

Chapter 4.2. Aquatic Ecosystems, Vernal Pools, and Other Unique Wetlands

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Introduction

Part of the rationale for the *Northeastern California Plateaus Bioregion Science Synthesis* is to more fully address portions of the Lassen and Modoc National Forests (hereafter the Lassen and the Modoc) representative of the Great Basin ecosystem (see Chapter 1.1, Dumroese, this synthesis, *The Northeastern California Plateaus Bioregion Science Synthesis: Background, Rationale, and Scope*). Although the Great Basin can be defined floristically, it can also be defined hydrologically as the area in the Western United States that is internally drained; in other words, precipitation does not ultimately flow to the oceans, but remains in the basin. Geologic changes since the Pleistocene (about 11,700 years before present) have led to a drying-out of the region. What was an area of extensive wetlands and marshes then is semi-desert today (Currey 1990). The recent hydrologic patterns have created unique aquatic habitats, especially vernal pools.

The wide annual fluctuation in the presence of water creates unique habitat conditions that drive unique adaptations of the flora and fauna. Many plants and animals are able to survive long dry periods, which makes them resilient to the potential changes in precipitation in the future. But many species also exist under a delicate balance of physiologic responses to environmental change (Steward et al. 2012). Trampling by livestock, vehicle passage, and trails created by foot traffic destroy refugia for quiescent and hibernating species. Vernal pools have been drained, or in some cases flooded to provide water for livestock (USFWS 2005). Fens have been drained or rechanneled, and intermittent stream channels have been used as irrigation ditches ultimately reducing, or eliminating, viable habitat for uniquely adapted creatures (Larned et al. 2010; Roche et al. 2012). While vernal pools have been fairly well described in the literature, much less is known about vernal wetlands and ecology and the importance of intermittent streams.

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Citation: Padgett, P.E. 2020. Aquatic ecosystems, vernal pools, and other unique wetlands. In: Dumroese, R.K.; Moser, W.K., eds. *Northeastern California plateaus bioregion science synthesis*. Gen. Tech. Rep. RMRS-GTR-409. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 101–111.

Other Relevant Science Syntheses

Portions of the water resources encompassed by the Lassen and the Modoc in Northeastern California have already been the focus of two recent science syntheses. The first is the *Science Synthesis to Support Socioecological Resilience in the Sierra Nevada and Southern Cascade Range* (Long et al. 2014), which has an entire section (Section 6) focused on water resources and aquatic ecosystems in the national forests of the Sierra Nevada. Chapter 6.1 – *Watershed and Stream Ecosystems* (Hunsaker et al. 2014) discusses factors that affect water quality and quantity. Chapter 6.2 – *Forested Riparian Areas* (Hunsaker and Long 2014) takes a broad look at these systems and in particular how they are affected by fire and grazing. Chapter 6.3 – *Wet Meadows* (Long and Pope 2014), focuses on grazing within herbaceous wetlands having fine-textured soils and shallow groundwater tables in summer. Chapter 6.4 – *Lakes: Recent Research and Restoration Strategies* (Pope and Long 2014) discusses the high social value of these resources, stressors on them, and ways to assess resilience and resistance; this discussion is pertinent to lakes within and adjacent to the Lassen and Modoc, such as Clear Lake (fig. 4.2.1). And, Chapter 9.5 – *Managing Forest Products for Community Benefit* (Charnley and Long 2014) includes substantial discussion about grazing in riparian areas. The second synthesis with relevance to the Lassen and the Modoc is the *Synthesis of Science to Inform Land Management within the Northwest Forest Plan Area* (Spies et al. 2018), which, in Chapter 7, lays out an aquatic conservation strategy to protect biodiversity, especially fish (Reeves et al. 2018).

Most of the information contained in those five chapters directly applies to the Modoc Plateau and the Warner Mountains of Northeastern California, including the predictions for precipitation changes due to climate change. Where the Modoc Plateau departs from the Pacific Northwest and most of the Sierra landscape is in the greater number of ephemeral and intermittent streams and wetlands and many closed-basin hydrologic systems. Much of the area is more akin to the Eastern Sierra than the Western or Northwestern parts of the range. Alkali lakes and playas (dry lakes) are a significant component of the Modoc Plateau aquatic ecosystems (Snyder 1962). “Wet meadows” are more likely to be ephemeral, where standing water is seasonal, only evident during some part of the year, or vernal wet meadows where subsurface water creates a temporary wet meadow ecosystem during the wet season, but dries out during the summer.

