**BIODIVERSITY COLLECTIONS NETWORK**

**NIBA Status Report: Assessments and Recommendations from Biodiversity Collections Network Workshop**

**January 5-6, 2017**

**Washington, DC**

**Updated December 2018**

## Background

I. The digitization effort, first outlined in a *Strategic Plan for a Network Integrated Biocollections Alliance (NIBA)* put forth a 10-year vision to:

- digitize data from all US biological collections, large and small, and integrate these in a Web-accessible interface using shared standards and formats

- develop new Web interfaces, visualization and analysis tools, data mining, and georeferencing processes and make all available for using and improving NIBA resources

- create real-time upgrades of biological data and prevent the future occurrence of non- accessible collection data through the use of tools, training, and infrastructure.

II.

## NIBA Implementation Goals—Summary

The *Implementation Plan for NIBA* (2013) identified six implementation goals:

*Implementation Goal 1:*
*Establish an organizational and governance structure that will provide the national leadership and decision-making mechanism required to implement NIBA and to fully realize its strategic plan.*

*Implementation Goal 2:*
*Advance engineering of the US biodiversity collections cyberinfrastructure. Implement adaptive technology strategies around core discipline standards to enable efficient digitization workflows, effective data management, permanent data archives, innovative and synthetic research, effective biodiversity policy, and ubiquitous educational engagement.*

*Implementation Goal 3:*
*Enhance the training of existing collections staff and create the next generation of biodiversity information managers.*

***Implementation Goal 4:***
*Increase participation in and support for NIBA from a broad spectrum of stakeholders, both nationally and internationally*

***Implementation Goal 5:***
*Establish an enduring and sustainable knowledge base.*

***Implementation Goal 6:***
*Infuse specimen-based learning and exploration into formal and informal education.*

## Status Report on NIBA Goals and Workshop Comments and Recommendations

***Implementation Goal 1:***
*Establish an organizational and governance structure that will provide the national leadership and decision-making mechanism required to implement NIBA and to fully realize its strategic plan.*

Accomplishments to Date:

Goal 1.1: Found the NIBA organization

- Following publication of NIBA Implementation Plan, representatives of the American Institute of Biological Sciences (AIBS), Society for the Preservation of Natural History Collections (SPNHC), Natural Science Collection Alliance (NSCA), and iDigBio met to consider next steps. Led by AIBS and with the active participation of the NSCA and SPNHC, the groups successfully submitted a Research Coordination Network proposal to NSF. A 5-year grant was funded in 2014 (NSF DBI-1441785).
- To date, the RCN has functioned as the NIBA organization, in loose collaboration with iDigBio—an NSF-funded National Resource addressing many NIBA goals (NSF DBI-1115210 and DBI-1547229).
- More than 20 organizations have endorsed the concept of NIBA via their formal endorsement of BCoN.

Goal 1.2: Establish a governance, administrative, and management structure for NIBA
- This has not yet been done.

Goal 1.3: Establish automated methods and metrics for measuring progress made toward NIBA's digitization goals

- iDigBio and NSF's Advancing Digitization of Biodiversity Collections (ADBC) program monitor digitization progress for those institutions funded by ADBC.
- Individual Thematic Collections Networks (TCNs) track progress toward digitization within their network.
- Beginning in 2017, *Index Herbariorum* will allow herbarium collections to self-report on their digitization progress.

Goal 1.4: Document workflow challenges and identify solutions for collections with specialized or particularly challenging specimens

- iDigBio has documented workflows for the digitization of various types of collections (https://www.idigbio.org/content/digitization-workflows and https://www.idigbio.org/wiki/index.php/Digitization_Resources).
- iDigBio has held multiple workshops to demonstrate digitization techniques and efficient workflows, and has held webinars to explore various tools for data capture and formatting (https://www.idigbio.org/wiki/index.php/IDigBio_Workshops).

