**Testimony: A Lawyer Remembers How a Key Provision Became the Law**

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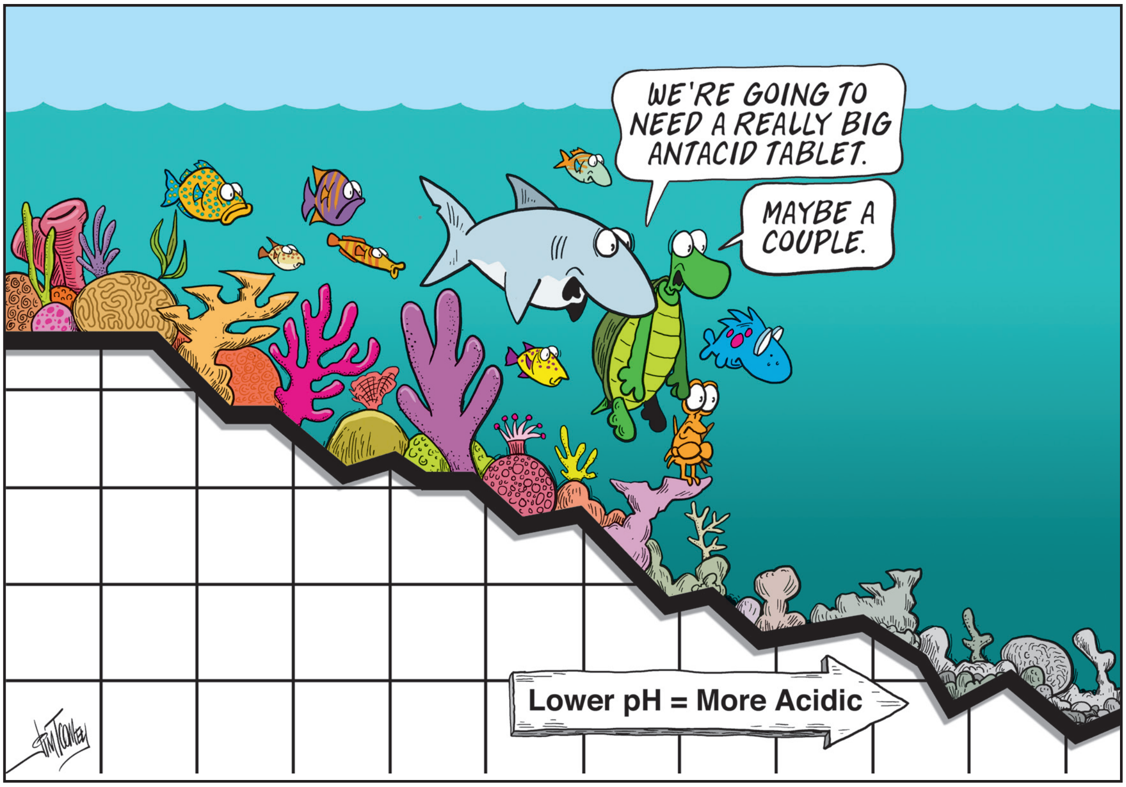


## Crisis for Sherman's Lagoon — And the Global Ocean

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# The Crisis Upon Us

*Carbon dioxide pollution is about more than air temperature. Resultant ocean acidification menaces not just marine plants and animals, but the entire biosphere. The evidence shows that this quiet change in chemistry poses an immediate threat to humanity and the planet*

