Are Sunscreens killing our corals?

Carys L. Mitchelmore UMCES Chesapeake Biological Laboratory Science for Citizens Seminar Series

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SPF

75

Risk to

coral?

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Mitchelmore Laboratory - Research Focus



Overview Of Talk

Coral Reefs

- Where and what are coral reefs?
- Current health status of the worlds coral reefs
- How do we assess environmental problems?: Risk assessments

Sunscreens

- Types and sources of sunscreen chemicals?
- Concentrations in seawater around reefs
- Impact of sunscreens on corals



Sunscreens and the coral reefs in Hawaii

- Our study Environmental concentrations of UV filters in Hawaii
- What does it tell us?
- Next steps
- What can <u>YOU</u> do?





CORAL REEFS: Global Distribution

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Limited to: clear, nutrient poor, warm waters

Importance of Coral Reefs

Keystone species:

- basis of a highly productive ecosystem
- Huge primary productivity and biodiversity
- Provide habitat and food
- Social and Economic importance
 - Fisheries
 - Tourism
 - Recreation
- Coastline protection and buffer to shoreline erosion







Photos from NOAA.gov

CORAL REEFS - nutrient-poor environments

- Tropical waters nutrient poor
- Yet MASSIVE productivity

HOW??? Adaptation in nutrient cycling; Animal : Algal symbiosis





Cnidarian-algal symbiosis

High light environment (safe?) Carbon dioxide Nitrogen (NH₄)



Organic carbon (e.g. glycerol, some amino acids)

- No loss of nutrients between trophic levels
- Important in nutrient poor tropical ecosystems
- Expand symbiosis to include bacteria (Holobiont all 3 partners)

Main threats to coral reefs...



Current Health Status of Coral Reefs

Generally, globally coral reefs are in decline

Increasing human population (especially in coastal areas) increases the impacts on coral reefs: urban and tourist destinations

World » Great Barrier Reef 'cooking and dying' as seas heat up, warn scientists CNN Severe damage to Great Barrier Reef revealed 00:51 (CNN) — More than two-thirds of the coral in Australia's CNN News Story highlights Great Barrier Reef is experiencing "shocking" amounts of **Report:** The Great Barrier Reef has had two major bleaching, new aerial surveys have revealed. bleaching events in two years Back-to-back bleaching events in 2016 and 2017 have April 15th The Australian government says climate change is mainly to blame devastated a 1,500 km (900 miles) stretch of the 2017 UNESCO World Heritage Site, Australian scientists told CNN Monday.

Before 2016 there had only been two bleaching events along the Great Barrier Reef in the past two decades, in 1998 and 2002.



Are chronic stresses are overwhelming the resilience (or the capacity for self-repair) of reef communities?

Local impacts weaken reefs, so harder to bounce back from global events

Coral Bleaching

- Bleaching can be loss of pigments
- Usually bleaching is symbiosis breakdown = loss of algae
- Corals die or severely compromised = breakdown of reef ecosystem





Causes of bleaching:

◆ **TEMPERATURE** – extent and duration

Also disease, pollution, shading (sediment/algae), freshwater input, UV

Coral Resiliency and Management Approaches

Questions:

- How to prioritize concerns to maintain and improve coral reef resiliency? (e.g. focus on local issues to minimize additive impacts to global change)
- Identify and promote mechanisms that make corals resilient to threats/stressors
- Adaptive management and coral replenishment projects



• Conduct risk assessments to determine problems

Ecological Risk Assessment

Determines nature and likelihood of harmful effects on organisms due to chemical contaminant (or any stressor)

Why do them?

(1)<u>Retrospective</u> risk assessment - estimate adverse effects after exposure

(1)<u>Prospective</u> risk assessment – predict adverse effects based on estimated exposure (e.g. used to regulate chemical release)

They are a valuable tool to:

Estimate the amounts of chemical in the environment associated with harm

Help guide environmental management / regulatory decisions

Inform public to make smarter choices

Ecological Risk Assessment

Specific examples:

- (1) Recommend or reject new chemical(s)
- (2) Evaluate benefits of remediation and restoration options at polluted sites
- (3) Evaluate if a chemical found in the environment will cause harm to organism in the same environment

GENERAL APPROACH: 3 parts

EXPOSURE HAZARD RISK

- <u>HAZARD</u> = potential cause harm (e.g. toxicity of the chemical)
- <u>RISK</u> = likely exposure and harm of that exposure

Sunscreens and UV filter Ingredients



Two main types



Sprays or creams



ACTIVE INGREDIENTS:

AVOBENZONE (3%), OCTOCRYLENE (10%), OXYBENZONE (5%).