Goal 1.5: Organize and facilitate both public and professional outreach to communicate NIBA's goals, programs, and accomplishments, as well as its broader societal benefits.
- BCoN organized a workshop to identify current communications and outreach resources and opportunities for increased community collaboration. A report from this workshop included specific actions for the community. These are now being developed and implemented via a Communications Working Group.
- A recommendation from the BCoN Communications Workshop was that biodiversity collection professionals needed to become more skilled with engaging non-technical audiences. In response, AIBS has developed a Communications Boot Camp for Scientists. Biodiversity scientists and collections staff have and continue to participate in these programs, further increasing the capacity of the community to engage new audiences.
- Presentations about BCoN and its objectives have been given at several meetings of professional societies.
- WeDigBio holds citizen science events to spur global public engagement in digitization activities::www.wedigbio.org.
- Notes from Nature provides an attractive and engaging platform for transcribing data from natural history specimens, including blog posts that explain the importance of natural history collections: www.notesfromnature.org.

Goal 1.6: Create a comprehensive, up-to-date, and publicly accessible registry of United States–based biocollections, their holdings, and curatorial staff.
- GRBio/GRSCiColl created the structure for a worldwide registry of collections: www.grbio.org.
- *Index Herbariorum* has been funded to expand the information collected from herbaria to include information about digitization, and also to reach out to all the world's herbaria for updated information: http://sweetgum.nybg.org/science/ih/.
- iDigBio curates a comprehensive list of all natural history collections in the United States of America -- https://www.idigbio.org/portal/collections.

Goal 1.7: Create incentives for innovation in biocollection digitization.
- ADBC program recommends that TCN proposals include innovations that could benefit digitization efforts for all institutions
- NSF and AIBS jointly administered the Beyond the Box prize challenge, a $1M prize competition seeking to incentivize a group to create an automated method for digitizing insect drawers. No successful solution was identified.

Goal 1.8: Support efforts by host institution and professional organizations to build, improve, and curate collections.
- The Natural Science Collections Alliance (NSCA) has developed a new organizational strategic plan to help it focus its efforts and those of its institutional leaders on this task.
- AIBS, BCoN, SPNHC, iDigBio, California Academy of Sciences and NSCA have

surveyed research collections to gather data about budgets, staffing, and priorities. A report is being written and should be submitted for publication by the end of 2017 or early 2018.

- AIBS, SPNHC, NSCA and others urged the NSF to reverse its decision to cut the Collections in Support of Biological Research (CSBR) program
- SPNHC, NSCA, professional societies and NSF have been quick to respond to collection emergencies, such as the transfer of specimens from University of Louisiana at Monroe to other institutions
- SPNHC is providing professional development through the emerging professional program that is engaging the next generation of biocollections staff professionals.
- SPNHC best practices wiki (http://spnhc.biowikifarm.net/wiki) is a depository for
- information about curation and collections development.

*Implementation Goal 2:*
*Advance engineering of the US biodiversity collections cyberinfrastructure. Implement adaptive technology strategies around core discipline standards to enable efficient digitization workflows, effective data management, permanent data archives, innovative and synthetic research, effective biodiversity policy, and ubiquitous educational engagement.*

## GOAL 2 STATUS REPORT

Goal 2.1: Create a national database of all digitized specimen records from US collections; document requirements; specify design; and incrementally implement storage, computational, information retrieval, and Web integration capabilities.

- iDigBio data portal currently contains >104 million records (includes data beyond that held at U.S. institutions): https://www.idigbio.org/portal.
- Regional or taxon-specific aggregations exist; most are duplicated in the iDigBio data portal, and many are in GBIF as well. (For networks, see http://usvhproject.org/#/networks, though out of date. Also: http://symbiota.org/docs/symbiota-introduction/active-symbiota-projects/.)
- BISON database is a unique, Web-based federal mapping resource for species occurrence data in the United States and its territories, with 375 million occurrence records, mostly insects: https://bison.usgs.gov/#home

Goal 2.2: Establish R&D environment to deliver new specimen digitization workflow methods, tools, and techniques; develop infrastructure for the exchange and publication of digitization workflow methods.

- NSF's Advances in Biological Informatics program (ABI) is supporting the development of Kurator, a project to develop a provenance-enabled Workflow Platform and Toolkit to Curate Biodiversity Data: http://wiki.datakurator.org/wiki/.
- iDigBio has documented workflows for the digitization of various types of collections -- https://www.idigbio.org/content/digitization-workflows and https://www.idigbio.org/wiki/index.php/Digitization_Resources.

Goal 2.2.1: Support development of projects and proposals to identify and fill gaps.
- No information available.

Goal 2.2.2: Define discrete workflow modules with individual performance metrics. Identify standards-based metadata schema and online repository for workflow process metadata.
- No information available.

