CORAL REEF IMPACTS

Prof Rupert Ormond
Heriot-Watt University
Marine Conservation International
International Society for Reef Studies

Corals & Reefs

- Coral colonies composed of small sea-anemone like individuals or polyps
- Skeletal cup (calyx) formed around each polyp
- Skeleton (of calcium carbonate) is external, secreted by base of polyps
- If coral tissue dies, this exposes the white skeleton underneath
- Polyps usually withdrawn into skeleton, but in some are fleshy
- Thin surface layer of tissue connects the polyps
- Reefs are underwater hill-like structures built up over many millennia
- They are composed of skeletal remains past generations corals, other calcareous organisms and sediment

Status of World's Reefs

- Recent decades wide range natural and anthropogenic impacts have caused global decline in reefs
- pre 1998 Caribbean (worst region) 21% destroyed, SE Asia 16%, but 1998 coral bleaching badly impacted Indian Ocean
- 2008 Status of Coral Reefs of the World (Global Coral Reef Monitoring Network) (Wilkinson et al. 2008)
  - –overall <u>19% of reefs effectively destroyed, 15% damaged or threatened</u> with destruction within near future.
  - –Caribbean & SE Asia worst regions, S Asia and E Africa also poor
  - –some recovery from 1998 bleaching that affected Red Sea & Indian Ocean
- In past three years widespread global coral bleaching caused greater impacts than in 1998
- <u>Main Impacts</u> (as per previous reviews) identified as:
  - –coral bleaching from warmer seawater due global climate change
  - –coral diseases, especially in Caribbean
  - –outbreaks of invasive species, especially Crown-of thorns starfish
  - –excess sediments flowing off the land or redistributed along coastlines
  - –pollution by nutrients arising from sewage input & agricultural run-off
  - –over-fishing and destructive fishing, especially of algal grazers
  - –destructive development of coastal areas.

Coral Mining

Affected Tanzania, Sri Lanka, Maldives, Indonesia, Philippines, Solomons where are only source building materials

Sri Lanka originally only emergent reefs mined, then mining of fringing reef caused coastal erosion to 300 metres over 50 yrs

Maldives est. ~100,000 m^3 mined from North Male atoll alone 1972-1985, originally only for public buildings, by 1990s extensively

- significant decline in coral cover & diversity and in fish assemblages
- no mining on Male since 1995 due controls and incentives

Oil Pollution

Most oil spills cause little if any effect, especially if pass over at high tide but impacts shown for a) long-term chronic pollution, and
b) in few cases acute spills, depending state of tide and type of oil

- Eilat, Gulf of Aqaba: impact first demonstrated, due chronic low level oil pollution near oil terminal
  - higher mortality, reduced breeding, fewer ova per gonad, reduced settlement in *Styllophora*
- Caribbean side Panama Canal: impact due acute major oil spill recorded coral cover decreased by 76% at .5 - 3 m, and 56% at 3-6 m on heavily oiled reefs
- Still concern that spill dispersants may be more harmful than the oil
- Concern following recent Deepwater Horizon blowout in Gulf of Mexico that deep water reefs may have been affected

Oiled coral exposed at low tide, Bahía Las Minas, Panama (Carl Hansen)

Sedimentation

- Extensive sediment impact globally due increased river sediment loads (deforestation, agricultural intensification), coastal erosion (coastal engineering), and dredging
- Considered one of greatest causes of reef degradation (Rogers 1990)

- Corals adapted to clear small amounts of sediment using cilia, mucous and tentacles
- Can tolerate high doses for short period, but succumb to low chronic sediment loads (Rogers 1983)
- Characteristic symptoms - sediment accumulates on top and upper surfaces of colonies leading to tissue death
- Even in most adapted species e.g. Brain corals affected

Sedimentation

- Other studies suggested little effect of sediment because can be diverse reef communities in conditions high turbidity & low visibility
- Susceptibility varies greatly between species due various active (e.g. cilia) and passive (e.g. shape) mechanisms
- Effect depends sediment size, fine sediment stays in suspension, smaller sediment can be removed
- Also depends nature of sediment – calcareous, siliceous, clay or organic
- Stress on adults due i) smothering, ii) abrasion, iii) shading, iv) infection
- In general non-impacted reefs experience settling 1-10 mg cm^{-2} day^{-1} and suspended sediment load of 10 mg l^{-1}

