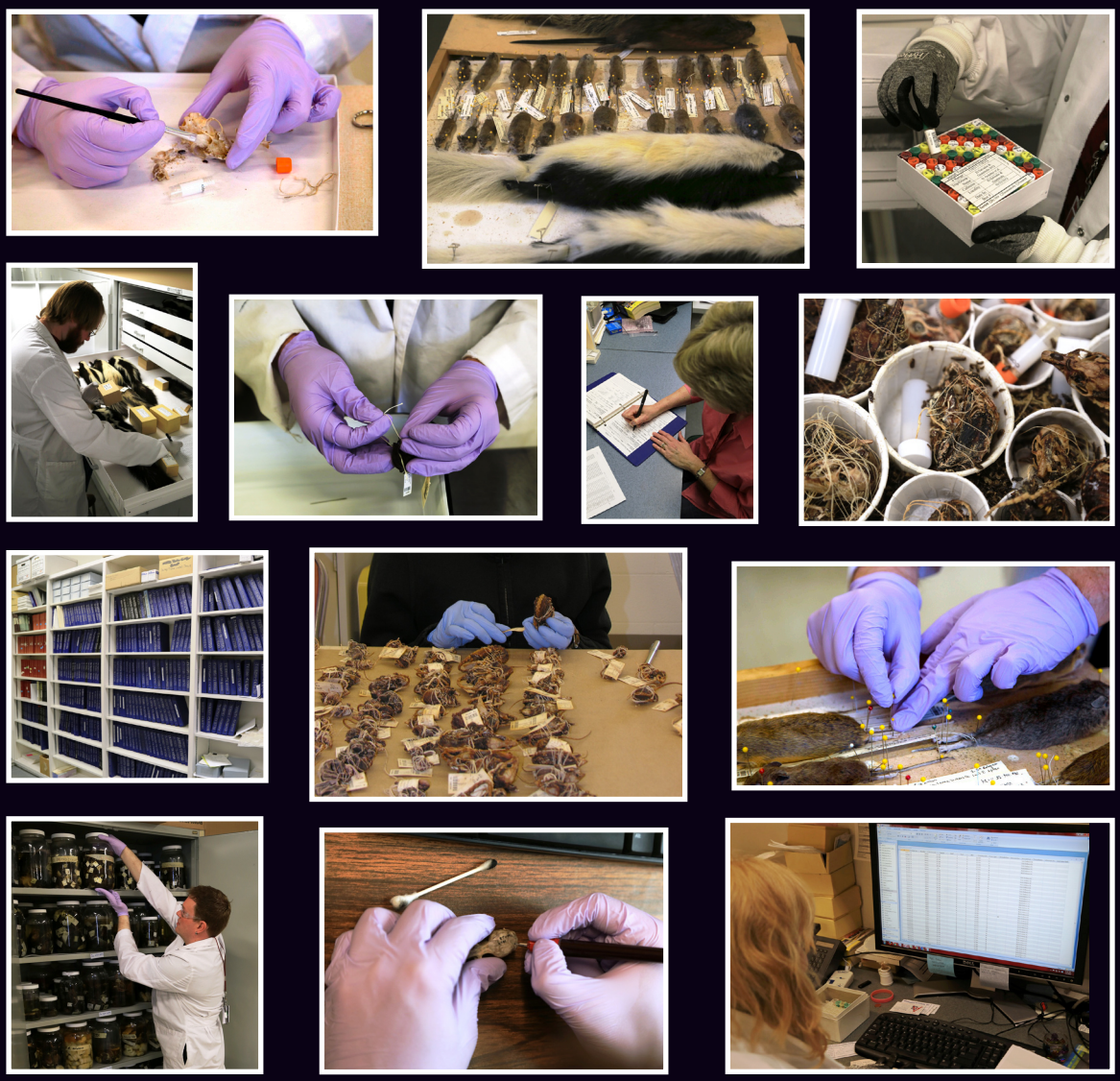
TEXAS TECH UNIVERSITY
Natural Science Research Laboratory

Occasional Papers

Museum of Texas Tech University
Number 323 17 April 2014



"Door to Drawer" Costs of Curation, Installation, Documentation, Databasing, and Long-term Care of Mammal Voucher Specimens in Natural History Collections

Editorial: Role of Museum of Texas Tech University in Fulfilling the University's Mission

Mission Statement of Texas Tech University: *As a public research university, Texas Tech University advances knowledge through innovative and creative teaching, research, and scholarship. The university is dedicated to student success by preparing learners to be ethical leaders for a diverse and globally competitive workforce. The university is committed to enhancing the cultural and economic development of the state, nation, and world.* From this, the tagline of Texas Tech University (TTU) is: "From Here it's Possible." The success of the students and faculty associated with the Museum is excellent justification for this tagline.

First, our collections provide an understanding of diversity of life. The natural history collections include >116,500 mammal specimens, >5,900 bird specimens, >4.2 million invertebrate specimens, and >300,000 vials of tissue samples for genetic and genomic research. The size and diversity of these collections make them invaluable as resources for research and education. The mammal collection has been the basis of more than 1,000 scientific publications by TTU students and faculty, and through loaning of specimens and genetic resources for research, untold numbers of additional publications by scientists at other universities. Twenty previously unrecognized mammal species, including a Texas pocket gopher and an Arizona shrew, were described from specimens in the NSRL.

