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Caithleen Daly
Technological Univerity Dublin, cathydaly@hotmail.com

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The Potential for Indicators in the Management of Climate Change Impacts on Cultural Heritage

caithleen h. daly

The Potential for Indicators in the management of climate change impacts on cultural heritage

Cathy Daly[1]

Abstract

The global scale and unpredictable nature of climate change impacts on cultural heritage poses a challenge for conservation management. This article explores the potential of indicators as an aid for decision makers in the heritage sector. The author proposes a new indicator tool for addressing long-term stone recession impacts that may be related to climate change. The indicator is being installed at two World Heritage sites in Ireland but no results are available. The prototype was developed during doctoral research at the Dublin Institute of Technology.

Keywords

Indicator, monitoring, cultural heritage, climate change, World Heritage.

1. Introduction

There is a large body of literature dealing with the ways in which climate change may alter rates or patterns of deterioration on monuments (Viles 2002; Cassar, Young et al. 2006; Berghall and Pesu 2008; Australian National University 2009; Bonazza, Messina et al. 2009). In order to distinguish between normal climate variability and so called 'climate change' researchers in this field address 30-100 year future periods. The predictions for the next century in Ireland suggest that there may be an increase in seasonal precipitation effects (salt cycles, surface recession and wet/dry cycles) while freeze/thaw will decrease and biological growth will alter (The Heritage Council and Failte Ireland 2009). Scientific monitoring schemes are vital for understanding the processes of deterioration affecting monuments, but can be hard to resource. In the case of monitoring climate-change impacts, many commonly used tools may also be unsustainable over the time-scale involved. In some situations proxy data from indicators can offer an alternative to scientific monitoring where staff and funding are limited. This paper presents some of the potential indicators for measuring climate change impacts on cultural heritage and landscapes, with a particular focus on Ireland. A stone-recession indicator tool developed during doctoral research is also presented. This tool is aimed at long-term tracking of surface deterioration mechanisms in stone materials at Ireland's two World Heritage sites (Brú na Bóinne and Skellig Michael).

2. Indicators in Theory

2.1 Defining indicators

Indicators can be used to complement direct monitoring or as an alternative where monitors are not available. They provide measurable data to corroborate qualitative assessments. Indicators are defined as quantifiable variables that, because of an established functional relationship, can be used as proxies for processes not directly observable or involving interactions over a long period (as in the case of climate change) (Schroeter, Polsky et al. 2005). Indicators should *both quantify and simplify information about complex phenomenon* (Berger 1996). Those chosen should be scientifically sound, understandable to stakeholders and clearly defined (including any omissions). Indicators are potentially of great worth in managing heritage values, which are often difficult to quantify directly.

2.2 Assessing vulnerability

Quantifiable indicators for measuring vulnerability to climate change have been outlined elsewhere (Moss, Brenkert et al. 2001; Adger, Brooks et al. 2004). Examples of proposed indicators for the World Heritage site of Brú na Bóinne are given in Table 1.

Table 1. Sample of indicators used for the vulnerability assessment of Brú na Bóinne to predicted climate change impacts (Daly 2008)

External impact	Indicator	Proxy for	Functional relationship
Extreme rainfall	Resistance of stone to abrasion	Sensitivity to physical erosion	↑ resistance = ↓ sensitivity
Change in agricultural practices	% arable farmed land	Exposure to disturbance of buried archaeology	↑ % = ↑ exposure
Changes to biodiversity	Invasive species	Adaptive capacity of eco-systems	↑ nos new species = ↓ capacity

[1] Dublin Institute of Technology, Ireland, cathydaly@hotmail.com

3. Selecting Indicators

Indicators should concentrate on elements that provide warning signals of impending problems. For the purposes of vulnerability analysis, indicators should relate to the key elements of exposure, sensitivity and adaptive capacity (Schroeter, Polsky et al. 2005). Inevitably there may be some issues with the tension between the desire for objectively quantifiable data and the subjectivity inherent in choosing and assessing indicators; this is best overcome by developing a transparent and rigorous process and clarifying any shortcomings (Hodge 1996). Complementary indicators are often required and a minimum data-set can be recommended (MDS) for specific objectives. Before selecting indicators (or monitoring solutions) it is essential to understand the aims and restrictions applicable (Forbes and Liverman 1996). For example while changes in insurance payouts could theoretically be used as an indicator for catastrophic climate change, this is limited in its application by the fact that cultural heritage is often not insured (Grontoft 2009). Indicators must be relevant to the stated objectives, be quantifiable, verifiable (i.e. repeatable by others) and suitable for comparative analysis over time (Elliott 1996). Some issues to consider when selecting indicators are:

- what are the key objectives?
- what are the spatial and temporal limits applicable (e.g. frequency of assessment)?
- what are the potential causes of error in interpretation of results?
- How will the final results be used (i.e. scientific or management purposes)?
- what is the overall context and how does the research fit into this?

