Post-Cedar Fire Arroyo Toad (*Bufo californicus*) Monitoring Surveys at Cuyamaca Rancho State Park, 2004

Final Report

Prepared for:

California State Parks

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

Post-Cedar Fire Arroyo Toad (*Bufo californicus*) Monitoring Surveys at Cuyamaca Rancho State Park, 2004

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ABSTRACT

From 2002 to 2004, California State Parks contracted with the U.S. Geological Survey to conduct daytime habitat evaluation and focused nocturnal surveys to determine the distribution of suitable habitat and presence of arroyo toads (*Bufo californicus*) within Cuyamaca Rancho State Park (CRSP). The 2002 and 2003 surveys documented breeding populations of arroyo toads at four high-quality sites along the Sweetwater River, but the effects of the Cedar Fire in late 2003 on these populations were unknown. The purposes of the 2004 surveys were to determine if there were changes in the distribution of arroyo toads and arroyo toad habitat as a result of the Cedar Fire, and to determine fire severity levels at the four previously known high-quality habitat locations. To accomplish this, we used daytime habitat evaluation surveys, fire severity transects, and nocturnal presence surveys. Each 250-m stretch of the river was re-evaluated based on the presence of key arroyo toad habitat characteristics: 1) the channel substrate and banks being predominately composed of depositional sand, 2) flat, exposed sandy terraces immediately adjacent to the channel, and 3) channel braiding. Furthermore, the reaches were surveyed diurnally and nocturnally for all life history stages of the arroyo toad and other riparian-associated animal species.

Of a total 17.0 km (10.6 mi) of riparian habitat surveyed, 7.8 km, or nearly half of the river within CRSP, was rated as high- (3.7 km) or good-quality (4.1 km) habitat for arroyo toads. Arroyo toads (particularly the immature stages) were abundant in the lower third of the Sweetwater River, found virtually continuously along a 5.2-km stretch of river. Breeding individuals and large numbers of young were also detected in the middle of the river within CRSP, thus documenting the presence and breeding of arroyo toads in all four sites from the previous two years. In addition, we recorded a large adult female at the highest known elevation (1,354 m; 4,442 ft) for arroyo toad occurrences in the Sweetwater River watershed, in a severely burned, dry portion of the river several kilometers upstream from the nearest surface water. Chytridiomycosis, a major infectious disease affecting amphibians, was detected in one arroyo toad and one Pacific treefrog which were collected dead during the surveys, possibly representing the first cases of the pathogen in amphibians in the watershed. According to the fire severity transects, fire severity levels were intermediate in the upland habitat surrounding the 2002-03 arroyo toad locations. It appears that the timing (i.e., occurring in fall when most juvenile and adult arroyo toads were underground in their upland burrow sites) and nature of the Cedar Fire and subsequent rainfall resulted in geomorphologic patterns (i.e., deposition of coarse sediments into Sweetwater River) that were not detrimental, but beneficial to the arroyo toad populations at CRSP in the year immediately following the fire. However, continued monitoring is recommended to track post-fire changes in the distribution of arroyo toads and arroyo toad habitat within the Sweetwater River in CRSP.

INTRODUCTION

The arroyo toad (*Bufo californicus*) was listed as endangered by the U.S. Fish and Wildlife Service (USFWS) in 1994 (Federal Register, 59 FR 241:64859-64866). The arroyo toad is considered to have the most specialized habitat requirements of any amphibian found in California (Jennings and Hayes, 1994). The arroyo toad is a mostly terrestrial amphibian that occupies upland habitats with sandy or other friable soil types in close proximity to their aquatic breeding sites. Their specific breeding pool requirements include: 1) proximity to sandy terraces, 2) low current velocity, 3) majority of pool < 30 cm (1 ft) deep, 4) extensive sand/gravel substrate, 5) gently sloping shoreline, or central bar, and 6) bordering vegetation low or set back such that most of the pool is open to the sky (Sweet 1992). Following adequate winter and spring rainfall, they migrate from upland habitats down to quiet pools that form along low-gradient drainages to breed in spring and summer.

In 1999, adult arroyo toads were observed foraging along the Sweetwater River at the southwest border of Cuyamaca Rancho State Park (CRSP), San Diego County, California. At that time, the extent of suitable habitat and the distribution of the arroyo toad within the Park were unknown, and in 2002 and 2003, California State Parks contracted with the U.S. Geological Survey - Biological Resource Discipline (USGS), to conduct daytime habitat evaluation and focused nocturnal surveys to determine the distribution of suitable habitat and presence of arroyo toads within CRSP. In 2002, four reaches qualified as “high-quality” arroyo toad habitat during daytime habitat evaluation surveys (Figure 1) and all were surveyed nocturnally in 2002 and 2003. In 2002, a total of 14 nocturnal surveys were conducted and resulted in the observation of two adult arroyo toads, each in a separate “high-quality” reach. The low number of observations was attributed to the cold and dry weather of the spring and summer of 2002. In 2003, a total of 13 nocturnal surveys were conducted and resulted in the observation of 43 arroyo toads throughout the four reaches, including all life history stages (i.e., egg strings, larvae, metamorphs, juveniles, and adults), and the documentation of breeding in two of the four reaches. The greater number of observations and confirmed breeding during the 2003 surveys were most likely due to the greater amount of rainfall that year and because surveys were shifted to later in the spring and summer when temperatures were higher (Ervin and Fisher 2003).

The status of the arroyo toad populations within CRSP was in question after the Cedar Fire of October 2003, which burned over 90 percent of CRSP and surrounding areas within the Sweetwater River watershed and severely altered the vegetation and habitat features. In the study reported herein, we sought to assess the degree of change in the arroyo toad distribution as well as the loss or alteration of toad habitat due to the fire and subsequent landscape changes (e.g., erosion). More specifically, our objectives were to survey the entire stretch of Sweetwater River within CRSP in order to determine if:

1) the 2002-03 distribution of suitable arroyo toad habitat changed as a result of the Cedar Fire;

2) the 2002-03 distribution of arroyo toads changed as a result of the Cedar Fire;

3) arroyo toad breeding was occurring post-fire and, if so, had the breeding distribution changed from the 2003 locations; and

4) the fire severity levels differed among the four sites previously identified as "high-quality" arroyo toad habitat in 2002-03.

None of the adjacent Lucky 5 Ranch properties or any creek or river systems, other than the main stem of Sweetwater River, surveyed by USGS in 2002-03 (Ervin et al. 2003, Ervin and Fisher 2003) were surveyed in 2004.

STUDY AREA

The study area, the Sweetwater River in Cuyamaca Rancho State Park, is located in the Cuyamaca Mountains of the Peninsular Ranges in San Diego County, California (Figure 1). CRSP currently consists of 10,400 hectares (25,700 acres), with elevations ranging from 1,055 m (3,465 ft.) to 1,985 m (6,512 ft.). The majority of CRSP is drained by the Sweetwater River system and, to a much lesser extent, by Boulder Creek (San Diego River watershed) and its tributaries on the Park's northern end. The creeks and rivers within CRSP range from 1^{st}- to 3^{rd}-order drainages with the Sweetwater River being the largest. The upper Sweetwater River, within CRSP and beyond, is not dammed at any point. This feature, which is rare in the region's watersheds, allows for an unaltered or natural flow regime in the river (Madden-Smith et al. 2003), and may contribute to the support of higher quality habitat for the Park's riparian-associated flora and fauna than would be present in an impeded channel. CRSP's climate, classified as "Mediterranean – Cool," is characterized by the most precipitation in semi-arid San Diego County, with a mean annual precipitation of 934.7 mm (36.8 in) and a mean annual temperature of 11.9ºC (53.4ºF). The mean summer high is 29.6ºC (85.2ºF) and the mean winter low is -2.2ºC (28.1ºF). Major plant communities in CRSP include coniferous forest, mixed chaparral, grassland (native and non-native), oak woodland, and willow riparian (CRSP 2004).

METHODS

To meet our objectives of clarifying the effects the fire had on the arroyo toad populations and on suitable habitat areas that were studied pre-fire, we used three types of surveys across the entire Sweetwater River within CRSP that consisted of: 1) daytime habitat evaluation surveys, 2) fire severity transects, and 3) nocturnal presence surveys. We surveyed the river channel and the immediately adjacent upland habitat in a reach-by-reach fashion, after breaking the river down into 69 reaches (labeled r1-r69 sequentially in an upstream direction; Figure 2). Initially, a small portion of the river, from the CRSP boundary in the Hulburd Grove area to about 0.7 km upstream in CRSP (reaches r1-r4), was surveyed following a refined version of the protocol (USGS unpubl. draft 2002) used in the 2002 CRSP daytime habitat surveys, and resulted in reach lengths of 100-300 m. This method proved too time-consuming and we switched to more streamlined methods of habitat evaluation based on Brehme et al. (2004), which evaluates arroyo toad habitat similarly, but in 250-m increments. Reaches r5-r69, spanning the much longer stretch of river from the upstream end of r4 to the northern boundary of CRSP, were delineated using TOPO!® software (National Geographic 2003). Geographic coordinates for all reaches are listed in Table 1 and 2002-03 sites in Appendix 1.

