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A comparative study of the vascular plants of three vernal pools in the San Joaquin Valley, California

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A COMPARATIVE STUDY OF THE VASCULAR PLANTS OF THREE VERNAL POOLS IN THE SAN JOAQUIN VALLEY, CALIFORNIA

A Thesis
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by

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INTRODUCTION

Vernal pools are bodies of water, large or small, which collect in depressions in the earth during winter rains. The pools have no inlets or outlets connecting them to other bodies of water. They persist into the spring, evaporating slowly and invariably becoming completely dry by late spring or early summer.

Three minimum conditions (Begg 1976) must be present for the formation of a vernal pool. First, the general topography must be able to support a pool. There needs to be depressions in the ground surface. Secondly, there has to be a source of water. The pools are formed primarily from rain, but also could be due to run-off from melting snow. The final condition for the formation of vernal pools is a limiting layer at the bottom of the depression capable of holding water for an extended period of time. It is necessary for this layer to be relatively dense with a low permeability. There are three types of soil layers which meet these requirements; clay, hard pan or one derived from lava. These soil types may be present separately or in any combination (Begg 1976).

Vernal pools themselves are geologically very ancient (Holland and Griggs 1976). The knowledge that they are of particular botanical interest is very recent. The importance of vernal pools was realized as more and more rare and endemic species were found on the sites. The 1950's marked the beginning of intensive research and a better understanding of these pools.

The first vernal pool plant known to be collected in California was in September of 1791 near Monterey by Thaddeus Henkey. The plant was Deschampsia danthonioides (Trin.) Munro ex Benth., 1857 (Gramineae). The specimen label contained the specific epithet, the vague location of collection (near Monterey), the date collected and the collector. Unfortunately, no reference was made to the habitat in which the plant was found (Crampton 1976).

In 1831 - 1832, with the construction of El Camino Real, David Douglas traveled and collected extensively in California. One of his important collections was a species of Limnanthes (Limnanthaceae), another vernal pool endemic (Crampton 1976).

In 1847 with the expeditions of Karl Hartweg around Yuba City and Chico, four new species were discovered. All of them are vernal pool endemics. They are species of Deschampsia (Gramineae), Limnanthes (Limnanthaceae), Navarretia (Polemoniaceae) and Pogogyne (Labiatae) (Crampton 1976).

In 1884 the first significant study of vernal pool flora was conducted. During the winter of that year, the San Diego area experienced a very abundant rainfall. C. R. Orcutt took advantage of this rainfall to do extensive collecting. However, he never associated the plant life he collected with standing water. The plants he collected were later shown to be vernal pool endemics. One of his specimens was later the basis on which the genus Orcuttia Vasey was described (Gramineae). Again this is a vernal pool endemic (Crampton 1976).

It was not until 1890, with the collection around Chico of Orcuttia greenei Vasey 1891, by Edward L. Greene, that the first association with standing water was made. Greene described the specimen as occurring in moist spots (Crampton 1976).

The term vernal pool was first used in the early 1900's (Jepson 1925). This association between these temporary pools and their unique floras was finally made after extensive research and study by Willis Linn Jepson (Crampton 1976).

Today a good deal is known about the general nature and flora of vernal pools. Nevertheless, there is very limited information or actual documentation in the scientific literature. Vernal pools need to be studied more extensively, and they still offer unlimited opportunities for such research (Holland and Griggs 1976).

The purpose of this investigation was to enumerate and compare the vascular plant species occurring at three vernal pools in the San Joaquin Valley of California.

Description of the study area

Three vernal pools, within an approximate range of 15 air-miles in the San Joaquin Valley of California were investigated. For the purpose of documentation, the three pools are designated Vernal Pool #1, Vernal Pool #2 and Vernal Pool #3 (Figure 1).

Vernal Pool #1 (Figure 2) is located 3.5 miles south of the junction of Highway 26 and Escalon-Bellota Road, San Joaquin County, California, T.2N, R.9E, Sec. 28 Mount Diablo Meridian. It is

