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AVIAN USE OF VERNAL POOLS AT THE SANTA ROSA PLATEAU PRESERVE, SANTA ANA MOUNTAINS, CALIFORNIA

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ABSTRACT—Vernal pools are temporary habitats formed by shallow depressions which fill with water during the winter and dry out during the summer. During the winter of 1984–1985, we determined the relative abundance of 55 species of birds in 11 vernal pools at the Santa Rosa Plateau Preserve, Riverside Co., California. Vernal pools were used primarily by ducks, shorebirds, and grassland species of passerines and less frequently by raptors and other birds. Only the red-winged blackbird (*Agelaius phoeniceus*) attempted to nest. Both bird species richness (mean number of species per count) and bird abundance (mean number of birds per count) of each pool were positively correlated with pool area; neither variable was correlated with pool depth or plant species richness.

RESUMEN—Las lagunas vernales son hábitats temporales formados por depresiones pocas profundas que se llenan de agua durante el invierno y se secan durante el verano. Durante el invierno de 1984–1985, se determinó la abundancia relativa de 55 especies de aves en 11 lagunas vernales en el Santa Rosa Plateau Preserve, Riverside Co., California. Las lagunas vernales fueron usadas especialmente por los patos, playeros, y paserinas de pastizales, y menos por las rapaces y otras especies de aves. Solamente el tordo de ala roja (*Agelaius phoeniceus*) intentó nidificar. La riqueza de especies de aves (cantidad promedio de especies por censo) y la abundancia de aves (cantidad promedio de aves por censo) de cada laguna fueron correlacionadas positivamente con el área de la laguna; ninguna variable fue correlacionada con la profundidad de la laguna ni la riqueza de especies de plantas.

Vernal pools are temporary habitats formed by shallow depressions which, because of their impervious substrates, fill with standing water during the wet winter months but dry out completely during the drier summer months (Jain, 1976; Jain and Moyle, 1984; Zedler, 1987). Although widely scattered throughout the world, vernal pools are generally restricted to Mediterranean climates where precipitation is high during the winter and low during the summer (Thorne, 1984; Zedler, 1987). In California, vernal pools were once numerous on coastal terraces and in the Central Valley, but many have been destroyed or altered in recent years by encroaching development (Holland and Jain, 1977; Zedler, 1987).

Although vernal pools vary greatly in size, they seldom exceed 10 ha in area and are always shallow. Because vernal pools are temporary patches of habitat contrasting with the surrounding semiarid vegetation, they can be viewed as islands in both space and time (Ebert and Balko, 1984). Several studies have focused on the relationships between the physical parameters of vernal pools, especially pool area, and species richness of plants (Holland and Jain, 1981; Ebert and Balko, 1984; Rosario and Lathrop, 1984) and invertebrates (Ebert and Balko, 1984).

The plants, invertebrates, and amphibians which are dependent upon vernal pools for the completion of their life cycles are unique in their adaptations to the environmental extremes of inundation and desiccation (Zedler, 1987). Further up the food chain, large numbers of birds and smaller numbers of snakes and mammals are attracted to the ephemeral resources of vernal pools during winter and spring but are generally absent when the pools are dry (Zedler, 1987). Fish and aquatic turtles are apparently unable to cope with the long periods of desiccation and are, thus, absent from vernal pools.

In addition to their role as consumers, birds are considered to be important dispersal agents of vernal plants and, thus, perform a vital function of the vernal pool ecosystem. However, with the exception of short lists of birds recorded in vernal pools of California (Zedler, 1987) and the Santa Rosa Plateau Preserve, Riverside Co., California (Ludlum, 1991), there is no published information about the use of vernal pools by birds. This study was designed to determine the species richness and abundance of birds in 11 vernal pools at the Santa Rosa Plateau Preserve and to evaluate the effects of pool area, pool depth, and plant species richness on species richness and abundance of birds.

MATERIALS AND METHODS—The Santa Rosa Plateau was a distinct topographic unit of rolling grassland and oak-woodland-chaparral hills located at the southeastern end of the Santa Ana Mountains in Riverside Co., California (Lathrop and Thorne, 1978). Thirteen vernal pools, ranging in size from 0.25 to 10.16 ha, were located on three lava-capped mesas: eight on Mesa de Burro, four on Mesa de Colorado, one on Mesa de la Punta (Fig. 1). In 1984, The Nature Conservancy established the Santa Rosa Plateau Preserve with the purchase of 1,281 ha of land, thus protecting all 13 vernal pools (Lathrop and Thorne, 1985).

