Oxybenzone & Octinoxate Sunscreen Pollution and the Threat to Maui's Coral Reefs

Craig A. Downs, PhD.
Executive Director
Haereticus Environmental Laboratory

What is at risk?

- Tourism Industry
- Restaurant Industry
- Recreational Industry
- Property Values
- Tax Revenue

- Cultural History/Identity
- Reputation
- Feedback Corruption
- Legacy

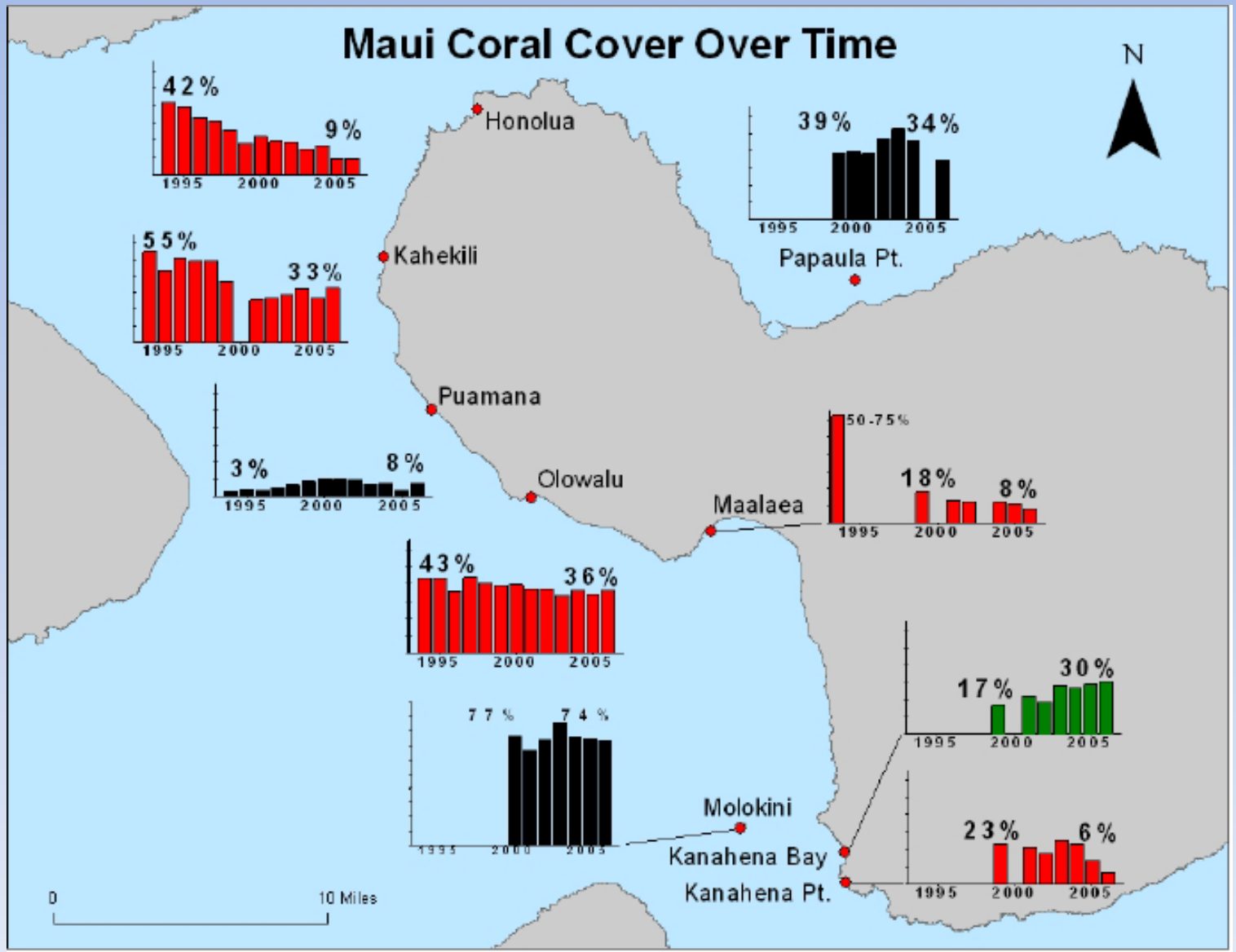
What is the Ecological Problem?

Photos courtesy of Dr. Phil Dustan

26.8°C
80.2°F

Disappearing Coral Reefs

Slow, almost imperceptible decline





Healthy

Recruitment/Growth

Death Rate

Coastal Reefs near populated areas

Death Rate

Recruitment/Growth

theguardian

world opinion sports soccer tech arts lifestyle fashion business travel environment all sections

nt › wildlife energy pollution climate change

'Zombie corals' pose new threat to world's reefs

Scientists discover corals that look healthy but cannot reproduce, dashing hopes such reefs could repopulate bleached areas

From a demographic and evolutionary perspective, populations with little to no recruitment are the 'living dead'---

Coral Reef Zombies

- Sea urchins
- Fish
- Shrimp/crabs
- Sea grass

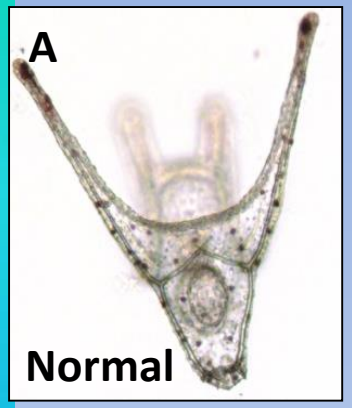
Environmental Investigation into impacts of Land-Based Sources of Pollution on Coral Health in West Maui, Hawaii

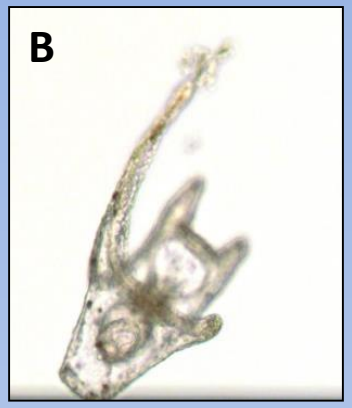
CRCP Project 502 Interim Report

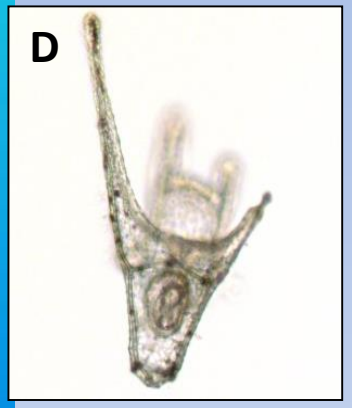
West Maui, HI has been plagued with reports of poor water quality in the near shore coastal zone, fecal indicators exceeding EPA standards, and algal blooms for over 20 years with a corresponding steady decline in coral cover from 70% (1990s) to 27% (2006). This interim report provides baseline fecal indicator data in dry (22 sites) and rainy (14 sites) seasons and porewater toxicity data for 16 locations on Maui to help clarify the role of wastewater injection wells may play in coral decline and assist in BMP monitoring efforts. This information can help strategically focus costly management efforts on the greatest risk factors.

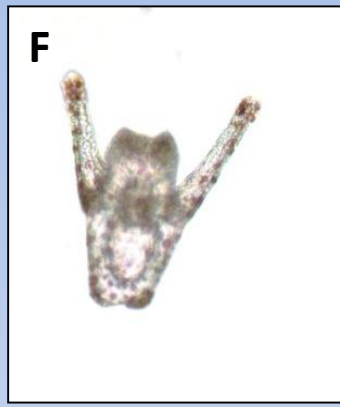
CORAL DISEASE & HEALTH CONSORTIUM
SOLUTIONS TODAY FOR REEFS TOMORROW.

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE



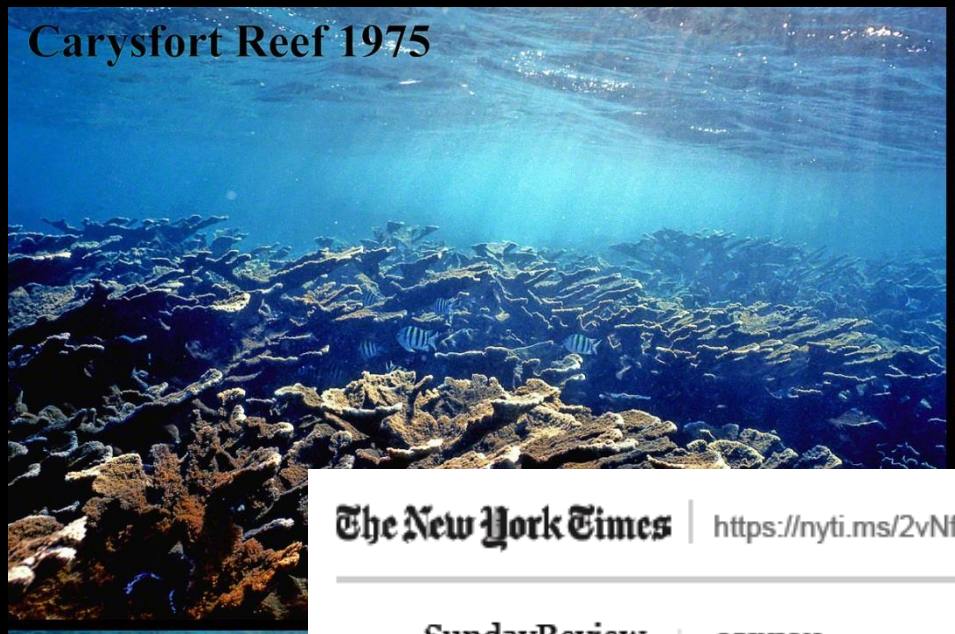


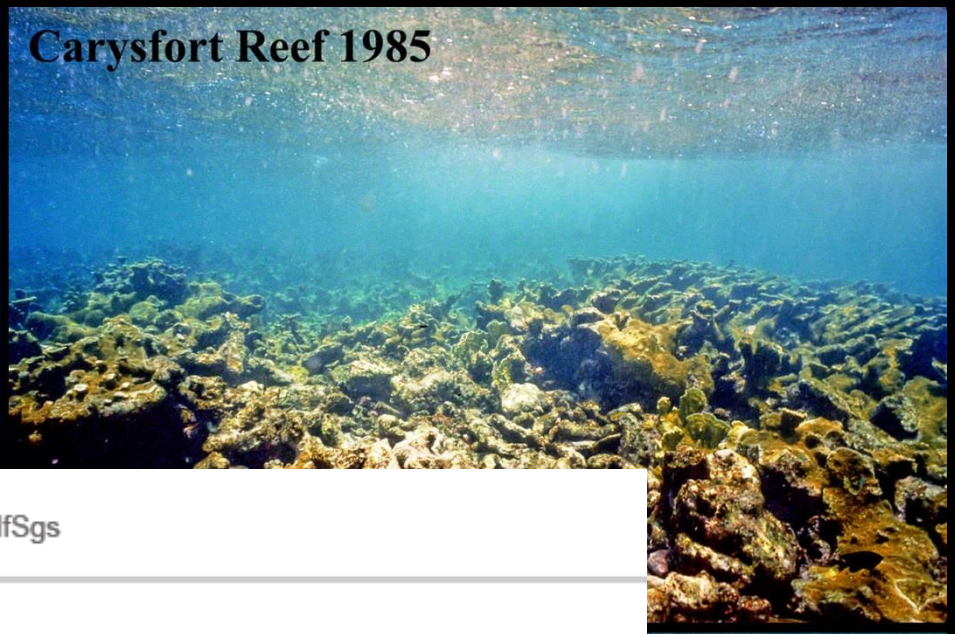




Cheryl M. Woodley[1], Craig A. Downs[2], Lisa A. May[3], Erin Looney[4], Darla White[5] and Kathy Chaston[6]

[1]NOAA National Ocean Service, Center for Coastal Environmental Health & Biomolecular Research, Charleston, SC
[2]Haereticus Environmental Laboratory, Clifford, VA
[3]JHT, Inc. Contractor to NOAA National Ocean Service, Center for Coastal Environmental Health & Biomolecular Research, Charleston, SC
[4]NOAA National Marine Fisheries Service, Pacific Islands Fisheries Science Center, Coral Reef Ecosystem Division, Honolulu, HI
[5]Special Projects Coordinator, Hawaii Department of Land and Natural Resources, Division of Aquatic Resources, Maui, HI
[6]Hawaii Coral Management Liaison and Pacific Watershed Specialist, NOAA Coral Reef Conservation Program, Pacific Services Center, Honolulu, Hawaii





The New York Times | https://nyti.ms/2vNfSgs

SundayReview | OPINION

Is Your Sunscreen Poisoning the Ocean?

By PEGGY ORENSTEIN AUG. 19, 2017

Photos courtesy of Dr. Phil Dustan

Sunscreen Pollution

Drug Facts

Active ingredients	Purpose
Avobenzone 3%	Sunscreen
Homosalate 15%	Sunscreen
Octisalate 5%	Sunscreen
Octocrylene 5%	Sunscreen
Oxybenzone 6%	Sunscreen

Uses • helps prevent sunburn • if used as directed with other sun protection measures (see **Directions**), decreases the risk of skin cancer and early skin aging caused by the sun

Warnings

For external use only

Do not use on damaged or broken skin

When using this product keep out of eyes. Rinse with water to remove.

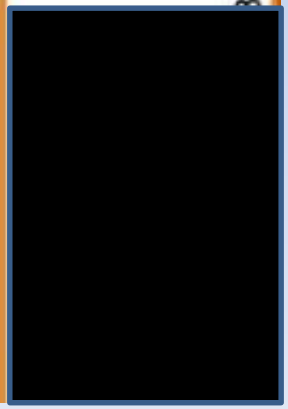
Stop use and ask a doctor if rash occurs

Keep out of reach of children. If swallowed, get medical help or contact a Poison Control Center right away.

