

2015 Project Abstract

For the Period Ending June 30, 2017

PROJECT TITLE: Minnesota Biodiversity Atlas for Enhanced Natural Resource Management

PROJECT MANAGER: Keith Barker

AFFILIATION: Bell Museum of Natural History, University of Minnesota

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FUNDING SOURCE: Environment and Natural Resources Trust Fund

LEGAL CITATION: M.L. 2015, Chp. 76, Sec. 2, Subd. 03d

APPROPRIATION AMOUNT: \$340,000

AMOUNT SPENT: \$ 326,614

AMOUNT REMAINING: \$13,386

Overall Project Outcome and Results

The Minnesota Biodiversity Atlas project aimed to digitally capture, integrate and disseminate data on Minnesota's plant and animal diversity and distributions, with a focus on specimens held by the Bell Museum, the state's official museum of natural history. The result of this work, the Minnesota Biodiversity Atlas (<http://bellatlas.umn.edu/>), makes the majority of these data specimen data available in one easily-accessible resource for the first time. The new Atlas includes data from over 326,000 specimens of nearly 9000 taxa (species and subspecies) collected from throughout Minnesota by museum curators and state biologists over the last 140 years. Importantly, this project has made georeference data (precise latitude and longitude coordinates) of nearly 223,000 Minnesota specimens available in an integrated platform that allows simultaneous mapping of specimens from distinct groups (e.g., birds and plants) interactively within the Atlas or with the user's own application of choice. The Minnesota Biodiversity Atlas also provides access to a massive archive of specimen images (currently over 135,000), particularly of plants, allowing direct access for identification, collection of phenology and other data, and label verification. In addition to being served directly through the Atlas to agency partners and the public, all of these specimen data, along with all of the Bell Museum's specimen data from other parts of the world, are now served directly to global biodiversity data resources including the National Science Foundation-funded iDigBio and the Global Biodiversity Information Facility, which are critical resources for managers and research scientists around the world. The Minnesota Biodiversity Atlas is now a key resource providing critical data to resource managers and scientists both in Minnesota and globally. Future development of the Atlas will integrate additional specimen data from collections throughout Minnesota, as well as observational data collected by state agency partners and others, creating an even more powerful management tool and a permanent archive for these critical data.

Project Results Use and Dissemination

The primary result of this work was production of the Minnesota Biodiversity Atlas (<http://bellatlas.umn.edu/>), an online resource interactively serving data on specimen records of Minnesota plants and animals to agency partners, the public, and scientists and managers worldwide. This Atlas is the primary means of disseminating data on Minnesota's biodiversity. Bell Museum curators have promoted use of this resource by: 1) interaction with and training of agency partners in use of the Atlas; 2) interviews with the media, including two radio interviews and at least two print interviews; 3)

training of participants in the Minnesota Master Naturalists program in specimen data capture (through a related project , *Mapping Change*, within the *Zooniverse* citizen science platform) and use of the Atlas, and 4) promotion of the Atlas through electronic exhibits within the newly-opened Bell Museum.



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Date of Report: 31 August 2018

Final Report

Date of Work Plan Approval: 11 June, 2015

Project Completion Date: 30 June 2018

PROJECT TITLE: Minnesota Biodiversity Atlas for Enhanced Natural Resource Management

Project Manager: Keith Barker

Organization: Bell Museum of Natural History, University of Minnesota

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Location: Statewide

Total ENRTF Project Budget:	ENRTF Appropriation:	\$340,000
	Amount Spent:	\$326,614
	Balance:	\$ 13,386

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 03d

Appropriation Language:

\$340,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota for the Bell Museum of Natural History to create a publicly accessible, online tool and repository that will electronically integrate over 600,000 existing biodiversity records, 300,000 existing images, and future data and associated imagery pertaining to Minnesota wildlife, plant, and fungi species in order to enhance research, guide field surveys, and inform conservation planning. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.



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I. PROJECT TITLE: Minnesota Biodiversity Atlas for Enhanced Natural Resource Management

II. PROJECT STATEMENT:

We will create a resource management tool, the Minnesota Biodiversity Atlas. This online, searchable interface will integrate an extensive set of data (over 600,000 records) on birds, mammals, fishes, plants, and fungi, and associated imagery (up to 300,000 high-resolution digital photographs). This interface will enhance agencies' capacity to perform a range of activities from biological surveys to conservation planning. As Minnesota's State Natural History Museum, it is our statutory mandate to preserve and make available all of our biodiversity data, including historic and ongoing contributions (both specimens and data) from the Bell Museum as well as from agency partners like the Minnesota Biological Survey and the Minnesota Pollution Control Agency. These critical data, including ~30,000 high-resolution digital photographs and more than 250,000 records currently ready to be loaded into the system, as well as nearly 450,000 currently inaccessible Bell Museum records, are the basis for the tool we seek to create.

Our agency partners have many information needs both at the office and in the field. For instance, the Minnesota Department of Natural Resources (in particular the Biological Survey) requires: 1) accurate species lists, 2) specimens confirming the identity and distribution of species, and 3) distribution data for species of critical concern and for invasive species for use in conservation planning. The Biodiversity Atlas will serve these and other needs by integrating Bell Museum and agency data into a single, easily usable tool. This tool will provide users with species lists for any geographic area based on the latest and most accurate information. Specimen imagery will allow agency biologists to check identifications and verify distributional details from the office or the field at any time, without the constraints of visiting the Bell Museum collections during business hours. Finally, updates to our specimen databases done as part of this project will allow creation of the most complete distribution information for both current and future species of conservation concern. These are critical data for planning of species recovery and management, and for environmental impact assessment.