Daytime habitat evaluation surveys

The arroyo toad is a habitat specialist known to breed only in rivers, creeks and streams and requires slow to quiet pools for spawning (Sweet 1992, Jennings and Hayes 1994, Campbell et al. 1996). Water flow is a function of gradient (i.e., lower gradient usually results in lower flow) and lower stream gradients are more likely to contain greater amounts of habitat features that are highly correlated with potential arroyo toad spawning habitat. The three key physical features associated with low-gradient drainages that are used to characterize riparian areas in terms of arroyo toad habitat quality include: 1) the channel substrate type being predominately composed of depositional sand and the presence of sandy banks, 2) the presence of flat, exposed sandy terraces immediately adjacent to the channel, and 3) channel braiding. The occurrence of a low gradient reach, in combination with a sandy substrate, often results in conditions conducive to the formation of seasonal quiet backwater breeding pools (Sweet 1992, Jennings and Hayes 1994, Campbell et al. 1996, Griffin and Case 2002).

Whereas drainage gradient cutoffs (e.g., around 2 or 3 percent) were included in the habitat evaluation definitions of the 2002-03 studies, they were excluded from the 2004 surveys. From our recent studies (Brehme et al. 2004, Madden-Smith et al. in press), we have concluded that 1) exact cutoffs are not appropriate since arroyo toads may be found in drainages with gradient levels slightly above the 3 percent level, and 2) since the presence of the three key physical features are dependent upon a low gradient, it is redundant to include the gradient cutoff in the definition. Thus, habitat evaluations in 2004 were based on these three physical features alone and did not include gradient.

We conducted daytime habitat evaluation surveys along all river reaches in 2004, whereas the daytime surveys in 2002-03 covered just the four known occupied sites and a few other reaches. Daytime surveys consisted of hiking along stream courses and noting the key physical features known to be associated with suitable arroyo toad habitat as either present or absent. After surveying the various conditions and combinations of upland (terrestrial) and stream channel (potential aquatic breeding pools) characteristics within each reach, it was assigned one of four habitat quality levels (high, good, marginal, or poor) based on the number of the three key physical features determined to be present within each 250-m (except r1-r4) reach. The following habitat quality levels are:

- High-Quality: Any given survey reach with all *three* of the key physical features present.

- Good-Quality: Any given survey reach with only *two* of the key physical features present.

- Marginal: Any given survey reach with only *one* of the three key physical features present.

- Poor: Any given survey reach with *none* of the three key physical features present.

While walking each reach during the daytime surveys, we also spent much effort visually searching for and documenting the presence of the immature life history stages (i.e., egg strings, larvae, or metamorphic individuals) of the arroyo toad, and all other potentially-occurring amphibians. Additionally, all human-induced disturbances as well as all native or non-native reptilian, fish, avian, and mammalian species believed to threaten or have an otherwise measurable effect on arroyo toads were recorded. Age-class and Global Positioning System (GPS) coordinates (or the 250-m reach in which it was observed) were recorded for each animal observation. Primarily dense stands of vegetation – including non-native mustards (e.g., *Brassica* spp., *Hirschfeldia incana*, and *Sisymbrium* spp.) and annual grasses (primarily *Avena* spp. and *Bromus* spp.), as well as native water cress (*Rorippa nasturtium-aquaticum*), and sedges/rushes and their allies (e.g., *Cyperus* spp., *Eleocharis* spp., *Juncus* spp., *Scirpus* spp., and *Typha* spp.) – within the channel which appeared to limit the available arroyo toad habitat were also documented.

Fire severity transects

We used a non-invasive technique of taking shrub skeleton measurements along a transect (Moreno and Oechel 1989) to quantify the fire severity at CRSP caused by the 2003 Cedar Fire. The burnt vegetation sampled was in the upland areas adjacent to the four sites known to be occupied by arroyo toads in 2002-03. The goal was to compare fire severity levels across the sites and to relate the estimates of fire severity to the detection or non-detection of toads at each site. Pilliod et al. (2003) suggest that the effects of fire may be greatest for amphibians that are habitat specialists (e.g., arroyo toads) compared to species that occupy different types of habitat and tolerate a range of environmental conditions. The potential effects include direct mortality from fire, lethal and sublethal effects from increased water temperature (as a result of canopy loss) on aquatic life stages of amphibians (eggs and larvae), effects of both fire smoke and fire retardants on water chemistry, effects of sedimentation in streams and ponds on amphibian reproduction and recruitment, and effects of fire and post-fire conditions on terrestrial movement patterns of amphibians (Pilliod et al. 2003).

Since we were looking for a quick and reliable method of characterizing the effects of the fire on the terrestrial landscape adjacent to the channel, we followed techniques used by Moreno and Oechel (1989) to estimate the single parameter: "fire severity index." This method is based on the premise that the smaller the diameter of the twigs remaining on a stand of shrubs, the lighter the immediate landscape was burned. A highly severe fire, though, completely consumes the smaller twigs, leaving behind only the larger twigs on the shrubs. As per Keeley (1998, and pers. comm.), we non-randomly selected in the field ten upland sites upon which to perform 50-m shrub skeleton transects. Transect sites were selected non-randomly to maximize the number of target shrubs. At three of the four sites, we positioned a pair of transects on opposite sides of the channel, near the midpoint of each site. We placed four transects instead of two around Site 1 since this site extended across a comparatively long stretch of the river. Both transects at Site 4 were conducted on the north side of the channel because the area opposite the channel did not burn in the recent fire [Figure 2; transects are labeled *(2002-03 Site #)* - *(within-site #)*, e.g., transect *3-2* is the second transect performed at Site 3]. Measurements were taken on the nearest individual shrub of the target species at 20 intervals (spaced 2.5 m apart) along the transect (Figure 3). Whereas we intended to use only chamise (*Adenostoma fasciculatum*) as the shrub measured on all transects, the lack of this target species at four of the 10 transect sites forced us to use other chaparral shrub species. We also measured Palmer's ceanothus (*Ceanothus palmeri*), birch-leaf mountain-mahogany (*Cercocarpus betuloides* var. *betuloides*), and scrub oak (*Quercus* sp.), but measured only one species across each transect.

At every 2.5 m along the transect (i.e., measuring tape), we located the nearest target shrub. Then, dial calipers were used to measure the diameter (to the nearest tenth of a millimeter) of the smallest twig remaining on the entire shrub. Each measurement was made only at a point on the twig that was still cylindrical, since splintered/broken twigs could have resulted in biased measurements. We often had to measure more than one twig on a shrub before getting the smallest reading, since visually locating the smallest twig was not always possible on the first attempt. The median and mean were calculated from the 20 measurements of each transect, and converted into an index value (which we called "raw" because the median and mean were not adjusted, contrary to below) based on the "Fire Severity Index 1" in Keeley (1998, and pers. comm.). The index value derived from measuring chaparral shrubs is an even number between 0-10 (with 0 being lowest and 10 highest on a fire severity scale) (Keeley 1998). Odd numbers are designated for coastal sage shrubs only, used in other studies (Keeley 1998). Both estimates of the distribution's center were used in our analysis because the mean was used by Moreno and Oechel (1989), but the median may be more appropriate for our transects since distributions were more commonly non-normal.

Furthermore, to account for differing pre-burn twig diameters (J. Keeley, pers. comm.) based on the unequal growth morphologies among the four shrub species used, we calculated an "adjusted" median and mean for each transect. In accordance with the shrub heights listed in the Jepson Manual (Hickman 1993) and our experience with representative individual shrubs, we compiled the following continuum showing the positions we would expect the four species to take when arranged in order of increasing relative twig thickness:

A. fasciculatum < *C. palmeri* < *C. b.* var. *betuloides* < *Quercus* sp.

A. fasciculatum was used as the base for which comparisons were made in this continuum, so the medians and means for the *A. fasciculatum* transects were not adjusted at all; they were divided by one. The medians and means for the transects of the other three species, however, were scaled down by the following numbers to account for their larger pre-burn expected twig thicknesses, relative to *A. fasciculatum*: the median and mean for the transect where *C. palmeri* was used were divided by 1.33, *C. b.* var. *betuloides* by 1.67, and *Quercus* sp. by two. This scaling resulted in the adjusted median and mean for each transect. For example, we would expect the thickest twigs of an average *Quercus* sp. shrub in the unburned state to be about two times those of an average *A. fasciculatum* twig. So, if a *Quercus* sp. transect resulted in a raw median value of 30 (and a mean value of 26), dividing these values by two would give an adjusted median of 15 (and mean of 13). Each adjusted median and mean value was then converted into an index value, just as discussed above with the raw median and mean. The index values from the raw median/mean from each of the *A. fasciculatum* transects (a subset of the 10 total) were then used to compare fire severity levels among the four known occupied sites of 2002-03. In addition, the fire severity levels were compared using data from *all* 10 transects, but incorporating the index values from the adjusted median/mean to account for the differences among the shrub species measured.

