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Research Paper

Optimizing preservation for multiple types of historic structures under climate change

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HIGHLIGHTS

- The Optimal Preservation (OptiPres) Model informs adaptation planning in NPS units.
- The OptiPres Model prioritizes preservation planning among multi-types of structures.
- Incremental funding is a feasible strategy to maintain cost-incentive structures.
- Adaptative use strategy improves the resource value of historical buildings.

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ABSTRACT

Cultural resources in coastal parks and recreation areas are vulnerable to climate change. The US National Park Service (NPS) is facing the challenge of insufficient budget allocations for both maintenance and climate adaptation of historic structures. Research on adaptation planning for cultural resources has predominately focused on vulnerability assessments of heritage sites; however, few studies integrate multiple factors (e.g., vulnerability, cultural significance, use potential, and costs) that managers should consider when making tradeoff decisions about which cultural resources to prioritize for adaptation. Moreover, heritage sites typically include multiple types of cultural resources, and researchers have yet to examine such complex tradeoffs. This study applies the Optimal Preservation (OptiPres) Model as a decision support framework to evaluate the tradeoffs of adaptation actions among multiple types of historic structures—wooden buildings, masonry and concrete buildings, forts, and batteries—under varying budget scenarios. Results suggest that the resource values of different types of historic structures vary greatly under a range of budget scenarios, and tradeoffs have to be made among different types of historical structures to achieve optimal planning objectives. Moreover, periodic, incremental funding and partial maintenance are identified as optimal funding strategies for preservation needs of cost-intensive historic structures. Also, adaptative use of historical buildings (e.g., building occupancy) can improve the resource values when budgets are constrained. The OptiPres Model provides managers with a unique framework to inform adaptation planning efforts for a broad range of historic structures, which is transferable across coastal parks to enhance historic preservation planning under climate change.

1. Introduction

Tangible cultural resources are the physical remains of human activities, and the cultural values embedded within them represent what is deemed significant to society (Vecco, 2010). In the US, the National Park Service (NPS) is responsible for the stewardship of cultural resources located within more than 85 million acres of land managed by NPS. Typical tangible cultural resources under the management of NPS include archeological sites, historic structures, cultural landscapes, and museum objects (NPS, 2014). Stewardship of cultural resources in NPS

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units often involves preservation of multiple types of cultural resources (NPS, 2014; Rockman, Morgan, Ziaja, Hambrecht, & Meadow, 2016).

In the Southeast US alone, more than 13,000 historic and archaeological sites have been estimated to be at risk of loss due to climate change and sea-level rise (Anderson et al., 2017). Cultural resource preservation and management are inherently challenged by the fact that these resources are often unique, non-renewable, and fragile (Laurenzi, Peeples, & Doelle, 2013). Limited fiscal resources, diverse and sometimes competing cultural and ecological values, increasing vulnerabilities to climate extremes (e.g., storm-related flooding and erosion, sea-level rise), and uncertainty of the timing and intensity of climate change impacts further challenge the preservation of cultural resources (Fatorić & Seekamp, 2017c; O'Brien, O'Keefe, Jayawickrama, & Jigyasu, 2015; Rockman et al., 2016). Moreover, cultural resources that have declined or degraded due to deferred maintenance, or those that contain sensitive materials, compound concerns presented by exposure to climatic and natural hazard impacts, thereby increasing the vulnerability of the resources' integrity and cultural significance (Daly, 2014; Fatorić & Seekamp, 2017b; Johnson & Germano, 2020; Xiao et al., 2019). The ability to adaptively reuse a historic structure (e.g., park offices, concessionaire space, or interpreted and open to visitors) may enhance preservation goals by elevating management attention when funding is scarce—particularly when adaptation is costly—but could also be detrimental to those same goals if other non-occupied structures that hold more historical significance or have increased vulnerability are ignored (Casey & Becker, 2019).

These challenges highlight the need to develop decision support tools that facilitate the preservation of historic resource values across a landscape. Such tools need to be dynamic and account for the influences of adaptation on historic resource values and climate change vulnerabilities, the timing of those actions, and the tradeoffs among resources and fiscal decisions under mid-range (e.g., 30-year) planning periods (Neil Adger, Arnell, & Tompkins, 2005; Caffery, Beavers, & Hoffman, 2018; Xiao et al., 2019). However, very few studies have integrated historical site significance, use potential, climate vulnerability, and adaptation costs in the adaptation decision frameworks. In this paper, we advance the Optimal Preservation (OptiPres) Model (Xiao et al., 2019), a pilot decision support tool that optimizes climate adaptation planning by evaluating portfolio tradeoffs among the above factors, to test its transferability to a different coastal setting and expand the consideration of diverse types of historic structures. Specifically, we examine model adjustments to four research objectives: 1) directly compare the transferability of the OptiPres Model to a second coastal national park; 2) modify the OptiPres Model to include diverse historic structures with differing decay and sensitivity dynamics (i.e. wooden buildings, concrete buildings, masonry buildings, concrete batteries, masonry fortifications, and a lookout tower) and evaluate the tradeoffs of adaptation actions and the timing of those actions; 3) identify alternative adaptation approaches for cost-intensive cultural resources; and, 4) assess the impacts of adaptative reuse (i.e., building occupancy) on the optimization of adaptation planning actions.

1.1. Climate change impacts on cultural resources

Extensive research has documented the impacts of climate change and climate extremes on natural resources (Bonan, 2008; Butchart et al., 2010; Vörösmarty, Green, Salisbury, & Lammers, 2000); however, research on climate impacts to cultural resources is notably nascent (Fatorić & Seekamp, 2017a). Climate change is threatening the short-term and long-term sustainability of cultural resources. The primary consequences of climate changes that act on cultural resources include sea-level rise, flooding, erosion, and storm events (St. Amand, Sandweiss, & Kelley, 2020; Westley, 2019), which often cause irreversible damages to cultural resources and cultural heritage (Davis, 2018). The uncertainty of climate change has direct impacts on risks and decision-making for the cultural heritage in parks and protected areas and has raised concerns for cultural resource preservation from a global perspective. For example, the United Nations Educational, Scientific and Cultural Organization (UNESCO) designated heritage sites are highly threatened by sea-level rise, and nearly 20% of the UNESCO heritage sites (136 sites) are predicted to be inundated under the global warming scenario with an increase of 3 °C in temperature for the next 2,000 years (Marzeion & Levermann, 2014). These climate-driven impacts on cultural resources are also manifested in the vulnerability assessments in parks and heritage sites from regional and park-specific scales (Peek, Tormey, Thompson, Young, Norton, McNamee, & Scavo, 2017; Reeder-Myers & McCoy, 2019; Reeder-Myers, 2015). For instance, a 5-meter sea-level rise will result in the loss of 32,000 archeological sites in the Southeastern US (Anderson et al., 2017), which highlights the need to conduct park-specific vulnerability assessment of cultural resources in coastal parks (Borrelli & Beavers, 2008).

Besides the primary drivers of climate change impacts on cultural resources (e.g., storm events, floods, sea-level rise, etc.), secondary impacts of climate change on cultural resources have started to be documented in the literature. These secondary impacts include climate-driven resettlement of communities surrounding archeological sites, changes in recreational needs at culture-oriented parks, and uncertainties in access and use of cultural resources. Weather-related hazards have led to more than 230 million people being displaced globally from 2008 to 2018; changes to infrastructure and socio-economic factors associated with such climate-driven migration has been documented as a threat to archeological sites (St. Amand et al., 2020). Moreover, changing climate conditions (e.g., hurricanes and warming temperature) are expected to result in declines in recreation demands for coastal parks which contain cultural resources that are damaged or inaccessible due to restoration (Woosnam & Kim, 2014). Climate-driven deterioration of and damages to cultural resources also raise concerns about the use potential of and safe access to cultural resources in coastal parks, which highlights the need to incorporate assessments of primary and secondary impacts of climate change in adaptation planning for cultural resources (Fatorić & Seekamp, 2017b).

1.2. Cultural resource adaptation planning and optimization modeling

Managers have recognized the importance of adaptation planning for cultural resources, and researchers are beginning to document and evaluate a variety of methods and approaches (Carmichael, 2016; Daly, 2014; Fatorić and Seekamp, 2017b, 2018; Huijbregts, Kramer, Martens, van Schijndel, & Schellen, 2012; Leissner et al., 2015; Nocca, 2017; Xiao et al., 2019). The majority of research on adaptation planning for cultural resources focuses on assessing the vulnerability under the risks of climate change. Vulnerability assessment of cultural resources uses GIS-based analytics and site monitoring surveys to quantify the vulnerability of historical sites, which can generate the maps of historical sites with different levels of climate risk to inform adaptation planning (Peek et al., 2017; St. Amand et al., 2020; Westley, 2019). Combining high-resolution satellite images with geospatial models of vulnerability, Reeder-Myers and McCoy (2019) predict the impacts of short-term climate catastrophes on archeological sites in Houston, Texas.