Coastal Development

- Development may be residential industrial, commercial or touristic
- Infilling for development causes <u>direct habitat loss</u> and <u>indirect damage via sedimentation</u>
- Dredging for boat channels or fill also causes direct habitat loss & damage via sedimentation
- Infilling, sea wall and beach creation also often causes much damage via subsequent <u>coastal erosion</u>

Tourism & Recreation Direct Impacts

- Souvenir collection was earliest concern
- Anchor damage originally main cause damage associated with dive boats & cruising yachts – still occurs
- Use of moorings now often compulsory
- Physically damage by snorkellers and bathers now major cause coral damage in e.g. Egypt, Hawaii
- Coral breakage, crushing, abrasion & increased sedimentation
- Some reef sites > 100,000 people / year

Nutrification & Algal Overgrowth

Many regions increased macro & filamentous algal cover has much reduced coral cover & diversity, especially Florida & Caribbean

Kaneohe Bay Hawaii in response discharge secondary treated sewage 1963 – 1977; reef community overgrown & dominated by green bubble algae *Dictyosphaeria cavernosa*

Jamaica following sea-urchin die-off due disease fleshy algae came to dominate reefs between 1980 & 1990 = phase shift (Hughes 1994)

Debate whether due increased nutrients (Lapointe 1997), or reduced grazing by herbivorous fish (Woodley et al. 1999)

Recent studies show wide-scale elevated nutrient levels in Florida and GBR

Other areas seems removal fish grazers (parrotfish, surgeonfish, rabbitfish) critical

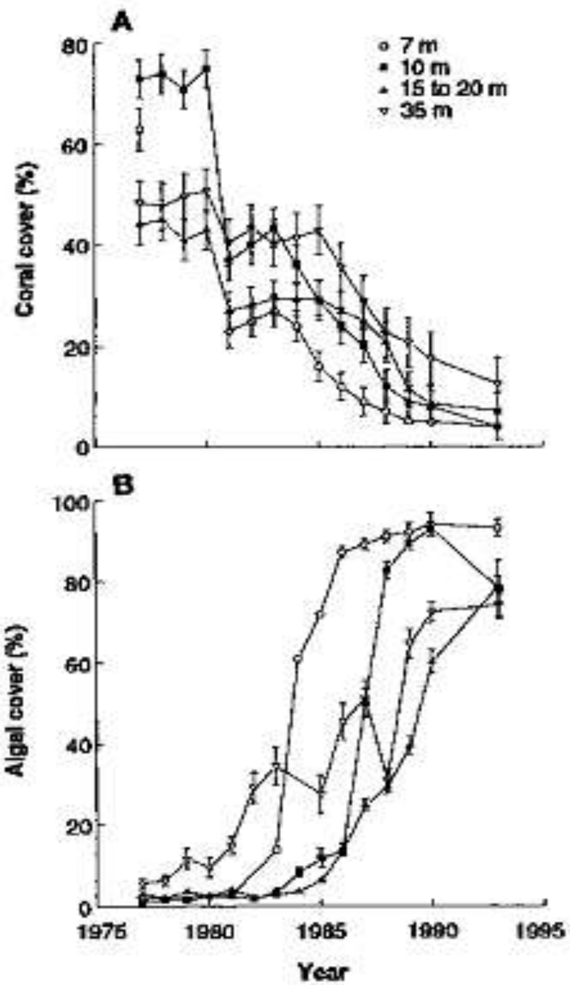


Fig. 3. Degradation of Jamaican coral reefs over the past two decades. Small-scale changes in (**A**) coral cover and in (**B**) macroalgal cover over time at four depths near Discovery Bay (32).

