Rings Around the Posies: Updates on the Classification of Vernal Pool Vegetation

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ABSTRACT. We all know that vernal pools have concentric rings, ribbons, and patches of showy flowers in the spring. These pink, yellow, white, and blue blossoms can serve as a diagram to the complex community types that occupy vernal pools. Early ecologists classified pools based on substrates and locations. Later they were grouped into regions characterized by locally restricted plant species. Michael Barbour, along with a team of local and international scientists, took into account the extensive flora of vernal pools and created a fine-scale vegetation classification system. The Barbour project identified a new class of vegetation and named it after two iconic vernal pool species—*Lasthenia fremontii* and *Downingia bicornuta*. This class now includes over 60 associations nested under 12 alliances demonstrating that vernal pool vegetation diversity is high. This paper provides a history of vernal pool plant community classification, current knowledge of fine scale vegetation classification, and insights into keying and using vernal pool vegetation classification.

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INTRODUCTION

One of the beautiful and challenging things about vernal pools is their variability. Even on a single property, you can see striking differences in pool vegetation with change driven by subtle differences in depth, shape, chemistry, etc.; there are rings and patches of different colored blossoms often clearly demarcating separate plant communities. There is also a great amount of seasonal and annual floristic variation due to the ephemeral nature of vernal pools. For decades, experts and enthusiasts have struggled to describe vernal pools in terms that portray the diversity of vegetation present across the state and even within a single vernal pool. Accurate vegetation descriptions will eventually become the scientific basis for determining commonalities between vernal pools and rarity amongst vernal pools to inform conservation efforts.

WHAT IS VEGETATION CLASSIFICATION?

Vegetation, in its simplest form, refers to all the plant species in a region and how they are arranged. As with any taxonomy, vegetation classification is a hierarchical structure used to simplify communication, share information, and arrange species within a landscape framework. The current National Vegetation Classification System recognizes eight levels from the broadest level of Class to the finest level of Association. At the broadest scales,

TABLE 1. Example hierarchy of vegetation classification for two plant communities – the blue oak-wedgeleaf ceanothus association and the *Eryngium* association. Note how the hierarchy steps down from physiognomy to biogeography to plant species composition.

Class	Forest & Woodland
Subclass	Temperate & Boreal Forest & Woodland
Formation	Warm Temperate Forest & Woodland
Division	Madrean Forest & Woodland
Macrogroup	California Forest & Woodland
Group	Californian Broadleaf Forest & Woodland
Alliance	*Quercus douglasii* Woodland
Association	*Quercus douglasii / Ceanothus cuneatus*
Class	Shrubland and Grassland
Subclass	Shrub & Herb Wetland
Formation	Temperate and Boreal Freshwater Marsh
Division	Western North American Freshwater Marsh
Macrogroup	Western North America Vernal Pool
Group	Californian Vernal Pool
Alliance	*Lasthenia fremontii – Downingia* (*bicornuta*)
Association	*Eryngium* (*vaseyi, castrense*)

emphasis is placed on physiognomy (structure) and biogeography (location). The finer scales are floristically based, considering assemblages of plants – who grows where and with whom. Table 1 shows the vegetation classification hierarchy for two typical California plant communities.

The earliest vegetation classifications used subjective groupings to fulfill a specific need. Cultural vegetation classification, still in use today, revolves around human use and manipulation of the environment. The broadest scales are based strongly on shared economic use or value (timber, rangeland). Finer scales are based on assemblages of plant species (hardwoods versus pine, perennial versus annual herbs). Modern vegetation classification expanded on earlier efforts in order to include information on natural vegetation assemblages independent of human derived use and values. In all of these vegetation classifications, the level or scale of the information needed is dependent upon the ultimate use of that information.

A Manual of California Vegetation, Second Edition (MCV2) (Sawyer et al*.,* 2009) treats California vegetation at the floristic level. An alliance is the basic unit of floristic classification, usually named by the dominant and characteristic species in the uppermost layer of vegetation. An association (or plant community) is the smallest fundamental unit of vegetation classification and typically includes species from other, more understory, strata. This fine-scale classification is important to understanding many details of the vegetation unit such as local and global rarity, fire characteristics, and management considerations.

