Collection Forum

SPNHC

Society for the Preservation of Natural History Collections

Winter 2001
Volume 15
Numbers 1–2

Collection Forum, the official journal of the Society for the Preservation of Natural History Collections (SPNHC), is published twice a year to disseminate substantive information concerning the development and preservation of natural history collections. The journal is available by subscription ($30US per year) and as a benefit of membership in SPNHC ($25US per year for individuals; $50US per year for associate members). Address all communications involving membership dues and subscriptions to the SPNHC Treasurer.

Collection Forum (ISSN 0831-5) is published by SPNHC, PO Box 797, Washington, DC 20044-0797, USA. POSTMASTER: Send address changes to *SPNHC* % Lisa Palmer, PO Box 797, Washington, DC 20044-0797, USA.

∞ This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).

PRIORITIES FOR NATURAL HISTORY COLLECTIONS CONSERVATION RESEARCH: RESULTS OF A SURVEY OF THE SPNHC MEMBERSHIP

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Abstract.—The SPNHC membership was surveyed to develop a list of priorities for natural history collections conservation research. The survey was mailed to 548 individual and institutional members and 229 responses (42%) were analysed. Ten topics were identified by at least half of the respondents with above average priority ratings. Additional topics were rated as priorities for transfer of information, with special attention given to conservation of documentation. These priorities reflect research needs that serve multiple disciplines and complement priorities identified for conservation research in art and historical collections. This paper represents the report submitted to the agency that funded the study in fulfillment of the grant requirements.

EXECUTIVE SUMMARY

The Society for the Preservation of Natural History Collections (SPNHC) is a multidisciplinary international organization composed of individuals and institutions who are interested in the development and preservation of natural history collections. Under the direction of the SPNHC Conservation Committee and its Research Subcommittee, the project coordinator surveyed the SPNHC membership by mail to develop an updated list of priorities for natural history collections conservation research. This report summarizes background information, development and implementation of the survey instrument, results and data analysis of this project.

The survey instrument was developed with input from a core group of 40 professionals. The results from a previous multidisciplinary project on the conservation of natural science collections (Duckworth et al. 1993) and projects on conservation research needs conducted by the American Institute for Conservation (Derrick 1996, Hansen and Reedy 1994) were used as a guide for the development of topics for research and/or transfer of information. Given the variety of disciplines and job functions represented within the SPNHC membership, the survey was structured to permit analysis of respondents' most critical needs based on their job functions and type of materials.

The survey was mailed to 548 individual and institutional SPNHC members in September, 1999. From the 244 surveys returned, 229 were used for analysis, representing 42% of the membership. Responses were analysed and tables included in the report show percentages and weighted averages for research priorities. Sixteen topics were rated with an above average priority rating. Ten of these topics were selected by at least half of the respondents as the highest two ratings:

- Impact of preparation materials and methodologies on chemical and physical properties of specimens;

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- Impact of preparation materials and methodologies on scientific utility of specimens;
- Development of preparation methodologies that maximize scientific utility of specimens;
- Impact of treatments on the scientific utility of specimens;
- Methods to assess systematically the condition of specimens over time;
- Methods to assess systematically the condition of a collection of specimens over time;
- Methods to assess risks to collections to rationally identify priorities for collection preservation investments and research;
- Proper relative humidity and temperature parameters for general collection;
- Materials specifications for containers;
- Methods for repair/restoration of damaged specimens.

All of these topics should be given the highest priority for natural history collections conservation research. Additional topics were rated as priorities for transfer of information (Table 5), with special attention given to conservation of documentation (Table 8).

Background

Natural history conservation is among the newest fields of conservation even though natural history specimens are among the most common of objects found in museums, visitor centers, and interpretive sites, numbering more than 2 billion worldwide (Howie 1993). Although there are the ubiquitous mounted specimens of birds and mammals, the bulk of natural history collections consists of research material reflecting the disciplinary specialties of natural science interests and research: anatomy, botany, entomology, evolutionary biology, geology, herpetology, ichthyology, invertebrate zoology, mammalogy, mineralogy, molecular biology, ornithology, paleontology. Natural history research collections can consist of the hundreds of thousands of specimens in a single institution, with only a small percentage (usually less than 1%) of the total representing "exhibit quality" material. These specimens document variation over time and space; they are irreplaceable as one can never travel back in time to collect sites that have become interstate highways or the foundations of schools. The value of natural history collections continues to grow as habitats disappear, geological and paleontological sites are destroyed, or as species become extinct (Cato 1990).

Our ability to learn from samples of our natural history diminishes as various agents speed their decay and destruction. It is essential that the conservation profession apply its collective knowledge and skills to improve the life expectancy of natural history specimens in museum collections. The needs of natural history specimens focus on a range from the treatment of individual specimens to the issue of providing the best storage environment for whole collections consisting of thousands of specimens. Preservation requirements also must address through research the myriad of materials that comprise natural history specimens: organics, inorganics, and composites (Duckworth et al. 1993).

Professionals working in the field recognize the need for accurate, useful information to improve preservation and conservation methodologies for natural history specimens. This is evident from the results of the 1989–1993 project supported by the National Science Foundation, the National Institute for the Conservation of Cultural Property (NIC), the Association for Systematics Collections (ASC), and the Society for the Preservation of Natural History Collections (SPNHC). This project brought together at a national level representatives from various natural science disciplines with conservation and materials science experts to discuss not only the conservation needs for collections and specimens, but areas of concern that needed to be addressed through research and the transfer of existing information in other fields. Natural history disciplinary and specialty groups were contacted, and more than 12 meetings held with the following groups to discuss needs and priorities: Mineral Museums Advisory Council; U.S. Federation of Culture Collections board; American Society of Mammalogists; American Society of Ichthyologists and Herpetologists; Council of Systematics Malacologists/American Malacological Union; American Institute of Biological Sciences; Mycological Society of America/Bryological and Lichenological Society/American Fern Society; American Society of Parasitologists/Society of Nematologists; American Ornithologists' Union; Paleontological Society/Society of Vertebrate Paleontologists; Mineralogical Society of America; Entomology Collections Network/Entomological Society of America; and Material Sciences panel. It becomes obvious, just from this listing of groups, that the variety of materials found in natural history collections are the result of an enormous range of project goals, collecting methodologies and protocols. It could be predicted that the range of concerns and preservation priorities would also be substantial.

Collection care needs and issues of concern raised during the various disciplinary meetings were summarized in a series of unpublished reports. These individual reports were used by the NIC project group to develop an extensive list of needs for preservation research and technology transfer that were organized into four divisions: fluid-preserved specimens, inorganic/organic matrices, plant material, and animal material. This list of research information needs is so extensive as to be overwhelming, yet valuable in providing an organized sense of the overall needs (Appendix B. Recommended Topics for Research and Technology Transfer in Duckworth et al. 1993).

The final report from this project, "Preserving Natural Science Collections: Chronicle of Our Environmental Heritage" (Duckworth et al. 1993) provides an excellent presentation for the need for conservation, the problems faced by stewards of natural history specimens, and the need for improved training and research in the field of natural history conservation. Although it lists and organizes the needs for conservation research in a general manner, it does not concentrate sufficiently on prioritizing those needs to provide guidance for researchers or to support funding requests for research projects. In addition, there has been progress in the field of conservation since the beginning of the NIC project, and many of the research topics may have been dealt with, at least indirectly. The Research Subcommittee of the SPNHC Conservation Committee felt it important to review the issue of priorities for natural history collections conservation. Thus it initiated a project to identify current priorities, looking at changes since the initiation of the NIC project in 1989 and its final publication in 1993, and efforts to identify research priorities in the related areas of conservation of art and cultural collections.

The primary objectives for this current project were to gather information through a literature search; to solicit input from active professionals working with collections care and conservation research for natural history collections; and to write a report summarizing and describing research priorities for natural history collections conservation. The literature search focused on published material relating to priorities and progress in the conservation of natural history collections with a particular emphasis on articles appearing since the 1993 publication resulting from the NIC project. Input from professionals was sought at two levels. (1) A core group of 40 individuals composed of the SPNHC Conservation Committee, SPNHC Executive Council, and several independent collection managers and researchers provided the first level of recommendations, comments and feedback through e-mail, letters, phone calls, a discussion meeting, and a pilot mail survey. (2) Using a mailed survey that had been tested by the core group, the SPNHC membership was then surveyed in order to gain a broader perspective through the input of individuals working in multiple disciplines and having differing job priorities.

Literature

Since the beginning of the NIC project in 1989, there has been an increase in the literature with respect to (1) clarifying the philosophical basis for natural history collections conservation and management; (2) formalizing the terminology and policies affecting natural history collections management; and (3) specific studies investigating the materials and methods used in natural history collections management and conservation. In addition, the American Institute for Conservation has supported and published research priorities that reflect conservator-driven needs for the specialties represented within AIC (Derrick 1996, Hansen and Reedy 1994).

The philosophical basis for the care of natural history collections was summarized in the "Guidelines for the Care of Natural History Collections" (Society for the Preservation of Natural History Collections 1994). Endorsed by the SPNHC Council, these guidelines were developed with the input of numerous professionals associated with the use and care of natural history collections. The first section of these guidelines clearly states the parameters that make these collections unique and how that uniqueness affects care and management of the collections. Part of the uniqueness of these collections originates with the idea that the inherent value of the specimen depends on *use*; the intended use dictates both the initial and the subsequent specimen preparations, and scientific research using the specimens enhances the value of the specimens. However, there is also recognition by professionals of their obligation to maximize the value of each specimen for future uses. Thus, there needs to be a balance between use and preservation, balancing the competing demands of today's use with future uses.

Another parameter is the *size* of these collections. Decisions made to conserve and manage these collections must take into account the vast size of most collections. Specimens are acquired in series and stored, handled, and used as part of a group. It is the rare exception that a single object or specimen is accorded the detailed scrutiny of a conservation assessment that might be given an object in an art or historical collection. The issue of size of the collections has been the driving force behind the growth of preventive conservation in natural history collections management, an approach discussed by Rose and Hawks (1995) and others in the volume, *Storage of Natural History Collections: A Preventive Conservation Approach* (Rose et al. 1995).

Williams and Cato (1995) emphasized the need to interweave the institutional functions of research (specimen use), collection management and conservation to maximize the long-term survival and value of natural history collections. Professionals who work in these functional areas approach the use and care of collections from differing perspectives, but it is necessary to achieve effective interaction of these different viewpoints in order to serve the long term needs of the collections. Conservation of collections can be effective only if it is inclusive and takes into consideration the perspectives of management and specimen use.

The issue of managing and caring for vast collections effectively has been approached as well using the principles of risk management. This philosophical approach, developed for natural history collections by Waller (1995), stresses the need to develop decision-making tools that are based on rational and analytical approaches. Recognizing the competitive pressures of limited critical resources and the need to preserve huge numbers of specimens, decision-making tools based on risk management can provide a more objective basis for analyzing an institutional situation. Specific examples of tools and applications reflecting this approach include those offered by Price and Fitzgerald (1996) and Williams, et al. (1996).

In addition to contributing to the philosophical basis for natural history collections management and conservation, the last few years have seen an increased emphasis in the literature on terminology and the formalization of standards and policies for various aspects of natural history collections management and care. When professionals in disparate fields begin to work together, there are frequent misunderstandings because of a lack of common definitions for a term. As an example, the terms conservation, preparation, and treatment have different definitions depending on one's perspective as a conservator, a collection manager, or a researcher in the natural science disciplines. Glossaries such as found in *Guidelines for the care of natural history collections* (Society for the Preservation of Natural History Collections 1994), and Rose et al. (1995) expand on terminology defined in Duckworth et al (1993) and Rose and de la Torre (1992). These glossaries help to improve the level of mutual understanding among conservators, collection managers and researchers, and are essential if conservation research is to play an active role in assisting the professional community to preserve natural history collections.

Standards and guidelines for developing policies for institutions housing natural history collections have been formalized and published by the Museums and Galleries Commission (1992a, 1992b, 1993), Cato and Williams (1993), and the Association for Systematics Collections (Hoagland 1994). These publications not only reflect the wide range of institutional concerns, but also particularly reflect issues that had not previously been addressed, such as sampling and destructive testing, preventive conservation, specimen treatment, and use of specimen data. Natural history collections conservation occurs within the context of both institutional and scientific discipline frameworks, and the development of professional standards and guidelines in these areas directly impacts the development of natural history conservation and its conservation research priorities.

The number of published studies investigating various aspects of natural history specimen preparation, storage, management and conservation has increased since the 1980s, but is still very small. As an example of a typical computerized bibliographic search using the Conservation Information Network on the Canadian Heritage Information Network (CHIN) for the years 1993–1999, an effort to find published research relating to the conservation of mammal collections using the keyword, mammal, resulted in 27 hits. Only 16 dealt with topics relating to conservation and/or preservation, and 5 of these were case studies. Of these 16 conservation-related articles, five were published in *Collection Forum,* two in *Geological Curator,* three in the *Journal of Archeological Sciences,* and one each in six other sources. The two in *Geological Curator* pertained to mammalian fossil material, and the three in the *Journal of Archeological Sciences* related to mammalian finds in zooarcheological sites, with minimal discussion of preservation.

During the period, 1993–1999, approximately 48% of the articles published in *Collection Forum,* the professional journal for SPNHC, reported on completed research, or on progress made in the analysis of materials, or on procedures used in the preparation and storage of specimens. This is a significant increase over the very small numbers reported in the past (Cato 1988). However, given the small size of *Collection Forum,* the total number of articles for this research arena is still quite limited.

Relevant conservation research, news and case studies have been published in a variety of other professional outlets as well, including: the *Journal of the American Institute for Conservation* (JAIC), *Geological Curator, Biological Curator, SPNHC Leaflet* series, *SPNHC Newsletter, Natural Sciences Conservation Group Newsletter, Natural History Conservation, Conserv-O-Gram, Conservation News, Journal of Archeological Science,* and the *Journal of the International Institute for Conservation-Canadian Group* (J. IIC-CG). The quantity and availability of information from conservation research reported in these other journals that is directly pertinent to natural history collections conservation through these avenues is small. Although several of these journals and newsletters focus on natural history, their circulation is small and their availability is limited. The ones that are more general, and have a larger circulation, have very few articles pertaining directly to natural history objects.

There also has been an increased effort to publish books reviewing the state of knowledge, and workshop proceedings on topics pertaining to areas of natural history collections conservation (e.g., Metsger and Byers 1999, Collins 1995, Rose et al. 1995, Child 1994a, 1994b). Williams (1999) reviews the effects of standard preservation techniques, concluding that many are in fact destructive and interfere with the potential scientific value of the specimens. These publications are particularly useful for the wider dissemination of information and for increasing the awareness of professionals to areas of need and concern. Most highlight or discuss areas of natural history collections conservation that need further research to determine the effectiveness or impact of existing procedures and techniques on the long-term preservation and scientific utility of specimens.

Finally, the fastest growing tool for dissemination of information has been web sites such as CoOL (Conservation OnLine; <http//palimpsest.stanford.edu/>) and the Heritage Forum: Resources section of the Canadian Heritage Information Network (<www.chin.gc.ca>). Not restricted to a single discipline, sites such as these encourage transfer of information among disciplines.

Development and Implementation of the Survey

Development of the survey instrument followed standard procedures for questionnaire design, beginning with input by the core group to focus the content and approach. This group received copies of relevant sections of three publications (Duckworth et al. 1993, Hansen and Reedy 1994, Derrick 1996) to initiate discussion; members were asked to consider terminology, gaps and areas of overlap in the framework presented by Duckworth et al. (1993), and how to best identify top priorities. Comments were received by e-mail, mail, and during a discussion at the Conservation Committee meeting (June 1999, annual SPNHC meeting).

The initial comments were varied. There was general support for the approach taken in Duckworth et al. (1993) because the categories were relevant to those who manage and use the collections. It was noted that priorities need to be defined in the context of the needs of the profession, and how the collections are to be used. Because a basic premise in the development of natural history collections is for the use of specimens, it was felt that the terminology of this survey would need to be different from that used by the AIC surveys which emphasized art and cultural materials collections. Several individuals noted that in the Duckworth et al. (1993) listing, many of the topics listed for research were very specific, too much so to be considered a profession-wide priority. A few noted that research has been done in several of the areas listed, and that the priority now should be to transfer the information to the natural history collections field.

The group's primary recommendations, therefore, were that (1) the objective of the research priorities be goal oriented not merely specific research topics; and (2) the priorities must reflect research that would have the biggest impact on the collections as a whole. The survey needed as well to indicate the primary focus of the respondent's work, such as, collection manager, curator, conservator, registrar, or administrator. An earlier survey by SPNHC (Cato 1991) identified these categories as distinct, relevant functional areas, regardless of job titles. It was also recommended that the survey be designed to permit analysis based on the perspective of the respondent given the scientific discipline(s) he/she works with and the degree to which he/she focuses on different materials. These distinctions are necessary in order to clarify the difference between the functional organization of most natural history collections (e.g., mammals vs. birds vs. fossils, etc.) from the material science approach of conservation (protein-based animal materials, inorganic materials, etc.).

With these recommendations, a four page pilot survey was designed. After review by the Chair of the Conservation Committee (D. Dicus) and the Chair of the Research and Technology Subcommittee (D. von Endt), the pilot was revised, then mailed to 32 members of the core group. The recipients were requested to (1) respond to the survey, and (2) comment on the content, wording and structure of the survey itself. Based on responses and comments from 16 individuals (8 collection managers, 8 conservators/conservation scientists), the pilot was revised and the final survey (see appendix) was prepared for mailing to the SPNHC membership.

An effort was made to balance the terminology and wording of the questions in the survey between the needs and perspectives of those who use the collections, and approach issues of collection care from the background of management or

Table 1. Percentage of respondents selecting ranking numbers 1 or 2 for listed materials.

Priority scale	1	1 + 2	Average
Animal materials	47.8%	60.1%	2.4
Fluid-preserved specimens	16.2%	32.5%	3.5
Inorganic materials	19.3%	28.9%	3.7
Plant materials	17.5%	25.9%	3.7
Inorganic/organic complexes	15.8%	23.2%	3.8

natural science-disciplines and with those who view collections from a background of materials science. The first half of the survey targeted broad priorities; the second half focused on whether a series of more specific topics should be the focus of research or transfer of information. At the end of the survey, a short series of questions asked which topics relating to conservation of documentation would be most useful for workshops or publications focusing on the perspective of natural history collections. (It was felt by the core group that most topics involving the conservation of documentation had been well researched already, but that technology transfer was critical.) In each area, respondents were given the opportunity to provide additional suggestions.

Surveys were mailed to 548 individual and institutional members of SPNHC. From the 244 surveys returned, 229 (42%) were used for analysis. The survey responses that were not used for analysis included five returned due to wrong addresses, and five from individuals who indicated they were not directly involved with natural history collections conservation and did not feel adequately informed to respond. Some questions were not answered by all respondents; results were analysed on the basis of the number of responses to the particular question.

Results

Almost half of the respondents (47%) work primarily with only one discipline, whereas 25% work with five or more disciplines. The majority of respondents (57%) described their work as collection manager, 22% as curator, 10% as conservator, and 11% marked the "other" category. The latter included 19 different job titles; five listed "registrar" and five listed administrator-type titles (e.g., director, administrator).

Respondents were requested to indicate the degree to which their priorities focused on each of five categories of materials. These categories were not intended to be exclusive, recognizing that the majority of respondents work with multiple types of materials. Using a relative scale (1 to 5, greatest to least priority) almost half indicated animal materials comprised a significant priority, with a priority ranking of 1 (Table 1). The other types of materials were considered to have a high priority by at least 15–20% of the respondents. When the top two priority rankings are considered, fluid-preserved specimens are rated by almost one-third of the respondents as a high priority; as this category might include animal, plant, or geological samples, it reflects a broad interest. The weighted average for each material was also calculated; a lower number means a higher priority, and the value of 3 is considered to be a moderate priority.

Table 2 summarizes responses to the survey questions to assign a priority rating for each of 30 topics in the areas of specimen preparation, post-preparation treat-

Table 2. Summary of priority ratings for 30 topics (n = 229). Sixteen above average priorities are indicated by an asterisk (*).

