TRACKING CHANGES IN NATURAL HISTORY COLLECTIONS UTILIZATION: A CASE STUDY AT THE MUSEUM OF SOUTHWESTERN BIOLOGY AT THE UNIVERSITY OF NEW MEXICO

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Abstract.—Natural history collections (NHCs) are used in many fields of study, but general knowledge regarding their uses is poor. Because of this, funding and support for NHCs frequently fluctuate. One way in which collections professionals can illustrate a collection's contribution to a variety of fields is based on the collection's history of use. Tracking NHC utilization through time can increase NHC value to others outside of the collection, allow for the analysis of changes in specimen-based research trends, and assist in effective collection management. This case study focuses on NHC usage records held by the Museum of Southwestern Biology (MSB), a currently growing university collection used in many research fields, and presents methods for quantifying collections utilization through time. Through an exploration of these data, this paper illustrates MSB's growth and changes in research produced over time and offers explanations for the changes observed. Last, this study provides suggestions for how collections professionals can most greatly benefit from considering NHC records as a data source. Understanding NHC usage from "the collection's perspective" provides a new way for NHC professionals to understand NHCs' value in the context of the research it supports and demonstrates the importance of this key infrastructure to a broader audience.

Key words.—collection management, loan history, outreach, museum studies, natural history, collections, museums, science, publication history, search phrases, visitor studies

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PROJECT DESCRIPTION

Natural history collections (NHCs) represent a valuable record of Earth's biodiversity and natural heritage with a variety of research and education applications (Allmon 1994, Lane 1996, Funk 2004). The professionals who steward them archive type specimens and research vouchers, provide a data source for new avenues of research, offer hands-on learning tools to educators, and allow many scientific studies to be repeatable (National Science and Technology Council Committee on Science, Interagency Working Group on Scientific Collections 2009, Pyke and Ehrlich 2010, Beaman and Cellinese 2012, Dunnum and Cook 2012). However, NHC value can deteriorate over time, putting NHCs at risk. Lack of consistent funding can imperil NHCs and exacerbate preservation concerns, hindering effective collections management. For NHCs, especially university NHCs, funding varies with time, even as collections grow in size and usefulness (Dalton 2003, Natural Science Collections Alliance 2010, Smithsonian National Museum of Natural History 2010). This extends not only to university museums, whose NHCs are often at risk of being lost (MacDonald and Ashby 2011), but to large museums as well. The National Museum of Natural History, due to a staff decrease in the Department of Entomology, deactivated more than 10 insect orders from its collections (Furth and Shockley 2013). Government funding for NHCs often relies on proving the value of NHCs as major scientific infrastructure (House of Lords 2013:341). To improve and stabilize the funding situation for NHCs, investigations of the growing importance of NHCs in critical research is needed.

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Determining specifically how value is assigned to NHCs and those who care for them is of special interest to NHC professionals, although it is an issue not thoroughly analyzed from their, or the "collection's," perspective. The monetary value of a collection can be calculated by a combination of factors for risk assessment (Price and Fitzgerald 1996). Collections professionals can also determine a collection's value, its perceived potential importance beyond the collection's walls, based specifically on its real-world utility. NHC usage records provide a means of following how NHCs have contributed to scientific progress or been of interest to people beyond the collections staff and are an ideal data source for justifying collections maintenance and preservation in perpetuity (Simmons 2002:100). Although a collection's value extends beyond what is recorded by museum records, analyzing the records of NHC use by a researchers and other users provides one working measure of how specimens are used, indirectly indicating their value. Evaluation of records for the benefit of collections outreach and support is, however, lacking. This study seeks to address a gap in methodological approaches to understanding and quantifying NHC usage.

Advances in research methods have enhanced collections use, illustrating that changes in utilization of NHCs can increase their value, as well as necessitating the evaluation and description of this change to better understand the place of NHCs in natural science research. Digitization of specimen data into online databases is expected to result in a higher quantity and quality of research (Baker 2011). This is especially true in biodiversity research, in which NHC data are critical (albeit used with limitations) (Shaffer et al. 1998, Newbold 2010, Beaman and Cellinese 2012). Innovative technologies and methods draw further data from specimens beyond what their collectors anticipated (McLean et al. in press). Stable isotope, genetic, contaminant, and other data gleaned from historical specimens have diversified their utility (Kelly et al. 2002, Wandeler et al. 2007, Vo et al. 2011). New sources of data thus allow collections to play new roles in popular fields such as conservation biology, environmental science, and emerging pathogen discovery (Graham et. al. 2004; Suarez and Tsusui 2004; Ward 2012; Winker 2004, 2014; Lavoie 2013). Studying NHC records can track shifts in usage over time, giving a complete picture of NHCs as dynamic institutions that maintain relevancy and importance through time.

Museum professionals can use NHC records to understand and communicate the changing ways in which NHCs have been important for a many interested parties. Administrators and policy makers should be well informed of the importance of the NHCs they fund and control. Quantifying a collection's many applications and users can help characterize a collection's unique needs to funding groups. Furthermore, they can illustrate funding needs to help allay costs of collections usage, as paying for such usage has become decreasingly quid pro quo (Simmons 2002:93). Annual reports, which summarize NHC utilization (Simmons 2002:107), can benefit from the additional information this research can provide.

Outside researchers can also benefit from increased awareness of NHC impact, and museum professionals can benefit from better communication with them. Researchers beyond a collection's purview may not be aware of an NHC's diverse uses, though their research may involve collecting specimens eligible for inclusion in an NHC. The opinion piece by Minteer et al. (2014) and the subsequent responses it generated highlight current disagreements surrounding collecting specimens, as well as a desire by museum professionals to communicate NHC value to other researchers (Rocha et al. 2014, Krell and Wheeler 2014, Winker 2014). A broader audience may also better understand NHC value due to enhanced communication with NHC professionals. The general public, usually exposed only to public natural history exhibits, is often presented with interchangeable taxidermy mounts contributing to a particular interpretive goal, rather than shown the importance of particular individuals or series of specimens (Conn 2009:50).

Besides helping to reach these different audiences, NHC analysis can also aid collection managers in stewarding their collections more effectively (Simmons 2002:107–108). Analyses that monitor an NHC's uses through time can identify particular specimens or areas of a collection that are most often used, which may alter how NHC professionals manage and care for them (Simmons 2002:100). They can also establish better planning and prioritization of current collecting efforts to satisfy an NHC's needs or point to areas of an NHC that may be underutilized. This can generate information that, along with other metrics that detect and prioritize a collection's unique needs (see the Collections Health Index proposed by McGinley 1993), will be invaluable in helping NHC professionals justify collections-related decisions and appropriately manage the specimens they steward. Indirectly, studying NHC records provides quantitative information on the roles that collections play in natural science research as a whole and even help in our understanding of research trends themselves more fully.

