Adaptations of Corals and Coral Reefs to Climate Change by Susan B. Colley

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Topics

- Zooxanthellae Symbiont Ecology
- Reproductive Aspects
- Reef Framework Structure
Eastern Pacific SST

- Gulf of Chiriquí: (28-29°C)
- Gulf of Panamá: (24-28°C)
- Galápagos Iss.: (21-26°C)
Percentage of Coral Mortality 1982-83

- >90% in Galápagos
- ~75% in Gulf of Chiriquí
- ~85% in Gulf of Panamá

Glynn et al. 2001
Additional Environmental Characteristics of the Eastern Pacific

- Dry (cool)/Wet (warm) Seasons
- Freshwater
- Sedimentation
- Nutrients/Detritus
- Tidal Exposures
- Turbidity
- High rates of Bioerosion
- Continental/oceanic island settings
- Discontinuous habitats (highly dispersed)
- Carbonate/basalt substrates
Aspects of Zooxanthellae Ecology
The Bleaching Response:

expulsion of zooxanthellae from the coral host or the loss of symbiont pigments
Gulf of Chiriquí, Panamá

Pocillopora spp.

1995

- Normal: 34
- Bleached: 25

1997

- Normal: 42
- Bleached: 29

Other species (Pavona, Porites, Gardineroseris, Psammocora)

- Normal: 24
- Bleached: 25

Shifts in dominant algal symbiont communities following mass bleaching to favor high-temperature resistant *Symbiodinium* in clade *D*

Evidence for an adaptive response of reef coral symbioses to climate change?

Transplanted corals from a cooler area on the GBR to a warmer area on the GBR. These corals contained Clade C. They bleached, but survived and regained color, however, now harbored Clade D. The thermal tolerance of these corals increased by 1-1.5 °C.

Zooxanthellae clade shuffling appears to be one way at least some thermally impacted coral species can increase their thermal tolerance to future seawater warming events, however, this appears to be limited (1-1.5°C)
Reproductive Aspects
Eggs Bundle Release
Sperm Release from Male Colony
Gamete maturation patterns and spawning

Depending on the species & location

P. lob.-G; P. eleg –U; P.gig.-G; P. spp.- U; G. of P

<table>
<thead>
<tr>
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<th>El Niño Effect</th>
<th>Non-El Niño Effect</th>
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<tr>
<td></td>
<td>Gulf of Chiriquí</td>
<td>Galápagos</td>
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<tr>
<td><strong>Poc. damicornis</strong></td>
<td>↓ (P&lt;0.05)</td>
<td>↑ mature</td>
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<tr>
<td><strong>Poc. elegans</strong></td>
<td>= (P&lt;0.05)</td>
<td>↑ mature</td>
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<tr>
<td><strong>Por. lobata</strong></td>
<td>= =</td>
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<td><strong>Por. panamensis</strong></td>
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<td><strong>Pav. gigantea</strong></td>
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<td><strong>Gard. planulata</strong></td>
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<td><strong>Pav. chiriquisiensis</strong></td>
<td>= (P&lt;0.001)</td>
<td>↑ 1991</td>
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<tr>
<td><strong>Pav. varians</strong></td>
<td>= =</td>
<td>↑ 1991</td>
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Colley et al. 2005
Conclusions from the Reproductive Aspects of ETP corals

- Eastern Pacific corals have adapted to a highly disturbed environment by increasing the number of cycles of gamete development and the number of spawning episodes per year.

- Numbers of cycles of gamete development appear to be temperature related in at least some species.

- Moderate sea surface warming (+1-2 °C) is associated with greater production of mature gametes of major reef building corals in the Galápagos.

Glynn and Colley (in press)
Thin accumulations of calcium carbonate

Small areal extent, 1-2 hectares

Limited to depths <10m

Patchily distributed

Diversity of corals
Reef framework components are only held in place by a thin envelope of encrusting organisms, namely crustose coralline algae and an organic matrix of sponges and other infauna.

Cementation of eastern Pacific reefs to be very limited.
Thin-section photomicrographs of cement distributions.

Abundant cementation in the intraskeletal cavities of a coral from Lee Stocking Island, Bahamas.

Uva Reef, Panama’. When present, the thickness, continuity, and size of the aragonite crystals are less than the cements in the sample from the Bahamas above.

Sample from San Cristóbal Island, Galápagos, in which no cement is present in any intraskeletal pore.

Manzello et al 2008
Oceans in the eastern tropical Pacific are already relatively acidic due to the strong upwelling forces bringing up CO$_2$-rich waters from the depths below, where decomposition of dead organisms is taking place.

\[ \text{(CO}_3^{2-} \text{)} \]

A low carbonate saturation state is associated with this high partial pressure of CO$_2$ in water.

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{HCO}_3^- + \text{H}^+ \\
\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{HCO}_3^- \\
\text{CaCO}_3 \rightarrow \text{Ca}^{2+} + \text{CO}_3^{2-} \text{(coral)}
\]
High CO$_2$ saturated water creates low carbonate (CO$_3$$^{2-}$) saturation which makes CaCO$_3$ secretion very limited.

Corals need high carbonate saturation to secrete a dense framework.
Eastern Pacific reefs are poorly cemented accretions and subject to bioerosion

After the 1982-83 El Niño, Galápagos reefs were completely eroded in approximately 10 years.
Coral reefs are an accumulation of net accretion of \( \text{CaCO}_3 \) minus loss of carbonate structure due to erosive forces.

High \( \text{CO}_2 \) and high nutrient content in the water is thought to encourage bioerosive forces and algal growth.
Conclusions: Reef Framework

ETP reefs and their environment may be a real-world example of net coral reef growth in low carbonate saturated waters.

Ocean acidification is expected to reduce the rate at which corals build their skeletons.

Acidification could also decrease the precipitation of binding cements, making coral reefs more susceptible to erosion.
Summary

- Symbiotic zooxanthellae (clade) shuffling may allow for enhanced ability to resist thermal impacts (El Niño) in at least some coral genera.

- Eastern Pacific corals have adapted to a highly disturbed environment by increasing the number of gamete cycles per year, and therefore, the number of spawning episodes.

- Moderate seawater warming (+1-2 °C) can be associated with enhanced reproductive activity of the major reef-building corals in the ETP (increased gamete production and numbers of mature gametes/spawning).

- Eastern Pacific reefs may be a real-world example for the future of reef growth and structure in light of expected global warming and ocean acidification (lack of cementation and high bioerosion).
Acknowledgments

Funding: National Science Foundation

Logistical support: Smithsonian Tropical Research Institute, Charles Darwin Research Station, University of Miami Rosenstiel School of Atmospheric Science


Website: rsmas.miami.edu/bms
Eastern Pacific coral reefs exist under nationally occurring high-CO2, low carbonate saturation conditions that encompass the range of expected changes for the entire tropical ocean surface with a doubling or tripling of CO2.

Manzello 2009 (in press)
Secondary cements are formed by the precipitation of calcium carbonate that acts to bind framework components and fill up the spaces and pores in the reef.

This is the glue that helps to bind the reef components together and may minimize the rates at which erosive processes occur on reefs.

Manzello et al. 2008
Gamete Development Patterns—1985-1998