The Acid Ocean Bogeyman

If pictures or diagrams are missing you can download a print-ready copy of this article from:

Viv Forbes
The Carbon Sense Coalition
May 2012

What is the "Problem"?

There are hundreds of articles on "ocean acidification". Almost all of them include this statement somewhere:

"Surface ocean pH is estimated to have dropped from near 8.25 to near 8.14 between 1751 and 2004."

As pH was first defined and measured in 1909, and is seldom measured to two decimal points, I wondered where this very accurate figure for the year 1751 came from.

It seems to go back to Mark Jacobson who, in 2005, published a report on a "new ocean chemical equilibrium model" (a computer simulation of the chemical processes going on in the oceans) that included this statement:

"Whereas surface ocean pH is estimated to have dropped from near 8.25 to near 8.14 between 1751 and 2004, it is forecasted to decrease to near 7.85 in 2100 under the SRES A1B emission scenario, for a factor of 2.5 increase in H+ in 2100 relative to 1751. This "ocean acidification" is calculated to cause a nontrivial transfer of ammonia from the atmosphere to the ocean and a smaller transfer of hydrochloric acid, nitric acid, and sulfurous acids from the ocean to the atmosphere. The existence and direction of these feedbacks are almost certain, suggesting that CO2 buildup may have an additional impact on ecosystems."

Link: http://adsabs.harvard.edu/abs/2005JGRD..11007302J

Since that report was published, the phrase "the increase in ocean acidity from 8.25 in 1751 to 8.14 in 1994" is quoted ad nauseum as if it were gospel truth, measured accurately. It is not a measurement. It is yet another computer model of something so large, so complex, and so interdependent that no computer model will ever model it accurately, and no lab experiment will prove it. (But careful observations of the range of current conditions, and of the past as recorded in the rocks and sea sediments, will provide valuable clues.)

Naturally, the great majority of acid-ocean articles blame the forecast increase in acidity on the carbon dioxide being added to the atmosphere by man's use of carbon fuels; and dire consequences for ocean life are forecast to follow that. A recent correspondent lectured me sternly: "the calcification ability of some key types of plankton, including young crustaceans and molluscs is already nearing the edge. Corals are in danger and we may be affecting whole ecosystems."

And to add the final scare to the oceans saga, James Hansen, the world leader of the climate alarmists said, in February 2012: "You can get to a situation where a runaway greenhouse causes the ocean to boil. . . . That's the end for everyone".
Measuring Ocean Acidity

Acidity/alkalinity in a solution is measured by pH (which is the log of the inverse of the "percentage of hydrogen ions"). The scale runs from 0 to 14. A pH of 7 is neutral, anything above a pH of 7 is termed "alkaline", and anything below a pH of 7 is termed "acid". This scale is logarithmic, so a pH of 6 is ten times more "acidic" than a pH of 7.

We have a very long way to go before sea water could honestly be described as "acidic". Even if pH has moved from 8.25 to 8.14 since 1751, that still leaves the water distinctly alkaline.

Moreover pH seems to have stagnated since 1999 at a pH of about 8.09, according to IPCC's own figures.


This claimed change over 240 years is within the normal range of variability of ocean pH. In fact, an 11 year study in the north-eastern Pacific Ocean off Washington State showed that even over the course of one day, the pH typically varies by 0.24 units, a consequence of the daily uptake and production of CO2 through photosynthesis and respiration.

This study noted:

"Biological processes, which are often left out of models of ocean pH, can have strong effects. … Over 70% of the variability in pH we observed can be related to changes in a small set of factors with known mechanistic links to pH: atmospheric CO2, water temperature, the daily photosynthesis-respiration cycle, phytoplankton abundance, upwelling of high CO2 subsurface water, alkalinity, salinity, and the Pacific Decadal Oscillation."

See: http://www.appinsys.com/GlobalWarming/OceanAcidification.htm

Oceans are never "acidic" (ie pH below 7) except in the case of acid water coming from submarine geothermal vents. These vents in ocean floors can emit large quantities of gases such as carbon dioxide and more corrosive acid-forming gases, as well as hot water. Hence it is common for the sea water surrounding such vents to be acidic (mainly from powerful acids such as sulphuric, hydrochloric and nitric acids). Even in that apparently hostile environment, life has evolved to survive.


Open oceans away from vents are always alkaline, not acid. "Reduced ocean alkalinity" does not make good headline material, which explains why we are always confronted by deceptive scare talk about "increased ocean acidity" caused by man-made carbon dioxide.

The alkalinity of sea water is highest during the day, in warm shallow tropical water where aquatic plants are flourishing. During the day, using photosynthesis, the marine plants extract the carbon dioxide from the water, and the warmer water tends to expel carbon dioxide in accordance with the gas laws we learned at school. Both processes tend to increase the pH or alkalinity. Unless that carbon dioxide is replaced, the plants will starve and then all creatures dependent on them will also eventually starve.
Replenishment occurs at night when photosynthesis ceases, plants stop consuming carbon dioxide, other aquatic life continues emitting carbon dioxide and the cooler water is able to absorb more of the gas of life from the atmosphere. Although the pH of the surface water reflects a decline in alkalinity at night it never approaches a pH of 7. It never becomes acid, just becomes less strongly alkaline.

No one can produce a single figure that accurately represents either the "average" temperature or the "average" carbon dioxide content of Earth's oceans or atmosphere. Nor is there a single figure that could represent "average" ocean pH. Ocean pH varies continually with temperature, depth, ocean currents, the time of day, the life in the ocean at that place and the amount of carbon dioxide in the atmosphere at that place.

See: http://carbon-sense.com/2010/10/24/gray-measurement/

At best, a series of measurements of pH observed at the same time of the day, the same season of the year, the same ocean depth and the same place over a long period of years MAY give an indication of trends in that place. However, such records are few, with only slight trends detectable in a noisy record.