Directions For sunscreen use: • apply generously 15 minutes before sun exposure • reapply: • after 80 minutes of swimming or sweating • immediately after towel drying • at least every 2 hours • **Sun Protection Measures.** Spending time in the sun increases your risk of skin cancer and early skin aging. To decrease this risk, regularly use a sunscreen with a Broad Spectrum SPF value of 15 or higher and other sun protection measures including: • limit time in the sun, especially from 10 a.m. – 2 p.m. • wear long-sleeved shirts, pants, hats, and sunglasses. • children under 6 months of age: Ask a doctor

Other information • protect the product in this container from excessive heat and direct sun

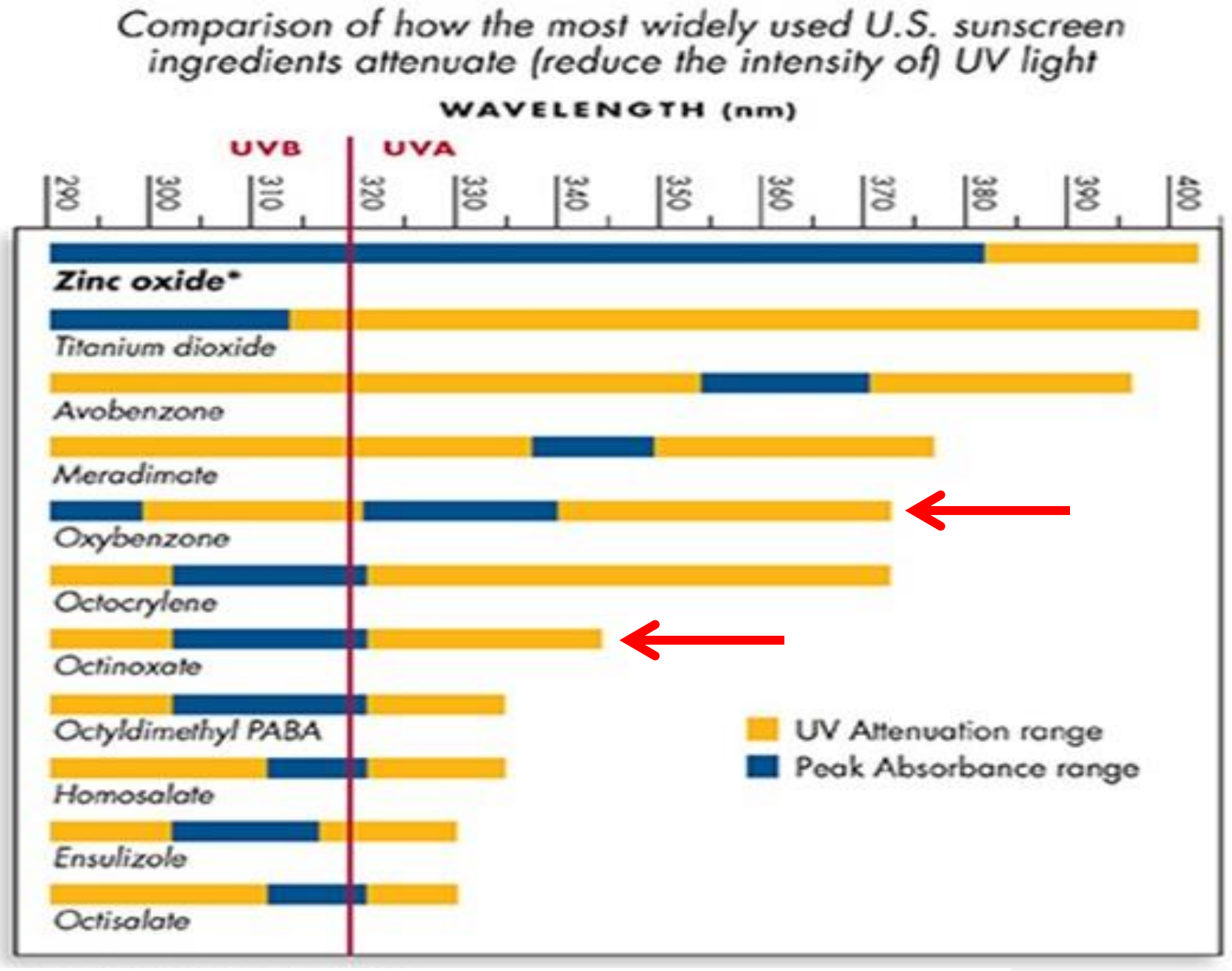
Inactive ingredients water, dimethicone, isododecane, styrene/acrylates copolymer, propanediol, glycerin, silica, isononyl isononanoate, inulin lauryl carbamate, nylon-12, caprylyl methicone, synthetic wax, poly C10-30 alkyl acrylate, PEG-8 laurate, stearyl alcohol, dimethiconol, triethanolamine, isoeugenol, fragrance, vitis vinifera (grape) fruit extract, phenoxyethanol, p-anisic acid, ammonium acryloyldimethyltaurate/steareth-25 methacrylate crosspolymer, chlorphenesin, disodium EDTA, tocopherol, sucrose tristearate, xanthan gum, polymethyl methacrylate



Drug Facts

Active ingredients	Purpose
Avobenzone 3%	Sunscreen
Homosalate 15%	Sunscreen
Octisalate 5%	Sunscreen
Octocrylene 5%	Sunscreen
Oxybenzone 6%	Sunscreen

34% of the content is UV chemical ingredient



Data Provided by Proctor & Gamble Beauty & Grooming

Estimated Contamination?

Ahihi Kina'u Bay (Natural Areas Reserve)

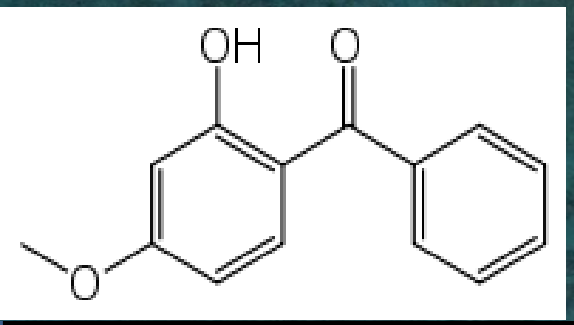
(2017 averaged 1,200 swimmers/day)

= 76.8 kilograms of sunscreen lotion a day. 64 grams per person (American Acad. Dermatol.)
= 2.3 kilograms of oxybenzone a day (3% oxybenzone).
= 69.1 kilograms of oxybenzone per month (~152 pounds per month)
= 829 kilograms of oxybenzone per year (1,828 pounds /year)
= 27,648 kilograms of sunscreen product per year (60,953 lbs/year)

Oxybenzone Contamination

- 868 pptrillion (2015)
- 1,850 pptrillion (2017)

425 pptrillion
(2015)



Acute Toxicity
62-280 pptrillion

Google earth

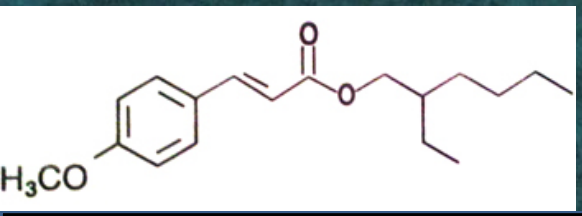
Sampled on July 27, 2015, 15:00 HST

Sampled on June 23, 2017, 17:05 HST

Octinoxate Pollution

- 1,516 pptrillion (2015)
- 5,490 pptrillion (2017)
- 74 pptrillion

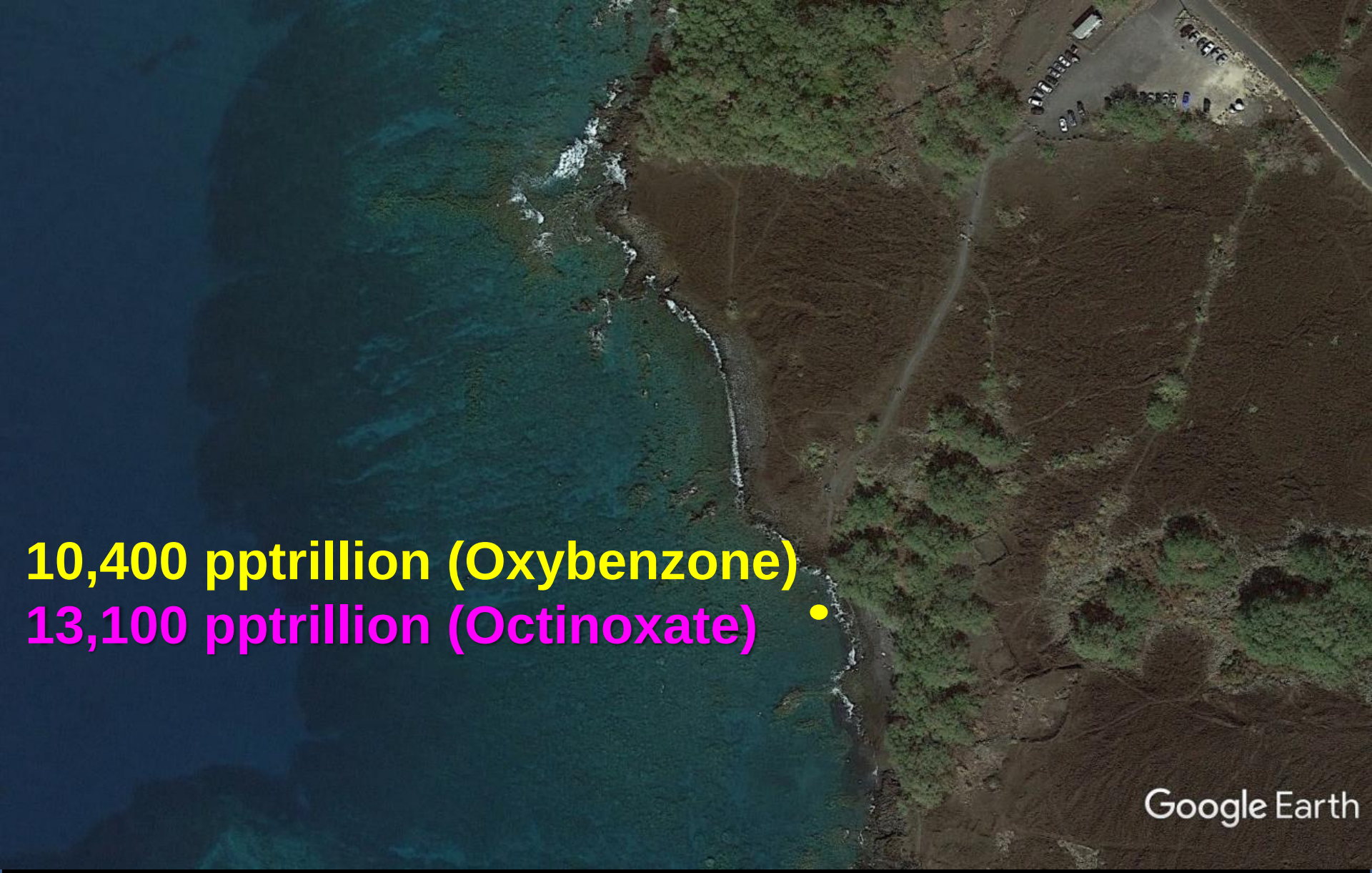
Acute Toxicity
105-220 pptrillion



Google earth

Sampled on July 27, 2015, 15:00 HST

Sampled on June 23, 2017, 17:05 HST



Oxybenzone & Octinoxate Contamination
Sampled on June 23, 2017, 16:19 HST

Oxybenzone Contamination

Summer 2015

881 ppt
607 ppt
125 ppt
1,904 ppt, Honolua Bay
344 ppt
996 ppt
4,252 ppt
136 ppt (Baby Beach)