Lakes, Streams, and Fish

The surface drainage on the Modoc Plateau is highly variable. It ranges from highly porous volcanic rock with rapid infiltration of precipitation and snowmelt to areas where soils are highly impermeable and intermittent pools and marshes are notable features. Seeps are common and large springs are numerous (fig. 4.2.2.A), even in areas of light precipitation. The principal streams draining the Modoc Plateau are the Pit River and its tributaries, and the headwater tributaries of the Klamath River (fig. 4.2.2.B). On the Modoc, two ranger districts, the Doublehead and the Devil's Garden, generally lack hydrologic connectivity of their stream networks. There are few, if any, perennial streams, but a relatively large number of seasonally flowing streams that drain into reservoirs, stock ponds, or other depressions in the ground (swales) and act to recharge the groundwater table. Streams on the western slopes of the Warner Mountains drain to Goose Lake or the Pit River

(fig. 4.2.2.C). Streams on the eastern side are much shorter, draining into Surprise Valley, and most of these streams have no outlet. Goose Lake once drained into the north fork of the Pit River, but the lake level in modern times has been below the outlet. Interestingly, Goose Lake has a history of drying up completely, as recorded in 1852, 1926, 1929–34, and in 1992. A series of fens, meadows, and other special aquatic features occur up and down both sides of the Warner Mountain Range (Sikes et al. 2013) (fig. 4.2.2.D).

Of the nearly 2,000 miles (3,219 km) of total stream length on the Lassen, nearly two-thirds (1,442 miles [2,321 km]) are intermittent streams that do not sustain year-round flows (USDA 2010a). Lakes and streams on the Lassen are equally diverse. Eagle Lake, the second largest natural lake entirely within California, is a closed basin that lies near the junction of the three provinces, the Cascades, the Sierra Nevada, and the Great Basin. Lakes Almanor and Britton are two large reservoirs in the Feather River and Pit River



Figure 4.2.1—Like many water bodies in the Lassen and Modoc, Clear Lake within the Clear Lake National Wildlife Refuge, is a manmade reservoir originally created for water management and irrigation. Now it is a prime recreation destination (photo by Modoc National Forest).

