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# Final Report: Status of the Arizona Toad (*Anaxyrus microscaphus*) in New Mexico

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## Abstract

This report covers the fourth consecutive year (2013-2016) of research on the population dynamics, ecology, and conservation status of the Arizona Toad (*Anaxyrus microscaphus*) in New Mexico. The year 2016 represented the rare opportunity to study the effects of El Niño, which typically brings above average precipitation to New Mexico, on the breeding behavior and ecology of the Arizona toad. We expected that the El Niño-driven above average precipitation during the winter of 2015 and spring of 2016 would result in increased detection of toads at breeding sites, especially those sites that were dry in 2013, 2014, and 2015. Furthermore, we expected to observe a decrease of tadpole mortality at breeding sites caused by streams and tanks drying before tadpole metamorphosis. These expectations were based on observations of Arizona Toad's breeding success in Arizona during El Niño years. In addition to breeding surveys, we continued monitoring Arizona toad populations for the amphibian fungal disease *Batrachochytrium dendrobatidis* and chigger skin parasites, which may cause toad mortality. Herein we also model stream environmental factors that regulate toad breeding and success and summarize disease prevalence in the region.

## Introduction

One of the greatest challenges in ecology and natural resource management is to understand how environmental variability will affect natural wildlife populations (Seebacher et al. 2014). The El Niño Southern Oscillation (ENSO) is the greatest source of rainfall variability, with two quasi-cyclic phases, La Niña and El Niño (Holmgren et al. 2001). In the southwestern United States, El Niño is typically associated with above average winter precipitation, and La Niña is associated with drier conditions. In both cases, their intensity can vary from weak to strong. Precipitation variability, driven by ENSO and dependent on intensity, can have severe effects on regional streamflows and monsoon timing (Molles et al. 1992) and La Niña is correlated with increased wildfires (Swetnam and Brown 2011). Historically, ENSO events occurred at 3–7 year cycles (e.g., Holmgren et al. 2001), but as global temperatures have increased over the last century, ENSO events are occurring more frequently and at greater intensities (Thornton et al. 2014), making high annual precipitation fluctuations the new norm (Power et al. 2013). Amphibian populations can greatly fluctuate in response to extreme precipitation rainfall (Ryan et al. 2015) or drought (Walls et al. 2011) related to ENSO events.

In the coming decades, the southwestern United States is expected to warm by 3–5 °C, as well as experience increased droughts punctuated with more extreme rainfall events (Seager et al 2007). The projected changes in precipitation can have profound impacts on riparian species populations and behaviors that can, in turn, increase species vulnerabilities to climate change (McCaffery et al. 2014; Ryan et al. 2014; Cayuela et al. 2016). More specifically, precipitation and hydroperiod are highly correlated to the breeding phenology of riparian species, and mismatches between water levels and reproductive timing may reduce annual breeding investment and thus recruitment, or force

a species to skip an entire breeding season (Warner 1998; Ruf et al. 2006; McCaffery et al. 2014; Cayuela et al. 2016). As the hydrologic cycle intensifies due to climate change, extreme rainfall and drought events are increasing in frequency, intensity, and duration (Easterling et al. 2008), resulting in more unpredictable hydrology at amphibian breeding sites (Walls et al. 2013). Any factors that affect reproduction or recruitment can lead to short-term population decreases, or if persistent, result in long-term population declines (Alford and Richards 1999; Mac Nally et al. 2010).

Amphibian populations intrinsically fluctuate, confounding the ability to detect decline trends, especially in the absence of baseline data (Pechmann & Wilbur 1994; Alford & Richards 1999; Marsh 2001; Green 2003). Determining amphibian population trends, requires multi-year studies that ideally include population turnover, that is immigration and emigration, as well as multiple generations (Connell & Sousa 1983; Semlitsch 2002; Adams et al. 2013). Such long-term monitoring provides valuable insights to decline stressors, population responses to environmental variation, and population resilience to perturbations and habitat change for at-risk species (Gibbons et al. 2006; Homyack & Hass 2009). It is also necessary in order to determine if populations are in decline or exhibiting natural fluctuations, and to identify proximate causes (Pechmann et al. 1991; Lips et al. 2003; Storfer 2003). Thus, multi-year monitoring is critical for evaluating species population trends and identifying how annual environmental variability, and which factors (i.e., rainfall, stream flow), affect population trends (Green 2003; Walls et al. 2013).

Amphibians are highly sensitive to changes in the hydrological cycle, and both dry and wet extremes can affect annual breeding success and abundance (Walls et al. 2013; Mac Nally et al. 2014; Ryan et al. 2015). This issue is especially pronounced for species that live in highly variable habitats, such as rivers in arid environments, which exhibit highly variable flow regimes (Kupferberg 1996; Ocock et al. 2014). For instance, annual flow variability can lead to gradual decreases in flow that desiccate eggs and tadpoles; conversely, abrupt flow increases can scour eggs and tadpoles (Kupferberg 1996) or preclude or shift breeding to poor quality habitats (Ocock et al. 2014). The influence of extreme hydrologic shifts can induce regional declines, even among species that may not currently be considered at risk (Mac Nally et al. 2014). To our knowledge, no studies to date have addressed the impacts of stream hydrology on arid, stream-breeding amphibian species.

In 2013, we initiated a field study to assess the status of the stream breeding Arizona Toad (*Anaxyrus microscaphus*) in New Mexico. The Arizona Toad is currently listed as a Species of Greatest Conservation Need in New Mexico and is protected, or considered a state 'sensitive' species, in Arizona, Nevada, and Utah (Hammerson & Schwaner 2004; Schwaner & Sullivan 2005; New Mexico Department of Game & Fish 2006 and 2016). In Arizona, Nevada, and Utah, habitat modification, disease, and hybridization are the primary threats to the species' long-term persistence (Schwaner and Sullivan 2005; Schwaner & Sullivan 2009; Dodd 2013). At the time of the initial conservation determination for New Mexico in 2006, threat risk was assigned based on disease-related declines of the sympatric

Chiricahua Leopard Frog, and hybridization-related declines in Arizona, Nevada, and Utah (Hammerson & Schwaner 2004; C.W. Painter, personal communication). Through our previous work, we have found that hybridization is not currently a threat to the Arizona Toad in New Mexico (Ryan et al., *in press*). However, we did identify climate change, habitat modification, forest fires, and disease to be major threats (Ryan et al. 2014a; Ryan et al. 2014b; Ryan et al. 2015).

The year 2016 represented a rare opportunity to study the impacts of what was predicted to be a strong El Niño on the Arizona Toad in New Mexico. In September 2015 there was a 95% probability of a strong El Niño event for winter 2015 and spring 2016, and New Mexico was expected to receive above average precipitation (Climate Prediction Center 2015). Since El Niño is a large-scale, cyclic climate event that occurs every 3-7 years, it is rare that frog population studies coincide with such events (Ryan et al. 2015). The 2016 El Niño offered a serendipitous opportunity to investigate if expected increased winter precipitation influenced Arizona Toad breeding success. Because we had monitored >75 Arizona Toad sites for three consecutive years (2013–2015), we had baseline data to detect deviations of calling behavior and breeding success in response to the 2016 El Niño event. During wet years associated with El Niño, many frog species are known to have an increase in breeding individuals at breeding sites (e.g., Mac Nally et al. 2014). Furthermore, Sullivan (Brian Sullivan, personal communication) has observed increased breeding efforts of the Arizona Toad in Arizona during and following El Niño events of the 1990s. Lovich (Robert Lovich, personal communication) reported the same observation in California for the Arizona toad's sister species, the Arroyo Toad (*A. californicus*). Based on these observations, we predicted that we would find more toads at breeding sites and find an increase in the number of occupied sites relative to observations in 2013-2015. In addition, we investigated the impact of stream flow on Arizona Toad breeding behaviors and the prevalence of disease and parasites in New Mexico.

## Methods

### Call Surveys and Site Occupancy

Our sampling protocol in 2016 followed that used in previous years (2013-2015). We conducted weekly call surveys in March and April, covering the breeding period for the Arizona Toad in New Mexico at 82 historical localities (Degenhardt et al. 1996; Ryan et al. unpublished). Our approach is a popular method to measure trends of populations. It uses historical occurrence data as a baseline and compares these data with present-day sampling to assess temporal changes in species presence/absence (e.g., Skelly et al. 2003; Tingley & Beissinger 2009). This approach may be biased if resurvey efforts are of short duration or if historical data is based on detections rather than detections and non-detections (Skelly et al. 2003; MacKenzie et al. 2006). Our study occurred over multiple periods and accounted for imperfect detection to assuage concerns of biased estimations of species occurrence and trend interpretations (MacKenzie et al. 2002; 2003).

Our call survey design was used to evaluate occupancy and provide an assay of relative abundance of males based on call intensity (Heyer et al. 1994). Each site was scored using an index established by the North American Amphibian Monitoring Program (Weir & Mossman 2005). We listened for toad vocalizations for 3 minutes at each site and intensity was categorized as 0 = no toads heard calling; 1 = individuals could be counted; 2 = calls overlapping but individuals can still be distinguished; 3 = full chorus, cannot distinguish individuals. This is an ideal method for detecting species with strong vocalizations that call regularly over the course of their breeding season (Heyer et al. 1994).