Research topics	% respondents Rating = 1	Rating = 1 + 2	Weighted average
Specimen preparation			
Impact of preparation materials and methodologies on chemical and physical properties of specimens	33.0	56.2	2.5*
Impact of preparation materials and methodologies on scientific utility of specimens	33.8	62.3	2.3*
Development of preparation methodologies that maximize scientific utility of specimens	28.1	57.0	2.4*
Post-preparation treatments			
Methods to assess systematically the condition of specimens over time	24.8	53.1	2.5*
Methods to assess systematically the condition of a collection of specimens over time	24.8	50.5	2.6*
Effect on specimens of adding and/or changing storage fluids	11.9	26.0	3.4
Techniques to clean specimens (e.g., greasy bone; specimens stained by pollutants, mold)	17.5	42.9	2.9*
Mechanisms of oxidation reactions	8.3	19.2	3.6
Methods to mitigate sampling of specimens for discipline-based research	7.4	27.5	3.3
Methods for repair/restoration of damaged specimens	26.2	58.5	2.5*
Impact of treatments on the scientific utility of specimens	20.1	56.3	2.5*
Understanding specimen/collection damage & functions			
Impact of pest control methods on chemical and physical properties of specimens	19.3	46.9	2.9*
Long-term impact of pest control residues on scientific utility of specimens	11.4	40.8	3.1
Proper relative humidity and temperature parameters for general collection	36.7	69.0	2.1*
Optimal parameters for particularly sensitive materials	10.9	30.1	3.1
Effects of visible light, infrared, and ultraviolet radiation on specimens	13.5	42.3	2.9*
Optimal environments for materials taken from or stored in extreme environments	6.5	24.2	4.0
Effects on specimens of glycerin, buffers and other additives to storage fluids	10.4	25.7	3.6
Impact of storage materials on histological and chemical analyses of specimens	10.4	23.9	3.6
Impact of currently used environments on the scientific utility of specimens	14.8	41.4	2.8*
Specifications for collection housing & use			
Methods to identify pest control residues on specimens	14.4	36.7	3.2
Impact of pest control residues relative to human safety	20.1	45.0	3.0
Materials specifications for containers (e.g., jars, lids, unit trays)	27.1	56.8	2.5*
Materials specifications for storage furniture	18.3	46.2	2.8*
Design specifications for specialized collections (e.g., marine core)	6.5	16.5	3.8
Cost-effective methods to create microclimates	13.5	30.5	3.3
Management of collections conservation and conservation research			
Methods to assess risks to collections to rationally identify priorities for collection preservation investments and research	29.7	61.6	2.3*
Methods to balance conservation parameters with specimen use for identified collections of like material or discipline (e.g., collections organized by strata rather than material; mammal collection)	13.1	41.9	2.8*
Methods to mitigate impact of inherent specimen properties (e.g., radon; oxidation of naturally occurring elements; water content of minerals)	10.4	23.5	3.4
Methods to integrate conservation research with other discipline-based analytical research	11.4	32.8	3.1

ments, understanding specimen and collection damages and functions, specifications for collection housing and use, and management of collections conservation and conservation research. The responses were summarized for both the top priority rating (1), and the top two ratings together (1+2); a weighted average was also calculated. The seven topics that were selected by at least one-quarter of the respondents as the highest priority (rating #1) were:

- Proper relative humidity and temperature parameters for general collection (36.7%);
- Impact of preparation materials and methodologies on chemical and physical properties of specimens (33.0%);
- Impact of preparation materials and methodologies on scientific utility of specimens (33.8%);
- Methods to assess risks to collections to rationally identify priorities for collection preservation investments and research (29.7%);
- Development of preparation methodologies that maximize scientific utility of specimens (28.1%);
- Materials specifications for containers (e.g., jars, lids, unit trays, etc.) (27.1%);
- Methods for repair/restoration of damaged specimens (26.2%).

When the top two ratings are combined, at least 50% of respondents selected the seven above, plus three additional topics:

- Methods to assess systematically the condition of specimens over time;
- Methods to assess systematically the condition of a collection of specimens over time;
- Impact of treatments on the scientific utility of specimens.

Using the weighted averages, there are 16 topics that were rated as above average (i.e., having less than a value of 3 which is average) in priority (Table 2). Thus, the choices with above average priority ratings include all three topics in the specimen preparation grouping; five from the post-preparation treatments group; four from the grouping, understanding specimen/collection damage and functions, and two each from the other two groups (specifications for collection housing and use, and management of collections conservation and conservation research).

Having reviewed this list of 30 topics, respondents were then requested to select the three areas that are the most critical of all these; for each of the three areas, respondents were asked to select a type of material for the research topic. The top seven responses, all of which were included in the top seven listed in Table 2, were:

- Methods to assess risks to collections to rationally identify priorities for collection preservation investments and research;
- Impact of preparation materials and methodologies on scientific utility of specimens;
- Proper relative humidity and temperature parameters for general collection;
- Impact of preparation materials and methodologies on chemical and physical properties of specimens;

Table 3. Top 3 priorities listed by respondents for a category of materials.

Category of materials	Topic	Number of responses
Fluid-preserved specimens	Effect on specimens of adding and/or changing storage fluids	17
	Impact of preparation materials and methodologies on chemical and physical properties of specimens	12
	Materials specifications for containers	12
Plant materials	Methods to assess risks to collections to rationally identify priorities for collection preservation investments and research	11
	Proper relative humidity and temperature parameters for general collection	9
	Impact of pest control residues relative to human safety	8
Animal materials	Techniques to clean specimens	21
	Methods to assess risks to collections to rationally identify priorities for collection preservation investments and research	18
	Impact of preparation materials and methodologies on scientific utility of specimens	17
	Methods for repair/restoration of damaged specimens	17
Inorganic materials	Methods to mitigate impact of inherent specimen properties	6
	Impact of preparation materials and methodologies on chemical and physical properties of specimens	5
	Impact of preparation materials and methodologies on scientific utility of specimens	5
	Proper relative humidity and temperature parameters for general collection	5
Inorganic/organic complexes	Methods to assess risks to collections to rationally identify priorities for collection preservation investments and research	8
	Methods to assess systematically the condition of specimens over time	7
	Proper relative humidity and temperature parameters for general collection	7

- Development of preparation methodologies that maximize scientific utility of specimens;
- Materials specifications for containers (e.g., jars, lids, unit trays, etc.);
- Methods for repair/restoration of damaged specimens.

Analysis by the type of material selected indicated a broader range of priorities. The top three responses according to material type are summarized in Table 3. (Many respondents chose to circle multiple types of materials rather than just one, and these responses are not included in Table 3.) There is overlap with the seven topics listed above, but more discipline- or material-specific topics were selected for each of the categories.

Respondents were given the opportunity to suggest additional, broad priorities

Table 4. Suggestions by respondents of "broad research priorities," grouped for analysis.

Preparation of sample/specimen; impact of materials, methods used.
- Ability to prepare (remove rock matrix from) ever smaller, more detailed morphologies in vertebrate fossils
- Impact of field collection techniques on scientific utility (e.g., tropical collection with ethanol in field for pest control interferes with DNA isolation from herbarium material)
- Most interested in consolidants/adhesives in paleontology
- Preparation techniques for skeletal materials
- Specific effects of freezing on skeletal material before and after preparation

Understanding specimen/collection damage
- Determination of the best storage media for fluid amphibian larvae with regard to concentration, pH, buffers, and maintaining neutrality. Is commonly used 10% formalin better for larval storage than 70% ethanol?
- Long-term effect of lipids present in specimens (bones and fluid-preserved specimens)
- Methods of pest control
- Methods to prevent/reduce/eliminate insect pests
- Protection of all specimens from pests (insects)

Specifications for collection housing and use
- Impacts of visitor handling of specimens on long-term preservation and on future scientific value
- Earthquake & fire ratings for available storage equipment
- Packing methods and materials used for transport of collection for loans, etc.
- Proper storage and handling of color photographs and slides
- Providing access to all elements of a collection (biological specimen, photograph, DNA sequence, etc.)
- Destructive sampling of collection material
- Use of tissue & frozen samples, DNA codes and relationship to vouchers
- Specimen labeling

Policies and decision-making protocols (a component of management of collections)
- Developing protocols for sample sizes & integrating storage problems with scientific or research use of such things as fossil tusks
- Development of a template for risk management and disaster mitigation of natural history collections
- Policies on consumptive/destructive sampling
- Uses of collections objects in public programs (exhibits, teaching, imaging) and related conservation priorities
- Valuation of collections by means of scientific parameters
- Impact of databasing a collection vs. future use (patterns) of the collection

Communication; education; information transfer
- Education of discipline-based researchers in best collection/preservation/storage methods for material they collect, research, and turn over to museums for long-term care
- Is there an area where curators and conservators can move together? There is a necessity to educate curators and museum managers to start thinking of the long-term life of their collections.

Other
- Paleontology has many problems not applicable to 'inorganic' in general
- Anthropology (ethnographic & archeological)
- Dried specimens of invertebrates

that were not already listed. Twenty-nine suggestions were made and then grouped for analysis (Table 4). The wording of some of the suggestions made interpretation difficult, so these groupings might change if the suggestion had been more fully described. The majority of additional suggestions fall within three categories:

preparation of samples/specimens and the impact of the methods and materials used; understanding specimen/collection damage and functions; and specifications for collection housing and use. Six suggestions relate to the development of policies and decision-making protocols or framework, a process that is an aspect of the management of collections. Two relate to the need for communication of information among fields.

The second major section of the survey questionnaire included a listing of 40 specific research topics; many of these were discipline-specific and some had been listed in Duckworth et al. (1993). Respondents were asked to indicate for each topic whether this should be a priority for research or for the transfer of information from allied fields (the term "technology transfer" was used in the pilot, but replaced as being field-specific jargon and too unclear for the majority of respondents.). A "don't know" option was also provided; respondents indicated this option was used as well when they felt the topic was not applicable to their discipline. Table 5 summarizes the responses for this section; the number of responses for each topic varied between 206 and 229.

The ten topics with the highest percentage response for *research priority* were:

- Quality of newer preparation methods and materials;
- Methods of assessing the impact of past and current preparation techniques on both long-term preservation and biochemical analyses of specimens;
- Quality of traditional preparation methods and materials;
- Impact of methods of removing flesh, fats and oils from bone on the long-term stability of skeletal material;
- Preservation of color in biological specimens;
- Impact of molding and casting materials on specimen preservation and specimen-based research;
- Impact of various consolidants and adhesives on the chemical and physical stability of specimens;
- Substitutes for formalin in the fixation of plant and animal material;
- Effects of cleaning and staining on the stability of bone;
- Impact of acid preparation on long-term stability and on biochemical analyses of paleontological bone and shell.

The ten topics with the highest percentage response for *transfer of information* were:

- Educating researchers in specific disciplines about best practices for specimen preparation;
- Understanding how specimens are used;
- Methods of packing and shipping field-prepared specimens;
- Understanding of technological applications;
- Development of integrated information system to share conservation research data;
- Methods of preparing specimens for specialized uses, such as educational programming;
- Specifications for materials used in specimen preparation;
- Methods of testing the alkalinity, acidity and general composition of the papers used in herbaria collections;

Table 5. Summary of responses indicating for each specific topic: a need for research, transfer of information from an allied field, or "don't know" (shown as %).

Specific topic	Research priority (%)	Transfer of information (%)	Don't know or not applicable
Substitute(s) for formalin in the fixation of plant and animal material	34.8	23.3	41.9
Appropriate buffers for fixatives	22.3	30.2	47.4
Methods of determining when fixation is complete	24.8	22.9	52.3
Preservation of color in biological specimens	36.9	26.2	37.4
Preservation of color in geological specimens	12.6	17.3	70.1
Mounting media for microscope slide preparations	18.2	26.2	55.6
Methods of ringing microscope slides to prevent deterioration of the mounting media	14.0	22.9	63.1
Clearing and staining agents for use in microscopic and macroscopic preparations	10.3	27.6	62.1
Impact of fixatives and clearing and staining agents on histological and biochemical analyses of specimens	23.8	17.8	58.4
Impact of methods of removing flesh, fats and oils from bone on the long-term stability of skeletal material	45.1	15.3	39.5
Effects of clearing and staining on the stability of bone	27.9	15.3	56.7
Impact of preparation chemicals such as formaldehyde, glacial acetic acid and other acidic preparation chemicals on the development of soluble efflorescent salts on calcareous specimens	24.8	21.0	54.2
Impact of various insecticides on the development of soluble efflorescent salts on calcareous specimens	18.2	18.2	63.6
Impact of acid preparation on long-term stability and on biochemical analyses of paleontological bone and shell	26.0	14.4	59.5
Impact of various consolidants and adhesives on the chemical and physical stability of specimens	34.9	25.6	39.5
Impact of molding and casting materials on specimen preservation and specimen-based research	35.3	22.8	41.9
Materials for temporary storage of specimens awaiting processing	20.9	41.4	37.7
Methods of testing the alkalinity, acidity and general composition of the papers used in herbaria collections	8.9	45.3	45.8
Optimum methods of attaching specimens to herbaria sheets	18.7	29.4	52.3
Cryopreservation methods for algae and slime molds	7.9	8.9	83.2
Methods of preserving plant tissue cultures that do not remain viable with current cryopreservation techniques	14.0	8.9	77.1
Effects of freeze-drying on plant materials	25.6	17.7	56.7
Methods of assessing the impact of past and current preparation techniques on both long-term preservation and biochemical analyses of specimens	51.2	21.4	27.4
New methods of field capture/killing	26.5	28.8	44.7
Specifications for materials used in specimen preparation (e.g., metal insect pins, support wires)	22.9	47.7	29.4
Specifications for adhesives and pointing materials for use in mounting insect specimens	14.0	31.3	54.7
Specifications for herbarium mounting and packet paper	14.9	36.3	48.8
Specifications for adhesives and consolidants for geological specimens	20.6	27.1	52.3
Methods of drying specimens in the field, particularly in tropical environments	20.6	31.8	47.6
Methods of packing and shipping field-prepared specimens	22.3	58.1	19.5

Table 5. Continued.

Specific topic	Research priority (%)	Transfer of information (%)	Don't know or not applicable
Methods of preparing specimens for specialized uses, such as educational programming	23.9	51.6	24.4
Preparation of tissue samples for histological and biochemical analyses	12.7	27.2	60.1
Preparation of subfossil material	20.7	15.0	64.3
Quality of traditional preparation methods and materials	47.5	32.3	20.2
Quality of newer preparation methods and materials	53.5	28.2	18.3
Understanding of technological applications	13.1	54.5	32.4
Understanding how specimens are used	16.4	59.2	24.4
Educating researchers in specific disciplines about best practices for specimen preparation	17.4	66.6	16.0
Integration of conservation research with other types of analytical research	20.7	43.7	35.6
Development of integrated information system to share conservation research data	24.9	53.1	22.1

- Integration of conservation research with other types of analytical research;
- Materials for temporary storage of specimens awaiting processing.

The highest percentage responses for the "don't know" category are for those topics that reflect very specialized areas of interest, e.g., cryopreservation methods for algae and slime molds.

Suggestions were made by 31 respondents for additional aspects of specimen preparation that should be a research priority, and 15 for the focus of a transfer of information (Tables 6, 7). Several of these suggestions repeat topics listed in the previous section, some are so general as to provide little direction for the topic, and a few refer to other aspects of collection management.

Respondents were also requested to indicate how useful a workshop or publication might be for a series of topics relating to the conservation of documentation if the workshop or publication were oriented specifically to natural history collections. All ten topics had weighted averages less than 3, indicating an above average rating for usefulness (Table 8). At least 62% of the respondents rated seven of the ten topics with a 1 or 2. The top three topics overall were:

- Standards for equipment and materials used to produce laser-printed labels or labels via photocopy processes;
- Specifications for materials used in specimen labeling, including durable red inks;
- Guidelines for the care and handling of a variety of field records, photographs, color slides, maps, original catalogs, etc.

Summary and Conclusions

Responses to the survey reflect the diversity of disciplines and work functions represented within the SPNHC membership. Responses also reflect concern with a variety of materials. Although 60% noted animal materials as their greatest

Table 6. Suggestions by respondents of aspects of specimen preparation that should be a research priority.

Accurate data especially dates and localities.
Add complete utilization of every specimen resulting in a standard specimen but also tissues, parasites, vocalizations, photographs, notes, electronic data.
Best all around preservation techniques for maximum uses, including unknown future uses.
Computer generated labels for wet collections; can a laser label hold up in alcohol or formalin?
Cryogenic collections are fraught with problems, not the least are cost and electrical service and mechanical reliability; surely research on new preparation techniques can identify better methods.
Degreasing.
Educating curators, collection managers and researchers in specific disciplines about best practices for specimen preparation and general collections preservation.
Effect of compactor movement in storage for wet collections.
Effect of temperature fluctuations on the evaporation of solutions used in wet specimen storage.
Effect of consolidants on geological specimens; of option of slow drying of specimens to reduce need for consolidants.
Effect of freezing/low temperature on a wide range of materials.
Effects of freezing cycles on herbarium specimens and sheets.
Effects of time between death and preparation on specimen quality.
Freezing and gluing of botanical specimens. The two processes do not complement each other yet just about every botanical institution continues to do this. Why?
How to salvage specimens that were poorly or improperly prepared.
I am working with specimens that break down to produce concentrated sulfuric acid (cell wall polysaccharides undergo anolytic process)—I am looking at inherent properties.
Impact of methods for removing fat, muscle, bone, etc. from specimens.
Impact of preservation techniques on the potential viability of algal, fungal, and bryophyte spores as well as seeds of vascular plants stored in herbaria.
Investigate feasibility of multiple techniques on individual specimens; of isolating/protecting specimens from post-preparation damage/contamination; utility of traditional preparation methods.
Long-term stability of adhesives used in vertebrate fossil preparations.
Minimizing damage to DNA in various specimen preparation techniques (e.g., plants-alcohol collecting).
Non-cryogenic methods of tissue preservation for DNA extraction.
Optimal concentration of preservative (and fixatives) for long-term preservation of wet specimens.
Preparation of succulent plants (drying techniques that render specimens most useful to researchers).
Preservation of mammal skins to prevent shedding hair in sensitive specimens, e.g., deer, cats.
Preservatives used in bird skins—how to handle old specimens on which arsenic was used.
Product reviews in terms of long-term stability and effect.
Quality of preparation methods and materials.
Should be a major thrust to coordinate "autopsy" procedures (necropsy).
Simple, inexpensive tests to determine composition and concentration of fluid preservatives for specimens of unknown or uncertain preservatives and to check for changes in concentration.
Specifications and methods for adhesives and mounting of herbarium plant material.

priority, inorganic and plant materials were each noted by more than 25% of the respondents. Fluid-preserved specimens, which can include samples of animal, plant or inorganic materials, were selected by approximately one-third as a high priority. In spite of the weighting towards animal materials, it is interesting to note that all of the highest research priorities are ones that encompass the needs of all the disciplines and material types. As evidenced by additional comments made by respondents, the specific materials and methods will vary with the discipline, however, and it is important that the research reflects the uniqueness of the disciplinary requirements. This situation is similar to a statement made in

Table 7. Suggestions of aspects of specimen preparation that should be the focus of a transfer of information.

Appropriate application of adhesives in vertebrate fossil preparation.
Assessing impact of plastic coverings on plant herbarium sheets.
Automation of locality label data using GPS/GIS.
Curation of seed collections (for herbaria); containers, labeling, storing; curation techniques for library books, reprints, proper labels, attach labels with Library of Congress call numbers, etc.
Deterioration and chemical changes to mammal and/or bird feathers brought about by lux, rH and chemical (off-gasses) vapors.
Digital imaging and archival, especially minute specimens.
Gathering of data during preparation.
Have a symposium where people present various methods of preparing specimens; devote a SPNHC conference to specimen preparation techniques.
Health and safety issues concerning exposure to pesticides (fumigants such as methyl bromide, naphtha, PDB) used on specimens.
Information already available in anthropology objects conservation literature dealing with bone, shell, feather, skins/leather, ivory, etc. should be reviewed to see what can be used.
Mount making.
Placing collections "on the web" to allow exchange of information, global search capabilities and educational tools for students.
Preparation of tissue samples for histological and biochemical analysis should be well understood within the medical professions.
Standardization of skeletal preparation methods; what is best method when considering time, materials, long-term effects on specimens?
Understanding preparation strategies as they apply to various applications provided by changing technology.

Table 8. Percentage of responses rating the usefulness of each topic for a publication or workshop oriented specifically to natural history collections (rating of 1 = very useful; scale 1 to 5).

Topic	% respondents Rating = 1	% respondents Rating = 1 +2	Weighted average
Paper substitutes and their potential utility for specimen labeling and other specimen or collections documentation	30.1	62.6	2.1
Clarification of terminology used in paper chemistry and in the description of paper stocks	11.2	34.0	2.7
Methods to test pH, and other testing methods to verify the quality of paper stock	13.1	37.8	2.6
Guidelines for the care and handling of a variety of field records, photographs, color slides, maps, original catalogs, etc.	42.6	77.0	1.8
Proper environments for the storage and display of archival and library materials	30.0	54.1	2.3
Specifications for materials used in specimen labeling, including durable red inks	44.0	72.0	1.8
Standards for equipment and materials used to produce laser-printed labels or labels via photocopy processes	45.9	74.4	1.8
Appropriate adhesives to attach labels to a variety of substrates including paper, glass and plastics	36.2	65.2	2.0
Deterioration of labeling materials	38.5	67.8	1.9
Effects of fats, oils, and preparation and pest control chemicals on the preservation of specimen labels	33.5	62.1	2.1

Derrick (1996) with respect to the responses from the seven specialty groups in AIC, that although there were several recurring priorities among the groups, each specialty targeted unique aspects of those broader priorities as specific issues of concern.

Topics listed in the second section of the survey were intentionally more specific, reflecting the individual natural history disciplines to a greater degree. This process allowed respondents to target issues that were more directly aligned with their disciplines, or indicate a lack of familiarity with the issue by selecting the "don't know" category. The topics selected as appropriate for "transfer of information" should be further investigated to develop review articles, books or workshops as appropriate.

There are some areas of overlap between the priorities identified in this survey and those recorded in the AIC survey. In particular, studies evaluating materials might be applicable to the priorities identified within this study. Research priorities identified in Derrick (1996) that might be relevant for natural history collections conservation include: aqueous cleaning methods and solutions; consolidation methods; deterioration of synthetic resins; in-situ and low-tech examination practices and analysis methods; and removal of adhesives and consolidants. However these depend on the systems used to approach the broader research question.

One of the most distinctive characteristics of the research priorities identified as part of this study is that many are in the context of the 'scientific value' of the specimen, and/or the size and extent of a large collection. As noted in the earlier sections of this report, these are characteristics that distinguish natural history collections from other types of collections and form the context for management and conservation of the specimens within the collections.

This project, based on direct input by the SPNHC membership, provides an updated set of priorities for research in natural history collections conservation. Ten topics were selected as the highest priorities by 50% of the respondents, and comprise the most critical research priorities. Of particular concern are methods and materials used in the initial preparation and subsequent treatment of specimens particularly as they impact the scientific utility of specimens, as well as methods to guide decision-making with respect to collection management and conservation, and materials and parameters for storage of collections.

