PLACER COUNTY VERNAL POOL FUNCTIONALITY ASSESSMENT METHOD

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INTRODUCTION

EcoAnalysts, Inc. was engaged by Placer County and TRA Environmental Sciences, Inc. to develop a quantitative method for monitoring the health and functionality of vernal pool wetlands. The purpose of developing this method was to provide a tool for estimating the quality of existing vernal pool habitat and defining vernal pool habitat restoration goals and standards. Quantitative bioassessment will be necessary to determine the ecological functions and values of selected preserve area and restored vernal pools to assess their suitability and value as preservation habitats.

Placer County's primary vernal pool conservation goal is to conserve and enhance vernal pool ecosystems supporting endangered species as well as other vernal pool ecosystem functions and biotic community structure through the acquisition of high quality contiguous habitats supporting extensive vernal pool complexes and restoring areas that once supported vernal pool grassland. Secure protection and management will partially reduce threats to vernal pools; 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) will be necessary to insure their long-term survival.

The bioassessment tool presented here is quantitative, replicable, and allows for direct comparisons between data sets. This tool is a modified form of aquatic bioassessment, which is a primary tool of regulatory agencies in measuring habitat health and water quality. Comparisons between bioassessment datasets are not possible without standardization; without data standardization the data become subjective. Therefore, it is paramount that the data gathered on the Placer County vernal pools are standardized. Actions based on biological data require standards of comparability and repeatability so that informed resource management decisions can be made quantitatively.

This method is simply a direct quantitative comparison of vernal pool macroinvertebrate community composition and densities between restored vernal pools and natural reference pools with the same phenology and geology, and at the same point in time. Impacted or impaired habitat tends to become dominated by opportunistic species, which may out-compete vernal pool obligate species if those species are stressed. Through monitoring of the macroinvertebrate community structure, any gradual shifts towards opportunistic species will be evident. If a drop in obligate species numbers and an increase in opportunistic species numbers is observed, then adaptive management contingency plans may be implemented to return the habitats to a normal, functioning vernal pool complex.

Reference pools will be used to define current conditions in the existing vernal pool habitat in order to interpret the trends and conditions in the restored vernal pool habitat. For example, if drought conditions cause the percentage of macroinvertebrates to decline in the reference pools, similar conditions in the restoration pools may be attributable to the drought and not to a failure in the restoration habitat. Performance standards may be adjusted during the monitoring period if conditions at the reference pools indicate such a need. All comparisons between conditions in

restored and reference pools would be made in the same year and between years to identify trends.

Bioassessment

Many methods of assessing vernal pool health and functionality have been proposed over the years and have always focused on vernal pool plant communities, endangered species and occasionally hydrology (USFWS database). Biological systems are better indicators of habitat health and functionality than chemical, hydrological or soils monitoring simply because the organisms are a function of the abiotic characters of the system. Different ecological conditions allow for the colonization and establishment of different organisms with different ecological needs. If the requirements for a given species are not present, that species cannot survive at that locality. Monitoring plant populations yields some information, but that information is greatly limited: vernal pool plants are typically annuals, and their presence or absence is indicative only for conditions on an annual cycle. Conversely, invertebrates may have anywhere from one to dozens of generations in a single season, and therefore will reflect small perturbations in a system far more readily. As a result, macroinvertebrates have become increasingly important as biological indicators in quantitative biological monitoring (bioassessment) (Plafkin et al., 1989; Hutchinson, 1993; Rogers, 1998; Karr & Chu, 1999; Resh & Jackson, 1993; Rosenburg & Resh, 1993).

The main objective of bioassessment is to provide biological indicators of potential and/or actual effects on habitat health and functionality, as well as to monitor and establish success criteria of restored habitats. Quantitative bioassessment was developed by the Environmental Protection Agency as a method of determining impacts to water quality, forage for fisheries, and stream productivity based on benthic macroinvertebrates (Plafkin et al., 1989). Rogers (1998) developed macroinvertebrate bioassessment methods for vernal pool habitats. Quantitative bioassessment sampling is used to help determine the type, extent and duration of impacts; baseline data to identify future impacts; water quality; and as a monitoring tool for assessing the functions of constructed habitats. This type of monitoring has become the legal standard in most states for mitigation and restoration projects. Hutchinson (1993), Karr and Chu (1999), Resh and Jackson (1993), Rosenburg and Resh (1993) and others have described justifications for invertebrate use as indicators of water and habitat quality. Additional advantages of macroinvertebrate-based bioassessment include long storage life for preserved samples and the establishment of voucher collections. Voucher collections may be evaluated by other investigators and serve as a source of information for taxonomists and resource managers.