Besides quantitative assessments of cultural resource vulnerability, qualitative methodologies have been applied to climate adaptation planning in the international context. For instance, a bottom-up (i.e., stakeholder-driven) approach has been applied to climate adaptation planning of indigenous heritage sites in Australia (Carmichael, 2016). The bottom-up approach enhances the capacity of local community groups to cope with climate-driven stresses and incorporate applied indigenous knowledge in the adaptation planning process. Guided by the four-pillar approach of climate adaptation planning (science, mitigation, adaptation, and communication) outlined by US NPS, Hambrecht and Rockman (2017) identify climate adaptation planning strategies and practices for international historical heritage sites and highlight research needs for developing a climate adaptation approach that can be transferrable to cultural heritage sites globally. Following this research effort, Rockman and Hritz (2020) assess the socio-environment of adaptation planning for archeology under climate change and suggest that a value-based approach involving site significance and funding allocation are critical factors in archeological climate adaptation planning.

Adaptation planning and decision making often involve complicated tradeoff evaluations, recognizing that adapting some resources may compromise the ability to adequately steward other resources (Fatorić & Seekamp, 2018). Relatedly, cultural resource adaptation planning is highly conditional on the costs of climate adaptation actions; therefore, integrating the costs of adaptation into the planning framework is essential to determine the feasibility of adaptation plans (Fatorić & Seekamp, 2017b; Seekamp, Post van der Burg, Fatorić, Eaton, Xiao, & McCreary, 2019). Unfortunately, limited guidance exists on approaches to integrate costs into climate adaptation planning frameworks for cultural resources (Seekamp et al., 2019; Xiao et al., 2019).

One effective framework to evaluate the tradeoffs of decisions is the portfolio approach; that is, to assess the expected management benefits of decisions as a collection of resources or investments rather than evaluating the priority of resources one by one (Klein et al., 2007). The portfolio approach applies statistical analysis or numerical optimization to find that combination of actions and resources ('assets') to include to best meet objectives (Keeney, 1982). To date, the portfolio approach has been predominately used to support climate risk assessments and climate adaptation planning in the context of ecological and natural resource conservation (Aplet & Mckinley, 2017; Eaton et al., 2019; Klein et al., 2007; Laurikka & Springer, 2003; Sandsmark & Vennemo, 2007).

In the context of cultural resources, Xiao et al. (2019) developed the OptiPres Model as a decision support framework to identify climate adaptation actions for historic buildings across a 30-year planning horizon, which was pilot tested at Cape Lookout National Seashore (CALO), North Carolina, USA. The objective function of the OptiPres Model is specified to achieve the maximum, cumulative resource value of historic structures over a planning horizon. Specifically, the OptiPres Model applies a portfolio approach for integrating the cost of adaptation actions with optimization dynamics related to how actions are predicted to affect the resource value (i.e., significance and use potential) and vulnerability (i.e., exposure and sensitivity) of historic buildings (Xiao et al., 2019). The CALO pilot study, which was limited to adaptation planning of historic buildings (Seekamp et al., 2019; Xiao et al., 2019), identified funding allocation thresholds for stewardship of these resources under climate change. In this study, we have expanded the OptiPres Model to examine adaptation strategies and tradeoffs among a broader variety of historic structures (i.e., wooden buildings, masonry buildings, concrete buildings, a masonry fort, concrete batteries, and a metal tower). In doing so, we recognize that diverse types of historic structures have different historical values, conditions, and vulnerabilities, and acknowledge the need to accommodate strategic funding of high-cost structures and better understand the influence of adaptative use on the resource value of historical structures.

2. Methods

In this study, we included the 28 historical structures at Gulf Islands National Seashore (GUIS) located on Santa Rosa Island, most of which fall within the Pensacola Harbor Defense Project District (listed in the National Register of Historic Places in 2017). We updated the OptiPres Model dynamics, parameters and optimization algorithm to address the inclusion of six different types of historic structures and to test both alternative funding strategies for high cost structures and the effect of adaptative use (i.e., occupational status of structure) on optimal solutions. In the following subsections, we describe the study area, the processes to develop and advance the OptiPres Model, the optimization algorithm, the adaptation actions included, and the budget scenarios we tested.

2.1. Study area

GUIS was designated in 1971 and includes 2 administrative units across 139,175 acres on the mainland and coastal barrier islands of Florida and Mississippi. The cultural resources in GUIS include historic buildings, batteries, and coastal fortifications, with coastal fortifications considered as one of the fundamental resources for GUIS. The increasing intensity and frequencies of climate extremes (e.g., storms, flooding, hurricane, etc.) have accelerated the rate of decay of cultural resources in GUIS; the needs to preserve and restore cultural resources and infrastructure are highlighted in the General Management Plan of GUIS (NPS, 2014). Under the guidance of GUIS managers, we included 28 historic structures (11 wooden structures, 3 masonry buildings, 3 concrete buildings, 9 concrete batteries, 1 metal tower, and 1 masonry fort) located on Santa Rosa Island (Supplement, Table 1).

Although Santa Rosa Island is low-lying, the structures vary in vulnerability due to their construction materials and base elevations, the location of an existing seawall (though some of it is compromised) that protects the structures located within it, and varying extents of sand accretion or depletion related to the sediment dynamics on the island. We used an existing data set of vulnerability metrics developed to assess assets located in 40 coastal NPS units (Peek et al., 2017). That assessment projects sea-level rise under a high (RCP 8.5) emission scenario, and quantifies multiple coastal hazards and climate change impacts (e.g., erosion, storms, sea-level rise, etc.) on historical resources and other park infrastructure. The vulnerability of historic structures was measured by exposure (including: flooding exposure based on FEMA flood maps; storm surge estimates of mean high tide during category 3 hurricanes; sea level rise projections for 2050 under a high [RCP 8.5] emission scenario; erosion and coastal proximity; and evidence of historical flooding) and sensitivity (including: flood damage potential; storm resistance; historical damage; and the presence of protective engineering) to climate change (Supplement, Table 1). Researchers at the Center for Coastal Dynamics at Western Carolina University, who developed and published the NPS vulnerability assessment, provided us with an additional vulnerability assessment to match our study's 30-year planning horizon.

2.2. The optimal preservation Model (OptiPres Model): A decision support framework

Details of OptiPres Model development for the CALO pilot test can be found in Xiao et al. (2019) and Seekamp et al. (2019). We modified the OptiPres Model for this study based on the following steps:

a) We conducted a two-day workshop with GUIS staff to explain the model's purpose and the dynamics of resource values by applying different adaptation actions (June 25–26, 2018),
b) We administered an online survey of current and retired GUIS staff after the workshop to collect information about the relative importance (weights) of the selected historic structures based on attributes of historical significance and use potential developed by Fatorić and Seekamp (2018) (Supplement, Table 1);
c) We conducted virtual meetings with GUIS staff to determine the annual decay rates on different types of historic structures and the dynamics associated with the application of each action considered on the different types of historic structures.

The total resource value of 28 structures at GUIS over a 30-year planning horizon is calculated and optimized by an objective function that integrates the components of historical significance, use potential, and vulnerability for the 28 structures:

$$maxRV = \sum_{j=1}^{n} \sum_{i=1}^{m} \left(\frac{(\sum_{k}^{o} H_{ijk} {}^{*} w_k)^{*} w_h + (\sum_{l}^{p} U_{ijl} {}^{*} w_l)^{*} w_u}{V_{ij}}\right) | b_j \leq B \quad (1)$$

where RV is the total resource value of all i structures over all j time steps; H represents the performance of each of the k historical significance attributes; w_k represents the weight of the significance sub-attributes; U represents each of the l attributes for use potential; w_l represents the weight of the use potential sub-attributes; w_h and w_u represent the weights given to the total values of H and U, respectively; V_{ij} represents the vulnerability of building i in the year j, b represents budget expenditure over year j, and B represents the annual budget constraint.