INACTIVE INGREDIENTS:

ALCOHOL DENAT., ACRYLATES/OCTYLACRYLAMIDE Copolymer, Water, Caprylyl Glycol, Peg-8 Dimethicone, Mineral Oil, Aloe Barbadensis Leaf Extract, Octyldodecanol, Retinyl Palmitate, Silica, Tocopheryl Acetate, Ascorbic Acid, Sodium Propoxyhydroxypropyl Thiosulfate Silica, Fragrance.

FDA Monograph Sunscreen Ingredients	Amount of Ray Protection	
	UVA	UVB
Aminobenzoic acid (PABA)	0	
Avobenzone	•	O
Cinoxate	Ð	•
Dioxybenzone	0	
Ecamsule	•	0
Homosalate	0	
Menthyl anthranilate	•	
Octocrylene	O	•
Octyl methoxycinnamate	۲	•
Octyl salicylate	0	
Oxybenzone	•	•
Padimate O	0	•
Phenylbenzimidazole	0	
Sulisobenzone	•	•
Titanium dioxide	0	
Trolamine salicylate	0	•
Zinc Oxide		•

Protection Level: • = extensive • = considerable • = limited • = minimal

Sources of UV filters in seawater



Benzophenone-3 (BP-3) Factsheet



Centers for Disease Control and Prevention CDC 24/7: Saving Lives, Protecting People™



Benzophenone-3 (BP-3) is a naturally occurring chemical found in some flowering plants. I

Media reports on Oxybenzone Harming Corals

MEMBER TO

MEMBER

AND CORAL

pollution,

The New Hork Times

SundayReview OPINION

Is Your Sunscreen Poisoning the Ocean?

By PEGGY ORENSTEIN AUG. 19, 2017



Maggie Chiang



Studies show that oxybenzone, a common chemical found particularly in sprayon sunscreens, contributes to coral bleaching and leaves reefs deformed

CORAL REE ARE DYIN and those in the waters of Hawai'i This dead tissue on a knobby brain coral (Pseudodiploria clivosa) in Bocas del Toro, Panama, is clear evidence of the careless SUNSCREEN touch of a diver



HURSDAY | 04,20,2017 | EXPRESS | 11

Media Reports: The other side

"WHEN ARE WE GOING TO STOP PRETENDING THAT +2°C IS SAFE FOR The great barrier reef, when +1°C Already bleaches 93% of it?"

Prof. Terry Hughes, ARC Centre of Excellence for Coral Reef Studies, James Cook University, 21 May 2016



Reefs have far bigger threats than sunscreen toxins

In October, the National Oceanic and Atmospheric Administration (NOAA) announced the world's third-ever global coral bleaching event was taking place.

This refers to the phenomena whereby coral turns white after expelling algae in response to higher water temperatures, among other factors, which make the corals more susceptible to bacteria and other sources of stress.

"The conclusion from the media is sunscreen is killing the world's coral, and that's laughable," "The conclusion from the media is sunscreen is killing the world's coral, and that's laughable," he said.

For its part, the report claims that at least 10% of the global reefs are at risk of exposure. "Many reefs are remote, without tourists, and many of them nonetheless are showing impact from climate change ... if you want to study global threats, you have to look on a global scale and they haven't done that," Hughes said of the sunscreen study.

Legislative action in Hawaii - 2018

Legislators Continue Push to Ban Sunscreen Products Containing Oxybenzone and Octinoxate

By WAYNE YOSHIOKA . JUN 21, 2017



Sunscreen Ban

Listen

Legislation to ban certain sunscreen chemicals in Hawai'i stalled in the final days of the 2017 session. But, state lawmakers are already starting their push to pass the bills next year. HPR's Wayne Yoshioka reports.



(L-R) Representative Nicole Lowen, Researcher Craig Downs, PhD, and Senator Will Espero will be pushing for a ban an sunscreens containing Oxybenzone and Octinoxate. CREDIT WAYNE YOSHIOKA

The chemical, oxybenzone, is an active

ingredient in many sunscreen products. Evidence provided by PhD environmental researcher, Craig Downs, links oxybenzone to the killing of baby coral and eventually entire reef systems in populated areas worldwide.



What sunscreen ingredients are banned?



Beginning January 1, 2021, Hawaii will ban the sale, offer of sale or distribution of any sunscreens containing oxybenzone or octinoxate without a prescription from a licensed health care provider. The chemicals might also be labeled as benzophenone-3 and octyl methoxycinnamate, respectively.

Concentrations of a chemical in seawater: terminology



Analytical detection does **NOT** mean harm

• Odds of winning tonight's Mega Millions is 1 in 259 million (or 3861 per trillion)

Toxicology basics: Concentration, time and form



"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."



