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16. ABSTRACT

In this study, we compare the diversity and quality of pollinator guilds of showy vernal pool plants in natural and created vernal pools, especially in Madera and Solano counties. Our surveys emphasize pollen host-specific andrenid bees on the assumption they are the most effective pollinators of the showy vernal pool plants. We demonstrated this for *Blennosperma nanum* and its principal pollinator, *Andrena (Diandrena) blennospermatis* in another Caltrans supported project. We find the oligolectic (pollen specific) bees in most natural relatively undisturbed vernal pool habitats, at least in the central portions of the ranges of the host plants. When created pools are constructed in areas where the bee fauna exists, they readily forage on their host plants growing in created pools. Adult andrenid bees may be held under refrigeration for at least a week. Only about 1% of adult bees exhibit evidence of reestablishing nests after release into another vernal pool habitat. We review the literature, published and unpublished on the vernal pool habitat and analyze it in relation to frequency through time, by all categories, and by faunal categories to determine the information available on the pollination process. We find only few recent references on the importance of this process to the viability of the vernal pool habitat.

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Vernal pool creation, pollination, oligolectic bees, bee diversity, bee dispersal, transplanting bees, vernal pool literature

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Determining Effective Mitigation Techniques for Vernal Pool Wetlands: Effect of Host-Specific Pollinators on Vernal Pool Plants

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CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quality	English Unit	Multiply By	To Get Metric Equivalent
Length	inches (in) or (")	25.40	millimetres (mm)
		.02540	metres (m)
	feet (ft) or (')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.432×10^{-4}	square metres (m^2)
	square feet (ft^2)	.09290	square metres (m^2)
	acres	.4047	hectares (ha)
Volume	gallons (gal)	3.785	litre (l)
	cubic feet (ft^3)	.02832	cubic metres (m^3)
	cubic yards (yd^3)	.7646	cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph)	.4470	metres per second (m/s)
	feet per second (fps)	.3048	metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G)	9.807	metres per second squared (m/s^2)
Density	(lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lb)	4.448	newtons (N)
	kips (1000 lb)	4448	newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb)	1.356	joules (J)
	foot-kips (ft-k)	1356	joules (J)
Bending Moment or Torque	inch-pounds (in-lb)	.1130	newton-metres (Nm)
	foot-pounds (ft-lb)	1.356	newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (°F)	$\frac{°F - 32}{1.8} = °C$	degrees celsius (°C)
Concentration	parts per million (ppm)	1	milligrams per kilogram (mg/kg)

NOTICE

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the STATE OF CALIFORNIA or the FEDERAL HIGHWAY ADMINISTRATION. This report does not constitute a standard, specification or regulation.

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Introduction

Vernal pools are isolated/temporary wetlands as legally defined by the Environmental Protection Agency (EPA) and as such are accorded protection by federal wetland regulations such as the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) referred to as the Clean Water Act (CWA). Section 404 of the CWA (33 U.S.C. 1344) as amended in 1977 gives the Corps of Engineers expanded juristiction to regulate the dredge and fill of vernal pools with some override by EPA. Several species of plants and animals that live in vernal pool, including some of the plants pollinated by oligolectic bees (e.g., *Blennosperma bakeri*, *Lasthenia conjugens*, and *Limnanthes vinculans*), are federally and state listed and therefore protected by the Endangered Species Act of 1973 under the juristiction of the US Fish and Wildlife Service (USFWS). However, there are human activities including highway expansion for which permits may be issued that may cause loss of vernal pools and require mitigation. Such permits may also require evaluation under the Fish and Wildlife Coordination Act of 1958 by USFWS and state fish and game agencies. Other federal provisions, the National Environmental Policy Act (NEPA) of 1969, and Executive Order 11990 issued by President Carter in 1977 also afford some protection of vernal pools.

Preservation of existing vernal pools is the most preferable mitigation method providing vernal pool habitats/ecosystems with intact high quality functions and values can be found. Restoration of degraded vernal pools and creation of new vernal pools are other potential methods of mitigation. Creation of new vernal pools has been attempted in a number of areas. The knowledge/technology for construction of depressions with adequate hydrological properties to hold winter rains and provide habitat for plants and animals that live in vernal pools is available. Seeds and cysts collected from source pools can be transplanted to inoculate created pools and produce initial guilds of species representative of the original pool community. Some organisms such as the more widespread species of fairy shrimp can exist for part of their life cycle at least in very temporary impoundments of water including tire ruts. However, few would argue that these are the equivalent of viable long-term vernal pools. Many of the wildflowers that produce the characteristic showy displays of bloom giving rise to such common names as: yellow carpet, goldfields, meadowfoam, and skyblue, will also produce initial showy displays from transplanted seed. But will these persist over time? We need a better understanding of the processes that maintain healthy thriving vernal pools and we need to extend our view to the overall habitat in which the pools exist. The long-term success of mitigation projects, especially construction of new pools needs to be validated through further research, especially on the processes that are critical to community maintenence.

Background and Objectives

Vernal pools and their inhabitants do not exsist by themselves. There are important associations with organisms that live in the surrounding uplands areas and perhaps with physical and chemical characteristisc of the uplands themselves. These associations may involve processes critical to the well being and long-term survival of organisms restricted to vernal pools. One critical process is pollination. Many endemic vernal pool flowering plants present showy displays in the spring that are considered by many to be the most striking characteristic of the pools. Many of these are pollinated by native bees that forage for pollen only on specific vernal pool flowers. These host-specific bees make their nests in the soils of adjacent upland areas and thus link the pools with the surrounding areas of the vernal pool habitat. It has been proposed by me that these host-specific native bees are the most abundant and efficient pollinators of these plants and therefore these bees are important to the reproductive success of the plants (Thorp 1969, 1976, 1990). Studies related to this hypothesis have been undertaken by my former graduate student, Joan Leong, for her PhD dissertation research and in this and another project supported by the California Department of Transportation (Leong and Thorp 1993, 1994, 1995; Leong 1994, 1995; Leong et al 1995).

This study was proposed to test the potential for long-term success of vernal pool mitigation projects. Especially projects involving construction in areas where pools had not previously occurred or where the vernal pool habitat had been so badly degraded that many of the organisms and processes had been lost or badly disrupted. The main focus of this research project is to further our understanding of the importance of what I have proposed as one of the critical processes involved with the maintenance of a viable vernal pool community. This process is the pollination of the most showy vernal pool flowering plants by native bees that are host-specific on them as sources of pollen for their brood. This association is mutually beneficial in that the reproductive success of both the flowering plants and the bees are enhanced. The bees depend on the flowers as sources of pollen. Can we demonstrate that the showy flowers similarly depend on these specialist bees for their reproductive success? There are generalist bees and other insects that visit many of these showy flowers. However, do they contribute significantly to pollination of these flowers? Do the showy vernal pool flowering plants depend significantly upon their pollen specialist bees for their long-term reproductive success?

Vernal pool flowers and their pollen specific bees:

Many of the showiest of the vernal pool flowers have highly specific interactions with some members of their pollinator guilds. Their principal pollinators are inconspicuous native solitary bees that are host-specific to these flowers for the pollen they collect as food for their offspring (oligolecty). It is likely that the flowering plants and their specialist bees have had a long evolutionary history of close association in vernal pool habitats of California. The principal genera of flowering plants that we will consider are: *Blennosperma*, *Lasthenia*, *Limnanthes*, and *Downingia*. Each of these plant taxa has a common name that reflects its showy nature: yellow carpet, goldfield, meadowfoam, and skyblue, respectively. Female bees that are host-specific for pollen of these plants belong to the family Andrenidae. These specialist bees include: *Andrena (Diandrena)blennospermatis* Thorp on *Blennosperma*; *A. (D.) submoesta* Viereck and *puthua* (Cockerell), and about six species of the subgenus *A. (Hesperandrena)* on *Lasthenia*; *A. (H.) limnanthis* Timberlake *and Panurginus occidentalis* (Crawford) on *Limnanthes*; and *P. atriceps* (Cresson) on *Downingia*. These bees fly only when their host plants bloom. We do not fully understand how the annual life cycles of the bees and plants are so closely synchronized, but the marvellous coincidence is repeated year after year.

Biology of native oligolectic bees of vernal pool habitats:

The life history of these pollen host-specific (oligolectic) bees is well illustrated by that of *Andrena blennospermatis*. Male bees emerge in early spring, a week or two before the females, and die off before the bloom season is complete. When the females emerge they mate before turning their attention to constructing nests in the upland areas near the pools. Each female digs a shallow hole in the soil and constructs a brood chamber. She then collects pollen from flower heads of *Blennosperma* and returns to the brood cell where she shapes the pollen into a small ball of dough-like consistency by adding some nectar. She lays an egg on top of the pollen provisions and seals the brood cell. She provides each offspring with all the food it needs to complete its development and has no further contact with her young. By the end of the bloom season of Blennosperma, she has completed a number of brood cells and nests. The female bees die while the next generation of bees is developing underground.

The larva hatches from the egg a few days after it is laid and consumes the pollen provisions. It develops rapidly during the spring and spends the summer resting in the brood cell as a post-feeding larva. In autumn. it pupates and transforms into an adult, but still remains in the brood cell underground throughout the winter. In early spring, the bees are ready to emerge from their nests and start the cycle again in synchrony with the bloom

of their pollen host plants. Because females mass provision each brood cell and have no contact with their developing young, they are known as solitary bees. They have only one generation per year. Unlike many insects, each female produces less than three dozen eggs, but puts maximum effort into providing a brood cell with all the food necessary for her each of her offspring. These solitary native bees thus differ greatly from the non-indigenous social honey bee.

Importance of oligolectic bees as pollinators of showy vernal pool flowers:

Among the characteristics of the bees oligolectic on the showy vernal pool flowers that suggest that they are important pollinators of these plants are their: abundance on; fidelity to; and seasonal synchrony with bloom of their host flowers. [Also the close correlation of geographic distributions of outcrossing species of the 4 plant genera and of their oligolectic bee associates. Most of the bee distributions are within those of their pollen host plants. Peripheral and amphitropical populations in the host plant genera are often self-compatible or selfing: e.g., *Limnanthes floccosa* sspp. (Arroyo 1974), *Blennosperma chilense* (Ornduff 1963,1964), *Lasthenia maritima* and *L. knuthii* (Ornduff 1963, 1966).

Although oligolectic bees have been suggested as the principal pollinators of the showy vernal pool flowers, there are few data in hand to support or deny this contention. Dr. J. M. Leong studied seed production in potted arrays of *Blennosperma nanum nanum* in natural relatively undisturbed vernal pool habitat of Jepson Prairie Reserve, Solano County, CA where the oligolectic bee, *Andrena* (*Diandrena*) *blennospermatis* and its pollen host plants were common (Leong 1994). She compared seed set with arrays presented to generalist pollinators in isolated mitigation areas in the freeway interchanges of CA 113 and I-80 southwest of Davis, Yolo County, CA. These pools were constructed in 1986 (Chainey 1989). However, no *Blennosperma* survived or were successfully transplanted nor have any oligolectic bees invaded or become established at the site. Her results suggest that the oligolectic *Diandrena* is an abundant pollinator at the natural site and that seed set is depressed in the constructed pool areas where the specialist bees do not yet exist. This type of study needs to be repeated with other combinations of plants and pollinators to determine whether the findings are of a more general nature. In this report we have added to our knowledge of potential polliantors of the showy vernal pool flowers by: 1) providing data on diversity of insects in the major flower visitor guilds (Appendices 3 & 4); 2) developing a bibliography of vernal pool litrature (Appendix 2); and 3) studying potential transplanting of adult female oligolectic bees. Some of this and other information will be summarized in a paper from a 1996 symposium talk (Thorp and Leong, in press).

Objectives of this study include:

1) Develop a better understanding of the role of pollinator guilds in the reporductive biology of flowering plants in the Central Valley vernal pools, including those on Route 41 north of Fresno, and in the Jepson Prairie area of Solano County.

2) Develop a data base on the diversity of pollinators of insect pollinated flowering plants especially host-specific bees in natural vernal pools.

3) Review data in literature, and conduct field work at vernal pool restoration sites to determine the reproductive success of insect pollinated flowering plants over more than one year.

4) Determine by field work how much, if any, refaunation by pollinators, especially host-specific bees has occurred since the initial year of bloom in constructed pools.

5) Develop techniques for enhancing refaunation of constructed vernal pools with pollinators, especially host-specific bees.

Methods

Although the original start date for this project is listed as 4 June 1992, the present work plan and funding were not available until October 1992. This was too late to initiate field studieson pollinators, but literature and musuem searches were initiated and meetings were held with PI's and their associates of two groups with DOT supported projects that planned to construct vernal pools in Madera and Solano counties (John Stebbins, CSU Fresno and Phil Northen, CSU Sonoma respectively). Our aim was to plan and coordinate our studies of pollinators with their studies of constructed pools. Construction of the artificial veral pools at the Bureau of Reclamation Equalization Reservior site in Madera County was initiated in September 1993 (Stebbins et al. 1995). Construction of vernal pools at Travis Airforce Base, Solano County was initiated in November 1993. [Raw data are in Appendices 3-5: for lists of specimens collected at all sites, see Appendix 3; for specific dates and summaries of field studies, see Appendix 4; for maps designating locations of field study sites see Appendix 5.]

Madera County sites:

Field studies of pollinators of natural and created vernal pools in Madera County, California supported by funds from the California Department of Transportation were initiated in spring 1993. An initial (pre-project) inspection for vernal pool flowers was made along Highway 145 between road 33 and Highway 41 (Four Corners) in March 1992. Study sites included: natural pools along Highway 145 between Road 33 and

Highway 41, Highway 41 between the Fresno County line and Highway 145, on the Finston Ranch between Road 15 and Highway 145, along Road 33 near junction with Road 400, and on Table Mountain; and natural and constructed pools at the Bureau of Reclamation Equalization Reservoir southwest of Hensley Lake. Pools at the latter site were constructed and seeded in September 1993 (Fig. 1).

Surveys for native, solitary, pollen-specific (oligolectic) bees were initiated in spring 1993 prior to creation of artificial pools to determine whether oligolectic bees were present at the created pool site. Surveys were also made at the seed source site (Finston Ranch) and in the surrounding areas to determine the diversity of pollinators associated with natural pools in Madera County. Primary emphasis was placed on surveying vernal pool species of *Lasthenia fremontii*, *Limnanthes douglasii rosea*, and *Downingia bicornuta*, and *D. ornatissima* all known to have specialist bees associated with them in other areas. Also examined were *Mimulus tricolor*, *Gratiola*, and *Plagiobothrys* in the pools and other plants in areas surrounding pools known to have oligolectic bees associated in other parts of their ranges including: *Eschscholzia lobii*, and*Agoseris heterophylla.*

Pan-traps mostly consisting of paired yellow and white plastic bowls containing a water/detergent solution were placed in patches of flowers to monitor pollinators in some of the natural and created pools at the Bureau of Reclamation site. [See section on Experiments and Observations at Jepson Prairie for more detailed description of the traps]. Samples were taken: 18 March 1994 (11:53 AM-13:00 PM) in "artificial dozer pool" with *Lasthenia* using two yellow pans; 15 April 1994 (11:20 AM-15:50 PM) in swales northwest corner (where *Limnanthes* had been previously) one plant of *Limnanthes* and mostly *Lasthenia* when sampled using six pairs of yellow and white pans in each of two swales; and 22 April 1995 (11:45 AM-17:10 PM) in swales in northwest corner with few *Limnanthes* and mostly *Lasthenia* using 4 pairs of yellow and white pans in each of two swales.

At the 200 acre site along the east side of Highway 41 just north of Avenue 12, newly acquired by CalTrans *Castilleja campestris* ssp. *succulenta* (=*Orthcarpus succulentus*) and *Downingia* were cursorily examined shortly after the pools were inundated by late rains. The large pool along Road 33 near the junction with Road 400. dominated by *Downingia* was also sampled in more than one year. Table Mountain was surveyed in May 1993. This was late in the bloom season, but plants known to have oligolectic bee associates including: *Lasthenia*, *Downingia*, and *Sidalcea* were still available to be surveyed.

Travis Airforce Base natural and mitigation pools:

Surveys for oligolectic bee pollinators were made of the natural pools in the vicinity of the site of construction of the created pools in the spring prior to (May 1993) and the spring immediately after (April and May 1994) pool construction. The constructed pools were basically sloping ramps with parallel sides constructed to determine the effects of slope on the zonation of vernal pool vegetation in relation to duration of inundation. Plants of interest included: *Downingia concolor*, *D. insignis*, and the endangered, *Lasthenia conjugens*. Due to its sensitive listed status, the latter species was not inoculated into the created pools. *Lasthenia glaberrima* , was also present, but of little interest since it is primarily self-pollinated.

Observations were made at the created pools early in the year following construction. However, none of the plants of interest came into bloom at the time although they were in bloom in the natural pools.

Roseville vernal pools (natural and mitigated):

Surveys of natural and mitigated pools in the Roseville, Placer Co., CA were made in spring 1995 with the aid and cooperation of Pete Balfour, Sugnet & Associates and Neila Stewart, Environmental Coordinator, City of Roseville. Areas surveyed include: Highlands (vicinity of Roseville Parkway and Pleasant Grove Boulevard); area near a PG&E substation (Harding Blvd. between Atlantic Street and Roseville Parkway); Silverado (vicinity of Pleasant Grove Blvd and Country Club Drive, and vicinity of Woodcreek Oaks and Junction Blvds.); and Kerry Downs (vicinity of Woodcreek Oaks and Junction Blvds., and blind west end of Killarney Street). Plants of interest include *Blennosperma nanum*, *Downingia bicornuta*, *D. cuspitdata*, *D. ornatissima*, and *Lasthenia fremontii*. Other plants observed and/or sampled include: *Agoseris*, *Layia*, *Eschscholzia lobii*, and *Sidalcea*.