The climate adaptation actions considered in the OptiPres Model for GUIS were adopted from those identified during the CALO case study (Seekamp et al, 2019; Xiao et al., 2019), with consideration of the appropriateness of adaptation actions for the setting and structure type, as well as the feasibility of cost estimation for adaptation actions determined by GUIS staff (Supplement, Table 2). The adaptation costs for each building were derived using square footage estimates for primary materials (masonry, concrete, wooden) provided by regional NPS staff. The costs were calculated by extrapolating the estimated costs for comparable actions applied to the structures at CALO, with additional increase adjustments for differences in construction costs between 2016 and 2018 (8%) and for city cost index differences between the two locations (1%). The cost estimates can be understood as an order of magnitude costs variable up to 40%, similar to an NPS class C estimate, which are considered to be comparable estimates sufficient for this study's optimization modeling. Interpretation and documenting estimates were provided by GUIS staff on a per-building basis.

The adaptation actions for GUIS include: 1) core and shell preservation using historic materials; 2) elevate; 3) document and monitor; 4) active removal. The OptiPres Model delineates that adaptation actions can only be applied to a structure one time during the 30-year planning horizon but also includes the ability to apply annual maintenance or to withhold action (e.g., no action) so that funding (e.g., annual maintenance costs) can be diverted to other structures for adaptation or high-cost maintenance. Annual maintenance and no action can be applied to a structure multiple times during the planning horizon.

The model dynamics described by Xiao et al. (2019) and Seekamp et al. (2019) detail how the application of each action influences the condition attribute, the remaining significance attributes[1], the use potential attributes, and the vulnerability attributes (exposure and sensitivity) of each structure. We updated the model parameters by structure type for the current study through consultation with GUIS staff who held structure-specific knowledge related to past storms and site-specific exposure as well as annual condition decay rates when no action or annual maintenance are applied (Supplement, Table 3).

Additional model modifications include: 1) introducing a more realistic annual maintenance action for large structures with high cost of annual maintenance (i.e., by applying annual maintenance to only a proportion of a structure); and, 2) integrating updated decision parameters for use potential for wooden and masonry structures, if occupied. In creating a proportional maintenance funding scheme, our intention is to determine if reducing the cost of annual maintenance to Fort Pickens, assuming 1/10th of the structure could receive maintenance annually (cost and capacity constraints), would increase the likelihood that this structure would be identified by the model for receiving this action. Our rationale for trying to force its selection is related to its prominence within the landscape and that its presence led to the construction of the other structures in the historic district. Our intention for updating the use potential dynamics was two-fold: increase the realistic management situation in which buildings in poor condition would be a threat to human health and safety (i.e., not usable) and explore if adaptative use (i.e., occupation of structures) enhances the preservation objective.

The OptiPres Model uses a stochastic search algorithm (simulated annealing) to calculate the maximum value of the objective function given an annual budget constraint (Possingham, Ball, & Andelman, 2000; Westphal, Field, & Possingham, 2007). Simulated annealing has been used in other applied ecological conservation (Arsenault, Poulin, Côté, & Brissette, 2014; Borges, Eid, & Bergseng, 2014; Vieira & Cunha, 2017) and historic preservation contexts (Xiao et al., 2019). The algorithm randomly proposes adaptation actions to structures as solutions and retains only the solutions that lead to an improvement of total resource value (for specific details, see Xiao et al., 2019; Seekamp et al., 2019).

2.3. *Historic preservation budget scenarios*

The budget scenarios are selected with assistance from GUIS staff. Specifically, a "typical" budget scenario is proposed based on the estimation of funding for historic preservation that GUIS is likely to utilize from fee collections. This estimate is provided by GUIS and regional NPS staff and reflects planned projects (2018–2022) under the Park's comprehensive fee plan, which is funded from visitor fees collected under the Federal Recreation Enhancement Act. The "low" budget scenario is ~ 80% lower than the typical budget scenario and was set to match the low budget scenario for the pilot test at CALO. The "high" budget scenario is ~ 50% higher than the typical budget scenario. An even higher budget scenario is developed, which is set to be the total cost for annual maintenance of all 28 structures, to explore how more costly adaptation actions are likely to perform.

To test the GUIS OptiPres Model for historic preservation and provide alternative planning solutions under different budget allocations, our study examines the following four objectives and corresponding budget scenarios:

1) Test the transferability of the OptiPres Model by comparing the adaptation actions for wooden structures under similar budgets at GUIS and CALO (scenario a: $758,330 annual allocation to wooden structures at GUIS; and scenario b: $222,000 annual allocation to wooden structures at CALO) to test the transferability of OptiPres Model (objective 1). In both scenarios, the budget allocations were 3.5 times of the total cost of annual maintenance for all wooden structures.
2) Identify the total resource values under varying budget allocations for multiple types of historic structures by conducting multiple model runs for GUIS with annual allocation of funding ranging from $0 to $1,000,000 with a $50,000 interval, followed by three specific budget scenarios with detailed adaptation actions across 30-year planning horizon, including: $50,000 annual allocation (scenario c: low budget scenario for GUIS), $400,000 annual allocation (scenario d: typical budget scenario for GUIS), and $750,000 (scenario e: high budget scenario for GUIS) annual budget allocations (objective 2).
3) Identify adaptation strategies for cost-intensive structures by multiple model runs for GUIS: $57,232,370 annual budget allocations (scenario f: total cost of annual maintenance for 28 historic structures); $32,747,905 annual budget allocations (scenario g: total cost of annual maintenance for 28 historic structures when 1/10 of Fort Pickens is maintained); annual allocation of $400,000 with additional $57,232,370 allocation every five years (scenario h: typical budget scenario with cyclic pulses for full annual maintenance) (objective 3).
4) Test the impacts of occupational use on historic preservation by conducting model runs for GUIS to compare the adaptation actions for wooden and masonry buildings at GUIS when all buildings are occupied (scenario i: $50,000 annual allocation) relative to when all

[1] We consider the historical significance attributes, not including the condition attribute, to be affected by actions (or inaction) in a way that compromises or enhances a structure's "integrity." In historic preservation, the idea of historic integrity indicates that managers should retain aspects of a structure's materials, design, feeling, location, association, workmanship, and setting (Savage & Pope, 1998).

buildings are empty (scenario j: $50,000 annual allocation) to test the impacts of occupational use on historic preservation (objective 4).

3. Results

We tested the OptiPres Model by the four objectives under varying budget scenarios. In the following subsections, we describe the outputs of the OptiPres Model and the tradeoffs among adaptation actions among the four objectives and corresponding budget scenarios. As some of the results are very detail-oriented, we provide an overview of the objectives, budget scenarios, and key findings in Fig. 1.

3.1. Examining the transferability of the OptiPres Model across coastal park units (Objective 1)

Under budget *scenario a* ($758,330 annual allocation to GUIS wooden structures), all wooden buildings received preservation actions for most years as well as one-time core and shell preservation at different time periods across the planning horizon (Fig. 2). Core and shell preservation actions were generally applied to the buildings in the middle of the planning horizon. The yearly resource values of GUIS increased slightly at the middle of the planning horizon and reached the highest at year-12 (99% of its original resource value) when core and shell preservation actions were applied, but decreased continuously after year-17 when only annual maintenance was applied. The resource value of the wooden buildings in GUIS decreased to 82% of its original resource value at the end of the planning horizon.

Comparing to GUIS, the portfolio of historic preservation at CALO under *scenario b* (222,000 annual allocation to CALO wooden buildings) was similar in a few ways. Annual maintenance was applied to all wooden buildings at CALO for most of the time across the planning horizon. In addition, neither document and monitor nor active removal was applied to the buildings, regardless of site location (i.e., GUIS vs. CALO). Core and shell preservation actions were applied to 63% of wooden buildings at CALO between year-6 to year-13, and the yearly resource value decreased continuously after year-13. Rather than applying core and shell preservation actions to all wooden buildings, the OptiPres Model applied relocation and elevation or relocation as adaptation actions to 30% of the buildings at CALO. The wooden buildings at GUIS were not able to be relocated due to the fact that no appropriate relocation zone was identified by GUIS staff; elevation was not selected at GUIS[2]. The resource value of the wooden buildings in CALO increased to 120% of its original resource value at year-5 because relocating the wooden structures would substantially reduce the vulnerability of wooden structures. The resource value decreased continuously after year-13 when only annual maintenance was applied. The resource value of wooden buildings at CALO in year-30 was 0.3% slightly higher than its original resource value.