But we do know that there are large natural cyclic fluctuations in ocean temperatures that will cause changes in the carbon dioxide content of the ocean and hence change the pH. These fluctuations seem to be caused by upwelling of cold, deep ocean currents saturated with carbon dioxide. As the sun warms this water, carbon dioxide is released. Man has no influence on these processes.

**Does Carbon Dioxide create Acidity in the Oceans?**

Carbon dioxide is very soluble in sea water.

The carbon dioxide that enters the ocean is first dissolved as a gas, which can bubble out again if the temperature of the water rises. The dissolved gas is soon converted to H2CO3, carbonic acid, which then forms bicarbonate and carbonate ions. These reactions release acidic hydrogen ions. It is therefore true that sea water absorbs carbon dioxide and this process will decrease its alkalinity.

However the acid created in this way has limited ability to change ocean pH. Carbonic acid is such a weak acid that we can drink it in soda water. It is easily converted to neutral compounds or used by marine organisms. Depending on the prevailing pH of the water, this weak acid can react with the abundant calcium bearing compounds being washed into the sea as rocks weather to form calcium carbonate. This will end up in the shells or skeletons of marine creatures, or precipitate out from the water forming limestone beds on the sea floor. In this way the ocean disposes of excess carbon dioxide.

Over the long term, strong acids such as naturally occurring sulphuric, hydrochloric and nitric acids are more likely to change ocean pH levels. These acids are created naturally by the many submarine volcanoes, by oxidation of various rocks and minerals on the land, by lightning and other reactions in the atmosphere and by open air combustion of biomass and natural hydrocarbons. They are also created by the operation of older dirty power stations and industrial plants, especially those using poor quality fuels producing SOX (sulphur) and NOX (nitrogen) contaminants and with inadequate clean-up facilities for their exhaust gases. Many other processes can affect the pH of coastal seas including disposal of treated and untreated human effluent and chemical runoff.
However nature has many insurance policies (or buffers) to protect against rising acidity. These include the massive deposits of limestone and other acid-neutralising rocks, and the basic igneous rocks likely to be right beside the major volcanic vents.

Much of the deep ocean floor is composed of basalt, some quite fresh and exposed in recent eras of volcanism and crustal movements along the mid-ocean rifts. The strong acids attack the basic minerals in these basalts, producing salts and water and consuming the H+ ions leaving a surplus of alkaline OH- ions and thus producing the generally alkaline environment in the oceans.

The following diagram from Wikipedia illustrates the massive natural chemical reactions occurring beneath the oceans:

Wikipedia described it thus:

"Compared to other rocks found on Earth's surface, basalts weather relatively fast. Chemical weathering of basalt minerals release cations such as calcium, sodium and magnesium, which give basaltic areas a strong buffer capacity against acidification. Calcium released by basalts binds up CO2 from the atmosphere forming CaCO3 acting thus as a CO2 trap. To this it must be added that the eruption of basalt itself is often associated with the release of large quantities of CO2 into the atmosphere from volcanic gases."

Despite the large quantity of carbon dioxide stored in the sea, the weak carbonic acid from carbon dioxide is very much a bit player in the acid/alkaline balance in the oceans.

**Ocean Temperature controls the Solubility of Carbon Dioxide**

Two main factors control the amount of carbon dioxide that can be absorbed by sea water – the concentration of carbon dioxide in the atmosphere and the temperature of the sea water.

At today's concentration of a minute 390 parts per million (ppm), the partial pressure of carbon dioxide in the atmosphere is very tiny, but it plays a small part in forcing carbon dioxide into solution in the oceans. If the carbon dioxide content of the atmosphere increases for any reason (volcanoes, the biosphere or man's industry), more carbon dioxide will be absorbed by the sea water, providing that nothing else changes in the sea at the same time.
The temperature of the ocean is a far more effective driver. Carbon dioxide is very soluble in cold water, but if that water warms up, the carbon dioxide is expelled (like bubbles in a warming beer). Thus these two effects (increased pressure and increased temperature) act in opposite directions, ie one counter-acting the effect of the other. As temperature changes dramatically on a daily and annual cycle, so does the movement of carbon dioxide between ocean and atmosphere.

Carbon dioxide in the atmosphere shows strong seasonal fluctuations as shown below. (The red line shows the monthly mean values. The black line is the 7 month moving average, designed to remove the seasonal cycle.)

![Graph showing recent monthly mean CO₂ at Mauna Loa](image)

Source: [http://www.esrl.noaa.gov/gmd/ccgg/trends/index.html#global](http://www.esrl.noaa.gov/gmd/ccgg/trends/index.html#global)

Ocean temperatures clearly control the large seasonal swings in carbon dioxide in the atmosphere – the huge southern oceans expel it in their summer and re-absorb it in their winter.

Careful study of the graph above shows a rapid drop in the level of carbon dioxide during the southern winter months when atmospheric carbon dioxide is absorbed by the colder seas. This seasonal swing is assisted by the summer cycle in the northern hemisphere where the northern forests are flourishing, also extracting carbon dioxide from the atmosphere to build new leaves.

As the surface of the southern seas warm up again in summer, they expel carbon dioxide back to the atmosphere. This is assisted by winter in the northern hemisphere where plant life is hibernating - leaves are falling and returning their carbon dioxide to the atmosphere, thus adding to the world-wide upswing in carbon dioxide in the atmosphere.

This variation shows there is rapid response of carbon dioxide atmospheric concentration to changing sea temperatures in agreement with Henry’s Gas Law. This is the major cause of the annual fluctuations of atmospheric carbon dioxide. These natural seasonal swings dwarf the effects of man's industry.


On a longer time scale, the ice core data, representing millions of years of Earth's history, shows that global temperature changes precede changes in atmospheric carbon dioxide, with a lead time of several hundred years. This proves that carbon dioxide does not control the large swings in earth's temperature. (Wet roads come after rain and thus cannot cause it.)

No one knows the reason for this lag but it may be related to the time for the deep oceans to change temperature and thus expel or absorb their carbon dioxide.

