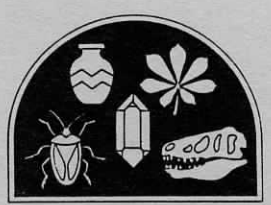
Collection Forum



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CURATION OF INVERTEBRATE FOSSIL COLLECTIONS AT THE MILWAUKEE PUBLIC MUSEUM

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Abstract.—In 1984 the Geology section of the Milwaukee Public Museum was awarded the first of three grants from the National Science Foundation to curate the invertebrate fossil collection and computerize the accompanying data. The SAS (Statistical Analysis System) database was chosen as appropriate software, and scientists and programmers worked together to determine the content and format of the database. A collections manager was hired to manage the project and perform most of the necessary duties. Data verification and entry have been in progress for six years. Specimens were cataloged by locality number and data entered into four data sets. The data sets were later combined by means of the locality number for reports. The project has been very successful and is scheduled for completion in August, 1991.

The Milwaukee Public Museum (MPM) began collecting paleontological specimens more than a century ago. Over the years a wide variety of geologists, students, and interested amateurs participated in the acquisition and curation of the fossil collections. The early collections were well documented and prepared, but the depression hit MPM very hard and qualified curatorial help was hard to obtain. Neglect, combined with subsequent rapid growth and a move to a new building seriously disrupted the collection. By the late 1970s inadequate labeling, sketchy notes, and poor organization caused research in the collection to be virtually impossible.

There have been attempts to manually untangle the confusion in the collection. The most ambitious effort came in the late 1970s when the curatorial staff began assigning locality numbers to specimens and recording the data on a series of 5 × 7 inch cards. The project lasted for about seven years. All new specimens received these locality numbers, but the retrospective curation never progressed beyond the Cambrian and part of the Ordovician collections. When computerization began, these locality numbers were abandoned due to inadequate data and differences in the criteria for assigning localities. The old numbers, however, have been referred to in the literature and were therefore cross-indexed in the new database.

NSF GRANT

By the early 1980s MPM had acquired a computer system linked to the Milwaukee County mainframe. The Vertebrate Zoology section had begun computerizing their collections using the SAS (Statistical Analysis System) database administered by the Information Management Services Division of Milwaukee County. In order to take advantage of the newly available technology and to regain control of the collections, the Geology Section applied to the Biological Research Resources Program of the National Science Foundation for funding.

The initial application requested funding for a half-time scientific assistant, a quarter-time programmer and four work-study students. The award in the amount of $50,684 over two years was granted in November, 1984, and covered the

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curation of the Cambrian and Devonian invertebrates. A second grant of $50,228 was awarded in January, 1987, to curate the Ordovician and half of the Silurian collections. The third and final award of $76,526 in August, 1989, provided for a full-time collections manager to complete the last half of the Silurian and the remainder of the Paleozoic and Mesozoic invertebrates over a period of two years.

Equipment and Personnel

When this project began there were no personal computers in the curatorial sections at MPM. The museum accessed the Milwaukee County mainframe using IBM 3180 terminals which operated through the museum's IBM 5360 running IBM System 36 and 3270 emulation. The Geology Section recently purchased a Compaq 386/20E with a 110 megabyte hard drive and enhanced IBM 5250 emulator and router. We have loaded PC SAS version 6 and will soon begin routine transfer of data between our PC and the mainframe.

Many people have participated in this project. Over the years the philosophy of who should participate and how has changed dramatically. The initial grant was written by Peter Sheehan, Project Director and head of the Geology section, with a junior curator as Co-Project Director. Sheehan was the only person who has been with the project from beginning to end. Most of the curation was done by the preparator who received half-time support from the grant. His job included supervising several students and volunteers who not only performed data entry, but often made decisions concerning the data. Students and volunteers were usually temporary and did not work many hours per week. They were unable to keep up with all of the conventions for data entry and the nuances of establishing collecting localities. The data clean-up that was later required proved this arrangement to be inefficient.

The second grant had just begun when a collections manager was hired. The collections manager became responsible for the daily business of the project including supervision of the students. The students' role was limited to specimen numbering, sorting, preparation and clerical duties. Assignment of localities, specimen identification and classification and all data entry became the responsibility of the collections manager. The project director worked with the collections manager on specimen identification, project organization, and proof-reading the data sets.

In February of 1988, a second senior curator was hired and replaced the junior curator as Co-Project Director. His research on the local Silurian faunas contributed a great deal to the Silurian curation. He assigned the localities to the local Silurian collections and will do the specimen identifications. The collection manager is entering the data and will curate the remainder of the Silurian.

Curation

Before we began this project the invertebrates were not stored in any rational order. The first step was to do a preliminary sort by geologic period. It was initially impossible to sort the collection further since many of the specimens did not have typed labels in the trays. A decision was made to completely curate all of the specimens from one period at a time. To date, the Cambrian, Ordovician, and Devonian collections have been completed, and the Silurian is in progress.

The data came from a variety of sources. Beginning in 1901, specimens were

given individual specimen numbers and their collecting data was recorded in ledgers. We tried to reunite specimens that have the collector's field numbers with the original field notes. Should a specimen have conflicting data from multiple sources we established a priority beginning with the original field notes, data with the specimen, and finally the catalogs. The first two were likely to be the collector's data while the information in the catalogs had been transcribed. The small percentage of specimens that were never numbered or have lost their accompanying tags were reviewed by the senior curators and used either in the comparative collection or as teaching specimens.

New specimens are documented using a field form (Fig. 1) which is completed by the collector. The locality numbers are assigned when the collector returns with the specimens. The forms are then turned over to the collection manager for data entry.

Once all of the specimens from a geologic period have locality data they are numbered with indelible ink, placed in new trays and returned to storage. The specimens are arranged first by time interval (system and series), then geographically (by country, state and county), then by formation and member, then finally by locality number. Then the drawers are labeled. Within localities the specimens are arranged systematically. As a rule the arrangement of the collection should depend on the type of collection, how it is most often used, and, of course, how it is cataloged. We have chosen to sort by locality, because systematic arrangements break up faunal assemblages and make population studies very difficult. Also, many paleontologists restrict a research project to a stratigraphic unit of a geographic area. When someone does request a particular taxon we simply search the database, obtain a list of the localities where that taxon occurs and pull the specimens for study.

Once the specimens have been sorted it is possible to identify and count the specimens that occur in each locality. Accurate identification of a genus and species requires a taxonomist. To attempt this for over 350,000 invertebrates in the midst of a complete retrospective curation is impossible. Our goal in this phase of the curation is to inventory the specimens in each locality at more general levels of classification. These inventories are made available to the scientific community. As interested individuals study and identify collections, specific data are substituted for the general identifications in the database.

Computerization

Before the grant application could be written, decisions about the format and content of the database had to be made. The choice of software was never an issue. We were instructed by the County administration that the SAS database they already had available would suit our needs. Fortunately, they were correct. The project director, the programmer and several staff met to get acquainted with the software and decide what data were necessary to catalog and the most efficient format for the database. The last important step was the establishment of conventions for data entry.

The compiled data are divided among four data sets. A fifth data set documents outgoing loans. All of the data sets have fields of fixed length. Field names are limited to eight characters, although the data screens will accommodate longer versions of the name for ease in reading. Data sets are combined for output using

Field Collection Data Sheet

COLLECTOR:_____ DATE:_____

LOC NO:_____ LOC NAME:_____ FIELD NO:_____

COUNTY:_____ STATE:_____ MAP QUAD/SCALE:_____

SECT:_____ TWP:_____ RGE:_____ LAT:_____ LONG:_____

ZONE:_____ FACIES:_____ GROUP:_____

FORMATION:_____ MEMBER:_____ BED:_____

GEOGRAPHIC NOTES:

GEOLOGIC NOTES:

METERS ABOVE BASE OF SECTION:_____

Figure 1. Field Collection Data Sheet.

the locality number field present on each record. Because a great deal of space is available on the mainframe, coded data is kept to a minimum and terms are spelled out wherever possible. Definitions of the types of fields and their relative advantages have been described in the literature (Woodward, 1989) and will not be discussed here.

The Data Sets

The locality database, GLOC, contains all of the collecting data. Each record contains thirty-seven fields on two screens (Fig. 2). The locality numbers are assigned consecutively as new records are created. All of the specimens assigned to a locality will receive this number. The numbers themselves have no significance except that certain series of numbers are assigned to periods of time (for example, the 30,000s are all Silurian). The IVP field indicates if there are invertebrates,

```
                          Edit SAS data set: Z.GLOC                    Screen  1
Command ===>                                                           Obs  3163

LOCALITY #: _____   I_V_P: ___   LOCALITY NAME: _________________
FIELD #: _____________________   COUNTY/COUNTRY: _____________  STATE: __
MAP QUAD: ____________________   SCALE: ____   SECTION: _____________
TOWNSHIP: ___   RANGE: ___   LATITUDE: _________   LONGITUDE: _________
SYSTEM: ___   L_M_U: _   SERIES: _____   STAGE: _____
ZONE: _____________________   FACIES: ____________________

GROUP: _____________   FORMATION: _____________   MEMBER: _____________
BED: ____________________   DONOR/COL: ____________________
DATE/COLL: _________

GEOG: ____________________________________________________________________
GEOG: ____________________________________________________________________
GEOG: ____________________________________________________________________

GEOL: ____________________________________________________________________
GEOL: ____________________________________________________________________
GEOL: ____________________________________________________________________

ENTERED BY: ___   ENTRY DATE: _________   ACC NO: ______   OLD_LOC: _____


                          Edit SAS data set: Z.GLOC                    Screen  2
Command ===>                                                           Obs  3163

NOTES: ____________________________________________________________________
       ____________________________________________________________________
       ____________________________________________________________________
       ____________________________________________________________________
```

Figure 2. Locality Data Screen.

vertebrates, plants or a combination at this locality. Locality names are either assigned by the collector or the name of a nearby city or landmark. Field numbers are assigned by the collector. The geographic data conform to standard usage including postal abbreviations for states. Series and Stage conform to the International Union of Geological Sciences correlation charts when available. The collector field may contain one or more last names of collectors separated by a break character. The geographic, geologic descriptions and notes are narrative fields which contain miscellaneous data that do not recur often enough to warrant creation of a fixed field. The initials of the person who created the record and the date are included on the bottom of each record. "Old loc" cross-indexes the numbers from the old card system.

The GGEN data set contains all of the taxonomic data including specimen counts (Fig. 3). There is one GGEN record for each taxon represented in each locality. Each taxon is classified using the Treatise on Invertebrate Paleontology (Moore, 1953–present). We are currently counting only total numbers of specimens of each taxon per locality. As research data becomes available, the numbers of individual parts of specimens, fully articulated specimens and minimum individuals are substituted and the totals are revised. SAS is a statistical program that will be used in the analysis of this data.

The GLOCGEN data set cross-references the new locality numbers to the specimen numbers from the old catalogs (Fig. 4). There is a record for each specimen that was previously assigned an individual specimen number. Genus and species are included to help verify that indeed both references are to the same specimen.

```
Command ===>                  Edit SAS data set: Z.GGEN                  Screen  1
                                                                         Obs  7484

  LOCALITY #:      60015
  PHYLUM:          BRACHIOPODA
  CLASS:           ARTICULATA              ORDER:          STROPHOMENIDA
  SUPERFAMILY:     CHONETACEA              FAMILY:         CHONETIDAE
  GENUS:           CHONETINELLA            SUBGENUS:       _____________
  SPECIES:         SP.                     SUBSPECIES:     _____________
  AUTHOR:          _____________           PART 1: PV NUMBER 1:    6
                                           PART 2: BV NUMBER 2:    1
                                           PART 3: IN NUMBER 3:    2
  ARTICULATED SPECIMENS:   17
  MINIMUM INDIVIDUALS:     24             NUMBER OF SPECIMENS:    26
```

Figure 3. Taxonomic Data Screen.

Type specimens also have individual specimen numbers, but because they require additional data they are cataloged in the TYPE data set (Fig. 5). The abbreviated citations refer to our catalog of type specimens (Munthe, 1980). We intend to revise and publish the catalog using the computerized data in 1991.

Outgoing loans are documented using the LOAN data set (Fig. 6). Loan data are typed into this "registrar approved" record, run off in hard copy, signed by the necessary people and given to the registrar. The department's record of the loan is the data set. We are still in the process of implementing this new procedure and no doubt there will be some changes made.

Editing

Unless otherwise protected, data in the data sets are changed simply by striking over the existing data. The changes take effect immediately and there is no cancel key. Individual fields may be protected from accidental obliteration using the screen modification procedure. Once protected, the edit procedure will not accept changes in these fields. This is not very practical at this stage since we are still making many deliberate changes in the data. When the project is completed we will protect certain fields in this manner.

```
Command ===>                Edit SAS data set: Z.GLOCGEN                 Screen  1
                                                                         Obs  7509

  LOCALITY NUMBER:  _____
  SPECIMEN NUMBER:  _____
  GENUS:            _____________
  SPECIES:          _____________
```

Figure 4. Data screen to cross-index locality numbers to specimen catalogs.

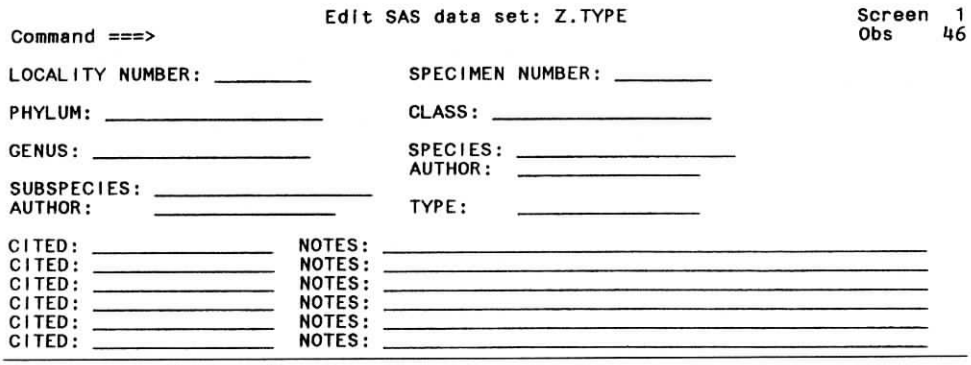

Figure 5. Type Specimen Data Screen.

Searching

Searching in the data sets is accomplished using the find and string commands and the index function. The find command retrieves data from the specified fields when the exact content of the field is known. An example of a find command is: F COLLECTR=SHEEHAN STATE=UT SYSTEM=SIL. The string command retrieves a character or group of characters from anywhere in the record regardless of what else is in the field. This is especially useful in retrieving data from narrative fields. The index function locates a character string from a user program.

Data Manipulation

Once entered, data can be manipulated using SAS utility programs or custom programs. The utilities are useful in manipulating data within one data set. The REPORT utility prepares pre-sorted data to be printed in a prescribed format. Output can be limited to only the desired fields. It will group data and total quantitative fields. The COPY utility will duplicate a data set, either whole or in part. Additional program statements may be introduced that will alter the data on the copy. The SORT utility sorts data by one or several variables at a time in

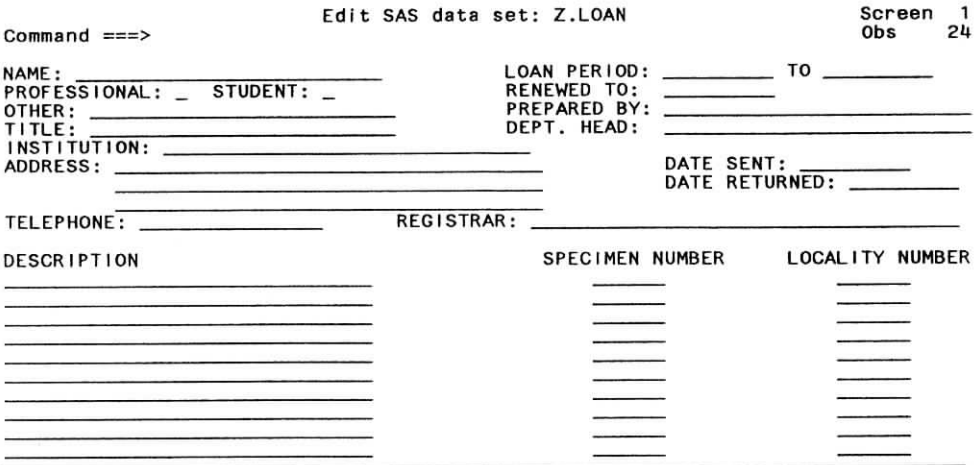

Figure 6. Outgoing Loan Data Screen.

the order they are listed. The GRAPH utility produces graphs of quantitative data. The utilities are not useful when merging data sets or when custom printing is required. In these cases we rely on our library of user programs. New user programs are created whenever the need arises. Some programs are created especially for one research request, while others are used many times. Writing these user programs requires knowledge and experience of SAS as a language.

