Berkeley Initiative in Global Change Biology

Rescuing and Integrating Biological and Environmental Data in the Face of Global Change

Rosemary Gillespie
University of California Berkeley

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Michelle Koo
Biodiversity Informatics & GIS Curator, Museum of Vertebrate Zoology
David Ackerly
Professor, Integrative Biology
Rosemary Gillespie
Professor, Environmental Science Policy & Management
Maggi Kelly
Professor & Cooperative Extension Specialist, Environmental Science Policy & Management
Faculty Director, Geospatial Innovation Facility
Kevin Koy
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ZOONIVERSE REAL SCIENCE ONLINE
CALIFORNIA ACADEMY OF SCIENCES
GEO
HOLOS BERKELEY ECOINFORMATICS ENGINE
iDigBio Integrated Digitized Biocollections
CalBug
VerNet
RopenSci
esri
GBIF
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GORDON AND BETTY MOORE FOUNDATION
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the philomathia FOUNDATION
ciee California Institute for Energy and Environment
CALIFORNIA ENERGY COMMISSION
NSF
ALFRED P. SLOAN FOUNDATION 1934
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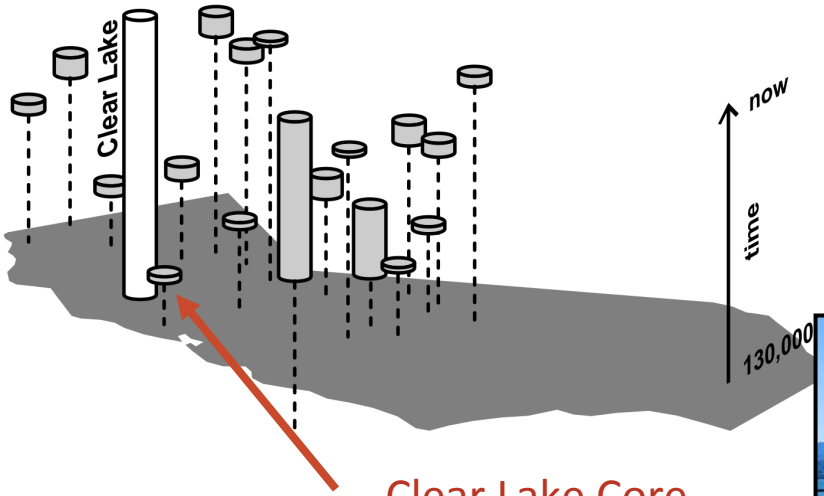
Berkeley Initiative in Global Change Biology

- **Understand and anticipate the effects of global change on biological systems**
- Launched in 2009
- 100+ affiliated faculty; 8 UCB departments
- Keck Foundation, Moore Foundation, NSF, & others

Drilling Clear Lake



Clear Lake Core
(to 135,000+ years ago)

High resolution climatic, flora, entomological, and fire history records will reveal how terrestrial biota responded to changes in California's climate both during and before human presence.

Cindy Looy

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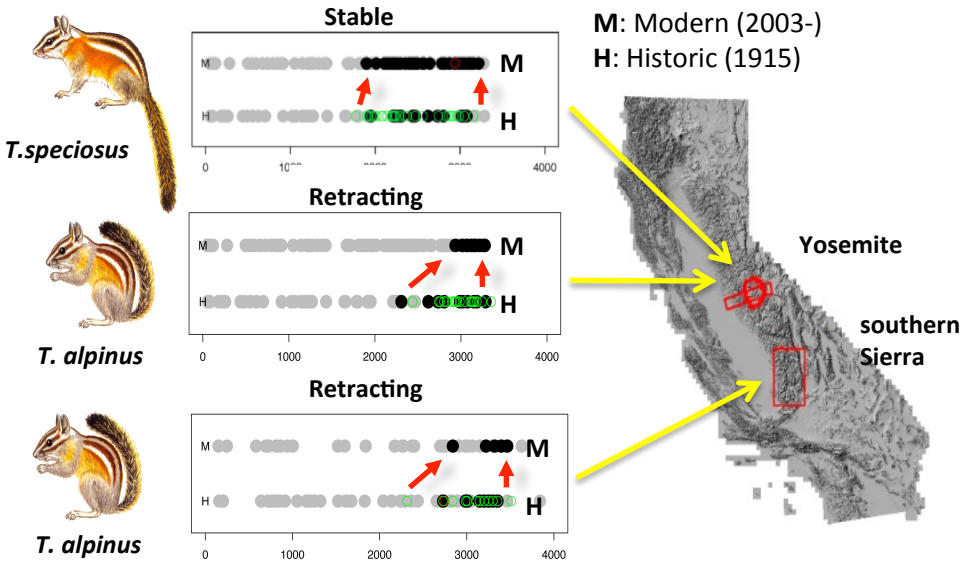
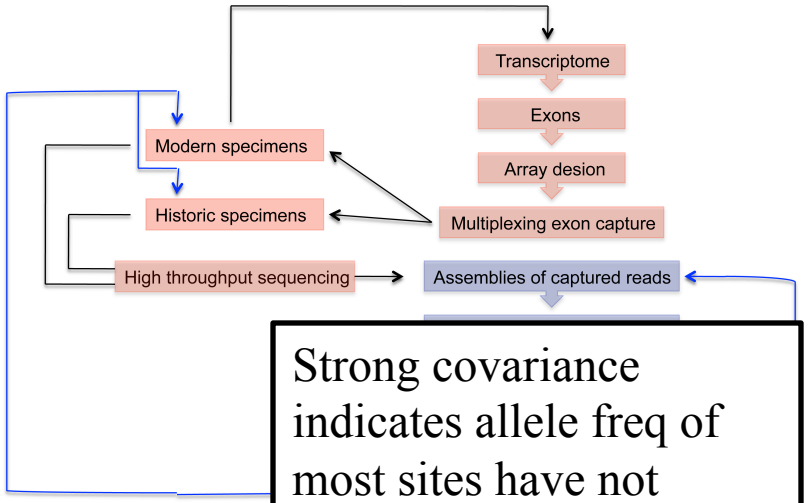
“Skinomics”: applying genomic tools to museum specimens to understand genomic response to climate change

Ke Bi, Tyler Linderoth, Dan Vanderpool, Rasmus Nielsen, Jeffrey M. Good, Craig Moritz

Study system



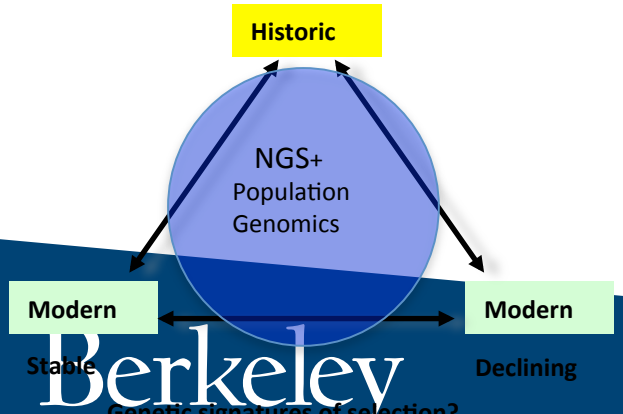
Pipelines



Transcriptome enabled exon capture

Strong covariance indicates allele freq of most sites have not changed. Sites showing freq differences may indicate selection.

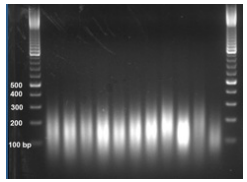
Strategy

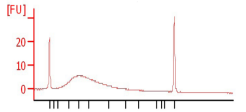


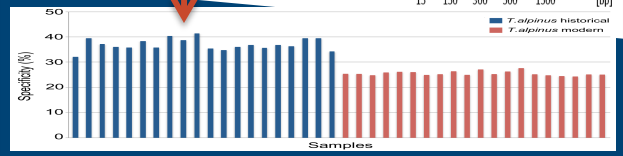
Genetic signatures of selection?

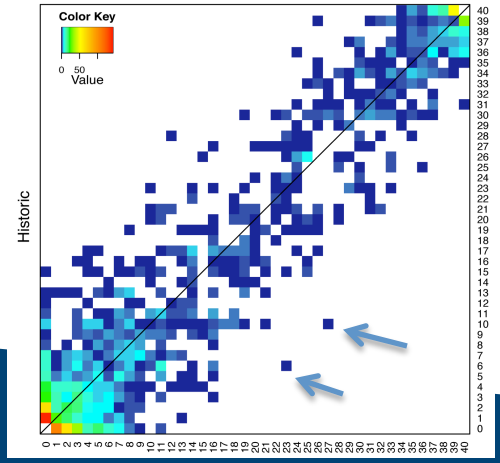
exon capture efficiency in historic samples higher than in modern samples.

...encing









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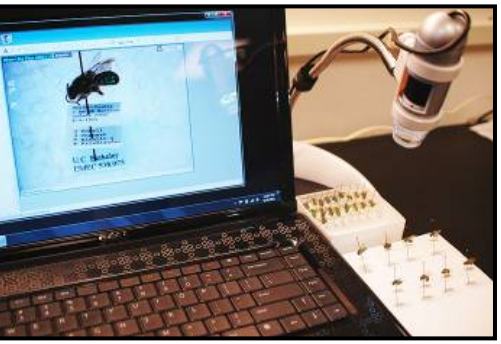
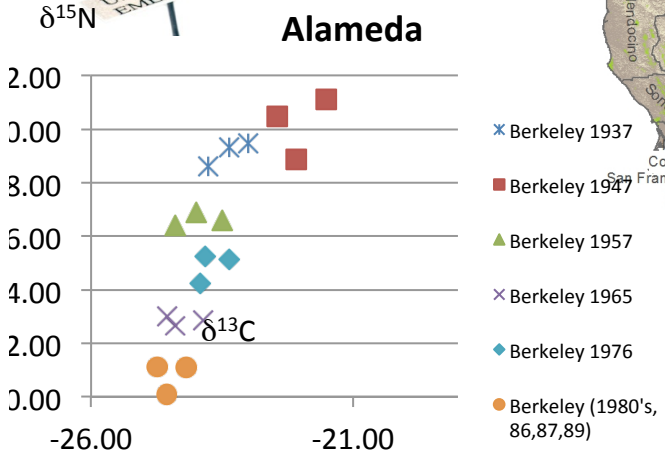
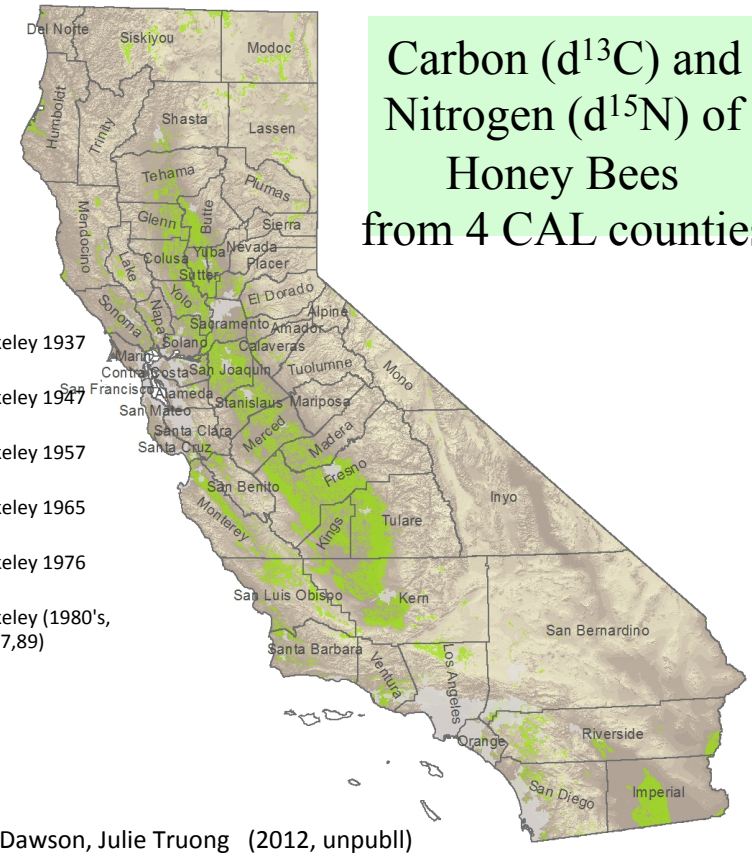
Genomics, isotopes and pollen: California bees







Carbon ($d^{13}C$) and Nitrogen ($d^{15}N$) of Honey Bees from 4 CAL counties

T. Dawson, Julie Truong (2012, unpubll)

Analysis of historical collections to document how honey bees, native bees, plants, and pollination activities have changed over the last ~100 years in response to urbanization, agricultural land conversion, etc.

Neil Tsutsui

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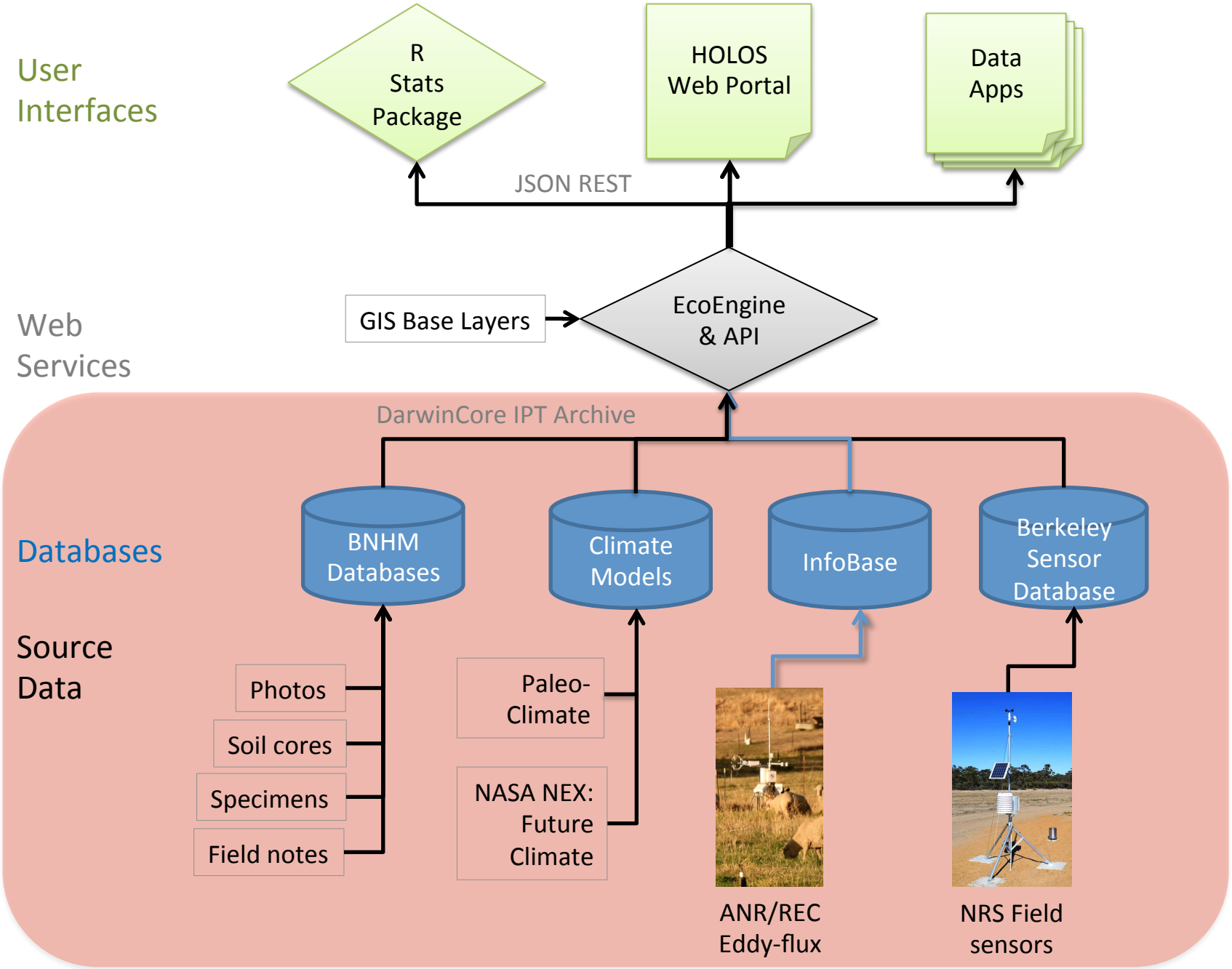
User Interfaces
R Stats Package
HOLOS Web Portal
Data Apps
JSON REST
Web Services
GIS Base Layers
EcoEngine & API
DarwinCore IPT Archive
Databases
BNHM Databases
Climate Models
InfoBase
Berkeley Sensor Database
Source Data
Photos
Soil cores
Specimens
Field notes
Paleo-Climate
NASA NEX: Future Climate
ANR/REC Eddy-flux
NRS Field sensors