HISTORY OF VERNAL POOL CLASSIFICATION

The first widely distributed vernal pool classification was published in *A Manual of California Vegetation* (Sawyer and Keeler-Wolf,

1995) and was based primarily on a white paper prepared by Dr. Bob Holland (Holland, 1986). Vernal pools were grouped into eight series based on location and substrate. These series were basically the vernal pool "type" names we have used for decades including "northern hardpan vernal pools" and "northern claypan vernal pools." There were species lists associated with these eight vernal pool types, but they were catch-all lists with no real analysis of vegetation or relationships for how certain species regularly co-occurred. While not as detailed as more recent vegetation classification, the Holland classification is important to our understanding that location and substrate play a vital role in the vegetation types that occur in California vernal pools.

A second, more refined classification of vernal pools was included in the California Vernal Pool Assessment Preliminary Report (Keeler-Wolf et al., 1998). This report presented a map showing 17 vernal pool regions based on abiotic and floristic similarities. The regions were further defined by biological uniqueness including known locations of endemic vernal pool species and communities. Each region was separately analyzed to show mapped vernal pool complexes and California Natural Diversity Database reported occurrences of vernal pool plant communities and rare plant species. This report also included the first ever comprehensive list of plants known to occur in, or be associated with, vernal pools. The *Recovery Plan for Vernal Pool Ecosystems* (USFWS, 2005) used this report to organize Recovery Units and drive recovery goals necessary for the conservation of vernal pool species.

While both of these landmark publications contain valuable information on vernal pool classification related to physiognomy and biogeography, neither looked at the small-scale vegetation patterns that can be seen in the ribbons and rings of colorful blooms commonly associated with California vernal pools. To tease out more detailed information on the floristics of vernal pool vegetation classification, a different level of effort would be required.

FINE-SCALE VERNAL POOL CLASSIFICATION

In 2000, Michael Barbour organized a team of California vernal pool experts and international vegetation ecologists with the goal of producing a fine-scale vegetation classification for vernal pools. The team faced numerous challenges in developing this classification. While there are ephemeral wetlands in other Mediterranean regions, at the time there were no floristically similar vegetation types defined anywhere else in the world. Over 100 plant species are endemic (or restricted) to vernal pools and these intermix with another 100 cosmopolitan aquatic plant taxa found in wetlands everywhere. The dominant plants of vernal pools can change from year-to-year and even week-to-week within any year; persistence over time of diagnostic species is an important component to consider in developing a robust classification (Buck et al., 2012). The diversity of species and how they co-occur across the state is mind-boggling.

The Barbour team spent five years collecting field data. Over 3,000 plots were collected in about 900 vernal pools across California. In addition to vegetation data on species composition and cover, the team recorded environmental variables such as pool depth, geomorphic surface and parent material, etc. Once these data were analyzed, a new vegetation type was described at the national vegetation classification hierarchy Group level – the California Vernal Pool Group (Barbour et al., 2007).

The California Vernal Pool Group is represented by diagnostic species that are common together or in part across most California vernal pool habitats, whether the pool is underlain by hardpan, claypan, or volcanics, neutral or alkaline soils, deep or shallow depth. This group includes vernal pool endemics such as goldfields *(Lasthenia)* and sky blues *(Downingia)*, as well as more widespread species like American pillwort *(Pilularia)* and water starwort *(Callitriche)*. Collectively these species differentiate pools from the surrounding vegetation (often grasslands, oak woodlands, or chaparral) and from other wetlands types in the state including playas and saline sinks. Table 2 shows an output of the classification analysis organized as a synoptic table from Barbour et al. (2007); the first grouping shows the diagnostic species of the California Vernal Pool Group.

