# Natural Threats

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# THREATS AND CHALLENGES: NATURAL CHANGES

This section will consider natural threats and damages to maritime heritage, some of which are very specific to the coastal and maritime zone, as they are driven by marine processes. We will examine both archaeological sites along the shoreline as well as those completely submerged beneath the ocean's surface.

Maritime heritage sites are vulnerable to a range of natural threats as coastal and marine environments have always been subject to natural fluctuations. Coastlines have historically experienced change, with some settlements and ports being lost to coastal erosion, while others have become landlocked due to sedimentation. Waves and currents continually eat away and move remains that are underwater or are located directly along the shore. This ongoing process is further influenced by extreme weather events, which can uncover new sites or damage known sites. Because the coastal environment is very dynamic and ever changing, it is important for maritime archaeologists and heritage practitioners to understand these processes in order to be able to record sites that are under immediate danger of being damaged or destroyed.

## COASTAL EROSION AND ACCRETION

*The 2nd millennium BCE coastal settlement of Tochni Lakkia in Cyprus is impacted by coastal erosion, with an estimated loss of land of about 0.5m every year. Site erosion and deterioration is further impacted by anthropogenic processes, including for example construction waste disposal (taken by Georgia Andreou, 2013).*

Coastal regions face two primary challenges: erosion and accretion. Coastal erosion, a well-known threat. It involves the removal of material from the shore by wave and tidal action, causing the coastline to recede inland. Conversely, accretion occurs when sediment accumulates, potentially extending the shoreline seaward or enlarging coastal

features like dunes. The interplay between these processes is influenced by the coast's composition and its resistance to erosion, such as whether it consists of sand or rock, as well as the intensity of marine sediment transport mechanisms. The rate and patterns of coastal erosion and accretion exhibit significant variations worldwide due to the diverse factors influencing these processes, including topography, geological characteristics, wave patterns, tidal variations, and sediment availability. Given the global diversity of these elements, the speed and patterns of erosion and accretion differ substantially across coastal regions worldwide.

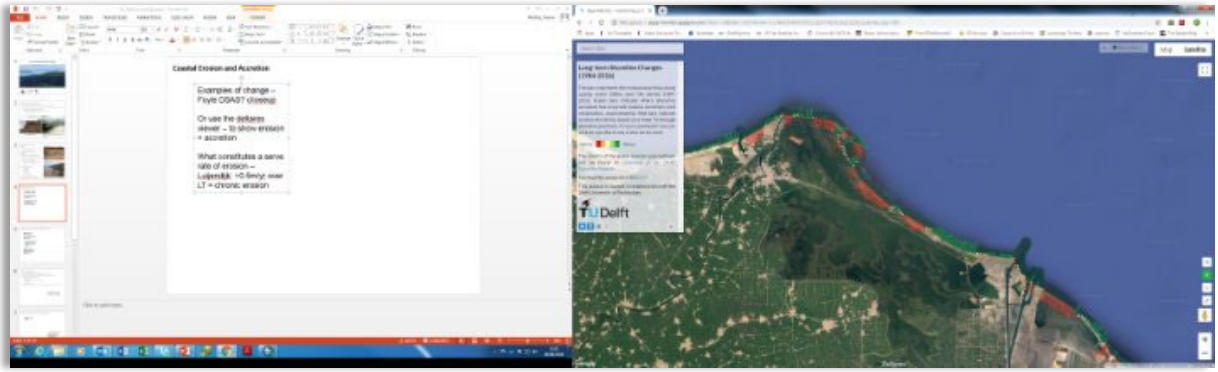
**Erosion**

- Removal of material from the coast by waves or tidal currents
- Landward retreat of shoreline

**Accretion**

- Accumulation of (beach) sediment
- Seaward advance of shoreline or upward growth of coastal landforms like dunes

Global rates of shoreline change between 1985-2016 have recently been produced. Here is an example from Egypt at Port Said, which used relatively low-resolution Landsat data spanning over the past 30 to 40 years. Although not ideal, this dataset represents the most comprehensive global compilation available to date (accessible here for you to explore http://aqua-monitor.appspot.com/). The image demonstrates both erosion (indicated in red) and accretion (shown in green) occurring within the same region. These changes result from a combination of natural processes (sediment transport eastward from the Damietta mouth) and human interventions (development of Port Said), as well as a decrease in sediment flow to the Damietta Mouth.