Thus the current rising trend of carbon dioxide could be reflecting rising temperatures that occurred in Medieval times.

They could also be reflecting increased submarine volcanism which is now releasing gases and heating the oceans especially along the mid-Atlantic Rift and under Arctic and Antarctic waters.

See: [http://iceagenow.com/Volcanoes_in_Arctic_Ocean.htm](http://iceagenow.com/Volcanoes_in_Arctic_Ocean.htm)
And: [http://iceagenow.com/Ocean_Warming.htm](http://iceagenow.com/Ocean_Warming.htm)

In the SeaChange report (referenced below), Bob Beatty has calculated the Atlantic Ocean temperature would only have to rise by 0.034°C to account for all of the increase in atmospheric carbon dioxide blamed on humans.

(For those who would like to explore more deeply into the chemistry and physics of the relationship between carbon dioxide and sea water and the effect of sea temperature on atmospheric content of carbon dioxide, check the report below.
See: [http://www.bosmin.com/SeaChange.pdf](http://www.bosmin.com/SeaChange.pdf)).

Earth's temperature cycles may also be related to warming and cooling phases of the sun, and affected by cyclic variations in the geometry of Earth's orbit about the sun, but they are certainly not caused by modern man's trucks, tractors, trains, planes and power stations.

**Is Human Production of CO2 likely to affect the Acidity of the Oceans?**

The claim is that as carbon dioxide levels rise because of human usage of carbon fuels, this will turn the oceans acidic and have deleterious effects on ocean life.

It is true that when there is more carbon dioxide in the atmosphere, this will increase the partial pressure of carbon dioxide in the atmosphere, resulting in more of the gas being dissolved in surface waters such as oceans, lakes and rivers. It is also true that to the extent that man's production of carbon dioxide causes an increase in carbon dioxide held in the atmosphere the amount of carbon dioxide dissolved in the oceans will rise.

However, the fact that there have been very large cycles and changes in the carbon dioxide content of the atmosphere long before humans learned to burn coal and oil suggests that man's industry has little effect on carbon dioxide in the atmosphere. And therefore man's effect on the huge deep oceans is miniscule. There is no credible evidence (except in simplistic computer models) that man's production of carbon dioxide could have a measurable effect on ocean pH or ocean life.

The gross tonnage comparisons are also relevant. Carbon dioxide is highly soluble in water and the hydrosphere is thus a huge storehouse of dissolved carbon dioxide and the carbonates derived from it.
However, carbon dioxide is but a tiny trace gas in the atmosphere (currently a mere 390 parts per million or 0.039%). Man contributes about 3% of total annual emissions of carbon dioxide reaching the atmosphere (this is a wild guess, and probably too high). Volcanoes, gas seeps and the biosphere contribute the rest. The total of carbon dioxide from all sources in the atmosphere is 390 parts per million parts of air. And the oceans weigh about 300 times more than the atmosphere.

The table below attempts to provide a sense of perspective between man's share of carbon dioxide in the atmosphere, and the total size of the oceans supposedly being acidified by man's carbon dioxide. Like all such figures, these are rough orders of magnitude only, but they serve to illustrate that man's activities do not rate highly in the broad scheme of things which may drive ocean acidity - just 12 in 300 million or 1 in 25 million – less chance than Lotto.

**Table 1**

Relative Masses of Ocean waters and Atmospheric gases

<table>
<thead>
<tr>
<th>Source or Location</th>
<th>Relative Masses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Oceans</td>
<td>300,000,000</td>
</tr>
<tr>
<td>Total Atmosphere</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Carbon Dioxide in the Atmosphere – 390 ppm **</td>
<td>390</td>
</tr>
<tr>
<td>CO2 Contributed by Man's Industry – say 3% of total</td>
<td>12</td>
</tr>
</tbody>
</table>

**Note: the 390 ppm is by volume, and the others are weights, but that has no real effect on the massive disproportion between oceans and man's industry.**

Compared to the massive power of the oceans, the effect of a trace of carbon dioxide in the thin veil of gases surrounding the Earth is scarcely significant.

That small atmospheric tail has a big job trying to wag that big oceanic dog. Man's industry is but one tiny flea on that tail.

**Almost everything affects the**

**Carbon Dioxide content of Oceanic Waters**

Ocean temperature and the amount and ratio of plant and animal life in the water have a major effect on carbon dioxide content and pH of oceanic waters. These vary with the season, the water depth and the daily temperature cycle.

Warm water expels carbon dioxide and cold water takes it into solution, so daily, seasonal and cyclic changes in ocean temperature have a major effect on the carbon dioxide dissolved in sea water.

All marine plants remove carbon dioxide from sea water, and aquatic animals get their carbon from plants. Therefore, to maintain healthy marine life requires a constant supply of carbon dioxide.

The carbon dioxide content of the ocean generally increases with depth because the deeper water is generally colder and also because plants that use photosynthesis to remove carbon dioxide from the water cannot operate this process without sunlight. In addition, deep sea animal life continues to exhale carbon dioxide and decaying organic material strips away oxygen and generates more carbon dioxide.
Once the deep ocean becomes depleted of oxygen, decomposition may favour the production of methane rather than carbon dioxide. (Some would also like to blame man for this methane production). Enormous quantities of natural methane are locked up in ice on the continental shelves.

Where these deep dark cold waters up-well, all sea life flourishes on the abundant nutrients in the water. These nutrients include carbon dioxide, and all the organic matter, nitrates and phosphates that result from decomposition of organic matter in the oxygen deficient environment that characterises the deep ocean. This upwelling cold water is still not acid – just somewhat less alkaline than most surface water. It is important to note that there is a profusion of aquatic plant and animal life in these cold carbon-rich waters.

Ocean upwelling occurs in cycles decades or more long. In one phase surface waters tend to be warmer, and in the cold phase such as the world appears to be entering, cold water from the deep comes to the surface.

