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Harnessing Remote Sensing Derived Sea Level Rise Models to Assess Cultural Heritage Vulnerability: A Case Study from the Northwest Atlantic Ocean

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Abstract: Climate change threatens cultural heritage across the globe. Of its varied impacts, sea level rise is critically pressing because of the long relationship between humans and the ocean. Numerous cultural heritage sites lie on the world's fragile coasts. Identifying cultural heritage sites at risk is an urgent need, but archaeological research programs do not always have the resources available to conduct large-scale cultural heritage vulnerability assessments. Given sea level rise poses myriad pressing issues, entities around the globe are developing sea level rise models for various management purposes (ecology, hydrology, real estate, etc.). These remote sensing-derived sea level rise models can be harnessed by archaeologists to assess cultural heritage site vulnerability. Here, such an analysis is realized for a northwest Atlantic Ocean coastal area experiencing relative sea level rise and with robust cultural heritage, including economically significant maritime heritage tourism. Combining archaeological and historic geospatial databases with LIDAR (Light Detection and Ranging)-derived relative sea level rise models illuminates coastal New Hampshire's cultural heritage vulnerability. This is informative for risk monitoring, mitigation, and preservation planning, especially for cultural heritage tourism. The analysis also raises the need for discussions around what kind and whose heritage gets priority in planning for future sea level rise impacts.

Keywords: sea level rise; cultural heritage; risk; remote sensing; archaeology; LIDAR; GIS

1. Introduction

It is well established that modern forces such as development, war, looting, and tourism-induced damage make tangible cultural heritage highly vulnerable to change [1–13]. Today, climate change poses a growing area of threat to cultural heritage sites. Groups from government entities to international organizations to indigenous communities to scholars are ever more aware of the fact that climate change "is eroding and will continue to erode our historic fabric, disturbing and destroying many archaeological, traditional, and historic sites" [14]; see also [15–20].

The impacts of climate change are here to stay and will cause further long-term changes in the climate system [21,22]. Sea level rise is one critical effect of climate change and there is high confidence its associated impacts will persist for millennia [22]. Global sea level rise is caused primarily by added water from melting ice sheets and glaciers and the expansion of seawater as it warms. Global sea level rise has been monitored by satellites by NASA since 1993 [23,24]. These satellite altimetry data indicate the rate of global mean sea level rise (GMSLR) is 3.3 mm per year (Figure 1).

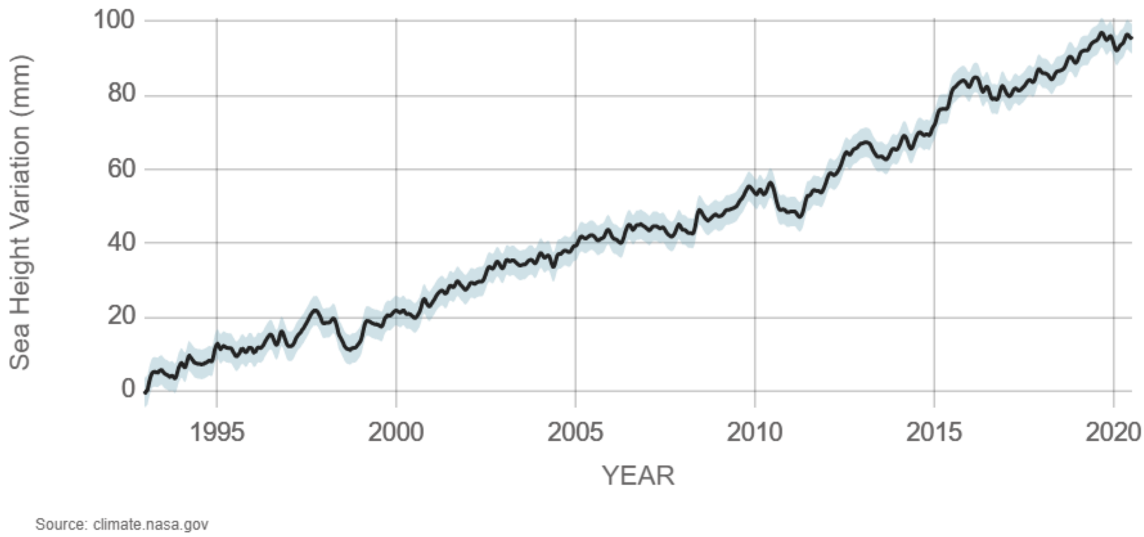

Figure 1. Global mean sea level rise (GMSLR) as monitored by NASA satellites, indicating a rate of change of 3.3 mm a year (credit: Goddard Space Flight Center, https://climate.nasa.gov/vital-signs/sea-level/).

Sea level rise is particularly pressing for cultural heritage management and risk mitigation because humans have had a long and intense relationship with the world's oceans [25–32]. Humans have been drawn to the sea and its resources for hundreds of thousands of years [33,34]. Today, there is disproportionate anthropogenic pressure on the world's marine coasts [35,36]. Ever-increasing human population presence has undercut the resilience of coastal and ocean ecosystems in a variety of ways, including overfishing, nutrient runoff, shoreline development, chemical pollution, alterations of bottom conditions, and dangers caused by atmospheric accumulation of CO_2 emissions, catastrophic weather events, global warming and ocean acidification [37,38]. Today, global coastal and ocean conditions are characterized as depleted, degraded, and distressed [39–41].

The consequent reduction in ecosystem services has profound impacts on the human populations reliant on coastal resources [37,38,42–46]. While the distressed state of the ocean is widely discussed as an ecological crisis, it also concurrently presents notable risk for decreasing cultural services, including, of focus here, cultural heritage. Numerous and iconic cultural heritage sites across the world lie on fragile coasts [25,32]. Global modeling has found that over the next two millennia, up to 19% of UNESCO World Heritage sites will become submerged by rising sea level and storm surges [47].

