Curation and Databasing of the Gordon Alexander Othoptera Collection at the University of Colorado

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I. Introduction

The value of museum collections and the data they contain are becoming increasingly important due to the loss of biodiversity and increasing human impacts on the environment (Krishtalka and Humphrey 2000, Suarez and Tsutsuie 2004). In this proposal, we outline a project to curate and database the Gordon Alexander Orthoptera Collection, composed of over 19,000 grasshoppers from the Rocky Mountain and Great Plain regions of Colorado. Roughly 75% of the Alexander Collection is composed of vouchers from a three-year (1958-1960) altitudinal gradient survey that processed nearly 65,000 grasshoppers representing 95 different species. The remaining 25% of the collection is composed of voucher specimens from other studies conducted in Colorado and neighboring states by Alexander and his students during the 1930's to 1960's. In addition to curating, georeferencing and databasing the 19,000 specimens currently in storage, we will also database and georeference over 4,000 Alexander specimens that are currently curated and in the entomology collection.

In the following pages, we first detail the composition of the Alexander Collection and discuss its utility as a baseline dataset for examining issues such as how global climate change and land use practices may impact species diversity and ranges. Second, we highlight our plans to curate and database the Alexander Collection in order to improve its physical condition and make its inventory available to researchers. Third, we highlight our plans to georeference and database the Alexander Collection inventory in a manner that allows researchers to quantify, among other things, diversity gradients, species phenologies and factors that may affect species' distributions. The collection data will be made available on the Internet in a format that will allow researchers and lay people alike access to the information. To allow for a more powerful meta-analysis of the information associated with the collection, we will also make relevant information, historical photographs of sites, and bibliographies of works by Alexander and his students available via the internet. At the conclusion of the proposal, we provide an introduction to the University of Colorado's Entomology Collections, the importance of its physical collections, our commitments to education and research, and our capacity to curate and house the Alexander Collection.

II. The Gordon Alexander Collection

a. Introduction to the Alexander Collection

Dr. Gordon Alexander (1901-1971) was a professor at the University of Colorado (1931-1966) where he served as the head of the Biology Department for 20 years (1939-1958) and was also an acting head of the University's Museum of Natural History (1943-1944). Alexander was a distinguished ornithologist and orthopterist, whose research resulted in publications that ranged from keys to the grasshoppers of Colorado (Alexander 1941), to descriptions of the general adaptations by organisms living along altitudinal gradients (Alexander 1962, Alexander and Hilliard 1969), to articles on the biogeography of birds (Alexander 1964a) and grasshoppers of the Front Range and Rocky Mountain regions of Colorado (Alexander 1937, 1964b).

The Gordon Alexander Collection is composed of over 19,000 grasshoppers from the Rocky Mountain and the Great Plains of Colorado. In addition, we have an additional 4,000 curated Alexander specimens in the Entomology Collection. About 75% of the uncurated collection was collected during the field seasons of 1958, 1959 and 1960 by Gordon Alexander and John Hilliard as part of an extensive survey of the distribution and phenology of species of Orthoptera along an altitudinal gradient. The eastern portion of this transect began in the Front Range near Boulder, Colorado and extended westward over a vertical range of more than 3,000 m (from 1,530 m above sea level in the plains to 3,660 m above sea level in the western alpine region (a map of the transect is available in Alexander and Hilliard 1969).

Five of the 14 most frequented collecting stations were located adjacent to permanent weather stations, one established in Boulder and four at the Mountain Research Station, which were established in 1952 and serviced by the Institute of Artic and Alpine Research (INSTAAR) of the University of Colorado (since the 1980s two more weather stations have been added). In addition to temperature and precipitation data, these stations provide information on wind speed and soil temperatures. While this 3-year survey focused on 14 primary collecting stations, specimens in this study were collected from over 120 unique collecting localities.

The above research and collections were supported by a grant from the National Science Foundation (NSF) (grant # G-5007) and resulted in an ecological monograph documenting the altitudinal distribution of grasshopper species, quantifing the phenology, diversity and population structures associated with altitude, and explored the factors that may be determining these altitudinal patterns (Alexander and Hilliard 1969). For the 36 most common species, Alexander and Hilliard also provided detailed information regarding their general biology, phenology and distribution along the altitudinal gradient.

While over 65,000 specimens were processed as part of the altitudinal study, only representatives of each instar of each species were preserved from each collecting event to validate records. What makes Alexander and Hilliard's survey collection unique, however, is that although only a portion of the surveyed specimens were included in the physical voucher collection (roughly 17,000 specimens (14,000 from the uncurated collection plus already 3,000 curated specimens)), all processed specimens were accounted for in three typed field notebooks. For each collecting event, these detailed notebooks provide locality data (directions to site, elevation and vegetational characteristics) and collector information (who were the collectors present and the duration of the collecting bout), as well as detailed information on the species that were surveyed. This information includes the species present, sex ratios, numerical abundances, and the numbers of adults and juveniles of each developmental stage that were present (Figure 1). Having the voucher specimens and notebooks available will allow us to reliably update any taxonomic changes that may have been made in the last 50 years and will provide researchers with detailed access to the field data collected during the survey.

Figure 1. The following represents an example of the detailed notes that accompany Alexander and Hilliard's (1969) altitudinal survey voucher collection. All orthoptera processed during each collecting event were accounted for in three typed notebooks, with each notebook containing information for over 140 separate collecting events. The number above the species designation refers to the number code given to each species.