Data Output

There are several ways of obtaining data output. Large jobs are printed in 8½ × 11 inch format on the County printers. For smaller jobs there is a pin feed dot matrix printer and laser printer in house.

Hard copy is generated to proof-read data, answer research requests, and to help safeguard the datasets. At the end of the curation of each geologic period we run a hard copy of all of the data and keep it in three-ring binders in the collections area. This would be used as a last resort should some unforeseen disaster destroy all of the datasets and the backup copies. Data on the mainframe are backed up on tape and stored in a records facility off site. Data on the hard drive of the Compaq are backed up on diskettes and stored in the museum vault.

Data Clean-up

Though we have taken steps to minimize the occurrence, no one will ever eliminate the human error factor. It is important to proof-read the data periodically and check for errors. Programs that sort the data and print it in columns are a quick way to spot typographical errors, blank fields and erroneous data. We check our new data approximately every week when data entry activity is heavy, less often when it is light. We avoid repeated proof-reading of the same data by keeping track of the range of observation numbers that has been entered since the last check.

Recommendations

The Manual

It is extremely important to keep good records of what has been done and why. Procedures, policies, conventions, programs, and examples should all be outlined in a project manual. This may seem like unnecessary housekeeping, but the effort is more than justified. In order to be useful a manual should be concise and easy to read for the novice. Remember, people often skim manuals rather than read them. It helps to divide it into sections rather than to have a long narrative. Bold headings and an index make topics easy to locate. Define all terms not common in ordinary English. Describe step by step procedures using easy to follow numbered lists rather than paragraphs. Use bold and underline to indicate especially important facts. Describe the normal operation of the equipment and solutions to common problems and include names and telephone numbers of persons to call should something go wrong. A good manual is an insurance policy and everyone associated with the project should be familiar with it.

Planning Ahead

There are many places to search for information on collections computerization. Contacting other institutions with similar collections is wise. Their software may

not be what you had in mind, but there are many parallels in data set structure that are not software dependent. It has been our experience that others are not only willing but anxious to share this information.

The literature contains manuscripts covering a range of topics relating to computerization and the preparation of specimens and data. Many have figures illustrating forms and screens that can be very helpful to someone designing them from scratch.

One of the best ways to obtain information is to attend the annual meetings of organizations involved in collections care. The information gleaned from these meetings will save the institution money by helping to avoid otherwise unforeseen errors. Meetings also provide a prime opportunity to talk to representatives of granting agencies.

Making Changes

No matter how thoroughly you research and plan, selective changes to the original plans are inevitable and we have made many over the years. Not only is experience the best teacher but the technology involved in this project has changed dramatically since the planning stages in 1983. Keeping up with new ideas has improved the quality of our database.

Summary

To date our National Science Foundation award totals $177,468. It has been the seed for successful consolidation of verified collections data into a data base useful to paleontologists and in collections management. Over 3,000 localities have been cataloged. By the end of 1991, we will have fully computerized the estimated 400,000 invertebrates and their documentation, creating a comprehensive research guide to the fossil invertebrates. We are in the process of informing the scientific community of our newly curated collections through the literature (Sumpter *et al.*, 1990) and at meetings. Requests for information and specimen loans have increased dramatically. The system is working very well, and we recommend the SAS database for the curation of paleontological collections.

Acknowledgments

The curation of the invertebrate collections is funded by the Biological Research Resources Program of National Science Foundation (BSR-8411571, BSR-8617390, and BSR-8906051). The author wishes to acknowledge Dr. Peter Sheehan for constructive criticism of this manuscript; Dr. Rodney Watkins, students, and volunteers for their contribution to this project; and Karen Heerhold and the staff of the Information Management Services Division of Milwaukee County for their assistance with the hardware and software.

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REHOUSING OF PALEONTOLOGICAL COLLECTIONS IN THE MUSEO NACIONAL DE CIENCIAS NATURALES, MADRID, SPAIN

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Abstract.—After evaluating various types of storage containers, the Museo Nacional de Ciencias Naturales has selected clear polystyrene boxes with lids to store its paleontological collections. Specimens which are too large for the boxes are stored in custom made polyethylene bags inside cardboard boxes.

For many years the Museo Nacional de Ciencias Naturales (M.N.C.N.) of Madrid, Spain, in common with many similar museums, has used cardboard boxes without lids to store paleontological specimens in closed wooden cabinets. During the late 1960s the museum purchased boxes of brown recycled plastic without lids. These were used initially for the storage of the rock collection and subsequently in the paleontological collection. In 1985 the paleontological collections were reorganized and for the first time brought together into one area with compact storage. The new storage units have open shelves without doors. Specimens are now being stored in clear polystyrene boxes with lids, or polyethylene bags.

EVALUATION OF STORAGE CONTAINERS

The cardboard boxes exhibited several problems due largely to deterioration of the materials from which they were made. Problems included: damage by insect pests or by other factors such as the acid by-products of pyrite decay and other pollutants; discoloration of box linings due to light and pollutants; failure of adhesives; and distortion of the boxes due to high RH or handling.

Boxes of brown recycled plastic 4 mm thick were purchased in two sizes (14 × 10 × 2 cm and 10 × 7 × 2 cm) without lids. These boxes overcame all the above problems. However the uncovered boxes exposed the specimens to dust, a factor which became a problem with the introduction of open storage. In addition, the open boxes increased the risk of loss or misplacement of labels, especially when the boxes were stored close together in crowded conditions.

In answer to the above problems the M.N.C.N. has started to transfer the collections to boxes of clear polystyrene, 1 mm thick, with tops. Twelve standard stock sizes of box were selected initially (Table 1). If necessary, other sizes may be added. For ease of handling, the plastic boxes are placed in large boxes of grey recycled cardboard, with lids, which are custom made to fit the adjustable shelves of the compact storage units.

In the four years that they have been in use the advantages of the new boxes have been demonstrated. The boxes are sturdy and do not deteriorate in light or fluctuating RH. Because the boxes are covered, specimens are protected from dust and the risk of loss or misplacement of labels is virtually eliminated. Because the contents are visible through the plastic, the need for handling specimens is reduced.

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Table 1. Dimensions in millimetres and cost in pesetas (pts) of clear polystyrene boxes. In November 1990, 1 peseta equaled approximately US$0.011.

Length (mm)	Width (mm)	Height (mm)	Cost (pts)
29	29	15	15
59	59	21	44
69	69	24	59
79	79	24	62
44	44	90	65
50	31	12	21
65	45	25	41
128	89	27	148
184	98	63	238
80	80	62	102
198	117	54	242
250	161	44	332

Exposure of light sensitive specimens is reduced by the placing of the plastic boxes into opaque cardboard cartons.

Specimens which are too large for the plastic boxes are sealed in custom made polyethylene bags. Tubular polyethylene 0.5 mm thick is purchased in rolls 50 m long and 10 cm, 20 cm, and 50 cm wide. These are cut to length and the open ends sealed using an electric heat sealing device. Specimens thus protected are placed in cardboard boxes for ease of handling. This process has proved to be 50% cheaper than using ready made plastic bags (about 2 pesetas compared to 4 pesetas for a bag 20 cm × 30 cm) and is more versatile.

The polystyrene boxes and tubular polyethylene are purchased from a local supplier, who also sells the heat sealing device.

Scope of the Project

The rehousing of specimens was started in January 1986, and as of October 1990, about 18,500 specimens and specimen lots have been placed in polystyrene boxes and 15,000 in polyethylene bags. This represents about 40% of the total collection. The average cost of the project has been 5,000,000 pesetas (about US$50,000) per year, including materials and labour. The work was carried out by temporary workers over approximately six-month periods, hired and paid through the State Employment Office (I.N.E.M.) (Table 2).

Table 2. Staffing of collection rehousing project.

Time period	Number of workers
December 1985–March 1986	8
July 1986–January 1987	10
October 1987–March 1988	2
July 1988–December 1988	7
August 1989–January 1990	12
August 1990–December 1990	1

SUMMARY

In selecting suitable storage containers it is necessary to consider both the properties of the specimens (shape, size, and preservation) and the features of the storage units. The value of covered plastic boxes and bags has been proved in four years of use by:

a) better security in loans and enquiries;
b) absolute absence of dust and protection of the specimens and labels;
c) perfect visibility of the specimens; and
d) protection against fluctuations in temperature and humidity. This was amply demonstrated when a flood in the basement caused water to flow over the compactors. The cardboard boxes were destroyed, but the plastic containers did not admit the water and the specimens were unaffected.

INVESTIGATION OF THE CAUSES OF STRUCTURAL DAMAGE TO TEETH IN NATURAL HISTORY COLLECTIONS

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Abstract.—A study of tooth deterioration in specimens of Recent mammals was conducted. The condition of several series of bat (*Artibeus jamaicensis*) skulls was monitored during field procedures, laboratory processing, and with controlled microenvironments that simulated temperature and relative humidity in permanent storage areas of many research collections. By monitoring the incidence of tooth cracking, particularly in canines and second premolars, it was determined that moisture changes and content were major factors in tooth stability. Moisture changes during washing procedures greatly accelerated cracking. Teeth subjected to relative humidities below 50% tended to be more fragile and susceptible to damage; below 40%, deterioration increased substantially because of desiccation.

The first visible deterioration of mammalian skulls often is associated with the teeth; ironically, the teeth are perhaps the most important morphological feature for differentiating taxonomic groups. Individual teeth will crack and eventually split, and may break into smaller pieces. Broken parts and loose teeth are often disassociated from the skull and possibly lost. To determine the seriousness of this deterioration, this study examined 793 skulls of large species of *Artibeus* maintained in collection storage; 100% had cracked or split canines; 6.8% had missing teeth. Although the incidence of tooth damage varies with different taxonomic groups, particularly those with dissimilar dentition, a related study documenting the condition of type specimens at eight major collections indicates that tooth deterioration is common to most mammalian skulls (unpublished data). However, because some specimens are in better condition than others in spite of age, poor storage conditions, and improper handling, there is a basis for critically reviewing current preservation practices and identifying the factors that provide better long-term stability.

Studies were initiated in 1986, to evaluate treatment and storage methods used for osteological materials. The skulls of Neotropical fruit bats (*Artibeus jamaicensis*) were used to examine field and laboratory treatments as well as collection storage. Part of this study, involving the relationship of field methods to the quality of cleaning by dermestids, was reported by Williams and Rogers (1989). The current study documents changes in the condition of teeth as a result of standard treatment procedures and storage.

Under no circumstances were the specimens used in this study exposed to conditions that would not normally be present in some form in most collections of Recent mammals. In some instances, the temperature and relative humidity were modified and controlled for observation and documentation purposes. Although deterioration of teeth was anticipated with some of the conditions tested, it is believed that it served as a useful lesson in specimen preservation for Recent mammal collections.

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Methods and Materials

Documentation of cracking of selected teeth provided a method of monitoring condition and evaluating the effects of treatments and storage conditions. The four canines and four second premolars of each specimen were particularly useful. In extreme cases, the first premolars and first molars were also useful. Teeth were examined under 20× magnification, using a binocular scope and a white fluorescent light attachment (Lite Mite Illuminator). During a three-year period, the condition of different series of bat skulls was monitored for as much as 12 months, from the time of collecting to the time the specimens were maintained in permanent storage. *Artibeus jamaicensis* was selected for the study because it was being collected for systematics research and it could be obtained in sufficient quantities for comparative purposes. Similar-aged adult individuals and nearly equal representation of sexes were used in this study for all comparisons involving teeth; Davis (1970) reported no significant secondary sexual variation for this species. Adult individuals were identified as having fused phalangeal epiphyses. Individuals with excessive toothwear, possibly representing older adults, were excluded from the study.

Skulls were removed from fresh, frozen, and fluid-treated specimens. The jaws were loosened and propped open so that the teeth could be easily examined under magnification. Care was taken to document and/or control temperature and relative humidity surrounding the skulls throughout the study. In the collection, the skulls were maintained under conditions free from light and fumigants.

Using the parameters described above, five different experiments were conducted to study tooth deterioration. The research was progressive in that the results of previous tests influenced the directions of subsequent tests.

Experiment 1.—Efforts were made to determine if the specimen treatments affected the condition of the skull. Preparation treatments for skeletal material have been described in the literature (Anderson, 1965; DeBlase and Martin, 1981; Hall, 1962; Hangay and Dingley, 1985; Knudsen, 1966; Nagorsen and Peterson, 1980; Wagstaffe and Fidler, 1968; Williams *et al.*, 1977). Six preparation methods were compared: *Group 1* consisted of 22 skulls removed from fresh specimens and air-dried; *Group 2* consisted of 21 skulls removed from fresh specimens, soaked three to six hours in water (for brain removal), and air-dried; *Group 3* consisted of 56 skulls removed from previously frozen specimens and air-dried; *Group 4* consisted of 10 skulls removed from fluid-treated specimens (10% formalin fixation followed by 70% ethanol storage), soaked for 14 hours in a 25% ammonia solution, and air-dried; *Group 5* consisted of 11 skulls treated the same as Group 4, except without the ammonia treatment; *Group 6* consisted of 13 skulls removed from fresh specimens stored in 95% ethanol and air-dried. The skulls of the six groups above were subsequently cleaned with dermestid larvae (*Dermestes maculatus*) and the color characteristics of the skulls and condition of the teeth were documented. Because no differences in deterioration could be detected between similar treatments in groups from Experiment 1, it was assumed that the combination of some groups would be permissible for the general comparisons made with the following tests.

Experiment 2.—Following the removal of non-osseous tissues, standard practices often involve washing skeletal material to remove grease, stains, and insect debris. Although washing may involve a simple rinsing with tap water, it is not uncommon for specimens to be soaked for several hours in detergents or alkaline solutions (Chapman and Chapman, 1969; Gross and Gross, 1966; Hoffmeister and Lee, 1963; Jakway *et al.*, 1970; Ossian, 1970). Working with the limited number of suitable skulls, the current study evaluated standard washing procedures.

To provide meaningful sample sizes for Experiment 2, *Series A* was formed from 33 skulls originating from fresh specimens (Groups 1 and 2); *Series B* was formed from 33 skulls originating from previously frozen specimens (Group 3); *Series C* was formed from 33 skulls originating from fluid-treated specimens (Groups 4, 5, and 6). Each series was subdivided into three subunits; skulls were distributed so that the subunits had similar percentages of cracked teeth. One subunit of 13 skulls from each of the three series (A, B, and C) were control samples; another set of subunits of 10 skulls each, were samples washed with tap water, and the remaining subunits of 10 skulls each, were soaked in 25% ammonia (14 hours) and rinsed with tap water. After the washing was completed, the test samples were allowed to air-dry. Skull weights were monitored to determine rate of moisture change through the air-drying process. Weights were measured with a Mettler balance (Model H35AR) which provided readings to 0.0001 g. After the weights stabilized, indicating drying was complete, the teeth were examined and compared to controls to determine the amount of damage resulting from washing procedures.

