Natural History and Recovery Analysis for Southern California Populations of the Mountain Yellow-Legged Frog (*Rana muscosa*), 2003

Annual Report

Prepared for:

California Department of Fish and Game - Betsy Bolster
Contract # P0185110
Angeles National Forest - Bill Brown
San Bernardino National Forest - Steve Loe and Kathie Meyer
Mount San Jacinto State Park – Geary Hund and Alissa Ing
Coachella Valley Association of Governments – Jim Sullivan
Bureau of Land Management – Greg Hill

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

Natural History and Recovery Analysis for Southern California Populations of the Mountain Yellow-Legged Frog (*Rana muscosa*)

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TABLE OF CONTENTS

Tables:

Figures:

This report should be cited as:

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INTRODUCTION

Mountain yellow-legged frog (*Rana muscosa*) populations have been declining throughout California since the late 1960's (Bradford *et al*., 1994; Jennings and Hayes, 1994; Stebbins and Cohen, 1997; Knapp and Matthews, 2000). In response to these declines, biologists have conducted surveys to determine the severity of the declines and investigate decline causes (Jennings, 1993, 1994, 1995, 1998, 1999; Bradford *et al*., 1994; Jennings and Hayes, 1994; Knapp and Matthews, 2000; Backlin *et al*., 2001, 2002, 2003). We began monitoring the remaining southern California populations in 2000, and conducted additional surveys for mountain yellow-legged frogs (MYLF) at historical locations and other areas with suitable habitat from 2000 – 2003. Extensive surveys by the U. S. Geological Survey (USGS), U.S. Forest Service (USFS), and the California Department of Fish and Game (CDFG) have revealed eight remaining populations in isolated headwater streams (Backlin *et al*., 2003). There are five known populations in the Angeles National Forest (ANF): Bear Gulch, Vincent Gulch, Little Rock Creek, Devil's Canyon and South Fork Big Rock Creek and three populations in the San Bernardino National Forest (SBNF): East Fork City Creek, Fuller Mill Creek and Dark Canyon. Sherri Sullivan (SBNF) and John Sunada (CDFG) rediscovered this last population in 2003. Three other recent populations have not been confirmed since the late 1990's. These include Hall Creek (SBNF), Lower Fuller Mill Creek (SBNF), and East Fork San Gabriel River (ANF) (Jennings, 1993, 1994, 1995, 1998, 1999).

On August 1, 2002 the U.S. Fish and Wildlife Service listed the remaining populations in southern California as endangered (U.S. Fish and Wildlife Service, 2002). The listing of these populations was based partly on genetic work showing that MYLF in this region are genetically distinct from Sierra Nevada populations (Macey *et al*., 2001). The small number of remaining populations and the small population sizes at these sites were also primary factors considered in the listing.

The parties responsible for MYLF management include the U.S. Forest Service, U.S. Fish and Wildlife Service, California Department of Fish and Game, and California State Parks. Our work reported here was funded and supported by the above agencies to obtain data essential for the management of this species. At the time of listing substantial gaps in our understanding of the basic natural history and ecology of this species prevented confident management. For example, little was known about the timing of key life history events such as breeding, metamorphosis, hibernation, patterns of movement, and the characteristics of suitable habitat. Even reliable size estimates for remaining populations were not available. The goals of our surveys have been to provide data on these key issues.

A specific issue of importance from a management perspective is to identify potential causes of decline. One of these suspected causes, the potential interaction between the MYLF and introduced trout, was the focus of an ongoing field study. Increasingly there is recognition that stocking sport fish to formerly fishless waters can have unforeseen ecological impacts (Donald *et al*., 2001; Schindler *et al*., 2001; Wiley, 2003; Vredenburg, 2004). Studies in the Sierra Nevada suggest that the widespread introduction of trout contribute to the restricted distribution and reduced abundance of MYLF observed there (Bradford, 1989; Bradford *et al*., 1994; Knapp and Matthews, 2000; Knapp *et al*., 2003). In addition, researchers have found that when formerly trout-stocked lakes become fish-free, MYLF from nearby populations colonize these sites and establish population sizes similar to other fish-free habitats (Knapp *et al*., 2001; Vredenburg, 2004). Although similar studies have not been conducted in southern California, trout introductions have been widespread here and have been suspected as one of the causes for the MYLF decline that has occurred.

This report summarizes our work on MYLF in southern California from 2000 to present (Backlin *et al*., 2003). We present data describing: 1) historic and current distributions of MYLF; 2) MYLF natural history; 3) estimated population sizes; 3) movements by marked MYLF; 4) characteristics of current MYLF habitat; and 5) surveys for as-yet undiscovered MYLF populations. In addition we provide an interim report on an experimental trout removal effort on one creek, and summarize our survey data relative to the degree of overlap observed between trout and MYLF populations. We discuss our observations relative to the conservation and recovery of the MYLF in southern California and conclude with management recommendations.

METHODS

Study Site Selection

USGS has been conducting MYLF surveys across three mountain ranges since 2000. These mountain ranges consist of the San Jacinto Mountains and the San Bernardino Mountains in the SBNF, and the San Gabriel Mountains in the ANF (Figure 1). Our 2003 surveys were an expansion and continuation of these prior MYLF surveys (Figure 2). No recent exhaustive surveys have been conducted in a 4th mountain range, the Palomar Mountains. During our 2003 surveys, the seven known locations with extant populations of the MYLF were monitored, and an eighth extant population was rediscovered. Twenty-one additional locations were chosen to survey for the presence of the MYLF based on historical records and/or modeled habitat. Habitat was modeled by the U.S. Forest Service (USFS) using GIS to isolate creeks within the historic range of this frog that had perennial water.

To select areas to study trout and frog interactions we looked for locations where populations of these taxa are adjacent to one another. These interactions were studied because trout are known predators of ranid frogs (Hayes and Jennings, 1986; Bradford, 1989; Knapp and Matthews, 2000), and removal of trout in Sierra Nevada lakes has resulted in MYLF re-establishment (Knapp *et al*., 2001; Vredenberg, 2002, 2004) whereas lakes with introduced trout appear to restrict MYLF distribution and abundance (Bradford, 1989; Knapp *et al*., 2003; Bradford *et al*., 1994; Knapp and Matthews, 2000). Introduced predators often pose a great threat to native fauna which have not evolved defense mechanisms to these foreign species (Keisecker and Blaustein, 1998; Lawler *et al*., 1998). Because of published evidence and experiments showing that trout negatively impact frogs, we want to investigate whether or not frogs are able to establish themselves in a stream section in southern California where introduced fish have been severely reduced.

Little Rock Creek was the MYLF site chosen to make observations on frog/fish interactions because it currently supports adjacent populations of the MYLF and introduced rainbow trout (*Oncorhynchus mykiss*). The project area is naturally divided into three sections by natural fish barriers one of which has been enhanced by USFS (Figures 3 and 3a). The uppermost section (herein referred to as the frog reach) contains the MYLF and no trout sightings as supported in a report by Jennings (1998) and by previous USGS surveys (Backlin *et al.*, 2001–2003). The next section down stream (herein referred to as the treatment reach) contains mostly trout with only a few sightings of a single MYLF, and the last section (herein referred to as the fish reach) appears to support only trout (Figure 3). Trout were experimentally removed in the treatment reach of this creek via electro-shocking and dip netting. Detailed methods of electro-shocking techniques are described later in the text.

An interesting natural experimental opportunity presented itself in South Fork of Big Rock Creek where the drought caused severe reduction of trout in the reach below where the MYLF occur (hereafter, treatment reach) thus providing a second study site for observations on frog responses to fish reduction. This creek is also naturally divided into sections by fish barriers (Figure 4) although in high water fish will be able to migrate back to the treatment reach from downstream sources.

Areas and tributaries surrounding these creek sections in both Little Rock Creek and South Fork of Big Rock Creek have been surveyed in recent years (Backlin *et al*., 2001, 2002, 2003) to look for frog habitat (Figures 5–6), but have not been surveyed exhaustively for fish or frogs because subsequent surveys focused on MYLF occupied areas due to limited funding. In Little Rock Creek and South Fork of Big Rock Creek we hope to determine if trout are limiting MYLF dispersal and population expansion by recording frog and fish habitat usage within the three reaches.

A third creek, the East Fork of City Creek was chosen to monitor as a control site to Little Rock and Big Rock Creeks because non native predatory trout (brown trout, *Salmo trutta*), and MYLF populations abut each other here, and because there did not appear to be changes in fish density between 2002 and 2003, therefore serving as a system that has a relatively stable predator density (Figure 7).

If introduced fish are a limiting factor in frog expansion and establishment due to predation we would expect to observe over time no established populations (all age classes present) in the fish reach of East Fork City Creek but established populations (all age classes present) occupying the treatment reaches of Little Rock Creek and South Fork of Big Rock Creek. If trout are not negatively impacting frogs we would expect to observe over time either no difference in where frogs occupy, or frogs and fish occupying the same areas simultaneously.

Life History

Presence/Absence Surveys

To determine presence/absence of the MYLF in 2003, surveys were conducted at 8 known occupied sites and 21 historical and USFS modeled habitat sites (Figures 3–4, 7–21) between April and September during the day when the MYLF is known to be most active in southern California (Zweifel, 1955; Backlin *et al*., 2001–2003). Surveys were conducted by walking slowly in or near the stream channel to look for MYLF adults, larvae and eggs. Repeated surveys were conducted at sites with known extant populations of the MYLF to study life history and estimate population size and extent. Because we were funding limited, single visits were made to all other sites to determine if the MYLF was present, or if MYLF habitat was present and could potentially have frogs. Several of the sites surveyed a single time in 2003, (Hall Canyon, lower Fuller Mill Creek, and Dark Canyon) have been monitored cooperatively by USGS and CDFG one to three times each year since 2000 to look for recent known populations, because these sites were occupied in the mid 1990's but frogs have not been observed there in several years (Backlin *et al.*, 2001–2003).

All presence/absence surveys were conducted during the peak activity season of these frogs (the end of April through September, 2003). Frogs were usually located basking on rocks in or near the water, and were captured by hand or with the aid of a small dip net. Captured frogs were weighed, measured (snout to vent length), and examined to determine gender and look for any deformities. Water and air temperatures were recorded for each capture. Adult frogs were scanned with a PIT tag reader to determine their recapture status. If not previously captured, adult frogs were injected with a PIT tag for later identification. The frogs were then photographed and their locations recorded with a handheld Global Positioning System (GPS). All frogs were released after being processed. MYLF larvae were captured with dip nets, identified, and checked for evidence of oral chytridiomycosis (Fellers *et al*., 2001). Had any dead or dying adult or larvae MYLF been found, they would have been collected and examined for disease and parasites. Tadpoles were measured (body length and total length), their Gosner stage was determined (Duellman and Trueb, 1986), and they were released at their place of capture. Detailed notes identifying visible potential threats (e.g., habitat degradation, high numbers of predators), and general suitability of the watercourse (i.e., presence of slow moving water, plunge pools, and basking areas) were recorded during each survey. Species lists for all amphibians, reptiles, and fish observed were also compiled.

Monitoring Surveys

Prior to 2003, there were seven sites with known extant MYLF populations. These seven sites were designated as monitoring sites. An eighth site (Dark Canyon) became a monitoring site and will be further investigated in 2004 because frogs were rediscovered here but had not been observed in several years prior to 2003. We collected baseline information on the life history of the MYLF at all eight sites with known extent MYLF populations. Monitoring sites were surveyed three times across the 2003 survey season; once in spring, once in the summer, and once in fall with the exception of two sites (Devil's Canyon and Dark Canyon). These two sites were surveyed only once in 2003, due to difficult access of Devil's Canyon, and because the recent rediscovery of frogs at Dark Canyon in late summer of 2003 did not provide enough time to visit three times during the active season of the MYLF. More surveys will be needed at Dark Canyon in 2004 to study life history and determine population size and extent. When frogs were found, we used the same methods as the presence/absence surveys (described above) for data collection.

Trout/Frog Interaction Observational Surveys

As part of a separate study with CDFG three supplementary surveys (in addition to the three monitoring surveys) were made to three of the extant MYLF populations to collect additional data on frog/fish interactions. These three sites include Little Rock Creek, South Fork of Big Rock Creek and East Fork City Creek, and are the only sites we will be using to make observations on fish and frog interactions. In consequence, between the life history monitoring surveys and the frog/fish interaction surveys, visits were made to Little Rock Creek, South Fork of Big Rock Creek, and East Fork City Creek once a month from April through September, making a total of 6 surveys at each site in 2003. When frogs were found, we used the same methods as the presence/absence surveys (described above) for data collection. Survey details on collecting supplementary data on trout/frog interactions are outlined in the trout reduction study section below.

MYLF Activity, Demographics and General Health

Adult body mass was plotted against snout-vent-length (SVL) in Microsoft Excel™ v. 10 as an index of body condition for the MYLF in southern California. This plot was used as a baseline data for the general health of the populations so that comparisons may be made from year to year. Sampling days and observations of each life stage were summarized to show the activity period of each life stage throughout 2003 as compared to 2002. Demographic charts were constructed for all eight monitoring sites to provide an overview of population structure at these locations and provide baseline data on age classes. However, sample sizes are extremely small at several sites therefore interpretation of the population structure is difficult.

MYLF Movement Patterns

Whenever possible, the MYLF captures are recorded with a GPS location. Within these steep, narrow canyons the signal strength is often too weak to obtain an accurate GPS location; these captures were not included in the movement analysis. Using the coordinates we obtained along with the PIT tag information we are able to calculate the distances moved by recaptured frogs between capture times. Number of PIT tagged individuals and captures of all age classes for 2003 were summarized in tabular form. USGS began systematic PIT tagging the MYLF in 2001 (Backlin *et al*., 2001) however several frogs had been PIT tagged during a prior study in 1997–1998 by Jennings (1998, 1999). USGS expects to continue PIT tagging individuals each year to gather further data on MYLF life history. Between the 2000 and 2003 field seasons, 42 different frogs were recaptured, between 1 and 6 times per frog, and their locations plotted on Topo!© California mapping program. Once plotted, we were able to measure the stream distance that individuals moved between the capture locations.

Detectability

To determine how effective our survey protocol was at detecting frogs, we analyzed the probability of detecting MYLF on any single survey using the log-linear modeling program PRESENCE (MacKenzie *et al*., 2002). This analysis was only performed on sites with known extant MYLF populations to obtain baseline information on how difficult it is to detect frogs when frogs are indeed present, even if present in low numbers. Detectability was calculated on a site-by-site basis and again by combining all sites together to see if there would be a difference in detection probability at individual sites versus all sites. Since all of the known populations are small (tens of individuals) population size was not expected to have biased our detectability outcome in favor of a high detectability. For example, if our detection probability is high even though there are few known individuals then we can expect our survey protocol to be effective in detecting frogs at undocumented sites where there is similar habitat and the MYLF is present in low numbers. Therefore, the baseline detectability obtained from this analysis will likely allow us to make better estimates of whether or not frogs are likely present in new locations surveyed. To calculate detectability and standard error, we input presence/absence data obtained from repeated visits to all survey sites for each survey year into the program PRESENCE. Yearly values were then used to calculate an overall average detection probability with 95% confidence limits for the MYLF in the Angeles and San Bernardino National Forests.

MYLF Habitat Evaluation

To better understand the habitat requirements for the MYLF, 32 habitat parameters were measured at 10 separate pools within each of seven known MYLF populations in southern California, providing a total of 70 pools (Table 1). We were unable to collect these habitat data at the eighth known MYLF population at Devil's Canyon due to the difficulty of accessing this site. The habitat parameters measured were chosen based on the biology of the MYLF, and what we have observed at current MYLF locations so that measurements of these parameters could be summarized and later compared to sites where frogs have not been found. Pools at which parameters were measured were chosen because they were known to have frog occupancy during one or more of the presence/absence monitoring surveys. Three additional parameters were recorded at pools where MYLF egg masses were found. Habitat data were summarized in graphical form to show the average and range of measurements of specific habitat components in pools occupied by the MYLF. Due to limited time and funding we currently do not have similar data for areas that no longer have MYLF populations, therefore, statistical comparisons cannot be made at this time between occupied and unoccupied sites. However, these data provide baseline information on the structure of the habitat where the MYLF has been able to persist and can be used to make future comparisons to places where they are now absent.

Additional data were gathered using temperature loggers, which were deployed at MYLF sites and set to collect water temperatures every 20 minutes, year-round. These data collectively establish what the water temperature regimes are at these locations, and help us gain a better understanding of what the habitable water temperatures are for the MYLF in southern California creeks. We hope these habitat data will give us insight as to why current populations exist in specific sections of only eight known creeks.

Water Quality and Analysis

Water quality was assessed by measuring temperature, pH, conductivity, and dissolved oxygen (D.O.) in each creek at the time of each survey. We also conducted a single water grab at each site for analysis of the nutrients and major ions in each of the creeks. Water samples were analyzed for ammonia, nitrite, nitrate, phosphates, and major ions by the National Water Information System Laboratory, and these data were incorporated into the USGS national water quality database. All water quality monitoring activity was carried out using the protocols and guidelines established in the USGS national field manual for the collection of water-quality data (U.S. Geological Survey, variously dated). By comparing temperature, basic water quality parameters, and nutrient levels among sites we were able to begin establishing baselines for environmental variables currently being experienced by the MYLF. These baseline data can also be used in the future to compare conditions at sites where the MYLF were historically found but no longer persist to see if water quality may be a likely cause for MYLF extirpation.

MYLF Population Size

We used multiple methods to obtain population size estimates for each site where the MYLF was detected. For comparison purposes, population sizes were estimated for 2001–

2003, and for 2003 alone. For the 2001–2003 estimate, each year was considered to be one sampling period. When using data collected within a single year, each visit was considered to be one sampling period. Estimated population sizes pertain only to the adult MYLF. Juveniles and metamorphs are difficult to quantify because they are too small, (less than 50mm snout to vent), to be fitted with PIT tags, as were tadpoles and eggs because we are unable to permanently mark them as well. Furthermore, the breeding population size is more biologically meaningful to the persisting population than if we included metamorphs, tadpoles, and egg masses in this estimate because mortality is naturally high in these younger age classes. Therefore including these age classes could bias the estimate towards a population size that is larger than the actual viable population. Population estimates for 2003 were compared to estimates for 2001 and 2002 to determine if there had been any fluctuation in population size from year to year. Since there were so few individuals at each site to calculate population size, caution should be exercised when using these estimates to make management decisions. However, these are the best possible data available to date.

The type of method used to estimate population size depended on how many sampling periods were recorded at each location. For sites that were visited on two occasions (once to mark individuals and once to recapture individuals), we used the Peterson method to estimate population size (Krebs, 1989). This method involves marking individuals, releasing them, and returning to the site to recapture individuals. The estimator for population size is calculated as:

$$N = \frac{Mn}{m}$$

where, N = Estimate of population size at time of marking

n = Number of individuals in the sample

M = Number of marked individuals released back into the population

m = Number of individuals in second sample that were marked

For estimation of population sizes using only the 2003 data, we treated marked individuals (from previous years' studies) during the initial 2003 site visit as being marked for the first time. Additionally, several assumptions are made for this model to be accurate, which include:

- The population is closed (no immigration, emigration, birth or death occurred between sampling periods)
- All animals have the same chance of getting caught in the first sample
- Marking individuals does not affect their catchability
- Animals do not lose marks between the two sampling periods
- All marks are reported on discovery in the second sample

The second population estimate we used was the Schnabel method (Krebs, 1989). This method is used when there are multiple sampling events but is equivalent to the Peterson method if only two sample periods are used. Individuals captured during each sampling event are examined for marks and, if they were not previously marked, they were marked and released. The estimator for population size is calculated as:

$$N = \frac{\sum_{t=1}^{t=T} n_t M_t}{\sum_{t=1}^{t=T} m_t}$$

where, N = Estimate of population size

n_t = Total sample collected at the t^{th} time

M_t = Number of marked individuals in the population just before the t^{th} sample is taken

m_t = Number of marked individuals collected in the sample at the t^{th} time

The Schnabel method makes the same assumptions that the Peterson method makes. However, the benefit of this method is that there are multiple sampling events, thus making it easier to detect any violations in the assumptions. Although birth and death likely occurred during the course of our sampling, we are assuming for the sake of this study that these events were minimal and will not skew our estimates too far from what we would obtain without birth and death events. ("Birth" in the case of our study would mean that frogs became large enough (>50mm) to PIT tag, thus adding individuals to the population). In addition, where sample sizes were large enough both estimators have been run "with" and "without replacement." For those samples run "with replacement" the program makes a mathematical correction for the fact that some individuals may have been replaced by others through birth, death, immigration and emigration.

Trout Reduction

Trout Reduction Surveys

The two sites that experienced fish reduction included Little Rock Creek and South Fork of Big Rock Creek. Although fish were severely reduced at these two sites, complete extirpation is unlikely. A third site, East Fork City Creek was used as a comparison site because it gave us an opportunity to observe a system with fish and frogs where predatory trout numbers had remained relatively stable from 2002–2003.

Trout removal techniques in Little Rock Creek were carried out twice over a period of three days each time (October 21–23, 2002 and October 21–23, 2003). Fish were systematically removed within a 2 km stretch of creek that is bounded by fish barriers (Figures 3 and 5). Two teams of CDFG biologists began on opposite ends of the reach and walked towards each other, using electro-shocking paired with dip netting to catch fish (Roger Bloom, pers. comm.). In general two people operated electro-shockers while two people followed with dip nets to remove stunned fish. Gill nets were set up in one pool that was too large for electro-shocking alone to be effective. A total of three passes were made over the entire stream reach (one each day for three days for each year). Before shocking each pool and riffle, the immediate area was searched for the MYLF to ensure none were accidentally injured. (Repeated visual encounter surveys of this reach in past years have only revealed a single frog in this area).

At South Fork of Big Rock Creek the trout population was severely reduced by the drought in 2002 when the entire creek had nearly dried up (only a few shallow pools remained; Figure 6). Trout counts made in this section of creek during visual encounter surveys conducted prior to 2003 were used to compare trout counts made in 2003 following the natural reduction (Figures 4 and 6).

Because trout numbers were not severely reduced at East Fork City Creek, we used this site for comparison purposes. Observational surveys were conducted at East Fork City Creek to document gross estimates of fish numbers, and to document fish and frog interactions in a stream that did not experience systematic or apparent natural fish reduction.

Trout/Frog Interaction Observational Surveys

Following trout reduction in Little Rock and South Fork of Big Rock Creeks, surveys were conducted at these two locations as well as in East Fork City Creek (for comparison) every month from April through September when frogs and fish would be most active and visible. This sampling followed the jointly developed USGS/CDFG/USFS study design (Fisher *et al*., 2002). We used visual encounter surveys that were time constrained to examine the habitat usage of both the MYLF and introduced trout within each of three sections of Little Rock and South Fork of Big Rock Creeks. One section was comprised of 1 km of habitat where only frogs have been found “frog reach”, the second was a 1 km section where fish were greatly reduced “treatment reach” (with a single frog known from this reach in each of the creeks), and the third was a 1 km section where only fish have been found “fish reach”. There were only two 1 km sections in East Fork City Creek because fish had not been reduced there. One section was comprised of habitat where mostly frogs have been found “frog reach” and the second was a section where mostly fish have been observed “fish reach” although there have been some observations of fish and frogs together at the interface of these two sections. During surveys in all three creeks, the numbers of frogs and fish were counted in each reach while timing how long each reach took to survey with a stopwatch. This allowed us to control for unequal effort over the sections of the creek. In all three creeks fish and frogs were counted upon visual observation using a mechanical counter. If any stops were made to process frogs or take breaks along the way, the stopwatch was stopped so as not to bias the time for our visual encounter surveys. We will be comparing these data with data we will be collecting in 2004 to better understand if the trout may be limiting the expansion of these MYLF populations. Statistical comparisons cannot be made at this time because these data are preliminary. These surveys will be repeated in 2004 so that statistical comparisons may be made in our final report.

Habitat Segregation of Fish and Frogs

Enhanced Fish Barrier

The fish barrier identified at the downstream end of the project area in Little Rock Creek was enhanced the week of October 6, 2003 (Figures 3 and 3a). This enhanced barrier was designed to block fish passage between flows with approximately 25 year recurrence intervals (George Heise, pers. comm.). The barrier now consists of a 5.5 meter wide, 1.2 meter high, 0.5 meter thick concrete plug that sits a top a steep constricted bedrock chute which slopes at approximately 45° and drops about 1.7 meters (Figure 3a).

Historic Records

In order to have a complete understanding of where the MYLF occurred historically in southern California, we queried several museums. These include the American Museum of Natural History (AMNH), California Academy of Sciences (CAS), California Academy of Sciences - Stanford University Amphibians (CAS-SUA), Kansas University Natural History Museum (KUNHM), Los Angeles County Museum (LACM), Museum of Vertebrate Zoology (MVZ), San Diego Natural History Museum (SDNHM), Santa Barbara Museum of Natural History (SBMNH), United States National Museum – Smithsonian Institution (USNM), and the University of Michigan Museum of Zoology (UMMZ). Museum records were particularly helpful in determining when the MYLF was last recorded from an area. To help verify declines, these voucher records were summarized to show the number of specimens recorded by decade. Records were also compiled and plotted in Topo!© California mapping program to demonstrate the historical geographic distribution of the species. For those records lacking specific GPS coordinates, locality descriptions were used to estimate geographic coordinates so that these records could be plotted in Topo!©.

In addition, we examined CDFG fish stocking files currently being held at the Chino Hills, CDFG headquarters. We were able to obtain CDFG fish stocking records for the San Gabriel, San Bernardino, and San Jacinto Mountains. In most cases, these records spanned from the 1940's to the 1990's and included the number and type of fish stocked at locations throughout the region. These data did not include specific geographic coordinates for stocking locations therefore coordinates given later in this report are estimates of where actual stocking took place according to locality descriptions. Years during which a given site was stocked were recorded. The number of years each location was stocked was categorized and color-coded on our fish stocking maps. We arbitrarily categorized these records into low, medium, and high intensity stocking based on the number of records found in order to differentiate between sites that may be more impacted by stocking than others. For example, if a site is stocked each year it is more relevant to frog/fish interactions than if it is only stocked a few times because continual stocking would expose frogs to a higher density of, and continuous exposure to these potential predators.

RESULTS

Life History

Present/Absent Surveys

All sites with known MYLF populations and one rediscovered population were surveyed to monitor MYLF populations and collect life history data in 2003. In addition, 21 localities with historic records and/or USFS modeled habitat were also surveyed for presence/absence of frogs, making a total of 29 sites. We detected the MYLF at all seven of the sites where we found them in 2002: Bear Gulch, Devil's Canyon, East Fork City Creek, Little Rock Creek, South Fork Big Rock Creek, Fuller Mill Creek, and Vincent Gulch (Backlin *et al*., 2001; 2002), and one re-discovered site (by USFS and CDFG) in 2003: Dark Canyon. We did not find the MYLF in any of our 21 additional historic or modeled habitat sites, which included: Middle Fork Alder Creek, Andreas Canyon, Morongo Lands (Burro Flats Bog, Cattle Pond, CSUN trench, Millard Canyon), Deep Creek, East Fork Devil's Canyon, East Branch Snow Creek, East Fork Snow Creek, Fall Creek (San Gabriel Mts.), Falls Creek (San Jacinto Mts.), Murray Canyon, Palm Canyon, San Jacinto State Park (Hidden Lake, Marion Creek, Round Valley, Stone Creek, Willow Creek, Tahquitz Canyon, and Whitewater River (Figures 11–21). Several historic and modeled sites had suitable habitat for the MYLF. Again, suitable habitat was defined by the presence of slow moving water, plunge pools, and basking areas required for the life history of the MYLF (Zweifel, 1955; Stebbins, 2003). These sites included Andreas Canyon, Deep Creek, Falls Creek (San Jacinto Mountains), Murray Canyon, Tahquitz

Canyon, Marion Creek, East Branch Snow Creek, and East Fork Snow Creek (Figures 12, 16, 18, 19, and 21).

Prior to 2003 we had PIT tagged 102 frogs at seven known occupied sites. In 2003 we PIT tagged 40 new frogs, bringing the total number of PIT tagged frogs to 142 at eight known occupied sites. The number of adults, juveniles, metamorphs, and tadpoles observed or captured at each site during 2003 were summarized (Table 2). This summary includes recaptured individuals across all visits. Tadpoles were examined at Bear Gulch, East Fork City Creek, Fuller Mill Creek, Dark Canyon, Little Rock Creek, and Big Rock Creek, and no evidence of chytrid fungus was found. No dead or dying MYLF of any life stage were found during any of our surveys. Three frogs appeared to have injuries in the form of scarring (at Bear Gulch, Devil's Canyon, and Little Rock Creek), and one of these had a crushed foot as well. In addition, one individual was found with a short right hind foot (at Bear Gulch), which could have been a deformity. Native and non-native predators were observed at 16 of the 29 sites (Table 3). Specifically, two-striped garter snakes (*Thamnophis hammondii*) were observed at four of our MYLF locations and non-native trout (*Salmo trutta* and/or *Oncorhynchus mykiss*) were present in adjacent sections of seven of the eight MYLF locations (Table 3).

