California Climate and Vegetation Change – Classroom Task

Level: High School and College

Overview

California, the third-largest state (163,696 mi^2) in the U.S., is located the Pacific Ocean margin and is remarkable in its floral diversity. Plant distribution is strongly linked to the variable amounts of precipitation received throughout the state. Fossil pollen studies have demonstrated that vegetation range shifts have occurred over time, reflecting changes in past climate. In this classroom task, students examine modern climate data from four disparate areas in the state and create climatographs. Using the Neotoma Paleoecology Database, students look at past records in each of these four regions to assess fossil pollen data as a proxy for climate change over time, and completeness of the record. Plant taxa in the fossil record are compared to modern plant tolerances and distribution available at CalFlora, and students then determine which plants are most sensitive to change by region, and preserve well as fossil pollen.

Next Generation Science Standards Standard Alignment
HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
HS-LS4-C. Adaptation. Distribution can change as population changes.
HS-LS4-3. Apply concepts of statistics and probability to support explanations that organism with an advantages heritable trait tend to increase in proportion to organisms lacking this trait.
HS-ESS2.E. Biogeology. Feedback with climate system; continual co-evolution of Earth's surface and the life that exists on it.
HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.
HS-ESS2.A. Earth Materials and Systems – vegetation can shift on a variety of scales

Information for Classroom Use

Connections to Instruction

This task is applicable to content on California native vegetation, climatic conditions throughout the state, biomes, and the complexity of real data on the fossil pollen record, and possible climate reconstructions from such paleobotany data. Creating climatographs reinforces plotting (e.g. determining scale and origin), and visual interpretion of data. The task components also introduce students to CalFlora and the Neotoma, online platforms based on rich modern vegetation and paleoecology datasets. Task components A – C support data graphing, interpretation, and evaluation. Components D – F support synthesizing data and information, particularly in writing.

The writing prompts of these later components can be adapted, depending on time available for the unit, and level of depth desired.

Duration

The entire task reasonably spans 3 – 5 class periods (~45 min/period).
Components A – B comprise 1 class period.*
Component C spans 1 – 2 class periods.*
Components D – F span 2 – 3 class periods, depending on adaptations (including if structured as individual or group work).

Additional instruction on core concepts will add time, depending on the instructor and background of the students. Necessary background instruction will likely require familiarity with taxonomic identification practices and naming conventions, visualizing core stratigraphy and the natural variation among pollen grains, and how to interpret a pollen diagram.

**Time estimation depends on whether unfinished parts are homework, and if computers are available during class.*

Assumptions/Background

• Completing the task effectively assumes that students understand how to set up graph axes from available data, the law of superposition (in lake deposits), and the basics of palynology (e.g. sampling, chemical processing, unique morphology of grains, slide counting, inherent bias in grain preservation and identification).
• Visuals of the differences between pollen grains can be taught/shown to help student understanding.
• Available computers and reliable internet connectivity that support online mapping platforms are necessary.
• Students should have a basic familiarity with the naming conventions of taxonomy. Practice using dichotomous keys in organism identification is also helpful.
• Instructor is familiar with, and has taught, the above topics, and has worked through components of each task him/herself.
• Instructor is comfortable guiding students as they 1) navigate online database platforms that may be new and unfamiliar, 2) interpret graphs of several paleoecological variables through time, and 3) make a reasonable interpretation of datasets that are complex and/or incomplete (rather than a binary "right/wrong" answer)

Materials Needed

• Computer and wireless access, and access to internet browsing and graphing software as needed (e.g. MS Excel)
• Worksheets and graphic organizer templates (as needed)

Accommodations

The “Duration” section is a framework that helps parse and scaffold the task. Task components can be differentiated, or assigned to groups of 2-4 to be completed collaboratively, foster discussion, and reduce classroom time devoted to the exercise. The option of writing or orally presenting answers to components D – F supports differentiation.

