

## Mellon Conservation Paper Conservation Research Project

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### Introduction

The Mellon funded meeting and report *Future Life of Collections*, 2004, identified three areas as being of the highest priority for conservation research in this field:

- Life-cycle prediction
- The storage environment
- Assessing damage to materials

The British Library prepared a collaborative research project to address these issues by the investigation of:

- The condition of identical books in different nationally-significant libraries
- The emission of acids by books and paper.

In December 2005, The Andrew W. Mellon Foundation awarded a grant of \$695,000 for the development of the conservation research agenda in the UK. The British Library (BL) led the project partnership with the 5 other Legal Deposit Libraries (LDL), Cambridge University Library (CUL), National Library of Scotland (NLS), National Library of Wales (NLW), Oxford University Library (OULS) and Trinity College Dublin (TCD), and The National Archives (TNA) and National Archives of Scotland (NAS). The project was planned to run from January 2006 to May 2009, culminating in an international conference at The British Library.

### Project plan and project reality

The project had three overall aims

- Estimating the effect of the past environment on the condition of library collections in order to predict future likely changes, starting in 2006. Centre for Sustainable Development, University of London.
- Measuring the volatile acids produced by ageing books in order to design systems to remove these damaging agents from stores, starting in 2007. Department of Pure and Applied Chemistry, University of Strathclyde
- The project would end with an international conference and a round table discussion on ways forward.

When the project started, the scope of work and methodologies were reassessed in the light of recent advances in paper science, enabling clarification of the questions to be addressed, while keeping within the overall scope. The implementation was split into six strands:

1. Choosing Identical Books (IBs): Types of books, choosing books by libraries, long-term use of identified books
2. Measurements by libraries: Methodology, sampling of books
3. Condition assessment: Current state of the art, using external academic researchers as contractors

4. Volatile Organic Compounds (VOCs): Current and novel methodologies, scoping VOCs produced by books, comparison with condition data, using external academic researchers as contractors, outputs and outcomes
5. Construction of model of paper degradation, correlating environmental with condition data, using external academic researchers as contractors
6. Capacity building: Training conservators (training trainers), building a community of research aware conservators, building and training external partners

<i>category/date</i>	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	<i>totals</i>
Art		2	2	3	2	2		2	2		2	17
Atlas	2	1	2	1	2	1	2	2	2		2	17
British Parliamentary Papers	5	6	2	1	2		2	2	2			22
Children's book	1	2	3	2	2	1	1	1	1		1	15
Reference book	1	2	2	2	2	2	2	2	2		2	19
Map	1	1	1	2		1	1	2	2		2	13
Music	2	2	2	2	2	2	2		1	2	2	19
Newspaper	1	1	1	1	1	1	1	1	1		1	10
Novel		1	2	2	2	1	1	2	2		2	15
Academic Journal	3	3	3	3	3	3	3	3	3		3	30
Popular Journal	3	3	3	3	3	3	3	3	3		3	30
Pulp fiction		2	1	2	1				3		2	11
CURL1905	19	1										20
CURL1915		16										16
CURL1925			19									19
CURL1935				20								20
CURL1945					24							24
CURL1955						22						22
CURL1975							19					19
CURL2005											17	17
<i>totals</i>	38	43	43	44	46	39	37	20	24	2	39	375

Table 1. Categories of publication chosen to reflect the range of papers used in the 20<sup>th</sup> century, with the number of items sampled for each decade, and available in every LDL. The CURL categories were randomly chosen monographs from the CURL database, with the search parameters of publication place – London, publication date - \*\*05.

## 1. Choosing Identical Books

The books to be studied were books published in the UK, 1900- 2005. The aim was to investigate the behaviour of the range of types of paper encountered in the collections. As it was not practicable to identify the type of paper in items as part of the choosing processes, the publication category was used as the surrogate measure of paper type, table 1. The target number of items was 400, derived from the statistical basis of the National Preservation Office's Preservation Assessment Survey methodology<sup>1</sup>. Work on the experimental design for the PaperTreat research project suggests that ca 1,200 items are needed for a statistically powerful random sample of books<sup>2</sup>. However after taking advice from epidemiological statisticians, this study deliberately targeted date and category series in order to use statistical analysis to identify trends in the data<sup>3</sup>.