Experiment 3.—To evaluate the influence of relative humidity on the condition of teeth, skulls were

removed from 18 fluid-treated *Artibeus jamaicensis* that had been fixed with formalin and stored in 70% ethanol since 1978; all specimens had the same sex, age, collecting locality, collecting time, and treatment. For 120 days (April to August) the skulls were subjected to the same room temperatures (19.5–30.0°C), under different relative humidities. Six of the specimens were maintained under slowly changing relative humidities ranging from 45% to 53% (average RH = 48.5%); six specimens were maintained under relative humidities that ranged between 42% and 70% (average RH = 55.9%), and occasionally fluctuated as much as 11% in less than 24 hours; and, six specimens were maintained under conditions subjected to more or less progressive desiccation from 51% to 18% RH over the 120-day period. The microclimates were maintained in polyethylene bags containing preconditioned silica gel. Temperature and relative humidity were measured with Tracon thermohygrometers and recorded twice each day. The condition of the teeth was monitored daily during the first week and essentially every other day for the remainder of the observation period.

Experiment 4.—This study involved a new series of *Artibeus.* Skulls were removed from 35 fresh specimens. Five series of six to eight specimens were stored temporarily in selected concentrations of ethanol (35%, 55%, 75%, or 95%) during field activities. To compare alcohol storage in the field with standard dry storage, fresh skulls were removed from six additional specimens and air-dried. Following field activities, the skulls stored in ethanol were air-dried and then maintained for six months in a closed pasteboard box. The skulls were checked every other day for six months to determine if the different concentrations of alcohol had any effect on tooth deterioration.

Experiment 5.—Because of problems encountered in controlling microenvironments with Experiment 3, modifications in the experimental design were made and the experiment was repeated. Using skulls that had been maintained for six months in a closed pasteboard box from Experiment 4, 23 specimens with undamaged teeth were chosen for further observation. Twelve of these undamaged skulls served as a control sample which was maintained in a microenvironment that had a relative humidity ranging from 51% to 63% (average RH = 54.7%) during the 100 days of observation (September to December). The remaining 11 skulls were maintained in a microenvironment where the relative humidity was slowly dropped from 63% to 19% over the 100-day period. The microenvironments were controlled in 1.9 liter glass jars using preconditioned silica gel. Temperature and relative humidity were again measured with Tracon thermohygrometers and recorded twice each day. The condition of the teeth was monitored on a weekly basis.

Results

Experiment 1 showed that initial treatments, such as freezing or use of fluids, affects the appearance of the bone after it has been cleaned by dermestids. Cleaned bone was examined for abnormal color changes such as whitening, yellowing, or darkening; bone obscured by the presence of non-osseous tissues was also noted (Fig. 1). Skulls removed from fresh specimens and air-dried seemed to maintain what would be considered a natural color. In contrast, skulls removed from previously frozen specimens were often yellowed or darkened, and skulls associated with ethanol storage were more white. Table 1 provides specific information regarding appearance associated with initial treatments.

Patterns of Tooth Deterioration

Examination of teeth from over 175 specimens of *Artibeus jamaicensis,* from the time they were collected, to the time they were housed in permanent storage, revealed several patterns of tooth deterioration. Natural damage is primarily restricted to surface crazing and to normal toothwear with age. Occasionally specimens will have the tips of one or more teeth broken off. No cracking of teeth was observed under field conditions with freshly captured specimens.

Teeth that had already sustained damage by natural causes were slower to show cracking than complete teeth; for this reason, specimens with damaged teeth were excluded from the study. Different sets of teeth tend to be more susceptible to cracking than others. Either the upper or lower canines are usually the first teeth

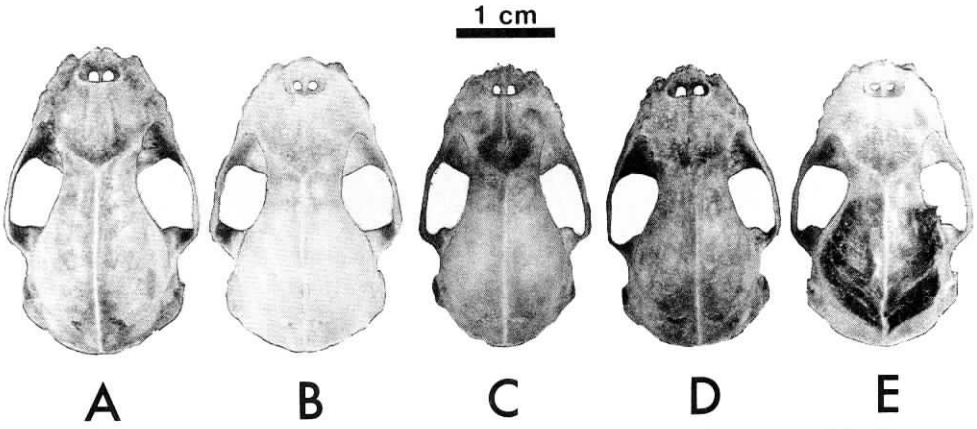

Figure 1. Photograph of dermestid-cleaned skulls, showing observed differences resulting from various preparation techniques: *A* = typical skull removed from fresh specimens; *B* = typical skull stored temporarily in ethanol; *C* (yellowed) and *D* (darkened) = typical skulls removed from frozen specimens; *E* = typical skull removed from formalin-fixed and ethanol-stored specimens.

to crack. These are followed by the second premolars. Often the upper second premolars will crack before the lower ones. After the canines and second premolars have cracked, either the first premolars or the first molars crack. In both of these cases, the upper teeth are more susceptible to cracking than the lower ones. The likelihood that upper or lower teeth will crack was assumed to be dependent on the configuration of individual teeth. Although cracking of incisors and other molars of bats has been observed previously in other specimens, this level of deterioration was not noted in the current study.

It was also noted that the susceptibility of teeth to crack varied among individual specimens. For unknown reasons, other than perhaps individual variation, some specimens from a series receiving exactly the same treatments were particularly susceptible to cracking while a few others were equally resistant. For instance, in Experiment 4, five series of six to eight specimens were subjected to one of four

Table 1. Summary of differences, attributed to specific preservation treatments, of 133 dermestid-cleaned skulls.

Group/Treatment	Sample size	Appearance				
		"Normal"	Yellowed	Dark-ened	Whit-ened	Ob-scured
Fresh specimens						
1. Air-dried	22	100.0%	—	—	—	—
2. Soaked, air-dried	21	95.2%	4.8%	—	—	—
Frozen specimens						
3. Air-dried	56	35.7%	35.7%	28.6%	—	—
Fluid-preserved specimens						
4. Formalin, ethanol, ammonia, air-dried	10	50.0%	—	10.0%	—	40.0%
5. Formalin, ethanol, air-dried	11	—	—	—	—	100.0%
6. Ethanol, air-dried	13	—	—	—	100.0%	—

ethanol concentrations for temporary storage during fieldwork. The specimens were removed from the alcohol under laboratory conditions, stored together, and monitored for more than seven months. Within 12 days, one or two specimens from each group developed canine cracks, usually involving both canines of the upper and/or lower tooth rows. This initial cracking accounted for 12.1% of the canine damage for the entire group of specimens. Relative humidity and temperature outside the pasteboard box that contained the specimens fluctuated daily as well as seasonally (30%–70% RH; 13.5–30.0°C). In spite of external fluctuations, subsequent cracking was infrequent and sporadic, resulting in only 8.6% more of the canines being damaged. At the end of seven months, 65.7% of the 35 specimens still had undamaged teeth.

Deterioration Associated With Treatments

It appears that initial preparation treatments may affect the amount of dental cracking. One comparison involving 99 skulls (Experiment 2) showed 97.1% of the canines cracked in skulls removed from fresh specimens, compared to 83% in skulls removed from previously frozen specimens and 49.3% in skulls subjected to fluid treatment. However, the difference of three months of air-drying between the fresh specimens and other treatments raises questions about the interpretation of these data. In another comparison that excluded time differences (Experiment 4), six skulls removed from fresh specimens and air-dried had 33.3% canine cracking compared to 11.8% with 35 skulls associated with various ethanol concentrations. The validity of these data could be questioned because of the small sample size of fresh specimens. There were no trends noted in the amounts of deterioration between samples treated with different ethanol concentrations (it was noted that the 35% and 55% solutions were discolored because of the decomposition of soft non-osseous tissues). Further work is needed before conclusions can be made about the influence of initial treatment techniques on the condition of teeth.

The impact of washing procedures on tooth condition was evaluated by monitoring moisture loss during drying procedures and by recording the incidence of cracking in canines and second premolars (Experiment 2). Skulls that were simply washed in running tap water for a few moments or soaked 14 hours in ammonia and then washed off with tap water retained moisture that could only be detected by monitoring weight changes. Following the moisture changes that resulted from the respective treatments, the skulls reached equilibrium with ambient winter conditions (23.3°C, 28% RH) in less than 48 hours; the greatest moisture loss was during the first 18 hours (Fig. 2). It is likely that the drying time would be prolonged with higher humidities during other seasons of the year.

Examination of teeth from test samples associated with standard cleaning procedures (Experiment 2) revealed substantial increases in deterioration. Figure 3 summarizes the increases in deterioration for the three groups of samples examined. The amount of additional cracking for the control samples ranged from 0% to 15%. After the skulls were cleaned the amount of additional cracking within the test samples accounted for 33% to 67% of the observed damages, depending on the amount of initial cracking. For all test groups, the cracking of canines and second premolars averaged 89.9%. Although it was assumed that desiccation was contributing to the cracking of untreated teeth, the differences noted between the

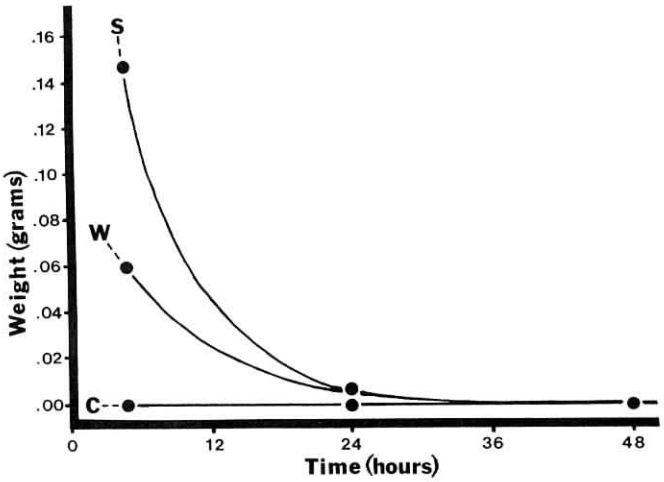

Figure 2. Moisture loss in series of skulls soaked overnight in ammonia solution and washed with tap water (S) and skulls briefly washed with tap water (W). The control group (C) received no treatment.

control groups and test groups showed that accelerated tooth deterioration was caused by the wetting and drying of the specimens. Furthermore, the effects of the washing procedures became apparent in teeth other than the canines and second premolars.

Deterioration Associated With Relative Humidity

Efforts to control microenvironments varied between methods used for Experiment 3 and Experiment 5. Because polyethylene is permeable to moisture vapor,

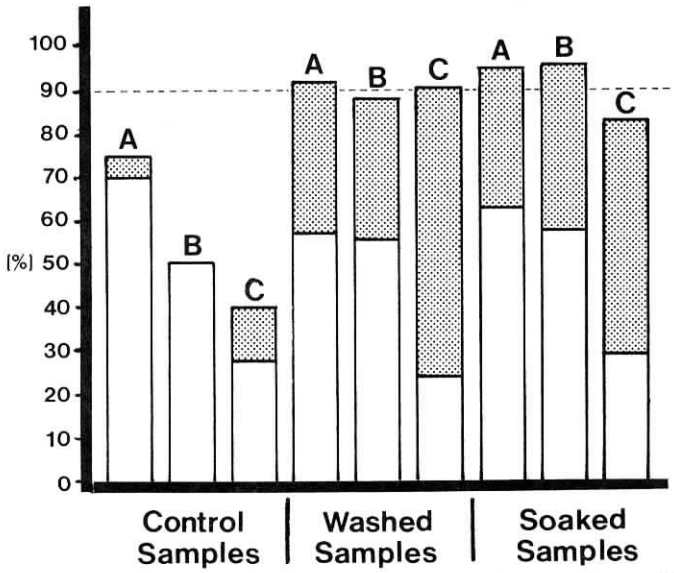

Figure 3. Canine and last premolar cracking observed in bats before and after washing procedures: *A* = fresh specimens; *B* = previously frozen specimens; *C* = fluid-treated specimens. Open portions of the bar-graphs represent amounts of observed cracking prior to the treatments; stippled areas indicate amounts of cracking observed immediately after washing procedures.

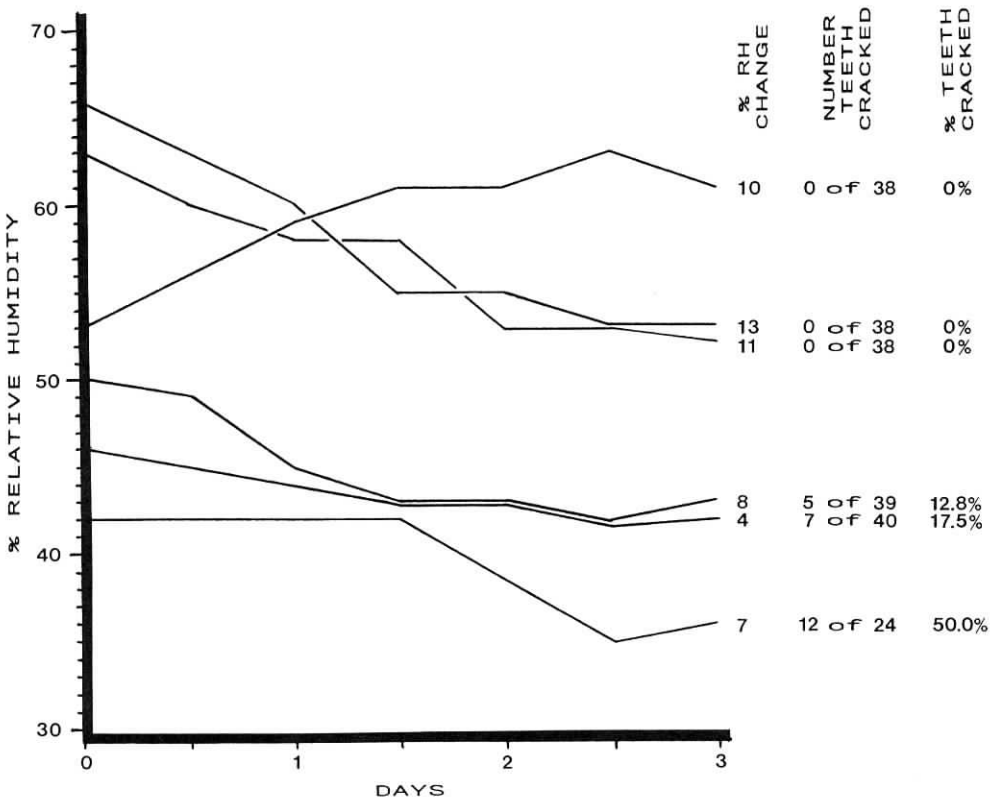

Figure 4. Observed responses of canine teeth to rapid changes in relative humidity.

it was difficult to maintain specific relative humidities, particularly if ambient conditions differed substantially; however, it was noted that sealed polyethylene bags can serve as an effective buffer to changing relative humidities. Efforts to control relative humidities in polyethylene containers occasionally resulted in more rapid relative humidity changes than intended. Because of these difficulties, subsequent studies (Experiment 5) employed other methods of controlling microclimates. It was possible to control microclimates in glass jars by manipulating preconditioned silica gel and adjusting lid tightness.