3.1 Management indicators

Indicators are frequently used in natural heritage management but are rarely thought of in systematic terms in the cultural sector. In Australia, where natural and cultural heritage are more closely linked than in Europe, the cross-over has happened faster. In a 1998 document on state of the environment reporting, forty-three key indicators for cultural heritage are named (Pearson, Johnston et al. 1998). The report focuses on indicators for condition (C) and response (R) similar to the sensitivity and adaptive capacity categories in vulnerability analyses. Alternatively, Woodside divides indicators of adaptive capacity into two groups, physical and systematic (Woodside 2006). Although structured in a different way to Pearson, the two approaches have much in common and are combined in Table 2 in relation to management issues.

Table 2. Management indicators for assessing adaptive capacity and sensitivity of cultural heritage to general impacts of climate change (Pearson, Johnston et al. 1998; Woodside 2006).

Indicator	Measurement Method
Knowledge of heritage resource	Numbers of listed monuments Numbers of monuments assessed to high level Availability of Management and/or conservation plan
Condition of heritage resource	Number of places destroyed or damaged Number assessed as being in good, average or poor condition
Financial resources	Funding for conservation Funding of heritage bodies Insurance Maintenance regimes
Human resources	Numbers of trained practitioners Access to skilled professionals Institutional support Number of training courses
Legislative Protection	Number of statutory mechanisms **actively** used to protect heritage Planning restrictions

3.2 Landscape indicators

Geo-indicators *are measures of surface or near surface geological processes and phenomena that vary significantly over periods of less than 100 years* (Berger 1996). By measuring the *extent and direction* of certain specific changes within the environment, geo-indicators can be applied over long time scales (Rowland 2008). Often used for State of the Environment reports in natural heritage, there is particular scope for their application to cultural landscapes. For example, changes within river systems such as erosion and aggradations can be indicated by water discharge (related to channel width and depth) and channel bed-level (often measured by stream flow gauges) (Osterkamp and Schumm 1996). Erosion on land can be estimated from vegetation change, such as measuring soil beneath the root collar of an old tree (Osterkamp and Schumm 1996). One very interesting concept, and one which deserves more attention, is the elaboration of ‘cultural’ landscape indicators. Edmunds raises this in relation to the development of a baseline indicator for groundwater levels. He suggests that patterns of traditional water use by indigenous peoples, who have adapted to cycles of drought over centuries, could indicate water availability and climatic influence (Edmunds 1996).

In many countries data sets of water and sediment discharge have existed for as much as a century, and these can be used as a valuable baseline for comparison with future trends. Fluctuations in water levels are an important parameter for peatlands, having impacts on the species present and the extent of the peat itself. The presence of 'indicator' species with particular tolerance ranges such as sphagnum moss can also denote environmental conditions (Warner and Bunting 1996). The palaeorecord in peat will provide valuable evidence of past response to climate change and thus suggest future behaviour (Warner and Bunting 1996). Changes in the mapped extent of certain ecosystems and vegetation types using aerial photography (e.g. wetlands, tundra, grasslands) may also be useful on a broad scale to indicate climate change.

3.3 Indicators in the burial environment

The predicted increase in annual temperatures is of grave concern for archaeological remains in sub-polar regions (Gheyle 2009). Monitoring of permafrost, snow cover and glacial retreat can be used as an indicator for preservation conditions in Alpine, and sub-polar climates. Outside of permafrost regions the best preserved archaeological remains are found in anaerobic waterlogged deposits. Whether any burial environment will be waterlogged depends on the soil type, the topography and the water supply (Holden, West et al. 2006). In the future, burial conditions may alter and water supplies could function as an indicator for this change. Piezometric levels are the first step in monitoring groundwater availability as an indicator for general water levels (and archaeological preservation) (Edmunds 1996). The impact of a lowered water table on archaeological deposits will vary however, depending on the ability of the soil to retain moisture and its permeability to oxygen. There is also a pattern of existing fluctuations within which the burial system functions without deterioration. Therefore, to use this measurement as an indicator requires a series of measurements and an understanding of soil conditions. Preservation within waterlogged archaeological deposits is partly controlled by redox potential; a stable reducing environment (low E_h) is an indicator of good conditions for organic preservation. Similarly, evidence suggests that having a pH around neutral (8-6) is associated with better preservation (Holden, West et al. 2006). Decreased recharge or increased abstraction rates may lead to an increase in salinity (and corrosivity) of groundwater and the main indicator for this is the level of Chloride (Cl) (Edmunds 1996). Many countries already carry out groundwater monitoring and may include some of the indicators of interest however, understanding the methodology utilized by the primary collectors is vital. In terms of water sampling, for example, some water quality tests for human consumption use pumped samples of mixed origin and would have no value for a site-based analysis.