Nocturnal presence surveys

Nighttime arroyo toad surveys were conducted at least once at all four of the occupied sites identified in the 2002-03 studies, regardless of the habitat quality level assigned during the 2004 (post-fire) daytime evaluation surveys. Additionally, nocturnal surveys were conducted at least once along all reaches classified as high- or good-quality arroyo toad habitat post-fire. Reaches that had habitat classified as marginal or poor, but were encountered while walking to or between high- or good-quality reaches were also surveyed. As a result, many more sections of Sweetwater River within CRSP were surveyed nocturnally in 2004 relative to 2002-03.

Nocturnal surveys entailed walking through each reach, covering both aquatic and adjacent terrestrial habitats, in search of any of the various life history stages (i.e., calling males, egg strings, larvae, and metamorphic individuals in the channel, and foraging juveniles and adults in the upland habitat) using visual observation and aural detection of calling males. All surveys were conducted by biologists familiar with the life history and ecology of the arroyo toad. This included the ability to distinguish between eggs and larvae of the western (or California) toad (*Bufo boreas halophilus*) and the arroyo toad, as well as identify the male arroyo toad advertisement call. As in the daytime surveys, all other herpetofauna, fish, avian, and mammalian species or impacts considered to have an effect on arroyo toads were noted. Headlamps with 45,000-candle power were used to provide the required amount of illumination to maximize detection (USFWS 1999b). Age-class and Global Positioning System (GPS) coordinates (or the reach in which it was observed) were recorded for each animal observation.

Nocturnal surveys were conducted using a modified version of the USFWS arroyo toad survey protocol (1999b). We found it necessary to deviate from the protocol in terms of the timing surveys are conducted because of the weather conditions at CRSP, a high-elevation site. As in the 2003 surveys, we pushed back the start of our surveys until June (rather than April in the protocol) due to colder nighttime temperatures occurring later into the year at CRSP. We commenced surveys as early as 30 minutes (the protocol advises 60 minutes) after dusk to take advantage of the darkness, but prior to lower air temperatures later in the night. The last surveys were pushed back to July and August after recording air temperatures at dusk of just 10 and 11ºC in June. All subsequent visits had starting temperatures clearly above the USFWS guideline of 13ºC at dusk.

All surveys were performed in the absence of wind, hard rains, and no closer than four days to a full moon (USFWS 1999b). Because the arroyo toad is restricted to breeding in lotic habitats with a range of hydroperiods (i.e., perennial, semi-permanent, seasonal, ephemeral) (Sweet 1992, USFWS 1999a), surveys were conducted irrespective of the presence of surface water. The protocol recommends six surveys during the breeding season to be "reasonably confident that arroyo toads are not present at a site," specifically intended for seekers of environmental clearance for a proposed activity. Since our purpose in the study was instead to document the distribution of arroyo toads of all age classes across the entire study site, we were confident that the modification of surveying each qualified reach on at least one nighttime visit, in addition to a daytime visit to all reaches, was sufficient in satisfying the objective. All other guidelines (i.e., regarding ambient conditions and care towards toads and habitat) in the protocol were exactly followed.

Specimens collected and sent for analyses

Three dead amphibian specimens and one live fish specimen were collected during the 2004 surveys. One dead arroyo toad metamorph and one dead adult Pacific treefrog (*Hyla regilla*) collected on 17 May, along with one dead arroyo toad adult collected on 1 June, were sent to D. Earl Green, D.V.M. (USGS National Wildlife Health Center) for pathology. On 1 June, one partially-armored threespine stickleback (*Gasterosteus aculeatus* var. *microcephalus*) was collected and sent to David Jacobs, Ph.D. (UC Los Angeles) for genetic research. In addition, tail clips were taken from five two-striped garter snakes (*Thamnophis hammondii*) and stored for future genetic analysis.

RESULTS AND DISCUSSION

Daytime habitat evaluation surveys

In 2004, habitat evaluation surveys were conducted along the entire Sweetwater River, on five separate days between 17 May and 12 July (Table 2). A total of 17.0 km (10.6 mi) of riparian habitat was hiked and evaluated for arroyo toad habitat quality. Of the 69 reaches, 15 were classified as "high-quality," 17 as "good-quality," 30 as "marginal", and 7 as "poor." So, 7.8 km (4.8 mi), or nearly half of the river within CRSP, was rated as high- (3.7 km) or good-quality (4.1 km) habitat for arroyo toads in the year immediately following the Cedar Fire. The remainder of the reaches were identified as marginal (7.5 km) or poor (1.8 km) because each lacked two or more habitat features known to be key for arroyo toad occurrence (Table 1; Figure 4). In some areas, the high- and good-quality reaches were contiguous (up to 3.25 km in length, as in r43-r54); whereas marginal or poor reaches separated high/good reaches from one another in other parts of the river. More reaches were classified as high/good in the 2004 habitat evaluation surveys compared to the 2002-03 surveys, in which only four sites, totaling just 4.3 km of the entire river length, were rated as high-quality habitat (there was no "good-quality" habitat found).

The substantial increase, relative to the pre-fire surveys, in the amount of suitable habitat found in 2004 may be due to several factors. In general, the fire decreased much of the vegetation, possibly opening up some reaches to shift towards conditions favoring arroyo toad inhabitation. Whereas post-fire erosion clearly added loads of ashy silt and plant debris in some reaches thus discouraging arroyo toad use, many reaches, which had silt or other non-friable substrates and riparian vegetation covering the channel and adjacent terraces in the pre-fire state, experienced post-fire effects beneficial to arroyo toads. The fire's removal of dense riparian vegetation including much of the canopy may have opened up both the pools for potential breeding habitat, and the terraces with friable soils for burrow sites. Additionally, reduced vegetation likely translated into less transpiration of water, which could have resulted in longer lasting or larger pools. The formation of these backwater pools may have been encouraged by the addition of coarse sediments (sand and fine gravel) from the erosion of unvegetated slopes in the upland, which deposited in the river, given the thinned vegetation. The beginning of 2004 was another period with less-than-normal rainfall, so large-scale erosion did not appear to take place, and many arroyo toad breeding sites were not filled up with fine sediments and plant material. Seventy-six percent of normal rainfall levels fell at CRSP in the two months following the Cedar Fire, November and December 2003. However, just 48 percent of normal precipitation levels had fallen in CRSP nine months through 2004 (DWR 2004).

During our 2004 daytime surveys in CRSP, we found the majority of the Sweetwater River downstream of Camp Cuyamaca ("camp;" the County of San Diego's outdoor environmental education program for sixth graders, near r43) had slowly flowing water until June. Later, surface water was only found discontinuously from the camp south to the Park boundary at Hulburd Grove. However, supplemental water from the septic leach fields at the camp seeps into the Sweetwater River in r41; its highest volume is during the normal school year from September to June (K. Marsden, pers. comm.). This runoff appears to be a significant factor in supplementing any precipitation-born river water south of this confluence. North of the camp, a few small areas of the channel appeared moist, but there was no surface water discovered during any of the surveys. This section was dry during the 2002-03 surveys as well, given that no surface water was found along the entire river within CRSP during the first two years of the study that was not present in 2004 (Ervin and Fisher 2003, pers. comm.). We recommend targeting this upper portion of the river within CRSP particularly in heavy rainfall years to determine when it becomes dry and to search for signs of breeding arroyo toads. The documentation of arroyo toad breeding near the Sweetwater River headwaters would represent a substantial addition to the known breeding locations in the watershed.

The daytime surveys produced the majority of our arroyo toad observations. Of the 67 total unique observations of either a solitary individual or a group of larvae, metamorphs, or juveniles, 45 occurred during the day (Appendix 2). Larvae and metamorphs were abundant throughout the lower third of the Sweetwater River. Including the metamorphs observed in r5 on a night survey, larvae and/or metamorphs were found in reaches r1 to r22 (a 5.2-km stretch of river) and in r40 and r41, bringing the total number of reaches with breeding observations to 24, which include parts or all of the four occupied 2002-03 sites (Figure 5). Arroyo toads were not observed in the dry portion of the channel upstream of the camp during daytime surveys. Observations of metamorphs ranged from a single individual to an estimated 100 individuals all within a single reach (Figure 6). As many as an estimated 2,000 larvae were observed in a single reach (r4); however, counts in the hundreds were more common. No arroyo toad egg strings, juveniles, or adults were found during the day surveys. Because our surveys started in mid-May, and given the large number of larvae observed, we may have missed the egg stage altogether. Juveniles and adults, although potentially active outside of their burrows during the day, are primarily nocturnal (USFWS 1999a).

