PLACER COUNTY VERNAL POOL RESTORATION FEASIBILTY ASSESSMENT

Prepared for:
Victoria Harris
TRA Environmental Sciences, Inc.
545 Middlefield Road, Suite 200
Menlo Park, CA 94025

and

Loren Clark
County of Placer
Community Development Resource Agency
Planning
3091 County Center Drive, Suite 140
Auburn CA 95603

Prepared by:
D. Christopher Rogers
EcoAnalysts, Inc.
PO Box 4098
Davis, CA 95616

INTRODUCTION

EcoAnalysts, Inc. was engaged by Placer County and TRA Environmental Sciences, Inc. to provide scientific support concerning vernal pool ecological issues as pertaining to the Placer County Conservation Plan (PCCP) development. The specific issues to be addressed are to determine:

- if there are sufficient restorable vernal pool habitats to meet or exceed PCCP conservation goals;
- the required effort to restore that habitat (develop the basis for a restoration plan);
- the success potential of the restoration effort, and;
- the costs associated with implementing that restoration.

Conservation of vernal pool habitat will be accomplished through the acquisition, management and restoration of vernal pool 'conservation areas' within western Placer County. The exact methods of acquisition and proportions to be acquired will be addressed elsewhere. Conservation areas will be large, contiguous, broad pieces of land that encompass as many different native habitat types as possible, where non-invasive management needs are minimal. Ideally, these areas will fulfill the PCCP vernal pool conservation needs. However, if there is insufficient high quality vernal pool habitat available, low quality vernal pool grassland habitat may need to be restored in order to meet the PCCP goals.

Prior to acquisition, all potential restoration areas must be evaluated as to their functionality and ecological health. Two types of restoration will be considered:

- direct restoration of existing, impacted vernal pools, and;
- direct reconstruction of obscured historical vernal pools.

In the first case, existing impacted vernal pool habitats that have a reasonably intact hydrological system will be evaluated using the Vernal Pool Assessment Method described elsewhere and the USFWS standard shrimp surveys for federally listed species (1996 or most recent version). This method will yield the following information on the invertebrate community structure: presence of federally listed crustacean species, level of general invertebrate abundance, taxa richness, taxa dominance, opportunistic taxa abundances, and obligatory taxa abundances. From this preliminary data restoration goals will be set on a per site basis, and an expected recovery end point can be forecast.

In the second case, obscured historical vernal pools and their supporting hydrology will be reconstructed. These habitats may not be directly functioning as vernal pools, however some evidence of the historic vernal pool hydrology is present and demonstrable. Once these habitats are reconstructed, then the Vernal Pool Assessment Method will be used to monitor the habitat's progress in the same way as above.

Historical habitats that have been entirely obliterated and/or the topography laser leveled, or in current rice production will not be considered as potentially restorable vernal pool habitat.

METHODS

EcoAnalysts is constrained in these analyses by circumscribed access to potential restoration areas. Three field visits to western Placer County were conducted. All three field visits were for data collection on potential restoration sites and all were conducted from public roads as no property access was available. Therefore these visual assessments were entirely qualitative.

All conclusions presented in this document are based upon these limited "look over the fence" visual assessments of selected parcels, and on the information contained in the map layers prepared by North Fork Associates. Additional information came from the monitoring reports from the Teichert Coon Creek vernal pool restoration areas north of Lincoln. Reports from other mitigation banks were not available from the bank owners.

A vernal pool grassland restorability index was developed by North Fork Associates for determining the overall desirability and potential level of effort for various parcels within the PCCP to be restored. This index is a basic guideline for determining potential restorability; however each must be independently evaluated to establish the actual restoration potential, costs, and long term sustainability.

ARE THERE ARE SUFFICIENT RESTORABLE VERNAL POOL HABITATS TO MEET OR EXCEED PCCP CONSERVATION GOALS?

According to the mapping efforts of North Fork Associates, there are XXXX acres of restorable vernal pool habitats in western Placer County. To date, it is expected that XXXX acres of vernal pool conservation habitat area is available and that XXXX acres are needed to meet the conservation and mitigation needs of the forecasted build out.

At this point in time, actual acreages are unknown and are only estimated due to lack of access to the parcels under consideration. North Fork Associates developed a "Vernal Pool Restorability Index" (VPRI) to categorize different layers of the maps being generated for this effort. This index also can be used as a descriptive tool for later use when access to potential restoration parcels becomes available. At that time the VPRI can be used to categorize not only parcels, but portions of the parcel and even individual features such that an overall potential restoration value can be ascribed to a parcel. This index is based on visual, qualitative features and should be used in conjunction with the Vernal Pool Assessment Method to provide quantitative values for restoration feasibility. The VPRI is presented here with a slight modification:

Vernal Pool Restorability Index (v3)

1 = High Restorability

- a. Landscape disturbed, but landform generally intact with only moderate changes (high degree of roadlessness, farm staging areas, edges, some wetlands filled)
- b. Relatively intact historic landform (little history of grading, little or no alteration to flow pattern)
- c. Large restorable area (>300 acres)
- d. Adjacent land use is compatible (vacant or grazed pasture land, any natural habitat)
- e. Adjacent land use is protected as in perpetuity open space
- f. Embedded in an open-space corridor network (i.e., any CARP boundary, Coon Creek/Doty Ravine watershed, and Bear River watershed)
- g. Site hydrology is intact and is predicted to be stable in the long-term

2 = Moderate Restorability

- a. Landscape fairly disturbed, and landform less intact with more significant changes (moderate degree of roadlessness, altered edges, stream channel alterations, many wetlands filled)
- b. Historic landform moderately altered but with restorable potential (flow patterns not altered)
- c. Moderately sized restorable area (>200 acres)
- d. Adjacent land use potentially compatible (almost any agricultural use)
- e. Open-space corridor potential exists
- f. Site hydrology is conducive to restoration. Some disturbance has occurred and/or there are threats to integrity of the watershed over time.

3 = Low Restorability

- a. Landscape highly disturbed
- b. Historic landform highly altered (abandoned contoured rice fields, cuts/fills from subdivision improvements) or not altered
- c. Small restorable area (<200 acres)
- d. Adjacent land use is not presently compatible (urban or rural residential) or future land uses are anticipated (e.g., approved projects, zoning or general plan designations) that are incompatible.
- e. No open-space corridor or linkage potential beyond the restorable area

With the subcategories labeled with letters a feature can then be ascribed a VPRI value of "3a,d" or "2b" or even "1a – g inclusive" as appropriate.

WHAT IS THE REQUIRED EFFORT TO RESTORE VERNAL POOL HABITAT IN WESTERN PLACER COUNTY?