The study presented in this article complements previous writings on the importance of NHCs. Primary research using NHC specimens may reference the importance of the collections they utilize (e.g., Hoberg et al. 2009, Casas-Marce and Fernandes 2012), and numerous reviews discuss the research that benefits from NHC utilization (Cranbrook 1995, Suarez and Tsusui 2004, Winker 2004, Pyke and Ehrlich 2010, Johnson et al. 2011). Collections professionals summarize NHC holdings via annual reports (Smithsonian National Museum of Natural History 2010), and collection manuals may discuss the kinds of records that might be useful to keep for future analysis (e.g., Simmons 2002:107). This research differs from previous research in three ways: (1) NHC utilization is quantified rather than generalized based on particular instances of NHC usage; (2) museum records are explored with analysis as the goal rather than description, as in annual reports; and (3) NHC utilization is assessed more objectively.

Research using NHC use records is an emerging field of study, with various theoretical or tested methodologies targeted to answer museum-oriented questions (Jeram 1995, Pyke and Ehrlich 2010). This study provides a history of how one NHC, used as a case study, has contributed to scientific studies through the records it keeps, and it explores that contribution through patterns and change over time. This research provides a methodology to track changes in NHCs in the form of an exploration of general trends in utilization.

Methods

Case Study Subject

For this study I focused on the collections records held by the Museum of Southwestern Biology (hereafter MSB, msb.unm.edu), located at the University of New Mexico (UNM) in Albuquerque. MSB is predominately a research collection with some teaching collections and was established in 1928 with the specimens of Edward F. Castetter. Though MSB lacks standard exhibit areas, it is open by appointment to the public and maintains well over 4.6 million specimens (estimates from collection managers and online databases, 2013–2014). It is a rapidly growing collection, typically adding thousands of specimens to its collections each year. Students gain exposure to MSB partly through organismal biology classes, many of which currently include specimen preparation or collection. MSB participates in other outreach programs to increase awareness for NHCs and biodiversity, including Advancing Integration of Museums into Undergraduate Programs (AIM-UP, www.aim-up.org) and the Bosque Ecosystem Monitoring Program (www.bosqueschool.org/bemp.aspx). The museum is regional in that many of its specimens have been collected in southwest United States, but it holds other New World and global collections as well. MSB has grown significantly in size and scope since the early 1990s, and today the MSB collections are divided into eight divisions or subsections, each with their own curators and staff. Museum records from MSB can thus help illuminate information on this museum's growth, its contributions to research, and its impact through outreach. For this study, I analyzed collections use in six of MSB's divisions: the Division of Arthropods, the Division of Birds, the Division of Fishes, the UNM Herbarium, the Division of Mammals, and the Division of Reptiles and Amphibians, as well as related tissues for the bird and mammal divisions found in the Division of Genomic Resources.

For this case study, I analyzed museum records held by the MSB. While there are many possible metrics one could use to determine NHC usage, I chose three that were the most uniform across collections and would provide different perspectives on NHC utilization. First, I explored the history of publications that reference MSB in some way. Second, I examined loan records, illustrating which NHC materials are being utilized externally. Last, I examined visitor records, which provide information on how and by whom collections are being used in-house. I provide my exploration of each of these records separately, first describing the record and associated predictions of trends in each dataset, based on expected changes in NHC use. I follow with the methods, results, and a brief discussion for each. I consider the implications of my findings in the evaluation and summary.

Publications

Predictions

One current way in which researchers have documented NHC use is by quantifying publications produced using NHCs. Numbers of publications and citations can quantitatively substantiate NHC value (Dunnum and Cook 2012, Suarez and Tsusui 2004), while grouping publications into categories has illustrated changing trends in research over time and gaps in knowledge (Holzenthal et al. 2010, Lavoie 2013, Zou 2015). To explore how MSB has been used in different research fields over time, I tracked publications that reference MSB and explored changes in how the subjects of these publications vary.

It has been suggested that digitization and web access to specimen data, combined with the application of new technologies, have increased collection utility in new and innovative areas of study over time (Winker 2004, Drew 2011, Johnson et al. 2011). Considering their growing utility in a variety of conservation and management research, as well as increased awareness of this utility, I expected the proportion of publications on this kind of research out of all publications to increase (Winker 2004, 2005; Pyke and Ehrlich 2010; Ryan et al. 2011). NHCs may show a proportional decrease of publications on more traditional research over time, particularly in collections containing vertebrates, for which much of the taxonomic research has already been done (Cranbrook 1995, Agnarsson and Kuntner 2007). I expected use of NHC specimens in publications on conservation research to be particularly high in MSB's ichthyology collection, considering that fishes are highly threatened in the state (Propst 1999). This hypothesis leaves the study of systematics in a complicated position. Although researchers have stated that systematics research makes collections most valuable (House of Lords 2002, O'Connell et al. 2004), taxonomy and systematics studies must be performed before other research may be done (Prance 1995, Wheeler 2004, Agnarrson and Kuntner 2007, Pyke and Ehrlich 2010), leading to a proportional increase of other research for which systematics is foundational (such as conservation research) over time. I expected the proportion of publications involving systematics research to be collections-specific but also high across divisions overall.

Methods

I obtained a list of nearly 2000 publications related to MSB, published between 1940 and May 2013. Publications included journal articles, books, and gray literature such as government reports and online diagnostic tools that cited MSB. These publications were collected from MSB's collection managers as well as search engines including Google Scholar, Web of Science, and BioOne. I used search methods somewhat similar to Pyke and Ehrlich (2010), explained in more detail in Appendix 1. I searched for publications that referenced any of MSB's divisions. I then read through publication titles, abstracts, and/or the publications themselves to decide which publications did not use MSB specimens (for example, where an MSB researcher did research elsewhere) and were removed from the study subjects dataset. I recorded the year of publication, the division to which the publication pertained, the title of the publication, and, where available, the journal or place of publication and keywords (see Appendix 1 for further explanation of this dataset). Duplicate titles were removed. Some journal titles were edited to accurately display the number of different publication venues that MSB contributed to each year (e.g., after editing, *Coleopterists Bulletin* and *The Coleopterists Bulletin* were counted as the same journal); however, this information was not changed for the subject searches described below.