*Screenshot of the results of Aquamonitor in Port Said, Sudan.*

# COASTAL EROSION AND ACCRETION: IMPACT ON MARITIME HERITAGE

The impact on maritime heritage sites is fairly straightforward. Erosion can cause direct harm to these sites, by either physically damaging them or by weakening the ground beneath them. On the other hand, accretion typically limits access to the site, but may also provide  increased protection.

Wave action and coastal flooding due to rising sea levels contribute to the degradation of coastal rocks, soils, and sands, a process known as coastal erosion. Evidence of seawater eroding land includes the wearing away of the foreshore, coastline recession, wetland degradation, and increased salt content in coastal aquifer groundwater. Both natural and anthropogenic factors play a role in the erosion of coastlines. The impacts of this erosion are extensive, impacting not only cultural heritage, but also marine ecosystems, causing terrestrial land loss, and posing risks to human lives and property.

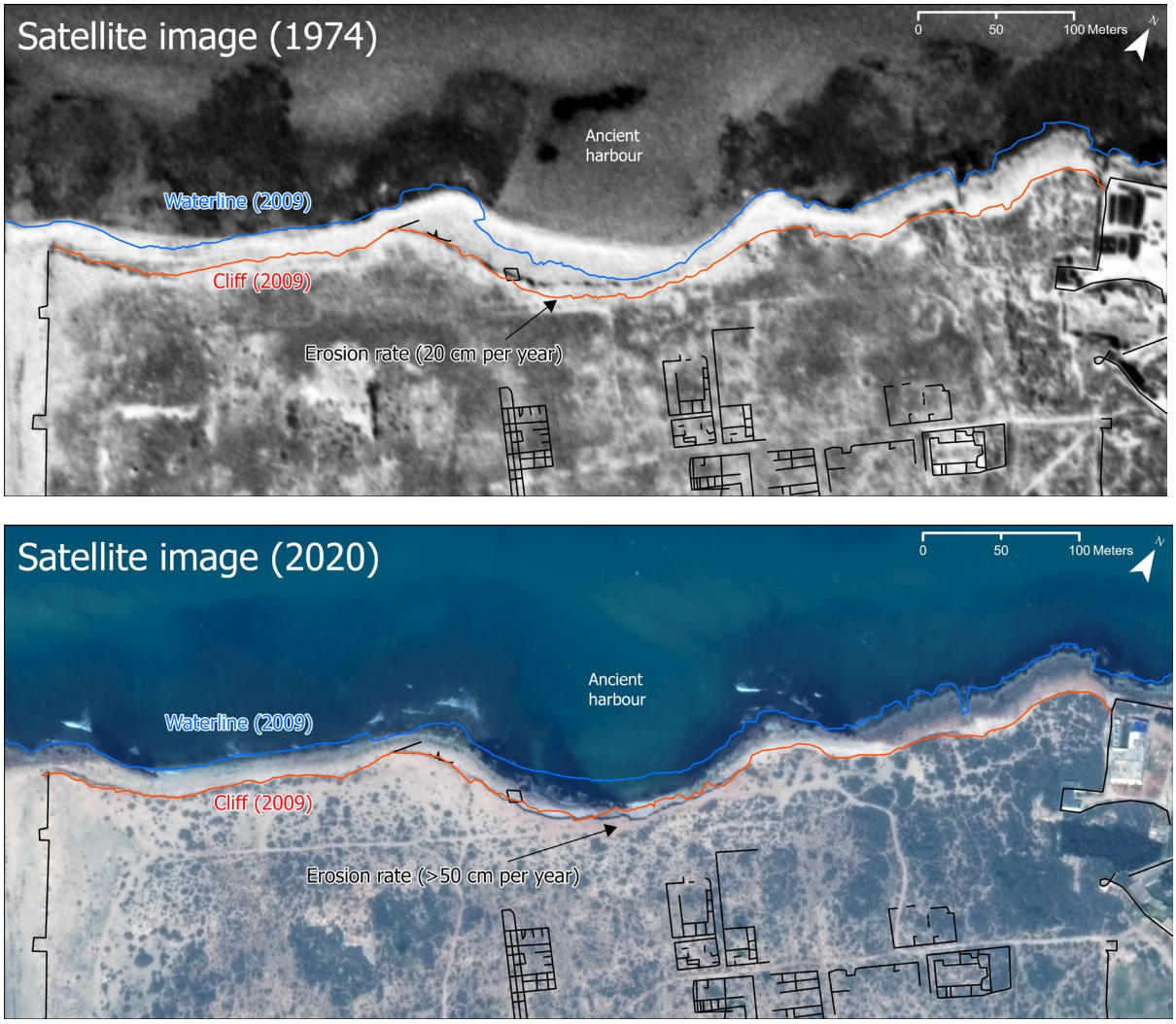

*The multiperiod harbour city of Anthedon in Gaza has been impacted by a combination of erosion accelerated by the construction of modern Gaza harbour and recurrent airstrikes. The site was ultimately completely destroyed in 2023 through a combination of airstrikes and bulldozing (produced by the GAZAMAP project).*

## CASE STUDY: TOCRA, LIBYA

An example of how coastal erosion can threaten, and damage cultural heritage comes from Tocra (ancient Taucheira) in eastern Libya. Tocra was founded in the late seventh century BC. We know this from pottery and other objects that were found at the sanctuary of Demeter and Kore which was located at the foreshore. Some evidence for an early walled settlement was also found there. At first, Taucheira served as a harbour for Cyrene and later Bakra.

Erosion can rapidly deteriorate ancient structures, potentially causing significant damage even during a single storm event. Ancient harbours such

as Tocra are particularly susceptible to erosion due to the proximity of numerous structures to the sea. Erosion can also expose previously undiscovered archaeological material. Since the 1960s, archaeologists have observed new structures and artifacts revealed by erosion at Tocra. However, the current rate of erosion is so rapid that newly exposed material is often destroyed before archaeologists can carry out thorough investigations.




*Satellite imagery of Tocra (Kh7 and from Google Earth Pro) showing coastal erosion at the site. Image: Kieran Westley*

Analysis of satellite imagery indicates that the coastal cliff has receded by up to 10 meters since 1974. Comparative analysis of these images reveals an increase in the average erosion rate. Prior to 2009, the rate was approximately 20cm per year. Currently, it exceeds 50cm per year in certain areas. Additionally, the beach fronting the cliff has nearly disappeared, allowing waves to more readily access and erode the unprotected cliff face.