Monitoring Sites

Little Rock Creek was both a monitoring site and a site used to observe fish/frog interactions following CDFG trout reduction. At Little Rock Creek 27 frogs and 23 tadpoles were processed and released (these include recaptures across all visits). Additional tadpoles were observed but not processed as our purpose was to get a general idea of tadpole health, and not to necessarily quantify tadpoles. A single MYLF was found during two separate surveys in the treatment reach in 2003 (Figure 3). This is the same frog that was found in this location in 2002 (Figure 5) as was determined by its PIT tag identification number. Fish removal efforts have continued in the removal reach during 2003 and we will continue to survey this area for fish and frog movements and interactions in 2004 as per our previously described methods.

The South Fork of Big Rock Creek was both a monitoring site and a site used to observe fish/frog interactions following natural trout reduction. We processed 85 frogs and observed 191 tadpoles and 3 egg masses in the tributary of South Fork Big Rock Creek (includes recaptures across all visits). Several of the tadpoles were found in the treatment reach (in a pool just below the tributary's fish barrier) during 2003, and a single new frog was captured in the treatment reach (in a pool about 1 km downstream of the MYLF tributary) (Figure 4). Prior to the drought in 2002 trout were abundant below the MYLF inhabited tributary in the South Fork of Big Rock Creek (Figure 6). During our survey on September 19, 2002 only a few pools remained in the creek. At that time USGS counted 255 trout within a 1 km stretch of creek below the tributary using visual encounter surveys combined with seining (Figure 6). Although several trout were still observed in this reach in 2003, the numbers of fish appeared to have been severely reduced (Figure 4). During our six surveys in 2003, between 0 and 12 (average of 4) trout were counted within the treatment reach (the 1 km stretch of creek below the tributary). The stream course has changed since 2002, and now circumnavigates the fish barrier between the frog reach and the treatment reach. Therefore, there is no longer any hindrance to fish entering the frog reach, and in fact an adult trout was observed in the frog reach for the first time since USGS began surveying this area in 2000 (Figure 4).

East Fork City Creek was both a monitoring site and a site used to observe fish/frog interactions. At East Fork City Creek, 35 frogs were captured, and 27 larvae were observed (includes recaptures across all visits; Figure 7). Surveys of this creek were extended upstream about 3.5 km further than 2002, but most of our surveys were concentrated in the lower reach of this creek in order to combine them with our fish reduction study (Figure 7). The majority of the MYLF population inhabits the creek above the highway 330 bridge overpass as was determined during USGS surveys in previous years (Backlin *et al*., 2001–2003). However in 2003 frogs were found all the way downstream just past the confluence of West Fork City Creek where the trout population resides. Several sections of the creek are typically dry, where the water presumably goes underground for up to 0.5 km. However, frogs inhabited the entire wetted reach on either side of these dry stretches. Metamorphs and tadpoles were recorded for the first time in City Creek, below the confluence of the East and West Forks, however no adults were found here (Figure 7). It is likely that breeding did not occur here, but that these tadpoles and metamorphs were washed down or migrated down from the frog reach because 1) we never found egg masses in this area, and 2) they were not detected until late summer even though we made repeated surveys through the area to look for them. In addition, the MYLF has not been detected above or below the confluence in the West Fork of City Creek when surveyed in past years.

We found 61 frogs, 76 tadpoles and one egg mass at the Bear Gulch monitoring site (includes recaptures across all visits). At the Vincent Gulch monitoring site, only two frogs were seen at this location in 2003, however we also found 11 first year larvae, therefore breeding likely occurred there this year (Figure 8). We have insufficient data as to whether there is gene flow between the populations at Bear Gulch and Vincent Gulch (which potentially connect through Prairie Fork) because we seldom find more than a few frogs at Vincent Gulch each year and have never recorded movements of marked frogs between these sites.

Several reaches were surveyed in Dark Canyon because frogs were known from this creek as recently as the late 1990's. Several frogs were found by CDFG in the historical location of Dark Canyon below Azalea campground (Sunada *et al*., 2003). Frogs had not been seen here since the late 1990's and a local extinction was considered possible. More frogs were found in a small tributary of Dark Canyon which was also only visited once during the active season of the frogs. Two females and one male were found at the Azalea campground site (Sunada *et al.*, 2003), whereas a total of 65 frogs and 18 tadpoles were found within a 250 m stretch of the Dark Canyon tributary (Figure 9). This tributary site was rediscovered by Sherri Sullivan (SBNF) in August, 2003. Because it was late in the year, we were unable to complete our usual protocol of three visits in 2003. Monitoring surveys, (three visits to collect mark and recapture data), will be conducted as per our 2003 methods (described above) at both locations within Dark Canyon for 2004.

At the Fuller Mill Creek monitoring site, a total of 15 frogs, and 51 tadpoles and one egg mass were observed this year (includes recaptures across all visits). All of the frogs and the egg mass were found in the two pools just above the waterfall in 2003 (Figure 9), although in past years frogs have been observed at various locations below the waterfall. Fish have not been detected in any of the areas that the frogs have been observed likely because annual drying of large sections of the creek inhibit fish survival, but provide enough water for frogs to remain. However, fish are known from the lower reaches of Fuller Mill Creek (below the Pine Wood community) as was documented during our 2001 surveys (Backlin *et al*., 2002).

Due to the difficulty of accessing the Devil's Canyon monitoring site, we visit this area only once each year. Although there was more water in 2003 than in 2002, we found only 4 frogs and 3 second-year larvae (Figure 10). We were unable to determine if breeding occurred at Devil's Canyon in 2003 because no first-year tadpoles or egg masses were observed. This survey reach does not extend much further than the falls because in past years we have not found water beyond this area (Backlin *et al*., 2001, 2002, 2003). However, surveys are planned in 2004 in a lower section of Devil's Canyon downstream of where our 2003 surveys ended.

MYLF Activity, Demographics and General Health

In 2003, mountain yellow-legged frogs were active from May until the beginning of October, when temperatures began to get cooler (Figure 22). First year larvae were not observed until June and second year larvae were no longer observed after August. Metamorphs were not observed until July. Therefore we estimate that hatching occurred in mid to late May and that second year larvae metamorphosed between July and August (Figure 22). Because we seen only a few egg masses but many tadpoles at some locations, we assume that breeding and oviposition sites are extremely secretive. Our plot of body mass versus body length for all populations in 2003 gives us a baseline of general body condition for the MYLF throughout southern California that we can use to compare with previous or subsequent years (Figure 23). In this graph, we can also see that the East Fork City Creek population appears to be almost entirely metamorphs. However, as previously mentioned, most of our surveys in 2003 were conducted in an area where we typically only find metamorphs. As stated earlier, the reach above highway 330 was not surveyed as often in 2003 versus 2002 because in 2003 we combined our monitoring surveys with our fish/frog interaction surveys. This upper reach typically contains mainly adults but this is not recorded in our 2003 data. The Dark Canyon population appears to be missing intermediate sized frogs (juveniles and young adults) and is primarily made up of large adults and metamorphs. Since we made only one visit to this site, this may not reflect the true demographics of the population. However, this could also indicate a problem with survivorship of post-metamorphic through intermediate age classes. Therefore, more visits are needed to better understand the population structure here. Having such small population sizes makes it difficult to draw any significant conclusions from the demographics tables (Figure 24). However, we can use these tables as baseline information to compare with previous and subsequent years.

MYLF Movement Patterns

Of the 42 MYLF recaptures across all sites, 17 of the frogs showed no measurable movement across the four years we have been following them. The remaining 25 frogs moved between approximately 40 and 1494 meters with an average movement of 216 meters over four years. The distances measured are between the two most separated points at which each frog was detected, (not including distance traveled at any points between). There were two frogs that moved long distances. One frog in the East Fork of City Creek moved approximately 1494 meters between July 2001 and May 2002, and another frog in Little Rock Creek moved approximately 512 meters between June 2002 and August 2003. This frog in Little Rock Creek is a male frog that has separated from the bulk of the population in this stream. It is the only frog that has been located downstream of the natural fish barrier (Figure 3), and has been captured during three different surveys. This frog may be moving greater distances in search of a mate. If the frog in East Fork City Creek (moving 1494 m) and the frog in Little Rock Creek (moving 512 m) are removed from the analysis, the average distance traveled of the remaining 23 recaptured frogs with measurable movements is only 133 meters, and the average movement of the additional 40 total recaptured frogs (regardless of measurable movement) over the four field seasons (2000–2003) is only 68 meters. These data are consistent with the literature pertaining to MYLF frog movements in other geographic areas. In general, these frogs appear to have high site fidelity during the middle of their active season, with longer migratory and dispersal movements just after emergence from aestivation in the spring, and just before they return to their hibernacula in the fall (Matthews and Pope, 1999).

Detection Analyses

Unfortunately we are dealing with extremely limited circumstances for estimating detection probability because there are so few known populations with few individuals in existence. Therefore, caution are should be used when interpreting these data. Our detection probability for the MYLF for all sites with known populations of this species was 89.9% (SE = 4.9%; 95% CI = 74.3–100%) for the four years of survey data available (Table 4). Detection probabilities ranged from 77–100% between the years 2000–2003. These probabilities are extremely high and confidence intervals are narrow, indicating that this species is highly visible where it currently occurs, and that we have a 0–26% chance of not detecting this species where it is actually present under our current protocol in similar habitats. However, since sample sizes are small we may not be able to rely on these data to confidently state presence/absence in other locations.

MYLF Habitat Evaluation

All of the wetland locations with current MYLF populations are remote sections of creeks or creek tributaries that are periodically disconnected from their corresponding main waterway. All are similar in that they contain flowing water with pooling areas. All creeks also have year-round water (in at least some portion of the reach). Creek widths were generally narrow, between one and three meters across on average. Reach lengths occupied by frogs varied from about 250 m (Dark Canyon) to >5000 m (East Fork City Creek). The riparian widths ranged from 8–25 m with canyon walls typically rising steeply on either side (Figure 25). Creek gradients were highly variable, from 7–34% (rise over run). Bank and pool substrates consisted of varying percentages of soil, sand, gravel cobble or rock (Figure 25). Pools were 1–10 m long, 0.5–7 m wide, and 0.01–1.8 m deep. All pools had some type of structure in the form of bank overhangs, downfall sticks, and/or rocks that could function as refugia for the MYLF, but there was minimal aquatic vegetation in the pools (Figure 26). Water chemistry parameters were within the expected range for this species. Ranges correspond to measurements recorded from all sites and all survey periods combined. The most consistent water parameter between all sites was pH which generally measured about 7–8. Conductance ranged from about 80–675 μm while dissolved oxygen (D.O.) was variable (23–128%; Figure 27) likely because measurements were taken at different times of the year from one site to the next (i.e., we expect higher

D.O. readings when water is flowing faster. In late fall, water flow slows, which causes pools to become more stagnant and therefore have lower D.O. readings). The range of water temperatures during the summer (June through August) at MYLF sites was between 9.0 °C and 30.3 °C with an average summer water temperature of 14.6 °C (Figure 27). Egg masses were found at three pools. Eggs were found between 3–30 (average 18) cm below the water surface, and water depths at the egg masses ranged from 7–40 (average 28) cm (Figure 28).

Water Quality and Analyses

Data from water grabs and water quality monitoring activities analyzed independently by USGS Water Resources were summarized (Table 5). Most sites had neutral to slightly basic pH, low conductivity and high D.O. readings, which is consistent with what we expected for the streams surveyed as these conditions would indicate a hospitable aquatic environment for the MYLF. Nutrient and major ion results differed from site to site, with a small subset of sites returning values not normally associated with high mountain streams. These sites were Fredalba and Deep Creeks, showing markedly higher values for major ions and nutrients than the other creeks. The grab sample for Fredalba Creek was taken near a series of settling ponds that appear to be part of a waste treatment facility for the community of Running Springs. Infiltration of treated waste water from this facility would explain the elevated nutrient and major ion values that were reported for this site. The grab sample for Deep Creek was taken downstream of a hot spring marked on USGS 7.5 min. maps and the elevated major ion values for this sample were similar to other sites with geothermal activity (C. A. Burton, USGS/WRD, pers. comm.). Excluding these creeks, there were no discernable differences in water quality variables measured during the current study among sites that contained frogs and sites that did not.

MYLF Population Size

We estimated the breeding population sizes on a site-by-site basis. Our population data indicate that all of the eight remaining breeding populations are relatively small (Table 6). Although many of the metamorphs, tadpoles and eggs not included in the estimates will not make it to adulthood, some will, and therefore total population sizes are assumed to be larger. Estimates with large confidence intervals should be treated with skepticism as large intervals indicate sample sizes were too small for an accurate estimate (e.g., Bear Gulch 2003; Table 6). Therefore, confidence intervals should be considered when drawing conclusions about the following population estimates. Having consistently small sample sizes at each site from year to year despite repeated surveys should be an indication of the high extinction risk of these populations even without accurate population size estimates. The following information may include more than one population size estimate per site because we used different methods of estimation whenever possible to help us double-check the accuracy of these estimates. We estimate that the breeding adult population at Bear Gulch has between 54 and 92 individuals, Devil's Canyon has approximately 20, East Fork City Creek has approximately 50, Fuller Mill Creek has between 9 and 13, Little Rock Creek has from 8 to 9, and the South Fork of Big Rock Creek has between 27 and 74 (Table 6). Some population estimates vary from year to year and have large confidence intervals because we were only able to obtain small sample sizes at these sites. There are too few breeding individuals to make a more accurate estimate at this time. In fact, we were unable to use statistical methods to estimate population size for Dark Canyon and Vincent Gulch this year because sample sizes were too small. However, in 2002 we were able to estimate that there were about 12 breeding adults at Vincent Gulch, and in 2004 we expect to have more data on the Dark Canyon population. In general, population sizes at the seven sites we have continually monitored have remained relatively consistent from year to year since our monitoring efforts began in 2000 (Backlin *et al.*, 2001, 2002, 2003). However this is a relatively short time period for population fluctuation to become evident therefore we cannot be certain that these populations are actually stable. In addition the small sizes of all of the populations makes them vulnerable to stochastic events. Overall, we have been able to mark only 142 breeding adults in four years of our survey efforts. This continues to indicate that the southern California population is in extreme peril.

Trout Reduction

In 2002, 352 trout were removed on the first pass of electro-shocking from Little Rock Creek by CDFG. A second pass removed 455 trout and a third pass removed 66, totaling 873 fish. In 2003, the first pass of electro-shocking produced only 75 fish, the second pass 14, and the third pass only 3 making a total of 92 fish (Figure 29). No new frogs have been found in the fish removal area since our electro-shocking efforts. Since we are using South

Fork of Big Rock Creek as a natural system for comparison, we did not electro-shock fish and do not know how many fish perished in the drought of 2002. During our systematic surveys of the reach in 2003, we counted up to only 12 fish on any given survey, whereas in 2002 we generally observed hundreds of fish in this reach (Figures 4 and 6). Therefore, the drought appears to have greatly reduced the trout population here although trout have not been completely eliminated. Since the trout reduction, one new frog, several metamorphs, and tadpoles have been found in the treatment reach of South Fork Big Rock Creek (2003). At East Fork City Creek we did not electro-shock trout, but counted them in 2003 to determine the number of trout relative to the number of frogs in this system and where they were located. In the frog reach we found zero trout with zero MYLF adults, and 20 metamorphs and tadpoles. In the fish reach we found 832 trout with zero MYLF adults, 29 metamorphs, and several tadpoles. These baseline data will be used to make comparisons with our 2004 surveys.

Habitat Segregation of Fish and Frogs

Prior to the implementation of the fish reduction study, there appeared to be a segregation of fish and frogs in each of the creeks surveyed as observed during our 2000–2002 surveys. In general, fish were not observed in the frog reaches and frogs were not observed in the fish reaches prior to 2003, although there were two exceptions to this, (one adult frog was known from the treatment reach of South Fork Big Rock Creek and one adult frog was known from the treatment reach at Little Rock Creek since 2001). Frog populations were clustered in areas that were separate from fish populations.

Following the two years of fish removal at Little Rock Creek, we did not find evidence of frogs moving into the treatment reach. However, we do not expect to see a rapid frog response to the fish removal here for several years because of the topography of the area and the small size of the current frog population. Specifically, there is a 300 m stretch of Little Rock Creek between the frog reach and the treatment reach that only contains water during storm events. Not only is the absence of water a hindrance to MYLF dispersal, but this dry area also has a steep gradient and consists of large boulders and several steep (> 5m) drop-offs, which would make it difficult for frogs to navigate through. Therefore, we expect that there needs to be several storms with high water before frogs could conceivably migrate, or wash into the treatment reach. In addition, having fewer frogs in the population means that there are fewer chances that migration or washing into the treatment reach will occur.

Following the drought and subsequent reduction in the fish population at South Fork Big Rock Creek our surveys revealed several tadpoles and metamorphs in the treatment reach near the interface of the frog reach and treatment reach. In addition, during our last survey in 2003 on October 22, we found an adult male frog at the downstream end of the treatment reach, (approximately 1 km downstream of where the bulk of the MYLF population occurs). This frog was a different individual from the one known (from previous years) to inhabit this section because it was not marked (the previous frog had been toe clipped and PIT tagged). Therefore, one adult frog was known prior to trout reduction and two adult frogs are currently known following trout reduction. To date, there is no fish barrier to prevent non-native trout from coming back into the South Fork of Big Rock Creek from downstream in the main stem, although there is an area between the main stem and South Fork Big Rock Creek that goes dry for long periods of time throughout the year (Figure 6).

At East Fork City Creek in 2003 we found MYLF tadpoles and metamorphs in the fish reach. This was the first year in which we were able to detect the MYLF in any life stage within this area. No adults have been recorded from this area in recent years despite several visual encounter surveys.

Historic Records

From 2000–2003, we chose where to survey for the MYLF based mainly on historical locations and USFS modeled habitat. With all of our survey years combined (2000–2003) we have conducted surveys for the MYLF at 95 distinct sites (Figure 1), most of which currently have trout (Backlin *et al*., 2001, 2002, 2003). To illustrate the overlap of trout stocking and former MYLF locations, all historic records for both the MYLF and trout stocking activities were mapped (Figures 30–31). Museum records provided 595 MYLF voucher specimen records corresponding to 142 historical MYLF locations throughout southern California. The MYLF records dated from 1903 to 1995 with a marked drop in the number of records after the 1960s (Figure 32). Trout stocking records furnished by the

CDFG Chino Hills Field Station provided 115 locations on the Angeles, San Bernardino and Cleveland National Forests where trout were stocked in regions known to have supported the MYLF. Records dated from 1940 to1999 for most locations. Forty-seven of these locations were classified as low intensity (stocked 1-5 times during 1940-1999). Twenty-eight were classified as moderate intensity (stocked 6-15 times during 1940-1999). Finally, 40 sites were classified as high intensity (stocked 16-52 times during 1940-1999; Figure 31; Appendix 2).

DISCUSSION

Life History

When comparing the locations of historical records where frogs were not found to those of current extant populations, and considering that no observations or vouchers of the MYLF have been recorded from most historical areas since the 1960s, it is evident that that the MYLF has disappeared from nearly all of its former range in southern California since the mid 1900s. Although declines seem obvious, a lack of knowledge in basic life history and population status of this species has hindered conservation and management decisions. Our studies have revealed several details about the biology of the MYLF that we hope will allow us to move forward with the conservation and restoration of this species to southern California leading to its recovery and delisting.

In summary, our external health examinations indicate that chytrid fungus and other diseases do not appear to be plaguing current populations, although we cannot determine if disease has been a factor in the past. We have evidence that the MYLF are incompatible with exotic species such as non-native salmonids, bullfrogs, and crayfish (Porter, 1967; Moyle, 1973; Hayes and Jennings, 1986; Bradford, 1989; Bradford *et al*., 1994; Kupferberg, 1997; Knapp and Matthews, 2000; Knapp *et al*., 2003; Saenz *et al.*, 2003; Vredenburg, 2004). Non-native salmonids exist in adjacent stream sections at 7 of the 8 known MYLF locations whereas bullfrogs and crayfish do not. We now understand the phenology and general timing of development of these frogs at their current locations. Our most recent data indicate that these frogs have high site fidelity, and have a high detection probability but will also travel distances >1 km on occasion (perhaps to find new territories and mates). Egg masses and tadpoles are difficult to detect because they are cryptic and often hidden under rocks, leaf litter, or other refugia in the pools. When tadpoles are detected, we have observed that they tend be found further and further downstream as the season progresses. This is an indication that downstream currents may contribute to tadpole dispersal especially after summer rains. We know that MYLF populations in southern California are currently only found in isolated headwaters or tributaries of creeks because we have been surveyed upstream and downstream of known localities in 2000–2002 (Backlin *et al*., 2001, 2002, 2003). We have characterized and quantified the general habitat components at these localities including baseline water quality data present within these environments. Temperature loggers at each of our sites have given us insight as to the aquatic thermal regimes that this species tolerates. Though it is unlikely that we will ever be able to recover the former diversity of genetics of this frog, we can apply the new knowledge learned about this frog's life history to help preserve the few populations that remain and manage this species for recovery.

With regards to water quality, there were no large differences between sites with and without MYLF. However we did detect significant and potentially negative differences in water quality at Fredalba Creek. This was almost undoubtedly due to the influence of wastewater treatment activities of the upstream community of Running Springs. Although there is currently no extant MYLF population in Fredalba, water quality at this location may factor into the long term recovery opportunities the frog has in this region. In general, additional water quality monitoring will be required before we can make more precise statements regarding the MYLF water quality requirements.

MYLF Population Size

Long-term data is needed to detect population trends over time, therefore population estimates will need to continue in the future. Because ranids are generally r-selected species, (their evolutionary life strategy is to have many offspring but they may be poor competitors and be relatively short-lived), they typically exhibit natural boom and bust population dynamics. These booms and busts should not be mistaken for population trends because they are transitory. However, when populations are extremely small, a "bust" year could mean local extinction, therefore we should monitor recruitment closely for small populations.

All of the remaining MYLF populations in southern California are small (<100 adults). Some are estimated to be so extremely small (Fuller Mill Creek, Devil’s Canyon, and Little Rock Creek; <20 adults), that they are highly susceptible to stochastic events and have little chance of long-term persistence without management intervention. Very small populations, consisting of less than 10 pairs, are likely to become extinct in the short term (Pimm *et al*., 1988) and immediate conservation actions should be taken to stabilize and rebuild these populations. In Appendix 3, we list several hypotheses that might help explain why this species has declined so rapidly in southern California over the past several decades.

All decline hypotheses are being considered for this species however, several pose more immediate and direct threats, and may have solutions that are more tractable than the others. For example, we cannot immediately reverse the effects of global climate change, or geomorphic changes that have occurred because of fires and flooding. Nitrogen deposition, and pesticide contamination would also be difficult problems to surmount and would take many years of cooperative efforts to understand, or may be impossible to remedy. Furthermore, we have little evidence of these later factors currently affecting the frogs at our particular sites according to our preliminary data on the water samples we tested. However, with comparatively minimal effort, we will likely be able to reduce or eradicate exotic species, prevent direct human impacts, and take precautionary measures against spreading disease.

Alleviating threats to the species is the single most effective way of preventing further declines; however, we must also consider that these populations have diminished to the point where simply alleviating extinction risks will not guarantee stability and persistence. We need to also begin expanding current populations and re-establishing new ones. Specific suggestions on how to enhance the MYLF populations in southern California will be discussed in our management recommendations.

Trout Reduction

All of our study sites have experienced the drought (reaching it's height in 2002). This condition actually made it possible to add South Fork of Big Rock Creek as a location having natural fish reduction. The drought also made electro-shocking efforts in Little Rock Creek easier and likely more effective. We did not find many tadpoles and metamorphs in East Fork City Creek until 2003, likely because drought conditions caused poor recruitment. However, detectability of the MYLF at all three sites appeared to be unaffected as presence was confirmed during each survey even in drought conditions.

There is a difference by about one order of magnitude between the fish electro-shocked out of Little Rock Creek in 2002 versus those removed in 2003, which suggests that shocking was effective in reducing the trout population in this section of creek. The drought undoubtedly aided the study in reducing trout numbers as well. Although we cannot guarantee that all fish will be permanently removed from this reach, the fish numbers will likely remain low with repeated electro-shocking. If fish are limiting frog expansion, keeping fish at low numbers should allow frogs to establish provided the MYLF is able to migrate, wash into, or be translocated to the treatment reach.

Preliminary data show that movement of frogs into the treatment reach may be occurring in South Fork of Big Rock Creek. We would expect to see a response to fish removal in this creek earlier than in Little Rock Creek for several reasons. First, the frog population is approximately ten times larger in South Fork of Big Rock Creek than Little Rock Creek. Second, the frog reach and fish removal reach are uninterrupted in the South Fork of Big Rock Creek, whereas there is a span of dry steep habitat between these two reaches in Little Rock Creek. However, without a fish barrier at the base of South Fork Big Rock Creek, fish numbers may be able to increase in this area quickly resulting in the reestablishment of a high predator density. Surveys in 2004 will continue to evaluate fish and frog numbers and locations in this creek. It is too soon to detect any significant response to fish removal in Little Rock Creek and South Fork of Big Rock Creek however, this study is expected to continue for at least one more year, and monitoring is expected to continue on a long-term basis at these sites.

Habitat Segregation of Fish and Frogs

Since no new movement into the treatment reach was discovered following trout reduction in Little Rock Creek, we cannot make preliminary statements on fish limiting frog expansion. However, as stated earlier, we do not expect to see an immediate response to fish reduction in this creek because of the topography of the area and the fact that there are so few frogs in this population (see Results: Habitat Segregation of Fish and Frogs section).

Tadpoles and one new adult frog were washed into or migrated into the treatment reach of South Fork Big Rock Creek in 2003. In South Fork of Big Rock Creek we hypothesize that the new adult seen in the treatment reach will be able to persist in this area and possibly reproduce here as well, should a female be able to migrate to the area. These preliminary observations of the MYLF in the treatment reach of South Fork of Big Rock Creek and in the fish reach of East Fork City Creek indicate that the MYLF may be able to establish themselves in the areas where fish densities have been reduced. More data will be collected on habitat segregation in 2004 to refute or support this supposition.

Our data suggest that MYLF tadpoles were either washed into or migrated into the fish reach of East and West Fork City Creek but if this has happened before, none have survived there in the past. These preliminary data suggest that the MYLF may perish in areas where fish occur (East Fork City Creek). In City Creek, we hypothesize that the fish reach could be acting as a sink for this population because although we would expect tadpoles to wash downstream into this area due to the natural course and flow of the waterway and during high summer rain flows, no breeding or adults have been observed here in past years. In retrospect, it is possible that tadpoles and metamorphs have washed into this area in the past, but that some factor is preventing them from developing into adults and establishing themselves. We hypothesize that this factor could be predation by non-native salmonids.

Unfortunately, East Fork City Creek has been affected by fire and subsequent run-off and scouring (in late fall of 2003). The fires and severe debris deposition in December 2003 in East Fork City Creek may have wiped out the entire fish and frog populations here. Therefore, this site will likely have to be removed from the study. Such action will be determined during our 2004 surveys. We will only be able to observationally correlate frog population expansion with fish removal if only the fish (not frogs) perished in these natural disasters and frogs begin to establish in the fish reach. If both species have been eliminated we will no longer be able to use this site in our study.

Combining museum record data with our current knowledge of MYLF locations, illustrates that the MYLF can no longer be found in most of its former range. Historic records of fish and frogs indicate that fish have been stocked in former MYLF locations. Although this does not directly link fish to frog declines, it provides further evidence that the introduced fish hypothesis should be examined more closely.

MANAGEMENT RECOMMENDATIONS

Managers and policy makers need to decide the extent to which actions are needed to recover this species. We need to determine if we want to preserve just some representatives of the species, or preserve this species as a functional part of the ecosystem as a whole. Approaches to these goals will differ significantly. Financial and ethical questions will play a major role in this decision in order to determine whether to manage for full recovery at the landscape level or if managing on a population by population basis would be more appropriate. With only eight populations remaining in southern California, not only must we make an informed decision quickly, but there are several tasks that should be accomplished while this decision is being made.

All eight known populations of MYLF should continue to be monitored annually for presence/absence, stability of population size, and general health. Additional studies need to be continued on habitat requirements, dispersal capabilities, aestivation sites, natural and anthropogenic threats, and potential translocation experiments, to better understand the frog’s natural history and potential for expansion and recovery. Modeled habitat should continue to be examined across the San Gabriel, San Bernardino, Palomar, and San Jacinto Mountains in order to better define potential habitat and possibly find additional populations or suitable areas for translocation. Because the MYLF appears to be relatively easy to detect where it occurs, and because this frog appears to exhibit high site fidelity and currently persists in small population sizes, all potential habitat needs to be surveyed including; springs, seeps, marshes, and small tributaries so that undocumented populations are not inadvertently overlooked.

It appears that non-native trout are the most immediate threat to current MYLF populations. Because the remaining eight populations are so small, it is likely that year-to-year recruitment has not been great enough to outweigh the MYLF lost to predation. If such is the case, MYLF populations inhabiting creeks with trout will never be able to increase in size and these populations will likely become extinct over time due to stochastic events. We therefore recommend continuing the trout removal study in Little Rock Creek, and South Fork Big Rock Creek, and expanding them to West Fork of City Creek, Dark Canyon, and Fuller Mill Creek. Fish have been naturally reduced and possibly removed from South Fork Big Rock Creek because in 2002 the drought rendered all but a few pools in this creek dry. Normally this creek would be too large to manually remove fish successfully, therefore in order to take advantage of this rare situation a fish barrier should be constructed so that fish cannot migrate into this area again. The placement of this barrier should be somewhere between the tributary where the MYLF currently occupy and the confluence with Big Rock Creek (Figure 4). The fate of the MYLF in City Creek is unknown. It is possible that some of the frogs will survive the direct and indirect effects of the Old Fire and that the brown trout will not. If this is the case, we recommend eliminating any stocking activities in City Creek and ensuring that exotic fish will be unable to migrate up from any sources at the base of the mountains. Surveys need to be conducted in 2004 to determine the status of fish and frogs in East and West Forks of City Creek.