**The Ocean is a powerful Buffer and Storehouse for Carbon Dioxide**

The oceans are like a complex well-buffered chemical soup with sediments, clays, dissolved salts and a myriad of large and small animals and plants all adding and subtracting matter from the living breathing soup they live in. A change in any one component tends to provoke chain reactions, both chemical and biological, which tend to restore the initial conditions. It is always seeking equilibrium but seldom getting there.

Nature routinely removes excess carbon compounds from the ocean waters in tonnages so massive that man can only measure and wonder. One has only to look at the White Cliffs of Dover to get a feel for the magnitude (44% by weight of these thick beds represents carbon dioxide that was extracted from the atmosphere by the ocean.)

![Carbon dioxide sequestered by the ocean – The Massive White Chalk Cliffs of Dover](image)

Author: [http://www.flickr.com/people/fanny/](http://www.flickr.com/people/fanny/)
Thick beds of shells and corals, limestone, dolomite, magnesite, siderite, marls, methane hydrate and oil/gas shales under the oceans also illustrate the enormous capacity of the oceans to extract and sequester carbon.

Nature has also laid down massive deposits of coal and lignite in fresh water swamps and lakes, thus removing further enormous quantities of carbon dioxide from the atmosphere. Many of these deposits were laid down when the carbon dioxide content of the atmosphere was far higher than it is today. Man's mining and industrial activities are thus harmlessly recycling some of this valuable carbon from the dead lithosphere back into the living biosphere.

Most of the carbon dioxide produced in modern times by the increased burning of carbon fuels (both hydrocarbons and cleared forests) has mysteriously disappeared. As man creates it faster, nature is removing it at a faster rate. It is either going into live tissues in the biosphere (increased production of wild and domestic plants and animals and increased human population) or the oceans are dumping excess carbonates on the sea floor.

Fine-grained clays and other reactive sediments eroded from the land and washed into the oceans by rivers also play a major role in buffering the pH of ocean waters. The system at any time is always tending towards a point of equilibrium where there is no net movement of carbon dioxide between the ocean and the atmosphere.

However, there is no equilibrium in any live system. As in other environments, life is continually reacting to environmental changes by adapting to take advantage of the new conditions (thus tending to reverse the changes). This process may cause changes within species as certain individuals cope better or it may encourage the replacement of one species by another. Life is never still.
Carbon Dioxide levels in the Atmosphere are currently close to Historic Lows

To keep today’s levels of carbon dioxide in perspective, we need to examine the long-term fluctuations in the amount of carbon dioxide in the atmosphere. In terms of geological time, we are close to record lows – not far above the level at which plant growth ceases (150 ppm), and lower than the level at which most life on Earth evolved.


![Comparison of Historic Atmospheric CO2](http://co2science.org/subject/images/1998/historic_co2.png)


The content of carbon dioxide in the atmosphere and ocean pH levels have varied significantly on all time scales and life has always adapted quite naturally to cope. There is no reason to suggest that ocean life will be incapable of coping with future changes.

To suggest, as some do, that the minor contribution of humans to carbon dioxide in the atmosphere will somehow put so much carbon dioxide into the oceans as to alter the blood chemistry of fishes and threaten their survival is drawing a very long bow indeed and simply unproven. Almost all life on Earth evolved in eras when there was far more carbon dioxide in the atmosphere than today; it will surely cope with any changes in water temperature or pH caused by man’s activities.
It is also relevant to note that submariners can live and work in an atmosphere with 5,000 ppm of carbon dioxide, our exhaled breath normally contains 40,000 ppm, and the blood in the lungs of humans is about 56,000 ppm (all compared to a tiny 390 ppm in today's atmosphere). Humans are not fish, but the laws controlling blood chemistry do not change significantly from species to species.

**Carbon Dioxide is Essential to Life on Land and in the Oceans**

The availability of carbon dioxide is the limiting factor for plant growth in water and is often the limiting factor for land plants. We can say unequivocally that more carbon dioxide in the atmosphere and in the oceans will dramatically increase plant growth. There is abundant experimental evidence of this.


It is also a myth that acidic water necessarily kills plant and animal life. Rain water is slightly acidic, sometimes with a pH as low as 5.5 – far more acidic than the oceans (approx. pH 8.1). However plants on our farm respond immediately to a shower of rain with its welcome load of nutrients (probably minute quantities of natural acids derived from carbon, nitrogen and sulphur). But once it gets stored in our concrete tank, rain water returns to a slightly alkaline state. Fresh water does not have the ability of the vast seas to buffer the acidity that can be caused by carbon dioxide or other stronger acids in the water. In fresh and saline swamps and reed beds the water can become quite acidic, but plant and animal life nevertheless flourish there. For example estuaries and embayments are often an essential nursery habitat for various marine animals and our most important commercial marine prawns depend on such areas.

Plant nurseries have long known the benefits of pumping carbon dioxide into the air in their greenhouses. Nurserymen who grow aquatic plants and animals have also found the benefits of water acidified by carbon dioxide.

Our extended family owns and operates three separate farming enterprises in south-east Queensland. Our livelihoods depend on the health of our soils, waters, plants and animals.

One farm combines energy from the sun with the gases of life from the atmosphere to grow natural pasture for cattle and sheep. To maintain sustainable soils, this farm applies mined minerals such as crushed basalt and limestone to maintain healthy soils. This rock dust replaces the minerals shipped off to market in animal bodies. Deep ripping also brings up minerals from the subsoils derived from weather bedrock.

The water cycle, the mineral cycle, the carbon cycle and the solar cycle drive everything. The atmospheric gases of life are crucial – oxygen for animals, carbon dioxide for plants, nitrogen for the soil and water for everything.
Grazing is a process of converting atmospheric gases and soil minerals into animal proteins and fats.

Protein contains about 53% carbon and carbohydrates about 44% carbon. Carbon is thus the key element in all farmed food but carbon dioxide is the rarest by far of the atmospheric gases of life, comprising just 0.039% of the atmospheric gases. Most life on earth is limited by this shortage of carbon dioxide.

