2000-2002 Anza-Borrego Desert State Park®
Amphibian Survey

Prepared for:

California State Parks
Anza-Borrego Desert State Park®

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

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March, 2004

Prepared for:

California State Parks
Anza-Borrego State Park®

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San Diego, California
2004

U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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Table of Contents

Table of Figures and Tables

Introduction

At various times six native species of frogs and toads have been recorded from Anza-Borrego Desert State Park®: red-spotted toads (*Bufo punctatus, BUPU*), western toads (*Bufo boreas, BUBO*), California red-legged frogs (*Rana aurora draytonii, RAAU*), California treefrogs (*Hyla cadaverina, HYCA*), and Pacific treefrogs (*Hyla regilla, HYRE*) (Klauber, unpublished field notes, SDNHM). The California red-legged frog is now listed as federally threatened. In addition there are questionable records for arroyo toads (*Bufo californicus, BUCA*; USFWS, 1999). All of the frogs and toads reported from the park are dependent on aquatic breeding sites for reproduction. Some species are able to breed in very small seeps and springs, but most prefer open pools associated with flowing water. We do not discuss newts and salamanders in this report, nor were any detected during the survey, although they have the opportunity to penetrate into the park from adjacent habitat. Species that may occur in the park in this fashion would include the garden slender salamander (*Batrachoseps major*, BAMA), desert slender salamander (*Batrachoseps aridus*, BAAR), and the large blotched salamander (*Ensatina eschscholtzii klauberi*, ENKL).

During the 1920's and 1930's the noted herpetologist Laurence Klauber worked in this same area, and based on his field notes we compiled a list of his study sites and the species he detected. In this report we assess the status and distribution of amphibians in Anza-Borrego Desert State Park® by resurveying areas with historical records, and additionally covering areas without prior documented surveys. In addition to surveying aquatic habitats for amphibians, we collected water quality data (pH, conductivity, temperature, dissolved oxygen level, nutrient level) to assess general habitat quality at focal sites, and collected parasite information on amphibians from an additional subset of sites.

Objectives

Our primary objective for this study was to catalog the current amphibian resources of the wetlands of Anza-Borrego Desert State Park® by surveying suitable habitats within the park. Additional objectives included quantification of exotic/invasive aquatic species and development of management recommendations relating to the native amphibian resources of the park. As part of this work we assessed the status of amphibian populations in Coyote Canyon following the closure of this site to off-road vehicular activities, including added water quality testing at the Coyote Canyon sites. Information specific to Coyote Canyon sites will be presented separately in this report when appropriate. Methods for meeting our objectives were otherwise identical across all sites.

Methods

Survey Area

Anza-Borrego Desert State Park® occupies the northwestern portion of the boundaries of the Sonoran desert. This region is characterized by warm summers with temperatures frequently above 40°C, and cool winters with temperatures frequently below 10°C. Rainfall in the Sonoran desert occurs both during winter and summer months, with monsoonal rain events often providing the only breeding opportunities for desert anurans in these regions (Jennings and Hayes, 1994a). The following passage taken from Jennings and Hayes 1994 paper "Decline of Native Ranid Frogs in the Desert Southwest" describes the geologic history of the desert region for the last 10,000 years.

> Prior to the last ice age, this entire region (Mojave and Sonoran deserts) was covered with numerous inland lakes and marshes, and was much more mesic than it is today (Miller, 1946; Smith and Street-Perrott, 1983; Van Devender et al., 1987). About 8,000 years ago, a drying trend began that has persisted into the present (Hubbs and Miller, 1948; "Xerothermic period" of Axelrod, 1979); freshwater habitats were essentially reduced... Except for the Colorado River, which drains a large basin outside the region we address, all other drainages at least in part within the region are ephemeral and lead to closed basins.

Survey Site Selection

Study sites were located by examining USGS 7.5 minute maps and a GIS coverage of the park for marked springs or wetlands. From the total list of park springs and wetlands, we selected a subset to survey based on the following criteria. First, to maximize our efficiency, priority was given to sites near roads. Second, to maximize the comparability of our surveys with earlier observations, we surveyed all sites with historic records. Third, because larger wetlands are more likely to support amphibian populations, we focused preferentially on these habitats. Finally, to provide as broad a coverage as possible, we distributed our efforts throughout the park.

Historic Data Comparisons

Prior to our surveys we examined Laurence Klauber's records for the 1920's and 30's. We identified the locations within the park where he recorded amphibians. Our goal was to visit all of these locations as well as other known wetlands within the park boundaries. We identified ten sites that had been surveyed by Klauber. Based on our relatively limited sample effort, if we did not record a species at a site we can not assume a local extinction, i.e., the species may still be present but wasn't detected at the time of our survey. However, these data allow us to infer whether or not amphibian distributions and abundances appear to have changed dramatically the past roughly 70 years.

Survey Locations

During the 2000 field season we surveyed the wetlands associated with Coyote Creek (including Lower Willows, Middle Willows, and Upper Willows, Tule, Alder, Sheep, and Cougar Canyon). We also surveyed Borrego Palm Canyon, Oriflamme Canyon and Sentenac Canyon (including the cienega). During the 2001 field season we surveyed Carrizo Marsh, Mountain Palm Springs, Dos Cabezas Spring, Hellhole Canyon, Culp Valley, Tubb Canyon, Borrego Spring, Grapevine Canyon, Yaqui Well, Oriflamme Canyon and Vallecito Spring. We also returned Borrego Palm Canyon, Sentenac Canyon, and to the wetlands associated with Coyote Creek including Tule Canyon, Alder Canyon, Lower Willows, Middle Willows and Upper Willows. In 2002 we surveyed Carrizo Gorge, and returned to Culp Valley, Sentenac Canyon, Tubb Canyon - Big Spring, and Yaqui Well (Table 1, Figures 1-5).

Survey Effort

In order to accomplish the goal of cataloging the amphibian resources of the park within a limited time frame, site visits were often limited to a single visit. At those sites where day and night surveys were conducted, surveyors would arrive on site, locate appropriate habitat, survey the reach during the day, wait for nightfall and begin the survey. Specific wetlands that were judged of greater importance, either for conservation, or based on historic records of species, were surveyed more than once (Table 1).

Survey Methods

Surveys consisted of two-person teams of field technicians familiar with the native and exotic amphibians of southern California. Day time surveys usually began before noon and ended at dusk and were almost always completed within a single day. Night surveys were conducted at a haphazardly chosen subset of sites. During each survey, the team would hike a stretch of streambed previously determined to retain some surface water. Any open pools or flowing stretches of the drainage were examined intensively both visually and with dip-nets for amphibian larvae and adults. In addition, audible calls that could be identified to species were noted. Surveys were conducted from May to August in 2000, 2001 and 2002. Basic habitat parameters were also recorded to evaluate relationships between amphibian distributions and habitat.

For each site we visually estimated percent cover of any vegetation in the stream channel, vegetation type for streambed and bank, substrate type for streambed and bank, and general descriptions of water flow including stream width, depth and qualitative estimates of flow. In addition to collecting data on habitat characteristics, all vertebrates and large macro-invertebrates observed were recorded. To assure accurate identification of animals, voucher specimens were collected from a subset of study sites and will be deposited with the California Academy of Sciences.

Water Quality

During the 2000 field season we collected a suite of water quality data including pH, conductivity, total dissolved solids, transparency, temperature, salinity and dissolved oxygen for a subset of sample sites. The field instruments used to measure these parameters were as follows: YSI 85 Handheld Dissolved Oxygen, Conductivity, Salinity and Temperature System™, Oakton TDSTestr-10™ for total dissolved solids, and Oakton pHTestr-2™ for pH. In addition we collected water samples from Upper Willows, Middle Willows, North Fork Alder Canyon and South Fork Adler Canyon, using USGS standard protocols for laboratory nutrient analysis at the National Water Quality Laboratory (USGS, variously dated).

Parasites

Throughout our surveys, field technicians examined captured animals for external parasites. In addition, during the 2001 season we collected live fish and amphibians from Sentenac and Coyote Canyon for more detailed parasite evaluation. These specimens were transported live to the Biology Department of San Diego State University. They were examined for parasites either locally by Dr. Victoria Matey or at the National Wildlife Health Center in Madison, Wisconsin by Dr. David Green. Dr. Green also examined animals for evidence of disease. Only live or freshly dead specimens were examined. Parasite examinations included 1) external examination of fins, skin, and gills; and 2) internal examination of the body cavity and major organs.