For upper division and beginning graduate students that will continue with advanced coursework or original research in paleoclimate, paleoecology, and/or fossil pollen analysis, it may be appropriate to assign individuals to complete all components independently.

Assessment

The following rubric is provided as a guide. Skills emphasized and grading will vary, depending on instructor and level taught.

Task Component	Criteria
A. Compare monthly climate data from 2010 at four locations to 20-year averages	• student notes that 2010 temperature data <u>generally</u> match averages (usclimatedata.com only shows high/low) • student notes that 2010 precipitation data are: **Eureka**: higher-than-average all months **Truckee:** comparable to average **SFO:** lower-than-average for wet months **Palm Springs:** higher-than-average for <u>most</u> months
B. Plot climatographs for each location	• climate data matched with appropriate location • precipitation (bars) and temperature (line graph) accurately plotted, with two y-axes that are appropriately scaled • all axes have labels that include units of measurement
C. Find and evaluate fossil pollen data that shows vegetation change over the past 10,000 years	Students may note the following observations: **Eureka:** nearby sites (≤100 km) are ≤5,000 years BP. Complete records of Holocene are 200+ km inland and show Early Holocene aridity. (How representative are they of coastal N. Calif.?) **Truckee:** *Pinus* dominates records in nearby records, and changes in other taxa are difficult to discern. Sierra sites towards the south show subtle mid-Holocene aridity (e.g. *Quercus, Artemisia,* Asteraceae) **SFO**: most nearby sites are young (≤2,000 years BP), with short-term variation. China Camp suggests a warm, moist Early Holocene (*Sequoia, Quercus*) while changes in Amaranthaceae reflect shoreline shifts more than climate. **Palm Springs:** Desert sites mostly middens, and not continous records. Several sites only span ~2,000 years. Sites towards coast suggest mid-Holocene drying and variable Late Holocene.
D. Develop a list of most-sensitive plant taxa in California pollen studies	• students may note the following: Pinaceae *Pinus*, Pinaceae *Abies*, Asteraceae *Ambrosia*, Asteraceae *Artemisia*, Apiaceae, Betulaceae *Alnus*, Cactaceae *Opuntia,* Amaranthaceae *Artiplex*, Amaranthaceae *Salicornia*, Cupressaceae *Juniperus,* Cupressaceae *Sequoia sempervirens*, Cyperaceae *Scirpus*, Fagaceae *Quercus*, Poaceae *Festuca*, Saliceae *Populus*, Typhaceae *Typha* • rank (family, genus or species), number of taxa, and Latin vs. common name requirements up to instructor discretion (3-5 per location at Family or Genus level suggested for full credit)
E. Summarize the last 10,000 years of climate change in California	• Early Holocene (~11,000 – 7,500 years BP) tends to be warm and dry in northern California and at sites in the Sierra Nevada • Middle Holocene (~7,500 – 3,000 years BP) tends to be arid in Sierra Nevada and S. California records • Late Holocene is quite variable across the state
F. Propose a new pollen research project that addresses gaps in the fossil record	Answers will vary. High quality responses exhibit persuasive writing, including: • gap(s) in the existing pollen record are noted • the target area/site for a new study is clear, with appropriate reasoning • good spelling, grammar, and appropriate use of terminology relevant to lake sediment records and palynology • astute answers may note that the largest geographic gap (Southeast California) is mostly desert, and likely to not have continuous lake records

Classroom Task

Context

Plants produce pollen each spring as part of their reproductive process. These grains can then be airborne or stream-transported to lake basins, where they settle on the lake bottom as a part of sediment deposition. Scientists often take sediment cores from the bottom of lakes to capture the (usually) undisturbed layers, and analyze changes in the deposit through time. This helps build a picture of what local vegetation and climate conditions were like before we started keeping instrumental records of precipitation and temperature in California ~160 years ago. Useful core records have good "age control:" a selection of different core horizons that were dated to determine how long ago they were deposited. This is often done with radiocarbon dating on wood pieces, charcoal, and seeds deposited into the lake sediment, and later captured with the coring device.

