MCBCP Arroyo Toad Monitoring Results for 2006 with Multi-Year Trend Analysis

Data Summary

Prepared for:

AC/S Environmental Security, Marine Corps Base Camp Pendleton

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

MCBCP Arroyo Toad Monitoring Results for 2006 with Multi-Year Trend Analysis

By Greta M. Turschak, Cheryl S. Brehme, Sara L. Schuster, Carlton J. Rochester and Robert N. Fisher[1]

U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

Data Summary

Prepared for:

AC/S Environmental Security, Marine Corps Base Camp Pendleton

[1]San Diego Field Station
USGS Western Ecological Research Center
4165 Spruance Road, Suite 200
San Diego, CA 92101

Sacramento, California
2008

U.S. DEPARTMENT OF THE INTERIOR
KEN SALAZAR, SECRETARY

U.S. GEOLOGICAL SURVEY
Suzette Kimball, Acting Director

Suggested citation:
Turschak, G. M., C. S. Brehme, S. L. Schuster, C. J. Rochester and R. N. Fisher. 2008. MCBCP Arroyo Toad Monitoring Results for 2006 with Multi-Year Trend Analysis. U.S. Geological Survey Data Summary prepared for Marine Corps Base Camp Pendleton. 55 pp.

For additional information, contact:

Center Director
Western Ecological Research Center
U.S. Geological Survey
3020 State University Drive East
Modoc Hall, Room 3006
Sacramento, CA 95819

Contents

Tables

Figures

MCBCP Arroyo Toad Monitoring Results for 2006 with Multi-Year Trend Analysis

By Greta M. Turschak, Cheryl S. Brehme, Sara L. Schuster, Carlton J. Rochester and Robert N. Fisher

Abstract

In 2003, the USGS implemented a new monitoring program for the endangered arroyo toad (*Anaxyrus californicus*) on Marine Corps Base Camp Pendleton (MCBCP). To address problems associated with large variations in adult toad activity, we employed a spatial and temporal monitoring approach to track arroyo toad breeding populations by documenting the presence of egg strings and larvae. We survey sites within three major watersheds up to four times per year to calculate and account for imperfect detection probabilities. We also conduct night surveys for adult toads, following a monitoring program initially implemented by Dan Holland in 1996. This report details results and analyses specific to the 2006 surveys, as well trends in occupancy, breeding and adult activity from 2003 to 2006.

Wide variations in seasonal rainfall have marked the past several years of arroyo toad monitoring at MCBCP. In 2006, we received only half the normal average rainfall (138 mm). Consequently, the largely ephemeral San Onofre and San Mateo Creeks remained partially dry throughout the 2006 breeding season. Over all watersheds, 64% of potential toad breeding habitat contained water during our survey efforts. However, 82.7% (se= 7.4) of the available wet habitat was occupied by breeding arroyo toads. We recorded the highest occupancy in the Santa Margarita Watershed (85.0%), followed by the San Mateo (22.3%) and San Onofre (0.0%) Watersheds.

Even in the wetted areas, San Mateo and San Onofre Creeks had unexpectedly low occupancy of arroyo toads. In particular, we found a significant 74.1% decrease in occupied breeding habitat within San Mateo Creek from 2005 to 2006. We hypothesize that this low occupancy for San Mateo and San Onofre Creeks may be the result of reduced sand cover, which dropped from an average of 26-50% in 2005 to only 11-25% in 2006. In general, the creek beds became rockier with few sandy areas available for arroyo toad breeding. Another possibility for the low occupancy of arroyo toads in San Mateo and

San Onofre Creeks could be the cool temperatures and relatively late rainfall of 2006. These factors can result in the absence of arroyo toad breeding activity.

Even though surface water availability was highly variable (44-95%) from 2003 to 2006, the overall extant of breeding toads in wetted areas was relatively stable (77-95%) with no significant change over the four year period. The night survey count data from 1996 to 2006 also showed extremely high annual variability (+/- 49% of mean) in arroyo toad activity, but overall activity has remained relatively stable over the last decade.

We generated percent area occupied (PAO) models for two different time spans, 1) single season models for 2006 and 2) multi-season models for 2004 to 2006. Due to the increased number of environmental covariates recorded from 2004 to 2006, we did not include 2003 data in the multi-season models.

In analyzing the 2006 single season models, we found the probability of detecting arroyo toad larvae to be positively associated with both the low flow index and the non-native species index. The positive association between non-native species and arroyo toads is unusual. However, we believe the limited availability of water in 2006 may have pushed all water dependent species into the same areas. This positive association will likely occur only in dry years. In 2006, occupancy for arroyo toads was positively associated with the sand cover index. Additionally, the odds of arroyo toads occupying sites with perennial water were 14.4 (se= 0.95) times greater than occupation of ephemeral sites.

In the 2004-2006 multi-season models, initial occupancy for arroyo toads was best explained by the presence of predatory fish, sand cover index, and non-native species index. The odds of arroyo toads occupying a site were 13.56 (se= 1.06) times lower when predatory fish were present and 2.69 (se= 0.52) times lower with each additional group of non-native species. Conversely, the odds of arroyo toad occupation were 7.89 (se= 1.65) times higher for each increase in the sand cover index. The rate of arroyo toad colonization/extinction was not constant over the 3-year period. From 2004 to 2005, the odds of an unoccupied site becoming occupied were 95:1 (se= 2.04). From 2005 to 2006, the odds of an unoccupied site becoming occupied were 1.6:1 (se= 0.27). Over the entire period, presence of the western toad was the strongest predictor of detecting arroyo toad larvae. The probability of detecting arroyo toad larvae increased an average of 5.13 (se= 0.45) times with western toad presence.

We expect the effects of urbanization, occurring largely outside MCBCP, to be the primary threat to the arroyo toad populations. Increased impervious surface area from development alters water runoff patterns and modifies natural water regimes. These modifications can change historically, ephemeral systems into perennial systems and create deeper, incised channels with faster water flow. The consequences may include the reduced availability of shallow pools for arroyo toad breeding, and successful colonization by aquatic non-native predators requiring permanent water sources. We expect these outcomes to be particularly relevant for the Santa Margarita Watershed and Cristianitos sub-Watershed. There is also concern about the negative impacts of the proposed Foothill-South Toll Road on arroyo toad populations in lower San Mateo Creek and Cristianitos Creek.

In terms of species management within MCBCP, we recommend modifying the water releases at the Temecula Gorge to simulate a more natural hydrology pattern with periods of summer drying. We recommend control of invasive riparian plants and non-native aquatic species, particularly crayfish and bullfrogs. We also advise continuation of the beaver removal program and management of military training activities in arroyo toad habitat. Lastly, we recommend the continued education of all MCBCP field personnel in the identification and basic biology of the endangered arroyo toad.

Introduction

The primary mission for Marine Corps Base Camp Pendleton (MCBCP) is "to operate the finest amphibious base possible; to promote the combat readiness of Marines and Sailors by providing necessary facilities and services; to support the deployment of the Fleet Marine Force and other organizations; and to provide support and services responsive to the needs of the Marines, Sailors, retirees and families aboard Camp Pendleton" (MCBCP 2006). In addition, MCBCP continues to fulfill stewardship and regulatory requirements for the natural resources on Base. These requirements include monitoring and management of the endangered arroyo toad as described in the Integrated Natural Resources Management Plan (MCBCP 2007).

As part of arroyo toad management efforts, MCBCP contracted U.S. Geological Survey (USGS) to develop a science based monitoring program for arroyo toad populations in 2002 (Atkinson et al. 2003). USGS implemented the monitoring program on Base in 2003. In this report, we discuss trends in arroyo toad occupancy, breeding, and adult activity from 2003 through 2006, focusing on the 2006 surveys and results. We also analyze these trends as they relate to environmental conditions and other variables within and among years.

The Arroyo Toad

The arroyo toad (*Anaxyrus californicus*) is a specialized amphibian endemic to the coastal plains and mountains of central and southern California and northwestern Baja California (Jennings and Hayes 1994). It primarily inhabits low gradient streams and rivers comprised of sandy soils and containing sandy streamside terraces (Sweet 1992, 1993, Barto 1999). Reproduction is dependent on availability of shallow, still, or low flow pools in which breeding, egg laying, and larval development occur. These habitat requirements are largely determined by natural hydrological cycles and scouring events (USFWS 1999, Madden-Smith et al. 2003).

Breeding and larval development within MCBCP typically occur between March and July (Holland et al. 2001), depending upon weather conditions. Female arroyo toads produce a single egg clutch each year. Following fertilization, toad larvae (tadpoles) emerge at 12 to 20 days and persist in breeding pools for the next 65-85 days. Newly metamorphosed toads may remain near the breeding pools for a few weeks to several months before dispersing into upland habitat for the winter months. As with most amphibians, arroyo toad survivorship during the developmental stages is reportedly very low

(Sweet 1992). The lifespan of the arroyo toad is unknown, but estimated to be approximately five to six years (Sweet 1992, 1993, R. Fisher unpublished data).

The arroyo toad currently occupies an estimated 25% of its previous habitat within the United States (Jennings and Hayes 1994). Contributing factors in this decline include extensive habitat loss, human modification to water flow regimes, and introduction of non-native predators. The U.S. Fish and Wildlife Service (USFWS) listed the arroyo toad as an endangered species in December 1994 (USFWS 1994) and released a Recovery Plan for the arroyo toad in 1999 (USFWS 1999).

Study Site

Marine Corps Base Camp Pendleton occupies approximately 50,600 hectares within the Peninsular Range of southern California. A narrow, sandy shoreline, seaside cliffs, coastal plains, low hills, canyons, and mountains rising to elevations of over 800 meters characterize the Peninsular Range (MCBCP 2007). Plant communities include oak woodlands, coastal sage scrub, native and non-native grasslands, coastal dunes, riparian forest/woodland/scrub, as well as wetlands.

MCBCP has a Mediterranean climate with relatively warm, dry summers and mild winters. The rainy season typically falls between October and April with most precipitation occurring in January, February and March. Yearly rainfall averages 274 mm (10.8 inches), but is highly variable among years largely due to the influence of the El Niño-Southern Oscillation (ENSO) cycle. This cycle is driven by temperatures in the Pacific Ocean. Warm ocean temperatures create wetter than normal conditions (El Niño), while cool ocean temperatures create drier than normal conditions (La Niña).

The cities of San Clemente, Oceanside, and Fallbrook border MCBCP to the northwest, south and east, respectively. The Cleveland National Forest and the Pacific Ocean form the northern and western boundaries of MCBCP. To date, the Base is largely undeveloped and encompasses the largest remaining expanse of undeveloped coastline and coastal habitat in southern California. Many species, including the arroyo toad, were once common throughout the Peninsular Range, and now find an important refuge within the borders of MCBCP. The arroyo toad populates three of MCBCP’s major watersheds: 1) Santa Margarita, 2) San Onofre, and 3) San Mateo. These watersheds support the only known remaining coastal populations of the arroyo toad in the United States and represent three of the 22 currently occupied watersheds in Monterey, San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange, Riverside, San Bernardino, and San Diego Counties (USFWS 1999).

The Santa Margarita River is a large fourth order stream. It is the largest drainage within MCBCP, and its watershed covers approximately 192,000 hectares. Over 90% of this watershed is located off Base (MCBCP 2007), and two main factors are expected to alter both current and future water flow. The first factor is continued off Base urban development in the upper drainage basin. Increased impermeable surface area in the basin is predicted to increase peak and total water discharge by 50%, resulting in larger and more frequent floods and wetter lowland conditions (Steinitz et al. 1996). The second factor is a Cooperative Water Resource Management Agreement (CWRMA) established between MCBCP and Rancho California Water District (RCWD) in 2002 (CWRMA 2002). In order to mitigate the impacts of increased outpumping of underground water in the upper watershed, RCWD agreed to release a minimum amount of water at the Temecula Gorge to simulate flows modeled from 1931-1996. Even during summer months, this agreement guarantees a minimum flow of 3 cubic feet per second (1 ft^3= 0.0283 m^3). Due to the size of this watershed and off Base activity in the upper drainage basin, the Santa Margarita River is expected to have increasingly higher volumes of flow during all years. In years of normal to high rainfall, this change in hydrology may result in significantly lower numbers of suitable breeding pools for the arroyo toad. In contrast, during drought years, this river may provide the only suitable breeding habitat for arroyo toads on MCBCP.

The San Mateo and San Onofre Watersheds are relatively small (35,500 and 11,100 hectares) and are comprised primarily of second and third order streams. Only 20% of the San Mateo Watershed is located on Base, while 100% of the San Onofre Watershed lies within the borders of MCBCP (MCBCP 2007). With little runoff, both streams are typically dry from July to October. In drought years, they frequently remain dry all year. According to model simulations, discharge in these basins is predicted to remain the same or decline in the future (Steinitz et al. 1996). These watersheds may account for most of the breeding and recruitment of arroyo toads at MCBCP in wet or normal rainfall years, but have little or no recruitment in periods of drought.

Within MCBCP, specific threats to arroyo toad populations may include:

1) Alteration of natural hydrology, increased siltation and decreased water quality due to increased upstream development in urban areas (e.g. Fallbrook, San Clemente, Murrieta and Temecula) and within MCBCP (e.g. Foothill-South Toll Road). These threats are particularly imminent for the San Mateo Watershed (Cristianitos Creek) and the Santa Margarita River (Steinitz et al. 1996).

2) Potential alteration of hydrology and lack of surface water due to excessive groundwater pumping for agriculture and human needs, particularly in the lower San Mateo Watershed (per Holland et al. 2001).

3) Loss of arroyo toad habitat due to large stands of exotic vegetation, including giant reed (*Arundo donax*), tamarisk (*Tamarix*) and non-native grasses (*Bromus, Avena*), which can hinder animal movement and stabilize stream banks.

4) Excessive predation by non-native species, including fishes, bullfrogs (*Lithobates catesbeianus*), and crayfish (*Procambarus*).

5) Loss of arroyo toad foraging and breeding habitat due to potential development on Base, the Foothill-South Toll Road project, or intense training activities.

6) Direct (crushing) and indirect (siltation, soil compaction) mortality due to training activities occurring during the arroyo toad breeding season.

Population Monitoring

In order to census populations of the arroyo toad, a monitoring program was implemented on MCBCP from 1996 to 2000 (Holland et al. 2001). Eight 1-km transects were established along the three occupied watersheds. Holland et al. (2001) conducted night surveys for juvenile, sub-adult, and adult toads along these transects an average of four times per year. Mean and median survey counts were utilized to look for trends in arroyo toad populations. However, the large night-to-night variation made it difficult to assess temporal trends in population size. To better assess population size, a capture-recapture program for arroyo toads was implemented in 1998. Adult arroyo toads were marked with Passive Integrated Transponders (PIT tags) (Holland and Sisk 2001). After three years of effort, the overall recapture rate (including multiple recaptures of the same individual) was still too low (20.8%) to perform any meaningful abundance analysis, as population estimate variances were too large.

To address problems associated with large variations in adult toad activity, we designed a spatial and temporal monitoring approach to track the presence of arroyo toad breeding populations by documenting the presence of eggs and larvae (Atkinson et al. 2003). This approach uses the log-linear modeling program, PRESENCE, to calculate annual estimates of proportion area occupied (PAO), as well as the probabilities of detection, colonization, and extinction over time (MacKenzie et al. 2002, 2003). Because the probability of detecting a species on any single survey is imperfect, site occupancy is often underestimated. In this model, site occupancy is determined after correcting for a detection probability calculated from data obtained on multiple visits. Percent site occupancy is then used as a metric to monitor long-term population trends. This model also allows for analysis of site and survey specific covariates. These covariates can be environmental and habitat variables that vary (survey specific) or do not vary (site specific) with each survey visit. They include variables affecting detection probabilities, such as weather and water variables, and others directly related to land use and management activities, including the presence of non-native plant and aquatic species, military activity on site, water quality, and human impacts to the hydrological regime. Therefore, the impacts of these activities can be assessed over time to make more informed management decisions on Base. This approach is currently being implemented across the country as part of the USGS Amphibian Research and Monitoring Initiative (Muths et al. 2005). Because only presence/absence data is collected, this program does not directly track trends in population abundance.

A workshop to devise the arroyo toad monitoring protocol reported above was conducted on August 27, 2002 with arroyo toad experts from USGS, U.S. Fish and Wildlife Service, MCBCP, U.S. Forest Service, California Department of Fish and Game, and Universities of California, at San Diego and Davis. Atkinson et al. (2003) details the discussion points, consensus, and complete theoretical protocol resulting from the workshop. In summary, suitable habitat within the three major watersheds on MCBCP (Santa Margarita, San Mateo and San Onofre) was divided into 60 linear 1.5-km blocks. Each of the 1.5-km blocks was then subdivided into six linear 250-m survey sites (Table 1, Figure 1). The average slope of a survey site was 1.9% with a range of 0 to 12%. One randomly chosen 250-m survey site within each block is surveyed annually (permanent). The remaining sites are surveyed on a five-year rotating basis. This design ensures that at least 60 sites are surveyed annually while the entire watershed is surveyed every five years. An important protocol decision was made to survey for egg strings and tadpoles during the breeding season, rather than to survey for adult toads. This survey technique increases probability of detection as, under normal conditions, egg strings and tadpoles are easily observable during the day. In 2003, a supplemental study confirmed that tadpoles were twice as likely to be detected as adults (Brehme et al. 2004). In addition, the presence of egg strings and tadpoles directly indicates the presence of reproductive adults.

Because we survey for eggs and tadpoles, this protocol requires both the presence of water and arroyo toad breeding activity. Dry waterways are not surveyed. Even with sufficient rains, breeding activity may be delayed or absent entirely. Sweet (1992) attributed the lack of arroyo toad breeding in the Los Padres National Forest in 1990 to cool, dry weather in the winter and spring of that year. He hypothesized that the dry period delayed foraging and vitallogenesis (egg formation). As a result, many female arroyo toads did not have mature clutches until after most males had ceased calling. As stated previously, the percent site occupied model is limited to breeding activity only. It should be noted that successful recruitment cannot be confirmed using this survey method.

