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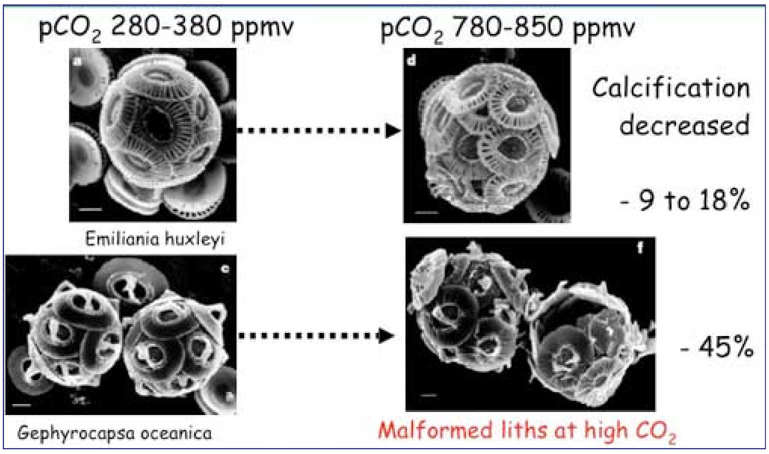
Updated June 25, 2008: Increasingly Acidic Pacific Coast Waters Threaten Marine Life

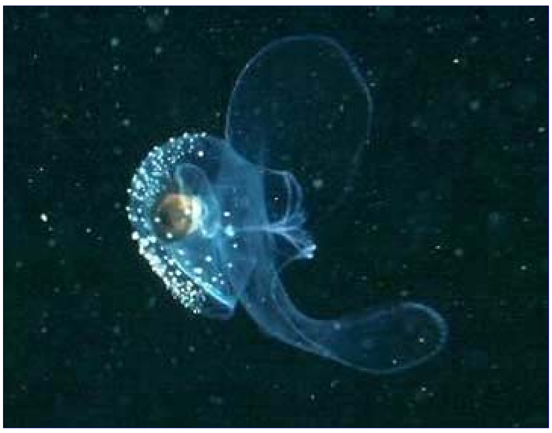
"We have already *seen in 2007 a drop in pH of 0.1,*
which equates to ~30% increase in acidity. By the end of this century
the models predict a total drop in pH of 0.4 which is actually more
like a 150% increase in acidity. *For ocean chemistry, this is very dramatic –*
a bigger change than we've seen for at least the last 5 million years on planet Earth.
And it's more than 100 times faster rate of change than we've seen
over that period." **-** Christopher Sabine, Ph.D., NOAA



Coccolithosphores, single-celled algae, that contain calcium carbonate shells.
When exposed to acidic water equivalent to the 800 ppm upwelling ocean samples in 2007
off the California coast, the Coccolithosphores become malformed and deteriorate.
Images by Riebesell and Zondervan in 2000 and 2001.

June 21, 2008 Corvallis, Oregon and Shelton, Washington - None of the global warming climate models saw open oceans increasing in acidity by 30% or more until the end of the 21st Century. But a new study published in the June 2008 journal, *Science*, shows that Pacific ocean water only four miles off the northern California shore, is already *30% more acidic* than normal. When I did my first Earthfiles.com report about the acidification of the world's oceans [**081304 Earthfiles**], computer models were projecting that open ocean acidity might seriously increase by at least 30% or more at the *end* of the 21st Century - not by 2008.

By 2008, it is estimated that oceans have absorbed 525 billion tons of greenhouse gases. All the carbon dioxide absorbed by seawater has produced increasing amounts of carbonic acid. The calcium carbonate shells of clams, oysters, corals, small snails called Pteropods and some planktons weaken and disintegrate in carbonic acid.



Sea Butterfly, a small Pteropod, or snail, that has a thin, calcium carbonate shell, which can easily dissolve in carbonic acid.

Sea creatures make their shells in the surface waters where there is a lot of calcium and carbonate. Deeper below, the ocean has such high concentrations of CO_2 from both atmospheric absorption and natural decay of organic material that the deep ocean CO_2 destroys carbonate ions which dissolves shells. That ocean level where carbon dioxide dissolves shells is getting higher and higher toward surface waters. And no one expected to see it break through now on the West Coast.

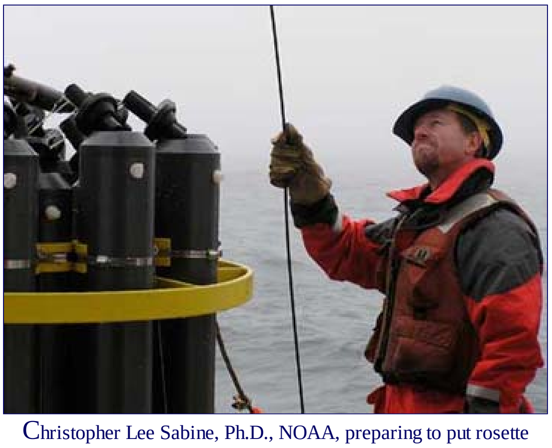
But last summer of 2007, NOAA and Oregon State University scientists sampled water during the spring and summer season of ocean upwelling when winds blow strongly from the north and push the surface waters away. In that displacement, deeper and much older water wells up to the surface carrying all its carbon dioxide. As CO_2 has increased in the Earth's atmosphere each year for nearly 200 years, that means upwelling ocean water has stored an ever-increasing amount of carbon dioxide, which can create more carbonic acid that dissolves calcium carbonate shells.