Coral Diseases

- Small number coral diseases first reported in early 1970s, notably White-band Disease (WBD) & Black-band Disease (BBD)
- Some 30 coral diseases now described, including variety of now ofetn called “White Syndromes”
- Caribbean reefs especially effected, diseases common on > 60% of reefs
- 2 of 3 main reef building corals in Caribbean (*Acropora palmata & A. cervicornis*) once abundant but now endangered due disease
- Regular surveys on GBR suggest sharp rise over last 20 or so yrs of 2 or 3 diseases (Willis et al, 2004)
- Recent research shows especially white syndromes associated marked changes in associated bacterial flora - <u>coral microbiome</u>



Crown-of-thorns starfish

- *Acanthaster planci:* multi-rayed starfish typically 25-35 cm diam. but can grow > 70 cm
- Feeds predominantly on hard corals by everting stomach and digesting coral tissue
- Several periods in last 50 yrs large population outbreaks especially on GBR (Australia)

- Also elsewhere in Western Pacific (e.g. Guam, Riyukus, Fiji) and Indian Ocean (e.g. Maldives), increasingly high numbers appear <u>endemic</u>
- Elsewhere occur in normal density <20 per km compared >30 per ha. (and often hundreds) on many reefs in outbreak areas
- Debate whether outbreaks natural occurrence or recent cycles due human actions

Hypotheses for outbreaks

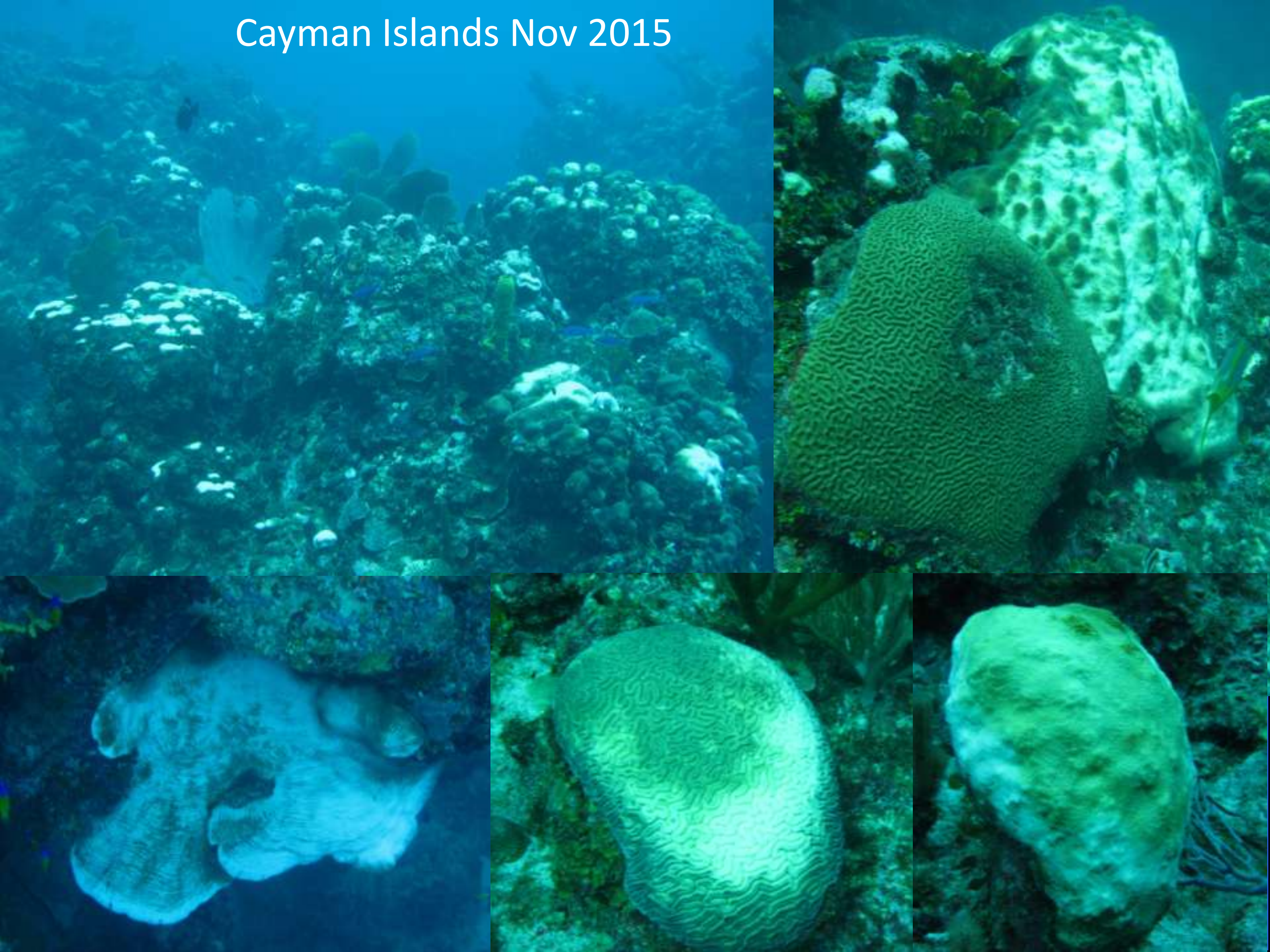
- Natural events hypothesis: fluctuations typical of many marine inverts and evidence *A. planci* locally abundant in some regions in past
- But so many large slow growing corals could not have survived large outbreaks taking place on a regular basis
- Terrestrial run-off hypothesis (Birkeland) suggests run-off of nutrients may increase phytoplankton food of starfish larvae
- Predator removal hypothesis proposed loss of population control by loss keystone predator - first suggested Giant Triton (*Charonia tritonis*)
- Own studies indicated outbreaks associated reduced numbers of Triggerfish (Balistidae) & Emperors (Lethrinidae)