Once a lake has been cored, a sample of sediment (usually 1 cm^3) is taken at different levels throughout the core. These can be chemically processed to remove most of the sedimentary material, while the durable layer of sporopellenin on fossil pollen protects it from digestion, leaving the grains intact and recognizable. Different plant families, genera, and sometimes species produce unique pollen shapes. For each horizon sampled, a slide is made and the fossil pollen are identified and counted with a microscope. Often, there are not enough distinct features to know the exact species of a pollen grain, so determination is made to the genus, or family, rank. Palynologists often use the term "taxa" to refer to all plant IDs in a study that have different taxonomic ranks.

After all samples throughout the core are counted, the percents of each plant taxa are calculated. Having several pollen samples and measurements for a site helps build a general picture of vegetation change at that location throughout time.

In this task, you will evaluate modern climate data from different regions of California, then assess the quality and sensitivity of available pollen records from each area. You will then create a list of plants that seem best for tracking climate change over the past 10,000 years based on their tolerances, and that you expect to be the most important in pollen analysis at California sites. The final step of the assignment is a short research proposal for a future study to fill gaps in the vegetation and climate record over the past 10,000 years.

Task Components

A. Describe how the 2010 monthly climate data at each location compare to the longer-term 20-year averages. Averages can be looked up by city here: http://www.usclimatedata.com.

B. Using the 2010 climate data from four stations in California, make a climatograph for each location. Climatographs use both the right and left y-axes. Total monthly precipitation is usually graphed as bars, with the righthand y-axis as reference. Average temperature is plotted as dots with a connecting line, with the lefthand y-axis for reference. The attached worksheet can be used to plot climatographs by hand, or you can use spreadsheet/graphing software.

C. Using Neotoma Explorer, find and evaluate California pollen records that are close to each of the four locations. See instructions/graphical organizer for how to set parameters for this search, and questions that will prompt your evaluation of these data. Consider especially the completeness and sensitivity of pollen records.

D. Determine a list of plant taxa that best track major changes in the amount of available precipitation. Use your knowledge from pollen records you evaluated, and information about the present-day distributions and favorable conditions of these taxa from CalFlora.

E. Explain how climate has changed over the past 10,000 years in California, citing evidence from the pollen records you evaluated and what you know about the environmental tolerances of key plants. Include descriptions of any geographical differences.