The results of this survey also provide guidance for topics that should be the subject of efforts to transfer information from allied fields. Respondents recognized a number of topics that would be useful for natural history collections conservation, particularly if oriented for the context of such collections.

Acknowledgments

This project was the result of the thoughtful input and effort of many individuals. In particular, the authors appreciate the guidance, discussion and recommendations provided by members of the SPNHC Executive Council, Conservation Committee, and Research Subcommittee. Those who carefully completed and returned the pilot survey with additional letters of comment provided exceptional assistance with the phrasing and terminology revisions that are always needed in such an endeavor. The authors would also like to thank the SPNHC membership for responding in substantial numbers to yet another survey; without that level of response the data would have limited value.

On behalf of the SPNHC membership and the natural history collections community, the authors thank the funding agency for its generous support of the survey costs. This publication was developed under a grant from the National Center for Preservation Technology and Training of the National Park

Service. Its contents are solely the responsibility of the authors and do not necessarily represent the official position or policies of the National Park Service or the National Center for Preservation Technology and Training.

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APPENDIX

BROAD RESEARCH PRIORITIES FOR NATURAL HISTORY COLLECTIONS CONSERVATION

RETURN BY OCTOBER 1, 1999

1	2	3	4	≥5	Circle the number of disciplines your focus on with your collections or research.
					Circle the description that BEST fits your work:
					Collection Manager **Conservator** **Curator** **Other:** ______

greatest				least	
1	2	3	4	5	Fluid-preserved specimens
1	2	3	4	5	Plant materials
1	2	3	4	5	Animal materials
1	2	3	4	5	Inorganic materials (earth science)
1	2	3	4	5	Inorganic/organic complexes (i.e., include a biological component)

Assign a PRIORITY rating for each topic. Use the "highest" rating *only* for topics that are the most critical to your work.

greatest				least	**Specimen Preparation**
1	2	3	4	5	(a) Impact of preparation materials and methodologies on chemical and physical properties of specimens
1	2	3	4	5	(b) Impact of preparation materials and methodologies on scientific utility of specimens
1	2	3	4	5	(c) Development of preparation methodologies that maximize scientific utility of specimens
greatest				least	**Post-Preparation Treatments**
1	2	3	4	5	(d) Methods to assess systematically the condition of specimens over time
1	2	3	4	5	(e) Methods to assess systematically the condition of a collection of specimens over time
1	2	3	4	5	(f) Effect on specimens of adding and/or changing storage fluids
1	2	3	4	5	(g) Techniques to clean specimens (e.g., greasy bone; specimens stained by pollutants, mold)
1	2	3	4	5	(h) Mechanisms of oxidation reactions
1	2	3	4	5	(i) Methods to mitigate sampling of specimens for discipline-based research
1	2	3	4	5	(j) Methods for repair/restoration of damaged specimens
1	2	3	4	5	(k) Impact of treatments on the scientific utility of specimens
greatest				least	**Understanding Specimen/Collection Damage & Functions**
1	2	3	4	5	(l) Impact of pest control methods on chemical and physical properties of specimens
1	2	3	4	5	(m) Long-term impact of pest control residues on scientific utility of specimens
1	2	3	4	5	(n) Proper relative humidity and temperature parameters for general collection
1	2	3	4	5	(o) Optimal parameters for particularly sensitive materials
1	2	3	4	5	(p) Effects of visible light, infrared, and ultraviolet radiation on specimens

APPENDIX (CONTINUED)

BROAD RESEARCH PRIORITIES FOR NATURAL HISTORY COLLECTIONS CONSERVATION

RETURN BY OCTOBER 1, 1999

greatest				least	
					Understanding Specimen/Collection Damage & Functions
1	2	3	4	5	(q) Optimal environments for materials taken from or stored in extreme environments (e.g., humid tropics; Antarctic ice columns; nonterrestrial specimens)
1	2	3	4	5	(r) Effects on specimens of glycerin, buffers and other additives to storage fluids
1	2	3	4	5	(s) Impact of storage materials on histological and chemical analyses of specimens
1	2	3	4	5	(t) Impact of currently used environments on the scientific utility of specimens
greatest				least	**Specifications for Collection Housing & Use**
1	2	3	4	5	(u) Methods to identify pest control residues on specimens
1	2	3	4	5	(v) Impact of pest control residues relative to human safety
1	2	3	4	5	(w) Materials specifications for containers (e.g., jars, lids, unit trays, etc.)
1	2	3	4	5	(x) Materials specifications for storage furniture
1	2	3	4	5	(y) Design specifications for specialized collections (e.g., marine core)
1	2	3	4	5	(z) Cost-effective methods to create microclimates
greatest				least	**Management of Collections Conservation and Conservation Research**
1	2	3	4	5	(aa) Methods to assess risks to collections to rationally identify priorities for collection preservation investments and research
1	2	3	4	5	(bb) Methods to balance conservation parameters with specimen use for identified collections of like material or discipline (e.g., collections organized by strata rather than material; mammal collection)
1	2	3	4	5	(cc) Methods to mitigate impact of inherent specimen properties (e.g., radon; oxidation of naturally occurring elements; water content of minerals)
1	2	3	4	5	(dd) Methods to integrate conservation research with other discipline-based analytical research

WHAT ARE THE TOP PRIORITIES?

Which 3 areas of the 30 listed above are the **most critical** of all the research priorities?
List the 3 areas below and circle the type of material that is most critical to you for that priority.

LETTER	**MATERIAL (circle one material)**				
1. ( )	fluid-preserved	plant	animal	inorganic	inorganic/organic
2. ( )	fluid-preserved	plant	animal	inorganic	inorganic/organic
3. ( )	fluid-preserved	plant	animal	inorganic	inorganic/organic

Is there a BROAD research priority you would add that is not included in the list above? Please describe.

APPENDIX (CONTINUED)

RESEARCH OR TRANSFER OF INFORMATION?

Specimen preparation varies greatly among disciplines and materials. The previous 2 pages dealt with *broad* priorities for the field at large. On these pages, we would like to identify *specific* areas that are research priorities. We also want to distinguish the need for research from the need to transfer information from allied fields.

Indicate which areas reflect primarily a **Research Priority (R)** and which are a priority for **Transfer of Information (T).**

Res. Priority	Transfer of Info.	Don't Know	
R	T	D	Substitute(s) for formalin in the fixation of plant and animal material
R	T	D	Appropriate buffers for fixatives
R	T	D	Methods of determining when fixation is complete
R	T	D	Preservation of color in biological specimens
R	T	D	Preservation of color in geological specimens
R	T	D	Mounting media for microscope slide preparations
R	T	D	Methods of ringing microscope slides to prevent deterioration of the mounting media
R	T	D	Clearing and staining agents for use in microscopic and macroscopic preparations
R	T	D	Impact of fixatives and clearing and staining agents on histological and biochemical analyses of specimens
R	T	D	Impact of methods of removing flesh, fats and oils from bone on the long-term stability of skeletal material
R	T	D	Effects of clearing and staining on the stability of bone
R	T	D	Impact of preparation chemicals such as formaldehyde, glacial acetic acid and other acidic preparation chemicals on the development of soluble efforescent salts on calcareous specimens
R	T	D	Impact of various insecticides on the development of soluble efflorescent salts on calcareous specimens
R	T	D	Impact of acid preparation on long-term stability and on biochemical analyses of paleontological bone and shell
R	T	D	Impact of various consolidants and adhesives on the chemical and physical stability of specimens
R	T	D	Impact of molding and casting materials on specimen preservation and specimen preservation and specimen-based research
R	T	D	Materials for temporary storage of specimens awaiting processing
R	T	D	Methods of testing the alkalinity, acidity and general composition of the papers used in herbaria collections
R	T	D	Optimum methods of attaching specimens to herbaria sheets
R	T	D	Cryopreservation methods for algae and slime molds
R	T	D	Methods of preserving plant tissue cultures that do not remain viable with current cryopreservation techniques
R	T	D	Effects of freeze-drying on plant materials
R	T	D	Methods of assessing the impact of past and current preparation techniques on both long-term preservation and biochemical analyses of specimens
R	T	D	New methods of field capture/killing
R	T	D	Specifications for materials used in specimen preparation (e.g., metal insect pins, support wires)

APPENDIX (CONTINUED)

RESEARCH OR TRANSFER OF INFORMATION?

Specimen preparation varies greatly among disciplines and materials. The previous 2 pages dealt with *broad* priorities for the field at large. On these pages, we would like to identify *specific* areas that are research priorities. We also want to distinguish the need for research from the need to transfer information from allied fields.

Indicate which areas reflect primarily a **Research Priority (R)** and which are a priority for **Transfer of Information (T).**

R	T	D	Specifications for adhesives and pointing materials for use in mounting insect specimens
R	T	D	Specifications for herbarium mounting and packet paper
R	T	D	Specifications for adhesives and consolidants for geological specimens
R	T	D	Methods of drying specimens in the field, particularly in tropical environments
R	T	D	Methods of packing and shipping field-prepared specimens
R	T	D	Methods of preparing specimens for specialized uses, such as educational programming
R	T	D	Preparation of tissue samples for histological and biochemical analyses
R	T	D	Preparation of subfossil material
R	T	D	Quality of traditional preparation methods and materials
R	T	D	Quality of newer preparation methods and materials
R	T	D	Understanding of technological applications
R	T	D	Understanding how specimens are used
R	T	D	Educating researchers in specific disciplines about best practices for specimen preparation
R	T	D	Integration of conservation research with other types of analytical research
R	T	D	Development of integrated information system to share conservation research data

Is there another aspect of specimen preparation that should be a *research priority*?

Is there another aspect of specimen preparation that should be the focus of a *transfer of information*?

APPENDIX (CONTINUED)

RESEARCH OR TRANSFER OF INFORMATION?

Specimen preparation varies greatly among disciplines and materials. The previous 2 pages dealt with *broad* priorities for the field at large. On these pages, we would like to identify *specific* areas that are research priorities. We also want to distinguish the need for research from the need to transfer information from allied fields.

Transfer of information occurs through publications, workshops, etc. Much information about documentation media exists in the conservation literature. To what degree would a publication or workshop *oriented specifically* to natural history collections be useful for the following topics?

Very useful				Not useful	
1	2	3	4	5	Paper substitutes and their potential utllity for specimen labeling and other specimen or collections documentation
1	2	3	4	5	Clarification of terminology used in paper chemistry and in the description of paper stocks
1	2	3	4	5	Methods to test pH, and other testing methods to verify the quality of paper stock
1	2	3	4	5	Guidelines for the care and handling of a variety of field records, photographs, color slides, maps, original catalogs, etc.
1	2	3	4	5	Proper environments for the storage and display of archival and library materials
1	2	3	4	5	Specifications for materials used in specimen labeling, including durable red inks
1	2	3	4	5	Standards for equipment and materials used to produce laser-printed labels or labels via photocopy processes
1	2	3	4	5	Appropriate adhesives to attach lables to a variety of substrates including paper, glass and plastics
1	2	3	4	5	Deterioration of labeling materials
1	2	3	4	5	Effects of fats, oils, and preparation and pest control chemicals on the preservation of specimen labels

Thank you for your time and effort!
Please return this survey by mail using the enclosed label, or by fax to: Paisley S. Cato, 619-232-0248.

DISASTER RECOVERY IN THE HERBARIUM

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Abstract.—In conjunction with developing a disaster preparedness and recovery plan for the R.L. McGregor Herbarium, we staged a mock disaster and recovery in which herbarium specimens of nine taxa were damaged by mud, by fire, or mechanically. Each damage treatment involved water. Recovery involved either immediately freezing the specimens, or waiting 24 hours before either press drying the specimens with either heated or unheated forced air, or air drying the specimens on a newspaper-covered table. Most of the damaged specimens required some minor repair. Mechanically damaged specimens fared best. The exsiccatae of the remainder of the specimens either needed to be transferred to new sheets as soon as possible, or were stable enough to transfer at a later date. Freezing further damaged the specimens. Air drying resulted in specimens inferior in quality to press-dried specimens, and is not an acceptable method. Of the specimens dried in presses, there was no difference in quality between those dried with heat vs. without heat. The most important lesson that we learned was that in the event of a disaster, there would not be enough time to recover the entire collection. Thus we have prioritized the collection for recovery.

No institution is immune from natural disasters such as flood and fire, technological disasters such as chemical spill, or security emergencies such as vandalism. As repositories of collections that could be destroyed by such crises, museums are not complete without disaster preparedness and recovery plans that detail how to avoid potential disasters and what to do in the event of a disaster. A comprehensive plan includes the emergency management steps of preparation, response, recovery, and mitigation (FEMA 1994). Implementation of the plan reduces the chaos that arises from a disaster and thus increases personal safety and recovery of objects.

Preparation procedures are designed to protect people and objects from potential disasters (FEMA 1994). Examples of preparation include posting emergency phone numbers, assembling emergency supplies, housing specimens in properly sealed cases, listing which objects will have priority in response and recovery, and providing staff with training in first-aid.

Response involves actions taken to respond to an emergency, to save lives and property, and to prevent further damage (FEMA 1994). A museum's plan should include response procedures for emergencies such as chemical spill, earthquake, fire, flood, power outage, and severe weather. The plan should also detail steps to stabilize collections. The first 48 hours following a disaster are crucial to the welfare of objects (Lord et al. 1994). Limited resources and time, and large numbers of objects, may make it impossible to stabilize everything within this critical time period. Many, but not all, types of materials can be frozen to stabilize water damage, and then dealt with at a later date (Lord et al. 1994). Knowing in advance what to do with the collections will increase response efficiency.

Recovery actions are taken to return activities to normal after a disaster (FEMA 1994). Repair of collection objects and associated equipment varies with the damage and the types of materials of which the objects and equipment are composed (Lord et al. 1994). The disaster preparedness and recovery plan should outline recovery steps by type of damage and material.

Collection Forum 2001; 15(1–2):26–35

Mitigation either prevents emergencies or minimizes their negative effects (FEMA 1994). Examples of mitigation include insuring museum property and backing up computers. Mitigation is closely related to preparedness and recovery.

Learning about other museums' experiences is one starting point in the formulation of a plan. Some recent examples are: recovery from a tornado strike to a storage facility for anthropology and paleontology collections at the Smithsonian Institution National Museum of Natural History (Mellon et al. 1995); recovery of fluid-preserved herpetological and ichthyological specimens from a 1992 flood in the Texas Cooperative Wildlife Collection (Vaughan and Arrizabalaga 1994); long-term recovery of vertebrate specimens from this flood (Vaughan et al. 1999); and case studies in herbarium design for disaster preparedness (Ertter 1999, Lull and Moore 1999).

Once a disaster preparedness and recovery plan has been developed, practicing it will help to address uncertainty and will give staff experience in performing the procedures. In conjunction with developing such a plan for the R.L. McGregor Herbarium (KANU), a unit of the University of Kansas Natural History Museum and Biodiversity Research Center, we staged a mock disaster and recovery. Our purpose for doing this was twofold. First, we wanted to examine qualitatively how damage and recovery interactions affect specimens, herbarium paper and boxes, and various glues and labels. Second, we wanted to practice recovery techniques, with an eye toward improving recovery efficiency and the outcome of an actual disaster.

We simulated several kinds of damage to herbarium specimens: mud, fire, and mechanical. Since disasters will most likely involve water damage, each damage treatment involved water. We wanted to see how freezing affected water damaged specimens, and compare the quality of frozen specimens with those that had not been recovered until 24 hours after damage. We also wanted to determine the most efficient method of drying water damaged specimens.

Materials and Methods

Specimens

Nine taxa were selected to reflect a variety of specimen characteristics (Table 1). Eighteen specimens of each taxon, except the *Malus* fruits, were pressed between newspapers and blotters, and then dried by forced hot air for a period of from 24 hours to five days, depending on the species. Prior to drying, *Opuntia* stems and fruits were sliced lengthwise in order to maximize exposed surface area, and thus minimize drying time. *Malus* fruits were sliced in half and air-dried for a period of three weeks.

"MO" type PVA resin herbarium glue, "Yes" paste, and "UC" type (68 m, 0.15 caliper) mounting paper were obtained from Herbarium Supply Co., Menlo Park, CA; "XX-heavy" weight mounting paper was obtained from University Products, Inc., Holyoke, MA; and barcode labels were obtained from Intermec Media Products, Fairfield, OH. Prior to damage, specimens were mounted on 100% rag standard-sized mounting paper using an over-all gluing method with "MO" type glue (thinned to six parts glue:one part water). *Pinus* specimens were mounted on "XX-heavy" weight paper, while the remainder of the specimens was mounted on "UC" type paper.

Table 1. Characteristics represented by specimens damaged in the mock disaster.

Taxon	Common name	Selected to represent:
Pinus nigra Arnold	Austrian pine	coniferous habit, bulkiness, fruit
Opuntia macrorhiza Engelm. var. *macrorhiza*	plains prickly pear cactus	succulent habit, fruit
Artemisia ludoviciana Nutt. var. *ludoviciana*	Louisiana sagewort	herbaceous habit, dense pubescence
Asclepias tuberosa L. subsp. *interior* Woods.	butterfly milkweed	herbaceous habit, dense pubescence
Agrostis stolonifera L. var. *stolonifera*	redtop	graminoid habit
Erigeron annuus (L.) Pers.	annual fleabane	herbaceous habit, delicateness, easily damaged and lost dried inflorescence and florets
Convolvulus arvensis L.	field bindweed	herbaceous habit, delicateness, thin and easily torn dried foliage
Impatiens capensis Meerb.	spotted touch-me-not	herbaceous habit, delicateness, thin and easily torn dried foliage
Malus pumila P. Mill. cultivar	domestic apple	woody habit, boxed fruit

An identification label was affixed with "Yes" paste. The identification label indicated taxon and which damage and recovery treatment the specimen would receive, in addition to whether or not it would be frozen or treated 24 hours following damage. Above this label, an annotation label was affixed with the "MO" type herbarium glue. Both labels were printed with a Hewlett-Packard LaserJet4 laser printer on Gilbert 100% rag paper. A self-stick plastic barcode label was affixed to the lower left corner. Dried *Malus* fruits were placed in 122 mm × 85 mm × 45 mm chipboard boxes (non-archival, brand unknown) to which were affixed the same labels as the mounted specimens. In addition, a second identification label was placed inside each box with the specimen.

Henceforth, unless otherwise specified, the term 'exsiccata' refers only to the pressed plant material; 'sheet' refers to the herbarium sheet; and 'specimen' refers to the exsiccata and its associated sheet and labels.

Damage

Each specimen was subjected to one of three damage treatments: mud and water, mechanical and water, or smoke, fire, and water. Fruit specimens were subjected to damage while in their boxes. Individual specimens were damaged to ensure that each was damaged to the same degree. *Mud and water:* Specimens were submerged for five minutes in a basin of sterilized mud suspended in water. *Mechanical and water:* Specimens were rolled along their widths, folded in half and unfolded, unrolled, and then submerged in a basin of water for five minutes. Boxes of fruit were stepped on to simulate mechanical damage, then submerged in water for five minutes. *Smoke, fire, and water:* Specimens were scorched and partially burned over a smoking grill, then submerged in water for five minutes. Following damage treatments, mounted specimens were segregated by recovery method, interleaved with waxed paper, and placed into genus folders (non-archival, brand unknown). Boxed specimens were placed in larger corrugated cardboard boxes.

To examine how well genus folders protect specimens, folders containing one specimen of each species were also damaged using one of the three treatments. Two different types of folders were used, "USC" type 42.2 cm × 61 cm (Herbarium Supply), and an unknown brand of non-archival materials. Folders and contents were then frozen without interleaving the specimens with waxed paper. After the freezing period, specimens were examined for quality, but not dried.

Recovery

The first stage of recovery was either to freeze the specimens immediately, or to wait 24 hours before treating the damage. Boxed specimens were recovered in a similar manner as the mounted specimens, but were not press-dried. *Freezing:* The entire folder of damaged specimens was frozen at −20°C for eight days. To thaw, folders were arranged on tables covered with newspapers. The frozen specimens could not be removed from the folders without damage. Frozen folders and specimens thawed in less than three hours. *Waiting 24 hours:* To maintain dampness, folders of damaged specimens were immersed in water, covered with a stack of wet newspapers, then placed in an herbarium case in the specimen drying room (not climate controlled).

Triage took place outside after either the 24-hour waiting period or the freezing period. We assumed that all specimens were important and should be saved. Many exsiccatae and labels had come loose from their sheets. We used gently running water to facilitate their removal and remounted some of the wet exsiccatae and labels from extensively damaged sheets. Others that we removed from the sheets were placed between waxed paper for press drying. Mud-damaged specimens were rinsed under gently running water and dabbed with sponges to remove the mud (Lord et al. 1994). Then all specimens and exsiccatae were either air dried, or were dried in presses with either heated (45–55°C) or unheated forced air. Time required for drying each specimen was noted.

Air drying took place in a temperature controlled room (21°C, 60% relative humidity) in another building. Twenty-four mounted specimens were arranged face-up on tables covered with newspapers. A fan was placed at the back of the room to maintain air circulation. Room temperature and relative humidity were monitored with a Bendia Psychron Model 566–3 psychrometer. Drying progress of the specimens was closely monitored and newspapers were replaced three hours after specimens were laid out.

The room in which specimens were press-dried was not temperature controlled (37°C, 44% relative humidity). Presses were assembled in the order of cardboard corrugated ventilator, specimen or exsiccata, waxed paper, repeat. Each press contained 24 specimens or exsiccatae. Boxed specimens were removed from their boxes and spread out on blotters to dry in this room. What we learned from the recovery efforts that took place 24 hours after damage (see Results section) was applied to the recovery efforts of the frozen specimens, so frozen specimens were press-dried only, with and without heat.