Micro-organisms are the main agent of organic decay in the burial environment. The identification and study of different organisms may in the future lead to their use as indicators for preservation conditions. To date however there is insufficient research into this area (Holden, West et al. 2006).

Table 3. Indicators for assessing unfrozen burial conditions based on Edmunds (Edmunds 1996)

Impact	Indicator	Measurement Method
Change in groundwater	Water level, Spring discharge	Piezometric meter
Redox potential	O_2, Eh, Fe^{2+}	Conductivity meter
Recharge rates	Cl	Field or lab testing
Water quality	HCO_3, Cl, pH, NO_3	Field or lab testing

3.4 Indicators for the coastal zone

Loss or damage of cultural heritage due to coastal change is one of the main concerns in relation to climate change (Murphy, Thackray et al. 2009; The Heritage Council and Failte Ireland 2009). There are a number of possible geo-indicators that policymakers can use to alert them to possible future loss at the coast and these are dealt with in detail by several authors (Forbes and Liverman 1996; Morton 1996; Young, Bush et al. 1996). Rowlands demonstrated their use in relation to archaeological resources in Queensland. He conducted risk assessment mapping of the coastal zone utilizing three geo-indicators for coastal change; dune formation, sea level rise and shoreline position.

Coastal processes that affect a given site are complex and even for experts it may be difficult to attribute changes to a single cause such as climate change. Young (Young, Bush et al. 1996) developed a methodology for assessing shoreline change using qualitative data. By repeating photographic and descriptive assessments, using a checklist of geo-indicators, heritage practitioners should be able to monitor shoreline change in a scientifically valid and inexpensive way. The authors write that although detailed long-term monitoring would be preferable to this qualitative method, financial backing for decade-long monitoring projects is difficult to obtain; *tools that can be of immediate application may be of a more far-reaching consequence than sophisticated methods relying on instrumentation and long-term, quality data-bases* (Young, Bush et al. 1996). Morton is more cautious about using qualitative data and argues that only quantitative, long-term analyses are truly reliable (see Table 4).

Table 4. Quantitative indicators for assessing coastal

change based on Morton (Morton 1996)

Impact	Indicator	Measurement method
Coastal Erosion	Shoreline position Beach width Beach type Beach materials	Ground survey Aerial photography Beach profile Field survey Mapping
Coastal Change	Wetlands distribution Water levels Salinity (water and soil) Sedimentation	Ground survey Aerial photography Water level Flood levels Chemical analysis Surface height
Sea Level Rise	Water level change Storm surge height & duration	Tide gauges Sea level Marine record

3.5 Climatic indicators

The instrumental recording of climate, carried out by meteorological stations can be supplemented by secondary indicators. These often have the advantage of being able to reflect local micro-climates. Phenological observations, for example, have been shown to be good natural indicators for climate change (Menzel, Sparks et al. 2006) and are relatively easy to record. The Irish phenological network was established in the 1960s to study the timing of recurring natural events, in particular the life cycle of trees, such as flowering and leaf drop (Department of Botany Trinity College Dublin 2011). There is already half a century of data available and the network also publish data sets on the migration and egg laying of certain bird species, behaviours that are closely linked to spring temperatures.

Lepidoptera (moths and butterflies) are recommended as indicators of climate change because they are relatively easy to identify and contain a large number of species indicative of various habitat types (Sweeney, Donnelly et al. 2002). A study of the first dates of appearance of the adults, and the number of generations per year, should provide useful comparative data (Mary Tubridy and associates, personal communication). Monitoring numbers of individuals within certain key species can point to changing environmental conditions, but in many cases the effect is complex. For example, Atlantic salmon that spawn in the river Boyne may be declining because of over-fishing at sea, pollution, sedimentation or rising water temperatures. Attributing lower numbers to climate change is simply not possible. Nonetheless monitoring species with a high cultural value, such as Boyne salmon, could be useful as an indicator for the intangible aspects of a site. These so-called 'flagship species' have a powerful symbolic function, and reaction to their conservation will also serve as an indicator of public interest and engagement.