Of particular concern is the potential for accelerated future erosion due to climate change. The Continued burning of fossil fuels is expected to accelerate sea-level rise, resulting in waves penetrating further inland and

causing more rapid erosion. The image above illustrates the projected area of impact over the next 20 years, assuming erosion rates remain consistent with current levels.

After 2050 it is likely that sea level rise will accelerate significantly if the burning of fossil fuels continues unabated. Under such circumstances, substantial areas of Tocra may be vulnerable by 2100. However, the situation is not irreversible. A drastic reduction in fossil fuel consumption by humans could mitigate this acceleration. While portions of numerous coastal archaeological sites will inevitably be compromised, the extent of damage will be considerably less severe than if the current rates of fossil fuel burning and destruction of natural lands and forests persist.


*Possible scenarios of future coastal erosion at Tocra. Image: Kieran Westley.*

## COASTAL FLOODING (INUNDATION)

Flooding poses another significant threat, characterized by the inundation of typically dry areas beyond the high-water mark. This phenomenon also contributes to coastline recession. While flooding occurs naturally, human activities can intensify its effects.

The impact of flooding varies across locations and time, influenced by factors such as local terrain (e.g., flat or steep), presence of protective structures (e.g., sand dunes, sea barriers), regional sea-level trends (rising or falling), and the erosion of coastal defences. It's important to note that many regions will experience elevated sea levels in the future due to climate change, consequently leading to increased flooding incidents.

Low-lying locations are particularly vulnerable to inundation, erosion, and destruction from inundation. According to the composite coastal vulnerability index map, 47% of the arid North African coast is extremely vulnerable. In addition, shoreline retreat along the North African coast in semi-arid places suggests an imbalance in coastal sedimentation processes caused by sudden changes in current precipitation patterns and urban expansion.

## COASTAL FLOODING (INUNDATION): IMPACT ON MARITIME HERITAGE

Archaeology faces a significant threat when marine processes encroach onto usually dry, terrestrial sites. Direct harm can be caused by wave action and tidal forces. Additionally, water exposure may lead to deterioration, such as the oxidation of metallic artifacts. With projected sea-level rise, numerous locations will become vulnerable in the coming years. Instances can be observed in the United States and Mediterranean region, with particular attention drawn to the moderate risk classification assigned to multiple World Heritage Sites in North Africa.