The Pacific Northwest Herbarium (<http://www.pnwherbaria.org/>) illustrates what is possible but not currently available for Minnesota. This web interface enables users to search for distribution maps of plants or browse digital images and historic records from across their region. Although similar specimen data for Minnesota birds, mammals, fishes, amphibians, reptiles, fungi, and plants are stored in the Bell Museum and in cooperating agency databases, a large portion of these data are not currently available, need to be digitized, and have not been integrated into a single comprehensive source. This project will improve access to biodiversity data by making them instantly and directly available online through a tool easily usable by resource managers, researchers, and citizens alike. Once constructed, this tool will also enable future integration of data from other providers (e.g., the UMN Duluth Herbarium, MN Breeding Bird Atlas).

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of December 31, 2015:

As of this writing, a fully functional test version of the Minnesota Biodiversity Atlas is running on an internal server at the Minnesota Supercomputing Institute. This instance has been populated with 256,011 specimen records from the Bell Museum's plant, fungal, and fish collections, including 92,633 images of plants and fishes, and is undergoing testing by museum staff and curators. A public version serving Bell collections data is planned for release in April 2016. Imaging of plants, fungi, and fishes continues and georeferencing of plant records with locality descriptions has begun. Through a competitive application process, the Bell Atlas team has partnered with Zooniverse (the premier citizen science crowdsourcing site, <https://www.zooniverse.org/>) to develop the crowdsourcing portion of our project that initiates in July 2016. Software development for this portion of our project is underway and completion is expected on schedule.

Amendment Request (12/31/2015):

We request addition of a personnel category (Civil service technician), and shifting of some personnel funds in Activities 2 and 3 from hiring of undergraduates to hiring into this new personnel category. Recent experience



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of Bell Museum curators with specimen imaging and georeferencing have taught that this work can be more efficiently accomplished by experienced technical staff to execute these tasks and to train incoming undergraduates. We propose shifting \$46,000 in personnel funds under activities 2 and 3 from supporting undergraduates to supporting civil service technicians.

Project Status as of June 30, 2016:

As of this writing, the Minnesota Biodiversity Atlas is online and has been made accessible to agency partners and the public. All Bell Museum collections (including plants, lichens, bryophytes, mammals, birds, fishes, amphibians, reptiles and molluscs) have been incorporated into the Atlas, for a total of 585,084 specimen records from 22,091 species, more than half from the state of Minnesota. The Atlas now comprises 123,406 images of Minnesota flora and fauna, and over 200,000 images in total. Of the records in the Atlas, nearly half have been georeferenced (pinpointed to a specific site on the globe). Our collaborative project with Zooniverse to capture locality data from specimen images using a crowdsourcing approach is complete and scheduled for public launch in mid-September.

Project Status as of 4 April 2017:

As of this writing, the Minnesota Biodiversity Atlas (<http://bellatlas.umn.edu/>) continues to serve Bell Museum specimen data to agency partners and the public, including users from 92 countries around the world. Currently, the Atlas comprises 320,068 records of 8,395 species of Minnesota's flora and fauna. Now included in the Atlas are 128,335 images of Minnesota plants, fish and fungi. As a result of recent georeferencing efforts, fully half of our specimen records are georeferenced (pinpointed to a specific site on the globe). In support of the Atlas, in September we launched our citizen science Mapping Change project on Zooniverse (<https://www.zooniverse.org/projects/zooniverse/mapping-change>). The data from this citizen science effort will be summarized, integrated into the Atlas, and used to georeference these specimens in the coming year and for the foreseeable future.

Project Status as of August 18, 2017:

As of this writing, the Minnesota Biodiversity Atlas continues to serve updated Bell Museum specimen data to agency partners and the public, including users from 110 countries around the world. Currently, the Atlas comprises 322,599 records of 8,526 species of Minnesota's flora and fauna, with data on a total of 668,723 specimens of 39,319 species from around the world. Now included in the Atlas are 283,680 specimen images, the majority of Minnesota plants and fishes. As a result of ongoing georeferencing efforts, nearly half (47%) of all records are georeferenced (pinpointed to a specific site on the globe). This number has gone down from previous reports because we have added many specimens to the database that have yet to be georeferenced. Our citizen science project Mapping Change has captured 53,919 specimen classifications from 2,665 volunteers, taking us 32% of the way to our goal of digitizing 17,000 specimens. These data will be integrated into the Atlas in the coming year.

Project Status as of February 28, 2018:

The Minnesota Biodiversity Atlas continues to serve updated Bell Museum specimen data to agency partners and the public, including users from 113 countries to date. Currently, the Atlas comprises 324,322 records of 8,843 species of Minnesota's flora and fauna, with data on a total of 670,024 specimens of 35,685 species from around the world. Now included in the Atlas are 306,209 specimen images, the majority of Minnesota plants and fishes. As a result of ongoing georeferencing efforts, nearly half (48%) of all records are georeferenced (pinpointed to a specific site on the globe), including more than 66% of Minnesota records. Our citizen science project Mapping Change has captured 72,430 specimen classifications from 3,241 volunteers, taking us 44% of



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the way to our initial goal of digitizing 17,000 specimens. These data will be integrated into the Atlas in the final phase of our project. In addition, ongoing digitization efforts of Bell Museum staff have made another 2,691 records mappable within the Atlas.