Initially, we also wanted to examine the efficiency of drying water-damaged specimens by microwave. Microwaving specimens has been examined for pest control (Hall 1981) and for decreasing drying time in the initial preparation of herbarium specimens (Baker et al. 1985, Bacci and Palandri 1985). Recommended irradiation (2450 MHz) times varied from two to four minutes for pest control (Hall 1981, Philbrick 1984), to 25–35 minutes to dry newly-collected succulents (Baker et al. 1985). Concerns about microwaving specimens include its effect on seed viability (Hill 1983, Philbrick 1984), and damage at the morphological and macromolecular levels (Philbrick 1984, Bacci and Palandri 1985). In a trial run, we smoked and charred a mounted woody specimen, then soaked it in water for five minutes. We dried it in a 2450 MHz Amana household microwave at 30 second intervals on power setting five. After 150 seconds, we saw sparks in the microwave, and the charred edge of the exsiccata caught fire. The specimen was still slightly damp, but for safety reasons we decided to discontinue the experiment and not use the microwave as a recovery method. Interestingly, the water damage had resulted in the detachment of the exsiccata from the sheet due to remoistenable mounting glue; microwaving re-adhered it to the sheet.

RESULTS

It took three hours to damage approximately 150 specimens. In the fire, the barcode labels melted, while the "Yes" paste turned brown and crisp and lost its adhesiveness (MSDS indicates a boiling point of 100°C). Wet folders and sheets tore easily, while wet exsiccatae were easily damaged.

Triage took approximately 6 person hours per 100 specimens. Wind made the work difficult and easily damaged wet exsiccatae. Also, the more wet or burned specimens were handled, the more damaged they became. The two types of genus folders suffered equally in their damage, which was primarily tearing along the fold. Their contents suffered less damage than the specimens we damaged individually.

Gently rinsing and blotting mud from specimens was preferable to rinsing with higher water pressure. Higher water pressure did not rinse off any more mud, but only rinsed away chunks of dirt from roots, in addition to rinsing away flowers and other plant parts. Because the "MO" type PVA resin herbarium glue is not fully water reversible, but only remoistenable, annotation labels remained stuck to the sheets and were difficult to remove without tearing. Labels affixed with the water reversible "Yes" paste, however, detached from the sheets and were easily transferred to new sheets, but did not securely re-adhere. Barcode labels were not removable. Their slick surfaces, however, were easily wiped clean of mud. The print on burned annotation and identification labels remained legible, but the labels themselves disintegrated easily.

Significant problems developed with the frozen specimens. The specimens came out of the freezer drier than those specimens that had been set aside for 24 hours prior to recovery, presumably due to some sublimation. This made mud more difficult to remove from frozen specimens and sheets. Also, freezing damaged many exsiccatae, especially delicate exsiccatae (*Impatiens* and *Erigeron*, but also *Artemisia* and *Agrostis*). Exsiccatae were discolored and mushy, probably due to cell damage. Only *Pinus* did not appear to be adversely affected by freezing.

Air-dried specimens took 18.5 hours to dry. Initially, room temperature was 21°C at 60% relative humidity. At the end of the drying time, room temperature

DAMAGE	RESPONSE	RECOVERY	*Agrostis*	*Artemisia*	*Asclepias*	*Convolvulus*	*Erigeron*	*Impatiens*	*Opuntia*	*Pinus*
fire	wait 24 hours	air dry							///////////	///////////
fire	wait 24 hours	press dry (heat)							///////////	///////////
fire	freeze	press dry (no heat)	///////////				///////////		///////////	///////////
fire	freeze	press dry (heat)					///////////		///////////	///////////
mud	wait 24 hours	air dry	///////////				///////////	///////////		
mud	wait 24 hours	press dry (heat)						///////////	///////////	
mud	freeze	press dry (no heat)								
mud	freeze	press dry (heat)	///////////				///////////			
mechanical	wait 24 hours	air dry	///////////							
mechanical	wait 24 hours	press dry (heat)								
mechanical	freeze	press dry (no heat)								///////////
mechanical	freeze	press dry (heat)								

Specimen requires no further repair.
Herbarium sheet should eventually be replaced, but specimen can remain as it is in the mean time.
///////// Herbarium sheet replaced during triage due to extensive damage. Specimen now requires no further repair.
Exsiccate requires repair and immediate transfer to a new herbarium sheet.
Specimen is not recoverable (due to severe burns).

was 25°C at 44% relative humidity. While air drying, edges and tips of organs became brittle and the sheets warped. *Pinus* specimens that had been rinsed of mud took the longest to dry due to water trapped among the needles. For these reasons, air drying was not as satisfactory as press drying, so we decided to press dry all frozen specimens. In addition, to determine if heat affected the degree to which sheets warp, we decided to press dry the frozen specimens using either heated or unheated forced air.

*Press-dried s*pecimens were dried with heated air for 19 hours or unheated air for 43 hours. There was no noticeable difference in quality between specimens dried with and without heat. The heavy mounting paper used for *Pinus,* however, did not warp as severely as the lighter paper. Exsiccatae removed from their sheets during recovery and dried between waxed paper adhered to the waxed paper as residual glue dried. Press-dried specimens were not as brittle as air-dried specimens.

All specimens were evaluated after they had dried (Table 2). Most specimens required at least some minor repair. Sheets became discolored from leached plant pigments, smoke, fire, and mud that either had been originally on roots or introduced during the damage process. Those exsiccatae that had been transferred to new sheets during triage could remain as they were without further repair.

No mechanically damaged specimen required immediate repair. The only non-recoverable specimens were four that had been severely burned (three *Convolvulus* and one *Impatiens).* All frozen, mud damaged (but one, *Artemisia*) and the remaining fire damaged (but one, *Asclepias*) exsiccatae required immediate transfer to new sheets. The remaining mud damaged exsiccatae (but one, *Agrostis*) were stable and could be left as they were until it was possible to transfer them to new sheets. We are keeping all damaged and recovered specimens and plan to examine them periodically in the future to monitor their stability.

Boxed specimens received little damage due to the protection provided by their boxes. The boxes had to be carefully emptied of water before freezing or drying. Freezing did not appear to affect the specimens. Distorted or damaged boxes and labels required replacement.

Discussion

This mock disaster was useful in the formulation of our disaster preparedness and recovery plan. The exercise revealed what we may expect in the event of a disaster involving water and it made clear how a plan can mitigate the results of a water disaster. Our disaster and recovery occurred under controlled conditions and involved a small number of specimens that occupied less than a quarter of an herbarium case. An actual disaster would most likely affect a large portion of the herbarium collection, and most certainly would be unexpected. Extrapolating the triage time of our mock disaster to the entire 350,000-specimen collection at KANU results in a total of 21,000 person hours required for triage, or 2,625 eight-hour days. This calculated triage time does not include post-triage steps of drying and remounting specimens, recreating labels, filing specimens, or recovering the herbarium's other holdings, such as computer equipment, library materials, and transparencies. We estimate that to remount the entire collection would take 17,500 person hours, or 2,188 eight-hour days. Even with a moderately large staff, recovery of the entire collection would be an impossible task to accomplish. The resources necessary for such large-scale recovery would soon be depleted. To remount and replace the labels and folders of the entire collection would cost over $90,000 in supplies and $122,500 in labor. Finally, it should be noted that most older, brittle specimens and specimens mounted with poor-quality materials would require more extensive treatment and would be more difficult to salvage than our disaster exercise specimens which were mounted with high-quality materials.

Freezing water-damaged specimens will buy time, but the additional damage caused by freezing must be considered. Thick-leaved and thick-stemmed specimens, such as *Pinus,* as well as boxed fruit specimens, fare better when frozen than do delicate or thin-leaved specimens. If the extent of damage requires that some specimens must be frozen, we recommend freezing the more robust specimens rather than the delicate ones.

Freeze-drying, a recovery alternative that we did not explore, is recommended for many types of objects when large numbers of items have been water damaged (Lord et al. 1994). However, Vaughan et al. (1999) found that freeze-drying may damage specimens. Specimens that are to be freeze dried must first be cleaned of mud or debris, for they will come out dry, but otherwise in the same condition as they went in.

The rise in relative humidity in the building housing the specimens is an additional factor placing water-damaged specimens at risk of deterioration from mold. After our damaged specimens were transferred to the herbarium case to await recovery, relative humidity rose to approximately 20% above ambient relative humidity. There is a great need to expedite specimen recovery. This can be facilitated by including in a disaster preparedness and recovery plan localities of recovery equipment, locations available for triage and relocation of specimens, and the names and phone numbers of people who will help with the recovery. Specifying details of removal and treatment of specimens and alternative methods may also increase recovery efficiency. For example, recovery from our mock disaster revealed that if forced-air heat dryers are in short supply, additional dryers that do not produce heat, such as box-fans, can be used.

Table 3. Outline of the University of Kansas R.L. McGregor Herbarium (KANU) Disaster Preparedness and Recovery Plan.

- I. Introduction
  - A. Purpose of the Plan
  - B. Location Covered by the Plan
  - C. Relationship of the Plan to the University of Kansas Natural History Museum and Biodiversity Research Center's Plan
- II. Summary of the Plan
- III. Preparation
  - A. Plan Revision Procedures
  - B. Photographic Records
  - C. Computer Back-up
  - D. Recovery Team
  - E. Relocation of Items
  - F. Chemicals and Material Safety Data Sheets
  - G. Priority Specimens and Library Materials
  - H. Criteria for Salvage of Specimens and Materials
  - I. Supplies Used in the Herbarium
  - J. Supply Vendors
- IV. Response
  - A. Emergency Procedures
  - B. Protection of the Collection and Equipment
- V. Recovery
  - A. Assessment of the Situation
  - B. Recovery Procedures
- VI. Appendix A. General Recovery Procedures for the University of Kansas Natural History Museum and Biodiversity Research Center
- VII. Appendix B. Floor Plans of the Herbarium
- VIII. Appendix C. Specimen Case and Bookshelf Dimensions
- IX. Appendix D. Disaster Preparedness and Recovery Training
- X. Appendix E. Recommendations

Given the time, expense, and effort that it would take to recover from a disaster, perhaps the most important lesson that we learned from our disaster was that a plan should prioritize specimens for recovery. We have categorized our collection by three levels of priority. Within each level there are specific criteria for determining which specimens to salvage. For the R.L. McGregor Herbarium, Priority Level One includes all type, loan, and fungal specimens. All specimens of Priority Level One will be salvaged irrespective of condition. Priority Level Two includes taxa that are particularly rich in historically important and voucher specimens. Priority Level Three includes the remainder of the specimens. Within both Priority Levels Two and Three, historically important and voucher specimens will be salvaged before others within the respective level. For the R.L. McGregor Herbarium, historically important specimens are those collected before or during 1930, a year arbitrarily chosen for the sake of reducing deliberation time. Because vouchers serve to confirm an identification published in a scholarly journal, they remain useful so long as someone can identify the specimen and even heavily damaged specimens are of potential use. A more lengthy discussion of our priority levels is available upon request.

Other preparatory steps will further mitigate the effects of a disaster. For instance, we recommend choosing the types of materials used to prepare specimens with an eye toward their recoverability. In our mock disaster, we discovered that wet exsiccatae mounted with dilute remoistenable glue were easily removed from their sheets and could be remounted during triage. Labels attached with water-reversible glue easily detached from their sheets, though they did not securely re-adhere. Labels affixed with remoistenable glue were not removable from the original sheets. Time was lost in recovering these labels, thus delaying the triage of the remaining specimens. Use of a water-reversible glue for all labels will improve the triage process, though care must be taken to ensure that the labels do not detach from the sheets until they can be attached more securely. One may also want to consider the use of a water-reversible glue for exsiccatae. Gibson (1999) noted the advantages and disadvantages of the water-reversible adhesive methyl cellulose and Down (1999) evaluated various adhesives.

A comprehensive disaster preparedness and response plan will delineate the four emergency management steps of preparation, response, recovery, and mitigation, reducing injury and damage to people, property, and the collections during crises, and increasing the efficiency of recovery from crises. This mock disaster has given the staff of the R.L. McGregor Herbarium practice in handling damaged specimens and valuable insight in developing our plan (Table 3).

Acknowledgments

We would like to thank C. Freeman for his evaluation of the specimens and participation in the disaster and recovery, and also J. Delisle and K. Miller who helped with the disaster and recovery.

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Associate Editor: Richard K. Rabeler

FIRE RECOVERY AT THE ROYAL SASKATCHEWAN MUSEUM: PART I—INITIAL RESPONSE AND IMPLICATIONS FOR DISASTER PLANNING

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Abstract.—On 16 February 1990, a fire burned in an unfinished gallery of the Royal Saskatchewan Museum in Regina, Saskatchewan. The result was extensive soot deposition on all surfaces of the building and its contents. Museum conservators gained a deeper understanding of fire prevention/suppression and were alerted to the importance of smoke suppression and containment during a fire involving modern fire-retardant materials. The disaster recovery process involved not only museum staff but also a multitude of external inspectors, managers and commercial firms. Within the context of the fire in Regina, conservators investigated the role of such external agencies in the vital decisions and procedures following a museum fire.

INTRODUCTION

There were at least 27 serious museum fires in Canada between 1970 and 1990 (Baril 1990a). Despite care and planning, fires initiate in museums or spread from neighbouring buildings. Of all the hazards existing in museums today, fire is the most serious threat to collections and buildings. It is quick and final. Recovery of remaining buildings and collections can easily cost millions of dollars. Even when a fire is extinguished before the building or significant portions of the collection are affected, the smoke generated can result in soot damage throughout the building.

The fire at the Royal Saskatchewan Museum (R.S.M.), then the Saskatchewan Museum of Natural History, in 1990 was unusual in that damage to collections was limited to soot deposition. While soot damage occurs relatively frequently as a result of either fires or furnace puff-backs, there is virtually no reference to its prevention or mitigation in the disaster planning literature, or to its treatment implications in the conservation literature. The authors hope that by documenting the extent of the damage at the R.S.M. and the difficulties associated with fire recovery, the implications of soot damage will become more widely appreciated. Those responsible for museum collections can learn more about disaster planning, fire protection equipment and critical external agencies.

THE FIRE

The Royal Saskatchewan Museum (R.S.M.) is housed in two buildings. The main museum building contains the exhibits, mounted specimen storage, and some offices. The curatorial offices, workshops and some remaining storage areas are located in a building across the street. The galleries, designed in the 1950s, were in the process of being renovated.

On the evening of 16 February 1990, an insulation company was brought into the new First Nations gallery to inject two-part polyurethane foam insulation behind a hollow replica of a rock wall. A museum technician who had been assisting the contractors watched the local news later that evening and learned that firefighters were trying to locate the source of a fire at the museum. The technician, suspecting that he knew the location of the fire, rushed to the scene and led firefighters through the dense, black smoke to the rock wall.

The unofficial cause of the fire was self-ignition of the foam due to heat which was trapped between the resin/fibreglass rock wall and the fire-separation gallery wall. The foam, and eventually the materials surrounding it, burned until an ionization smoke detector in the central return duct indicated the presence of smoke. This triggered an alarm system that alerted the fire station. Firefighters arrived at the building only two minutes later but saw no evidence of fire. A minute later, thick billows of smoke appeared in the windowed lobby and firefighters broke into the smoke-filled building. This incredible speed of smoke build-up, typical of a modern fire, combined with other factors to prevent the crew from finding the fire until almost an hour later. Once located, the fire was extinguished in minutes.

The modern construction materials in the gallery—fire separation walls, steel studs and fire retardant gyprock—prevented ignition of the wood structure of the original museum building. However, the smoke generated by the fire was carried on air currents further into the First Nations Gallery. As smoke accumulated, it travelled through ducts that were left open during construction operations into the Life Sciences Gallery located on the upper floor. It then travelled down the aisles and stairs, and through the air handling ducts to the rest of the building. The rapid and comprehensive spread of this thick, black, sticky smoke proved to be the greatest tragedy of all.

While the gallery was under construction, some basic precautions had been neglected. Smoke detectors at the site were capped in order to avoid their contamination by dust produced during renovations. Although this protection is standard practice on construction sites, the dust covers were not removed at the end of the work day. A daily fire watch, consisting of a patrol of the renovation site for one to three hours after closing, should also have been implemented. Generally, the need for a fire watch can be incorporated into a contractor's agreement (Baril 1990b, UK Working Party 1992).

Fire alarm and suppression systems had been designed to the Canadian National Building Code, which was insufficient protection for collections. The fire alarm and security systems in the building were compromised during renovation and the building lacked a fully zoned fire alarm system and sprinklers. Not only was there no indication as to the location of the fire because the annunciation panel was hidden from view behind the reception desk, but firefighters had difficulty entering the building and moving within it because doors were closed tight with magnetic locks. A new security system that was to incorporate automatic opening of doors in the event of a verified fire had not been completely installed when the fire occurred.

There were some positive elements that mitigated the disastrous effects of the fire: 1) fire-retardant material used in the construction of the gallery slowed the spread of flames; 2) firefighters were very sensitive to the nature of the building's contents; 3) there were no artifacts in the fire-ravaged First Nations Gallery (fitting of objects in cases was done with replicas to minimize artifact handling); and 4)

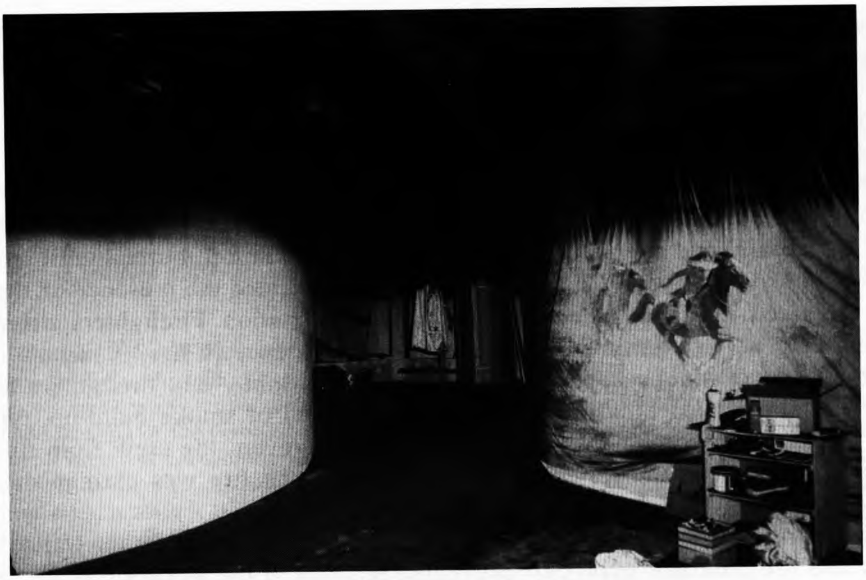

Figure 1. Walls of the First Nations Gallery showing soot coverage.

the alarm system automatically alerted the fire department and saved the museum from much greater loss.

The Building

After the fire, the building had a bitter smoke smell. It was blackened with soot that transferred itself to anyone who touched it. Mechanical and electrical systems were shut down. The First Nations Gallery had been a series of white, freshly plastered curving walls and empty cases; now, horizontal surfaces were covered with a thick matte black soot layer. A black band surmounted the walls where the soot-filled air had accumulated (Fig. 1). The band was over a meter deep on walls near the burn site, with the soot forming web-like filaments up to an inch long. Farther from the burn site, the band tapered to 25 cm and the soot lay as a fine powdery mat.

At the burn site, a few portions of the blackened replica rock wall clung to the remnants of gallery walls. Metal ducts, tools, and equipment were deformed by heat, and everything in the area had been partially incinerated. The fire separation wall and fire door at the burn site had prevented the penetration of fire to the neighbouring Earth Sciences gallery but soot had reached it through air ducts, depositing in a thick layer on all surfaces. Small holes used for lighting installation allowed soot into otherwise sealed cases. Some surfaces, such as plastics, appeared to attract soot more than others (Fig. 2).

The Life Sciences galleries located on the second floor featured birds and animals displayed in dioramas. The glass fronts were not tightly sealed to the diorama shells (acrylic paint on plastered forms or commercial tempera on primed canvas marouflaged to gyprock). Fine soot penetrated this small gap, depositing in such an even fashion that the full extent of damage was not immediately apparent.

Figure 2. Moose diorama in the Life Sciences Gallery, showing soot accumulation on the artificial snow.

Bird storage, in closed cabinets, was located in the basement far from the burn site. Soot, carried through the ductwork, had infiltrated cabinets and drawers (Fig. 3), depositing in a thin layer on approximately 1,500 mounted specimens.

Initial Response to Recovery of the Museum Building and Collection

Following the fire, it was decided that most of the collection would not be moved off site for cleanup. It was the middle of winter, and a speedy transfer of the delicate objects (mostly natural history specimens) to a secure site would not be simple. In addition, there were only three conservators and no technical assistance in the early stages, meaning that in-situ cleaning of dioramas, fixed objects and displays would be undertaken by the same conservators who would clean the moveable collection and supervise the commercial cleaning and renovation that took place around fixed displays and objects. Covering more than one location was simply not feasible. The museum briefly considered renting a large moving van to hold the moveable collection in the parking lot. Instead, an arrangement was worked out whereby the collection and dioramas/displays were cleaned in the museum while the building itself was being cleaned by commercial compa-

Figure 3. Storage cabinet showing fine soot coverage after mounted bird specimens were removed.

nies. The work of the conservators thus required coordination with the private firms.

External Agencies

The severity of damage to building, grounds, furnishings and collections, and the complexity of recovery will force a fire-damaged museum into a working partnership with several external agencies and persons. At the R.S.M., these included the insurance adjuster, subcontractors, cleaners, and property management, all of whom had well established roles and procedures in post-fire recovery. Museum staff had no disaster contingency plan, and therefore found themselves scrambling to make rapid decisions and to establish their own priorities.