I sorted publications by specific search phrases (particular words or word parts) used in the titles, journal titles (that is, places of publication), or keywords of the publications (if available), which I then consolidated into groups according to their similarity. These groups, hereafter referred to as subjects, categorized the publications into different disciplines. For example, the subject "Evolution" included publications that contained the search phrases "evol," "adapt," and/or "speciation" in the title, journal title, and/or publication keywords (Appendix 2). I organized the publications into 10 subjects. I designated subjects to cover several main aspects of biological research (capitalized here to refer to the subject groups rather than the aspects of research themselves): Biogeography, Conservation, Disease, Ecology, Evolution, Genetics, Life History, Morphology, Systematics, and Variation. What I chose to focus on in the choice of subjects was subjective; however, this methodology produced recorded information for how a publication's designation in a particular subject came to be. These methods are therefore customizable to make similar studies possible for collection managers as well as future researchers answering other questions. This method is simple, related to complex text categorization methods explored in informatics research (Náther 2005), and it allowed me to visualize changes in NHC utility over time by comparing proportions of the counts in each subject out of total count data for each decade. Some publications did not contain any of the search phrases I looked for, whereas others sorted into more than one subject; this allowed me to specifically look at trends in *topics* of study separately from publications. After obtaining count data of each subject for each year, my final dataset contained 1,417 publications, from which I obtained 2,559 counts with associated division and year of occurrence for the various subjects. To control for changing numbers of publications that contributed to each subject, I compared proportions of subjects out of all total subject counts for each decade and observed changes in those proportions between decades.

To determine if innovative uses of NHCs were increasing in comparison to traditional uses, I consolidated some of my subjects further into two usage categories: subjects related to what are considered newer uses of specimens (containing Genetics, Disease, and Conservation) and those relating to uses that are viewed as more traditional (Life History, Morphology, and Variation). I then combined count data in each of these categories into two periods, before and after 1990, to determine if there were changes in these categories between the two periods. These periods were chosen as a compromise between having equal subject counts as well as equal periods in each. Considering that MSB has experienced much of its growth since the 1990s, I expected to see the greatest difference in research subjects occur between these two periods. It is important to note here that, much like the subjects above, what subjects I considered "traditional" and "newer" uses of specimens are relatively subjective, and certainly some publications bridge these categories.

This study is exploratory, and given my small dataset and focus on one museum, I did not perform extensive statistical analysis. However, I utilized some statistical analyses on the publications dataset with caveats. I performed a Spearman signed-rank test (McDonald 2009:221–223) to act as a guide for determining which subjects increased or decreased over time, though I do not display any P-values for these tests. In order to explore the possibility of performing statistical analysis on this kind of data, I performed a multinomial linear regression for ordinal responses on the total subject data from the Division of Mammals, which contained by far the greatest number of publications from the greatest time span. I used this test to determine which subjects correlated significantly with time in decades (MatLab and Statistics Toolbox 2013). Since publications could contribute to the counts of one or more subject, I corrected for autocorrelation between subjects by calculating the correlation coefficients between subject proportions per decade, and I compared only subject proportions that displayed correlation coefficients of less than $\pm$ 0.6: Biogeography, Disease, Ecology, and Evolution. It is important to note that since this dataset includes only data from one division, in theory I have only a sample size of one; however, I conducted this analysis to demonstrate the feasibility of performing such tests on similar data and support that larger datasets of this kind can be more robustly tested by future researchers with significant results. Last, I composed a 2×2 chi-square contingency table of the two usage categories before and after 1990 and performed a chi-square test to determine differences between the two categories over the two periods (Preacher 2001).

Results

The number of publications and number of publication places per year increased over time (Fig. 1A). Most of the publications that contributed to this dataset came from the Division of Mammals and the Division of Reptiles and Amphibians (Fig. 1B).

Since the 1940s, the proportion of subjects changed from decade to decade, differing between divisions. I observed that, among other trends, the Division of Arthropods and the UNM Herbarium increased in Morphology, and the Division of Fishes increased in Conservation over time. The subject Disease in the mammals division increased significantly in the regression model ($P < 0.01$, coefficient $= -244.1900$) (Fig. 2).

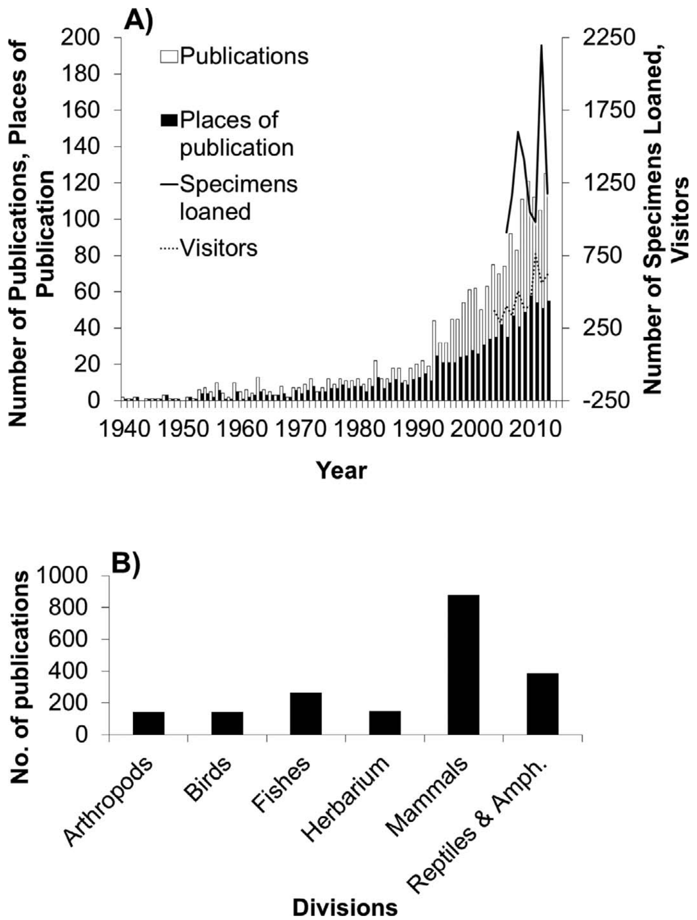

Figure 1. (A) Growth of MSB's arthropods, birds, fishes, herbarium, mammals, and reptiles and amphibians divisions per year, 1940–2012. The white bars show the increase of publications produced per year. The black bars show the increasing number of places of publication per year. The black line depicts the increase of the number of specimens loaned, as recorded in Arctos for the mammals and birds divisions (and their respective tissue loans, not including returns or gifts), 2005–2012. The dotted line depicts the increasing number of visitors to MSB for the birds, fishes, herbarium, and mammals divisions, 2003–2012. (B) Number of publications by division.

