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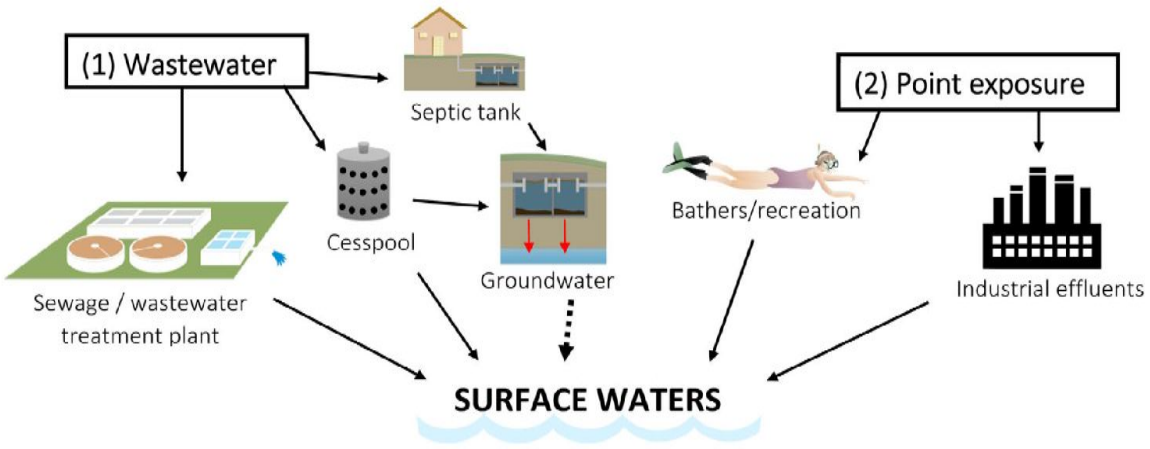
The Sunscreen E-Summit | May 15, 2022

Sunscreens & Coral Reefs: Research Update

Emily Burns, Ph.D., Environmental Scientist, PCPC

Environmental safety concerns : Coral Reefs and UV Filters

MARINE ENVIRONMENTAL EXPOSURE PATHWAYS FOR UV FILTERS



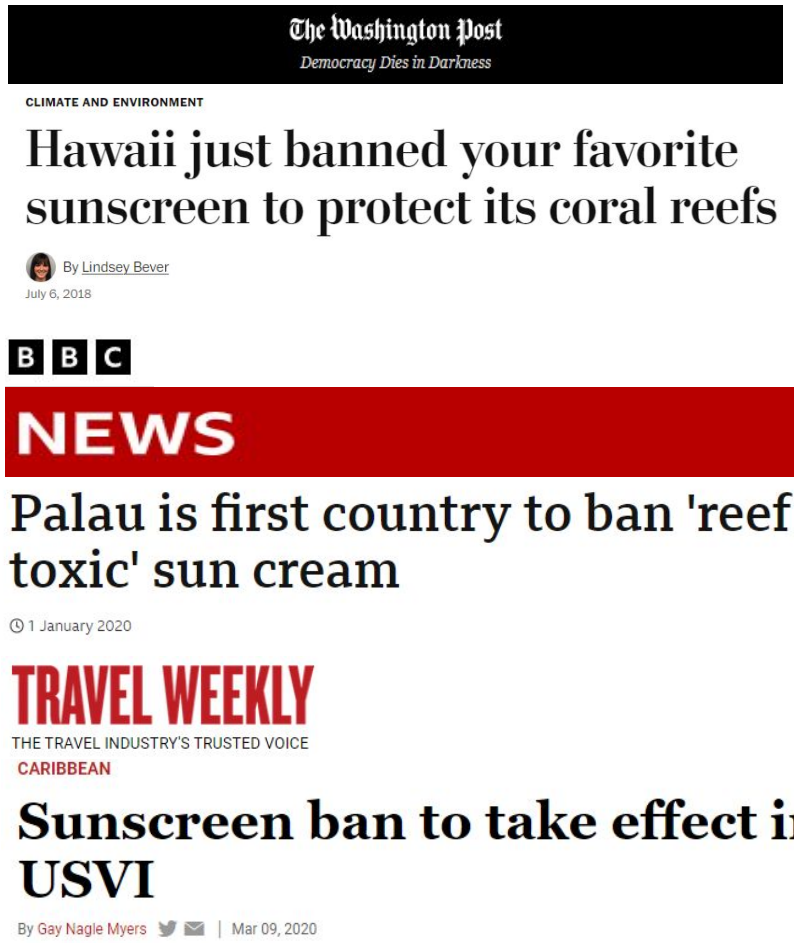
Two major pathways for UV filters to enter aquatic environment:

- Direct wash-off from swimmers/bathers during recreation
- Washed-off at home and released down-the-drain to wastewater

Mitchelmore et al. (2021). *Environmental Toxicology & Chemistry*. **40**(4): 967-988.

Coral Reefs and UV filter bans

Restrictions targeting octinoxate and oxybenzone


The Washington Post
Democracy Dies in Darkness

CLIMATE AND ENVIRONMENT

Hawaii just banned your favorite sunscreen to protect its coral reefs

By Lindsey Bever
July 6, 2018

BBC NEWS

Palau is first country to ban 'reef toxic' sun cream

1 January 2020

TRAVEL WEEKLY
THE TRAVEL INDUSTRY'S TRUSTED VOICE
CARIBBEAN

Sunscreen ban to take effect in USVI

By Gay Nagle Myers | Mar 09, 2020


khon2
WORKING FOR HAWAII

LOCAL NEWS

Maui aims to ban all chemical sunscreens; Big Island takes steps to protect Hawaii's coral reefs

by: Ray Anne Galzote
Posted: Nov 20, 2021 / 05:07 PM HST
Updated: Nov 20, 2021 / 05:07 PM HST

Expansions proposed to cover more or all organic UV filters

Does the science support proposed or existing bans?

Establishing Environmental Safety: Environmental Risk Assessment

"All things are poison and nothing is without poison. Solely the dose determines that a thing is not a poison"

- Paracelsus c. 1538

Environmental risk assessment evaluates the likelihood that an adverse ecological effects will occur as a result of exposure to a stressor.

-US EPA

Drinking water necessary to maintain adequate hydration

Drinking too much water

Water poisoning

More sensitive life stages

Hyponatremia

Environmental Safety Assessment: Coral Environmental Risk Assessment

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Environmental exposure assessment

Hazard assessment

Risk characterization

1. Environmental exposure assessment

- How much of a UV filter is in the water near coral

2. Hazard assessment

- What level of a UV filter harms a coral?

3. Risk characterization

- Is there enough UV filter in the environment to harm coral?

