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# EVALUATING THE UTILITY OF NATURAL HISTORY COLLECTIONS IN RESEARCH AND FOR THE PUBLIC

Bethany Abrahamson

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**EVALUATING THE UTILITY OF NATURAL HISTORY  
COLLECTIONS IN RESEARCH AND FOR THE PUBLIC**

**BY**

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**BACHELOR OF SCIENCE, BIOLOGY**

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**THESIS**

Submitted in Partial Fulfillment of the  
Requirements for the Degree of

**Master of Science**

**Biology**

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## **DEDICATION**

This thesis is dedicated to my parents, Sheryl G. and John V. Abrahamson, as well as my siblings, Megan B. Abrahamson and Nathan J. Abrahamson. I also dedicate this work to the many friends and family members who made this thesis happen.

S. D. G.

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**B.S., Biology, University of New Mexico, 2012**

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**ABSTRACT**

Natural history collections (NHCs) are useful in many fields of study, but knowledge about how they are used in the modern day is poor. The first part of this study, focused on the collections data held by the Museum of Southwestern Biology (MSB), analyzes specimen-based publications, specimen loan records, and guestbook information to determine how NHCs have been used in scientific study over time. Using a novel methodology, I objectively sorted the publications into ten research subjects via particular phrases found in publication titles, places of publication, and keywords. I observed from this dataset the proportions of particular subjects for different divisions in MSB over time, to judge which subjects increased or decreased over time. From MSB loan records I analyzed the proportion of state-collected specimens loaned over time, as well as the

proportion of different specimen parts that have been loaned as recorded for MSB Mammals and Birds divisions. Lastly, I explored guestbook data to determine the major affiliates of visitors to different divisions and the proportion of visits unrelated to research over time. The patterns shown here illustrate that new uses of MSB specimens 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. Analyses that quantify the use and impact of NHCs demonstrate the importance of this key infrastructure to the scientific community and beyond. In Chapter 3, I summarize and analyze an exhibit I created in collaboration with MSB and the New Mexico Museum of Natural History and Science (NMMNHS), which explains how NHCs are used by researchers to further conservation efforts in New Mexico.

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## CHAPTER 1. INTRODUCTION

Natural history collections (NHCs) are valuable scientific infrastructure that must be maintained in perpetuity and made available if they are to be useful to current and future researchers. Because these collections are expensive to build and manage, researchers and museum professionals must explain how NHCs are useful to a broader audience. Administrators often require museums to justify their activities, and this requirement spans across all kinds of museums and even the different kinds of natural history institutions, from both research collections to the more famous natural history displays in science museums. Rather than focus on simply one aspect of this need, this study investigates how NHCs can tackle this in scientific spheres and in public ones (that is, in display-focused museums). Research collections and display museums serve often very different audiences, and to explain NHCs and how they are used to those audiences requires consideration of those differences.

There is a divide between research collections and educational museum displays in the field of biology (Conn 2009). This thesis aims to help research collections integrate more fully with public outreach efforts in a mutually-beneficial relationship, where research collections gain access to exhibition spaces and audiences. Research collections can further gain the opportunity to illustrate their importance beyond the ivory tower, cultivating general pride and appreciation for scientific inquiry and the protection of natural areas and biodiversity. Stronger ties to public exhibits can substantially increase

the audiences that research collections reach to further justify their importance to a broader audience.

**Objectives and intended outcomes.**

The main objective of this research was to analyze NHC utilization in the Museum of Southwestern Biology at the University of New Mexico, and from that analysis, determine directions for informing a wider circle of people about how specimens and associated data are used. In consideration of the diverse audiences that natural history institutions serve, this project explored differing methods for analyzing utilization, and determined their usefulness in producing meaningful results. Most directly this project intended to produce information on how collections use at MSB has changed and expanded over time. Exploring collections use leads to a better understanding of how different kinds of datasets add to academic, administrative and public appreciation for collections. Chapter 2 of this thesis analyzes natural history collections use from a scientific perspective in the form of a case study of MSB. In chapter 3, I provide a narrative discussing how I explain collections use to a public audience via the exhibit *Conserving New Mexico*, which allowed me to integrate research collections and museum displays. Both of these parts together form a picture of the diverse ways in which collections contribute to science and society in the past and how they might be expected to contribute in the future.

## **CHAPTER 2. A QUANTITATIVE EVALUATION OF NATURAL HISTORY COLLECTION USE IN ONE UNIVERSITY MUSEUM**

### **Introduction.**

The scientists and professionals who work with natural history collections (hereafter NHCs or collections) are stewards of the paramount record of Earth's biodiversity and natural heritage. Their collections provide a place to archive valuable type specimens and vouchers from published and unpublished research, and act as repositories of the diversity of life for comparative biology. They serve as a data source for new avenues of research, providing a wealth of samples and knowledge to researchers of all kinds (National Science and Technology Council 2009). These physical samples act as data points that make many scientific studies testable and repeatable by current and future researchers, and are thus an unmatched and irreplaceable scientific resource (Winker 2014). NHCs are representative of the present and past natural world and are extremely valuable to a variety of scientific and nonscientific fields (Allmon 1994, Lane 1996, Funk 2004, Pyke and Ehrlich 2010).

Determining specifically how scientists and the public assign this value is of special interest to NHC professionals, although it is an issue not thoroughly analyzed from the collection's perspective. The value of any research collection as a whole can be judged by how it is utilized. Objective analysis of this utilization is, however, lacking. This study seeks to address a gap in methodological approaches to analysis of NHC use, and quantify NHC utilization via several metrics.

*NHC utilization changes over time-* The value of a collection can be calculated by a combination of its scientific, historical and cultural value for risk assessment purposes (Price and Fitzgerald 1996). However, when considering a collection's value in terms of its real-world utility to science and society, assigning value becomes much more difficult to quantify. Digitization, as well as novel methods and technologies used on museum specimens, both allow NHCs to be used in new fields of study over time, but complicate our understanding the history of how NHCs have been utilized.

From a functional perspective, the digitization of collections and other new technologies have made NHCs more valuable than ever before. These innovations are in large part responsible for diversifying collection use from the stereotypical roles that NHCs have played in taxonomy and life history research throughout the history of biology (Winker 2004, MacDonald and Ashby 2011, McLean et al. *in prep*). Disseminating the historical record of museum data in online databases allows for the production of large-scale research on species distribution and biodiversity, and provides the baseline data necessary to create robust ecological niche models (Shaffer et al. 1998, Peterson et al. 2006, Baker 2011). Critical research into the effects of climate change is impossible without mass digitization of NHC data (Johnson et al. 2011). By integrating museum locality data, collections digitized and entered into online databases have the potential to create a dynamic "Map of Life" that may prove critical in establishing species distributions and, through legislation, assist in conserving the earth's biodiversity (Jetz et al. 2011).



Other new sources of data, gathered with the help of innovative technologies and methods, draw far more information from historical specimens beyond what their original collectors anticipated. Stable isotope data gleaned from tissues has extended the utility of museum specimens into studies of migration, diet and climate change (Fleming et al. 1993, Smith et al. 1995, Kelly et al. 2002). Genomics and molecular biology can shed more light on the relationships and evolution of species through NHCs than previously thought (Wandeler et al. 2007, Cappellini et al. 2013, Nachman 2013). Museum specimens have even proven useful in studying the spread and impact of environmental contaminants and important diseases via tissue and parasite analyses (Vo et al. 2011, Zhu et al. 2014). Museum collections are still a primary source of knowledge of undescribed species discovered during taxonomic work, and, given the developing biodiversity crisis, may eventually be the only place where many species can be examined because of their extinction in nature (Winker 2004). Researchers predict that the value of NHCs is increasing over time, particularly through NHC use in the currently-popular topics of conservation research and emerging pathogen discovery (Graham et al. 2004, Suarez and Tsusui 2004, Winker 2004, Miller et al. 2004, Miller-Rushing et al. 2006, Lips 2011, Ward 2012, Lavoie 2013).

*A review of NHC evaluation-* Publications on the importance of NHCs for biological research have taken varying forms, from specific case studies to more sweeping literature reviews. Primary research produced using NHC specimens often references the importance of the collections they utilize, even though it is not the main focus of the research (Hoberg et al. 2009, Casas-Marce et al. 2012, Ross et al. 2012). Other

publications have emphasized specific examples from research projects to illustrate the importance of NHCs (Suarez and Tsusui 2004) or discussed NHCs in relation to their potential and realized role in education (Sunderland 2012, Cook et al. in press 2014). Researchers have also analyzed the usefulness of NHC data to improve other studies such as species distribution models and evaluating biodiversity (Ponder et al. 2001, Solow and Roberts 2006). Some reflections on NHCs take a much wider approach, discussing the overall importance of NHCs to science in the past and predicting more uses for the future (Cranbrook 1995, Winker 2004, Chilton and Fuller 2005, Dosmann 2006, Pyke and Ehrlich 2010, Johnson et al. 2011). Despite the large amount of literature that exists in support of NHCs, little research has quantitatively demonstrated how NHCs have been used, and few objective methods currently exist to allow collection managers, curators and policy-makers to track changes in use or impact over time.

In its most fundamental form, closely examining museum records can provide findings for museum professionals about their collections as basic as the discovery of long-lost specimens (Richards 1987) or the descriptions of current collection coverage for particular species (Nelson et al. 2013). However, research using museum records to analyze the utility of NHCs is an emerging field of study, with various theoretical or tested methodologies targeted to answer museum- and division-specific questions (Jeram 1995, MacDonald and Ashby 2011). Researchers can easily quantify what is stored in collections—essentially recording accessions, numbers of species, and other “statistics” that show NHC contents (Dornburg et al. 2011, Voisin and Voisin 2010). Museum professionals have provided historical records of how their collections have grown over

time (McGinley 1993, Platania 1997). Both approaches can be useful in characterizing a collection, but do not analyze changes of use or its value to the scientific community. A close approximation to an analysis demonstrating NHC use and value are museum annual reports, which are not widely distributed and focus more on growth over time in collections rather than analyzing changes in use (Samper 2010).

One current way in which researchers have documented collections use is by quantifying numbers of publications that use specimens in NHCs, since they show precisely why and how NHCs are utilized to yield new scientific findings. Numbers of publications, their quality, and publication citations are widely-used tools for substantiating a collection's value in a general sense (Suarez and Tsusui 2004, Samper 2010), though much more information can be gleaned through deeper analysis. Jeram (1995) suggested such analyses by quantifying a collection's scientific value using publications. Counting publications has also been used to show the cumulative value of individual specimens over time (Dunnum and Cook 2012). Subjective grouping of publications into categories has shown significant results with regards to illustrating changing trends in scientific studies over time (Holzenthall et al. 2010). Subjective categorization of publications that specifically relate to research collections has shown historical gaps in scientific knowledge that could be filled using NHCs and illustrates NHCs continued importance into the future (Lavoie 2013). Tracking science publications and the number of citations they accumulate has the potential to provide data concerning the impact of particular publications or researchers, which can be used to evaluate the influence of museums as well (Diem and Wolter 2011, Wang et al. 2013); it can also prove useful in and can

support a call for increasing staff and funding for museums (Winker and Withrow 2013).