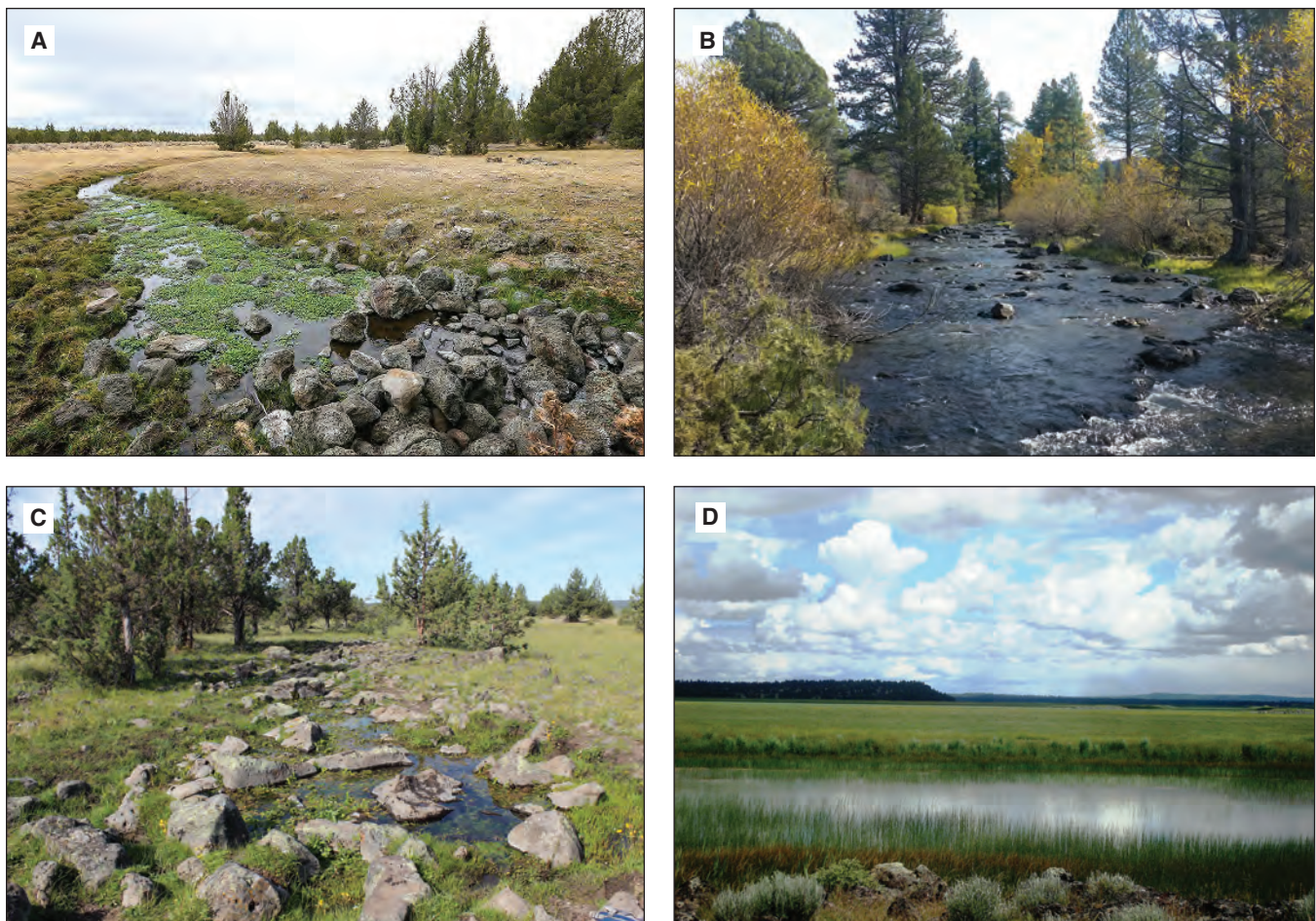


Figure 4.2.2—The Modoc Plateau has many unique aquatic features. Springs and fens are fed by ground water and support plants that may occur nowhere else. They are also magnets for wildlife. (A) Warm Valley spring (photo by Shaun Hunger, used with permission). (B) South Fork Pit River on the Modoc National Forest flows to the main-stem Pit River, which is an important segment of the Sacramento River watershed (photo by Ken Sandusky, Forest Service). (C) Goose Lake Creek (photo by Laura Snell, UC Cooperative Extension, used with permission) where the rocky landscapes keep the banks intact from livestock, wild horses, and wildlife. (D) Fairchild Swamp, a permanently wet ecosystem in the Modoc National Forest, is, like other wetlands, an important water resource for a variety of flora and fauna (photo by John Cichoski, Forest Service).

watersheds, respectively. In addition, numerous small alpine and pothole lakes dot the landscape, many located in the Caribou and Thousand Lakes Wildernesses. Lands east of the Cascades are relatively dry and drain eastward through two main streams, Pine Creek (to Eagle Lake) and the Susan River (to Honey Lake). The dry lands of the Modoc Plateau to the north drain westward through the Pit River, a tributary of the Sacramento River. In these drier areas, there are natural seasonal flowing streams and ponds as well as developed stock ponds, wildlife ponds, and small reservoirs designed to capture limited stream flow and snow runoff. Many of these ponds and reservoirs dry up each season as water slowly evaporates or percolates down through the porous substrate. The west side of the Lassen is much wetter and has many streams that flow to the

Sacramento River. These include Battle Creek, Antelope Creek, Mill Creek, Deer Creek, Butte Creek, and the North Fork of the Feather River (fig. 4.2.3).