For the external examination each specimen was first measured (total and standard length in mm.), and visually inspected for wounds, deformities, scale abnormalities and tumors were noted. Visual analysis was followed by a microscopic examination of mucus scrapings for parasitic protozoans. Body surface and eyes were examined visually and under the dissecting microscope for parasitic protozoans, crustaceans and monogeneans. The nasal cavities were irrigated and resultant fluid was examined under the dissecting microscope. The fins, tail, and gills were examined visually and under the dissecting microscope followed by an examination under a compound microscope for parasitic protozoans, monogeneans and crustaceans. All parasitic organisms found were collected, identified and counted separately. Parasites selected for light microscopy (LM) and scanning electron microscopy (SEM) were fixed in appropriate fixative solutions.

Each specimen was then examined for internal parasites. First, the body cavity was opened and examined visually. Internal organs such as heart, liver, spleen, kidneys, gonads, gall bladder and swim bladder were dissected out, placed in separate containers and than dissected and examined using dissecting and compound microscopes. The gastrointestinal tract was removed, split from mouth to rectum and examined for parasites in the lumen and attached to the walls. All helminthes were collected, counted, examined with a dissecting and compound microscopes, and than fixed for LM and SEM.

Identification of parasites was based on the LM and SEM data. Specimens selected for LM were fixed in 70% ethanol, AFA, or 5% formalin, stained with hematoxylin, and examined with a Diastar microscope. Specimens of protozoans and helminths selected for SEM were fixed in Karnovsky's solution, processed according to standard methods, and examined with a Hitachi S-2700 scanning electron microscope. Prevalence, mean intensity, abundance and infection sites for each parasite were determined for each species of parasite.

Results

Current Survey Results

During the course our surveys we visited 23 sites, and detected 4 native amphibian species. We did not detect any exotic amphibians, which is notable given the widespread distribution of exotic species such as bullfrogs (*Rana catesbeiana*, RACA) closer to the coast. We detected amphibians at 19 of the 23 sites (no amphibians were detected at Grapevine Canyon, Indian Canyon, Mangalar Spring or Tubb Canyon Big Spring, Table 2).

Historic Data Comparisons

Our surveys overlapped with 10 of the sites surveyed by Klauber. Compiled across these sites Klauber had a total of 20 species/site records. At these same sites we recorded 20 species/site records. In 12 cases we detected the same species at these historic sites. In addition in 8 instances we detected species that Klauber had not recorded from those sites, and in 8 instances we failed to relocate a species recorded by Klauber (Table 3). For the five frog species known from the park, comparison with Klauber's data are discussed under species accounts.

Western Toad (*Bufo boreas*):

In general, this species continues to persist throughout its historic range within the park and in adjacent habitat in undeveloped areas of San Diego County. An artificially subsidized population of western toads persists in the Borrego Springs area where agriculture and landscaping activities provide water and forage. Western toads are habitat generalists, persisting in desert floor wetlands and larger watersheds wherever pooled surface water exists long enough for them to complete their lifecycle.

Historical Comparison

Both ours and Klauber's surveys detected western toads at Borrego Springs, Carrizo Marsh and Sentenac Canyon. We found them at Palm Canyon and Lower Willows where Klauber did not record them. And finally Klauber found them at Vallecito Spring where we did not record them. The vegetative community is so dense at Vallecito Spring that amphibian detection during current surveys was entirely through identification of audible calls. The call of the western toad is difficult to detect and has not been heard during current surveys at any location in the park, making this species difficult to detect in areas like Vallecito Spring.

Red-spotted Toad (*Bufo punctatus*):

In general the red-spotted toad continues to persist throughout its historic range within the park although it is uncommon west of the park boundaries. Its rarity west of the park is a reflection of its natural distribution and does not appear to be because of any declines. Red-spotted toads appear to congregate in the washes and oasis that form in larger drainages. They were found breeding in slow flowing water and gentle backwaters, but were not in smaller seeps and springs. They were not observed breeding in pools without flow input, but it is unlikely that this is a habitat restriction.

Historical Comparison

Both we and Klauber found red-spotted toads at Palm Canyon. We found them at Lower Willows and Vallecito Spring where he did not record them. And finally, Klauber detected them at Yaqui Well where we did not record them. Due to the limited size of the wetland associated with Yaqui Well, the failure to detect red-spotted toads may be significant. No amphibians were recorded during our first visit in 2001 to Yaqui Well, but during an additional survey in 2002 at this location we detected Pacific treefrogs.

California Treefrog (*Hyla cadaverina*):

In areas where breeding habitat does exist, California treefrogs can often be found in estimated densities approaching 10 per m^2 for larvae and 2 per m^2 for adults (Pers. Obs.). California treefrogs were collected from the Lower Willows site for parasite analysis; it was the only species observed that was infested with parasites visible to the human eye (seen as nodules on the skin of the animal in Figure 6). California treefrogs are strongly associated with drainages dominated by rock and boulders. Like red-spotted toads, California treefrogs were not observed breeding in pools without flow and may require flowing surface water to reproduce.

Historical Comparison

Both we and Klauber detected California treefrogs at Middle Willows, Lower Willows, Borrego Palm Canyon and Vallecito Spring. We detected them at Sentenac Canyon where Klauber did not record them, and Klauber detected them at Culp Valley and Tubb Canyon where we did not record them. Culp Valley and Tubb Canyon share a common watershed, and the failure to detect California treefrogs at these locations may be related. Appropriate breeding habitat was not detected at either location and may have been eliminated at some time in the past by fluctuations in ground water level.

Pacific Treefrog (*Hyla regilla*):

In general the Pacific treefrog remains the most widespread amphibian in the park, occurring at all locations with suitable breeding habitat. An excellent example of this is the spring at Dos Cabezas. In a small basin less than one meter square but containing pooled water, both western toad and Pacific treefrog larvae were present. The spring was extremely isolated and the closest wetland to this location (Carrizo Gorge) is almost three miles away. Pacific treefrogs are habitat generalists, occupying most locations where pooled water exists long enough for their development to metamorphosis.

Historical Comparison

Both we and Klauber detected Pacific treefrogs at Carrizo Marsh, Culp Valley, Sentenac Canyon and Yaqui Well. We detected them at Middle Willows, Lower Willows, and Palm Canyon where he did not, and we failed to detect them at Borrego Springs, Tubb Canyon and Vallecito Spring where he detected them. This was the greatest number of differences in detection recorded for any of the 5 species. But it should also be noted that the Pacific treefrog is the most widespread native amphibian species in California, and had the highest number of observations recorded for both Klauber's data and the current survey effort.

The absence of detection at Borrego Spring is probably due to survey effort, as surveys in the area were restricted to human developments that favored western toads. There is some confidence in the negative observations at Tubb Canyon due to lack of appropriate habitat, and additional surveys have increased our confidence that they were absent from this location. Vallecito Spring was densely vegetated and the only amphibian observations made at this location were through auditory surveys. We did not detect Pacific treefrogs through the auditory surveys, but several return visits would be necessary to place any confidence in the conclusion that this species is truly absent from this location.

California Red-legged Frog (*Rana aurora draytonii*):

Historical Comparison

Klauber detected California red-legged frogs at Sentenac Canyon while we did not and there were no other observations within the boundaries of the park in Klauber's or the current survey. Because multiple day and night surveys were performed at locations where appropriate habitat was present, we are confident that this species does not currently occur in Sentenac Canyon. The last records for the observation of this species at Sentenac Canyon date to the 1960's (Jennings and Hayes, 1994a).

Habitat Accounts

Desert riparian habitats varied tremendously in the park, with some covering over 6.5 square kilometers (2.5 square miles, 617 acres, estimated area of Carrizo Marsh), with others covering just one square meter (estimated area of Dos Cabezas Spring). We identified multiple habitat types while conducting surveys in the park. For ease of discussion we have grouped them into the following general categories: Springs and Seeps, Smaller Watersheds, Larger Watersheds and Low Gradient Oasis.

Springs and Seeps

Springs and seeps were usually situated in larger watersheds, but often separated within the drainage by extremely xeric habitat from other such springs or riparian areas. Even with this high degree of isolation, some springs were observed to support amphibian populations during the current survey, and all had historic amphibian records associated with them. The sites we surveyed falling into this habitat type included: Culp Valley Springs Complex, Dos Cabezas Spring, Grapevine Canyon, Mangalar Spring, Mountain Palm Springs, Tubb Canyon (Figure 7), Vallecito Spring, and Yaqui Well.

