Reef Statistics

Area coverage: 600,000 km²

Economic value: \$375 billion/year Fishing/Aquaculture

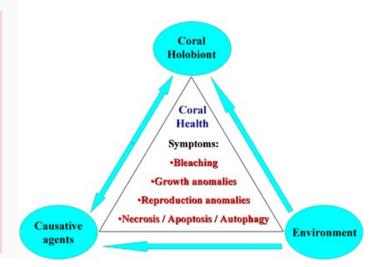
Tourism

Aquarium Industry Building Materials Ornamentals

Medical compounds

Shoreline protection **Nutrient recycling** Support of other habitats Aesthetic value Biodiversity

- 15% of the world's population lives within 100 km of a coral reef and most are in tropics-subtropics (mostly developing countries)
- 56% of all coral reefs are considered at moderate to high risk from direct human impacts (predominantly overexploitation and development) - WRI, 1998
- 27% of world's reefs considered dead (half of this is due to climate change



What Is Happening?

What Is Likely To Happen In This Century?

Addressing Knowledge Gaps

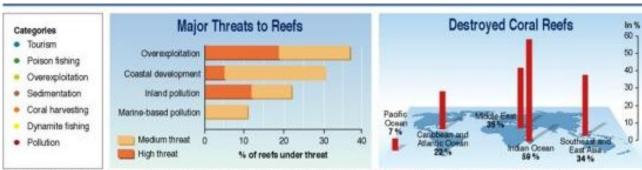
Key Adaptation Options

Sea surface warming has led to extensive coral bleaching events and declines in coral condition on the Great Barrier Reef and on north-western reefs (HIGH confidence). Ocean acidification and increased thermal stress are the likely causes of a >10% reduction in the growth rates of massive Porites corals on the Great Barrier Reef (MEDIUM confidence)

Frequency and severity of mass coral-bleaching events will increase as temperatures warm, leading to declines in coral reef health (HIGH confidence). Ocean acidification will reduce coral growth rates making reefs more susceptible to erosion and disturbance from storms (HIGH confidence)

Undertake experimental studies to strengthen predictions of thresholds for coral-algal phase shifts and loss of ecosystem function under climate change

Improve and maintain coastal water quality and healthy populations of herbivorous reef fishes to help sustain the resilience of coral reefs



Source: Bryant et al., Reefs at Risk; a Map-Based Indicator of Threats to the World's Coral Reefs, World Resources Institute (WRI), Washington DC, 1996.

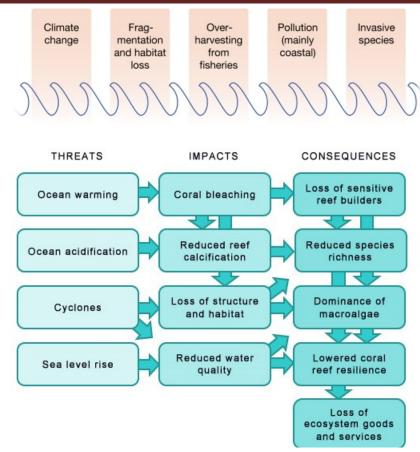
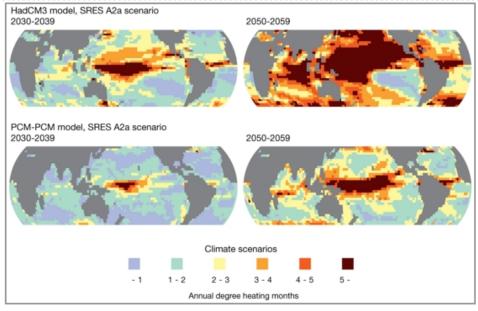


Figure 1. Flow diagram of functional links between climate-change threats, biological and ecological impacts and downstream consequences for ecosystem function. Only a subset of the key links and interactions (arrows) are shown.

Tropical sea temperature rises and coral reefs - climate change scenarios



Click here, or on the graphic, for full resolution.

Tropical sea temperature rises and coral reefs - climate change scenarios. The impacts of coral reefs from rising sea temperatures. When coral reefs become heat-exposed they die, leaving the white dead coral, also known as bleaching. With even moderate pollution, the coral are easily overgrown with algae, or broken down by wave activity or storms, leaving only "coral rubble" on the ocean bed.