Problem Statement

Identifying cultural heritage sites that are vulnerable in the face of sea level rise is an urgent need. While archaeologists have increasingly recognized this need, archaeological research programs do not always have the resources available to conduct large-scale cultural heritage risk assessments. Archaeologists need to find accessible and affordable ways of conducting cultural heritage risk assessments. One solution emerges from the fact that many entities, from local and regional municipalities to national governments to global environmental nonprofits, are developing spatialized sea level rise models for various management purposes (ecology, hydrology, real estate, insurance, zoning, economy, etc.). Available geospatial maps of projected sea level rise coastal flooding, even if not created for archaeological purposes, can be productively and creatively harnessed by archaeologists for the benefit of assessing the vulnerability of cultural heritage sites.

Here, such analysis is realized for a coastal area of the northwest Atlantic Ocean that has rich cultural heritage sites and that is experiencing many of the effects of climate change seen globally, including sea level rise [48–50]. Orienting from the water, coastal New Hampshire is located in the northwest Atlantic Ocean (Figure 2). In addition to experiencing impacts from climate change today, coastal New

Hampshire has a rich history of human occupation and so hosts a rich landscape of cultural heritage sites that includes both indigenous precontact sites and post-contact historic sites. The region also has an economically significant maritime heritage tourism industry based around several of its Euro-American historic cultural heritage sites. By combining archaeological and historic site geodatabases with LIDAR (Light Detection and Ranging)-derived coastal flooding projection datasets made for six different relative sea level rise scenarios, the range of vulnerability of coastal New Hampshire's cultural heritage resources is illuminated. Tethering between macro-global understandings of the challenges presented by sea level rise, this kind of regional-scale remote sensing-based vulnerability assessment and local site-based preservation action plans offers a productive approach to cultural heritage resource risk monitoring and mitigation.

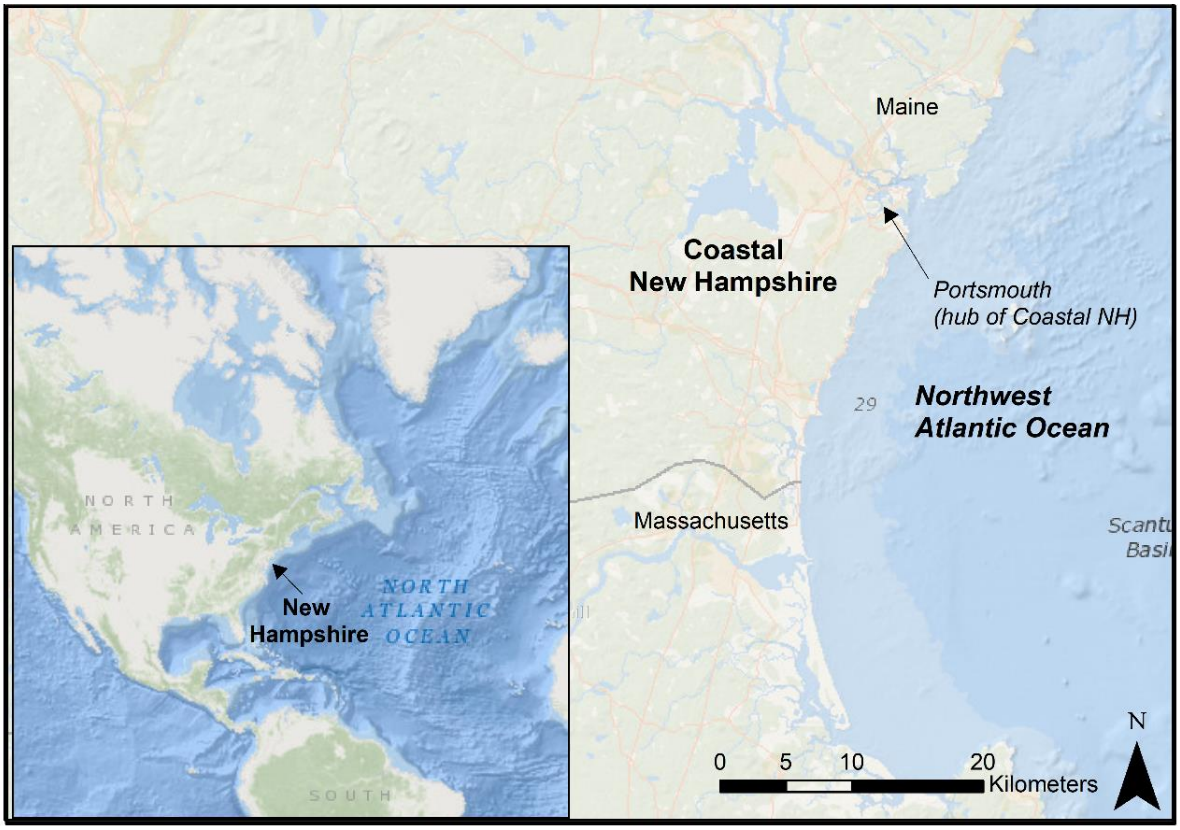

Figure 2. Locator map of coastal New Hampshire in the Northwest Atlantic Ocean (base data from ESRI).

2. Materials and Methods

2.1. Study Area

Looking east each day to the Atlantic Ocean for thousands of years, indigenous peoples knew their home (and many continue to know it today) as *ndakinna*—"our land", the place "to which we belong". Long before colonists came and re-inscribed it as "New England", this place was called *Wabanaki* or *Wôpanâak*. It is characterized by interlocking ecosystems produced as the ocean and the land meet at the coast. Freshwater from streams and rivers mingles with the ocean in large coastal bays and sprawling estuaries, and forests extend inland along the waterways. The East is the land where the sun is born in a startling array of light every day as it rises over the Atlantic Ocean [51] (Figure 3).

Figure 3. The rising sun over the northwest Atlantic Ocean in Ndakinaa, the land of the dawn, at Star Island in the Isle of Shoals, off the coast of New Hampshire (photographed by Paul and Denise Pouliot, the speakers of the Cowasuck Band of the Pennacook Abenaki People, used with permission).