Non-target species

Other incidental animals which were recorded during the daytime surveys and entered into the database included three bird species (brown-headed cowbird, *Molothrus ater*; Steller's jay, *Cyanocitta stelleri*; wild turkey, *Meleagris gallopavo*), one fish (partially-armored threespine stickleback), three frogs (California treefrog, *Hyla cadaverina*; Pacific treefrog; western toad), two mammals (mule deer, *Odocoileus hemionus*; an unknown fossorial small mammal, likely the broad-footed mole, *Scapanus latimanus*), and five snakes (California kingsnake, *Lampropeltis getulus*; southern Pacific rattlesnake, *Crotalus viridis*; speckled rattlesnake, *Crotalus mitchelli*; two-striped garter snake, *Thamnophis hammondii*; western ringneck snake, *Diadophis punctatus*) (Figure 7; Appendix 2). The frogs were the most frequently detected (136 observations of 168 total observations; 81.0 percent), and the garter snake was fairly common (11 observations), while the birds, fish, mammals, and other snake species were recorded in much lower numbers. Although mammalian tracks of mule deer, raccoon (*Procyon lotor*), bobcat (*Lynx rufus*), coyote (*Canis latrans*) and possibly mountain lion (*Puma concolor*) were common throughout most of the channel, the specific locations of only two mammals were recorded.

Possible impacts observed

A Steller’s jay was observed in r12 and appeared to be foraging along the edge of the water. This reach was documented as being populated by hundreds of arroyo toad larvae and several metamorphs that same day. Given that common ravens and American crows (*Corvus corax* and *C. brachyrhynchos*, respectively) are known predators of arroyo toads (USFWS 1999a), it is possible that the related jay behaves similarly. All three corvids are common residents of CRSP. Wild turkeys were observed in 2004 both along reaches where arroyo toads were found (r13 and r40), as well as in areas where toads were not detected (r32, and six separate reaches upstream of the camp). Since the early 20th century, wild turkeys have been introduced onto lands adjacent to CRSP by state agencies for recreational hunting purposes, and now inhabit CRSP. Turkeys potentially prey on arroyo toads and are commonly sited within the woodlands of CRSP because hunting is not permitted within state parks (Ervin and Fisher 2003, and references therein). Brown-headed cowbirds, which are known to be nest parasites of many native songbirds, were noted due to their effect on the overall health of the avian community, although they most likely have no effect on arroyo toads.

Just one individual fish, a stickleback (captured in r13), was detected across all day and night surveys. Although there is no current evidence that suggests sticklebacks consume amphibian eggs and/or larvae as prey, the fish may otherwise affect arroyo toads by spreading parasites (Ervin and Fisher 2003). No other fish were observed in 2004 throughout Sweetwater River in CRSP, despite our searching for them in all surface water, focusing primarily on large pools. Although it is not probable that we located the only fish in the river, the relative absence of fish that we observed is a significant finding. In contrast to the large number of non-native fish observed in the 2002-03 surveys, the near nonexistence of non-native predatory fish in 2004 will likely benefit the populations of arroyo toads and other native species. Non-native fish, such as the rainbow trout (*Oncorhynchus mykiss*) and goldfish (*Carassius auratus*) are thought to be predators of arroyo toads and may spread disease (Sweet 1992, Ervin and Fisher 2003). One potential cause for the disappearance of fish in the river is an extreme flash-flooding event which took place locally on 24 Dec 2003 and may have washed populations downstream and out of CRSP (S. Shelton and K. Marsden, pers. comm.). Allen Greenwood (co-founder of San Diego Trout, a fish conservation group), however, believes that the Cedar Fire exterminated the trout in the upper Sweetwater River via direct mortality from the wildfire itself, or by the loss of foliage which shades and keeps the water temperatures cool, and post-fire debris and ash flow which can deplete dissolved oxygen (Rodgers 2004). If the fire is responsible for removing the stocked trout observed in 2003 (Ervin and Fisher 2003), it may have removed the non-native goldfish and stickleback as well.

One or more potential disturbances and/or threats to arroyo toads were recorded in 55 of the 69 reaches during the daytime surveys (Table 1). Human foot traffic (other than from our surveys) was the most common disturbance type, with documentation in 32 reaches. Potentially restrictive (i.e., dense) vegetation in the channel or on terraces were the second-most widespread form (26 reaches), followed by garbage (23), horse traffic (12), and automobile or bicycle tracks (6). More than half (13/25, 52 percent) of the reaches where arroyo toads were observed had foot traffic. Likewise, 10 of the 12 reaches (83 percent) where horse activity was recorded had arroyo toads. The majority of the trails along Sweetwater River in CRSP were open to the public over the course of the 2004 surveys (G. Lyons, pers. comm.).

Fire severity transects

Ten shrub skeleton transects were performed in May-June 2004 around the four 2002-03 occupied sites (Table 3). We determined that the uplands immediately adjacent to the four sites experienced mid-range levels of fire severity. First, including just the six transects conducted using *A. fasciculatum* as the target shrub (each site included at least one of these), *raw* index values were either 4 or 6 (based on a scale of 1-10, with 10 being the highest severity), depending on the transect. Furthermore, if all 10 transects are included (incorporating all four species and using the *adjusted* index values), the average index value per site is between 4 and 5. Lastly, the average of all 10 transects' adjusted values is either 4.4 or 4.6, depending on whether transect 1-B2's index value 2 (from the median) or 4 (from the mean) is used in the calculation. The adjusted value in transect 1-B2 represented the sole case where the median and mean translated into different index values. Otherwise, for each transect, the raw median and mean resulted in the same index values, as did the adjusted median and mean.

Therefore, the levels of fire severity on the landscape around the four 2002-03 sites did not appear to differ enough to cause any differences observed in the distribution of arroyo toad habitat and individuals. If the upland adjacent to one site exhibited post-fire effects considered of high severity, we would expect landscape processes such as erosion to differ from a site classified as low severity. Since the upland around all sites experienced mid-range severity, we assume the geomorphology along the channel at each site was similarly influenced by post-fire processes. This is not to say that the fire burned homogenously through the Sweetwater River channel in CRSP, as patches of unburned vegetation were observed along several reaches.

Mid-range fire severity was physically characterized in the upland chaparral community by stands of shrub skeletons through which walking was fairly easy (Figure 3). Above-ground material of nearly all shrubs was killed by the fire, leaving behind charred branches with relatively few small twigs. However, nearly all individuals survived the fire, as they were resprouting from basal burls or lignotubers. All four shrub species used in the transects were observed regenerating; in fact, new growth at the base of each shrub considerably aided in species identification. New growth following the fire was not limited to woody plants, as nearly 100 native species of annual and perennial herbs could be found in the surrounding chaparral community, taking advantage of the opened canopy (Franklin and Spears 2004).

Nocturnal presence surveys

Five nighttime surveys were conducted between 7 June and 11 August 2004 to survey at least once each of the four 2002-03 sites and all reaches classified as "good-" or "high-quality" arroyo toad habitat in the 2004 evaluation surveys (Table 1). Across the 51 reaches [a length of approximately 13 km (8 mi)], arroyo toads were found in 14 reaches, one of which (r66) only included a detection during nocturnal surveys (Figure 5;

Appendix 2). We observed arroyo toads 22 different times during the night surveys. We documented toads nocturnally in all of the 2002-03 sites except for Site 2. However, metamorphs were found at night in the reach (r21) immediately upstream of Site 2, as well as the reach (r17) just 250 m downstream of Site 2. Metamorphs, observed singly or in loose groups of up to about 100 individuals, accounted for most (14) of the 22 observations, and were seen up through 9 August, the second to final survey. The rest of the detections included five adults (one of which is pictured in Figure 8), two juvenile observations (one lone individual, and a group of five individuals), and one cluster of about 250 tadpoles. Larvae were not observed in the day or night surveys following the 9 June survey.

Among the adult observations, one was a large female discovered on 7 June in a completely dry reach (r66, very near the headwaters of the Sweetwater River), about 6 km up the channel from the nearest surface water present in the channel at that time. This individual (Figure 9) also represented a high elevation record for arroyo toads in the Sweetwater River watershed: 1354 m (4442 ft). This was exactly 100 m in elevation greater than the previous record, which was found at a position about 5 km down the channel, in r47 within Site 1, on 22 July 2003 (Ervin and Fisher 2003). Notably, the female observed in 2004 was observed nearly 3 km up the channel from the northern end of 2002-03's Site 1, which was the most upstream area of suitable habitat classified prior to the fire. On 9 June, we heard a calling male arroyo toad and, shortly thereafter, saw a male right next to a burrow in approximately the location where we would have placed the origin of the call. Therefore, we cannot be certain that there was more than one arroyo toad detected that night in r41 (Site 1). The other two adults were found in the lower third of the river within CRSP, one in r2 (also Site 4) on the night of 20 July and the other about four hours later, in r11 (Site 3).

Fewer adults were detected in the 2004 surveys compared to those of 2003 (Ervin and Fisher 2003). Only two arroyo toad adults were observed during the 2002 surveys, but 33 adults were recorded in 2003 (possibly including an unknown number of recounted individuals). However, the day and night surveys combined in 2004 documented 59 observations of larvae and metamorphs, compared to seven observations in 2003. The start and end dates for surveys (mid-May to mid-August) were extremely similar across years 2003 and 2004. The much greater number of observations of adults relative to immature arroyo toads in 2003 is likely because the 2003 surveys were more heavily focused on the nocturnal component (when adults are typically active), with seven nights spent across Sites 1-4. Only Site 1 and the water underneath the State Route 79 bridge were surveyed once during daylight hours in 2003. As mentioned previously, we spent five full days in 2004 conducting the daytime surveys, covering the entire river within CRSP. Because we spent considerably more time surveying during the day, it is not surprising that we documented a large ratio of immatures to adults. Furthermore, the significance to the population of detecting few adults in 2004 is unknown, since we saw hundreds to thousands of larvae and metamorphs, indicating a viable population.

