



Gaps in our floristic knowledge: The Cima Cinder Cones of eastern San Bernardino County is a vast region that has only recently received attention from botanists. There are many similarly unexplored regions in California where data gaps exist, especially in the deserts. Photograph by Jim André.

A POWERFUL RESOURCE FOR PLANT CONSERVATION EFFORTS: THE CONSORTIUM OF CALIFORNIA HERBARIA REACHES TWO MILLION SPECIMENS

by Staci Markos, Richard L. Moe, and David Baxter

Plants are all around us. They provide food, medicine, shelter, beauty, and ecosystem functions. There are approxi-

mately 350,000 plant species worldwide and 50,000 to 75,000 remain to be described (P. Raven, pers. comm. 2014). In the face of unprec-

edented rates of climate change, an important component of conserving biodiversity is the protection of wildlands. These areas will serve as

refugia for species (and their genes), and it is from these areas that species will migrate and adapt to new environments. To understand what areas need the most protection in California, we need to understand what species occur in the state, how those species are related to each other, and how they are distributed across the landscape.

Describing and cataloging plant diversity is a daunting task, but botanists have been formally doing this work since the mid 18th century. It continues today with initiatives like the *Jepson eFlora* that contains taxonomic treatments and identification keys for over 8,000 native and naturalized plant taxa occurring in wildlands or otherwise outside of cultivation in California (ucjeps.berkeley.edu/IJM.html). This work relies on botanical collections stored in herbaria. It is here that the foundations of our understanding reside. From these collections, we have a window into our past and can understand more deeply the present. And with DNA sequencing, improved phylogenetic techniques, digitization of herbarium collections, and powerful new modeling techniques, scientists have been able to depict future scenarios related to biodiversity and how it might be distributed across the globe.

WHAT IS A HERBARIUM?

Herbaria are collections of specimens from all plant groups—angiosperms, gymnosperms, ferns, bryophytes, and algae. Fungi and lichens are also included. Typically, the process of making a plant specimen begins in the field by taking a plant (or part of a plant) and pressing it between two sheets of paper. Field notes accompany each collection and detail the location and other important site features. Once in the plant press, specimens are dried, mounted on acid-free paper, and accessioned into the collection. Botanical specimens are an irreplace-

MAKING A HERBARIUM SPECIMEN

The process of making a herbarium specimen begins in the field where the collector records details including date, location, habitat, features of the plant, and associated species. A documentation field book is often used (pictured is the *Plant Collecting and Documentation Field Notebook*, 3rd Edition, by Michael G. Simpson). Once the plant is collected, it is put in a plant press and dried. The identity of a plant can be determined in the field or laboratory/office using a resource like the second edition of *The Jepson Manual* (pictured) and, if necessary, careful examination with a dissecting microscope. Once dried, the plant and label are mounted on acid-free paper. Each herbarium loads data from labels into a database that is then shared with the Consortium of California Herbaria. Photograph by Staci Markos.



able, tangible record of biodiversity at a particular time and place.

WHY HERBARIA ARE IMPORTANT

In California, herbaria maintain plant collections dating from the mid-1800s to the present. Traditionally, herbaria were used as a resource for identifying plants, establishing their geographic range, and describing new species. Specimens and their associated data are also powerful tools for researchers seeking to answer a wide array of questions ranging from evolution and local patterns of diversity to global climate change. Specimen data have also been used to address questions related to invasive species, conservation, and natural resource management.

WHAT IS THE CONSORTIUM OF CALIFORNIA HERBARIA (CCH)?

The Consortium of California Herbaria is a gateway to informa-

tion from California vascular plant specimens that are housed in 35 participating herbaria (Figure 1; ucjeps.berkeley.edu/consortium/). Through a single interface, the CCH serves over 2 million specimen records, over 71% of which are georeferenced (i.e., include latitude and longitude; Figure 2). With support from the California Digital Library, the CCH began in 2003 with botanical collections from the University and Jepson Herbaria and it quickly expanded into what the CCH is today, a truly collaborative network of herbaria from throughout the state and beyond.

