THE STATUS OF THE CALIFORNIA TIGER SALAMANDER (*Ambystoma californiense*), CALIFORNIA RED-LEGGED FROG (*Rana draytonii*), FOOTHILL YELLOW-LEGGED FROG (*Rana boylii*), and other AQUATIC HERPETOFAUNA IN THE EAST BAY REGIONAL PARK DISTRICT, CALIFORNIA

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Rana draytonii

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Steven Bobzien and Joseph E. DiDonato: East Bay Regional Park District
2950 Peralta Oaks Court, P.O. Box 5381, Oakland, CA 94605.

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ABSTRACT

The East Bay Regional Park District ("District") currently manages 65 regional parks, recreation areas, wilderness lands, shorelines, preserves, and land bank areas which encompass over 97,000 acres in Alameda and Contra Costa Counties. Approximately 80 percent of District lands are protected and operated as natural parklands. Many factors, including habitat loss and fragmentation, contaminants, extended periods of drought, and the introduction of non-native predators have been implicated in contributing to the decline of the California tiger salamander (*Ambystoma californiense*), the California red-legged frog (*Rana draytonii*), and the foothill yellow-legged frog (*Rana boylii*). Since 1990 we have been monitoring California tiger salamander, California red-legged frog, foothill yellow-legged frog and other aquatic herpetofauna within the District. This progress report presents information on: (1) the current distributional range and status of California tiger salamanders, California red-legged frogs, and foothill yellow-legged frogs on District lands, (2) methods which the District employs to survey populations and monitor population trends, (3) biotic and abiotic variables affecting herpetofauna in the District, (4) subadult and adult movement and dispersal in the California red-legged frog, and (5) the integration of the District's land management, e.g. grazing, with herpetofauna monitoring. This preliminary report compiles information from intensive field work undertaken primarily between 1996 to the present.

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INTRODUCTION

The East Bay supports a diverse assemblage of herpetofauna where 12 amphibian and 30 reptilian species range within East Bay Regional Park District ("District") lands. These include terrestrial, semi-aquatic, and aquatic taxa. Several species are polytypic with regional variation. Herpetofauna populations can be particularly vulnerable to anthropogenic and natural environmental conditions. Within Alameda and Contra Costa Counties, conversion of natural areas to a human dominated landscape has highly fragmented habitats and significantly reduced California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana draytonii*) and foothill yellow-legged frog (*Rana boylii)* populations. While the California tiger salamander still occurs throughout much of its historic range, research suggests that approximately 75 percent of the species historic habitat (vernal pools) has been lost (USFWS 2004). Moreover, the California red-legged frog has been extirpated from 70 percent of its former range (USFWS 1996 and 2002). In addition, compelling evidence suggests populations of other taxa are declining in the East Bay, including foothill yellow-legged frogs which only occur in a small portion of their former range.

STUDY AREA AND METHODS

Study Area

The study area is exclusively in the East Bay Regional Park District, Alameda and Contra Costa Counties, California. The District's 97,000 acres includes parklands along the shorelines of San Francisco, San Pablo, Suisun Bays and the Delta Region, and inland areas throughout the valleys, coastal and transverse ranges of the East Bay. Elevation within the District ranges from sea level to 3817 feet. Annual precipitation varies with cismontane mesic conditions in the Berkeley-Oakland hills (26.30 inches) to xeric transmontane rain shadows in eastern Alameda and Contra Costa Counties (13.30 inches), based on 30 year monthly precipitation averages (Appendix A).

Currently the District contains 271 fresh water ponds, 12 larger lakes, and copious miles of various stream types. Typical lentic waterbodies are inland depressions or dammed stream channels. They vary in size and depth from small ponds less than 10 square meters and a few centimeters deep to larger waterbodies covering several square kilometers with depths greater than ten meters. Lotic habitat consists of very small ephemeral and seasonal drainages to intermittent and larger volume perennial streams. Associated habitats include redwoods, montane hardwood conifers, montane hardwoods, blue oak woodlands, valley oak woodlands, coast oak woodlands, blue oak gray pine woodlands, eucalyptus, montane riparian woodlands, valley foothill riparian woodlands, mixed chaparral, chamise-redshank chaparral, coastal scrub, annual and perennial grasslands, saline emergent wetlands, and estuarine.

Herpetofauna Surveys

To assess aquatic habitat suitability District biologists initiated surveys in 1990 and systematically surveyed 271 freshwater ponds in 1996, 2000, and 2004. During these extensive efforts we surveyed and were able to collect data from 179, 210, and 186 of the 271 ponds in 1996, 2000, and 2004, respectively for California tiger salamanders, California red-legged frog and other aquatic species within our properties throughout Alameda and Contra Costa Counties. In 1997 we conducted extensive surveys at 100 stream stations on 42 District streams to evaluated lotic habitat suitability for California red-legged frogs and foothill yellow-legged frogs. During 1998 and 1999 we concentrated our effort on areas previously not surveyed or regions with gaps in the distribution of these species. In addition, at several locations we have been monitoring the reproductive viability, movements, and dispersal of California red-legged frogs. This information provides a general assessment of the presence, distribution, and habitat utilization within the District of California tiger salamander, California red-legged frog, foothill-yellow-legged frog, and other aquatic herpetofauna.

Specific sites were selected and visited at the beginning of the breeding season (to evaluate initial reproductive effort) and re-visited when larvae began to metamorphose (to evaluate reproductive success). We focused our survey effort during the peak of the breeding season so a maximum number of adults, larvae, tadpoles, and/or metamorphs would be documented. Over the survey period, active and passive visual encounter surveys were conducted. The passive methods included using binoculars for bankside observation, surveying at night with binoculars and flashlights, and during daylight hours carefully walking pond and streambanks to observe and detect frogs. Active surveys for all taxa included capture and release of adults, juveniles, metamorphs, and larvae using the following methods: 1) capture by hand (wet hands), 2) dip-netting, 3) seining, 4) scooping up by container, and 5) incidentally using minnow traps while conducting California tiger salamander larval surveys.

During our survey we documented the presence of all aquatic invertebrates, other amphibian species, aquatic reptiles, and fish species. At each location we identified riparian vegetation and visually estimated the percentages of submerged vegetation, emerged vegetation, and canopy. In addition, we recorded the following physical characteristics and components: air temperature, surface water temperature, stream flow, substrate composition, stream reach length, and pond size. To assess water quality in lotic and lentic waterbodies, we recently evaluated surface water temperature, pH, dissolved oxygen, nitrate, and turbidity within the distributional range of California tiger salamander, California red-legged frog, and other aquatic herpetofauna throughout the District.

Most abiotic variables were dynamically sampled at each of the lotic and lentic waterbodies. Air and surface water temperatures were measured in Celsius using 165mm glass stem mercury thermometers. We used a YSI 550A hand-held digital meter to measured dissolved oxygen in mg/L and surface water temperatures in Celsius. A portable Hach OH1 pH meter was used to measure pH. Standard water colorimetric analysis test kits were used to measure nitrate in ppm. In 2004, under static conditions, water samples were removed from 185 District ponds, and using a Hach 2100P bench-top Photoelectric Nephelometer turbidity meter, individual samples were measured in nephelometric turbidity units (NTU).

To evaluate stream habitat suitability we examined the affect of various stream gradients on the occurrence, distribution, and reproduction of California red-legged frogs throughout the District. For each stream reach we used ortho-photography and ArcView to determine total stream length, sinuosity, and elevation change. This allowed an accurate calculation of stream gradient in percent and degree of slope. Sinuosity, vertical and longitudinal profiles were created for each stream reach (Appendix B). We modified

(Rosgen 1994) stream channel types and combined stream gradient types into four categories. 1) Low Gradient Streams – streams with gradients <2% and glide-pool-riffle systems characterized by meandering point bars, deep and back-water pools, alluvial channels with well defined flood plains and substrate consisting of silt-clay, sand, gravel and cobble. 2) Moderate Gradient Streams – streams with gradients ≥2-4%, where runs, riffles and infrequently spaced pools dominate, moderately entrenched channels with stable banks, profile, and plains, and substrate consisting of cobble, gravel, sand and/or silt-clay. 3) High Gradient Streams - streams with gradients >4-10%, with steep, narrow, high energy, cascading, plunge pool systems, stable bedrock boulder channels, and substrate consisting of cobble, gravel, sand and/or silt-clay. 4) Extreme Gradient Streams - streams with gradients >10%, with steep, narrow, high energy, cascading plunge pool systems, very stable bedrock boulder channels, and substrate consisting of cobble, gravel, sand and/or silt-clay.

Data Analysis

We evaluated our data and identified potential impacts to the California tiger salamander, California red-legged frog, and foothill yellow-legged frog, determined distribution and habitat suitability, and identified many enhancement opportunities. We mapped the distribution of California tiger salamanders, California red-legged frogs, and foothill yellow-legged frogs throughout the District's lands (Appendix C: maps).

We used a t-test to compare the number of ponds occupied by California tiger salamanders and predacious aquatic hexapods and the number of ponds with California tiger salamanders without predacious aquatic hexapods. Chi-square non parametric tests were also used to compare expected values and observed values. We compared the number of ponds with California tiger salamanders only, predacious aquatic hexapods only, with California tiger salamanders and predacious aquatic hexapods, and ponds with neither taxa.

We used an analysis of variance (ANOVA) to test for correlations between the presence of California tiger salamanders, California red-legged frog, Pacific tree frog (*Hyla regilla)*, Western toad (*Bufo boreas*), California newt (*Tricha torosa*), and garter snakes

(*Thamnophis sp*.) in lentic waterbodies after satisfying requirements and testing homogeneity of variance.

To evaluate if emerged riparian vegetation may influence the presence and survival of California red-legged frogs, we analyzed our 1996 pond data using a t-test (two sample, unequal variance). In addition, 1996 pond data were analyzed using a t-test (two sample, unequal variance) to assess the effect of non-native aquatic predators, specifically bullfrogs (*Rana catesbeiana*) and warm-water fish, on California red-legged frog distribution and reproduction in lentic habitat.

Radiotelemetry/Pit-tag Study

For several years researchers have been investigating adult California red-legged frog seasonal movements and dispersal. From 2000 to 2001 while working directly on site with Dr. Gary Fellers and Patrick Kleeman (USGS biologists at Point Reyes National Seashore) we inserted pit-tags and placed radio transmitters on subadult and adult California red-legged frogs. The pit-tags are microchips which were inserted intra-dermal and dorsally in all captured individuals. Our objectives of the pit-tag and telemetry study were to: (1) investigate the behavioral response of subadult and adult frogs to seasonal changes in lentic and lotic systems, especially with respect to the effects of El Nino or dry and drought conditions, (2) to evaluate various stream flow regimes and their influence on in-stream movements and upland dispersal of frogs, and (3) to monitor source population dispersal and the natural colonization of subadult and adult frogs into restored and/or newly developed lentic habitat(s).

Movements and dispersal of California red-legged frogs were tracked using a combination of radiotelemetry and pit-tags. Radio transmitter and pit-tag studies occurred at Round Valley Regional Preserve (Round Valley Creek), Sunol-Ohlone Regional Wilderness (Alameda Creek), and at a pond in Brushy Peak Regional Preserve. Using dip-nets, seines, and wet-hand, California red-legged frogs were captured and placed in damp cloth bags for processing. For each location we placed radio transmitters (150 MHZ) on subadult or adults frogs. Pit-tags were inserted in these individuals along with other subadult and adults captured. In addition, the snout to vent length (SVL, cm), weight (grams), sex (male, female, unknown), and GPS location were recorded for all captured frogs. After processing we released all individuals at their capture locations. At each site we also recorded a variety of other biotic and abiotic factors. We closely monitored radio-transmittered frogs on a weekly basis. Locations were entered into a GPS unit. Since radio transmitters have an average life of twenty weeks, and depending on the data collected, at approximately eighteen weeks, some transmitters were either replaced or removed from individual frogs. All re-captured frogs were scanned for pit tags, processed, sexed, measured, and weighed.

RESULTS AND DISCUSSION

California Tiger Salamander

General Distribution and Breeding Ecology

Subadult and adult California tiger salamanders spend the majority of the year in the uplands of grazed grasslands and oak savannas. Based on our surveys, California tiger salamander occur within the District from near sea level to above 3,600 feet and are widely distributed in 13 parkland units of eastern Alameda and Contra Costa Counties (Table 1). Most of these areas have abundant California ground squirrel (*Spermophilus beecheyi*) populations or have other burrowing rodents including California vole (*Microtus californicus*) and Botta's pocket gopher (*Thomomys bottae*) that create burrows which can be utilized by California tiger salamanders and other amphibians.

Table 1. Parks with California tiger salamanders (*Ambystoma californiense*) in the East Bay Regional Park District, Alameda and Contra Costa Counties, California 1990 - 2006.

Alameda County	**Contra Costa County**
Brushy Peak Regional Preserve	Black Diamond Mines Regional Preserve
Del Valle Regional Park	Clayton Ranch Regional Preserve
Garin Regional Park	Contra Loma Regional Park
Mission Peak Regional Wilderness	Round Valley Regional Preserve
Ohlone Regional Wilderness	Vargas Plateau Regional Park
Pleasanton Ridge Regional Park	Vasco Caves Regional Preserve
Sunol Regional Wilderness	

Within the District, 170 ponds were determined to be in the projected distributional range and potentially provide habitat for California tiger salamanders. From 1990 through

2004, we documented tiger salamander breeding in 75 distinct ponds, although not all of these ponds consistently supported reproduction in every year (Table 2). A pond was identified as "available for breeding" if it contained the constituent elements required to support breeding and in previous years documented to have reproductive events. In 1996 we documented California tiger salamander breeding in 29 of 61 ponds known to support reproduction, in 2000, salamander reproduction occurred in 35 of 70 ponds known to support breeding, and in 2004 they reproduced in 33 of 75 ponds known to support breeding. These results indicate that California tiger salamanders used ≤50% of the documented breeding locations in any one year. Specifically, for the three survey years, 1996, 2000 and 2004, the percentage of available ponds with evidence of breeding was 47.5%, 50%, and 44%, respectively (Table 2).

Table 2. California tiger salamander (*Ambystoma californiense*) breeding in the East Bay Regional Park District during surveys in 1996, 2000, and 2004.

California tiger salamander (*Ambystoma californiense*) reproduction			
SURVEY YEAR	**NUMBER OF PONDS WITH BREEDING**	**NUMBER OF PONDS AVAILABLE FOR BREEDING**	**PERCENT OF AVAILABLE PONDS WITH BREEDING**
1996	29	61	47.5 %
2000	35	70	50.0 %
2004	33	75	44.0 %

On District lands, California tiger salamanders breed almost exclusively in seasonal and perennial stock ponds. The rock-outcrop depressions at Vasco Caves Regional Preserve and Frick Lake at Brushy Peak Regional Preserve are the only natural waterbodies where we have documented California tiger salamander larvae other than stock ponds. California tiger salamander reproduction can be explosive and include two egg deposition periods, with one occurring in December followed by another in February. Although California tiger salamanders require little or no vegetative structure for egg deposition,

they do often place eggs on submerged blades of grass, small stems, or rocks. Eggs normally hatch within 10-14 days and larvae develop for several months until they reach a critical size for metamorphosis. In mid to late summer, metamorphic juveniles emerge from the ponds. However, we have documented over-wintering salamander larvae in several permanent ponds in the Ohlone Regional Wilderness. We have not fully investigated the factors affecting larvae over-wintering phenomenon.

Factors affecting occurrence of breeding California tiger salamanders in lentic waterbodies

To evaluate reproductive suitability we examined several biotic and abiotic factors that could influence the reproductive distribution and success of California tiger salamanders in District ponds. The biotic variables included the influence of non-native predators, aquatic predacious hexapods, emerged and submerged vegetation, and other aquatic herpetofauna. From our 2004 data set we also examined abiotic characteristics including water temperature, dissolved oxygen, nitrate, turbidity, and hydro-period.

In evaluating all the District ponds within the projected distributional range of California tiger salamanders, we found a total of 170 ponds that could potentially provide aquatic habitat for breeding salamanders. However, California tiger salamanders were not observed in 95 of these ponds (Table 3). Twenty of the 95 ponds were considered unsuitable breeding habitat because they contained predators including exotic fish or bullfrogs. An additional 14 of the ponds were completely dry during the survey periods, while 13 of the 95 ponds dried out too early in the season for successful salamander reproduction. In the latter case, some California tiger salamanders deposited eggs in several of these ponds only to have them desiccate when these waterbodies dried out. Such ponds may represent reproductive sinks for these individuals and reduce regional populations over time. Of the remaining subset of 48 potentially suitable ponds without California tiger salamanders, 34 or 71% of the ponds contained aquatic predacious hexapods. These results suggest that besides the presence of non-native predators, the presence of aquatic predacious hexapods could contribute to the exclusion of California tiger salamanders from ponds. The remaining 14 ponds contained neither California tiger salamanders nor any predacious aquatic hexapods (Table 3).

Table 3. Occurrence of biotic and abiotic factors in 95 potential suitable ponds lacking California tiger salamanders (*Ambystoma californiense*) in 1996 and 2000.

Biotic or Abiotic Factor	Number of Ponds
+ Non-native Predator, - Hexapods	10
+ Non-native Predator, + Hexapods	10
Pond Dry	14
Early Desiccation	13
+ Hexapods only	34
- Non-native predator, - Hexapods	14

Predaceous aquatic hexapods

The effect of predacious aquatic hexapods on California tiger salamander reproduction, larvae development, and overall reproductive success is not well understood. Several hexapod taxa are known to predate amphibians and small fish (Frost 1959, Borror 1976, Atkins 1978, Hirai 2002). Predacious aquatic hexapod taxa are visual predators with large compound eyes and some have grooved mandibles and piercing mouth parts for inserting enzymes that paralyze and rapidly digest their prey (Hirai and Hidaka 2002). Conversely, several taxa of aquatic hexapods avoid predation by emitting pungent odor plumes or protective secretions that are distasteful to many predators (Rhodes 1994). The occurrence in ponds of predacious aquatic hexapods, known to be the primary predators of Pacific tree frogs (*Hyla regilla*) and small fish (Frost 1959, Borror 1976, Atkins 1978, Hirai 2002), was examined in relation to California tiger salamander occurrence. These included giant water bug (*Belostomatidae),* predacious diving beetle (*Dytiscidae),* waterscorpion (*Nepidae)*, and dragonfly nymphs (*Anisoptera)*.

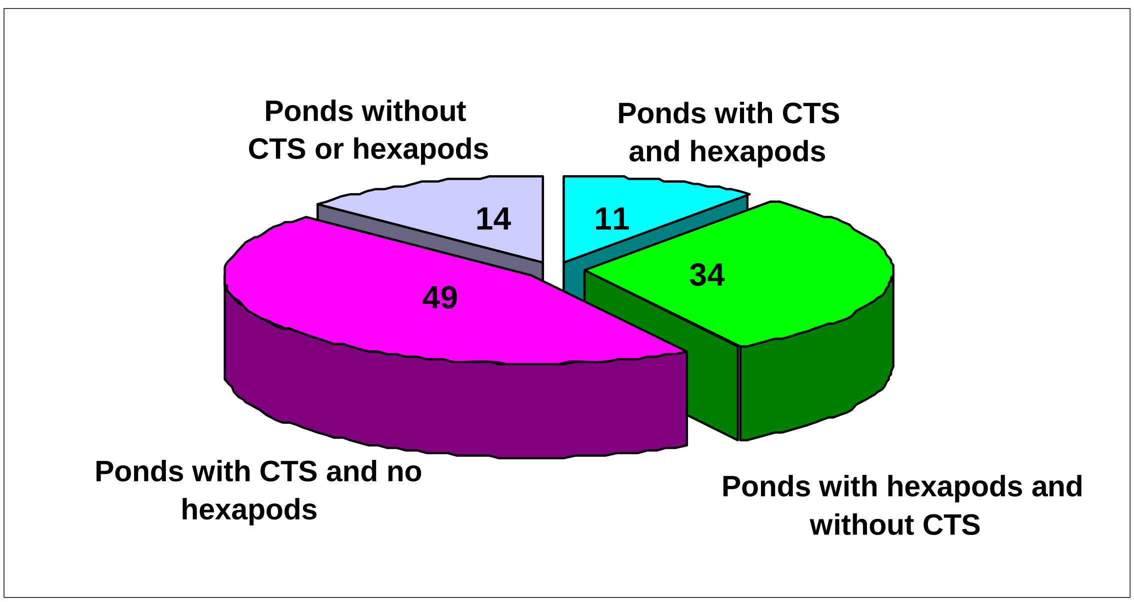
Data sets from 1996 and 2000 were used to analyze the co-occurrence of aquatic predacious hexapods in ponds supporting California tiger salamanders. In 1996 we documented California tiger salamander in 29 ponds, of which only 5 ponds had one or more predacious aquatic hexapod taxa. Similarly, in 2000 we documented California tiger salamander in 35 ponds, of which only 8 ponds had one or more predacious aquatic hexapod taxa. In both years we found a statistically significant, negative association between the proportion of ponds containing both salamanders and hexapods and those ponds containing only California tiger salamanders (Table 4).

Table 4. Co-occurrence of predacious aquatic hexapods in ponds with California tiger salamanders (*Ambystoma californiense*)-*CTS* in 1996 and 2000 ($p < 0.05$).

Survey Year	Total Number of *CTS* Ponds	Total Number of *CTS* Ponds with Predacious Aquatic Hexapods
1996	29	5 (17.3%)
2000	35	8 (25.7%)

Combining data sets from 1996 and 2000 (Tables 3 and 4) illustrates the overall presence of California tiger salamanders and one or more taxa of predacious aquatic hexapod (Fig. 2). A total of 49 ponds contained California tiger salamanders but no predacious aquatic hexapod taxi, 11 ponds had both California tiger salamanders and predacious aquatic hexapod taxa, 34 ponds had hexapods but no California tiger salamanders, and 14 ponds contained neither California tiger salamanders nor hexapod taxa. Again, we found a statistically significant, negative association between the presence of predacious aquatic hexapods and the occurrence of California tiger salamanders (Fig. 2).

Fig. 2. Presence/absence of California tiger salamanders (*Ambystoma californiense*) (CTS) and predacious aquatic hexapods ($p < 0.01$).



California tiger salamanders and predacious aquatic hexapods have the ability to disperse and migrate between waterbodies. Using our data from 1996 and 2000, we tallied District ponds that experienced a shift in supporting either California tiger salamanders or predacious aquatic hexapods between survey years (Table 5). A total of 9 ponds occupied by California tiger salamanders in 1996 were colonized by predacious aquatic hexapods by 2000. Consequently, no larval salamanders were found in these 9 ponds in 2000. Likewise, three ponds that contained only predacious aquatic hexapods in 1996 but which subsequently vanished, were inhabited by California tiger salamander larvae in 2000. Thus, a total of total of 12 ponds experienced a shift whereby the appearance or departure of predacious aquatic hexapods appears to have resulted in the disappearance or colonization of the pond by California tiger salamanders (Table 5).

Table 5. District Ponds with change in California tiger salamander (*Ambystoma californiense*) and predacious aquatic hexapod occurrence in 1996 and 2000.

POND LOCATION	**YEAR WITH *CTS* AND NO *HEXAPODS SPP.***	**YEAR WITH *HEXAPODS SPP.* AND NO *CTS***
OH001	1996	2000
OH002	1996	2000
OH003	1996	2000
OH004	1996	2000
OH027	1996	2000
OH029	1996	2000
OH034	1996	2000
MP002	1996	2000
RV001	1996	2000
OH036	2000	1996
OH042	2000	1996
DV015	2000	1996
TOTAL	**12**	**12**

Although the foregoing represents a small sample of ponds, the dramatic shift in presence or absence infers a negative association between predacious aquatic hexapods and

California tiger salamanders. The occurrence and shifting distribution of predacious aquatic hexapods and California tiger salamanders between pond complexes warrant further investigation.

Aquatic vegetation

Although California tiger salamanders can use alternative substrates other than vegetation for egg deposition, predaceous aquatic hexapods require some vegetative structure for perching, egg deposition, and to allow nymphs to climb out of the water for metamorphosis into winged-adults. To assess whether aquatic vegetation and hexapods are complementary, we examined the presence of aquatic submerged and emerged vegetation with the occurrence of predacious aquatic hexapods and California tiger salamanders. During 1996, 13 of 29 ponds (44.8 %) with California tiger salamanders had some submerged or emerged vegetation (Table 6). In 2000 we documented a slight increase in this percentage: 17 of 29 ponds (58.6 %) with California tiger salamanders had some submerged or emerged vegetation. Over this same time period, the number of California tiger salamander ponds containing aquatic vegetation and predacious aquatic hexapods increased from 4 of 5 ponds in 1996 to 7 of 7 ponds in 2000. Although sample sizes of ponds containing all three elements, California tiger salamanders, predacious aquatic hexapods and aquatic vegetation, were relatively small, we documented an increase in hexapod occurrence in ponds as the number of ponds with aquatic vegetation increased (Table 6).   This trend is highlighted by an 11:1 ratio of vegetated to non-vegetated California tiger salamander ponds that contained predacious aquatic hexapods (Table 6).

Table 6. Occurrence of aquatic vegetation and predacious aquatic hexapods in California tiger salamander (*Ambystoma californiense*) ponds in 1996 and 2000.

