A Framework for Assessing the Vulnerability of Archaeological Sites to Climate Change: Theory, Development, and Application

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The predicted impacts of climate change on cultural heritage are likely to be dynamic and complex. Understanding the potential risks at site level is vital to ensure that appropriate adaptation and mitigation measures are put in place. There is, however, a dearth of tools and methodologies suitable for use by heritage managers. In this paper the potential of vulnerability analysis for site-based assessment is explored. A six-step vulnerability framework, adapted for cultural heritage, is illustrated utilizing material from two case-study sites (Brú na Bóinne and Skellig Michael). The implementation of each step in the proposed framework is demonstrated to aid those wishing to apply the method in practice. The ‘values based’ approach taken is suitable for a wide range of cultural heritage including landscapes, monuments, and buried archaeology. The six-step framework and the utilization of indicators provide a method that allows comparison between sites and yet is sufficiently flexible to account for localized concerns. The framework will aid decision makers with planning and prioritization.

KEYWORDS climate change, vulnerability assessment, cultural value, heritage management, World Heritage

Introduction

Although it is conceptually quite simple to envisage the impact of climate change on individual processes, the difficulty comes in trying to weigh up the importance of different impacts. (Viles, 2002: 410)

The impacts of climate change on heritage values are likely to be dynamic and complex (Figure 1). Thus any assessment of climate change risk at site level will require a multi-faceted approach capable of addressing the many variables and uncertainties
involved. It will be argued in this paper that ‘vulnerability analysis’ answers these requirements. An exploration of the theoretical development of vulnerability analysis and of the methods documented in the literature will be carried out. The methodology chosen and its adaptation for use at heritage sites will be detailed and demonstrated utilizing material from two case-study World Heritage sites in Ireland (Brú na Bóinne and Skellig Michael). The material presented here is part of the author’s doctoral thesis for the Dublin Institute of Technology funded by ABBEST (Daly, 2014).

**Vulnerability and climate change**

Assessing vulnerabilities to climate change, as opposed to carrying out risk analysis, has become a common approach in many sectors since the IPCC issued its Third Assessment Report (TAR) (Hinkel, 2011; Adger, 2006; The Allen Consulting Group, 2005). That report recommended vulnerability assessment as a precursor to developing adaptation responses to climate change impacts (Figure 1). The advantage of the vulnerability approach over traditional risk analysis is that it does not rely solely on an evaluation of exposure and sensitivity to hazards, but also on the internal ability of a system to adapt and recover (Turner, et al., 2003a; Luers, et al., 2003). Vulnerability analysis entails a holistic approach, it recognizes that humans and the environment are inextricably linked, and analysts therefore assess what is termed the ‘coupled human-environment system’.

The TAR definition of vulnerability is widely referred to in the literature (Adger, et al., 2004; The Allen Consulting Group, 2005; Hinkel & Klein, 2006; Ford & Smit, 2004). It defines vulnerability as:
The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. (McCarthy, et al., 2001: Annex B)

While this definition states that vulnerability is a function of exposure, sensitivity, and adaptive capacity, it has been criticized for failing to explain this relationship or to give direction to those seeking to apply the theory into practice (Adger, et al., 2004; Hinkel & Klein, 2006). The result of this lack of clarity is that, while the terminology may be common across studies, methods of analysis can vary quite substantially.

Vulnerability analysis in practice

As a growing field with multi-disciplinary origins, it is not surprising that there are a variety of approaches described as vulnerability assessment. Currently, formulations stem from the needs of each individual case and there is no single recognized way of analysing cause and effect within systems (Adger, 2006). The multiple concepts and applications published in the literature can therefore be confusing for an individual attempting to conduct an assessment. For example, the US National Park Service’s vulnerability assessment of coastal heritage resources takes a ‘biophysical’ approach using a combination of desk top mapping and site visits to produce the assessment (Toscano, 2004). Although there is a strong place-based element in this assessment, the final result takes very little account of socio-economic factors involved, and is not very different to risk analysis. In another example, the Great Barrier Reef (GBR) Marine Park World Heritage site in Australia produced a vulnerability analysis of the site to climate change impacts (Marshall & Johnson, 2007). The analysis is qualitative, based on past vulnerabilities and expert judgement, and adaptive capacity is considered in relation to indigenous culture and coastal industries. In the Summary of Impacts, however, each impact is assessed according to vulnerability, certainty, and timeframe, more akin to the probability and magnitude rankings of risk analysis than vulnerability theory, despite the terminology.

