Science Topics 09-23-23

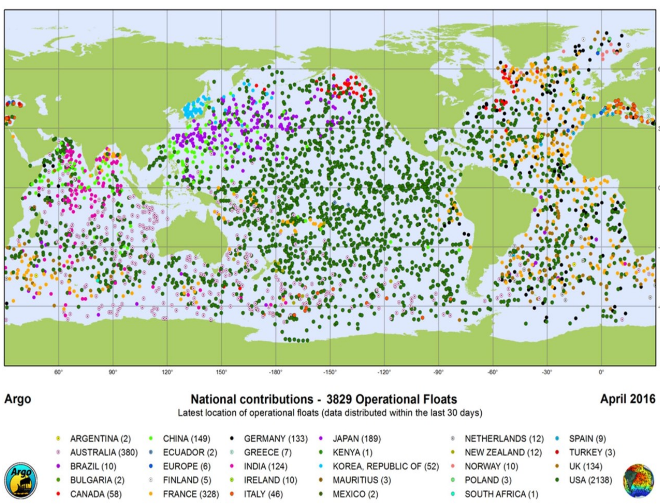
CliSciPol

Climate Science and Policy for Nonscientists

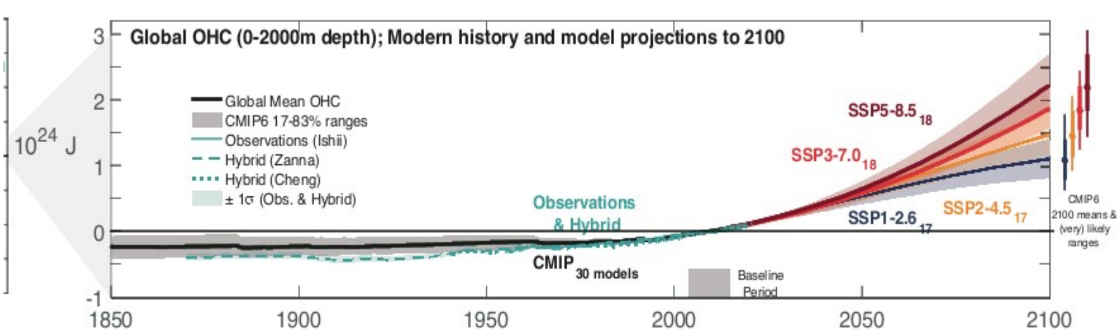
One picture is worth a thousand words.

Ocean Temperatures and Acidity are Rising - How Much?

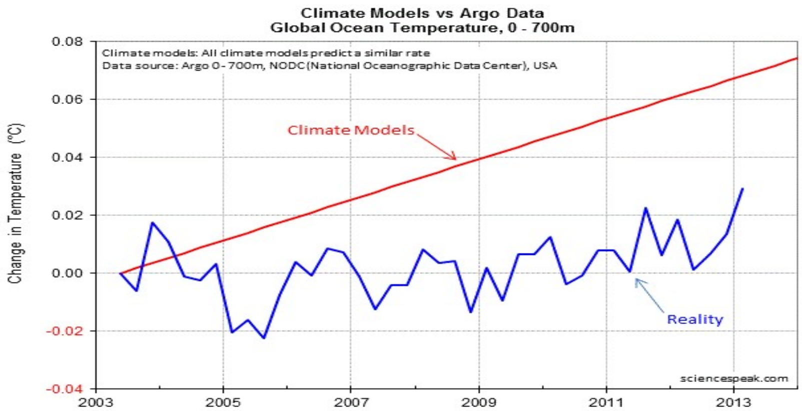
The average ocean temperature is about 39 F, and the average atmospheric temperature is about 59 F, so the atmosphere is, on average, warming the oceans, and this warming will continue as long as the atmosphere is warmer than the oceans. But how much are the oceans warming? The heat capacity of the oceans is about 1,000 times greater than the heat capacity of the atmosphere. If the oceans absorb enough heat energy to reduce atmospheric temperatures by 10 degrees, the oceans warm only by 0.01 degrees, a trivial amount.



Scientists in 2003 launched the Argo Project to obtain comprehensive measurements on ocean temperatures and other variables. There are now over 3,900 Argo floats in operation throughout all the oceans of the world. Since 2003 for the first time scientists have comprehensive data on ocean temperatures down to 2000 meters (1.2 miles), the limit of the Argo floats. On average the oceans are about 2.4 miles deep. Scientists had relatively limited data on any ocean temperatures before 2003, and they still have relatively limited data on ocean temperatures below 2000 meters (the lower half of the oceans), which IPCC AR6 admits are "poorly sampled." (IPCC AR6 WGI p.350)



AR6 does not cite actual Argo temperature data. Rather it cites Ocean Heat Content ("OHC") as in this graph showing OHC to be relatively unchanged from 1850 to the present with the rate of rise projected to increase by different amounts depending on various assumptions of atmospheric temperature rise.



