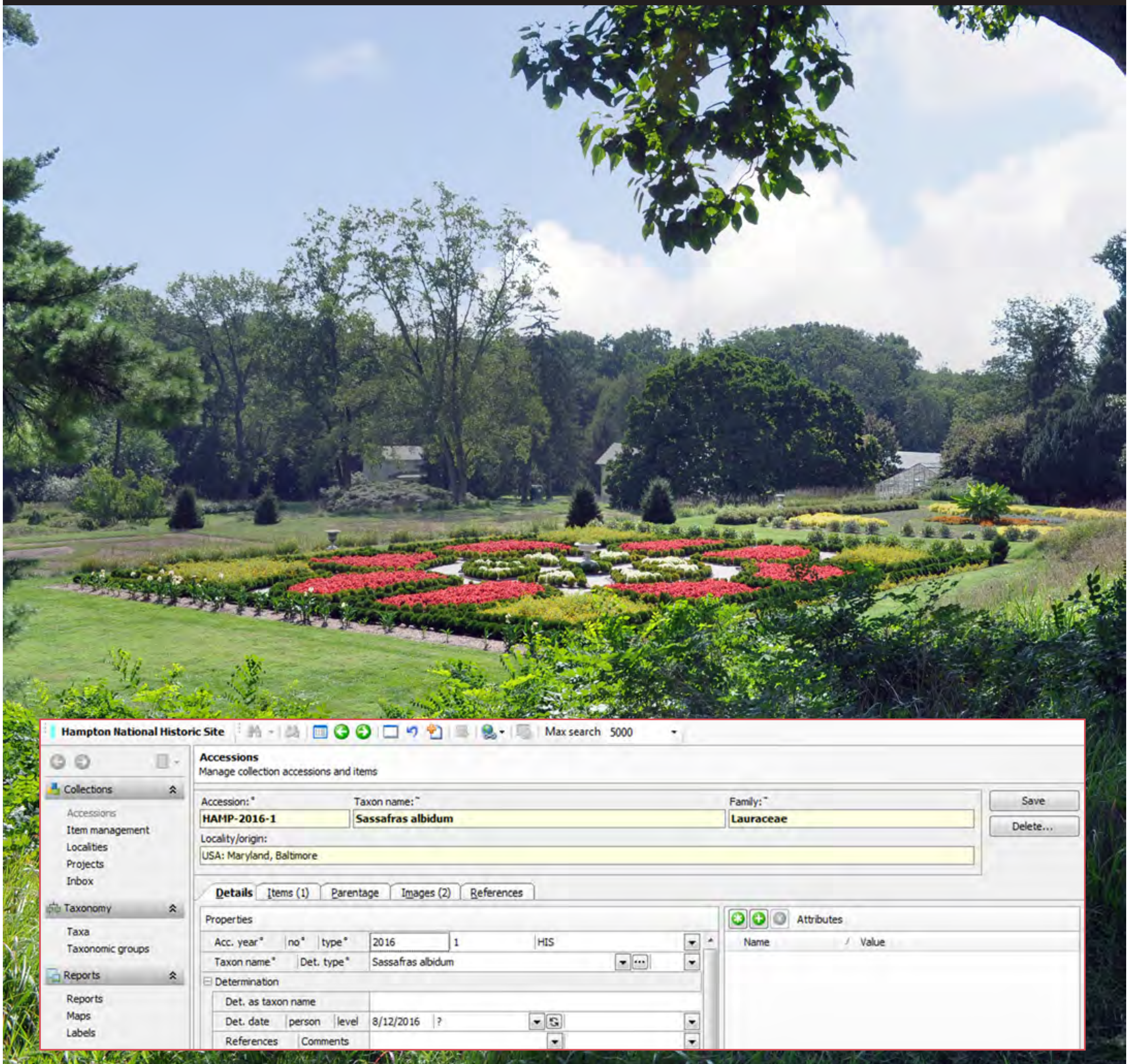
National Park Service
U.S. Department of the Interior



Olmsted Center
for Landscape Preservation

Modernizing Plant Records Management

An Overview and Evaluation of Digital Recordkeeping Tools

"We are drowning in information, while starving for wisdom. The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely."

E. O. Wilson
Consilience: The Unity of Knowledge, 1998

Modernizing Plant Records Management

An Overview and Evaluation of Digital Recordkeeping Tools

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The Olmsted Center for Landscape Preservation promotes the stewardship of significant landscapes through research, planning, and sustainable preservation maintenance. The Center accomplishes its mission in collaboration with a network of partners including national parks, universities, government agencies, and private nonprofit organizations. Techniques and principles of preservation practice are made available through training and publications. The Olmsted Center perpetuates the tradition of the Olmsted firms and Frederick Law Olmsted's lifelong commitment to people, parks, and public spaces.

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Cover image: View of the Hampton National Historic Site Falling Gardens paired with an IrisBG Accessions tab screenshot, showing a sample record for a specimen planting at the park (IrisBG and National Park Service, Olmsted Center for Landscape Preservation, hereinafter OCLP).

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Introduction

This report introduces readers to digital plant records management, provides a comparative analysis of the leading digital plant recordkeeping tools, and outlines considerations related to use of these tools to enhance plant care, public education, and research. This report is intended for a National Park Service (NPS) audience, but may also be useful to other land managing organizations that are assessing plant records management options.

The summary of findings that follows describes:

- How plant records are currently tracked in national parks (page 5)
- What a plant records management database is and how it can be used (page 7)
- Plant records management database options, including strengths and weaknesses (page 17)
- Considerations related to adopting use of a plant records management database (page 45)

The evaluative portion of this report is intended to aid selection of a plant records management database that is best suited to a landscape and staff, recognizing that needs and goals differ among NPS units.

APPROACH

In 2016, the NPS Olmsted Center for Landscape Preservation received funding from the NPS National Center for Preservation Technology and Training to evaluate the capabilities of leading plant record management databases. The project team worked with employees across cultural resources, natural resources, and maintenance disciplines at four national historic sites, John Muir, Hampton, Frederick Law Olmsted, and Longfellow House Washington's Headquarters.

The project team selected the ArcGIS Public Garden Data Model, *BG-BASE*, BRAHMS, and IrisBG as the leading software applications to evaluate, along with

Figure 2. An interpretive ranger explains the unique ecosystem of Great Falls Park to visitors (NPS).

FMSS. A needs assessment, conducted with staff at partner parks, identified key criteria for evaluation. The project team used sample data from partner parks in trial versions of each database to assess their capabilities in data management, maintenance, interpretation, and research, as well as their ease of use and associated costs.

This research, combined with insights from software developers, scholars, and key users of plant records management databases at allied institutions, offered insights into the applicability and value of plant records management software to national parks.

CONTEXT

Plants are a cornerstone of our national landscapes. Not only do plants provide living, tangible links to the past, they also possess great ecological and scientific value. Many national parks are home to endemic plant species, including Yellowstone, Great Basin, and Haleakalā. A greater number still provide habitats for endangered plant species critical to pollinators and other at-risk wildlife.

Landscapes stewarded by NPS reflect the nation's ecological and historical diversity. Managing these often delicate public lands for long-term preservation and use requires collaboration across NPS disciplines.

Plant collections in national parks are enjoyed by visitors and cared for by park staff for their aesthetic, cultural, historical, and scientific significance. Access to plant records, documenting the history, condition, and care of wild and cultivated plants, is essential to understanding these resources. This understanding leads to wider appreciation for park landscapes and their long-term preservation. In a microcosm, this is the NPS mission, to preserve our nation's natural and cultural resources for enjoyment, education, and inspiration.

There are many digital tools to aid in plant recordkeeping, management, scientific research, and education. Yet, there is currently no tool currently available to NPS employees to manage interdisciplinary plant records data for both internal management and external research and education.

Plant records management databases are capable of organizing plant records information to inform stewardship and science, while adapting suitable information for public access on web and mobile platforms. Plant records databases integrate data about vegetation in the landscape, seed collections, herbarium specimens, and greenhouse operations. Aggregated, this information makes possible effective stewardship decisions and an expanded understanding of the natural world. Plant records are as important as the resources they document. Wise management and use of information about plants is central to a sustainable future.

Given global climate change and habitat destruction, the value of an interdisciplinary database for use in plant inventory, management, scientific research, and interpretation cannot be understated. Plant

A Note on Terminology

The term "living collections" is broadly understood by botanic garden and arboreta professionals to refer to a group of plants grown for a defined purpose, categorized by geographic, taxonomic, thematic, or ecological significance.[2] NPS, however, has defined living collections as "biological material that is permanently retained *ex situ* for the purpose of generating and providing living or otherwise biologically active material for research, restoration, education, or other purposes."[3] This includes living plant material from national parks that is grown outside of the park (e.g. scions from apple trees at Sleeping Bear Dunes National Lakeshore that are grafted onto apple trees in the surrounding community), living plant material from national parks that is grown in greenhouses, maintained in seed collections, and preserved in the form of herbarium specimens. NPS *Director's Order #77-10* specifically defines plants growing *in situ* at parks as outside the scope of "living collection."[4] For purposes of clarity and cohesion, this report will refer to what are traditionally considered "living collections" as "plant collections," which are tracked and documented through the creation of "plant records."

records management software presents NPS with an opportunity to join the community of scholars and scientists who have benefitted from use of these tools.

OPPORTUNITY

As NPS moves into its second century, continuing its stewardship of culturally and ecologically significant landscapes, social and environmental changes require thinking critically and creatively about the manner in which landscapes are managed. These challenges are not unique to the NPS, but are faced by land managing organizations around the world. Institutions that steward plant collections are turning to technology to enhance the stewardship, interpretation, and research potential of their plant collections, and to open doors to new opportunities for collaboration. Although not glamorous, digitizing plant records is the first step in this process.

Plant recordkeeping is much more than a didactic exercise. The understanding that sound plant records afford underscores the relationship between people and plants, food, medicine, shelter, and fuel, alongside the impacts of individual and collective actions on the environment, including human-induced climate change. While the technologies and techniques for plant recordkeeping outlined in this report may be new to NPS, their purpose—enhancing data collection and application to inform maintenance decisions, inspire and engage the public, and support scientific research—has been reflected in the agency's mission for 100 years.

Director's Order #100: Resource Stewardship for the 21st Century defines resource stewardship as both the responsibility to steward parks, unimpaired, for future generations and the applications of the necessary expertise to meet this duty. Recognizing that resource management in national parks occurs amidst ongoing social and environmental change that is not fully understood, *Director's Order #100* calls for increased reliance on scientific guidance, coordination with partners outside of park boundaries, engaging diverse public audiences, and improved integration of natural and cultural resources management. Strategic incorporation of emerging technologies to conduct sound science and engage the public is key among the solutions identified in *Director's Order #100*. All of these goals can be advanced through the use of plant records management technology.

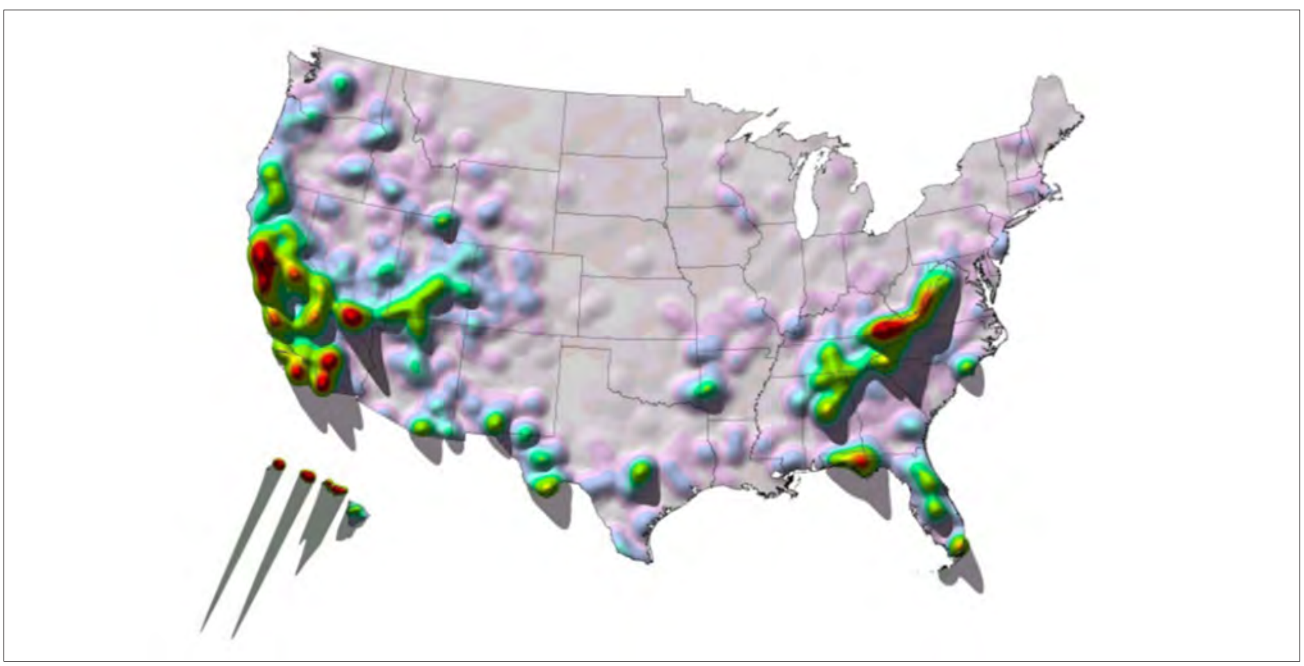

Figure 1. Digitized records and advanced mapping tools can be used to identify biodiversity hotspots within the United States (Alliance for Public Gardens GIS).

How Does NPS Currently Track Plant Records?

Parks currently track and preserve plant records in many different ways, including handwritten notes and maps, digital spreadsheets, and GIS layers. Park personnel use different data organization strategies depending on their goals, resulting in task specific information. However, this often results in unnecessary data duplication and causes difficulties sharing information across disciplines. For instance, a park horticulturist may have digital spreadsheets of plants incorporating specific maintenance notes, such as how to treat invasive bittersweet. A natural resource manager may have created a GIS map of invasive species throughout the park. Neither, however, necessarily has access to the other's information.

Several NPS databases include information on plant records, including the Cultural Landscapes Inventory (CLI), Facility Management Software System (FMSS), NPSpecies database, the Integrated Resources Management Applications (IRMA) portal, and the Public Lands Flora project (see sidebar on page 46). None of these include comprehensive information on a specific plant specimen or group or has the capacity to aggregate different types of information, including taxa, cultural history, maintenance history, and biological data.

A database designed specifically for the management of plant records across disciplines allows detailed information about plants and landscape areas to be stored in a single location where users can query information and display only what is pertinent to their needs, while retaining aggregated information across disciplines, parks, and regions of the National Park System.

Plant Collecting at Arboreta, Botanic Gardens, and National Parks

There are nearly 1,800 botanic gardens and arboreta globally, each with a unique collection and purpose. Scientific research and collection development are primary functions of many gardens and arboreta, which often dictates a need for collecting specimens of wild provenance. Provenance refers to where a specimen was collected. Most broadly, provenance is identified as wild origin or cultivated. Wild collections, or those collected where they grow naturally, serve an important purpose in the conservation world. Species that have a varied natural range often display slight genetic differences that benefit botanical and conservation research.[5] Wild origin collection expeditions are generally organized around institutions' missions. For example, members of the Arnold Arboretum undertook an expedition in 2015 to collect paperback maple (*Acer griseum*) seeds and DNA in alignment with their commitments to developing their *Acer* collection and cultivating specimens of high conservation value.[6]

Plant collections are slightly different in national parks, where collection development is not a primary objective. More often, collection development occurs by removing or replacing failing vegetation that does not align with the historic character or natural resources management goals of the park. Development of plant collections within cultural landscapes tend to focus on historic significance over biological significance.

Recording provenance is still important for conservation research in the future. Provenance helps to inform which specimens should receive genetically identical replacements through propagation, like the Jefferson Elm (see case study on page 6), or which may be replaced in kind by the same species or a genetic variety.

While wild collection occurs internally, such as seeds collected in Yellowstone National Park that are used for vegetation restoration efforts within the park, outside wild collections are rarely introduced to national parks.[7] Visiting scientists and researchers also collect within national parks, working through the NPS Research Permit and Reporting System. This online system manages access to scientific studies and enables park managers to attract specific types of scientific activity based on research needs: https://irma.nps.gov/rprs/

Case Study: The Jefferson Elm on the National Mall

On the National Mall, in Washington, D.C., over two hundred American elms (*Ulmus americana*) have succumbed to Dutch elm disease since 1952. In the intervening years, NPS has replaced American elms lost to disease with a range of elm species, including many Dutch elm disease-tolerant cultivars of the American elm. One of these cultivars, the Jefferson elm (*U. americana* 'Jefferson'), is defined by a unique genetic characteristic—three sets of chromosomes as opposed to the traditional four for American elms—that confers natural tolerance to the micro-fungus (*Ophiostoma ulmi*) that causes Dutch elm disease.

While widespread planting of the Jefferson elm is new, the original Jefferson Elm was discovered on the Mall in the 1970s. Unknowingly, it had been purchased from a nursery in New Jersey and planted across Jefferson Drive from the Freer Gallery of Art in 1935, in the wake of World War I and during implementation of the McMillan Plan. When park staff noticed that this specimen was not suffering from Dutch elm disease like its neighbors, they began monitoring the tree. Collaborative screening was conducted by scientists James Sherald, NPS, and Alden Townsend, U.S. National Arboretum. In 2015, the cultivar was released jointly by NPS (U.S. Department of the Interior) and Agricultural Research Service (U.S. Department of Agriculture). It is now available at wholesale nurseries across the country and was recently used to replace the iconic "Olmsted Elm" at Frederick Law Olmsted National Historic Site (see case study on page 32).

How a Plant Records Management System Could Have Helped

A plant records management database could have helped in the screening of the Jefferson Elm by tracking genetic information and sharing this information among interagency collaborators. As the tree was propagated and grown on, the location and condition of propagules could have be traced in connection with the parent tree on the Mall. If discovery of the Jefferson Elm had occurred today, the provenance information included in a plant records management database would be useful in meeting the requirements of *Director's Order #77-10* on Benefits Sharing (2013), since NPS would stand to benefit from the discovery of a commercially viable plant on public land.

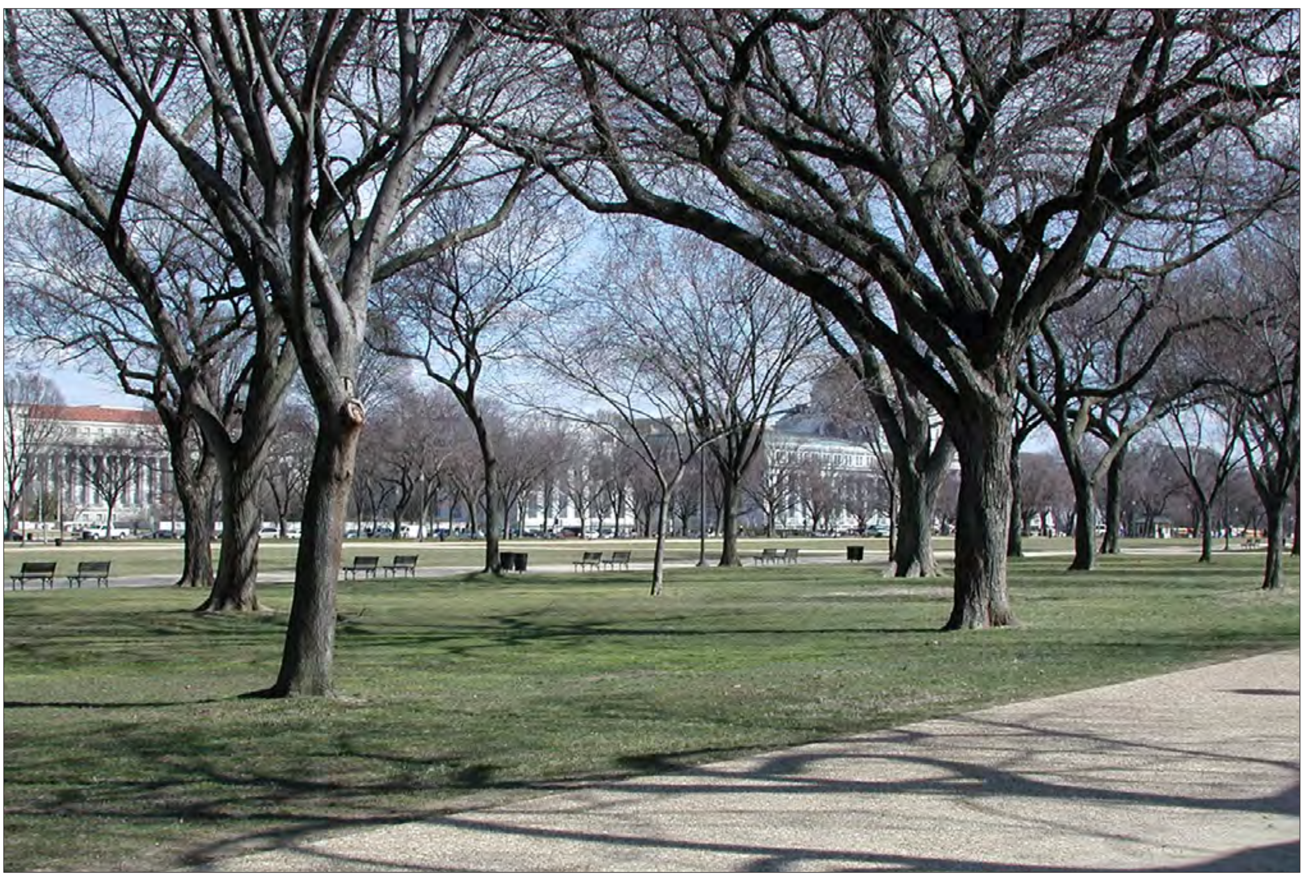

Figure 3. The "Jefferson Elm," on the National Mall and Memorial Parks, led to an unexpected breakthrough in the fight against Dutch Elm disease (NPS).