Ford and Smit concluded from their literature survey that there were two basic approaches to vulnerability: biophysical and social (Ford & Smit, 2004). In the ‘biophysical’ approach, vulnerability is conceptualized as a pre-existing condition determined by exposure and sensitivity to hazard, it is similar to risk but differs in the absence of probability as a function (Adger, et al., 2004). In the ‘social’ approach, vulnerability is dependent on the social, political, and economic determinants that control resistance and recovery, i.e. adaptive capacity. A growing number of researchers are now combining these two approaches (Turner, et al., 2003b).

Terminology: the three elements of vulnerability

Existing terms and definitions for the three elements of vulnerability (sensitivity, exposure, and adaptive capacity) require adaptation for application to heritage systems.

Exposure

The IPCC definition of exposure speaks only of climatic variations and not other changes in the environmental system brought about by climate effects, stating
exposure is the **nature and degree to which a system is exposed to significant climatic variations** (McCarthy et al., 2001: Annex B). This can be adapted for cultural heritage by including ‘related impacts’ and specifying a values-based approach. The suggested definition is:

Exposure is the degree to which an identified heritage value is exposed to climatic variations and their related impacts. It is determined by environmental conditions (physical and atmospheric).

**Sensitivity**

Sensitivity of tangible heritage is likely to be dependent on material properties and physical condition or integrity, while at system level environmental or organizational fragility would also be relevant. Using the IPCC TAR wording (McCarthy, et al., 2001: Annex B) as a starting point, the proposed definition for sensitivity of cultural heritage refers to ‘value’ and also specifies scale:

Sensitivity is the degree to which an identified heritage value is affected, either adversely or beneficially, by [climate-related] stimuli. The effect may occur at artefact, assemblage or system level.

**Adaptive capacity**

Unlike exposure and sensitivity, this is not an inherent quality of the system and deliberate efforts to increase the capacity to cope with (or avoid) the impacts of climate change are possible (The Allen Consulting Group, 2005). The IPCC defines adaptive capacity as:

The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. (McCarthy, et al., 2001: Annex B)

This applies for any system and does not need to be reworded for application to cultural heritage.

**Vulnerability**

Based on the IPCC wording (McCarthy, et al., 2001: Annex B) the following definition for the vulnerability of cultural heritage to climate change is proposed:

Vulnerability is the degree to which an identified cultural heritage value is susceptible to, or will be adversely affected by, effects of climate change, including climate variability and extremes. Vulnerability \( V \) is a function of exposure \( E \), sensitivity \( S \), and adaptive capacity \( AC \) as represented by the equation \( V = (E + S) - AC \).

**Designing a vulnerability assessment framework**

There is a desperate need for tools that can assess risks to archaeological sites from environmental threats. (Holden, et al., 2006: 80)

An eight-step method to guide vulnerability assessments published in 2005 (Schröter, et al., 2005) was recommended by the UNESCO report on strategies for managing...
climate change (Colette, 2007). Unlike some vulnerability techniques, this is a ‘place-based’ approach, designed for specific stakeholders, allowing public and collaborative professional involvement (Turner, et al., 2003a). In a Master’s thesis for University College London, Woodside applied the Schröter methodology to an assessment of the Tower of London World Heritage site (Woodside, 2006). Following on from the work of Schröter and Woodside a six-stage framework (Table 1) for assessing the vulnerability of cultural heritage to climate change was developed and implemented by the author at two case-study sites in Ireland, Brú na Bóinne and Skellig Michael.

### Implementing the six-step framework

#### Step 1: Define the heritage values to be assessed

This first step requires knowledge of the nature and extent of all heritage values considered important for the site. For example, are views important or specific elements of the landscape? In some cases these will be defined in existing conservation plans or designation documents. Spatial boundaries should also be determined at this point, if not already established. The case-study sites were World Heritage (WH) properties and already have clearly defined boundaries and described values. The vulnerability of the sites was analysed at different levels, accounting for both national and WH values (Table 2).
Step 2: Understand exposure, sensitivity, and adaptive capacity of these values over time