Actual Argo data shows ocean temperature rising only a few hundreths of a degree per decade. But, as usual with IPCC models, the models calculate much greater rise than is actually occurring. The measured temperature rise is much too small to have any significant effect on coral or other ocean life

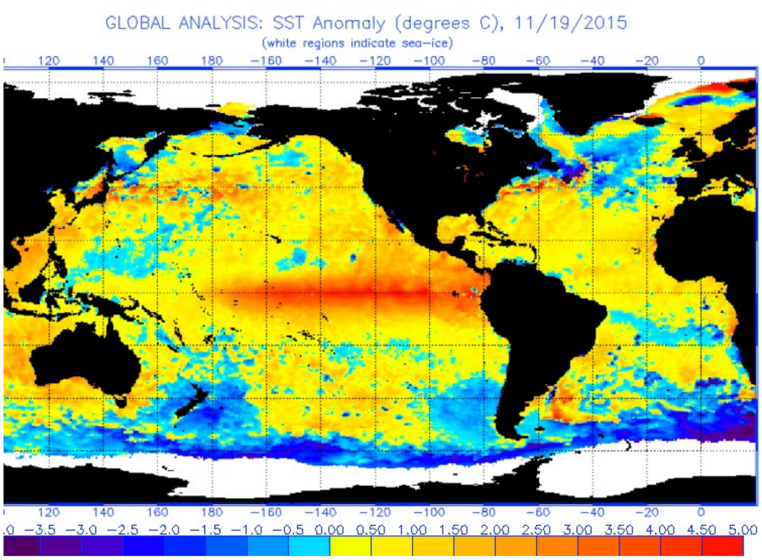
Beside temperature rise AR6 also discusses "marine heat waves," which AR6 claims "can lead to severe and persistent impacts on marine ecosystems" including coral, and which are "increasing" in frequency. (AR6 WGI p.1227). But the term "heat wave" lacks any clear definition. AR6 provides no quantification of the temperatures involved, or the increase in frequency. There is no explanation as to how rising atmospheric CO_2 levels (CO_2 being an evenly distributed gas in the atmosphere) and rising atmospheric temperatures can cause a marine heat wave as opposed to a general warming of the oceans

Marine Heatwave

A period during which water temperature is abnormally warm for the time of the year relative to historical temperatures with that extreme warmth persisting for days to months. (WGI Glossary 37)

Heatwave

Heatwaves and warm spells have various and, in some case, overlapping definitions. (WGI Glossary 30)



AR6 does not discuss heat wave causation. El Ninos can cause heat waves that are hot enough to cause coral bleaching on the Great Barrier Reef, e.g. in 2015-2016, the only coral bleaching incident mentioned in AR6. (AR6 WGI p.1842). Also underwater volcanic eruptions can cause "blobs" of very hot water that can cause coral bleaching. The massive El Hierro submarine volcano eruption in the Canary Islands, which lasted from October 2011 to March 2012, caused a blob that was still hot enough to melt sea ice when it arrived in the Arctic due to ocean currents. One volcanologist estimates that about 75% of the world total volcanic activity occurs below sea level.

The pH scale only runs from 0 to 14. A pH of 7.0 is neutral. Above 7 is alkaline. Below 7 is acidic. But for most of the 0-14 scale any effect on the skin is hard to detect. Lemon juice has a pH of around 2. An apple around 3. Clean rain is 5.6. Sea water presently averages around 8.1, which is significantly on the alkaline side of neutral, and it varies from around 7.8 to 8.5 by location, by depth, and from day to day. As atmospheric CO_2 levels rise, the oceans absorb more CO_2 from the air, and this reduces the oceans' pH.

