SOUTH DAKOTA'S NATURAL HISTORY COLLECTIONS: AN ENDANGERED TEACHING AND RESEARCH RESOURCE

M. L. Gabel
Department of Biology
Black Hills State University
Spearfish, SD 57799

P. J. Johnson
Plant Science Department
South Dakota State University
Brookings, SD 57007

G.E. Larson
Biology and Microbiology
South Dakota State University
Brookings, SD 57007

D. J. Ode
South Dakota Natural Heritage Program
Department of Game, Fish and Parks
Pierre, SD 57501

H. A. Downing
College of Arts and Science
Black Hills State University
Spearfish, SD 57799

G. M. Kostel
Department of Biology
Black Hills State University
Spearfish, SD 57799

ABSTRACT

Natural history collections including plants, fungi, insects and vertebrates are the critical base for research and teaching in the biological sciences. There are several important and irreplaceable natural history collections associated with the institutions of higher education in South Dakota that are the result of over a century of work by biologists in the state. Unfortunately, at the present time there are looming dangers to these collections including lack of staffing, and constant threats due to insects, fungi, and unstable environmental conditions. It is critical to provide support for these collections to ensure the preservation of valuable information in the collections, to allow future generations of South

Dakotans access to their natural heritage, to study biodiversity, to support basic and applied science, to plan for future endeavors, to monitor pest species, and to provide baseline data for future studies. Recommendations are made for support for collections in the university system.

IMPORTANCE AND USES OF NATURAL HISTORY COLLECTIONS

Natural history collections contain a wealth of data including genetic and phylogenetic information within the organisms, and ecological and biogeographical information on the specimen labels which yield a scientific specimen of great intrinsic value (Lane, 1996). Natural history collections are the acknowledged foundation of research in biological sciences. The information content of a natural history collection is tremendous. Biological specimens document: (a) the time of appearance or disappearance of an organism in a particular locality; (b) the range of variation within a species; (c) the nature of evolutionary processes; and (d) the life cycles of a particular organism. They also (e) provide material for study away from the field or during another season. They serve as: (f) voucher specimens, that document the identity of organisms used in taxonomic, chemical (i.e., DNA), or cytological, or other studies, and as (g) type specimens upon which names are based.

A few examples of their uses include the following:

- contribute "unique and invaluable insights to the study of pathogens, vectors of disease and environmental contaminants" (Suarez and Tsutsui, 2004),
- provide for the study of numerous environmental contaminants including mercury, DDT and atrazine (EPA, 2002; Hickey and Anderson, 1968; Hayes et al., 2002),
- document the pace and ecological consequences of biological change caused by habitat loss (Shaffer et al., 1998),
- document the effects of climate change on numerous organisms including changes in distribution and changes in the biology of particular species in response to climate change (Suarez and Tsutsui, 2004), and
- determine the distribution of invading species, identify the source of the invasion, and to gauge the ecological impact of the invaders (Suarez et al., 2001).

Scientific collections are obviously essential for taxonomic and systematic research, but collections also make significant contributions to basic and applied science, including anatomy, botany, ecology, genetics, morphology, mycology, phylogenetics, population biology, structural biology and zoology, by providing raw data and logistical support for these and other disciplines. In science, repeatability is a keystone of the process, and specimens used for scientific investigations must be vouchered in collections to ensure that species identifications can be confirmed and results interpreted correctly (Ruedas et al., 2000). Natural history collections are becoming increasingly important with new advances in biotechnology. It is now possible to use very small amounts of preserved mate-

rial for extraction and analysis of DNA to answer very important biological questions such as the origins and spread of Lyme disease (Persing et al., 1990). For these reasons professionally maintained natural history collections should be viewed as self-evidently essential to most biological investigations.

Because natural history collections play such an important role in societal endeavors, continuous physical and financial support is absolutely critical. Collections are most valuable in their original institutional and geographical context. Because they contain historical records linked to a time and place, lost collections cannot be replaced. Moreover, many populations of organisms documented in natural history collections no longer exist. Furthermore, some specimens cannot be replaced due to the imposition of constraints on collecting. Therefore institutions need to maintain their collections in perpetuity. Once an institution divests itself of a collection, the institution can never regain the benefits associated with the collections.

