CHAPTER FIVE

Mono and Southeastern Great Basin

The eastern fringe of California slices off a thin strand at the edge of a vast interior biome, the Great Basin. Often characterized as an immense and homogeneous sagebrush (*Artemisia* sp.) sea, this region in fact encompasses great topographic, geologic, climatic, and vegetative diversity, haunting in expansiveness of landscape, surprising in richness of hidden canyons and wetlands. Long lines of basin and range draw the eye outward to where land meets sky; wave after wave of mountain ranges pounding the sage surf. If only a slice, California is fortunate to have what it does of this Great Basin.

The crest of the Sierra Nevada defines the western hydrologic edge of the Great Basin, within which waters drain into interior basins. The entirety of the Sierra Nevada was built by similar geologic forces that created the Great Basin. The narrative for vegetation in this chapter starts with the lower montane (~2,500 m at the latitude of Mono Lake) and basin bottom environments of the eastern Sierra Nevada, and goes on to embrace the entire elevation gradients from basin to summits of the mountain ranges eastward to the California-Nevada state line. Their names sing of romance

Above: The crest of the Sierra Nevada defines the western edge of the Great Basin in central eastern California. The Mono Basin, with its crown jewel Mono Lake, exemplifies the character of the California part of this province, with expansive cold-adapted sagebrush steppe intermixed with hardy forbs and grasses.
Robert Wick

Opposite: A winter evening along Hot Creek, with rubber rabbitbrush and sagebrush spread over rolling hills of the Long Valley Caldera.
Jeff Bisbee

*The great height of the Sierra Nevada (background) creates a rainshadow effect on lands to the east, leaving the Great Basin much drier than the California floristic province. Both the basin floors, such as the Owens Valley south of Bishop, and the higher slopes, such as the White and Inyo Mountains, maintain an arid character, and support dry-adapted plants such as cottontop cactus (*Echinocactus polycephalus).
Robert Wick

and adventure: Sweetwater, Bodie, Glass, White, Inyo, Grapevine, Coso, Panamint, Amargosa, Argus, Last Chance, Funeral. Even the most recently named range of the Great Basin, the Zunamed Mountains (east of Ebbetts Pass), evokes mystery. Summits extend from 1,800 m in the smaller ranges to 4,342 m atop White Mountain Peak in the White Mountains, California's third highest mountain. Basin bottom elevations generally run higher in the north (above 1,800 m), with southern basins averaging about 1000 m. California's oldest and most important land-survey reference, the Mt. Diablo Baseline (~38° N), runs through the Mono Basin, dividing the region into north and south parts. Taken together, the landscape of this chapter, hereafter referred to as the California Great Basin, includes nearly 1.9 million ha (4.7 million ac) or 4.6% of California's land area.

The dominant climate of the California Great Basin is cool and dry (annual precipitation ranges from 52 cm in northern uplands to 11 cm in southern basins), although low basins bordering the Mojave province in the south are warmer and drier. Farther interior in the Great Basin, continental climates drive very cold winters and hot summers; the California borderlands are mostly buffered from these extremes. Despite semi-aridity, the region's climate is dominantly influenced by winter storm tracks and high pressure originating from the Pacific Ocean and then moving eastward over the Sierra Nevada. Orographic effects catalyze waves of precipitation on the west slopes, contrasting with progressively stronger rain-shadows in the lee of mountain crests. The impressive height and location of the Sierra Nevada—as the first major range downwind from Pacific storms—capture and

hold precipitation in deep snowpacks. Precipitation declines down the mountains and farther east (e.g., 70 cm annually at Tioga Pass, 35 cm in the western Mono Basin, and 13 cm in the eastern Mono Basin). Snow falls on the high peaks of the adjacent California Great Basin ranges, but in far lesser amounts than on the Sierra Nevada, leaving the lee mountains to be among the driest in the Great Basin for their latitudes.

Secondary climatic influences vary with geography and season. A common winter pattern is the Great Basin High that develops over cold central Nevada. This blocks and diverts Pacific storm tracks northward, leaving the California Great Basin dry, clear, and cold for long periods. In summer, the southern California Great Basin often receives monsoon influence from the Gulf, and convectional forces deliver an artillery of thunderstorms to the uplands throughout the region. Both result in minor amounts of summer precipitation in the mountains. Occasionally, summer storms stall over the high slopes, driving impressive flash floods down mountain canyons.

These environmental forces also shape the region's vegetation. As elsewhere in California, gradients of climate create repeating changes in vegetation across the California Great Basin. Elevation is commonly associated with changes in climate and vegetation—temperatures being on average colder with increasing altitude. This is not always the case, however, as inversions and other types of cold-air drainage—that is, where temperatures decrease as elevations decline—are common. In depressions, valley bottoms, and basins, plant communities must be able to tolerate super-cold temperatures that occasionally develop. Latitude and longitude also correspond to gradients in climate and vegetation response across the region, especially in regard to rain shadow and eastward effects. The degrees of latitude (> 4) spanned by the California Great Basin weave a tapestry of vegetation diversity from north to south. Northern communities align more with cold shrub- and forest types, while southern communities border warm deserts and support dry scrublands. Finally, changes in substrate create their own repeating patterns of vegetation. In many basins, for instance, gradual changes in sediment size and salinity (often the legacy of ancient

Top: Summer convectional storms blow up frequently in the California Great Basin province, delivering welcome rainbursts during the otherwise long, dry summers, yet also igniting fires in the woodlands and sagebrush steppe.
Julie M. Evens

Above: Big sagebrush in the snow- covered Mono Basin.
Connie Millar

Above: The Racetrack in Death Valley National Park is one of the old lake beds, or playas, occupying isolated basins of the Great Basin. Todd Keeler-Wolf

*Top right: Royal penstemon (*Penstemon speciosus*) here on Freel Peak in the Carson Range, joins other showy plants that provide a riot of color to the alpine zone of the California Great Basin.*

Opposite, top: The botanically diverse Sweetwater Mountains, north of Bridgeport, contain a suite of endemic plants, as well as species hailing from the Sierra Nevada to the west and Great Basin provinces to the east. The former reflects upland connections among the ranges, which function as biogeographic corridors.