Pan-traps were used to sample at PG &E and Highlands sites in addition to net sampling. Traps were set within dense flower displays primarily consisting of *Lasthenia* and/or *Downingia*. One pan of each color, yellow, white, and blue were set in two flower patches at each site.

Other natural and mitigated vernal pool habitats surveyed for pollinators:

The focus of this project has been natural and mitigated vernal pools in Madera, Placer, and Solano counties. As opportunities arose during the tenure of this project, other vernal pool habitats were surveyed for showy flowering plants of interest and their

pollinators, especially oligolectic bees. Many of these surveys were made in conjunction with other bee research and pollination projects, but they seem of value to report upon here.

These areas included: an area south of Chico, east of Durham, Butte County; areas north of Los Banos, near Stevinson, Merced County; Santa Rosa, Sonoma County; and Santa Cruz Island, Santa Barbara County.

The area south of Chico included large patches of *Blennosperma nanum*, in paddocks and along the side of the old Oroville-Chico road about 4 miles east of Durham and 10 miles south of Chico. Yellow pan-traps were set out in the patch in early morning and retrieved in late afternoon during visits to an almond orchard in the vicinity. Limited observations and net collections were made during the middle of the day when pollinators were active.

The Los Banos area included: Arena Plains Park NWR south of Hwy 140 ca 18 miles NNE of Los Banos; and Grasslands State Park, east of Hwy 165 (J14) ca 14 miles N. Los Banos. These sites were visited in early May 1993 when the vernal pool plants of interest: *Lasthenia* at Arena Plains, and *Downingia* at Grasslands were past their peak of bloom. Visitors to the plants of interest were visually observed and/or sampled by net.

The Santa Rosa site is on Alton Lane in the northwest area of the city. It is a mitigation site where there are significant populations of the endangered,*Blennosperma bakeri*. There are both natural and created pools at this site. Studies of the reproductive biology of *B. bakeri* were being conducted by J M Leong at this site. There are also populations of *Limnanthes* at this site.

On Santa Cruz Island, the extreme northwest peninsula, Fraser Point, boasts extensive populations of *Lasthenia chrysostoma*, net collections and white pan-traps were used to sample flower visitor populations.

Experiments and observations at Jepson Prairie Reserve:

Historical information on oligolectic pollinators: The bee fauna of the Jepson Prairie Reserve is one of the best known for any vernal pool habitat. Collections have been assembled from classes and especially the personal efforts of R. W. Thorp since before the area was purchased by TNC and became a part of the UC Natural Reserve System. Most of these collections are in the R. M. Bohart Museum of Entomology, U. C. Davis. Many of the critical experiments performed by Dr. J. M. Leong to determine the effect of a pollen specialist bee on one of the showy vernal pool plants were conducted here.

Search for nests of oligolectic bees: Prior to this site being purchased by TNC, a number of nest sites of solitary ground nesting bees were identified and sampled by students from UCD. These were based primarily on visual searches for tumuli and nest

holes, especially in bare soil also watching females with pollen drop to the ground or into vegetation away from flowers. Most of the prime nesting area identified is now within the area designated as Argyle Park, but outside the moto-cross track itself. Other nests have been noted over the years, especially along paths and other areas of exposed soil in the upland areas. Most of the observations of the locations of these nests have been casual and no concerted effort has been made to identify and study the nesting behavior of these bees.

Pan-trap sampling design: Plastic bowls ("Party Bowls" by Solo Cup Co., Urbana, IL) with an outer (target) diameter of 15 cm at the top; inner diameters of: 12.5 cm (top), 11 cm (middle), and 8.5 cm (bottom); and a depth of 4 cm with 2 cm to the middle were filled to mid level with a scentless detergent and water mix (1 ml detergent/ 1 liter water). Bowls colored yellow, white, and blue were set up in a 3x3 Latin Square design with taps separated by one meter. At Jepson Prairie Reserve they were placed in patches of the white flowered *Limnanthes douglasii* var. *rosea* to test the efficiency of the method for sampling oligolectic bees (Leong and Thorp 1995). The focus of our sampling was the oligolectic bee, *Andrena* (*Hesperandrena*) *limnanthis* Timberlake. These pan-traps were also used to monitor natural and constructed pools and at several sites outside of Jepson Prairie Reserve including: Bureau of Reclamation Equalization Reservoir, Madera Co.; Roseville, Placer Co.; S of Chico, Butte Co., and Fraser Point, Santa Cruz Island, Santa Barbara, Co. Since oligolectic bees of vernal pool flowers are active mostly in the middle of the day (ca 10AM -3PM) we try to set out the pans before 9AM and collect them after 4PM.

Translocation of adult bees: Two experiments were conducted to determine the feasibility of transplanting adult females of oligolectic bees. The first phase consisted of attempts to determine the longevity of storage of adults on ice for transportation between sites and to account for possible delays in release at new sites due to inclement weather. In May 1993, adult females that had already established nests were collected by net while foraging for pollen at host flowers at several sites including: Merced Co. on *Downingia*; Sonoma County on *Downingia*; Solano County on *Downingia* and on *Lasthenia*. Two to six female bees were transferred to small plastic viles (film canisters 3 cm in diameter by 5 cm tall) containing two to four of the host flowers. The vials were placed in a cooler with blue ice at about 4°C and returned to the Davis campus. The vials were then stored in a refrigerator at about 4°C. The vials were removed periodically and brought to room temperature (at about 24°C)to check for mortality. Specimens were categorized as: "Alive" if they were able to right themselves and actively crawl around the vial; "Twitching" if there was any perceptable movement of legs or antennae after 10 minutes warming; or "Dead" if no movement or response to probing after 10 minutes warming. Dead bees were removed

and pinned as vouchers. Most alive bees became active within a couple of minutes at room temperature. Bees that were alive or exhibited some twitching response were returned to refrigeration. These observations continued for up to 4 weeks.

The second phase involved capture of 91 nesting females while gathering pollen from *Lasthenia* south of Olcott Lake, Jepson Prairie Reserve, Solano County, CA in April 1994. The females were transferred to plastic vials and placed in an ice chest on blue ice. They were transported to Davis. That evening they were categorized by size, identified, and marked with an orange spot of Testors® acrylic paint on the middle of the thoracic dorsum. They were placed into cardboard photo slide boxes (5.5x10.5x2.5cm) and stored overnight in a refrigerator at about 4°C. Since these were all Andrena females that do not sting, they were easily manipulated by hand during the sorting, identification, and marking. The next morning (07:35 AM) they were transported on ice and released at the Reserve about one mile north of the site of capture in an area with good bloom of *Lasthenia*. The slide boxes with bees were placed on a larger cardboard tray (40x27x6cm) weighted with rocks to prevent being blown over. The slide boxes were opened partially so that the bees could escape and yet be protected from bird predation while still groggy. As soon as the slide boxes were openned, bees began crawling up their sides. The release boxes were checked that afternoon (13:05 PM) to evaluate the success of release. Surveys were made to determine the presence of the marked bees at the release site and at the site of original capture one mile south. Subsequent surveys for marked bees were made three and eight days after release.

Museum surveys:

The extensive holdings of vernal pool bees in the collections of the R. M. Bohart Museum of Entomology, U C Davis were used as a basis for comparison with and identification of vernal pool pollinators collected during the tenure of this project. Special emphasis was placed on the solitary, ground nesting, oligolectic, bees of the family Andrenidae. New records of the distribution, adult flight season, and floral associations of *Andrena* (*Diandrena*) *blennospermatis* Thorp were emphasized.

Literature surveys:

Standard searches were made through the resources of the main campus library, Shelds Library, at U C Davis to find published literature on the vernal pool habitat and its flora and fauna. The more difficult literature to access is the so called "gray literature" such as unpublished reports to various agencies sponsoring research on vernal pool topics. Some was accessed through the courtesy of the California Department of Fish and Game,

who allowed us to peruse their files and copy pertinent articles. Other reports have been obtained through the courtesy of private consultant firms such as Sugnet & Associates, Roseville, CA; Dames & Moore, Goleta, CA; Jones and Stokes Associates, Sacramento, CA. Other publications, bibliographies, proceedings papers and abstracts, and reports have been made available by individuals including: Ellen Bauder, Kerry Dawson, Peggy Fiedler, Sean Gallagher, Steve Greco, Richard Hill, Gary Jolliff, Jamie King, David Kistner, Marilyn Murphy, Neila Stewart, Paul Zedler. Pertinent references have been compiled in an Appendix entitled "Vernal Pool Bibliography." Analyses of the literature entered through 1994 by: 1) publication date to obtain historical trends; 2) category to determine frequency of topics and relative frequency of publication.

Results

Madera County sites:

Bloom of vernal pool plants on the Finston Ranch and environs was not extensive in 1993. No oligolectic bees were found in association with either *Lasthenia* or *Downingia*. Generalist bees, visited some of the upland flowers (Appendix 3). Generalist flies (Anthomyiidae), and micro-Hymenoptera (Braconidae) were found on *Lasthenia*. Since these were not considered to be important pollinators, no voucher specimens were collected.

At the Equalization Reservoir site, some created pools produced good bloom of *Downingia*, and some *Lasthenia*, *Gratiola*, and *Mimulus tricolor*. Only generalist bees and flies were found in association with *Lasthenia* and *Mimulus*. The same generalist bees were found in association with *Eschscholzia* and *Agoseris* in the surrounding grasslands. Females of the specialist pollinator, *Panurginus* sp., were found collecting pollen from the flowers of *Downingia* in created pools in 1994. No bees were found at *Gratiola*. A few natural pools were found west of the tiered series of created pools at Site 4 along the north shore of the reservoir (Fig. 1). These contained *Limnanthes douglasii rosea* and *Lasthenia*. A species of oligolectic bee, *Andrena* (*Hesperandrena*) *limnanthis* Timberlake was found associated with flowers of *Limnanthes*. Some of the natural pools north of Site 1 contained *Downingia*, but never in sufficient abundance (more than 100 flowers) during this study to permit effective sampling for pollinators (Fig. 1).

Pan trap samples from natural pools (swales) west of the created pools north of the reservoir produced bees of the genus *Panurginus* which are oligolectic on *Downingia*. These pools contained plants in flower: primarily *Lasthenia* and some *Limnanthes*, but none of their pollen host plant, *Downingia*, at the time of sampling. Most of the bees

found in the pan traps were generalist foragers including: *Dialictus*, *Halictus* (*Seladonia*) [Halictidae], *Osmia* [Megachilidae], *Synhalonia* [Anthophoridae], and *Apis* [Apidae]. The most abundant of these were the halictids, especially *Dialictus*. Females of two species of *Andrena*: *A.* (*Diandrena*) *subchalybea* Viereck and *A.* (*Scoliandrena*) *osmioides* Cockerell were found in pan traps in 1995. The *Diandrena* is oligolectic on ligulate (Cichoriae) Asteraceae that occur in the grasslands surrounding the pools. The *Scoliandrena* is oligolectic on *Cryptantha* and gathers nectar from *Plagiobothrys*. The most abundant insects picked up by the pan traps were flies. They were represented in significantly greater numbers in the yellow traps as compared to the white traps in 1994 (Table 1), but the reverse occurred in 1995. None of the other taxa showed any significant differences in abundance due to trap type in 1994. The yellow pan-traps in the "artificial dozer pool" with *Lasthenia* collected only Diptera (8), Chrysididae (6), and one Homoptera (Leafhopper) in mid March 1994.

The 200 acre site along the east side of Highway 41 just north of Avenue 12, newly acquired by CalTrans was shown to me in spring 1995 by Dr. John Stebbins. Plants of special interest were *Downingia* and *Orthocarpus succulentus*. The site had been reinundated by recent rains and most of the *Orthocarpus* was in the water. *Downingia* had mostly flies and a few generalist bees associated with it. Follow-up observations as the pools dry out again are needed.

The large pool along Road 33 near the junction with Road 400 contained another species of *Downingia*. It had primarily flies and a few generalist bees associated with it. This pool is surrounded by plowed land. The pool is also usually plowed as soon as it is dry. However, the *Downingia* apparently has sufficient time to set seed each year judging by the repeated annual bloom at this site.

One visit was made to Table Mountain late in the bloom season (May) of 1993, after bloom of *Blennosperma* and *Limnanthes* had finished and most of the *Lasthenia* had gone to seed. Plants of interest in bloom at the time included *Downingia* and some late *Lasthenia* in the pools and *Sidalcea* in the surrounding areas. Oligolectic bees were found in association with *Downingia* (*Panurginus* sp.) and *Sidalcea* (*Diadasia nigrifrons* (Cresson)). Pools on this and adjacent tables may serve as sources for oligolectic bees for future experiments to try transplanting oligolectic bees to created pool sites. Subsequent trips to Table Mountain and Kennedy Meadows planned in 1994 and 1995 had to be cancelled due to weather.

Travis Airforce Base naural and mitigation pools:

Surveys of natural pools determined by visual observation that pollen collecting females of *Lasioglossum titusi* (Crawford) were visiting *Lasthenia conjugens* in May 1993 and in early April 1994 along with males and pollen collecting females of *Andrena* (*Hesperandrena*) sp. 1. Net sampling showed that females of these same bees were also collecting pollen from *Layia* in early April 1994 and that males of *A.* (*Diandrena*) *chlorosoma* Linsley & MacSwain, males and pollen collecting females of *A.* (*Hesperandrena*) sp. 1, and pollen collecting females of *A.* (*Hesperandrena*) sp. 2 were also foraging on *Layia* at the same time. Pollen collecting females of *Panurginus atriceps* were found in association with *Downingia concolor* in natural pools.

Observations of mitigated pools showed none of the plants of interest came into bloom by mid May 1994 although it appeared that *Downingia* would bloom in some of them.

Roseville vernal pools (natural and mitigated):

Surveys of natural and mitigated pools and pan-trap samples produced pollen-specific (oligolectic) bees in association with several flowering species. Males and pollen collecting females of *Andrena* (*Diandrena*) *blennospermatis* were found foraging in association with *Blennosperma nanum* at the Highlands site in early March 1995. Males and pollen collecting females of *Panurginus atriceps* were found in association with *Downingia* spp.at all sites in early May (except Silvarado southwest where no effort was made to resurvey in May). Pollen collecting females of *Andrena* (*Diandrena*) *submoesta* Viereck were found in association with *Lasthenia* spp. at the PG&E and Highlands sites in early May. The only other pollen specialist bees found at the Roseville sites were: a female of *Lasioglossum titusi* (Crawford) with pollen from *Layia*; in early May at the PG&E site, and *A.* (*Diandrena*) *subchalybea* Viereck with one male and three females found at flowers of *Eschscholzia lobii* in early March at the Highlands site. The latter three females had pollen in their scopae (pollen transport structures), but the pollen was small and white and was not from *Eschscholzia*. The presumed pollen hosts for this bee are ligulate Asteraceae such as *Agoseris* (Thorp 1969). However, *Agoseris* was not noted at the time of collection and the pollen is the wrong color for this host. The pollen was possibly a mixed load and may contain some *Blennosperma*., but this awaits confirmantion.

Pan-trap sampling confirmed the pollinator species diversity found in aerial net samples made at the PG&E and Highlands sites in early May.

Other natural and mitigated vernal pools surveyed for pollinators:

Net collections and yellow pan-trap samples from roadside populations of *Blennosperma nanum* in the Chico area produced very few visitors. This was partly due to cold, windy, and/or overcast weather conditions during the times of sampling February and March 1994 and 1995. The predominant visitors were the introduced honey bee, *Apis mellifera* L., and miscellaneous flies, all generalist pollinators. The honey bee does not frequently visit *Blennosperma* at most sites, but will collect pollen from it and did so at this site.

At the Arena Plains NWR site north of Los Banos, the only vernal pool plant we found at the time of our late visit was Lasthenia. It was well past its peak of bloom and had few insects visiting it. One male *Andrena* was observed on the flowers, but it is not likeley that it was a member of a species oligolectic on *Lasthenia.* There was a fair diversity of flowering plants in the areas surrounding the pools that might facilitate populations of generalist pollinators of the vernal pool flowers. At the Grasslands State Park area north of Los Banos populations of *Downingia* were observed to be past their peak of bloom. Most of the visitors were the generalist sweat bee, *Halictus* (*Seladonia*) sp., but a few pollen collecting females of the oligolectic *Panurginus atriceps* were observed.

At the Alton Lane mitigation site in Santa Rosa, males and females of *Andrena* (*Diandrena*) *blennospermatis* were observed visiting flowering heads of *Blennosperma bakeri* in early April 1993. Females of two other species of *Andrena* were also occasionally observed visiting *B. bakeri.* Females of *A.* (*Hesperandrena*) *limnanthis* an oligolege of *Limnanthes* were also observed at this site.

At Fraser Point, Santa Cruz Island, the extensive flowering population of *Lasthenia,* was being heavily visited by several species of oligolectic andrenid bees. Samples included: *A.* (*Diandrena*) *submoesta*; *A.* (*Hesperandrena*) 2 species; and *Perdita* sp. and other bees and flies. The dominant visitorswere oligolectic bees of the subgenus *Hesperandrena.*

Experiments and observations at Jepson Prairie Reserve:

Historical information on oligolectic pollinators: Most of the published historical information on oligolectic bees at Jepson Prairie Reserve can be found in Thorp (1976, 1990).

Search for nests of oligolectic bees: Nests of solitary, ground nesting, oligolectic bees are not commonly encountered without intensive search. Casual observations at this site only located occasional bee nests. These nests were not identified to species due to

inability to locate and associate the founding females with them. As a result no attempt was made to excavate them or to use them in transplant experiments.

Pan-trap sampling design: Generalist and specialist bees were readily attracted to the pan-traps. Females of the oligolectic *A*. (*Hesperandrena*) *limnanthis* were the most abundant bees collected. The color preferences based on pan-trap abundance data indicate that blue and white were equally attractive to these females (Leong & Thorp 1995, 1996). However, males of this species were not abundant in the pan-traps. Overall species richness was marginally higher in yellow than white traps. White traps accumulated greater numbers of bees per trap than either blue or yellow.