**Mark Spalding** is president and chair of the board of directors of The Ocean Foundation.

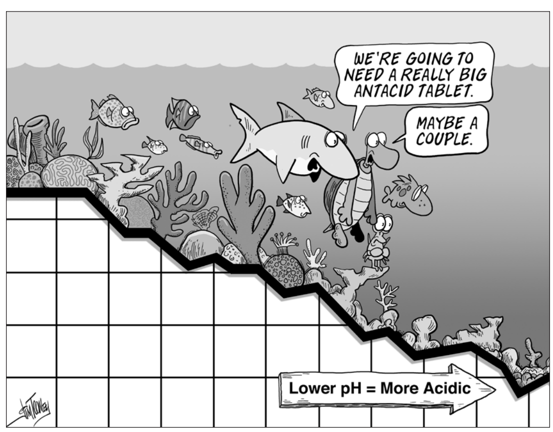
My deep connection with the ocean began as a boy growing up in the Central Valley of California. Each time on our trips to the beach as we crested the coastal range and the Pacific came into view, it was like being reborn. And during my graduate school education, the buildings at University of California's San Diego campus opened on the sea. Then and ever since, the ocean has been a constant presence in my life. Meanwhile, unobserved while I went about my daily tasks, it was absorbing great swaths of carbon dioxide from the atmosphere and thereby slowing the rate of global climate change. But that alteration in chemistry has created a quiet crisis that now threatens all life on the planet, on land as well as in the sea, with economic effects measured in trillions of dollars and ecological effects of possible mass extinctions as both the marine environment and the atmosphere undergo vast changes.

Since the beginning of the industrial revolution, when humans began to burn increasing amounts of fossil fuels, there has been a sharp rise in the carbon dioxide composition not just of our atmosphere but the ocean too. In the air, the result has been an increase in temperature, as $CO_2$ absorbs heat. The ocean has absorbed some of that heat, and scientists can point to resulting threats to marine life. But perhaps more important, when dissolved in water, those $CO_2$ molecules changed the pH of the marine ecosystem. This alteration upsets the delicate balance between thriving life at a neutral point and a corrosive environment — an effect we now call ocean acidification.

The early warning signs of this change were easy to overlook and ignore. The seas looked the same on the surface, if a little warmer and a little higher. The problem of acidification seemed limited to certain areas at certain times, and we continued in our anthropocentric belief that the ocean could take care of whatever we threw at her.

The first glimpse of the gravity of the ocean acidification problem surfaced in a 1974 article published in *Nature* magazine. Since then, continuous measurements of surface seawater chemistry have been made. During the last ten years, the scientific measurements have stunned the most hardened skeptics, and the potentially catastrophic biological and ecological — and in turn, economic — consequences are coming into focus. The UN Intergovernmental Panel on Climate Change's latest report, issued last November, affirmed the immediate risk to life in the ocean from acidification, which has already increased 26 percent over the pre-industrial baseline.

In the United States, the Government Accountability Office recently criticized the National Oceanic and Atmospheric Administration, the Department of Agriculture, and the Environmental Protection Agency for not taking bold action to address this crisis. Ocean acidification is a threat to commercial fishing, tourism, and other parts of the economy. The financial consequences of harm to coastal and deepwater shellfish populations is significant — albeit difficult to pin down and relate to specific pH levels. Acidification makes it hard for shellfish and corals, among other marine organisms, to form their hard structures. NOAA estimates that the value of the 2011 U.S. harvest of bivalve mollusks (think clams, scallops, and mussels) alone was $1 billion. That market is threatened by ongoing acidification.




To look at individual states, Atlantic lobsters, which make up 80 percent of the value of Maine's seafood landings, brought in $378 million in 2013. These crustaceans too are under assault. The potential inability of corals to regenerate or thrive due to ocean acidification could cost Hawaii alone more than $364 million a year in reef-related tourism. Florida's reef tracts from Palm Beach to Key West are estimated to generate more than $2 billion in economic activity each year — and that does not even count the value of the reef systems in mitigating the force of storms. For example, to look at a maritime nation, Bermuda's reefs, a natural sea wall for the island, have been valued at $722 million per year — or 13 percent of that country's GDP.

Globally, shoreline protection by coral reefs has been estimated in value at $9 billion a year; shoreline protection plus reef-supported fisheries is valued at $30 billion a year. And then we note that a huge percentage of tourism is reef-related (over 30 percent of GDP for some island nations). In the end, the global cost of ocean acidification on mollusks and tropical coral reefs is estimated to be over $1 trillion annually.

The ocean absorbs roughly one third of the atmospheric carbon dioxide that human activities generate. Not only is the amount in the water important, but so too is the speed at which it is changing, which is ten times faster than any time in the past 300 million years. This rapid pace gives marine organisms, ocean ecosystems, and humans less time to adapt, evolve, or otherwise adjust to the changing circumstances. As the current rate of global carbon dioxide emissions increases, the average acidity of the surface ocean is expected to rise by 100–150 percent over pre-industrial levels by the year 2100.