Second, these resources allow TTU to compete for excellent students that are interested in research in fields such as systematics, zoonoses, genomics, toxicology, and parasitology. To date, at least 95 Ph.D. degrees and 127 Master of Science degrees have been granted to TTU students that utilized the Museum's NSRL collections for their research. These students are uniquely trained to fill society's needs in scientific research and academia and have obtained tenure-track positions at major universities, the CDC, the Defense Threat Reduction Agency, and medical institutions. The database and collections of the NSRL also provide hands-on experience for students in a unique, terminal Master of Arts program in Museum Science and Heritage Management, which has granted more than 500 M.A. degrees since 1976. Graduates are successful as curators, collection managers, and administrators of museums throughout the U.S. and internationally. Many undergraduate students also have received field collection experience, training in laboratory research (e.g., molecular biology, morphometrics, data analysis), and hands-on training utilizing the Museum's NSRL collections through research projects with TTU faculty. As a result, many of these students have had outstanding careers in science and medicine.

Third, faculty associated with the Museum have been among the most highly recognized faculty at our university. Texas Tech honors scholarly achievement by faculty with the designation of Horn Professorship, the highest academic rank given by TTU. Since the Horn Professorship honor was established in 1967, 9 of the 82 faculty members named as Horn Professor have had Museum affiliations. These are: Russell Strandtmann (Biology; invertebrate parasites); Alton Wade (Geology; Antarctic research); Sankar Chatterjee (Geology; vertebrate paleontology); Marilyn Phelan (Law School; museum law); J. Knox Jones, Jr. (Biology; mammalogy); Willard Robinson (Architecture; historic preservation); Clyde Jones (Biology; African primates); Eileen Johnson (Museum Sciences; Lubbock Lake Landmark); and Robert J. Baker (Biology; faunal significance of Chernobyl). We interpret this association of Museum faculty with TTU academic departments as a synergistic mechanism that achieves a leadership role in excellence in teaching and research.

Fourth, the Museum's NSRL successfully received line-item funding from the State of Texas legislature for development of a Biological Database. This line-item has resulted in many benefits to TTU, but a significant achievement is that at the turn of the 21st century, NSRL-affiliated faculty and students archived the mammal fauna of Texas Parks and Wildlife properties and created a database from those collections, which will be critical in understanding future changes in mammalian fauna across the state and the implications to biodiversity. An example of how time-sensitive collections can provide significant data to answer questions critical to society is the collection of specimens from the environment created by the Chernobyl meltdown in April 1986. Studies of a rodent species have provided data demonstrating that multi-generational exposure to chronic low-dose radiation has altered the mitochondrial genome. Archived Museum specimens were the foundation of this insight into the significance of radioactive pollution to life forms.

Fifth, research utilizing the NSRL collections has brought international recognition to TTU. For example, the NSRL collections have been particularly valuable to recent studies of rodent-borne diseases, including hantaviruses and arenaviruses, to identify new viral strains, vector species, reservoir species, modes of transmission, and geographic origin of hosts and viruses. NSRL samples documented that the Four Corners Disease (Sin Nombre virus) was a naturally-occurring virus and not an escaped biological weapon.

The Museum has played a significant role in accomplishing the Mission of TTU. The role of museums in science, education, innovation, and scholarship is an ever-changing landscape. We foresee unlimited opportunities for the Museum to further the Mission of TTU and to accomplish even higher goals. From here it's possible.

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Front cover: Photographs illustrating activities associated with curation, installation, documentation, databasing, and long-term care of the mammal collection at the Natural Science Research Laboratory of the Museum of Texas Tech University. All photographs by Bill Mueller.

"Door to Drawer" Costs of Curation, Installation, Documentation, Databasing, and Long-term Care of Mammal Voucher Specimens in Natural History Collections

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Abstract

Natural history specimens and their associated data are a valuable resource to the scientific and educational communities, with each specimen representing a unique sample from a specific locality and a specific point in time. Given this intrinsic value to research and education, a few studies have attempted to assign a monetary value or worth to specimens and their associated data. For example, a recent study determined the costs associated with collecting and preparing a mammal voucher specimen in the field; however, little information is available for costs associated with incorporating these specimens and their data into a natural history collection and providing access to these data by the scientific community and society. Herein, we review the costs required for curating, installing, documenting, databasing, and caring for a representative sample of 3,356 mammal voucher specimens, associated genetic resources, and accompanying data in the Natural Science Research Laboratory, Museum of Texas Tech University. The average cost for curation, installation, documentation, and databasing is conservatively estimated to be $17.51 per specimen, with additional costs of $0.25 per year per specimen for long-term care.