The authors are convinced that a recognition of all external agencies that will become involved in a post-fire recovery, and communication with such agencies to clarify their roles, is key to the success of a fire contingency plan. Conservators investigated this aspect within the context of the R.S.M. fire, and a general description of the findings is described below.

Owners

A museum may not be the sole owner of the building and its collections. Governments, boards of directors, museum "friends" organizations, property and grounds management corporations, or private individuals may wield ultimate authority in certain areas of disaster recovery. This will certainly affect the rapidity and priority of collections recovery. All owners should be included in, and authorize, the disaster plan.

In most of the literature on museum fires, note is taken that individuals and groups who have little day-to-day involvement, such as boards, may have an important say in priorities and procedures when it comes to major events such as disasters. Conversely, a conservation staff that has gained a measure of respect in matters of collections care may be passed over in favour of outside cleaning expertise after a fire due to a perceived lack of experience and expertise in this area. It is important to consult other conservators who have experience in soot removal or the treatment of water-damaged material, but the in-house staff should coordinate these efforts to ensure that the approach to treatment is consistent with the long-term care of a particular collection, and to guarantee that adequate documentation is retained by the museum.

At the R.S.M., the collection is owned by the Museum, which is ultimately owned by the governing institution—the provincial government. The building is owned by a provincial government property management corporation, the grounds by a municipal authority, and the gift shop by the museum "friends." Each owner had its own project manager, and its own vested interest and priorities. For example, the priorities of the building's owners were such that they feared soiled objects would recontaminate their cleaned building. Authority over personnel was not the Museum's; temporary technical staff could only be hired by the government personnel department, which led to months of delay in hiring staff to aid in recovery, and to inadequate screening of applicants.

In the matter of authority within a museum during disaster situations, the authors believe that while certain problems may be avoided by involving conservators in all decision-making that affects the collections, the most effective means of ensuring collection safety is to educate upper management in recovery priorities. These individuals are in a position to cut through red tape at a time when speed and efficiency are of paramount importance. It is easier to instill an understanding of conservation concerns before a disaster strikes than to try to change an entrenched hierarchy in the midst of an emergency.

Insurance

The insurance adjuster is hired by the insurance underwriters to interpret and carry out the intent of the insurance contract. The insurance agent should be contacted at the disaster planning stage to list the coverage and determine how the extent of coverage could affect the recovery work for the building and its furnishings, the grounds, and the collection. After a fire, the insurance adjuster will be a vocal part of the decision-making team. The adjuster should be chosen through the insurance agent during the disaster planning process, becoming what is termed an "adjuster of record". The adjuster should be made aware of the needs of a museum and of all aspects of the contingency plan, including the specialists within and outside the organization who have expertise in disaster recovery, appraisal and conservation.

At the R.S.M., collections were self-insured by the government, which meant that costs associated with collection clean-up had to be managed almost entirely out of the annual budget of the Museum. The building was insured through the property management corporation.

Construction Manager and Subcontractors

After a fire, many of the decision-makers may believe that the complete restoration of the building must take priority over the restoration of the collections.

If parts of a collection, such as dioramas or reconstructed dinosaur skeletons, cannot be physically moved out of the building until the latter is fully cleaned and refurbished, the methods and materials involved in building restoration will significantly affect the conservation of collections. As a member of the disaster planning and recovery teams, a conservator can work to balance the needs of the collections and the building.

To smooth the process of large-scale building refurbishment, an insurance adjuster may elect to hire a project management company, normally connected to a construction firm. The construction manager ensures better cost control, provides constant supervision, completes general construction tasks that fall between the mandates of subcontractors and serves as a liaison between subcontractors, owners and the insurance adjuster. Local firms should be called as part of disaster planning. If the chief organizer of all the trades is informed of the museum's recovery priorities and of special needs, he/she will regulate working procedures accordingly. The museum, and other owners (e.g., the building and gift shop owners), may write their own specifications for the construction company and subcontractors prior to a disaster, as in new construction projects. The general specifications may include such points as the disclosure of material formulations and techniques, handling and care instructions and even design requirements and paint colours.

An up-to-date list of specialized disaster recovery companies should be an appendix to the disaster plan. These firms deal with all facets of building cleanup including walls, ceilings and ductwork, decorative finishes, carpets, and often furnishings. Companies should be called to determine their capabilities, including types of equipment, amount of experience, and degree of understanding of the needs of the museum. It is to the organization's advantage to meet with a pre-selected company, to identify roles and learn of methods and materials involved.

In Regina, the conservation and salvage teams arrived on the scene completely unaware of each other's existence until that moment. The construction project manager tried, sometimes successfully, to coordinate the needs of subcontractors and conservators. Some problems were encountered, such as the subcontractors shifting carefully placed protective polyethylene sheeting, and the fact that conservators were unaware that HVAC fans were left running to clear the air, which redeposited airborne soot onto cleaned artifacts.

Fire Department

The local fire station must be contacted for assistance with a fire disaster plan. In Regina, the fire department will produce a "pre-plan" which is used to aid firefighters at the scene. Pre-plans include, among other things, a site plan and a layout of each floor with locations of interest (e.g., flammable materials storage, hose cabinets, etc.).

Museum representatives can make special additions to the pre-plan to ensure maximum protection for collections in the event of a fire. Such points include designating secondary search rooms that will only be entered if the fire cannot be found elsewhere. This will protect particularly sensitive collections from the unnecessary influx of smoke.

Pre-plans, if locally available, should be updated every time areas in the museum are altered—for instance, when changing the design of exhibit rooms—and a copy should be kept at the museum. The technical details found in the pre-plan could be useful as appendices to the museum disaster plan.

Arrangements should be made to tour all the shifts of firefighters from all responding stations through the museum so that those who will actually be searching the building will be better prepared. An open house for the firefighters could be held whenever major exhibits change. This is a proven method that is not used enough, and that should also be extended to the police department. At the same time, the fire department will obtain the museum's emergency evacuation plans and details of its fire prevention activities. These can serve as the basis for an improved prevention plan.

The fire department noted that certain factors at the R.S.M. combined to make firefighting difficult and to slow location of the fire:

a) the winding design of the new galleries was unfamiliar and difficult to negotiate
b) fire hoses did not reach to the end of the galleries
c) security doors remained locked throughout the fire search
d) keyed doors inside the building locked behind firefighters
e) the thickness of smoke forced a search on hands and knees
f) heavy smoke and a lack of flame prevented easy sighting of the fire.

Smoke Containment in Museum Buildings

The National Building Code (Canada) is designed primarily for life safety, with property protection being incorporated insofar as it applies to preventing the spread of a fire to other buildings. Building contents are viewed only as possible hazards, and specific provisions are not made for safeguarding them. An architect who is not aware of the special needs of museums may therefore design according to a Code that falls short of protecting collections. The problem of smoke damage is a prime example.

The R.S.M. fire burned a two-part, fire retardant, foam-in-place insulation found in many buildings. Depending upon the type of materials and flame-retardant systems used in building construction, smoke is evolved in varying quantities. The chemistry of fire-retardants is complex but the literature (Mark et al. 1985) indicates that, in the future, smoke-suppressant properties will play an increasing role in the choice of retardant systems for polymeric materials.

Nevertheless, the problem of heavy soot generation by plastics in modern buildings indicates that museums must consider not only fire containment but also smoke containment. Smoke detection in modern buildings is best effected by ionization detectors which spot the products of combustion before soot is generated. Smoke generation can then best be controlled by fire suppression with sprinklers. Baril (1990a, 1990b) provides a convincing argument for the installation of sprinklers in museums.

However, a great deal of smoke will be generated in a modern materials fire before there is enough heat to activate the sprinkler heads. The quantity of air moved through HVAC systems in museums can slow the build-up of heat considerably. This provides a strong argument for smoke control in the fire zone. Normally, the fans in the HVAC system are connected to a smoke detector, and will shut down automatically. This basic response would have prevented a certain amount of smoke damage at the R.S.M..

Currently, there are at least two options for advanced smoke containment. The first is a system now implemented in hospitals. Dampers that close in response to smoke are installed in ducts and serve to compartmentalize smoke while the exhaust from the fire zone is directed out of the building. The drawback is the high cost of the system. Some museums have a second option. Computer-based controls of air handling systems are easily adapted for smoke containment. Air supply to the fire zone can be decreased, and the exhaust, which contains the soot and smoke, can be moved from the room directly to the outside. At the same time, the system can supply air to surrounding rooms to generate a positive pressure and to prevent air movement from the fire zone into the unaffected rooms.

Experience has shown that in the "modern" museum room, fitted with fire-retardant materials and equipped with fire suppression systems, the possibility of smoke damage to surrounding areas may be greater than the possibility of damage due to flames. In a museum, even a small amount of soot can cause extensive damage of certain collections. Research continues on the effect of a smoke control system on heat detection and sprinkler initiation. (Tamura, pers. comm.) Museums interested in upgrading their fire protection system to enhance its smoke suppression and containment capabilities should discuss options with the companies responsible for their air handling and sprinkler systems, as well as with their local fire department.

Conclusion

Once museum staff have prepared for disasters such as fire by making the necessary connections with outside agencies, the chances for effective recovery of collections will be greatly increased. By developing a co-operative relationship with interested parties, and by training all museum personnel in emergency response and recovery, we believe that rising from the ashes can be swifter and less painful than was the case at the Royal Saskatchewan Museum.

Acknowledgments

Gratitude is expressed to the R.S.M.'s former Director, Ron Borden, for his willingness to disseminate this information, and to those persons from within and outside the museum who shared information regarding their participation in fire recovery.

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Associate Editors: Thomas Strang, Janet Waddington

FIRE RECOVERY AT THE ROYAL SASKATCHEWAN MUSEUM: PART II—POST-DISASTER CLEAN-UP AND SOOT REMOVAL

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Abstract.—A fire at the Royal Saskatchewan Museum burned for over an hour, depositing soot throughout the building and its contents. Cleanup of collection and displays was carried out within the building while it was being cleaned and refurbished. Over months of cleaning, a cleaning technique consisting of refined stages was adopted to deal with the factors specific to soot removal. To clean soot-covered feathers, a vacuum wand nozzle was designed. Testing was undertaken for vacuum, dry and wet cleaning of soot from delicate feathered and fur-bearing mounts.

INTRODUCTION

The fire at the Royal Saskatchewan Museum (R.S.M.) in Regina, formerly the Saskatchewan Museum of Natural History, occurred on 16 February 1990. For a description of the initial conservation response to this disaster, and implications for disaster planning see Graham and Spafford (this volume).

The authors hope that in presenting a record of their experience with soot removal at the R.S.M., others responsible for museum collections will not only have a useful reference for future soot removal work, but will more clearly understand the importance of preventing a sooty disaster from occurring. Soot clean-up is a time-consuming and therefore expensive task, however the adaptation of certain techniques used in other fields, from building cleaning to taxidermy, was demonstrated to be time-saving and cost-efficient.

BUILDING CLEANING AND RESTORATION

Due to complications outlined in Part I, sections of the museum's collection remained in the damaged building while the latter was being restored. The restoration of the building is relevant for two reasons. Firstly, strong cleaners and sealants introduced by the commercial cleaners remain in the air following application. What effect could these products have on artifacts and specimens? Actual products and techniques used by building cleaners and other subcontractors should be detailed and approved at the time of bidding for fire-recovery. Conversely, some of the products and techniques used by the building cleaning specialists proved to be very useful in cleaning collection material.

Building cleaners draw on a well-defined procedure using products designed specifically for fire clean up. Three passes of progressively thorough cleaning were undertaken by the building cleaners at the R.S.M. They first disposed of nonrecoverable building features and removed loose soot from all surfaces by vacuuming. Walls were scrubbed with rubber Chemical Sponges™. Any porous or hard-to-reach surfaces were sprayed with Kilz™, a thick alkyd-based sealant paint. A final pass consisted of cleaning and polishing, as well as deodorization with fragrances.

Clean-up of Collection and Non-Collection Material

Coordination was paramount as cleaning involved conservators, technical staff and volunteers working in many locations throughout the museum and the warehouse, in concert with building cleaners and subcontractors. Charts with cleaning test results were stored in a master binder, and short written procedures for particular objects or displays were posted to aid technicians and volunteers. Volunteers logged their hours and duties on a sign-in sheet in the lobby. A detailed portable chart was updated at the end of each day to note what objects or areas had been cleaned or partially cleaned. This was a useful aid in the organization of tasks, since projects often had to be abandoned to make way for commercial cleaning staff or subcontractors, and then resumed some days later.

One room was set aside within the museum to store cleaning kits and gear, and another to store and clean dismantled displays, objects and specimens. Various rooms had to be cleared of objects and specimens on a few occasions to accommodate a cleaning pass or a subcontractor. When work stopped on the dioramas and displays, they were wrapped in polyethylene to prevent contamination of the cleaned surfaces by airborne soot and construction-related dust.

Properties of Soot

Soot represents the liquid and solid fragments of pyrolysis—an oily, tarry matrix containing hundreds of compounds combined with carbon. Soot particles are tiny (about 7 microns), but the sticky oils cause them to form loose agglomerations of various sizes.

Samples of soot from the interior surfaces of the R.S.M. were analyzed by the Canadian Conservation Institute (CCI Analytical Report No. ARS 2861). The composition represented carbon and pyrolysed products of the polyester and polyurethane that had burned. Soot taken from various places in the museum had identical composition, but had formed different sized agglomerations. The soot was acidic (pH 4–4.5). Organic solvents easily wetted and dispersed the particles, and extracted a brown oily residue. Water neither wetted nor extracted components from the soot.

Soot Removal

Museum conservators conducted cleaning tests during the week following the fire. Over one hundred surfaces, from fossils to diorama paintings on canvas, were tested with a vacuum, mechanical cleaning tools such as Chemical Sponges™ and Groomstick™, and a variety of solvents, with and without surfactants (Table 1). Many objects required several test areas because of their varying composition or surface treatment. A chart was used to document test results and the time estimates for each area.

Similar surfaces responded differently to the same cleaning product or technique. The response to cleaning depended upon the size of soot agglomerations, "setting" of soot into warm surfaces near the fire, the thickness of the soot layer (in turn often dependent upon distance from the fire and the angle of the object surface), the degree to which soot was attracted to a particular surface, and the

Table 1. Supplies and products used in cleanup.

Tools and materials	Solvents and mixtures	Protective clothing
HEPA vacuums (high efficiency particulate air)	Saliva	White disposable coveralls
Plastic pails, small and large	De-ionized water	Respirators
Polyethylene bottles, many sizes	2% Orvus™ in de-ionized water	Dust masks
Solvent dispensers	2% Aerosol OT™ in water	Cotton gloves
Spray bottles for aqueous mixtures	2% ammonia in water	Latex gloves
Household sponges cut into small squares	4% ammonia in water	
Chemical Sponges™, natural rubber sponges	Sodium perborate in water	
Groomstick™ (mouldable sticky eraser)	10% ethanol in water	
Webril™ wipes, sheets of compressed cotton batting	50% ethanol/50% water	
Art gum erasers	100% ethanol	
Tac cloth	Mineral spirits	
Scum-X™	The Eliminator™ and Seabrite™, commercial taxidermy cleaners	
Fine gauge glass beads		
Cotton swabs		

Note: Please see APPENDIX—Materials and Suppliers for more information on commercial products.

time soot was allowed to rest on a surface prior to cleaning. Soot became more difficult to remove as time went on, especially from textured and porous surfaces.

Soot removal differs greatly from the removal of dirt and other accretions, as the soot agglomerations are easily broken into minute particles of carbon which quickly become part of even the smoothest surface. It is the first stages of soot disruption that will ultimately determine the degree of completeness of soot removal. For example, we found that if a soot-covered arborite text panel were touched, ingrained fingerprints would remain after cleaning. Vigorous wet cleaning of the same panel resulted in a grey wash of ingrained dirt, whereas vacuuming followed by wet cleaning produced a clean result. The most thorough removal of the minute soot particles was accomplished by using a progressive cleaning technique first involving direct vacuuming (which removed almost all of the soot), then dry methods that lifted more particles from the surface and, lastly, wet methods if appropriate.

Vacuuming—the first step in all soot removal—lifted soot without breaking up the agglomerations and involved minimal pressure upon, and ingraining of, the soot. A crevice tool was used directly on the surface in a suction-and-lift technique, or elevated very slightly above the surface with a finger under one end of the tool (Fig. 1). Conventional protective techniques such as placing a screen over the surface or brushing into a vacuum caused ingraining of soot, which could not subsequently be removed.

The dry cleaning materials listed above were tested using a variety of techniques. Groomstick™ attracted and held soot from any surface. It proved particularly effective on surfaces that could not be wet-cleaned or rubbed, on porous materials such as concretions (rocks formed by the precipitation of mineral matter about a nucleus such as a leaf or a piece of shell), on textured surfaces, and from tiny recesses. The crumbs of Scum-X™ eraser powder effectively lifted and held soot from many surfaces including paper, books, smooth minerals and hides.

Figure 1. Vacuuming a diorama painting using a crevice tool propped on a finger.

Chemical Sponges™ (Moffatt 1992), designed for commercial building clean-up, were indispensable. Rubbed across canvas diorama backdrops, wall paintings, book covers and smooth stone, the rubber crumbs captured and rolled away the soot (Fig. 2). Webril™, a disposable soft wipe, was used in a gentle lifting motion on smooth and on some delicate surfaces. Soft goat hair (Hake) brushes were

Figure 2. Cleaning a diorama painting using a soot sponge.

used in the same manner to lift and hold soot. They were never used in a broad brushing motion as this caused ingraining of the soot. Art gum erasers were used to clean soot from paper. Kneaded erasers and tac cloths were tested on a variety of surfaces but were found to perform less effectively than Groomstick(TM) and Webril(TM) wipes, respectively.

Wet cleaning was carried out where appropriate and was always preceded by vacuuming and often by dry cleaning. Although commonly recommended for soot removal, the oily solvents such as varsol and stoddard received no use, since cleaning tests revealed that they simply dispersed small particles of soot on the surface rather than lifting it off on the swab. When tested by Scott Williams of the Canadian Conservation Institute, these solvents also extracted oily components. This was not desirable since the goal was the pick up the particle as a whole, including the oily components. The carbon itself cannot be solubilized, therefore a lifting action rather than a solubilizing action was preferred.

For wet cleaning, the following aqueous solutions were the most useful: 2% Orvus(TM) (effective in almost all circumstances); 2% and 4% ammonia (the apparent cutting action lent itself to cleaning of diorama backdrops of varnished acrylic on canvas, and wall-paintings); 2% Aerosol OT(TM); sodium perborate; and saliva. Absolute ethanol or a 1:1 ethanol/water solution was used on shells, stone and other surfaces where water or other wet cleaners would have been unsuitable due to moisture-enhanced deterioration processes. Solutions were applied on barely dampened swabs, pads of Webril™ or pieces of sponge. In some instances, items were dipped in pails or were sprayed with the solution.

Although pre-tested and approved conservation cleaning materials were used almost exclusively, cleaning techniques were tailored to the individual object. For example, a rare dinosaur cast (acrylic media on fiberglass/resin) was cleaned with vacuum and Groomstick™, and then with 2% Orvus™ on either small sponges or Webril™ wipes. Alternatively, plastic plants from an underwater diorama were swished in garbage pails filled with 2% Orvus™, rinsed, and spread out to air dry on polyethylene sheeting. Books in a resource library were first vacuumed *in situ,* then the edges of the text blocks were cleaned with Chemical Sponges™ and art gum erasers while the book was held tightly closed. The covers and spines were then wiped with sheets of Webril™. Paper objects used in education programs were placed in paint trays half filled with Scum-X™ eraser powder and the powder was gently rolled across the surface.

Removal of Heavy Soot from Bird Mounts

Birds displayed in dioramas on the upper floor animal gallery were covered with a heavy soot layer. When viewed under an operating microscope, it was evident that the intricate web of barbules had trapped soot at the surface. Soot seldom penetrated below the top feathers. Cleaning methods that broke up the soot agglomerations and drove soot deep into the feather mat were avoided.

Months of previous experience with soot removal pointed to vacuum suction as the best way to lift soot. A dental evacuator reported as useful for feather cleaning (Green and Storch 1988?) proved too expensive, therefore an attachment with a small and versatile shape, adjustable suction, and adequate protection for feathers was constructed for use with the museum's high efficiency particulate air (HEPA) vacuum.

After several prototypes were constructed, a Plexiglas™ wand vacuum nozzle was developed (Fig. 3). Two rows of extraction holes were drilled into a side of the wand near the tip to allow free movement over the curved parts of a bird of any size (Fig. 4). A nylon butterfly net fabric welded with a hot tip into a tube shape freely rotated over the extraction holes, and a large suction control hole was located at the base of the wand. The wand performed exceptionally well, removing about 85% of the soot from feathers with no disruption to structural condition of the feathers (Fig. 5). The percentage cleaned was estimated by visually comparing, under the microscope, cleaned and uncleaned areas on the same feather. Residual soot was revealed when an overlapping feather was pulled away to expose a protected feather beneath. This soot, which resembled a shadow, was not entirely removed by any of the cleaners subsequently tested.

Various dry and wet cleaners were chosen for testing, based on methods noted in the literature (Horie 1983, 1988) and on personal experience with soot removal. All tests followed the use of the vacuum wand and were carried out on feathers removed from the tail of a Canada Jay and on test patches on the back of a mounted pelican. Analysis before and after cleaning was compared to a control that had been vacuumed only, assessed visually under the operating microscope, and recorded on photomicrographs.