Conservation Area Selection

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 acquisitions and proportions to be acquired will be addressed elsewhere. Prior to acquisition, potential conservation areas must be evaluated as to their conformity with the standards outlined below. Conservation areas will be large, contiguous, broad pieces of land that

encompass as many different native habitat types as possible, where minimal non-invasive management actions are needed (except in the case of restoration). Ideally, these areas will need little (e.g. grazing management) or no human intervention, yet in certain circumstances may be used for restoration; but not to the detriment of existing, functioning habitat. Management activities will be appropriate to the goals of the management plans (e.g. restoration, control of exotic invasive species, litter removal, grazing, and fire).

Pre-acquisition surveys to determine whether the desired functions and values of the potential preserve areas are present will be conducted by a qualified, invertebrate ecologist bearing the requisite permits for the listed vernal pool crustacean species.

Although not preferable, conservation areas may also include smaller preserve areas which although may lack the broader habitat diversity and protectiveness of larger preserves, may support particular significant occurrences of covered species. All restoration will have the goal of restoring or enhancing the habitat to where human intervention is no longer necessary. In some instances adaptive management may be all that is necessary for long-term habitat viability.

Conservation areas will support a wide variety of vernal pools and other seasonally astatic freshwater habitats, with their subtending watersheds and associated uplands as near ecologically intact as possible (based upon current ecological understanding), although areas with good potential for successful restoration may also be acquired. Vernal pool invertebrates are a function of vernal pools and other seasonally astatic freshwater aquatic systems. These systems are fundamentally disturbance-based systems, which function as wetlands for one portion of the year and uplands for the remainder of the year. Invertebrates that exploit these habitats are essentially opportunistic in their use of temporary waters. 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. These habitats were once exploited by native herds of large ungulates, which would graze and even wallow in these systems (Brewer, quoted in Johnson et al., 1993). These wetlands are dependent upon intact sub-watersheds, the surrounding uplands that support those watersheds, and the natural allochthonous materials they provide (McLay, 1973; Cushing, 1988). Vernal pool habitat is a component of the larger grassland ecosystem of the California Great Central Valley.

Conservation areas must be buffered from adverse impacts including: industrial, urban, or agricultural run-off; point source pollution; off-road vehicle use; and dumping of refuse or fill material. Conservation areas must not be used for stormwater storage from urban and suburban areas, but serve as natural stormwater retention facilities collecting the water precipitated on site. The smaller the conservation area the more difficult it is to protect and buffer the preserve from extrinsic effects.

Conservation areas must be buffered from excessive noise, light or other human activity that may reduce wildlife use (such as waterfowl and wading birds) of the habitat. Vernal pool crustaceans are a component of the zooplankton community and therefore are important as food to other wildlife, particularly migratory waterfowl and some amphibians (Wissinger et al., 1999). This relationship is reciprocal in that waterfowl and amphibians expel viable eggs in their excrement, often at locations other than where they were consumed, thereby dispersing vernal pool

crustaceans, as well as their genes (Rogers, 1998, 2002a, b, In prep.). In this way genetic integrity may be maintained and the potential for population collapse from inbreeding is reduced.

As it is impossible to bring back the original herds of Tule Elk and Pronghorn, conservation areas will be grazed moderately as appropriate to the habitats. In addition, prescribed burning should be used to prevent fire fuels build-up and unnatural thatch that may load habitats with excessive nutrients.

Conservation areas will support seasonally astatic habitats that are naturally dry during the summer months. Astatic habitats may be grass or mud-bottomed, with clear to highly turbid water. These include vernal pools, seasonally ponded areas within vernal swales and clay flats. Habitats in the conservation areas should support seasonal pool habitats that exhibit a variety of depth, area, and volume as appropriate to the geomorphic surface on which they occur, tend to be neutral to slightly alkaline, and low in dissolved salts. Habitats that remain wet long into summer, or bear a constant subsurface water table that maintains moist soil through the summer months are not conducive to vernal pool crustaceans. Habitats that stay too wet for too long, or that are infused with water artificially during the dry phase, will cause vernal pool crustacean eggs to fungus and die.