To compare the new approach and provide continuity with 1996-2000 monitoring efforts, we designed eight 1-km blocks to overlay the same transects surveyed by Holland et al. (2001) (Figure 2). We conducted night count surveys for adult arroyo toads along each of these blocks. The night surveys were designed to compare adult counts to the 1996-2000 data and to gather information on individual toads PIT tagged from 1998-2000 (Holland and Sisk 2001). We conducted night count surveys three times throughout the breeding season.

TABLE 1. ARROYO TOAD OCCUPANCY MONITORING: LOCATION AND NUMBERING OF DAY SURVEY BLOCKS AND SITES

Watershed	River/Creek[1]	Length of potential habitat (km)	No. blocks (1.5 km each)	No. site lengths[2] (250 m)	Designated[3] block/site names
San Mateo		32.3	21.5	129.0	39A-60F
	Lower San Mateo Creek	4.5	3.0	18.0	39A-41F
	Upper San Mateo Creek	12.8	8.5	51.0	42A-50C
	Cristianitos Creek	4.2	2.8	17.0	51A-53E
	Talega Creek	10.8	7.2	43.0	53F-60F
San Onofre		18.0	12.0	72.0	27A-38F
	Lower San Onofre Creek	9.0	6.0	36.0	27A-32F
	Upper San Onofre Creek	4.5	3.0	18.0	33A-35F
	South Fork San Onofre Creek	1.2	0.8	5.0	36A-36E
	Jardine Canyon Creek	3.3	2.2	13.0	36F, 37A-38F
Santa Margarita		39.0	26.0	155.9	1A-26F
	Lower Santa Margarita River	15.0	10.0	60.0	1A-10F
	Upper Santa Margarita River	14.5	9.7	58.0	11A-20E (-12F)
	Deluz Creek	7.2	4.8	29.0	12F, 21A-25D
	Roblar Creek	2.3	1.5	9.0	26A-26F, 20F, 25E, 25F
Total		89.2	59.5	356.9	1A-60F

[1] "upper" and "lower" designations are arbitrary and primarily based upon location within MCBCP, stream order, or vegetation characteristics.

[2] Six site lengths are designated within each block. They are labeled with the block number followed by the letter A, B, C, D, E, or F.

[3] Because not all waterways of the defined potential breeding habitat were perfectly divisible into a whole number of 1.5 km blocks, some blocks were split up amongst the upper ends of creeks within the same watershed.

FIGURE 1. LOCATION OF DAY SURVEY BLOCKS AND SITES FOR ARROYO TOAD EGG STRINGS AND LARVAE WITHIN MCBCP

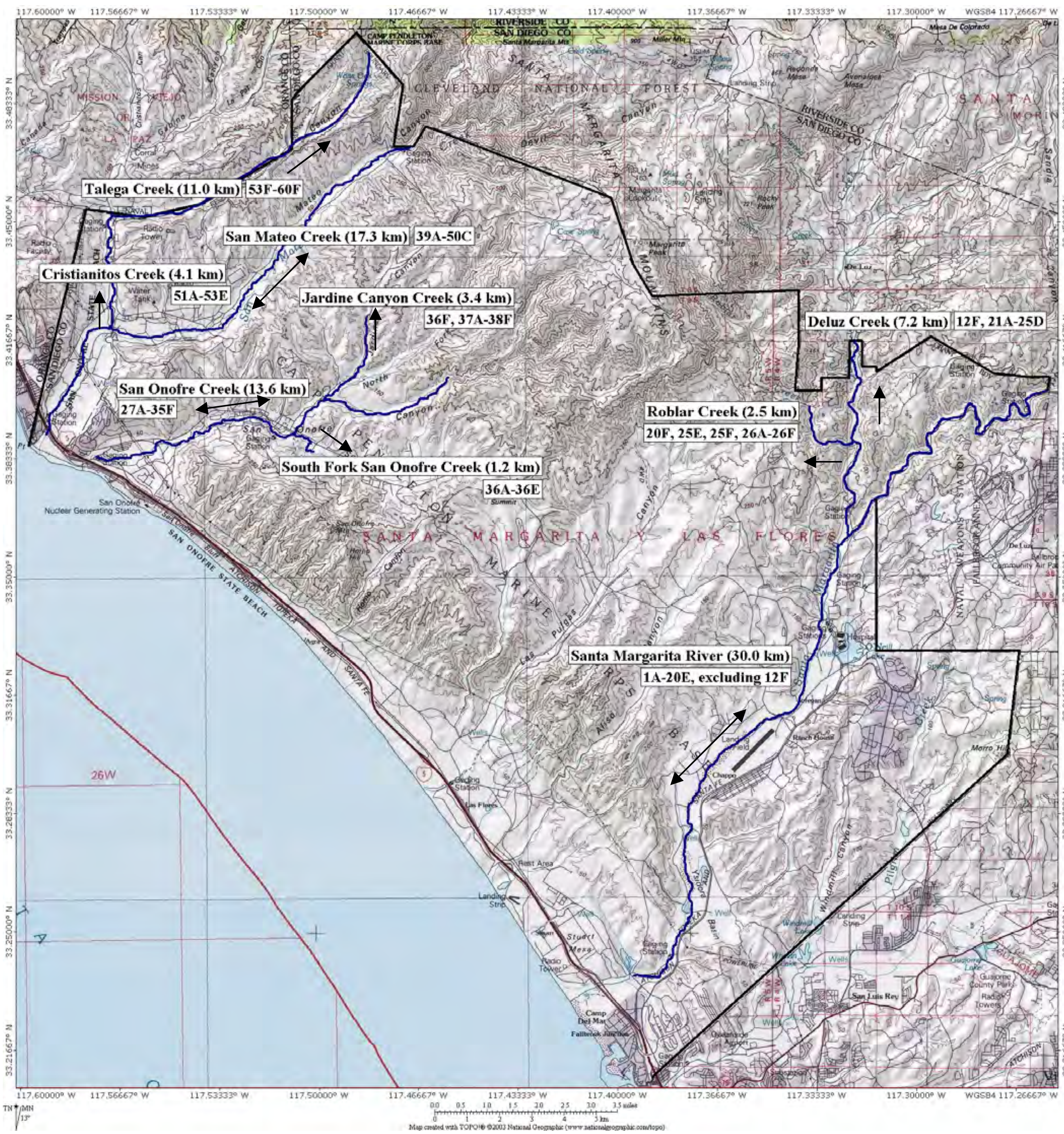
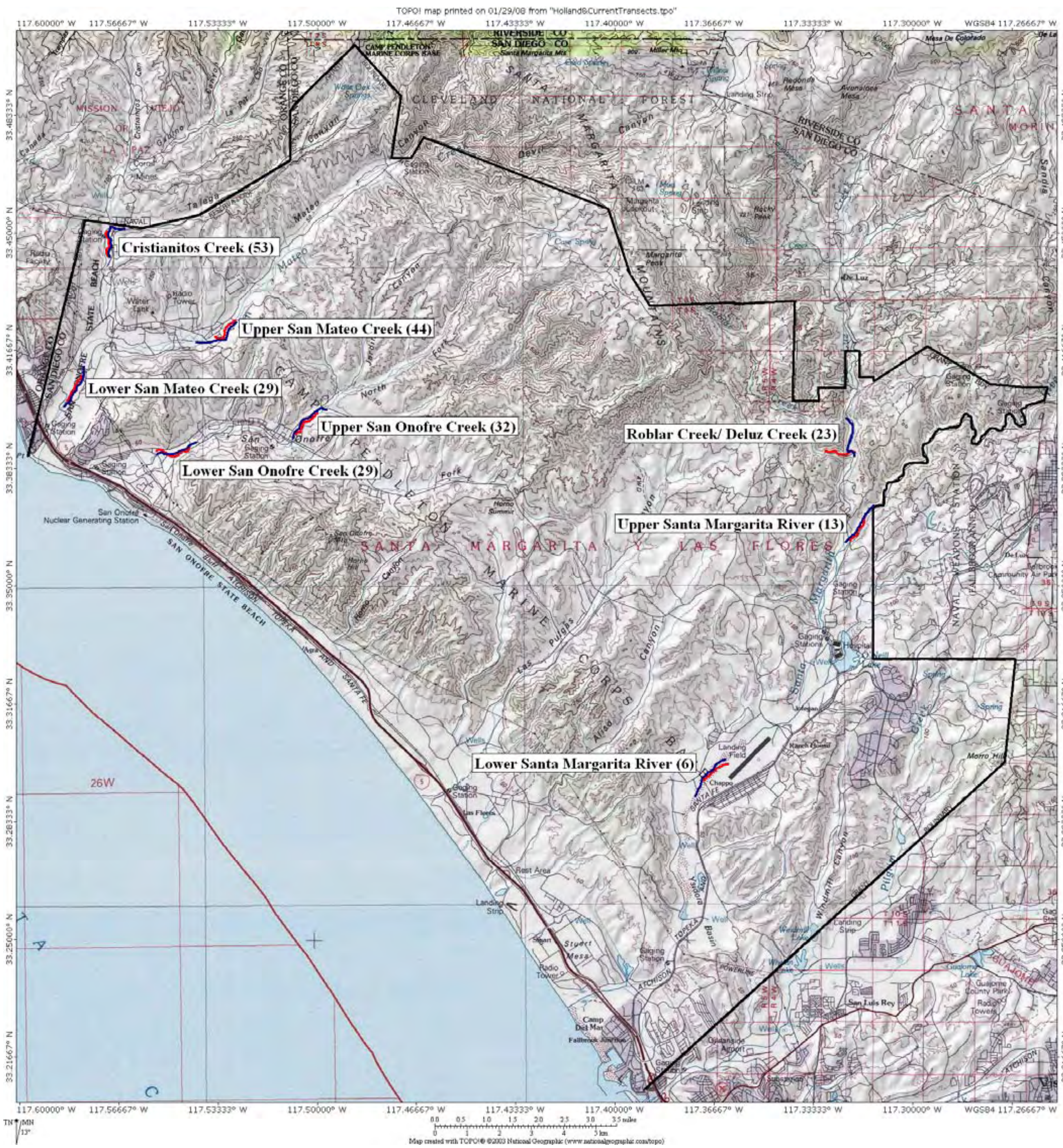


FIGURE 2. LOCATION OF NIGHT SURVEY BLOCKS FOR JUVENILE, SUB-ADULT, AND ADULT ARROYO TOADS WITHIN MCBCP



Red lines = 1996-2000 survey blocks

Blue lines= 2003-2006 survey blocks

Methods

Survey Methods

We utilized three survey methods to monitor arroyo toads from 2003 through 2006, 1) initiation of breeding surveys, 2) day surveys for presence of arroyo toad egg strings and larvae, and 3) night count surveys for juvenile, sub-adult, and adult arroyo toads. Detailed field protocols for both the day and night surveys are included as appendices in Brehme et al. (2006). General methods and changes to the day protocol implemented in 2006 are described below. We present survey methods and results individually for each of the three survey types.

Initiation of Breeding

We conducted initiation of breeding surveys to determine when arroyo toad breeding within MCBCP began for the season. Following confirmation of arroyo toad breeding activity, we scheduled subsequent day surveys for egg strings and larvae.

The advertisement call of the arroyo toad is a unique clear, whistling trill lasting between four and nine seconds (Sweet 1992). Arroyo toad females lay eggs at the male calling sites in linear envelopes ranging from 3 to 10 meters in length and containing approximately 5,000 eggs (Sweet 1992). The egg strings are very similar to those of the western toad (*Anaxyrus boreas*). However, the western toad primarily lays its eggs in deeper water (13-29 cm) on submerged vegetation. Arroyo toad egg strings are generally found in shallow water (1.5-14 cm) removed from any vegetation. Due to this association, Sweet (1992) suggests that eggs can be identified to species by microhabitat alone. Nonetheless, species determination is not conclusive until larvae have hatched. For the purposes of this survey, we confirmed breeding activity with the detection of calling males and the observation of arroyo toad larvae.

In February to early March, typically when mean temperatures warm to approximately 15°C (60°F), we checked for arroyo toad breeding activity across the Base. Every few weeks, we monitored the watersheds for positive breeding conditions (presence of low flow, shallow water along waterway edges and pooling water within the channels) and the presence of egg strings. We also began night count surveys during this period and actively listened for calling male arroyo toads. Following detections of calling male toads, we continued to monitor MCBCP for egg strings and arroyo toad larvae until breeding was verified.

Day (Presence) Surveys

Following confirmation of arroyo toad breeding activity, day surveys were scheduled at all wet permanent sites and year specific sites (5-yr rotation, Atkinson et al. 2003). We conducted these surveys to document the presence of arroyo toad egg strings and larvae, which directly indicate the presence of breeding adults. We performed one to four surveys per site in 2006. The number of surveys per site depended upon site designation and arroyo toad presence or absence on the first visit (Table 2). In 2004, we implemented some minor changes in the distribution and number of repeat surveys per site in an attempt to increase the precision of parameter estimates and our ability to fit logistic models to the data (Brehme et al. 2004).

TABLE 2. PRESENCE SURVEYS: SURVEY FREQUENCY IN 2003 VS. 2004-2006

Year(s)	Number of Sites	Site Type*	Frequency (surveys per year)	Notes
2003	16	permanent & 5-yr rotation (intensive)	4	2 sites within each of 8 blocks (coupled)
	104	permanent & 5-yr rotation	1-2	2nd survey only if not detected on 1st survey
2004-6	16	permanent (intensive)	4	not coupled - 8 new sites randomly chosen
	44	permanent	2	
	60	5-yr rotation	1-2	2nd survey only if not detected on 1st survey

* "permanent" = surveyed annually, "5-yr rotation" = surveyed every 5 year period

We attempted to survey all sites in a spatially and temporally stratified order to avoid issues of autocorrelation. However, because breeding (i.e. water flow) conditions are not uniform across the Base, there is some temporal order to surveys among watercourses. We scheduled initial surveys in the order of past breeding patterns to capture all breeding activity, particularly in the ephemeral watercourses. Arroyo toad breeding patterns at MCBCP largely correspond to hydroperiod length, from the shortest (Lower San Onofre, Talega, Cristianitos, and Roblar Creeks) to the longest (Santa Margarita River). We conducted repeat day surveys one week to one month following the first survey and closer to the latter if tadpoles were not detected on the first survey.

Two field biologists, trained in identification of arroyo toad egg strings and larvae, conducted each day survey. For each survey site, biologists walked slowly upstream and carefully scanned the water for arroyo toad egg strings and larvae. Upon discovering the first egg string or larvae, arroyo toad presence was recorded. In addition, we characterized the pool containing the initial egg string or larvae. Subsequent arroyo toad egg strings and larvae encountered during the site survey were not recorded, as presence was already established. While walking the site length, we recorded all other aquatic species observed. Upon completing the site, if no arroyo toad eggs strings or tadpoles were found, we returned to the most likely potential arroyo toad breeding pool and recorded pool characteristics. We also recorded several other landscape and water attributes at each site (Table 3). These attributes were updated in 2004 to better characterize channel and water flow conditions for use with a wider range of species and analyses.

Additionally, we began collecting arroyo toad larval abundance data during day surveys of 2006. We recorded information including, 1) a total count of tadpoles (0, 1-10, 11-25, 26-50, 51-100, 101-250, 251-500, >1000), 2) percentage of 250m-site with tadpoles, 3) percentage of early stage tadpoles, 4) percentage of mid-stage tadpoles, and 5) percentage of late-stage tadpoles. (Percentages were recorded in the following categories: 0 %, 1-10 %, 11-25 %, 26-50 %, 51-75 %, and 76-100 %.) These data are necessary in modeling any relationship between detection probability and abundance, as well as investigating the relationship between abundance and spatial distribution. However, this dataset is still relatively small, and we were unable to use abundance indices in the 2006 models.

Night Count Surveys

We conducted three surveys per year along each of the eight 1-km transects to count juvenile, sub-adult, and adult arroyo toads. We completed the first night surveys in February to early March, when nighttime temperatures warmed to approximately 15°C (60°F). We then conducted repeat night surveys at month-long intervals. Two field biologists, trained in the identification of arroyo toads, conducted each night count survey. Beginning at least 30 minutes after sunset, survey teams slowly walked the stream and adjacent floodplains using headlamps to locate and count adult arroyo toads. All toads found on land were measured (snout to urostyle length) and scanned for PIT tags using an Avid Mini Tracker©. The field protocol is provided in Brehme et al. (2006).

Vouchers and Biological Samples

We digitally photographed a subset of arroyo toad larvae and adults as vouchers. Non-target aquatic species encountered incidentally were also photographed or preserved in 95% ethanol as voucher specimens. This procedure was in accordance with CDFG Permit SC-4186 and accompanying USGS/USFWS Memorandum of Understanding. We also obtained approval from AC/S Environmental Security personnel on Base. All vouchers are stored at the USGS/WERC specimen repository in the San Diego Field Station.

In 2006, we also began swabbing a representative number of arroyo toad adults and larvae for amphibian chytrid fungus (*Batrachochytrium dendrobatidis*). Amphibian chytrid or *Bd* is a fungus linked to amphibian mortality and population declines worldwide (Berger et al. 1998, Bosch et al. 2001, Muths et al. 2003, Lips et al. 2004, Stuart et al. 2004). It attacks keratinized parts of the body (Berger et al. 1998), particularly affecting amphibians during and after metamorphosis. We sent samples collected within MCBCP to the Zoological Society of San Diego's Center for Conservation and Research for Endangered Species (CRES) facilities located at the San Diego Wild Animal Park in Escondido, CA. All laboratory analyses were performed at CRES.