Land plants are very dependent on rain, warmth and carbon dioxide. Pastures flourish best after the first summer storms. This is a time when the ocean is expelling carbon dioxide, the sun is providing more warmth and the clouds are delivering rain – these are the three key ingredients for maximum plant growth. Here is the above farm after the rains came:
The next family farm concentrates on breeding and growing aquatic plants and animals. This farm buys 6 tonnes of compressed liquefied carbon dioxide per month which, every day, is bubbled into the water which is pumped through the troughs in which all of the aquatic animals and plants live.

The picture below shows the carbon dioxide injection equipment – the large supply tank, the control panel, flow meters, defroster and the emergency supply cylinders:

![The large Carbon Dioxide supply tank with small emergency cylinders (in case the farm runs out of the Gas of Life).](image)

The pH of the water is monitored continuously. Carbon dioxide injection starts at sunrise as soon as there is enough sunlight to start photosynthesis. At this time pH of the water is about 7.3. By 11am pH has fallen to 6.8, which is acidic and far lower than ever recorded in the open ocean. Aquatic plants, fish, shrimps, snails, small crustaceans, algae and plankton flourish in that acidic water. Even if the pH gets as low as 6.0, the owner/manager says it only takes about one day for the plants to strip out the dissolved carbon dioxide and return the water to a slightly alkaline pH of 7.7.5.

![Two of the sheds which house troughs in which Aquatic plants and animals are raised in water enriched with carbon dioxide.](image)
The reject water is pumped into an irrigation system for growing lucerne. The lucerne benefits from any excess carbon dioxide left in the water and from any other organic nutrients in the water.

Without the carbon dioxide injection system, the production of plants from the same area of troughs would be halved, and plants would be smaller, grow more slowly and look less healthy and vigorous. Without the carbon dioxide, the farm would need twice the area of troughs and sheds to produce the same volume of plants. Several varieties of fish are also raised in the carbon enriched waters. The fish seem to prefer a pH of 7.3-7.4 but are not worried by acidic water with pH as low as 6.5.

The third farm also breeds and grows aquatic plants and animals, with the same injection of carbon dioxide into the water. The water here is recycled.

Many customers who buy the aquatic plants and animals have aquariums (including corals) and also pump carbon dioxide into their water.

Nature also injects carbon dioxide into the oceans at many places along the oceanic rifts. For example there are several natural submarine geothermal vents in waters off Papua New Guinea where concentrated carbon dioxide bubbles from the sea bed, saturating the sea water with carbonic and other acids. In some places more corrosive gases like hydrogen sulphide (rotten egg gas) are also present. Sea grass and corals flourish in this environment.

One well-known vent called "The Bubble Bath" is located off the coast from Dobu Island, an extinct volcano. Corals, plants and fish are flourishing there. The sea water in some of the bubble streams is acid (pH 6.54) but the open ocean nearby is strongly alkaline with a pH of 8.23.

For a full report with pictures of these geothermal vents and their luxuriant life see: http://www.goldendolphin.com/WSarticles/CO2%20Vents%20in%20PNG.pdf

Walter Starck, the author, said "It seems that coral reefs are thriving at pH levels well below the most alarming projections for the year 2100."

It is impossible to forecast the precise consequences arising from changes to the alkalinity of sea water, because ocean life adapts and in that process causes compensating changes. Moreover, the salts and other chemicals in the oceans buffer and dampen the effects of any chemical change.

Such a large open complex system cannot be simulated in test-tube experiments nor do spot observations represent all that is occurring in the wider ocean. In general however, as on land, more carbon dioxide in the ocean is beneficial for life as it greatly encourages plant growth. This flourishing plant life provides the food for sea creatures and all animal life benefits – shellfish, coral, algae, sea grass, kelp, plankton and fish.

**Is Man's Carbon Dioxide going to "Destroy" the Great Barrier Reef?**

Corals have existed on Earth since Ordovician times (500 million years) and more than 2,300 species of coral are alive today. Most modern corals have fossil histories going back about 100 million years.
Corals have survived global extinctions of other species, ice ages, warm eras, rising and falling sea levels, cyclones and hurricanes, epochs of massive volcanic activity and carbon dioxide levels far higher (5 to 10 times higher) and lower than exist in the atmosphere today.

Corals have even survived nuclear blasts (at Bikini Island).

Corals also made a surprising recovery after the world’s biggest oil spill in Kuwait:

"However, to date, the extent of coral reef damage directly attributable to the Gulf Spill has been remarkably minor."

There is abundant evidence that corals are a persistent part of the environment despite the rise and fall of oceans, the rise and fall of carbon dioxide content in the atmosphere and the rise and fall of global temperatures. They are not delicate organisms.
See: [http://www.pnas.org/content/99/7/4167.full](http://www.pnas.org/content/99/7/4167.full)

Australia's Great Barrier Reef itself is very young. Just 20,000 years ago, sea levels were about 130 metres lower, and where the reef now sits was dry land. The reef has only been in its current position for about 7,000 years. There may have been a reef much further seawards, but the evidence has been hidden by rising sea waters.

Corals cope with climate change the same as many other species do – by moving as the climate moves or by adapting to the changes. There have been times in the past when the speed of natural and calamitous climate change has overwhelmed many species and many individuals in surviving species, but man’s production of carbon dioxide does not even begin to register on that scale of global catastrophe.

The Earth has had several periods of global warming in just the last 10,000 years. The current modern warming is not unusual. History records there were warm epochs in Roman and Medieval times long before human's used coal and oil.

Even if the IPCC (Inter-governmental Panel on Climate Change) forecasts of additional warming of 1-2°C over this century takes place, this will not destroy the Great Barrier Reef. It will cope, adapt or move gradually to cooler waters. Water temperatures already vary by about 8°C along its full length from summer to winter, and there are also wide local variations in pH. Corals already cope with extreme ENSO temperature changes. Some individuals die but the reef recovers quickly once conditions reverse.

