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A Visual Guide and Morphometric Analysis of Leaf Shapes of Common Shrubs of the Santa Ana Mountains of Southern California

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The Mediterranean climate of Southern California largely supports shrub dominated communities such as the chaparral (Fig. 1). Many of these shrubs have similar looking sclerophyllous leaves that make it difficult to identify species when the plants are not in flower. I created a visual guide to vegetative characteristics of common shrubs in the Santa Ana Mountains to help identify these shrubs for a vascular plant flora checklist (Fig. 2). The use of images alongside key characteristics can provide a way to quickly identify plants in the field[2].

Figure 1. Map of the distribution of chaparral in California from *Introduction to California Chaparral*[1]. The green shaded areas indicate chaparral which may be relatively larger than actual chaparral area due to inclusion of associated plant communities.

In addition to the visual guide, I compared leaf shapes to determine if shrub species found on the coast have different leaf shapes compared to closely-related species found in the chaparral. During the winter, Southern California coastal areas tend to be 4˚C warmer compared to inland areas, whereas inland areas tend to be 14˚C warmer during the summer[3]. These varying temperatures and other environmental differences between the coast and chaparral can affect growth rates of plants and select for smaller leaf sizes in chaparral shrubs[4,11]. I tested if the leaf blade shape was also different.

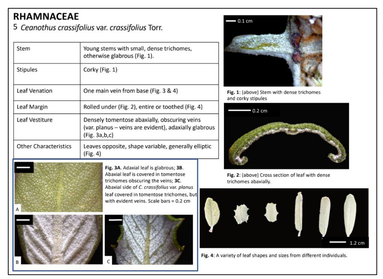

Figure 2. Example page of the visual guide. Scan the QR code to access a pdf of the guide.

Scan for a pdf

Fresh leaves from flowering plants were collected in the field (permit from the Cleveland National Forest to A. Fisher) and leaves from herbarium specimens from CCH2[7] (cch2.org) specimen images (LOB, RSA-POM) were used for the visual guide. The plants were identified to species using the *Jepson eFlora*[5] and *Wildflowers of Orange County and the Santa Ana Mountains*[6]. Leaf and stem characteristics were photographed with a Leica EZ4W dissecting microscope and camera.

LOB specimens of Rhamnaceae were imaged using an Ortery light box, a Nikon D810, and Lightroom (Adobe) and were uploaded to CCH2[7]. Specimen images for 14 shrub species from the families Anacardiaceae, Namaceae, Rhamnaceae, and Rosaceae were downloaded from CCH2[7]. For each species, three leaves were measured on five specimens (15 leaves per species) and assigned landmark points in ImageJ[8]. 12 landmark points were assigned along the outline of the leaf: at the junction of the blade and petiole, leaf apex, and 10%, 25%, 50%, 75%, and 90% of total leaf length (Fig. 3). Leaf outlines for each species were compared to one or more closely related relatives (Table. 1).

Landmark data was uploaded to MorphoJ[9] for a Principal Components Analysis (PCA) and a Discriminant Function analysis with a 1000 replicate cross validation. Species in each family predominantly found in chaparral or the Southern California coast were compared to each other in separate analyses and then the entire dataset was combined in one analysis.

Table 1. Species compared found in the chaparral and species found in coastal areas. Each species was compared to closely related species.

Family	Chaparral	Coastal
Anacardiaceae	*Rhus ovata*	*R. integrifolia, Malosma laurina*
Namaceae	*Eriodictyon crassifolium*	*Eriodictyon californicum*
Rhamnaceae	*Ceanothus crassifolius*	*C. leucodermis, C. spinosus*
Rhamnaceae	*Rhamnus ilicifolia*	*R. ilicifolia*
Rosaceae	*Cercocarpus betuloides*	*C. minutiflorus*
Rosaceae	*Prunus ilicifolia* subsp. *ilicifolia*	*P. ilicifolia* subsp. *lyonii*

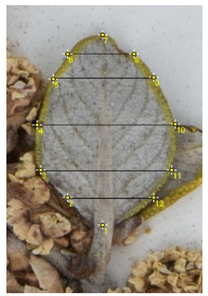

Figure 3. Landmark map of a *Ceanothus crassifolius* leaf from specimen *L. Ball 26* LOB. The same 12 landmarks were used to compare leaf shape across all species.

Figure 4. Leaf morphospace. Blue dots are individuals growing in coastal scrub and black dots are individuals growing in chaparral. The graphs were generated from axes 1 and 2 of PCAs. Wire frame graphs show that chaparral leaves tend to be narrower than leaves from coastal plants. The combined data (right) includes 13 taxa and the leaf shapes of species in these habitats are not distinct. However, the leaf shape of *Rhus ovata* in chaparral is distinct from *R. integrifolia* and *Malsoma* in coastal scrub. In *Rhamnus* we compared 10 individuals of the same species and found that growing in either chaparral or coastal habitat did not determine their leaf shape.