Environmental Safety Assessment: Coral Environmental Exposure Assessment

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Environmental exposure assessment

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Hazard assessment

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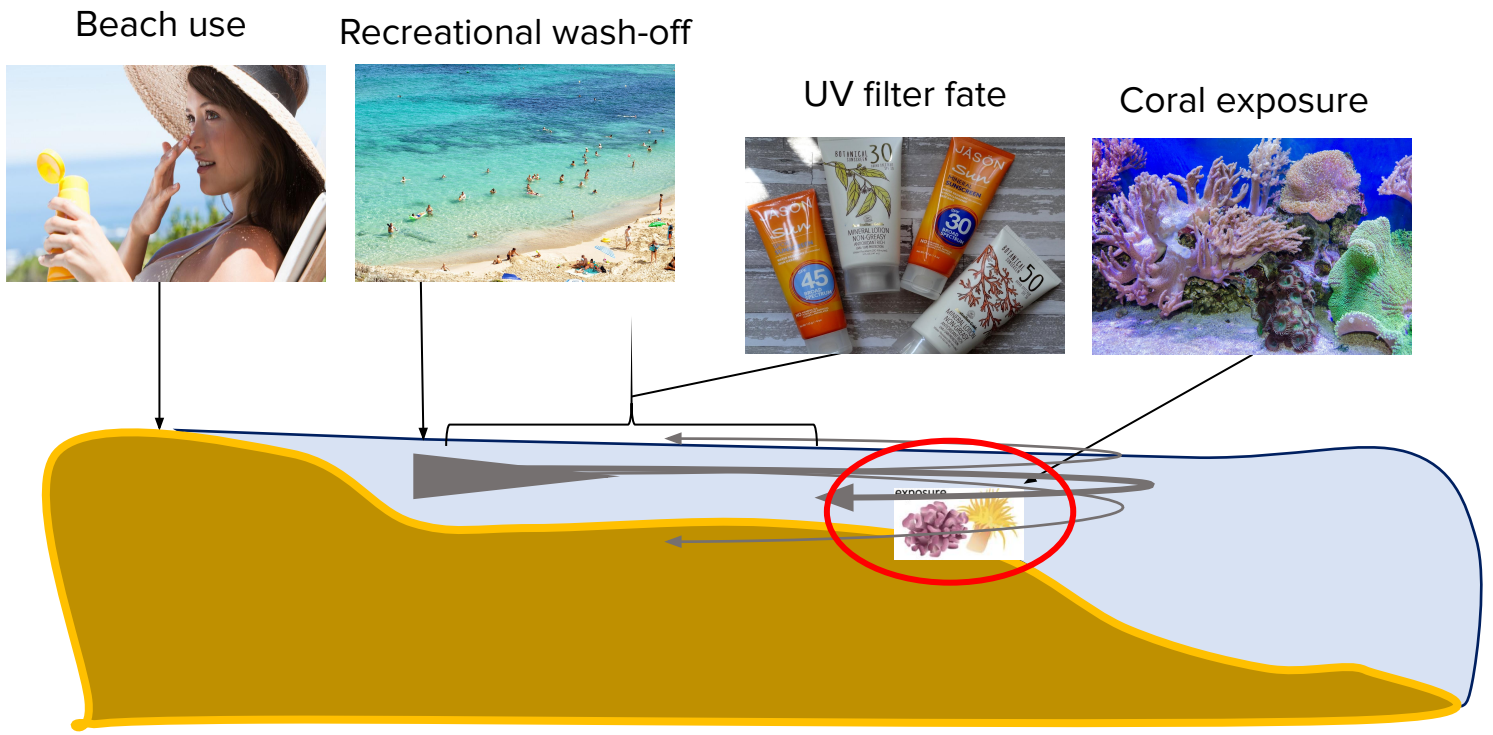
Risk characterization



Targeting samples collected near coral reefs
 Most representative of coral exposure

Coral Exposure Assessment: How much is found where globally?

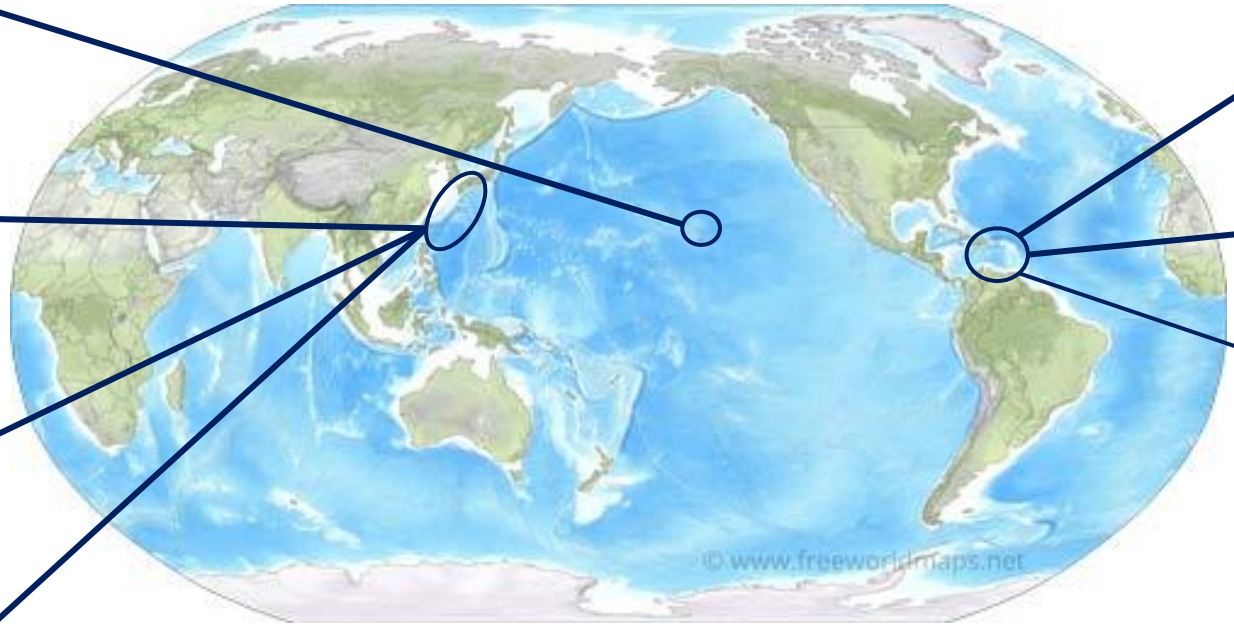
Pacific

Hawaii
Downs (2016)
Mitchelmore (2019)

Hong Kong
Tsui (2014)
Tsui (2017)
Tsui (2019)

Taiwan
Kung (2018)
He (2019)

Japan
Tashiro & Kameda (2013)