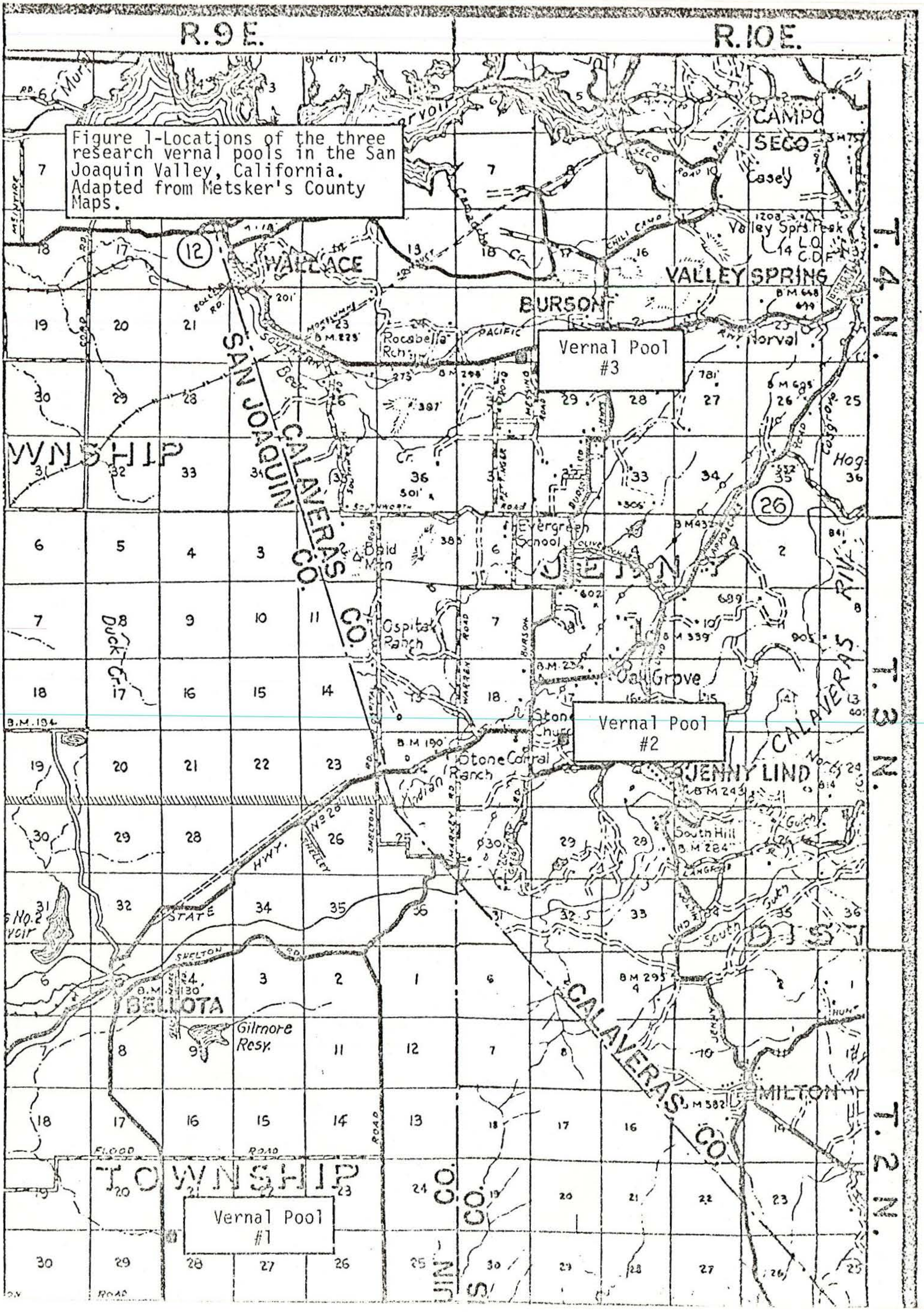

Figure 1-Locations of the three research vernal pools in the San Joaquin Valley, California. Adapted from Metsker's County Maps.

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Figure 2

Vernal Pool #1 - 3.5 miles south
of the junction of Highway 26
and Escalon-Bellota Road,
San Joaquin County, California.
Located on the corner of a
fenced pasture.

immediately beyond and to the right of a cattle guard in a large fenced pasture. At its maximum level, water covers an approximate area of (75' x 200') 15,000 square feet and the maximum depth is 4 feet. This pool is in a large pasture, which is used for the grazing of cattle.

Vernal Pool #2 (Figure 3) is 0.3 mile north of Milton Road on Roach Drive (the back entrance to Scenic Valley Ranchos) near Jenny Lind, Calaveras County, California, T.3N, R.10E, Sec. 20 MDM. At the time of the investigation, the small dirt road cut through the west corner of the pool. At its maximum level, water covers an approximate area of (70' x 90') 6,300 square feet and the maximum depth is 2 feet. This pool is within an area which is being developed for vacation homes.

Vernal Pool #3 (Figure 4) is beside Messing Road, 0.1 mile south of the junction of Highway 12 and Messing Road, 1.1 miles west of Burson, Calaveras County, California, T.4N, R.10E, Sec. 19 MDM. It is approximately 30 feet from the road. At its maximum level, water covers an approximate area of (10' x 130') 1,300 square feet and the maximum depth is 1 foot. This pool is in a large open area among oak trees (Quercus lobata) and buck brush (Ceanothus cuneatus). The area is used by local dirt bike riders and is criss-crossed by numerous bike trails.

The climate is the same at all three pools and is characterized by relatively short, mild winters and long, hot summers. Average annual rainfall approaches 15 inches, but is subject to wide annual

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Figure 3

Vernal Pool #2 - 0.3 mile north of Milton Road on Roach Drive (the back entrance to Scenic Valley Ranchos) near Jenny Lind, Calaveras County, California. Located on land being developed for vacation sites.

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Figure 4

Vernal Pool #3 - 0.1 mile south of the junction of Highway 12 and Messing Road on Messing Road, 1.1 miles west of Burson, Calaveras County, California. Located in an open area on the side of a country road.

differences ranging from 6 - 27 inches (U. S. Weather Bureau at Stockton). The relative humidity is consistently low during the spring and summer months. The wind is usually mild, but occasionally a strong, gusty wind occurs at the vernal pool sites.

The soil at the three pools is composed of sand with some parent rock and considerable organic material.

METHODS AND MATERIALS

The three vernal pools investigated were chosen after a visual survey of the area on 21 February, 1975. At that time, the water level of each pool was considered to be at its maximum. On this date, no collections were made due to the immature condition of the specimens. The pools were reexamined on 14 March, 1975 and 28 March, 1975. Again, no collections were made. The first date that specimens were actually collected was 4 April, 1975. Further trips were made to the vernal pools weekly and collections were made when new vegetation appeared. These weekly collections continued regularly until 8 August, 1975. By August, no new plant species were observed.

The vernal pool sites were examined again on 31 October, 1975, 16 January, 1976, 27 February, 1976 (Figures 5, 6 and 7), 19 March, 1976 and 16 April, 1976 (Figures 8, 9 and 10). No further collections were made on any of these dates due to the absence of new species. The pools were checked in 1976 to supplement the original collections, but due to the drought in 1976, the vernal pools were virtually nonexistent.

The perimeter of each study area was defined as a line ten feet from the edge of the pool at its maximum level. These borders remained constant throughout the investigation. Included within these boundaries was the area of the vernal pool itself, both with standing water and once dry. Every vascular plant within the area defined above was considered in the investigation.

Figure 5

Vernal Pool #1 - 3.5 miles south
of the junction of Highway 26
and Escalon-Bellota Road,
San Joaquin County, California.
27 February, 1976.

