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The potential uses seen for this model are: 1) A starting point for IPM planning or instruction. 2) For classifying risks to collections from pest activities during collections surveying. 3) A contribution to setting guidelines for institutions offering tax benefits, or hosting exhibitions indemnified by government programs.

Climate control in an uncontrollable building

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Introduction

In this study we present our collections storage building as a case study demonstrating the effectiveness of attempts at climate control using the limited available means in an antiquated building. A central aim of this is to estimate the value of the staff time investment required for manual intervention (control of climate by radiator adjustments). This is a key factor for the NMINH since staffing levels are low, with just three full-time curatorial staff and one technician (divided between two buildings) for a collection of approximately two million specimens. Furthermore, we intend to determine the reliability of earlier decisions made about building usage, particularly in light of specimen storage and researcher access. The majority of visitors to the collections building are researchers working through the Museum's partnership with University College Dublin (Collections-based Biology in Dublin; CoB*i*D), and the establishment of effective (and comfortable) research space is of increasing priority.

Methods

Temperature and relative humidity data have been digitally monitored (using the MEACO Museum Monitor, www.meaco.com) continuously in the NMINH collections building since May 2002, prior to this Casella T9420 analogue monitors were in use in limited areas. Shortage of technical staff (four in 1990, only one today) limited environmental monitoring until the MEACO system was introduced. Our study period reported here ends in March 2005, although the system remains in place. Half-hourly measurements that are logged (via a radio telemetry system) by a central computer, and all readings are stored electronically in a dedicated stand-alone computer.

From January 2004, the NMINH's technician initiated a programme to moderate internal climate within the collections building, by responding to pre-defined non-optimal conditions identified by the MEACO system. An optimal range (from 40% to 55% RH and from 15°C to 18°C) represents the recommended climate values for the safe and stable storage of material throughout building. On two to three days per week the technician would review the reading from each monitor, and take action to adjust the internal climate in particular rooms when the immediate climate was found to outside the these optima. This intervention programme was maintained for a period of 15 months until March 2005.

We compared the total internal (building) climate records with external (weather) climate conditions, supplied by the Irish National Meteorological Service, Met Éireann. The data were divided into two phases: non-intervention and intervention. During the period of monitoring the collections building was heated between late October and mid-May. Although direct-action means to control room conditions were unavailable when the heating was turned off, the technician intervention programme also included a regime of electric lights being switched off when not in use (to prevent unnecessary warming in collections spaces) and all doors between rooms were kept closed at all times. These collections space management strategies were implemented throughout the year.

For analysis, we determined the average climate within the building as a whole, using the mean hourly temperature and RH across fourteen monitors (one was excluded due to unreliable data). The average daily range was calculated as the mean difference between maximum and minimum temperature and RH recorded by each sensor over a 24-hour period. We visually examined time-series plots of daily maxima and minima of temperature and RH (external and internal) to assess how much time the collections experience outside generalised optimal conditions, as imposed by the climate intervention programme. We also compared the magnitude (i.e. difference between daily maximum and minimum values) of temperature and RH ranges in the "winter" (i.e. heated) periods during intervention and non-intervention phases using pair-wise single factor analysis of variance (ANOVA) tests for external and internal climate data. Finally, we further compared the magnitude of internal daily fluctuations as a percentage of the external diurnal fluctuations.

Results and discussion

Most interestingly, and more distressingly, the building climate only very rarely stayed within optimal conditions throughout the whole monitoring history. Correlations between temperature and RH values during extreme conditions inside the building are to be expected, but interestingly the temperature variation has not seemed to have dramatic influence on the humidity regime. The daily building temperature was outside the optimum maximum and minimum readings for 73% of the time since 2002, and the RH for 70% of the time. The majority of this is in the upper part of the range; that is, the minimum humidity exceeds 55% RH for 32% of the time. However, the temperature varies dramatically over the three-year period, spending in total about equal time with the minimum daily temperature exceeding 18˚C (13% of time) or the maximum daily temperature staying below 15˚C (17% of time).

Comparing the periods with and without intervention, the programme has had a limited effect on narrowing the internal temperature range, with measurements falling outside the MEACO optima for 35% of time during the non-intervention period, compared to 26% of time with intervention. However, the climate intervention programme has had dramatic negative results on the building humidity regime, with measurements falling outside the optimum values for 74% of time, compared to 58% of time before intervention. What is also visible from plots of the RH measurements is that the oscillations within the building become more extreme during the period of intervention. Examining the fluctuations in temperature and RH as a percentage of the external daily range, we note that during the period of intervention the magnitude of fluctuations in internal humidity exceed external fluctuations more often, and are generally greater during the intervention period.