Key words: archival costs, genetic resources, natural history collections, searchable database, voucher specimens

Introduction

The importance and role of natural history collections to science and education have been discussed by many authors (Lane 1996; Suarez and Tsutsui 2004; Wandeler et al. 2007; Mares 2009; Anderson 2012). The comparison between natural history collections and libraries (Winker 2004) is apropos; both provide an opportunity for educational advancement through examination of the material contained within their respective walls (specimens or books). Libraries and natural history collections expend substantial efforts in obtaining new acquisitions; although this is a necessary step for initiating and expanding each resource, it is only the beginning phase. Eventually, both entities must develop a system to effectively and efficiently archive these resources for an extended period of time (perhaps hundreds of years) and ultimately provide the appropriate clientele/users access to the items contained within their collections. In addition, once the resource is established, substantial efforts and resources are required to maintain the facility on a daily basis and to provide various types of services to its users. Thus, acquiring, caring for, and providing access to archived collections requires substantial monetary investment, in perpetuity. For natural history collections, few studies have been conducted that attempt to put a dollar value on specimens (Bradley et al. 2012). However, with sources of funding for research, academia, and natural science collections becoming increasingly limited and competitive, it is critical to understand the financial investment involved in collecting, archiving, and providing access to these important resources.

Concerning the acquisition side of institutional efforts, Bradley et al. (2012) reviewed the costs associated with collecting, preparing, and transporting mammal voucher specimens and associated tissues to the door of the Natural Science Research Laboratory (NSRL), a division of the Museum of Texas Tech University (MoTTU). Sixty-one field trips, conducted between 2000 and 2011, and the specimens collected

during those trips were chosen as representative of collecting efforts of the NSRL (local, regional, and international trips, various preparation types, various trip durations, etc.). Using that subset of data as a model, it was determined that the average cost per voucher was $41 for specimens collected locally or regionally and $74 for specimens collected on international trips (Bradley et al. 2012).

Although the study by Bradley et al. (2012) provided an estimate of the cost of obtaining specimens at a field site and transporting them to the NSRL, it did not consider the cost of the additional activities associated with readying specimens and their associated data for installation into the collection (and ultimately providing access to the specimens and data to the scientific community and to society), nor did it estimate the cost of long-term care for the collection. In fact, only a few studies provide cursory information concerning these costs (Anderson 1973; Anderson and Choate 1974; Lee et al. 1982; Blackmore et al. 1997; Genoways et al. 2003) and essentially no study provides a detailed, comprehensive view that allows for an accurate estimate of the total expenses required for archiving and properly caring for natural history collections. The study by Blackmore et al. (1997) provides a cursory estimate for the acquisition, curation, and accommodation (maintenance) for a variety of collections housed in The Natural History Museum of London; although their values are useful in a broad sense, they lacked the specific details necessary for calculating cost on a per specimen basis. Herein, we extend our initial efforts in Bradley et al. (2012) by estimating the costs from "door to drawer" associated with curating, installing, and documenting mammal voucher specimens and their associated tissues, providing an online, searchable database, and the annual cost of caring for such collections.

METHODS

Costs were separated into three primary categories: curation and installation; documentation and databasing; and long-term care. For the purposes of this manuscript, we define "curation" as the initial procedures required to prepare specimens for permanent installation in the collection (e.g., placing skeletal material in the bug colony for cleaning, osteoscribing bones, placing cleaned skulls and skeletons in vials and boxes, etc). Each category is explained in more detail below. For each category, costs for consumable supplies and labor were estimated on a per specimen basis. Non-consumable supplies (e.g., computers and printers, laboratory instruments such as forceps, tongs, etc.) were not factored into supply costs. Supply costs were based on current (2013) prices when ordered in quantities typical for the NSRL. Minutes-per-specimen estimates for each procedure were determined based on the results of time-trials conducted by NSRL personnel experienced in the pertinent tasks. Labor costs were based on the average FY 2013-2014 salary rates of the NSRL personnel that typically conduct each task (Table 1). Procedures and supplies that were considered in our estimates are provided in Appendices I and II, respectively. All NSRL procedures used in the generation of the database for this manuscript follow the Collection Management Policy and Procedures of the Museum of TTU (www.depts.ttu.edu/museumttu/facilities&policies.html) and are the basis of accreditation by the American Society of Mammalogists and the American Alliance of Museums.

Time-trials to estimate minutes-per-specimen for each procedure represented "best-case scenarios" and did not account for interruptions and problems that are typically encountered during actual curatorial procedures (e.g., replacing ink cartridges, deciphering hand writing, etc.). Therefore, we consider these estimations to be reflective of the minimum time required to complete each task. Similarly, we did not attempt to account for situations that potentially could result in wasted supplies during curatorial activities (e.g., fluid spills, misprinted labels and tags), and consequently, we consider our estimates for supply expenses to be a minimum cost per specimen. Also, it is important to recognize that time and expenses associated with curating, installing, documenting, and caring for a mammal collection may vary, relative to that reported herein, depending on the experience and efficiency of staff, type of specimens, unique or specific collection operating procedures, opportunities to purchase supplies in bulk quantities, etc.

Table 1. Personnel salaries used in calculating labor costs for the curation, installation, documentation, databasing, and long-term care of mammal voucher specimens, tissue samples, and associated data.