Conservation area habitats must support a broad range of obligate vernal pool plants and invertebrates. Conservation areas must not be producing large numbers of mosquitoes, necessitating intervention (in the form of pesticide applications or habitat modification) from the Placer County Mosquito Abatement District or the State Health Department.

Conservation areas should be available for organized education purposes, as well as ecological and biological research activities, increasing our understanding of these species and their habitats.

Vernal Pool Invertebrates

Obligatory vernal pool invertebrates 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.

Various physiochemical factors have been examined in 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 the federally threatened fairy shrimp *Branchinecta lynchi* 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 vernal pool habitats. However, the importance of many of these parameters has recently been called into question with evidence that the 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 oxidizes 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 organisms. Over-grazing tends to allow a great deal of manure into vernal pools. The organic waste oxidizes the water, leaving the gill-breathing invertebrates 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 invertebrate community structure includes mostly planktonic Crustacea including Copepods, cladocerans, and ostracods, as well as flatworms, and a suite of insect species, including: vernal pool haliplid beetle, scimitar backswimmers, Ricksecker's Hydrochara, fraternal water loving beetle, and many others (Rogers, 1998). These habitats are usually low in opportunistic species like mosquitoes and chironomid midges in the genus *Chironomus* (Rogers, 1998).

VERNAL POOL BIOASSESSMENT METHOD

Limitations

Restoration and creation of vernal pool habitat has been demonstrated to be feasible (for example: Rogers, 1998). However, specific habitat parameters for vernal pool invertebrate species are still poorly understood. For example, there appears to be a need by fairy shrimp species to have a minimum pool volume and a minimum pool surface area within a given habitat to be occupied. Since fairy shrimp, like the threatened *Branchinecta lynchi*, have been found in a wide variety of natural and artificial vernal pool habitats, it is likely that in some respects they are opportunists, as most temporary water fauna must be.

The primary data gap regarding vernal pool invertebrate conservation is lack of species distributional data. Management data gaps include the role of the surrounding uplands in vernal pool habitats, and the role, seasonality and intensity of grazing and other disturbances in vernal pool ecosystems. Furthermore, quantitative bioassessment may be necessary to determine the ecological functions and values of selected preserve area vernal pools to assess their suitability and value as preservation habitats.

The bioassessment method presented below has some limitations, which are not insurmountable. Most importantly, because of the potential for federally threatened or endangered crustacean species to be present in any vernal pools or similarly seasonally astatic wetland habitats, all field sampling must be conducted by biologists who have a valid 10(A)1(a) permit in coordination with the US Fish & Wildlife Service under the terms and conditions of that permit.

There is also a limitation involved with the sample processing and identifications. There is no one book or reference available for any individual to use to identify vernal pool invertebrates. Rather, identifications must be done by a trained invertebrate diagnostician or invertebrate taxonomist. The person or persons making the identifications must be a member of the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT, see www.safit.org) and utilize SAFIT's most recent version of the Standard Taxonomic Effort List as a taxonomic guide where applicable, as recommended by the State of California Surface Water Ambient Monitoring Program (http://www.waterboards.ca.gov/water_issues/programs/swamp/).

The sampling is also limited by periodicity. The habitat cannot be assessed at any time, because the samples can only be collected during the wet season. This wet season may be compressed into one or two month in dry years or spread out over six months during El Niño event years.

Sampling sites

Since Placer County plans to conserve and enhance vernal pool ecosystems through the acquisition of high quality contiguous habitats and restoring areas that once supported vernal pool grassland, a wide variety of habitat should be available for sampling. Samples from existing vernal pool habitat to determine its value and sampling of restored habitat to monitor its success will require high quality reference habitat. Specific guidelines in selecting vernal pool habitat for conservation must 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 and for movement out of and into the pool.
- Vernal pools selected for restoration must exhibit the same biological and geomorphological functions as the reference habitat to which it is compared. For example: pools occurring on Mehrten formations tend to be very shallow, and cannot be used as reference for deeper pools occurring on other landforms.
- Unimpaired vernal pools exhibiting a diverse invertebrate and botanical community are
 desirable as reference habitat for bioassessment, rather than habitat that lacks the same
 functions and values as typical vernal pools (such as a railroad toe-drain that supports
 listed fairy shrimp but no other obligatory invertebrates or plants).

