

Floristic discoveries in mid-elevation sky islands and surrounding valleys in the northern Mojave Desert, Inyo County, California

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ABSTRACT—The Nopah Range and Resting Spring Range in Inyo County, California are mid-elevation sky islands in the northern Mojave Desert that are composed primarily of calcareous rock. These mountain ranges have seen very little botanical documentation; however, calcareous soils are known to hold several rare and endemic plant species. Surrounding these mountains are valleys that contain exceptional water resources; these isolated wetlands or “hydrological islands” are also rich in endemic plant species. The 1,710 km² (660 mi²) study site is located in southeastern Inyo County at the intersection of two major floristic provinces, the Mojave Desert and the Great Basin Desert. This study presents preliminary findings including notable floristic diversity within the Nopah and Resting Spring Ranges, and the surrounding valleys. We include a summary of disjunct populations, species at the edge of their range, and rare and endemic taxa native to the region.

Introduction

Desert sky islands are known to hold increased species richness and endemism compared to neighboring lowlands (Kraft 2010). These islands exhibit topographic relief and heterogeneity that provide remarkable conditions for isolation and subsequent divergence, creating a landscape rich in endemic species. Variable environmental conditions along the elevation profile allow species ranges to expand or contract through time in shifting climates, creating opportunities for isolated refugia which provide a rich source of diversity in isolated habitats such as mountain ranges and wetlands (Millar 2016). The flora of the California deserts is remarkable, with an estimated 2,500 native vascular plant taxa documented in the region (André 2014). However, many regions in the Mojave Desert lack basic botanical documentation due to a lack of access (large areas occur in designated wilderness and do not have road or trail access) and rugged terrain. Issues of access have hampered botanists through time to thoroughly document plant diversity via specimen-based studies, leaving this region relatively understudied and under-documented compared to the rest of the state (Taylor 2014).

The study of biodiversity depends upon the presence of verifiable research collections housed in museums (e.g. herbaria; Bebbler et al 2010). Thus, specimen-based research such as floristic studies form the foundation for understanding plant diversity. Floristic research has the objective of cataloging plant diversity through space and time, and brings to bear knowledge of species distributions and habitats. Despite the wealth of botanical

expertise, tools, and resources in California, much of the Mojave Desert remains poorly documented (CCH1 2019, Jepson eflora 2019, Taylor 2014). Specimen-based floristic research is especially important in regions with high plant diversity such as western North America, where rates of plant species discovery remain continuous (Ertter 2000). California’s deserts are particularly fertile ground in this respect, as the rate of discovery of new plant taxa outpaces the rate of discovery for the entire state (André 2014).

The Nopah Range and Resting Spring Range of the northern Mojave Desert in Inyo County, California are mid-elevation sky islands composed primarily of calcareous rock. These mountain ranges have seen very little botanical documentation; however, calcareous soils are known to hold several rare and endemic plant species. Higher elevation sky islands such as the Kingston Range and the Clark Mountain Range in nearby San Bernardino County have been relatively well-studied, but mid-elevation mountain ranges in the Mojave Desert with high elevations that range between 1,520 to 1,980 m (5,000 to 6,500 ft) have had little to no formal botanical documentation. The term “sky-island” was originally coined to describe forested mountains that are surrounded by a desert sea, and it was first applied to high altitude mountains of southern Arizona (Heald 1967). The term has since been extended across the arid southwest to described isolated high altitude mountains with forested peaks (Kraft 2010, Reimann & Ezcurra 2009). Here we modify the term and extend it to include mid-elevation mountains that lack a forested canopy, but instead are dominated by shrub-lands composed of plant species



Figure 1. Map of the study area. The study area is outlined and prominent physical features are labeled.

associated with mid-elevation bands; hence the term “mid-elevation sky island”.

This study outlines preliminary findings based on recent floristic expeditions in the Nopah Range and Resting Spring Range and surrounding valleys in the Amargosa River Watershed. The study site sits at the intersection of two major floristic provinces, the Mojave Desert and the Great Basin Desert, and also the boundary between California and Nevada. As such, a botanical study in this region will contribute to our understanding of these two major desert regions, fill in gaps for plant species that occur at mid-elevations across a vast desert archipelago, and contribute to our knowledge of plant species distributions within California and Nevada.