Ken Caldeira, Ph.D., at the Carnegie Institution for Science, Department of Global Ecology, Stanford University, pointed out in 2006 that "the oceans naturally absorb just 0.1 gigatons more CO_2 per year than they release. Now they are soaking up an extra 2 gigatons a year, more than 20 times the natural rate. Even if we halve emissions, that will merely double the time until we kill off your favorite plant or animal. ...The last time the oceans endured such a drastic change in chemistry was 65 million years ago, at about the same time the dinosaurs went extinct."

What are the future implications of an increasingly acidic ocean? I asked both Christopher Sabine, Ph.D., and Prof. Burke Hales, Ph.D., oceanographers, who are two of the co-authors of the June 2008 *Science* journal study, plus Brett Bishop, a shellfish grower in Shelton, Washington.

Interviews:

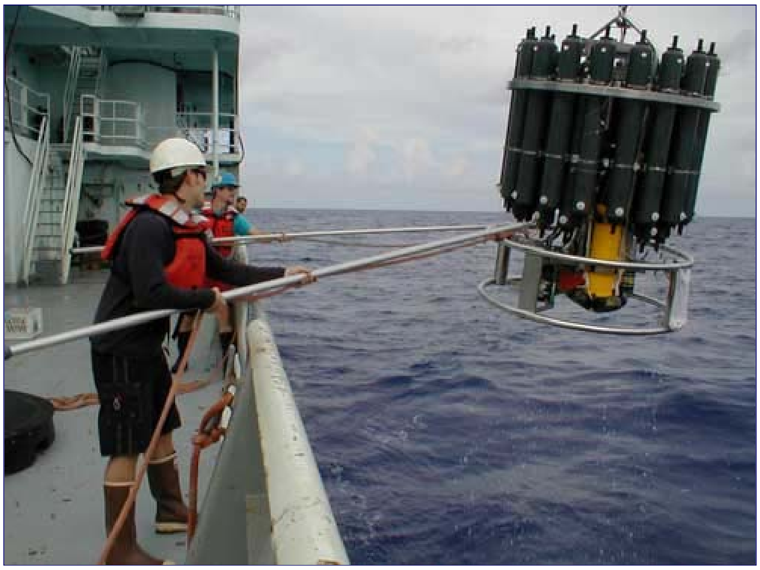
"We have already *seen in 2007 a drop in pH of 0.1, which equates to ~30% increase in acidity. By the end of this century the models predict a total drop in pH of 0.4 which is actually more like a* 150% increase in acidity.*"* - Christopher Sabine, Ph.D., NOAA



Christopher Lee Sabine, Ph.D., NOAA, preparing to put rosette of water sampling bottles into the Pacific Ocean during spring 2007 ocean upwelling research. Image courtesy NOAA.

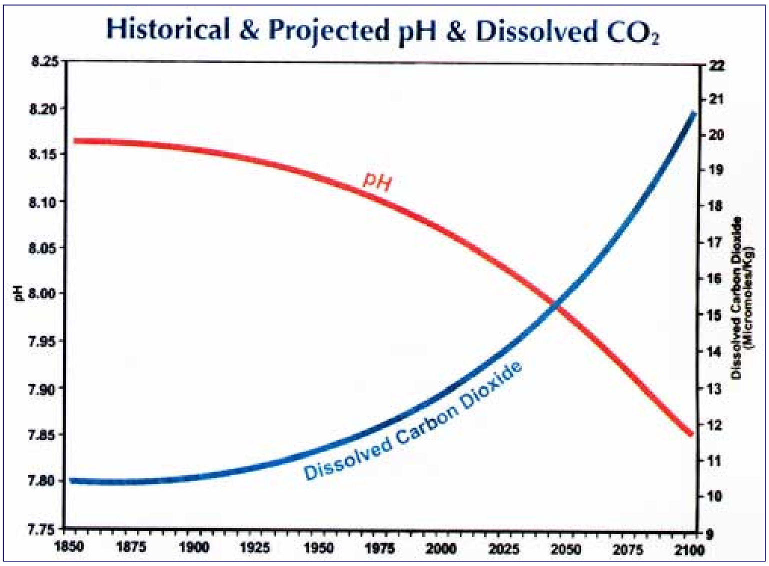
Christopher Lee Sabine, Ph.D., Chemical Oceanography, Pacific Marine Environmental Laboratory (PMEL), National Oceanic and Atmospheric Administration (NOAA), Seattle, Washington: "We thought the acidified water would not reach the surface for 50 years. In fact, we found it during our survey cruise all the way to the surface. We found water, which had a pH of 7.8, which is much lower than we expected to see, which can corrosively dissolve shellfish calcium carbonate shells at the surface waters right near the California and Oregon border. That's where we saw the most acidified water. And of course, that's where all the shellfish industries are on the shelf!

I know that none of us really expected to find these acidified waters making it all the way to the surface. So, we were quite shocked.



