Assessing the Value of Natural History Collections and Addressing Issues Regarding Long-Term Growth and Care

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Natural history collections serve as important sources of biological data for scientists, educators, and the general public. These collections are a crucial cornerstone for systematics, natural history, ecology, and many other specialized disciplines, whose research depends on either the specimen or the associated data. Recent studies have provided baseline information pertaining to the monetary costs associated with collecting scientific specimens and curating and caring for those specimens after they have been accessioned into a natural history collection. Here, we provide a synopsis of the primary benefits that natural history collections provide to science and society. Furthermore, given that financial support is crucial for long-term growth and care, we present several ideas that should be considered by curators and users of systematic collections.

Keywords: collection and archival costs, collections policy, destructive sampling, natural history collections, scientific value, tissue loans, voucher specimens

In recent years, the utility and value of natural history collections to the scientific community and general public have been emphasized (Pettitt 1991, Allmon 1994, Lane 1996, Blackmore et al. 1997, Nudds and Pettitt 1997, Suarez and Tsutsui 2004, Wandeler et al. 2007, IWGSC 2009, Mares 2009, Rowe et al. 2011, Anderson 2012). Many of these authors stressed the importance of archived material for systematics, genomics, natural history, ecology, zoonoses, ecotoxicology, niche and distributional modeling, and so on. In addition, voucher specimens, in particular, are the basis for zoological nomenclature and provide the foundation for assigning new scientific names. Other authors have discussed the importance of chronological records that relate past biological records and data to the present (Mares 2009, Anderson 2012). In addition, some authors have lauded the potential value of natural history collections for future research pertaining to societal issues such as biodiversity, extinctions (local and global), invasive species, emerging zoonoses, climate change, and environmental degradation (Suarez and Tsutsui 2004, Winker 2004, 2005, Wandeler et al. 2007, Mares 2009, Rowe et al. 2011, Anderson 2012). Given this breadth of importance and relevance, it would be difficult to imagine anyone dismissing the value of natural history collections to society relative to the research, education, and training of next generation scientists. However in recent years, natural history collections have been subjected to challenges such as reduced budgets and academic support, decreases in or elimination of staff positions, competition for research and classroom space, and an overall loss of curatorial expertise. Unfortunately, this declining support comes at a time when specimen-based research is increasing in importance across several scientific disciplines.

Recent studies by Bradley and colleagues (2012) and Baker and colleagues (2014) were conducted to document and raise awareness of the financial importance and requirements of collections and to provide researchers with data for justifying or determining the value of their collections in monetary terms. These studies took place at the Natural Science Research Laboratory (NSRL) of the Museum of Texas Tech University (MoTTU), a repository for natural history specimens and their associated data (e.g., physical, written, and electronic). Both studies, which are briefly summarized below, involved recently acquired mammal specimens in the Recent Mammal Collection (RMC) as a basis to determine the average cost of collecting a specimen at a field site (Bradley et al. 2012) and for archiving and caring for a specimen once it has reached the NSRL (Baker et al. 2014). The estimates derived from these two studies were not used to account for the intrinsic or future value of voucher

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Table 1. Record of expenses associated with local, regional, and international field trips conducted over a 10-year time frame that were used to estimate an average cost per specimen collected (from Bradley et al. 2012).

Type of trip	Duration (in days)	Personnel (in man-days)	Salaries	Transportation	Meals	Lodging	Specimen preparation	SAC	Total expenses	Total number of specimens collected	Average cost per specimen
Local or regional	227	2482	$193,956	$43,910	$32,664	$1188	$16,796	$14,750	$303,266	7454	$41
International	269	2492	$210,161	$72,905	$39,894	$53,698	$28,285	$29,757	$452,801	6136	$74

Note: All values were rounded to the nearest dollar. Bradley and colleagues (2012) provided detailed information and explanations for the calculations of these expenses. Abbreviation: SAC, standardized additional cost (see Bradley et al. 2012 for details).

Table 2. Record of annual expenses associated with curating, installing, documenting, data entry, and maintenance of 3356 representative mammal voucher specimens and their associated tissues and data (from Baker et al. 2014).

