CO$_2$ Science's Ocean Acidification Database

A new tool to evaluate climate-alarmist claims of widespread marine species destruction due to the ongoing rise in atmospheric CO$_2$.

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**INTRODUCTION**

According to climate-alarmist *theory*, as the air’s CO₂ content rises in response to ever-increasing anthropogenic CO₂ emissions, and as more and more carbon dioxide therefore dissolves in the surface waters of the world's oceans, the pH values of the planet's oceanic waters should be gradually dropping.

It has been estimated, for example, that the globe's seawater has been *acidified* (actually made less basic) by about 0.1 pH unit relative to what it was in pre-industrial times; and model calculations imply there could be an additional drop somewhere in the neighborhood of between 0.3 to 0.7 unit by the year 2300. A potential pH reduction of this magnitude is viewed by many as a cause for great concern; because it has been postulated to harm calcifying marine life such as corals, not only by reducing the calcifying rates of marine organisms, but also by negatively impacting their metabolism, growth, fertility and survival.

This *ocean acidification hypothesis* has gained great momentum in recent years, because it offers an independent path to regulate fossil fuel emissions in addition to that provided by concerns about global warming. For even if the models employed by climate alarmists are proven not to be correct with respect to their predictions of unprecedented temperature increases, more frequent and more destructive extreme weather events, accelerated glacial melt, rapid sea level rise, or any other environmental catastrophe, those who seek to regulate and reduce CO₂ emissions now have a *fall-back position*, which posits that no matter what happens to the planet's climate, the nations of the earth must reduce greenhouse gas emissions because of their direct negative impacts on marine organisms via ocean acidification.

Over time, the rhetoric of these *acidification alarmists* has risen tremendously, as illustrated in a couple of quotes from a short, 21-minute film released in late 2009 by the National Resources Defense Council (NRDC) entitled *Acid Test: The Global Challenge of Ocean Acidification* (Natural Resources Defense Council, 2009). Featuring Sigourney Weaver as its narrator, the film highlights the alarmist views of a handful of scientists, a commercial fisherman and two employees of the NRDC, as they discuss what they claim is a *megadisaster-in-the-making* for Earth’s marine life.
The villain of the story is *industrial man*, who has "altered the course of nature" by releasing large quantities of carbon dioxide into the air via the burning of coal, gas and oil. According to Ken Calderia, a professor at Stanford University, "by mid-century, if we continue emitting carbon dioxide the way we have been, entire vast areas of both the Southern Ocean and the Arctic Ocean will be so corrosive that it will cause sea shells to dissolve," leading him to conclude that "we're really in the last decades of coral reefs on this planet for at least the next, let's say million plus years, unless we do something very soon to reduce CO₂ emissions. We're moving from a world of rich biological diversity into essentially a world of weeds."

Not to be outdone, Dr. Ove Hoegh-Guldberg of The University of Queensland says:

"We know that coral reefs are particularly sensitive to ocean acidification. And the reason for that is that corals are unable to form their skeletons as quickly as they used to, and reefs are starting to crumble and disappear. We may lose those ecosystems within 20 or 30 years. ... We've got the last decade in which we can do something about this problem. But it is very, very clear that if we don't start to deal with it right now, with very, very stern cuts to emissions, we are going to condemn oceans to an extremely uncertain future."

The ocean chemistry aspect of the ocean acidification theory is rather straightforward; but it is not as solid as model projections, alarmist scientists, politicians, or movie stars make it out to be. For example, a number of respected researchers have published papers claiming that the drop in oceanic pH will not be nearly as great as the IPCC and others predict.

The figure below shows much of the past and projected history of fossil-fuel carbon utilization, together with historical and projected atmospheric CO₂ concentrations out to the year 2500, as calculated by NOAA's well-respected Pieter Tans (2009). As can be seen here, his analysis indicates that the air's CO₂ concentration peaks well before 2100 and at only 500 ppm, as compared to an 800 ppm value predicted in one of the IPCC's scenarios. It is also worth noting in this graph that by the time the year 2500 rolls around, the air's CO₂ concentration actually drops back to about what it is today.
When these emissions estimates are transformed into reductions of oceanic pH, it can readily be seen in the figure to the left that Tans' projected pH change at 2100 is far below that of the IPCC. And Tans' analysis indicates a pH recovery to values near those of today by the year 2500, clearly suggesting that things are not the way the world's climate alarmists make them out to be when it comes to anthropogenic CO$_2$ emissions and their effects on the air's CO$_2$ content and oceanic pH values.