Very low concentrations CAN cause harm especially over long time periods

Concentrations of oxybenzone/octinoxate in water, sediment and coral tissues from Hong Kong (Tsui et al. 2014, 2017):



Take Home Message:

- ◆ Concentrations in the ng L⁻¹ (parts per trillion) range
- **Environmental** Science & Technology

Article



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Occurrence, distribution and fate of organic UV filters in coral communities

Mirabelle M.P. Tsui, James C.W. Lam, Tsz Yan Ng, Put O. Ang, Margaret B. Murphy, and Paul Kwan-Sing Lam Environ. Sci. Technol., Just Accepted Manuscript • DOI: 10.1021/acs.est.6b05211 • Publication Date (Web): 29 Mar 2017 Downloaded from http://publs.acs.org on April 1. 2017

- Seawater concentrations varied with site and season and water depth
- Reflect increased recreational activity at those sites in the wet season

Concentrations of oxybenzone/octinoxate in seawater in US

Virgin Islands (Bargar et al. 2015):



Marine Pollution Bulletin Volume 101, Issue 1, 15 December 2015, Pages 193–199



Synthetic ultraviolet light filtering chemical contamination of coastal waters of Virgin Islands national park, St. John, U.S. Virgin Islands

Timothy A. Bargar^{a,} 📥 📟, David A. Alvarez^ь, Virginia H. Garrison^c



Take Home Message:

◆Concentrations in the ng L⁻¹ (parts per trillion) to μg L⁻¹ (parts per billion) range

Levels varied by site and season but also by distance from shoreline

Concentrations of oxybenzone in seawater in Hawaii and US Virgin Islands (Downs et al. 2016):



Take Home Message:



◆VERY high concentrations in US Virgin Island; up to 1.395 parts per million (mg L⁻¹)

•Only 1 of 5 sites in Oahu measured concentration @ 19.2 parts per billion (μ g L⁻¹)

Toxicity studies on Oxybenzone impact to Corals

Environ Health Perspect. 2008 Apr; 116(4): 441-447. Published online 2008 Jan 3. doi: 10.1289/ehp.10966 Research

Sunscreens Cause Coral Bleaching by Promoting Viral Infections

Roberto Danovaro,¹ Lucia Bongiorni,¹ Cinzia Corinaldesi,¹ Donato Giovannelli,¹ Elisabetta Damiani,² Paola Astolfi.³ Lucedio Greci,³ and Antonio Pusceddu¹

Author information ► Article notes ► Copyright and License information ►

Arch Environ Contam Toxicol DOI 10.1007/s00244-015-0227-7

Toxicopathological Effects of the Sunscreen UV Filter, Oxybenzone (Benzophenone-3), on Coral Planulae and Cultured Primary Cells and Its Environmental Contamination in Hawaii and the U.S. Virgin Islands

C. A. Downs¹ · Esti Kramarsky-Winter^{2,3} · Roee Segal² · John Fauth⁴ · Sean Knutson⁵ • Omri Bronstein² • Frederic R. Ciner¹ • Rina Jeger³ • Yona Lichtenfeld⁶ · Cheryl M. Woodley^{7,8} · Paul Pennington⁸ · Kelli Cadenas⁹ · Ariel Kushmaro³ · Yossi Lova²

Received: 17 July 2015 / Accepted: 13 September 2015

Take Home message:

- Only TWO studies
- Single laboratory experiment
- Red sea coral larvae, in vitro cell culture
- Concentrations of oxybenzone added were not measured (analytically verified)

Danovaro et al., 2008

Downs et al., 2016

Highlights possible potential for impact to coral larvae = ' red-flag'

More research warranted





PMCID: PMC2291018

Published studies on Octinoxate Concentrations in Seawater from Hawaii:

Studies on the toxicity of octinoxate on corals:

Do you think Oxybenzone and Octinoxate Impact Corals ?

Evidence : Oxybenzone

- Ubiquitous in seawater, including near corals
- Most concentrations in parts per trillion concentrations (ng L⁻¹)
- Only <u>ONE</u> measured concentration from seawater from Hawaii (4 non detects)
- <u>TWO</u> toxicity studies in corals



Evidence : Octinoxate

- Some concentrations in seawater, including near coral reefs
- Most concentrations in parts per trillion concentrations
- <u>NO</u> published concentrations in seawater from Hawaii
- <u>NO</u> toxicity studies in corals

IS THERE ENOUGH EVIDENCE FOR HAWAII?