The proportion of Systematics and Conservation, across divisions, generally increased or remained steady since the 1990s, with the arthropods and fishes divisions showing highest proportions in each subject since the 2000s, respectively (Fig. 3).

When comparing the proportions of the new uses category to the traditional uses category for all six divisions, new uses increased after 1990 from 13% to 25% while traditional uses decreased. The proportion of the category containing subjects outside of these groupings remained similar between the two periods (only changing by 2%). When tested, the new and traditional use category sums and the two periods were nonindependent ($P < 0.01$, $X^2 = 34.108$).

Discussion

MSB has grown in its scientific impact and increased its production of publications. The increase in publications and publication venues illustrates MSB's growth since the

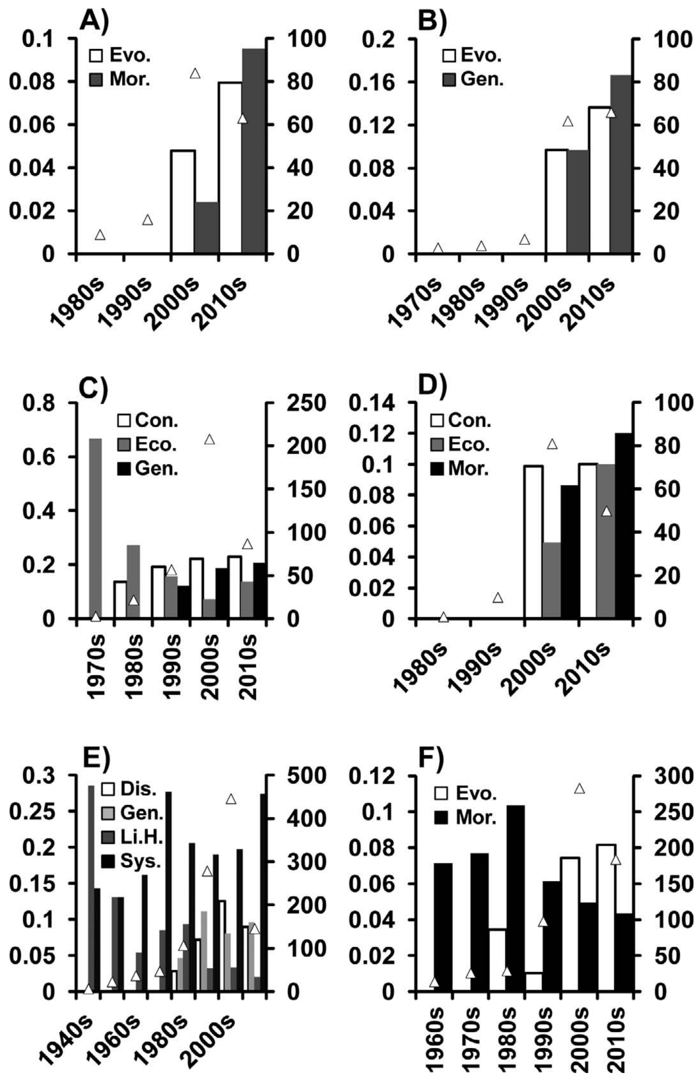

Figure 2. Increases and decreases of select proportions of research subjects for each division per decade: (A) arthropods, (B) birds, (C) fishes, (D) herbarium, (E) mammals, and (F) reptiles and amphibians. Bars, associated with the left axis, indicate the proportions of the subjects, while triangles, associated with the right axis, indicate the total counts in all subjects for each decade. While the dataset grows larger with time, proportions of different subjects for different divisions change as well: for example, the Division of Arthropods (A) and the UNM Herbarium (D) increased in the subject Morphology, and the Division of Fishes (C) increased in the subject Conservation. The Division of Mammals increased in the subject Disease over time. Abbreviations for the subjects are Biogeography (Bio.), Conservation (Con.), Disease (Dis.), Ecology (Eco.), Evolution (Evo.), Genetics (Gen.), Life History (Li. H.), Morphology (Mor.), Systematics (Sys.), and Variation (Var.)

1990s as a major provider of data for the scientific community. Publication subjects illustrate that research fields differ between divisions and change over time, and these results can be used to support more specific hypotheses. For example, the increase in publications dealing with morphology for both the Division of Arthropods and the UNM Herbarium (but not for any other groups) indicates that collections are critical data sources for morphological research in these groups. The increase of conservation-related

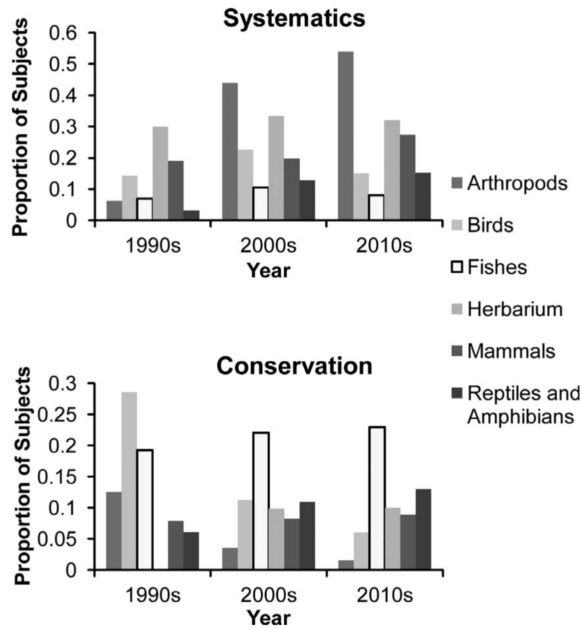

Figure 3. The proportions of the subjects Systematics and Conservation across divisions (from left to right: arthropods, birds, fishes, herbarium, mammals, and reptiles and amphibians) per decade, 1990–2013. Note that for the last two decades the proportion of the subject Systematics is high for division of Arthropods and the UNM Herbarium; the proportion for the subject Conservation is high for the Division of Fishes and the Division of Reptiles and Amphibians.

publications in ichthyology most likely reflects the increased awareness of, and interest in, New Mexico's endangered fish species and the state's related water issues. The statistically significant increase of disease research in the Division of Mammals is most likely related to the increasingly popular investigation of hantavirus in the Southwest (Childs et al. 1994, Yates et al. 2002). This analysis produced a myriad of results that can provide useful insight to specific questions for more focused future research.