- 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 between topomorphy, area, depth, botanical community structure, invertebrate community structure, and vertebrate use. Therefore, restored 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.

Recommended reference pool sites include: A. Teichert & Son's Coon Creek Vernal Pool Preserve, and; Twelve Bridges Vernal Pool Preservation Area. The Coon Creek site has natural vernal pools and restored vernal pools that have been functioning for more than a decade, all supporting listed vernal pool crustaceans. Other pools on the site support rare plants. Furthermore the site has a mixture of deep and shallow vernal pools on various landforms as well as supporting a clay flat.

The Twelve Bridges site also have a variety of natural and restored vernal pools, and the vast majority are on Mehrten soils, a geomorphic surface common in Placer County. Mehrten pools have a unique geomorphology, and tend to be shallow and flashy, but still may support listed plant and animal taxa.

Sampling Periods

Each pool will be sampled three times (early, mid, and late season) during the wet season. The timing of each sampling event will be determined by the ecological succession stage (Rogers, 1998). The Early Season Sampling Event will occur approximately after the pools have been continuously inundated for two weeks. The Mid Season Sampling Event will occur when the first floating hydrophytes (i.e. *Ranunculus bonariensis* var. *trisepalus*, *Callitriche marginata*) appear and begin to cover the pool margins. The Late Season Sampling Event will occur during the early stages of drying and subsequent collapse of the aquatic component of the vernal pool community. These stages are selected as sampling periods rather than temporal increments due to variability in temperature and rainfall, which prolongs or shortens the different stages of the ponding cycle.

As stated above, reference pools will be used to define existing conditions in the existing vernal pool habitat in an effort to interpret the trends and conditions in the restored vernal pool habitat. All comparisons between conditions in restored and reference pools would be made in the same year and between years to identify trends. For example, if drought conditions cause the percentage of macroinvertebrates to decline in the reference pools, similar conditions in the restoration pools may be attributable to the drought and not to a failure in the restoration habitat.

Sampling Method

Macroinvertebrates communities will be sampled from each selected pool (restored, conserved or reference). Reference pools must represent a range of habitat with varying hydrologic, geomorphic and floristic conditions typical at the site being assessed.

Samples are collected using a fine mesh sweep net with a mesh size between 1-2 mm. Mesh larger than 2mm would allow desired invertebrate specimens to escape. Mesh less than 1mm will catch too much debris and specimens, clogging the net, and pushing the water and specimens ahead of the net, rather than gathering them. The net aperture should be close to $0.0451 \, \mathrm{m}^2$. If another net aperture size is used it should not be significantly smaller in size. Each sample is collected from the water column by pulling the net through 1.5 horizontal meters of the pool, thereby sampling $0.0677 \, \mathrm{m}^3$ of the pool. If the pool depth is only half the net aperture height, then two 1.5 meter sweeps should be taken. If a different size aperture is used, then the aperture area multiplied by the 1.5 meters of the sweep will yield the appropriate volume of the pool that was sampled.

Each sample is placed in its own unique labeled container. The samples are preserved immediately in 90% ethanol. All samples must be labeled with the following information as appropriate: location, pool or collection number, station, date, time, collector, and area sampled. The samples must be transported to a laboratory for processing. After 24 hours, the ethanol in each sample must be replaced with fresh 70% ethanol to ensure preservation of all specimens within the sample.

Laboratory Methods

Each sample is emptied into a sorting tray, and the macroinvertebrates (invertebrates $> 2000/\mu m$ in size) are removed from the remaining debris into a separate labeled container. This process is laborious and time consuming especially when the invertebrates are entangled in filamentous algae.

After sorting, the specimens are identified and enumerated under a dissection microscope to the lowest justifiable taxonomic ranking. Taxonomic standards for aquatic macroinvertebrates are set by SAFIT in the STE (Richards & Rogers, 2006 or most recent version). The current taxonomic limitations are presented in Table 1. All organisms must be identified to the lowest practicable level as defined by SAFIT. All identification and enumeration data is then entered into a spreadsheet program.

Table 1. Current taxonomic limitations.