Other arroyo toad studies have shown that when a site is wet, the detectability of eggs, larvae and metamorphs is much greater than that of adults during night surveys (Atkinson et al. 2003, Brehme et al. 2004, and this report). Therefore, monitoring the immature life stages may be a better way of showing site occupancy and providing a direct measure of reproduction. The major purpose of the surveys for all three years was to gain arroyo toad distribution information. The 2002-03 surveys provided pre-fire toad occurrence and habitat distribution data and the 2004 surveys provided post-fire toad and habitat data. Numbers of individuals detected have not been used to estimate population sizes, as mark-recapture studies would be needed for this. Overall, the greater number of arroyo toad observations, relative to 2002-03, in the year immediately following the Cedar Fire (2004) may be due to the larger distribution of high/good-quality habitat and/or a direct response of fish removal from the system resulting in greater recruitment success.

Non-target species

Nighttime observations of species other than the arroyo toad were again dominated by the Pacific treefrog, of which 34 detections included larvae, metamorphs, juveniles, and adults, often times in considerable numbers. We also documented several California treefrogs, western toads, four southern Pacific rattlesnakes, and a single Jerusalem cricket (*Stenopalmatus* sp.). No fish were observed during the night surveys. Additionally, as in 2002-03, there were no observations throughout all 2004 day and night surveys of the non-native aquatic predatory species [crayfish (*Procambarus clarkii*), bullfrogs (*Rana catesbeiana*), African clawed frog (*Xenopus laevis*), mosquitofish (*Gambusia affinis*) and warm-water game fish such as the largemouth bass (*Micropterus salmoides*) and green sunfish (*Lepomis cyanellus*)], which are commonly found in coastal southern California wetlands and known to negatively effect native amphibians species (Sweet 1992, Jennings and Hayes 1994, USFWS 1999b, Hathaway et al. 2002).

Specimen pathology report

The three amphibian specimens sent to Dr. Green (USGS National Wildlife Health Center) for pathology were analyzed and a report was issued on 2 December 2004 (USGS NWHC unpubl. data). Two of the three anurans collected were infected with the disease chytridiomycosis, caused by the chytrid fungus, *Batrachochytrium dendrobatidis*. Green stated that these two cases may be the first incidences of this serious, contagious disease to be detected in amphibians in the Sweetwater River watershed. An adult arroyo toad and adult/sub-adult Pacific treefrog were each infected in the skin of the ventral body and feet. The infection in the adult arroyo toad was determined to be severe and was the probable cause of death. The treefrog had a mild chytrid infection, and so it was uncertain whether this disease contributed to its death. The arroyo toad was collected in r12 and the treefrog at least 1 km downstream, in r7. The cause of death for the third anuran collected, the immature arroyo toad, was not determined, but neither chytridiomycosis nor any other infectious diseases were found (USGS NWHC unpubl. data). Results from analyses on the stickleback and garter snakes will be conveyed to the client as soon as they are known.

Chytridiomycosis is reported to be one of the biggest threats facing amphibian species survival worldwide, and its dissemination appears to be in large part due to the international trade of a major host of the chytrid fungus, the African clawed frog (Weldon et al. 2004). Although no clawed frogs were found in CRSP during the 2002-04 surveys, it is possible that we missed detecting its presence. Consequently, the origin of the chytrid fungus in the upper Sweetwater River system remains unknown. The prevention of clawed frog propagation throughout the Park should be a continuous goal in order to safeguard the endangered arroyo toad and other native amphibians, both from future cases of chytridiomycosis as well as other negative impacts.

RECOMMENDATIONS

After documenting the ecology and life history of the arroyo toad within Cuyamaca Rancho State Park over the two-year period prior to the Cedar Fire and the first year immediately following the fire, we recommend further studies in 2005 and beyond to better understand the long-term effects of this large-scale wildfire on the population dynamics of this federally endangered amphibian.

- In years with heavier rainfall, conduct daytime and nocturnal surveys for arroyo toads in the northern third of the Sweetwater River within CRSP to determine the extent of the arroyo toad's distribution and breeding while these reaches are still wet. We suggest a first survey in late March and continued into April and May, but perhaps when dusk temperatures approach 13ºC or greater.

- Assess the effects of any recent heavy rainfalls on the CRSP arroyo toad habitat (i.e., did erosion and scouring of previously suitable habitat occur?). In October 2004, a total of 389.9 mm (15.4 in) of rain was recorded for the vicinity, ending one of the longest dry spells in the San Diego region's history. Moreover, an additional 259.3 mm (10.2 in) of rain fell on CRSP in the final two months of 2004 (DWR 2004). These assessments will help determine whether the heavy rains were beneficial or detrimental to the arroyo toads in CRSP.

- During each of the next five years, repeat daytime habitat evaluation surveys along the entire Sweetwater River within CRSP to study the effects of post-fire succession on arroyo toad habitat and distribution. Additionally, use these surveys to look for eggs, larvae, and metamorphs to monitor site occupancy and reproduction success.

- Conduct nocturnal surveys for adult arroyo toads along all reaches in the Sweetwater River within CRSP identified as good- or high-quality habitat and begin a mark-recapture study for the purpose of estimating population sizes. Population trends may then be tracked in future years.

We recommend the following actions and management policies to protect and conserve the arroyo toads within Cuyamaca Rancho State Park. While allowing the public to continue to enjoy compatible recreational programs and activities, we suggest that efforts be made by California State Parks to:

- Continue to discourage off-trail horse riding, biking, and hiking; restrict public access to the Sweetwater River's reaches identified as suitable arroyo toad breeding habitat and upland. Install unobtrusive informational signs to make the public aware of the restrictions and justifications. The signs should be designed so that they do not provide perches from which corvids search out and prey on arroyo toads. These displays should provide information regarding the ramifications of disturbing, collecting, or killing protected species. Outreach should also involve working with Park Rangers that patrol areas with known arroyo toad populations.

- Work with the California Department of Fish & Game to prohibit future stocking of fish (particularly hatchery-stock rainbow trout) in Sweetwater River within CRSP, as well as in any tributaries that may connect with the river.

- Develop a protocol with maps delineating safe zones (outside of arroyo toad breeding and upland habitat) within which heavy machinery can be brought on site and operated when fire conditions or post-fire management actions (e.g., creation of roads for firefighting, dead tree removal) require them. Arroyo toads would be at greatest risk of being crushed in the riparian zone between the start of the first warm rains of winter through late summer (roughly January through September), and in upland habitat during the fall and early winter (September through December) (Sweet 1992).

- Evaluate the purity and overall quality of runoff water from Camp Cuyamaca to ensure that harmful chemicals are not present. This consistent water flow may be extending the arroyo toad breeding season further into the typically-dry summers.

- Conduct periodic surveys along Sweetwater River for introduced species (rainbow trout and other predatory fish, crayfish, African clawed frogs, bullfrogs, goldfish, etc.) in reaches where arroyo toads are present, as well as places easily accessed by Park visitors such as Hulburd Grove, Green Valley Falls Campground and the State Route 79 bridge crossing. Invasions from Sweetwater River portions downstream of CRSP, as well as ponds outside of the Park are possible, and should be monitored. Initiate efforts to capture and remove the non-natives before they become established and more widely distributed within CRSP. Pay particular attention to preventing the introduction and/or spread of clawed frogs to reduce the likelihood of a chytridiomycosis outbreak among the native amphibians.

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Table 1. Length, latitude/longitude coordinates, elevation, and daytime habitat evaluation results for all reaches.