Opposite, center: Pacific alpine gold dances and shimmers on the high slopes of Ferris Canyon in the Sweetwater Mountains. Connie Millar photos

terminal lakes) can create concentric rings of vegetation. Elsewhere, exposures of substrates that impose nutrient deficiencies and toxicities to plants, such as dolomites and hydrothermally altered soils, define vegetation mosaics that can have extremely abrupt boundaries.

The California Great Basin abuts the Sierra Nevada flank at mid-low montane elevations along a broad north-south zone. As described in the Sierra Nevada chapter, bands of elevationally-adapted vegetation rise in altitude as latitude decreases, making the boundary of the Sierra Nevada and California Great Basin regions higher in the south than north. In the north, the smaller ranges east of the Sierra, such as the Sweetwater, Zunamed, Bodie Hills, and Glass Mountains, do not show strong latitudinal effect, but reflect east-west rain shadows compounded by biogeographic connections that their west slopes have with the Sierra Nevada. The latter provide access of Sierra Nevada species into these adjacent ranges, and also tend to draw storm tracks from the Sierra Nevada eastward into adjacent uplands. By contrast, the high and expansive White-Inyo Mountain chain is isolated from the Sierra Nevada by the broad, low, and deep Owens Valley, so it reflects a more interior character. Smaller ranges in the south, such as Coso, Last Chance, Funeral, and Grapevine, have vegetation affinities with southern Nevada and Mojave communities.

Alpine Herbaceous Communities

Alpine communities—those that occur above climatic treeline—clothe those mountains of the California Great Basin that rise above 3,300 m in the north and above 3,475 m in the south. These cold, arid environments are dominated primarily by herbaceous species, including many bunch grasses and sedges, although some hardy shrubs dot the landscape, especially in sheltered locations. Given the harshness of the environment, alpine species are specifically adapted to these conditions and many occur only in these elevations. Species that are widespread across elevational gradients and creep into the alpine zone are discussed later. Topography, snow accumulation pattern, and soil depth, impose a patchwork pattern of deep brilliant greens, silvery grays, and cheery yellows and pinks to the patterns of vegetation. Soggy tussock meadows alternate with exposed gravelly alpine hills, steep talus slopes, and outcrops dotted with occasional brilliant blues of sky pilot (*Polemonium eximium*), cushion

buckwheat (*Eriogonum ovalifolium*), or cut-leaved daisy (*Erigeron compositus*).

In rocky fell fields of the highest ranges, such as the White and Inyo Mountains and the Sweetwater Mountains, the charming fell-fields with California heath-goldenrod and Pacific alpine gold (*Ericameria discoidea–Hulsea algida*) sparsely vegetated alliance greet the high mountain traveler with flowers beaming vibrant hues of yellow and gold. Both species scent the thin air with distinctive and pungent aromas. California heath-goldenrod is a multi-stemmed subshrub with dense and delicate inflorescences, while Pacific alpine gold stands tall on single, erect stems. The sturdy composite floral head of the latter is showy and glows a rich, incandescent orange. While California heath-goldenrod grows commonly across rocky slopes, Pacific alpine gold seems to prefer the windiest ridge crests and most exposed alpine summits, often found grouped in cheery clusters seeming impossibly out of place amidst the harsh environment. Common co-occurring species include several buckwheats (*Eriogonum* spp.), in particular the widespread cushion buckwheat, graceful blue-flowered silverleaf phacelia (*Phacelia hastata*), delicate King's sandwort (*Arenaria kingii* ssp. *kingii*), the common sub-shrub granite prickly phlox (*Linanthus pungens*), and perennial bunch grasses such as pine needlegrass (*Achnatherum pinetorum*), squirreltail (*Elymus elymoides*), prairie junegrass (*Koeleria macrantha*), and Wheeler's bluegrass (*Poa wheeleri*).

The expansive lunaresque alpine slopes and fell fields of the Sweetwater Mountains host diverse alpine species, including many rare species endemic to California. A characteristic alliance is the cushion phlox (*Phlox pulvinata*) fell-fields, with spiny milkvetch (*Astragalus kentrophyta*), Gordon's ivesia (*Ivesia gordonii*), and white ballhead gilia (*Ipomopsis congesta*). Cushion phlox has

Left: Hardy plants adapted to cold, windy, and arid conditions of Great Basin alpine ecosystems grow in the high elevations. Here rayless shaggy fleabane (Erigeron aphanactis) *and cushion buckwheat provide bursts of color against the light soils of the Sweetwater Mountains.* Connie Millar

Above: Swathes of cushion phlox alliance along Wheeler Peak in the Sweetwater Mountains.

Opposite, top: Tufted hair grass alpine communities on Wheeler Peak of the Sweetwater Mountains often contain scattered krummholz conifers, such as whitebark pine, near upper treeline.

Opposite, bottom: Low sage-steppe communities of little sagebrush and Rothrock's sagebrush dominate alpine slopes of Great Basin mountains, here in the Cottonwood Basin of the White Mountains.
Connie Millar photos

an indescribably sweet aroma when it flowers in early summer, blanketing dry, upper slopes of the Sweetwater Mountains visually and aromatically with intoxicating beauty. Squirreltail is common in this alliance, and throughout California, where it is widespread in diverse habitats.

Tufted hair grass (*Deschampsia cespitosa*) meadows are common from sea level to high mountains, but in the California Great Basin they are restricted to the alpine zone. In the White Mountains and meadows of the Sweetwater Mountains this bunchgrass grows with forbs such as fireweeds (*Epilobium* spp.), yampah (*Perideridia parishii*), little elephant heads (*Pedicularis attollens*), and others varying by locale. Several sedges often co-occur in these meadows, including Nebraska sedge (*Carex nebrascensis*), dark alpine sedge (*C. subnigricans*), and beaked sedge (*C. utriculata*).