Coral reefs also cope easily with rising sea levels by either building higher or migrating to higher ground. Many coral atolls started as island-fringing reefs. As sea levels rose, islands disappeared but the corals kept building the reef higher, keeping pace with the rising water levels. Where the island once stood, there is now a lake ringed by coral reefs.

Most corals are able to grow their reefs faster than even the most extreme forecast of sea level rises. Falling sea levels (caused by growth of ice sheets) would pose more of a problem for coral reefs.

Corals also cope well in waters with pH as low as 7.8 – still alkaline but closer to acidic and lower than seen on the Great Barrier Reef.

Carbon dioxide is an essential resource for all corals for two reasons.
Firstly, carbon dioxide is essential to creating more carbonates in sea water. These carbonates are the building blocks for coral formation and for the calcification of shells of other marine creatures.

Secondly, corals exist in a symbiotic relationship with minute plants (algae) which are greatly enriched by increased carbon dioxide in the water. As the algae flourish, so do the corals. Operators of amateur aquariums know this and inject carbon dioxide into their tanks.

Coral bleaching is usually an indication of stress or death of these plants. Like land pastures, coral pastures are stressed by sudden bouts of high temperature. The sudden high temperature itself cause stress, and this is multiplied when the high water temperature drives off the carbon dioxide which is the food of plants. Such bleaching episodes are usually caused by ENSO events. When the temperature stabilises, more carbon dioxide is dissolved in the water and the algae recover. As global temperatures have been stable for a decade despite rising carbon dioxide emissions by industry, it appears that man-made global warming is no real threat to the Great Barrier Reef.

It is possible that corals may be harmed by runoff from the land such as herbicides that may damage algae, or pesticides that may harm coral polyps. Excessive amounts of sewerage sludge may even cause a deficiency of oxygen or an excess of harmful bacteria. But it is hard to imagine or point to a circumstance where atmospheric carbon dioxide from any source has harmed or could harm corals.

An extensive new study of the Great Barrier Reef covering 35,000 coral colonies on 33 reefs across the full length of the Great Barrier Reef concluded that the changes forecast under "business as usual greenhouse gas emissions" are unlikely to cause great harm to the reef. There is already a great variation in temperatures and pH along the reef and coral species and associated aquatic life have adapted to cope with them all. As in every environment on Earth, some species may decline with changes in climate but others will flourish or mutate to accommodate the changes.

Man's production of carbon dioxide is highly unlikely to be noticed by reef dwellers.

See Appendix 1 and:

**But won't the Acidity Dissolve Corals & Sea Shells?**

One of the first things science students do in the chem lab is to put a drop of hydrochloric acid onto a piece of limestone to see it fizz as acid "eats" the limestone dissolving the carbonate and releasing carbon dioxide. Thus arises the fear that acid oceans will dissolve the skeletons of corals and the shells of other marine creatures.

However, the ocean is not a chemistry lab where pure chemicals are tested in sterile isolation. And not all acids are the same, and not all carbonates are the same. There are even three versions of simple carbonates used by marine organisms – calcite, aragonite and mag-rich calcite. These vary in solubility in acids. The sea also contains carbonates and basic chemicals and clays all of which buffer any disturbance to ocean pH making it difficult for natural carbon dioxide to create acidic water in open oceans.
For this reason, many experiments use stronger acids and bases to control pH in test areas – guess what acid they use? Unbelievably, they use hydrochloric acid to increase acidity. This is a corrosive chemical sold to dissolve and clean concrete paths. It is not surprising that it may corrode carbonate shells and corals. And to reduce acidity they use caustic soda, a powerful alkali used to clear clogged drains. Unlike soda water, the acid formed by dissolving carbon dioxide in water, both hydrochloric acid and caustic soda are lethal to life.

Corals, molluscs and fish rely on abundant calcium carbonate in the water to build their skeletons and shells. Adding carbon dioxide to sea water increases the availability of carbonate ions to all marine life. Adding hydrochloric acid to sea water causes the destruction of carbonates and the release of carbon dioxide.

The real tests take place in living wild and domestic aquariums where additional carbon dioxide always benefits life.


### Are we likely to "Boil the Ocean"?

James Hansen, probably the current world leader of the climate alarmists, has said:

"You can get to a situation where a runaway greenhouse causes the ocean to boil. . . . That’s the end for everyone".

Ocean covers 71% of the earth's surface and much of it is 3-5 km deep. The oceans weigh 300 times as much as the atmosphere and they have a huge heat capacity.

Carbon dioxide comprises just 0.039% of the atmosphere and man contributes about 3% of this. Thus the oceans weigh about 25 million times more than the carbon dioxide gas which is supposed to warm them alarmingly. (See Table 1, page 6)

Carbon dioxide is not a fuel – it does not generate heat. At most, it delays the passage of solar energy through the atmosphere. Its capacity to do this is limited and almost exhausted.

To think that one slightly warmer carbon dioxide molecule will cause dangerous warming of a share of the land surface, plus 2,500 molecules of other gases in the atmosphere, plus 25 million cold water molecules in the ocean is just plain silly.

The main sources of ocean heat are the sun, and the hot interior of the earth, not the trace quantities of a colourless non-combustible gas in the atmosphere.

If solar energy increases, this will warm the oceans, the land and the atmosphere. The heated surfaces will radiate more heat away, reaching a slightly higher warmer "average" temperature. These changes are generally gradual, and to some extent, predictable.

Moreover, the ocean has its own temperature control – as the water heats, evaporation increases, taking heat from the ocean and limiting the temperature rise (just like the old evaporative coolers). This cooling effect increases as water temperature increases. For all practical purposes the temperature of large bodies of water on the earth's surface will not exceed about 31°C.
The wild card that does have the capacity to cause sudden and dangerous warming of the ocean is geothermal energy, released in volcanoes and along the massive mid-ocean rifts. When large quantities of molten lava meet cool water, the water will boil. The water in the kettle is not boiled by the hot air above the stove – it is heated by the hot coals in the firebox below.