TABLE 3. PRESENCE SURVEYS: COVARIATES RECORDED IN 2003 VS. 2004-2006

2003	2004-6
Landscape attributes	
Presence of sand (>10m)	Proportion of channel with sand
Presence of sandy terraces (>10m)	Proportion of 2nd level (flood plain, terrace, or upland) with sand
Presence of channel braiding (>10m)	*
Habitat Quality Rating (based on above variables)	*
*	Entrenchment ratio (bank width/ flood plain width)
Water conditions	
*	Water temperature
*	Water depth (at thalweg)
*	Wetted channel width
*	Surface water velocity
*	Water chemistry (pH, conductivity, dissolved oxygen)
Vegetation	
Presence of non-native aquatic/ riparian plants (record species)	Presence of non-native aquatic/ riparian plants (record species)
*	Channel vegetation type
*	Percent cover- aquatic submerged/floating vegetation
*	Percent cover- aquatic emergent vegetation
*	Percent cover- algal mat
*	2nd level: Presence of floodplain/terrace or upland
*	Vegetation type
*	Percent cover- herb layer
*	Percent cover- shrub layer
*	Percent cover- tree layer
Pool characterization	
Percent cover- sand	Percent cover- sand
*	Percent aquatic submerged/floating vegetation
*	Percent aquatic emergent vegetation
Percent overhead cover	Percent overhead cover
Water temperature	Water temperature
Pool depth	Pool depth
Pool turbidity	Pool turbidity
Other	
Presence of other native & non-native aquatic animals (record species)	Presence of other native & non-native aquatic animals (record species)
*	Index of arroyo toad larval abundance (counts, percent of reach with larvae present)

* no data taken

Data Analyses

We analyzed arroyo toad presence data from the day surveys using the log-linear modeling program, PRESENCE (MacKenzie et al. 2002, 2003). During the day surveys, we collected a large amount of environmental, landscape and water covariate data that were hypothesized to affect detection probability, occupancy, colonization, and/or extinction probabilities for the arroyo toad (Table 3). To understand multivariate patterns and to reduce our number of possible covariates, we first ran Pearson and Spearman rank tests for all covariates to determine which were correlated. If two or more covariates were highly correlated (i.e. Bonferroni adjusted $p<0.05$ and $r>0.25$), we chose the single variable most likely to directly affect arroyo toad occupancy or detectability. Before running any models, we generated our *a priori* hypotheses from this reduced set of covariates (Table 4). All hypotheses were carefully formulated to prevent issues with 'data dredging' and high probabilities of Type II errors leading to incorrect inferences (Burnham and Anderson 2002).

In summary, our *a priori* expectation was that the probability of detecting arroyo toad egg strings and larvae would be greater when water conditions were favorable for breeding (low flow shallow water index). We expected egg strings and larvae to be difficult to detect in the presence of large amounts of aquatic vegetation (aquatic vegetation index) and in the presence of predators and competitors, although this relationship could be temporarily positive as we expect predators to congregate in areas of high prey density. We hypothesized that several factors would affect probabilities of occupancy and colonization. Arroyo toads are known to prefer high sand cover (sand cover index) and low vegetative cover (aquatic vegetation index). They may require a minimum hydroperiod (watershed, ephemeral/perennial) to breed successfully, which in turn may influence their continued occupancy or colonization in future years. Conversely, very long hydroperiods may increase the numbers of non-native aquatic species and have a negative or nonlinear effect. We also tested the possibility that detection and colonization probabilities would vary by year for all parameters.

In 2004, we incorporated the measurement of several water flow and landscape variables that were not part of the survey data in 2003 (see Table 3, Atkinson et al. 2003, Brehme et al. 2004). Analysis of multi-season datasets in PRESENCE requires that covariate values exist for all values of the response variable (arroyo toad detection). Therefore, we used only 2004 to 2006 data in the multi-season models. We also used single season models to test the 2006 arroyo toad data individually.

We used Akaike's Information Criterion (AIC) and model selection procedures described by Burnham and Anderson (2002) to rank and compare models. We approached model building in a stepwise manner. First, we focused on modeling detection probabilities. Then, we selected the best models from that analysis to use in modeling first year occupancy, colonization, and extinction probabilities. For each parameter, covariates were evaluated individually. If more than one covariate resulted in model AIC values that were substantially lower than the null model, they were then evaluated together. Models that showed evidence of overfitting (i.e. no convergence reached, variance-covariance matrix unable to be produced, standard error of a parameter estimate greater than parameter estimate) were not evaluated. The PRESENCE software is currently incapable of calculating model fit parameters for multi-season data (i.e. dispersion or c-hat) which can be used to calculate adjusted quasi-AIC and standard error values (MacKenzie and Bailey 2004, Darryl MacKenzie personal communication). Without a model fit parameter to adjust for underestimated standard errors, we have no indices to determine how well the top models fit our survey data. Therefore, the unadjusted values presented should be interpreted with caution.

We calculated the percentage of wet area on Base by dividing total number of wet sites by the total sites surveyed. The percentage of wet area occupied was obtained from PRESENCE. We obtained the 2003-2005 values for wet area occupied from the 2003-2005 multi-year model as described in Brehme et al. (2006). We determined the 2006 values for wet area occupied from the 2006 single-season model presented in this report. The percent area occupied by arroyo toads was calculated by multiplying percentage of wet area occupied by percentage of wet area. We used multiple linear regression to analyze the night count survey data from 1996-2001 (Holland et al. 2001) in combination with our 2003-2006 adult count data.

TABLE 4. *A PRIORI* PAO MODEL HYPOTHESES

Covariate	Definition	Correlated Variables	Hypothesized Effect
Detection probability/ Activity (ρ)			
Year	Year of survey	n/a	n/a
*Low flow shallow water index	Proportion of site containing low flow shallow water	Channel velocity, discharge, dissolved oxgen (DO_{sat})	Positive
*Aquatic vegetation cover index	Total cover of submergent, emergent, algae mat	Component variables correlated	Negative
Presence of predators and/or competitors (tested individually)	Western toad, crayfish, bullfrog, predatory fish, non-native species index	Species data: detected, not detected. Non-native index is sum of crayfish, mosquitofish, predatory fish and bullfrog detections.	Negative
Initial Presence/ Absence (Ψ) and Colonization/Extinction (γ, ε)			
Year	Year of survey	n/a	n/a
*Channel sand cover index	Proportion of channel with sand	Flood plain sand cover	Positive
*Aquatic emergent vegetation index	Yearly estimates of total cover from emergent vegetation	Aquatic submergent vegetation index, aquatic cover index	Negative
*Disturbance level index	Level of disturbance from training activities (artillery, troops, heavy equipment)	n/a	Negative
Watershed	Each of the three watersheds is given unique value	n/a	Both
Ephemeral/Perennial	Each survey block is evaluated as ephemeral or perennial	n/a	Both
Presence of predators and/or competitors (tested individually)	Western toad, crayfish, bullfrog, predatory fish, non-native species index	See above	Negative

Landscape/Vegetation Index Values (0= 0%, 1= 1-10%, 2= 11-25%, 3= 26-50%, 4= 51-75%, 5= 76-100%)
Disturbance Index values (0= none, 1= low, 2= high)
* Covariate data collected in 2004, 2005, and 2006. Not collected in 2003.

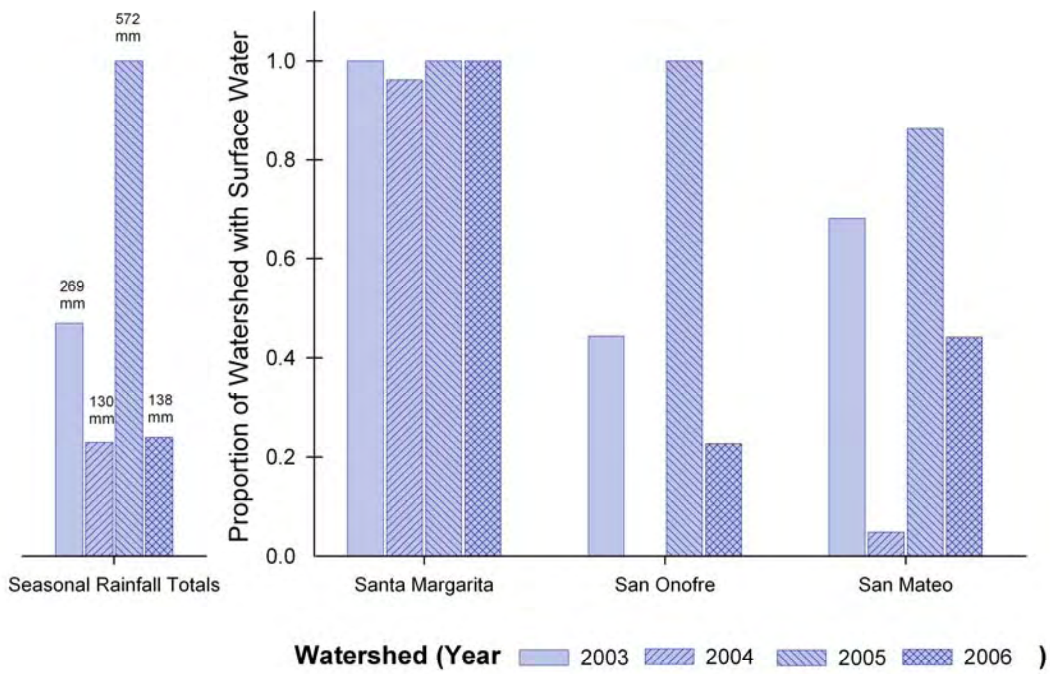
Results

Weather and Watershed Patterns

From July 2005 to June 2006, seasonal rainfall totaled 138 millimeters (5.4 inches) in San Diego County (NCDC 2007). This amount is approximately half the historic average of 274 millimeters (10.8 inches). Consequently, the largely ephemeral San Onofre and San Mateo Creeks remained partially dry throughout the 2006 arroyo toad breeding season from March to June.

Wide variations in seasonal rainfall have marked the past several years of arroyo toad monitoring at MCBCP. Seasonal rainfall totals for San Diego County (July to June) and the proportion of each watershed with surface water at the onset of the breeding season are shown in Figure 3. The intermittent availability of surface water directly influences arroyo toad breeding, larval development, and the chance of metamorphosis.

FIGURE 3. PROPORTION OF EACH WATERSHED WITH SURFACE WATER AND SEASONAL RAINFALL TOTALS FROM 2003-2006



In addition to availability of surface water, the timing and quantity of rain, along with channel characteristics, affect the frequency, magnitude, and duration of flow events, which in turn affect channel morphology and stream habitat (USEPA 1997, McMahon et al. 2003). These measures varied widely among years and among watersheds (Table 5). All values were calculated from daily USGS water gauge data (USGS 2008). Data were limited to active USGS gauges located at the upper portions of the Santa Margarita River and San Mateo Creek and at the lower portion of San Onofre Creek.

TABLE 5. RAINFALL AND STREAM HYDROLOGY CHARACTERISTICS

	2002-3	**2003-4**	**2004-5**	**2005-6**
Seasonal Rainfall (mm)	269	130	572	138
Santa Margarita River (gauge 11044300 - upstream from MCBCP border)				
frequency (no. of pulses > 100 ft^3/sec)	5	3	10	5
duration (no. of days > 100 ft^3/sec)	14	5	51	7
magnitude(maximum discharge ft^3/sec)	2500	662	4840	603
San Mateo Creek (gauge 11046300 - downstream from mouth of Devil's Canyon at MCBCP border)				
frequency (no. of pulses > 100 ft^3/sec)	3	0	8	1
duration (no. of days > 100 ft^3/sec)	8	0	58	2
magnitude(maximum discharge ft^3/sec)	816	72	3740	325
San Onofre Creek (gauge 11046250 - upstream from mouth)				
frequency (no. of pulses > 100 ft^3/sec)	2	0	3	0
duration (no. of days > 100 ft^3/sec)	2	0	16	0
magnitude(maximum discharge ft^3/sec)	341	54	1600	0

$1 ft^3 = 0.0283 m^3$

Vegetation

Native riparian plant communities varied within and among the watersheds (Appendix 1). Mulefat riparian scrub and southwestern willow scrub were the most commonly recorded vegetation types. Mulefat riparian scrub is dominated by mulefat (*Baccharis salicifolia*) with lesser components of willow (*Salix*), cottonwood (*Populus fremontii*), and sycamore (*Platanus racemosa*). It is often found in the channel and floodplain, associated with coarse alluvial soils and subject to regular disturbance events (i.e., episodic flooding, scouring). Southern willow scrub is dominated by willow with a lesser component of mulefat (Zedler et al. 1997). It exists on flood plains and terraces subject to less frequent water inundation or disturbance events. Mulefat riparian scrub was common along the floodplains and terraces of the San Onofre and San Mateo Watersheds, while terraces along the Santa Margarita River contained mainly southern willow scrub.

In 2003 and 2004, the upper Santa Margarita River also had large amounts of aquatic emergent vegetation in the channel and floodplains, including dense cattails (*Typha latifolia*) and sedges (*Carex*) along the river margins. These species apparently had a stabilizing effect on the riverbanks, as they were typically associated with deep, narrow portions of the river. The occurrence of cattails and sedges was greatly reduced following the 2005 scouring events. In 2006, these species again became more prevalent along the Santa Margarita River. In fact, the median percent cover within the Santa Margarita River channel increased from 1-10% in 2005 to 11-25% in 2006. A similar pattern was observed between 1998 and 2000 during USGS-San Diego State University (SDSU) fish surveys of the Santa Margarita River (Warburton et al. 2000). We also documented increases in channel cover for San Mateo Creek in 2006 (Appendix 1).

Of the non-native species recorded, grasses (*Bromus*, *Avena*, *Cynodon dactylon*), mustard (*Brassica*), and fennel (*Foeniculum vulgare*) were the most widespread, occurring in all major drainages and watersheds. Prevalence of giant reed (*Arundo donax*) was reduced due to recent removal efforts. However, we observed scattered patches along portions of the San Mateo Creek, and large contiguous stands along the lower Santa Margarita River. Similarly, we recorded tamarisk along portions of all watersheds, but large stands persisted only along the lower Santa Margarita River. Watercress (*Rorippa nasturtium-aquaticum*), an aquatic emergent plant, has become well established within the upper and lower sections of the Santa Margarita River, as well as Deluz Creek. We also observed scattered patches of watercress in the upper portions of San Mateo and San Onfre Creeks. Other non-native plants observed included, exotic thistle (*Centaurea*, *Cirsium*, *Cyanara*), castor bean (*Ricinis communi*s), palm tree (Palmaceae), tree tobacco (*Nicotiana glauca*), hemlock (*Conium*), and periwinkle (*Vinca*). Patch size classes and locations of the most common species among years are presented in Appendix 1.

Non-Target Aquatic Species

We documented larvae and adults of many non-native aquatic species within MCBCP (Appendix 2). These species included bullfrog, mosquitofish (*Gambusia affinis*), bullhead catfish (*Ameiurus*), common carp (*Cyprinus carpio*), green sunfish (*Lepomis cyanellus*), bass (*Micropterus*), crayfish, Asian clam (*Corbicula fluminea*), and beaver (*Castor canadensis*). All were detected in the Santa Margarita River. We also observed bullfrog, mosquitofish, bullhead catfish, green sunfish, and bass in San Mateo Creek, which can be perennial in wet years. Non-native aquatic species went undetected in the ephemeral San Onofre Watershed. During surveys from 2003 to 2005, we did not record any non-native species in Roblar Creek, but mosquitofish were documented in 2006.

Aside from non-native species, we documented seven non-target native aquatic species (Appendix 3). These species included western toad, California treefrog (*Pseudacris cadavarina*), Pacific treefrog (*Pseudacris regilla*), California newt (*Taricha torosa*), arroyo chub (*Gila orcutti*), two-striped garter snake (*Thamnophis hammondii*), and western spadefoot toad (*Spea hammondii*). The Pacific treefrog, California treefrog, western toad and two-striped garter snake were the most widespread, occurring in all three watersheds. We also observed arroyo chub during all years along the Santa Margarita River. Infrequently, we observed spadefoot toads or larvae along upper San Mateo Creek, Cristianitos Creek, and Jardine Canyon. These observations should be considered purely incidental, as spadefoot toads primarily live and breed in upland areas, rather than creeks and rivers.

The California newt (*Taricha torosa*) was largely isolated to Roblar Creek, particularly associated with a perennial plunge pool that exists approximately 750 m from the confluence of Deluz Creek. Detections of this species were variable among years due to a combination of fire and flood events. In 2003, we observed 24 newts at the Roblar plunge pool and creek. The pool completely filled with sediment in 2004, and subsequent surveys detected a single newt in nearby Deluz Creek. In 2005, water scouring recreated the pool and we recorded 37 newts, a newt larva, and a single egg mass. A survey at Roblar Creek in 2006 resulted in the detection of a single adult newt.

