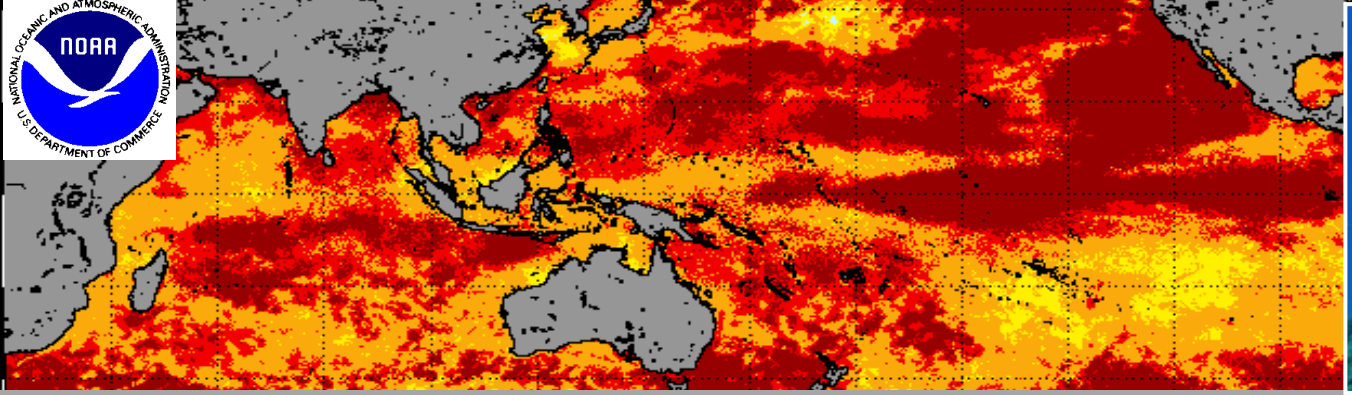


The 2014-17 Global Coral Bleaching Event and Coral Bleaching in the Anthropocene

Dr. C. Mark Eakin

W.J. Skirving, S.F. Heron, G. Liu, T.P. Hughes,
S.Donner, E.F. Geiger, J.L. De La Cour,
A.M. Gomez, B.L. Marsh, and D. Devotta

NOAA Coral Reef Watch
https://coralreefwatch.noaa.gov

The Washington Post

Energy and Environment

Scientists say a dramatic worldwide coral bleaching event is now underway

Key Messages:

- Rising temperatures are causing bleaching, disease, and death of corals
- 2014-17 was the worst bleaching ever
- Climate change is increasing bleaching frequency and intensity and will get worse

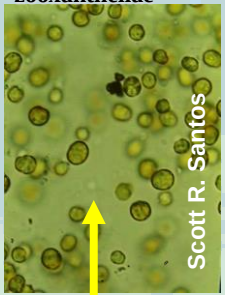
- 3 actions needed:
  - Reduce CO_2
  - Reduce Local Stress
  - Radical Conservation

- There is hope, but we need to act now

What is Coral Bleaching?

- Most of corals' food comes from photosynthesis

zooxanthellae

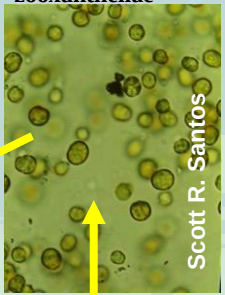


Symbiotic algae

What is Coral Bleaching?

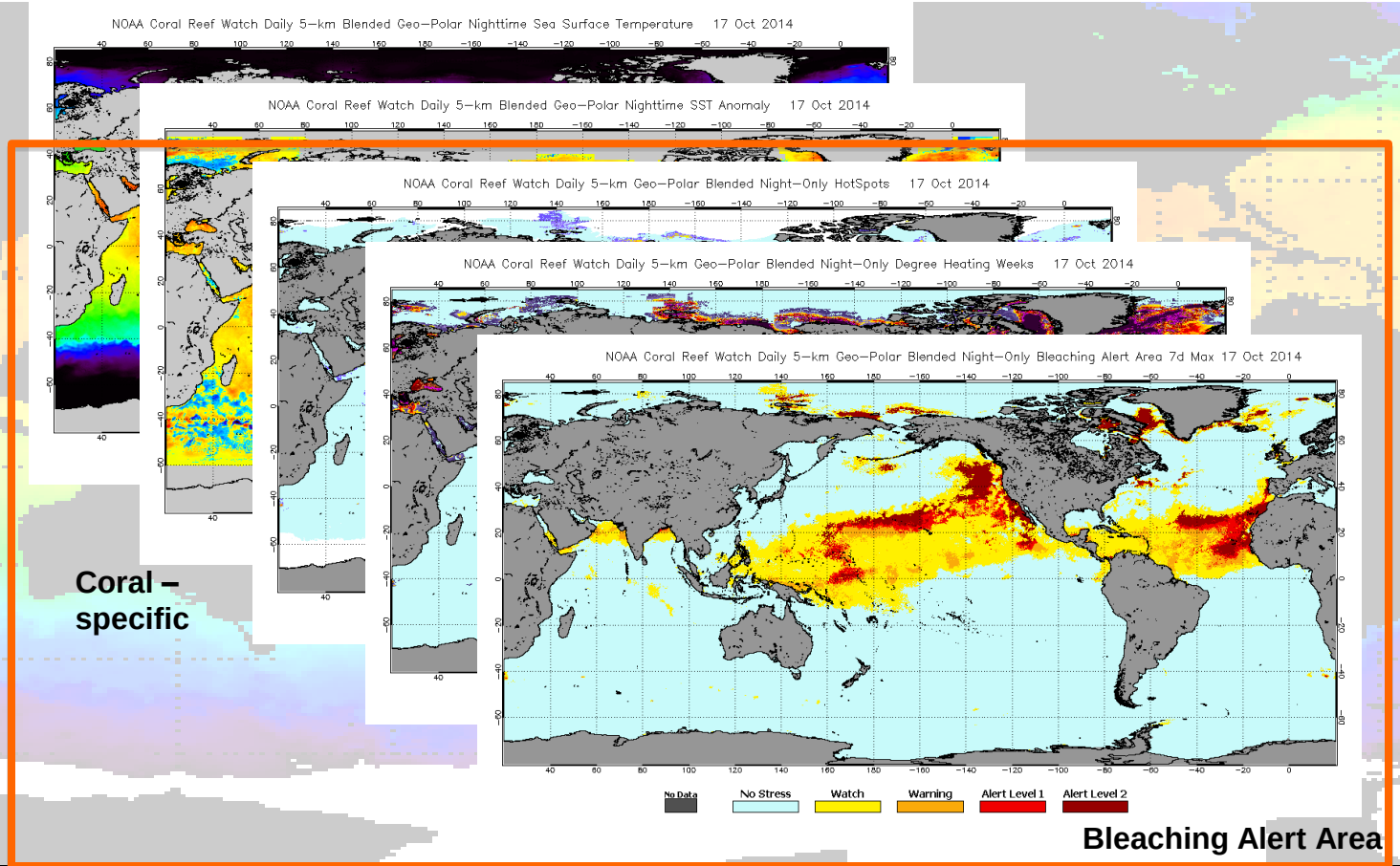
- Most of corals' food comes from photosynthesis
- Corals can "bleach" due to stress
- Corals exposed to high temperatures and/or high light become stressed
- Corals eject their algae; coral appears "bleached"
- If stress is mild or brief, corals recover, otherwise they die

zooxanthellae

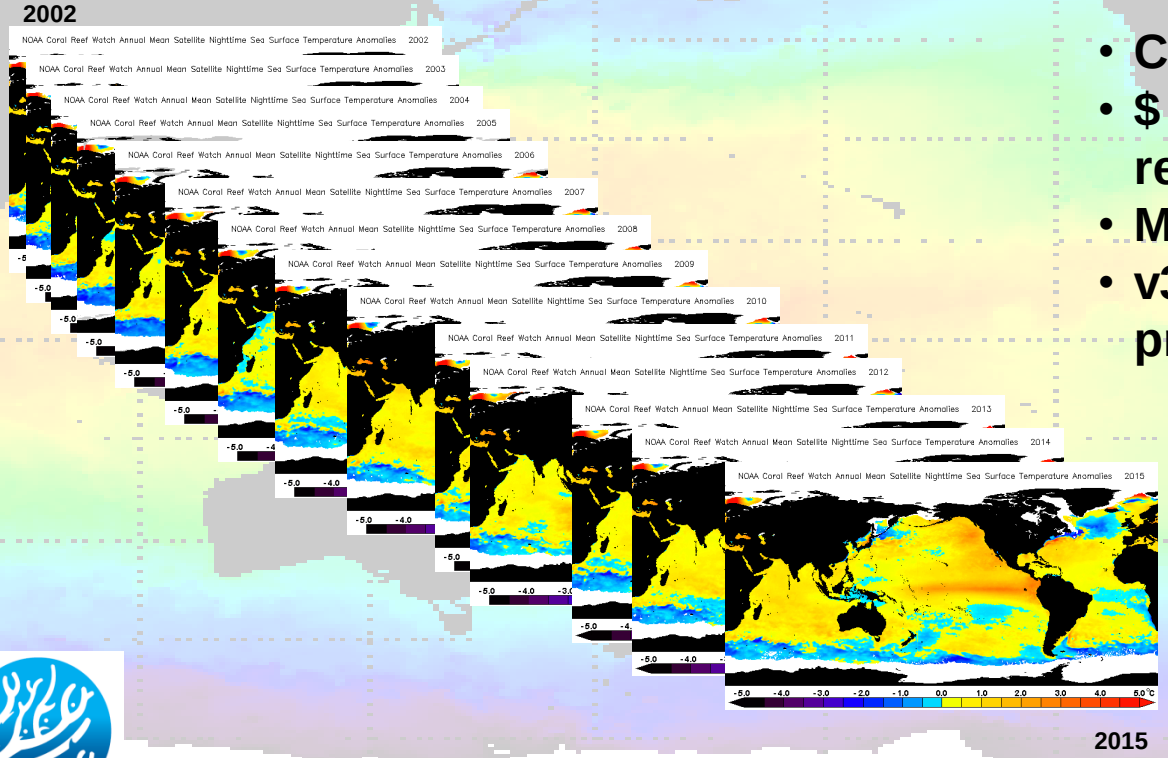


Symbiotic algae

Coral Reef Watch
5-km Satellite-Based Products



5 km CoralTemp Dataset (v3.1)

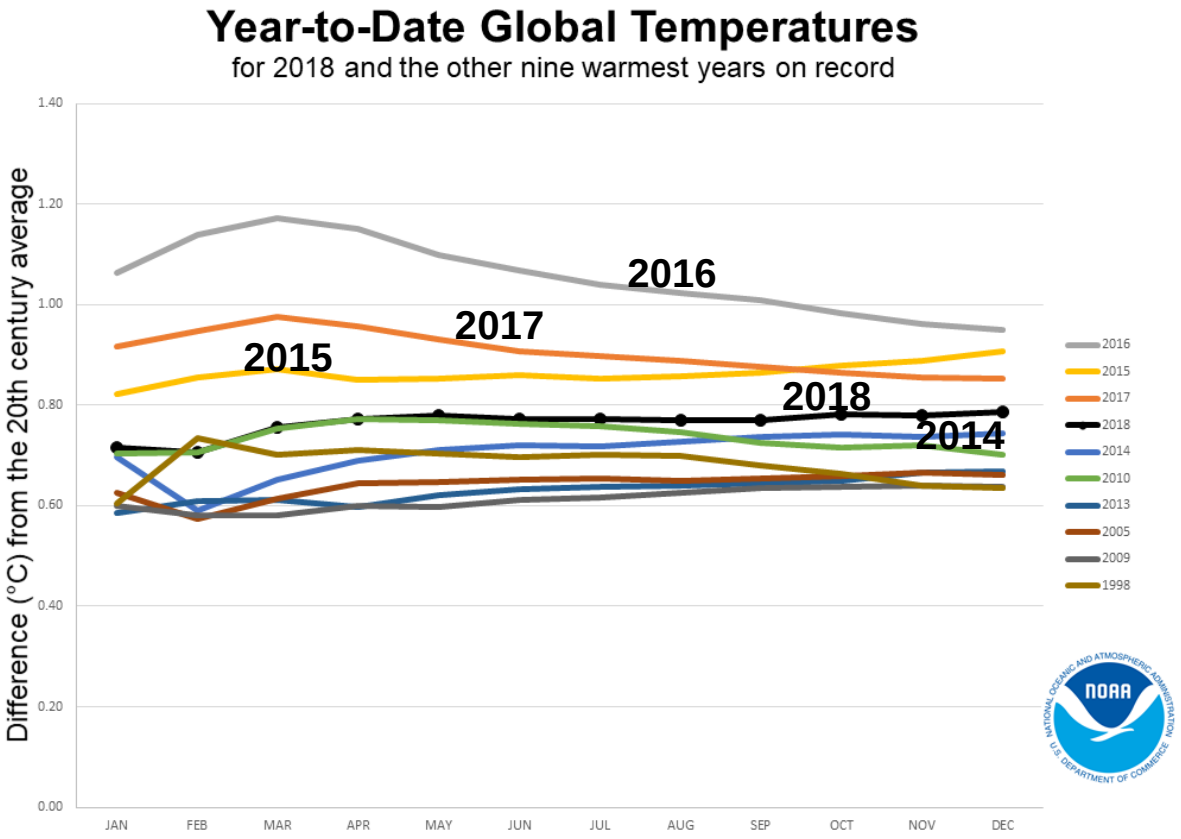


- Consistent dataset 2002-2015
- $ Multi-million NESDIS reprocessing effort
- Merged with OSTIA 1985-2002
- v3.1 CoralTemp and CRW products
  - Data online
  - Products coming soon

http://coralreefwatch.noaa.gov

“Warming of the climate system is unequivocal”