Goal 2.3: Develop needed standards and protocols; establish a working group to guide this activity; complete and maintain standards and software for mapping specimen data with interfaces and semantics of other research communities and organizations.
- Digitization best practices: https://www.idigbio.org/wiki/index.php/Recommendations_for_the_Acquisition,_Processing,_and_Archiving_of_Digital_Media.
- Standards developed by TDWG community, such as Darwin Core and Audubon Core; improvement of collections management system platforms such as Symbiota to meet needs of collaborative digitization efforts: http://www.tdwg.org/standards/.
- There have been many workshops funded through iDigBio to share best practices and efficient workflows for digitization: https://www.idigbio.org/wiki/index.php/Digitization_Resources#iDigBio_Workshops.2C_Reports.2C_and_Wikis.
- The practice of assigning identifiers is becoming more standard in specimen databases and is accommodated by the iDigBio database and other aggregators.
- Genbank/NCBI is providing voucher linkage to specimen records while collections databases are beginning to record Genbank sequences associated with specimens.
- The NSF-funded Wholetale initiative (www.wholetale.org) is looking at mechanisms to merge science and cyberinfrastructure pathways while the Pensoft data integration tool (http://arpha.pensoft.net/) is enabling the direct publication of specimen

examined data from iDigBio, GBIF, and DataOne. BiSciCol
(http://biscicol.blogspot.com/) is also tackling the problem of interoperability of
disparate data sources.
- Symbiota and Specify open-source collections management platforms now have over
350 and 500 collections, respectively, using and contributing to their software. They
both present online and recorded workshops, training modules, and webinars on
effective use and maintenance and have large online resources of training
documentation. A large number of the TCN's are using these software packages to
manage the data being generated and served to the community.

Goal 2.4: Develop methods for accreditation and promotion of robust software tools, network
computation services, and data integrity; Establish a community software evaluation committee
to assess maturity and interoperability of available software.
- No information available.

Goal 2.5: Invent and facilitate the future of biodiversity specimen integration; organize existing
examples of leading-edge integration; identify likely new areas leading to research insight.
- Both the EarthCube RCN and the Paleobiology Database Project (https://paleobiodb.org)
have made progress in this area along with various paleo and Earth science–specific
workshops and working groups through iDigBio. There is also a paleo extension to
Darwin Core that allows for better mapping of paleo-specific data. Some of the existing
models include Dryad, DataOne and iDigBio. iDigBio has also addressed this with their
Data Management Working Group[1]
- BiotaPhy is a project to integrate research pipelines to link data, CI, and analytical tools
established by recent NSF investments in biodiversity science—the Open Tree of Life,
iDigBio, Lifemapper, and tools for comparative methods in Arbor. For example, Arbor
(arborworkflows.com/; Harmon et al. 2013), hopes to provide streamlined, powerful
workflows for evolutionary analyses. Although workflows/linkages are in development,
the underlying biodiversity programs developed by diverse authors as R packages are
already available for use: http://wiki.biotaphy.org/index.php?title=Main_Page.

Goal 2.6: Develop an implementation plan for long-term data archiving of specimen information,
including 2D and 3D images and text information; survey and estimate the volume of storage
needed; identify existing storage options, project options with technology changes.
- The Cyverse data store has been used as an archive for several TCN projects:
www.cyverse.org
- Morphosource is a project-based data archive that allows researchers to store and
organize, share, and distribute their own 3D data, and download and print 3D fossils:
www.morphosource.org.
- Zenodo is a research data repository. Launched in 2013, it allows researchers in any
subject area to upload files up to 50 GB: https://zenodo.org.

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[1] https://www.idigbio.org/wiki/index.php/Data_Management_Interest_Group

- Data Observation Network for Earth (DataONE) is a community driven project providing access to data across multiple member repositories, supporting enhanced search and discovery of Earth and environmental data. DataONE promotes best practices in data management through responsive educational resources and materials: www.dataone.org.