Sea-Urchin Outbreaks

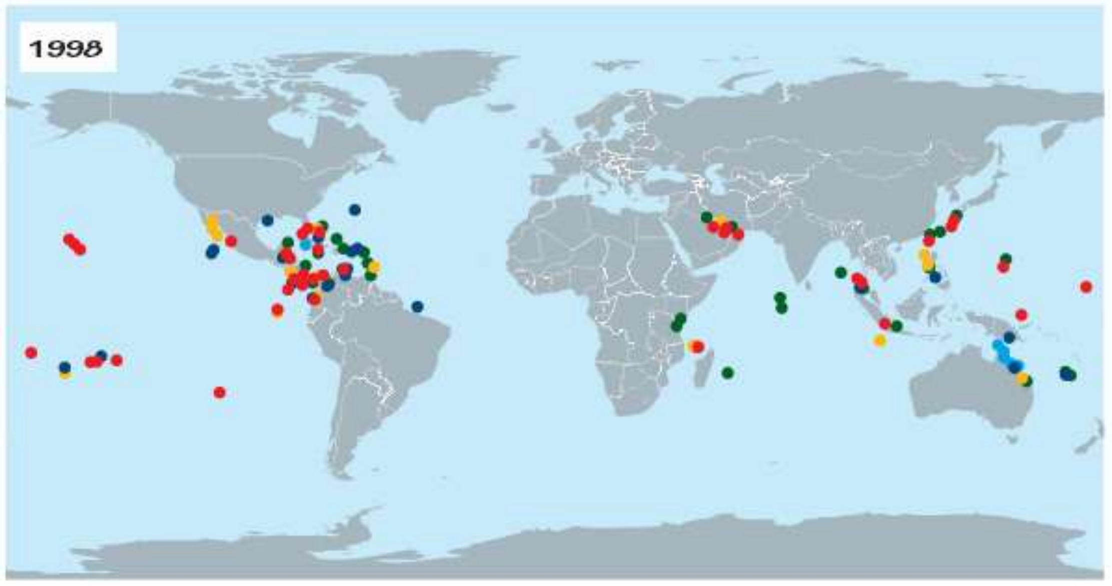
- Sea urchins densities (*Diadema & Echinothrix)* densities in Caribbean and W. Indo-Pacific originally about 0.5 – 5 per m^2
- in 1970s in Caribbean high densities *D. antillarum* grazed on coral causing extensive mortality & erosion (though in 1980s became scarce due spread of disease from Pacific)
- Later in Indo-Pacific high urchin abundances caused coral mortality through erosion & collapse of corals e.g. Kenya, Arabian Gulf
- Strong evidence (especially from Kenya) that outbreaks due removal of fish predators – more fish & fewer urchins in existing & new MPAs