In comparing divisions for the subjects of Systematics and Conservation, taxa with high species counts showed the highest proportion of systematic research, while groups with the fewest taxa in the state have high proportions of conservation studies associated with them (though other factors are surely involved). This supports the contention that systematics is foundational to conservation research. The prediction regarding changing proportions of traditional and new uses of collections overall was also supported—publications pointing to newer uses of specimens have increased over time. This change indicates that MSB, while providing a steady source of data for particular fields in ways that are not likely to change any time soon (such as ecology and evolution), has also been able to provide data for different scientific pursuits throughout history.

In trying to answer the question of collections utilization I discovered advantages and disadvantages to the methods investigated here. Publications are an indirect measure of use, because not all publications cite the specimens they use. Older publications are more likely to have improperly cited the specimens used, leading to an artificial increase of publications over time. Publications in major journals may further bias results. For instance, publications that focus on systematics, which are published in journals with a narrow audience, may be more likely to cite the usage of specimens than those that focus on popular topics such as macroevolution (which highly influential journals tend to publish) (T. White, personal communication, 7 August 2014). Future studies could include more focused or intensive searches of specific journals, since most major journals are now archived online and are often text searchable.

The methodology of using search phrases to analyze trends of use in publications takes these assumptions a step further and can be problematic. Searching for specific phrases for inclusion in the subject groups keeps searches objective but may leave out important publications or include unrelated ones. Misspellings and journal abbreviations can change the results of such studies. However, since the search phrases can be easily recorded, this method allows other researchers to know exactly how the groups were divided and even allows different researchers to tailor their search phrases to fit their collections and to answer more specific questions. Given the ease with which one can study a large series of publications from many sources using online searchable databases, publications are an effective way to study the changing relationships between NHCs and research.

Loans

Predictions

Loan records can answer questions that publications alone do not readily reveal. Specifically, loans provide information on the specific specimens that are of interest to other researchers and institutions. I expected to see the loans of local species predominate over others, given that MSB has a strong collection from the southwest United States (Museum of Southwestern Biology 2009). Local collections often hold extremely important specimens from their particular region (Snow 2005, Casas-Marce and Fernandes 2012). Considering that the availability of comparable specimens in collections outside of MSB is variable according to scientific interests particular to each division, it is likely that the loans of specimens collected from New Mexico will be division-specific. I expected that MSB's specimen growth in the last 25 years has widened MSB's scope such that a higher proportion of non-NM specimens were loaned recently in comparison to past years. The popularity of molecular studies has increased over time, and more researchers are collecting specimen parts rather than whole vouchers for vertebrate groups (Bates et al. 2004). Therefore, I expected to observe a decrease in traditional specimens (skins and skeletons) loaned.

Methods

I compiled nearly 1,800 loan records from electronic and paper loan records in each division to assemble a loan history dating back to 1968. My collection efforts were focused on digital copies of loan forms (except in the case of the UNM Herbarium, which held only paper records). Once again, the largest dataset came from the Division of Mammals. For the mammals and birds divisions, I utilized the Arctos database (arctos.database.museum) to obtain loan records (as well as their associated tissue specimens from the Division of Genomic Resources) and had a complete record of loans for those divisions from 2005 to 2012. I recorded the loan number, the species and specimen part loaned, the locality (state/province), and the number of specimens loaned from each locality (see Appendix 1 for more information). This dataset allowed me to observe the proportion of loans of specimens collected from New Mexico compared to specimens from elsewhere based on named locality, and to then determine changes in this

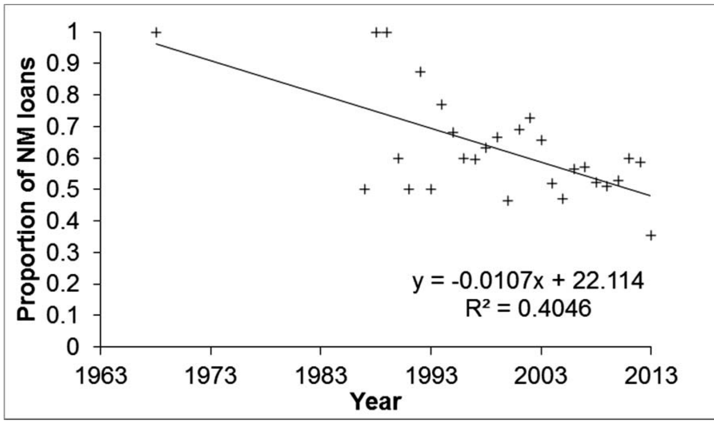

Figure 4. The proportion of loans containing specimens collected in New Mexico, from all loans with recorded collection localities, 1968–2013. Crosses depict proportions per year while the black line depicts the downward trend with a linear line of best fit, with equation and R^2 value shown.

proportion over time. I obtained an R^2 value and equation for a line of best fit for the proportion of loans containing specimens collected in New Mexico over time.

The mammals and birds divisions also had a detailed record of loans available through Arctos, including data regarding loan parts (skins, blood samples, skeletons, etc.). From these data I determined which mammalian and avian specimen parts were being loaned most often as well as how the proportions of "traditional" specimen parts for these groups (skins and skin parts, and skeletons and skeletal parts) have increased or decreased over time.

Results

The number of loaned specimens per year increased over time for the mammals and birds divisions (Fig. 1A). The majority of the top five most-loaned species from each division (by number of specimens loaned) have ranges that include New Mexico. However, loans containing specimens collected in New Mexico proportionately decreased over time (Fig. 4).

In the mammals and birds divisions, the most-often loaned specimen parts were tissues (hearts, kidney, and liver) and skulls (where the tissues are most likely frozen tissue samples preserved for genetic and molecular studies, and skulls are most likely dried and used in morphology research). Interestingly, the proportion of loans of skins and skeletons, usually considered more traditional specimens compared to tissue samples, fluctuated but did not show a marked decrease or increase over time.

Discussion

Loan records illustrate changes in what scientists, other institutions, and other users require of NHCs as research and educative interests change. For some divisions, the decrease in NM loans may be linked to more specimens and associated data being made available online. This trend suggests that regional collections like MSB not only are sought after for the local specimens they store, but also accumulate useful holdings of specimens from outside of their specialty region as their collections grow. In the bird and mammal divisions, the proportion of traditional specimen parts loaned has remained fairly constant in recent years and suggests that research based on skins and skeletons continues to form a substantial utilization of these divisions. While borrowing researchers make requests for material, those who provide specimens to NHCs (curators, graduate students, and others) are responsible for building data-rich collections and thus strongly influence the materials researchers seek.