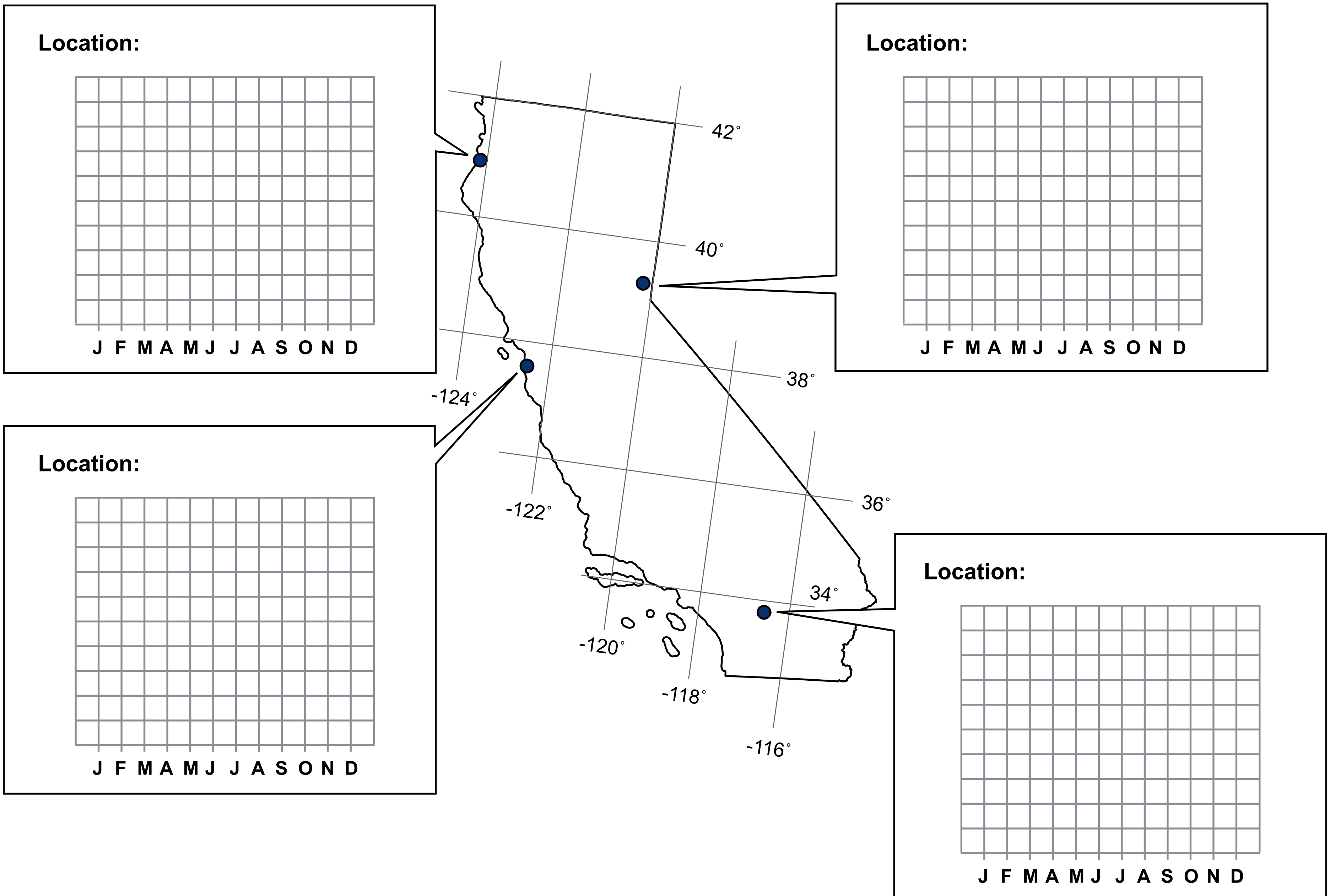
F. Write a short proposal describing where you would take a core for a potential fossil pollen study. Defend how this would address the gaps and limitations you observed in California's current fossil pollen record.

Climate Data: Monthly average 2010 temperature and precipitation data from select California stations.

City/Station	**San Francisco Airport**		**Truckee**		**Eureka**		**Palm Springs**	
Elevation	2 m		1775 m		61 m		128 m	
Coordinates	37.658˚N, 122.438˚W		39.333˚N, 120.173˚W		40.978˚N, 124.109˚W		33.828˚N, 116.505˚W	
Monthly Average Data	**Temp. (˚F)**	**Precip. (in)**	**Temp (˚F)**	**Precip. (in)**	**Temp. (˚F)**	**Precip. (in)**	**Temp. (˚F)**	**Precip. (in)**
January	50.3	4.19	27.8	5.14	47.0	8.23	57.5	1.00
February	52.9	4.06	30.0	4.98	47.2	6.55	60.3	1.03
March	54.9	2.96	34.8	4.35	47.8	6.28	65.7	0.61
April	56.9	1.29	39.7	2.16	48.8	4.36	70.9	0.11
May	59.6	0.47	47.5	1.30	51.7	2.69	79.1	0.13
June	62.2	0.11	54.9	0.73	54.0	1.34	86.5	0.06
July	63.7	0	61.7	0.28	56.0	0.29	92.3	0.25
August	64.5	0.04	61.0	0.43	56.6	0.42	91.8	0.34
September	64.7	0.17	54.5	0.87	55.2	0.95	86.4	0.36
October	61.8	0.95	45.3	1.82	53.2	2.87	75.7	0.44
November	55.8	2.38	34.8	3.83	49.3	6.73	64.4	0.53
December	50.6	4.03	27.6	5.35	46.4	8.44	55.7	0.88
Annual Total:		*20.65*		*31.24*		*49.15*		*5.74*