WHY THE CCH IS IMPORTANT

Before the CCH existed, the only way for researchers to access plant specimens and their data was to personally visit a herbarium and go into “the stacks,” where the pressed specimens are stored in herbarium cabinets. A few herbaria had online databases but comparative research entailed accessing data in different formats that could not be readily

TABLE 1. A FULL LIST OF PARTICIPANTS IN THE CONSORTIUM OF CALIFORNIA HERBARIA.

ACRONYM	COLLECTION FULL NAME
BLMAR	Bureau of Land Management Arcata Field Office Herbarium
CATA	Catalina Island Conservancy Herbarium
CAS/DS	California Academy of Sciences (incl. Dudley Herbarium)
CDA	California Department of Food and Agriculture Herbarium
CHSC	Chico State Herbarium, CSU Chico
CLARK	Riverside Metropolitan Museum Herbarium
CSUSB	CSU San Bernardino Herbarium
DAV/AHUC	UC Davis Center for Plant Diversity Herbarium
GMDRC	Sweeney Granite Mountains Desert Research Center
HSC	Vascular Plant Herbarium, Humboldt State University
IRVC	UC Irvine Herbarium
JOTR	Joshua Tree National Park Herbarium
JROH	Oakmead Herbarium, Jasper Ridge Biological Preserve
LA	UC Los Angeles Herbarium
MACF	Fay A. MacFadden Herbarium, CSU Fullerton
OBI	California Polytechnic State University Herbarium
PASA	Pasadena City College Herbarium (in Huntington Botanic Garden)
PGM	Pacific Grove Museum of Natural History
RSA/POM	Rancho Santa Ana Botanic Garden Herbarium (incl. Pomona College Herbarium)
SACT	CSU Sacramento Herbarium
SBBG	Santa Barbara Botanic Garden Herbarium
SCFS	Sagehen Creek Field Station Herbarium
SD	San Diego Natural History Museum Herbarium
SDSU	San Diego State University Herbarium
SFV	CSU Northridge Herbarium
SJSU	Carl W. Sharsmith Herbarium, San Jose State University
UC/JEPS	University and Jepson Herbaria, UC Berkeley
UCR	UC Riverside Herbarium
UCSB	Cheadle Center for Biodiversity and Ecological Restoration (CCBER) Herbarium, UC Santa Barbara
UCSC	UC Santa Cruz Herbarium
VVC	A. Louise Baartz Memorial Herbarium, Victor Valley College
YM	Yosemite National Park Herbarium

EXTRA-CALIFORNIA PARTICIPANTS

HUH	Harvard University Herbaria
NY	Steere Herbarium, New York Botanic Garden
SEINET	Southwest Environmental Information Network

Source: David Baxter, University and Jepson Herbaria, 2015.

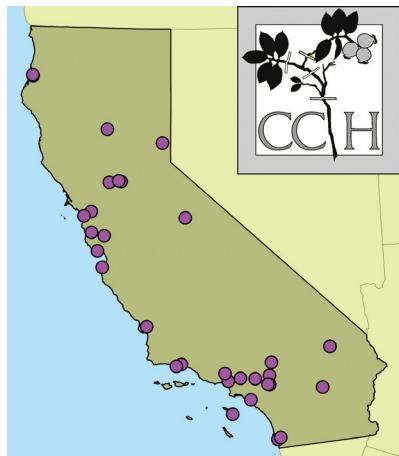
combined. The CCH has revolutionized the way these data can be accessed by collating a tremendous amount of information contained on specimen labels from large and small herbaria and placing these

records online in a way that permits a variety of comparisons.

There are several advantages to having a statewide representation of herbaria participating in the CCH. First, since some herbaria have a

regional emphasis, a broad geographic representation of herbaria significantly strengthens the CCH's power to display a taxon's geographic range (via georeferenced localities). A good example is *Salix*

FIGURE 1. LOCATIONS OF CALIFORNIA HERBARIA PARTICIPATING IN THE CCH.



A wide range of herbaria participate in the CCH. They include collections at colleges and universities, government agencies, private institutions, botanic gardens, and natural reserves and field stations.