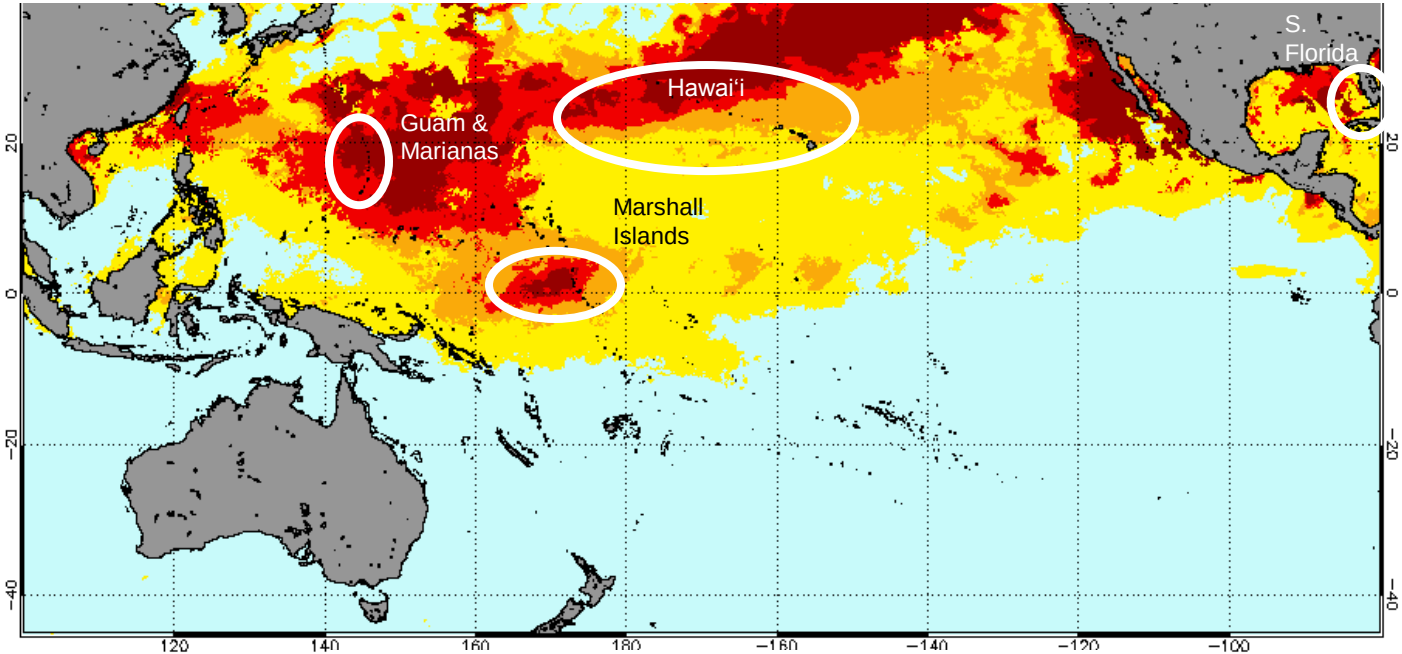
– IPCC AR5, 2014



https://www.ncdc.noaa.gov/sotc/global/201813/supplemental/page-1

Global Bleaching: Last Half of 2014

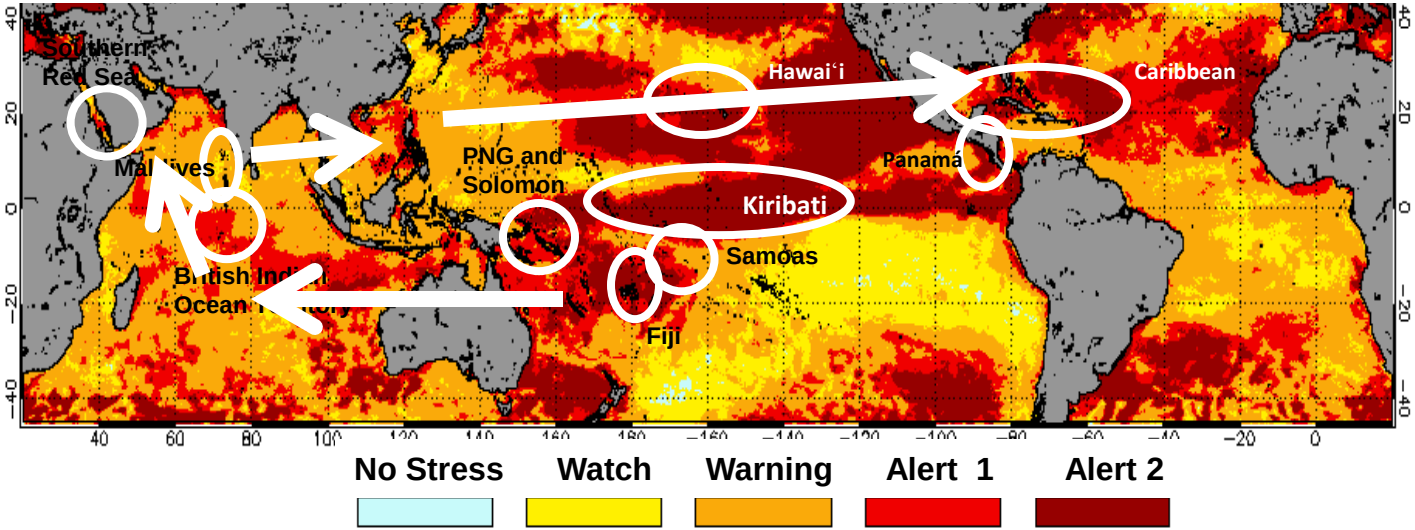
NOAA Coral Reef Watch Satellite Coral Bleaching Alert Area
15 September 2014



No Stress | Watch | Warning | Alert 1 | Alert 2

Global Bleaching: 2015

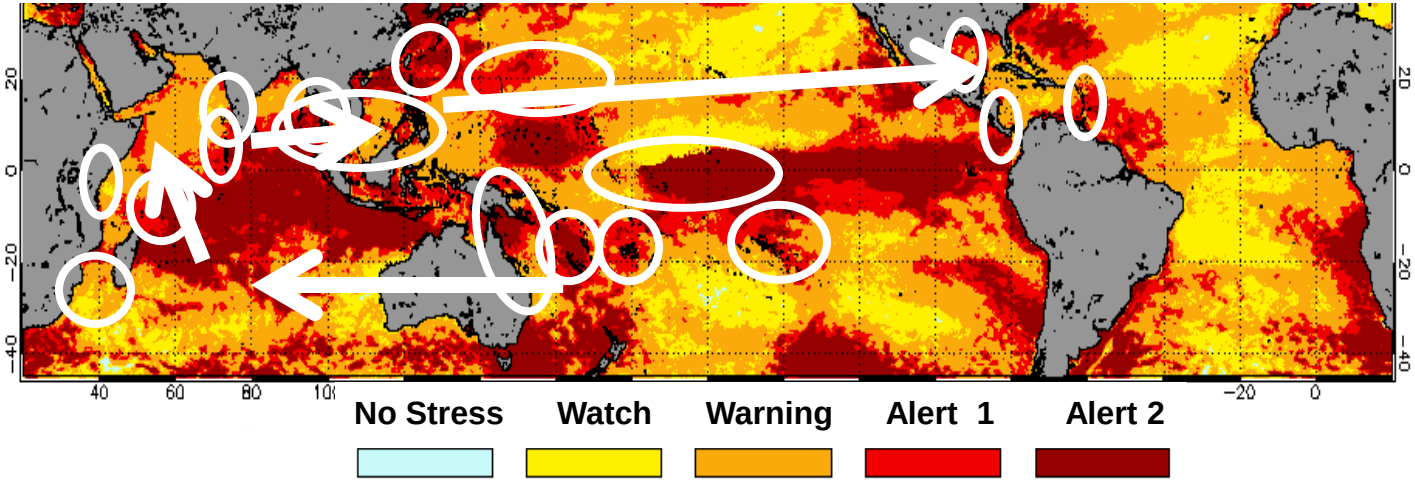
NOAA Coral Reef Watch Annual Maximum Satellite Coral Bleaching Alert Area 2015



http://coralreefwatch.noaa.gov

Global Bleaching: 2016

NOAA Coral Reef Watch Maximum Satellite Coral Bleaching Alert Area 2016



Western India
Seychelles
Kenya/Tanzania
Mozambique
Madagascar

Taiwan
Maldives
Mauritius
Maldives

Vietnam
Philippines
Réunion

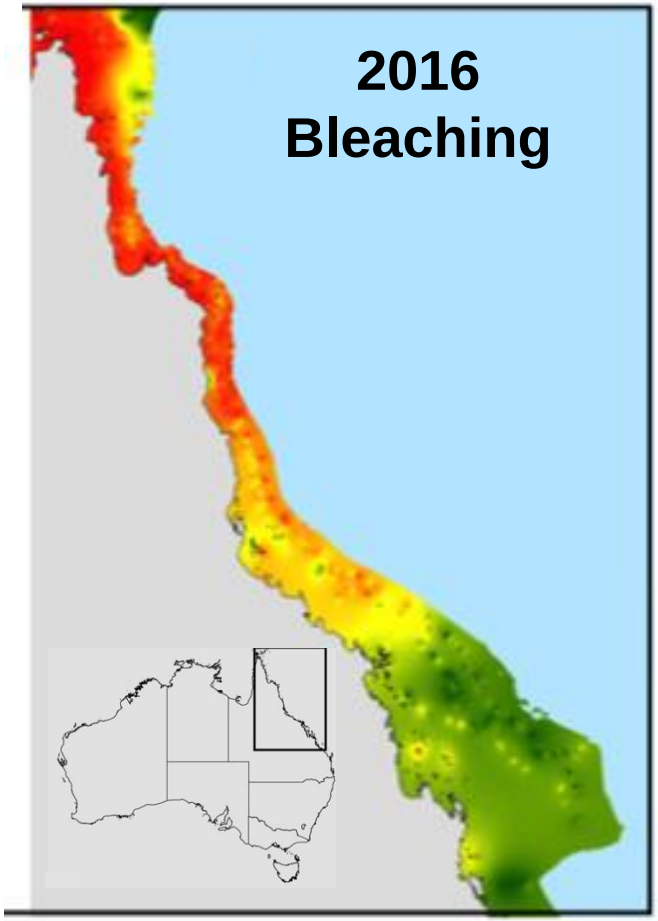
Marianas
New Caledonia
Thailand
Indonesia
Japan
E. Australia

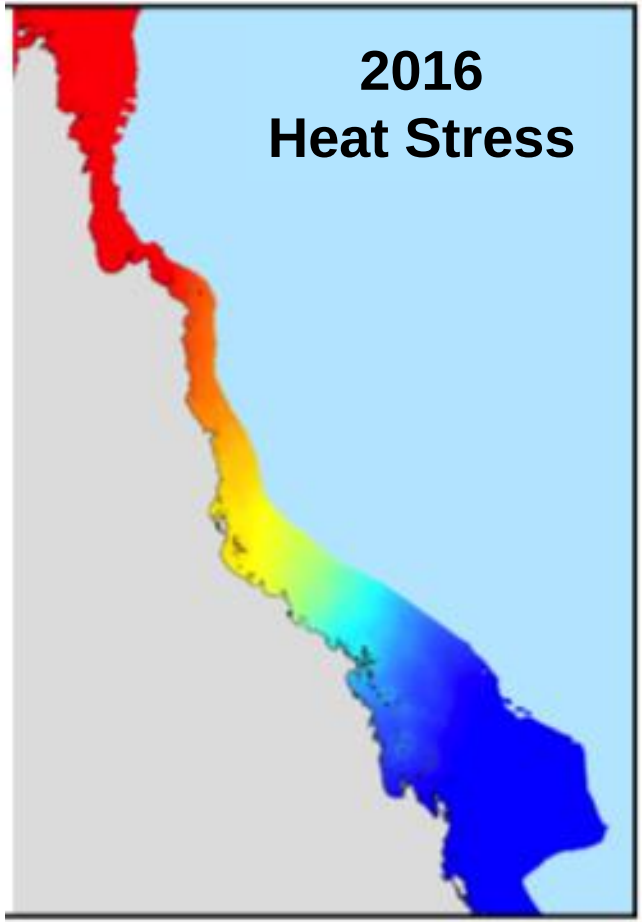
Kiribati
Palau
Fiji
Micronesia
Marshall Is.

French Polynesia

Flower Gardens
Yucatan
Saba
Belize

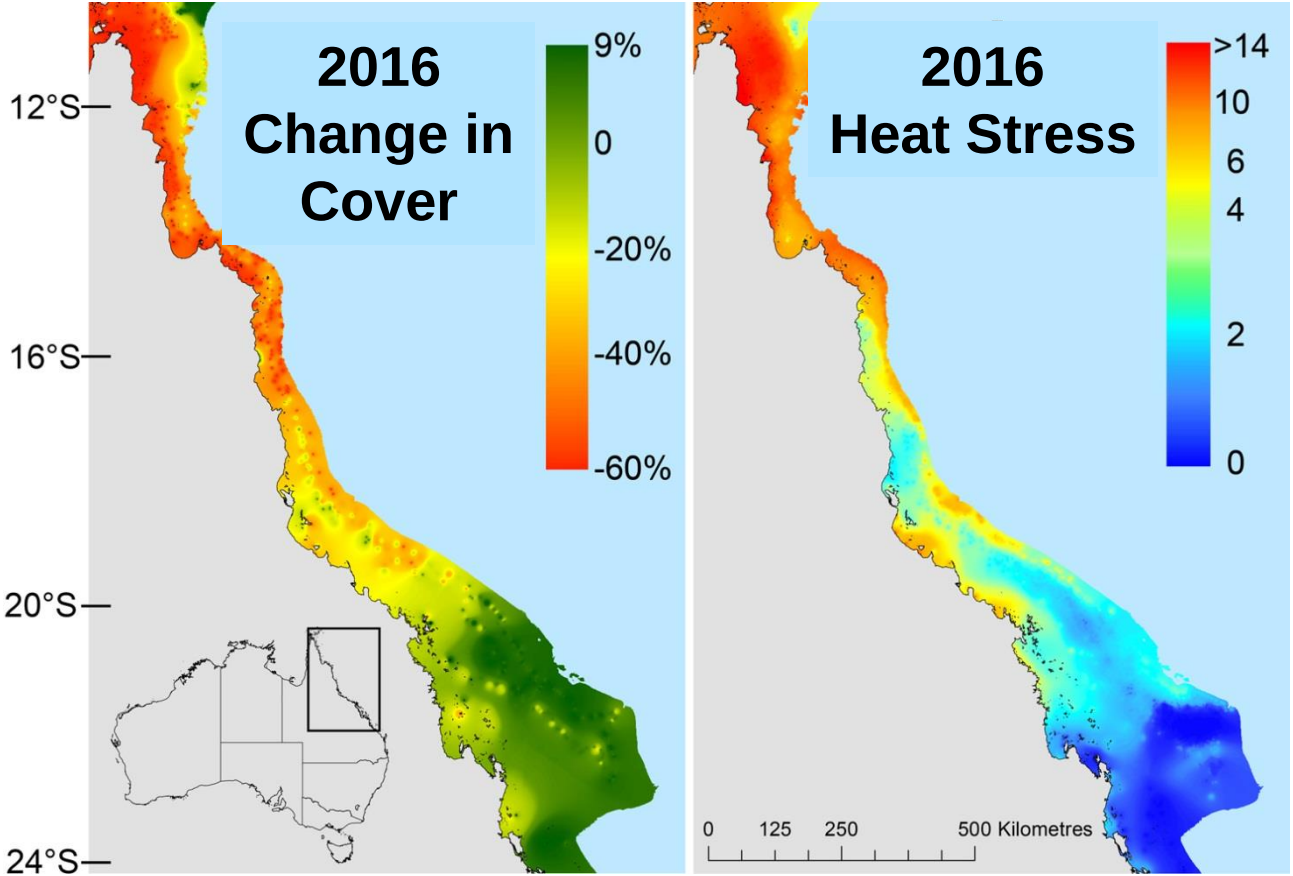
Great Barrier Reef Bleaching: 2016





Hughes et al. (2017) Global warming and recurrent mass bleaching of corals **Nature** 543, 373–377