Another reason to not jump on the ocean acidification bandwagon is the fact that, with more CO$_2$ in the air, additional weathering of terrestrial carbonates is likely to occur, which would increase delivery of Ca$^{2+}$ to the oceans and partly compensate for the CO$_2$-induced decrease in oceanic calcium carbonate saturation state. In addition, as with all phenomena involving living organisms, the introduction of life into the ocean acidification picture greatly complicates things, as several interrelated biological phenomena must also be considered; and when they are, it becomes much more difficult to draw such sweeping negative conclusions. In fact, as demonstrated in numerous reviews of the scientific literature, these considerations even suggest that the rising CO$_2$ content of earth's atmosphere may well be a beneficial phenomenon with many positive consequences (Idso, 2009).

Nevertheless, articles continue to be published in peer-reviewed scientific journals on both sides of the issue, making it very difficult to get to the bottom of what impacts rising atmospheric carbon dioxide will really have on earth's marine life. For every article that seems to present the issue in a negative light, there is a counter article that presents it in a positive light. Now, however, our understanding of this important issue has taken a giant leap forward, with the creation of an online Ocean Acidification Database maintained by the Center for the Study of Carbon Dioxide and Global Change.
THE DATABASE

Available free of charge at [http://www.co2science.org/data/acidification/acidification.php](http://www.co2science.org/data/acidification/acidification.php), the online database debuted in October 2010, showcasing over 1100 experimental results from the peer-reviewed scientific literature. Specifically, the Ocean Acidification Database is an ever-growing archive of the responses of various growth and developmental parameters of marine organisms immersed in seawater at or near today's oceanic pH level, as well as at levels lower than that of today. The measured parameters include variables that pertain to changes in calcification, growth, metabolism, fertility and survival. The data are arranged by marine organism, accessible by selecting an organism's common or scientific name; but the data have also been grouped into similar types of organisms, such as bivalves, corals, fish, nematodes phytoplankton, etc. An example of a typical record in the database, that of Blue Crab (*Callinectes sapidus*) pertaining to calcification, is presented below.

![Image of database interface](image.png)

On each organism page (or grouped types of organisms) there are two data tables, one with a blue background and one with yellow. The first table (blue background) presents statistical information that is derived from the second table (yellow background) below it, and includes
(1) the number of experimental results archived for that organism/category, (2) the arithmetic mean of the results, and (3) the standard error of the mean, all listed as a function of an incremental decline in pH from the present.

The second table, with the yellow background color, lists the individual experimental results. Each individual record contains three pieces of information: (1) an abbreviated reference to the journal paper from which the results were obtained, (2) a short description of the experimental conditions under which the author(s) conducted the original study (full journal citations are available by clicking on the Journal References link found at the top of the first column in this table), and (3) the change in the measured parameter (calcification, growth, metabolism, fertility or survival) relative to present seawater pH conditions, grouped into one of five categories of pH decline intervals from the present (0 to 0.09, 0.09 to 0.17, 0.17 to 0.3, 0.3 to 0.5 and More than 0.5). Changes in the measured parameters are expressed as ratios, where any number less than 1 corresponds to a decline and any number greater than 1 represents an increase, all of which values are relative to the control treatment at current pH. For example, in the figure above, a value of 1.38 in the 0.17 to 0.30 pH decline category for blue crab indicates the researchers observed a 38% increase in calcification of blue crabs relative to their calcification at current pH. Likewise, a value of 0.85 would indicate a 15% decrease in the measured parameter.

The five pH decline intervals, illustrated in the figure below, have been chosen based on the following criteria:
**pH Decline of 0 to 0.09**
This category represents the pH decline range from the present to that projected by Tans (2009).

**pH Decline of 0.09 to 0.17**
This category represents the maximum pH decline range projected by Tans (2009), which projection is probably the most accurate and likely to occur in the future.

**pH Decline of 0.17 to 0.3**
This category represents the pH decline range between that projected by Tans (2009) and the IPCC.

**pH Decline of 0.3 to 0.5**
This category represents the maximum pH decline range typically projected to occur by the Intergovernmental Panel on Climate Change, or IPCC.

**pH Decline of More than 0.5**
This category represents the pH decline range beyond that typically projected by the IPCC, and is therefore extremely unlikely to occur.

In considering the organisms’ responses posted in the database, it is important to recognize that out of the 5 pH decline ranges in which the data are organized, only the first two (0 to 0.09 and 0.09 to 0.17) represent conditions that might possibly occur in the future. Beyond that, interpretation of the data becomes almost meaningless, because the larger pH decline ranges will likely never occur.

**The Results**

As of October 2010, over 1100 individual records appear in the database; and the following graphics are presented to help discern the major message and sub-messages of those data. These figures will be updated periodically on the database website as the number of records in the database grows.