In order to ensure the protection of this species, we also recommend that recreational activities in areas where these frogs exist be diverted away from the frog habitat. At Little Rock Creek, the trail to a popular rock climbing area (Williamson Rock) follows the creek where the frogs reside. A new trail could be constructed that would eliminate foot traffic from the frog area and offer a more direct route to the climbing area as well. Educational signs about the MYLF and about sound sanitation practices (i.e., not defecating in the creek bed) could also improve the current condition of the frog habitat here. For the populations at Bear and Vincent Gulch, we recommend that the Prairie Fork Campground remain closed in order to protect these populations from excessive foot traffic and accidental take. There is a great need to involve the fishing public in our conservation and restoration plans. Making management decisions that affect fishermen unbeknownst to them will only incite animosity, create backlash, and encourage uncooperative attitudes. In general the MYLF populations are found in the upper reaches of streams whereas fishing has been observed in mainly the lower stream reaches. If we can designate and enhance good fishing areas while protecting MYLF habitat with fish barriers, all will benefit.

Since the few remaining populations are small, it would be prudent to begin captive rearing and breeding to preserve the already diminished genetic diversity of existing populations, and provide frogs for possible future reintroductions. Currently, there are 11 juvenile frogs at the LA Zoo captive rearing facility. These frogs were salvaged from the East Fork City Creek population that burned in the Old Fire this year. Mudslides, severe scouring, siltation, and debris deposition now pose an added threat to this denuded habitat. If the population at East Fork City Creek has been extirpated, the 11 juvenile frogs, even if released to the same habitat would likely perish. First, the habitat is no longer suitable for the MYLF here as there is no longer any pool habitat and several feet of debris have been deposited throughout the former creek bed. Second, having only 11 frogs to establish a population would be very risky. Third, we do not know the gender of any of these frogs because they are too young to determine. Fourth, we do not know if being kept in captivity for long periods of time may promote disease and pathogen infestation and we do not want to inadvertently introduce any foreign pathogens into natural systems. Fifth, these frogs have been hand fed in captivity and may have lost or diminished their ability to forage for food on their own. Therefore, these frogs should be reared and bred in captivity, and tested for disease and pathogens before considering putting them or their offspring back into the wild. Captive breeding will also enable us to provide a larger population base on which to experimentally build new populations either in City Creek, if it should become suitable at a later date, or elsewhere. Additionally, establishing new populations from egg masses or head-starting tadpoles has been shown to be affective in reintroducing similar species in California (Paul Johnson, pers. comm.). In order to preserve the full remaining genetic complement of the southern California MYLF and prevent genetic bottlenecks in reintroduced populations, establishing captive breeding programs for the other seven MYLF populations in southern California should be considered as a precautionary measure if we want this species to persist. Captive rearing, reintroduction, and translocation have been successful for *Rana onca* in Lake Mead National Recreational Area (Ross Haley, pers. comm.) and for *Rana aurora* in Pinnacles National Monument (Paul Johnson, pers. comm.). We recommend conducting reconnaissance surveys to find historical locations with current suitable conditions or locations where suitable conditions can be rendered through habitat restoration for future reintroductions before we lose this species.

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Table 1. Summary of habitat parameters recorded at 70 MYLF pools.

Date: **Observers:** **Start Time:** **End Time:**	
General Site Info.:	Site Name gradient average riparian width (m) average stream width (m)
Pool structure:	pool ID Latitude Longitude Elevation (m) breeding or general use (B or G) flow (category) pool length (m) pool width (m) pool average depth (m) pool maximum depth (m) pool substrate (% composition) bank substrate (% composition) % cover understory within 5 m buffer (0-10, 10-20 etc.) % cover overstory within 5 m buffer (0-10, 10-20 etc.) dominant terrestrial vegetation types (use %'s)
Refugia:	% banks with overhangs (1-10,10-20; perimeter only) average horizontal depth of overhangs (m) maximum horizontal depth of overhangs (m) % cover of downfall/sticks in pool (0-10, 10-20 etc.) % rock refugia (1-10, 10-20; excluding banks) avg. depth bank leaf litter (m) % cover leaf litter in H20 avg. depth H20 leaf litter (m) % cover of aquatic vegetation & type
Water chemistry:	water temperature (ºC) pH conductivity D.O. (% Sat.)
Oviposition sites:	what is egg mass attached to depth of egg mass below surface (m) depth of water at egg mass (m)
Frogs seen:	# adults # juveniles # metamorphs
Threats:	
Notes:	

Table 2. Summary of MYLF captures by age class, 2003. (Summary includes recaptured individuals across all visits).

Age Class	Bear Gulch	Dark Canyon	Devil's Canyon	East Fork City Creek	Fuller Mill Creek	Little Rock Creek	South Fork Big Rock Creek	Vincent Gulch	Total	# PIT tagged[1]
Adults	27	11	4	3	12	13	47	2	119	67
Juveniles	29	54	0	0	3	14	28	0	128	1
Metamorphs	5	0	0	32	0	0	10	0	47	0
2nd Year larvae	50	0	3	20	0	1	15	0	89	0
1st Year Larvae	26	18	0	7	51	22	176	11	311	0
Egg Masses	1	0	0	0	1	0	3	0	5	0

[1] Individuals under 50mm SVL are too small to receive a PIT tag.

Table 3. Summary of other species observed at study sites in 2003.

Site Name	Common Name	Scientific name	Sensitivity Listing[1]	Age Classes Observed	Latitude[2]	Longitude[2]
Andreas Canyon	California treefrog	*Hyla cadaverina*		adults, tadpoles	33.74925	116.58333
	two-striped garter snake	*Thamnophis hammondii*	CDFG:CSC, BLM Sensitive, FS Sensitive	juveniles	33.74820	116.58073
Bear Gulch	rainbow trout	*Oncorhynchus mykiss*	Exotic	adult		
	two-striped garter snake	*Thamnophis hammondii*	CDFG:CSC, BLM Sensitive, FS Sensitive	juvenile		
Deep Creek Hot Springs	black bullhead catfish	*Ictalurus melas*	Exotic	adults and juveniles		
	rainbow trout	*Oncorhynchus mykiss*	Exotic	adults		
Devils Canyon - SG	California mountain kingsnake	*Lampropeltis zonata*		adult		
	western rattlesnake	*Crotalus viridis*		adult		
East Branch Snow Creek	banded rock lizard	*Petrosaurus mearnsi*		juvenile		
	brown trout	*Salmo trutta*	Exotic	adults		
	California treefrog	*Hyla cadaverina*		adults, metamorphs, tadpoles	33.86482	116.68787
East Fork City Creek	brown trout	*Salmo trutta*	Exotic	adult		
	California mountain kingsnake	*Lampropeltis zonata*		adult	34.18582	117.17783
	California treefrog	*Hyla cadaverina*		adults, tadpoles	34.17182	117.18043
	common kingsnake	*Lampropeltis getula*		adult	34.16733	117.18128
	southern alligator lizard	*Elgaria multicarinata*		adult		
	Santa Ana speckled dace	*Rhinichthys osculus*	CDFG:CSC, FS Sensitive	adults		
	two-striped garter snake	*Thamnophis hammondii*	CDFG:CSC, BLM Sensitive, FS Sensitive	adult	34.18977	117.17483

[1] State of California, The Resources Agency, DEPARTMENT OF FISH AND GAME, Wildlife and Habitat Data Analysis Branch, California Natural Diversity Database, **SPECIAL ANIMALS (669 taxa),** July 2003.
[2] All GPS coordinates are presented in WGS 84.

Table 3. Summary of other species observed at study sites in 2003 (continued).

Site Name	Common Name	Scientific name	Sensitivity Listing[1]	Age Classes Observed	Latitude[2]	Longitude[2]
East Fork Snow Creek	brown trout	*Salmo trutta*	Exotic	adults		
	California treefrog	*Hyla cadaverina*		adults, juveniles, tadpoles	33.86048	116.69087
	common side-blotched lizard	*Uta stansburiana*		adults	33.85608	116.67352
	granite spiny lizard	*Sceloporus orcutti*		juvenile		
	southern alligator lizard	*Elgaria multicarinata*		adult	33.85602	116.67443
	two-striped garter snake	*Thamnophis hammondii*	CDFG:CSC, BLM Sensitive, FS Sensitive	adult	33.85667	116.67477
Falls Creek	banded rock lizard	*Petrosaurus mearnsi*		juvenile	33.85565	116.66802
	California treefrog	*Hyla cadaverina*		adults, juveniles	33.85990	116.66972
	granite spiny lizard	*Sceloporus orcutti*		juvenile	33.85453	116.66793
	southern alligator lizard	*Elgaria multicarinata*		adult	0.00000	0.00000
	western skink	*Eumeces skiltonianus*	CDFG:CSC, BLM Sensitive	adult	33.85000	116.66823
Hidden Lake	western toad	*Bufo boreas*		metamorphs	33.80020	116.64155
Little Rock Creek	rainbow trout	*Oncorhynchus mykiss*	Exotic	adult	34.36492	117.90113
	striped racer	*Masticophis lateralis`*		adult		
	two-striped garter snake	*Thamnophis hammondii*	CDFG:CSC, BLM Sensitive, FS Sensitive	adult		
	western rattlesnake	*Crotalus viridis*		adults, juvenile	34.36102	117.88020
	western skink	*Eumeces skiltonianus*	CDFG:CSC, BLM Sensitive	adult	34.36097	117.88018
Marion Creek			none observed			

[1] State of California, The Resources Agency, DEPARTMENT OF FISH AND GAME, Wildlife and Habitat Data Analysis Branch, California Natural Diversity Database, **SPECIAL ANIMALS (669 taxa),** July 2003.
[2] All GPS coordinates are presented in WGS 84.

Table 3. Summary of other species observed at study sites in 2003 (continued).

Site Name	Common Name	Scientific name	Sensitivity Listing[1]	Age Classes Observed	Latitude[2]	Longitude[2]
Morongo Lands						
• Burro flats Bog	bullfrog	*Rana catesbeiana*	Exotic	adult	33.99270	116.84375
	mosquitofish	*Gambusia affinis*	Exotic	adult	33.99270	116.84375
• Cattle Pond	bullfrog	*Rana catesbeiana*	Exotic	adult	33.99080	116.84250
	green sunfish	*Lepomis cyanellus*	Exotic	adult	33.99075	116.84248
	largemouth bass	*Micropterus salmoides*	Exotic	adult	33.99082	116.84248
	mosquitofish	*Gambusia affinis*	Exotic	adult	33.99067	116.84260
	rainbow trout	*Oncorhynchus mykiss*	Exotic	adult	33.99070	116.84263
	western toad	*Bufo boreas*		adult	33.99068	116.84268
• CSUN trench	western whiptail	*Aspidoscelis tigris*		juvenile	34.00430	116.86565
• Millard Canyon	Pacific treefrog	*Hyla regilla*		juvenile	33.98638	116.78683
Murray Canyon	California treefrog	*Hyla cadaverina*		adults, tadpoles	33.74025	116.58712
	banded rock lizard	*Petrosaurus mearnsi*		juvenile	33.73903	116.59912
	granite spiny lizard	*Sceloporus orcutti*		adult	33.73865	116.59888
	Pacific treefrog	*Hyla regilla*		adults, metamorphs, tadpoles	33.74063	116.58660
	two-striped garter snake	*Thamnophis hammondii*	CDFG:CSC, BLM Sensitive, FS Sensitive	juvenile	33.73789	116.60188
Palm Canyon	California treefrog	*Hyla cadaverina*		adults, tadpoles		
	common chuckwalla	*Sauromalus obesus*		adult		
	Pacific treefrog	*Hyla regilla*		tadpole		
	red spotted toad	*Bufo punctatus*		adult, metamorphs, tadpoles	33.71900	116.53412
	two-striped garter snake	*Thamnophis hammondii*	CDFG:CSC, BLM Sensitive, FS Sensitive	adult	33.73017	116.53707
	western shovel-nosed snake	*Chionactis occipitalis*		adult	33.73025	116.53698

[1] State of California, The Resources Agency, DEPARTMENT OF FISH AND GAME, Wildlife and Habitat Data Analysis Branch, California Natural Diversity Database, **SPECIAL ANIMALS (669 taxa),** July 2003.
[2]All GPS coordinates are presented in WGS 84.

Table 3. Summary of other species observed at study sites in 2003 (continued).

Site Name	Common Name	Scientific name	Sensitivity Listing[1]	Age Classes Observed	Latitude[2]	Longitude[2]
San Jacinto State Park	western toad	*Bufo boreas*		juveniles	33.80260	116.66390
South Fork Big Rock Creek	black bear	*Ursus americanus*		adult, juvenile		
	California mountain kingsnake	*Lampropeltis zonata*		adult	34.38005	117.83188
	rainbow trout	*Oncorhynchus mykiss*	Exotic	adults	34.37725	117.83025
	two-striped garter snake	*Thamnophis hammondii*	CDFG:CSC, BLM Sensitive, FS Sensitive	adults, juveniles	34.38320	117.82937
	western rattlesnake	*Crotalus viridis*		juvenile	34.37752	117.83087
	western toad	*Bufo boreas*		tadpoles		
Stone Creek	Pacific treefrog	*Hyla regilla*		tadpoles	33.77650	116.73338
Tahquitz Creek	brown trout	*Salmo trutta*	Exotic	adults	33.79945	116.59783
	California treefrog	*Hyla cadaverina*		tadpoles	33.79957	116.59507
	rosy boa	*Charina trivirgata*	BLM: Sensitive FS: Sensitive	adult	33.79995	116.59475
	speckled rattlesnake	*Crotalus mitchellii*		adult	33.80008	116.59463
	two-striped garter snake	*Thamnophis hammondii*	CDFG:CSC, BLM Sensitive, FS Sensitive	juvenile	33.79475	116.60457
Vincent Gulch	California mountain kingsnake	*Lampropeltis zonata*		adult	34.35140	117.72478
	gopher snake	*Pituophis catenifer*		adult	34.34493	117.71688
	rainbow trout	*Oncorhynchus mykiss*	Exotic	adults		
	western rattlesnake	*Crotalus viridis*		adults	34.35142	117.72480
Whitewater River	California treefrog	*Hyla cadaverina*		adults, tadpoles	33.99027	116.65912
	Pacific treefrog	*Hyla regilla*		tadpole	33.99043	116.65920
	red diamond rattlesnake	*Crotalus ruber*	DFG: CSC	adult	33.98543	116.65323
	red spotted toad	*Bufo punctatus*		adult, metamorphs, tadpoles	34.00320	116.66595
	two-striped garter snake	*Thamnophis hammondii*	CDFG:CSC, BLM Sensitive, FS Sensitive	adult	33.99012	116.65915
	western banded gecko	*Coleonyx variegatus*		adult	33.99677	116.66080

[1] State of California, The Resources Agency, DEPARTMENT OF FISH AND GAME, Wildlife and Habitat Data Analysis Branch, California Natural Diversity Database, **SPECIAL ANIMALS (669 taxa),** July 2003.
[2]All GPS coordinates are presented in WGS 84.

Table 3. Summary of other species observed at study sites in 2003 (continued).

Site Name	Common Name	Scientific name	Sensitivity Listing[1]	Age Classes Observed	Latitude[2]	Longitude[2]
Whitewater River (continued)	western toad	*Bufo boreas*		adults, tadpoles	34.00188	116.66473
	western whiptail	*Aspidoscelis tigris*		adult	33.99217	116.65887
	rainbow trout	*Oncorhynchus mykiss*	Exotic	adults		
Willow Creek	western toad	*Bufo boreas*		metamorph	33.79018	116.66897

[1] State of California, The Resources Agency, DEPARTMENT OF FISH AND GAME, Wildlife and Habitat Data Analysis Branch, California Natural Diversity Database, **SPECIAL ANIMALS (669 taxa),** July 2003.
[2]All GPS coordinates are presented in WGS 84.

Table 4. Detection Analyses for the MYLF.

Yearly Data

Year	**Detection Probability**
2000	1.000
2001	0.944
2002	0.880
2003	0.771

Summary Data (all four years)

	Detection Probability
Median	0.912
Mean	***0.899***
95% CI Upper	***1.055***
95% CI Lower	***0.743***
Std. Error	0.049
Standard Dev	0.098
Variance	0.010
C.V.	0.109

Table 5. Water quality parameters for a subset of MYLF survey sites. Values marked as ND were below detectable limits for the parameter in question. Values marked as "No Value" were unavailable for reporting at the time of publication.

LOCATION		East Branch of Snow Creek	South Fork of Big Rock Creek	Little Rock Creek	East Fork of Snow Creek	Vincent Gulch	Bear Gulch	East Fork of City Creek	Andreas Canyon	Murray Canyon	Deep Creek	Willow Creek	Fredalba Creek
	Date	9/9/2003	9/17/2003	9/16/2003	9/9/2003	9/10/2003	9/9/2003	10/7/2003	8/21/2003	9/18/2003	8/18/2003	9/16/2003	10/7/2003
BASIC	Dissolved Oxygen, mgl	11.4	7.5	5.7	5.8	8.6	9.1	6.2	6.8	8.2	3.9	6.1	7.2
	pH	7.8	8.3	7.8	7.7	8.1	8.2	8.0	8.2	7.9	7.5	7.6	7.9
	Specific Conductance	111	497	391	101	466	455	385	266	402	289	51	613
	Temperature, Celsius	16.5	13.9	16.0	18.0	17.6	14.6	16.5	21.0	20.0	22.1	10.0	17.2
MAJOR IONS	Calcium, mgl	12.7	61.4	72.5	13.1	75.6	61.9	50.9	41.9	59.8	26.5	4.2	44.1
	Magnesium, mgl	0.85	28.50	7.65	1.46	19.40	20.80	7.60	3.21	8.42	5.00	0.60	8.40
	Potassium, mgl	1.96	6.75	3.11	2.50	2.71	3.68	1.26	3.13	4.74	1.69	1.03	5.52
	Sodium, mgl	9.7	13.4	8.1	4.8	9.4	10.8	27.2	13.4	23.6	28.9	5.7	72.0
	Alkalinity	55	175	147	50	124	136	199	No Value	171	No Value	24	149
	Chloride, mgl	1.18	2.55	1.68	1.39	3.56	3.39	9.78	3.44	6.24	9.40	2.55	70.90
	Floride, mgl	0.2	0.2	0.2	0.2	0.2	0.4	1.7	0.2	0.2	2.3	0.2	0.6
	Silica, mgl	19.1	14.9	21.1	16.5	12.8	16.6	35.3	30.2	47.4	27.9	26.7	34.1
	Sulfate, mgl	1.4	51.6	6.7	0.4	59.2	64.0	13.3	17.5	43.0	5.0	0.2	31.7
	Residue, mgl	75	306	250	74	279	299	262	192	298	191	59	409
	Orthophosphate, mgl	0.02	0.02	0.02	0.02	0.02	0.02	0.006	0.18	0.02	0.01	0.02	1.33
	Phosphorus, mgl	0.010	0.014	0.003	0.002	0.004	0.004	0.016	0.011	0.007	0.048	0.027	1.360
	Iron, mgl	4	8	9	8	8	7	6	33	28	61	12	35
	Manganese, mgl	0.4	1.8	5.6	1.0	0.6	0.4	6.2	3.8	3.0	112.0	0.9	219.0
NUTRIENTS	Ammonia, mgl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.19
	Nitrite + Nitrate, mgl	ND	ND	ND	ND	ND	ND	0.14	ND	ND	ND	ND	9.7
	Nitrite, mgl	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.154
	Organic Carbon, mgl	0.5	1.4	1.8	1.0	0.6	0.9	1.7	2.4	3.2	3.5	3.1	3.0

Table 6. 2003 MYLF population estimates.

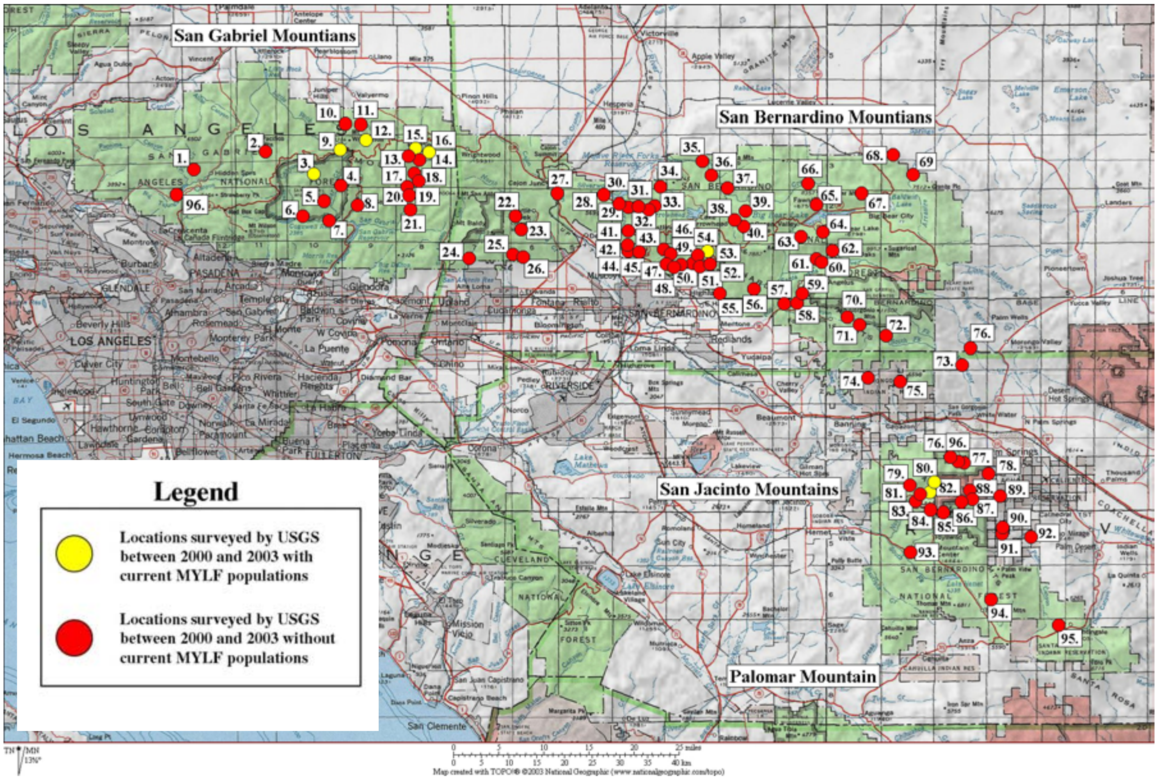
	Trapping Period (capture, recapture, new)										
Site	**1**	**2**	**3**	**4**	**5**	**6**	**# of samples**	**Method**	**Pop. Size**	**95% lower**	**95% upper**
Bear Gulch 2001-03	21,0,21	14,8,6	17,6,11				3	Schnabel	**54**	33	93
[1] Bear Gulch 2003	10,0,10	6,0,6	2,1,1				3	Schnabel	**92**	17	1804
[2] Dark Canyon 2003		sample size is too small to estimate									
Devil's Canyon 2002-03	3,0,3	5,2,3	4,0,4				3	Schnabel	**20**	6	110
[2] Devil's Canyon 2003		sample size is too small to estimate									
East Fork City Creek 2002-03	11,0,11	18,3,15	2,2,0				3	Schnabel	**50**	22	127
[3] East Fork City Creek 2003		sample size is too small to estimate									
Fuller Mill Creek 2002-03	3,0,3	6,1,5					2	Peterson with replacement	**11**	6	95
Fuller Mill Creek 2002-03	3,0,3	6,1,5					2	Peterson w/o replacement	**13**	6	119
Fuller Mill Creek 2003	4,0,4	2,1,1	2,1,1				3	Schnabel	**9**	3	51
Little Rock Creek 2001-03	5,0,5	8,5,3	6,5,1				3	Schnabel	**9**	5	17
Little Rock Creek 2003	1,0,1	1,0,1	2,1,1	3,0,3	3,3,0	1,1,0	6	Schnabel	**8**	3	19
South Fork Big Rock Creek 2000-03	4,0,4	2,0,2	8,3,5	8,3,5	9,5,4	6,4,2	6	Schnabel	**27**	17	50
South Fork Big Rock Creek 2003	1,0,1	4,0,4	22,2,20	37,12,25			4	Schnabel	**74**	45	128
[4] Vincent Gulch 2001-03		sample size is too small to estimate						Schnabel			
[4] Vincent Gulch 2003		sample size is too small to estimate						Schnabel			
Total 2003									**183**		

[1] Large confidence interval indicates this estimate is not very accurate. Upper 95% number is not possible

[2] Only a single visit was made during this time period. Therefore estimates could not be made.

[3] All but 2 frogs captured at East Fork City Creek in 2003 were metamorphs and therefore too small to be PIT tagged.

[4] In 2001 only 4 adult frogs were found during 2 of 3 surveys. In 2002 only 2 adult frogs were found during 1 of 3 surveys. In 2003 only 1 adult frog was found during 1 of 3 surveys.



Name	Site Name	Name	Site Name	Name	Site Name	Name	Site Name
1	Fall Creek (San Gabriel Mountains)	25	Day Canyon	49	Sand Canyon	73	Whitewater River
2	Middle Fork Alder Creek	26	Etiwanda Creek	50	City Creek Watershed	74	Burro Flats Bog
3	Devil's Canyon	27	Cajon Canyon	51	City Creek	75	Millard Canyon
4	Bear Creek	28	West Fork Mojave River	52	Little Mill Creek	76	Mission Creek
5	West Fork Bear Creek	29	Sawpit Creek	53	West Fork of City Creek	77	Falls Creek (San Jacinto Mountains)
6	Chileno Canyon	30	Burnt Mill Canyon	54	East Fork City Creek	78	Chino Canyon
7	West Fork San Gabriel River	31	Seeley Creek	55	Plunge Creek	79	Hall Creek
8	North Fork San Gabriel River	32	Houston Creek	56	Warm Springs Canyon	80	Fuller Mill Creek-Pine Wood
9	Little Rock Creek	33	Miller Canyon	57	Green Canyon	81	Lower Fuller Mill Creek
10	Punchbowl Canyon	34	Grass Valley	58	Mountain Home Creek	82	Dark Canyon
11	Holcomb Canyon	35	Deep Creek	59	Glen Martin Creek	83	San Jacinto River
12	South Fork Big Rock Creek	36	Deep Creek	60	Santa Ana River	84	Stone Creek
13	Mine Gulch	37	Deep Creek	61	Mile Creek	85	Marion Creek
14	Vincent Gulch	38	Deep Creek	62	Hamilton Creek	86	Willow Creek
15	Bear Gulch	39	Crab Creek	63	Siberia Creek	87	Hidden Lake
16	Prairie Fork	40	Green Valley Creek	64	Metcalf Creek	88	Round Valley
17	Alder Gulch	41	East Fork Devil Canyon	65	Grout Creek	89	Tahquitz Canyon
18	Fish Fork	42	Ben Canyon	66	Holcomb Creek	90	Andreas Canyon
19	Iron Fork	43	Badger Canyon	67	Caribou Creek	91	Murray Canyon
20	East Fork San Gabriel	44	Sycamore Canyon	68	Blackhawk Canyon	92	Palm Canyon
21	Allison Gulch	45	Twin Creek	69	Arrastre Creek	93	Dry Creek
22	Middle Fork Lytle Creek	46	Strawberry Creek	70	Falls Creek (San Bernardino Mts.)	94	Pipe Creek
23	South Fork Lytle Creek	47	Borea Canyon	71	Mill Creek	95	Omstott Creek
24	Cucamonga Creek	48	Little Sand Canyon	72	South Fork-Whitewater	96	Big Tujunga Canyon

Figure 1. Overview of USGS MYLF surveys 2000-2003.