Great Barrier Reef Mortality: 2016



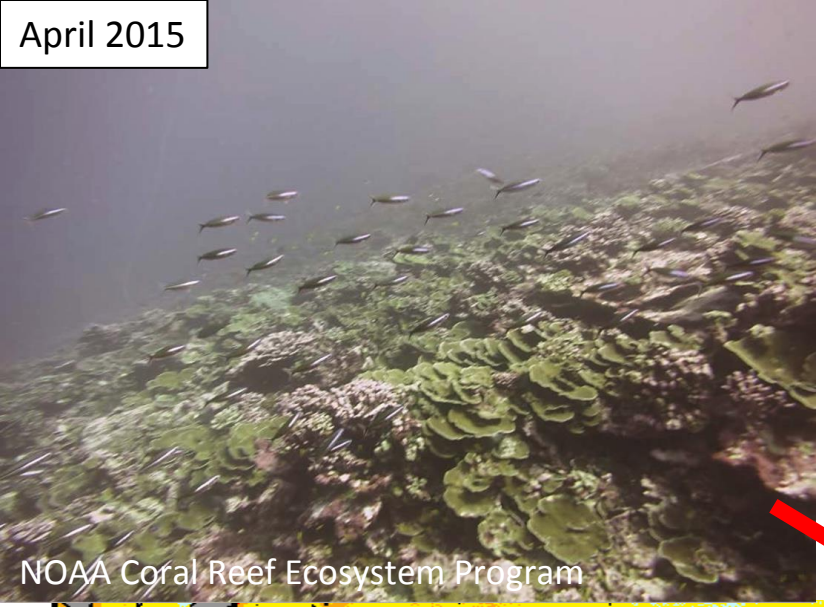
Hughes et al. (2018) Global warming transforms coral reef assemblages. **Nature** 556: 492–496

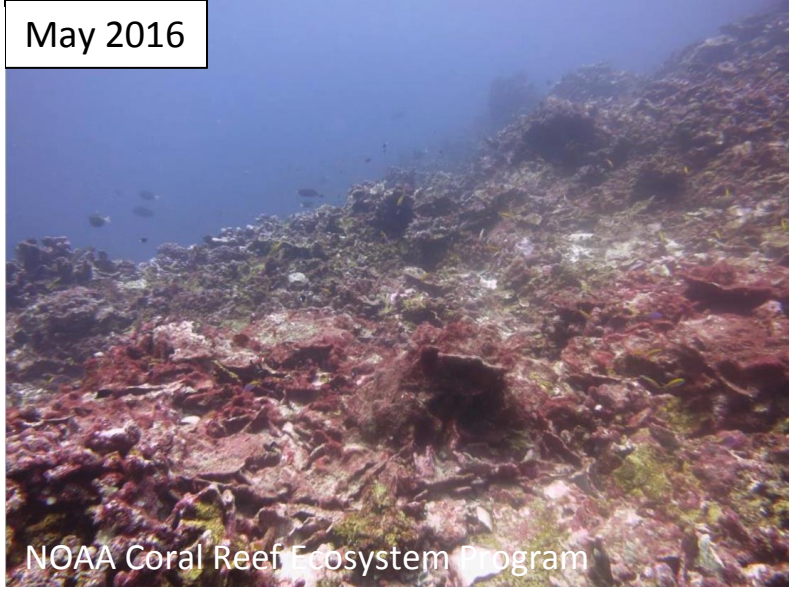
The lack of fish was an indication that there was “complete ecosystem collapse”

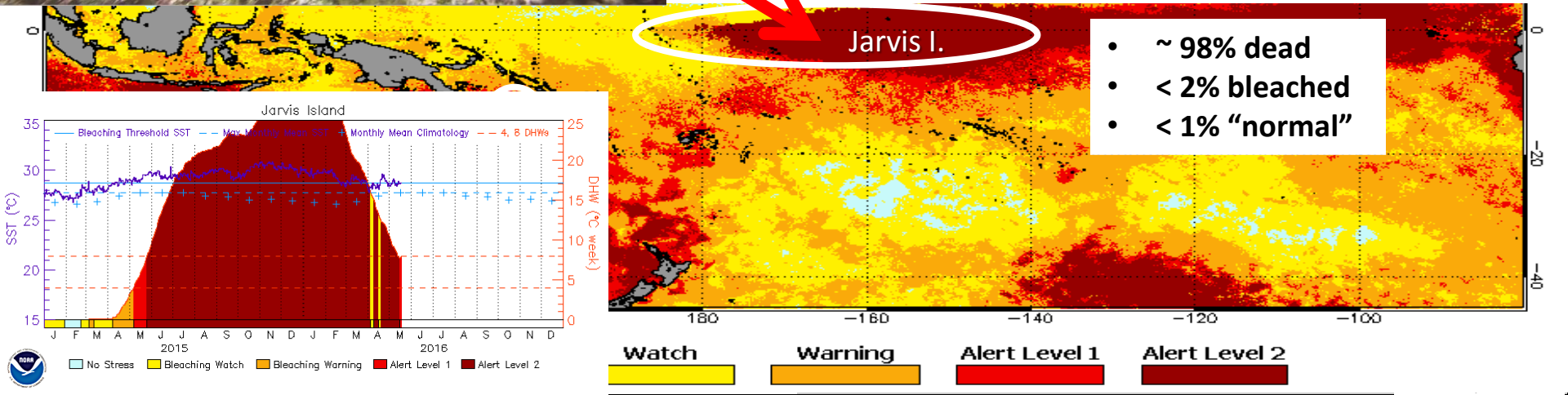
Justin Marshall, Univ. of Queensland

The Guardian 21 July 2016

Jarvis Island: 2015-6

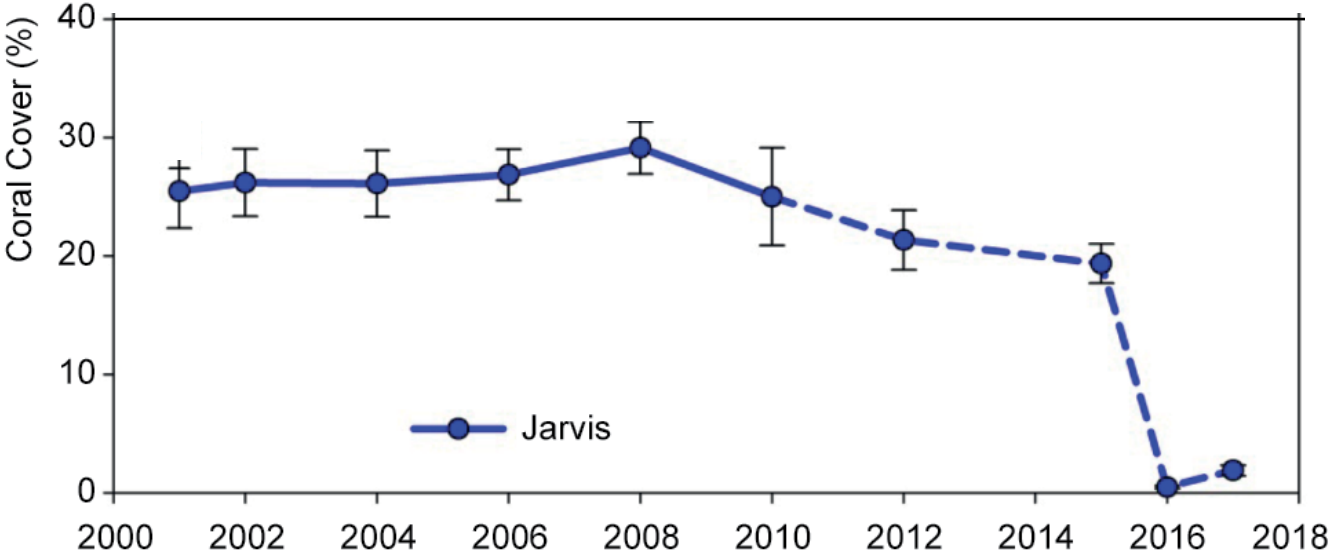






- ~ 98% dead
- < 2% bleached
- < 1% “normal”

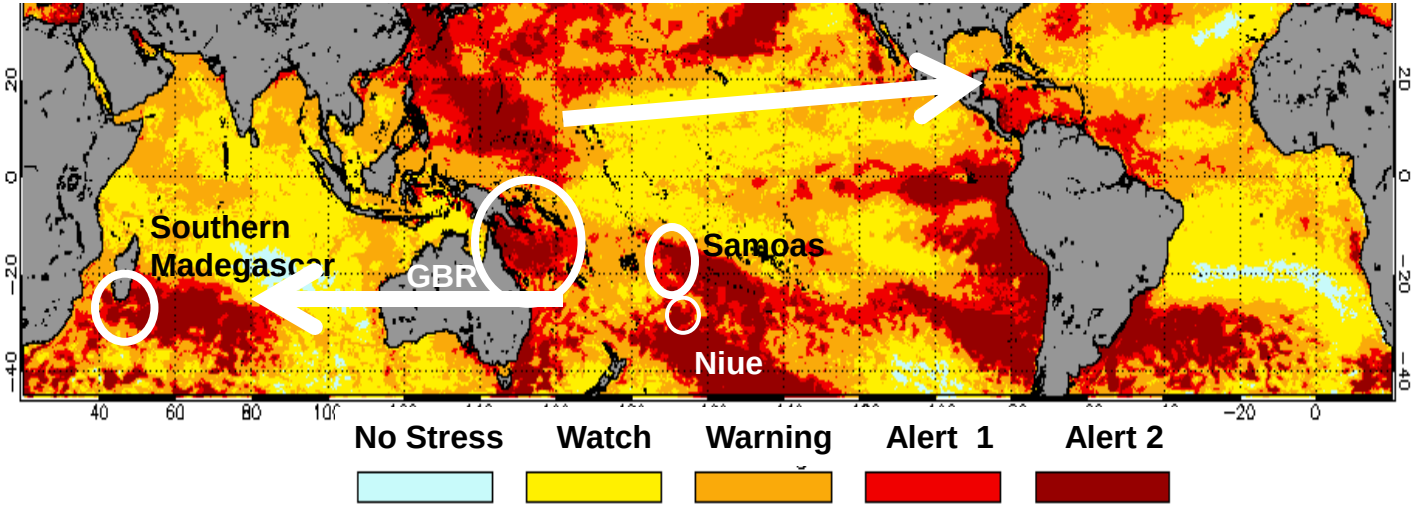
Jarvis Bleaching 2016



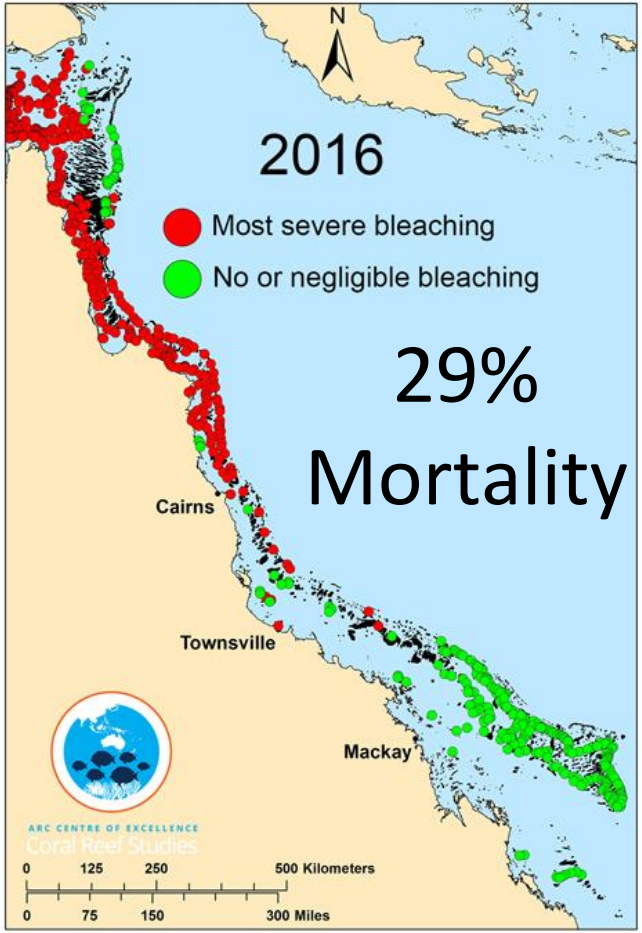
Brainard et al. (2018) Ecological impacts of the 2015/16 El Niño in the Central Equatorial Pacific. ***Bull. Amer. Meteor. Soc.*** DOI:10.1175/BAMS-D-17-0128.1