	YEAR	Ponds with Aquatic Vegetation	Ponds without Aquatic Vegetation	Total Ponds
Number of Ponds with *CTS*	1996	13	16	29
	2000	23	12	35
	TOTAL	**36**	**28**	64
Number of Ponds with *CTS* and hexapods	1996	4	1	5
	2000	8	0	8
	TOTAL	**11**	**1**	12

To further examine the influence of pond vegetation we analyzed the frequency of California tiger salamander occurrence associated with percent of emerged and submerged vegetation. During the 2004 survey period, 84% of the California tiger salamander ponds (21 of 33 ponds) had ≤ 5% emergent vegetation, while no salamanders were found in any pond with > 35% emerged vegetation (Fig. 3). Similarly, 64% of the salamander ponds (27 of 33 ponds) had ≤ 5% submerged vegetation, while an additional 12% of the ponds had > 5% and ≤ 10% submerged vegetation (Fig. 4). The remaining 23% of the ponds with California tiger salamanders ranged between 35% and 95% submerged vegetation (Fig. 4).

Fig. 3. Frequency of California tiger salamander (*Ambystoma californiense*) occurrence associated with the percent of emerged pond vegetation in 2004.

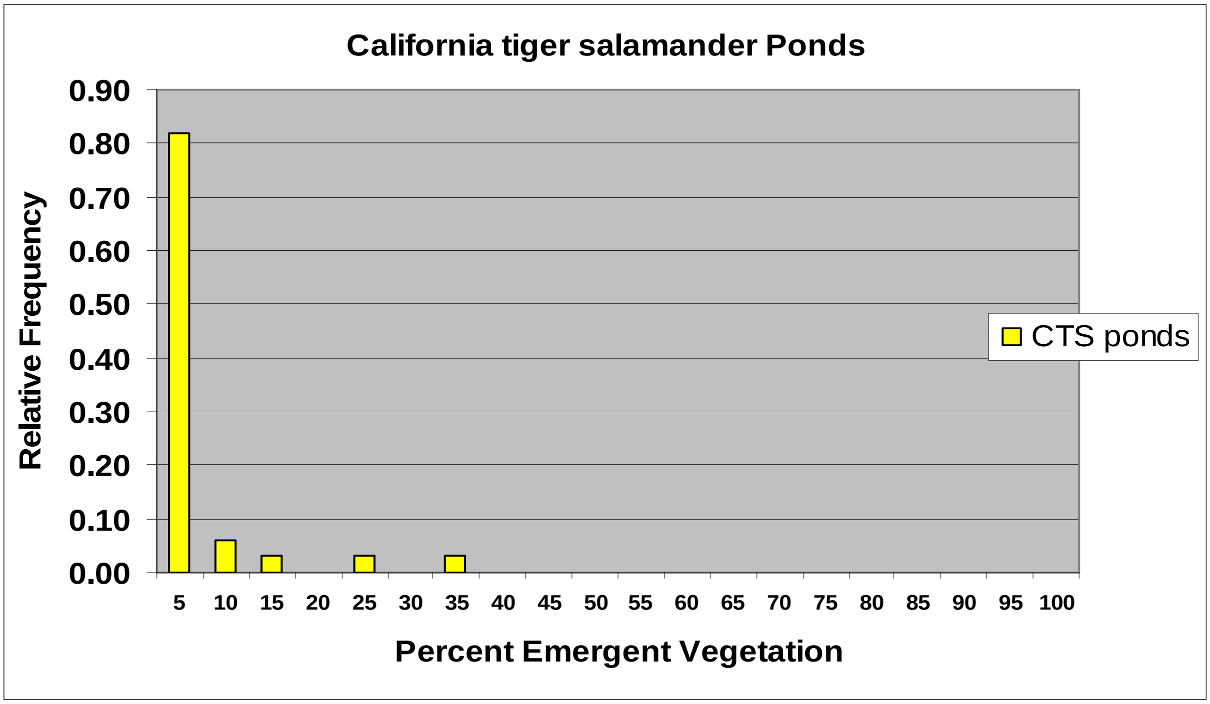
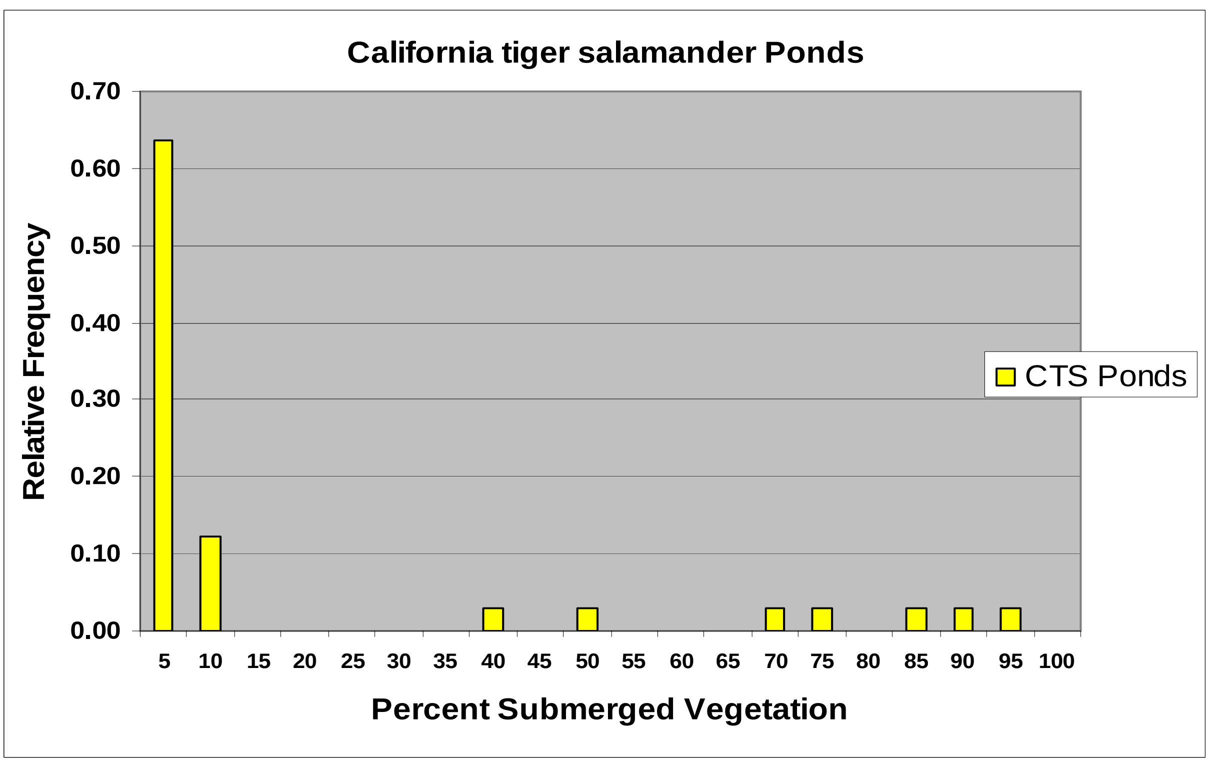


Fig. 4. Frequency of California tiger salamander (*Ambystoma californiense*) occurrence associated with the percent of submerged pond vegetation in 2004.



These results suggest that California tiger salamanders are very closely associated with ponds that contain little or no aquatic vegetation. In contrast, predacious aquatic hexapods appear to require more aquatic vegetative structure. California tiger salamanders were generally not present in ponds occupied by *Belostomatidae, Dytiscidae, Nepidae,* and/or *Anisoptera* (nymphs). Moreover, there appears to be a negative association between the presence of these predacious aquatic hexapods and the occurrence of California tiger salamanders.

California tiger salamanders and predaceous aquatic hexapods: a shifting predator-prey relationship?

Our results suggest a density-dependent, predator-prey relationship may exist between the California tiger salamander and predacious aquatic hexapods. In lentic waterbodies increased densities of one taxon may retard the population growth of other taxa by increasing mortality and decreasing fecundity. Perennial ponds often support a mosaic of aquatic vegetation types including filamentous green algae, submerged vascular plants, floating rooted-aquatics, and the emerged monocots. These ponds provide highly suitable habitat for predacious aquatic hexapods and have the ability to support dense populations throughout the year. California tiger salamanders entering such ponds to reproduce would deposit their eggs in a system “pre-loaded” with predatory hexapods, and thus the predation rate on salamander larvae could be intense enough to prevent successful reproduction. Conversely, in ponds with high densities of California tiger salamanders, predation by salamander larvae on aquatic hexapods may be severe enough to reduce or prevent successful colonization of the ponds by predacious aquatic hexapods.

The timing of immigration events may be fundamental to developing a shifting predator-prey relationship between the California tiger salamander and predaceous aquatic hexapods. During the first saturating rain events, typically in December or January, reproductively active California tiger salamanders migrate from adjacent uplands to the breeding ponds. In winter, adult salamanders deposit their eggs in both seasonal and perennial waterbodies, the former of which tend to be free of predacious aquatic hexapods. Within seasonal ponds, California tiger salamanders larvae thus may have the opportunity to develop and grow with little or no exposure to predatory hexapods. In the spring, aquatic hexapods disperse from perennial sites and re-colonize seasonal ponds which commonly harbor high salamander larvae densities. California tiger salamander larvae are suction predators and feed on a variety of prey including aquatic hexapods, other invertebrates, tadpoles, and smaller conspecific larvae (Petranka 1998). At this point, immigrating predacious aquatic hexapods are exposed to well-developed salamander larvae and predation. Although our preliminary results suggest density dependence, the predator-prey relationship between California tiger salamanders and predacious aquatic hexapods, including survivorship of these taxa in seasonal and perennial ponds, would benefit from further investigation.

Other biological and abiotic factors may affect the apparent shifting predator-prey relationship between California tiger salamanders and predacious aquatic hexapods. The backswimmer *Notonecta spp.* is widely distributed and very common in the District's ponds. Backswimmers are explosive breeders producing ten of thousands of individuals, and often co-occur in high densities with California tiger salamanders. Moreover, backswimmers prey exclusively on other aquatic invertebrates and can reduce species richness and density or even eliminate larger pelagic or neustonic species (Leon 1998). Strong evidence suggests that *Notonecta maculata* is an important organizer of pond community structure (Leon 1998). Within District ponds, the suppression or removal of larger predacious aquatic hexapods by other predators such as *Notonecta* may enable California tiger salamander larvae to successfully develop into metamorphic juveniles, but this requires further investigation.

California tiger salamanders and other aquatic herpetofauna

The District lentic waterbodies support other aquatic herpetofauna and interspecific interactions and competitive associations among taxa may influence the distribution and reproductive success of California tiger salamanders. We examine below the allopatric and sympatric distribution of California red-legged frog, Pacific tree frog, Western toad, California newt and garter snake relative to the California tiger salamander (see also Table 7).

California red-legged frog

On District lands, the California red-legged frog has a wider distributional range than the California tiger salamander and occurs in a greater variety of aquatic habitats including 75 ponds, 23 drainages, and three spring boxes. The two amphibians are sympatric in 11 distinct parkland units, where California red-legged frogs co-occur in 39% of California tiger salamanders ponds, but the frogs only reproduce in 29% of the salamander ponds (Table 7). The diet of adult California red-legged frogs is highly variable, however, Hayes and Tennant (1985) found invertebrates to be the most common food items. Though larger California red-legged frogs are known to forage on vertebrates such as Pacific tree frogs, California mice (*Peromyscus californicus*), and cannibalize smaller individuals, they typically take prey near or at the surface, where predation on salamander larvae would be minimal. Thus, it is likely that predation by California red-legged frogs on California tiger salamanders is minimal. Moreover, except for low incidence of California red-legged frog reproduction in ponds containing tiger salamanders, we did not find a positive or negative trend between California red-legged frog and California tiger salamander occurrence.

Pacific tree frog

The Pacific tree frog is very common and widely distributed throughout the District. They occur in variety of lotic and lentic habitats from very mesic coastal areas to the xeric eastern parklands. We documented Pacific tree frogs co-occurring in 72% of the ponds containing California tiger salamander (Table 7). Tree frogs deposit their eggs in almost any waterbody and late season tadpoles may be primary prey for large California tiger salamander larvae.

Western toad and California newt

Similar to Pacific tree frog, the Western toad and California newt also occur in a variety of lentic and lotic habitats, but they infrequently co-occurred in District ponds with California tiger salamanders. We documented Western toads in only 6 of 60 (10%) and California newts in 9 of 60 (15%) of the salamander ponds (Table 7). Although Western toads are widely distributed within the District, adult densities appear to be low and breeding is sporadic, especially in lentic waterbodies sympatric with California tiger salamanders. In contrast, California newts tend to be relatively abundant in and closely associated with mesic habitats such as redwood forests, deciduous hardwood forests, and oak bay woodlands. California newts and California tiger salamanders are only sympatric in xeric regions of oak savannas and open woodland habitat types. We found a statistically significant, negative association in pond co-occurrence between the California tiger salamander and the Western toad and California newt, respectively (Table 7).

Garter snake

Garter snakes (*Thamnophis spp*.) are wide ranging and often locally abundant throughout the District. Large garter snakes are the primary predator in fishless waterbodies and will prey on all of the amphibians noted above, including California tiger salamander larvae (Petranka 1998). We documented garter snakes in only 18% or 11 of 60 California tiger salamander ponds (Table 7). We found a significant negative association between garter snakes and California tiger salamanders (Table 7).

Table 7. California tiger salamander (*Ambystoma californiense*) breeding ponds and the sympatric occurrence of other aquatic herpetofauna from 1996 to 2002. ($*p < 0.05$).

SURVEY YEAR	SPECIES					
	Ambystoma californiense	*Rana draytonii*	*Hyla regilla*	*Bufo boreas*	*Tricha torosa*	*Thamnophis sp.*
1996	29	8	17	0	4	8
2000	34	6	15	2	5	4
2001-2002	14	12	14	4	3	1
TOTAL	60	24	43	**6***	**9***	**11***

California tiger salamanders and livestock grazing

Within the District, California tiger salamanders spend the majority of their subadult and adult lives in upland habitats. California tiger salamanders prefer open grassland habitat types to areas with continuous woody vegetation (Trenham *in revison*). There appears to be a strong association between grazed communities, burrowing mammals-especially ground squirrels, and the presence of California tiger salamanders. Adult salamanders primarily use the burrows of California ground squirrel and valley pocket gophers as their underground retreats (Barry and Shaffer 1994, Trenham 2001). In addition, livestock grazing is effective in maintaining open grassland and oak savanna communities that support these rodents. Livestock can also be very effective in removing pond vegetation. This maintains the pond's open water characteristic and reduces the vegetative structure available for predacious aquatic hexapods (cling taxa). Furthermore, evidence suggests that compaction of pond bottoms and removal of vegetation by livestock can increase the duration of inundation in vernal pools and seasonal ponds (Marty 2005). The development of stockponds for livestock has created highly suitable reproductive habitat for California tiger salamanders and other aquatic species in the District. In fact, with the exception of vernal pools within the sandstone rock outcrops at Vasco Caves and Frick Lake at Brushy Regional Preserve, California tiger salamanders breed exclusively in the District's seasonal and perennial ponds that are exposed to livestock grazing.

California Red-legged Frog

General distribution and breeding ecology

Within the District, the California red-legged frog has a wider distributional range than California tiger salamanders, and has been documented in 21 distinct parkland units of Alameda and Contra Costa Counties (Table 8).

Table 8. The distribution of California red-legged frogs (*Rana draytonii*) in the East Bay Regional Park District, Alameda and Contra Costa Counties, California 1990 - 2006.

Alameda County
Brushy Peak Regional Preserve
Camp Ohlone Regional Wilderness
Del Valle Regional Park
Dry Creek Pioneer Regional Park
Garin Regional Park
Mission Peak Regional Wilderness
Ohlone Regional Wilderness
Pleasanton Ridge Regional Park
Sunol Regional Wilderness

Contra Costa County
Black Diamond Mines Regional Preserve
Briones Regional Park
Castle Rock Regional Recreation Area
Clayton Ranch Regional Preserve
Diablo Foothill Regional Park
Las Trampas Regional Wilderness
Morgan Territory Regional Preserve
Round Valley Regional Preserve
Sobrante Ridge Regional Preserve
Sycamore Valley Regional Preserve
Tassajara Creek Regional Park
Vasco Caves Regional Preserve

In 1996 we observed California red-legged frogs at 51 of 179 ponds surveyed, and breeding was documented at 38 ponds or 74% of ponds. During 2000 we surveyed 219 ponds and documented California red-legged frogs in 73 ponds. California red-legged frog breeding was confirmed in 65 ponds or 89% of ponds with frogs. Recently, in 2004 we surveyed 186 ponds and documented frogs in 64 ponds with breeding occurring in 47 ponds or 73% of ponds (Table 9).

Table 9. Presence of California red-legged frogs (*Rana draytonii*) in ponds of the East Bay Regional Park District from 1996, 2000, and 2004.

California red-legged frogs (*Rana draytonii*)			
SURVEY YEAR	NUMBER OF PONDS OCCUPIED	NUMBER OF PONDS WITH BREEDING	PERCENT OF PONDS WITH BREEDING
1996	51	38	74.0 %
2000	73	65	89.0 %
2004	64	47	73.0 %

Factor affecting occurrence of California red-legged frogs in lentic waterbodies

Population trends and rainfall

Our data suggest the District's population of California red-legged frogs increased between 1996 and 2000. Although the District acquired additional lands with existing California red-legged frog ponds between the survey periods, several intervening years of favorable rainfall inundated existing "dry" and other ponds to enable frog reproduction. Thus, in 2000 we observed a substantial increase in the number of ponds supporting both frogs as well as breeding (Table 9). In contrast, in 2004 we documented a notable decrease in the percent of breeding in ponds from 89% in 2000 to 74% (Table 9). During winter of 2003-2004, annual precipitation was below average with very few significant rainfall events after January. Many ponds either did not receive enough water to support frog breeding or dried out early in the season. This resulted in a temporary loss of 63 ponds as effective or potentially suitable reproductive habitat within the District.

Aquatic vegetation

To evaluate if emerged riparian vegetation may influence the presence and survival of California red-legged frogs, we analyzed our 1996 data using a t-test (two sample, unequal variance). We separated ponds (n=51) where we observed California red-legged frogs into one of three "vegetation" categories: ponds (n=15) with 0% emerged vegetation = vegetation type 1 (VT1); ponds (n=19) with < 15% emerged vegetation = vegetation type 2 (VT2); and ponds (n=17) with ≥ 15% emerged vegetation = vegetation type 3 (VT3) (Table 10). For each category we separated the life stages into adults, juveniles, and tadpoles (Table 11).The data were analyzed to compare mean number of adults between VT1, VT2 and VT3 ponds (Table 11). The mean number of adults in VT1 ponds was 4.07, in VT2 ponds it was 4.75, and in VT3 ponds it was 3.00. There was no significant difference between the mean number of adults in VT1 and VT2 ponds (P(1)=0.322). VT1 ponds and VT3 ponds did not exhibit a significant difference in mean number of adults (P(1)=0.203). The difference in the mean number of adults in VT2 and VT3 ponds (P(1)=0.090) was also not statistically significant.

The data were then analyzed for total number of California red-legged frogs (including adults, subadult, metamorphs, and tadpoles) (Table 10). The mean totals of individuals in

VT1, VT2, and VT3 ponds were, 44.4, 114, and 8.2 respectively. The difference between VT1 ponds and VT2 ponds was statistically significant (P(1)=0.198). The difference between VT2 and VT3 ponds was not statistically significant (P(1)=0.097). However, the mean total in VT1 ponds was significantly greater than VT3 ponds (P(1)=0.029). The difference between VT1 and VT3 could be explained by the difference in detectability of various life stages, where the amount of aquatic vegetation structure affected our ability to visually detect and/or capture individuals to accurately quantify total number of individuals for each pond.

Table 10. The 1996 California red-legged frog *(Rana draytonii)* occurrence associated with emerged pond vegetation on East Bay Regional Park District, Alameda and Contra Costa Counties, California.

Ponds with No Emerged Vegetation		**Ponds with <15% Emerged Vegetation**		**Ponds with ≥15% Emerged Vegetation**	
Park/Pond	CRLF Numbers	Park/Pond	CRLF Numbers	Park/Pond	CRLF Numbers
BD001	63	*BN005	3	BD014	10
BN013	1	DV006	1	*BN002	1
BN019	1	DV010	7	*BN003	9
MT009	7	MP007	12	BN018	3
MT012	3	MT004	9	DV001	1
MT013	112	*MT010	4	GD009	9
*MT014	12	OH003	15	MP002	26
MT027	157	OH006	1	MP007	12
OH029	16	OH007	1	*MT002	3
OH040	10	OH016	2	*MT011	33
OH043	22	OH021	1501	OH008	20
PR014	4	OH024	2	OH014	10
SN002	11	OH025	112	OH022	1
SN011	22	OH026	96	OH023	1
VC004	225	OH027	236	OH032	7
		OH028	30	OH033	18
		OH030	108	OH045	4
		OH034	11	VC003	2
		OH038	15		

Key:

BD = Black Diamond Mines
BN = Briones
DV = Del Valle
GD = Garin/Dry Creek
MP = Mission Peak
MT = Morgan Territory
OH = Ohlone
PR = Pleasanton Ridge
SN = Sunol
VC = Vasco Caves

* Fenced ponds = excluded from grazing
Shaded ponds represented breeding populations/non-shaded ponds represent adults only (breeding unconfirmed).

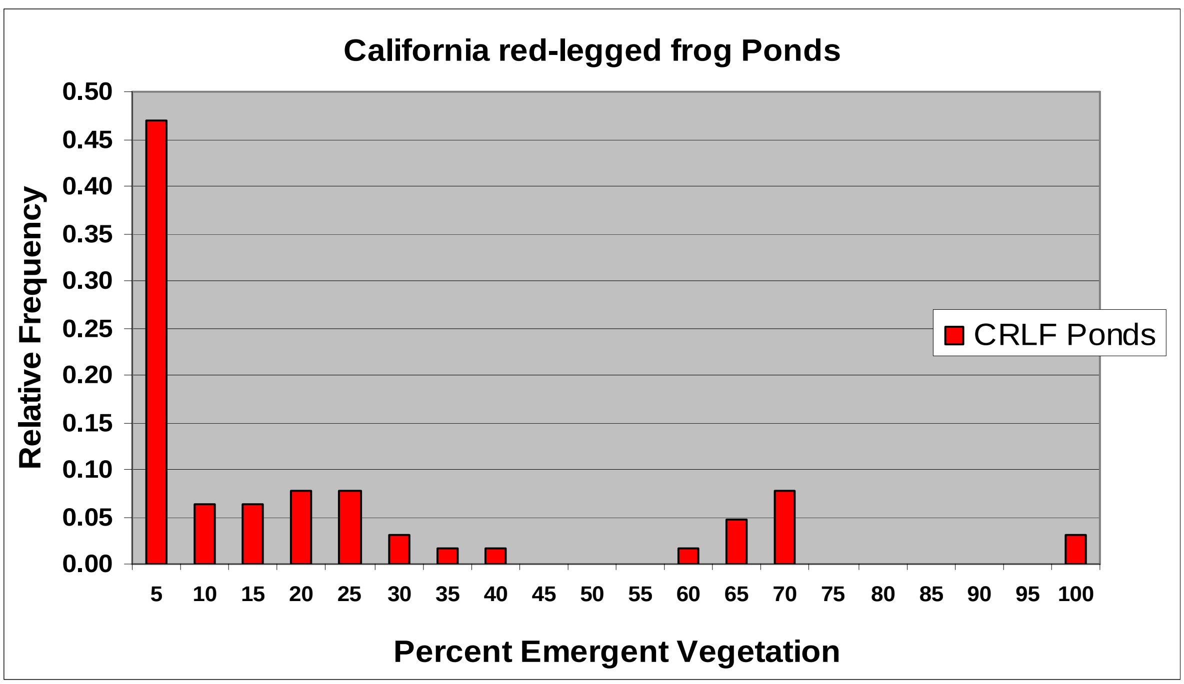
Table 11: The distribution of California red-legged frog (*Rana draytonii*) adult-subadults, metamorphs, and tadpoles associated with emerged pond vegetation in the East Bay Regional Park District in 1996. Note:* Fenced ponds excluded from livestock grazing.

CALIFORNIA RED-LEGGED FROG (*Rana draytonii*) POND TYPE					
PARK/POND	**ADULT**	**METAMORPH**	**TADPOLE**	**TOTAL**	**% EMERGED VEGETATION**
BD001	3	0	60	63	0
BN013	0	0	1	1	0
BN019	1	0	0	1	0
MT009	4	1	2	7	0
MT012	3	0	0	3	0
MT013	10	2	100	112	0
MT014 *	2	10	0	12	0
MT027	4	150	3	157	0
OH029	6	0	10	16	0
OH040	0	0	10	10	0
OH043	2	0	20	22	0
PR014	4	0	0	4	0
SN002	2	2	7	11	0
SN011	5	7	10	22	0
VC004	15	10	200	225	0
BN005 *	0	0	3	3	<15
DV006	1	0	0	1	<15
DV010	6	1	0	7	<15
MP007	12	0	0	12	<15
MT004	2	2	5	9	<15
MT010 *	1	0	3	4	<15
OH003	4	1	10	15	<15
OH006	1	0	0	1	<15
OH007	1	0	0	1	<15
OH016	2	0	0	2	<15
OH021	1	0	1500	1501	<15
OH024	2	0	0	2	<15
OH025	10	1	101	112	<15
OH026	7	1	88	96	<15
OH027	8	0	288	236	<15
OH028	1	0	29	30	<15
OH030	8	0	100	108	<15
OH034	8	0	3	11	<15
OH038	15	0	0	15	<15
BD014	10	0	0	10	≥15
BN002 *	0	0	1	1	≥15
BN003 *	1	0	8	9	≥15
BN018	3	0	0	3	≥15
DV001	1	0	0	1	≥15
MT002 *	2	1	0	3	≥15
MT011 *	3	0	30	33	≥15
OH008	1	0	19	20	≥15
OH014	9	0	1	10	≥15
OH022	1	0	0	1	≥15
OH023	1	0	0	1	≥15
OH032	4	0	3	7	≥15
OH033	4	0	14	18	≥15
OH045	3	0	1	4	≥15
VC003	2	0	0	2	≥15

Ponds with 0% emerged vegetation showed a significantly greater mean number of total individuals (adults, juveniles, tadpoles) (44.4) than ponds with > 15% emerged vegetation (8.2).