Alpine Shrublands

Low sage-steppe communities are widespread in the alpine zones of the California Great Basin and extend across high-elevation ridges in the White Mountains and upper slopes of the Inyo, Cottonwood, and Panamint Mountains. Little sagebrush (*Artemisia arbuscula* ssp. *arbuscula*) and Rothrock's sagebrush (*A. rothrockii*) dominate alliances of their names. They occur in areas of shallow soils, often at margins of high-elevation meadows; Rothrock's sagebrush scrub

alliance grows in soils derived from a variety of bedrock types, from granitic to carbonate-rich dolomites and limestone, as in the White and Inyo Mountains. While technically a tree species, extensive thickets of stunted (krummholz) conifers grow in the alpine zone. These include whitebark pine (*Pinus albicaulis*), the queen of krummholzing conifers, which extends above treeline in the Sweetwater and Glass Mountains, as well as clusters of wind-ravaged limber pine (*Pinus flexilis*) in the Bodie Hills and the Sweetwater, Glass, White-Inyo, and Last Chance Mountains. Bristlecone pine (*Pinus longaeva*), the other high-elevation conifer, rarely takes on a stunted form above treeline. Low thickets of shrubby aspens (*Populus tremuloides*), glowing

Top: Whitebark pine krummholz matts can extend for more than 300 m in a band above upright trees at the thermal treeline, as in Sweetwater Canyon in the Sweetwater Mountains.

Above: Limber pines growing near treeline, here in Sweetwater Canyon on the east slopes of the Sweetwater Mountains, respond to harsh conditions less by adopting krummholz form but more through stripbark growth and spiral grain, which gives trees a corkscrew appearance.
Connie Millar photos

golden in the fall, spread clonally up from subalpine meadows to surround talus slopes at even higher elevations than the bristlecone pines in McAfee Creek, Crooked Creek, and other canyons on the eastern slopes of the White Mountains.

Montane Forests

Below the alpine zone a kaleidoscope of forest, shrub, and herb communities paints the California Great Basin landscape, wherein plant communities follow preferences of topography, aspect, micro-climate, soils, competition, and gradients of moisture. Forests are the major architect of vegetation in the montane zones of the eastern Sierra Nevada and northern ranges, although they are often sparse, especially near upper and lower treelines. Comprising the greatest area of forest are conifer types, and among these, pines dominate. The most common subalpine conifer vegetation in mountain ranges of the California Great Basin is limber pine woodland, which occurs in the Bodie Hills, the Sweetwater, Glass, White-Inyo, Panamint, and Last Chance Mountains—and possibly high points elsewhere, including the Grapevine Mountains. In the eastern Sierra Nevada, limber pine occurs mostly above the elevation of the California Great Basin region, and is not documented north of Sonora Pass. Limber pine woodlands range from closed forests (less common) mixed with other species such as lodgepole pine (*Pinus contorta* ssp. *murrayana*), as in the Glass Mountains, to open sparse woodlands of scattered old-growth trees, as on the high slopes of the Sweetwater and White-Inyo Mountains. Long-lived (to 1,700 years), the limber pines' trunks often appear wizened as strips of bark commonly die back over time, and the deeply furrowed stems glow golden-red with age.

Limber pine grows with the iconic and photogenic bristlecone pine in the

highest southern ranges of the region, the White-Inyo Mountains and the Panamint Range. Bristlecone pines are widely appreciated for their longevity, and individuals have been measured living more than 4,800 years. Tree-ring scientists have deciphered eleven millennia of climate records from annual growth rings by combining live and dead tree records. Like limber pine woodlands, bristlecone pine woodlands reach into the California Great Basin from their broader distribution outside California, which includes high peaks of southern-central Nevada, the Colorado plateau, and western Rocky Mountains (including related *Pinus aristata*). In the California Great Basin these forests are most often very open woodlands, with old-growth trees separated many meters apart. In middle elevations, younger stands approach closed-canopy conditions, but never so dense as in ranges east of the state line. In the White and Inyo Mountains, bristlecone pines cleanly define substrate transitions with their capacity to grow on dolomite and limestone, which exclude many other species. In areas where carbonate soils meet sandstones and shales, for instance, the contact is revealed as an abrupt boundary dividing open bristlecone pine woodland with little to no understory on one side and dense sagebrush steppe on the other.

Whitebark pine forests are the most common subalpine forest type in high elevations of the eastern Sierra Nevada,

Above: Aspen groves follow rocky stream courses and fringe wet meadows in Great Basin mountains, as in McGee Creek.
Jeff Bisbee

Below: Bristlecone pines in the White and Inyo Mountains rarely take shrubby stature even near treeline. Their capacity to endure for more than five millennia testifies to their endurance in the cold, arid environments, as here in the Inyo Mountains.
Robert Wick

Top: Bristlecone pines growing on dolomite soils near Patriarch Grove in the White Mountains.
Jeff Bisbee

Above: Whitebark pine in the California Great Basin grows scattered on granitic knobs along the lower slopes of the Sierra Nevada, as here below Mt Dunderberg.

Right: Whitebark pine depends on Clark's nutcracker to open cones and plant the seeds.
Connie Millar photos

but the occurrence of the species in California Great Basin elevations of the Sierra Nevada is limited to admixture in forests dominated by other conifers. In several of the northern ranges, whitebark pine forests are extensive—for instance in the Zunamed, Sweetwater, and Glass Mountains, they dominate the subalpine zones and form upper treeline. In those areas, whitebark pine forests comprise clusters of trees established from seed caches of Clark's Nutcracker (*Nucifraga columbiana*), a handsome relative of the crow that plays an essential, co-adapted role in dispersal of the pine seeds.