Vulnerability is a function of three elements (exposure, sensitivity, and adaptive capacity) and the widest possible range of primary and secondary sources should be used to gain an understanding of these factors (Turner, et al., 2003b). At the case-study sites this included both published and unpublished documentation, repeated site visits and interviews with stakeholders. Site visits develop a first-hand understanding of the relationship between the heritage values and the surrounding environment, such as topography, aspect, patterns of wear, and land use. Ideally, the site should be visited in different seasons to ascertain any areas prone to seasonal effects such as flooding or frost. Stakeholders may include heritage professionals, researchers, site staff, local residents, or visitors. They should represent a wide breadth and depth of knowledge. During the case-study assessments structured interviews were undertaken with stakeholders around how climate has, and may in the future, impact on heritage values. The interviewees were shown an impacts matrix (Table 3) to help them identify issues of concern under future climate change.

Future climate conditions can be ascertained from a suitable Regional Climate Model (RCM). Downscaled RCM projections with a resolution of 10 km$^2$ were utilized for the case studies. The data was provided by the Max Plank Institute under the auspices of Climate for Culture (CfC) from the REMO 2009 regional climate model (Jacob, et al., 2012). In addition to the standard parameters of temperature, precipitation, and radiation, the CfC data included specific concerns for heritage such as RH, surface temperature, and wind direction. Managers should be cognisant that different emissions storylines underlie climate projections and that they may not indicate the ‘worst case scenario’. For example, the CfC model uses a medium–low emissions storyline and actually represents a fairly positive view of the future. For the purposes of assessing the case studies, the control period (1960–91) was compared with the far future period (2070–2101) (e.g. Table 4).

Exposure

By combining future projections with evidence gathered from stakeholders and secondary research, it becomes possible to describe the exposure of heritage values to the main climatic parameters (wind, rainfall, and temperature) and their associated impacts (e.g. Table 5).
### TABLE 3
**IMPACTS MATRIX**

<table>
<thead>
<tr>
<th>No. of days/quarter with rainfall &gt;5 mm/hr</th>
<th>Jan–Mar</th>
<th>Apr–Jun</th>
<th>Jul–Sep</th>
<th>Oct–Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960–91</td>
<td>12</td>
<td>16</td>
<td>33</td>
<td>23</td>
</tr>
<tr>
<td>2070–2101</td>
<td>10</td>
<td>27</td>
<td>72</td>
<td>50</td>
</tr>
<tr>
<td>Projected change</td>
<td>↑ 17%</td>
<td>↑ 69%</td>
<td>↑ 118%</td>
<td>↑ 117%</td>
</tr>
</tbody>
</table>

### TABLE 4
**INTENSITY OF PRECIPITATION PROJECTIONS FOR BRÚ NA BÓINNE (REMO MODEL/IPCC AR4 A1B SCENARIO)**

<table>
<thead>
<tr>
<th>Climatic parameter and impact</th>
<th>Degree of exposure</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall - impact on flooding, landscape use, wetting and drying patterns, salt, and microbiological activity. Summer drought leading to vegetation die back, soil erosion, subsidence, and deterioration of water quality. The REMO model shows drier summers and wetter winters. The greatest change in precipitation is in increased intensity.</td>
<td>There is a 90% rise in the number of days where rainfall is projected to exceed 5 mm/hour. July–September will see the greatest escalation in heavy rain, followed by October–December. The decrease in summer volume (July) at 7% is significant when combined with 2–3° C. Rise in ground temperatures.</td>
<td>Concrete canopies at Knowth and Newgrange partially shelter the kerbstones from horizontal rain. Although volume remains constant, the shift towards short periods of intense rainfall will alter wetting and drying cycles considerably. Concerns expressed for K1, the exposed entrance stone at Newgrange.</td>
</tr>
</tbody>
</table>

### TABLE 5
**POTENTIAL IMPACTS AND DEGREE OF EXPOSURE TO PREDICTED CHANGES IN RAINFALL (BRÚ NA BÓINNE)**

<table>
<thead>
<tr>
<th>Climatic parameter and impact</th>
<th>Degree of exposure</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall - impact on flooding, landscape use, wetting and drying patterns, salt, and microbiological activity. Summer drought leading to vegetation die back, soil erosion, subsidence, and deterioration of water quality. The REMO model shows drier summers and wetter winters. The greatest change in precipitation is in increased intensity.</td>
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<td>Concrete canopies at Knowth and Newgrange partially shelter the kerbstones from horizontal rain. Although volume remains constant, the shift towards short periods of intense rainfall will alter wetting and drying cycles considerably. Concerns expressed for K1, the exposed entrance stone at Newgrange.</td>
</tr>
</tbody>
</table>