So, what happens when the ocean gets more acidic? The concentration of carbonate ion in seawater decreases. Carbonate ion is an essential building block required by many marine animals — primarily bivalves, crustaceans, and corals — and some plants to form the mineral calcium carbonate, which the organisms use to build hard parts. As the amount of carbon dioxide in seawater increases, and the amount of carbonate ions decreases, it is more difficult for calcifiers to build calcium carbonate–based body parts.

The easiest way to visualize the effects of ocean acidification is to experiment with a piece of chalk, derived from deposits of calcium carbonate made by ancient shelled animals. Take that chalk and drop it into a glass of water. Plain water — neutral pH — produces no change. But if you drop the same piece of chalk into a glass of vinegar, the chalk will dissolve, just like the hard parts of living marine organisms in today's ocean.

Because acidification is uneven across temporal and geographic frames, critical thresholds can be (and have been) breached at a fairly local scale and episodically, causing significant harm to species and ecosystems, and giving us a hint of what is to come at an even larger scale. "The effects of ocean acidification will be seen worldwide," says Martin Rees of the National Academy of Science of the United Kingdom and the Commonwealth, "threatening food security, reducing coastal protection, and damaging the local economies that may be least able to tolerate it." The ocean generates up to 70 percent of the oxygen we breathe. The most dire prediction for ocean acidification is a pH where ultimately the Earth will have a very different atmosphere than can support life as we know it.

But, there are short-term consequences as well. One in seven people depends on marine life for protein. That number is only going to increase, given the UN's recent population growth projections. Many species that are important to human economies such as corals, oysters, mussels, clams, crabs, and plankton, and in fact, those organisms that depend on them for food or ecosystem services — all marine life today — have never experienced such rapid change in ocean chemistry

The Pacific Northwest is already feeling the consequences of ocean acidification — and letting us know what is to come. Along with the absorptive load of $CO_2$, the area's coastal regions suffer from cold upwelling of waters from the deep ocean floor. This water is naturally rich in nutrients and carries an ever-growing load of human-generated carbon dioxide. This deep $CO_2$ was absorbed several decades ago when the water was last in contact with the atmosphere; these upwellings are slow. As water rises and adds to the surface carbon dioxide load, it is more corrosive to calcifying organisms such as mollusks and pteropods than might be seen from natural conditions alone. Pteropods are the chemically vulnerable bottom of the food chain — these tiny snails are an important part of the diet of young salmon and other commercially and ecologically important species.

For the last decade, Washington State oystermen have been dealing with what was originally thought to be a bacterial disease that was killing their oyster seed (baby oysters). Instead, the cause turned out to be increasingly acidic coastal waters. No seed means no oysters, no shellfish industry, no income for fishermen, no tax revenue for the state. So discovering that ocean acidification was the root cause of a crisis in oyster seed production sounded alarms from the coast to the state capital.

The acidification scenario in Washington State's waters provides an example of how far-reaching the effects of ocean acidification will be, and how acidification cuts across not just the marine food chain and the seafood industry, but also associated services, such as transportation, tourist enterprises, employment, government and private finances, and food security. Washington is one of the United States' top providers of farmed oysters, clams, and mussels, with 85 percent of U.S. West Coast sales of farmed shellfish, and an estimated annual economic impact during 2011 of $270 million in this one state alone.

The economic benefits of the state's wild and hatchery-based seafood extend well beyond the value of the harvest. Licensing for recreational shellfish harvesting generates $3 million annually, and recreational oyster and clam harvesters contribute more than $27 million a year to coastal economies. Overall, Washington's seafood industry generates over 42,000 jobs in the state and contributes at least $1.7 billion to the gross state economy through profits and employment at seafood restaurants, distributors, and retailers. All that is at risk.

But the ramifications don't stop with the economic stakes of shellfish farming. Many calcifiers provide important services to society and other organisms. For example, oysters, clams, and crabs improve water quality by removing floating organic particles. Deep-water corals off the Washington coast provide habitat, shelter, and host food for many plants and animals, including rockfish and sharks.