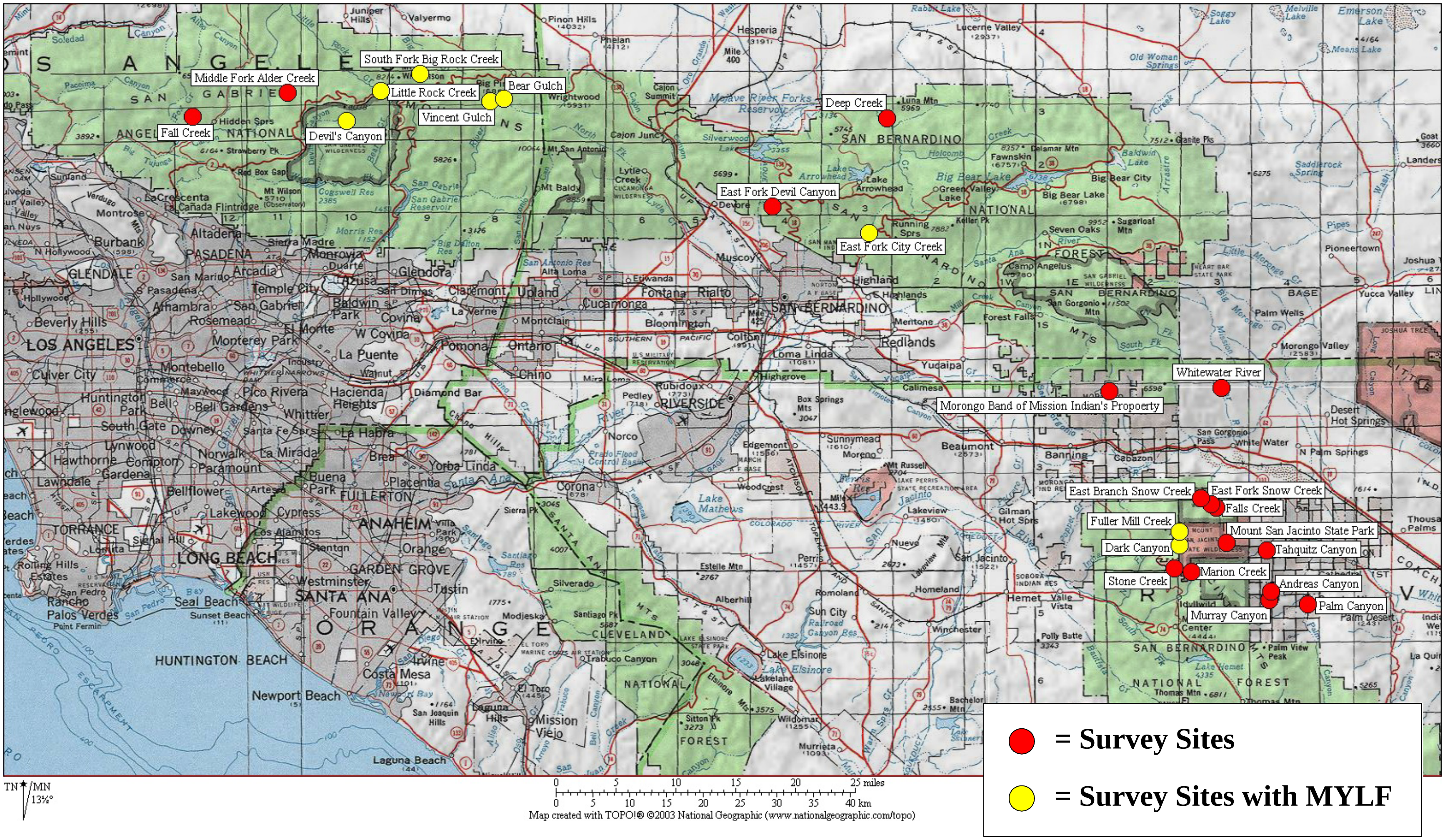


Figure 2. 2003 MYLF survey locations.

An average of 35 fish (range = 0-89) were counted throughout the fish reach during 6 time constraint surveys in 2003.

Fish were not found in the frog reach during any of the 6 time constraint surveys in 2003.

92 fish removed throughout the treatment reach. After removal, an average of 1 fish (range = 0-2) was counted during 6 time constraint surveys in 2003.

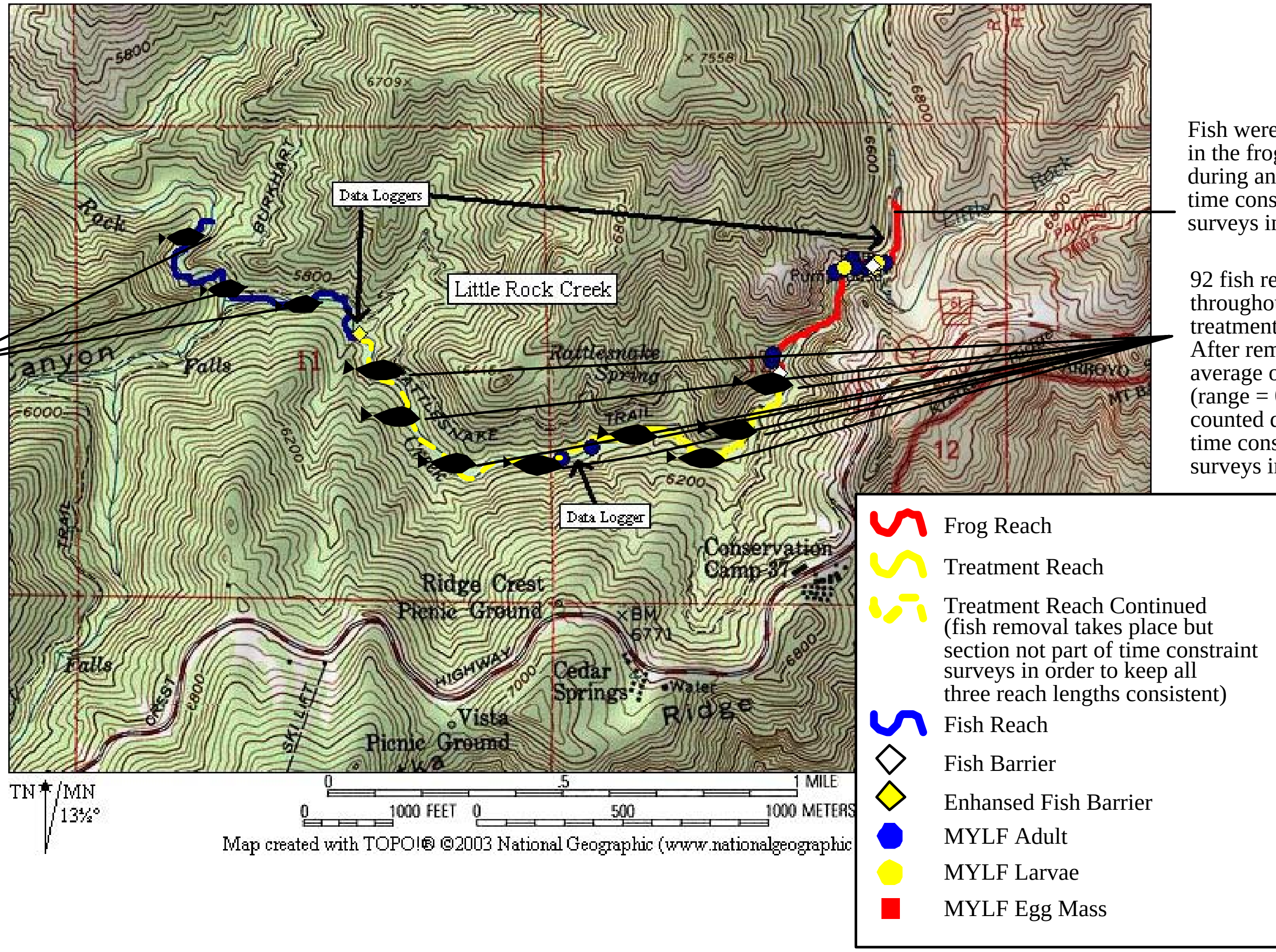


Figure 3. 2003 Little Rock Creek surveys including fish and frog locations.

Figure 3a. Enhanced fish barrier at Little Rock Creek. (photo by Bill Brown, USFS)

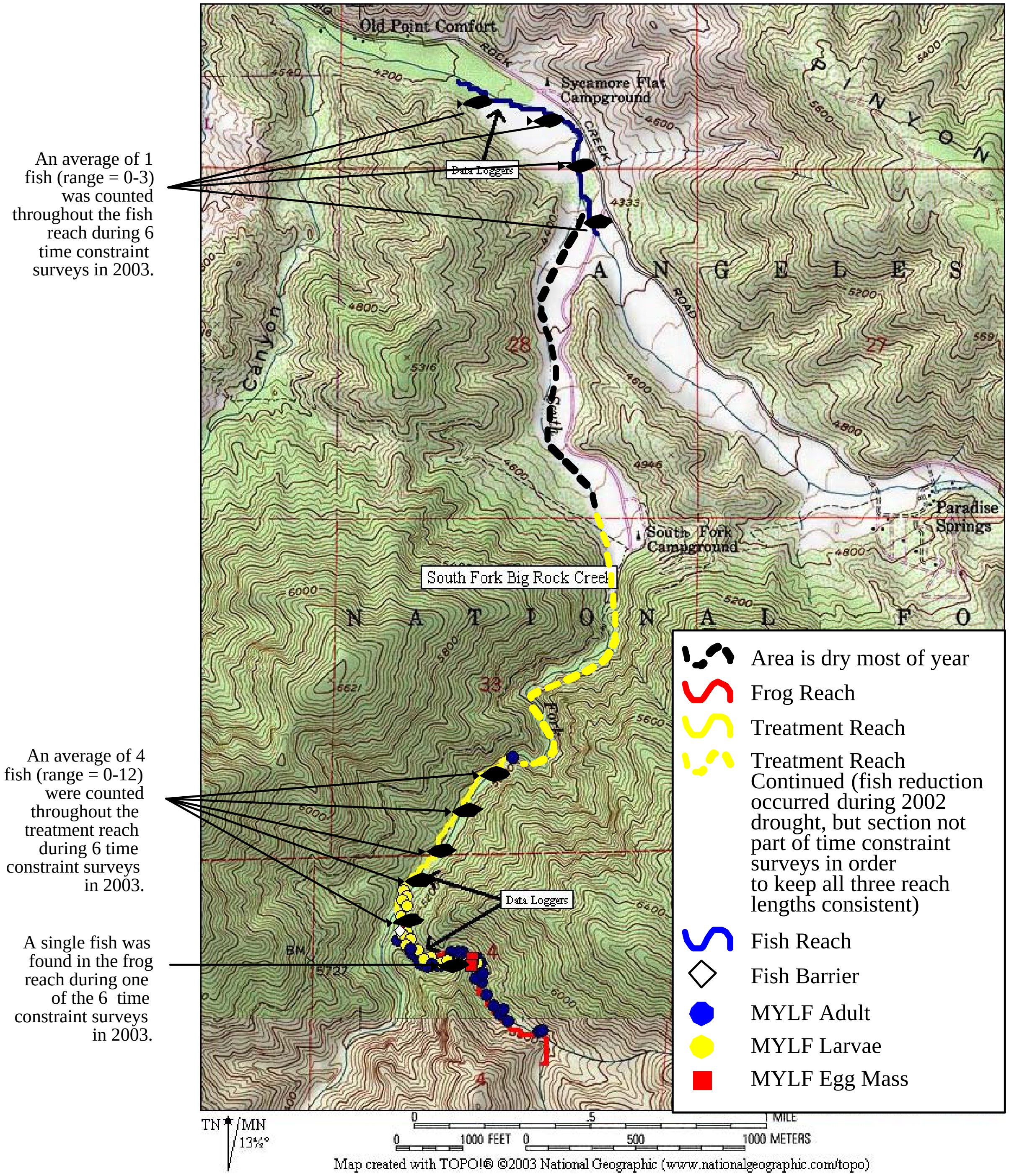


Figure 4. 2003 South Fork Big Rock Creek surveys including fish and frog locations.

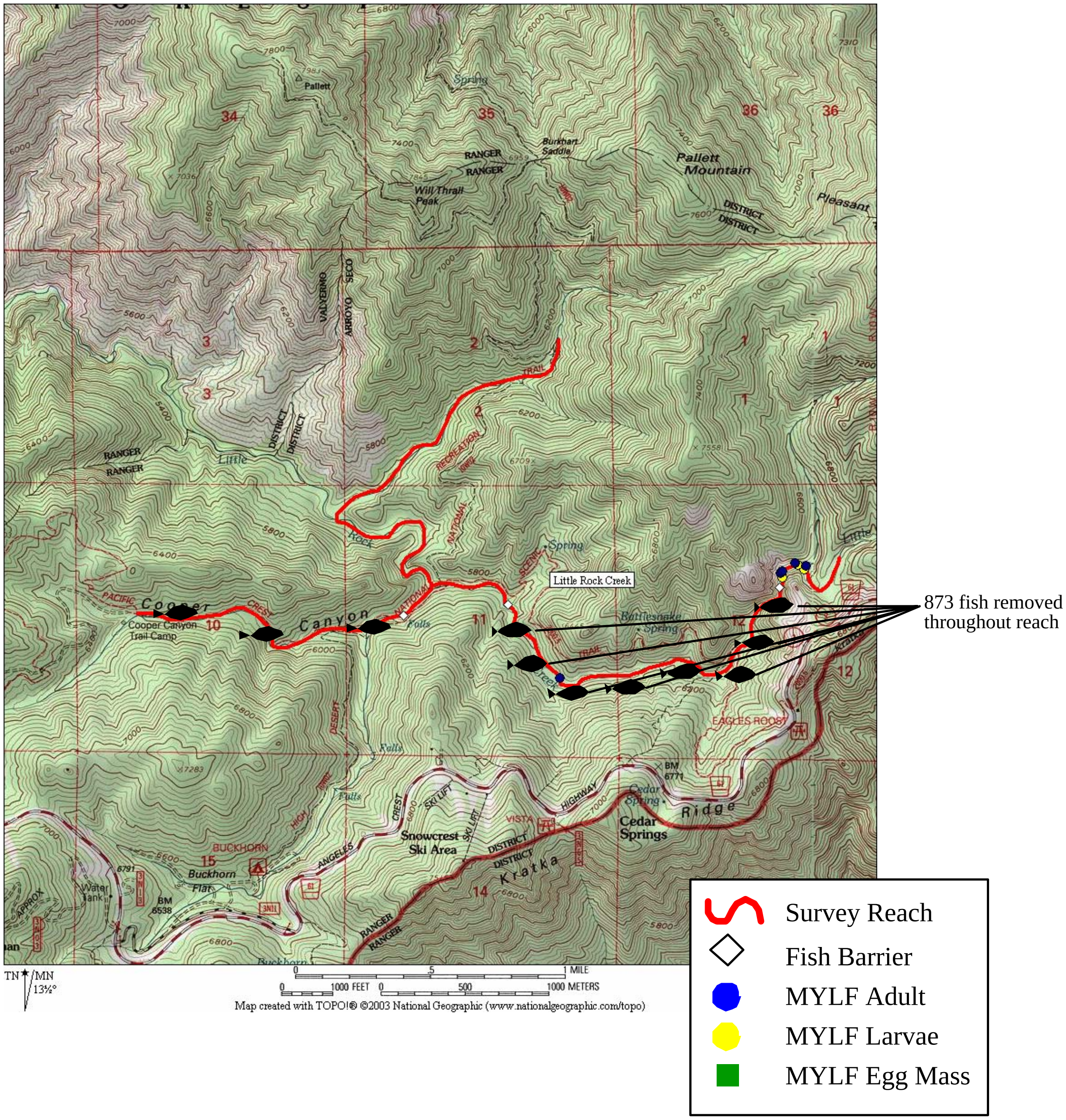


Figure 5. 2002 Little Rock Creek fish and frog locations. The area where fish removal took place (treatment reach) consisted of 29 pools, several of which were still connected by shallow (< 10cm) flowing water at the time of the drought. Fish were not found above the treatment reach and were present but not counted below the treatment reach in 2002.

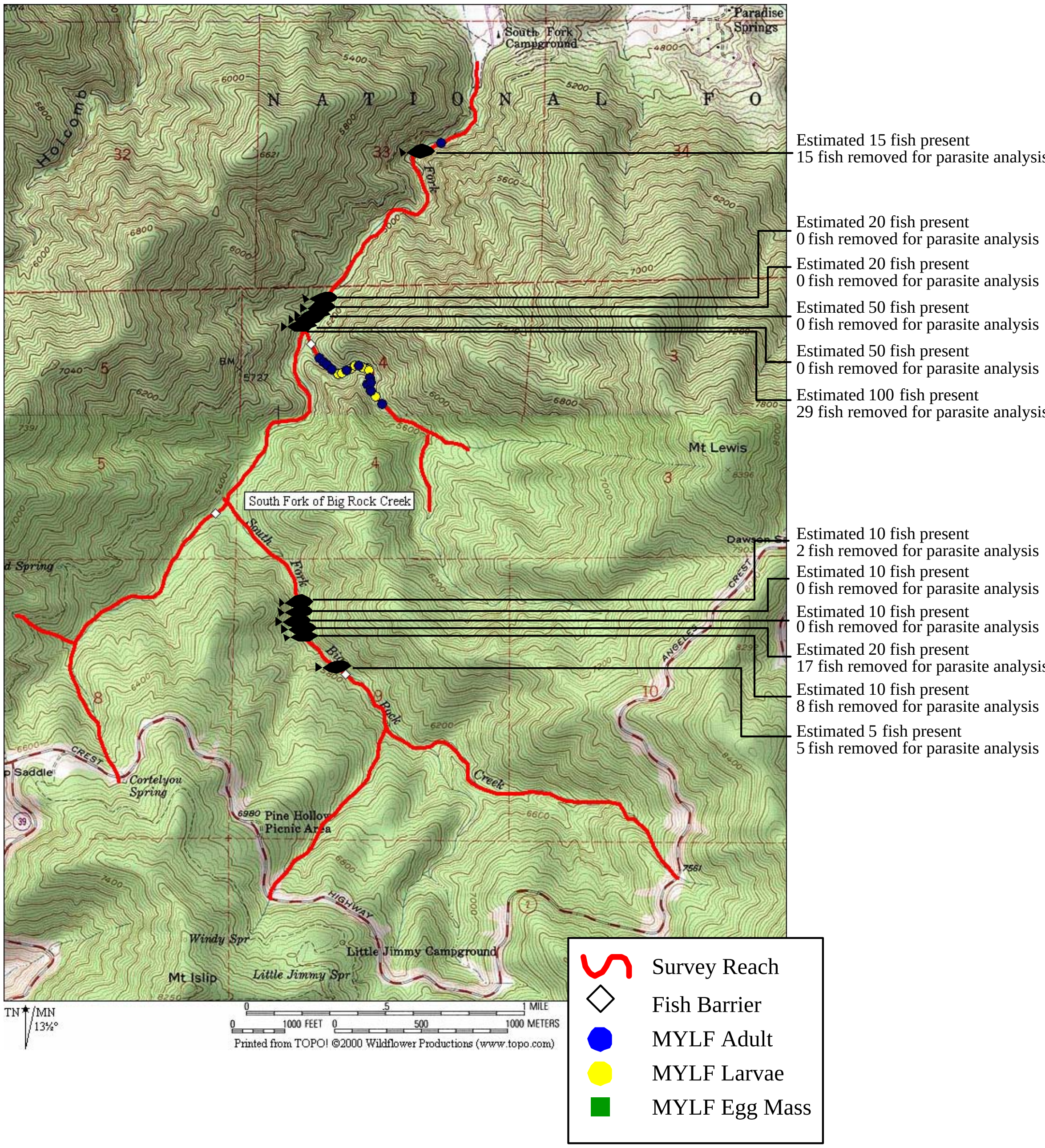


Figure 6. 2002 South Fork of Big Rock Creek fish and frog locations. All areas surveyed (in red) between fish and frog symbols on map were dry in summer 2002. Animals were located in small pools that remained during this time.

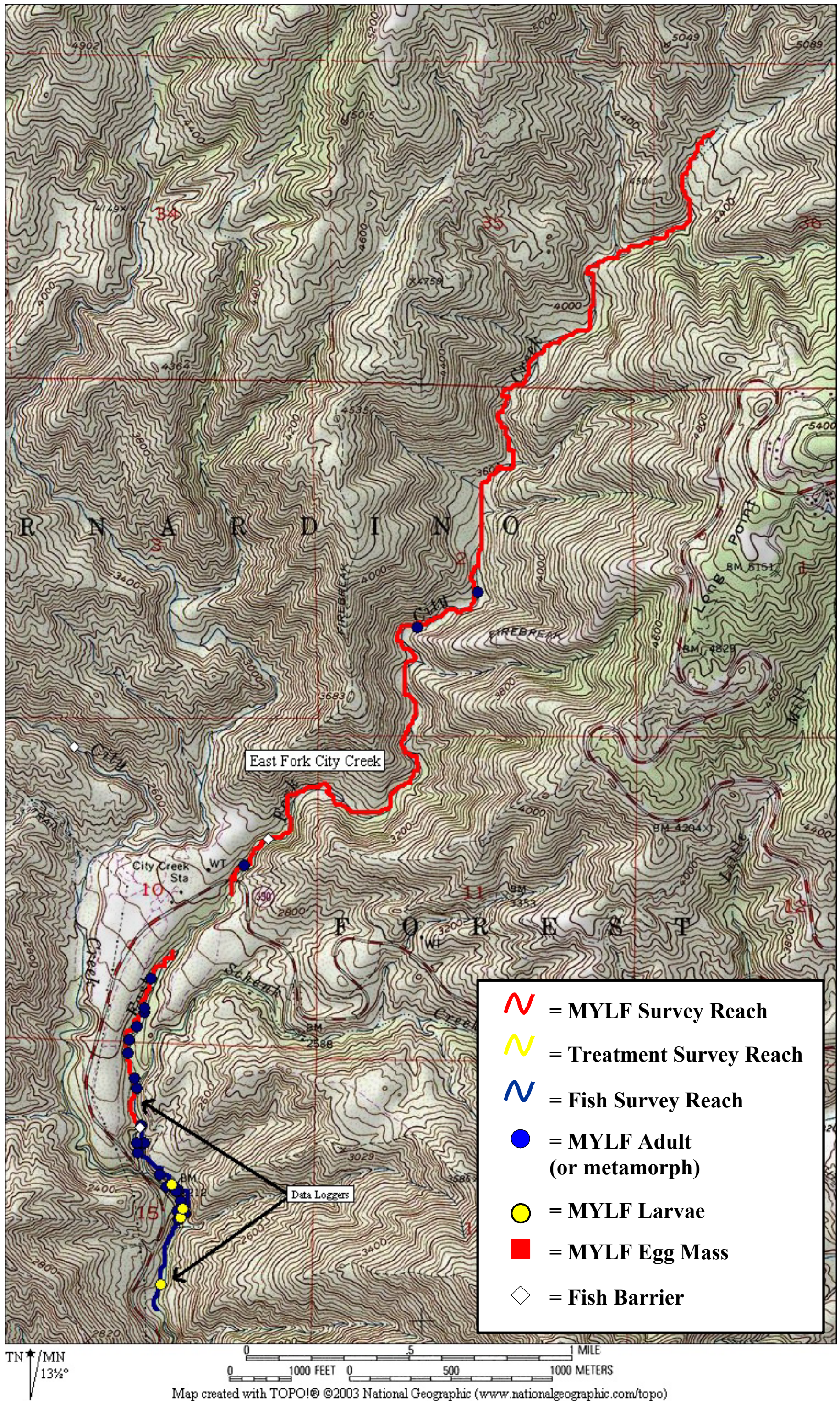


Figure 7. 2003 East Fork City Creek survey reaches.

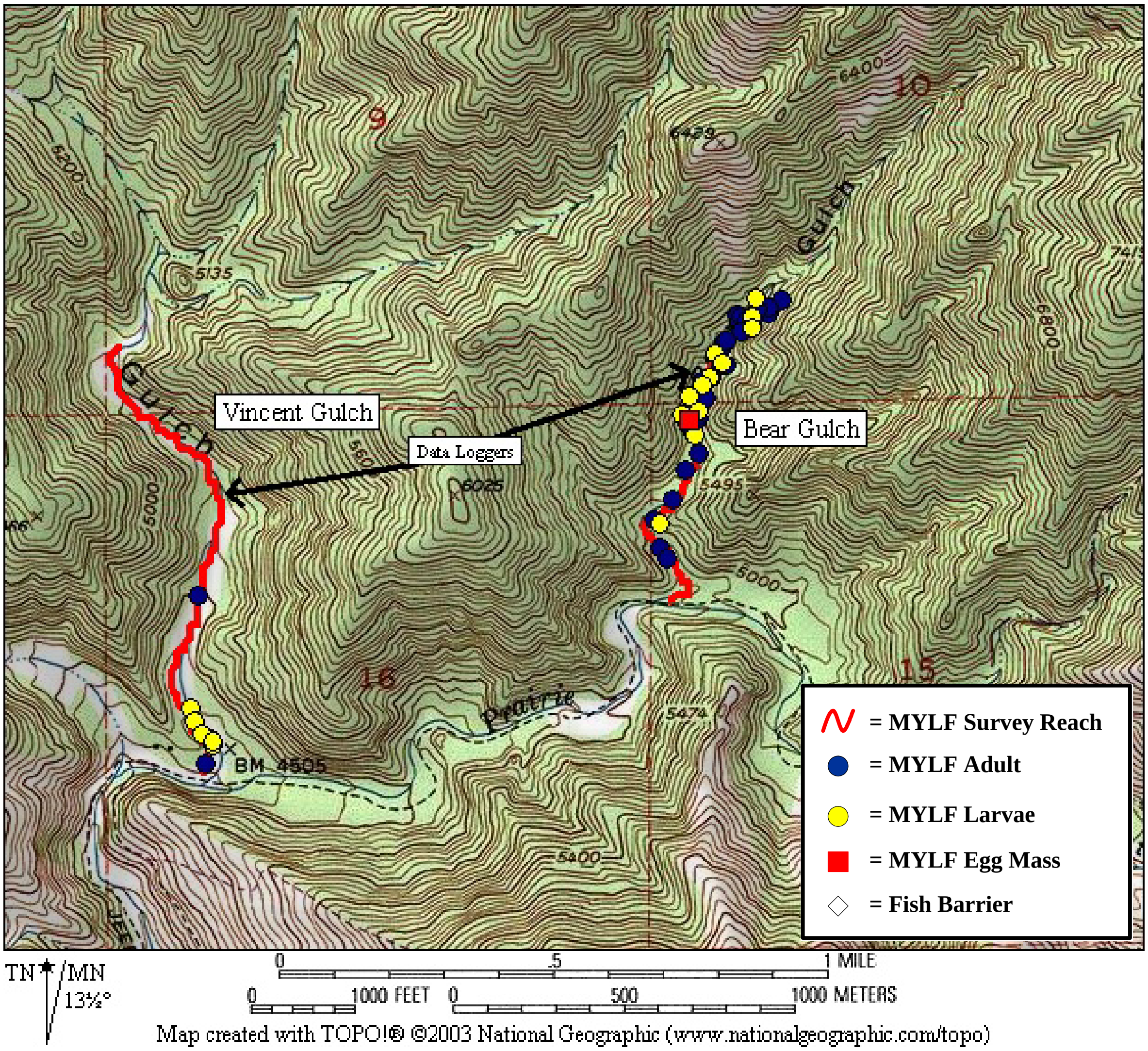


Figure 8. 2003 Bear Gulch and Vincent Gulch survey reaches.

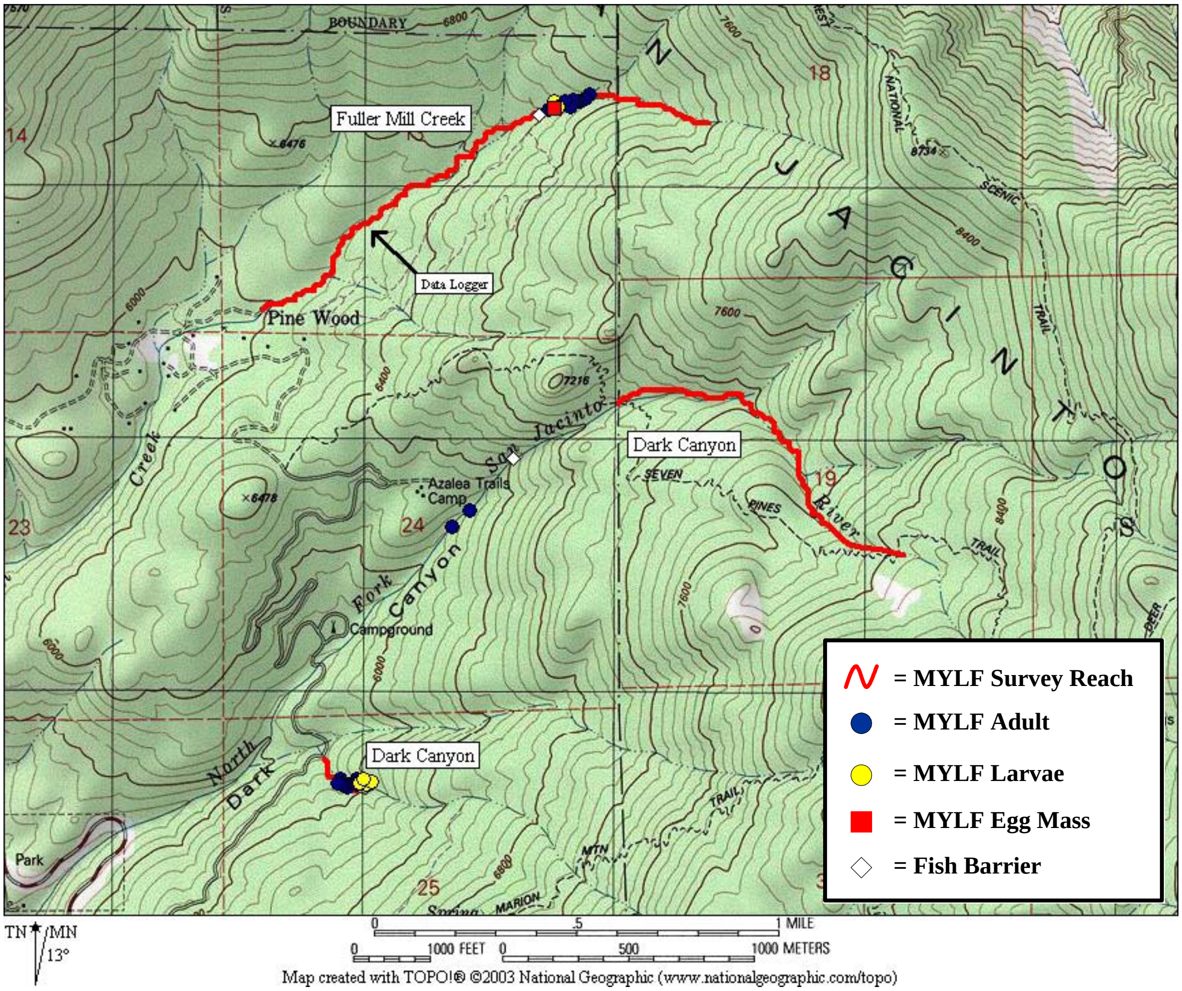


Figure 9. 2003 Dark Canyon and Fuller Mill Creek survey reaches.