Curation and installation								
Traditional preparations	Skeleton-only preparations	Fluid preparations	Tissue vials	Documentation and data entry	Total expenses for curation, installation, documentation, and data entry	Total number of specimens	Average Curation, installation, documentation, and data entry cost per specimen	Average annual maintenance cost per specimen
$24,961.21	$3,953.43	$5,850.85	$20,393.30	$3,590.92	$58,749.70	3,356	$17.51	$0.25

Note: All values were rounded to the nearest cent. Baker and colleagues (2014) provided detailed information and explanations for the calculation of these expenses.

specimens, such as scientific potential, uniqueness to collections, and rarity.

In the present article, our goal is to briefly review the financial investment associated with growing and properly caring for natural history collections, as was reported in Bradley and colleagues (2012) and Baker and colleagues (2014), and to expand the discussion to the larger issues regarding the true value and importance of these collections not only to the research community but to society in general. Perhaps more important, we also hope to stimulate a dialogue concerning loan policies, reciprocation agreements, acceptability and responsibility of loan recipients, and how best to continue enhancing collections that benefit both natural history museums and the scientific community.

Monetary considerations

Bradley and colleagues (2012) estimated the costs of conducting fieldwork associated with collecting and preparing mammal voucher specimens and transporting material from field sites to a museum. Their calculations were based on the expenses relative to the number of specimens (13,590) obtained during 61 fieldtrips (50 local or regional and 11 international) conducted from 2001 to 2011 (table 1). They reported that the overall cost per specimen averaged $41 for local and regional trips and $74 for international trips, with an average of $56 per specimen for all trips combined. Using these values, the current RMC at the NSRL (116,500 catalogued specimens: 71,410 local or regional and 45,090 international) would be valued minimally at $6,264,470.

Baker and colleagues (2014) estimated the costs of curating, installing, documenting, and entering into a database 3356 mammal voucher specimens and their associated data. These estimates were based on the costs accrued from the time the specimen entered the museum door until the specimen was placed into its final archival location (museum case or alcohol cabinet) and included the cost of museum cases, cabinets, ultralow temperature freezers, vials, trays and other supplies, equipment, and assets, as well as curatorial and identification efforts, the development of electronic databases for specimen records, and staff salaries (table 2). Baker and colleagues (2014) concluded that it cost an average of $17.51 per specimen to curate, install, and computerize the associated data, plus an additional $0.25 per specimen per year for long-term care of the collection. Using this average and the 116,500 catalogued mammal specimens currently housed in the NSRL, it is estimated that it cost approximately $2,039,915 to ready these specimens, tissues, and the associated data for examination by the scientific community. In addition, Baker and colleagues (2014) estimated an annual cost of $29,125 to care for this collection on the basis of its current size and scope.

According to the results of the studies by Bradley and colleagues (2012) and Baker and colleagues (2014), the cost for obtaining and housing mammal vouchers averaged

Table 3. Recent growth and impact of the Mammal Collection and the Genetic Resources Collection of the Natural Science Research Laboratory (NSRL), Museum of Texas Tech University (TTU).

	2009	2010	2011	2012	2013
Mammal specimens catalogued	2833	1025	2312	4535	3408
Genetic resources acquired (individuals)	3116	3489	2111	3066	1820
Mammal loans granted	29	18	22	33	33
Mammal specimens loaned	536	482	393	708	531
Genetic resource loans granted	97	71	60	67	61
Genetic resource samples loaned	5630	2339	1804	1851	1623
Data requests	168	127	118	188	177
Publications by TTU faculty and students	26	25	17	14	20
Graduate degrees granted	5	10	4	2	6
Graduate students trained	35	34	30	29	29
Undergraduate students trained	18	14	17	17	10
Internet access (approximate number of hits, in millions)	1.8	1.6	2.3	2.1	1.6
NSRL visitors	235	159	380	244	229

$73.21 per specimen, or $8,563,915 for the entire mammal collection of the NSRL. Relative to mammal collections at other institutions, these values would be expected to vary depending on the geographic and taxonomic composition of each respective collection; however, these estimations should provide curators and museum staff with a means by which to evaluate the approximate value of their respective collection.