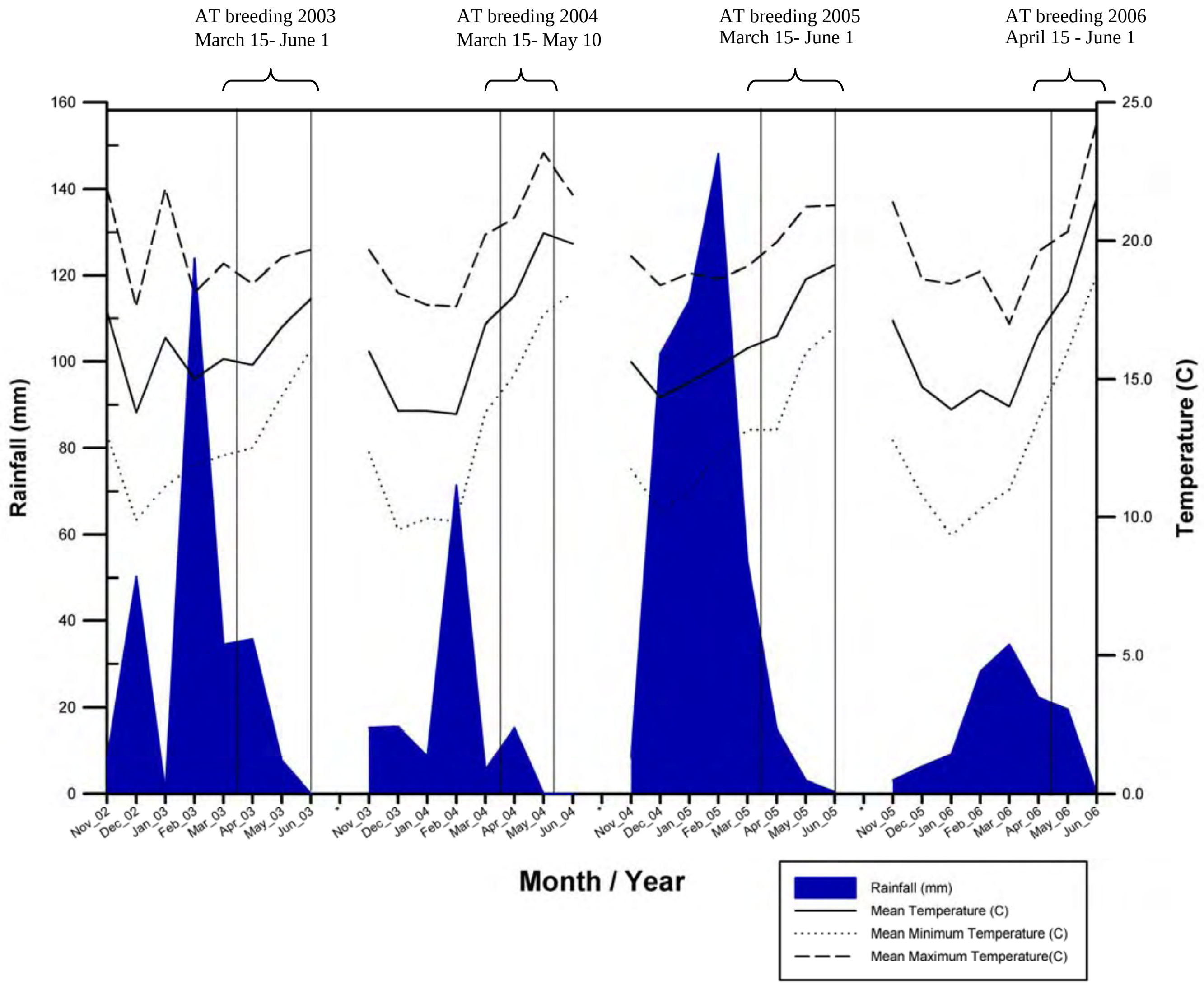
Arroyo Toad: Initiation of breeding

The arroyo toad breeding season of 2006 was preceded by a cool winter and relatively late rainfall. Monthly rainfall totals peaked in March, and mean air temperatures warmed to approximately 15°C (60°F) in April (NCDC 2007). We documented arroyo toads calling in late March along lower reaches of the Santa Margarita River and Deluz Creek, but did not observe egg strings or tadpoles until late April. The majority of breeding activity took place in May.

The weather conditions of 2006 varied from those conditions recorded in previous years. Mean air temperatures warmed to approximately 15°C (60°F) in January, March, and February of 2003, 2004, and 2005, respectively (NCDC 2007). Rainfall peaked in February of each year, and arroyo toads began breeding consistently in mid-March when the rainfall largely subsided. The cooler temperatures and late rains of 2006 delayed arroyo toad breeding within MCBCP by over a month.

Arroyo toad breeding was not temporally homogenous across the Base. Four years of data collection demonstrate that the timing of breeding largely follows a hydroperiod gradient. Egg laying occurred up to one month earlier in streams with the shortest hydroperiods, as compared to the mostly perennial Santa Margarita River. We calculated periods of breeding on MCBCP using egg string records and back-calculating ages of young larvae. The breeding periods are presented overlaying monthly rainfall, as well as mean, mean minimum and mean maximum temperatures from 2003 to 2006 (Figure 4).

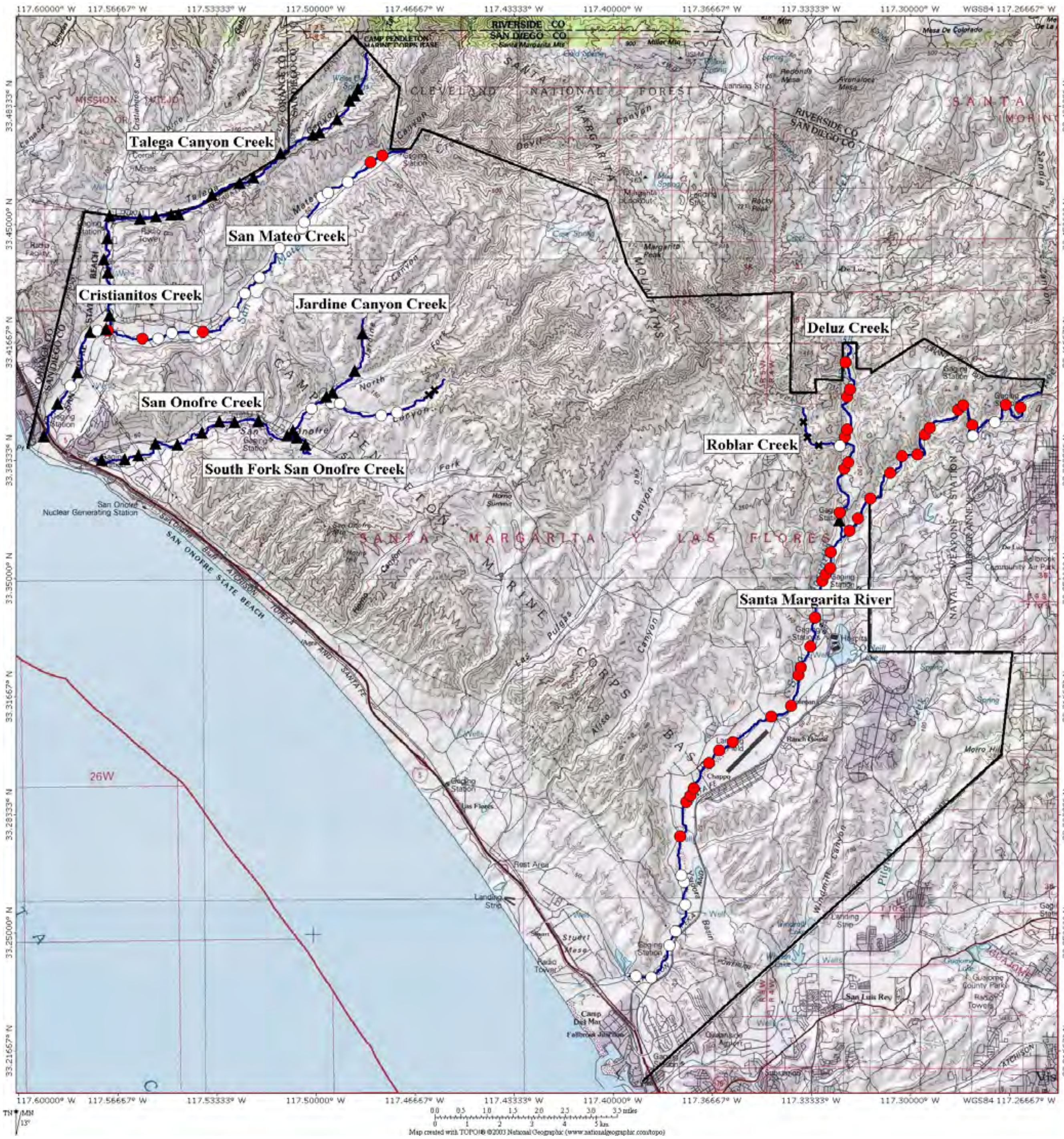
FIGURE 4: ARROYO TOAD BREEDING PERIODS AND CLIMATIC DATA



Arroyo Toad: Day (Presence) Surveys

During the 2006 field season, we conducted presence surveys for arroyo toads at 114 sites within MCBCP. Sixty-four percent of sites surveyed contained water during our first survey efforts (Table 6, Figure 5). Dry areas included Talega Canyon Creek, portions of Cristianitos Creek, San Onofre Creek, and Jardine Canyon Creek. None of the sites located along the Santa Margarita River were dry. Survey results are presented in Figure 5.

FIGURE 5. RESULTS OF THE 2006 ARROYO TOAD PRESENCE SURVEYS



Black triangle = Dry site

White circle = Wet site with no arroyo toad larvae detected after 2 visits

Red circle = Wet site with arroyo toad larvae detected after 1-2 visits

Black cross = Inaccessible site, not visited

TABLE 6. ARROYO TOAD OCCUPANCY WITHIN AND AMONG WATERSHEDS

	2003	2004	2005	2006
All MCBCP Arroyo Toad Habitat				
% Area wet	78.9	44.4	94.9	64.0
% Area Occupied (se)	72.0 (2.8)	34.2 (3.4)	90.1 (2.3)	52.9 (4.7)
% Wet Area Occupied (se)	91.1 (3.5)	77.1 (7.6)	95.0 (2.5)	82.7 (7.4)
Among Watersheds				
Santa Margarita				
% Area wet	100.0	96.2	100.0	100.0
% Area Occupied	84.8 (5.9)	78.5 (7.3)	99.5 (2.1)	85.0 (7.2)
% Wet Area Occupied	84.8 (5.9)	81.6 (7.6)	99.5 (2.1)	85.0 (7.2)
San Mateo				
% Area wet	68.2	4.9	86.4	45.5
% Area Occupied	66.7 (4.4)	0.0	74.5 (5.5)	10.1 (4.6)
% Wet Area Occupied	97.9 (6.5)	0.0	86.2 (6.4)	22.3 (10.0)
San Onofre				
% Area wet	44.4	0.0	100.0	22.7
% Area Occupied	40.4 (3.9)	0.0	91.9 (6.2)	0.0
% Wet Area Occupied	90.9 (8.7)	0.0	91.9 (6.2)	0.0

Proportion Area Occupied (PAO)

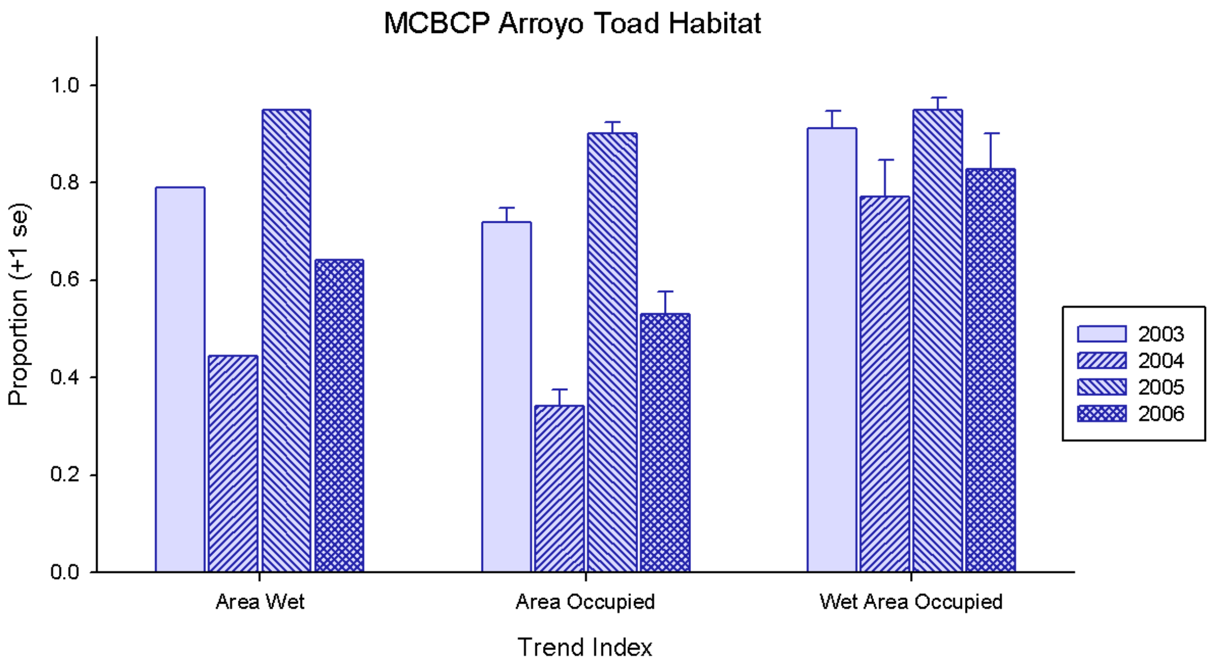
The proportion of arroyo toad habitat containing surface water during breeding season was highly variable among the years (44-95%). Similarly, the percentage of habitat occupied by breeding toads was highly variable (34-90%). Normalizing the data for available surface water resulted in a more stable metric for arroyo toad occupancy within MCBCP (77-95%). Using this metric, we found a 15.4% (se= 8.95) overall decline in occupied habitat from 2003 to 2004, followed by a 23.2% (se= 12.56) increase in occupied habitat from 2004 to 2005. Arroyo toad occupancy declined again by 12.9% (se= 8.12) from 2005 to 2006 (Table 6, Figure 6).

From 2003 to 2006, the mean percentage of habitat occupied by breeding toads was more variable along the ephemeral watersheds, San Mateo (0-98%) and San Onofre (0-92%), than the predictably seasonal Santa Margarita Watershed (82-100%). In the San Onofre Watershed, no breeding was documented in either 2004 or 2006. In the San Mateo Watershed, there was no breeding in 2004, but we detected limited breeding in 2006. In comparing the wet years, 2003 and 2005, there were no significant changes in occupancy for the San Onofre and San Mateo Watersheds.

In 2006, only 64% of potential arroyo toad breeding habitat contained water during our survey efforts. However, 82.7% (se= 7.4) of the available wet habitat was occupied by breeding arroyo toads. We recorded the highest occupancy in the Santa Margarita Watershed (85.0%), followed by the San Mateo (22.3%) and San Onofre (0.0%) Watersheds. The percentage of wet area occupied by arroyo toads was lower than expected in both San Mateo and San Onofre Creeks. Although San Onofre contained 22.7% wet area, we detected no arroyo toad breeding. In San Mateo Creek, arroyo toads occupied only 22.3% of the wetted area, resulting in a significant 74.1% (se= 11.76) decrease in occupied breeding habitat from 2005 to 2006. We comment further on this result in the Discussion section of this report.

The perennial Santa Margarita River contained water during the spring months of all years. Mirroring the overall changes in occupancy, the Santa Margarita River saw a 4.0% (se= 11.16) decrease in occupied breeding habitat from 2003 to 2004. This decrease was followed by a significant 22.1% (se= 11.64) increase from 2004 to 2005. The 2005 increase in occupancy was followed by a decrease of 14.6% (se= 7.46) in 2006 (Table 6, Figure 7).