Source: NOAA National Centers for Environmental Information

B. California Climatographs Worksheet



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Neotoma Explorer - Graphic Organizer for observations on California pollen data

Instructions for loading Neotoma Explorer and California pollen sites:

1. Navigate to http://www.neotomadb.org and click “Explorer” button
2. click “Advanced” search option
3. select “pollen” for Dataset type
4. expand “Time.” Enter 10000 to 0 as “Age range” and select “intersects result age range”
5. expand “Space” and select “search by geopolitical unit”
   - select “United States” for “Country” and “California” for “State/Prov”
6. click “Search” button

Instructions for exploring individual sites and loading its pollen diagram:

1. zoom into map
2. click on site to view box with “Site ID” and information
3. hover cursor over to the right of site hyperlink and click on eye icon (Figure 1) to expand site information
4. select “Diagram” tab from top of pop-up box, then “Draw” in left-hand column (Figure 2) to see pollen diagram
5. close Site ID pop-up box when ready to explore other sites

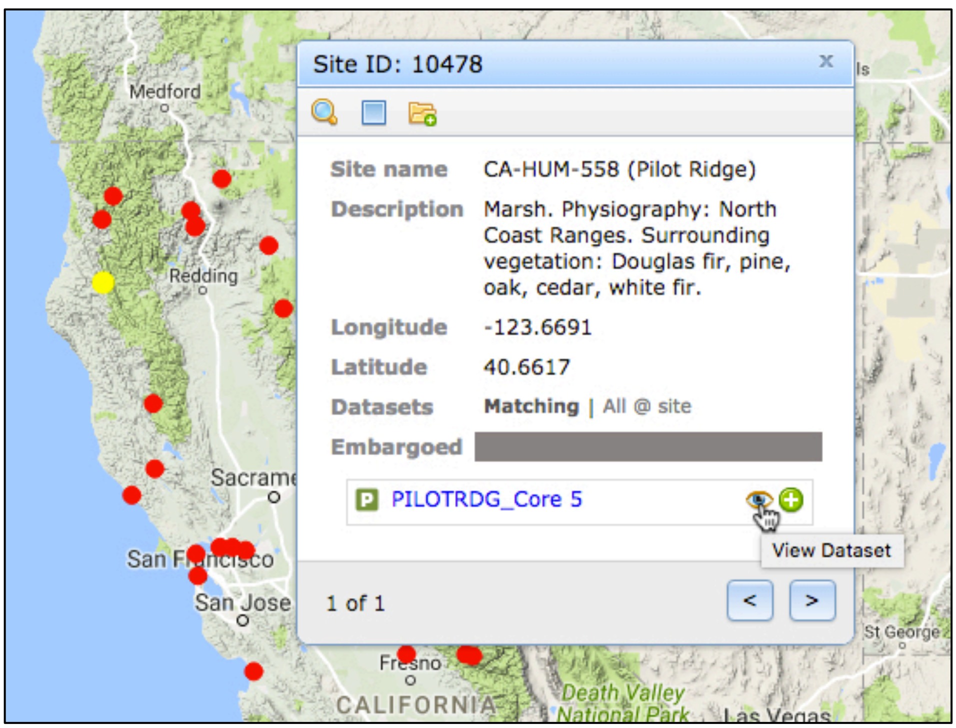

Figure 1. After selecting site, select “eye” icon to view dataset and pollen diagram.