The soils of the vernal pools consisted of Murrieta stony clay loam, ranging in depth from 22 to 50 cm over the Pleistocene olivine basalt bedrock (United States Department of Agriculture, 1971). Each vernal pool was surrounded by grassland. Earlier studies of the vegetation and physical parameters of the vernal pools were reported by Thorne and Lathrop (1969, 1970), Kopecko and Lathrop (1975), Collie and Lathrop (1976), Lathrop (1976), Lathrop and Thorne (1976*a*, 1976*b*, 1983), Rosario and Lathrop (1984), Stagg and Lathrop (1984), Martin and Lathrop (1986), and Lathrop and Workman (1991).

The mean annual precipitation on the Santa Rosa Plateau was 53 cm for the years 1949 to 1971 (Snow, 1972) and 44.3 cm for the years 1974 to 1977 (Johnston and Lathrop, 1978). A total of 45.7 cm of precipitation was recorded between 1 November 1984 and 30 April 1985 (Fig. 2). The pools filled up with standing water in early December 1984 and remained relatively full until April 1985.

Nine censuses were conducted in vernal pools C1 to C4 between 21 December 1984 and 31 March 1985; six censuses were conducted in pools B1 to B6 and P1 between 2 February and 31 March 1985. Censuses were made while walking around the perimeter of each pool and counting all birds seen within the pool and up to 5 m beyond the water's edge; birds within 5 m of the water's edge were usually within the moist zone of the vernal pools. Birds observed flying over the pools (e.g., raptors, gulls) were also counted because of the possibility that they were attracted to the pools in search of prey. Identification of birds was facilitated by 7×35 binoculars. Although water levels in each pool fluctuated during the study period, all censuses were conducted during a period when all pools were relatively full with standing water. Censuses were conducted only during periods of good visibility. The duration (minutes) of each bird census was recorded to determine whether equivalent amounts of time were spent per unit area censusing birds in each pool. Because censusing all pools required an entire day, censuses were conducted throughout daylight hours. In addition to censusing birds, an effort was made in spring 1985 (both during and after the census period) to find bird nests in the vernal pools.

Tracks or solitary individuals of the following mammalian predators were occasionally seen along the pool margins: coyote (*Canis latrans*), domestic dog (*Canis familiaris*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), long-tailed weasel (*Mustela frenata*), mountain lion (*Felis concolor*), and bobcat (*Felis rufus*). We rarely encountered humans at the vernal pools during the study period.

The maximum area (hectares) of each pool (Table 1) was determined in the field using a compass and meter tape, supplemented by compensating polar planimeter measurements on aerial photographs (Lathrop and Thorne, 1983). Maximum depth (centimeters) of each pool (Table 1) was measured with a stadia rod and surveyor's compass; the deepest point in the pool was noted and later corroborated by depth measurements in the pool when it was full (Rosario and Lathrop, 1984). Plant species richness (number of typical vernal pool species; Lathrop and Thorne, 1983) was determined for each pool (except P1; Table 1) during biweekly surveys during the 1977–1978 growing season (Rosario and Lathrop, 1984), which coincided with a record high of 143 cm of precipitation at the preserve; Holland and Jain (1984) showed that plant species richness of vernal pools was greatest during years with high precipitation. Bird species richness of each pool was calculated as the mean number of bird species per count. Bird abundance of each pool was calculated as the mean number of bird individuals (of all species) per count.