Habitat Requirements and Ecology

Vernal pool organisms are entirely dependent upon the aquatic environment provided by vernal pool wetland ecosystems. These organisms depend upon the presence of water in the winter and early spring and the absence of water during the summer. These specific vernal pool wetlands are dependent upon intact sub-watersheds, and the surrounding uplands that support those watersheds. Vernal pool habitat is a component of the larger grassland ecosystem of the California Great Central Valley.

Pool volume is important for various vernal pool organisms because deeper pools with a large surface area can more easily maintain their dissolved oxygen levels. Similarly, deep pools will pond long enough to allow slower species to complete their life cycle.

Various physiochemical factors have been examined in existing vernal pools habitats including alkalinity, total dissolved solids (TDS), and pH (Keely, 1984; Collie & Lathrop, 1976; Eriksen & Belk, 1999). The U.S. Fish and Wildlife Service (1994) described the water in pools occupied by Vernal Pool Fairy Shrimp as having low conductivity and chloride, however specific data were not provided. Eriksen & Belk (1999) presented a range of attributes measured by different workers, reporting alkalinity ranging from 22-274 ppm, TDS of 48-481 p.p.m., and pH ranging from 6.3-8.5 in occupied habitats. However, the importance of many of these parameters has recently been called into question with evidence that type and amount of dissolved salts may be a more important habitat requirement (Rogers 2002a). Considering the daily fluctuations in pH of a given habitat, this is to be expected. During the daylight hours, the hydrophytes are photosynthesizing, removing the CO₂ (from HCO₃) from the water, and raising the pH. During the night, the hydrophytes are respiring, increasing the CO₂ (and thereby, the HCO₃) in the water lowering the pH. If there is rainfall, the distilled precipitation will lower the pH, as will winds that cause surface action. When the habitats are drying and losing volume through evaporation, the pH, alkalinity, TDS, and electrical conductivity will increase, just as they decrease when the pools inundate or reinundate (Rogers, 2002a).

Some vernal pools need a certain amount of grazing. Vernal pools that have all grazing removed become overgrown with native and exotic plants that generate deep thatch layers on the pool substrate, unless some other disturbance (i.e., weed control programs, vehicular use of pools, fire fuels control) prevents thatch deposition. As this thatch layer decomposes, it also removes oxygen from the water, which can suffocate gill-breathing invertebrates (Rogers, 1998). Therefore, moderate grazing may be a necessary habitat suitability component. Conversely, excessive livestock grazing can be detrimental to Vernal Pool Fairy Shrimp. Over-grazing tends to allow a great deal of manure into vernal pools. The organic waste removes oxygen from the water, leaving the gill-breathing invertebrates like the Vernal Pool Fairy Shrimp without oxygen (Rogers, 1998, pers. obs.). It is important not to alter grazing regimes in conservation areas until the importance of grazing to those particular systems are assessed.

The vernal pool invertebrate community includes mostly planktonic Crustacea dependent upon temporary wetlands including branchiopods, copepods, cladocerans, and ostracods, as well as flatworms, and a suite of insect species (Rogers, 1998). These habitats are usually low in opportunistic species like Mosquitoes and Chironomid Midges in the genus *Chironomus* (Rogers, 1998).

Optimal habitat tends to be neutral to slightly alkaline, clear or turbid vernal pools, low in dissolved salts, dominated with vernal pool plants, and sustaining a complex vernal pool invertebrate community (Eriksen & Belk, 1999; Rogers, pers. obs., 1998, 2001a). Unfortunately, little effort has been made to accurately quantify these parameters.

Restoration goals

The primary goal for vernal pool restoration within the PCCP study area is to conserve and enhance vernal pool ecosystems supporting specific vernal pool ecosystem functions and biotic community structure through the acquisition of restorable habitat contiguous with other conservation and restoration habitats supporting extensive vernal pool complexes. Secure protection and management will partially reduce threats to vernal pools within the PCCP study area; however, by itself this is insufficient to enhance the current habitat. Restoration of impacted habitats or destroyed habitats, followed by quantitative, long-term monitoring with implementable contingency plans (if needed) is necessary to enhance the existing habitat within the PCCP, and insure their long-term survival.

Specific guidelines in selecting vernal pool habitat for conservation of vernal pools and their dependant organisms shall consider:

- Vernal pools are not independent microcosms. Active movement of organisms occurs between adjacent pools within complexes, between adjacent complexes, and between distant complexes (for example: Amat, et al. 1991; Eng et al., 1990; Eriksen & Belk, 1999; Proctor, 1964; Rogers, 1998, In prep; Rogers & Fugate, 2001; Wissinger et al., 1999).
- Vernal pools are dependent upon the surrounding topography (which may be mound-intermound) as a watershed. In the California Central Valley, depending upon rainfall, these habitats may only receive enough water to be dampened one year and be violently flooded by an El Niño event the next.
- Vernal pool organisms are functions of vernal pools and other seasonally astatic
 freshwater aquatic systems, which are fundamentally disturbance-based systems,
 functioning as wetlands for one portion of the year and uplands for the remainder of the
 year. Organisms that exploit these habitats are essentially opportunistic in their use of
 temporary waters.
- Vernal pools selected for conservation and restoration must exhibit the same biological
 and geomorphological functions as the habitat being compensated for. For example:
 pools occurring on Mehrten formations tend to be very shallow, and cannot be used to
 replace deeper pools occurring on other landforms.

- Impacted vernal pools exhibiting a diverse invertebrate and botanical community are desirable for restoration, whereas artificial habitat, such as a railroad toe-drain that supports listed fairy shrimp but no other vernal pool invertebrates or plants is not.
- Vernal pool habitat comprises a spectrum of variation including pools that are shallow, deep, of long ponding duration, of short ponding duration, densities, occurring on various geomorphic surfaces, soil types and supporting various invertebrate and plant communities to reflect the diversity of vernal pool habitats as well as protect species through extreme climactic fluctuations. It is imperative to preserve the greatest range of variation and attributes within vernal pool complexes.
- Vernal pools within complexes tend to vary broadly in topomorphy, area, depth, botanical community structure, invertebrate community structure, and vertebrate use. Therefore, restored or constructed vernal pool habitats must reflect the diversity of natural, adjacent, unimpaired reference systems.
- No estimates are currently available regarding the minimum self-sustaining population size, vernal pool size or habitat complex size for vernal pool organisms. The estimated loss of extant habitat (for example: Holland, 1978, 1988, 1998; Bauder & McMillan, 1988) suggests that these species need the maximum amount of available habitat.
- Vernal pools are systems that require participation from all aspects of the floristic and faunistic community, including vertebrates. To insure success, moderate, managed grazing is needed (see discussion above, under 'Habitat Requirements and Ecology').