WHAT IS A PLANT RECORDS MANAGEMENT DATABASE?

In his book, *Things Great and Small: Collections Management Policies*, John Simmons defines collections management at museums as "everything that is done to take care of collections, develop the collections, and make the collections available for use."[8] Management of plant collections is no different. Depending on the institution, there are many appropriate ways to record information, ranging from card catalogs to digital spreadsheets to relational databases.

Joining the Botanic Community

Digitizing plant records is the industry standard for botanic gardens and arboreta that seek to advance preservation, conservation, public engagement, and research. This action is not symbolic, but conservation development driven. For instance, the Plant Collections Network, a collaboration between the American Public Gardens Association and the USDA Agricultural Research Service, offers special resources, opportunities, and funds to institutions caring for Nationally Accredited Plant Collections™. Becoming accredited requires an institution to prove, among other qualifications, that they maintain their records according to professional standards, provide reasonable access to collections for research, evaluation, and introduction, and maintain a "living collections" policy. Selected members of the Plant Collections Network include the Arnold Arboretum of Harvard University, the UC Davis Arboretum, and Smithsonian Gardens.

Similar benefits and requirements apply to internationally accredited arboreta through ArbNet, a collaboration among the Morton Arboretum, the American Public Gardens Association, and Botanic Gardens Conservation International. Through these collaborative associations, notable public gardens and arboreta are leading the way in climate change and biodiversity conservation research, and developing innovative visitor engagement strategies. As the Botanic Gardens Conservation International Manual on Planning, Developing, and Managing Botanic Gardens states, "it cannot be overemphasized that well documented collections give added value and distinguish botanic gardens from institutions such as public parks or display gardens."[1]

PEN AND PAPER

Card catalogs and written notes can be used to answer simple questions like, "when was the *Acer rubrum* planted?" They are most useful for a collection accessed by a small number of knowledgeable staff who primarily use the information internally. It is important that card catalogs and written notes are organized according to an agreed upon system. Hand drawn maps and other graphics are common for small sites, and are most useful when they contain a clear key and directly references catalog cards or ledger notes.

PRELIMINARY DIGITIZATION

Using a well formatted digital spreadsheet can help to answer more complex questions like, "what percentage of the tree collection is *Acer rubrum*?" Digital spreadsheets, also known as flat files, provide an additional level of utility by allowing for more advanced queries and flexibility to work with other digitized systems. Digital spreadsheets are often designed to allow only unique data values, for instance, genera and species represented in separate columns. Quality control measures, such as drop down menus, can improve the accuracy of digital spreadsheet records.

With some experience, digital spreadsheets can also be loaded into a Structured Query Language (SQL) server or a Geographic Information System (GIS), which offer enhancements over hand drawn maps. Risks associated with the loss or destruction of hard copy records (pen and paper) are reduced through preliminary digitization and data backup.

RELATIONAL DATABASE

A relational database can easily answer complex, multi-factor questions like, "how many *Acer rubrum* were planted in the south lawn after 1950?" Relational databases are designed to recognize relationships among stored information and are the most powerful records management tool. An ability to link data tables together based on common factors, such as genera or location, gives relational databases the most complex and flexible querying potential. Many modern relational databases used to manage plant records can store images and link directly to mapping tools, providing an additional level of data visualization and analysis.

Like digital spreadsheets, relational database software provides a level of permanence that written records lack. Database software also adds an additional level of security by allowing for functions such as flexible user restrictions, two-step deletion, and other safeguards that help prevent erroneous data entry or loss.

Ultimately, plant records database software streamlines records management by providing a centralized home for digitized asset information that can be accessed across disciplines.

Table 1. Types of Plant Records Management Systems*

	"Lite"	"Regular"	"Extra Strength"
Plant Records	Index cards Notebooks	Microsoft Excel spreadsheets Access (flat file)	ArcGIS for Parks & Gardens *BG-BASE* BRAHMS IrisBG
Maintenance	Written work orders Calendar records Word of mouth	Digital work orders Excel spreadsheets	Multi-level integrated systems (FMSS) Map integrated relational databases (see list above) GIS reports for workflow management
Interpretation	Signage Printed flyers	Interpretive rangers Guided tours Reenactments	Interactive digital tools Mobile applications
Mapping	Hand drawn Printed from the internet (reference only)	"Heads up" digitization (drag and drop/draw on screen) ArcGIS (basic license)	ArcGIS (standard or advanced) license Digital basemaps Accurate GPS data captured with digital tools (Trimble, etc.)
Research	Pen and paper inventories Basic calculations Hand drawn maps	Basic digitized reports Plant records accessible for internal research Baseline spatial analysis (ArcGIS standard license)	Sophisticated GIS analysis (ArcGIS advanced license) Integrated literary resources (relational database) Web-accessible plant records for external researchers

*Adapted from and courtesy of Mary Burke, University of California Davis Arboretum[9]

Databasics

Database Management System

Database management systems (DBMS) are the heart and soul of any database. They allow users to read, access, and analyze data by managing communication between the data and the database application. Fundamentally, they contain the rules and structure of a particular database. DBMS are designed to consistently process large amounts of data and execute multiple tasks without input from the end users. Security, system updates, backup logistics, and other seemingly routine functions are also managed behind the scenes by DBMS. There are many different types of DBMS depending on the database structure and intent

What is a Relational Database?

The majority of plant records databases are relational databases. A relational database is one where data exists in collections, called tables. Tables represent logical, thematically connected pieces of data. Each table consists of rows and columns, like a spreadsheet. Rows represent individual records and are all identified by a unique value. Columns are used to store the data contained in each table, which can be restricted based on data type. For example, the accessions table may include an accession number, year, genus, species, and place of origin. For instance, the values for the year column may be restricted to only four digit numbers.

If a separate table is created to represent taxonomic information, the data in the genus column of the accessions table would have a relationship with a row in the genera column in the taxon table. Since every entry in every table is identified by a unique value, having entries in tables refer to other tables is trivial. This ability gives relational databases their name and makes them extremely powerful. For example, if the value *Acer* is selected from the genus table, every instance of *Acer* in every related table can easily be found.

What is a Geodatabase?

A geodatabase is the primary model used for ArcGIS, a geographic information system (GIS) produced by ESRI. At its core, a geodatabase is a relational database that is set apart by its capacity to map. By incorporating spatial and temporal information, data can be accurately displayed as points, lines, or polygons on maps or orthophotos to reveal relationships, patterns, and trends.[10] In ArcGIS, a geodatabase consists of tables, feature classes, raster datasets, and annotations. Tables in a geodatabase function the same way as tables in a standard relational database. Feature classes are the points, lines, or polygons that can be created to represent data, and raster data includes the maps or real world imagery that feature classes are displayed over.

How Do Databases Talk?

Computers can understand many languages ranging from special purpose to general purpose. Most relational databases rely on the special purpose programming language SQL, or structured query language, to manage their data. Standardized SQL statements execute tasks such as updating or querying data. For instance, a query for all the living oak accessions would be driven behind-the-scenes by the SQL statement: ‘SELECT quercus FROM accessions WHERE condition = “alive.”’ The standardized nature of the language makes sharing data between programs and databases easier. For example, many relational databases are designed to execute appropriate SQL statements for seemingly routine commands, such as exporting or importing data with Excel, with minimal customization. For bigger tasks, such as migrating data from one relational database to another where both use SQL, less customization and additional programming is required than transferring records between databases that employ different programming languages.

WHAT IS DIGITAL RECORDKEEPING?

Digital recordkeeping is the use of specialized technology to maintain information digitally in a tabular format. Digital recordkeeping offers many benefits over narrative records, including consistency and quality control measures, increased querying and analysis potential, and ease of visualization.

In order to be useful, data must be consistent, complete, and correct.[13] In a database, most data fields are single entry values, and essential data fields are required to have appropriate information before a record can be saved. For instance, a database may not allow a record to be saved without an accession year in four digit format. This process helps remove error and improve recordkeeping.

In digital recordkeeping, splitting data into unique fields improves querying power. For instance, a handwritten maintenance note for a particular linden may say “powdery mildew present, spray with wettable sulfur by June 15 before summer heat, prune to increase air flow.” In a database, these values would be attached to the accession record for the linden, and separated into two unique maintenance records for disease treatment and pruning. Further details would also be split, such as a field for “disease” where the value would be powdery mildew, a field for “treatment” where the value would be wettable sulfur, and a field for beginning and end dates associated with the best time to apply the treatment. This information can now be queried easily in many different ways. A query could produce all the open records for disease treatment, all the maintenance that should be completed before June 15, or all the maintenance for lindens. Each of these unique queries would return this particular incidence, because each value is discreet.

A standard set of data fields are included in most plant records databases. Data fields such as taxonomy, location, and condition can often be programmed to include a drop-down dictionary of acceptable information, such as a list of genera. Restricting entries to pick lists adds another level of quality control by reducing clerical errors and standardizing vocabulary so entries can be understood across park disciplines and preserved through staff turnover. For definitions of standard data fields, see the sidebar on page 12.

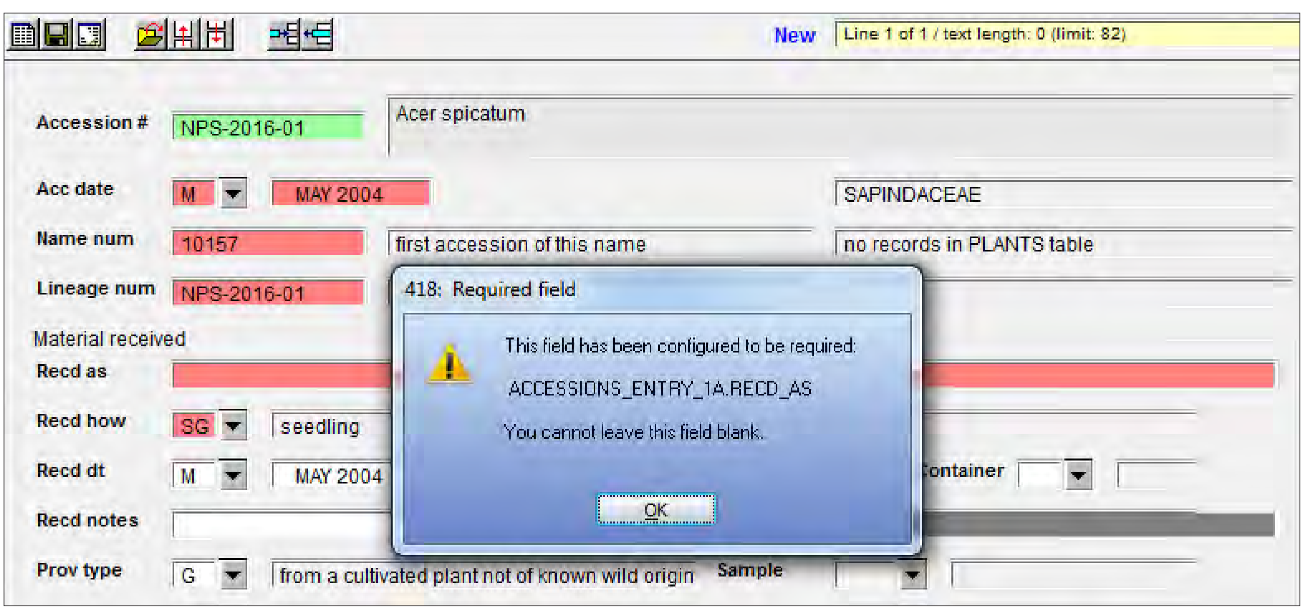

Figure 4. Database administrators can put quality control checks in place, such as requiring data entry in key fields (*BG-BASE*).

Key Terms

Taxon: Taxonomic information, or the biological classification of related populations of organisms, is the backbone of a plant records database. This includes information about plant families, genera, and species (taxonomic ranks). Recording specific and accepted taxonomic information improves representative accuracy, such as ensuring a historic asset is replaced in kind when it dies, allows maintenance staff to understand specific needs or likely pests, and allows for better biodiversity related research. A generic record for "oak" is less informative than a record for "*Quercus coccinea*."

Common Name: Common names provide a less specific, but still important means of identifying plants. Like the name implies, they are often commonly understood and easy to remember for people without a botanical background. For instance, *Quercus coccinea* is commonly referred to as scarlet oak. Because a plant can have multiple common names, and the common name for a plant in one region may be used colloquially as the common name for a different plant in another region, they should only be used for interpretation and not be relied on to organize a plant records. For instance, in the United States, corn generally refers to maize, but in Scotland refers to rye or barley.

Provenance: Provenance refers to the origin of an accession. For plants, this often refers to whether it originated in the wild, the garden, or is unknown. While this can be helpful for record keeping purposes, provenance information can aid with genetic diversity. For instance, volunteers in Yellowstone National Park collect native grass seeds such as purple needlegrass (*Nassella pulchra*) and California fescue (*Festuca californica*) that are used to restore disturbed areas where those grasses used to thrive.

Accession Number: Accession numbers are used by museums, arboreta, botanic gardens, and parks to identify unique records. They are never deleted or reassigned even if the specimen is removed, destroyed, or dies. This creates a framework of comprehensive historic and current data. Every organization formats their accession numbers differently, although related institutions may create a standardized format to improve data sharing. For instance, one format could be "Year planted – order planted," so the sixth plant added in 2016 would be 201606. If multiple plants of the same species were added at the same time, nested accessions can reflect this such as 201606a, 201606b, 201606c so that each ultimately receives unique information while relating to their shared accession origin.

Condition: The condition field can be as simple as "excellent, fair, and poor" and often contains a data field for condition descriptions. For instance, a tree listed as "poor" may contain additional information in a related field describing damage that happened on a particular date during a storm. Condition notes streamline maintenance prioritization by allowing users to query by condition across the entire collection in a single search. Additional descriptions for condition often include crown size, diameter at breast height (DBH), and height, which can be measured over time to assess tree health.

Phenology: Phenology refers to cyclical changes that plants undergo in response to changes in season or climate. These include leafing out, flowering, and fruiting. Recording phenology can assist with public interpretation, such as creating a bloom time walking map for visitors, as well as provide important clues about different species' reaction to climate change over time by querying historic phenology data.

Plant collections: Plant collections include all the vegetation that comprises a park, garden, or arboreta. Plant collections are organized by geographic, taxonomic, thematic, or ecological significance, usually according to the mission statement of the institution that stewards them.

Plant records: Plant records are the documentation of characteristics, histories, images, maps, and future stewardship related to plant collections. Most institutions maintain plant records as catalog cards, digital spreadsheets, or in a plant records management database. Plant records generally include a standard set of critical data fields, such as taxon information, accession number and date, provenance, location, and condition.

Is a Plant Records Database Right for Your Team?

WHO USES A PLANT RECORDS MANAGEMENT DATABASE?

The versatility and breadth of information that can be stored in a plant records management database makes it useful to staff members across disciplines. Although the amount of information can seem initially overwhelming for new users, most plant records management databases allow for flexible querying that can produce only the desired data in a matter of seconds.

Because information pertaining to all disciplines is managed in a unified home, however, staff across disciplines can access data they may not need on a regular basis without having to navigate a new or unfamiliar system.

HORTICULTURISTS AND GARDENERS

A plant records database stores detailed taxonomic information and maintenance histories to create cohesive inventories, streamline routine work, and help to create short term work plants and long term stewardship plans. Plant records databases allow horticulturists and gardeners to maintain complex records and maps in a single location. By standardizing data fields, a plant records database also makes it easy to share information and avoid clerical errors.

NATURAL RESOURCE MANAGERS

Mapping and reporting tools built into many plant records databases allow natural resource managers to track trends in the landscape over time, enhancing

Figure 5. A resource manager describes the role that the landscape played during the American Revolution at Minute Man National Historical Park (OCLP).

understanding of the natural and cultural processes that effect plants. Comprehensive analysis of database records helps natural resource managers allocate resources and create work plans. Plant records databases can be utilized for natural resource inventories and condition assessments.

CULTURAL RESOURCE MANAGERS

Cultural histories, historic photographs, and maps stored in a plant records database provide cultural resource managers primary source data to enhance understanding of change over time and inform treatments necessary to perpetuate historic character. This information can also be used to develop cultural landscape inventories/reports or historic resource studies.

INTERPRETIVE RANGERS

Taxonomic and cultural information stored in a plant records database acts as an interdisciplinary teaching tool for interpretive staff. Interactive maps can be created that combine physical locations in the landscape with information from the plant records database. Interpretive staff can access database information to create thematic programming and train seasonal employees.

GEOGRAPHIC INFORMATION SYSTEMS SPECIALISTS

A plant records database provides a unified home for global positioning system (GPS) data that can be visualized and analyzed in a geographic information system (GIS), and many plant records databases can import data from preexisting GIS layers. Multiple programs can store pertinent information about the same asset in the same place, which improves data sharing and decreases the need for duplicate data entry. GIS specialists can use a plant records database to run complex multivariable geospatial analysis, identify trends, and improve decision making for the future

VOLUNTEERS AND INTERNS

By utilizing flexible user restrictions, a plant records database can benefit from and be enhanced by volunteers and interns with diverse experience. Running reports and analysis can identify appropriate inventory and stewardship projects for volunteers and interns, and read only access can provide necessary information to enable independent routine work. Advanced interns and volunteers can be allowed to update records by exporting database information into a digital spreadsheet for them to work with, with quality control checks before data is reimported.

VISITORS AND RESEARCHERS

Plant records databases make it easy to share and interpret information. Visitors can access seasonal maps, wheelchair accessible routes, or participate in citizen science field reporting. Non-sensitive records can be queried by remote researchers online or using mobile apps, and visiting researchers can submit new findings for inclusion in the database. Conservation research, forecasting the effects of climate change, and comprehensive landscape health analyses can benefit both individual parks and the global research community.

BUILDING TIME FOR TRAINING

In order to maximize the potential of any database, building in time for training is essential. The amount of time dedicated to training individual staff members can be determined by their relationship to the plant collection. For example, a horticulturist who works continuously and intimately with the collection must be allotted ample resources to understand data management functions, maintenance tracking capabilities, mapping, and reporting, whereas interpretation staff would be better served mastering web and mobile capabilities. For parks who wish to grant volunteer or seasonal employees access, a brief training on read-only functions of the database, such as querying information or viewing pending tasks, would be sufficient.

Before choosing a plant records database, a park should decide what level of training commitment they are willing and able to make.[11] The learning curve varies among options, and parks should be wary only to choose a complex program if staff is committed to regular training. While this may initially be influenced by the available time, interest, and technological skills of current staff, future team members should be considered as well. Training standards should exist for new employees to ensure continuity and consistency in use. It is beneficial to write these training requirements and allowances into job descriptions to ensure that new personnel have the appropriate skills to complete their jobs efficiently and according to records management standards. Examining past database experience when considering job applicants and including database training and responsibilities in job descriptions is fundamental to the success of a plant records management database (refer to Appendix A for desirable skillsets for database professionals).