**Sensitivity**

Following consultation with stakeholders, impacts were numerically ranked according to the number of respondents concerned with each one. Based on these results, and other primary and secondary research, a number of issues in respect to the sensitivity of heritage values were noted. These ‘key sensitivities’ were then described and illustrated as a precursor to evaluating vulnerability. When describing the sensitivity of a site there may be a degree of overlap, e.g. between assemblages and systems. In the detailed evaluation, general sensitivities described under cultural landscape criteria can be refined in relation to specific elements, i.e. structures and buried deposits (Table 6).
Adaptive capacity
The United Nations Development Programme names four strategic areas (see below) where adaptive capacity should be analysed (GEF Global Support Programme, 2005). For the case studies these were subdivided further to characterize potential resilience.

1. Policies and Programmes (e.g. management structures, visitor management, legislative protections)
2. Information and Knowledge (e.g. climate change, human resources, population)
3. Implementation (e.g. conservation and maintenance)
4. Monitoring/Feedback

It is also important to consider capacity at the different scales at which it can be affected, e.g. local and individual as well as national and institutional. For example, when the Office of Public Works (OPW) are on Skellig Michael carrying out conservation works and managing visitors, adaptive capacity is high. During the winter the site is unmanned, however, and access can be very difficult, thus management capacity during this period is very low.

Step 3: Identify likely hazards for each value under future climate using the matrix of impacts
The production of a vulnerability hypothesis (who is vulnerable to what?) must be based on knowledge of the heritage values and of the likely impacts of climate change. The potential hazards for each heritage value under the projected future climate are initially identified while assessing sensitivity and exposure. In this step...
all the available evidence is combined in order to ‘imagine’ possible future impacts under projected conditions. Although the impacts matrix provides a useful reference for developing the vulnerability hypothesis, it should not be viewed as a definitive list of all potential impacts e.g. indirect impacts are not included (Daly, 2011a). In addition, individualized parameters such as topography, aspect, and material properties should be accounted for separately by the user. The uncertainty of the climate change model projections means that any hypothesis formulated on the basis of these future scenarios will need to be kept under constant review. Finally, the assessor has also to bear in mind that the stakeholders may be considering the issue of climate change impacts for the first time. Interpretation of stakeholder responses is the responsibility of the expert assessor and original contributions should be combined with collected data in a measured way.

**Step 4: Develop indicators for the elements of vulnerability**
The selection and application of indicators is a complex topic (Daly, 2014; 2011b). In general, indicators should be place based and relate to (at least) one of the key elements of vulnerability of heritage values to climate change impacts, i.e. exposure, sensitivity, or adaptive capacity. Quantifiable indicators for measuring vulnerability to climate change have been outlined in other disciplines and it may be possible to adapt some of these ideas to cultural heritage (Moss, et al., 2001; Sweeney, et al., 2002; Forbes & Liverman, 1996). Assessors should attempt to find the most useful indicators for the impacts with which they are concerned, and this can be challenging. Some examples of indicators proposed for ongoing evaluation at Skellig Michael are outlined in Table 7 by way of example.

**Step 5: Assess vulnerability by entering values for exposure, sensitivity, and adaptive capacity into the Causal Model**
A Causal Model developed by the author on the cause to consequence orientation (Table 8) is proposed for this step (Daly, 2008). In the model, sensitivity (S) and exposure (E) to hazard are positive values and adaptive capacity (AC) is negative. The ‘measure of vulnerability’ (MV) is then calculated; a positive value indicating vulnerability and a negative one resilience. The scale is a basic 1–3 range, where 1 is low.

In order to run the model, values for sensitivity, exposure, and adaptive capacity must be ascertained by interrogating the primary and secondary data. For example, gaps in the data for the case studies, due to a lack of site-based monitoring, were addressed by utilizing stakeholder information. The model therefore relies on the person entering the data having a high level of knowledge, gathered in steps 1–4, in order to produce a credible set of values (Table 9). The application of indicators provides a quantifiable evidence base for the future review of this qualitative assessment.