Restoration Area Selection

Each restoration area must have a corresponding high quality conservation preserve for comparative monitoring and standards as a reference site. A corresponding reference site must be on the same or range of same geomorphic surface types as its associated restoration site. Similarly, the reference site must have the same range of variation of vernal pool morphology (area, fetch, depth) as the corresponding restoration site. Suitable high quality reference sites should be selected prior to restoration area selection, so that restoration sites can be correlated with suitable respective reference sites.

The greatest threat to vernal pools is the elimination, loss, or modification of their habitat by development. The filling of vernal pools or modification of the watershed that supports those pools either eliminates the habitat or disrupts the pool ecosystem to where it is overcome by opportunistic invertebrate species and invasive, opportunistic and non-native plants, that out compete the obligatory vernal pool species (Rogers, 1988). However, some or most of these impacts can be reversed through restoration. Proposed restoration areas may have one or more various types of impacts:

• Overgrazing or undergrazing. Both lack of and excessive grazing cause an increase in organic matter in the habitat that eliminates the natural vernal pool invertebrate

community, and promotes opportunistic and invasive species, that out compete the obligatory vernal pool species (Rogers, 1998). Therefore, moderate grazing, or other similar disturbance may be a necessary habitat suitability component, and the removal of grazing or excessive grazing are threats to vernal pool habitats.

- **Discing, plowing, or other alterations to the topography.** Any practices that alter the landscape topography have the potential to alter the hydrology of vernal pools. Typically discing and plowing is conducted as part of agricultural practices or as fire breaks. Open field farming can obliterate pool and swale margins, often eroding them to the point where features increase in shallowness, and eventually disappear. Laser leveling and fill will obliterate features under layers of soil and/or fill material. Laser leveled and active rice farmed parcels are not considered restorable.
- Watershed alteration. Damage to the watershed that supports vernal pools and vernal pool complexes will impact vernal pool biological communities. Elimination of the watershed will not allow the pools to pond properly and will curtail the movement of nutrients into the pool from overland flow (Rogers, 1998). Furthermore, vernal pools are sometimes intentionally drained to eliminate perceived mosquito problems or to increase arable land, or are dug deeper to hold more water for longer periods for livestock or aesthetic or recreational use.
- Runoff. Road runoff entering the watershed and conveyed to vernal pool habitat through the watershed may carry petroleum byproduct residue or sediment from vehicles or paving or road maintenance activities. Furthermore, pesticide, herbicide, fertilizer, manure and sediment runoff from agricultural or landscaping activities may enter the watershed and be conveyed to vernal pool habitats. Ground disturbance from development activities may loosen soil that may enter the watershed and be conveyed to occupied habitat as sediment, which can bury egg and seed banks or possibly coat gills, preventing respiration.
- Invasive species. Non-native invasive species are a threat to vernal pool communities. There is concern that Bullfrogs (*Rana catesbeiana*) may feed upon federally protected vernal pool crustaceans (Balfour & Morey, 1999). Manna Grass (*Glyceria declinata*) and Italian Rye Grass (*Lolium multiflorum*) are both exotic vernal pool plants, which tend to produce heavy thatch and eventually organic loads upon decomposition, which remove oxygen from the water (Rogers, 1998). In addition, people may introduce the non-discriminating predatory Mosquito Fish (*Gambusia affinis*) into vernal pools to control perceived local mosquito problems (Rogers, pers. obs.).
- **Fragmentation.** Habitat fragmentation is a threat to vernal pool communities in that development surrounding small pool complexes may prevent waterfowl or shorebirds from feeding at the pools, thereby preventing genetic flow between occupied habitats. Furthermore small pool complexes surrounded by development will not be buffered against the run-off from developed areas, and concomitant changes in the watershed hydrology.

• **Recreational use.** Many vernal pool wetlands are used for "mud bogging", where off road vehicles are driven around and through a pool. This activity typically causes great mechanical damage to the pool topography and causes direct mortality of the organisms in the pool by crushing them or displacing them outside the pool.

Opportunities for vernal pool grassland habitat restoration would be evaluated by determining the historical presence of a temporary wetland landscape as evidenced by signatures of annual pools on recent and historical aerial photographs, topographic features, and soil survey data. Potential restoration areas should be selected based on appropriate soils, topography, and likely historic annual pool locations. Areas adjacent to potential preservation areas should be given preference because combining preservation and restoration areas meets the PCCP goal of conserving large areas of contiguous, hydrologically connected habitat rather than fragmented areas.

Soils data should be collected from potential restoration sites. The primary purpose of the soil data would be to determine whether any remnant of the native wetland clay layer is still present, making habitat restoration potentially feasible. Damaged hardpan or duripan (silica cemented hardpan) layers will not allow pools to maintain their hydrology. Soils data also should be collected from the existing vernal pool reference habitats to determine soil characteristics that support those wetlands, including: alkalinity, dissolved salts (e.g. Na, Ca, K), and soil pH.

Vernal pool grassland habitat would be created in appropriate areas using excavation techniques on topographically suitable terrain and soils. Design criteria for vernal pool grassland habitats would be based on characteristics of existing pools on the reference sites, including the reference pools and mima mound topography if present, as well as what topographic features can be descried from historical photographs and soils data. Key physical features would include pool size and depth, depth to hard pan layer, landscape position, and topography.

These large branchiopod habitat restoration guidelines are conceptual and present the overall program for vernal pool grassland habitat restoration and preservation. After this plan has been approved by Placer County and the regulatory agencies and after exact locations for annual pool preservation and creation have been determined, detailed construction documents (plans and specifications or plans and detailed notes) for restoration of vernal pool grassland would be developed, based on the conceptual design and soils data collected. Restoration excavation activities restoring the basins would be monitored by a qualified biologist.

Where soil conditions remain that are capable of supporting restored vernal pools, specific upland areas in the project site would be altered to create vernal pool microtopography. The soil conditions in the restored vernal pool basins would replicate a range of soil profile conditions present in existing vernal pool habitat (i.e., a shallow layer of native clay soils underlain by a clay hardpan or durapan layer. This replication would result in restoration of vernal pool basins to depths and durations similar to those of the reference conservation sites. The soil analysis of reference vernal pool habitat would be used to determine restored vernal pool soil profiles in the restored basins. The restoration design would reflect the natural rise and fall of the overall landscape, as well as the natural hydrology of existing vernal pool habitat. The restored uplands

would be revegetated using site-specific native upland topsoil material to minimize the need to use commercial seed in the revegetation process.