The skulls subjected to three different microclimates (Experiment 3) revealed different patterns of tooth damage. All three groups showed initial cracking of canines as attempts were made to slowly dry the specimens to approximately 50% RH over a two-week period. After 120 days of observation, damages sustained by specimens in a stable environment were almost as high as those that fluctuated with ambient conditions. However, the rate of deterioration in the stable environment was considerably slower. During the first 35 days, 33.3% of the damages were observed in a more stable relative humidity, compared to 90.9% in ambient conditions that fluctuated as much as 11% within a 24-hour period. Specimens subjected to desiccation received the greatest amount of damage. During 120 days, all of the canines, all of the second premolars, five first molars, and four first premolars were damaged. Furthermore, when the relative humidity reached

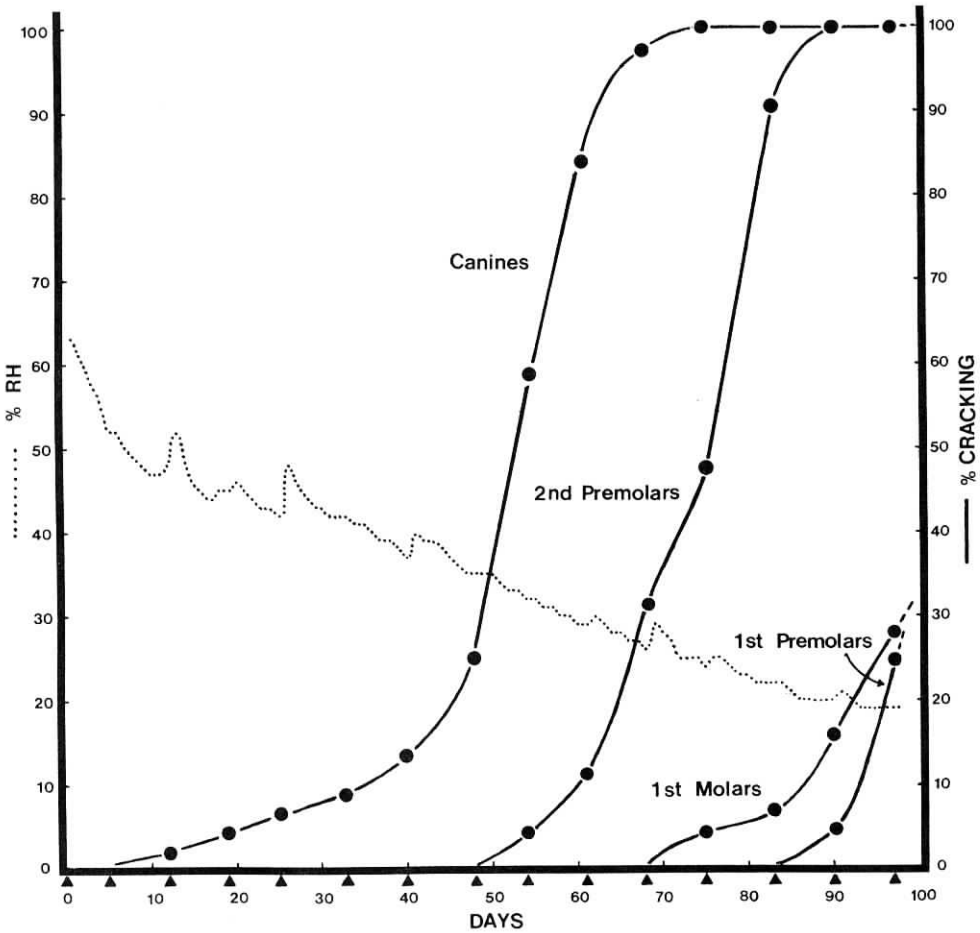

Figure 5. The effect of relative humidity changes on tooth cracking. No damage occurred with skulls maintained at relative humidities above 50%. Triangles on the horizontal axis indicate times of examination.

about 20%, the cracks of five canines expanded so that a split formed. Although insufficient control of the microclimate dictated the need for further testing with different conditions, it was noted that sudden drops in relative humidity in short periods of time (< 24 hours) were more apt to cause cracking when the relative humidity was below 45%. For instance, a 13% drop in relative humidity from 66% (including a 9% drop in 24 hours) caused no new damage, whereas a 7% drop from 42% for the same amount of time caused half of the undamaged teeth to crack (Fig. 4). This observation was particularly significant because there were initially fewer undamaged teeth remaining with the latter group.

The effects of slow desiccation were further tested with skulls that remained undamaged after seven months of minimal protection from ambient fluctuations (Experiment 5). No damage occurred in the control group maintained in an environment with relative humidities between 51% and 63%. Skulls that were subjected to relative humidities that dropped from 63% to 19% over a 100-day period (Fig. 5) revealed definite patterns of deterioration. The canines were the first to

crack. Cracking increased substantially when the relative humidity dropped below 40%. The second premolars started to crack at 32% RH. When the relative humidity was between 29% and 24%, all of the canines had cracked, cracking in second premolars increased substantially, and cracking started occurring in some of the first molars. At 20% RH, all of the second premolars had cracked and cracking in first molars and first premolars increased (Fig. 5). (Note: This response to dry conditions is probably the cause of initial deterioration observed in Experiment 2; see Fig. 3.)

Discussion

The structural properties of teeth have been discussed in detail in the literature (Holiday, 1971; MacGregor, 1985; Rose and Von Endt, 1984). Specific characteristics of *Artibeus* dentition are described by Farney (1975) and Phillips *et al.* (1977, 1982). Most teeth consist of enamel, dentine, and cementum. These components combined with the bone and connective tissue of the skull result in a rather complex object—a composite object made up of materials that can potentially respond independently to environmental influences. Because dentine is the primary component of most teeth, including tusks from some mammals, considerable information can be extrapolated from references dealing with the deterioration and care of ivory. Lafontaine and Wood (1982) demonstrated that the primary factor contributing to dentine deterioration is moisture change. Changes in environmental moisture will cause dentine, which is hygroscopic, to expand and contract. Because these movements are anisotropic, internal stresses will develop. If these stresses exceed the tensile strength of the tooth, cracking will occur (Lafontaine and Wood, 1982).

In general, the dental deterioration discussed in the literature (Holiday, 1971; Lafontaine and Wood, 1982; Werner, 1968) is consistent with damages observed in this study. As cracks develop, deterioration is accelerated because surface areas are increased and fragments of the tooth respond more quickly to moisture changes (Holiday, 1971). Although the current study used the cracking of teeth as an indication of deterioration, it must be realized that the teeth are perhaps the most resistant parts of the skull to degradation processes. The porous nature of bone makes it particularly sensitive to environmental influences (Holiday, 1971; Rose and Von Endt, 1984), thus the structural changes observed in the teeth are also occurring elsewhere in the skull.

There are described methods of using consolidants and adhesives to repair osteological materials (Snow and Weisser, 1984), but such procedures are discouraged because of the possibilities of affecting research value and potentially causing more serious damages. Therefore, a preferred approach to the problem would be to gain a better understanding of the causes of deterioration so that preventive measures may be attempted.

This study was unable to definitely determine if deterioration was caused by initial preparation procedures, such as air-drying, freezing, and fluid treatments. It is possible that ambient relative humidities over 50% in the field or lab would keep skeletal material from drying to levels where cracking would be a risk. It is suspected that more xeric conditions in the field or lab, would cause increased amounts of tooth damage. Under excessively dry field conditions, skeletal material could be protected from desiccation if it were stored in 70% ethanol.

Perhaps the most obvious indications that initial preparation procedures may influence deterioration is the appearance of skulls resulting from different treatment methods. The appearances differed enough to suspect physical differences in the bone could influence the long-term preservation of the skull. For instance, the whitening of the bone associated with ethanol storage suggests that the fats and oils in the bone may have been dissolved and removed. This may cause later problems with desiccation and embrittlement *or* it may be beneficial because these substances are removed and will not contribute to deterioration through oxidation and the formation of acidic by-products. Early discussions concerning fats in osseous tissues by Boettcher (1912) support procedures that remove fats and their by-products.

With regard to further evaluation of cleaning procedures, the effects of taking dried skulls, soaking them in water or alkaline solutions, and drying them again, is of major concern. This study clearly demonstrated that these procedures cause significant damage to skulls. Generally, exposing bone and dentine to high moisture levels for any purpose is discouraged because of predictable damage that will occur (Canadian Conservation Institute, 1983; Guldbeck and MacLeish, 1985). Furthermore, the use of strong alkaline solutions on collagenous tissues is a destructive and irreversible process which involves breaking (thus weakening) the collagen chains (Balfe, 1948; Gustavson, 1956; Rose and Von Endt, 1984). The stability of collagen quickly deteriorates at alkaline conditions exceeding a pH of 9 (Gustavson, 1956; Horie, 1987). A 25% solution of commercial ammonia, typically used for osteological material, has a pH of about 11; if the typical 10% bleach solution is also used to whiten the skulls, the proteins in the bone are being subjected to solutions with a pH of about 12. Also, the differential resistance of tissues to alkaline solutions causes the non-osseous portions to be lost first. Although it is desirable to remove these parts to clean bone surfaces, it is equally desirable to retain minute amounts of these tissues to assist in holding components of the skull together. If all of the connective tissues are removed, the teeth, and perhaps other cranial components, will separate from the skull. For *Artibeus,* teeth and auditory bullae are the most common parts disassociated from the skull. Based on the current knowledge of bone and dentine response to high and low moisture levels and the effect of alkaline solutions on collagenous tissues, it is understandable why some skulls in research collections are severely damaged.

The dilemma of cleaning skeletal material without the use of water may seem like a serious problem. However, the reasons for cleaning should be analyzed. If cleaning is done primarily for aesthetic reasons instead of for research or preservation purposes, then the need for the procedure should be questioned. The usual reason for cleaning is to expose the bone so that it can be examined in detail and so that precise measurements can be taken. If fine non-osseous tissues or remains from dermestids are present in sufficient quantities to obscure details or serve as a source of moisture through hygroscopic properties, then further cleaning efforts may be justified. In situations involving non-osseous tissues, the cleaning procedure might be easily accomplished with better management of the dermestid colony (for instance, use the colony so that finer cleaning is done by younger larvae). This may be troublesome, but if it avoids the use of water and thus promotes the long-term preservation of the object, it is certainly worth consideration. Another procedure that may be used independently or in conjunction

with better dermestid management is dry-cleaning. Methods used at the Royal British Columbia Museum involve delicate vacuum cleaning (M.-L. E. Florian, Royal British Columbia Museum, personal communication). Some authors (Guldbeck and MacLeish, 1985; Plenderleith and Werner, 1971) suggest the careful use of brushes or non-abrasive probes to clean bone. If cleaning of the skeletal material requires a washing procedure, some sources recommend the use of water and mild soap (Canadian Conservation Institute, 1983); however, results of the current study are in agreement with Guldbeck and MacLeish (1985) in stating that water should be avoided. It may be possible to use ethanol sparingly as suggested by Plenderleith and Werner (1971). In any case, there is a definite need to evaluate these methods before any procedure is fully adopted, particularly when one realizes that different types of osteological material may require specific cleaning methods.

With regard to environmental conditions, it has been reported that the preferred relative humidity for bone preservation is 45%–65% at normal indoor temperatures (Canadian Conservation Institute, 1983; Kuhn, 1986; Stolow, 1987). Under similar conditions and with minimal effort, it was possible to maintain skulls without any tooth damage for more than seven months. Because the parts of the skull are constantly adjusting to reach equilibrium with relative humidities, these stresses can be minimized with stable relative humidity. The current study clearly demonstrates that tooth deterioration significantly increases at relative humidities below 40%. It also demonstrates that teeth are more fragile at the lower end of the scale (below 50%). This increased fragility makes it more difficult to protect the teeth under stressful conditions. Rapid changes in relative humidity or careless handling of skulls under such conditions will exacerbate damages. Closed storage can maintain a more desirable environment and protect specimens from fluctuations in relative humidity (Thomson, 1986), while prolonged exposure of skulls to adverse conditions (for example, dry heat during winters) increases the risk of cracking. If cases are kept closed (except for removing or replacing specimens) and specimens are not left out, changes caused by differences in relative humidities between internal and external environments (commonly as much as 20% in collections without humidity control) can be minimized.

With regard to handling, dropping fragile skulls onto uncushioned surfaces (for example, vials or working areas), can also contribute to cracking, particularly with prominent teeth like canines. Good work habits can reduce the risk of damage.

Conclusions

This study evaluated some of the current practices used with osteological materials and how these practices affect long-term preservation. It was demonstrated that deterioration of skeletal material is a serious problem in research collections and that some tooth deterioration might be slowed down, if not eliminated, with more appropriate procedures and storage conditions.

Although not conclusive, it seems that initial preparation may partially affect the long-term preservation of osteological material. Further work needs to be completed to properly evaluate this possibility. With regard to cleaning procedures, it has been shown that the use of water and/or alkaline solutions and subsequent drying contribute to increased cracking of teeth. Improper relative humidities exacerbate osteological damages. Desiccation below 40% RH is perhaps the greatest cause of tooth cracking. Therefore, there are several factors that

compromise the integrity of specimens. Collectively, these factors can seriously impair the efforts of long-term preservation, unless corrective measures are taken.

If osteological materials are to be maintained for future research, it is important that collection workers provide the best possible care for them by improving procedures and storage conditions. This study showed that controlling moisture levels in all environments that the skull is exposed to can reduce tooth deterioration. This basic information provides a starting point for improving procedures and storage conditions. However, before any practices are fully adopted, the treatments must be documented and critically evaluated. To better appreciate the factors contributing to tooth deterioration, there is a need to know how different relative humidities encountered in field and laboratory conditions may alter the amounts of cracking. It would also be useful to know if different taxa are affected the same way by similar conditions.

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COMPUTERIZATION BENEFITS FOR SMALL INVERTEBRATE NATURAL HISTORY COLLECTIONS WITH PARTICULAR REFERENCE TO INSECTA

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Abstract.—The computerization of a small size invertebrate collection (less than 100,000 specimens) can have many advantages, such as easier accessibility to collection data, and clearer perception of areas needing development and of the general evolution of the collection. Of many important results of automation, nine are discussed. These gains are: the improvement of collection organization; phylogeny standardization; taxonomic updating; networking with other collections; protection of collection data; supplemental data storage; identification of future collection projects; quick generation of specific reports; and improved public relations. The process involved in the establishment of an Insecta database for the 'A. D. Pickett Entomological Museum' at the Nova Scotia Agricultural College, is also detailed.

During the last decade, collection computerization has developed from a theoretical concept to one of actual operational systems. As to be expected, most museums that attempted computerization at first were large, well-staffed, prestigious collections with ready access to funding, and expertise, including large computer systems already in place. The literature on the subject also reflects this trend: Homulos (1983) from the National Inventory Program, Ottawa—currently the Canadian Heritage Information Network (Cox, 1986); McAllister (1983) of the National Museum of Natural Sciences, Ottawa; McLaren *et al.* (1986) of the Carnegie Museum of Natural History, Pittsburgh; and Woodward (1989) of the Royal Ontario Museum, Toronto. This may lead to the misconception that computerization is only for large, prominent collections, difficult to manage without computerization, and therefore that such an undertaking would not benefit smaller collections. It also should be noted that some very large entomological museums, such as the Lyman Museum of McGill University, have not computerized their collections, not necessarily because of insufficient availability of funds for computer hardware and software, but rather because of the very expensive cost of staff required for data entry and validation.

Recent advances in the storage capabilities and speed of microcomputers has brought automation within the grasp of small collections. While our collection, at the Nova Scotia Agricultural College, was automated on a minicomputer system, we believe that by relaying our experiences and the advantages that we discovered while doing so, we may encourage other museum curators to take on a similar project with the aid of a microcomputer.

Through the process of automating our relatively small Insecta collection (10,924 identified specimens representing 1,554 species) at the 'A. D. Pickett Entomological Museum', we not only improved our data retrieval system but also our collection organization, phylogeny, taxonomic updating, and the identification of areas (both geographical and taxonomic) that lacked representation. Without computerization, our sole mandate would have remained the collection and addition

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of specimens to the existing collection, and the continuation of the time-consuming manual record system. Although our mandate has not really changed, the organization and easy access of our records is now giving us guidance as to what area to further develop. The system allows us to be constantly abreast of the strengths and weaknesses of our collection.