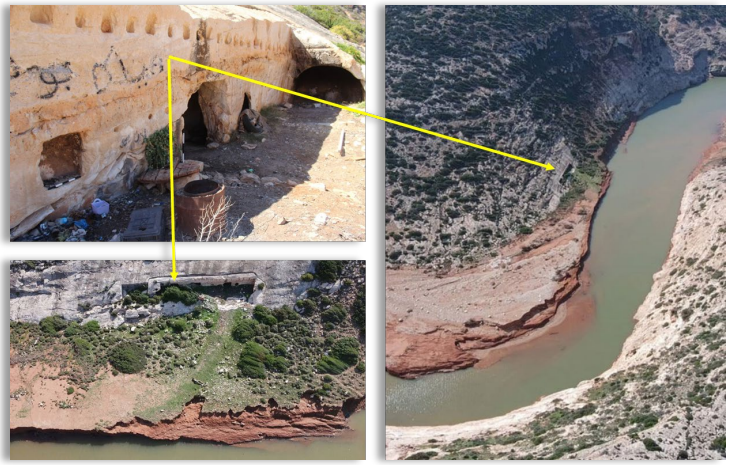
## RAPID HIGH MAGNITUDE EVENTS

Flooding and erosion frequently occur gradually over extended periods, but they can also happen rapidly due to storms, tsunamis, and earthquakes. These sudden events often cause more severe damage than long-term processes.

It is important to stress that, oftentimes, multiple factors contribute to rapid erosion and flooding events, and identifying the primary cause of such occurrences is often complex. Potential factors include climate change-induced sea-level rise, unrelated anthropogenic activities such as the obstruction of wadis by urban or infrastructural expansion, or a combination thereof. In the case of Storm Daniel, the construction of dams and roads exacerbated the severity of the floods in locations such as Derna and Sousa, as the water was compelled to seek alternative pathways to reach the sea.

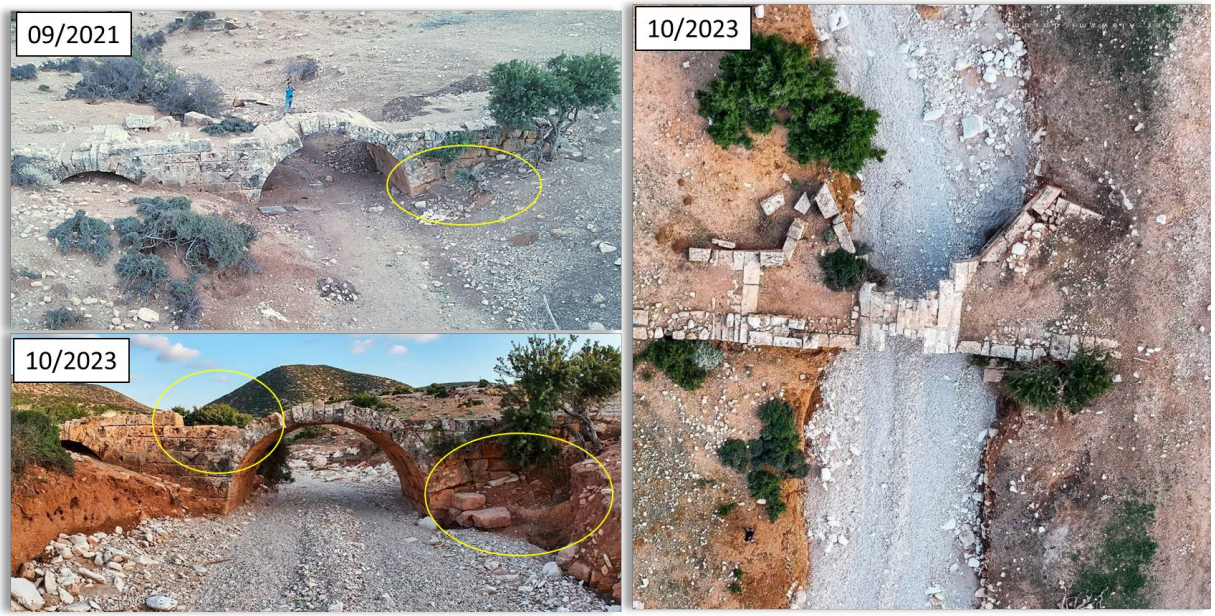
## CASE STUDY: STORM DANIEL

On September 9, 2023, a severe tropical-like cyclone made landfall along the coast of Cyrenaica in Libya, affecting both coastal and inland areas. Intense rainfall resulted in significant flooding, with particularly catastrophic consequences for the cities of Derna and Sousa.