The springs surveyed were all very different from each other in their setting, with some having been capped and channeled into basins (Dos Cabezas, Grapevine Canyon, Mangalar), some occurring as seeps not associated with a clearly defined stream channel (Culp Valley, Yaqui Well), and finally as wetlands within clearly defined stream channels created by geologic features that force subsurface water up (Tubb Canyon, Vallecito Spring, Mountain Palm Springs).

The capped springs were the smallest wetlands encountered, often occupying 1-2 square meters of wetted area. Although small, these areas often supported several wetland plant species and in one case (Dos Cabezas) both Pacific treefrogs and western toads.

The seeps all supported obligate wetland plants such as tules (*Scirpus* spp.) and cattails (*Typha* spp.). Although we only observed Pacific treefrogs at these locations, historical records exist for red-spotted toads at Yaqui Well, and for California treefrogs at Culp Valley.

Springs formed by geologic features within stream channels were often much larger than capped springs and seeps, and supported dense riparian vegetation. Red-spotted toads were observed at both Vallecito and Mountain Palm Springs, Pacific treefrogs were observed at Mountain Palm Spring, and California treefrogs were observed at Vallecito Spring. Notably, no amphibians were observed at Tubb Canyon, although amphibian habitat was present and records exist for both tree-frog species.

Smaller Watersheds

Smaller watersheds often consisted of stream channels overgrown with vegetation and filled with sandy silt. Although surface water was present when we surveyed, the wetted areas at these sites often consisted of seeps or pools with very little flowing water. This habitat type also had very little exposed bedrock in the stream channel, corresponding to the thicker plant cover observed at these locations. Common plants at these locations included mulefat (*Baccharis salicifolia*), catclaw (*Acacia greggii*) and mesquite (*Prosopis* spp.). The sites we surveyed falling into this category included: North Fork Alder, South Fork Alder (Figure 8), Tule, and Oriflamme Canyon.

Alder and Oriflamme Canyons were similar to each other, having smaller watersheds, and although steep, did not capture enough water to scour the drainage and form long reaches of exposed bedrock channels although such features do occur infrequently. This reduced scouring resulted in much thicker riparian zones with dense underbrush. Although we found treefrogs (California treefrog, Pacific treefrog) in these canyons, we did not detect the red-spotted toad and assumed that its habitat requirements were not met by these smaller order streams during survey periods because of the lack of available breeding pools. Surface water at these locations was restricted to intermittent seeps and trickles or stagnant pools. Tule was the exception to this in that it possessed large stretches of exposed bedrock and red-spotted toads were detected.

Sentenac Canyon

Sentenac Canyon (Figure 9) did not fall into an easily distinguishable category and was best defined as being a transition between smaller and larger watersheds. Furthermore it was the only survey location that transitioned from low gradient marsh habitat into high gradient bedrock pool habitat. The cienega at the top of the gorge was the most likely location for the persistence of ranid frogs, exotic or otherwise, however none were detected. The only native amphibians detected were California treefrogs and Pacific treefrogs, which persisted in pools choked with chara (*Chara chara*), a green algae common to freshwater environments, but were absent from pools with less vegetation. Sentenac Canyon was the first of two locations where exotic invasive crayfish (*Procabarus clarkii,* PRCL) were detected.

Larger Watersheds

A third habitat type was associated with larger watersheds or confluences of smaller drainages and consisted of exposed bedrock channels with vegetation restricted to the margins of the channel. The wetted areas at these sites consisted of larger pools and visible flow. Vegetation at these sites consisted of larger trees and was more open than for smaller watersheds. Common plants at these locations included California fan palm (*Washintonia filifera*), sycamore (*Platanus racemosa*) and cottonwood (*Populus freemontii*) as well as mulefat, catclaw and mesquite. Sites we surveyed that fell into this category included: Carrizo Gorge, Sheep, Cougar, Indian, Hellhole, and Borrego Palm Canyon (Figure 10).

Sheep, Cougar and Hellhole Canyons had similar morphology and plant communities, and terminated in sandy washes that did not retain much surface water. We found California treefrogs and red-spotted toads at all large watersheds, but the red-spotted toads were always found in the lower reaches near or in the sandy washes. Borrego Palm Canyon was similar to both Sheep and Cougar in its overall vegetative composition but had larger palm groves than the other two locations. As with the other sites, the red-spotted toads were restricted to the base of canyons where they became less steep and more open, while the treefrog species were found in all available water throughout the canyons. We also detected Pacific treefrogs and western toads in Borrego Palm Canyon, most likely because it is a larger canyon (than the others mentioned) with more available permanent water. Although Carrizo Gorge was a larger watershed, it lacked the water and extensive riparian areas found in the other sites. In addition to finding California treefrogs, we also detected exotic invasive crayfish and mosquitofish (*Gambusia affinis*, GAAF) in the gorge.

Low Gradient Oasis

A fourth habitat type was associated with the floor of Coyote Canyon and was comprised of the Lower Willows, Middle Willows, and Upper Willows (Figure 11) sites and with the terminus of the Carrizo watershed before it enters the Salton Sea. These sites were all extremely low gradient and densely vegetated. The vegetation at all Willows sites included a dense canopy of cottonwood and sycamore trees surrounded by catclaw and mesquite upstream. This canopy gradually thinned into willow and tules as the stream channel became more developed downstream. Open water at these sites consisted of stagnant pools and seeps in the upper portion, transitioning into well-developed pools and flowing stream channels downstream. The Carrizo Marsh site also includes a large component of salt-cedar (*Tamarix* spp.), and catclaw. Tules and cattails dominate the wetted stream channels. In addition Carrizo lacked the cottonwoods, sycamore and willows present at the other sites.

Lower Willows was the wettest of the three low gradient oases on the floor of Coyote Canyon, and was impacted by off-road vehicle traffic. This impact consisted of a jeep trail that snaked through the downstream portions of the site, crossing the stream channel at two points. Where the jeep trail crossed the stream channel, the banks and stream were completely denuded of vegetation, and large pools were formed. Apart from this it kept the pattern described above for the Willows sites. However, the stream channel was not as strongly defined as the Middle and Upper Willows locations and appeared to braid during high flow.

Middle Willows possessed similar habitat to that of Lower Willows with the exception of the road crossing pools. During night surveys we found red-spotted toads foraging in the under story of the upstream portion and during day surveys found red-spotted toad tadpoles in backwaters of the stream channel in the downstream portion. We also observed adults and tadpoles of both treefrog species in the downstream portion.

Upper Willows differed from Lower and Middle Willows in that it experienced more disturbance from wild horses. Evidence of the presence of wild horses was present at Lower, Middle and Upper Willows locations and indeed at all Coyote Canyon field sites. However, Upper Willows appears to be the primary watering hole and was highly disturbed compared to other sites. It possessed the typical canopy of oak and sycamore associated with the headwaters of the Willows, but the lane of willow that followed the stream channel out of the canopy and downstream had been trampled and grazed to a point of complete exposure of the channel (i.e., no plant material/riparian zone). In addition, the channel lost definition in this area and was broken into a series of irregular pools through which water flowed. We found adult amphibians as well as evidence of reproduction in this area (Pacific and California treefrogs and red-spotted toads) and it is unclear whether the presence of the horses is adversely affecting amphibian populations.

Carrizo Marsh was the largest wetland surveyed and one of two sites impacted by off-road vehicle traffic. Off-road vehicle impacts observed in this area consisted of channels that were denuded of riparian vegetation. It was unclear as to whether the off-road vehicular activity was creating the channels or that pre-existing channels were being utilized for this activity. The plant community in Carrizo Marsh was dominated by salt-cedar, which often grew densely enough to exclude the field technicians from observing the stream channel. Accessible water in the area was restricted to an off-road vehicle track where it followed the stream channel, and it was in this location that both Pacific treefrogs and western toads were observed.

Water Quality

Basic water quality parameters collected within the park varied little from site to site and are reported in table 4. All the sites showed elevated mineral levels, reflected in salinity, dissolved solids, and conductivity readings. Nutrient parameters for selected sites were all at or below minimum detectable levels (Table 5). Reference values from San Francisquito Canyon in the Angeles National Forest were provided as a comparison for sites in the park. Methods were identical, making values roughly comparable.