3.2. Resource values of and optimized adaptation actions among different types of historic structures under varying annual allocation budget scenarios (Objective 2)

We ran the OptiPres Model for an uncertain budget ranging from $0 to $1,000,000 annual allocation with a $50,000 interval under a 30-year planning horizon (Fig. 3). The original resource value of historic structures is displayed by the red dashed line in Fig. 3 (assuming the resource value does not change across the planning horizon). In the $0 allocation scenario (i.e., no action scenario), the total resource value decreased by 45%. The resource value of wooden buildings improved substantially under the scenarios of $50,000 to $300,000, with only marginal increases under the budget scenarios with annual allocations greater than $300,000. The resource value of masonry and concrete buildings, however, only improved substantially from $0 to $50,000 allocation, followed by a relatively constant increasing rate under the scenarios of $50,000 to $750,000 annual allocation. The resource value of the tower increased most substantially under the budget scenarios of $150,000 to $200,000 annual allocations, then remained consistent after the threshold of $250,000 annual allocation. Fort Pickens and the batteries, however, have consistent resource values across the planning horizon, because the costs of annual maintenance for Fort Pickens and all batteries are much higher than the annual allocation budget scenarios. Therefore, it is not surprising that the total accumulated resource value was lower than the original resource value under the budget scenarios of $0 to $1,000,000 annual allocations.

To assess the possible adaptation actions and evaluate tradeoffs among multiple types of historic structures, we compared actions and yearly resource values of different types of historic structures under the three specific budget scenarios (Fig. 4). Under the low budget scenario (*scenario c*: $50,000 annual allocation), only preservation actions (e.g., annual maintenance; core and shell preservation) were selected. Specifically, annual maintenance was applied to three wooden buildings, one concrete building, and one masonry building for the majority of time across the planning horizon, while core and shell preservation was applied to six wooden buildings and two concrete buildings. Since concrete structures received the highest level of annual maintenance across the planning horizon, the yearly resource value of concrete structures had the lowest decay rate among six types of structures, but still lost 45% of its yearly original resource value at year-30. Although a few wooden buildings received these preservation actions, the yearly resource value decayed to 40% of its original resource value at the end of the planning horizon due to the rapidly declining conditions. Fort Pickens and batteries received no action across the planning horizon. The resource values of the batteries and Fort Pickens decreased to 45% and 40%, respectively, at the end of the planning horizon. It is also important to note that the resource value of the tower had the highest decay rate among all types of historic structures, resulting in a nearly 80% loss of its original resource value by year-30.

Since the budget of the *scenario c* is very limited, the wooden, concrete, and masonry structures selected for preservation actions were determined by the cost. When the core and shell preservation action was applied, the model had to make other structures "unmanaged" (i.e., no action) to allocate additional funds to the target structure receiving core and shell preservation. The tradeoffs of core and shell presentation and no action can also be found in the timing of preservation actions: the structures with higher historical value were selected for core and shell preservation as early as possible, while the ones with lower historical values were upgraded at the end of planning horizon to create the largest boosts to those structures' conditions.

The prevalence of actions and yearly resource values of different types of cultural resources changed greatly under the typical budget scenario (*scenario d*: $400,000 annual allocation) from the low budget scenario (*scenario c*); however, no adaptation actions were selected (only preservation actions). Under this budget scenario, annual maintenance was the dominant action for most wooden buildings, concrete buildings and masonry buildings, and the tower. The batteries and Fort Pickens were still not eligible to receive any type of action due to budget insufficiencies. The tower received core and shell preservation at the beginning of the planning period and annual maintenance across the rest years of the planning horizon, resulting in a high level of improvement of resource value when comparing to *scenario c*.

Under *scenario d*, the application of preservation actions to the tower resulted in a higher accumulated resource value (103% of its original

[2] We suspect that elevation was not selected because the wooden buildings are already elevated above the base flood elevation threshold used in the vulnerability assessment; therefore, elevating the buildings further would not alter the vulnerability score as currently calculated. However, it is important to note that the buildings have been previously flooded during storm events and that further elevation may indeed be an option for climate adaptation at GUIS.

Objective 1: Testing the transferability of the OptiPres Model

Scenario a: $758,330 annual allocation to wooden structures at GUIS	**Scenario b:** $222,000 annual allocation to wooden structures at CALO

Key Findings

- Annual maintenance is applied for all wooden structures at GUIS and CALO for most of the time across the planning horizon.
- Core and shell preservation is applied once to all structures at GUIS and 63% of structures at CALO in the middle of the planning horizon.
- 30% of wooden structures at CALO receive adaptation actions to reduce vulnerability.

Objective 2: Identify the total resource values under varying budget allocations for multiple types of historic structures at GUIS

Accumulated resource value of historical structures under **$0-$1 million budget allocation scenarios**	**Scenario c:** $50,000 annual allocation for GUIS (low budget scenario)	**Scenario d:** $400,000 annual allocation for GUIS (typical budget scenario)	**Scenario e:** $750,000 annual allocation for GUIS (high budget scenario)

Key Findings

- Resource value thresholds of multiple types of structures are different under $0-$1 million budget allocation scenarios.
- Fort Pickens and all batteries receive no action under $0-$1 million budget allocation scenarios.
- The low, typical, and high budget scenarios involve decision tradeoffs among different types of structures.
- Document and active removal are not selected as optimal adaptation actions to maintain the resource values under all tested scenarios.

Objective 3: Identify adaptation strategies for cost-intensive structures for GUIS

Scenario f: $57,232,370 annual budget allocations (total cost of annual maintenance for 28 historic structures)	**Scenario g:** $32,747,905 annual budget allocations (total cost of annual maintenance for 28 historic structures at GUIS when 1/10 of Fort Pickens is maintained)	**Scenario h:** annual allocation of $400,000 with additional $57,232,370 allocation every five years (typical budget scenario with cyclic pulses for full annual maintenance)

Key Findings

- Scenario g yields a 1.3% decline of resource value while a 43% decrease in allocated budget comparing to scenario f.
- Scenario h yields a 14% decline of resource value while an 80% decrease in allocated budget comparing to scenario f.

Objective 4: Testing the impacts of occupational use on historical preservation on GUIS

Scenario i: $50,000 annual allocation when all buildings are occupied	**Scenario j**: $50,000 annual allocation when all buildings are empty

Key Findings

- The total resource value of scenario i is 8% higher than scenario j.
- Core and shell preservation actions were applied earlier to structures under scenario i than scenario j.

Fig. 1. Objectives (blue), budget scenarios (yellow), and key findings (grey) for optimizing preservation and adaptation of historic structures. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

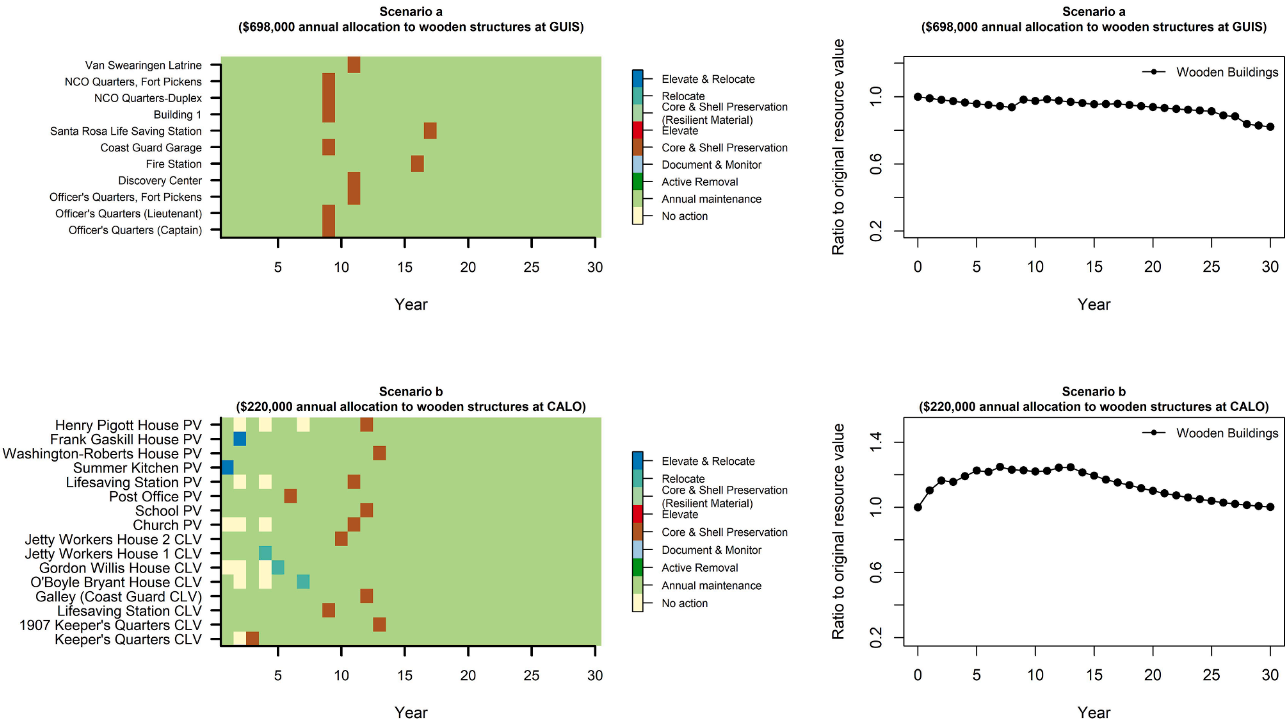

Fig. 2. Adaptation actions and the ratio of yearly resource values to original resource values for wooden buildings at GUIS (*scenario a*) and CALO (*scenario b*).