*The alteration in ocean chemistry has created a quiet crisis that now threatens all life on the planet, on land as well as in the sea, with economic effects measured in trillions of dollars*

Other species that are important to marine food webs, ecological community structure, and diversity may be sensitive to acidification in ways unrelated to shell building, particularly if they feed on shelled animals and affected plants. Yet, the responses of many groups of animals and plants to ocean acidification remain unstudied. Each new published article adds another species to the list of those known to be vulnerable to changes in ocean chemistry.

Ocean acidification is not only a growing threat, it is a present and visible problem, causing harm to economies and the environment. Acidification is both general (overall change in surface water pH) and geographically episodic (exacerbating events due to local conditions). Ocean acidification is exacerbated by other stressors (e.g., typically regulated water pollution). Impacts on human and other systems is certain. We know that extinctions are in prospect. We need to know more about where and when ocean acidification spikes occur and we need better global monitoring to understand current and evolving conditions.

"There is growing evidence that human release of carbon dioxide will have a profound impact on marine ecosystems," says NOAA oceanographer Christopher Sabine. "We as a society must decide if we are willing to accept these changes or we are prepared to modify our ways to minimize these impacts." Slowly, the global community is waking up to the problem and recognizing both the severity and the magnitude of ocean acidification. These responses, however, are just a start

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Sidebar

# Responding to a Sea Change

For at least a century, marine chemists have predicted that people could change ocean chemistry through the burning of fossil fuels. Now that change has been definitively documented. Carbon dioxide absorbed by global oceans is literally causing a sea change, threatening the chemical balance of ocean and coastal waters from pole to pole. Ocean acidification is a challenge that will define human interactions with the planet over centuries to come. It has serious implications not only for natural systems, but for food security, jobs, and economies at all levels. The stakes are high. Scientists, community and industry leaders, and governmental officials are developing the knowledge and tools we need to change our trajectory and find opportunities for mitigation, remediation, and adaptation.

The National Oceanic and Atmospheric Administration is leading the U.S. response to ocean acidification. As more resources are dedicated to ocean acidification efforts, we are moving out of the start-up phase to reach towards the full capacity of our capabilities. Here, I outline the goals driving our work on ocean acidification, defined as vision statements, and provide examples of NOAA work being done to meet these goals.

*Coastal industries, such as aquaculture, and managers have actionable information on ocean acidification.* Users of living marine resources need information to understand what ocean chemistry conditions are now and what they may be in the near to distant future, which species are sensitive to ocean acidification and how ecosystems might be changed by it, and what actions can be taken to prevent, mitigate, remediate, and adapt to ocean acidification.

Ocean observations and basic research, the core of NOAA's investments on ocean acidification, are the foundation for building this knowledge. But, to be useful to managers and industry, knowledge from research needs to be turned into actionable information. Ocean observations and understanding of regional oceanography *are* being transformed into early warning systems about ocean acidification events in the Pacific Northwest. Forecasts should not stop at ocean chemistry conditions, but should extend to biological and socioeconomic impacts. Such forecasts are vital as we plan to manage and preserve living marine resources in a time of change. NOAA is supporting groups pushing the bounds to make these forecasts a reality, and, with its international partners, is making these forecasts a priority for investment globally.

*Society understands which communities will be most affected by ocean acidification and develops adaptation strategies.* Communities will not be affected by ocean acidification equally. Coastal communities who depend on coral reefs for food, tourism, and protection from waves and storms are, given our current understanding, likely to be especially vulnerable. How ocean acidification will affect communities beyond those dependent on coral reefs is currently not as straightforward. NOAA-led research has explored vulnerability of Alaskan communities to acidification. This research assessed vulnerability through analysis of socio-economic information such as food security, subsistence, jobs, and educational opportunities. Communities in Alaska that are most dependent on shellfish, salmon, and other finfish also have relatively lower income and employment options. As carbon dioxide levels rise, the presence and abundance of these economically valuable species will change, making these communities more vulnerable. Alaska's fishing industry supports more than 100,000 jobs, generates more than $5 billion in annual revenue, and is critical to America's balance of trade.


Libby Jewett

*The American public understands enough about ocean acidification to take action to reduce its impacts.* Robust action on ocean acidification requires support by the general public. Currently just ten percent of our nation's citizens know that it is happening. Educators from schools to aquariums are seeking ways to spread information. NOAA is helping them share resources and experiences through collaboration and networking.