Background

The 'A. D. Pickett Entomological Museum and Research Laboratory' housed at the Nova Scotia Agricultural College, consists primarily of northeastern insects collected since the late 1940s. Donations to the collection of large numbers of specimens from other institutions followed a fire in 1947. This fire had destroyed the previous extensive collection that dated back to the inception of the College at the turn of the century.

After a move to new facilities in 1984, the automation of the collection was undertaken. It was determined that the collection should be broken into two separate units. The main collection of adult insects (the "dry" collection), and a smaller collection of alcohol preserved immature specimens (the "wet" collection). This allowed the dry collection to be reported phylogenetically, although, the order in which records are entered is irrelevant. The wet collection is recorded sequentially as it is stored. Separate database structures and procedures were used for these two collections as there is no need to print a combined report for the two collections. This paper will focus on our dry collection.

Standardization

In view of future information sharing, it appeared advantageous to use the field names and descriptions from the Natural Sciences Data Dictionary of the Canadian Heritage Information Network (CHIN) used by PARIS (Pictorial and Artifact Retrieval and Information System) system (Delroy *et al.,* 1985). This standardized our data fields with that of other computerized Canadian natural history collections.

Because our collection was to undergo a major reorganization, it was decided to establish a standardized classification system of taxa prior to the implementation of other changes in the records or in the collection organization proper. The classification presented by Danks (1978) in *Canada and its Insect Fauna,* was selected for this purpose. While following Dank's phylogeny for higher taxa, in our system all genera within a family and all species within a genus are recorded and stored in alphabetical order for simplicity.

Hardware and Software

The 'A. D. Pickett Entomological Museum' system was developed on a Digital Equipment Corporation (DEC) VAX 11/750 minicomputer. Although this is one of DEC's discontinued products, the VMS (Virtual Memory System) operating system guarantees that this computerized system will run on any of DEC's wide range of minicomputers. The decision to use this equipment was based on four factors: 1—the minicomputer had over 500 megabytes of disk storage available; 2—backups and machine maintenance were supplied by the Computer Centre; 3—the minicomputer had a high-speed line printer useful for lengthy reports; and

4—a database system was available. The second and third factors are still relevant presently.

The two layered software products used to develop the system were Datatrieve (version 4.2) and Forms Management System (FMS; version 2.3) running under VMS (version 5.2). Datatrieve is a comprehensive fourth-generation data management tool that provides both interactive and program-callable access to data in sequential, indexed, and relative file organizations.

Automation

With the assistance of a computer system manager, a database was established and data entry procedures were written. Twenty-seven fields were chosen from the Natural Sciences Data Dictionary of CHIN used by PARIS (Delroy *et al.*, 1988); one field is the species accession number; seventeen contain taxonomic information; the remaining fields deal with identification, location, and description of each specimen.

The design of a database is always a trade-off between efficiency of data storage and efficiency of data recovery. Many design considerations are controlled by the programmer's understanding of the system that is being designed. One of the primary concerns of a database design, is the selection of a 'unique index' (i.e., a series of alphanumeric characters) which can identify a record, or a specimen. Our design is presented in Figure 1 where the fields that are stored in our dry collection are listed as an example.

In our case, the ten-digit species accession number demonstrated in Figures 2 and 3, was selected as the field to index. This accession number proved very important in the development of the database as it allowed collection records to be sorted numerically as well as providing speed and efficiency in accessing data. Because future entries will be recorded immediately upon collection, the species accession number allows a computer sort of all specimens and their inclusion in the phylogenetic sequence prior to the creation of reports.

Our species accession number system is divided into three columns. The first column of two digits represents the order (i.e., 23 for Hemiptera, or 28 for Coleoptera). The second column of five digits represents species (e.g., 23 01500 is *Euschistus tristigmus*) within the order Hemiptera. The last two digits of this column are entered as zeros for all known species. This allows for ninety-nine additional species to be inserted between currently existing species without disrupting the organization of the collection. The third column of three digits represents individual specimen numbers. This allows for the immediate tally of the actual number of specimen records of that species.

It is important to note that the first and second number groups (columns) duplicate data of the alphabetic field 'order' and the fields 'genus' and 'species' respectively (Fig. 2). From a curatorial point of view, this provides the capability to make revisions to genus and species without the unpleasant task of modifying the index. In the future we will attempt to have the database access a table of names using the species accession number. We could then remove the order, family, genus, and species fields. This would lessen memory requirements as well as accelerate queries and report productions. On the other hand it may introduce an undesirable level of 'non-standardization'.

Datatrieve has many features that proved to be particularly beneficial to a

```
DEFINE RECORD DRY_REC USING
01 DRY_REC.
   05  ACCESSION_NUMBER                    QUERY_NAME IS AN.
       10 FIRST              PIC X(2)      EDIT_STRING IS 99.
       10 SECOND             PIC X(5)      EDIT_STRING IS 9(5).
       10 THIRD              PIC X(3)      EDIT_STRING IS 9(3).
   05  CLASS                 PIC X(20)     QUERY_NAME IS CL
                                            DEFAULT VALUE IS "Insecta".
   05  ORDER                 PIC X(20)     QUERY_NAME IS ORD.
   05  SUBORDER              PIC X(20)     QUERY_NAME IS ORDS.
   05  SUPERFAMILY           PIC X(20)     QUERY_NAME IS SUPFAM.
   05  FAMILY                PIC X(20)     QUERY_NAME IS FAM.
   05  SUBFAMILY             PIC X(20)     QUERY_NAME IS SUBFAM.
   05  TRIBE                 PIC X(20)     QUERY_NAME IS TR.
   05  GENUS                 PIC X(20)     QUERY_NAME IS GEN.
   05  SPECIES               PIC X(20)     QUERY_NAME IS SP.
   05  SUBSPECIES            PIC X(20)     QUERY_NAME IS SSP.
   05  SPECIES_AUTHORITY     PIC X(20)     QUERY_NAME IS SPA.
   05  SPECIES_DATE          PIC X(6)      QUERY_NAME IS SPD.
   05  SYNONYM               PIC X(50)     QUERY_NAME IS SYN.
   05  COMMON_NAME           PIC X(40)     QUERY_NAME IS CN.
   05  FRENCH_NAME           PIC X(60)     QUERY_NAME IS FN.
   05  COLLECTOR             PIC X(20)     QUERY_NAME IS MCOL.
   05  LOCALITY_NAME         PIC X(50)     QUERY_NAME IS LOCNM.
   05  DATE_COLLECTED        PIC S9(8)     QUERY_NAME IS CPDA
                                            EDIT_STRING IS  Z(7)9.
   05  HABITAT               PIC X(50)     QUERY_NAME IS HAB.
   05  AGE_STAGE             PIC X(40)     QUERY_NAME IS AS
                                            DEFAULT VALUE IS "Adult".
   05  SEX                   PIC X(20)     QUERY_NAME IS S
                                            DEFAULT VALUE IS "Undetermined".
   05  SPECIES_NUMBER        PIC S9(4)     QUERY_NAME IS SPN
                                            EDIT_STRING IS -Z(3)9.
   05  DETERMINATOR          PIC X(20)     QUERY_NAME IS DET.
   05  DATE_DETERMINED       PIC S9(8)     QUERY_NAME IS DPDA
                                            USAGE IS LONG
                                            EDIT_STRING IS Z(7)9.
   05  FORMER_GENUS.
       10  FORMER_GENUS_1    PIC X(70)     QUERY_NAME IS GENF1.
       10  FORMER_GENUS_2    PIC X(70)     QUERY_NAME IS GENF2.
   05  FORMER_SPECIES.
       10  FORMER_SPECIES_1  PIC X(70)     QUERY_NAME IS SPF1.
       10  FORMER_SPECIES_2  PIC X(70)     QUERY_NAME IS SPF2.
;
```

Figure 1. Record structure of the dry collection of the 'A. D. Pickett Entomological Museum'.

natural history database, such as the possibility to access several databases concurrently. The most useful statement seemed to be the 'Find' statement which was used to provide a subset of the entire database. The syntax of this statement is 'Find domain with field = value'; this syntax is close to that of the dBASE IV LOCATE command. It is important to note, however, that if the field in the Datatrieve FIND command is indexed, an index key search will be used, whereas the dBASE IV LOCATE command always uses a sequential search. In addition, although the species accession number is one field, Datatrieve allows for the use of the subfields, such as FIRST, SECOND, and THIRD, to perform searches. Several examples using the FIND command follow:

NOVA SCOTIA AGRICULTURAL COLLEGE
A.D. PICKETT ENTOMOLOGY MUSEUM

DRY COLLECTION
TAXONOMIC REPORT

Hemiptera
Heteroptera
Pentatomoidea
Pentatomidae
Pentatominae

ACCESSION NUMBER	GENUS NAME	SPECIES NAME	SUB-SPECIES	SPECIES AUTHORITY	SPECIES DATE	COMMON NAME	FRENCH NAME	SPECIES NUMBER
23 00800 001	Banasa	dimidiata		(Say)	1831	Banasa stink bug	Punaise du cormie	182
23 00900 001	Banasa	sordida		(Uhl.)	1894			186
23 01000 001	Brochymena	quadripustulata		(Fabr.)	1775	Fourhumped stink bug	Punaise bossue de	85
23 01000 002	Brochymena	quadripustulata		(Fabr.)	1775	Fourhumped stink bug	Punaise bossue de	85
23 01000 003	Brochymena	quadripustulata		(Fabr.)	1775	Fourhumped stink bug	Punaise bossue de	85
23 01100 001	Chlorochroa	uhleri		Stal.	1872			106
23 01100 002	Chlorochroa	uhleri		Stal.	1872			106
23 01100 003	Chlorochroa	uhleri		Stal.	1872			106
23 01200 001	Coenus	delius		(Say)	1831			139
23 01200 002	Coenus	delius		(Say)	1831			139
23 01200 003	Coenus	delius		(Say)	1831			139
23 01200 004	Coenus	delius		(Say)	1831			139
23 01300 001	Cosmopepla	bimaculata		(Thomas)	1865	Twospotted stink bug	Punaise bimaciule	149
23 01300 002	Cosmopepla	bimaculata		(Thomas)	1865	Twospotted stink bug	Punaise bimaciule	149
23 01300 003	Cosmopepla	bimaculata		(Thomas)	1865	Twospotted stink bug	Punaise bimaciule	149
23 01300 004	Cosmopepla	bimaculata		(Thomas)	1865	Twospotted stink bug	Punaise bimaciule	149
23 01400 001	Euschistus	euschistoides		(Voll.)	1868		Punaise obscure	121
23 01400 002	Euschistus	euschistoides		(Voll.)	1868		Punaise obscure	121
23 01400 003	Euschistus	euschistoides		(Voll.)	1868		Punaise obscure	121
23 01500 001	Euschistus	tristigmus		(Say)	1831	Dusky stink bug	Punaise a trois t	125
23 01500 002	Euschistus	tristigmus		(Say)	1831	Dusky stink bug	Punaise a trois t	125
23 01510 001	Euschistus	variolarius		(P.B.)	1805	Onespotted stink bug	Punaise variee	126
23 01600 001	Mormidea	lugens		(Fabr.)	1775			111
23 01600 002	Mormidea	lugens		(Fabr.)	1775			111
23 01700 001	Neottiglossa	undata		(Say)	1831			145
23 01700 002	Neottiglossa	undata		(Say)	1831			145
23 01700 003	Neottiglossa	undata		(Say)	1831			145
23 01700 004	Neottiglossa	undata		(Say)	1831			145
23 01700 005	Neottiglossa	undata		(Say)	1831			145

Figure 2. Printout of species records inclusive of the accession number and the taxonomic fields used.

NOVA SCOTIA AGRICULTURAL COLLEGE
A.D. PICKETT ENTOMOLOGY MUSEUM

DRY COLLECTION
DESCRIPTION REPORT

Hemiptera
Heteroptera
Pentatomoidea
Pentatomidae
Pentatominae

ACCESSION NUMBER	COLLECTOR	LOCALITY NAME	DATE COLLECTED	HABITAT	AGE STAGE	SEX	DETERMINATOR	DATE DETERMINED
23 00800 001	J.R. Gates	Canada;Ontario;Manotick	19470		Adult	F	J.R. Gates	0
23 00900 001	J.R. Gates	Canada;Ontario;Guelph	1948		Adult	M	D.C. Eidt	0
23 01000 001	R.K. Cook	Canada;Nova Scotia;Colchester Co.;Truro	19490719		Adult	M	V.R. Vicker	0
23 01000 002		Canada;Ontario	0		Adult	F	D.C. Eidt	0
23 01000 003		Canada;Ontario	0		Adult	M	D.C. Eidt	0
23 01100 001	Eidt/Morehouse	Canada;Nova Scotia;Kings Co.;Kentville	19480716		Adult	F	D.C. Eidt	0
23 01100 002	V.R. Vickery	Canada;Nova Scotia;Kings Co.;Kentville	19480920		Adult	M	V.R. Vicker	0
23 01100 003	R.E. Morehouse	Canada;Nova Scotia;Hants Co.;Windsor	19480923		Adult	M	V.R. Vicker	0
23 01200 001	R.H. Ozburn	Canada;Ontario;Guelph	19310819		Adult	U	D.C. Eidt	0
23 01200 002		Canada;Nova Scotia	0		Adult	U	D.C. Eidt	0
23 01200 003		Canada;Nova Scotia	0		Adult	U	D.C. Eidt	0
23 01200 004		Canada;Nova Scotia	0		Adult	U	D.C. Eidt	0
23 01300 001	M.D. Payne	Canada;Nova Scotia;Colchester Co.;Truro	19311002		Adult	M	H.G. Payne	0
23 01300 002	W.V. Potter	Canada;Nova Scotia;Kings Co.;Kentville	19470630		Adult	F	V.R. Vicker	0
23 01300 003	V.R. Vickery	Canada;Nova Scotia;Kings Co.;Kentville	19480625	grass pastur	Adult	F	V.R. Vicker	0
23 01300 004	D.C. Eidt	Canada;Nova Scotia;Kings Co.;Kentville	194807		Adult	M	V.R. Vicker	0
23 01400 001	D.C. Eidt	Canada;Nova Scotia;Kings Co.;Kentville	194807		Adult	F	V.R. Vicker	0
23 01400 002	R.E. Morehouse	Canada;Nova Scotia;Hants Co.;Windsor	19480923	strawberries	Adult	F	V.R. Vicker	0
23 01400 003	R.E. Morehouse	Canada;Nova Scotia;Hants Co.;Windsor	19480923		Adult	F	V.R. Vicker	0
23 01500 001	C.A. Good	Canada;Nova Scotia;Digby Co.;Bear River	19140730		Adult	M	H.G. Payne	0
23 01500 002	V.R. Vickery	Canada;Nova Scotia;Kings Co.;Kentville	19500523		Adult	M	V.R. Vicker	1950
23 01510 001	C.Y. Hovey	Canada;Ontario;Chatham	1948		Adult	M	D.C. Eidt	0
23 01600 001	V.R. Vickery	Canada;Nova Scotia;Kings Co.;Kentville	19480721		Adult	U	V.R. Vicker	0
23 01600 002	J.F. McAlpine	Canada;Ontario;Marmora	19480718		Adult	U	D.C. Eidt	0
23 01700 001	D.C. Eidt	Canada;Nova Scotia;Shelburne Co.;Barringto	19500615		Adult	U	V.R. Vicker	1950
23 01700 002	D.C. Eidt	Canada;Nova Scotia;Shelburne Co.;Barringto	19500615		Adult	U	V.R. Vicker	0
23 01700 003	D.C. Eidt	Canada;Nova Scotia;Shelburne Co.;Barringto	19500615		Adult	U	V.R. Vicker	0
23 01700 004	P. Grainger	Canada;Nova Scotia;Kings Co.;Kentville	19510515		Adult	U	V.R. Vicker	0
23 01700 005	R.L. Horsburg	Canada;Nova Scotia;Kings Co.;Canard	19540714		Adult	U	R.L. Horsbu	0

Figure 3. Printout of species records inclusive of the accession number and other non-taxonomic fields.

