

Global Warming, Sea Level Rise, and Coastal Erosion—Our Endangered Maritime Heritage

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ABSTRACT

Models of global warming predict that world sea levels may rise two meters or more during the 21st century. Warming oceans are predicted to foster larger and more frequent storms that threaten densely-populated coastal communities. Rising seas and stronger storms will accelerate coastal erosion that threatens millions of significant archaeological sites around the world. For most of the last 20,000 years, global warming and sea level rise were natural processes, but they have become increasingly anthropogenic over the last century. Coastal archaeological sites contain valuable scientific data on human history, including past adjustments to climate and geographic changes, and human impacts on ancient island and coastal ecosystems. Due to global warming, these historical records are increasingly endangered. Archaeologists, government agencies, and marine scientists need to accelerate efforts to inventory and evaluate coastal sites, mitigating the effects of global warming and accelerated erosion on significant sites before they are lost.

Keywords

climate change, rising seas, coastlines, archaeology, erosion.

1. INTRODUCTION

Nearing the end of the 20th century, warming climate, melting glaciers, rising seas, and collapsing marine fisheries and ecosystems became increasingly emblematic of the growing impacts of humanity on our oceans and planet. Now, early in the 21st century, a rising chorus of scientific, political, and media voices warns us of the growing threats that global warming and climate change pose to earth's ecosystems, cultures, and geopolitical stability. Today, nearly half of the humans on earth live within 100 km of a coastline and over 100 million people live in coastal areas lying less than a meter above sea level [1]. Long-term climatic records show that increasing levels of carbon in earth's atmosphere are closely linked to rising temperatures and that atmospheric carbon concentrations are headed for levels not seen in at least the last 400,000 years [2]. Over the last several decades, the natural process of global postglacial warming that began ~20,000 years ago has become an increasingly anthropogenic phenomenon—one whose magnitude and repercussions are still poorly understood.

In this short paper, I raise an issue that has been underappreciated by scientists concerned with the effects of global warming on coastal ecosystems, cultures, and nations around the world: the impacts of rising seas, intensified coastal storms, and accelerated coastal erosion on the long, complex, and diverse history of human use of

coastlines. This includes the deep archaeological history of fishing societies, maritime migrations, human seafaring and island colonization, and the varied effects of humans on coastal and island ecosystems through space and time.

2. BACKGROUND

Anthropologists have long viewed postglacial sea level rise as one of the key factors in the development of agriculture and human civilizations [see 3]. This 'rising tide' may have contributed to the nearly universal flood myths of human cultures around the world [4:167]. As global sea levels rose ~120 meters in the last 20,000 years, the effects were global. Vast expanses of coastal lowlands were inundated, shorelines in some areas (northern Australia, Beringia, etc.) shifted laterally hundreds of kilometers, the Americas were separated from Asia, and Japan, Taiwan, Tasmania, Sri Lanka, the British Isles, and many other lands once connected to continents became islands. Ancient coastal peoples around the world had to adapt to rapid ecological changes even as their territories shrank or disappeared—causing physical displacement, increased population densities, and heightened tensions or conflicts with neighboring peoples.

Due to global warming, mean sea levels were recently predicted to rise between 20 and 200 cm in the 21st century [5], estimates that some now fear may be too low [6]. If the Greenland ice sheet disintegrates and melts, for instance, global sea levels will rise about 6-7 meters—to levels comparable to the height of the Last Interglacial. Sea level rise of anywhere between one and six meters over the next century will have devastating effects on coastal landscapes, property, people, and infrastructure throughout the Pacific Basin and around the world. Today, billions of dollars are being spent annually to study global warming, predict its effects on ecosystems and human communities, and help mitigate its impacts. Governments, insurance companies, environmental groups, and other non-governmental organizations are planning for the economic and cultural disruptions that may result from the effects of global warming on sea level rise, intensified storm cycles, marine erosion, and other processes. With rising seas generally linked to accelerated coastal erosion [1, 7]—although the specific effects may be modified by a variety of local and regional factors—the potential economic costs of damages to coastal properties around the world are staggering [5].

3. EROSION OF HUMAN HISTORY

Despite extensive discussion of global warming, rising seas, and coastal erosion, there has been relatively little recognition of the threats posed to literally millions of cultural resources—archaeological, historical, and paleontological sites located along the coastlines of the

world [4]. If left unchecked, rising seas, accelerated erosion, and larger and more frequent storms will destroy many of the world's most important coastal archaeological sites, including numerous major tourist attractions that support the economies of local coastal communities. In a single disastrous 2005 storm, Hurricane Katrina caused enormous human suffering, billions of dollars in property damage, and the loss of approximately 1000 archaeological or historical sites along the low-lying and highly vulnerable deltaic coastlines of the northern Gulf of Mexico [8].