While scientific value of specimens and scientific use do not overlap completely, analyzing the amount of scientific work produced from NHCs provides a working measure of how specimens are used as well as indirectly indicating their value.

This research differs from previous research in a number of ways. NHC utilization is quantified rather than generalized based on particular famous uses of NHCs; museum records are analyzed rather than simply described, as in annual reports; and NHC utilization is assessed more objectively. This study arrived at a history of how NHCs have contributed to scientific studies through the records they keep, and explored that contribution through patterns and change over time. My research, therefore, takes the form of an exploratory analysis of general trends in NHC utilization over time.

### **Materials and Methods.**

*Case study subject-* For this study I have focused on the collections held by the Museum of Southwestern Biology (hereafter MSB, [msb.unm.edu](http://msb.unm.edu)), located in Albuquerque in the University of New Mexico (UNM). Though it lacks public exhibits, it maintains a research collection of well over 4.6 million specimens in its various divisions. It is a rapidly-growing museum, typically adding thousands of specimens to its collections each year. The museum is regional in that the largest portion of its specimens have been collected in the Southwest, but it holds very important collections from South and Central America and around the world as well. MSB has grown in size and scope quite

dramatically since the early 1990s. For this study, I analyzed collections use in six MSB divisions: Division of Arthropods, Division of Birds, Division of Fishes, UNM Herbarium, Division of Mammals, and Division of Reptiles and Amphibians, as well as related tissues for the Birds and Mammals divisions found in the Division of Genomic Resources.

*Records analyzed and predictions-* 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 which were the most uniform across collections and which would give different perspectives on NHC utilization. First, I explored the history of publications that reference MSB, tracking changes in how the subjects of these publications vary over time (explained in further detail in the Materials and Methods). It has been suggested by other researchers that digitization and web-access to specimen data, combined with the application of new technologies, have increased collections' utility in new and innovative areas of study over time (Newbold 2010, Drew 2011). Utilizing specimens for traditional forms of research should show proportional decrease over time (Winker 2004, 2005, Pyke and Ehrlich 2010). Considering their growing utility in a variety of conservation-related and wildlife management research, as well as increased awareness of this utility, I expected these studies in particular to increase (Winker 2004, 2005, Ryan et al. 2010). NHCs containing vertebrate groups may display this trend more strongly, considering that much of their taxonomic research has already been done (Cranbrook 1995, Agnarsson and Kuntner 2007). I expected conservation use

of NHC specimens to be particularly high in MSB's ichthyology collection, considering that fishes are the most threatened fauna in the state (Propst 1999).

This hypothesis leaves the study of systematics in a complicated position. While other researchers have stated that systematics studies are a major type of collections use, systematics studies must be performed before other research may be done (Prance 1994, House of Lords 2002, O'Connell et al. 2004), leading to a proportional increase of other research for which systematics is foundational (such as conservation research) over time (Wheeler 2004, Agnarrson and Kuntner 2007). Given the importance of systematics to taxa with a rapidly-increasing species count, such as Arthropods and Herbaria, I expect that the proportion of systematics studies will be collections-specific but also high across divisions overall. Lastly, I expected to see curators influence the direction of research in their particular divisions over all.

Secondly, I examined loan records, which illustrate what NHC materials are being utilized. I expected to see the loans of local species predominating over others, given that MSB has a strong collection from the Southwestern United States (Snow 2005, MSB General Information 2009). Widespread specimens collected from specific regions like the Southwest are more likely to be found in regional collections than anywhere else (Casas-Marce et al. 2012). Considering that the availability of comparable specimens in other collections outside of MSB is variable according to the division's research interests and the broader scientific interest in particular species, it is likely that the loans of specimens collected from New Mexico will again be division-specific. I also expect that

MSB's specimen growth in the last twenty-five years has widened the collection's scope such that a larger number of non-NM specimens have been loaned over time. 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 fewer traditional specimens (such as skins and skeletons) have been loaned over time for those groups.

Lastly, records of guest visits provide information on how collections are being used in-house, in addition showing how the collections have been used by both the scientific and non-scientific communities. 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 Fishes division most often. Regarding the purpose of visits, for all six divisions I expected to see a combined increase in the number of non-research visits (in the form of tours or visits) over time as MSB has become more well-known.

*Publications dataset-* I obtained a list of 1,961 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 which cited MSB. These publications were collected from MSB's collection managers as well as article search engines including Google Scholar, Web of Science, and BioOne. I searched for

publications that contained a reference to one of MSB's divisions. I then read through abstracts, articles and/or titles to determine which publications did not use MSB specimens (for instance, where a current MSB researcher did research elsewhere) and removed them from the study of publication subjects. 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).

I sorted publications by specific search phrases (particular words or word parts) used in the titles, journal titles, or keywords of the publications, which I then consolidated into groups according to their similarity. These groups, hereafter referred to as subjects, categorized the publications into different disciplines. For instance, the subject 'Evolution' included publications which contained the search phrases 'evol', 'adapt' and/or 'speciation' in the title, journal title, and/or article keywords (Appendix 2). I organized the publications into ten subjects. I designated subjects to cover several main aspects of biological research: 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 publications 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 type of text categorization is similar to that found in informatics (Náther 2005), and 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 obviously did not contain any of the search phrases I looked for while others sorted into more than one subject—this allowed me to look at trends in *topics* of study rather than publications. After obtaining count data of each subject for each year, my final dataset contained 1,417 publications from which I obtained 2,560 counts with associated division and year/decade of occurrence for the various subjects. To control for changing numbers of publications that contributed to each subject over time, I compared proportions of subjects out of all total subject counts for each decade, and observed changes in those proportions over time.

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 time periods, before and after 1990, to determine if there were changes in these categories between the two time periods. These time periods were chosen as a compromise between having equal subject counts as well as equal time 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 time periods.

This study is exploratory, and given my small dataset and focus on one museum, extensive statistical analysis would lead to less rigorous results. However, I utilized some statistical analyses on the publications dataset with caveats. I performed a Spearman signed-rank test (McDonald 2009) to guide which subjects I determined as increasing or decreasing in each division, 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 Mammals Division, 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 auto-correlation between subjects by calculating the correlation coefficients between subject proportions per decade, and I only compared 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 only includes data from one division, in theory I only have a sample size of one; however, I conducted this analysis only 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. Lastly, I composed a 2x2 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 time periods (Preacher 2001).

In order to determine if curators or other researchers impacted the direction of research in a particular division, I also compared frequencies of subjects in the curator's particular research interests before and after curator hire, also determining if this was linked to the curator's time in the position or the division's publication productivity.

*Loans dataset-* I compiled loan records from electronic and some paper loan records in each division to get loan records dating back to the 1968. My collection efforts were focused on digital copies of loan forms (except in the case of the Herbarium, which held only paper copies). Once again, the largest dataset came from the Mammals division. For the Mammals and Birds divisions, I utilized the Arctos database ([arctos.database.museum](http://arctos.database.museum)) to obtain loan records (as well as their associated tissue specimens from the Division of Genomic Resources). I recorded the loan number, the species and specimen part loaned, the locality (state/province), and the number of specimens loaned from each locality. Where no locality was recorded, I only recorded the number of specimens and the species loaned. When more than one locality was recorded but not the number of specimens in each, I used the known proportion of specimens in the collection for the localities to determine the most likely proportion of specimens from each locality. Aside from the Birds and Mammals divisions, for which I had a complete record of loans from 2005 to 2012, considering the method of my compilation of loan records in this iteration of this study, the loans considered here could not be verified as a complete record of all loans for each division. I did not include records of 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 (i.e., exchanges). 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 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 an extensive and 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.

*Guestbooks dataset-* I recorded guestbook data, which, except for Arthropods and Reptiles and Amphibians, represents the complete record of guest visits for the time period given. These records included the affiliation of the visitor and often the purpose of the visit. Arthropods only had a record of visits for one month in 2013, while 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 10,332 records of visits. I recorded the number of visitors, the year of visit, the affiliation of the visitor, and, if available, the purpose of their visit. From 2003-2012, wherein I have a complete record 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 of specific phrases to sort the affiliations into different Affiliation Groups in a similar method to that described above for publications (Appendix 2). How purposes were recorded varied greatly except for wording related to non-research visits; I only used search phrases “tour” and “visit” to determine how non-research visits changed over time. I observed how these non-research visits changed in proportion to other visits over time, in all six divisions as a whole, and obtained a linear trend-line and  $R^2$  value and equation for that trendline.

## **Results.**

The number of publications, number of publication places, visitors, and loaned specimens per year increased or remained steady for the six divisions over time (Figure 1A). Most of the publications that contributed to this dataset came from the Mammals division and the Reptiles and Amphibians division (Figure 1B). Most of the loans came from the Mammals division.

*Publications-* Since the 1940s, the proportion of subjects changed from decade to decade, differing between divisions: Arthropods increased in Evolution and decreased in Morphology; Birds increased in both Evolution and Genetics; Fishes increased in Conservation and Genetics and decreased in Ecology; Herbarium increased in Conservation, Ecology, and Morphology; Mammals increased in Disease, Genetics, and Systematics, and decreased in Life History; and Reptiles and Amphibians increased in

Evolution and decreased in Morphology (Figure 2). The subject Disease in the Mammals division decreased significantly in the regression model ( $P < 0.01$ , coefficient = -244.1900). The proportion of Systematics and Conservation, across divisions, generally increased or remained steady since the 1990s, with Arthropods and Fishes being highest in each subject since the 2000s, respectively (Figure 3).

When comparing the proportions of the new uses category to the traditional uses category for all six divisions, new uses increased after 1990 while traditional uses decreased. The proportion of the category containing subjects outside of these groupings remained similar between the two time periods (Figure 4). When tested, the new and traditional use categories and the time periods were non-independent ( $P < 0.01$ ,  $X^2 = 34.108$ ). It is important to remember when combining the datasets in this test, that the divisions have produced different numbers of publications.

Divisions differed in how particular subject proportions changed before and after the most current curator hires; however, the proportion of time the current curator held the position and the proportion of publications produced after the curator was hired did not change with curator influence in any predictive manner. These trends appear to be independent, leading to no clear-cut relationships between any of the factors observed.

*Loans*- Most of the top five most-loaned species from each division (by number of specimens, all species by number of loans) have ranges that include New Mexico. However, loans containing specimens collected in New Mexico proportionately

decreased over time (Figure 5). In the Mammals and Birds divisions, heart, kidney, liver, and skull were the most-often loaned specimen parts, and numbers of loans containing these parts increased over time. Interestingly, the proportion of loans of skins and skeletons, usually considered more traditional specimens compared to tissue samples and DNA, have remained steady over time (Figure 6).

*Guestbooks-* Guests who identified themselves as affiliates of government agencies comprised the majority of visits to the Arthropods and Fishes divisions. UNM affiliates were the major visitors to the Birds, Mammals, and Reptiles and Amphibians divisions, while museum affiliates were the major visitors to the Herbarium. From 2003-2012, for which I obtained complete guest records for four divisions, Herbarium and Mammals divisions had the largest number of visitors, with the number of Mammals visitors per year clearly increasing over time (Figure 8). The proportion of non-research visits out of all visits for the six divisions together increased over time. This pattern appears to be driven by the Birds and Mammals divisions, which show the most obvious increase out of the divisions (Figure 9).