NOAA research team recovered the water sampling package called a rosette.
Each of the gray cylinders can be closed at whatever depth the scientists choose.
Each bottle traps 11 liters of water that can then be sub-sampled by the various analysts on the ship for a variety of measurements. Image courtesy NOAA.

The pCO2 of the upwelled waters off of California was over 800ppm. This is because manmade industrial CO2 is adding to waters that were already naturally high in CO2 after the natural decomposition of organic matter in the water column. The surface waters are generally close to atmospheric CO2 concentrations (385ppm), but as you go deeper in the water column, the CO2 concentrations increase from the accumulation of biological CO2. These vertical gradients will still exist in the future, but as atmospheric CO2 increases, the whole curve will increase. Instead of going from 385 to 800 between the surface and deeper, we could be seeing 800 to 1300ppm between the surface and deeper ocean water by the year 2100.



As the ocean concentration of carbon dioxide inicreases, so does acidity, causing pH to decline. Graphic courtesy NOAA.

Ocean Level That Can Dissolve Calcium Carbonate Shells Keeps Rising

THE IMPLICATION FOR 2008 AND GOING FORWARD IS WHAT?

Next year, we estimate from the chemistry and the rate at which the oceans are taking up CO2 that the dissolving-shells-level is getting shallower by about 1 meter per year, or a little more than 3 feet. So, this year of 2008, it's going to be that much more shallow and more acidified water is going to get up on the continental shelf. Next year, it will be even shallower. This will just keep continuing. So, the chemistry is going to get worse and worse every year.

The oceans are absorbing about 2 billion metric tons of carbon per year. Every year, it absorbs 2 more billion, 2 more billion, 2 more billion. And as long as atmospheric CO2 continues to increase, the oceans will continue to absorb that CO2. That's going to continue to change the chemistry of the oceans.

SINCE THE DEEP UPWELLING OCEAN WATER ALREADY CONTAINS MORE CO2 THAT IT HAS ABSORBED IN SOME PAST YEAR FROM THE ATMOSPHERE, DOESN'T THIS ALSO IMPLY THERE IS NO WAY NOW THAT HUMAN CIVILIZATION CAN CHANGE THIS INCREASE OF CARBONIC ACID CURRENTLY IN THE OCEANS?

If we have some way of decreasing atmospheric CO2, it can be reversed. But generally, that's not likely to happen. And even if it did, it's a very long process that can take thousands of years at best.

SO ARE WE IN KIND OF AN IRRETRIEVABLE SITUATION NOW?

In terms of the chemistry, it would be very difficult to reverse this. And one of the things we are concerned about is the viability of coral reefs. And the corals not only are affected by ocean acidification, but are also affected by coral bleaching, which is a temperature affect, and are affected by pressures from the boating industry and pollution and all these sorts of things.

LIKE WARM TEMPERATURES FROM GLOBAL WARMING IN THE WATER.

Exactly. As bad as ocean acidification is, it seems to be worse at high temperatures!

Dr. Sabine: "Corals are dissolving from carbonic acid exposure in this image and you can actually see holes in the coral structure."
Image © Jason Hall-Spencer, The Royal Society, London, U.K.

Will Rising Carbonic Acid Levels Cause Marine Extinctions?

HOW IN THE WORLD WOULD ANY OF THESE LIFE FORMS MAKE IT OUT OF THIS CENTURY WITH THE INEVITABLE INCREASE OF CARBONIC ACID?

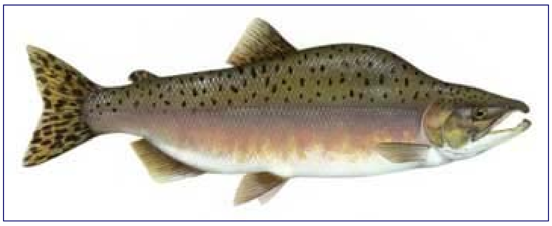
That's our concern. That's why we're trying to make the public aware of this. I don't know exactly what the solutions will be. We're trying to remain optimistic trying to find some way out of this, but until we fully understand what's going on and what the ecological consequences are going to be, we can't really say what the future is going to hold for us. But I agree, it does not look great.

ON THE OTHER SIDE OF NOT LOOKING GREAT ARE A LOT OF EXTINCTIONS, CORRECT?

Potentially. My biggest fear is that we're going to sit and ignore this until it's too late. It's a cascading effect. As soon as you start to lose organisms at the lower end of the food chain, it will just propagate right on up the food chain. We don't know what the consequences of that will be. But once a species goes extinct – and I don't know if it will or not – but if it does, then there is no getting it back. That's when it's too late.

ONE SCIENTIST SAID TO ME THAT WHAT HE SEES HAPPENING THIS CENTURY IS THAT THE SALMON WILL BE REPLACED BY JELLY FISH.

There is evidence that jelly fish do live better in higher CO2 environments. They are one of the species that seems to do better in a higher CO2 environment. For salmon, we've seen, for example, that the pink salmon at a particular juvenile stage have 40% of their diet is made of these Pteropods, which produce calcium carbonate shells. So, if we lose those Pteropods, that's potentially a major food source for these salmon.



Pink Salmon, *Oncorhynchus gorbuscha*.
Illustration by Timothy Knepp for U. S. Fish and Wildlife Service.