The Museum of Vertebrate Zoology at Berkeley

UC & Jepson Herbaria

University of California Museum of Paleontology

UCMP

Geolocated specimens

Berkeley Natural History Museums

- Vertebrates: 700,000 specimens (100% digitized)
- Plants: 2.2 million specimens (~16%)
- Fossils: 6.5 million specimens (<5%)
- Insects: 6.5 million specimens (<2.5%)

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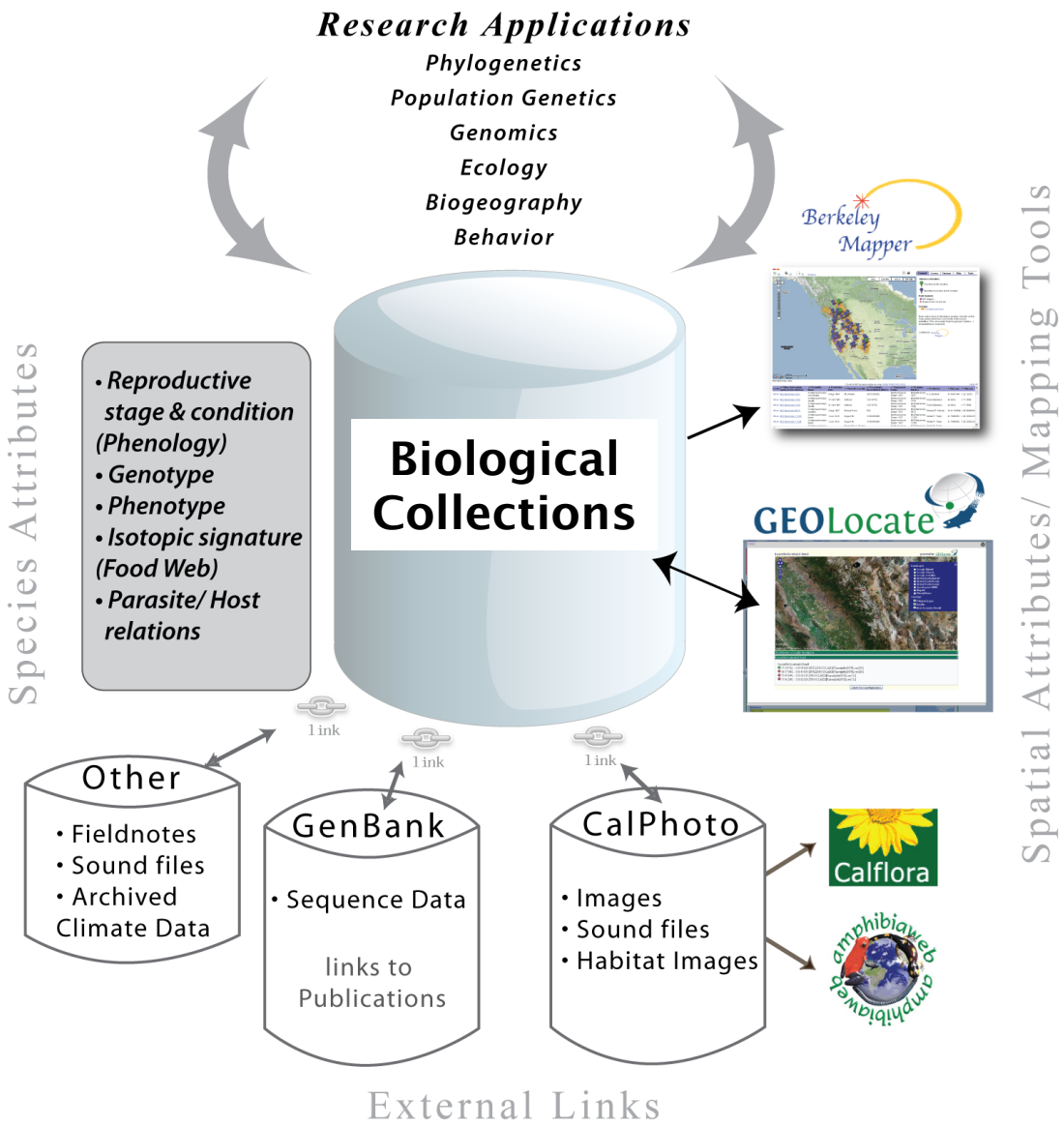

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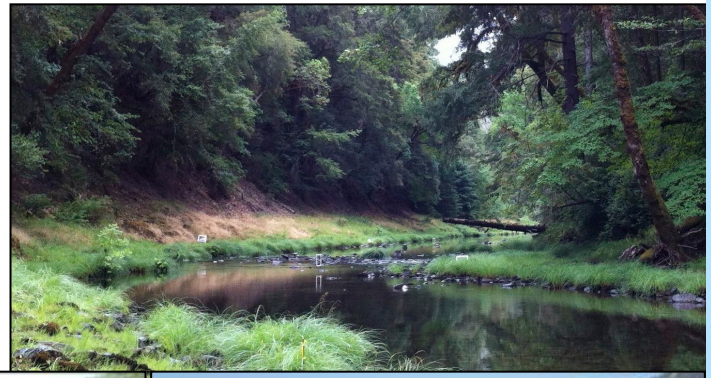
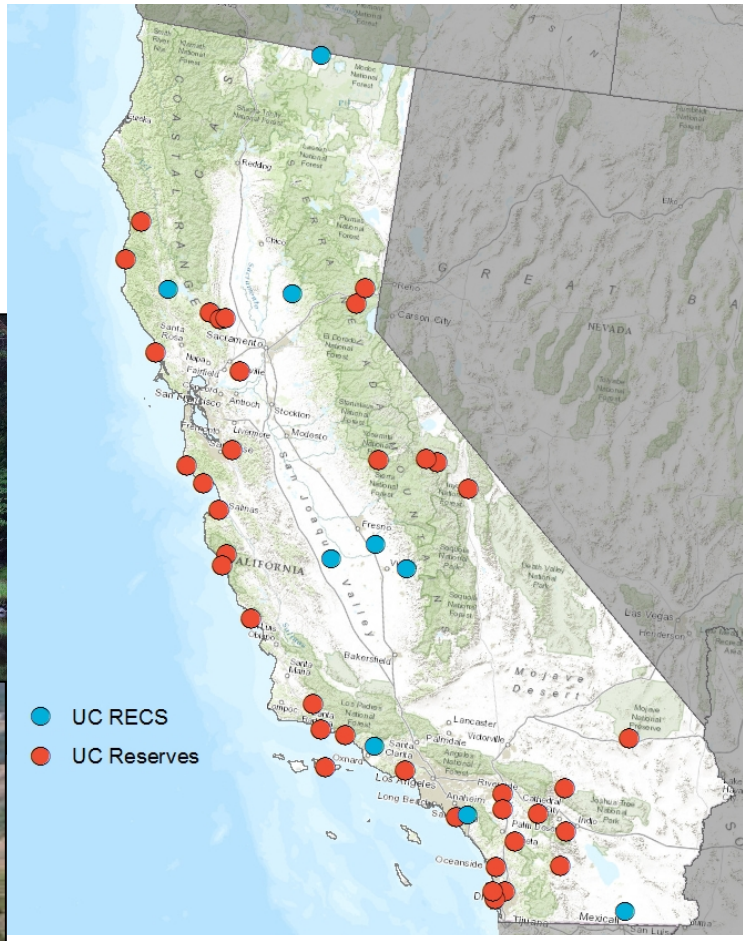
Field station records

100+ years of data collection

- Field notes
- Species lists
- Photos





Field station records

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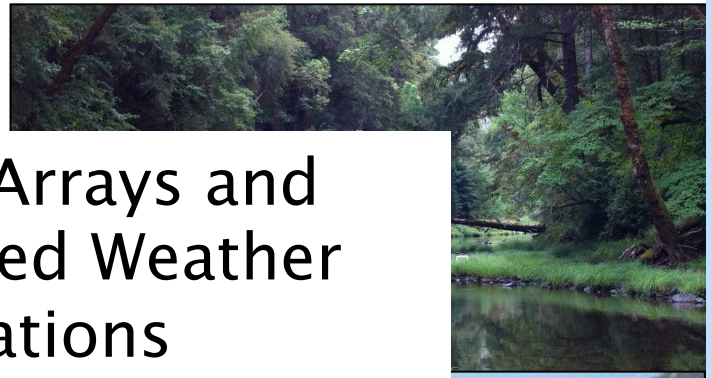
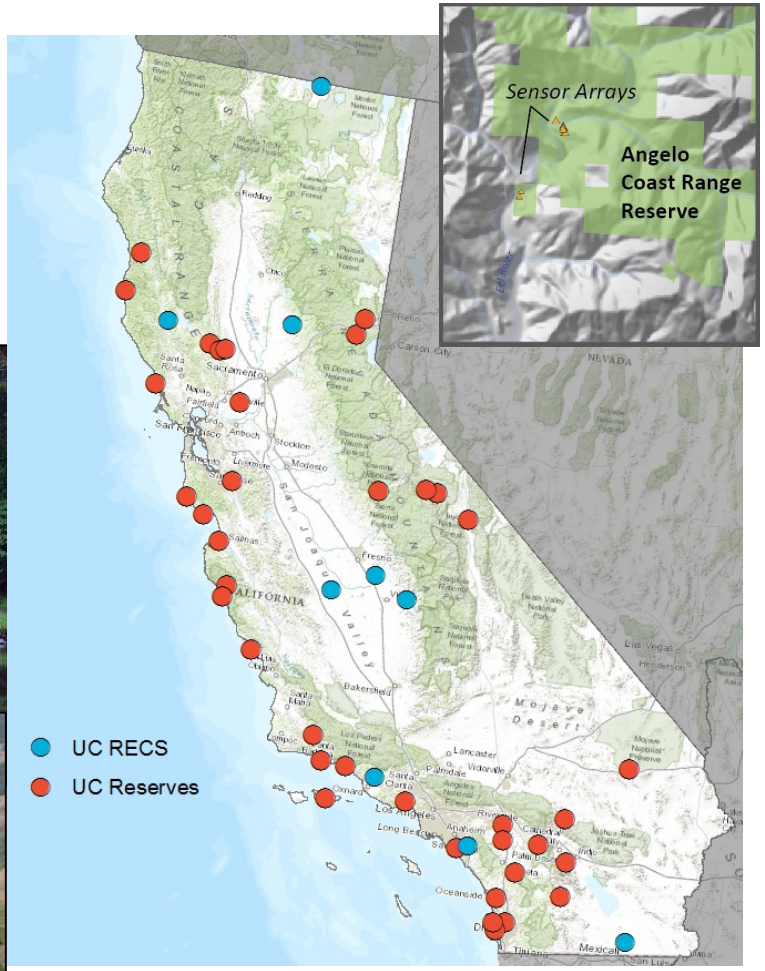
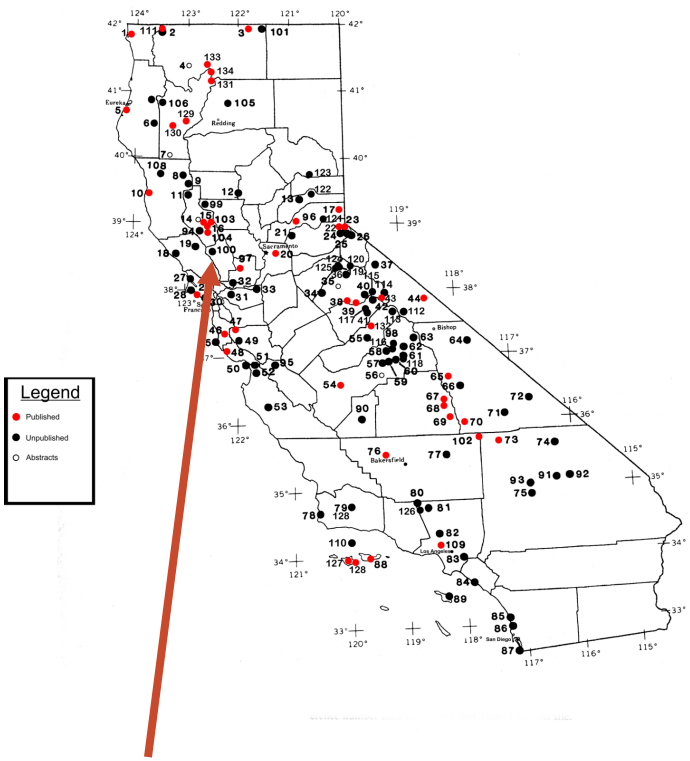
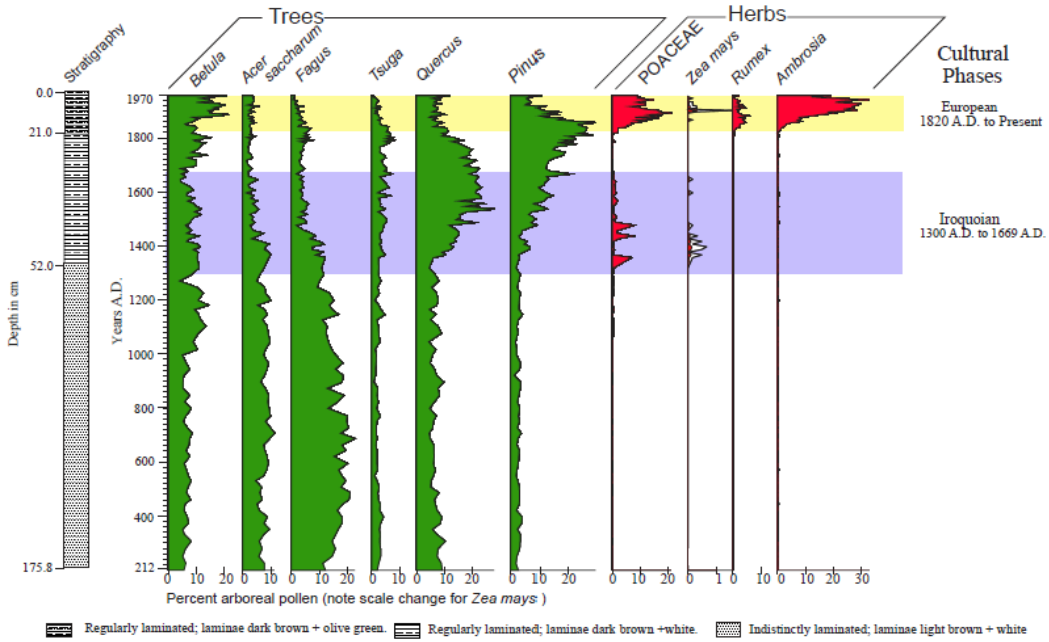


