This is the print version of the Skeptical Science article 'Corals are resilient to bleaching', which can be found at http://sks.to/bleach.

How global warming is driving mass coral bleaching

What The Science Says:
On a world scale coral reefs are in decline. Over the last 30-40 years 80% of coral in the Caribbean have been destroyed and 50% in Indonesia and the Pacific. Bleaching associated with the 1982 -1983 El-Nino killed over 95% of coral in the Galapagos Islands and the 1997-1998 El-Nino alone wiped out 16% of all coral on the planet. Globally about 1% of coral is dying out each year.

Climate Myth: Corals are resilient to bleaching
"Three recent articles give us reason to question the alarmists' claims that coral reefs are in deep trouble due to the buildup of greenhouse gases." (World Climate Report)

Despite what you may read or see in the mainstream media, out in the real world, massive and rapid changes are taking place in many ecological systems as a result of global warming. The Earth seems to be already convinced of global warming and is responding quickly.

Perhaps the most significant, and likely most enduring, are the shifts taking place in the Earth's oceans. Whilst many readers may have read or heard about Ocean Acidification, there are numerous other changes taking place in the oceans which should be equally as concerning. One such phenomena to appear in the last few decades is mass coral bleaching, a consequence of the continued warming of the oceans. Once vast stretches of colourful reefs teeming with marine life are being reduced to lifeless rubble covered in seaweed or slime. Many areas are not recovering, and the scale and frequency of bleaching worldwide is getting worse. In fact, early reports suggest 2010 may have witnessed the largest single bleaching event ever recorded (Baird et al. 2010).

The lowdown on coral bleaching

Reef-coral are actually a symbiosis (a mutually beneficial relationship) between the coral polyp, an anemone-like creature, and tiny algae called zooxanthellae. The coral provide shelter and nutrients for the algae , and in exchange the algae provide carbohydrates (food) to the polyp, using energy from the sun (photosynthesis) and the nutrients provided by the coral. These algae live in the skin tissue of the polyp and produce the coloured pigments which make coral reefs so visually spectacular. When this partnership breaks down the polyps expel the algae, which leads to the "bleached" effect. Although the polyp does feed using its tentacles to snare food, the bulk of its nutrition (90%+) comes from the algae, and they are a critical component of coral skeleton formation and therefore reef maintenance and growth. Without symbiotic algae, the coral can die from starvation, or become so weakened by a lack of food, that it succumbs to harmful bacteria (Mao-Jones et al. 2010), and/or seaweeds which can poison and kill coral on contact.

Because reef-coral have adapted tolerance to a narrow band of environmental conditions, bleaching can occur for a number of reasons, such as ocean acidification, pollution, excess nutrients from run-off, high UV radiation levels, exposure at extremely low tides and cooling or warming of the waters in which the coral reside. Typically these events are very localized in scale and if bleaching is mild, the coral can survive long enough to re-acquire new algal partners. So bleaching in itself is not something new, but mass coral bleaching on the huge scale being observed certainly appears to be, and represents a whole new level of coral reef

decline.

Ocean warming is driving mass coral bleaching

As coral reefs operate very near to their upper limit of heat tolerance(Glynn & D'Croz 1990), bleaching en masse happens when the surface waters get too warm above their normal summer temperature, and are sustained at this warmer level for too long. The intensity of bleaching corresponds with how high, and how long temperatures are elevated and, as one might expect, the intensity of bleaching affects the rate of survival. Small rises of 1 -2 degree C, for weeks at a time, usually induce bleaching.

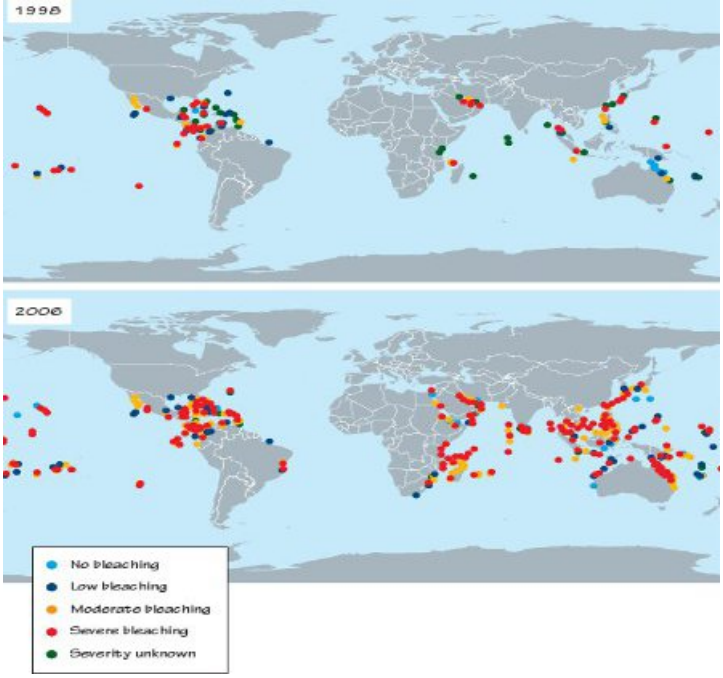
This episodic ocean warming has been most pronounced worldwide during El-Nino events, when the Pacific Ocean exchanges heat to the atmosphere and surface waters. In recent years though, severe mass bleaching is happening outside of El-Nino because of the "background" ocean warming. The huge mass bleaching in the Caribbean in 2005, a non El-Nino year, and again this year is a prime example of this (Eakin et al. 2010) . Evidence connecting warm surface waters and mass coral bleaching has strengthened to the extent that the National Oceanic and Atmospheric Administration (NOAA) has a coral bleaching alert system in place. This alert system accurately forecasts mass coral bleaching based on satellite data of sea surface temperatures.