The Legal Deposit Libraries are a unique and valuable resource. They hold, indefinitely, published books deposited under the UK copyright acts. Theoretically therefore they should receive identical copies of books from UK publishers. Only the BL receives every book by right, while the other LDLs have a right to receive items on request. As a result, the BL's copyright collection has the most complete selection of UK published books, though even this lacks some items. Each library had its own collecting priorities, for example the academic libraries concentrated efforts of collecting (and cataloguing) on academic publications. In some cases, losses have occurred by flood or fire. We were fortunate that other researchers had carried out investigations into some books published in the UK, particularly a set of British Parliamentary Papers<sup>4</sup>, which guided our choice in items to study.

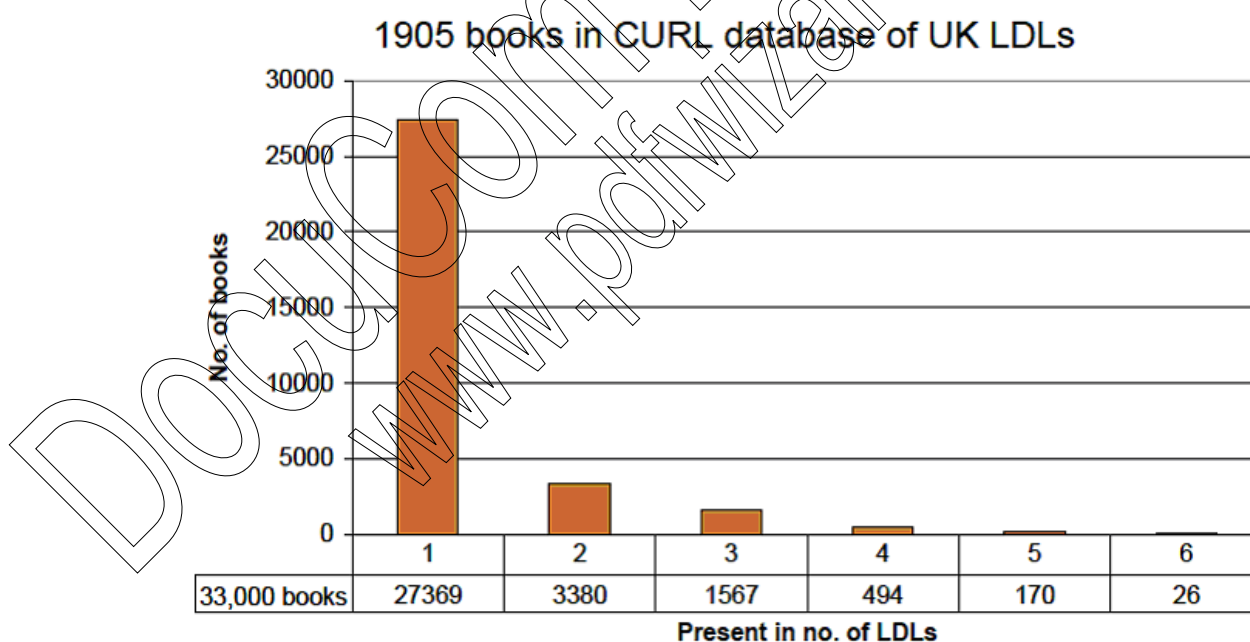


Figure 1. The CURL database was searched for items with publication place – London, publication date – 1905. The resultant output was manually sorted to identify 26 items common to all LDLs. Subsequent sorting of the CURL search outputs was carried.

The LDLs have different cataloguing policies and conventions. For instance, the BL has a single catalogue entry for its British Parliamentary Papers, dated 1805, and similarly for other serials. Individual issues are therefore invisible in searches by year. Initial searches of LDLs holdings used the computerised union database held on CURL servers<sup>5</sup>. The individual source databases are idiosyncratic. For instance, the NLW is undertaking a major retrospective input of its non-

Welsh books on card catalogues onto the computerised database, and had reached “D” at the time of the IB searches. Almost none of the libraries had externally accessible catalogues of their (large) music and map holdings. The CURL database showed that many of the books are catalogued in only one or two libraries, Figure 1.

The only practicable way to identify the actual holdings was to enlist the expertise, and time, of specialist curators in each of the libraries. Each library volunteered to create two of the required specialised lists, 4 items per decade. These were then circulated around the specialists in other libraries, missing items deleted and further items added, aiming to have at least 2 items per decade in each category, Figure 2. In parallel, the CURL database was searched for items by decade then manually sorted to identify further items, largely monographs. Some categories proved particularly difficult. For instance, a major newspaper has a succession of daily editions and multiple printing sites, making “identicalness” across libraries unlikely and often impossible to check. Copies of newspapers in some libraries had been subjected to conservation treatments.