Although not as dramatic as the effects of Hurricane Katrina, millions of archaeological sites around the world are being damaged or lost to marine erosion each year. If global sea levels rise a meter or more in the 21st century, large expanses of coastal lowlands will be flooded in many areas. Where cliffed coasts are present, Bruun's rule predicts that many shorelines will see horizontal erosion of 50 to 200 times any vertical rise [9, 10], depending on the local geology, wave energy, and other factors.

Erosion on such a scale will destroy some of the world's oldest and most important archaeological sites, including the Klasies River Mouth, Die Kelders, and Pinnacle Point cave complexes in South Africa [11, 12, 13], where anatomically modern humans exploited marine shellfish, penguins, and pinnipeds between about 165,000 and 50,000 years ago. They include Gorham's and Vanguard caves in Gibraltar, where *Homo neandertalensis* and later *Homo sapiens sapiens* lived and foraged along the shores of the Mediterranean beginning at least 100,000 years ago [14, 15]. They include sites such as Daisy Cave on California's Channel Islands, occupied by seafaring Paleoindian peoples as much as 12,000 years ago [16]. And they include millions of younger sites that are of major religious, cultural, historical significance to communities around the world. Accelerated coastal erosion will also destroy untold numbers of archaeological sites whose significance is unknown because they have not yet been recorded, excavated, or dated.

In a study of the effects of coastal erosion on the Grand Bay site on the Caribbean island of Carriacou, Fitzpatrick et al. [17] effectively quantified the problems we face on a local scale. This large shell midden, dated between about AD 400 and 1200, is being lost to coastal erosion exacerbated by littoral sand-mining. Careful mapping and monitoring of the site showed that the shoreline retreated roughly one meter per year between 1999 and 2006, with almost 300 cubic meters of site soils lost each year. Test units excavated through the deep midden deposits revealed that almost 80,000 kg of cultural materials were being lost at the Grand Bay site annually, including thousands of ceramic pot sherds, vertebrate bones, and shellfish remains, as well as hundreds of other artifacts.

Extrapolated to a global level, the loss of our communal island and coastal heritage is a rapidly unfolding and accelerating crisis for human history. The crisis is happening right now, with increasingly devastating effects, as archaeological sites around the world calve into the sea like receding glaciers. Ironically, these sites are being lost just as scientists and policy makers are beginning to understand the contributions archaeology can make to current environmental problems [18, 19, 20]. Marine erosion is destroying the very coastal sites that can tell us how past societies adapted to earlier episodes of sea level rise and coastal geographic change that had such profound effects on human history. Studying

the effects of rising postglacial sea levels on past societies—including great civilizations like those of the Mediterranean, the Tigris-Euphrates delta, China, the coastal Maya, and many others—may help us learn from the experiences of our ancestors.

The scale of the potential losses to our communal history and heritage is enormous. Many governments around the world have neither the resources nor the political will to protect coastal sites from existing threats, much less the accelerated erosion that global warming and sea level rise will cause in decades to come. Even in the more affluent nations, where strong laws often protect historical, archaeological, and paleontological sites, relatively little has been done to plan for or mitigate the effects of sea level rise and coastal erosion. The dearth of concerted action may have two primary causes: (1) the size of the problem is simply overwhelming, especially to agency personnel accustomed to budget cuts and limited resources; and (2) the mistaken belief that coastal erosion is a wholly natural process that requires no mitigation except under extraordinary circumstances.

It is true that rising seas and coastal erosion have been driven largely by natural processes for most of the past 20,000 years. In the last century or so, however, they have become increasingly anthropogenic as humans have played an ever greater role in damming rivers and reducing littoral sediment supply, constructing breakwaters and jetties, sand mining, dredging, filling of wetlands, and other shoreline modifications that have accelerated the erosion of our coasts. Now anthropogenic global warming is magnifying the effects of these earlier human impacts in a rising tide of destruction. It is imperative that we recognize the increasingly anthropogenic contributions to the erosion of our maritime history and take greater responsibility for their mitigation.

4. CONCLUSIONS

To better understand and plan for the effects of sea level rise on modern coastal populations around the world, we must study the successful and failed responses of past societies that faced similar challenges. We cannot stand idle as the long and diverse history of maritime migrations, human fishing, and coastal cultures around the world [21] is lost to accelerating erosion. We need a public dialog about the nature of the threats that rising seas and coastal erosion pose to both human history and our future. We need a collaborative and global effort to bring the problem to the attention of government leaders and the general public. We must focus the attention of archaeologists, heritage resource managers, and government agencies on better understanding the age and contents of those sites that are most imperiled. Most of all, around the world, we need to accelerate our efforts to inventory, investigate, and interpret the history of endangered coastal sites before they are lost forever. We must act for we are racing a rising tide.

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