Sensor Arrays and Networked Weather stations
–streamed soon from 39 reserves



Pollen Cores
(history of vegetation)





Moore Funded
Clear Lake Core
(to 135,000 years ago)

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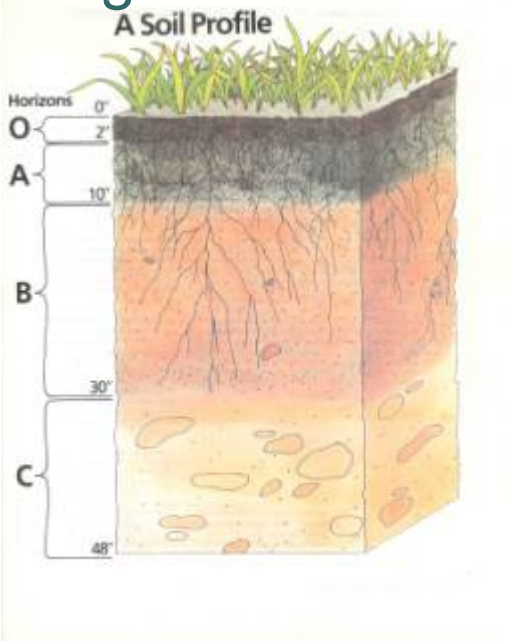
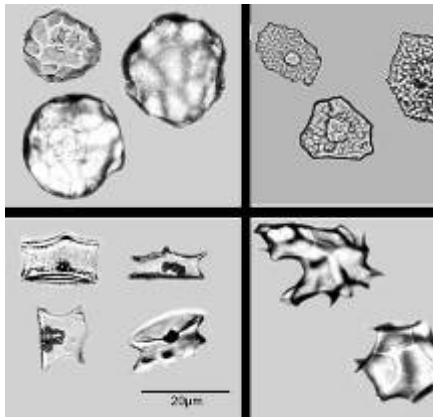
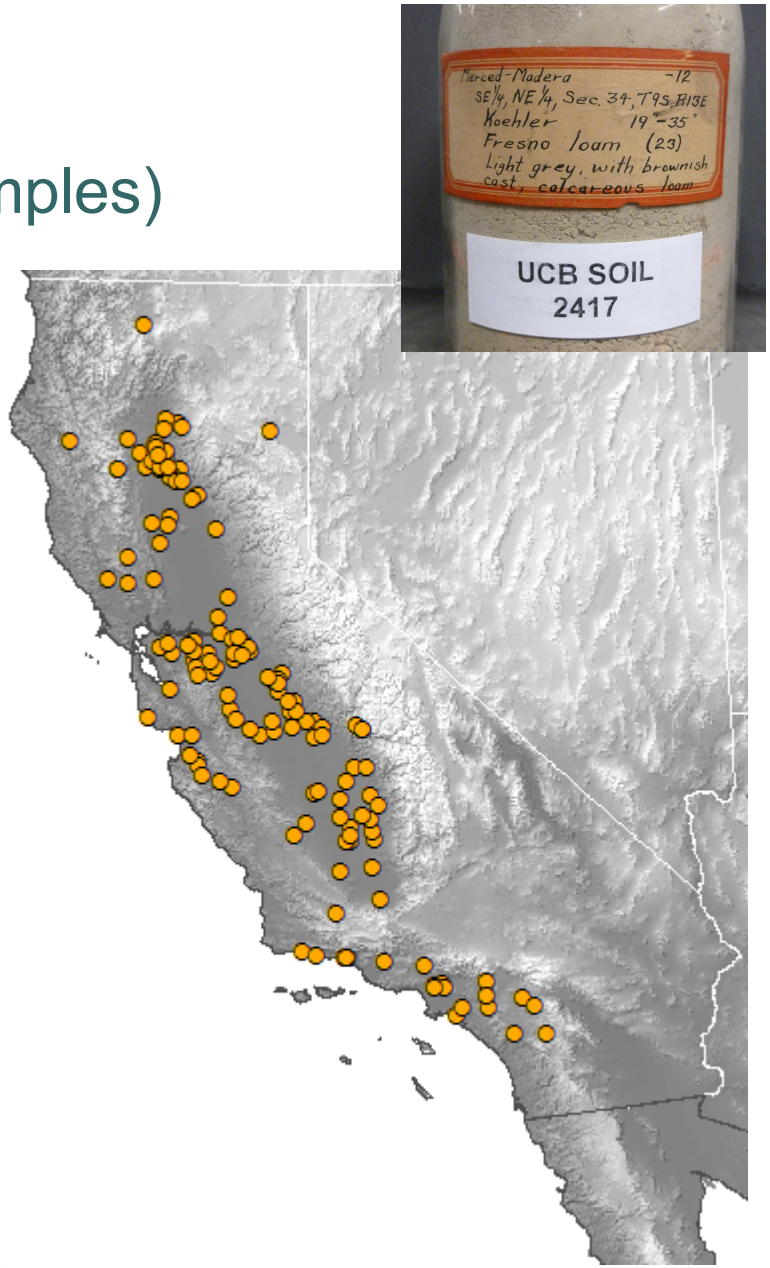
Soils in Jars

3,000 georeferenced sites (15,000 samples)



Soil phytoliths
used to reconstruct
vegetation/habitat





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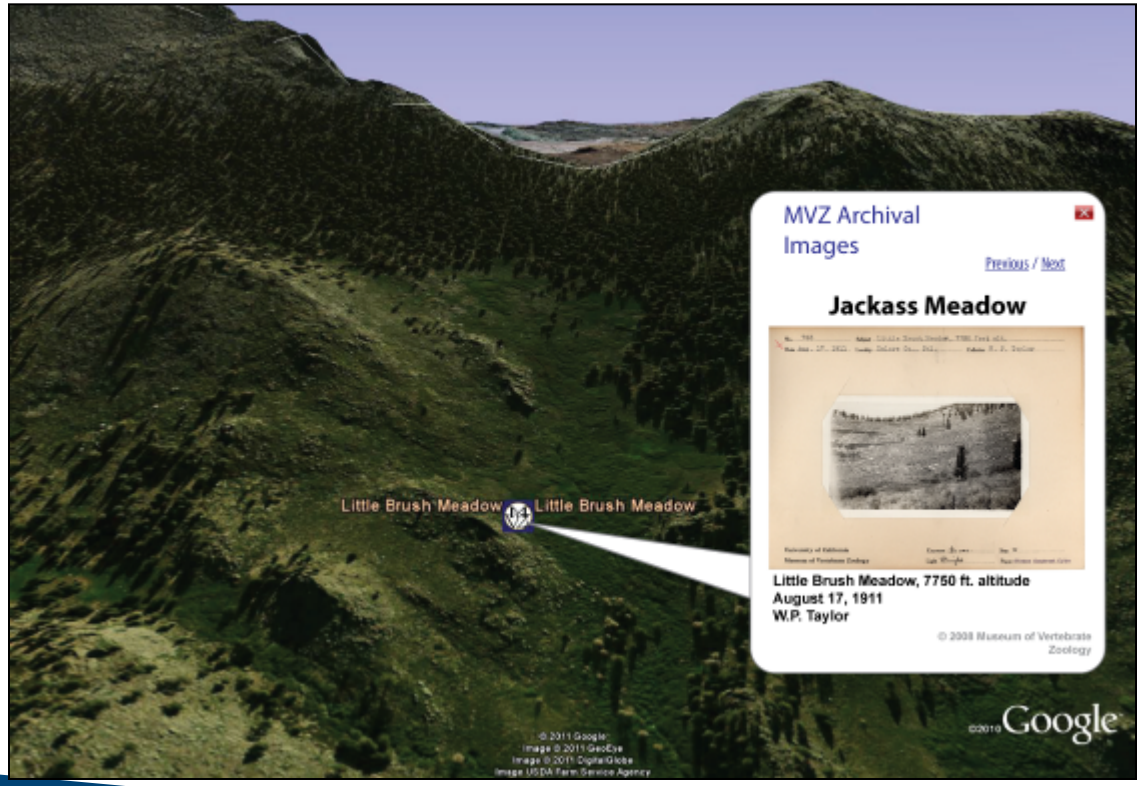
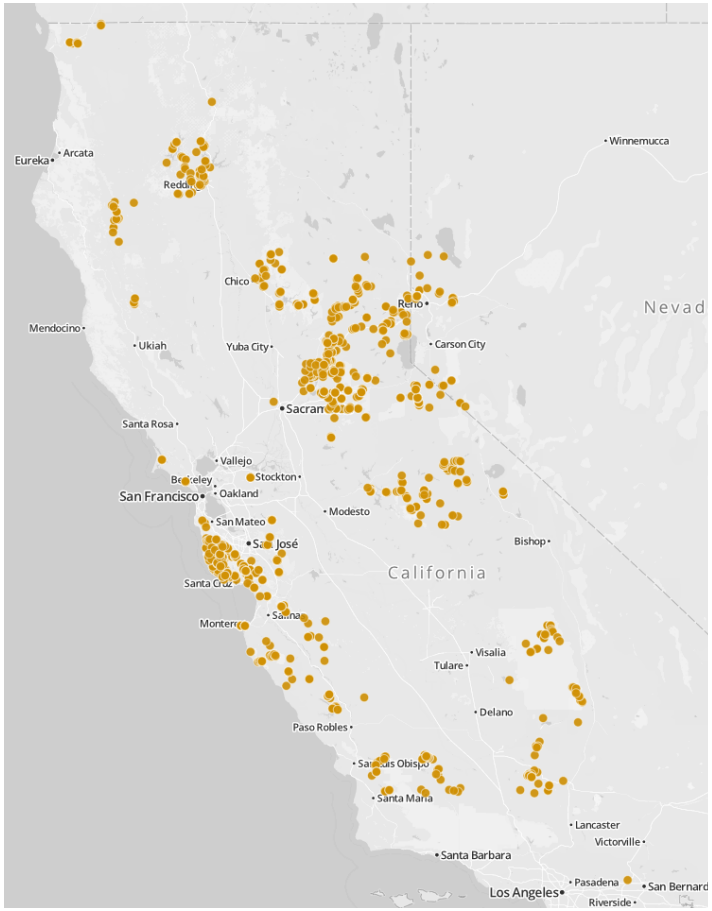
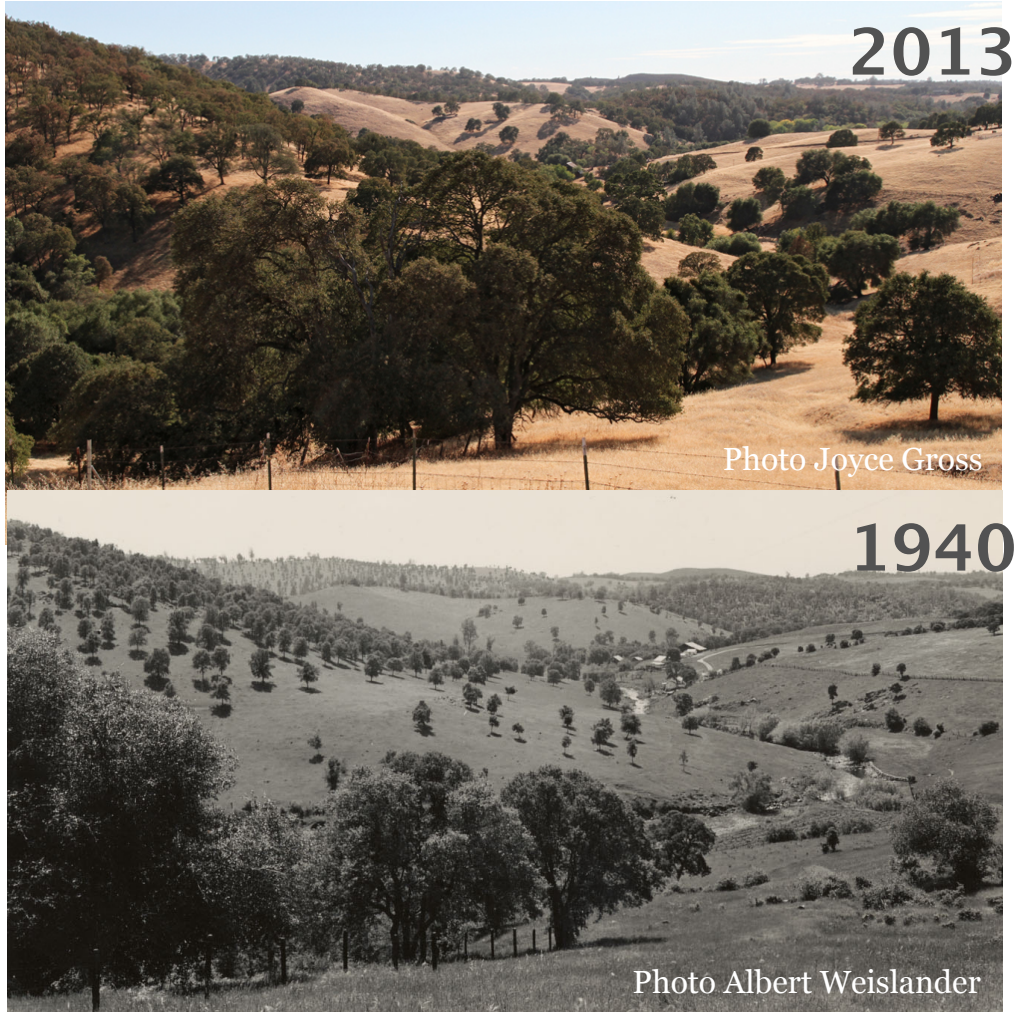
Photographs: CalPhotos

- Largely Californian field areas and taxa (> 300,000 images)
- Richly annotated
- Interoperable with other databases (e.g., Encyclopedia of Life)
- Historic images integrated with museum databases (see right)



Photos - Historical & Recent





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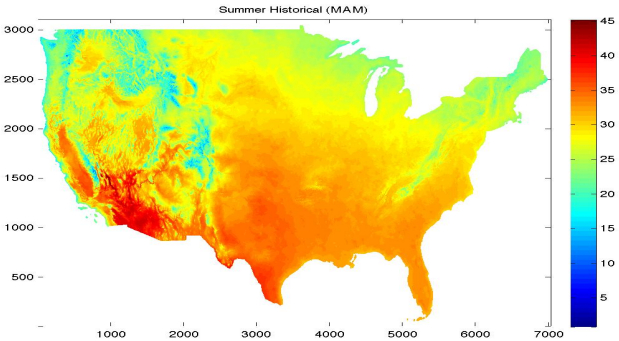
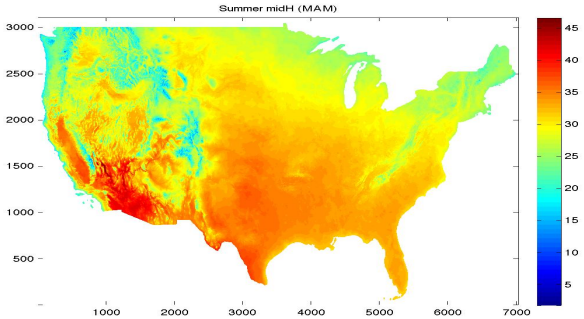
Paleo Climate Models