Collection # 14. June 24, 1958.
Collectors: The Acridian Research Group, Univ. of Colo.
(Dr. Alexander, John Hilliard, Don Van Horn, Kathy Alexander)

Station I-A. Elevation 7000'. Collected from about 11:20-11:45 am.
(This is weather station of University of Colorado Alpine Research Group A-1)
Weather: cool, overcast, threatening rain.
Slope: not measured...about 15-20°. Exposure: South facing mixed vegetation meadow.
More herbaceous plants than grasses. Dominant trees: Ponderosa pine.
Plants identified (tentatively):

1. Chrysopsis foliosa Nutt. The Golder Aster. The most conspicuous herb on the slope.
2. Opuntia sp. Prickly pear.
3. Eriogonum umbellatum. (Evidence indicates a feeding relationship between Melanoplus dodgei incultus and this plant. Trichomes (very dense and cottony on the underside of the leaves of this plant) of Eriogonum umbellatum resemble very closely fibrous trichomes found in the crops of Melanoplus dodgei specimens collected at this locality.
4. Potentilla hippiana Lehm. Wooly Cinquefoil.
5. Potentilla fissa Nutt. Sticky cinquefoil.
6. Bromus japonicus Thub.(or more probably Bromus tectorum L. Downy chess)
7. Geranium fremontii Torr.
8. Artemesia ludoviciana Nutt. (fairly common on slope.)
9. Helianthus annus L. (?) uncommon.
10. Phacelia heterophylla Pursh.

Total Specimens Collected:

Acridinae:
Eritettix simplex tricarinatus [70] 10 male; 5 female adult.
Aeropedellus clavatus [60] 1 (5) female.
Oedipodinae:
Xanthippus corallipes [57] 1 male adult.
Arphia conspersa [33] 3 male adult; 2 female adult. (all with yellow wing discs)
Trimerotropis p. pallicipennis [54] 1 male adult.
Rust colored Oedipodine with black and white banded hind femur. 1 (2); 1 (3); 1 (4). [91 combined]
Oedipodine with yellow hind tibia, grey colored, 1 notch in median carina. 3 (4).
Cyrtacanthacridinae:
Melanoplus confusus [16] Scudder 5 male adult; 3 female adult.
Melanoplus dodgei incultus [19] 10 male adult; 6 female adult; 3 female & 4 male (5); 1 emale(4
Melanoplus occidentalis [27] occidentalis (Thomas) 1 male adult.
Melanoplus m. mexicanus [29] 3 (4) males, 1 (4) females; 2 (3) males, 1 (2) male, 2 (1)
Melanoplus bivittatus [14] 1 (4) male.
Hesperotettix viridis [10] 1 (3) male. (fairly common, a group of specimens brought in alive; about 3rd instar.

A smaller portion of the Alexander Collection we propose to curate (about 25%) is composed of voucher material collected independently of the NSF project by Alexander and his students during the 1930s-1960s. These specimens correspond primarily to three sets of research projects: 1) studies conducted to survey high altitudinal mountain tops throughout Colorado (Alexander 1951, Alexander and Hilliard 1964), 2) regional and altitudinal diversity studies (Alexander 1933) and 3) specimens used to produce a key to the Orthoptera of Colorado (Alexander 1941). Finally, we currently have an additional 4,000 curated Alexander specimens in the Entomology Collection (these are vouchers from other studies and also include specimens collected during the Alexander and Hilliard 1969 survey) and we propose to database, georeference and validate the identifications of these specimens.

b. The Significance of the Proposed Project

Alexander's Orthoptera collection is of scientific importance and we propose to curate and database the collection for several reasons.

1) This collection is composed of historically important research vouchers that represent the diversity of grasshoppers from the Front Range of Colorado.

2) This collection serves as a source of baseline information for understanding the effects of land use practices and climate change on species distributions and diversity.

3) This collection must be curated in order protect it and make it available to researchers, land-use managers and students.

The Alexander Collection is composed of historically important research vouchers. The importance of Alexander and Hilliard's altitudinal studies (Alexander 1964, Alexander and Hilliard 1964, 1969), for example, can be seen in the numerous times they have been cited by researchers interested in Orthoptera diversity gradients and biology in Colorado (e.g. Craig et al. 1999) as well as other states (e.g. Dingle et al. 1990, Lockwood et al. 1994, Wacther et al. 1998) and throughout the world (e.g. Willott 1998) (these three studies have been cited at least 45 times since 1980). Not only does the collection as a whole allow researchers to reevaluate specimens utilized in Alexander's previous studies, it also provides physical examples of grasshopper species of the region. As the presence of juveniles of a species is an important criterion for determining where grasshoppers are residents and where they are transported accidentally, researchers interested in determining the range of grasshoppers in the region will also have access to identified juvenile material (nearly 1/3 of all grasshoppers collected by Alexander are juveniles).

Natural history collections contain data critical for making proper conservation decisions and for examining biodiversity and the underlying causes for changes in biodiversity (Krishtalka and Humphrey 2000, Suarez and Tsutsuie 2004). Although datasets from natural history collections have provided key insights into how organisms respond to human impacts, only a few thus far have been used to quantitatively measure and document the long-term effects of humans on the biotic landscape (see Shaffer et al. 1998). The Front Range and Rocky Mountain regions have and will continue to experience an increase in human impacts due to population growth and changes in land use practices (Long and Nucci 1997) as well as the introduction of invasive species (e.g., cheatgrass, Russian olive, European paper wasp, the West Nile Virus) (Stohlgen et al. 1998).

Orthoptera are ideal for the study of ecological principles and human impacts on natural communities. They are widely distributed, conspicuous, easily observed and collected, well known taxonomically, and readily studied under laboratory conditions. Grasshoppers also often have specialized habitat and food requirements, and the number of species and individuals are large enough for striking ecological differences to be evident within a single community as well as among communities. As grasshoppers are commonly used as indicator species to monitor the environmental effects of pesticides and mining outputs (Hoffmann et al. 2002, Quinn et al. 1993), land management practices (Baldi and Kisbenedek 1997, Craig et al. 1999), the effects of disturbances (Andersen et al. 2001) and species introductions (Samways et al. 1991, Welch 1991), Alexander's collections and research target a taxonomic group that is sensitive to environmental and ecosystem changes and thus one that may record the effects of long term human impacts (i.e. Lockwood and DeBrey 1990).

