Documenting and optimizing storage conditions at the National Museum of Denmark

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Abstract

New technology and approaches to environmental assessment in preventive conservation have been developed at the National Museum of Denmark (NMD) during a museum-wide project from 2004-2007. The Image Permanence Institute (IPI), a preservation research laboratory in the College of Imaging Arts and Sciences of Rochester Institute of Technology, Rochester, NY, USA was contracted by NMD to design and help conduct the assessment of storage conditions, working together with NMD staff. More than 240 locations were monitored in the course of the project, creating formidable difficulties with organization, analysis and reporting. To cope with these difficulties, a web database of environmental data and collection management information was created and given the name *MyClimateData.* An interface for this web site was devised, allowing for analysis of groups of locations via a hierarchy of site, building, floor, room and location, as well as through searches based on any type of collection characteristics saved in the database. Analysis of the 'preservation quality' of the environments was performed and reported using IPI's environmental metrics (algorithms for transforming temperature and RH data into numerical estimates for specific decay rates). The project was successful in helping NMD clarify its storage needs and future construction plans.

Introduction

In recent years increasing emphasis has been placed on the role of preventive conservation in museum management. There is general agreement that the foundation for successful interventive conservation programs is to apply collection management techniques that identify and minimize risks to collection objects, lengthening the useful life of collections and reducing the need for repair of preventable damage [1]. Another important trend in museum management is to divide collections into different categories based on value [2]. This is done to help ensure that resources for collections care and storage are applied in a fashion that reflects the cultural significance of collections and furthers the overall mission of the institution. It also helps focus interest on the quality of storage conditions for the most valuable objects. Often such evaluations are done in conjunction with improvements in databases used for inventory and various other logistic functions. The common thread among all these trends is the need for tools and approaches that enable museums to set priorities, measure progress, and document good stewardship.

Measuring and analyzing storage conditions has for many years formed an important part of conservation management and preventive conservation of museum collections [3,4]. From the point of view of museum management, a reasonable expectation is that a monitoring project would result in useful, standardized determinations of the degree of risk—and benefit—posed by environmental conditions to the major types of collection objects, or even to single objects of great importance. Hygrothermographs, the traditional pen-and-chart type recording instruments for temperature and humidity data, have now been replaced in many museums by electronic data gathering. While electronic dataloggers offer many advantages over hygrothermographs, there are a number of remaining difficulties that make it very hard in practice for museums to assess the quality of storage environments. These can be summarized as a lack of staff time and expertise, the difficulty of determining the degree of risk (or benefit) to collections, and the challenge of organizing, maintaining, and reporting on mountains of data. (In large museums it is not uncommon to have hundreds of locations to monitor [5].)

In 2004 the National Museum of Denmark, a national cultural history museum with large and diverse collections, undertook a three-year effort to assess the preservation quality of its existing collection storage facilities. This effort was part of a larger strategic assessment of NMD's capabilities and priorities conducted with the support and encouragement of Denmark's Ministry of Culture. The environmental assessment and optimization project, now nearly complete, resulted in the development of a prototype for a web-based system of environmental assessment and reporting, together with a prototype of a web database for centralizing

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collection management information. The web system was given the name *MyClimateData*.

The aims of the environmental assessment project at NMD were to determine whether existing facilities were delivering conditions appropriate to the collections stored there, to judge whether there was sufficient capacity overall to adequately preserve the important elements of the NMD collections, and to generate documentation of the need for improvements. The Image Permanence Institute (IPI), a preservation research laboratory in the College of Imaging Arts and Sciences of Rochester Institute of Technology, Rochester, NY, USA was contracted by NMD to design and help conduct the assessment of storage conditions, working together with NMD staff. This paper describes the project and in particular new methods of environmental assessment developed during its evolution.