We don't know what happens if you take away that major food source for the juvenile salmon. But we could potentially lose the salmon.

ALREADY THE SALMON ARE FIGHTING FOR THEIR LIVES ALONG THE PACIFIC COAST IN ALMOST ALL OF THE SPECIES.

Exactly. The problem with ocean acidification is that there is a tremendous momentum to the system – that it's just going to continue to get worse and worse and worse. It's not the kind of thing that you can just turn off once it gets going.

Can Ocean Carbonic Acid Be Neutralized?

SO, THE IDEA OF TAKING SODA POWDER AND SPREADING IT ON TO THE OCEANS TO NEUTRALIZE CARBONIC ACID IS NOT EFFECTIVE OR ECONOMICALLY FEASIBLE?

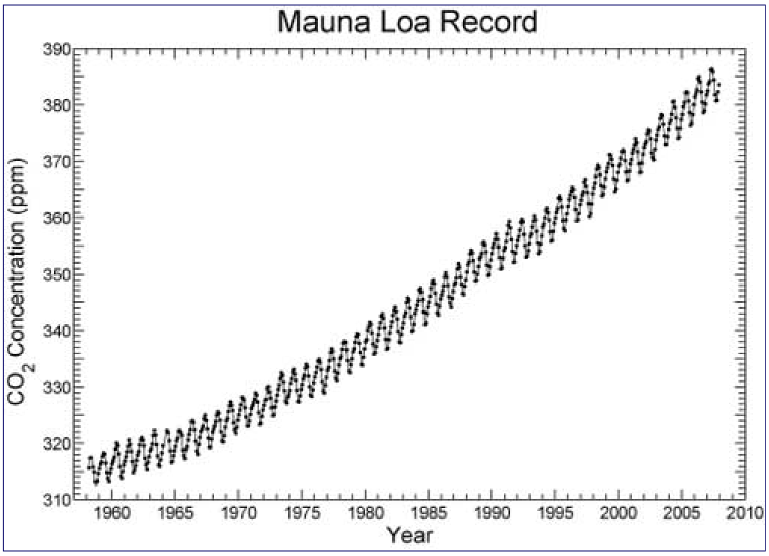
It's not really economically feasible. And we worry about any time you're trying to add another chemical to counteract the chemicals you are putting into the ocean. Either way, you are changing the chemistry of the ocean. We don't know that adding some material that would neutralize the carbon would not be just as bad in a different way as the carbon. If there is anything we've learned from history is that when we leap into trying to manipulate the environment to our own needs, we frequently cause bigger problems than we intended.

So, the ultimate solution for this is just to remove that CO2 from the atmosphere and stop driving it into the oceans. The oceans will generally clean themselves up. It will be a slow process, but if we can find a way to stop putting CO2 into the atmosphere and find a way to get it out of the atmosphere, then I think the oceans can fix themselves.

BUT WHERE IS THERE ANY EVIDENCE THAT WE'RE SLOWING DOWN CO2 GOING INTO THE ATMOSPHERE AND WATER?

Oh, we're not! We're definitely not slowing down. But if we can at least slow it down, then that's something! Even if you cooled the planet, ocean acidification would continue. That's my concern with people who have suggested technological solutions to global warming by, for example, shielding, putting up sulfate aerosols to lower global temperatures, or shielding some of the solar energy coming into the Earth to try to lower temperatures. Those are great – they would reduce temperature. But they don't do anything for the rising CO2. So, you will still have ocean acidification. The only solutions that will help us are actually reducing the CO2 directly.

Intergovernmental Panel on Climate Change (IPCC) Projects Atmospheric CO2 Will Double in 21st Century



Mauna Loa Observatory, Hawaii, monthly average carbon dioxide concentration from late 1950s through 2007, data from Scripps Institution of Oceanography CO2 Program, University of California-San Diego.

THE IPCC PROJECTS THERE WILL BE ALMOST A DOUBLING, I BELIEVE, IN THE ATMOSPHERE IN THIS REMAINING 90 YEARS IN THE REMAINDER OF THIS CENTURY FROM 383 PPMV NOW TO ABOUT DOUBLE THAT (766 PPMV). IF THAT IS WHERE CO2 ENDS UP OVER THE NEXT 90 YEARS, WHAT WOULD HAPPEN TO CARBONIC ACID IN THE OCEANS?

In the last 200 years, we’ve seen a drop of about .1 pH units. It’s projected that if we double the CO2 from today’s concentration, by the end of this century we’ll see another .4 drop in pH. So, that’s four times the change we’ve seen so far over the last 200 years. That’s because this is an exponential increase and then we don’t know what the impact on the ecosystems will be.

We have already seen in 2007 a drop in pH of 0.1, which equates to ~30% increase in acidity. By the end of this century the models predict a total drop in pH of 0.4 which is actually more like a 150% increase in acidity. For ocean chemistry, this is very dramatic – a bigger change than we’ve seen for at least the last 5 million years on planet Earth. And it’s more than 100 times faster rate of change than we’ve seen over that period. For ocean chemistry, this is very dramatic – a bigger change than we’ve seen for at least the last 5 million years on planet Earth. And it’s more than 100 times faster rate of change than we’ve seen over that period.