Physical setting of the study area

The Nopah Range, Resting Spring Range and surrounding valleys are located in southeastern Inyo County, California. The study site is 1,710

km² (660 mi²) in area and encompasses the entire Nopah Range and Resting Spring Range and portions of the Lower Amargosa River Valley, California Valley, Chicago Valley, Pahrump Valley, Stewart Valley, and Tecopa Basin within the state of California (Fig. 1). The Nopah Range is underlain primarily by limestone rocks of Cambrian through Pennsylvanian age (570 to 290 million years before the present), and is characterized by deep canyons, steep precipices, long narrow ridgelines, and extremely rugged topography (Armstrong et al. 1987; Fig. 2). In contrast, the Resting Spring Range is underlain predominantly by Late Proterozoic sedimentary rocks and displays less rugged

topography (Fig. 3). Some volcanic rock is present in both ranges (Armstrong et al. 1987). The intervening valleys contain alluvial deposits from the surrounding mountains and fluvial conglomerate and sandstone, along with clays deposited in playas, marshlands, and alkali meadows. An extensive carbonate-rock aquifer feeds isolated wetlands



Figure 2. Unnamed canyon on the north side of the Nopah Range showing rugged topography.



Figure 3. Looking northwest at Stewart Point in the Resting Spring Range.

in the region (Belcher et al. 2019). Elevation in the study area ranges from 420 m (1,375 ft) in the Tecopa Basin to 1,949 m (6,394 ft) at Nopah Point in the Nopah Range.

Methods

Historical herbarium specimens, literature, and records from the California Natural Diversity Database (CNDDDB 2019) were reviewed prior to surveys. Historical specimens were compiled via queries of the Consortium of California Herbaria (CCH1 2019) and the SEINet data portal (SEINet 2019). Botanical surveys were conducted between April 2016 and January 2019. General floristic surveys focused on assessing all habitat types (e.g. wetlands, playas, upland slopes and alluvial bajadas), occurrences of plant species with conservation status, and identifying plant species that have not been well documented in the region. Approximately 42 field days have been spent surveying the study site and more than 200 herbarium collections have been made thus far. Plant identifications were made using several references, including the Jepson eflora (eds., 2019), Flora of North America (2019), and reference specimens at the Rancho Santa Ana Botanic Garden's (RSA) herbarium. Vouchers from this study will be deposited at RSA with duplicates distributed to University of California at Riverside (UCR) and elsewhere as available.

Results

Approximately 859 historical specimens have been collected within the 1,710 km² study area; these represent 306 minimum-ranked taxa (SEINet 2019). This is in contrast with a neighboring sky island, the Kingston Range in San Bernardino County, which has well over 2,000 herbarium specimens collected within its

boundaries, documenting 544 minimum-ranked taxa (CCH1 2019, SEINet 2019). The findings reported here are preliminary for the study area because floristic expeditions are ongoing. However, upon completion of this study, we expect to contribute well over 1,500 new herbarium specimens in collections from the study site. With increased surveys and collections, we estimate that diversity in the study area will approach similar levels of floristic diversity as have been documented in the Kingston Range.

Despite poor botanical documentation, significant floristic diversity is suspected to occur within the study area. This includes plant species that are on the

leading or trailing edge of their range, significant range disjunctions, and plant species with conservation status—many of which are endemic to calcareous substrates. In California, 35% of the 1,742 rare plant species in the state occur on special substrates including calcareous types such as limestone and dolomite (Damschen et al. 2012).

Plants at the leading or trailing edge of their range

Some of the unique discoveries we have uncovered within the study area include plants at the leading or trailing edge of their distribution (Table 1). Populations at the edge of a species range may be important to species persistence, especially in periods of rapid climate change. Range-edge genotypes are thought to be better adapted to extreme climate events relative to core populations and may facilitate range expansions (Rehm et al. 2015). For example, *Ferocactus cylindraceus* (Engelm.) Orcutt (California barrel cactus) is one such species within the study area at the edge of its range (Fig. 4). It is relatively common in the Mojave and Sonoran Deserts in western North America, spanning California, Arizona, Nevada, and Utah in the U.S. and surrounding the Gulf of California in Mexico (SEINet 2019). *Ferocactus cylindraceus* is relatively abundant within the Nopah Range where it reaches the northwestern limit of its distribution, but prior to this study *F. cylindraceus* had not been formally documented by an herbarium specimen. *Cylindropuntia ramosissima* (Engelm.) F.M. Knuth (pencil cholla) is another species in the cactus family (Cactaceae) at the northern edge of its range. As a result of this study, this species was documented for the first time within the study area on the northern flank of Shadow Mountain at



Figure 4. *Ferocactus cylindraceus* (California barrel cactus) with an old rosette and stalk of *Agave utahensis* var. *eborispina* (ivory spined agave).

the north end of the Resting Spring Range. The Shadow Mountain population represents the northwestern edge of this species range.