A). Find dry with FIRST = 23 and SECOND between 800 and 1700
This finds all records in the order Hemiptera with index values ranging from 00800 001 to 01700 999.

B). Find dry with COLLECTOR = "V.R. Vickery"
This will find all records collected only by V. R. Vickery but will not include records collected by Vickery *et al.*

C). Find dry with COLLECTOR containing "V.R. Vickery"
This will locate all records in which V. R. Vickery's name occurs anywhere within in the collector field.

D). Find dry with COLLECTOR starting with "V.R."
This will find all records in which the collector field begins with "V.R.". This reduces the retrieval time as the computer only searches the first four characters of the field, however, as opposed to 'containing' it may miss record containing "V.R." when it is not the first term. 'Starting with' remains useful for quick examinations.

The 'Find' statement generates a subset of the entire database, which then may be used to create reports or summaries or to modify the database. Reports may appear on the screen, on a printer, or be directed to a file. Report printouts provide the museum with a quick and up-to-date listing of the catalog.

FMS (Forms Management System) was used to provide a user-friendly interface to the data entry and editing portions of the museum computer system. All accesses to FMS are done at the Datatrieve command level, so the curator is not required to be overly conversant with the FMS system. The Computer Centre staff designed data entry, data edit, and data deletion procedures for the collections as well as close to ten standard reports. These procedures are equivalent to a dBASE IV program but contain Datatrieve commands. Most of the reports are designed to work on a collection which the curator has produced by means of a FIND statement, thus with the flexibility to subset the data. This removes the burden to learn the details of the Datatrieve report commands.

The data entry procedure prompts the user for a species accession number followed by the presentation of a blank form on the screen (Fig. 4). The data editing procedures also prompts for an accession number and then presents the record's existing data. Information can then be added to, or deleted from any of the fields in the database by appropriate use of cursor movement and editing keys. In some fields, default options are entered automatically. These could either be complete entries such as "Adult" for AGE STAGE, or partial entries requiring additional information. An example is the field for COLLECTION LOCATION. As most specimens are collected within Nova Scotia, the default "Canada;Nova Scotia;" is entered automatically in the record, thus requiring the operator to type in only the county and town. If the data differ from the default, the field can be modified by typing over the default information.

As a card file catalog of specimen information existed prior to automation, our task of data capture was significantly simplified. Summer assistants were hired to enter the information from the card catalog. Because many specimens often shared similar taxonomic and/or collection information, the original data entry procedure, which consisted of a list of fields requiring input, ended with a menu. This allowed the operator to immediately duplicate a previous record up to any selected

```
 STORE DRY COLLECTION   FIRST __     SECOND __     THIRD __
CLASS    Insecta        ORDER                      SUBO
SUPERF                  FAM                        SUBF
TRIBE
GENUS                   SPEC                       SUBS
SPECIES_AUTH                        SPECIES_DATE
SYNONYM
COMMON NAME
FRENCH NAME
COLLECTOR
LOCALITY     Canada;Nova Scotia;
DATE COLL
HABITAT
AGE STAGE    Adult
SEX
SPECIES NUM
DETERMINATOR
DATE DETERM
FORMER GENUS
FORMER SPECIES                                     ANOTHER ?
```

Figure 4. Blank form for data entry, showing default settings for CLASS, AGE STAGE, and LOCALITY as it appears on the terminal monitor.

field. Thus multiple records could be entered very quickly without the need to retype duplicate information. We have since modified the data entry procedure into the blank form type (Fig. 4). The cursor moves from field to field as the data are entered. Once entry is completed the user is asked if he/she wishes to enter or edit another specimen record. If so, the form is redrawn with all fields filled, and the third component of the accession number is incremented. The user can then alter any field. Datatrieve has no command which is equivalent to the SET CARRY ON command or the CARRY FORWARD attribute, thus procedures were written towards that end. The dBASE II available in 1985 did not provide the CARRY FORWARD attribute or forms either.

Reports

Reports can be generated from the database to check for accuracy or to produce a desired output. A report can include all or some of the fields in the collection. To check the accuracy of the data entered, two reports were generated that included only certain selected fields (Figs. 2, 3). These reports were used as edit sheets. It was necessary to create two separate reports due to the limits in width of the

printouts. It is important to note, however, that both the taxonomic field on the one report and the non-taxonomic fields on the other, make up a complete specimen record. The information from both reports are matched by means of the species accession number. Some fields, however, were truncated in order to maximize space on the printout. These reports were validated by comparing them one by one to the actual collections. During this step, many omissions were identified and some lost and/or damaged specimens were noted. Other procedures were written to allow for the single, multiple, and global correction of existing records. The use of such procedures increased the speed by which corrections were made.

We also developed a report procedure to search the database and to list unique species (first instance of every species). This report is called "Brief Species Report" (Fig. 5). This resulted in a species list for the collection against which we could check phylogenetic arrangement. Both the organization of the specimens and the specimen database underwent many changes to follow the phylogeny established by Danks (1978).

The species reports also allowed us to compare our phylogeny with that of recent publications and checklists. From this we established that our collection was extremely archaic in its taxonomic arrangement. For instance, when we checked the order Lepidoptera against the *Check List of the Lepidoptera of America North of Mexico* (Hodges *et al.*, 1983) we found the following: of the 560 identified lepidopteran species in the collection, 3 families, 180 genera, and 72 species required amendment. Once these changes were identified, we corrected both the computer records and the actual collection with relative ease. The species reports also can be used to produce typed labels for wooden label blocks in the collection, thus eliminating tedious work for secretarial staff and the associated problem of spelling errors.

Discussion

The primary objective for the computerization of a natural history collection is to improve data retrieval. By using a 'Find' statement the database program can locate and isolate either single or multiple specific records. The use of this statement, along with a set of report procedures, enables the curator to generate reports that reflect the diversity of organisms within a geographical area or conversely the distribution of a given species.

The database can also provide valuable history on the collection, identifying old records and lists of specimens collected or identified by a specific collector. The storage of supplemental data, such as detailed habitat descriptions that would not necessarily be stored with the specimen, is another advantage.

The development of national computer networks has provided researchers with the possibility to network smaller collection systems with larger ones. This most effective use of the wealth of data stored in all collections, could provide beneficial research tools and results. The data can also be transferred from the minicomputer to the hard drive of a microcomputer, therefore isolating and protecting the original records from tampering and computer viruses.

While the record size of our dry collection database may seem large (882 bytes), the 10,924 records take up only ten megabytes of disk space. This is well within the hard drive limits of most microcomputers, which can have anywhere from

NOVA SCOTIA AGRICULTURAL COLLEGE
A.D. PICKETT ENTOMOLOGY MUSEUM

BRIEF SPECIES REPORT

FIRST	SECOND	FAMILY	SUBFAMILY	GENUS	SPECIES	SUBSPECIES	SPECIES AUTHORITY
23	00100	Cydnidae	Thyreocorinae	Corimlaena	pulicaria		(Germ.)
23	00200	Cydnidae	Thyreocorinae	Galgupha	atra		(A. & S.)
23	00300	Cydnidae	Thyreocorinae	Galgupha	nitiduloides		(Wolff)
23	00400	Cydnidae	Cydninae	Sehirus	cinctus		(P.B.)
23	00500	Pentatomidae	Pentatominae	Acrosternum	hilare		(Say)
23	00600	Pentatomidae	Asopinae	Apateticus	bracteatus		(Fitch)
23	00700	Pentatomidae	Asopinae	Apateticus	cynicus		(Say)
23	00800	Pentatomidae	Pentatominae	Banasa	dimidiata		(Say)
23	00900	Pentatomidae	Pentatominae	Banasa	sordida		(Uhl.)
23	01000	Pentatomidae	Pentatominae	Brochymena	quadripustulata		(Fabr.)
23	01100	Pentatomidae	Pentatominae	Chlorochroa	uhleri		Stal.
23	01200	Pentatomidae	Pentatominae	Coenus	delius		(Say)
23	01300	Pentatomidae	Pentatominae	Cosmopepla	bimaculata		(Thomas)
23	01400	Pentatomidae	Pentatominae	Euschistus	euschistoides		(Voll.)
23	01500	Pentatomidae	Pentatominae	Euschistus	tristigmus		(Say)
23	01510	Pentatomidae	Pentatominae	Euschistus	variolarius		(P.B.)
23	01600	Pentatomidae	Pentatominae	Mormidea	lugens		(Fabr.)
23	01700	Pentatomidae	Pentatominae	Neottiglossa	undata		(Say)

Figure 5. Brief Species Report. Printout of a database search procedure which lists the first occurrence of each species.

ten to a several hundred megabytes of disk storage. In the future we would like to attempt the conversion of our records to an advanced microcomputer (Intel 80386 or 80486 CPU based) which would speed up our operation time considerably. At present our operating time is limited by the number of users on the minicomputer system and the functions being performed. The database could probably be handled with one of the currently available microcomputer database programs such as dBASE IV which permits a record length of 4,000 bytes.

The use of a removable megadrive would allow for the transportation and storage of data. This would provide an insurance for all collection data as duplicate records could be stored in a separate location. This would prevent the loss of valuable data if the actual collection is destroyed by fire or damaged by water.

Future plans for the computerization of our museum collection include the development of a separate registry for all type specimens to be included in the collection and a procedure to record and manage specimen loans. We would then establish a loan procedure not only to record the lender and date borrowed, but also the due date. If the specimen is not returned on time the curator will be able to have the computer automatically print out a 'personalized' form letter asking for the return of specimens.

These advantages benefit both large and small collections. It is felt, however, due to the limitations in funding, staff, and available expertise, that automation should be a priority for small collections. In the perceived static world of museums, the use of computer equipment seems to surprise both visitors and administrators. It may give to laypersons an easier grasp of the significance and dimension of the information stored in a natural history collection. Also computer conscious administrators and benefactors are also impressed by attempts to modernize a seemingly archaic and dull process.

Possibly the most important advantages are to curators, as computerization provides them with the opportunity to review the collection, upgrade and make vast changes to the organization—changes that under normal practices would probably never be undertaken. It also allows curators to easily identify weak areas in the collection, providing information for the development of collection policies.

While the automation of a collection is a challenging, relatively expensive, and time consuming task, the benefits to such an undertaking are numerous. With recent developments in microcomputer technology, such as increased storage capacity and speed of operation, small institutions that do not have access to a minicomputer or mainframe system are not excluded from the advantages of automation.

RESUME

L'utilisation de l'informatique pour une collection d'invertébrés de dimension limitée (moins de 100,000 spécimens) peut résulter en de nombreux avantages, tel qu'une meilleure acccessibilité aux données de la collection, une perception plus évidente des domaines nécessitant d'être développés et de l'évolution générale de la collection. Des nombreux importants résultats de l'utilisation de l'informatique, neuf sont discutés. Ces gains sont: une amélioration de l'organisation de la collection; la normalisation de la phylogénie; la mise-à-jour de la taxonomie; la possibilité d'échange via un réseau d'autres collections similairement informatisées; la protection des données informatisées de la collection; la possibilité

d'accroître la capacité de mémoire pour les données; l'identification de projets futures pour la collection; la production rapide de rapports spécifiques; et l'amélioration des relations publiques. Le processus impliqué dans le développement d'une base de données d'insectes, pour le "Musée entomologique A. D. Pickett" du Collège d'agriculture de la Nouvelle-Ecosse, est aussi décrit.

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ALGINATE IMPRESSION MATERIAL

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Abstract.—Alginate molds are as accurate as molds made from other impression materials commonly used in paleontology. When the correct procedures for mixing and taking the impression are followed, alginate provides an inexpensive and quick means of obtaining accurate casts, for example, when visiting other institutions or when specimens being examined are unavailable for loan. We have standardized a cost-effective, time-efficient procedure using alginate in the production of casts for paleontology. Alginate is especially accurate in reproducing dentitions, but has been used in the casting of other skeletal structures.

The many casting techniques available to the paleontological researcher or technician allow the reproduction of any fossil, regardless of its size and configuration. The production of a cast involves two separate steps: preparation of a mold from an original specimen and casting a replica from the mold. Often, the method chosen to prepare a mold depends on the casting material used, which in turn is determined by size, shape or other attributes of the fossil. One of several common techniques is best suited to a specimen; e.g., very large fossils, which would weigh a tremendous amount if poured in plaster, can be cast in fibreglass; fibreglass casts are often prepared from a latex mold (Converse, 1983, 1984). No single technique is restricted for use in only one situation and it is important to select the combined materials and techniques to advantage.

Alginate has been used by other casters who have obtained satisfactory results (H. G. McDonald, personal communication), but most of these workers doubt alginate's accuracy and, therefore, use it only to make quick "throw-away" casts. However, these workers used modelling clay, plasticene or cardboard to construct trays or barriers (if a tray was used at all) in preparing alginate impressions. However, alginate molds are at least as accurate as other molding materials used for paleontological casting if the procedures for mixing and taking the impression are followed. It is essential that a tray, which is a support structure for the impression, be used and that the tray be made from an inflexible material. It is equally important that the tray be provided with a locking mechanism to secure the impression to the tray during removal of a specimen.

Before proceeding to the description of the procedures for alginate molding techniques, we urge that the following precautions and conditions be considered when casting with any material. Molding procedures are generally highly destructive to fossils; expediency and thrift should not be the only or most important considerations in production of a mold. Each specimen should be examined and a decision should be made as to which molding material will produce a satisfactory cast while minimizing damage to the specimen. The consistency and flexibility of alginate is such that removal of a sturdy specimen will usually inflict little, if any, damage to it; but care should be taken with more fragile specimens. Of greater concern is that alginate will wet a specimen. A separator, such as Butvar or a sprayable separator, should be used with poorly consolidated and porous specimens. Use of a separator also facilitates mold release and reduces tears due to

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undercuts. J. P. Lamb (personal communication) has warned against the use of alginate on any fossil that contains pyrite, as it would accelerate the decomposition of the fossil. No material should be applied or work done to any specimen without the permission of the responsible curator or collection manager.

Molding Procedures

Tray construction.—A standard dental tray may be used for animals up to the size of a domestic cat, but custom trays must be made for larger animals. A graduated series of three or four deltoid shaped trays to take the impressions of dentitions up to the size of a bear should be prepared. These are made from an acrylic tray mix, which consists of powder and a liquid hardener that form a hard inflexible solid when combined. The powder and liquid are available in different sizes and may be purchased together or separately; a plastic scoop (for dispensing the powder) and a vial (for measuring the liquid) are included.

The palate from the largest animal determines the tray size. Adequate space between the tray's walls and the bone or teeth is provided by baseplate wax, which does not adhere to the specimen. The wax is cut to size, softened above a flame, placed around the jaws and pressed closely onto the specimen. Two layers of wax provide sufficient space (3–4 mm). The walls of the wax layers (against which the tray's walls are formed) are kept vertical and must not lie parallel to the jaw's lateral surface, otherwise the hardened tray cannot be removed from the specimen.

Hardened acrylic is strong but not brittle and resists bending, and a 2–3 mm thick lamina is sufficient. Suggested quantities of powder are: four, six or nine scoops of powder for tray lengths of 10 cm (adequate for animals as large as *Vulpes*), 16 cm (e.g., large *Canis*) and 23 cm (e.g., large *Ursus*), respectively. The top of the tray's walls should be level with the dorsal edge of the zygomatic arch.

The required quantities of powder to liquid hardener are mixed according to label specifications with a disposable spatula into a thick dough. The mix ceases to be tacky to the touch some two minutes after mixing, and is rolled into a ball, which is then kneaded, flattened and spread over the wax. After curing, the tray is lifted from the specimen. ¼″ or ⅛″ holes are drilled into the tray to provide keys that will secure the alginate impression to the tray during specimen removal.