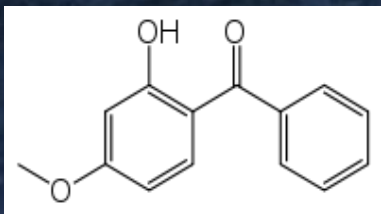
Acute Toxicity
62-280 pptrillion

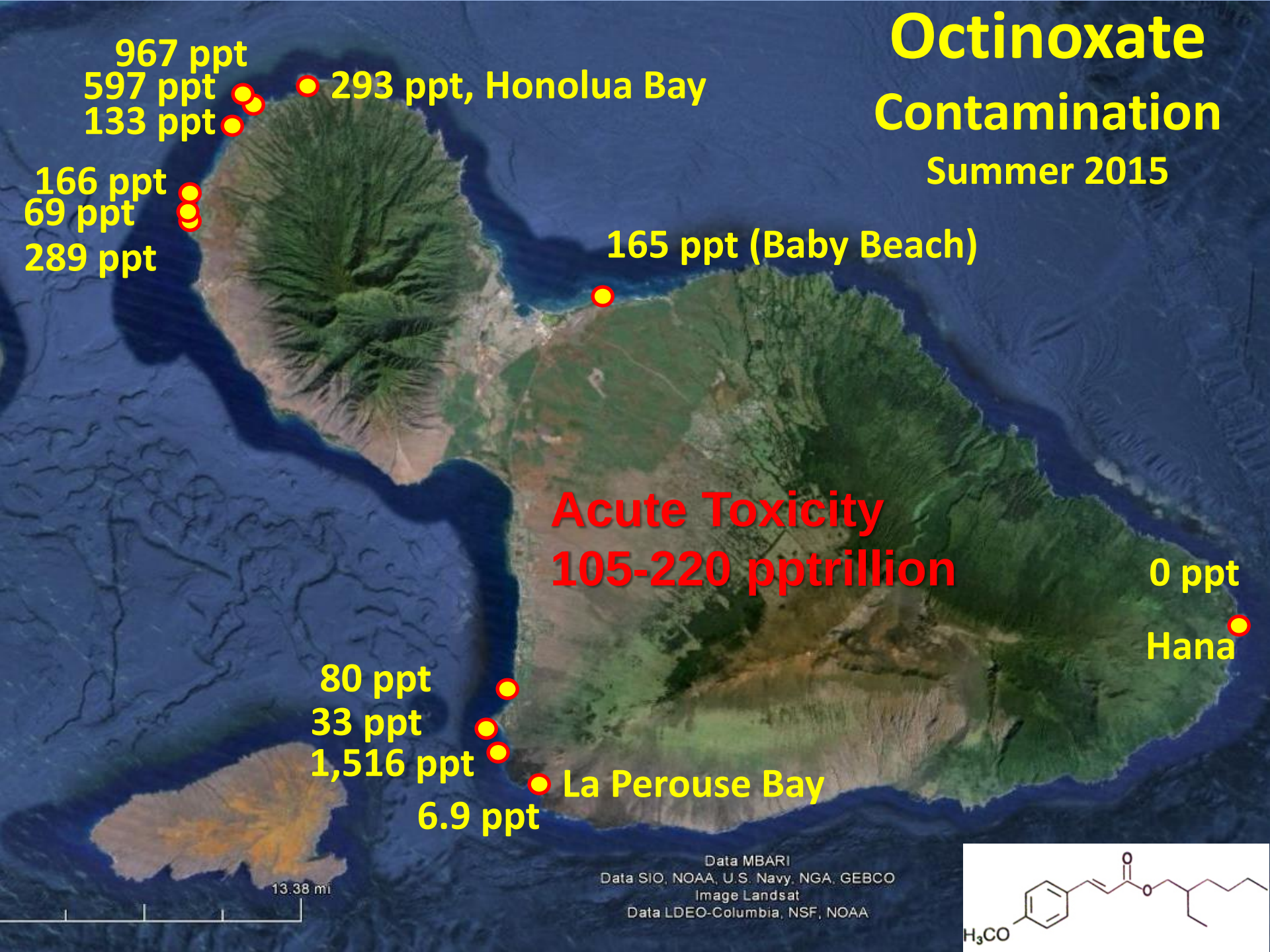
0 ppt
Hana

1,096 ppt
340 ppt
868 ppt
La Perouse Bay
0 ppt

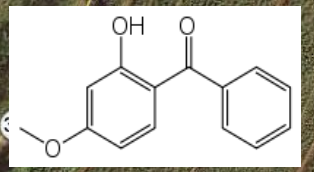
13.38 mi

Data MBARI
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
Data LDEO-Columbia, NSF, NOAA




Octinoxate
Contamination
Summer 2015
967 ppt
597 ppt
133 ppt
293 ppt, Honolua Bay
166 ppt
69 ppt
289 ppt
165 ppt (Baby Beach)
Acute Toxicity
105-220 pptrillion
0 ppt
Hana
80 ppt
33 ppt
1,516 ppt
La Perouse Bay
6.9 ppt
13.38 mi
Data MBARI
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
Data LDEO-Columbia, NSF, NOAA
H3CO
O
O

Oxybenzone Pollution



1,655 pptrillion

1,904 pptrillion

Honolua Bay

Honolua Bay Access Trail

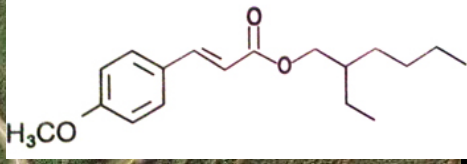
553 ft

Mokuleia Bay

Google earth

Honolua Bay, Maui, Hawaii
July 2015

Octinoxate Pollution



34 pptrillion

293 pptrillion

Honolua Bay

Honolua Bay Access Trail

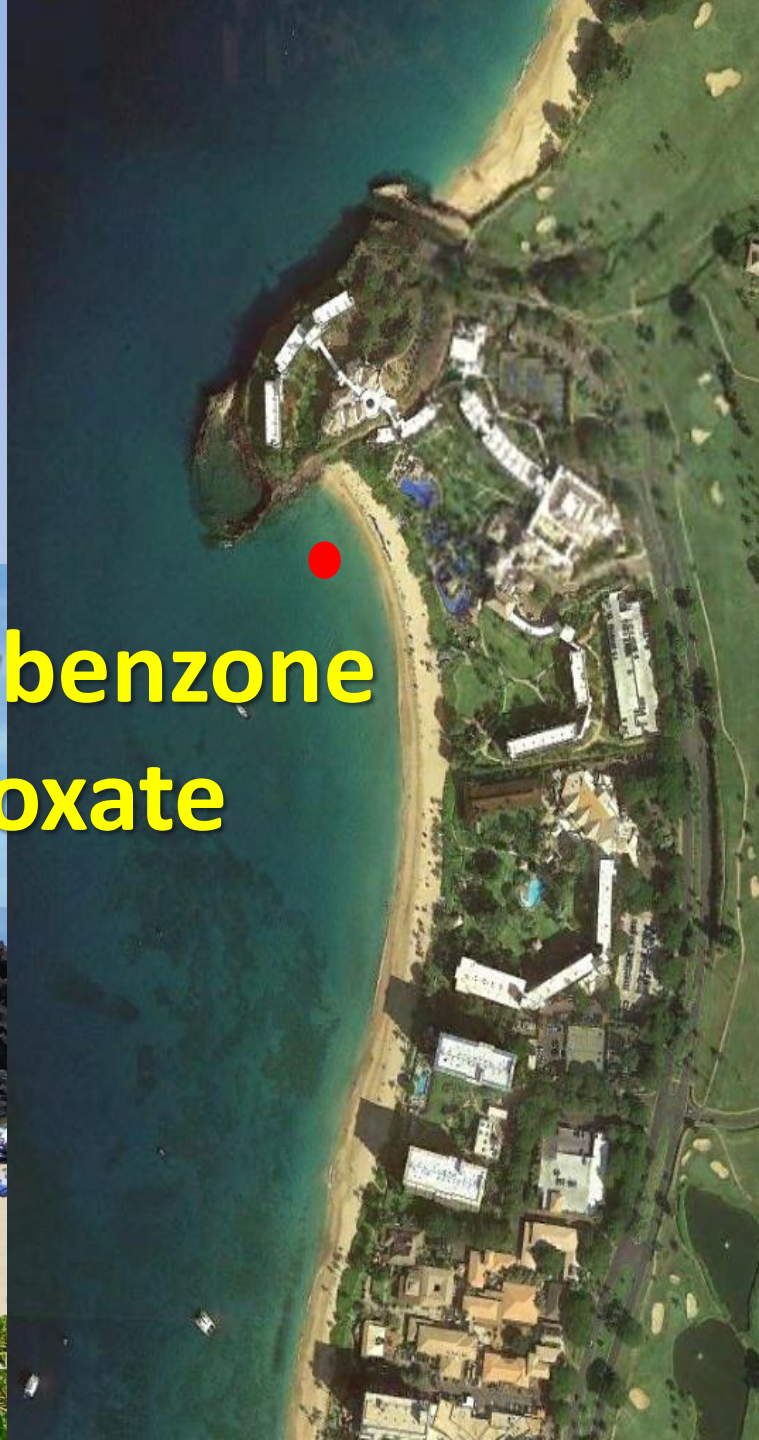
553 ft

Mokuleia Bay

Google earth

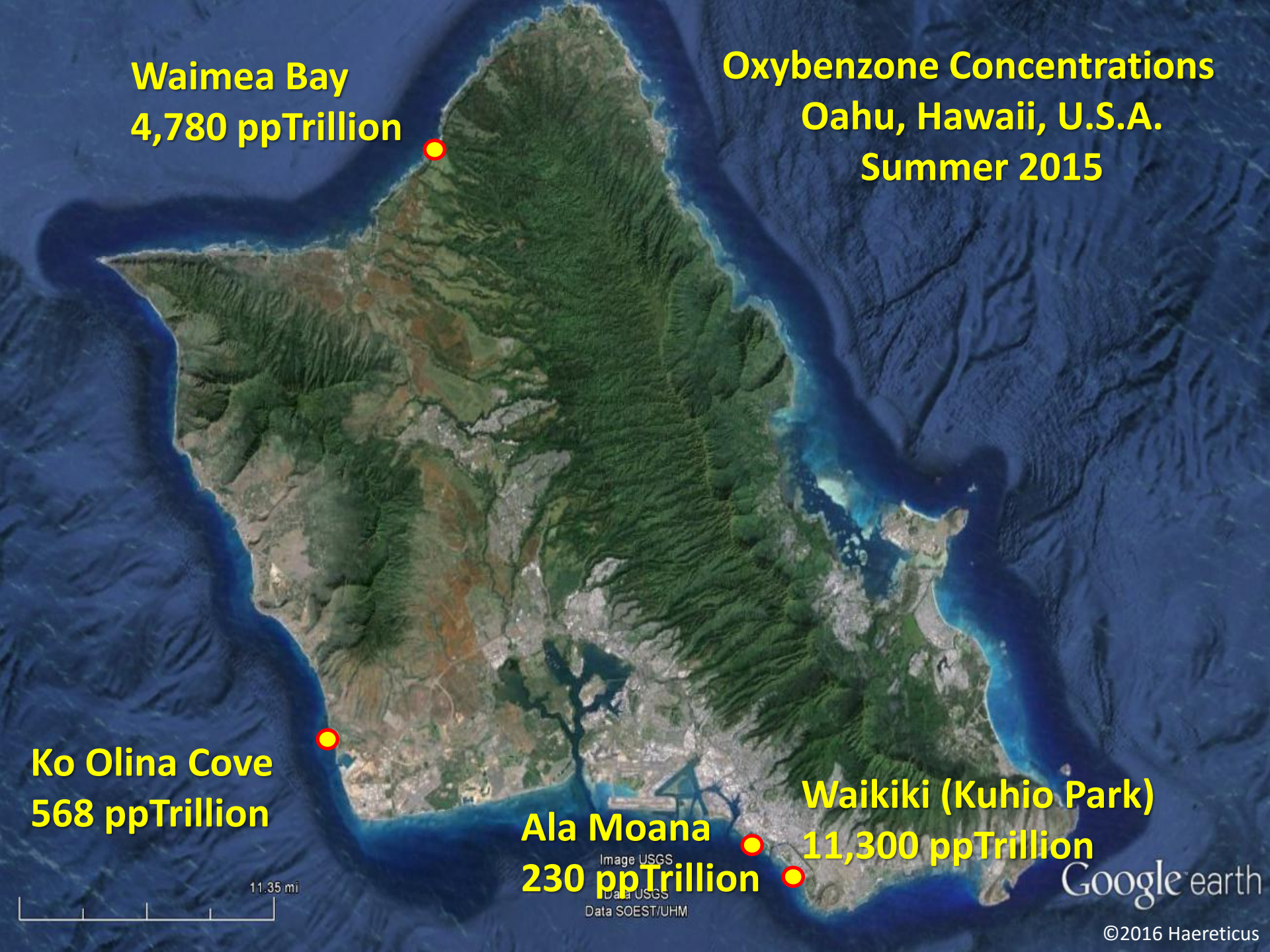
Honolua Bay, Maui, Hawaii
July 2015

Black Rock Beach
Maui, Hawaii

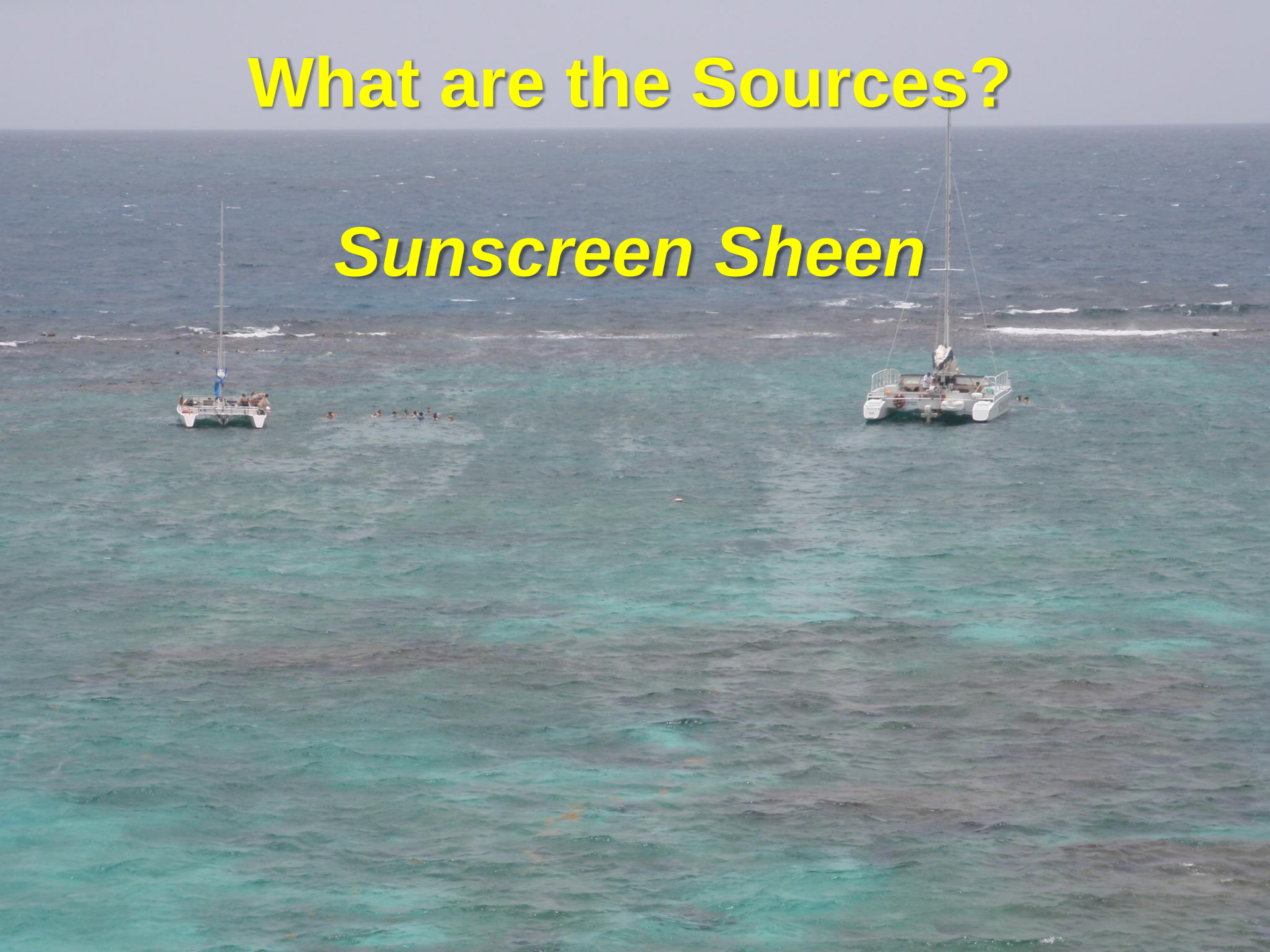


4,252 ppt Oxybenzone

289 ppt Octinoxate


Waimea Bay
4,780 ppTrillion
Oxybenzone Concentrations
Oahu, Hawaii, U.S.A.
Summer 2015
Ko Olina Cove
568 ppTrillion
Ala Moana
230 ppTrillion
Waikiki (Kuhio Park)
11,300 ppTrillion
Image USGS
Data USGS
Data SOEST/UHM
11.35 mi
Google earth
©2016 Haereticus

What are the Sources?