Downscaled Paleoclimate Models

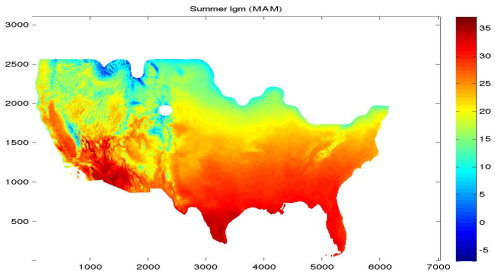
Now-ish



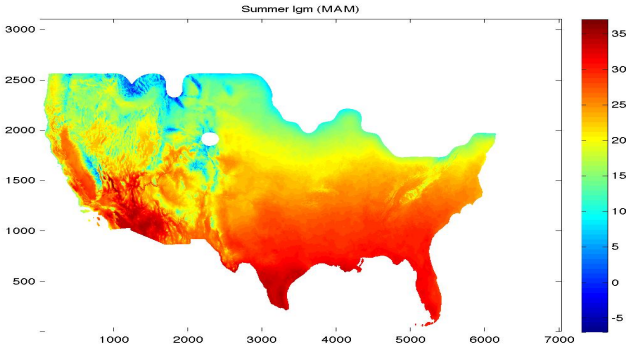
Mid-Holocene
(6,000 yr BP)

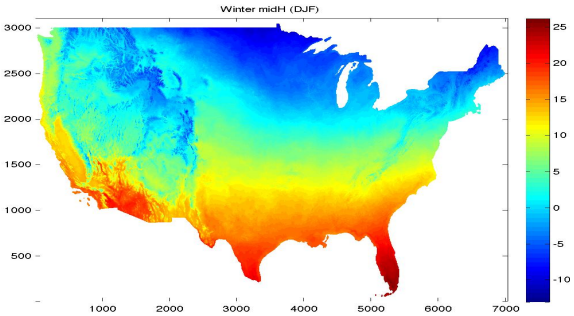


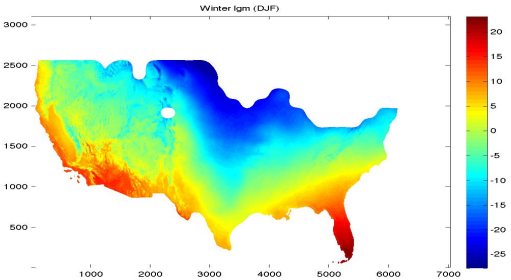
Last Glacial Max.
(21,000 yr BP)



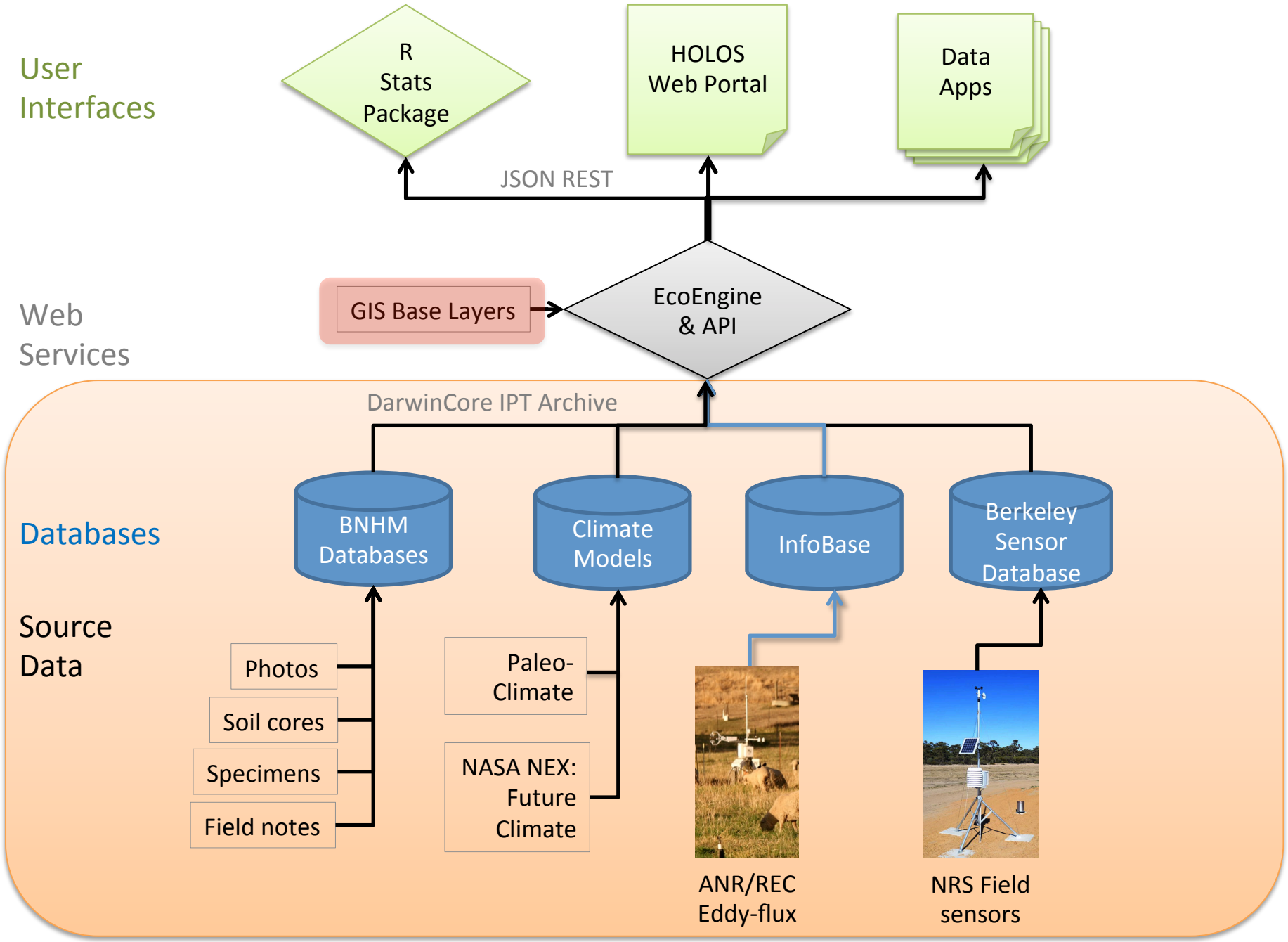
Summer



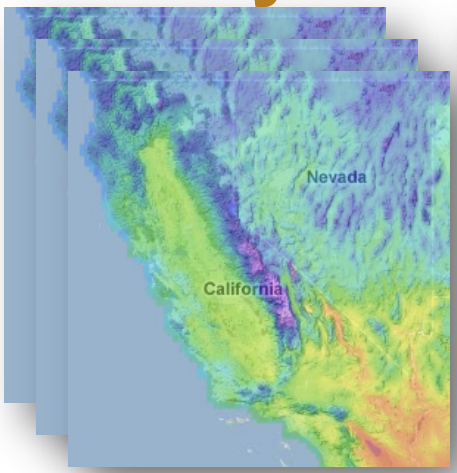




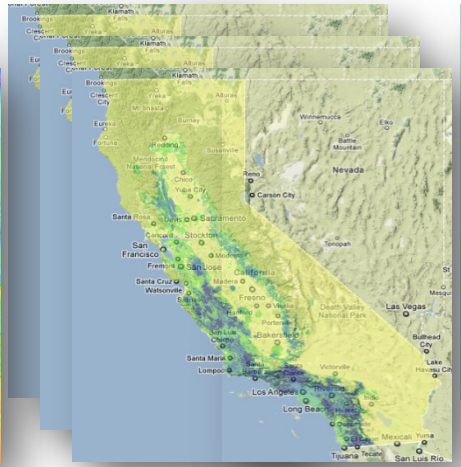
Winter


User Interfaces
R Stats Package
HOLOS Web Portal
Data Apps
JSON REST
Web Services
GIS Base Layers
EcoEngine & API
DarwinCore IPT Archive
Databases
BNHM Databases
Climate Models
InfoBase
Berkeley Sensor Database
Source Data
Photos
Soil cores
Specimens
Field notes
Paleo-Climate
NASA NEX: Future Climate
ANR/REC Eddy-flux
NRS Field sensors

Publicly available data layers



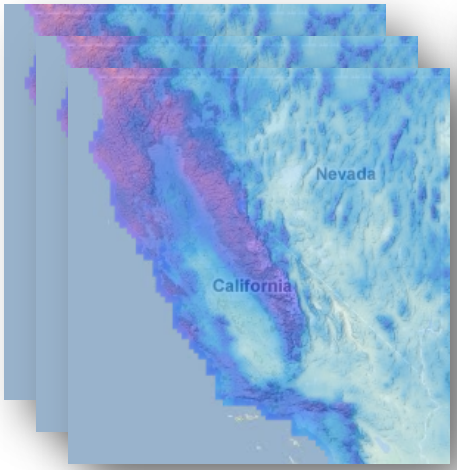
Temperature (max, min, mean)
Past, Present, Projected Future



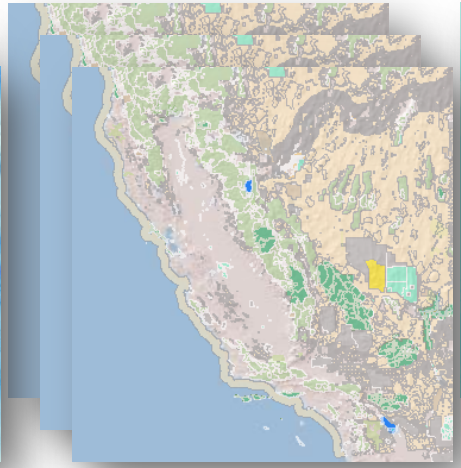
Species Distributions
Past, Present, Projected Future

Land Cover

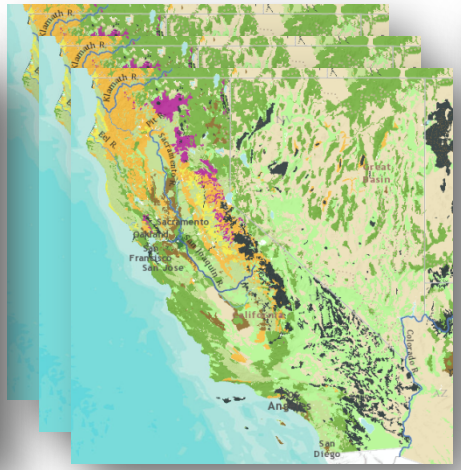
Topography



Precipitation
Past, Present, Projected Future



Land Use
Private, Public, and Protected



Soils

Hydrology

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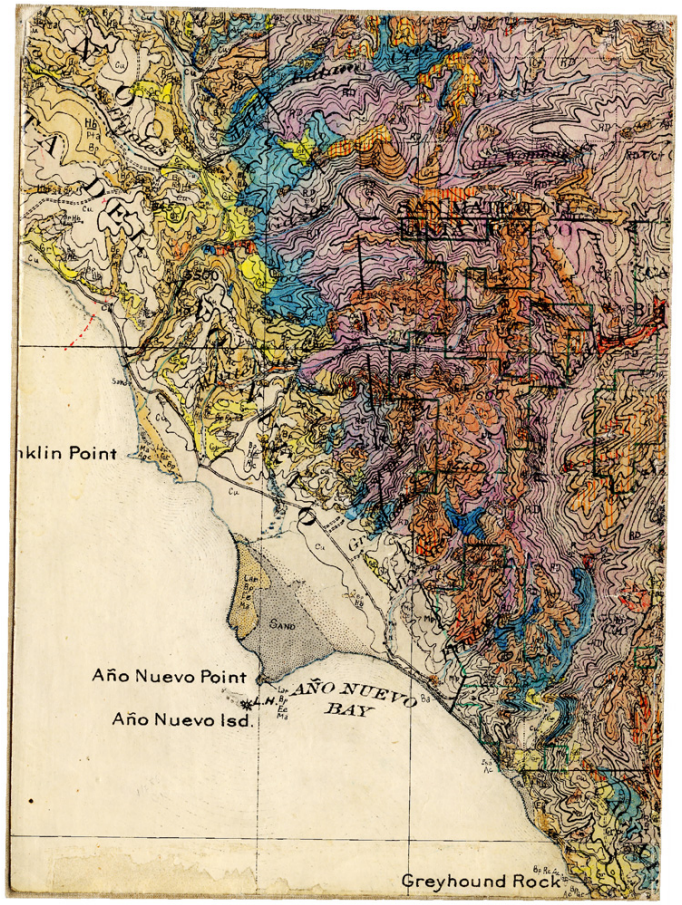
Wieslander Vegetation Survey 1928-1942



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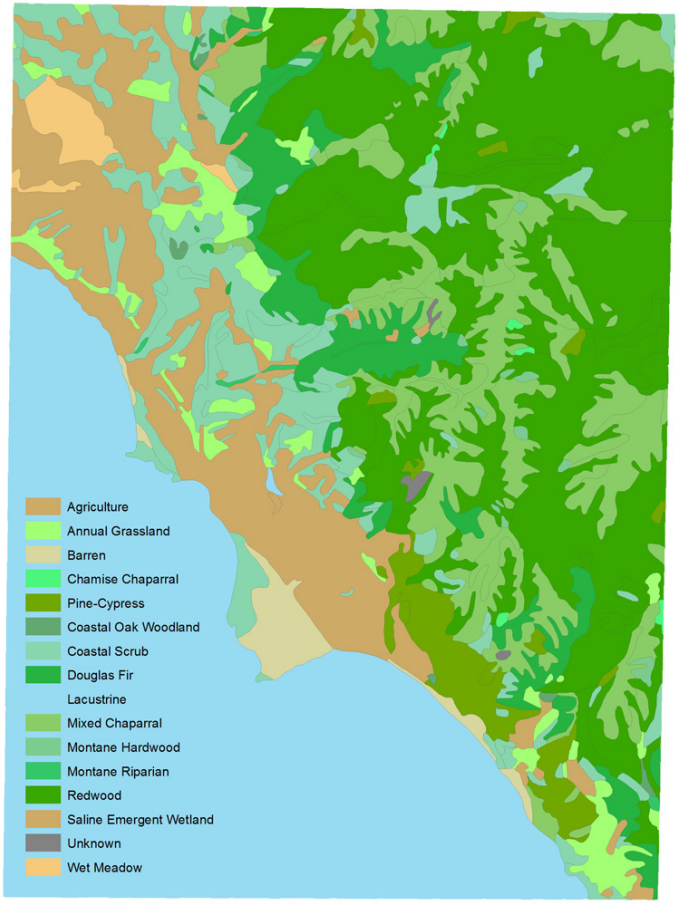
Wieslander Vegetation Survey 1928-1942