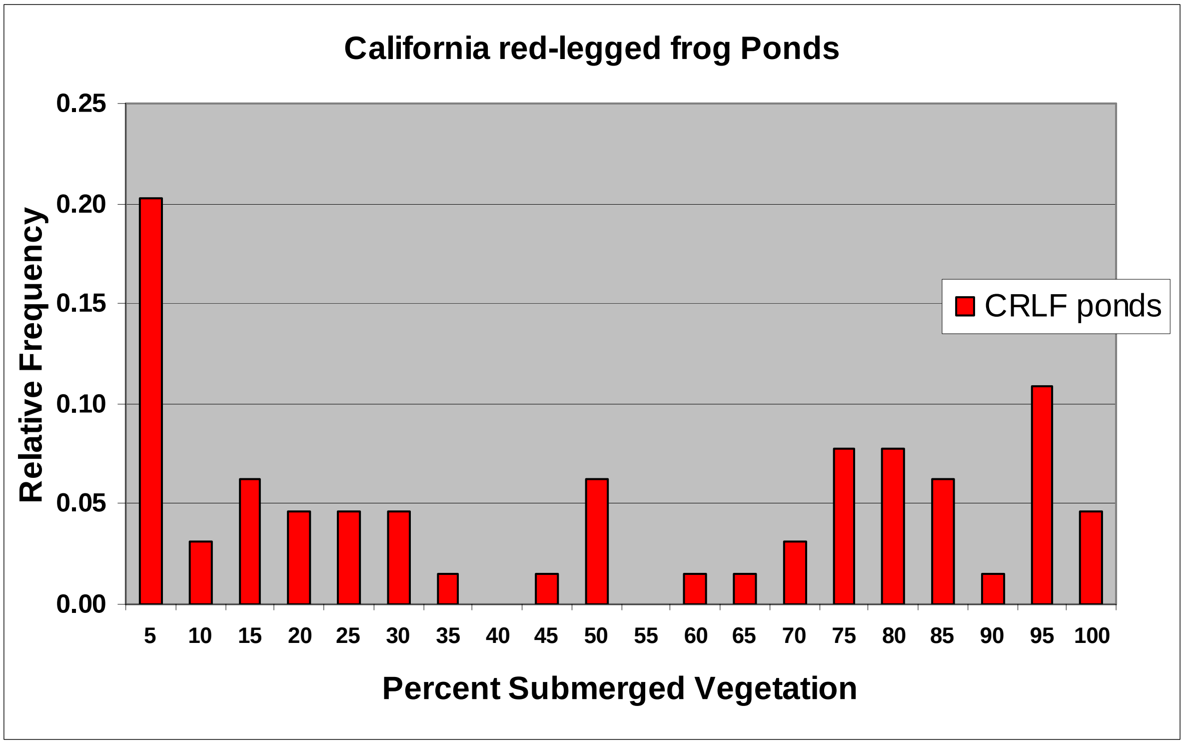
To further examine the influence of pond vegetation we analyzed the frequency of California red-legged frog occurrence associated with percent of emerged and submerged vegetation. The 2004 survey shows that 47% of the ponds where California red-legged frogs occurred had ≤ 5% emerged vegetation (Fig. 5). An additional 26% of the occurrences were relatively evenly distributed in ponds with ≤ 35% emerged vegetation. Although we observed California red-legged frogs in ponds with various amounts of emerged vegetation, they appear to be closely associated with ponds containing < 40% emerged vegetation (Fig. 5).

Fig. 5. Frequency of California red-legged frog (*Rana draytonii*) occurrence associated with the percent of emerged pond vegetation in 2004



In evaluating the frequency of California red-legged frog occurrence associated with percent of submerged vegetation, we observed frogs more evenly distributed throughout the submerged pond vegetation spectrum. Nevertheless, frog occurrence was considerably higher in ponds with ≤ 5% submerged vegetation than in all other percent categories (Fig. 6).

Fig. 6. Frequency of California red-legged frog (*Rana draytonii*) occurrence associated with the percent of submerged pond vegetation in 2004.



Non-native predators

Introduced predators are implicated in contributing to the decline of California red-legged frog (USFWS 1996, USFWS 2002). The 1996 pond data were analyzed to determine whether non-native predators within the District lands are adversely affecting the California red-legged frogs. The predators include large mouth bass (*Micropterus salmoides),* bluegill (*Lepomis macrochirus)*, green sunfish (*Lepomis cyanellus)*, mosquitofish (*Gambusia affinis)*, and bullfrogs (*Rana catesbeiana*). For each pond surveyed we estimated and determined the number of California red-legged frog (including adults, juveniles/metamorphs, and tadpoles).

We separated the ponds where we observed California red-legged frogs (n=51) and ponds with non-native predators (n=45) into the following categories: ponds with California red-legged frogs and without non-native predators ("control ponds" n=39); ponds with California red-legged frogs and non-native predators ("predator ponds" n=12); ponds with California red-legged frogs and non-native fish ("fish ponds" n=9); ponds with California red-legged frogs and bullfrogs ("bullfrog ponds" n=6); and ponds with breeding California red-legged frogs and non-native predators (n=5). If one or more ponds within a park contained California red-legged frogs, all ponds within that park were designated potential California red-legged frog habitat. Although "potential habitat" is a subjective determination, it was necessary to exclude ponds in the data set that were obviously uninhabitable by California red-legged frogs.

We analyzed the data using a two-sample t-test, assuming unequal variances. Initially, ponds without predators ("control ponds") were not found to have a significantly greater number of California red-legged frogs than "predator ponds" (P(1)=0.2349). However, Pond OH021 had a high number of California red-legged frogs (1 adult and 1500 tadpoles; Table 11), so the data were further analyzed without this pond in an effort to reveal any patterns, which may have been masked by this possible outlier. After removing pond OH021 from the data set, the "control ponds" had a significantly greater number of California red-legged frogs than the "predator ponds" (P(1)=0.0034).

The pond data were analyzed for non-predator type: fish and bullfrogs. Initially, "control ponds" were not found to have a significantly greater number of California red-legged frogs than "fish ponds" (P(1)=0.1981), but after removing OH021 from the data set, the difference was statistically significant (P(1)=0.0021). "Control ponds" were also found to have a significantly greater number of California red-legged frogs than "bullfrog ponds" (P(1)=0.0034).

In addition, the data were analyzed to determine the influence of predators on California red-legged frog breeding. We assumed breeding ponds to be any ponds that contained tadpoles and/or metamorphs (newly metamorphosed tadpoles). Predators were not found to have a significant effect on breeding (P(1)=0.2345), although after removing pond OH021 from the data set, the effect was significant (P(1)=0.0045). Fish were not found to significantly affect breeding (P(1)=0.1986), but upon removal of pond OH021, the effect was significant (P(1)=0.0024). The presence of bullfrogs appears to significantly decrease breeding California red-legged frogs (P(1)=0.0046). Similarly, combining non-native predators (fish & bullfrogs) resulted in a significant effect on breeding.

California red-legged frogs and livestock grazing

In 1996 we observed California red-legged frogs in 51 ponds, where breeding occurred in 38 ponds (Table 9). It is interesting to note that only 7 of 16 perennial ponds, which were fenced to exclude livestock, had breeding frogs. In contrast, 43 ponds that were exposed to grazing supported frog populations, often with explosive breeding. These 43 ponds exhibited a range of emerged riparian vegetation profiles (Tables 10 and 11). Thus, in the District's lentic waterbodies we were unable to document a negative effect of grazing on occurrence or reproduction of California red-legged frogs.

Movements and dispersal/radiotelemetry

At Round Valley Creek we placed radio transmitters on eight subadult and/or adult California red-legged frogs and inserted pit-tags into seven other individuals. In addition, 17 California red-legged frogs were previously pit-tagged by Trish Tatarian in 1999 as part of her MS thesis work (Sonoma State University). She also placed radio transmitters on 10 adults. Collectively, we placed transmitters on 18 California red-legged frogs and inserted pit-tags in 25 individuals. Their movements were monitored from November 1999 - January 2001 and from May 2001 – November 2001. During this period the majority of their movements were restricted to Round Valley Creek, and most individuals remained very close to their capture sites. However, Tatarian (unpubl. observation) documented an adult frog moving 60 meters into a blue oak savanna woodland during an October rain event. In addition, we documented and observed daily (diurnal and nocturnal) movements of California red-legged frogs including small metamorphs and/or juveniles utilizing areas above top-of-bank and in adjacent uplands where several were observed at the entrances of ground squirrel burrows.

At the Camp Ohlone study site on Alameda Creek we placed radio transmitters on 20 subadult and/or adult California red-legged frogs and inserted pit-tags into 30 individuals. We monitored their movements weekly from November 4, 2000 through October 18, 2001. During this period, six frogs remained very close to their in-stream capture sites and four frogs moved into adjacent pools or deep still water reaches. Overall these 10 individuals moved very little throughout our study. In contrast, 10 other California red-legged frogs moved > 50 meters and most of these individuals traveled > 100 meters into various upstream and downstream locations within the channel. One adult male originally captured in a dry tributary moved 54 meters to Alameda Creek within four days, and then another 640 meters to a downstream pool. Moreover, in September 2001 we documented an adult male dispersing a minimum distance of 132 meters into dry rocky upland habitat. This frog was located in a ground squirrel burrow where it appeared to have remained for three weeks until it returned to a pool in Alameda Creek for an overall minimum movement in the uplands of 264 meters.

At our Brushy Peak Regional Preserve pond study site we inserted pit-tags and placed radio-transmitters on 10 subadult and/or adult California red-legged frogs. These individuals were monitored weekly from May 2001 – March 2002. Throughout the hot dry season, the pond rapidly lost volume and significantly decreased in size. During these months, all monitored California red-legged frogs remained in this shrinking waterbody. Individual frogs buried themselves in pond mud and were often difficult to detect. In early November 2001 several large storms released significant precipitation and runoff quickly inundated the pond. During the first week in December an adult male and 2 adult female California red-legged frogs left the pond and moved into the uplands. We located the male 120 meters from the pond, one female 79 meters from the pond, and the other female 51 meters from the pond. All the California red-legged frogs were found in ground squirrel burrows, where the male remained for two weeks until returning to the pond. Moreover, the two adult females remained in the ground squirrel burrows for two months and were documented returning to a fully inundated pond in early February 2002. On March 13, 2002 we documented two California red-legged frog egg masses in this pond.

In summary, from November 1999 to March 2002 using radio telemetry, 48 California red-legged frogs were monitored at three locations: Alameda Creek, a cismontane stream; Round Valley Creek a transmontane stream; and a Brushy Peak stockpond, a lentic waterbody. Throughout the study we documented considerable movements at the Alameda Creek and Brushy Peak study sites. Four adult California red-legged frogs, two males and two females, moved up to 132 meters into surrounding uplands and utilized ground squirrel burrows, and one adult male, originally captured in a dry tributary, moved 54 meters to Alameda Creek and another 640 meters within the stream. In contrast, in Round Valley Regional Preserve the California red-legged frogs with radio transmitters generally remained in or near the stream and demonstrated site fidelity. Although, after an October rain event, one adult moved approximately 60 meters into a blue oak savanna woodland.

Overwintering California red-legged frog tadpoles

Since 1997, in Round Valley Creek, we suspected that some California red-legged frog tadpoles may be remaining in the larval stage beyond the normal seasonal period typically associated with this species. This phenomenon is referred to as "overwintering". Within the District, most adult frogs typically lay their eggs in March. Eggs require approximately 18-22 days to develop into tadpoles, and tadpoles require 11 to 20 weeks to reach metamorphosis. Nevertheless, we have documented metamorphs in March and April and have observed several of these metamorphs each year. These frogs were relatively small in size (38-50mm) and still had posterior scar tissue where their tails were located. One of the larger metamorphs measured 47mm in length and weighed 11 grams. Furthermore, we observed numerous tadpoles late in the fall (October and November) and several in December and January. The majority of these individuals measured between 60-68 mm, had rudimentary or developed hind limbs (Gosner 34-37), and appeared to overwinter at this stage. We have documented tadpoles overwintering at other sites including Morgan Territory Regional Preserve in pond MT011 and several ponds in the Ohlone Regional Wilderness.

Overwintering in California red-legged frogs may be influenced by water temperature, an important factor in determining the rate of tadpole development (Altig and McDiarmid 1999). We would expect to encounter overwintering tadpoles most frequently in high altitude regions such as Morgan Territory Regional Preserve and the Sunol and Ohlone Regional Wildernesses where the warm season is relatively short. In addition, California's Mediterranean climate may influence the timing of oviposition in winter and metamorphosis in summer-fall. During winter, high flow events are normal in East Bay streams and undoubtedly provide strong selective pressure for frogs to delay egg-laying and for larvae to complete metamorphosis before winter storms.

Stream habitat suitability

California red-legged frogs were present in 26 of the 42 surveyed creeks and we confirmed breeding in ten streams (Table 12). Currently, four streams, Alameda, Pine, Sand, and Round Valley Creeks have sizable breeding populations of California red-legged frogs. The population stability at Pine and Sand Creeks is unknown, whereas the number of frogs in Alameda and Round Valley Creeks appear to have increased 1995-1997 and stabilized 1998-2001 with some variation the last several years (2003-2005). These two streams consistently support > 60 subadult and adult California red-legged frogs.

Most of the reproductively successful drainages are still relatively free of non-native predators (i.e. bullfrogs and centrarchids), which probably contributes to the breeding success of the frogs. Breeding also occurs in Marsh Creek, but relatively few adults, juveniles, metamorphs, and tadpoles were identified in our 1997, 1998 and 1999 surveys. In the Arroyo Del Valle, Livermore, (lower section) we observed only three California red-legged frog tadpoles in 1995. Since this observation we have not observed any California red-legged frogs in the upper or lower reaches of the Arroyo Del Valle and these populations appear to be extirpated. Both Marsh Creek and Arroyo Del Valle are inhabited by native fish, non-native centrarchids, and bullfrogs, which are known to adversely affect California red-legged frogs (USFWS 1996, USFWS 2002).

Currently, 15 of the 26 streams appear to support non-breeding populations. These include Alameda Creek (tributary), Arroyo Del Hambre, Bear, Bollinger, Brushy (Vasco Caves-east reach), Castro, Dry, Indian, Markley, Marsh (Morgan Territory), San Antonio, Sinbad, Somersville, and Tassajara Creeks, where only adult frogs have been observed. Abundant populations of non-native predators occur in eight of the drainages, and we suspect these California red-legged frog populations will have limited breeding success until the bullfrogs and non-native fish are systematically removed. Based on location and habitat features another 13 of the District streams could potentially support California red-legged frogs (Table 12).

Table 12. Stream Distribution and Habitat Assessment of California red-legged frogs (*Rana draytonii*) in the East Bay Regional Park District, Alameda and Contra Costa Counties, California, 1997-2006

CALIFORNIA RED-LEGGED FROG STREAM DISTRIBUTION AND HABITAT ASSESSMENT		
STREAMS WITH BREEDING	**STREAM POPULATIONS BREEDING UNCONFIRMED**	**STREAMS WITH POTENTIAL HABITAT FOR CALIFORNIA RED-LEGGED FROGS**
Alameda Creek (Sunol Regional Wilderness)	Alameda Creek (Camp Ohlone-Sunol Regional Wilderness)	Agua Caliente (Mission Peak Regional Preserve)
Altamont Creek (Brushy Peak Regional Preserve)	Arroyo Del Hambre Creek (Briones Regional Park)	Arroyo Del Valle Creek (Del Valle Regional Park)
Arroyo Del Valle (Del Valle Regional Park)	Bear Creek (Briones Regional Park)	Homestead Creek (Black Diamond Mines Regional Preserve)
Marsh Creek (Round Valley Regional Preserve)	Bollinger Creek (Las Trampas Regional Wilderness)	Indian Joe Creek (Ohlone Regional Wilderness)
Pine Creek (Diablo Foothills Regional Park)	Brushy Creek (Vasco Caves Regional Preserve)	Kennedy Creek (Kennedy Grove Regional Recreation Area)
Round Valley Creek (Round Valley Regional Preserve)	Castro Creek (Sobrante Ridge Regional Preserve)	Kirker Creek (Black Diamond Mines Regional Preserve)
Sand Creek (Black Diamond Mines Regional Preserve)	Dry Creek (Dry Creek and Garin Regional Parks)	Marsh Creek (Clayton Ranch Regional Preserve)
Sycamore Creek (Sycamore Valley Regional Park)	Indian Creek (Ohlone Regional Wilderness)	Mill Creek (Mission Peak Regional Preserve)
Brushy Creek (Vasco Caves Regional Preserve)	Markley Creek (Black Diamond Mines Regional Preserve)	La Costa Creek (Ohlone Regional Wilderness)
Brushy Creek tributary (Vasco Caves Regional Preserve)	Marsh Creek (Morgan Territory Regional Preserve)	Shafer Creek (Ohlone Regional Wilderness)
	San Antonio Creek (Ohlone Regional Wilderness)	Welch Creek (Sunol Reegional Wilderness)
	Sinbad Creek (Pleasanton Ridge Regional Park)	West Antioch Creek (Black Diamond Mines Regional Preserve)
	Somersville Creek (Black Diamond Mines Regional Preserve)	Whitlock Creek (Sunol and Ohlone Regional Wilderness)
	Tassajara Creek (Morgan Territory Regional Preserve)	
	Tassajara Creek (Tassajara Creek Regional Park)	

Stream gradients

Stream gradient directly influences geomorphic process, hydrologic regime, physical and chemical characteristics, and biological suitability. Gradient is a key factor in determining stream profiles and patterns. We modified (Rosgen 1994) stream channel types and combined stream gradient types into four categories: low, moderate, high, and extreme gradient, respectively. California red-legged frogs were documented in 26 of 42 streams and in all stream gradient types. We confirmed breeding in 10 streams and 16 streams supported non-breeding (unconfirmed) individuals. Unconfirmed breeding populations consist of subadult and adult individuals. Streams with California red-legged frogs were placed into stream gradient type and separated into streams with breeding and stream populations with unconfirmed breeding. Unconfirmed breeding populations were relatively evenly distributed in all stream gradient types, where five low gradient, two moderate gradient, six high gradient, and three extreme gradient streams supported subadult or adults frogs. Similarly we found breeding in six low gradient, two moderate gradient and two high gradient stream types. However, no reproduction was documented in extreme gradient stream types (Table 13).

Table 13. Stream gradient distribution of breeding and non-breeding (unconfirmed) populations of California red-legged frogs (*Rana draytonii*) in the East Bay Regional Park District (1997-2002).

STREAM GRADIENT TYPE	***STREAMS WITH CONFIRMED BREEDING N=10***	***STREAMS WITH UNCONFIRMED BREEDING N=16***
Low Gradient Streams <2%	***6***	***5***
Moderate Gradient Streams ≥2-4%	***2***	***2***
High Gradient Streams >4-10%	***2***	***6***
Extreme Gradient Streams >10%	**0**	***3***

To further examine the influence of gradient, the percent slope was calculated for each stream occupied by California red-legged frog. Frogs occurred in all stream types with gradients ranging from 0.4% to 21.0% slopes (Table 14). Individual non-breeding subadult and adults were evenly distributed in streams with slopes ranging from 0.6 % to 13.7%, with one population in Alameda Creek tributary, a stream with a 21.0% slope. In contrast, California red-legged frog breeding populations were mostly restricted to streams types with ≤ 4% gradients. Although breeding populations were also detected in Altamont Creek and Brushy Creek, with gradients of 4.7% and 5.5%, respectively, these drainages are at the lower range of high gradient stream types (Table 14).

Table14. Distribution of breeding and non-breeding (unconfirmed) populations of California red-legged frogs (*Rana draytonii*) by stream gradient type and slope in East Bay Regional Park District (1997-2002).

STREAM GRADIENT TYPE	STREAMS WITH CONFIRMED BREEDING		STREAMS WITH UNCONFIRMED BREEDING	
Low Gradient Streams <2%	***Marsh Creek***	***0.4%***	***Tassajara Creek***	***0.6%***
	Alameda Creek	***1.1%***	***Dry Creek***	***0.8%***
	Arroyo Del Valle	***1.1%***	***Sinbad Creek***	***1.6%***
	Round Valley Creek	***1.5%***	***Tassajara Creek***	***1.7%***
	Alameda Creek	***1.7%***	***Castro Creek***	***1.9%***
	Sycamore Creek	***1.7%***		
Moderate Gradient Streams ≥2-4%	***Pine Creek***	***2.0%***	***Dry Creek***	***2.3%***
	Sand Creek	***2.8%***	***Bear Creek***	***3.9%***
High Gradient Streams >4-10%	***Altamont Creek***	***4.7%***	***Brushy Creek***	***4.5%***
	Brushy Creek	***5.5%***	***Indian Creek***	***4.7%***
			Marsh Creek	***6.4%***
			Markley Creek	***6.8%***
			Bollinger Creek	***7.1%***
			Arroyo Del Hombre	***8.3%***
Extreme Gradient Streams >10%	**-----NA-----**		***Indian Creek***	***10.4%***
			San Antonio Creek	***13.7%***
			Alameda Creek tributary	***21.0%***

The most stable populations with the highest breeding densities inhabit low and moderate stream gradient types such as Alameda Creek, Round Valley Creek, Pine Creek, and Sand Creek. These streams tend to have favorable still water conditions including deep-water pools, plunge pools, back water pools and eddies, flood plain pools, and perched oxbows.

Using hydrographs we broadly separated each stream into intermittent and perennial stream types and evaluated the occurrence and reproduction of California red-legged frogs. The hydrograph stream type was determined by average precipitation and flow. It is important to note that during long periods of drought, several perennial streams become intermittent. In contrast, during "El Nino" events, some intermittent streams had continuous flow throughout the year. Breeding and non-breeding California red-legged frogs populations were evenly distributed in intermittent and perennial streams in each gradient type (Table 15). Based on this relatively small sample size, we found no difference between intermittent and perennial stream type and gradient within the District.

Table15. Distribution of breeding and non-breeding (unconfirmed) populations of California red-legged frogs (*Rana draytonii*) by intermittent and perennial stream gradient and stream type within the East Bay Regional Park District (1997-2002).

STREAM GRADIENT AND TYPE	NUMBER OF STREAMS WITH BREEDING N=10	NUMBER OF STREAMS POPULATIONS WITH UNCONFIRMED BREEDING N=16
LOW GRADIENT STREAMS		
Intermittent	**3**	**2**
Perennial	**3**	**3**
MODERATE GRADIENT STREAMS		
Intermittent	**----**	**1**
Perennial	**2**	**1**
HIGH GRADIENT STREAMS		
Intermittent	**2**	**3**
Perennial	**----**	**3**
EXTREME GRADIENT STREAMS		
Intermittent	**----**	**2**
Perennial	**----**	**1**

To illustrate percent slope and sinuosity, vertical and longitudinal profiles for each stream and gradient type are presented in Appendix B. Sinuosity can significantly reduce stream velocity. The hydrologic regime including flow velocity, duration, and power directly influences stream reach characteristics and determines the sequence of pools, riffles, runs, glides, and cascades. As gradients increase, glide-riffle-pool systems change to high energy cascading streams with infrequently spaced pools and the proportion of suitable habitat decreases. Based on our surveys, stream breeding California red-legged frogs appear to be very selective and consistently deposit eggs at or near the surface on vegetation in deep water pools, plunge pools, back water pools, and eddies. Successful breeding occurs in stable stream environments and at sites capable of supporting egg hatching and developing tadpoles. As stream scouring increases with gradient, fine sediments are transported downstream to settle in still water areas, which creates highly suitable tadpole habitat. California red-legged frog tadpoles are negatively buoyant and escape by rapidly descending and burying themselves in fine silt, clay, or sandy substrate.

Stream gradient may be a factor in population density and reproductive viability; although our preliminary data suggest that stream gradients are not limiting the distribution of California red-legged frogs. Regardless of stream gradient, individuals occur in streams with favorable conditions and the availability of still-water habitat appears to be a factor in successful stream breeding.

