PERVERSE SEA CHANGE: Underwater Cultural Heritage in the Ocean is Facing Chemical and Physical Changes

By Mark J. Spalding

Is the loss of our Underwater Cultural Heritage accelerating?

The term "underwater cultural heritage"[1] (UCH) refers to all remnants of human activities lying on the seabed, on riverbeds, or at the bottom of lakes. It includes shipwrecks and artifacts lost at sea and extends to prehistoric sites, sunken towns, and ancient ports that were once on dry land but now are submerged due to manmade, climatic, or geological changes. It can include works of art, collectable coinage, and even weapons. This global underwater trove forms an integral part of our common archaeological and historical heritage. It has the potential to provide invaluable information about cultural and economic contacts and migration and trade patterns.

The saline ocean is known to be a corrosive environment. In addition, currents, depth (and related pressures), temperature, and storms affect how UCH is protected (or not) over time. A lot of what once was considered stable about such ocean chemistry and physical oceanography is now known to be shifting, often with unknown consequences. The pH (or acidity) of the ocean is changing — unevenly across geographies — as is salinity, because of melting ice caps and freshwater pulses from flooding and storm systems. As the result of other aspects of climate change, we are seeing rising water temperatures overall, shifting global currents, sea level rise, and increased weather volatility. Despite the unknowns, it is reasonable to conclude that the cumulative impact of these changes is not good for underwater heritage sites. Excavation is usually limited to sites that have immediate potential to answer important research questions or which are under threat of destruction. Do museums and those responsible for making determinations about the disposition UCH have the tools for assessing and, potentially, predicting the threats to individual sites that come from changes in the ocean?

What is this ocean chemistry change?

The ocean absorbs substantial amounts of the carbon dioxide emissions from cars, power plants, and factories in its role as the planet's largest natural carbon sink. It cannot absorb all such CO2 from the atmosphere in marine plants and animals. Rather, the CO2 dissolves in the ocean water itself, which decreases the pH of the water, making it more acidic. Corresponding with the increase in carbon dioxide emissions in recent years, the pH of the ocean as a whole is falling, and as the problem becomes more widespread, it is expected to adversely affect the ability of calcium-based organisms to thrive. As the pH drops, coral reefs will lose their color, fish eggs, urchins, and shellfish will dissolve before maturation, kelp forests will shrink, and the underwater world will become gray and featureless. It is expected that color and life will return after the system re-balances itself, but it is unlikely that mankind will be here to see it.

The chemistry is straightforward. The forecasted continuation of the trend towards greater acidity is broadly predictable, but it is hard to predict with specificity. The effects on species who live in calcium bicarbonate shells and reefs are easy to imagine. Temporally and geographically, it is harder to predict harm to oceanic phytoplankton and zooplankton communities, the basis of the food web and thus of all commercial ocean species harvests. With regard to UCH, the decrease in pH may be small enough that it has no substantial negative effects at this point. In short, we know a lot about "how" and "why" but little about "how much," "where," or "when."

In the absence of a timeline, absolute predictability, and geographic certainty about the effects of ocean acidification (both indirect and direct), it is challenging to develop models for present and projected effects on UCH. Moreover, the call by members of the environmental community for precautionary and urgent action on ocean acidification to restore and promote a balanced ocean will be slowed by some who demand more specifics before acting, such as what thresholds will affect certain species, which parts of the ocean will be most affected, and when these consequences are likely to occur. Some of the resistance will come from scientists who want to do more research, and some will come from those who want to maintain the fossil-fuel-based status quo.

One of the world's leading experts on underwater corrosion, Ian McLeod of the Western Australian Museum, noted the potential effects of these changes on UCH:

> All in all I would say that increased acidification of the oceans will most likely cause increased rates of decay of all materials with the possible exception of glass, but if the temperature increases as well then the overall net effect of more acid and high-

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> er temperatures would mean that conservators and maritime archaeologists will find that their underwater cultural heritage resources are diminishing.[2]

We may not yet be able to evaluate fully the cost of inaction on affected shipwrecks, submerged cities, or even more recent underwater art installations. We can, however, begin to identify the questions that we need to answer. And we can start to quantify the damages that we have seen and that we expect, which we have already done, for example, in observing the deterioration of the USS Arizona in Pearl Harbor and the USS Monitor in the USS Monitor National Marine Sanctuary. In the case of the latter, NOAA accomplished this by pro-actively excavating items from the site and seeking ways to protect the hull of the vessel.