Several fish species are endemic to the Lassen and the Modoc and two are listed as threatened or endangered species: shortnose sucker (*Chasmistes brevirostris*) and Lost River sucker (*Deltistes luxatus*). These are described in the Modoc Travel Management Plan (USDA 2010b). Additionally, two subspecies of rainbow trout—one of each forest—are of special concern (see textbox 4.2.1). The first, the Eagle Lake rainbow trout (*Oncorhynchus mykiss aquilarum*), is endemic to the Eagle Lake watershed, residing in the lake and primarily Pine Creek. The second is the Goose Lake trout (*Oncorhynchus mykiss* pop 6), which



Figure 4.2.3—Mill Creek flows from the southern slopes of Lassen Peak to the Sacramento River and supports the highest-elevation spawning areas for spring-run Chinook salmon in California (photo by John Cichoski, Forest Service).

is endemic to Goose Lake and its major tributaries (Lassen and Willow Creeks in California and the extensive Thomas Creek system and Crane Creek in Oregon), as well as to smaller streams such as Cottonwood Creek in California and several small streams in Oregon (fig. 4.2.4).

Textbox 4.2.1

“Native rainbow trout east of the Cascades are commonly called ‘redband trout’ (*Oncorhynchus mykiss* ssp.). Redband trout are a primitive form of rainbow trout and are an evolutionary intermediate between ancestral ‘cutthroat’-like species and coastal rainbow trout. Redband trout are described as inland populations of *O. mykiss*, with few morphological and meristic characters distinguishing them from coastal rainbow trout. Although there is no consensus on the classification of redband trout east of the Cascades, there is some agreement that at least two broad groups exist in Oregon: the Interior Columbia Basin redband trout and the Oregon Great Basin redband trout. In addition, redband trout in the upper Klamath Basin (e.g., Sprague and Williamson Rivers) represent a third evolutionary group within Oregon. Populations of redband trout in the Great Basin have been isolated for thousands of years and therefore evolved distinct genetic lineages (ancestries).” (USFWS 2009)



Figure 4.2.4—Goose Lake trout, an endemic species to its namesake and the Lassen and Willow Creeks on the Modoc National Forest, is a Forest Service Sensitive Species. While ongoing management efforts to improve water quality aid the species, changes in land use and implementation of water-use policies challenge this species' status (photo by Ken Sandusky, Forest Service).

Given the isolation, both strains of rainbow trout are now considered unique subpopulations and are threatened by implementation of changes in land use and water-use policy. The Goose Lake is on the northern border with Oregon, thus conservation strategies are shared between California and Oregon (see textbox 4.2.2). The lake is a closed basin, therefore it continues to increase in alkalinity and salinity. The redband trout native to Goose Lake has evolved specialized adaptations to cope with alkalinity and salinity. Conservation is largely driven by a two-State, cooperative management group, the Goose Lake Watershed Council. A Conservation Strategy was prepared in 1996, and that document (Heck et al. 2008) continues to guide conservation efforts by maintaining or improving water quality and quantity while striving to maintain a balance between competing uses such as agriculture and recreation. It also calls for protecting and increasing habitat conditions for the trout to provide spawning, resting, and foraging habitat.

The Eagle Lake redband trout are long-lived relative to other rainbows, and are considered among the hardiest of the subspecies, well-adapted to the harsher conditions of an inland lake. The population within the lake is relatively robust, but has only one remaining spawning stream—Pine Creek. The most recent report on the status of the Eagle Lake redband is in the *State of the Salmonids: Status of California's Emblematic Fishes* (Moyle et al. 2017), commissioned by California Trout. The report calls the fishery unsustainable largely because of inconsistent access to Pine Creek by spawning trout (fig. 4.2.5), and

Textbox 4.2.2

“Since 1995, conditions for Goose Lake Redband trout in California have steadily improved because large sections of Lassen Creek and other streams have increased protection from grazing due to changes in [Forest Service] allotments and otherwise been restored. These conservation measures have likely improved habitat conditions, which can benefit runs of lake fish to re-establish themselves when hydrologic conditions are favorable. Presumably, headwater populations have increased as well, thanks to better management. Recent habitat improvements in Oregon actually led to an expansion of the distribution of the species from 1995 to 2007, according to ODFW surveys (Scheerer et al. 2010).” Moyle et al. (2017)