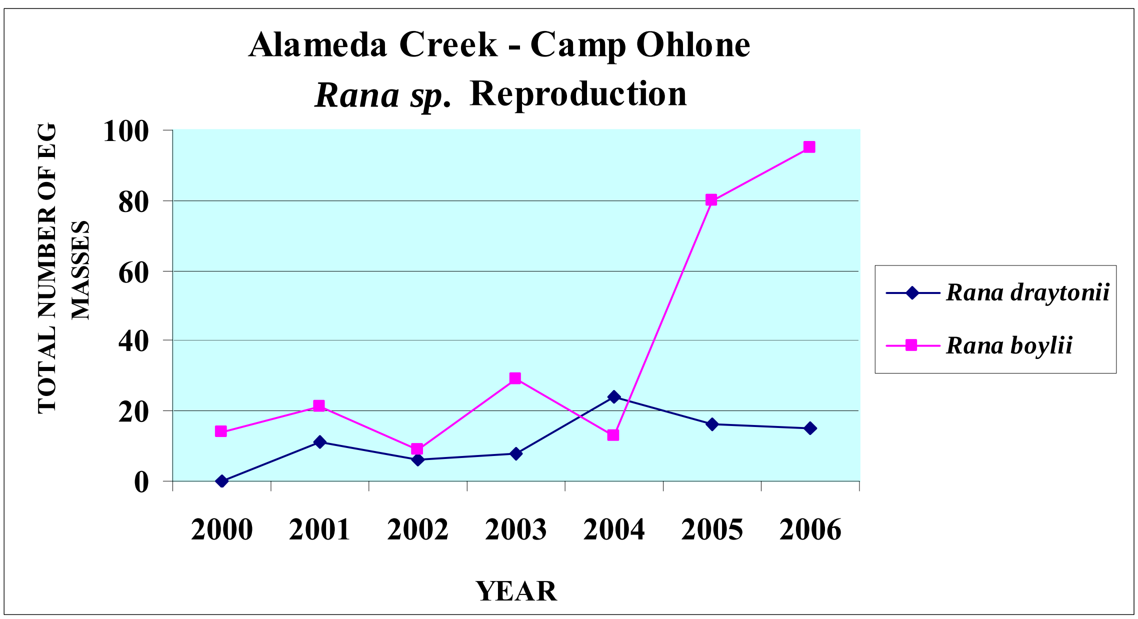
California red-legged frog and foothill yellow-legged frog in Alameda Creek

Within the District, California red-legged frog and foothill yellow-legged frog are sympatric in the Alameda Creek watershed. Unlike the California red-legged frog, the foothill yellow-legged frog only occurs in lotic systems and their complete life cycle is associated with fluvial environments. Both taxa inhabit Alameda Creek within the Sunol and Ohlone Regional Wilderness. As previously documented, California red-legged frogs typically occur in still water areas and attach their eggs to vegetation at or near the surface. Whereas, foothill yellow-legged frogs are common along rocky stream reaches and attach their eggs to submerged cobble, boulder or bedrock substrate within glides, runs, and pools.

To evaluate population trends we have been monitoring the reproductive output (egg deposition) of California red-legged frogs and foothill yellow-legged frogs in Alameda Creek. We selected two sites, a one mile stream reach in Camp Ohlone, and a two mile stream reach near the Sunol Visitor Center. Based on our stream surveys, egg deposition peaks for the California red-legged frog typically occur in mid to late March and for the foothill yellow-legged frog in mid April. Similar to California red-legged frog, foothill yellow-legged frog eggs typically hatch within 18-22 days and tadpoles metamorphose by fall. We conducted weekly surveys and documented the developmental state of each egg mass to determine the total number for each stream reach per year. General stream habitat conditions of all oviposition sites were documented and deposition locations were recorded with a hand-held GPS unit.

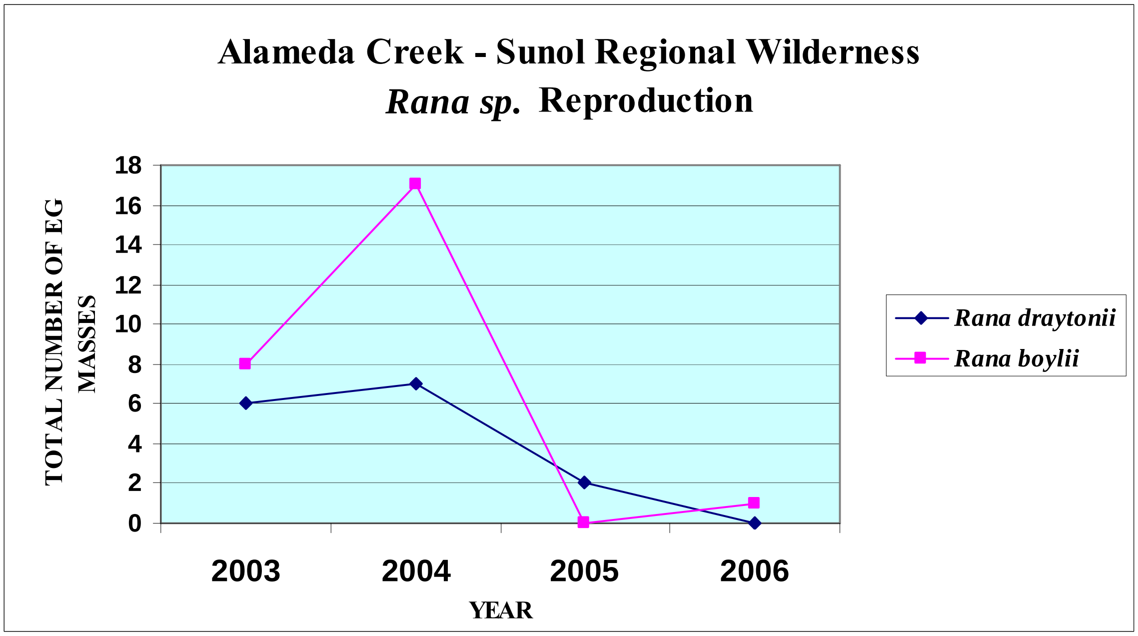
During our survey period from 2000 to 2006 at the Camp Ohlone study site, annual reproductive output for California red-legged frogs ranged from 0 to 24 egg masses, whereas for foothill yellow-legged frogs it ranged from 9 to 95 egg masses (Fig. 7). Stream conditions in Camp Ohlone appear to have been very suitable for California red-legged frogs in 2004, and extremely favorable in 2005 and 2006 for foothill yellow-legged frogs, where for the latter we documented a 276% and 328% increase in reproductive output, respectfully compared to previously recorded years (Fig. 7).

Fig.7. Reproductive output of California red-legged frog (*Rana draytonii*) and foothill yellow-legged frog (*Rana boylii*) within a one mile stream reach site at Camp Ohlone, 2000-2006.



The results from our survey period 2003-2006 at the Sunol study site showed that California red-legged frog reproductive output ranged from 0 to 7 egg masses, whereas foothill yellow-legged frog ranged from a high of 17 egg masses in 2004 to a low of 0 in 2005 (Fig. 8).

Fig.8. Reproductive output of California red-legged frog (*Rana draytonii*) and foothill yellow-legged frog (*Rana boylii*) within a two mile stream reach site in Sunol Regional Wilderness, 2003-2006.



In general, from 2003-2006, a two-mile stream reach, Sunol had significantly fewer California red-legged frog and foothill-yellow legged frog oviposition sites than the one-mile stream reach in Camp Ohlone. Overall, the reproductive output for California red-legged frog in the Sunol stream reach appears very low. Similarly, foothill yellow-legged frog reproduction was extremely variable. Relative to Camp Ohlone, the reproductive success of California red-legged frog and foothill yellow-legged frog in the Sunol stream reach site for most years was considerably lower.

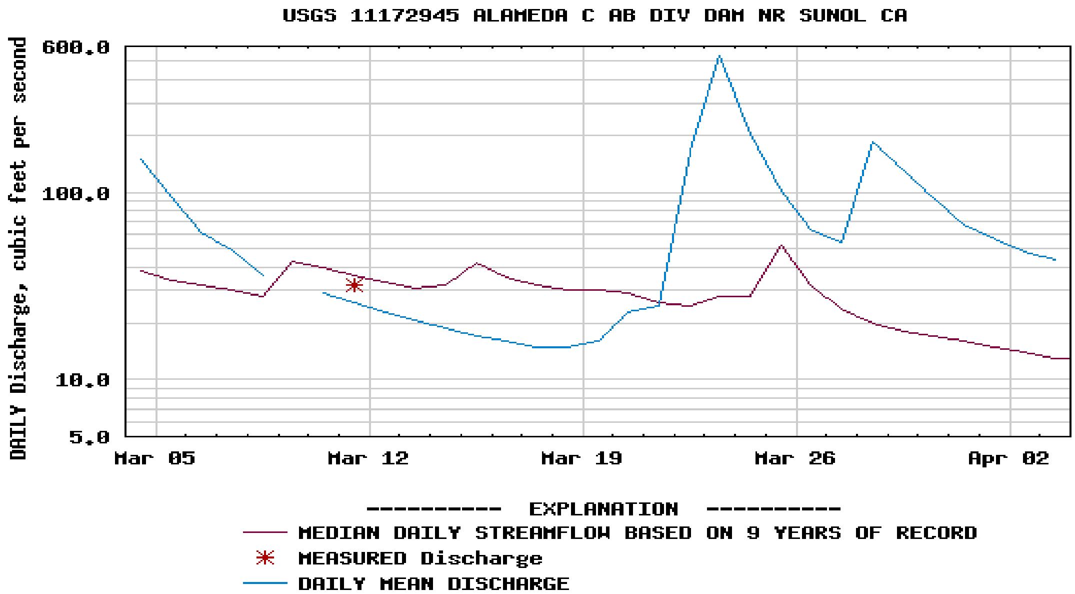
Stream flow regimes and ranid reproductive output

Alameda Creek, like most coastal streams, is rainfall dependent with tremendous seasonal range from winter flood flows to being intermittent or subsurface during years of drought. Lotic frogs tend to delay egg-laying until the end of spring flooding which normally coincides with the end of the winter rainy season (Appendix A). We evaluated the influence of flash flow, pulse flow, and irregular flow releases with breeding activity and reproductive success of California red-legged frog and foothill yellow-legged frog within Alameda Creek. To assess the effect of flow we compared egg deposition data with flow regime at the Sunol and Camp Ohlone study sites.

Flow regime is the condition of the stream with respect to average flow as measured by the volume passing a particular point (U.S. Team of Federal Agencies 1998). We used U.S. Geological Survey (USGS) hydrograph data from two flow stations in Alameda Creek. A USGS flow station is located above a Diversion Dam and Calaveras Creek while the other USGS flow station is located below the Diversion Dam and Welsh Creek. The flow station above the dam represented the "control" stream reach site, which thus measured natural flows. In contrast, the station below the dam represented the "experimental" stream reach site, with flows affected by diversion and/or pulse releases from Calaveras Reservoir into Alameda Creek. The control study site at Camp Ohlone was a one mile stream reach with a gradient of 1.1%. The experimental site at Sunol Regional Wilderness was a two mile stream reach with a gradient of 1.7%. Flow frequency, duration, and discharge measured in cubic feet per second (cfs) produced cumulative histograms that were used for analysis.

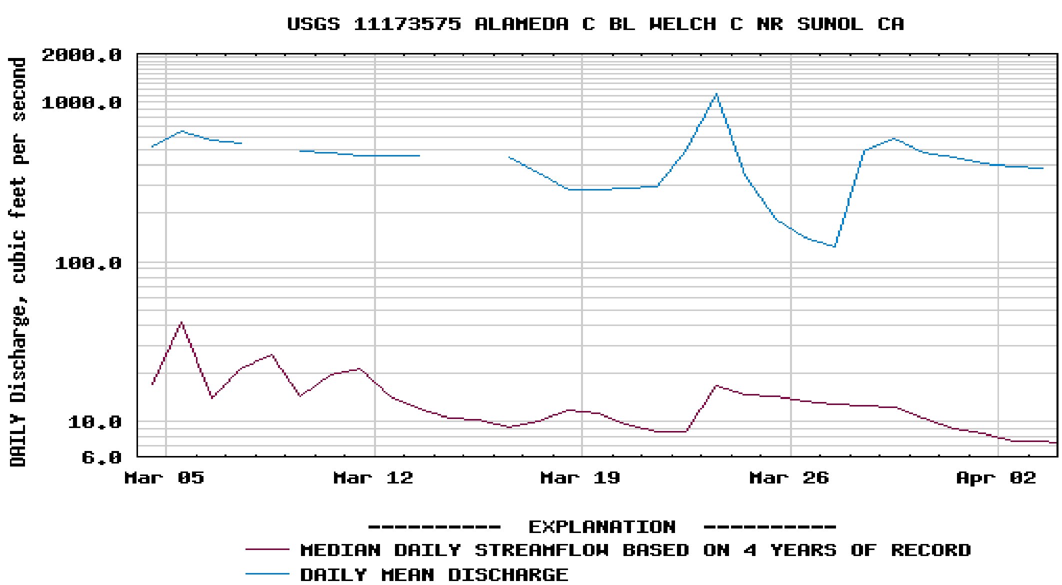
While conducting California red-legged frog and foothill yellow-legged frog surveys from March through May of 2005, measured water discharge was generally above the median streamflow at both the control and the experimental sites (Figs. 9 and 10). In March at the control site, flow ranged from a low of 16 cfs to a high of 520 cfs on March 23 and 24, the only two days with a notably higher discharge than the median daily streamflow based on 9 years of records (Fig. 9). During this period of peak egg deposition for the California red-legged frog, we documented a total of 18 egg masses in Alameda Creek at Camp Ohlone, a number consistent with previously recorded years.

Fig.9. USGS flow station results in Alameda Creek above the dam at the control stream reach site for March 5 to April 4, 2005.



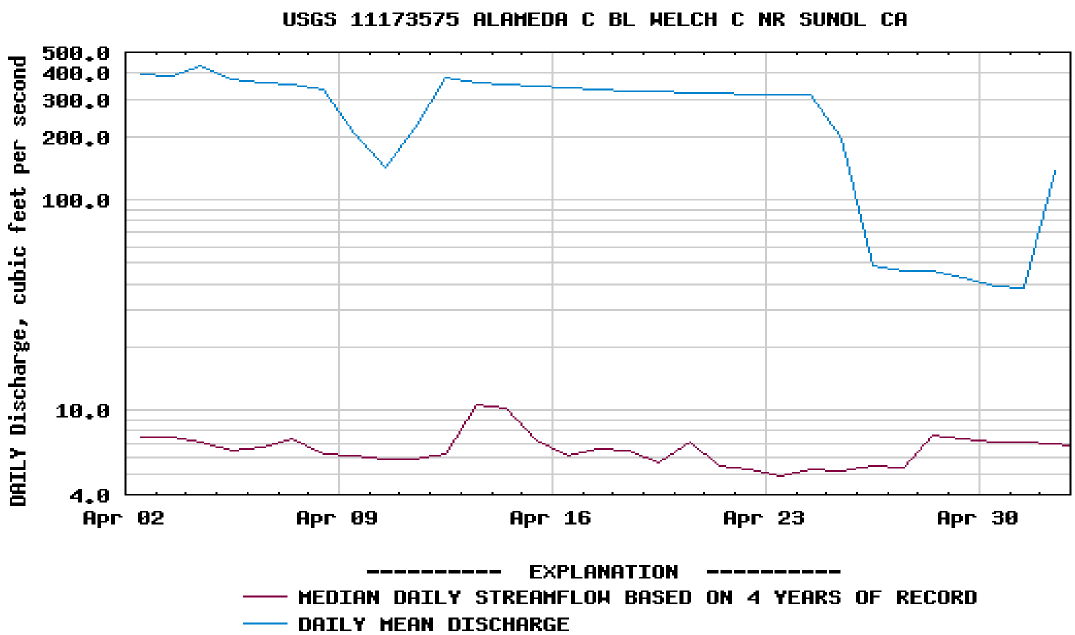
In contrast, during March 2005 at the experimental site, discharge ranged from 130 cfs to 1200 cfs and the entire month had significantly higher discharge than the median daily streamflow based on 4 years of records (Fig. 10). Furthermore, egg deposition for the California red-legged frog was considerably lower than in previous years, and the only 2 egg masses documented were dislodged and damaged by the high stream flow.

Fig.10. USGS flow station results in Alameda Creek below Calaveras Reservoir at the experimental stream reach site for March 5 to April 4, 2005.



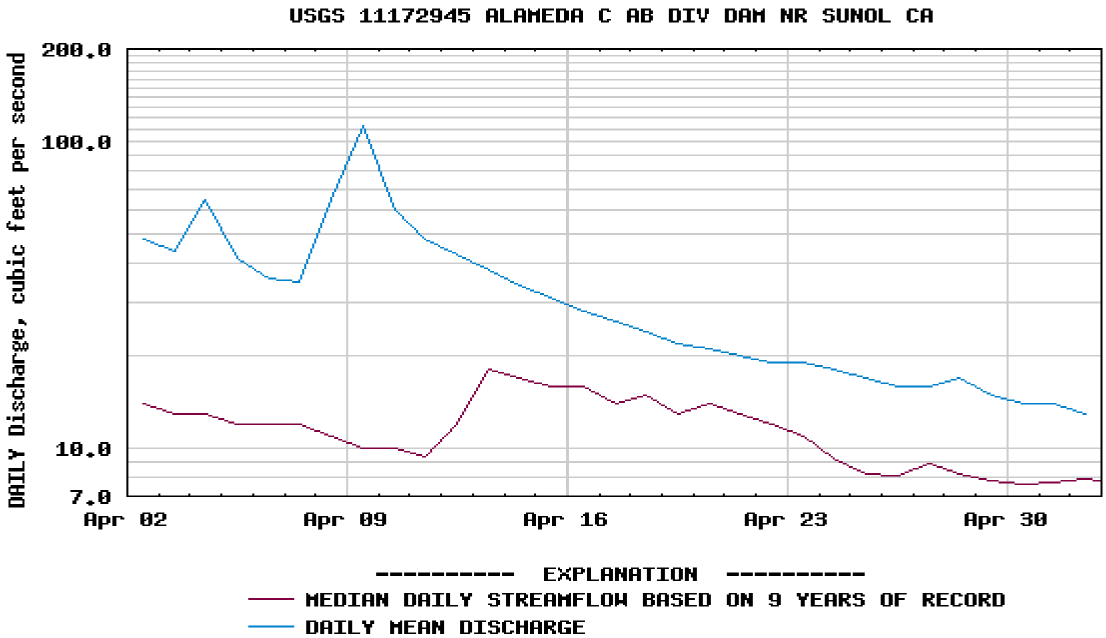
At the experimental site, the irregular high releases from Calaveras Reservoir continued through April and into early May, 2005, and flows were significantly higher than median daily streamflow. The discharge ranged from 39 cfs to 450 cfs, and for approximately three weeks the flow was consistently above 300 cfs (Fig. 11). During this period we did not document any foothill yellow-legged frog reproduction.

Fig.11. USGS flow station results in Alameda Creek below the Calaveras Reservoir at the experimental stream reach site for April 4 to May 3, 2005.



Throughout April at the control site, daily mean discharge ranged from 13 cfs to 112 cfs. Although flows were consistently higher than the median daily streamflow, they closely mimic the natural discharge patterns (Fig. 12). In contrast to the poor reproductive conditions below Calaveras Reservoir, stream conditions at the control study site appear to have been very favorable for foothill yellow-legged frog, where a total of 80 egg masses were documented.

Fig. 12. USGS flow station results in Alameda Creek above the dam at the control stream reach site for April 4 to May 3, 2005.



Water Quality

Several water quality variables are often identified as the probable cause for deleterious effects on aquatic biota and wildlife. To assess water quality in lotic and lentic waterbodies, we evaluated the influence of water temperature, pH, dissolved oxygen, nitrogen, and turbidity within the distribution of California tiger salamander, California red-legged frog, and other aquatic herpetofauna throughout the District.

Surface water temperature

During our pond and stream surveys, surface water temperatures were measured at each site. In addition, throughout the year we documented water temperature at several stream and pond locations. Water temperature is considered a crucial factor in stream habitat suitability for many aquatic species, e.g. *Anura spp.* and *Salmonid spp.* (Zug 1993, Flosi *et al.* 1998).

Annual stream surface water temperatures ranged from –1.0°C to 22.5°C (Table 16, Fig. 13). In some stream reaches daily water temperature fluctuated by as much as 6.0°C (Table 16). Individual California red-legged frogs and their egg masses appear to tolerate periodic and brief surface freezing. However, we suspect that cold water can affect timing and duration of breeding, delay tadpole development, and prolong metamorphism. We have documented that some California red-legged frog tadpoles overwinter, and this may be temperature related where low water temperature may suppress metamorphosis (Fellers et al. 2001). Thus in colder streams, breeding period may be delayed and reproductive output limited. In addition, cold water can limit the production of algae thus reducing the food availability for tadpoles. Most tadpoles in Round Valley Creek metamorphose into frogs from July through September. This coincides with surface water temperatures ranging between 18˚C and 21˚C, the latter of which was the highest measured throughout the year (Table 16). In September, water temperatures began to cool to between 14˚C and 16˚C. In November they dropped further to between 11.0˚C and 13.0˚C, and by December temperatures dropped to a low of 3.5˚C (Table 16). These cold water temperatures appear to suppress growth and development and induce some late season tadpoles with rudimentary limbs to overwinter in this stage. We are currently monitoring water temperature to evaluate whether it is a key factor in this overwintering phenomenon.

Surface water temperatures were influenced by seasonal air temperatures. The direct effect from solar and radial loading increased the daily surface water temperatures 0.5 to 6.0 ˚C in Round Valley Creek (Table 16).

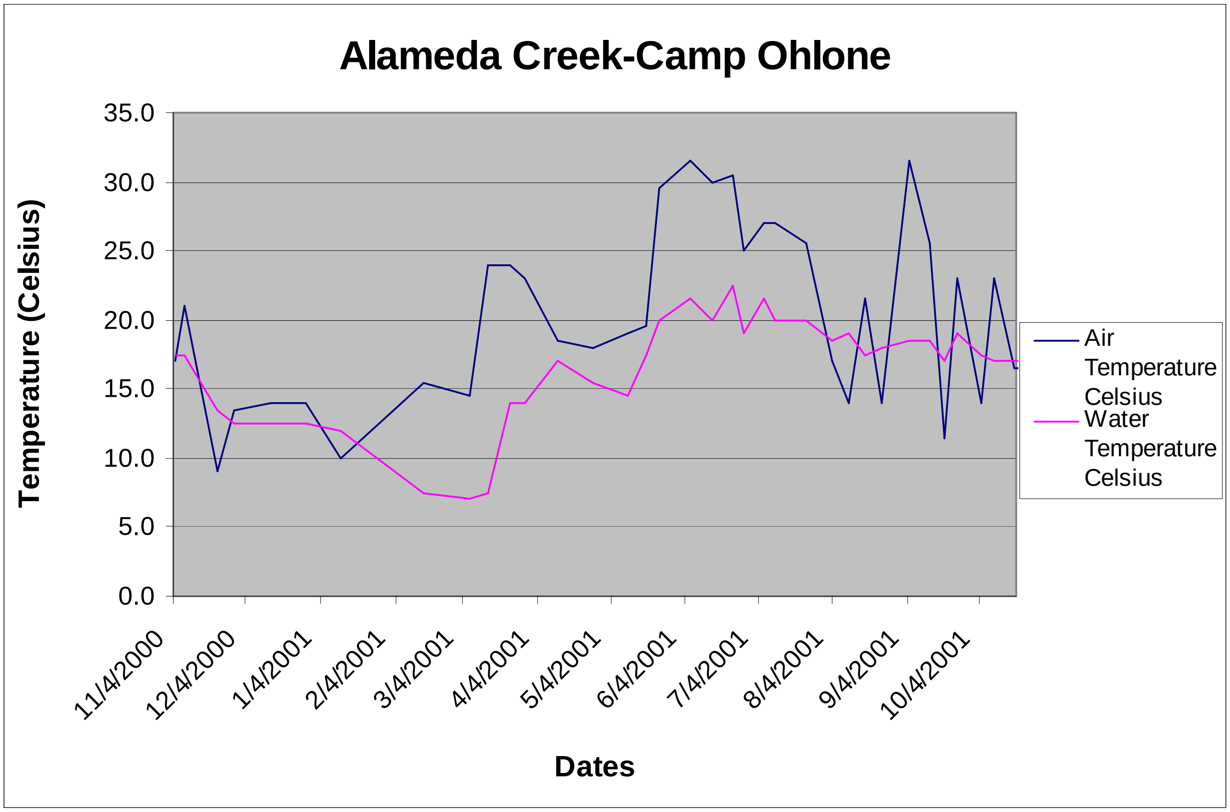
Table16. Round Valley Creek measurements of surface water temperature (Celsius) at Round Valley Regional Preserve, Contra Costa County, California, 1999. Water temperatures were recorded at the same location using the same thermometer.

MONTH	SURFACE WATER TEMPERATURE ˚C	DAILY WATER TEMPERATURE RANGE ˚C
January	4.0 ˚C	Not measured
February	6.5 ˚C	Not measured
March	11.0 - 16.0 ˚C	5.0 ˚C
April	12.0 - 18.0 ˚C	6.0 ˚C
May	13.0 ˚C	Not measured
June	14.0 - 17.0 ˚C	5.0 ˚C
July	18.0 ˚C	Not measured
August	18.0 - 21.0 ˚C	3.0 ˚C
September	14.0 - 16.0 ˚C	2.0 ˚C
October	13.5 ˚C	Not measured
November	11.0 - 13.0 ˚C	2.0 ˚C
December	3.5 - 4.0˚C	0.5 ˚C

Air temperature and surface water temperature

In Alameda Creek at Camp Ohlone we documented air temperature and surface water temperature each week from November 4, 2000 through October 18, 2001. During this period, air temperatures ranged from 9.0 ˚C to 31.5˚C and surface stream temperatures range from 7.0 ˚C to 22.5 ˚C. Temperatures were measured at various times which illustrated some of the rapid and extreme change in weekly air temperature (Fig. 13). Nevertheless, throughout the year surface water temperature was influenced by air temperature.