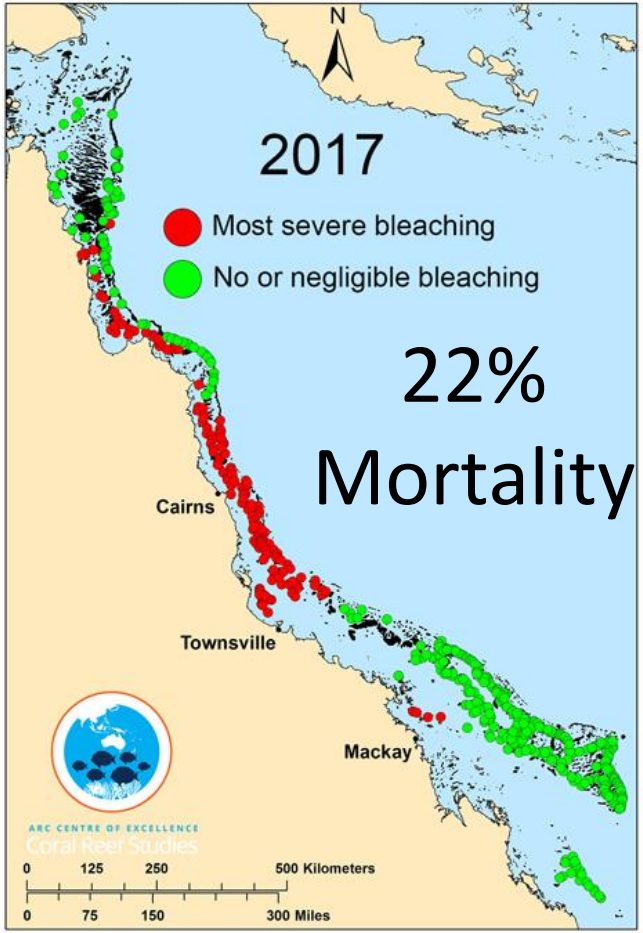
Global Bleaching: 2017

NOAA Coral Reef Watch Annual Maximum Satellite Coral Bleaching Alert Area 2017

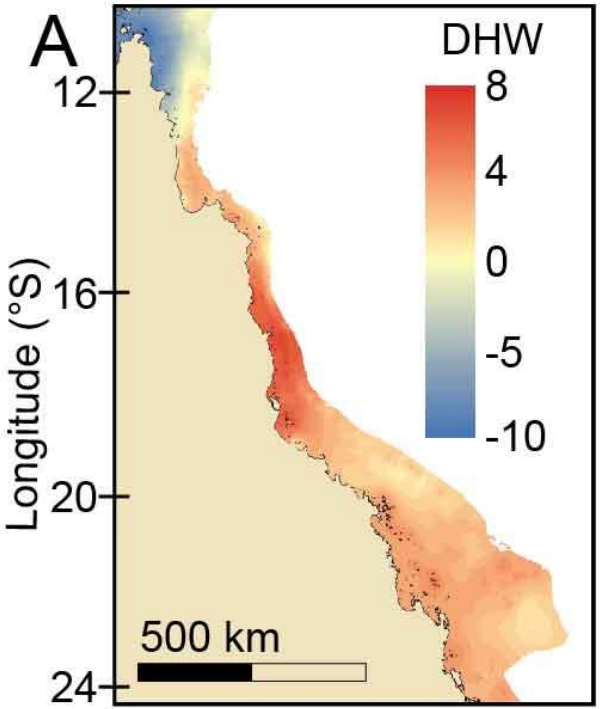


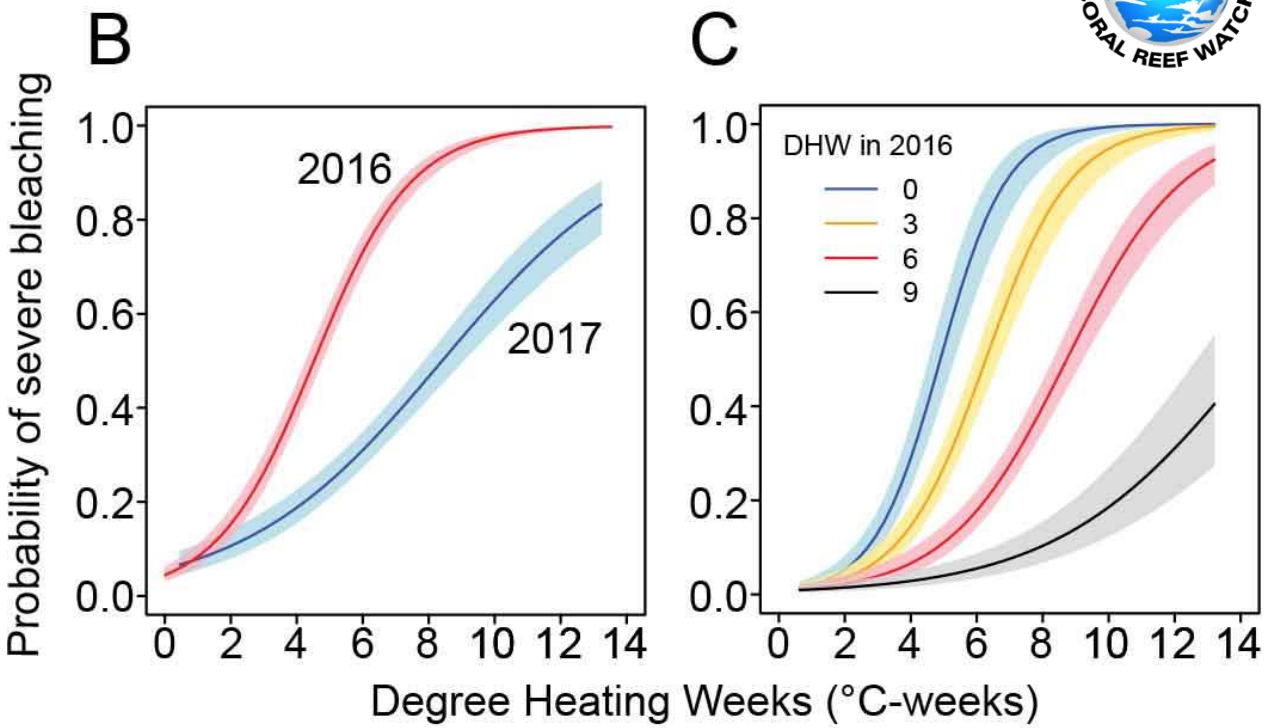
Multi-Year GBR Bleaching





Ecological Memory in Multi-Year GBR Bleaching

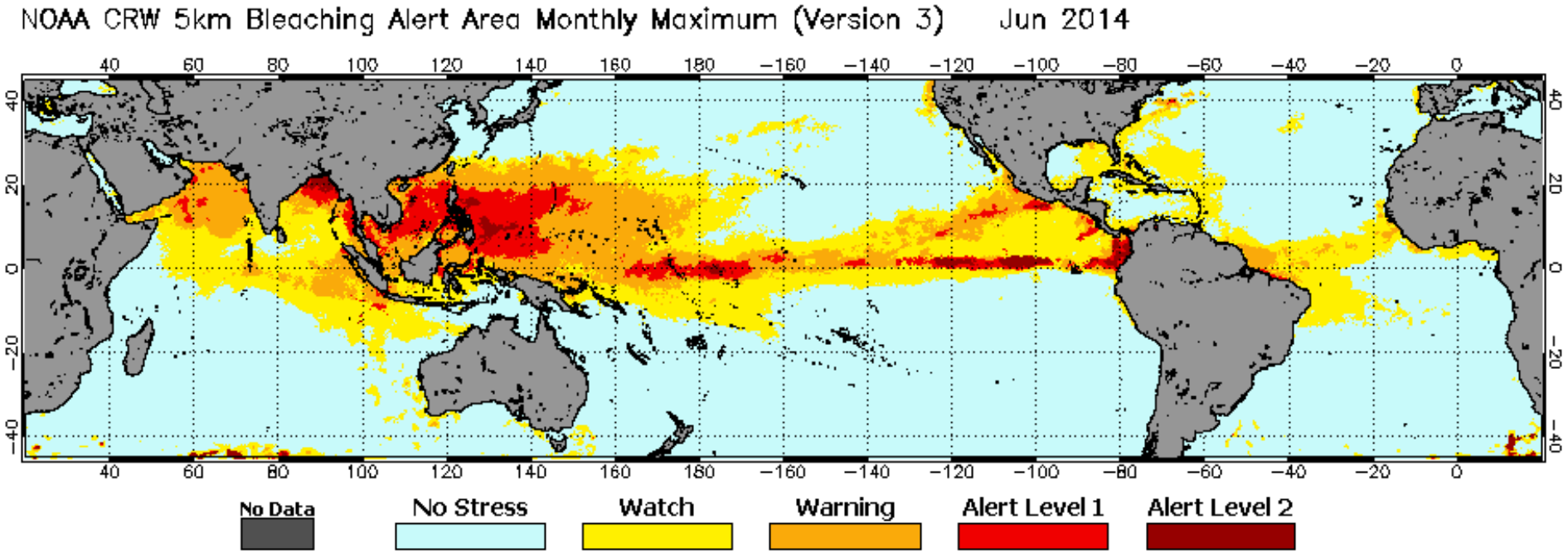




nature climate change

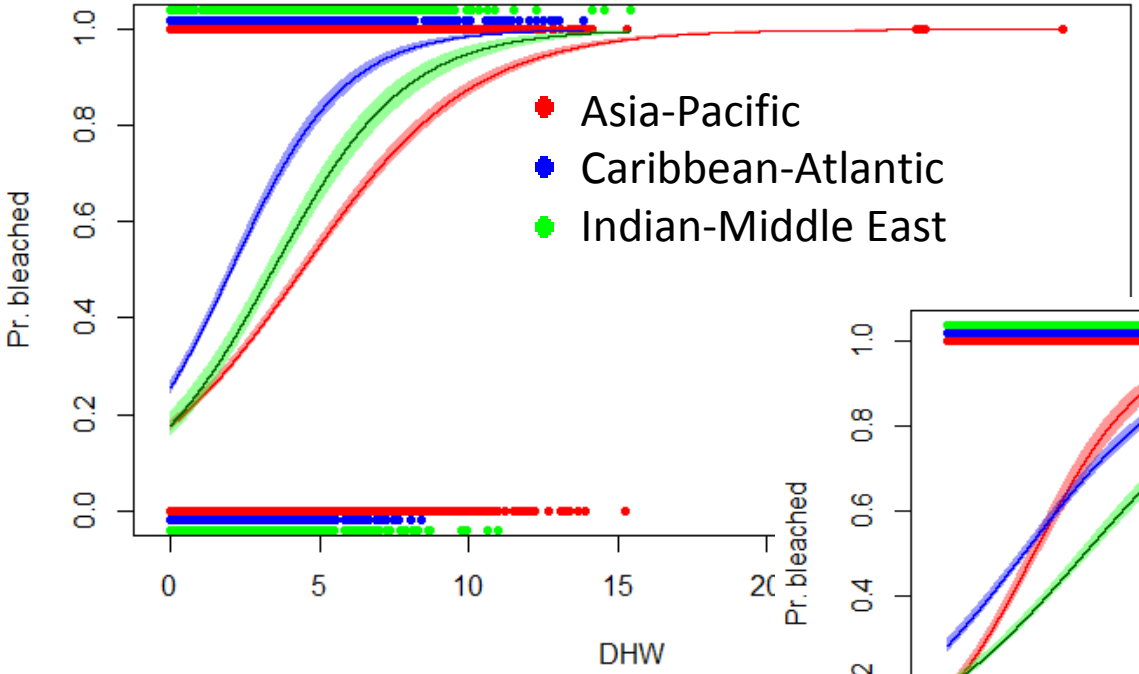
Hughes et al. (2019) Ecological memory modifies the cumulative impact of recurrent climate extremes. **Nature Climate Change**, 9: 40–43

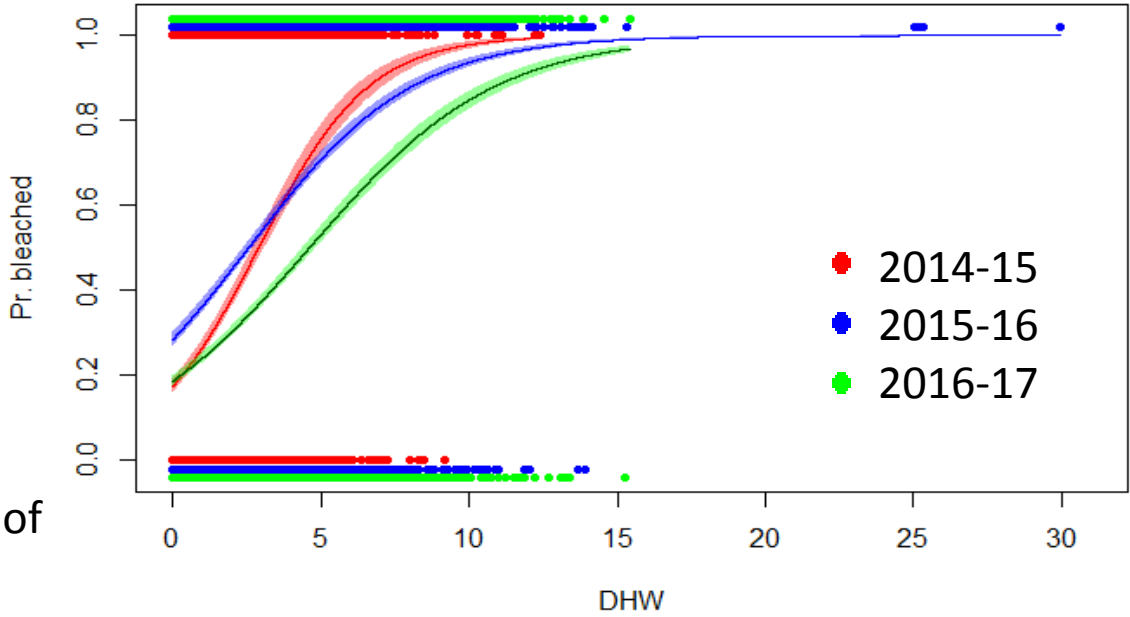
June 2014 - May 2017 Heat Stress



http://coralreefwatch.noaa.gov

2014-17 Bleaching Analysis

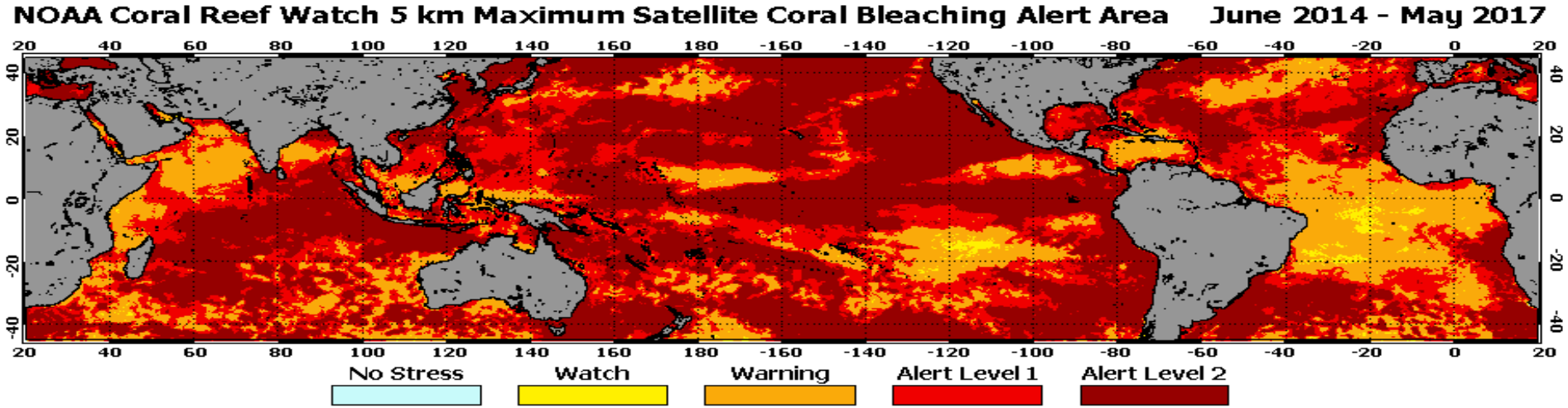




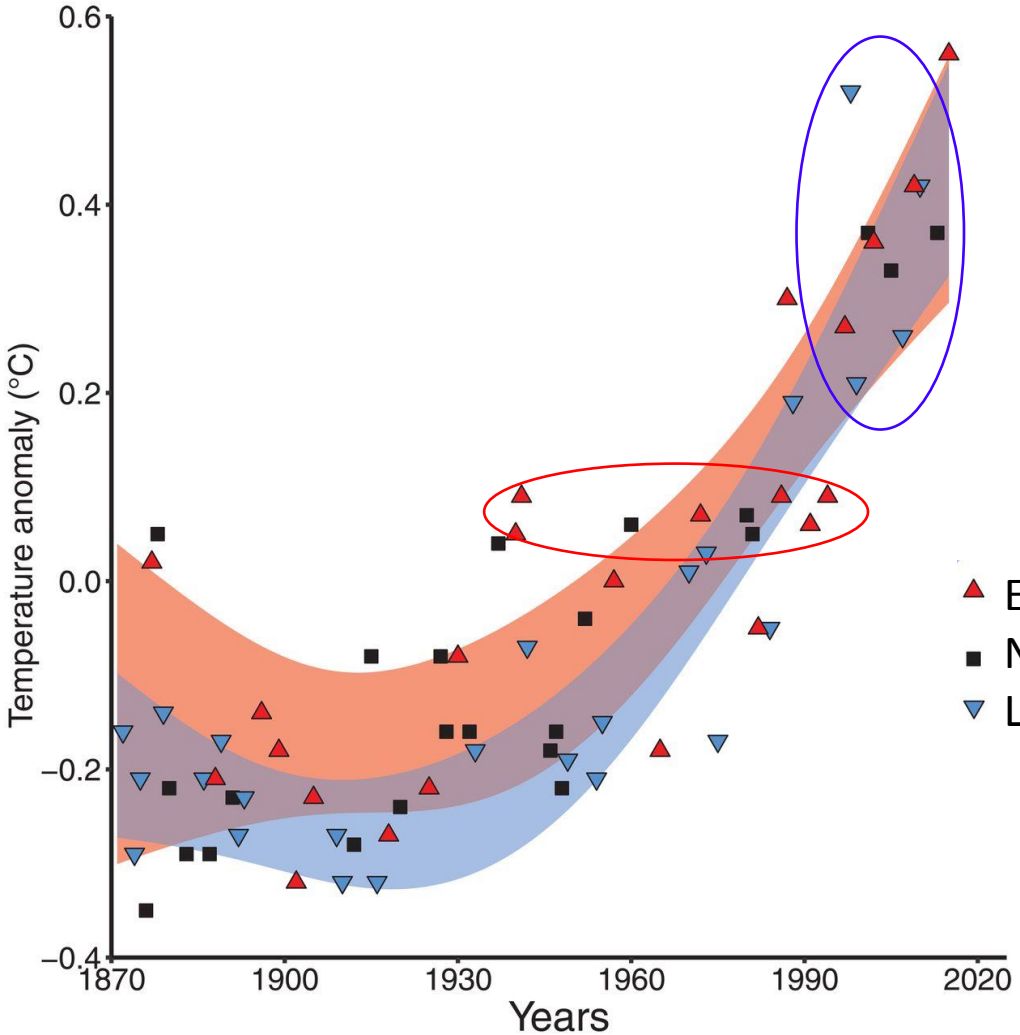
Database of over 15,000 observations of
Mortality / bleaching / non-bleaching