Overall Project Outcomes and Results:

The Minnesota Biodiversity Atlas project aimed to digitally capture, integrate and disseminate data on Minnesota's plant and animal diversity and distributions, with a focus on specimens held by the Bell Museum, the state's official museum of natural history. The result of this work, the Minnesota Biodiversity Atlas (<http://bellatlas.umn.edu/>), makes the majority of these data specimen data available in one easily-accessible resource for the first time. The new Atlas includes data from over 326,000 specimens of nearly 9000 taxa (species and subspecies) collected from throughout Minnesota by museum curators and state biologists over the last 140 years. Importantly, this project has made georeference data (precise latitude and longitude coordinates) of nearly 223,000 Minnesota specimens available in an integrated platform that allows simultaneous mapping of specimens from distinct groups (e.g., birds and plants) interactively within the Atlas or with the user's own application of choice. The Minnesota Biodiversity Atlas also provides access to a massive archive of specimen images (currently over 135,000), particularly of plants, allowing direct access for identification, collection of phenology and other data, and label verification. In addition to being served directly through the Atlas to agency partners and the public, all of these specimen data, along with all of the Bell Museum's specimen data from other parts of the world, are now served directly to global biodiversity data resources including the National Science Foundation-funded iDigBio and the Global Biodiversity Information Facility, which are critical resources for managers and research scientists around the world. The Minnesota Biodiversity Atlas is now a key resource providing critical data to resource managers and scientists both in Minnesota and globally. Future development of the Atlas will integrate additional specimen data from collections throughout Minnesota, as well as observational data collected by state agency partners and others, creating an even more powerful management tool and a permanent archive for these critical data.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1:

Description: Creation of the Minnesota Biodiversity Atlas, a tool for management

We will create a centralized, online Atlas of Minnesota's biodiversity. This point of access to Minnesota animal, fungal, and plant data will integrate diverse sources of information in ways never before possible. Among other functions (see above), this Atlas will be used to: 1) dynamically generate species checklists for user defined areas, 2) create distributions of individual species over time and across the state, 3) access a rich library of imagery and species information pages (including descriptions, classification, distribution maps, field images, etc.), and 4) assist in specimen identification using interactive keys.

Under the supervision of MSI supervisor Benjamin Lynch and in collaboration with Bell Museum curatorial staff and Symbiota software developers, MSI programmer Tom Prather will implement the above Atlas functionalities using the open source code base of Symbiota (<http://symbiota.org/docs/>). The Atlas will be made available on University servers within 8 months of the start of scheduled work (i.e. by April 2016). Prather will commit 35% of his time to this project (as well as developing the crowdsourcing portion of the project under Activity 3, see below) during the first year (July 2015-June 2016), then 20% of his time during the second year (divided between troubleshooting the Atlas codebase and continued work on crowdsourcing), and 5% during the last year (primarily focused on troubleshooting and streamlining future maintenance), for a total of 60% FTE over three years. We have also budgeted for ongoing development support by the Symbiota project, to facilitate adaptation of existing code to our implementation, as well as to support integration of new code developed by



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our project into the Symbiota code base. In addition, we will train an MSI help staff contact (Tom McGowan) in use of the Atlas, in order to handle user questions and manage software problems and complaints.

In preparation for the Atlas rollout, we will actively seek feedback on beta test versions from government and other partners through email surveys, one on one interviews, and meetings with partner agency managers. As necessary, we will work with our development team to adjust functionality and design details to maximize the utility of this product. Once a full release has been made, we will seek additional feedback and reoptimize as necessary. We will work with Atlas partners to train staff in the functionalities and use of the Atlas (see Section 5: Dissemination, below).

Summary Budget Information for Activity 1:

ENRTF Budget: \$ 104,607
Amount Spent: \$ 91,221
Balance: \$ 13,386

Outcome	Completion Date
1. Integrated access to >250,000 records and >30,000 images currently on hand	April 2016
2. Integrated access to >600,000 records and ~300,000 images	June 2018

Activity Status as of December 31, 2015:

This activity has been the primary focus of work on the Atlas to date. This has involved initiation of work by MSI staff on setting up the Symbiota platform to support the Atlas, coordination of long-term archiving plans with the University of Minnesota Libraries, developing protocols for porting of data between the Bell Museum collections databases and the Atlas, and collation, uploading, and integration of specimen imagery into the Atlas. As of this writing, a fully functional test version of the Minnesota Biodiversity Atlas is running on a server at the Minnesota Supercomputing Institute. This instance has been populated with 256,011 specimen records from the Bell Museum’s plant, fungal, and fish collections, including 92,633 images of plants, and fishes, and is undergoing testing by museum staff and curators. A public version serving Bell collections data is planned for release in April 2016.

Activity Status as of June 30, 2016:

As of this writing, the Minnesota Biodiversity Atlas is online and has been made accessible to agency partners and the public. All Bell Museum collections (including plants, lichens, bryophytes, mammals, birds, fishes, amphibians, reptiles and molluscs) have been incorporated into the Atlas, for a total of 585,084 specimen records from 22,091 species, more than half from the state of Minnesota. The Atlas now comprises 123,406 images of Minnesota flora and fauna, and over 200,000 images in total. In developing the Atlas, we identified a key area (involving a taxonomy tree that includes both plants and animals) of the underlying software (Symbiota) in need of development. Although we have a temporary workaround, we have contracted (drawing on funds in our ENRTF contracts budget) with the software developer to address this issue over summer 2016.

Activity Status as of 4 April 2017:

As of this writing, the Minnesota Biodiversity Atlas continues to serve the Bell Museum’s biodiversity data to agency partners and the public. Currently, the Atlas comprises 629,089 specimen records of 39,359 species from around the globe, including 320,068 records of 8,395 species of Minnesota flora and fauna. In this period, the Atlas hosted 4,911 unique sessions with 20,675 unique page views, originating from 92 countries around the world. We improved the Atlas by contracting the developer of Symbiota (the software in which the Atlas is built) to update how the software handles taxonomy, so that it handles data from multiple kingdoms of life. We continue to add data to the Atlas through image capture (see Activity 2 below), transcription of specimen data



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from images (see Activity 3 below), and georeferencing efforts of trained undergraduate and graduate students (see Activity 3 below).