Additional expenses include the up-front capital costs of establishing a natural history museum and the ongoing building maintenance costs of such a facility. These include the construction of the building itself (e.g., a 1672-square-meter addition to the NSRL completed in 2005 cost approximately $5 million); furnishings and equipment for the building, such as desks, filing cabinets, computers, and so on (initial costs, as well as repairs and replacements); utilities (e.g., electricity, water), pest control, custodial services, and security services. These costs are largely dependent on the size and type of the facility rather than on the number of specimens housed within the facility. Therefore, Baker and colleagues (2014) did not include these factors in their cost-per-specimen estimates; however, these costs are real and pertinent to collections and should be considered by museum and university administrators.

Further expenses incurred by natural history museums could include those associated with providing professional services for the scientific community, such as preparing and shipping loans, conducting inventories, answering information requests, providing identification services, and the publication of scientific articles. Natural history museums also conduct outreach activities for the public, such as hosting tours of the collections and preparing museum exhibits using the collections. Expenses associated with these services and activities were not reported in Baker and colleagues (2014), but they represent additional costs of doing business for most natural history museums and certainly add to the annual expenses of an active natural history collection.

Benefits from collections

Although the financial investment required to collect, prepare, install, enter into a database, and properly care for a natural history collection can be quantified using a variety of methods (e.g., travel expenses, preparation supply costs, salaries of staff), the monetary value determined from those calculations does not address the full worth of a collection to science, education, and society. In most cases, these factors simply cannot be evaluated in terms of dollars and cents, but it is possible to quantify certain aspects of a collection's productivity and its contributions to advancements in science and education. For example, data regarding the recent growth and impact of the Mammal Collection and Genetic Resources Collection of the NSRL are presented in table 3.

In box 1, we summarize the data and the primary benefits resulting specifically from the collecting trips and archival activities analyzed in Bradley and colleagues (2012) and Baker and colleagues (2014). This summary exemplifies why science and society should continue to support the collection of voucher specimens and their long-term maintenance and care.

Issues regarding the long-term growth and care of collections

Given the extraordinary value of natural history collections—in monetary terms as well as in their past and potential

Box 1. Benefits from collections.

A total of 13,590 voucher specimens were collected during 61 field trips (Bradley et al. 2012), representing at least 384 species (we are still conducting research to verify the field identifications of some individual specimens), 101 of which were new to our mammal collection. Nearly all of the individual specimens are associated with tissue samples (i.e., blood, heart, kidney, liver, lung, muscle, and spleen) that are stored in the Genetic Resources Collection (GRC) at –80 degrees Celsius. In addition, many individuals were karyotyped, and their chromosome cell suspensions are archived in the GRC. All of the vouchers were georeferenced, the specimen information was incorporated into online databases, and the samples were made accessible to qualified researchers.

To date, the coauthors have described 10 new species of mammals (Baker et al. 2002, 2004, 2009, Bradley et al. 2004a, 2004b, 2014, Mantilla-Meluk and Baker 2006, Solari and Baker 2006, Larsen et al. 2010, Baird et al. 2012) from those specimens and will probably add at least 3 others, pending the results of ongoing research. At least 11 other taxa were elevated from subspecific to specific status. Other researchers will undoubtedly identify additional mammalian species and undescribed species of parasites, bacteria, viruses, and so on, in areas for which they are experts.

Eight new viruses (arenaviruses, hantaviruses, and a tick-borne encephalitis) were described from the analyses of blood and tissue samples obtained from these specimens (Milazzo et al. 2006, 2008, 2012, Cajimat et al. 2007, 2011, 2012, 2013, Inizán et al. 2010, Briggs et al. 2011). Those discoveries were fortuitous, in that we provided samples to collaborating virologists without prior knowledge of viruses being present at the collecting localities; without the voucher specimens, these findings would not have been possible.

To date, at least 100 scientific articles have been published by the coauthors on the basis of specimens and data collected during those trips. Those articles pertained to a variety of fields, including systematics, population genetics, speciation, natural history, ecology, zoonoses, and so on, and many were the result of discoveries originating from the opportunities provided by the collection of these specimens. Additional publications have been produced by scientists who received loans of specimens or data collected during those trips.