IMPORTANCE OF NATURAL HISTORY COLLECTIONS TO SOUTH DAKOTA

Natural history collections are important in understanding the history of our state and are critical for comparing modern and historical distributions of species by providing baseline data for future studies. These collections are also important in monitoring the presence of plant, fungal and insect pests in the state. Collections of biological organisms are present in all South Dakota universities, but size and importance of the collections varies widely. Some collections are larger and have significant research importance. Nearly all biology departments have small teaching collections of various organisms (Table 1).

South Dakota is one of the least biologically known areas in the United States (Great Plains Flora Association, 1986). Samson et al. (1998) reported that

Table 1. Natural history collections in South Dakota.

Institution	Type of collection	Number of specimens	Curator
Black Hills State University	Plants and Fungi	35,000	M. Gabel
South Dakota State University	Plants	45,000	G. Larson
South Dakota State University	Insects	1,200,000	P. Johnson
University of South Dakota	Plants	25,000	M. Nepokroeff
Smaller and Teaching* Collections in South Dakota			
Dakota Wesleyan University	Plants	3,500	
Northern State University	Plants	3,000	
South Dakota State University	Fishes	3,000	
South Dakota State University	Mammals	2,000	
South Dakota State University	Birds	500	
W.H. Over Museum	Birds	1,700	

* Note that nearly all institutions have small teaching collections including invertebrates, amphibians, reptiles, mammals, birds and plants not included in this table.

the Black Hills and surrounding grasslands in South Dakota and Wyoming are a priority landscape of biological significance with regard to biodiversity and ecological dynamics. Unfortunately, "basic floristic information is still lacking for …the grasslands of Montana, Wyoming, Colorado and the Dakotas" (Great Plains Flora Association, 1986)." The density of G1 to G3 species (G rankings indicate global rarity, e.g., G1 indicates that the species is found at five or fewer sites or is represented by 1000 or fewer individuals) in the Black Hills is 2.5 times greater than anywhere else in the Great Plains (Ostlie et al., 1997). Our natural history collections provide the primary information for understanding regional biotas and are thus the central critical elements in biodiversity and ecological studies.

Natural history collections are used widely to provide teaching specimens in South Dakota universities. While all universities have their own small teaching collections of major groups of plants and animals, teaching specimens are often augmented by research collections for instruction of undergraduate and graduate students.

The Severin-McDaniel Insect Research Collection (SMIRC) at South Dakota State University is estimated to contain approximately 1.2 million specimens and available rankings of collections place it as the largest in the northern Great Plains and one of the largest university-based arthropod collections in the United States. The collection is composed largely of insects and spiders from South Dakota and adjacent states, but approximately 15-20% of the specimens are from Colorado, Alaska, Yukon, Solomon Islands, Costa Rica and other national and international areas. The SMIRC also houses a small fossil collection and the historically important W.H. Over collection of mollusks that includes numerous specimens of freshwater clams that are extinct or near extinction in many river systems.

The Black Hills State University Herbarium is a rapidly growing facility with most collections from the Black Hills. The oldest specimens date to the 1870s, but the herbarium was not founded until the 1880s. In addition to approximately 35,000 vascular plant specimens, it is home to 10,000 plant fossils from the Great Plains and about 3000 fungal specimens including nearly all of the state record collections. At this writing the approximately 8,000 specimens of the Augustana College (Sioux Falls) Herbarium are being incorporated into the BHSU collection.

The South Dakota State University Herbarium (SDC) began at the inception of the institution in 1881, and indeed, the collection includes specimens collected in that year. The SDC includes an estimated 45,000 plant specimens emphasizing South Dakota and the Great Plains region. Professors Taylor, Gary E. Larson, and their students have been the principal collectors in recent times. Specimen trades with other herbaria in North America, including the University of Wyoming, Oregon State University, the University of Kansas and Northeast Louisiana State University, have expanded the geographic coverage of the herbarium.

Duplicate specimens from the herbarium are used in training students in botany courses that include Plant Systematics, Plant Ecology, Grasses and Grasslike Plants, Range Plant Identification, and Aquatic Plants. Many plant

samples are submitted for identification from personnel in the S.D. Cooperative Extension Service, federal agencies, and the public at large. Identifications of unknown plant samples are best verified by comparison with identified specimens in the herbarium. In this role, the herbarium is much like a reference library and it is used in the very same manner by graduate students and others conducting botanical field work in the region.