Goal 2.7: Support the development of a robust, Web services based architecture for handling taxonomic names applied to specimens as determinations and annotations; Bring data services associated with global names projects into production computing environments to provide open communication of taxonomic names among database systems.
- The Global Names Architecture project has produced a Global Names Resolver: http://resolver.globalnames.org/.
- Cyverse has funded the Taxonomic Names Resolution Service for plants: http://tnrs.iplantcollaborative.org.
- Kurator: http://wiki.datakurator.net/web/Kurator[2].
- Ontobrowser: https://github.com/Novartis/ontobrowser.
  - Animal Diversity Web: http://animaldiversity.org/site/about/technology/index.html/.Biodiversity Collections Ontology (BCO):
  - https://github.com/BiodiversityOntologies/bco.

*Implementation Goal 3:*
*Enhance the training of existing collections staff and create the next generation of biodiversity information managers.*

**GOAL 3 STATUS REPORT**

Goal 3.1: Develop training programs in biodiversity informatics for museum professionals; develop curriculum, determine proficiency level and requirements for attainment; promote new undergraduate curricula and graduate programs in biodiversity informatics; expand museum studies programs to include software engineering and informatics activities; identify topics and curriculum and funding resources, leverage existing programs.
- A course has been developed at the University of Florida that explores the use of collections data for research. Online enrollment in the course was enabled to increase access to the course.
- TCN projects have provided hands-on training for a significant number of undergraduate students.
- iDigBio has developed and continues to offer a series of workshops and training opportunities that focus on digitization of particular kinds of biological specimens, with emphasis on those that present special challenges.
- SPNHC Emerging Professionals Committee has developed a list of courses on various aspects of collections management that are routinely shared with students and early career professionals.
- Biodiversity Literacy in Undergraduate Education (BLUE) is an initiative to build partnerships among biodiversity and education researchers to identify strategies, centralize resources, and develop educational materials: http://www.biodiversityliteracy.com/blue-about.

Goal 3.2: Establish career paths, retention incentives for data or specimen management and curation; develop evaluation mechanisms as well as standardized position nomenclature and promotion path.

- BCoN co-sponsored and participated in an AIBS-organized meeting addressing biological informatics education and workforce issues during which these issues were explored. A report (https://www.aibs.org/events/council_meeting_2015.html) from that meeting was shared with professional societies, data management and analysis organizations, and education organizations.

Goal 3.3. Define career paths and stimulate institutional employment of professional software developers; establish workshop to define professional roles, institutional benefits, and sources of biodiversity informatics staff.

- Monfils, A.K. 2015. Biological informatics training needs for systematics and digitization. Addressing Biological Informatics Workforce Needs: American Institute of Biological Sciences. 2015 AIBS Council Meeting, Washington DC.
- Crandall, K., R. Gropp, and A.K. Monfils. 2016. Addressing Biological Informatics Workforce Needs. American Institute of Biological Sciences Webinar Series.

***Implementation Goal 4:***
*Increase participation in and support for NIBA from a broad spectrum of stakeholders, both nationally and internationally.*

## GOAL 4 STATUS REPORT

Goal 4.1: Achieve buy in and participation from a broad spectrum of stakeholders for NIBA's vision, activities, and services; convene a workshop with representatives of these groups to share objectives and implementation strategies to reveal areas of common interest.

- See BCoN (www.bcon.org) and iDigBio (www.idigbio.org) for lists of workshops, webinars, symposia, and other programs. There have been many per year since 2011.

Goal 4.2: Develop industry partnerships and outreach meetings with potential industrial partners.

- Picturae (https://picturae.com) has developed a business of high-throughput specimen digitization, especially for herbarium specimens.
- CISCO funded at 2-day "Pit Stop" meeting to bring collections professionals together with small to mid-sized technology companies at the Natural History Museum in London to explore way to make specimen digitization more efficient—iDigBio participated in this meeting.

Goal 4.3: Promote the use of digitized specimen data in research; enlist assistance of funding agencies to incentivize collections support and use; publicize the availability of specimen data to scientific societies; provide help-desk functions for ad hoc questions about how to use collections data.