The scientific community also benefited from the training received by 39 graduate and 136 undergraduate students at Texas Tech University (TTU), as well as students from other institutions and countries that took part in those expeditions. These students received valuable training preparing them for future employment in science-related fields. During the 40-year history of the Natural Science Research Laboratory (NSRL), more than 255 graduate students at TTU have used the resources of the NSRL as a basis for their thesis and dissertation research. Many of those graduate students used their collections-based training in field biology, systematics, and ecotoxicology to gain employment at major research universities (e.g., Texas A&M, Penn State, Yale, Purdue, Harvard, Oklahoma State), natural history collections (e.g., the American Museum of Natural History, the National Museum of Natural History, the Museum of Zoology at the University of Michigan), and federal government agencies (e.g., the Centers for Disease Control, the Defense Threat Reduction Agency, the National Center for Ecological Analysis and Synthesis). Others have been appointed to influential positions at the US Geological Survey, the National Science Foundation, and state and federal advisory boards. Furthermore, many international students of TTU have returned to their native countries and participated in building or improving their own natural history collections. Although we cannot assign a monetary value that specimen-based research contributed to the education of our students or to the potential benefits that these students will contribute to science and society because of their training in field biology and museum operations, those opportunities undoubtedly affected their professional careers. This training is important in times when taxonomic impediments and a lack of taxonomic training have been identified as a major restriction to the biological sciences (Ebach et al. 2011, Drew 2011).

contributions to science, education, and society—it is imperative that the growth and care of these collections continue to be supported by the academic and scientific communities and by funding agencies. However, there are several issues facing natural history collections today that need to be addressed by curators and users of systematic collections. Below, we present our thoughts on these issues and offer some potential solutions. We suspect that not all scientists will agree with these positions; however, our goal is to initiate a dialogue that functions to illustrate the value—both financial and otherwise—of biological research collections and to strengthen efforts to ensure that the scientific community continues to support their long-term growth and care.

Voucher specimens housed in natural history collections provide a point-in-time sampling for our planet's biota. These specimens serve as a resource for documenting and studying biodiversity, genetic variation, distributions, ecology, zoonoses, epidemiology, the impacts of climate change, ecotoxicology, and so on, relative to increments of time (i.e., 5, 20, 100, 200 years ago). This insight into history is invaluable and irreplaceable; we cannot go back in time and resample (see Mares 2009). Therefore, it is of utmost importance to develop plans for the preservation, conservation, and wise use of this resource. Concerning natural history collections housed at academic institutions, as financial support declines and as administrators demand an accounting for space and other resources, it is crucial for curators to determine both the financial value and the scientific significance of natural history collections relative to the role and mission of the academic institution. This is especially relevant given the current economic environment, in which the National Science Foundation (NSF) reduced funding opportunities for natural history collections by changing the submission of proposals to the Collections in Support of Biological Research (CSBR) program to a 2-year cycle (although this decision was recently reversed). As institutions (e.g., universities, private and federal museums) supporting natural history collections face reduced financial support from the NSF and other funding agencies, the cost of curating, growing, and caring for these collections becomes a mounting concern.

The value of scientific specimens and their associated data will continue to increase over time. As new scientific techniques are developed (e.g., genomics and niche modeling), scientists are finding new ways to extrapolate data from voucher specimens (Rocque and Winker 2005, Wandeler et al. 2007, Rowe et al. 2011). The fields of systematics, epidemiology, and ecotoxicology routinely use tissue samples collected 30 years or more ago as a data source. In the last two decades or so, molecular methods have allowed researchers to isolate DNA from skin and bone samples, thereby allowing data (DNA sequences or other genetic markers) to be obtained from previously collected specimens that may represent populations and species that are now extinct, rare, or threatened or that are from regions unavailable for sampling because of political reasons, land-use changes, urban sprawl, or habitat destruction. In addition, new informatic disciplines, such as niche modeling and phylogeography, require accurate distribution records, taxonomic identifications, and other sources of specimen data. Feeley and Silman (2011) and Anderson (2012) proposed that additional specimen-based data are needed to produce more-accurate models. We predict that specimen-based research will continue to exploit these developing opportunities to meet the future needs of science and to address issues of importance to society. For example, specimens and their associated data are crucial for analyzing historical trends and making long-term predictions and in assessing unanticipated scenarios for which their relevance have not yet been realized (IWGSC 2009). As Winker (2008) so eloquently stated when arguing for the preservation of the entire specimen "future questions are probably more important to society than the question(s) for which the specimen was preserved in the first place" (p. 395).