						Physical Characteristics [3]			
Reach [1]	Length (km)	Latitude ° N	Longitude ° W	Elevation, m	Quality Level [2]	Sandy Substrate	Sandy Terraces	Channel Braiding	Disturbances & Threats
r1	0.1	32.87328	116.61469	1069	Good		X	X	H, V
r2	0.1	32.87226	116.61411	1059	High	X	X	X	H, V
r3	0.2	32.87162	116.61364	1067	Marginal			X	F, V
r4	0.3	32.87079	116.61214	1069	High	X	X	X	F, H, V
r5	0.25	32.86988	116.60916	1064	Good	X		X	
r6	0.25	32.87178	116.60804	1064	Good	X		X	
r7	0.25	32.87373	116.60732	1072	Good	X		X	
r8	0.25	32.87562	116.60613	1113	Marginal			X	V
r9	0.25	32.87708	116.60442	1116	Poor				H
r10	0.25	32.87906	116.60338	1118	Marginal		X		H, V
r11	0.25	32.88111	116.60252	1118	Marginal	X			V
r12	0.25	32.88289	116.60112	1120	High	X	X	X	
r13	0.25	32.88436	116.59941	1122	Marginal		X		F
r14	0.25	32.88645	116.60010	1126	Marginal			X	F
r15	0.25	32.88858	116.59991	1132	Marginal			X	F, H
r16	0.25	32.89001	116.59797	1148	Marginal		X		F, H
r17	0.25	32.89190	116.59684	1156	Good	X	X		F, H
r18	0.25	32.89398	116.59666	1156	Good		X	X	F, H, T
r19	0.25	32.89592	116.59546	1157	High	X	X	X	F, G, H, T
r20	0.25	32.89778	116.59412	1157	Marginal		X		F, V
r21	0.25	32.89964	116.59299	1157	Good	X		X	F
r22	0.25	32.90017	116.59067	1166	Marginal	X			F, G
r23	0.25	32.89953	116.58820	1167	High	X	X	X	F
r24	0.25	32.89892	116.58575	1170	Good	X	X		F, G
r25	0.25	32.90016	116.58390	1179	Poor				F, G
r26	0.25	32.90129	116.58184	1194	Marginal			X	F, G
r27	0.25	32.90338	116.58243	1194	Marginal			X	F
r28	0.25	32.90544	116.58326	1202	Marginal	X			F, G, V
r29	0.25	32.90703	116.58197	1205	Poor				F, G, V
r30	0.25	32.90810	116.57982	1207	Poor				F, G, V
r31	0.25	32.90911	116.57752	1209	Marginal	X			G, V
r32	0.25	32.91018	116.57540	1217	Poor				F, G, H, V

Table 1 (continued).

Reach [1]	Length (km)	Latitude ° N	Longitude ° W	Elevation, m	Quality Level [2]	Physical Characteristics [3] Sandy Substrate	Sandy Terraces	Channel Braiding	Disturbances & Threats
r33	0.25	32.91083	116.57308	1219	Marginal			X	F, G, V
r34	0.25	32.91207	116.57165	1220	Poor				
r35	0.25	32.91348	116.56973	1220	Marginal		X		F, V
r36	0.25	32.91550	116.56909	1230	Marginal		X		F
r37	0.25	32.91653	116.56697	1231	Marginal		X		V
r38	0.25	32.91832	116.56558	1230	Good		X	X	
r39	0.25	32.92001	116.56405	1231	Marginal		X		G
r40	0.25	32.92066	116.56169	1232	Marginal		X		
r41	0.25	32.92229	116.56007	1241	Good	X	X		F, V
r42	0.25	32.92439	116.55936	1242	Marginal		X		
r43	0.25	32.92622	116.55793	1243	High	X	X	X	F
r44	0.25	32.92816	116.55681	1243	High	X	X	X	F, G, H, V
r45	0.25	32.93008	116.55565	1244	High	X	X	X	F, G
r46	0.25	32.93186	116.55419	1249	High	X	X	X	G
r47	0.25	32.93351	116.55269	1253	High	X	X	X	G
r48	0.25	32.93473	116.55058	1255	High	X	X	X	G
r49	0.25	32.93657	116.54964	1257	High	X	X	X	F, G
r50	0.25	32.93821	116.55007	1257	High	X	X	X	G
r51	0.25	32.93927	116.55183	1260	Good		X	X	G
r52	0.25	32.94089	116.55037	1264	Good		X	X	G
r53	0.25	32.94284	116.54920	1266	High	X	X	X	V
r54	0.25	32.94463	116.54797	1267	High	X	X	X	V
r55	0.25	32.94636	116.54664	1277	Good	X		X	T
r56	0.25	32.94820	116.54520	1278	Marginal	X			V
r57	0.25	32.95024	116.54428	1285	Marginal	X			
r58	0.25	32.95226	116.54326	1294	Good	X		X	T
r59	0.25	32.95434	116.54251	1303	Good	X		X	
r60	0.25	32.95639	116.54164	1309	Marginal	X			
r61	0.25	32.95837	116.54074	1317	Good	X	X		F, G, T
r62	0.25	32.96029	116.53983	1327	Marginal	X			F, V
r63	0.25	32.96244	116.53943	1332	Marginal	X			V
r64	0.25	32.96453	116.53902	1340	Marginal	X			F, T, V

Table 1 (continued).

Reach [1]	Length (km)	Latitude ° N	Longitude ° W	Elevation, m	Quality Level [2]	Physical Characteristics [3]: Sandy Substrate	Sandy Terraces	Channel Braiding	Disturbances & Threats
r65	0.25	32.96660	116.53815	1352	Good	X		X	
r66	0.25	32.96867	116.53797	1359	Marginal	X			
r67	0.25	32.97080	116.53800	1373	Marginal	X			V
r68	0.25	32.97290	116.53778	1380	Poor				
r69	0.25	32.97480	116.53653	1395	Marginal	X			G, V
r69		32.97690	116.53618	1415					
Totals					High	Good	Marginal	Poor	
Length	17.0				3.7	4.1	7.5	1.8	
# Reaches	69				15	17	30	7	

[1] Geographic coordinates (WGS84) and elevation values correspond to the downstream end of each reach. The upstream end of each reach is geographically the same point as the values listed in the reach in the row immediately below. Reach r69 has two rows because there are no further reaches upstream.

[2] Quality level: 3 of 3 physical characteristics present (X) = High, 2 = Good, 1 = Marginal, and 0 = Poor.

[3] A "checkmark" indicates any portion of the reach contains ≥10 m of continuous sandy substrate, sandy terraces, or channel braiding. Disturbance & threat codes used: F = human foot traffic, G = human-deposited garbage, H = horse tracks, T = tire tracks from automobile or bicycle, V = vegetation considered to limit arroyo toad habitat (includes exotic mustards and annual grasses, water cress, and sedges/rushes).

Table 2. Survey date, type, region and distance surveyed, and surveyors.

Date	Type	Reaches Surveyed	Distance (km)	Observers
17-May-04	Day	r1 → r7	1.86	M. Mendelsohn, D. Palmer
19-May-04	Day	r43 → r32	2.94	M. Mendelsohn, D. Palmer
1-Jun-04	Day	r8 → r18	2.58	M. Mendelsohn, D. Palmer
2-Jun-04	Day	r19 → r31	3.14	M. Mendelsohn, D. Palmer
7-Jun-04	Night	r69 → r46	5.84	M. Mendelsohn, D. Palmer
9-Jun-04	Night	r45 → r41 [a]	1.22	M. Mendelsohn, D. Palmer
12-Jul-04	Day	r69 → r44	6.34	M. Mendelsohn, D. Palmer
20-Jul-04	Night	r1 → r11	2.83	M. Mendelsohn, D. Clark, E. Ervin
9-Aug-04	Night	r17 → r24	1.95	M. Mendelsohn, D. Clark
11-Aug-04	Night	r38 → r54	4.15	M. Mendelsohn, D. Clark, K. Marsden (w/ J. & C. Dice & N. Kawazoe for part of survey)

[a] Early end of survey due to cold (6°C) ambient temperature.

Table 3. Latitude/longitude coordinates, elevation, and results of the fire severity transects; see Fig. 2 for geographic locations.

Transect	Fire Severity Index 1		Species	Latitude ° N [1]	Longitude ° W	Elevation, m
	Raw	Adjusted				
4-1	6	6	*Adenostoma fasciculatum*	32.87384	116.61424	1090
4-2	4	4	*Adenostoma fasciculatum*	32.87435	116.61494	1097
3-1	4	4	*Adenostoma fasciculatum*	32.88511	116.60152	1140
3-2	4	4	*Adenostoma fasciculatum*	32.88372	116.59836	1146
2-1	8	6	*Ceanothus palmeri*	32.89812	116.59291	1180
2-2	4	4	*Adenostoma fasciculatum*	32.89850	116.59538	1189
1-A1	2	2	*Cercocarpus betuloides* var. *betuloides*	32.92807	116.55224	1282
1-A2	6	6	*Adenostoma fasciculatum*	32.93078	116.55798	1287
1-B1	6	6	*Quercus* sp.	32.94026	116.54776	1282
1-B2	4	2 / 4 [a]	*Cercocarpus betuloides var. betuloides*	32.94222	116.55207	1288

[1] Coordinates in WGS84.

[a] This is the sole case where the index value differed (2 vs. 4) when converted from the median and mean, respectively.