While Group species characterize all vernal pools, a number of other plant species found in vernal pools vary as you visit different regions of the state. In fact, in one study along a broad transect of pools extending from the central valley north to Modoc County, three vernal pool regions (as described in Keeler-Wolf et al*.,* 1998) only shared about 14% of their flora (Buck, 2004). Vernal pools are isolated habitats which have undergone strong selective forces for morphological specialization and speciation. Many vernal pool species are endemic to certain geographic areas. This "species turnover" from region-to-region suggests vernal pool plant speciation is the result of different conditions of wetting, drying, temperature, and soil chemistry among the Californian vernal pool landscapes. In many cases, plant species within genera will replace themselves geographically; for example, *Pogogyne floribunda* occurs up in the Modoc area and in San Diego you'll see *Pogogyne abramsii* or *Pogogyne nudiuscula*. A new as-of-yet undescribed Pogogyne has also been noted from vernal pools in Baja California.

The Barbour project clearly demonstrated that community diversity is high; there are more than 60 described vernal pool plant associations in California nested under 12 alliances. These alliances and associations fall within three general habitats—deep, shallow, and alkaline. Table 3 shows a list of alliances grouped by these three general categories. While some pools consisted of just one community, on average pools have 2-3 associations, typically controlled by depth or other microhabitat changes within pools. Community types repeat from pool to pool and some are rare, while others are more widespread. Rare plant species, many of which are federally listed as threatened or endangered, are often tightly linked with particular community types (Lazar, 2006), enabling more targeted sampling for these species as well as better predictions for distribution modeling.

Keying Out Vernal Pool Vegetation

The vernal pool vegetation classification and the keys used to determine associations and alliances are still works in progress. The online MCV contains membership rules that can be used to determine which alliance a particular vegetation stand belongs. Other publications, (i.e., Barbour et al., 2007; Buck-Diaz et al., 2012) contain dichotomous keys to vernal pool associations. Table 4 is an excerpt of a dichotomous key to vernal pool vegetation.

An important note in determining alliance or association membership, through use of membership rules or a dichotomous key, is that absence of a particular species listed as an associate does not necessarily mean that your stand of vegetation is not within that alliance or association. While groups of species routinely co-occur and may have been used to name the unit, sometimes one (or more) of the species will be missing from the suite.

Application and Uses

One of the most useful purposes in developing a vegetation classification for vernal pools is

TABLE 2. Output from floristic classification analysis across California vernal pools; this synoptic table summarizes plant species and percent constancy within surveys – excerpted from Barbour et al. (2007). The table lists the California Vernal Pool Group diagnostic species in the first block. The lower three blocks highlight diagnostic species of vernal pool vegetation characteristic of deep, shallow, and alkaline habitats, respectively.

Vegetation type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Eryngium vaseyi	100	89	92	100	80	79	75	79	60	91	64	37	62	83	29	68
Plagiob stipitatus	100	56	82	64	72	74	66	36	100	13	73	48	43	25	.	43
Lasthenia fremontii	100	67	64	36	51	83	70	81	.	87	55	59	68	8	83	81
Psilocarphus brevissimus	80	72	75	43	54	69	80	52	.	70	18	19	60	.	100	88
Crassula aquatica	40	72	57	29	72	83	73	76	40	100	18	33	46	.	58	43
Deschampsia danthonioi	20	22	29	71	49	78	60	64	.	78	46	74	73	33	25	51
Callitriche marginata	80	72	21	7	35	47	43	41	.	61	18	11	62	25	13	5
Navarretia leucocephala	.	.	79	43	33	36	36	7	.	.	64	63	.	8	.	77
Juncus bufonius	.	.	21	.	33	64	47	21	60	74	36	44	19	42	.	14
Pogogyne ziziphoroides	.	11	14	.	23	52	43	38	80	87	46	96	.	.	17	1
Eleocha acicula	20	.	25	14	51	53	27	5	.	.	.	.	54	8	8	18
Alopecurus saccatus	.	72	32	71	47	12	33	41	.	44	18	4	24	8	4	10
Pilularia americana	.	28	18	14	28	66	39	26	.	26	.	.	11	.	29	5
Isoetes orcuttii	20	28	14	.	30	50	33	21	.	65	9	11	22	.	.	.
Veronic peregri	.	17	.	.	5	.	22	17	80	22	27	11	.	.	63	30
Lasthenia glaberrima	100	100	100	100	100	5	8	21	.	13	.	4	16	.	33	1
Eleocharis palustris	40	50	79	100	81	38	8	33	.	22	.	.	5	17	54	36
Limnanth douglas s. ro	40	33	4	.	.	.	15	41	20	87	64	30	78	58	.	.
Trifolium depauperatum	.	.	7	.	14	2	17	17	60	57	100	30	14	8	.	.
Hemizonia fitchii	.	17	.	.	12	48	19	7	60	17	64	41	3	50	29	1
Lepidium nitidum	.	.	.	.	.	3	5	10	80	22	18	70	46	17	.	.
Plagiobothrys greenei	.	.	.	.	2	10	12	10	100	78	9	26	.	.	.	.
Blennosper nanum v. na	.	6	.	.	.	3	5	14	.	57	.	59	51	42	.	.
Cicendia quadrangulari	.	.	.	.	14	17	25	24	.	74	.	41	.	.	.	1
Hypochaeris glabra	.	6	7	.	14	12	39	52	100	100	18	82	35	33	.	.
Erodium botrys	.	28	7	.	28	17	40	64	60	96	18	44	11	25	.	.
Vulpia bromoides	.	6	4	.	16	3	19	43	20	83	18	11	35	.	8	1
Bromus hordeaceus	.	6	7	.	7	17	34	19	100	26	36	78	41	.	29	5
Plantago elongata	.	6	.	.	.	.	5	21	.	9	9	48	5	.	79	60
Downingia insignis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	67	56
Cressa truxillensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	38	77
Myosurus minumus	.	17	.	.	.	.	2	7	.	13	.	4	3	.	42	53
Polypogon monspeliensi	.	.	.	.	21	7	2	.	.	.	.	.	.	.	100	56
Crypsis schoenoides	.	.	.	.	.	.	0.9	.	.	.	.	.	.	.	79	55
Cotula coronopifolia	.	17	.	.	7	.	2	10	.	.	.	.	.	.	79	21