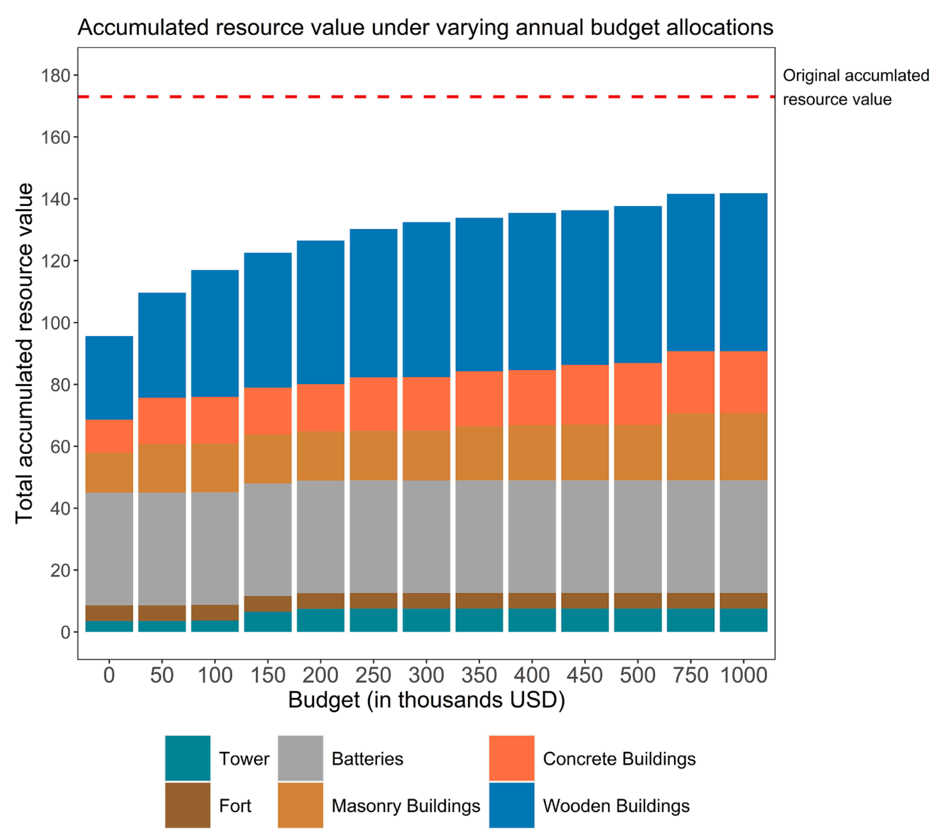

Fig. 3. Accumulated resource values at the end of the 30-year planning period of multiple types of historic structures under \$0-\$1,000,000 annual allocation budget scenarios.

resource value). The wooden buildings also received more consistent preservation, as core and shell preservation actions were applied for every structure and no action was only applied six times across the planning horizon. As a result, the resource value of wooden buildings had a lower decay rate than other types of historic structures (with the exception of the tower). One concrete building and one masonry

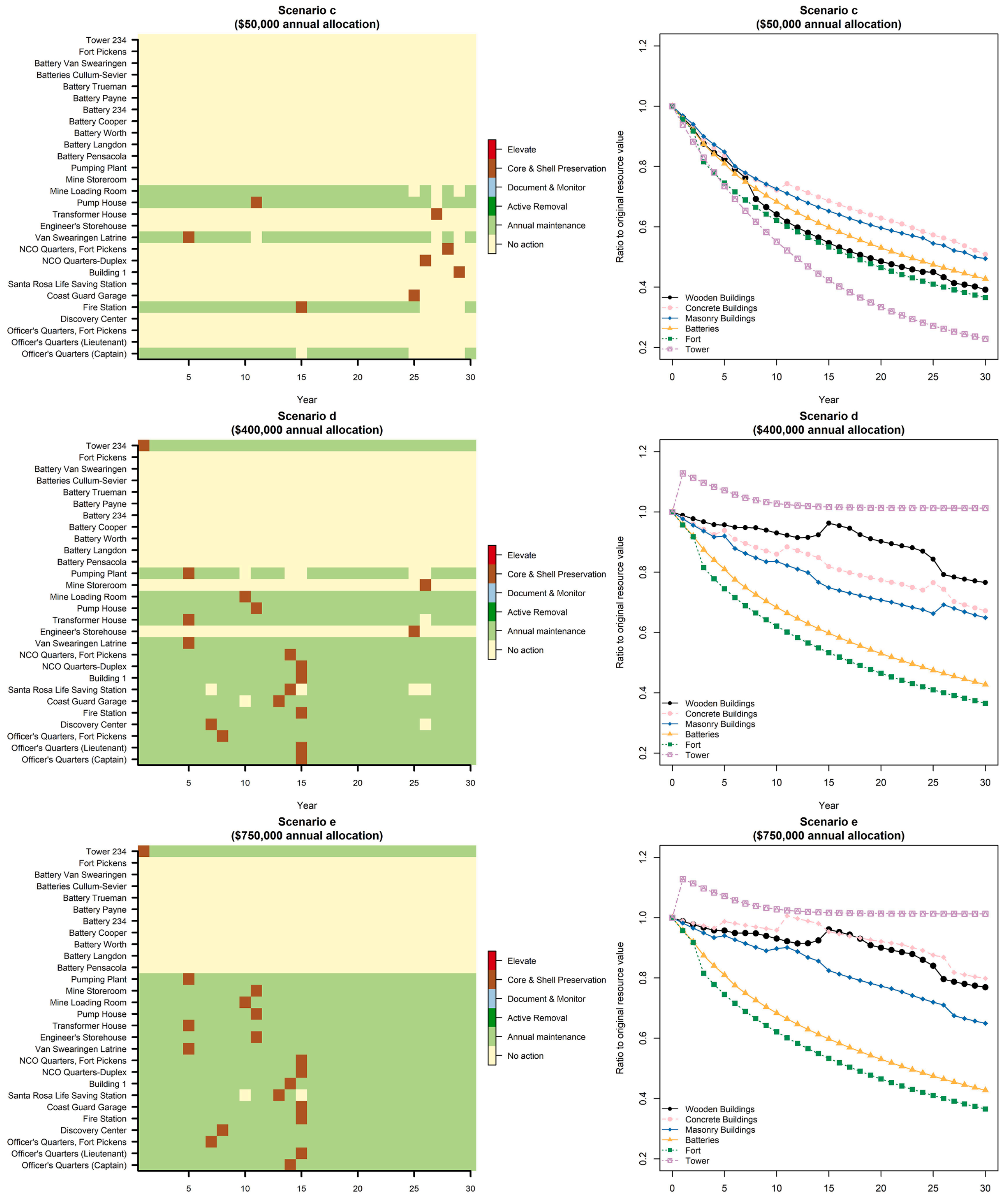

Fig. 4. Adaptation actions and the ratio of yearly resource values to original resource values by different types of historic structures at GUIS under scenarios c, d, and e.

building received no actions in most years across the planning horizon, except when each received core and shell preservation. To achieve the maximum total resource value, the model applied core and shell preservation actions earlier for masonry buildings and concrete buildings and later for wooden structures because concrete and masonry structures were generally in poorer conditions than wooden structures, and applying core and shell preservation later for wooden structures could achieve higher one-time improvement of conditions. At the end of the planning horizon, yearly resource values for wooden buildings, concrete buildings, masonry buildings, batteries, and Fort Pickens decayed to 76%, 67%, 65%, 43%, and 37% of their original resource values, respectively. The yearly resource values for wooden structures, masonry structures increased most substantially at year-4 and year-15 because core and shell preservation was applied to multiple structures in those years.