Activity Status as of August 18, 2017:

As of this writing, the Minnesota Biodiversity Atlas continues to serve the Bell Museum's biodiversity data to agency partners and the public. Currently, the Atlas comprises 668,723 specimen records of 39,319 species from around the globe, including 322,599 records of 8,526 species of Minnesota flora and fauna. In this period, the Atlas hosted 4,650 unique sessions with 42,948 unique page views, originating from 81 countries around the world. We continue to add data to the Atlas through image capture (see Activity 2 below), transcription of specimen data from images (see Activity 3 below), and georeferencing efforts of trained undergraduate and graduate students (see Activity 3 below).

Activity Status as of February 28, 2018:

The Minnesota Biodiversity Atlas continues to serve the Bell Museum's biodiversity data to agency partners and the public. Currently, the Atlas comprises 670,024 specimen records of 34,685 species from around the globe, including 324,322 records of 8,843 species of Minnesota flora and fauna. In this period, the Atlas hosted 4,617 unique sessions with 54,936 unique page views, originating from 81 countries around the world. We continue to add data to the Atlas through image capture (see Activity 2 below), transcription of specimen data from images (see Activity 3 below), and georeferencing efforts of trained undergraduate and graduate students (see Activity 3 below).

Final Report Summary:

The primary deliverable of this project, the Minnesota Biodiversity Atlas, is online at <http://bellatlas.umn.edu>. Currently, the Atlas comprises 672,796 specimen records of 35,774 taxa (species and subspecies) from around the world, including 326,024 records of 8,940 taxa of Minnesota flora and fauna. The Atlas provides global, free access to 305,403 specimen images, including 135,070 images of Minnesota flora and fauna. As of this writing, the Atlas has been visited by 8,994 unique visitors from 121 countries around the world. The Atlas has served 187,357 page views in 20,458 sessions, with an average of 9.2 pages per session. All specimen data in the Atlas are now served to global specimen data aggregators, including the National Science Foundation funded iDigBio (<https://www.idigbio.org/>) and the Global Biodiversity Information Facility (<https://www.idigbio.org/>), the two primary sources of biodiversity distribution data for managers and scientists around the world, and are archived by the Minnesota Supercomputing Institute and University of Minnesota Libraries to assure long-term accessibility.

An account balance of \$13,386 for this activity was returned to LCCMR. These funds were allocated for consulting work with the developer of the underlying platform of the Atlas, Symbiota. We were unable to predict the exact amount of work required, and our initial estimates proved overly generous, resulting in overbudgeting for this item and consequently the unspent funds.

ACTIVITY 2:

Description: Creating images for biodiversity data capture, verification, and identification

Among the four million specimens housed at the Bell Museum are more than 600,000 specimens of Minnesota wildlife, plants and fungi that span the entire period from the founding of our state in 1872 to the present. Although some of the data associated with these specimens are currently available, the majority are not. We will digitally photograph specimens (primarily plants and fungi) and their accompanying documentation. These photographs will be immediately useful for



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online verification of identifications and locality data (e.g., verifying county occurrences); in addition, they are a critical first step in subsequent data capture (see Activity 3).

Image capture begins with retrieval and organization of the specimens from Museum cabinets and drawers. Specimens are organized according to taxonomic group (e.g. families, genera, and species) and referenced according to a unique accession number that was assigned to the specimen at the time it was deposited in the Museum. Accession numbers are located on the label documentation that accompanies each specimen. The next step is to associate a numerical barcode with each accession. Pre-printed barcode labels are affixed to the specimen label and captured digitally using a hand-held barcode scanner. If a specimen accession consists of multiple prepared objects stored separately (e.g. feathers, bones, eggs), unique barcodes are assigned to each object under the same accession number. Specimen labels (and specimens in the case of plants) are placed in a digital imaging station, photographed, and digital image files are named using the hand-held barcode scanner. Digital imaging stations include a lighted copy stand equipped with a neutral background, ruler, and color reference palate, and a digital SLR camera.

Sets of raw images (approx. 40 MB each) are processed in bulk using Photoshop Lightroom for quality, consistency, and generation of smaller JPEG files (approx. 8 MB). Smaller image files and corresponding associations between barcodes and accession numbers are then uploaded to the Symbiota server for translation of image documentation as described in Activity 3. The larger raw image files and associated data will be provided to University Libraries for archival digital preservation.

Image capture is ongoing, and will continue as necessary throughout the course of the grant. Under the supervision of curatorial staff and a graduate curatorial assistant, civil service technician and undergraduate employees will capture images using two high resolution imaging systems already purchased by the University. The herbarium sheets and consequently their images include a barcode that is linked directly to the electronic image file. Subsequent to capture, internet-servable versions of these images will be made available through the Atlas portal. In addition, under the supervision of John Butler and Jon Nichols, high quality versions of these images will be stored and brought under preservation management in the in the University Libraries’ digital archiving system, which will provide: 1) a highly stable image back up in case of data loss, and 2) a digital “back up” of the physical herbarium sheet, and 3) creation and management of preservation metadata for digital collection files.

Summary Budget Information for Activity 2:

ENRTF Budget: \$ 66,464
Amount Spent: \$ 66,464
Balance: \$ 0

Outcome	Completion Date
1. Capture and addition to the Atlas of up to 300,000 digital images	June 2018

Activity Status as of December 31, 2015:

To date, we have captured specimen images from 91,634 vascular plants, 60,198 bryophytes, 5,889 fungi, and 999 fishes. Vascular plant and fish images have already been integrated in the Atlas. Bryophytes and fungi will follow and we anticipate serving over 150,000 of images of Minnesota biodiversity to the public by April 2016. Imaging of Minnesota plants, fungi, and fishes is ongoing.

Activity Status as of June 30, 2016:

The Atlas now comprises 123,406 images of Minnesota flora and fauna, and over 200,000 images in total. These images are primarily of plants, bryophytes, and fishes. Currently, we are focused in image capture from additional plants and particularly fungi. Over 40,000 of these images are currently awaiting integration into the Atlas, and will comprise the first set of images digitized through our partnership with Zooniverse (see Activity 3, below).