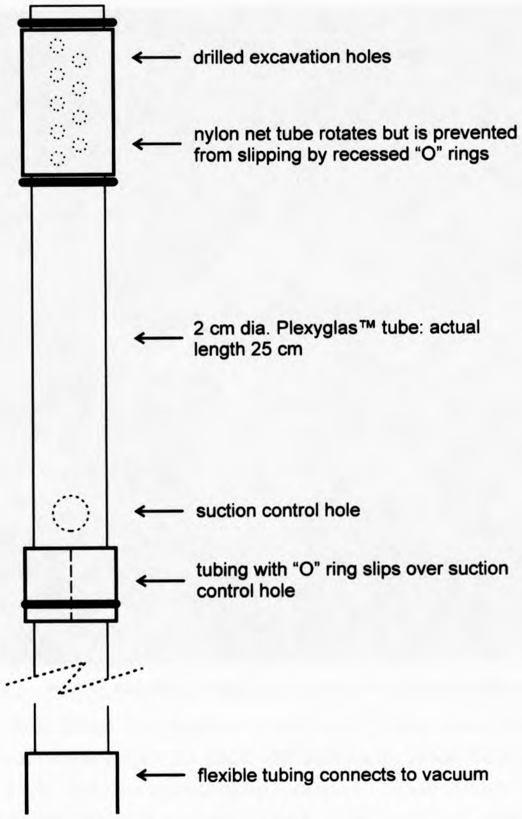

Figure 3. Vacuum wand for soot removal from feathers.

The following dry cleaning materials were tested by wiping over the feather surface in the direction of growth: tack cloth, Groomstick™, and Webril™ (torn into 1" strips and wound around a long wood applicator stick to be used like a large swab, with layers peeled off as they became soiled). Groomstick™ and Webril™ removed about 25% of the remaining soot without disturbing the feather structure.

The wet cleaners tested were as follows: 2% Orvus™ in distilled water followed by a distilled water rinse; 1% Orvus™ in 5% ethanol in water followed by a 5% ethanol in water rinse; absolute ethanol; trichloroethylene; 1:1 absolute ethanol/trichloroethylene; 1% Vulpex™ in trichloroethylene with a trichlorethylene rinse; and 2% ammonia in distilled water followed by a distilled water rinse. Webril™ pads, barely dampened with cleaners, were applied for 60 strokes along the direction of feather growth. Where a rinse was required, 30 strokes of cleaner were followed by 30 strokes of primary solvent. Wet sites were dried with a stream of cool air. Standard health and safety precautions were taken when working with the solvents. These included the wearing of protective gloves, glasses and respirators as well as the use of a localized exhaust system (i.e., "elephant trunks").

All water-based solutions yielded approximately 30% removal and resulted in a slightly grey appearance, excessive tide lines, and moderate to severe disarticulation and matting of feather barbs. The ammonia solution yellowed feathers.

Figure 4. Use of a vacuum wand to remove soot from a Canada Goose.

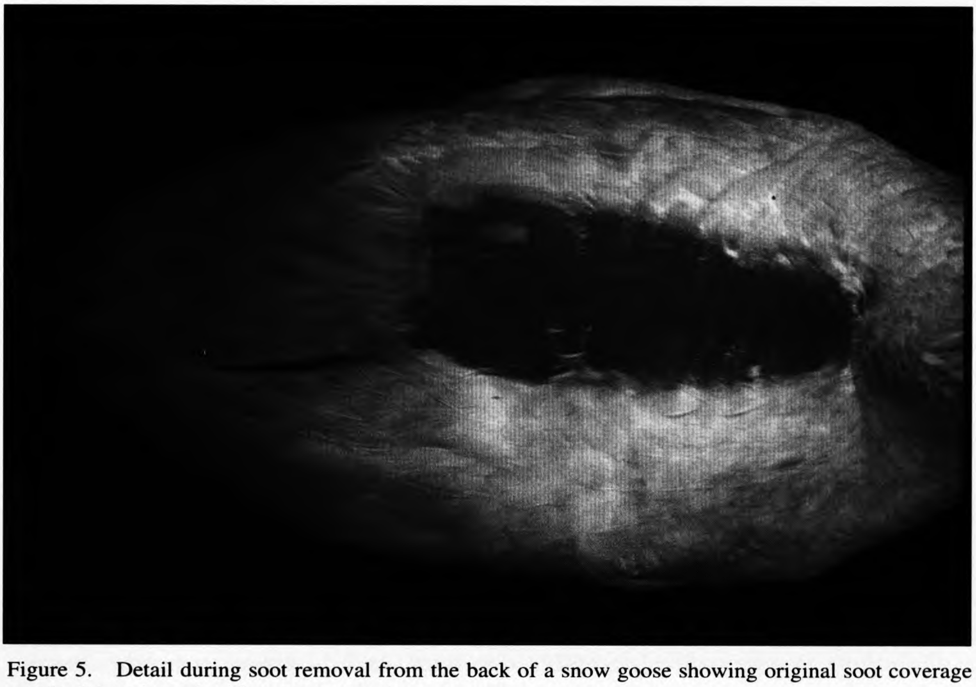

Figure 5. Detail during soot removal from the back of a snow goose showing original soot coverage and feathers cleaned with vacuum wand.

Ethanol removed about 50% of the remaining soot, but left no coloration on the swab and created tide lines by pulling soot toward the evaporating edge. The most effective cleaning solution appeared to be 1% Vulpex™ in trichloroethylene at about 60% removal with little effect on feather structure. The proven ability of this solvent to remove natural constituents from the feathers and skin must be taken into consideration. In addition, Vulpex is alkaline and its use on proteinaceous materials should therefore be questioned. In the future, the use of straight trichloroethylene is recommended.

Cleaning methods were chosen according to the test results. Dry methods (Groomstick™ and Webril™) and wet cleaners (ethanol and 1% Vulpex™ in trichloroethylene/rinse) were used, alone and in combination, but always following vacuuming with the wand. Cleaning materials were chosen depending on the particular type of feathers being cleaned and the degree of soot coverage. For example, wet cleaning was not necessary on lightly soot-covered specimens and was unsuitable for use on downy feathers.

Removal of Light Soot from Bird Mounts

The bird mount collection of 1500 specimens had been stored in closed cabinets in rooms far from the fire and had only a dusting of soot. The birds were cleaned using a variety of tools, though the size of the project precluded use of the vacuum wand. Wood bases were cleaned with a Hake brush, pieces of Chemical Sponge™, and Groomstick™. An owl wing was used with a whisking motion in the air to blow loose particles free from the feathers, and was then used for gentle brushing. A vacuum was in continuous use to pick up airborne soot before it settled again on the feathers. To pick up the remaining soot, 1″ wide strips of Webril™ were rolled several layers thick onto a wooden stick and brushed gently over the feathers. Soiled Webril™ was removed one layer at a time. Tweezers and dental tools were used for some feather realignment. The eyes, feet, and legs were cleaned with Groomstick™, ethanol, 2% Orvus™, or distilled water as appropriate.

Removal of Heavy Soot from Fur-Bearing Mounts

Removal of heavy soot from mammals stored and exhibited in the soot-filled upper galleries was more difficult than anticipated. Soot broke into fine particles as it filtered through the fur and deposited over the entire surface of the hair shafts. Soot was particularly attracted to and held by the natural oils of the hair, and to oily sprays that taxidermists had used to add sheen to specimens. Whereas feather cleaning techniques had endeavoured to lessen filtration of the soot into the feather mat by keeping to the surface, fur cleaning would involve delving all the way to the base of the hair in order to reach all of the hair surfaces.

Vacuuming with a conventional crevice tool and with the vacuum wand (without the nylon screen) removed more than 85% of soot from short haired mammals. By contrast, the crevice tool removed only 10% of soot from the longer haired specimens while the wand removed nothing.

Based on methods noted in the literature (Horie 1988, Garner 1988) and on personal experience with soot removal, tests were conducted using dry and wet cleaning materials. Cleaning tests were performed after the vacuum crevice tool was used, and were applied to test patches on the back of an arctic fox (long soft hair) and a weasel (short stiff hair).

Groomstick™, Webril™, Chemical Sponge™ and tack cloth, were wiped along the direction of hair growth but resulted in little soot removal. Cornmeal, 13 gauge glass beads and magnesium carbonate were dusted on, rubbed into the fur, and then vacuumed. Although cornmeal removed between 50% (fox) and 70% (weasel) of the soot, some cornmeal remained behind, becoming a potential source for pest infestation. The carbonate powder stuck to the fur along with the soot. Greater than 85% removal of soot was achieved by the use of glass beads on the shorthaired weasel; soot was attracted to the large surface area presented by the beads, which rolled easily from the fur. On the longhaired specimen, the glass beads removed only 50% of the soot and were difficult to control.

Because wet cleaning appeared a necessary step in cleaning the longhaired animals, wet cleaning tests were conducted on the arctic fox. All cleaners were applied to a Webril™ pad and stroked 40 times onto pre-vacuumed fur: 1% Orvus™ in distilled water/rinse; 1% Orvus™ in 5% ethanol/rinse; 1% Orvus™ in 50% ethanol/rinse; absolute ethanol; trichloroethylene; 50% ethanol/50% trichloroethylene; 1% Vulpex™ in ethanol/rinse; 2% ammonia/rinse; and commercial mount-cleaning preparations (The Eliminator™ and Seabrite™). Sites were dried with a cool stream of air along the direction of growth.

Ethanol was effective at about 75% removal from the hair shaft, leaving a pleasant soft hair, but no soot was deposited on the pad. Soot appeared to have wicked with the ethanol down the hair shaft and accumulated at the base. Aqueous solutions were disappointing, at about 20% removal; the exception was ammonia, which removed 50% of the soot but left a yellowed fur. Trichloroethylene removed 85% of the soot, but left the fur dried out. The commercial mount cleaners left the fur extremely clean, but unacceptably dry and frizzy.

The technique used for removal of heavy soot from shorthaired mammals was vacuuming with a crevice tool, followed by application of 13 gauge glass beads. Straight vacuuming with a crevice tool and then wet cleaning with either ethanol or trichloroethylene were the most successful alternatives for the animals with longer hair. Recommended cleaning techniques are summarized in Table 2.

Conclusion

Post-fire cleanup of a natural history collection can involve the added complication of cleanup within a building that is itself being cleaned and refurbished. Careful coordination and documentation are essential.

Soot removal from a wide variety of surfaces was accomplished through use of a progressive cleaning technique involving vacuum suction, followed by dry and, sometimes, wet cleaners. Some cleaning products lent themselves well to soot removal by lifting minute particles with minimal breakup, dispersion and extraction. Dry cleaning materials used with success were those that mechanically lifted and held soot; wet solutions were primarily aqueous. Cleaning of soot-covered feathers was undertaken with a specially designed vacuum wand, Webril™, Groomstick™ and trichloroethylene. Cleaning of feathers with light deposits of soot involved the use of an owl wing and Webril™. Soot removal from mammals was accomplished with use of a vacuum crevice tool followed by ethanol or trichloroethylene in the case of longhaired mammals, and by additional mechanical removal with glass beads in the case of shorthaired mammals.

Table 2. Recommended cleaning methods for different surfaces.

Surface	Dry cleaning methods	Wet cleaning methods
Arborite™	vacuum	
Plastic replica material	vacuum; Groomstick™ or ChemSponge™	2% Orvus™ in water; 4% ammonia in water; 50% ethanol/50% water; 100% ethanol
Diorama paintings–acrylic on canvas; acrylic varnish	vacuum; ChemSponge™	4% ammonia in water
Diorama paintings–acrylic on canvas; no varnish	vacuum; ChemSponge™	4% ammonia in water
Diorama paintings directly on the wall	vacuum; ChemSponge™	4% ammonia in water
Rocks, minerals, fossils	vacuum; Groomstick™ or Webril™	
Bone and ivory	vacuum; Groomstick™	50% ethanol/50% water
Paper documents	Scum-X™	
Books	vacuum; Scum-X™; Groomstick™; Webril™	2% Orvus™ in water on some vinyl bindings
Wood, unfinished	vacuum; Groomstick™	
Wood, finished	vacuum; Chemsponge™; Webril™	
Birds–heavy soot	vacuum wand; Webril™; Groomstick™	trichloroethylene
Birds–light soot	vacuum wand; owl wing; Webril™	
Animals, short hair	vacuum; glass beads	
Animals, long hair	vacuum	ethanol or trichloroethylene

Acknowledgments

Gratitude is expressed to former Museum Director, Ron Borden, for his willingness to share this information. Our thanks go out to all those who participated in the cleanup of the Royal Saskatchewan Museum.

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Associate Editors: Thomas Strang, Janet Waddington

APPENDIX

Materials and Suppliers

Aerosol OT™ (Sodium dioctylsulfosuccinate) is a surfactant and is available from chemical suppliers.

Chemical Sponge™ (vulcanized cis-1,4-polyisoprene, calcium carbonate filler). Chemical Sponge™ and other brands of these sponges may be obtained from suppliers of conservation materials (e.g., Carr McLean in Canada) or from disaster recovery companies (or their suppliers).

The Eliminator™ (nonylphenyl ethylene oxide, sodium bicarbonate, silicate). Warrick Co., IN, USA.

Glass beads (fine gauge) are available from industrial finishing equipment suppliers.

Groomstick™ (cis-1,4-polyisoprene). Picreator Enterprises Ltd., 44 Park View Gardens, London, England NW4 2PN. Distributed in Canada by Carr-McLean, Toronto, Ontario and distributors of University Products.

Kilz™ (alkyd-based paint). Manufactured by Masterchem, Antonia, Missouri. Distributed in Canada by Beaver Lumber. Available from hardware stores.

Orvus™ liquid (ammonium lauryl sulfate). Distributed by Conservation Materials Ltd., PO Box 2884, Sparks, NV, USA 89431.

Scum-X™ (Dietzgen). Distributed by Talas, 213 West 35th Street, New York, NY, USA 10001-1996.

Seabrite™ (content unknown). Seabrite Inc., PO Box 2368, St. Louis, MO, USA 63121.

Tack- or tac-cloth is a generic name for wax-impregnated cloths that may be purchased in hardware stores. The most common use for tack cloth is to remove dust from wood surfaces prior to applying a protective finish.

Vulpex™ (potassium methyl cyclohexyloleate). Distributed by Conservation Materials Ltd.

Webril™. Veratech, 6 Curity Ave., Toronto, ON, Canada, M4B 1X2. Webril™ and other brands of compressed cotton batting may be obtained from graphic arts suppliers or suppliers of janitorial materials.

LENGTH CHANGES IN WHITE STURGEON LARVAE PRESERVED IN ETHANOL OR FORMALDEHYDE

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Abstract.—We examined the effects of two preservatives on the notochord and total lengths of white sturgeon (*Acipenser transmontanus*) larvae. White sturgeon larvae that were one, seven, and 14 days old were measured live and then preserved in 95% ethanol or 10% formaldehyde. Length changes were then determined at 20 and 95 days after preservation. We found mean length changes ranging from 0.4% to 3.4% shrinkage. Length changes varied with preservative, age of larvae, and length of time preserved. Constant length correction factors are provided for 10% formaldehyde or 95% ethanol valid for larvae between 1 and 14 days old preserved for less than 100 days.

Estimation of live lengths from preserved fish larvae requires knowledge of the effects of preservation on length because preservation results in length changes. Preservation effects vary between species and lifestages (e.g., Fey 1999, Jennings 1991, Tucker and Chester 1984) and preservative induced length changes have been described extensively for marine species (e.g., Fey 1999, Fowler and Smith 1983, Hay 1981, 1982, Radtke 1989, Schnack and Rosenthal 1978, Theilacker 1980, Tucker and Chester 1984) and to a lesser extent for freshwater species (e.g., DiStefano et al. 1994, Jennings 1991, Leslie and Moore 1986, Morkert and Bergstedt 1990, Sagnes 1997, Treasurer 1992). However, no studies have documented the effects of preservation on lengths of white sturgeon (*Acipenser transmontanus*) or other acipenserid larvae. Further, few studies have examined whether or not preservation affects different developmental stages of a single species similarly.

The developmental and structural characteristics of white sturgeons suggest preservation may affect their lengths differently than other fishes. The early development and skeletal structure of Chondrosteans differ from most fishes because they develop holoblastically, possess an intraembryonic yolk endoderm, have a cartilaginous skeleton, and have a jaw that does not articulate with the skull. The present study examines changes in notochord and total length of three different age groups of white sturgeon larvae following preservation in 95% ethanol or 10% unbuffered formaldehyde. Specifically, we had four objectives: (1) calculate length changes for each age group and each preservative to allow back-calculation of live lengths from preserved specimens; (2) examine length changes to determine if the effects of 95% ethanol and 10% unbuffered formaldehyde were different between age groups and preservatives; (3) examine different preservation intervals to detect when length changes occurred for each age group and preservative; and (4) provide constant length corrections that can be used to estimate live lengths of white sturgeon larvae.

MATERIALS AND METHODS

White sturgeon larvae were obtained from a commercial hatchery on 6 June 1996 and transported to our laboratory within 24 hours of hatching. Larvae were held in 227 liter circular tanks at 15.2 ± 0.5°C. We examined larvae at one, seven, and 14 days old. Ninety larvae of each age were randomly divided into three groups. Each larva was anaesthetized with tricaine methanesulfonate (MS-222), measured, allowed to recover in freshwater, and then placed into a vial containing either 95% ethanol or 10% unbuffered formaldehyde. All larvae were preserved at the same concentration as the respective fixative. The approximate ratio between preservative volume and specimen volume was 19:1.

Notochord and total length of the left side of each fish were measured at three intervals: zero (live), 20, and 95 days. One to two drops of water were placed on larvae fixed in ethanol to mitigate the rapid evaporation effects of air (Fowler and Smith 1983). Measurements were made rapidly (within 30 s) to minimize potential effects due to contact with the water. All measurements were made with a dissecting microscope equipped with a calibrated ocular micrometer. Measurements were made with a 1.0× objective lens on the microscope for larvae less than 18 mm and with a 0.5× objective lens for larvae greater than 18 mm. After adjusting for scale, our level of resolution for all measurements was 0.16 mm. Changes in lengths were expressed as a percentage of live length and were defined as: ([length at time T − live length]/live length) × 100.

We used two different Analysis of Variance (ANOVA) models to evaluate the effects of preservation on total and notochord length. A two-way ANOVA was used to evaluate differences in notochord and total length between one, seven, and 14-day-old larvae preserved in 10% formaldehyde and 95% ethanol for 95 days. This ANOVA was followed by planned pairwise comparisons using the Least Significant Difference Test (SAS Institute 1989). To test whether changes in notochord and total lengths varied significantly between preservation intervals of zero to 20 days and 20 to 95 days for the different age groups, we used a two-way repeated measures ANOVA. This model separates the within-cell variance into variance among subjects within groupings (preservative and age) and variance within subjects over trials (time). We chose this model because length measurements were repeated on the same larvae and thus the assumption of independent observations of the two-way ANOVA model could not be met. Data were examined to ensure the assumptions of normality and equal error variances were met without transformation (Sokal and Rohlf 1995).

Results

The pattern of length changes across age groups and between preservatives was similar for notochord (Table 1) and total lengths (Table 2). Mean changes in notochord and total lengths for one and seven-day-old larvae preserved in 10% formaldehyde were less than or approximately equal to the smallest length increment we were able to measure (e.g., 0.16 mm), suggesting there were no measurable changes in lengths. For the 14-day-old larvae preserved in formaldehyde the greatest change in length occurred within the first 20 days, while for all age groups preserved in 95% ethanol, most changes in length occurred between 20 and 95 days. Mean percent change in notochord lengths ranged from 0.4% expansion for one-day-old larvae preserved for 20 days in 10% formaldehyde to 3.4% shrinkage for 14-day-old larvae preserved for 95 days in 10% formaldehyde (Table 1). Mean percent change in total lengths ranged from 0.3% expansion for

Table 1. Mean initial notochord length (mm) for each age group and mean percent shrinkage from 0 to 20 days, 20 to 95 days, and 0 to 95 days for white sturgeon larvae preserved in 10% unbuffered formaldehyde and 95% ethanol. Standard deviations are in parentheses. Negative numbers represent shrinkage; positive numbers represent expansion. For each fixative, mean percent changes in notochord lengths of larvae preserved 95 days with different superscripts are significantly different (Least Significant Difference Test, $P \leq 0.05$; df = 87).

Age (days)	*n*	Mean initial notochord length (mm)	Mean percent change in notochord length: 0 to 20 days	20 to 95 days	0 to 95 days
			10% unbuffered formaldehyde		
1	30	12.70 (0.24)	0.4 (0.8)	−0.8 (0.7)	−0.4 (0.9)[a]
7	30	16.26 (0.66)	0.0 (1.3)	−0.9 (0.5)	−0.9 (1.6)[a]
14	30	19.25 (0.80)	−2.0 (1.1)	−1.4 (1.6)	−3.4 (1.4)[b]
			95% ethanol		
1	30	12.69 (0.23)	−0.5 (0.8)	−2.4 (1.0)	−2.9 (1.4)[a]
7	30	16.17 (0.50)	0.1 (1.6)	−2.7 (1.3)	−2.6 (1.8)[a]
14	30	19.36 (0.72)	0.2 (1.0)	−2.9 (1.7)	−2.7 (1.7)[a]

seven-day-old larvae preserved for 20 days in 95% ethanol to 3.2% shrinkage for one-day-old larvae preserved for 95 days in 95% ethanol (Table 2).