The University of South Dakota Herbarium houses about 25,000 specimens, and contains numerous historically important specimens collected by W. H. Over, S. S. Visher and A. C. McIntosh, workers important in the early botanical exploration of the state. The collection was the basis of the state flora (Van Bruggen, 1996), and the only South Dakota collection represented in the Flora of the Great Plains (Great Plains Flora Association, 1986). It is currently participating in the databasing project of plants from Western South Dakota and Eastern Wyoming.

ROLE OF THE CURATOR IN NATURAL HISTORY COLLECTIONS

A description of the job of the curator provided by the U.S. Department of Labor Bureau of Labor Statistics is as follows: "Curators administer the affairs of museums, zoos, aquariums, botanical gardens, nature centers, and historic sites.... Curators direct the acquisition, storage, and exhibition of collections, including negotiating and authorizing the purchase, sale, exchange, or loan of collections. They are also responsible for authenticating, evaluating, and categorizing the specimens in a collection. Curators oversee and help conduct the institution's research projects and related educational programs. Today, an increasing part of a curator's duties involves fundraising and promotion, which may include the writing and reviewing of grant proposals, journal articles, and publicity materials, as well as attendance at meetings, conventions, and civic events" *(http://www.bls.gov/oco/ocos065.htm).*

Curatorial duties taken from a composite of job advertisements for curators in various disciplines include: strategic collection development, supporting departmental research programs, making collections available to a wide audience, management of loans, responding to inquiries for identifications and distributions, managing conservation procedures for specimens, maintaining a strong research program, database management, cataloging, various administrative duties, serving on committees, promoting the use of collections, participating in outreach and maintaining and expanding the collection.

The curator must arrange to have a significant library of specialized literature (floras, faunas, reprints, monographs) and electronic resources (CD-ROMs, Internet access) to operate a modern collection (Snow, 2005). Some of these resources cost several hundreds or thousands of dollars each and are very difficult to purchase on limited budgets.

A significant task not mentioned above is the role of the curator in informing the upper level academic administrators about the importance of the collection (Snow, 2005). Often administrators are not long-term employees of an

institution. The more successful the collection becomes the more work that is required by the curator. It is sometimes difficult to convince administrators that a successful collection requires additional work (Snow, 2005).

MONETARY VALUE OF COLLECTIONS

A little known fact is that museums save both time and money. Natural history collections are "biological libraries" that are cost efficient repositories of accumulated knowledge and resources. Frequently, collections eliminate the need for expensive, time consuming and occasionally dangerous fieldwork because increasing costs of travel to distant locations cost the scientific community millions of dollars annually. Reducing the costs of studying vectors of disease, biological invasions and climate change provide direct financial and social benefits to society (Suarez and Tsutsui, 2004). Savings will increase as more collections are available online.

Various authors or groups have calculated the approximate value of natural history specimens. These calculations are typically based on the value of the collector's time and the value of the curator and staff time, but the real monetary value of the specimens contained in these collections is difficult to ascertain, since historical specimens cannot be replaced. Recent discussions on a herbarium list server *(herbaria@scarab.nacse.org)* indicate that calculating the value of specimens is still an inexact exercise. Suggested value per specimen in collections ranged from $5 to $70. Commercial values for insects range in price from $2 to $15,000 per specimen *(http://insectworld.com).* Numerous attempts to evaluate collections of different taxa are documented in Nudds and Pettitt (1997).

Individual plant specimens have been valued from $10 (American Systematics Collections) to $52.50 (Armstrong, 1992). Insect specimens have been estimated by the South African Museum to cost about $22 (U.S. dollars) per replacement specimen *(http://www.museums.org.za/sam/muse/entman/b_intro.html).* Mammal specimens have been estimated to cost $43 (U.S. dollars) from field collection to incorporation in a research collection (Lee et al., 1982). The University of New Mexico natural history collections are insured by the State of New Mexico Risk Management Office. The collections in the herbarium are valued at $10 per specimen. This amount will not allow replacement of the irreplaceable historical specimens but the collection managers could partially re-build the collection if disaster were to strike. Whatever the figure, none take into account the intrinsic scientific value of the specimen. Since the collections are irreplaceable setting an absolute value per specimen is pointless since replacement is impossible.