## **Discussion.**

*Conclusions: Publications-* MSB has grown in its scientific impact and increased its production of research over time. The increase of publications (and publication venues), loans, and visitors illustrates MSB's growth since the 1990s as a major provider of data and as an influence in the scientific and general community. Further comparison to other

museums of comparable size, or to the overall increase in the number of scientific journals over time, would make this apparent increase in utilization more robust.

Publications produced by MSB illustrate that research fields differ between divisions and change over time. The increase in publications dealing with morphology for both Arthropods and Herbarium (but not for any other groups) supports the expectation that collections of taxa with high species richness still provide powerful and useful morphological data for researchers to study, genetics aside. Furthermore, it reaffirms that collections are critical data sources for morphological research. The increase of genetics and conservation topics coupled with proportional decrease of life history and morphology studies were generally as expected for vertebrate groups, supporting a visible change in research interests in these groups as questions are answered and new ones are proposed. The increase of conservation in ichthyology research in particular 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 Mammals division is most likely related to the investigation of hantavirus in the Southwest, with first Sin Nombre virus research produced in 1994 (Childs et al. 1994). Since then, disease research has been a major component of publications produced by the Mammals division, and has been associated with other research including systematics and genetics (Dragoo et al. 2006, Arai et al. 2008, etc.). These corresponding subjects have also increased with time accordingly.



In comparing divisions for the subjects 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. These results help situate systematics as foundational to conservation research (Prance 1995). The rise in collections use for conservation studies and the continued prominence of systematics studies makes maintaining collections that are pertinent to those studies (historical specimens, specimens from surveys, undescribed species, and the like) of special importance for future research.

My prediction regarding changing proportions of traditional and new uses of collections was also supported—publications regarding newer uses of specimens have increased over time, at the expense of some traditional uses and with little change in the proportions of other research. This difference 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. Since the Mammals division contributed the most publications to the dataset, it is most likely driving this change. Nevertheless, NHCs should continue to be relevant to many branches science by being utilized in heretofore unexplored areas of research and in various fields.

Divisions displayed the spectrum of potential changes in curators' particular areas of research interest. This seemed unrelated to the curators' time in office and equally unrelated to the amount of research produced before and after the curator was hired.

While there may be evidence here for different curators producing different research results in their divisions, it would be unwise to establish strong conclusions from the results I obtained. Other factors, including how many NHC-related publications are being produced by outside researchers, broader trends in the field, and the outreach performed by the division to outside researchers and the public may easily affect how much a curator can affect the topics of publications produced. Curators clearly affect what parts of their collection are most used, but the factors that contribute to curator influence are highly complex, and it may be detrimental to over-analyze them in this capacity.

*Conclusions: Loans-* While most of the top species loaned were taxa whose ranges include NM, there was an overall proportionate decrease in NM loans over time. For some divisions, this decrease may be linked to more specimens and associated data being made available online over time. This trend suggests that regional collections like MSB are not only sought after for the local specimens they store, but also accumulate useful holdings of foreign specimens as their collections grow. In the Birds and Mammals 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. Curators certainly contribute to building data-rich collections, and thus strongly influence what materials are sought for loans.

*Conclusions: Guestbooks-* Each division has primarily served different interested parties in the form of in-house visits. The increased number of visitors affiliated with UNM is understandable, particularly for those divisions containing charismatic fauna (like

Mammals and Birds) as well as divisions that perform more public outreach (again, Mammals and Birds showed proportional increase of non-research visits over time). The high number of government affiliates visiting the Fishes division in part illustrates 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. The high proportion of museum affiliates that visit the Herbarium are the product of its strong connection to Natural Heritage New Mexico, a major conservation group in the state and affiliate of the museum. While it seems obvious that research is the main use of a collection, non-research visits form an increasing subset of MSB users, due to both increased outreach conducted by MSB and the available staffing to support tours and other similar visits.

This case study shows 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 sheds light on how the use of NHCs might be quantified in other museums. While new uses and users of collections are expected, all new patterns of use may not be observable yet, and further study is likely to shed more light on what science looks like from the collection's perspective. Overall, since NHC use has changed over time with popular topics in scientific research, NHCs like MSB are likely to remain as relevant sources of data and contribute to future science in powerful ways.

*Future directions-* There are many ways in which these methods can be extended and modified for future research. Records that keep track of how NHCs are utilized hold a wealth of information beyond that which was studied here. More detailed loan information, specific specimens linked to publications, and the demographics of visitors are just a few data sources that can yield further interesting information about NHC utility through time. Obtaining more complete loan and publication histories from more divisions could yield more information on how collections are utilized, and answer more different kinds of questions. Metadata like the number of citations on a significant specimen-based publication and database website ‘hits’ are other avenues researchers can use to explore NHC utilization according to their large-scale impact.

Beyond simply collecting more data, further questions both broad and specific can be asked of the data gleaned from these records. More powerful statistical tests beyond linear regression models, such as multivariate analyses of covariance, could be performed on similar datasets from multiple institutions to answer a wide variety of both sweeping and specific questions with more rigorous results. From a sociological and historical perspective, analyzing NHC utility in conjunction with cultural trends in biological study via content analysis (e.g. comparing museum records to changes in gender demographics or political biases) is imperative to fully understand the trends observed in certain types of specimen-based studies.

This research will be more vastly more illuminating when compared to trends in other university museums, public museums, and the biological sciences overall. MSB is only

one museum, which, unlike many other museums, is rapidly increasing in its holdings, and its patterns of growth and utilization may drastically differ from that of a well-established museum with slow or no growth. Researching one university museum, from the broader perspective of natural history museum studies, only provides one data point. More studies of this kind, performed on different museums and at various local, regional, and national scales, are necessary to fully illuminate collections use and allow for more confident predictions of how NHCs might be used in the future.

*Future considerations: NHC analysis-* This research is a fairly new method for understanding NHC usage, and studying these records as metrics for measuring utilization is largely exploratory. My work with these records, while a relatively straightforward assessment of trends, has shed light on the differences between collections that should be taken into consideration when forming conclusions on such trends.

NHCs analysis as a whole presents several challenges, which are exacerbated in a multi-division study of this nature. Different divisions in collections have differing research applications, according to the legacy of research that has already been done. Age, size, and other collection- and division-specific factors, such as the collection's particular access policies and priorities, differ as well. These alter where a division's research focus might be in a variety of ways that for a study of this kind are difficult to quantify and control for. Collections and divisions differ in their methods, and different collections prioritize different information and collection practices according to the needs of their

particular specimens. All divisions differ in the priorities of their particular curators, who have their own specific research programs and interests that can shape how their holdings grow and are utilized. Their attitudes to different kinds of collections usage shift over time and, as discussed earlier, curator influence itself is difficult to quantify. Despite these differences, the metrics that NHCs collect can provide different perspectives on how collections impact science, and, as far as the metrics studied here, are common across divisions. Museum records of this kind can provide helpful sign-posts to determine where a collection is headed and how it is different from other divisions or collections, even if the aforementioned confounding factors complicate more rigorous analyses.

*Future considerations: Methodology-* In trying to answer the question of collections utilization I discovered advantages and disadvantages to the specific museum records and methods investigated here. Publications, currently the best quantitative measure of collections utilization, are an indirect measure of use, since not all publications cite the specimens they use. Older publications are more likely to have improperly cited collections and even today there are publications that simply do not cite the collections that they use for their research. The publications dataset attempts to be comprehensive; however, poorly-cited or lesser-known publications can often be undiscoverable and thus left out. Future studies could include more systematic searches of specific journals that reference a collection's specimens, 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 in more ways. Searching for specific phrases for inclusion in the subject groups keeps

searches objective, but may leave out important publications that cover the same subject using different phrases. Altering the search phrases can also lead to getting different results. However, since the search phrases can be easily recorded (which cannot be done with subjective determination), 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 series of publications from many sources using online searchable databases, publications are an effective way to study how the collection as a whole has been used.

Since specimens are often not linked to publications, loan requests and uses of specimen data tracked through online databases can answer questions regarding what species are being studied, where the most-loaned species are being collected, and what parts of specimens are being loaned—questions which are difficult to answer via publications alone. However, aside from recent digitization of loan records into collections databases (such as Arctos), format of loan records is often too unwieldy for the benefits of such study to outweigh the costs. To obtain a historical record of loans, interested parties may have to examine a combination of paper loan records, letters of request, and digital files of both, which makes assembling a data-rich and comprehensive record of loans particularly time-intensive. Loan forms alone often did not include more than the catalog numbers of the specimens loaned. While more detailed information may be available elsewhere, including concise information regarding the specimens being loaned and the purpose within the loan forms themselves would provide a cornucopia of additional data

in one location, without mining databases and catalogs to fill in the blanks. However, loans are an important aspect of collection use—their records are almost like publications in their own right for how much information they potentially hold regarding NHC utilization. Since a loan record links a specimen with a researcher for a particular purpose, loans can be a powerful tool for determining how collections are being used specimen by specimen, in ways that can be lost in publications data.

While loans of material and published papers show that the scientific community in universities, research agencies, and museums use NHCs, they provide little information on who is making use of NHCs beyond this community. Artists, school groups, resource agencies and educators all make use of NHCs, particularly through tours, and this vital utilization of NHCs is recorded in guestbooks and nowhere else (aside from annual reports). In-house guestbooks provide a simple means of tracking who visits NHCs and, ideally, for what purpose. If properly utilized, they can provide a wealth of knowledge regarding NHC utilization over time. Even simple metrics like recording the number of visitors per year can provide insight to policy-makers attempting to quantify how often a particular NHC is being used. Guestbooks also provide information on how NHCs are utilized by the general public, information which is often lacking and much-desired by administrators. Standardizing guestbooks and the information visitors record put in them, will simplify the collection of data and allow us to answer more complicated questions about who is visiting NHCs.



*Proposed standards to enable collections analysis-* The problems I encountered in this case study may be lessened or eradicated with appropriate standards established by museums for the recording of this kind of information. Such standards can bolster even small NHCs as major pieces of scientific infrastructure and establishing strategies for the improvement of NHC investment, utilization and access. First, it is imperative that collections and their associated documentation of usage be digitized and made available in online databases. Analyses aside, digitization is vitally important for the viability of collections, especially smaller ones (Snow et al. 2005, Baker 2011). Not only does digitization provide a back up of the data stored in collections, but it can also make analyses of collections use easier for future researchers providing data in an already-compiled format. A prime example of this is VertNet's Portal Statistics, which present some data on collections usage (<http://portal.vertnet.org/stats>). from handwritten and hard-copy records. Much-needed discussions regarding the methods and benefits of digitizing collections are emerging (Ang et al. 2013, Balke et al. 2013), and major initiatives to fund and promote digitization, including the Global Biodiversity Information Facility (GBIF, [www.gbif.org](http://www.gbif.org)) and Integrated Digitized Biocollections (iDigBio, [www.idigbio.org](http://www.idigbio.org)), are already taking place. Continued conversations on this topic will make collections 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 help make possible the compilation of records of NHC utilization for institutions. This compilation should be comprehensive and include lists of

publications produced by particular NHC divisions, loan records, guestbooks, and more. Publications records for museums are currently most easily assembled and linked to individual specimens. The digitization standards established in Darwin Core, for instance, provide easy provisions to link specimens to publications (Darwin Core Terms: Associated References 2009). Furthermore, many journals now require (or at least advise) the proper citation of specimens used in studies before they can be published. Citation software and online publications databases make the creation of complete publications lists even easier. Publications remain one of the most important ways in which NHCs can illustrate their continued relevance to scientific inquiry, and it is just as much the responsibility of the museum to store this information as it is to store information on the specimens it holds.