There are a few Paleo-Indian finds in coastal New Hampshire, but the first occupation sites date to the Archaic period (ca. 8000–1000 BC). Archaeological evidence indicates a marine adaptation among indigenous communities was well developed here by the Middle Archaic period (ca. 6000–3000 BC), continued in the Late Archaic period (ca. 3000 BC–1000 BC), and lasted throughout the Woodland period (ca. 1000 BC to European Contact ca. 1500–1600 AD) [52–54]. Faunal remains from precontact archaeological sites demonstrate that indigenous populations used a diverse mix of marine species (mammal, seabird, fish, and shellfish) throughout all seasons [55]; see also [52,54,56,57]. Reciprocal networks and cyclical seasonal movements between coastal and interior ecosystems functioned to sustain the diversity of the environment and the survival of its many inhabitants before Europeans arrived [58–60].

The marine resources of the northwest Atlantic Ocean were a chief attraction for early European explorers [33,61,62]. Fisheries were established in Newfoundland as early as the early 1500s. A century later, New England explorers described enormous "shoals" of monstrous cod as big as men off the shores of New England and marveled at how much bigger, more plentiful, and closer to shore they were than in Newfoundland. The first Europeans in coastal New Hampshire were fishermen participating in the expanding commercial fishery, settling permanently on the Isle of Shoals in the early 1600s [63]. By the 1620s, British settlers moved onto the region's coast, establishing colonial farming and fishing villages. Colonial exploitation of natural resources quickly transcended subsistence-based levels and dried fish, saltmarsh hay, furs, and, above all, lumber, processed in saw-mills for use in ship-building, became key export commodities for the larger West Indies trade [64,65].

Over the course of the 1600s and early 1700s, coastal New Hampshire was part of the British colony, but its geographic position left it in a frontier zone between French Quebec and English Boston [66]. The French and British each made alliances and treaties with Native American groups as they battled for control of the region. Indigenous communities were powerful entities in these frontier settings. Many early British colonial settlers lived in garrisons (fortified houses) to protect themselves from attacks by French and indigenous groups [67]. Despite indigenous attempts to remove them and the tensions of the period, British settler colonialists stayed because they continued to prosper off of their commodification of the region's rich natural resources.

By the time of the American Revolution in the late 1700s, it was clear many fish species were no longer abundant in the area's rivers. The forests could not keep pace with the lumber industry [68].

By the early 1800s, the lumber industry in coastal New Hampshire had all but collapsed. During the 1800s, now-Americans living on the seacoast had to look for other economic opportunities beyond the natural resource base. Manufacturing rose in importance, including paper mills and cotton factories [69]. When the Boston and Maine railroad came to New Hampshire in 1835, it became the choice means of shipping manufactured goods from the region to commercial hubs and the region's waterways, once central to the economy, instead became a dumping ground for manufacturing's sewage and industrial waste.

Over the course of the 1800s, people left coastal New Hampshire in the face of economic decline. They left a landscape littered with the contaminated residue of human development but also what would come to be seen as a rich suite of maritime cultural heritage remnants. After the decline of the lumber industry, the area's forests experienced second-growth reforestation. In the late 1800s and early 1900s, New Englanders living in more urban areas such as Boston began to increasingly romanticize the sea and seek out coasts for respite and recreation [70]. This was a global trend during this time, where, "under the tourist gaze, coasts became regarded as places where human life was simple and picturesque, turning them into places of heritage and generating new forms of income, i.e., tourism" [71]. Coastal New Hampshire with its increasingly "natural" feel from forest regrowth and its "historic" maritime charm in the remnant buildings from the previous centuries, began seeing such coastal tourism and this trend continued throughout the 1900s.

Today, tourism remains a key factor behind strong demographic, social, and economic growth in coastal New Hampshire and the region's remnant historic heritage sites and maritime cultural landscapes are significant tourist draws. While Rockingham and Strafford counties, New Hampshire's two coastal counties, are only two of 10 counties in the state, they contributed 37.5% of the total state meals and room tax revenue in fiscal year 2014, accounting for $104.7 million [48]. Of course, COVID-19 has impacted tourism and economics in coastal New Hampshire this year (as across the globe). However, the City of Portsmouth, the major hub of coastal New Hampshire's tourist industry, has shown more resilience than other parts of the state, suggesting the continued economic importance of maritime cultural tourism here [72] (Figure 2).

2.2. LIDAR-Derived Relative Sea Level Rise Flooding Extent Maps

In any given coastal area, sea level rise, while influenced by global patterns, is also subject to processes operating on more regional scales and localized phenomena [21,50,73]. Relative sea level rise is measured by tidal gauges and so accounts for changes resulting from vertical motion of both the land and the sea surface [21]. In New Hampshire, tidal gauge data collected in Portsmouth Harbor over decades show relative sea level is rising and as it does, the region is experiencing increased coastal flooding that is only expected to increase in frequency and severity in the future, is experiencing more extreme precipitation events, is ever more subject to damaging storm surges and astronomical tides, and is likely to experience coastal land submersions within the next 50 to 100 years [50].

In New Hampshire, a private–public partnership called Carbon Solutions New England, working with the National Ocean and Atmospheric Administration (NOAA), has developed regional models of a range of climate change impacts (snow cover, mean temperature, precipitation, etc.). The aim of systematic assessments of climate change impacts by this collaborative group is to aid the development of municipal and regional climate adaptation plans in the New Hampshire coastal watershed [49]. Sea level rise is one of the critical climate change impacts focused on in these efforts. Carbon Solutions New England used projections of global eustatic sea level rise and combined them with regional tidal gauge sea level rise data. They conducted a statistical analysis of available tidal gauge data to create a 100-year coastal still-water elevation (the elevation of the water surface that does not account for waves and run-up) [49]. Next, to this estimated still-water flood elevation they added the elevation of mean higher high water (MHHW) to create a coastal flooding scenario that occurs at the highest daily tide, which offers a benchmark of flooding from storm surges. The Intergovernmental Panel on Climate Change (IPCC) makes comprehensive reports about the state of scientific knowledge on climate change for guidance purposes across the globe [22]. In many places, stakeholders and researchers use IPCC reports to inform their work on the impacts of climate change, including sea level rise. Accordingly, Carbon Solutions New England used two IPCC global emissions scenarios, a high and an intermediate emissions scenario. For both the intermediate and high emissions scenarios, Carbon Solutions New England estimated what the 100-year still water and storm surge flood height would be at mid-century (2050) and the end of the century (2100). Together, they then modeled six sea level rise scenarios:

- High Emissions Scenario 2050
- High Emissions Scenario 2050 Storm Surges
- Intermediate Emissions Scenario 2100
- Intermediate Emissions Scenario 2100 Storm Surges
- High Emissions Scenario 2100
- High Emissions Scenario 2100 Storm Surges

While Carbon Solutions New England could create scenario projections, they could not spatialize these sea level rise projections for the region and make actual coastal flooding extent maps until they gained access to high-resolution topographic data. Such topographic data were necessary because the likelihood of an area flooding depends on its topographic positioning and elevational properties. The requisite high-resolution topographic data became available in spring of 2011 when detailed airborne LIDAR (Light Detection and Ranging) topographic data were collected over coastal New Hampshire [49]. The output LIDAR Digital Elevation Model (DEM) was 2 m resolution with a bare-earth vertical accuracy of 15.0 cm or better [73]. With the availability of high-resolution remotely sensed topographic data, Carbon Solutions New England was able to generate spatialized datasets of the areas that are prone to flooding and water-over-land submersion in each of the six sea level rise scenarios on the New Hampshire seacoast. The output was six rasters (10 × 10 m resolution) reflecting the extent of coastal flooding in each of the six sea level rise scenarios. In each raster, every grid cell has a value field reporting the estimated water inundation depth (in feet) [49]. The six sea level rise raster grids are available and were downloaded for this project as a geodatabase (.gdb) from NH GRANIT, New Hampshire's statewide GIS clearinghouse.

As noted above, these LIDAR-derived relative sea level rise coastal flooding extent geospatial datasets were created for government climate adaptation plans [49]. These high-resolution regional geospatial sea level rise models were not created for cultural heritage vulnerability assessment. However, it became apparent that these sea level rise flooding maps offered an opportunity to examine the risk cultural heritage faces in terms of sea level rise in coastal New Hampshire. Of note, this analysis was started in an effort to raise awareness of this issue for state and regional stakeholders who may not have considered cultural heritage in their adaptation planning and a public policy brief was disseminated [74]. Given the many pressing concerns over sea level rise around the globe, such datasets are increasingly available. Archaeologists can, as has been done here, harness these data at no to low cost and repurpose them to conduct cultural heritage vulnerability assessments.

2.3. Methodology

2.3.1. Cultural Heritage Vulnerability Assessment

As indicated above, coastal flooding extent maps for six relative sea level rise (SLR) scenarios were created for non-archaeological purposes for coastal New Hampshire based on high-resolution airborne LIDAR data that indicate which areas are prone to flooding and water-over-land submersion. While created for other purposes, these geospatial datasets were repurposed for an assessment of the region's cultural heritage vulnerability to sea level rise. To start the cultural heritage vulnerability analysis, a geodatabase of 383 known precontact and historic period sites for New Hampshire's two coastal counties, Strafford and Rockingham, was acquired from the State of New Hampshire's

Division of Historic Resources. This geodatabase was transformed so as to align with the sea level rise (SLR) coastal flooding extent rasters. Known archaeological sites were overlaid on each of the six sea level rise (SLR) scenario rasters for coastal New Hampshire (High Emissions Scenario 2050; High Emissions Scenario with Storm Surge 2050; Intermediate Emissions Scenario 2100; Intermediate Emissions Scenario with Storm Surge 2100; High Emissions Scenario 2100; High Emissions Scenario with Storm Surge 2100). Again, each of the six SLR scenario rasters (10 × 10 m resolution) has a value field reporting the estimated inundation depth across the grid (in feet) [49]. For each of the six SLR scenarios, the value of the estimated inundation depth was extracted for each archaeological site (all work done in ArcGIS 10.3 and 10.8). Sites were then sorted by this value for each of the six SLR rise scenarios. This allowed for the identification of the range of vulnerability of heritage sites to damage and/or destruction by sea level rise.

Working with the known archaeological geospatial site database, an evaluation of whether precontact and historic sites stand to experience differential impacts from sea level rise was conducted. To conduct this evaluation, a dominant cultural heritage era designation was assigned for each site. While there are sites that have both precontact and historic components in the region, in most cases, one of these occupation eras dominates the site (and/or heritage conceptions and valuations of the site). For instance, Strawbery Banke has precontact components, but is dominated by its historic era cultural heritage, and this is what is packaged and consumed as a maritime heritage tourist site today [73]. Likewise, Seabrook archaeological sites include historic components, but Seabrook is most known as a suite of critically significant precontact indigenous sites in the region [54]. Sites where a dominant era designation could not be determined were excluded from this specific analysis (seven sites). With assigned dominant time period designations, the number of precontact and historic sites with water inundation in each SLR scenario was computed and the results were compared.

2.3.2. Historic Graveyard Assessment

Historic graveyards are a common, and iconic, feature of cultural heritage landscapes across New England [75]. The archaeological geospatial site database of known precontact and historic heritage sites does not include historic cemeteries (known precontact burial sites are included). These are an important aspect of the region's cultural heritage and historic graveyard vulnerability to sea level rise is important to assess. Indeed, burial sites may demand the most imminent attention in any adaptation and mitigation planning done by local, state, and/or federal entities.