Are the oceans warming alarmingly?

The diagram below suggests that the Pacific Ocean surface temperature is not rising - in fact it looks to be slowly turning into a cooling phase.

![CO2 vs Ocean Temperature](http://www.c3headlines.com/2012/04/runaway-greenhouse-effect-hansen-boiling-oceans.html)

All evidence points to the conclusion that ocean temperature controls carbon dioxide content of the oceans and the atmosphere, often with long lead times.

There is no evidence that man's use of cars, trucks, tractors, trains and planes is causing global temperatures to rise and man's carbon dioxide in the atmosphere is such a puny force it could never cause oceans to boil.

**The Precautionary Principle**

Some people of alarmist inclination say "but let's take action in case the worst scenario happens".
If we could burn all of Earth's large resources of carbon fuels in a short time, it is perhaps possible but not likely that the carbon dioxide produced could cause significant changes to the atmosphere and measurable but temporary change to ocean chemistry. Neither of these effects is likely to cause irreversible harm to the biosphere. They are however quite likely to result in a much greener Earth with more life on land and in the oceans.

However, to cease using carbon fuels in case our industry causes some problem to life on Earth would cause massive dislocation and increased starvation for Earth's people. Forcing unnecessary constraints and costs on the use of carbon fuels will damage our ability to produce our food, shelter and transport and is not a rational precaution.

On the contrary, it is a huge and reckless risk.

There are many environmental and pollution problems more important and far more deserving of our attention than this.

For example, read about the load of toxic plastic debris floating on the ocean: [http://thesunbreak.com/2012/04/30/a-staggering-mess-as-tsunami-debris-hits-alaska-coast-early/](http://thesunbreak.com/2012/04/30/a-staggering-mess-as-tsunami-debris-hits-alaska-coast-early/)

Instead of wasting community savings on futile "solutions" to imaginary "problems" we could also be flood-proofing highways and airports, drought-proofing towns and cities and removing feral pests and weeds from National Parks.

**Conclusions**

**The Ocean Acidification Fiction**

In light of these several diverse and independent assessments of the two major aspects of the ocean acidification hypothesis -- a CO2-induced decline in oceanic pH that leads to a concomitant decrease in coral growth rate -- it would appear that the catastrophe conjured up by the world's climate alarmists is but a wonderful work of fiction.

Sherwood, Keith and Craig Idso

[http://www.co2science.org/articles/V12/N22/EDIT.php](http://www.co2science.org/articles/V12/N22/EDIT.php)

1. Oceans are alkaline and never acidic, except locally near active submarine volcanic vents. It is deceptive to suggest that sea life is threatened by "the rising acidity of the oceans". The oceans are still quite alkaline. Nothing unusual or abnormal has yet been detected.

2. It is impossible to determine a meaningful figure for "average" ocean acidity (pH). It is also impossible to say with any certainty that average ocean pH has changed because of man's use of carbon fuels. Such "measurements" are an exercise in guided guesswork. ("What would you like the answer to be?")
3. The pH of the oceans varies naturally from place to place and time to time, depending on temperatures and the activities of plant and animal life.

4. Careful study of the graph recording carbon dioxide levels in the atmosphere shows a very rapid response of carbon dioxide atmospheric concentration to changing sea temperatures in agreement with Henry’s Gas Law. If global temperatures rise, that will expel carbon dioxide from the ocean.

5. It is a myth that acidic waters necessarily kill aquatic life. Rain water is slightly acidic and many fresh water lagoons, swamps and reed beds are also acidic. Nevertheless, aquatic life flourishes in these wetlands.

6. Oceans cover about 71% of the Earth's surface and the hydrosphere contains over 300 times the mass of gases in the atmosphere. The oceans have a huge capacity to buffer any variations in heat content or gas content emanating from the thin veil of atmospheric gases. The effect of man's supposed 3% contribution to the tiny 0.039% of carbon dioxide in the Earth's thin atmosphere would not register a long-term effect in the massive oceans.

7. Cold ocean currents from the deep ocean periodically up-well to the surface. These currents are rich in dissolved carbon dioxide and other chemicals and decayed organic matter. Where this cold nutrient-rich water surfaces, there is a staggering profusion of aquatic life.

8. The oceans have a huge capacity resist being destabilised by changes in temperature or composition of the atmosphere. Whenever there is a change, the reactions of other chemicals or life in the sea act to moderate and even reverse those changes.

9. Oceans have an unlimited ability to remove carbon dioxide from their waters and store it in thick beds of shells and corals, limestone, chalk, dolomite, magnesite, siderite, marls, methane hydrate and oil shales. Fresh water swamps and lakes on land have also laid down massive deposits of coal and lignite formed from carbon dioxide extracted from the atmosphere. Many of these deposits were laid down when the carbon dioxide content of the atmosphere was far higher than it is today.

10. Carbon dioxide present in the oceans is essential to plant life and current very low levels of carbon dioxide in the atmosphere and the ocean are limiting plant growth. All animal life depends on these plants. Man's mining and industrial activities are harmlessly recycling some of this valuable carbon dioxide from natural limestones and hydrocarbons buried in the dead lithosphere, back to the living biosphere.

11. Corals are hardy and adaptable and have survived for 500 million years. During that time they have had to cope with warmer eras, ice ages, extinction events, eras of massive volcanic activity, dramatic rising and lowering in sea levels and eons of time when levels of atmospheric carbon dioxide were far higher than today.

12. A very recent extensive study of the Great Barrier Reef concluded that the changes forecast under the "business as usual greenhouse gas emissions" were unlikely to cause great harm to the reef.