Restoration Actions

Depending on the type of impacts a vernal pool has accumulated, one or more restoration actions may be required to promote habitat recovery. Each habitat to be restored must be evaluated independently, and an individual restoration plan for that site must be developed. Potential restoration actions will include (but are not limited to):

- Removal of organic overburden. Pools that have been subject to excessive grazing, or have had all grazing removed for many years may have excessive organic material in the habitat. Excessive thatch, weeds, manure or other organic waste must be removed for a pool to function properly. By maintaining a moderate grazing regime that prevents thatch build up and limits manure input will help maintain the habitat integrity. Sheep are good for vernal pool grazing in that they are more efficient at converting vegetation to energy, and thus their droppings are harder and lower in free organic material. Furthermore, leasing grazing rights to a restoration site may help defray monitoring costs.
- **Removal of inappropriate debris.** Removal of anthropogenic litter from restoration wetlands is imperative.
- **Grading.** If a vernal pool or swale has been actively disced or plowed the habitat margins and basin may be obliterated and friable, making the margins conducive to erosion. Careful grading and compacting of habitat substrate will maintain the desired topography and reduce the erosion and filling of the habitat.
- Excavation. Features that have been filled either by erosion or direct fill may be excavated to their original dimensions. Laser leveled and active rice farmed parcels are not considered restorable.
- Drainage and sediment barriers. Habitats that receive water from irrigation, landscaping, farming, or road runoff must be protected via drainage ditches or retention basins that keep artificial water sources from filling vernal pool grassland wetland features during the dry season. Furthermore sediment barriers and drainage ditches can be employed to keep potentially harmful chemicals like petroleum byproduct residue, pesticides, herbicides, fertilizers, manure and sediment out of restored habitats during winter storm events.
- **Invasive plant species removal.** Non-native invasive species established in vernal pool grassland can be reduced through controlled burning and mechanical removal. Herbicides should not be used in the restored habitats.
- Connectivity. Fragmented habitat can suffer from localized stochastic extinctions of native species, leaving niches available to invasive taxa. Establishing connectivity

between restored habitat areas with conservation areas will allow for colonization and increased gene flow between habitats.

• **Barriers to vandalism.** Strong steel gates and fence posts to prevent off road vehicle use of restoration areas will be required at all sites.

Colonization and Inoculum

Restored vernal pool may naturally be colonized by vernal pool plants and invertebrates or, if the restored habitat is too distant from natural functioning vernal pools (greater than 0.5 km distant) be inoculated with soil salvaged from vernal pools that would be affected by proposed projects or inoculum selected from conservation area pools. Ideally, the only inoculum used will be upland inoculum lightly dusted in the pool basins. All inoculum must be collected dry, stored dry with access to air, and applied to the restored habitat during the dry season and in a dry condition. Conservation vernal pool inoculum must come from specifically selected pools of similar size, depth, fetch, ponding duration and geomorphic surface as the restoration pools to be inoculated. No more than 5% of the surface area of a conservation pool may be taken, and the pool substrate must not be penetrated for inoculum deeper than 1 cm. There are no limits on the surface area to be removed from pools to be lost due to development; however, the inoculum should never be taken from greater than a 1 cm depth. All inoculum placed in restored vernal pools would be spread evenly and sparsely onto the restored vernal pool substrate to introduce vernal pool organisms propagules.

Design Criteria and Vegetation Establishment

Restored vernal pool habitat would be designed to replicate the habitat values of the reference pools and other high quality annual pools found on or near the restoration site. The restored pools would be designed to provide functions and values similar to those of the reference pools. Design details and performance standards would be developed, based on the environmental conditions observed at both the vernal pools to be restored and the reference pools. Performance standards established from the reference conservation sites would be used as the measure of success during the monitoring period (see Placer County Vernal Pool Functionality Assessment Method).

Restored vernal pool habitat sizes, shapes, and depths must be designed to fit the existing terrain and soil conditions. Detailed grading plans would be prepared based on reviewed topographic maps, historical photographs and detailed soil analysis. To ensure that the correct acreage of vernal pool habitat is restored, as-built plans of each wetland would be prepared and the as-built wetland area would be compared to the designed area. Hydrologic and botanical monitoring would be conducted to confirm the extent of ponding, wetland plant species association, and weed invasion.

Restoration specifications (e.g., depth of excavation and limits of excavation) would vary depending on the soil conditions and topography at each pool. Depths of excavation would vary because depths to the restrictive layers in the vernal pool restoration areas would vary.

To ensure that the restored vernal pool habitat replicates the physical conditions of natural pools, the following design criteria would be followed during preparation of vernal pool restoration grading plans:

- Vary side slopes from 3:1 to 5:1 or greater. Pools with smaller diameters and narrow portions of larger pools may have steeper side slopes.
- If required, apply a sparse layer of vernal pool inoculum to restored pools greater than 0.5 km from natural functioning vernal pools.
- Incorporate swales into the vernal pool grassland habitat design to hydrologically link the restored habitat as a vernal pool complex, as appropriate.

Mitigation Monitoring and Performance Standards

A monitoring program must be implemented to assess the establishment and continued maturation of restored vernal pool habitat. Performance standards would be used as the measure of restoration success during the monitoring period. Monitoring of restored vernal pool habitats is necessary to insure that the restoration is successful. The primary purposes of monitoring the restored habitats are to:

- document the degree of success in achieving the performance standards, and;
- identify the need for remedial actions.

The secondary purposes of monitoring are to:

- identify needed adjustments in management methods;
- evaluate the effectiveness and suitability of the habitat restoration procedures and performance standards used at the site;
- broaden knowledge of habitat creation procedures, and;
- document baseline conditions for long-term habitat monitoring at each site.

A qualified vernal pool ecologist whose qualifications are acceptable to the regulatory agencies would supervise all phases of the restoration program from initial installation through project monitoring.

Standards will be based on the simultaneous conditions in the reference conservation habitats (see Placer County Vernal Pool Functionality Assessment Method). These standards were derived from mitigation and monitoring guidelines prepared by the U.S. Army Corps of Engineers (1994) and by the U.S. Fish and Wildlife Service (1994) and are based on EcoAnalysts, Inc. extensive, previous experience with similar projects. The biological and hydrological performance standards must be met throughout the restored habitat. For the restoration of any given site to be successful, a minimum of 90% of the acres of restored habitat at each restoration site must meet the performance standards at the end of the 10-year monitoring period.

Once this preliminary restoration and monitoring plan is approved, and restoration sites are selected the existing functions of the habitat to be affected by the restoration project would be assessed and additional data regarding vegetation and hydrology would be collected. The performance standards outlined in the final plan would be based on this data.