Project design

NMD staff from the Conservation, Conservation Research, Registration, and Storage and Logistics departments collaborated on a plan to monitor temperature and relative humidity in more than 200 locations among NMD's multiple sites and buildings in and around Copenhagen. The project also included limited monitoring in the Royal Library of Denmark, the Conservation Center in Vejle, and the Collection of antiquities in Ribe. The project involved acquiring 150 new Preservation Environment Monitor® (PEM) dataloggers as well as using existing Tiny Tag® portable dataloggers already owned by NMD. In addition, current and historical data from NMD's building management computer system (BMS) was included in the project. Data analysis was performed by IPI using its *Climate Notebook*® software. IPI's team working on the project included several staff scientists, a computer programmer, and a consultant with expertise in energy-efficient operation of heating, ventilation, and air-conditioning (HVAC) systems. The plan was to deploy the loggers and monitor storage conditions for at least a year to obtain a baseline of data showing the seasonal cycle. In the meantime, allied information necessary for the assessment task, such as the types of objects stored in each location, details of building construction, nature and capabilities of mechanical systems (if they existed) were to be gathered and stored in a MS Access® database.

The first lesson taught by the project was that strategic as well as tactical considerations must be considered in all aspects of project planning and data analysis. Many different points of view must be taken into account in determining which spaces to monitor and how the analysis will be used. Curators, museum managers, collection managers, facilities staff, conservators and registration staff all have an interest in the data and conclusions resulting from the project. On the strategic level, the important objectives were to create a reasonable overview of storage conditions in the entire institution and to evaluate alternatives in the design of future storage facilities. On the tactical level, there were many previously unmonitored locations as well as those with known environmental defects that NMD staff wanted to explore in greater depth. There was also a need to ensure that certain collections and significant objects were included, and that important curatorial and administrative units were not left out. Even with more than 200 data collection devices, there was concern about missing coverage of the many spaces and buildings owned by NMD. In the end, the number of data collection devices was not enough to cover every location of interest, but was sufficient to obtain a strategic overview and to serve most of the tactical objectives.

Difficulties with data

The main difficulty was not lack of dataloggers but lack of organizational tools to help plan and execute a project so large and to keep track of data and information. NMD staff knew the museum and its collections well, and had kept very good documentation of collection management information. Initially it was thought that simple spreadsheets and databases would be enough to track where dataloggers were, when data needed to be uploaded, and so on. Analysis and reporting were planned to be done with IPI's *Climate Notebook*® software, which had been designed to evaluate data sets one at a time, or in small groups. It soon became apparent that everyday tasks of working with environmental data files (naming of folders and files, matching data sources, updating files, etc.) as well as the larger task of analysis and interpretation of data were rather time consuming and difficult, when extended to hundreds of data sets. Naming locations with unique but meaningful identifiers is vitally important in project design because the location name is the key upon which all the retrieval and interpretation of data depends. In this project, a naming scheme was ultimately chosen that incorporated coded information about the site, building, floor, room and data source (logger or BMS system).

Custom programming was required to reconcile the data formats of the three main data-gathering devices used in the project. The PEM® data could directly be used in *Climate Notebook*®, but data from the BMS systems and Tiny Tag® dataloggers could not. Museums considering similar projects and having several different data sources should be aware of the difficulties of incompatible data formats.

Interpreting environmental data

After some months, the initial organizational phase of the project was concluded and data began to be collected. At this point we realised that a formidable challenge lay ahead in the task of analysis and reporting. Analysis on the strategic level meant quantitatively determining and comparing the degree of risk or benefit that environmental conditions pose to collections and using that information to determine storage needs and to determine if preservation goals are being met. The strategic level of analysis obviously requires joining multiple locations into composite overviews for a building, a department, a site, or the entire institution. The tactical level of analysis is concerned with similar estimations of risk but also with understanding what factors (climate, mechanical systems, water leaks, rising damp, building characteristics, etc.) influence a particular environment and what might be done to improve it (modify set points, install new equipment, remove collections entirely, etc.). To meet the NMD project's goals, both types of analysis were required.

In both strategic and tactical analysis the observed environmental characteristics are merely the starting point for evaluation of the preservation quality of a storage or display space. The nature and needs of collection objects present in the space must be taken into account. The value and importance of objects and collections also must be considered. As research has made clear, there is no single environmental condition that is benign and optimal for all collection materials [6,7,8]. Collections and individual objects often have multiple deterioration mechanisms. It is necessary to consider risks arising from specific decay mechanisms, and then prioritize which mechanisms are important to the deterioration rate. Preventive conservators should not forget that they need to measure and demonstrate successful stewardship of collections as much as they need to diagnose problems and risks.