Figure 6

Vernal Pool #2 - 0.3 mile north
of Milton Road on Roach Drive
(the back entrance to Scenic Valley
Ranchos) near Jenny Lind,
Calaveras County, California.
27 February, 1976

Figure 7

Vernal Pool #3 - 0.1 mile south of the junction of Highway 12 and Messing Road on Messing Road, 1.1 miles west of Burson, Calaveras County, California.
27 February, 1976

Figure 8

Vernal Pool #1 - 3.5 miles south
of the junction of Highway 26
and Escalon-Bellota Road,
San Joaquin County, California.
16 April, 1976

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Figure 9

Vernal Pool #2 - 0.3 mile north
of Milton Road on Roach Drive
(the back entrance to Scenic Valley
Ranchos) near Jenny Lind,
Calaveras County, California.
16 April, 1976

Figure 10

Vernal Pool #3 - 0.1 mile south of the junction of Highway 12 and Messing Road on Messing Road, 1.1 miles west of Burson, Calaveras County, California.
16 April, 1976

Six general collection sites were arbitrarily determined as follows: ten feet from the maximum standing water level; five feet from the maximum standing water level; on the edge of the maximum standing water level; emergent from standing water; submerged; and dry areas which previously held standing water in that season.

Vernal Pool #3 contained standing water on 11 April, 1975 and lacked standing water on 18 April, 1975 (Figure 11). Vernal Pool #2 contained standing water on 18 April, 1975 and lacked standing water on 25 April, 1975 (Figure 12). Vernal Pool #1 contained standing water on 25 April, 1975 and lacked standing water on 2 May, 1975 (Figure 13).

The relative abundance of each species was also determined during the investigation. This is documented by the standard ecological terminology: very rare; rare; infrequent; abundant; and very abundant (Oosting 1956).

Using the information available in Munz (1958), each species was categorized as to whether it is endemic to vernal pools (Table 1), native to California, but not endemic to vernal pools or introduced to California.

When collections were made at the pools, the specimens were pressed in a standard plant press the same day. A sufficient number of individuals of each specimen were collected for use in identification, as well as for voucher specimens. After being pressed, the specimens were dried in a drying cabinet for approximately four days (depending on the size and succulence of particular material).

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Figure 11

Vernal Pool #3 - 0.1 mile south of the junction of Highway 12 and Messing Road on Messing Road, 1.1 miles west of Burson, Calaveras County, California.
18 April, 1975
Note the lack of standing water.

Figure 12

Vernal Pool #2 - 0.3 mile north
of Milton Road on Roach Drive
(the back entrance to Scenic Valley
Ranchos) near Jenny Lind,
Calaveras County, California.
25 April, 1975
Note the lack of
standing water.

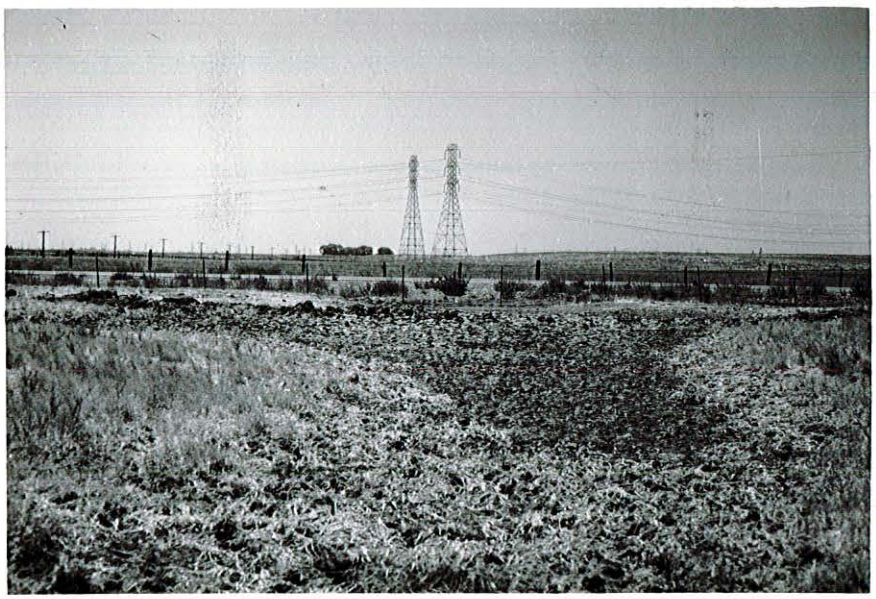

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Figure 13

Vernal Pool #1 - 3.5 miles south
of the junction of Highway 26
and Escalon-Bellota Road,
San Joaquin County, California.
2 May, 1975
Note the lack of
standing water.

Table 1

List of vernal pool endemics collected in San Joaquin Valley, California (February 1975 - August 1976).

Blennosperma nanum (Hook.) Blake.

Callitriche marginata Torr.

Deschampsia danthonioides var. danthonioides (Trin.) Munro ex Benth.

Deschampsia danthonioides var. gracilis Munro ex Benth.

Downingia bella Hoov.

Downingia pulchella (Lindl.) Torr.

Eryngium pinnatisectum Jeps.

Heleocharis palustris (L.) R. & S.

Juncus bofonius L.

Lasthenia glabrata Lindl.

Mimulus tricolor Hartw. ex Lindl.

Montia verna Neck.

Navarretia intertexta (Benth.) Hook.

Navarretia leucocephala Benth.

Pilularia americana A. Br.

Plagiobothrys stipitatus (Greene) Jtn.

Pogogyne zizyphoroides Benth.

Psilocarpus brevissimus Nutt.

The identification of the specimens was done from pressed and dried material. A California Flora (Munz 1959) and Supplement to a California Flora (Munz 1968) were used as the standard reference for the identification. Manual of the Grasses of the United States (Hitchcock 1950) was used extensively for the identification of the grasses collected.

Voucher specimens are deposited at the University of the Pacific Herbarium (CPH).

CATALOGUE OF PLANTS

PTEROPHYTA

MARSILEACEAE - Marsilea Family

Pilularia americana A. Br., (McNeal 1309) abundant; Vernal Pool #1; submerged and emergent from standing water; endemic; May.

ANTHOPHYTA

DICOTYLEDONEAE

BORAGINACEAE - Borage Family

Plagiobothrys greenei (Gray) Gray, (154, 170, 189) abundant; Vernal Pool #'s 1, 2 and 3; on the edge of the maximum standing water level; native non-endemic; April.

Plagiobothrys nothofulvos (Gray) Jtn., (151, 175) abundant; Vernal Pool #'s 1 and 2; on the edge of the maximum standing water level; native non-endemic; April.