By having access to Alexander's collection and survey data, as well as to climatic and land use data, researchers will be able to quantify changes in community structure that may have accrued over the last 50 years. By resurveying the field sites previously surveyed by Alexander and Hilliard, researchers could, for example, pose the following questions:

1) Have phenological patterns changed significantly over time and do they correlate with changes in climatic variables (Fitter and Fitter 2002, Walther et al. 2002)?
2) Have species composition and population sizes changed over time and, more specifically, have some species (e.g., specialists, those with small population sizes, rare species) been impacted more than others (Fitter and Fitter 2002, Walther et al. 2002)?
3) Does the mid-domain model explain patterns of grasshopper diversity now or in the past (Colwell and Lees 2000)?
4) Are species ranges shifting upwards in altitude as predicted by climate models? (Parmesan et al.1999)?

Because the location of the altitudinal gradient utilized by Alexander and Hilliard's survey is adjacent to the University of Colorado, baseline information provided by the Alexander Collection will be an important regional dataset. The gradient utilized by Alexander has, for example, been well studied by geologists (Chronic and Chronic 1972), biogeochemists (Williams et al. 2002, Seastedt et al. 2004), paleontologists (Elias 1991), biologists (Weber and Wittman 1996, Korb and Ranker 2001) and meteorologists (Pepin 2000, Greenland and Kittel 2002) interested in both understanding physical processes and in measuring long term ecological phenomena. While the Alexander Collection data will serve as a baseline inventory of grasshopper diversity and distributions a half century ago, the dataset also has great utility as a teaching tool. In the future, we propose to develope a web curriculum, for example, that teachers and students will be able to use to explore issues of diversity and how one may use climatic variables to examine distribution patterns.

Finally, while we have had requests to borrow specimens from or visit the Alexander Collection, the specimens are currently sealed in 258 Schmidt boxes and not accessible for research purposes. Curation of the Alexander Collection will not only make the collection available to researchers, it will also provide the specimens with proper storage conditions. With the recent move to a new building and increased space and resources (see Section IV b), the Entomology Section views the preservation and availability (both electronically and physically) of the Alexander Collection as a priority.

III. Project Design, Management and Implementation

The primary goals of the proposed project are: 1) to curate and identify the Alexander Orthoptera collection, 2) to database and georeference all Alexander specimens and 3) to make the collection available to researchers, students and lay-people alike, via the Internet. To accomplish these tasks we will need additional computer and curatorial equipment, and both a ½ time Professional Research Associate (PRA) to work on and coordinate the project and a ½ time Graduate Assistant (GA) to help with the project implementation. Co-PI Guralnick and the Museum Informatics Manager will be instrumental in the database design and web implementation components of the project.

This two-year project will have two main phases. Phase I is designed to curate and database the Alexander Collection. Phase II is designed to 1) implement a web page that will make the Alexander collection and relevant metadata accessible via the Internet and 2) compile and link the Alexander Collection data and associated metadata files in a manner that will allow one to manipulate, coordinate and make relational comparisons within the database.

a. Phase I –Curation, Identification and Databasing of the Alexander Collection

Phase I will be initiated during the first year, but will continue into the first part of the second year. Phase I will begin by compiling and entering locality and collection date data from the Alexander Collection notebooks into our Biota database. This will streamline the specimen data entry by standardizing locality and collection date information which will both eliminate potential duplications when setting codes for these records as well as allow us to determine whether we do in fact have vouchers for each collecting event. Having this locality information will also allow us to georeference localities before all specimens are databased. We estimate that in total, there will be at least 210 unique localities (210 * 10 min = 35 hours; based on timed trials) among all of the Alexander collections.

After compiling and entering the locality and collection data, we will move all specimens from the 258 Schmidt boxes to drawers. As each specimen is transferred it will be entered into our database and receive a bar code label as a unique identifier. In addition, any specimens that need locality labels (we estimate about 10% of collection) will be labeled at this time--this information is taped to the outside of every Schmidt box. Based on time trials of a subset of the Alexander Collection, it takes 2.5 hours to database, bar-code, add a locality label if necessary, and move the specimens from an average Schmidt box into unit trays (Table 1). We estimate the total time needed for this task will be about 645 hours = 16 weeks for 2 people 1/2 time (258 boxes * 2.5 hrs per box)

After all specimens have been placed into unit trays, we will begin to sort and identify the specimens in the Alexander Collection. Since the majority (95%) of the specimens are acridids, we will be relying on *Grasshoppers (Acrididae) of Colorado: Identification, Biology and Management,* by J.L. Capinera and T. S. Sechrist (1982), and *The North American Grasshoppers Volumes 1 and 2* by Daniel Otte (1981 and 1984, respectively). Previously identified specimens in our collection will also serve as comparative material. Although it is difficult to determine exactly how long this will take, we estimate that, given that there are roughly 95 species in the 1958-1960 Alexander Collection, and because juveniles are often in series with their adult counterparts within the Schmidt boxes, that this part of the project will require approximately 930 hours = 23 weeks of 2 people working half-time (Alexander has identifications in his field notes that we can use as a guide for identifying specimens as well). Prior to the requested start date for the current proposal, in the fall of 2004, co-PI Nufio will work half-time to continue the databasing and curation of our current Orthoptera collection and this training should stream line the identification process during the course of the grant.