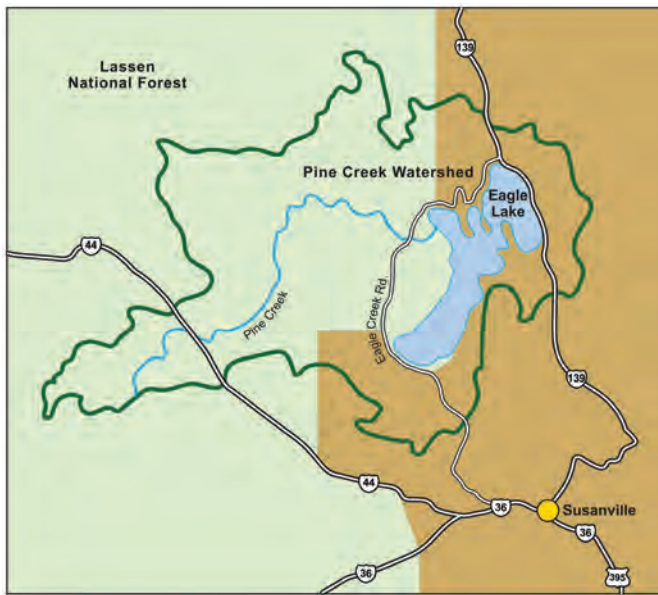


Figure 4.2.5—The Pine Creek Watershed provided critical habitat to sustain Eagle Lake redband trout, but inconsistent access to Pine Creek now requires this species to be reared in hatcheries (adapted from California Department of Fish and Wildlife 2019).

the need to rear redbands in hatcheries. As of 2017, most fish that move up into Pine Creek to spawn are trapped at a weir and artificially spawned. Eggs are hatched and fry are reared at several hatcheries in California. While this has maintained the adequate populations in the lake, without human intervention the long-term success of the subspecies is in doubt because the species is not self-sustaining. While few fish species that have been introduced over the years are able to withstand the alkalinity of the lake, the introduction of brook trout to Pine Creek in the 1930s and '40s has greatly limited the redband's reproductive success. Redband trout do not compete well with the Eastcoast native, and mature brook trout are major predators of redband fry (Moyle et al. 2017).

Vernal Pools and Other Unique Aquatic Habitat

Vernal pools are seasonal wetlands that do not follow the classic geologic successional pattern where ponds accumulate organic material over time to become wetlands that further fill in to become meadows and eventually forests. Vernal pools rarely have water sources other than precipitation, therefore no surface water inlets or outlets (fig. 4.2.6). They are formed over unusually impermeable soils and rocks which enables precipitation to accumulate during the rainy season and evaporate as the temperatures

warm. However, many of the natural processes that lead to permanent intermittent pools are not completely understood (Norwick 1991).

Vernal wet meadows have similar subsoils, but seasonal water remains below the surface. While intermittent pools and wetlands are not unique to the Lassen and the Modoc, the number and the importance of these distinctive habitat types across the landscape does require a thoughtful examination of the significance to management decisions. An estimated 80 to 90 percent of the vernal pools in the Central Valley of California have been lost to various agricultural activities such as drainage, ditching, and sub-soil disturbances (Holland 1998). On the Modoc, Holland (2006) mapped 660 vernal pools, of which more than 30 percent had some indication of hydrologic disturbance. Much of knowledge related to vernal pools has been gathered from the Central Valley complexes. While it is likely that the geomorphic processes are similar between valley and upland, or montane vernal pools, Bovee et al. (2018) suggests that there may be significant differences in the biological components and processes. Once lost, constructing functioning vernal pools de novo or restoring degraded pools is challenging (Lamers et al. 2015; Schlatter et al. 2016). Department of the Interior, U.S. Fish and Wildlife Service, signed a recovery plan for vernal pools (USFWS 2005) for California and Southern Oregon, although progress has been slow and the success rates low (Schlatter et al. 2016). Additional discussion about vernal pools from a climate change perspective can be found in



Figure 4.2.6—Vernal pools, such as this one on the west side of the Warner Mountains, occur where impermeable soil conditions allow shallow pools of water to occur, although they may dry out during summer. These unique wetlands host a variety of plants and animals, some of which depend on these features (photo Gary Nafis, used with permission).