Plagiobothrys stipitatus (Greene) Jtn., (215) abundant; Vernal Pool #2; dry areas which previously held standing water; endemic; April.

Callitriche marginata Torr., (164, 180) abundant; Vernal Pool #'s 1, 2 and 3; submerged; endemic; April.

CAMPANULACEAE - Bellflower Family

Downingia bella Hoov., (201) abundant; Vernal Pool #2; dry areas which previously held standing water; endemic; April.

Downingia pulchella (Lindl.) Torr., (200, 219) Vernal Pool #1, infrequent; Vernal Pool #2, very abundant; Vernal Pool #3, infrequent; dry areas which previously held standing water; endemic; April.

CARYOPHYLLACEAE - Pink Family

Cerastium viscosum L., (166, 169) very abundant; Vernal Pool #'s 1, 2 and 3; ten feet from the maximum standing water level, five feet from the maximum standing water level, on the edge of the maximum standing water level and dry areas which previously held standing water; native non-endemic; April.

COMPOSITAE - Sunflower Family

Blennosperma nanum (Hook.) Blake., (152) abundant; Vernal Pool #1; emergent from standing water; endemic; April.

Holocarpha virigata (Gray) Kech., (274) infrequent; Vernal Pool #2; dry areas which previously held standing water; native non-endemic; July.

Holocarpha sp., (246, 263) very rare; Vernal Pool #'s 1 and 2; dry areas which previously held standing water; (too immature to identify to species); May.

Holozonia filipes (H. & A.) Greene, (276) very rare; Vernal Pool #1; dry areas which previously held standing water; native non-endemic; August.

Hypochoeria glabra L., (224) rare; Vernal Pool #2; five feet from the maximum standing water level; introduced; May.

Lasthenia chrysostoma (F. & M.) Greene, (177, 188) very abundant; Vernal Pool #'s 1, 2 and 3; ten feet from the maximum standing water level, five feet from the maximum standing water level, on the edge of the maximum standing water level, dry areas which previously held standing water and emergent from standing water; native non-endemic; April.

Lasthenia glabrata Lindl., (161) very abundant; Vernal Pool #'s 1, 2 and 3; dry areas which previously held standing water and emergent from standing water; endemic; April.

Layia fremontii (T. & G.), (195) infrequent; Vernal Pool #2; ten feet from the maximum standing water level; native non-endemic; April.

Psilocarpus brevissimus Nutt., (216, 249) abundant; Vernal Pool #'s 1, 2 and 3; dry areas which previously held standing water; endemic; May.

Senecio vulgaris L., (157) infrequent; Vernal Pool #1; five feet from the maximum standing water level; introduced; April.

CRUCIFERAE - Mustard Family

Capsella bursa-pastoris (L.) Medic., (159) very abundant; Vernal Pool #1; on the edge of the maximum standing water level; native non-endemic; April.

Lepidium nitidum Nutt., (158, 179) abundant; Vernal Pool #'s 1 and 2; five feet from the maximum standing water level; ~~introduced~~ Native; April.

EUPHORBIACEAE - Spurge Family

Eremocarpus setigerus (Hook.) Benth., (272, 273, 275) abundant; Vernal Pool #'s 1, 2 and 3; dry areas which previously held standing water; native non-endemic; July.

GENTIANACEAE - Gentian Family

Centaurium venustum (Gray) Rob., (252) abundant; Vernal Pool #2; dry areas which previously held standing water; native non-endemic; May.

GERANIACEAE - Geranium Family

Erodium botrys (Cav.) Bertol., (183, 194) Vernal Pool #2, abundant; Vernal Pool #3, very abundant; five feet from the maximum standing water level; introduced; April.

Erodium cicutarium (1.) L'Her., (165) abundant; Vernal Pool #1; ten feet from the maximum standing water level; introduced; April.

Erodium obtusiplicatum (Maire, Weiller & Wilcz.) J. T. Howell, (193) abundant; Vernal Pool #1; five feet from the maximum standing water level; introduced; April.

Geranium carolinianum L., (202) very abundant; Vernal Pool #3; five feet from the maximum standing water level; native non-endemic; April.

Geranium dissectum L., (209) very abundant; Vernal Pool #1; five feet from the maximum standing water level; introduced; April.

LABIATAE - Mint Family

Lamium amplexicaule L., (184) very rare; Vernal Pool #3; five feet from the maximum standing water level; introduced; April.

Pogogyne zizyphoroides Benth., (268) very abundant; Vernal Pool #3; five feet from the maximum standing water level; endemic; May.

LEGUMINOSAE - Pea Family

Lupinus bicolor Lindl., (155, 178) infrequent; Vernal Pool #'s 1 and 2; ten feet from the maximum standing water level; native non-endemic; April.

Medicago hispida var. confinis (Enoch) Burnat., (156) very rare; Vernal Pool #1; ten feet from the maximum standing water level; introduced; April.

Trifolium tridentatum Lindl., (208) rare; Vernal Pool #1; five feet from the maximum standing water level; native non-endemic; April.

LIMNANTHACEAE - False Mermaid Family

Limnanthes douglassii R. Br., (191) abundant; Vernal Pool #1; dry areas which previously held standing water; native non-endemic; April.

LYTHRACEAE - Loosestrife Family

Lythrum hyssopifolia L., (248) infrequent; Vernal Pool #1; dry areas which previously held standing water; native non-endemic; May.

ONAGRACEAE - Evening-Primrose Family

Boisduvalia densiflora (Lindl.) Wats., (271) infrequent; Vernal Pool #1; dry areas which previously held standing water; native non-endemic; June.

Clarkia biloba (Durand) Nels. & Macbr., (259, 265) infrequent; Vernal Pool #'s 2 and 3; dry areas which previously held standing water; native non-endemic; May.

Clarkia purpurea (Curt.) Nels. & Macbr., (258, 270) Vernal Pool #2, rare; Vernal Pool #3, very rare; dry areas which previously held standing water; native non-endemic; May.

