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Restored Vernal Pools in California and post-creation Monitoring and Management

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Introduction

Vernal is derived from the Latin word for spring. A vernal pool is a spring pool that dries up in May or June and isn't refilled until the winter rains come again (Chester, 1996). Vernal pools were a distinctive part of California's Central Valley. The soil structures, climatic regimes, and geologic conditions that are necessary for vernal pool survival are present in the Central Valley. The Central Valley of California is where many vernal pools can be found. The valley covers about 21,300 square miles (55,100 square km), which is about the size of Vermont and New Hampshire combined (CWIS website, 2001). It is located between the Sierra Nevada Mountains and the Pacific Ocean. The pools found in California are typically found in the midst of the oak woodlands and the California Interior Chaparral and Woodland ecoregion that enclose the Central Valley (National Geographic.com, 2001). The lands between the coast and the mountains of California have been subject to development since the gold rush in 1849. It is the interest in reversing the effects of the intensive development of the land for human uses that has driven vernal pool restoration efforts.

Vernal Pool Context

Natural vernal pools are shallow, saucer-like depressions that are ephemerally ponded. Consequently, recreating them requires a careful balance between water storage and loss. Vernal pools form on impermeable soils such as hardpan, clay pan, or volcanic basalt. These pools are typically small in scale; averaging 5 to 7 acres (2-3 ha); they tend not occur as a single pool but as interconnected clusters of ponds. The rainy and dry seasons that typify the Central Valley hydrologic cycle fills and drains the pools. These wetlands can fill up several times a year with each cycle lasting anywhere from a few days to a few months.

The unpredictable cycling of water levels combined with the limited water sources (rain) creates a distinctive habitat for plant and animal species.

Biota of Vernal Pools

Plant and animal species must, therefore, be both flood and drought tolerant to survive in a vernal pool ecosystem. Only species that have been able to adapt to vernal pools' unusual ecosystem can survive and begin their life cycles as the winter rains fill the pools (Fryer, 1996).

The vernal pool tadpole shrimp, *Lepidurus packardi*, is a good example of the type of freshwater invertebrate has adapted to the seasonal filling and draining of the vernal pool. After the winter rains fill the pool, the population is reestablished from cysts that lie dormant in the dry pool sediments. They lay their eggs in the bottom of the pools between the time they hatch and the time the pool dries up for the year.

The vernal pools that dot the Central Valley also serves as a primary migratory pathway and breeding area for many neotropical migratory birds (National Geographic.com, 2001). The Yellow-billed Magpie, *Pica nuttalli*, the tri-colored blackbird, *Agelaius tricolor*, and Nuttall's woodpecker, *Picoides nuttalli*, are all endemic to the valley and use the vernal pools as either wintering homes, rest stops, or breeding grounds (National Geographic.com, 2001).

The vernal pools' signature is the spectacular early spring blooming of wildflowers that ring the edges of the pools. Meadowfoam, *Limnanthes douglasii* ssp. *Rosea*, which belongs to the meadowfoam family, is endemic to vernal pools. Meadowfoams usually bloom in mass and are pollinated by solitary ground-dwelling bees.

What/Who Degrades Vernal Pools?
Vernal pools historically were impacted by agriculture, but urbanization is increasingly a factor in their degradation. Degraded pools often receive either an excess or deficit of which dramatically changes the fragile ecosystem. Human development has directly destroyed or indirectly disturbed the balance of nutrients within a vernal pool. Human disturbances of vernal pools include things like agricultural practices, housing construction, road construction, water diversion, channeling of rivers, conversion of habitat for livestock grazing and impounding for waterfowl enhancement. It is these human interactions with the landscape that has had adverse, if not destructive, effects on vernal pools.

Who cares about Vernal Pools?
Certain groups and organizations that have taken an interest in preserving and creating vernal pools in areas that have not been developed. Such groups include: the US Army Corps of Engineers, Environmental Protection Agency, US Fish and Wildlife Service, Natural Resources Conservation Service, California Department of Fish and Game, and several county planning departments (CWIS, 2001). It has only been in the last ten or fifteen years that county planning departments have joined the vernal pool protection and creation movement. Previously, they had been part of the groups destroying vernal pools with housing developments, road construction and other community development projects. Currently, there are environmental laws requiring agencies and landowners to consider the effects of a proposed action. If the effects are deemed to be harmful, then a less damaging alternative is required. They are also required to obtain and comply with necessary wetland permits and to obey endangered species laws. Compensatory mitigation may be imposed to ensure that projects do no result in the loss of wetland functions (CWIS, 2001).