Accurate measures of detectability are critical when assessing a species' conservation status because non-detection may not mean that a species is truly absent from a study site (MacKenzie et al. 2002). This issue is especially important when using call surveys, where daily climatic variability can influence whether individuals vocalize (e.g., Saenz et al. 2006). Repeated sampling of sites over the course of a single season allows for robust calculation of species detection and site occupancy estimates and address biases associated with examining raw presence/absence data (MacKenzie et al. 2006).

We used program PRESENCE (MacKenzie et al. 2002) to estimate the detection probability of toads and the probability of occupancy for sites where toads were not detected. This approach makes several assumptions: 1) occupancy does not change during the sampling period; 2) detections are independent of detections at other sites; 3) detectability is constant across sites and surveys or it can be modeled using site or survey covariates. To model detection probability, we considered models where detection probability was either constant or survey-specific. For purposes of occupancy analyses, all sites sampled within a 48-hour period were considered to fall into the same sampling period. There were seven sampling periods in 2016. We then used Akaike's Information Criterion (AIC) to rank models by calculating Akaike weights (Burnham & Anderson 2002) and selected the highest-ranking model to calculate probability of occupancy for each sampling site where toads were not detected.

### Abiotic Factors and Calling Behavior

The reproductive strategies of stream breeding amphibians are well suited to flow perturbations at long-time scales, but are vulnerable to reproductive failure during annual disturbances (e.g., Kupferberg 1996; Ocock et al. 2014). The flow regime of the major rivers of western New Mexico (Gila and San Francisco) is highly variable, with potential flashfloods from spring runoff and summer storms, and, conversely, very low water levels in years with low winter snow accumulation and drought conditions (Gori et al. 2014). Such variability in flow rates can be a determining factor for whether riparian breeding species call or reproduce, especially during periods of above average flow (e.g., Kupferberg 1996; Bondi et al. 2013). Even at short time scales, high flow rates resulting from severe storms or other climatic perturbations can influence whether frogs call and breed, affecting annual reproduction (Kluge 1981; Fukuyama & Kusano 1992; Ocock et al. 2014). Other factors, such as temperature, cloud cover, and lunar cycles, have also been shown to influence frog and toad breeding activity (Fukuyama & Kusano 1992; Saenz et al. 2006). Understanding the effect of abiotic factors, such as stream flow, on call behavior is critical for monitoring programs and management actions (Bondi et al. 2013).

We tested the effects of multiple abiotic variables on toad calling activity (calls detected/not detected and call intensity). We used logistic regression to analyze nightly call survey data with air temperature, wind speed (Beaufort wind scale), moon phase, index of cloud cover percentage, and river flows (cubic feet per second [cfs]; obtained from the USGS U.S. Stream Flow database <http://waterdata.usgs.gov/nwis/rt>) for the date of each survey. We limited the analyses to call survey data collected between 2013 and 2016 from the Gila, Mimbres, and San Francisco Rivers, the only rivers with USGS gauge stations. We set call detection (yes or no) and call intensity (ranked 0-3) as the dependent variables and the environmental factors as predictor variables. We combined data for all years and produced models for each river separately.

We measured air temperature, wind speed, and cloud cover at the time of each survey. We obtained lunar cycle information (% moon visible) from NASA. We downloaded river flows from the U.S. Geologic Survey U.S. Stream Flow database. Discharge data, in cfs, came from USGS gauging stations at Gila River near Gila (USGS Gauge 9430500), Mimbres River near Mimbres (USGS Gauge 08477110), San Francisco River near Reserve (USGS Gauge 9442680), and San Francisco River near Glenwood (USGS Gauge 9444000) (online at <http://waterdata.usgs.gov/nwis/rt>).

There are no gage stations on the Tularosa River, but we followed Propst et al. (2008) in assuming the San Francisco station near Reserve reflected flows along the Tularosa River. Similarly, we assumed the Mimbres River flow station near Mimbres reflected flows of Sapillo Creek, because they are similar order streams and meet approximately 20 miles upstream from the gage station at Mimbres.

We ran a series of logistic regression models with cfs, the only variable significantly associated with calling activity (see results below) from the first analysis. The models are: Model 1 – detection and cfs with all years and streams combined; Model 2 – detection and year for all streams combined; Model 3 – detection and cfs by individual stream with years combined; Model 4 – call intensity and cfs for all years and streams combined; Model 5 – call intensity and year for all streams combined; and Model 6 – call intensity and cfs by individual stream with years combined. We did not produce a model of detection and year by stream because of a lack of observations when the data are separated by stream and year.

### Breeding Success

Amphibian breeding success cannot be determined solely by the presence of calling males, eggs, or tadpoles (Richter et al. 2003) but requires observing metamorphosed toadlets dispersing from breeding sites. Hydroperiod length (i.e., the number of days a water body maintains water; Semlitsch 1987; Pechmann et al. 1989; Rowe & Dunson 1995) and hydrologic conditions (i.e., consistent water levels; Kupferberg 1996; Richter et al. 2003) of water bodies used for breeding are critical for amphibian breeding success (i.e., emergence of metamorphosed froglets). Reproductive failure can occur from drying of breeding habitats or flashfloods before metamorphosis (Richter et al. 2003; Kupferberg et al. 2011; Bondi et al. 2013), even if calling, egg laying, and tadpoles are observed.

We visited focal sites (i.e., sites where toads were detected in March and April) to

determine if Arizona Toad reproductive effort in 2016 resulted in metamorphosed toadlets dispersing from breeding sites. We visited Black Canyon Creek, West Fork of the Gila River, and the confluence of the Gila River and Little Creek. These focal sites do not represent all sites where calling was detected, but are sites on public land that we were able to access for visual encounter surveys.

### Collection and Analyses of *Bd* Samples and Other Diseases

We used a total of 63 Arizona Toads to test for presence of the fungal disease *Batrachochytrium dendrobatidis* (*Bd*) from a total of from nine localities (Indian Tank, Snow Lake, Hell's Hole, Gila River West Fork, Poverty Creek, O-Bar-O Tank, two sites along the San Francisco River, and one site on NM State Road 12). All samples were collected between March and May and were analyzed by Pisces Molecular Laboratory. Samples were submitted to Pisces Molecular in pools of multiple swabs, which allowed for multiple samples to be tested for the presence of *Bd* simultaneously. If a pooled sample tested positive, a second analyses was to be run on that pool to determine which animal tested positive.

In addition to presenting the *Bd* sampling results from 2016, we provide a summary of *Bd* sampling for the entire duration of the Arizona Toad surveys from 2013 to 2016. This includes information collected by us, as well as information collected by Dr. Jamie Voyles and Gabriela Rios-Sotelo (currently at University of Nevada - Reno).

In 2015 we described the presence of a new skin parasite, the chigger *Hannemannia bufonis*, on the Arizona Toad (Ryan et al. 2016b). The infestation of this chigger is known to cause mortality in Canyon Treefrogs (Sladky et al. 2000), and we have circumstantial evidence of mortality in Arizona Toads. The distribution of the chigger parasite is unknown in New Mexico. Diagnostic evidence of the chigger parasite infection can be observed by the presence of orange to red spots on the toad's arms, legs, and ventral surfaces. We examined hundreds of wild toads for the presence of the parasite in the field. If we found red spots, we collected the infected specimens for further lab work to verify infection.

In 2014, we found evidence of a potential new skin fungal disease (Ryan et al. 2014), which was preliminarily identified as *Amphibiothecum* sp. or *Amphibiocystidium* sp. fungi (Kiryu et al. 2014). It was not possible to accurately identify the novel skin fungal pathogen from 2014 because the specimens examined were preserved in formalin (following standard protocols), and histology alone is not a reliable method for fungal identification. The *Amphibiothecum* sp. or *Amphibiocystidium* sp. fungi are known to cause mortality in European frogs (Pascolini et al. 2003; Densmore & Green 2007), and there is one case of mortality in a North American newt (Raffel et al. 2008). In the case of the newt, the species of fungi was a new species and appears to be an emerging pathogen capable of causing high rates of mortality (Raffel et al. 2008). With regards to the Arizona Toad, there is an urgency to determine the identity of the fungal pathogen found in 2014. During our 2016 surveys, we captured toads to inspect them for physical signs of infection, which include small lesions, as well as behavioral signs of infection, including the inability to right themselves when placed on their dorsum. Any sick toads encountered were transported live back to the University of New Mexico, or if freshly dead, placed on ice or preserved in 95% ethanol for molecular screening in Dr. Joe Cook's laboratory.



## Results

### Call Surveys and Site Occupancy

Between 10 March and 16 April 2016, we sampled 82 localities where we conducted a total of 470 call surveys (Tables 1, 2, Fig 1) and detected toads at 28 (33%) of the sampling localities. Each site was visited an average of 3.9 times (median 4, range 2-6). Of the 28 occupied sites, 20 (71%) had a maximum call intensity of 1; 6 (22%) had a maximum call intensity of 2; and only 2 sites (7%) had a maximum call intensity of 3. In 2016, the number of occupied sites (sites where call intensity was at least 1) and the number of sites with maximum call intensity of 3 were similar to results in 2014, but greater than in 2013 (Table 2). This suggests that regional population status was relatively stable in the last three years, but the naïve (without accounting for variation in detectability) number of occupied sites has decreased compared to the number of historically occupied sites (i.e., a decline of ~70% range-wide because only an average of 31.6% of historic sites surveyed were occupied in 2013-2016).