Significant differences (at most, $P \leq 0.002$) in the percent change of notochord and total lengths for larvae preserved 95 days were detected between age groups and preservatives (Table 3). Further, a significant interaction between age and preservative ($P < 0.001$) was shown, suggesting that the preservatives did not affect the lengths of different age white sturgeon larvae in the same manner. Mean percent change in notochord lengths were significantly different ($P < 0.05$, df = 87) between one-day-old and seven- and 14-day-old larvae preserved 95 days in 10% formaldehyde (Table 1). Conversely, no significant differences in the percent change in mean notochord length were detected between one-, seven-, and 14-day-old larvae preserved in 95% ethanol. Mean total length changes in formal-

Table 2. Mean initial total length (mm) for each age group and mean percent shrinkage from 0 to 20 days, 20 to 95 days, and 0 to 95 days for white sturgeon larvae preserved in 10% unbuffered formaldehyde and 95% ethanol. Standard deviations are in parentheses. Negative numbers represent shrinkage; positive numbers represent expansion. For each fixative, mean percent changes in total lengths of larvae preserved 95 days with different superscripts are significantly different (Least Significant Difference Test, $P \leq 0.05$; df = 87).

Age (days)	*n*	Mean initial total length (mm)	Mean percent change in total length: 0 to 20 days	20 to 95 days	0 to 95 days
			10% unbuffered formaldehyde		
1	30	12.94 (0.24)	0.1 (0.9)	−0.5 (0.9)	−0.4 (1.1)[a]
7	30	16.65 (0.68)	−0.2 (1.4)	−0.8 (0.6)	−1.0 (1.3)[b]
14	30	19.57 (0.83)	−1.8 (0.9)	−0.9 (1.0)	−2.7 (1.0)[c]
			95% ethanol		
1	30	12.92 (0.20)	−0.9 (0.8)	−2.4 (1.0)	−3.2 (1.3)[a]
7	30	16.49 (0.52)	0.3 (1.8)	−2.7 (1.3)	−2.4 (1.6)[b]
14	30	19.70 (0.71)	0.2 (0.8)	−2.9 (1.7)	−2.4 (1.8)[b]

Table 3. The results of a two-way ANOVA evaluating the effects of 95% ethanol and 10% unbuffered formaldehyde on notochord and total lengths of 1-, 7-, and 14-day old white sturgeon larvae preserved 95 days.

Source of variation	df	*F*-ratio	*P*
Percent change in notochord length from 0 to 95 days			
Age	2	16.15	<0.001
Preservative	1	29.55	<0.001
Age × Preservative	2	18.73	<0.001
Error	174		
Percent change in total length from 0 to 95 days			
Age	2	6.33	=0.002
Preservative	1	41.16	<0.001
Age × Preservative	2	20.02	<0.001
Error	174		

dehyde preserved larvae were significantly different ($P < 0.05$) among all age groups while for larvae preserved 95 days in ethanol, there were significant differences ($P < 0.05$, df = 87) between one-day-old and seven- and 14-day-old larvae (Table 2).

We observed similar trends in the length changes of larvae preserved zero to 20 days and 20 to 95 days. The results of the repeated measures analysis indicated that there were significant differences between age groups and preservatives, significant effect of time (duration of preservation), and significant interactions among main effects (age × preservative) and among trial effects (time × preservative, time × preservation × age) (all $P \leq 0.02$) (Table 4). However, the time × age interaction for changes in notochord length was marginally insignificant ($P = 0.097$). The significant interactions suggest the preservatives do not affect each age group similarly over time.

Since the percent change in length varied significantly for 1-, 7-, and 14-day-old white sturgeon larvae preserved in 10% formaldehyde for 95 days, we used linear regressions to describe the relation between changes in notochord and total lengths and the age of white sturgeon larvae (Fig. 1). For white sturgeon larvae preserved in 95% ethanol for 95 days, we propose that the mean of the pooled observations for 1-, 7-, and 14-day-old larvae can be used to estimate the percent change in notochord length ($\bar{x} = -2.78$, SE = -0.17) and total length ($\bar{x} = -2.67$, SE = -0.17).

Discussion

Length changes in white sturgeon larvae preserved in 95% ethanol and 10% formaldehyde were similar to those observed for other freshwater fishes. We found mean length changes in white sturgeon larvae ranging from 0.4% expansion to 3.4% shrinkage. Reductions in lengths ranging from zero to 4.9 % have been reported for several freshwater fish species (DiStefano et al. 1994, Leslie and Moore 1986). We also observed increases in mean notochord and total lengths for white sturgeon larvae preserved for 20 days in ethanol and formaldehyde. Increases in larval length following preservation have been reported for other

Table 4. The results of a repeated-measures two-way ANOVA evaluating the effects of 95% ethanol and 10% unbuffered formaldehyde on notochord and total lengths of 1-, 7-, and 14-day old white sturgeon larvae with two grouping factors (age and preservative) and one within factor (time).

Source of variation	df	*F*-ratio	*P*
Percent change in notochord length from 0 to 20 days and 20 to 95 days			
Between-subjects effects			
Age	2	15.88	<0.001
Preservative	1	28.68	<0.001
Age × Preservative	2	18.77	<0.001
Error between	174		
Within-subjects effect			
Time	1	116.36	<0.001
Time × Preservative	1	42.37	<0.001
Time × Age	2	2.37	=0.097
Time × Preservative × Age	2	7.93	<0.001
Error within	174		
Percent change in total length from 0 to 20 days and 20 to 95 days			
Between-subjects effects			
Age	2	15.88	=0.002
Preservative	1	28.68	<0.001
Age × Preservative	2	18.77	<0.001
Error between	174		
Within-subjects effects			
Time	1	80.02	<0.001
Time × Preservative	1	52.55	<0.001
Time × Age	2	4.20	=0.017
Time × Preservative × Age	2	6.77	<0.001
Error within	174		

freshwater fish larvae (Leslie and Moore 1986) and for marine fish larvae preserved in freshwater-mixed formaldehyde (Billy 1982).

We conclude that length changes in white sturgeon larvae were generally greater following preservation in 95% ethanol than 10% formaldehyde. Other reported differential changes in lengths due to preservation in formaldehyde and ethanol vary among species, lifestage, concentration of preservatives, and duration of preservation (Fey 1999, Fowler and Smith 1983, Theilacker 1980, Tucker and Chester 1984). Fowler and Smith (1983) found that length changes were greater for silver hake (*Merluccius bilinearis*) larvae preserved in 95% ethanol than 10% formaldehyde. Conversely, Theilacker (1980) showed no change in standard length in northern anchovy (*Engraulis mordax*) larvae preserved in 80% ethanol, but anchovy preserved in 5% formaldehyde decreased by 8% of live length. DiStefano et al. (1994) determined that central stonerollers (*Campostoma anomalum*) shrank more in 10% formaldehyde (2.6%) than 100% ethanol (1.2%). Other studies have shown no difference between preservatives relative to length changes in freshwater species over time (Leslie 1983, Leslie and Moore 1986). However, comparisons were between 60% ethanol and 4% formaldehyde in these studies and for preservation periods of up to five years.

The duration of preservation differentially affected length changes of white sturgeon larvae relative to age and preservative. The greatest change in lengths

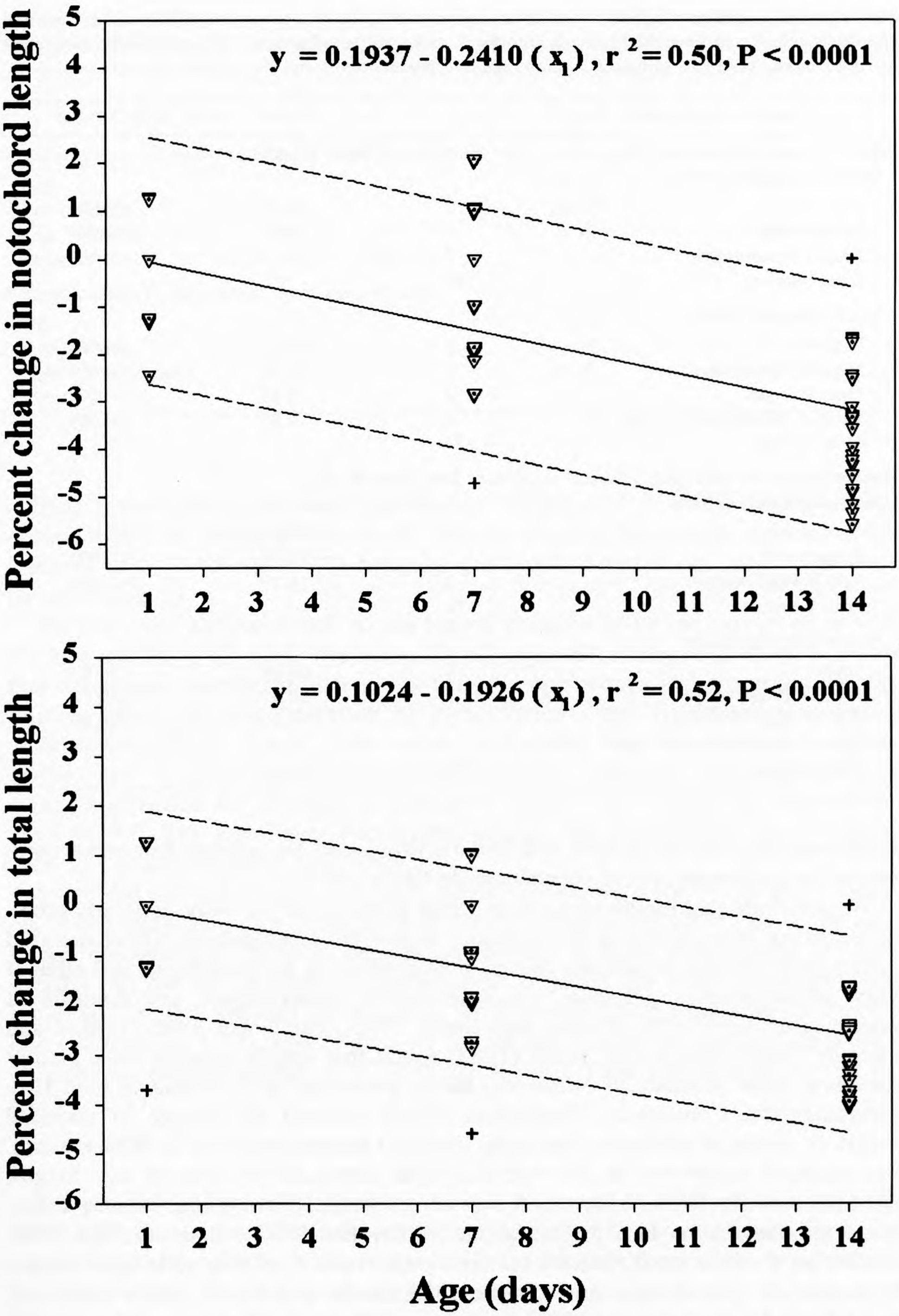

Figure 1. Linear regressions and 95% prediction intervals describing the relation of percent change in notochord and total length to the age of white sturgeon larvae reared at 15.2 ± 0.5°C and preserved in 10% formaldehyde for 95 days. Deleted observations that were identified as outliers are denoted by + symbols.

of 14-day-old white sturgeon larvae preserved in formaldehyde took place during the first 20 days while length changes of all age groups preserved in ethanol occurred 20 to 95 days after preservation. For formaldehyde, this is consistent with reports of other authors (Farris 1963, Fowler and Smith 1983, Leslie and Moore 1986) on the preservation effects on young fishes, but is inconsistent with published effects of ethanol (DiStefano et al. 1994, Fowler and Smith 1983).

Our observation of greater shrinkage in older white sturgeon larvae preserved in formaldehyde was consistent with shrinkage of larger larval sea lamprey (*Petromyzon marinus*) (Morkert and Bergstedt 1990), but contrary to most other researchers' findings of decreasing shrinkage with increasing larval length (Fowler and Smith 1983, Hay 1981, 1982, Schnack and Rosenthal 1978). Rigidity following ossification and squamation has been suggested as an explanation for reduced shrinkage in older fish (Jennings 1991). The absence of this process in white sturgeons and lampreys, which retain cartilaginous skeletons as adults, may partially explain the similarity of shrinkage in larval lampreys and sturgeons. Leslie and Moore (1986) hypothesized that length changes should be more prevalent in younger larvae due to their increased water content when compared with older larvae. Similarly, data presented by Cui et al. (1996) suggest the water content of white sturgeon larvae is also greater in younger than older larvae. Takizawa et al. (1994) found changes in larvae of three marine species to vary with age instead of size and suggested this effect may be due to ontogenetic changes in type and distribution of tissue. Sagnes (1997) suggested the differential effects he found with two 0+ grayling (*Thymallus arcticus*) populations were due to physiological differences in tissues caused by factors such as diet.

Without quantitative estimates of the effects of preservation on the lengths of fish larvae, biologists are forced to either ignore potential biases or speculate as to the direction and magnitude of biases. Length changes due to preservation could affect the accuracy of descriptions of developmental characteristics (Snyder 1988), growth, mortality, and recruitment estimates (Fey 1999, Fowler and Smith 1983, Morkert and Bergstedt 1990). We provide constant length correction factors that can be used to estimate the live lengths of white sturgeon larvae if, (1) the type and concentration of preservatives are known, (2) preservative effects on white sturgeon larvae of different lengths are accounted for, (3) the duration of preservation is known, and for white sturgeon larvae preserved in formaldehyde (4) the age (developmental stage) of the larvae can be estimated. Ages of white sturgeon larvae can be estimated by referencing the developmental stages described by Beer (1981) and then using the relationship between water temperature and timing to developmental stages presented in Wang et al. (1985).

Acknowledgments

The authors thank D. M. Gadomski, J. G. Seelye, K. M. Kappenman, and two anonymous reviewers for valuable comments on an earlier version of the manuscript.

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Associate Editor: John E. Simmons

A STUDY IN TEAM-BUILDING: THE COLLECTIONS MANAGERS' GROUP AT THE ROYAL ONTARIO MUSEUM

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Abstract.—The Collections Managers' Group (CMG) was initiated at the Royal Ontario Museum in April 1992. The group was developed by collections managers to establish a forum to openly discuss and effectively disseminate collections management information. By March 1996, the core participants of the CMG included collections managers from natural science, art, and archaeology departments, and representatives from conservation, registration, preparators, the library, and the discovery centre. Initially the CMG focused on preservation, storage and maintenance needs of research collections of arts, archaeology, and science disciplines. With further professional awareness in preventive conservation, members of the group were motivated to broaden their traditional approach to collections management and strive for a greater level of quality of collections care within their respective disciplines. By 2000, museum-wide concerns that have been addressed include 1/ pest management, 2/ standardization, documentation and conservation-testing of materials and supplies, and, 3/ development of emergency management (disaster preparedness) plans. This group promotes a collaborative workplace for collections managers to ensure the long-term, safe-keeping of the museum's most valued asset—its collections.

INTRODUCTION

Cato (1991) surveyed 64 institutions in the United States and Canada, including the Royal Ontario Museum (ROM), to develop a profile of staff positions that include responsibilities for the direct care of natural science collections. Cato's survey indicated that such positions hold responsibility for the care and curation of collections, as well as for the automation and documentation of information systems associated with them. Staff prepare and accession specimens as well as provide general collections support, maintenance, and administration. Other activities include management and supervision of personnel, teaching, public service and programming, research, and publication.

The tasks listed by Cato (1991) for collections manager-type positions accurately reflect the activities of the collections staff at the ROM. However the ROM has no formal title of *Collections Manager.* In fact, Cato's survey indicated that only 40% of the respondents formally held the official title of *Collections Manager.* The term has, however, become commonly used amongst the curatorial staff at the ROM, and will be used, herein, in the context described by Cato (1991) for collections manager-type positions.

HISTORY OF THE COLLECTIONS MANAGERS' GROUP

The role of collections manager at the ROM, as with other institutions, has evolved over time to fill both general and specific needs. Although the ultimate accountability for the collections' well-being lies with the curators, their primary function as researchers often does not afford them the time nor the specialization to address the wide-ranging topics associated with collections care and management (Cato 1988, Cholewa 1997). Staff at the ROM with job titles of either assistant curator or technician have assumed the role of collections manager. As a result, the breadth of tasks, responsibilities and priorities is highly variable not only between disciplines but also because of different job descriptions that are governed by different collective agreements. For example, research and publication are explicit responsibilities and rights of all assistant curator positions, while these are acceptable activities for only some of the technician positions. Publication topics undertaken by the curatorial staff responsible for collections management have traditionally been specific to the academic discipline represented by the type of collections, but over the past ten years, topics more frequently include those related to collections care, conservation, information systems, and database management. Also, assistant curators may hire temporary staff, may manage temporary and full-time technicians, and are expected to serve on committees for various administrative activities within the ROM and external professional groups of which they are members. These disparities in job responsibilities between assistant curators and technicians, as well as differences in management practices amongst the staff within disciplines, creates highly varying proportions of tasks (Cato 1988) being undertaken by ROM staff who identify themselves as collections managers. Correspondingly, the level of ability, responsibility, authority, independence, access to and interest in professional development as a collections manager, varies greatly across the group of individuals filling this role.

Historically, collections staff have worked somewhat in isolation with little or no ongoing communication with collections staff from other disciplines. In the mid 1980s, however, a number of the collections managers who were interested in professional development became involved in the Society for the Preservation of Natural History Collections (SPNHC). Conference and workshop attendance and presentations, committee participation, and peer-reviewed, collections-related publications increasingly became a part of their activities. A growth in knowledge regarding collections care and management led to the development and implementation of new ideas, methodologies, and practices. It became clear that because of overlapping activities and common issues, collections managers at the ROM could benefit from greater interdisciplinary collaboration. Formulation of the CMG provided the opportunity to discuss numerous topics resulting from attendance at conferences held for specialists in collections management, conservation, or database management.

With the consent of senior management, the first meeting of the CMG was held in April 1992. Initially, ten natural science departments were involved. Collections managers participated in tours of collections to better understand and appreciate the needs and issues of other disciplines. Show-and-tell sessions were held to demonstrate and discuss the archival qualities of supplies and equipment used in each of the collections. These sessions concentrated on specific products such as paper, plastics, and glass containers. Presentation and discussion topics included automation of specimen data and database management.

Senior management encouraged the collections managers of the nine art and archaeology departments to join the CMG in 1994, along with departmental representatives of the ROM library and archives, and the discovery centre (a hands-on, interactive, learning centre for children). As the activities of the group expanded, staff from a number of other non-curatorial departments were invited to join the meetings, including conservators, the head of collections management, preparators, and registrars. Depending on the focus of specific agenda items, staff from purchasing, information services, security, facilities, or senior management have been invited to attend.

By June 1995, the CMG formalized its general goals. The following is the revised mandate accepted by the CMG in November 1997:

The Collections Managers' Group represents science, art, and archaeology departments and provides an official forum for the introduction and discussion of collections-related topics. The goals are to:

1) facilitate communication and cooperation both among curatorial departments, and between those departments and staff of relevant non-curatorial departments,
2) augment the access to, and interactions with, ROM conservators, and
3) encourage and promote professional development of those having direct collections-related responsibilities.

The group focuses on issues relating to the preservation and maintenance of collections, database management, and institution-wide concerns such as pest management, disaster preparedness, facilities (including environmental conditions), security, and resource sharing. This group meets on a monthly basis to discuss issues, and promote collaborative activities and collective problem-solving to ensure the long-term safe-keeping of the ROM's most treasured asset—its collections.

Attendance at monthly meetings has generally remained high throughout the life of the group, clearly indicating that the CMG is valued by the collections managers. Agendas and minutes of meetings are circulated to collections managers via the ROM's Local Area Network. An electronic bulletin board (*Collections Info*) on the ROM Intranet promotes broad and timely communication of minutes, as well as other collections-related notices and information to interested staff throughout the museum.

Major Initiatives

Early initiatives of the CMG concentrated on the more immediate needs of the collections, such as identification of archival-quality products, database management, and grant applications for upgrading storage equipment. In time, the group addressed broader preventive conservation issues that affect collections across the institution. The following are the major proactive initiatives addressed by the CMG over the past eight years. The CMG goals of communication, preventive conservation, and professional development serve to unify these initiatives.

Resource Database

A collections supplies and equipment database was developed by the Resources Committee of SPNHC for presentation in May 1992 at the International Symposium and First World Congress on the Preservation and Conservation of Natural History Collections, in Madrid, Spain. The CMG adapted this database for the ROM's internal use to document resources, supplies, and equipment used for collections. The original database included basic distributor and product information, as well as uses of and comments regarding the product. Fields were added to the database structure to document conservation test results and materials. The database serves as a resource to collections managers providing information regarding the quality, availability, and utilization of collections products. An electronic copy of the database is available to all staff via the museum's Intranet. Although the CMG explored the possibilities of group purchasing and standardizing collections-related products, neither of these initiatives proved feasible because of economics and highly variable collections' practices between disciplines.

Grant Applications

In 1992, the CMG was instrumental in initiating and collaborating with senior management on a grant application to the Museum Assistance Program (a federally funded granting program in Canada). A grant of nearly $100,000 was awarded to and matched by the museum to support upgrades to the collections and to begin to address health and safety issues. Collections enhancements included expansion of existing compaction storage, replacement of wooden cabinets and drawers contaminated with paradichlorobenzene (PDB), and upgrading some of the oak cabinets to metal cabinets. Collection needs for a wide variety of collections, including molluscs, birds, mammals, maps, toy soldiers and archaeological artefacts, were addressed.

The ROM Foundation co-ordinates external fund-raising operations for a wide range of museum initiatives, including research and collections acquisitions. The CMG was instrumental in instigating the inclusion of criteria for collections management in grant applications to acknowledge and budget for the costs of storage and maintenance of new collections obtained through field collection, donation or purchase. This initiative was intended to invoke more cost-effective and conscientious decisions with regards to collection acquisitions.