Parasites

Specimens were collected for parasite analysis from the Lower Willows and from Sentenac Canyon. Specimens were collected from Sentenac Canyon on both January 4th and February 6th of 2001 and from the Lower Willows on June 19th, 2001. Red-spotted toads and California treefrogs collected from Lower Willows were infected with a diverse parasite fauna. This fauna included the metacercaria (larval stage) of the trematode *Clinostomum* sp., an unidentified nematode species, an unidentified cestode species, *Opalina* sp. (a ciliated protozoan), and *Hannemania* sp. (a chigger species). Pacific treefrogs collected from Sentenac Canyon were infected with *Opalina* sp. Exotic unarmored threespine sticklebacks (*Gasterosteus aculeatus williamsoni*) collected from Sentenac were infected with *Gyrodactylus* sp. and the protozoan *Trichodina* sp. (Table 6).

Discussion

General Distribution of Amphibians within Anza-Borrego Desert State Park®

Wetlands are rare and fragile habitats in desert regions and are often isolated by extensive dry landscapes. Consequently, amphibian communities utilizing these habitats may be isolated from other populations, making immigration rare or non-existent. Furthermore, these populations are often naturally small and subject to stochastic fluctuations in size due to unpredictable rainfall (Miller and Stebbins, 1964). Thus, degradation of these aquatic habitats may potentially put populations at risk of extirpation by adversely affect the recruitment of these species through direct habitat loss or reduction in habitat quality. For example, disturbances in the creek during breeding and development, such as vehicle, horse or foot traffic may reduce breeding success. Exotic fish, crayfish, and frogs can also adversely affect native amphibians through competition, direct predation and potentially through disease transfer (Mao *et al.*1999). Exotic vegetation can also degrade the quality of the upland and aquatic habitats for breeding and survival. To determine if management activities are required to protect these resources, monitoring populations and habitat quality is necessary.

Due to their discrete and often isolated condition, desert amphibian habitats are ideal for comparative studies using historic records. Even with this advantage, the area of discrete habitats can often range from 6.5 square kilometers (2.5 square miles, 617 acres, estimated area of Carrizo Marsh) to as little as one square meter (estimated area of Dos Cabezas spring). When surveying wetlands, confidence in detecting all species at a given location in one survey is low, and even after multiple surveys under good conditions, rare species may still elude detection. The high degree of seasonality associated with desert amphibian habitat further confounds the detectability of amphibians in these habitats. In the current survey, sites that possessed high flows one month could be observed dry the next.

Because most surveys are of limited temporal scope, certain species may have been present but were not detected. This is also true for historic records, and although we can be reasonably confident that no false positive records were included in Klauber's data, we cannot make any statements about failures during the current survey to observe a species at a given location. This is illustrated nicely by the high number of cases where we observed species not reported by Klauber (9 instances at 10 sites) and vice versa (8 instances at 10 sites). Faced with the issues raised, and with no clear trend evident in comparisons with Klauber's data, we would hesitate to make any assumptions about long-term amphibian population trends in the park.

Declining Amphibians

Amphibian declines have been well documented throughout the continental United States and much of the world (Blaustein and Wake, 1990, Houlahan *et al*., 2000). Within the Anza-Borrego Desert State Park® region, only the California red-legged frog has declined, and this is consistent with its disappearance from nearly all historically occupied southern California sites (Jennings and Hayes, 1994b). In the case of the red-legged frog, multiple factors may have led to its extirpation from the park (Davidson *et al*., 2001). The first potential factor is a 500-year flood event that occurred in 1968-69. California red-legged frogs as well as many other native ranid frog species experienced significant declines during this spectacular event, and there are no records of this species from Sentenac Canyon from that date on (Jennings and Hayes, 1994a). The second factor that may have contributed to its disappearance from the drainage is the introduction of the unarmored threespine stickleback to this drainage in 1973 and again in 1981 (Swift *et al.* 1994). This may have resulted in the unintentional extirpation of red-legged frogs by introduction of viral pathogens that the frog is susceptible to (Mao *et al.* 1999). However, fish sampled from this location in 2001 tested negative for the presence of the viral pathogen linked with the decline of California red-legged frogs in other drainages. It may be that since the time of introduction that the virus passed out of the system. The presence of red swamp crayfish in this drainage may have also aided in the frog's disappearance.

Off-Road Vehicle Activities

Off-road vehicle activities in wetlands were only observed at two locations during the current survey. These were the Lower Willows and Carrizo marsh.

At Lower Willows we observed amphibians in road crossing pools. Adults and eggs of both western toads and red-spotted toads were seen in road crossing pools, but we never saw tadpoles, leading us to hypothesize that toad tadpole survivorship in road-crossing pools is poor. We did observe toad tadpoles just below Lower Willows Third Crossing in a shallow backwater, and it is assumed that successful recruitment in the Lower Willows area as a whole is occurring. We also observed toad tadpoles at both

Upper and Middle Willows, indicating that reproduction is not dependent on pool formations formed by off-road vehicular traffic. In contrast, California treefrog tadpoles were observed in abundance in road crossing pools and apparently had no problems persisting in the face of disturbance by motorized vehicles. This difference in survivorship may be due to morphological differences between treefrog and toad tadpoles. If indeed toad tadpoles are unable to persist in these pools due to disturbance by motorized vehicles, then the pools are creating an attractive nuisance for toads, because the adults seemed drawn to these areas and reproductive efforts by both toad species were observed (Warburton and Fisher, 2000).

In Carrizo Marsh, we did not detect any evidence of reproduction by either of the species detected. However, the only wetted areas that surveyors could examine were channels in the vegetation maintained by off-road vehicular activity. Due to the marsh's large area and densely vegetated condition, it is likely that suitable habitat was present but not detected.

Off-road activity visibly disrupts riparian areas where amphibians forage and reproduce. Although some amphibians persist in areas with off-road vehicle activity, the negative effects on wetland habitats are obvious. These negative effects included the physical displacement of riparian vegetation and alteration of stream bank morphology. Riparian areas where off-road activity has taken place in the past but has since been halted appear to recover rapidly and we are not aware of amphibian species having been extirpated from a site within the park due to such activity. In terms of species diversity (presence/absence of a species from a site) there was no detectible difference between sites with and without historic off-road activity.

Water Quality

Nutrient assessments of water samples from Coyote Canyon indicated levels similar to other streams that have been sampled using this protocol, and well below levels known to stress amphibians (Schuytema and Nebeker, 1999). Basic water quality parameters measured at Coyote Canyon sites were comparable with results from other stream environments in wilderness settings.

Parasites

Although parasite analysis revealed a diverse and abundant parasite fauna in Coyote Canyon, all the parasites detected appear to be naturally occurring species, and these infections appear to be a natural part of the life history of the animals involved. Quoting Dr. David Green's Southern California ARMI Sub-Region Amphibian Health Surveillance & Mortality Events Progress Report (2003):

> Metacercaria of the trematode, *Clinostomum* sp., were found in heavy numbers in the muscle and under the skin of larval *Hyla cadaverina* from… (Coyote Canyon) in 2001. Deaths due to this parasite have not been observed or reported, nor have limb malformations been linked to the metacercaria. Similar infections of other anuran and caudate species have been observed in California and nationwide.

Introduced Species in the Park

Three exotic aquatic species, the red swamp crayfish, the unarmored threespine stickleback and the western mosquitofish were detected in Anza-Borrego Desert State Park®. The red swamp crayfish is an extremely destructive species and is capable of extirpating native species once it is introduced into a drainage (Gamradt, Kats and Anzalone, 1997). Because of the absence of amphibians from pools lacking submerged vegetation, it is assumed that crayfish were able to prey on and extirpate treefrogs in these pools because of the lack of cover. Because crayfish are hardy and aggressive colonizers, their introduction into Carrizo Gorge and Sentenac Canyon may have been facilitated by any number of methods. However, there is little room for the crayfish to expand its range based on its current location. Human transport and introduction of the crayfish or any other common exotic species is of real concern to all aquatic habitats in the park. The presence of the unarmored threespine stickleback, a native of southern California but not the drainage is due to purposeful introductions by California Department of Fish & Game (Swift *et al.* 1994).