Fendlerella utahensis (S. Watson) A. Heller (yerba desierto) in the hydrangea family (Hydrangeaceae) is relatively widespread throughout the southern Great Basin Desert and Colorado Plateau, but is only known in the Mojave Desert from mountain ranges that rise above 1,220 m (4,000 ft) in elevation with limestone outcroppings, such as the Clark Mountain Range, Last Chance Mountains, Mescal Range, Panamint Range, and White Mountains (SEINet 2019). The occurrence in the Nopah Range is the westernmost known population for this species. *Stanleya elata* M.E. Jones (Panamint prince's plume) is another species native to the Great Basin Desert that reaches the southern edge of its distribution in the Nopah Range (Table 1).

Significant range disjunctions

Atop Stewart Point, the highest peak in the Resting Spring Range (1605 m; 5269 ft), we documented several species that were previously unknown to occur in the range. Two of these records include: *Astragalus purshii* Douglas var. *tinctus* M.E. Jones (wollypod milkvetch) and *Toxicoscordion paniculatum* (Nutt.) Rydb. (foothill deathcamas). Both of these taxa are known to occur ca. 50 km (30 mi) to the east in Nevada's Spring Mountains;

however, the known distribution for these two species is patchy across the vast California desert. *Astragalus purshii* var. *tinctus* also occurs 50 km (30 mi) to the southwest in the Avawatz Mountains in San Bernardino County, and the occurrence in the Resting Spring Range fills in a geographic gap between these mid-elevation sky islands. However, *Toxicoscordion paniculatum* is a species known primarily from the Great Basin Desert; the closest known occurrence in California is in Inyo County, in the White Mountains, ca. 200 km (130 mi) to the north (CCH1 2019). Another exciting discovery from Stewart Point is the CNPS-listed *Astragalus tidentromii* (Rydb.) Clokey (Tidentrom's milkvetch). Though this species had previously been documented in the Nopah Range, it occurs in disjunct populations on the Bonanza King Formation, which is exposed in the northern Mojave Desert, including in the Resting Spring and Nopah Ranges, and in the San Bernardino Mountains, over ca. 160 km (100 mi) to the southwest.

Castela emoryi (A. Gray) Moran & Felger (Emory's crucifixion thorn) is known to occur in the vicinity of the southern Nopah Range, but has not yet been formally documented with a herbarium specimen (iNaturalist 2019). The closest occurrence is 64 km (40 mi) to the south in the Soda Mountains in San Bernardino County. It has also been documented at a similar latitude 110 km (70 mi) to the west in Trona in San Bernardino County. These disjunct occurrences mark the northern extent of the species range. *Castela emoryi* grows in relatively moist microhabitats within some of the driest parts of the Mojave and Sonoran deserts in alluvial soils and dry washes (Sanders 1998). It is a rare plant listed by the CNPS inventory of rare and endangered plants (CNPS 2019) and is has been described as "never abundant" at the locations where it is found, aside from a single large population with over 2,000 individuals in Rice Valley, Riverside County (Wiggins 1964, Bell and Herskovitz 2013).

Yabea microcarpa (Hook. & Arn.) Koso-Pol. (California hedge parsley) occurs throughout the American west from Baja California to British Columbia, primarily in coastal regions and in the eastern Mojave and Sonoran Deserts, but is not commonly found in the Mojave Desert of California. The only known records for Inyo County were documented in 1978 by Mary DeDecker in the Nopah Range, and the nearest occurrence is in the Kingston Range. Beyond the Kingston Range, the next closest occurrence in California is 110 km (70 mi) south near the Providence Mountains in the Mojave National Preserve. Interestingly, this species only occurs in three places in Nevada, the Spring Mountains, Mormon Mountains, and the Virgin Mountains, but it is much more common in Arizona, including on the Arizona Strip north of the Colorado River, which is dominated by the flora of the Mojave Desert (SEINet 2019).