Natural history collections are sometimes easy targets for administrators during budget crises (Gropp, 2003). Suarez and Tsutsui (2004) have argued that the housing and maintenance of natural history collections is inexpensive when compared to the potential costs of their absence. As an example, Mann (1997) described the costs of a "typical" foreign trip for obtaining specimens which included salaries and modest travel and in-country expenses totaling about $63,000. Raven (2003) asked how a state could beneficially use or preserve its natural capital if there are no institutions in which its diversity is documented.

CHALLENGES AND OPPORTUNITIES FACING NATURAL HISTORY COLLECTIONS IN SOUTH DAKOTA

None of the natural history collections in South Dakota have ever had designated staff positions. There is an urgent need to implement measures to protect the specimens from insect and fungal pests to ensure the very survival of these collections for posterity. Increasing demands of teaching, research and service on the curators of herbaria and animal collections in the state have resulted in less time for management and improvement of research collections.

Current curators of natural history collections in South Dakota are aging. The senior author (Gabel) who is at BHSU retired in 2003, but is still working in the herbarium as a volunteer. It is not known how long he can continue to fill this role. The person hired to fill Gabel's teaching responsibilities does not have herbarium experience, nor does he have the time to work in the herbarium. Larson at the SDSU Herbarium has been curator for 27 years and is approaching retirement age. It is unknown what qualifications his replacement will have, or if the replacement will have the time or knowledge to manage the herbarium. Johnson at SDSU has an overwhelming responsibility to maintain the burgeoning insect collection as well as continue his other duties.

The University of South Dakota Herbarium was actively curated by T. Van Bruggen until 1988. At that time a replacement for Dr. Van Bruggen was hired who did not expend sufficient time or effort with the collection. At least 500 specimens from the collection were damaged by pest insects and discarded, including about 100 specimens of rare "lower" vascular plants on loan from BHSU to USD that were damaged severely. That person has since left but the damage to the collection remains a stark warning of the vulnerability of South Dakota natural history collections. Molly Nepokroeff at USD, while interested in the herbarium, has a research program in molecular biology.

In addition to convincing administrators of the value of the collections, it is incumbent upon natural history science staff to convince colleagues of the importance of the collections. When curators retire it is critical that they be replaced with qualified scientists.

Museums and universities must bear the cost of operations of their collections including maintaining databases and keeping the original specimens in good condition (Pennisi, 2005). The National Science Foundation (NSF) Biological Research Collections program limits awards to one-time support of specific goals or projects, with about half of the $4.5 million budget used for long-term digital data collection (Pennisi, 2005). Thus, though a good source for major renovation funds, the NSF is not a reliable source of operational support.

DATABASES AND NATURAL HISTORY COLLECTIONS

We have entered the Century of Biology (Carey, 1998). The demand for biological information is expected to increase exponentially to address issues such as invasive species, human health, sustainable development, biodiversity, endan-

gered species and environmental problems. The capacity to deliver information is one of the most important growth factors in any endeavor, and some natural history collections are poised to meet this demand.

The South Dakota Natural Heritage Database was established in 1981 and is currently funded by the Department of Game, Fish and Parks. The Natural Heritage Program is a member of NatureServe, an international network of biological inventories. The taxa represented in the database are generally those that are rare, threatened or endangered. Data searches are free to state agencies and available for a fee to others.

In South Dakota the only natural history collection currently web accessible is the grass database at Black Hills State University, with more than 10,000 specimen records from 15 herbaria, thanks to funding from the National Fish and Wildlife Foundation *https://www.bhsu.edu/artssciences/asfaculty/mgabel/herbariumdatabase/databaseIntroduction.html.* The National Science Foundation has recently awarded a grant to BHSU to increase BHSU Herbarium storage capacity and to construct a consolidated database of all vascular plant specimens for western South Dakota and eastern Wyoming. This database will include data from 16 herbaria including SDSU, USD, and numerous other collections. Web accessibility for the vascular plants of the study area will be available in 2009. Similar projects at the other collections in the state are at best in the proposal stages for grants and not explicitly supported by their institutions.

It is important that all specimens in the South Dakota natural history collections be incorporated into web accessible databases to fill gaps in natural history distributions (Card et al., 2005), and that the data from the state and region be present in international databases such as the Global Biodiversity Information Facility (GBIF). Web accessible databases are important to better understand the natural history of the state, to make baseline data available for various agencies including the South Dakota Wildlife Diversity program, *(http://www.sdgfp.info/Wildlife/Diversity/index.htm),* various regulatory agencies, land managers, pest control agencies, state researchers and researchers from around the world. Computing power has allowed the construction of databases of large amounts of information from natural history collections (Card et al., 2005). Web presence can be achieved relatively easily, but a far more valuable service for the scientific community (including faculty and students from South Dakota) and a much more prestigious web presence for databases can be achieved by participation in the GBIF *(http://www.gbif.org/).* This is a metadatabase of collections of specimens from around the world containing 91 million records from 168 providers (as of April, 2006).