its use in conservation planning. Existing and newly acquired data can be used to identify rare vernal pool vegetation types and summarize their distribution. The design of vernal pool preserves can incorporate the information to prioritize maximum vegetation diversity. Adequate conservation cannot be obtained by the legal creation of only one or even a few preserves, because such preserves can only capture a small percentage of total community

TABLE 3. List of 12 alliances currently defined under the California Vernal Pool Group in the online edition of the Manual of California Vegetation (CNPS, 2018). Bracketed numbers correspond to the count of associations nested under the corresponding alliance.

Vegetation of long-inundated pools
- *Lasthenia glaberrima* alliance [6]
- *Eleocharis macrostachya* alliance [7]

Vegetation in shallower pools
- *Eleocharis acicularis* alliance [3]
- *Lasthenia fremontii – Downingia* [*bicornuta*] alliance [8]
- *Centromadia* [*pungens*] alliance [3]
- *Deinandra fasciculata* alliance [2]
- *Layia fremontii – Achyrachaena mollis* alliance [5]
- *Montia fontana – Sidalcea calycosa* alliance [1]
- *Trifolium variegatum* alliance [5]

Vegetation of alkaline/saline pools
- *Cressa truxillensis – Distichlis spicata* alliance [9]
- *Lasthenia fremontii – Distichlis spicata* alliance [14]
- *Grindelia* [*camporum, stricta*] provisional alliance [1]

diversity, no matter how large those preserves are. Conservation can only be achieved by creating a network of multiple preserves capturing the full array of different vernal pool communities throughout the various regions of the state.

Regulatory uses of vernal pool vegetation data have not yet been fully developed; however, use of vernal pool vegetation data during the process of environmental review is helpful to the environmental community. Vegetation data can be used to determine the rarity or irreplaceability of any vernal pools to be destroyed. Vegetation data can also be used to improve restoration success through emphasizing community diversity, selection of appropriate reference pools, and more focus on important diagnostic species instead of those that are dominant and widespread.

Management uses of vernal pool vegetation classification are not well developed at this time. Given that the tools available to manage vernal pool landscapes are limited, vegetation classification data are unlikely to be determining factors in stocking rates or prescribed burns. However, vegetation data collection could detect shifts in community composition due to grazing or climate change. Vegetation data collected on preserves would also contribute to long-term data sets which could aid our overall understanding of California vernal pool systems.