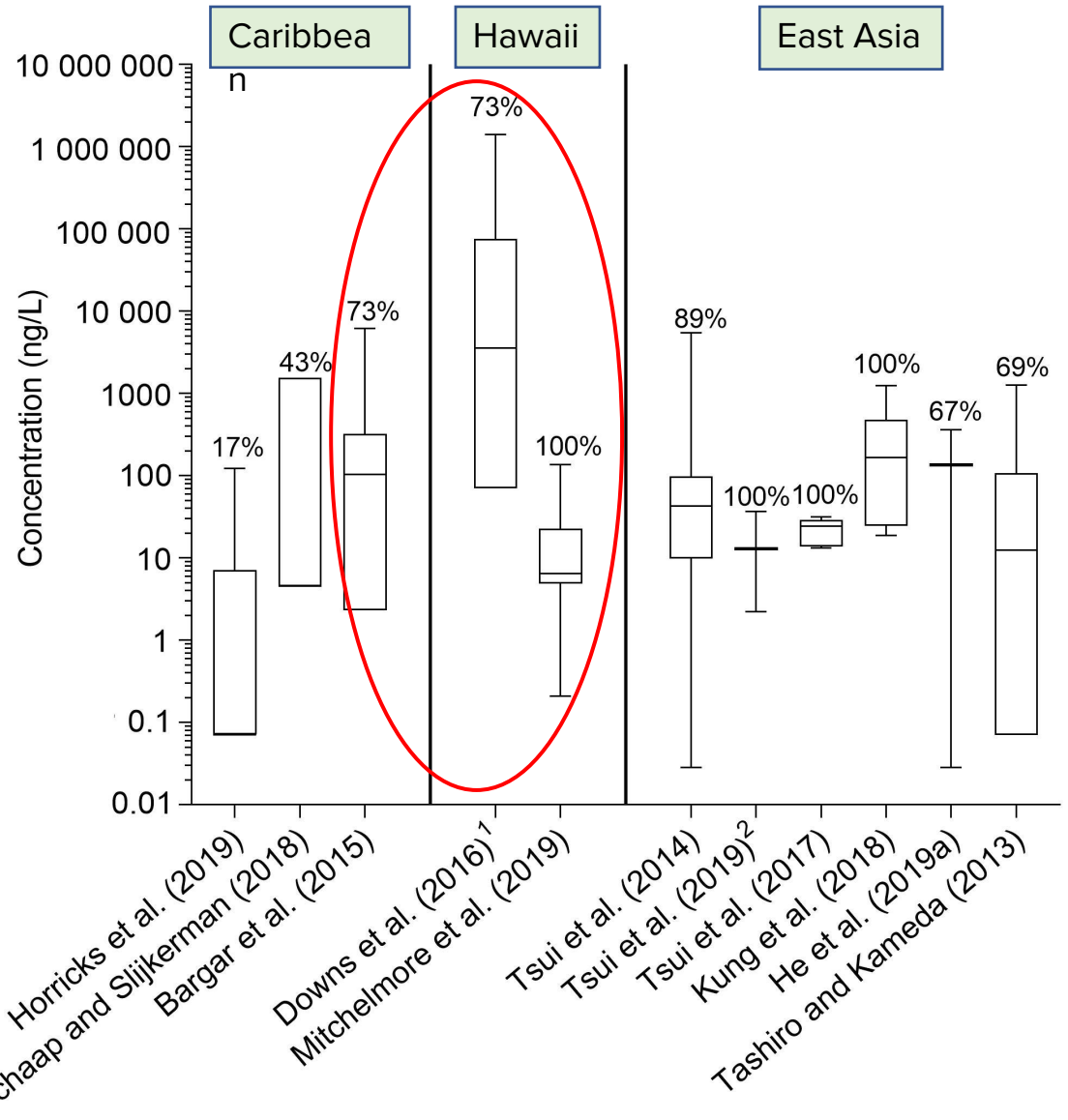
Atlantic

U.S.V.I.
Bargar (2015)
Downs (2016)

Bonaire
Schaap and Slijkerman (2015)

Grenada
Horricks (2019)

Coral Exposure Assessment: Near-reef Oxybenzone Monitoring



- Oxybenzone was detected in near-shore areas globally at ng/L range
- Often high variability is observed in individual studies
- Evidence of best sampling/analytical practices not having been followed:
  - Methodological issues

Coral Exposure Assessment: Near-reef Monitoring

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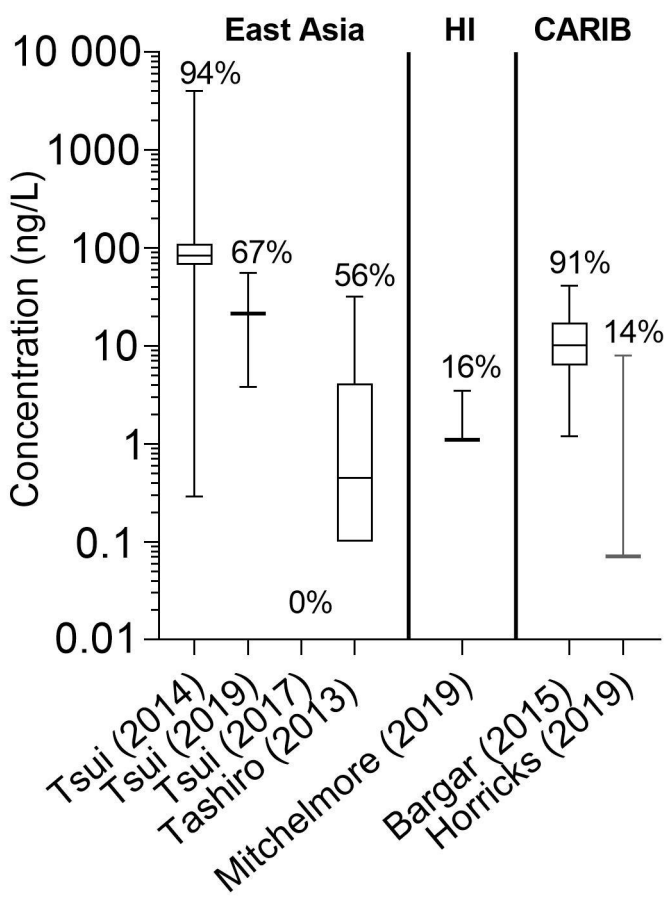
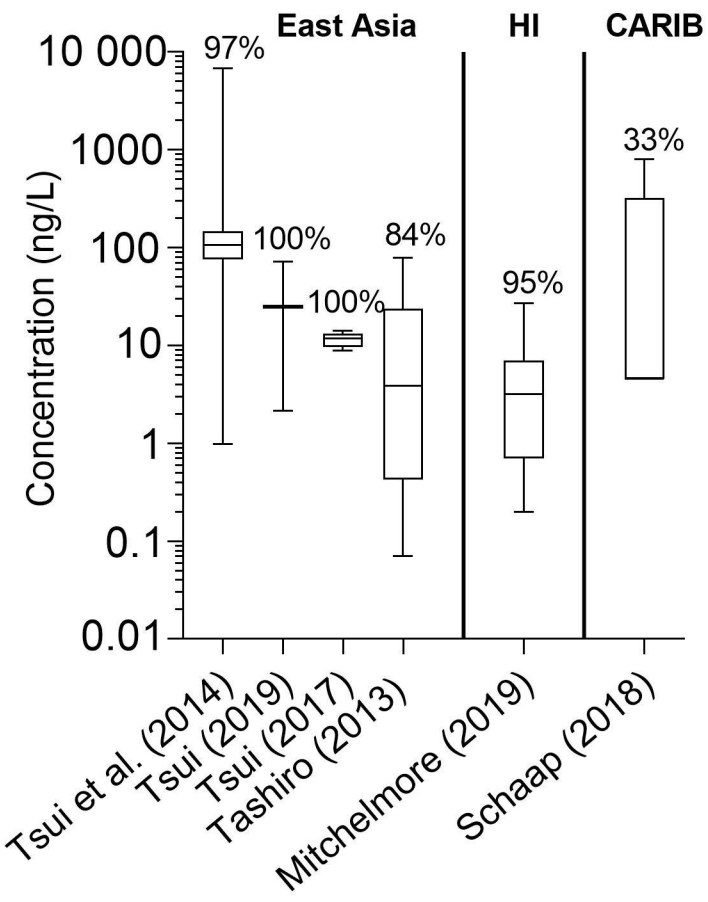
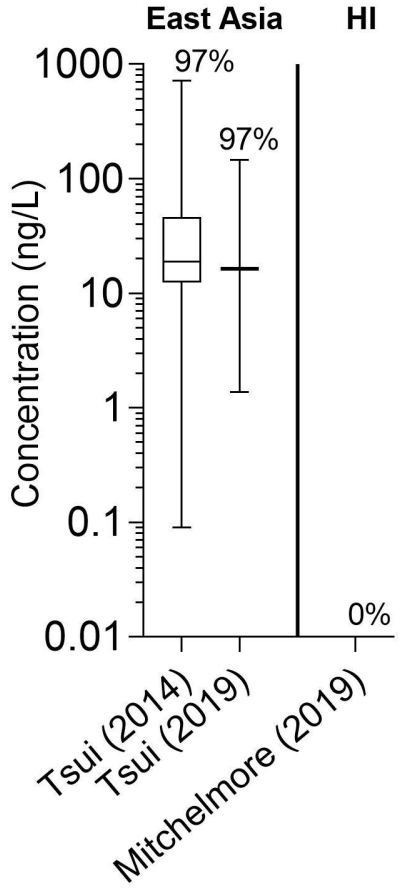
Octinoxate