- BCoN established a Research Working Group, which participated in this workshop.
- NSF established a postdoctoral fellowship to support research using biological collections.
- This is a major current focus of iDigBio, with activities such as booths and professional society meetings, symposia at professional meetings, Research Spotlight

(https://www.idigbio.org/tags/research-spotlight), and social media posts.
- The iDigBio data portal uses technology to make data accessible, such as specimen identifiers and APIs, and to answer questions from the community about how to use the data.
- Paleoniches TCN and iDigBio created a mapping plugin that can generate maps of fossil specimen localities (https://github.com/iDigBio/wp-leaflet-idigbio-geojson-data).
- TDWG Biodiversity Data Quality Interest Group is working toward developing standardized terminology and tools for assessing the research fitness-for-use for biodiversity data: http://www.tdwg.org/activities/biodiversity-data-quality/interest-group-charter/.
- A collaboration between iDigBio, Encyclopedia of Life (EOL), and Jorrit Poelen (freelance software engineer, GloBI) is resulting in two tools using iDigBio primary biodiversity data and other data sources: Effechecka is a taxonomic checklist generator which uses spatial and trait data, and FreshData enables researchers to receive notification as to when new biodiversity data, based on a particular query string, has become available from various data sources, such as iDigBio.
- iDigBio is working with the San Diego Super Computer facility to develop a SuAVE extension for curating and exploring large collections datasets, support domain standards, interface with taxonomies, and make them available through an analysis platform. SuAVE uses technical approaches from image analytics, faceted search, and online map navigation as an online tool for exploratory data analysis.
- Pensoft's ARPHA publishing Platform has been developed to streamline the import of biodiversity occurrence records from iDigBio and other databases into the Biodiversity Data Journal: http://arphahub.com/.
- ePANDDA (Enhancing Paleontological and Neontological Data Discovery) is a new API being developed for geoscience database connectivity -- https://epandda.org/
- An NSF-funded project called "Connecting resources to enable large-scale biodiversity analyses"—which is known as BiotaPhy—is developing a cyberinfrastructure framework linking diverse data (phylogeny, morphology, ecology, fossils, geography, and climate) across several data-driven community research tools: http://wiki.biotaphy.org/index.php?title=Main_Page.
- PhyloJIVE (Phylogeny Javascript Information Visualiser and Explorer) is to be upgraded to Phylolink, which integrates taxon information across phylogeny, biogeography, geology, and paleobiology: http://phylolink.ala.org.au/. A joint project of iDigBio and Atlas of Living Australia.

Goal 4.4: Create metadata infrastructure to track specimen data usage for automatic attribution and credit reporting for source institutions; develop an information architecture for logging collection data object usage for databases, Web services, and Web pages.
- GBIF has developed tools for dataset metrics: https://devpost.com/software/gbif-dataset-metrics-xfvzns

Goal 4.5: Expand NIBA to include digitization of federal collections; NIBA and NSF outreach to federal interagency committees and agencies on leveraging NIBA resources.
- Nothing was reported.

- Several federal institutions are working in collaboration with current TCNs including the Fossil Insect TCN (Smithsonian National Museum of Natural History and Florissant Fossil Beds/National Park Service) and the EPICC TCN (Smithsonian National Museum of Natural History). These institutions are funding the digitization through internal federal sources.
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Goal 4.6: Develop nonfederal collaborations with international, regional, state, and local agencies with an interest in species occurrence data; outreach activities that market available collection data resources.
- PhyloJive (Phylogeny Javascript Information Visualiser and Explorer), to be upgraded to Phylolink, integrates taxon information across phylogeny, biogeography, geology and paleobiology (http://phylolink.ala.org.au/). A joint project of iDigBio and Atlas of Living Australia.
- Workshop held in Frankfurt, Germany, in March 2017 explored the international collaboration between biodiversity information projects and infrastructure, and produced a broad commitment from all participants to try to develop better mechanisms to make this possible.
- The Global Biodiversity Informatics Outlook proposes a framework that will help harness the immense power of information technology and an open data culture, to gather unprecedented evidence about biodiversity and to inform better decisions: http://www.gbif.org/resource/80859.
- The GBIF Task Force, Accelerating the Discovery of Biocollections Data. This international task force sought to canvass the international collections community about the status and priorities for digitization, to document best practices from ongoing content mobilization, and to provide guidance on establishing priorities for digitizing biocollections:  http://www.gbif.org/resource/83022.

Goal 4.7: Initiate international collaboration to deliver US collection data to a global resource; document the role of US national specimen data standards, then design for international interoperability of specimen data objects beyond Darwin Core.