Coral Bleaching

- Corals turn partly or wholly pale or white but retain tissue, due loss from cells of symbiotic algae known as zooxanthellae (0.5 - 5 x 10^6 per cm^{-2})
- If conditions prolonged (> week) corals die revealing white skeleton
- Occasionally observed in past due shading or other factors
- In past 3 decades "Mass Bleaching" events associated high sea temperatures, often also calm conditions and clear skies
- If impact mild effects only more sensitive spp. (*Acropora, Pocillopora*) or causes blotchy pale areas mainly over upper surfaces
- Characteristic features: <u>tissue present at first</u>, often <u>blotchy appearance</u>, <u>more towards light</u>, affects <u>widespread</u> over 100s m to 10s kms, affects <u>all corals of given species</u> within an area down to a particular depth

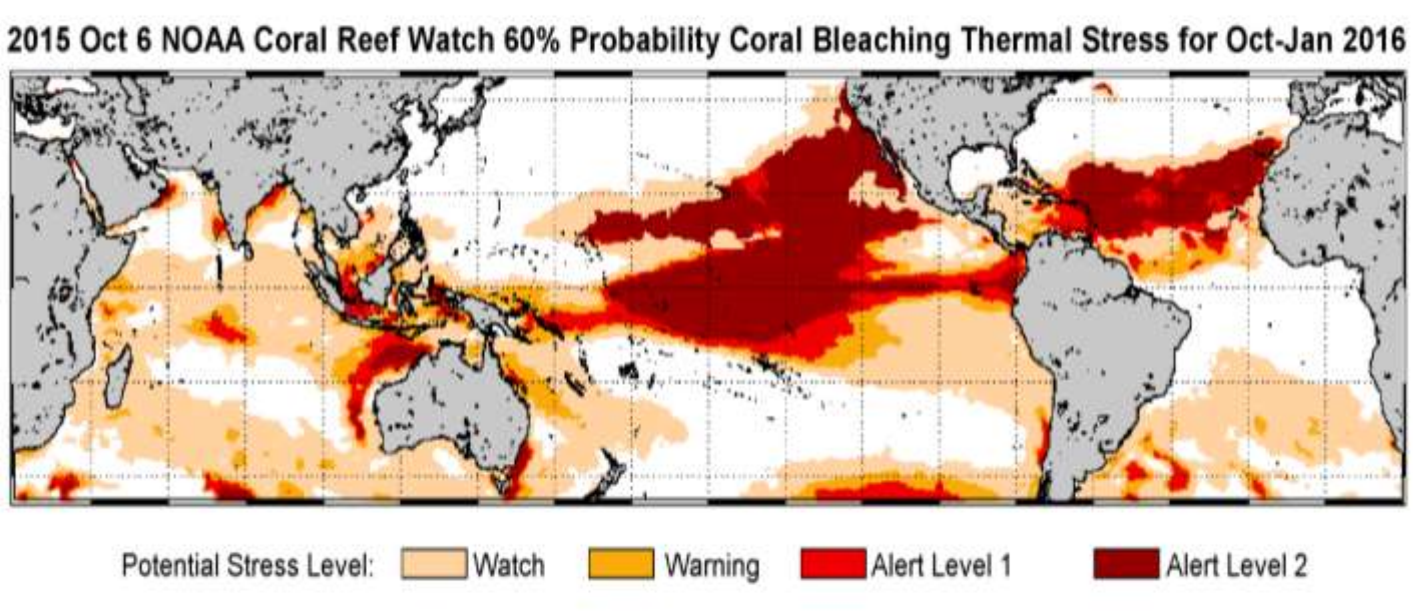

Cayman Islands Nov 2015

Cause: unusually high ocean temperatures (SSTs)



- Primary cause is elevated SST > 1ºC above normal summer maximum, critical temperature varies with location 28.3 - 30.2 ºC
- Many correlations site temperatures and bleaching e.g. Tahiti – repeated bleaching when SST >1 ºC above normal
- Identical bleaching if expose corals to experimental increase in temperature (in outdoor culture tanks)
- Coral bleaching not recorded before 1979; “mass” bleaching first noted in Eastern Pacific 1982-83 & Caribbean 1987-88
- Subsequent increasing frequency; most severe events to date in 1997-98 (when Indian Ocean affected for first time) and 2015-16
- In 1997-98 95% bleaching in Bahrain, Maldives, Sri Lanka, Tanzania; 50-70% in Seychelles, Kenya, Chagos, Thailand, Palau & Belize