Octocrylene



Avobenzone



Mitchelmore et al. (2021). *Environmental Toxicology & Chemistry*. **40**(4): 967-988.

Coral Exposure Assessment: Near-reef Monitoring

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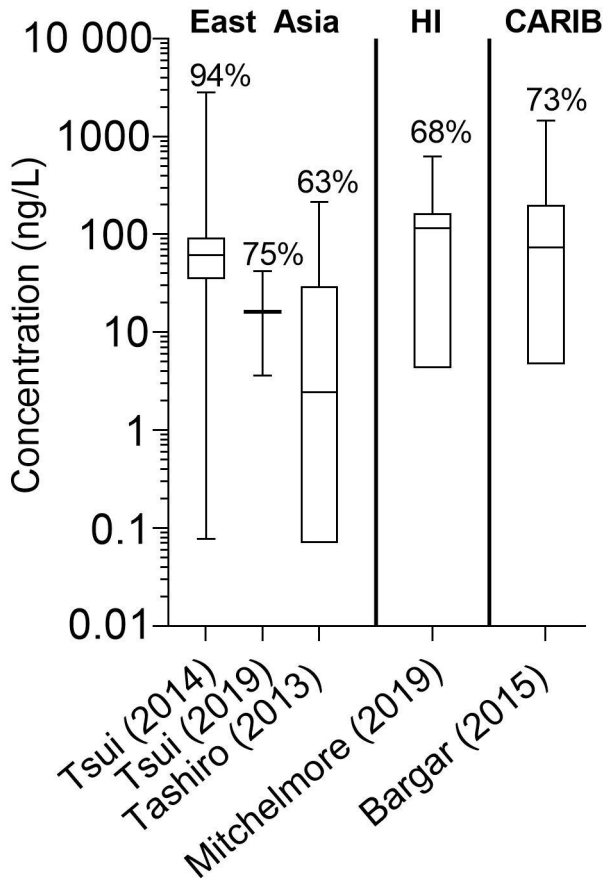
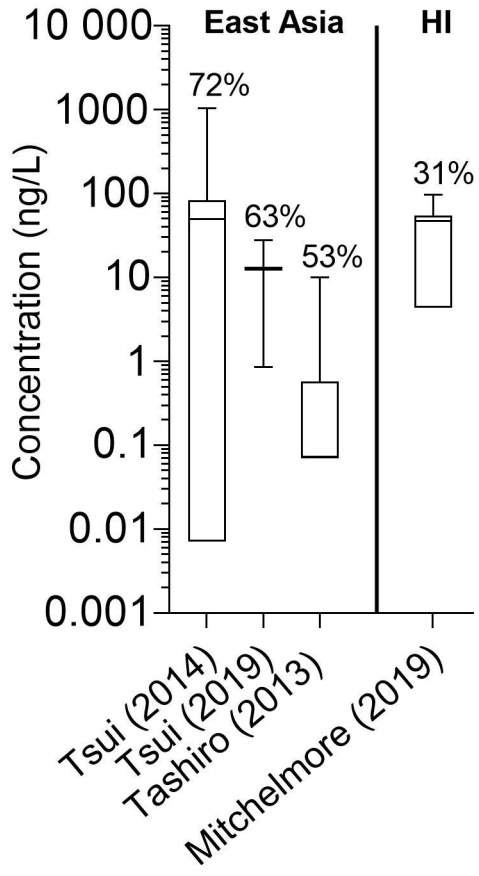
Homosalate

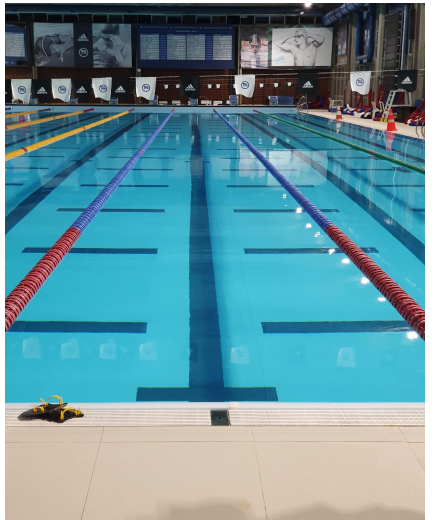


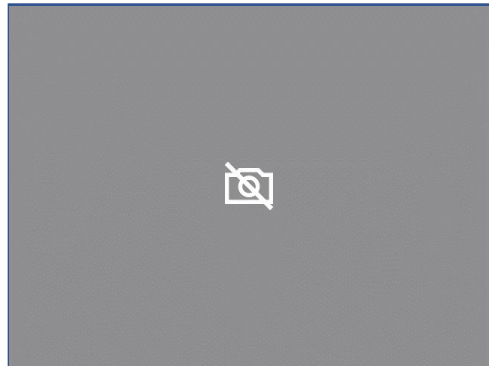
Octisalate



- Variability in concentrations between and within studies
- UV filters detected mainly at low ng/L levels (~ 10 – 100 ng/L)
  - Majority less than 1 µg/L (1000 ng/L)

1 drop in 1 billion drops of water or
about 1 drop of water in a swimming pool





Mitchelmore et al. (2021). *Environmental Toxicology & Chemistry*. **40**(4): 967-988.