Practically, collecting complete publications lists has the greatest benefits for the collection compared to the time cost involved. However, there are other practical measures that NHC managers can take to make compilation of NHC usage data easier. Adding check-boxes onto loan request forms, such as purpose of use or specimen origin (in-state or out) or other information, can provide more information on what is being used in an easily-obtainable manner that requires little extra time to complete. Similarly, guestbook entries can be streamlined in some ways, by either taking more specific information from visitors (e.g., species observed), or by standardizing responses (e.g. providing check boxes for particular visit purposes like research, visits, and government business). Small 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 specimens which have been utilized extensively, and thus hold great value. Specimens valuable to particular trending topics in science may also be made more available to researchers to improve the results of their studies. Regional collections should determine which specimens are being loaned in order to give due consideration to international as well as local specimens. While tissue samples are valuable, traditional skin and skeletal parts are still valuable, and may be more valuable in the future. Specimens of special interest to particular affiliates and the public should be made more readily available. Data utilization is affected by data storage and access methods (Sunderland 2013), and information on how NHCs are used can then help inform methods for appropriate collections management. On a larger scale, these 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.

*Justification-* Much can be gained from even this introductory type of collections analysis, particularly when applied by collection managers and other museum professionals on their own collections. Perhaps most importantly, these kinds of studies

are necessary because of the reality that collections value fluctuates with time. Despite the need for sustained maintenance of these valuable collections, collections have experienced devaluation on two related fronts. One of the biggest concerns is the preservation of collections. Due to pests, improper collection curation and under-researched preservation practices, NHCs can easily deteriorate over time (Waller and Simmons 2003, Williams 1999, Callomon and Rosenberg 2012, Miller et al. 2013). Lack of funding is perhaps a more important factor that can imperil collections and exacerbate storage and preservation issues, which has been a major problem throughout the history of these collections. For NHCs, especially university NHCs, funding varies with time, even as collections grow in size and usefulness (Dalton 2003, Funk 2004, Chilton and Fuller 2005, Snow 2005, Funding, facilities and staffing 2010, Samper 2010). This not only extends to university museums, whose collections are often at greatest risk of being lost (MacDonald and Ashby 2011), but large museums as well. The National Museum of Natural History, due to a staff decrease in the Department of Entomology, has recently been forced to de-activate many of its collections (including over ten insect orders) (Furth and Shockley 2013). Even highly valued and popular collections are not necessarily safe—for instance, many of the specimens collected during the Lewis and Clark expedition are lost to us today (Spamer et al. 2012). 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 through evaluation of how its holdings are utilized is needed.

Studying how NHC use has changed from the collection's perspective establishes concretely why NHCs have been and still are important for many interested parties. Administrators and policy-makers should be well-informed of the importance of the NHCs they fund and control, especially in the case of local collections that are often funded by universities or their respective state (MacDonald and Ashby 2011). For these groups, annual reports illustrate summarily how collections have contributed to research per year (e.g. Samper 2010); they would benefit from the additional information a historical perspective would provide.

Other groups would also benefit from increased awareness of how NHCs impact scientific research and beyond. Many researchers, for instance, may not be aware of NHC contributions outside of taxonomy. Scientists and state agencies also have much to gain from understanding the value of storing voucher specimens in perpetuity after scientific studies have been completed (Beaman and Cellinese 2012, McLean et al. *in prep*). The general public, usually only exposed to public natural history exhibits, does not have a very deep understanding of how series of individual natural history specimens, rather than interchangeable taxidermy mounts, are useful or important outside of academia (Conn 2009:50).

With such analyses, NHC managers can determine how collections might be expected to be used in the future and how to prioritize future collecting efforts. This study, as well as the constant new innovations and ideas, make predicting collections usage difficult. However, given that there are few studies of NHC use that analyze the collections

themselves, a form of analysis which allows managers to monitor collections usage over time and can show quantitatively how collections have a wide range of uses may prove extremely useful in detecting potential trends in collections usage. These trends can be used to help establish plans for satisfying future collections needs. This study has begun to fill a gap in knowledge concerning collections use, and can provide baseline results for future researchers to perform similar studies. Lastly, the methods explored here form a powerful tool for analysis that can be applied used to answer a wide range of collections questions. More research of this kind will help illustrate the importance of recording Earth's biological legacy to the scientific community and beyond.

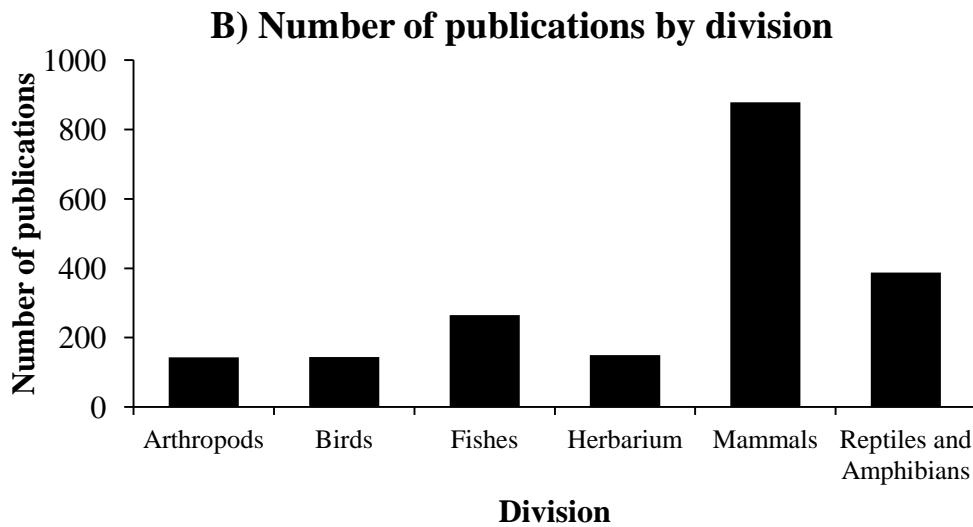
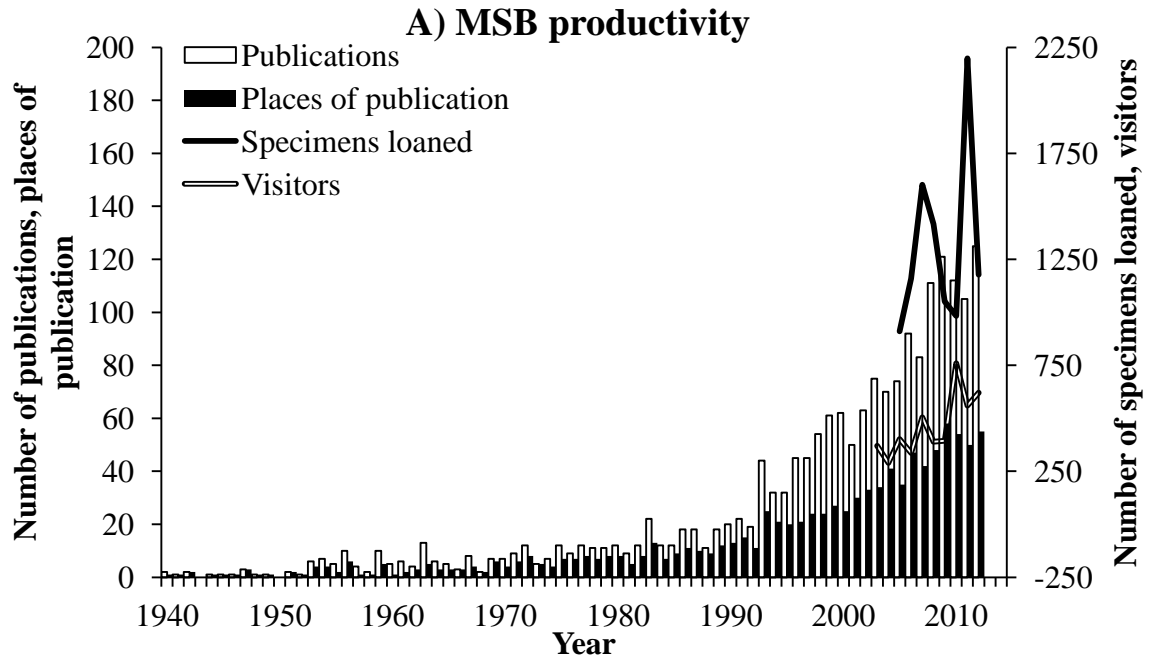


Figure 1. A) depicts the total publications, loans, and visitors of MSB's Arthropods, Birds, Fishes, Herbarium, Mammals, and Reptiles and Amphibians divisions per year, 1940-2012. The black line depicts the number of specimens loaned, as recorded in Arctos for the Mammals and Birds divisions (and their respective tissue loans), 2005-2012. The shadowed double line depicts the totaled number of visitors to MSB for the Birds, Fishes, Herbarium, and Mammals divisions, 2003-2012. B) shows the number of publications by division.