BRINGING IN DEDICATED DATABASE STAFF

Hiring a dedicated staff member to manage the database can significantly improve its potential, especially during the early implementation stages. This takes pressure off staff members whose primary responsibilities lie elsewhere. A dedicated staff member with database experience can consult with members of each division to assess their needs and concerns, and streamline these functions in the database. Bringing in a neutral party helps ensure that the database benefits all invested parties, and avoids accidental bias. Hiring a database manager or relying on the software developers to handle the initial data migration also exponentially decreases the amount of time staff members without database experience may need to digitize pre-existing plant records. While these options may be expensive up front, relying on technology professionals allows for less trial and error during set up, and makes the database more quickly accessible for use by staff members.

Potential Funding Opportunities

National Center for Preservation Technology and Training, Preservation Technology and Training Grants
Award: $25,000 - $40,000 for innovative research that develops new technologies or adapts existing technologies to preserve cultural resources.
Federal agencies permitted: Yes

National Geographic, Conservation Trust Grant
Award: $15,000 - $20,000 for projects that contribute significantly to the preservation and sustainable use of the Earth's biological, cultural, and historical resources.
Federal agencies permitted: Yes

Stanley Smith Horticultural Trust
Award: $5000 - $20,000 for projects furthering research or education in ornamental horticulture in North and South America.
Federal agencies permitted: No

Institute of Museum and Library Services, National Leadership Grant
Award: $5,000 - $1,000,000 for projects advancing the ability of museums and public gardens to serve the public through learning experiences, acting as community anchors, and collections stewardship.
Federal agencies permitted: No

National Endowment for the Humanities, Digital Projects for the Public
Award: Discovery stage: Up to $30,000 for aspects such as exploring existing evidence and research surrounding digital tools that reach diverse audiences and expand access to the humanities.
Prototype stage: Up to $100,000 for aspects such as refinement of content, design creation, and evaluating audience perception.
Production stage: Up to $400,000 for aspects such as final design and distribution, production of complementary components, and outreach.
Federal agencies permitted: No

National Science Foundation, Advanced Digitization of Biodiversity Collections Grant
Award: Open, for enhancing and expanding the national resource of digital biological data and improving access to digitized information in vouchered scientific collections.
Federal agencies permitted: No

Case Study: National Park Service Herbaria

A herbarium is a library for preserved plant material that serves as a static counterpart to living collections in public gardens and arboreta. The majority of herbarium specimens are dried, pressed, and mounted on large sheets of paper with labels describing when, where, and by whom the specimen was collected, as well as taxonomic and phenologic information. Herbarium specimens are often used for research because they preserve both genetic information and physical snapshots in time. They can also be used to study changes in vegetation over time, the distribution of species, and to track environmental responses to climate change.

While specimens have been collected from many national parks, only a handful of parks maintain herbaria.* The herbarium at Yellowstone National Park houses nearly 20,000 specimens, including vascular plants and non-vascular plants, such as lichen and fungi. Yellowstone National Park is located on the spine of the Rocky Mountains, affording a diversity of ecosystems, including Great Basin and Great Plains flora, and particularly unique lichen and fungi populations associated with the park's geothermal systems. Park taxa include several endemic species, as well as a comprehensive collection of aquatic plants which are often underrepresented in herbaria.

Specimens collected in national parks over the years have helped park scientists and external researchers answer questions about the past and to predict ecological trends for the future. The Yellowstone National Park herbarium is currently being digitized in partnership with the University of Wyoming Rocky Mountain Regional Digital Herbarium. Park-specific GIS data is maintained for many of the herbarium specimen collection points, in addition to rare plants and seed collection GIS databases.

How a Plant Records Management System Can Help

While many park herbaria are digitized, relatively few NPS herbarium specimens are managed in conjunction with digital information about their living specimen of origin. A plant records management database offers opportunities to link existing repositories with information about *ex situ* plant materials, including herbarium specimens and seed collections, to provide a comprehensive dataset about a particular specimen or plant population in the landscape. This multi-disciplinary approach to data management offers opportunities for enhanced stewardship of park resources, research, and science. In the future, a plant records management database may also be used to fulfill the requirements of the forthcoming NPS guidance on managing "Living Collections."[12]

Notes: *Other national park herbaria, many of which are built and maintained in collaboration with academic partners, include Acadia National Park, Bighorn Canyon National Recreation Area, Crater Lake National Park, Death Valley National Park, Everglades National Park, Glacier National Park, Grand Canyon National Park, Grand Teton National Park, Great Smoky Mountains National Park, Isle Royale National Park, Joshua Tree National Park, Lassen Volcano National Park, Mesa Verde National Park, North Cascades National Park, Sequoia & Kings Canyon National Park, and Yosemite National Park.

Figure 6. Herbarium specimens of *Grayia spinosa* (left) represent the living specimen in Mesa Verde National Park (right) (The Public Lands Flora/SEINet).

Overview of Leading Options

ArcGIS PUBLIC GARDEN DATA MODEL

The ArcGIS Public Garden data model was created as a collaboration between Environmental Systems Research Institute (ESRI) and the Alliance for Public Gardens in 2011 to create a GIS system that parks and gardens can use to map and record plant data without having to build an ArcGIS data frame from scratch.

The Data Model is a modular system built on a base map that is georeferenced to a real world coordinate system. The initial three modules include basic plant record, tree assessment, and facilities and infrastructure. The first module records individual plants and mass plantings with related taxonomic information; the second records comprehensive health, hazard, and benefits of trees; the third records information about hardscapes and circulation. All three modules can be used simultaneously, or users can select only the options pertinent to their collection.

Version 1.0.4 of the Publica Garden Data Model was evaluated for this report, but has since been superseded by the Parks and Gardens Information Model 2.0, which is available as an official ArcGIS Solution product from ESRI. The current version of the model includes expanded capacity for asset management, dedication management, utilities, and plant records management.

Key Users: The Beta version of the data model was tested by the Arnold Arboretum of Harvard University, the UC Davis Arboretum, and the Smithsonian Gardens.

BG-BASE

BG-BASE was developed in 1985 by a team of programmers at the request of the Arnold Arboretum of Harvard University to address the issue of storing large amounts of complex data in a unified, query optimized program. *BG-BASE* consists of seven linked modules which each contain their own subset of tables, such as the accessions table in the living collections module. The modules are living collections, preserved collections, conservation, education, propagations, ArcGIS Connector, and HTML/web. Users and administrators can customize or restrict particular modules on a user-to-user basis.

Key Users: Arnold Arboretum of Harvard University, Bureau of Land Management Seeds of Success program, and the Morris Arboretum of the University of Pennsylvania

DIY Database

Creating a custom relational database requires both computer skills and time, as they are often products of trial and error while working through what data fields to include, how to format table relationships, and building queries. Because they are customized, they also run the risk of becoming unwieldy or even obsolete due to staff turnover. Generally, institutions with the most success using a custom database are those with a dedicated IT staff, such as Missouri Botanical Garden and Stanford University. Small sites without an in-house candidate for database manager who are interested in using a custom database should consider contracting a database professional for creation and plan for adequate and prolonged tech support to maintain data integrity. In the absence of strong IT support, however, programs like Microsoft Access or Filemaker can be very useful short term solutions for organizing handwritten data, digital spreadsheets, and GIS data in one place to understand what plant records database system would best synthesize the existing data.

BRAHMS

The Botanical Research and Herbarium Management System (BRAHMS) was developed in 1990 by the Department of Plant Sciences at the University of Oxford as an affordable and practical means of managing collections. BRAHMS includes various integrated modules that can be enabled or disabled depending on need. Within each module are thematic relational tables, such as the accessions, plants, and events tables found in the living collections module. Information can be viewed and edited as either a classic spreadsheet or through forms. Users or administrators can customize or restrict particular modules on a user-to-user basis. BRAHMS Version 7 was evaluated for this product, but BRAHMS Version 8 Alpha is slated for release at the end of 2016. The newest version reflects major functional and aesthetic upgrades, including self-documentation and more flexible extension options, such as enhanced linked file structures and more diverse mobile and web capability, and will be extended to manage animal data, as well as plants.

Key Users: The Oxford University Herbaria, the Morton Arboretum in Illinois, and the Millennium Seed Bank

FMSS

For the past four decades, NPS has been implementing the use of computer-aided facility management software to manage park infrastructure and track associated costs. The latest version is the Facilities Management Software System (FMSS), a customized version of IBM's Maximo Asset Management. FMSS uses enterprise asset management principles to inventory facilities and infrastructure to plan for and track maintenance needs for all aspects of a park, and report on actual resource inputs into facility work, such as labor hours and costs. The 3100 Maintained Landscapes asset type pertains most closely to plant collections. Assets are tracked in FMSS in a hierarchy of site, location, and asset. FMSS is used primarily by park maintenance staff for inventorying facilities systems and components, identifying work, tracking and reporting maintenance activities, and securing funding.

Key Users: The National Park Service

IRISBG

IrisBG was developed in 1996 by Digital Forvaltning AS in collaboration with Oslo University Botanical Garden to increase database usability for employees while maintaining comprehensive records. IrisBG is primarily accessible in form view and relies on a series of integrated modules to connect related tables of information. These include the standard plant records data, such as taxa, images, accessions, and tasks. From the basic package, IrisBG can be built out to include both additional functionalities, such as mapping and publishing data, and technical support, such as web hosting.

Key Users: Smithsonian Gardens, UC Davis Arboretum, and the Trustees of Reservations in Massachusetts

Evaluating the Options

While all of the plant records management databases evaluated for this report can store far more information than was evaluated for this report, key fields were identified by conducting a needs assessment with the core team (see Appendix B for needs assessment results). The needs assessment allowed partners in maintenance, and natural and cultural resource management at four partner parks to rank the importance of a variety of data fields and tools in relation to their site specific needs. Input from database users at allied institutions also shaped the key considerations for evaluation for this report. Maintenance tracking and planning fields were identified for evaluation, and are discussed later as a unique consideration.

Key Data Fields Evaluated

- **Scientific name**
- **Common Name**
- **Accession number**
- **Accession date**
- **Source**
- **Condition**
- **Deficiencies**
- **Photography**
- **Size/diameter at breast height (DBH)**
- **Phenology**
- **Deaccession date**
- **Deaccession reason**

Figure 7. Park staff compare digital fieldwork tools for managing vegetation at Minute Man National Historical Park (OCLP).

ArcGIS PUBLIC GARDEN DATA MODEL

Without customization, the ArcGIS Public Garden data model contains all the primary key data fields except phenology. With intermediate knowledge of ArcGIS, however, a field for phenology can easily be added to the mass planting or plant center tables. As the ArcGIS Public Garden data model does not contain a separate table for taxon querying, phenology data must be entered at the accession level and not the species level, which will cause some repetitive data entry. With intermediate knowledge of ArcGIS, taxonomic tables could be created and linked to the larger data frame, where phenology could then be recorded at the species level. The ArcGIS Public Garden data model currently comes with most family names built in, and adding new names or removing unnecessary ones is straightforward. While genus and species information is entered by hand in the default version, drop down tables for these values could also be easily created with basic knowledge of ArcGIS to avoid misspellings and standardize the use of accepted scientific names.

Data stored in the ArcGIS Public Garden data model is most commonly viewed and edited using the attributes table function of ArcGIS. Because the data is geovisualized, the point, line, or polygon associated with the selected record is highlighted on the map. Layers containing thematic data tables can be turned on an off to simplify viewing. Data can be imported and exported from the ArcGIS Public Garden data model most easily using digital spreadsheets that have been properly configured to share data field names.

Website: publicgardensgis.ucdavis.edu

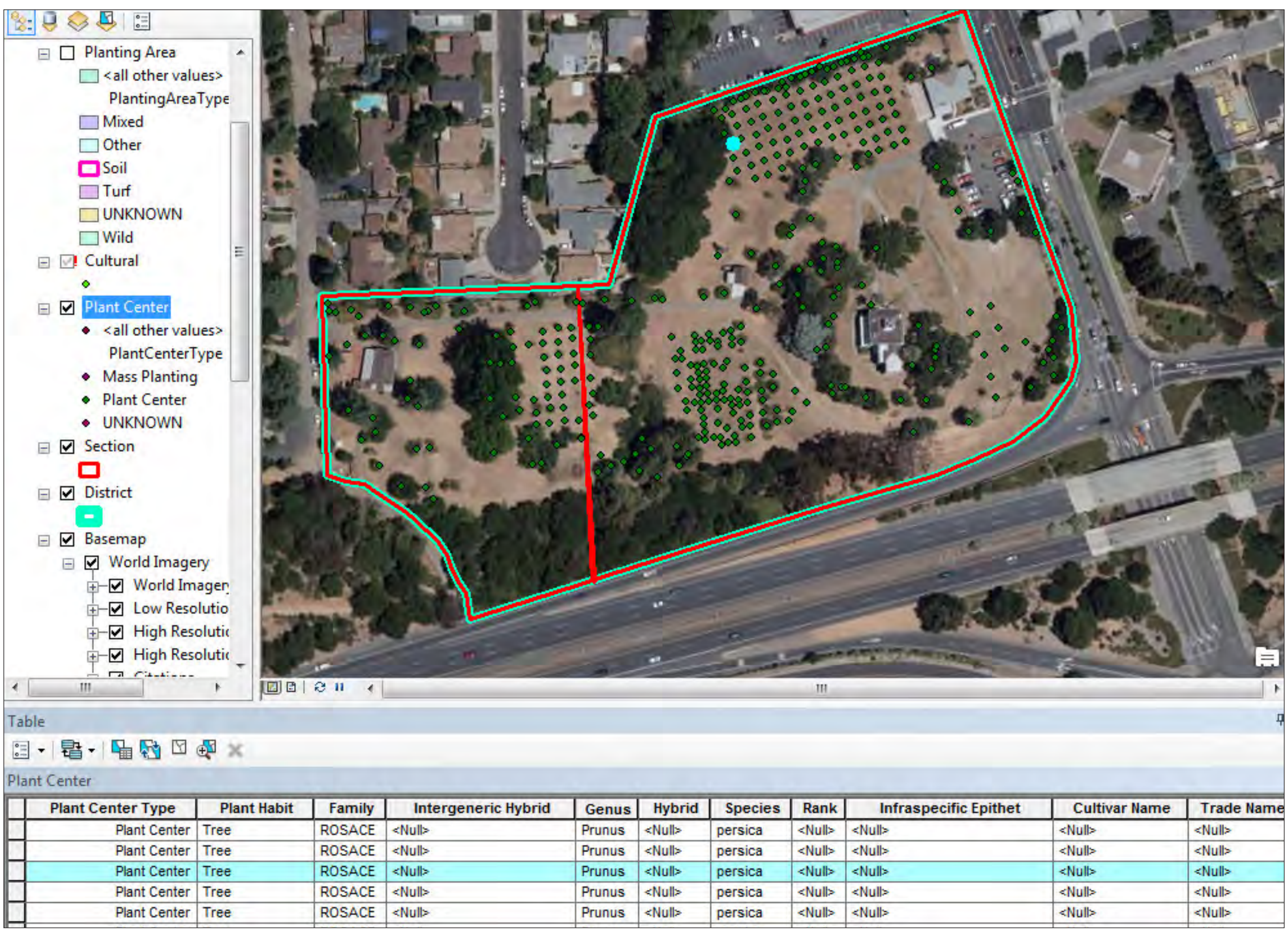

Figure 8. The ArcGIS Public Garden data model manages data using related attributes tables connected to georeferenced shapefiles, as shown in this example from John Muir National Historic Site (Alliance for Public Garden GIS).

BG-BASE

Of the systems evaluated, *BG-BASE* has the greatest breadth of data fields, including those primarily evaluated for this report. Administrators can customize the institutional settings for forms and set access controls for individual users to improve data accuracy and protect sensitive information. Within personalized accounts, individual users can further customize their available forms to simplify navigation through the database and create shortcut connections to their most frequently used tables on the main page. Data fields that are not in use can be greyed out to prevent data entry, and restrictions can be put in place to avoid saving forms with key data fields left blank. Customized pick lists can be created by contacting *BG-BASE* for inclusion to further reduce data entry time and reduce the likelihood of misspelled information.

Users almost exclusively interact with *BG-BASE* data in form view, which allows for both data entry and viewing pertinent information from related tables. Thematic tables that store large amounts of information, such as the Accessions table, contain multiple forms that users can tab through to reduce confusion. Within the data fields on each form, users can access context-sensitive help for definitions and descriptions. While batch data imports can only be carried out with assistance from the *BG-BASE* programming team, data can be exported from *BG-BASE* into multiple formats that range in complexity from digital spreadsheets to HTML.

Website: www.bg-base.com

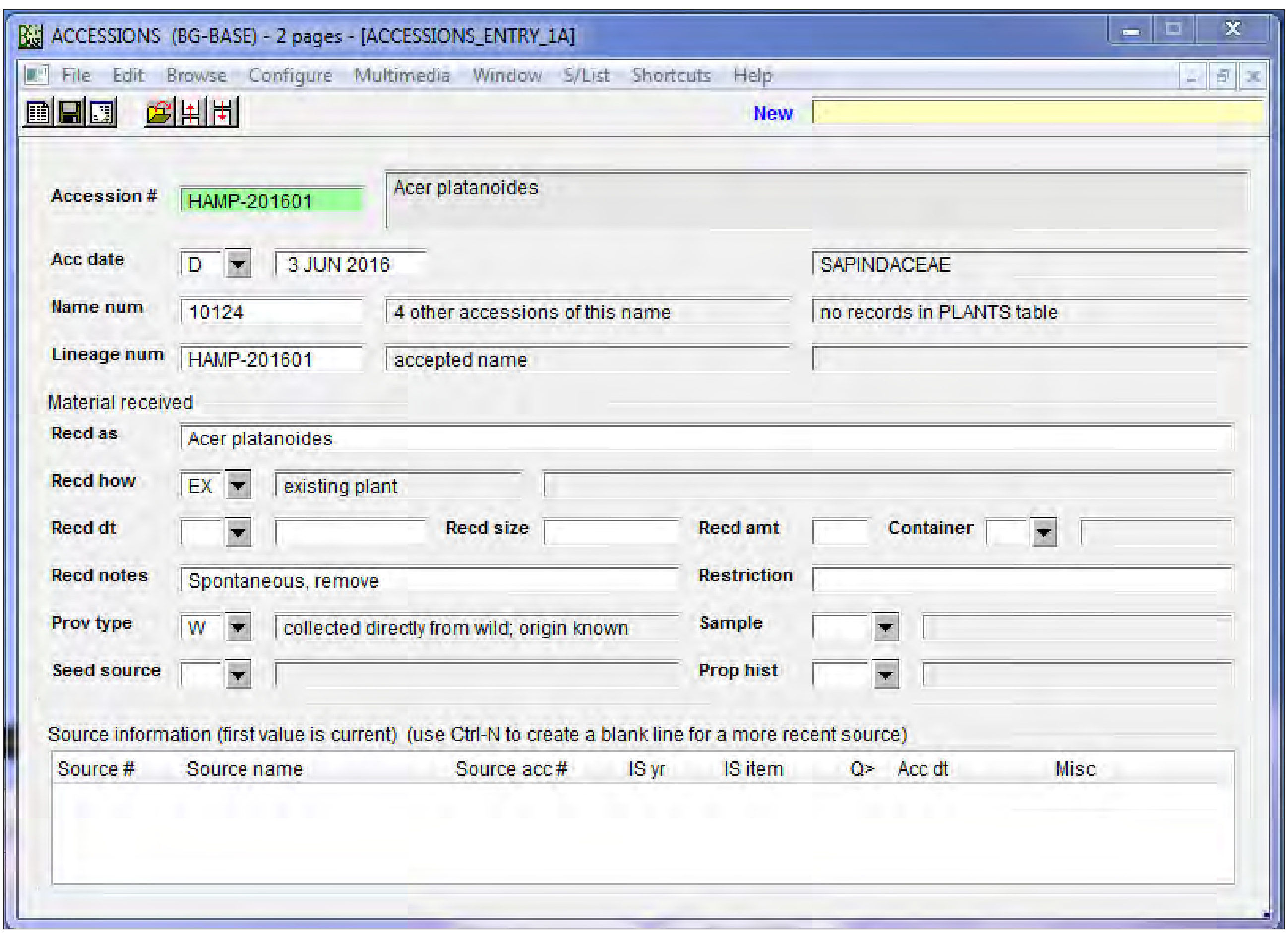

Figure 9. Entry forms in *BG-BASE* can be customized to streamline data entry and improve data accuracy by minimizing human error, as shown in this example from Hampton National Historic Site (*BG-BASE*).