Translocation of adult bees: Adult females from several sites brought to Davis on ice and stored in a refrigerator to determine the length of storage under refrigeration showed considerable variation in survivorship. Some mortality was found within the first two days, but about one-half of the bees were still alive after two weeks of storage. Over 72% of the bees were alive after one week. Maximum length of survival in cold storage was 26 days.

Of the 91 marked bees released the morning after capture at Jepson Prairie Reserve, only five were found dead in the release box 5.5 hours after release. No dead bees were found in the vicinity of the release box. It is assumed that 86 marked bees were released. Samples of 132 bees at the release site and 75 bees at the original collection site produced no marked bees on the day of release. Three days after release one marked bee was observed collecting pollen at *Lasthenia* at the release site out of 37 bees surveyed. By the 8th day most of the *Lasthenia* was spent, but 12 bees were observed at the release site, none were marked.

Museum surveys:

Collections/Museums: Collections in the R M Bohart Museum of Entomology, University of California, Davis contain large numbers of vernal pool oligoleges and generalist pollinators. These have accumulated over the years through the efforts of RW Thorp and his long-term studies on oligolectic bees and vernal pool pollination systems. Many of the collections were made in the 1970's when cooperative studies with Dr. Subodh Jain, Agronomy and Range Sciences, UC Davis on *Limnanthes* and with Dr. James R. Estes, Univ. Oklahoma, Norman, who spent a sabbatic leave at UC Davis in 1974 to work on vernal pool plants in general, were being conducted. Most of these collections are in need of detailed identifications of the bees and other pollinators and to be currated and entered into a database system for ease of use. One of the reasons the bees have not been fully identified is that the the bulk of the bees, associated with *Lasthenia*

belong to *Hesperandrena*, the only North American subgenus of *Andrena* that remains to be revised, and many are undescribed new species. This group is scheduled for revision by W. E. LaBerge, Illinois Natural History Survey and R. W. Thorp by 1999. Specimens from many museum collections have been acquired and accumulated by R. W. Thorp in preparation for this taxonomic study.

New records and distribution of *Andrena (Diandrena) blennospermatis* Thorp: New records have been accumulating in the collection of the R. M. Bohart Museum of Entomology, U. C. Davis since the description of the species was published by Thorp (1969). The known distribution at the time the species was described included only: the type locality, Esparto, Yolo County and from Contra Costa, Sonoma, and Lake counties. Additional records found by us include: Solano, Sacramento, San Joaquin, El Dorado, and Placer counties.

Literature surveys:

Pertinent references have been compiled in Appendix 2, entitled "Vernal Pool Bibliography." Analyses of the literature entered through 1994 incicate a sharp increase in publicatons on vernal pool topics since the 1960's (Fig. 2). Most of the unpublished "gray literature" has appeared since the 1980's. The most considered category has been the flora of the vernal pool habitat, accounting for 60% of the total literature (Fig. 3). Only about 4% of the publications consider pollination. A large proportion of the Mitigation/restoration/creation of vernal pools is unpublished. Most of the studies on the vernal pool fauna have been conducted on the aquatic invertebrates (Fig. 4).

Discussion

Madera County sites:

The vernal pool areas in the eastern San Joaquin Valley of Madera County do not seem to be rich in oligolectic bee species, but conditions for surveys have not been ideal due to a prolonged series of drought years preceeding the surveys. During these years when there was normal or near normal rainfall, the pattern was abnormal with most rain being in March or February rather than starting in October-November. This pattern of late onset of rainfall is not conducive to good bloom of the vernal pool plants and appears to have adverse effects on emergence and reproduction of the associated oligolectic bees. The low diversity of oligolectic bees at the created pool site is likely due to the lack of good populations of vernal pool flowers in the natural pools. Although one species of oligolectic bee was found in association with the *Limnanthes* in a natural pool at the site, no

Limnanthes are present in the created pools. However, *Limnanthes* could be seeded in the created pools and monitored to determine how long it would take for natural spread of the oligolectic bee.

Net collections in 1994 documented the presence of *Panurginus* sp. an oligolege of *Downingia* in created pools at the Reservoir site. This find was confirmed by finding these bees in pan-trap samples in nearby natural pools/swales in 1995. Although these were primarily occupied by *Lasthenia* with very little *Downingia* the latter does occur in other natural pools at the site. This suggests that there was a resident population of bees in the area that was available to service the plants derived from inoculum in the created pools.

The nearby table areas seem to contain some of the oligolectic bees of interest and may be good sources of bees for experimental transplants to the created pool site in the valley. Reproduction of bloom of vernal pool flowers such as *Downingia* and *Lasthenia* in the created pools should be monitored and surveys to determine the diversity of pollinators should be continued.

Travis Airforce Base natural and mitigation pools:

Surveys of natural pools - Does the co-ocurrence [overlap] of bloom of *Layia* and *Lasthenia conjugens* and the fact that they share of some members of their pollinator guilds result in facilitation or competition between the two plant species for pollinators (Rathke 1983)? Or is there little or no effect from this overlap? A further study of this situation would be critical to sound management practices for the endangered *L. conjugens*.

Observations of mitigated pools - If *Downingia* do bloom in the created pools, it is expected that the oligolectic bee, *Panurginus* would easily find and visit them due to the viable populations of this bee on *Downingia* in close proximity to the creation site.

Roseville vernal pools (natural and mitigated):

At least one of the oligolectic bees was found in association with each of the showy vernal pool flora examined: *Blennosperma, Lasthenia,* and *Downingia* in both natural pools and nearby created/restored pools. This is due to the fact that the created/restored pools were in close proximity to natural pools that retained most of the critical species of their pollinator guilds. This argues well for the perpetuation of the flowers in these pools as long as the upland habitats do not become degraded and the oligolectic bee populations lost.

Other natural and mitigated vernal pools surveyed for pollinators:

The apparent absence of the oligolectic bee, *Andrena* (*Diandrena*) *blennospermatis*, from the population of Blennosperma nanum south of Chico may be an artifact of the brief

and non-ideal observation periods. However, it may be that this population is in fact peripheral to the distribution of the specialist bee and relies soley on generalist insect pollinators for its reproduction. This situation is in need of further investigation.

The lack of specialist pollinators on *Lasthenia* at the Arena Plains site is most likely explained by the flowers being well past their peak of bloom at the time of observation. The low numbers of the oligolectic Panurginus atriceps observed at Downingia at the Grasslands site north of Los Banos again were probably due to the late time of observation in relation to the bloom period fo the flowers.

At the Alton Lane mitigation site, the principal oligolectic bees associated with both *Blennosperma* and *Limnanthes* were found to be present due to the historic presence of natural pools at the site. However, the increasing construction of new pools at the site in mitigation for actions elsewhere in the county, is reducing the amount of upland areas to suport these pollinators. With the future increase in abundance of the flowering plants and the loss of potential habitat for nest construction by the oligolectic bees, it appears inevetible that there will be severe competition among the plants of the pools for the services of both oligolectic bees and generalist pollinators.

The abundance and diversity of oligolectic and generalist pollinators at Lasthenia on Fraser Point, Santa Cruz Island, bodes well for the continuation of a healthy ecosystem since minimal disturbance should occur here. However, if fennel invades the area and continues to spread as it has done on many other parts of the island, the habitat will be severely degraded for both the plants and their associated bees.

Experiments and observations at Jepson Prairie Reserve:

Historical information on oligolectic pollinators: The diversity of oligolectic pollinators and the pollinator guilds of the showy vernal pool plants are well documented in publication (Thorp 1976, 1990; Leong and Thorp 1993; Leong 1994). This site contains a viable diversity of vernal pool flowers and their oligolectic bee pollinators as well as many generalist pollinators.

Search for nests of oligolectic bees: Nests of solitary, ground nesting, oligolectic bees are not commonly encountered without intensive search and good luck. As a result it will be difficult to depend upon location of nests for potential transplant experiments, much less large scale transplants needed to support the flora in created pools as mitigations if they are far off site from the source pool habitat.

Pan-trap sampling design: Pan-traps have proven useful for sampling agricultural pests, especially aphids (Southwood 1978, Chapter 7). The modified traps and design developed here are potentially useful for sampling bees in a wide variety of diversity,

conservation, and pollination studies. We have shown that they are effective for sampling bees oligolectic on vernal pool flowers. The low sampling costs, passive rather than active sampling, and the capability for one individual to monitor several sites at the same time make these especially effective monitoring tools.

Translocation of adult bees: The cold storage experiment demonstrated that solitary bees can be transported on ice and stored under refrigeration without feeding up to a week without appreciable loss. This would allow considerable time for long distance transportation to another site. It also suggests that they can be safely held over periods of inclement weather for release under suitable flight conditions.

The question of successful establishement after release is at least partly indicated by the transplant experiment carried out at Jepson Prairie Reserve in 1994. Although only one of 91 marked bees was found at the release site, the fact that this female was collecting pollen indicates that she had established a new nest at the release site. More experiments of this nature are needed. In addition, location, excavation, and transplantation of nests needs to be carried out.

In tranferring adult bees of the genus *Andrena* precautions should be taken to ensure that individuals infested with parasites of the genus *Stylops* are not included. These individuals are easily recognized with a hand lens and collectors can easily be trained to discriminate between healthy and parasitized bees. Cuckoo bees of the genus *Nomada* should not be included in any "inoculum" for release into new habitats either.

Museum surveys:

There are still considerable areas throughout the range of the outcrossing species of *Blennosperma* where the bee, *A.* (*Diandrena*) *blennospermatis* has not yet been found. Thus far, the bee has been found primarily across the center of the range of *B. nanum* and including the range of *B. bakeri*. Based on the increase in distribution records we have found, it is likely that the bee is more widespread throughout the range of its pollen host plants. Reasons why it has not been collected more frequently include its early and short season of activity, inclement weather during this season that affects both the bee population size and intensity of collection efforts by entomologists, lack of interest by pollination biologist, and limited access to vernal pool habitats. In 1996, museum records of the distributions of the primary oligolectic bees and guilds of all visitors to vernal pool flowers were compiled and summaries of these were presented at a vernal pool conference in Sacramento in June 1996 (Thorp and Leong, in press).

Literature surveys:

Since most of the literature on mitigation, creation, and restoration of vernal pools is in the form of unpublished reports, it is relatively unavailable to most research scientists and the public at large. Our literature survey is far from complete, especially in the area of the "gray" literature (unpublished reports). However, it is apparent from the analyses our survey that there has been a marked increase in interest in the vernal pool habitat, especially the flora and aquatic invertebrate fauna of vernal pools. Relatively little attention has been given to terrestrial organisms living beyond the margins of the pools, or to the ways in which they may influence organisms living in the pools. The focus of this project, the effects of oligolectic bees versus generalist pollinators on the pollination and reporductive success of showy vernal pool flowers is a relatively small part of the literature (less than 5%). It is only one of many potential such processes that may influence the life histories and reproductive success of organsims living in the pools. Other such processes might include: competition for pollinators by alien weeds; competition for space from alien weeds (e.g. *Lippia*); interference or degredation of habitat for the Delta Green Ground Beetle (*Elaphrus viridus*) by alien weeds; potential facilitation of herbivores of pool plants by alien weeds; and many other as yet unidentified potential interactions. The full bibliography resulting from our literature search efforts appears in Appendix 2.

General considerations and questions raised-

We know too little about the various critical functions, processes, and interactions among community members of the vernal pool habitat. Are the bees that are host specific for pollen (oligoleges) keystone species in the community? Will lack of oligoleges cause lower seed set in all plants associated with specialist pollinators? Will this result in decline of the showy flower populaitons over time? Will this have a cascade effect on other flowering plants and animals in the system through a lack of facilitation (e.g. inability of the system to support sufficient numbers of generalist pollinators and/or lack of sufficient seeds to facilitate ant and other seed disperser populations that other plants depend upon for seed production and dispersal)? Further studies are needed to determine whether the significant decrease in seed set we found in *Blennosperma* where its oligolege was missing and it was serviced only by generalists can be generalized to other vernal pool plants (Leong and Thorp 1993, Leong 1994). This means repeating some of the same type of studies initiated by Leong (1994) using other flower/oligolege systems in the vernal pool habitat.

Conclusions

1. Pollination is one of the processes/interactions/ecological functions of the vernal pool habitat that transcends the boundaries/margins of the pools and yet has a strong influence on maintenance of the flora of the pools.
2. Guilds of insect visitors/pollinators of the genera of showy vernal pool flowers emphasized in this study (*Blennosperma*, *Downingia*, *Lasthenia*, and *Limnanthes*) include specialist (pollen specific = oligolectic) bees and generalist flower visitors, including bees.
3. Flower visitor guilds associated with *Blennosperma* and *Downingia* have the least diversity while those associated with *Limnanthes* and *Lasthenia* have the greatest diversity.
4. Not all visitor guilds of flowers in natural pools in the Madera/Fresno area contain oligolectic bees (e.g., *Lasthenia* at Finston Ranch and vicinity).
5. It is important to know the composition of the visitor/pollinator guilds of a habitat before and after creation of new pools. Pollinators such as oligolectic bees may be useful as indicator species for predicting reproductive success of the showy characteristic vernal pool flowering plants.
6. Insects that comprise the guilds of visitors/pollinators of the showy vernal pool flowers require upland habitat for part of their life cycle.
7. Solitary pollen specific (oligolectic) bees are often the most abundant visitors and probably most important pollinators of showy vernal pool flowers. They construct their brood nests in upland soils and therefore, are not among the banks of seeds/eggs/cysts of the flora and fauna that are captured from source pools for inoculation into pools created for mitigation. As a result such created pools will be missing a critical element of their natural processes unless they are constructed in close proximity to existing pools with an adequate fauna of oligolectic bees already on site that can provide immigrants to the new pool habitat.
8. Natural refaunation of created pools by specialist (oligolectic bee) pollinators occurs when there are natural pools with pollen host plants and oligileges on site.
9. Transplanting oligolectic vernal pool bees may be attempted if no natural populations of pollen host plants and oligoleges occur within the vicinity of created pools. Bees can be kept refrigerated sufficient time to move them to a new site for release.
10. Addition of new pools to areas set aside for mitigation reduces upland habitat required by pollinating insects and increases the density of pool flora setting up potential competition among increased flowers for decreasing pollinators.
11. Plants flowering outside vernal pools may provide alternative pollen and nectar sources that facilitate or compete for services of pollinators with the flora restricted to the

pools. Such pollinators are often generalists, but they may also include some specialist bees. Oligoleges of *Lasthenia* for example, often collect pollen from vernal pool as well as dry habitat species of the genus and some have been found collecting pollen from other species of Asteraceae such as *Layia*.

12. Some oligolectic bees cannot be fully identified, because they have not yet been named.

Recommendations

1. The necessity of pollination, especially by oligolectic bees, should be taken into account whenever mitigations involving restoration of degraded vernal pools and/or creation of new pools is contemplated.
2. Criteria for success of created/restored mitigated vernal pools need to consider the overall biotic diversity (including flower visitor guilds) with that of source habitats.
3. Target species including characteristic showy vernal pool flower genera such as: *Blennosperma*, *Downingia*, *Lasthenia*, and *Limnanthes*, even their common non-listed species, should be monitored to determine success of created pools.
4. Their reproduction should be evaluated, especially in comparison with "source" or "natural" populations where full pollinator guilds are present.
5. Monitoring periods should exceed five years before determinations successes of created pools are made.
6. Attempts to construct/create vernal pools in habitats where they do not already exist needs to take into account the distance from existing vernal pool habitats as sources of pollinators that may migrate into the new areas.
7. Further study of the pollination process and the roles of oligolectic bees and other members of the visitor/pollinator guilds in the reproduction of showy vernal pool flora taxa similar to that done for *Blennosperma* in our previous report is recommended.
8. Further studies are needed on: 1) dispersal ecology of the oligolectic bees; and 2) feasibility of transplanting oligolectic bees (e.g., immature stages; new vs nesting females).
9. Upland areas in source pool habitats that are to be destroyed should not be disturbed until after bee emergence in early spring to allow for dispersal of bees to nearby created pool habitats or for opportunity to transplant.
10. The effects of adding new pools to areas set aside for mitigation need to be reevaluated. Limits as to how many new pools may be constructed in an existing vernal pool habitat need to be determined since every new pool reduces the amount of upland habitat upon which these bees depend as nest site sources.

11. More research needed to determine whether facilitation or competition between upland plants and vernal pool plants for services of pollinators.
12. Taxonomic studies need to be conducted on some of the taxa of oligolectic bees, especially bees of the *Andrena* subgenus, *Hesperandrena*, and of the genus *Panurginus* so that they can be identified accurately.
13. To ensure accurate identification of flower visitor guild taxa all identifications should be made or confirmed by experts and voucher specimens from all field studies should be deposited in public musuems where they will be available to future researchers to validate earlier studies.

Implementation

1) A copy of this report will be sent to all Caltrans biologists who work with vernal pool restoration or vernal pool organisms. The information in this report will be discussed at biologists meetings and transferred to the districts during consultations on vernal pools.
2) The information in this report will be abstracted and placed in the vernal pool section of Volume III of the Environmental Handbook. This will include the following:
- Tentative procedures for surveying for/monitoring oligolectic bees in vernal pool habitats:
    Net (aerial insect) collections
    Visual [requires familiarity with ID of visitors]
    Pan-traps
    Identification & deposition of voucher specimens
        -Identifications should be confirmed by an expert in bee systematics
        -Vouchers should be deposited in a public museum (e.g., Bohart Museum of Entomology, Univerisity of California, Davis)
-Tentative procedures for transplanting adult oligolectic bees:
    Field capture & temporary storage
    Longer term storage
    Sorting/ID [vouchers] & Marking
    Transportation to & release in new habitats
    Monitoring to determine success of releases
-Tentative procedures for protecting and enhancing oligolectic bees at mitigation sites:
    Adequate bloom of pollen host plants
    Suitable uplands conditions for nesting, e.g.: soil type, cover, depth, moisture.

