Great Valley Vernal Pool Distribution, Photorevised 1996

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ABSTRACT. I remapped the distribution of vernal pool habitats throughout California's Great Valley and up to the conifer zones in the surrounding Cascade - Sierra Nevada and Coast Ranges. I examined over 40,000 vertically oriented, true color slides (vintage 1987-1995) and mapped complexes of vernal pools and surrounding grasslands onto part or all of 562 7.5' USGS quadrangles, extending from Shasta Dam to Tehachapi Valley and west to Lake and Sonoma counties. I qualitatively scored habitat density within each polygon as low, medium, or high. These polygons have been digitized at the California Department of Fish and Game's Natural Diversity Data Base using ARC-INFO. They provide a recent, detailed synopsis of vernal pool distribution throughout the Great Valley and North Bay counties.

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INTRODUCTION

Several species of vernal pool-inhabiting plants and animals have been listed as Threatened or Endangered under provisions of the U. S. Endangered Species Act (U. S. Fish and Wildlife Service, 1993). Pursuant to that Act, Recovery Plans for each of these taxa must be prepared by the U. S. Fish and Wildlife Service. Citing their common association with vernal pool habitats, the Service has proposed to address many of these taxa in a single, omnibus "ecosystem recovery plan."

Early in the planning phase, the Service recognized a need for a current, comprehensive understanding of where these habitats still persisted. The only available valley-wide mapping of habitat distribution (Holland, 1978) was based on air photos taken as long ago as the early 1960s and was much too coarse in resolution for the Service's needs. The purpose of this study was to remap the distribution of vernal pool habitats throughout the Great Valley and surrounding Cascade-Sierra Nevada and Coast Range foothills including Lake, Napa, and Sonoma counties using terminal twentieth century technology.

METHODS

Air Photo Interpretation

After considering several alternative technologies, each of their limitations, and their costs, I selected a low budget air photo interpretation approach. Available satellite technologies are costly and provide too-coarse resolution to map reliably features as small as vernal pools, precluding an image processing approach. Likewise, the costs associated with acquiring new photography of adequate resolution for such a large area were prohibitive. Instead, I utilized a series of slide images acquired over the years by the Land and Water Use Mapping Program of the California Department of Water Resources. This program monitors the production, distribution, and utilization of irrigation water throughout California. The irrigated portions of every California county are flown every few years in support of county-wide mapping of what kinds of crops are irrigated where. The program takes vertically-oriented true color 35 mm slides from a specially-equipped aircraft that is flown at 5000 feet above the ground surface. Each slide covers about 1 mile north to south and about 1.4 miles east to west. Systematic flight lines are spaced about 1 mile apart, providing about 10-20 per cent front lap and side lap with adjacent slides. Between 70 and 90 slides are required to cover a 7.5' quadrangle.

Usually one or two counties are flown each year by each of three District Offices in Red Bluff, Sacramento, and Fresno. The slides are used to map individual fields throughout the irrigated part of each county. Fields as small as 1 acre are routinely mapped.

These slides can be projected at any scale. I tried several projection methods and settled on a "display projector" that illuminated a television-like screen on the front of the projector, rather than the customary screen on the wall. This machine projected the slides at approximately 1:10,400 scale, or about 2.3 times that of a standard 7.5' topographic quadrangle. At this scale one can read (albeit marginally) driver warnings such as "STOP AHEAD" painted on roadways. This projector provided an optimum solution to conflicting requirements of image brightness, resolution, and ability to work in a lighted room.

Signature

The slides generally are taken during early summer, when irrigation demand is highest. At this time of year, naturalized annual grassland and associated vernal pools generally have browned off. Even though biological activity is seemingly nil, it still is easy to differentiate vernal pools from their surrounding grasslands because of the difference in standing cover of dead plants (high in grasslands, low in vernal pools), the characteristic shapes of vernal pools, and their patterns of dispersion over the ground. Vernal pools appear as light gray to light tan, irregular, often dendritically arranged blobs in an otherwise darker, tawny brown matrix of grassland. The lighter color associated with vernal pool beds reflects the higher albedo of barren vernal pool beds when compared with the dried thatch and mulch covering adjacent grassland soils.