Clarkia sp., (261) very rare; Vernal Pool #2; on the edge of the maximum standing water level; (too immature to identify to species); May.

POLEMONIACEAE - Phlox Family

Navarretia intertexta (Benth.) Hook., (253) abundant; Vernal Pool #2; dry areas which previously held standing water; endemic; May.

Navarretia leucocephala Benth., (249) infrequent; Vernal Pool #1; dry areas which previously held standing water; endemic; May.

PORTULACACEAE - Purslane Family

Montia perfoliata (Donn.) Howell, (182) abundant; Vernal Pool #3; on the edge of the maximum standing water level; native non-endemic; April.

Montia verna Neck., (163) abundant; Vernal Pool #1; emergent from standing water; endemic; April.

PRIMULACEAE - Primrose Family

Dodecatheon clevelandii ssp. patulatum (Greene) H. J. Thomps., (186) abundant; Vernal Pool #'s 2 and 3; five feet from the maximum standing water level; native non-endemic; April.

RANUNCULACEAE - Crowfoot Family

Ranunculus alveolatus Carter in L. Benson & Carter, (160) abundant; Vernal Pool #1; on the edge of the maximum standing water level; native non-endemic; April.

Ranunculus muricatus L., (162) abundant; Vernal Pool #1; emergent from standing water; introduced; April.

SCROPHULARIACEAE - Figwort Family

Gratiola abracteata Benth., (207) infrequent; Vernal Pool #1; dry areas which previously held standing water; native non-endemic; April.

Mimulus guttatus Fisch. ex DC., (192) abundant; Vernal Pool #1; five feet from the maximum standing water level; native non-endemic; April.

Mimulus tricolor Hartw. ex Lindl., (196, 197, 205) very abundant; Vernal Pool #'s 1, 2 and 3; dry areas which previously held standing water; endemic; April.

Orthocarpus attenuatus Gray., (214) abundant; Vernal Pool #1; ten feet from the maximum standing water level; native non-endemic; May.

Orthocarpus erianthus Benth., (168, 190) very abundant; Vernal Pool #'s 1, 2 and 3; ten feet from the maximum standing water level, five feet from the maximum standing water level, on the edge of the maximum standing water level and emergent from standing water; native non-endemic; April.

VIOLACEAE - Violet Family

Viola douglassii Steud., (185) infrequent; Vernal Pool #3; ten feet from the maximum standing water level; native non-endemic; April.

UMBELLIFERAE - Carrot Family

Eryngium pinnatisectum Jeps., (246, 254) very abundant; Vernal Pool #'s 1, 2 and 3; dry areas which previously held standing water; endemic; May.

Lomatium utriculatum (Nutt.) Coult. & Rose, (184) infrequent; Vernal Pool #3; ten feet from the maximum standing water level; native non-endemic; April.

MONOCOTYLEDONEAE

AMARYLLIDACEAE - Amaryllis Family

Brodiaea coronaria (Salisb.) Engler, (255, 266) very rare; Vernal Pool #2, on the edge of the maximum standing water level; Vernal Pool #3, dry areas which previously held standing water; native non-endemic; May.

Brodiaea elegans var. elegans Hoover., (250) very rare; Vernal Pool #1; dry areas which previously held standing water; native non-endemic; May.

Brodiaea pulchella (Salisb.) Greene, (174, 181) abundant; Vernal Pool #'s 2 and 3; ten feet from the maximum standing water level; native non-endemic; April.

CYPERACEAE - Sedge Family

Heleocharis palustris (L.) R. & S., (257) abundant; Vernal Pool #2; dry areas which previously held standing water; endemic; May.

GRAMINEAE - Grass Family

Aira caryophyllea L., (222) abundant; Vernal Pool #1; ten feet from the maximum standing water level; introduced; May.

Alopecurus howellii Vasey., (237) abundant; Vernal Pool #1; ten feet from the maximum standing water level; native non-endemic; May.

Avena barbata Brot., (235) very abundant; Vernal Pool #1; ten feet from the maximum standing water level; introduced; May.

Briza minor L., (211) very abundant; Vernal Pool #2; on the edge of the maximum standing water level; introduced; April.

Bromus catharticus Vahl., (226) abundant; Vernal Pool #1; ten feet from the maximum standing water level; introduced; May.

Bromus mollis L., (176, 231) very abundant; Vernal Pool #1, ten feet from the maximum standing water level; Vernal Pool #2, five feet from the maximum standing water level; introduced; April, May.

Bromus rigidus Roth., (243) abundant; Vernal Pool #1; ten feet from the maximum standing water level; introduced; May.

Bromus rubens L., (230) very abundant; Vernal Pool #1; ten feet from the maximum standing water level; introduced; May.

Deschampsia danthonioides var. danthonioides (Trin.) Munro ex Benth., (239) very abundant; Vernal Pool #1, ten feet from the maximum standing water level; Vernal Pool #2, five feet from the maximum standing water level; dry areas which previously held standing water; endemic; May.

Deschampsia danthonioides var. gracilis (Trin.) Munro ex Benth., (212) very abundant; Vernal Pool #2; on the edge of the maximum standing water level and dry areas which previously held standing water; endemic; April.

Elymus caput-medusae L., (221) abundant; Vernal Pool #'s 1 and 2; ten feet from the maximum standing water level; introduced; May.

Festuca dertonensis (All.) Asch. & Graebn., (225, 232) Vernal Pool #1, very abundant; Vernal Pool #2, abundant; ten feet from the maximum standing water level; introduced; May.

Festuca megalura Nutt., (223) very abundant; Vernal Pool #2; five feet from the maximum standing water level; native non-endemic; May.

Festuca myuros L., (236) very abundant; Vernal Pool #1; ten feet from the maximum standing water level; introduced; May.

Festuca tracyi Hitchc., (233) abundant; Vernal Pool #1; ten feet from the maximum standing water level; native non-endemic; May.

Hordeum hystrix Roth., (206) very abundant; Vernal Pool #1; five feet from the maximum standing water level; introduced; April.

Hordeum leporinum Linc., (234) very abundant; Vernal Pool #1; ten feet from the maximum standing water level; introduced; May.