BRAHMS

BRAHMS contains all the primary data fields evaluated for this report, which can be accessed and edited using thematic tables. Additional detail is added to the standard mainframe using linked files, or related tables that can be customized by the user or institution. As their name implies, these tables are linked to individual records to include information that may be specific to the particular site or institution, or provides a more specific level of detail. BRAHMS automatically displays the related linked information as the user selects records in the main tables. Custom pick lists can be created for many fields. To further ensure data accuracy and protect sensitive records, the database administrator can restrict users' viewing and editing access to pertinent tables.

Individual users can further customize their database view to hide modules and options they use infrequently.

Data including image files can be imported and batch edited in the database by using Rapid Data Entry (RDE). RDE files are flat files similar to digital spreadsheets that have a flexible design structure allowing them to be customized to specific projects or tasks. This ranges from field survey data to taxonomic information. For instance, BRAHMS contains an RDE tool for importing data from the International Plant Names Index. All RDE file information is checked by the database before it is accepted for import into BRAHMS. Records stored in BRAHMS can be exported into a wide range of different formats for data sharing, editing, and visualization.

Website: herbaria.plants.ox.ac.uk/bol/

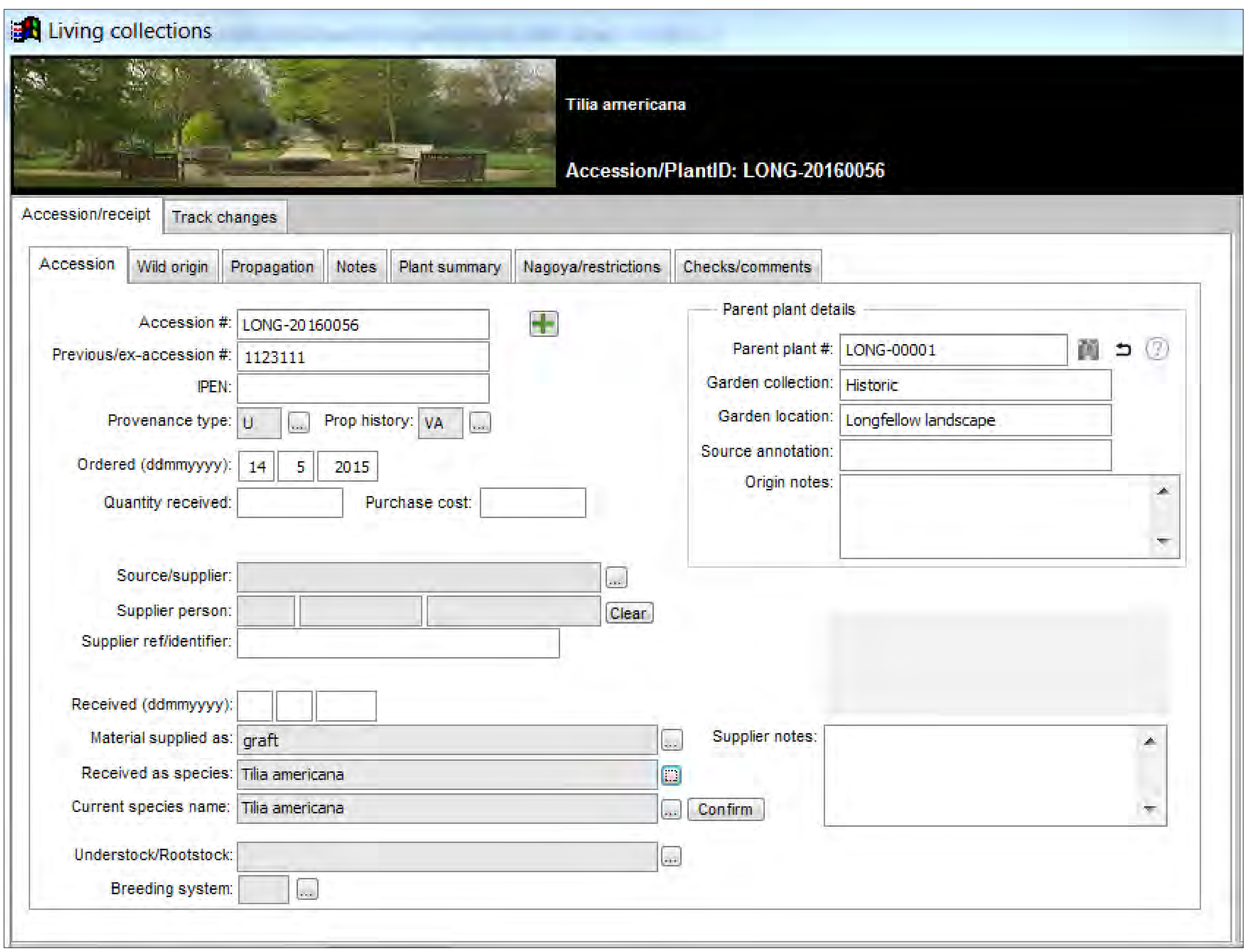

Figure 10. BRAHMS data can be entered using thematic forms, classic spreadsheet view, or uploading information using Rapid Data Entry, as shown in this example from Longfellow House Washington's Headquarters National Historic Site (BRAHMS).

FMSS

FMSS contains data fields for maintenance histories, condition, and size, and diameter at breast height, as well as many maintenance related fields not specifically evaluated for this report. As FMSS was created specifically for NPS, it contains many data fields specific to the National Park system, such as park alpha codes and cultural landscape inventory information. Because a standard version of FMSS is used by parks in all regions of the National Park system, data fields and drop down menus cannot be added or customized at the park level. Parks wishing to change the way their locations are defined in FMSS can contact their regional FMSS office to request a park hierarchy. FMSS contains a free entry field for additional notes, which can be used for entering taxonomic information. This is especially beneficial for parks who do not wish to use an additional database, or who want to avoid duplicating entry between systems by including report information from a separate plant records management database in the free entry field for reference.

FMSS is primarily accessed and edited by users in form view or information can be accessed in the form of reports produced using the Asset Management Report System (AMRS). While batch data imports can only be carried out at the regional level, FMSS data is exported from AMRS as a digital spreadsheet. Data in a digital spreadsheet is very flexible, and with proper formatting can be imported into an additional plant records management database, or into a GIS.

Website: pfmdportal.nps.gov/index.cfm (NPS only)

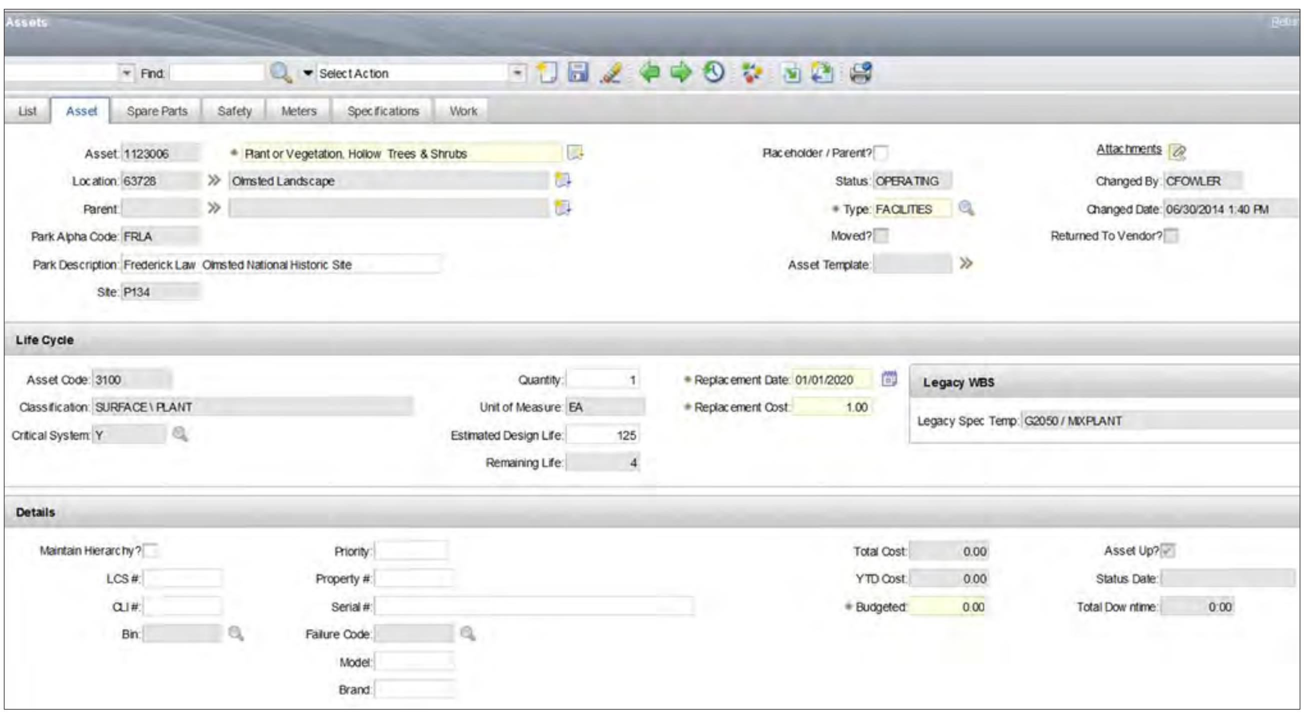

Figure 11. FMSS data fields are programmed to produce park specific information and link to other FMSS databases, as shown in this example from Frederick Law Olmsted National Historic Site (NPS).

IRISBG

IrisBG contains all the primary data fields evaluated for this report except phenology. With a basic understanding of IrisBG, however, users can add phenologic information to records in the taxon table by using the custom attributes function. Specimen-specific custom attributes can also be attached to records in the accessions table. To improve data quality and protect sensitive information, the database administrator can restrict users' viewing and editing access to only pertinent tables. Using the Definitions control function in IrisBG, drop down menus for data fields can be easily customized to reduce necessary data entry, improve data accuracy, and fit the terminology used by NPS, such as contributing and non-contributing for collection information.

Users most commonly view and edit records in IrisBG using forms organized by thematic tables. Most data fields allow users to conduct simple queries by placing the cursor in that field and then selecting the binoculars icon in the menu bar. Users can navigate the tables by using the menu found to the left of every form, or by using the querying tools to conduct specific, multi-field searches. Large amounts of data can be edited or imported by purchasing the data import module, which allows users to upload data in a variety of formats. IrisBG has created an Excel add-in to streamline preparing spreadsheets to be imported into Excel, and all files are checked by the database before they can be successfully imported into IrisBG. Data from IrisBG can be exported in formats compatible with many different systems.

Website: www.irisbg.com

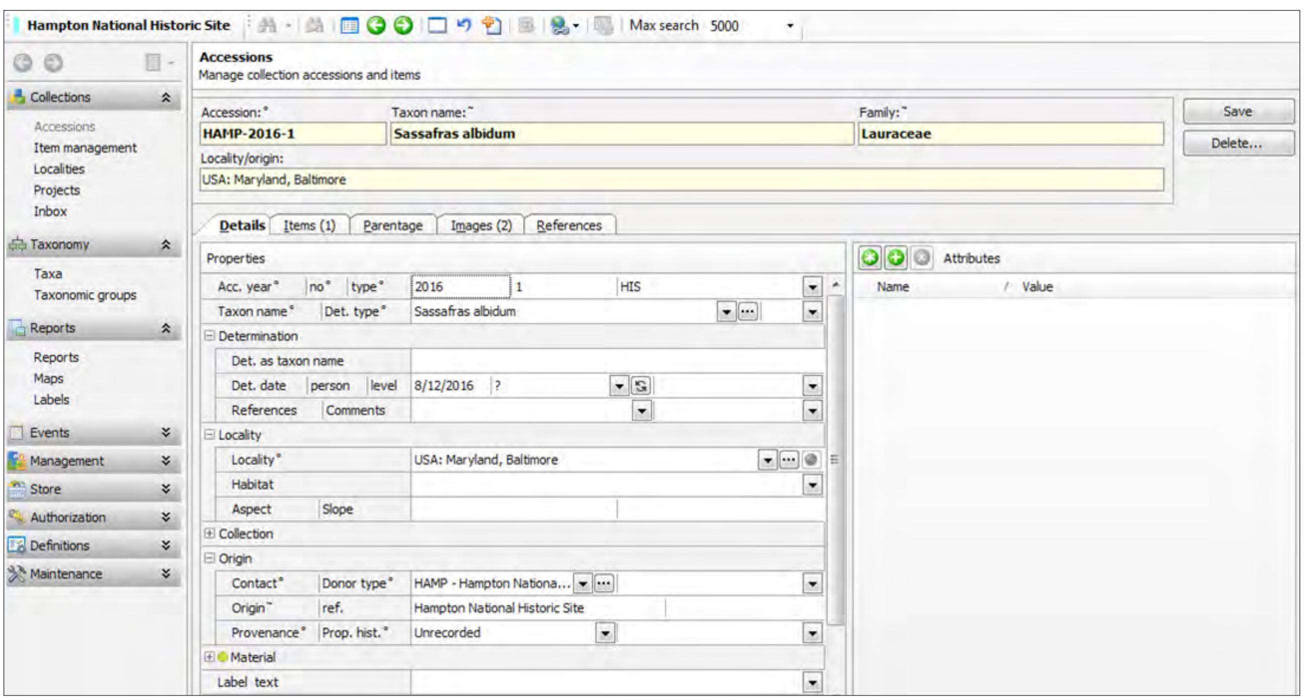

Figure 12. IrisBG allows users to enter data through thematically organized forms that can be customized by the database administrator, as shown in this example from Hampton National Historic Site (IrisBG).

Maintenance Capabilities

Maintenance in a database usually includes historic and requested maintenance. Depending on the database, maintenance histories and requests can often be linked to accessions, taxa, or locations. For instance, a specific *Quercus coccinea* may need to be pruned, whereas all the goutweed may need to be pulled in a particular section of the landscape. Like most key fields in a relational database, maintenance histories and requests can be queried with multiple concurrent factors to return information in a matter of seconds. For instance, querying "prune," "open," and "Quercus" simultaneously would return all the oaks scheduled for pruning.

Maintenance histories are nested in chronological order in most databases, so users can quickly see the complete work history when viewing a record. This not only offers practical assistance, but conserves institutional memory surrounding maintenance with staff turnover. For instance, imagine a certain shrub is exposed to more sunlight than nearby shrubs of the same species and therefore requires more water to maintain comparable health. Over time, this knowledge becomes rote for the gardener, who may fail to pass this information on to their successor as it has become commonplace. If the historical information has been saved in the database, however, the new gardener can see the attached maintenance record indicating abnormally frequent watering, and treat the shrub accordingly w;ith no loss of vegetation or time spent identifying an issue that has already been solved.

ArcGIS PUBLIC GARDEN DATA MODEL

Maintenance tracking is included in the data model related specifically to plant centers, but with an intermediate understanding of ArcGIS, a linked maintenance table can be related to any feature. The data fields and menu options are highly customizable

Figure 13. Maintenance staff and interns care for the parterre planting beds in Falling Gardens at Hampton National Historic Site (OCLP).

for both pre-existing and newly created tables, and maintenance histories are chronologically saved beneath pending work orders. The current version of the data model includes a comprehensive solution for inspections, work order generation, and maintenance history for facilities as well as plants.

Fieldwork options: The Collector App for ArcGIS, also created by ESRI, is a free application download for Apple and Windows devices that interfaces directly with the ArcGIS Public Garden data model through ArcGIS Online. Collector can be used on a phone or tablet to collect data and images in the field with or without an internet or data connection, and information can later be synced with the ArcGIS Public Garden data model on the desktop. GPS coordinates collected in the field with a Trimble or similar device can be easily incorporated into the ArcGIS Public Garden data model with or without the Collector App.

BG-BASE

BG-BASE can store maintenance information in several manners across different tables. Within the standard living collections module, special treatment information, survey results such as condition and DBH, propagation information, and mortality dates and reasons can be saved using the Plants table. Taxon specific maintenance information, such as soil and sun requirements, can be saved in the Names table. Specific tasks can be created and linked to plants and projects using the Hort_Tasks table. Conservation area maintenance can be managed by purchasing the additional conservation module.

Fieldwork options: While *BG-BASE* itself does not have a fieldwork option, the developers of complimentary mapping software BG-Map (see "Mapping Capabilities," page 29) have created Garden Notepad Plus for purchase, which can be used on Apple and Windows devices without a data plan or internet connection. Information can be automatically uploaded into the main database. Garden Notepad Plus does not require purchase of BG-Map, but does require the purchase and installation of the BG-Map web interface, Web-VQF (see "Interpretive Capabilities," page 33).

BRAHMS

The BRAHMS living collection module contains preset fields for propagation histories, survey information, and death or removal of a plant. Historic maintenance and survey results are linked to the Events and Observations table, and pending maintenance is linked to the

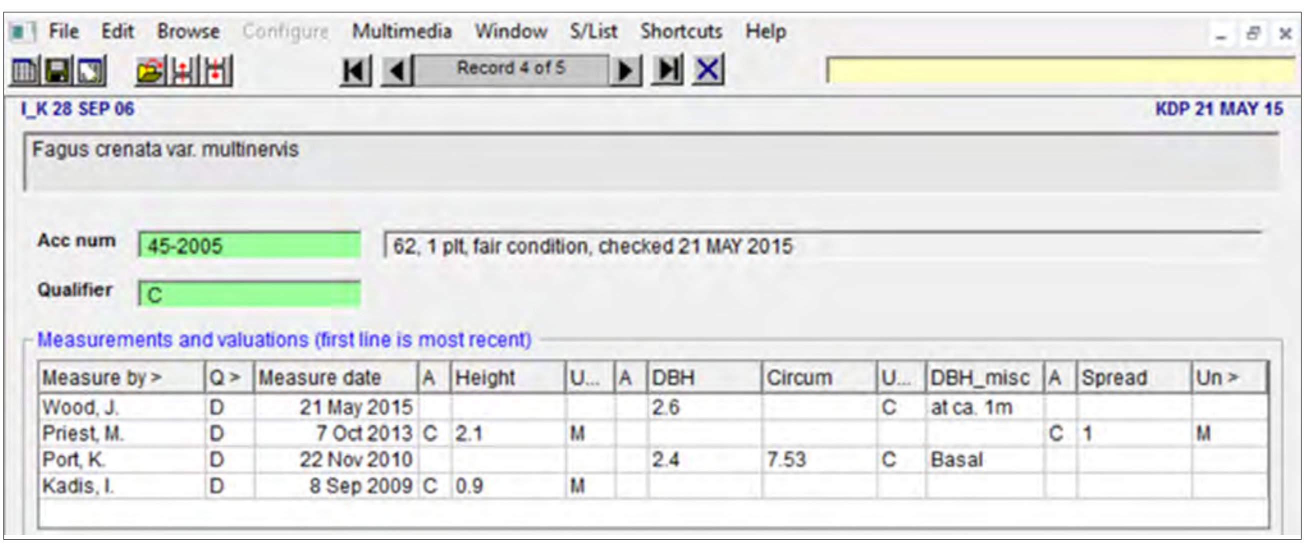

Figure 14. Comprehensive survey information, like status and measurements, can be saved chronologically using the Plants table in *BG-BASE* (*BG-BASE*).

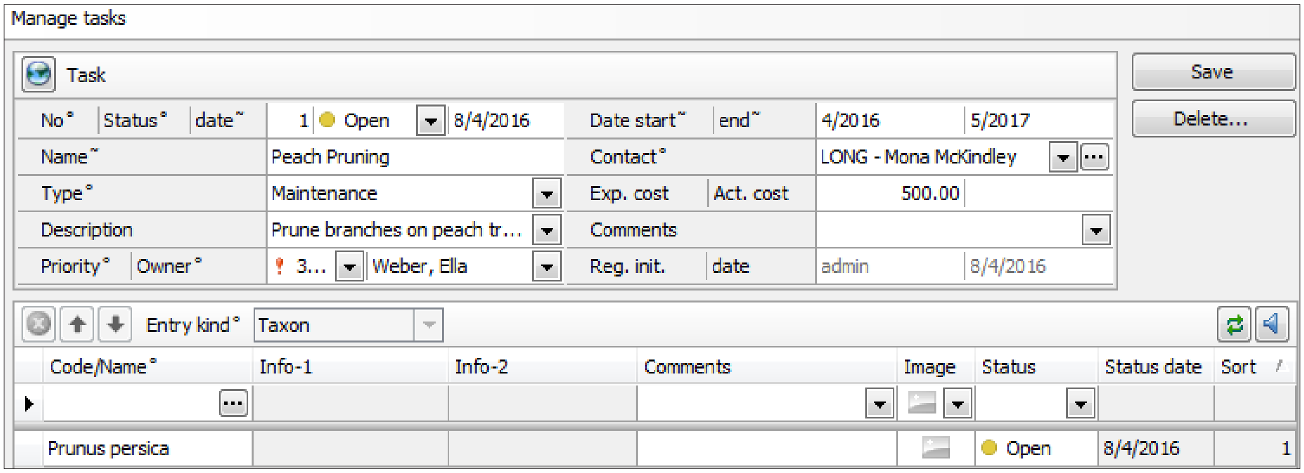

Figure 15. Pending and completed tasks can be documented in IrisBG, including relevant personnel, images, and priority ratings, as shown in this example from Longfellow House Washington's Headquarters National Historic Site (IrisBG).