Making the alginate impression.—The required amount of alginate is measured into a holding container. The required volume of water is poured into a flexible, rubber mixing bowl. Specifications for powder to water ratios and for mixing and setting times appear on the product label. The powder is added to the water and mixed with a flat, wide and round-ended spatula. It should be mixed with a vigorous stropping action which squeezes the mixture between the spatula and side of the bowl (Phillips, 1982; Craig *et al.*, 1983). The bowl is held obliquely in the hand and manipulated so that it spins, while the spatula, held more or less stationary, squeezes the mixture between itself and the bowl. A normal setting alginate is spatulated for about 45 seconds; transferring the paste onto the tray usually takes less than a minute and setting should occur between 1.5 and 2.5 minutes after spatulation and transfer.

Mixing time and spatulation are important; the procedure described for spatulation and the directions for mixing time on the product label should be followed as strength of gels may be reduced by 10% if mixing is incomplete (Phillips, 1982). The ratio of water to powder may be varied by about 10% without adverse effects.

The mixed paste is transferred to the tray with the spatula immediately, and pressed into all corners of the tray to remove air spaces.

The tray is hand-held and the teeth are pressed into the alginate. The specimen's posterior part is pressed in first and its anterior end is then swung down (Fig. 1). Sufficient impression material must be used to cover the specimen at least to the alveolar borders. Gently press the alginate toward the surface of the specimen to ensure that all surfaces being cast are faithfully reproduced.

When taking an impression from a specimen with undercuts or large recurved canines the following steps should be taken. A small quantity of alginate mix should be applied to the distal edge of the recurved canine before pressing the specimen into the tray and mix. Once the specimen is embedded in the alginate, some of the alginate distal to the canine should be pushed gently mesially. This procedure is necessary because the canine cuts a groove in the alginate as it is forced in, and this may not refill naturally. Analogous steps may be adopted for other undercut areas (see below).

The specimen may be removed from the alginate once it is no longer tacky (3–5 min), but should be left in place for an additional 3 to 4 minutes to obtain increased strength of the alginate (see below). Ideally the specimen should be removed in a single, steady and firm motion. This may be accomplished by holding the tray and specimen with its anterior end pointing upward and inclined slightly to one side. If righthanded, hold the tray in the left hand and incline to the right; the specimen is gripped with the free hand. The anterior end of the specimen should be pulled out first; to effect this action, rotate the wrists outwardly with a steady motion. Rapid extraction is advised because it increases the strength of alginates: rapid deformation imparts greater strength (Craig *et al.*, 1983). Even so, common sense should be exercised during removal of a specimen. Many specimens can withstand rapid removal; most cannot. Delicate and fragile specimens should not be extracted in one motion but should be eased out to prevent damage.

Pouring the cast.—An alginate impression contains a large quantity of water. If stored in air the water will evaporate, causing shrinkage; if stored in water the impression will absorb water and expand. Thus, an impression cannot be stored for a long time (see below), and a cast should be poured from the impression as soon as possible. Plaster should be poured carefully to eliminate large air bubbles; a vibrator or a vacuum chamber may be useful in eliminating air bubbles.

More plaster is poured over the surface of the mold and left to harden. When the plaster begins to set, a base may be formed by constructing a retaining wall to outline the cast from strips of baseplate wax. Insert the retaining wall through the setting plaster onto the flat surface of the alginate mold. Do not drive the wall through the impression material, as this causes distortion. The retaining wall may then be filled with plaster to a desired depth and levelled.

Discussion

Characteristics

Alginate is widely used in dentistry as an impression material because it is flexible, easily mixed and manipulated, inexpensive, yields highly accurate single reproductions and is easily prepared (Phillips, 1982). It is typically used to prepare study models of the human dental arcades (Craig *et al.*, 1983).

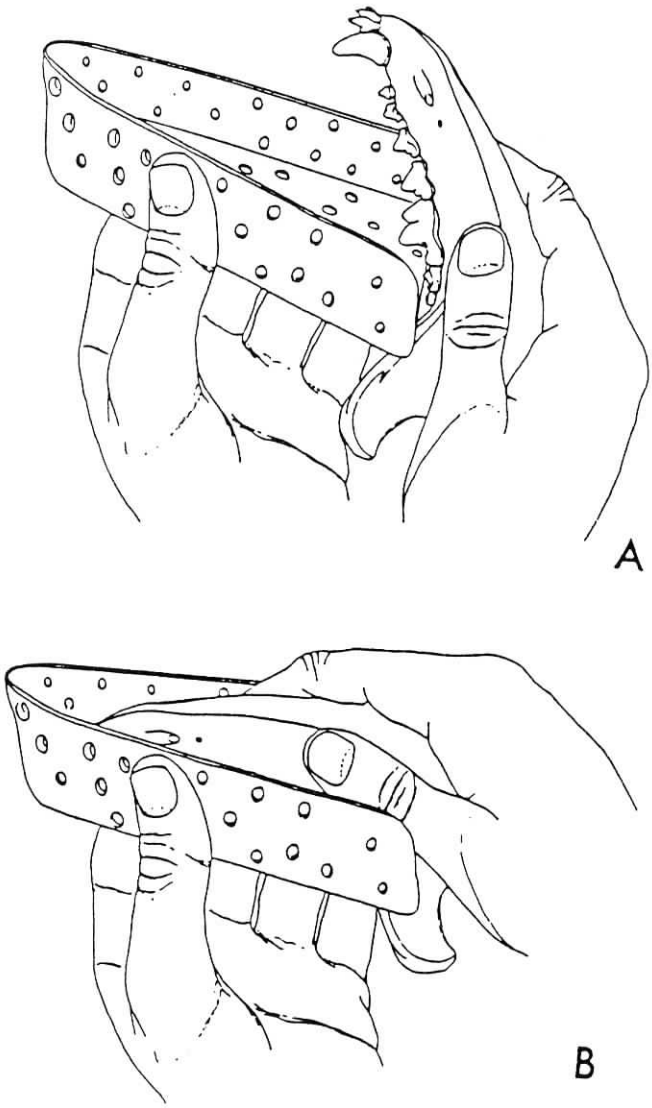

Figure 1. Placement of specimen in tray: *A.* posterior end of specimen inserted first; *B.* anterior end is then pushed in (alginate paste omitted to show distribution of holes in tray).

When combined with water, alginate forms a smooth plastic that hardens into an irreversible gel minutes after mixing. It is available commercially from dental suppliers and is packaged in bulk or in preweighed packets containing enough powder for a single full-arch human dental impression (Phillips, 1982). The bulk size is recommended as it is more economical and its shelf life (once opened) is about one year when stored at about room temperature and 100% humidity (Phillips, 1982). Both fast and normal setting alginates are commercially available. The setting time is measured from the beginning of mixing until setting; the difference in setting times is about two minutes (fast: 2.5 min; normal: 4.5 min) (Phillips, 1982), and is important to the dentist, who must hold the alginate and

Table 1. The function and composition of ingredients in alginate powder.

Ingredients	% by weight	Function
Potassium, sodium or triethanol amine alginate	15%	dissolves in water and reacts with calcium ions to form insoluble calcium alginate;
Calcium sulphate	16%	supplies calcium ions which combine with alginate salt to form calcium alginate;
Sodium phosphate	2%	retarder; acts preferentially with calcium ions to delay formation of calcium alginate;
Diatomaceous earth or silicate powder	60%	filler; increases strength and stiffness of alginate gel; produces smooth texture; ensures that firm gel is not tacky;
Zinc oxide	4%	acts as a filler; has influence on physical properties and setting time of gel;
Potassium titanium fluoride	3%	ensures a hard dense stone cast; counteracts inhibiting effect of alginate on setting of gypsum model or die

tray in a patient's mouth, but not to paleontologists. A normal-setting alginate is recommended as it allows longer working times.

Chemistry.—The chief ingredient of alginate impression materials is a linear polymer of the sodium salt of anhydro-β-D-mannuronic acid. The alginic acid is insoluble in water, but its sodium, potassium and ammonium salts are soluble (Phillips, 1982). The alginic acid is readily converted to an ester salt because its polar carboxyl groups are free to react. Sodium, potassium and triethanol amine alginate are used in dental impression materials (Table 1). Sodium phosphate delays the precipitation of calcium alginate and allows time for spatulation.

Calcium alginate precipitates a fibrous network, the intervening capillary spaces of which are filled with water to form a hydrogel. As the dimension of the network is colloidal (<0.5 μm), and the setting reaction cannot be reversed, the impression material is termed an irreversible hydrocolloid (Craig *et al.*, 1983).

Reproduction of detail.—American Dental Association (ADA) specifications require that an impression material be capable of transferring a line of 0.075 mm thickness onto a gypsum model.

Dimensional change.—The results of studies on the relative accuracy of impression materials show that alginate is slightly less accurate than agar and polysulphide rubber impressions but superior to silicone impression materials (Fig. 2A). Alginate gel contains a large amount of water, and if left in air loses water by evaporation and shrinks; serious deformation does not occur if the gel remains for up to one hour in air at about 100% relative humidity (Craig *et al.*, 1983).

Permanent deformation.—The ADA requires that less than 3% deformation occur when alginate is compressed 10% for 30 seconds, simulating removal from the mouth; many commercial alginates have permanent deformation values of 1.5%. Permanent deformation increases when the time before testing is shortened (Fig. 2B), the amount of distortion during removal is increased, the time that it is held under compression is increased (Fig. 2C), and the water to powder ratio is increased.

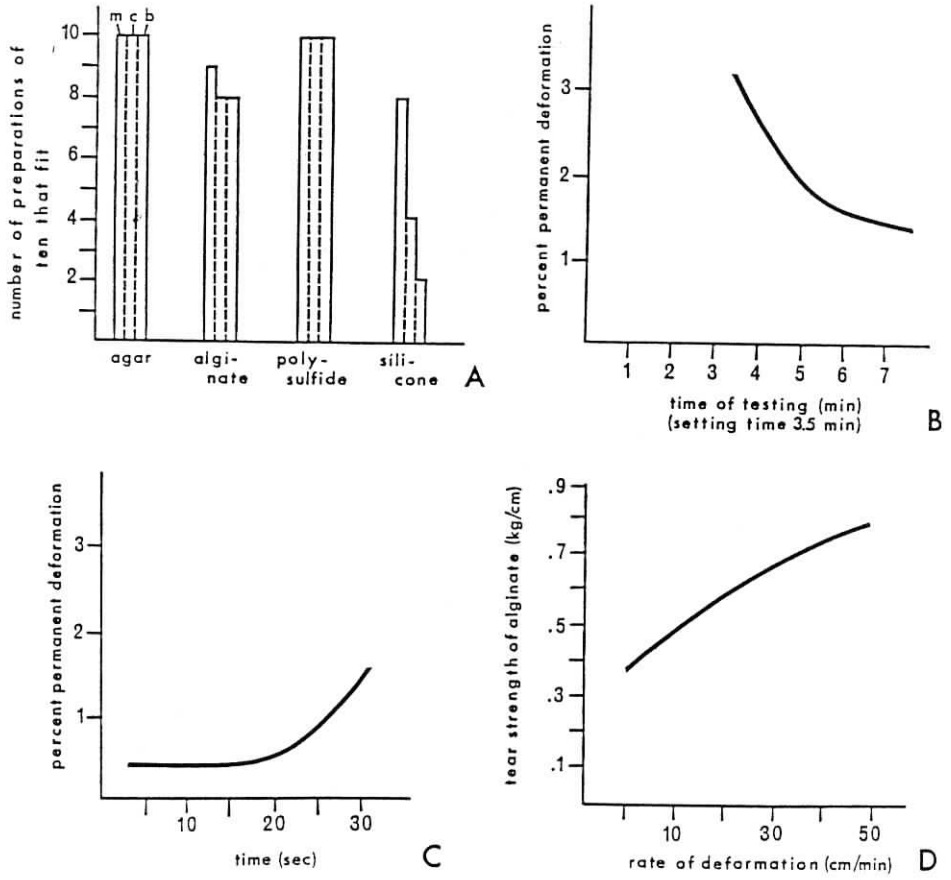

Figure 2. Graphs illustrating various properties of alginate impression material (adapted from Craig *et al.*, 1983). *A.* Represents the accuracy of fit of inlays (m = mesial-occlusal-distal), crowns (c), and bridges (b) on intracoronally and extracoronally prepared teeth. The Y-axis may be interpreted as success rate expressed as a percentage value, i.e., a crown inlay has a success rate of 80%, or is accurate 80% of the time. Multi-unit preparations (b) are more difficult to reproduce accurately than are single-unit preparations (m and c). *B.* Demonstrates that permanent deformation is reduced if deformation is delayed up to a maximum of 7 minutes after the alginate impression has set (3.5 min). *C.* Demonstrates the increase in permanent deformation with time that the impression is held under compression. *D.* Demonstrates the increase in tear strength of alginate with increase in rate of deformation; thus, the more rapidly an impression is deformed, the less likely it is to tear.

Strength.—Tear and compression strengths are the qualities tested. The ADA requires a minimum compressive strength of 350 g/cm^2 when the impression material is removed from the mouth. Values for most commercial alginates range from 5,000 to 7,000 g/cm^2. The tear strength varies from 358 to 716 g/cm. Care must be taken when a section of alginate is thinner than about 2 cm, because a small applied force can lead to tearing. The strengths of alginates are increased when the rate of deformation is increased (Fig. 2D), the time of removal is delayed (there is a dramatic increase in strength up to about three minutes after setting; Fig. 2B), and thicker mixes (i.e., decrease the water to powder ratio) are used.

Disadvantages

The advantages of using alginate for reproducing dental arcades are readily apparent, but disadvantages are that only one cast may be prepared from each impression, size of a specimen is limited, and casting of whole specimens is limited.

That only one cast may be prepared from an impression is usually not serious to a researcher: highly accurate additional casts may be made quickly and inexpensively later from a first cast. Remolding the original is possible as well, of course, but should be avoided. J. P. Lamb (personal communication) has produced multiple casts from a single alginate mold; additional casts from a single mold will not be as accurate as a first cast, but do produce satisfactory study models.

The specimen size is restricted to a large *Ursus* dentition because it becomes increasingly difficult to mix properly larger quantities of alginate. This limit assumes that one person is taking the impression, as when a researcher is visiting a collection. As with conventional molding materials, undercuts pose problems. Severe undercuts as on the lingual surface of the cheek teeth in *Castor,* usually result in a torn alginate impression. A large tear may alter the detail of the region above the undercut or, if small, may not affect the detail, and the alginate may be pushed back into place with only a line marking the tear visible on the cast. Accurate study models may therefore still be obtained from specimens with severe undercuts. One solution to undercuts that cause serious deformations is to cast each half of the arcade separately.

Complexly shaped structures such as skulls cannot be cast in alginate, but more simply shaped structures such as long bones can be. J. P. Lamb (personal communication) makes the point that alginate can be used to produce accurate casts of structures other than dentitions, as he has done for mosasaur frontals, humeri, vertebrae, and "reptilian" jaws. According to Lamb, the shape of jaws is often more informative than the details of dental morphology.

Materials—Sources and Expenses (1989 prices)

A.) Alginate Impression Material (Plastodent Elastic Impression Powder: Plastodent Inc., 2881 Middletown Rd., Bronx, NY 10461, USA); round-ended spatula; a flexible rubber mixing bowl; a measuring cup. A 454 g tub of alginate costs about US $6.00 and yields 60 scoops, at about $0.10 each, so that the cost of taking an impression of the jaws of a large dog, requiring six scoops of powder, is about $0.60.

B.) Instant Tray Mix (Lang Dental Mfg. Co. Inc., Chicago, IL 60647, USA); disposable cups and spatula. A 1,360 g tub of acrylic tray mix, yielding 54 scoops, and a 0.47 liter tin of liquid hardener costs about US $35.00 when purchased together; thus, each scoop of powder and matching vial of liquid costs $0.65. The amount of tray mix required to make a tray for a dog's jaws, requiring six scoops of powder, is about $3.30. Thus, the cost of making all the three gradated trays is under $15.00, but since the 1,360 g tub is the smallest size commercially available, $35.00 has to be spent.