***Implementation Goal 5:***
*Establish an enduring and sustainable knowledge base.*

**GOAL 5 STATUS REPORT**

Goal 5.1: Identify and assess alternative economic models for sustaining NIBA; convene a cross-cutting panel to lay out economic models for sustaining NIBA and address other relevant issues, such as intellectual property concerns.
- Director's Summit sponsored by iDigBio at SPNHC 2017 in Denver brought together directors of collections institutions to discuss the value of digitization to institutions and strategies to sustain this effort.

Goal 5.2: Institute changes in federal grant policies to support NIBA objectives.
- A Data Management Plan is now required as part of NSF proposals.

Goal 5.3: Secure institutional-level support for digitization and access to staffing for collections and technical informatics support; articulate compelling arguments for increased and sustained institutional support for digital curation of collections data; commission a future-looking study that addresses innovations in digitization, as well as in related long term data storage, databases, archiving, and data stewardship.

- BCoN convened a Communications Workshop, which has helped engage biodiversity collections professionals in communications training and to help them better understand how to engage novel communities.
- Director's Summit at iDigBio SPNHC 2017 in Denver brought together directors of collections institutions to discuss the value of digitization to institutions and strategies to sustain this effort.

Goal 5.4: Create a technology vision plan for the next generation digitization future of NIBA; commission a future-looking study that addresses innovations in digitization, as well as in related long-term data storage, databases, archiving, and data stewardship.

- The iDigBio External Advisory Board is providing iDigBio and ADBC with advice about long-term data storage, databases, archiving, and data stewardship.

### *Implementation Goal 6:*
*Infuse specimen-based learning and exploration into formal and informal education.*

### GOAL 6 STATUS REPORT

Goal 6.1: Implement methods that allow K–20 educators to use specimen data as an integral part of curricula in science; identify and initiate partnership opportunities with education researchers and teachers to develop modular, accessible curriculum material.

- CollectionsWeb Research Coordination Network (2007–2013) identified grand challenges associated with integrating museum specimens into K-12 and undergraduate education and produced three manuscripts related to natural history collections in undergraduate education:.
  - Powers, K. E., L. A. Prather, J. A. Cook, J. Woolley, M. Blackwell, H. L. Bart, Jr., A. K. Monfils, P. Sierwald. 2013. CollectionsWeb Workshop Report: New Approaches to Specimen-based Education. Unpublished report submitted to the US National Science Foundation.
  - Monfils, A.K., K.E. Powers, C.J. Marshall, C.T. Martine, J.F. Smith and
  - L. Alan Prather. 2016. Natural History Collections: Teaching about Biodiversity across Time, Space, and Digital Platforms. *Southeastern Naturalist*. In press.
  - Powers, K.E., L.A. Prather, J.A. Cook, J. Woolley, H.I. Bart, Jr., A.K. Monfils, and P. Sierwald. 2014. Revolutionizing the use of natural history collections in education. *The Science Education Review* 13 (2): 24–33.

- Advancing the Integration of Natural History Collections: AIM-UP! Research Coordination Network - Undergraduate Biology Education (2010–2016) was effective at developing specimen based educational modules, advocating for using specimens and specimen based data in the undergraduate classroom, and growing a network of engaged

faculty and collections professionals interested in integrating museums into undergraduate programs. A program evaluation was conducted and submitted to NSF, this includes an assessment of ongoing needs and future directions. Several publications resulted from the network.

- Monfils, A.K. 2016. Advancing Integration of Museums into Undergraduate Education: AIM-UP! Program Evaluation. Unpublished report submitted to the US National Science Foundation.
- E.A. Lacey, T.T. Hammond, R.E. Walsh, K. Bell, S.V. Edwards , E.R. Ellwood, R. Guralnick , S.M. Ickert-Bond, A.R. Mast, J. McCormack,
- A.K. Monfils, P.S. Soltis, D.E. Soltis, and J.A. Cook. 2017. Climate Change, Collections and the Classroom: Using Big Data to Tackle Big Problems. Evolution: Education and Outreach. In press.
- Cook, J.A., E.A. Lacey, S.M. Ickert-Bond , E.P. Hoberg, K.E. Galbreath,
- K.C. Bell, S.E. Greiman, B.S. McLean, S.V. Edwards. 2016. From Museum Cases to the Classroom: Emerging Opportunities for Specimen- Based Education, Pp in Pavlinov, I., ed. "Aspects of Biodiversity" Volume 54 of the Archives of Zoological Museum of Moscow State University. In press.
- Cook, J.A., S.V. Edwards, E. Lacey, R.P. Guralnick, P.S. Soltis, D.E. Soltis, C. Welch, K.C. Bell, K.E. Galbreath, C. Himes, J.M. Allen, T.A. Heath, A.C. Carnaval, K.L. Cooper, M. Liu, J. Hanken, and S. Ickert-Bond. 2014. Natural History Collections as Emerging Resources for Innovative Education. BioScience 64: 725–734.
- Ho, S-H. and J.A. Cook. 2013. Co-Evolving Pedagogies. ARID: A Journal of Desert Art, Design and Ecology. Vol. 2, published online
- Dunnum, J. L., and J.A. Cook. 2012. Gerrit Smith Miller: His influence on the enduring legacy of natural history collections. Mammalia 76: 365-373.