June 2014 - May 2017 Heat Stress

- Longest global bleaching event ever
- Over ½ exposed twice (Guam 4 of 5 years)
- >65% suffered bleaching-level heat stress
- Most widespread ever, area > Washington State
- Most damaging on record

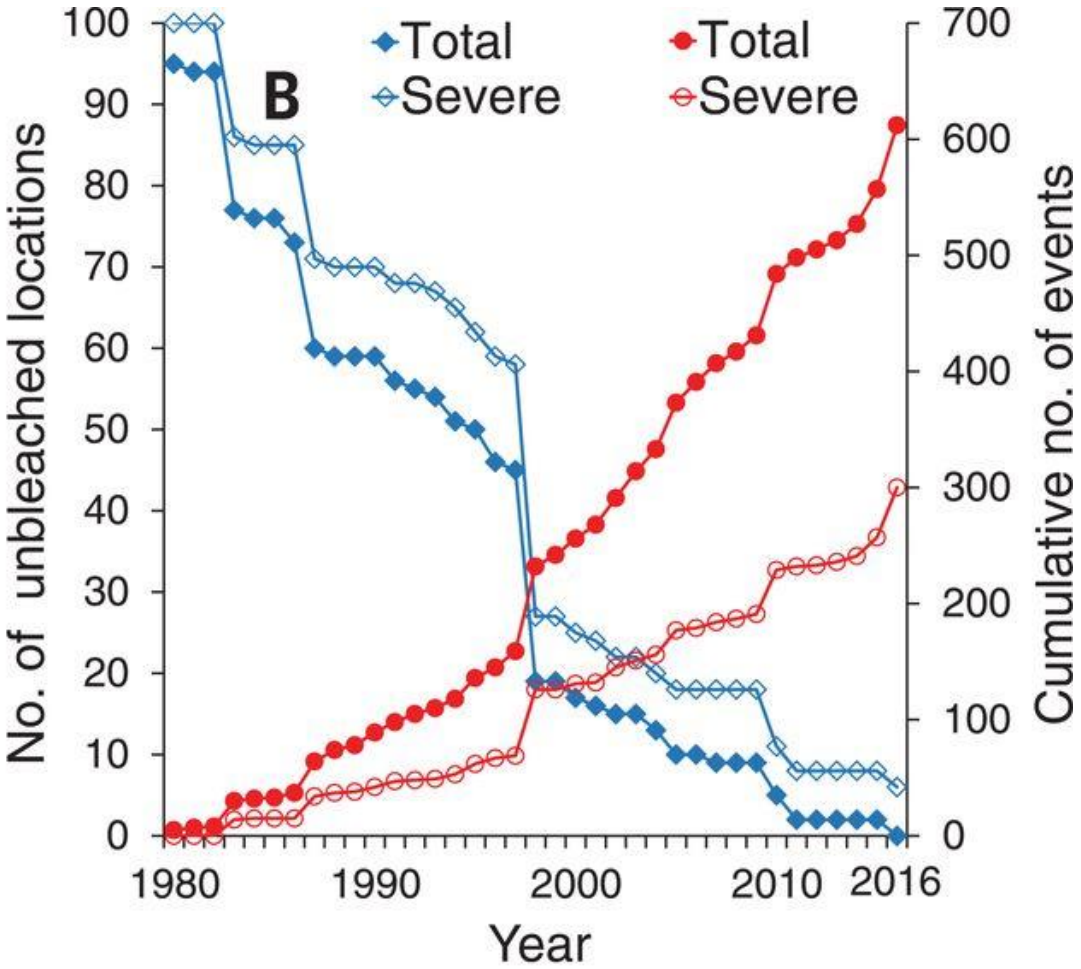


Rising Global Reef Temperatures



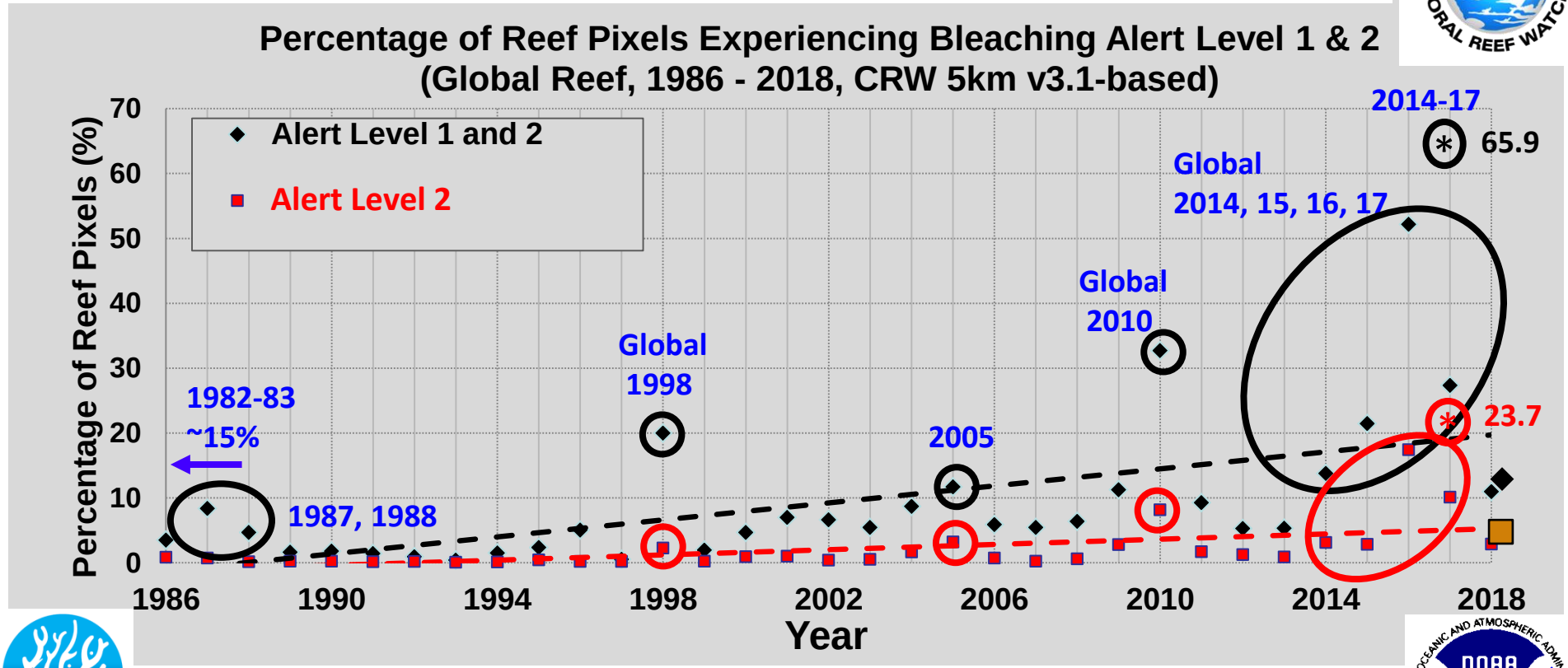
Hughes et al. (2018)
Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. ***Science*** 359 (6371): 80-83

Ocean Warms, Bleaching Increases

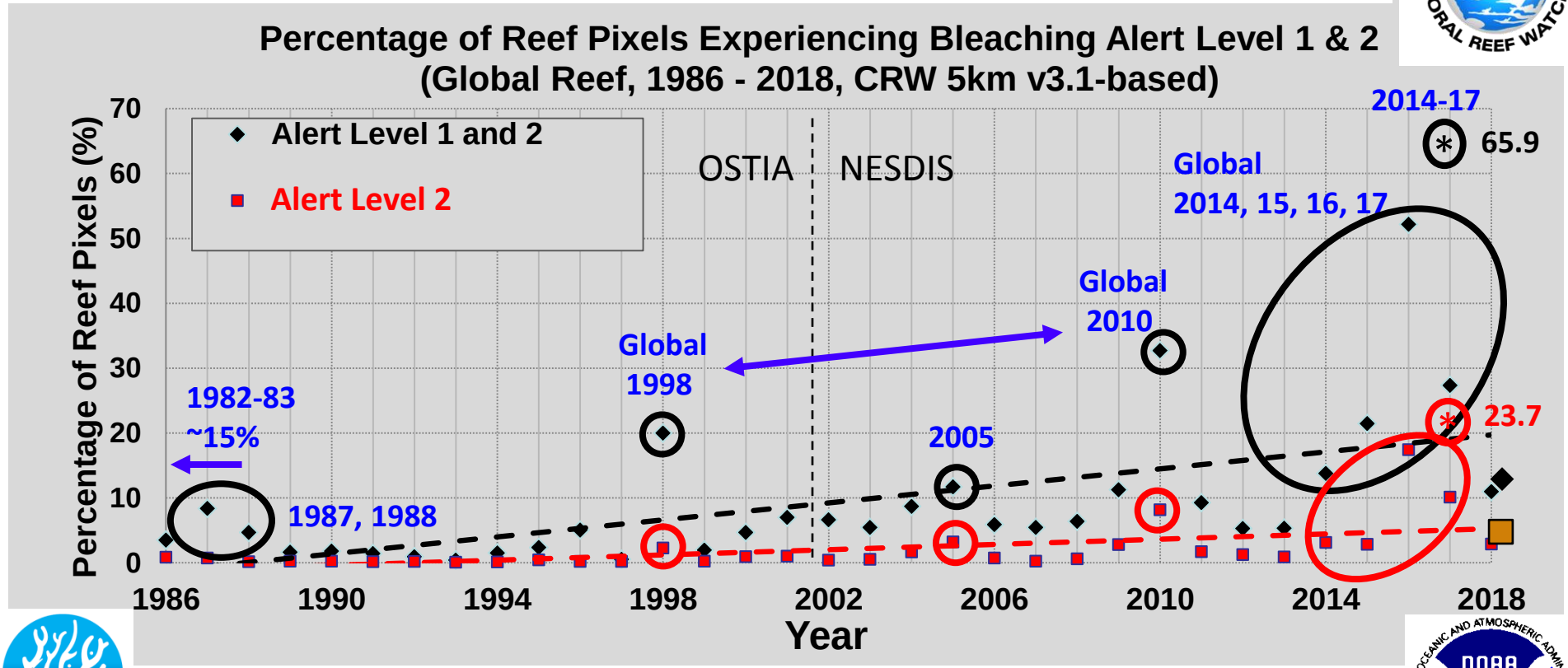


Hughes et al. (2018) Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. ***Science*** 359 (6371): 80-83

Ocean Warms, Bleaching Increases

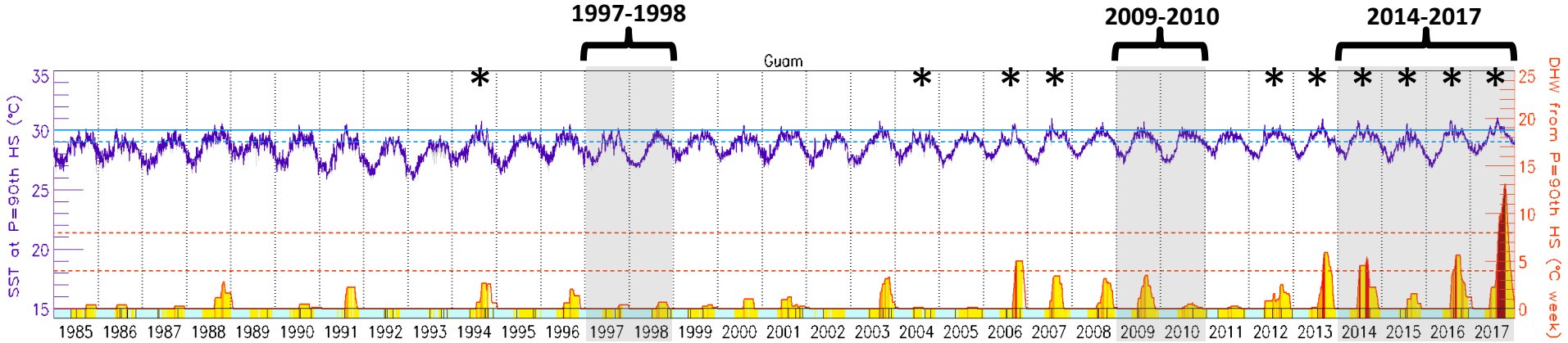


Ocean Warms, Bleaching Increases



Coral Bleaching in Pago Bay, Guam during the 2017 bleaching event. Photo credit: Dave Burdick/University of Guam Marine Lab.