Taxonomic Group	Identification Level		
Phylum Porifera	Phylum		
Phylum Platyhelminthes	Class		
Phylum Nemata	Phylum		
Phylum Nematomorpha	Genus		
Phylum Ectoprocta	Genus		
Phylum Mollusca	Genus		
Subclass Acari	Subclass		
Order Anostraca	Species		
Order Notostraca	Species		
Order Laevicaudata	Species		
Order Diplostraca	Genus		
Class Ostracoda	Class		
Class Maxillopoda	Subclass		
Subphylum Hexapoda	See current SAFIT STE		

Aquatic bioassessment is a primary tool for regulatory agencies in measuring habitat health and water quality. Comparisons between bioassessment datasets are not possible without standardization; without data standardization the data become subjective. Therefore, it is paramount that taxonomic practices are standardized as they apply to bioassessment. Actions based on biological data require standards of comparability and repeatability. The Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT) is currently mandated to provide guidance to the California State Water Resources Control Board's Surface Water Ambient Monitoring Program (SWAMP), with the ultimate goal of providing the same guidance to all entities conducting bioassessment in the Southwest.

Data Calculations

Various metrics calculated from the macroinvertebrate data will yield information from which conclusions may be drawn concerning the functionality of vernal pool habitats. These metrics yield quantitative numeric data that are directly comparable with data from other pools assessed using this method.

General Abundance

Invertebrate abundance is the total number of individual invertebrates per cubic meter. Typically, the higher the overall abundance, the healthier that habitat; a vernal pool with few or no invertebrates is probably negatively impacted. However, if the pool has high abundance but is entirely dominated by one or two opportunistic species, then again it may be assumed that the pool is negatively impacted. Ideal conditions have high abundance coupled with high taxa richness (see below).

Taxa Richness

Richness is the total number of individual taxa and is used as a means of determining the overall health of an aquatic habitat (Plafkin, et al. 1989). In general, the higher the water quality and

greater the habitat suitability and variety, the higher the taxa richness will be. Taxa richness is a measure of biodiversity.

Dominance

Dominance is a measure of the taxa that are most common in a given sample. In typical, functioning, Placer County vernal pools below 1,500 feet elevation, the obligatory vernal pool planktonic crustacean *Simocephalus* sp. tends to be dominant, followed closely by copepods and turbellarians. Occasionally, anostracans may be dominant. Opportunistic taxa, such as mosquitoes, midges in the genus *Chironomus*, or ostracods as dominant taxa are indicative of a failing vernal pool system.

Opportunistic Taxa Abundance

By measuring the abundance of invertebrate families least sensitive to changes in water quality and habitat suitability, the relative extent of habitat affected can be examined. Mosquitoes, Chironomid midges of the genus *Chironomus*, and ostracods are generally considered as opportunistic and tend to be resistant to adverse environmental conditions, and the ratio of these taxa to all other groups increases with decreasing water quality (Plafkin, et al., 1989; Rogers, 1998). Opportunists are species that are not dependent on a specific trophic function (ie; filter feeders, predators) but can feed and sustain themselves in many trophic regimes, and are typically not limited to vernal pool habitats (Rogers, 1998). It should be mentioned that high numbers of ostracods with high numbers of obligate taxa, does not always mean that the pool is in jeopardy.

Obligatory Taxa Abundance

Similar to the opportunists, obligatory taxa abundances are a strong indicator of habitat health and functionality. By measuring the abundance of invertebrate families most sensitive to changes in water quality and habitat suitability, the relative health of the habitat can be determined. Crustacean taxa are among the most obligatory taxa in vernal pools: they cannot fly, they must breathe via gills, and they must complete their entire lifecycle in the pools. Therefore the ratio of these taxa to all other groups increases with increasing habitat and water quality (Plafkin, et al., 1989). Obligatory taxa are species that typically are dependent on specific trophic functions, and are limited to vernal pool habitats (Rogers, 1998). Obligatory taxa include fairy shrimp, tadpole shrimp, clam shrimp, cladocerans, copepods, ostracods, bryozoans, and turbellarians.