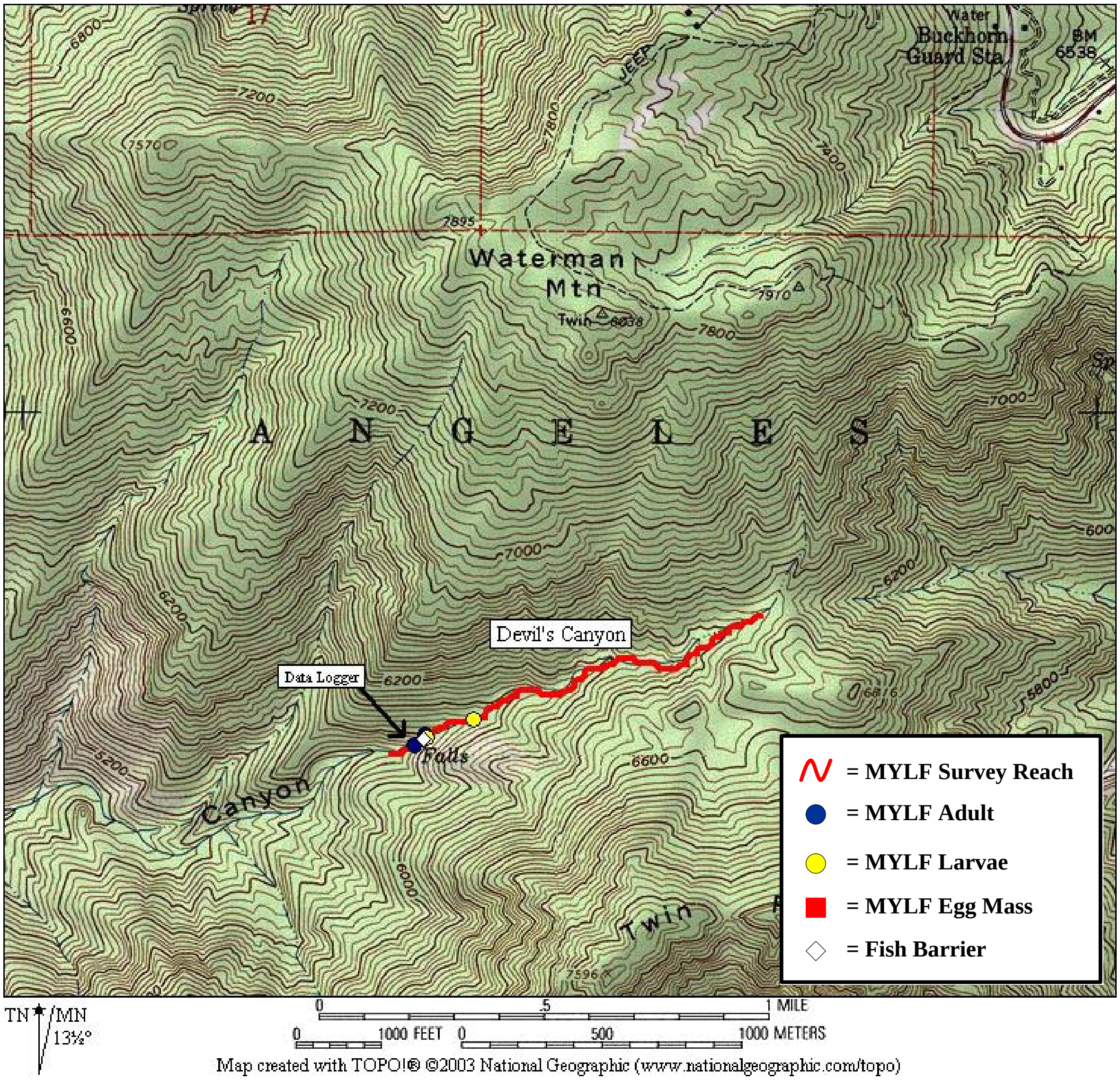


Figure 10. 2003 Devil's Canyon survey reach.

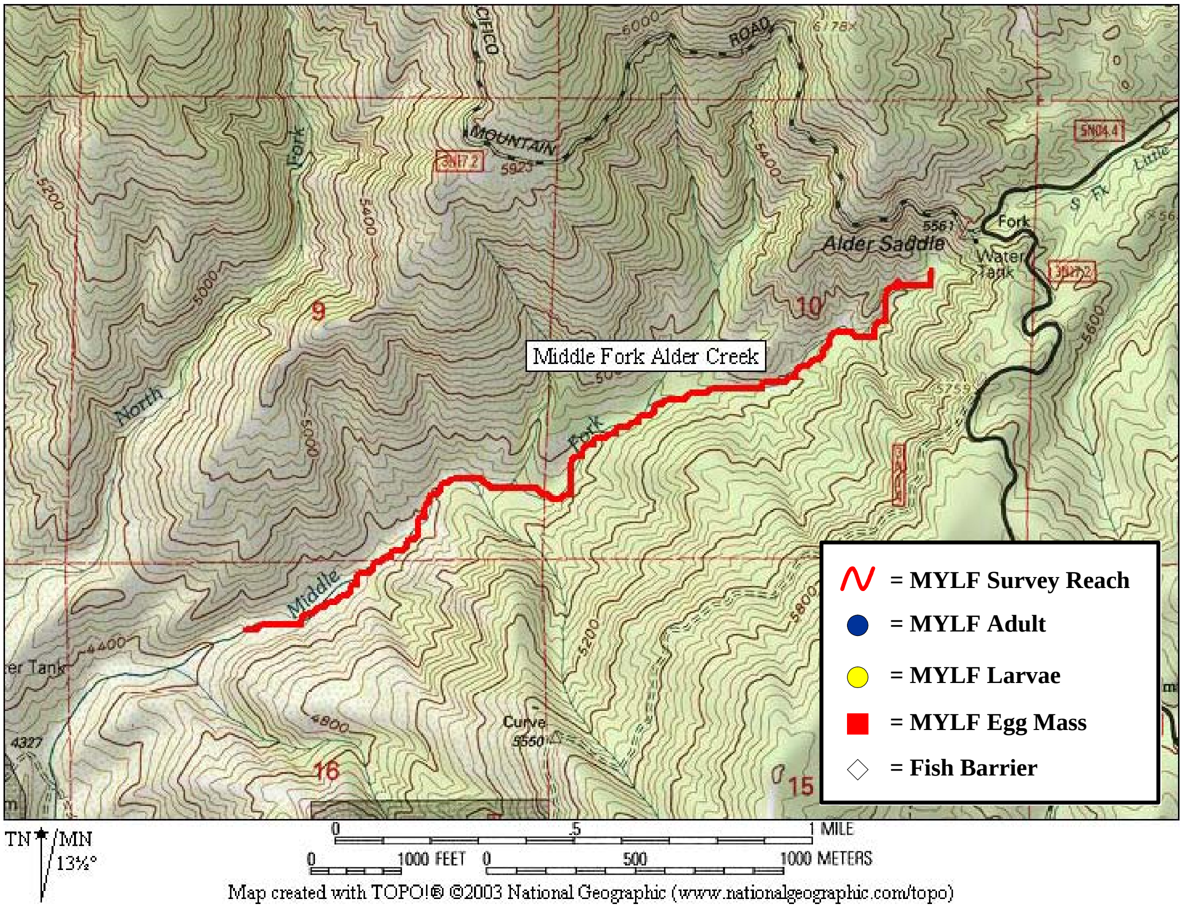


Figure 11. 2003 Alder Creek survey area.

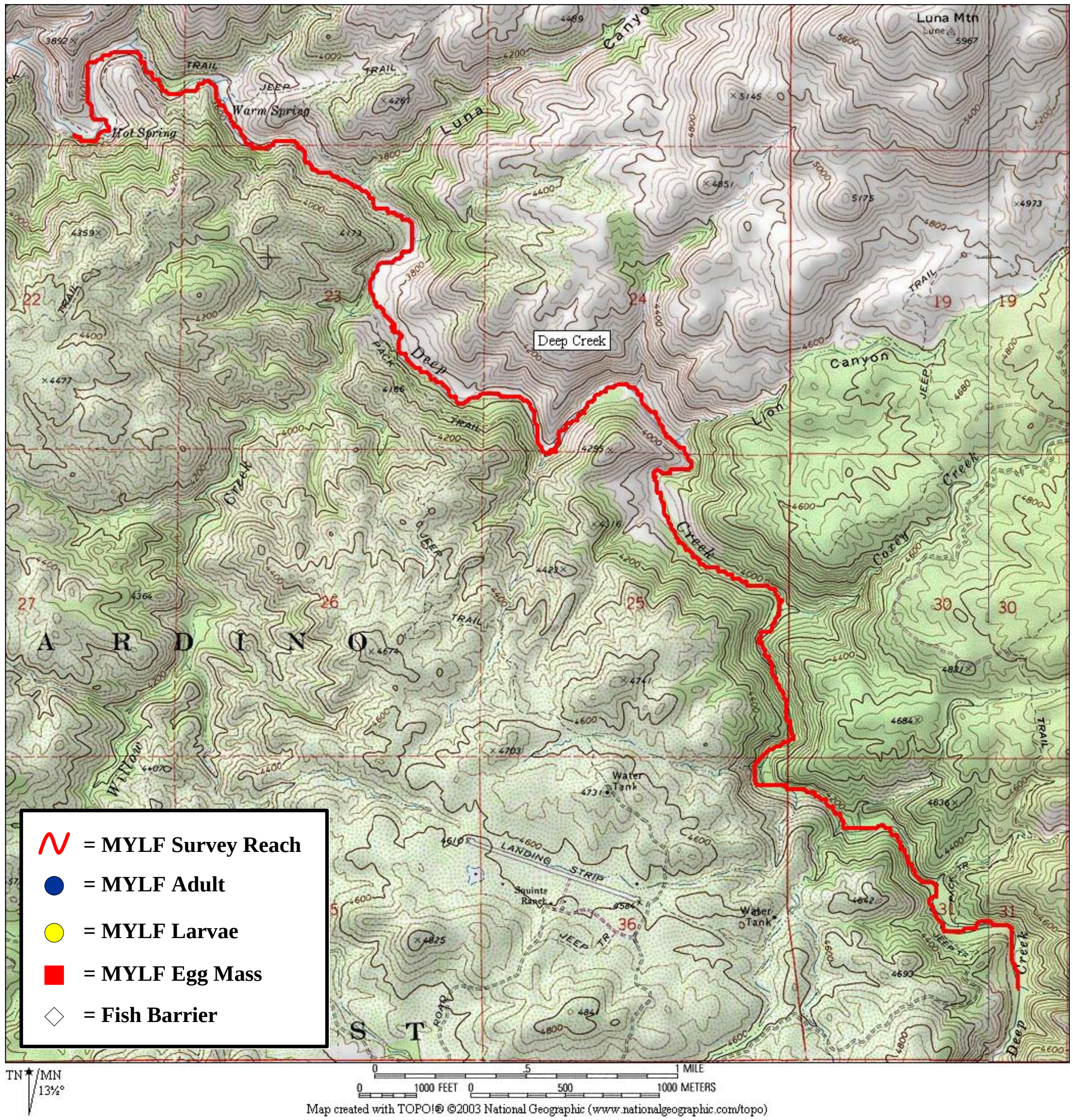


Figure 12. 2003 Deep Creek survey reach.

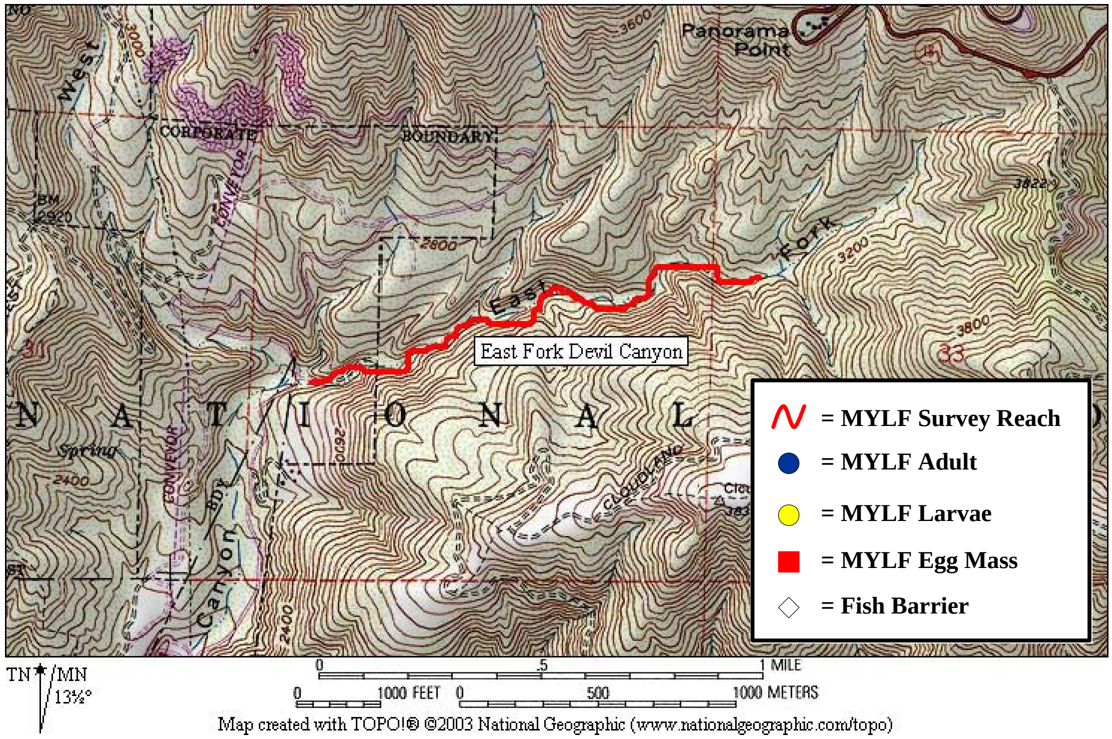


Figure 13. 2003 East Fork Devil's Canyon survey reach.

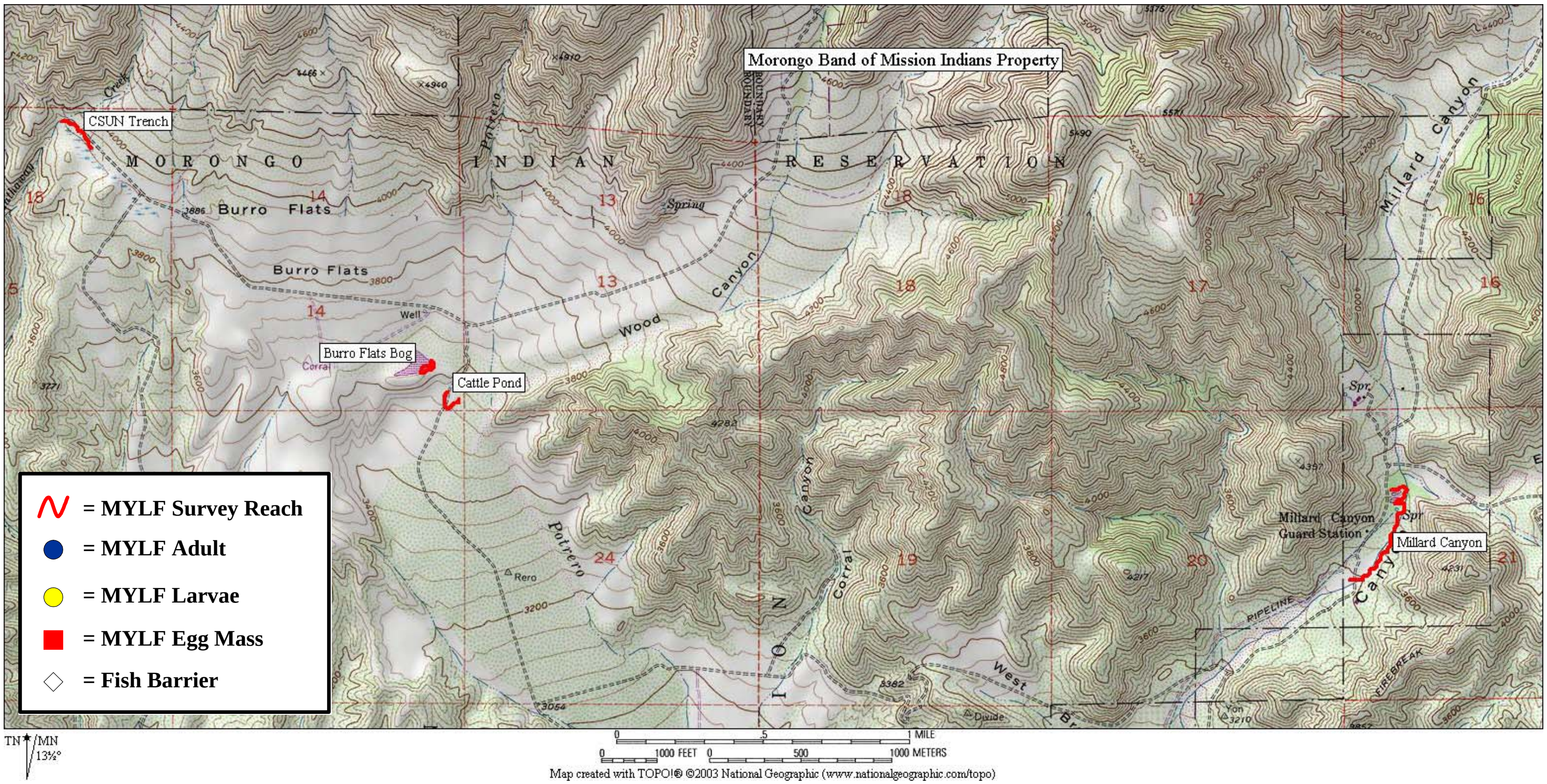


Figure 14. 2003 Morongo Band of Mission Indians survey areas.

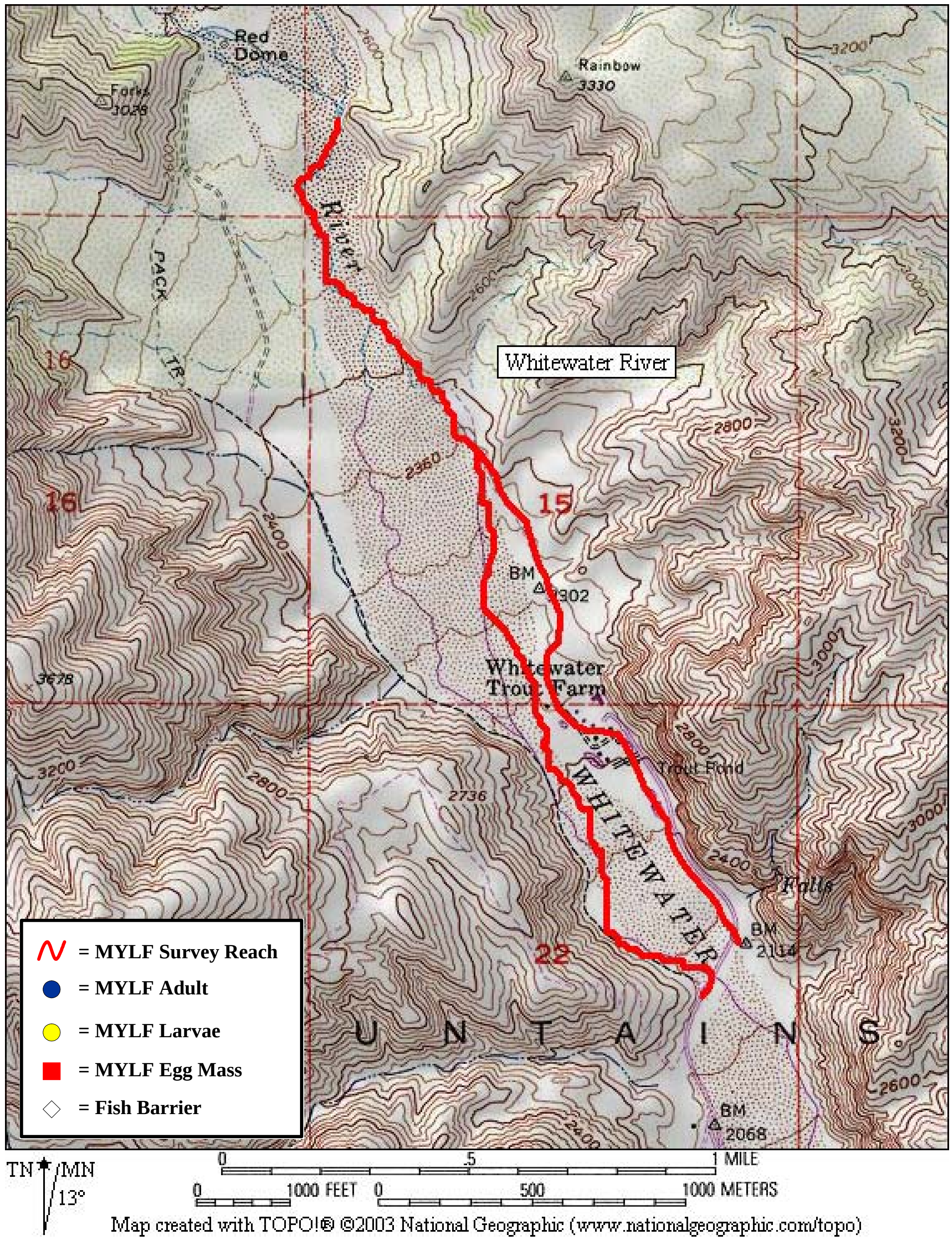


Figure 15. 2003 Whitewater River survey reaches.

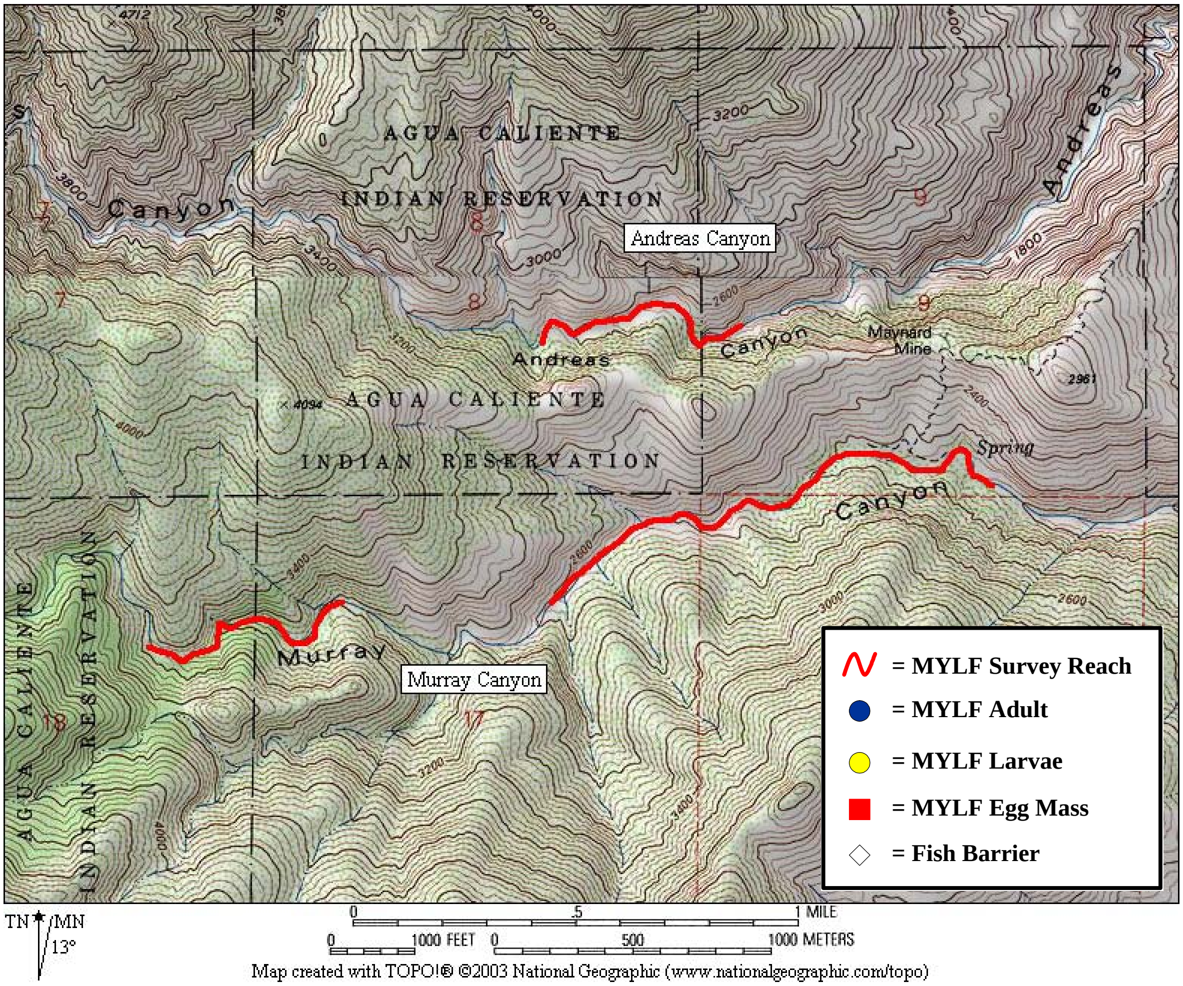


Figure 16. 2003 Andreas Canyon and Murray Canyon survey reaches.

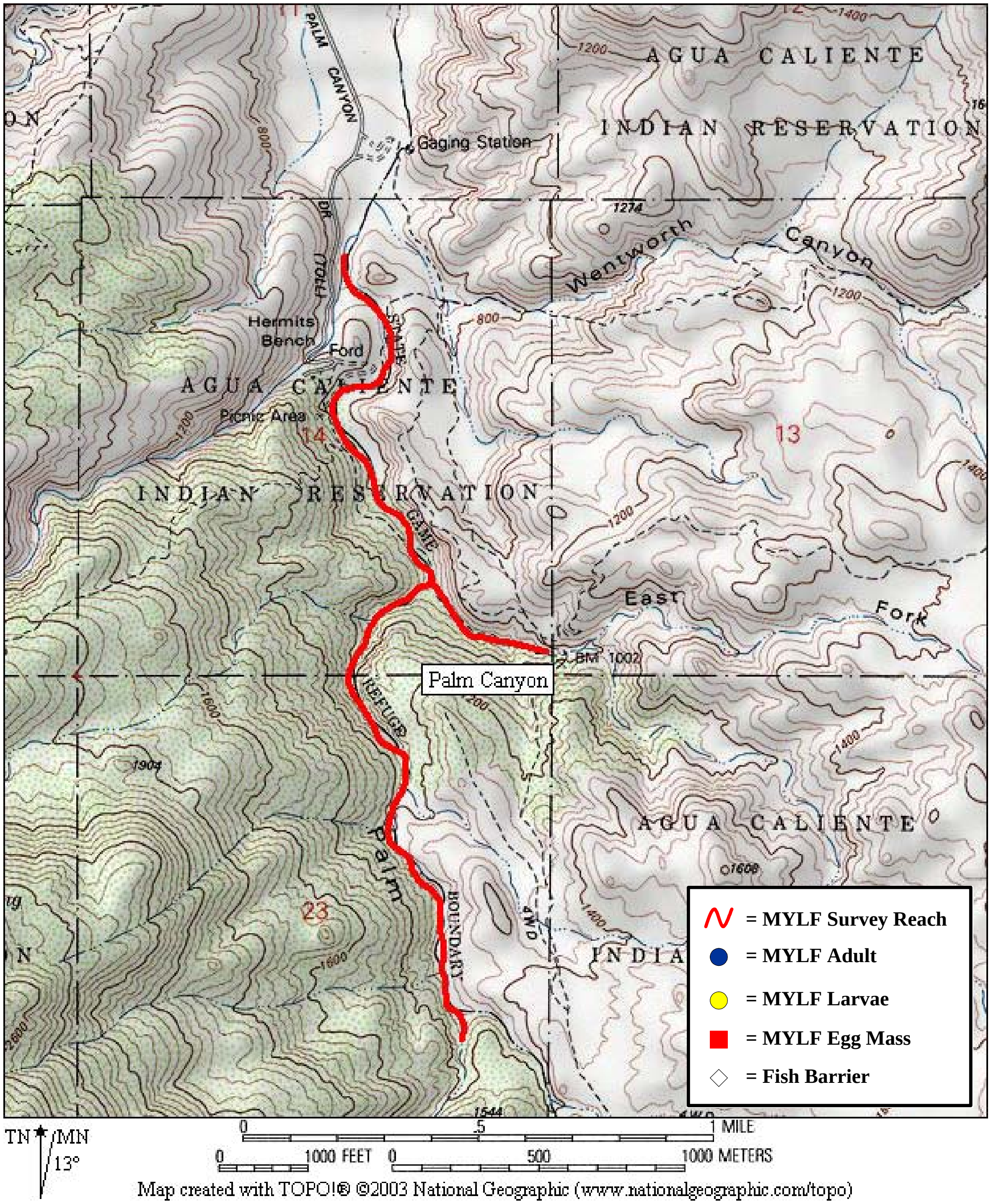


Figure 17. 2003 Palm Canyon survey reach.