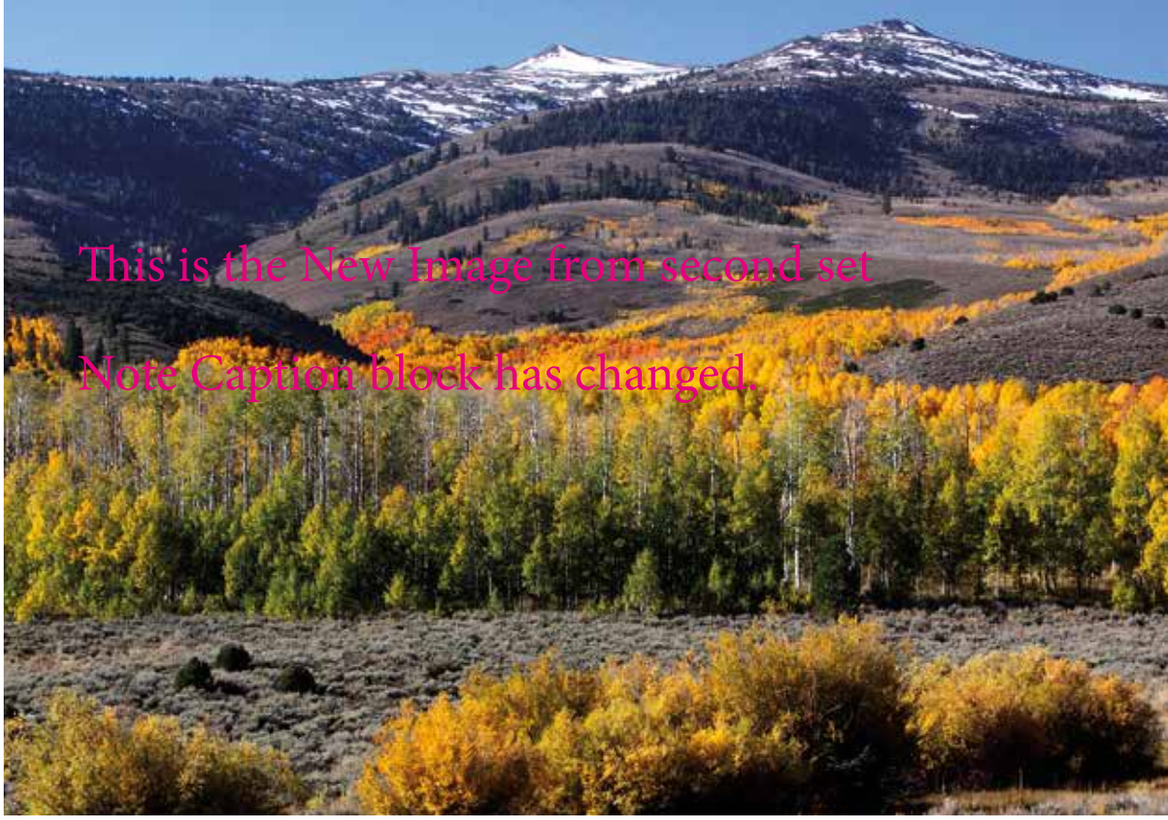
Mixed conifer forests typical of

mid-elevations on the western slope of the Sierra Nevada are less widespread along the eastern escarpment and their compositions there are simpler. In the zone of contact between the Sierra Nevada and California Great Basin regions, a patchwork of conifer forests includes alliances with varying dominances of lodgepole pine, white fir (*Abies concolor*), and Jeffrey pine (*Pinus jeffreyi*). Western white pine (*Pinus monticola*) and western juniper (*Juniperus occidentalis*) are occasional partners. These forests also grow at mid-to-upper elevations in the northern ranges of the California Great Basin, the Zunamed, Sweetwater, Bodie Hills, and Glass Mountains, where the intrepid botanist can find mountain hemlock (*Tsuga mertensiana*) as a rare component.

In these ranges, open Jeffrey pine forests are common, often monotypic, but in some cases intermixed with lodgepole pine, especially on dry, sterile, or fire-prone sites, and with white fir in more mesic locales. Jeffrey pine was prized for lumber during the early mining and settlement era of the region, so historic harvest levels were high and the largest remaining old-growth forests are in the Indiana Summit Research Natural Area, south of Mono Lake in the Glass Mountains. An interesting aspect of the Jeffrey pine forest in the southern Mono Basin are remnants of piagi rings, or trenches, surrounding the base of old-growth trees. These were dug by native Paiutes to harvest the large and nutritious larvae of the Pandora moth (*Coloradia pandora*), which undergoes irregular and episodic outbreaks in the Jeffrey pine forests. Sentinel Meadow Research Natural Area to the east along the crest of the Glass Mountains also contains fine stands of Jeffrey and lodgepole pines, mixed with ancient limber pines. The Volcanic Tablelands of Bishop tuff south of the

Top: Jeffrey pine occurs in riparian corridors of the lower eastern Sierra Nevada, here in Convict Canyon.
Jeff Bisbee

Above: Jeffrey pine in the Indiana Summit Research Natural Area, Mono Basin. This "Piagi tree" has trenches around its stem dug by early Paiute people to collect larvae from the Pandora moth.
Connie Millar



Above: Jeffrey pine woodlands near Swall Meadows above the Owens Valley often mix with big sagebrush steppe, where diverse herbs and small shrubs bloom, including lupine (Lupinus spp.)*, paintbrush* (Castilleja spp.)*, and sulphur buckwheat* (Eriogonum umbellatum)*.*
Wallace Woolfenden

Right: Aspen groves glowing in fall color along cool, moist slopes near Upper Summer Meadows in the eastern Sierra Nevada.
Rollie Rodriguez

Below: Long-eared owl (Asio otus) *in an aspen grove.*
John Sterling

Glass Mountains support old-growth, if sparser, forests of Jeffrey pine and lodgepole pine forests.