Jaccard Coefficient of Community Similarity

Jaccard Coefficient of Community Similarity (Plafkin et al., 1989) is a specialized metric for determining similarities between the reference and study pool community samples. It is calculated:

Jaccard		# of taxa common to both samples				
Coefficient	=	#of taxa common to	+	# of taxa in comparison	+	# of taxa in reference
of		both samples		and not in reference		and not in comparison
Community		-		sample		sample
Similarity				•		•

The Jaccard Coefficient of Community Similarity estimates the degree of similarity between samples based on presence or absence of taxa. The coefficient values range from 0.00 to 1.00. The higher the coefficient, the greater the similarity between the samples compared. Typically, desirable coefficients are between 0.85 and 1.00.

Special Status Shrimp

Presence or absence of federally listed vernal pool crustaceans is typically only indicative of those federally listed vernal pool crustaceans. The absence of one or more of these species does not indicate that the pool sampled is in any way impacted. Not all vernal pools can support listed shrimp, and not all listed shrimp habitat are vernal pools. Three federally listed vernal pool crustaceans are present or may be present in vernal pool habitats in western Placer County: *Branchinecta lynchi*, *B. conservatio*, and *Lepidurus packardi*.

- Branchinecta lynchi Eng, Belk & Eriksen, 1990 is federally-listed as a threatened species. This shrimp species is found in vernal pools throughout the Central Valley and western Riverside County in California, and near Medford, Oregon (Eriksen & Belk, 1999). This fairy shrimp species occurs in neutral to slightly alkaline vernal pools throughout the California Central Valley, and in rock outcrop pools along the Interior Coast Ranges, south of the Sacramento River Delta.
- Branchinecta conservatio Eng, Belk & Eriksen, 1990 is federally-listed as endangered. This species needs large deep vernal pools and winter lakes to complete its long life cycle. It occurs in a handful of localities in Tehama, Solano, Yolo, Merced and Ventura counties. Recently a single specimen was found in a pool in western Placer County. However, the habitat is not typical for the species, only one was found and no more animals have been seen at that same habitat since. Therefore that one animal was probably the result of a stochastic colonizing event. It is unlikely that the species could become established in western Placer County in the existing natural habitat.
- Lepidurus packardi Simon, 1886 is federally-listed as an endangered species. This tadpole shrimp species is found in vernal pools throughout the Sacramento Valley (Rogers, 2001). Typically Lepidurus packardi is green in color, but it may be mottled with brown in highly turbid water. Lepidurus packardi is omnivorous and generally forages on the bottoms of pools in dense vegetation. Tadpole shrimp tend to be slow growing and are usually collected after the vernal pool has been ponded for 30 days (Rogers, 2001). This species is virtually unknown from Placer County.

Success Criteria

Protected and restored vernal pool habitat must maintain the same or higher numbers of vernal pool obligate and opportunistic invertebrate species as the reference pools. Similarly, invertebrate population composition should be the same or better than the reference pools. The statistical measurements described above will be used to determine performance of the preserved and restored habitat relative to the standards set by the reference pools for that given year. Therefore, success is primarily defined as the monitored pools having the same or better functions and values as the reference habitats. Monitored pools must have the same or better general abundance, taxa richness, dominance, opportunistic taxa abundances, and obligatory taxa abundances as the reference pools. The Jaccard's coefficient is used as a direct measurement of community similarity.

Monitoring Reporting and Adaptive Management

Invertebrate communities will be quantitatively sampled in all selected reference and conservation habitats every year according to the Monitoring Schedule (see below). There should be one reference site per each geomorphic setting supporting conservation areas. Reference sites should have at least five pools designated as reference pools, which reflect a variety of pool attributes (i.e., depth, area, fetch, and hydrology). If protected and restored habitats at a given preservation site support federally listed species, the reference sites and reference habitats used for comparison must support the same listed species as well. Qualified, permitted biologists must conduct all covered invertebrate sampling using the appropriate protocols.

Pre and post acquisition surveys to establish the invertebrate functions and values of the potential preserve areas, as well as determine the presence of federally protected vernal pool species, will be conducted by a qualified, permitted invertebrate ecologist prior to establishment of the preserve areas.

Through monitoring of the macroinvertebrate community structure, any gradual shifts towards opportunistic species will be evident. As mentioned above, impacted or impaired habitat tends to become dominated by opportunistic species, which may out-compete vernal pool obligate species if those species are stressed. If a drop in obligate species numbers and an increase in opportunistic species numbers is observed, then adaptive management contingency plans may be implemented to return the habitats to a normal, functioning vernal pool complex. Remedial action plans will be evaluated for each site and be adapted on a case-by-case basis.