- All datasets fully digital and **unified to make new science possible**



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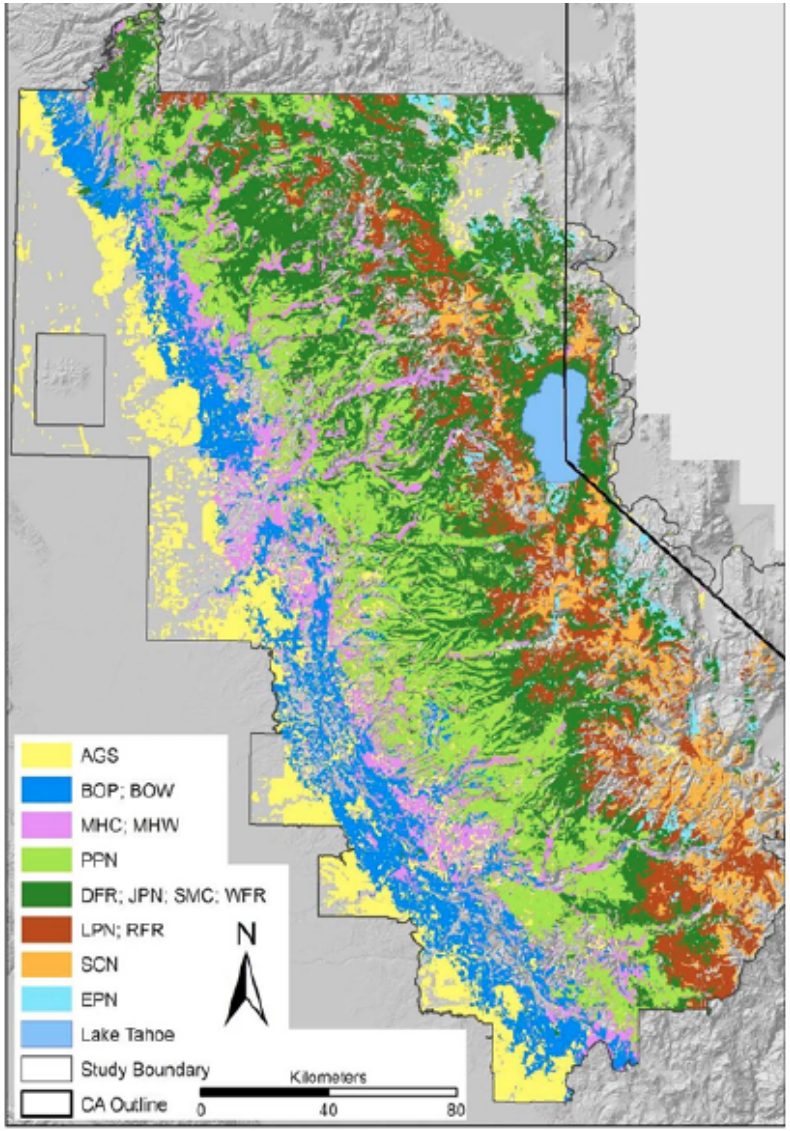
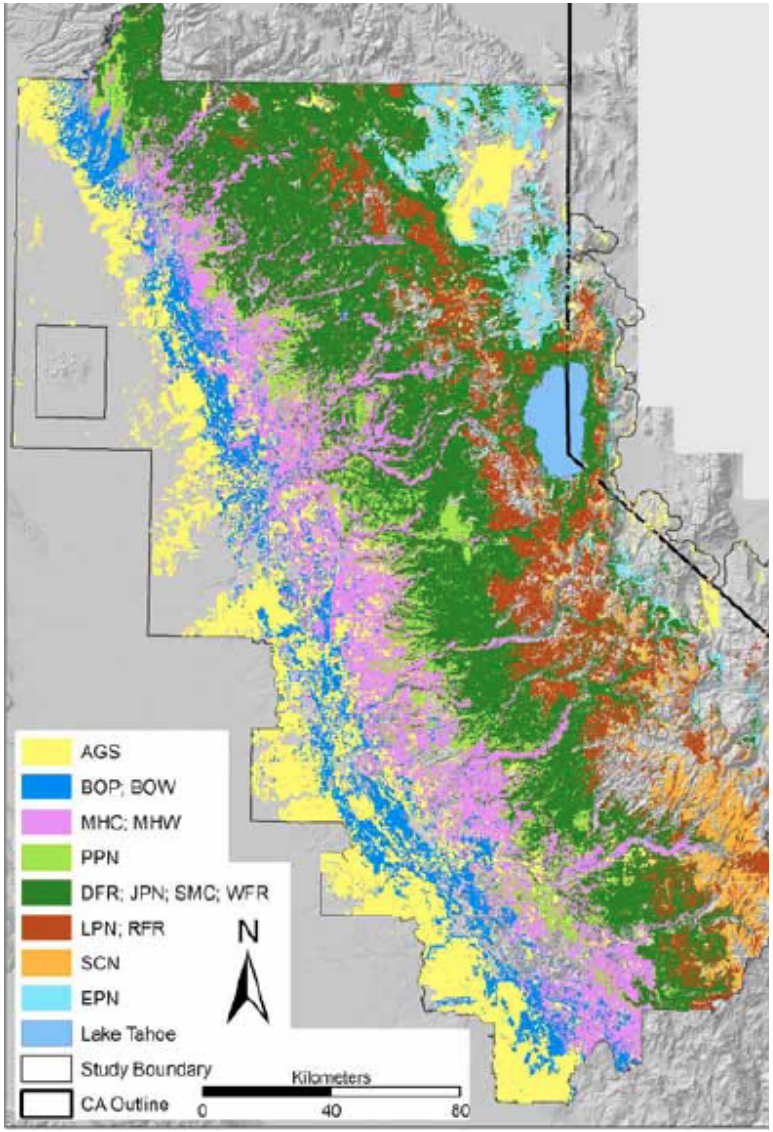


Historic



Modern

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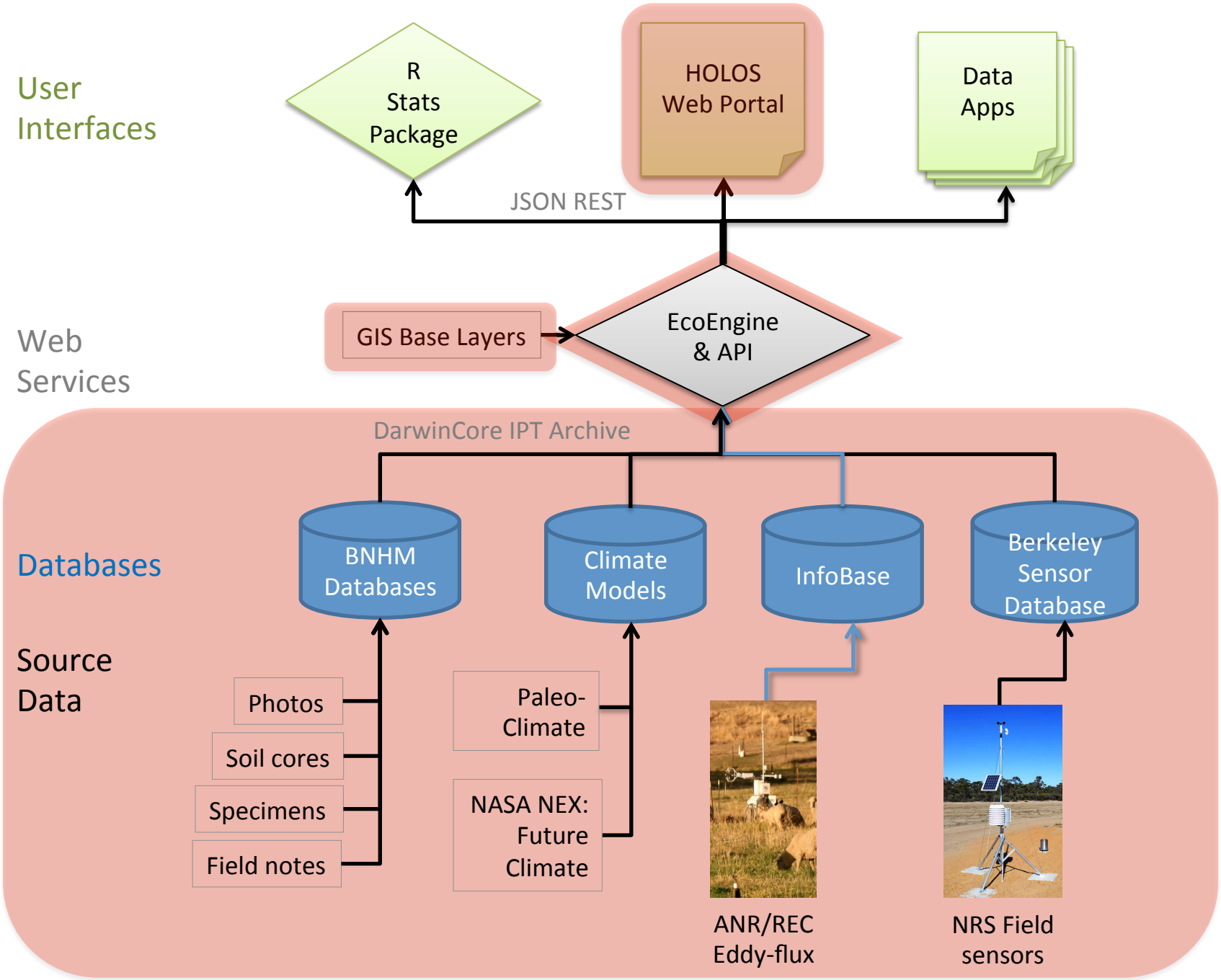
Thorne (2009) *Madroño*


User Interfaces
R Stats Package
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NASA NEX: Future Climate
ANR/REC Eddy-flux
NRS Field sensors

HOLOS
BERKELEY ECOINFORMATICS ENGINE

Explore tool

Search | Species or Location | Begin Date | 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 | End Date | Reset | Advanced | Queries

Filters

These bar charts display the distribution of data across multiple facets. Click on a bar to toggle a filter for each field.

Resource
- Observations (966)
- Photos (26)

Observation type
- Specimen (932)
- Photo (34)

Georeferenced
- True (966)

Country
- United States (966)

State province
- California (992)

Kingdom
- Animalia (843)
- Plantae (1)

Phylum
- Chordata (483)
- Arthropoda (362)
- Magnoliophyta (1)

Class
- Amphibia (423)
- Insecta (356)
- Reptilia (54)
- Mammalia (6)
- Arachnida (5)
- Magnoliopsida (1)

Order
- Caudata (386)
- Hymenoptera (239)
- Coleoptera (53)
- Anura (37)
- Odonata (25)
- Squamata (24)
- Trichoptera (19)
- Sauria (12)
- Ephemeroptera (10)
- Soricomorpha (4)

Family
- Plethodontidae (334)
- Eulophidae (48)
- Perilampidae (39)
- Pteromalidae (38)
- Psephenidae (31)
- Scelionidae (28)
- Salamandridae (24)
- Encyrtidae (24)

Boundaries
None

Environment
VTM Plots

Basemap
Stamen Terrain

Data Layers
- Observations
- Photos
- Sensors
- Reserves
- Jepson Regions

Bounding Box Search

Footprint

Selecting a footprint performs a simple bounding box query that contains the region

Angelo Coast Range Re
Select Jepson Region

OpenStreetMap, under CC BY SA.

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Explore tool

Search | Species or Location | Begin Date | 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 | End Date | Reset Advanced Queries

Share

Hide

Copy this URL to share the page. Note that dropdown selections (such as raster layers) are currently not saved. Only parameters used to query the observations API are shared.

http://studio.stamen.com/berkeley/show/ecoengine/explore/#&q=&bbox=-121.80747985839844,37.35310217159924,-121.63427352905272,37.41857228032001&page_size=1000

Export

These are the queries used to generate the interface on this page.

Observations

https://dev-ecoengine.berkeley.edu/api/observations/?format=geojson&q=&bbox=-121.80747985839844,37.35310217159924,-121.63427352905272,37.41857228032001&page_size=1000

Search

https://dev-ecoengine.berkeley.edu/api/search/?format=json&q=&bbox=-121.80747985839844,37.35310217159924,-121.63427352905272,37.41857228032001&facets_limit=100

Photos

Photo Gallery
https://dev-ecoengine.berkeley.edu/api/photos/?format=geojson&q=&bbox=-121.80747985839844,37.35310217159924,-121.63427352905272,37.41857228032001&page_size=80page=1

Sensors

https://dev-ecoengine.berkeley.edu/api/sensors/?page_size=5000&format=geojson

Raster Layers

Layers https://dev-ecoengine.berkeley.edu/api/layers/
Rasters ..//static/js/stamen/rstore.json

Footprints

Jepsen Regions https://dev-ecoengine.berkeley.edu/api/layers/jepson-regions/features/?page_size=500
Reserves https://dev-ecoengine.berkeley.edu/api/layers/reserves/features/?page_size=500

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Explore tool

Time filter

Search | Species or Location | 1900-01-01 | 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 | 1930-12-31 | Reset | Advanced | Queries

Filters

These bar charts display the distribution of data across multiple facets.
Click on a bar to toggle a filter for each field.

Resource
- Observations (9985)
- Photos (14)

Observation type
- Specimen (9024)
- Plot survey (949)
- Photo (12)

Georeferenced
- True (9985)

Country
- United States (9084)
- USA (901)

State province
- California (9999)

Kingdom
- Animalia (5059)
- Plantae (54)

Phylum
- Chordata (4959)
- Arthropoda (100)
- Magnoliophyta (52)
- Pteridophyta (1)
- Coniferophyta (1)

Class
- Mammalia (2314)
- Aves (1811)
- Amphibia (599)
- Reptilia (235)
- Insecta (100)
- Magnoliopsida (39)
- Liliopsida (13)
- Actinopteri (7)
- Pinopsida (1)
- Filicopsida (1)

Order
- Rodentia (1728)
- Passeriformes (1493)
- Anura (568)
- Carnivora (227)
- Soricomorpha (183)
- Squamata (157)
- Piciformes (115)
- Chiroptera (88)
- Lagomorpha (70)
- Sauria (65)

Boundaries
None

Environment
None

Basemap
OpenStreetMap

Data Layers
- Observations
- Photos
- Sensors
- Reserves
- Jepson Regions

Bounding Box Search

Footprint
Selecting a footprint performs a simple bounding box query that contains the region

Select Reserve
Select Jepson Region

Bishop

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Explore tool

Search | Species or Location | 1969-02-13 | 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 | 2000-02-12 | Reset | Advanced | Queries

Filters

These bar charts display the distribution of data across multiple facets.
Click on a bar to toggle a filter for each field.