Hawaii Institute of Marine Biology (HIMB) - Coconut Island



Project Pl's:

Dr. Lee Blaney (UMBC) Drs. Carys Mitchelmore, Michael Gonsior and Andrew Heyes (UMCES-CBL)

Rick Younger (Consultant, Diver, MD)

Graduate Students (UMBC): Ke He and Ethan Hain





Captain John Benson III (JT) and crew



Our Study Design and Methods



Matched samples of:

- Surface water
- Sediment
- Corals: Porites spp.
- Deep/shallow sites



Kaneohe Bay, Oahu, 10 feet

Kailua Bay, Hawaii, 20 feet

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

Measured Concentrations of:

- Oxybenzone (BP-3) and octinoxate (EHMC)(all matrices)
- 11 additional UV filters & hormones (all matrices)
- Conducted October 2017

Study locations and sites



Site Selection: High Tourism site – Waikiki Beach, Oahu

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



Our results: Oxybenzone concentrations in seawater



S3:am

D4:pm

- Oxybenzone found at all sites in parts per trillion concentrations
- Most sites $< 10 \text{ ng L}^{-1}$ (i.e. 12/19)
- Highest concentrations at Waikiki Beach with most bathers/tourists
- Lower concentrations further offshore and variable over the day

TAKE HOME MESSAGES:

- Oxybenzone ubiquitous; NO measured levels of octinoxate
- Concentrations variable spatially (sites and distance shore) and temporally (time of day)

QUESTIONS: Need more data on variability with depth, distance shore, time day, season, persistence in seawater, natural sources?.

Our Oxybenzone seawater concentrations in context

TAKE HOME MESSAGES:

Very few reported studies of concentrations in Hawaii

The one detected value by Downs et al (2016) in seawater is over two-orders of magnitude higher than our highest detected value (i.e. 136 versus 19,200 ng L^{-1}) – VERY VARIABLE?

♦ Very similar seawater concentrations to those from Hong Kong coral reefs (i.e. 0.2-136 versus 13-32 ng L⁻¹) all parts per trillion

◆ Values from US Virgin Islands are very variable and similar to or higher than ours



Our oxybenzone concentrations compared to toxicity values

Test Organism	Coral	Toxicity	Exposure	Concentration	Concentration	
	species	endpoint	Time*	(µg L ^{.1})	(ng L ⁻¹)	
Coral planula	Stylophora	Mortality;	24 hr	139	139,000	
	pistillata	LC50				
Coral planula	Stylophora	Deformity;	24 hr	49	49,000	
	pistillata	EC50				
In vitro cell culture	Stylophora	Cell death;	th; 4 hr	42	42,000	DOWNS et al. 2016
	pistillata	LC50				
In vitro cell culture	Pocillopora	Cell death;	4 <u>hr</u>	8	8,000	*; note all results
	damicornis	LC50				show the worse case
In vitro cell culture	Acropora	Cell death;	4 hr.	9	9,000	scenario with
	cervicornis	LC50				exposures conducted
In vitro cell culture	Montastrea	Cell death;	4 hr.	74	74,000	in the light that
	annularis	LC50				snows nigner toxicity
In vitro cell culture	Montastrea	Cell death;	4 hr.	52	52,000	duration under study
	cavernosa	LC50				(i o 24 rather than 8
In vitro cell culture	Porites	Cell death;	4 hr.	340	340,000	hours for the
	astreoides	LC50				planula).
In vitro cell culture	Porites	Cell death;	4 hr.	340	36,000	
	divaricata	LC50				

TAKE HOME MESSAGE:

Oxybenzone levels we detected in Oahu, HI (0.2 to 136 ng L⁻¹) are:

60 - 2,500 times LOWER than toxicity thresholds reported by Downs et al (2016)

Conclusions and Take Home Messages

- Oxybenzone ubiquitous but VARIABLE
- The concentrations of oxybenzone we detected in HI were very low;

below reported harmful levels to corals

- Octinoxate was not present in HI sites at measurable concentrations
- We also found surfactants, hormones, PAHs, many reported chemicals in reefs; trash and plastic items.





What's next?

- Need more data on environmental concentrations (differerent sites and times)
- ♦ How persistent are they?
- Sources (including natural)?
- Need to repeat and expand on toxicity studies
- More longer-term exposures and assessments, multiple species and life stages
- Measure levels taken up by corals in controlled experiments
- Are the proposed mineral sunscreens safer?
- What are the chemicals of most concern in a reef?
- Are we targeting the right ones?



What can <u>YOU</u> do?

- Stay informed, keep investigating the facts
- Be cautious of media and social media reports
- This is environmental NOT human harm
- Be aware of marketing ploys:
- 'Reef Safe' sunscreen? there are <u>NO</u> official, approved tests or certifications for REEF SAFE OR OCEAN-SAFE PRODUCTS
- Organic' sunscreen? often used to describe the mineral inorganics!
- 'Biodegradable' sunscreen?
 - what does this mean?
 - oxybenzone is biodegradable
 - biodegrade to MORE harmful chemicals?
- Use more hats, cover-ups; make sure they are UV protective!
- Support our research and especially our graduate students







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