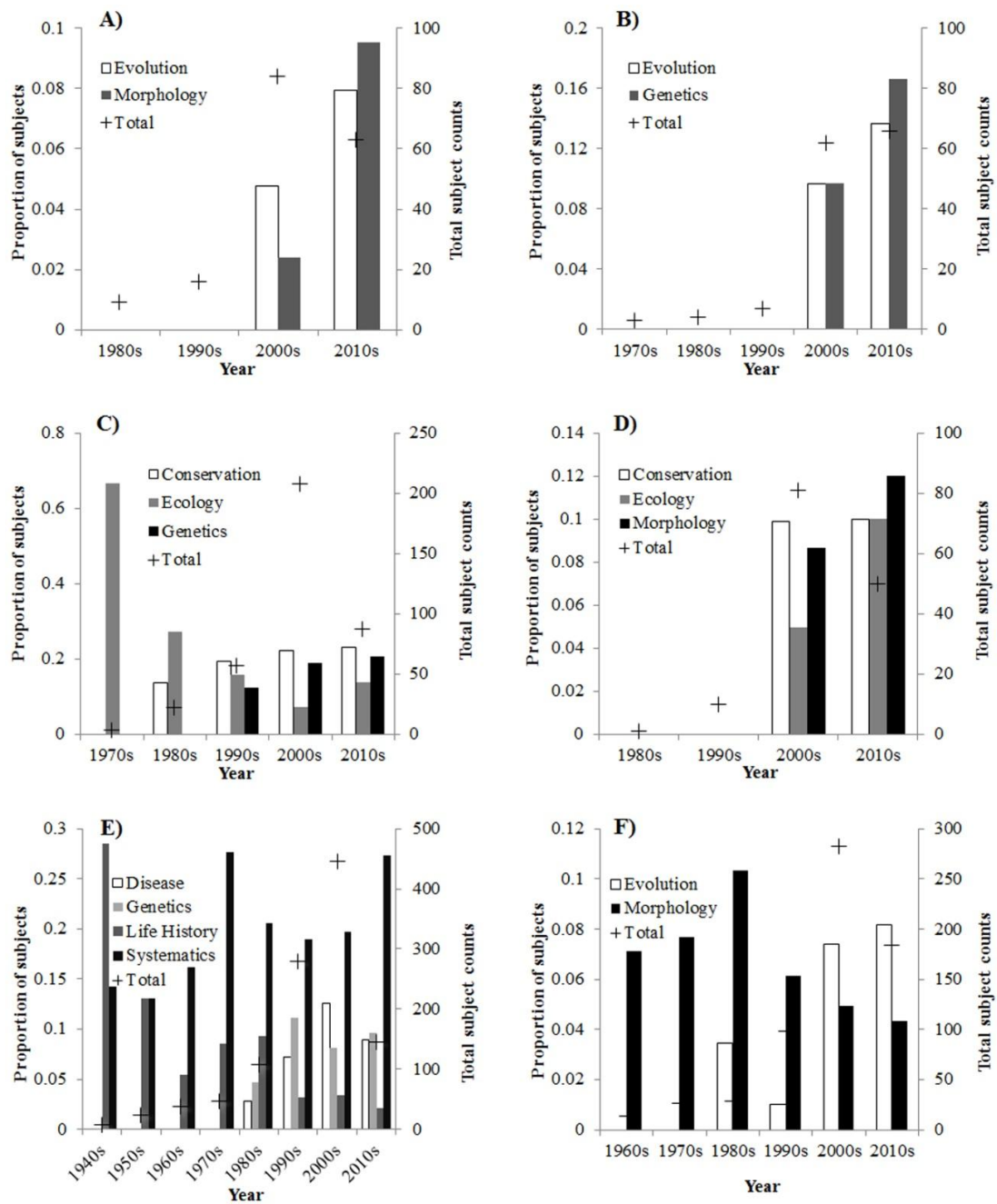


Figure 2. The proportions of pertinent subjects for each division per decade: (A) Arthropods, (B) Birds, (C) Fishes, (D) Herbarium, (E) Mammals, and (F) Reptiles and Amphibians. Bars indicate the proportions of the subjects, while crosses on the secondary axis indicate the total counts in all subjects for each decade.



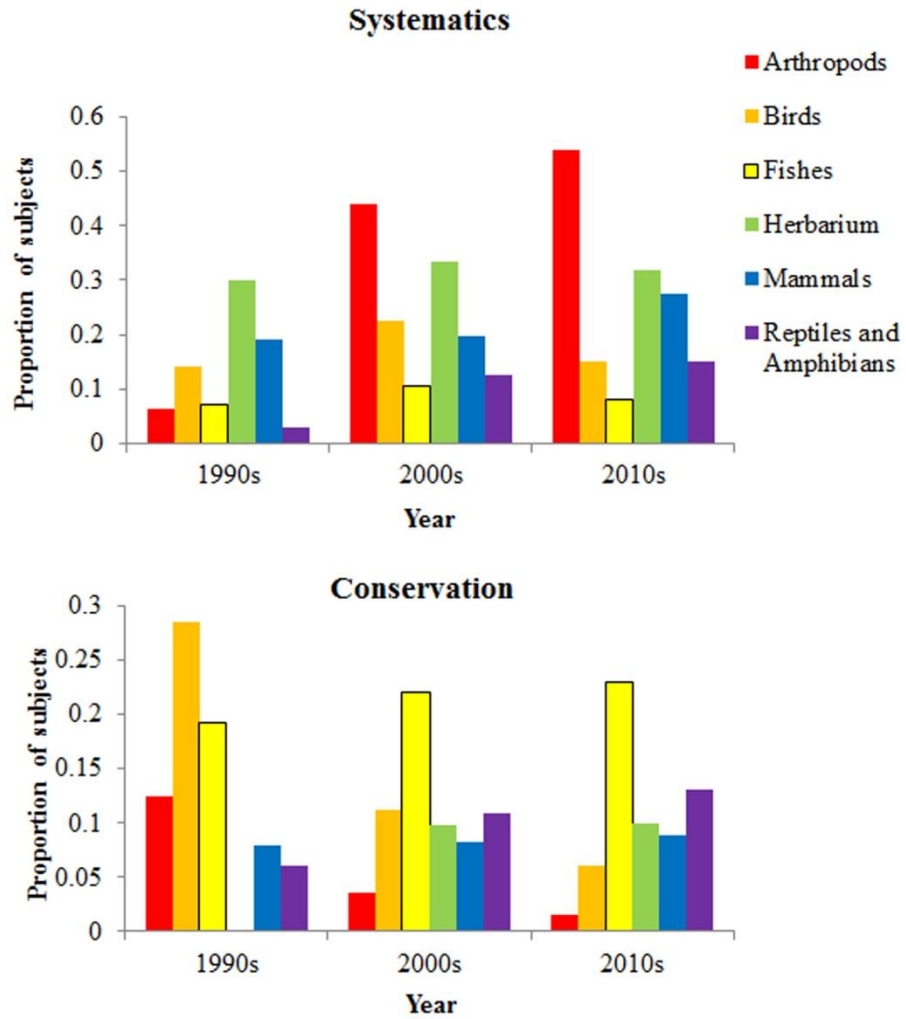


Figure 3. The proportions of the subjects Systematics and Conservation across divisions per decade, 1990-2013. Note the high proportion of the subject Systematics for taxa with high numbers of species, and the high proportion of the subject Conservation for taxa with relatively few species.

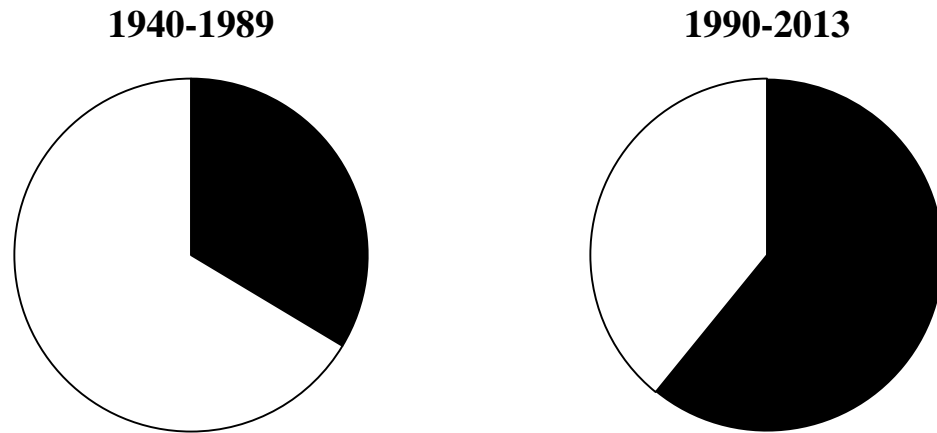


Figure 4. The ratio of the new usage category (black) to the traditional usage category (white; see Appendix 2), shown for the two time periods, 1940-1989 (n=128) and 1990-2013 (n=902). The proportion of the new usage category increased significantly in the second time period, with a proportional decrease of the traditional usage category ( $P < 0.01$ ,  $X^2 = 34.108$ ).

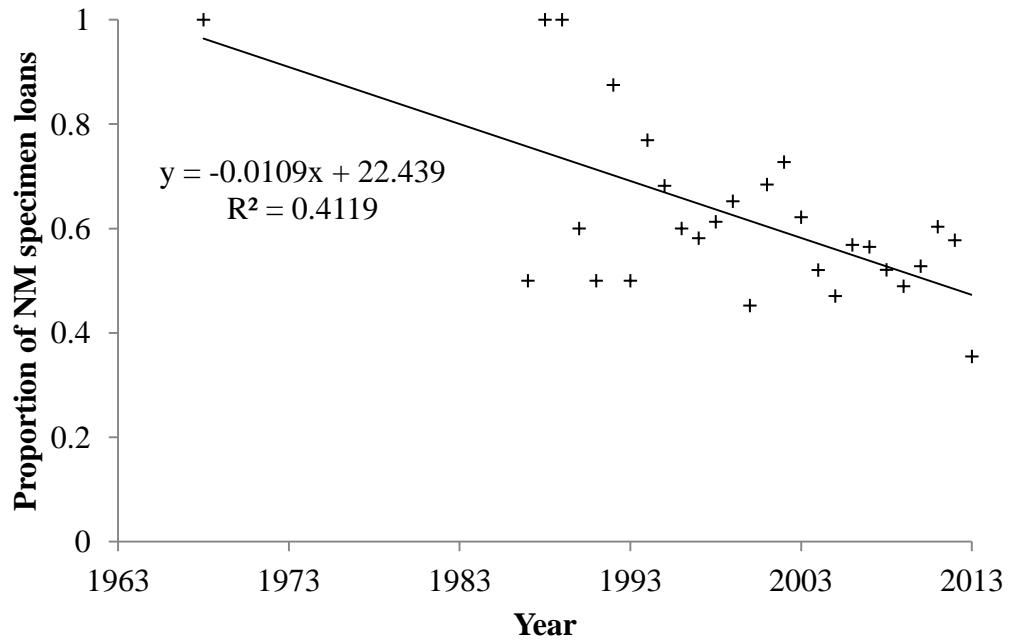


Figure 5. The proportion of loans containing specimens collected in New Mexico, from all loaned specimens with recorded localities of collection, 1968- 2013. Crosses depict proportions per year while the black line depicts a linear line of best fit, with equation and  $R^2$  value shown.

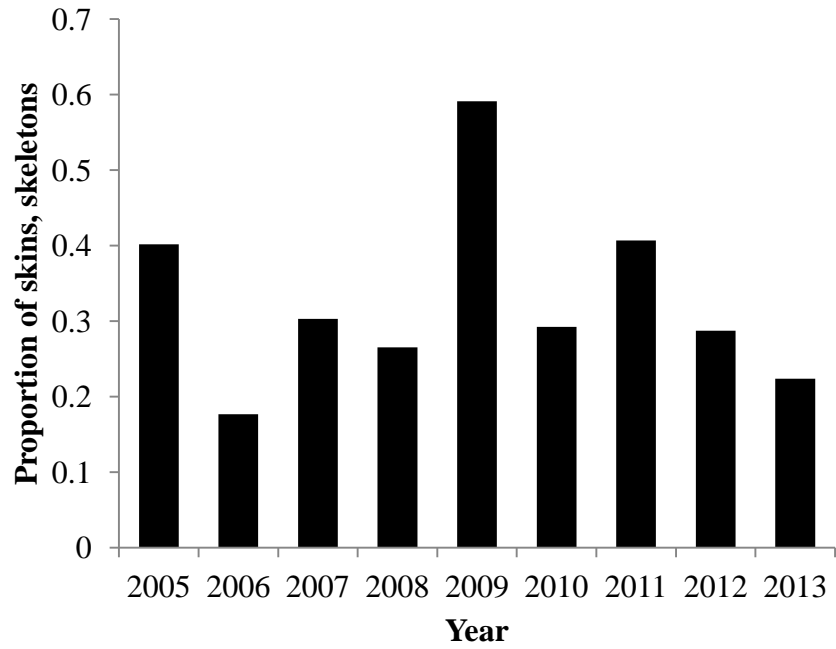


Figure 6. The proportion of skins and skin parts (not ear clips) and skeletons and skeletal parts (not whole organisms) from all parts loaned from the Mammals and Birds divisions, including tissue loans from MSB's Division of Genomic Resources for those divisions, 2005-2013.