Aside from recent digitization of loan records into collections databases, format of loan records is often unwieldy. To obtain a historical record of loans, interested parties may have to examine paper loan records, letters of request, and digital files. This could make assembling a data-rich and comprehensive record of loans time-intensive compared to assembling digital loan records from a database. String-finding and other text-searching technologies can make mining information from these and other records more automated (Zou 2015). Loans can be a powerful tool for understanding collections use—a loan record is similar to a publication, linking specimens with researchers for a particular purpose. Even if that purpose is not wholly explained in loan records, loans provide data on specific specimens themselves, information not easily gleaned from publications alone.

Guest Books

Predictions

Guest books provide information on how NHCs are utilized by the general public, information that is often lacking and much desired by administrators, making them valuable records for museums overall. MSB's growth over time indicates that in-house visits should also have increased over time. Considering that MSB is a university-based museum, I expected that UNM affiliates would visit the collection most often. Given the value of natural water resources in the Southwest and the large number of endangered New Mexico fishes, I expected that government agencies would visit the Division of Fishes most often. Nonresearchers tend to make use of research collections, particularly through educational tours. Therefore, I expected to see a combined increase in the proportion of tours or visits over time as MSB has become more well known.

Methods

I collected guest book records, which included visitor numbers, affiliations, and often the purpose of the visit. The Division of Arthropods had a record of visits only for one month in 2013, while the Division of Reptiles and Amphibians had sporadic records from 1971 to 2012. I recorded each visit as a single individual visiting a collection on a single day, and in this way obtained a dataset of more than 10,000 records of visits. I recorded the number of visitors, the year of visit, the affiliation of the visitor, and the purpose of their visit (see Appendix 1 for more information). For the years 2003–2012, wherein I have a complete record of numbers of visits for four divisions (birds, fishes, herbarium, and mammals), I compared numbers of visits between divisions over time. To observe differences in the major affiliation of visitors as well as their purpose of visiting across divisions, I performed searches for specific phrases to sort the affiliations into different affiliation groups in a similar method to that described above for publications (Appendix 2). I used search phrases "tour" and "visit" to count the number of nonresearch visits each year and observed how these nonresearch visits changed in proportion to other visits over time, in all six divisions as a whole. I obtained a linear trend line and R^2 value and equation for that trend line.

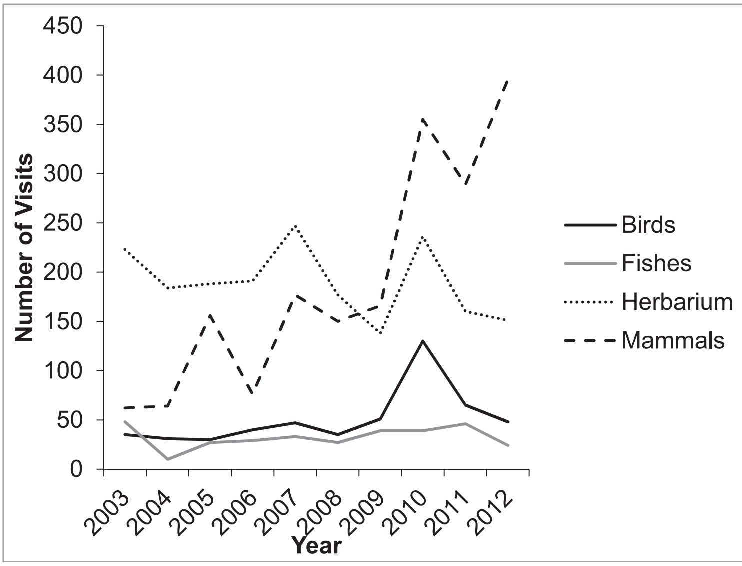

Figure 5. The number of visitors per year to the bird (black line), fish (gray line), herbarium (dotted line), and mammal (dashed line) divisions, 2003–2012.

Results

The number of visitors per year for the totaled birds, fishes, herbarium. and mammals divisions increased over the time studied (Fig. 1A). Guests who identified themselves as affiliates of government agencies comprised the majority of visits to the arthropods and fish divisions. UNM affiliates comprised the majority of the visitors to the bird, mammal, and reptile and amphibian divisions, and museum affiliates were the major visitors to the herbarium. The UNM Herbarium and the Division of Mammals had the highest number of visitors, with the number visitors per year to the mammals division increasing over time (Fig. 5).

The proportion of nonresearch visits increased over time. This pattern appears to be driven by the bird and mammal divisions, which show the most obvious increase out of the divisions (Fig. 6).

Discussion

Visitor records illustrated that MSB has grown as a provider of materials to the general as well as scientific community, though each division has primarily served different parties. The bird and mammal divisions had a high number of UNM-affiliated visitors and showed a proportional increase of nonresearch visits over time, suggesting that the increased number of UNM-affiliated visitors may be a result of increased on-campus outreach performed by these divisions. Like publications, guest books can support specific hypotheses regarding collections usage. The high number of government affiliates visiting the Division of Fishes, for instance, may illustrate the complicated issues surrounding New Mexico and its water resources as well as the roles that government agencies play in providing information on and implementing management of endangered species. Although it seems obvious that research is the main use of a collection, nonresearch visits form an increasing subset of MSB users, due to both increased