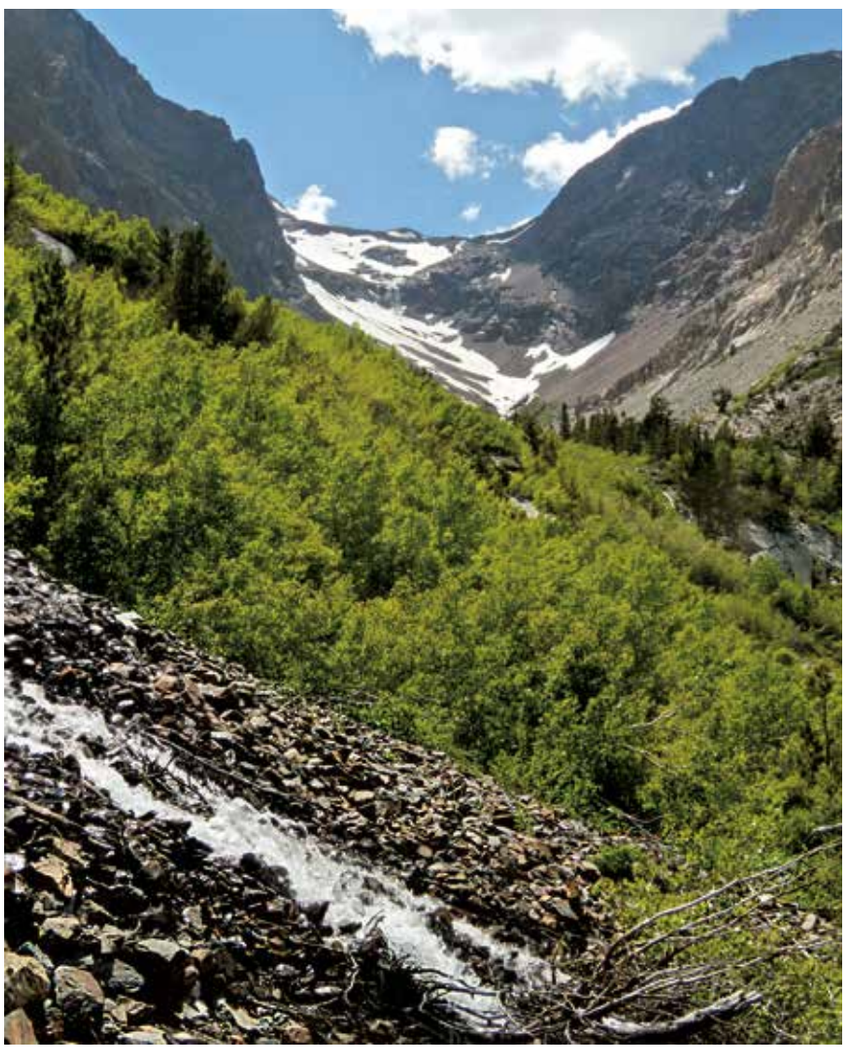
In the interior ranges south of the Glass Mountains and the Tablelands, these montane conifers are rare to absent. White fir and western white pine are absent, while Jeffrey pine, lodgepole pine, and western juniper grow only at single to a few locations each, and these in the White Mountains. Their presence there is likely relictual from past wetter, cooler climatic regimes that supported more widespread distribution of these conifers. At present their occurrence in these arid ranges is limited to alluvial and glacially derived soils where moisture is adequate.

Cool slopes with high water tables and rocky soils support extensive aspen groves along the eastern Sierra Nevada as well as in northern ranges of the California Great Basin. Where conditions are windy and exposed, these can take shrubby forms, growing as dense and stunted thickets that blaze the slopes red, orange, and yellow in autumn. Aspen groves also occur in riparian and meadow-fringe contexts, where trees are upright and have large, straight boles. The capacity of aspen to root-sprout and spread clonally is legendary, but recent genetic research suggests that seedling establishment is also common and aspen clones can be genetically diverse. Aspen groves provide important hiding cover as deer fawning habitat, and many other woodland creatures seek shelter in aspen groves.

Across the western U. S., concern for aspen decline has raised questions about its ecology, pathologies, and conservation, invoking many lines of research. Some of the change in aspen demographics is likely natural: populations are short-lived and dying, even-aged patches are readily apparent on the landscape. Aspen are also sensitive to changes in water levels, and climate dynamics tend to mobilize boundaries of groves readily. Sudden aspen decline (SAD) is of special concern, and has been linked to severe drought and specific environmental contexts (e.g., low, flat aspects) that exacerbate hot and dry conditions. SAD has been observed only in the last decade, and then mostly in the Rocky Mountains, but conservationists are watching for signs of it in California. Excess livestock grazing of young sprouts also inhibits persistence of aspen stands and is a serious conservation issue.

Mountain mahogany shrublands,

a dry, upland counterpart to aspen, extend across low-to-mid elevation slopes of the California Great Basin. Two alliances form these dense shrublands in our region. Curl leaf mountain mahogany (*Cercocarpus ledifolius*) scrub is widespread at cooler middle elevations of the eastern Sierra Nevada and in other northern ranges extending south to the White, Inyo, and Panamint mountains, where they occur on and off carbonate soils. Shrublands have expanded significantly in recent decades, creating fire risk and also serving as cover for mountain lion (*Puma concolor*), mule deer (*Odocoileus hemionus*), and Sierra Nevada bighorn sheep (*Ovis canadensis sierrae*). Conservation plans for recovery of this



Top: Evergreen curl leaf mountain mahogany forms dense stands of large shrubs or small trees along dry slopes of California Great Basin ranges, as here in Lundy Canyon of the eastern Sierra Nevada.

Right: Shrubby aspen stands provide hiding cover for hares, rabbits, young of mule deer, and bighorn sheep high in Parker Canyon. Connie Millar photos

Above: Lower slopes with curl leaf mountain mahogany scrub are found commonly along the eastside of the Sierra Nevada, as in Big Pine Canyon.
Julie M. Evens

Below: Singleleaf pinyon forms extensive woodlands throughout the low elevations of Great Basin mountains, often in pure stands, as in the southern White Mountains looking west to the Sierra Nevada.
Connie Millar

endangered bighorn sheep include burning stands of mahogany along eastern Sierra Nevada canyons.

Small leaf mountain mahogany (*C. intricatus*) scrub is found on warmer, drier, and generally lower sites. This alliance is far less abundant in the California Great Basin than curl leaf mahogany scrub, and restricted to carbonate substrates in the southeast ranges. When in bloom and backlit by the sun, both species display a shimmering lacey adornment, the delightful effect of hundreds of plume-like styles protruding from the many small flowers.