Hordeum vulgare L., (228) abundant; Vernal Pool #1; ten feet from the maximum standing water level; introduced; May.

Lolium multiflorum Lam., (241, 262, 269) Vernal Pool #'s 1 and 2, abundant; Vernal Pool #3, infrequent; Vernal Pool #1, ten feet from the maximum standing water level; Vernal Pool #'s 2 and 3, dry areas which previously held standing water; introduced; May.

Lolium perenne L., (244) infrequent; Vernal Pool #1; five feet from the maximum standing water level; introduced; May.

Phalaris paradoxa L., (267) infrequent; Vernal Pool #3; dry areas which previously held standing water; introduced; May.

Poa annua L., (199) very abundant; Vernal Pool #1; five feet from the maximum standing water level; introduced; April.

Poa fibrata Swall., (240) very abundant; Vernal Pool #1; ten feet from the maximum standing water level; native non-endemic; May.

Poa scabrella (Thurb.) Benth ex Vasey, (229) very abundant; Vernal Pool #1; ten feet from the maximum standing water level; native non-endemic; May.

Polypogon maritimus Willd., (260) rare; Vernal Pool #2; dry areas which previously held standing water; introduced; May.

Schimus arabicus Nees., (227) abundant; Vernal Pool #1; ten feet from the maximum standing water level; introduced; May.

JUNCACEAE - Rush Family

Juncus bufonius L., (McNeal 1310) infrequent; Vernal Pool #2; dry areas which previously held standing water; endemic; May.

LILACEAE - Lily Family

Chlorogalum angustifolium Kell., (256) very rare; Vernal Pool #2; on the edge of the maximum standing water level; native non-endemic; May.

RESULTS

Due to the particular location, or more precisely, the respective misuse of each of the vernal pools by man, certain variations were expected and found. These variations are expressed in different ratios between the number of vernal pool endemic species, California native non-vernal pool endemic species and introduced species (Table 2).

Vernal Pool #1 is on the corner of a large pasture used for the grazing of cattle. There were cattle in the pasture through the duration of the investigation. They consistently used the pool for drinking. Consequently, the cattle are continually in and around the pool, and frequently defecate in the area.

At Vernal Pool #1, a total of 54 different species were collected. Considering these 54 species, 22 (41%) of them were introduced to California, 22 (41%) were native to California but non-endemic to vernal pools, and 10 (18%) were endemic to vernal pools (Table 2).

It was anticipated that many grasses (Gramineae), particularly introduced species used for the feeding of cattle, would be found. This pool is relatively large and within an open area, hence a substantial number of California native non-vernal pool endemic species common throughout the San Joaquin Valley were also expected. The large number of dominant grasses apparently affected the occurrence of vernal pool endemic species by increasing competition; however,

Table 2

Numbers of endemic, native non-endemic and introduced species at three vernal pools in the San Joaquin Valley, California, with total numbers of each at the three pools combined.

	Endemic	Native Non-Endemic	Introduced	Total
Pool #1	10	22	22	54
Pool #2	14	17	10	41
Pool #3	7	14	4	25
Total	31	53	36	120

due to the large size of the pool, a significant number of endemics were also expected.

Vernal Pool #2 is on what used to be an open field on private ranch land. It appears to have been there and relatively untouched, until recently. The effects of recent (1975 - 1976) disturbance of this area will be considered in the Implications for the Future.

At Vernal Pool #2, a total of 41 different species were collected. Considering these 41 species, 10 (24%) of them were introduced to California, 17 (41%) were native, but non-endemic to vernal pools, and 14 (35%) were endemic to vernal pools (Table 2).

Considering that there were no unusual circumstances influencing this pool during or prior to the investigation, a relatively small number of introduced species were anticipated. At the same time, a substantial number of species native to California but non-endemic to vernal pools were expected. Because of the ideal location of this pool and its viability over a number of years, a very substantial percentage of vernal pool endemic species were also anticipated.

Vernal Pool #3 is on the side of a small country road in the middle of an open area. It is relatively untouched by humans, except for a few dirtbikers who run through it.

At Vernal Pool #3, a total of 25 different species were collected. Considering these 25 species, 4 (16%) of them were introduced to California, 14 (56%) were native to California, but non-endemic to vernal pools, and 7 (28%) were endemic to vernal pools (Table 2).

This pool is very small and the size is highly variable from year to year, depending upon the amount of rainfall. Since the pool is smaller, it holds less water in a normal year, and the water would evaporate more rapidly here than in the other pools. In a dry year, this pool may not contain standing water at all. Hence, overall, a smaller number of species were anticipated. A very small number of species introduced to California were expected. At this pool, the number of species native to California, but non-endemic to vernal pools was anticipated to occur in the largest percentage. Ideally, due to its location, this pool should contain a large number of vernal pool endemics. It was expected, however, that because of the radical shift in water levels from year to year, the number of vernal pool endemics could be somewhat less.

DISCUSSION

The three pools are at least 15 air-miles apart. The floras are separate and distinct from one another. Because of the distance between them, it is doubtful that any exchange of species occurs between the pools. Therefore, in this research, it is appropriate to ask the question: is there a significant difference between the species in every vernal pool or is the plant life of all the vernal pools basically similar?

Diversity in the flora of a vernal pool, as seen in the total number of species present, seems to be related to the size of the pool, which in turn is related to the duration of the pool. The ratio of endemic, native non-endemic and introduced species at each pool is related to the use by man of the pool and its surrounding area. Hence, Vernal Pool #1 exhibits an extremely large percentage of introduced species (41%). Vernal Pools #2 and #3 have considerably lower percentages in this category, with 24% and 16% respectively. The great number of fodder grasses on the grazing land account for the high percentage of introduced species at Vernal Pool #1. Again, this is due to its location in a pasture where cattle are feeding and defecate after consuming a variety of introduced grains.

Data concerning floras of individual vernal pools in California is not generally available. This research indicates that 15% to 41% of the species associated with vernal pools would be introduced, and that the figure will vary according to the use of a specific pool by

man. Areas which are not used for agriculture or recreation would have the smallest number of introduced species, while those used for grazing cattle and other livestock would have the highest. Further research will be necessary to substantiate this conclusion.

