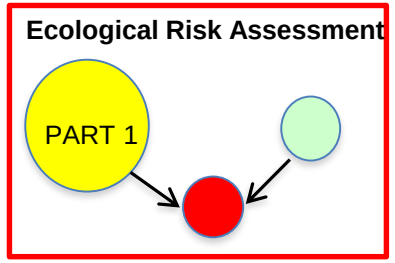
Porites spp. dominant in Hawaii. One of the more sensitive coral species.

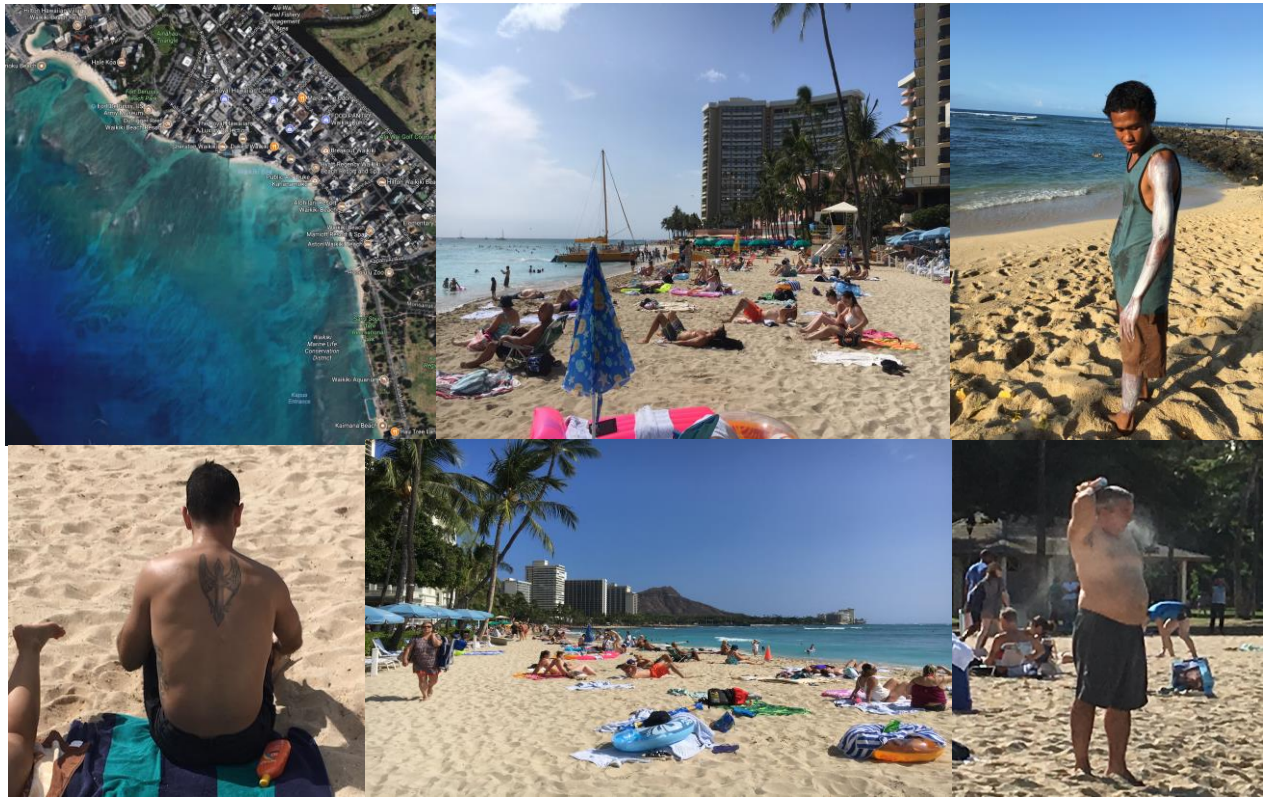
Take Home Messages

- Robust and comprehensive sampling design; **replicates!**
- All locations **multiple sites (n=19 total)**
- Each site **triplicate samples (n=57-76 total)**
- Detailed protocols, quality control and chain of command
- **First USA study to look in coral tissue and sediment**

Hawaii Location Selection: High Tourism – Waikiki Beach, Oahu

- Hypothesized ‘Worse case’ scenario: hundreds of people!
- Beach and waters contained many people at time of visit in the water (swimmers, snorkeling, diving, surfing), and on beach. Could smell sunscreen!





Take Home Messages:

- Oxybenzone ubiquitous detection (found at ALL sites in the study); variable site/time day
- **All concentrations in parts per trillion** (similar to Hong Kong studies)
- 12 of the 19 sites **very low concentrations** i.e. < 10 parts per trillion (ng L^{-1})
- Waikiki Beach had the highest level (136 ng L^{-1}) which is **141 times lower** than the HI sample (Downs et al. 2016)
- **NO measured levels of octinoxate at any of the 19 sites (i.e. 57 samples)**

State of the Science – Toxicity Studies

Take Home Messages

VERY FEW STUDIES: in TOTAL 4 (2 just from this month!)