Curators and museum personnel are often asked whether there remains a need to continue collecting scientific specimens. For a number of reasons, the answer is a resounding *yes*. We and others (Patterson 2002, Edwards et al. 2005, Winker 2005, Stoeckle and Winker 2009, Feeley and Silman 2011) posit that, presently, museums do not have adequate samples of voucher specimens to understand the world's biodiversity and its significance to science and society. In addition, as we document here, new scientific discoveries still remain in the realms of systematics and natural history. Despite this need, the growth of natural history collections and overall scientific collecting has been declining over the last decade. Several variables, including fewer field- and taxon-based biologists, a reduction in funding for collecting and collections, declining interest in field biology, restrictions on collecting, permit and importation restrictions, a fear of contracting zoonotic diseases, airline regulations (e.g., restrictions or embargos on liquid nitrogen, weight limits), more specialized research, increased danger, and so on, have negatively affected fieldwork and scientific collecting. In addition to these impediments, inflationary costs continue to add to the cost of obtaining voucher specimens; consequently, not only will the cost per specimen increase in the future, but fewer specimens will be available for study. Furthermore, it appears that fewer students are being trained in field and collecting methods, which has contributed to the overall decline in the growth of natural history collections.

Perhaps the greatest potential contributor to the increased cost of a voucher specimen is in the reduction of general, opportunistic, or institutional collecting. As researchers become more specialized, they concentrate more on collecting a few taxa or perhaps even a single taxon. For example, on a general collecting trip, a field crew may collect several species of rodents, shrews, bats, and carnivores; accordingly, the mammalian diversity of a collection is enhanced, and the cost is distributed across a number of individuals and taxa. However, a researcher whose specialty is restricted to shrews might go to the same collecting site and forgo the opportunity to collect any taxon other than shrews (or may be restricted from doing so by collecting permit limitations), thereby reducing the potential contribution to the diversity of natural history collections. In addition, changing sentiments relative to collecting and increasingly restrictive collecting regulations by local, state, and federal agencies have served to reduce the growth of natural history collections (ironically, data from natural history specimens are routinely used by these same agencies in solving wildlife crimes, human health issues, and livestock diseases). This continued reduction in general collecting, ultimately, will negatively affect the number of individuals, point-in-time samples, and diversity of specimens available for loans from collections. In addition, this narrow focus limits the overall growth and enhancement of natural history collections and places a higher monetary and research value on previously collected specimens.

It is important for institutions and users to have a realistic understanding of the actual costs incurred in obtaining voucher specimens. To this end, three points are pertinent. First, natural history collections, their affiliated institution, faculty members, and students shoulder a disproportion of the burden in supporting scientific research through loans (specimens or tissues) to researchers. For example, as is evidenced in the studies by Bradley and colleagues (2012) and Baker and colleagues (2014), a request for tissue loans may involve specimens that would cost tens of thousands of dollars to collect and archive for a specific study. These costs would certainly be realized if the material were not available via a loan and the requestor had to collect the material him- or herself. Second, because an increasing number of samples are used in research requiring destructive sampling (i.e., DNA and genomic methods), funds may be needed to replace depleted samples. Many loan requests involve a large number of individuals or involve requests only for rare or uncommon species. Consequently, natural history collections need financial support to collect, archive, and provide access to specimens and data. Third, financial support is paramount if we are to grow and improve collections for future research. It is crucial for future generations of researchers that we continue to support collection activities.