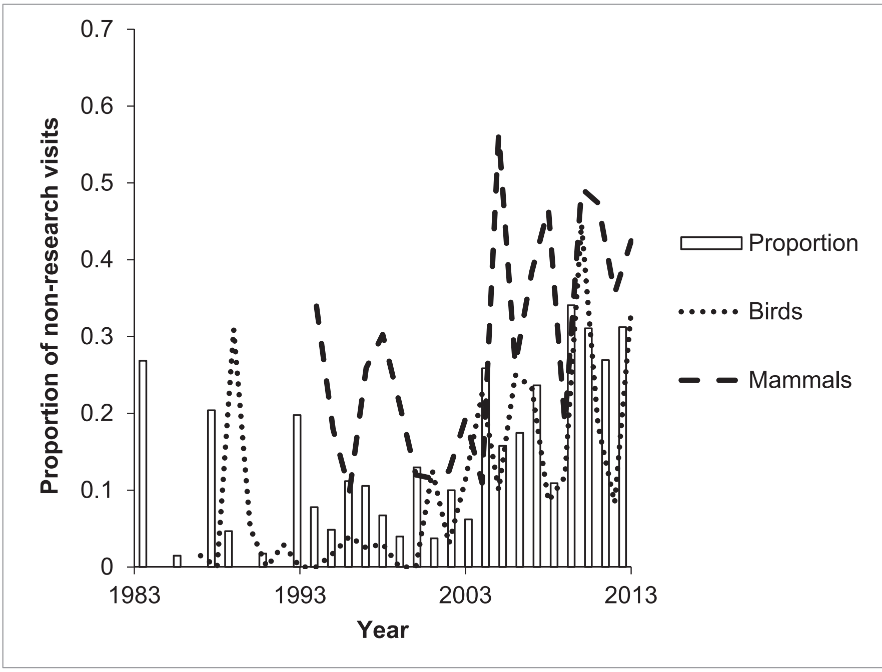

Figure 6. The total proportion of nonresearch visits to the six divisions out of all visits per year, increasing over time from 1987–2013 (white bars). Lines depict the proportion of nonresearch visits in the Birds (dotted line) and Mammals (dashed line) divisions, which show the most marked increase. However, the proportion varies widely year to year.

outreach conducted by MSB and the available staffing to support tours and other similar visits.

As quantitative records of NHC usage, guest records can be problematic, given the freedom that visitors may have in making entries and differing emphasis on detailed record keeping. Using search phrases to determine affiliation or purpose of visit is also subjective (as discussed in the publication section above). If properly utilized, however, they can provide a wealth of knowledge regarding NHC utilization over time. Simple metrics such as the number of visitors per year can provide powerful insight to policy makers.

Evaluation

The results of this case study suggest that new uses of MSB in research are on the rise, that loans are changing as MSB's holdings grow and become more cosmopolitan, and that more of MSB's visitors are coming for tours every year. Such results reveal MSB's steps onto a larger stage in both research and public spheres and shed light on how the use of NHCs might be quantified in other museums. NHCs like MSB are likely to remain as relevant sources of data and contribute to future science in powerful ways.

This research presents a new method for understanding NHC usage, and studying these records as metrics for measuring utilization is largely exploratory. This investigation shed light on the differences between collections that should be taken into consideration when forming conclusions on such trends. NHC analysis as a whole presents several challenges, which are exacerbated in a multidivision study of this nature.

Many factors can thus influence and affect the kinds of results that are produced. Every collection has differing research applications according to its unique strengths and legacy of research. Age, size, and other collection- and division-specific factors, such as access policies and priorities, collection practices, and information prioritization, may also differ. All divisions differ in the priorities of their particular curators, who have their own specific interests and attitudes that can shape how their holdings are utilized and make their influence difficult to quantify. These differences affect each division's research focus and usage and are difficult to control for. Despite these differences, the metrics that NHCs collect (at least those studied here) are likely to be relatively common across divisions, and these metrics can highlight division differences to great advantage. Furthermore, it is not the intention of this research to assume that NHC value can simply be quantified into numbers: high-impact publications and influential outreach programs, for instance, may reveal a different kind of perceived value. Analyzing NHC records can, however, provide a new perspective on NHC value, giving helpful signposts to determine where a collection is headed and how it is different from other divisions or collections, even if the aforementioned confounding factors complicate rigorous analyses.

The problems I encountered in this case study may be lessened or eradicated by establishing standards for working with this kind of information. Primarily, NHC professionals need to document NHC usage (Cato 1986:67, 69, Simmons 2002:107–108). When NHC staff possess a record of usage, it is imperative that the NHCs themselves and their associated documentation of usage be digitized and further made available in online databases. Analyses aside, digitization is important for the viability of NHCs (Baker 2011, Snow 2005). Not only does digitization provide a back-up of the data stored in collections, but it can also make analyses easier for future researchers. Much-needed discussions regarding the digitization of collections are emerging (Ang et al. 2013, Balke et al. 2013), and major initiatives to promote digitization, including the Global Biodiversity Information Facility (GBIF, www.gbif.org) and Integrated Digitized Biocollections (iDigBio, www.idigbio.org), are already taking place. VertNet's Portal Statstcs already provide some data on usage of their databases (http://portal.vertnet.org/stats) that could integrate into administrative reports. Continued conversations on this topic will make NHCs and their data more easily accessed and analyzed for future research.

Records of how particular specimens are used should be included in digitization initiatives, which would make possible the compilation of NHC usage records. This compilation should be comprehensive and include lists of publications produced by particular NHC divisions, loan records, guest books, and others. The digitization standards established in Darwin Core, for instance, provision for linkages between specimens and publications (Taxonomic Databases Working Group 2009). Some journals, such as *PloS ONE,* now require or advise the citation of some specimens used in research prior to publication (*PloS ONE* Manuscript Guidelines 2015); NHC professionals can discuss and share methods for ensuring that all specimen-based publications properly cite NHCs. Citation software and online publications databases make the creation of complete publications lists even easier. It is just as much the responsibility of the museum to store information on NHC usage as it is to store specimen data. Further practical measures can make tracking and digitizing NHC usage in other records easier. Adding information to loan request forms, such as specific purpose of use or the specimen's general locality data, can provide more information on what is being used in an easily obtainable manner that requires little extra time to complete. Similarly, guest book entries can be streamlined in some ways, either by taking more specific information from visitors (e.g., species observed) or by standardizing responses. Changes to standardize the form in which usage data is collected can have huge benefits to making the ways in which collections are utilized more readily apparent.

Once complete records of specimen use are made easily obtainable and analyzed, they can be a powerful tool for determining collections care priorities and other management aspects. NHC professionals should consult such records when evaluating the costs and benefits of storing, handling, digitizing, and/or exhibiting particular collections. Collections valuable to particular trending topics or particular groups may also be made more available to researchers to improve their studies. Data utilization is affected by data storage and access methods (Sunderland 2013), and information on how NHCs are used can help inform methods for appropriate collections management, as well as garner funding. It is important to note that comparing NHC use records between divisions or kinds of divisions has the potential be detrimental to collections if such data is taken with a competitive, rather than educative, slant. Museum professionals, when presenting NHC usage data on behalf of the NHC, should present NHCs in a unified manner for the benefit of the museum overall. When appropriately and constructively utilized, NHC utilization data should assist museum professionals in thinking more progressively about the many current applications of their collections and in planning how to provision for collections as future scientific resources. Future researchers may consider consolidating NHC utilization metrics to create an index of use, which may become standard in assessing collections usage.