The greatest percentage of species occurring at the three vernal pools are those native to California, but non-endemic to vernal pools. Vernal Pool #1 and #2 had 41% of the species in this category, while Vernal Pool #3 had 56%.

With the application of this data, the 95% confidence interval about the total frequency of natives extends from 35% to 53% at any vernal pool. This constancy is probably due to the large source of native annuals available in areas surrounding vernal pools. Should a species be eliminated by grazing or by other means in one season, its seeds or those of other native species have an excellent chance of being reintroduced from the surrounding area.

Although it is expected that vernal pool endemics will occur at vernal pools, the exact percentages can be highly variable. Eighteen percent of the species occurring at Vernal Pool #1 were endemics. Vernal Pool #2 had 35% and Vernal Pool #3, 28%.

It is conceivable that the low percentage of vernal pool endemics occurring at Vernal Pool #1 is related to the large number of introduced grasses occurring there. The grasses are a highly competitive family, capable of growing in the most extreme environmental conditions. It is possible that the grasses have exerted

dominance to the point of causing the extinction of some of the vernal pool endemics or precluded their introduction.

Until recently, Vernal Pool #2 was without human interference. Under this condition, the pool was highly prolific and supported an impressive number of vernal pool endemics. Since this pool was under natural conditions, with normal environmental stress, the percentage of endemics at this pool is most characteristic of vernal pools.

Vernal Pool #3 is a small pond, and, consequently, can be highly variable from year to year. If there is not an abundant rainfall one year, the pool may not contain any water. Due to lack of rain, the pool could be essentially dormant for a year or more at a time. This phenomenon likely has drastic effects on the vernal pool endemics that occur there.

More extensive research must be conducted on vernal pools in order to obtain more precise values. However, without further research, the conclusion must be that, under natural conditions, approximately 35% of the species occurring at vernal pools are endemic to them. In contrast to California native species, should an endemic species be eliminated, by whatever means, it would be extremely difficult for it to be reintroduced due to the frequently great distances between seed sources.

Numbers of species of the three pools were combined in order to obtain ratios for endemic, native non-endemic and introduced species. The greatest percentage in this combination was, as expected, those

that are native to California, but non-endemic to vernal pools (44%) (Table 2). It is possible when considering a larger number of vernal pools, that the percentages, thus obtained, will be applicable; because the pools chosen for this investigation represent different conditions. The combined percentage of species introduced to California represents 30% of the species collected, and as anticipated, the lowest percentage of species were those endemic to vernal pools (26%) (Table 2).

According to the research of Robert F. Holland, a graduate student at the University of California, Davis, every vernal pool is distinct and different as to the vascular plants occurring there. Holland went as far as to state that vernal pools differ even in close proximity, or within a common field, and may have no species or only a few that are prevalent to other pools in that same region (Holland 1976).

As stated previously, the three vernal pools investigated were an appreciable distance apart, as well as varying greatly in size. The findings of this research showed differing results from those of Holland, particularly as to endemic species. The collections at the three research vernal pools yielded 84 different species. Of these 84 different species, 59 or 70% occur only at one or another of the three vernal pools, while 13 or 15% occur at two of the vernal pools simultaneously; and, finally, 12 or 15% occur at all three of the vernal pools (Table 3). The percentage of species occurring at only one of the pools by far exceeds the percentage of species occurring

Table 3

Comparison of location of different species at the three vernal pools in the San Joaquin Valley, California.

	Number of different species
Occurring only at Vernal Pool #1	35
Occurring only at Vernal Pool #2	17
Occurring only at Vernal Pool #3	7
Occurring at Vernal Pool #'s 1 and 2	8
Occurring at Vernal Pool #'s 1 and 3	0
Occurring at Vernal Pool #'s 2 and 3	5
Occurring at all three Vernal Pools	12

at all three pools. Nevertheless, these results do show a similarity between the three pools in contrast to the data from Holland. However, while not explicitly stated, Holland was apparently concerned only with vernal pool endemics.

If, in fact, Holland was only referring to vernal pool endemics when he stated that similar species may not be found at different vernal pools, then the results of this research are somewhat more contradictory. There were a total of 18 different vernal pool endemics collected at the three pools. Of these 18 endemics, 11 or 61% occur at only one of the three pools (Table 4). Only 1 or 5% of the endemics occur at two of the pools simultaneously (Table 4). However, 6 or 33% of the endemic species occur at all three of the pools (Table 4). These results seem to conflict with Holland's in that the occurrence of vernal pool endemics showed a considerable similarity between the three pools.

A comparison between the species found at the three pools in the spring and the species found at the three pools in the summer was made in this investigation. During the spring, considerable differences in species composition were noted between the three pools. However, in the summer, after the soil was completely dry at all three of the pools, they appeared to be alike in the endemic species that developed. In fact, if a particular vernal pool endemic species occurred at one of the pools, it was invariably found at the other two pools. During the spring and summer seasons, no such dichotomy was observed in the native non-endemic flora.

Table 4

Comparison of location of different vernal pool endemic species at the three vernal pools in the San Joaquin Valley, California.

	Number of vernal pool endemic species
Occurring only at Vernal Pool #1	3
Occurring only at Vernal Pool #2	7
Occurring only at Vernal Pool #3	1
Occurring at Vernal Pool #'s 1 and 2	1
Occurring at Vernal Pool #'s 1 and 3	0
Occurring at Vernal Pool #'s 2 and 3	0
Occurring at all three Vernal Pools	6

The duration of this investigation was intended to include a single growing season, from spring 1975 through summer 1975. An attempt was made to add supplemental collections from spring 1976 to summer 1976 to augment the original collections, but the winter drought of 1976 ended this attempt with no further collections being made. The drought caused a drastic reduction in the amount of standing water the three pools contained during this period. Vernal Pool #1 suffered the greatest effects. The maximum level of water, even after the heaviest rain of 1976, was approximately 1% of the level of the previous year. Also in 1976, the flora of this pool did not develop. In 1976, Vernal Pool #2 attained a standing water level close to 25% of the level of 1975. There was a substantial bloom at this pool in 1976, but even here much reduced over the previous year. The smallest pool, Vernal Pool #3 occasionally showed moist soil, but at no time was standing water observed at this pool. Only a small percentage of the vascular plants recorded in 1975 appeared at this pool during 1976.