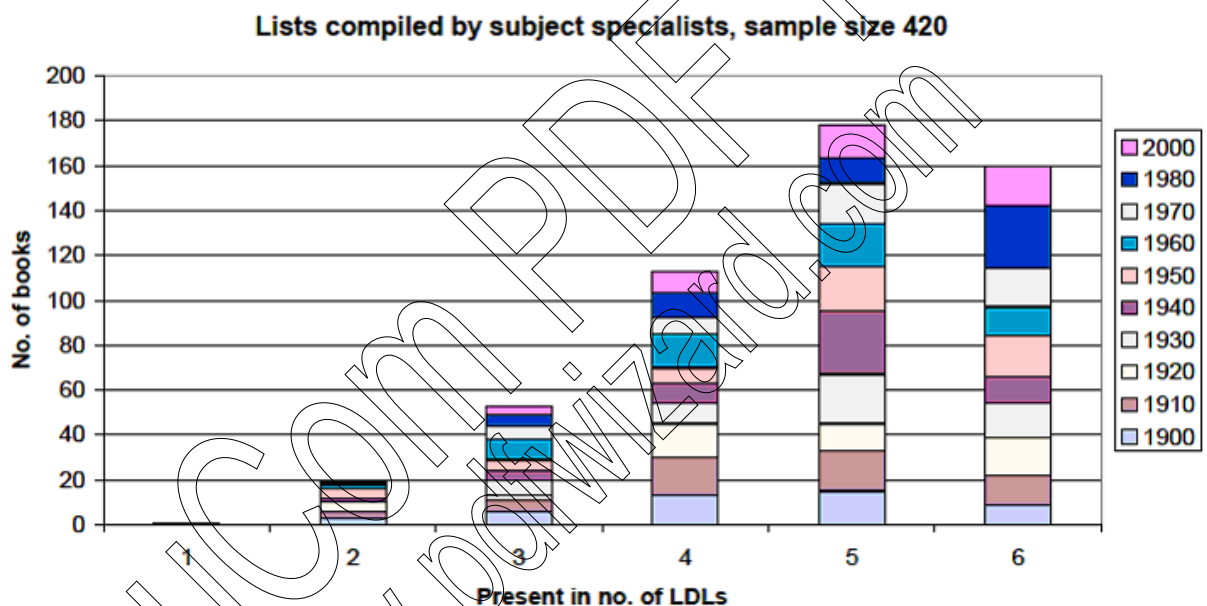


Figure 2. For each publication category, a list was compiled by a subject specialist in one library, 4 titles per decade. Specialists in the other libraries then checked if these items were present. The graph indicates the success in identifying items

Much of the initial identification of the books was made using catalogue records. During the next stage of the project, when calling the books to be measured in individual libraries, a number of items were found to be missing or to be variant editions. Although the “final” list had 376 items, 267 of these were found in all libraries. When a sample of 345 IBs at the BL and NLW were examined using the SurveNIR tool, two of the IBs pairs were found to be printed on different paper<sup>6</sup>. Also during the measurement stage, it was discovered that libraries had rebound many items, both serials and monographs. Apart from introducing variability in the materials of binding, rebinding had frequently included trimming of pages. Comparing the identical books was made less certain because a legal deposit item cannot be removed from its host library. The IBs were compared by photographs of the title pages and the measurement page, and the memory of the travelling researchers.

The choosing process, initially estimated to take 5 days, lasted 7 months, finishing in June 2007.

## 2. Measurements and sampling by libraries

The primary data gathering was carried out by nominated conservators in the libraries. A large amount of data was gathered in order to characterise the IBs.

**Identification:** The shelf number or other unique identifier of the IB was recorded, in order to distinguish between multiple holdings of a title. Photographs were taken of the title page and the measured page, before and sampling. In retrospect, a photograph of the cover and measurements of the text block would have been useful. The storage location was recorded. Each IB was given a unique identifier, e.g. Whitaker's Almanack (1903) was BL211, with the letters indicating the library and the number being the same across all the libraries. In order to reduce variability between measurements, the following protocols were used.

The same page in each of the IB sets was used, with the page on the right when the volume was opened. A page was chosen to be at least 15 leaves from the endpapers, to reduce the effect of contamination from the binding case<sup>7</sup>. For some of the items with few pages such as music or pamphlets, this was not possible.

**PAS:** Part of the NPO PAS methodology was used to carry out a visual evaluation of individual volumes, condition of the bindings and text block. Categories of damage are physical, biological, chemical and result of repairs, measured on a scale of 0 (minor) to 2 (severe).