Personnel	Average Salary
Faculty Curators	$58.04 per hour
Curator of Collections	$20.96 per hour
Genetic Resources Collection Manager	$17.60 per hour
Graduate Students	$7.75 per hour
Undergraduate Students	$7.50 per hour

The first expense category that we considered was the cost associated with curating and installing specimens. The procedures, supplies, and time involved in this process vary depending on the type of specimen preparation (traditional dried skin, skeletal materials, fluid-preserved) or specimen component (tissues), as well as the size of the specimen. For our analysis, specimens were subjectively classified to size as follows: extra-small (e.g., *Reithrodontomys*, *Perognathus*, shrews); small (e.g., *Peromyscus*, bats); medium (e.g., *Sigmodon*, *Neotoma*); or large (e.g., *Sylvilagus*, *Sciurus*, *Mephitis*). There obviously are larger mammal categories not included in our calculations, such as large carnivores, ungulates, elephants, whales, etc., but no large specimens were collected during the six field trips used in our analyses, nor are they common specimens in most natural history collections. However, we acknowledge that large mammal vouchers would have greater associated costs for supplies and curatorial procedures.

The typical procedures for curating and installing traditional specimens upon their arrival at the NSRL can be summarized as follows: 1) assignment of material to appropriate staff members and inventory of incoming items (specimens, tissues, field notes and data books, etc.); 2) skin and skeletal specimens subjected to pest management protocols (frozen at -20°C for 2 weeks); 3) skeletal material enters the dermestid colony, followed by hand cleaning and osteoscribing; 4) skeletal material is stored in appropriate box or vial; 5) skeletal material is matched with skin; 6) specimen is catalogued (after data are proofed and species identification is confirmed); and 7) specimen is installed into the appropriate drawer and case of the collection. For fluid specimens, the field preservative (formalin or ethanol) is decanted, specimens are inventoried, rinsed in ethanol (multiple times as needed), re-labeled with alcohol resistant ink and tags (if needed), housed in appropriate jars, catalogued, and installed into cabinets. For tissues, the vials are inventoried, sorted, re-labeled as necessary, cell-boxed, and installed into -80°C freezers or on shelves (non-frozen samples in EtOH or lysis buffer) in the Genetic Resources Collection.

The second expense category estimated pertains to costs associated with documentation and handling of data. Documentation procedures include: scanning and organizing field notes and storing in archival boxes, proofing TK books (TK books contain the primary data page for each specimen) for complete data and entering data into spreadsheets, proofing spreadsheets and importing into online, searchable databases, updating TK books with assigned catalogue numbers and species identifications, scanning TK books, and completing accession documentation with the Registrar.

The third expense category we considered was the cost of long-term care for proper maintenance of the specimens. These costs result primarily from the time involved (personnel salaries) to conduct routine surveys and duties required under normal collection activities. Few supplies, other than ethanol to replace fluids in the Fluid Collection, are required during maintenance activities. Maintenance procedures considered in our estimates include: complete inventories every 10 years

for the dry and fluid collections (~10% of each collection per year), periodic spot checks (~1.5% of each collection per year), checking fluid levels in the Fluid Collection and replacing ethanol as needed (~5% of Fluid Collection per year), checks of the dry collection for pests (quarterly), monitoring freezers (daily), checking organization of dry and fluid collections (~10% of collection per year), and database updates (~ 8 hours/week). These are recurring expenses that, although they may be periodic in occurrence, continue in perpetuity as part of normal collection responsibilities of curation. Therefore, we extrapolated each expense to a yearly basis to determine the annual maintenance cost per specimen by preparation type. We did not include time or cost estimates for general collection maintenance procedures that are independent of the number or type of specimens being archived. For example, we did not include the time involved in general cleaning and organization of the collection areas or the monitoring of insect pest activity in the building through the use of sticky traps, etc.

Bradley et al. (2012), in order to determine an overall average cost to prepare a specimen in the field, selected six field trips that were considered representative of recent NSRL collecting efforts with regards to the ratio of specimen sizes and preparation types. The number of mammal vouchers, by preparation type and size, and the number of tissue samples obtained from the six field expeditions are presented in Table 2. In this study, we utilized the samples from these same six field trips in order to calculate an overall average "door to drawer" cost per specimen. After estimating the labor and supply costs for curating and installing, documenting and databasing, and caring for a single mammal voucher specimen of each preparation type and size, as explained above, we multiplied these values by the number of specimens of each type and size that were obtained from the six field trips. Total costs were then divided by the total number of specimens (3,356) to determine an overall average cost per specimen.

Table 2. Number of mammal voucher specimens, by preparation type and size, and number of tissue vials obtained during six NSRL field expeditions. These trips are considered representative of NSRL collecting efforts in terms of the ratios of specimen preparation types and sizes.