Why Restore Vernal Pools?
Some say that vernal pools are representative of the cooperation between original landowners and the pre-development landscape and should be restored to remind future landowners of the region's natural heritage. Vernal pools have also been a refuge for native species that provides an important reservoir of genes that could provide natural pharmaceutical compounds. The Central Valley and its vernal pools provide rest and guidance to migratory waterfowl making the long trip from Alaska to South America (CWIS, 2001). Vernal pools, as well as other wetlands, act as water collectors and filters, so protecting the pools from contamination and decreased efficiency is vital. It is the natural heritage and people's connection to the land that provides for them that has increasingly become the motivation for restoring vernal pools.

USFWS Vernal Pool Restorations in California
Project Introduction
The Sacramento Field Office of the United States Fish and Wildlife Service (USFWS) is concerned with vernal pool degradation. In 1987, they constructed their first of many pool constructions that would end up totaling over 1500 vernal pools in Placer, Sacramento, and Butte Counties. Placer County is located just west of Lake Tahoe, while Butte County is north of Sacramento, CA. Each constructed pool was to have some form of monitoring and aftercare implemented to help determine the success of the project. The construction of so many vernal pools in so many different places was a seven year effort (1987-1994). The monitoring and management of these sites began immediately in 1987 and continues at regular intervals. What can be shared are the construction techniques and the immediate findings of the USFWS as they monitored and managed these sites through the end of the 1980s and '90s.

Goals
The USFWS had clearly defined, species-targeted goals prior to the construction of their first mitigated vernal pool. In nearly all of the projects, they set out to mitigate the loss of vernal pool wetlands and the loss of habitat for several endangered species like the Butte County Meadowfoam, *Limnanthes*

floccosa (Butte County Endangered Vernal Pool Restoration, 2000). The habitats were, in most cases, lost due to housing development and highway construction.
The USFWS also had a minor focus on vernal pool habitat research and looked forward to sharing any information they gathered.

Site selection
Careful site selection prior to constructing any wetland is important but was the top priority of the USFWS's list in the early '80s. They set out to construct on historically supported vernal pool sites and sites that offered appropriate soil types. They also sought sites that were slightly removed from the development site that destroyed the original vernal pool. These sites offered the best opportunity for success because they were adequately buffered from other development and disturbances.

Construction Techniques
Once possible pool sites were selected, construction techniques and dimensions were identified. The sizes of constructed pools ranged anywhere from 5 acres to 520 acres (2-200 ha) with most sites being in a range of 25-50 acres (10-20 ha) (DeWeese, 1994). The excavation of the new pools was done in an attempt to duplicate hydrologic depth, surface area, and inundation period (DeWeese, 1994). Early pool constructions excavated side slopes at a 3:1 and 4:1 ratios with a maximum depth of 13 to 18 inches (30 to 45 centimeters). Shortly after these dimensions were constructed and monitored, biologists observed that these pools held water much longer than natural pools. They realized quickly that maximum depths of 18 inches (30 centimeters) needed to be set to mimic natural inundation periods. They decided that side slopes were too steep and needed to be changed to 8:1 or 10:1 (DeWeese, 1994).

The USFWS debated for some time whether to seed or to use seedlings to vegetate the newly constructed pools. In most cases, they discovered an already established seed bank and thus seeding was limited. On sites that did not have a very well established seed bank, hydro seeding of vernal pool species like, *Downingia bella, Allium hyalinum, Limnanthes douglasii*, was attempted immediately following construction to jump-start the plant communities. This strategy was successful by year five in most pools needing seeding. It was also discovered in post-construction monitoring that plantings performed poorly when excavation spoil was used, especially after any length of storage. Therefore, spoils became labile and needed to be hauled off-site so new soil could be brought in.

Site Maintenance
The USFWS recognized a need for post-construction site maintenance to ensure the construction dimensions and materials remained unaltered by human disturbances. In the first three years following most pool creations, the USFWS documented many uncontrolled disturbances. Most of these disturbances were caused by humans and could be curtailed with some type of site maintenance. The most frequent disturbances reported were trash dumping and ATV use resulting in ruts. Ultimately, the trash was picked up on site and removed while signs were posted to prevent ATV's from driving through constructed pools.