4. Development of a New Indicator Tool

4.1 Background

Given that climate change is measured in 30-100 year periods, it is evident that impact monitoring should operate over a similar timescale, as a legacy for the future (Brimblecombe 2010). In many cases however the options available require levels of staff involvement, funding or equipment maintenance which would likely be unsustainable over a century (Daly, Cox et al. 2010). For this reason the potential of indicators was explored in the author's postgraduate research and a new tool for measuring the effects of surface weathering on stone developed. This tool is presented below for the first time. It is in the early stages of testing at Ireland's two World Heritage sites (Brú na Bóinne and Skellig Michael).

4.2 Exposure trials

The exposure of fresh stone allows study of stone decay patterns under real-world environmental conditions without compromising the integrity of historic monuments. Short-term exposure trials have been used in many scientific studies for understanding decay patterns and thus for predicting future behaviour.

Exposure trials provide an important link between knowledge of decay processes derived from laboratory-based experimentation and observed decay of stone buildings and monuments (Turkington, Martin et al. 2003).

To date, most exposure trials have been conducted to investigate pollution effects and have often focused on calcareous stone (i.e. limestone and marble) (Turkington, Martin et al. 2003). The vast majority are also short-term projects, and even in the long-term studies the longest sample exposure is approximately eight years (Viles, Taylor et al. 2002). One of the most extensive exposure trials is that carried out by the International Co-operative Programme (ICP) on effects on materials, including historic and cultural monuments (Swerea KIMAB AB 2009). The ICP have exposed standardized materials at a network of test sites across Europe between 1987 and the present. The stone tests were conducted on Mansfield sandstone and Portland limestone blocks (50x50x8mm) fixed to a rotating carousel (ICP Materials Programme Centre 2006). The British National Materials Exposure Programme (NMEP) ran from 1987-1995 and fed into the ICP programme. The samples were assessed according to a variety of criteria, including weight, salt content, colour change and SEM (Viles, Taylor et al. 2002). In addition the Buildings Research Establishment (BRE) has data from Portland limestone studies dating back to 1955 (Yates 2003).

In Ireland the STEP project exposed samples (mainly in Dublin city centre) in order to determine the rate of dissolution of stone due to pollution (Cooper, Bell et al. 1991) and the focus was on Portland limestone. The samples were exposed in standardized micro-catchment units and the runoff was collected and analysed to quantify the amount of loss accurately. At Queen's University in Northern Ireland, Turkington exposed 50x50x10mm blocks of sandstone on north-facing racks to study pollution effects (assessed using visual and chemical analyses) (Turkington, Martin et al. 2003). Queen's is currently carrying out exposure trials related to climate-change impacts. Blocks of sandstone exposed across the province to monitor 'greening' or biological growth and test walls using three types of sandstone (including Peakmoor) are being used to study deep wetting (Smith, McCabe et al. 2010; McAllister 2011).

5. Creating an Indicator Tool

The majority of Ireland's pre-eighteenth-century heritage buildings are constructed from local stone (Pavia and Bolton 2001). The deterioration of stone surfaces due to climate effects is therefore of major interest to conservation managers. The World Heritage sites of Brú na Bóinne (a Megalithic passage grave assemblage) and Skellig Michael (an early-medieval monastery) are both stone-built. Brú na Bóinne also holds an unsurpassed collection of Western Megalithic rock carvings that are of particular concern with regard to surface weathering. The issue of sustainability over the period of climate change *vis à vis* staffing, equipment and funding was noted as an issue during doctoral research into the various monitoring solutions. In addition to techniques such as laser scanning and photography, it was felt by stakeholders that an embedded tool, suitable for long-term use, could be of value. It was decided to develop a sacrificial object that would alert management to changes in the severity and/or magnitude of weathering patterns (see figure 1). The aim of the tool is to track the *direction* of any change by illustrating actual weathering occurring at heritage sites. Over time the condition of the object will contribute to understanding the influence of climate change on these patterns (e.g. increase or decrease in incidence and severity) by relating it to climate data. The assessment of climate change impacts will require at least 30 years of data, equal to the period referred to as the 'climate norm' by meteorologists.