FIGURE 6. TRENDS IN ARROYO TOAD OCCUPANCY WITHIN MCBCP



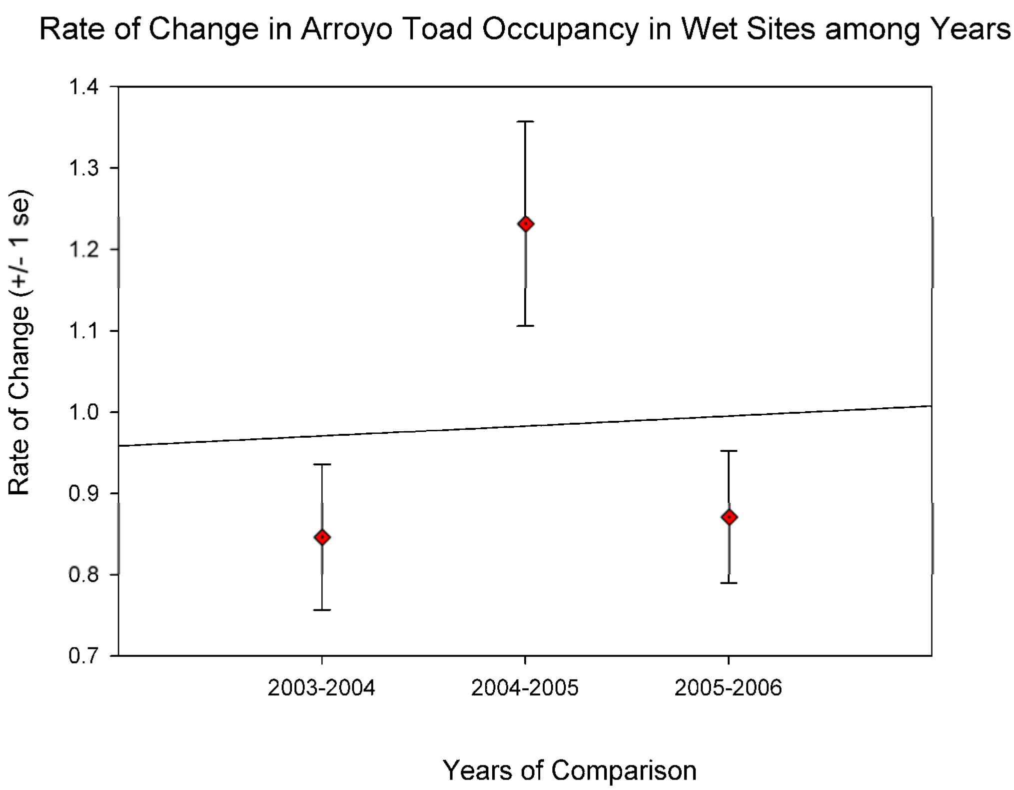
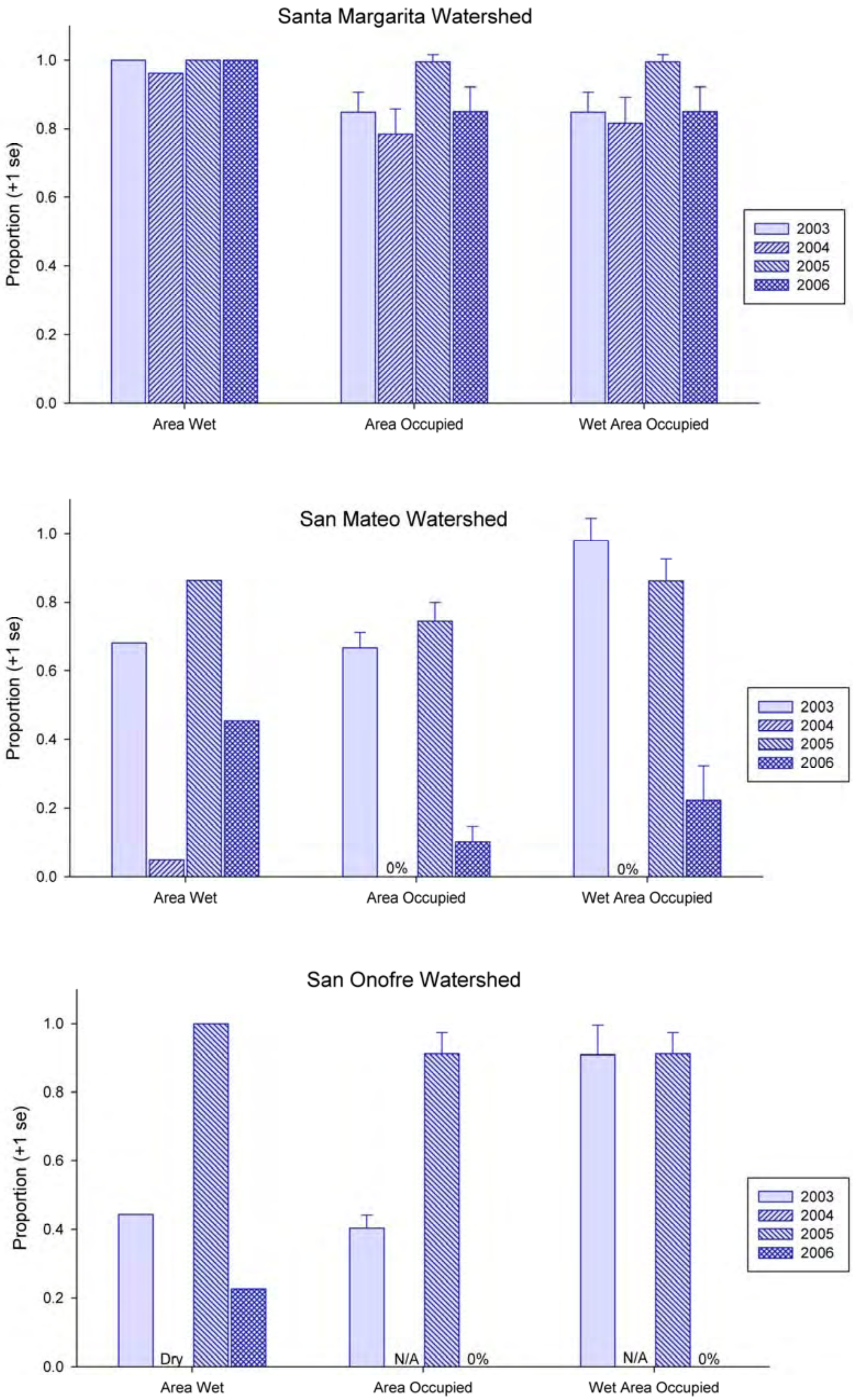


FIGURE 7. TRENDS IN ARROYO TOAD OCCUPANCY AMONG WATERSHEDS



Occupancy Models

We generated PAO models for two different time spans, 1) single season models for 2006 and 2) multi-season models for 2004 to 2006. For each set of predictive models, covariates significantly explaining variability in detection probability (ρ) and occupancy (ψ) are presented. All multi-season models also include colonization (γ) and extinction (ε). Extinction was calculated as a function of colonization (ε =1-γ), because convergence could not be reached when the two parameters were estimated separately.

Single Season Models - 2006

Three similar models best explained the variability in arroyo toad occupancy and accounted for 93% of total model weights (Table 7). In the top model, the low flow index (LowFlow) was the strongest predictor of detecting arroyo toad larvae. The low flow index represents a measure of the amount of low flow shallow water (appropriate breeding habitat) present within a 250-m site. The index ranges from 0-5 as a percentage of site length from 0%, 1-10%, 11-25%, 26-50%, 51-75%, and 76-100%, respectively. For these analyses, the 0 and 1 indices were combined into the 1 index (0-10%) due to low numbers of 0 values. In 2006, the odds of detecting arroyo toad larvae averaged 1.79 (se= 0.44) times higher for each increase in the low flow index. This means we had 10 times higher odds of finding arroyo toad larvae at a site containing 76-100% low flow shallow water than a site containing less than 10% low flow shallow water. The average probability of detecting arroyo toad larvae if they were present was 0.70 (se= 0.07).

The second and third models highlight the non-native species index (NonNativeIndex) as another predictor of detection. The non-native species index ranges from 0-4 and represents a count of the following species observed within a 250-m site: bullfrog, mosquitofish, crayfish, and large predatory fish (bullhead catfish, common carp, green sunfish, and bass). In 2006, the probability of detecting arroyo toad larvae increased an average of 1.58 (se= 0.37) times with each additional aquatic non-native species category, so at a site with all four non-native species categories, we were 6 times more likely to find arroyo toad larvae. This information runs counter to our predictions, as well as results of the 2003-2005 models presented by Brehme et al. (2006). The decrease in AIC with the inclusion of this covariate in the model is minimal, but the result is interesting and warrants further comments found in the Discussion section of this report.

Occupancy for arroyo toads in 2006 was best explained by the sand cover index (SandCover). This index ranges from 0-5 as a percentage of site length from 0 %, 1-10%, 11-25%, 26-50%, 51-75%, and 76-100%, respectively. The odds of arroyo toads occupying a site were 1.9 (se= 0.23) times higher for each increase in the sand cover index. Therefore, sites containing 76-100% sand cover were 25 times more likely to be occupied by arroyo toads. Although the sand cover index was the best predictor of arroyo toad occupancy, models that included ephemeral versus perennial (Ephem/Peren) site classifications also outperformed the null model (Table 7). In these models, the odds of arroyo toads occupying a perennial site were 14.4 (se= 0.95) times greater than occupation of an ephemeral site.

TABLE 7. ARROYO TOAD OCCUPANCY MODEL COMPARISON FOR 2006

PARAMETERS: OCCUPANCY = PSI (ψ), DETECTION PROBABILITY = P (ρ)

Model	AIC	delta AIC	AIC wgt	Model Likelihood	No.Par.	(-2*LogLike)	
psi(SandCover2006),p(LowFlow_06)	153.43	0.00	0.40	1.00	4	145.43	*best models in green*
psi(SandCover2006),p(LowFlow_06, NonNativeIndex_06)	153.80	0.37	0.34	0.83	5	143.80	
psi(SandCover2006),p(NonNativeIndex_06)	154.97	1.54	0.19	0.46	4	146.97	
psi(Ephem/Peren),p(LowFlow_06, NonNativeIndex_06)	158.51	5.08	0.03	0.08	5	148.51	
psi(Ephem/Peren),p(LowFlow_06)	158.90	5.47	0.03	0.06	4	150.90	
psi(Ephem/Peren),p(NonNativeIndex_06)	160.33	6.90	0.01	0.03	4	152.33	
psi(.),p(LowFlow_06, NonNativeIndex_06)	164.90	11.47	0.00	0.00	4	156.90	
psi(.),p(LowFlow_06)	168.60	15.17	0.00	0.00	3	162.60	
psi(.),p(NonNativeIndex_06)	169.01	15.58	0.00	0.00	3	163.01	
psi(.),p(AquaticVegIndex_06)	172.24	18.81	0.00	0.00	3	166.24	
psi(.),p(.)	172.37	18.94	0.00	0.00	2	168.37	*null model*

Note: Other covariates tested for psi included: Disturbance Index, Non-Native Species Index, PRCL presence, BUBO presence, RACA presence, Predatory Fish presence, Aquatic Emergent Vegetation Index and Watershed. Models are not shown if AIC values were less than null model or showed evidence of poor fit (no convergence, no covariance matrix, standard errors > parameter estimates).

Multi-Season Models for 2004-2006

Two similar models best explained the variability in arroyo toad observations from 2004 to 2006. These two top models accounted for 88% of total model weights (Table 8). In both, presence of the western toad (BUBO) was the strongest predictor of detecting arroyo toad larvae. On any given survey, the probability of detecting arroyo toad larvae increased an average of 5.13 (se= 0.45) times with western toad presence. The average probability of detecting arroyo toad larvae if they were present was 0.85 (se= 0.02).

Initial occupancy for arroyo toads in 2004 was best explained by the presence of predatory fish (PredFish), the sand cover index (SandCover), and non-native species index (NNSp2004). The odds that arroyo toads occupied a site were 13.56 (se= 1.06) times lower when predatory fish were present and 2.69 (se= 0.52) times lower with each additional group of non-native species. Conversely, the odds of arroyo toad occupation were 7.89 (se= 1.65) times higher for each increase in the sand cover index.

The model including year (Season) was superior to the model which assumed colonization was constant over time. This ranking indicates that the rate of colonization/extinction was not constant over the 3-year period. From 2004 to 2005, the odds of an unoccupied site becoming occupied were 95:1 (se= 2.04). From 2005 to 2006, the odds of an unoccupied site becoming occupied were 1.6:1 (se= 0.27).

TABLE 8. ARROYO TOAD 3-YEAR OCCUPANCY MODEL COMPARISON 2004-2006

PARAMETERS: OCCUPANCY = PSI (ψ), COLONIZATION = GAMMA (γ), EXTINCTION = 1-GAMMA, DETECTION PROBABILITY = P (ρ)

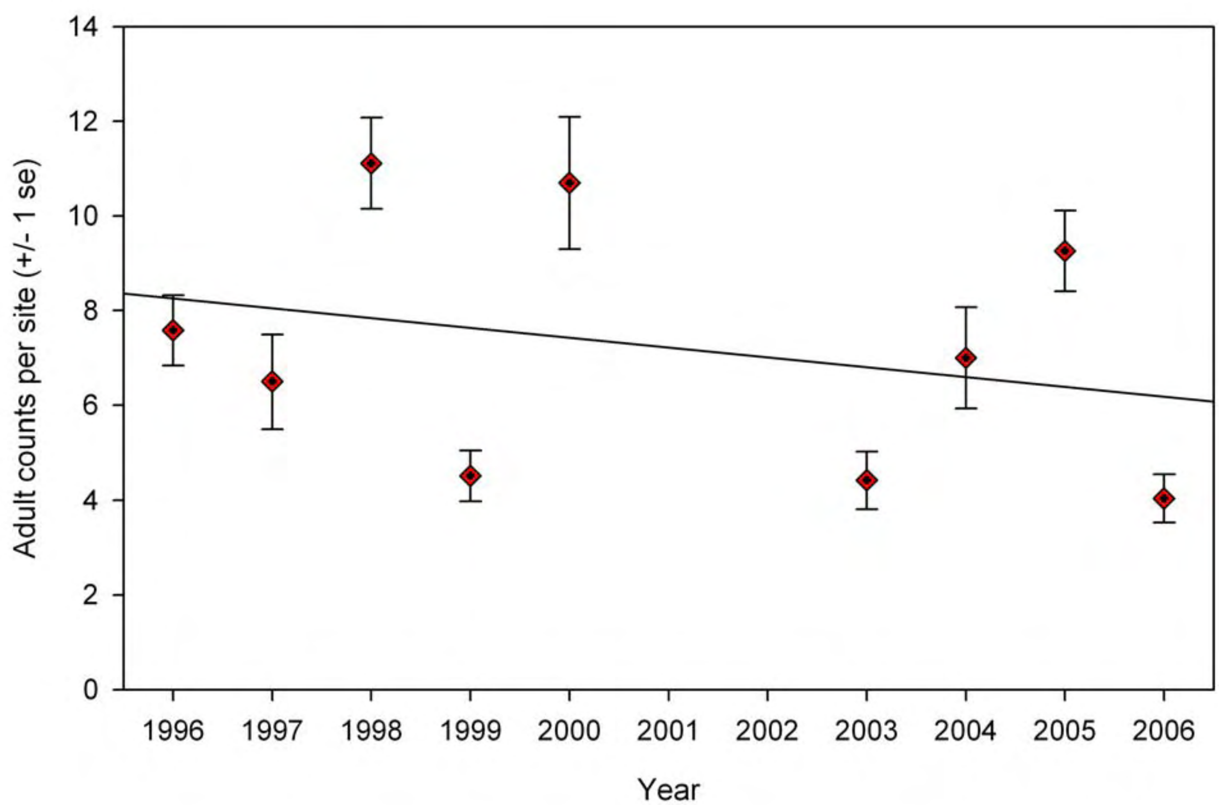
Model	AIC	deltaAIC	AIC wgt	Model Likelihood	No.Par.	(-2*LogLike)	
psi(PredFish2004),gam(Season),eps=1-gam,p(BUBO_04-6)	426.65	0.00	0.72	1.00	6	414.65	*best models in green*
psi(SandCover2004-2006),gam(Season),eps=1-gam,p(BUBO_04-6)	429.64	2.99	0.16	0.22	6	417.64	
psi(NNSp2004),gam(Season),eps=1-gam,p(BUBO_04-6)	430.71	4.06	0.09	0.13	6	418.71	
psi(.),gam(Season),eps=1-gam,p(BUBO_04-6)	433.50	6.85	0.02	0.03	5	423.50	*γ varies by year*
psi(PredFish2004),gam(.),eps=1-gam,p(BUBO_04-6)	458.65	32.00	0.00	0.00	5	448.65	
psi(SandCover2004-2006),gam(.),eps=1-gam,p(BUBO_04-6)	461.76	35.11	0.00	0.00	5	451.76	
psi(NNSp2004),gam(.),eps=1-gam,p(BUBO_04-6)	462.82	36.17	0.00	0.00	5	452.82	
psi(.),gam(.),eps=1-gam,p(BUBO_04-6)	465.61	38.96	0.00	0.00	4	457.61	
psi(.),gam(.),eps=1-gam,p(NonNativeIndex_04-6)	469.88	43.23	0.00	0.00	4	461.88	
psi(.),gam(.),eps=1-gam,p(PredFish_04-6)	471.25	44.60	0.00	0.00	4	463.25	
psi(.),gam(.),eps=1-gam,p(AquaticVegIndex_04-6)	476.93	50.28	0.00	0.00	4	468.93	
psi(.),gam(.),eps=1-gam,p(PRCL_04-6)	477.37	50.72	0.00	0.00	4	469.37	
psi(.),gam(.),eps=1-gam,p()	482.47	55.82	0.00	0.00	3	476.47	*null model*

Note: Other covariates tested for psi & gamma included: PRCL presence, BUBO presence, RACA presence, Aquatic Emergent Vegetation Index, Watershed, and Ephemeral/Perennial. Models are not shown if AIC values were less than null model or showed evidence of poor fit (no convergence, no covariance matrix, standard errors > parameter estimates).

Arroyo Toad: Night Count Surveys

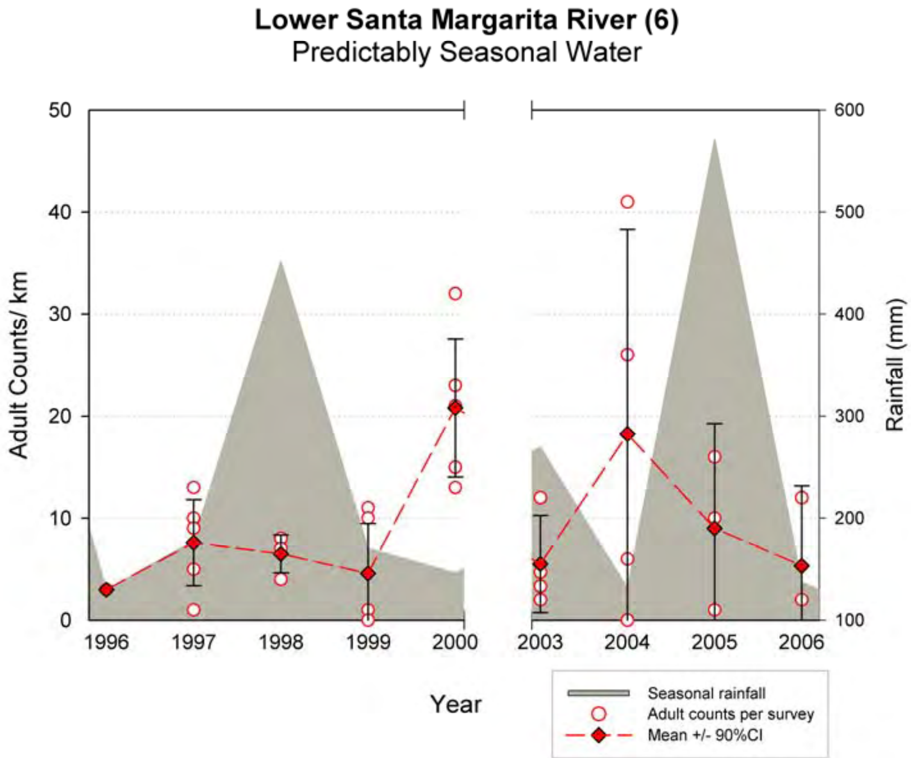
We interpreted adult count data as a combined function of arroyo toad abundance and activity patterns. From 2003 to 2006, we surveyed each of the eight 1-km transects established by Holland et al. (2001) three to four times per year. Combining these data, we found that evening counts of adult toads were highly variable both within and among transects. From 1996 to 2006, an average of 7.5 adult arroyo toads (>4 cm in length) were observed per survey per site with annual variability peaking at +/- 49% of the mean. Over the entire sampling period, there was an insignificant decrease of 20.8% (se= ± 26.3%). Despite extreme short-term fluctuations, these findings do not indicate any long-term trends in arroyo toad activity over the past decade (Figure 8).