Percent composition of each species of bird was determined by dividing the sum of all birds observed of a given species during all censuses combined by the total number of birds observed during all censuses combined and multiplying the quotient by 100. To facilitate comparisons between ecologic-taxonomic groups of birds, each species was placed into one of the following five groups: 1) waterfowl (Pelecaniformes, Anseriformes); 2) raptors (Falconiformes); 3) shorebirds (Charadriiformes); 4) other non-passerines (Colum-

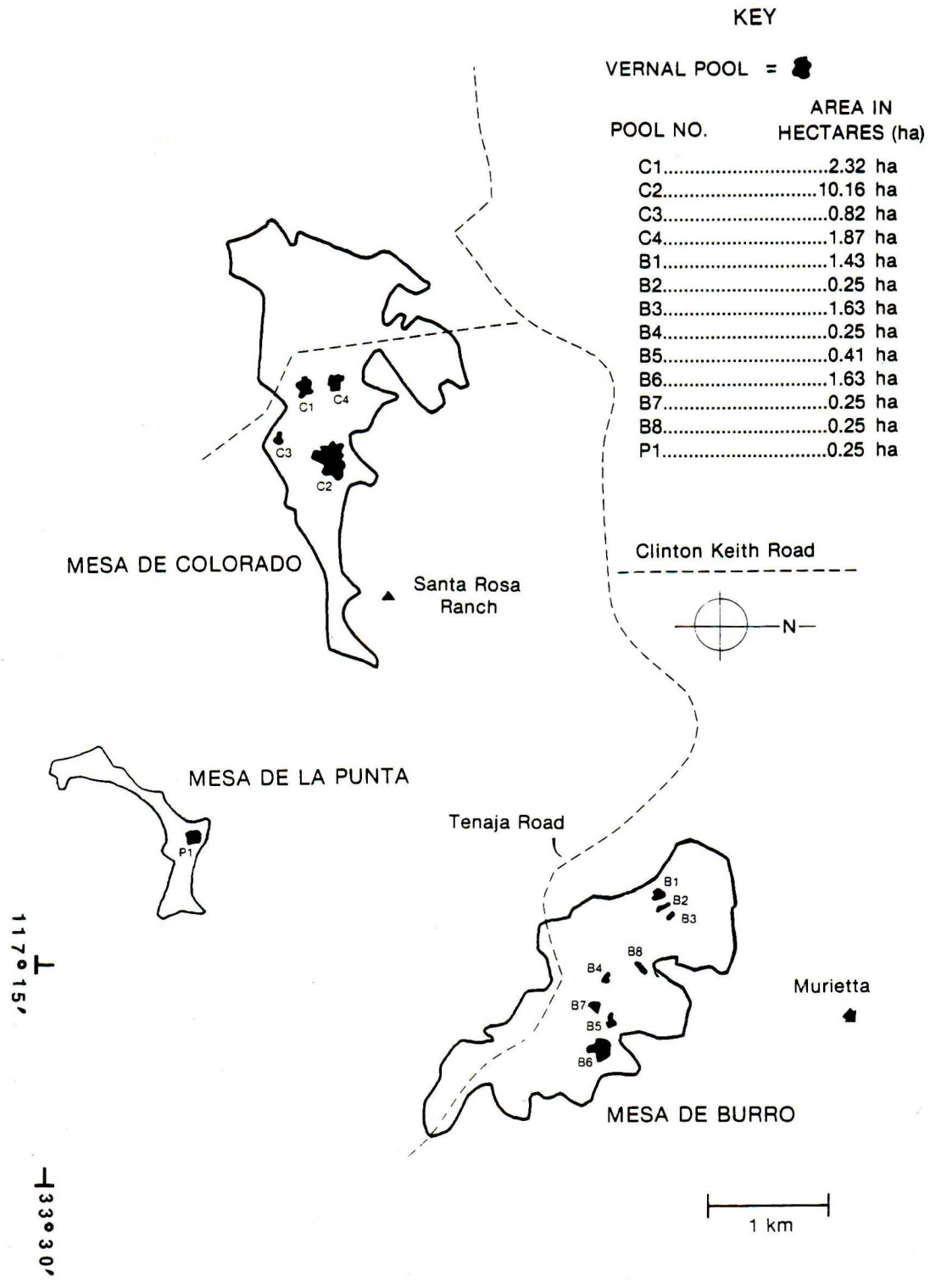

FIG. 1—Map showing locations of vernal pools on the three mesas of the Santa Rosa Plateau Preserve, Riverside Co., California. Drawing by Mark Ford, used by permission of *Aliso*.