5.1 Design

The indicator tool consists of five 50mm cubes of freshly cut stone material attached to a plate and mounted at the heritage site. They should be visually unobtrusive and easy to handle, which is why the size was restricted to $50mm^3$. By using cubes of 50mm the results will be limited in application and refer only to near-surface effects. Smith argues convincingly that deep wetting is an important factor in stone-deterioration mechanisms (Smith, Warke et al. 2004) and Goudie (Goudie, Viles et al. 1997) emphasizes that salt solutions at depth cause chemical breakdown, paving the way for later damage. Unfortunately it was not feasible to use blocks on a masonry scale to reflect all the possible processes, and this does limit the tool's application.

5.2 Choice of materials

5.2.1 Samples

When choosing samples it was important to balance site-specific concerns with the need for scientific baseline data. There are five cubes on each plate, four reference cubes common to all sites and one site-specific cube. The reference stones can act as a control for the site-specific stone and for comparisons between locations, either within one site or between different ones. The site specific stones used was Gallstown Greywhacke at Brú na Bóinne and Old Red Sandstone in Skellig Michael. The reference materials include two natural stones and two manufactured materials. The stones chosen are Portland limestone and Peakmoor sandstone both of which have previously been used in weathering research (Viles, Taylor et al. 2002; Turkington, Martin et al. 2003; Yates 2003; McAllister 2011). The manufactured cubes are concrete and machine-made historic brick. Concrete provides a standardizable sample with known composition, and unlike natural stone, the degradation of cement tends to a linear path (Gaspar and de Brito 2008). While the advantage of using modern concrete is the control over the initial properties of the stone, it is important to be aware that chemical processes will be continuing in the samples over time, independent of the action of weathering, such as hydration changes and carbonization. Both brick and concrete are important for heritage buildings and substantial concrete engineering solutions have been made to the archaeological monuments at Bru na Boinne and Skellig Michael. In addition the two materials offer an interesting contrast in their weathering patterns to the natural stone and will be more sensitive to certain weathering forms (Chandler 1991).

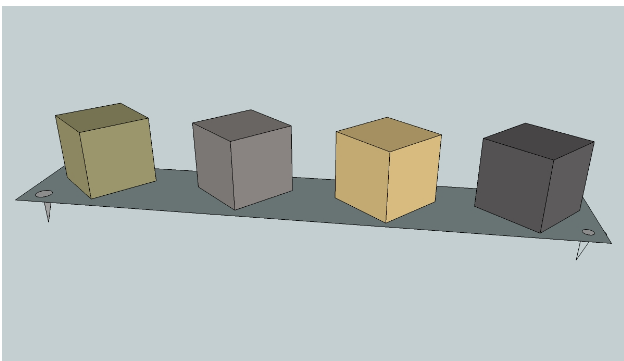

Figure 1. Sketch of indicator tool (final version has

five cubes)

5.2.2 Support

The stones require an inert support that will not interfere in any way with weathering mechanisms. It has to be stable over a minimum of 100 years and ideally for much longer. Initially, several materials were considered including resins, plastics and corrosion-resistant metals such as titanium (Ti), stainless steel and aluminium (Al).

Table 5. Relative corrosion rates after 4-5 years of exposure in a marine atmosphere for copper, aluminium, 316 stainless steel, & titanium (Boyd and Fink 1979).

	Cu	*Cu-zinc alloy*	*Al alloy*	*316*	*Ti*
Corrosion Rate	.095	.028	.01-.025	.0013	Nil

The choice was quickly reduced to stainless steel or titanium. In general high-strength stainless steel austenitic grades (e.g. 304 and 316) are resistant to the marine atmosphere, considered the most aggressive natural environment for metals (Boyd and Fink 1979). In tests by the British Stainless Steel Association grade 316 took 260 years to develop pits of 1mm depth in a marine environment (British Stainless Steel Association). Crevices, shielded areas and high temperature welds are the only potential areas of weakness. Unlike stainless steel, titanium is not susceptible to crevice attack or pitting and is one of the most corrosion-resistant metals available. The cost of titanium is approximately three times that of 316 however, and as that expense was not justifiable, on the basis of the corrosion resistance tests, the stainless steel was selected. The galvanic effect of combining two metals means that screws chosen have to be of the same potential as the plate, otherwise corrosion of the less noble metal will occur (Boyd and Fink 1979).