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Table 1. Collections of Hymenoptera (HYM), Diptera (DIP) and other orders of insects (OTH) from yellow and white pan traps, six each set in two natural swale pools containing *Limnanthes douglasii rosea* and *Lasthenia fremontii* on April 1, 1994 at the Bureau of Reclamation Equalization Reservoir mitigation site. [p values at each site from nonparametric paired comparisons between yellow and white pan traps using Wilcoxon signed-rank].

	Swale A			Swale B		
Totals	HYM	DIP	OTH	HYM	DIP	OTH
White	27	41	63	17	109	54
Yellow	20	219	22	15	439	39
Mean (SD)						
White	4(2)	8(5)	10(2)	3(1)	18(4)	9(4)
Yellow	4(2)	36(12)	4(1)	2(2)	73(23)	6(2)
p =	.465	.028	.028	.787	.028	.173

Figures

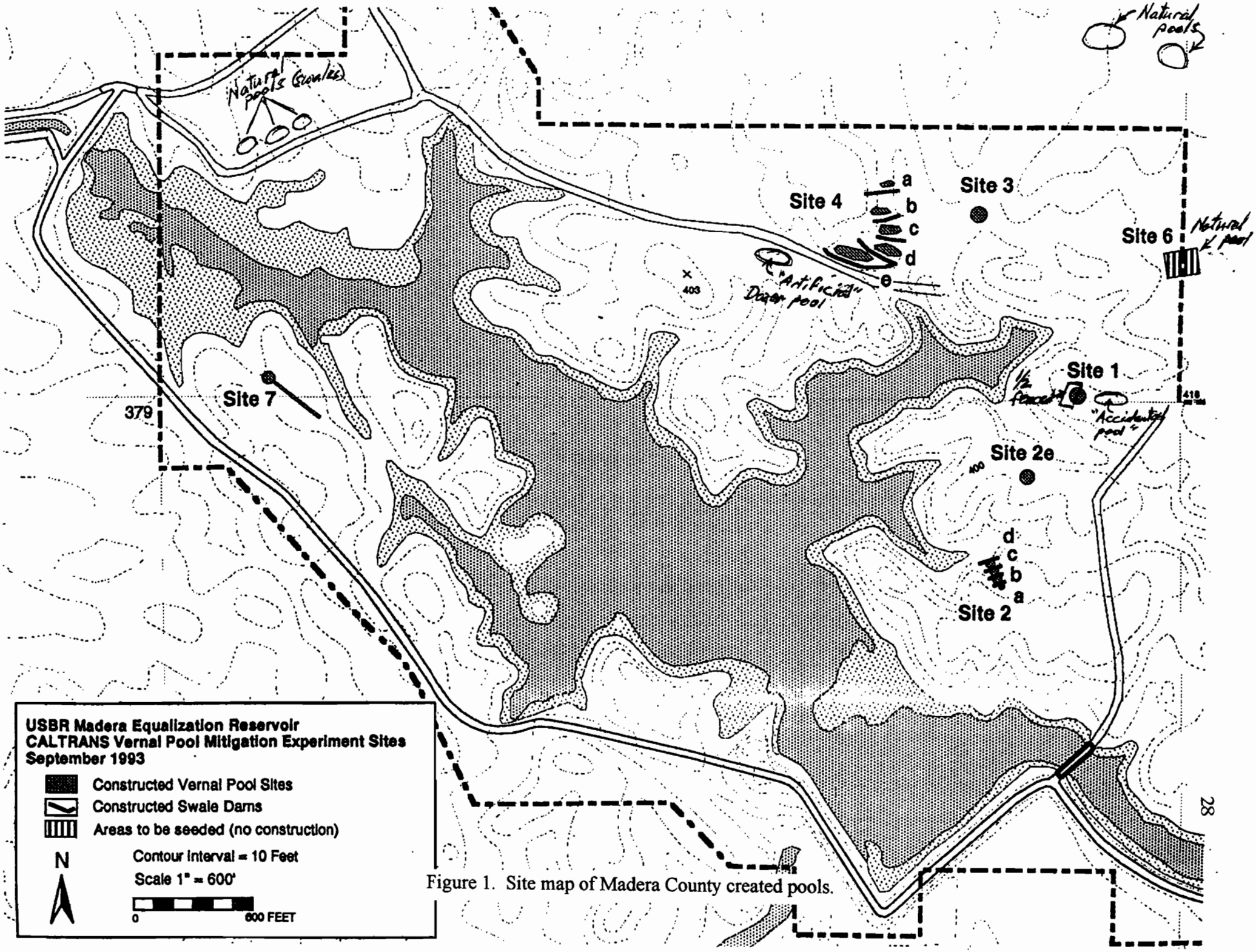

Figure 1. Site map of Madera County created pools.

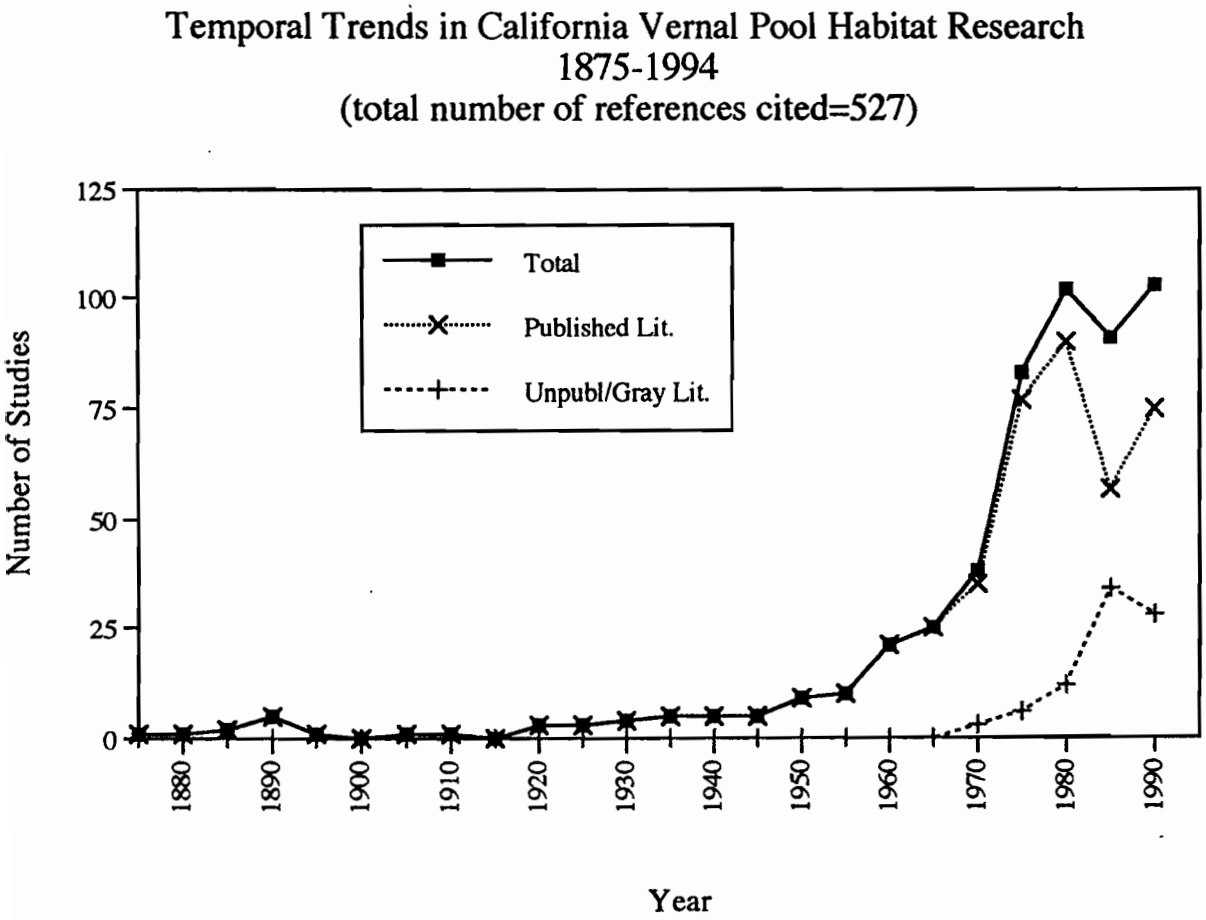

Figure 2. Temporal trends in California vernal pool habitat research 1875-1994.

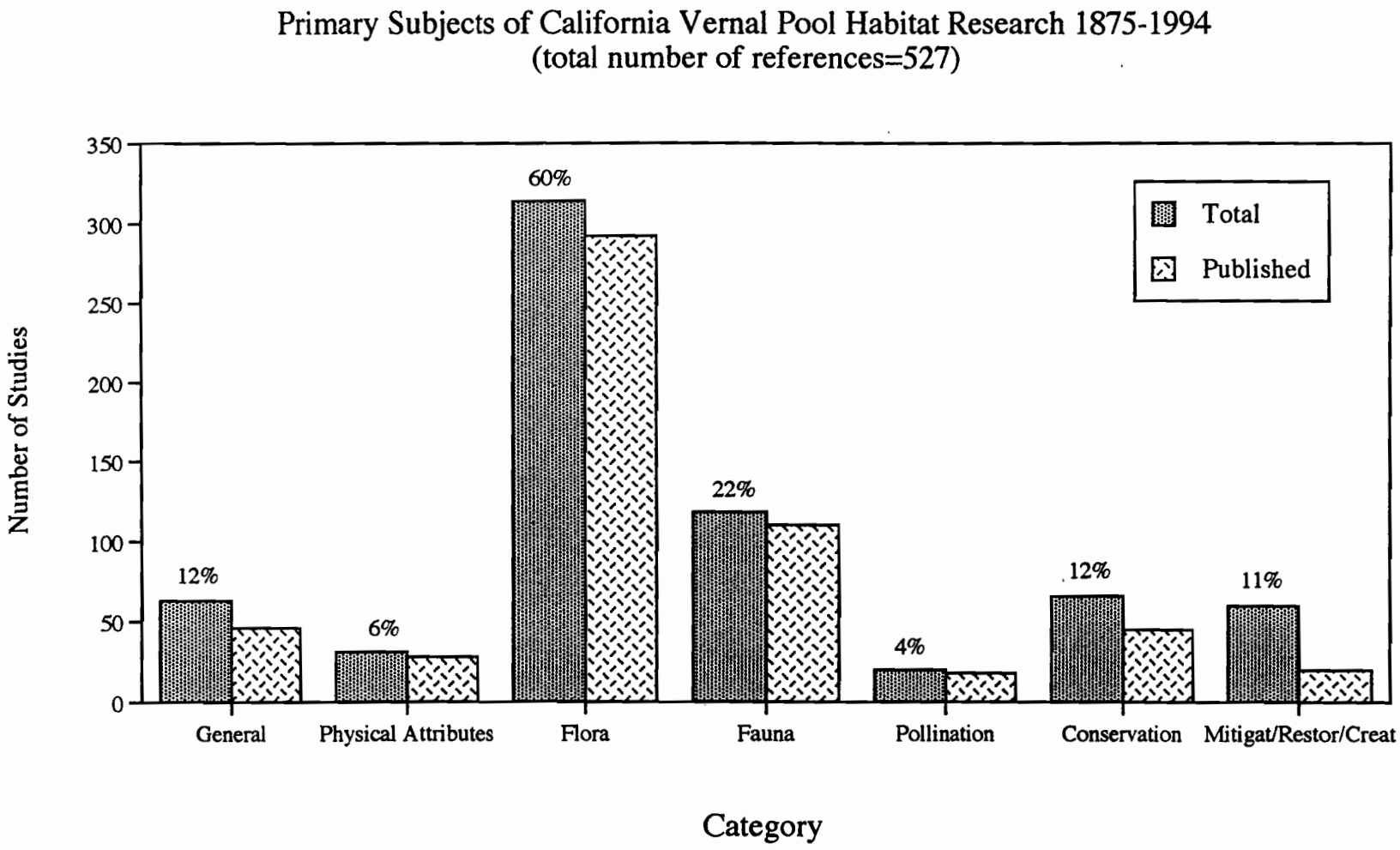

Figure 3. Primary subjects of California vernal pool habitat research 1875-1994.

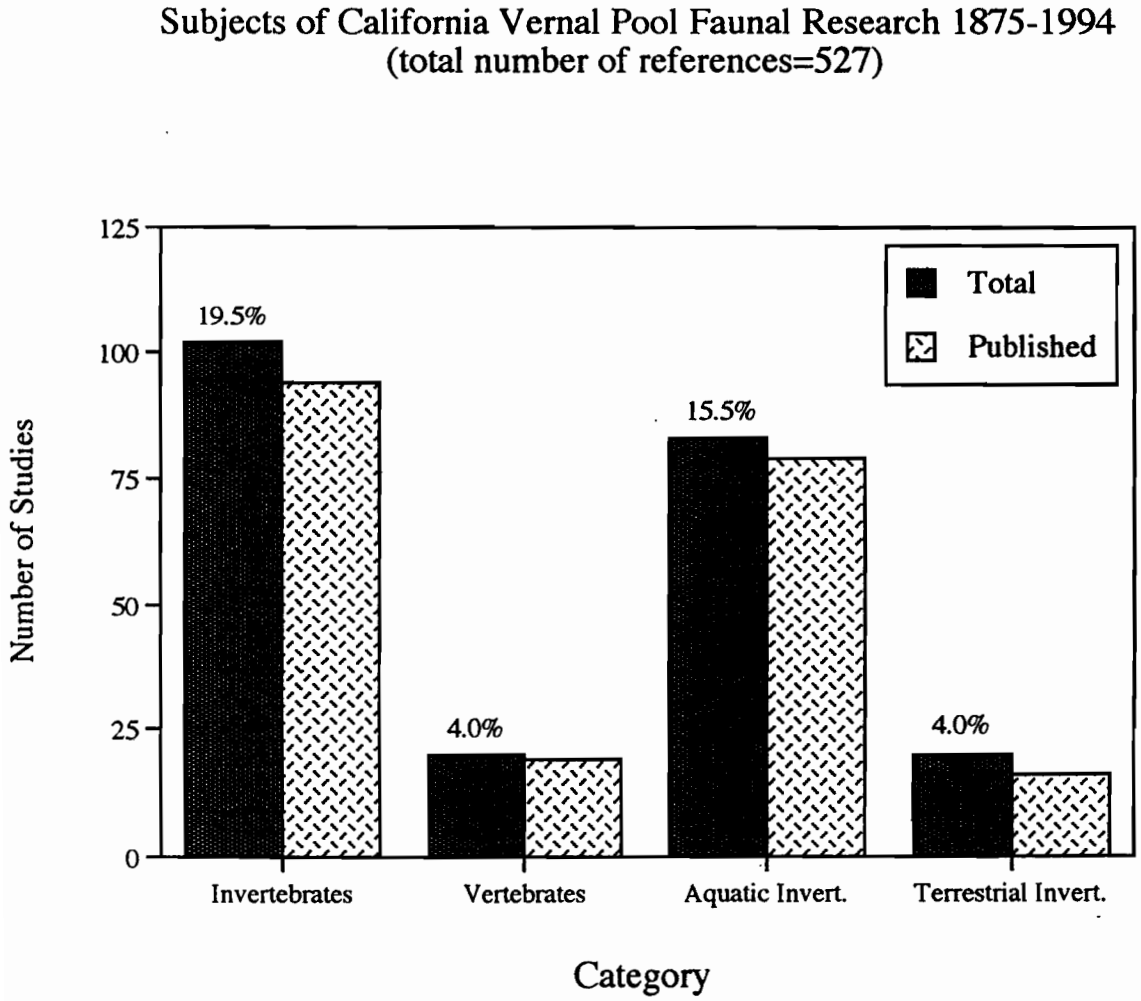

Figure 4. Subjects of California vernal pool faunal research 1875-1994.

Appendices 1-5

Appendices

Appendix 1: Publications, Theses, Abstracts, Reports, and Talks

Publications:

Leong, J. M., R. P. Randolph, and R. W. Thorp. 1995. Observations of the foraging patterns of *Andrena* (*Diandrena*) *blennospermatis* Thorp (Hymenoptera: Andrenidae). Pan-Pacific Entomologist 71(1):68-71.

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Thesis:

Leong, J. M. 1994. Pollination of a patchily-distributed plant, *Blennosperma nanum*, in natural and artificially created vernal pool habitats. Ph.D. dissertation, Graduate Group in Ecology, University of California, Davis.

Abstracts:

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Appendix 3 - Raw Data from Field Collections

Abbreviations of Headings and Taxa Names

Headings:

ORD = Order; FAM = Family; YY MM DD = Year Month Day; FE = Females; MA = Males; NO = Total numbers

Orders:

COL = Coleoptera; DIP = Diptera; HET = Heteroptera; HOM = Homoptera; HYM = Hymenoptera; LEP = Lepidoptera; ORT = Orthoptera; THY = Thysanoptera.

Families of:

COL: CAN = Cantheridae; COC = Coccinellidae; DAS = Dasytidae; DER = Dermestidae; STA = Staphylinidae.

DIP: ACA = Acalypteratae; ANT = Anthomyiidae; ASI = Asilidae; BOM = Bombyliidae; CAL = Calliphoridae; CON = Conopidae; DOL = Dolichopodidae; EMP = Empididae; EPH = Ephydridae; NEM = Nematocera; SAR = Sarcophagidae; SYR = Syrphidae.

HOM: APH = Aphididae; CIC = Cicadellidae.

HYM: AND = Andrenidae; ANT = Anthophoridae; API = Apidae; CHA = Chalcidoidea; CHR = Chrysididae; COL = Colletidae; EUM = Eumenidae; HAL = Halictidae; MEG = Megachilidae; POM = Pompilidae; SPH = Sphecidae.

LEP: NOC = Noctuidae.

ORT: ACR = Acrididae.