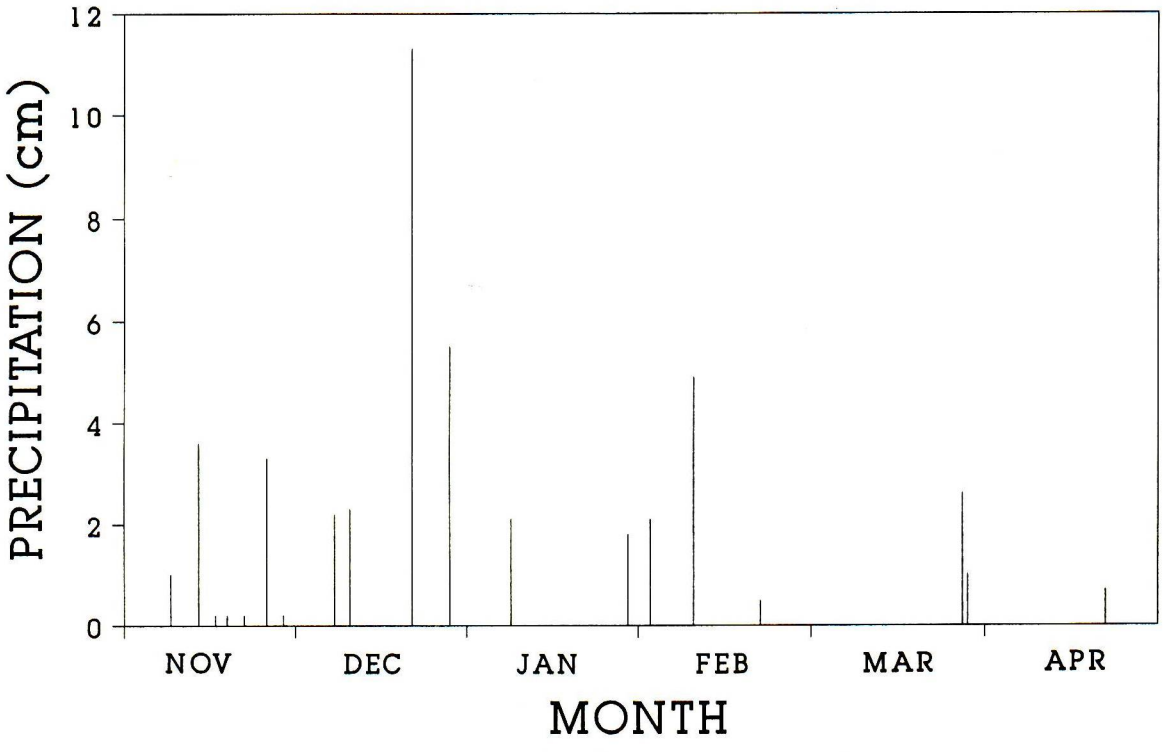

FIG. 2—Temporal distribution of rainfall at the Santa Rosa Plateau Preserve, Riverside Co., California, from November 1984 to April 1985.

biformes, Cuculiformes, Apodiformes); 5) passerines (Passeriformes). Taxonomy follows the American Ornithologists' Union (1983, 1989).

All variables (excluding percent composition) were $\log_e$-transformed to meet the assumptions of parametric statistical tests. Pearson product-moment correlation coefficients (Zar, 1984) were used to evaluate the relationships between each variable, and unweighted simple linear regressions (Zar, 1984) were performed using bird species richness and bird abundance as the dependent variables and pool area, pool depth, and plant species richness as the independent variables. All statistical tests were performed using *Statistix* software (Heisey and Nimis, 1985). All probability values are two-tailed, with $\alpha = 0.05$.

RESULTS AND DISCUSSION—*Faunal Composition*—The mean duration of each census for each pool was positively correlated with pool area ($r = 0.752, P < 0.01$), indicating that roughly equivalent amounts of time per unit area were spent censusing birds in each pool. A total of 2,593 birds of 55 species were recorded at the vernal pools during the censuses (Table 2). Of these, 15 species were observed only flying over the pools: double-crested cormorant (*Phalacrocorax auritus*), turkey vulture (*Cathartes aura*), osprey (*Pandion haliaetus*), black-shouldered kite (*Elanus leucurus*), red-tailed hawk (*Buteo jamaicensis*), ferruginous hawk (*Buteo regalis*), golden eagle (*Aquila chrysaetos*), prairie falcon (*Falco mexicanus*), Bonaparte's gull (*Larus philadelphia*), herring gull (*Larus argentatus*), band-tailed pigeon (*Columba*

TABLE 1—Maximum area (hectares), maximum depth (centimeters), plant species richness, bird species richness and bird abundance (see text for definitions) of vernal pools at the Santa Rosa Plateau Preserve.