Preparation	Honduras 2001	Honduras 2004	Kyrgyz Republic 2007	Mexico 2008	Texas, Oklahoma 2010	Texas, Oklahoma, Kansas 2011
Traditional (skin plus skeleton)						
extra-small	10	3	13	43	21	36
small	433	425	0	276	227	289
medium	1	2	1	11	55	74
large	2	0	0	0	1	4
Skeletal material only						
extra-small	0	0	1	52	14	8
small	1	183	1	50	18	172
medium	0	0	6	4	0	6
large	2	2	0	0	4	0

Table 2. (cont.)

Preparation	Honduras 2001	Honduras 2004	Kyrgyz Republic 2007	Mexico 2008	Texas, Oklahoma 2010	Texas, Oklahoma, Kansas 2011
Fluid-preserved						
Initially fixed in 10% formalin	664	0	157	67	0	0
Initially fixed in 70% ethanol	0	0	0	0	11	0
Tissue vials						
Frozen or ethanol-preserved	5,528	3,710	492	2,989	2,063	3,532
Lysis-preserved	0	0	449	0	0	0
Total specimens	1,113	615	185[1]	503	351	589

[1] Six specimens were represented by tissues only.

RESULTS

Results of our analysis of the estimated time, labor costs, and supply costs for the curation and installation (by preparation type and specimen size), documentation and databasing, and annual maintenance of a single mammal voucher specimen and tissues (by vial) are presented in Table 3. As expected, time and labor costs for curation and installation were higher for larger voucher specimens. The cost of curating and installing fluid preparations was slightly higher for specimens initially fixed in formalin than those initially fixed in ethanol, due to the extra rinsing required as the specimens are transferred into 70% ethanol. Overall, curation and installation of fluid preparations were less expensive than for most categories of dried preparations. Curation and installation costs for tissues averaged approximately $1 per vial. Documentation and databasing costs were a relatively minor component of the overall cost of a voucher. Documentation and databasing primarily involves time (labor costs) but few consumable supplies, due to the fact that most documentation activities are electronic (scanning, entering data into databases, etc.). Similarly, long-term care costs were almost exclusively dependent on personnel time and involve few supplies.

When the estimated costs per preparation type and size (Table 3) were applied to the 3,356 specimens collected during the six field expeditions (Table 2), the total estimated cost to curate, install, and document these specimens was $58,749.70, for an overall average cost of $17.51 per specimen (Table 4). Of the $17.51 per specimen, $12.11 was for personnel salaries and $5.40 was for supplies and materials. The estimated annual maintenance cost for these specimens was $823.26, for an overall average cost of $0.25 per specimen per year, of which $0.23 was for personnel salaries and $0.02 was for supplies and materials. When analyzing the numbers in terms of time, rather than cost, we estimated that an average of 48 minutes of personnel time was required to curate, install, and document each specimen, and at least 1 minute per specimen was required for maintenance activities each year.

Table 3. Estimated time (minutes), labor costs, and supply costs for the curation and installation, documentation and databasing, and annual care of a single mammal voucher specimen (by specimen preparation type and size) and associated tissues (per vial). See Appendices I and II for summaries of NSRL procedures and supplies, respectively, considered in these estimates. All costs are rounded to the nearest $0.01.

Item	Estimated minutes per specimen	Estimated labor cost per specimen	Estimated supply cost per specimen	Estimated total cost per specimen
Curation and Installation				
Traditional specimen (skin plus skeleton)				
extra small	34	$9.25	$1.96	$11.21
small	34	$9.33	$3.67	$13.00
medium	36	$9.50	$4.03	$13.53
large	39	$9.88	$11.61	$21.49
Skeletal material only				
extra small	27	$3.98	$1.95	$5.93
small	27	$3.98	$3.66	$7.64
medium	29	$4.24	$4.01	$8.25
large	32	$4.62	$11.59	$16.21
Fluid preparation				
Initial fixation in 10% formalin	11	$5.96	$0.55	$6.51
Initial fixation in 70% ethanol	11	$5.89	$0.47	$6.36
Tissues (per vial)				
Frozen or ethanol-preserved	3	$0.62	$0.47	$1.09
Lysis-preserved	3	$0.61	$0.35	$0.96
Documentation and Databasing	4	$1.06	$0.01	$1.07
Long-term Care[1]				
Traditional and skeletal preparations	0.46	$0.07	$0.00	$0.07
Fluid preparations	0.37	$0.09	$0.01	$0.10
Tissues (per vial)	0.10	$0.03	$0.00	$0.03

[1] Long-term care costs are adjusted for frequency of occurrence of each procedure, to reflect an average annual effort.

Table 4. Estimated costs associated with the curation and installation (C and I), documentation and databasing (D and D), and long-term care (LTC) of 3,356 mammal voucher specimens and associated tissues resulting from six NSRL field expeditions. Curation and installation costs take into account the number of specimens of each size and preparation type resulting from each trip (Table 2). Curation, installation, documentation, and databasing costs are one-time expenses for each specimen. Long-term care costs are based on an average one-year cost, and continue in perpetuity.