Vernal Pool Flower Visitor Guilds												
ORD	FAM	Genus (Subgenus)	species	CA County	Locality	YY	MM	DD	FE	MA	NO	Flower
HYM	AND	Andrena (Hespera-)	limnanthis	Sonoma	Santa Rosa, Alton Lane	93	JN	7	3		3	Limnanthes
HYM	API	Bombus (Pyrob-)	vosnesenskii	Sonoma	Santa Rosa, Alton Lane	93	MY	7	1		1	Downingia
HYM	AND	Andrena		Sonoma	Santa Rosa, Alton Lane	93	MY	7	1		1	Downingia
HYM	HAL	Lasioglossum		Sonoma	Santa Rosa, Alton Lane	93	MY	7	5		5	Downingia
DIP	SYR			Sonoma	Santa Rosa, Alton Lane	93	MY	7			1	Downingia
DIP	SYR			Sonoma	Santa Rosa, Alton Lane	93	MY	7			1	Downingia
HYM	HAL	Lasioglossum		Solano	Travis AFB	93	MY	10	8		8	Lasthenia conjugens
HYM	HAL	Evylaeus		Solano	Travis AFB	93	MY	10	1		1	Downingia
HYM	AND	Andrena		Solano	Travis AFB	93	MY	10	1		1	Downingia
DIP	SYR			Solano	Travis AFB	94	MY	13			1	Downingia concolor
HYM	AND	Panurginus		Solano	Travis AFB	94	MY	13	3		3	Downingia concolor
DIP	EPH			Solano	Travis AFB	94	MY	13			1	Downingia concolor
HYM	AND	Panurginus		Solano	Travis AFB	94	MY	13	1		1	Downingia insignis
HYM	HAL	Dialictus		Solano	Travis AFB	94	MY	13	1		1	Downingia concolor
COL	DER			Solano	Travis AFB	94	MY	13			1	Downingia concolor
HYM	AND	Panurginus		Solano	Travis AFB	94	MY	15	4		4	Downingia concolor
HYM	AND	Andrena (Tylandr-)	sublayiae	Solano	Travis AFB	94	AP	5	1		1	Layia
HYM	ANT	Synhalonia		Solano	Travis AFB	94	AP	5		1	1	Layia
HYM	HAL	Evylaeus		Solano	Travis AFB	94	AP	5	2		2	Layia
HYM	HAL	Halictus	ligatus	Solano	Travis AFB	94	AP	5	2		2	Layia
HYM	HAL	Lasioglossum		Solano	Travis AFB	94	AP	5	5		5	Layia
HYM	AND	Andrena (Hespera-)		Solano	Travis AFB	94	AP	5	5		5	Layia
HYM	AND	Andrena (Hespera-)	[Yellow clyp]	Solano	Travis AFB	94	AP	5		7	7	Layia
HYM	AND	Andrena (Diandr-)	chlorosoma	Solano	Travis AFB	94	AP	5		9	9	Layia
HYM	AND	Andrena		Solano	Travis AFB	94	AP	5	1		1	Layia
HYM	AND	Andrena (Euandr-?)		Solano	Travis AFB	94	AP	5	1	1	2	Layia
HYM	ANT	Nomada	[2 spp.]	Solano	Travis AFB	94	AP	5	3		3	Layia
DIP	SYR		[2 spp.]	Solano	Travis AFB	94	AP	5			3	Layia

DIP	EMP			Solano	Travis AFB	94	AP	5			3	Layia
DIP	CAL			Solano	Travis AFB	94	AP	5			1	Layia
DIP	???			Solano	Travis AFB	94	AP	5			4	Layia
COL	CAN			Solano	Travis AFB	94	AP	5			1	Layia
HYM	HAL	Dialictus		Solano	Travis AFB	94	AP	5	1		1	Layia
HYM	HAL	Lasioglossum		Solano	Travis AFB	94	AP	5	1		1	Lasthenia conjugens
HYM	AND	Andrena (Hespera-)	[>1 spp.?]	Solano	Travis AFB	94	AP	5	12	9	21	Lasthenia conjugens
HYM	ANT	Nomada		Solano	Travis AFB	94	AP	5			1	Lasthenia conjugens
DIP	EMP			Solano	Travis AFB	94	AP	5			1	Lasthenia conjugens
HYM	AND	Panurginus		Solano	Travis AFB	94	AP	5			1	Plagiobothrys
HYM	HAL	Dialictus		Madera	Firnston Ranch, Rd. 15	93	AP	12	7		7	Eschscholzia
HYM	HAL	Dialictus		Madera	DOT, Ave 12 & Hwy 41	95	MY	3	3		3	Downingia
HYM	COL	Colletes		Madera	USBR Equaliz. Reservoir	93	AP	11		1	1	Layia
HYM	AND	Panurginus	occidentalis	Madera	USBR Equaliz. Reservoir	93	AP	11		1	1	Layia
HYM	HAL	Halictus	ligatus	Madera	USBR Equaliz. Reservoir	93	AP	11	1		1	Layia
HYM	AND	Andrena		Madera	Rd 33 nr. Rd. 400	95	MY	3	1		1	Downingia
HYM	HAL	Halictus (Seladonia)		Madera	Rd 33 nr. Rd. 400	95	MY	3	1		1	Downingia
HYM	MEG	Osmia		Madera	Rd 33 nr. Rd. 400	95	MY	3		1	1	Downingia
DIP	SYR			Madera	Rd 33 nr. Rd. 400	95	MY	3	5	1	6	Downingia
DIP	SYR			Madera	Rd 33 nr. Rd. 400	95	MY	3			1	Downingia
HYM	API	Apis	mellifera	Butte	Durham, 5 mi E	94	FE	22	7		7	Blennosperma nanum
HYM	AND	Andrena		Butte	Durham, 5 mi E	94	FE	22		1	1	Blennosperma nanum
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	30	1	2	3	Downingia ornatisima
HYM	API	Apis	mellifera	Madera	USBR Equaliz. Reservoir	94	AP	30	1		1	Downingia ornatisima
COL	DAS			Madera	USBR Equaliz. Reservoir	94	AP	30			2	Downingia ornatisima
DIP	SYR		#4	Madera	USBR Equaliz. Reservoir	94	AP	30			2	Downingia ornatisima
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Downingia
DIP	ANT			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Downingia
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Eschscholzia
HYM	AND	Andrena (Diand-)	subchalybea	Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Pan Trap W-2
HYM	AND	Andrena (Scoliand-)	osmioides?	Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Pan Trap W-2
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	95	MY	3	1		1	Downingia

DIP	SYR		#4	Madera	USBR Equaliz. Reservoir	95	MY	3			4	Downingia
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	95	MY	3	1		1	Downingia
HYM	API	Apis	mellifera	Madera	USBR Equaliz. Reservoir	94	MA	18	1		1	Limnanthes
HYM	AND	Andrena (Hespera-)	limnanthis	Madera	USBR Equaliz. Reservoir	94	MA	18	1	3	4	Limnanthes
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	MA	18	6		6	Limnanthes
HYM	CHR			Madera	USBR Equaliz. Reservoir	94	MA	18			1	Limnanthes
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	MA	18	1		1	Lasthenia
HYM	API	Apis	mellifera	Madera	USBR Equaliz. Reservoir	94	MA	18	2		2	Eschscholzia
HYM	HAL	Evylaeus	[2 spp.]	Madera	USBR Equaliz. Reservoir	94	MA	18	2		2	Eschscholzia
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	94	MA	18	1		1	Eschscholzia
HYM	HAL	Dialictus	#1	Madera	USBR Equaliz. Reservoir	94	MA	18	2		2	Eschscholzia
HYM	HAL	Dialictus	#2	Madera	USBR Equaliz. Reservoir	94	MA	18	20		20	Eschscholzia
DIP	ANT			Madera	USBR Equaliz. Reservoir	94	MA	18			1	Eschscholzia
HYM	ANT	Synhalonia		Merced	Arena Plains	93	MY	5	12		12	Phacelia
HYM	AND	Calliopsis (Nomad-)		Merced	Arena Plains	93	MY	5	18	2	20	Phacelia
HYM	COL	Colletes	#1	Merced	Arena Plains	93	MY	5	1	1	2	Phacelia
HYM	COL	Colletes	#2	Merced	Arena Plains	93	MY	5	2	1	3	Phacelia
HYM	AND	Calliopsis (Nomad-)	#2	Merced	Arena Plains	93	MY	5		1	1	Phacelia
HYM	MEG	Osmia	#1	Merced	Arena Plains	93	MY	5	1		1	Phacelia
HYM	MEG	Osmia	#2	Merced	Arena Plains	93	MY	5	2		2	Phacelia
HYM	CHR			Merced	Arena Plains	93	MY	5			1	Phacelia
DIP	ASI			Merced	Arena Plains	93	MY	5			1	Phacelia
HYM	AND	Andrena		Merced	Arena Plains	93	MY	5	1		1	Hemizonia pungens
HYM	ANT	Synhalonia		Merced	Arena Plains	93	MY	5	1	1	2	Cirsium vulgare
HYM	MEG	Osmia	#1	Merced	Arena Plains	93	MY	5	3		3	Cirsium vulgare
HYM	AND	Panurginus		Merced	Grasslands State Park	93	MY	5	2	1	3	Downingia
HYM	HAL	Lasioglossum		Merced	Grasslands State Park	93	MY	5	1		1	Downingia
HYM	HAL	Dialictus	(red abdom-)	Merced	Grasslands State Park	93	MY	5	1		1	Downingia
HYM	HAL	Halictus (Seladonia)		Merced	Grasslands State Park	93	MY	5	10			Downingia
DIP	SYR		#4	Merced	Grasslands State Park	93	MY	5			1	Downingia
HYM	HAL	Halictus (Seladonia)		Solano	Jepson Prairie Preserve	93	JY	31	16		16	Neostapfia
HYM	HAL	Dialictus		Solano	Jepson Prairie Preserve	93	JY	31	2	1	3	Neostapfia

HYM	AND	Andrena		Solano	Jepson Prairie Preserve	94	MA	5		2	2	Blennosperma nanum
HYM	AND	Andrena (Hespera-)	limnanthis?	Solano	Jepson Prairie Preserve	94	MA	5		2	2	Blennosperma nanum
HYM	AND	Andrena		Solano	Jepson Prairie Preserve	94	AP	18	1		1	Lasthenia
HYM	AND	Andrena (Hespera-)		Solano	Jepson Prairie Preserve	94	AP	18	4		4	Lasthenia
HYM	ANT	Melissodes		Solano	Jepson Prairie Preserve	94	AP	18	3	5	8	Frankenia
HYM	HAL	Halictus (Seladonia)		Solano	Jepson Prairie Preserve	94	AP	18	20	16	36	Frankenia
HYM	HAL	Dialictus		Solano	Jepson Prairie Preserve	94	AP	18	17	14	31	Frankenia
HYM	COL	Hylaeus		Solano	Jepson Prairie Preserve	94	AP	18		2	2	Frankenia
DIP	CON			Solano	Jepson Prairie Preserve	94	AP	18			1	Frankenia
HYM	AND	Andrena (Diandr-)	blennospermatis	Placer	Roseville - Highlands	95	MA	6	1	3	4	Blennosperma nanum
HYM	AND	Andrena		Placer	Roseville - Highlands	95	MA	6		4	4	Blennosperma nanum
HYM	HAL	Evylaeus		Placer	Roseville - Highlands	95	MA	6	1		1	Blennosperma nanum
DIP	SYR		[3 spp.]	Placer	Roseville - Highlands	95	MA	6			6	Blennosperma nanum
HYM	AND	Andrena (Diandr-)	subchalybea	Placer	Roseville - Highlands	95	MA	6	3	1	4	Eschscholzia
HYM	AND	Panurginus		Placer	Roseville - Pleasant Gr	95	MA	6		1	1	Downingia
HYM	HAL	Dialictus		Placer	Roseville - Pleasant Gr	95	MA	6	1		1	Downingia
DIP	SYR			Placer	Roseville - Pleasant Gr	95	MA	6			1	Downingia
HYM	AND	Panurginus		Placer	Roseville - Kerry Downs	95	MA	6		1	1	Downingia
HYM	AND	Panurginus		Placer	Roseville - Silvarado	95	MA	6	4	1	5	Downingia
HYM	HAL	Dialictus		Placer	Roseville - PG&E	95	MA	6	1		1	Agoseris
HYM	AND	Andrena (Diandr-)	submoesta	Placer	Roseville - PG&E	95	MA	6	1		1	Lasthenia
HYM	HAL	Lasioglossum		Placer	Roseville - PG&E	95	MY	4	1		1	Layia
HYM	HAL	Dialictus	[2 spp.]	Placer	Roseville - PG&E	95	MY	4	3		3	Downingia
HYM	AND	Andrena (Diandr-)	submoesta	Placer	Roseville - PG&E	95	MY	4	2		2	Downingia
HYM	AND	Andrena		Placer	Roseville - PG&E	95	MY	4		1	1	Downingia
HYM	AND	Panurginus		Placer	Roseville - PG&E	95	MY	4	1	3	4	Downingia
DIP	BOM			Placer	Roseville - PG&E	95	MY	4			1	Downingia
DIP	SYR			Placer	Roseville - PG&E	95	MY	4			1	Downingia
HYM	AND	Andrena (Diandr-)	submoesta	Placer	Roseville - PG&E	95	MY	4	10		10	Lasthenia
HYM	HAL	Halictus	ligatus	Placer	Roseville - PG&E	95	MY	4	1		1	Lasthenia
HYM	HAL	Dialictus		Placer	Roseville - PG&E	95	MY	4	1		1	Lasthenia
HYM	AND	Panurginus		Placer	Roseville - PG&E	95	MY	4		5	5	Lasthenia

DIP	SYR			Placer	Roseville - PG&E	95	MY	4			2	Lasthenia
HYM	AND	Andrena (Diandr-)	submoesta	Placer	Roseville - Highlands	95	MY	4	2		2	Lasthenia
HYM	HAL	Dialictus		Placer	Roseville - Highlands	95	MY	4	5		5	Lasthenia
HYM	AND	Panurginus		Placer	Roseville - Highlands	95	MY	4		1	1	Lasthenia
HYM	HAL	Dialictus		Placer	Roseville - Highlands	95	MY	4	13		13	Downingia
HYM	AND	Panurginus		Placer	Roseville - Highlands	95	MY	4	1	4	5	Downingia
DIP	SYR			Placer	Roseville - Highlands	95	MY	4			1	Downingia
DIP	BOM			Placer	Roseville - Highlands	95	MY	4			1	Downingia
DIP	DOL			Placer	Roseville - Highlands	95	MY	4			1	Downingia
HYM	HAL	Halictus	ligatus	Placer	Roseville - Silvarado 1	95	MY	4	1		1	Agoseris
HYM	AND	Panurginus		Placer	Roseville - Silvarado 1	95	MY	4	5	3	8	Downingia
DIP	SYR			Placer	Roseville - Silvarado 1	95	MY	4			2	Downingia
HYM	AND	Panurginus		Placer	Roseville - Kerry Downs	95	MY	4	3		3	Downingia
HYM	API	Apis	mellifera	Madera	USBR Equaliz. Reservoir	94	AP	1	1		1	Mimulus
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	1	2		2	Mimulus
HYM	MEG	Osmia		Madera	USBR Equaliz. Reservoir	94	AP	1		2	2	Limnanthes
HYM	HAL	Dialictus	[2 spp.]	Madera	USBR Equaliz. Reservoir	94	AP	1	2		2	Lasthenia
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	2		2	Mimulus
HYM	AND	Panurginus		Madera	USBR Equaliz. Reservoir	94	AP	15	9	1	10	Downingia
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	94	AP	15	7		7	Downingia
HYM	HAL	Dialictus	[2 spp.?]	Madera	USBR Equaliz. Reservoir	94	AP	15	2		2	Downingia
HYM	ANT	Syhalonia		Madera	USBR Equaliz. Reservoir	94	AP	15		1	1	Plagiobothrys
HYM	MEG	Osmia	[2 spp.+?]	Madera	USBR Equaliz. Reservoir	94	AP	15		5	5	Plagiobothrys
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T W-2 A
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T W-6 A
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	4		4	Lasthenia P-T W-1 A
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T W-3 A
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T W-4 A
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	3		3	Lasthenia P-T Y-3 A
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	2		2	Lasthenia P-T Y-5 A
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T Y-2 A
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T Y-6 A

HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T Y-4 A
HYM	MEG	Osmia		Madera	USBR Equaliz. Reservoir	94	AP	15		1	1	Lasthenia P-T W-6 A
HYM	MEG	Osmia		Madera	USBR Equaliz. Reservoir	94	AP	15		1	1	Lasthenia P-T W-3 A
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T W-3 A
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T W-4 A
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	4		4	Lasthenia P-T W-1 B
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T W-5 B
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T W-6 B
HYM	MEG	Osmia		Madera	USBR Equaliz. Reservoir	94	AP	15		1	1	Lasthenia P-T W-4 B
HYM	ANT	Syhalonia		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T W-4 B
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T Y-1 B
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T Y-4 B
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T Y-1 B
HYM	MEG	Osmia		Madera	USBR Equaliz. Reservoir	94	AP	15	1		1	Lasthenia P-T Y-1 B
HYM	CHR			Madera	USBR Equaliz. Reservoir	94	MA	18			6	Lasthenia P-T Y
DIP			[2 spp.]	Madera	USBR Equaliz. Reservoir	94	MA	18			8	Lasthenia P-T Y
HOM	CIC			Madera	USBR Equaliz. Reservoir	94	MA	18			1	Lasthenia P-T Y
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	95	AP	22	2		2	Lasthenia P-T W-1
HYM	AND	Panurginus		Madera	USBR Equaliz. Reservoir	95	AP	22		1	1	Lasthenia P-T W-1
HYM	CHA			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-1
DIP	F 1	[sp. 1]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-1
DIP	F 2	[sp. 2]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-1
DIP	F 3	[sp. 3]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-1
DIP	F 4	[sp. 4 + 3 others]		Madera	USBR Equaliz. Reservoir	95	AP	22			25	Lasthenia P-T W-1
HYM	AND	Andrena		Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Lasthenia P-T W-2
HYM	AND	Andrena (Diand-)	subchalybea	Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Lasthenia P-T W-2
HYM	AND	Panurginus		Madera	USBR Equaliz. Reservoir	95	AP	22		4	4	Lasthenia P-T W-2
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Lasthenia P-T W-2
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	95	AP	22	2		2	Lasthenia P-T W-2
HYM	CHA			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-2
HYM	CHR			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-2
COL	COC			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-2