Changing ocean chemistry and related biological effects will endanger UCH

What do we know about the effect of ocean chemistry changes on UCH? At what level does change in pH have an impact on artifacts (wood, bronze, steel, iron, stone, pottery, glass, etc.) in situ? Again, Ian McLeod has provided some insight:

> With regard to underwater cultural heritage in general, the glazes on ceramics will deteriorate more rapidly with faster rates of leaching of the lead and tin glazes into the marine environment. Thus, for iron, increased acidification would not be a good thing as artifacts and the reef structures formed by concreted iron shipwrecks would collapse faster and would be more prone to damage and collapse from storm events as the concretion would not be as strong or as thick as in a more alkaline microenvironment.
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> Depending on their age, it is likely that glass objects might fare better in a more acidic environment as they tend to be weathered by an alkaline dissolution mechanism that sees the sodium and calcium ions leach out into the sea water only to be replaced by acid resulting from hydrolysis of the silica, which produces silicic acid in the corroded pores of the material.
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> Objects such as materials made from copper and its alloys will not fare so well as the alkalinity of the seawater tends to hydrolyze acidic corrosion products and helps to lay down a protective patina of copper(I) oxide, cuprite, or Cu_2O, and, as for other metals such as lead and pewter, the increased acidification will make corrosion easier as even the amphoteric metals such as tin and lead will not respond well to increased acid levels.

An example of damage from shipworms.
(Courtesy of Rygel, M.C., via Wikimedia Commons.)

> With regard to organic materials the increased acidification may make the action of wood boring mollusks less destructive, as the mollusks will find it harder to breed and to lay down their calcareous exoskeletons, but as one microbiologist of great age told me, . . . as soon as you change one condition in an effort to correct the problem, another species of bacterium will become more active as it appreciates the more acidic microenvironment, and so it is unlikely that the net result would be of any real benefit to the timbers.

Some "critters" damage UCH, such as gribbles, a small crusta-

An actual shipworm.
(Courtesy of the U.S. Geological Survey, via Wikimedia Commons.)

PERVERSE SEA CHANGE *(cont'd)*

cean species, and shipworms. Shipworms, which are not worms at all, are actually marine bivalve mollusks with very small shells, notorious for boring into and destroying wooden structures that are immersed in seawater, such as piers, docks, and wooden ships. They are sometimes called "termites of the sea."

Shipworms accelerate UCH deterioration by aggressively boring holes in wood. But, because they have calcium bicarbonate shells, shipworms could be threatened by ocean acidification. While this may be beneficial for UCH, it remains to be seen whether shipworms will actually be affected. In some places, such as the Baltic Sea, salinity is increasing. As a result, salt-loving shipworms are spreading to more wrecks. In other places, warming ocean waters will decrease in salinity (due to melting freshwater glaciers and pulse freshwater flows), and thus shipworms that depend on high salinity will see their populations will decrease. But questions remain, such as where, when, and, of course, to what degree?

Are there beneficial aspects to these chemical & biological changes? Are there any plants, algae, or animals that are threatened by ocean acidification that somehow protect UHC? These are questions for which we have no real answers at this point and are unlikely to be able to answer in a timely fashion. Even precautionary action will have to be based on uneven predictions, which might be indicative of how we proceed going forward. Thus, consistent real-time monitoring by conservators is of crucial importance.

Physical ocean changes

The ocean is constantly in motion. The movement of water masses due to winds, waves, tides, and currents has always affected underwater landscapes, including UCH. But are there increased effects as these physical processes become more volatile due to climate change? As climate change warms the global ocean, the patterns of currents and gyres (and thus heat redistribution) change in a way that fundamentally affects the climate regime as we know it and accompanies the loss of global climate stability or, at least, predictability. The basic consequences are likely to occur more rapidly: sea-level rise, alterations of rainfall patterns and storm frequency or intensity, and increased siltation.

The aftermath of a cyclone that hit the shore of Australia in early 2011[3] illustrates the effects of physical ocean changes on UCH. According to the Principal Heritage Officer of the Australian Department of Environment and Resource Management, Paddy Waterson, Cyclone Yasi affected a wreck called the *Yongala* near Alva Beach, Queensland. While the Department is still assessing the impact of this powerful tropical cyclone on the wreck,[4] it is known that the overall effect was to abrade the hull, removing most soft corals and a significant amount of hard corals. This exposed the surface of the metal hull for the first time in many years, which will negatively affect its conservation. In a similar situation in North America, the authorities of Florida's Biscayne National Park are concerned about the effects of hurricanes on the 1744 wreck of the *HMS Fowey*.