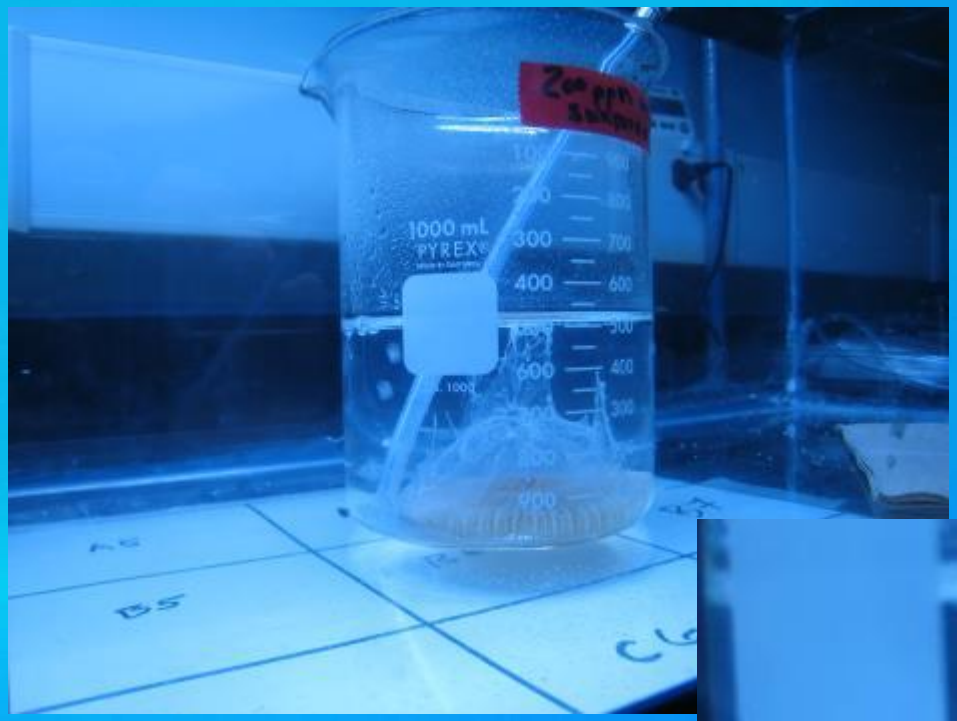


Sewage

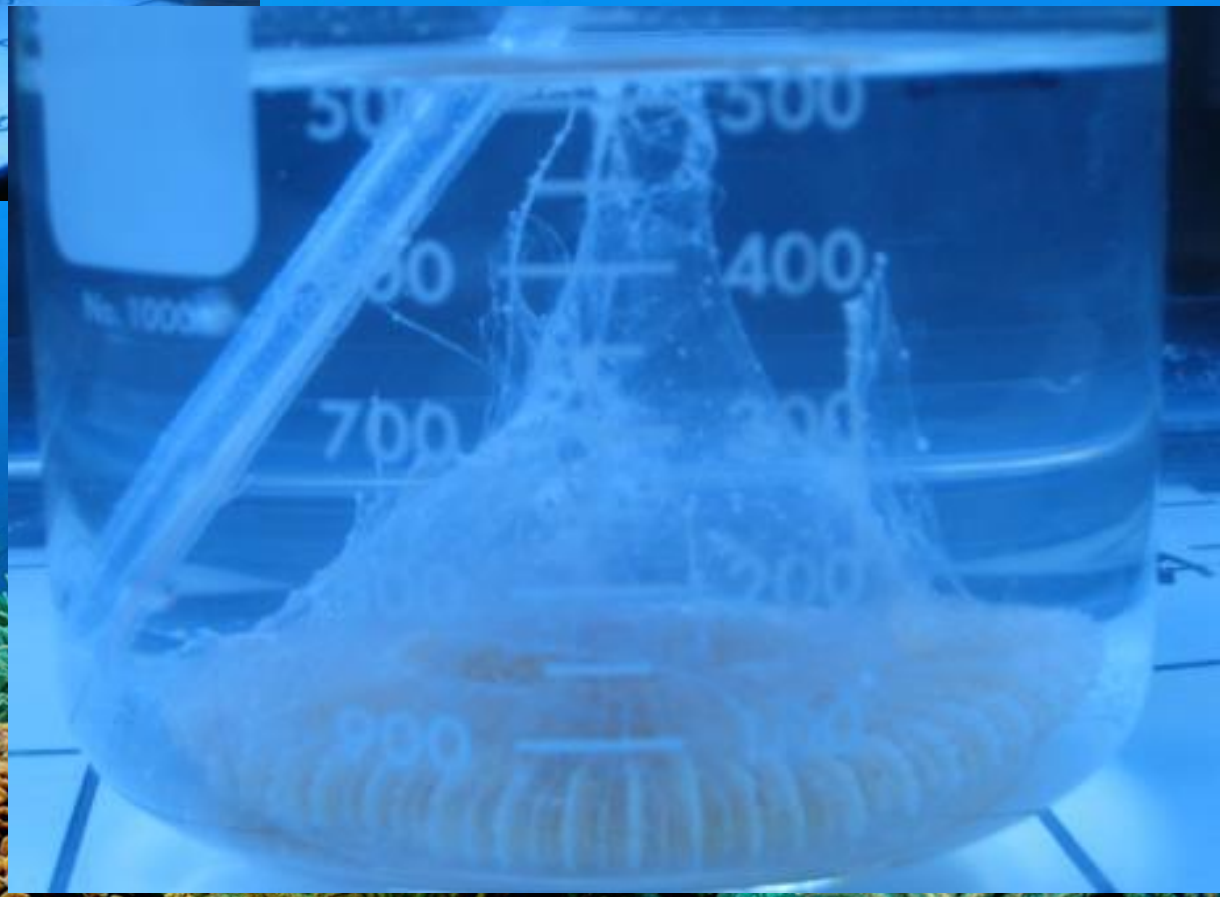
- **30min after application, detect in urine**
- **Residue on skin, wash off in shower**

Oxybenzone contaminates:

Coral
Fish
Marine Mammals
Bird Eggs
Sea Turtle Eggs



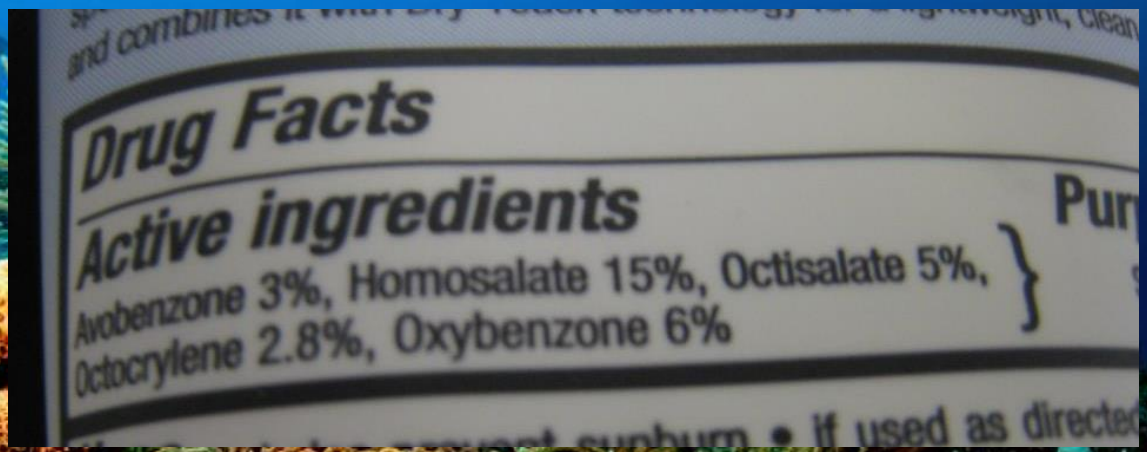
23 hour incubation after placing in Sunscreen WAF 200 ppm



WAF-Sunscreen Lotion Exposure
48 hours

Oxybenzone	Benzophenone-1	Benzophenone-2	4,4DHbenzophenone
220.70	0.2	0	10.4
	Avobenzone	Octocrylene	
	10.2	0?	

Extraction from one *Fungia* polyp 60 mm in diameter
All concentrations in parts per trillion



ENVIRONMENTAL Science & Technology

Subscriber access provided by Libraries of the | University of Hawaii at Manoa

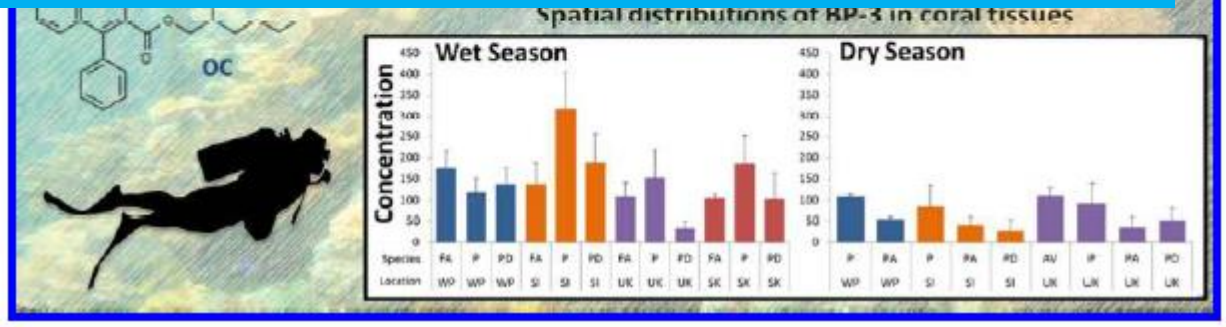
Article

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

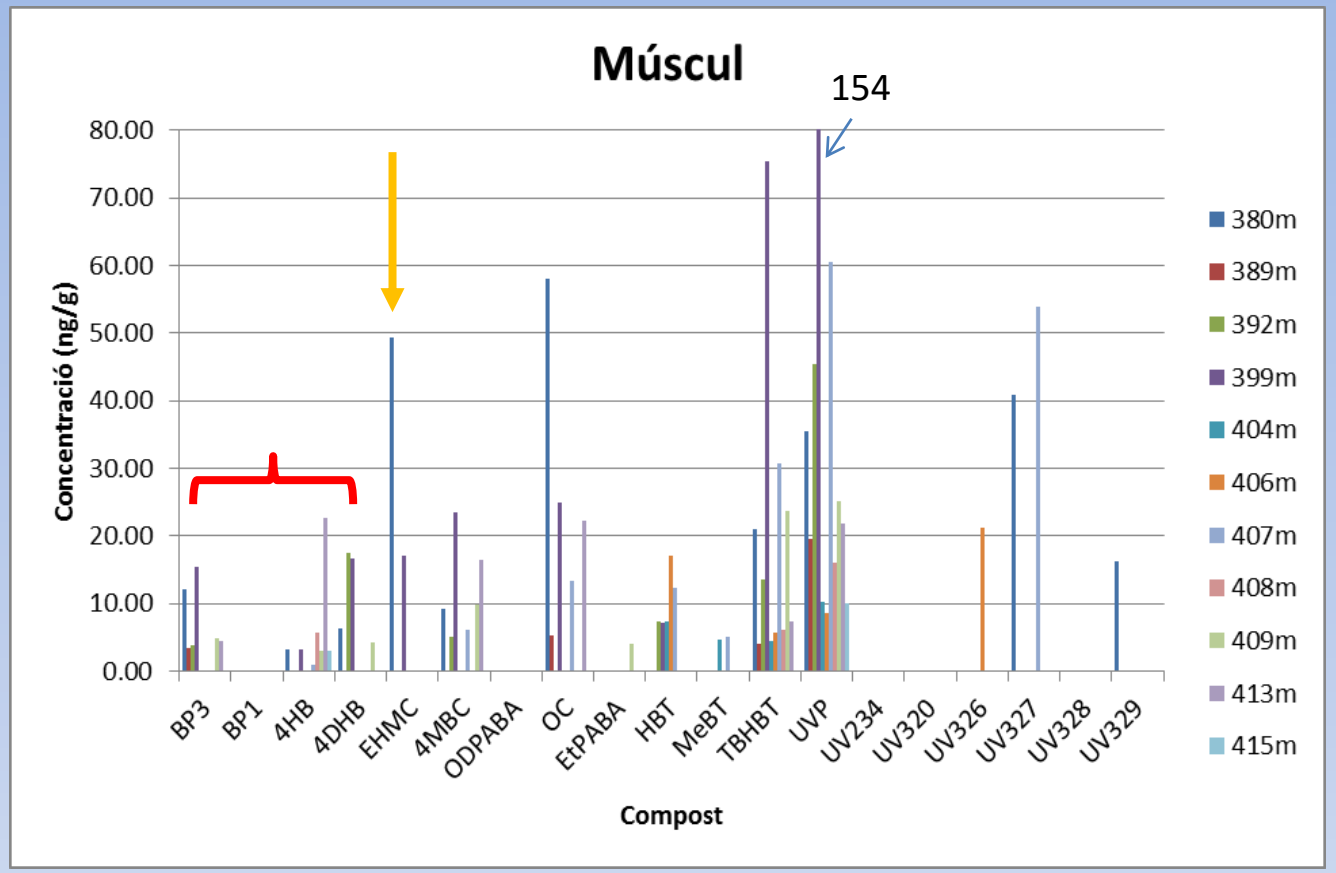
Environ. Sci. Technol., **Just Accepted Manuscript** • DOI: 10.1021/acs.est.6b05211 • Publication Date (Web): 29 Mar 2017

"The results of a preliminary *risk assessment* indicated that over 20% of coral samples from the study sites contained OXYBENZONE concentrations exceeding the threshold values for causing larval deformities and mortality… Higher probabilities of negative impacts of OXYBENZONE on coral communities are predicted to occur in wet season."