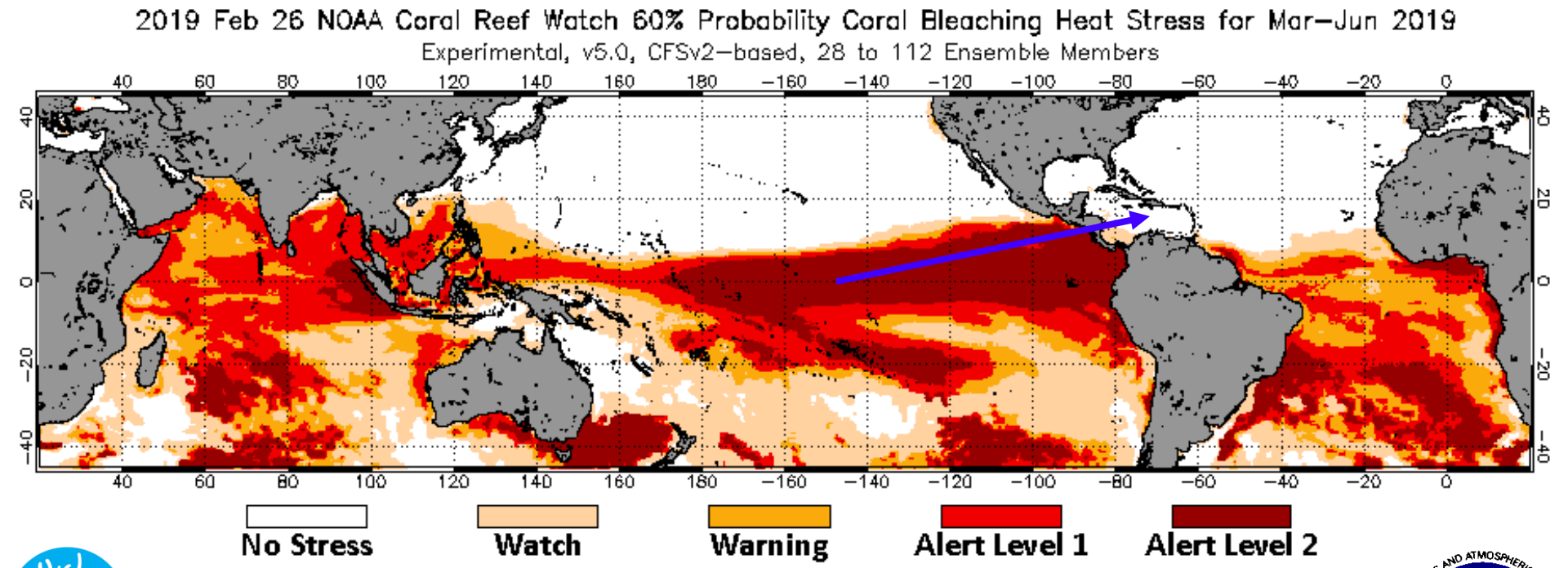
Guam



Bleaching Threshold SST — Max Monthly Mean SST — 4, 8 DHWs — 5km SST Range

* **Year with *in situ* bleaching report**

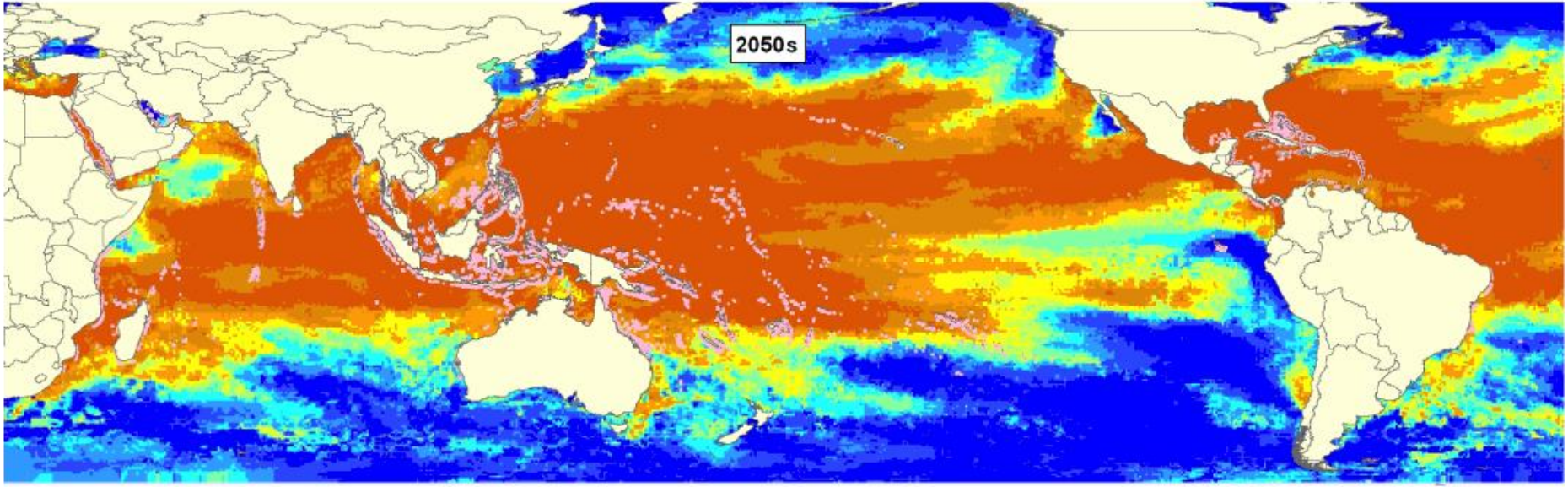
Coming Months



Future Warming

Models show most coral reefs with severe bleaching annually by 2050

Reefs at Risk Revisited, 2011



Coral Reefs

Frequency (Percent of Years) of NOAA Bleaching Alert Level 2 Events

0 - 10	21 - 30	41 - 50	61 - 70	81 - 90
11 - 20	31 - 40	51 - 60	71 - 80	91 - 100

Source: Adapted from Donner, S.D. 2009. "Coping with Commitment: Projected thermal stress on coral reefs under different future scenarios." PLoS ONE 4(6): e5712 for use in the *Reefs at Risk Revisited* project.

Addressing Climate Impacts on Reefs

<u>3 Actions Needed:</u>

1. Act Locally to reduce Stressors and help recovery
2. Act Globally to reduce CO_2
3. Radical Conservation

All are necessary

None is enough alone

Solutions: Reduce Local Stressors

Local managers can:

- Increase survival
- Reduce disease prevalence
- Reduce other stressors

http://coralreefwatch.noaa.gov

World Heritage Reef Bleaching

Heron S.F., Eakin C.M., Douvere F. et al. 2017. Impacts of Climate Change on World Heritage Coral Reefs: A First Global Scientific Assessment. *UNESCO World Heritage Centre.* 12pp.

Reef-containing World Heritage Site	Decadal Severe Heat Stress 1985-2013
Great Barrier Reef	0.0
Lord Howe Island Group	1.0
Ningaloo Coast	2.1
Shark Bay, Western Australia	2.8
Belize Barrier Reef Reserve System	0.0
Brazilian Atlantic Islands	0.3
Malpelo Fauna and Flora Sanctuary	1.0
Cocos Island National Park	0.3
Area de Conservación Guanacaste	0.0
Galápagos Islands	3.4
Lagoons of New Caledonia	0.0
Komodo National Park	0.3
Ujung Kulon National Park	0.0
Ogasawara Islands	1.0
Phoenix Islands Protected Area	2.8
Gulf of California	0.3
Archipiélago de Revillagigedo	1.0
Sian Ka'an	0.0
Rock Islands Southern Lagoon	0.3
Coiba National Park	0.7
Tubbataha Reefs Natural Park	0.0
Aldabra Atoll	0.0
East Rennell	0.0
iSimangaliso Wetland Park	0.0
Sanganeb Marine National Park	0.0
Everglades National Park	0.7
Papahānaumokuākea	0.0
Ha Long Bay	0.0
Socotra Archipelago	0.0

World Heritage Reef Bleaching

Heron S.F., Eakin C.M., Douvere F. et al. 2017. Impacts of Climate Change on World Heritage Coral Reefs: A First Global Scientific Assessment. *UNESCO World Heritage Centre.* 12pp.

Reef-containing World Heritage Site	Severe Heat Stress 1985-2013	Severe Heat Stress 2014-17
Great Barrier Reef	0.0	2
Lord Howe Island Group	1.0	0
Ningaloo Coast	2.1	0
Shark Bay, Western Australia	2.8	3
Belize Barrier Reef Reserve System	0.0	1
Brazilian Atlantic Islands	0.3	0
Malpelo Fauna and Flora Sanctuary	1.0	2
Cocos Island National Park	0.3	1
Area de Conservación Guanacaste	0.0	0
Galápagos Islands	3.4	3
Lagoons of New Caledonia	0.0	2
Komodo National Park	0.3	3
Ujung Kulon National Park	0.0	2
Ogasawara Islands	1.0	1
Phoenix Islands Protected Area	2.8	3
Gulf of California	0.3	2
Archipiélago de Revillagigedo	1.0	3
Sian Ka'an	0.0	3
Rock Islands Southern Lagoon	0.3	0
Coiba National Park	0.7	2
Tubbataha Reefs Natural Park	0.0	1
Aldabra Atoll	0.0	0
East Rennell	0.0	1
iSimangaliso Wetland Park	0.0	0
Sanganeb Marine National Park	0.0	0
Everglades National Park	0.7	3
Papahānaumokuākea	0.0	2
Ha Long Bay	0.0	2
Socotra Archipelago	0.0	0

1°C

After D. Wachenfeld, GBRMPA

Future World Heritage Reef Bleaching

Heron S.F., Eakin C.M., Douvere F. et al. 2017. Impacts of Climate Change on World Heritage Coral Reefs: A First Global Scientific Assessment. *UNESCO World Heritage Centre.* 12pp.

	Future Severe Stress RCP8.5		Future Severe Stress RCP4.5	
Reef-containing World Heritage Site	(a) Projected Year of 2x/decade	(b) Projected Year of Annual	(c) Projected Year of 2x/decade	(d) Projected Year of Annual
Great Barrier Reef	2035	2044	2041	2051
Lord Howe Island Group	2034	2043	2036	2055
Ningaloo Coast	2041	2049	2052	2074
Shark Bay, Western Australia	2038	2047	2045	2074
Belize Barrier Reef Reserve System	2028	2036	2036	2044
Brazilian Atlantic Islands	2028	2039	2035	2049
Malpelo Fauna and Flora Sanctuary	2038	2050	2056	2077
Cocos Island National Park	2019	2032	2028	2036
Area de Conservación Guanacaste	2030	2043	2040	2055
Galápagos Islands	2017	2036	2027	2042
Lagoons of New Caledonia	2031	2040	2039	2050
Komodo National Park	2017	2025	2021	2032
Ujung Kulon National Park	2032	2043	2042	2053
Ogasawara Islands	2030	2038	2041	2049
Phoenix Islands Protected Area	2020	2035	2028	2040
Gulf of California	2044	2052	-----	-----
Archipiélago de Revillagigedo	2031	2042	2043	2052
Sian Ka'an	2025	2033	2033	2041
Rock Islands Southern Lagoon	2028	2036	2032	2044
Coiba National Park	2030	2043	2040	2053
Tubbataha Reefs Natural Park	2030	2039	2037	2048
Aldabra Atoll	2028	2036	2034	2042
East Rennell	2025	2033	2030	2044
iSimangaliso Wetland Park	2031	2040	2036	2048
Sanganeb Marine National Park	2037	2046	2055	2069
Everglades National Park	2036	2044	2056	2071
Papahānaumokuākea	2029	2041	2044	2052
Ha Long Bay	2077	2086	-----	-----
Socotra Archipelago	2040	2048	2061	2077

Severe bleaching stress threshold defined as DHW of 8 °C-weeks.

Future World Heritage Reef Bleaching

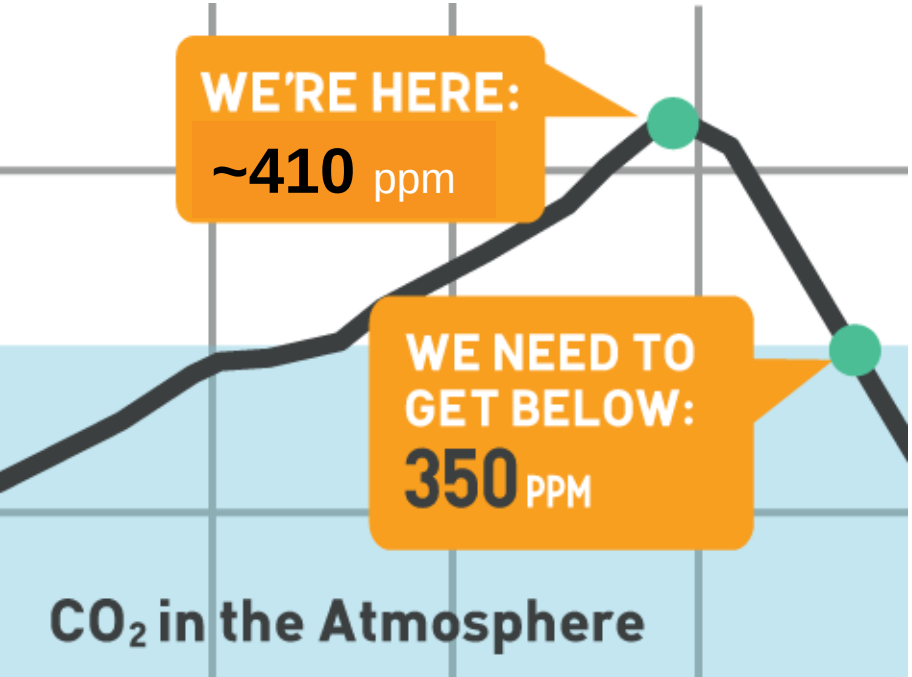
Heron S.F., Eakin C.M., Douvere F. et al. 2018. Impacts of Climate Change on World Heritage Coral Reefs: Update to: A First Global Scientific Assessment. *UNESCO World Heritage Centre.* 5pp.

	Future Severe Stress - RCP8.5		Future Severe Stress - RCP4.5		Future Severe Stress - RCP2.6	
Reef-containing World Heritage site	(a) Projected Year of 2x/ decade	(b) Projected Year of Annual	(c) Projected Year of 2x/ decade	(d) Projected Year of Annual	(e) Projected Year of 2x/ decade	(f) Projected Year of Annual
Great Barrier Reef	2035	2044	2041	2051	-----	-----
Lord Howe Island Group	2034	2043	2036	2055	-----	-----
Ningaloo Coast	2041	2049	2052	2074	-----	-----
Shark Bay, Western Australia	2038	2047	2045	2074	-----	-----
Belize Barrier Reef Reserve System	2028	2036	2036	2044	-----	-----
Brazilian Atlantic Islands	2028	2039	2035	2049	-----	-----
Malpelo Fauna and Flora Sanctuary	2038	2050	2056	2077	-----	-----
Cocos Island National Park	2019	2032	2028	2036	2062	-----
Area de Conservación Guanacaste	2030	2043	2040	2055	-----	-----
Galápagos Islands	2017	2036	2027	2042	2070	-----
Lagoons of New Caledonia	2031	2040	2039	2050	-----	-----
Komodo National Park	2017	2025	2021	2032	-----	-----
Ujung Kulon National Park	2032	2043	2042	2053	-----	-----
Ogasawara Islands	2030	2038	2041	2049	-----	-----
Phoenix Islands Protected Area	2020	2035	2028	2040	2038	-----
Gulf of California	2044	2052	-----	-----	-----	-----
Archipiélago de Revillagigedo	2031	2042	2043	2052	-----	-----
Sian Ka'an	2025	2033	2033	2041	-----	-----
Rock Islands Southern Lagoon	2028	2036	2032	2044	-----	-----
Coiba National Park	2030	2043	2040	2053	2053	-----
Tubbataha Reefs Natural Park	2030	2039	2037	2048	-----	-----
Aldabra Atoll	2028	2036	2034	2042	-----	-----
East Rennell	2025	2033	2030	2044	-----	-----
iSimangaliso Wetland Park	2031	2040	2036	2048	-----	-----
Sanganeb and Dungonab Bay-Mukkawar Island MNPs	2037	2046	2055	2069	-----	-----
Everglades National Park	2036	2044	2056	2071	-----	-----
Papahānaumokuākea	2029	2041	2044	2052	-----	-----
Ha Long Bay	2077	2086	-----	-----	-----	-----
Socotra Archipelago	2040	2048	2061	2077	-----	-----

Severe bleaching stress threshold defined as DHW of 8 °C-weeks.