> In 1972 and 1973, 458 fish from upper Soledad Canyon were placed in upper San Felipe Creek and Sentenac Canyon, Salton Sea drainage, San Diego County. These did well until the winter of 1979-1980, after which they disappeared. In 1981, 180 more fish were placed in the stream, and these have survived…

The stickleback is listed as endangered and the introduction was intended to establish a reserve stock. Parasite analysis of stickleback from this location showed that they were infected with *Gyrodactylus* spp. and *Trichodina* spp. (both of which are common native parasites). The presence of western mosquitofish in Carrizo Gorge is probably due to their purposeful introduction for vector control purposes to private inholdings upstream of the Gorge. Although mosquitofish are also hardy and aggressive colonizers there are little or no opportunities for it to invade additional habitat in the park. Mosquitofish share the crayfish's ability to extirpate native amphibian species, and studies have shown that they prey preferentially on amphibian larvae (Goodsell and Kats, 1999). There is a single record for bullfrogs from within the park's boundaries taken in 1997 at Lews Spring in Culp Valley (CAS 210847). We surveyed this location twice, finding it dry the first time, and occupied by Pacific treefrogs on the following visit. Based on the observed conditions within the park and this area specifically, we conclude that bullfrogs are no longer present within the park boundaries.

Occurrence of Arroyo Toads in the Park

The Recovery Plan for the Arroyo Southwestern Toad (USFWS 1999) erroneously lists two occurrences of arroyo toad (*Bufo californicus*) within Anza-Borrego Desert State Park®. The first report is from the San Felipe basin (Borrego Springs area) on July 25, 1950. Voucher specimens were collected by W. E. Duellman and deposited at the University of Michigan Museum of Zoology. The second report was from Vallecitos Creek basin on April 12, 1954; a voucher of three tadpoles was collected by R. C. Stebbins and deposited at the Museum of Vertebrate Zoology in Berkeley, California. Recent examination of these vouchers shows the Duellman specimens to be western toads and the Stebbins specimen to be California treefrogs (Ervin and Fisher 2002).

As part of current surveys, we conducted surveys for the arroyo toad in the three locations within the park that were recommended by the U.S. Fish and Wildlife Service (Borrego Palm Canyon, Borrego Springs, Coyote Canyon) and no arroyo toads were discovered. In light of current surveys and the work by Ervin and Fisher, we conclude that there are no confirmed records of arroyo toads within the boundaries of Anza-Borrego Desert State Park®.

Management Recommendations

Results from this study are very encouraging. Most of the habitat surveyed was in very good condition. Likewise, most amphibian species detected were abundant and widespread. Anza-Borrego Desert State Park® continues to possess some of the least disturbed and intact habitat for amphibians in San Diego County.

Based on all information available to us; our general habitat surveys, visual encounters, call records, water quality records, and historic amphibian records, we have developed the following recommendations, based on expert opinion, for management of amphibian populations within Anza-Borrego State Park®.

1. Additional Monitoring: Monitoring of wetlands within Coyote Canyon following the removal of wild horses in 2003 would be most informative with regards to the response of wetlands to the removal of this disturbance. Furthermore there are additional remote wetland locations that have not yet been inventoried and we suggest an effort be made to survey these locations in the near future.
2. Exotic Species Control and Eradication: We recommend that a combination of monitoring for introduction and expansion of, restricting access to, and educating the public about exotic species be pursued by the park. Target species for this effort would include bullfrogs, crayfish, mosquitofish and stickleback. There are potential opportunities for bullfrogs to colonize into the park from adjacent wetlands (primarily San Felipe Creek above Sentenac Canyon). Crayfish eradication efforts in Sentenac canyon would be the highest priority, followed by the crayfish and mosquitofish populations in Carrizo Gorge. Sentenac stands out because of the excellent potential for re-introduction of California Red-legged frogs following such eradication efforts. In addition, stickleback eradication efforts could be pursued concurrently with crayfish eradication at this location, although stickleback are considered a lower priority because of the lack of evidence pointing to direct negative interactions with native amphibians.
3. Off-road Vehicular Activity: We recommend that current restrictions on off-road activity be maintained in order to help sustain habitat quality and health of amphibian populations both within and outside areas currently designated for such activity.

Acknowledgements

The authors would like to acknowledge all those that made this work possible including the State Park Service for their generous support and Mark Jorgenson, who shared his unmatched knowledge of the park and its animals with us. Kim Marsden, Chris Peregrin, and Jim Dice from the State Park Service and Pete Trenham from USGS/BRD provided critical feedback on the report. Tim Hovey from the California Department of Fish and Game assisted in collection efforts. Finally, thanks to the many dedicated field workers of the USGS/BRD San Diego field station.

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Table 1. All survey sites visited in the current study and survey dates.

SITES		SURVEY DATE		
WATERSHED	SITE NAME	2000	2001	2002
BORREGO VALLEY	BORREGO SPRINGS		May-01	
BORREGO VALLEY	CULP VALLEY		July-01	July-02
BORREGO VALLEY	HELLHOLE CANYON		May-01	
BORREGO VALLEY	PALM CANYON	June-00	May-01	
BORREGO VALLEY	TUBB CANYON BIG SPRING		July-01	July-02
COYOTE CANYON	ALDER CANYON NORTH FORK	May-00	May-01	
COYOTE CANYON	ALDER CANYON SOUTH FORK	May-00	May-01	
COYOTE CANYON	COUGAR CANYON	May-00		
COYOTE CANYON	INDIAN CANYON	May-00		
COYOTE CANYON	LOWER WILLOWS	May-00	June-00	
COYOTE CANYON	MANGALAR SPRING		June-00	
COYOTE CANYON	MIDDLE WILLOWS	May-00	May-01	
COYOTE CANYON	SHEEP CANYON	May-00		
COYOTE CANYON	TULE CANYON	May-00	May-01	
COYOTE CANYON	UPPER WILLOWS	May-00	May-01	
COYOTE WASH	DOS CABEZAS		June-01	
SAN FELIPE	GRAPEVINE CANYON		May-01	
SAN FELIPE	SENTENAC CANYON	June-00	June-01	July-02
SAN FELIPE	YAQUI WELL		July-01	July-02
VALLECITOS	CARRIZO GORGE			April-02
VALLECITOS	CARRIZO MARSH		June-01	
VALLECITOS	MOUNTAIN PALM SPRING		June-01	
VALLECITOS	ORIFLAMME CANYON	July-00	June-01	
VALLECITOS	VALLECITO SPRING		May-01	

Table 2. Survey locations and vertebrate aquatic species detected.

SITES		SPECIES							
WATERSHED	SITE NAME	BUPU	HYRE	HYCA	BUBO	RAAU	GAAF	GAAC	PRCL
BORREGO VALLEY	BORREGO SPRINGS				X				
BORREGO VALLEY	CULP VALLEY		X						
BORREGO VALLEY	HELLHOLE CANYON	X		X					
BORREGO VALLEY	PALM CANYON	X	X	X	X				
BORREGO VALLEY	TUBB CANYON BIG SPRING								
COYOTE CANYON	ALDER CANYON NORTH FORK			X					
COYOTE CANYON	ALDER CANYON SOUTH FORK		X	X					
COYOTE CANYON	COUGAR CANYON	X		X					
COYOTE CANYON	INDIAN CANYON								
COYOTE CANYON	LOWER WILLOWS	X	X	X	X				
COYOTE CANYON	MANGALAR SPRING								
COYOTE CANYON	MIDDLE WILLOWS		X	X					
COYOTE CANYON	SHEEP CANYON	X		X					
COYOTE CANYON	TULE CANYON	X	X	X					
COYOTE CANYON	UPPER WILLOWS	X	X	X					
COYOTE WASH	DOS CABEZAS		X		X				
SAN FELIPE	GRAPEVINE CANYON								
SAN FELIPE	SENTENAC CANYON		X	X	X			X	X
SAN FELIPE	YAQUI WELL		X						
VALLECITOS	CARRIZO GORGE			X			X		X
VALLECITOS	CARRIZO MARSH		X		X				
VALLECITOS	MOUNTAIN PALM SPRING	X	X						
VALLECITOS	ORIFLAMME CANYON		X	X					
VALLECITOS	VALLECITO SPRING	X		X					

KEY

BUBO	WESTERN TOAD
BUPU	RED SPOTTED TOAD
HYRE	PACIFIC TREEFROG
HYCA	CALIFORNIA TREEFROG
RAAU	RED LEGGED FROG
GAAF	MOSQUITOFISH
GAAC	STICKLEBACK
PRCL	CRAYFISH

Table 3. Results of comparisons between current and historic sites previously surveyed by Klauber in the 1920's and 1930's.