Resource
- Observations (6719)
- Photos (125)

Observation type
- Specimen (6662)
- Photo (55)
- Observation (2)

Georeferenced
- True (6719)

Country
- United States (6719)

State province
- California (6832)

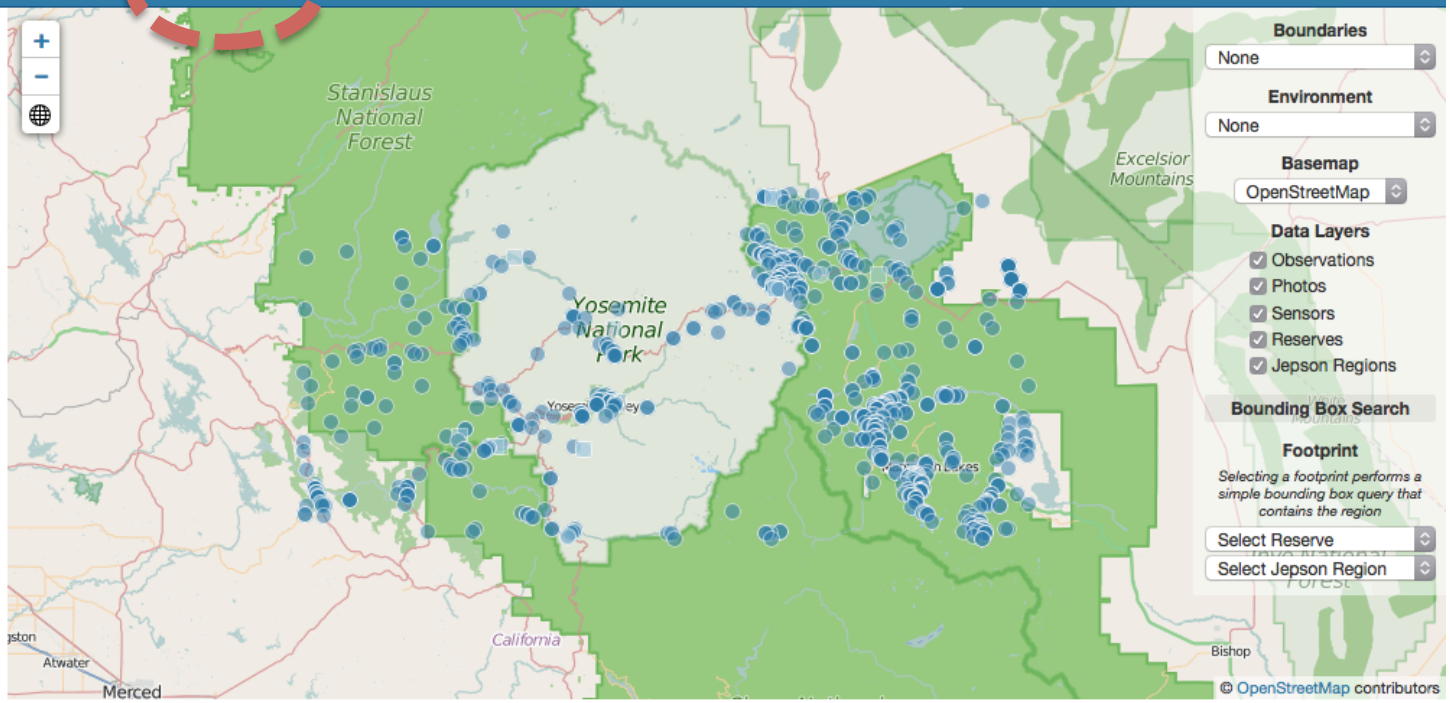
Kingdom
- Animalia (1322)
- Plantae (120)

Phylum
- Chordata (1228)
- Magnoliophyta (113)
- Arthropoda (96)
- Pteridophyta (4)
- Coniferophyta (3)

Class
- Amphibia (507)
- Mammalia (469)
- Reptilia (151)
- Aves (96)
- Insecta (95)
- Magnoliopsida (80)
- Liliopsida (33)
- Actinopteri (6)
- Actinopterygii (5)
- Filicopsida (4)

Order
- Rodentia (396)
- Caudata (333)
- Anura (174)
- Passeriformes (76)
- Squamata (69)
- Carnivora (56)
- Sauria (41)
- Serpentes (40)
- Odonata (35)
- Poales (32)

Family



Boundaries: None

Environment: None

Basemap: OpenStreetMap

Data Layers
- Observations
- Photos
- Sensors
- Reserves
- Jepson Regions

Bounding Box Search

Footprint

Selecting a footprint performs a simple bounding box query that contains the region

Select Reserve

Select Jepson Region

Observations

View data or export as CSV, JSON, or GeoJSON from the Berkeley Ecoinformatics Engine

Results 1 to 1000 of 6719 - 1 2 3 4 5 6 7 Page size 20 50 100 500 1000 2000

Record	Scientific name	Country	State province	Begin date	End date	Geojson	Observation type
SD106417	Hulsea brevifolia	United States	California	1980 Aug 14	1980 Aug 14	Yes	specimen
UCR104202	Erigeron coulteri	United States	California	1997 Aug 11	1997 Aug 11	Yes	specimen
SD93521	Veratrum californicum	United States	California	1975 Aug 10	1975 Aug 10	Yes	specimen
OBI64684	Cirsium arizonicum var. arizonicum	United States	California	1982 Aug 24	1982 Aug 24	Yes	specimen
HSC94957	Solidago elongata	United States	California	1994 Aug 9	1994 Aug 9	Yes	specimen
HSC94852	Ericameria nana	United States	California	1994 Aug 9	1994 Aug 9	Yes	specimen
POM369958	Betula occidentalis	United States	California	1970 Sep 9	1970 Sep 9	Yes	specimen
JEPS101530	Mimulus filicaulis	United States	California	1998 Aug 2	1998 Aug 2	Yes	specimen
RSA618293	Eriogonum umbellatum var. covillei	United States	California	1974 Jul 27	1974 Jul 27	Yes	specimen
CAS:BOT:821751	Salix lutea nutt.	United States	California	1981 Aug 10	1981 Aug 10	Yes	specimen
CAS:BOT:820766	Salix lutea nutt.	United States	California	1974 Oct 5	1974 Oct 5	Yes	specimen

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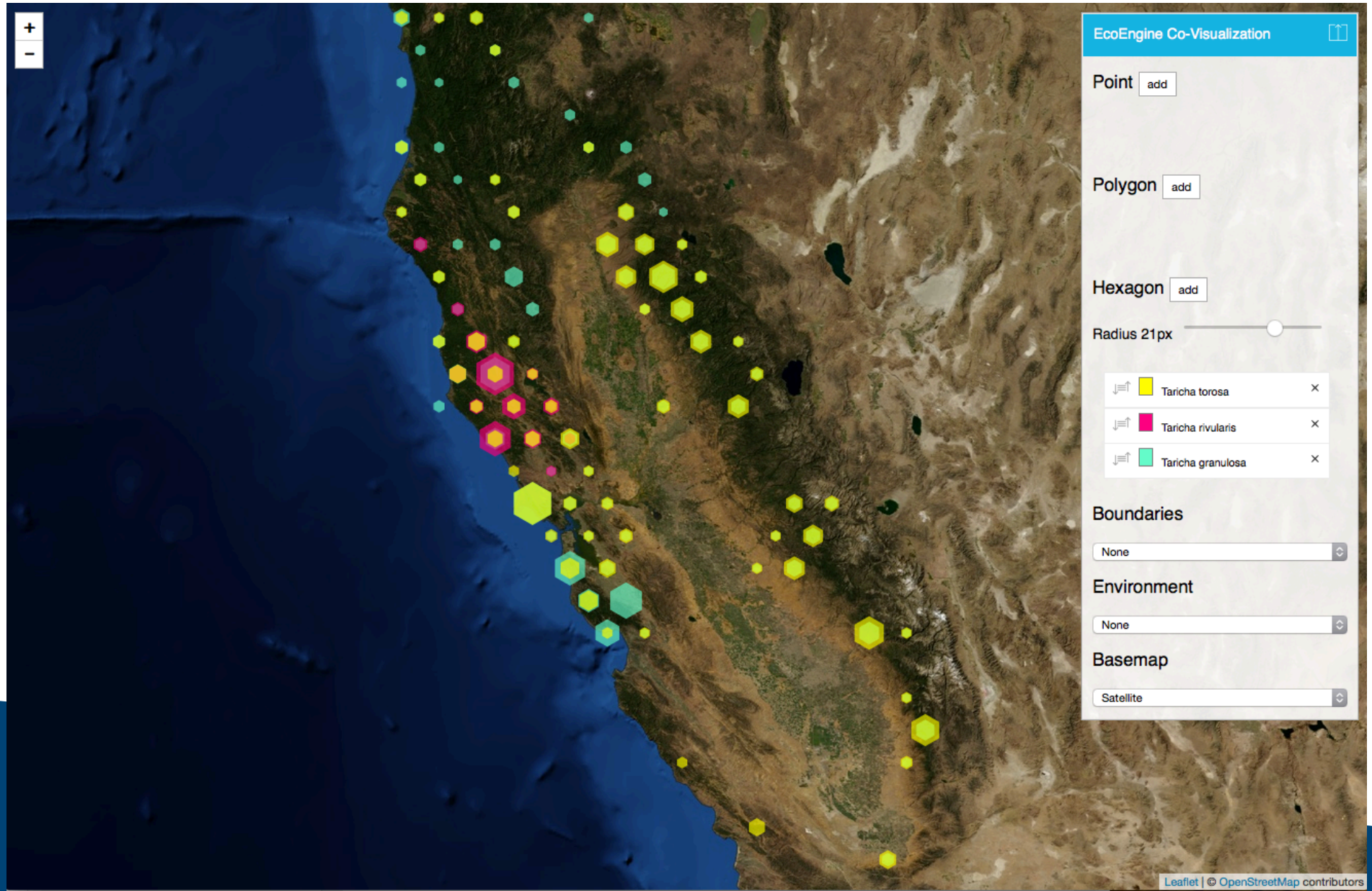
Compare tool