Finally, we plan to host a visiting Orthoptera specialist during the second year to spend a week in our collection verifying our identifications as well as those proposed for the previously curated Alexander materials. Dr. Daniel Otte, an internationally known orthopterist from the Academy of Natural Sciences of Philadelphia, has agreed to take on this task. As the collection should be curated and organized by species, we expect this task to be relatively straightforward (i.e., we estimate in total, there will be roughly 150-175 different species that must be verified). For groups where taxonomic identities are unresolved, or if more time is required to validate species identifications, will send samples to taxonomists to get species identifications/ verifications. After specimens are identified and verified, we will update the database. Based on time trials, we estimate that rescanning each Alexander specimen barcode will be a relatively straight forward task requiring another 160 hrs.

To accomplish the tasks outlined in Phase I, we are requesting both a ½ time Professional Research Associate (PRA) to work on and coordinate the project and a ½ time Graduate Assistant (GA) to help with the project implementation (See Budget Justification). This project will require additional computer and curatorial equipment. Our trials showed that approximately 1/3 of a drawer was required to house the material from a single Schmidt box; thus that we will need to purchase 80 drawers to house the incoming Alexander Collection. We will also need to purchase 1,240 unit trays, a bar code reader and bar code labels for this task. As our two microscopes are actively used by curitorial staff, visiting Adjoint Curators, and by other visitors interested in getting identifications, we will need to purchase a dissecting scope and light source to dedicate to this project. We are also requesting funds for a Visiting Curator of Orthoptera who will spend two weeks checking the identifications from this project.

Table 1. Time required for the tasks described in this proposal. This work will be accomplished primarily by a ½ PRA and 9 month ½ GA time but will have support from Co-PI Guralnick and the Museum Informatics Manager.

	# of hours	**# of Weeks @40h/wk**	**Year task Accomplished**	**Cumulative 40h/wks**
Entering locality and collection date data into Biota	20	1 / 2	Year 1	1 / 2
Transferring and databasing the Alexander Orthoptera from Schmidt boxes into unit trays	645	16	Year 1	16 ½
Georeferencing locality information for all Alexander Orthoptera (est. 210 sites)	35	1	Year 1	17 ½
Identify and verify specimen identifications	930	23	Year 1-2	40 ½
Update specimen identifications in the database	160	4	Year 2	44 ½
Recurate all Alexander specimens	80	4	Year 2	48 ½
Adding 47,750 unvouchered specimens to the database	796	20	Year 2	68 ½
Prepare relevant meta-data files, develop web page & implementation	480	12	Year 1-2	80 ½
Student supervision, training, grant coordination	400	10		90 ½

b. Phase II- Technology Implementation

Maintenance and proper dissemination of the data and metadata collected in the Alexander Collection are two of the main goals of this proposal, and we have assembled a team of museum curators, collections managers and informaticians to implement this goal. Below we document four steps necessary to make the Alexander Collection maximally useful to multiple audiences of systematists, ecologists, land managers, and the general public: 1) Create a new DarwinCore 2 compliant datamodel for the collections information and other ancillary data (e.g. historical climate data) and implement the datamodel in MySQL; 2) Georeference the Alexander Collection (210 unique sites estimated); 3) Distribute the database via DiGIR provider software and from our own website; 4) Link the georeferenced database into existing geodatabases and online GIS visualization and research tools developed by Co-PI Guralnick.

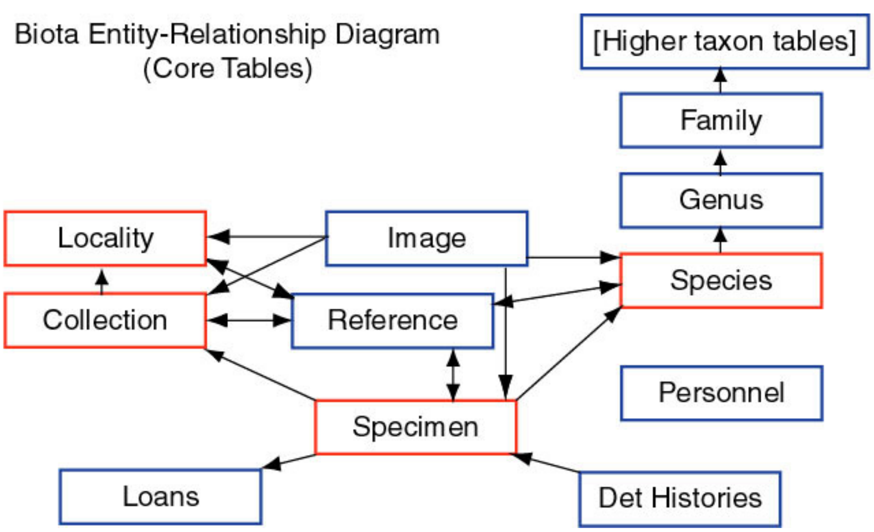
1. Datamodel and Database Design

The Entomology Section currently uses Biota as its main program for structuring collections data and metadata as well as for storing its accumulated records. Biota specifies a datamodel for collections, a way to enter records into the database, and provides a set of tools for managing collections information (e.g. a loan tracking system).

The Biota (and Biota 2) datamodel is sufficient for all the collections information concerning the Alexander Collection and we will enter all the Alexander voucher specimens to the existing Biota database. However there are compelling reasons to export the data from Biota into a database program, such as MySQL, in order to create a datamodel that more specifically incorporates the Alexander Collection's data and associated metadata. MySQL is an open source software that uses Structured Query Language (SQL) to store, access and process data in a relational database. Structured Query Language is the most common language used to access databases. MySQL will be used to create a relational database that will store associated information on the habitat where the material was collected and this information is not specifiable through Biota. For example, climate information from nearby weather stations is available from the time of Alexander's major NSF-funded survey work (see http://culter.colorado.edu/), and this information is value-added data that should be associated directly to the collection dataset. Alexander's field notes, for example, list many more specimens per site than were actually vouchered, and both the voucher specimens and unvouchered specimens (listed as observations in the DarwinCore2 field Basis of Record) will need to be stored within the relational database. Finally and perhaps most importantly, we will distribute the collections information to the global community using Distributed Generic Information Retrieval (DiGIR) protocols and Biota does not currently support DiGIR software queries (see below).