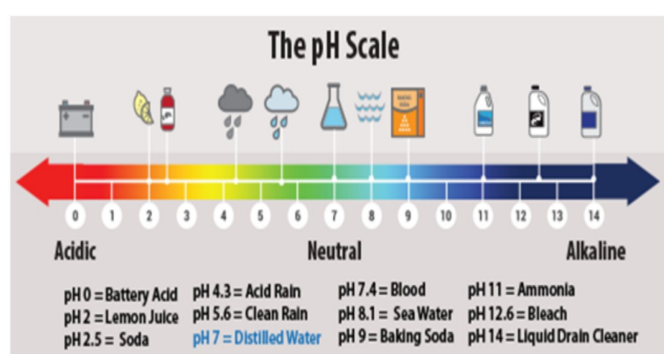
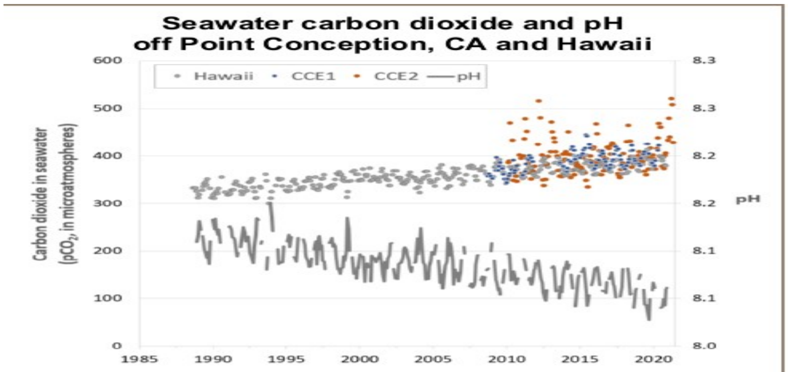


Figure 1: Comparison of the pH of common substances. Data source: U.S. Environmental Protection Agency

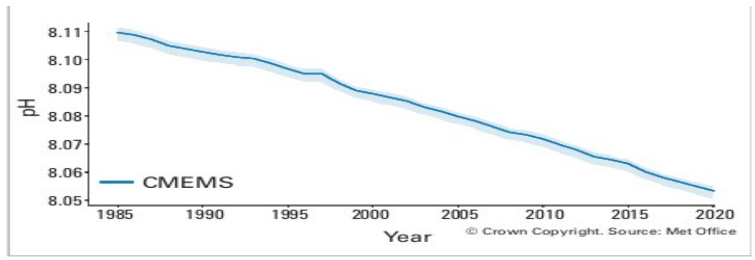


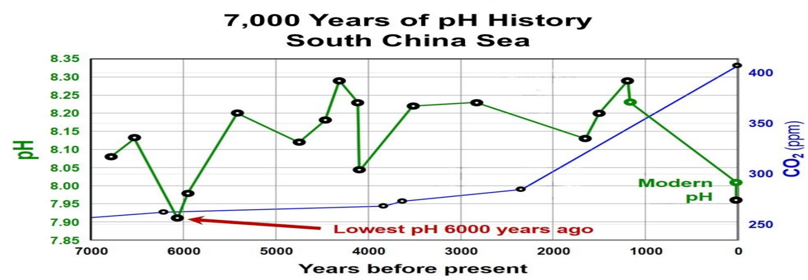
Levels of carbon dioxide in seawater off Hawaii have increased (by about 1.8 microatmospheres per year) over the past three decades, accompanied by increasing acidity (decreasing pH). While not long enough to show a trend, levels off Central Califomia over the same period are similar (CCE1), but are more variable closer to the coast (CCE2).

Scientists have extraordinarily meager measured data on ocean pH. The existing measured data is only from a few locations going back only 30-40 years or so. Even today very few of the Argo floats measure pH. This variable (ocean pH) was not considered an issue prior to 2003 when the phrase "acidification" was coined for its shock value. The oceans are not becoming acidic. They are becoming slightly less alkaline. Such measured data as exists shows only slight pH reduction. For example, the pH of the ocean water around Hawaii and around Central Californiahas declined (become more alkaline) from about 8.14 to 8.10 over the 30 year period 1990-2020.

The British Met Office shows ocean pH falling from about 8.11 in 1985 only to about 8.05 in 2020, a period of 35 years.

Figure 9. Global mean ocean surface pH (blue) covering the period 1985–2020. The shaded area indicates the estimated uncertainty in each estimate. Data from Copernicus Marine Environment Monitoring Service. *Source:* Met Office, United Kingdom.

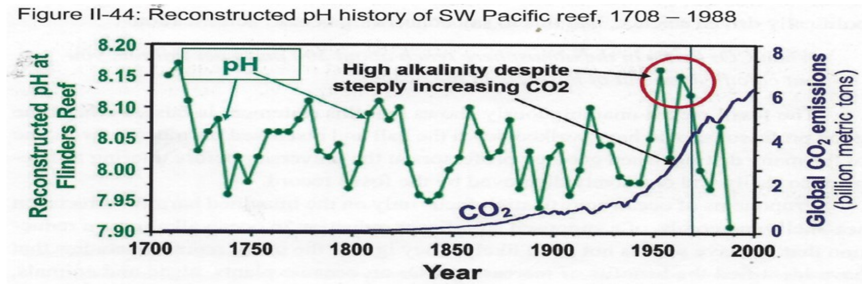




Source CO^2 data: Barnola, et al., 2003. Historical Isotopic CO2 Record from the Vostok Ice Corehttp://cdiac.ornl.gov/trends/co2/vostok.html
pH Data: Reconstructed pH history of the South China Sea. Created from Table 1 of Liu et al. (2009)

Proxy data shows that ocean pH varied from 7.9 to 8.3 over the last 7,000 years, but never approached 7.0, the transition to acidic. There is no apparent correlation with atmospheric CO2 levels.