WHAT DO YOU SAY TO THE SHELLFISH GROWERS IN WASHINGTON, OREGON AND CALIFORNIA WHO ARE SAYING THEY ARE SHOCKED BY LEARNING ABOUT CARBONIC ACID IN THE WATERS AND WONDER WHAT KIND OF CLAM INDUSTRY WILL I HAVE IN FIVE YEARS, TEN YEARS, FIFTEEN YEARS?

(ironic laugh) I mean, what can you say? We know very well that you can’t change the chemistry and this is going to get worse. I’m hopeful that technologies will be developed that can help us find a way out of this problem.

IF THAT DOES NOT HAPPEN, WHAT?

If that doesn’t happen, then we will be living in a very different world 50 years from now and our kids will have to deal with that.

DO YOU THINK IT’S REALISTIC TO SAY AS SOME SCIENTISTS DO THAT ON LAND THAT IT WILL BE THE ROACHES, RATS AND WEEDS THAT WILL TAKE OVER AND JELLY FISH IN THE OCEANS?

I honestly don’t know. I hope not. That’s not the kind of world I want to live in.”

Burke Hales, Ph.D., Assoc. Professor of Oceanography, Oregon State University, Corvallis, Oregon: “What we did is that we showed that there are acidity levels that are potentially corrosive to these marine animals at the surface water today.

AND EXPANDING, CORRECT?

Should be. Upwelled water takes a long time to get here. So, the water that is upwelling today was actually exposed to an atmosphere about 50 years ago (in 1958), which had lower carbon dioxide concentration then. So, since the atmosphere's concentration of CO2 has increased over that time, the water that's on its way here has seen ever-increasing carbon dioxide levels. As a result, the water that upwells along the Pacific Ocean this summer will have a higher acidity as its starting point than the water that upwelled last summer and so on.

We think somewhere between one-third and one-half of the carbon dioxide that's been produced by human processes over the Industrial Revolution is now in the ocean. What we found is that upwelling areas of the coastal ocean are experiencing these corrosive conditions sooner than we would have expected based on our studies of the open ocean.

IN FACT, THE COMPUTER MODELS DID NOT HAVE THIS KIND OF ACIDITY OCCURRING BEFORE THE END OF THE 21ST CENTURY, CORRECT?

For the open ocean, that's correct. What we do know now is that things are this bad now (in the upwelling water along the Pacific Coast) when that water was originally exposed to an atmosphere that had 310 parts per million carbon dioxide and we're now already up to 385 ppm. What we expect is that the upwelling water we see between now and the next fifty years is going to increase in acidity and increase in corrosiveness to the carbonate shells and it's probably going to be an effect that is three or four times more acidic than we see today.

What Will Happen to Marine Life?

We don't really know that yet. What we've seen in the laboratory studies that look at this is that in the coral reefs, their growth rate decreases. There have been some other studies that show economically important species of muscles and oysters start to decrease their shell growth rate. What we don't know is how the ecosystem as a whole will respond to that (slower growth of muscles and oysters and other carbonate-shelled marine life). Can the organisms adapt or will they just be lost from the ecosystem and the ecosystem will change? We don't know that.

California mussels have calcium carbonate shells that can dissolve in carbonic acid. Other marine creatures with calcium carbonate shells that are threatened by increasing ocean acidity are clams, oysters, corals, Pteropods and some plankton species.

ARE THERE ANY STUDIES THAT INDICATE CLAMS AND OYSTERS WON'T BE ABLE TO SURVIVE AT ALL?

No, there is data that suggests they do worse when it gets acidic, but as to whether they won't survive at all, we just don't know.

We know it will hurt their survival. We don't know the extent of it. We know that in laboratory experiments, when you change the acidic conditions, they don't do well. What we don't understand is whether the clams and oysters and so on have adaptation strategies? Or if a little bit of acidification makes them more vulnerable to predators, for example? It's very possible that an oyster in the absence of predators could live just fine with a thinner shell. On the other hand, things that like to eat oysters probably are going to do much better in breaking down the oyster shells and getting to them to eat.

WHAT OTHER LIFE FORMS THAT WE REALLY NEED IN THE FOOD CHAIN ARE AFFECTED BY CARBONIC ACID?

Essentially anything that makes a carbonate-based shell – whether it is calcium carbonate or magnesium carbonate – those organisms are going to be sensitive to ocean acidification. Those are not limited to just corals and clams and muscles and oysters and barnacles. A number of plankton organisms make calcium carbonate shells. And these are very low on the food chain, which means they provide sustenance for so many other creatures up the food chain.

There have been some studies that suggest some forms of plankton do better in a high carbon dioxide world than in a low carbon dioxide world. So we don't know how this acidity is going to change things in terms of the total number of plankton biomass. What is fairly clear is that there will be changes in the food web structure.

Will Jelly Fish Take Over the Oceans?

Jelly fish thrive in low pH water and high carbon dioxide.

One example is there have been some studies that suggest jelly fish do very well in a low pH, high carbon dioxide world. So, it might be rather than widespread mortality in the oceans that we change to one that has a higher proportion of jelly fish in the food web.

THAT'S LIKE SOME ZOOLOGISTS AND BOTANISTS HAVE PROJECTED THAT ON LAND THERE WILL BE AN INCREASE IN ROACHES AND RATS AND WEEDS!