Biological Performance Standards

Biological conditions in the restored pools must meet or exceed the range of biological conditions at the reference pools for a given year by the third year following the methods outlined in the Placer County Vernal Pool Functionality Assessment Method. Additionally, biological performance standards would also include:

- Restored vernal pool habitats must maintain the same or higher numbers of habitat occupied by native vernal pool plant species. Similarly, the surrounding uplands must emulate or exceed the numbers of associated native plant species as the reference pool adjacent uplands. Non-native invasive plant species must occur at the same or lower abundances than the reference pools and their corresponding uplands.
- Restored vernal pool grassland habitats must maintain the same or higher numbers of native vernal pool plant pollinator species.
- Qualitative monitoring of wildlife use will be performed concurrently with the invertebrate and botanical surveys. Incidental monitoring will record presence of amphibians and presence of, or evidence of, waterfowl use.

Pre-acquisition surveys to determine the extent of impact using the monitoring described in the Vernal Pool Assessment Method, as well as establish the invertebrate functions and values of the potential restoration areas will be conducted by a qualified, permitted invertebrate ecologist prior to restoration efforts to establish a baseline to compare pre and post restoration efforts.

Invertebrates

Monitoring of aquatic invertebrates in all restored vernal pool habitat would be conducted by a qualified, permitted invertebrate ecologist in years 1-10 of the initial 10 year monitoring period (every year for 10 years), then once every five years for the life of the PCCP permit, and then once every five years in perpetuity, following the methods outlined in the Placer County Vernal Pool Functionality Assessment Method.

Pollinators and their predators will be monitored once per year during peak bloom on sunny days with very little to no wind. Pollinators will be quantitatively collected using a sweep net along meandering transects through the vernal pool grassland areas where native flowering plants are most abundant, including in the vernal pools themselves. Each transect will be a timed transect, consisting of the number of pollinators collected in five minutes. The number of transects is determined by the number of acres on a given site: one transect for every 1 to five acres of vernal pool grassland.

All invertebrates collected during these transects will be preserved in at least 70% ethanol, and labeled appropriately. After 24 hours the ethanol will be replaced. Each transect will be placed in a separate container. The contents of each sample will be examined for macroinvertebrates which will be removed from any debris in the sample. Macroinvertebrates collected from each sample will be identified using standard taxonomic references, enumerated, and recorded, in order to establish diversity, taxa richness, abundance and community indices. Species indices would be determined by average numbers of individuals per site.

At the end of year 7, any pools or grasslands not meeting or approaching the performance standards may be remediated and would still have 3 years of monitoring during which to meet performance standards and be considered successful by the end of the 10-year monitoring period. Pools requiring remediation would be monitored yearly to determine whether improved performance has resulted from the corrective measures implemented. Remedial actions are discussed in greater detail below.

Vegetation

Restored vernal pool grassland habitat and must maintain the same or higher numbers of appropriate native vernal pool grassland plant species as their corresponding reference sites. A qualified botanist will estimate percent cover and abundance of native vernal pool grassland plant species, opportunistic species, and other non-native invasive weedy species. Uplands adjacent to constructed large branchiopod habitat will be monitored and evaluated to establish percent cover and population composition. Cover and composition of vegetation within and adjacent to restored habitat will be compared to the designated reference habitats. Non-native invasive plant species should occur in the same or lower abundances than the reference pools and their corresponding uplands. Floristic monitoring of all restored vernal pool grassland habitat would be conducted three times a year by a qualified botanist (in the spring) on years 1-10 of the initial 10 year monitoring period (every year for 10 years), then once every five years for the life of the PCCP permit, and then once every five years in perpetuity. At the end of year 7, any pools

not meeting or approaching the performance standards may be remediated and would still have 3 years of monitoring during which to meet performance standards and be considered successful by the end of the 10-year monitoring period. Pools requiring remediation would be monitored yearly to determine whether improved performance has resulted from the implemented corrective measures. Remedial actions are discussed in greater detail below.

Hydrology

Restoration of proper vernal pool hydrology is required if vernal pool plant and animal communities are to be established. All restored vernal pool grassland will be monitored by a qualified ecologist following restoration to determine whether the pools pond water or contain saturated soils for sufficient duration during the rainy season to support annual pool plant and animal communities as compared to the reference sites. Monitoring will occur during years 1-5 and years 7 and 10 and then every five years for the remainder of the PCCP permit. After year 10, collected botanical data may be used as a surrogate for annual pool hydrology. That is, pools with a flora dominated by annual pool species characteristic of intact annual pools occurring at the project site would serve as an indicator of successful annual pool hydrology; pools dominated by facultative species may indicate a problem with pool hydrology, such as insufficient ponding depth or duration.

Wildlife Use

This monitoring program primarily involves monitoring restoration areas for invertebrates, vegetation, and hydrology. However, qualitative monitoring of waterfowl and amphibian use would occur concurrent with the invertebrate surveys. Incidental monitoring of wildlife populations would be conducted at all restored habitat and the reference sites during the wet season. Although no performance standards are specified for wildlife use, the collected data would provide a basis for determining if the restored pools are increasingly being used by wildlife.

Hydrologic Performance Standards

Physical conditions in the restored pools must emulate the physical conditions in the reference pools for a given year. Physical performance standards would include depth and duration of saturation or ponding.

Restoration Activity Phase Monitoring

It is extremely likely, especially in the "High Restorability" vernal pool grassland areas that individual habitats that do not require restoration will exist. The following measures would be used to protect those existing functioning habitat during restoration activities:

- Existing habitats to be avoided during restoration activities, both within the restoration areas and adjacent to access routes, must be flagged or have some sort of barrier for protection, prior to implementation of the restoration activities.
- A qualified biologist would regularly monitor construction activities. This biologist would have the authority to stop construction activities if they could be detrimental to existing optimal vernal habitat. Restoration would be allowed to resume only after the biologist is satisfied that corrective actions have alleviated further detrimental activities.
- Erosion control practices would be implemented as needed, including grading or excavating during the dry season, placing silt fences or straw bale dikes across swales that could carry sediments into wetlands, and seeding exposed ground with native plant taxa. These practices would be identified on the restoration documents.

Purpose and Extent of Monitoring Programs

All restored and reference vernal pool habitat would be monitored for a minimum of years 1-10 of the initial 10 year monitoring period (every year for 10 years), then once every five years for the life of the PCCP permit, and then once every five years in perpetuity following habitat restoration. Continuous achievement of performance standards by the restored wetland habitat must be demonstrated during the last 3 years of the 10-year monitoring program. If contingency measures are required to meet performance standards, monitoring of the remediated wetlands would continue for three additional growing seasons to verify that performance standards are satisfied without further human intervention. Potential contingency measures will be detailed in the construction documents. The monitoring period would be deemed complete when all involved agencies confirm in writing that the performance criteria have been met and that no further mitigation is required.