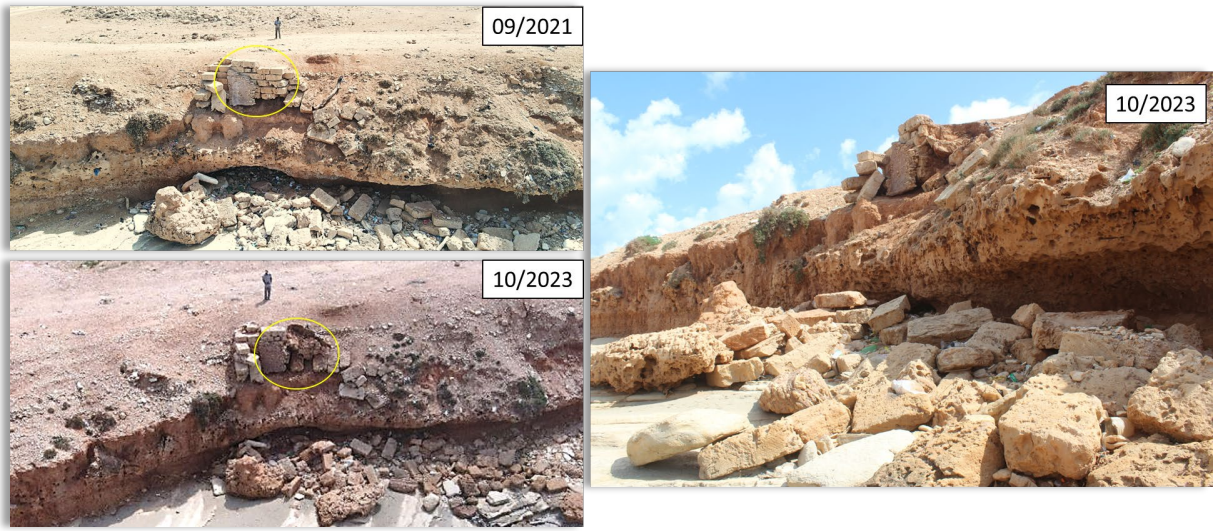
*Effects of Storm Daniel on the Wadi Maqyounis, Eastern Libya (Image: Cyrenaica Coastal Survey Project).*

In October 2023 the Cyrenaica Costal Survey (CCS) Project - team, (a collaboration between MarEA, the Department of Antiquities Libya, and Benghazi University) surveyed the area between Tocra and Apollonia with the primary objective to assess the damage caused by the medicane. The CCS project had surveyed this area in 2022, and could, therefore, assess and compare changes in the condition of sites between 2022 and 2023. The most extensive damage caused by Storm Daniel was attributed to runoff water that surged through wadi channels, eroding elements of the sites. This phenomenon is evident in the image depicting Wadi Maqyounis and the Roman-period bridge in the Wadi Ziwana.