In New Hampshire, the New Hampshire Old Graveyards Association is an organization dedicated to preserving the historical graveyards of New Hampshire [76]. As part of this, they work on mapping the location of historic graveyards. In 2000, 20 years ago, the locational data available at that time were translated into a digital spatial database. The data in this data layer were "performed on the basis of data submitted by individual communities, and thus the quality and completeness of the record will vary considerably across the state" [77]. These data can be accessed from NH GRANIT by request and subject to approval (and cannot be shared). While recognizing these available graveyard data are somewhat dated and form what might be considered "fuzzy" data, it was still important to find a way to include them when considering cultural heritage vulnerability for coastal New Hampshire.

Working with the provided data layer, all graveyards in Rockingham and Strafford counties were extracted (again, New Hampshire's two coastal counties). Given this cemetery database has a level of locational uncertainty (as described), to address its "fuzzy" nature, a 100 m buffer was computed around cemetery point data. Working with the "worst-case" sea level rise scenario, High Emissions Scenario with Storm Surge 2100, sea level rise inundation values were extracted for each of these polygons (the buffers around historic graveyards).

3. Results

Figure 4 presents the coastal flooding extent (water inundation) for each of Carbon Solution New England's six sea level rise scenarios. On top of these coastal flooding maps are the known cultural heritage sites from New Hampshire's two coastal counties (Strafford and Rockingham). This figure helps illustrate the results of the cultural heritage vulnerability assessment. It shows how in each of the six sea level rise scenarios, known cultural heritage sites in New Hampshire's two coastal counties, Strafford and Rockingham, will be impacted by coastal flooding from sea level rise and associated storm surges and that some scenarios will impact more sites overall.

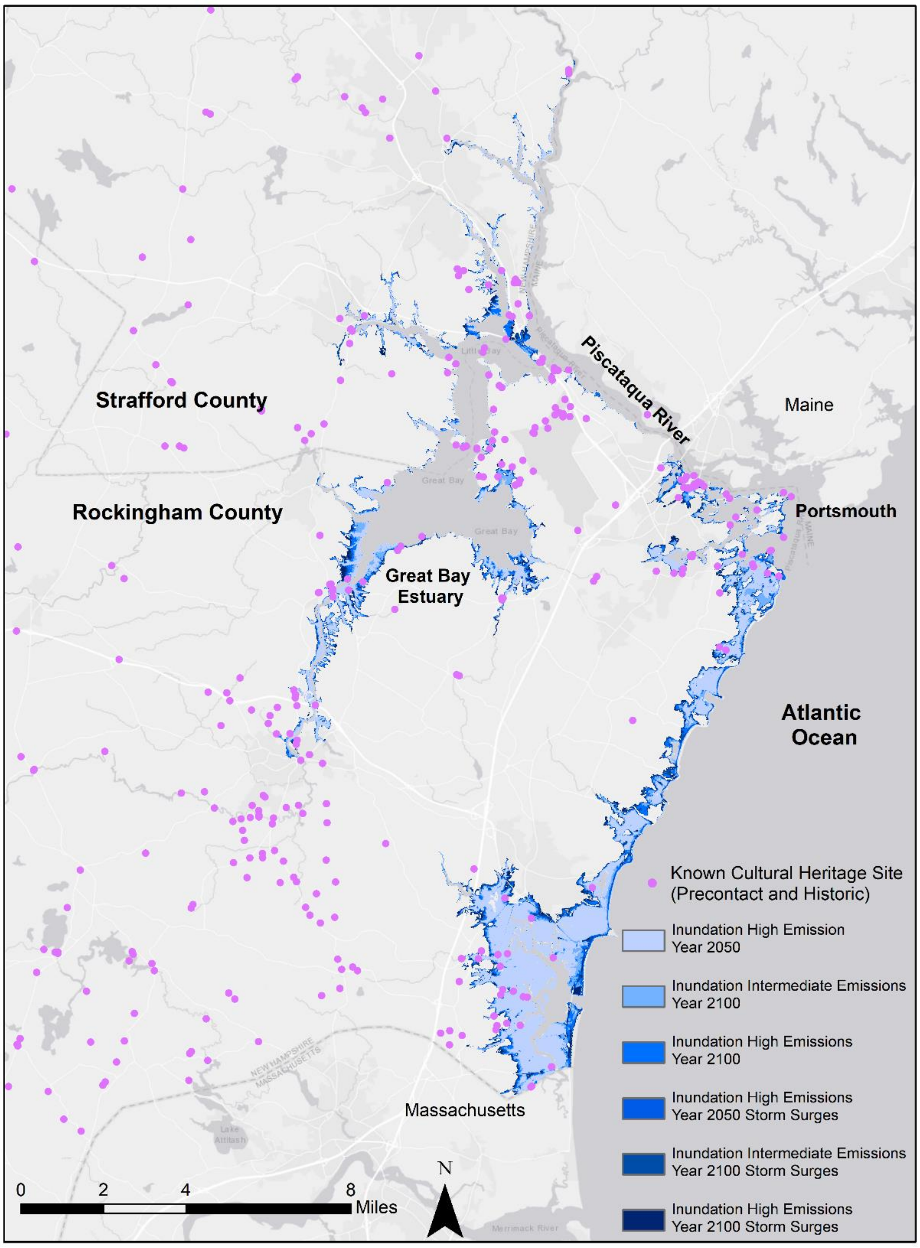

Figure 4. The six sea level rise coastal flooding rasters presented at full extent of water inundation with the geodatabase of known cultural heritage sites (historic and precontact) in New Hampshire's two coastal counties (Strafford and Rockingham). Water inundation values were extracted for known sites from each raster to identify how many and which sites stand to be damaged and/or destroyed in each of the six SLR (sea level rise) scenarios. (SLR data from NH GRANIT; archaeological site data from the New Hampshire Division of Historical Resources; not publicly available data due to site sensitivity).

Again, the water inundation value was extracted for each known cultural heritage site in each scenario. As is reflected in Figure 4, the lowest impact sea level rise scenario, High Emissions Scenario 2050, is projected to create the least extent of coastal flooding and thus damages the least number of sites. Likewise, the highest impact sea level rise scenario, High Emissions Year 2100 Storm Surges, creates the most coastal flooding and damages the most sites. The pie charts in Figure 5 break down the percentage of known cultural heritage sites that will be damaged and/or lost in each sea level rise coastal flooding scenario. In the lowest impact scenario, 5% of currently known sites will be impacted and in the highest scenario, 14% of known cultural heritage sites will experience some level of water damage and many complete water inundations (Figure 5).