Hot water + Coral = Dead coral

So how does hot water kill coral? It requires both high water temperatures and sunlight. Oxygen is released as waste during photosynthesis and like all chemical processes this is affected by temperature, speeding up as more energy (warmth) is applied. When water temperatures rise too high the protective mechanisms to prevent heat damage, employed by the coral and the algae, are overwhelmed. The zooxanthellae algae produce high levels of oxygen waste which begin to poison the coral polyp. In acts of self-preservation the coral kick out the algae, and in doing so become susceptible to starvation, opportunistic diseases, competitive seaweeds and macroalgae (slime to you and me) . Coral can succumb to the effects of bleaching years later, and for those coral that survive, growth effectively ceases and full recovery can take anything up to a decade.

Coral resilience is futile

On a world scale coral reefs are in decline, and it makes for rather depressing reading for an avid diver like myself. Over the last 30-40 years 80% of coral in the Caribbean have been destroyed (Gardner et al. 2003) and 50% in Indonesia and the Pacific (Bruno & Selig 2007). Bleaching associated with the 1982 -1983 El-Nino killed over 95% of coral in the Galapagos Islands (Glynn & D'Croz 1990), and the 1997-1998 El-Nino alone wiped out 16% of all coral on the planet. Globally about 1% of coral is dying out each year. Not all of this continual decline is solely down to bleaching of course, pollution and other human activities are also contributing, but bleaching is speeding up the loss of coral.



Looking only at bleaching though, we find that the incidence of mass coral bleaching increases dramatically in the last few decades. Despite modern records being biased by better monitoring and reporting in recent times, there seem to be little evidence of mass coral bleaching further back in time when examining long-lived coral communities. Studies from around the world show no signs of bleaching dating back many thousands of years, until recent decades (Abram et al. 2003), (Aronson et al. 2003). In the Caribbean there are no signs of previous mass bleaching dating back 220,000 years (Pandolfini & Jackson 2006)

So where does this resilience claim originate you may ask?. Perhaps from studies that have shown some coral, in secondary bleaching events, have lower rates of death. A few coral are in more fact tolerant to bleaching, some algae for instance manufacture their own "organic sunscreen". However this a only small proportion, major reef-building coral species seem incapable of forming long-lasting partnerships with these heat tolerant algae (Coffroth et al. 2010), and the coral polyp themselves have a very poor genetic ability to adapt to warming (Csaszar et al. 2010). However the "resilience" fallacy arose, there's no evidence a few hardy individuals will somehow prevent the loss of most coral worldwide.

The importance of coral reefs - the oasis in a marine desert

So what does this all have to do with the average man or woman in the street?, well, as far as humans are concerned, there is a rather large dollar value attached to coral reefs. Goods and services derived from coral reefs are very roughly estimated to be between $172 to $375 billion dollars per year (Martinez et al. 2007). Not only that, but reefs directly provide food and income to over half a billion people worldwide. The decline of coral reefs is going to not only impact those that directly depend on them for a living and sustenance, but eventually have dramatic effects on economies worldwide, and will likely drastically drive up world food prices as fish populations nosedive.

Ecologically speaking the value of coral reefs is even greater because they are integral to the well being of the oceans as we know them. It might serve to picture them as the undersea equivalent of rainforest trees. Tropical waters are naturally low in nutrients because the warm water limits nutrients essential for life from welling up from the deep, which is why they are sometimes called a "marine desert". Through the photosynthesis carried out by their algae, coral serve as a vital input of food into the tropical/sub-tropical marine food-chain, and assist in recycling the nutrients too. The reefs provide home and shelter to over 25% of fish in the ocean and up to two million marine species. They are also a nursery for the juvenile forms of many marine creatures .

I could go on, but the similarity with the rainforest should now be clear. Eliminate the undersea

"trees", which mass coral bleaching is in the process of doing, and you'll eliminate everything that depends on it for survival, a point best exemplified in the following sequence of photos. (sequence of healthy coral-bleached coral-rubble & slime)

A grim outlook for coral

The critical issue with global warming induced coral bleaching, as it is for many eco-systems, is the speed of warming. They are simply not being given sufficient time to evolve tolerance. The coral's algal partners have short lifetimes and possess genetic traits which may enable successful adaptation to warming. Coral themselves aren't so lucky, somewhat in contrast to their algae, they possess a poor genetic ability to combat warming stress and have decadal lifetimes. It's likely therefore that many coral will die because the speed of warming is too great within an individual communities lifetime.

Perhaps a useful way of looking at it, is that the "bar" is continually being set higher and higher, and the recovery time between bleaching events becoming smaller and smaller. Gradually this continual ocean warming will start to impact areas which have so far escaped unscathed, and these coral will succumb too. Of course coral reefs aren't just under fire from bleaching, as mentioned earlier, humans are hurting them in many other ways. Ocean Acidification in particular is a large looming threat (Veron et al. 2009). The increasing frequency and severity of bleaching, coupled with the persistent decline in coral around the world, should however immediately dispel any myths about coral resilience.

Intermediate rebuttal written by Rob Painting

Update July 2015:

Here is a related lecture-video from Denial101x - Making Sense of Climate Science Denial

[*see video at* ***this link***.]

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