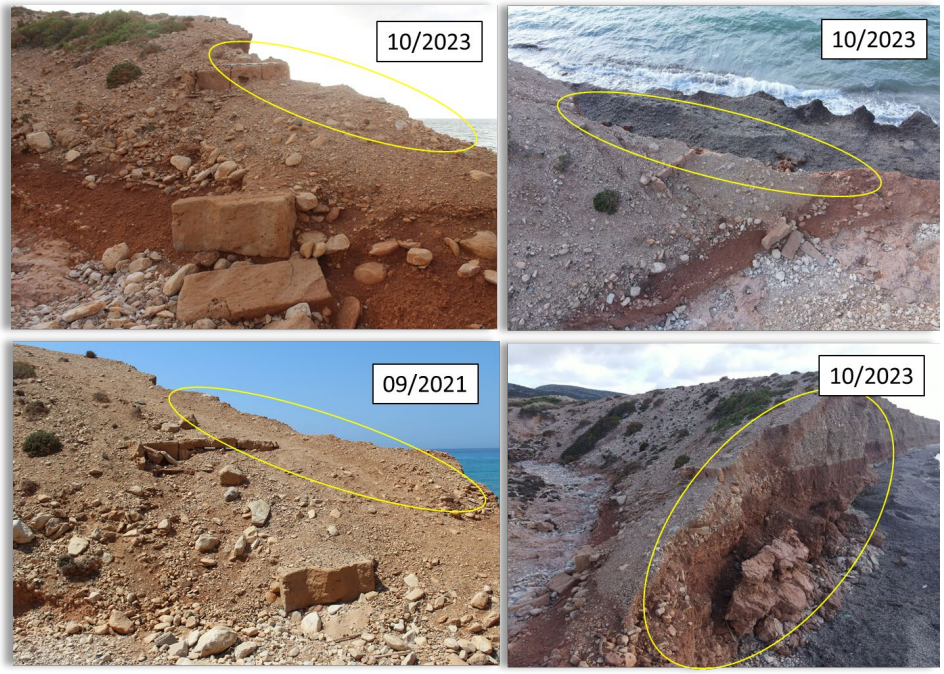

*Damage to the bridge at Wadi Ziwana, Eastern Libya. (Image: Cyrenaica Coastal Survey Project).*

Coastal erosion emerged as the second most significant concern. Buildings that were already located close to coastal cliffs collapsed further, caused by high wave impact.




*Coastal erosion caused by strong wave action west of Ptolemais. (Image: Cyrenaica Coastal Survey Project).*

Structures located in proximity to wadi outflows were particularly susceptible to damage, as they were affected by both the impact of waves and inland runoff water. An illustrative example is the water channel of the Aqueduct that once supplied the classical-period port town of Ptolemais. The water channel was subjected to coastal erosion due to wave impact as well as erosion resulting from runoff water.




*Coastal erosion and run-off water damage east of Ptolemais. (Image: Cyrenaica Coastal Survey Project).*

On the other hand, this type of rapid erosion can also reveal archaeological features that were previously concealed, such as a waterproof floor of a building east of Tocra.

*A new site is being recorded that was previously covered by sediment. (Image: Cyrenaica Coastal Survey Project).*

## DAMAGE TO UNDERWATER HERITAGE

Structures, shipwrecks and artifacts that are submerged underwater over a prolonged period of time face several additional threats. In the underwater environment, natural processes are typically categorized into three groups: physical, biological, and chemical. Physical processes involve water movement, such as waves and currents, which affect submerged sites and nearby sediment. This often results in localized erosion and deposition (scour) around archaeological remains, as evidenced by shipwrecks. Waves and currents can significantly disturb a site and move objects away from their original location, and sediment movement can lead to sites being covered or exposed. If the site is covered, it may help to prevent at least some of the biological processes discussed in the next paragraph, as most of the organisms responsible for biological damage require oxygen.

Biological processes encompass various organisms that impact underwater artifacts. Especially oorganic matter and fragile objects can be destroyed when exposed to seawater over an extended period of time, and types of algae, fungi and bacteria start to grow and feed on them. Wood-boring creatures like teredo worms (or ship worms) form colonies in the timber and consume it over a long period of time. Other marine organisms form encrustations on submerged structures, and bacteria that degrade archaeological materials are further processes that affect sites. A notable example is the Titanic, which is gradually being consumed by bacterial activity. Chemical processes involve reactions such as metal corrosion which causes rust.

Similar to coastal regions, underwater environments undergo changes over time. Long-term physical alterations occur in response to climate and sea-

level fluctuations, while short-term changes can happen rapidly due to events such as storms.

**Summary**

Maritime heritage faces a variety of natural hazards, with proximity to the ocean being a primary factor in many of these threats (such as waves, tides, and storms). Coastal locations are particularly vulnerable to inundation, erosion, and sediment accumulation. Submerged sites are impacted by physical, biological, and chemical processes. In all instances, the effects evolve over time. The extent of damage to a specific site is determined by its nature, the intensity and rapidity of the threat, and the characteristics of the site itself.

**Disclaimer:** The materials and information presented in these lectures have been compiled from a range of academic sources, which are listed in the Bibliography and Further Reading section of this course.