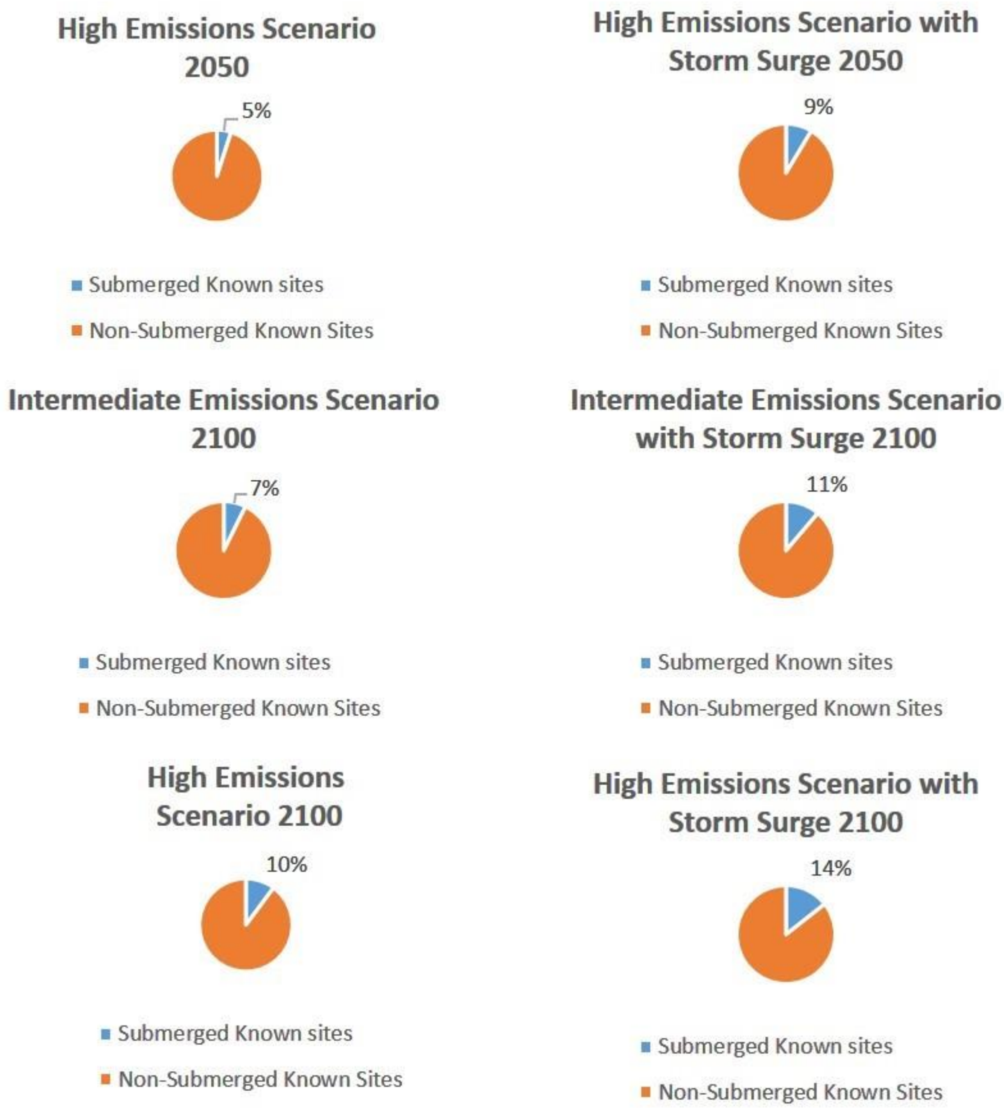

Figure 5. Known precontact and historic sites experiencing water inundation in each of the six sea level rise (SLR) coastal flooding map scenarios.

Of note, there is no scenario in which sites on the National Register of Historic Places will not be impacted. The National Register of Historic Places is the United States' official list of historic and archaeological resources worthy of preservation [78]. In the High Emissions Scenario with Storm Surge 2100, a notable 12 sites on the National Register of Historic Places will be impacted. Each of these sites is important in the region's economically significant maritime heritage tourism industry.

Figure 6 shows the percentage of precontact and historic sites lost in the least impact scenario (High Emissions Scenario 2050) and the most SLR impact scenario (High Emissions Scenario with Storm Surge 2100). Running chi-square tests (using numbers of sites) for each of these end scenarios showed no significant difference in sea level rise impact for either scenario between precontact and historic sites. While there are no statistically significant differences between precontact and historic sites, this assessment does show a notable jump in terms of sea level rise vulnerability for historic sites between the least and most SLR impact scenarios. This difference in impact between the low and high SLR scenarios for historic sites may be useful for planning in terms of heritage tourism activities. Given a recent review of coastal flooding and relative SLR in New Hampshire [50] indicates the low SLR scenario model is unrealistic and impacts are going to be more severe, the 15.5% of historic sites impacted in the highest SLR scenario may be an informative base figure to consider in ongoing and future mitigation and planning efforts for the region's maritime heritage tourism (such as those included in the report by the New Hampshire Coastal Risk and Hazards Commission, 48).