		Curation and Installation (C and I)								
Date	Locality	Traditional Preparations	Skeleton-only Preparations	Fluid Preparations	Tissue Vials	Documentation and Databasing (D and D)	Total Expenses for C, I, D and D	Total Specimens	Average Cost per Specimen for C, I, D and D	Average Annual Cost per Specimen for LTC
3-24 Jul 2001	Honduras	$5,797.61	$40.06	$ 4,322.64	$6,025.52	$1,190.91	$17,376.74	1,113	$15.61	$0.24
10-25 Jul 2004	Honduras	$5,585.69	$1,430.54	$0.00	$4,043.90	$658.05	$11,718.18	615	$19.05	$0.25
16 Jun-3 Jul 2007	Kyrgyz Republic	$159.26	$63.07	$1,022.07	$967.32	$197.95	$2,409.67	185	$13.03	$0.25
12-29 Jul 2008	Mexico	$4,218.86	$723.36	$436.17	$3,258.01	$538.21	$9,174.61	503	$18.24	$0.25
27 Jul-9 Aug 2010	Texas, Oklahoma	$3,952.05	$285.38	$69.96	$2,248.67	$375.57	$6,931.63	351	$19.75	$0.24
22 Jul-6 Aug 2011	Texas, Oklahoma, Kansas	$5,247.74	$1,411.02	$0.00	$3,849.88	$630.23	$11,138.87	589	$18.91	$0.25
Total		$24,961.21	$3,953.43	$5,850.85	$20,393.30	$3,590.92	$58,749.70	3,356	$17.51	$0.25

DISCUSSION

The costs determined for initial curation, installation, documentation and databasing, and long-term care of voucher specimens reported herein were based on our personal and professional experiences with mammal specimens deposited in the NSRL. All costs were based on standard NSRL procedures, typical NSRL supply costs, and NSRL staff salary rates. These costs are expected to vary for other natural history museums, depending on factors such as the procedures and supplies utilized by a museum, specific curatorial needs of the collections, database requirements, and personnel availability, experience, and salary rates. As a reminder, the estimates presented herein represent a conservative approach, and in some instances are not all-encompassing relative to the total expenses experienced during curation, installation, and documentation and databasing activities. Further, our estimated costs are not expected to be applicable for collections of other taxonomic groups (birds, reptiles, amphibians, fish, invertebrates, etc.) or non-traditional types of collections (e.g., taxidermy, pelts); however they should provide a gross estimate for similar activities. Although the values reported herein apply specifically to the NSRL's mammal collection, they nevertheless are enlightening and provide a point of discussion and comparison. We encourage other natural history museums to conduct similar studies of the costs associated with collecting specimens (e.g., Bradley et al. 2012) and the costs of curating, installing, documenting, and caring for specimens of other taxonomic groups and specimen preparation types, for comparison and valuation purposes.

Although there are some limitations to the data presented in this manuscript, the data provide researchers and natural history museum administrators with documented examples of the costs for archiving mammal specimens in a museum accredited by the American Society of Mammalogists and the American Alliance of Museums. This type of data, in part, can be useful for justifying the current financial value of a collection, anticipating costs associated with collection growth, and estimating future curatorial expenses. For example, using the average cost of collecting, field-prepping, and transporting a specimen to the NSRL ($56; Bradley et al. 2012) and the average cost of curating, installing, documenting, and databasing a specimen as reported in this manuscript ($17.51), it would cost a minimum of $8,563,915 ($6,524,000 for collecting and $2,039,915 for curation activities) in today's dollars to replace the Mammal Collection of the NSRL (116,500 catalogued specimens and the associated tissues and data), with additional collection care and maintenance costs of at least $29,125 annually. In addition, the time required to curate, install, and document and database the 116,500 mammal specimens currently housed in the NSRL is minimally estimated to be 93,200 personnel-hours. Further, the maintenance procedures considered in our analysis are estimated to require at least 1,942 personnel-hours per year for the entire mammal collection.

The total monetary cost of expanding, maintaining, and operating a natural history collection, however, goes far beyond the costs associated with specimen acquisition and care that are reported in Bradley et al. (2012) and in this paper. For example, there are costs associated with providing services to the scientific community (e.g., processing and shipping loans, answering information requests, providing identification services, providing on-site access to specimens by visiting researchers, other activities required to be accredited by professional organizations such as the American Society of Mammalogists and the American Alliance of Museums), conducting outreach activities (e.g., giving tours, developing museum exhibits), handling daily operations (e.g., ordering supplies, training students), and administering such a facility, as well as substantial costs for physically establishing and maintaining the facilities that house the collections (e.g., building construction, furnishings and equipment such as replacement freezers, specimen cabinets, computer upgrades, etc., electricity and other utilities, custodial services, pest control, security services, building maintenance and repairs, etc.). These costs are largely dependent on the size and type of facility, available staffing, and the use of the facility by the science, education, and public communities. Therefore these expenses cannot reasonably be viewed on a cost-per-specimen basis, but they represent real costs of operating a natural history museum and contributing to advancements in scientific research, education, and public outreach.