States are taking a large role in raising the issue of ocean acidification. Washington and Maine have each convened commissions of elected officials, scientists, industry leaders, environmental stewards, and other stakeholders to outline what local actions can be taken. Their recommendations range from education, to reducing nutrient run-off into coastal water, to slowing carbon dioxide emissions. Action at state and local levels is necessary to fully address acidification and increase public awareness. NOAA is providing expertise to these state commissions and is helping build regional efforts, such as the Northeast Coastal Acidification Network.

Making these visions a reality will take time, investment, and the engagement of many stakeholders across the globe. Decades of research within NOAA and with other federal and state agencies, stakeholders, and other countries have provided a solid foundation. Partnerships such as these ensure efficient, coordinated approaches to maintain the integrity of our oceans in the face of this global threat.

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**Libby Jewett** is the director of the NOAA Ocean Acidification Program.

— knowledge of the extent of the problem is growing faster than acidification itself.

The United States has passed legislation and established programs to confront the pending threats. Secretary of State John Kerry's special convening on the ocean last June focused on solutions to ocean acidification as one of its three priority issues for the United States and its partners. Private foundations and NGOs are exploring ways in which they can participate. The European Project on Ocean Acidification combined the talents and minds of scientists from 10 different countries.

In 2009, Congress passed the Federal Ocean Acidification Research and Monitoring Act. This legislation established NOAA's ocean acidification office and related research programs, and outlined a coordinated process for federal agencies to create plans for effective monitoring of the processes and consequences of ocean acidification on marine organisms and ecosystems. Through the FOARAM-chartered Interagency Working Group, NOAA is coordinating closely with other federal agencies that have strong ocean acidification research or policy portfolios. These include the National Science Foundation, the U.S. Geological Service, the National Atmospheric and Space Administration, the Department of State, the Fish and Wildlife Service, and the Environmental Protection Agency. It should be noted that the increasing acidification of freshwater systems, such as the Great Lakes, is also being monitored by the working group. NSF is wrapping up its five-year, $50 million ocean acidification grant program to "improve understanding of and capacity to respond to ocean acidification, recognizing the potential adverse impacts of an acidifying sea upon marine ecosystems."

*The scientific measurements have stunned the most hardened skeptics, and the potentially catastrophic biological and ecological — and in turn, economic — consequences are coming into focus*

The states are also taking steps. For example, then-Washington governor Christine Gregoire established the Blue Ribbon Panel on Ocean Acidification in response to the shellfish crisis. The panel convened scientists, state and federal government officials, nongovernmental organization representatives, state legislators, shellfish industry scientists, business owners, and prominent citizens. In 2012, the governor's follow-on executive order incorporated the scientific findings and recommended actions that resulted from this coordinated process, specifying an interdisciplinary, interagency approach.

Washington's process should serve as a model for other states and multi-state actions and spur other studies. An example is the Partnership for Interdisciplinary Studies of Coastal Oceans, a long-term ecosystem research and monitoring program focused on understanding the dynamics of the coastal ocean ecosystem along the U.S. west coast.

Meanwhile, the international response is promising. In Monaco, the International Atomic Energy Agency's Environment Laboratories host the Ocean Acidification–International Coordination Center. The center's goal is to increase awareness and participation through collaboration and multidisciplinary research projects, database development, capacity building, and information dissemination among member states. Another goal is to create a global network for ocean measurement and analysis. It has pursued a number of projects investigating the economic consequences of ocean acidification.

The United Kingdom ocean acidification program is a five-year international research collaboration, primarily with the German ocean acidification program, the European research program, the Mediterranean research program, and the U.S. ocean acidification research program. Scientists from 30 different countries are participating in the Global Ocean Acidification Observing Network, or GOA-ON, a collaborative international approach to document the status and progress of ocean acidification in open-ocean, coastal, and estuarine environments, to understand the drivers and impacts of ocean acidification on marine ecosystems, and to provide spatially and temporally resolved biogeochemical data necessary to optimize modeling. Its supporting arm is the Friends of GOA-ON, an initiative of The Ocean Foundation in partnership with key funders and private foundations to provide additional financial resources.