Coral Exposure Assessment: Predictions vs. measurements

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Measured concentrations

- Concentrations vary through time and space
  - Single grab samples are just a 'snapshot in time'
- Problems with analytical methods and sampling

Predicted concentrations

- Currently no model to predict reef and beach concentrations of UV filters from recreational wash-off
- Wash-off rates vary by UV filter and product type[1]
- Work is on-going to develop a conservative approach

Current monitoring data is useful for ERA

Exposure assessment should be improved

↓ Robust and representative monitoring

↓ Develop predictive model

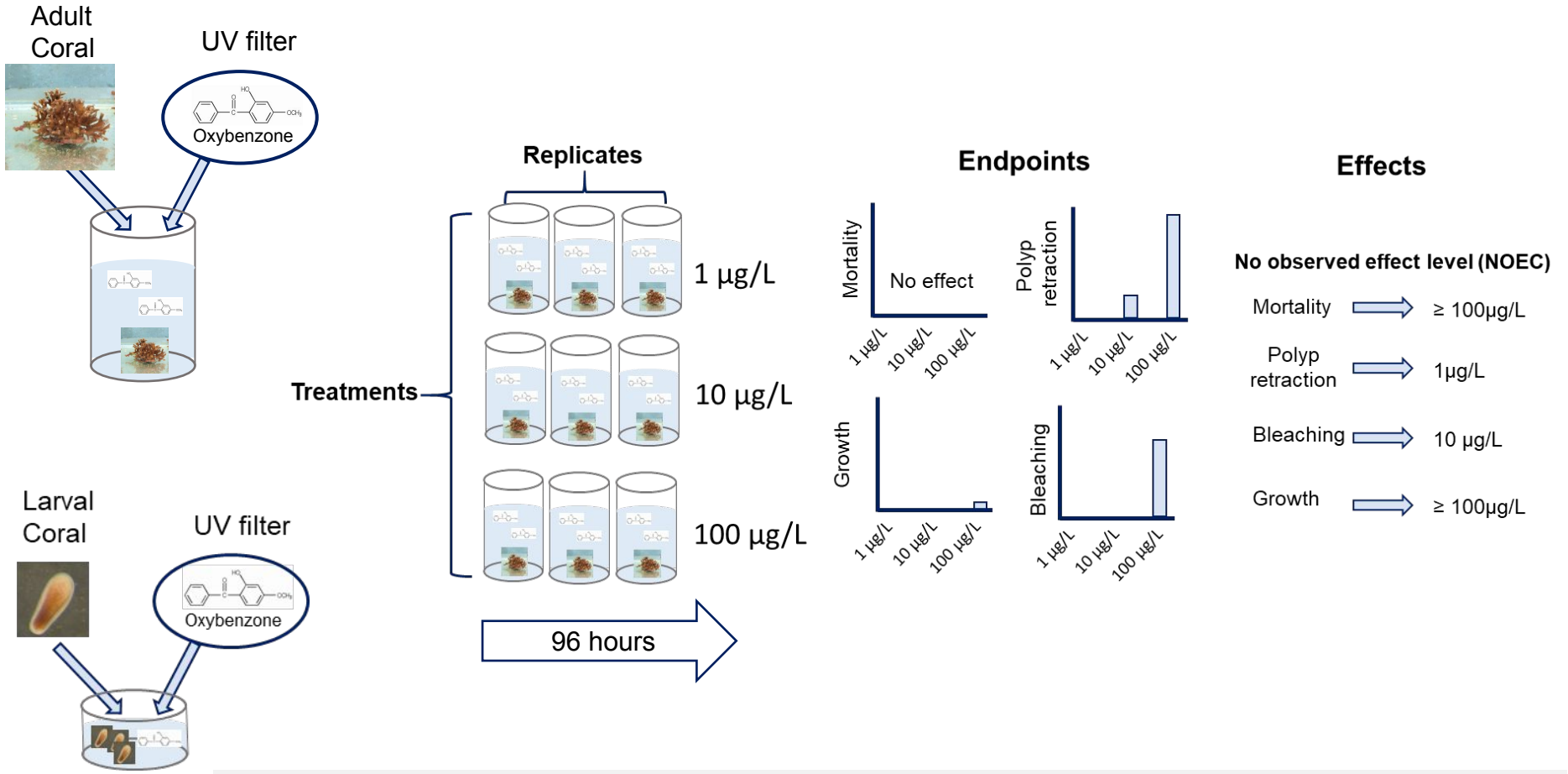
[1]Saxe et al. (2021) IEAM. **17**(5):961-966

Environmental Safety Assessment: Coral Hazard Assessment

Environmental exposure assessment

Hazard assessment

Risk characterization



Laboratory studies in controlled environments

- Identifying no observed effect concentration (NOEC) per endpoint

Coral Hazard Assessment: What studies are out there?

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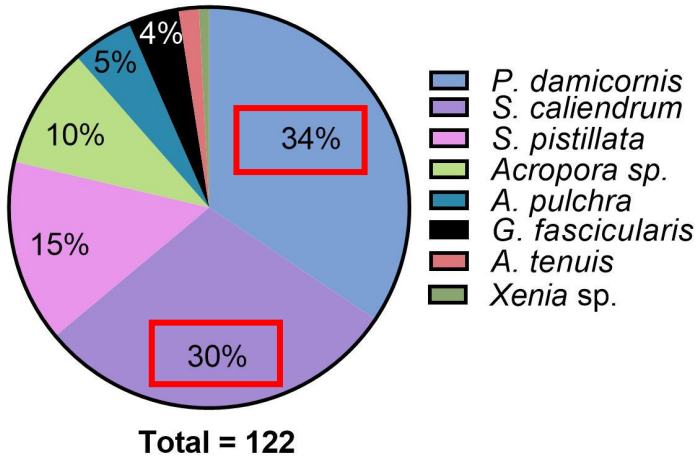
Larval stage

Downs (2016)

He (2019b)



Adult stage

Danovaro (2008)

McCoshum (2016)

Fel (2019)

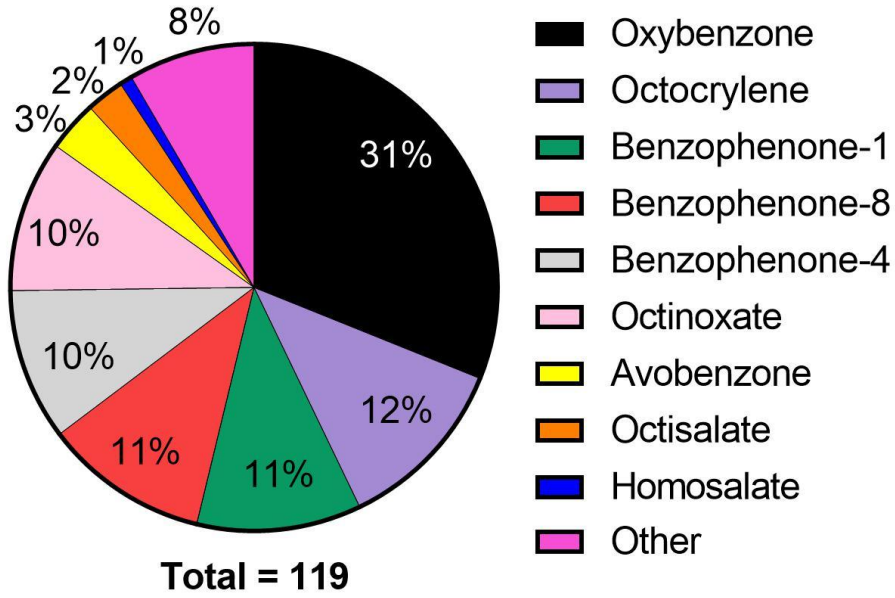
He (2019a,b)

Stien (2019)

Wijgerde (2019)

Stein (2020)