In the high budget scenario (*scenario e*: $750,000 annual allocation), all of the concrete buildings, masonry buildings and wooden buildings received consistent preservation for most of the years and the one-time core and shell preservation action. The increased funding reduced the times of no action to a large extent. The batteries and Fort Pickens were not eligible for any adaptation action. The model applied the core and shell preservation actions to all masonry and wooden structures and

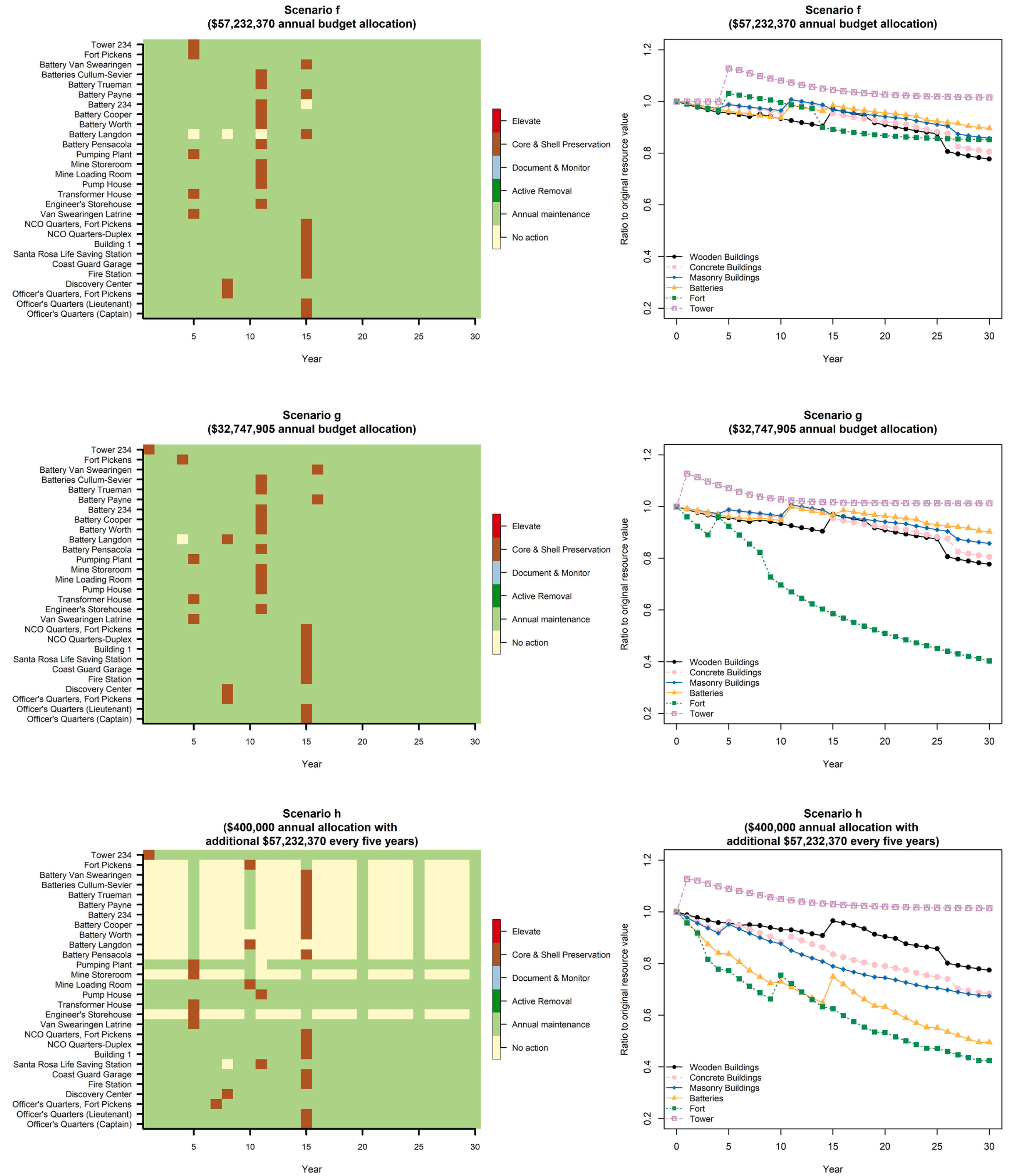

Fig. 5. Adaptation actions and ratio of yearly resource values to original resource values by different types of historic structures at GUIS under scenarios f, g, and h.

Tower 234 before the middle of the planning horizon to delay the timeline of structures decaying to poor conditions, which had a much higher decay rate than fair or good conditions (Supplement, Table 3). Although the allocated budget was nearly 2 times the typical budget scenario (*scenario c*) for this park, the tradeoffs still had to be made between applying core and shell preservation to a masonry building and making another wooden structure unable to be managed at two times during the planning horizon.

Since adaptation actions and core and shell preservation actions can only be applied once to each structure, and no action was only applied twice across the planning horizon in *scenario d*, increasing funding allocation might only have a marginal effect to improve resource value. Therefore, this budget scenario was identified as the threshold of total resource values for the budget scenarios of $0 to $1,000,000 annual allocation, as the annual budget allocations were insufficient for annual maintenance of Fort Pickens and batteries. At the end of the planning horizon, the yearly resource value of Tower 234 was 101% of its original resource value. The yearly resource values for wooden buildings, concrete buildings, masonry buildings, batteries, and Fort Pickens decayed to 77%, 80%, 65%, 43%, and 37% of their original resource values, respectively.

3.3. Alternative adaptation approaches for cost-intensive structures (Objective 3)

Fort Pickens serves as the landmark of the historic district but it was not eligible for any preservation actions under the budget scenarios of $0 to $1,000,000 annual allocation due to the extremely high costs estimated for preservation actions; therefore, there is the potential that the continual decay of Fort Pickens would result in an “undesirable” management situation. To identify alternative preservation pathways for Fort Pickens, we developed an incremental funding approach for Fort Pickens (1/10th of the cost) that may be more realistic, particularly when considering the human resource capacity of park maintenance. To test this incremental funding approach, we also needed to rectify the issue that the surrounding batteries also didn’t receive any preservation actions under *scenarios c, d, and e*. Therefore, we created three additional hypothesized budget scenarios: $57,232,370 annual budget allocations (*scenario f*: total cost of annual maintenance for 28 historic structures); $32,747,905 annual budget allocations (*scenario g*: total cost of annual maintenance for 28 historic structures when 1/10 of Fort Pickens is maintained annually); and $400,000 annual allocations with additional $57,232,370 allocation every five years (*scenario h*: typical budget scenario with periodic funding pulses sufficient for preserving all structures) (Fig. 5).

Under *scenario f*, the total resource value of all historic structures was 163 at the end of the planning horizon (Supplement, Table 4). Fort Pickens received core and shell preservation in year-5, and annual maintenance in all other years. The yearly resource value of Fort Pickens peaked when core and shell preservation was applied, but decayed after year-5 to 85% by the end of the planning horizon. The total resource value of Fort Pickens was 92% of its original total resource value across the planning horizon. Most of the batteries received annual maintenance for all years, as well as one-time core and shell preservation, with the exceptions of Battery Langdon and Battery 234, which received no action for four times to allocate those funds to other structures for core and shell preservation actions. The accumulated resource value of the batteries was approximately 95% of their original accumulated resource value at the end of the planning horizon.

Under *scenario g*, the total resource value of all historic structures was 161 at the end of the planning horizon (Supplement, Table 4). Fort Pickens received core and shell preservation at year-5 and annual maintenance for all other planning years. The ending accumulated resource value of Fort Pickens was about 60% of its original accumulated resource value. All batteries received relatively consistent preservation actions, including core and shell preservation, across the planning horizon, resulting in only a 4% loss of their original accumulated resource values across the planning horizon. Notably, the allocated budget of scenario g was 43% lower than scenario f, but the ending total accumulated resource value of scenario g was only 1.3% lower than scenario f.