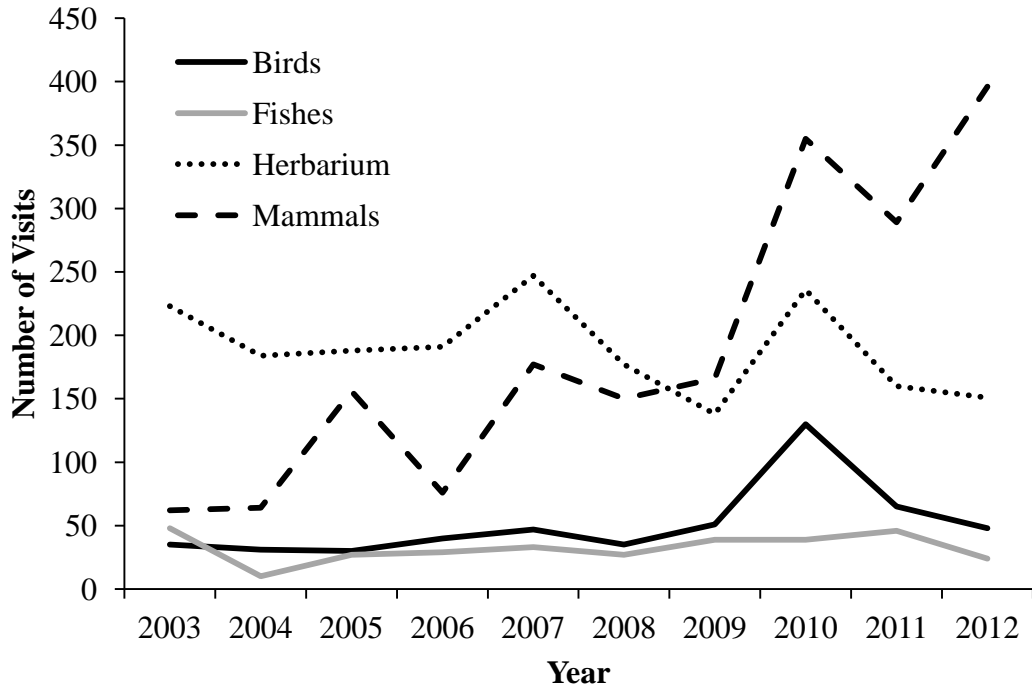


Figure 7. The number of visitors per year to the Birds, Fishes, Herbarium, and Mammals divisions, 2003-2012. Visits to the Mammals division have increased over time most strongly.

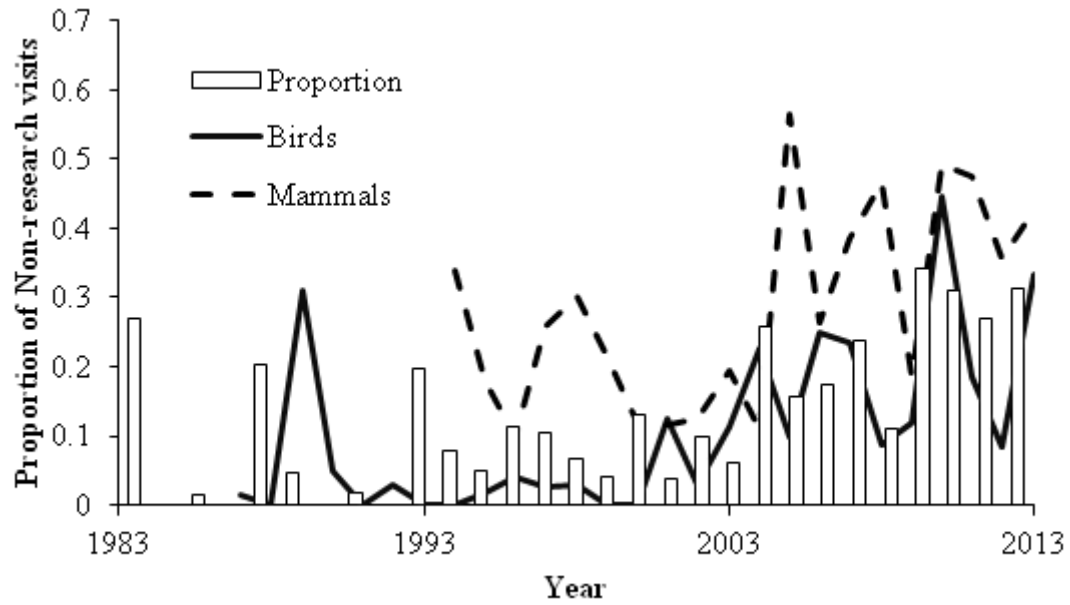


Figure 8. The total proportion of non-research visits to the six divisions out of all visits per year, 1987-2013 (white bars). Lines depict the proportion of non-research visits in the Birds and Mammals divisions, which show the most marked increase.

## **CHAPTER 3. AN EXHIBIT ILLUSTRATING NATURAL HISTORY SPECIMEN USE IN CONSERVATION RESEARCH IN NEW MEXICO**

The following narrative is based on the narratives for science exhibitions in McLean and McEver (2004).

### **Exhibit Information.**

*Museum-* New Mexico Museum of Natural History and Science (NMMNHS)

*Title-* Conserving New Mexico: protecting nature's history in museum research collections

*Budget-* \$900.00 with budget assistance from NMMNHS.

*Main Participants-* Bethany Abrahamson, Curator; Dr. A. Burdett, Co-Curator;  
NMMNHS Committee: M. Celeskey, R. Dominguez, C. Ellison, P. Gegick, B. Grace, J. Hevey, D. Novak, M. Pierce, M. Sanchez, D. Secrist, and P. Toledo; MSB Committee: Dr. J. Cook, Dr. T. Lowrey, Dr. K. Miller, Dr. H. Snell, Dr. C. Witt, Dr. J. Dunnum, Dr. T. Giermakowski, A. B. Johnson, D. Lightfoot, and P. Tonne.

### **Exhibit Description.**

“Natural history collections allow researchers to go back in time and see a glimpse of New Mexico’s natural world of the past. They also help us understand how to conserve the state’s beautiful wildlife for the future” (Appendix 4). This exhibit explores through six vignettes how research collections have contributed to learning more about and protecting New Mexico’s wildlife. Exhibit planning began in September 2013 and was completed in January 2014.

### **Background.**

Natural history collections are central to almost every aspect of biology and are especially vital to the field of conservation. The specimens stored in natural history collections provide information for a variety of conservation-related projects, including studies of distribution, population sizes, and effects of pollutants and climactic change (Pyke and Ehrlich 2010, Winker et al. 2010). Without scientific collection of plants and animals, government-sanctioned conservation programs would not exist. However, the broader public and even some academics have little knowledge or understanding of how collections are used in conservation efforts, and public understanding of how current scientific issues are being explored in museum collections is lacking (Schmidly 2005, Conn 2009:51, Valdecasas et al. 2010, Bennett 2013). This is problematic, considering how invaluable these collections are in helping to monitor the planet’s biodiversity and environmental change (Winker 2004, Suarez and Tsusui 2004, Johnson et al. 2011).



I created this exhibit to educate the public about the importance of natural history collections for conserving the world's wildlife. The idea for the exhibit was first conceived of in the wake of a Memorandum of Understanding between MSB and NMMNHS, which encouraged increased collaborations between the museums. MSB is a research collection with few opportunities for public exhibits. Therefore, I intended this exhibit to link biological research with education and providing a forum for MSB to interface with the public without being detrimental to MSB's research projects. This exhibit would also assist the University by interacting with the public to demonstrate how important natural history collections are, which can have a positive influence on public awareness and future funding for MSB and other university-based collections.

This exhibit allowed me to explore how museums can best illustrate the importance of collections for the public. By building an exhibit, I received hands-on experience as well as research experience with museums, which were essential for me to appropriately focus my degree in Museum Studies. Building a publicly-focused exhibit from the ground up provided me with experience in multiple aspects of museum work and effectively prepared me for a career in museums. Working directly with two different museums and gaining multiple perspectives of museum work allowed me to synthesize across museum departments and facilitate cooperation between those departments in the future.

This exhibit furthered NMMNHS's mission by educating viewers about how scientists have learned about the wildlife of New Mexico to better conserve nature, thus helping visitors better understand New Mexico's scientific heritage. It featured specimens from

New Mexico and utilized NMMNHS and MSB collections to give visitors a rare glimpse into our state's natural heritage.

This kind of exhibit benefits the community by educating viewers in a popular venue about scientific study of the wildlife of New Mexico and encourages visitors to appreciate New Mexico's scientific and natural heritage. Lastly, it was intended to raise awareness for how museums help conserve the natural world, illustrating the crucial role biological collections play in understanding the natural world.

After entering into talks with NMMNHS Director Charlie Walter, MSB Director Dr. Joseph Cook, and NMMNHS BioScience curator Dr. Ayesha Burdett, the concept for the exhibit was established and a proposal was created. The exhibit was accepted in the spring of 2013 and production began in September of the same year.

### **Funding and Budget.**

The original budget for the exhibit was based on conversations with NMMNHS staff as well as personal research. The exhibit was funded by a grant from the UNM Biology Department's Graduate Research Allocations Committee and by the UNM Graduate and Professional Student Association Student Research Grant, giving the exhibit a total budget of \$900.00. If more funds were procured, the exhibit size could have been expanded. As it was, costs were reduced by borrowing two vitrines and one temporary

display wall from NMMNHS and re-furbishing them. After the funding was secured, the final exhibit expenses were determined and a final budget was created (Appendix 3).

### **Exhibit Learning Goals.**

Natural history collections are critically important for preserving biodiversity on the planet. It was originally intended that the exhibit focus on how specimens and collections contribute to conservation efforts in three ways: by mapping species distribution changes, tracking extinction, and understanding adaptation to changes in the environment.

However, as the exhibit was further developed and the budget solidified, we determined that each story the exhibit covered would point toward the main learning goal instead of trying to establish three secondary learning goals. This left the exhibit with the final learning goal: “Natural history collections allow researchers to go back in time and see a glimpse of New Mexico’s natural world of the past. They’re also an important part of putting a pause on extinction.”

### **Audience.**

This exhibit focused on people who wonder why scientists collect animals and plants and how collections help to conserve the Earth’s wildlife. The target audience was adults and students, but it was also intended to be understandable and inspirational to children.