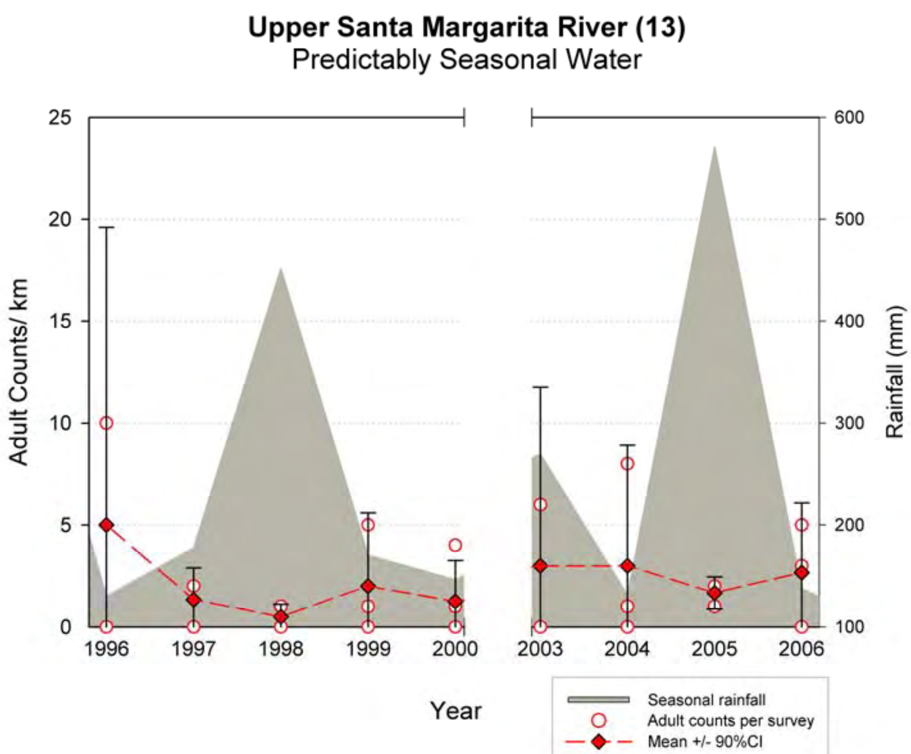
FIGURE 8. TRENDS IN MEAN NUMBER OF ADULT COUNTS FROM 1996 TO 2006

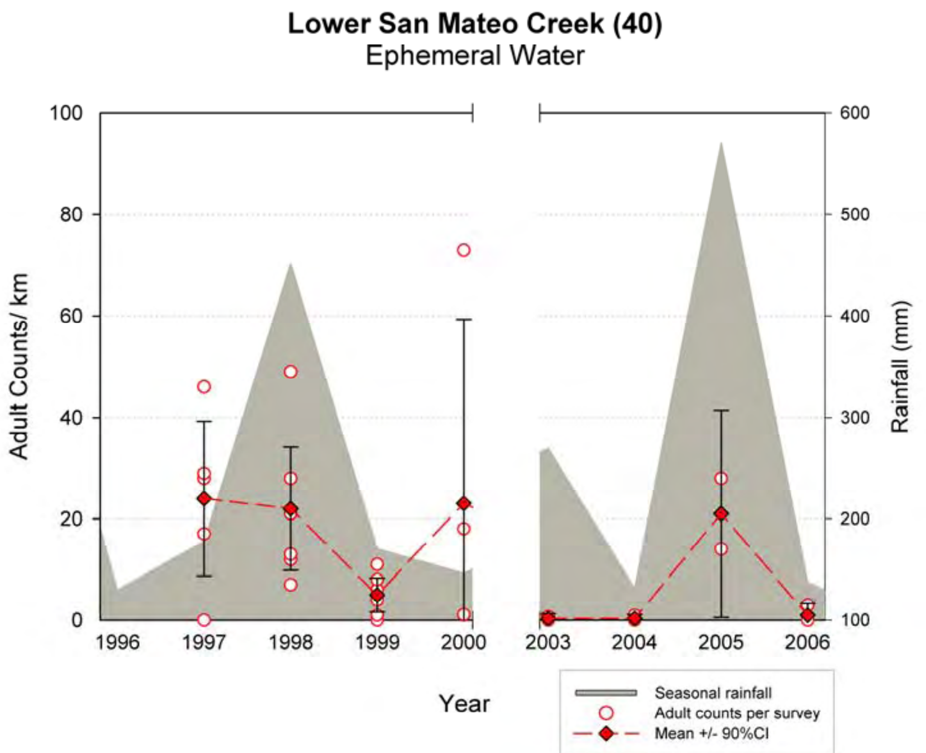


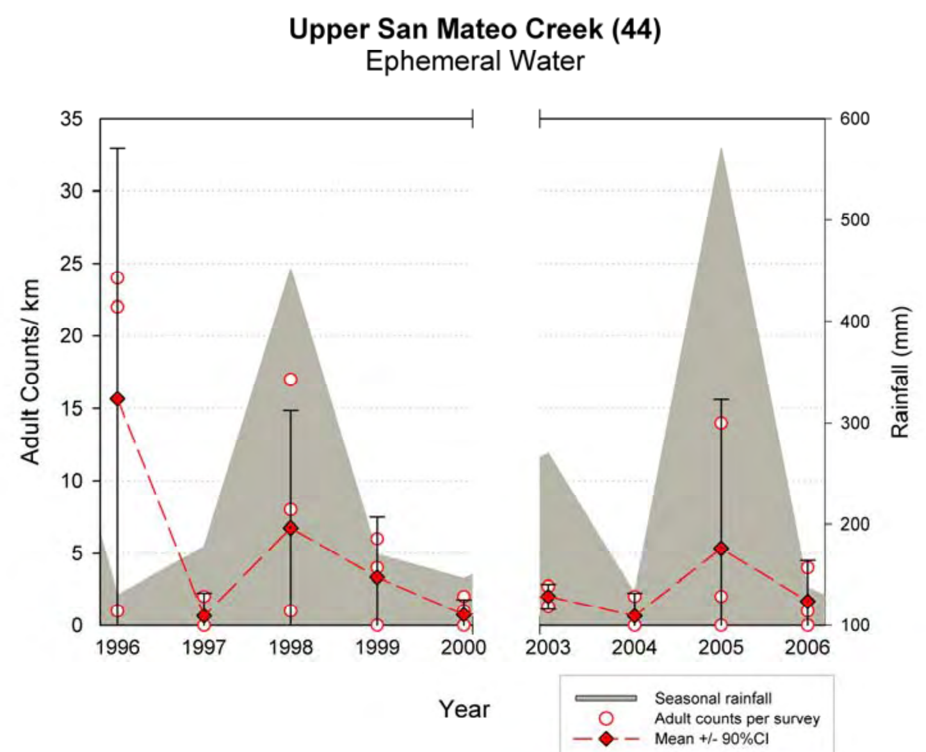
We also continue to follow the yearly trends in the number of toads observed during evening surveys within each site (Figure 9). These data are presented overlaying seasonal rainfall totals. The positive associations between arroyo toad counts and rainfall in the ephemeral creeks, as well as the lack of association in the Santa Margarita River, are apparent in most of the graphs. There is also a lack of association noticeable in the DeLuz Creek transect. The hydroperiodicity of DeLuz Creek, a tributary of the Santa Margarita River, is intermittent falling between predictably seasonal and ephemeral.

FIGURE 9. SITE TRENDS IN MEAN NUMBER OF ADULT ARROYO TOADS WITH COMPARISON TO SEASONAL RAINFALL

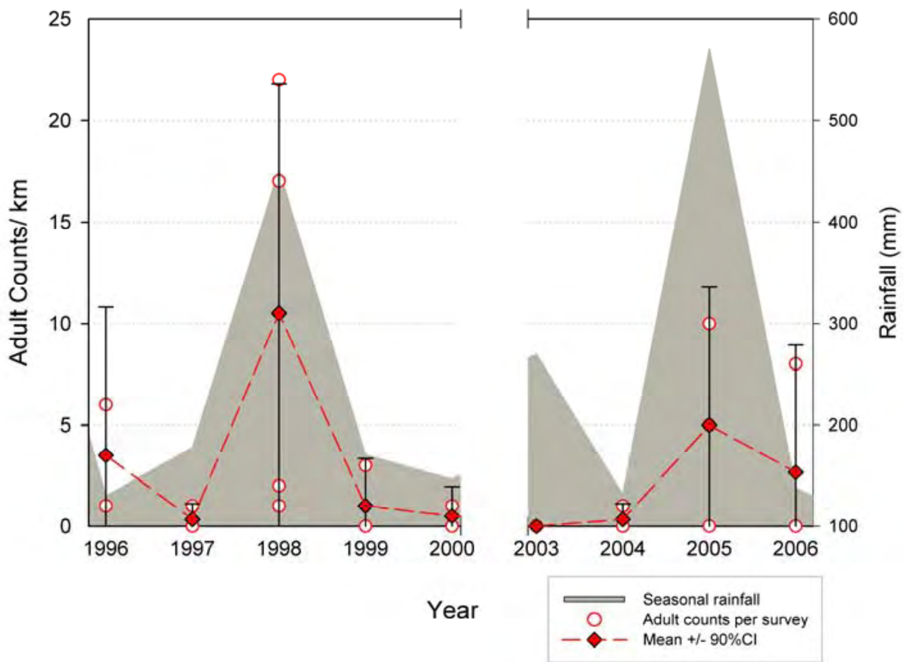




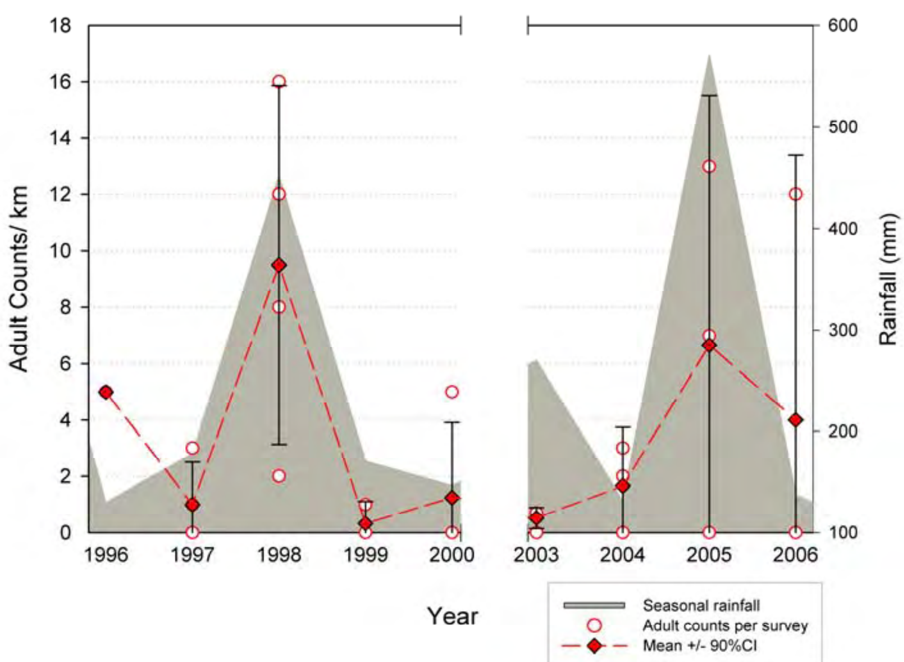

Lower San Mateo Creek (40)
Ephemeral Water
Adult Counts/ km
Rainfall (mm)
Year
Seasonal rainfall
Adult counts per survey
Mean +/- 90%CI

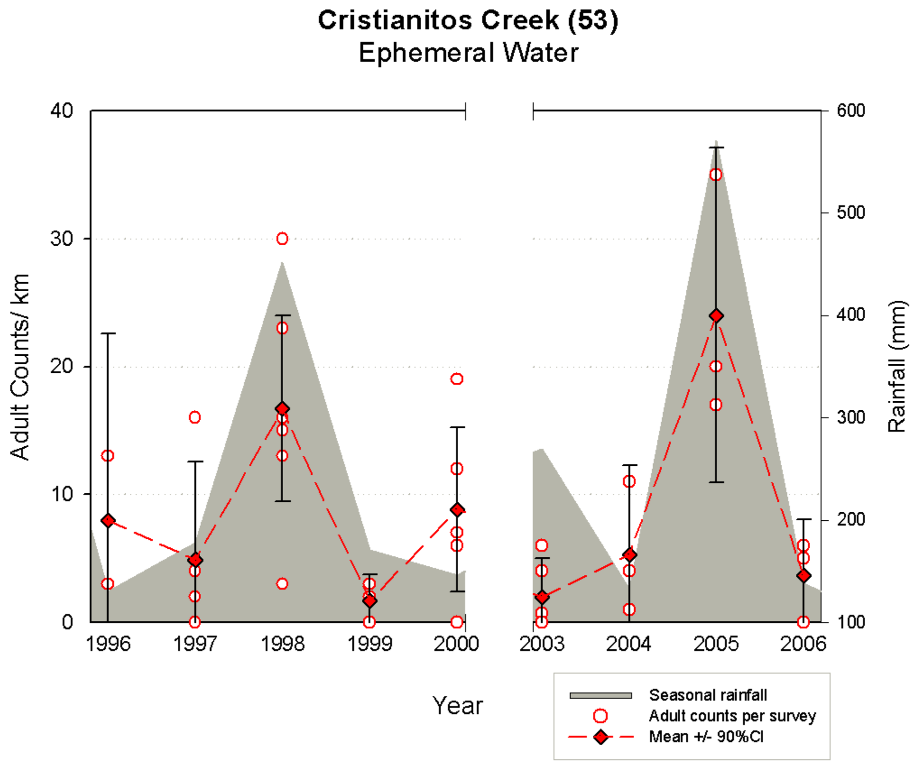

Upper San Mateo Creek (44)
Ephemeral Water
Adult Counts/ km
Rainfall (mm)
Year
Seasonal rainfall
Adult counts per survey
Mean +/- 90%CI

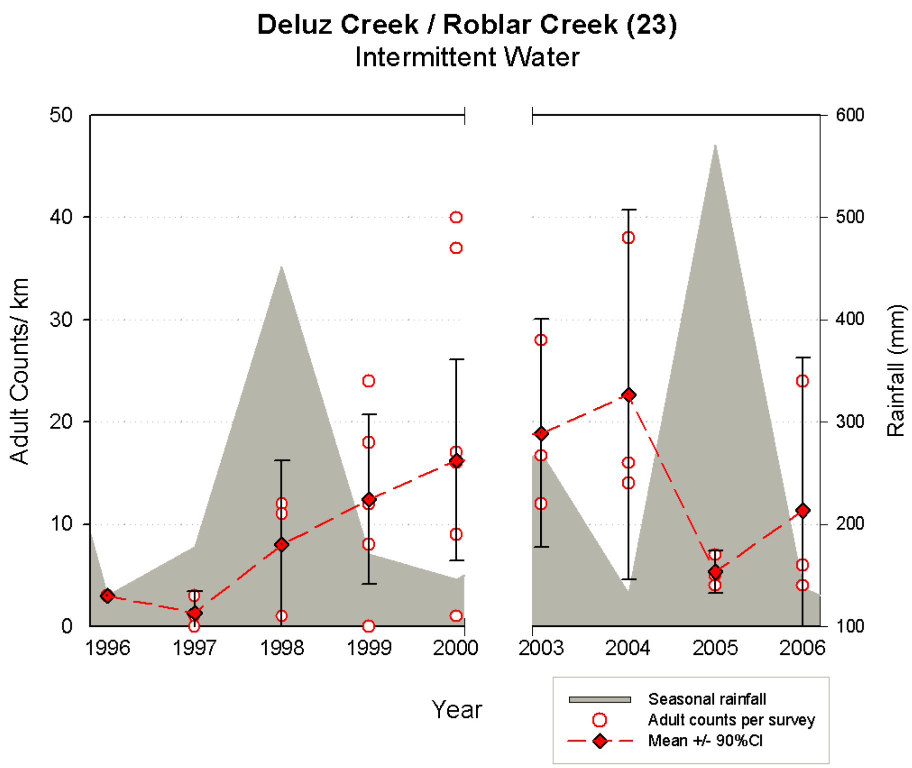
Lower San Onofre Creek (29)
Ephemeral Water



Upper San Onofre Creek/ Jardine Canyon Creek (32)
Ephemeral Water




Cristianitos Creek (53)
Ephemeral Water
Adult Counts/ km
Rainfall (mm)
Year
Seasonal rainfall
Adult counts per survey
Mean +/- 90%CI


Deluz Creek / Roblar Creek (23)
Intermittent Water
Adult Counts/ km
Rainfall (mm)
Year
Seasonal rainfall
Adult counts per survey
Mean +/- 90%CI

Biological Samples

We swabbed 106 individuals of a variety of amphibian species (arroyo toad, western toad, California treefrog, Pacific treefrog, bullfrog) for amphibian chytrid fungus during surveys in 2006. We obtained samples from all three watersheds within MCBCP, and a subset of 81 swabs was sent to CRES for laboratory analysis. All swabs obtained from San Mateo (26 samples) and San Onofre (16 samples) Creeks tested negative for *Bd*. However, 11 of 39 samples tested for the Santa Margarita Watershed were positive for *Bd*. The positive results came from an arroyo toad in Deluz Creek and 10 bullfrogs in the Santa Margarita River.

Discussion

Day and Night Count Surveys -Arroyo toad occupancy within MCBCP

The Mediterranean climate and influence from the ENSO cycle in southern California result in highly variable annual rainfall. Consequently, ephemeral creeks may remain dry in low rainfall years and experience extensive flooding and scouring in high rainfall years. Both conditions were represented during our four years of monitoring. Although the arroyo toad is reported to require permanent or predictably seasonal streams to support breeding populations (Sweet and Sullivan 2005), two of the watersheds representing 56% of arroyo toad habitat within MCBCP are largely intermittent to ephemeral, flowing only in response to rain events. Therefore, breeding and recruitment in these creeks only occur in normal to high rainfall years. This dependency on rainfall results in extreme annual variability in arroyo toad breeding activity and spatial distribution on Base.