Historically, most natural history collections have operated under the premise that other scientists would be able to borrow and use material with the understanding that reciprocity with other museums would occur at a later date. For example, the director and curators of the NSRL are pleased to loan a requestor material that we have collected, installed, computerized, curated, maintained, and for which we have made substantial investments in money and time, if a requestor's affiliated collection returns the favor to our scientists and students. Initially, this system worked quite well. However, in the last decade, because fewer scientists have an interest or training in field biology, scientific collecting, or museum science and because many are unaffiliated with a natural history museum (some may have never deposited a specimen in a natural history collection), loans are becoming a one-way arrangement. Many contemporary molecular biologists use natural history voucher specimens or tissues for their research, but they do not necessarily reciprocate or contribute to replacing depleted material or to growing collections for future scientists to use, and rarely do they offer to include the field researchers who made the collections on any publications that result from the use of these materials. In fact, many requestors often assume that loan requests exist as an entitlement (including correct taxonomic identification by the curators or biologists at the loaning institution) without any consideration of the financial and time commitment made by the natural history collections and their supporting institution. The phrase *dissertation from a freezer* probably best describes the reality of the situation. In effect, senior researchers often find that they are taking risks; are investing time, money, and intellectual effort; and are merely acknowledged as being helpful assistants to the authors of studies whose very research is absolutely dependent on the research efforts of the museum scientists.

To whom does the collection belong, and who makes decisions concerning loan conditions and policies? This may seem fairly straightforward: The institution owns the collection. However, when various funding agencies (the National Institutes of Health, the NSF, state and federal agencies, donors, or even individual researchers) contribute funds for collecting purposes, assessing ownership or controlling rights becomes complicated. For example, the NSF recently implemented a new policy that prevents CSBR from funding proposals supporting specimens collected on federal lands that are held in trust by museums but that officially remain the property of the federal agency. Similarly, ownership may become complicated when acquiring orphan and private collections.

Additional constraints are often placed on specimens and data by permit conditions or federal regulations. For example, many countries require a prearranged agreement concerning specimen deposition before they will issue a collecting or export permit. Under such an agreement, a portion (sometimes all) of the collection may be designated for return to the country of origin. Furthermore, conditions or restraints may be placed on access to the collection, including restrictions prohibiting economic gain from biotechnical advances or patents. Finally, importation regulations of the US Department of Agriculture, the US Fish and Wildlife Service, and the Centers for Diseases Control may dictate whether and how biological materials are transferred and ultimately used in research. In many cases, natural history museums are bound by law and accreditation standards to adhere to a broad set of conditions that preclude a simple interpretation of ownership and usage.

Generally, the institution housing the collection develops policies concerning the accession of artifacts (voucher specimens and tissues, in this case). Therefore, when an accession number is assigned to a specimen, it then becomes the property of that institution. Most accession policies are in effect to ensure the long-term care of the collection, and, typically, the institution places the decisions associated with approving loans in the hands of the curators, because they are most likely to be familiar with the value of the specimens and the credentials of the potential requestors. It is the policy of the MoTTU (as required for accreditation by the American Alliance of Museums) that all destructive loans be approved by the curator responsible for the collection, as well as by the executive director of the museum. Consequently, decisions affecting loans, reciprocity agreements, and costs associated with loans are determined by the curators and the executive director.

Is it appropriate for natural history collections to charge a fee to individuals (users) conducting research involving destructive sampling? As has been shown in Bradley and colleagues (2012), Baker and colleagues (2014), and this article, the cost of obtaining and caring for scientific specimens is substantial in terms of both money and time. Given that a major portion of this cost is underwritten by the natural history collection, what are the conditions under which it would be reasonable to implement a fee per specimen?

Beyond the monetary costs of collecting specimens that were addressed in Bradley and colleagues (2012), the intangible costs are borne by the curator or collector who conducts the fieldwork. For example, many field personnel (e.g., faculty, curators, students) spend a month or more each year on collecting trips. During the 11-year window (2001–2011) considered by Bradley and colleagues (2012), NSRL field crews spent 4974 person-days (13.6 years in total time) in the field. This equates to a loss of productivity relative to writing manuscripts, preparing grant proposals, interacting with graduate students who are not on the trip, and so on, not to mention the inconvenience of time away from home and family and the often-harsh conditions associated with conducting fieldwork. Although most collectors gladly bear these intangible costs, is it fair for them to give away their time, expertise, and potential research material in the form of a loan to another individual who has not invested an equal amount of time, energy, or finances in developing and maintaining natural history collections?