- **Extremely limited amount of data; *emerging field***
- 3 studies oxybenzone
- 2 studies octinoxate

MANY problems and limitations of the studies

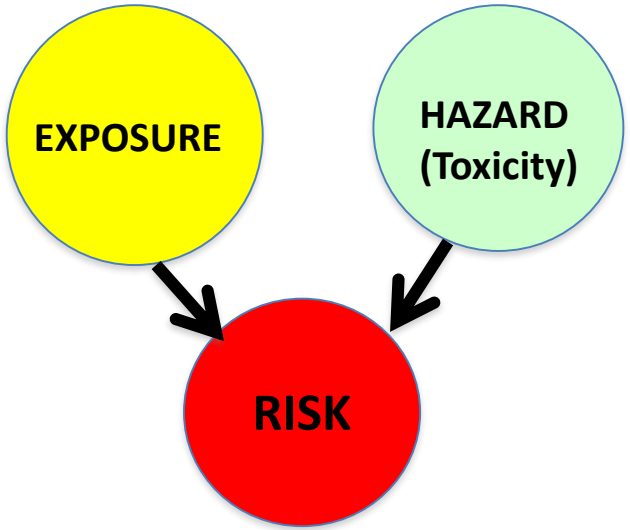
- High to **VERY high** exposure levels used
- Many lack analytical verification and positive controls
- Study designs limited (unreplicated)
- **Not enough data for a risk assessment**
- Overall effects occur at **much higher** concentrations (high ppb or ppm) than is found in seawater near coral reefs (most parts per trillion to low ppb)
- **Much more research on the toxicity to corals is needed**

Oxybenzone risk to Hawaii Corals

Seawater monitoring data:

(1) Mitchelmore (this study)
0.2 to 136 ng L^{-1} (n=57)

(2) Downs et al. 2016
19,200 ng L^{-1} (n=1; 6 other sites were < LOD)



Toxicity thresholds from:

(1) Downs et al. 2016 (24 or 4 hour exposures)
EC50 Planula: 49,000 ng L^{-1}
LC50 Planula: 139,000 ng L^{-1}
LC50 cell culture: 8,000 – 340,000 ng L^{-1}

(2) He et al. 2019a (7 and 14-day exposures)
LC50 larvae and nubbins ≥ 1,000,000 ng L^{-1}

Maximum concentrations:
136 – 19,200 ng L^{-1}

Toxicity values:
8,000 - 1,000,000 ng L^{-1}

TAKE HOME MESSAGE:

- Oxybenzone levels in seawater in seawater Oahu, HI from our 2017 study are:

  60 to 2,500 and 7,350 times LOWER than toxicity thresholds

- **Scientists (from academia, government and industry) need to work together to conduct many more studies to determine what are the priority pollutants of concern**

Summary on Oxybenzone and Octinoxate Impact to Corals

Evidence: Oxybenzone

- Ubiquitous but variable in seawater near corals
- Most concentrations parts per trillion
  concentrations to low ppb
- THREE toxicity studies in corals; effects at ppb to ppm concentrations.
- In Hawaii levels in seawater much lower than toxicity risk threshold levels

IS THERE ENOUGH EVIDENCE FOR FLORIDA KEYS?

Evidence: Octinoxate

- Few reported concentrations in seawater
  near coral reefs
- Most concentrations in the parts per trillion
- NO measurable levels in our HI study
- TWO toxicity studies in corals; no effects or effects only seen in some species/life stages at the highest exposure concentration (ppb to ppm)

YES? **NO?**

Need more data!

- Coral reefs are in decline, we **need to protect them**
- **Very limited data** on the concentration of UV filters in seawater near corals and their toxicity to corals
- **Much more research is needed** for an accurate risk assessment to guide management and policy decisions
- **Thousands of chemical contaminants are** in seawater near reefs
- **Are UV filters a priority risk** compared with other coral stressors (temperature, disease) and other chemical contaminants?
- **Will a ban make a difference to coral health?**

Acknowledgements

Thank you for your time and attention.

Please contact me if you would like any further information on the monitoring project or copies of any references or further help and explanation: **mitchelmore@umces.edu**

UV filters Hawaii Monitoring Project:

Dr. Lee Blaney (UMBC)
Ke He (Graduate student, UMBC)
Dr. Michael Gonsior (UMCES CBL)
Dr. Andrew Heyes (UMCES CBL)
Ms. Cheryl Clark (UMCES CBL)
Rick Younger (Consultant)
Ke He (Graduate student/Postdoc, UMBC)
Ethan Hain (Graduate student, UMBC)
Ms. Anna Feerick (Graduate student, UMBC)
Annaleise Conway (Graduate student, UMCES CBL)
Philippe Schmitt-Kopplin (Helmholz, Germany)
Hawaii Institute of Marine Biology (HIMB), HI
Captain John Benson III and boat personnel (Oahu, HI)

Funding for the Hawaii monitoring project provided by The Personal Care Products Council as a research grant to the University of Maryland Center for Environmental Science