The time when the building heating was turned on is critical for analysis, as this is the period when direct actions on climate control were possible. During the winter, the building environment is well buffered from fluctuations in outside temperature; it is less well insulated from fluctuations in external humidity (Figure 1). The average daily range (fluctuation) of temperatures has decreased slightly, but statistically significantly, during the intervention phase from a difference of 1˚C to a difference of 0.9˚C (ANOVA comparing 249 data points, $F=11.99$, $p=0.0006$). However, the range of humidity fluctuation has increased significantly during the intervention period, from a range of 4.6% to 5.6% ($F=11.09$, $p=0.0009$). These changes in the internal climate occur irrespective of external climate, since there is no difference in external range between the years compared.

These data paint a rather negative picture of the impact of manual intervention in climate control on the collections environment in Dublin. Stable humidity is the most important factor for object conservation (Rose and Hawks 1995), and although the intervention programme aimed to control humidity via temperature regulation, the efforts made have exacerbated humidity fluctuations. This kind of rapid oscillation in humidity has been reported previously in similar environments with attempted control of humidity by warming, with the conclusion that such buildings must be controlled by direct dehumidification (Padfield and Jensen, 1990, Padfield 1996). The natural buffering provided by the building material and the thick walls creates a chaotic and uncontrollable internal climate as the building responds to the external environment. The building materials in this case are probably the best regulator of humidity, as the natural porosity of limestone acts as a buffer to decrease internal humidity (Eshoj and Padfield 1993). However, we have noted that during a period of heating failure, in wet Irish winters, cold and wet conditions led to "rising damp" as groundwater seeped up into the stone floors of the building. It seems unlikely that in the absence of heating this could be practically controlled by dehumidification in the large space of this building. Therefore, controlling humidity by heating is essential, but we cannot rely on fine-tuning it to affect the collection environment.

Footfall has increased over the whole study period, as the CoB*i*D partnership has increased accessibility of the collections to university researchers and students, as well as outside visitors. However, this access has been limited to very specific areas of the collection, and few of the rooms used have monitor devices. Since this analysis reflects an average of readings across all monitors, all of which were subject to the climate intervention programme, the human traffic cannot account for the variability we find. In addition, human activity would be expected to increase internal relative humidity (Padfield, 1999), yet we do not see such an increase in RH. Finally, user activity cannot account for the reduction in temperature fluctuations seen (one success of this intervention programme), so it is clear that increased footfall has not been a determining factor in the outcome of this study.

Evapotranspiration rather than rainfall, seems be most important in determining external humidity (especially given that rainfall is more or less constant in Ireland throughout the year). The urban setting of our building may be directly beneficial, as there is a relatively low density of vegetation surrounding it, which may result in lower local humidity. The environment, although far from ideal, is not dire. Low levels of seasonal fluctuations in the Irish climate mean that temperature and humidity regimes operate in a relatively narrow (although sub-optimal) band. The importance of storage furniture in reducing the climatic fluctuations experienced by specimens was illustrated when one monitor was placed in a sealed drawer at a point during this study. The data from this monitor were not used here, since the monitor was not subject to the same conditions as the other devices, but it is interesting to note that the buffering offered by the closed unit reduced climate fluctuations dramatically. A quantitative study investigating this effect is currently underway. By ensuring that specimens are maintained in sealed cabinetry that provides an additional envelope of protection, we can maintain adequate environmental standards for our collections.

Here we conclude that in a poorly sealed building with inadequate levels of staffing, manual control of temperature in an effort to reduce fluctuations in humidity is an inefficient use of human resources. Intervention has not improved the storage environment in the NMINH storage building; rather, it has made the situation measurably worse. The manual control of radiators as a means of controlling climate in this building was found to have less influence than fluctuations due to changes in weather. Furthermore, any influence may occur more slowly than diurnal fluctuations, thereby amplifying the fluctuations occurring over the course of the day. The natural architectural climate buffers offer the best protection to the collections housed in this building. The way forward in caring for collections in this environment is to integrate solutions at a large scale (such as through building modifications) and at a small scale (such as control of specimen microenvironment). There is too much work to be done in this case, and in any museum, to continue attempts to control an uncontrollable situation; our time can be better spent.

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