Due to the heavy workload of the curatorial staff, the labor intensive nature of the work, and lack of financial support, it is unlikely given current staffing, that databasing will be completed without external funding. As such, South Dakota research and teaching institutions are not part of the global community of biology research, hence derelict in their public responsibility in managing natural resources. For example, the BHSU curator did not have time to write a fundable grant proposal until he retired and donated his time to the herbarium. It is critical that natural history collection curators have sufficient time to devote

to supervision of collections and to seek external funding for database development.

RECOMMENDATIONS TO ADMINISTRATORS REGARDING INSTITUTIONAL SUPPORT

Natural history collections "clearly embody the primary mission of higher education, which is the discovery and dissemination of knowledge" (Snow, 2005). They are also the original source of much of the knowledge we have about life on Earth. The emergence of molecular biology has not changed this fact, but has instead reinforced the importance of the collections.

Inactive natural history collections lose their value since species, genus, families and even higher order taxa are often renamed and realigned and need to be updated. Unattended specimens can become worthless as a result of damage from insects, fungi, heat, light or moisture. Specimens that are well-curated and well-preserved do increase in value with time (Snow, 2005). New digital technologies increase the value of specimens since data are more accessible to scientists.

Funding agencies such as the National Science Foundation (NSF) increasingly require evidence of continued institutional support for such facilities if grant applications are to be given serious consideration. NSF realizes that curation requires time and resources and these must be supplied internally (Pennisi, 2005). Snow (2005) reported several factors that are considered when reviewing grant proposals for collection activities including:

- Consistent, internally provided budgets for operations and maintenance are required (it is not realistic for curators to seek external funding to support routine operation).
- Proposals to NSF are highly competitive and require 6-10 weeks or more to complete.
- Staff in addition to the curator greatly expands the potential for activities.

Snow (2005) also noted that hiring a molecular taxonomist as a curator of a natural history collection may lead to neglect of the facility.

There are four large and irreplaceable natural history collections at universities in South Dakota, as well as several smaller valuable collections (Table 1). It is incumbent upon state institutions to provide operational support for natural history collections (Pennisi, 2005). Due to increased responsibilities in teaching, research and service it is not possible for the current curators to expand their duties to include proposals for large extramural grants without additional support. It is essential that the large collections, and secondarily the smaller collections be included in a modern web accessible database documenting the biodiversity of the state.

To this end we recommend that a minimum of 0.5 FTE be assigned to each of the four large collections (Table 1) by the Board of Regents. If, at some

later date an administrator should decide to give away a collection, the 0.5 FTE would follow that collection, assuming it was given to another state university. We are recommending that each institution contribute an additional 0.25 FTE to the curator position. The 0.25 FTE would be used to help maintain teaching collections. Teaching collections receive heavy use and frequently need to be repaired, remounted or replaced. The resultant 0.75 FTE would not be used for new teaching assignments, but for curatorial duties. This proposition is in agreement with the resolution passed unanimously by the South Dakota Academy of Science in April, 2006 (Gabel and Hutcheson, 2006).

With additional personnel support, curators will have time to write grant proposals for extramural funding. The three herbarium curators have already been in discussions concerning a proposal to the National Science Foundation for production of a database of all plant specimens from eastern South Dakota. These databases would be incorporated into a master dataset to produce a searchable database through the National Biological Information Infrastructure and the Global Biodiversity Information Facility (GBIF).

CONCLUSIONS

Nothing can or will replace the taxonomic information and training that is provided by natural history collections. Without these collections a major component of the history and natural history of South Dakota will be lost. The benefits of this knowledge are important to the inhabitants of the state as is this contribution to the understanding of global biodiversity. Development of natural history collections will undoubtedly produce new and unpredicted benefits. Failure to support natural history collections is certain to eliminate current and potential benefits. Those who sacrifice permanent values for short-term political expediency must be held accountable for their actions (Raven, 2003).

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