As-Built Drawings

To ensure that the correct acreage of habitat is restored, an as-built plan of each habitat would be prepared and the as-built wetland and upland areas would be compared to the designed areas. Hydrologic and botanical monitoring would be conducted to confirm the extent of ponding. In years 2, 5, and 10 of the monitoring program, the extent of restored wetland hydrology (i.e., the extent of surface ponding or saturated soils in the excavated basin) would be compared against the as-built drawings. The extent of wetland hydrology would be assessed by aerial photography or field measurements.

Monitoring Reporting Schedule

Brief summary reports of monitoring results would be prepared for each year that the required monitoring occurs and would be submitted to Placer County, the US Army Corps of Engineers, the US Fish & Wildlife Service, the California Department of Fish & Game and other interested

regulatory agencies. The reports would summarize data collected from the restoration areas and compare them with data collected from the reference pools. Each restoration site will have its own, stand alone annual report. The annual reports would also include qualitative observations of the habitat conditions in the large branchiopod habitat creation areas compared with the habitat affected, along with photographs documenting typical conditions as needed. Incidental wildlife observations made during monitoring visits also would be included in the monitoring reports. A summary report of wildlife observations made during the spring and winter wildlife monitoring conducted in each year of monitoring would be included in the mitigation monitoring report prepared during those years. It is paramount that these monitoring reports draw defensible quantitative conclusions about the progress and success of the restoration efforts, and suggest remedial actions or additional monitoring as necessary.

Adaptive Management

Modification of restoration area management and/or management practices may be necessary over the course of time to insure that the required biological and ecological functions and values are maintained in the conservation areas. If monitoring data demonstrates that the conservation habitats are not maintaining the same ecological and biological functions and values as the associated reference sites, then measures must be taken to restore those functions and values. Similarly, future research may advance our understanding of vernal pool ecosystems, and provide better management techniques.

Biological and ecological function and value performance standards will be defined by the concurrent monitoring at specific reference sites. These standards would provide the framework for ensuring that no net loss of wetland area, function, and value would occur. Contingency measures may be required for vernal pool grassland habitats that do not approach or surpass the performance standards within the first 5 years, especially small restoration areas that have little buffer from developed areas. However, variations in physical and climatological conditions can affect the rate at which created wetland habitat establishes. Restored or constructed vernal pool grassland habitats that do not initially meet one of the performance standards may still have function and value and may meet the performance standards at some point during monitoring. Continual improvement in habitat conditions, such as increased vegetative cover by obligate vernal pool plant species, is an indication that the effort is trending toward success. Sometimes, therefore, an appropriate contingency measure may be to simply extend the monitoring period for a few more years.

Before any contingency measures are initiated, the need for additional establishment time should be weighed against the need for specific invasive management actions. Regulatory agency personnel and resource agency biologists would be consulted to review the contingency measure recommendations if any are needed. Remedial action plans will be evaluated for each site and be adapted on a case-by-case basis.

The following corrective actions could be implemented if hydrologic, vegetation, or invertebrate monitoring does not indicate a trend toward meeting the performance standards:

- Control of non-native invasive plants both in the pools (i.e. Manna Grass, Curly Dock), at the pool margins (Italian Rye Grass), and in the surrounding uplands (i.e. Medusa-head Grass, Wild Oats);
- Prevention through controlled burns and grazing of thatch that may build-up and add to the organic load of the pools or their watersheds, as well as fuel for periodic wild fires;
- Re-seed upland areas to control excessive erosion and sedimentation of pools;
- Allow limited grazing as and where appropriate to control vegetation, and disturb and compact pool bottoms;
- Construct or maintain barriers to ground water or surface water run-off that may carry excessive influxes of nutrients (i.e. topsoil, organic material or fertilizers) or other pollutants (i.e. pesticides, road oils, industrial products);
- Alteration of depth in restored or constructed habitats, where they may be too shallow or too deep to support the desired functions and values.

Other adaptive management techniques may be used depending upon innovations in restoration ecology, increase in knowledge of vernal pool grassland ecology, the validation or falsification of the assumptions presented above, or unforeseen circumstances. Furthermore, the assumptions, methods, management, and goals of this document will be re-assessed and re-evaluated every five years by Placer County to determine its effectiveness, and further needs for adaptive management.

SUCCESS POTENTIAL OF THE PCCP RESTORATION EFFORTS

Vernal pool grassland restoration feasibility has been a contentious subject for many years. Although there are many who have taken the stance that vernal pool habitat cannot be constructed, there is the fact that numerous artificial vernal pools have formed naturally in various situations, supporting not only federally listed plants and animals, but other vernal pool functions as well.

In Placer County, more than 100 vernal pools were restored or constructed by A. Teichert & Son at their Lincoln site. These pools were assessed and monitored using the methods described in the Placer County Vernal Pool Functionality Assessment Method developed by EcoAnalysts, Inc. (EcoAnalysts, 2008). The constructed and natural reference vernal pools are situated south of Riosa Rd, north of Lincoln and east of Sheridan. In addition to the standard macroinvertebrate community metrics, special status shrimp populations were also assessed during the fieldwork. The constructed pools were developed as mitigation for both past and potential future impacts to vernal pools during mining activity. The Lincoln site contains vernal pool habitats that were constructed in 1996 and 1997 as well as numerous natural vernal pools. The 2008 surveys represented the 11th year conditions following construction.

By the end of the monitoring period, the constructed pools demonstrated more robust desired vernal pool functions and values than the natural reference pools (EcoAnalysts, 2008). Since these pools were never specifically inoculated with temporary pool biota or soils, newly colonizing species have flourished and receded as a balance was slowly established, and invertebrate community structure developed. The constructed pools bore a greater resemblance to the natural reference pools in 2003 and 2005 than in any years previous to 2005. However, since 2005 the constructed pools have consistently outperformed the natural reference pools in terms of diversity, abundance and levels of opportunistic and obligatory taxa. The pool complexes that perform the best tend to have a variety of plants and invertebrate taxa and have varied margins and depths. The constructed pools at the Lincoln site exhibit this diversity of habitat. As a result, the plant and invertebrate diversity is high, and amphibian (pacific chorus frog, western toad) and waterfowl (mallards, green-winged teal, Canada geese, tundra swan, greater sandhill crane, greater yellowlegs, common snipe, killdeer) usage has increased since their inception (EcoAnalysts, 2008).