Bioaccumulation of UV filters in fish

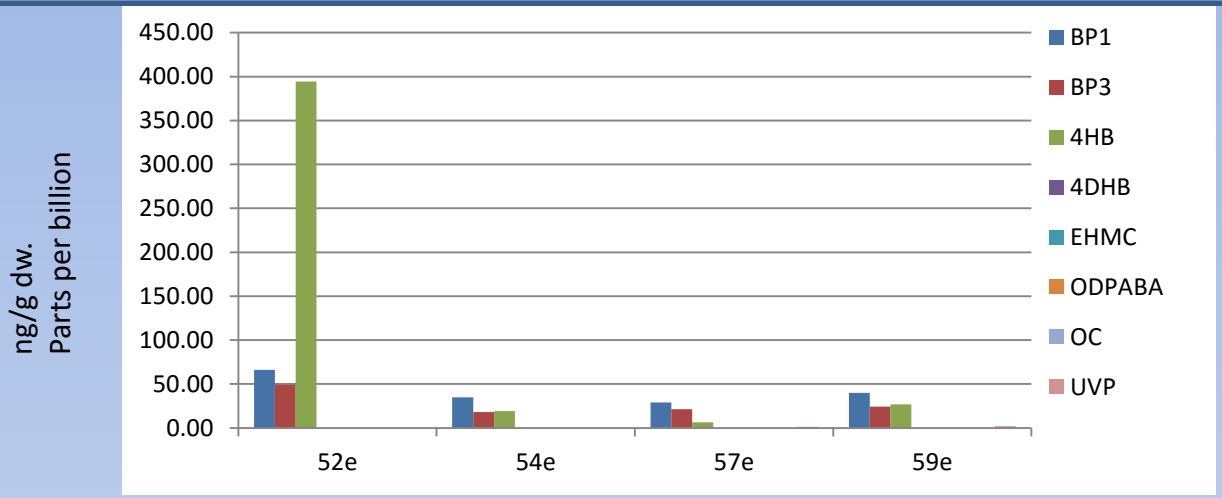
Muscle analysis



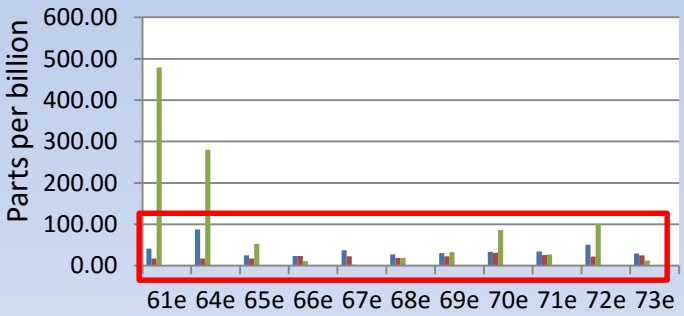
- BP3 = oxybenzone. BP1, 4HB, & 4DHB are metabolites of oxybenzone. OC = octocrylene; EHMC = methoxycinnamate

  → **This is the edible part of the fish**

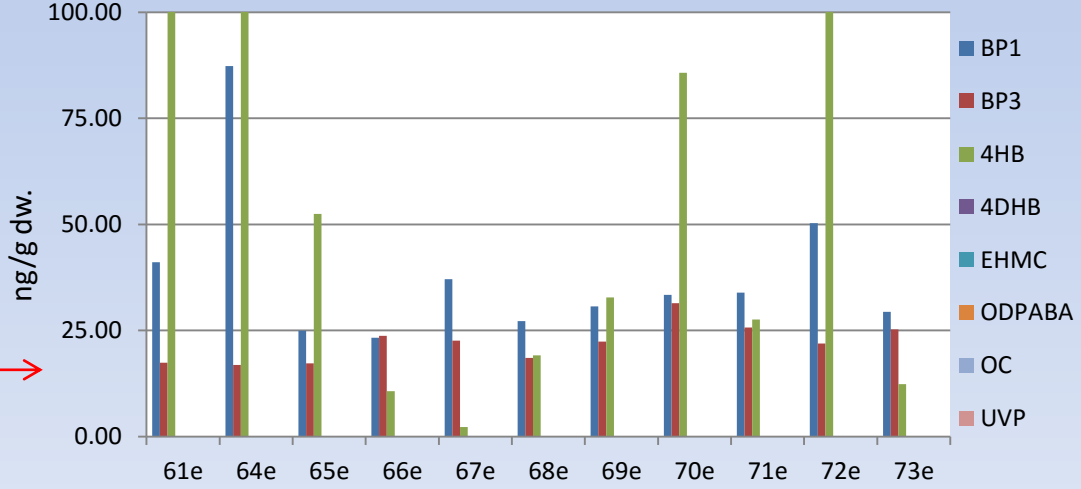
UV Filters in eggs of birds from a preserved natural area



Gelochelidon nilotica



Anas strepera



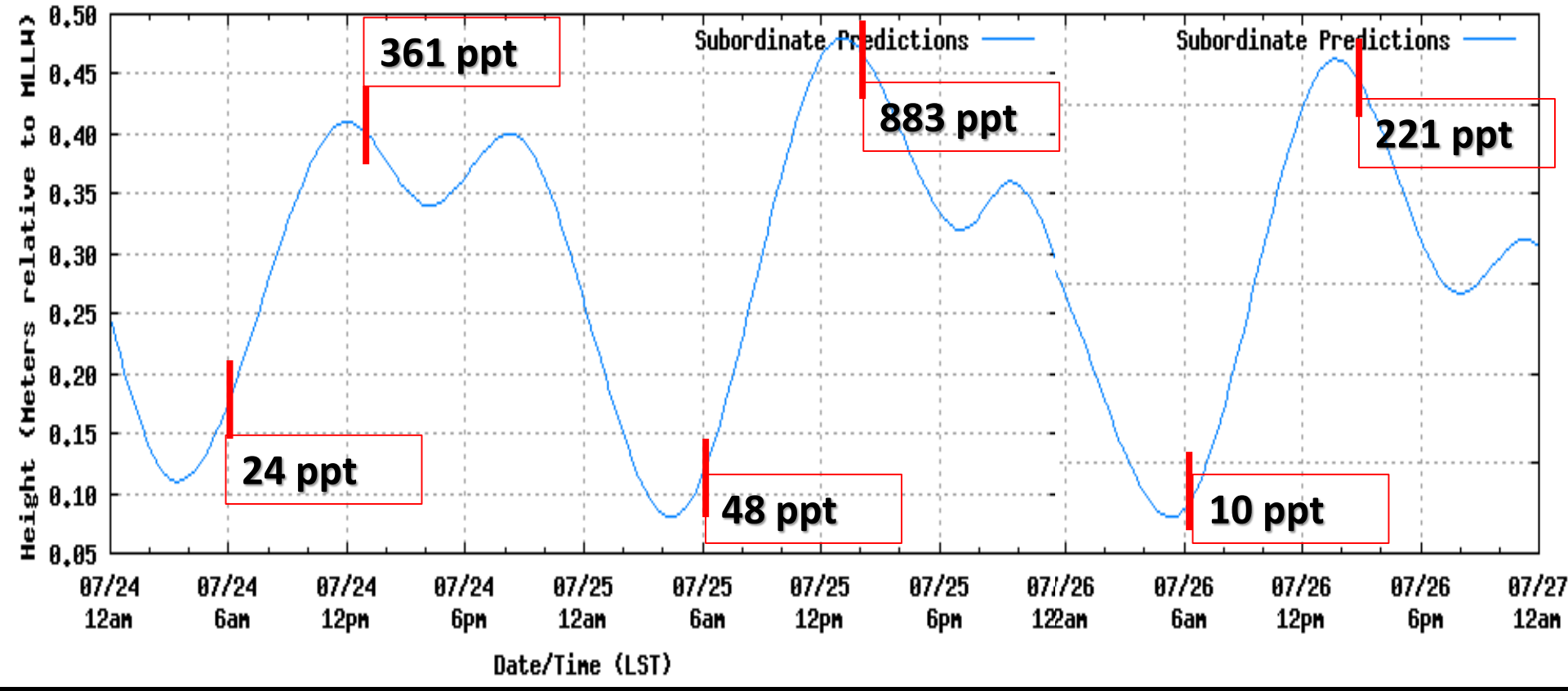
D. Molins-Delgado and M.S. Díaz-Cruz, In press, 2018.

How far does aerosol sunscreen mist carry?

Kapalua Bay

Kapalua Bay

(Maui, Hawaii)



Tidal fluctuations of Oxybenzone Concentration

Correlation = 0.7698, p = 0.0034

Is Oxybenzone Found in Beach Sand?

Yes!

Napili Bay = 478 ng/kg Oxybenzone

Kapalua Bay = 1,004 ng/kg Oxybenzone

Sea Turtle Nests?

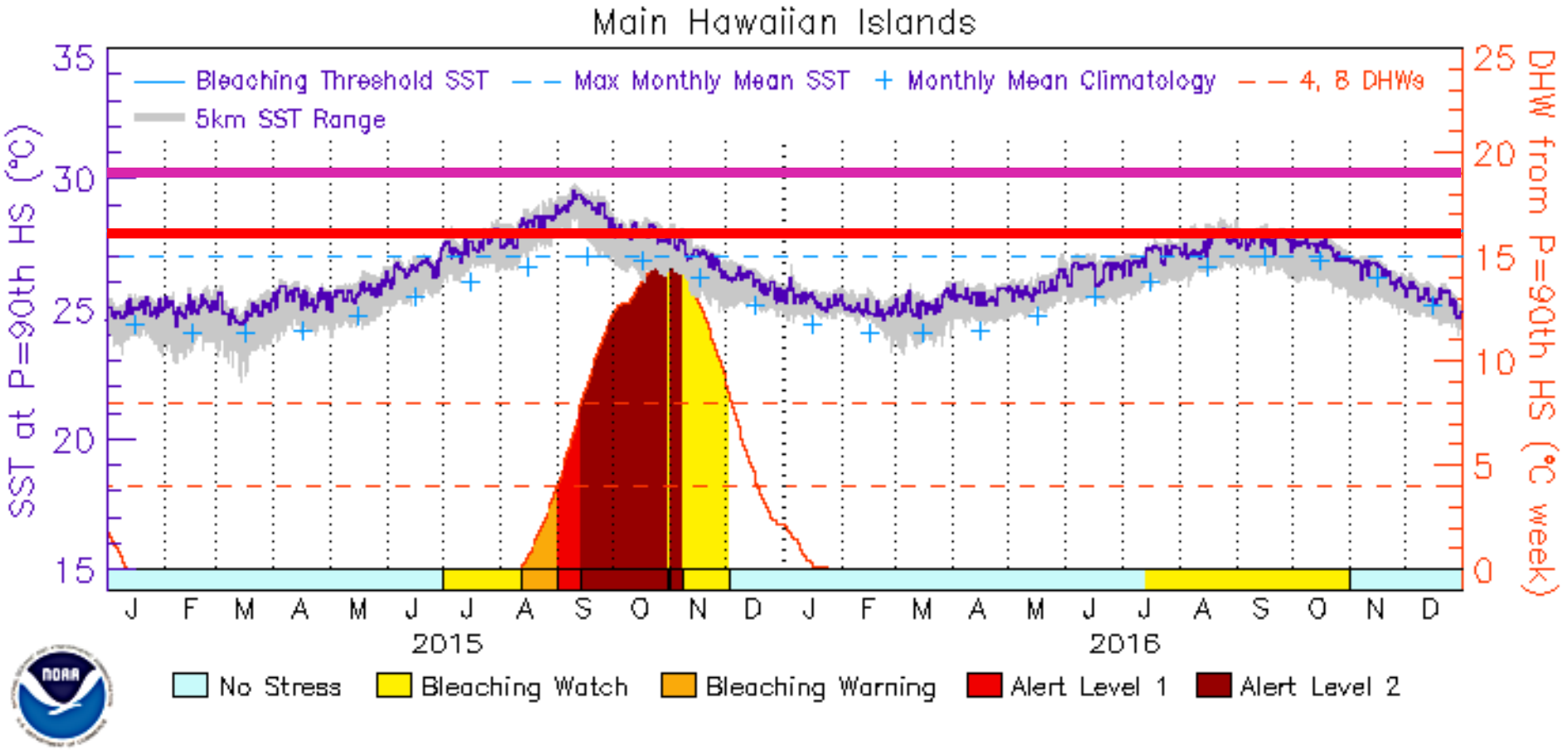
Is OXYBENZONE & OCTINOXATE TOXIC to Coral Reefs?