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Activity Status as of 4 April 2017:

The Atlas currently comprises 238,349 images in total, including 128,335 images Minnesota flora and fauna. These images are primarily of plants, bryophytes, and fishes, but we are currently expanding our database of microfungi. We expect additional substantial additions to our image database through NSF- and ENRTF-funded efforts in the coming year.

Activity Status as of August 18, 2017:

The Atlas currently comprises 283,680 images in total, including 133,750 images of Minnesota flora and fauna. These images are primarily of plants, bryophytes, and fishes, but we are rapidly expanding of our database of both macro- and microfungi. We will continue image creation and integration into the Atlas through the end of the grant period.

Activity Status as of February 28, 2018:

The Atlas currently comprises 306,209 images in total, including 141,212 images of Minnesota flora and fauna. These images are primarily of plants, bryophytes, and fishes, but we continue to expand our database of both macro- and microfungi. We will continue image creation and integration into the Atlas through the end of the grant period.

Final Report Summary:

As of this writing, the Atlas comprises 305,403 specimen images, including 135,070 images of Minnesota flora and fauna. These images are primarily of plants, bryophytes, fishes, macro- and microfungi.

ACTIVITY 3:

Description: Translating specimen documentation into digital distribution data

Generating images of specimens and accompanying documentation is only the first step in enabling access to high-quality specimen data. Documentation consists of specimen label information including the name of the collector, the date of collection, the geographic location of the collection, and other associated data. Documentation must be captured, curated, and then georeferenced (assigned latitude and longitude coordinates for subsequent distribution mapping). In the case of typed specimen labels, the Symbiota platform includes a state-of-the-art optical character recognition (OCR) and natural language processing (NLP) module that automatically processes labels images and assigns label documentation to corresponding fields in the database. This step in the process will be examined for quality and accuracy by project team members. However, much of the label documentation is hand-written where data capture will require manual transcription. Crowd-sourcing, the coordination of massive volunteer effort over the web, will accelerate this work by enabling volunteer citizen scientists to efficiently enter and verify data. Our staff will then compile the data to generate coordinates using established mapping standards. In other projects, citizen scientists have identified African wildlife, discovered new planets, and mapped the surface of the moon by interpreting images and data posted online (see <http://www.zooniverse.org>). Natural history museums now use these same tools to process data on birds, fungi, insects, and plants (see <http://www.notesfromnature.org/#/archives>).

Under the supervision of MSI supervisor Benjamin Lynch and in collaboration with Bell Museum curatorial staff, MSI programmer Tom Prather will implement the crowdsourced capture of specimen label data in collaboration with development staff at Zooniverse, as a test case for its development of an open source platform for citizen science. The crowdsourced data entry functionality will be go online within one year from the start of scheduled work (i.e. by July 2016). The use of Prather's time is detailed under Activity 1 above.

In concert with rollout of crowdsourced specimen label capture, the Bell Museum will advertise to relevant citizen scientist groups, including amateur plant and wildlife enthusiasts (e.g., Minnesota Native Plant Society, Minnesota Ornithologists' Union, Minnesota Herpetological Society), paraprofessional groups (e.g., the Minnesota Master Naturalists' Program),



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University and K-12 student groups, and professionals (e.g., University faculty, DNR staff) to recruit participants. As necessary, label capture efforts will be supplemented by civil service technician and undergraduate employee staff time (primarily budgeted for image capture under Activity 2).

As locality descriptions are captured, their latitude and longitude coordinates will be estimated by a graduate curatorial assistant (CA), as well as by civil service technician and undergraduate employees trained and supervised by the CA. Coordinate capture will follow accepted georeferencing standards (<http://manisnet.org/GeorefGuide.html>). Locality descriptors and point coordinates will be posted to the Atlas on at least a quarterly basis.

Summary Budget Information for Activity 3:

ENRTF Budget: \$ 168,929
Amount Spent: \$ 168,929
Balance: \$ 0

Outcome	Completion Date
1. <i>Begin crowdsourced capture of specimen label data</i>	July 2016
2. <i>Publish georeferenced coordinates for up to 325,000 specimen records to the Atlas</i>	June 2018

Activity Status as of December 31, 2015:

Work on this activity has focused on developing software capability for text capture from specimen images. The Bell Atlas team successfully competed among proposals within the University of Minnesota for developer support of text capture capability within Zooniverse, the premiere online science crowdsourcing site (<https://www.zooniverse.org/>). This collaboration will complement LCCMR support for our MSI developer and significantly raise the profile of the Atlas project, supporting more ambitious crowdsourcing goals and reaching a broader, even global, audience for our collections and data. Development of the crowdsourcing component of this work continues apace, and an alpha test version of the text capture process has already been implemented and tested. We are currently on track for public release in July 2016.

Activity Status as of June 30, 2016:

Currently, nearly half (290,429) of the records in the Atlas have been georeferenced (pinpointed to a specific site on the globe), only 35,000 short of our goal. This reflects a major push to georeference amphibian and reptile work that occurred this spring, as well as repatriation of ~40,000 georeferenced points for birds from a national georeferencing effort (Ornis). Our remaining georeferencing efforts will focus on newly-imaged specimens, primarily of plants and fungi. This work depends on capture of locality text descriptions from specimen images; consequently, we have focused on finalizing our collaborative digitization effort with Zooniverse. This collaboration has produced a functional beta test interface that we have used to capture a test data set. These test data have been used to develop a georeferencing pipeline that will automatically find coordinates for many specimens, and flag other specimens that will need hand editing or clarification. We will soon be ready to launch this crowdsourcing effort: final launch is now scheduled for mid-September.