Chapter 6.1, Wright, this synthesis, *Ecological Disturbance in the Context of a Changing Climate: Implications for Land Management in Northeastern California*.

“Swales” are a form of intermittent wetland. They may connect pools or stand alone and are generally of shorter inundation. They differ from vernal pools in that after filling from winter precipitation, the surface water slowly infiltrates into the underlying substrate rather than evaporating, as is typical of vernal features. Swales may be natural or manmade. Many infiltration ponds constructed for groundwater recharge are constructed swales.

Unlike vernal pools and swales, “fens” are wet year-round (fig. 4.2.7). They are aquatic features that are fed by groundwater seeps. Like bogs, they accumulate peat over hundreds to thousands of years. They differ from bogs, however, in that they are groundwater-dependent rather than relying on precipitation. Bogs do not occur in regions with pronounced dry seasons, such as California (Lamers et al. 2015; Sikes et al. 2013). Fens are among the most

sensitive habitat types in the Sierra Nevada Ecoregion (Sikes et al. 2013). They often contain unique assemblages of plant species and those assemblages can vary widely from fen to fen, making vegetation classification difficult (Patterson and Cooper 2007). The Warner Mountains on the Modoc are particularly rich in fens and the rare plants associated with them (Sikes et al. 2013; USDA FS 2010b, p. 138). Holland (2006) mapped 132 fens on the Modoc. Sixty fens have been identified by ground surveys on the Lassen, which represents approximately 80 percent of the total estimated in the Travel Management Plan (USDA 2010a). The Forest Service Pacific Southwest Region, in collaboration with the California Native Plant Society and many others, published the *Fen Conservation and Vegetation Assessment in the National Forests of the Sierra Nevada and Adjacent Mountains, California* in 2010 and revised in 2013 (Sikes et al. 2013). Fens are generally small geographic features (less than a hectare) and often part of larger meadow complexes. They are difficult to identify from satellite or aerial technologies (Holland



Figure 4.2.7—Fens, such as this one on the Antelope Plains of the Modoc National Forest, are important aquatic features for a variety of flora and fauna, but are also the most sensitive to degradation. Fens are supported by groundwater and often host unique plant communities. While this image shows open water, most fens are not easily detected, as water is often obscured by accumulation of peat (photo by John Cichoski, Forest Service).

2006), and can be missed, or mis-identified during land surveys (Sikes et al. 2013). Therefore, distribution, natural history, and ecology of these features is largely unknown (Chimner et al. 2010). Because they are a year-round water source in a dry climate, they are attractive to wildlife, livestock, and people. By definition, fens require decades, if not centuries, to accumulate their characteristic peat base. Hooves, tire tracks, and modification of hydraulic patterns can easily degrade fens and the associated flora and fauna. Similar to vernal water bodies, once damaged, fen restoration is difficult (Lamers et al. 2015).

Research is scant on intermittent or ephemeral streams in the Great Basin. These water features are a significant component of the aquatic resources on the Lassen and the Modoc. According to the 2011 Perennial Stream assessment (SWAMP 2011) 78 percent of the streams on the Modoc Plateau are nonperennial, and as noted earlier in this chapter, the Lassen has 1,442 miles of intermittent streams as compared to 558 miles of perennial streams (USDA 2010a). Projections for climate change suggest that the miles of intermittent streams are likely to increase with time (Larned et al. 2010; Datry et al. 2016). Similar to vernal features, the ecology of intermittent streams requires organisms to survive periods of desiccation and periods of inundation. They can also provide seasonal connectivity between more permanent aquatic features (Leigh et al. 2016). The confusion in legal classification of intermittent streams has contributed to the paucity of data and information. They do not generally fall within the network of aquatic resource rules and regulations. And while threatened, endangered, or endemic species may be associated with them, very little has been published or recorded about the flora and fauna of nonperennial waterways (Leigh et al. 2016). What has been reported regarding intermittent streams in the United States is derived from research in the Southwest. While many of the general principles undoubtedly apply, little is known about species richness for systems outside the Southwest, and the unique survival mechanics of organisms subjected to the combination of hot summer temperatures and cold winters typical of the Great Basin.