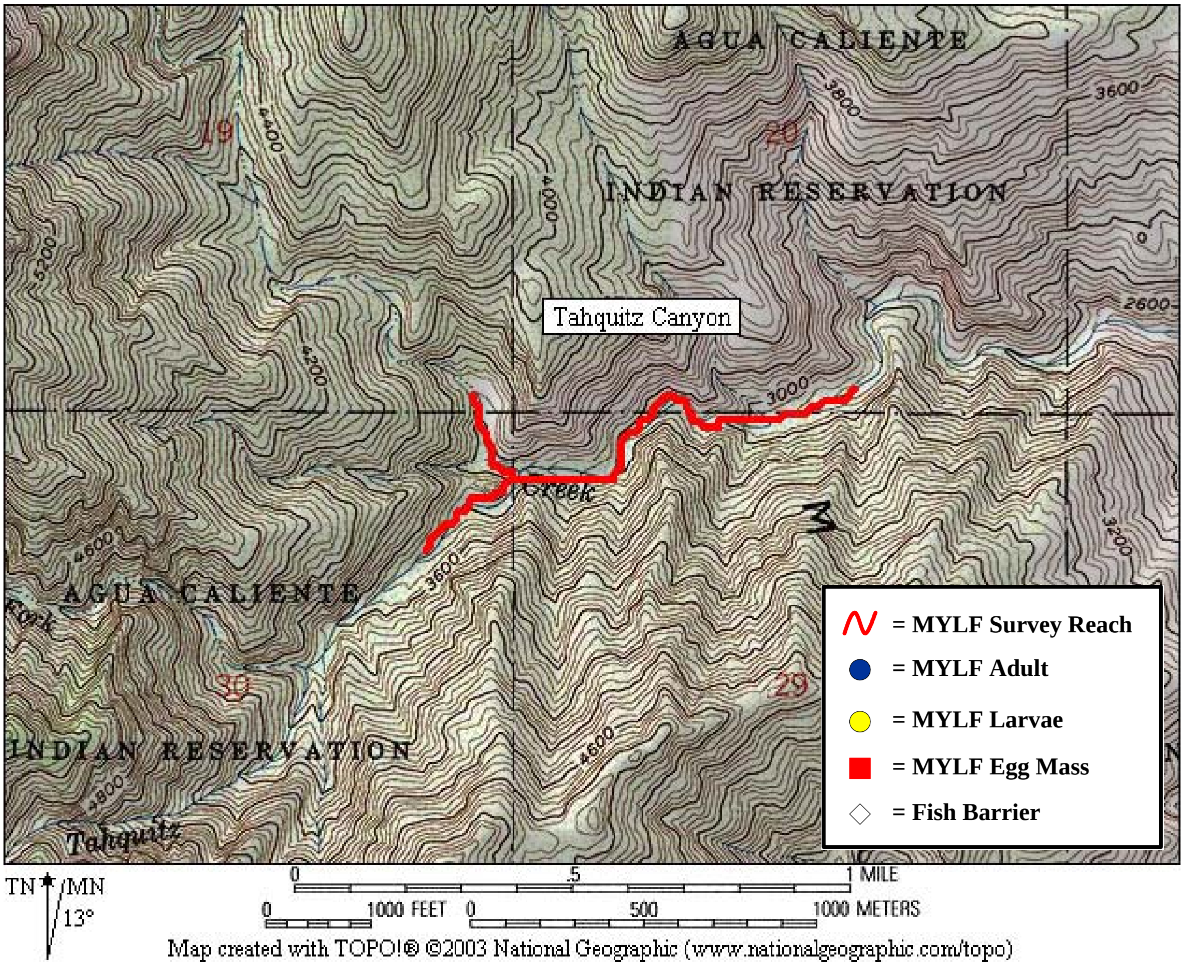


Figure 18. 2003 Tahquitz Canyon survey reach.

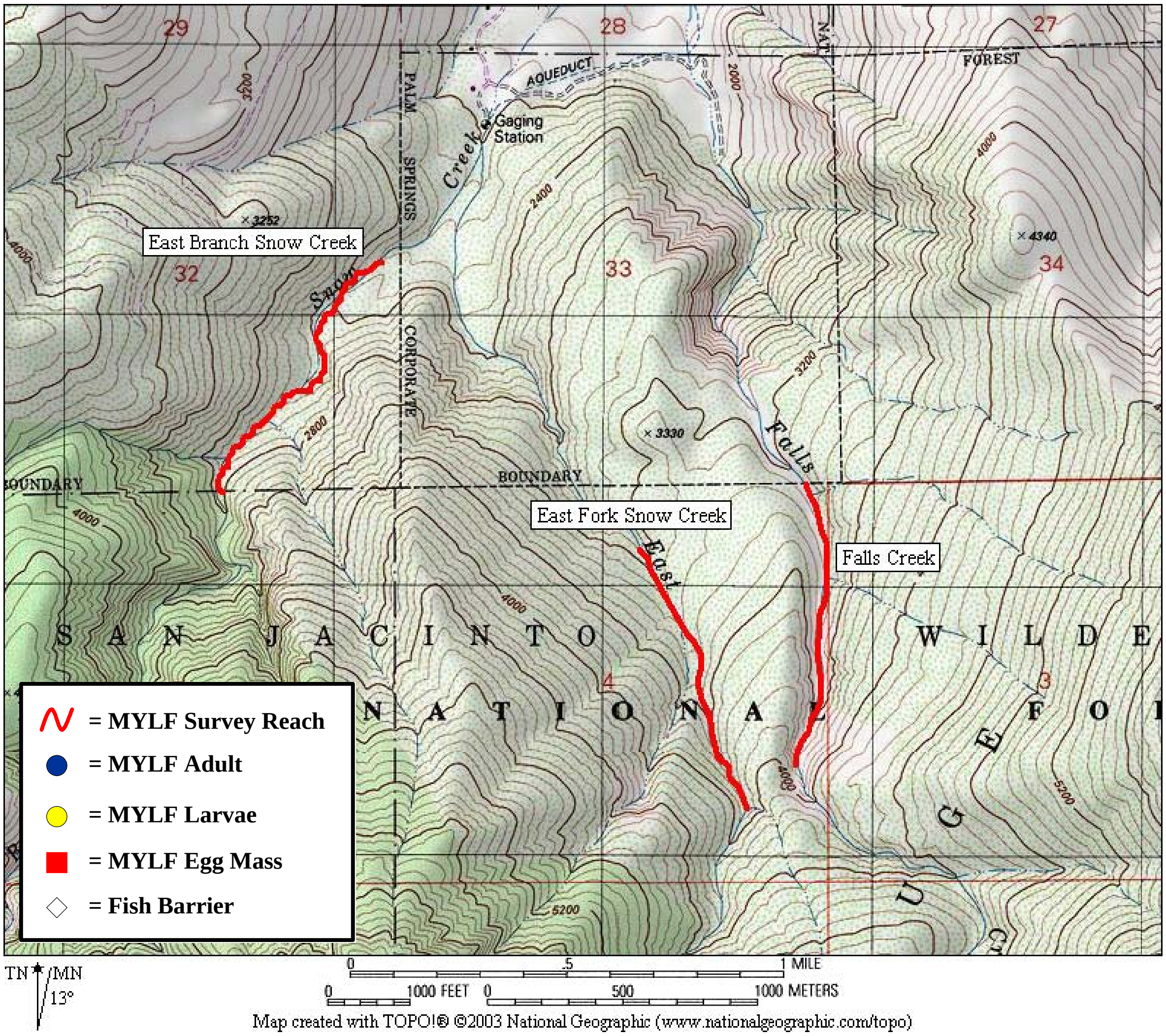


Figure 19. 2003 East Branch Snow Creek, East Fork Snow Creek, and Falls Creek survey reaches.

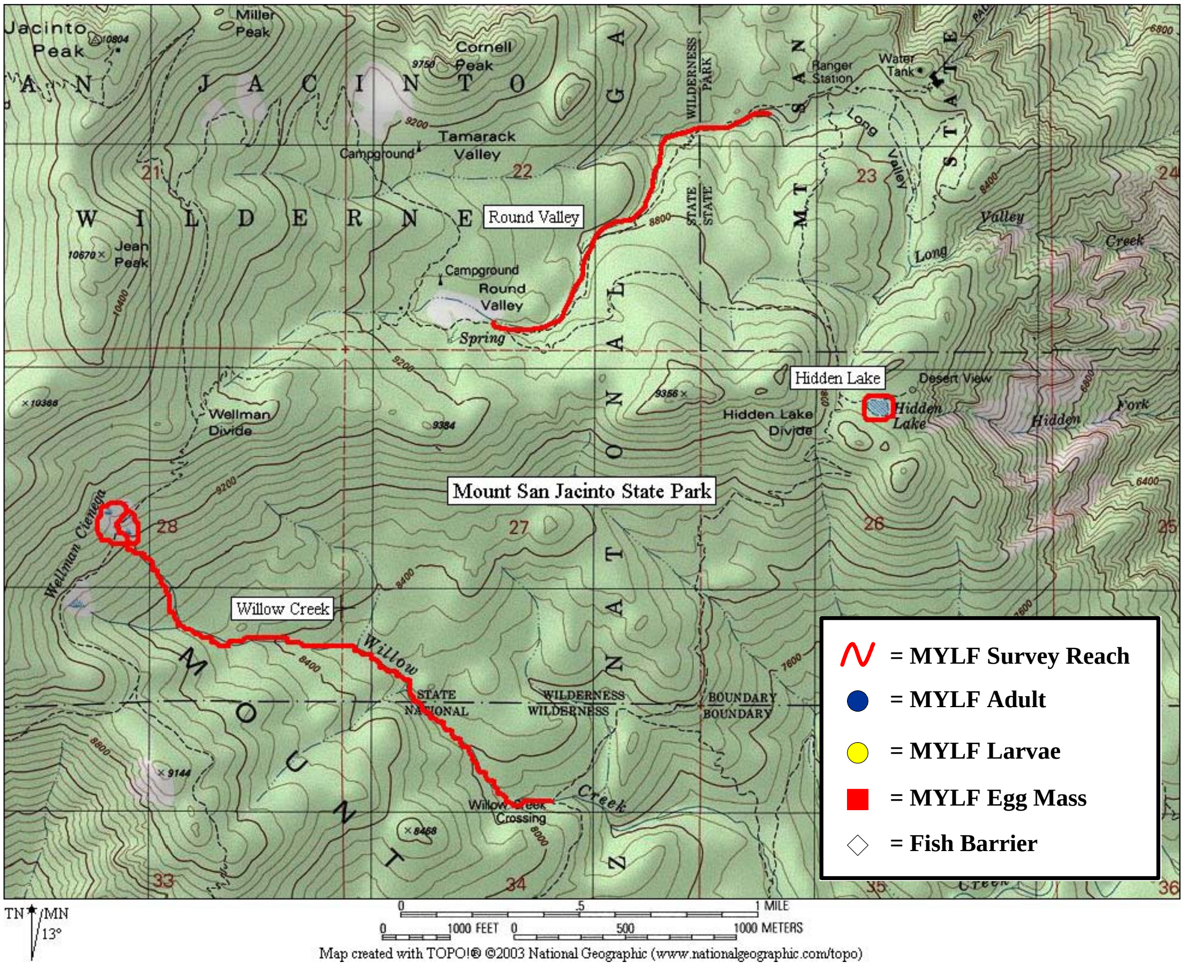


Figure 20. 2003 Mount San Jacinto State Park survey reaches.

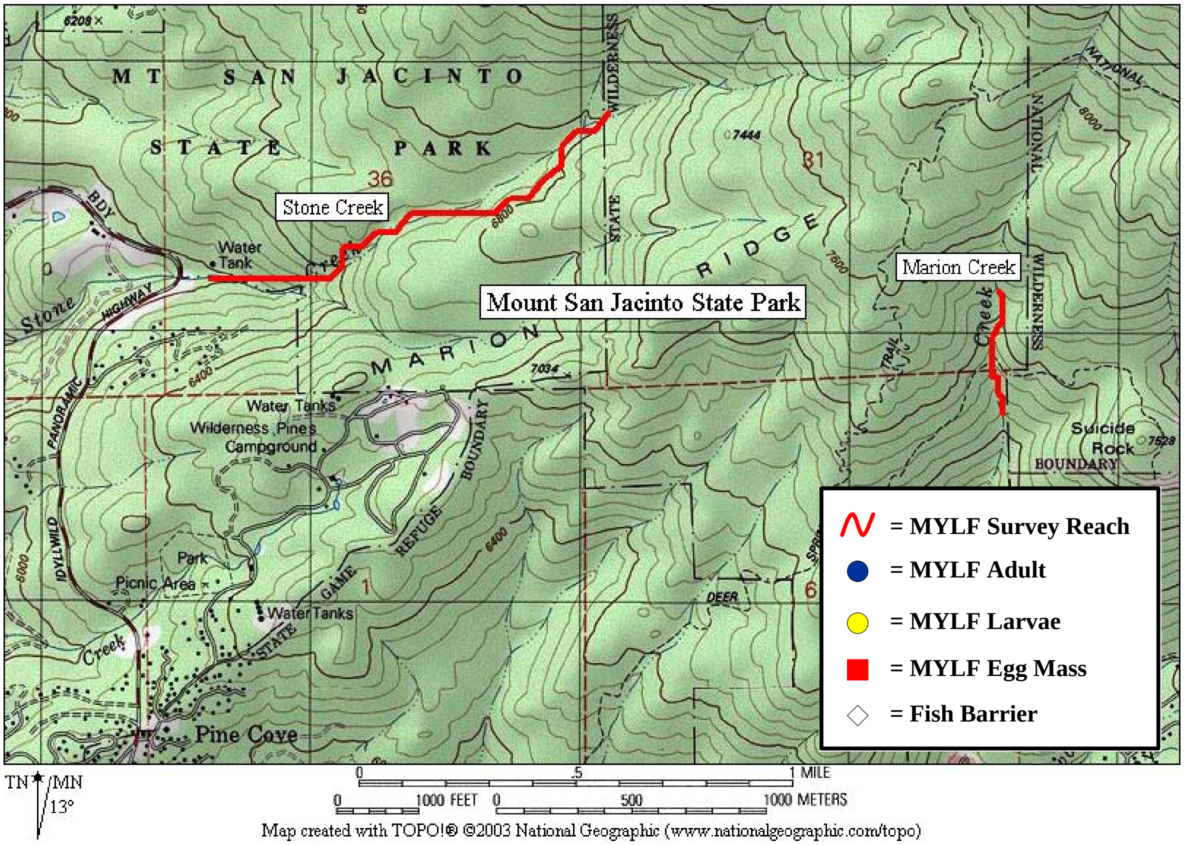


Figure 21. 2003 Stone Creek and Marion Creek survey reaches.

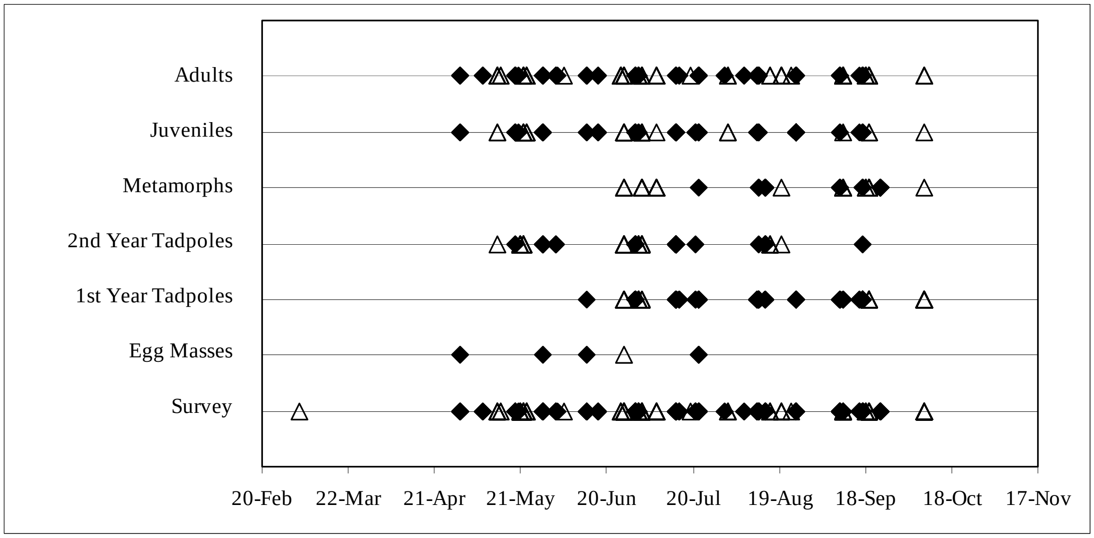


Figure 22. 2002 (△) and 2003 (◆) MYLF observations by life stage.

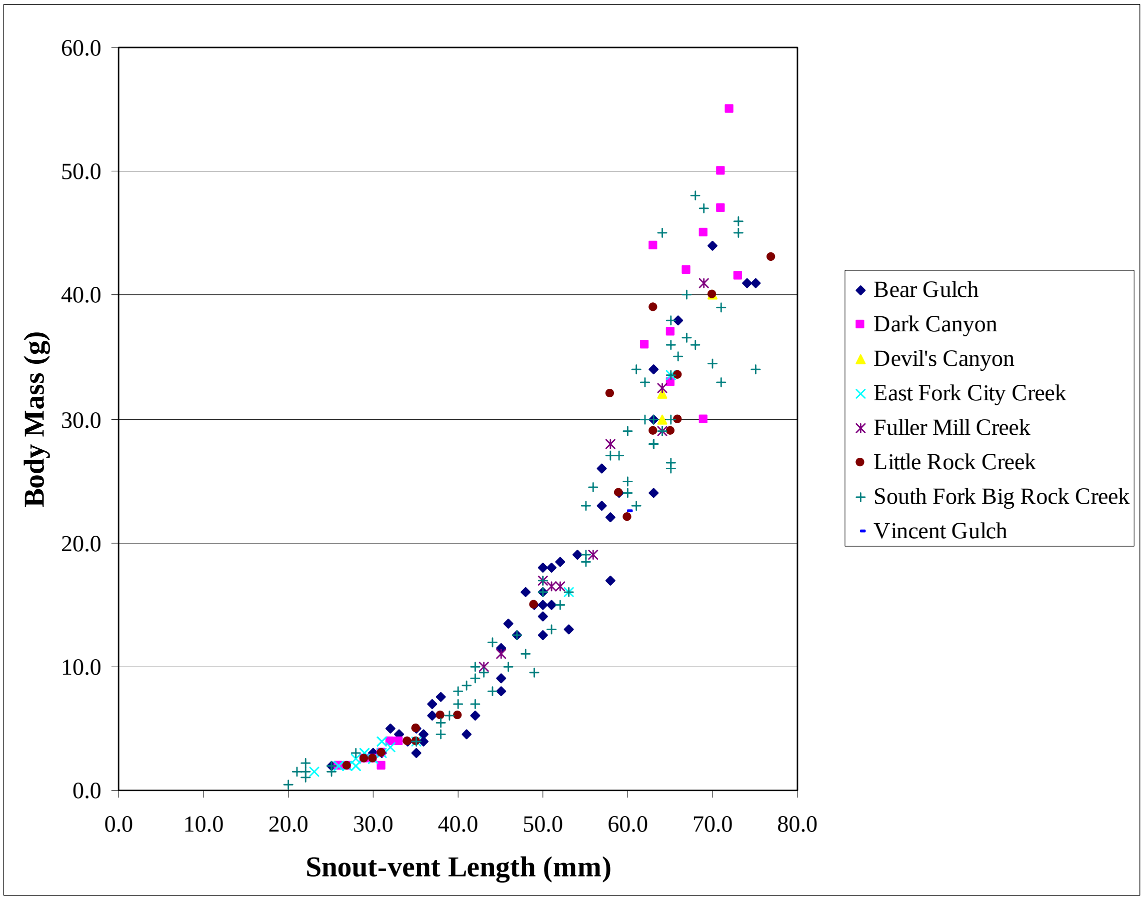


Figure 23. 2003 MYLF length by body mass as baseline information regarding the general health of southern California populations. (Includes recaptures across all visits).

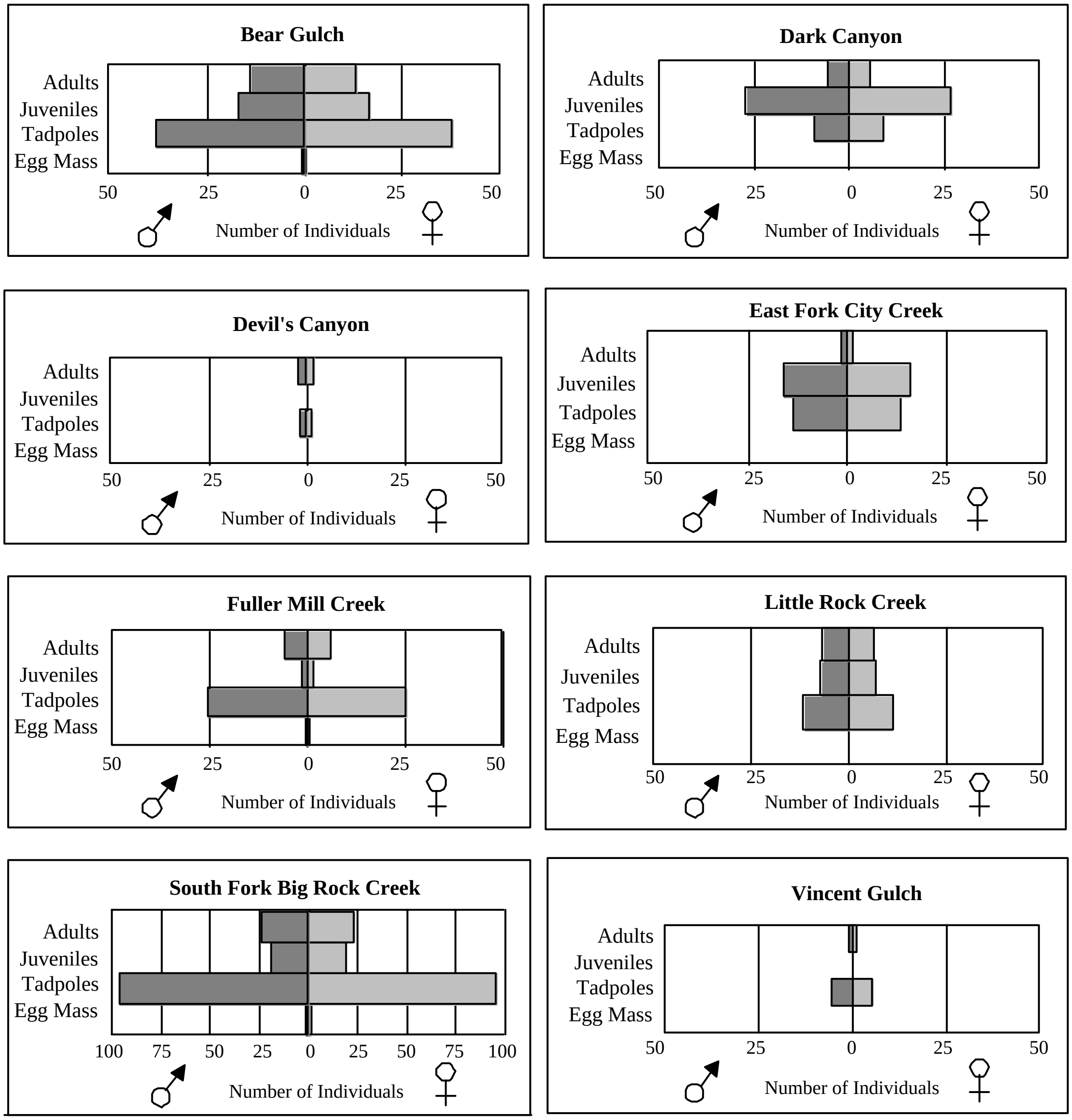
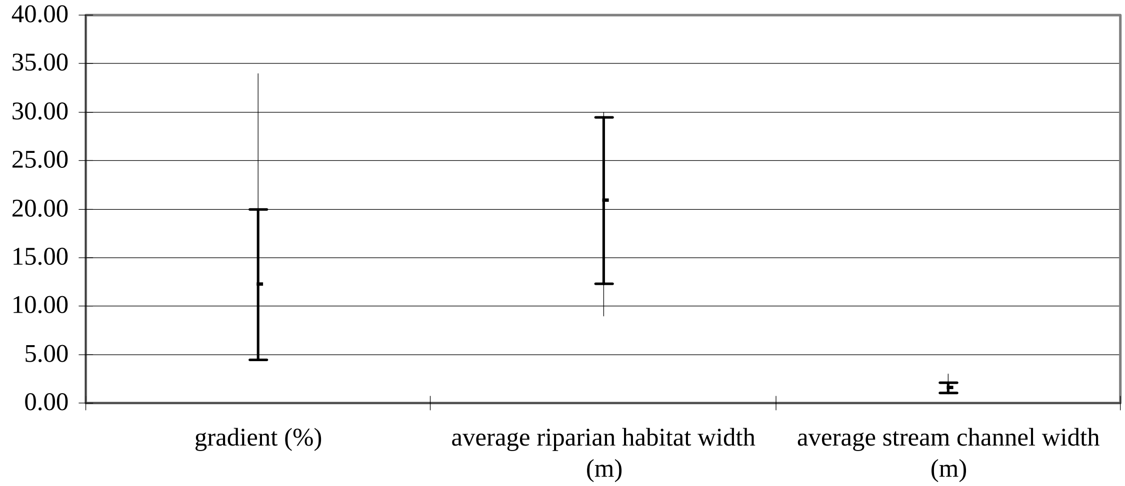


Figure 24. 2003 MYLF demographic charts. Assuming equal sex ratios, the number of individuals in each age class is shown in comparison with other age classes observed.

Riparian Properties



Substrate

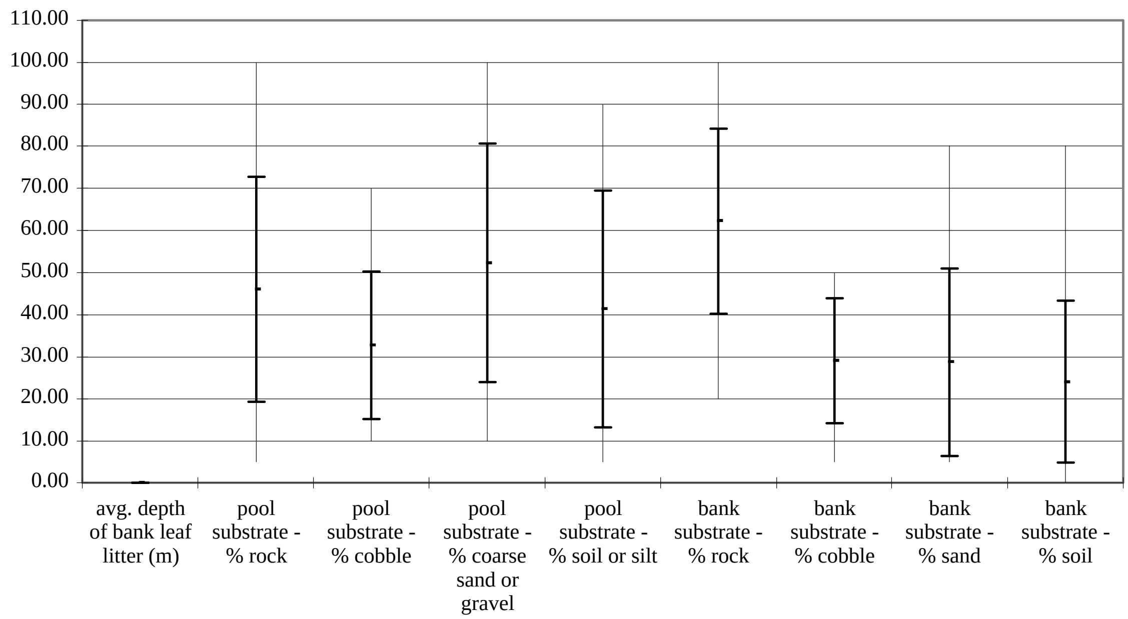
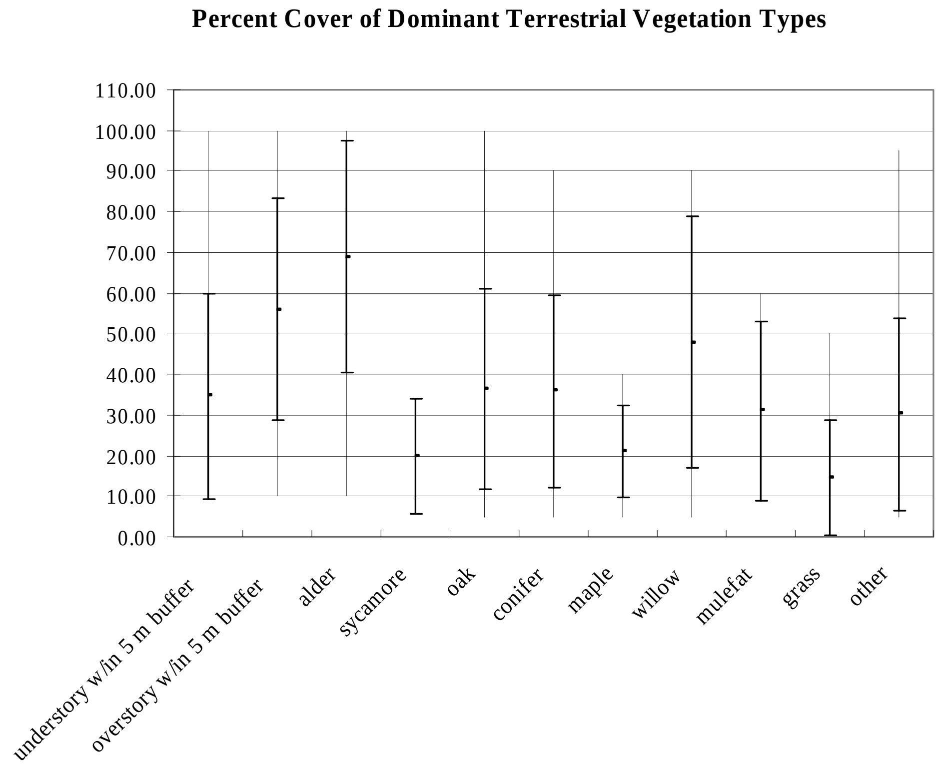


Figure 25. MYLF habitat variables showing minimum, maximum, mean and standard deviation of measurements taken in 70 pools that the MYLF inhabits. (Pools in which eggs were found are included in these data).