Currently, these issues are on track to worsen. Storm systems, which are becoming more frequent and more intense, will continue to disturb UCH sites, damage marking buoys, and shift mapped landmarks. In addition, debris from tsunamis and storm surges can easily be swept from the land out to sea, colliding with and potentially damaging everything in its path. Sea level rise or storm surges will result in the increased erosion of shorelines. Siltation and erosion may obscure all sorts of nearshore sites from view. But there may be positive aspects as well. Rising waters will change the depth of known UCH sites, increasing their distance from shore but providing some added protection from wave and storm energy. Likewise, shifting sediments may reveal unknown submerged sites, or, perhaps, sea level rise will add new underwater cultural heritage sites as communities are submerged.

In addition, the accumulation of new layers of sediment and silt will likely require additional dredging to meet transportation and communication needs. The question remains as to what protections should be afforded to in situ heritage when new channels have to be carved or when new power and communication transmission lines are installed. Discussions of implementing renewable offshore energy sources further complicate the issue. It is, at best, questionable whether the protection of UCH will be given priority over these societal needs.

What can those interested in international law expect in relation to ocean acidification?

In 2008, 155 leading ocean acidification researchers from 26 countries approved The Monaco Declaration.[5] The Declaration may provide the beginning of a call to action, as its section headings reveal: (1) ocean acidification is underway; (2) ocean acidification trends are already detectable; (3) ocean acidification is accelerating and severe damage is imminent; (4) ocean acidification will have socioeconomic impacts; (5) ocean acidification is rapid, but recovery will be slow; and (6) ocean acidification can be controlled only by limiting future atmospheric CO2 levels.[6]

Unfortunately, from the perspective of international marine resources law, there has been an imbalance of equities and insufficient development of facts relating to UCH protection. The cause of this problem is global, as are the potential solutions. There is no specific international law related to ocean acidification or its effects on natural resources or submerged heritage. Extant international marine resources treaties provide little leverage to force large CO2 emitting nations to change their behaviors for the better.

As with broader calls for climate change mitigation, collective global action on ocean acidification remains elusive. There may be processes that can bring the issue to the attention of the parties to each of the potentially relevant international agreements, but simply relying on the power of moral suasion to embarrass the governments into acting seems overly optimistic, at best.

Relevant international agreements establish a "fire alarm" system that could call attention to the ocean acidification problem at the global level. These agreements include the UN Convention on Biological Diversity, the Kyoto Protocol, and the UN Convention on the Law of the Sea. Except, perhaps, when it comes to protecting key heritage sites, it is difficult to inspire action when the harm is mostly anticipated and widely dispersed, rather than being present, clear, and isolated. Damage to UCH may be a way to communicate the need for action, and the Convention on the Protection of the Underwater Cultural Heritage may provide the means for doing so.

The UN Framework Convention on Climate Change and the Kyoto Protocol are the main vehicles for addressing climate change, but both have their shortcomings. Neither refers to ocean acidification, and the "obligations" of the parties are expressed as voluntary. At best, the conferences of the parties to this convention offer the opportunity to discuss ocean acidification. The outcomes of the Copenhagen Climate Summit and the Conference of the Parties in Cancun do not bode well for significant action. A small group of "climate deniers" have devoted significant financial resources to making these issues a political "third rail" in the United States and elsewhere, further limiting political will for strong action.

Similarly, the UN Convention on the Law of the Sea (UNCLOS) does not mention ocean acidification, although it does expressly address the rights and responsibilities of the parties in relation to protection of the ocean, and it requires the parties to protect underwater cultural heritage under the term "archaeological and historical objects." Articles 194 and 207, in particular, endorse the idea that parties to the convention must prevent, reduce, and control pollution of the marine environment. Perhaps the drafters of these provisions did not have harm from ocean acidification in mind, but these provisions may nevertheless present some avenues to engage the parties to address the issue, especially when combined with the provisions for responsibility and liability and for compensation and recourse within the legal system of each participating nation. Thus, UNCLOS may be the strongest potential "arrow" in the quiver, but, importantly, the United States has not ratified it.

Arguably, once UNCLOS came into force in 1994, it became customary international law and the United States is bound to live up to its provisions. But it would be foolish to argue that such a simple argument would pull the United States into the UNCLOS dispute settlement mechanism to respond to a vulnerable country's demand for action on ocean acidification. Even if the United States and China, the world's two largest emitters, were engaged in the mechanism, meeting the jurisdictional requirements would still be a challenge, and the complaining parties likely would have a hard time proving harm or that these two largest emitter governments specifically caused the harm.