**Step 6: Use stakeholder review to refine and communicate results**
Given the difficulties in obtaining quantifiable data appropriate to cultural heritage it was decided that ‘Stakeholder Review’ of the results would be used to provide validation. Appropriate feedback mechanisms need to be developed to suit the requirements of each group of stakeholders. At the case-study sites the stakeholders were sent hard copies of the final results and asked to complete a feedback form. Dialogue with
TABLE 7
EXAMPLE OF PROPOSED INDICATORS OF VULNERABILITY FOR SKELLIG MICHAEL TO POTENTIAL CLIMATE CHANGE IMPACTS

<table>
<thead>
<tr>
<th>Impact</th>
<th>Indicator</th>
<th>Proxy for</th>
<th>Functional relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion of soil</td>
<td>% vegetation cover</td>
<td>Exposure to soil erosion</td>
<td>↑ % cover = ↓ exposure</td>
</tr>
<tr>
<td>Wave damage - salt dosing and mechanical action</td>
<td>% vegetation die back on south east slope</td>
<td>Exposure landscape to increased frequency and severity of storms/waves</td>
<td>↓ % cover = ↑ exposure</td>
</tr>
<tr>
<td>Change in biodiversity</td>
<td>Species survey (birds, lichens)</td>
<td>Sensitivity of natural heritage to changing climate</td>
<td>↑ change = ↑ sensitivity</td>
</tr>
<tr>
<td>Changed microbiological growth</td>
<td>Lichen survey</td>
<td>Sensitivity of microbiological organisms to changes in climate</td>
<td>↑ change = ↑ sensitivity</td>
</tr>
<tr>
<td>Structural damage by wind - stone throw</td>
<td>Number of stones dislodged outside of visitor areas/season</td>
<td>Sensitivity of structures to damage by wind</td>
<td>↑ volume = ↑ sensitivity</td>
</tr>
<tr>
<td>Surface weathering by wind and rain</td>
<td>Stone cube indicator tool</td>
<td>Exposure of monuments to surface erosion</td>
<td>↑ measured loss = ↑ exposure</td>
</tr>
<tr>
<td>Disruption of access to island</td>
<td>Number of boat landings</td>
<td>Adaptive capacity re. conservation and maintenance regime</td>
<td>↓ landings = ↓ adaptive capacity</td>
</tr>
<tr>
<td>Increased visitor pressure</td>
<td>Length of season</td>
<td>Exposure to mechanical damage</td>
<td>Longer season = ↑ exposure</td>
</tr>
<tr>
<td>All</td>
<td>Human and civic resources = No change in professional staffing levels</td>
<td>Adaptive capacity (management)</td>
<td>Stagnant recruitment = ↓ adaptive capacity</td>
</tr>
</tbody>
</table>

TABLE 8
CAUSAL MODEL FOR SITE SPECIFIC EVALUATIONS OF VULNERABILITY TO CLIMATE CHANGE IMPACTS

<table>
<thead>
<tr>
<th>Matrix input</th>
<th>Indicators</th>
<th>Exposure (E)</th>
<th>Sensitivity (S)</th>
<th>Adaptive Capacity (AC)</th>
<th>Measure of Vulnerability (MV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of concern</td>
<td>Ind. E.</td>
<td>1 to 3</td>
<td>1 to 3</td>
<td>1 to 3</td>
<td>MV = (E+S) - AC</td>
</tr>
<tr>
<td></td>
<td>Ind. S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ind. A.C.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 9
EXAMPLE OF CALCULATION OF MV — EROSION OF BURIED DEPOSITS, SKELLIG MICHAEL

<table>
<thead>
<tr>
<th>Climatic parameter</th>
<th>Sector or W. H. value</th>
<th>Impact</th>
<th>Indicator</th>
<th>Sensitivity</th>
<th>Exposure</th>
<th>Adaptive Capacity</th>
<th>Measure of Vuln.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>Buried deposits</td>
<td>Erosion &amp; exposure</td>
<td>% vegetation cover</td>
<td>1 - Low (deposits only in monastery)</td>
<td>1 - Low (sheltered position)</td>
<td>2 - Medium (rescue excavation possible)</td>
<td>Low (0)</td>
</tr>
</tbody>
</table>
stakeholders throughout the assessment process is essential to ensure a final product that is both credible and relevant. Communication of the final results should be through presentations, publications, summary reports, and direct feedback to the contributing stakeholders. To establish an easily understandable and comparable ranking of vulnerabilities, a summary table of vulnerabilities (Figure 2) using the ICOMOS standard colour coding for expressing ‘significance of change’ was adopted for the case studies (e.g. Table 10) (ICOMOS, 2010).