Reference pools will be used to define existing conditions in the existing vernal pool habitat in an effort to interpret the trends and conditions in the protected and restored vernal pool habitat. For example, if drought conditions cause the percentage of macroinvertebrates to decline in the reference pools, similar conditions in the protected and restored pools may be attributable to the drought and not to a failure in the protected and restored habitat. Performance standards may be

adjusted during the monitoring period if conditions at the reference pools indicate such a need. All comparisons between conditions in protected, restored and reference pools must be made in the same year and between years to identify trends.

Monitoring Schedule

All conservation areas and preserves, whether natural or restored must be monitored to determine if the conservation goals and objectives have been met each year for the minimum of the Placer County Conservation Plan permit term, 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. Continuous achievement of performance standards of protected and restored vernal pool grassland habitat must be demonstrated during the last 10 years of the PCCP permit monitoring program, as well as the 10 years following the end of the permit term. If contingency measures were required to meet performance standards, monitoring of the remediated wetlands would continue for five additional wet seasons to verify that performance standards are satisfied without further human intervention. Potential contingency measures are described in the "Contingency Measures" section below.

Reference habitat on existing preserves, as near pristine as is current ecological understanding, will be selected and monitored each year coincident with the compensation habitat monitoring schedule described above to provide ecological data for comparative purposes to determine whether the compensation pools are meeting effectiveness performance standards. The reference pools would be used as a basis for defining desired functions in the preserved and restored habitat on a year-by-year basis to account for seasonal variability. The reference pools must have the same desired biological and ecological functions and values as the compensation habitat. Ideally, a minimum two years of baseline conditions quantitative data will be gathered on the reference habitat (using the same quantitative methods as described below for habitat comparisons) to insure that the reference habitats have the desired ecological and biological functions prior to comparative analyses years. The compensation pools should demonstrate similar ecological and biological functions as those identified in the reference pools in the same year after four years.

Brief summary reports of monitoring results will be prepared for each year that the required monitoring occurs and would be submitted to Placer County, the USFWS, DFG and any other regulatory agency that requests copies. At five-year intervals a comprehensive report summarizing all monitoring to that date, with data, inferences and conclusions concerning compliance will be prepared. The reports will summarize data collected from the compensation covered vernal pool invertebrate species habitats and compare them with data collected from the reference pools and analyze trends, if any. These trends must be interpreted within the framework of the overall ecology, land use and extrinsic activities at that site.

Monitoring of macroinvertebrates in all compensation vernal pool habitats will be conducted by a qualified invertebrate ecologist, with the requisite 10(A) 1(a) vernal pool crustacean incidental take permit. Pools requiring remediation will be monitored yearly to determine whether improved performance has resulted from the corrective measures implemented. Remedial actions are discussed in greater detail below.

This monitoring program primarily involves monitoring compensation areas for vernal pool invertebrates, vegetation, and hydrology. However, qualitative monitoring of waterfowl and amphibian use will be conducted concurrent with the invertebrate monitoring. Incidental monitoring of wildlife will be conducted at all compensation vernal pool habitats and the reference pools during the wet season. Although no performance standards are specified for wildlife use, the collected data would provide a basis for determining if the compensation pools are increasingly being used by wildlife. Waterfowl and shorebird use is of particular interest, as these birds are known to transport special-status shrimp eggs between pools.

Photographic documentation of preserved and reference vernal pool habitats also will be conducted. The vernal pool habitat sites will be photographed from a fixed location during each year of the 10-year monitoring period. Representative photographs would be included in the monitoring reports.

Adaptive Management

Modification of conservation 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 compliance monitoring or effectiveness 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 concurrent monitoring at specific reference sites. These standards would provide the framework for ensuring that no net loss of vernal pool grassland 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 preserve areas that have little buffer between from developed areas, or in restored habitats. However, variations in physical and climatological conditions can affect the rate at which wetland habitat establishes. Restored 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 actions. Regulatory agency personnel and resource biologists would be consulted to review the contingency measure recommendations if any are needed.

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 water sheds, 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. manure, 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 method should be re-assessed and re-evaluated every five years by the PCCP to determine its effectiveness, and further needs for adaptive management.

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