THY				Madera	USBR Equaliz. Reservoir	95	AP	22			3	Lasthenia P-T W-2
DIP	F 1	[sp. 1]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-2
DIP	F 2	[sp. 2]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-2
DIP	F 3	[sp. 3]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-2
DIP	F 4	[sp. 4]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-2
DIP	F 5	[sp. 5 + 2 others]		Madera	USBR Equaliz. Reservoir	95	AP	22			18	Lasthenia P-T W-2
HYM	API	Apis	mellifera	Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Lasthenia P-T W-3
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Lasthenia P-T W-3
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Lasthenia P-T W-3
HYM	AND	Panurginus		Madera	USBR Equaliz. Reservoir	95	AP	22		5	5	Lasthenia P-T W-3
COL	STA			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-3
THY				Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-3
DIP	F 1	[sp. 1]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-3
DIP	F 2	[sp. 2]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-3
DIP	F 3	[sp. 3]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-3
DIP	F 4	[sp. 4 + 2 others]		Madera	USBR Equaliz. Reservoir	95	AP	22			26	Lasthenia P-T W-3
HYM	HAL	Halictus (Seladonia)		Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Lasthenia P-T W-4
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	95	AP	22	1		1	Lasthenia P-T W-4
HYM	AND	Panurginus		Madera	USBR Equaliz. Reservoir	95	AP	22		6	6	Lasthenia P-T W-4
COL	COC			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-4
DIP	F 1	[sp. 1]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-4
DIP	F 2	[sp. 2]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-4
DIP	F 3	[sp. 3]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T W-4
DIP	F 4	[sp. 4 + 1 other]		Madera	USBR Equaliz. Reservoir	95	AP	22			18	Lasthenia P-T W-4
HYM	HAL	Dialictus	[2 spp.]	Madera	USBR Equaliz. Reservoir	95	AP	22	3		3	Lasthenia P-T Y-1
THY				Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-1
HOM	CIC			Madera	USBR Equaliz. Reservoir	95	AP	22			4	Lasthenia P-T Y-1
DIP	F 1	[sp. 1]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-1
DIP	F 2	[sp. 2]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-1
DIP	F 3	[sp. 3]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-1
DIP	F 4	[sp. 4 + 2 others]		Madera	USBR Equaliz. Reservoir	95	AP	22			27	Lasthenia P-T Y-1
HYM	HAL	Dialictus	[2 spp.]	Madera	USBR Equaliz. Reservoir	95	AP	22	2		2	Lasthenia P-T Y-2

HYM	AND	Panurginus		Madera	USBR Equaliz. Reservoir	95	AP	22		2	2	Lasthenia P-T Y-2
HOM	CIC			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-2
HOM	APH			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-2
THY				Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-2
DIP	F 1	[sp. 1]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-2
DIP	F 2	[sp. 2]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-2
DIP	F 3	[sp. 3]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-2
DIP	F 4	[sp. 4 + 1+ others]		Madera	USBR Equaliz. Reservoir	95	AP	22			13	Lasthenia P-T Y-2
HOM	CIC			Madera	USBR Equaliz. Reservoir	95	AP	22			2	Lasthenia P-T Y-3
THY				Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-3
DIP	F 1	[sp. 1]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-3
DIP	F 2	[sp. 2]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-3
DIP	F 3	[sp. 3]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-3
DIP	F 4	[sp. 4 + 1+ others]		Madera	USBR Equaliz. Reservoir	95	AP	22			32	Lasthenia P-T Y-3
HYM	HAL	Dialictus		Madera	USBR Equaliz. Reservoir	95	AP	22	3		3	Lasthenia P-T Y-4
HYM	AND	Panurginus		Madera	USBR Equaliz. Reservoir	95	AP	22		1	1	Lasthenia P-T Y-4
HYM	SPH			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-4
HOM	CIC			Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-4
HOM	APH			Madera	USBR Equaliz. Reservoir	95	AP	22			2	Lasthenia P-T Y-4
THY				Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-4
DIP	F 1	[sp. 1]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-4
DIP	F 2	[sp. 2]		Madera	USBR Equaliz. Reservoir	95	AP	22			1	Lasthenia P-T Y-4
DIP	F 3	[sp. 3 + 1+ others]		Madera	USBR Equaliz. Reservoir	95	AP	22			15	Lasthenia P-T Y-4
HYM	AND	Andrena		Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29	2	1	3	Lasthenia P-T Y-1
DIP	SAR			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T Y-1
DIP	ACA			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			6	Lasthenia P-T Y-1
COL	DAS			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T Y-1
HOM	CIC			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			2	Lasthenia P-T Y-1
HYM	EUM			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T Y-2
DIP	ACA			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			3	Lasthenia P-T Y-2
HOM	CIC			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T Y-2
HYM	AND	Andrena		Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29	2		2	Lasthenia P-T Y-3

HYM	CHA			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T Y-3
DIP	SAR			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T Y-3
DIP	ACA			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			2	Lasthenia P-T Y-3
HOM	CIC			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T Y-3
HYM	AND	Andrena		Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29	3	3	6	Lasthenia P-T Y-4
COL	DAS			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T Y-4
DIP	ACA			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			7	Lasthenia P-T Y-4
HOM	CIC			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			3	Lasthenia P-T Y-4
HYM	CHR			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29	2		2	Lasthenia P-T W-1
HYM	POM			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T W-1
DIP	ACA			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			35	Lasthenia P-T W-1
HOM	CIC			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T W-1
ORT	ACR			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T W-1
HYM	AND	Nomadopsis		Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29	1		1	Lasthenia P-T W-2
HYM	CHR			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T W-2
DIP	ACA			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			19	Lasthenia P-T W-2
HYM	HAL	Dialictus		Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29	1		1	Lasthenia P-T W-3
HYM	CHR			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			5	Lasthenia P-T W-3
HOM	CIC			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T W-3
DIP	ACA			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			23	Lasthenia P-T W-3
HYM	AND	Andrena		Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29	2	3	5	Lasthenia P-T W-4
HYM	CHA			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T W-4
DIP	ACA			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			12	Lasthenia P-T W-4
DIP	NEM			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T W-4
HOM	CIC			Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			2	Lasthenia P-T W-4
HET				Santa Barbara	S Cruz Isl, Fraser Point	94	MA	29			1	Lasthenia P-T W-4
HYM	HAL	Halictus (Seladonia)		Placer	Roseville - Highlands	95	MY	4	1		1	Lasthenia P-T B
HYM	AND	Panurginus		Placer	Roseville - Highlands	95	MY	4		15	15	Lasthenia P-T W
LEP	NOC	Schinia		Placer	Roseville - Highlands	95	MY	4			1	Lasthenia P-T W
HYM	CHR			Placer	Roseville - Highlands	95	MY	4			1	Lasthenia P-T W
DIP		[2 spp.]		Placer	Roseville - Highlands	95	MY	4			6	Lasthenia P-T W
HYM	AND	Panurginus		Placer	Roseville - Highlands	95	MY	4		11	11	Lasthenia P-T Y

HYM	HAL	Evylaeus		Placer	Roseville - Highlands	95	MY	4	1		1	Lasthenia P-T Y
HYM	HAL	Halictus (Seladonia)		Placer	Roseville - Highlands	95	MY	4	1		1	Lasthenia P-T Y
HYM	AND	Andrena (Diandr-)	submoesta	Placer	Roseville - Highlands	95	MY	4	1		1	Lasthenia P-T Y
DIP		[3 spp.]		Placer	Roseville - Highlands	95	MY	4			12	Lasthenia P-T Y
HYM	AND	Panurginus		Placer	Roseville - Highlands	95	MY	4		7	7	Downingia P-T B
HYM	CHA			Placer	Roseville - Highlands	95	MY	4	1		1	Downingia P-T B
DIP		[4 spp.]		Placer	Roseville - Highlands	95	MY	4			9	Downingia P-T B
HYM	AND	Panurginus		Placer	Roseville - Highlands	95	MY	4		3	3	Downingia P-T Y
DIP		[3 spp.]		Placer	Roseville - Highlands	95	MY	4			22	Downingia P-T Y
HOM	CIC			Placer	Roseville - Highlands	95	MY	4			1	Downingia P-T Y
HYM	AND	Panurginus		Placer	Roseville - Highlands	95	MY	4		17	17	Downingia P-T W
HYM	HAL	Halictus (Seladonia)		Placer	Roseville - Highlands	95	MY	4	1		1	Downingia P-T W
DIP		[3 spp.]		Placer	Roseville - Highlands	95	MY	4			26	Downingia P-T W
HYM	HAL	Halictus (Seladonia)		Placer	Roseville - PG&E	95	MY	4	1		1	Lasthenia P-T B
HYM	HAL	Dialictus		Placer	Roseville - PG&E	95	MY	4	1		1	Lasthenia P-T B
HYM	AND	Panurginus		Placer	Roseville - PG&E	95	MY	4		1	1	Lasthenia P-T B
DIP		[2 spp.]		Placer	Roseville - PG&E	95	MY	4			3	Lasthenia P-T B
HYM	AND	Panurginus		Placer	Roseville - PG&E	95	MY	4		1	1	Lasthenia P-T W
DIP		[3 spp.]		Placer	Roseville - PG&E	95	MY	4			7	Lasthenia P-T W
HOM	CIC			Placer	Roseville - PG&E	95	MY	4			1	Lasthenia P-T W
HOM	APH			Placer	Roseville - PG&E	95	MY	4			1	Lasthenia P-T W
COL				Placer	Roseville - PG&E	95	MY	4			1	Lasthenia P-T W
HYM	AND	Andrena (Diandr-)	submoesta	Placer	Roseville - PG&E	95	MY	4	3		3	Lasthenia P-T Y
HYM	HAL	Dialictus		Placer	Roseville - PG&E	95	MY	4	1		1	Lasthenia P-T Y
DIP		[3 spp.]		Placer	Roseville - PG&E	95	MY	4			11	Lasthenia P-T Y
THY				Placer	Roseville - PG&E	95	MY	4			2	Lasthenia P-T Y
DIP		[2 spp.]		Placer	Roseville - PG&E	95	MY	4			2	Downingia P-T B
HOM	CIC			Placer	Roseville - PG&E	95	MY	4			1	Downingia P-T B
DIP		[1 sp.]		Placer	Roseville - PG&E	95	MY	4			17	Downingia P-T Y
THY				Placer	Roseville - PG&E	95	MY	4			2	Downingia P-T Y
DIP		[3 spp.]		Placer	Roseville - PG&E	95	MY	4			6	Downingia P-T W
HYM	SPH			Placer	Roseville - PG&E	95	MY	4		1	1	Downingia P-T W

Appendix 4: Summaries of Field Notes on Pollination Studies

Madera County natural and created vernal pools:

1992:
Mar 24- Hwy 145 to 4 Corners: No showy vernal pool flora

1993:
Feb 26- Equalization Reservoir: No bloom; Ave 15 to 36 to Hwy 145.
28- Hwy 145: No bloom
Mar 21- Hwy 145: No bloom; Ave 15 to 38 & 17 & 37 no bloom, but *Eschscholzia.*
Apr 11- *Downingia* at Rd 33 nr. Rd. 400. Equalization Reservoir: *Layia* & *Lasthenia*, water in pools. Collected on *Layia*, primarily *Apis.*
12- Finston Ranch: Apiary. *Downingia*, *Eschscholzia* with *Dialictus.* Monreal Rd. *Lasthenia*: No bees.
May 2&3- Road 38: *Downingia*; Hwy 145: water in pools; Ave 17: *Downingia.* Finston Ranch: Apiary, scattered *Downingia*, *Mimulus tricolor.* Ave 15: *Lasthenia*, *Downingia*, no bees.
Table Mountain: *Lasthenia* (late), *Downingia* with *Panurginus*, *Sidalcea* with *Diadasia.*
24- Hwy 145: bit of water, no bloom, grasses browning.
Oct 22- Equalization Reservoir: Newly constructed pools, Photos (also by Joan).

1994:
Feb 24- Equalization Reservoir: Photos of pools with water & fenced.
Mar 18- Equalization Reservoir: *Dialictus* collected on *Eschscholzia.* & *Lasthenia* also seen "swarming" and on Judy's white shirt & van. *Limnanthes* in natural pool to west, collected *Apis* (P) & *Dialictus* & saw many flies on it; later collected the oligolege, *Andrena* (*Hesperandrena*) *limnanthis* on it. More *Eschscholzia* on south hillside, collected several species of Halictidae on it + *Apis* (P). Yellow pan traps in *Lasthenia* in dozer pool below [4?]: collected Chrysididae & small flies.
Apr 1- Visit by Joan Leong- Met with Alisa (CSU Fresno). Table Mountain not accessible. Visited Finston Ranch & Equalization Reservoir. Net collections at 4A with *Mimulus tricolor*, *Downingia*, *Plagiobothrys*, best display of all created pools. *Dialictus* most abundant, honey bees common, one queen bumble bee seen. Natural swale west of 4: *Limnanthes* with *Osmia* &*Lasthenia* with *Dialictus.* Photos.
7&8- Hwy 145: most pools dry & green. Equalization Reservoir: *Downingia bicornuta* in most pools. *Gratiola*: small flowers probably not insect pollinated. Saw queen of *Bombus vosnesenskii* crawlint over & probing *Downingia* in 1b (="Accidental" pool). Weather cool, drizzly. *Lasthenia*, *Mimulus tricolor.* *Agoseris* in upland grasses.
15- Visit by Joan Leong- Equalization Reservoir: Pools drying. Natural swale: only one *Limnanthes* plant in flower most *Lasthenia* gone to seed. Six pairs of white and yellow pan traps set out in each of two swales. Pan trap collections- White (12): *Dialictus* (14F); *Halictus* (*Seladonia*) (2F); *Osmia* (3M); *Synhalonia* (1F); Yellow (12): *Dialictus* (10F); *Halictus* (*Seladonia*) (1F); *Osmia* (1F). Less *Minulus*, more *Plagiobothrys*, and more *Downingia* than two weeks ago at created pool clusters 1, 2, and 4. Collections- *Dialictus* on *Mimulus*; *Panurginus* (oligolege), *Halictus* (*Seladonia*), and *Dialictus* on *Downingia.* *Synhalonia* and *Osmia* males on *Plagiobothrys.* Photos.
May 20- Hwy 145: some pools still with water from recent rains. Equalization Reservoir: *Downingia ornatissima* with "feet" in water. Alien grasses closing in.

1995:

Feb 18- Equalization Reservoir: Water in pools, but not deep. Lots of alien grass growing into pools, very weedy looking, Photos, no bloom.

Mar 31- Hwy 145 & Road 33: lots of water in pools. Equalization Reservoir: Many pools with murky gray water, except 1b ("Accidental" pool) with lots of vegetation on bottom. *Plagiobothrys* (some). Few *Lasthenia* starting in "Dozer" pool. Some *Limnanthes & Lasthenia* starting in natural pools to west. Too late in day to check for bees.

Apr 22- Equalization Reservoir: *Agoseris* in grass. Little bit of *Limnanthes & Lasthenia* in natual pools to west, set up pan traps (4 yellow & 4 white) in AM (primarily in *Lasthenia*). Nothing seen on *Agoseris*, *Triteleia*, a few flies on *Lasthenia*. Fair bit of *Plagiobothrys* in created pools, *Downingia* abundant in 1b & a few *Lasthenia*. Swept 1b, mostly flies, especially dung flies, 1 female *Halictus* (*Seladonia*). Also collected two female *Halictus* (*Seladonia*) on *Eschscholzia*. Picked up pan traps in PM. Natural swale with *Lasthenia*. Pan trap collections: White (4): *Dialictus* (5F); *Panurginus* (oligolege of *Downingia*) (16M); *Halictus* (*Seladonia*) (4F); *Andrena* (1F); *A.* (*Diandrena*) *subchalybea* (oligolege of Cichoriae) (1F); *Apis* (1W). Yellow (4): *Dialictus* (8F); *Panurginus* (3M).

30- *Downingia* abundant in pool along Road 33, plowed field. Equalization Reservoir: *Downingia* (primarily *ornatissima* now), *Mimulus tricolor* swept both: *Downingia* (in 1b): flies, small beetles, micro-Hymenoptera; *Downingia* (in 3): *Hylaeus*, *Dialictus*, *Apis*. Photos.

May 3- Puddles along roadside east of Madera from rain on Monday (1st). Water in pools along Hwy 145. CalTrans 200A (ca 5 mi S 4 Corners): pools all reinundated. *Downingia* abundant, much in water, swept: primarily flies and a few *Dialictus*. *Orthocarpus succulentus* not primarily under/in water, small flowered, probably selfing, no visitors observed, but not best of conditions for observations, Photos. Some *Agoseris* in grass. Equalization Reservoir: not refilled, rains must have missed. Lots of *Downingia*, lots of sweeps: primarily Syrphidae, 1 female *Halictus* (*Seladonia*) & 1 female *Dialictus*. Checked *Downingia* (larger flowered species) at Roads 33 & 400: primarily Syrphidae, few *Andrena* (medium size).

Roseville vicinity, Placer County natural and created vernal pools:

1995:

Mar 6- With Joan Leong. City Hall: picked up maps & reports from Neila Stewart. Highlands area- *Blennosperma* in good early bloom, all in natural areas not in constructed pools. Collected *Andrena blennospermatis* (M&F), also *Lasioglossum* (F) and other *Andrena* spp. including *A. subchalybea* (an oligolege of Cichoriae) (M&F) on *Eschscholzia*. Silverado created pool sites- more marsh/stream sites, no vernal pool plants in bloom. Kerry Downs created pools- again more marsh/stream, but may have *Downingia* later. No vernal pool plants in bloom.