The substantial costs of collecting and properly archiving specimens as estimated in Bradley et al. (2012) and in this study illustrate, in part, the need for financial support for natural history collections by university and museum administrators, scientific communities, and funding agencies such as the National Science Foundation, National Institutes of Health, and the Institute of Museum and Library Services. It is clear that it is expensive to collect, prepare, and properly archive natural history collections and to ensure that these irreplaceable specimens and data are available to researchers for future use. As new methods continue to be developed for extracting genetic and toxicological data from specimens (Baker 1994; Rocque and Winker 2005; Wandeler et al. 2007; Rowe et al. 2011;) and as new uses for traditional specimen data become more pertinent (e.g., ecological niche modeling, GIS, climate modeling, and distributional studies - Anderson 2012; Feeley and Silman 2011; Suarez and Tsutsui 2004), the potential for resolving scientific questions that can be addressed by well-curated and accessible collections and associated data will increase (Baker et al. 1998; Parker et al. 1998). Toward this end, we agree with Gropp and Mares (2009) and many others that it is imperative to encourage funding agencies and administrators to identify the mechanisms to adequately fund the activities required of natural history collections so that they can continue to support the scientific community. Further, we support the contention of Blackmore et al. (1997) that it is appropriate for the systematics community to present sound calculations concerning the value of scientific collections so that others less knowledgeable of these resources can appreciate their true worth.

The goal of this study was simply to estimate the monetary costs necessary to: 1) archive mammal voucher specimens and their associated tissues, 2) database specimen information and make that information available and searchable via online data portals, and 3) provide proper maintenance and care for specimens and their data. From the onset, it was realized that the results of this study could be interpreted as a negative cash flow, and the natural history collection potentially could be construed as a liability to the university. However, if the cost of archiving and caring for the collection is viewed as a "monetary investment" by the university (and other funding agencies), then rubrics can be defined to measure the "success" of such an investment. Although we object to the idea that simple accounting methods be used to determine the true value of a scientific resource, the initial comparison to a library resurfaces. Libraries require a substantial investment (buildings, new acquisitions, salaries, maintenance, utilities, etc.) by the institution and at the end of the day this investment is gauged by the quality of the education received by the students and the scholarship of the faculty. Likewise, for natural history collections, one could quantify: 1) the number and quality of publications produced by the users (faculty and students), 2) the number of graduate students utilizing the collections for their research degrees, 3) placement of graduate students in professional or influential positions, 4) grants received for research associated with specimens and data housed in the collection, 5) number of loans to the scientific community, etc., and determine if the recognition returned to the university exceeded the investment (see Editorial, page *i*). Many of these factors are beyond the scope of this study and will be addressed in Bradley et al. (in prep.), in which we discuss the importance and value of natural history collections to science, education, and society.

ACKNOWLEDGMENTS

We thank the many students, staff, and faculty who care for the NSRL collections and contribute to the day-to-day operations of the facility. We acknowledge G. Edson and E. Johnson (former and current Executive Directors of the Museum of Texas Tech University, respectively) for financial and administrative support of the NSRL. We thank M. Corley-Keith, C. Dunn, M. R. Mauldin, N. Ordoñez-Garza, C. D. Phillips, and E. K. Roberts for comments on an earlier version of the manuscript. Photos were kindly provided by Bill Mueller. Support for some NSRL activities was provided by a State of Texas line-item for the Biological Database Project. We acknowledge J. Sowell for funding the Sowell Expeditions that resulted in some of the specimens and data reported on herein.

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Editor for this manuscript was Eileen Johnson, Executive Director, Museum of Texas Tech University.

APPENDIX I

Typical procedures utilized by the NSRL for curation and installation (by preparation type), documentation and databasing, and long-term care of mammal voucher specimens and tissues. Curation and installation procedures are presented in general chronological order, from the time the specimens are brought to the NSRL facility until the specimens are installed in their permanent locations in the NSRL collections.

Curation and Installation

Traditional (dried skin and skeleton) preparations:

Dried skins:
- Unpin skins from pinning board
- Bag, box, and freeze skins for 2 weeks (pest control measure)
- Remove from freezer and allow to acclimate for 24 hours
- Remove skins from bag, box, and sort by TK number
- Arrange skins in specimen trays
- Conduct an inventory of skins and enter into a computer file
- Arrange inventoried skins in temporary holding cabinets

Skeletal material:
- Freeze skeletal material for 2 weeks (pest control measure)
- Place skeletal material into vent hoods for drying
- Pre-sort large skeletal collections (numerically) into sub-lots
- Inventory skeletal material (into computer file) and arrange into numbered lots
- Arrange skeletal material in numbered ziplock bags by lot number
- Freeze for 2 weeks (additional pest control measure)
- Remove from freezer and allow to acclimate for 24 hours
- Place in holding cabinet until the dermestid colony is available
- Place skeletal material in dermestid colony by lot number
- Periodically check condition of specimens/maintain colonies
- Remove skeletal material from dermestid colony and place in storage bins
- Freeze for 2 weeks
- Let acclimate for 24 hours
- Hand clean and re-house skeletal material into appropriate sized vial or box
- Organize skeletal material by TK number

Skins and skeletons:
- Match skins with skeletal material
- Update inventory file
- Identify specimens to species (confirm or correct field identifications)
- Update inventory file and store matched specimens in temporary holding cabinet
- Generate database printout for osteoscribing
- Osteoscribe skeletal material and write catalogue number on skeleton tag
- Print data labels for skeletal material
- Insert labels with skeletal material
- Write data and catalogue number on skin tags as necessary

APPENDIX I (CONT.)