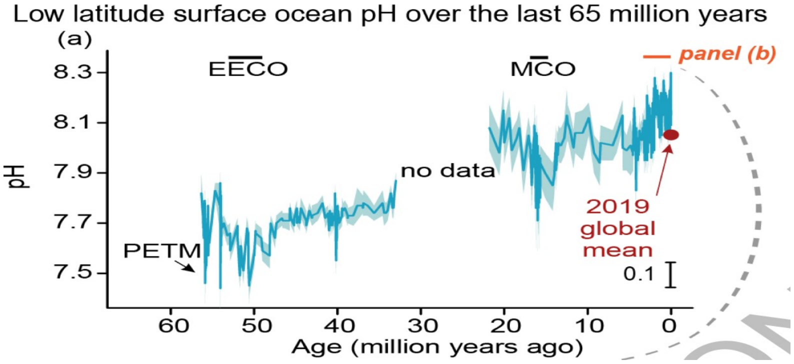
Figure II-44: Reconstructed pH history of SW Pacific reef, 1708 – 1988



(pH: modified from Pelejero 2005; Source CO_2: Boden 2016)

Here is another study using proxy data for the period 1708-1988 also showing ocean pH erratically varying from 8.17 to 7.91 over 280 years with no correlation between ocean pH and CO2 emissions.

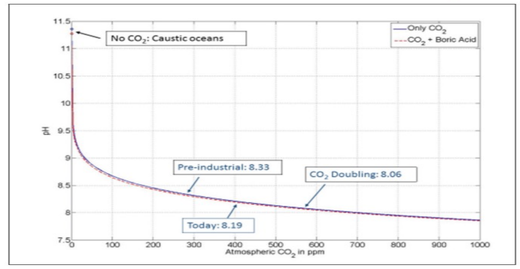
Low latitude surface ocean pH over the last 65 million years



Proxy data from 35-55 million years ago suggests that modern pH is unusually high. Atmospheric CO2 during this period was around 1,000 ppm, much higher than today's 420 ppm, but pH then was in the range of 7.6-7.8, slightly lower than today and nowhere near acidic. Coral existed during this period and survived.

Theoretical calculations show that increasing CO2 levels from today's 420 ppm to 1,000 ppm will have minimal effect on ocean pH and will not bring ocean pH any where near to 7.0 neutrality, let alone turn the ocean acidic (pH below 7.0)

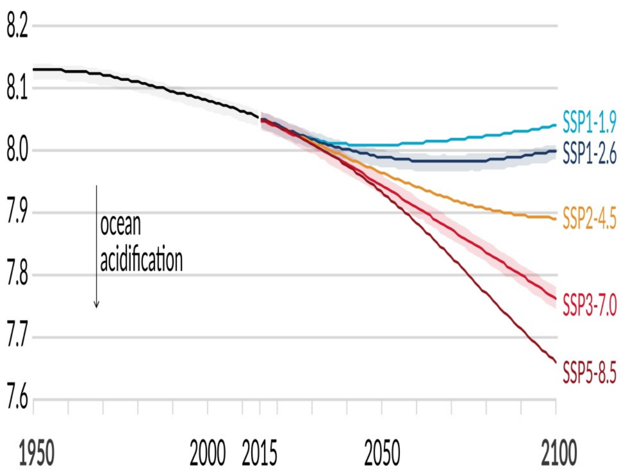
Figure 15. Computed pH of Ocean Water vs. Atmospheric CO_2 Concentration*



*Curves show the buffering effect of CO_2 alone and for CO_2 plus ocean boron content (0.42×10^{-3} M). The alkalinity of the ocean is assumed to be 2.3 mM. Increasing CO_2 from today's value, 400 ppm, to 500 ppm will reduce ocean pH by approximately 0.08; to 600 ppm will reduce pH by 0.15. The projected ocean pH reduction for a doubling of CO2 since the beginning of the industrial revolution (around 280 ppm in 1800) is 0.27, half of which has already occurred. A simple extrapolation of the current rate of increase of atmospheric CO_2 of 2 ppm per year would result in 600 ppm in the year 2100.