Requests table. When a request is closed, the record automatically registers as an event. With an intermediate understanding of BRAHMS, users can create more detailed custom fields for the Events and Observations and Requests tables, as well as custom drop down values.

Fieldwork Options: Fieldwork observations can be batch uploaded into the database from digital spreadsheets and other digital formats using the Rapid Data Entry function in BRAHMS. A fieldwork application for internal use is currently being developed in collaboration between BRAHMS and the Morton Arboretum which will sync information collected in the field with the main database.

FMSS

The 3100 Maintained Landscapes asset type includes data fields that pertain to elements of the constructed landscape, including vegetation and hardscapes. Records in FMSS can be used to calculate costs of materials and labor required, as well as determining the Asset Priority Index and Facility Condition Index. Considered together, these scores are used to prioritize funding and implementation priority. Maintenance is related to location records and cannot be related directly to assets, which nest under location records.

When a maintenance request, or work order, is closed, the record is automatically saved as a maintenance history.

Fieldwork Options: While there are currently no digital fieldwork options available for FMSS, a spreadsheet application could be used on a smartphone or tablet to create a sheet containing key FMSS fields and drop down menus. The Collector App for ArcGIS could also be set up with a data frame to match FMSS requirements as a digital fieldwork option. In both

Interoperability with FMSS

Data from ArcGIS, *BG-BASE*, BRAHMS, and IrisBG can be easily exported into Excel, which can be imported with regional assistance into FMSS. For this transition to go smoothly, data field names, such as Location_ID and Asset_ID, need to be identical in both platforms. Batch imports for FMSS can only be triggered at the regional level, however, and are not feasible for frequent data editing. Running reports in all four systems is fairly straight forward and can be used to organize data for manual input in FMSS, while allowing more detailed data to remain stored in the plant records database. FMSS also includes comments box where information can be copied from an external database report. Parks that wish to track detailed maintenance histories and requests in FMSS, and therefore are not interested in the maintenance capability of a plant collections database, should consider a system that has strengths that compliment FMSS, such as mapping or interpretive potential. Regardless of if or how parks choose to relate FMSS to a plant records management database, it is always in the interest of good collection management to record the scientific names of assets whenever possible.

scenarios, data would have to be retyped into FMSS; however, this would be more secure and standardized than handwritten notes or maps.

IRISBG

IrisBG records maintenance through events that are defined either as inspections or tasks. While inspections are only related to accession items, tasks can be assigned to taxon, accession, item, location, or asset/hardscape. Both options allow the user to create custom drop down menus for standard categories, such as maintenance task type or contact personnel. Tasks and inspections can be linked to multiple records simultaneously to sort by maintenance type, or duplicate task and inspection records can be copied onto unique records to sort by record type. Once an end date is added to a task or inspection, a history of that record remains in the events category. While repeating tasks and inspections cannot be created, such as an annual alert for a particular fertilizing, full records can be copied and pasted. To create a repeating task, whoever sets the end date would need to copy and paste the details into an open task or inspection.

Fieldwork options: For purchase, IrisBG has a mobile application for Windows embedded handheld devices that can be used without a data plan or internet connection. Field information and photographs are synced with the mainframe database through a USB connection, and a quality control step is required before data is accepted.

Case Study: Emerald Ash Borer at Hampton National Historic Site

The emerald ash borer (*Agrilus planipennis*) is an exotic, wood-boring beetle that threatens green (*Fraxinus pennsylvanica*), white (*F. americana*), black (*F. nigra*), and blue (*F. quadrangulata*) ash tree populations across the country. The beetle typically kills infested trees within 3 to 5 years of infestation. In 2015, Emerald Ash Borer was identified in Baltimore County, Maryland, home to Hampton National Historic Site. Hampton National Historic Site preserves a 62-acre portion of a once vast residential, agricultural, commercial and industrial enterprise that was home to the Ridgely family for nearly two centuries. The park landscape includes forests, fields, specimen trees, and formal gardens, with a great diversity of exotic and native tree species, including some 210 ash trees grown in both ornamental and forest settings. Together, these ash trees comprise about 10% of the total open-grown landscape trees within the park.

With the arrival of Emerald Ash Borer in Baltimore County in 2015, the park began planning for management options, including chemical insecticide applications, biological controls (i.e. natural insect enemies of the borer), tree removal and replacement, and no action. The park worked with the U.S. Department of Agriculture to develop a Biological Evaluation for Emerald Ash Borer and the NPS Olmsted Center for Landscape Preservation and NPS Northeast Region Integrated Pest Management (IPM) Coordinator to develop a response strategy using vegetation inventory data from a recently completed cultural landscape report. This response involves treating high priority, historic open-grown landscape trees with insecticide to protect them from Emerald Ash Borer, while monitoring forest trees and planning for replacement upon decline.

How a Plant Records Management System Can Help

A plant records management system would be useful in inventorying trees for Emerald Ash Borer susceptibility and infestation, and categorizing trees for distinct treatment approaches based on species, location, size, and historical significance. Detailed assessment information may also reveal if any specimens show resistance to Emerald Ash Borer. Like the Jefferson Elm on the National Mall, such a fortunate discovery could lead to a new introduction to the nursery trade (see sidebar on page 6). Throughout treatment, the database could be used to track insecticide applications on open-grown trees and monitor condition of forest trees in conjunction with the park's IPM program. Upon loss and replacement of susceptible forest trees (with substitute species), the database would provide a record of the forest's pre-infestation composition to inform both the historical record and planning for enhancement of ecological values. Through web-publishing capabilities, a plant records databases could also be used to communicate with the public and park partners as specimens require treatment, conditions change, or replacement is required.

Mapping Capabilities

Landscape and vegetation mapping is important on a practical level for maintenance and directions, and can be extremely powerful for planning, research, and interpretation when coupled with a GIS or other dynamic mapping system. Georeferencing vegetation improves the accuracy of maintenance tracking and execution, and allows visitors to orient themselves in a landscape, or make decisions about specific areas they would like to visit. Mapping trends in a particular landscape can assist in planning decisions by showing change over time. For instance, mapping vegetation that has died repeatedly over the years may reveal that a particular area is unsuitable for what had historically been planted there. Combining mapped vegetation with larger datasets can provide visualization for research questions, such as “how has invasive bittersweet been spreading across New England since it was introduced?” For all the systems evaluated for this report, users can select records individually or through specific queries when generating maps.

In recent decades, NPS has recognized the importance of adhering to standards for geospatial data to improve the transfer of knowledge between disciplines, parks and regions, and ensure high-quality data is being captured that will be useful to stewardship efforts. Existing geospatial data adhering to NPS standards can be accessed using the enterprise GIS maintained by the Washington Support Office (WASO) Cultural Resources GIS Facility. An ArcGIS Toolbox of GIS tools, scripts, and instructional guidance is also available servicewide to improve standard procedures for creating, displaying, and managing cultural resource GIS data. Incorporating data from the enterprise GIS into a plant records management database not only reduces data entry duplication, but creates an additional layer of data standardization. Conversely, data stored in a plant records management database can be geovisualized in adherence to NPS standards and shared using the NPS enterprise GIS to further the creation of a complex GIS for research and management decision making.

Figure 16. Park staff at Lake Ross National Recreation Area rely on maps to inform management decisions and communicate with visitors (NPS/Michael Liang).

ArcGIS PUBLIC GARDEN DATA MODEL

As the ArcGIS Public Garden data model is specifically designed for ArcGIS, mapping is not only straightforward but the most basic component. Data can be displayed on a variety of base layers, including imported orthophotos, topographic maps, and street maps. Preexisting GIS layers from multiple branches of the park service can be incorporated with the ArcGIS Public Garden data model. With an intermediate understanding of ArcGIS, maps created using the ArcGIS Public Garden data model can be translated into Google Earth and other open source mapping platforms, or embedded in a web page. The ArcGIS Public Garden data model requires the institution to purchase either a standard or advanced license of ArcGIS. NPS has a standing contract with ESRI that affords parks licenses for ArcGIS at no additional cost. Interested parks should contact their regional coordinator for more information.

BG-BASE

BG-BASE has two mapping options for purchase. BG-Map is a separate product that was created to compliment *BG-BASE* using AutoCAD, a design and drafting program similar to ArcGIS that can georeference points, lines, and polygons as well as raster data. Alternately, there is an ArcGIS Connector module for *BG-BASE* that synchronizes data between the two programs. This option requires extensive configuration and is only recommended by *BG-BASE* for users that have extensive in-house GIS support. Both options require the institution to purchase a license for either AutoCAD or ArcGIS, respectively.

BRAHMS

BRAHMS is packaged with links allowing users to map data to a preferred platform, which ranges from Google Earth to ArcGIS. Database information transitioned to the map can range from all the related information from

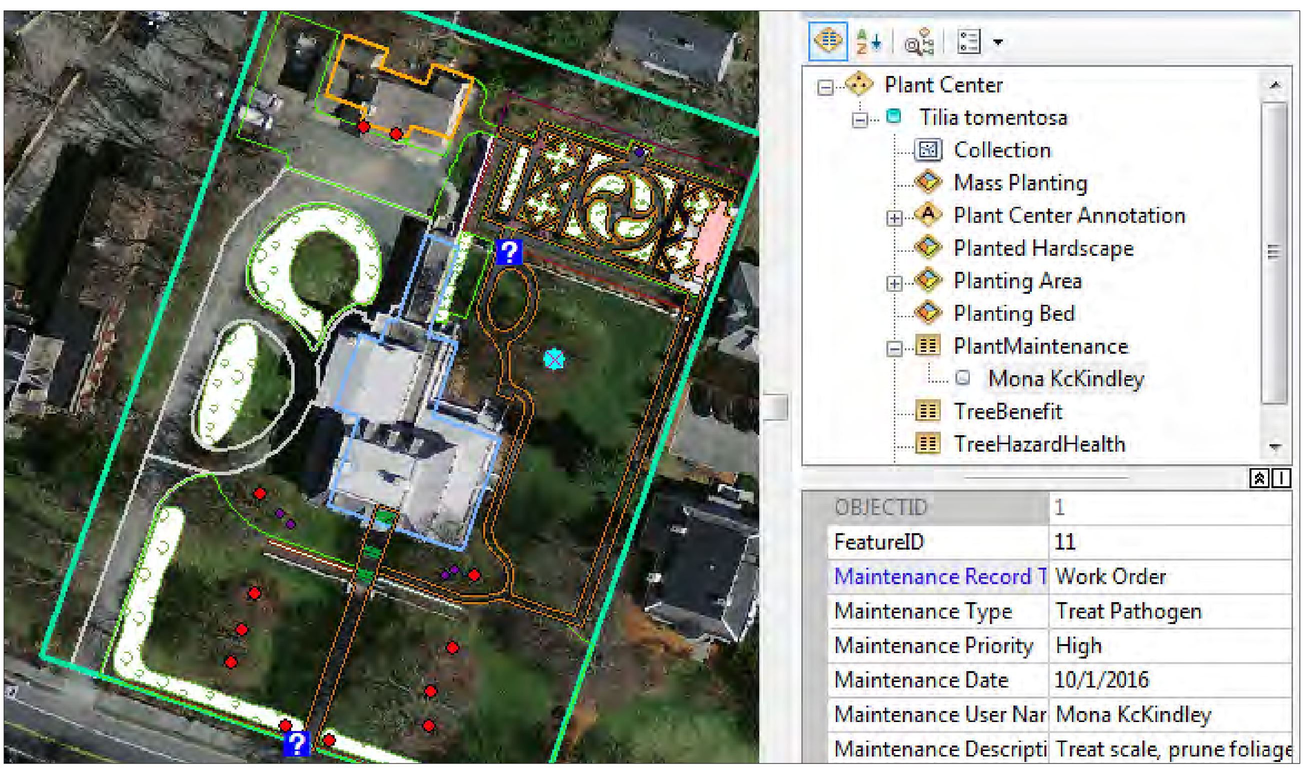

Figure 17. Plant maintenance tracked using the ArcGIS Public Garden data model includes tasks, tree benefits, and tree hazard health, as shown in this example from Longfellow House Washington's Headquarters National Historic Site (Alliance for Public Gardens GIS).

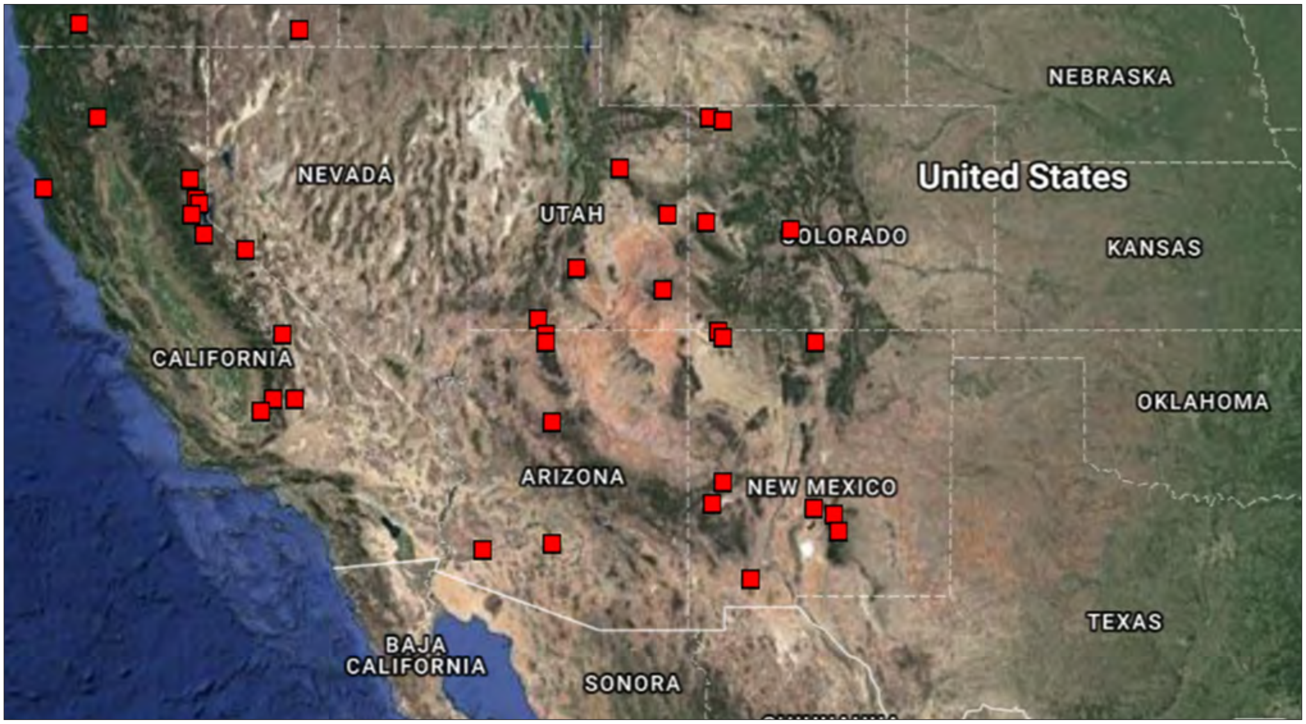

Figure 18. Plant record data from BRAHMS can be mapped directly from an institutional database or collaboratively across multiple databases using BRAHMS online (BRAHMS).

a given table to only latitude, longitude, and species name. Maps can be used internally or easily published to the web using BRAHMS online. Data published to BRAHMS online can be mapped alongside information from other BRAHMS online users. Users wishing to map with ArcGIS are required to purchase a license for the program.

FMSS

FMSS includes data fields for GPS coordinates, but currently has no direct connection to any mapping platforms. Data can be manually exported from FMSS using the NPS Asset Management Reporting System (AMRS) to create an Excel-based report with coordinates and from there imported into a GIS or other compatible mapping platform. Users wishing to use ArcGIS or another for-purchase program are required to purchase a license.

IRISBG

IrisBG has a mapping module available for purchase that displays on a variety of internet maps or can interface with preexisting web map service hosted GIS layers, such as NPMap. Exact coordinates can be added to the data records or there is a drag and drop option on the map for marking approximate locations. Maps created in IrisBG can be exported as KML files which can be used with compatible programs like Google Earth and ArcGIS. The ArcGIS IrisBG Sync, developed by the Alliance for Public Gardens and UC Davis Arboretum, loads plant collection data from IrisBG directly into ArcGIS in line with the APGG data model. Users who wish to use the ArcGIS mapping functions are required to purchase a license for the program.

Figure 19. Frederick Law Olmsted National Historic Site embodies noteworthy characteristics of Olmsted's design approach (NPS).

Case Study: Historic & Contemporary Plans of Fairsted, Frederick Law Olmsted National Historic Site

Frederick Law Olmsted National Historic Site preserves the final home and office of Frederick Law Olmsted, Sr. (1822–1903) and the offices of the successor firms that operated from the site until 1979. The 1.75-acre grounds of Fairsted, as the property is known, reflect their appearance about 1930, at the height of the firm's operation. The grounds embody the design characteristics of Olmsted Sr.'s most noteworthy landscapes, including the key concepts of scenery, suitability, style, subordination, separation, sanitation, and service.

As the primary repository of the firm's records for over 6,000 projects, the Olmsted Archives include 160 plans related to the firm's work at Fairsted, a fraction of the approximate 138,000 plans and drawings in the archives. Olmsted Sr., and later his sons and successor firms, developed the property's landscape from the time of purchase in 1883, including removal of selected pre-existing plantings and extensive additions. As the site's building complex grew, garden areas were redesigned to accommodate the burgeoning design firm. Accordingly, garden areas and plantings were redesigned throughout the historic period. Since Olmsted Associates vacated the property in 1979, the site has been restored to its circa 1930 appearance. This work involved planting plans that detailed removal of vegetation that post-dated 1930 and installation of new plant specimens to replace those removed between 1930 and 1979.

How a Plant Records Management System Can Help

With nearly two hundred plans tracing the development of Fairsted from 1883 to present, a plant records database would provide a georeferenced platform for managing information about changes to the site's planting over the past hundred and thirty years, including details of ongoing efforts to preserve historic plantings and replace missing historic specimens. This information would be useful to park gardeners, horticulturists, landscape architects, and historians who seek to understand the evolution of the landscape and reasons for plant viability to inform future management decisions. Through web publishing, information about the historical development of the site's plantings would be accessible to visitors who are both experienced researchers or learning about Frederick Law Olmsted and the field of landscape architecture for the first time.

Interpretive Capabilities

Interpretation at national parks includes a wide range of activities and audiences, from self-guided tours to youth education programs. In an increasingly diversifying country, visitors include individuals of different racial, religious, and gender identities, span multiple generations, and come from urban, rural, and suburban areas with different socioeconomic and educational backgrounds. Identifying and adapting to visitors' needs effectively empowers them to appreciate and participate in the mission of NPS.[14]

Incorporating the often complex cultural histories of living landscapes alongside their aesthetic and ecological value is an important aspect of interpretation. Preserving cultural and natural resource information together in a database helps streamline interpretation of these disciplines. For instance, educational programming for a group of school children could be produced around vulnerable species, which could be easily queried in a plant records database, related photos printed, and students tasked with identifying the plants in the landscape and learning about related conservation and preservation efforts. Alternately, ethnobotanical information could be saved in the database and information could be shared with visitors about how these plants are traditionally used or spiritually significant to members of American Indian tribes.[15] Allowing seasonal or volunteer interpretive staff read-only access the database could also allow them to explore their personal interests within the landscape, which could shape the way they interact with the public.

Figure 20. Interpretive rangers in national parks create programming to connect with audiences of all ages at North Cascades National Park (NPS/Deby Dixon).