We used data from all 82 sites in constructing a model to estimate probabilities of detection and occupancy for 2016. The best model included sampling period as a covariate affecting detectability. The estimated mean detection probability for all sites was 0.444, and ranged from 0.0128 to 1, with 1 representing the sites where toads were detected. Estimates varied considerably between sampling periods, which may be attributed to short-term weather variation or seasonal shifts in calling behavior. However, the mean detection probability estimates for all sites did not vary among 2014, 2015, and 2016 (ANOVA:  $P=0.36$ ;  $R^2=0.006$ ; F-ratio = 0.836). The naïve occupancy (proportion of sites occupied without accounting for detection probability) for all surveyed sites was 0.342, whereas the estimated proportion of sites occupied was slightly higher (0.398), but within the range of the standard error. Probability of occupancy estimates for sites where toads were not detected ranged from 0.012 to 0.286 (Table 3), suggesting a low probability of presence of toads at sites identified in presence/absence surveys as unoccupied.

We did not detect toads at Rain Creek, Rocky Canyon, or the Gila River in the Burro Mountains. Stream conditions along Rain Creek appeared to constitute suitable habitat, and toads were found in similar habitats along the Tularosa River. The stream in Rocky Canyon dried out notably by early April, which would have precluded breeding if toads do occur in this creek. Surveys along the Gila River in the Burro Mountains did not yield Arizona Toads, but we did find large numbers of Woodhouse's Toad metamorphosed toadlets dispersing in June and July. We infer from this effort, and previous call surveys from 2014 and 2015, that the Arizona Toad is now extirpated from the Burro Mountains. The cause of this extirpation is unclear, but may be related to practices on nearby farms and agricultural disturbances. The nearest Arizona Toad breeding sites are approximately 5 miles north, near the Gila Riparian Preserve and Turkey Creek Trailhead. The habitat between these sites and the Burro Mountains is now converted to agriculture fields with little forest cover. The elimination of forest cover, in combination with farming practices that cause the proliferation of slow or non-moving bodies of water, may have contributed to the loss of the Arizona Toad in this area. In contrast, Woodhouse's Toad is highly adaptable to disturbance and appears to have benefited from local habitat modification.

## Abiotic Factors and Calling Behavior

We found that stream flow was the only abiotic factor that predicted calling activity (i.e., intensity, Table 4). Because of this result, we did not conduct further analyses on cloud cover, temperature, wind speed, and moon visible percentage, and therefore focused on cfs among rivers.

Mean daily flows (measured as cfs at gage stations) from 1 March to 18 April for the Gila, San Francisco and Mimbres Rivers differ considerably between rivers (Table 5) and were highest in 2013 (Fig 2). In addition, mean daily cfs was significantly variable among years for each river (Fig 2; ANOVA: F-ratio = 867.73, 903; P = 0.0001). All logistic regression models produced significant results ( $p < 0.05$ ) of cfs predicting detection of calls and intensity for all rivers and years: Model 1 – detection and cfs for all years and streams combined; Model 2 – detection and year for all streams combined; Model 3 – detection and cfs by stream with years combined; Model 4 – call intensity and cfs for all years and streams combined; Model 5 – call intensity by year for all streams combined; and Model 6 – call intensity and cfs by stream with years combined.

The logistic regression models for each individual river included only cfs as a predictor of detection of calls and call intensity. From each model, we were able to estimate the cfs threshold above which toads did not call according to our nightly survey data (Fig 3). The predicted cfs for detecting toads varied among streams according to stream size and indicated that toads did not call when cfs was above 142.2 cfs along the Gila River, 63.8 cfs along the San Francisco near Glenwood, 16.2 cfs along the Mimbres River, 14.3 cfs along Sapillo Creek, 7.4 cfs along the San Francisco near Reserve, and 7.8 cfs along the Tularosa River. When applied to historical data on river flows, there are longer stretches of consecutive years in the Gila and San Francisco Rivers above the cfs threshold for toad breeding than consecutive years below the threshold, when breeding should occur (Fig 4). In addition, we calculated that for the Gila and San Francisco Rivers, toads may not be able to breed in a majority of years: 55% of years for the Gila, 52% for San Francisco at Glenwood, 67% for San Francisco at Reserve, but may be able to breed in a majority of years in the Mimbres River (59%). This assumes that, for a given year, toads will still breed if the number of days in a year over the threshold is equal to or less than 50% (Fig 5).

## Breeding Success

Reproductive success (emergence of metamorphosed toadlets) was lower than expected in 2016, with toadlets being detected at Black Canyon, Middle Fork and West Fork of the Gila River. Only six sites (i.e., call survey stations) from the Middle Fork Trailhead to the West Fork Trailhead had toadlets dispersing in July. Toadlets were observed emerging from protected side channels or backwaters along the Gila River Middle and West Fork stretches, with minimal detection of toadlets coming from the main channel. This is in contrast to 2015 when toadlets were observed in large numbers (i.e., thousands) emerging and dispersing from the main channel along the West Fork of the Gila River. We hypothesize that the change in numbers, and habitats from which emergence was observed (main channel versus side channels/pools), may be due to high stream flows in the main channel of the Gila River in 2016. The high flows may have forced toads to breed in side

channels or pools instead of the main channel, or eggs laid in the main channel may have been washed away, leaving behind those laid in more protected, side channels.

### Collection and Analyses of *Bd* Samples and Other Diseases

None of the 63 samples, from nine localities, analyzed tested positive for *Bd* in 2016 (Table 6).

Despite capturing and inspecting dozens of Arizona Toads for parasite infection or clinical signs of fungal infections in 2016, we did not find evidence of either. We inspected the toads' ventral surface and limbs for the diagnostic red spotting indicative of a *Hannemannia bufonis* chigger parasite infection. The lack of red spotting is surprising, but may be driven by the fact the most heavily infected locality in 2015, Indian Tank, was dry and no toads were present in 2016.

Our field review for the *Amphibiothecum* sp. or *Amphibiocystidium* sp. fungi did not identify any toads with lesions, and all toads were able to right themselves when placed on their dorsum. At this time, we are unaware of another technique to identify possibly infected toads, and there is no non-invasive technique similar to *Bd* swabbing and diagnostic laboratory detection. As is the case for the chigger infection, the sick toad from 2014 was found at Indian Tank, which was dry in 2016, therefore we were unable to test for infection at this site. At this time molecular primers for detecting the *Amphibiothecum* sp. or *Amphibiocystidium* sp. fungi have been purchased and are stored at Dr. Joe Cook's laboratory at the University of New Mexico. If sick or dying toads are found in the future, they should be sent to Dr. Cook's lab immediately for genotyping and sequencing to identify the pathogen.

## Discussion

### 2015-2016 El Niño

During El Niño, the southwestern United States receives above average precipitation, resulting in deep snowpacks that lead to increased streamflows, especially during late winter and early spring months. The streamflow variability of the watersheds in the eastern Mogollon Rim of New Mexico (e.g., Gila River) is strongly associated with precipitation anomalies driven by El Niño events. As of December 2015, El Niño conditions had persisted for 10 consecutive months and all prognostications indicated it would be a strong event and last through spring 2016 (CLIMAS Dec 2015). By March 2016, El Niño conditions had persisted for 13 consecutive months, but the anticipated above average precipitation never materialized for the southwestern United States (CLIMAS Feb 2016). Precipitation during the 2015-2016 El Niño was well below average for the southwest, especially for southern New Mexico, despite this event being one of the strongest on record (CLIMAS Apr 2016). The below average precipitation for the southwestern United States during the 2015-2016 El Niño was in part driven by a anomalous and persistent high pressure system over Arizona and New Mexico between October 2015 and March 2016 (CLIMAS Apr 2016).

We obtained monthly precipitation data from three weather stations: Frisco Divide, Silver City, and Gila Hot Springs from 2013 to 2016. We averaged monthly rainfalls across the three stations and then summed to obtain average annual precipitation across the region. The 2016 data only covers up to October, as November and December data are not yet available from NOAA. The mean annual precipitation (from the three stations) shows variation during our study period.

In December 2015, we visited five streams in the western Gila that had not had aboveground water flow for the last four-years. These five streams were all flowing due to increased precipitation. In addition, many tanks that were dried, or had low water levels, in 2015 were filled with water at the end of 2015. The fall and winter precipitation associated with the 2016 El Niño initially appeared to have greatly increased the number of potential Arizona Toad breeding sites. Initially, the expectation was that the excess water would prevent tanks and smaller streams from drying during the breeding season, potentially increasing regional reproductive success. However, there were anomalously low precipitation levels associated with the 2015-2016 El Niño event.