With these results in mind, the potential for restoration success would appear very positive, assuming that the restoration and monitoring, as well as remedial actions (if required) as presented here and in the Placer County Vernal Pool Assessment Method are implemented. Therefore with these caveats, it is assumed that successful vernal pool restoration in Placer County is feasible.

COSTS ASSOCIATED WITH IMPLEMENTING RESTORATION

Vernal pool restoration has numerous associated costs. To achieve the goals of the PCCP, Placer County will need to determine which parcels will fulfill the PCCP needs, delineate the available restorable habitat, and assess the restoration potential of each parcel. Only if the habitat is actually restorable will any given parcel be acquired. Determining the actual per acre cost of restorable parcels is beyond the scope of this document as real estate prices are falling dramatically, and actual property values are expected to be much different when this plan is implemented. As of 26 June 2009, open land in western Placer County was priced between \$12,000.00 and \$20,000.00 per acre.

After restoration parcels are acquired, each parcel must have a restoration design, restoration activities implemented (ranging from grading and excavation to trash, thatch or weed removal), hydrological and biological monitoring, fence maintenance, and (possibly) remedial management. Monitoring will be required during restoration activities as well. Furthermore endowments will be required by the regulatory agencies to insure in perpetuity monitoring and management for each parcel. There will be an economy of scale, in that restoring a few large parcels will be less expensive than restoring several small parcels.

All costs provided here are estimates only. The actual costs must be established per restoration site. Furthermore, due to the vagaries of the economy, real estate prices, consulting fees and other estimated costs presented here will likely be different by the time this plan is implemented. The costs presented here are not a bid to conduct the work described.

Parcel Access

North Fork Associates is at this time developing GIS files that establish where the most likely restorable habitat occurs in western Placer County. From these files Placer County will need to work with individual land owners to obtain property access and permission to assess the restoration potential of the vernal pool habitats. This will probably require legal documents to be signed by the landowners allowing Placer County staff or their designees access to the property within certain limitations, and stipulating that no offer of purchase has been made by Placer County at that time. The costs associated with this aspect are difficult to quantify primarily because there is no way to gauge the level of cooperation the land owners will provide. A conservative estimate would be \$50,000.00 in toto, not per acre. This cost is based on the potential number of landowners, legal fees, mailing fees, follow up with land owners, meetings with the land owners, and possible court costs.

Parcel Assessment

The type of impairment to the vernal pool habitats on a given parcel will determine the extent of assessment. If the impacts are uniform, it is probable that only a few representative habitats will need to be assessed, whereas if various impacts have affected one or more vernal pool grassland features, it may be that all features will need to be assessed individually. For the purposes of this analysis, it is assumed that the vast majority of sites will only need representative features quantitatively assessed. Therefore the estimated associated cost of assessment is \$10,000.00 per acre. This cost is based upon the protocols in the Vernal Pool Assessment Method, a minimum of 10 features to be sampled at a reference site, plus three reference features. The larger the restoration site the lower the per acre cost will be.

Special Status Species Surveys

Prior to any restoration activities that may radically affect the substrate (i.e.; grading, excavating, compacting) a qualified biologist must conduct special status shrimp surveys. Even if a habitat is greatly impacted, if it still has an intact vernal pool astatic, seasonal hydrology (wet in winter and spring, dry in summer) there is the potential that feature may support federally listed shrimp species. If one or more federally listed shrimp species are present, restoration activities that could impact them may need to be mitigated. However, since the goal is to restore the habitat of these shrimp species, and the overall impact would be positive, the restoration activities may mitigate their own impacts. Regardless, concurrence must be sought from the USFWS prior to implementation of any activities that may impact federally listed shrimp species. Possibly, language may be written into the PCCP that will allow the USFWS to waive these requirements.

These surveys must be performed according to USFWS protocols (1996) and may consist of two seasons of wet sampling or one season of wet and one season of dry sampling, which would reduce the survey time by 50%. According to the USFWS guidelines for the wet season sampling, each inundated habitat must be sampled every two weeks until special status shrimp

species are found, or the habitat has experienced 120 days of continuous ponding, or until the habitat dries. Once a particular habitat has had special status shrimp species identified as occurring there, that site will no longer need to be surveyed. Dry season surveys consist of a single visit to the feature, a soil sample is collected and then processed in a laboratory, then analyzed for special status shrimp eggs. Sites identified as occupied during the dry sampling surveys will not be sampled during the wet season surveys and vice versa.

This cost is presented as a "worst case scenario", i.e.; it is presented with the assumption that no special status shrimp are detected during the surveys, and that all pools must be surveyed every two weeks for the entire 120 days of ponding and dry sampling must be conducted. In reality, the actual effort is expected to be much less, due to pools drying early, or shrimp being found. As each site is different, with different numbers of pools and differences in accessibility, and terrain, each proposed survey must be cost separately. The estimated cost of special status shrimp surveys per acre are \$15,000.00.

Restoration Plan

Each proposed restoration site must have a specific restoration plan developed. All vernal pool grassland features to be restored must be delineated, a restored topomorphy defined, and as built plans prepared. The estimated associated cost with this task is \$50,000.00 per acre.

Restoration Implementation

Restoration activities may be as simple as removal of trash, an organic overburden, or invasive weeds or could be as intensive as grading, excavation or realigning swales. Therefore this estimated cost is presented in a "worst case scenario", expecting that each site will need some sort of topographical modification, weed management, and revegetation. This "worst case scenario" estimated cost is \$30,000.00 per acre. In actuality the cost is expected to range from \$5,000.00 to \$30,000.00, however this would have to be assessed on a per site basis. Furthermore, this cost per acre is expected to decrease the larger the restoration site.

Implementation Monitoring

A qualified vernal pool ecologist/biologist must be present to monitor and/or conduct all vernal pool restoration activities. Contractors using excavation and grading equipment typically have little or no knowledge of vernal pool grassland topomorphy and should not be expected to. The as built drawings should supply enough detailed information that the contractor/operator can restore the vernal pool topomorphy with a certain degree of accuracy. However, an onsite monitor who is a vernal pool ecologist/biologist will insure that the design plans are adhered to. The cost of implementation monitoring is again presented as a "worst case scenario". The estimated associated cost is \$20,000.00 per acre.

Restoration Monitoring

The specific restoration monitoring and schedule are described above and in the Vernal Pool Assessment Method. The cost presented here assumes that this schedule and methods are followed. The estimated associated cost of monitoring per annum is \$100,000.00 per acre. Again, this cost per acre will be lower for larger parcels, and if representative habitats are monitored rather than all restored habitats.