Summary

With current lag in the support for NHCs, museum professionals must arm themselves with tools to adequately justify the continual existence of NHCs to a broad range of groups. I presented a method for using museum records to illustrate how NHCs contribute to scientific innovation and societal understanding of the natural world and increase awareness about the many ways in which NHCs earn value through use over time. By exploring records that point to the myriad of uses that NHCs fulfill, museum professionals can understand their collections more fully. Studying past usage by no means illustrates the comprehensive value of an NHC into the future. However, this case study has begun to fill a gap in knowledge concerning collections use and can provide baseline information for future researchers to perform similar studies. The methods explored here further illuminate ways in which NHC professionals can proactively defend and critically evaluate their NHCs and its practices: through compilation, digitization and further investigation of NHC use records. More research of this kind will help highlight NHCs as a much-needed record of Earth's biological legacy for administrators, the scientific community, and others.

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Appendix 1: Explanation of Data

Publications Data

The publications dataset includes publications which referenced MSB. Most of the citations retrieved are journal articles that cite MSB specimens or MSB itself, although the dataset also includes books, technical and government reports, and websites. Publications obtained from MSB collection managers included publications produced by MSB personnel and publications using MSB specimens. Thus, these publications lists may also have included publications by researchers who were or are employed by MSB, which are considered MSB-related even without direct use of specimens. When polled, the collection managers that provided data for this project said that they received most of the publications that reference their collections directly from the researchers or users themselves, through colleagues, or by using search engines to search for publications of individuals who were loaned specimens (four of four responses). Collection managers either used search engines when looking for publications or planned to do so in the future. Search terms that collection managers used (or planned to use) to look for publications via search engines included "Museum of Southwestern Biology" and "MSB" as well as more specific terms such as "mammal" and "distribution: UNM." One collection manager noted that he also researches publications that likely used MSB specimens via GenBank. Given these circumstances, it is likely there is some bias toward newer publications being included in the dataset.

Publications I obtained online contained the keywords "MSB," "Museum of Southwestern Biology," "University of New Mexico Collection of Vertebrates," "UNM Herbarium," "UNM Arthropods," "UNM Mammals," "UNM Birds," "UNM Fishes," or "UNM Amphibians and Reptiles" when searched. Publications also could have included "Museum SW Biol" or "Museum of Southwestern Biology" in the address.

The inclusion of "gray literature," which forms an important but often overlooked use of museum materials, has led to a gray area of included publications which requires further explanation. One dissertation was included, on the grounds that it was cited in another publication. Three conference presentations were included, on the grounds that lengthy descriptions of the research are published online. Four publications based on personal collections of UNM researchers were included, on the grounds that these publications came after their hire at UNM, and thus were likely produced in association with MSB. Nine publications were included because

MSB supported the research, although it was not determined if MSB specimens were specifically used. These publications were included to be as inclusive as possible in creating a dataset that shows the myriad ways in which collections are utilized. Theses and dissertations were not specifically sought for inclusion in the study because the completion of such research projects are considered to be a university-mandated requirement. Overall, I estimated that 8.3% of the publications included in the dataset fell in the gray literature category (i.e., not journal articles or books) and comprised 6.3% of the final subject counts dataset.

Not all publications were read to verify the use of specimens. Therefore, use of specimens was often extrapolated from the title of the publication. I coded all publications in the dataset into differing degrees of likelihood (0–4) that specimens were used by the author(s) of each publication. Publications that did not use MSB specimens and/or were not produced via affiliation with MSB (Code 0) were not included in the study.

Loans Data

Considering the method of my compilation of loan records in this iteration of this study, the loans considered here are an incomplete record of all loans for the other divisions. I did not include records that were designated gifts or return loans in this dataset if that information was recorded on the loan record; however, I attempted to include other types of specimen transactions that indicated the recipient desired the material (e.g., exchanges). Tissue loans, though most often destructive (and thus could be considered gifts), were still considered in this dataset because MSB's tissue collection is large, and it is likely that, unlike the gift of a whole specimen, a tissue sample likely represents only a part of the holistic specimen that still resides with the loaning institution. MSB furthermore maintains ownership of tissues (J. Cook, personal communication, 12 Feb. 2015).

Where no locality was recorded in the records I studied, I recorded only the number of specimens and the species loaned. When more than one locality (including New Mexico) was recorded but not the number of specimens in each, I used the known proportion of specimens in the collection from New Mexico to determine the most likely proportion of specimens from New Mexico.

Guest Book Data

Data was recorded from handwritten entries with varying use of acroynms. Therefore, some interpretation went into recording this data, at my discretion with occasional assistance from pertinent collection managers. For some visit records, the affiliation and/or purpose were not recorded in this study. Last, search phrases to group affiliates listed in Appendix 2 were chosen subjectively (for instance, BEMP grouped with UNM because of the close ties shared between these organizations).

Appendix 2: Search Phrases and Their Associated Groupings

A. Subjects with Associated Search Phrases and Usage Categories for the Publications Dataset

Subject	Search Phrases	Category
Biogeography	distrib; geograph; range; habitat; record; survey; monitoring; occur; endemi; dispers	Other
Conservation	conservation; invasive; contamin; pollut; endangered; threatened; manag; urban not disturbance; climate change; abundan; inventory; status; population size; environmental; extinct; species richness	New
Disease	virus; virology; viral; disease; infect; epidemiolog; transmission; health; medic	New
Ecology	ecol; parasit; mutuali; keystone; niche; compet; commun not short communications; assemblage; troph; interaction; predat	Other
Evolution	evol; speciation; adapt	Other
Genetics	genet not phylo; DNA; genom	New
Life history	life histor; natural histor (not journal); diet; feed; behavior; migrat; reproduct; mating; sex; breeding; food	Traditional
Morphology	morpho; phenotyp; anatom	Traditional
Systematics	systemat; diversi; phylo; taxonom; new species; new genus; new genera; classif; taxa; checklist; revision	Other
Variation	Vari	Traditional

B. Search Phrases Used on the Guestbook Dataset with Respective Affiliation Groups

Affiliation Group	Search Phrase
Government agency	NMDGF; Sev; FWS; NPS; Forestry; BLM; USGS; forest service; wildlife service
Museum	museum; herbarium; MSB; NHNM; NMNHP; NMMNHS
Other	none of the above
Private	private; self
University	univ; college
UNM	UNM; BEMP