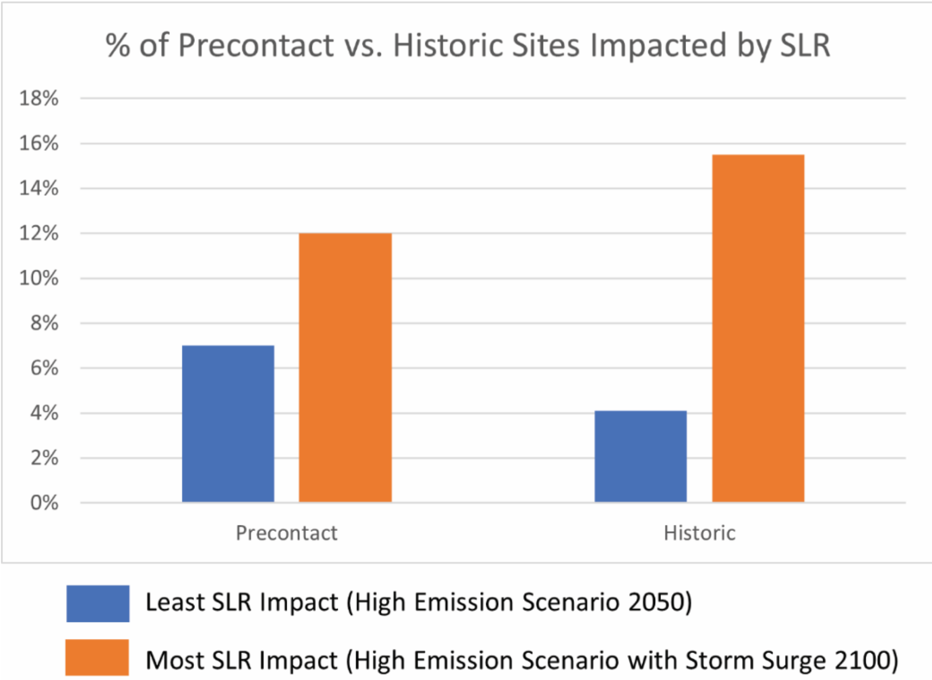

Figure 6. Percentage of precontact and historic sites lost in the least impact scenario (High Emissions Scenario 2050) and the most SLR impact scenario (High Emissions Scenario with Storm Surge 2100).

The "fuzzy" analysis working with the database of community-reported historic graveyards for coastal New Hampshire was run working with the "worst-case" sea level rise scenario, the High Emissions Scenario with Storm Surge 2100. The extracted sea level rise inundation values for the polygon buffers around historic graveyards showed that over 80 known historic graveyards in New Hampshire's two coastal counties, Strafford and Rockingham counties, are at risk of water inundation damage or complete submersion by sea level rise. The available graveyard dataset documents 1400 historic graveyards in these counties. The estimated impact on 80 historic graveyards means 17.5% of known graveyards in the region are at risk of coastal flooding from sea level rise. As noted above, these graveyards may demand the most imminent attention in any adaptation and mitigation planning done by local, state, and/or federal entities.

4. Discussion

Sea level rise is increasingly a fact of the present, but it looms as a significant, ominous, and not fully predictable fact of the future. This analysis asked how vulnerable cultural heritage is in coastal New Hampshire to damage by sea level rise. The results show a range of potential impact risk levels across available sea level rise projections, but there is no sea level rise model in which known precontact and historic sites as well as historic graveyards in coastal New Hampshire are not going to be subject to damage and/or destruction from increased coastal flooding.

It is important to emphasize the word "known" in this statement. Both the archaeological site and graveyard databases available and used here represent known cultural heritage features. Only small portions of New Hampshire's two coastal counties, Strafford and Rockingham counties, have seen any professional systematic survey for historic and precontact sites and the graveyard database available is, as noted, dated and incomplete. The majority of recorded precontact sites in these two counties come from individual amateur collectors [79]. The Great Bay Archaeological Survey (GBAS), launched in 2016, represents a recent systematic effort aimed at increasing attention on the region's cultural heritage, however, it is the first university-based archaeological research program in the region since 1980. These facts considered together highlight the critical need for more archaeological research across the region and also make it clear that there are potentially numerous sites and graveyards that have yet to be discovered. This is especially the case for cultural heritage sites with no standing architecture left, which includes all precontact indigenous sites as well as early historic cemeteries (1600s–early 1700s), which were marked with small fieldstones rather than cut stone engraved markers.

Figure 7 offers an example of the quite nondescript fieldstones that were used as grave markers during the early colonial period of the 17th and early 18th centuries before the region had its own stone cutter. These fieldstones are hard to distinguish as grave markers. The Great Bay Archaeological Survey (GBAS) has found multiple previously unlocated 17th-century graveyards in coastal New Hampshire with a combination of archival work, detailed walkover survey, and intensive on-the-ground mapping and post-processing analysis. The grave marker shown in Figure 7 is from one of these previously unlocated (and therefore not mapped in any database) 17th-century historic cemeteries. Without standing architecture or distinct gravestones, sites and cemeteries are harder to find and therefore are underrepresented in these known archaeological site and graveyard databases. As these numbers do not account for unknown sites, the vulnerability of cultural heritage resources in the region to sea level rise is higher than available data can capture.

Figure 7. Example of a 17th-century British colonial fieldstone grave marker in coastal New Hampshire. This picture shows the subtle nature of these features, illustrating the difficulty in identifying these cultural heritage places.

As noted above, tourism is a key factor behind what has been years of strong demographic, social, and economic growth in coastal New Hampshire and the region's remnant historic maritime heritage sites and cultural landscapes are significant tourist draws [48]. Again, coastal New Hampshire's revitalization during the 1900s was the direct result of the growth of tourism that saw coasts as places of leisure and simplicity. Today, a notable part of why people come to, and stay in, coastal New Hampshire remains the desire for a connection to an authentic historic marine lifestyle experience, an experience that is materialized in buildings and landscapes left from earlier times. The terms "sea," "charming," "historic," and "romantic" are used regularly in tourist promotional materials for the region today [80,81]. Even with the widespread impacts of COVID-19, coastal New Hampshire is showing more service-industry economic resiliency than other parts of the state and is still being recognized for its historic tourism appeal [72,80].