Essential: Reduce Global CO_2

See 350.org for why we need to get <u>back</u> to 350 ppm in the atmosphere

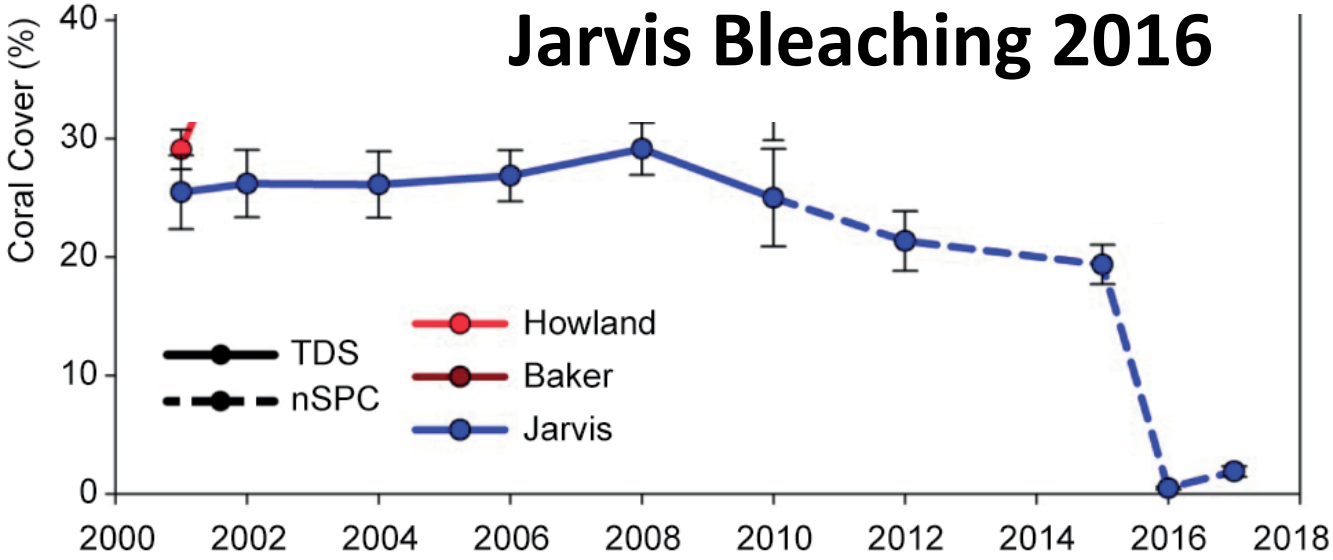


Essential: Reduce Global CO_2

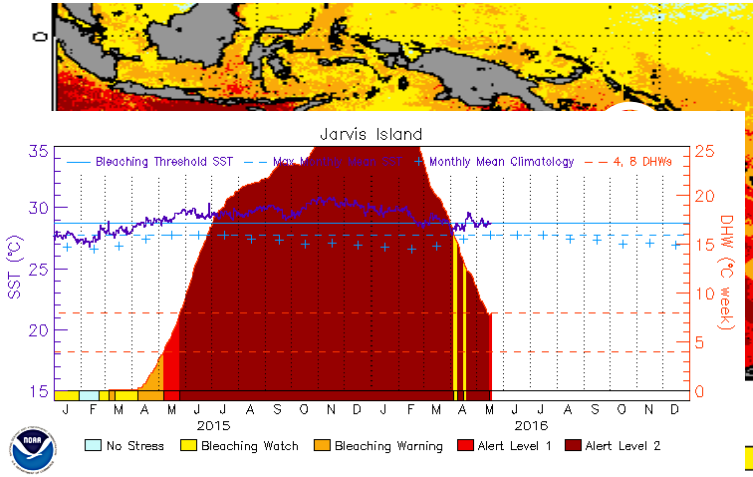
Many countries in Europe, and the US, have decreased their emissions from fossil fuels, mostly with energy efficiency and demand reduction

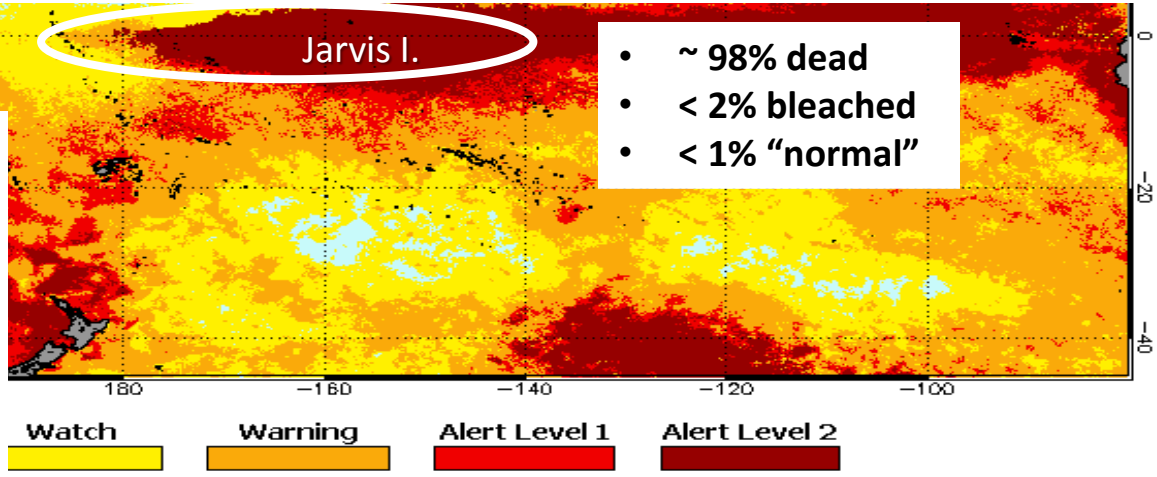
Nature Climate Change **9:** 213–217 (2019)

Jarvis Bleaching 2016



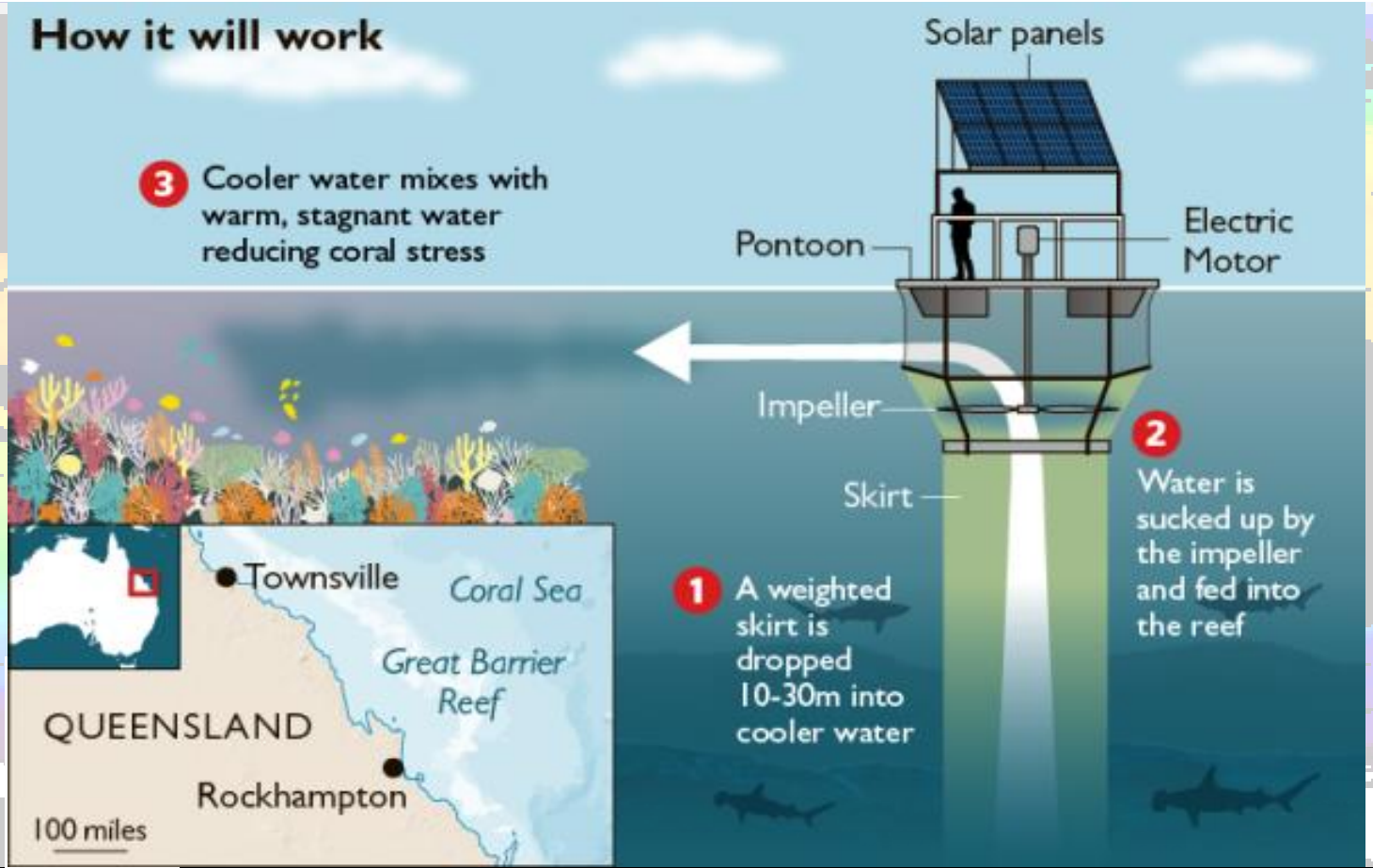
- Low island
- 300 km from Kiritimati
- Population ~5000





- **~ 98% dead**
- **< 2% bleached**
- **< 1% "normal"**

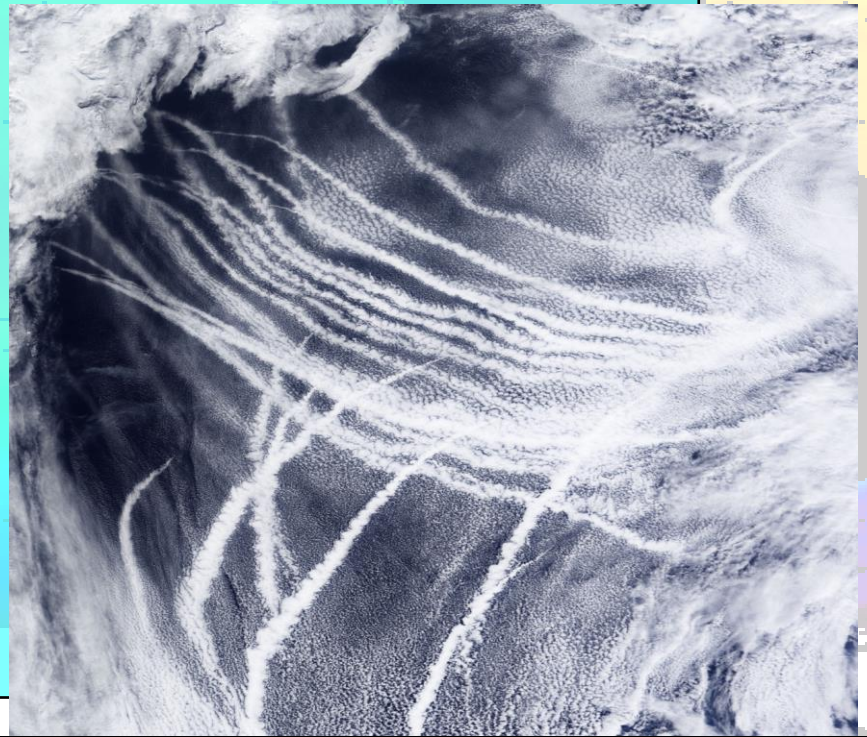
Radical Conservation: Local Geoengineering



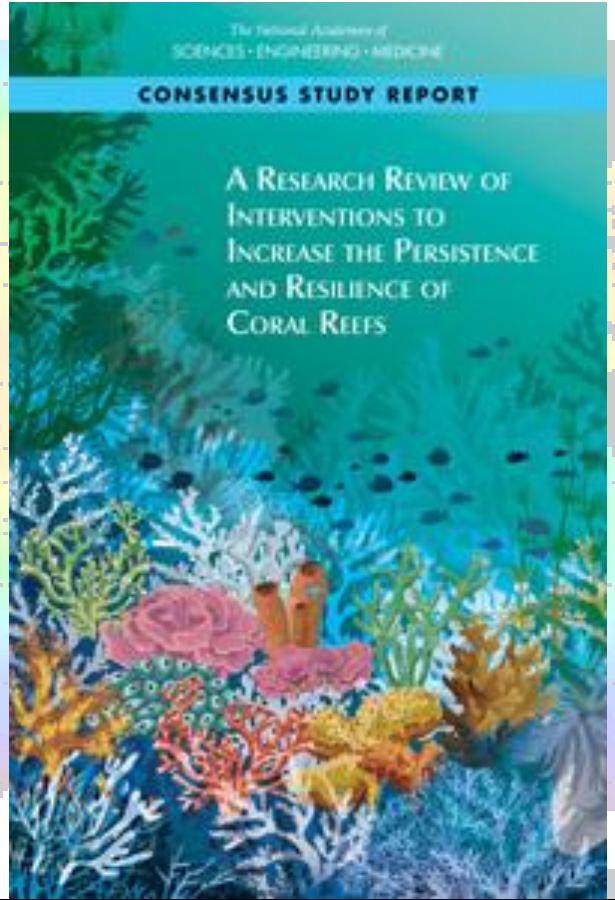
Radical Conservation: Regional Geoengineering

Large Scale Environmental Engineering

- Reduce light stress
- Cool reefs



NAS Study: *A Research Review of Interventions to Increase the Persistence and Resilience of Coral Reefs*



http://dels.nas.edu/Study-In-Progress/Interventions-Increase-Resilience/DELS-OSB-17-01

Key Messages:

- Rising temperatures are causing bleaching, disease, and death of corals
- 2014-17 was the worst bleaching ever
- Climate change is increasing bleaching frequency and intensity and will get worse

- 3 actions needed:
  - Reduce CO_2
  - Reduce Local Stress
  - Radical Conservation

- There is hope, but we need to act now

Thank you from the NOAA Coral Reef Watch Team!!