Figure 5. *Agave utahensis* var. *eborispina* (ivory spined agave) growing from a limestone rock outcrop with *Sclerocactus johnsonii* (Johnson's fishhook cactus) and *Echinocereus engelmannii* (Engelmann's hedgehog cactus).

Rare and endemic plant species

The Nopah and Resting Spring Ranges harbor many interesting plants endemic to the mountains of the Mojave Desert (Table 1). The rare and endemic species that occur in upland montane habitats are generally edaphically restricted to rocky, calcareous terrain. The most well-known is *Agave utahensis* var. *eborispina* (Hester) Breitung (ivory spined agave) which is endemic to the Nopah and Resting Spring Ranges in California and also occurs in isolated limestone ranges in southern Nevada (SEInet 2019; Fig. 5). Prior to this study, it was only known from the Nopah Range in California, but during a floristic expedition in 2018 we documented it near the summit of Stewart Point in the Resting Spring Range, thereby extending its known range. Though this species is considered rare due to its extremely restricted distribution, the ridges of these mountains harbor abundant populations of this charismatic plant species.

Another rare plant, *Arctomecon merriamii* Coville (white bear poppy), occurs in scattered populations in the northern Mojave Desert from Death Valley to southeastern Nevada. The closest known occurrence of this species outside of the study area is 55 km (35 mi) southeast in the Clark Mountain Range (CCH1 2019). This species is scarcely documented within the study area and we expect to document many more occurrences as a part of ongoing floristic research. Several previously undocumented occurrences have been identified as a part of this study in 2018 and 2019.

Hedeoma nana (Torr.) Briq. var. *californica* W. S. Stewart (California false pennyroyal) is distributed in

the mountains of the Mojave Desert in Arizona, California, and Nevada (Fig. 6). This species is most abundant in California, where it is restricted to Inyo and San Bernardino counties. It has only been collected 11 times in Nevada and three times in Arizona. This study documented this species for the first time in the Resting Spring Range. Occurrences in the Nopah and Resting Spring Ranges represent the northwestern edge of its distribution. *Penstemon stephensii* Brandegee (Stephens' penstemon) is endemic to California and is limited to only five desert ranges including the Granite Mountains, Kingston Range, Nopah Range, Old Woman Mountains, and Providence Mountains. The occurrences within the study site are the northernmost extent of this pink-flowered herbaceous species.

The associated wetlands of the Lower Amargosa River Valley, California Valley, Chicago Valley, Pahrump Valley, Stewart Valley, and Tecopa Basin include springs, seeps, river channels, alkali meadows, and playas. The exceptional water resources available in these habitats provide unique opportunities for isolated wetland species to occur in the vast arid region of the Mojave Desert. Most of the wetland species are thought to be relicts that have persisted in this region from a wetter historical climate; their continued persistence is attributed to the availability of perennial water that is associated with an extensive groundwater basin (USFWS 1990, Belcher 2019). Rare and endemic



Figure 6. *Hedeoma nana* subsp. *californica* (California false pennyroyal) in flower in the Resting Spring Range.

Table 1. Notable plant populations documented within the study area including disjunct populations, species at the edge of their range, and select rare and endemic taxa native to the region.

Family	Taxon	Specimen Record	Category
Agavaceae	<i>Agave utahensis</i> var. <i>eborispina</i>	Fraga 6146 (RSA)	Rare Plant
Apiaceae	<i>Yabea microcarpa</i>	DeDecker 4560 (RSA)	Disjunction
Asteraceae	<i>Almutaster pauciflorus</i>	Fraga 6160 (RSA)	Rare Plant
Asteraceae	<i>Crepis runcinata</i>	Kerr s.n. (CAS)	Rare Plant
Asteraceae	<i>Ericameria albida</i>	Fraga ?? (RSA)	Rare Plant
Brassicaceae	<i>Stanleya elata</i>	Andre 14318 (UCR)	Range edge
Cactaceae	<i>Cylindropuntia ramosissima</i>	inaturalist.org/observations/18911718	Range edge
Cactaceae	<i>Ferocactus cylindraceus</i>	inaturalist.org/observations/11815710	Range edge
Cleomaceae	<i>Cleomella brevipes</i>	Fraga 3768 (RSA)	Rare Plant
Cyperaceae	<i>Cladium californicum</i>	Fraga 5974 (RSA)	Rare Plant
Fabaceae	<i>Astragalus purshii</i>	Fraga 6149 (RSA)	Disjunction
Fabaceae	<i>Astragalus tidestromii</i>	Sanders 39143 (RSA)	Disjunction
Lamiaceae	<i>Hedeoma nana</i> var. <i>californica</i>	Fraga 6154 (RSA)	Rare Plant
Melanthiaceae	<i>Toxicoscordion paniculatum</i>	Fraga 6153 (RSA)	Disjunction
Orobanchaceae	<i>Chloropyron tecopense</i>	Fraga 6192 (RSA)	Rare Plant
Papaveraceae	<i>Arctomecon merriamii</i>	Beatley 12165 (RENO)	Rare Plant
Plantaginaceae	<i>Penstemon stephensii</i>	DeDecker 4258 (RSA)	Rare Plant
Simaroubaceae	<i>Castela emoryi</i>	inaturalist.org/observations/10393569	Disjunction/Rare Plant