SITE NAME	BUBO	BUPU	HYCA	HYRE	RAAU	
BORREGO SPRINGS	HC			H		
CARRIZO MARSH	HC			HC		
CULP VALLEY			H	HC		
LOWER WILLOWS	C	C	HC	C		
MIDDLE WILLOWS			HC	C		
PALM CANYON	C	HC	HC	C		
SENTENAC CANYON	HC		C	HC	H	
TUBB CANYON BIG SPRING			H	H		
VALLECITO SPRING	H	C	HC	H		
YAQUI WELL		H		HC		SUM
(H) HISTORIC NO CURRENT	1	1	2	3	1	8
(C) CURRENT NO HISTORIC	2	2	1	3	0	8
(CH) CURRENT AND HISTORIC	3	1	4	4	0	12

KEY

BUBO	WESTERN TOAD
BUPU	RED SPOTTED TOAD
HYRE	PACIFIC TREEFROG
HYCA	CALIFORNIA TREEFROG
RAAU	CALIFORNIA RED LEGGED FROG

Table 4. Water quality parameters by site.

Location	Date	Water Temp (°c)	Salinity (parts per thousand)	Dissolved Oxygen (percent saturation)	Total Dissolved Solids (parts per million)	Conductivity (microsiemens)	pH
Lower Willows, 2nd xing	5/18/2000	24.7	0.4	91	525	815	8.4
Lower Willows, 2nd xing	8/31/2000	23.7	0.4	78	590	849	8.4
Lower Willows 3rd xing, upstream of road xing	5/18/2000	22.5	0.4	106	498	762	8.5
Lower Willows 3rd xing, at road xing	5/18/2000	25.7	0.4	112	516	817	8.4
Lower Willows, 3rd xing	5/18/2000	23.9	0.4	106	416	778	8.5
Lower Willows, 3rd xing, middle of road xing	5/18/2000	22.5	0.4	105	505	761	8.4
Lower Willows, 2nd xing, at pool 100m upstream	5/19/2000	21.6	0.4	120	530	775	8.5
Middle Willows, after constriction at blocked road xing	5/23/2000	22.6	1.0	87	1530	1789	8.2
Upper Willows	5/23/2000	23.8	0.8	86	103	1609	7.8
San Felipe Creek at Hwy 78 xing	6/1/2000	20.9	0.4	87	577	836	8.4
San Felipe Creek / Sentenac cyn at cieniga	6/1/2000	17.4	0.4	86	925	1288	8.4
Alder Cyn	5/15/2000	20.2	1.1	88	na	1870	7.7
Oriflamme Cyn	7/27/2000	21.3	0.6	78	800	1088	7.8
Borrego Palm Cyn, Ist palm oasis	8/31/2000	22.3	0.6	55	825	1185	7.9
Borrego Palm Cyn, Ist palm oasis	6/7/2000	21.3	0.6	40	704	1038	7.6
Borrego Palm Cyn, 2nd palm oasis	6/7/2000	22.8	0.6	75	804	1196	7.9

Table 5. Nutrient data summarized by site. Study sites within Anza-Borrego Desert State Park® compared with a reference site.

Site Name		nitrogen, ammonia	nitrogen, ammonia + organic nitrog	nitrogen, nitrite	nitrogen, nitrite + nitrate	phosphorus, phosphate, ortho
Study Sites	Upper Willows	<0.04	0.30	<0.006	<0.05	<0.02
Study Sites	Middle Willows	<0.04	0.40	<0.006	<0.05	<0.02
Study Sites	North Fork Alder Canyon	<0.04	0.80	<0.006	<0.05	<0.02
Study Sites	South Fork Alder Canyon	<0.04	0.20	<0.006	<0.05	<0.02
Reference Sites	San Francisquito Canyon	<0.04	0.21	0.008	<0.05	0.03
Reference Sites	San Francisquito Canyon	<0.04	0.17	0.008	<0.05	<0.02

Table 6. Parasites of sampled fish and amphibians

Species Length Range (cm) Date	Location # of specimens		Parasite Monogenea	Trematoda	Nematoda	Cestoda	Protozoa	Acari
Gasterosteus aculeatus 2.3cm - 6.1cm 1/4/2001	San Felipe Creek 14	Parasite Species % Infected Average # of parasites	Gyrodactylus 100% 5.4 (1-14)				Trichodina 78.80% dozens	
Hyla regilla 2.6cm - 3.0cm 2/6/2001	San Felipe Creek 3	Parasite Species % Infected Average # of parasites					Opalina 100% dozens	
Bufo punctatus 5.4cm - 6.0cm 6/20/2001	Coyote Canyon 2	Parasite Species % Infected Average # of parasites		metacercaria 50.00% 20	adult/colon 100% 46 (31-61)	adult/intestine 50% 8	Opalina 100% dozens	Hannemania 100% 3 (2-4)
Hyla cadaverina 3.1cm - 3.5cm 6/20/2001	Coyote Canyon 3	Parasite Species % Infected Average # of parasites		metacercaria 100% 85.6(57-100)	adult/lungs 100% 2.6 (1-5)		Opalina 100% dozens	

Figure 1. Map of all sites surveyed in Anza-Borrego Desert State Park®

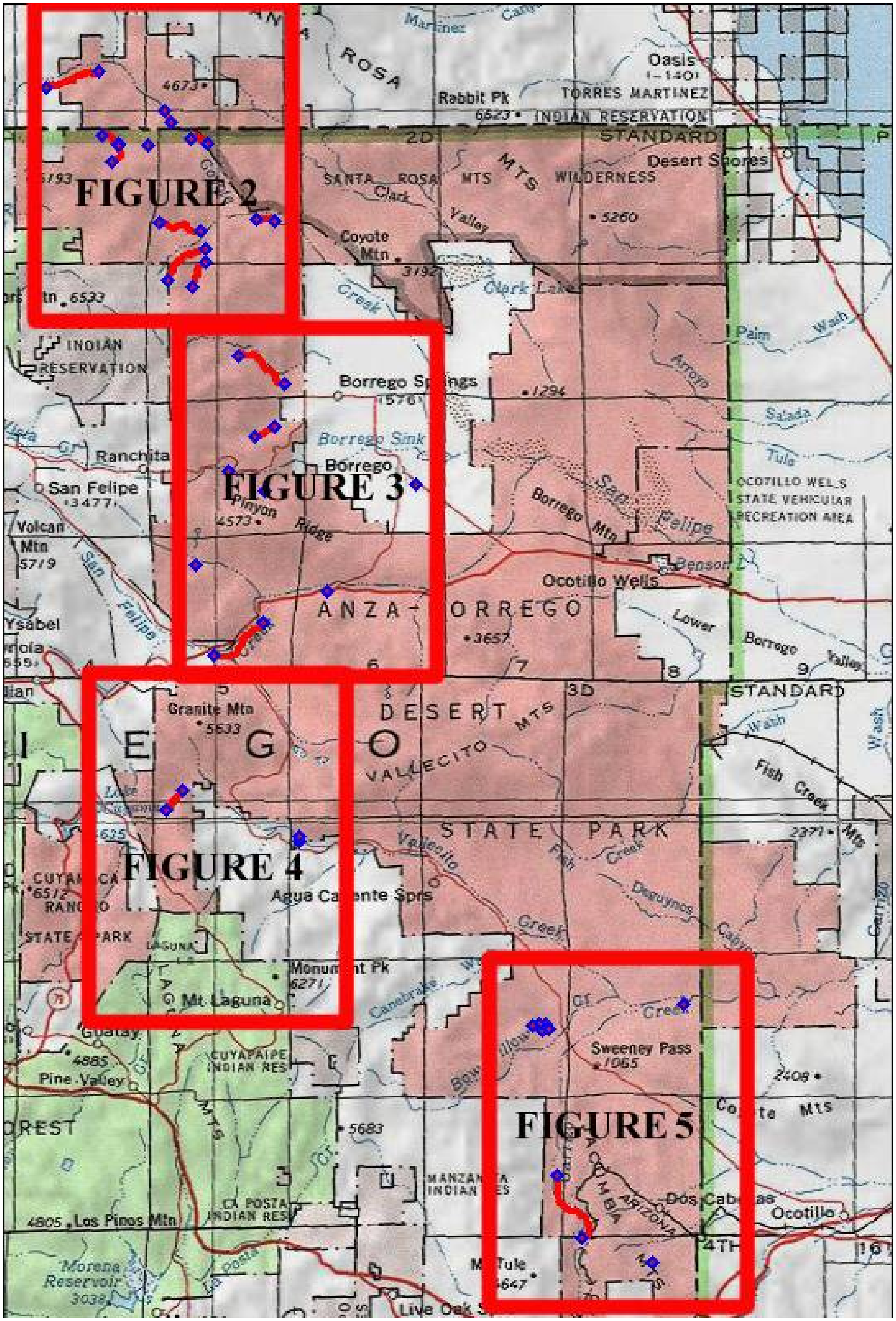


Figure 2. Coyote Canyon survey sites.