NEXT STEPS

While much has been described about the extensive vernal pools in the Great Valley, classification is still needed in other areas of the state such as Modoc County where pools range in size from small to very large – more like vernal lakes – underlain by volcanic and basalt substrate. The larger pools in this region tend to have wide, shallow bands of unique vernal pool vegetation with associations that share similarities with Great Basin ephemeral wetlands. Pools along the north and central coast typically occur on marine sediments and tend to be scattered and isolated; more data

TABLE 4. An excerpt of the field key to vernal pool vegetation types of the Great Valley, California (Buck-Diaz, et al., 2012).

IIA.2. Vegetation characterized by herbs of ephemeral wetlands in swales and vernal pools with very gradual or no slope. All have standing water during the winter and early spring, which may fill and evaporate multiple times during a normal rainy season ("flashy" hydrology). *Deschampsia danthonioides*, *Frankenia salina, Plagiobothrys stipitatus*, *Lasthenia fremontii*, *Downingia bicornuta*, *D. cuspidata*, *D. ornatissima*, and/or *Eryngium castrense* may be characteristic. *Layia fremontii*, *Trifolium variegatum*, and other species of moist stands described elsewhere are typically absent or not high in cover. Deeper pools with longer inundation periods and *Eleocharis* spp. diagnostically present may also be keyed here...

IIA2.a. *Lasthenia fremontii*, *Downingia* spp., *Navarretia leucocephala*, and/or *Eryngium* (*castrense*, *vaseyi*) are present and *Deschampsia danthonioides* is characteristic. Upland species such as *Holocarpha virgata*, *Trifolium variegatum*, *Trifolium depauperatum*, *Hypochaeris glabra*, *Erodium botrys*, *Bromus hordeaceus*, and *Vulpia bromoides* are typically absent. Found in shallow pools and broad pool margins throughout the region…

***Lasthenia fremontii* – *Downingia* (*bicornuta*) Herbaceous Alliance**

IIA2.b. *Lasthenia glaberrima* is dominant or characteristically present in the herbaceous layer with *Eleocharis macrostachya* and other vernal pool species including *Eryngium vaseyi, Lasthenia fremontii, Plagiobothrys stipitatus* var. *micranthus, Psilocarphus brevissimus* var. *brevissimus, Myosurus minimus* and others…

***Lasthenia glaberrima* Herbaceous Alliance**

IIA2b.i. *Lasthenia glaberrima* is dominant or characteristically present in the herbaceous layer with *Eleocharis macrostachya* and *Downingia insignis*; stands occur within claypan pools of the Solano-Colusa and Northern Sacramento Valley vernal pool regions;

***Lasthenia glaberrima* – *Downingia insignis* Herbaceous Association**

IIA2.c. *Eleocharis macrostachya* has at least 2% cover, and is often dominant. Stands are usually found in wetland ponds and may contain a high combined cover of other species including *Lolium perenne*. In vernal pools and swales, stands may contain *Eryngium castrense*, but do not include other typical vernal pool species such as *Lasthenia fremontii* and *Downingia* spp…

***Eleocharis macrostachya* Herbaceous Alliance**

are needed from the pools of this region. Pool types in southern California range from shallow flashy pools embedded in coastal sage scrub to large isolated pools such as those on the Santa Rosa Plateau or Skunk Hollow. New surveys collected in pools down into Baja, Mexico have yet to be analyzed and described.

After publication of additional regional vernal pool classifications, we need to identify and rank rare vernal pool vegetation associations. Vernal pool locations and rare vegetation associations need to be highlighted in the Important Plant Areas project of the California Native Plant Society for use in conservation planning. Vernal pool vegetation also needs to be cross-walked with different classification schemes used by others, such as The Wildlife Habitat Relationships system (Mayer and Laudenslayer, 1988).

Finally, the key to vernal pool vegetation needs to be revised to make it more user friendly. A comprehensive key should emphasize plant species with the highest constancy (how often the species is encountered within plots of that vegetation type) and persistence (the plants that occur year after year independent of annual rainfall), as well as geographic region or driving environmental factors if important. Once the key is simplified, the benefit of using vernal pool vegetation alliances and associations for the purposes of more precise communication will become evident.

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