Figure 1 shows the general scheme of the Biota data model. We will construct a data model that does not only incorporate the Biota data model and be DiGIR complient; it will also capture most of the available metadata associated with the Alexander Collection as well as species-specific information (e.g. known life history characteristics), environmental variables (e.g. climate, altitude and ecosystem information) and georeferencing information. We estimate that 75% of the Alexander Collection we propose to curate (19,000 specimens) and 75% of the already curated Alexander specimens (4,000 specimens) are vouchers that correspond to the 1958-1960 altitudinal study. In order to database all specimens for the study we will therefore need to add an additional 47,750 (65,000 – 17,250) unvoucherd specimen data records to the database that are currently accounted for in the three data notebooks. After streamlining the process, while databasing the voucher specimens, we estimate that it may take 1 min to add each of the unvouchered records to the database and that this should take an additional 796 hours (47,750/ 60min; Table 1).

Figure 1. The diagram below illustrates the general links made between the Core tables in Biota. (Appendix from Biota 2, Cowell 2004).



The database and web site (see below) will reside on the current Museum database and web server, a Dell PowerEdge 2600 server running Red Hat Linux, MySQL database server software, and Apache web server software. The server is maintained by the informatics staff at the University of

Colorado Museum and is backed up daily to a tape library. The hardware specifications are as follows: 2.0GHz Xeon processor, 1GB SDRAM, three 36GB hard drives (RAID 5). The server is connected to the Internet via a 100Megabit Fast Ethernet connection.

2. Georeferencing

Once we have exported the Biota data to our new database program, we will add relational tables and their attributes to capture georeferencing information. Georeferencing is crucial for the importation of data into Geographic Information Systems (GIS). Our coordinate system of choice is the Universal Transmercator (UTM) 1983 North American Datum. UTM coordinates simply measure in meters east and north from two perpendicular reference baselines. Because the Gordon Alexander records derive from historical rather than recent collecting activities, geocoding using UTM coordinates or latitude and longitude was not available at the time. Instead, Alexander provided varying levels of information in a description of the locality, usually as a locality description. Given Alexander's locality information, nearly all localities appear to be geocodable. We plan, as a first step, to use locality information from the Gordon collection to geocode those localities in UTM NAD83. Eventually, UTMs and latitude/longitude data will also be exported back to our Biota database.

With the advent of digital topographic maps and Geographic Names Databases (e.g., GNIS) the process of geocoding is not as tedious as in the past. Using National Geographic TopoMaps and the Geographic Names Information Services, a worker can input the name of a landmark to get to the general area and then track exact distances to the collection locality on the map using the tools on the CD-ROM. The quality of georeferenced locality information does vary from record to record and is based on the exactness of the collector.

The University of Colorado Museum is currently georeferencing already databased vertebrate and botanical material as part of MaPSTeDI (Mountain and Plains Spatio-temporal Database and Informatics Initiative), an NSF-funded project ending in August 2004 (Neufeld et al. 2004). Co-PI Guralnick is PI of that project and has developed an efficient system for both georeferencing and for assigning confidence intervals to each georeferenced record. This confidence interval represents the radius of error around a particular georeferenced record. Typically, the error for most records is a 1-5 km radius. The details of the MaPSTeDI georeferencing protocols are available online (http://invertoffice1.colorado.edu/mapstedi/protocols/mapstedigrp.pdf), and in a manuscript that is currently in review (Murphey et al.). The protocols developed in the MaPSTeDI project will be incorporated into this project. Once the specimen's locality has been geocoded, the UCM number, confidence interval, and coordinates can be added to a list of geocoded records. The list of the geocoded records can then be linked as a relational table to the original database.

3. Database Dissemination via DiGIR and the Alexander Website

We will publish the Gordon Alexander specimen data online by becoming a Distributed Generic Information Retrieval (DiGIR) data providerWe will publish the Gordon Alexander specimen data online by becoming a Distributed Generic Information Retrieval (DiGIR) data provider. DiGIR is essentially the protocol and software that allows communication of information from multiple data providers back to the end users in a usable format. DiGIR has three main components: Data providers distributed globally; A registry containing information about the available data providers and their data and; A portal where end users can create queries to perform searches of multiple providers. For example, when a user inputs a data query at a portal (such as "show me the Orthoptera at the University of Colorado"), the DiGIR protocol sends that query in the right format to the data contributors (in this case CU Entomology section's data stored on the Museum server), which is then translated into a search on that local database and then sent back along with other results from other providers back to the portal and end user. The process of becoming a data provider through DiGIR has become simplified with the release of DiGIR provider software which semi-automates the process. And we already have experience setting up providers as part of a collaborative research project for the vascular flora of the southern Rockies (NSF BRC #DBI-0237149). Over the last year, over sixty institutions have become DiGIR providers and by so doing have made available over 25 million specimen records through public portals such as GBIF (http://www.gbif.org). By providing our data via our DiGIR provider, we can assure the largest user base for the material.

Although there are no insect specific data portals as there are for mammals (MaNIS – http://manis.mvz.berkeley.edu/pres/PresentationServlet?action=home) and herpetological material (http://herpnet.digir.net:10080/pres/PresentationServlet?action=home), GBIF provides a main portal for all those providers who register with the GBIF portal (http://www.gbif.net/portal/index.jsp). The Alexander Collection will be registered with GBIF and potentially other, more taxon- or research-specific data portals, as they come online.