In 2006, we received only half the normal average rainfall. Consequently, the largely ephemeral San Onofre and San Mateo Creeks remained partially dry throughout the 2006 breeding season. Over all watersheds, only 64% of potential arroyo toad breeding habitat contained water during our survey efforts. However, 82.7% (se= 7.4) of the available wet habitat was occupied by breeding arroyo toads. We recorded the highest occupancy in the Santa Margarita Watershed, followed by the San Mateo and San Onofre Watersheds.

Even in the wetted areas, San Mateo and San Onofre Creeks had unexpectedly low occupancy of arroyo toads. In particular, we found a significant 74.1% decrease in occupied breeding habitat within San Mateo Creek from 2005 to 2006. We hypothesize that this low occupancy for San Mateo and San

Onofre Creeks may be the result of reduced sand cover. During our 2005 surveys, the sand cover for these creeks averaged 26-50% for each site, but in the 2006 surveys the average sand cover dropped to 11-25% per site. In general, the creek beds became rockier with few sandy areas available for arroyo toad breeding. Another possibility for the low occupancy of arroyo toads in San Mateo and San Onofre Creeks could be the cool temperatures and relatively late rainfall of 2006. These factors can result in the absence of arroyo toad breeding activity. Sweet (1992) attributed the lack of arroyo toad breeding in the Los Padres National Forest in 1990 to cool, dry weather in the winter and spring of that year.

Even though surface water availability was highly variable (44-95%) from 2003 to 2006, the overall extant of breeding toads in wetted areas remained relatively stable (77-95%) with no significant change over the four year period. The night survey count data from 1996 to 2006 also showed extremely high annual variability (+/- 47% of mean) in arroyo toad activity, but overall activity has remained relatively stable over the last decade.

In analyzing the 2006 single season models, we found the probability of detecting arroyo toad larvae to be positively associated with both the low flow index and the non-native species index. Typically, these two variables are negatively correlated with one another, as non-native species are normally associated with deeper, faster flowing water. The unusual case of non-native species acting as a positive indicator of arroyo toad detection runs counter to past results. In fact, Brehme et al. (2006) found that the probability of detecting arroyo toad larvae decreased an average of 2.3 times with the addition of each non-native species in 2003-2005 multi-season models. However, the limited availability of water in 2006 may have pushed all water dependent species into the same areas. We think the positive association between arroyo toad detection and non-native species will only occur in dry years with low seasonal rainfall.

In analyzing the 2004-2006 models, we found the probability of detecting arroyo toad larvae was positively associated with the presence of western toad. We normally associate western toads with slightly deeper water than that preferred by arroyo toads. However, the two species appear to coexist without competition. The positive association between arroyo toad detection and western toad presence probably occurs more often in wet years. In examining the raw survey data, we found that arroyo toads and western toads were most frequently detected in the same areas during 2005, following major flooding and channel scouring throughout MCBCP. Both the arroyo toad and the western toad may have taken advantage of the enormous availability of slow moving, shallow water in 2005.

After further analysis of the 2004-2006 multi-season models, we determined that arroyo toad occupancy was best explained by the presence of predatory fish, sand cover index, and non-native species index. The odds of arroyo toads occupying a site were lower when predatory fish and non-native species were present. Conversely, the odds of arroyo toad occupation were higher for each increase in the sand cover index. These findings support our initial hypotheses predicting positive arroyo toad response to high sand cover and negative response to non-native species, including predatory fish. They also demonstrate the importance of multi-year trend analysis. If only the 2006 single-season models were considered, we could conclude that non-native species are positive predictors of arroyo toad detection or occupancy.

As seen in the 2006 single-season models, arroyo toad occupancy differs between the ephemeral watersheds and the predictably seasonal Santa Margarita River Watershed. Additionally, linear regression results show adult arroyo toad counts to be significantly associated with the amount of rainfall for the ephemeral San Onofre and San Mateo Watersheds, but not for the Santa Margarita Watershed. In years of low rainfall, arroyo toads in the ephemeral systems likely expend minimal energy on breeding and spend less time foraging above ground to avoid desiccation. This conservation of energy and moisture could explain the lowered animal counts and reduced breeding distribution in dry years. In wet years, arroyo toads likely breed earlier to increase the chances of larval metamorphosis before surface water dries. In contrast, arroyo toads breed yearly in the perennial Santa Margarita River, regardless of rainfall patterns. Our data indicate that breeding typically occurs later in the Santa Margarita, from mid-April through June, depending upon surface water flow and the availability of shallow pooling water.

Arroyo toads in the lower order watersheds appear to be primarily influenced by stochastic processes (i.e. amount of rainfall), while those in the Santa Margarita Watershed are primarily influenced by deterministic processes (i.e. predation, competition, habitat alteration). Therefore, we expect the occupancy and abundance of toads in the San Mateo and San Onofre Watersheds to be more highly variable among years (Ross et al.1985, Death and Winterborn 1994, Therriault and Kolasa 2000). Early trends in our occupancy data and the night survey counts (combined Holland et al. 2001 and USGS) show that annual variability is in fact much higher in these ephemeral watersheds. These populations are at increased risk of extirpation from a prolonged drought and may be dependent upon dispersal from more stable sites for recolonization. In contrast, we expect less temporal variability and increased population persistence within the Santa Margarita River. Variability in arroyo toad occupancy and adult counts has been relatively low in this watershed. However, the threat of extirpation of amphibians by non-native species predation and associated habitat loss is an immediate and well-documented threat (See Future Concerns and Management Recommendations; review by Kats and Ferrer 2003).

It is important for us to understand the change in the spatial extant and abundance of toads over both the short-term and the long-term within MCBCP. As we have discussed, in such widely variable populations, threat of extirpation can lie in both extraordinary short-term stochastic events (i.e. disease, weather and water extremes, excessive predation) or long-term responses to negative environmental conditions (habitat loss, stream channelization, water pollution, predation/competition with invasive species). Often, no one factor is responsible. Instead, extirpation occurs due to a combination of stressors (Carey et al. 2003, Bridges and Little 2005). By understanding the factors that have the greatest influence on the arroyo toad, we can take early management actions to lessen the chances of local decline and extinction.

Future Concerns

We expect the effects of urbanization, occurring largely outside MCBCP, to be the primary threat to the arroyo toad populations on Base. The effects of urbanization on stream hydrology are well-documented (USEPA 1997, McMahon et al. 2003, Riley et al. 2005). Increased impervious surface area from development increases magnitude and duration of water flow. Additionally, water runoff from domestic and agricultural uses can increase year-round water flow. These modifications affect both channel morphology and riparian habitat. They can change ephemeral systems into perennial systems and create deeper, incised channels with faster water flow. The consequences may include reduced availability of shallow pools for arroyo toad breeding, and successful colonization by aquatic non-native predators requiring permanent water sources (Riley et al. 2005).

Invasion by non-native species is a major cause of biodiversity loss in the few remaining native habitats. Numerous studies have implicated invasive species in local amphibian extirpations and significant native species declines (i.e., Fisher and Shaffer 1996; see reviews by Kats and Ferrer 2003, Beebee and Griffiths 2005). Invasive species can adversely affect native amphibians through competition for resources, and disease transmission. Kats and Ferrer (2003) question whether native amphibians and invasive predators can co-exist in the long-term. They predict that in a matter of time following the introduction of invasive species, amphibian populations will be reduced to such low numbers that they will ultimately disappear.

The non-native aquatic species documented in MCBCP thrive in areas with increased water flow, depth, and longevity. These species (catfish, bass, green sunfish mosquitofish, crayfish, and bullfrogs) are all known to prey upon amphibian eggs, larvae, or adults (Sweet and Sullivan 2005). The mosquitofish may be a significant predator of arroyo toad eggs (Grubb 1972), and alter the physical and biological characteristics of arroyo toad breeding pools (Hurlbert et al. 1972). Crayfish are opportunistic omnivores known to eat amphibian eggs and tadpoles (Fernandez and Rosen 1996, Saenz et al. 2003). They have been associated with declines in native fish and amphibian populations (Warburton et al. 2003, Riley et al. 2005). Finally, bullfrogs are known to prey upon juvenile and adult toads in the wild and may be responsible for declines in several amphibian populations (Moyle 1973, Sweet 1993, Jennings and Hayes 1994, Griffin 1999). Aside from the direct predation impacts, there is also evidence that bullfrogs carry amphibian chytrid fungus (Dasak et al. 2004, Hanselmann et al. 2004, Garner et al. 2006).

The impact of non-native aquatic species is most relevant for the largely perennial Santa Margarita River, which harbors the largest densities and numbers of invasive species within MCBCP. The 2004-2006 occupancy models for wet habitat indicated that predatory fish and the number of non-native species had a large negative impact on arroyo toad occupancy. Since discharge of water into the Santa Margarita drainage basin is guaranteed even in drought years (CWRMA 2002) and is predicted to increase in the future (Steinitz et al.1996), we expect invasive aquatic species to be an ongoing problem. Most non-native aquatic species require perennial or near permanent water for survival (Gasith and Reth 1999, Adams 2000). The constant discharge of water into the Santa Margarita River prevents seasonal drying cycles, which typically result in local extirpation of invasive aquatic species. These cycles represent natural hydrology in which surface water dries by mid-September and returns with rainfall in late winter and early spring (Steinitz et al. 1996).

The Cristianitos Creek sub-Watershed is another concern with regard to urbanization and stream alteration. Development in the northern portion of the Cristianitos Creek sub-Watershed is occurring at a rapid rate, and it is expected to increase with the proposed Orange County Southern Subregion Natural Community Conservation Plan (SSNCCP). Along the northern border of MCBCP, we have already observed a lengthened hydroperiod within Cristianitos Creek and the ensuing abundance of aquatic emergent vegetation. We expect increased discharge to continue in this creek with resulting threats of channelization, decreased water quality and invasive aquatic species.

Our final concern is the proposed Foothill-South Toll Highway. The proposed route would begin at Oso Parkway in Rancho Santa Margarita and end along Interstate 5 at Basilone Road within MCBCP. It would run adjacent to lower San Mateo Creek and Cristianitos Creek (Federal Highway Administration 2005). We estimate negative effects for approximately 9 km of arroyo toad habitat or 10% of the total arroyo toad population within MCBCP. The proposed highway is a potential threat to all arroyo toad populations located within the project footprint. Specific concerns include direct mortality of individual arroyo toads and habitat loss during construction. Indirect consequences of construction include siltation, altered hydrology, reduced water quality, and noise pollution. If the highway reaches completion, the concerns remain much the same. Vehicle mortality, noise and light disturbance, compromised water quality, and modified hydrology could all adversely affect arroyo toad dynamics.

Management Recommendations:

1) Consider modifying the water releases at the Temecula Gorge (as specified in the Cooperative Water Resource Management Agreement between MCBCP and Rancho California Water District) to simulate a more natural hydrology pattern with periods of summer drying. This effort may aid in the removal or control of non-native aquatic species and non-native plant species.

2) Continue eradication efforts of non-native aquatic species, particularly crayfish and bullfrogs, which are suspected to have the greatest impact on arroyo toad populations. This effort involves active removal of these predators. We suspect that crayfish, bullfrog tadpoles, and bullfrog adults would be easiest to control during the late summer or fall, when deeper perennial pools become smaller and more isolated.

3) Continue eradication efforts of non-native plant species, particularly those that alter the natural hydrology of the arroyo toad occupied watersheds. Removal of giant reed and tamarisk is expected to increase available habitat for the arroyo toads by opening up vegetation-choked areas and allowing toad movement. Additionally, the resulting destabilization of stream banks

would restore the natural stream flow dynamics, upon which the arroyo toad depends. Removal of watercress may become necessary as waterways convert to perennial systems.

4) Continue the beaver removal program. We documented the presence of beaver dams in the upper sections of the Santa Margarita River in 2003 and 2004. These dams increase water levels, potentially reducing the number of breeding pools and creating suitable habitat for invasive aquatic species. The dams may also inhibit upstream and downstream movement of arroyo toad larvae and adults.

5) Investigate whether pumping of ground water for agriculture, domestic, and industrial use is at sustainable levels. This issue may be especially important for the San Onofre and San Mateo Watersheds, where loss of surface water due to pumping could further reduce water in ephemeral streams. Reduced water availability may result in lack of arroyo toad breeding and recruitment success, as documented during the spring of 2000 in lower San Mateo Creek (Holland et al. 2001).

6) Continue to manage nighttime military training activities within riparian areas during the early breeding season (February- April). This management could prevent or minimize direct trampling of active adult arroyo toads by vehicles or troops.

7) Continue to manage military training activities in wet areas during the larval development period (March-July). This management could prevent or minimize the direct take of arroyo toad larvae and juveniles. If training activities cannot be avoided, we recommend confining the training to small areas and minimizing activities on stream edges and banks where larvae and juveniles aggregate.

8) Prevent or minimize habitat loss in upland areas. Adult toads are known to over-winter in these areas. We recommend avoiding or minimizing upland habitat loss within one kilometer of known arroyo toad breeding areas.

9) Continue to educate MCBCP training personnel in the identification and basic biology of the arroyo toad. We recommend emphasizing good environmental stewardship, including the avoidance of arroyo toads and their habitat whenever possible.

10) Support creation of models and mitigation measures to address impacts of the Orange County Southern Subregion Natural Community Conservation Plan (SSNCCP), Santa Rosa Plateau development, and the proposed Foothill-South Toll Highway on the hydrology of the San Mateo Watershed within MCBCP.

11) Support the creation of models and mitigation measures to address impacts of the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP) and the North San Diego Subarea Multiple Species Conservation Plan (MSCP) on the hydrology of the San Margarita Watershed within MCBCP.

Acknowledgements

We are especially grateful to the AC/S Environmental Security at MCBCP for both funding and logistical support on this project. In particular, we thank Sherri Sullivan and Eric Kershner, for project support and review of the draft manuscript. From USGS, we thank Denise Clark, Drew Stokes, Joe Deas, Stacie Hathaway, Dustin Wood, and Adam Backlin for contributing many hours to collect these field data.

References Cited

Adams, M. J. 2000. Pond permanence and the effects of exotic vertebrates on anurans. Ecological Applications 10:559-568.

Atkinson, A. J., B. S. Yang, R. N. Fisher, E. Ervin, T. J. Case, N. Scott, and H. B. Shaffer. 2003. Marine Corps Base Camp Pendleton arroyo toad monitoring protocol: 1. Summary of results from a workshop on August 27, 2002; 2. Monitoring protocol and targeted studies. U.S. Geological Survey technical report prepared for Marine Corps Base Camp Pendleton. 42 pp.

Barto, W. S. 1999. Predicting potential habitat for the arroyo toad (*Bufo microscaphus californicus*) in San Diego County using a habitat suitability model and digital terrain data. M. S. thesis, San Diego State University, San Diego, California.

Beebee, T. J. C., and R. A. Griffiths. 2005. The amphibian decline crisis: a watershed for conservation biology? Biological Conservation 125:271–285.

Berger, L., R. Spear, P. Daszak, D. E. Green, A. A. Cunningham, C. L. Goggin, R. Slocombe, M. A. Ragan, A. D. Hyatt, K. R. McDonald, H. B. Hines, K. R. Lips, G. Marantelli, and H. Parkes. 1998. Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. Proceedings of the National Academy of Sciences 95:9031-9036.

Bosch, J., I. Martinez-Solano, and M. Garcia-Paris. 2001. Evidence of chytrid fungus infection involved in the decline of the common midwife toad (*Alytes obstetricans*) in protected areas of central Spain. Biological Conservation 97:331-337.

Brehme, C. S., A. J. Atkinson, and R. N. Fisher. 2004. MCB Camp Pendleton arroyo toad monitoring results, 2003. U.S. Geological Survey technical report prepared for Marine Corps Base Camp Pendleton. 105 pp.

Brehme, C. S., S. L. Schuster, C. J. Rochester, S. A. Hathaway, and R. N. Fisher. 2006. MCBCP arroyo toad monitoring program: 3-year trend analyses for 2003-2005. U.S. Geological Survey data summary prepared for Marine Corps Base Camp Pendleton. 102 pp.

Bridges, C. M., and E. E. Little. 2005. Toxicity to amphibians of environmental extracts from natural waters in National Parks and Fish and Wildlife Refuges. Alytes 22:130-145.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, 2nd ed. Springer-Science + Business Media, LLC, New York, NY.

Carey, C., D. F. Bradford, J. L. Brunner, J. P. Collins, E. W. Davidson, J. E. Longcore, M. Ouellet, A. P. Pessier, and D. M. Schock. 2003. Biotic factors in amphibian population declines, pp 153-208. In G. Linder, D. W. Sparling, and S. K. Krest (eds.), Amphibian decline: an integrated analysis of multiple stressor effects. Society of Environmental Toxicology and Chemistry, Pensacola, FL.

Cooperative Water Resource Management Agreement between Camp Pendleton and Rancho California Water District. March 2002.

Dasak, P., A. Strieby, A. A. Cunningham, J. E. Longcore, C. C. Brown, and D. Porter. 2004. Experimental evidence that the bullfrog (*Rana catesbeiana*) is a potential carrier of chytridiomycosis, an emerging fungal disease of amphibians. Herpetological Journal. 14:201-207.

Death, R. G., and M. J. Winterbourn. 1994. Environmental stability and community persistence: a multivariate perspective. Journal of the North American Benthological Society13:125-139.

Federal Highway Administration. 2005. South Orange County Transportation Infrastructure Improvement Project (SOCTIIP) Final Subsequent Environmental Impact Report. TCA EIR FHWA-CA-EIS-04-01-D. http://www.ftcsouth.com/home/index.asp

Fernandez, P. J., and P.C. Rosen. 1996. Effects of the introduced crayfish *Orconectes virilis* on native aquatic herpetofauna in Arizona. Technical report to the Heritage Program, Arizona Fish and Game Department, IIPAM Project No. I94054.