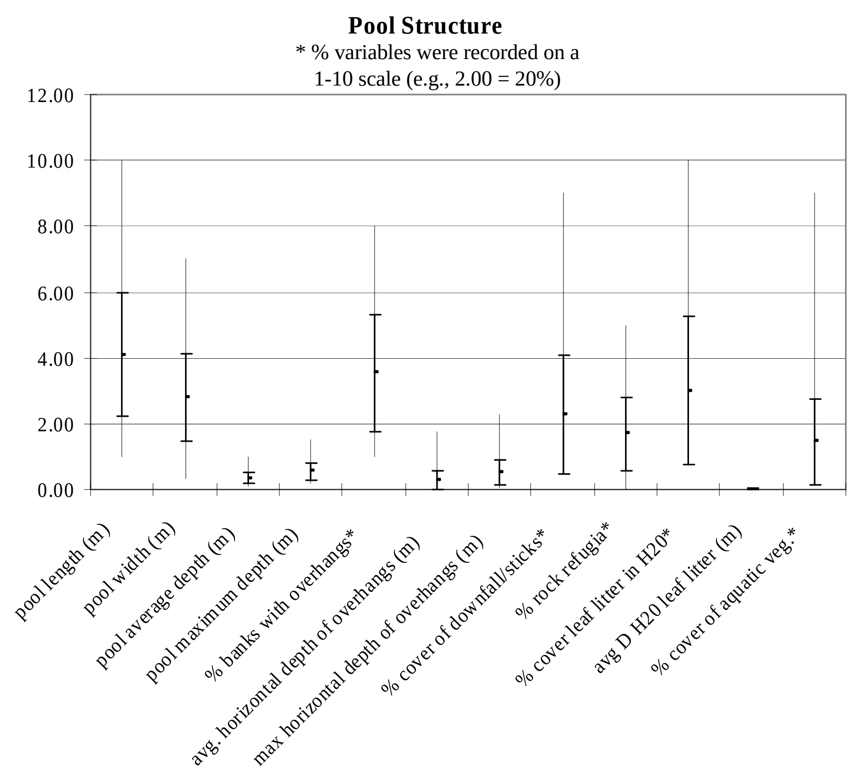


Figure 26. MYLF habitat variables showing minimum, maximum, mean and standard deviation of measurements taken in 70 pools that the MYLF inhabits. (Pools in which eggs were found are included in these data).

Water Properties

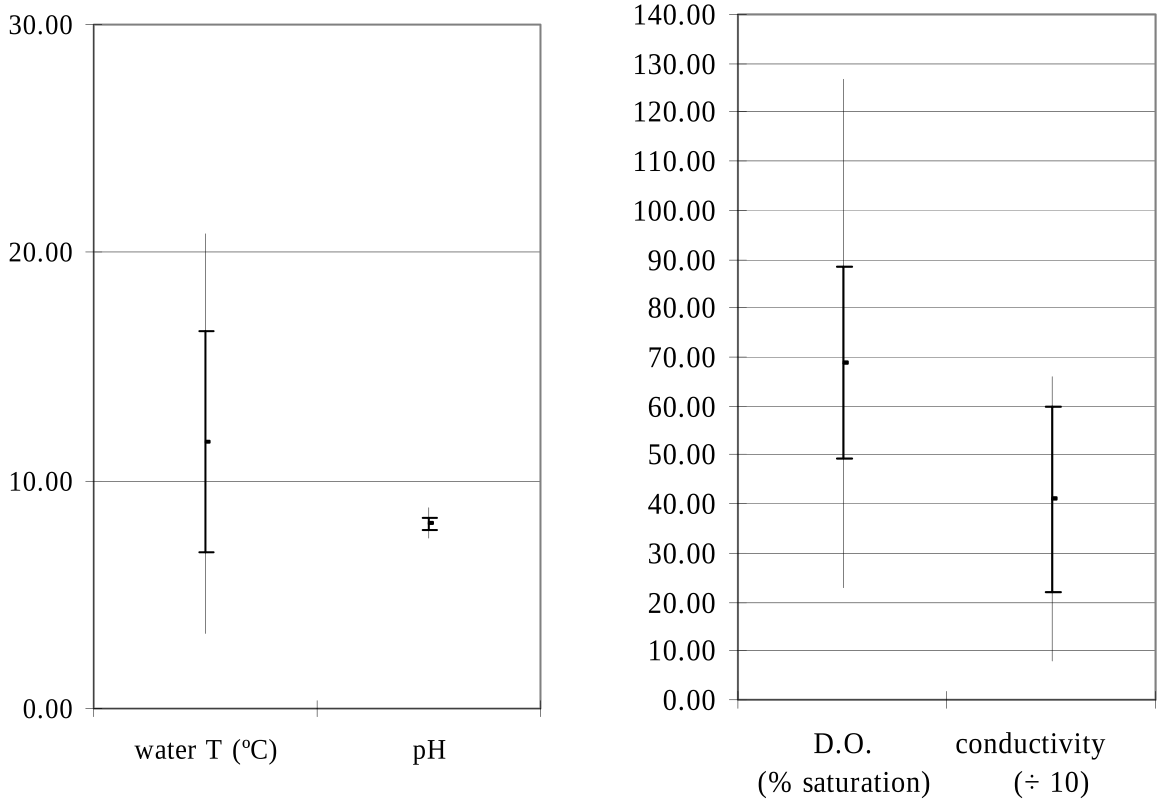


Figure 27. MYLF habitat variables showing minimum, maximum, mean and standard deviation of measurements taken in 70 pools that the MYLF inhabits. (Pools in which eggs were found are included in these data).

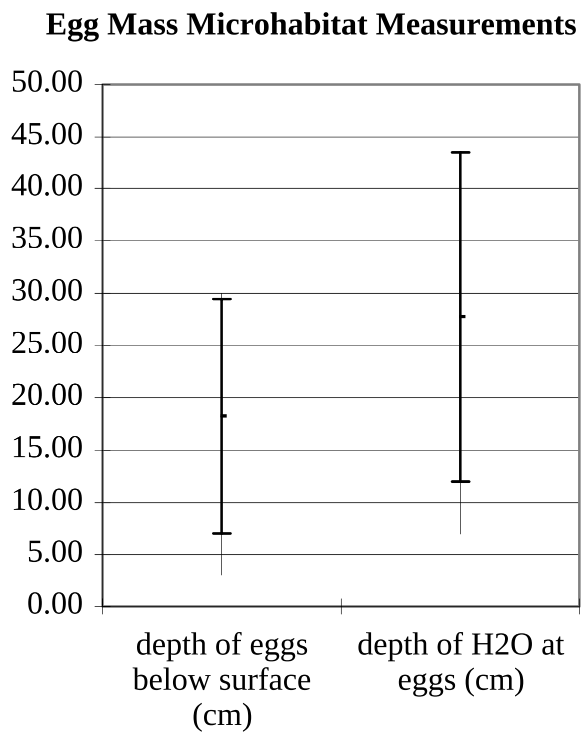
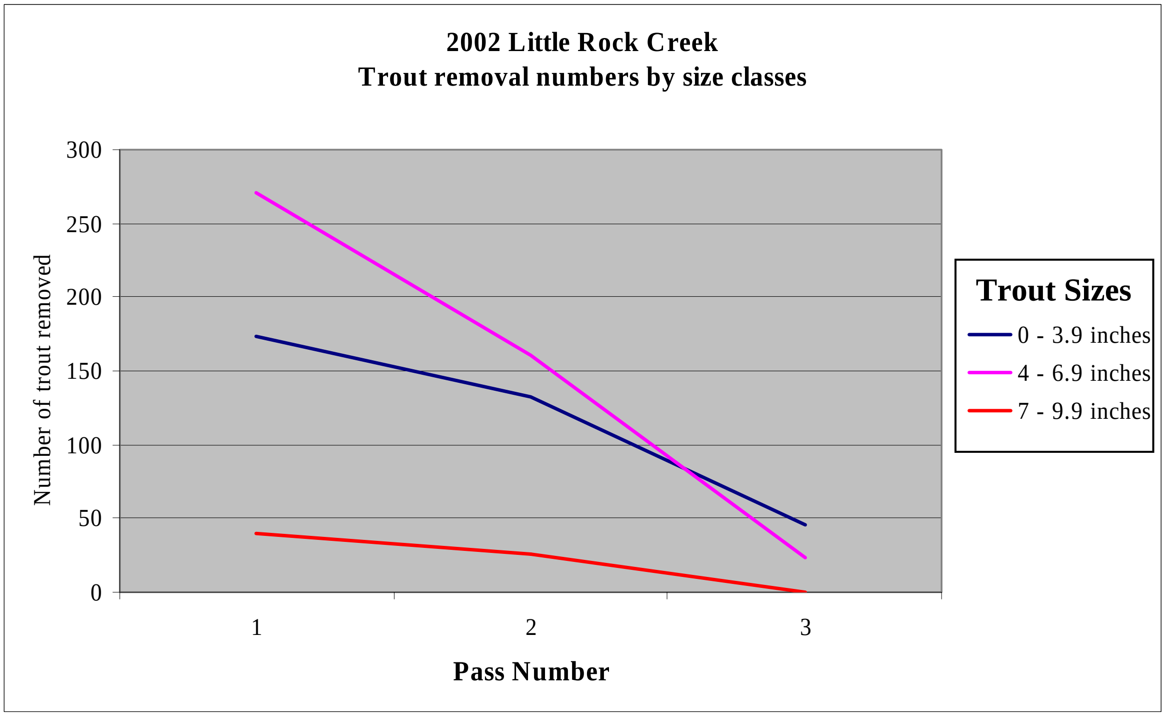


Figure 28. Additional habitat parameter measurements taken at pools in which eggs were found showing minimum, maximum, mean and standard deviation ($N = 3$).



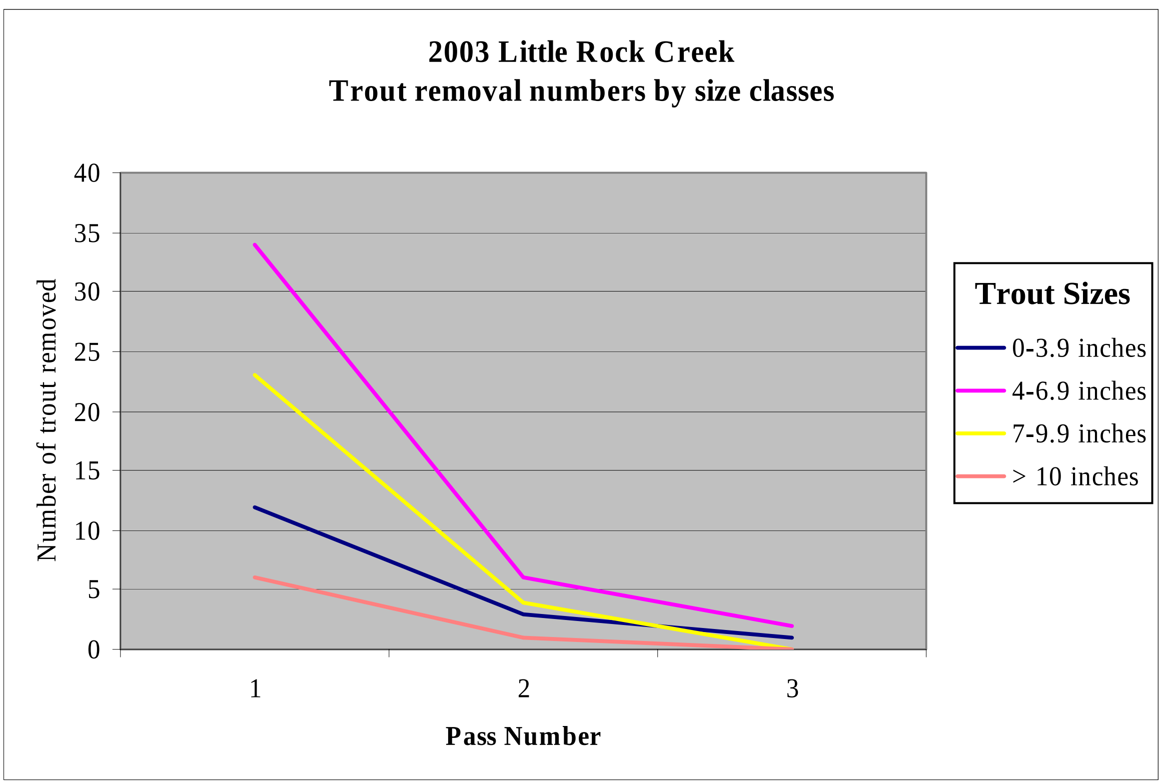


Figure 29. 2002 (top) and 2003 (bottom) trout removal numbers (provided by Roger Bloom, CDFG).

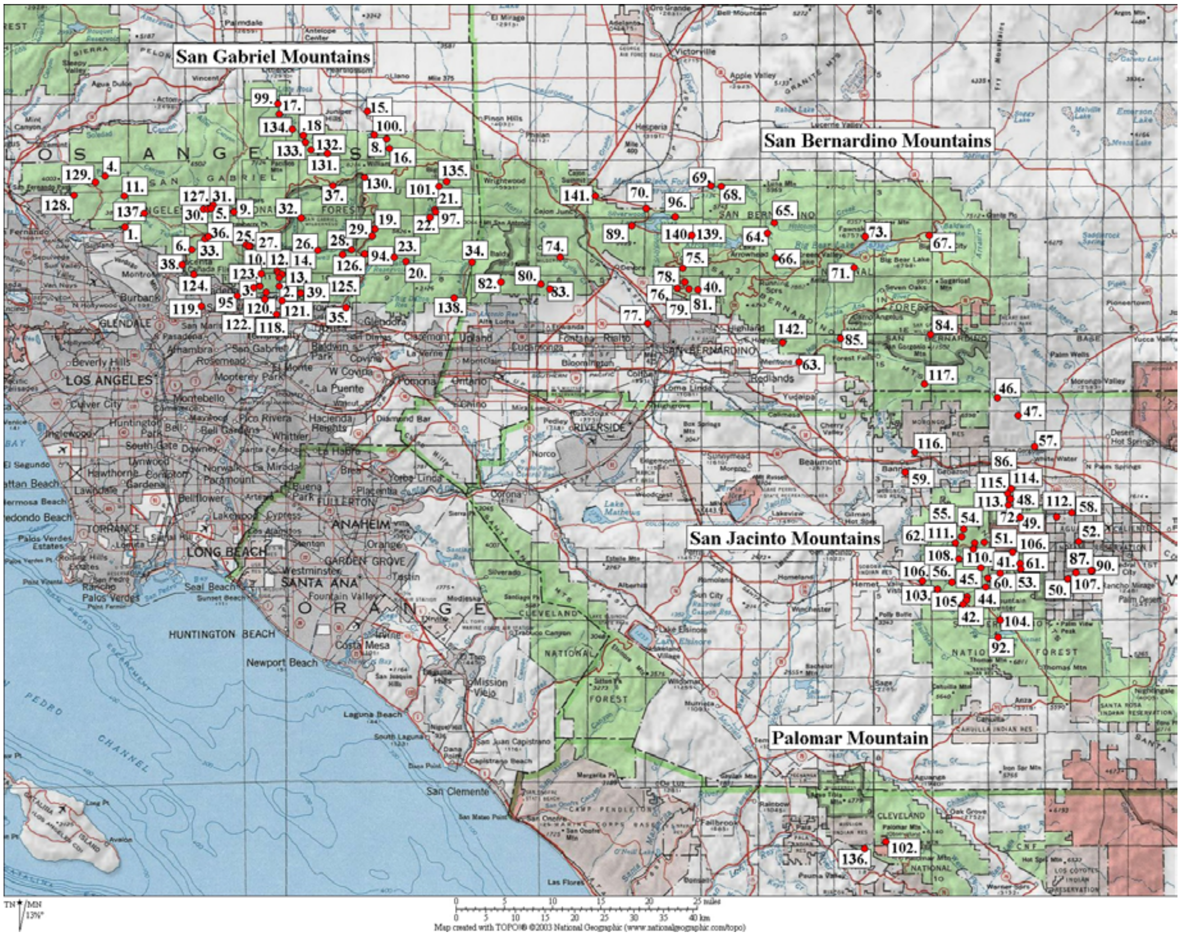


Figure 30. MYLF historical sites determined from museum records. Numbers correspond to location names referenced in Appendix 1.

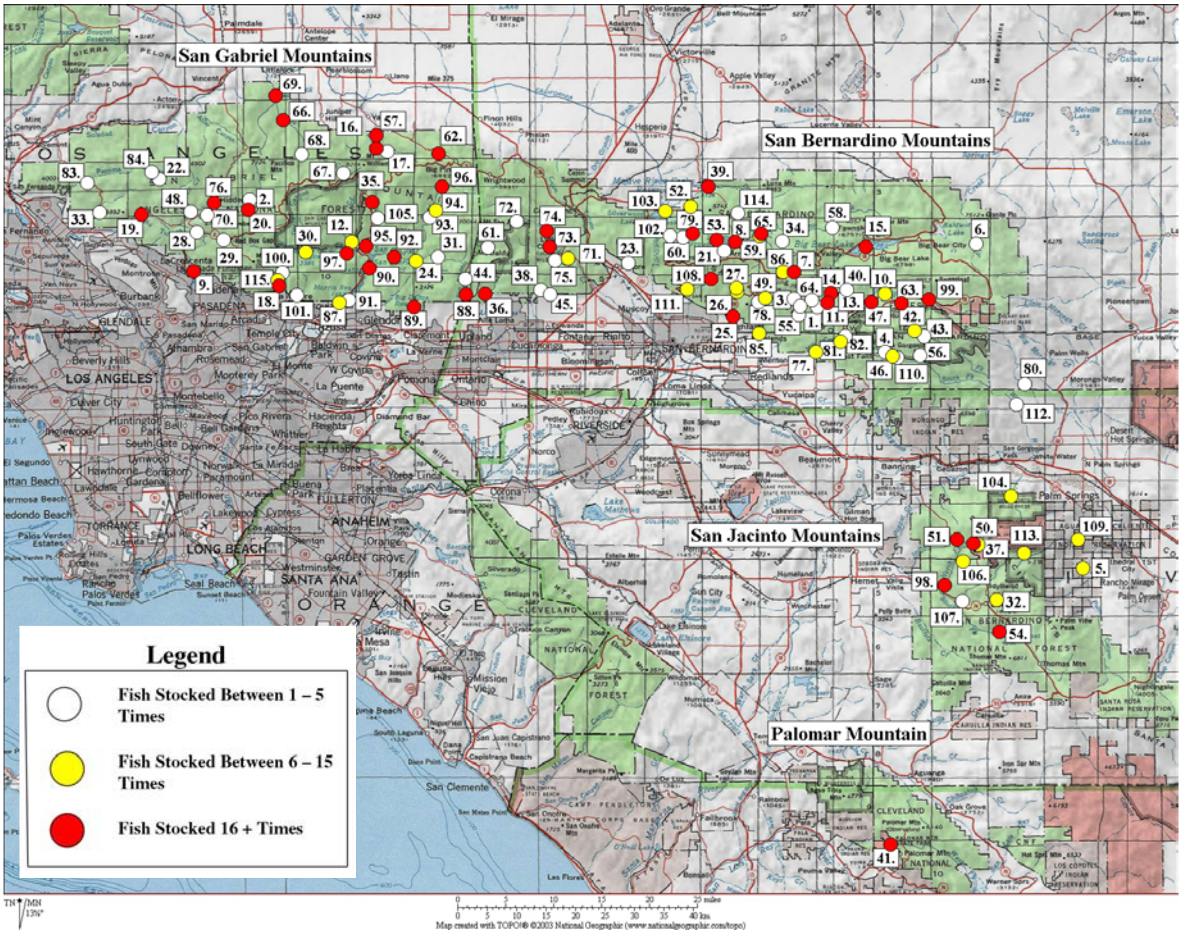


Figure 31. Fish stocking locations from the 1940's to the 1990's. Numbers correspond to location names referenced in Appendix 2.

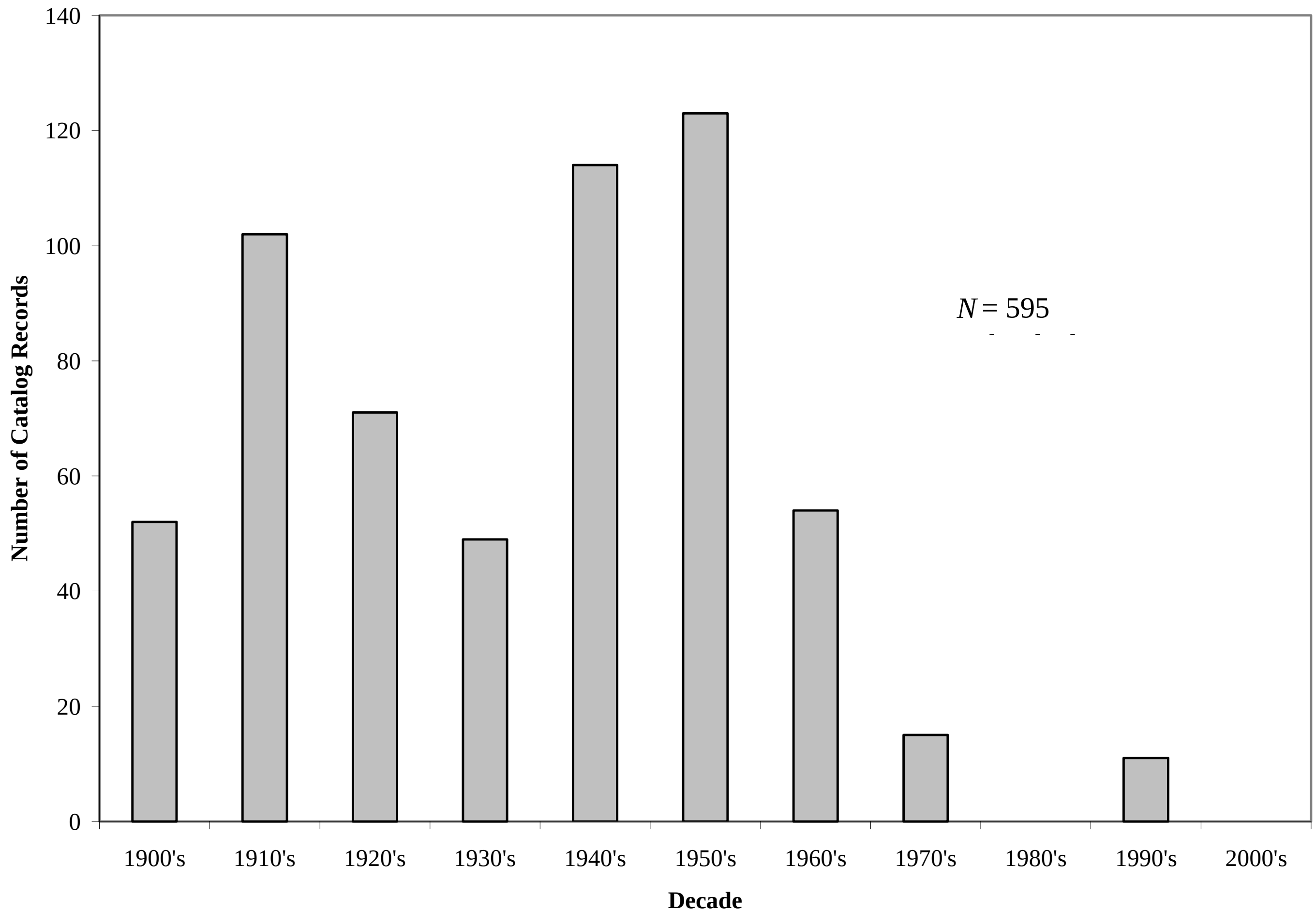


Figure 32. Number of MYLF collected from 1900 to 2004.

Name	Location	Year	County	Museum
1	Tujunga Wash	1916	Los Angeles	USNM
2	Big Santa Anita Canyon	1930	Los Angeles	LACM, SDNHM
3	Sierra Madre Canyon	1918	Los Angeles	LACM
4	Pacoima Canyon	1918	Los Angeles	LACM
5	Tujunga Canyon	1962	Los Angeles	LACM, USNM
6	Arroyo Seco, Pasadena	1936	Los Angeles	LACM
7	West Fork San Gabriel River	1911	Los Angeles	LACM
8	Big Rock Canyon, Sycamore Flats Camp Grounds	N/A	Los Angeles	LACM
9	Big Tujunga Canyon, Wickiup Camp Ground	N/A	Los Angeles	LACM
10	Big Santa Anita Canyon; 0.5 miles North of Winter Creek	N/A	Los Angeles	LACM
11	Gold Creek Canyon, Branch of Little Tujunga	1917	Los Angeles	AMNH
12	Big Santa Anita Canyon, Cascade Public Camp	N/A	Los Angeles	LACM
13	Santa Anita Creek, Hermits Camp	1911	Los Angeles	CAS
14	Santa Anita Creek, 1.5 mi above Hermits Camp	1911	Los Angeles	CAS
15	Big Rock Creek, Valyermo	1943	Los Angeles	LACM
16	Big Rock Creek, Isla Hermosa	1947	Los Angeles	LACM
17	Little Rock Canyon, 2.5 miles North of Sycamore Camp Ground	N/A	Los Angeles	LACM
18	Little Rock Creek, Sycamore Camp Ground	1953	Los Angeles	AMNH
19	San Gabriel Canyon	1933	Los Angeles	LACM, USNM
20	East Fork San Gabriel River	1947	Los Angeles	LACM
21	East Fork San Gabriel River, at Fish Fork	1947	Los Angeles	LACM
22	East Fork San Gabriel River, Iron Fork Camp Ground	N/A	Los Angeles	LACM
23	East Fork San Gabriel River, 2.3 miles from Shady Oaks Camp	N/A	Los Angeles	LACM
24	West Fork San Gabriel River, 4.5 miles from Red Box Ranger Station	N/A	Los Angeles	LACM
26	West Fork San Gabriel River, 1.5 miles East of Cogswell Dam	N/A	Los Angeles	LACM
27	Barley Flat Branch Canyon	1911	Los Angeles	CAS
28	Bear Creek; 1.5 miles north of West Fork San Gabriel River	N/A	Los Angeles	LACM
29	North Fork San Gabriel River, 3.7 miles from Camp Rincon	1950	Los Angeles	LACM
30	8 miles south of Mill Creek Summit	N/A	Los Angeles	LACM
31	Mills Creek	1950	Los Angeles	LACM
32	Devil's Canyon-Bear Canyon Wild Area	1946	Los Angeles	LACM
33	Upper Switzer Campground	1946	Los Angeles	LACM
34	San Antonio Canyon	1950	Los Angeles	LACM
35	Azusa Canyon, by bridge up 1 mile	1957	Los Angeles	LACM
36	Switzer's Camp	N/A	Los Angeles	LACM
37	Waterman Guard Station	1950	Los Angeles	LACM
38	Woodwardia Canyon	1941	Los Angeles	LACM
39	Monrovia Canyon	1932	Los Angeles	LACM
40	Strawberry Creek, 1 mile east of Waterman Canyon	N/A	San Bernardino	LACM
41	Strawberry Creek, at Fern Valley	1947	Riverside	LACM
42	Strawberry Creek	1946	Riverside	LACM
43	Strawberry Creek and Juction F Hwy 74	1954	Riverside	LACM
44	3.2 km southwest of Idyllwild, Strawberry Creek	1957	Riverside	KUNHM
45	Idyllwild; in the pine belt	1921	Riverside	USNM
46	Whitewater Canyon. 3.9 miles from Mouth	N/A	Riverside	LACM
47	Whitewater Canyon	N/A	Riverside	LACM
48	Snow Creek at reservior	1953	Riverside	LACM
49	Snow Creek	1970	Riverside	LACM
50	Andreas Canyon	1956	Riverside	AMNH, LACM
51	North Fork San Jacinto River, 0.5 miles upstream from Dark Canyon Campground	1991	Riverside	CAS
52	Tahquitz Canyon, 0.5 mi. southwest end of Ramon Road, Palm Springs	N/A	Riverside	LACM
53	Palm Springs, upper Tahquitz Canyon	N/A	Riverside	LACM
54	0.5 mi below Black Mtn Lookout, unnamed NE tributary to Hall Canyon	1990	Riverside	CAS
55	Hall Creek	1950	Riverside	AMNH
56	North Fork San Jacinto River	1908	Riverside	LACM
57	2.5 miles north Hwy 10 on Whitewater	N/A	Riverside	LACM

Appendix 1. MYLF Historic Records.