Our raw call survey data collected between 2013 and 2015, and results from detection and occupancy modeling from 2014 and 2015, show consistent results among years, with an approximate 70% decline in the number of occupied Arizona Toad localities compared to historic surveys (Tables 1, and 2; Ryan et al. 2014a). The largest annual variation in occupied sites was between 2013 and 2014, which was due to high river flow rates along the Gila River in 2013 (Fig 2), which appears to influence detection and breeding activity. The below-average rainfall in recent years has led to the drying of many small tributaries along the river systems in the Gila, thus excluding many potential breeding sites. The reduction in available breeding sites may be the driving factor in the low number of occupied sites we have found over the last three years. The current El Niño brought high amounts of winter precipitation in the region and many of the previously dried tributaries were flowing in December 2015 (Ryan personal observation).

Consistent with the number of occupied sites between 2013 and 2015 is the proportion of occupied sites that have small numbers of breeding males. Our call intensity assays show that in 2014 and 2015, 2% and 5% of sites, respectively, had a call index of 3, indicating a very small number of large breeding congregations. This pattern continued in 2016, with only 2% of sites with large congregations. While there was an increase in large congregations between 2013 and subsequent years, this confirms that populations at the majority of occupied sites are relatively small and therefore vulnerable to extirpation from stochastic events. It is likely that this is, in the long-term, a stable strategy for the Arizona Toad given the highly dynamic nature of their riparian breeding habitats. Flashfloods are a common occurrence for the rivers of the Gila Region, which can alter riparian habitats in a shifting mosaic. We hypothesize that the small number of large breeding congregations act as core sources for colonization of the smaller, satellite congregations following flashfloods. Under this scenario, river systems that lack large source congregations are at greater risk of local extirpation. To date, we are unaware of any large breeding congregations along the San Francisco River, Whitewater Creek, and Willow Creek, which all consist of small breeding congregations. Conversely, the Gila River, Mimbres River, and Black Canyon Creek have large breeding congregations, which may preserve the integrity of the metapopulation

dynamics within these rivers. Our call intensity assay data and inferences are in need of testing and quantification using population genetic analyses to determine dispersal patterns within drainages in relation to large breeding congregations. This information will be invaluable to conservation managers in planning any recovery or management actions.

The disease chytridiomycosis (*Bd*) has been responsible for many enigmatic amphibian population die-offs and declines (Wake & Vredenburg 2008), and is responsible for declines in some New Mexico species (e.g., Ryan et al. 2014b). *Bd*-driven amphibian population declines are typically associated with mass die-offs (dozens to hundreds of individuals) at breeding sites, often occur at middle elevations, may effect stream species more than terrestrial species, and occur uniformly across the landscape (Bradley et al. 2002; Lips et al. 2003 and 2006). The apparent declines we have observed in the Arizona Toad (a decrease in occupied localities spanning 1959—2007) do not necessarily fit the pattern of a *Bd* outbreak. For example, during the period of time when *Bd* moved through New Mexico, causing declines in the Chiricahua Leopard Frog, there were no reported incidents of mass die-offs of the Arizona Toad (e.g., Ryan et al. 2014b). In addition, extant toad populations occur in scattered localities across the Gila Region from low to high elevations (Fig 1) and do not conform to a spatial pattern that would suggest a pattern driven by a *Bd*-decline. Furthermore, even though *Bd* has been detected in the Arizona Toad, prevalence rates are low (Ryan et al. 2014b), and many amphibian species can exist with *Bd* but not show signs of decline (e.g., Lannoo et al. 2011; Olson et al. 2013). While we cannot conclusively rule out *Bd* as a causative or contributing agent of the apparent declines in site occupancy by the Arizona Toad, other factors, such as land-use change or climatic conditions, appear to be driving declines since historic surveys (Ryan et al. 2014a).

The results presented in this report need to be examined in the context of the proposed Gila River Diversion Project (Fig 1) and subsequent flow changes to the Gila River. The proposed diversion project would occur near Turkey Creek and could potentially impact flow rates and lead to habitat change up to 60 miles upstream based on impacts that have been observed in Arizona (Schwaner & Sullivan 2009). This has the potential to negatively impact the largest Arizona Toad populations in New Mexico. A side effect of riverine diversions in the southwest is the facilitation of the spread of the native Woodhouse's Toad, which may hybridize with and threaten the persistence of the Arizona Toad (Hammerson & Schwaner 2004; Sullivan et al. 2015). Contact between *A. woodhousii* and *A. microscaphus* primarily occurs in modified riparian habitats, and hybridization is unidirectional with female *A. woodhousii* mating with male *A. microscaphus* (Malmos et al. 2001). The resulting hybrid toads are fertile and, over decades, hybrids with *A. woodhousii* alleles replace and dominate *A. microscaphus* alleles in populations within contact zones (Schwaner and Sullivan 2009; Sullivan et al. 2015). Currently, there is no evidence of hybridization between the Arizona and Woodhouse's Toads in New Mexico (Ryan et al. *in press*).

## Management Recommendations

These recommendations are based on a synthesis of all four years of the Arizona toad work, not just 2016. We reference previous reports when necessary, but the reports are not included as appendices.

### **1. POPULATION MONITORING.**

Justification. The breeding success and biology of the Arizona toad in New Mexico is one that can be characterized as sporadic and highly vulnerable to stochastic environmental variation. Stream flow (i.e., cfs) is the greatest regulator of whether toads will breed in a given year, and late spring or early summer storms can destroy a cohort of tadpoles before they metamorphose. Toads have not been detected at ~70% of historical sites, suggesting that widespread declines have occurred in New Mexico over the past few decades. Furthermore, there are few sites that we monitored that had large breeding choruses, which is an indicator of a large breeding population. Additionally, our analyses of long-term streamflows shows that stream conditions are often not appropriate for breeding (Figs 3-5). In spite of this, many of the populations we have monitored between 2013 and 2016 appear to be stable. However, given the Arizona Toad's vulnerability to environmental stochasticity (i.e., flood events, drought, forest fires and associated, post-fire floods), many populations may be prone to local extirpation. Therefore, annual population monitoring is needed to identify populations most at risk and potential die-offs from disease or parasites, so that conservation actions can be taken promptly.

Methods. The most effective manner to institute population monitoring is to conduct weekly call surveys between 1 March and 18 April at key locations. Criteria for these locations include apparently large populations, areas on routes of convenience (to minimize cost), and areas at risk from previously acknowledged threats. We have identified sites on highways NM-15 near the Cliff Dwellings, sites along NM-35 and NM-61, Hell Hole on NM-12, and areas in the Gila-Cliff Valley. These identified sites are easily accessed and it would be possible to sample these sites with collaborations between U.S. Forest Service, National Park Service, and New Mexico Department of Game and Fish. Data collected can be compared to this study and provide trends on occupancy.

### **2. IDENTIFICATION OF "SOURCE" POPULATIONS FOR RELOCATION.**

Justification. There is a strong likelihood that certain populations will experience prolonged years of failed reproduction and/or recruitment (e.g., Fig 4A). In cases deemed appropriate, such as during a year with ideal streamflows and few eggs laid, egg masses or tadpoles can be relocated to supplement these at risk localities. This can bolster local abundances to compensate for consecutive years with zero recruitment.

Methods. Standard egg mass or tadpole handling and transportation methods would have to be developed. We have identified two locales that can be used as source pools for relocation; Indian Tank and West Fork of the Gila River near the Gila Cliff Dwellings. Indian Tank represents an interesting case study because in 2014 and 2015 it had the highest density of breeding toads out of all study sites. Arizona toads do not naturally breed in cattle tanks, and normally eggs deposited in tanks do not survive to metamorphosis. In

2014 and 2015 we estimated 300,000 to 500,000 eggs laid in this tank, and none survived to metamorphosis due to drying of the tank. In 2016, Indian Tank was dry and no reproduction occurred. Therefore, all evidence suggests that Indian Tank is a sink for Arizona Toads, and these eggs and tadpoles can be used to supplement small, at risk populations with a better chance of survival to metamorphosis.

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## Publications and Abstracts

This list includes all manuscripts, published papers, and abstracts resulting from this project since 2013.

### Published and Accepted:

Ryan, MJ, IM Latella, TJ Giermakowski, & H Snell. No evidence of hybridization between the Arizona Toad (*Anaxyrus microscaphus*) and Woodhouse's Toad (*A. woodhousii*) in the Gila Region of Southwestern New Mexico. *Herpetological Conservation and Biology*, in press.

Ryan MJ, IM Latella, TJ Giermakowski, G Gustafson, & H Snell. (2016) ANAXYRUS MICROSCAPHUS. Diet. *Herpetological Review*, 47:436.

Ryan MJ, CT McAllister, LA Durden, Y Kiryu, JH Landsberg, IM Latella, & JT Giermakowski. (2016) ANAXYRUS MICROSCAPHUS (Arizona Toad) ECTOPARASITES. *Herpetological Review*, 47:436-438.

Ryan, MJ, IM Latella, CW Painter, JT Giermakowski, BL Christman, RD Jennings, JL Voyles (2014) First record of *Batrachochytrium dendrobatidis* in the Arizona toad (*Anaxyrus microscaphus*) in southwestern New Mexico, USA. *Herpetological Review* 45:616-618.