Mapping Mechanics

I mapped each county by first arranging the appropriate quadrangles in flight line sequence, then systematically examining every slide in each flight line while tracking my location on the quadrangles. When I found mappable habitat, I sketched the boundaries of the grassland-vernal pool complex from the display projector screen onto the topographic sheets. Polygon boundaries generally followed landscape features except where modified by cultural practices. Thus, a given polygon could have along part of its perimeter a smooth, curvilinear trajectory following an obvious physiographic transition, and have part of its perimeter a straight, rectilinear feature following the edge of cultivation or urbanization.

Polygons generally exceeded 40 acres in size, although there were several exceptions to this minimum mapping unit rule. Forty acres (a quarter of a quarter of a section) fit the geometry of parcel subdivision. On the display projector, a 40-acre square field is about 1.5 inches on a side. On a quadrangle, a 40-acre square field is about 0.6 inch on a side. Forty acres of center-pivot irrigation map as a circle about the size of a nickel. While a 40 acre minimum mapping unit may seem large, it is vanishingly small in relation to the total survey area, on the order of 1:2,500,000.

Polygon Attributes

Vernal pools are not distributed uniformly within their surviving range. Rather, their density and size vary considerably. Accordingly, I scored habitat density within each polygon using the qualitative criteria of Table 1. Where apparent, disturbances were coded as well. Most disturbed polygons involved fallow grain fields. Others were uncultivated lands whose drainage had been modified by small-scale ditch work, or had been pocked by imported mitigation projects. One site turned out to have been a toxic spill. All of these attributes were coded directly onto the manuscript maps.

Digitizing

Craig Turner of the California Department of Fish and Game's Natural Diversity Data Base used an Arc-Info-based geographic information system to digitize all the polygon boundaries on each manuscript quadrangle as each county was completed.

TABLE 1. Attribute class characteristics.

Attribute Class	Characteristics
0	Cut-outs, *e. g.* a cultivated field surrounded by habitat.
1	Pools are small; widely and patchily scattered. At least 2 and usually 5 or more pools within the delineated vernal pool complex.
2	Pools are larger; more numerous and more pervasively scattered, although still patchy within the delineated vernal pool complex.
3	Pools are all sizes and numerous. Pools are distributed over the entire delineated vernal pool complex. Also includes large, isolated playa-like pools.
4	Pools are present and persist in spite of obvious cultivation, usually of hay crops.
5	Pools are present and still visible in spite of subdivision into "starve your horse slowly" parcels smaller than minimum mapping size.
6	Not used
7	Not used.
8	As in Attribute Class 1, but with obvious signs of disturbance.
9	As in Attribute Class 2, but with obvious signs of disturbance.

Error Control

Errors are inevitable in a project of this magnitude. Three obvious error sources are mapper inconsistencies, typographic errors during attribute entry, and digitizing errors. Errors were assessed by two separate, distinct processes. One assessment was premeditated, the other was a fortuitous consequence of the project's scale and extent.

One source of error is inevitable individual inconsistencies in delineating polygons or scoring habitat density associated with changes in the mapper's mood, fatigue level, *et cetera*. Many polygons covered hundreds or thousands of acres and were extensively ramified. These obviously required several flight lines to tile together. Even more problematic were polygons that cross county lines, necessitating reference to two or even three separate flights (usually from different years) before the polygon could be circumscribed. Thus, a complex-shaped polygon could have been scored repeatedly and independently over several weeks or even months. Only three of several hundred such ramified polygons were inconsistently scored when finally circumscribed. This suggests that I was consistent in scoring habitat density.

Check plots proved effective at trapping data entry errors. A check plot of each quadrangle was printed following digitizing. Liz Molacek (U. S. Fish and Wildlife Service) then compared each check plot back to the manuscript map, flagging whatever discrepancies she could find. Her scrutiny caught dozens of data entry errors (*i. e.* wrong density class recorded) and several digitizing errors.

These check plots also revealed my mapping errors. About 25 polygons lacked density scores. There also were about 40 "unclosed arcs" – dangling line segments that went nowhere. The software was ruthless at pointing these out. Once all these errors had been identified, my maps and I returned to the slides to close the open polygons and score the missing attributes.