**Colour:** Measurements were made at two locations on one page, using a Konica 2600 reflection spectrophotometer.

**Samples:** For most of the libraries a sample was taken at two locations on one page, while for BL and NLW an additional two samples were taken adjacently. For many of the libraries, the taking of samples from collection items was unprecedented. We are grateful for their acceptance of the principle and their cooperation in developing the criteria and methods for sampling.

Samples were taken from the page in the gutter, near the top edge and near the middle, designated like BL211-T and BL211-M. The samples were taken with a sharpened hypodermic needle, creating a sample and hole ca 1mm in diameter. The samples were placed in labelled centrifuge sample tubes, Simport T330-7N ClikLok 1.5ml tubes. One (aborted) research line addressed the take-up of sulfur by the paper in the books. A duplicate set of samples for this study were taken from the BL and NLW IBs, using the templates.

Templates were constructed for each page to be measured<sup>8</sup>. A sheet of Melinex (transparent polyethylene terephthalate) had holes punched to locate the positions of colour measurement (6mm diameter) and sampling (3mm diameter). Initially the sheet was located on the page by folding the sheet so that it fitted snugly over the top and fore edges. Unfortunately, this system of location failed for books whose edges had been trimmed. The template sheet was modified by marks locating text blocks so that it could be lined up with significant text on the page.

A measurement kit and instructions were constructed to send around the libraries. This included the templates, the Konica, computer, camera, sampling materials, and pH measuring equipment.

Conservators were nominated from each library to carry out the measurement. These conservators were trained together (February 2007) in the project procedures and the techniques of measurement. They were also trained to take micro-pH measurements, but this technique

proved too delicate and difficult to carry out in multiple sites. There were relatively few changes in the conservators involved during the process.

Each library in turn collected together their IBs. When the measurement kit arrived, the procedures were revisited, lessons learned from previous measurements and any difficulties sorted out. These inter-library visits proved very valuable in discovering different curatorial practices and the history of collections which affected their condition.

The main campaign of measurements started in May 2007, finishing January 2008, with final measurements of missing items in February 2009

### **3. Condition assessment**

Three measures of the state of the paper were evaluated, the fibre make-up of the paper (the furnish), the pH of a micro sample, and the molecular weight of the sample. The original plan was for trained conservators to carry out the pH measurements on the micro-samples. Unfortunately, this proved impracticable. Most of the samples were assessed for pH, a pair of IB collections were assessed for furnish and, because of cost limitations, only a number of sets (BL, NLW, TCD) of IB samples were measured for molecular weight.

Preliminary experiments on the sulfur distribution across a book page indicated that levels fell from a maximum to background levels within 5mm from the external surface. Unfortunately, trimming of the edges at an unknown date and consequent ambiguity of the sampling position meant that sulfur measurements in the samples could not be correlated with position. These measurements were therefore not carried out.

Towards the end of the measuring period, the SurveNIR measuring tool<sup>9 10</sup> became available. Spectra and derived estimates of furnish, pH, molecular weight etc were obtained for the BL and NLW IBs, with measurement positions at the top right corner and middle of the page.

### **4. Volatile Organic Compounds**

The original proposal was to carry out an innovative survey of stores in the institutions, alongside some measurements of the VOC emissions from books. During the recasting of the project, the emphasis was reversed to focus on quantifying VOC emissions from the IBs. This work was led by Dr Lorraine Gibson of Strathclyde University.

Each institution chose 2 storage areas and an internal circulation area for study. Strathclyde developed a VOC collection kit that could be deployed without a specialist analyst being present. The kit comprised diffusion tubes to collect organic acid and aldehydes, and a pumped Tenax tube. Conservators were trained in the techniques, deploying and returning the tubes for analysis.

Previous researchers had shown that the emissions of VOCs from papers and books showed differences. It was postulated that the pattern of VOCs from an item can be correlated with its composition, history, age and condition. If the correlation can be established, measurements of VOCs might be used to establish the condition of an item or collection, using completely non-contact methods, perhaps automatically.

Methods for quantifying VOCs from books were developed, described more fully in other contributions to these proceedings. Previously used methods had included collecting VOCs on a number of absorbing chemicals, such as SPME (solid phase microextraction) fibres and Tenax tubes then analysing using gas chromatography –mass spectrometry. All these are selective absorbers and are difficult to tie to absolute concentrations in a book or in air. Methods were sought that could quantify the VOC concentrations in order to establish significant markers for the evaluation of the books.