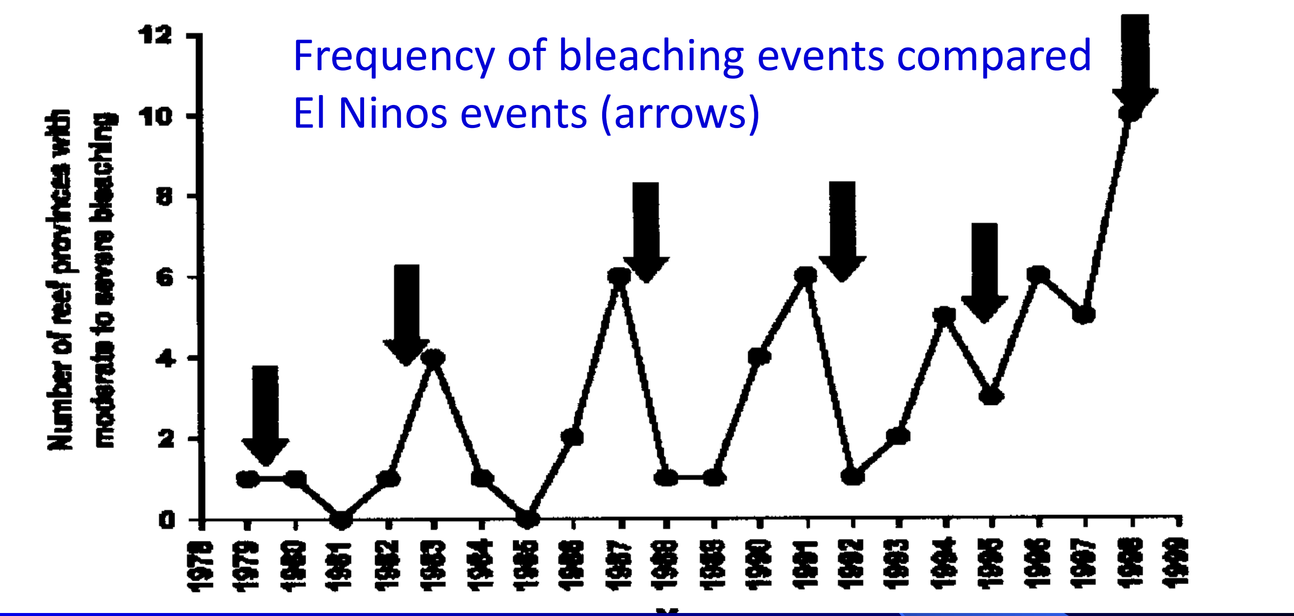
Link with Warming Oceans



- Ocean wide monitoring by satellite also shows bleaching associated bleaching with above normal SSTs (see 1998 above)
- Now bleaching regularly observed in situ after “hotspots” detected by satellite and bleaching predicted (Strong, NOAA)
- 1998 and 2015 warmest years for 600 years (for which estimates available)
- Modern satellite, ship and buoy data show warming at increasing rate - over last 20 years now 1.5 - 2.5 ^{o}C 100 yrs^{-1}
- Pattern confirmed by analysis of coral cores which reveal annual growth rates and SST via isotope ratios