Monitoring Environmental Conditions

Agents of deterioration of museum specimens and artefacts have been well documented (Michalski 1992, Schultz et al. 1992, Rose and Hawks 1995). The ROM, with disciplines encompassing arts, archaeology, life sciences and earth sciences, has under its purview and fiduciary responsibilities a diverse range of artefacts and specimens. Maintaining optimal environmental conditions within the collections is an important function of the facilities staff but collaboration and continual dialogue between collections managers and facilities (and when appropriate, contractors) is a critical link when system equipment, installation or repairs are being implemented. For example, in 1994 a new cost-saving Energy Management and Control System (EMCS) was installed by the ROM's facilities department to computer-control the temperature and relative humidity within the 286,789 square foot curatorial centre of the museum building. A number of times during a 3–4 month installation period, substantial fluctuations occurred in several of the collections' cold storage units and in some cases complete shutdowns of temperature and relative humidity control were experienced. The CMG provided a vehicle to alert all collections managers to be especially vigilant in monitoring their collections and detecting any impact of these environmental fluctuations.

Departmental Emergency Management Plans

In 1994, the CMG pursued the development of emergency management plans (still referred to as "disaster preparedness plans" at the ROM) on a departmental basis. The task was intended to highlight the specific needs of each discipline as a supplement to the ROM's more general disaster plan document (April 1998). The departmental plans assess issues relating to risks, mitigation and recovery procedures for collections, equipment and documentation. The risk assessment approach to preventive conservation (Michalski 1992, Waller 1995) introduced at the 1994 SPNHC Training Workshop on Risk Assessment and Management (SPNHC 9th Annual Meeting, St. Louis, MO, USA) was used in preparing these documents. This task was not completed by many disciplines. Where reports were completed, however, health and safety risks in some collections were identified and funding from the head of collections management permitted the situations to be remedied. For example, the real threat of earthquake damage (Shilts 1995) to the wet mammal collection, stored in glass jars on open metal shelving, was countered with the design and installation of removable containment bars.

Pest Management

As museums face increasing internal and external pressures to become more self-sufficient (Janes 1995, American Association of Museums 1998), the demands of space rental, commercial enterprises, and programming activities involving food or the introduction of infested materials, can compromise institutional pest management policies and practices. Greater communication and understanding through teamwork can go a long way towards the alleviation of such conflicting priorities across museum administrative divisions. A preventive approach to pest management is particularly important since recent Canadian health and safety laws have imposed limitations on the use of pesticides in public and collections spaces. Also, some of the traditional, invasive methodologies used at the ROM have proven not only ineffective for pest control but unsafe for the staff, visitors, and likely, the specimens. In an effort to achieve a more open dialogue and consultation with staff in all divisions of the museum, the CMG has worked to generate a greater awareness of the threats posed to collections that are displayed in public spaces.

In 1993, a Pest Management Review Committee was formed by the CMG to investigate issues associated with pest management at the ROM. A report was prepared but many of the recommendations of this broadly-represented committee have not yet been introduced. One recommendation that was implemented was the removal of decorative planters housing live plants, soil, and wood chips, in curatorial and gallery spaces of the museum. This resulted in a dramatic reduction, and eventually, the virtual disappearance of an Australian cockroach population that was breeding in these planters and dispersing into gallery spaces and washrooms nearby. Another recommendation from the pest management report that was implemented immediately, was the development of a pest incident report form. The report form improves the quality and consistency of the information captured in the existing ROM pest incidence database. Some of the collections managers whose collections are vulnerable, have initiated pest monitoring programs as an integral part of their collections management activities as a result of this pest management exercise.

Database Management, Data Release and Copyright

In May 1995, the Canadian Heritage Information Network (CHIN) announced the outcome of a re-evaluation of its goals and objectives. Two primary objectives of this federally-funded organization were eliminated: 1) to act as the centralized agency through which Canada pursues the nation-wide automation of collections documentation, thereby enhancing access to and standardization of the data; and 2) to encourage and support all institutions throughout the country to automate their collections data. Consequently, all collections data housed and managed by CHIN (Cox 1986) were repatriated to the home institutions by March 1998. A CHIN Migration Committee was formed by the head of information services to develop and implement an action plan for the repatriation of the ROM's collections data (over a million records). A second mandate of this committee was to assess the software options available for development of an on-site system. The CMG requested that members of the group sit on this committee to encourage access to practical information regarding database and collections management and to facilitate informed decision-making. This project was completed on schedule through effective consultation and planning.

Policies and procedures surrounding copyright of specimen and artefact data and their release also have been addressed by the CMG. Copyright regulations in Canada do not yet specifically protect electronic collections data from unauthorized use. Collections data release agreements, developed by some members of the CMG, are routinely used resources. These contracts formalize the use and publication of collection data provided to researchers, government agencies, conservation groups, and others. Plans to include collections-based information in the ROM's website (www.rom.on.ca) may provide further motivation to revisit the copyright issue as the ROM considers releasing specimen and artefact data via the Internet.

DISCUSSION

In response to external challenges and opportunities over the past several decades, operations within museums world-wide have been greatly affected by infrastructure reorganization, downsizing, and management changes (American Association of Museums 1998, Janes 1995, Hudson 1998, Butler et al. 1998). The ROM is no exception, having experienced all of these changes within the last five or six years. A common outcome of these challenges has been a primary shift in direction of museum goals, missions and activities from research-based institutions to public programming ones. Yet the reality of addressing and integrating public service, research, and long-term care of collections while addressing the essential business priorities of any museum is indeed a daunting task (Emery 1993, Griffin 1987, 1988, 1993, Janes 1995, Hudson 1998, Butler et al. 1998).

At the very core of long-term care of collections has been a persistent lack of clarity in what constitutes an institution's responsibility with regard to managing its collections (Cato et al. 1996). This is compounded by the lack of a widely accepted definition of collections management (Williams and Cato 1995, Cato et al. 1996). Furthermore, Williams and Cato (1995) argue that collections management activities within institutions can be obscured by broadly defined roles and responsibilities, as well as substantial overlap with research and public programming functions. ROM staff positions of assistant curator and technician and their assumed roles of collections managers reflect this juxtaposed diversity and lack of clarity of responsibilities.

The CMG evolved as a solutions-oriented group to address the many common issues and problems challenging collections managers at the ROM. Its developmental history provides a study in team building and an interdisciplinary, collaborative approach to collections management. As a self-help group, three clear incentives were identified: 1) a basic interest in sharing and communicating collections-related information; 2) a readiness to address the preventive conservation needs of collections; and 3) a desire for professional development and recognition. The CMG responded to the perceived needs of the collections managers and the collections themselves, in a *bottom-up approach* rather than *top-down* (Barr 1989). Barr describes the bottom-up approach as one which enables collections managers to do the job for which they are best qualified—developing detailed procedures of care that get the job done correctly and efficiently.

After eight years, we feel that the CMG has made great strides forward. It has provided collections managers with an important opportunity to openly discuss and explore both good and bad aspects of collections management. The CMG has tackled and successfully improved intra- and interdepartmental communication and cooperation among collections staff. It has been recognized and lauded by senior management for its success in communicating across disciplines, and across administrative divisions within the institution. The museum is a complex organism that can only operate as a unit if staff are willing to minimize political barriers and network across boundaries. The members of the CMG were able to do this because of their common interests, goals, and dedication to the collections.

While some institution-wide issues have been successfully addressed by the CMG, others have not. The resource database is complete and currently undergoing an update. The repatriation of all collections data from CHIN was successfully completed in 1998. Despite what would appear to be the obvious importance of emergency management plans, not everyone completed the survey of their collections. Lack of motivation, accountability, or other priorities were certainly contributing factors to the failure of this initiative. However, the lack of authority at the level of the CMG to instigate what should be an institution-wide initiative is likely the major factor. Progress towards the development of an integrated pest management system (Strang 1999) for the ROM is probably the most disappointing endeavour. Instead, the smaller victories resulting from the initiative, including funding of collections enhancements and implementing a standardized pest incident reporting mechanism, cannot be minimized.

During the most intense period of reorganization and management change at the ROM (1995–1999), it was difficult for the CMG to maintain momentum and enthusiasm. The two-year period in which the position of Head of Collections Management was vacant, resulted in a significant drop in attendance at the monthly meetings. The CMG, however, was always ready to galvanize forces in support of the collections whenever critical initiatives at the museum appeared to pose a threat. A Director of Collections Management was appointed in 1999. Collections managers were not coalesced under that umbrella, but rather remained associated with their curatorial discipline. The Director routinely attends the CMG meetings with the result that there is renewed support and recognition of the CMG. The lines of communication with senior management have once again opened up, and the benefits of both top-down and bottom-up management reinforced.

Finally, the support of collections management activities through institutional funding has perhaps been the most encouraging recognition and reinforcement for the validity of the CMG. Funding for new collections is now part of the granting process, while some existing collections issues may be resolved through funding from a bequest and two endowments amalgamated to form the Collections Care Fund.

Future projects of the CMG will likely include several previously unresolved initiatives in addition to several new ones. There is a renewed interest in pursuing the installation of a quarantined examination room for all incoming materials, as recommended by the CMG's 1993 Pest Management Report. Also, a previous attempt to document the characteristics of cabinets currently being used and to develop appropriate and preferred standards of cabinets for future purchases, may prove fortuitous given some recent developments at the ROM. The museum is presently undergoing development of a master plan, which among other initiatives includes a review of collections space. Two large collections presently stored offsite are being moved onsite, and it is likely that additional collections presently onsite at the ROM will also be relocated. Also, the fumigation chamber, routinely used to treat collection material with Phostoxin, was officially decommissioned on 03 April, 2000. The conversion to new methods (freezing, heating, and CO_2) of treating specimens and artefacts for pests has renewed discussion of an integrated pest management system. Finally, there is renewed interest in reviewing database management systems for collections management, registration and conservation that also address the use of images and data of specimens/artefacts for web page and e-commerce initiatives. The CMG is playing an active role in all of these aspects, ensuring an open dialogue, and due consideration and consultation regarding collections management.

CONCLUSION

The CMG is both a proactive and reactive group that meets to discuss issues and promote collaborative activities, collective problem-solving, and professional development. The group has served as a significant means of communication across disciplines and has raised the general awareness of collections care throughout the museum. The long-term goal of the CMG is to motivate a greater level of quality and professionalism in the care and management of collections in all areas of the museum. As museums around the world find themselves in an era of change, collaborative efforts and a bottom-up approach as demonstrated by the ROM Collections Managers' Group, become even more important to ensure the long-term safe-keeping of museum collections.

ACKNOWLEDGMENTS

The authors would like to express thanks to the members of the CMG for their dedication, not only to the group, but also to their collections. It is this interest and dedication that keeps the CMG alive and provides a sincere approach to collections care. Thanks go to Shannon Elliott, David Barr, Tosh Yamamoto, and Yvonne Schiks for critically reviewing this manuscript. We would especially like to thank Janet Waddington for her editorial contributions to an early draft of this paper. Thanks also to the external reviewers for their helpful comments and suggestions that lead to a rewrite and what we think is a much improved paper.

This publication is contribution number 172 of the Centre for Biodiversity and Conservation Biology at the Royal Ontario Museum.

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Associate Editor: Linda L. Thomas

REVIEWERS

Special thanks are extended to the following for reviewing manuscripts:

P.F. Beelitz, G. Brown, J.W. Burke, C. Collins, D. Dicus, J. Golden, G.E. Harlow, C. Herbel, T. Holmes, J. Jacobs, J. Johnson, M. Kapches, J.B. Kristoffersen, J. Levinson, D.Q. Lewis, J. MacKnight, R. McGinley, S.B. McLaren, E. Merritt, B. Moore, J. Mygatt, C. Niezgoda, J. Price, C. Ramotnik, S.M. Rossi-Wilcox, L. Ruedas, S.Y. Shelton, K. Shepherd, J.E. Simmons, J. Snider, A. Snyder, J.C. Solomon, T. Strang, A.Y. Suzumoto, S. Tse, N. Tuross, D.W. von Endt, J. Waddington, H.J. Walker, R.R. Waller, S.L. Williams, S.M. Woodward

BOOK REVIEWS

DESTRUCTIVE PRESERVATION: A REVIEW OF THE EFFECT OF THE STANDARD PRESERVATION PRACTICES ON THE FUTURE USE OF NATURAL HISTORY COLLECTIONS, 1999, S. Williams. (ACTA Universitatis Gothoburgensis, Sweden, 206 pp.) Despite recent progress in the conservation of natural history collections, the concept "destructive preservation" has arisen to describe the standard practices that contribute to the damage of natural history collections. This realization, if at first a bit disconcerting to many preservation practitioners, should be taken very seriously from the context of this volume, which features an ambitious, comprehensive scope and detailed scholarly analysis. However, applying the data presented in the book to practical collection management may be a challenge for many professionals for various reasons. The book should be considered required reading for all preservation professionals and used as the standard reference because of its empirical data.

The book is comprised of 9 chapters including the summary and bibliography, and also includes 31 figures, 33 tables, and 7 appendices. A brief summary of the topics covered follows:

1. *Introduction:* Places the preservation discipline within the museum context specifically and within the growth of empirical science and the humanities. A summary of the structure, mechanical properties, and deterioration of osteological materials as well as risks to bone in collection storage is provided. A summary table provides a succinct and detailed outline of studies presented in the book, which will help to ensure its usefulness as a manual for professionals. Also included are sections on public trust, ethics, and standards of practice which are relevant to all museum professionals (and advocates, including those who function in a voluntary capacity, whether or not they are conservators). The author advocates for accreditation and conservation education PhD programs while realistically listing the potential obstructions to such an endeavor. The author maintains that the current challenge is differentiating preservation intent from preservation practice.

2. *Stabilization:* Investigates stabilization treatments in order to document differences in preservation quality among treatments, to define methods that facilitate effectiveness, and to document problems of the stabilization practice.

3. *Processing:* The studies presented include organismal cleaning, effects of water temperature, effects of washing treatments, and the effects of processing treatments in general.

4. *Storage:* Challenges the assumptions regarding static storage conditions, where risk has been assumed to be minimal. Damage to specimens is demonstrated through fairly simply tests. Reassurance is achieved though, as some damage is shown to be preventable.

5. *Maintenance:* Truly an exhaustive effort, packed with pertinent tables and references. The conclusions are well grounded, with clear objectives, methods and comments throughout.

6 and 7. *Discussion* and *Summary* are informative for any student, museum staff, and board member. One table in this chapter lists standard preservation practices and their relationships to preventable types of damage.

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8. *Bibliography:* Although readers will find a few references relative to archeological, historical and/or ethnographic objects, the focus is clearly on zoological/osteological specimens, with little attention to physical anthropological collections.

Unfortunately, at $160, this book may never reach the audience it would help the most. Overall the author takes on global issues and places museums and natural history collections specifically in context, with a focus on osteological materials. By identifying strategies for enhancing value, purpose, and visibility for existing collections, this volume is not merely a detailed critique of current practices, but may serve as a most distinguished scientific guide to all preservation and conservation efforts.—*Jennifer Hope Antes, Museum of Natural History, Roger Williams Park, Providence, Rhode Island 02905.*

Book Review Editor: Marilyn R. Massaro

Museum Collection Resources Display Available for Loan

The Resources Subcommittee of the Conservation Committee (SPNHC) maintains two displays of supplies and materials used by many museums for the storage and preservation of natural history collections. Examples of items included in the displays are: materials used in the construction of storage containers and specimen supports; equipment for monitoring storage environments (e.g., humidity, temperature, air quality, insects); and a variety of containers for the storage of collections and documentation. Some of the products are discipline-specific (e.g., pH-neutral glassine for interleaving between herbarium sheets) but most can be used in multidisciplinary collections (e.g., Ethafoam™ for lining shelves and drawers; Tyvek™ tape for box and tray construction). The displays are available for loan to interested parties for meetings, conferences, and other museum-related activities. Shipping costs to and from the requested venues are the responsibility of the borrower. There is no loan fee but SPNHC invites borrowers to make a voluntary contribution to cover the costs of routine maintenance. For additional information, or to borrow a display, contact:

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MANAGING THE MODERN HERBARIUM—AN INTERDISCIPLINARY APPROACH, 1999, D. A. Metsger and S. C. Byers, eds. (Society for the Preservation of Natural History Collections, Washington, DC, 384 pp.) *Managing the Modern Herbarium* is the hard-copy byproduct of a workshop on herbarium management held in Toronto, Canada in 1995. Sponsored by the Botany Department of the Royal Ontario Museum and the Education and Training Committee of the Society for the Preservation of Natural History Collections, the workshop and book set out to "foster communication between herbarium personnel, researchers, conservators, and members of other disciplines in order to more effectively manage and preserve systematic collections of plants and fungi."

Forty-one authors contributed the 384 pages of text, 21 chapters, eight abstracts and short papers, eight tables, and 38 figures that were organized into the three Parts of *Managing the Modern Herbarium.* Part I, Preventive Conservation and Collections Management, is subdivided into three sections that contain topics as seemingly unrelated as the eradication of insects and the properties of plastics. Of course, when I learned that some biodegradable plastics used in herbaria "have edible components such as starch to encourage insect and bacterial attack," the interrelatedness of the topics suddenly became apparent. The three sections of Part I are really a book-within-a-book, and offer the bulk of insights into herbarium operations.

Chapters on pest management and collection care define Section I. The compendium of organizations, centers, publications, and on-line information sites provided by Carolyn Rose (Chapter 2) will serve as an invaluable conduit to a wealth of knowledge pertaining to herbaria. For example, would you like a directory of the world's public herbaria? Simply follow your fingers to page 53, and your computer mouse to http://www.nybg.org/bsci/ih/ih.html.

Section II focuses on herbarium design and renovation. Barbara Ertter's shared wisdom extracted from her experiences at the University and Jepson Herbaria of the University of California at Berkeley (Chapter 6) is particularly instructive and insightful. For sheer reading enjoyment, my favorite chapter in this section is the case study in herbarium design at the Brooklyn Botanic Garden by Kerry Barringer (Chapter 8). Anyone who can weave the following into a serious discourse on herbaria has my admiration: 1) the solution to visitors' complaints about cool herbarium temperatures—distribute sweatshirts; 2) "Well-sealed cases should protect specimens from most leaks and floods provided they are not submerged for long periods of time"; and 3) linoleum was the product of choice "to cover theatre stages as it is preferred by dancers for its resilience and flexibility."

Section III depicts the properties of paper, glue, and plastic in excruciatingly great detail. Although I can't deny that these chapters initially struck me as overkill, I must admit they are an interesting read.

After delving into the topic of bar code use in herbaria, the remainder of Part II, Contemporary Issues Facing Herbaria, tackles the issue of destructive sampling of preserved specimens as it relates to the expanding field of molecular systematics. This is clearly the most protracted coverage of any single issue in *Managing the Modern Herbarium*, and deservedly so. To those faced with deciding whether specimens should be subjected to subsampling for DNA analysis, the quandary is non-trivial. The opportunities are significant, but so may be the risks. Emily Wood, Torsten Eriksson, and Michael Donoghue admirably discuss the salient points of the debate (Chapter 15) and did us all a favor by sharing the current Policy Statement and Authorization Form developed to govern the destructive sampling of specimens in the Harvard Herbaria. This document, reproduced as an Appendix, will undoubtedly serve as a template for some herbaria, a starting point for others, and a focal point for scores of heady discussions.

The entomological and vertebrate perspectives on this debate were also characterized in Part II. The two chapters that contain this information first struck me as odd inclusions in a book on herbaria, but I held the hope that novel cross-kingdom insights might emerge that would be pertinent to herbarium management. For the most part, they did not. The remnant voucher system described in Chapter 18 seems infinitely more suited to insects than plants, the frozen soft-tissue vertebrate samples discussed in Chapter 19 are vastly different from dried plant specimens, and most of the other policy issues broached had already been addressed in previous plant-oriented chapters.

The eight one- to four-page entries that make up Part III, Abstracts and Short Papers from the Herbarium Information Bazaar, include vignettes on topics such as using egg cartons as volume-consuming shipping aids, processing fragile aquatic plants, freeze-drying fungal specimens, and retrofitting gaskets on storage cases.

Editing such a book is always a Herculean task, and with the exception of the omission of an occasional comma and the inconsistent spelling of off-gassing, the text is nearly flawless. The selection of figures, however, could have benefited from more editorial scrutiny. Figures of Mylar strips, plastic collection bags, a cardboard box full of samples, an open refrigerator full of cardboard boxes full of samples, a storage case with an open drawer, and a "pinned specimen of a carabid beetle, with preserved genitalic dissection associated with it using a genitalia vial" seem less than instructive, at least to me. It was also somewhat disconcerting to read a three-page "technique" contribution only to stumble onto an Editor's note at the end of the article alerting the reader to the fact that the technique had been discontinued at the author's institution.

Managing the Modern Herbarium is a discourse on many of the topics and issues that are relevant to the development and operation of a successful herbarium. Its strengths are in its diversity and breadth of coverage, the timeliness of its assessment of the debate over destructive sampling of preserved materials for DNA analysis, and the unanticipated windfall lessons about everything from fish glue, to foxing, to "fungus-kickers." The fact that it is organized as a suite of standalone contributions makes it more difficult from which to extract specific information about herbarium techniques than a highly integrated techniques text, but it is no less informative, and most likely, much more entertaining. What botanical text do you know of that dares to inform the concerned curator that loss of warranty is a consequence of retrofitting an upright Magic Chef freezer to hold an entire herbarium case of specimens?—*Keith T. Killingbeck, Department of Biological Sciences, University of Rhode Island, Kingston, Rhode Island 02881.*

Book Review Editor: Marilyn R. Massaro

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Jones, E.M. and R.D. Owen. 1987. Fluid preservation of specimens. Pp. 51–64 in *Mammal Collection Management* (H.H. Genoways, C. Jones, and O.L. Rossolimo, eds.). Texas Tech University Press, Lubbock, Texas. 219 pp.

Thomson, G. 1986. *The Museum Environment*, 2nd ed. Butterworth's, London, England. 293 pp.

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