Name	Location	Year	County	Museum
58	Palm Springs	1918	Riverside	LACM
59	Banning	1925	Riverside	USNM
60	1 mile southwest Idyllwild	1949	Riverside	LACM
61	3.5 miles from Idyllwild on foot trail in stream in Skunk Cabbage Meadow	1957	Riverside	LACM
62	Fulmor	1953	Riverside	LACM
63	Mill Creek	1929	San Bernardino	LACM
64	Deep Creek & Little Bear Creek	1953	San Bernardino	LACM
65	Holcomb Creek, 1 mile above Deep Creek	N/A	San Bernardino	LACM
66	Deep Creek, 2 miles north Camp O-ongo	1955	San Bernardino	LACM
67	Caribou Creek, near Big Bear Lake	1949	San Bernardino	LACM
68	Deep Creek	1958	San Bernardino	LACM
69	Mojave River, East Fork, Miller USFS Camp	1947	San Bernardino	USNM
70	West Fork Mojave River, Horsethief Canyon	1947	San Bernardino	LACM
71	Bluff Lake	1949	San Bernardino	CAS, LACM
72	Snow Valley	1954	San Bernardino	LACM
73	Grout Creek, 1 mile west of Fawnskin	1949	San Bernardino	LACM
74	Lytle Canyon	1958	San Bernardino	SDNHM
75	3.1 mi. N. mouth of Waterman Cyn; along small creek	N/A	San Bernardino	LACM
76	3 miles northwest San Benardino, 2 miles northwest on Hwy 18	N/A	San Bernardino	LACM
77	5 miles north on Hwy 30 from Highland & Orange Ave. in Highland	N/A	San Bernardino	LACM
78	0.5 miles north Hwy 18, 1 mile east Waterman Canyon Road	N/A	San Bernardino	LACM
79	1 mile north, 0.5 miles east junction Waterman Canyon Road & Hwy 18	N/A	San Bernardino	LACM
80	Day Canyon	N/A	San Bernardino	LACM
81	Arrowhead Springs	N/A	San Bernardino	LACM
82	Cucamonga Canyon; from wash to lower falls at impassable area of creek	N/A	San Bernardino	LACM
83	Etiwanda Canyon	N/A	San Bernardino	LACM
84	Dry Lake	1908	San Bernardino	CAS-SUA
85	Mountain Home Canyon	N/A	San Bernardino	USNM
86	Indian Creek	1927	Riverside	CAS-SUA
87	Snow Creek	1970	Riverside	CAS-SUA
88	Palm Springs, Andreas Canyon	1941	Riverside	CAS-SUA
89	West Fork Mojave River	1942	San Bernardino	UMMZ
90	Andreas Canyon, near Palm Springs	1941	Riverside	CAS-SUA
91	Keen Camp	1912	Riverside	CAS
92	Hemet Lake	1917	Riverside	CAS
93	Eaton Canyon, near Pasadena	1930	Los Angeles	CAS-SUA
94	West Fork San Gabriel River	1911	Los Angeles	CAS
95	Eaton Canyon	1915	Los Angeles	CAS-SUA
96	2 miles north of West and East Forks Mojave River	1942	San Bernardino	UMMZ
97	San Gabriel River, 20 ft downstream from confluence with Fish Fork	1994	Los Angeles	CAS
98	Vincent Gulch, near mouth	1993	Los Angeles	CAS
99	Little Rock Creek, 1 mile south of Reservoir	1969	Los Angeles	CAS
100	Punchbowl Canyon	1970	Los Angeles	CAS
101	Vincent Gulch	1970	Los Angeles	CAS
102	Doane Valley, Palomar Mountain State Park	1951	San Diego	MVZ
103	8.6 miles southeast of Hemet	1939	Riverside	MVZ
104	Keen's Camp	1970	Riverside	MVZ
105	Strawberry Valley	1908	Riverside	MVZ
106	San Jacinto River, 7 miles east of Hemet	1950	Riverside	MVZ
107	Andreas Canyon	1947	Riverside	MVZ
108	North Fork, San Jacinto River	1950	Riverside	MVZ
109	near Schain's Ranch	1908	Riverside	MVZ
110	North Fork San Jacinto River, near Fuller's Mill	1908	Riverside	MVZ
111	Fuller's Mill	1908	Riverside	MVZ
112	Chino Canyon, Palm Springs	1960	Riverside	MVZ
113	Base of San Jacinto Mountains near Cabazon	1908	Riverside	MVZ
114	Snow Creek	1953	Riverside	MVZ
115	Snow Creek near Whitewater	1908	Riverside	MVZ
116	Banning Canyon in San Gorgonio River	1956	Riverside	MVZ

Appendix 1. MYLF Historic Records (continued).

Name	Location	Year	County	Museum
117	Burnt Canyon, San Gorgonio River	1956	Riverside	MVZ
118	near Sierra Madre, Big Santa Anita Wash	1908	Los Angeles	MVZ
119	Arroyo Seco Canyon, near Pasadena	1903	Los Angeles	MVZ
120	Sierra Madre, Little Santa Anita Canyon	1908	Los Angeles	MVZ
121	Sierra Madre, Big Santa Anita Canyon	1908	Los Angeles	MVZ
122	1.5 miles north Sierra Madre	1918	Los Angeles	MVZ
123	trail up Mt. Wilson, below Half-Way house	1913	Los Angeles	MVZ
124	Arroyo Seco	1903	Los Angeles	MVZ
125	Sierra Madre, Santa Anita Canyon, the Falls	1918	Los Angeles	MVZ
126	West Fork San Gabriel River	1909	Los Angeles	MVZ
127	Mill Creek, near Big Tujunga Creek	1952	Los Angeles	MVZ
128	1 mi above mouth of Pacoima, San Fernando Canyon	1918	Los Angeles	MVZ
129	Honeybee Public Camp, Upper Pacoima Canyon, 4-7 miles northeast San Fernando	1937	Los Angeles	MVZ
129	Honeybee Public Camp, Upper Pacoima Canyon	1939	Los Angeles	MVZ
130	East Fork of West Fork Mohave River, 1.25 miles east of Cedar Springs Camp	1939	Los Angeles	MVZ
131	Little Rock Canyon	1911	Los Angeles	MVZ
132	Little Rock Creek	1953	Los Angeles	MVZ
133	Sycamore Campground, Little Rock Creek	1953	Los Angeles	MVZ
134	Little Rock Creek	1953	Los Angeles	MVZ
135	0.2 mi upstream from mouth of Bear Gulch	1999	Los Angeles	MVZ
136	Palomar Mountain, Pauma Creek	1934	San Diego	SDNHM
137	3-8 miles northeast of Sunland	1940	Los Angeles	UMMZ
138	Evey Canyon 5 miles north of Claremont	1967	Los Angeles	UMMZ
139	3.25 miles east of Cedar Springs	1940	San Bernardino	UMMZ
140	East Fork of West Fork Mojave River	1942	San Bernardino	UMMZ
141	bridge opposite of Summit Valley	1940	San Bernardino	UMMZ
142	mouth of Santa Ana Canyon	1940	San Bernardino	UMMZ

Appendix 1. MYLF Historic Records (continued).

Name	Site Name	Number of Times Stocked	First Stocked	Last Stocked	County
1	Alder Creek	1	1979	1979	San Bernardino County
2	Alder Creek	2	1940	1969	Los Angeles County
3	Alder Creek, (Middle Fork)	1	1973	1973	San Bernardino County
4	Alger Creek	2	1955	1966	San Bernardino County
5	Andreas Creek	9	1949	1968	Riverside County
6	Arrestre Creek	1	1955	1955	San Bernardino County
7	Arrowbear Lake	29	1947	1984	San Bernardino County
8	Arrowhead Lake	30	1940	1969	San Bernardino County
9	Arroyo Seco Creek	43	1947	1998	Los Angeles County
10	Barton Creek	6	1940	1955	San Bernardino County
11	Bear (Canyon) Creek	10	1947	1977	San Bernardino County
12	Bear Creek	26	1940	1976	Los Angeles County
13	Bear Creek (Lower)	1	1976	1976	San Bernardino County
14	Bear Creek (Slide Lake)	24	1940	1970	San Bernardino County
15	Big Bear Lake	45	1940	1984	San Bernardino County
16	Big Rock Creek	51	1947	1998	Los Angeles County
17	Big Rock Creek (South Fork)	4	1948	1953	Los Angeles County
18	Big Santa Anita Creek	20	1947	1986	Los Angeles County
19	Big Tujunga Creek	35	1947	1998	Los Angeles County
20	Big Tujunga Creek (Upper)	50	1947	1998	Los Angeles County
21	Blue Jay Creek	3	1941	1945	San Bernardino County
22	Buck Creek	1	1979	1979	Los Angeles County
23	Cable Canyon Creek	1	1952	1952	San Bernardino County
24	Cattle Canyon Creek	6	1951	1972	Los Angeles County
25	City Creek	21	1940	1979	San Bernardino County
26	City Creek (East Fork)	11	1949	1979	San Bernardino County
27	City Creek (West Fork)	11	1949	1979	San Bernardino County
28	Clear Creek	1	1979	1979	Los Angeles County
29	Cloudburst Creek (and Squaw Creek)	1	1979	1979	Los Angeles County
30	Cogswell Reservoir	6	1962	1985	Los Angeles County
31	Coldwater Canyon Creek	6	1952	1957	Los Angeles County
32	Coldwater Creek	4	1948	1979	Riverside County
33	Cottonwood Creek	1	1985	1985	Los Angeles County
34	Crab Creek	1	1958	1958	San Bernardino County
35	Crystal Lake	50	1947	1998	Los Angeles County
36	Cucamonga (Canyon) Creek	44	1940	1984	San Bernardino County
37	Cucamonga (Guasti Park Lake)	11	1974	1984	Riverside County
38	Day Creek	1	1979	1979	San Bernardino County
39	Deep Creek	34	1940	1973	San Bernardino County
40	Deer Creek	1	1970	1970	San Bernardino County
41	Doane Lake	48	1952	1999	San Diego County
42	Dollar Lake	7	1946	1966	San Bernardino County
43	Dry Lake	1	1954	1954	San Bernardino County
44	Dry Lake	2	1954	1967	Los Angeles County
45	Etiwanda Creek	2	1973	1979	San Bernardino County
46	Fall Creek	7	1940	1954	San Bernardino County
47	Forsee Creek	16	1940	1970	San Bernardino County
48	Fox Creek (Big Tujunga Creek)	3	1979	1988	Los Angeles County
49	Fredalba Creek	6	1947	1979	San Bernardino County
50	Fullermill Creek	34	1948	1984	Riverside County

Appendix 2. Trout Stocking Records.

Name	Site Name	Number of Times Stocked	First Stocked	Last Stocked	County
51	Fulmor Lake	24	1957	1984	Riverside County
52	Grass Valley Creek	8	1949	1956	San Bernardino County
53	Green Valley Lake	36	1947	1984	San Bernardino County
54	Hemet Lake	34	1949	1983	Riverside County
55	Hemlock Creek (Left Fork)	3	1942	1973	San Bernardino County
56	High Creek	1	1940	1940	San Bernardino County
57	Holcomb Creek	1	1954	1954	Los Angeles County
58	Holcomb Creek	30	1954	1983	San Bernardino County
59	Hook Creek	13	1942	1957	San Bernardino County
60	Huston Creek	1	1940	1940	San Bernardino County
61	Ice House Canyon Creek	4	1942	1958	San Bernardino County
62	Jackson Lake	49	1947	1998	Los Angeles County
63	Jenks Lake	37	1947	1984	San Bernardino County
64	Keller Creek	1	1942	1942	San Bernardino County
65	Little Bear Creek	16	1955	1970	San Bernardino County
66	Little Rock Creek	44	1947	1998	Los Angeles County
67	Little Rock Creek (North Fork)	1	1979	1979	Los Angeles County
68	Little Rock Creek (South Fork)	1	1979	1979	Los Angeles County
69	Little Rock Reservoir	51	1947	1998	Los Angeles County
70	Lucas Creek (Upper Big Tujunga)	1	1984	1984	Los Angeles County
71	Lytle Creek	10	1940	1949	San Bernardino County
72	Lytle Creek (Coldwater Fork)	2	1957	1958	San Bernardino County
73	Lytle Creek (Middle Fork)	35	1949	1984	San Bernardino County
74	Lytle Creek (North Fork)	36	1949	1984	San Bernardino County
75	Lytle Creek (South Fork)	3	1949	1952	San Bernardino County
76	Mill Creek	8	1948	1970	Los Angeles County
77	Mill Creek	43	1940	1983	San Bernardino County
78	Mill Creek (Little)	1	1979	1979	San Bernardino County
79	Miller Canyon Creek	17	1951	1971	San Bernardino County
80	Mission Creek	1	1951	1951	San Bernardino County
81	Mt Home Creek	12	1945	1976	San Bernardino County
82	Mt Home Creek (East Fork)	1	1955	1955	San Bernardino County
83	Pacoima Creek	1	1958	1958	Los Angeles County
84	Pacoima Creek (upper)	1	1970	1970	Los Angeles County
85	Plunge Creek	8	1942	1975	San Bernardino County
86	Rainbow Lake	11	1951	1965	San Bernardino County
87	Roberts Canyon	8	1948	1961	Los Angeles County
88	San Antonio Creek	32	1947	1984	San Bernardino County
89	San Dimas Reservoir	44	1947	1998	Los Angeles County
90	San Gabriel Reservoir	21	1947	1995	Los Angeles County
91	San Gabriel River (below Morris Dam)	2	1952	1956	Los Angeles County
92	San Gabriel River (East Fork)	52	1947	1998	Los Angeles County
93	San Gabriel River (East Fork-Iron Fork)	1	1978	1978	Los Angeles County
94	San Gabriel River (Fish Creek)	7	1947	1958	Los Angeles County
95	San Gabriel River (North Fork)	51	1947	1998	Los Angeles County
96	San Gabriel River (Prairie Fork)	19	1947	1970	Los Angeles County
97	San Gabriel River (West Fork)	50	1947	1998	Los Angeles County
98	San Jacinto River (North Fork)	36	1948	1984	Riverside County

Appendix 2. Trout Stocking Records (continued).

Name	Site Name	Number of Times Stocked	First Stocked	Last Stocked	County
99	Santa Ana River (South Fork)	45	1940	1984	San Bernardino County
100	Santa Anita Creek (East Fork)	4	1963	1980	Los Angeles County
101	Sawpit Reservoir	1	1974	1974	Los Angeles County
102	Seeley Creek	1	1942	1942	San Bernardino County
103	Silverwood Reservoir	13	1972	1984	San Bernardino County
104	Snow Creek	7	1948	1953	Riverside County
105	Soldier Creek	2	1954	1972	Los Angeles County
106	Stone Creek	9	1950	1959	Riverside County
107	Strawberry Creek	4	1943	1947	Los Angeles County
108	Strawberry Creek	32	1948	1984	Riverside County
109	Tahquitz Creek	11	1952	1968	Riverside County
110	Vivian Creek	1	1940	1940	San Bernardino County
111	Waterman (Canyon) Creek	10	1944	1979	San Bernardino County
112	Whitewater River	2	1959	1967	San Bernardino County
113	Willow Creek	3	1952	1958	Riverside County
114	Willow Creek	13	1940	1958	San Bernardino County
115	Winters Creek	9	1947	1980	Los Angeles County

Appendix 2. Trout Stocking Records (continued).

Appendix 3. Hypothesis for MYLF Decline.

In southern California, the MLYF was historically found in a variety of wetland habitats including lakes, rivers, creeks, ponds, and marshes. The only locations that they exist today are in remote sections of creeks or in creek tributaries that are periodically disconnected from their corresponding main waterway. Therefore there must be some factor or set of factors in these remaining creeks and tributaries that have allowed for MYLF persistence while conspecific populations in other wetlands have been extirpated. Many hypotheses have been suggested for amphibian declines. Below is a summary of the most often cited decline causes and their pertinence to MYLF declines in southern California. Some decline hypotheses are more relevant to the southern California MYLF than others. It is most likely that combinations or interactions of the hypothesized decline causes are impacting the MYLF and that no single hypothesis can account for MYLF declines in southern California.

Global Climate Change

Long-term climate data indicate a general warming trend during the last century (McCarty, 2001). Climate change has been implicated in the decline of several anuran species in seemingly pristine areas, i.e., the golden toad (*Bufo periglenes*) and harlequin frog (*Atelopus varius*), (Crump *et al*., 1992; Pounds and Crump, 1994). Changes in climate and associated factors such as increased UV radiation and increased drought pose both direct and indirect effects to amphibians. UV radiation has been shown to cause mortality in western toad (*Bufo boreas*) eggs (Blaustein *et al*., 1994b). Increased drought or changes in mean water temperatures can stress amphibians causing them to be more susceptible to stochastic events, pathogens, and disease. Important secondary effects of climate change would include the changes caused by El Niño / La Niña event frequency and magnitude, which might disproportionately impact small fragmented populations. Even slight changes in climate and mean temperatures may cause microhabitats to dry, breeding times and life cycles to shift, and interstitial habitat to become unsuitable as dispersal corridors. Since these changes can only be detected over long periods of time, they would not be obvious over the course of time we have been conducting our surveys but should be considered when making management decisions.

Geomorphic Change Due to the 1968, 1969 Floods

Many researchers hypothesize that the current pattern of decline for all native ranid frogs in southern California began with the flood events during the 1968, 1969 winter. These events were combined with the already existing fragmentation of populations. During this winter, heavy flooding resulted from extraordinary levels of localized rainfall over a brief interval (Jennings and Hayes, 1994). This heavy rainfall scoured the canyons, changing the structure of the streams and likely removed many of the plunge pools that the MYLF thrives in. This event likely washed many of the frogs downstream into the Los Angeles basis where before urbanization; frogs may have ended up in wetlands and would later migrate back to their higher elevation habitat. By 1969 the Los Angeles basin had become more urbanized and many of the wetlands had been converted into cement drainage channels. Frogs washed into these conditions would likely have been unable to return to their original habitat and probably perished in the unsuitable conditions. The remaining eight known MYLF populations in southern California all occur in the uppermost headwaters (lower stream order) of creeks and may have been able to avoid the powerful surges of water that typically have drastic effects on lower elevation and higher order streams.

Our compilation of MYLF historical records (Figure 32) shows that the number of frogs collected and deposited in the museums queried between the 1900s and the 1960s was on average about 80 frogs per decade. From the 1970s through present, the numbers of frogs collected drops on average to approximately 7 frogs collected per year with zero frogs collected in the 1980s and in the 2000s. This reduction in frogs collected is likely due to fewer frogs available to collect rather than researchers collecting fewer vouchers. The decrease in the number of frogs collected coincides with the timing of the 1968, 1969 floods.

Exotics and Predators

Rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) are non-natives that have been associated with MYLF declines in California with the majority of the studies being conducted in the Sierra Nevada (Knapp and Matthews, 2000; Vredenburg, 2004). At our survey locations where intact habitat remains, introduced trout appear to be the most obvious threat to the MYLF. Seven of the eight MYLF southern California sites contained adjacent trout populations. Trout deleteriously impact frogs in several capacities. Trout have been observed preying on MYLF larvae and metamorphs (Hayes and Jennings, 1986; Bradford, 1989). Additionally, studies in California have shown that removal of trout in Sierra Nevada lakes has resulted in MYLF re-establishment (Knapp *et al*., 2001; Vredenberg, 2002, 2004) whereas lakes with introduced trout appear to restrict MYLF distribution and abundance (Bradford, 1989; Bradford *et al*., 1993; Knapp and Matthews, 2000; Knapp *et al*., 2003). The MYLF is especially susceptible to fish predation because their larvae are completely aquatic, generally take a minimum of two years to metamorphose into frogs, and juveniles never stray far from water (Zweifel, 1955). In the summer and fall months, many of these streams dry to perennial pools. This drying concentrates the trout and the MYLF larvae into a small area for several months, severely reducing the larvae's chances for survival. Trout may also compete for the aquatic invertebrate prey upon which adult frogs depend (Long, 1970). Dispersal along waterways may also be negatively impacted by the presence of trout. With dispersal routes impeded, most of the remaining MYLF populations in southern California represent sink populations (Bradford *et al*., 1994). These small remaining populations of frogs are extremely susceptible to stochastic events, such as the 2002 drought, the 2003 wildfires, and subsequent mud slides and scouring from rain events.

Of the native predators found during our surveys, we were particularly interested in the presence of native two-striped garter snake (*Thamnophis hammondii*). Garter snakes are associated with the presence of amphibians and may depend on the MYLF as a primary food source where they occur (Jennings *et al*., 1992; Mathews *et al*., 2002). Without this food source, the garter snake may decline as well, or may prey on other species that may in turn decline.

Environmental Contaminants

Pesticide drift may be an important factor in the decline of ranid frogs (Bridges and Semlitsch, 2000; Hayes *et al*., 2002; Davidson *et al*., 2001, 2002; Sparling *et al*., 2001). There have been few studies on pesticide drift in southern California to date but current research indicates that pesticides are playing a role in the decline of the MYLF in central

California and may therefore be a likely decline factor in southern California as well (Davidson *et al*., 2001; Sparling *et al*., 2001).

Nitrogen deposition could also be playing an important role in the decline of the MYLF in southern California. Experiments have shown that related ranid frogs, the spotted frog *Rana pretiosa* and the cascades frog *Rana cascadae*, experience negative developmental effects to increased nitrate and nitrite concentrations (Marco *et al*., 1999; Marco and Blaustein, 1999). The larvae of *R. pretiosa* showed reduced feeding activity; swam less vigorously; showed disequilibrium, abnormalities and paralysis; and many eventually died when exposed to higher nitrate concentrations. These frogs are similar to the MYLF in that they are primarily aquatic and can live in high elevation streams (Stebbins, 2003). Most of the current MYLF habitat in southern California is bordered by the Los Angeles Basin. Due to the large amount of aerial pollutants produced here, wildland ecosystems within the South Coast air basin, which include four counties in the Los Angeles area, receive the highest nitrogen deposition in the country (Fenn *et al*., 2003a). Likewise, stream water nitrate concentrations from montane watersheds downwind of greater Los Angeles are the highest in North America (Fenn *et al*., 2003b).

Results from our baseline water quality monitoring show basic water quality ranges currently being experienced by the MYLF in the streams they inhabit. Nutrient values for most sites were comparable with reference sites outside the study area. We did see elevated nutrient and major ion levels in creeks that had just burned. Because analysis was limited to a single sample for each site, we currently have no data as to how these nutrients and ions are behaving in the system. However we expect that these elevated levels will return to normal as water flushes through the system.

Although sample readings in MYLF locations are similar to those in control creeks, we have not yet sampled these areas in the winter. We hypothesize that there is burst of nitrogen entering stream systems during the 1st winter rains which may affect over-wintering tadpoles. This could explain in part why we have not seen severe declines in native treefrogs (*Hyla regilla* and *Hyla cadaverina*), because the treefrog tadpoles do not over winter and would not be exposed to such an event. We have no supporting evidence of this yet, but will be collecting additional water samples in 2004 to explore this hypothesis further.

Direct Human Impacts

Human impacts have undoubtedly accelerated the decline of the MYLF in southern California. Direct human impacts that modify habitat, such as water diversions, dam and reservoir construction, and urbanization have caused habitat loss or degradation, and reduced the range of the MYLF significantly. In fact, habitat loss and degradation is the most often cited and most likely cause of amphibian declines worldwide (Wyman, 1990; Wake, 1991; Blaustein *et al*., 1994a; Corn, 1994; Jennings and Hayes, 1994; Lehtinen *et al.*, 1999). Not only do these activities make habitat unsuitable for many species, but they also cause fragmentation of habitats. Fragmentation causes large interconnecting populations to become smaller and more isolated from one another. Isolation prevents immigration and emigration, and gene flow ceases. Not only are small populations more vulnerable to stochastic events, but when these populations are severely fragmented, recolonization becomes impossible and extirpation is likely.

Other human induced impacts on the MYLF include the activities and byproducts of heavy recreational use. Hunting, fishing, camping, mining, swimming, and hiking are prevalent activities in southern California forests. Several drainages have well-worn trails, and trash present in the waterway. Impacts can range from direct frog mortality from people inadvertently crushing eggs and tadpoles, to collecting frogs and removing them from the system. For example, in Little Rock Creek, a popular rock climbing area, we documented people hiking, leaving trash and defecating in the water in the same places we have found frogs. Jennings (1995) observed rock climbers inadvertently scaring adult frogs as they walked through the study area. Without realizing the presence of this endangered frog, they could have potentially crushed tadpoles and larvae as well. Jennings also made observations of people swimming, washing clothes and “scrawling graffiti” on the rocks at this site (Jennings, 1995).

Disease and Parasites

Fortunately, no chytrid fungus or iridoviruses were detected during this study. These pathogens have been attributed to amphibian population die-offs and local extinctions worldwide. Chytrid fungus attacks the keratinized parts of the body (Berger *et al*., 1998), affecting the frogs during and after metamorphosis. The fungus attacks the mouthparts of the larval stage but is not fatal to tadpoles (Fellers *et al*., 2001). When a population is infected with chytrid fungus there is a mass die off of frogs while the tadpoles remain. This contrasts our observations of adults and tadpoles; all larvae mouthparts inspected were intact and we found no evidence of any die-offs. It is important to note that iridoviruses can be naturally transmitted between animals from different taxonomic classes, (i.e. from fish to amphibians; Mao *et al*., 1999). With worldwide transportation of fish more widespread than ever, it is of sufficient concern that introduced or stocked fish species may also introduce an iridovirus to MYLF populations.

We did not detect any evidence of parasites as a result of any of our surveys. No external parasites were detected upon visual inspection, and because we did not find any sickly or dead frogs of any life stage, no frogs were collected for laboratory parasite analysis, (internal or external) as we are only permitted to collect dead or moribund individuals.

Although amphibian declines due to disease and parasites have been documented in many parts of the world, it appears that disease related declines in the southern California MYLF are minimal at this time. However, disease-borne die-offs could have caused declines in the past and therefore measures should be taken to prevent the spread of disease in the remaining systems as well as in areas that could be future translocation sites. Efforts such as cleaning boots, nets and any other equipment that may come in contact with the water, with a diluted bleach solution, should be employed when visiting known and potential MYLF locations to reduce the chance of introducing disease into frog populations.

Fire

With only eight sites and a small number of individuals within each site, fire poses a serious threat to MYLF persistence in southern California. Even though the MYLF has evolved with fire, with the current population isolation, if frogs are locally extirpated there will be no outside recruitment to repopulate these areas. In 2003, the Old Fire burned the entire watershed that the MYLF occupies in City Creek, which is also the only known MYLF population in the San Bernardino Mountains. The result of this fire could cause up to 20 feet of sediment to be deposited on the bottom of the creek bed, with low to average rain fall. With high rain fall, the water and sediment may scour the creek bed resulting in a bedrock chute with few plunge pools (Vic Andresen, pers. comm.), effectively eliminating the MYLF habitat in either case. Gamradt and Kats (1997) found that three years after a chaparral fire in 1993 in the Santa Monica Mountains of southern California, the largest and deepest pools were still absent due to the sedimentation following that fire. Evidence of severe scouring and sedimentation has already been observed at this location, and it is likely that the MYLF population in City Creek has been severely reduced or eliminated by direct and indirect effects of this fire.

There is evidence that these frogs may be able to survive such events assuming the habitat remains intact. In 1997 a fire burned most of the watershed that supports the MYLF population in Bear and Vincent Gulches (ANF), (Jennings, 1998, 1999). Following this fire USGS caught a MYLF with burn scars at Bear Gulch. According to our population estimates and survey observations, the frogs appear stable in Bear Gulch, currently one of the three largest populations in southern California, but have declined since 1997 in neighboring Vincent Gulch. The effect fire has on MYLF populations is poorly understood and should be investigated at City Creek in 2004. The current infestation of the bark beetle continues to cause die-offs of large stands of trees, which in turn poses an increased risk of large fires across southern California mountains. A strategy needs to be developed to deal with situations that potentially threaten entire MYLF populations.