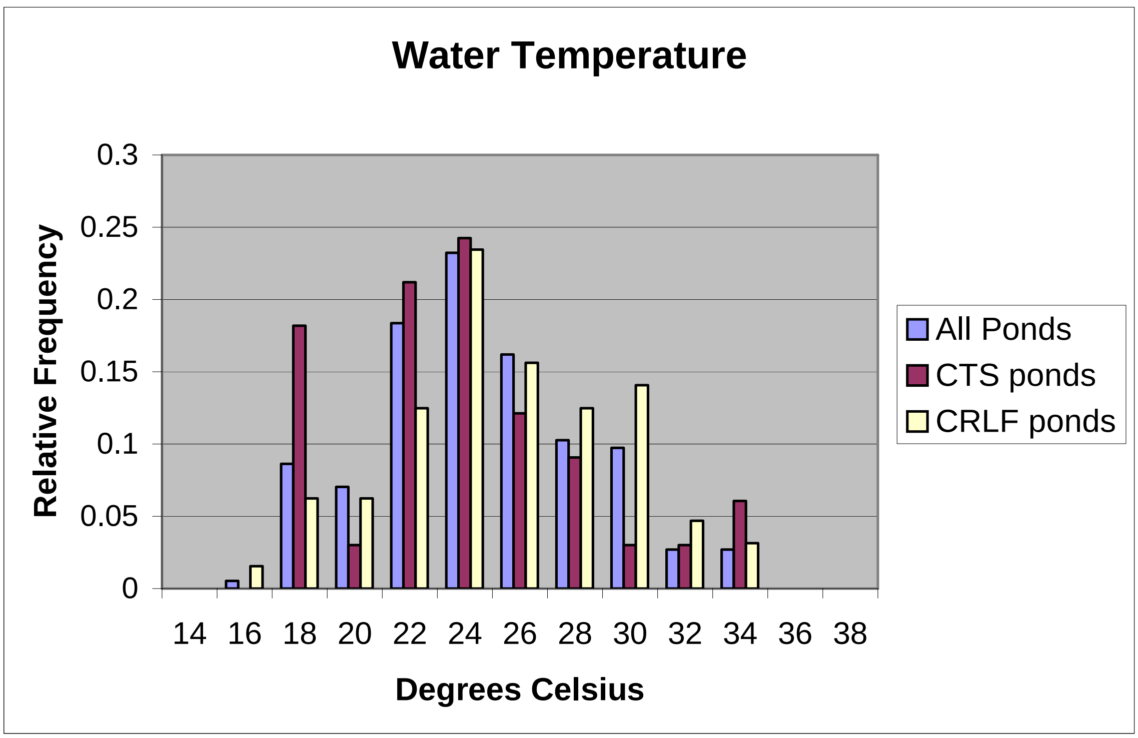
Fig. 13. Air and surface water temperatures (Celsius) in Alameda Creek at the Camp Ohlone study site in Sunol Regional Wilderness, Alameda County, California, 2000-2001. Water temperatures were recorded at the same location using the same thermometer.



The Camp Ohlone stream reach in Alameda Creek supports robust populations of California red-legged frog and foothill yellow-legged frog. In addition, other aquatic herpetofauna including California newt, Western toad, Pacific tree frog, and Western pond turtle (*Clemmys marmorata*) co-occurred with these ranids and were reproductively successful in this stream reach.

As previously noted, water temperature may influence physiological, metabolic processes, and distribution of aquatic organisms. In 2004, we compared the surface water temperature for lentic waterbodies to the distribution of aquatic herpetofauna within the District. During late spring and summer, California red-legged frogs occurred in ponds with surface water temperatures ranging from 15.3˚C to 33.2˚C. The median surface water temperature for this period was 24.4 ˚C with an absolute of range of 17.9 ˚C. Similarly, California tiger salamanders larvae were documented in ponds with surface water temperatures ranging from 16.2 to 33.2˚C. The median surface water temperature in California tiger salamander ponds was 22.3 ˚C with an absolute range of 17.0 ˚C. The relative frequency profile of surface water temperatures for California red-legged frog ponds was comparable to the relative frequency profile of surface water temperatures for all ponds measured within the District (Fig. 14). The relative frequency of surface water temperatures of California tiger salamander ponds varied more than the relative frequency of surface water temperatures for all ponds (Fig. 14). In summary, the surface water temperature profile of California red-legged frog ponds was similar to that found in all ponds, whereas the surface water temperature profile of California tiger salamander ponds showed more variation than all ponds in the District.

Fig. 14. Relative frequency of surface water temperatures (Celsius) within all lentic waterbodies, California red-legged frog (*Rana draytonii*) ponds and California tiger salamander (*Ambystoma californiense*) ponds, throughout the District in 2004.



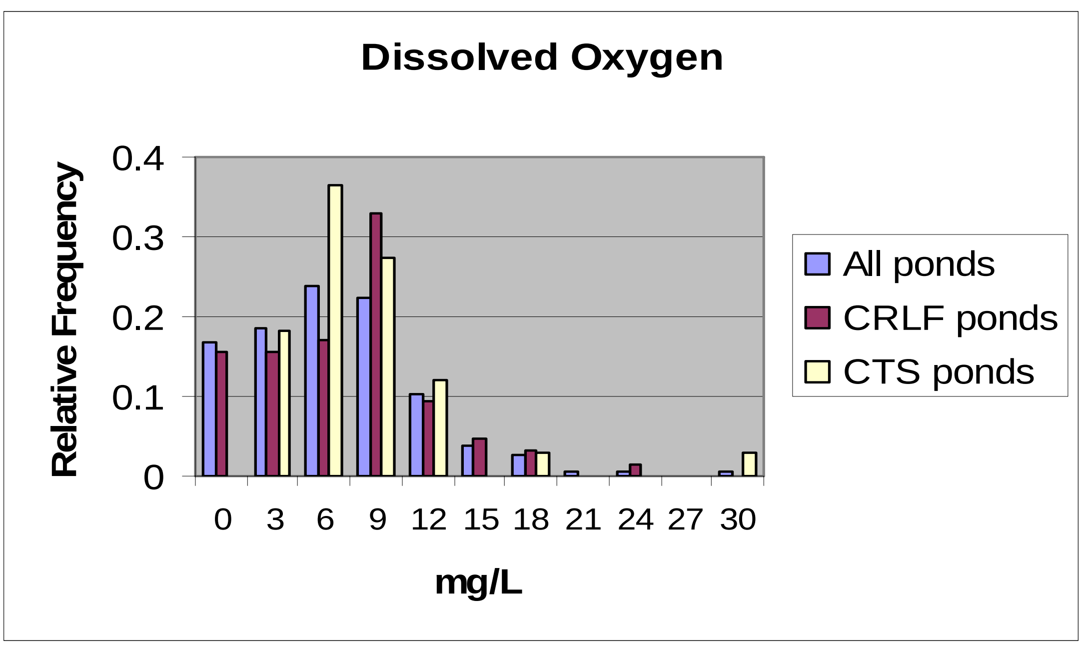
During the survey period, California newt and the Pacific tree frog occurred in very warm ponds up to a maximum surface water temperature of 38.5 ˚C, and absolute ranges of 21.0 ˚C and 23.2 ˚C, respectfully. In contrast, bullfrogs inhabited the cooler ponds, up to a maximum surface water temperature of 25.3 ˚C and an absolute range of only 8.8 ˚C.

Dissolved oxygen

Water temperature directly influences dissolved oxygen (DO), whereby warmer temperatures decrease DO solubility. Dissolved oxygen is considered a limiting factor for aquatic systems and a basic requirement for healthy aquatic ecosystems (U.S. Team of Federal Agencies 1998). In Round Valley Creek, dissolved oxygen ranged from 2.9 to 10.6 mg/L. This stream supports a viable breeding population of California red-legged frogs, where in some years adult numbers can exceed 70 individuals. In addition, Round Valley Creek provides highly suitable aquatic and reproductive habitat for Pacific tree frog and Western toads.

For 2004 we compared the distribution of aquatic herpetofauna with dissolved oxygen in our lentic waterbodies. During late spring and summer, we documented California red-legged frogs in ponds with DO ranging from 0.0 to 24.5 mg/L. The median DO in California red-legged frog ponds was 9.6 mg/L, with an absolute range of 24.5 mg/L. The relative frequency of DO levels in California red-legged frog ponds was comparable to the relative frequency of DO levels measured across all ponds within the District (Fig. 15). The median DO in California tiger salamander ponds was 8.7 mg/L, with an absolute range of 26.9 mg/L (Fig. 15). The DO in California tiger salamander ponds ranged from 3.2 mg/L to 30.1 mg/L (Fig. 15), although the majority of the ponds with larvae had DO levels that ranged from 7 mg/L to 17 mg/L (Fig. 15).

Fig. 15. Relative frequency of dissolved oxygen within all lentic waterbodies, California red-legged frog (*Rana draytonii*) ponds and California tiger salamander (*Ambystoma californiense*) ponds throughout the District in 2004.



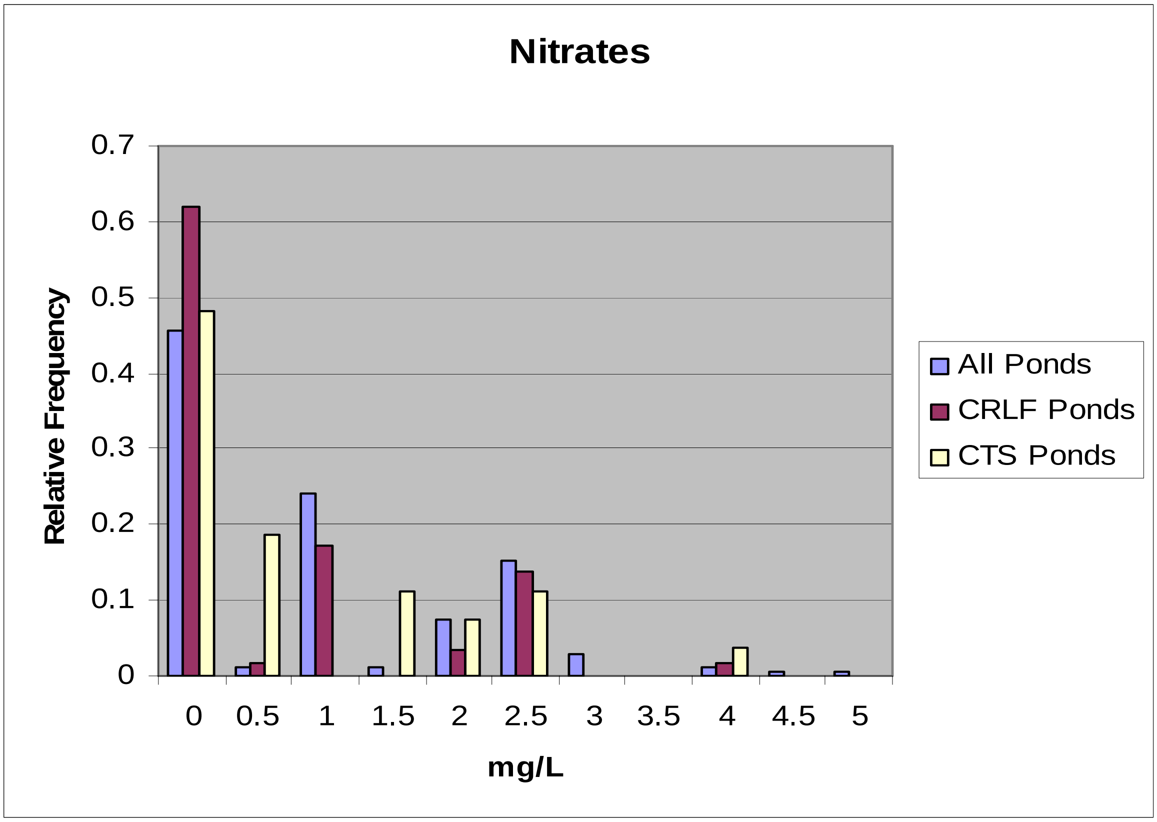
In addition, California newt and the Pacific tree frog occurred in ponds with almost identical levels of DO, from a minimum of 0.0 mg/L to maximums of 22.5 mg/L and 24.5 mg/L, respectfully. Bullfrogs, however, were documented in ponds with DO levels ranging from a minimum of 0.1 mg/L to a maximum of 16.8 mg/L. Thus, bullfrog ponds exhibited the narrowest absolute DO range, 16.7 mg/L.

Nitrogen

In aquatic systems, nitrogen can exist in several forms including dissolved nitrogen gas, ammonia and ammonia ion, nitrite, and nitrates (U.S. Team of Federal Agencies 1998). We collected data on nitrates because of their immediate water quality impacts associated with non-point sources including livestock grazing. However, the effect of nitrates on amphibians in natural waterbodies is not well understood. Nevertheless, a recent study found that several tadpole taxa (i.e. Oregon spotted frog, Northern red-legged frog, Pacific tree frog and bullfrogs) raised in water with low levels of nitrates < 7 mg/L suffered paralysis and eventually died (Blaustein 2000). The study concluded that nitrates themselves exhibit low toxicity but cause problems once they are reduced to nitrites.

In 2004 we examined nitrate levels in our lentic waterbodies associated with the distribution of aquatic herpetofauna within the District. Although the majority of these waterbodies are exposed to livestock grazing during late spring through summer, nitrate levels in all ponds were < 5.0 mg/L, and 92.5 % of all ponds exhibited nitrate levels of < 2.5 mg/L (Fig. 16). The median nitrate level for all ponds was 1.0 mg/L. These low nitrate levels were even documented in extremely small, very shallow (10 cm deep) ponds with livestock. Moreover, in nearly half (45.6%) of all ponds, nitrate levels were non-detectable and measured 0.0 mg/L. The relative frequency of nitrate levels in California tiger salamander ponds was similar to the nitrate levels of all ponds, ranging from 0.0 to 4.5 mg/L (Fig. 16), with a mean of 1.1 mg/L and a median of 1.0 mg/L. California red-legged frogs were more frequent in ponds with low nitrate levels (Fig. 16). Nitrate levels in 62% of California red-legged frog ponds was 0.0 mg/L, and ranged up to 4.0 mg/L with mean of 0.7 mg/L, and a median of 0.0 mg/L (Fig. 16).

Fig. 16. Relative frequency of Nitrates within all lentic waterbodies, California red-legged frog (*Rana draytonii*) ponds and California tiger salamander (*Ambystoma californiense*) ponds, throughout the District in 2004.



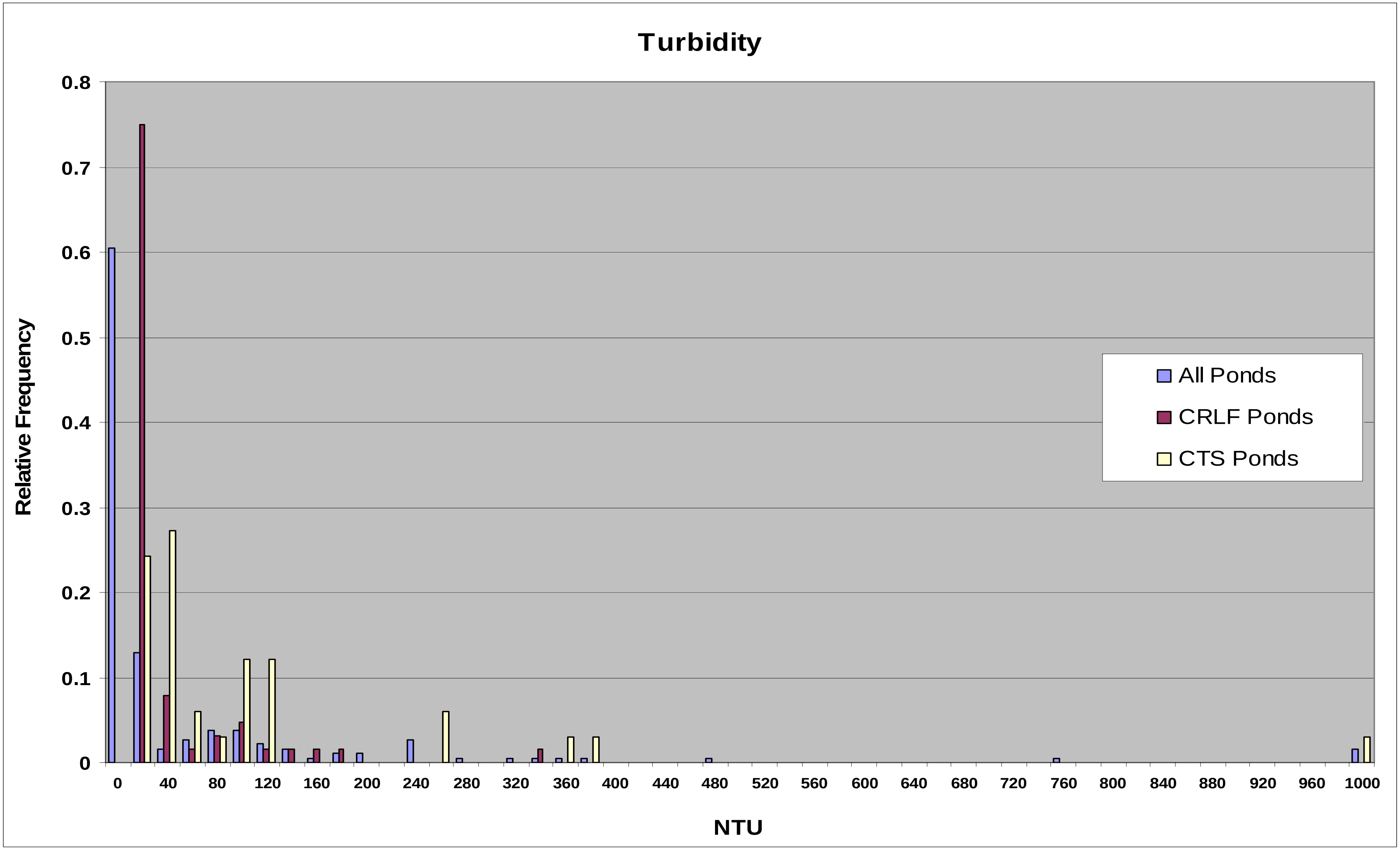
During the survey period, in 21 ponds occupied by bullfrogs, the nitrate levels ranged from 0.0 mg/L to 2.5 mg/L. California newt and the Pacific tree frog occurred in ponds with almost identical nitrate levels, ranging from a minimum of 0.0 mg/L to maximums of 3.0 mg/L and 4.0 mg/L, respectfully.

Turbidity

Water may contain various suspended and dissolved matter such as clay, silt, fine organics, plankton, and other microscopic organisms. These small solids can affect the color and cause the water to be turbid or cloudy. Turbidity is recognized as an indicator of the "health" of a waterbody. Although, sediments are an important and vital component of instream habitat, gravels should be reasonably free of fine sediment in order for several amphibians and salmonids eggs and larvae to survive. However, the effect of turbidity on most lentic amphibians is not well understood.

Turbidity was measured in nephelometric turbidity units (NTU). During late spring through summer in 2004, turbidity in all ponds ranged from 0.7 NTU in very clear water to 1000.0 NTU in extremely turbid conditions (Fig. 17). The mean for all ponds (N = 185) measured District-wide was 67.3 NTU, and the median was 10.1 NTU. We observed California red-legged frog in turbidities ranging from 0.9 NTU to 326.0 NTU (mean = 27.0 NTU, median = 4.6 NTU), and 75% of the California red-legged frog ponds exhibited turbidities ≤ 20 NTU (Fig. 17). Compared to all ponds, California red-legged frogs inhabited "visually clear" waterbodies. Conversely, California tiger salamanders were documented in a wide range of ponds with turbidities from 1.6 NTU to 1000 NTU. Moreover, the relative frequency of California tiger salamander occurrence was more closely associated with moderate to very turbid conditions (Fig. 17), where 76% occurred in ponds with ≥ 40 NTU (mean =106.1 NTU, median = 35.5 NTU). Furthermore, we found that ponds with higher turbidities contained higher larvae densities than clear waterbodies exhibiting turbidities of <10.0 NTU.

Fig.17. Relative frequency of turbidity in all lentic waterbodies, California red-legged frog (*Rana draytonii*) ponds, and California tiger salamander (*Ambystoma californiense*) ponds throughout the District in 2004.



Within our lentic waterbodies, California newt and the Pacific tree frog occurred in ponds with similar turbidities with means of 50.6 NTU and 63.7 NTU, respectively, and medians of 7.9 NTU and 10.2 NTU, respectfully. However, Pacific tree frogs inhabit ponds with a wider turbidity series ranging from 0.9 NTU to 1000.0 NTU. Similar to California red-legged frogs, bullfrogs were documented in visually clear waterbodies, where 81% occurred in ponds with turbidities of ≤ 20 NTU (mean = 28.1 NTU, median = 3.7, absolute range = 357.4 NTU).

Stream pH

Acidity and alkalinity are important water parameters that influence chemical reactions and affect habitat suitability. Like water temperature, stream pH varies seasonally, and we have documented California red-legged frog in streams with pH ranging from 2.8 to 10.8. A pH of 5 is considered moderately acidic. In contrast, a pH of 9 represents moderately alkaline conditions. The most acidic stream conditions were found in Markley Creek (Black Diamond Mines Regional Preserve), a condition attributed to the presence of mine tailings within the watershed. As previously noted, breeding California red-legged frogs have not been documented in this creek (Table 12).

Salinity

Other water variables, such as salinity, influence aquatic systems. California red-legged frogs are very sensitive to high salinity conditions. For example, laboratory experiments on California red-legged frogs have shown that salinity levels greater than 4.5 parts per thousand (ppt) caused 100% egg mortality (Jennings and Hayes 1990), and salinity levels > 7.0 ppt caused 100% tadpole mortality (Jennings 1993). Within the District, California red-legged frog and California tiger salamander are restricted to inland waterbodies with low salinity. In contrast, Pacific tree frogs and Western pond turtles have been found near several coastal lagoons and Delta channels, where they appear to tolerate higher salinity levels.

Additional water quality results in lentic waterbodies for the various herpetofauna taxa are in Appendix. Although these preliminary water quality results provide some information, the affects of these and other water characteristics on the lentic and lotic herpetofauna warrant further investigation.

Biotic factors

Pathogens and parasites may influence behavior and affect survivorship of their host species (Johnson *et al*., 2001). We recently confirmed and documented limb deformities in Pacific tree frogs at a pond (brpond018 located at 37˚56.675N; 122˚08.033W) in Briones Regional Park. Relative densities of abnormal frogs were low compared to normal individuals. Abnormal metamorphs exhibited hemi and ectromely (missing limbs), while others exhibited polydactyly or polymely (extra digit and limbs). These morphological deformities are consistent with symptoms associated with infection by a trematode, the parasitic flatworm *Ribeiroia sp.* (Johnson *et al*., 2001). This particular pond also contained an exceptionally high density of aquatic snails, which can serve as intermediate host for *Ribeiroia*. In addition, the primary hosts of *Ribeiroia*, waterfowl and herons, frequent this pond. Although the aquatic snails were not keyed-out, they did appear similar to *Palnorbella tenuis*, a species of snail that serves as the usual host for miracidia of *Ribeiroia*. After the initial snail infestation, free swimming trematode cercaria attack tree frog tadpoles and form metacercarial cysts in the pelvic girdle and hind limbs. Such cysts are often found in close association with abnormal or extra limbs of frogs (Johnson *et al*., 2001).

Parasitic tremetodes are likely to adversely affect the survivorship of infected tadpoles and metamorphs of the Pacific tree frog. Within the District, outbreaks of deformed Pacific tree frogs occurred in 2003 and 2005, during years with above average rainfall. Although Pacific tree frog malformations have occurred in several Bay Area Counties, based on all our surveys from 1990 – 2006, the frequency of abnormal individuals appears to be extremely low within District waterbodies.

In 1999 several California red-legged frog tadpoles in Round Valley Creek were diagnosed having chytrid fungus (*Batrachochytrium dendrobatidis*). These tadpoles showed few clinical signs of the disease except for their mouths and mouth parts, which had become deformed. Whether the chytrid fungus is responsible for California red-legged frog mortality or declines is still unknown. We are currently examining tadpoles throughout the District to determine the extent of the fungal infestation.

One of the chytrid-infected California red-legged frog tadpoles, collected by Gary Fellers (USGS) on November 3, 1999 and subsequently sent to a toxicologist had an "enlarged liver." It was determined that this tadpole was unlikely to survive because of its liver condition. Water samples collected from Round Valley Creek tested positive for *Microcystis aeruginosa*-like algae. *Microcystis aeruginosa* is a native freshwater algae which can cause liver damage (Fellers pers. commication). Apparently, when stream water temperatures are high, water pH is neutral or slightly alkaline, and the water contains ample nutrients (i.e. nitrogen and phosphorus), *M. aeruginosa* will release the toxin microcystin as it expires (Fellers pers. commication). We are continuing to examine and monitor this situation.