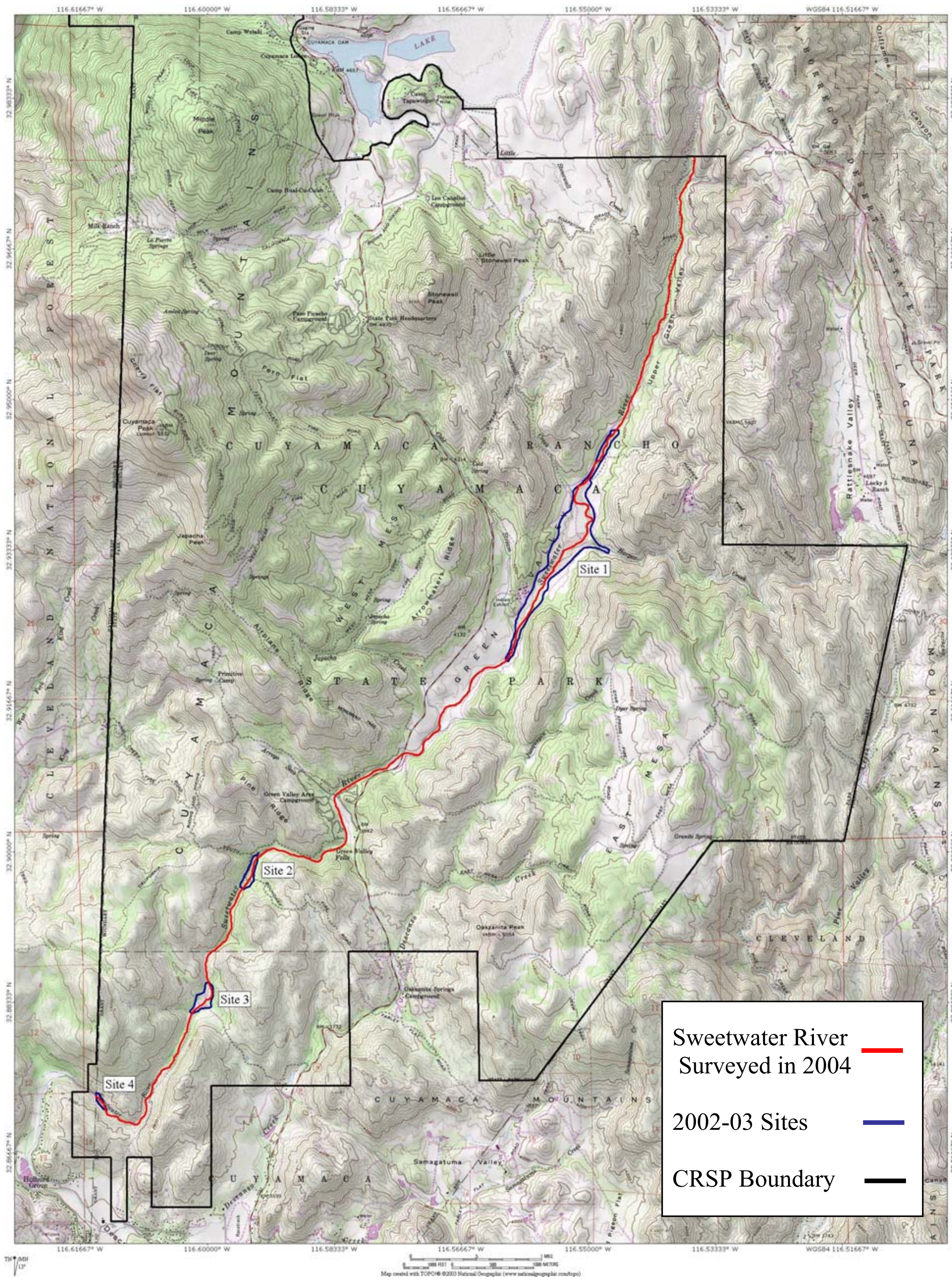

Figure 1. Study site: Sweetwater River in Cuyamaca Rancho State Park.

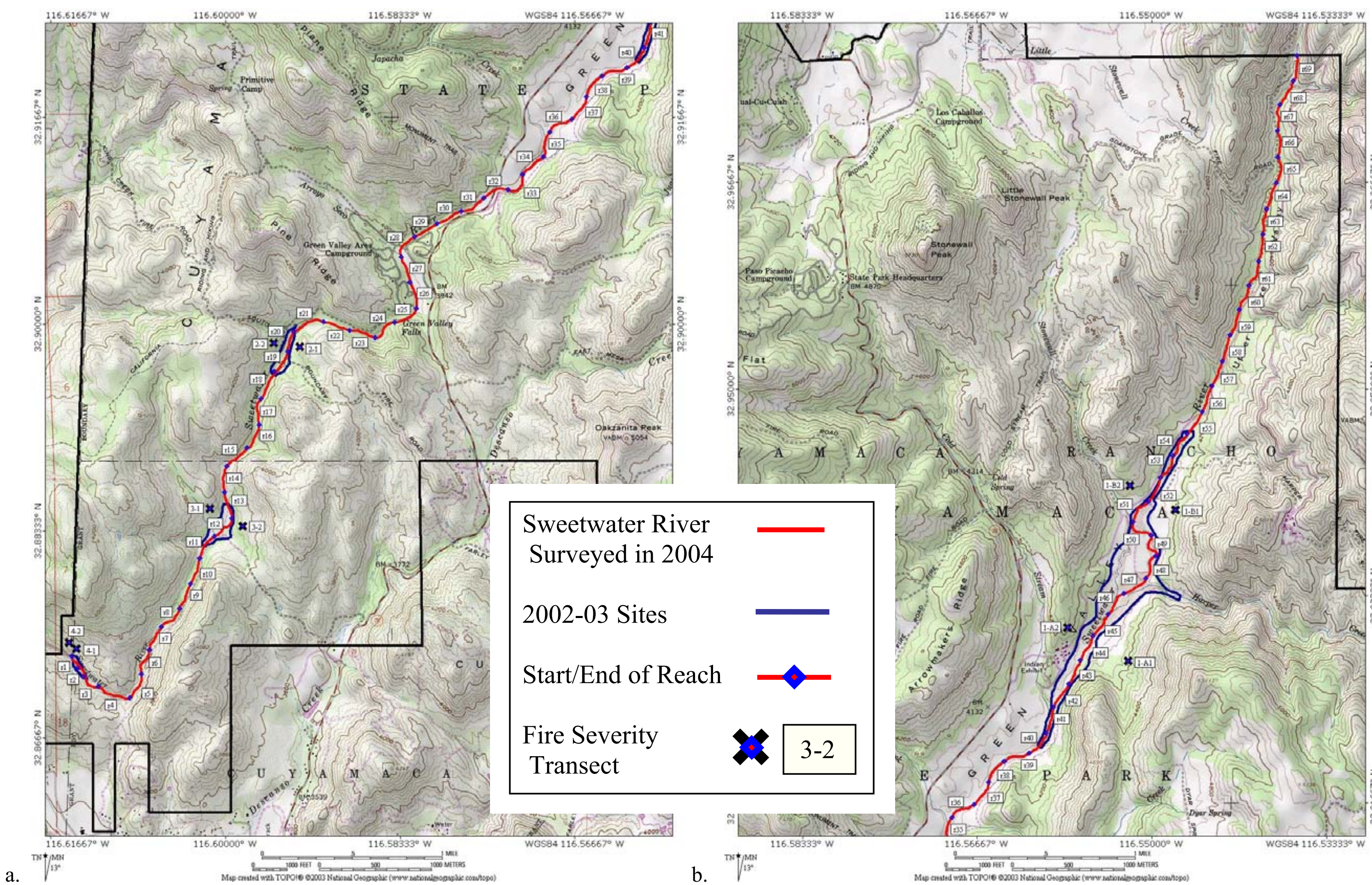

Figure 2. Lower (a) and upper (b) regions of the study site, including the 250-m (except r1-r4) reaches labeled "r_" and bounded by points, and fire severity transects.


Figure 3. USGS researcher measuring the diameter of the smallest twig on a shrub skeleton.