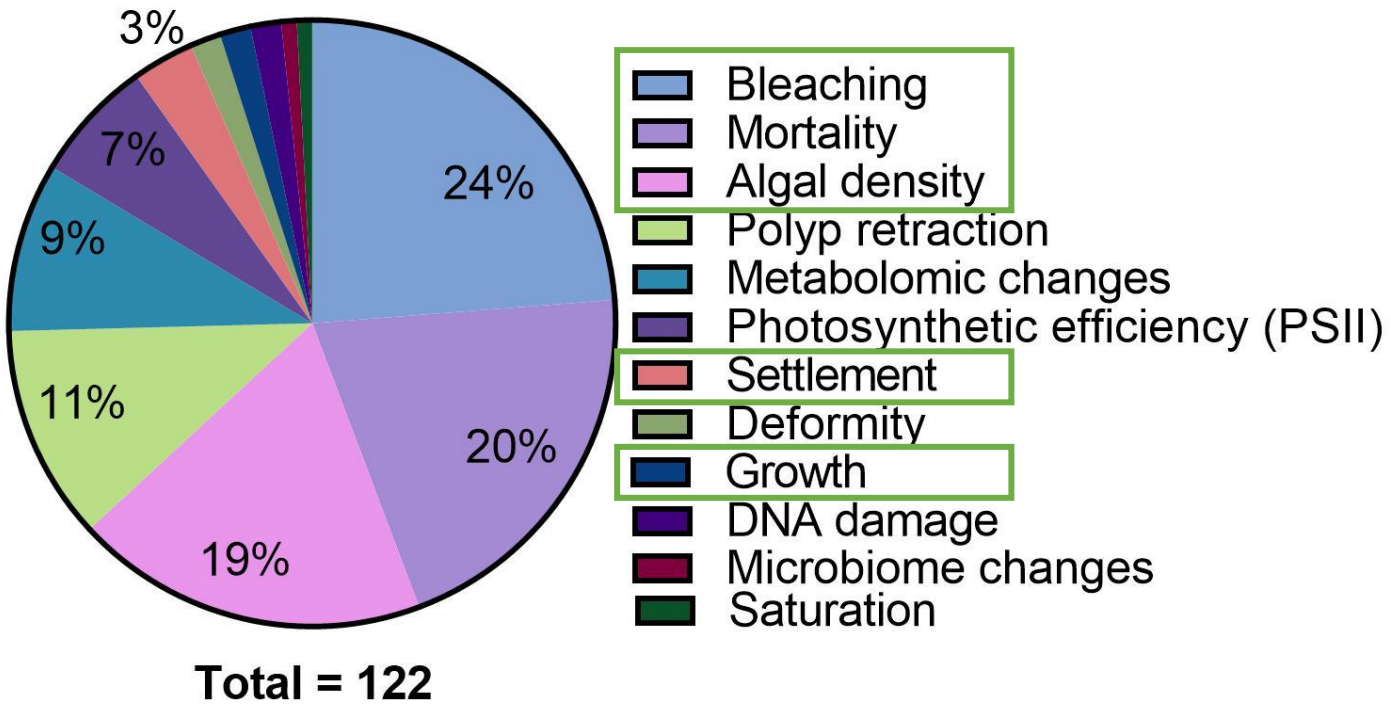
Conway (2021)



In vitro

Downs (2016)

Coral Hazard Assessment: What studies are out there?



Ecological relevance[1]

- Generally endpoints related to mortality, reproduction and growth
  - Have a population-level effect
- Of studies to date, **68%** of endpoints are considered ecologically relevant

Only **45%** of endpoints are below UV filter **solubility**
- **37%** are **below solubility** and **ecologically relevant**

[1]Warne et al. (2018) Guidelines for Fresh and Marine Water Quality.

Coral Hazard Assessment: Coral Toxicity Data Summary

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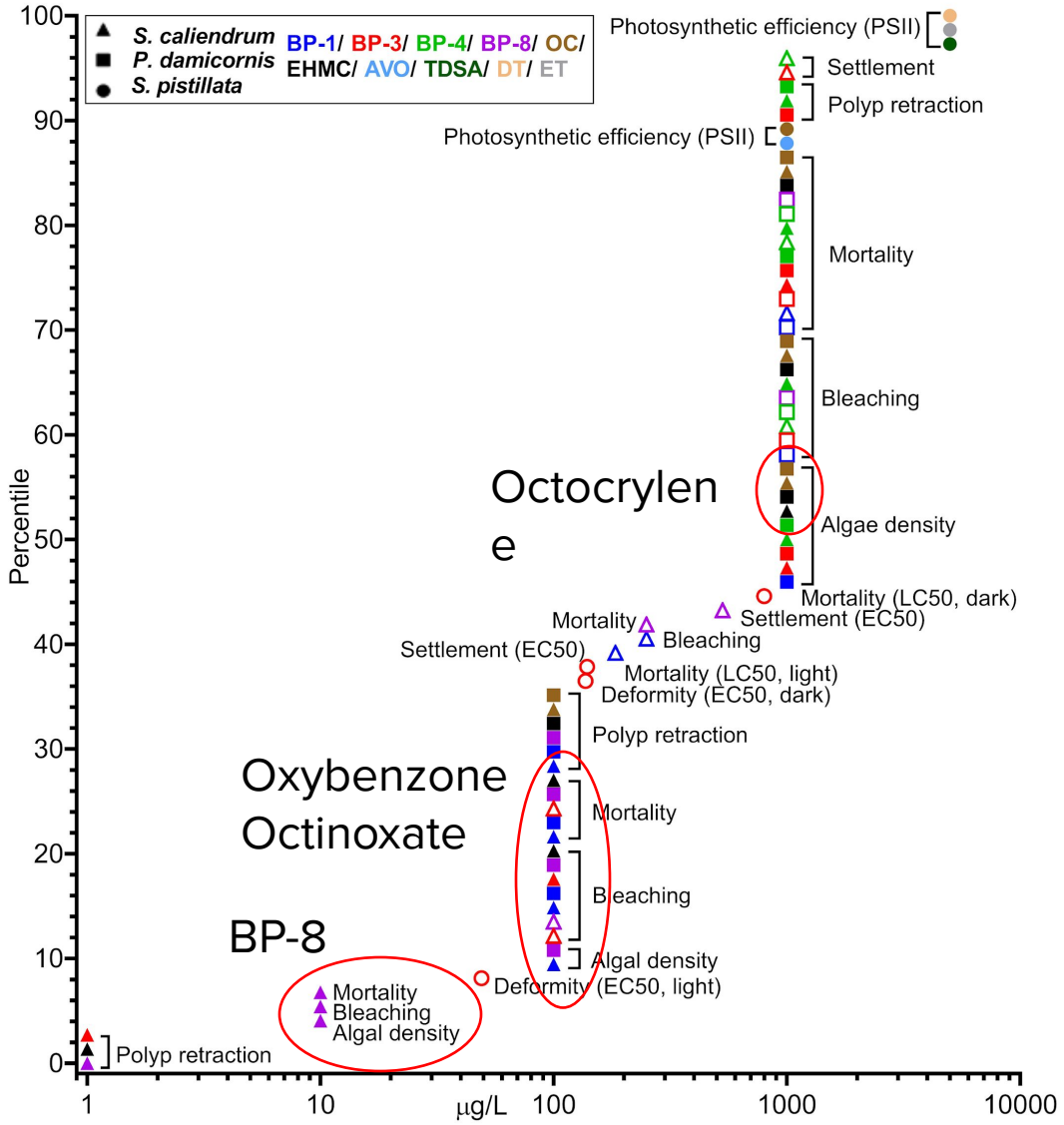

Coral cumulative endpoint distribution for UV filters.
Endpoints are NOECs unless stated.