Under what is otherwise considered optimal conditions, California red-legged frogs are not ultilizing streams in the District that are dominated by eucalyptus (*Eucalyptus spp*.) and/or California bay laurel (*Umbellularia californica*). Eucalyptus and bay laurel are allelopathic and their very aromatic leaves may secrete toxic chemicals into the water that somehow affect California red-legged frogs. Alternatively, the densely vegetated closed canopies of eucalyptus and California bay laurel drainages may not allow enough sunlight penetration into the stream to allow for adequate thermoregulation. Based on our observations, California red-legged frogs are closely associated with riparian habitats having sunny streams reaches. Nonetheless, it is interesting that we have not observed California red-legged frogs in any drainage or pools with eucalyptus and/or bay laurel as the dominant bankside vegetation.

The arrangement of habitat features appears to influence the demographic distribution of California red-legged frogs in lotic systems. Subadult and adult frogs tend to occupy highly suitable stream reach habitat. Conversely, metamorphs and juveniles are widely distributed throughout the stream, appearing to exhibit avoidance behavior and segregating themselves away from the adults. Overall, very little is known about metamorph-juvenile movements and dispersal. During a 1998 spring survey we observed two juveniles in a vernal pool approximately 110 meters from Round Valley Creek. Dispersing into and occupying marginal habitat is likely to expose metamorphs and juveniles to higher predation risks, but may reduce the risks from adult cannibalism in their natal ponds. By September we typically observe a significant decrease in their numbers, which typically coincides with notable increases in predator activity. Predators on metamorhps and juveniles documented by us include raccoons (*Procyon lotor*), garter snakes (*Thamnophis spp.*), great blue herons (*Ardea herodias*), red-shouldered hawks (*Buteo lineatus*), Western scrub jay (*Aphelocoma californica*), and adult California red-legged frogs. We have observed garter snakes predating California red-legged frog egg masses and tadpoles, including one instance when a very small garter snake (28-30 cm) wrapped itself around an egg mass and preyed upon the emerging embryos. California newts have been observed cannibalizing egg masses and may also predate frog eggs.

SUMMARY

Many anthropogenic and natural environmental conditions affect amphibians in the wild. Because most amphibians require aquatic and terrestrial ecosystems they tend to be excellent environmental barometers. Furthermore, there is increasing recognition that a variety of indirect and direct variables independent or in conjunction may influence their distribution and survivorship. Thus, developing reliable sampling techniques and methods for analyzing robust data-sets is essential in assessing amphibian populations over time.

Since 1990 District biologists have been monitoring aquatic herpetofauna populations on our lands within Alameda and Contra Costa Counties, California. To evaluate lentic habitat suitability we have systematically surveyed over 271 freshwater ponds. On District lands, California tiger salamanders breed almost exclusively in seasonal and perennial stock ponds. Not all of the potentially suitable District ponds supported California tiger salamander breeding, and not all of the breeding ponds were used by salamanders every year. Within the District, a total of 170 ponds are in the distributional range of California tiger salamanders and they have been documented breeding in 75 or 44% these ponds.

Our data and analyses suggest that California tiger salamanders are most reproductively successful in ponds containing relatively low aquatic diversity. We found a negative association between predacious aquatic hexapods and California tiger salamanders: salamanders were generally not present in ponds with predacious hexapod taxa, and in some ponds, the occurrence of either predacious aquatic hexapods or salamanders shifted between survey years. Aquatic vegetation, whether submerged or emerged, appeared to have a negative effect on the occurrence of California tiger salamander breeding: the majority of salamander breeding ponds had ≤ 5% aquatic vegetation. However, California tiger salamanders were more likely to occur in ponds with a wider range of submerged vegetation versus emerged vegetation. Conversely, predacious aquatic hexapods were abundant in ponds with higher percentages of aquatic vegetation. It appeared that predacious aquatic hexapods required more vegetative structure to cling to, deposit their eggs, and for metamorphic nymphs to emerge out of the water as they changed to winged adults.

Significant negative associations were detected in pond occurrence between California tiger salamanders and several native predators/competitors including the Western toad, California newt and garter snakes. Non-native predators such as bullfrogs and warm water fish also negatively affected the occurrence of salamander breeding in ponds. Conversely, Pacific tree frogs and California red-legged frogs co-occurred in 72% and 39% respectively, of the California tiger salamander breeding ponds. In some years and ponds, rapid drying led to documented egg desiccation in ponds with reduced water levels.

Within the District California red-legged frog has been documented in 75 distinct ponds, 23 drainages, and several spring boxes. The percentage of occupied ponds with reproduction ranged from 73% to 89% during our 1996, 2000, and 2004 survey periods.

California red-legged frogs occur in ponds with and without emerged and submerged vegetation but require some open water edge habitat for egg deposition. The lack of significant differences between ponds of varying vegetation types in our 1996 data could be attributed to several things, including small sample size, outlying data points and inconsistent sampling technique. Several ponds could not be adequately surveyed to determine the total number of individuals due to submerged and/or emerged vegetation. Nevertheless, the 2004 results suggest that California red-legged frogs appear to be closely associated with ponds containing < 40% emerged vegetation and frog occurrence was also considerably higher in ponds with ≤5% submerged vegetation. The highest breeding densities were consistently documented in ponds with a relatively high percentage of open water and vegetative edge habitat utilized as oviposition sites. In contrast, ponds dominated by emerged vegetation, especially *Typha spp.*, tend to support non-breeding subadult and adult California red-legged frogs. Over time, heavily vegetative waterbodies accumulated sediment, which diminished open water and became less suitable for successful frog breeding.

Based on our observation and analysis, the California tiger salamander co-exists and benefits from managed livestock grazing. Annual grasslands, mixed grasslands or oak savannah dominate the uplands surrounding the breeding ponds. The District uses livestock grazing for vegetation management and uplands are seasonally grazed to the vegetation standards that translate into 4 to 6 inches of standing vegetation or 700 to 1000 pounds (lbs.) of Residual Dry Matter (RDM). Livestock grazing maintains upland habitat for burrowing mammals and the open water characteristics of the ponds. Uplands are critical for this species, and there appears to be a strong positive correlation between ground squirrel burrows, grazed grasslands and stock ponds, and the occurrence of California tiger salamander. Grazing appears to be an important mechanism that provides ecological opportunities for California tiger salamanders.

Similarly, our observations and results suggest a positive association with the presence of livestock grazing and the occurrence of California red-legged frog on District lands. The vast majority of ponds and all 26 stream reaches with California red-legged frogs are exposed to livestock. Consistently throughout the District, the lentic and lotic habitats with open water edge exhibited the highest rates of annual breeding. In 2004, virtually all the California red-legged frog ponds with successful breeding populations were exposed to grazing and had $\leq$35% emerged vegetation. In addition, the most reproductively viable streams: Alameda, Pine, Round Valley, and Sand Creeks are moderately grazed. By maintaining the open water emerged vegetative edge habitat livestock grazing has a neutral to beneficial effect on California red-legged frogs.

Clearly, stock ponds are essential for reproduction and the long-term survival of the California tiger salamander and California red-legged frog populations on District lands. Overall, the development of artificial ponds for livestock water has created highly suitable reproductive habitat which has augmented the California tiger salamanders and California red-legged frog populations in the East Bay. Continued management of the District's stock ponds and surrounding uplands is essential in maintaining suitable breeding and terrestrial habitat for California tiger salamanders and California red-legged frogs.

Changes in topography and precipitation directly influence aquatic habitats, where during extreme periods of drought many perennial waterbodies become seasonal. Conversely, in years with extraordinary rainfall many seasonal waterbodies have continued flow or contain water throughout the year. These lentic waterbodies are highly variable and complex where many environmental factors may influence the distribution, reproduction, and survivorship of predacious aquatic hexapods, California tiger salamanders, and other aquatic herpetofauna. Within sympatric habitat other important factors among these taxa include microhabitat partitioning, spatial and temporal separation, and interspecific competition. Many of these factors are not well understood and would benefit from further investigation.

Within the District, we evaluated 26 distinct stream reaches to examine the effects of various stream gradients to the distribution and reproduction of California red-legged frog. Although stream gradient may influence population density and reproductive viability, our preliminary data suggest that stream gradients per se were not limiting the distribution of California red-legged frogs. Individual subadult and adults were documented in low, moderate, high, and extreme gradient stream types with slopes ranging from 0.4 - 21.0%. In addition, California red-legged frog occupied intermittent and perennial streams of each gradient type. Regardless of stream gradient, individuals occur in streams with favorable conditions and the availability of still-water habitat appears to be a factor in successful stream breeding. As stream gradient decreased the proportion of glide-riffle-pool reaches increased and we found the most reproductively viable populations occur in streams with gradients ≤4%.

Other factors, including extremely high stream flows appeared to influence the distribution and reproduction of California red-legged frogs and other ranids. The reproductive behavior of adult frogs and their selection of egg deposition sites is the most basic or elementary step of parental investment (Zug 1993). Within Alameda Creek, California red-legged frog and foothill yellow-legged frog are sympatric where both taxa occur at similar sites. However, there appears to be spatial and habitat partitioning in that each species typically deposited its eggs in different stream reach and substrate types. The selection of oviposition sites is critical to successful California red-legged frog and foothill yellow-legged frog reproduction in Alameda Creek. Egg masses need to be deposited at sites that avoid desiccation if flows significantly drop during their development. Conversely, eggs should be attached at sites that avoid scouring and detachment associated with late season discharge. There is no adaptive value to the production of healthy eggs if they are deposited in a lethal environment; in fact it is energetically costly to the parents (Zug 1993).

While comparing the effect of various flow regimes at the control and experiment study sites within Alameda Creek we documented a considerable difference in reproductive output of both taxa. The control site with natural flow regimes and discharge had notably higher California red-legged frogs and foothill yellow-legged frogs egg deposition than the experimental site. The unnatural and consistently higher discharge and irregular flows associated with releases from Calaveras Reservoir appears to be a major factor in the poor reproductive conditions along the experimental stream reach site.

Natural runoff generated from high-intensity storms also produced pulse and flash flow events. During our survey period, major rain events occurred during the breeding seasons of both California red-legged frogs and foothill yellow-legged frogs. These events led to significant flow increases and discharge in Alameda Creek. Similarly, irregular release and pulse flows were documented during periods of egg deposition and tadpole development at the Sunol "experimental" stream reach site. Some flash and pulsed flows were channel-forming events, where the discharge was well above bankfull. Under these conditions the subadult and adult frogs appeared to escape into backwater areas, smaller tributaries, or above bankfull and into upland regions. However, extreme late seasonal fluctuation in water discharge during egg deposition and larva development caused mortality in both stream reach study areas, but most notably in the experimental site. Although pulse flow and irregular flow may naturally occur during the breeding season, an increase in flow magnitude and intensity above seasonal averages can pose a serious threat to lotic breeding ranids.

Although several water quality variables are often identified to have harmful effects on aquatic biota, our preliminary results suggest that most taxa have relatively broad tolerances for the variables we examined. In 2004 we systematically surveyed 186 lentic waterbodies, 125 perennial and 61 seasonal ponds, where for each pond one series of water quality parameters were sampled. In contrast, since 1999 data have been collected from several streams during various periods throughout the year. Overall, California red-legged frogs occurred in surface water temperatures ranging from -1.0˚C - 33.2˚C. California tiger salamanders occurred in ponds with surface water temperatures ranging from 0.5 to 33.2 ˚C. The data from a variety of our lentic and lotic waterbodies indicates that California red-legged frog and California tiger salamanders can tolerate a wide range of surface water temperatures. Similarly, the California newt and Pacific tree frog occurred in a wide range of surface water temperatures including extremely warm water of 38.5 ° C. Conversely, bullfrogs inhabited cooler perennial waterbodies with a maximum surface water temperature of 25.3 ° C (Appendix D). However, for each of these taxa the minimum and maximum water temperature range within lentic and lotic waterbodies needs further investigation.

Another critical water quality parameter is dissolved oxygen. Many aquatic hexapods and most fish respire dissolved oxygen. In general, 5mg/L DO is associated with the normal activity of most fish (Walburg 1971). Dissolved oxygen can fluctuate under natural conditions and is influenced by temperature, salinity, and wind mixing. Furthermore, excessive plant growth and respiration followed by decomposition can deplete dissolved oxygen in a waterbody (U.S. Team of Federal Agencies 1998).
In 2004 California red-legged frogs and California tiger salamanders occurred in ponds with similar median DO of 9.6 mg/L and 8.6 mg/L, absolute range of 24.5 mg/L and 26.9 mg/L, respectfully. Likewise, California newt, Western toad, and Pacific tree frog were documented in lentic waterbodies with very similar ranges of dissolved oxygen. In contrast, bullfrogs inhabited perennial ponds, which typically had a high percentage of emerged and submerged vegetation with narrower ranges of dissolved oxygen, a median of 7.7 mg/L and absolute range of 16.7 mg/L (Appendix D). Our results suggest these species are adapted to low concentrations of dissolved oxygen and can successfully reproduce in lentic habitats under near-anaerobic conditions. Typically, in waterbodies with little or no dissolved oxygen, amphibian larvae are frequently observed coming to the surface to gulp air.

Nutrient loading often refers to a significant increase in nitrate of a particular waterbody (U.S. Team of Federal Agencies 1998). As previously noted the vast majority of the District's lentic and lotic waterbodies are exposed to livestock grazing. Cattle typically have access to and often frequent these aquatic systems during the amphibian egg deposition, hatching, and larval development periods. In 2004 during this sensitive reproductive period we collected nitrate data from 171 ponds and all were < 5mg/L, which is considerably less than an in vitro level of 7mg/L documented to have adverse affect on several tadpole taxa (Blaustein 2000). Although we documented some variation, the median nitrate levels in District ponds were very similar for all the aquatic herpetofauna taxa (Appendix D). Moreover, in nearly half (45.6%) of all ponds, nitrate levels were non-detectable and measured 0.0 mg/L. These results suggest that many lentic waterbodies the volume of water can dilute the associated effects of nitrate from all sources including livestock.

Various natural geological features and anthropogenic landscape modifications can directly affect the turbidity of aquatic systems. In 2004 turbidity samples were collected from 185 ponds within the District, ranging from 0.7 to 1000 NTU. We observed Pacific tree frogs and California tiger salamanders in ponds with the widest range of turbidities, 0.9 to 1000 NTU and 1.6 to 1000 NTU, respectfully. Moreover, unlike all other amphibian taxa, California tiger salamander larvae were more closely associated with turbid waterbodies, with a median of 35.5 NTU and a mean of 106.1 NTU. Although during a particular year California tiger salamanders appear to only utilize 50% of known breeding locations, these turbid ponds consistently have salamander reproduction and contain high larvae densities. Our observations and these results suggests that turbid water may provide protective cover for California tiger salamander larvae and decrease the risk of predation from visual predators, thus increasing survivorship and fidelity to these turbid ponds. Conversely, California red-legged frog and Western toad typically occurred in more visually "clear" ponds with a much narrower absolute turbidity range of 325.1 NTU and 272.1 NTU, respectfully (Appendix D).

Although our preliminary water quality results provide some information, the affects of these and other water characteristics on the lentic and lotic herpetofauna warrant further investigation. The 2004 water quality results for the various herpetofauna taxa are in Appendix D.

The District's lakes, perennial ponds and streams are susceptible to invasions and/or introductions of non-native predators. The 1996 data indicates that bullfrogs and several species of non-native predatory fish negatively affect California red-legged frog populations in lentic water habitats. In addition, the most reproductively successful California red-legged frog streams are relatively free of bullfrogs and centrarchids. Likewise, California tiger salamanders were generally absent from ponds that contained these exotic species. The establishment of bullfrogs and several non-native predatory fish populations appear to be a contributing factor of aquatic habitat suitability and negatively affected the occurrence of California tiger salamanders and California red-legged frogs.

The current status and distribution on District lands reveals that the California red-legged frog has vanished from western low-land parks near urbanization (west of Highway 80 &

580). However, frogs still occur in small isolated populations in the East Bay foothills (between Highway 580 and 680), and are thriving in several of the eastern parklands of Alameda and Contra Costa Counties. Whereas, extant California tiger salamander populations occur in most parklands east of highway 680, except for Morgan Territory Regional Preserve. In addition, several ponds in Vargas Plateau Regional Park support breeding salamanders, and a recent introduction of California tiger salamanders into a pond at Pleasanton Ridge Regional Park appears to have been successful. In contrast, foothill yellow-legged frog is extirpated throughout most of the Alameda and Contra Costa Counties with extant populations restricted to several drainages within the Alameda Creek watershed (Appendix C maps).

The District is continuing studies on general ecology, population viability, and abiotic and biotic variables affecting various herpetofauna. In addition, we are developing a long-term riparian monitoring program within Alameda Creek and currently collecting base-line data on a number of water quality parameters, geomorphologic and hydrologic conditions, aquatic and riparian vegetation, macro invertebrates, aquatic herpetofauna, fisheries, and utilization of various avian fauna and bat species within the riparian zone.

The data and results will provide important guidance for developing adaptive management strategies to assist in the conservation and recovery of each species. Moreover, the District is continuing to identify valuable habitat areas with aquatic linkages for land acquisition. Since 1989, throughout Alameda and Contra Costa Counties, we have acquired over 18,040 acres of land that support California red-legged frog and 10,880 acres of land with California tiger salamander populations. Overall, land acquisition of suitable aquatic and terrestrial herpetofauna habitat, especially adjacent to existing parklands or other public lands is essential to minimize fragmentation, buffer populations, and maintain connectivity between metapopulations within the East Bay.

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DISCLOSURE

REFERENCES

Akkins, M.D. 1978. Insects in Perspective. MacMillan Publishing Co. Inc. New York. 513 pp.

Barry, S.J., and H.B. Shaffer. 1994. The Status of the California tiger salamander (*Ambystoma californiense*) at Lagunita: A 50-year Update. Journal of Herpetology 28(2), 159-164.

Beard, R.L., 1963. Insects and Toxins and Venoms. Annual Review of Entomology 8, 1-18.

Borror, D.J., D.M. Delong, and C.A Triplehorn. 1976. Study of Insects. Holt¸ Rinehart and Winston. 852 pp.

Corben, C. and G. M. Fellers. 2001. A Technique for Detecting Eyeshine of Amphibians and Reptiles. Herpetological Review, 2001. 32(2), 89-91.

Duellman, W.E. and L. Trueb. 1986. Biology of Amphibians. McGraw-Hill Publishing Company. 670 pp.

Fellers, G. M., and P. M. Kleeman. 2005. California Red-Legged Frog (*Rana draytonii*) Movements and Habitat Use. In press.

Fellers, G. M., A. E. Launer, G. Rathbun, S. Bobzien, J. Alvarez, D. Sterner, R. B. Seymour, and M. Westphal. 2001. Overwintering Tadpoles in the California Red-legged Frog (*Rana aurora draytonii*). Herpetological Review, 2001. 32(3), 156-157.
Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 1998. California Salmonid Stream Habitat Restoration Manual. 1998. State of California Agency Department of Fish and Game, Third Edition.

Frost, S.W. 1959. Insect Life and Insect Natural History. Dover Publications, Inc. New York. 526 pp.

Hirai, T., and Kasumasa Hidaka. 2002. Anuran-dependant predation by giant water bug, *Lethocerus deyrollei* (Hemiptera: Belostomidatidae), in rice field of Japan. Ecological Research, 17 (6), 655-661.

Jennings, M. R. and M. P. Hayes. 1990. Final report of the status of the California red-legged frog in the Pescadero Marsh Natural Preserve. Prepared for the California Department of Parks and Recreation. 1990. Academy of Sciences. 30 pp.

Jennings, M. R. and M. P. Hayes. 1994. Amphibian and reptile species of special concern in California. Report prepared for the California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova, California. 255 pp.

Johnson P.T.J., Lunde K. B., Thurman E. M., Ritchie E.G., Simon N. W., Surtherland D. R., Kapfer J. M., Frest T. J., Boerman J., and Blaustein A. R. 2001. Parasite (*Ribeiroia ondatrae*) infection linked to amphibian maliformations in the Western United States. Ecological Monographs, 2001. Vol 72, No. 2 pp. 151-168.

Johnson P.T.J., Lunde K. B., Ritchie E.G., and Launer A. E. 1999. The effect of trematode infection on amphibian limb development and survivorship. 1999. Science 284: 802-804.

Leon, B. 1998. Influence of the predatory backswimmer, *Notonecta maculata*, on invertebrate community structure. 1998. Ecological Entomology, 23 (3), 246-252

Loredo, I. and D. Van Vuran. 1996. Reproductive Ecology of a Population of the California tiger salamander. 1996. Copeia 1996(4), 895-901.

Marty, J. 2005. Effects of Cattle Grazing on Diversity in Ephemeral Wetlands. Conservation Biology, October 2005. Volume 19. Page 1626.

Pyke, C.R. and J. Marty. 2005. Cattle Grazing Mediate Climate Change Impacts on Ephemeral Wetlands. Conservation Biology, October 2005. Volume 19. Page 1619.

Pyke, C.R. 2005. Assessing Suitability for Conservation Action: Prioritizing Interpond Linkages for California Tiger Salamander. Conservation Biology, April 2005. Volume 19. Page 492.

Petranka, J.W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press. 592 pp.

Rhodes, R., 1994. A Review of Predator Avoidance Defenses by aquatic Insects through the Use of Chemical Substances. 1994. Chemical Entomology, pp 1-7.

Rosgen, D. L. 1994. A classification of natural rivers. Catena 22 (1994) 169-199.

Stebbins, R.C. 2003. A field guide to Western Reptiles and Amphibians. Houghton Mifflin Company, Boston, MA. 554 pp.

Stebbins, R.C., and N.W Cohen,. 1997. A Natural History of Amphibians. Princeton University Press. 336 pp.

Shaffer, H. B., G. M. Fellers, S.R. Voss, J. C. Olivers and G. B. Pauly. 2004. Species boundies, phylogeography and conservation genetics of the red-legged frog (Rana aurora/draytonii) complex. Molecular Ecology (2004) 13, 2667-2677.

Shaffer, H. B., and P. C. Trenham. 2002. Distinct Population Segments of the California Tiger Salamander. Sections of Evolution and Ecology, and Center for Population Biology, University of California.

Trenham, P.C., H.B. Shaffer, W.D. Koening and M.R. Stromberg. 2000. Life History and Demographic variation in the California tiger salamander (*Ambystoma californiense*). Copeia. 2000(2), 365-377.

Trenham, W.D. Koening P.C., and H.B. Shaffer. 2001. Spatially autocorrelated demography and interpond dispersal in the salamander *Ambystoma californiense.* Ecology 82(12), 3519-3530.

Trenham, W.D. 2001. Terrestrial Habitat Use by Adult California tiger salamanders. Journal of Herpetology 35(2), 343-346.

U.S. Team of Federal Agencies: The Federal Interagency Stream Restoration Working Group. 1998. Stream Corridor Restoration: Principles, Processes, and Practices.

U.S. Fish and Wildlife Service (USFWS) 1996. Endangered and Threatened Wildlife and Plants: Determination of threatened status for the California red-legged frog (*Rana aurora draytonii*). Federal Register, pp 25813-25833. Portland, Oregon.

U.S. Fish and Wildlife Service (USFWS) 2002. Recovery Plan for the California red-legged frog (*Rana aurora draytonii*). pp. vii + 173. USFWS, Portland, Oregon.

U.S. Fish and Wildlife Service (USFWS) 2006. Endangered and Threatened Wildlife and Plants; Determination of Critical Habitat for the California Red-legged Frog, and Special Rule Exemption Associated With Final Listing for Existing Routine Ranching Activities; Final Rule 50 CFR Part 17.

U.S. Fish and Wildlife Service (USFWS) 2003. Endangered and Threatened Wildlife and Plants; Listing of the Central California District Population Segment of the California tiger salamander; Proposed Rule 50 CFR Part 17.

U.S. Fish and Wildlife Service (USFWS) 2004. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the California tiger salamander; a Special Rule Exemption for Existing Routine Ranching Activities; Final Rule 50 CFR Part 17.

U.S. Fish and Wildlife Service (USFWS) 2005. Revised Guidance on Site Assessment and Field Surveys for California red-legged frog. 25 pp.

U.S. Fish and Wildlife Service (USFWS) 2003. Interim Guidance on Site Assessment and Field Surveys for Determining Presence or a Negative Finding of the California Tiger Salamander. 12 pp.

Zug, G. R. 1993. Herpetology: An Introductory Biology of Amphibians and Reptiles. Academic Press, Inc. 527 pp.