The first figure depicts the percent changes in all five of the major life characteristics examined in the database (calcification, metabolism, growth, fertility and survival) as a function of the experimentally-orchestrated declines in seawater pH from the present, where each entry in the database is represented by its own individual data point.
As indicated, Figure 1 portrays an extremely wide range of pH reduction values, the greatest of which corresponds to an increase in the atmosphere's CO₂ concentration in excess of 100,000 ppm, which is a couple orders of magnitude greater than what anyone is expecting will ever occur. Hence, Figure 2 highlights (in grey) the vast bulk of this pH reduction range as being "far, far beyond the realm of reality."

The low-end boundary of the unrealistic highlighted region of pH reduction in Figure 2 is 0.5, which represents the high-end or maximum value of most IPCC-based projections of CO₂-induced pH reduction, which occurs in the vicinity of AD 2300. Thus, there should be little argument – even from people who think ocean acidification is going to be a problem – in excluding all values beyond a pH decline of 0.5 when considering how ocean acidification might realistically affect earth's marine life.

In the next figure, the results of all experiments that employed a seawater pH decline that fell somewhere in the still-more-likely-to-occur range of 0.0 to 0.3 are plotted, where the latter value is the approximate IPCC-derived pH decline in the vicinity of AD 2100. Then, within this range, highlighted in grey, is the much smaller seawater pH reduction range that derives from the work of Tans (2009), who derived a maximum pH decline that could fall anywhere within an uncertainty range of 0.09 to 0.17 by about AD 2100, after which seawater pH begins its long-term recovery. We chose to emphasize the Tans prediction range in this manner because we consider his analysis to be more realistic than the analysis of the IPCC. Thus, data within the pH reduction range of 0.0 to 0.17 should be considered as being most characteristic of what might possibly occur in the real world, as time marches on and fossil fuel burning continues as per business as usual. And, interestingly enough – and even incorporating pH reduction data all the way out to 0.30 – the linear trend of all the data is actually positive, indicating an overall beneficial response of the totality of the five major life characteristics of marine sea life to ocean acidification, which result is vastly different from the negative results routinely predicted by the world's climate alarmists.
The next two graphs illustrate the averages of all responses to seawater acidification for all five of the life characteristics of the various marine organisms analyzed over the five pH reduction ranges. The first of these "All-Studies" graphs is depicted in Figure 4, where the mean percent changes in the five life characteristics (calcification, metabolism, growth, fertility and survival) are plotted vs. the mean declines of seawater pH from the present (control treatment) value to the mean values of the pH declines that occur within each of the five pH reduction ranges described in the previous section.

This figure is provided simply to illustrate the totality of all the data contained in the Ocean Acidification Database; and it can be seen from the plots that they all extend into the region defined previously as "far, far beyond the realm of reality." Therefore, Figure 5 presents only the portions of the plots that extend into and through the domains of Tans, ending at the upper-bound predictions of the IPCC.

The most striking feature of Figure 5 is the great preponderance of data located in positive territory, which suggests that, on the whole, marine organisms likely will not be harmed to any significant degree by the expected decline in oceanic pH. If anything, in fact, the results suggest that the world's marine life may actually slightly benefit from the pH decline, which latter possibility was earlier borne out by the scatter plot of all the experimental data pertaining to all life characteristic categories over the same pH decline range, as shown in Figure 3.
CONCLUSION

The results depicted in the figures above suggest something very different from the doomsday predictions of the climate alarmists who claim we are in "the last decades of coral reefs on this planet for at least the next ... million plus years, unless we do something very soon to reduce CO₂ emissions," or who declare that "reefs are starting to crumble and disappear," that "we may lose those ecosystems within 20 or 30 years," and that "we've got the last decade in which we can do something about this problem." Clearly, the promoting of such scenarios is not supported by the vast bulk of pertinent experimental data.

Two other phenomena that suggest the predicted decline in oceanic pH will have little to no lasting negative effects on marine life are the abilities of essentially all forms of life to adapt and evolve. Of those experiments in the database that report the length of time the organisms were subjected to reduced pH levels, for example, the median value was only four days. And many of the experiments were conducted over periods of only a few hours, which is much too short a time for organisms to adapt (or evolve) to successfully cope with new environmental conditions. And when one allows for such phenomena, the possibility of marine life experiencing a negative response to ocean acidification becomes even less likely.

Based on the experimental findings presented in the Center for the Study of Carbon Dioxide and Global Change's Ocean Acidification Database, and analyzed above, it should be clear that claims of impending marine species extinctions driven by increases in the atmosphere's CO₂ concentration are not founded in empirical reality.

For more information on this subject, please see the many reviews written on this subject that are archived under the headings of Calcification, Marine Biota, and Ocean Acidification on the CO₂ Science website's Subject Index at http://www.co2science.org/subject/subject.php.

REFERENCES