Source: David Baxter, University and Jepson Herbaria, 2015.

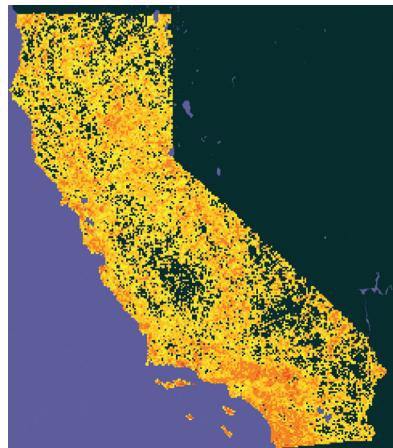
laevigata (Figure 3). The CCH helps put the puzzle pieces together by displaying a more complete representation of the taxon's geographic range than is represented by any single collection. Second, some areas in California remain underrepresented by collections and floristic exploration is still needed. Researchers working at remote herbaria can help fill gaps in our floristic knowledge by adding to the collections and fleshing out patterns of biodiversity in the state. Third, herbaria provide undergraduate students from all over California with training opportunities and exposure to natural history collections, hopefully leading them to a life-long appreciation of nature and interest in protecting native plants.

USES OF DATA FROM THE CCH

The CCH has been cited in over 100 publications including floristic studies, phylogenetic investigations, and studies of invasive species.

Additional research has used data from the CCH to address questions related to climate change, adaptation, and evolution (Google Scholar page, ucjeps.berkeley.edu/consortium/citations/). Importantly, the CCH provides a reliable source of information on the distribution of rare plants and these data help support conservation efforts throughout the state. The California Natural Diversity Database uses the CCH to update occurrence information. The Rare Plant Program of CNPS uses data from the CCH to help determine California Rare Plant Ranks and to prioritize taxa and locations for Rare Plant Treasure Hunts. In addition to aiding with conservation status reviews, information from the CCH such as elevation ranges, blooming periods, species associates, habitat, and edaphic substrates is utilized in the CNPS Rare Plant Inventory, by consulting biologists, and by individual botanists gather-

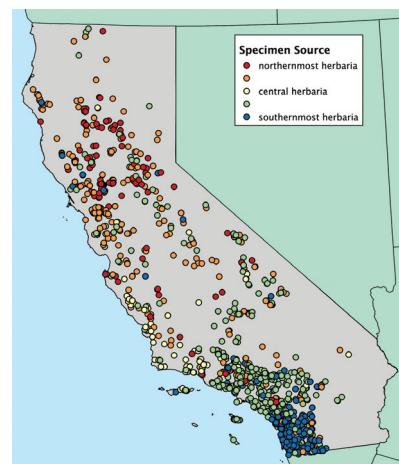
FIGURE 2. DENSITY MAP OF GEOREFERENCED SPECIMENS SERVED BY THE CCH.



This map shows the varying collection density in California. Darker shades of orange indicate a higher number of specimens collected from a grid cell. Note that only specimens with known latitude and longitude data (71% of records) are mapped. Some parts of the state remain to be documented.

Source: Global Biodiversity Information Facility, www.gbif.org, 2015.

FIGURE 3. GEOREFERENCED RECORDS OF *SALIX LAEVIGATA* SPECIMENS SERVED THROUGH CCH.



Points are categorized into five groups according to the latitude of the institution holding the specimen, in order to demonstrate regional emphasis.

Source: David Baxter, University and Jepson Herbaria, 2015.

ing information about rare and common taxa. The CCH is also the largest contributor to the Calflora Observation Database.

Due to the efforts of many individuals and institutions, including administration and software development by the University and Jepson Herbaria (UC Berkeley), the CCH has helped bring herbaria into the 21st century and join the global effort to share data that was formerly stored only in collections. Members of the California Native Plant Society have an important role in the CCH. By supporting herbaria, volunteering in the collections, adding new specimens, and commenting on records in the CCH interface, everyone can contribute to our shared goals of understanding and conserving the California flora.

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