Coral Reef Ecosystems in a Changing Climate: Global Perspective and USCRTF Efforts

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NOAA Coral Reef Watch
Outline

- **2 Major Climate Change Threats**
  - Rising Temperatures and Coral Bleaching
  - Rising CO₂ and Ocean Acidification

- **Actions Needed to Protect Coral Reefs**
  - Reduce Global Emissions
  - Reduce Local Stressors

- **The US CRTF Resolution on Corals and Climate Change**
Temperature Increases: Last Century

Warming of the climate system is unequivocal.

"Warming of the climate system is unequivocal."
- IPCC 4th Assessment Report, Working Group I
“Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.” - IPCC 4th Assessment Report, WG 1
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400,000 Years of CO$_2$ and Temperature Change from Antarctic Ice Cores

“It is very likely that [man-made] greenhouse gas increases caused most of the average temperature increase since the mid-20 century”
- IPPC 4th Assessment Report

Global Climate Change Processes
- Greenhouse gases including CO$_2$
- Increased global temperatures
- Sea level rise
- Loss of sea ice
- Loss of biodiversity
- Ocean acidification

Graph showing CO$_2$ concentration and temperature change over 450,000 years before present.
Anthropomorphic "Sweet Spot" for Corals?

Average temperature over past 10,000 years = 15°C

Is this an Anthropomorphic "Sweet Spot"?

IPCC (2001) forecast: +2–3°C, with band of uncertainty

21st century: very rapid rise

End of last ice age

Younger Dryas

Little ice age in Europe (15th–18th centuries)

Holocene Optimum

Medieval Warm

Vikings in Greenland

Mesopotamia flourishes

Agriculture emerges

CO₂ (ppm)

750

550

450

Adapted from Robert Corell

4.5°C

1.5°C
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
Highest Thermal Stress Recorded?

% Reefs with Bleaching Stress

- World
- Pacific
- Caribbean

Year


% Reefs with Bleaching Stress

0 20 40 60 80
135 Years of Thermal Stress Increase
Wide Range of Coral Reef Threats

- Human Population Growth
- Overfishing
- Coastal Development
- Lack of Laws / Enforcement
- Sedimentation (unnatural)
- Lack of Education
- Nutrient Enrichment
- Algal Competition

- **Climate Change / Bleaching**
- Habitat Destruction
- Tourism

2004 Survey: 276 Coral Reef Scientists
Kleypas and Eakin (2007)
Worldwide Reef Deterioration

- 2/3 of reefs are severely degraded
- 1/4 of reefs may be past recovery
- Over 15% of the world’s reefs died in 1997-1998 El Niño after bleaching
Thermal Stress in Corals

Average Heating Stress Index

Year

1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005

Bleaching
Expected
Mass Bleaching and Mortality
Thermal Stress in Corals

Average Heating Stress Index

Year

1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005

- Bleaching
- Expected
- Mass Bleaching and Mortality
Thermal Stress in Corals

Average Heating Stress Index

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NOAA

Bleaching
Expected
Mass Bleaching and Mortality
Thermal Stress in Corals
Thermal Stress in Corals

Average Heating Stress Index

Year

1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005

0 1 2 3 4 5

Bleaching
Expected
Mass Bleaching and Mortality
Thermal Stress in Corals

Average Heating Stress Index

- Bleaching Expected
- Mass Bleaching and Mortality

Year

1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005
Thermal Stress in Corals

Average Heating Stress Index

Year

1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005

Bleaching
Expected
Mass Bleaching and Mortality
Thermal Stress in Corals

Average Heating Stress Index

Year

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Bleaching
Expected
Mass Bleaching and Mortality
Thermal Stress in Corals
Percent of Coral Colonies Bleached

Colony Bleached by Jurisdiction
23 Jurisdictions, 890 Surveys

\[ Y = 2.86X + 19.9 \]
\[ r^2 = 43.8\%, \text{ RMS} = 14.2 \]
\[ p < 0.001 \]

Mean Coral Colonies Bleached (%)

Mean Operational Maximum Degree Heating Week (°C week)

Error bars indicate Standard Error of the Mean.
Bleaching Can Lead to Disease

• Many bleached colonies have become diseased

• Some diseases are rapid and devastating

Inshore patch reefs
Middle Florida Keys

Marilyn E. Brandt
University of Miami
Virgin Islands N.P. Coral Bleaching Surveys