RESULTS

Final survey area

The original scope of work called for mapping "within the Central Valley Hydrographic Basin and several coastal counties." Operationally, this became all the Great Valley counties from Shasta to Kern, plus Lake, Napa, and Sonoma counties. In Figure 1 (foldout map bound as an endpaper at the back of this volume) the shaded area represents those quadrangles partially or entirely covered. These 562 quads in 30 counties collectively cover about 20.3 million acres. This overstates the true survey area because most of the quadrangles around the survey area periphery had only partial photo coverage. Disallowing the 144 quadrangles around the survey area periphery leaves 418 sheets covering about 14.8 million acres. Likewise, this understates the true survey area. I conclude that the survey area encompassed around 18 million acres.

How Many Polygons?

Working at 24,000 scale, I drew 7,034.3 miles of polygon boundary around 1,781 polygons that covered 1,027,067 acres of habitat. Polygons were mapped on 345 quadrangles. Half of the quadrangles had three or fewer polygons. The most polygonaceous quadrangle had 43 polygons. The largest polygon represents 36,447 acres of attribute class 3 habitat gerrymandered through 5 quadrangles in eastern Merced County. Table 2 summarizes by county the number and aggregate area of polygons within each habitat density class.

COMPARISON WITH PREVIOUS MAPPING

When viewed at arm's distance, both maps portray a similar picture: a bath tub ring of habitat around the Great Valley's perimeter, together with a swath in the basin lands along the valley trough. There still is habitat in every county, although habitat fragmentation is evident, for example, when Sacramento and San Joaquin County are compared with Tehama and Shasta county. Familiar areas such as Jepson Prairie in Solano county, the Vina Plains in Tehama County, or the Grasslands in Merced County are prominent in the map. The map's resolution is so much of an improvement over the 1978 map that landform shapes are visible, as in the Vina Plains fanglomerate or the Table Mountains east of Fresno and in Tuolumne County.

Habitat persists along the west side of the Great Valley as far south as Fresno County, especially in the small interior valleys of the Coast Ranges. The Livermore area of Alameda County and the area between Los Vaqueros and Brentwood in Contra Costa County are especially prominent.

Equally prominent is the half-circle of habitat in Kings and Tulare counties. This area east of the former Tulare Lake has experienced considerable habitat modification over the past century. This is former marsh land that has dried with falling water tables and is the "nascent" habitats of my 1978 map. Most of the polygons mapped as "obviously disturbed" were in this area.

Quantitative comparisons with my previous map are enticing, but hardly straightforward. The earlier map used a 640 acre mapping unit (one section, or 640 acres) with 71 acre resolution (640/9), the present one had a 40 acre minimum map unit and was not constrained to a rectilinear grid. The earlier survey covered the floor of the Great Valley, generally up to or slightly into the oak belt, or about 15.6 million acres. The present survey extends to the conifer belt (adding mapping in Calavaras, Eldorado, Mariposa, and Tuolumne counties) and also includes Lake, Marin, and Napa counties. This adds about 3 million acres to the survey area.

Table 3 attempts to compare habitat acerages for each county for which comparisons are possible. Paradoxically, there is an increase in total acreage, from 628,477 acres in the early 1970s to 994,787 acres in the early 1990s. This is nearly a sixty per cent increase that plainly contradicts habitat losses documented by the environmental review process.

Some of this apparent increase indubitably stems from the poorer resolution and cartographic sophistication of the earlier mapping. A second complication is habitat lost in each county in the time since the second photo date (which was as long ago as 1987). Another apparent factor stems from the foreign policy arena of the Nixon administration, which arranged large grain

TABLE 2. Number (above) and collective area (acres, below) of polygons within habitat density classes in each surveyed county.