C.) Baseplate Wax (Denco, Division of Sybron Canada Ltd., 120 Norfinch Ave., Downsview, Ont., Canada, M3N 1X3). A 2.2 kg box of baseplate wax, the smallest quantity commercially available, costs about US $16.00. However, wax is reusable and may be used for retaining walls when forming bases for the cast. Under $10.00

worth of wax will be used in tray construction. Used wax is cleaned by melting in hot water and allowing to cool as a surface film over water in a broad pan.

Time Involved

The time required to make a cast using alginate is approximately 30 minutes. The actual time needed to take the impression is under 10 minutes and the longest step in the procedure is the pouring and setting of the plaster. Construction of each tray takes about 30–40 minutes.

Acknowledgments

We are grateful to C. S. Churcher for his advice and encouragement, and for financing the research, and Gina Filippi for her encouragement and help. We thank D. S. Chaney, Smithsonian Institution, J. P. Lamb, Red Mountain Museum, and J. Waddington, Royal Ontario Museum, for reviewing the manuscript and offering numerous recommendations. We are also grateful to the SVP members at the 1986 Annual Meeting at Philadelphia for their enthusiasm; this paper is a result of their prompting.

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BOOK REVIEWS

CONSERVATION AND EXHIBITIONS, 1987, N. Stolow (Butterworths, London, 266 pp.). Traveling exhibitions play a major role in most museums' activities today, becoming bigger and more complex all the time. Unless done correctly, this activity can put our cultural and artistic heritage at great risk. The author's stated intention is to "examine not only the conservation aspects of exhibitions, storage, handling and transport, but also the related concerns of curators, exhibition coordinators, designers, architects, registrars and transportation specialists." The book covers a broad range of topics of interest to a diverse group of professionals involved in exhibitions as well as those responsible for the care, handling, and storage of collections. Information can be just as valuable to a curator lending a single research specimen to another institution as to an exhibits team planning a major tour. The book is comprised of fourteen chapters, a references and notes section, and five appendices dealing with specific topics. Each chapter is written to stand alone and may be used as an individual reference. The book is packed throughout with helpful illustrations, photographs, and charts.

The second chapter discusses basic conservation principles and should be required reading for anyone responsible for the care and preservation of museum collections. To help the reader approach preventative conservation in exhibition, the author has included a general discussion on relevant issues of conservation and collections management. The major causes of deterioration that might effect art and artifacts in travel and while on exhibition are also considered, including a look at humidity and temperature and how these environmental factors affect specific types of material, the hazards of atmospheric pollutants and dust, deterioration from light, micro-organisms, insects and pests, and last but not least, the human factors of neglect and physical abuse.

The importance of examination techniques and of thorough and accurate condition reports is stressed in the third chapter. Sample condition report forms are illustrated which could serve as valuable prototypes. The section concludes with a discussion on loan criteria and means of establishing guidelines for loans.

Another important section deals with the preparation of materials for loan and shipment and necessary handling instructions for a wide variety of objects. The subject is well handled and very complete, including information on the preparation and handling of fine art, ethnographic collections and archaeological materials. The chapter also includes a brief discussion on the acceptable methods for moving collections within the museum itself. A later portion of the book covers the purpose and importance of loan agreements and insurance issues, and provides critical information for all exhibition organizers, registrars, curators and potential lenders.

Several chapters are devoted solely to providing useful information about packing and crating. Traditional as well as more contemporary packing techniques and materials are covered in a comprehensive manner. Case and container design and fabrication, including information on specifications, materials used in the construction of cases or containers, and the identification and labeling of cases also are discussed well. The numerous illustrations are especially valuable. One section is devoted to the construction of cases for especially fragile or delicate objects requiring a controlled environment within the travelling and exhibit case.

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Methods of controlling and monitoring the relative humidity, temperature and pollutants within closed cases are examined. Shipping itself is discussed in detail with practical advice on the various transportation modes, strategies and equipment provided.

Preventative conservation is stressed through many examples and illustrations of case designs, alternative stable materials, and safe mounting techniques that could be employed for a variety of objects. There is a valuable chapter that covers design of special exhibition galleries and provides a wealth of conservation-sound information for museum personnel and architects planning the renovation or construction of new exhibition galleries and facilities.

Storage is an inevitable part of any exhibition, whether viewed as temporary housing of loan materials or time spent en route in warehouses. Therefore the author devotes one chapter to storage issues, including environmental requirements, storage devices and equipment, storage methods, and fire control within storage areas.

The final chapter serves as a valuable instant reference. It contains a concise listing of guidelines for preparing, packing, transporting, and exhibiting all kinds of art and objects.

The author's overall objective for the book "is to arrive at systems, techniques, and standards to minimize deterioration to collections from their use in exhibition and interpretation activities." This objective is met in a slim, readable, well illustrated volume packed full of practical information. Anyone involved with the organization and management of traveling exhibitions and loans of any scale will consider this book to be a valuable reference.—*D. Ashe, Registrar's Department, Denver Art Museum, 100 W. 14th, Avenue Parkway, Denver, Colorado 80204-2788.*

ARCHAEOLOGICAL WOOD, PROPERTIES, CHEMISTRY, AND PRESERVATION, 1990, R. M. Rowell and R. J. Barbour, eds. (American Chemical Society Advances in Chemistry Series No. 225, Washington, D. C., 449 pp. $79.95). This book was developed from a symposium sponsored by the Cellulose, Paper, and Textile Division at the 196th National Meeting of the American Chemical Society in September 1988. It is the first book to combine the chemistry, mechanisms of deterioration, and preservation of archaeological wood. The book is divided into two main sections, each with an introductory chapter. The first section covers the chemistry and properties of archaeological wood, including: structure and degradation; physical and mechanical properties; chemistry; and biological degradation. This section is introduced with a chapter reviewing the effects of the burial environment on wood and the history of the development of the technology for its preservation.

The second section, dealing with the preservation of archaeological wood, is divided into chapters concerned with waterlogged wood and dry wood. Topics covering waterlogged wood include its treatment with 1) polyethylene glycol; 2) radiation-curing monomers and resins; 3) freeze-drying; and 4) finishes for outdoor wood. The preservation of dry wood section includes chapters on: 1) simple and integrated consolidation systems; 2) consolidation with thermoplastic resins; 3)

gluing; and 4) exhibition and storage. The preservation section is prefaced by a chapter reviewing treatments used in the preservation of archaeological wood.

The aim of the book is to provide "understanding, from a scientific perspective, of archaeological wood, its properties, its chemistry, and its preservation." The strength of the book lies in the chapters dealing with the chemistry and properties of archaeological wood. The first section, therefore, will be of most use to museum professionals, especially conservators. These chapters bring together in a single volume a wealth of information for both conservators and archaeologists. The structure, chemistry, and degradation processes of archaeological wood are all clearly explained, and the extensive use of excellent scanning electron photographs and photomicrographs greatly enhance these chapters. Each chapter also has an extensive list of references which will provide the reader with an excellent bibliography for further reading. Of particular interest to conservators is the chapter by Blanchette *et al.* on microbial degradation of wood. As well as discussing the microbes responsible for damaging wood, the author illustrates how decay characteristics can be used to determine the microorganism responsible for the decay. It also provides important insights into the condition of wood deteriorated by microorganisms. In so doing, the museum professional is provided with valuable information relevant to the care and handling of archaeological materials.

The section on preservation will be less useful to museum professionals. While some of the chapters on various methods of treating archaeological wood will provide a useful review for conservators, no new information is presented. In this section, two chapters will be of interest to museum professionals. Feist's chapter on outdoor weathering of wood provides a clear, concise discussion of the photochemical reactions that occur in wood. Everything that is said about these reactions is applicable to wood in a museum collection. Harvey and Freedland's chapter on exhibition and storage of archaeological wood comprehensively covers the problems associated with this topic. This is the only chapter in the entire book aimed specifically at a museum audience.

Given the restricted topic and the hefty price of this book, it will be of interest to a limited number of museum professionals. There are sections of the book, however, that will attract a wider audience.—*C. Sease, Field Museum of Natural History, Roosevelt Road at Lake Shore Drive, Chicago, Illinois 60605.*

THE CARE OF PHOTOGRAPHS, 1987, S. Rempel (Nick Lyons Books, New York, NY, 184 pp.) *The Care of Photographs* by Siegfried Rempel is good reference material for the professional photo archivist or curator, but a greater value may be found by professionals in other fields whose collections also contain photographic images. The wide variety of materials, chemicals, and processes used to produce photographs over the years makes the care and understanding of these images a highly complex problem. Rempel is meticulous and detailed almost to a fault in his coverage of complicated subjects. Readers are taken through a series of step-by-step instructions on everything from how to turn a photograph over to specific cleaning and stabilization procedures.

The book is laid out in a logical sequence, and each specific subject is clearly headlined making it quick and easy to locate sections of immediate relevance.

Rempel begins with detailed descriptions of a variety of historical and modern photographic processes. These intricate descriptions often tend to obscure rather than enlighten, however, and it is questionable if all photographs and negatives could be easily identified from this source alone.

Notwithstanding, the ensuing chapters are extremely useful. Chapter two discusses various methods for examining and handling photographic images, while chapter three explains inherent and induced causes of deterioration.

Chapter four is entitled "Cleaning and Stabilizing Photographs." It should also be sub-titled "proceed with extreme caution," because several of the procedures described require considerable expertise and access to fully equipped laboratories. These should be left entirely to skilled photo conservators, or, at the very least, performed under their direct supervision.

The remaining chapters address maintaining proper storage and work environments and equipment. The author includes a detailed description of proper storage containers for specific types of materials, and conveniently lists names and addresses of suppliers.

Rempel also stresses some negative aspects—things that should not be done in the course of curation and briefly explains the rational behind these cautions. These explanations should be especially helpful to the novice or non-specialist curator as many problems are not immediately apparent.

The book could be a stronger tool, however, if there were more photographs, especially to illustrate all the procedures discussed in the text. It is sometimes difficult to adequately visualize some of the steps described. Rempel tends to become overly technical, especially when discussing chemical compositions. While this may be relevant to photo conservators, it tends to be rather bewildering to the average reader whose primary interest may be in correct collections management and curation of photographic collections. However, despite these criticisms, the book is basically a good and useful tool and would be an excellent reference for anyone responsible for preserving a photographic collection.—*E. H. Clancy, Photo Archives, Denver Museum of Natural History, City Park, Denver, Colorado 80205.*

1992 ANNUAL SPNHC MEETING

The seventh annual meeting of the Society for the Preservation of Natural History Collections will be hosted by the University of Nebraska State Museum, 1–6 June 1992. The conservation workshop will focus on pest management. Suggestions concerning symposia topics, workshops and field trips should be sent to the Local Committee Chair: Charlie Messenger, Nebraska State Museum, University of Nebraska, Lincoln, NE 68588 USA, tel: (402) 472-8366.

INTERNATIONAL SYMPOSIUM ON THE PRESERVATION AND CONSERVATION OF NATURAL HISTORY COLLECTIONS MAY 10–15, 1992—SPAIN

Hosted by the Museo Nacional de Ciencias Naturales, the symposium will focus on the concerns of the natural history community for the status and future of anthropological, biological, and geological collections in a world that is changing technologicaly, politically, and environmentally. Issues such as education and training, methodologies, research, resource utilization for collection care and cooperative programs will be addressed.

For information, contact: Cesar Romero-Sierra, Dept. Anatomy, Queen's University, Kingston, Ontario, K7L 3N6 Canada OR Julio Gisbert & Fernando Palacios, Museo Nacional de Ciencias Naturales, J. Gutierrez Abascal, 2, 28006 Madrid Spain.

ERRATUM

In the feature article, "Integrating specimen documentation, processing, and data automation in a mammal collection: A case study of an accession database" (Collection Forum, 6(2):82–98), the legends for two figures were interchanged. The legend for the bottom figure on page 88 should read "Figure 5. Curation Listing", whereas the legend for the figure on page 89 should read "Figure 6. Database Management Listing". Our apologies to the author.

ADVERTISING

Advertising in Collection Forum is intended to serve the efforts of SPNHC members to manage and conserve natural history specimens. Ads should focus on products, services and/or applications that might be new to our members. Ads appearing in the journal do not constitute an endorsement by SPNHC. For information concerning rates and schedules, contact the Associate Editor for Advertising.

Preparation of Manuscripts

General.—It is strongly recommended that, before submitting a paper, the author ask qualified persons to appraise it. The author should submit three copies of the manuscript either typewritten or printed on letter quality printers. **All parts of the manuscript must be double spaced** with pica or elite type on 8½ × 11 inch (21.6 by 27.9 cm) or A4 paper and at least one inch (2.5 cm) margins on all sides. Manuscripts should not be right justified, and manuscripts produced on low-quality dot matrix printers are not acceptable.

Each page of the manuscript should be numbered. Do not hyphenate words at the right-hand margin. Each table and figure should be on a separate page. The ratio of tables plus figures to text pages should generally not exceed 1:2.

The first page includes the title of the article, names of authors, affiliations and addresses of authors, and the abstract if present. In the top left-hand corner of the first page, indicate the name and mailing address for the author to whom correspondence and proofs should be addressed. All subsequent pages should have the last names of the authors in the upper left-hand corner.

The preferred language for manuscripts is English, but a summary in another language can precede the literature cited, if appropriate. Manuscripts written in other languages will be considered if the language uses the Roman alphabet, an English summary is provided, and reviewers are available for the language in question.

Abstract.—An abstract summarizing in concrete terms the methods, findings and implications discussed in the paper must accompany a feature article. The abstract should be completely self-explanatory and should not exceed 200 words in length.

Style and abbreviations.—Symbols, units, and nomenclature should conform to international usage. Cite all references in the text by the author and date, in parentheses. Footnotes should be avoided. For general matters of style authors should consult the "Chicago Manual of Style," 13th ed., University of Chicago Press, 1982.

Literature cited.—This section includes only references cited in the manuscript and should be typed double spaced. References are listed alphabetically by authors' names and take these forms:

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, 219 pp.

Sarasan, L. 1987. What to look for in an automated collections management system. Museum Studies Journal, 3:82–93.

Thomson, G. 1986. *The Museum Environment,* 2nd ed. Butterworths, London, 293 pp.

Tables and illustrations.—Tables and illustrations should not repeat data contained in the text. Each table should be numbered with arabic numerals, include a short legend, and be referred to in the text. Column headings and descriptive matter in tables should be brief. Vertical rules should not be used. Tables should be placed one to a page, after the references.

All figures must be of professional quality as they will not be redrawn by the editorial staff. They may include line drawings, graphs or black and white photographs. All figures should be of sufficient size and clarity to permit reduction to an appropriate size; ordinarily they should be no more than twice the size of intended reductions and whenever possible should be no greater than a manuscript page size for ease of handling.

Photographs must be printed on glossy paper, with sharp focus and high contrast essential for good reproduction. Photos should be trimmed to show only essential features.

Each figure should be numbered with arabic numerals and be referred to in the text. Legends for figures should be typed on a separate sheet of paper at the end of the manuscript. Magnification scale, if used, should be indicated in the figure by a scale bar, not in the caption. Notations identifying the author and figure number must be made in pencil on the back of each illustration. All illustrations must be submitted as an original and two copies. Note placement of tables and illustrations in the margins of the manuscript.

Evaluation of a manuscript.—Authors should be aware that the following points are among those considered by the editorial staff when evaluating manuscripts: 1) Is the content appropriate to the purpose of the journal and society? 2) Are the contents clearly and logically presented and the paper well organized? 3) Is the methodology technically and logically sound? 4) Does the paper contribute to the body of knowledge and literature? 5) Is the study integrated with existing knowledge and literature? Is the literature cited appropriate for the study? 6) Are the conclusions supported by sufficient data? 7) Does the title reflect the thrust and limitations of the study? 8) Are the tables and figures clearly presented? Are they necessary to support the text?

Submission Procedure

Manuscripts intended either as feature articles or general notes should be submitted in triplicate (original and two copies) to the Managing Editor. Letters to the Editor and correspondence relating to manuscripts should be directed to the Managing Editor. Books for review should be sent to the Associate Editor for Book Reviews.

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