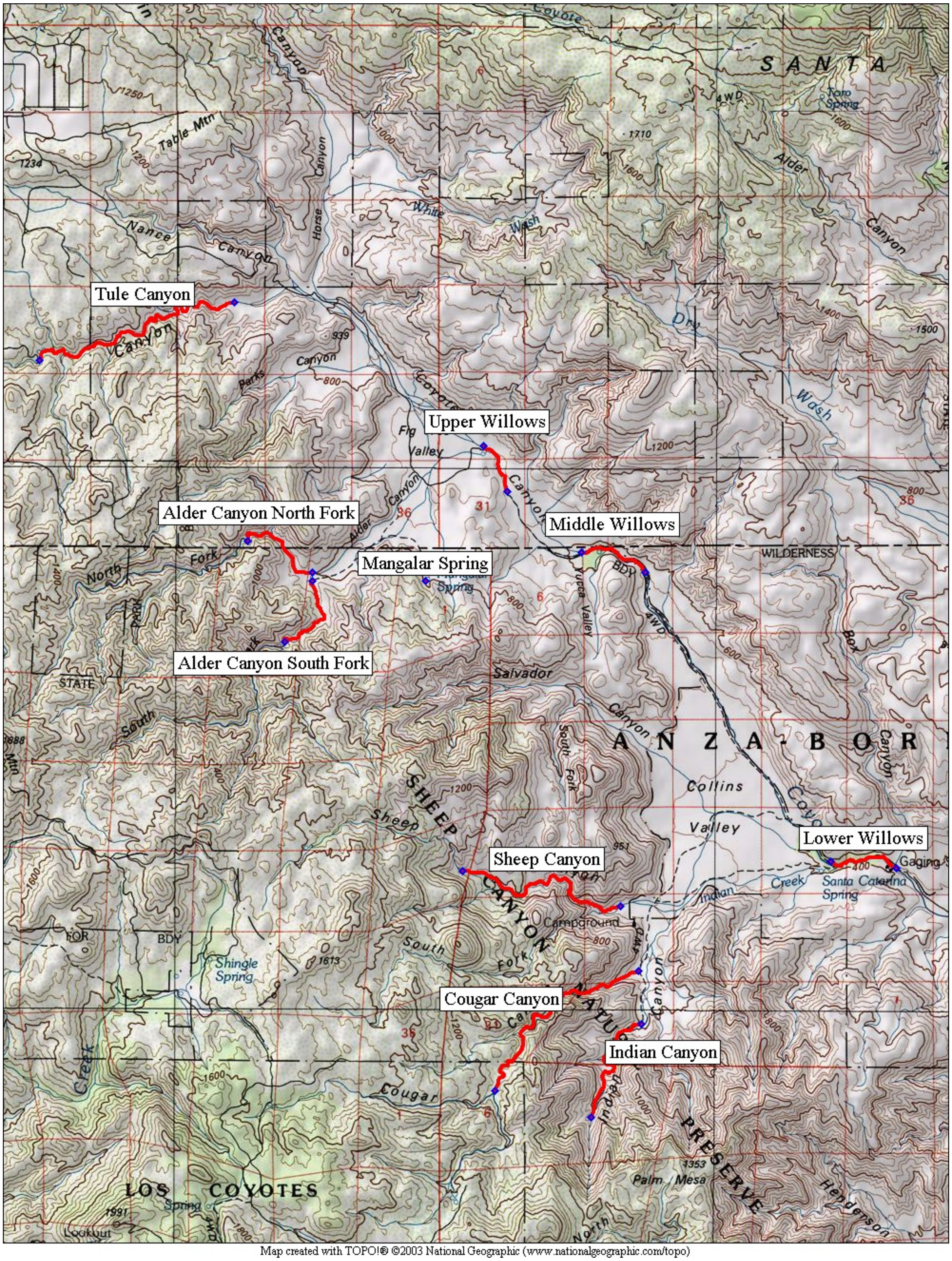
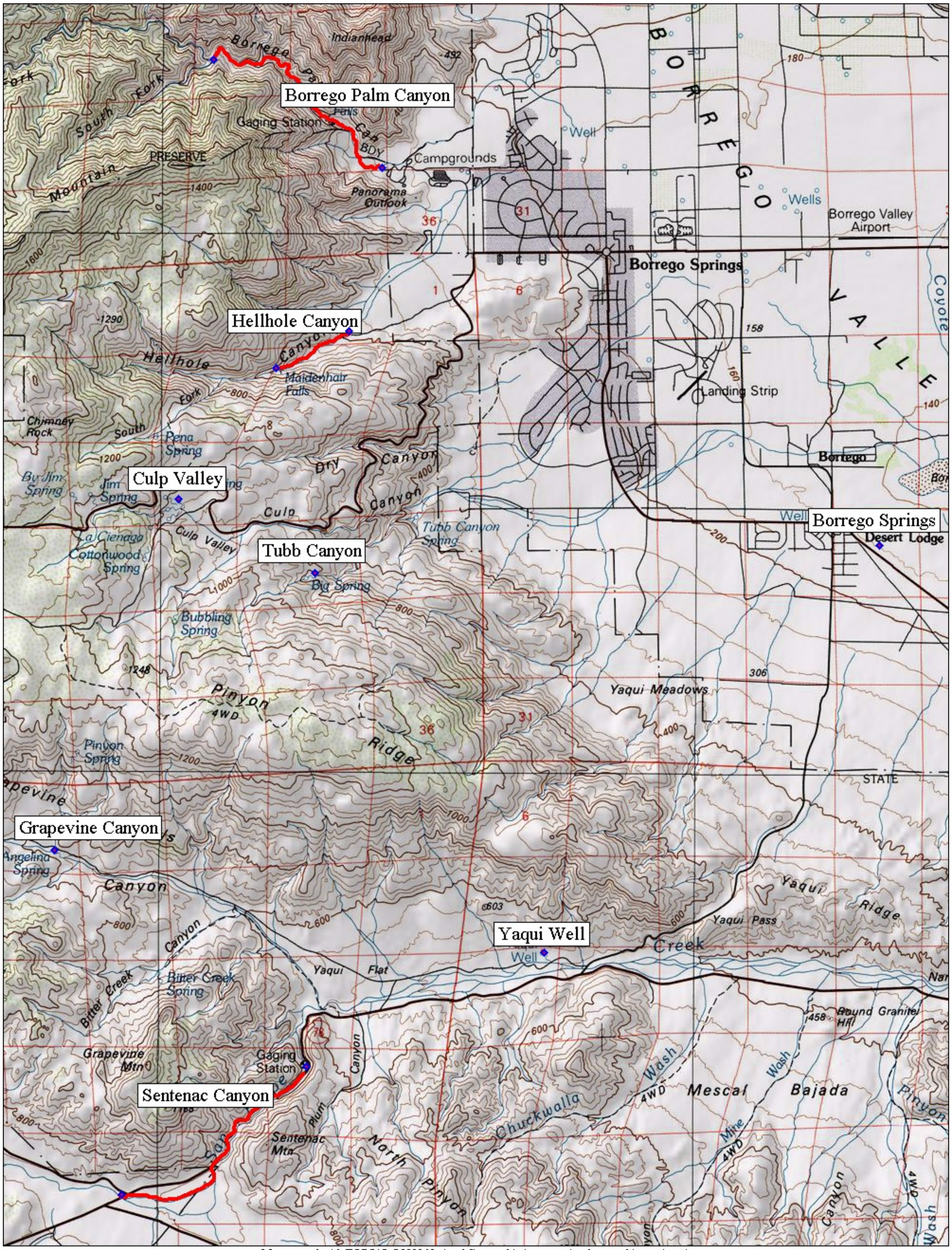


Figure 3. Borrego Valley survey sites.



Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)

Figure 4. Vallecito Drainage survey sites.

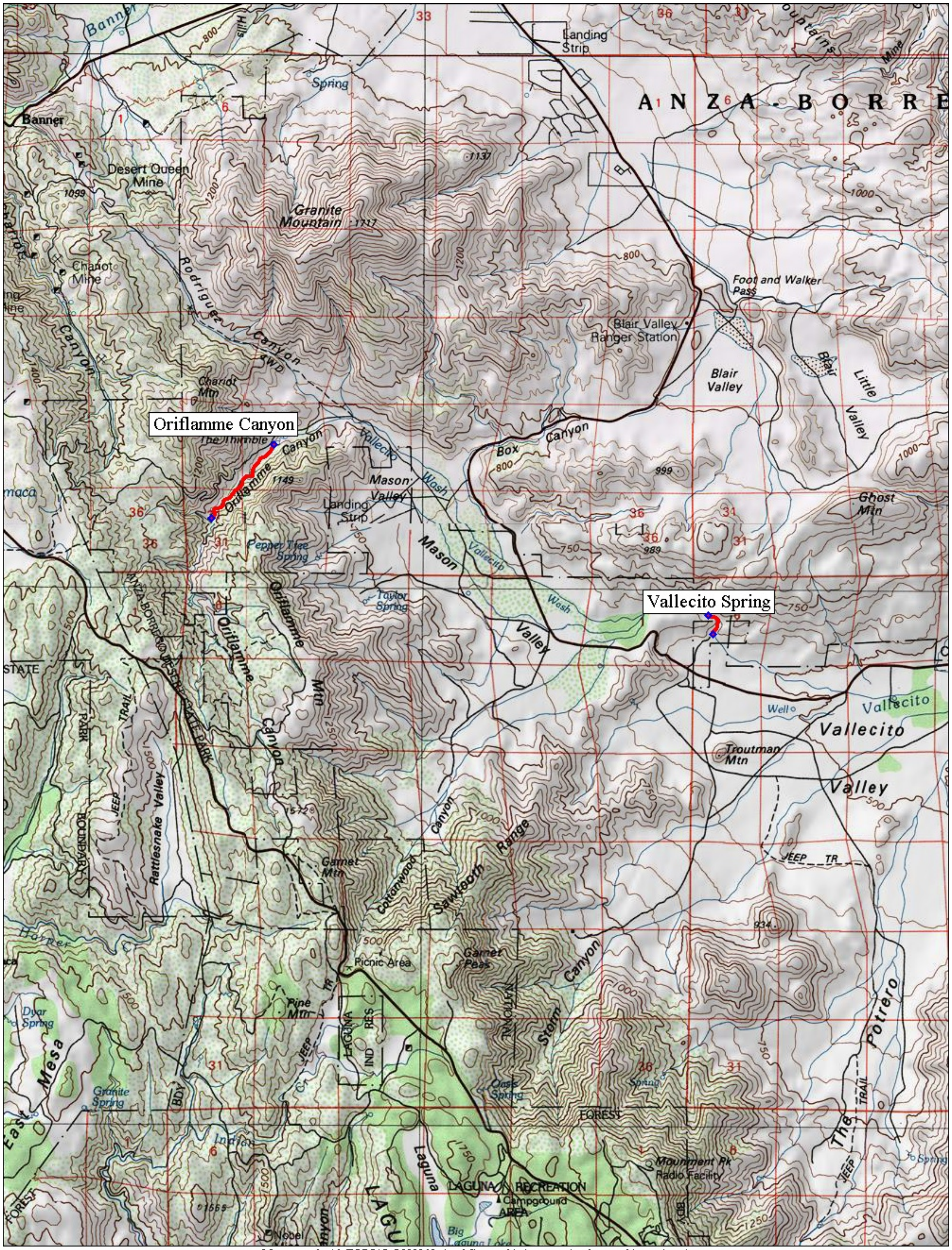


Figure 5. Carrizo Drainage survey sites.

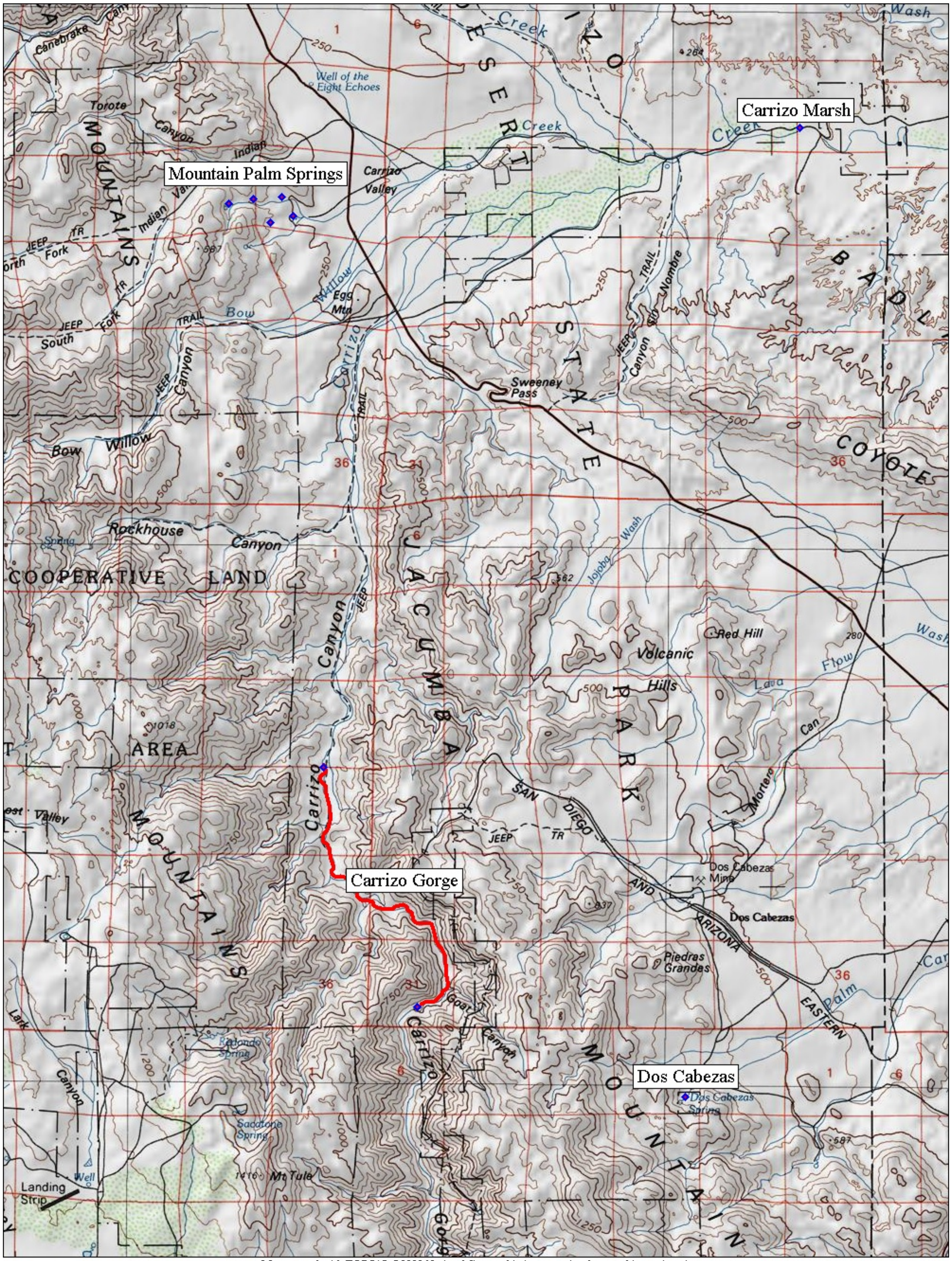


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Figure 6. California treefrog from Lower Willows infested with trematode metacercaria

Figure 7. Tubb Canyon Big Spring

Figure 8. South fork of Alder Canyon

Figure 9. Sentenac Canyon just above the Highway 79 Bridge

Figure 10. Borrego Palm Canyon

Figure 11. Upper Willows with horse disturbance