**Figure 2** Six-step vulnerability framework for Cultural Heritage.
the vulnerability of archaeological sites to climate change

Value and rankings

The aim of an initial vulnerability assessment is to be as comprehensive as possible so that an understanding of the system-wide ‘structure of vulnerability’ can be gained (Adger, et al., 2004). Subsequent assessments can be designed to focus on specific values or impacts highlighted by the general analysis. The measure of vulnerability (MV) does not include a weighting for the relative value of a heritage asset or the degree to which that value will be diminished by any projected physical losses. Thus the final result requires interpretation before it is used to set priorities for adaptation or monitoring. ICOMOS recommends that the weight given to heritage values should be proportionate to the significance of the place and the impact of the change upon it (ICOMOS, 2010: 2–1–5). Thus in the case of World Heritage properties most weight should be given to impacts on heritage values that contribute to the Outstanding Universal Value (OUV) defined for UNESCO.

Frequency of stakeholder responses was used to rank impacts for the case-study assessments, but this is not an accurate determination of relative significance. Some stakeholders will be more knowledgeable than others about specific topics, while some may be answering outside of their comfort zone. To allow for this, Woodside assigned a weighting to the stakeholders themselves and used that as a multiplier to create a ranking of impacts (2006). The weighting of stakeholder input relies on a judgement on the value of one person’s views over another, however. It is unlikely to be a palatable task for site managers when processing contributions by their colleagues and peers, and therefore it is not suggested as part of the methodology. It is important, nonetheless, to be aware of the issue of competency when drawing conclusions from the views of stakeholders.

### TABLE 10
EXAMPLE OF SUMMARY FOR DECISION MAKERS OF PREDICTED CLIMATE CHANGE VULNERABILITIES — RESULTS OF SKELLLIG MICHAEL ASSESSMENT

<table>
<thead>
<tr>
<th>Buried Deposits</th>
<th>Structures and features</th>
<th>Cultural Landscape</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Impacts for which Vulnerability is High (priority 1)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure collapse</td>
<td>Soil Erosion</td>
<td></td>
</tr>
<tr>
<td>Erosion of foundations</td>
<td>Loss of vegetation</td>
<td></td>
</tr>
<tr>
<td>Structural damage by wind</td>
<td>Change (loss/gain) of species</td>
<td></td>
</tr>
<tr>
<td>Access</td>
<td>Rock fall</td>
<td></td>
</tr>
<tr>
<td><strong>Impacts for which Vulnerability is Medium (priority 2)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsoil instability</td>
<td>Changed microbial growth</td>
<td>Landslip</td>
</tr>
<tr>
<td></td>
<td>Mechanical abrasion</td>
<td>Wave damage</td>
</tr>
<tr>
<td></td>
<td>Infrastructural changes1</td>
<td>Damage by water run-off</td>
</tr>
<tr>
<td></td>
<td>Salt crystallization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thermoclastic weathering2</td>
<td></td>
</tr>
<tr>
<td><strong>Impacts for which Vulnerability is Low</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Added following stakeholder review.
2 Although overall this is low, the west face of the south peak is extremely vulnerable to this form of weathering (Rourke, pers. comm.)
Conclusions

Vulnerability assessment takes a system-wide approach, considering stakeholder input, socio-economic and institutional factors, as well as the physical hazards of climate change. This flexible multi-disciplinary analysis is well suited to cultural heritage management. The emphasis on case-study assessment, the holistic methodology, and the highlighting of capacity for adaptation to change, all contribute to this suitability. By assessing the coupled human-environment vulnerability assessments can accommodate the lack of accuracy inherent in future climate projections better than the statistical approach of risk analysis.

There are a wide variety of applications and methodologies in the literature, some are more akin to risk assessment but utilize the terminology of vulnerability. The conceptual six-step framework and key terms defined here provide a values-based methodology that is specific to cultural heritage. The procedure for applying the method is outlined and illustrated with case-study examples in order to aid those interested in conducting a vulnerability assessment. Assessment will be difficult, given the many uncertainties involved, and the framework provides a roadmap to get the process underway. It can be seen as the first step in a long journey of evidence gathering and review.

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Notes

1 Risk assessments deal with the combination of the probability of a consequence and its magnitude (Willows & Connell, 2003: 43).

Bibliography


Notes on contributor

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