May 4- With Joan. Stopped at City Hall to meet with Neila Stewart who took us to see pools at PG&E substation on Harding near Roseville Parkway. Pools have lots of *Downingia* and *Lasthenia*. Some *Navaretia* and a little *Blennosperma*. Swept *Downingia* and *Lasthenia*. Photos. Set out two sets of three pan traps (yellow, blue, and white). Highlands area- Lots of *Downingia* and *Lasthenia*, some late *Blennosperma*. Swept *Lasthenia & Downingia*. Set up two sets of three pan traps (yellow, blue, and white). Silverado area- Collected on *Downingia* and found oligolectic *Panurginus*. Kerry Downs- Collected on *Downingia* and found oligolectic *Panurginus*. Looked at area west of High School, but "No parking" inhibited close inspection. Picked up pan traps at two first sites. Traps in *Downingia* had best catch, especially white, blue was poorest at both sites. Found

oligoleges of *Downingia* (*Panurginus*) and Lasthenia (*Andrena submoesta*) at both PG&E and Highlands sites.

Jepson Prairie Preserve, Solano County:

1993:

Mar 6- *Blennosperma* in good bloom. Joan Leong and crew marking *Andrena blennospermatis* females for foraging behavior study. Photos. Tumuli of bee nests (*Hesperandrena* &or *Diandrena*?) noted in bare areas north of Olcott Lake.

Apr 3- Lots of *Limnanthes* at north end east side also along Olcott Lake, some *Lasthenia* on west side, both near RR tracks, some *Blennosperma* still blooming. Some *Andrena* collecting pollen from *Lasthenia* and nesting in larger bare areas. Males cruising and landing in bare spots. Most bees observed on ground rather than on flowers on this cool breezy overcast morning. Photos

25- *Lasthenia* near Olcott Lake pretty well gone to seed, better bloom to south of lake. *Downingia* abundant and *Limnanthes* common. Photos. *Andrena* observed collecting pollen on *Lasthenia.*

1994:

Mar 5- With Joan Leong. *Blennosperma* in good bloom, but not yet at peak. Cold (ca 16° C) and overcast most of the day. Saw females of *Andrena blennospermatis* collecting pollen on it from about 10:20 on, but bees only active when sun is on flowers. Collected males and females of two species of *Andrena* cruising *Blennosperma* during brief sunny episodes. Set out two cages each with a live *Andrena* females containing female *Stylops* parasites to attract free flying males- none found. Discussed Phil Northen's proposed study on monitoring soils for road runoff pollutants with Kevin Williams, UC Staff Steward of Jepson Prairie Reserve.

Apr 5- With Joan Leong, Kevin Williams and Phil Northen (CSU Sonoma). Gave Phil a tour along Hwy 113 perimiter of Jepson Prairie Reserve, stopping to look for likely sites for sampling soils for studies emissions pollutants runoff. *Lasthenia* in good bloom, abundant and dominant. *Limnanthes* common, *Blennosperma* past peak.

18- With Joan Leong. *Lasthenia* in good bloom, common north of Olcott Lake, abundant south of the lake. *Downingia* common. Collected female bees (on *Lasthenia*) several species of *Andrena* south of Olcott Lake for mark-release transplant experiment Netted bees and put them in small plastic vials with some heads of *Lasthenia*, then put the vials into baggies and on blue ice in a 6-pack cooler. Checked release site, one mile to the north. Flowers and soil look appropriate, some small females of *Andrena* foraging for pollen on *Lasthenia* here. Marked 91 bees each with a dot of orange acrylic dope on the thorax in the evening at home. At least 4 species of *Andrena*, mostly *Hesperandrena*:: 53 small, 15 medium, 21 large, and 2 extra large. Kept marked bees in 5.5x10.5x2.5cm cardboard photo slide boxes in refrigerator overnight.

19- Released bees ca 07:35 AM (ca 11°C) at north end of Reserve by partially opening slide boxes placed in a 40x27x6 cm cardboard tray with rocks to keep it from blowing over. Only some of the bees began crawling up the sides of the slide boxes, especially those in the sun, before I left at 07:45. Returned at 13:05. Only 5 dead marked bees in release boxes. None found in larger tray nor on ground nearby. Assume other 86 able to fly away. Surveyed *Lasthenia* in area, collected 132 females by 13:28, none marked. Did see patches of *Downingia* with females of *Panurginus* collecting pollen. Went to area south of Olcott Lake where bees were collected yesterday (1.2 miles south of release site) and sampled bees on *Lasthenia*, none of the 75 bees were marked.

22- Joan Leong monitored bees at the release site. From 13:30-13:45PM, 36 bees were visually observed on *Lasthenia*, none were marked. At 13:50 one marked female was seen. At 14:21 a marked female was observed collecting pollen from *Lasthenia*. May have been the same female as observed at 13:50.
28- Very little *Lasthenia* bloom left. Swept up 12 bees, none marked.

1995:
Feb 4- *Blennosperma*, fair bit in bloom, but closed due to foggy conditions at 10:30AM, lots of buds. No bee activity by 12:01 noon.
Apr 15- Lots of *Lasthenia* and *Limnanthes*. A bit of *Blennosperma* remaining south of Olcott Lake. Photos. Apparent bee nests found on mound with patches of bare dirt (packed tailings of pocket gopher activity). Measured site location to revisit and excavate in autumn or winter.

Travis AFB, Solano County natural and created vernal pools:

1993:
May 12- With Joan Leong, met Phil Northen and Doug Eakins (CSU Sonoma) at Travis. *Downingia concolor* abundant in natural pools also a few *D. insignis* and fairly common. *Lasthenia conjugens*. Photos. Mostly flies (Syrphidae, Calliphoridae, and Anthomyiidae) seen on *Downingia*, but did collect a female each of *Andrena* and *Lasioglossum* on it. Met Base Agronomist, Bob Holmes. Collected *Lasioglossum* females foraging for pollen on *Lasthenia conjugens*

1994:
Apr 5- With Joan Leong, met Phil Northen and Susan Holvey (CSU Sonoma) at Travis. Visited created pools, rectangular sloping ramps, with varying degrees of ponding. Photos. Lots of *Lasthenia glaberrima* at source natural pool site (*L. conjugens* is still in bud). Some *Downingia concolor* in early bloom. Collected a *Lasioglossum* female with pollen on *Lasthenia*, lots of dance flies (Empididae) seen on it. Also collected a male and female of the oligolectic *Andrena* (*Hesperandrena*) on it at 10:50. Quite a few male *Andrena* seen hovering around *Lasthenia*. Some patches of *Layia* among grasses, swept sample of bees from it. One pool had a bit of *Downingia insignis*. Swept *Plagiobothrys* and collected one male of *Panurginus* (the *Downingia* oligolege). Also swept *Layia* intermixed with *Orthocarpus*.
May 13- With Joan Leong met Doug Eakins and Susan Holvey (CSU Sonoma) at Travis. *Downingia concolor* and *D. insignis* in bloom in natural pools. Observed small bees working upside down on long column *D. insignis*. Collected females of the oligolectic *Panurginus* on both species ca 10:00-15 also collected a *Dialictus* female with pollen, small black beetles (Dasytidae), and one large fly (Syrphidae) on *D. concolor* ca 10:36. Still some *Lasthenia*, but no bees seen on it.

Butte County (S of Chico):

1993:
Mar 12- Most of what had been vernal pools with *Limnanthes*, etc. in 1970's west of Hwy 99 along Thermalito Forebay dam is now rice fields. Some remnants of pools just south of junction with Hwy 162 and between Shippee Road to east and to north of Nelson-Shippee roads to west. Mostly almond orchards north of that. Most of the yellow in these areas is *Orthocarpus* and *Lasthenia*.

1994:

Feb 22- Lots of standing water in small pools, but no bloom from Thermalito Forebay to Nelson-Shippee Road. *Blennosperma* in bloom to N, scattered patches. Took Pence-Durham turnoff to W and up old Oroville-Chico Hwy to NW found *Blennosperma* on both sides, extensive patches for about a mile along road. Saw *Apis* with white pollen loads on it at 14:22 and collected one with pollen at 14:25. Swept through *Blennosperma*, no oligolectic *Andrena*, but ca 6 more *Apis* with pollen. More *Blennosperma* along Neal Road and across Hwy 99 to E.

Mar 4- No vernal pool flowers in pools W of Thermalito Forebay. Some *Blennosperma* in vicinity of Nelson-Shippee Road. *Blennosperma* in bloom near junction of Durham and old Oroville-Chico Roads. Set out three yellow pie plate traps in flower patch by 13:39, cool (20°C), light breeze. Picked up traps at 16:14, 19°C. No bees, only a few flies (Anthomyiidae) in traps.

1995:

Feb 11- Quite a bit of standing water in scattered vernal pool areas from Richvale area N, but no bloom yet. Lots of *Blennosperma* at old Oroville-Chico Road site. Flower heads still closed at 09:10, temperature ca 11°C also lots of buds.

Mar 28- Most bloom around Nelson-Shippee Road is *Orthocarpus* sith some small patches of *Layia*. Quite a bit of *Limnanthes* E of Hwy 99 just S of Pentz-Durham offramp. More *Limnanthes* on both sides of old Oroville-Chico Road site, also some *Lasthenia* and *Layia*. *Blennosperma* pretty well finished. Saw one cuckoo bee, *Nomada*, on *Lasthenia* in 5 minutes observation ca 12:30 and 19°C. Saw one *Apis* without pollen on *Blennosperma*, overflying *Lasthenia*. Saw another *Apis* with pollen on *Lasthenia*. Only 5 *Apis* seen in 5 minutes (the other three were on *Arenaria*) ca 14:55-15:00 at 21 °C. Are honey bees the main pollinators of the vernal pool and other plants at this site?

Santa Rosa, Alton Lane, Sonoma County natural and created vernal pools:

1993:

Apr 7- Patches of *Limnanthes douglasii douglasii* along Adobe Road E of Petaluma. Met Joan Leong at Alton Lane mitigation site NW of Santa Rosa. The site has lots of good patches of *Blennosperma bakeri*. Many new pool areas scraped out with lots of bare areas of surrounding birm. Water standing in many pools. Sunny, warm, still. Several species of *Andrena* active on *Blennosperma* including *Diandrena* females and males. Some *Limnannthes* with female and male *Andrena* active also one *Apis* seen on it. Some *Lasthenia* in drier pool in NW corner of site. Met with Dianne Steek and Diane Ikeda CDF&G. More *Limnanthes* to S along Piner Road just W of junction of Marlow and Pinecrest roads. *Limnanthes douglasii douglasii* seen at junction of Frates & Adobe Roads just E of Petaluma. Photos.

Los Banos vicinity, Merced County (Grasslands State Park, Arena Plains):

1993:

May 5- Toured Arena Plains (+Sunset Ranch) with Gordon Frankie (UCB) and Mike Peters (USFWS, Los Banos). Dry grasses browning most typical vernal pool plants finished blooming, except for a bit of *Lasthenia*. No bees seen on *Lasthenia*. Found some *Downingia* still in bloom at Grasslands State Park on the W side of Hwy 165 [N of Los Banos at mile marker: MER 23.00]. Collected a few females of the oligolectic *Panurginus*, and many of the generalist *Halictus* (*Seladonia*). Photos.

Appendix 5: Maps Designating Locations of Field Study Sites

Map 1. Butte County: Chico area: ca 10 miles SSE of Chico, 4 miles E of Durham.

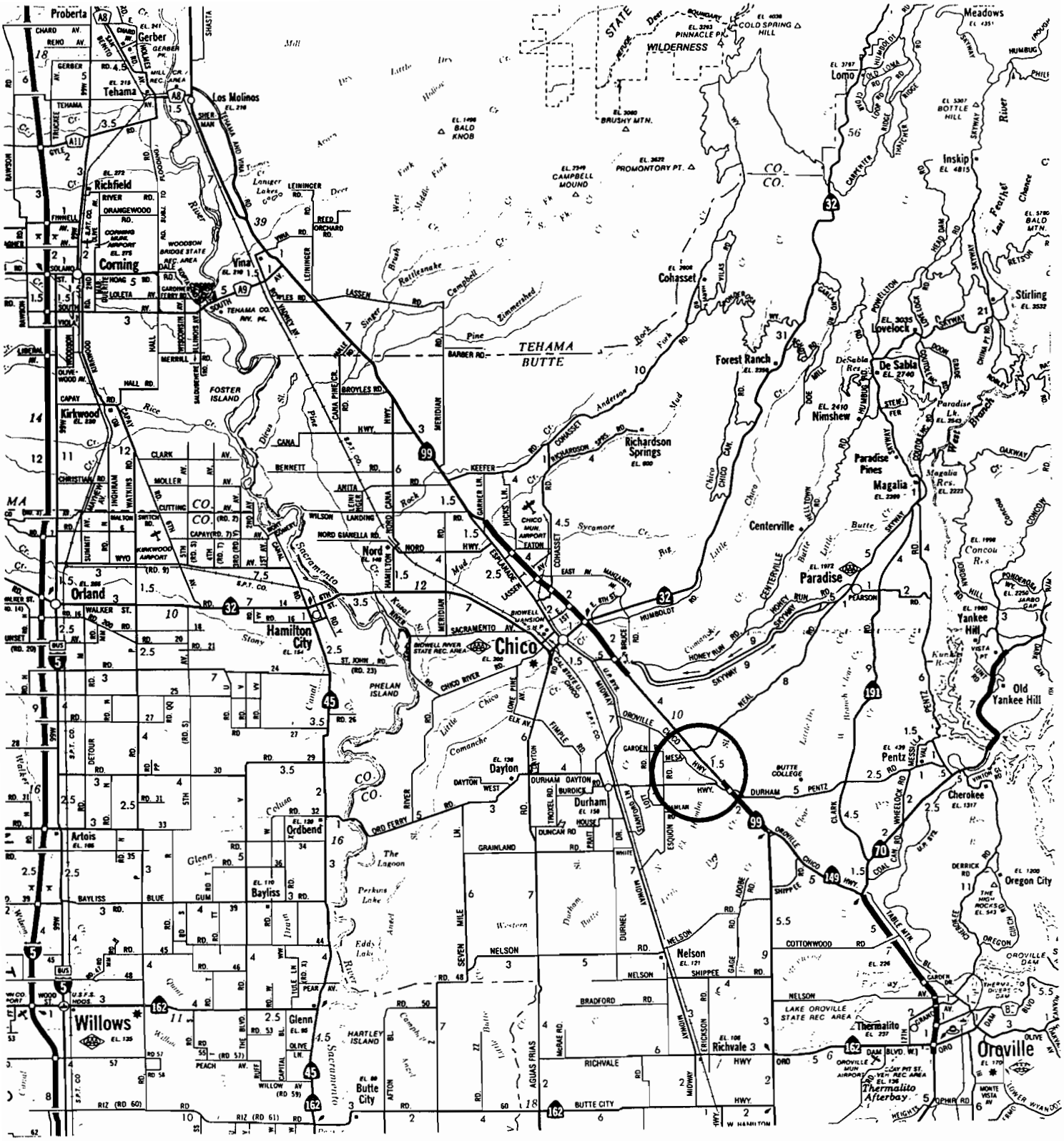
Map 2. Sonoma County: 1) Alton Lane NNW of Santa Rosa; 2) Adobe & Frates Roads E of Petaluma.

Map 3. Solano County: Travis Airforce Base mitigation site (CSU Sonoma); Jepson Prairie Preserve (TNC & UC NRS), ca 11 miles S of Dixon.

Map 4. Placer County: Roseville area: 1) Highlands site; 2) PG&E substation site; 3) Silverado and Kerry Downs sites.

Map 5. Merced County: 1) Arena Plains Park National Wildlife Refuge; 2) Grasslands State Park.

Map 6. Madera/Fresno Counties: 1) Bureau of Reclamation Equalization Reservoir mitigation site (CSU Fresno); 2) Road 33 and Road 400; 3) Finston Ranch N of Ave. 15 and W of Hwy 41; 4) CalTrans 200 acres E of Hwy 41 near Ave 12; 5) Table Mountain.