### **Physical walkthrough.**

This exhibit was built around a small column in the atrium, and was composed of two vitrines and one wall-mounted case. Upon approaching the exhibit, the visitor first sees the title panel, which encapsulates the message of the exhibit. Directly below, the visitor finds the first specimens—a pair of newly-discovered insects from White Sands, displayed on their natural substrate (gypsum-mineral substrate from White Sands) with magnified pictures of the insects and their natural environment. Here, the visitor discovers how naming and describing species is the first step to conservation. The visitor may head in either direction around the column at this point, but if she continues to the other specimens in the case she finds a large image of a deformed frog from Los Lunas combined with comparable specimens displayed in a jar. The accompanying story explains how previous collections of deformed frogs can be compared to current ones to determine why, when, and where deformations occur (Figure 9). Continuing around in the case, the visitor observes a typical research specimen and understands what they are and what information they hold (Figure 10). Next the visitor sees a series of three pikas collected in New Mexico, a map of where pikas have been collected, and information about how distribution of pikas can be reliably mapped using museum specimens (Figure 11). Here, the visitor's eye may quickly be drawn to the large taxidermied otter specimen that is presented in its own case and is positioned on a life-like sandy riverbank. The otter curiously 'observes' the visitor while she reads that the otter displayed is the only Southwestern River Otter collected in New Mexico, and learns about the re-introduction of otters into New Mexico. After observing the otter, the visitor looks up and sees images of Southwestern Willow Flycatcher specimens, as well as a painting of a Southwestern

Willow Flycatcher in its natural habitat. The accompanying text explains how their range contraction, tracked using museum specimens, allowed the bird to be listed as an endangered species (Figure 12). The visitor ends their journey by observing the Holy Ghost ipomopsis and sees that collections hold yet-to-be-made discoveries that can save species from extinction (Figure 13). A credits panel gives acknowledgements and funding sources. Appendix 4 gives the script in its entirety, as well as a list of specimens used.

This exhibit was housed in the atrium. NMMNHS's permanent exhibits focus on prehistoric animals; therefore the atrium, which houses many temporary exhibits, is best-suited to house an exhibit focused on modern New Mexico species and science.

### **Development Process and Changes.**

Before attempting to create an exhibit for the general public, I was able to practice the skills required to put together an exhibit (including choosing specimens, writing labels and coordinating with other museum professionals), for a display case located in Castetter Hall at UNM. The exhibit, titled *Seeking Out Specimens*, allowed me to experiment with constructing an exhibit from the ground-up and provided me with the basic knowledge of potential hazards and considerations in a more positive learning environment (Figure 14).

*Exhibit Team-* When the project began, I was in charge of arranging meetings between interested parties in both MSB and NMMNHS. This first involved working with

personnel at MSB and NMMNHS to establish a schedule for the steps that would need to be completed for the exhibit and making sure everyone involved with the exhibit was in agreement with it. I researched the stories I wanted to share in the exhibit and worked extensively with Ayesha Burdett, Patti Gegick, and MSB collection managers and interested curators at MSB to write the text with a focus on being scientifically accurate as well as concise. I obtained information for the exhibit from them and from other sources (including Johnson et al. 2003, Holy Ghost ipomopsis 2005, Stuart 2008, Hafner and Smith 2010, McDonald 2010, Tests under way in deformed frog waters 2010, and Erb et al. 2011), while the collection managers performed final fact-checking of the information. Janet Hevey and Chris Ellison, as well as Matt Celeskey, worked with me on the construction. With their assistance in editing and choosing images, I created the graphics while the exhibits team at NMMNHS built and assembled the display cases. I oversaw and was involved with the final construction, including its installation at NMMNHS.

*Text Design-* The proposed specimen list included the Silvery Minnow (*Hybognathus amarus*), Southwestern River Otter (*Lontra canadensis sonora*), Rio Grande Bluntnose Shiner (*Notropis simus simus*), American Pika (*Ochotona princeps*), and deformed bullfrogs (*Rana catesbeiana*). Of these, I eventually decided to use the American Pika, deformed bullfrogs, Southwestern River Otter, and added the Southwestern Willow Flycatcher, gypsum grasshoppers from White Sands National Monument, and Holy Ghost ipomopsis. Both the Southwestern River Otter and the White Sands insects were added in during after the first drafts of the text were completed.

Telling six stories in such a small space is no easy task. The greatest design challenge was creating stories that fit the size of the specimen. Unfortunately, some specimens were small and telling their complete story became difficult, and in some cases the words appeared to overcrowd the specimens. Images of specimens and researchers aided in breaking up the text, as did the ADA requirements. The text was also edited to reflect a lay audience, and the text went through five drafts before the final was completed. As the exhibit developed, the text word count decreased; however, we decided to maintain the proposed number of specimens and stories as was originally intended. This was done in order to maintain focus on the exhibit's learning goal and keep visitors visually interested by providing choices in different kinds of objects to look at. A public natural history museum provides information in an informal way, and giving visitors the chance to explore many objects and have many opportunities for gaining interest in the topic became more important than providing copious amounts of scholarly information.

*Exhibit Design-* An L-shaped case, a standard vitrine, and an installed wall unit were all borrowed from materials already present at NMMNHS. This reduced costs and allowed more of the budget to be spent on graphics. The box that housed the herbarium sheet was custom-built for the exhibit. Text, graphics, and specimens were measured and arranged on a digital version of the exhibit layout before mock labels and specimens were created to arrange in the actual cases. Text and graphics were created and arranged within ADA compliance parameters.

Keeping both museums on the same page proved to be the most challenging aspect of the exhibit's development. This exhibit brought together two different museums with different missions, and attempted to link them cohesively. The largest difficulty with this was getting MSB appropriately involved, considering that their focus is on research rather than public outreach.

Since this exhibit utilized research specimens, protecting them from exposure to light, humidity, excessive temperatures and pests was of top priority. The specimen with the greatest number of conservation concerns was the Holy Ghost ipomopsis. Herbarium sheets are usually stored flat and kept out of direct light, so displaying a specimen to the public required that NMMNHS build a special case that would hold the herbarium sheet by itself under appropriate conditions. To cut down on costs, there was only one viewing window into the case, with the window being made of UV-resistant plexiglass. The case was lined with acid-free foamcore to protect the specimen from paint and the specimen was set at a slight incline. I worked with NMMNHS and MSB's Herbarium collection manager to make sure that the specimen was visible but also well-protected. Other specimens were also protected from harm in communication with their respective collection managers. The pikas and the bird specimen were both placed on cloth to keep them from touching painted surfaces, and the insects were securely pinned in boxes. All specimens were positioned out of direct sunlight.

## **Evaluation.**



When this exhibit was constructed, I intended to write a report to include the building process, the success of the exhibit using analysis of visitor use, and a discussion of how museums like MSB might better illustrate their importance to the public and policy-makers.

In practice, this meant observing exhibit outputs (Wells et al. 2013). I spent ca. ten hours observing visitors at the exhibit on Fridays and Saturdays, between late morning and early afternoon hours (ca. 10:30 AM-2:00 PM). I counted the number of visitors that approached the exhibit, their age category (adult or child), and the approximate time a visitor stayed at the exhibit if longer than ca. one minute (in trying to remain an anonymous observer, a small number of visitors may have gone unrecorded).

During these hours of observation I counted 273 visitors, amounting to an average of ca. 28 visitors per hour. Adults comprised over 50% of these visitors, and most visitors spent less than a minute observing the exhibit. The longest time that a visitor spent at the exhibit was approximately 153 seconds; an average of about two visitors per hour remained at the exhibit for longer than ca. one minute. The average number of visitors per hour decreased about a week after the exhibit opened.

Considering that most attendees at natural history museums are children (Conn 2009:138-171), my results illustrate the focus that my exhibit had on adult or young adult audiences. Children appeared to be interested in the animals, while adults spent more time observing labels and interpreting them for their children and friends. The exhibit is

small, and at least one of the six stories displayed can easily be fully explored in under a minute, explaining the majority of under-minute observations of the exhibit. Those that spent more than a minute at the exhibit took their time to see the entire exhibit, which is a sign of learning success for those visitors (Serrell in Hein 2002:107). If the first week is not taken into account, there were an average of about 20 visitors per hour, leading to a projected impact of nearly twenty-seven thousand visitors reached in the entire run of the exhibit.

I also held two training sessions to educate museum volunteers and docents further on the exhibit and prepared them to discuss the exhibit with visitors and answer their questions. At these training sessions I expanded on the topics covered in the exhibit in more detail and answered questions about the exhibit. This experience helped me concisely summarize the exhibit and expand on particular topics for the museum's interpreters in an informal environment. This also gave me the opportunity to evaluate my exhibit, even if changes could not be made at that point.

### **Lessons Learned.**

I plan to take what I've learned from the exhibit-building process and apply it in future exhibit endeavors.

Much of what I learned about how to create a cohesive exhibit was absorbed during the months and weeks that I spent working with MSB and NMMNHS before the exhibit

opened. An exhibit designer and curator requires a number of skills to build an effective exhibit, such as the ability to work with others, adequately research the topic, and apply knowledge about design, conservation of specimens, and prioritize visitor accommodations. I found that instructing myself regarding best museum practices, for instance, in label writing, was most applicable in the earliest stages of the exhibit's development. Once the exhibit was in production, however, the instruction available from purely academic venues did not provide much assistance—my problems were too specific for general books on exhibit to be of use. Budget allocation decisions had to be made well in advance, making late additions of interactive elements or other additions impossible to implement. Therefore, I believe that researching exhibit methods well in advance of exhibit production would allow lessons learned from books on museum interpretive theory to be better applied.

In post-production and after the visitor observations and docent trainings, there were several aspects of the content that I would change in future iterations of the exhibit. The first is accessibility. While I originally intended my audience to be adults, it is a reality that science museums are most frequented by children. I included too few learning perspectives that could engage a wide variety of learners, meaning that my message may not have been interpreted well. Increased information on the wildlife itself, as well as providing information on the mechanics of how researchers prepare specimens, since these were the topics I received the most questions about, may have assisted in engaging visitors with the subject matter. Lastly, interactive elements which allowed visitors to participate in an activity, a different sensory perception such as a video or sound clip, or

open-ended questions to spark discussion, might reach more viewers and improve learning from the exhibit.



Figure 9. *Conserving New Mexico*, entrance-facing angle. Images shown in photo courtesy of Mason Ryan, David Lightfoot, and UNM Art and Ecology.



Figure 10. “What is a research specimen?” in *Conserving New Mexico*. Image shown in photo courtesy of UNM Art and Ecology.



Figure 11. “Pikas: Using the Past to Predict the Future” in *Conserving New Mexico*. Images shown in photo courtesy of Sally Thomson and NMMNHS.





Figure 12. Southwestern River Otter specimen and Southwestern Willow Flycatcher images in *Conserving New Mexico*. Images in photo courtesy of James N. Stuart, Andrew B. Johnson, and Bethany Abrahamson.





Figure 13. Holy Ghost ipomopsis in *Conserving New Mexico*. Images shown in photos courtesy of Phil Tonne.