13. Any change in global temperature or the carbon dioxide content of the atmosphere will cause life on land and in the ocean to adjust and adapt. However, on balance, a warmer world with more plant food in the atmosphere and a more vigorous water cycle is very beneficial for the biosphere. The killer climates are associated with ice ages when the atmosphere is cold and dry, the sea levels are much lower and much of Earth's fresh water is locked up in vast lifeless sheets of ice.
14. There is no justification to use the baseless fear of "acidification of the oceans" as an excuse for a massive dislocation of our transport, food and energy industries.

15. We should instead be focussing on real pollution problems (such as man’s rubbish floating in the oceans) and/or on preparing to cope with real and likely natural disasters (such as earthquakes, volcanic eruptions, tsunamis, floods, fires, cyclones and droughts).

Viv Forbes

The author, Viv Forbes, has a Degree in Applied Science (Geology, Chemistry, Physics and Maths) and experience in geology, financial analysis, farming and mining. He is also Chairman of the Carbon Sense Coalition. He can be contacted at forbes@carbon-sense.com or phone 0754 640 533.

Assistance from several members of the Carbon Sense Coalition is acknowledged with significant help from Bob Beatty and Bob Greenelsh. However, Viv Forbes takes all responsibility for any errors that may remain.

Further Selected References (for those who wish to dig deeper):


And: http://www.seafriends.org.nz/issues/global/acid2.htm

CO2 Science at: http://www.co2science.org/

Here is one of the best single reports: An 85 page pdf:

---

Corals not Threatened by Carbon Dioxide or Global Warming

"Atmospheric CO2 enrichment has been postulated to possess the potential to harm coral reefs both directly and indirectly.

"With respect to marine life – and especially that of calcifying organisms such as corals and coccolithophores - neither increases in temperature, nor increases in atmospheric CO2 concentration, nor increases in both of them together, have had any ill effects on the important processes of calcification and growth.

"In fact, out in the real world of nature, these processes have actually responded positively to the supposedly unprecedented concomitant increases in these “twin evils” of the radical environmentalist movement."

The Conclusion from a detailed study "CO2, Global Warming & Coral Reefs – Dr Craig Idso
Appendix 1.

[Link to Article]

**Why climate change might not spell death for the Reef**

BRIDIE JABOUR
13 Apr, 2012 03:00 AM

Rising ocean temperatures caused by climate change are unlikely to mean the end of the coral on the Great Barrier Reef, according to a new scientific study.

The Cell Press journal Current Biology this morning published what it says is the first large-scale investigation of climate effects on corals and found while some corals were dying, others were flourishing and adapting to the change in water temperatures.

For the study researchers identified and measured more than 35,000 coral colonies on 33 reefs across the length of the Great Barrier Reef to see how they were responding to warming ocean waters.

In results they have described as “surprising” the study found while one species declined in abundance, other species could rise in number.

One of the researchers, Professor Terry Hughes from James Cook University, said while critical issues remained he now believed rising temperatures were unlikely to mean the end of the coral reef.

“The good news is that, rather than experiencing wholesale destruction, many coral reefs will survive climate change by changing the mix of coral species as the ocean warms and becomes more acidic,” he said.

“That’s important for people who rely on the rich and beautiful coral reefs of today for food, tourism, and other livelihoods.”

He said earlier studies of climate change and corals had been done on a much smaller geographical scale, with a primary focus on total coral cover or counts of species as rather crude indicators of reef health.

“We chose the iconic Great Barrier Reef as our natural laboratory because water temperature varies by 8 to 9 degrees Celsius along its full length from summer to winter, and because there are wide local variations in pH,” he said.

“Its regional-scale natural gradients encompass the sorts of conditions that will apply several decades from now under business-as-usual greenhouse gas emissions.”

The warming of the ocean’s temperatures due to climate change will change the composition of coral reefs and while this will mean the end for some species it will mean others are adapting to survive.
APPENDIX 2.
Ocean “Acidification” - A Note by Dr Martin Hertzberg

Dr Hertzberg is a combustion research scientist who has served as a meteorologist in the US Navy and has been studying the global warming issue for the last twenty years.

The ocean has an average pH of 8, which means that its hydrogen ion concentration, $[H^+] = 10^{-8}$ moles per litre. That means that $[OH^-] = 10^{-6}$. The ratio of hydrogen ion to hydroxyl ion is 100, which means that the ocean is 100 times more basic than acidic.

How does increasing CO2 in the atmosphere make the ocean less basic?

\[
\begin{align*}
\text{CO}_2 + \text{H}_2\text{O} & = \text{H}_2\text{CO}_3 = \text{H}^+ + \text{HCO}_3^- \\
\text{HCO}_3^- & = \text{H}^+ + \text{CO}_3^{2-} \\
\text{Ca}^{2+} + \text{CO}_3^{2-} & = \text{CaCO}_3 \text{ (solid)}
\end{align*}
\]

This is a “buffered system” that is very resistant to changes and maintains a fairly constant pH. Increasing CO2 merely causes more Calcium Carbonate solid to form without much change in pH. Decreasing CO2 dissolves more Calcium Carbonate to restore the balance.

Thus, doubling the current value of 395 ppm CO2 to 790 ppm will reduce the pH by only 0.2; that is, from 8.0 to 7.8. That change is well within the current range of actual measurements of the ocean’s pH. And no-one is seriously expecting a doubling of atmospheric CO2 concentrations within any foreseeable future. Here is the data for Monterey Bay:

For questions or to gain access to the data archive please contact either Roger Phillips (rphillips@mbayaq.org) or Eric Kingsley (ekingsley@mbayaq.org) at the Monterey Bay Aquarium.
Other cities along the California coast show similar fluctuations of about 0.2 pH with no discernible downward trend.

The current average pH of the Arctic Ocean is 8.23 and that of the Indian Ocean is 8.01. A few other samples of ocean pH are shown below.

Independent experimental measurements on the effect such changes in pH will have on calcification, metabolism, growth, fertility, and survival of oceanic life, show no significant effects. For details go to: [www.co2science.org](http://www.co2science.org)

*Martin Hertzberg*