Under *scenario h*, the surge of funds enabled Fort Pickens and most batteries to receive some type of preservation action at each of the 5-year intervals. The additional funding pulses greatly improved the resource values of Fort Pickens and the batteries compared to *scenario d* ($400,000 annual allocation). The accumulated resource values of Fort Pickens and batteries were 63% and 69%, respectively. Notably, the accumulated resource value of *scenario h* was 14% and 12% lower than *scenario f* and *scenario g*, respectively for Fort Pickens and the batteries, while the total cost of this scenario was 80% and 67% lower than the cost of *scenario f* and the cost of *scenario g*, respectively.

3.4. The impact of occupational use on adaptation planning (Objective 4)

Our study also tested the impact of occupational use (i.e., park operations, third party use, or visitor use)[3] on the adaptation portfolio of historic structures and resource value. Occupational use assumes that structures are in good condition and regularly maintained to enable continued use. When the budget scenario is very limited (~80% less than the typical budget scenario), using the wooden, concrete, and masonry buildings for some type of occupation use might be a possible way to improve their resource values. The total resource value of *scenario i* ($50,000 annual allocation when the buildings were occupied) was 8% higher than *scenario j* ($50,000 annual allocation when the buildings were not occupied). Moreover, occupying wooden, concrete, and masonry buildings meant core and shell preservation should be applied earlier to a few structures (when compared to *scenario i* that had no change in occupational use; Fig. 6); specifically, the core and shell preservation actions were applied to six wooden buildings and two concrete buildings before year-18. The accumulated resource values of occupied buildings were 69% their original values, which demonstrated an improvement when compared to the buildings not being occupied (64%).

4. Discussion

This study uses dynamic metrics of resource value and a portfolio management approach to evaluate the tradeoffs of historic preservation and climate adaptation among different types of historic structures at GUIS across a 30-year planning horizon, and considering a range of budget scenarios. This study tests the transferability of the OptiPres Model for climate adaptation planning at different coastal sites and for multiple types of historic structures. By extending the OptiPres Model from the CALO pilot study (Xiao et al., 2019), we demonstrate that the OptiPres Model can be customized to serve as a decision support framework to NPS units in general (objective 1), including NPS units that have multiple types of historic structures (objective 2). Additionally, this study demonstrates that alternative funding approaches may reduce unwanted management situations when faced with budget shortfalls (e.g., for large, costly iconic landmarks within historic districts (objective 3), as well as identifying the historic preservation benefits of adaptative reuse of historic buildings (objective 4).

[3] Occupational use is conceptualized as having the “use potential” scores for park operations (e.g., housing, storage, visitor centers), third party use (e.g., concessionaire or partner organization), and visitor use (i.e., visitors allowed to enter buildings for such reasons as viewing interpretive materials, a visitor center, campground registration, lodging, etc.) upgraded to the highest scores, which corresponds to “currently in use.” Non-occupational use is conceptualized as having those same “use potential” scores degraded to the lowest scores, which corresponds to “not currently in use.”

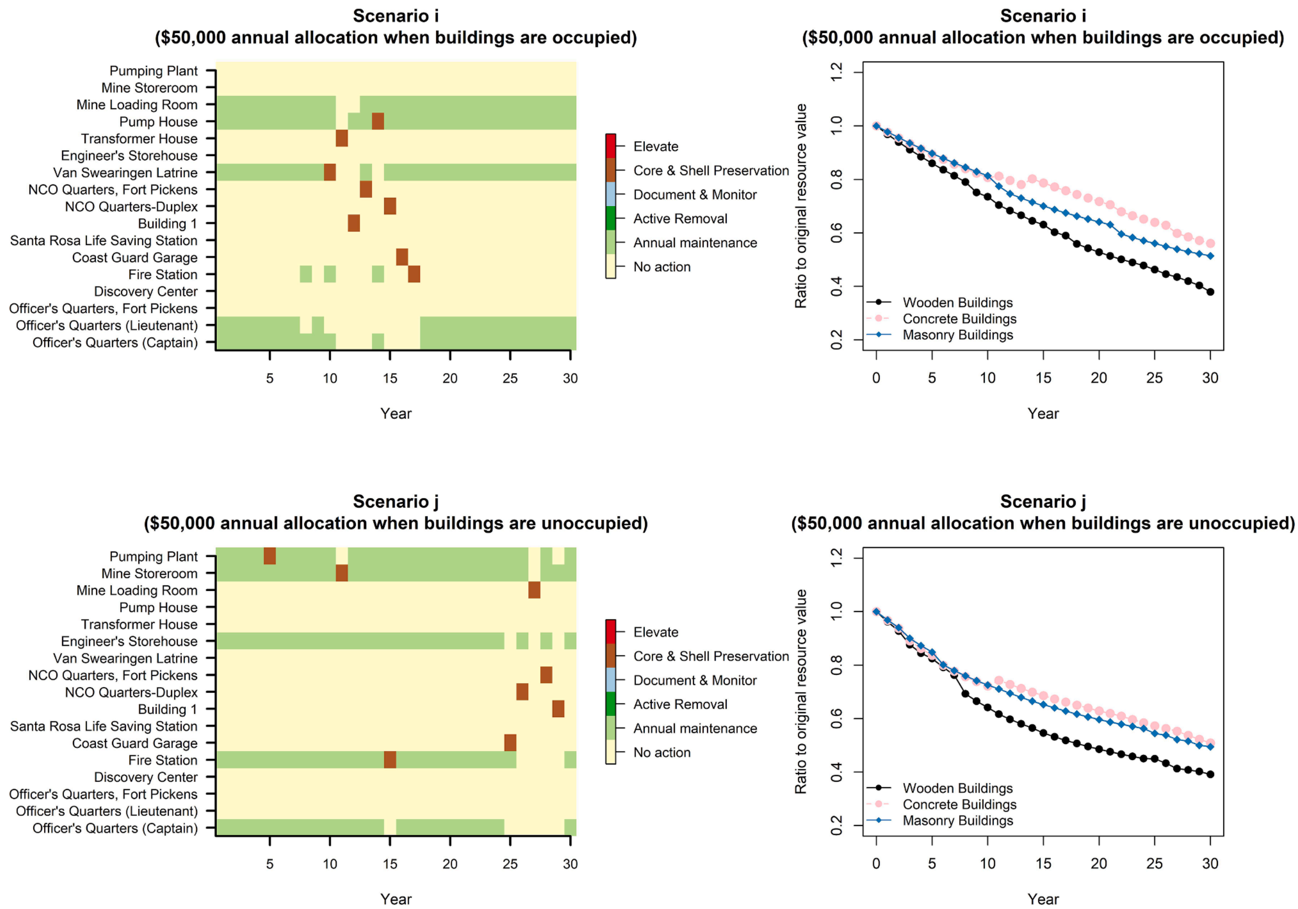

Fig. 6. Adaptation actions and ratio of yearly resource values to original resource values of occupied (scenario i) and unoccupied (scenario j) buildings at GUIS with $50,000 annual budget allocation.

Similar to the CALO pilot test results (Xiao et al., 2019), two actions (document and monitor and active removal) continue to be suboptimal strategies (i.e., not applied to any structures at GUIS within any of the tested budget scenarios) due to the substantial declines in resource values, particularly if a structure is removed from the landscape. When considering the lower costs associated with annual maintenance yet similar resource value decay rates to document and monitor, it is logical that document and monitor is not an optimal action when the goal is to maximize resource values across the historic district (i.e., actions that are the least detrimental to the accumulated resource value). However, under a typical annual budget allocation (*scenario d*), many of the structures would likely decline to unsafe conditions and some form of human health and safety response, such as the addition of fencing to document and monitor, would be needed. Moreover, the decline in a structure's condition over multiple years when no action is applied—akin to deferred maintenance—would likely have conflated impacts on its historic resource value and sensitivity to climate change impacts (Johnson & Germano, 2020) that are currently not represented in the OptiPres Model.

Differing from the CALO pilot study (Xiao et al., 2019), we also found that elevate was not selected as an optimal adaptation strategy at GUIS. Upon consultation with the researchers who conducted the vulnerability assessment, we identified that elevating the historic buildings (not an option for a masonry fort or concrete batteries) would not reduce the vulnerability score as many of the historic buildings are located within the Fort Pickens' sea wall and sited at the highest elevation within the historic district. As such, the cost and reductions in historic value associated with elevating the buildings deterred the model from selecting elevation as part of an optimal solution. Yet, elevation may be a viable adaptation option at other coastal park locations, as evidenced by the CALO results in which relocation and elevation was optimal for several buildings (*scenario a*). Although a relocation zone was not identified at GUIS, relocation or relocation and elevation were viable adaptation actions to maximize resource values when a relocation zone can be defined (*scenario a*). Further examination of the dynamics related to elevation as a possible adaptation action is needed, as it was not selected at either study location. It appears that the integration of more refined vulnerability metrics may enable NPS managers to consider elevation as a feasible adaptation action that aligns with current agency recommendations (Rockman et al., 2016).