NOAA Bleaching Alert

NOAA's Definition of Bleaching Threshold:

When corals start to become stressed when the SST is 1°C warmer than the highest monthly mean temperature

Glynn & D'Croz, 1990. Experimental evidence for high temperature stress as the cause of El Niño coincident coral mortality. Coral Reefs, 8, 181-191.



Coral bleaching has been attributed to a variety of disturbances:

- high and low temperature,
- subaerial exposure,
- calm sea conditions,
- freshwater dilution,
- High and low turbidity,
- sedimentation,
- high and low light levels & UV radiation,
- parasite infections, and
- **pollutants**

(Brown 1987; Ogden and Wicklund 1988; Williams and Bunkley-Williams 1988; Coffroth et al., in press).

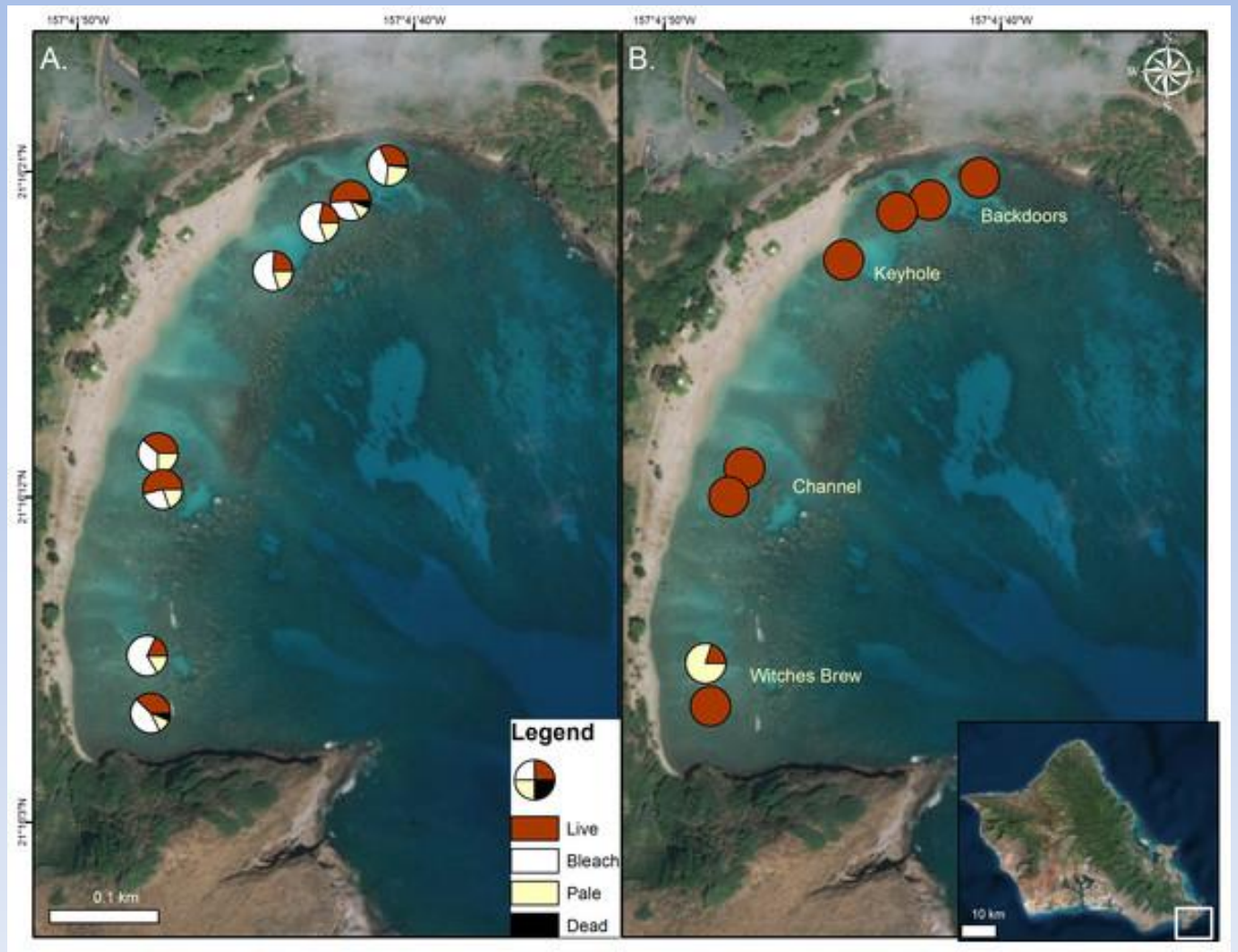
Hanauma Bay Nature Preserve

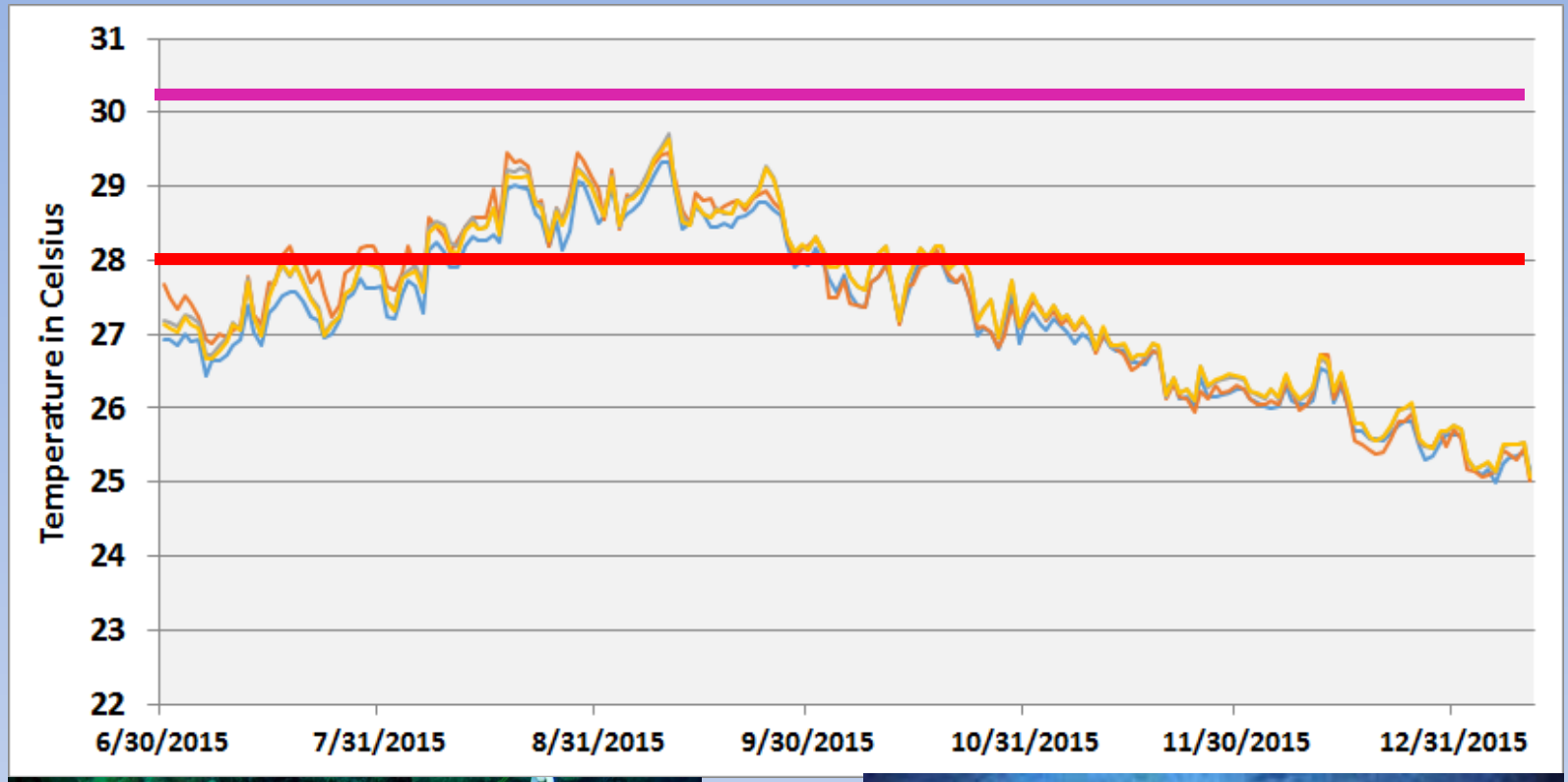
Courtesy of www.aloha-hawaii.com/oahu/beaches/hanauma-bay/

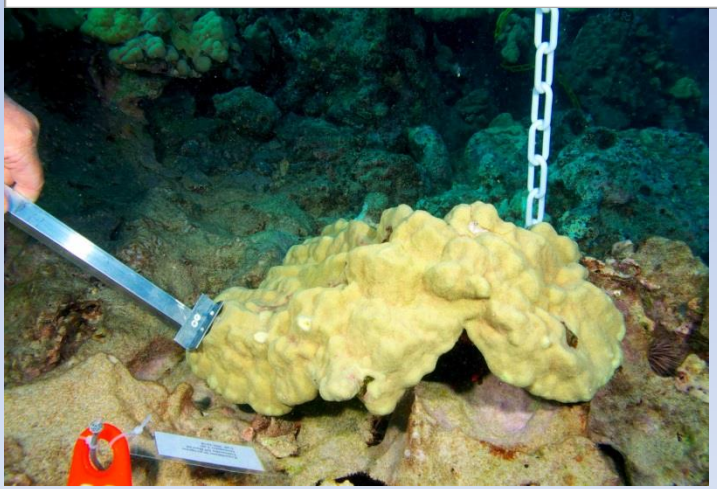
Factors that reduce coral homeostasis (resiliency) to heat stress events (e.g., El Niño event)

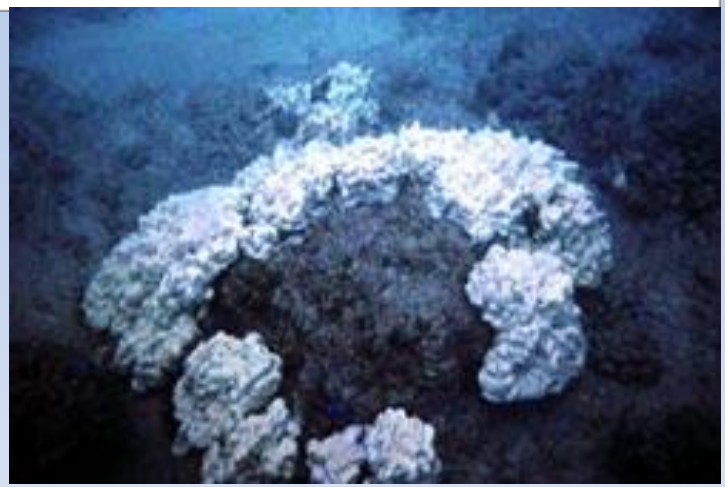
Hanauma Bay, Oahu, Hawaii

Coral Condition in October 2015 Coral Condition in January 2016









Rodgers KS, Bahr KD, Jokiel PL, Richards Donà A. (2017) Patterns of bleaching and mortality following widespread warming events in 2014 and 2015 at the Hanauma Bay Nature Preserve, Hawai'i. PeerJ 5:e3355 https://doi.org/10.7717/peerj.3355

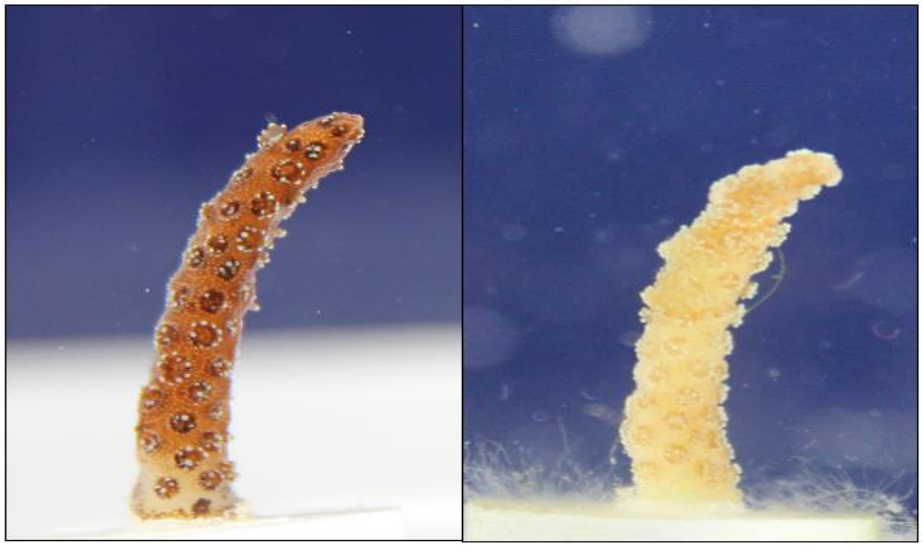
Honour Booth survey - > 1,500 pptrillion Oxybenzone

Hanauma Bay

(2015 averaged 2,600 swimmers/day)