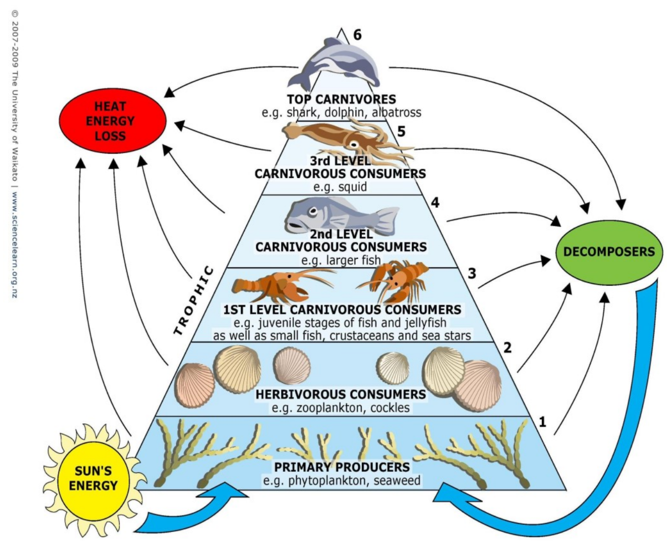
Source: R. W. Cohen and W. Happer, *Fundamentals of Ocean pH* (2015), http://co2coalition.org/fundamentals-of-ocean-ph/

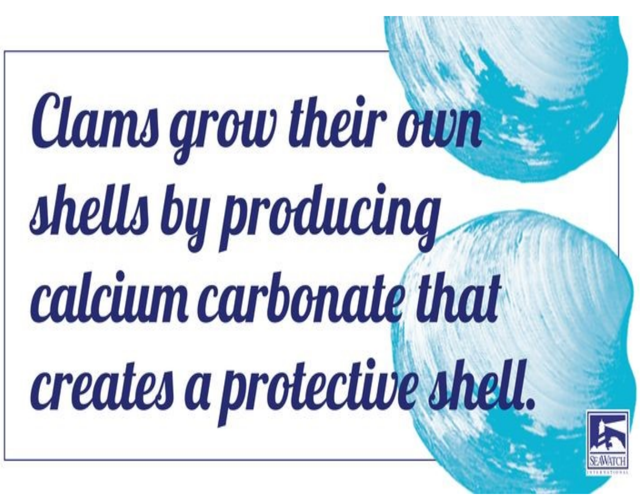
c) Global ocean surface pH (a measure of acidity)



This graph came from AR6. (WGI p.22). It uses the words "acidity" and "acidification," but what the graph actually shows is ocean alkalinity declining from about 8.14 in 1950 to 8.05 in 2015, a 65 year period and a trivial amount that is nowhere near turning acidic. Projections through 2100 are shown based on 5 different sets of assumptions. Scientists now generally agree that the assumptions in SSP3-7.0 and SSP5-8.5 are implausible, and that the earth is evolving on a path causing less chlimate change than the assumptions in SSP2-4.5, which puts pH in 2100 around, or slightly above, 7.9, a number that is far above 7.0 neutrality.

Increased CO2 concentrations in the oceans is beneficial to ocean life in general. CO2 is plant food, so increasing CO2 levels increase the production of plankton and algae, which are at the base of the ocean food chain. Coral depends on algae for food. As the amount of food at the base of the food chain increases, populations of organisms all up the food chain increase.





Also coral and shelled organisms use the CO2 in the ocean to make the calcium carbonate (CaCO3), which forms their structures and shells: CaO + CO2 = CaCO3. So increasing CO2 concentrations in the oceans can facilitate this process so long as pH levels do not actually fall significantly below 7.0 neutrality. Freshwater lakes commonly have acidic pH (between 6 and 7), yet many shelled species, e.g. types of clams and mussels, live in such lakes.

Conclusion as to Ocean Warming and Declining pH

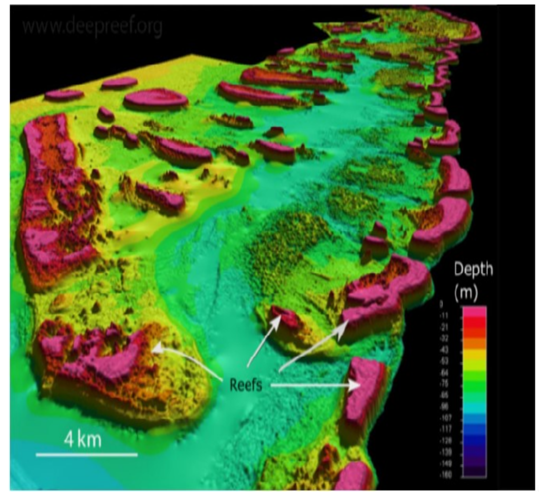
The oceans are warming at a trivial rate as measured by the Argo project. Measurements show that the ocean pH is in the range of 7.9-8.1, which is alkaline, not acidic. The pH is declining at a slow rate but by the year 2100 pH is predicted to still be far from turning acidic, which occurs at pH 7.0 on the pH scale of 0 to 14. The combined effect of slight ocean warming and slight pH reduction is more likely to be beneficial than to be harmful for coral and other shelled organisms, as further discussed below