Identifying the dynamic changes of resource values of different types of historic structures under varying budget scenarios provide insights for park managers to make wise budget investments and balance the needs of maintenance among types of historic structures for long-term planning. Similar types of transparency within heritage asset accounting has been advocated by Biondi and Lapsley (2014) to advance good public governance. At GUIS, the resource values of wooden buildings were projected to improve with an annual allocation increases up to $300,000, while the thresholds for resource values of masonry buildings, concrete buildings, and the metal tower are identified as $750,000, $500,000, and $250,000 annual allocation, respectively. The resource values of Fort Pickens and the batteries consistently declined under the annual budget scenario of $0 to $1,000,000 given the inability to manage them. Under a typical budget scenario, the total resource value of historic structures in GUIS was 22.4% lower than the original total resource value, which primarily resulted from the dramatic decay of conditions and loss of integrity at Fort Pickens, the batteries, and other masonry and concrete buildings. This result was also caused by the fact that the total cost of annual maintenance for all structures was much higher than the typical budget scenario.

By testing the OptiPres Model for historic preservation under multiple budget scenarios, managerial transparency—strategy that has been touted in natural resource management for more than a decade (Lockwood, Davidson, Curtis, Stratford, & Griffith, 2010)is enhanced for making the types of tradeoff decisions required in adaptation planning and cultural resource stewardship. Transparent tradeoffs are particularly necessary when allocations are insufficient to perform even routine annual maintenance for all cultural resources under mandated stewardship (Fatorić & Seekamp, 2018). At GUIS, we find that the resource values of different types of historic structures vary greatly. The tradeoffs associated with different types of structures or different timing of actions are found in most scenarios. In particular, our results suggest that applying core and shell preservation often involves the tradeoff of neglecting one or more other structures to allocate funding for this more expensive type of cyclical preservation. Moreover, the timing of core and shell preservation appears to be determined by the interactive effects of historical value, condition, and decay rate of the structure. Our results indicate that the OptiPres Model is likely to recommend core and shell preservation to the structures that have higher historical values earlier in the planning horizon to achieve a higher accumulated resource value. Although the resource value of historic structures is projected to decay under these budget scenarios, the OptiPres Model (a) provides transparent and operational management guidance to maximize resource values under insufficient budget scenarios, and (b) identifies the types of structures that have higher risks of losing resource values, which can serve as a signal to seek additional funds for adaptation (e.g., user charges, partnerships; Roelich, 2015).

Additionally, we have tested the OptiPres Model by developing more realistic budget allocation scenarios for cost-intensive structures: incremental funding and pulses of special projects funding. Incremental funding has been identified as an economic principle in enhancing disaster resilience (Godschalk, 2003). In particular, we were interested in assessing if incremental funding for the most expensive—and likely the most iconic—structure in the historic district could potentially alleviate an unwanted management situation in which substantial deterioration would occur in the absence of unrealistic annual funding allocations (i.e., the cost of annual maintenance of Fort Pickens is more than 50 times that of the typical annual allocation scenario). We found that by applying a proportional approach of the annual maintenance task of Fort Pickens (1/10th annual maintenance cost) to the typical annual budget with five-year pulses of sufficient annual maintenance funds for all structures increased the feasibility of maintaining this iconic structure as well as its associated batteries. Such a partial maintenance approach, supplemented by substantial periodic funding, demonstrates the need for more realistic modeling specification to accommodate realistic management strategies to enhance cultural resource stewardship.

Our study also evaluated the impacts of adaptative reuse (i.e., occupational use) on historic buildings on meeting preservation goals. Occupying historic buildings can not only improve the resource values, but the results from the OptiPres Model also demonstrate that the timing of core and shell preservation for occupied buildings has implications on accumulated resource values. Specifically, occupation of historic buildings results in the application of core and shell preservation earlier in the planning horizon to minimize incremental degradation and ensure the longevity of occupation. These results support the adaptative reuse philosophy within historic preservation as a way to mitigate the negative climate impacts of new construction (for a recent review, see: Sesana, Bertolin, Gagnon, & Hughes, 2019). Additionally, third party occupation of buildings (e.g., partner organizations, concessionaires) may also lend to reduced annual funding allocation needs, provided that contractual agreements stipulate annual maintenance be provided by the third party or are associated with adequate fees to cover (or at a minimum share) those costs. As such, third party use may be a promising alternative approach for the NPS to meet historic preservation goals under limited budget scenarios.

Finally, our study results document the process, data needs, and research efforts to extensively apply the OptiPres Model to general climate adaptation planning of historical resources in coastal parks (Appendix A). The current fragmented approach to historic preservation and climate adaptation in the NPS (Rockman & Hritz, 2020), as well as the limited capacity to integrate the financial costs to climate adaptation planning frameworks (Xiao et al., 2019), highlight the need to advance the generalizability of the OptiPres Model. The four objectives analyzed in this study demonstrate how the OptiPres Model can be adopted, revised, and advanced to evaluate tradeoffs of historic preservation and climate adaptation. The protocol developed in this study (Appendix A) informs NPS managers of the knowledge, scientific data, analytical methods, and outcomes of the OptiPres model, which is aligned with the principles of the four-pillar approach of climate adaptation planning (science, mitigation, adaptation, and communication) outlined by the NPS (Hambrecht & Rockman, 2017) and can assist resource stewards in systematically addressing the challenges of cultural resource preservation in a changing climate.

4.1. Limitations

Although our study develops the OptiPres Model and evaluates the tradeoffs of adaptation actions among different types of historic structures, our study has several limitations. First, the OptiPres Model has not integrated the impacts of stochastic storm events, which likely increases risks to structures that receive preservation or adaptation actions later in the planning horizon. Therefore, it would be prudent to design future modeling efforts that use more localized vulnerability data, incorporate the probabilities of stochastic events, and also evaluate risks associated with delayed management response, adaptation, or both (Sofaer et al., 2017). Including storm events into future models could also enable examination of how post-storm recovery funding is allocated among resources, the types of optimal actions that may be taken to avoid loss, and the changes in accumulated resource values when losses occur. Relatedly, the vulnerability assessment of historical structures in this study relied on a high emission scenario (RCP 8.5), which underrepresents the broad spectrum of projections in future climate change. Integrating additional emission scenarios into the OptiPres Model could more robustly quantify climate change uncertainty (Peterson, Cumming, & Carpenter, 2003; Rowland, Cross, & Hartmann, 2016; Runyon, Carlson, Gross, Lawrence, & Schuurman, 2020; Star et al., 2016) as well as addressing risks associated with specifying portfolio adaptation strategies under climate uncertainty (Eaton et al., 2019).

Finally, the OptiPres Model does not include local stakeholders' preferences for historical significance and use potential attributes. The weights associated with these attributes were assessed by current and former GUIS staff. Future studies should integrate external stakeholders' values and preferences—such as, local community members, citizens and staff from associated Tribal Nations, the visiting public, the general public, State Historic Preservation Office staff—in modeling efforts to perform a sensitivity analysis of the OptiPres Model among stakeholder groups. Such efforts would also enhance the integration of additional "good public governance" principles identified by Biondi and Lapsley (2014) in the OptiPres Model and provide additional considerations for decision making.

5. Conclusion

Our study extends the prior OptiPres Model to optimize preservation for multiple types of historic structures by testing 30-year adaptation plans for 28 historic structures under 8 different budget scenarios at GUIS, and demonstrates the transferability of OptiPres Model to different parks and protected areas. Study results identify that partial funding strategies accompanied by periodic increases in annual budget allocations enhance the stewardship of cost-intensive structures. Additionally, our findings suggest that adaptative reuse of historic buildings can be an alternative strategy to enhance stewardship when budgets are constrained. However, additional research is needed to examine the influence of more localized vulnerability data, the risks of storm events on the selection of adaptation measures, and the preferences and priorities of diverse stakeholders. Such studies can enhance the robustness of modeling efforts and better guide climate adaptation planning of cultural resources. As managers continue to face difficult tradeoffs to achieve stewardship goals of diverse and vulnerable cultural resources, the systemic process employed by the OptiPres Model enhances decision making transparency.

Disclaimer

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2021.104165.

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