(laughs) Well, the jelly fish is a good analogy there.

BECAUSE IF THE OCEANS FILL UP WITH JELLY FISH, THEN WHAT WILL HAPPEN IN THE DOMINO EFFECT ON THE FOOD CHAIN?

Yes. If the jelly fish are favored, they are going to have to displace something else from the food web.

WHAT EATS JELLY FISH?

Sea turtles and big giant sunfish.

BUT ALL OF THE GREAT MARINE LIFE THAT WE HAVE DEPENDED UPON FOR THOUSANDS OF YEARS FOR NOT ONLY HUMANS BUT THE WHOLE FOOD CHAIN WEB, IT IS GOING TO DECLINE WHILE THINGS LIKE JELLY FISH WILL INCREASE.

With what we know now, things don't look good. We don't have a sense of how adaptive the system is. What we don't know is if the organisms can shift from more soluble forms of calcium carbonate shells to less soluble? Or can they live fine with smaller or less massive shells? Or is there an organism that will take over their spot on the food web that won't result in as negative a result as we might think? We don't have a good handle on those things.

WE LOSE SALMON AND WE GAIN JELLY FISH!

Well, yeah! (laughs) We don't know exactly how the ecosystem is going to respond. Most laboratory studies suggest there will be a negative impact on the food web as we know it. Whether that means that things are going to get a lot worse? Or things are just going to be different but not worse? We just really don't know yet.

No Way to Slow Down Carbonic Acid

Increase in Oceans?

IF I'M UNDERSTANDING YOU, THERE IS NO WAY THAT HUMANS CAN STOP THE CARBONIC ACID BUILD UP IN THE PACIFIC OCEAN NOW. WE HAVE A PROCESS THAT IS GOING TO HAVE TO PLAY ITSELF OUT THROUGH ALL THE UPWELLINGS OF DEEP WATERS FROM THE PAST FIFTY YEARS THAT ARE GOING TO BE RELEASING MORE AND MORE CARBON DIOXIDE AND INCREASING THE OCEAN ACIDITY.

That's true. If we stopped manmade carbon dioxide increase in the atmosphere immediately, we would find out that the upwelled waters would increase in their acidity for 50 years – even if we stopped CO_2 emissions now.

There are a number of suggestions about what to do to mitigate this, such as putting sodium carbonate into the oceans, which is a basic mineral that could dissolve and neutralize some of the carbonic acid. So, the notion that we can reverse engineer this is probably a little far fetched right now.

WHAT IS THE DOWNSIDE IN TRYING TO NEUTRALIZE THE CARBONIC ACID?

Energetically, it's a very difficult thing to do. If you're talking about making a lot of soda lime or sodium carbonate, that takes a bunch of energy. If you're talking about steaming out into the ocean with ships and getting this stuff distributed broadly enough and into the right depths, that takes a bunch of energy. In the process of doing this, you've generated a lot more carbon dioxide, which is ultimately going to dissolve into the ocean and increase the acidity.

IF THERE ARE 525 BILLION TONS OF ABSORBED GREENHOUSE GASES THAT HAVE PRODUCED THE CARBONIC ACID, TO NEUTRALIZE THAT AT CURRENT LEVELS WOULD TAKE A HUGE AMOUNT. SO, WHAT YOU ARE SAYING IS WE ARE IN A SQUEEZE PLAY WHERE WE'RE TRYING TO SLOW DOWN THE RELEASE OF CO_2 AND METHANE AND OTHER GREENHOUSE GASES. BUT TO COUNTERACT THAT TAKES ENERGY THAT IS CONTRIBUTING TO THE SAME PROBLEM.

Exactly.

WHAT A WORLD!

Yeah!

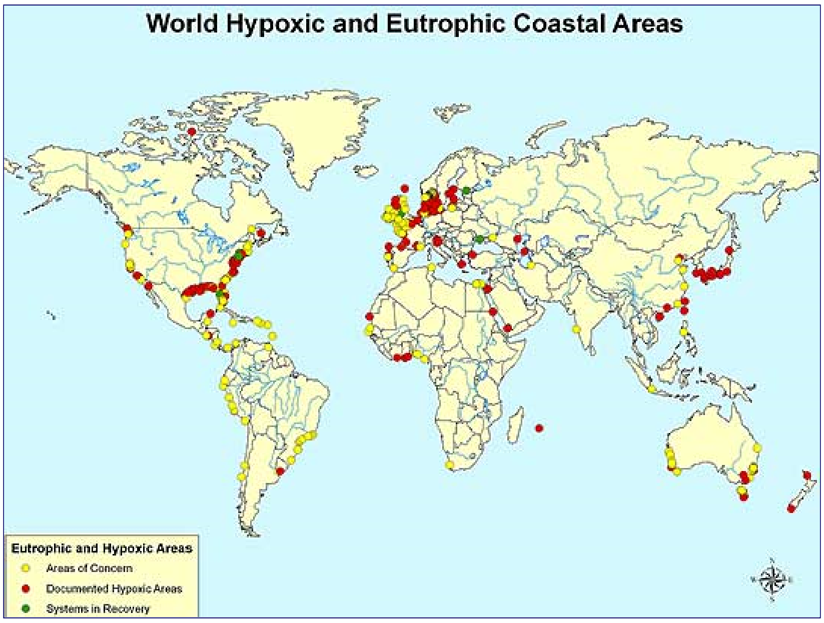
WHAT DO YOU WORRY ABOUT THE MOST?