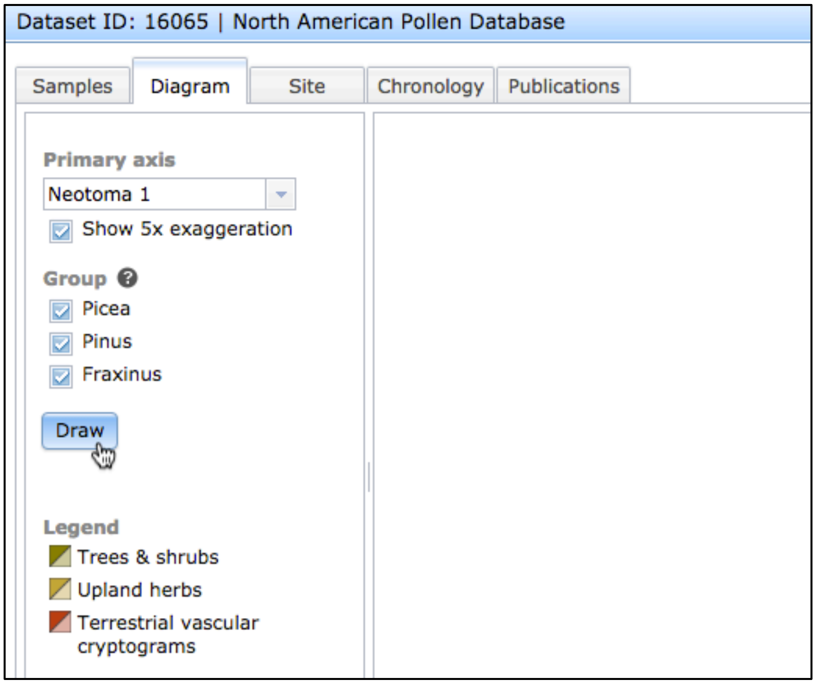

Figure 2. Select “Diagram” tab and “Draw” button to see pollen diagram

Task component C asks that you find and evaluate California pollen records close to each of the four locations in components A – B over the past 10,000 years. The attached template may be used to organize your notes as you explore sites in Neotoma.

Some things to consider in your evaluation:

- Can you find pollen records close to the location of the climate station from parts A – B? How far away from the site do you need to look to find records? Do you think there are subtle (or major) climate differences at the sites with higher-quality records, compared to the data station?
- Look at the age of sites. How complete are the available records in covering the past 10,000 years?
- What taxa in the pollen diagrams change the most? How (i.e. decrease, increase) and when do changes occur?
- Are there certain locations (e.g. desert, mountains, northern California, southern California, coast, inland) where the completeness, sensitivity, and number of pollen records available seem to be the best? Where are records limited?

Task Component C Graphic Organizer

Pollen records in coastal Northern California (**Eureka, CA**)
Observations:
Pollen records in coastal north-central California (**San Francisco Airport**)
Observations:
Pollen records in Sierra Nevada mountains (**Truckee, CA**)
Observations:
Pollen records from inland Southern California (**Palm Springs, CA**)
Observations:

Task Component D: CalFlora – instructions for navigation and graphic organizer

1. Navigate to http://www.calflora.org
2. Enter the Latin name of a plant taxa you determined as sensitive to change in task component C, select "status: native to California" and search
3. If search results are too broad/numerous, search again and change "community" selections from "any" to 1 or 2 plant communities you most expect to find at that location
4. Explore the plants in your search results:
    - click on "name" to see a map of its modern-day distribution
    - scroll to page bottom and click "Location Suitability" to see the plant's environmental tolerances
5. Plant taxa at the Family and Genus rank may return several results. Select a few species, and compare their environmental tolerances.

Notes on sensitive plant taxa, their rank, and environmental tolerances:

Scientific name	**Rank (e.g. Family, Genus, Species)**	**Observations/Notes from CalFlora**

CalFlora notes, cont.

Scientific name	**Rank (e.g. Family, Genus, Species)**	**Observations/Notes from CalFlora**

Make your final list of most-sensitive taxa in California fossil pollen record on a separate sheet.