Activity Status as of 4 April 2017:

Probably the most significant landmark of this reporting period was the launch on the Zooniverse citizen science platform of our digitization effort: Mapping Change. Launched in September, this project aims to capture label data from images produced in the course of our work on the Atlas. Our initial image set included 16,990 plant subjects in need of locality data capture and georeferencing. To date, this project has captured 38,741 classifications and “retired” (i.e. adequately transcribed) a total of 4,955 subjects. In support of this project, we participated in the national WeDigBio digitization effort in October (<https://www.idigbio.org/content/wedigbio->



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[2016-0](#)) by offering a workshop in specimen transcription to the Minnesota Master Naturalists. We trained ~20 naturalists in the Mapping Change workflow and transcribed specimen data for two hours. These naturalists form a core among the 2,164 unique volunteers that have contributed to this project to date. The transcriptions completed on Mapping Change will be curated, integrated into the Atlas, and used to obtain mapping coordinates for the corresponding specimens, adding data to the Atlas now and for the foreseeable future.

Activity Status as of August 18, 2017:

Data collection through Mapping Change continues. We supported this digitization effort by hosting a data transcription workshop at the University of Minnesota, in conjunction with the Minnesota Master Naturalists' Gathering Partners of Natural Resources conference. This workshop had ~15 attendees who were trained in recognizing and transcribing critical specimen data. To date, Mapping Change has captured 53,919 classifications logged by 2,665 volunteers, and our first batch of specimens is currently ~32% transcribed. With MSI partners, are currently developing protocols for automated grooming and georeferencing of these data, in preparation for their integration into the Atlas.

Activity Status as of February 28, 2018:

Data collection through Mapping Change continues. We supported this digitization effort by hosting a data transcription workshop at the University of Minnesota, in conjunction with the Minnesota Master Naturalists'. This workshop had ~20 attendees who were trained in recognizing and transcribing critical specimen data. To date, Mapping Change has captured 72,430 classifications logged by 3,241 volunteers, and our first batch of specimens is currently 44% transcribed. With MSI partners, are continue developing protocols for automated grooming and georeferencing of these data, in preparation for their integration into the Atlas. In addition to these efforts, museum staff have begun georeferencing plant records directly in the Atlas using its built-in georeferencing module. This has resulted in georeferencing of 2,691 additional plant records, making them available for mapping within the Atlas.

Final Report Summary:

Although the current Atlas project has ended, label data collection through Mapping Change—our citizen science project on the Zooniverse platform—continues. As of this writing, Mapping Change has had contributions from 3,564 volunteers, adding up to 81,212 classifications on 17,713 images. Nearly 9,000 images have completed the data capture process. With MSI partners, we have developed protocols for automated grooming and georeferencing of these data, and these data will be integrated into the Atlas in the coming months. Ongoing georeferencing efforts by Bell Museum curatorial staff, as well as efforts funded by this project, have resulted in 68.4% of all 326,024 Minnesota specimen records in the Atlas having precise latitude and longitude coordinates, allowing use of these records in generation of range maps and regional inventories.

V. DISSEMINATION:

Description:

This project requires two major dissemination activities. First, our focus on crowdsourcing of specimen label capture will require outreach to recruit potential contributors. This recruitment will be accomplished by targeted advertising through Bell Museum and University outlets to specific groups with high potential for participation: undergraduate students, secondary school students, naturalists (e.g., participants in the University master naturalist program), paraprofessionals and hobbyists (Minnesota Native Plant Society, Minnesota Herpetological Society, Minnesota Ornithologists' Union), and others. Once up and running, the Atlas itself will disseminate museum data and images directly. However, we will also advertise and demonstrate the use of the



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Atlas to targeted user groups (DNR staff, MNPCA staff, and others) through email announcements and hands-on workshop activities.

Status as of December 31, 2015:

To date, formal dissemination activities have not begun, since the Atlas is not planned for public release until April 2016, and crowdsourcing is scheduled to begin in July 2016. Principal investigators George Weiblen and Andrew Simons attended a November 2015 meeting in Arlington, Virginia of the National Science Foundation project Integrating Digitized Biocollections, where they shared the Atlas project with >100 participants from across the country. They attended sessions on best practices in data management and sharing which were later shared with other Atlas project participants. We intend to work with Bell Museum public programs and communications staff to promote the Atlas as we move toward public access in April 2016.

Status as of June 30, 2016:

The Minnesota Biodiversity Atlas became accessible to the public in May 2016. Launch of the Atlas was announced via Bell Museum social media and a formal press release. Principal investigator Barker was interviewed live on WTIP (North Shore Community Radio; <http://www.wtip.org/u-mn-bell-museum-launches-online-biodiversity-atlas>) and on tape for Access Minnesota (Jim du Bois; <http://www.accessminnesotaonline.com/2016/05/25/the-biodiversity-atlas/>). Prior to its official launch, principal investigator George Weiblen also demonstrated use of the Atlas at the Minnesota Native Plant Society (<http://mnnps.org/event/2016-symposium/>). Our collaboration with Zooniverse will form the basis for an October transcription event in conjunction with the Minnesota Master Naturalist program and the national WeDigBio effort (<https://www.wedigbio.org/content/master-naturalists-mapping-change>).

Status as of 4 April 2017:

The Minnesota Biodiversity Atlas continues to serve data to Minnesotans and researchers around the world, including users from 92 countries. Curator George Weiblen discussed the Atlas during an interview on MPR (<http://www.mprnews.org/story/2016/08/22/bell-museum>). During this reporting period, we launched the our transcription project Mapping Change on the citizen-science platform Zooniverse (<https://www.zooniverse.org/projects/zooniverse/mapping-change>). To date, more than 2,000 unique volunteers have contributed to data transcription on this project. In support of this project, we hosted a WeDigBio digitization effort in October (<https://www.idigbio.org/content/wedigbio-2016-0>), with ~20 participants. In addition, reports on both the Atlas and Mapping Change were presented at the annual meeting of the Minnesota Ornithologists' Union in December.