The findings of this analysis certainly suggest a possible looming impact on the region's economy. The 12 sites on the National Register of Historic Places that stand to be impacted by sea level rise include many of the key maritime heritage tourism destinations, from museums to historic houses to a thriving historic district with restaurants, shops, and bars. Most people seeking out cultural heritage tourism desire authenticity of place and experience. It has been documented that higher perceptions of authenticity during cultural heritage tourism leads to greater economic expenditures [82]. The results presented here may therefore raise concerns for future tourism revenue. Restaurants once situated in renovated historic buildings and districts will eventually lie in tidal marshes. If adaptation plans decide to move wharfs, docks, and historic buildings once dotting the coast inland for their preservation, how might this impact tourists' conceptions of their authenticity?

The significant contribution coastal New Hampshire makes to the state's tourist revenue certainly makes revenue loss an important variable to consider and the economic impacts of COVID-19 certainly raise the profile of fiscal concerns in most any discussion today. However, even in the face of economic constraints, it is important to consider multiple values and potential issues. What are the ramifications if revenue becomes the key factor in determining which cultural heritage is addressed in future planning? All of the vulnerable sites on the National Register of Historic Places are post-contact European/Euro-American dominated sites. New Hampshire, like all of New England, epitomizes a place where the arrival of colonists has been constructed as what constitutes "first" and the start of authentic history [83,84]. The region's cultural heritage tourism industry reflects this fact; what tourists seek starts with the settler colonialists of the 17th century, not the indigenous peoples who greeted the sun each morning and engaged in their reciprocal seasonal movements across this region for millennia prior to the arrival of Europeans.

As people across coastal New Hampshire grapple with the threat sea level rise poses to cultural heritage, challenges will arise around what heritage gets priority in risk management and mitigation plans. Can we avoid conflating the value of cultural heritage with economic value, and if so, how? The loss of precontact indigenous sites will go much less noticed by the broader public than the loss of a historic period house that is today the site of tourism. If programs and policies around sea level rise are developed that focus on stopping or mitigating the transformation of heritage sites with the most economic significance, the result will be that only post-contact European/Euro-American-dominated cultural heritage will be preserved.

With this, the false creation of authentic history starting with Europeans will be replicated into the future. In a recent interview, Denise Pouliot, Sag8moskwa, lead female speaker of the Cowasuck Band of the Pennacook Abenaki People, eloquently described the dangers of this kind of history, explaining that to have a shared future we have to have a shared past and that means telling the whole story [85]. While there are no easy solutions to this issue, a critical step is to include indigenous stakeholders in sea level rise planning processes. Indeed, across the state of New Hampshire, as elsewhere today, mutual collaborations with indigenous peoples to advance knowledge and enact socioeconomic changes are emerging [86,87]. Engaging and expanding collaborative efforts will be critical if cultural heritage vulnerability is to be addressed comprehensively.

5. Conclusions

Human pressure on global systems is accelerating and coastal cultural heritage is vulnerable to these pressures. Sea level rise poses a particularly looming threat to tangible coastal cultural heritage sites. Being able to systematically assess which sites are at risk of damage or destruction from sea level rise and how is an urgent need. While archaeologists increasingly recognize this need, the reality of archaeological research funding poses constraints in terms of resources for large-scale cultural heritage risk assessments. However, there are productive and creative ways to work around such limitations. Because sea level rise is impacting so many ecological and cultural services, numerous entities are actively developing accurate predictive models of sea level rise for various (non-archaeological) management purposes (ecology, hydrology, real estate, economics, etc.). Archaeologists, while not the intended audience, can work with these models to achieve archaeological ends. Indeed, the geospatial revolution in archaeology, from its start, creatively repurposed remote sensing data and technology designed for other purposes [88].

Here, LIDAR-derived sea level rise models created for local, regional, and national government mitigation and adaptation planning were harnessed productively to assess the vulnerability of coastal New Hampshire's cultural heritage resources. This analysis showed there is no sea level rise scenario in which known historic and precontact stie are not damaged and/or completely destroyed. The analysis also showed clearly impending risk to economically significant tourist sites in the region. That said, it is also important to keep in mind that economic value in future cultural heritage preservation and mitigation plans is not the only value to consider; if it becomes so, Euro-American cultural heritage sites will be overrepresented in the future (and consequently, indigenous heritages further marginalized). In addition to known sites, unknown sites and cemeteries are also at risk, but without more systematic documentation of these sites, that risk cannot be assessed. Therefore, while the analysis presented here is one step in the process, the full extent of cultural heritage vulnerability in coastal New Hampshire remains unknown. Advancing forward, this kind of regional-scale modeling should be connected with local risk monitoring and planning efforts to advance actual on-the-ground preservation and mitigation. Strawbery Banke, an important coastal New Hampshire maritime heritage tourist destination on the National Register of Historic Places found in this analysis to be at risk from sea level rise, has already begun, and so serves as a prime model for local, detailed site-based monitoring and planning [73]. More site-based work, increased documentation of unknown archaeological and historic sites in the region, community outreach around valued local heritage sites, and collaborating with indigenous groups around ancestral cultural heritage knowledge and places are all necessary for a comprehensive approach to this looming issue.

A closing point important to note here is that while many entities are developing sea level rise models that archaeologists can use for the kind of analysis presented here, coverage and data availability is uneven. Regionally specific detailed sea level rise models, as well as the kind of archaeological and historic site database available for this analysis, are more commonly found in the Global North. Indeed, one can find remote sensing-derived sea level rise models for the entire United States through NOAA [89]. Recognizing and respecting the challenges of this unevenness when calling for a research approach is important. While detailed sea level rise models and site files may not be readily available everywhere, sea level rise is such a pressing global issue that there are ever-growing global resources about its impacts. An archaeologist working somewhere with no available regional specific sea level rise models or robust site databases can still access open-source sea level rise models from places like Climate Central [90]. Working with these open-source visualization tools obviously cannot allow for specific quantifications of site vulnerability, but it can provide a qualitative means of assessing site risk. Moreover, archaeologists could work with such tools to identify areas most at risk so any available fieldwork time and resources could be targeted to these places. This would allow researchers to focus efforts on places most likely to become inundated, helping document and learn at least something from cultural heritage sites before they are irreversibly damaged or destroyed by sea level rise.

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