### In Preparation:

Ryan MJ, IM Latella, TJ Giermakowski, & H Snell. Going with the flow: toad breeding behavior and success influenced by stream flows. Target Journal: *Freshwater Biology*.

Ryan, MJ, IM Latella, JT Giermakowski, G Gustafson. Toads eat the craziest things: diet of the Arizona Toad (*Anaxyrus microscaphus*) in New Mexico. Target Journal: *Journal of Herpetology*.

Ryan, MJ, IM Latella, JT Giermakowski. The decline of another anuran in the southwestern United States? Recent population trends of the Arizona Toad in west-central New Mexico. Target Journal: *Biological Conservation*.

### Reports:

Ryan MJ, IM Latella, TJ Giermakowski, & H Snell. (2016) Effects of El Niño on breeding behavior of the Arizona Toad (*Anaxyrus microscaphus*) in New Mexico. New Mexico Department of Game & Fish, Interim Report, 12 pp.

Ryan MJ, IM Latella, TJ Giermakowski, & H Snell. (2015) Patterns of occupancy and distribution of the Arizona Toad (*Anaxyrus microscaphus*) in New Mexico. New Mexico Department of Game & Fish, Final Report, 58 pp.

Ryan, MJ. Arizona Toad (*Anaxyrus microscaphus*) comments to U.S. Fish & Wildlife Service (2015). Endangered and Threatened Wildlife and Plants 90-Day Findings on Petitions.

Ryan MJ, IM Latella, & TJ Giermakowski. (2014) Current status of the Arizona Toad (*Anaxyrus microscaphus*) in New Mexico: Identification and evaluation of potential threats to its persistence. New Mexico Department of Game & Fish, Final Report, 48 pp.

Ryan MJ & IM Latella. (2013) Current status of the Arizona Toad (*Anaxyrus microscaphus*) in New Mexico: Identification and evaluation of potential threats to its persistence. New Mexico Department of Game & Fish, Final Report, 29 pp.

Abstracts:

Ryan, MJ, IM Latella, JT Giermakowski. The decline of another southwestern anuran species? Recent population trends of the Arizona Toad in west-central New Mexico. New Mexico & Arizona Chapters of The Wildlife Society annual meeting (Feb 2015).

## Tables

Table 1. Summary of calling intensity for all surveys between 2013 and 2016. A survey was assigned to a category based on the highest calling intensity recorded during the March through April sampling. Intensity criteria are: 0 = no toads heard calling; 1 = individuals could be counted; 2 = calls overlapping but individuals can still be distinguished; 3 = full chorus, cannot distinguish individuals.

<i>Call intensity category</i>	<i>2013 # Surveys (% of surveys)</i>	<i>2014 # Surveys (% of surveys)</i>	<i>2015 # Surveys (% of surveys)</i>	<i>2016 # Surveys (% of surveys)</i>
0	294 (86%)	261 (80%)	315 (86%)	434 (92%)
1	32 (10%)	32 (9%)	33 (9%)	28 (5%)
2	9 (3%)	17 (5%)	9 (2%)	6 (1%)
3	0 (0%)	15 (4%)	9 (2%)	2 (0.04%)
<b>TOTAL</b>	<b>294</b>	<b>325</b>	<b>366</b>	<b>470</b>

Table 2. Summary of maximum call intensity by site for 2013-2016. Without accounting for variation in detectability of occupied sites, the number of historically occupied sites has declined ~70% range-wide.

<b><i>CALL INTENSITY CATEGORY</i></b>	<b><i>2013 # SITES (% OF SITES)</i></b>	<b><i>2014 # SITES (% OF SITES)</i></b>	<b><i>2015 # SITES (% OF SITES)</i></b>	<b><i>2016 # SITES (% OF SITES)</i></b>
<b>0</b>	61 (78%)	50 (69%)	54 (71%)	54 (66%)
<b>1</b>	15 (19%)	17 (18%)	12 (16%)	20 (24%)
<b>2</b>	5 (6%)	13 (9%)	6 (8%)	6 (7%)
<b>3</b>	0 (0%)	4 (2%)	4 (5%)	2 (2%)
<b>TOTAL</b>	<b>78</b>	<b>84</b>	<b>76</b>	<b>82</b>



Table 3. Summary of PRESENCE analyses estimating probability of occupancy for 2016.

<i>Site name</i>	<i>Probability of occupancy</i>	<i>Standard Error</i>	<i>CI low</i>	<i>CI high</i>
<i>FS 150-01</i>	0.1177	0.096	0.0213	0.4496
<i>FS 150-02</i>	0.1177	0.096	0.0213	0.4496
<i>FS 150-03</i>	1	0	1	1
<i>FS 150-04</i>	0.1177	0.096	0.0213	0.4496
<i>FS 150-05</i>	1	0	1	1
<i>FS 150-06</i>	1	0	1	1
<i>FS 150-07</i>	0.1177	0.096	0.0213	0.4496
<i>FS 150-08</i>	0.1177	0.096	0.0213	0.4496
<i>FS 150-09</i>	0.1177	0.096	0.0213	0.4496
<i>NM 12-02</i>	0.2429	0.1046	0.0952	0.4944
<i>NM 12-03</i>	1	0	1	1
<i>NM 12-04</i>	1	0	1	1
<i>NM 12-05</i>	1	0	1	1
<i>NM 12-06</i>	0.2103	0.0991	0.0763	0.4618
<i>NM 15-01</i>	0.2151	0.1	0.079	0.4668
<i>NM 15-02</i>	0.2103	0.0991	0.0763	0.4618
<i>NM 15-03</i>	0.2103	0.0991	0.0763	0.4618
<i>NM 15-04</i>	0.2103	0.0991	0.0763	0.4618
<i>NM 15-05</i>	0.2103	0.0991	0.0763	0.4618
<i>NM 15-06</i>	0.2103	0.0991	0.0763	0.4618
<i>NM 15-07</i>	1	0	1	1
<i>NM 15-08</i>	1	0	1	1
<i>NM 15-09</i>	1	0	1	1
<i>NM 15-10</i>	1	0	1	1
<i>NM 15-11a</i>	0.2103	0.0991	0.0763	0.4618
<i>NM 15-11b</i>	1	0	1	1
<i>NM 15-12</i>	1	0	1	1
<i>NM 15-13a</i>	1	0	1	1
<i>NM 15-13b</i>	1	0	1	1
<i>NM 15-14</i>	0.2103	0.0991	0.0763	0.4618
<i>NM 15-15</i>	1	0	1	1
<i>NM 15-16</i>	0.2103	0.0991	0.0763	0.4618
<i>NM 15-bridge</i>	1	0	1	1
<i>NM 211-01</i>	0.2623	0.1066	0.1077	0.5114
<i>NM 293-01</i>	0.2623	0.1066	0.1077	0.5114
<i>NM 35-01</i>	1	0	1	1

<i>NM 35-02</i>	0.1086	0.0906	0.0191	0.4328
<i>NM 35-03</i>	0.1086	0.0906	0.0191	0.4328
<i>NM 35-04</i>	0.1086	0.0906	0.0191	0.4328
<i>NM 35-05</i>	0.1086	0.0906	0.0191	0.4328
<i>NM 35-07</i>	0.1086	0.0906	0.0191	0.4328
<i>NM 35-08</i>	0.1086	0.0906	0.0191	0.4328
<i>NM 35-09</i>	0.1086	0.0906	0.0191	0.4328
<i>NM 35-10</i>	0.1182	0.096	0.0216	0.4493
<i>NM 35-11</i>	0.1182	0.096	0.0216	0.4493
<i>NM 35-5A</i>	1	0	1	1
<i>NM 35-A</i>	1	0	1	1
<i>NM 435-01</i>	1	0	1	1
<i>NM 435-02</i>	1	0	1	1
<i>NM 59-01</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-02</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-03</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-04</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-05</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-06</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-07</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-08</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-09</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-10</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-11</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-12</i>	0.1177	0.096	0.0213	0.4496
<i>NM 59-13</i>	0.1177	0.096	0.0213	0.4496
<i>NM 61-01</i>	0.1086	0.0906	0.0191	0.4328
<i>NM 61-02</i>	1	0	1	1
<i>NM 61-03</i>	0.1086	0.0906	0.0191	0.4328
<i>NM 61-04</i>	0.1086	0.0906	0.0191	0.4328
<i>NM 61-05</i>	1	0	1	1
<i>NM 61-06</i>	1	0	1	1
<i>NM 78-01</i>	1	0	1	1
<i>NM 78-02</i>	0.2442	0.1045	0.0962	0.4951
<i>North Tank</i>	0.1177	0.096	0.0213	0.4496
<i>Rock Core Tank</i>	:	0.421	0.0931	-
<i>Saw Mill Tank</i>	:	0.2309	0.1332	-
<i>US 180-01</i>	1	0	1	1
<i>US 180-02</i>	0.2279	0.1019	0.0866	0.4788
<i>US 180-03</i>	0.233	0.1027	0.0896	0.4838

<i>US 180-04</i>	0.2442	0.1045	0.0962	0.4951
<i>US 180-05</i>	0.2103	0.0991	0.0763	0.4618
<i>US 180-06</i>	0.2257	0.1021	0.0849	0.4781
<i>US 180-10</i>	1	0	1	1
<i>US 180-11</i>	0.2855	0.1084	0.1236	0.531
<i>US 180-12</i>	1	0	1	1

Table 4. Mean cfs, on the day of each call survey (mean±SD), for each major stream by call intensity. Note that lower index of calls typically corresponds to higher flows of the river. Range in parentheses.