= 187 kilograms of sunscreen lotion a day. 64-72 grams per person
= 5.61 kilograms of oxybenzone a day (3% oxybenzone or octinoxate).
= 168 kilograms of oxybenzone per month (~370 pounds per month)
= 68,255 kilograms of sunscreen product per year (150,476 lbs/year)
= 2,048 kilograms of oxybenzone per year (4,515 pounds /year)

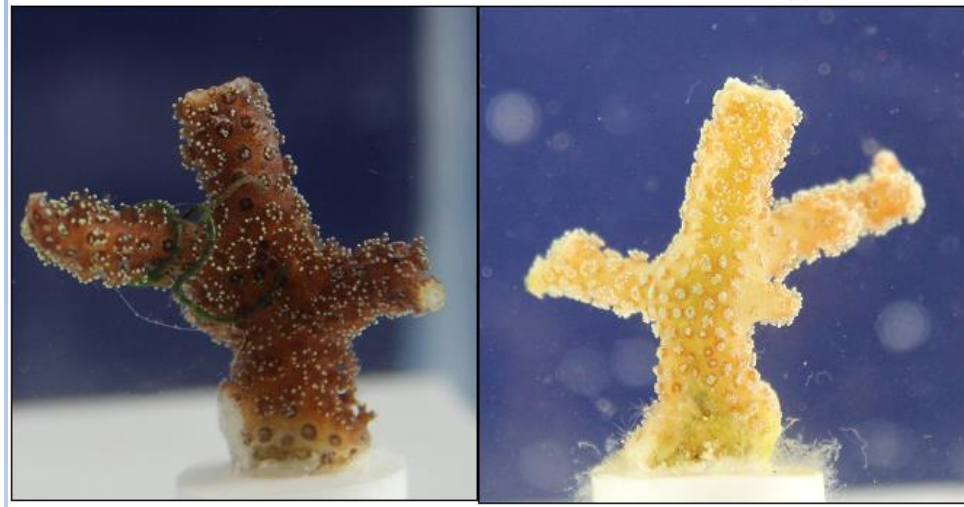
Octinoxate Induces Coral Bleaching



Control

1 part per billion
Octinoxate
14 days

Octinoxate Induces Coral Bleaching



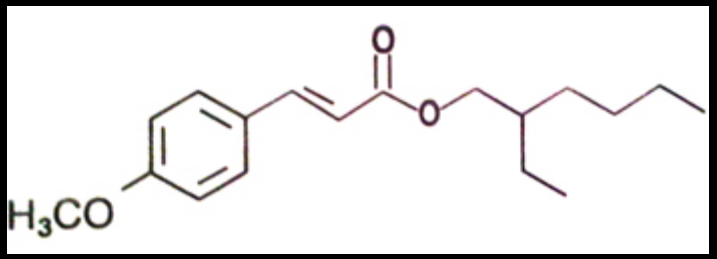
Time 0

500 parts per trillion
Octinoxate
14 days

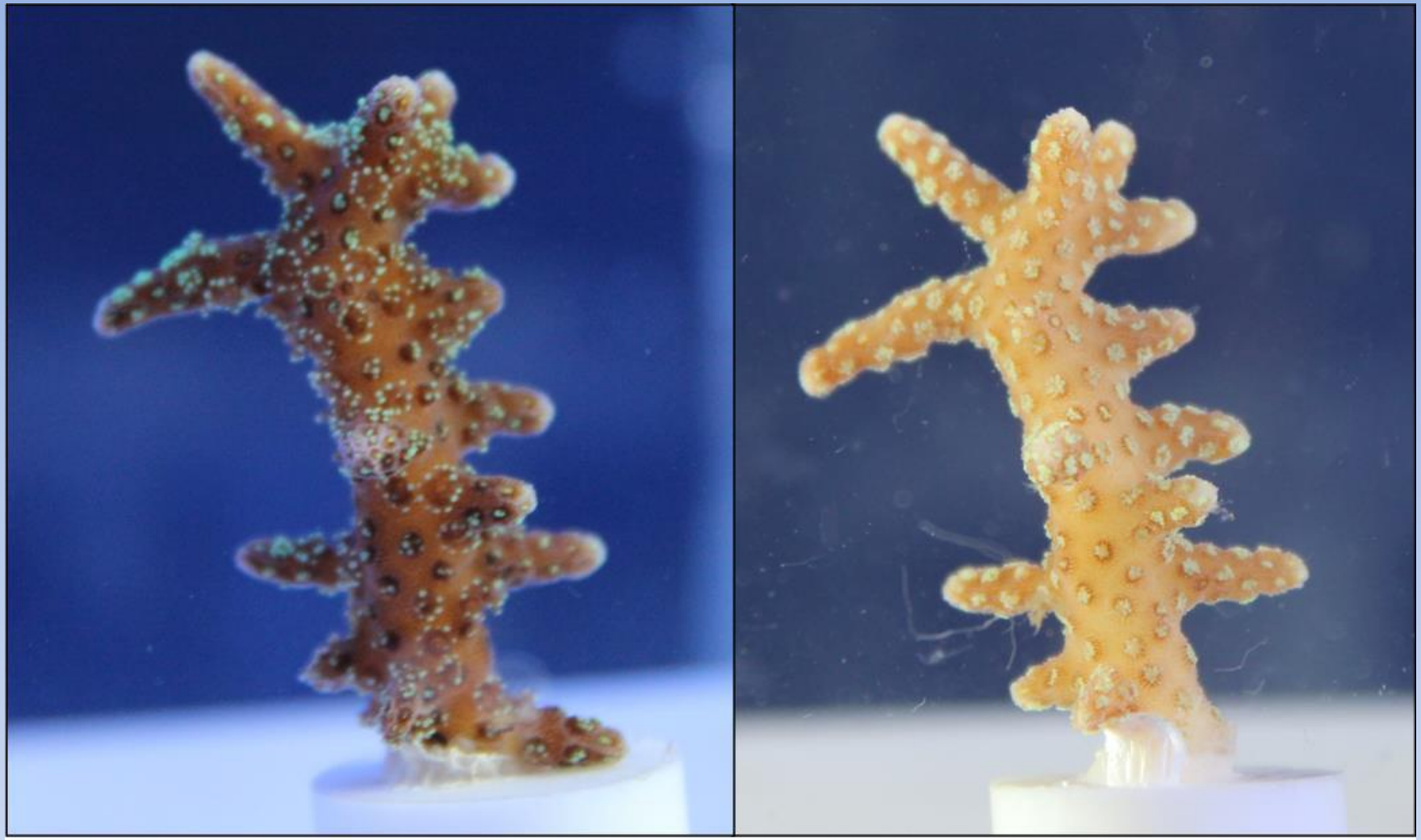
Octyl methoxycinnamate (octinoxate)

- Endocrine Disruptor
  - Reduced sperm count
  - Reduced gonad tissue
  - Reduced thyroid function
  - Reduced neurological function

Sunscreen chemical in sunscreen lotions



- Developmental Disruptor
- Sea urchin Embryo EC_{20} = 900-49,000 pptrillion
- Clown Fish Embryo EC_{20} = 223 ppTrillion



Time 0

500 pptrillion
Oxybenzone
14 days

L'Oreal & Monaco Marine Science Center
Tested whether Oxybenzone induced Coral Bleaching

PREDICTIVE LABORATORY METHODOLOGY TO ASSESS CORAL BLEACHING / APPLICATION TO UV FILTERS

Jean-Pierre-Fel[1], Éric Béraud[2], Alaa Bensetra[1], Catherine Lacherez[1], Sakina Mezzache[1], Marc Léonard, Denis Allemand[2], Christine Ferrier-Pages[2].

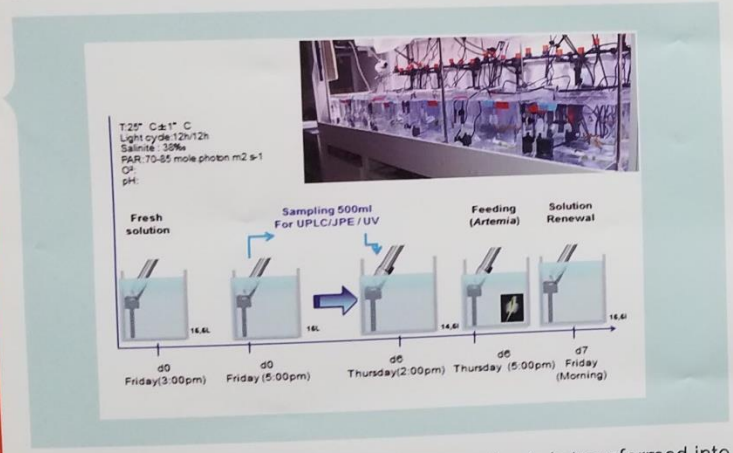
[1] L'Oréal Research & Innovation, Aulnay-sous-Bois, France

[2] Centre Scientifique de Monaco, Marine Biology Department, Principauté de Mo

Contact: jpfel@rd.loreal.com Phone number: +33 1 48 68 89 20

MATERIAL AND METHODS

Coral nubbins of Stylophora pistillata were exposed for 5 weeks at low concentrations of UV filters and herbicides in 15 liters aquaria, using closed-circuit system with weekly seawater renewal. PSII photosynthetic efficiency of the symbiotic micro-algae was monitored using PAM (Pulse Amplitude Modulation), to predict sublethal endpoint of coral bleaching. A specific analytical methodology was developed, combining automated solid phase extraction with UPLC-UV detection, to monitor the UV filter concentrations in seawater and analyze large number of samples

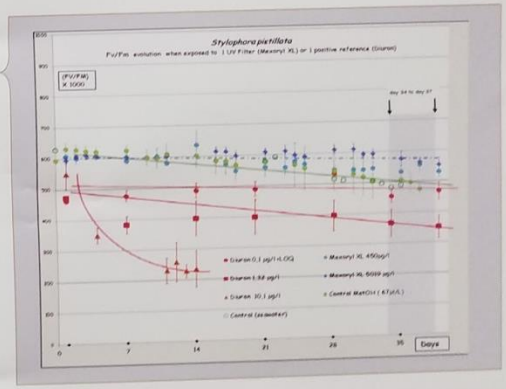


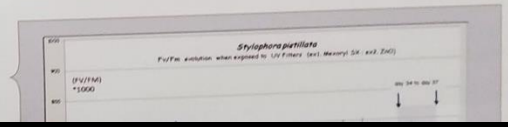
Light absorbed during the process of photosynthesis is transformed into

MEASURE OF THE PHOTOSYNTHETIC EFFICIENCY

Monitoring PAM

Bionef





Yes, OXYBENZONE induced Coral Bleaching

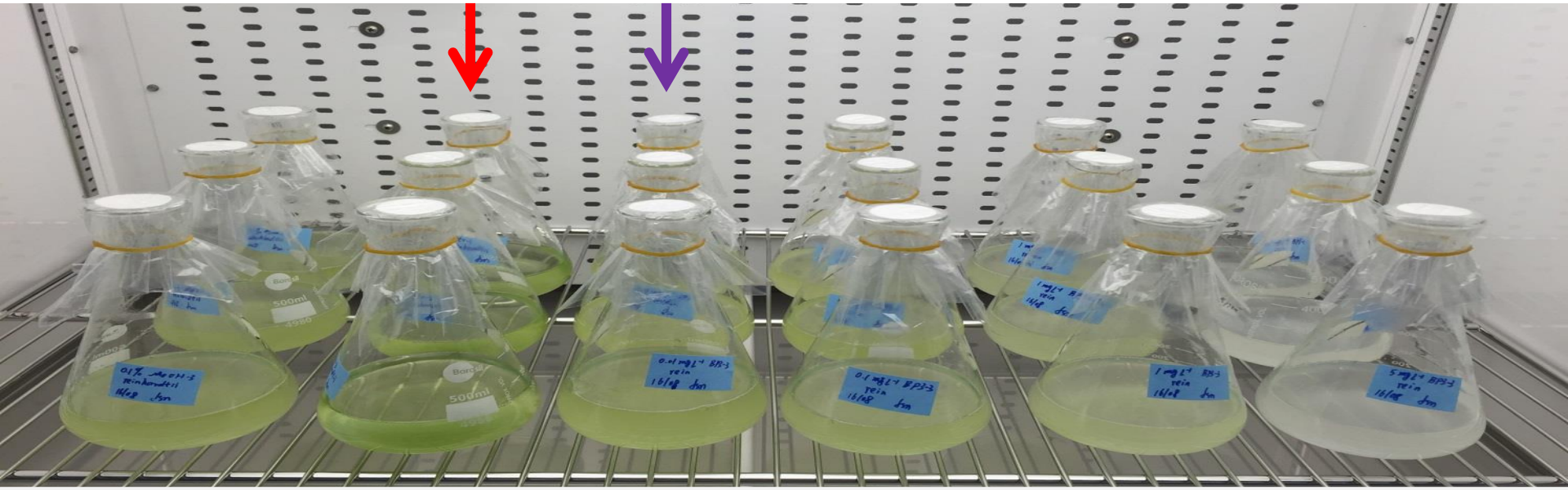
Contents lists available at ScienceDirect

Aquatic Toxicology

journal homepage: www.elsevier.com/locate/aqtox

Effects of benzophenone-3 on the green alga *Chlamydomonas reinhardtii* and the cyanobacterium *Microcystis aeruginosa*