Two other agreements bear mentioning, here. The UN Convention on Biological Diversity does not mention ocean acidification, but its focus on conservation of biological diversity certainly is triggered by concerns about ocean acidification, which have been discussed at various conferences of the parties. At the very least, the Secretariat is likely to monitor actively and report on ocean acidification going forward. The London Convention and Protocol and the MARPOL, the International Maritime Organization agreements on marine pollution, are too narrowly focused on dumping, emitting, and discharge by ocean-going vessels to be of real assistance in addressing ocean acidification.

The Convention on the Protection of the Underwater Cultural Heritage is nearing its 10th anniversary in November 2011. Not surprisingly, it did not anticipate ocean acidification, but it does not even mention climate change as a possible source of concern — and the science was certainly there to underpin a precautionary approach. Meanwhile, the Secretariat for the UNESCO World Heritage Convention has mentioned ocean acidification in relation to natural heritage sites, but not in the context of cultural heritage. Clearly, there is a need to find mechanisms to integrate these challenges into planning, policy, and priority setting to protect cultural heritage at the global level.

Conclusion

The complex web of currents, temperatures, and chemistry that fosters life as we know it in the ocean is at risk of being irreversibly ruptured by the consequences of climate change. We also know that ocean ecosystems are very resilient. If a coalition of the self-interested can come together and move quickly, it is probably not too late to shift public awareness toward promotion of the natural re-balancing of ocean chemistry. We need to address climate change and ocean acidification for many reasons, only one of which is UCH preservation. Underwater cultural heritage sites are a critical part of our understanding of global maritime trade and travel as well as the historic development of technologies that have enabled it. Ocean acidification and climate change pose threats to that heritage. The probability of irreparable harm seems high. No mandatory rule of law triggers reduction of CO_2 and related greenhouse gas emissions. Even the statement of international good intentions expires in 2012. We have to use existing laws to urge new international policy, which should address all of the ways and means we have at our disposal to accomplish the following:

- Restore coastal ecosystems to stabilize seabeds and shorelines to reduce the impact of climate change consequences on nearshore UCH sites;
- Reduce land-based pollution sources that reduce marine resilience and adversely affect UCH sites;
- Add evidence of potential harm to natural and cultural heritage sites from changing ocean chemistry to support existing efforts to reduce CO2 output;
- Identify rehabilitation/compensation schemes for ocean acidification environmental damage (standard polluter pays concept) that makes inaction far less of an option;
- Reduce other stressors on marine ecosystems, such as in-water construction and use of destructive fishing gear, to reduce potential harm to ecosystems and UCH sites;
- Increase UCH site monitoring, identification of protection strategies for potential conflicts with shifting ocean uses (e.g., cable laying, ocean-based energy siting, and dredging), and more rapid response to protecting those in jeopardy; and
- Development of legal strategies for pursuit of damages due to harm to all cultural heritage from climate-change-related events (this may be tough to do, but it is a strong potential social and political lever).

In the absence of new international agreements (and their good faith implementation), we have to remember that ocean acidification is just one of many stressors on our global underwater heritage trove. While ocean acidification certainly undermines the natural systems and, potentially, UCH sites, there are multiple, interconnected stressors that can and should be addressed. Ultimately, the economic and social cost of inaction will be recognized as far exceeding the cost of acting. For now, we need to set in motion a precautionary system for protecting or excavating UCH in this shifting, changing ocean realm, even as we work to address both ocean acidification and climate change.

1. For additional information about the formally recognized scope of the phrase "underwater cultural heritage," *see* United Nations Educational, Scientific and Cultural Organization (UNESCO): Convention on the Protection of the Underwater Cultural Heritage, Nov. 2, 2001, 41 I.L.M. 40.
2. All quotations, both here and throughout the remainder of the article, are from email correspondence with Ian McLeod of the Western Australian Museum. These quotations may contain minor, non-substantive edits for clarity and style.
3. Meraiah Foley, *Cyclone Lashes Storm-Weary Australia*, N.Y. Times, Feb. 3, 2011, at A6.
4. Preliminary information about the effect on the wreck is available from the Australian National Shipwreck Database at http://www.environment.gov.au/heritage/shipwrecks/database.html.
5. Monaco Declaration (2008), *available at* http://ioc3.unesco.org/oanet/Symposium2008/MonacoDeclaration.pdf.