A second dissemination mechanism will be a specific Gordon Alexander Collection website that we will develop. The website will provide a web interface to the MySQL database allowing users to formulate more sophisticated queries on all the information available, including for example climate information. It will also contain process documentation, literature references for Alexander's and his students' works, photographs and other value-added information that we discover during the course of the project.

4. Linking Databases to Web Mapping and Analysis Applications

One of the great challenges in the coming decade is for museums to link their databases to Geographic Information Systems (GISs) in order to examine spatial and temporal patterns of biodiversity. By doing so, museums can transition from providing researchers with specimen loans to actually providing toolkits for analyzing biodiversity based on shared collections. Since museums are one of the few sources of longitudinal diversity data, the creation of methods to visualize and analyze museum collections data is particularly critical given our current biodiversity crisis (Krishtalka and Humphrey 2000; Neufeld et al. 2004).

The Gordon Alexander collection is a perfect dataset for further visualization and exploration in the context of an online, freely available GIS for three reasons. First, Alexander's collections represent a mix of careful survey and opportunistic collecting that likely effectively sampled the grasshopper diversity present at that time. Thus, this dataset is potentially an excellent baseline biodiversity dataset for Rocky Mountain grasshoppers to compare against potential changes over the last fifty years. These datasets, with vouchered specimens intact and stored in a museum, are rare. Second, most of the data are localized within the southern Rocky Mountain region along a major altitudinal gradient. Abundance and richness patterns along altitudinal or latitudinal gradients remain areas of active research and education, and this dataset can be reexamined in the context of new theory (e.g. Colwell's mid-domain effect (Colwell and Lees 2000)) and questions (e.g. are montane and alpine species more likely to be affected by climate change?). Third, species richness and abundance can be examined in the context of climate parameters collected at the time and that are still available today given the close proximity of weather stations to survey sites (raw weather data from Niwot ridge available here: http://culter.colorado.edu:1030/Niwot/Niwot_Ridge_LTER_data.html). This means that not only can users examine a well-sampled dataset of grasshoppers, but also examine those patterns in the context of year-by-year environmental variability (particularly for the 1958-1960 survey).

The infrastructure necessary for producing on-the-fly maps for the orthopteran collections is beyond the scope of this project. However, MaPSTeDI (see above), is a concurrent regional project designed to link museum data and online mapping applications (Neufeld et al. 2004). The main goal of MaPSTeDI is to create a prototype distributed mapping visualization and analysis service for all museum collections material in a six state region defining the South-Central Rockies and plains. The online tool (now available for demonstration at http://www.geomuse.org) provides an easy-to-use interface for users to explore biodiversity across the landscape. Given the close connections between MaPSTeDI personnel and this project's personnel, it is to link this database into MaPSTeDI as the next step in that project.

c. Process Documentation Dissemination

For this project, the co-PI's and team plan to disseminate not only the data and metadata about the collections through DiGIR, but we will also provide, via our Alexander website, all process documentation regarding our plan for collections improvement and data management. Written documentation will be distributed in HTML, PDF, and Word formats. The team will also document internal assessments and how the process changed as better solutions were found.

IV. THE ENTOMOLOGICAL COLLECTIONS AT CU MUSEUM

a. Scope, History and Importance of the Collections

The University of Colorado Museum of Natural History was first established in 1902 and houses anthropological, botanical, entomological, paleontological and zoological collections. The mission of the CU Museum is threefold; 1) to provide support for collections-based scholarly research, 2) to provide instructional support for the university and local community, and 3) to provide extra-classroom educational opportunities for members of the university and general public. In recognition of the Museum's accomplishments and ability to meet these goals, it was recently awarded accreditation by the American Association of Museums.

The Entomology Collections of the University of Colorado Museum contain approximately 550,000 insect and 50,000 arachnid specimens dating back to the 1870's. Most of the insect specimens are pinned adults. Among these, the most abundant insect orders are the Hymenoptera (37.0%), Lepidoptera (19.0%), Coleoptera (17.5%), Diptera (11.6%) and Orthoptera (7.7%). The collections are especially rich in material from the Rocky Mountain Region, but have representations from throughout the United States as well as some material from around the world. While our focus is the Rocky Mountain and plains regions, the entomological collections from outside this geographic area provide important comparative information on a taxonomic level and are valuable for teaching purposes.

The Entomology Collections contain several historically important collections, including those made by T. D. A. Cockerell, one of the Museum's founders (all insects, especially Hymenoptera); H. Rodeck, former Museum Director (Hymenoptera); M. T. James (Diptera); C. J. McCoy (western Colorado Insects); B. Vogel (Hymenoptera and spiders), and U. Lanham (Hymenoptera). There are also several important collections in addition to Alexander's collection, that have been donated or deposited in the Entomology Collection. These include collections by F. M. Brown (Lepidoptera, Diptera and Hymenoptera); W. N. Burdick (Lepidoptera); D. Eff (Lepidoptera); C. W. Hicks (Hymenoptera); T. Kincaid (Hymenoptera and other insects of the Pacific northwest); B. Rotger (Coleoptera and Lepidoptera), F. K. Smith (Coleoptera), and L. Macior (Hymenoptera).

b. Growth and Support for the Collections

1. Specimens

In the past six years, 33,900 specimens have been added to the Entomology Collections (Table 1). These additions are largely the result of collecting projects, donated material and voucher collections from faculty, staff, and students conducting research projects. During this time, the Entomology section housed over 75,000 specimens on loan from over 35 institutions and provided space for 6 researchers to examine and process specimens. We have also hosted 686 visitors, including tour groups and classes (Biology, Museum and Field Studies) interested in the Entomology Collections (Table 2), and responded to 1,096 inquiries.