species associated with the Amargosa River Valley that rely on these perennially wet habitats include: *Almutaster pauciflorus* (Nutt.) Á. Löve & D. Löve (alkali marsh aster), *Chloropyron tecopense* (Munz & J. C. Roos) Tank & J. M. Egger (Tecopa bird's beak), *Cladium californicum* (S. Watson) O'Neill (California sawgrass), *Cleomella brevipes* S. Watson (short-pedicelled cleomella), *Crepis runcinata* (A. James) Torr. & A. Gray (fiddleleaf hawksbeard), *Ericameria albida* (M. E. Jones ex A. Gray) L. C. Anderson (white flowered rabbit brush), *Euphrosyne acerosa* (Nutt.) Panero (copperwort), *Fimbristylis thermalis* S. Watson (hot springs fimbristylis), *Grindelia fraxinipratensis* Reveal & Beatley (Ash Meadows gumplant), *Juncus cooperi* Engelm. (Cooper's rush), and *Nitrophila mohavensis* Munz & Roos (Amargosa niterwort; CNPS 2019; Table 1). These species typically flower in the heat of the summer between the months of May and September. Annual species that occur in seasonal wetland habitat like playas and alkali flats include: *Atriplex argentea* Nutt. var. *longitrichoma* (Stutz & G.L. Chu & S.C. Sand.) S.L. Welsh (Pahrump orache), *Eriogonum bifurcatum* Reveal (Pahrump Valley buckwheat), and *Phacelia parishii* A. Gray (Parish's phacelia). These species flower in the early spring between the months of February and May. Threats to the rare and endemic plant species of wetland habitats in the surrounding valleys include agricultural development, hydrological alteration, climate change, proliferation of invasive species, mineral mining, off highway vehicle

activity, habitat degradation, and trampling by horses (USFWS 2007a, USFWS 2007b).

Conclusion

Sky islands and isolated wetlands floras provide a link between the past, present, and future by supporting refugial populations that were once widespread and may serve as future sources of diversity under changing environmental conditions. In this study we have outlined several examples of notable populations in the Nopah and Resting Spring Ranges and the surrounding valleys, including species at the edge of their range such as leading or trailing edge populations, disjunct populations across patchy habitat, and endemic species that are edaphically restricted (Table 1). These patterns demonstrate that the study site may facilitate survival of plant diversity under adverse conditions. As such, a systematic floristic inventory of these mid-elevation sky islands and surrounding valleys are important for conservation and land management efforts. Relative to their higher elevation counterparts (e.g. Kingston Mountains), the Nopah and Resting Spring Ranges are poorly documented and ongoing studies will improve our understanding of the region. Establishing a botanical baseline with a specimen-based study will allow managers and scientists to gauge change through time, especially with impending threats such as climate change. Despite preliminary findings of exceptional and unique plant diversity, botanists have yet to complete a comprehensive

inventory of plant species for this region. However, such inventories are in progress (Fraga in prep; Mills in prep) and will likely yield remarkable discoveries, including range extensions and increased understanding of rare plant diversity. Thorough documentation will provide important information on the distribution and patterns of plant species across the American west and will contribute to our overall knowledge of plant geography, including boundaries between floristic provinces (Great Basin and Mojave Deserts) and across state lines (California and Nevada).

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