Effects have been observed down to low µg/L levels

Most sensitive end-points are polyp retraction, mortality, bleaching, and algal density

No ecologically relevant endpoints for:
Avobenzone
Homosalate
Octisalate

Mitchelmore et al. (2021). *ET&C*. **40**(4): 967-988.
Burns & Davies. (2021). *ET&C*. **40**(12): 3441-3464.

Coral Hazard Assessment: Are the Data Suitable for ERA?

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Governmental organizations evaluate data quality prior to using it in an ERA

Information Quality Act → US EPA developed quality criteria a study must meet

Regulatory agencies globally have variations on these methods

Environment & Climate Change Canada
Breton et al. (2009)

European Chemicals Agency
Moermond et al. (2016)

Data reliability assessment is conducted to make sure data are suitable for ERA

Coral Hazard Assessment: Are the Data Suitable for ERA?

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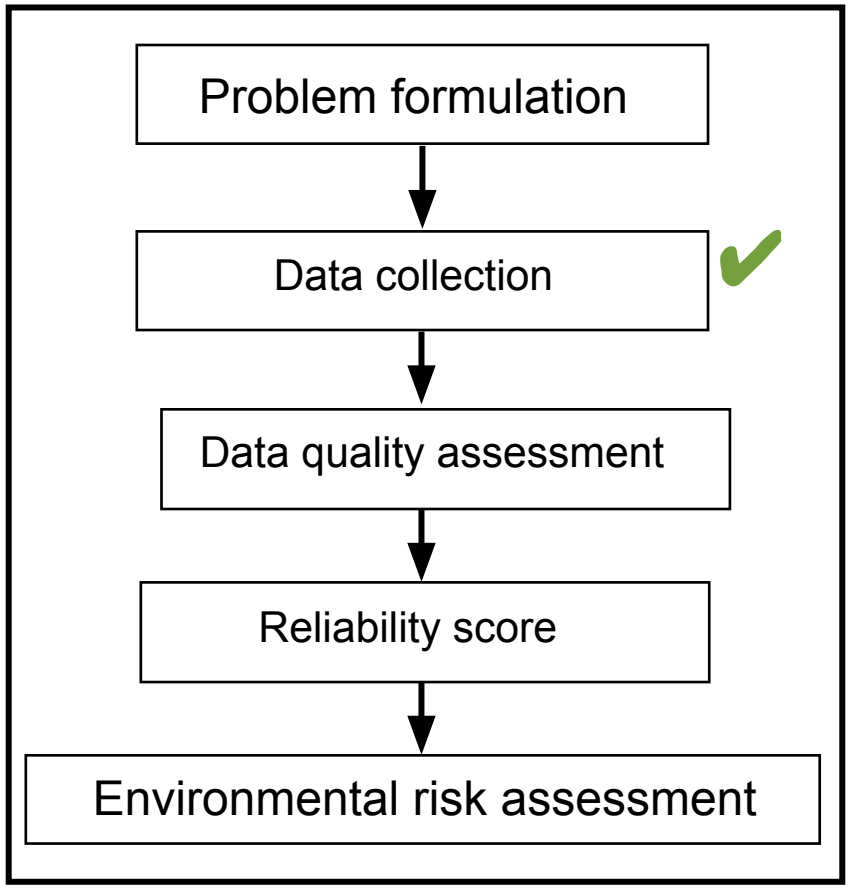
Is coral hazard data reliable enough for ERA?



Evaluate a series of criteria focusing on key aspects of a study:

- ✔ Test setup
- ✔ Test compound
- ✔ Test organism
- ✔ Test design/conditions
- ✔ Results and statistics

A score is rewarded based on criteria fulfilment

Score determines how study can be used in ERA

Burns & Davies. (2021). *Environmental Toxicology & Chemistry*. **40**(12): 3441-3464.

Coral Hazard Assessment: Ecotoxicological Data Quality Evaluation

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Suitable for ERA

23-Question Data Quality Assessment

Topic	Criteria	Score
Test setup	3 questions	25 points
Test compound	2 questions	8 points
Test organism	2 questions	6 points
Test design	10 questions	39 points
Results/statistics	6 questions	22 points

Prioritize repeating

Fel (2019)

He (2019a)

He (2019b)

Not suitable

Downs (2016)

Did not pass screening

Danovaro (2008)

McCoshum (2016)

Stein (2019)

Wijgerde (2020)

No studies suitable for preliminary ERA)

Burns & Davies. (2021). *Environmental Toxicology & Chemistry*. **40**(12): 3441-3464.

Coral Hazard Assessment: Summary of issues with current data

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UV filters

Poorly soluble

'Sticky' (high logKow)