Well.... (laughs) We've set something in motion that we don't have any good regulatory control over. That is definitely a concern.

THE IMPLICATIONS OF YOUR GEOCHEMISTRY WORK ON THIS CARBONIC ACID IMPLY THERE WILL BE A LOT OF DEATH AND POSSIBLY EXTINCTIONS OF MARINE LIFE.

Well, what we are seeing are conditions in the ocean that people have done laboratory studies that show negative impacts at these levels of acidity. Yes, those are the conclusions you would draw from that.

Ocean Dead Zones Increase Ocean Acidity



2008 map shows 169 documented no-oxygen hypoxic areas (red), 233 areas of concern (yellow), and 13 systems in recovery (green). Data compiled from various sources by R. Diaz, M. Selman and Z. Sugg, World Resources Institute.

Dead fish in oxygen-depleted waters of a “Dead Zone,” a lethal water that cannot sustain aquatic life. A new study has found that the tropical ocean's dead zones are growing in size and intensity as sea temperatures rise, posing risks to many marine organisms and fisheries. Image courtesy Kerry St. Pe, World Resources Institute.

We’ve had a lot of publicity about low oxygen regions off our Pacific coast. The reason you have low oxygen conditions is because of decomposition of organic matter, which consumes oxygen and produces carbon dioxide. That decreases the pH and makes the waters more corrosive. There have been suggestions that these dead zones off our coasts are actually increasing in frequency and size. Those might be related to changes in wind and circulation patterns that might be related to climate change.

What’s happening is that dead zones will worsen the ocean acidity problem. If those things are becoming more frequent, then the ocean acidity problem is going to become worse.

AND THE LESS ABILITY FOR CORALS, OYSTERS, CLAMS, PTEROPODS AND PLANKTON TO SURVIVE?

Exactly.

RIGHT NOW IN JUNE 2008, THERE IS A FUTURE POTENTIAL THAT THE INCREASING ACIDIFICATION OF OCEAN WATERS COULD END UP KILLING SO MUCH PLANKTON THAT IT COULD ALSO STARVE A LOT OF LIFE IN THE OCEANS?

What will happen is that the food web will change. We don’t know if there is going to be more life or less life. What we know is that the life that will be there will be different.”

“This Scares Me Right Down to My Bones”

One of the biggest shellfish industries in the United States is in Washington state, which produces 85% of all shellfish for the West Coast. The *Science* journal report by Prof. Burke Hales and NOAA's Christopher Sabine and Richard Feely has stunned many Pacific coast shellfish farmers, including Brett Bishop, who has been in the shellfish business since leaving the U. S. Navy in 1983 to join his family as a fifth generation co-owner of the company, Little Skookum Shellfish Growers, in Shelton, Washington. Their specialty is raising and wholesaling Manila clams.

Manila clams, Little Skookum Shellfish Growers, Shelton, Washington.

Brett Bishop, Co-Owner, Little Skookum Shellfish Growers, Shelton, Washington: “When I was made aware of that scientific report that was published in the journal, *Science,* it caught me by surprise. I was not aware that there was an issue with acidification of ocean water. So, I read the report and realized what a big deal it could be to us and then saw the data on how far ahead of the prediction the acid level was. What they found off the coast of Oregon were levels of acidification that their computer models had not predicted to occur for another 50 to 100 years. So, that certainly shook me awake and got my attention. Frankly, it scares me.

Basically the underlying physics is that carbonic acid dissolves calcium carbonate and calcium carbonate is what the shells of corals, Pteropods, clams and oysters are made of. So, it’s pretty simple. The physics means to me that if a certain level of acidification in seawater reaches my shellfish beds, it could potentially dissolve the shells of my crops (clams) and make it impossible to grow shellfish. That’s what it would mean personally to me. But in a much larger sense, it could mean the collapse of the whole food chain in the marine ecosystem. So, it’s very, very disturbing and troubling.

GIVEN THE AMOUNT OF ACIDITY THAT IS THERE RIGHT NOW, IS THERE ANYTHING THAT YOU AND OTHERS IN THE SHELLFISH INDUSTRY CAN DO?

Right now, I think we are limited to watching and monitoring it. The scale of the problem in ocean upwelling that occurs over hundreds of miles of coastline is just beyond any remedy that I can think of as far as fixing it. I don’t think flying up and down the coast with a plane load of baking soda and dumping it into the ocean – I just don’t think that’s practical. So, I think we have to address the problem on the contributing end. In other words, what are the things contributing to the problem in the first place?

Not being a scientist, what I came away with was the explanation that increased carbon dioxide put into the air by industrial uses, the burning of fossil fuels, is what’s creating this acidification. So, I think the only thing we can do about it is to try to cut off the supply of atmospheric gases that are contributing to the problem. I don’t think we can do anything about the amount of seawater that’s already been acidified. I think we are just going to have to weather that storm and try to stop feeding the cycle.