All of these hydrologic features are highlighted by unique flora and fauna, often existing nowhere else but in a single pool, or series of pools, stream reach, or montane fen (fig. 4.2.8). In vernal pools and wetlands, the flora is dominated by low-growing species of annual grasses and forbs adapted to germination and early growth under water, and completing their life cycle during the dry period. These

organisms have evolved mechanisms that allow them to remain dormant under very harsh conditions for several years if necessary, as precipitation volume varies widely from year to year, and vernal pools and wetlands may remain dry for a few years in a row before a wet winter refills the basin. These small aquatic features often contain plant and animal species that occur nowhere else, and many of which have been preserved in place for hundreds of thousands of years (Norwick 1991). In vernal pools on the Lassen, slender Orcutt (*Orcuttia tenuis*), known to occur in 22 locations, and Green's tuctoria (*Tuctoria greenei*), found in only one location, are federally listed (threatened and endangered, respectively). These two grasses also occur on the Modoc in vernal pools and vernal wet areas in the Devil's Garden Ranger District, and within ponderosa pine forests of the Big Valley Ranger District and parts of the Doublehead Ranger District. Along with these two grass species, five other plant species are listed as species of conservation concern (see definition above) in vernal pools, swales, and wetlands: disappearing monkeyflower (*Erythranthe inflatula*; syn = *Mimulus evanescens*), playa yellow phacelia (*Phacelia inundata*), Boggs Lake hedgehyssop (*Gratiola heterosepala*), profuseflower mesamint (*Pogogyne floribunda*), Red Bluff



Figure 4.2.8—Many unusual plants, such as this sundew (*Drosera anglica*) growing on the Lassen National Forest, are obligate wetland plants (photo by Craig Odegard, Forest Service).

dwarf rush (*Juncus leiospermus* var. *leiospermus*), woolly meadowfoam (*Limnanthes floccosa* ssp. *bellingeriana*), and Newberry's cinquefoil (*Potentilla newberryi*).

The threats to special aquatic habitat are two-fold: (1) surface disturbances from unmanaged livestock and wild horse grazing (Merriam et al. 2016), and off-road vehicle use (a particular problem near Redding and in forested areas of the Modoc Plateau); and (2) changing the hydrology by installing drain tile in swales and fens, or year-round flooding of vernal pools and wetlands, or using intermittent streams as irrigation ditches. It is important to note that while invasive plants have a significant impact on vernal features in other parts of the State, particularly in the Central Valley (Faist and Beals 2017), they comprise a small fraction of the plant cover in the vernal pools of the Modoc.

The effects of cattle grazing on vernal pools and wetlands is complicated (Bovee et al. 2018; Merriam et al. 2016; see also Chapter 6.1, Wright, this synthesis, *Ecological Disturbance in the Context of a Changing Climate: Implications for Land Management in Northeastern California*). While excessive trampling is destructive to some native plants, grazing has been used as a means for reducing invasive weed populations, for example (Faist and Beals 2017). However, Bovee et al. (2018) studying grazing effects in the montane vernal pools of the Modoc Plateau found that grazing had stronger effects on vernal pool specialists than on the plants considered “habitat generalists” and favored annuals over perennials (fig. 4.2.9). Much of the ongoing research on conservation of vernal pools has been focused on preservation and restoration of the endangered endemic species, slender Orcutt. Although it has been debatable whether cattle consume slender Orcutt, Merriam et al. (2016) and Bovee et al. (2018) concluded that it was unpalatable and was not eaten even when no other grasses were available. When herds are well managed by monitoring hoofprint coverage and vegetation consumption, they can effectively reduce nondesirable weedy plants and reduce litter accumulation that alters hydraulic characteristics (Marty 2015). However, that may be at the expense of some native perennial species (Merriam et al. 2016).

The effects of grazing in fens and wet meadows are similar to those found for vernal features. However, because fens do not have a dry season, the effects may be of longer duration and more intense. Understanding the effects of cattle on fens is also complicated by the tendency of fens

to be incorporated into larger meadow complexes, and the likelihood that many fens may have been lost during the early settlement years (van Diggelen et al. 2006). In many cases, the nature of “pristine” fens is difficult to establish, so the effects of grazing are studied by exclusion treatments. Merriam et al. (2017) in a study on the Plumas National Forest, demonstrated that exclusion of cattle for 8 years greatly changed the plant community composition, favoring tall, high-nutrient-demand graminoids. Much of the change in plant community structure was related to litter and biomass accumulation. Grazing can be effective in reducing the negative consequences of litter accumulation (Middleton et al. 2006).