The Entomology Collections have been a valuable source of materials for the external research community (such as taxonomists, ecologists, and geneticists) as well as for members from the more applied and conservation oriented fields. For example, during the last six years, 15,108 of our specimens have been loaned to 98 institutions for research and teaching purposes (Table 3) and during that time we processed 15,313 specimens from 80 returned loans. The interactions with investigators that have utilized our collections have resulted in at least 25 peer reviewed publications in the last few years (Table 2 and 3).

The Entomology Collections are currently databased using the program *Biota* (Colwell, 1996). The list of identified species in the collection currently contains 15,658 databased species names and 14,074 specimens have been fully databased. As part of the databasing process, each specimen receives a unique bar-code. Our bar-coding methods follow those proposed by the Entomology Collections Network in which the label is placed face down at the bottom level of the pin. We also use *Biota* for other purposes such as preparing loan forms, printing unit tray labels and creating species lists. Lists of identified species names and type specimens (which include 124 holotypes, 14 allotypes and 34 specimens labeled as "type") in the collections are available on-line (http://cumuseum.colorado.edu/Research/Entomology). The Entomology section's policies including accessions and loans are provided in Supplimental 1 of the supplementary documents section.

Table 2. Activity in the Entomology Collections during last six years.

ACTIVITY	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
# of specimens added	1,300	1,600	3,800	17,000	2,000	8,200
Visitors*1	105	135	84	44	181	137
Inquires, IDs, Questions	285	273	148	126	125	139
# Loans/# Specimens						
Outgoing	12/ 580	27/ 2,254	15/ 1,097	13/ 1,097	17/ 7,276	14/ 2,804
Returned	10/ 3,225	24/ 1,405	16/ 2,076	7/ 410	14/ 1,827	9/ 6,370
Publications	8	3	2	1	5	6

*There was little activity in the Entomology Collections from the fall of 2000 through the spring 2002 because the collections were closed and moved to the new facilities.
1 Groups counted as 1.

2. Facilities

The University of Colorado Museum's Entomology Collection is located in seven rooms on the third floor of the newly renovated Bruce Curtis Museum Collections Building (MCOL) on the Boulder Campus. This building houses the Entomology, Paleontology, Zoology and a portion of the Botany sections, and the Museum and Field Studies Program office. This six million dollar project was funded by the State of Colorado, the University of Colorado and many private donors – which demonstrates the support the Museum has from both the University and local communities. Each section in the Museum participated in the design and specifications of their own space. The result is a museum facility that is designed with the unique needs of each section's collections in mind. As part of the move to the new quarters, the Entomology Section added four replacement cabinets for wet storage, two new double wide cabinets for housing our riker mounted butterflies, and a total of

13 doublewide cabinets for dry collection. Each of the 13 new cabinets holds 48 drawers for a total of 312 additional slots available for incorporating new specimens.

Table 3. Five representative entomology publications.

Althoff, D. M., J. D. Groman, K. A. Segraves, and O. Pellmyr. 2001. Phylogeographic structure in the bogus yucca moth *Prodoxus quinquepunctellus* (Prodoxidae): Comparisons with coexisting pollinator yucca moths. Molecular Phylogenetics and Evolution 21:117-127.

Collinge, S.K., K. Prudic, and J. Oliver. 2003. Effects of local habitat characteristics and landscape context on grassland butterfly diversity. *Conservation Biology* 17:178-187.

Douglas H. 2003. Revision of Cardiophorus (Coleoptera: Elateridae) species of eastern Canada and the United States of America. The Canadian Entomologist 135: 493-548.

Kondratieff, B. C. and R. W. Baumann. 2002. A review of the stoneflies of Colorado with description of a new species of *Capnia* (Plecoptera: Capniidae). Trans. Amer. Entomol. Soc. 385-402.

Lodge R.J. and J.R. Freeland. 2003. The use of Odonata museum specimens in questions of molecular evolution. Odonatologica 32; 375-380.

The largest room (393.8 sq. m.) in the Entomology Collection houses the dry collections, including the Type collection (Supplimental 2). The pinned dried insect collections are housed in foam-bottomed trays, in glass-topped Cornell or USNM drawers in metal cabinets. The wet collections room (36.6 sq. m.) houses the spider collection and insects preserved in alcohol, which are stored in metal cabinets. In addition there is a wet preparation room (101.5 sq. m.) with a double sink, five-foot fume hood, air/gas/vacuum jets, and a built-in bench for students and visiting entomologists. The Entomology reference library is housed in its own room (70.1 sq. m.). This library houses relevant entomological keys, catalogues, books, journals, and reprints. There is also a databasing room (33.5 sq. m.) and two offices (31.7 and 28.0 sq. m.) for the co-PI's Bowers and Nufio and the Collections Manager. There is an eighth room in the basement (57.9 sq. m.) for the storage of field equipment.

All rooms are equipped with sprinkler systems for fire suppression. There is an HVAC system in the building that provides climate control. The doors have keypad access locks that are individually programmable. The building has a receiving room and walk-in freezer.

3. Faculty and Staff

The staffing of the Entomology section of the Museum includes one Curator, a Collections Manager and one half-time graduate Research Assistant (20 hours per week (Supplimental 3). In 1998, the Section received funds to increase the position of the Collections Manager to full-time (from three-quarters time).