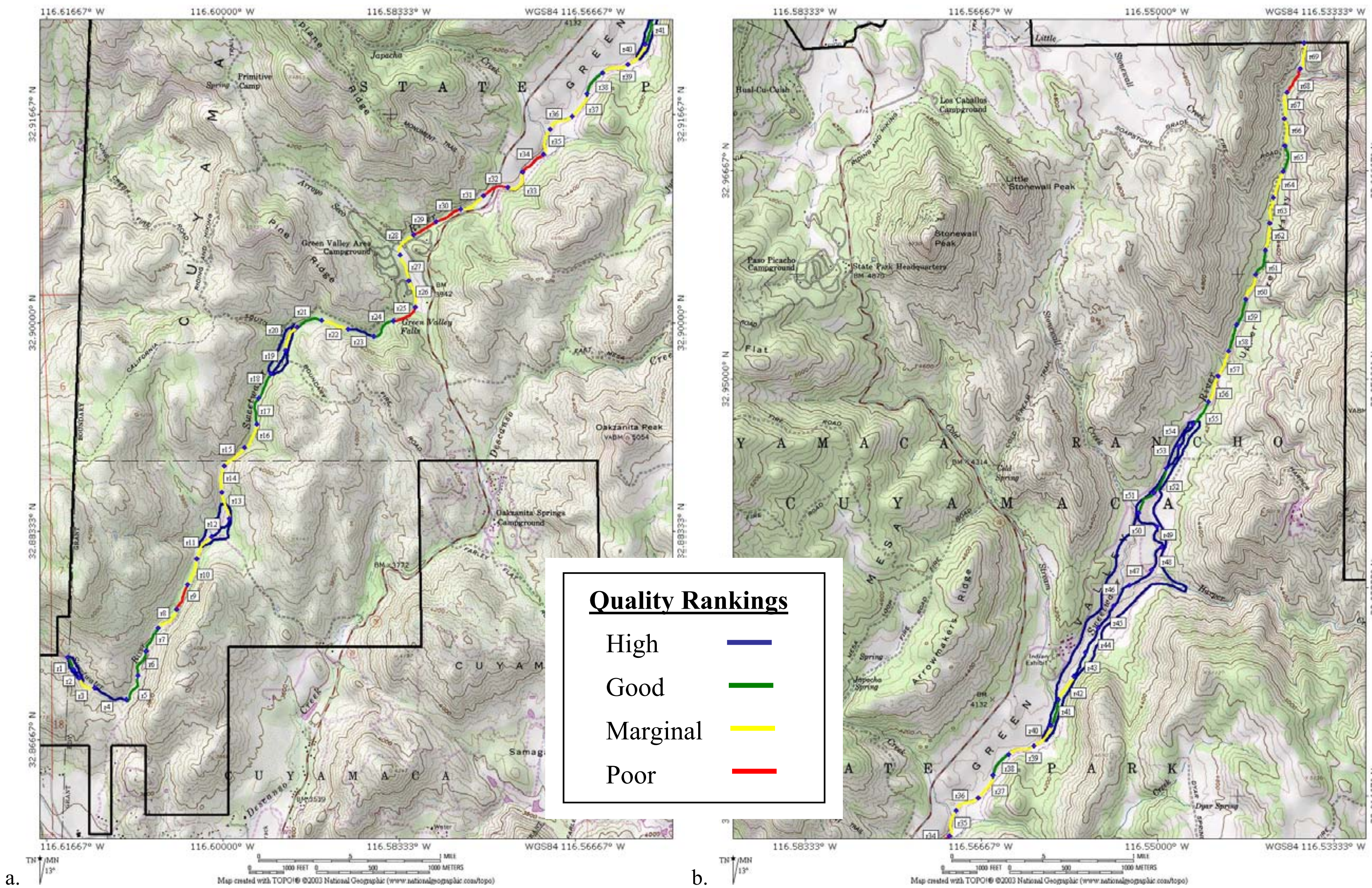

Figure 4. Quality rankings assigned to reaches during daytime habitat evaluation surveys in the lower (a) and upper (b) regions of the study site.

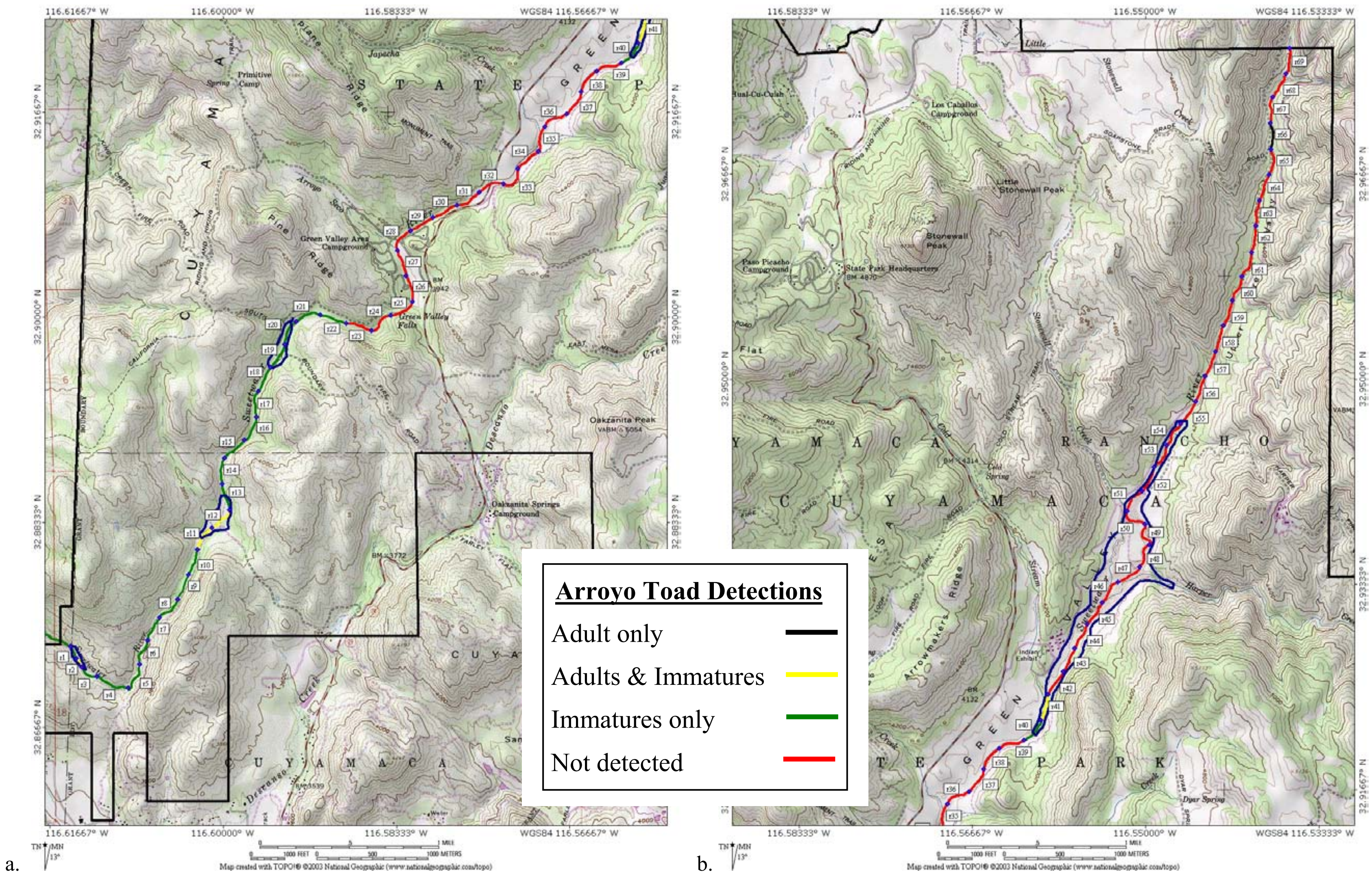

Figure 5. Presence of arroyo toads (all life history stages; immatures include larvae, metamorphs, and juveniles) within reaches, compiled across all surveys in the lower (a) and upper (b) regions of the study site.

a.

b.

Figure 6. Arroyo toad larvae cluster (a) and metamorph (b) observed on daytime surveys.

Figure 7. A few of the non-target species observed during the surveys: (a) Pacific treefrog (*Hyla regilla*), (b) speckled rattlesnake (*Crotalus mitchelli*), and (c) two-striped garter snake (*Thamnophis hammondii*).

Figure 8. Adult arroyo toad observed on 20 July just south of the 2002-03 Site 3.

Figure 9. Adult female arroyo toad observed on 7 June in reach r66, at an elevation record for arroyo toads in the Sweetwater River watershed: 1354 m (4442 ft).

Appendix 1. Coordinates bounding each 2002-03 site, listed in an upstream direction.

Site	Latitude ° N [1]	Longitude ° W	Elevation, m
4A	32.87309	116.61480	1063
4B	32.87133	116.61330	1065
3A	32.88213	116.60211	1120
3B	32.88560	116.59997	1122
2A	32.89586	116.59563	1157
2B	32.89953	116.59337	1157
1A	32.92118	116.56092	1232
1B	32.94669	116.54638	1279

[1] Coordinates in WGS84.

Appendix 2. Animal species recorded during the daytime and nighttime surveys. Arroyo toad observations are in BOLD.

[Table removed due to sensitive data.]

Appendix 3. Species recorded during daytime and nighttime surveys.

Species Code [1]	Common Name	Scientific Name	Notes [2]
BHCO	Brown-headed Cowbird	*Molothrus ater*	a
BUBO	Western (or California) Toad	*Bufo boreas halophilus*	
BUCA	Arroyo Toad	*Bufo californicus*	d, e
CRMI	Speckled Rattlesnake	*Crotalus mitchelli*	
CRVI	Southern Pacific Rattlesnake	*Crotalus viridis*	
DEER	Mule Deer	*Odocoileus hemionus*	
DIPU	Western Ringneck Snake	*Diadophis punctatus*	
GAACMI	Partially-armored Threespine Stickleback	*Gasterosteus aculeatus* var. *microcephalus*	b
HYCA	California Treefrog	*Hyla cadaverina*	
HYRE	Pacific Treefrog	*Hyla regilla*	
LAGE	California Kingsnake	*Lampropeltis getulus*	
STJA	Steller's Jay	*Cyanocitta stelleri*	
THHA	Two-striped Garter Snake	*Thamnophis hammondii*	e
UNMA	Unknown Mammal	N/A (or *Scapanus latimanus*?)	
WITU	Wild Turkey	*Meleagris gallopavo*	c

[1] Species codes from Appendix 2.
[2] Notes codes: a = invasive nest parasite, b = native fish to southern California, introduced into upper Sweetwater River, c = non-native species, d = endangered species (U.S. Fish and Wildlife Service), e = species of special concern (California Department of Fish and Game).