<b>Drainage</b>	<b>Call Intensity</b>			
	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Gila</b>	150.9±48.1 (58.0–237.8) n = 272	105.3±36.2 (64.6–185.5) n = 39	98.4±19.4 (79.3–126.8) n = 18	89.7±18.4 (79.3–122.0) n = 5
<b>Mimbres</b>	17.0±7.6 (3.2–30.1) n = 154	10.3±7.6 (3.2–22.3) n = 26	17.7±1.5 (16.0–19.0) n = 4	18.0±1.7 (16.0–19.0) n = 3
<b>Sapillo Creek</b>	15.9±7.8 (3.2–30.1) n = 87	9.3±8.2 (3.5–22.3) n = 18	11.7±10.3 (4.4–19.0) n = 2	n = 0
<b>San Francisco (Tularosa)</b>	8.0±2.4 (4.3–13.7) n = 38	6.4±0.6 (5.7–7.3) n = 6	6.6±0.7 (5.5–7.1) n = 4	n = 0
<b>San Francisco (Reserve)</b>	7.7±2.4 (3.7–13.7) n = 72	6.1±1.1 (3.7–7.3) n = 10	5.0±1.0 (4.3–5.8) n = 2	n = 0
<b>San Francisco (Glenwood)</b>	67.0±22.4 (27.6–110.5) n = 42	39.6±10.8 (27.6–51.9) n = 9	59.9±NA (59.9–59.9) n = 1	59.9±NA (59.9–59.9) n = 1

Table 5. Hydrologic attributes of the Gila River drainages in New Mexico at stream flow gauging stations. Mean annual and 1 March – 18 April cfs±SD were calculated from long-term, mean monthly totals. The mean cfs 1 March – 18 April represent flow rates during the breeding period of Arizona Toad (*Anaxyrus microscaphus*) in New Mexico.

<b>USGS Gage</b>	<b>Watershed area (km<sup>2</sup>)</b>	<b>Mean annual cfs</b>	<b>Mean cfs 1 March – 18 April</b>	<b>Time Period</b>
<b>Gila River at Gila</b>	4828	151.1±214.7	272.2±342.9	1928-2015
<b>Mimbres River at Mimbres</b>	296	17.6±28.8	23.4±31.6	1979-2015
<b>San Francisco River at Reserve</b>	906	23.5±45.9	56.7±94.1	1960-2015
<b>San Francisco River at Glenwood</b>	4281	85.9±156.6	164.3±260.2	1928-2015

Table 6. Summary of Arizona Toad *Batrachochytrium dendrobatidis* results from 2013 to 2016 for the eastern Mogollon Rim in New Mexico. All samples were collected in March and April, and because they were collectively, it is not possible to identify specific month for each sample. The exceptions are noted with \* and were collected by Dr. Jamie Voyles and Gabriela Rios-Sotelo and analyzed in Dr. Voyles' laboratory at New Mexico Tech. In total, we found three cases of *Bd* infection in Arizona Toads, one in 2013 and two in 2015.

<b>Year</b>	<b>Site</b>	<b># samples</b>	<b>Bd +/-</b>	<b>Bd infection load</b>	<b>Month</b>
<b>2016</b>	Indian Tank	8	-	0	Mar-Apr
<b>2016</b>	Snow Lake	8	-	0	Mar-Apr
<b>2016</b>	Hell's Hole	8	-	0	Mar-Apr
<b>2016</b>	Gila River, West Fork	8	-	0	Mar-Apr
<b>2016 &amp; 2015</b>	Poverty Creek	5	-	0	Mar-Apr
<b>2016 &amp; 2015</b>	O-Bar-O Tank	6	-	0	Mar-Apr
<b>2016 &amp; 2015</b>	San Francisco River Day-use	7	-	0	Mar-Apr
<b>2016 &amp; 2015</b>	NM 12-3	8	-	0	Mar-Apr
<b>2016 &amp; 2015</b>	San Francisco River US 180-1	6	-	0	Mar-Apr
<b>*2015</b>	Gila River, Cliff Dwellings	1	+	5403.93448	May
<b>*2015</b>	Gila River, Cliff Dwellings	1	-	0	May
<b>*2015</b>	Gila River, Cliff Dwellings	1	+	6983.99353	May
<b>*2015</b>	Snow Lake	1	-	0	May
<b>2013</b>	Gila River, West Fork	16	+	NA	Mar-Apr
<b>2013</b>	Mimbres River, Cooney Camp	3	-	0	Mar-Apr
<b>2013</b>	Hell's Hole	8	-	0	Mar-Apr
<b>2013</b>	San Francisco River - US 180-1	6	-	0	Mar-Apr
<b>2013</b>	San Francisco River - US 180-2	6	-	0	Mar-Apr

Fig 1. Map of the study area indicating per-site detection probability. Black circles denote an occupied site (probability of occupancy is 1), whereas grey circles represent an estimated probability of occupancy (see Results and Table 3). Size of grey circle is proportional to the probability of occupancy. Note that majority of sites where toads were not detected have a low probability of occupancy (<0.25). Red area marks the location of the proposed Gila River Diversion Project.

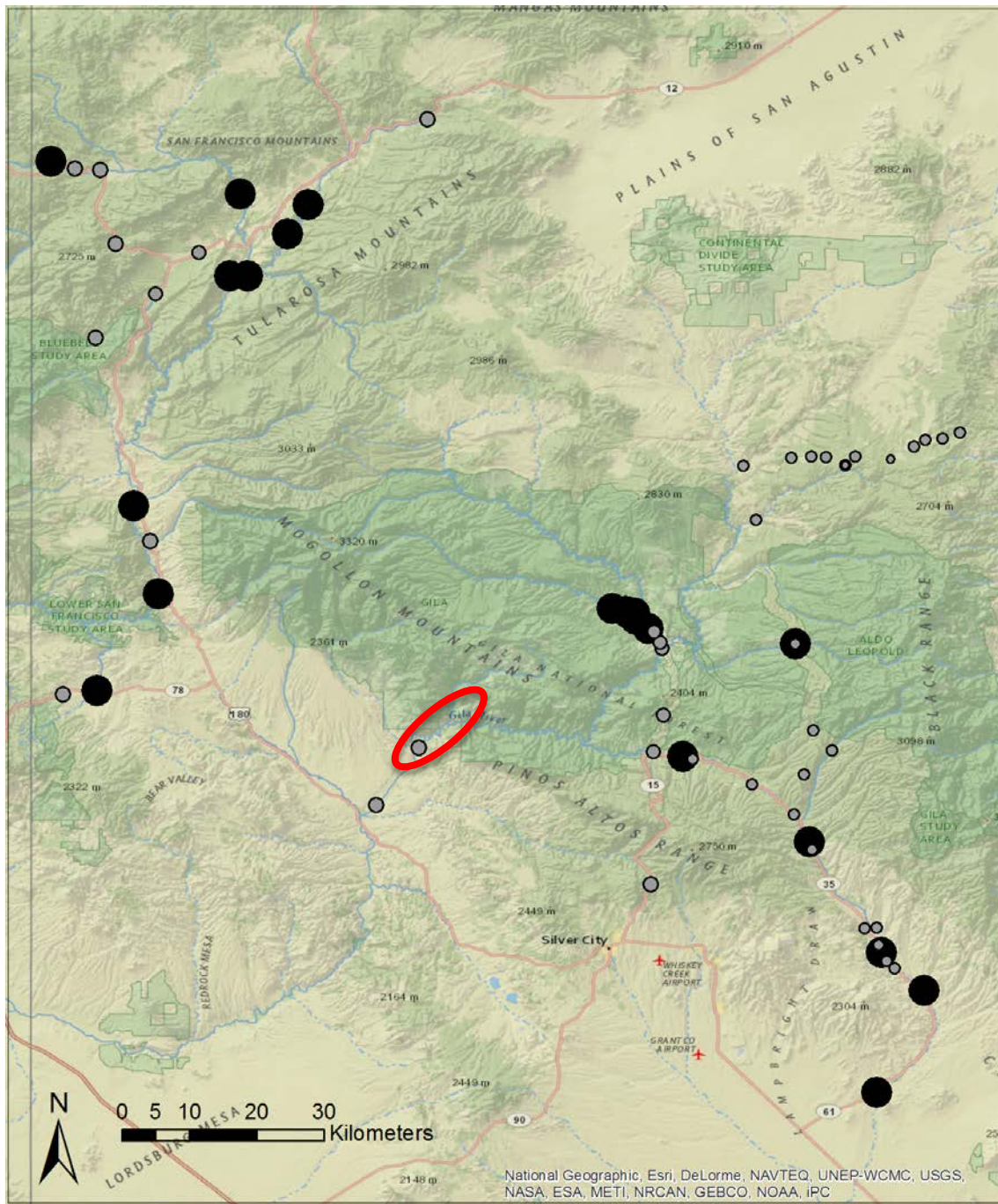


Fig 2. Mean daily cubic feet per second (cfs) from 1 March to 18 April for USGS gage stations. SF = San Francisco River. In 2014, the Mimbres USGS gage station was not operational.