In the last several years the Museum and University have increased their commitments to, and support of, the collections. Beginning in 1999, the Museum has compensated Museum Curators for their collection-related work in the summer at a rate of 20% time. In addition, within the last five years, the Museum has had 8 permanent staff hires including 3 replacement curators, 2 special opportunity curators, a created curator position to direct the graduate program and 2 collections managers. The museum has also hired a full-time Informatics Manager to provide technologies support and encourage web based education. Finally, in the last several years, all Graduate Research Assistant positions in the Museum were increased from 9-month appointments to 12-month appointments

V. EDUCATIONAL IMPORTANCE OF THE COLLECTION

a. Departments and Outreach Programs that are Served by the Entomology Collections

The Entomology Collections are an integral part of teaching in the classroom and are used for interaction, education, and communication with the general public. Materials from the Entomology Collections have been used in numerous lecture and laboratory courses, at both the undergraduate and graduate level. These courses have been taught primarily in the Department of Ecology and Evolutionary Biology and the Museum and Field Studies Graduate Program. In order to facilitate the utilization of specimens by courses and educators, the Entomology Section maintains a separate teaching collection used by courses, such as "Insect Biology" and the museum's "Field Research: Basic methods and new technologies". Students in these courses not only actively use the collections, but in some cases add valuable specimens to the collection.

The Entomology Section and the Museum provide substantial outreach support for grade school classes interested in learning about insects. These programs include several insect displays and live insects that are used to introduce K – 6 students to insect biology and ecology. For example, the Curator, Collections Manager and graduate assistant have given talks and demonstrations to a Museum Education Section program (Girls At the Museum Exploring Science) designed specifically to expose, encourage and excite 4th and 5th grade girls of color about science education and careers. Members of the section have also hosted groups, such as the Boy Scouts and members of the 4H Club, and have participated in field oriented class trips. The Entomology Section, for example, regularly participates in the Museum's yearly "Bug walk" and "Discovery Days", designed for K - 6 children. This year the Entomology Section will be part of the first Boulder Bioblitz. The goals of Bioblitz are to create a taxonomic inventory for an area and to introduce the public to what biodiversity is and that it can occur within an urban environment.

b. Museum and Field Studies Program

The Museum and Field Studies program is an interdisciplinary program leading to a Master of Science degree (MS) (http://cumuseum.colorado.edu/MFS/). Through this program, students gain expertise in museum theory and practice, as well as knowledge in a cognate discipline. Students may select one of two tracks for their program of study. The Public/Administration Track is for students who are interested in the public side of museums; including education, exhibits, interpretation, and administration. Alternatively, students may choose to pursue the Collections/Field Track if they are interested in collection management, collections and research, and curatorial work.

The Museum and Field Studies Graduate Program provides a unique opportunity for students to learn about entomology collections by working alongside entomologists. This is because students work closely with the curator, who serves as the academic advisor, and the collection management staff. Students in good academic standing have the opportunity to receive 12-month appointments as graduate assistants in the section. These students are integral to the daily operation of the section, as they assist with the collection, preparation, databasing, and cataloguing of specimens. Upon graduation, our students have gone on to become collection managers or science educators, and some have entered PhD programs in their cognate discipline and continued in academia.

c. Museum Exhibits

The CU Museum of Natural History has exhibit space with six halls that are open to the University community and the general public. In the 2003 fiscal year approximately 20,000 people visited the Museum, including nearly 7,000 K-12 students. The Entomology Section has been actively involved in educating the public by playing a part in the creation and production of a number of exhibits. In 2002, Deane Bowers, the Entomology Curator, was a co-curator of the "CU Museum Centennial: A Window to the Past, A Door to the Future" exhibit. This exhibit displayed 5,948 specimens from the

Entomology Collections. This year, the exhibit entitled "Moth Matters: With Images by Joseph Scheer", highlighted the diversity of the moths of Colorado and Scheer's photographic images of moths. This exhibit was curated by Virginia Scott, the Entomology Collections manager, and exhibited 125 of the Collections' moths. Members of the section hosted numerous speakers for this exhibit as well as led an associated "Caterpillar Walk" for K - 6 students. We were also a part of the Butterfly Pavilion's (http://www.butterflies.org/) "behind the scenes" tour for members. In addition, Bowers is a member of the Butterfly Pavilion's science advisory board.

VI. Intellectual Merit and Broader Impacts of the Proposed Project

Intellectual Merit: The proposed project for the conservation and databasing of this important voucher collection will, for the first time, make the Alexander Orthoptera Collection available to researchers, both physically and over the internet. This project will greatly improve the Orthoptera holdings of the University of Colorado Museum and ensure that specimens are available for study, research, and education. In addition, the databasing and georeferencing portion of the project will allow researchers access to the detailed ecological data associated with the collection. While access to the curated materials will be particularly important to researchers, providing electronic access to the Alexander Collection database, and its relevant meta-data, will allow a wide audience access to a source of baseline information for understanding how abiotic factors influence species distribution and diversity patterns. Making these detailed data available over the internet will dramatically increase their accessibility.

Broader Impacts: This project will allow electronic and physical access to the historically important Alexander Orthoptera collection. Access to this collection and the data it contains will be important for our understanding of the effects of altitude, land use practices and climate change on species distributions and diversity, using grasshoppers as a model. The PIs of this project are also very committed to using the implementation of this project as an educational tool for providing research training to graduate and undergraduate students. The students working on this project will be introduced to the importance of curating, maintaining and databasing collections. These students will also learn how collections can be used to formulate and test hypotheses as they will help implement a web page that allows researchers and lay people to use a relational database to examine Alexander's survey and collection data. In the future, students will also work to develop an electronic curriculum that will allow other students and the community to utilize the Alexander study to illustrate species estimation techniques and how diversity may be correlated with physical factors, such as temperature and precipitation. The PIs will also encourage and attempt to recruit undergraduates interested in research experience from both CU's Undergraduate Research Opportunity Program (UROP), the Summer Multicultural Access to Research Training Program (SMART). The PIs feel strongly that the Alexander Collection can be used as an instructive educational tool and are also currently developing a proposal from supplemental funding from the NSF Informal Science Education Program (after Consultation with the ISE Program Officer) to make this data accessible as teaching modules.

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