Vernal pool	Pool area	Pool depth	Plant species	Bird species	Bird abundance
B1	1.43	33	25	4.2	12.5
B2	0.07	38	23	2.3	7.7
B3	0.30	10	15	2.2	11.5
B4	0.25	61	15	0.7	1.5
B5	0.50	192	26	0.8	1.2
B6	1.63	89	27	4.2	10.3
C1	2.32	30	30	4.3	18.4
C2	10.16	45	32	15.1	183.6
C3	0.82	28	25	0.9	4.1
C4	1.87	50	26	4.7	51.2
P1	0.10	90		1.2	1.5

TABLE 2—Mean number (range given in parentheses) of birds per count and percent composition (all censuses combined) of birds in each vernal pool at the Santa Rosa Plateau Preserve.

Species	Vernal pool											Percent composition
	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	P1	
Waterfowl												
Double-crested cormorant										0.2		<0.1
Phalacrocorax auritus										(0–2)		
Canada goose								5.4				1.9
Branta canadensis								(0–49)				
Green-winged teal							1.8	26.0				9.6
Anas crecca							(0–16)	(10–53)				
Mallard						2.0		19.2				7.1
Anas platyrhynchos						(0–10)		(4–34)				
Northern pintail								4.6				1.6
Anas acuta								(0–15)				
Cinnamon teal							3.0	15.0		4.4		7.8
Anas cyanoptera							(0–14)	(0–56)		(0–17)		
Northern shoveler	0.2					1.0		1.2				0.7
Anas clypeata	(0–1)					(0–6)		(0–3)				
Gadwall								3.8				1.3
Anas strepera								(0–14)				
American wigeon						0.7	0.1	21.4				7.6
Anas americana						(0–2)	(0–1)	(0–40)				
Ring-necked duck								2.2				0.8
Aythya collaris								(0–20)				
Ruddy duck							0.1					<0.1
Oxyura jamaicensis							(0–1)					
Raptors												
Turkey vulture								0.1			0.2	<0.1
Cathartes aura								(0–1)			(0–1)	
Osprey								0.1		0.1		<0.1
Pandion haliaetus								(0–1)		(0–1)		
Black-shouldered kite										0.1		<0.1
Elanus caeruleus										(0–1)		
Northern harrier							0.1	0.1			0.2	0.1
Circus cyaneus							(0–1)	(0–1)			(0–1)	

TABLE 2—Continued.

Species	Vernal pool											Percent composition
	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	P1	
Red-tailed hawk					0.2		0.1	0.3		0.2	0.7	0.4
Buteo jamaicensis					(0–1)		(0–1)	(0–2)		(0–2)	(0–2)	
Ferruginous hawk								0.1				<0.1
Buteo regalis								(0–1)				
Golden eagle					0.7							0.2
Aquila chrysaetos					(0–3)							
American kestrel								0.2			0.2	0.1
Falco sparverius								(0–2)			(0–1)	
Merlin								0.2				<0.1
Falco columbarius								(0–1)				
Prairie falcon	0.2										0.2	<0.1
Falco mexicanus	(0–1)										(0–1)	
Shorebirds												
Killdeer		0.2	6.0	0.3			2.3	30.7		13.7		17.7
Charadrius vociferus		(0–1)	(0–36)	(0–2)			(0–14)	(3–87)		(0–58)		
American avocet								0.1				<0.1
Recurvirostra americana								(0–1)				
Greater yellowlegs	2.5		0.8			0.7	1.6	4.6	1.1	1.1		3.8
Tringa melanoleuca	(1–10)		(0–2)			(0–1)	(0–5)	(1–8)	(0–6)	(0–2)		
Spotted sandpiper								0.1				<0.1
Actitis macularia								(0–1)				
Least sandpiper			0.7				0.6	1.2		1.6		1.3
Calidris minutilla			(0–3)				(0–5)	(0–11)		(0–6)		
Long-billed dowitcher	2.0		2.3				1.3	1.8		2.8		3.0
Limnodromus scolopaceus	(0–12)		(0–14)				(0–12)	(0–15)		(0–14)		
Common snipe	1.0	2.0	0.3				0.3	5.1		6.8		5.0
Gallinago gallinago	(0–3)	(0–7)	(0–1)				(0–2)	(0–11)		(0–17)		
Bonaparte's gull								0.1				<0.1
Larus philadelphia								(0–1)				
Herring gull								1.2				0.4
Larus argentatus								(0–11)				

TABLE 2—Continued.