Metrics for assessing environmentally-induced collection risks

The starting point for analysis of environmental data in the NMD project was the use of environmental metrics. These are algorithms that transform temperature and RH values into quantitative predictions of the likelihood and severity of specific forms of collection decay. These algorithms have been developed by IPI over the last several years and have been refined in the course of the NMD project [9, 10, 11]. Environmental metrics enable a concise, standardized overview of the characteristics of environmental conditions. The names and types of decay mechanisms addressed by the metrics are given in Table 1. Each of these metrics yields a number that is an estimate of the tendency of the environment to cause or prevent collection deterioration via a specific pathway (mould, corrosion, etc.)

The metrics are intended to be one tool among many techniques and approaches used by preventive conservators and collection managers in dealing with environmental analysis and reporting. Metrics describe general characteristics of conditions in a standardized way. They save time in dealing with large amounts of data by providing a rapid screening for particularly dangerous conditions. To use the metrics in practice one must be familiar with how they are calculated and have a feeling for the meaning of the numerical values that result from them. One must also know what sorts of collection materials are present and must consider which forms of deterioration—and therefore which of the metrics—will be given the most weight in

Metric	Deterioration Type	Basis for Analysis	Algorithm
TWPI	Spontaneous chemical change in organic materials	Generalized treatment of hydrolysis reaction kinetics	Integrates over time, weighting each time interval according to the reaction rate
Mould Risk Factor	Mould	Based on empirical studies with food grains	Integrates over time, creates running sum of progress toward mould germination
Dryness	Shrinkage and stress related damage in wood, leather, etc	Based on physical behaviour of an averaged wood species	Estimates moisture content using moving averages of T & RH
Dampness	Expansion and compressive stress related damage in wood, leather, etc.	Based on physical behaviour of wood	Estimates moisture content using moving averages of T & RH
Dimensional Change	Fatigue and stress related damage in wood, leather, etc.	Based on physical behaviour of wood	Estimates dimensional change based on moisture content
Corrosion	Metal corrosion	Moving average RH value	Two levels of severity based on adjusted RH

Table1

the analysis. Metrics can yield a quick overview of multiple locations by creating a ranked list from best to worst from the point of view of a particular type of deterioration. For an individual location, metrics can be used to determine whether the collections actually present are at risk, or else what types of collections might be stored there with minimal risk. In the NMD project the metrics proved especially useful in developing overviews of conditions organized by building, department, and collection type.

Development of a web database and web interface to climate data

The original intent of the project was to perform all analysis and reporting using Climate Notebook® (CNB) software. As the project developed, the limitations of this software when applied to such a large monitoring effort became apparent. Although the CNB software was a powerful tool for manipulation and analysis of data, it was organized around dealing with one location at a time, or at most a group of 20 locations. CNB allowed for a certain amount of information to be kept alongside the environmental data for a particular location, and did allow for computation and display of the environmental metrics listed above, but the need for a more robust and flexible database to organize the large-scale monitoring and analysis effort became quite clear. Something had to be done to ease the formidable organizational difficulties resulting from naming, filing, modifying, and reconciling separate small databases containing various elements of the assessment project. It also was apparent that a number of people throughout the museum needed access to the environmental data as well as to the associated database of information about the collections.

The project team then embarked upon the development of a prototype web database for environmental data and analysis, which was given the name *MyClimateData*. Leon Zak, president of Zak Software Inc. of Rochester New York, USA was the lead developer for the web prototype. In this prototype, analysis of the temperature and RH data was done off-line using Climate Notebook®. Environmental metrics and summary statistics were calculated, graphs produced, and then moved to the web. Plans for future versions of the web tool call for all data storage and analysis to be accomplished on the web server without the need for off-line use of CNB.

Design issues for web database of collection storage information

The database design used in the NMD project is extensible, meaning that any type of textual or numerical information can be added as the need arises. This was accomplished by having a database structure of only four distinct fields, with the name of the location (which defines where the environmental data was gathered from) as the unique identifier and organizing principle. The other three fields were ‘ID #’, ‘kind’, and ‘data’. Each record in the database was tied to a particular value of the ‘location’ field. The ability to extend the database by adding a new type of information—for example, “emergency contact number”—was enabled by saving “emergency contact number” in the ‘kind’ field and the telephone number itself in the ‘data’ field. To the user, it appears as if there are many fields to the database, while in reality only four exist. This database design avoids the problem of having to pre-determine the field structure. In the NMD project, about 40 different kinds of information were stored in the database. These were organized into five categories for presentation to the user: Location Information, Collection Information, Mechanical System Information, Logger Information, and Administrative Information.