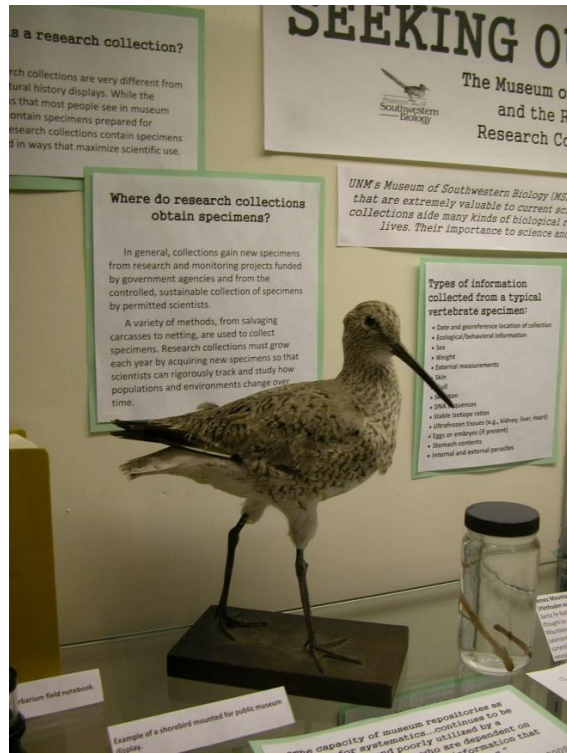


Figure 14. The preliminary exhibit, *Seeking Out Specimens* (2013). Images shown in photo courtesy of David Lightfoot.

## CHAPTER 4. CONCLUSIONS

I have shown that regional NHCs like MSB are a major scientific infrastructure, particularly for the state but also for outside audiences as well; research NHCs in particular are beneficial far beyond academia. They make themselves useful through their application in a wide variety of important studies, but that utilization can be explained in many meaningful ways according to the questions asked and the audiences they are answered for. My research hoped to provide some ways for NHCs to be explained to a broader audience of funding groups, administrators, other scientists and the public. MSB in particular is growing into a larger role in the scientific community, making these kinds of justifications even more necessary. However, justification cannot and should not be uniform across audiences. Considering the diverse groups that NHCs serve, careful thought must be given to how their uses are explained according to the audience. There are many ways in which utilization can be analyzed, and I hope that my research has provided some insight into different methods for this purpose that can be integrated into future research. More research of this nature can help museums forecast future uses of collections and establish strategies for how collections can continue to be useful and beneficial.

## APPENDICES

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## **Appendix 1. Explanation of publication data.**

The publications dataset included publications which referenced the Museum of Southwestern Biology. Mostly this definition encompasses journal articles that cite MSB specimens or MSB itself, although the dataset includes books as well as 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/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 which 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 (4 of 4 responses). Collection managers either used search engines when looking for publications or planned to do so in the future. Search phrases that collection managers used (or planned to use) to look for publications via search engines included general phrases like “Museum of Southwestern Biology” and “MSB” as well as more specific phrases including “mammal” and “distribution: UNM.” One collection manager noted that he also researches publications that likely used MSB specimens via GenBank.

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 require 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 as the completion of such research projects are considered to be a university-mandated requirement. Overall, 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.

## Appendix 2. Search phrases with their associated groupings.

In (A) the subjects are shown with their associated search phrases and usage categories for the publications dataset. (B) depicts the search phrases used on the guestbook dataset and are shown with their respective affiliation groups.

A.

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

Appendix 2 continued on next page.



Appendix 2 (continued)

B.

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

**Appendix 3. Initial (A) and final (B) budgets for *Conserving New Mexico*.**

**A) Initial budget.**

<b>Item</b>	<b>Cost (USD)</b>
Graphics	500.00
Collections-style drawers- four at 125.00	500.00
UV filter acrylic for one case (opt.)	268.00
Two Cases (3/4" MDF base + 0.25" acrylic top, 2'x4') x 2	1400.00
<b>TOTAL</b>	<b>2668</b>

**B) Final budget.**

<b>Item</b>	<b>Cost (USD)</b>
Paint- Three quarts	37.82
Herbarium case- UV filtering plexiglass	33.50
Herbarium case: Sheet stock, fasteners, glue, and paint	~15.00
Herbarium case: Acid-free backing board	3.00
Matte	2.06
Paper- 20.22 sq. ft. foam core, paper, and laminates, at 11.00 per sq. ft.	233.42
<b>TOTAL</b>	<b>324.80</b>

#### **Appendix 4. Final text script and specimen list for *Conserving New Mexico*.**

##### *Final text script-*

Title Panel- CONSERVING NEW MEXICO / Preserving nature's history in museum research collections / Natural history collections allow researchers to go back in time and see a glimpse of New Mexico's natural world of the past. They also help us understand how to conserve the state's beautiful wildlife for the future.

Panel 1: Text, image, and caption- What is a research collection? / Research collections aren't your typical taxidermy displays. While the collections that most people see in museums contain animals and plants prepared for display, research collections store specimens behind-the-scenes, preserved in ways that maximize their use to science. These collections are crucial for many kinds of study, and data from these studies can pave the way for the conservation and management of threatened species. / The Museum of Southwestern Biology research collection, located at the University of New Mexico. Photo by Bethany Abrahamson.

Section Label 1: Text- Monitoring wildlife over time keeps track of where species are in comparison to where they've been. This helps us conserve animals and their habitats by establishing management plans and designating protected lands.

Story 1, Label 1: Text, image, and caption- Pikas: Using the Past to Predict the Future / Pikas are small mammals that populate the Rocky Mountains of New Mexico and

beyond. High elevation animals, like pikas, live in cold isolated mountaintop habitats. Researchers predict the cold habitats will be lost as the world gets warmer. This puts them at a greater risk of becoming endangered, and even going extinct.

Story 1, Label 2: Text- Information about where and when pikas have been found is stored in collections. Researchers use data from collections as a baseline to make surveys of pika populations and develop distribution maps. When these areas are surveyed repeatedly, information can be combined with research collection data to see how distributions have changed through time.

Specimen Label- Pika (*Ochotona princeps*) NMMNHS 122, 2650, 1762.

Story 2, Label 1: Text, image, image caption - Holy Ghost Ipomopsis: A Ghost in the Collection / Species aren't always identified correctly at first sight. In fact, the shelves of research collections can be the stage for all-new discoveries. Researchers first named the beautiful Holy Ghost Ipomopsis in the 1980s. However, it had been collected and stored in a research collection since 1929. / Photo courtesy of Phil Tonne.

Specimen Label- Holy Ghost Ipomopsis (*Ipomopsis sancti-spiritus*). MSB 76373.

Story 2, Label 2: Text, image, image caption- Using the historical record of specimens, researchers discovered this rare flower had only been observed in the Holy Ghost Canyon of New Mexico. However, they also realized that the areas where it could reliably be

found were rapidly dwindling. One forest fire could wipe out the species forever. This has spurred timely conservation efforts that will help protect the plant from extinction and preserve one of New Mexico's unique natural treasures. / Holy Ghost Ipomopsis restoration in action. Photo courtesy of Phil Tonne.

Panel 2: Text- What is a research specimen? / A research specimen consists of a collected animal, plant or other organism with data about where and when it was collected. Both parts are essential for a useful research specimen.

Specimen Label- Research specimen with catalog sheet. NMMNHS 235.

Section Label 2: Text- How wildlife changes to cope with alterations in its environment can help us see how future changes might affect New Mexico's wildlife.

Story 3, Label 1: Text, image, image caption- Southwestern Willow Flycatcher: Impacts of Habitat Change / The Southwestern Willow Flycatcher is an endemic subspecies of songbird found in riparian habitats (along rivers) in the southwestern United States. As humans altered their habitat, flycatcher populations declined, even though they adapted to nest in habitats with introduced vegetation like salt cedar. Documentation of its restricted range and declining population status that eventually led to conservation efforts (including its listing under the Federal Endangered Species Act) was dependent upon specimens archived in museum collections.

Painting Label- Southwestern Willow Flycatcher (*Empidonax traillii extimus*) Painting  
by Andrew B. Johnson.

Story 4, Label 1: Text, image, image caption- American Bullfrogs: Mysteries of Change /  
Deformed frogs found in a pond near Los Lunas alerted scientists to a change in the  
environment that might have caused the deformations: the arrival of a trematode parasite.  
While these parasites occur naturally in the Midwestern United States, the abnormalities  
that often result from a trematode infection had not been documented in New Mexico  
until 2010. Epidemics can indicate subtle changes in the ecosystem and can often be  
investigated using research collections. / Frog specimen collected near Los Lunas.  
Infections often cause deformities or prevent growth of limbs. / Photo courtesy of Mason  
Ryan.

Story 4, Label 2: Text, image, image caption- Biologists can explore historical collections  
to discover where and when deformities have been found in frog populations. When  
combined with new information, biologists can then make predictions regarding where  
problems of this kind are likely to show up next and why. / Researchers explore the pond  
where deformed frogs were found. Photo courtesy UNM Art and Ecology.

Specimen Label- American Bullfrogs. (*Rana catesbiana*). MSB 78289, MSB 78281.

Story 5, Label 1: text, 4 images with captions, overall caption- Gypsum Grasshoppers:  
Discovering a New World / The discovery of new insect species is not uncommon in the  
Southwest, especially in areas with unique environments. Habitats like the gypsum dunes

and outcrops at White Sands National Monument are home to several insects that are adapted to live on or in gypsum soils and occur nowhere else in the world. Developing a baseline for species diversity in New Mexico's one-of-a-kind habitats is the first step to conservation. / *Cibolacris* sp. nov.; *Trimerotropis* sp. nov. 1 / Gypsum dunes; gypsum mineral outcrop / These grasshopper species, pictured on their natural gypsum substrates, were discovered in White Sands National Monument in Alamogordo, New Mexico.

Story 5, Label 2: Text- Collections of specimens help researchers learn about the evolution of new traits, like camouflage coloration in these gypsum grasshoppers. They also give us a better idea of what kinds of fascinating creatures call New Mexico home. Without this knowledge, we would not understand how best to conserve and manage these precious environments.

Specimen Label- Gypsum Grasshoppers, new species (*Cibolacris*, *Trimerotropis*). D. Lightfoot collection.

Story 6, Label 1: Text- This otter, collected in the 1950s, is the only surviving specimen collected in New Mexico. Just this one specimen, along with the field notes of past researchers, has led current biologists to believe that otters used to thrive as New Mexico natives.

Specimen Label- Southwestern River Otter (*Lontra canadensis sonora*). MSB 50000.

Story 6, Label 1: Text, image, image caption- With the information that this specimen has given us, the New Mexico Department of Game and Fish started a re-introduction program in 2008, and released 33 otters into the Upper Rio Grande. / Otter release site.

Photo courtesy of James N. Stuart.

*Specimens borrowed for Conserving New Mexico, with their respective catalog numbers.*

*Institution codes are for the New Mexico Museum of Natural History and Science*

*(NMMNHS), the Museum of Southwestern Biology (MSB), and the private collection of*

*D. C. Lightfoot (DCL):*

*Carpodacus mexicanus* (NMMNHS 235); *Cibolacris* sp. nov (DCL); *Ipomopsis sancti-*

*spiritus* (MSB 76373); *Lontra canadensis sonora* (MSB50000); *Ochotona princeps*

(NMMNHS 122); *Ochotona princeps* (NMMNHS 2650); *Ochotona princeps* (NMMNHS

1762); *Rana catesbiana* (MSB 78289); *Rana catesbiana* (MSB 78281); *Trimerotropis* sp.

nov. (DCL)



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