- iDigBio Education and Outreach Working Group (2012–present) has a mission to coordinate education and outreach (E&O) activities among iDigBio, TCNs and other partnering projects, share E&O related resources, tools, and training with the ADBC community and beyond, and plan, develop and implement E&O activities of interest to the HUB and TCNs.
  - iDigBio Undergraduate Education Workshop: Building and Disseminating Resources for Collections-Based Undergraduate Education-- https://www.idigbio.org/wiki/index.php/Resources_for_Collections-Based_Undergraduate_Education
  - iDigBio K–12 Education Workshop: Incorporating K–12 Outreach into Digitized Collections Programs-- https://www.idigbio.org/wiki/index.php/Incorporating_K-12_Outreach_Into_Digitized_Collections_Programs_Workshop
  - 3D Digitization of Fossils for Educators & Citizen Scientists -- https://www.idigbio.org/wiki/index.php/3D_Digitization_of_Fossils_for_Educators_%26_Citizen_Scientists:A_collaborative_workshop_among_iDigBio,_the_FOSSIL_Project,_and_K12_Science_Educators

- Biodiversity Literacy in Undergraduate Biology: BLUE (2016 –present) formed to build from the AIM-UP! momentum, synergize efforts with the QUBES Hub, incorporate WeDigBio educational initiatives, and work with educational initiatives at iDigBio. This collaborative has submitted a successful workshop proposal to iDigBio for an education

workshop in spring of 2017, outlined a workflow for developing educational modules using natural history collection data, produced an educational module for an introductory core curriculum bringing in partners from Esri, Kurator, and Ecological Society of America (ESA), and run workshops and developed faculty mentoring networks using museum data at both the BioQUEST, Science Case Net and QUBES-sponsored 2016 National Academies Special Topics Summer Institute on Quantitative Biology *"Lowering the Activation Energy: Making Quantitative Biology More Accessible"* summer institute 2017 and the *Resources for Ecology Education Fair & Share* (REEFS) workshop at ESA 2016. The goals of this group include bringing new partners together to advance undergraduate educational initiatives, combine resources, avoid duplicate efforts, and disseminate educational materials. This includes engaging new and early adopters of educational materials to support effective educational modules through implementation.

- T. Barbaro, D. Bloom, J. Cook, S. Donovan, E. Ellwood, D. Linton, A.K. Monfils, M. Phillips, and J. Whorley 2016. Incorporating Digitized Natural History Collections Data into the Classroom. 2016 National Academies Special Topics Summer Institute on Quantitative Biology

- "Lowering the Activation Energy: Making Quantitative Biology More Accessible." Raleigh, NC. (Resource Session and Poster Presentation).

- Monfils, A.K., E. Ellwood, D. Linton and M. Phillips. 2016. Evolution (and Co-Evolution) of Angiosperms: Collections in the Classroom.

- REEFS: Resources for Ecology Education, Fair and Share. 2016 Ecological Society of America Annual Meeting, Fort Lauderdale, FL

- Biological Collections Network: BCoN Research Coordination Network (2014–present) has supported educational initiatives (both workforce training and undergraduate) that address the needs of the collection community. Support was provided for the BLUE collaborative to present at the 2016 National Academies Special Topics Summer Institute. Efforts include co-sponsoring the 2015 AIBS Council Meeting, in Washington DC, on biological informatics workforce training needs for systematics and digitization. This meeting resulted in a report and webinar.

- Monfils, A.K. and S. Donovan. 2016. BCoN Workshop: Integrating Resources and Growing the Community: Data Resources and Data Literacy. Scheduled for November 17–20, 2016.