S. Fore Reef, BUIS
96% coral cover bleached
42% coral cover dead

Tektite, VIIS
90% coral cover bleached
54% coral cover dead

Haulover, VIIS
96% coral cover bleached
45% coral cover dead

Mennebeck, VIIS
94% coral cover bleached
49% coral cover dead

Yawzi, VIIS
71% coral cover bleached
39% coral cover dead

Newfound, STJ
92% coral cover bleached
53% coral cover dead

South Florida/Caribbean Network I&M Program

J. Miller (unpublished)
Current Thermal Bleaching: August 2007
Current Thermal Bleaching: August 2007
Future change

Coral bleaching threshold

Photos by Ray Berkelmans, AIMS

Hoegh-Guldberg (1999)
The Oceans and CO$_2$: Ocean Acidification

After Wolf-Gladrow et al., 1999
Linear Decrease in Calcification with Increasing Ocean CO₂

Since anthropogenic CO₂ has already lowered the carbonate ion concentration by ~15%, these systems are already being affected by anthropogenic CO₂.

Net growth

Net dissolution

After Turley et al., 2005
Future Changes in Reef Calcification

IPCC IS92a 'business-as-usual'

Aragonite Saturation Levels in 1765

Coral Reef Calcification
- 1765 Adequate
- 2005
- 2100

Future Changes in Reef Calcification

IPCC IS92a 'business-as-usual'

Aragonite Saturation Levels in 2005

Coral Reef Calcification
- 1765 Adequate
- 2005 Marginal
- 2100

Future Changes in Reef Calcification

IPCC IS92a 'business-as-usual'

Calcification rates in the tropics may decrease by 30% over the next century

After Feely et al. (in press) with Modeled Saturation Levels from Orr et al. (2005)
Rising temperatures and increasing CO$_2$: 
Rising temperatures bleach & kill corals
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Rising temperatures bleach & kill corals 
Rising CO$_2$ and acidification threaten reef structures
Two Part Solution:
1) Reduce Global CO₂ Emissions

- Stabilizing CO₂ concentrations requires reducing emissions
- Stabilization of greenhouse gas concentrations is the goal of the Framework Convention on Climate Change.
“Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.”
- IPCC 4th Assessment Report, Working Group 1
Reducing Emissions Is Not Enough!

- Human Population Growth
- Overfishing
- Coastal Development
- Lack of Laws / Enforcement
- Sedimentation (unnatural)
- Lack of Education
- Nutrient Enrichment
- Algal Competition
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Two Part Solution:
2) Reduce Local Stressors

- Driven by US Coral Reef Task Force
- Result of international workshop, research, and planning
- Addresses local reef management in light of changing climate

Available at coralreef.noaa.gov
Reef Manager’s Guide: Training Workshops

**Responding to Climate Change: A Workshop for Coral Reef Managers**

*Practical Training Based on “A Reef Manager’s Guide to Coral Bleaching”*

Pago Pago, American Samoa
27-30 August 2007

- **First course Lady Elliot Island, Australia**
  (July 2007)

- **Second course HERE next week**
## US CRTF Resolution: Coral Reefs and Climate Change

### Highlights
1. Reaffirms threat of climate change to coral reefs;
2. Recognizes members and partner actions to reduce greenhouse gas emissions;
3. Need to assess coral reef vulnerability of coral reefs to climate change;
4. Need adaptation strategies to promote resilience;
5. Affirms Marine Protected Area (MPA) networks as important tools;
6. Recognizes island and coastal communities as especially vulnerable;
7. Forms a standing Climate Change Working Group (CCWG);
US CRTF Resolution: Coral Reefs and Climate Change

Highlights
8. Charges the CCWG to
   a) develop a toolbox of management actions;
   b) improve understanding of ocean acidification;
   c) expand education and outreach;
   d) cooperate with other climate-focused programs (i.e., CCSP);
      a) report to CRTF.
9. Encourages federal partners to address impacts of climate change;
10. Supports development of local action strategies (LAS);
11. Supports development coral bleaching response plans for all jurisdictions;
12. Make USCRTF meetings and documents carbon neutral.
Thank You
There is a fundamental asymmetry between the time scales that the climate system reacts to increases in greenhouse gases and the time scales to recover from such increases.
The Last 20,000 Years seems to have been Ideal for the Development of Human Societies. Is this a Historic "Sweet Spot" that Enabled Humans to Flourish?
Coral Reefs and Major Extinctions

From Signor (1990)
Deciding the future for coral reefs

![Graph showing reef condition from 1950 to 2100 with CO2 and temperature trends](image)

- **Reef condition**
- **Year** 1950, 2000, 2150, 2100
- **CO2 & Temperature**

The graph illustrates the decline in reef condition from 1950 to 2100, with a significant drop around 2006. The trend shows a rising CO2 and temperature, impacting the reefs negatively.
Calcification rates in the tropics may decrease by 30% over the next century.