Naturally, due to the reduction of standing water at the three vernal pools in 1976, the soil was considerably drier at an earlier date. A prime example was exhibited by Vernal Pool #1. In 1975, at the deepest part of the pool, the ground was not severely cracked by drying until late July. During the drought of 1976, at the same part of the pond, the ground was extremely cracked in early May (Figure 14).

In the years 1975 and 1976, another interesting phenomenon was observed. There were differences in the actual time certain species

Figure 14

Deepest portion of Vernal Pool #1 showing extreme cracking upon drying. May 1976.

flowered in 1975 as compared to 1976. There were various examples (Holocarpha virigata, Holozonia filipes, Eremocarpus setigerus) where species, in a normal year, flowered in the middle of the summer. In 1976, the same species that appeared in the summer during 1975, bloomed as early as April and May. An additional contrast between the two years was the actual location where some of the species grew. A few of the species that normally occurred on the perimeter of the pool, appeared growing in the middle of the pool during the drought. Apparently, the plants required more moisture, and, consequently, only germinated in the middle of the vernal pools, where the maximum amount of water was.

It was suggested by Holland that the 1976 drought would affect the number of individuals of each species that normally occur at vernal pools, but would not alter the species that normally occur at vernal pools (Holland 1976). Again, the findings of this research differ. This extreme drought drastically reduced both the number of species that occurred at the three pools, as well as the number of individuals of each species that did occur at the pools. There were various plants that were not found in 1976 that were collected in 1975 (Hypochoeris glabra, Layia fremontii, Senecio vulgaris, Lamium amplexicaule, Lupinus bicolor, Medicago hispida, Clarkia purpurea, Gratiola abracteata, Brodiaea coronaria, Brodiaea elegans var. elegans, Briza minor, Hordeum hystrix, Poa fibrata, Polypogon maritimus, Chlorogalum angustifolium). No new or different species were

observed at any of the pools in 1976. Consequently, no further collections were made after 8 August, 1975.

IMPLICATIONS FOR THE FUTURE

Vernal pools have been characteristic in California for centuries. If proper precautions are not taken, these unique plant communities may be lost forever. As is the case with most aspects of nature, with the exploitation and/or negligence of man, these natural habitats become more and more endangered. Even though the early 1950's marked the beginning of extended research and better understanding of vernal pools, the possible extinction of these ephemeral ponds was first mentioned in the botanical literature as early as 1959 (Crampton).

Vernal Pool #1 is located on private land within a pasture. There is no immediate danger of the extinction of this pool, but dependent upon the owner (who looks at the vernal pool as a source of drinking water for his cattle), this could change at any time. As mentioned earlier, Vernal Pool #2 is located within an area presently being developed as vacation home sites in the country. When this research began in February 1975, a small dirt road cut through the west corner of the pool. As the research continued, steel posts were set running directly through the center of the pool. The entire area about the pool was first burned and then the adjacent land was leveled. Eventually, construction began on a small, wooden storage shed immediately southeast of the pool. This construction went uninterrupted until, at the conclusion of this research in April 1976, the small dirt road was enlarged to run through a quarter

of the pool, the steel posts supported a barbed wire fence and the wooden shed was completed. There is considerable doubt that this vernal pool will survive. It can be speculated that Vernal Pool #2 will be nonexistent by the spring of 1977. Vernal Pool #3, because of its small size, is always in danger. As long as it remains untouched, it has a possibility of continuing to support vegetation. Unfortunately, at various times throughout the research, dirtbike trails have been observed running through this small pool. If this type of destruction continues, it is also anticipated that this vernal pool will become extinct.

It is of great concern to this investigator that these three pools, as well as other vernal pools in California, are in danger of extinction. At the present time, professional as well as amateur botanists interested in vernal pools, are primarily concerned with the protection and preservation of these rare and endangered plant communities, as well as educating land owners as to their value. With the neglect and lack of concern, as well as the ignorance of the public in general, it is possible for these one of a kind plant communities to be destroyed. Hopefully, with the present interest in California vernal pools by professional and amateur botanists alike, the preservation of these communities can be achieved.

SUMMARY

The flora of three vernal pools in the San Joaquin Valley of California was studied from February 1975 through August 1976. The first date for the actual collection of specimens was 4 April, 1975. The last date of the collection of specimens was 8 August, 1975.

As was expected, those species which are native to California, but not endemic to vernal pools, occur in the greatest amounts (44%). The percentages of species endemic to vernal pools and introduced to California are very close, 26% and 30% respectively. In comparing the percentages of vernal pool endemic, native non-endemic and introduced to California species, between the three vernal pools, Vernal Pools #2 and #3 are similar. These two pools contained the species native to California, but not endemic to vernal pools in the highest percentage, with the introduced species in the lowest percentage. This differed from Vernal Pool #1, which had the species native to California, but not endemic to vernal pools as well as the species introduced to California in the highest percentage. Also opposing the two similar pools, was the species endemic to vernal pools, which occurred in the lowest percentage. This phenomenon is directly related to the large number of grasses occurring at Vernal Pool #1, which in turn is related to the feeding of livestock at this site.

Even though every vernal pool is in its own way unique and separate, there appears to be a noticeable similarity between vernal

pools in general. While 70% of the species occur at only one or another of the three pools, 15% of the species occur at all three of the pools. This apparent similarity is more striking when considering only the vernal pool endemic species. Sixty-one percent of the species endemic to vernal pools occurred at only one of the pools, while 34% of these species occur at all three of the pools concurrently.

Drought conditions in 1976 greatly reduced the number as well as the abundance of the species occurring at the three vernal pools. Not only were the number and abundance affected, but also the specific time of the season in which the species flowered varied from 1975 to 1976. The obvious affect of the drought on the vernal pool flora, manifests the close relationship between flora and water source in these habitats.

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