Species	Vernal pool											Percent composition
	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	P1	
Other non-passerines												
Band-tailed pigeon							0.1					<0.1
Columba fasciata							(0–1)					
Mourning dove		1.7				0.2		0.2				0.5
Zenaida macroura		(0–10)				(0–1)		(0–2)				
Greater roadrunner								0.1				<0.1
Geococcyx californianus								(0–1)				
Anna's hummingbird					0.2	0.3		0.3				0.2
Calypte anna					(0–1)	(0–1)		(0–3)				
Passerines												
Black phoebe								0.6				0.2
Sayornis nigricans								(0–2)				
Say's phoebe								0.7	0.1		0.2	0.3
Sayornis saya								(0–2)	(0–1)		(0–1)	
Horned lark	0.7	2.0	0.3			0.3		12.0		0.9		5.2
Eremophila alpestris	(0–3)	(0–10)	(0–2)			(0–2)		(0–46)		(0–5)		
Tree swallow								4.3				1.5
Tachycineta bicolor								(0–36)				
Cliff swallow								1.1				0.4
Hirundo pyrrhonota								(0–10)				
American crow			0.2				0.2	2.9				1.1
Corvus brachyrhynchos			(0–1)				(0–2)	(0–20)				
Common raven	0.8							1.7	0.1			0.8
Corvus corax	(0–2)							(0–9)	(0–1)			
Rock wren		0.2				0.2		1.3				0.5
Salpinctes obsoletus		(0–1)				(0–1)		(0–3)				
Western bluebird						2.0						0.5
Sialia mexicana						(0–12)						
Mountain bluebird						0.7		0.3				0.3
Sialia currucoides						(0–4)		(0–3)				

TABLE 2—Continued.

Species	Vernal pool											Percent composition
	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	P1	
American pipit								0.1		10.9		3.8
Anthus rubescens								(0–1)		(0–40)		
European starling						0.2						<0.1
Sturnus vulgaris						(0–1)						
California towhee								0.2				<0.1
Pipilo crissalis								(0–2)				
Lark sparrow		0.3		0.2		0.3		2.9				1.2
Chondestes grammacus		(0–2)		(0–1)		(0–1)		(0–13)				
Savannah sparrow	0.5	1.0		0.5		0.5	0.8	0.3				1.0
Passerculus sandwichensis	(0–2)	(0–5)		(0–3)		(0–2)	(0–3)	(0–3)				
Grasshopper sparrow	0.2									0.2		0.1
Ammodramus savannarum	(0–1)									(0–2)		
White-crowned sparrow								0.3				0.1
Zonotrichia leucophrys								(0–3)				
Dark-eyed junco								1.0				0.3
Junco hyemalis								(0–5)				
Red-winged blackbird							0.1	0.1				<0.1
Agelaius phoeniceus							(0–1)	(0–1)				
Western meadowlark	4.5	0.3	0.8	0.5	0.2	1.3	4.4	0.6	2.8	1.0		4.8
Sturnella neglecta	(0–18)	(0–2)	(0–2)	(0–3)	(0–1)	(0–5)	(0–24)	(0–4)	(0–25)	(0–6)		
Brewer's blackbird							1.4	7.0		7.2		5.6
Euphagus cyanocephalus							(0–13)	(0–49)		(0–65)		

fasciata), Anna's hummingbird (*Calypte anna*), tree swallow (*Tachycineta bicolor*), cliff swallow (*Hirundo pyrrhonota*), and American crow (*Corvus brachyrhynchos*). All others were observed on at least one occasion either in a pool, along the pool margins or perched on exposed wooden posts within a pool.