Temperature & Coral Stress

Episodic warming

- An increase in max temperature
- Coral bleaching due to 'algal stress'

Chronic warming

- An increase in <u>average</u> temperature
- Coral bleaching due to 'physiological stress' (thinning of coral tissues)
- Coral disease

Death toll

 1997-1998: 15% of coral reefs worldwide destroyed by bleaching.



Coral Bleaching

"canaries in the coal mine"

Loss of zooxanthellae triggered by stress:

@ temperature, light, salinity



Natural process - affects many symbiotic organisms

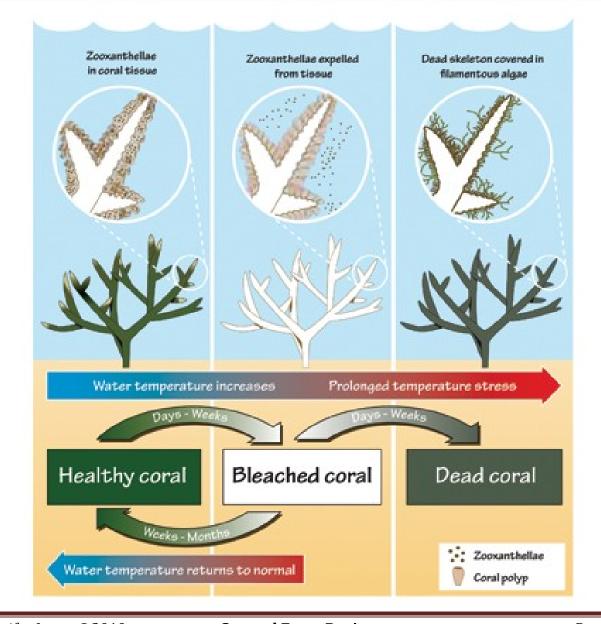
o hard and soft corals, anemones, giant clams, sponges

Association with increases in max SSTs, (ENSO-related)

- widespread
- often followed by mortality
- loss of 300⁺ year-old corals

Apparent increase in coral bleaching in past two decades*

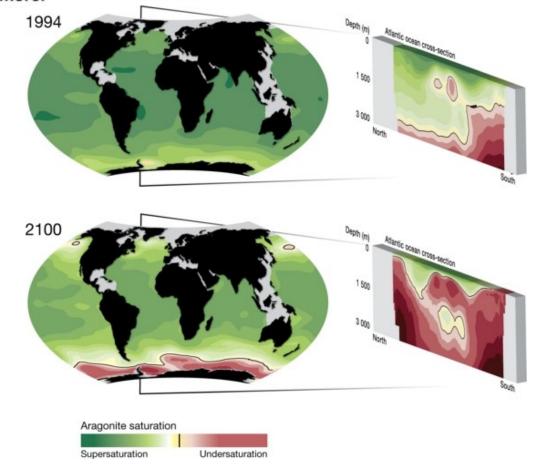
*confounded by increase in observations after 1950's