Status as of August 18, 2017:

The Minnesota Biodiversity Atlas continues to serve data to Minnesotans and researchers around the world, including users from 110 countries. During this period, we supported our digitization efforts by hosting a data transcription workshop at the University of Minnesota, in conjunction with the Minnesota Master Naturalists' Gathering Partners of Natural Resources conference. This workshop had ~15 attendees who were trained in recognizing and transcribing critical specimen data.

Status as of February 28, 2018:

The Minnesota Biodiversity Atlas continues to serve data to Minnesotans and researchers around the world, including users from 81 countries during this reporting period. During this period, we supported our digitization efforts by hosting a data transcription workshop at the University of Minnesota, in conjunction with the Minnesota Master Naturalists' program. This workshop had ~20 attendees who were trained in recognizing and transcribing critical specimen data.



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Final Report Summary:

The primary result of this work was production of the Minnesota Biodiversity Atlas (<http://bellatlas.umn.edu/>), an online resource interactively serving data on specimen records of Minnesota plants and animals to agency partners, the public, and scientists and managers worldwide. This Atlas is the primary means of disseminating data on Minnesota’s biodiversity. Bell Museum curators have promoted use of this resource by: 1) interaction with and training of agency partners in use of the Atlas; 2) interviews with the media, including two radio interviews and at least two print interviews; 3) training of participants in the Minnesota Master Naturalists program in specimen data capture (through a related project, *Mapping Change*, within the *Zooniverse* citizen science platform) and use of the Atlas, 4) a permanent link to the Atlas at the Bell Museum’s Research and Collections web page, and 5) promotion of the Atlas through electronic exhibits within the newly-opened Bell Museum. Promotion of the Atlas within the new Bell Museum happens at two points: 1) in a discussion of citizen science at the Discovery Station in the Tree of Life exhibit, and 2) at a Discovery Station in the Touch and See room where users can interact with the Atlas directly.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	\$ Amount	Overview Explanation
Personnel:	\$ 316,129	The bulk of this project involves data collection and programming by paid personnel: 15% FTE development supervisor, 60% FTE developer, 14% FTE technical support, 24% FTE digital preservation and repository development, 24% FTE digital preservation analyst, 50% FTE graduate curatorial staff, <u>75% FTE civil service technician</u> , and 375% <u>160%</u> FTE undergraduate curatorial staff.
Professional/Technical/Service Contracts:	\$ 7,614	This contract with the Symbiota Software Project will fund support of our independent software development within the Symbiota codebase, as well as troubleshooting implementation of the Atlas using Symbiota software.
Equipment/Tools/Supplies:	\$ 2,871	This line supports purchase of two workstations to increase the museum’s capacity for digital coordinate capture.
TOTAL ENRTF BUDGET:		\$ 326,614

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than \$5,000: N/A

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 6.12



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Number of Full-time Equivalent (FTE) Estimated to Be Funded through Contracts with this ENRTF

Appropriation: N/A

B. Other Funds:

Source of Funds	\$ Amount Proposed	\$ Amount Spent	Use of Other Funds
Non-state			
	\$	\$	
State			
University of Minnesota, in kind	\$41,699	\$6,950	2% FTE for curatorial staff (Barker, Bates, Cholewa, Jansa, Simons, and Weiblen) over three years
University of Minnesota, in kind	\$10,236	\$0	3% FTE for Libraries management and coordination (Nichols)
University of Minnesota, in kind	\$25,500	\$0	Library hosting of image data
TOTAL OTHER FUNDS:	\$77,435	\$0	

VII. PROJECT STRATEGY:

A. Project Partners:

Bell Museum curators will contribute taxonomic expertise including Scott Bates (fungi and Symbiota software management), Keith Barker (birds), Sharon Jansa (mammals), Andrew Simons (fishes), and George Weiblen (plants). Minnesota Supercomputing Institute personnel will provide database and programming expertise including Benjamin Lynch (UMN MSI project management) and Tom Prather (software development). The University of Minnesota Library will support our image archiving needs, with experts including John Butler (UMN Library project management) and library staff under his supervision. In addition, we will be working with the *Symbiota* project (<http://symbiota.org/docs/>) to adapt their software platform for use in the Atlas (for a total of \$21,000 ENRTF dollars).

B. Project Impact and Long-term Strategy:

The Atlas proposed here will be of immediate, practical use to a diverse community of managers and scientists including field workers, ecologists, conservation planners, and policy-makers, as described above. The Museum is committed to the creation and long-term maintenance of this tool as part of our ongoing, constructive relationship with partner agencies including the Minnesota Biological Survey and Minnesota Pollution Control Agency (see letters). We are supported in this effort by the UMN Libraries, who will host the image data from this project according to archival standards. Outcomes from this LCCMR-funded work will leverage grant proposals to the US National Science Foundation for improving Minnesota’s biological collections.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	\$ Amount
Hatch Fund, National Institute of Food and Agriculture: Geocoding of herbarium specimens	Current	\$30,000
NSF: Digital photography of bryophyte collection	Current	\$74,000
NSF: Digitization of aquatic invasive species	Current	\$46,476

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:

A. Parcel List: N/A

B. Acquisition/Restoration Information: N/A



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IX. VISUAL COMPONENT or MAP(S): See attached graphic.

X. RESEARCH ADDENDUM: N/A

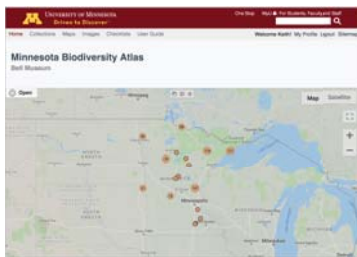
XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than 31 December 2015, 30 June 2016, 31 December 2016, 30 June 2017, and 31 December 2017. A final report and associated products will be submitted between 30 June and 15 August 2018.