5.3 Measurement

Ideally the cubes should be measured at regular intervals (3-5years) to monitor the effects of weathering. The tool has been designed for long-term exposure however, therefore if this regime is interrupted or abandoned assessment can begin again at a far-future date. To future-proof the measurements taken now, hand-held callipers will be used in combination with more accurate (but potentially less durable) high-tech methods. Initially a hand-held laser scanner was considered for the detailed measurement of the cubes. Given the micro-meters (0.001mm) of change that are likely over the short term, it was felt that a stationary object scanner of higher accuracy would be more appropriate, although this will require the cubes to be returned to a laboratory periodically. The Coordinate Measuring Machine (CMM) chosen has much greater accuracy than laser scanning. Laser scanners produce a point cloud from which a virtual surface is constructed and comparative measurements would therefore be between these virtual surfaces. By contrast the CMM takes a series of point measurements on each surface and then presents an object-specific series. The flatness of the stone surfaces and the distances between opposite façades can be identified and used to indicate dimensional and geometric change that may occur over time. Measurement is achieved by a highly sensitive touch-trigger probe that makes contact with the object at several places across the surface. Comparative analysis can be made using known points on the surface of the stone and the accuracy is typically in the region of +/-0.002mm. Additional assessment will be made by the use of surface-roughness instruments. This type of instrument draws a fine stylus over the surface of the object being assessed. The profile of the surface is magnified greatly through software and various parameters are used to quantify the surface (e.g. Ra, Roughness Average). This method of assessment will highlight any changes in surface characteristics, e.g. surface pitting or granulation.

5.4 Transmission to the future

The tool is designed to be as self-explanatory as possible using standardized cubes (equal on each axis) and including materials that will weather at different rates. No matter how clearly damage can be read from the tool itself however, contextual information will be needed to maximise this communication (Kornwachs 1999). In order to ensure that all the relevant information about the cubes will be available to future generations of conservators, it was necessary to consider possibilities for archiving the data. The Irish Meteorological service (Met Eireann) collect and store climate data from the national network of stations and it is highly likely that this will survive far into the future. Object and site-related data requires the same level of careful planning and centralized archiving if it is to be readily available to researchers at the end of this century or the next. Digital information is particularly problematic in terms of longevity. Technology changes so rapidly that the software and hardware necessary to read stored data are quickly becoming obsolete and constant migration from one format to another is required. This is unsustainable and will result ultimately in the loss of much information. All of the data related to the recession tool will be lodged in paper format with the National Archives, an institution with permanent status. The accession number of the archived files will be engraved on each indicator, thereby linking the tool to the data in an enduring manner.

6. Discussion

One of the main problems with using test pieces for assessing climate-change impacts is the difficulty of extrapolating from one stone to another. Stone decay is determined by the properties of the stone itself as well as the environmental conditions. Each material reacts differently and within stone types, even within single blocks, structural and mineralogical variations can be significant (Warke, Smith et al. 2004). The possibility of using historic examples as indicators of future performance has been investigated elsewhere in relation to assessing building stone (Scheffler and Normandin 2004). The authors concluded that the method lacked accuracy but that it would be useful in combination with mechanical and accelerated weathering tests. While this may be possible in the building industry, for most cultural monuments it is probably unfeasible. Another issue with interpreting the cubes is that the results may be misleading because in general *surface decay and soiling do not show a clear, linear progression over time* (Viles, Taylor et al. 2002). Thus a lack of visible degradation could be followed by sudden and catastrophic loss. Non-destructive methodologies for describing changes in the stone, such as surface roughness, only look at the façade, overlooking any internal changes that may in fact be driving decay. These unseen reactions can result in unexpected loss of the surface and make recession measurements redundant. The cubes will be more responsive to fluctuating temperature and moisture cycles than masonry stone, due to their small size. The small mass is most comparable to sculptural stone. This sensitivity to climatic influences should make the cubes a good early indicator of weathering patterns. The cubes are a sacrificial indicator and therefore it is necessary that they be more sensitive than the monument itself, so they can act both as a warning and a testimony. The main aim of the tool is to create a point of reference for future research; as such it is not expected to yield significant results earlier than 2042. It is merely one step on the long journey towards understanding how climate change may impact our heritage.

7. Conclusion

The potential for indicators as additional tools in the heritage manager/conservator's arsenal is one that deserves more attention. While scientific monitoring and high-tech sensors provide valuable data they are not always feasible, given either limited resources or extended time-scales. This is particularly relevant when discussing climate change, as the periods being studied are inter-generational. It is hoped that the presentation of a newly developed surface recession tool for stone materials at the EWCHP will generate critical discussion. There are several shortcomings with the tool but it is anticipated that over time useful results will be gained. It is also intended that feedback from experts and end-users could go towards improving the design of the tool and perhaps result in its use at heritage sites outside of Ireland.

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