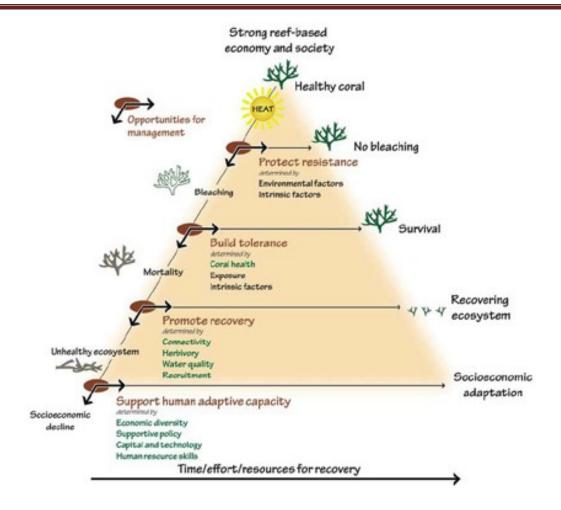


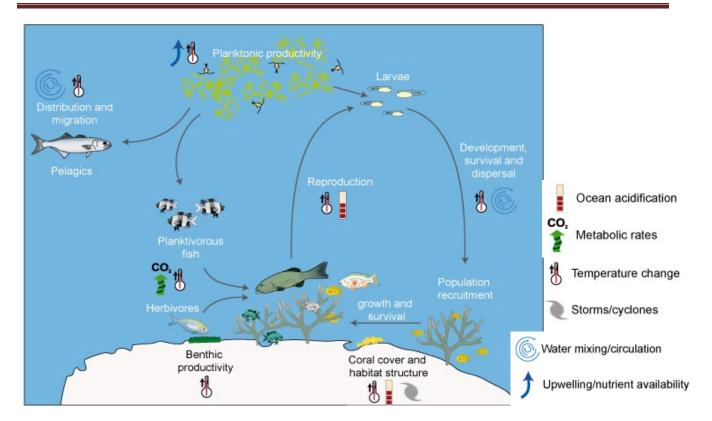
Provided

Pictured at left is the typical coral reef today on the southern Great Barrier Reef, which has endured a rise of 1 degree C and 375 parts per million of atmospheric carbon dioxide concentration. The middle frame shows what a reef would look like if global temperatures rise one more degree and CO2 concentrations increase, as predicted. The right frame shows what a reef would like if temperatures and CO2 levels rise even more.

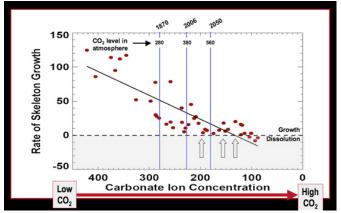


Coral Conceptual Model Energy Environmental Landuse Economic Fishing Tourism Management Decisions Management Decisions Management Development Regulations Policy, Regulatory, Economic, Stakeholder Anthropogenic Drivers Environmental Drivers Local Climate Fishery Contact Water Hurricanes Variability Change Quality Harvests Uses. **Boat Groundings** Erosion Sewage Tourism Ocean Solar Sea Physical **△** Stressors ↑CO₂ Pathogens Substrate Grazers Sediment HNutrients || Contaminants Adaptive Management circulation radiation temperature Damage Growth, Survival, Competition Reproduction, Deterioration Habitat Process ∆ Ecosystem Stony Soft Corals Invertebrates Structure Food Finfish Algae Corals Sponges Shellfish Function Grazing Biomass, Biomass, Type, Size, Type Abundance Supporting **∆** Ecosystem Regulating Provisioning Cultural Services Erosion Land Nutrient Primary CaCO₃ Fishing Pharmaceuticals Recreation Biodiversity Production Cycling Control Formation Deposition △ Value \$\$\$\$\$ Non-Economic Value **A** Human Well-being





Skeletal Growth in the B2 Reef Decreased Under Future CO₂ Conditions



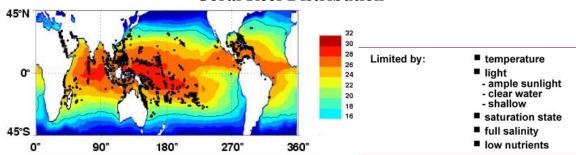
As greenhouse gases rise, they push down the levels of calcium carbonate in the oceans, resulting in a slower rate of coral skeletal growth.

Slowing Down the Carbonate Factory



Slowing down the 'carbonate factory' adversely effects ecosystems that are dependent on the reefs. (figure: Joannie Kleypas, NCAR)

Coral Reef Distribution



The natural distribution of coral is affected by ocean temperature, light, clear and shallow water, salinity, ocean chemistry and available nutrients (figure: Joannie Kleypas, NCAR)

Conclusions

Projected changes in climate will drive temperature and seawater chemistry to levels outside the envelope of modern reef experience

This hinders our ability to predict how coral reefs will respond in the future

We should expect surprises in how coral reefs will respond:

- x "Surprises" have already occurred
- x Climate surprises are likely

Our 'best' predictions are that climate change will lead to major changes in coral reef ecosystems, both biologically & geologically

- x Species assemblages will be pulled apart
- x Geological functioning of reefs will change



Projected changes in climate will drive temperature and seawater chemistry to levels outside the envelope of modern reef experience. Researchers are trying to determine what the possible long-range changes to our oceans might be, whether ecosystems can adapt to the predicted changes, and why certain reef systems are adapting to current changes better than others. This will help us to understand how our oceans, and the whole earth system, may change.

(figure: Joannie Kleypas, NCAR)