The lowest elevation conifer forests in the California Great Basin are dominated by singleleaf pinyon (*Pinus monophylla*) woodlands and, with less representation in this region, Utah juniper (*Juniperus osteosperma*) woodlands. Singleleaf pinyon and Utah juniper might be thought of as tree counterparts of sagebrush for their ubiquity across the Great Basin. Short-lived, fire-prone, and prized by native people and wildlife for large, wingless, and protein-rich seeds, singleleaf pinyon are currently considered by some range managers and ranchers as weedy and disruptive of native shrublands. Conditions of the late twentieth century, including climate change, invasive species, and historic land uses, have created a golden opportunity for singleleaf pinyon and Utah juniper establishment and woodland expansion. Along historic range margins, the forest type is rapidly expanding, and infill is

common. Concern for displacement of sagebrush steppe—the prime habitat of greater sage-grouse (*Centrocercus urophasianus*)—directly or by heightening fire risk has become a contentious conservation topic. Aggressive forest management actions are attempting to limit spread and reduce the area of these woodlands throughout the Great Basin. Pinyon-juniper woodlands grade most commonly to sagebrush and other shrub communities at their low-elevation ecotone, creating distinctive lower treelines on many California Great Basin ranges.

The extensive and rather low-diversity singleleaf pinyon and Utah juniper woodlands are sometimes displaced by scattered stands of montane conifers growing far lower than would be expected from their typical range limits. These populations occur on isolated patches of hydrothermally-altered andesitic soils. These exceptional habitats have chemical deficiencies strong enough to exclude many shrubs and herbs, yet montane conifers are able to establish secure if sparse footholds. The woodlands occur as pure or mixed stands of limber pine, Jeffrey pine, and lodgepole pine. The red-to-yellow-to-greenish soils are highly erosive, and reveal severe chemical alterations. Nutrient sterility and toxicities exclude most understory species, making these sites appear even more dramatic. To California botanists these patches might be reminiscent of other pine/cypress types occurring on isolated exposures of sterile ultramafic or sandstone derived soils in the western regions. In the California Great Basin, altered soils and exceptional pine stands occur in the northern ranges. They can be found on low slopes of the Sweetwater Mountains and Bodie Hills, where volcanism was extensive and hydrothermal activity common.

Joshua tree (*Yucca brevifolia*) woodlands, widespread in southeastern California and indicator of the lower tree limit in Mojave Desert mountains, are scattered in the California Great Basin in the Coso, Cottonwood, and Inyo Mountains. There they mix with stands of big sagebrush (*Artemisia tridentata*), shadscale (*Atriplex confertifolia*), and black brush (*Coleogyne ramosissima*). Long-

Above: Pinyon and juniper woodlands expanding into sagebrush scrub.
Connie Millar

Below: Greater sage-grouse male forages near Crowley Lake.
John Sterling

lived and fast growing, Joshua trees are conspicuous, picturesque, but relatively short-lived, with individuals persisting only 15–200 years. When stands are dense, mature trees scatter across the landscape rather than growing in clusters, which suggests that Joshua trees compete for water taken up by their dense networks of fibrous roots and stored

Above: Joshua tree woodlands, here in the Inyo Mountains, are scattered in disjunct parts of the California southern Great Basin. They can extend to mid-slope elevations in areas that do not get extensive sub-freezing temperatures.
Julie M. Evens

Left: Scattered patches of hydrothermally altered soils in the western Great Basin can support montane conifers at elevations lower than typical ranges—Jeffrey pines grow with Utah juniper and singleleaf pinyon in the Bodie Hills.
Connie Millar

between rains in the plants. Curiously, dispersal of seeds was at one time provided by the now-extinct Shasta ground sloth (*Nothrotheriops shastensis*), suggesting that adaptive range shifts under present changing climates may be difficult now that the species lacks its dispersal partner.

Montane Shrublands

While forest and woodlands are keystone habitats in California Great Basin mid-montane ecosystems, upland shrublands are extensive and diverse across lower slopes and basins, especially in the more arid south. Most common are the various sagebrush communities, and best known among them is big sagebrush shrubland alliance, which blankets plains, valley bottoms, alluvial fans, ridge slopes, and openings in forests and woodlands. Big sagebrush dominates where soils are sandy, well-drained, non-saline, and deep. The bouquet of sagebrush foliage is beloved widely as the incense of the steppe, and sage is prized by native people for curative powers. Big sagebrush shrubland is critical habitat to many signature Great Basin animals, of particular concern for greater sage-grouse and pygmy rabbit (*Brachylagus idahoensis*), both of which depend on old-growth sage stands. Many subspecies of big sagebrush exist whose identifications challenge the most determined botanist. Bitter brush (*Purshia tridentata*) often is a companion in big sagebrush communities, and, where common, bitter brush forms communities of its own, a situation typical also of rubber rabbitbrush (*Ericameria nauseosa*) and pink-flowering desert peach (*Prunus andersonii*). Mormon tea (*Ephedra viridis*), with its striking yellow-green stems, also commonly comingles with big sagebrush, as does roundleaf snowberry (*Symphoricarpos rotundifolius*), whose white berries

Top: Extensive shrublands of big sagebrush, the iconic plant of the Great Basin, form sagebrush seas from the valley basins below the singleleaf pinyon woodland zone to upland high plateaus; along County Line Hill in the White Mountains.

Above: Fire is an important component to keeping native shrublands healthy, although cheatgrass invasion is drastically altering natural fire regimes in the region.
Connie Millar photos

Above: Rubber rabbitbrush and bitter brush often mix with big sagebrush to form textured and colorful steppe, as along Mono Lake.
Connie Millar

Below: Silver sagebrush (Artemisia cana) *with Douglas' sedge* (Carex douglasii) *in a moist meadow below Convict Lake.*
Julie M. Evens

provide important forage for shrubland birds, but are poisonous to humans. Mixed in mesic swales and watered slopes of the northern uplands are montane chaparral communities of tobacco brush (*Ceanothus velutinus*), and mountain whitethorn (*C. cordulatus*), such as in the Glass and Sweetwater Mountains.