Endowments and Fees

To insure monitoring and adaptive management in perpetuity, regulating agencies require an endowment to be set aside for each restoration site. The annual interest earned by the endowment would pay for monitoring, fence repairs and adaptive management. The actual size of the endowment will depend upon the size of the restoration site and the amount of required monitoring and management. The average mitigation bank typically requires an endowment of \$1 million dollars. However, until a monitoring and management plan is established for each restoration site, a reasonable endowment cannot be estimated.

Additional fees earned by Placer County from grazing leases on the restoration sites may help defray the cost of monitoring and maintenance.

Management

Annual management costs are difficult to estimate. Typical management costs include assembling and submitting the monitoring reports to the agencies, ensuring that the restoration site is in compliance with the PCCP permit, gate, fence and road maintenance, and vandalism repairs. However, if the restored habitat is not meeting or exceeding the success criteria, then remedial actions will have to be implemented. Assuming that remedial actions are not required, the annual management costs per acre are estimated at \$10,000.00.

Restoration Cost per Acre

As of 26 June 2009, open land in western Placer County was priced between \$12,000.00 and \$20,000.00 per acre, with a median of \$16,000.00 per acre. The cost of restoration (exclusive of restoration monitoring or endowments), assuming the \$16,000.00 per acre, and assuming that special status shrimp surveys must be conducted is estimated to be \$143,000.00 per acre, plus an annual estimated cost of \$110,000.00 per acre for monitoring and management. These costs do not include the endowment, which also would be a onetime cost.

These costs are only gross estimates, and may change as the economy and the real estate market fluctuate and as the restoration, monitoring and management needs of each restoration site are determined.

LITERATURE CITED

- Amat, F., A. Gozalbo, J. C. Navarro, F. Hontoria, & I. Varó. 1991. Some aspects of *Artemia* biology affected by cestode parasitism. Hydrobiologia 212:39 44.
- Bauder, E. T. & S. McMillan. 1998. Current distribution and historical extent of vernal pools in southern California and northern Baja California, Mexico. Pp. 56-70 *In*: Witham, C. W., E. T. Bauder, D. Belk, W. R. Ferrin Jr., and R. Orduff (eds.). Ecology, conservation, and management of vernal pool ecosystems proceedings from a 1996 conference. California Native Plant Society, Sacramento, CA.
- Collie, N. & E. W. Lathrop. 1976. Chemical characteristics of the standing water of a vernal pool on the Santa Rosa Plateau, Riverside County, California. Pp. 27-31 *In:* S. Jain (ed.) Vernal Pools, their Ecology and Conservation. Institute of Ecology Publication 9. University of California, Davis, California.
- Cushing, C. E. 1988. Allochthonous detritus input to a small, cold desert spring-stream. Verh. Internat. Verein. Limnol. 23:1107-1113.
- Eng, L., D. Belk, and C. Eriksen. 1990. Californian Anostraca: Distribution, Habitat, and Status. Journal of Crustacean Biology 10(2):247-277.
- Eriksen, C. and D. Belk. 1999. Fairy shrimps of California's pools, puddles, and playas. Mad River Press, Eureka, California.
- Holland, R. F. 1978. The geographic and edaphic distribution of vernal pools in the Great Central Valley, California. California Native Plant Society Special Publication No. 4. Sacramento, CA.
- Holland, R. F. 1988. Vernal Pools. Pp. 1012-1014 *In:* M. E. Barbour and J. Major, eds., Supplement to Terrestrial Vegetation of California (new expanded edition). California Native Plant Society Special Publication No. 9. Sacramento, CA.
- Holland, R. F. 1998. Current distribution and historical extent of vernal pools in southern California and northern Baja California, Mexico. Pp. 71-75 *In*: Witham, C. W., E. T. Bauder, D. Belk, W. R. Ferrin Jr., and R. Orduff (eds.). Ecology, conservation, and management of vernal pool ecosystems proceedings from a 1996 conference. California Native Plant Society, Sacramento, CA.
- Johnson, S., G. Haslam, & R. Dawson. 1993. The Great Central Valley, California's heartland. University of California Press, Berkeley.
- Keeley, J. E. 1984. Photosynthetic characteristics of certain vernal pool species. Pp. 218 222 in: S. Jain & P. B. Moyle (eds), Vernal pools and intermittent streams. Institute of Ecology Publication 28. University of California, Davis, California.

McLay, C. L. 1973. Wind-blown dust as a source of nutrients for aquatic plants. Environmental Pollution, 5:173-180.

Proctor, V. W. 1964. Viability of crustacean eggs recovered from ducks. Ecology 45:656-658.

Rogers, D. C. 1998. Aquatic macroinvertebrate occurrences and population trends in constructed and natural vernal pools in Folsom, California. Pp. 224-235 *In*: Witham, C. W., E. T. Bauder, D. Belk, W. R. Ferrin Jr., & R. Orduff (eds.). Ecology, conservation, and management of vernal pool ecosystems – proceedings from a 1996 conference. California Native Plant Society, Sacramento, CA.

Rogers, D. C. 2002a. Draft: Distribution and habitat parameter surveys Branchinecta mesovallensis (Crustacea: Branchiopoda: Anostraca). Report to US Fish & Wildlife Service. Jones & Stokes Associates.

Rogers, D.C. 2002b. Amplexial morphology of selected Anostraca. Hydrobiologia 486:1-18.

Rogers, D.C. In prep. Dispersal and speciation in the Branchiopoda (Crustacea).

Rogers, D.C. & M. Fugate. 2001. *Branchinecta hiberna*, a new species of fairy shrimp (Crustacea: Anostraca) from western North America. Western North American Naturalist 61(1):11 – 18.

Silveira, J. 1996. Avian uses of vernal pools and implications for conservation practice. Pp. 92-106 *In*: Witham, C. W., E. T. Bauder, D. Belk, W. R. Ferrin Jr., & R. Orduff (eds.). Ecology, conservation, and management of vernal pool ecosystems – proceedings from a 1996 conference. California Native Plant Society, Sacramento, CA.

United States Fish & Wildlife Service. September 19, 1994. Federal Register Final Rule; determination of endangered status for the conservancy fairy shrimp, longhorn fairy shrimp, and the vernal pool tadpole shrimp; and threatened status for the vernal pool fairy shrimp.

United States Fish & Wildlife Service. 1996. Interim Survey Guidelines to Permittees for Recovery Permits under the Endangered Species Act for the Listed Vernal Pool Branchiopods. Sacramento, CA.

Wissinger, S. A., A. J. Bohonak, H. H. Whiteman, & W. S. Brown. 1999. Habitat permanence, salamander predation and invertebrate communities. *In:* Invertebrates in Freshwater Wetlands of North America: Ecology and Management, edited by D. P. Batzer, R. B. Bader, and S. A. Wissinger, John Wiley & Sons, Inc. NY