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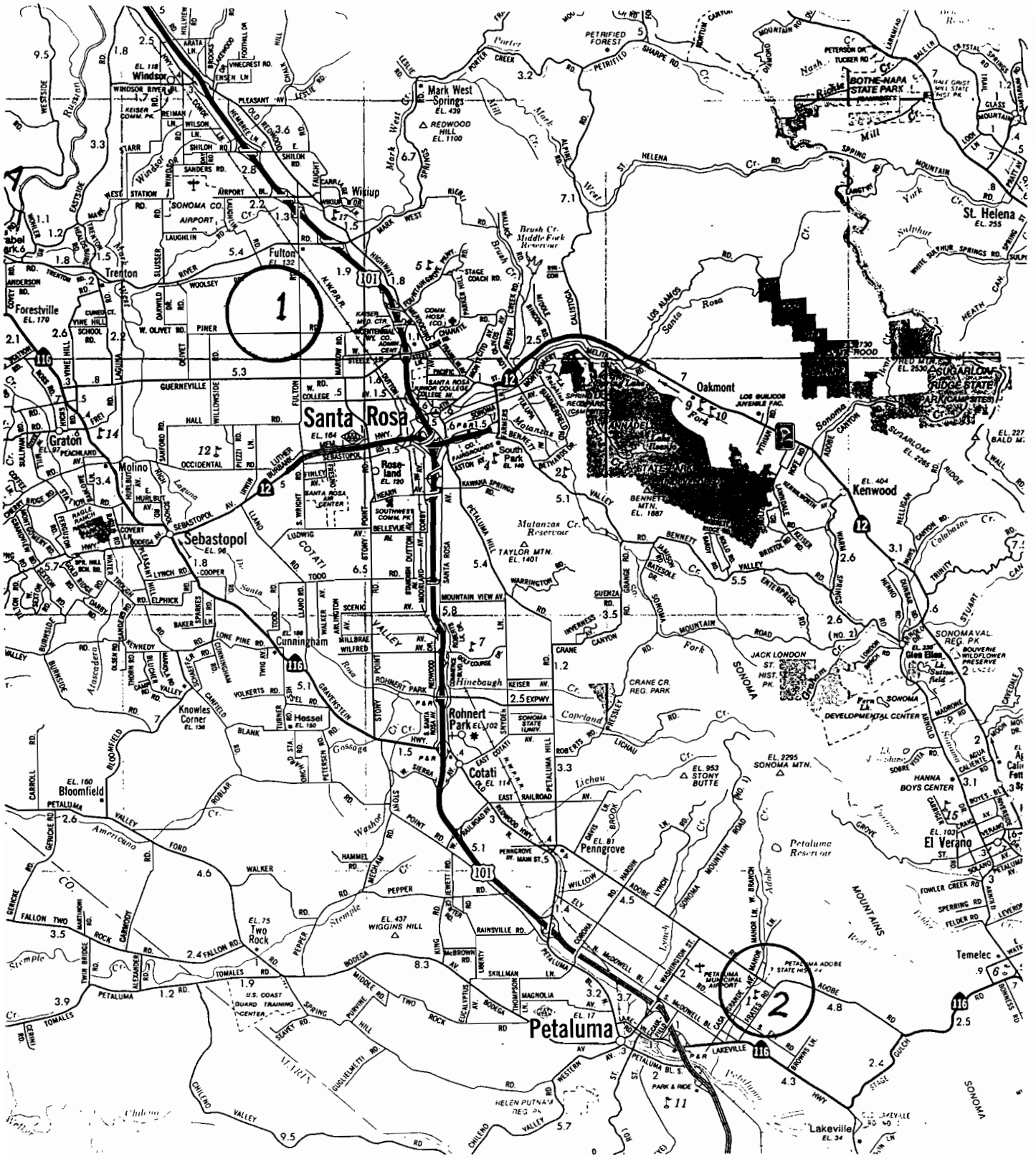

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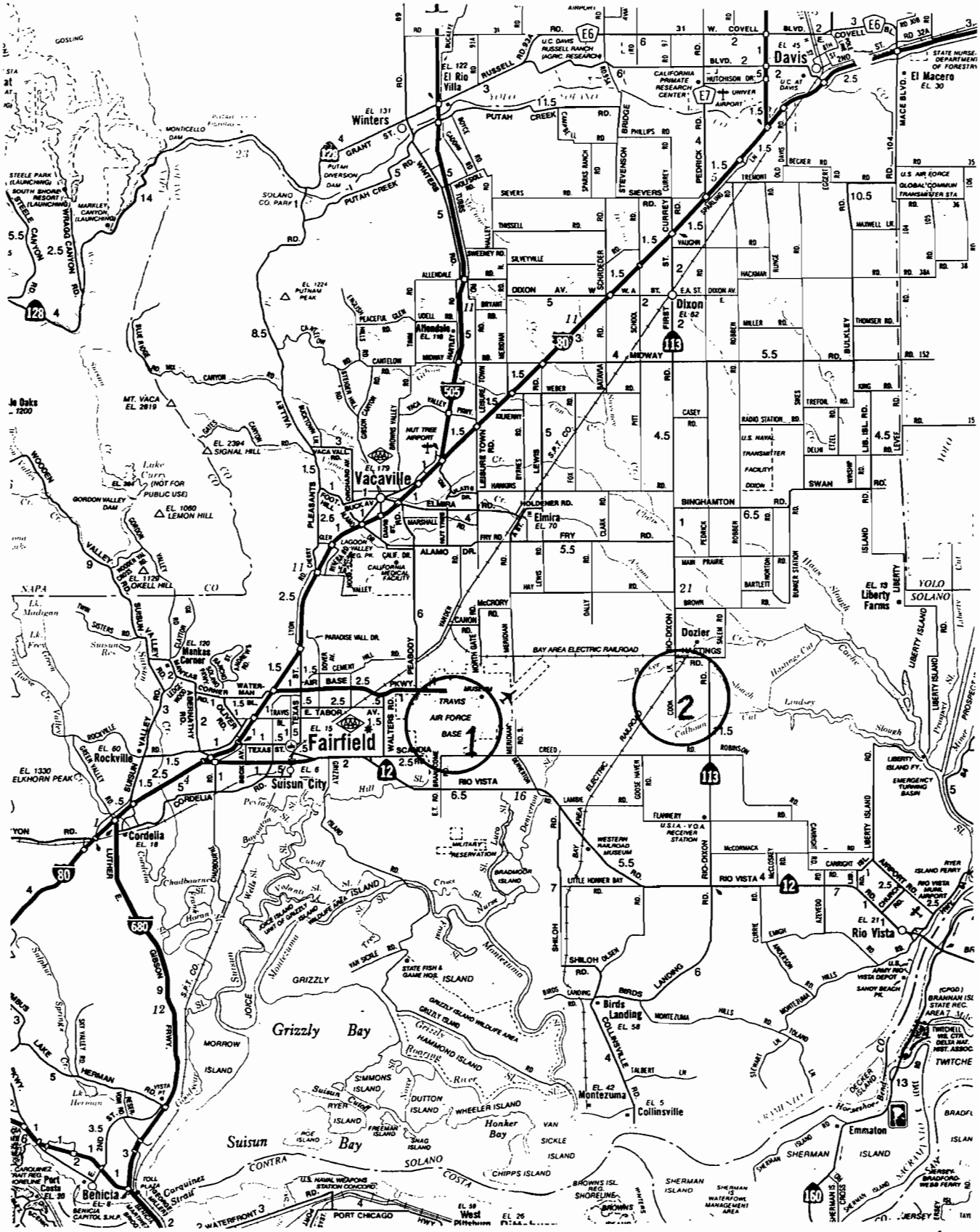
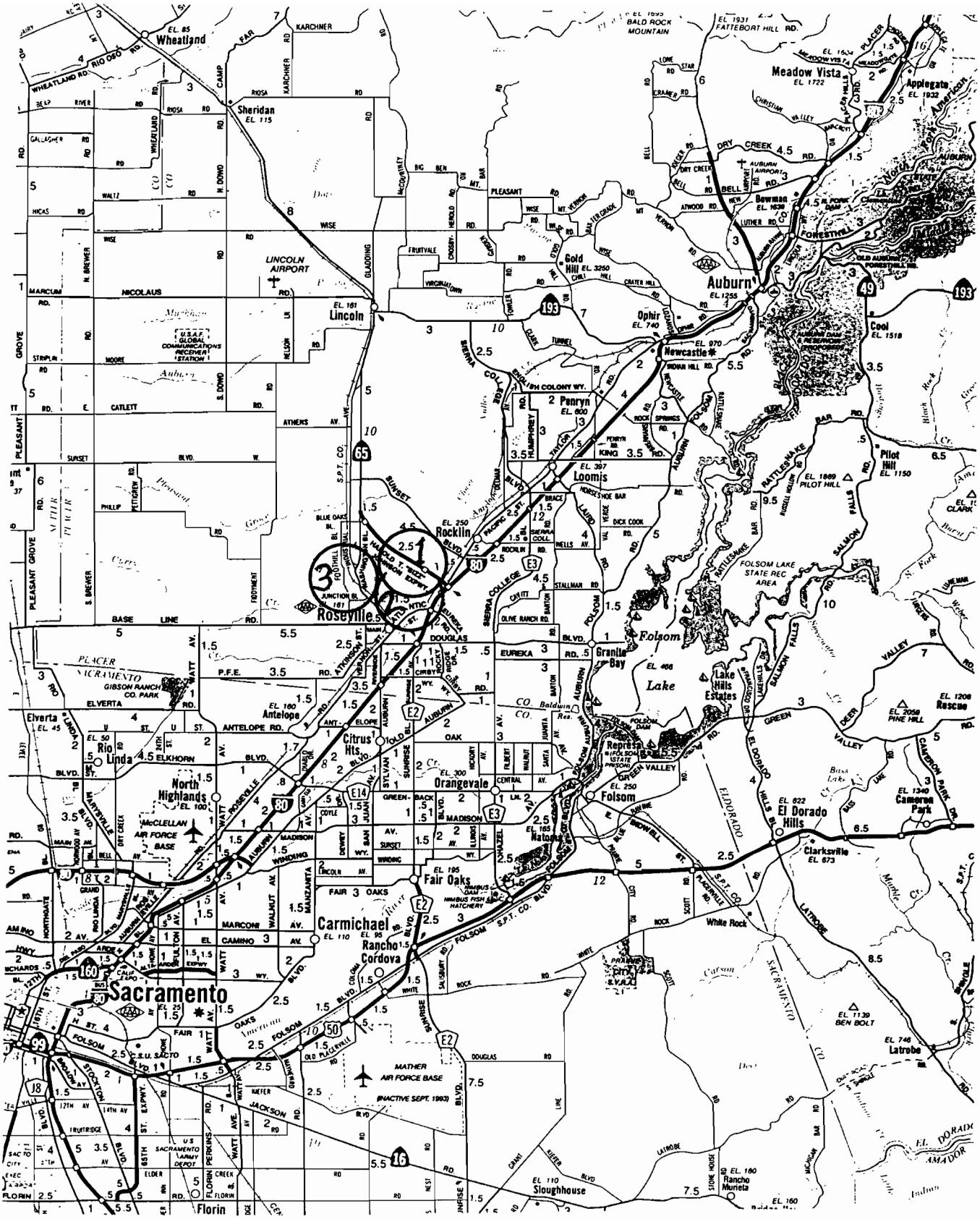
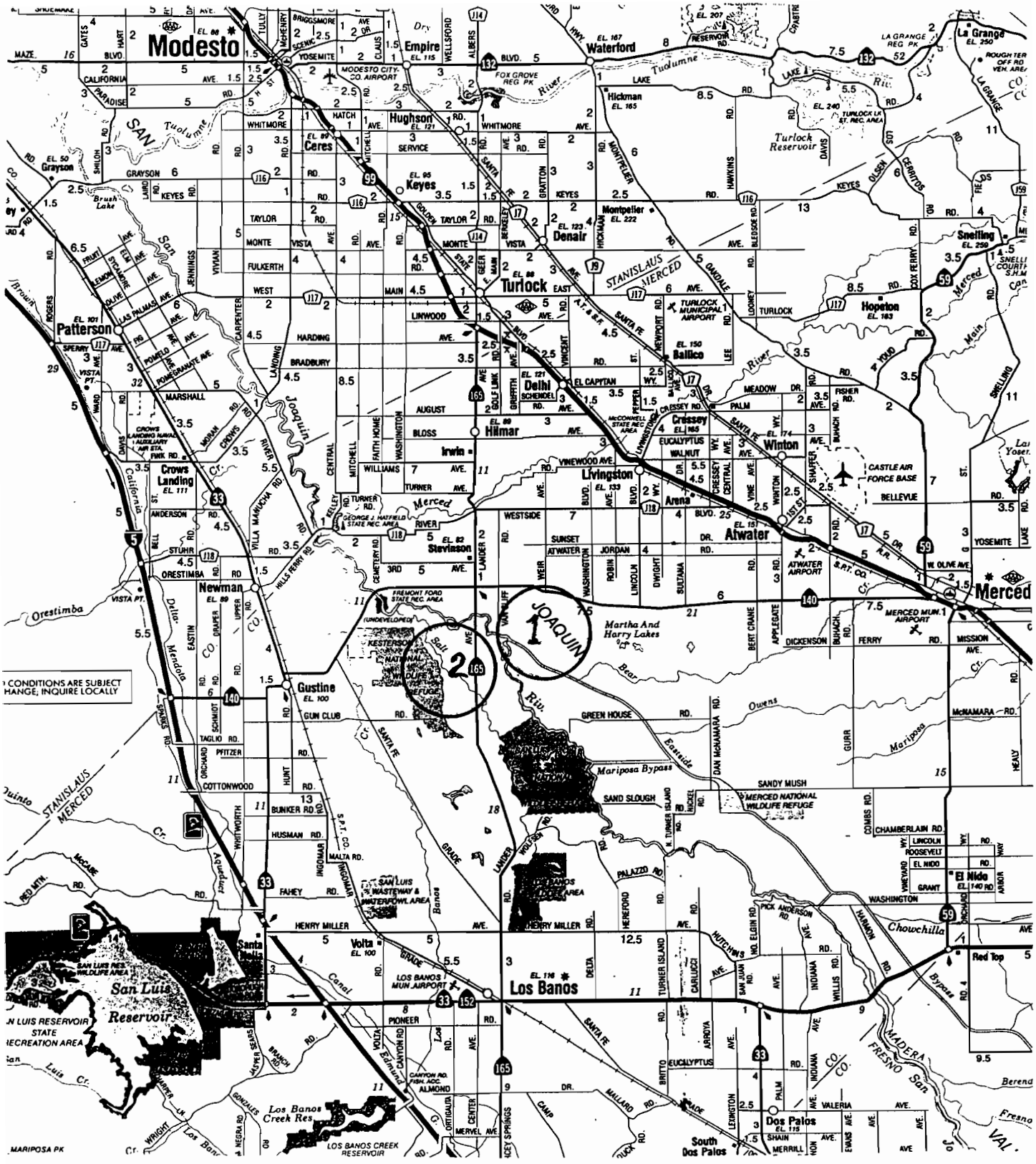


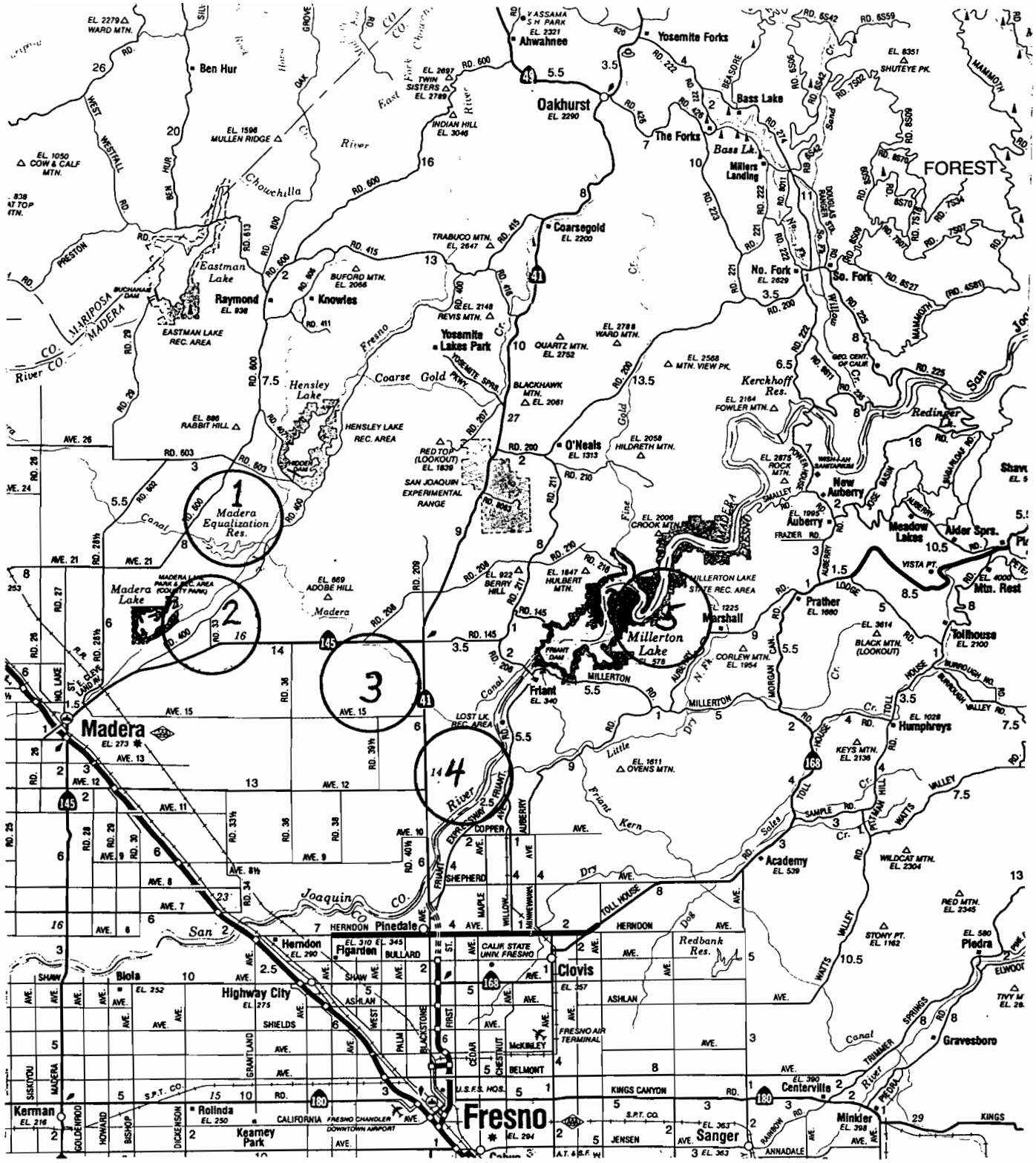
Map 3. Solano County: Travis Airforce Base mitigation site (CSU Sonoma); Jepson Prairie Preserve (TNC & UC NRS), ca 11 miles S of Dixon.



Map 4. Placer County: Roseville area: 1) Highlands site; 2) PG&E substation site; 3) Silverado and Kerry Downs sites.



Map 5. Merced County: 1) Arena Plains Park National Wildlife Refuge; 2) Grasslands State Park.



Map 6. Madera/Fresno Counties: 1) Bureau of Reclamation Equalization Reservoir mitigation site (CSU Fresno); 2) Road 33 and Road 400; 3) Finston Ranch N of Ave. 15 and W of Hwy 41; 4) CalTrans 200 acres E of Hwy 41 near Ave 12; 5) Table Mountain.