Montane Herbaceous Communities

Forests and shrublands of the montane California Great Basin zones are broken by many openings with herbaceous alliances. Often these are highly diverse wet to dry meadows, and species mixes depend on soils, elevation, and degree of moisture saturation. Sedge meadows abound in seasonally or permanently saturated soils of wet meadows, lakeshores, and creeksides at middle to subalpine elevations; these include Sierra alpine sedge (*Carex scopulorum*) turf in Sierra Nevada, Sweetwater Mountains, and Carson/Walker drainages. Adjacent to willows (e.g., *Salix exigua, S. lutea*), water sedge and lakeshore sedge (*Carex* [*aquatilis, lenticularis*]) meadows are common at many elevations of the eastern Sierra Nevada, Glass Mountains, and Sweetwater Mountains. Other wetland sedge communities are common at middle elevations in the northern California Great Basin, including Nebraska sedge (*Carex nebrascensis*) meadows and beaked sedge meadows around fens, and in seeps and swales of the Truckee, Carson, and Walker drainages and the Sweetwater Mountains.

Mimicking fields of corn to which the common name attests, tall-growing white corn lily (*Veratrum californicum*) unfurls long, corrugated, and deep-green leaves with showy clusters of white flowers tightly packed along branched floral stems. The white corn lily patches alliance occurs on wet soils

near streams, wet meadows, and forest borders. White corn lily is often associated with livestock grazing, given that high levels of alkaloids in its foliage are toxic to large mammals, as a result they are not grazed. An extract from white corn lily, cyclopamine, is being tested as an antitumor drug for humans.

Occupying diverse wetland sites, including wet meadows, fens, marshes, and sloughs, Baltic and Mexican rush (*Juncus [arcticus* ssp. *littoralis*, *mexicanus*]) marshes range from lowlands to high mountains with circumboreal distribution. Plants of Baltic rush lack leaf blades and grow up to 1 m tall. In the California Great Basin, rush marshes occur in Bridgeport Valley, and Fish Slough. Pale spike rush (*Eleocharis macrostachya*) is a matt-forming rush, with tall stems and long floral spikes. Stands are common in sloughs and slow-moving waters near Benton and Bridgeport, for instance, and in seeps and springs of the Inyo Mountains. Similarly, American bulrush (*Schoenoplectus americanus*), and California bulrush (*S. californicus*) marshes are common in many parts of California, and grow, for instance, in Fish Slough, Benton region, and springs of the Argus Range in the California Great Basin.

At mid-montane elevations of the eastern Sierra Nevada, grass communities are common. Widely distributed meadow barley (*Hordeum brachyantherum*) patches, for instance, form moist meadows, swales, and associate with wetland woody vegetation. Broad ecological tolerance gives this grassland frequent appearance in wet upland habitats of the California Great Basin. Also common and widespread across many elevations in California, curly blue grass (*Poa secunda*) grasslands extend along meadow edges and California Great Basin habitats in situations where water tables are shallow.

Above: Glass Creek Meadow in the Owens River Headwaters Wilderness has a mosaic of soil types, from saturated to dry, which are colonized respectively by sedges, grasses, and many flowering herbs.
Rollie Rodriguez

Below: White corn lilies spring up along streams and in wet meadows of the Great Basin.
Connie Millar

Top: Meadows are common in wetlands of the region, often with diverse sedge species, as in Swauger Canyon, Sweetwater Mountains.
Connie Millar

Above: Yellow-headed blackbird (Xanthocephalus xanthocephalus) *at Mono Lake.*
John Sterling

Left: Baltic rush, American bulrush, and California bulrush grow in sloughs and still waters of the low basins from Bridgeport through to Death Valley.
Wallace Woolfenden

Riparian Communities

In the cooler, more mesic northern mountains of the California Great Basin, riparian communities are mostly dominated by angiosperm trees, including, as noted above for higher elevations, aspen. Well-watered upland riparian communities are dominated by black and narrowleaf cottonwoods (*Populus trichocarpa* and *P. angustifolia*). They grow with an assortment of willows, most often sandbar willow (*Salix exigua*) and arroyo willow (*S. lasiolepis*), as well as Sierran willow (*S. eastwoodiae*) in the Carson and Walker drainages, and yellow willow (*S. lutea*) and greenleaf willow (*S. lucida* ssp. *caudata*) in the Sweetwater Mountains. Bitter cherry (*Prunus emarginata*), with its red, shiny bark and delicate white flowers, dots the edges of riparian forests.

In more arid mountains, from the Glass Mountains southward, riparian communities are commonly dominated by dense corridors of water birch (*Betula occidentalis*) thickets, whose lime-green, silver-dollar-sized leaves shimmer in the clear sunlight, illuminating the glowing orange bark of the birch stems. Buffalo berry (*Shepherdia argentea*), with leathery blue-grey leaves, is a welcome indicator of high water table in riparian, spring, or wet locations such as in the Bridgeport and Mono Basins, and scattered locations along the eastern escarpment south to about Big Pine Creek. Black willow (*Salix gooddingii*) thickets replace riparian shrubs along the upper Owens Valley and scattered locations farther south. Prior to water extraction, black willows once formed extensive riparian gallery forests along the Owens River.

Above: Narrow riparian corridors along perennial streams are almost always dominated by willow species.
Connie Millar

Below: In a water birch thicket, trees have characteristic orange-hued bark and lime-green leaves in summer.
Julie M. Evens

With newly restored water supplies, new young stands are growing in the lower reaches of the river north of Owens Lake. Along a number of low canyons in the eastern Sierra Nevada from lower Rock Creek southward, ponderosa pine (*Pinus ponderosa*) forms gallery forests that extend into Owens Valley. California black oak (*Quercus kelloggii*) often associates with this forest, giving the visitor a feeling of being in a western Sierra Nevada forest, but with an eastern California escarpment backdrop.