Organization and presentation of environmental data on the web

During the NMD project the web interface evolved considerably, ultimately including navigation tools and search functions where analysis could be organized based on location or on any type of information contained in the database. The interface also included summaries of environmental risks, presentations of mismatches between collection materials and their storage environments, a search function whereby locations suitable for storage of specific materials could be identified, comparisons among spaces, and screens for displaying and editing information contained in the database of locations. In addition, the interface also contains the ability to call up photographs of storage locations, maps and floor plans marked with icons showing loggers, water leaks, etc. There is also a separate database of collection component materials (iron, wood, etc.). This database is also extensible and allows the user to set her own limits for environmental risks, as defined by a particular institution for its collections. User access to the web site is via username and password, administered by a superuser. The web site is protected by a Secure Socket Layer (SSL) certificate.

One of the most interesting challenges for the website design was the problem of navigation, i.e., selection of single or multiple locations grouped for analysis. The most common way users want to view data is by physical location. The solution chosen as a default navigation interface was a 'directory tree' similar to the one found in MS Windows Explorer®, in which users can click on tree levels to expand or collapse them to greater or lesser levels of detail. This tree view is based on certain fields in the location database. When adding a location, it is mandatory to enter values in these fields to enable the geographical navigation using the tree. For each location, a hierarchy consisting of institution, site (group of buildings), building, floor, room and location must be entered. By default, only the site and building level are shown. When the user clicks on any part of the tree, they are presented with an environmental risk summary on the right hand side of the screen. This summary shows all the locations in the hierarchy contained in or below the tree level that the user clicked. In this way, the user can review a group of geographically related locations, for example, all of the locations in a single building, or all of the locations in on one floor. It is also possible to select a group of locations based on any criteria stored in the location database using a 'search by' function (example: show all locations with objects belonging to the Modern Danish History Department) or 'search for' function (example: show all locations containing objects made from skin or fur). Reports joining multiple locations can be generated using a separate comparison function.

Environmental risk summary

After selection of one or more locations, the user is presented with a screen that summarizes the general environmental characteristics of the location. This is in the form of a color-coded environmental risk summary. This shows the list of locations and four columns labeled "Natural Aging',' Mechanical Damage',' Mould Growth' and "metal Corrosion'. Each of these columns can contain values of "Good" (colored green), "OK" (colored Gray) and "Risk" (colored red). These words and color codes are based on the environmental metrics calculated from temperature and RH data and listed in Table 1. They are a simplification based on either defined levels of a single metric (TWPI in the case of Natural Aging) or a combination of them.

Also shown in the Environmental Risk Summary is the time period used in the calculation of the metrics. The analyst always needs to know what span of time his or her analysis deals with. The IPI metrics are most informative when calculated for a years' span of time because usually the most important sources of environmental variation are seasonal. Integrating the analysis over a 12-month span gives a more accurate impression of the conditions and allows for easy comparison of one year with another. In the NMD project, the *MyClimateData* web prototype used pre-defined one-year time periods. For each location, the analyst could review graphs and metrics for each year in which data had been collected, as well as choose an integrated analysis of all the data over the entire logging period. By default, analysis of the most recent 12 months was shown.

The purpose of the Environmental Risk Summary is twofold. It is meant to be a quick presentation of the general preservation quality of the environment measured in each location. It allows the analyst to process lots of information at a glance and to report it in a simple, easy to understand way to non-specialists. The second purpose for the Environmental Risk Summary is to be an interface for detailed analysis of individual locations shown in the summary. Clicking on a location name brings up an individual location summary, where the analyst can choose from a number of different types of information, from graphs to photos, floor plans, and so on.

Conclusion

The NMD project is now in its final analysis phases. The metrics and risk summaries have made it possible to identify and rank various environmental risks to NMD collections, and the web database has made accessible a variety of useful collections management information.

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