Degradable

Coral

S

No standard test

Challenging animal husbandry

Inappropriate exposure design

Colonial species

Laboratory acclimation

Best practice

No dose-response relationship

Test concentrations not measured

Missing controls

Too much solvent

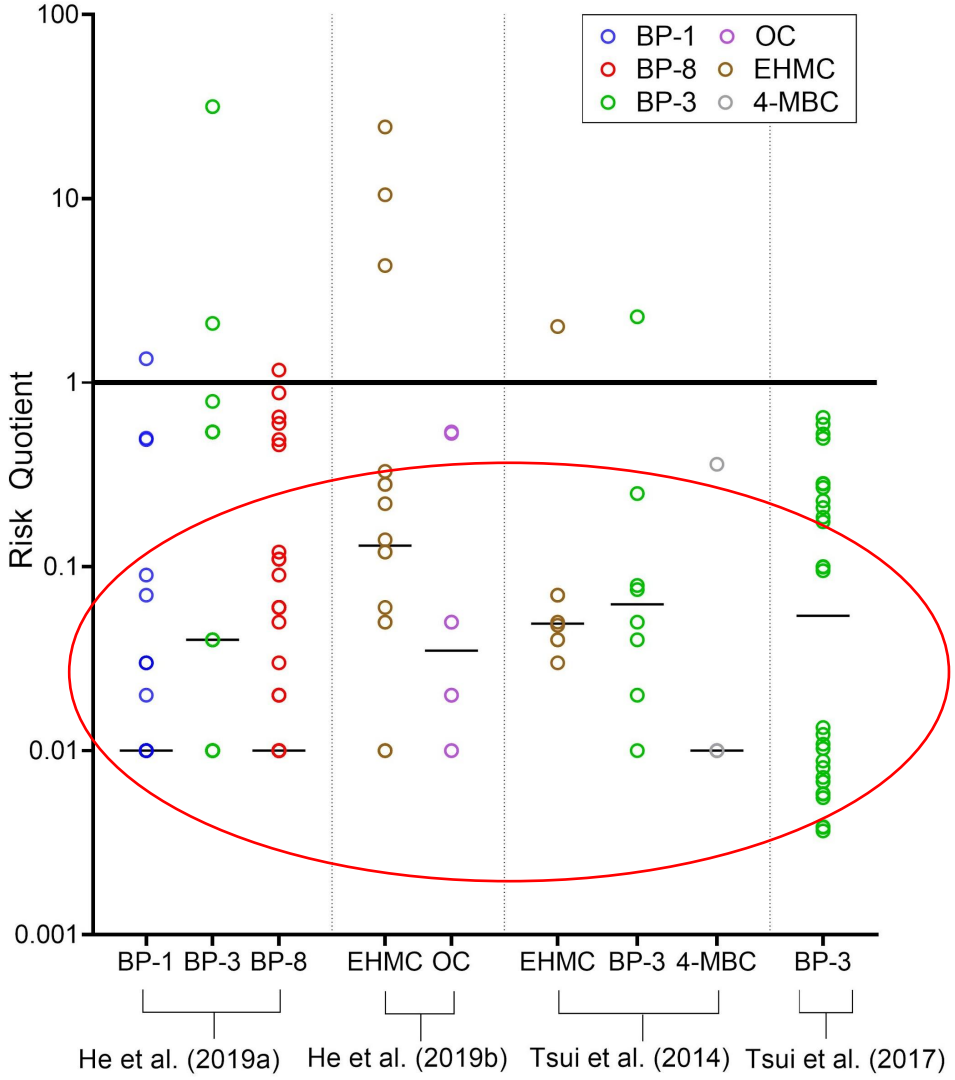
Low or pseudoreplication

Test concentration spacing

Lacking basic validity criteria

Much to consider for the ecotoxicological testing of corals and UV filters!

Coral Risk Assessment: Preliminary assessments in literature



- Conducted by one research group
- Coral toxicity data has clear reliability issues
- Same exposure dataset used for the assessment (Tsui 2014)

Risk quotient from each study below 1

Mitchelmore et al. (2021). *ET&C*. **40**(4): 967-988.

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UV Filter Environmental Safety Assessments for Coral

KEY PRIORITIES

Exposure	Representative exposure data needed • Develop predictive model • Representative monitoring
Hazard	Develop standard test protocol to generate relevant/reliable endpoints • Follow best practice • Maintains UV filter concentrations • Good animal husbandry
Risk assessment	Conduct ERA following regulatory guidance • Once appropriate exposure and toxicity data collected

Environmental Safety Assessment: Inorganic UV filters

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Limited hazard data

TiO_2

Corinaldesi (2018)

Jovanovic and Guzman (2014)

ZnO

Fel (2019)

Corinaldesi (2018)

Limited exposure data

No near reef monitoring studies identified

Nanoparticles difficult to monitor

- Proxies have been used

Labille (2019)

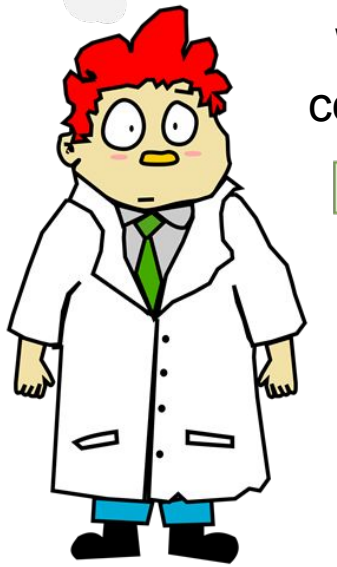
- French beach monitoring study
- Concentrations decreased with distance from shoreline

Data for inorganic UV filters more limited than organic UV filters

Currently working on inorganic UV filter environmental safety assessments

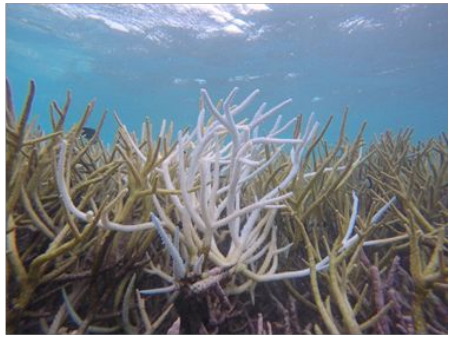
A Different Approach: Eco-epidemiology

A Different Approach: Eco-epidemiology

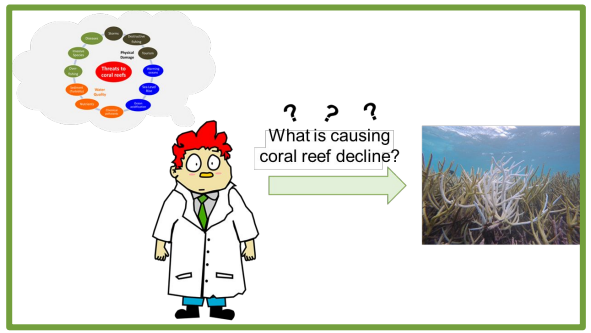


? ? ?

What is causing coral reef decline?

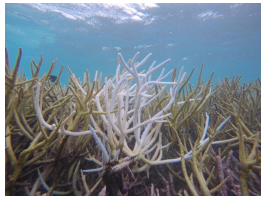


A Different Approach: Eco-epidemiology



Holistic assessment of how stressors and environmental conditions impact coral health

Stressors



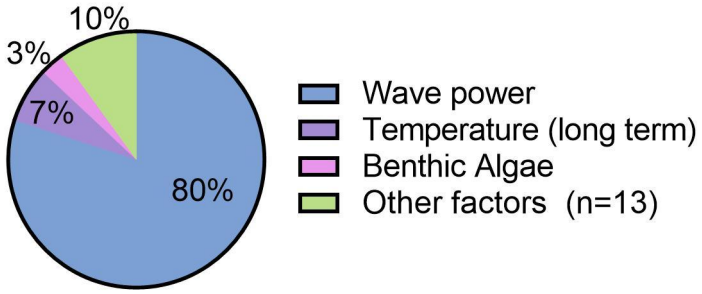
Coral health

1. Warming oceans
2. Invasive Species
3. Chemical pollutants

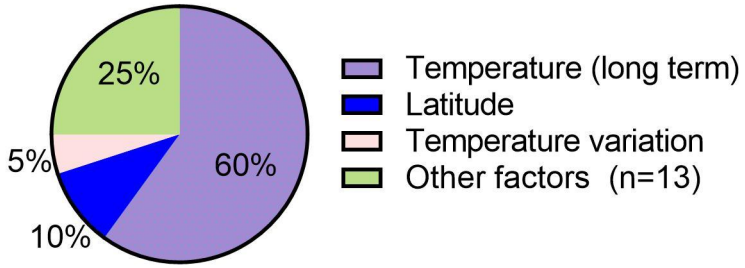
Eco-epidemiology: Preliminary results

Relationship with coral health

Coral diversity



Coral cover



Based on current dataset, UV filters not a key driver of coral health

Largely driven by sea temperature, wave power, geography

Other factors:

Beach visits	Recreational fishing
Benthic macroalgae	Sediment export
Commercial fishing	Sewage effluent
Cesspool systems	Total UV filter concentration
Population density	Longitude
Land cover	Oxybenzone

Dyer et al. (2022) Use of Eco-epidemiology to Assess the Potential Risks of UV Filters to Corals in Hawaii. *In prep*.

Conclusions

- Environmental safety concerns over UV filters have led to key scientific questions being posed
- Marine environments are exposed to UV filters and ERAs are being conducted to evaluate their safety
- Limited coral toxicity data are suitable for preliminary ERA purposes and more reliable data are needed for conclusive assessments to be conducted

Ongoing work

Reliable test methods for adult coral are in development

Robust and representative UV filter monitoring in beach environments and near reefs is being conducted

⇩

Predictive exposure models for recreational wash-off in beach environments are being developed

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