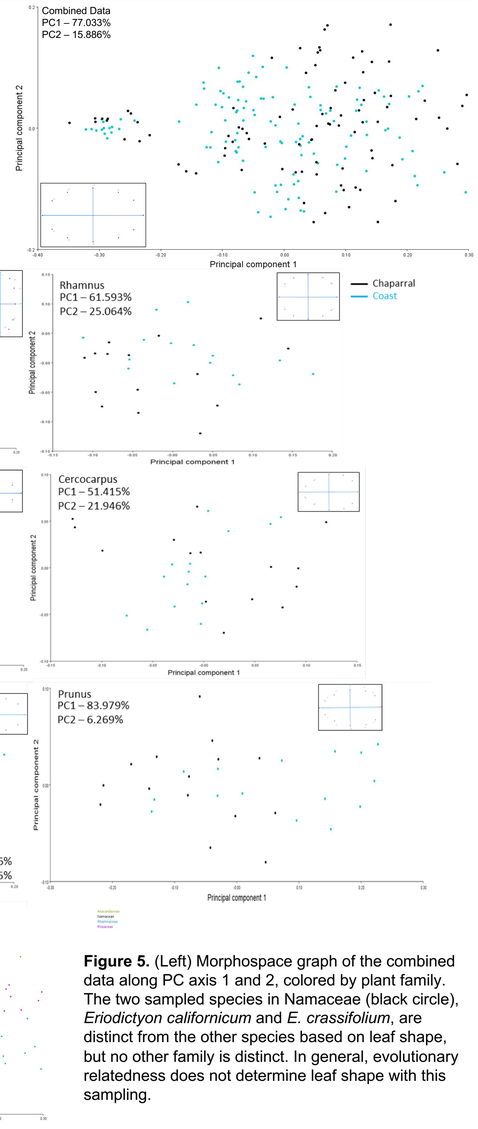

Figure 5. (Left) Morphospace graph of the combined data along PC axis 1 and 2, colored by plant family. The two sampled species in Namaceae (black circle), *Eriodictyon californicum* and *E. crassifolium*, are distinct from the other species based on leaf shape, but no other family is distinct. In general, evolutionary relatedness does not determine leaf shape with this sampling.

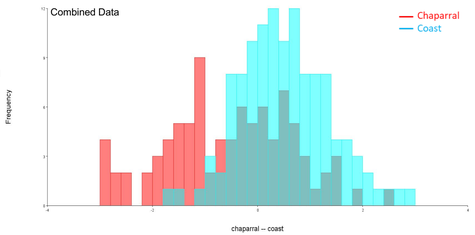

Figure 6. (Right) Discriminant Function analysis of the 13 taxa grouped by habitat. Many of the leaf shapes overlap, but chaparral plants (red) tend to have narrower leaves (towards 0), whereas coastal plants (blue) tend to have wider leaves.

Coastal and chaparral leaf shapes

A morphometric analysis of the leaf outline of 13 shrubs from Southern California found that species predominantly found in chaparral tend to have narrower leaves than species predominantly found in coastal scrub. The leaf shapes of species in these communities were not distinct (Fig. 4), with the exception of the three Anacardiaceae species sampled (*Rhus* and *Malsoma*) that have distinct groups of chaparral and coastal scrub leaf shapes (Fig. 4). An analysis of the combined data did not show a distinction in leaf shape in plants from the two habitats, but the wire frame graphs show that in most cases the chaparral plants have narrower leaves than coastal plants (Fig. 4). Leaf shapes also did not necessarily cluster into groups according to plant families (Fig. 5), with the exception of Namaceae. *Eriodictyon* sampled here have linear leaves, whereas the other families sampled have elliptic or ovate leaves.

Leaves from chaparral species tend to have smaller leaf sizes[10] and here I show that chaparral species also tend to have narrower leaves, whereas coastal leaves tend to be wider (Fig. 4). However, principal coordinate analyses for each family and the combined data, and the Discriminant Function analysis do not support that there is a distinct chaparral leaf "type." We tested if evolutionary relationships are more important than habitat in determining leaf shape, but found that only the Namaceae were distinct (Fig. 5).

Smaller, narrower leaves may make chaparral shrubs better able to tolerate higher temperatures during drought conditions[4]. Coastal scrub and chaparral habitats are both subject to the Mediterranean climate of Southern California, but chaparral experiences drier summers and more frequent fires. During these conditions, plants may try to reduce water loss by closing their stomata, but that can increase the risk of overheating as they are no longer evaporative cooling. Larger leaf surfaces are more likely to over heat compared to smaller leaves and this may favor a narrower leaf shape.

Paleoclimate data suggests that the Mediterranean climate in California is rather recent, arising around 5 mya, while paleobotanical data suggests that chaparral adapted plants appeared much earlier[10]. The chaparral species we examined most likely evolved from an ancestor already adapted to drought.

To further expand this analysis, more chaparral and coastal scrub species could be included. Also, different traits may need to be examined, such as leaf thickness or leaf vein density.

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Acknowledgements

This work was supported by a National Science Foundation grant #1802192 to A. Fisher and the Consortium of California Herbaria. Collections were done under a collection permit given to A. Fisher by the Cleveland National Forest.