Reference Monitoring
The USFWS determined that the only way they could effectively project biological viability in their restorations was to first monitor intact natural vernal pools, or reference pools.
These pools were selected according to proximity to the future constructed pools and by selecting pools that were minimally disturbed. In total, the USFWS monitored and measured 36 reference vernal pools prior to construction. These reference pools were used to determine the overall success of their construction techniques, maintenance practices and whether or not the pools were recovering on its

own. These pools were evaluated and measured to determine goals and requirements for constructed pools according to the performance standards that the USFWS defined.

Performance Standards
To better organize and understand the information gathered through their monitoring efforts, the USFWS designed performance standards. These standards are first based on the establishment of a reference pool and the understanding of the hydrology and vegetation. Standards were also based on hydrology and vegetation.

The establishment of a reference pool and the understanding of its hydrology and vegetation were critical to the monitoring of created pools. The reference pools' data gave a basis for comparison once the new pools were constructed and functioning as an ephemeral pond. The USFWS measured several aspects of the reference pool and then measured the same aspects in the created pools to come up with some sense of success or failure. They measured the size of the reference pools according to surface area of open water, as well as the side slopes, which was taken into consideration at the time of construction. They also measured the maximum depth and period of inundation in reference pools. The goal of the comparison was for the created pools to mimic the structure and function of the reference pools. The success of the construction techniques was determined by how similarly the created pools functioned to the reference pools. The success of their construction is important because it helped them determine if and when and what kind of changes they needed to make to successfully mitigate vernal pool habitat loss.

The USFWS recorded measurements from created pools on a variable basis according to how often the corresponding reference pool filled up. The hydrologic goal for created pools was for an inundation depth and period of no more than 125% of that of the reference pool. In 1996, all construction was complete and vernal pool age was between two and nine years. At that time, 96% of created pools were within the designated depth of inundation range, while 91% of created pools were within the designated period of inundation (DeWeese, 1994). Based on these results, the USFWS concluded that the created pools were indeed successful but further monitoring was needed. The USFWS also observed the vegetative cover in created pools at the same time they measured for hydrologic standards. They were looking for an absolute and relative cover by vernal pool endemics (VPE), like*Limnanthes floccosa,* that was no less than that found in the compared reference pool. In 1996, 66% of created pools were observed to have no less absolute cover than the reference pool, while 78% were observed to have the relative cover by VPEs. They recognized that some pools had experienced more growing seasons than others but that four years after construction, 89% of pools met the absolute cover standards.

Habitat Replacement Evaluation
The USFWS also did a habitat replacement evaluation to determine how successful they were in replacing vital vernal pool habitat for both plants, like *Limnanthes floccosa,* and animal species, like*Lepidurus packardi*. The habitat replacement evaluation was a subjective measurement that was linked to the performance standards. They determined how closely each created pool functioned in relation to its reference pool to help evaluate their success in replacing habitat for animals like,*Lepidurus packardi* and the Delta Green Ground Beetle, *Elaphrus viridis,* which live on the edges of vernal pools throughout the Central Valley.
The USFWS initially determined that their side slope constructions were preventing migratory waterfowl and shorebirds from using the ephemeral ponds. They were able to learn from that and thus altered their side slopes during construction.

Conclusions
Vernal pool ecosystems within Placer, Sacramento, and Butte Counties have shown significant recovery as a result of the USFWS' restoration efforts. It is apparent that the USFWS not only learned about the fragility of vernal pool habitat but also about construction of these shallow, saucer-like, ephemeral

ponds. They learned how to construct a pool that would naturally balance its water loss through evaporation and its water storage after the winter rains.
The magnitude of the restoration also presented some learning opportunities for the USFWS. The attempt was to mitigate vernal pools that had been destroyed by development by mimicking local pools. The large amount of reference pools required to accurately recreate a new pool in each place made for a confusing task. They realized that a standardization of performance standards and fewer variations in monitoring would increase their understanding of the project.
Post-construction management of the pools helped the USFWS see the affects of their construction techniques and their understanding of the reference pools. The most interesting revelation was the evolution of their understanding of the delicate balance between water storage and loss resulting in ephemeral ponding. Their construction techniques also evolved to a point where their future constructions will be much closer to natural vernal pools than their initial attempts were.

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