The Lassen and the Modoc adopted Travel Management Plans (USDA 2010a, b) in 2010 designed to greatly reduce off-road vehicle traffic. Using dry riverbeds and arroyos as roads is very common in the Southwest, and most likely in the sagebrush steppe as well (Levic et al. 2008), although little was noted in any published literature.

Changes in hydrology, draining, channeling, and flooding is mostly a relic of past management activities, and does not seem to be part of current management activities. It appears that the Lassen and the Modoc are engaged in repairing past “improvements,” often attempting to identify what the original natural aquatic feature was (USDA and USDOJ 2008).

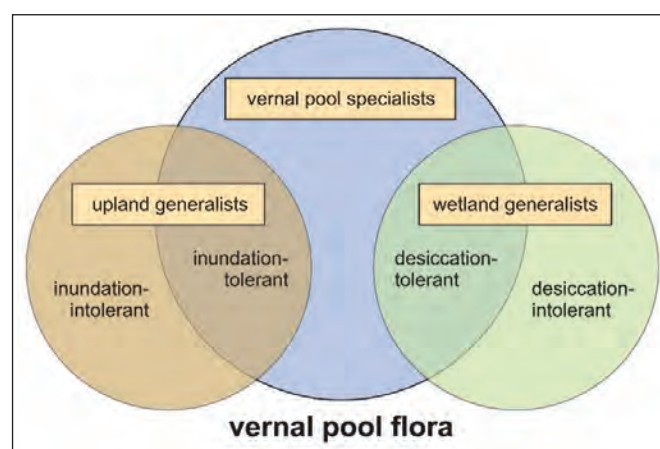


Figure 4.2.9—In vernal pools, plant species can be either endemic (specialists), requiring the vernal pool habitat, or able to grow in vernal pools as well as in other habitats (generalists). Vernal pool specialists are adapted to long periods of complete flooding as well as long periods of desiccation. When the hydrology of a vernal pool is altered, the specialists no longer have suitable habitat and decline, allowing the generalists to take over the site (modified from Bovee et al. 2018).

As noted earlier, restoration of vernal pools and vernal wet areas, in particular, is difficult. Restoration requires the manipulation of the physical, chemical, and biological characteristics of a site with the goal of returning the natural and historic functions to a former or degraded vernal pool (USFWS 2005). Vernal pool restoration may include diverting excess surface runoff (e.g., from agriculture, roads, or other urban hardscapes), reconstructing the characteristic depth from the overlying soil surface to the impermeable layer beneath (e.g., removing silt accumulation from agricultural use or repairing damage due to off-road vehicle use), managing grazing, and/or removing competing species.

The creation of vernal pools, where they had not existed before, is attempted as a means of habitat exchange. Recent literature (Schlatter 2016) indicates, however, that success for construction *de novo* is very limited. For this reason, preservation must be the fundamental strategy in maintaining vernal pool ecosystems within the planning area (USFWS 2005).

Fens fall into the same restoration category as vernal pools and wetlands—very difficult to accomplish. In order to be labeled a fen, the peat must reach a certain depth, a process that takes centuries. Once peat is removed, the fen is no longer a fen and the organisms reliant on that unique habitat will disappear as well. As presented above with vernal habitat, conservation is the best course of action.

Swales and intermittent streams can be restored and reconstructed. Manmade swales are often constructed in modern times as part of groundwater recharge stations. For example, the U.S. Environmental Protection Agency published a fact sheet explaining to homeowners how to make vegetated swales for storm water infiltration (US EPA 1999). One of the major issues with intermittent streams that have been flooded continuously is the invasion of nonnative species and the loss of native species. The ability to restore the original flora and fauna is poorly researched, but efforts are underway, globally, to improve the understanding of the ecology of intermittent streams (Datry et al. 2016).

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