Using sub-ambient thermal volatilisatation analysis (SATVA), all the VOCs present in a book were extracted and partially separated. This is enabling the quantification of the VOCs in total and individually. In parallel, two emerging technologies were explored for potential for assessing items within a few seconds. Field Asymmetric Ion Mobility Spectrometry (FAIMS)<sup>11</sup> is available as a portable device which provides a fingerprint of VOCs. Selected Ion Flow Tube Mass Spectrometry (SIFT-MS)<sup>12</sup> provides absolute concentrations of VOCs in air samples. Both require calibration of the analytes of interest for book and paper conservation and, as with other techniques, have different strengths and weaknesses. They can quantify analytes that are not accessible with GC-MS.

The VOC work attracted a Natural Environment Research Council grant to access the Molecular Spectroscopy Facility at the Rutherford Appleton Laboratory. The aim was to investigate laser spectroscopy to identify low levels of VOCs. However, preliminary investigations revealed and quantified emissions of carbon monoxide from books, which had not been found previously.

## **5. Environmental modelling**

The environmental modelling was carried out by the Centre for Sustainable Heritage, University College London.

The original proposal was to correlate the current condition of the IBs with their environmental history. A preliminary survey of the LDLs would reveal which had the most useful historical data on the internal and external environments, and building changes. Unfortunately, few surviving environmental records were more than 15 years old and there were few records of building changes that would enable estimations of the resulting changed response to the external environment, which itself was poorly documented for periods more than 30 years ago. Even if it had been possible to reconstruct the environmental history of individual library buildings, the normal, unrecorded, movement of collections around libraries made a coherent environmental history of an individual item impossible to unravel. To provide data for the current project and to start the process of data collection for future, year long surveys of relative humidity and temperature distributions were measured in stores and circulation areas in the BL and NLW.

It is known that a major cause of damage to paper is historic exposure to sulfur dioxide. A study of the short term and year long concentrations of sulfur dioxide, nitrous oxides and ozone was therefore established in the same stores in the BL and NLW. These libraries had been subject to pollution research as part of the British Leather Manufacturers' Research Association 1930s long term study into leather book binding deterioration, followed up by the ENVIRONMENT project<sup>13</sup>. These results were to be calibrated with the sulfur analyses of items from those areas. Although sulfur analyses of paper from the IBs would not have been valid, the pollution measurements provide a valuable additional record of the long term conditions of storage.

There is considerable interest in the British Library's Additional Storage Building at Boston Spa, which uses a low oxygen atmosphere to stop combustion. Accelerated ageing experiments on a variety of papers at low oxygen were carried out to help judgements about the difference in rate of change due to the new storage conditions.

## **6. Capacity Building**

A major purpose of the project was to improve the capability for use and understanding of research in the libraries and archive sector. The Mellon project built upon a network of connections established over a number of years. The National Preservation Office and related initiatives had brought the libraries and archives together in order to build mechanisms for collection care, wider than individual institutions or sectors. The BL was a collaborator in the major European Union PaperTreat<sup>14</sup> and SurveNIR<sup>15</sup> research projects. The redesign and implementation of this project benefited considerably from these contacts, their expertise and enthusiastic support. The input of an international expert Advisory Panel was significant in ensuring the aims and methods were current and relevant.

The BL's research strategy for conservation research is to develop long-term partnerships with high quality academic (and other) researchers at the forefront of their subjects. The number of such partnerships is limited by the number of initiatives that can be accommodated with the internal priorities of the BL. Two such partnerships (with University of Strathclyde and University College London) were included in the original proposal. Others were explored during the project, with successful collaboration achieved with three small enterprises, Morana, Owlstone Nanotechnology and Syft Technologies. The resulting technical insights and methods of approaching problems have improved conservation science at the BL and the other partners.

Within the libraries and archives, the scientific input has added considerably to their knowledge of collections and their care. The work has highlighted the importance of the material aspects of the collections and demonstrated the methods of analysing these aspects, using both non-destructive and sampling techniques. Staff in all parts of the libraries enthusiastically participated in this project, from bench conservators to curators to facilities managers. There is considerable will to carry scientific collaboration forward.

The extensive, successful, collaboration both between the partners and the researchers has attracted attention from the overseas library and archive community, resulting in invitations to speak in conferences at La Bibliothèque nationale de France and the Library of Congress, the latter being followed up with a week at the LC to develop a joint research strategy. Similar invitations have been received within the UK.