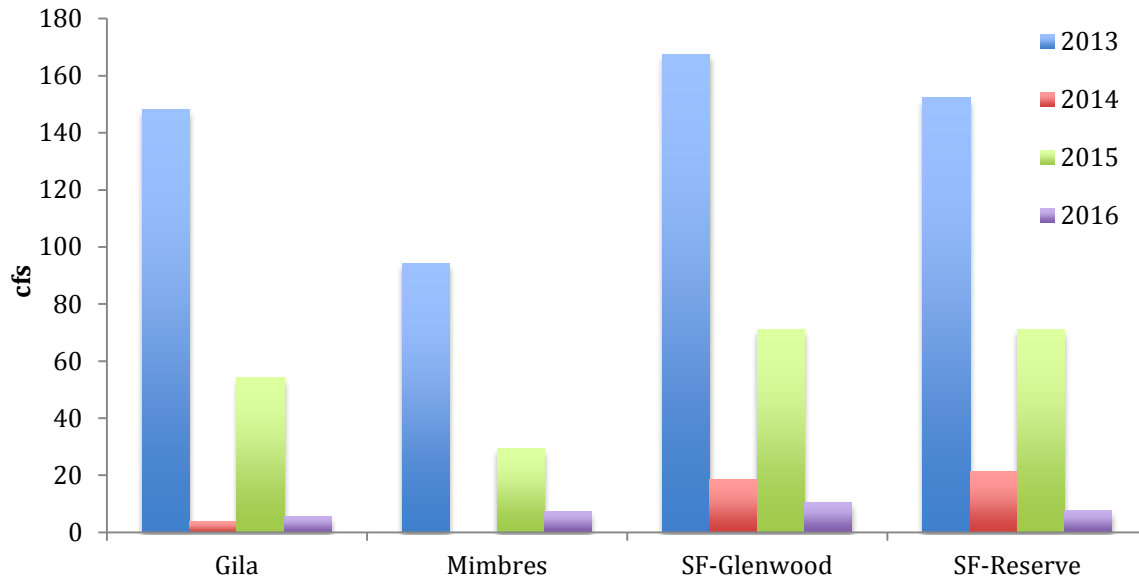




Fig 3. Long-term historical annual cubic feet per second (cfs) summary for years above or below the estimated critical cfs threshold for each gage station during the seasonal breeding time of the Arizona toad, 1 March to 18 April. Periods for each river are as follows: Gila River: 88 years (1929-2016); Mimbres: 39 years (1978-2016); San Francisco at Glenwood: 89 years (1928-2016); San Francisco at Reserve: 58 years (1959-2016). Critical cfs thresholds were calculated from the call detection x cfs logistic regression model and are: Gila River = 142.2; San Francisco at Glenwood = 63.8; Mimbres River = 16.2; San Francisco at Reserve = 7.4. Toads do not call, and presumably do not breed, in years with cfs greater than a stream's given threshold.

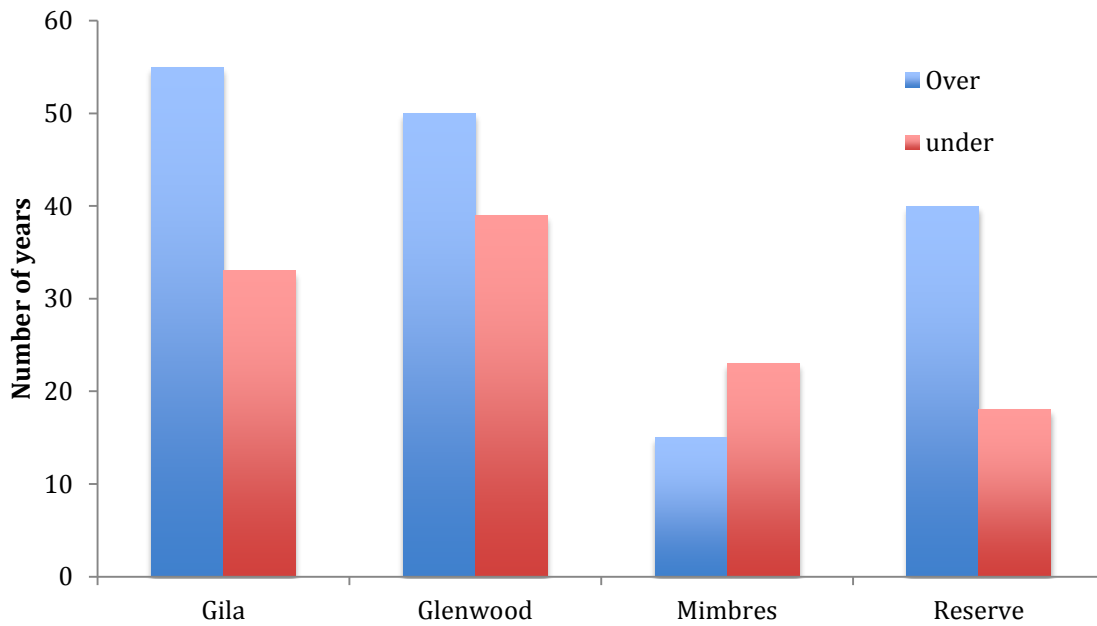
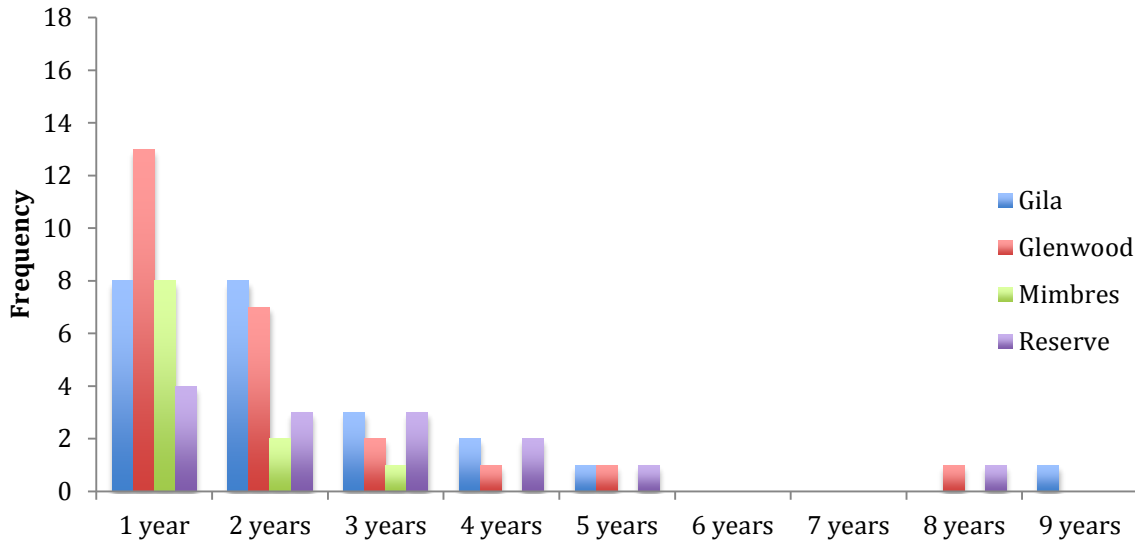


Fig 4. Summary of year streaks A) Over or B) Under the predicted cfs threshold for toad breeding activity for each river. This summary illustrates that there are longer stretches of consecutive years in the Gila and San Francisco Rivers above the cfs threshold for toad breeding than consecutive years below the threshold, when breeding should occur.

A.



B.