County	Photo Year	Attribute Class								Total
		0	1	2	3	4	5	8	9	
Alameda	1986		7	4						11
			1480	*1280*						*2760*
Amador	1983		11	3						14
			809	*723*						*1532*
Butte	1994	11	33	28	8					80
		1248	*23334*	*31641*	*3434*					*59657*
Calaveras	1983	1	15	8	1					25
		381	*2144*	*3606*	*166*					*6297*
Colusa	1993	1	22	8						31
		18	*4472*	*808*						*5298*
Contra Costa	1985		14	3	1					18
			2295	*495*	*278*					*3068*
Eldorado	1983		15							15
			1232							*1232*
Fresno	1994	3	29	10	11					53
		239	*13821*	*9962*	*4171*					*28193*
Glenn	1993		12	8						20
			6499	*4677*						*11176*
Kern	1990		8	1				8		17
			1644	*414*				*5246*		*7304*
Kings	1991	2	6	2	1			6	2	19
		188	*1408*	*358*	*3875*			*2016*	*3236*	*11081*
Lake	1995		35			2				35
			2450			*221*				*2671*
Madera	1987	1	36	23	5	2			1	68
		63	*9358*	*70700*	*5945*	*451*			*1636*	*88153*
Marin	1986		2							2
			262							*262*
Mariposa	1976		4	1						5
			7325	*236*						*7561*
Merced	1987	13	83	63	29	19	1			208
		2824	*69625*	*142849*	*73131*	*2485*	*215*			*291129*
Napa	1987	1	6	1						8
		19	*680*	*623*						*1322*
Placer	1994	15	46	29	17	4				111
		1532	*10807*	*28353*	*7673*	*1529*				*49894*
Sacramento	1993	1	134	46	9	3				102
		25	*22429*	*14409*	*18272*	*255*				*55390*
San Joaquin	1988	17	87	41	21					166
		2596	*18787*	*10058*	*7712*					*39153*
Shasta	1995	1	53	6	7					67
		27	*13392*	*1605*	*9282*					*24306*
Solano	1994	7	43	12	1					63
		1105	*12494*	*8112*	*18270*					39981
Sonoma	1986		36	19	1					56
			2436	*1986*	*54*					*4476*
Stanislaus	1988	7	58	56	15	7				143
		638	*57818*	*20557*	*6321*	1727				*87061*
Sutter	1990		18	3						21
			927	*328*						*1255*
Tehama	1994	1	118	37	15	3				174
		127	*82121*	*41843*	*13586*	*600*				*138277*
Tulare	1993	4	42	16	10			12	3	87
		766	*4599*	*8286*	*21664*			*2748*	*468*	*38531*
Tuolumne	1976		8	4						12
			976	*3142*						*4118*
Yolo	1989		18	1						19
			3262	*388*						3650
Yuba	1995		33	7	4					44
			6810	*3862*	*1558*					*12230*
Total		86	1032	434	156	40	1	26	6	1781
		11803	*385711*	*411316*	*195399*	*7271*	*215*	*10011*	*5341*	*1027067*

TABLE 3. Apparent changes in habitat extent in those counties for which comparisons are possible. Data indicate for each county the total area of habitat mapped and date of photography.

	1978 Survey		This Survey		
County	Photo date	Acres	Photo date	Acres	Difference
Butte	1970	27733	1994	59657	31924
Colusa	1970	498	1993	5298	4800
Contra Costa	1966	1635	1985	3068	1433
Fresno	1973	40035	1994	28193	-11842
Glenn	1970	1422	1993	11176	9754
Kern	1973	3556	1990	7304	3748
Kings	1971	4622	1991	11081	6459
Madera	1973	84480	1987	88153	3673
Merced	1973	96569	1987	291129	194560
Placer	1971	23751	1994	49894	26143
Sacramento	1972	85902	1993	55390	-30512
San Joaquin	1968	5902	1988	39153	33251
Shasta	1969	23395	1995	24306	911
Solano	1972	27946	1994	39981	12035
Stanislaus	1970	15858	1988	87061	71203
Sutter	1971	5760	1990	1255	-4505
Tehama	1972	102969	1994	138277	35308
Tulare	1973	36907	1993	38531	1624
Yolo	1971	2062	1989	3650	1588
Yuba	1971	37475	1995	12230	-25245
Totals		628477		994787	366310

sales to the former Soviet Union. In the late 1960s and early 1970s (the time of the earlier photos), price supports for closely spaced grains were so generous that thousands of acres were drilled, though not deep ripped. These subsidies have been replaced by programs that have succeeded in removing marginal lands, including wetlands, from production. Because the fields had not been deep ripped, hydrologic conditions apparently persisted through the period of cultivation and continue to structure the existing vegetation in ways that are visible in air photos.

Whatever its cause, this increase in habitat extent is not uniformly operant. Fresno, Sacramento, and Yuba counties show especially marked reductions in habitat extent over the 20 or more years between photo dates, presumably a consequence of burgeoning urban expansion.

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