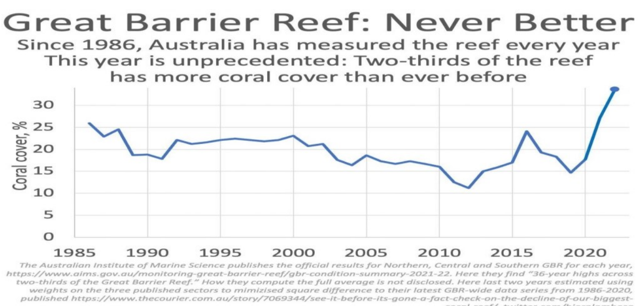
Coral

Scientists have relatively meager data on coral. By far the most studied reef in the world is the Great Barrier Reef ("GBR") off the East coast of Australia. This reef is over 1,400 miles long, running from North to South, and is more accurately described as a collection of over 3,000 individual reefs. Reefs come and go as ocean levels rise and fall. Most reefs today are only between 5,000 and 10,000 years old.

Figure 2: Reef structure

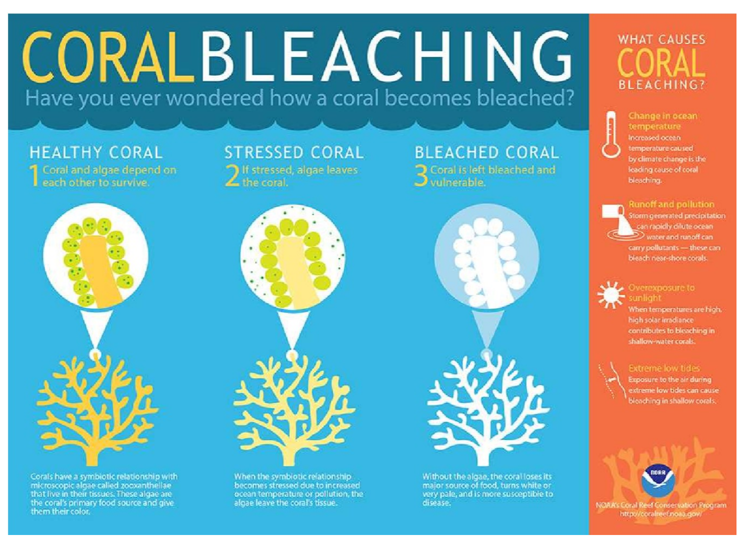
Coral reefs are a thin veneer of living coral residing on a pile of coral rubble or thick beds of consolidated coral rubble. These reefs from the Great Barrier Reef are flat–topped underwater hills around 50–100 metres high sitting on a relatively flat continental shelf. Coral reefs require continuous coral death to grow to the sea-surface. (Courtesy R. Beaman, deepreef.org)





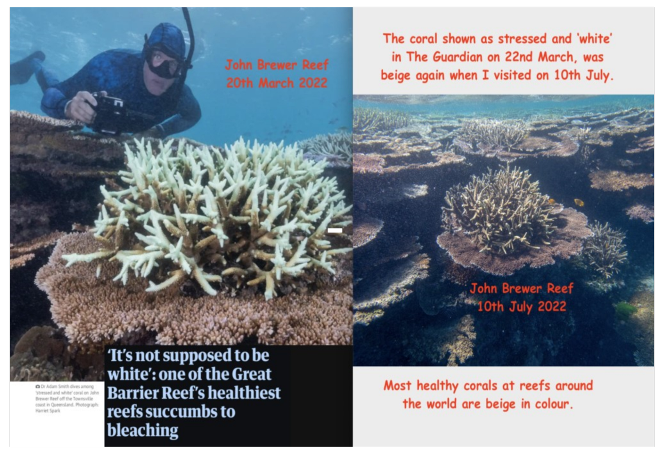
The GBR has been monitored since 1986 by the Australian Institute of Marine Science. ("AIMS"). The most recent AIMS data which covers from 1986 to 2022 shows that reef coverage presently is the highest it has ever been over the 36 year period.