Waterfowl (11 species) were the most conspicuous component of the vernal pool avifauna, comprising 38.6% (in number of individuals) of all birds recorded. The most common species were (in descending order) green-winged teal (*Anas crecca*), cinnamon teal (*Anas cyanoptera*), American wigeon (*Anas americana*), and mallard (*Anas platyrhynchos*), which together accounted for 83.5% of the waterfowl recorded (Table 2). Unlike other ecologic-taxonomic bird groups, waterfowl were never recorded in pools with an area of <1 ha (Tables 1 and 2). Nearly all of the ducks recorded were "dabblers" rather than "divers."

Raptors (10 species), which represent the top avian consumers in the vernal pool ecosystem, collectively accounted for only 1.2% (in numbers) of the vernal pool avifauna. They were usually observed flying over the pools, apparently in search of prey. The red-tailed hawk (*Buteo jamaicensis*) was the most common raptor (Table 2).

Shorebirds (nine species), which usually foraged in shallow water along the edges of the pools, comprised 31.4% (in numbers) of the vernal pool avifauna. The killdeer (*Charadrius vociferus*) was the most common shorebird (56.3% of all shorebirds) and also the most common species of the vernal pool avifauna, representing more than a sixth of all birds recorded (Table 2).

Passerines (21 species), which usually foraged along the wet margins of the pools, accounted for 28.0% (in numbers) of all birds recorded. The most common passerines were (in descending order) Brewer's blackbird (*Euphagus cyanocephalus*), horned lark (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), and American pipit (*Anthus rubescens*), which together comprised 69.6% of all passerines recorded. Western meadowlark was recorded at more vernal pools (10) than any other species of bird (Table 2). Most of the passerine species recorded during this study typically inhabit grasslands, marshes, or open areas. Two exceptions, rock wren (*Salpinctes obsoletus*) and California towhee (*Pipilo crissalis*), were usually associated with brushlands. The remaining 0.8% (in numbers) of the vernal pool avifauna was composed of other nonpasserines (four species; Table 2), all of which were usually associated with brushlands and were relatively rare.

The only species of bird that we observed nesting in the vernal pools was the red-winged blackbird (*Agelaius phoeniceus*), a typical marsh-nesting species. On 26 and 27 April 1985, we found six nests containing 20 eggs and five chicks ($\bar{X}$ offspring/nest = 4.17, SD = 0.41, range of 4 to 5) in sedges (*Eleocharis macrostachya*) of pool C1, which was just becoming dry. By 4 May 1985, all nests had been destroyed by coyotes, as indicated by the presence of tracks; no eggs or chicks were found. Ground-nesting grassland species which may also nest in or near vernal pools include killdeer, horned lark (nests found nearby), savannah sparrow (*Passerculus sandwichensis*), grasshopper sparrow (*Ammodramus savannarum*), and western meadowlark.

At least 13 other species of birds have been recorded from vernal pools at the Santa Rosa Plateau Preserve (I. P. Ludlum, pers. comm.) but not during the study period. These include eared grebe (*Podiceps nigricollis*), great blue heron (*Ardea herodias*), blue-winged teal (*Anas discors*), redhead (*Aythya americana*), lesser scaup (*Aythya affinis*), bufflehead (*Bucephala albeola*), hooded merganser (*Lophodytes cucullatus*), American coot (*Fulica americana*), black-necked stilt (*Himantopus mexicanus*), willet (*Catoptrophorus semipalmatus*), whimbrel (*Numenius phaeopus*), ring-billed gull (*Larus delawarensis*), and California gull (*Larus californicus*). This raises the vernal pool avifauna of the Santa Rosa Plateau Preserve to 68 species.

Zedler (1987) reported 19 species of birds from vernal pools in California which have not yet been recorded from the Santa Rosa Plateau Preserve, although some may be expected. These include pied-billed grebe (*Podilymbus podiceps*), great egret (*Casmerodius albus*), green-backed heron (*Butorides striatus*), tundra swan (*Cygnus columbianus*), Ross' goose (*Chen rossii*; presumably this species rather than Ross' gull, *Rhodostethia rosea,* as reported in Zedler, 1987), wood duck (*Aix sponsa*), California quail (*Callipepla californica*), sandhill crane (*Grus canadensis*), black-bellied plover (*Pluvialis squatarola*), lesser yellowlegs (*Tringa flavipes*), northern rough-winged swallow (*Stelgidopteryx serripennis*), bank swallow (*Riparia riparia*), barn swallow (*Hirundo rustica*), scrub jay (*Aphelocoma coerulescens*), bushtit (*Psaltriparus*

TABLE 3—Matrix of Pearson product-moment correlation coefficients for $\log_e$-transformed variables of pool area and depth, plant species richness, bird species richness, and bird abundance (see text for definitions) of 11 vernal pools at the Santa Rosa Plateau Preserve. For plant species richness, $n = 10$ (data missing for pool P1); for other variables, $n = 11$.