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Compare tool

HOLOS

BERKELEY ECOINFORMATICS ENGINE

Compare tool - download

```
state_province,coordinate_uncertainty_in_meters,recorded_by,begin_date,end_date,source,url,country,scientific_name,locality,record,remote_resource,observation_type,long,lat
California,1000,None,1893-03-27,1893-03-27,https://ecoengine.berkeley.edu/api/sources/6/,https://ecoengine.berkeley.edu/api/observations/CAS%3ASUA%3A192/,United States,Taricha torosa torosa,Palo Alto,CAS:SUA:192,,
California,623,AH Brame,1957-03-03,1957-03-03,https://ecoengine.berkeley.edu/api/sources/2/,https://ecoengine.berkeley.edu/api/observations/LACM%3AHerps%3A29335/,United States,Taricha torosa torosa,Stanford; Golf
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California,152,Collector(s): William J. Riemer,1953-04-04,1953-04-04,https://ecoengine.berkeley.edu/api/sources/14/,https://ecoengine.berkeley.edu/api/observations/MVZ%3AHerp%3A61416/,United States,Taricha granulo
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California,3256,AH Brame Jr.,1957-03-01,1957-03-01,https://ecoengine.berkeley.edu/api/sources/2/,https://ecoengine.berkeley.edu/api/observations/LACM%3AHerps%3A29261/,United States,Taricha granulosa,Portola State
California,333,"""F.E. Ely""",2001-01-23,2001-01-23,https://ecoengine.berkeley.edu/api/sources/6/,https://ecoengine.berkeley.edu/api/observations/CAS%3AHERP%3A218640/,United States,Taricha granulosa,"Alpine Rd, 3.
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California,1298,"""G.S. Myers, T.P. Maslin and A.E. Daugherty""",1942-03-01,1942-03-01,https://ecoengine.berkeley.edu/api/sources/6/,https://ecoengine.berkeley.edu/api/observations/CAS%3ASUA%3A7593/,United States,
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```

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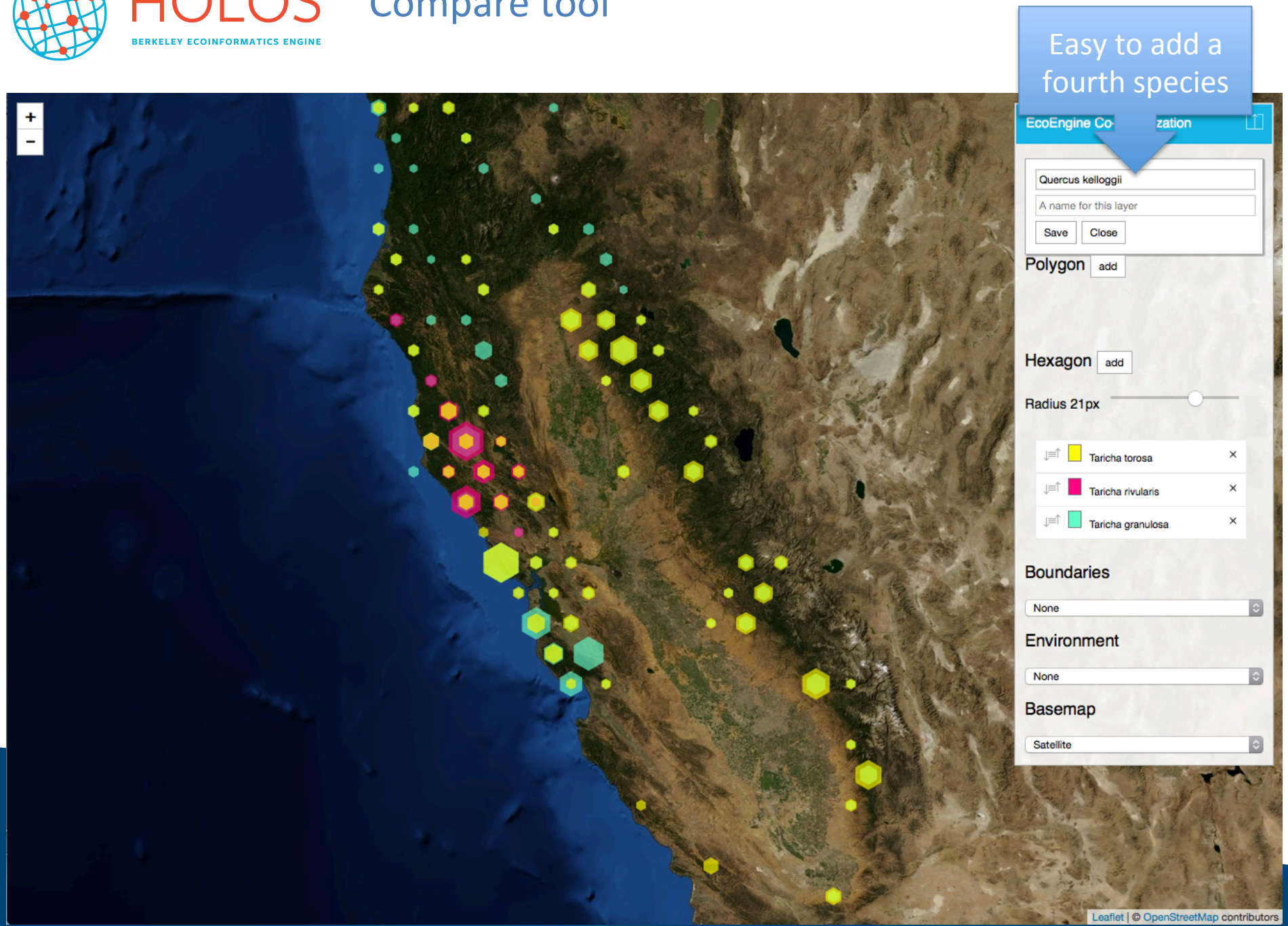
BERKELEY ECOINFORMATICS ENGINE

Compare tool



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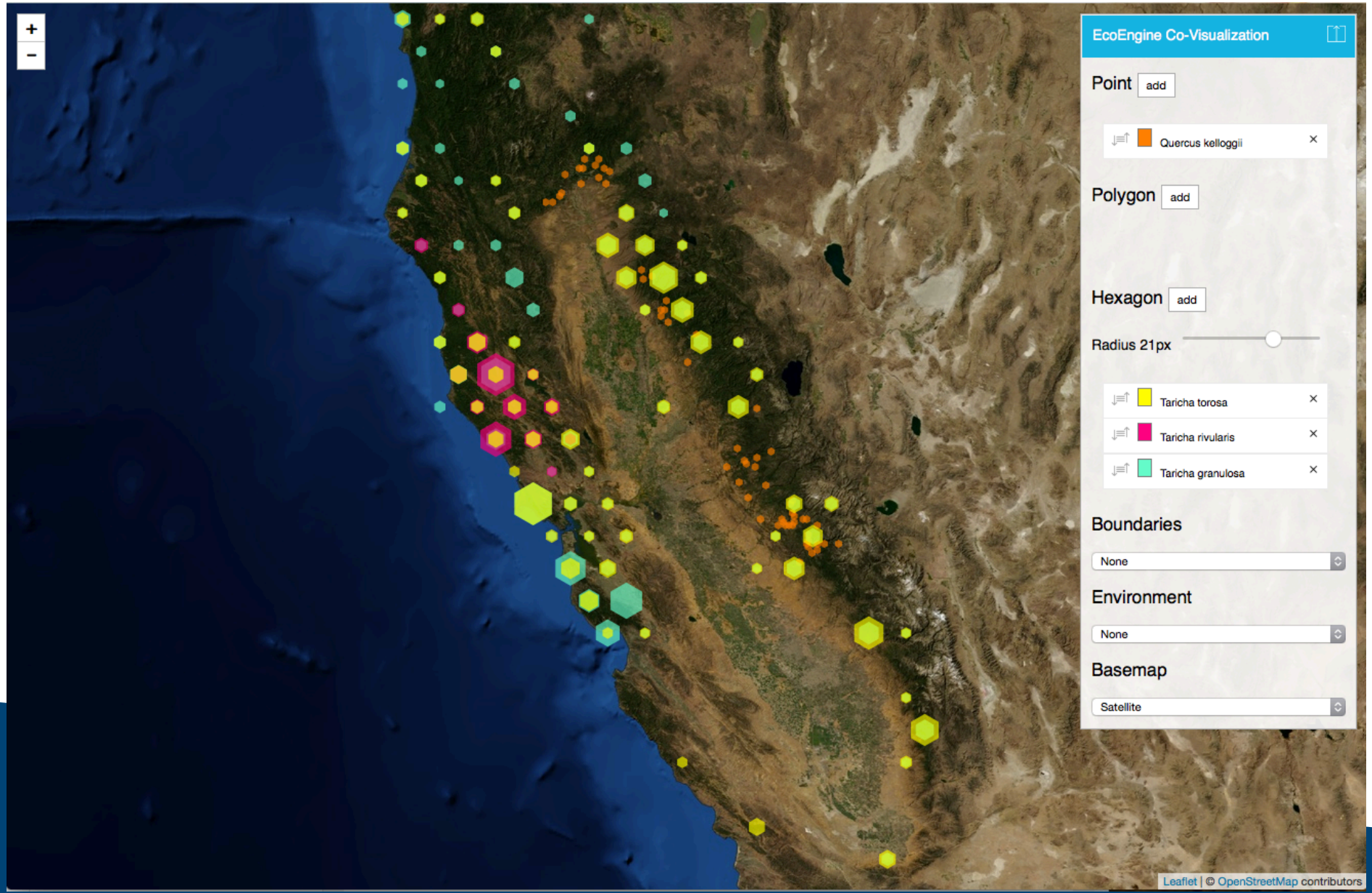
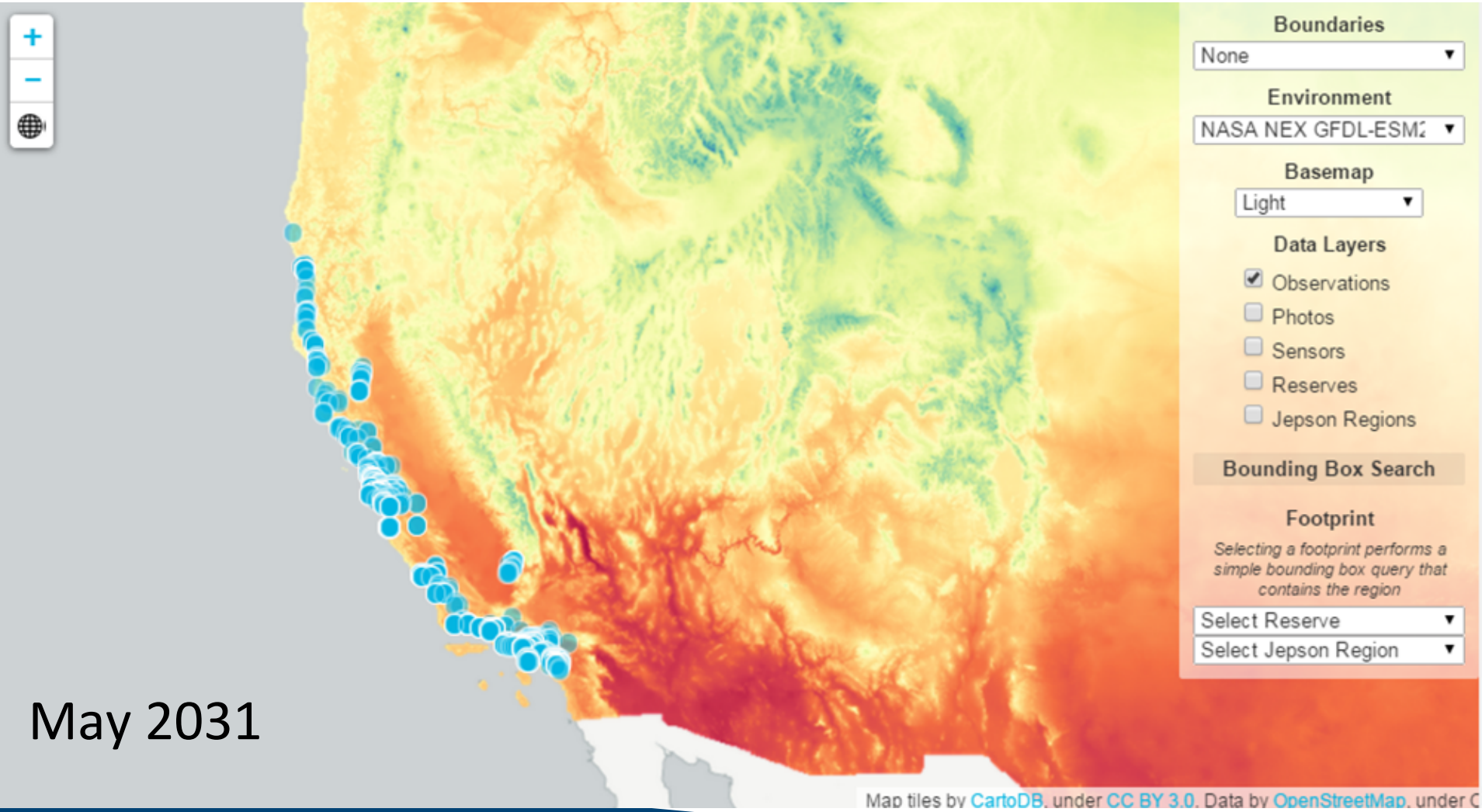
Compare tool



Can Dial-Up Projected Climates (here from NASA)

NASA NEX-DCP30 datasets



May 2031

Batrachoseps attenuatus

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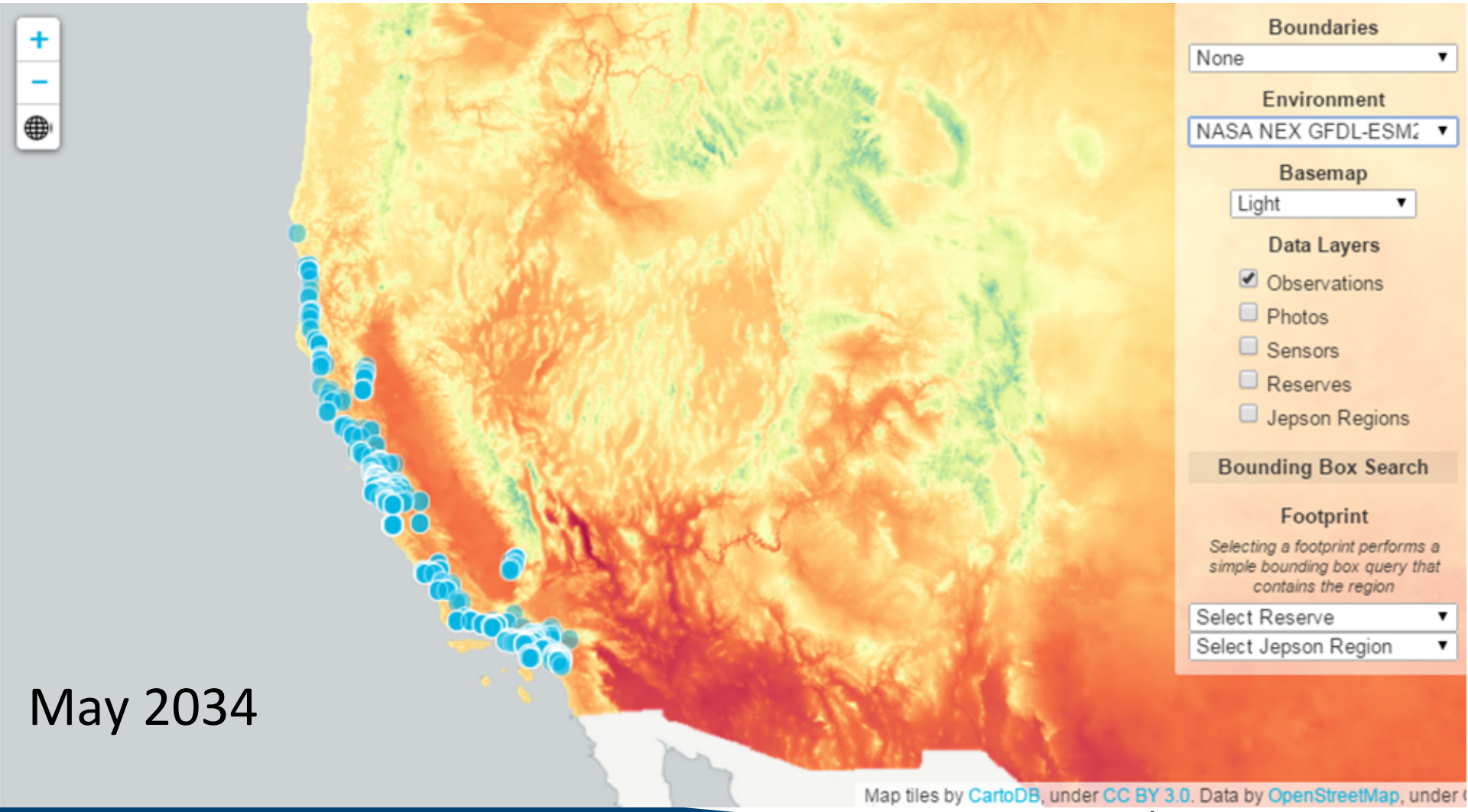
Can Dial-Up Projected Climates (here from NASA)

NASA NEX-DCP30 datasets



May 2034

Batrachoseps attenuatus

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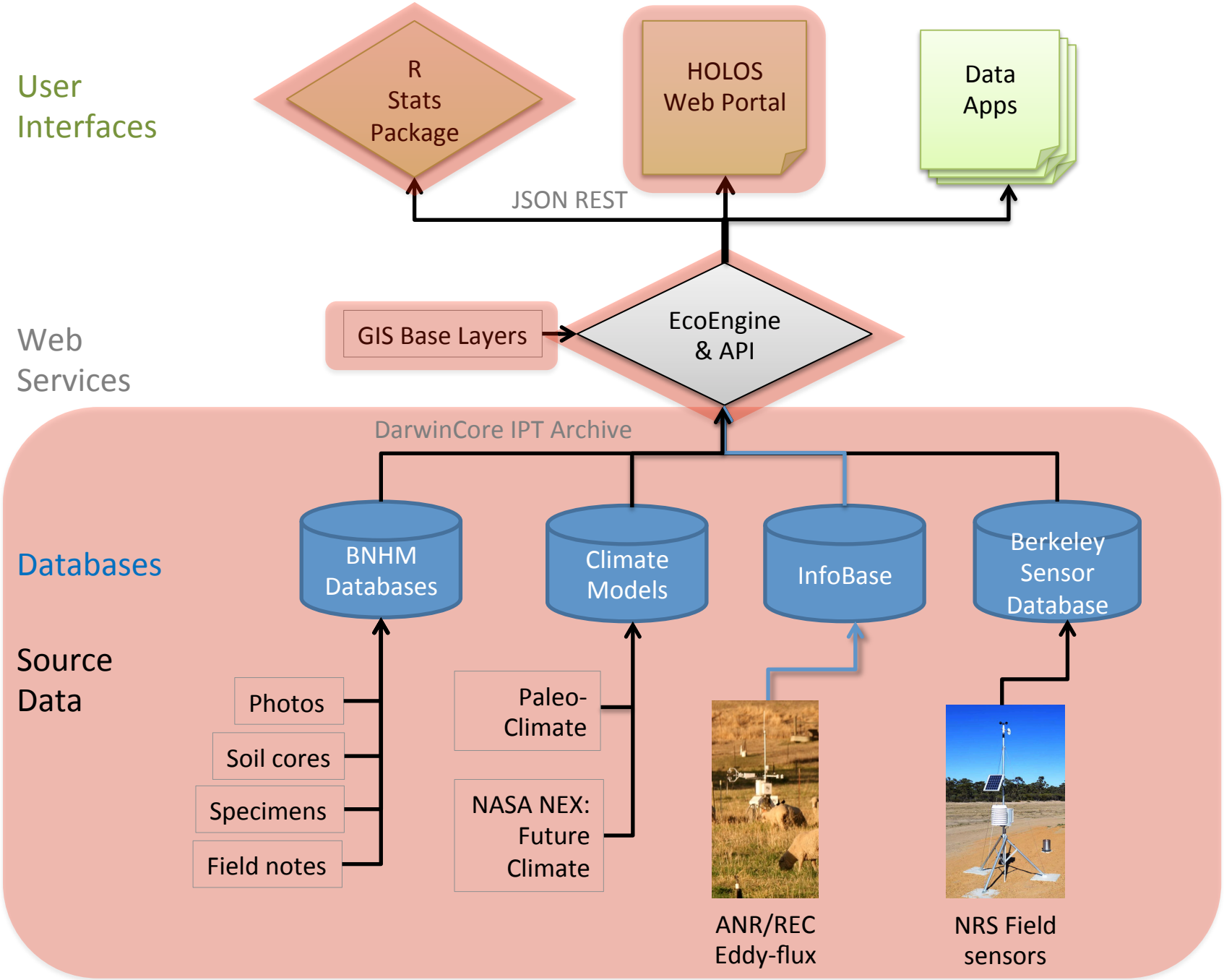
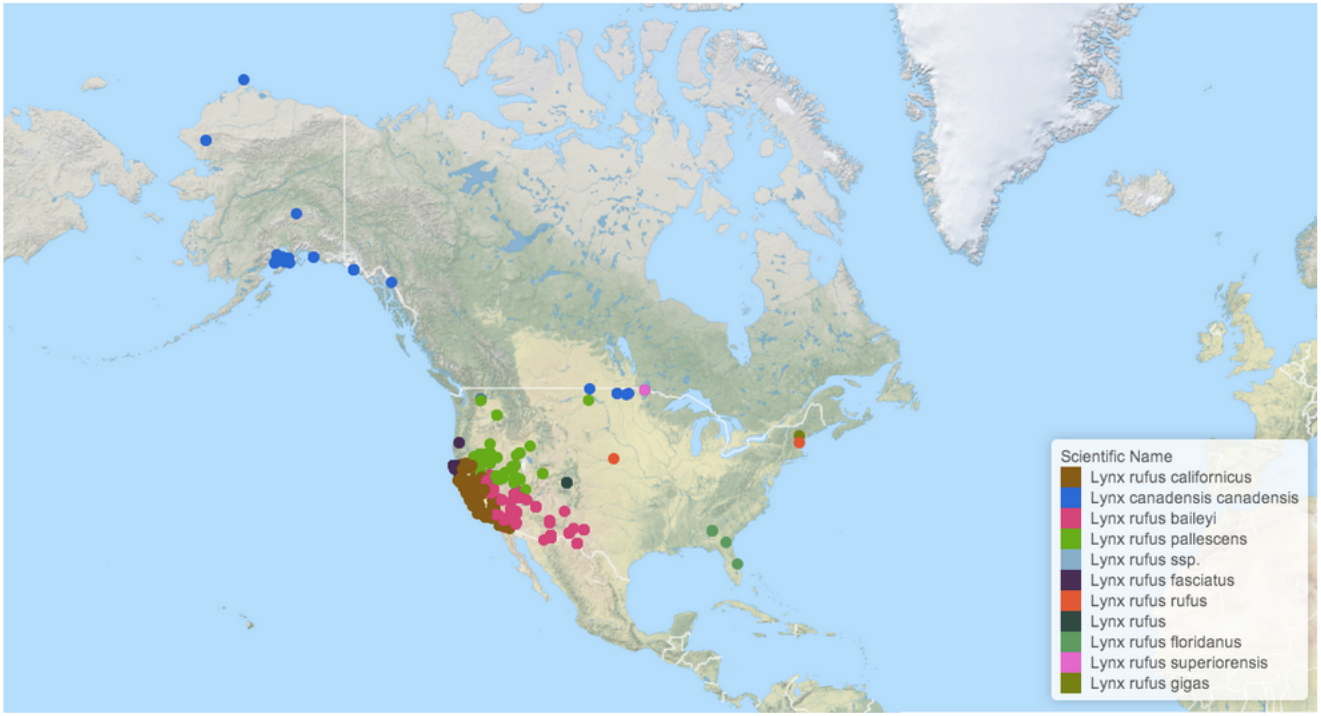

User Interfaces
R Stats Package
HOLOS Web Portal
Data Apps
JSON REST
Web Services
GIS Base Layers
EcoEngine & API
DarwinCore IPT Archive
Databases
BNHM Databases
Climate Models
InfoBase
Berkeley Sensor Database
Source Data
Photos
Soil cores
Specimens
Field notes
Paleo-Climate
NASA NEX: Future Climate
ANR/REC Eddy-flux
NRS Field sensors

Ecoengine package

Mapping observations

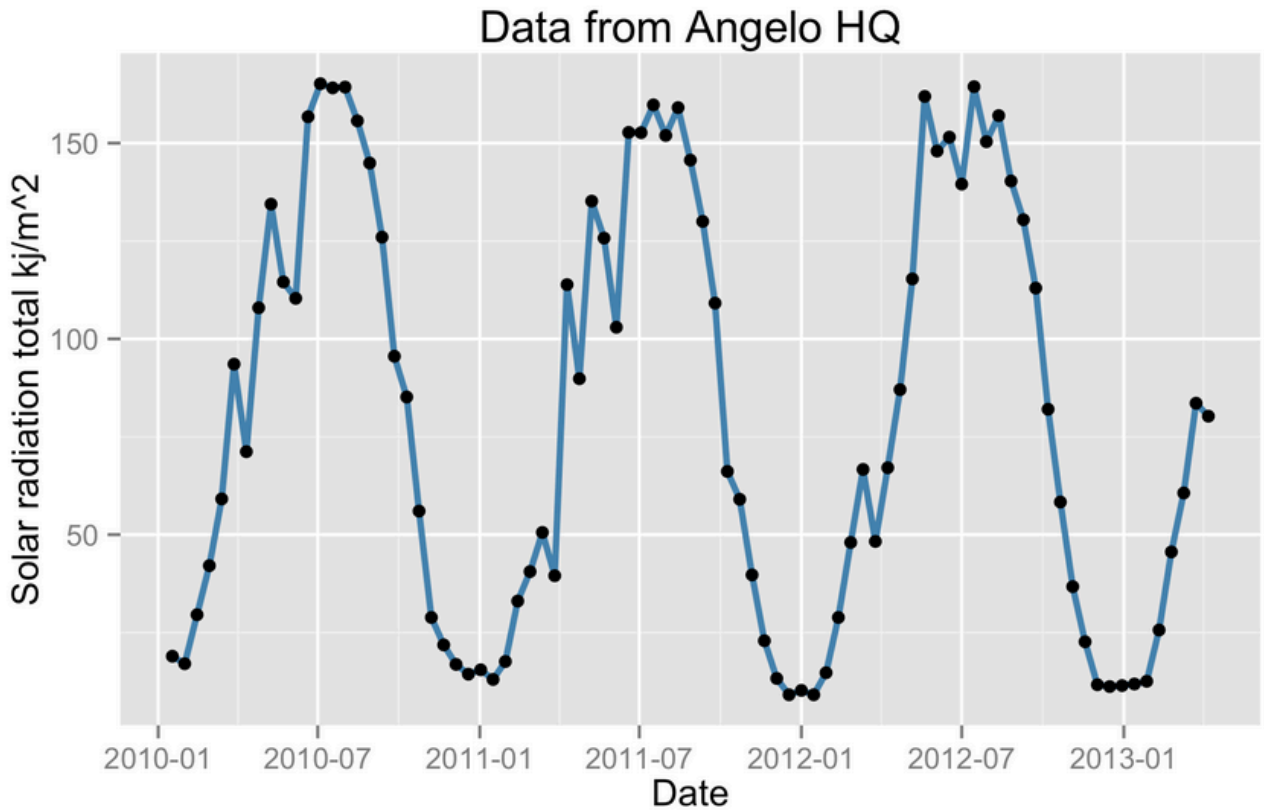
The development version of the package includes a new function `ee_map()` that allows users to generate interactive maps from observation queries using Leaflet.js.