Fisher, R. N., and H. B. Shaffer. 1996. The decline of amphibians in California's great Central Valley. Conservation Biology 10:1387-97.

Garner, T. W. J., M. W. Perkins, P. Govindarajulu, D. Seglie, S. Walker, A. A. Cunningham, and M. C. Fisher. 2006. The emerging amphibian pathogen *Batrachochytrium dendrobatidis* globally infects introduced populations of the North American bullfrog, *Rana catesbeiana*. Biology Letters 2:455-459.

Gasith, A., and V. H. Reth. 1999. Streams in Mediterranean climate regions: abiotic influences and biotic responses to predictable seasonal events. Annual Review of Ecology and Systematics 30:51-81.

Griffin, P. C. 1999. *Bufo californicus*, arroyo toad movement patterns and habitat preferences. M. S. thesis, University of California, San Diego, California.

Grubb, J. C. 1972. Differential predation by *Gambusia affinis* on the eggs of seven species of anuran amphibians. The American Midland Naturalist 88:102-108.

Hanselmann, R., A. Rodriguez, M. Lampo, L. Fajardo-Ramos, A. A. Aguirre, A. M. Kilpatrick, J. P. Rodriguez, and P. Dasak. 2004. Presence of an emerging pathogen of amphibians in introduced bullfrogs *Rana catesbeiana* in Venezuela. Biological Conservation 120:115-119.

Holland, D. C., and N. R. Sisk. 2001. Habitat use and population demographics of the arroyo toad (*Bufo californicus*) on MCB Camp Pendleton, San Diego County, California. Final report for 1998-2000. Prepared for AC/S Environmental Security, MCB Camp Pendleton, California.

Holland, D. C., N. R. Sisk, and R. H. Goodman. 2001. Linear transect censusing of the arroyo toad (*Bufo californicus*) from 1996-2000 on MCB Camp Pendleton, San

Diego County, California. Prepared for AC/S Environmental Security, MCB Camp Pendleton.

Hurlbert, S. H., J. Zedler, and D. Fairbanks. 1972. Ecosystem alteration by mosquitofish (*Gambusia affinis*) predation. Science 175:639-641.

Jennings, M. R., and M. P. Hayes. 1994. Amphibian and reptile species of special concern in California. Final Report to the California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova, California. Contract 8023. 255 pp.

Kats, L. B., and R. P. Ferrer. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. Diversity and Distributions 9:99-110.

Lips, K. R., J. R. Mendleson, A. Munoz-Alonso, L. Canseco-Marquez, and D. G. Mulcahy. 2004. Amphibian population declines in montane southern Mexico: Resurveys of historical localities. Biological Conservation 119:555-564.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy when detection probabilities are less than one. Ecology 83:2248-2255.

MacKenzie, D. I., J. D. Nichols, J. E. Hines, M. G. Knutson, and A. B. Franklin. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. Ecology 84:2200-2207.

MacKenzie, D. I., and L. L. Bailey. 2004. Assessing the fit of site occupancy models. Journal of Agricultural, Biological, and Environmental Statistics 9:300-318.

Madden-Smith, M. C., A. J. Atkinson, R. N.Fisher, W. R Danskin, and G. O. Mendez. 2003. Assessing the risk of Loveland Dam operations to the arroyo toad (*Bufo californicus*) in the Sweetwater River channel, San Diego County, California. USGS final report to the Sweetwater Authority, Chula Vista, California. 58pp.

Marine Corps Base Camp Pendleton, 2006. MCB Camp Pendleton strategic plan. http://www.pendleton.usmc.mil/base/mcb.asp.

Marine Corps Base Camp Pendleton, 2007. Integrated natural resources management plan. http://www.cpp.usmc.mil/base/environmental/inrmp.asp.

McMahon, G. M., J. D. Bales, J. F. Coles, E. M. P. Giddings, and H. Zappia. 2003. Use of stage data to characterize hydrologic conditions in an urbanizing environment. Journal of the American Water Resources Association. Paper No. 03058.

Moyle, P. B. 1973. Effects of introduced bullfrogs, *Rana catesbeiana*, on the native frogs of the San Joaquin Valley, California. Copeia 2001:18-22.

Muths, E., P. S. Corn, A. P. Pessier, and D. E. Green. 2003. Evidence of disease-related amphibian decline in Colorado. Biological Conservation 110:357-365.

Muths, E., R. E. Jung, L. L. Bailey, M. J. Adams, P. S. Corn, C. K. Dodd Jr., G. M. Fellers, W. J. Sadinski, C. R. Schwalbe, S. C. Walls, R. N. Fisher, A. L. Gallant, W. A. Battaglin, and D. E. Green. 2005. Amphibian research and monitoring initiative (ARMI): A successful start to a national monitoring program in the United States. Applied Herpetology 2:355-372.

National Climate Data Center. 2007. Annual Climatological Summary. http://cdo.ncdc.noaa.gov/ancsum/ACS.

Riley, S. P. D., G. T. Busteed, L. B Kats, T. L. Vandergon, L. F. S. Lee, R. G. Dagit, J. L. Kerby, R. N. Fisher, and R. M. Sauvajot. 2005. Effects of urbanization on the distribution and abundance of amphibians and invasive species in southern California streams. Conservation Biology 19:1894-1907.

Ross, S. T., W. J. Matthew, and A. A. Echelle. 1985. Persistence of stream fish assemblages: effects of environmental change. American Naturalist. 126:24-40.

Saenz, D., J. B. Johnson, C. K. Adams, and G. H. Dayton. 2003. Accelerated hatching of southern leaopard frog (*Rana sphenocephala*) eggs in response to the presence of a crayfish (*Procambarus nigrocinctus*) predator. Copeia 2003:646-649.

Steinitz, C., M. Binford, P. Cote, T. Edwards Jr., S. Ervin, R. T. Forman, C. Johnson, R. Kiester, D. Mouat, D. Olson, A. Shearer, R. Toth, and R. Wills. 1996. Biodiversity and landscape planning: alternative futures for the region of Camp Pendleton, California. M. A. thesis, Harvard University, Cambridge, MA. Available at http://www.gsd.harvard.edu/studios/brc/brc.html.

Stuart, S. N., J. S. Chanson, N. A. Cox, B. E. Young, A. S. L. Rodrigues, D. L. Fischman, and R. W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306:1783-1786.

Sweet, S. S. 1992. Initial report on the ecology and status of the arroyo toad (*Bufo microscaphus californicus*) on the Los Padres National Forest of southern California, with management recommendations. Contract Report to USDA, Forest Service, Los Padres National Forest, Goleta, California. 198 pp.

Sweet, S. S. 1993. Second report on the biology and status of the arroyo toad (*Bufo microscaphus californicus*) on the Los Padres National Forest of southern California, with management recommendations. Contract Report to USDA, Forest Service, Los Padres National Forest, Goleta, California. 73 pp.

Sweet, S. S., and B. K. Sullivan. 2005. *Bufo californicus*, pp. 396-400. In M. Lannoo (ed.), Amphibian declines: the conservation and status of United States species. University of California Press, Berkeley and Los Angeles, CA.

Therriault, T. W., and J. Kolasa. 2000. Patterns of community variability depend on habitat variability. Community Ecology 1:196-203.

U.S. Environmental Protection Agency. 1997. Urbanization and streams: studies of hydrological impacts. EPA841-R-97-009. Washington, D.C.

U.S. Fish and Wildlife Service. 1994. Endangered and threatened wildlife and plants: determination of endangered status for the arroyo southwestern toad. Federal Register 59:64859-64866.

U.S. Fish and Wildlife Service. 1999. Arroyo southwestern toad (*Bufo microscaphus californicus*) recovery plan. U.S. Fish and Wildlife Service, Portland, Oregon. vi+119 pp.

U.S. Geological Survey. 2008. National Water Information System: Web Interface. http://waterdata.usgs.gov/nwis.

Warburton, M. L., C. C. Swift, and R. N. Fisher. 2000. Status and distribution of fishes in the Santa Margarita River Drainage. Final report to The Nature Conservancy. 27pp.

Warburton, M., A. Atkinson, and R. Fisher. 2003. The status and distribution of the unarmored threespine stickleback in San Francisquito Canyon in the Angeles National Forest. 2002 Annual report to U.S. Forest Service, Angeles National Forest, California. 20pp.

Zedler, P., S. DeSimone, J. Giessow, D. Lawson, J. Else, and S. Bliss. 1997. The plant communities of Camp Pendleton Marine Corps Base, California. Report to AC/S Environmental Security, MCB Camp Pendleton, California. 28pp.

APPENDIX 1. VEGETATION & NON-NATIVE PLANT OBSERVATIONS

		Watershed- creek/river										
		San Mateo				San Onofre			Santa Margarita			
	Year	Lower	Upper	Cristianitos	Talega	Lower	Upper	Jardine	Lower	Upper	Deluz	Roblar
Vegetation	*Block*	*39-41*	*42-50*	*51-53*	*54-60*	*27-32*	*33-36*	*37-38*	*1-10*	*11-20*	*21-25*	*26*
Dominant Type Riparian/Upland	2003	MRS	MRS	MRS	MRS	MRS	MRS	MRS	SWS	SWS	SWS	SWS
	2004	~~d~~	CSS		~~d~~	~~d~~	~~d~~	~~d~~	SWS	SWS	MRS	~~d~~
	2005	MRS	MRS	MRS	MRS	MRS	MRS	NNG	SWS	SWS	SWS	MRS
	2006	MRS	MRS	~~d~~	~~d~~	MRS	MRS	~~d~~	SWS	SWS	SWS	MRS
Dominant Type Channel	2003	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2004	~~d~~	MRS		~~d~~	~~d~~	~~d~~	~~d~~	OWC	OWC	OWC	~~d~~
	2005	OWC	OWC	OWC	OWC	OWC	OWC	OWC	OWC	OWC	OWC	OWC
	2006	OWC	OWC	~~d~~	~~d~~	MRS	MRS	~~d~~	OWC	OWC	OWC	MRS
Median Percent Cover in Channel	2003	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	2004	~~d~~	1-10%		~~d~~	~~d~~	~~d~~	~~d~~	11-25%	25%	1-10%	~~d~~
	2005	1-10%	1-10%	1-10%	1-10%	1-10%	1-10%	1-10%	1-10%	1-10%	1-10%	1-10%
	2006	11-25%	26-50%	~~d~~	~~d~~	1-10%	1-10%	~~d~~	11-25%	11-25%	11-25%	0%
Non-native Plants	*Block*	*39-41*	*42-50*	*51-53*	*54-60*	*27-32*	*33-36*	*37-38*	*1-10*	*11-20*	*21-25*	*26*
Giant reed	2003		F	F					S	S		
	2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~	L			~~d~~
	2005	F	S		S	F		F	L	S		
	2006	F	S	~~d~~	~~d~~			~~d~~	L			
Tamarisk	2003		S	S					L	F	F	F
	2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~	L	F	F	~~d~~
	2005	F	F	L					L	F	S	
	2006	F	F	~~d~~	~~d~~		F	~~d~~	L	F	S	
Watercress	2003											
	2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~	L	L	L	~~d~~
	2005		S				S		L	S	L	
	2006		S	~~d~~	~~d~~		S	~~d~~	L	S	L	
Non-native thistle	2003	F	S	S	S	S		F				
	2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~				~~d~~
	2005	F										
	2006			~~d~~	~~d~~			~~d~~				
Castor bean	2003	F										
	2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~		F		~~d~~
	2005	S							S	S		
	2006	F		~~d~~	~~d~~			~~d~~				
Fennel	2003	F	F	F	S	L	S	S	L	L	L	S
	2004	~~d~~	F		~~d~~	~~d~~	~~d~~	~~d~~		F	F	~~d~~
	2005	L	S	F	S	F	S	L	L	S	S	F
	2006		S	~~d~~	~~d~~	F	S	~~d~~	S	F	S	
Mustard	2003	L	L	L	L	L	L	L	L	L	L	L
	2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~	L	S	L	~~d~~
	2005	L	L	L	L	L	L	L	L	S	L	S
	2006	L	L	~~d~~	~~d~~	S	S	~~d~~	L	S	S	
Tree tobacco	2003											
	2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~				~~d~~
	2005		S			F	F			F		
	2006			~~d~~	~~d~~		F	~~d~~		F		
Palm tree	2003											
	2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~				~~d~~
	2005					F	F					
	2006			~~d~~	~~d~~			~~d~~				
Non-native grasses	2003	S	L		L	L	L	L	L	L	L	S
	2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~	S	S	S	~~d~~
	2005	L	L	L	L	L	L	L	L	L	L	L
	2006	L	L	~~d~~	~~d~~	L	L	~~d~~	L	L	S	L

~~d~~= dry throughout year, day surveys not conducted, n/a = specific data type not collected in 2003

Vegetation Codes: MRS = mulefat riparian scrub, SWS = southern willow scrub, OWC = open water/ channel, CSS = coastal sage scrub, NNG = non-native grassland

Size Classes: F = few plants, S = scattered patches, L = large contiguous stands (largest size class recorded among surveys is presented)

APPENDIX 2. NON-NATIVE AQUATIC SPECIES OBSERVATIONS

			Watershed- creek/river										
			San Mateo				**San Onofre**			**Santa Margarita**			
Common Name	Scientific Name	Year	Lower	Upper	Cristianitos	Talega	Lower	Upper	Jardine	Lower	Upper	Deluz	Roblar
Amphibians		*Block*	*39-41*	*42-50*	*51-53*	*54-60*	*27-32*	*33-36*	*37-38*	*1-10*	*11-20*	*21-25*	*26*
Bullfrog	*Lithobates catesbeianus*	2003	X	X						X	X		
		2004	~~d~~	X		~~d~~	~~d~~	~~d~~	~~d~~	X	X	X	~~d~~
		2005		X						X	X		
		2006	X	X	~~d~~	~~d~~			~~d~~	X	X		
Fish													
Mosquitofish	*Gambusia affinis*	2003	X	X	X	X				X	X		
		2004	~~d~~		X	~~d~~	~~d~~	~~d~~	~~d~~	X	X	X	~~d~~
		2005			X					X	X	X	
		2006	X	X	~~d~~	~~d~~			~~d~~	X	X	X	X
Bullhead Catfish	*Ameiurus sp.*	2003								X	X		
		2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~		X		~~d~~
		2005		X									
		2006		X	~~d~~	~~d~~			~~d~~		X		
Common carp	*Cyprinus carpio*	2003								X			
		2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~		X		~~d~~
		2005								X	X		
		2006			~~d~~	~~d~~			~~d~~	X	X		
Green sunfish	*Lepomis cyanellus*	2003		X							X		
		2004	~~d~~	X		~~d~~	~~d~~	~~d~~	~~d~~		X		~~d~~
		2005											
		2006	X	X	~~d~~	~~d~~			~~d~~		X		
Bass	*Micropterus sp.*	2003								X	X		
		2004	~~d~~	X		~~d~~	~~d~~	~~d~~	~~d~~		X	X	~~d~~
		2005											
		2006		X	~~d~~	~~d~~			~~d~~	X			
Invertebrates													
Asian clam	*Corbicula fluminea*	2003									X		
		2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~		X		~~d~~
		2005											
		2006			~~d~~	~~d~~			~~d~~				
Crayfish	*Procambarus clarkii*	2003								X	X		
		2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~	X	X	X	~~d~~
		2005								X	X		
		2006			~~d~~	~~d~~			~~d~~	X	X		
Mammal													
Beaver	*Castor canadensis*	2003									X		
		2004	~~d~~			~~d~~	~~d~~	~~d~~	~~d~~		X		~~d~~
		2005											
		2006			~~d~~	~~d~~			~~d~~				

X = species observation

~~d~~ = dry throughout year, although some species may have been found during night surveys

APPENDIX 3. NON-TARGET NATIVE AQUATIC SPECIES OBSERVATIONS

			Watershed- creek/river										
			San Mateo				**San Onofre**			**Santa Margarita**			
Common Name	Scientific Name	Year	Lower	Upper	Cristianitos	Talega	Lower	Upper	Jardine	Lower	Upper	Deluz	Roblar
Amphibians		*Block*	*39-41*	*42-50*	*51-53*	*54-60*	*27-32*	*33-36*	*37-38*	*1-10*	*11-20*	*21-25*	*26*
Western toad	*Anaxyrus boreas*	2003	X	X	X	X	X		X	X	X	X	
		2004	d	X		d	X	X	d		X	X	d
		2005	X	X	X	X	X	X	X	X	X	X	
		2006		X	d	d			d	X	X	X	
Spadefoot toad	*Spea hammondii*	2003											
		2004	d	X	X	d	d	d	d				d
		2005							X				
		2006			d	d			d				
California tree frog	*Pseudacris cadavarina*	2003					X					X	X
		2004	d	X		d	d	d	d		X	X	d
		2005		X	X	X	X	X			X	X	X
		2006		X	d	d	X	X	d		X	X	
Pacific chorus frog	*Pseudacris regilla*	2003	X	X	X	X	X	X	X	X	X	X	X
		2004	X	X	X	d	X	X	d	X	X	X	d
		2005	X	X	X	X	X	X	X	X	X	X	X
		2006	X	X	d	d	X	X	d	X	X	X	X
California newt	*Taricha torosa*	2003											X
		2004	d			d	d	d	d			X	d
		2005											X
		2006			d	d			d				X
Fish													
Arroyo chub	*Gila orcutti*	2003								X	X		
		2004	d			d	d	d	d	X		X	d
		2005								X		X	
		2006			d	d			d	X			
Reptile													
Two-striped garter	*Thamnophis hammondii*	2003		X	X	X	X		X	X		X	X
		2004	d	X	X	d	X	d	d		X		d
		2005		X	X	X		X		X	X	X	X
		2006	X	X	d	d	X		d	X	X		

X = species observation

d = dry throughout year, although some species may have been found during night surveys