Variables	Variables			
	Pool area	Pool depth	Plant species	Bird species
Pool depth	−0.052			
Plant species	0.683*	0.358		
Bird species	0.726**	−0.248	0.577	
Bird abundance	0.746**	−0.402	0.497	0.943***

* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

minimus), Bewick's wren (*Thryomanes bewickii*), wrentit (*Chamaea fasciata*), California thrasher (*Toxostoma redivivum*), and sage sparrow (*Amphispiza belli*). Future observations will undoubtedly add to the list of birds using California's vernal pools.

Distributional Ecology—Bird species richness in each pool ranged from 0.7 in pool B4 to 15.1 in pool C2, and bird abundance varied from 1.2 in pool B5 to 183.6 in pool C2 (Table 1). Both bird species richness and bird abundance were positively correlated with pool area; however, neither variable was significantly correlated with pool depth or plant species richness (Table 3). Bird species richness and bird abundance of vernal pools were highly correlated (Table 3). The results of the regression analyses show that pool area was the best single predictor of both bird species richness and bird abundance (Table 4).

Significantly positive correlations of pool area and plant species richness have been previously reported for vernal pools of the Santa Rosa Plateau Preserve ($r = 0.68$, $n = 10$; Rosario and Lathrop, 1984), San Diego Co. ($r = 0.52$, $n = 53$; Ebert and Balko, 1984), and scattered throughout California ($r = 0.26$, sample size not given; Holland and Jain, 1981). In the same pools in San Diego Co. ($n = 53$), Ebert and Balko (1984) reported a significantly positive correlation between pool area and crustacean species richness ($r = 0.52$), but no significant correlation was found between pool area and rotifer species richness ($r = 0.10$).

In addition to pool area, two other parameters have been correlated with species richness of vernal pool organisms. In San Diego Co. ($n = 53$), Ebert and Balko (1984) reported significantly negative correlations between the number of times a pool dried during the study period and species richness for plants ($r = -0.45$), crustaceans ($r = -0.81$), and rotifers ($r = -0.52$), indicating that species richness for these organisms was greatest in pools with more stable environments. Holland and Jain (1981) also reported a significantly positive correlation between latitude and plant species abundance ($r = 0.71$, sample size not given) in vernal pools scattered throughout California, surprisingly indicating a more diverse flora farther north.

The z-value (slope) of the area versus bird species richness plot is relatively high ($z = 0.47$; Table 4) in comparison with typical species-area curves (Conner and McCoy, 1979). Furthermore, it is considerably higher than the reported values for plants in vernal pools at the Santa Rosa Pla-

TABLE 4—Results of unweighted simple linear regressions using bird species richness and bird abundance as dependent variables. For plant species richness, $n = 10$; for pool area and depth, $n = 11$.

Variable	Slope	Intercept	F
Bird species richness			
Pool area	0.47	1.04	10.04*
Pool depth	−0.31	2.06	0.59
Plant species richness	0.22	−5.88	4.00
Bird abundance			
Pool area	0.78	2.44	11.26*
Pool depth	−0.81	5.27	1.74
Plant species richness	2.90	−6.83	2.63

* $P < 0.01$.

teau Preserve (z = 0.13; Rosario and Lathrop, 1984), in San Diego Co. (z = 0.17; Ebert and Balko, 1984), and scattered throughout California (z = 0.04; Holland and Jain, 1981), and for crustaceans in San Diego Co. (z = 0.36; Ebert and Balko, 1984). This indicates that species richness increases more rapidly with increasing pool area for birds than for other organisms in vernal pools. The much higher slope of the area versus bird abundance plot (z = 0.78; Table 4) is not surprising given that bird species richness is a subset of bird abundance.

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