Researchers outside the library field have shown interest. A presentation has been made at a Sensors Knowledge Transfer seminar and a poster will be given at the major International Union of Pure and Applied Chemistry in Glasgow.

The project has demonstrated research excellence with the library and archives and the wider cultural fields, at a time when the relationship between Science and Heritage in the UK has received considerable attention and funding.

## **Conclusions**

The research results are already proving useful. Methods being developed for VOC analysis are being applied in the development of protective packaging for the BL's Newspaper Project. Knowledge about the (lack of) effect of reduced oxygen on paper deterioration rates is useful in developing alternative strategies to increase the life time of collections.

The final conference brought together some of the main players in the field, who put the results and achievements of the project in a wider context. Although the scientific papers arising from the project will take the topic forward considerably, the mass of collected data will be mined for years to come, with new questions and concerns in mind. We shall be making the data available on the BL web site.

## **Acknowledgements**

This project would not have been possible without the active involvement of a large number of people. It has truly been a multi-disciplinary, multi-author, effort, challenging and immensely rewarding because of the enthusiasm of the participants.

Contributors to the initial discussions led to the publication of "Future Life of Collections".

The partners developed the project proposal and oversaw its fulfilment: Helen Shenton, Barry Knight (BL), Alan Farrant, Brian Jenkins (CUL), Linda Ramsay (NAS), Iwan Meical Jones, Alan Vaughan Hughes (NLW), Rab Jackson (NLS), David Howell (OULS), Suzie Bioletti (TCD), Nancy Bell, Kostas Ntanos (TNA).

Staff in the partners' institutions put in far more time and energy than could be expected:

Giordana Santoro, Almut Boehme (NLS), Richard Price, Caroline De Stafani, Stephen Seargeant, John Tuck, Andra Patterson, John Lowery, Clive Billenness (BL), Deborah Farndell, Jim Bloxham, Andrew Alexander (CUL), Saho Arakawa (NAS), Huw Bonner, Dilwyn Williams, Brian Dafis (NLW), Kristie Short-Taylor, Sandrine Decoux (OULS), Andrew Megaw, Matt Hatton, Barbara McDonald, Charles Benson (TCD).

Members of the International Advisory Panel were essential in testing and refining our developing ideas: Nels Olson, Eric Hansen (Library of Congress), Gerhard Banik (Staatliche Akademie der Bildenden Künste Stuttgart), John Havermanns (TNO, Netherlands), Henk Porck (National Library of the Netherlands).

The number of scientific collaborators grew during the project, adding to the richness of the input and outputs: Jana Kolar (Morana RTD, Slovenia), Matija Strlič, Nigel Blades, Phil Biddulph, May Cassar (Centre for Sustainable Heritage, UCL), Lorraine Gibson, Jim Lewicki, Claire Robinson, Kirstie Shields (University of Strathclyde), Greg Francis, Stephen Guilfoyle (SYFT UK), Max Allsworth, Chris Prior-Jones, Billy Boyle (Owlstone Nanotechnologies), Andy Smith, Robert McPheat, Pavel Matousek (Rutherford Appleton Laboratory), Dirk Lichtblau (ZFB, Leipzig).

Interns from University of Texas at Austin: René Payne, Rebecca Holte.

We received help and advice from many external sources: Naoko Sonoda (National Museum of Ethnology, Osaka), Chris Pond (House of Commons Library), Alison Walker (National Preservation Office), Olga Tolstikova (Library for Foreign Literature, Moscow), H K Kaul (Delnet-Developing Library Network, New Delhi), Sarah Davenall (Consortium of University and Research Libraries), Peter Brimblecombe (University of East Anglia), Chris Calnan (National Trust), Christiane Baryla (IFLA-PAC), David Broadhurst, Chris Carr (University of Manchester), Robin Higgons (Sensors & Instrumentation Knowledge Transfer Network), participants in the SurveNIR and PaperTreat projects, Tim Padfield, Philip Eden, Tom French.

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- <sup>5</sup> We are grateful to Sarah Davanall and colleagues at the Consortium of University and Research Libraries database in Manchester for assistance in interrogating the database in an unconventional manner.
- <sup>6</sup> Dik Lichtblau, *The surveys at the National Library of Wales (NLW) and at the British Library (BL)*, unpublished report ZFB, (2009)
- <sup>7</sup> We are grateful to Dr Matija Strlic for this advice.
- <sup>8</sup> Giordana Santoro of the NLS ably prepared the templates and visited each library for their measurement campaign.
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