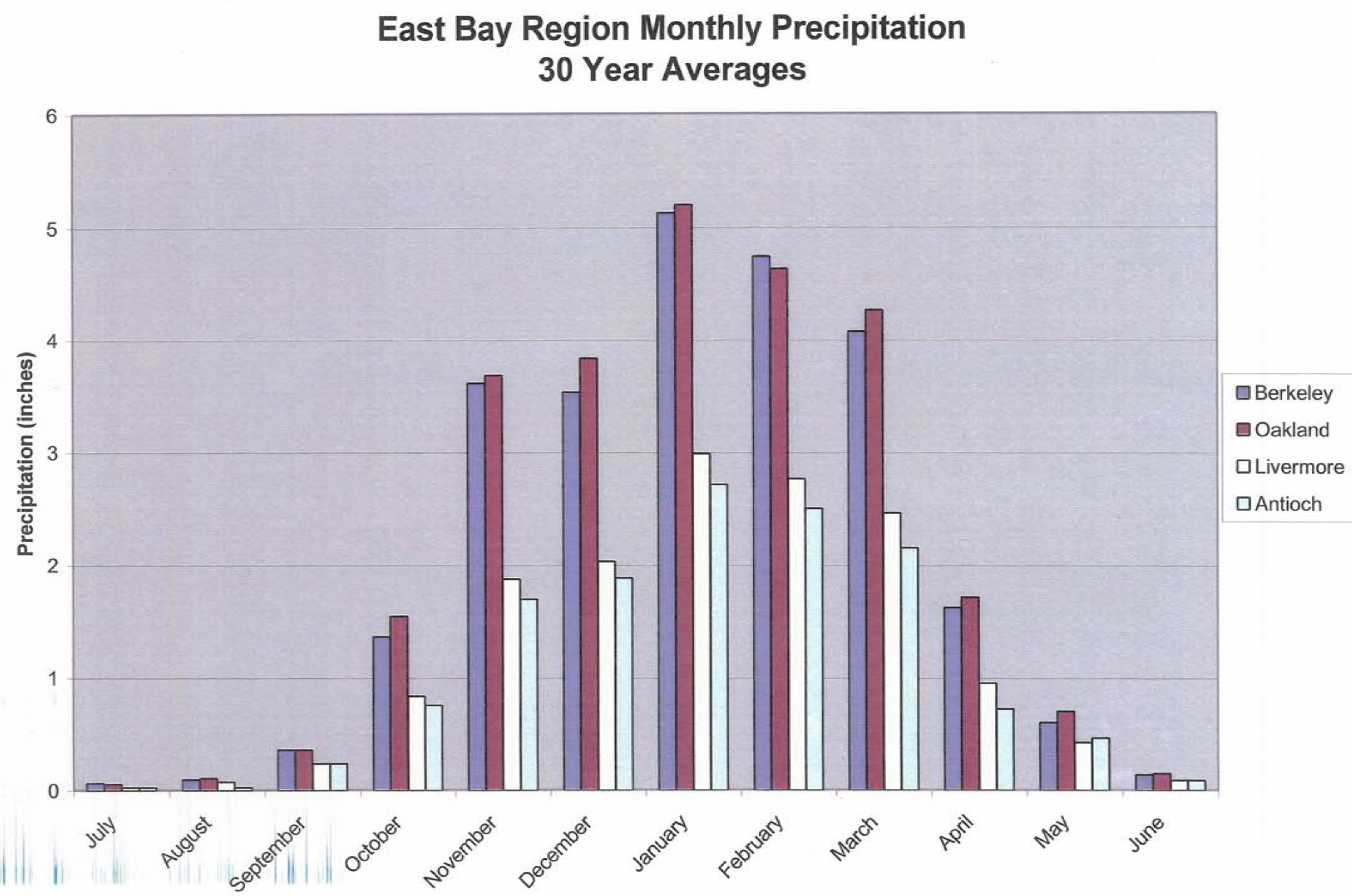
APPENDICIES

A. East Bay Monthly Precipitation Averages

B. Stream Vertical and Longitudinal Profiles

C. Distribution Maps for California tiger salamander, California red-legged frog, and foothill yellow-legged frog

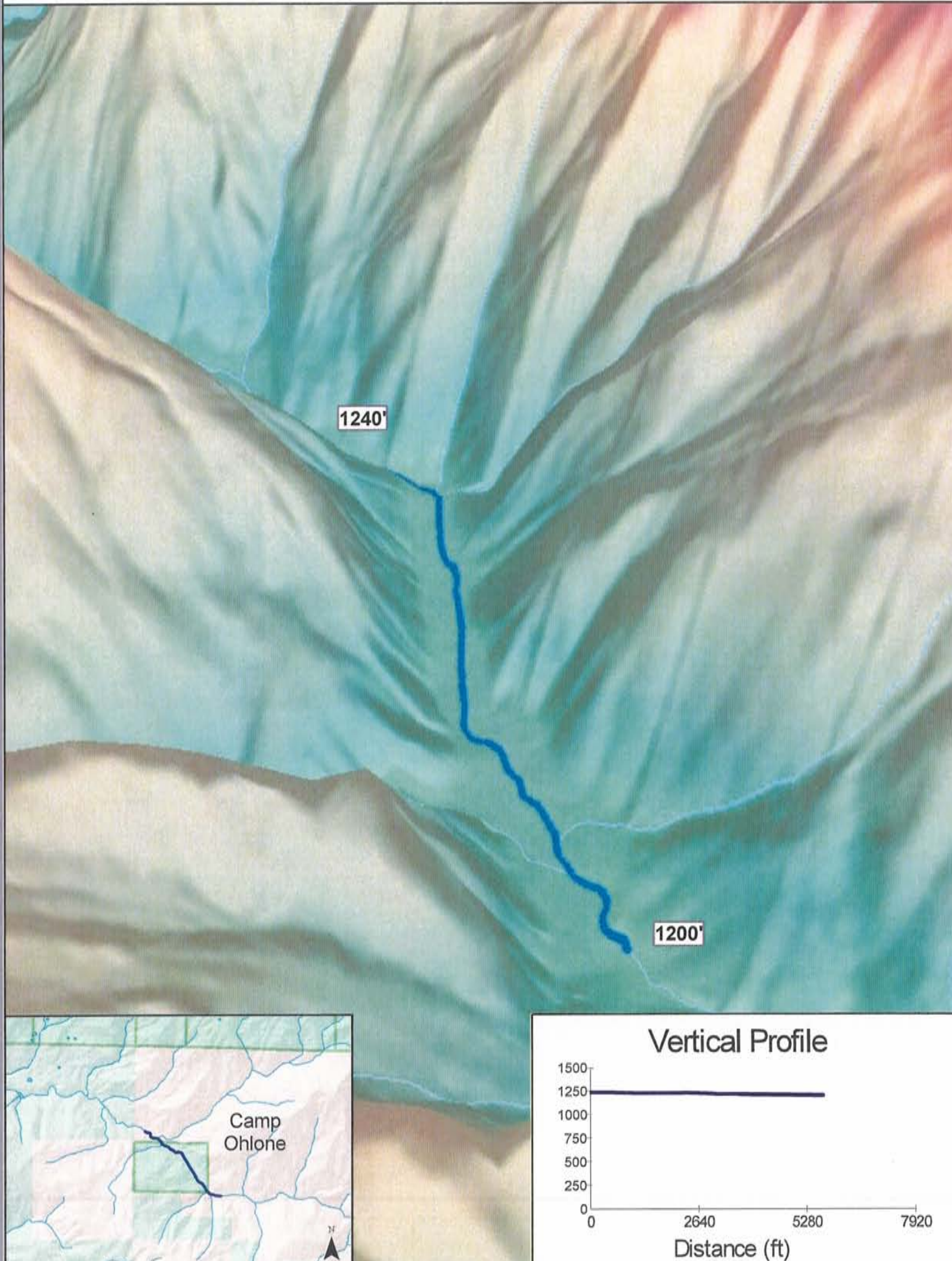
D. Various Aquatic Herpetofauna and Lentic Water Quality Statistics for Surface Water Temperature, Dissolve Oxygen, Nitrate, and Turbidity


East Bay Region Monthly Precipitation
30 Year Averages
Precipitation (inches)
0
1
2
3
4
5
6
July
August
September
October
November
December
January
February
March
April
May
June
Berkeley
Oakland
Livermore
Antioch

ALAMEDA CREEK - CAMP OHLONE

Low Gradient 1.1%
Camp Ohlone Regional Wilderness

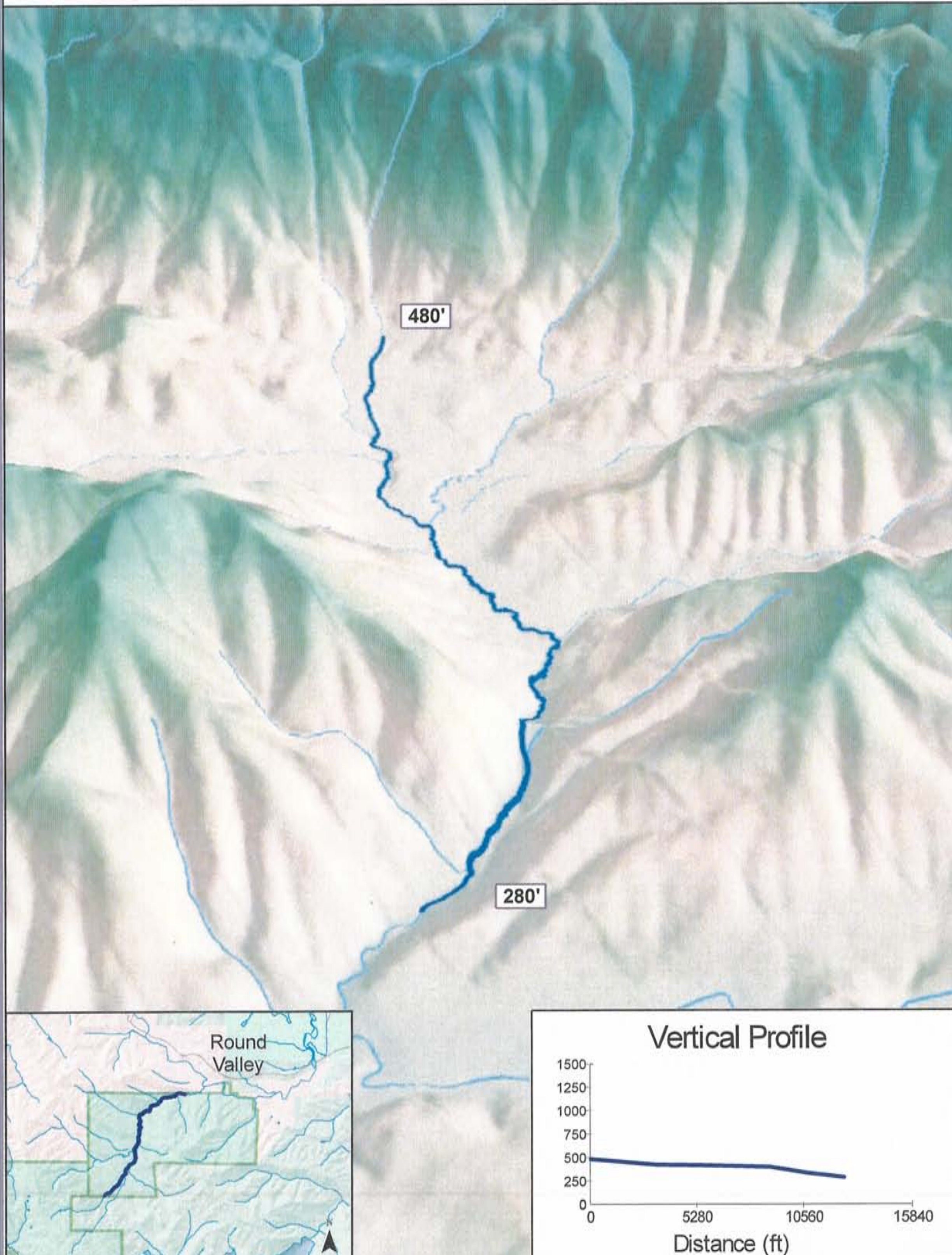
Prepared By:
Planning,
Stewardship,
& GIS Services



ROUND VALLEY CREEK

Low Gradient 1.5%
Round Valley Regional Park

Prepared By:
Planning,
Stewardship,
& GIS Services



September 27, 2006 kn U:\Projects\Stewardship\streams\rv_stream_3d.mxd

SAND CREEK

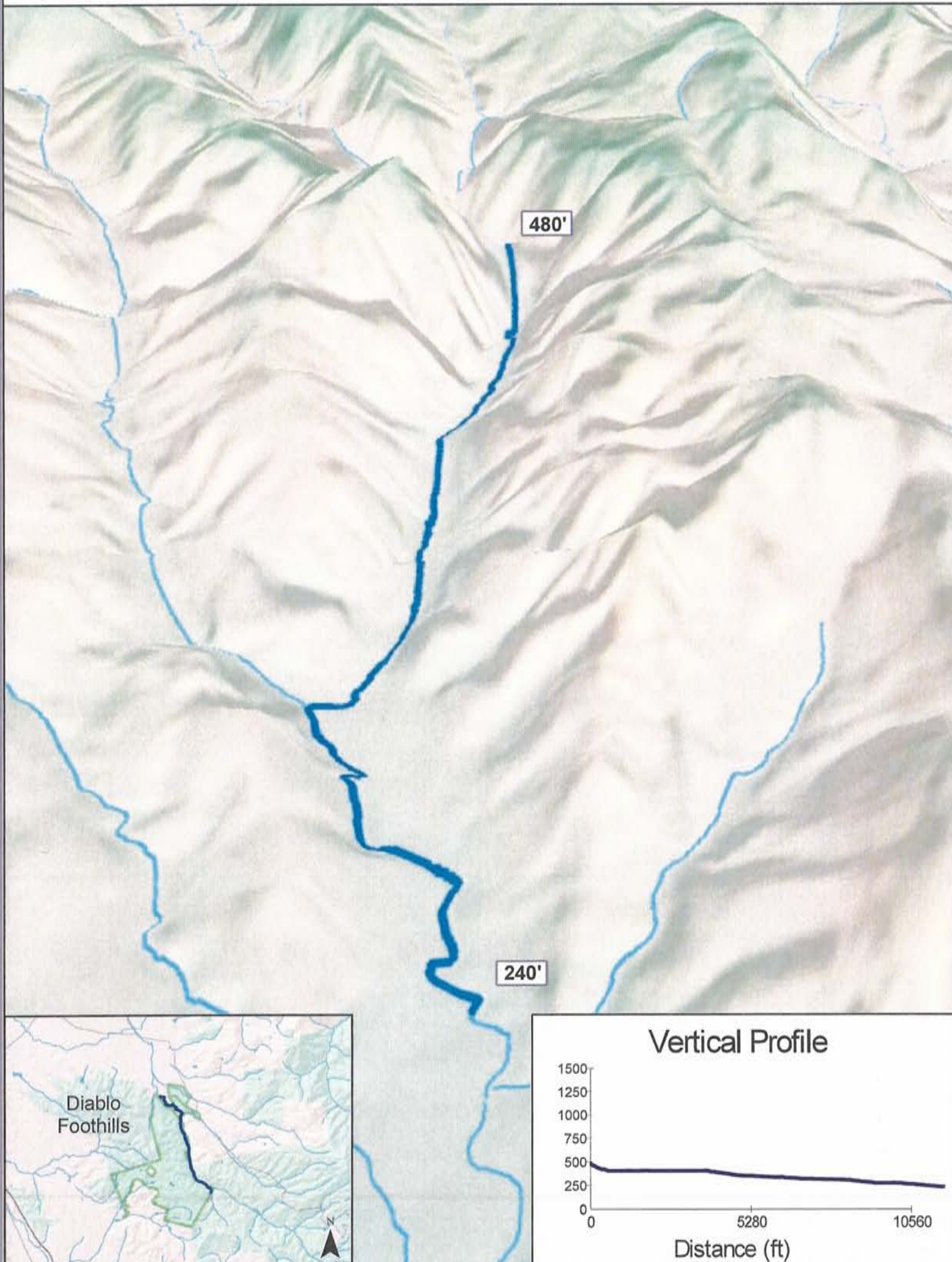
Moderate Gradient 2.8%
Black Diamond Mines Regional Preserve

Prepared By:
Planning,
Stewardship,
& GIS Services

PINE CREEK

Moderate Gradient 2.0%
Diablo Foothills Regional Park

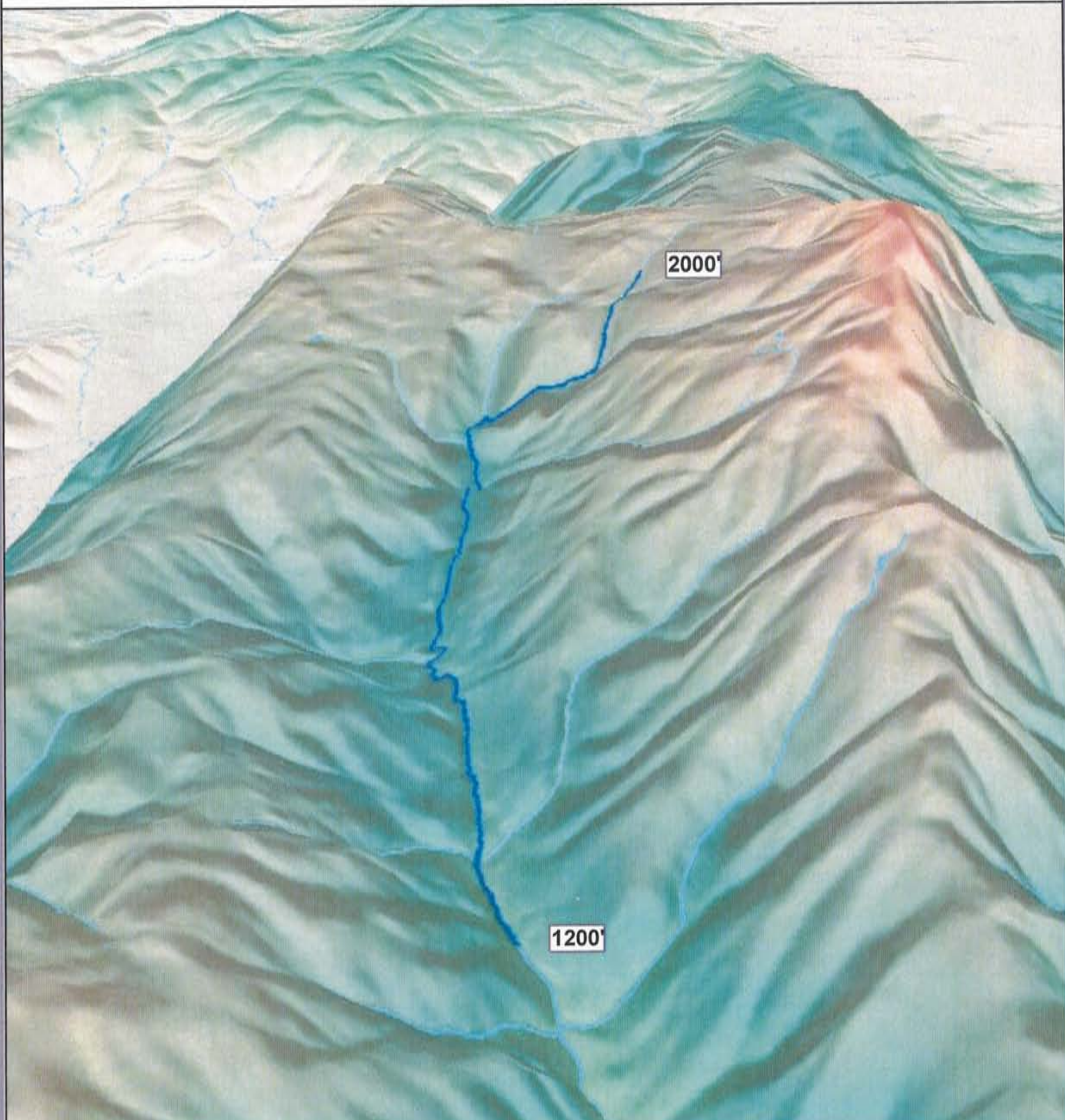
Prepared By:
Planning,
Stewardship,
& GIS Services

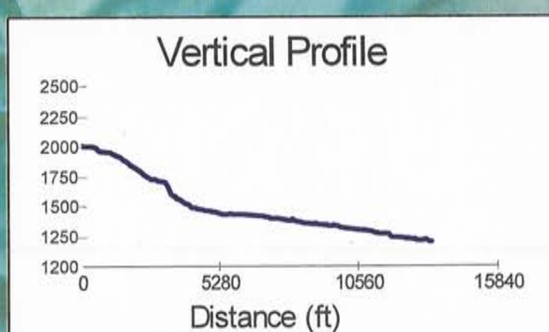


MARSH CREEK

High Gradient 6.4%
Morgan Territory Regional Preserve

Prepared By:
Planning,
Stewardship,
& GIS Services



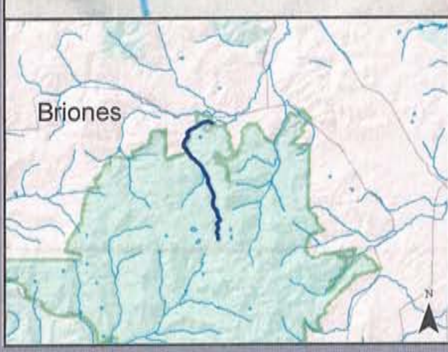


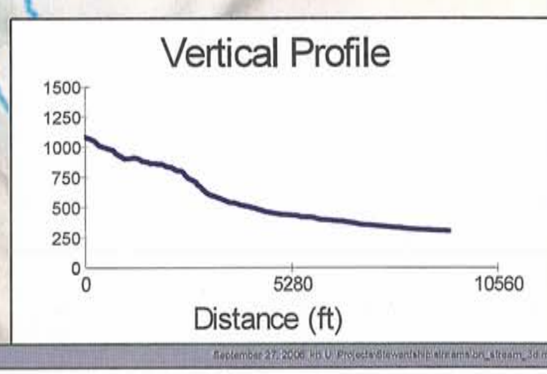
September 27, 2006

ARROYO DEL HAMBRE CREEK

High Gradient 8.3%
Briones Regional Park

Prepared By:
Planning,
Stewardship,
& GIS Services

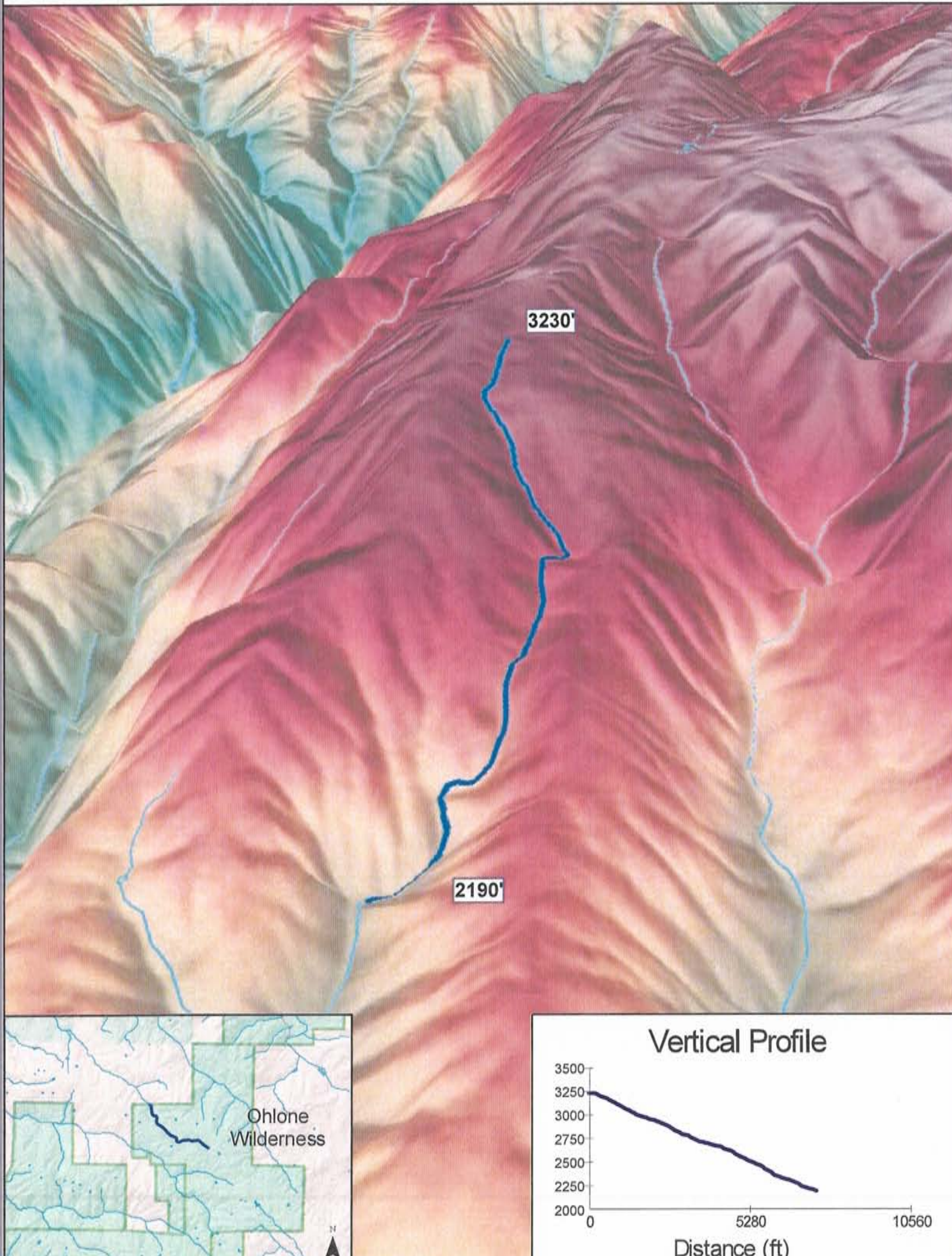




SAN ANTONIO CREEK

Extreme Gradient 13.7%
Ohlone Regional Wilderness

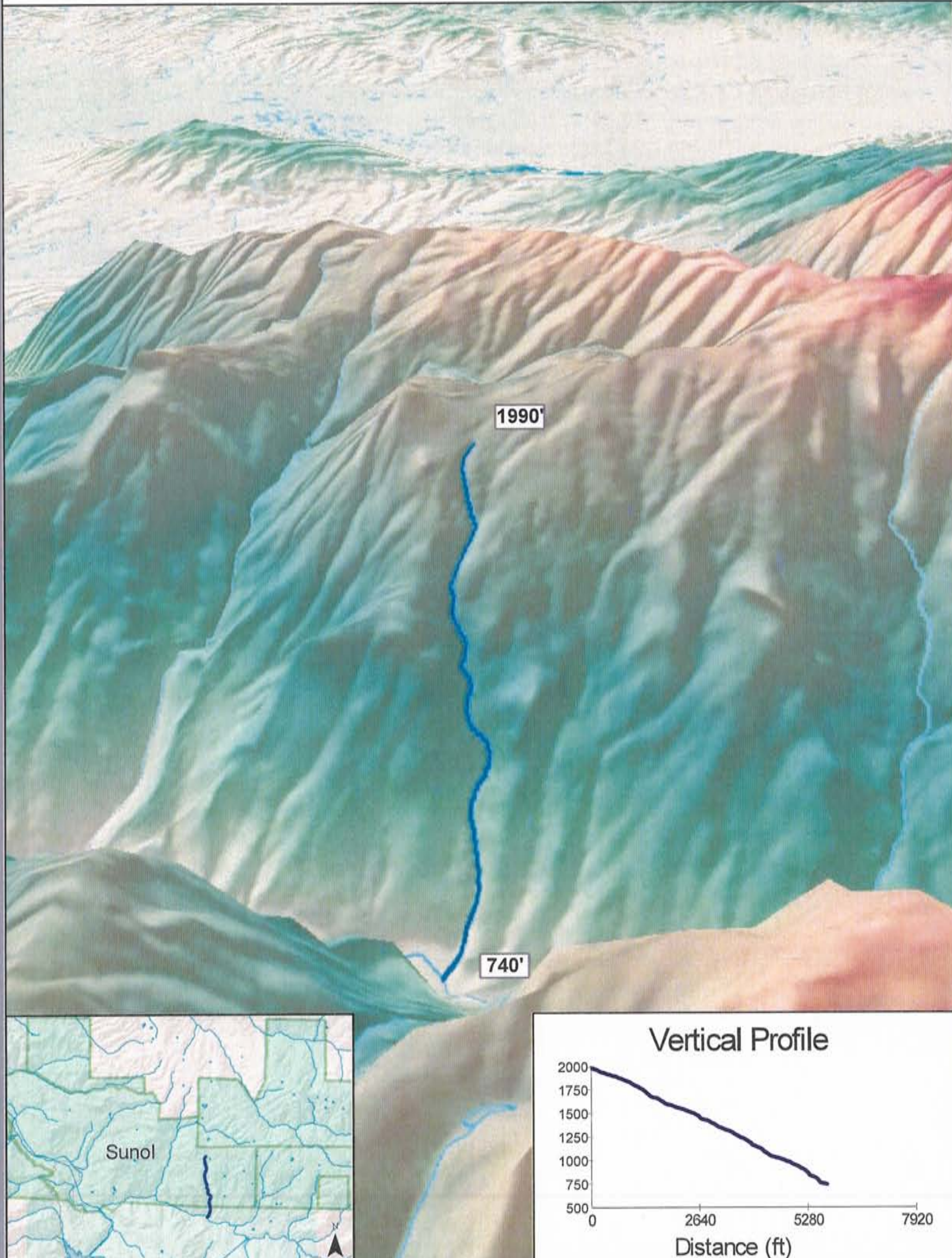
Prepared By:
Planning,
Stewardship,
& GIS Services