```
lynx_data <- ee_observations(genus = "Lynx", georeferenced = TRUE, page = "al
l", quiet = TRUE)
ee_map(lynx_data)
```



Ecoengine package

```
library(ggplot2)
ggplot(sensor_df$data, aes(begin_date, mean)) +
geom_line(size = 1, color = "steelblue") + geom_point() +
theme_gray() + ylab("Solar radiation total kj/m^2") +
xlab("Date") + ggtitle("Data from Angelo HQ")
```



Ecoengine package

shinyapps.io

Powered by RStudio

Taxa over time

Number of records in the Berkeley Ecoinformatics Engine for six major taxa in California from 1900-present

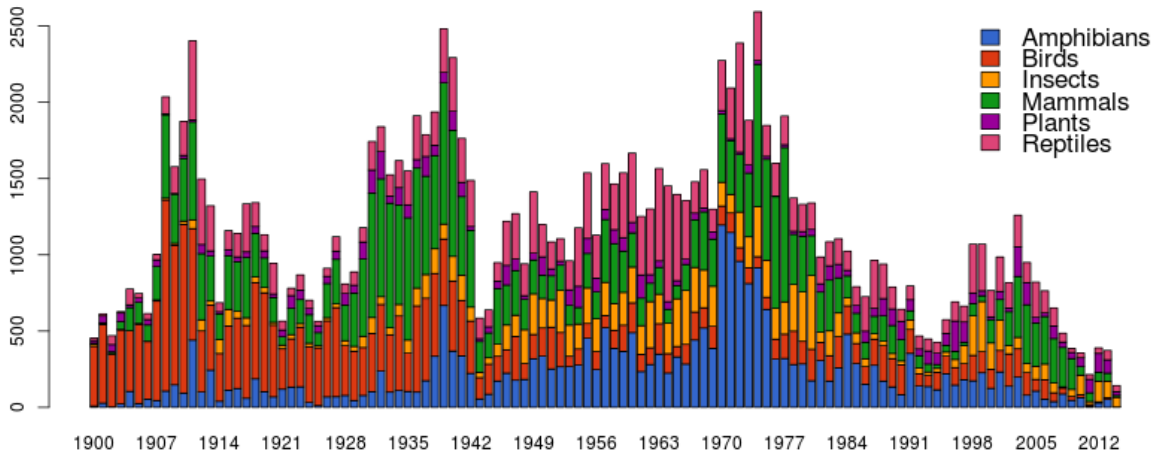
Taxon to show:

- [x] Amphibians
- [x] Birds
- [x] Insects
- [x] Mammals
- [x] Plants
- [x] Reptiles

Year range:

1,900 — 2,015

1,900 1,912 1,924 1,936 1,948 1,960 1,972 1,984 1,996 2,008 2,015



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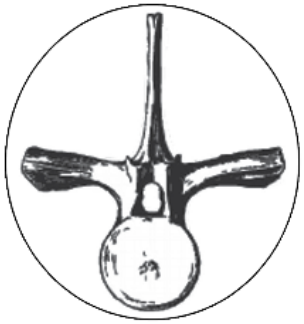
Wieslander Vegetation Map Project (VTM)

Natural Reserve System Field Station Data

Calphotos



VertNet

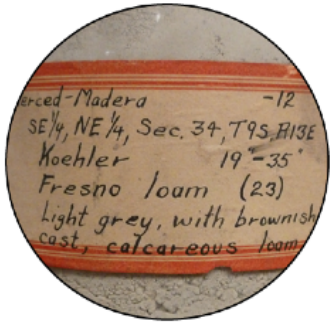
University and Jepson Herbaria

University Museum of Paleontology

Essig Museum of Entomology

Museum of Vertebrate Zoology

Pollen Core Data



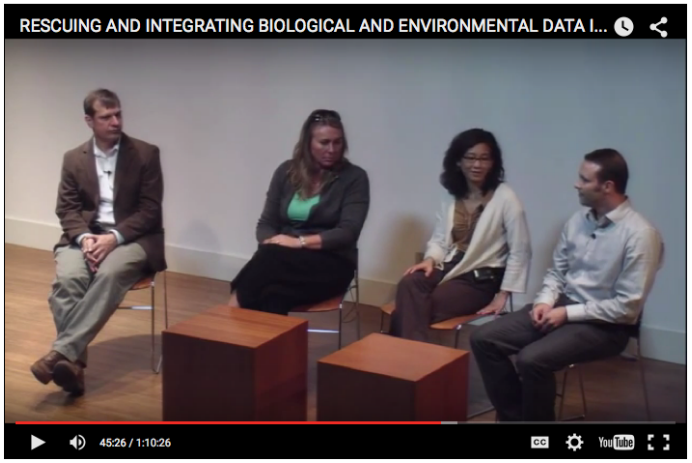
Soil Database

Natural Reserve System Environmental Sensor Array

Climate Data

Bioinformatics Collaboratory

- Building and leveraging **technological advances**
- Developing and implementing **universal data standards**
- Forging technical, ***social*** **and** ***cultural*** **bridges**



GIF workshop participants complete a GIS exercise

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The Holos Team

Integrative Biology
David Ackerly
Mary Power

Geospatial Innovation Facility
Brian Galey
Kevin Koy
Shruti Mukhtyar
Falk Schutzenmeister

Essig Museum of Entomology
Rosemary Gillespie

Museum of Vertebrate Zoology
Michelle Koo

Environmental Science Policy & Management
Maggi Kelly
Shufei Lei

Information & Technology Services
Joyce Gross

Berkeley Initiative in Global Change Biology
Sarah Hinman
Patrick McIntyre
Giovanni Rapacciuolo
Jessica Rothery

Office of the Vice Chancellor of Research
Verna Bowie

UC Museum of Paleontology
Charles Marshall

Earth & Planetary Sciences
John Chiang
Yoshi Mondal
Ginger Ogle

Australia National University
Craig Mortiz

Information Center for the Environment (UC Davis)
James Thorne

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Funding provided by
W.M. Keck Foundation

W.M. KECK FOUNDATION

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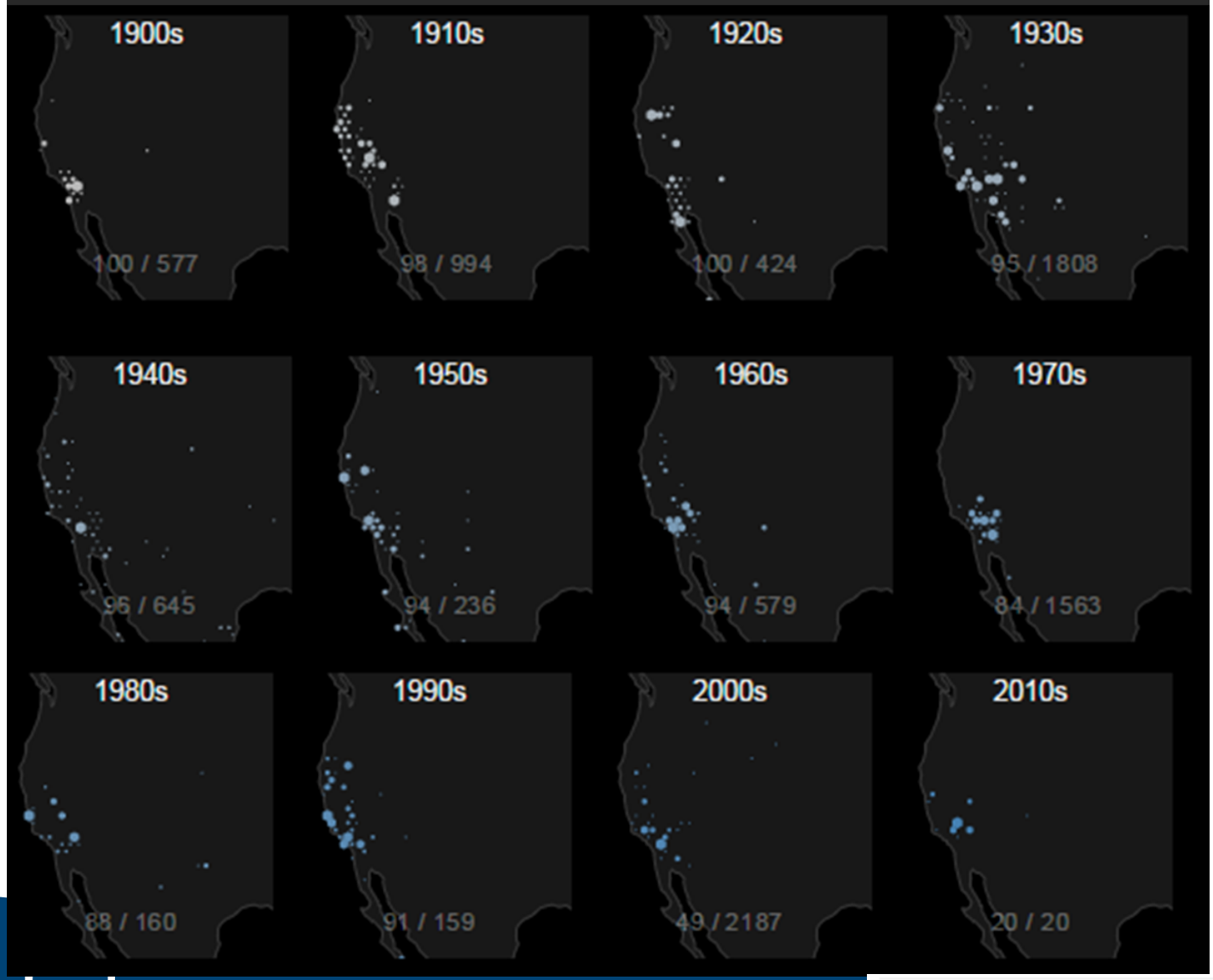
Dusky-Footed Woodrats over Decades



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