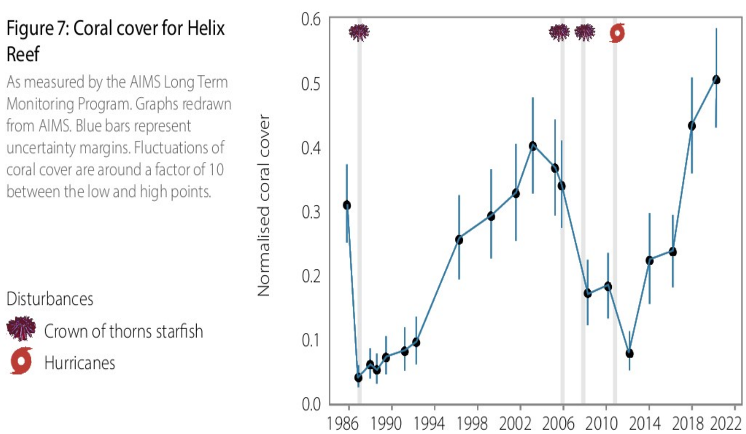
Coral and algae have a symbiotic relationship. Algae lives within the structure of hard corals and provides food for the coral and also creates the apparent color of the coral. Various events cause the coral to eject its resident algae. This causes the color to become white, the color of calcium carbonate or limestone ($CaCO3$) of which hard coral is made. Such coral is commonly referred to as "bleached" although this is a distortion of the dictionary meaning of "bleach." The ejection of algae is a voluntary action undertaken by the coral itself.



The image shows some bleached coral. Scientists are still trying to understand the significance of bleaching. One theory (that is often implied, if not stated, in the media) is that bleaching is substantially equivalent to death. Since coral's ejection of its algae is a voluntary action, this is equivalent to saying that coral commits suicide.

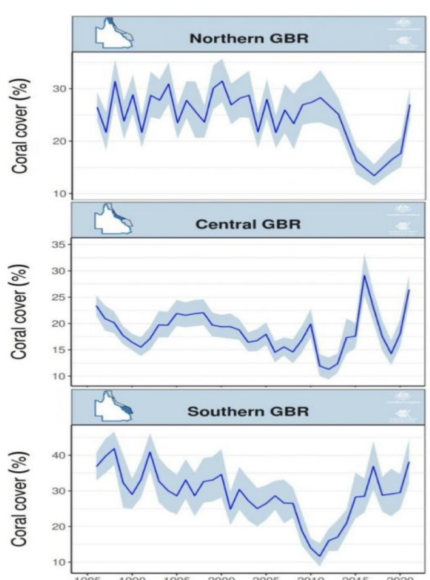
Scientists are increasingly studying coral recovery from bleaching and are documenting dramatic coral recovery, as shown here. Trees shed their leaves in response to the cooling stress of fall weather, but trees then come back to life in the spring. Scientists are increasingly understanding coral bleaching in these terms. It is the only explanation for the present health of the GBR after supposedly suffering four major bleaching incidents in recent years, the most recent occurring in 2015-2016.

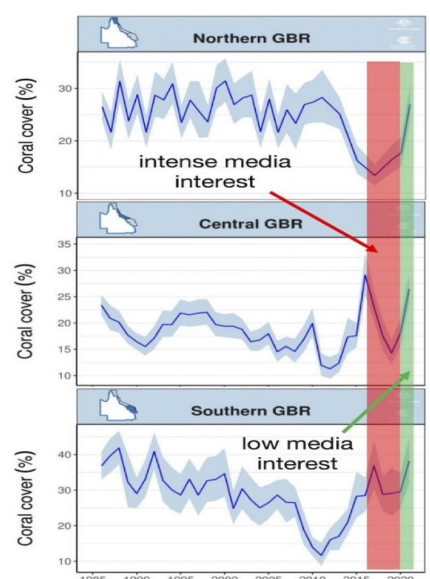




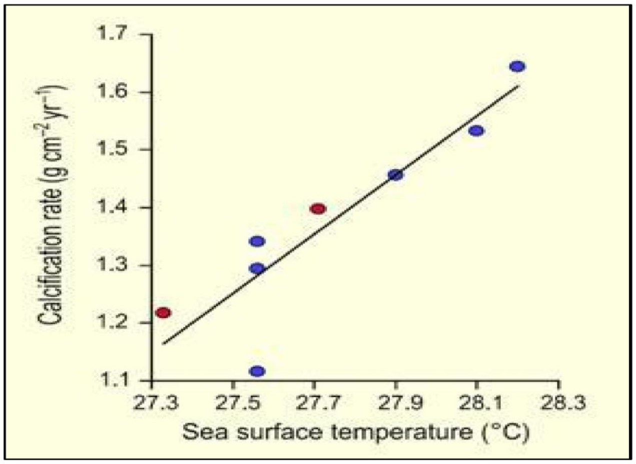
Scientists are increasingly documenting massive changes in reef coral cover on particular reefs over relatively short periods of time, demonstrating both the vulnerability of coral to particular events and the ability of coral to reestablish itself. The principal causes of coral death are major storms and predators such as the crown-of-thorns starfish.