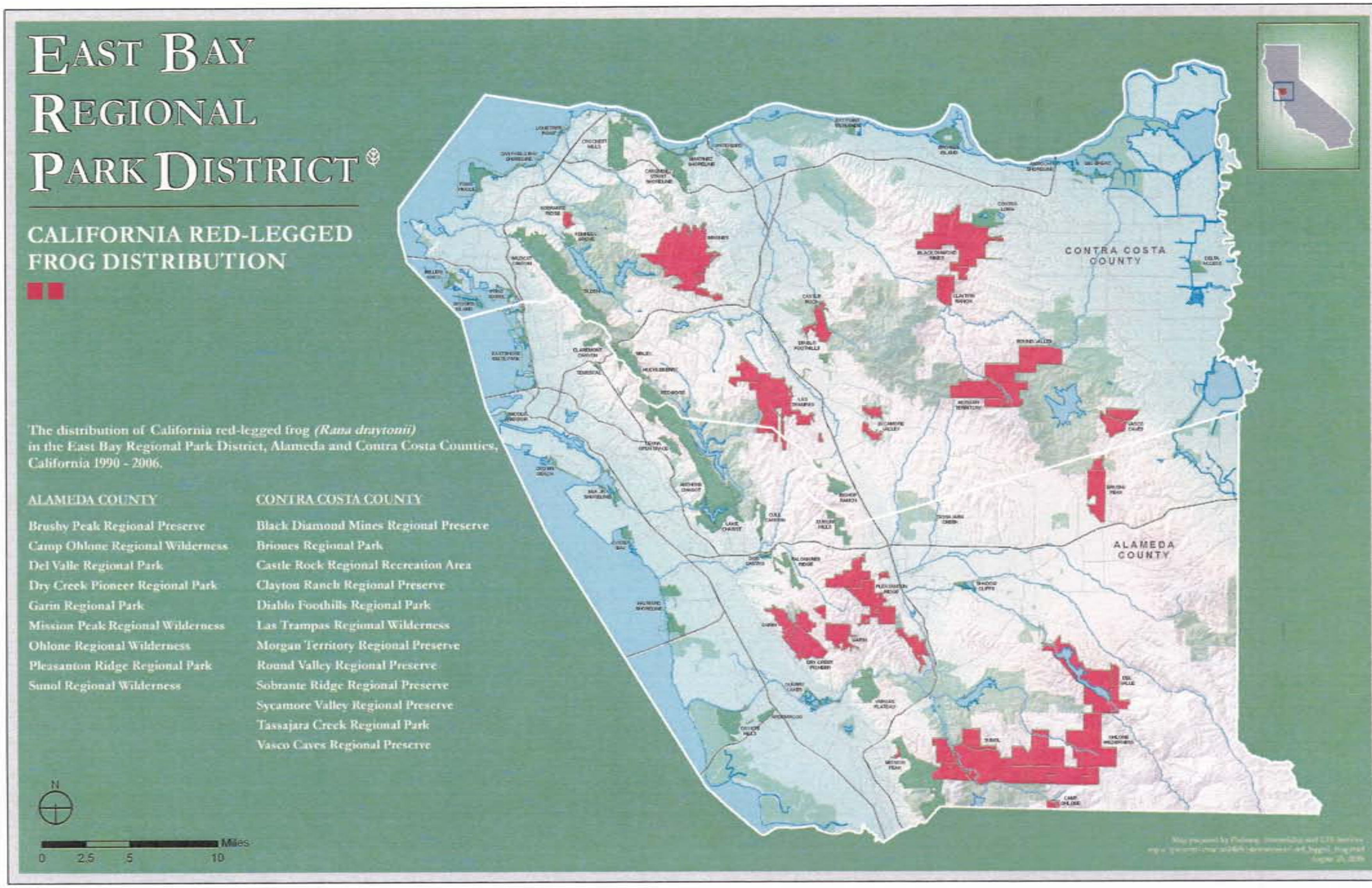


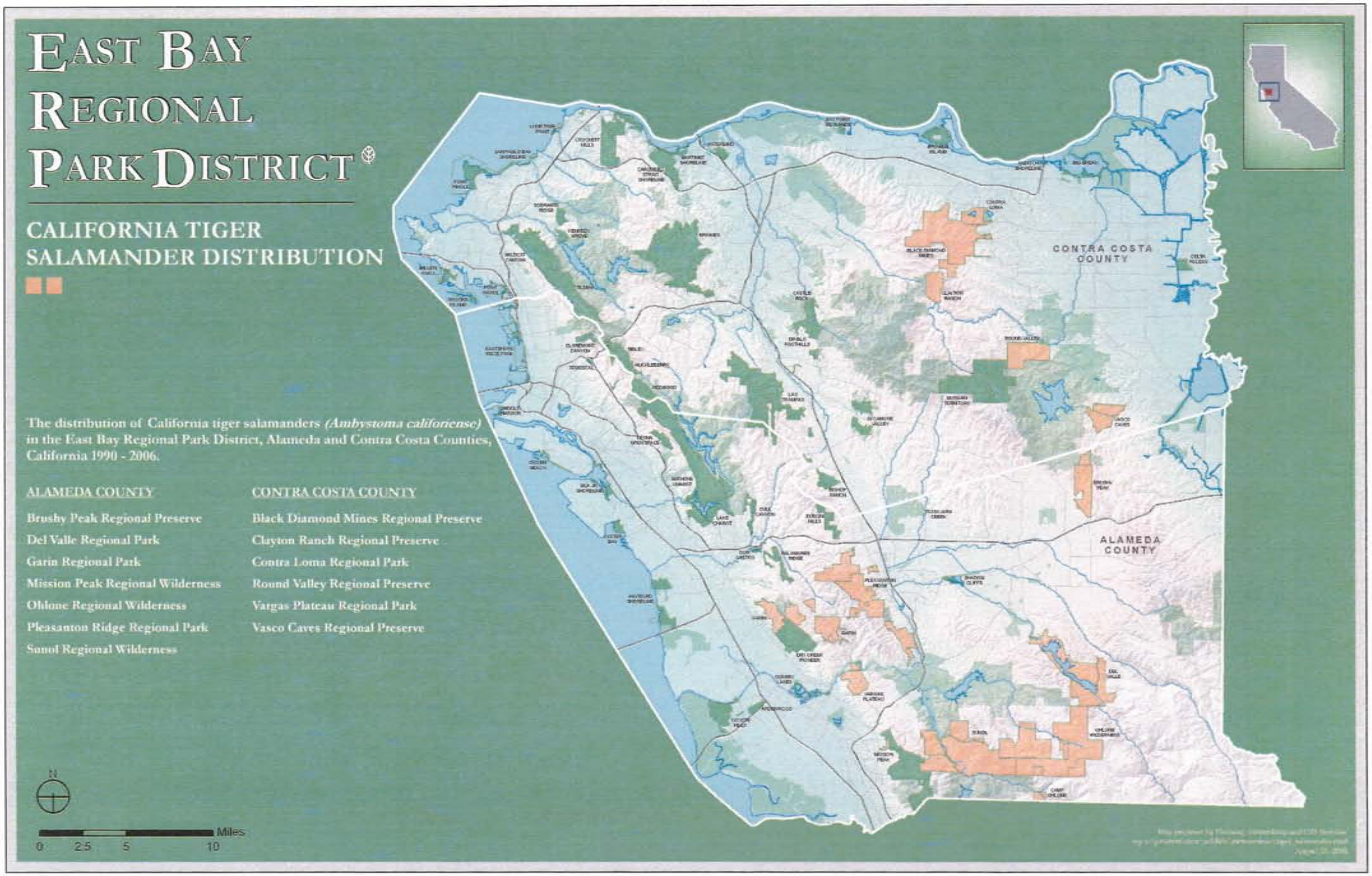
ALAMEDA CREEK TRIBUTARY

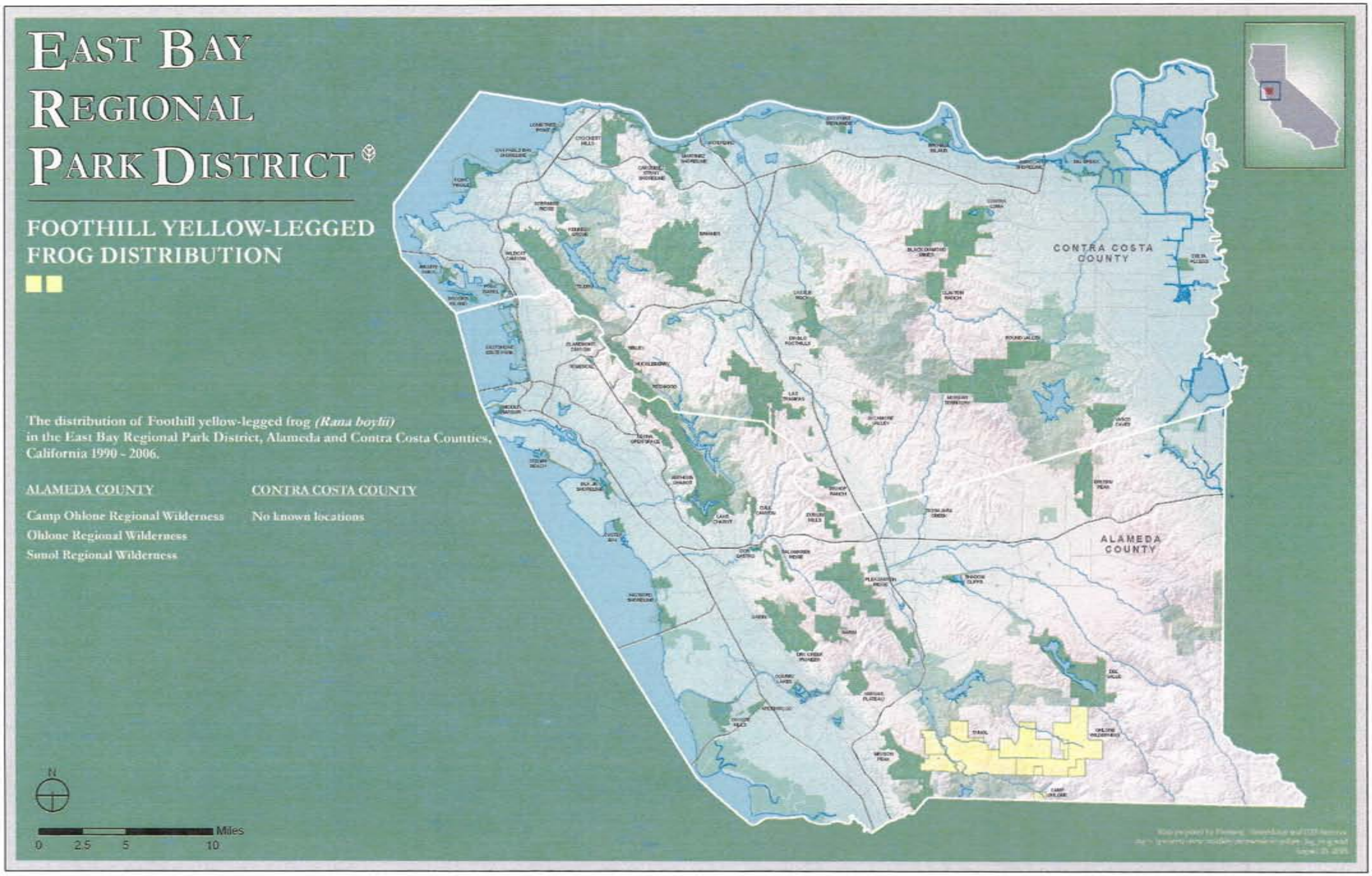
Extreme Gradient 21.0%
Sunol Regional Wilderness

Prepared By:
Planning,
Stewardship,
& GIS Services




EAST BAY REGIONAL PARK DISTRICT
CALIFORNIA RED-LEGGED FROG DISTRIBUTION
The distribution of California red-legged frog (Rana draytonii) in the East Bay Regional Park District, Alameda and Contra Costa Counties, California 1990 - 2006.
ALAMEDA COUNTY
Brushy Peak Regional Preserve
Camp Ohlone Regional Wilderness
Del Valle Regional Park
Dry Creek Pioneer Regional Park
Garin Regional Park
Mission Peak Regional Wilderness
Ohlone Regional Wilderness
Pleasanton Ridge Regional Park
Sunol Regional Wilderness
CONTRA COSTA COUNTY
Black Diamond Mines Regional Preserve
Briones Regional Park
Castle Rock Regional Recreation Area
Clayton Ranch Regional Preserve
Diablo Foothills Regional Park
Las Trampas Regional Wilderness
Morgan Territory Regional Preserve
Round Valley Regional Preserve
Sobrante Ridge Regional Preserve
Sycamore Valley Regional Preserve
Tassajara Creek Regional Park
Vasco Caves Regional Preserve
N
0 2.5 5 10 Miles
CONTRA COSTA COUNTY
ALAMEDA COUNTY


EAST BAY REGIONAL PARK DISTRICT
CALIFORNIA TIGER SALAMANDER DISTRIBUTION
The distribution of California tiger salamanders (Ambystoma califoriense) in the East Bay Regional Park District, Alameda and Contra Costa Counties, California 1990 - 2006.
ALAMEDA COUNTY
Brushy Peak Regional Preserve
Del Valle Regional Park
Garin Regional Park
Mission Peak Regional Wilderness
Ohlone Regional Wilderness
Pleasanton Ridge Regional Park
Sunol Regional Wilderness
CONTRA COSTA COUNTY
Black Diamond Mines Regional Preserve
Clayton Ranch Regional Preserve
Contra Loma Regional Park
Round Valley Regional Preserve
Vargas Plateau Regional Park
Vasco Caves Regional Preserve
CONTRA COSTA COUNTY
ALAMEDA COUNTY
N
0 2.5 5 10 Miles



EAST BAY
REGIONAL
PARK DISTRICT
FOOTHILL YELLOW-LEGGED
FROG DISTRIBUTION
The distribution of Foothill yellow-legged frog (Rana boylii) in the East Bay Regional Park District, Alameda and Contra Costa Counties, California 1990 - 2006.
ALAMEDA COUNTY
Camp Ohlone Regional Wilderness
Ohlone Regional Wilderness
Sunol Regional Wilderness
CONTRA COSTA COUNTY
No known locations
CONTRA COSTA COUNTY
ALAMEDA COUNTY
N
0 2.5 5 10 Miles

Appendix D. Lentic Water Quality Statistics Associated with Various Aquatic Herpetofauna within the East Bay Regional Park District, in 2004.

	Nitrates (mg/L)						
	all ponds	CRLF	CTS	CA Newt	WAGS	PTF	Bullfrog
Mean	1.0	0.7	1.1	1.0	0.7	1.0	1.0
Standard Error	0.1	0.1	0.2	0.1	0.1	0.1	0.2
Median	1.0	0.0	1.0	1.0	0.0	1.0	1.0
Standard Deviation	1.1	1.0	1.3	1.1	0.9	1.1	0.9
Range	5.0	4.0	4.5	3.0	2.5	4.0	2.5
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum	5.0	4.0	4.5	3.0	2.5	4.0	2.5
Count	171.0	58.0	27.0	68.0	39.0	113.0	21.0
Confidence Level (95.0%)	0.2	0.3	0.5	0.3	0.3	0.2	0.4

	Dissolved Oxygen (mg/L)						
	all ponds	CRLF	CTS	CA Newt	WAGS	PTF	Bullfrog
Mean	8.3	9.0	9.6	9.1	8.9	8.5	6.5
Standard Error	0.4	0.6	0.9	0.6	0.8	0.4	0.9
Median	8.2	9.6	8.7	8.7	8.7	8.7	7.7
Standard Deviation	5.2	5.1	5.0	5.4	4.8	4.8	4.2
Range	30.1	24.5	26.9	22.5	20.8	24.5	16.7
Minimum	0.0	0.0	3.2	0.0	1.7	0.0	0.1
Maximum	30.1	24.5	30.1	22.5	22.5	24.5	16.8
Count	184.0	64.0	33.0	69.0	40.0	124.0	21.0
Confidence Level (95.0%)	0.8	1.3	1.8	1.3	1.5	0.9	1.9

	Temperature (oC)						
	all ponds	CRLF	CTS	CA Newt	WAGS	PTF	Bullfrog
Mean	23.7	24.4	23.0	25.0	25.5	23.8	21.3
Standard Error	0.3	0.5	0.8	0.5	0.6	0.4	0.5
Median	23.6	24.1	22.3	24.5	25.0	23.3	21.0
Standard Deviation	4.0	4.1	4.4	4.3	3.7	4.4	2.1
Range	23.2	17.9	17.0	21.0	14.2	23.2	8.8
Minimum	15.3	15.3	16.2	17.5	19.0	15.3	16.5
Maximum	38.5	33.2	33.2	38.5	33.2	38.5	25.3
Count	185.0	64.0	33.0	69.0	40.0	125.0	21.0
Confidence Level (95.0%)	0.6	1.0	1.6	1.0	1.2	0.8	1.0

	Turbidity (NTU)						
	all ponds	CRLF	CTS	CA Newt	WAGS	PTF	Bullfrog
Mean	67.3	27.0	106.1	50.6	33.3	63.7	28.1
Standard Error	11.4	6.8	32.6	14.3	11.0	12.5	17.2
Median	10.1	4.6	35.5	7.9	4.9	10.2	3.7
Standard Deviation	155.5	54.2	187.2	118.6	69.7	139.3	78.9
Range	999.4	325.1	998.4	765.4	325.1	999.1	357.4
Minimum	0.7	0.9	1.6	0.7	0.9	0.9	0.7
Maximum	1000.0	326.0	1000.0	766.0	326.0	1000.0	358.0
Count	185.0	64.0	33.0	69.0	40.0	125.0	21.0
Confidence Level (95.0%)	22.6	13.5	66.4	28.5	22.3	24.7	35.9

Lentic Water Quality Statistics and Aquatic Herpetofauna

Nitrates (mg/L)

	All ponds	*R. draytonii*	*A. californiense*	*T. torosa*	*Thamnophis sp.*	*H. regilla*	*R. catesbeiana*	*B. boreas*
Mean	1.0	0.7	1.1	1.0	0.7	1.0	1.0	1.2
Standard Error	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.2
Median	1.0	0.0	1.0	1.0	0.0	1.0	1.0	1.0
Standard Deviation	1.1	1.0	1.3	1.1	0.9	1.1	0.9	1.3
Range	5.0	4.0	4.5	3.0	2.5	4.0	2.5	5.0
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum	5.0	4.0	4.5	3.0	2.5	4.0	2.5	5.0
Count	171.0	58.0	27.0	68.0	39.0	113.0	21.0	34.0
Confidence Level (95.0%)	0.2	0.3	0.5	0.3	0.3	0.2	0.4	0.9

Lentic Water Quality Statistics and Aquatic Herpetofauna

Dissolved Oxygen (mg/L)

	All ponds	*R. draytonii*	*A. californiense*	*T. torosa*	*Thamnophis sp.*	*H. regilla*	*R. catesbeiana*	*B. boreas*
Mean	8.3	9.0	9.6	9.1	8.9	8.5	6.5	9.5
Standard Error	0.4	0.6	0.9	0.6	0.8	0.4	0.9	0.6
Median	8.2	9.6	8.7	8.7	8.7	8.7	7.7	9.1
Standard Deviation	5.2	5.1	5.0	5.4	4.8	4.8	4.2	4.0
Range	30.1	24.5	26.9	22.5	20.8	24.5	16.7	17.5
Minimum	0.0	0.0	3.2	0.0	1.7	0.0	0.1	2.7
Maximum	30.1	24.5	30.1	22.5	22.5	24.5	16.8	20.2
Count	184.0	64.0	33.0	69.0	40.0	124.0	21.0	38.0
Confidence Level (95.0%)	0.8	1.3	1.8	1.3	1.5	0.9	1.9	2.6

Lentic Water Quality Statistics and Aquatic Herpetofauna

Temperature (^{o}C)

	All ponds	*R. draytonii*	*A. californiense*	*T. torosa*	*Thamnophis sp.*	*H. regilla*	*R. catesbeiana*	*B. boreas*
Mean	23.7	24.4	23.0	25.0	25.5	23.8	21.3	23.3
Standard Error	0.3	0.5	0.8	0.5	0.6	0.4	0.5	0.6
Median	23.6	24.1	22.3	24.5	25.0	23.3	21.0	23.8
Standard Deviation	4.0	4.1	4.4	4.3	3.7	4.4	2.1	3.8
Range	23.2	17.9	17.0	21.0	14.2	23.2	8.8	15.0
Minimum	15.3	15.3	16.2	17.5	19.0	15.3	16.5	17.0
Maximum	38.5	33.2	33.2	38.5	33.2	38.5	25.3	32.7
Count	185.0	64.0	33.0	69.0	40.0	125.0	21.0	39.0
Confidence Level (95.0%)	0.6	1.0	1.6	1.0	1.2	0.8	1.0	2.5

Lentic Water Quality Statistics and Aquatic Herpetofauna

Turbidity (NTU)

	All ponds	*R. draytonii*	*A. californiense*	*T. torosa*	*Thamnophis sp.*	*H. regilla*	*R. catesbeiana*	*B. boreas*
Mean	67.3	27.0	106.1	50.6	33.3	63.7	28.1	44.5
Standard Error	11.4	6.8	32.6	14.3	11.0	12.5	17.2	12.4
Median	10.1	4.6	35.5	7.9	4.9	10.2	3.7	7.0
Standard Deviation	155.5	54.2	187.2	118.6	69.7	139.3	78.9	77.4
Range	999.4	325.1	998.4	765.4	325.1	999.1	357.4	325.1
Minimum	0.7	0.9	1.6	0.7	0.9	0.9	0.7	0.9
Maximum	1000.0	326.0	1000.0	766.0	326.0	1000.0	358.0	326.0
Count	185.0	64.0	33.0	69.0	40.0	125.0	21.0	39.0
Confidence Level (95.0%)	22.6	13.5	66.4	28.5	22.3	24.7	35.9	58.0