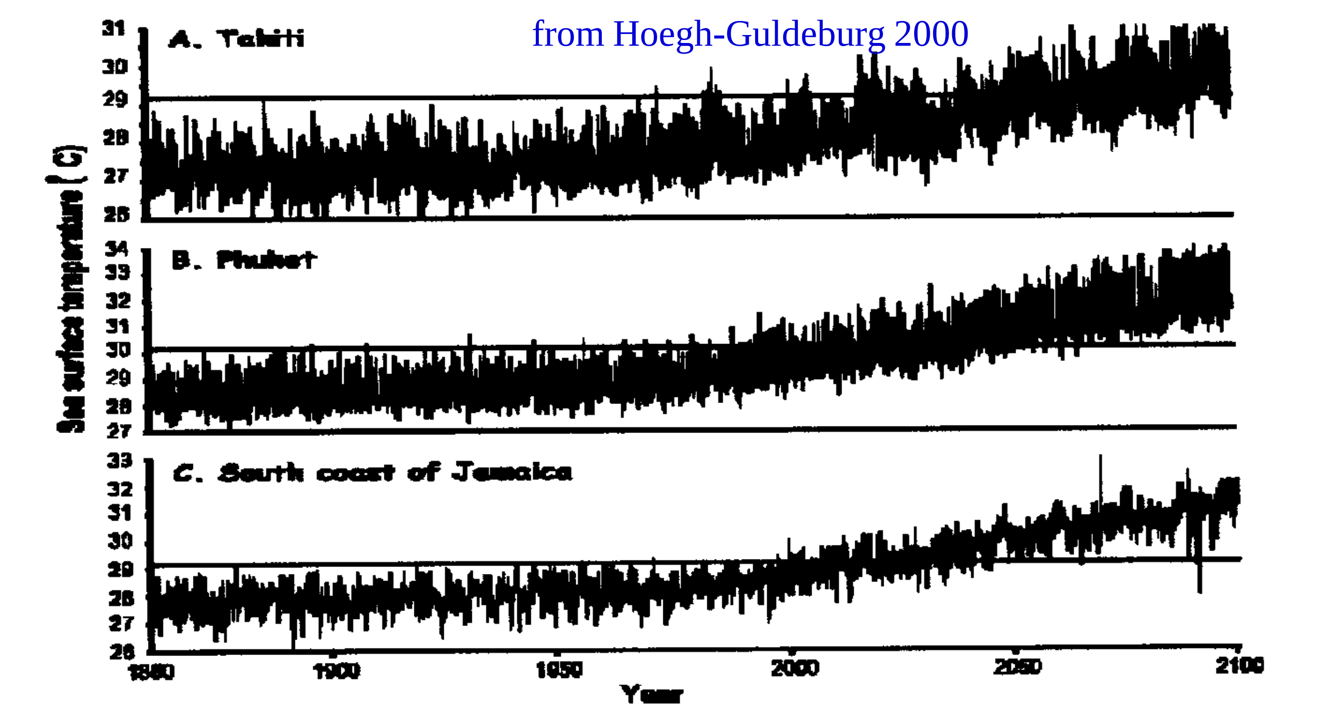
Coral Bleaching

El Nino and Light



- Bleaching tends to occur in El Nino / ENSO events when SSTs above normal; 1997/98 El Nino was strongest on record
- Now appears may also be statistically significant increase in frequency El Nino events
- Temperature effects exacerbated by intense light, hence bleaching more on upper surfaces or in direction of sun
- Corals have protective mechanisms against excess light, including UV absorbing pigments & reactive oxygen scavengers
- Evidence high temperatures damage these protective mechanisms

Modelling Ocean Warming



- Outputs of 4 General Climate Models incorporating greenhouse effect support relationship with increasing SSTs
- Models indicate slow rate of increase until about 1960s
- Then SSTs begin surpass thresholds for coral bleaching in warmest (= El Nino) years from about 1980
- Explain why corals now appeared to exist <u>so close to tolerance limit</u>
- Due time lag between atmospheric CO2 and global temperatures continuing increase in SST ineviatble
- Predict most regions experience bleaching every year within 30-50 yrs
- Coral communities take up to 10 plus years to recover

The Paris Climate Change Conference
(November – December 2015)

- The International Society for Reef Studies calls on all nations and negotiators at the Paris Climate Change Conference to commit to limiting atmospheric carbon dioxide (CO_2) concentrations to no more than 450 ppm in the short-term, and reducing them to 350ppm in the long-term.
- This should keep average global temperature increase to less than 2°C (or 3.6°F) in the short-term, and less than 1.5°C (or 2.7°F) in the long-term, relative to the pre-industrial period. This would prevent global collapse of coral reef ecosystems and allow coral reefs to survive in perpetuity.

Concluding Remarks

- Not always immediately clear if particular impacts are natural or anthropogenic – coral bleaching, echinoderm outbreaks
- Evidence reef diversity may be maintained or enhanced by intermediate levels disturbance
- Was past debate over real extent impacts and whether reefs fragile or robust in view of their long geological history
- Importance different impacts not match public assumptions – sedimentation, nutrification, disease all very important, oil pollution not
- Impacts of climate change (coral bleaching) now over-riding all other threats and other management advances
- Also clear chronic anthropomorphic stress tends prevent recovery from natural stressors (e.g. hurricanes, bleaching)