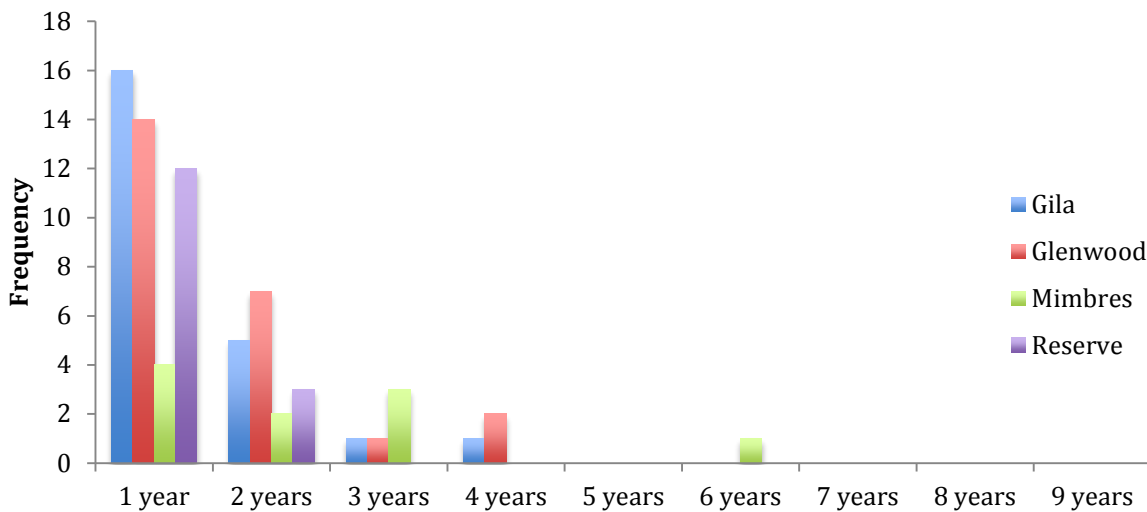
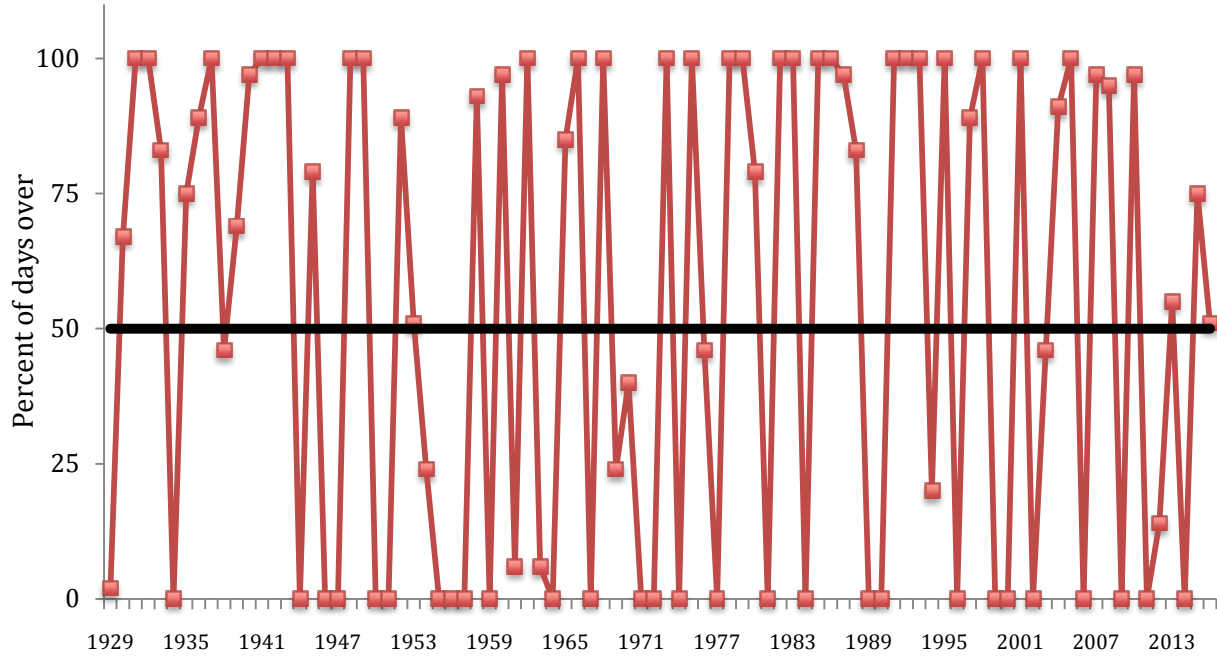
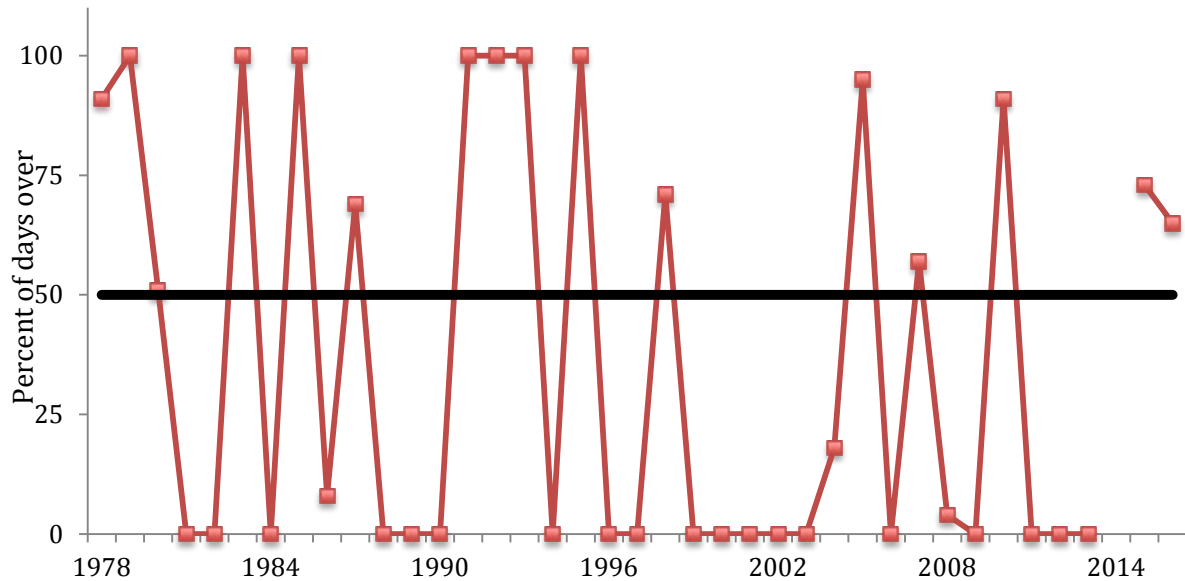


Fig 5. Percent of days over threshold cfs at the Gila, Mimbres, San Francisco at Glenwood, and San Francisco at Reserve gage stations between 1 March and 18 April. We estimate that toads may be able to breed in a given year if the number of days over the threshold is equal to or less than 50% for a given year.

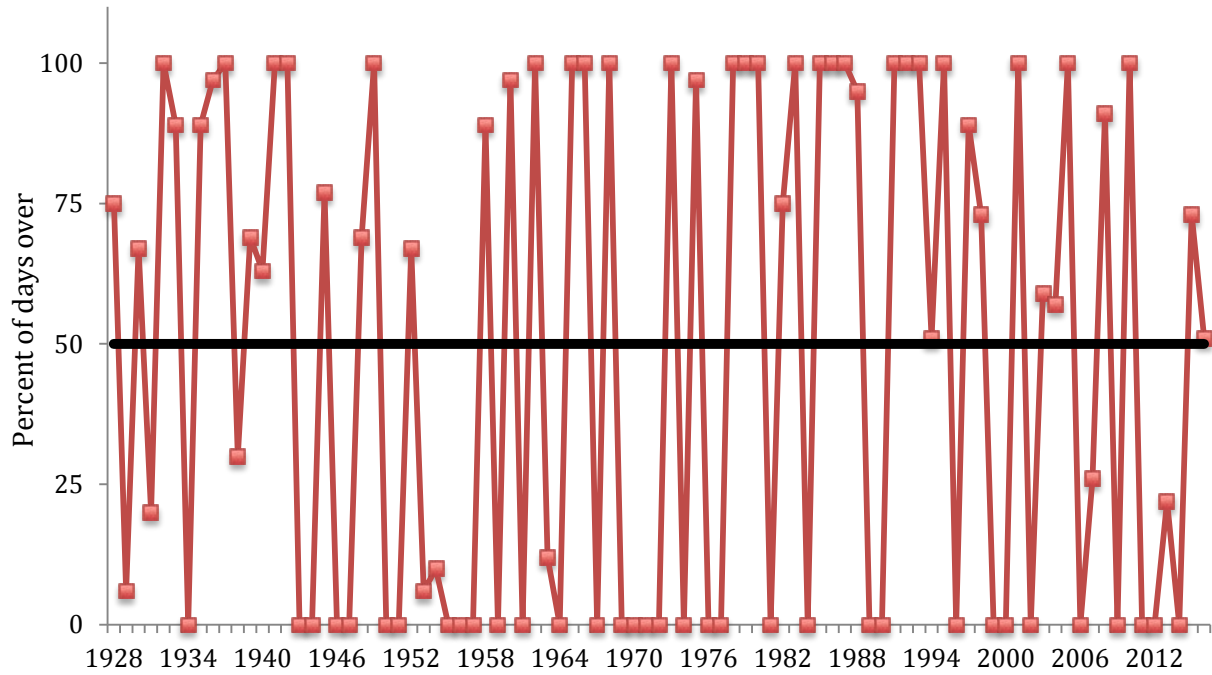
A. Gila – 55%, or 49 out of 88 years, are above the critical cfs for >50% of the days in the breeding season, thus breeding is unlikely to occur in those years.



B. Mimbres – 41%, or 16 out of 39 years, are above the critical cfs for >50% of the days in the breeding season, thus breeding is unlikely to occur in those years.



C. San Francisco at Glenwood – 52%, or 47 out of 89 years, are above the critical cfs for >50% of the days in the breeding season, thus breeding is unlikely to occur in those years.



D. San Francisco at Reserve – 67%, or 39 out of 58 years, are above the critical cfs for >50% of the days in the breeding season, thus breeding is unlikely to occur in those years