Above: Riparian vegetation in the wetter areas of the eastern Sierra Nevada, such as lower McGee Canyon, often contain black cottonwood as well as water birch. Together with moist lower slopes of aspen, they form a palette of gold in autumn.
John O. Sawyer

Left: Creosote bush and white bursage in the Haiwee area, south of Lone Pine.
Wallace Woolfenden

Basins, Bajadas, and Playas

In lower, drier, and more southerly reaches of the California Great Basin, sagebrush steppe is replaced by or intermingles with black sagebrush (*Artemisia nova*) scrub mixed with shadscale and other salt bush (*Atriplex* spp.). These extend broadly across low slopes, rocky hills, and bajadas, and along basin bottoms and playa edges. The wide-ranging community crosses diverse soils, including carbonates, sand, clay, and even desert pavement, occupying a spectrum of successional roles, from seral to climax. Occasionally intermingling with salt bush are scrublands dominated by spiny hop sage (*Grayia spinosa*). Like shadscale, spiny hop sage grows in diverse but warm, dry locations, ranging across mountain slopes to basin bottoms, preferring deep alluvial soils that vary from alkaline to calcareous, to sandy. Large stands of

desert holly (*Atriplex hymenelytra*) scrub occur on cinder fields and other volcanic and alkaline soils east of Owens Lake and widely through the southeastern parts of the California Great Basin.

Another shrub alliance of dry, lower slopes and upper bajadas is black brush scrub, which is common in the upper Owens drainage north of Bishop, and throughout the southern ranges of the California Great Basin. Scattered stands of Nevada joint fir (*Ephedra nevadensis*) scrub occur in the Alabama Hills above Independence and the southeastern ranges. This clonal species spreads readily and individuals live as long as 100 years. Nevada joint fir scrub stands have extremely high shrub richness, often with as many as 35 associated species within the community.

The dominant shrubland type of American low deserts, creosote bush (*Larrea tridentata*) scrub reaches from the Mojave province into the California Great Basin in low basins such as Eureka Valley and Saline Valley, and finds its northernmost extent just south of Bishop. White bursage (*Ambrosia dumosa*) is a common associate and also dominates the white bursage scrub alliance along old washes and river terraces of dry low-elevation environments, extending down fans, bajadas, and stabilized sand dunes.

In the far eastern section, white bursage scrub occurs on limestone outcrops, but usually these are on sandy or clay-rich soils. In disturbed areas adjacent to creosote bush scrub, especially those heavily grazed, needleleaf rabbitbrush (*Ericameria teretifolia*) scrub spreads from acidic to saline soils. White-flowered rabbitbrush (*Ericameria albida*) is perhaps one of the most restricted of the rabbitbrush clan, only forming stands around the edges of alkaline meadows and springs as at Fish Slough and Grapevine Springs.

Top: Spiny hop sage scrub with spring-blooming annual plants such as pincushion flower (Chaenactis fremontii) *along an intermontane valley and slope of the Last Chance Range, Death Valley National Park.*
Julie M. Evens

Above: Shadscale shrub replaces sagebrush steppe in lower drier basins and slopes of the southern Great Basin in California, here in Titus Canyon in the Grapevine Mountains of Death Valley National Park.
Wallace Woolfenden

Above: Nevada joint fir, spiny hop sage, and Anderson's boxthorn (Lycium andersonii) *intermix in diverse shrublands above Eureka Valley in the Saline Range.*
Julie M. Evens

Opposite, top: The east slopes of the Sweetwater Mountains overlook singleleaf pinyon woodlands that are recruiting into sagebrush scrub. Scattered Jeffrey pines in the middle slope dot this eastward view toward the Pine Grove Mountains and Wassuk Range in Nevada.
Connie Millar

Opposite, bottom: Non-native grasses including cheatgrass quickly invade areas after fire that previously contained lush stands of bitter brush, sagebrush, and singleleaf pinyon and other native vegetation in the eastern Sierra Nevada along Highway 89 below Monitor Pass, Mono County.
Julie M. Evens

Conservation and Restoration

Primary among conservation challenges at low-to-mid-elevations throughout the California Great Basin is the expanding tide of invasive cheatgrass and red brome (*Bromus tectorum* and *B. rubens*, respectively). In their native dry, arid-Mediterranean environments, these annual grasses evolved in the presence of grazing mammals and are highly adapted to thrive where grazing pressure is high and fire frequent. Cheatgrass has infiltrated ecosystems of the Great Basin widely over the past century, displacing native herbs and shrubs, altering natural fire regimes, and vastly transforming ecological structure and function. The main culprit in the California Great Basin is cheatgrass, which sets up a highly successful feedback cycle by converting natural fire regimes (responsible for maintaining ecosystem health in native scrub and pine woodlands) into more frequent and flashy unnatural regimes that further promote spread of cheatgrass at the expense of natives. Cheatgrass emerges, blooms, and dries early in the warm season, creating continuous fuels in otherwise discontinuous vegetation. Fires spread rapidly, eliminating native herbs, shrubs, and pines, and enhancing conditions for further cheatgrass spread. In Nevada, cheatgrass and red brome have converted vast slopes and basins of native plant communities into depleted monocultures. Control efforts in the wake of these invasions have been mostly futile. The primary management goals are to minimize entry of cheatgrass and red brome into virgin habitats, or to decelerate the rate of spread of exotics.

Another issue on center stage is spread of two native tree species, singleleaf pinyon and Utah juniper, into sagebrush steppe, which some conservationists and managers interpret as unnatural behavior catalyzed by improper land-use practices.

As mentioned before, these tree species have accelerated in their capacity to recruit, establish, and expand within the past 150 years. The resulting fragmentation and loss of intact sagebrush communities have been considered partly to blame for declining populations of native vertebrates that depend on the shrublands for habitat. In particular, greater sage-grouse is a candidate endangered species under federal law, promoting widespread management efforts to eradicate pine and juniper in areas where they are spreading. Complex interactions uncertainly related to climate change, modified fire regimes, expansion of non-native invasives, and altered hydrology have motivated a widespread yet controversial effort to remove these species where they are expanding.

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