IF THE ACIDIFICATION IS DIRECTLY RELATED TO THE INCREASING AMOUNTS OF CARBON DIOXIDE, METHANE AND OTHER GREENHOUSE GASES IN THE ATMOSPHERE OF THE EARTH AND WE CAN’T SEPARATE THE TWO – INCREASING ACIDITY OF OCEANS AND INCREASE OF CO_2 AND GREENHOUSE GASES, WHERE DO YOU THINK THAT LEAVES YOU AND THE SHELLFISH INDUSTRY?

If what you just said is true, that they are linked, that the two are going forward together and global warming is part and parcel of ocean acidification, as a shellfish grower I would realize that the first thing we have to do is to convince people to behave differently, to change their lives so there could be a reduction in greenhouse gases. And hope we could educate and persuade before we lose our shellfish farm.

But if ocean acidification starts interrupting production of Pteropods and algae and coral, it could be a system-wide crash. The marine ecosystem seems to be very versatile and capable of adapting, but if you force it to adapt too quickly, the process might fall down before it reboots, you know? I'm very concerned over that.

THE BOTTOM LINE IS THAT YOU AND OTHERS WOULD NO LONGER HAVE AN INDUSTRY IN WHICH TO EARN A LIVING?

Right, we'd have a very nice piece of beachfront property that used to be a (shellfish) farm. In the meantime, we still have a mortgage that needs to be paid. I have two teenage sons who think they might want to be shellfish growers when they grow up. All of that is at stake.

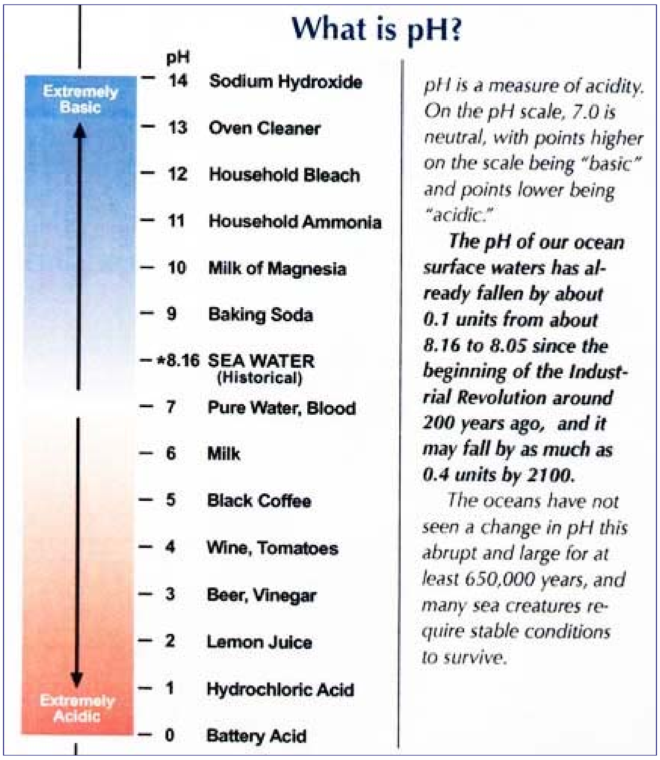
I'm the fifth generation in my family to grow shellfish and live on the old homestead. I always took it for granted that if we did our part and farmed industriously and we took care of the water quality that the rest would take care of itself. And then I hear this news about ocean acidification and what it says to me is that no matter what you do in your own neighborhood – no matter how hard you try or how good you do it, this problem could just come in and wipe you out and you would not have a thing to say about it. It's very humbling. It makes me feel at the mercy of forces larger than I can control or even understand.

RIGHT. AND MR. BISHOP, I THINK THAT'S HOW THE WHOLE WORLD IS BEGINNING TO FEEL.

Yeah, we're all in that same boat together, aren't we?

AND IT IS VERY WORRISOME.

Extremely worrisome. This scares me right down to my bones."



Graphic courtesy NOAA, 2008.

More Information:

For further information about ocean acidity, please see **Earthfiles Archive** reports listed below:

- 12/13/2007 — Update: As CO2 Increases, Carbonic Acid Build Up in Oceans Expected to Kill Off Coral Reefs by 2050
- 08/14/2004 — Oceans Are Absorbing A Lot of Greenhouse CO2. As Chemistry Changes, What Happens to Sea Life?

Websites:

NOAA Ocean Acidification: http://www.pmel.noaa.gov/co2/OA/

NOAA Fact Sheets: http://www.pmel.noaa.gov/co2/OA

/Ocean_Acidification%20FINAL.pdf

http://iodeweb3.vliz.be/oanet/Resources.html

NOAA Pacific Marine Environmental Laboratory: http://www.pmel.noaa.gov/

http://www.noaanews.noaa.gov/stories2008/20080522_oceanacid.html

World Resources Institute:
http://www.wri.org/map/world-hypoxic-and-eutrophic-coastal-areas

http://earthtrends.wri.org/maps_spatial/maps_detail_static.php?map_select=201&theme=1

OSU College of Oceanic and Atmospheric Sciences:
http://www.coas.oregonstate.edu/

Stanford University Carnegie Institution for Science: http://www.ciw.edu/news/fossil_fuels_earth_s_minerals_kept_co2_check

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