There are ways in which ecosystem protection and restoration is being used to address ocean acidification. The Blue Climate Coalition seeks enhanced international recognition of the opportunities to certify carbon credits in coastal carbon environments and facilitate the inclusion of the carbon value of coastal ecosystems in the accounting of ecosystem services. SeaGrass Grow! is one campaign to naturally offset greenhouse gas emissions in the ocean — known as blue carbon. Seagrass meadows store carbon on scales larger than land-based forests, account for 11 percent of organic carbon stored in the ocean, and protect nearby coral reefs and other calcium-based organisms from the effects of ocean acidification.

The Blue Carbon Calculator was developed by The Ocean Foundation to help an individual or organization calculate its annual $CO_2$ emissions to, in turn, determine the amount of blue carbon necessary to offset them (acres of seagrass to be restored or the equivalent). The revenue from the blue carbon credit mechanism can be used to fund restoration efforts, which in turn generate more credits. Such programs allow for two wins: creation of a quantifiable cost to global systems of $CO_2$- emitting activities and, second, restoration of seagrass meadows that form a critical component of coastal ecosystems and are in sore need of recovery.

Finally, in response to the problem of insufficient data on acidification that bedevils sound science, the X-Prize Foundation is offering an Ocean Health Prize for a global competition that challenges teams to create pH sensor technology that will efficiently measure ocean chemistry. There are two prizes: a $1 million accuracy award (to produce the most stable and precise pH sensor) and a $1 million affordability award (to produce the least expensive and easy-to-use pH sensor).

*The only way to fully address ocean acidification is to make sure it is on everyone's agenda — from clean air to energy to restoration to climate change, even to food and security*

"This is a turning point. If we continue business as usual, we are in real trouble," says renowned oceanographer Sylvia Earle. "Think of the world without an ocean and you've got a planet like Mars. No life support system. In a way we are all like sea creatures . . . no ocean . . . no life . . . no us." We've passed the point of knowing we are in trouble. What we need now are personal commitment, legislation, and a focus on solution-driven strategies.

Obviously, the most important thing that any of us can do is actively put our skills toward reducing the amount of carbon dioxide we are spewing into the atmosphere. If we are all part of the problem, we are also all part of the solution. We cannot count on governments alone to solve the staggering problem caused by burning fossil fuels. It falls on our shoulders to examine our personal lifestyle choices, look deeper for solutions, fund programs and organizations, and support policies that reduce our impact on the air and the seas.

There are small-scale steps that can and should be taken. First, we need to educate the public about ocean acidification and its consequences for oxygen production, the stability of marine ecosystems, and the underpinnings of national economies. Second, nearshore sea life benefits from enforcing existing clean water laws and statutes governing air emissions. Steps should be taken to revise existing and adopt new water quality standards to make them relevant to ocean acidification. Limiting nutrient discharges entering marine waters from septic systems, municipal wastewater plants, and agricultural facilities allows communities to limit the stressors on ocean life that affect adaptation, recovery, and survival. Moving forward on stormwater plan implementation and promoting best management practices will have similarly positive effects.

For wild and farmed aquatic species, there are critical research and data collection needs. Understanding the association between water chemistry variables and ocean productivity for diverse species of plants and animals is one important need. One step would be to investigate selective breeding for ocean acidification tolerance in shellfish and other vulnerable marine species. Another is to identify, monitor, and manage more neutral pH marine areas as potential refuges to support adaptation and survival.

We do know that small-scale restoration activities can help address local acidification. Thus, we should promote the expansion of municipal, state, and federal partnerships to restore seagrass, mangroves, marsh grasses, and other blue carbon ecosystems that will take up and fix dissolved carbon dioxide and prevent or at least slow changes in pH. Given the percentages of these critical life-supporting ecosystems we have lost over time, this investment can have both immediate and longer-term benefits for natural systems and the human communities that depend on them.

The only way to fully address ocean acidification is to make sure it is on everyone's agenda — from clean air to energy to restoration to climate change, even to food and security. We need to rewire the way we look at our responsibility to the world in which we live. The sanctity and survival of the planet — and our place on it — are contingent on changing the course of our actions and remediating the damages we have done. **TEF**