ArcGIS PUBLIC GARDEN DATA MODEL

The ArcGIS Public Garden data model's strongest interpretation capability is map creation. Interactive maps can be published to the web and accessed by computer or smartphone. It is easy to restrict what data is published to the web; however, any data that is stored in the ArcGIS Public Garden data model can potentially be shared with the public. ESRI's Explorer for ArcGIS is the most straightforward way to share ArcGIS maps. A web manager can easily embed an interactive GIS map onto a website. With intermediate understanding of GIS and HTLM coding, anyone comfortable with technology can manage web publishing using the instructions available from ArcGIS online. ArcGIS lends itself especially well to geospatial ecological analysis and modeling, and can visualize scenarios such as "what would the landscape look like in 50 years if the global temperature rises at the most extreme possibility compared to if it rises at the least extreme possibility?" This data can be very powerful for researchers at local, regional, and international levels.

BG-BASE

Records from *BG-BASE* can be selectively exported from the database in a number of different formats from print to web compatible, and a web manager could easily export data into a preexisting website and create a searchable dataset. Users who purchase BG-Map can also purchase the Web-VQF, or Visitors QuickFinder, at an additional cost to add interactive maps with images, plant searches, tours, and other geovisualized garden information to a preexisting website.

BRAHMS

Using BRAHMS online, select information from the database can be published to a website which can be hosted either by BRAHMS or by a third party. Most of what can be stored in the database can be published to the web, allowing online visitors to query the collection, view images, and interact with maps. Users who choose to publish their information through the

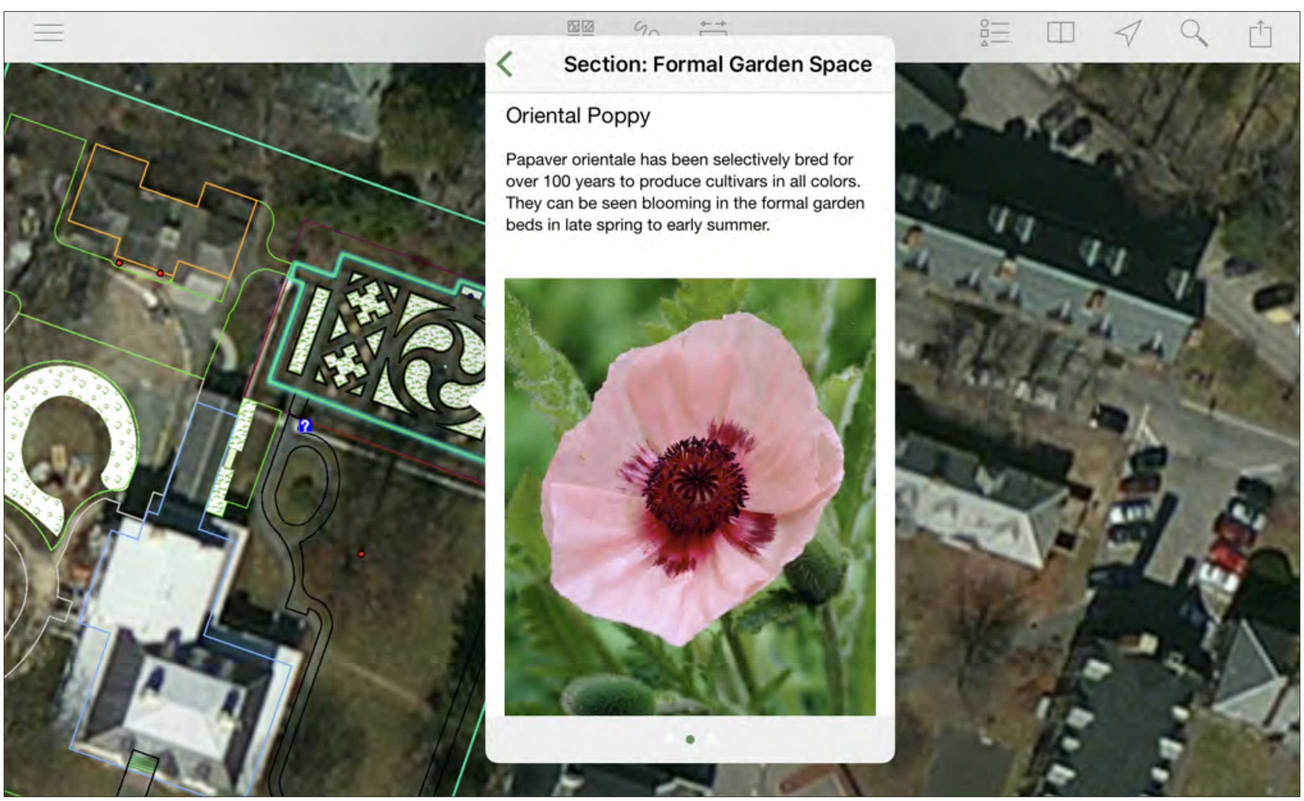

Figure 21. Educational data and images saved in the ArcGIS Public Garden data model can be shared through ArcExplorer maps, as shown in this example from Longfellow House Washington's Headquarters National Historic Site (Alliance for Public Gardens GIS).

BRAHMS online site are displayed collectively with other BRAHMS users' sites, and data can be queried to include all published information.

FMSS

FMSS is an entirely internal application for NPS that does not have an interpretive aspect. Data can be exported from FMSS and potentially used in a third party interpretive tool; however, the data in FMSS is not generally of interest to the public since it is mostly related to maintenance and funding.

IRISBG

For additional purchase, IrisBG has developed a garden explorer website that publishes data, images, and maps to the web directly from the database. The site is mobile optimized, meaning the website content will appear in a format that is easy to read and interact with on a smartphone or tablet. While individual sites can customize what is available through their garden explorer site, most parks publish interactive maps and guided tours, photographs, and read only search access to non-sensitive records.

Interpretive Tools

Plants Map

Plants Map is a free web and mobile-friendly platform that allows institutions to post photos, summaries, events, landscape maps, themed tours, and taxonomic names and information for specific plants. Users can follow and receive updates from sites on Plants Map, and connect information directly to Facebook, Twitter, Pinterest, Instagram, and other social media platforms. Plants Map is in use by Fredericksburg and Spotsylvania National Military Park to interpret the plant collection at Chatham: https://www.plantsmap.com/

Open Tree Map

Open Tree Map is a web and mobile-friendly platform available through a monthly subscription service. Site owners can map trees, import and export taxonomic and health data, and share information on social media platforms. Advanced modules include mapping ecosystem resources and estimating eco-benefits of a region. Trees information can be uploaded by the organization, or submitted by citizen scientists and verified by the site owner. Pricing for Open Tree Map ranges from $73 per month to $346: https://www.opentreemap.org/

Nature's Notebook

Nature's Notebook is a phenology recording project run by the USA National Phenology Network to provide scientifically significant observations for research and decision making. Nature's Notebook relies on citizen scientists to collect and record observations and phenologic information. NPS is already involved in collaborative projects with Nature's Notebook. NPS observations have produced tools like the phenophase visualization in Sequoia National Park and contributed to climate research: https://www.usanpn.org/natures_notebook

Figure 22. The Hoyt Arboretum in Oregon uses the Garden Explorer to share interactive plant maps, with photos and information (IrisBG).

Figure 23. Participants in a youth education program at John Muir National Historic Site enjoy peaches from the historic orchard (OCLP).

Case Study: Phenology at John Muir National Historic Site

Phenology is the study of cyclic or seasonal biological events, such as plant leaf-out and flowering, insect emergence, and animal migration. Understanding the frequency and change in frequency of these events informs climate science, pest and invasive species management, plant and animal migration patterns, and agricultural practices, among many other factors.

John Muir National Historic Site in Martinez, California preserves the home and orchards of America's most famous and influential naturalist and conservationist. In addition to 9 acres of orchard blocks planted with almonds, apricots, cherries, grapes, peaches, pears, European plums, Japanese plums, and black and English walnuts, the park includes a 236-acre natural area, replete with native trees and wildflowers covering a 600-foot ascent named for one of Muir's daughters, Wanda.

Beginning in 2010, John Muir National Historic Site partnered with the USA National Phenology Network to initiate the California Phenology Project. Designed to assess the effects of climate change on California's biodiversity and natural resources, the project involves seven units of the National Park System. Working with the University of California, Santa Barbara, the partnership has identified over 60 high priority plant species for phenological monitoring in California, 8 of which grow at John Muir National Historic Site.

The work has engaged students from the Martinez Unified School District and local citizen scientists in collection and interpretation of phenological data, encouraging visitors to observe the world around them through a new lens. The park also created ethnobotany cards that foster visitors' appreciation for California Native People's knowledge and uses of plants.

How a Plant Records Management System Can Help

A plant records management database would provide a framework for gathering, sharing, and analyzing phenological data from all seven units of the National Park System involved in the California Phenology Project. Through use of the database's administrative controls, volunteers, interns, and park staff could all access the database at varying levels to update and verify phenological data. The public could also view web published plant information to enhance the parks' interpretation of native and cultivated vegetation, phenology, and climate change impacts. Networked across several parks – or even the entire nation – a phenological data aggregated in a plant records management system would be even more impactful, systematically expanding our understanding of climate change through indicator data. Over time, georeferenced plant records data may also reveal secondary climate change impacts, such as species migration.

Research Capabilities

According to a 2014 report from Botanic Gardens Conservation International, only an estimated 5% of threatened plant species are currently included in recovery and restoration programs around the globe.[16] The first step to protecting and managing areas that support an increased number of threatened species involves developing detailed inventories and surveys that reflect change over time. It is important to know not only what is growing in the landscape, but where, how, and in concert with what other species. Climate change and biodiversity research can be facilitated at the park, regional, and national levels through a plant records database using reporting and analytical tools. Many databases are also capable of linking to reference sources, such as the United States Department of Agriculture PLANTS database, to ensure data accuracy and standardization. Library resources, such as pertinent journal articles or publications that reference park research, can also be stored in many databases and linked to related vegetation or locations in the landscape. Ongoing research project information can also be stored in a database to produce robust records that include information that may fall outside the purview of routine survey data collection in a particular park. For instance, information currently being gathered for the Denali National Park and Preserve Tree Ring Analysis project could be imported into a plant records database for future stewardship use, and eliminate the need to duplicate that collection effort in the future.

Figure 24. An Olmsted Center research associate collects GPS data for vegetation inventory on the Boston Harbor Islands (OCLP).

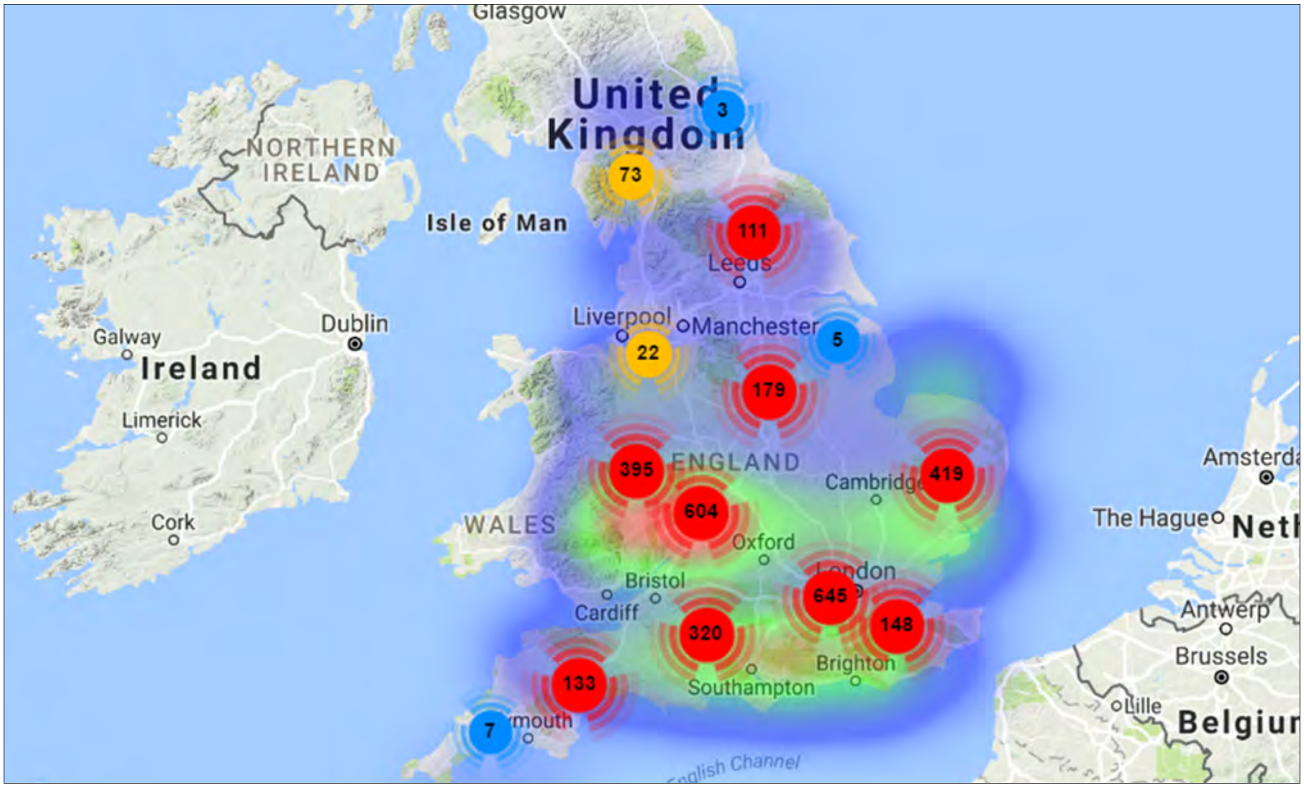

Figure 25. Data sharing using BRAHMS online allows researchers to create maps like this incidence and density map of oaks of England (BRAHMS).

ArcGIS PUBLIC GARDEN DATA MODEL

ArcGIS is a powerful research tool that lends itself especially well to geospatial ecological analysis of relationships and trends over time. ArcGIS can model complex scenarios using multiple datasets, such as "what might the landscape look like in 50 years if the global temperature rises at the most extreme possibility compared to if it rises at the least extreme possibility?"

The ArcGIS Public Garden data model does not have it own research capabilities. Rather, it allows parks to record standardized georeferenced data that can be used to produce robust research analysis and predictions using ArcGIS.

BRAHMS

As a key research asset of the Department of Plant Sciences at Oxford University, BRAHMS is well designed for biodiversity, ecology, and conservation reporting and analysis, and records can be exported in compatible formats for publishing, data analysis, and distribution mapping. Statistics and numeric counts can be automatically populated alongside the datasheets as the user moves through the records. BRAHMS can store reference literature, including digital sources, and contains direct links to many reference databases, such as USDA Plants, that can be searched based on records selected in the database. Records in the database can contribute to largescale bio-quality analyses using the Star Rating System developed at the Department of Plant Sciences.

FMSS

While data contained in FMSS is largely related to maintenance and does not generally include information that would be considered pertinent to botanic research, reports could be produced using the NPS Asset Management Reporting System (AMRS) to reflect vegetation change in the parks landscape and combined with their related GPS information to contribute to distribution maps.

BG-BASE

BG-BASE includes reporting and analysis tools and can store reference literature, and additional functionalities are available with purchase of the conservation module. Reports can be produced ranging from simple inventory queries to complex multi-factor queries. Geographic distribution patterns can be created at the taxon and species level for analysis. The conservation module expands distribution information, legal status, such as CITES, and improves management of conservation area inventories.

IRISBG

Reports can be created through IrisBG from simple inventory queries to complex, multi-factor queries, and can be exported into a variety of formats for analysis and print or web publishing. Data can be exported from IrisBG in several botanic organization data sharing formats, including the Botanic Gardens Conservation International Plant Search Upload. Library references, including digital sources, can be linked to determination history, accession, or taxon records. Geographic distributions can be visualized using the mapping module.

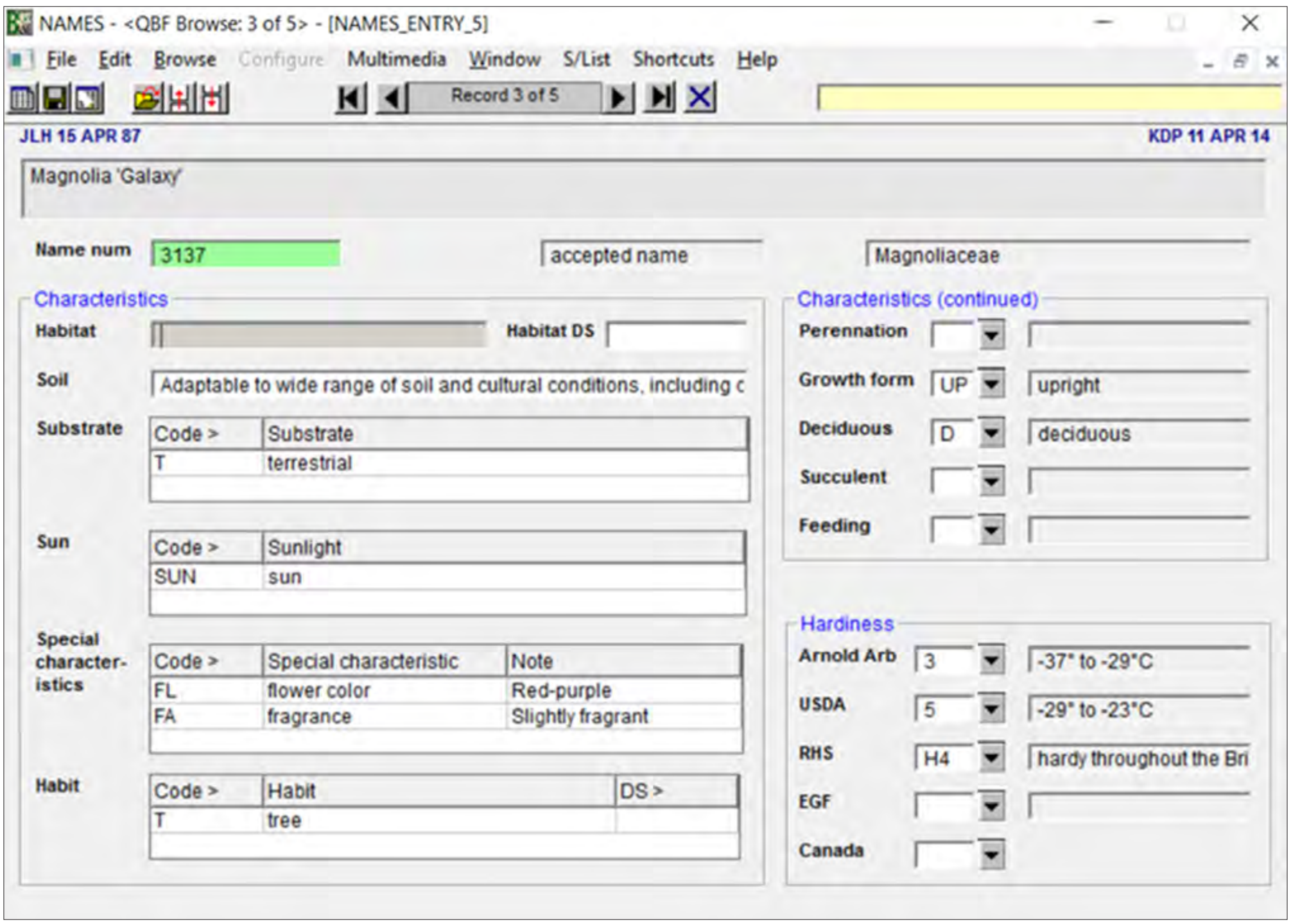

Figure 26. Comprehensive ecological and phenological information pertinent to research can be saved in the *BG-BASE* Names table (*BG-BASE*).

Case Study: The Algernourne Oak at Fort Monroe National Monument

Fort Monroe National Monument in Hampton, Virginia is one of America's newest national parks. Strategically located at the mouth of the Chesapeake Bay on a 565-acre peninsula known as Old Point Comfort, Fort Monroe is a place of astounding beauty and inspiration. The northern stretch of the peninsula is largely open, with over three miles of Chesapeake Bay beachfront. At the southern end of the peninsula, an imposing 63-acre stone fort is the focal point of the park.