Assessing a fee for destructive sampling is a difficult and controversial decision that many natural history collections are encountering, especially as support for collecting and maintenance of collections wanes. As usage by molecular biologists that are unaffiliated with natural history collections increases, it may be appropriate to consider a user fee to help augment the investment made by the collection or institution. Would implementation of such fees deter scientific inquiry? Perhaps, but no more than do the normal costs encountered by any scientist during routine studies. Users could request money from their funding agencies to cover the costs associated with destructive loans, just as molecular biologists request money to cover the costs of enzymes; consumables; cell lines; student, postdoc, and faculty salaries; sequencing costs; and so on.

The idea of a user fee is not without precedent; for example, university libraries usually require the purchase of a library card, membership, or a tuition-based fee. Funds from such a fee are then used to replace lost or damaged books, to purchase new holdings, and perhaps to support the salaries of library personnel. Employment of such a fee in a natural history collection could be implemented to help cover the replacement costs of specimens, to assist with long-term care expenses, and to help ensure the growth and stability of the collection for other researchers. Alternatively, these funds could be used to help support the salaries of collection personnel, to replace ultra-low temperature freezers, to purchase additional specimen cabinets, and so on.

Conclusions

Natural history collections are a crucial cornerstone for systematics, ecology, and many other disciplines whose research depends either on specimens or their associated data. The long-term growth and care of these collections are crucial not only to the science disciplines but in resolving everyday issues affecting society. In fact, where would biological science and society be without natural history collections, collectors, and curators? Natural history specimens contain a wealth of information that is pertinent to our everyday lives, ranging from environmental and human health issues to the pursuit of basic scientific knowledge. Countless scientific papers are published each year based on either museum specimens or their associated data. Given this broad-based importance, it is imperative to find mechanisms to help secure funding for natural history collections. This may involve unpopular decisions (e.g., a user fee per specimen, restriction of loans to reciprocating entities or scientists). However, perhaps other creative solutions may be identified. For example, the NSF could implement a model similar to that used in the 1970s and 1980s, in which collections that exhibited substantial workloads (large numbers of loans) were subsidized at some level. Other possibilities might include endowments, donors, and collaborations with the private sector. Winker (2004) discussed innovative ideas for developing a business model for nontraditional partnerships; along this line, natural history collections should perhaps consider a broader spectrum of financial supporters.

Although we have highlighted the need for continued cataloguing and growth, as well as the need for better funding, we should not ignore the need for increasing the number of professionals entering the natural history field. Today's students in systematic biology and museum science are the future collectors and curators that will be responsible for our collections; training and support to encourage these young people are a must. Perhaps all biology and museum science students should be required to participate in collecting trips, prepare voucher specimens, clean skulls and skeletons, osteoscribe, install and curate specimens, and be familiar with cataloging and other database activities. It is imperative that, as curators associated with natural history collections, we prepare a new generation of students well trained in natural history collections and museum science and with an appreciation for the value and importance of voucher specimens and the resources required to care for them.

In box 1, we highlighted a few of the contributions resulting from our own collecting and research efforts from 2001 to 2011. One point, the description of at least 10 new species of mammals, was particularly interesting and worthy of further comment. These new species were identified using DNA sequence data, molecular systematics, cladistics methodology, and criteria of the genetic species concept (see Bradley and Baker 2001, Baker and Bradley 2006). Although new species of mammals are occasionally discovered (e.g., the olinguito; Helgen et al. 2013), the identification of new mammal species most often is the result of analyses of genetic data and the splitting of a taxon into two or more species. Baker and Bradley (2006) postulated that, on the basis of the rate of new species names being described in the recent literature, approximately 40% of mammal species remained to be described by scientists. Reeder and colleagues (2007) further commented that perhaps as many as 2000 species of mammals remained to be identified. If these statements are remotely correct for mammals, we can only guess at the number of undescribed species in lesser-studied groups, such as invertebrates, plants, and single-celled organisms. The answers to this and many other questions await in the cabinets and freezers of natural history collections and with the next generation of scientists being trained to collect, archive, and conduct specimen-based research. Therefore, it is imperative to keep the doors open, the lights on, and the specimens coming in.

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