Write final species ID on skin tag in pencil
Sort specimens for installation and arrange in final specimen tray
Place skeletal material in vial trays and install specimens in permanent collection location

Fluid Preparations:

Unpack specimens, unwrap, and rinse in water
Inventory specimens
For specimens originally preserved in formalin, place in jars with 35% ethanol for 1 week, then 50% ethanol for 1 week
Place all specimens in jars with 70% ethanol
Identify specimens
Prepare alcohol tags (print, trim, drill, cut, string)
Tie catalogue number tags on specimens
Change out ethanol and sort into install jars
Double-check inventory per jar and print and affix jar labels
Place jars in collection

Tissues:

Remove frozen vials from liquid nitrogen dewar
Place all vials into temporary boxes
Record tissues into processing log
Conduct initial inventory (into computer file) of temporary boxes
Sort tissues for cell boxing
Print and adhere replacement barcodes as necessary
Place sorted tissues in cryo boxes
Add/correct numbering on tissue caps as necessary and verify inventory
Print tissue box summary labels
Install in final location
Update location in processing log and incorporate inventory into database

Documentation and Databasing

Scan collector field-notes and enter into database
Create summary list and organize field notes
Email a PDF copy of field notes to collector
Place original field notes in archival storage box
Complete accession paperwork with catalog numbers for Registrar
Registrar completes accessions paperwork for specimens
Check TK book (data, missing data, inventory, etc.) and enter TK book data into Microsoft Excel spreadsheet
Proof spreadsheet and import finalized data into Vertebrate Database
Update database with accession information from Registrar
Update TK book with catalogue numbers
Update species identifications in TK book
Scan TK book
Export data to online, searchable database portals

APPENDIX I (CONT.)

Long-term Care

Check fluid collection levels and replace as necessary
Perform spot-checks of collection inventories
Monitor temperatures of freezers in the Genetic Resources Collection
Check for pests in dry specimen cabinets
Check organization of collections and reorganize as necessary
Update online, searchable database as necessary
Perform complete dry and fluid collection inventories every 10 years

APPENDIX II.

Consumable supplies utilized by the NSRL for curation, installation, documentation, databasing, and long-term care of mammal voucher specimens and tissues. Costs of these supplies were considered in estimating supply costs per specimen (by preparation type and size).

Curation and Installation

Traditional (skin and skeleton) preparations:

replacement straight pins
disposable nitrile gloves
150 liter trash bags
1.9 liter and 0.9 liter zippered plastic bags
rubber bands
rapidograph pens, replacement tips, and ink for osteoscribing
regular ink pens
permanent markers for labeling plastic bags
toner for printer
cotton swabs, for removing rapidograph ink
95% ethanol, for removing rapidograph ink
100% cotton rag paper for labels
archival foil-backed label stock for box labels
plastic vials to protect specimen tag while in dermestid colony
soufflé cups for separating specimens in dermestid colony
glass shell vials (2 & 7 dram) for skulls and skeletons
archival boxes for skull/skeleton boxes (various sizes)
archival paper trays for organizing specimens and skeletal material
foam to line shelves and specimen drawers
% drawer space (purchase drawers as necessary)
% case space (purchase cases as necessary)

APPENDIX II (CONT.)

Fluid-preserved specimens:

jars (3.8 liter, 1.9 liter, 0.9 liter)
95% ethanol (diluted to 70%)
spun bound polyester medium for tags and labels
thermal transfer printer ribbon for tags and labels
linen string
% cabinet space (purchase cabinets as necessary)

Tissues (frozen, ethanol-preserved, lysis-preserved):

cardstock for cryo box summaries
toner for printer
tape
permanent markers
cryo boxes and cell dividers
replacement cryo labels
% freezer rack (purchase racks as necessary)
% freezer space (purchase freezers as necessary)
lysis tissue sample boxes and dividers
parafilm
% lysis rack (purchase racks as necessary)
% lysis shelving unit (purchase shelving as necessary)

Documentation and Databasing

archival boxes for storing field notes

Long-term Care

95% ethanol, diluted to 70%, for refilling jars

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Layout and Design: Lisa Bradley
Cover Design: Photographs by Bill Mueller
Production Editor: Lisa Bradley

This book was set in Times New Roman and printed on acid-free paper that meets the guidelines for permanence and durability of the Committee on Production Guidelines for Book Longevity of the Council on Library Resources.

Printed: 17 April 2014

Library of Congress Cataloging-in-Publication Data

Occasional Papers of the Museum of Texas Tech University, Number 323
Series Editor: Robert J. Baker

"Door to Drawer" Costs of Curation, Installation, Documentation, Databasing, and Long-term Care of Mammal Voucher Specimens in Natural History Collections

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ISSN 0149-175X

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