Within the moated walls of the fort, a large parade ground is bordered by historic buildings and a striking collection of mature live oak trees (*Quercus virginiana*). One particularly majestic specimen, known as the Algernourne Oak, is estimated to be nearly 500 years old—Algernourne being the name of the first fort on Old Point Comfort (1609–12). These trees are living witnesses to events that shaped both our nation and millions of individuals' lives: Old Point Comfort saw critical events that led to both the beginning of slavery in England's American Colonies and the end of slavery in the United States.

In addition to its cultural significance, the Algernourne Oak is the subject of scientific interest. It grows far north in the geographic range of the species and is thus particularly cold hardy. In 2012, the Arnold and Morris arboretums completed a joint collecting trip to the Virginia Tidewater region to gather acorns from live oak trees. Read more about "The Quest for the Hardy Southern Live Oak" in *Arnoldia: The Magazine of the Arnold Arboretum* (2013, v. 65, no. 3).

How a Plant Records Management System Can Help

Aggregated, genetic and phenologic information about live oaks in units of the National Park System along the mid-Atlantic and southeastern seaboard offer opportunity to better understanding genetic variation among live oak populations and trace the effects of changing climates on a specific plant population over a large area. In conjunction with the NPS Research Permit and Reporting System, a robust plant records management database could also support the reporting requirements of Research and Collecting Permits. A plant records database has the capacity to track papers and findings associated with research on specific plant specimens, population, and species by linking to third party repositories, such as *Arnoldia,* referenced above. Through web publishing, information on the scientific value of park resources could be made available to the general public.

Figure 27. Trees, like this 500-year-old white oak at Fort Monroe National Monument, bore witness to key moments in American history and are of particular scientific interest (The Arnold Arboretum of Harvard University).

LEARNING CURVE

ArcGIS PUBLIC GARDEN DATA MODEL

Learning to use the ArcGIS Public Garden data model itself is fairly straightforward. The Alliance for Public Gardens GIS has created comprehensive training resources that make using the data model easy. Along with the seven-part training video posted to their website, nearly 50 instructional videos and conference recordings are available on their public YouTube page. They have also created a twenty-seven-page written document that includes step-by-step instructions with descriptive screenshots.

Using the data model requires a firm grasp of ArcGIS for set-up, data entry, and analysis. ArcGIS is a large and complicated program; however, there are many resources available online through ESRI and third party organizations that offer free step-by-step training. The Alliance for Public Gardens offers free online ESRI training to member institutions, and Massachusetts Institute of Technology's OpenCourseWare program has several free online courses.

Ensuring that a specific site's data model is well designed within ArcGIS from the beginning will make it easier to maintain and train new staff members in the long run. The latest version of the ArcGIS Public Garden data model can be hosted entirely on ArcGIS online to reduce the learning curve associated with ArcGIS desktop products.

Figure 28. NPS/Student Conservation Association Research Associates learn about maintaining the unique mountaintop ecosystem at Acadia National Park (OCLP).

BRAHMS

Learning to use BRAHMS is fairly straightforward for basic functions, but can initially be challenging for customized functions, such as creating linked files. Purchase of BRAHMS comes with Skype and email support provided by advisory group members, and a three day training course can be arranged in-house or at the University of Oxford at for an additional cost. Free of charge, BRAHMS has created an eighty-eight-page written training guide with step-by-step instructions and descriptive screenshots which can also be accessed as a live digital document.

BG-BASE

Learning to use *BG-BASE* can be challenging because it is an immense and powerful system that can initially be intimidating for users without previous database experience. Purchase of *BG-BASE* comes with two days of off-site training in either Dallas, Texas or Portland, Maine, as well as a year of unlimited technical support through phone, email, remote access, and discussion forum. Continued technical support agreements can be purchased after the first year. For an additional cost, in person training and retraining can be arranged, as well as training seminars that are offered regularly in Portland and Dallas. Free of charge, *BG-BASE* has created a comprehensive seventy-two-page written document with step-by-step instruction and descriptive screenshots. The database also includes a “search by field” function that opens a pop-up help window that explains the functions of a particular data field.

IRISBG

IrisBG was intentionally designed to be user friendly and minimize training time. Purchase of the database includes free, self-paced online training as well as a question and answer session with a product team member at the beginning and end. For an additional cost, in-person or live web training can be arranged. IrisBG has also created an online video training series organized into introductory, intermediate, and advanced, as well as a thirty-one-page written document that includes step-by-step instructions with descriptive screenshots. Additionally, the manager of IrisBG holds an informational Q&A session on the first Thursday of every month.

FMSS

Learning to use FMSS can be challenging due to the complexity of the system, its broad focus on all components of facility inventory and maintenance, and because users cannot customize their experience, meaning the amount of available information can often be overwhelming for those executing simple vegetation maintenance tasks. The majority of the available FMSS courses available on DOI Learn are not offered regularly, including the two courses related specifically to cultural landscapes, “Cultural Landscapes and FMSS–Asset Inventory” and “Cultural Landscapes and FMSS–Work Identification and Planning.” Because much of the data entry for FMSS requires knowledge of NPS convention, the system can be confusing without proper training and reference documents.

Cost

VARIABLE PRICING

Prices in this section represent the starting cost for one site for a single concurrent user, three concurrent users, and ten concurrent users (see Table 2 on page 44). All programs offer large-scale and national licensing for a significant number of sites and concurrent users. Interested parties should contact the developers to obtain a quote. Because many programs offer discounts for bulk purchasing or multi-year licensing, it is always advisable to contact the individual software developers to discuss cost options and request an exact quote before making a purchase.

MULTIPLE USERS V. CONCURRENT USERS

Most databases determine their cost in part by the number of concurrent users. Concurrent users are determined by how many people will be logged into the database simultaneously, whereas multiple users are determined by how many people have access. It's important not to conflate concurrent users with multiple users.

There are many ways to decide which license is best for your park. A single concurrent user license is fine for small site using their own system, those reporting to a database manager, or if it is unlikely users will need access at the same time. A large park that uses the database heavily might opt for a three concurrent user license. If many sites across the country want to use the same database, also known as an enterprise database, a large license or national license is best.

Additional concurrent user licenses can always be purchased as they become necessary, so it may be advantageous for sites to begin with only a handful of concurrent users initially, and purchase more licenses as more personnel are given database access.

NAVIGATING MODULES

LIVING PLANT COLLECTIONS MODULE

A standard living plant collections module includes aspects of accession, item, and locality management including, but not limited to, the primary functions outlined in this report. These include taxonomic data, histories, photos, and maintenance information (see sidebar on page 19).

MAPPING MODULE

A mapping module handles all elements of geovisualizing data. This includes connections to mapping platforms, incorporation of descriptive data such as taxon information, and the ability to interface with mobile and web compatible platforms.

PRESERVED COLLECTIONS MODULE

A preserved collection module includes all aspects of management related to herbarium specimens, seed collections, and other stored plant material. This information can often be recorded alongside living plant collections records or as a separate collection. The latter option would be used for collections that were primarily collected from plants that are not part of the park's living plant collection.

WEB PUBLISHING

Web publishing tools handle the selective migration of data to be incorporated into a pre-existing website or a new website hosted by the database provider.

Table 2. Cost Comparison of Plant Record Management Databases

Application	Module	One Concurrent User	Three Concurrent Users	Ten Concurrent Users
ArcGIS Public Garden Data Model*	**n/a**	Free*	Free*	Free*
BG-BASE	**Living Collections**	$4,250 $875 *optional support agreement after first year*	$8,000 $975 *optional support agreement after first year*	$12,750 $1,725 *optional support agreement after first year*
	Mapping	$1,500 (ArcGIS Connector) $7,200 (BG-Map)	$7,950 (BG-Map)	Contact BG-Map
	Preserved Collections	$3,000 *when purchased with living collections module* $4,250 *stand alone*	$6,750 *when purchased with living collections module* $8,000 *stand alone*	$11,500 *when purchased with living collections module* $12,750 *stand alone*
	Web Publishing	Included with purchase of Living Collections Module		
BRAHMS**	**Living Collections**	$620 *annual*	$1,850 *annual*	$6,200 *annual*
	Mapping	Included with purchase of Living Collections Module		
	Preserved Collections	Included with Purchase of Living Collections Module		
	Web Publishing	$620/site *hosted by BRAHMS* $1,850 unlimited sites *hosted by third party*		
FMSS***	**n/a**	Free to NPS	Free to NPS	Free to NPS
IrisBG	**Living Collections**	$2,380 $480 *annual support agreement*	$4,570 $910 *annual support agreement*	$9,510 $1,900 *annual support agreement*
	Mapping	$760 $150 *annual support agreement*	$1460 $290 *annual support agreement*	$3030 $610 *annual support agreement*
	Preserved Collections	$300 $60 *annual support agreement*	$570 $110 *annual support agreement*	$1,190 $240 *annual support agreement*
	Web Publishing	$900 $180 *annual support agreement*	$1,720 $340 *annual support agreement*	$3,590 $720 *annual support agreement*

Notes:

* The ArcGIS Public Garden data model is available as a free download and only requires that institutions acquire a license for either a standard or advanced license of ArcGIS. GIS licenses are available to units of the National Park System through NPS regional offices at no additional cost.

** BRAHMS licenses are based on an average cost, but are open to pragmatic negotiation based on the size and financial resources of the interested institution.

*** NPS contracts at a national level for FMSS at no additional cost to parks.

Making the Move to a Digital Records System

CONSIDERING CURRENT NEEDS AND FUTURE GOALS

Databases exist to secure standardized transfer of institutional knowledge over time. Therefore, it is important to think about possible future applications of a database from the outset. Creating a timeline to realize needs and desires can be a useful way to conceptualize this development. For instance, the first year might be devoted to importing existing data and creating a realistic workflow for future data entry and management. During the second year, the plan may be to incorporate map creation and interpretive tools.

It's also important to consider the goals of all invested parties when creating a plan. For instance, a natural resources manager may want to compile invasive species maps from the past ten years to predict future trends, and an interpretive ranger may want to plan a community project discussing climate change in the park. These goals could be addressed simultaneously by focusing effort on importing invasive vegetation information and locations first, and simultaneously flagging these records to a specific interpretation program.

After evaluating current needs and future desires, it is also possible that a park will determine a complex database system is not an appropriate fit at the time, but may be of interest in the future (see Table 1 on page 8). This presents an opportunity to critically consider current plant record management methods and develop stronger standardization to improve workflows and preserve institutional memory. Many of the principles of a relational database apply in these situations, such as creating unique data fields for unique entities and using standardized language. Adhering to them in even the most basic digital spreadsheets can make moving to a comprehensive system easier at a later date. Similarly,

Figure 29. Digitizing records relevant to national park stewardship requires teamwork across resource management disciplines, as shown here at Cape Cod National Seashore (OCLP).

producing a collaborative plant collections philosophy is beneficial regardless of how records are maintained (see page 47).

GETTING STARTED

While this document provides a framework for choosing an appropriate database system, talking to institutions that are already using the leading database under consideration can be helpful and provide detail outside the scope of this report. Reaching out to programmers of the system under consideration to discuss specific existing data, planned uses for the database, and future desires is similarly helpful. It is often possible to share a small dataset with the programmer, who can model an example of how their system interacts with real site data. All three for-purchase systems, *BG-BASE*, BRAHMS, and IrisBG, have free trial versions. Parks with the appropriate ArcGIS license can also download the ArcGIS Public Garden data model at any time. Independently testing a trial database and introducing its functions to all staff members who may use it in the future is an excellent way to grasp whether it will be appropriate for your park.

COMPILING YOUR DATA

Without knowing what records already exist and in what format, it can be difficult to pick an appropriate system. Technological tools cannot be substituted for the necessary analysis, planning and organization required to development and operate of good documentation systems.[22] Before moving forward with a specific database, existing data should be gathered from all invested divisions, including cultural and natural resources, maintenance, and interpretation. It is important to consider all handwritten data before making a decision because considerable time may be required to digitize these records before they can be imported into a given system. In cases where large amounts of handwritten data exists, it is also critical to talk with support staff for the chosen system about what digitized format can be imported into their system most easily. Often this will be digital spreadsheets, which can be formatted before purchasing the software for time and cost effectiveness.

Compiling data is an effective way to gauge how much tech support will be needed to migrate data into the chosen system. A reasonable amount of data stored in digital spreadsheets can be imported in-house or entered by hand without much time commitment. Where there is a large amount of complicated data from multiple sources, it is likely most time and cost effective to involve third party IT support or purchase data migration services from database programmers.

NPS Resources for Plant Data

***BG-BASE*, BRAHMS, and IrisBG are all capable of linking to external web pages to gather information, produce citations, and provide verification of information included in the database. NPS maintains a number of thematic inventories that can provide data for a plant records management database.**

The Cultural Landscapes Inventory is a comprehensive, evaluated inventory of all cultural landscapes in the National Park System that have historical significance, including vegetation inventories for developed areas: https://irma.nps.gov/DataStore/Reference/Profile/2180647

NPSpecies is a repository for all flora and fauna occurrences, and includes information such as abundance and native status: https://irma.nps.gov/NPSpecies

The Natural Resource Report Series includes published reports that address high-priority issues for natural resource managers: https://irma.nps.gov/DataStore/Reference/Profile/2007603

The Taxonomy Search is a list of species' accepted scientific and primary common names, which can be referenced to ensure standardized taxonomic language: https://irma.nps.gov/App/Taxonomy/search

The Public Lands Flora Project is an interagency information system designed to manage floristic biodiversity data for plants on U.S. public lands, including herbaria for many units of the National Park System: http://symbiota.org/nps/index.php

Crafting a Plant Collection Philosophy

WHAT IS A PLANT COLLECTION PHILOSOPHY?

Around the world, arboreta, public gardens, herbaria, and museums maintain collections philosophies that broadly outline their institutional mission, scope of collection, and management strategies. Because every institution is unique, the nature of a plant collection philosophy varies greatly. Ultimately, the goal of a plant collection philosophy is to frame an institution's mission in terms of the relationship between the collection, the landscape, employees, and visitors.[17] While a plant collection philosophy offers an overview of an institution's methods of achieving its mission, it is intended to be supplemented by new and existing management procedures. This allows the collections philosophy to be a dynamic and enduring document, even as the specific methods for enacting the philosophy may change. A great deal of relevant procedural information already exists with respect to NPS landscape management, which can easily be referenced in a plant collection philosophy.

WRITING A PHILOSOPHY FOR YOUR PARK

Because collection philosophies are increasingly becoming the industry standard for arboreta and public gardens, many helpful resources and examples are available online from allied institutions. This section draws heavily on the experiences of collections managers at arboreta and public gardens who shared their processes and philosophies, as well as Chapter 3 of *From Idea to Realisation: BGCI's Manual on Planning, Developing, and Managing Botanic Gardens* and *Things Great and Small: Collection Management Policies* by John Simmons. While the latter was written for museums, the broad concepts remain applicable.

At its most basic, creating a collections philosophy is broken down into a planning stage, a review stage, and an implementation stage. An interval of time should be decided upon to revisit the philosophy periodically for review and revision to ensure it is still pertinent to the park's mission and understood by current staff. Although many institutions' philosophies are available to the public, it is never advisable to simply adopt another institution's philosophy even when there appear to be clear parallels and shared visions. Every collection is unique and every institution faces unique challenges. By writing a unique philosophy, team members have an opportunity to explore and discuss their specific concerns, and craft a philosophy tailored to the future of their institution (see Appendix C for a sample plant collection philosophy).

WHO TO INCLUDE

When preparing to write a plant collection philosophy, it's important to gather input from all divisions of park staff who work with the living landscape.[18] While this can be time consuming, an inclusive approach encourages teamwork and creativity by expanding viewpoints and discovering new alternatives for the future, which in turn leads to a more relevant and enduring philosophy.[19] Relying on a diverse group for input also ensures that the plant collection philosophy won't contradict procedures or goals that are already in place across park disciplines.

WHAT TO CONSIDER, WHAT TO LEAVE OUT

Philosophies that use clear and familiar terminology are generally the most successful. Before writing the philosophy, parks should consider what current procedures or literature will be used for reference. A philosophy is not a "how-to" guide, but a way to clearly identify shared goals and values, and specific related policies that should be referenced, but not reiterated, in the philosophy. For instance, a park that identifies reintroducing native species to natural areas as one of the primary goals in their philosophy would simply refer to related policies or the management plan for specific details rather than include them in the philosophy. NPS resources related to landscape management include:

- Director's Order 6 – Interpretation and Education
- Director's Order 25 – Land Protection
- Director's Order 28 – Cultural Resource Management
- Director's Oder 42 – Wilderness Stewardship
- Director's Order 77-10 – NPS Benefits Sharing
- Director's Order 79 – Integrity of Scientific and Scholarly Activities
- Director's Order 100 – Resource Stewardship for the 21st Century
- NPS Management Policies 2006
- NPS Management Policy 75 – Natural Resources Inventory and Monitoring
- Natural Resource Management Reference Manual 77
- A Call to Action – Preparing for a Second Century of Stewardship and Engagement
- Department of the Interior Social Media Policy

WHEN TO REVISIT THE PHILOSOPHY

Like any other policy, a plant collection philosophy is useless if it is outdated, ignored, too complex to be followed, too simplistic to be useful, or does not serve the institution's mission.[20] Revisiting the philosophy periodically helps avoid these pitfalls, and many institutions include a timeframe for revisiting the philosophy within the document itself. The Arnold Arboretum's philosophy, for example, includes a commitment to revisit it every five years. While the philosophy does not necessarily need to be revised each time it is revisited, returning to it at regular intervals helps maintain focus and resource allocation on shared goals. Similarly, it is advisable to revisit the philosophy after a major change, such as significant staff turnover or serious impact from a natural disaster, and adjust the philosophy accordingly.

MAKING THE PHILOSOPHY PART OF PARK CULTURE

At its most basic, a plant collection philosophy exists to manage people so that organization goals can be achieved.[21] A shared philosophy that is understood by all employees is the first step in creating a collaborative spirit to achieve organizational goals. The philosophy can help guide which projects will be prioritized and justify requests to reporting and funding bodies by producing evidence that the park holds a clear mission. By including input from all divisions, the philosophy provides a roadmap for collaborative culture. If park staff is communally involved in a producing and maintaining a philosophy, this shared sense of mission can help streamline maintenance decisions, educational programming, and historic research by capitalizing on connectivity between divisions.

Conclusion

Digitizing plant records data is the way of the future. The terrestrial and aquatic area protected by NPS has grown to 84 million acres over the past 100 years, spanning all 50 states, the District of Columbia, American Samoa, Guam, Puerto Rico, and the Virgin Islands. These lands and waters are repositories of cultural and botanical knowledge and indicators of the way the Earth is changing.

Dedication to unifying data and collaborating with other organizations that are leading the way in plant collections management could have a significant impact on public engagement and global conservation. As Botanic Gardens Conservation International notes in their *Global Strategy for Plant Conservation*, "of urgent concern is the fact that many plant species, communities, and their ecological interactions, including the main relationships between plant species and human communities and cultures, are in danger of extinction."[23]

Director's Order #100: Resource Stewardship for the 21st Century recognizes the stewardship goal of NPS as "manag[ing] resources in a context of continuous change that we do not full understand in order to preserve and resort ecological, historical, and cultural integrity, contribute as an ecological and cultural core of national and international networks of protected lands, water, and resources, and provide visitors and program participants with opportunities for transformative experiences that educate and inspire."[24]

Many of the actions outlined in *Director's Order #100* to achieve this goal correlate directly with use of plant records management databases. These actions include:

Figure 30. Reaching broad audiences, such as students shown here at Biscayne National Park, through innovative methods encourages thoughtful stewardship for the next 100 years of the National Park Service (NPS).

- Strategically incorporating emerging technologies, when applicable and feasible, into park resource management to conduct sound science and engage the public.
- Participating and collaborating in interagency and non-governmental efforts to promote connectivity that, in particular, address climate change. These efforts may include large land/seascape conservation efforts, regional networks of protected areas, and wilderness preservation.
- Establishing partnerships with educational and scientific institutions to identify, encourage, and promote scientific and scholarly research needed to better understand the complexities and uncertainties of the future.
- Conducting and/or facilitating scientific and scholarly inquiry that is directly applicable to current or expected resource management challenges.
- Developing and maintaining broad and inclusive public engagement strategies to identify and understand long-term public interest and foster "co-stewardship" of natural and cultural resources.

The National Park Service stewards one of the greatest collections of plants in the world. However, unless information about this collection can be aggregated and accessed, its greatest potential remains untapped. Plant records management systems, particularly networked (enterprise) databases, enhance communication by providing a unified platform for data sharing and analytical decision making. Associated web and mobile publishing tools allow information to be shared with the public and third-party researchers as well, empowering NPS to reach broader audiences and participate in global discourse on research, climate change and biodiversity science with greater confidence and impact. Adopting the use of digital plant records management tools is fundamental to NPS leading the way in twenty-first century resource stewardship, science, and interpretation.