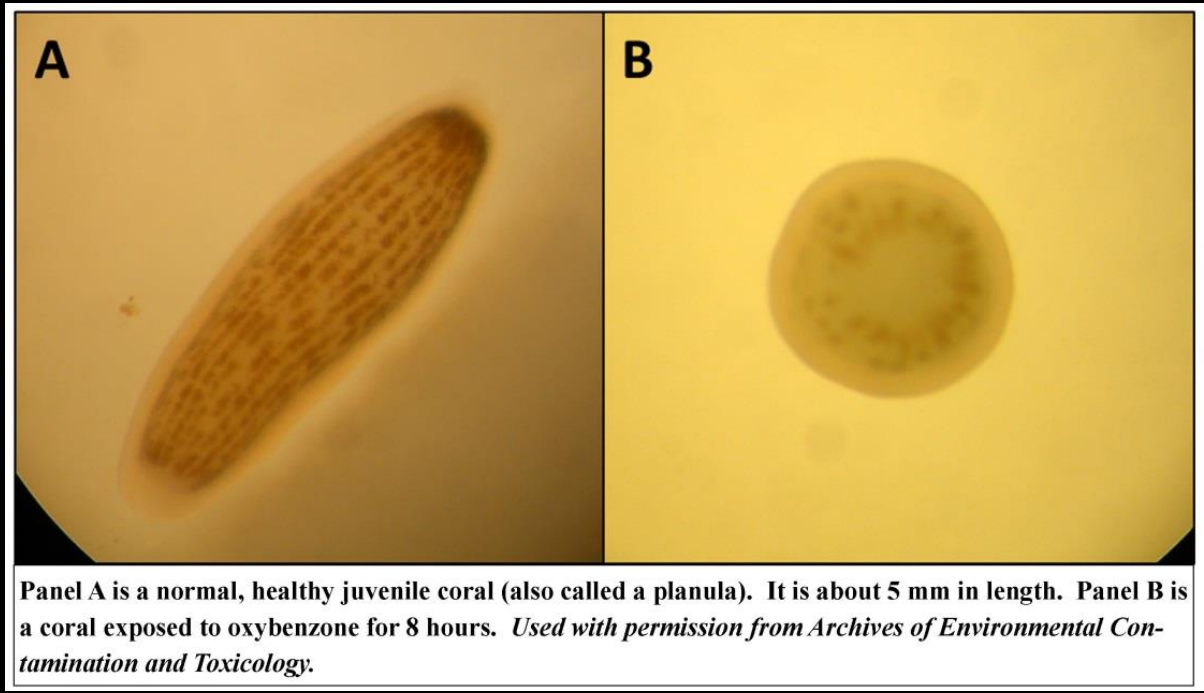
Feijian Mao[a], Yiliang He[b], Ariel Kushmaro[c], Karina Yew-Hoong Gin[a,d,*]



Control 0.01 0.1 100 1000 5000

parts per billion Oxybenzone

Coral Reef Ecotoxicology of Oxybenzone



Panel A is a normal, healthy juvenile coral (also called a planula). It is about 5 mm in length. Panel B is a coral exposed to oxybenzone for 8 hours. *Used with permission from Archives of Environmental Contamination and Toxicology.*

- DNA Damage 8h EC_{20} = 129 ppTrillion
- Bleaching 8h EC_{20} = 695 ppTrillion
- Skeletal Endocrine Disruption

Coral Planula LOEC = 62 parts per trillion

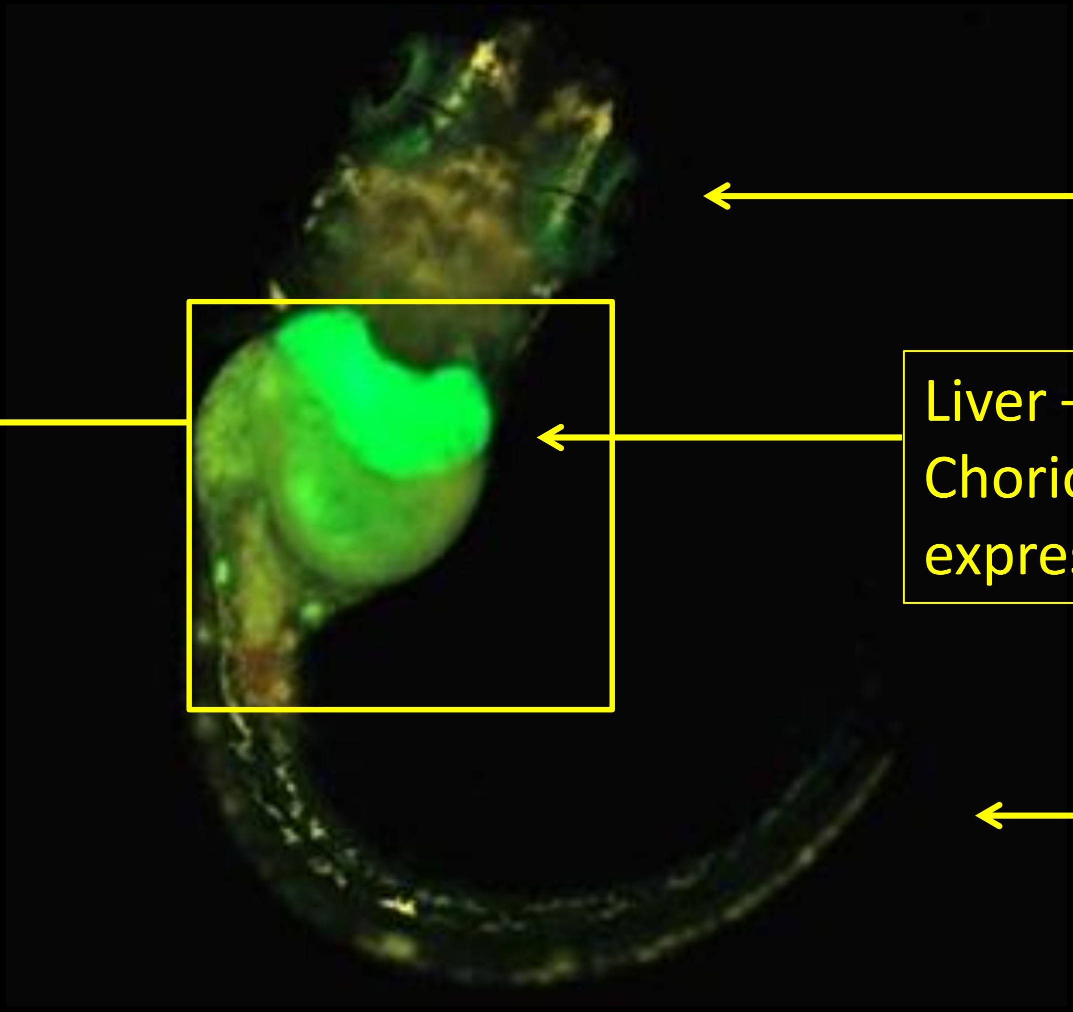
Clownfish (*Amphiprion ocellaris*)

Fish Embryo Acute Toxicity Test

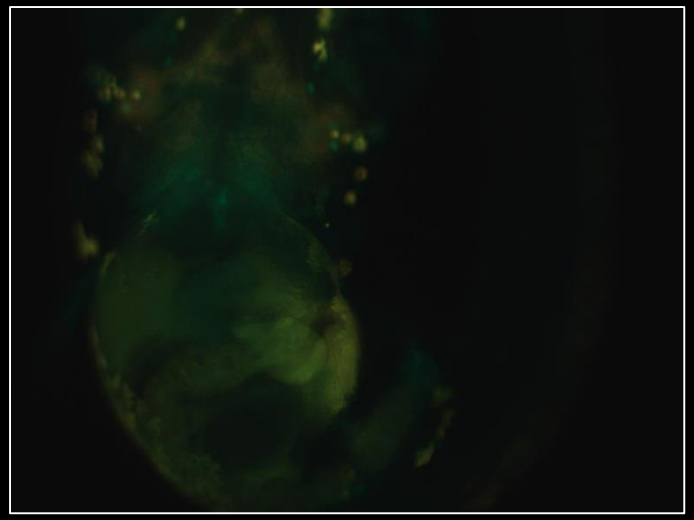
Control
48-hr exposure

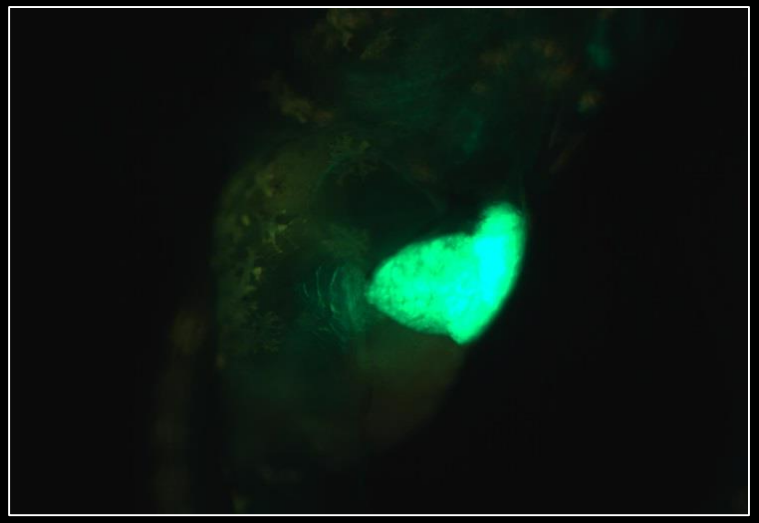
1 ppbillion oxybenzone
48-hr exposure

Genetically Modified Medaka
Estrogen Endocrine Axis Disruption
Inappropriate induction of choriogenin (egg protein)



Control ➡





Benzophenone - 1

Oxybenzone
(Benzophenone-3)

Ecotoxicology (2016) 25:302–309
DOI 10.1007/s10646-015-1588-4

UV-filter benzophenone-3 inhibits agonistic behavior in male Siamese fighting fish (*Betta splendens*)

Te-Hao Chen[1,2] · Yea-Ting Wu[2] · Wang-Hsien Ding[3]

2,500 pptrillion Oxybenzone

Equivalent to estrogen

Sequential Hermaphroditism

- Males turn into Females
- No Males

- Clown Fish
- Wrasses
- Moray Eels
- Gobies
- Parrot Fish

Hydrobiologia
DOI 10.1007/s10750-016-2746-2

PRIMARY RESEARCH PAPER

Direct and indirect effects of sunscreen exposure for reef biota

Shaun M. McCoshum · Alicia M. Schlarb · Kristen A. Baum

Reduces Polyp Formation

Suppresses population growth

Oxybenzone & Octinoxate are toxic to Shrimp/Crab, Bivalves and Sea Urchin Embryos!

SCIENTIFIC REPORTS

OPEN

Sunscreen products impair the early developmental stages of the sea urchin *Paracentrotus lividus*

6 March 2017
6 July 2017

Cinzia Corinaldesi[1], Elisabetta Damiani[2], Francesca Marcellini[2,3], Carla Falugi[2], Luca Tiano[2], Francesca Brugè[4] & Roberto Danovaro[2,5]

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Ecotoxicological evaluation of four UV filters using marine organisms from different trophic levels *Isochrysis galbana*, *Mytilus galloprovincialis*, *Paracentrotus lividus*, and *Siriella armata*


"Sunscreen Footprints of Death"
Koko Kai Beach Park
Honolulu, Hawaii
Courtey of Malina Fagan

IS THIS POLLUTION A THREAT?

Old U.S. EPA Method

- **Oxybenzone in AHIHI**
  HQ = 28, YES
- **Honolua Bay in Hawaii**
  HQ = 0.1, NO

Ecological Risk Assessment

- **Oxybenzone in AHIHI**
  RA = 114, Yes
- **Honolua Bay in Hawaii**
  RA = 21, YES

Used EC_{50} 24-h deformity at 20% PAR
17 ppbillion

https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/technical-overview-ecological-risk-assessment-risk

What is the impact of OXYBENZONE to coral reefs?

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
Hollings Marine Laboratory
331 Fort Johnson Road
Charleston, South Carolina 29412

April 24, 2017

Senator Will Espero
Senate District 19
Hawaii State Capitol
Room 226
415 S. Beretania St
Honolulu, HI 96813

Dear Senator Espero:

"While additional research may incrementally add to our understanding of its impacts to additional coral reef species, additional research on the impacts of oxybenzone should not be a prerequisite to management action."

Dr. Cheryl Woodley
U.S. NOAA

Cheryl M. Woodley, PhD
Coral Health & Disease Program and
Coral Disease & Health Consortium

Ua Mau ke Ea o ka 'Aina I ka Pono

Oxybenzone and Octinoxate pose a significant threat to the sustainability of Maui's Coral Reefs

There MUST be a REDUCTION in Pollution

- Legislative County-Wide restriction-of-sales of products
- Legislative restriction-of-use in County Recreation areas
- Public Education, Multi-Industry Engagement


Reef Friendly: Sunscreen Criteria
ALL good
+
Reef Friendly
NO Chemical Sunscreens
Oxybenzone, Octinoxate, Octocrylene, PABA, Enzacamene, Octisalate, Homosalate, and Avobenzone - the Ugly Eight!
OCEAN Potion
PROTECT & NOURISH
FORTIFIED WITH VITAMIN D3
KIDS
OXYBENZONE FREE
Tropic
Sheer Touch
Lotion Sunscreen
"IF WE BAN OXYBENZONE THERE WILL BE NO OPTIONS"
Goddess Garden Sunscreen:
REEF SAFE AND BIODEGRADABLE
NO
or Ad
Parabens,
"You are only as GOOD as your Regulations!"
-Oil Industry Historian
CORAL SAFE
YES to 3rd Party Testing
Don't take our word for it - or theirs - make sure the sunscreen is 3rd party tested!
Join the campaign to promote Reef Friendly!
allgoodproducts.com/reeffriendly
#ReefFriendly
ALL good
Protect Where You Play
SURFRIDER FOUNDATION
NON-NANO
Sunscreen
Oxybenzone-Free
Sunscreens
Tested – Non-Harmful to Coral Reef and Fish

Oxybenzone & Octinoxate Sunscreen Pollution and the Threat to Maui's Coral Reefs

MAHALO!

Craig A. Downs, PhD.
Executive Director
Haereticus Environmental Laboratory