The Minnesota Biodiversity Atlas

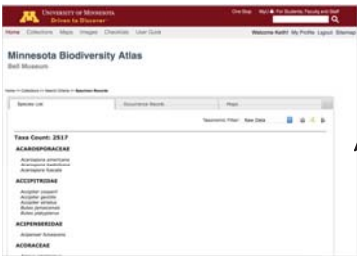
A Tool for Management

Home Page: <http://bellatlas.umn.edu>



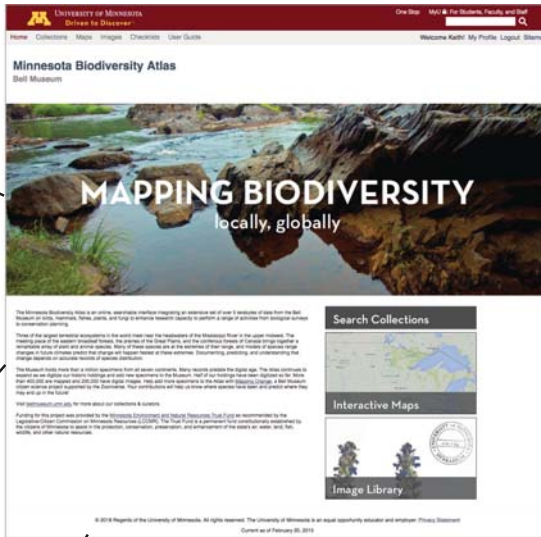
Red-backed Vole (*Myodes gapperi*) in Minnesota

Species Range Maps

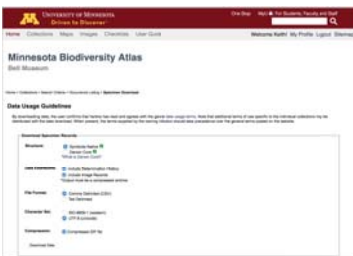


Taxa in Lake County, Minnesota

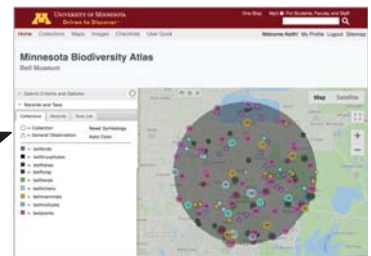
Regional Species Lists



Data Export and Sharing



Mapping Multiple Collections



All specimens within a circle centered on Pinewood, MN

Specimen Detail



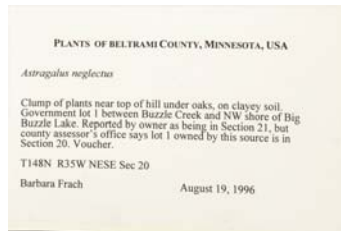
Specimen Images



Shows specimen detail



Legible label data



**Environment and Natural Resources Trust Fund
M.L. 2015 Project Budget**



Project Title: *Minnesota Biodiversity Atlas for Enhanced Natural Resource Management*

Legal Citation: *M.L. 2015, Chp. 76, Sec. 2, Subd. 03d*

Project Manager: *F. Keith Barker*

Organization: *Bell Museum of Natural History, University of Minnesota*

M.L. 2015 ENRTF Appropriation: \$ 340,000

Project Length and Completion Date: *3 Years, 30 June 2018*

Date of Report: *4 April 2017*

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	<i>Creation of the Minnesota Biodiversity Atlas</i>			<i>Creating images for biodiversity data</i>			<i>Translating specimen documentation</i>				
Personnel (Wages and Benefits)	\$83,607	\$83,607	\$0	\$66,464	\$66,464	\$0	\$166,058	\$166,058	\$0	\$316,129	\$0
<i>Benjamin Lynch, Atlas Development Supervisor; \$20,028 (74.7% salary, 25.3% fringe) 5% FTE for 3 years (Total: 15% FTE)</i>											
<i>Tom Prather, Atlas Developer; \$76,837 (74.7% salary, 25.3% fringe) 20% FTE for 3 years (Total: 60% FTE)</i>											
<i>Tom McGowan, Atlas support specialist; \$14,611 (74.7% salary, 25.3% fringe) 7% FTE for 2 years (Total: 14% FTE)</i>											
<i>Digital Preservation and Repository Developer; \$27,295 (74.7% salary, 25.3% fringe) 8% FTE for 3 years (Total: 24% FTE)</i>											
<i>Digital Preservation Analyst; \$20,231 (74.7% salary, 25.3% fringe) 8% FTE for 3 years (Total: 24% FTE)</i>											
<i>Graduate Curatorial Assistant; \$75,752 (51% salary, 49% fringe) 50% FTE for 2 years (Total: 100% FTE)</i>											
<i>Undergraduate Curatorial Assistants; \$35,375 (100% salary) 25% FTE for 3 years (Total: 160% FTE)</i>											
<i>Civil service technicians; \$46,000 (23.6% fringe), 50% FTE for 1.5 years (Total: 75% FTE)</i>											
Professional/Technical/Service Contracts											
<i>Symbiota Software Support; Symbiota Software Project</i>	\$21,000	\$7,614	\$13,386	\$0	\$0	\$0	\$0	\$0	\$0	\$21,000	\$13,386
Equipment/Tools/Supplies											
<i>Computer Workstations for Georeferencing</i>	\$0	\$0	\$0	\$0	\$0	\$0	\$2,871	\$2,871	\$0	\$2,871	\$0
COLUMN TOTAL	\$104,607	\$91,221	\$13,386	\$66,464	\$66,464	\$0	\$168,929	\$168,929	\$0	\$340,000	\$13,386