- Barbaro, T., D. Bloom, J. Cook, S. Donovan, E. Ellwood, D. Linton, A.K. Monfils, M. Phillips, and J. Whorley 2016. Incorporating Digitized Natural History Collections Data into the Classroom. 2016 National Academies Special Topics Summer Institute on Quantitative Biology "Lowering the Activation Energy: Making Quantitative Biology More Accessible." Raleigh, NC. (Resource Session and Poster Presentation)

- American Institute of Biological Sciences. 2016. Addressing Biological Informatics Workforce Needs: A Report from the 2015 AIBS Council of Member Societies and Organizations Meeting. Reston, Virginia.

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Informatics Workforce Needs. American Institute of Biological Sciences Webinar Series.
- The BCoN RCN supported a working group meeting, titled "Integrating Resources and Growing the Community: Data Resources and Data Literacy." Anticipated workshop outcomes include a manuscript submission to *BioScience* on data literacy and workforce needs and a specific plan and timeline for creating a network of educators and data providers working together to further data literacy in the foundational undergraduate community.

Goal 6.2: Engage citizen scientists in digitization projects; Partner with existing citizen science platforms and projects.
- Notes from Nature (www.notesfromnature.org) —a crowdsourcing platform that is part of Zooniverse. Provides a variety of projects for transcription, along with blogs and other sources of information to help participants understand the context and use of collections in research
- BIOSPEX (http://biospex.org) -- a tool to provision, advertise, and lead public biodiversity digitization expeditions.
- Worldwide Engagement for Digitizing Biocollections: WeDigBio (2014–present, www.wedigbio.org) is a citizen science event of collaborative, interactive biocollection transcription with strong formal and informal educational goals. As a global event, WeDigBio encourages participants to learn about biodiversity science locally and internationally. Several university classes participated in the inaugural WeDigBio event (2015) and used formal biodiversity-related activities such as a lesson plan developed jointly by collectionseducation.org and WeDigBio, and lessons created for specific class use.
- The Smithsonian Transcription Center has developed best practices for transcription projects: https://transcription.si.edu/tips
- Digivol (https://volunteer.ala.org.au) is a crowdsourcing platform developed by the Australia Museum that is used by 32 institutions

NOTE: There is substantial effort being leveraged on these goals by numerous players. However, integration of the disparate initiatives and entities into a collaborative, consistent framework is still needed. This integration must align the different components into a data pipeline that encompasses all of the major players in this realm—field biologists, collections, and collections managers, aggregators, researchers and other end users, publishers, data packagers (like Genbank, and so forth) and funders (like NSF). The goal for some sort of governance, or national coordination function, remains unfinished, which contributes to the current lack of integration, despite the great deal of progress that has been made. Forward movement in education, formal, informal, and career, is also evident. However, full implementation of education initiatives will have to be integrated, in an iterative process, with the ongoing developments in the data systems and knowledge bases that support NIBA goals.

Restatement of Goal:
Infuse specimen-based data into all levels of formal and informal education resulting in a diverse and empowered data literate society, data=enabled workforce, and cross-disciplinary data-savvy researchers that leverage the vast collection infrastructure, meta-data, resources and information as we address the grand challenges of science in the 21st century.

Proposal for the Future:
- Integrate educational efforts and centralize products to efficiently use time and resources.
- incorporate biology educators into research efforts.
- Develop meaningful undergraduate research experiences incorporating specimen curation continuum.
- Provide best practices for mentoring student workers in natural history collections.
- Develop and refine educational modules involving natural history collection data:
  - In introductory coursework
  - Across the biology curriculum
  - Across the science curriculum
  - Across all disciplines
  - Disseminate materials
- Introduce modules in educational venues (education conferences and journals)
- Incorporate partners into digitization efforts
- Better prepare educators to use biodiversity collections data.

Citizen Science
- Develop materials to incorporate citizens as biodiversity sensors.
- Incorporate students as data providers.
- National Network of CitSci Endeavors—integrate efforts.
- Link out to other citizen science initiatives (NPN, National Parks).
- Regional networks.
- Work with eBird, eButterfly, ePlants.
- Crowdsourcing.
- Best practices for quality control.

Immediate Action Items:
No immediate actions were specified