The four leading plant records databases assessed for this report, including the ArcGIS Public Garden Data Model, *BG-BASE*, BRAHMS, and IrisBG all have potential to advance these goals significantly. As a plant records management tool, FMSS falls short.

Data fields: *BG-BASE*, BRAHMS, and IrisBG offer the greatest built-in data field options, without customization, followed closely by the ArcGIS Public Gardens Data Model.

Maintenance: *BG-BASE*, FMSS, and IrisBG offer the greatest work tracking and work planning potential, followed by the ArcGIS Public Gardens Data Model and BRAHMS. For more information on maintenance capabilities, see page 25.

Mapping: The ArcGIS Public Garden Data Model, BRAHMS, and IrisBG have the strongest mapping capabilities and ease of use, followed by *BG-BASE*. For more information on mapping capabilities, see page 29.

Interpretation: BRAHMS and IrisBG offer the most streamlined web-publishing and mobile-optimized interpretive capabilities, followed by the ArcGIS Public Garden Data Model and *BG-BASE*. For more information on interpretive potential, see page 33.

Research: *BG-BASE* and BRAHMS have the strongest research applications, followed by the ArcGIS Public Garden Data Model and IrisBG. For more information on research capabilities, see page 37.

Learning curve: The ArcGIS Public Garden Data Model and IrisBG are the easiest to learn and offer the best training resources, followed by *BG-BASE* and BRAHMS. For more information on learning curve, see page 41.

Cost (to NPS): The ArcGIS Public Garden Data Model and FMSS are effectively free to NPS units. Initial purchase of a full-suite license to BRAHMS is moderately priced, below the $3,500 NPS micropurchase limit. Initial purchase of full-suite licenses to IrisBG and *BG-BASE* are both above the NPS

Table 3. Summary Comparison of Plant Records Management Databases

	ArcGIS Public Garden Data Model	BG-BASE	BRAHMS	FMSS	IrisBG
Data Fields	∧	∧∧	∧∧	∨	∧∧
Maintenance	∧	∧∧	∧	∧∧	∧∧
Mapping	∧∧	∧	∧∧	∨∨	∧∧
Interpretation	∧	∧	∧∧	∨∨	∧∧
Research	∧	∧∧	∧∧	∨	∧
Learning Curve	∧	—	—	∨	∧
Cost (to NPS)	∧∧	∨	∧	∧∧	—

micropurcahse limit. Annual support agreements for all applications are below the NPS micropurchase limit. For more information on cost, see page 43.

In the table above, software programs are rated comparatively based on data fields included in each application, effectiveness with respect to key uses (maintenance, mapping, interpretation, and research), and administrative considerations (learning curve and cost). This summary evaluation presents the strengths and weaknesses of each application, but does not draw a single conclusion about the best plant records management application, since needs and goals differ among NPS units. The considerations summarized above are intended to guide selection of a database that is best suited to a particular park landscape and staff.

Key	
Excellent	∧∧
Good	∧
Fair	—
Poor	∨
Not applicable	∨∨

Endnotes

1. Karim, Nura Abdul, “Collection Record Management Systems,” in *From Idea to Realisation – BGCI’s Manual on Planning, Developing and Managing Botanic Gardens* (Chicago, IL: Botanic Gardens Conservation International, 2016), 89.

2. BGCI. “Living Collections.” BGCI.org, https://www.bgci.org/resources/living_collections/ (accessed June 24, 2016).

3. U.S. Department of the Interior, National Park Service, “Director’s Order #77-10: NPS Benefits Sharing,” *Management Policies 2006*, https://www.nps.gov/policy/DOrders/DO_77-10.pdf (accessed June 24, 2016).

4. U.S. Department of the Interior, National Park Service, “Living Collections Interim Guidance” (draft 2016), 6-7.

5. Toomer, Simon. *Planting and Maintaining a Tree Collection* (Portland, OR: Timber Press, 2010), 69.

6. Michael S. Dosmann, “Curatorial Notes: An Updated Living Collections Policy at the Arnold Arboretum,” *Arnoldia* 66, no. 1 (2007): 16.

7. Roy Renkin et al., *Progress Report: Implementation of Pilot Native Vegetation Restoration Efforts in the Gardiner Basin, Yellowstone National Park, 2008-2014* (Yellowstone National Park, WY: Yellowstone Center for Resources, 2014).

8. John E. Simmons, *Things Great and Small: Collections Management Policies* (Washington, DC: American Association of Museums, 2006).

9. David Michener, “Collections Management,” in Public Garden Management: A Complete Guide to the Planning and Administration of Botanical Gardens and Arboreta, ed. Donald A. Rakow & Sharon A. Lee (Hooken, NJ: John Wiley & Sons, Inc., 2011), 264.

10. Mary Burke, Mia Ingolia, Brian Morgan, and Barry Nickel, *Guide to GIS for Public Gardens: Botanical Gardens, Zoos, and Parks* (Davis, CA: Alliance for Public Gardens, 2015), 1.

11. Timothy C. Hohn, *Curatorial Practices for Botanical Gardens* (Lanham, MD: AltaMira Pres, 2008), 92, 128.

12. U.S. Department of the Interior, National Park Service, “Director’s Order #77-10: NPS Benefits Sharing,” *Management Policies 2006,* https://www.nps.gov/policy/DOrders/DO_77-10.pdf (accessed June 24, 2016).

13. Mitu Dhull and Archana Sharma, “Testing the Relational Database,” *International Journal of Computer Science* 7, no. 5 (2010): 48.

14. Kitty Connolly, “Interpreting Gardens to Visitors,” in *Public Garden Management: A Complete Guide to the Planning and Administration of Botanical Gardens and Arboreta*, ed. Donald A. Rakow & Sharon A. Lee (Hooken, NJ: John Wiley & Sons, Inc., 2011), 219.

15. U. S. Department of the Interior, National Park Service, “Regulation for Gathering of Certain Plants of Plant Parts by Federally Recognized Indian Tribes for Traditional Purposes.” *Federal Register* 81, no. 133 (July 12, 2016): 45024. https://www.gpo.gov/fdsys/pkg/FR-2016-07-12/pdf/2016-16434.pdf

16. BGCI (comp.), *North American Botanic Garden Strategy for Plant Conservation 2016-2020* (Chicago, IL: Botanic Gardens Conservation International, 2016), 22.

17. John E. Simmons, *Things Great and Small: Collections Management Policies* (Washington, DC: American Association of Museums, 2006), 44.

18. Dave Aplin, “No Plant Collection without Strategy or Policy,” in *From Idea to Realisation – BGCI’s Manual on Planning, Developing and Managing Botanic Gardens* (Chicago, IL: Botanic Gardens Conservation International, 2016), 51.

19. Kayri Havens, “Research at Public Gardens,” in *Public Garden Management: A Complete Guide to the Planning and Administration of Botanical Gardens and Arboreta*, ed. Donald A. Rakow & Sharon A. Lee (Hooken, NJ: John Wiley & Sons, Inc., 2011), 301.

20. John E. Simmons, *Things Great and Small: Collections Management Policies* (Washington, DC: American Association of Museums, 2006).

21. John E. Simmons, *Things Great and Small: Collections Management Policies* (Arlington, VA: American Alliance of Museums, 2006).

22. Timothy C. Hohn, *Curatorial Practices for Botanical Gardens* (Lanham, MD: AltaMira Press, 2008).

23. *Convention on Biological Diversity, Global Strategy for Plant Conservation: 2011-2020* (Richmond, UK: Botanic Gardens Conservation International, 2012), 11.

24. U.S. Department of the Interior, National Park Service, "Director's Order #100 – Resource Stewardship for the 21st Century," (draft 2016, accessed November 2, 2016).

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Based on personal experience, everyone views plants differently. This overview and evaluation of plant records management systems is intended to take a fresh look at on an old challenge for the National Park Service (NPS), not just of plant records management, but of integrating different perspectives. In this overview and evaluation of plant records management systems, we have many people to thank for their professional insights, generosity, and good humor.

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References

Alliance for Public Gardens GIS. *Guide to GIS for Public Gardens: Botanical Gardens, Zoos, and Parks*. Davis, CA: Alliance for Public Gardens GIS, 2015.

Botanic Garden Conservation International. *From Idea to Realisation – BGCI's Manual on Planning, Developing, and Managing a Tree Collections*. Chicago, IL: Botanic Garden Conservation International, 2016.

Byrne, Mary and Peter Gordon. "Seeds of Success: Using Technology to Help Build a National Collection of Native Seed." *Public Garden* 24 (2009): 21-22.

Cady, Paul. "Managing Organizational Memory in Public Gardens." Master's thesis, University of Georgia, 2015.

Cook, Robert E. *The Director's Report: Arnold Arboretum*. Boston, MA: The Arnold Arboretum of Harvard University, 1995.

Dhull, Mitu and Archana Sharma. "Testing the Relational Database." *International Journal of Computer Science Issues*. 7 (2010):47-52.

Hohn, Timothy. "Documenting Collections." *Curatorial Practices for Botanical Gardens*. Lanham, MD: AltaMira Press, 2008, 64-103.

Koch, Marcus A., Christof N. Schroder, Markus Kiefer, & Peter Sack. "A Treasure Trove of Plant Biodiversity from the 20th Century: the Werner Rauh Heritage Project at Heidelberg Bontanical Garden and Herbarium." *Plant Systematics and Evolution* 299 (2013): 1793-1800.

Lawford, G. Ross. "Beyond Success: Achieving Synergy in Teamwork." *The Journal for Quality and Participation* 26 (2003): 23-27.

Morgan, Brian J. "Geographic Information Systems for the Plant Sciences." *Arnoldia* 69 (2011): 15-22.

National Park System Advisory Board Science Committee. *Revisiting Leopold: Resource Stewardship in the National Parks*. Washington, DC: National Park Foundation, 2012.

Primack, Richard B. and Abraham J. Miller-Rushing. "The Role of Botanical Gardens in Climate Change Research." *New Phytologist* 182 (2009): 303-313.

Rakow, Donald and Sharon A. Lee. *Public Garden Management*. Hoboken, NJ: John Wiley & Sons, Inc., 2011.

Renkin, Roy. *Progress Report: Implementation of Pilot Native Vegetation Restoration Efforts in the Gardiner Basin, Yellowstone National Park, 2008-2014*. Yellowstone National Park, Wyoming: Yellowstone Center for Resources, 2014.

Simmons, John E. *Things Great and Small: Collections Management Policies*. Arlington, VA: American Alliance of Museums, 2006.

Steinhoff, Kathryn Theres. “An Exploratory Research Study of Collection Management Tools for the Knoxville Botanical Gardens and Arboreta’s Living Plant Collections.” Master’s thesis, University of Tennessee, 2003.

Toomer, Simon. *Planting and Maintaining a Tree Collection*. Portland, OR: Timber Press, 2010.

US DOI. *United States Department of Interior – Directors Order 77-10 – NPS Benefits Sharing*. Washington, DC: US Department of the Interior, 2013.

US DOI. *United States Department of the Interior – Directors Order 100 – Resource Stewardship for the 21st Century* draft. Washington, DC: US Department of the Interior, 2016.

Appendix A: Desirable Skillsets for Database Professionals

BASIC

- Intermediate proficiency with Excel
- Intermediate proficiency with GIS
- 2+ years of database experience with a focus on data entry, data export, reporting and analysis

INTERMEDIATE

- Advanced proficiency with Excel
- Advanced proficiency with GIS including mapping complex datasets
- Basic to intermediate coding experience with a focus on SQL
- 3+ years of database experience with a focus on data analysis, mapping, web publishing

ADVANCED

- Advanced proficiency with Excel
- Basic to intermediate proficiency with statistical modeling software (STATA, SPSS)
- Advanced coding experience with a focus on SQL and HTML
- Extensive experience with ArcGIS including advanced data analysis and modeling
- 5+ years of database experience with a focus on advanced statistical modeling and creating connections between databases and other data management programs

Appendix B: Needs Assessment Results

The August 2016 needs assessment allowed NPS staff in maintenance, and natural and cultural resource management at partner parks to rank the importance of a variety of plant records management database capabilities and data fields and tools in relation to their site specific needs on a scale of 1 (low) to 5 (high). The findings, including average ranking (in parenthesis), follow.

HIGH PRIORITY (AVERAGE RANKING 4 AND ABOVE)

USES

- Vegetation Inventory (5)
- Mapping (5)
- Condition Assessment (4.75)
- Hazard Tree Management (4.5)
- Maintenance Recordkeeping (4.25)

DATA FIELDS

- Taxonomy (4.75)
- Condition (4.75)
- Accession Number/Date (4.5)
- Deaccession Date/Reason (4.5)
- Source (4.25)
- Deficiencies (structural, pest, disease, etc.) (4.25)
- Significance Evaluation (4.25)
- Photography (4.25)
- Size/DBH (4)
- Cultural History (4)

TECHNICAL CONSIDERATIONS

- PC (Windows) Compatibility (5)
- Tracking Groups of Vegetation (as opposed to just individual specimens) (4.75)
- Ease of Data Import (4.5)
- GIS-based Mapping Component (4.5)
- Ease of Data Query (4)
- Multiple User Data Input (as opposed to single user) (4)

ADMINISTRATIVE CONSIDERATIONS

- (None ranked 4 or above)

MEDIUM PRIORITY (AVERAGE RANKING 3 UP TO 4)

USES

- Work Prioritization (3.75)
- Developing Training Information for Interpreters (3.25)
- Developing Interpretive Materials for Visitors (web/ mobile-based and hardcopy) (3.25)
- Tracking Propagation/Greenhouse Operations (3)

DATA FIELDS

- Replacement Strategy (3.5)
- Design Intent (and associated maintenance needs) (3.5)
- Phenology (3.25)
- Link Specimens to Research Papers, Projects, etc. (3)

TECHNICAL CONSIDERATIONS

- Track Multiple Collections in One Database (i.e. for multiple sites) (3.75)
- Field Work Compatible (with tablet over wifi or mobile network) (3.75)
- Ease of Data Export (3.25)
- Volunteer/Intern Data Entry (3.25)
- Aesthetics of Database Interface (3)

ADMINISTRATIVE CONSIDERATIONS

- Remote Training Option (web/teleconference) (3.25)
- IT Security (3.25)
- In-person Training Option (3)

LOW PRIORITY (AVERAGE RANKING BELOW 3)

USES

- Work Planning/Work Orders (2.5)
- Tracking Seed Collection (2.5)
- Deep Science/Research/Analysis (2.25)
- Tracking Herbarium Specimens (2)

DATA FIELDS

- Related Information, such as Soils, Weather, Irrigation, etc. (2.75)
- Genetic Information (2.75)
- Traditional Uses (2.5)

TECHNICAL CONSIDERATIONS

- Administrative Controls (to restrict access for certain users) (2.75)
- Apple (Mac) Compatibility (2)
- AutoCAD-based Mapping Component (1.25)

ADMINISTRATIVE CONSIDERATIONS

- Annual Maintenance Cost of Software (2.75)
- Up-front Software Cost (2.5)

ADDITIONAL CAPABILITIES SUGGESTED BY NEEDS ASSESSMENT PARTICIPANTS

- Integrated Pest Management treatments
- Data fields for hardscape and built features in the landscape (date of installation and materials)
- Mapping areas of archeological sensitivity (and station points)
- Mapping of irrigation system and shut-offs, landscape drainage systems
- Mapping key view points for visitors and employees (for repeat photography)

Appendix C: Sample Plant Collection Philosophy

NATIONAL PARK SERVICE MISSION STATEMENT

The National Park Service preserves unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations.

PARK HISTORY AND VISION

[Name of the Park] was established in [year] to preserve and broaden access to [Overview of Purpose]. The landscape encompassing [Name of the Park] serves to educate the general public, inspire appreciation of our natural and cultural histories, and benefit research in the arts, sciences, and humanities.

INTRODUCTION

PURPOSE OF THE PHILOSOPHY

The Plant Collection Philosophy at [Name of the Park] serves to direct the park's commitment to the sound management, interpretation, and development of the living landscape. A representative team assembled across disciplines writes and administers the Plant Collection Philosophy, and is responsible for reviewing and revising it as necessary every five years. This team is composed of the natural resources manager, cultural resources manager, interpretation lead, maintenance lead, and park horticulturist. The philosophy is subject to approval by the park superintendent.

PURPOSE OF THE PLANT COLLECTION

The plant collection at [Name of the Park] contributes to the cultural and ecological significance of the landscape through an accurate representation of the physical conditions of the landscape during [the period of significance]. Empowering visitors and researchers to gain insights into our cultural and natural history and apply new knowledge bases to our future is the primary goal of [Name of the Park]. The plant collection contributes to this goal by providing access to historically significant vegetation, restoring culturally significant and biologically important areas, and providing diverse interpretation for visitors of all backgrounds and identities.

SCOPE OF COLLECTIONS

CONTRIBUTING

Contributing plants at [Name of Park] are those that directly enhance the cultural and natural significance of the park. They are the highest priority and receive the greatest allocation of resources to maintain, develop, and interpret. At [Name of Park] there are two primary categories of contributing plants stewarded by park staff.

Historic: Historic trees contribute to the historical significance of the landscape and date to the period of significance. At [Name of Park] there are [#] of historic plants.

Witness: Witness plants represent a particularly special group of historic plants. They are plants that witnessed a particular historic event, such as a battle, the building of a significant structure, or the birth of an important figure in our nation's history. At [Name of Park] there are [#] witness plants that bore witness to [Name of Event].

NON-CONTRIBUTING

Non-contributing plants do not enhance the landscape's representation of the period of significance. At [Name of the Park] they fall into three categories and their priority depends on the manner in which they are or could influence the landscape.

Native: Non-contributing native plants may be maintained and incorporated if they are culturally significant, provide an important habitat for beneficial wildlife, are endangered, or are acting as a deterrent to invasive species. Non-contributing native plants that do not represent significant benefit to the landscape are removed in instances where they detract from factors contributing to the period of significance.

Non-native, non-invasive: Non-contributing, non-native, non-invasive plants are managed in accordance with non-contributing native plants.

Invasive: Invasive plants threaten the cultural and ecological preservation of [Name of the Park] as well as the surrounding ecosystem. They receive high priority attention and resource allocation for treatment and removal.

MAINTENANCE AND CARE

Plant maintenance pertaining to the living landscape at [Name of the Park] is primarily designated to the chief of natural resources and the chief of maintenance, who will prioritize and delegate work orders based on FMSS analyses, available funds and resources, and impact on the overall significance of the cultural landscape. Top priority will be given to the safety of the public, park staff, and historic structures.

ACCESS, EDUCATION, AND RESEARCH

Public access, education, and research pertaining to the plant collection at [Name of the Park] are primarily designated to [X]. Primary attention and allocation of resources will be designated to programs seeking to expand access to demographics that have been historically underrepresented at [Name of the Park], as well as tools for education and research that incorporate new and existing technology to promote innovation.

RECORDKEEPING AND ROUTINE ASSESSMENTS

Information pertaining to the care, location, biologic and cultural significance of the plant collection will be recorded in the plant collections database by the park horticulturists. Taxonomic and geographic information and deliverables will be prioritized with a focus on collaborative survey work between natural and cultural resources staff.

EXISTING NATIONAL PARK SERVICE POLICY TO DRAW FROM

- Director's Order 6 – Interpretation and Education
- Director's Order 25 – Land Protection
- Director's Order 28 – Cultural Resource Management
- Director's Oder 42 – Wilderness Stewardship
- Director's Order 77-10 – NPS Benefits Sharing
- Director's Order 79 – Integrity of Scientific and Scholarly Activities
- Director's Order 100 – Resource Stewardship for the 21st Century
- NPS Management Policies 2006
- NPS Management Policy 75 – Natural Resources Inventory and Monitoring
- Natural Resource Management Reference Manual 77
- A Call to Action – Preparing for a Second Century of Stewardship and Engagement
- Department of the Interior Social Media Policy
- Regulation for Gathering of Certain Plants of Plant Parts by Federally Recognized Indian Tribes for Traditional Purposes

LEGAL AND ETHICAL CONSIDERATIONS

- National Historic Preservation Act, Native American Graves Protection and Repatriation Act, etc.
- Permitting, cost sharing, benefits sharing, etc.

National Park Service
U.S. Department of the Interior

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