Mark Eakin

Iacquie De La Cour (CICS-UMD)

Gang Liu (CICS-UMD)

Erick Geiger (CICS-UMD)

Ben Marsh
(ReefSense)

Andrea Gomez
(CUNY & NOAA-CREST)

William Hernandez Lopez
(CUNY & NOAA-CREST)

Denise Devotta (GST)

William Skirving (ReefSense)

Scott Heron (U. Queensland)

Rob Warner (NOAA/NOS)

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NOAA CORAL REEF CONSERVATION PROGRAM

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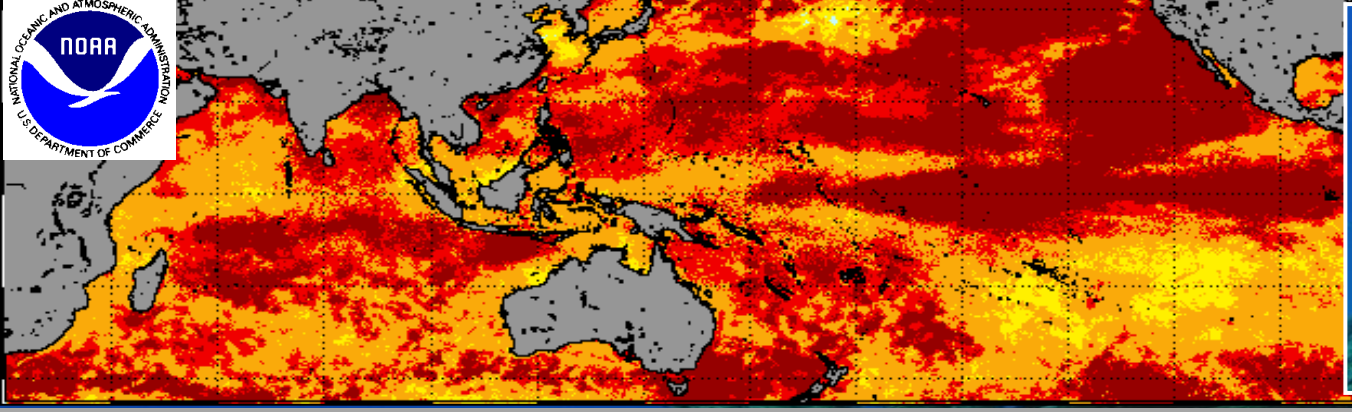
Dr Sean Connelly
Joanne Moneghetti
U. Queensland



Thank You

The 2014-17 Global Coral Bleaching Event and Coral Bleaching in the Anthropocene

Dr. C. Mark Eakin

W.J. Skirving, S.F. Heron, G. Liu, T.P. Hughes, S.Donner, E.F. Geiger, J.L. De La Cour, A.M. Gomez, B.L. Marsh, and D. Devotta

NOAA Coral Reef Watch

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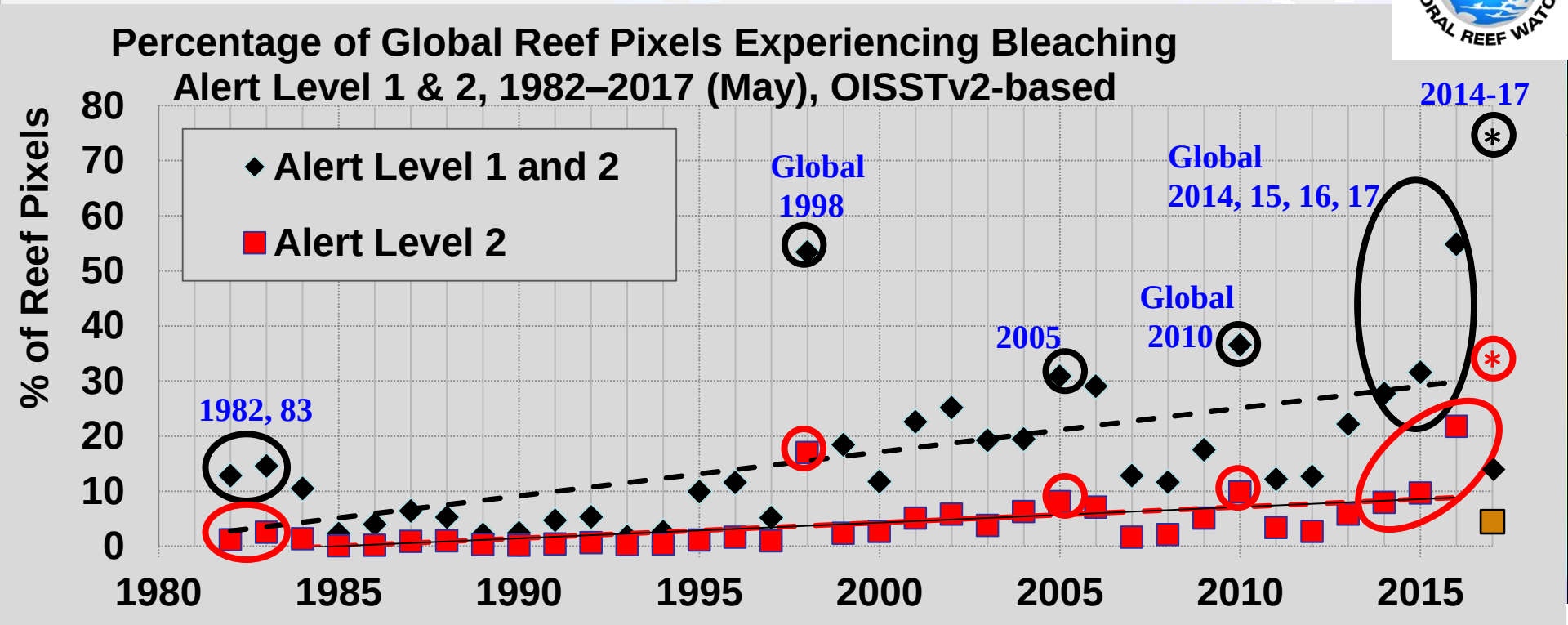
CoralReefWatch

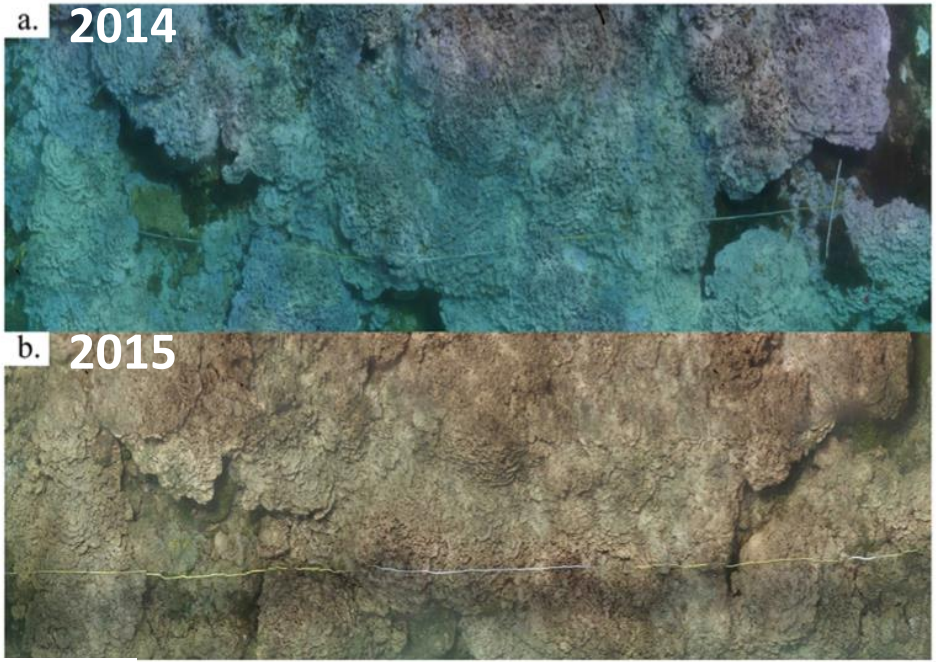
CoralReefWatch.NOAA.Gov

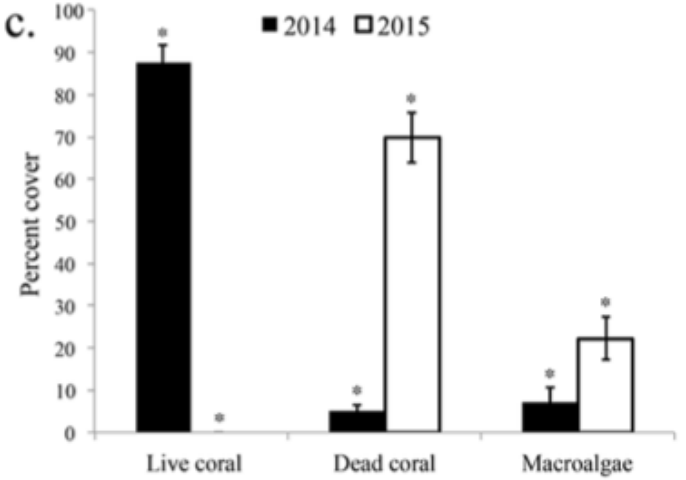
Ocean Warms, Bleaching Increases

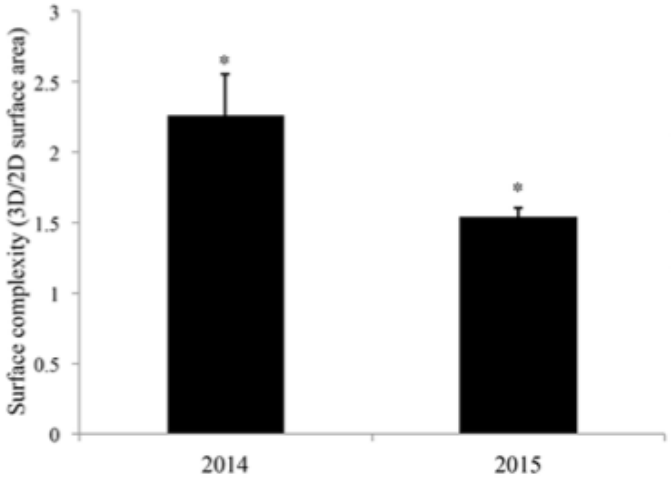


http://coralreefwatch.noaa.gov

Rapid Erosion After Mortality

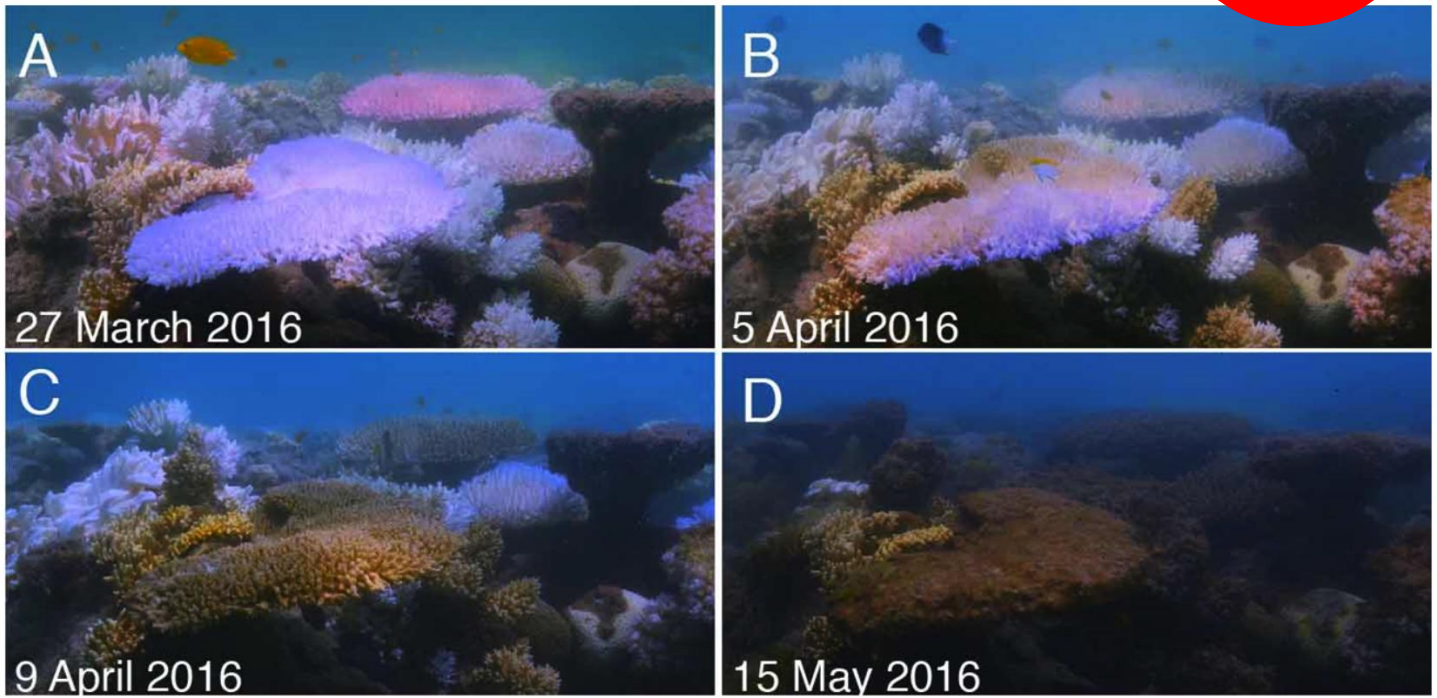






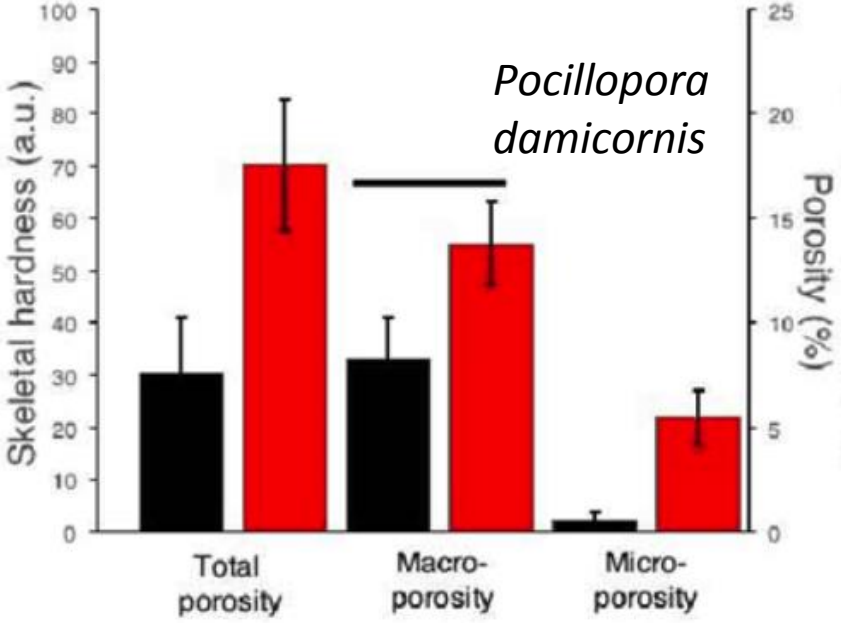
Couch et al. (2017) Mass coral bleaching due to unprecedented marine heatwave in Papahānaumokuākea Marine National Monument (Northwestern Hawaiian Islands) **PLoSone**

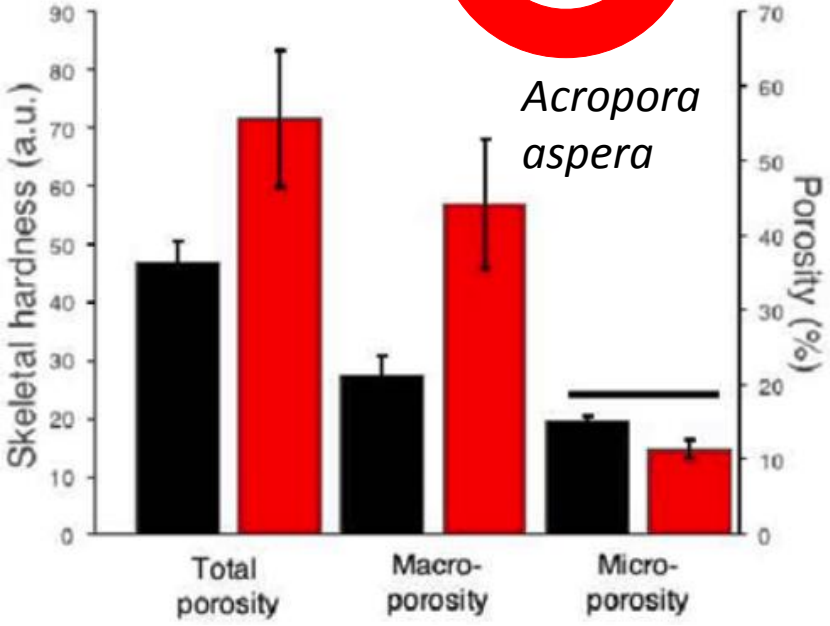
Rapid Erosion After Mortality



Ainsworth et al. (in review) Nature Sustainability

Rapid Erosion After Mortality





Ainsworth et al. (in review) Nature Sustainability