Since the GBR is so long (1,400 miles), the AIMS breaks the data down by a Northern, Central, and Southern regions. All three of the regions have periods of coral death, but the periods are not the same. This shows that coral death has regional causes rather than general causes, such as gradual ocean warming or gradual pH decline. For example, the large decline in coral in the Southern Region in 2009-2010 was caused by Tropical Cyclone Hamish.





Positive impact of warmer temperatures on reef-building coral in the Caribbean



It is being increasingly documented that algae are more sensitive to ocean temperature than coral. As ocean temperature rises or falls, coral may eject its algae and then import a different species of algae more suited to the new temperature. Coral reacts to temperature rise by growing faster. One study indicates a 15% greater rate of growth per 1 C increase in temperature. The warmer parts of the GBR are growing faster than the colder parts. This contradicts the AR6 projection that a further world warming of only 0.4 C will result in the decline of 70-90% of coral reefs. (WGI p.1966).

The warmest place in the world's oceans, known as the Coral Triangle, has the most diverse and the healthiest coral reefs in the world. The water there is significantly warmer than the water surrounding the GBR.

Figure 1. Coral Reef Locations Worldwide

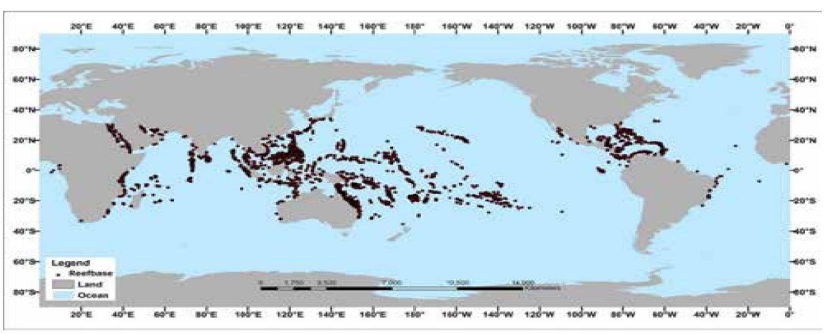


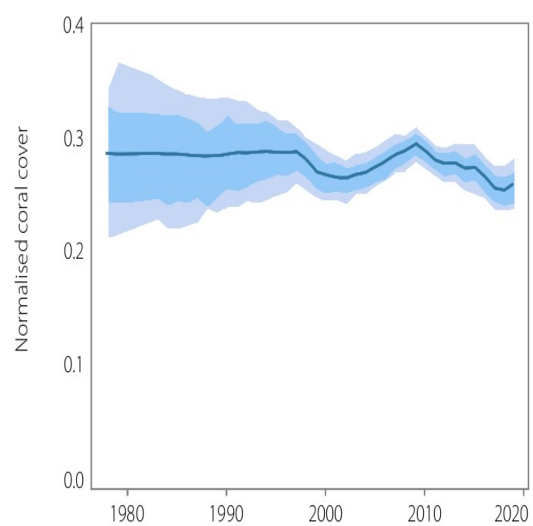
Figure 1. Corals thrive in the warmest of Earth's waters. *Source*: National Ocean Service, "Where Reef Building Corals Found," National Oceanic and Atmospheric Administration, accessed July 26, 2021, https://oceanservice.noaa.gov/education/tutorial_corals/media/supp_coral05a.html

The range of coral growth is limited by cold water, not by hot water. Thus as the oceans warm, the range of coral reefs will grow both North and South away from the tropics, thus expanding in total area.

Scientists have only about 25 years of reliable data on the extent of world hard coral reef coverage. Such data as exists shows a relatively stable condition. This contradicts the AR6 statement that the scope and severity of coral bleaching and mortality events have increased in recent decades. (WGI p.212). But AR6 gives no quantification or explanation for its claims.

Figure 8: Global cover of hard coral

Estimated global average cover of hard coral (solid line) and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Graph redrawn from GCRMN data report. Note, data before 1998 has very high uncertainty due to low number of measurements and problems with randomisation of sampling sites.



Conclusion

Ocean temperature is slightly rising, and ocean pH is slightly declining, but the claims that these changes will negatively effect coral growth or other ocean organisms lack significant support, and there is much contrary evidence. There is reason to believe that the net effect of slight temperature increase and slight pH decline will be positive on coral.

Work Cited

The United Nations Intergovernmental Panel on Climate Change Assessment Report 6, Working Group I, The Physical Science Basis (2021) (WGI)