The Houston toad 2007:

Annual summary of research and monitoring

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By

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SUMMARY

The Houston toad was the first amphibian on the Endangered Species list for the United States in 1970. Unlike many endangered amphibians worldwide, we have fairly extensive, management-relevant field data on its life history, habitat, and ecology. We also have long term monitoring datasets from two locations within its remaining habitat from which to extrapolate trend data. In addition, we have the background information documenting its extirpation from several parts of its historical range.

The Houston toad, like many temperate amphibians, is an *r* strategist. Its life history strategy is to produce many more offspring than will survive, with relatively little reproductive investment in any one of those eggs. Thus, the egg and juvenile life stages normally have a much higher mortality than does the adult stage (i.e., only very few survive). Furthermore, we believe that Houston toads, like other amphibians, occurs in periodic "pulses", is correlated with environmental conditions. That is, recruitment is higher during years when preciptation, temperature, and other environmental variables favor toad breeding, and lower during years without favorable conditions. In the most recent population viability analysis (PVA), Hatfield and his coauthors (2004) generated models using long term monitoring data on the Houston toad. They concluded that with several, (a minimum of two), subpopulations, an adult population size of 5000, and a juvenile survivorship rate of 1%, the Houston toad did not go extinct. This juvenile survivorship rate was speculative at that time, as no data on actual measurements of mortality were available. Similarly, and this is the emphasis of those authors' conclusions, having less than two subpopulations substantially increased the risk of extinction in the near term. Hard won information in our current multi-year monitoring program on Houston toads in Bastrop County seeking the actual juvenile survival rate reveals it to be that it is less than 1% (in fact, the replacement rate estimate from a mark-recapture study was 0.03%) and data from range-wide surveys in 2006-2007 would argue that a second subpopulation may no longer be available. Thus, according to the most recent PVA (Hatfield et al. 2004), these data suggest that Houston toads would be extinct in the near future if no action/conservation strategies are developed and initiated that would allow us to increase both juvenile survival and numbers of subpopulations, and thus stabilize populations of Houston toad.

The Houston toad has undergone several significant reductions in its overall population numbers in the last 60 years. The first of these was immediately during and after its recognition as a species in the 1950s when the Houston toad disappeared from the three counties in Texas from which it was known (25% of the total range), coincident with the terrible drought years of that time. The monitoring efforts by Price (1990-2005) show a similar impact of drought on the remaining populations in Bastrop County during the 1990s (Price 2003).

Unfortunately the coupled impacts of habitat fragmentation, drought, and other less obvious reductional forces have left little remaining resiliency in the Houston toad population. The drought of 2005-2006 was particularly severe, potentially as severe as the drought of the 1950s for this area. The already reduced populations may well be at significant risk of complete collapse. Several significant, recently determined factors about the Houston toad only increase that risk. There are solutions to the current situation, and those solutions provide long-term recovery advances and the eventual goal of stability and growth in the Houston toad population over the coming decades. The stakeholders are involved and aware, and generally supportive of recovery for this species. Significant planning, stakeholder involvement, and Habitat Conservation Planning have enabled an informed stakeholder group whose efforts can now be focused on active stewardship toward recovery.

While very serious, the future is not bleak, provided we act appropriately to prevent any worsening of the current situation. Although from all available data it appears that circumstances are certainly critical, and may be even more grim if the drought conditions continue into the coming winter and spring, the species has several intrinsic factors that make it a particularly good candidate for active stewardship and recovery programs. Thus, there are solutions to enable Houston toad recovery at the same time we act to prevent its extinction.

At the end of 2006, the lead author provided an update on the situation, consequent of the severe (and, at that time, continuing) drought. A group of four potential options and their contributions to the solution were offered at that time along with a proposed budget for their implementation. In the last twelve months progress has been made on all four, with much work remaining to be done in the coming years:

1. *Headstarting* - The Houston toad has a tremendous reproductive potential, with the heaviest mortality associated with the larval and juvenile lifestages. If we can influence more juveniles to survive we can rapidly increase the population of Houston toads. The best opportunity to increase the number of individuals would be by "headstarting", which is the same type of program that quickly and positively influenced the recovery of another endangered species, the American alligator. Headstarting is an approach in which, eggs, tadpoles, and juveniles are protected, and, when individuals are large enough to better survive, they are released back into the habitat. Unlike that program on American alligators, however, the Houston toad is neither large nor dangerous, hence such a program would be more cost-effective, practical, and most likely accepted by stakeholders. During 2007, without funding, the Houston Zoo and Forstner's group undertook headstarting at Bastrop County locations, recycling stock from natal ponds after growth. Success will be assessed during the coming years.
2. *Habitat improvement* - Unlike nearly every endangered species in the U.S., this species lives in concert with people, as long as our subdivisions, housing tracts, and homesteads do not radically alter the habitat. So Houston toads will coexist with people, not just within preserves. However, the current habitat in Bastrop County is dangerously fire suppressed, threatening both the citizens and the Houston toad. To increase the adult population we need to safely improve the habitat quality, which can be achieved with low impact mechanical understory removal/fuel load reduction. Both the safety of Bastrop County citizens/property owners and the health of the forest ecosystem will recover, alongside the adult Houston toad populations relying on it. During 2007, Landowner Incentive Program funding was secured to begin fire management of key properties, fire management plans are under development and permit requests for those prescribed fires accompany this report under separate cover.
3. *Chytrid fungus* - A new emerging amphibian pathogen has decimated populations of amphibians around the world, Chytrid fungus. We have recently confirmed the findings of Dr. O'Donnell, by detecting Chytrid fungus in Barton Springs salamanders in Austin, Texas. Providentially, we have begun working with detection of Chytrid fungus across Central Texas and are now able to test both amphibian and environmental samples for the pathogen in order to develop a strategy to address this looming problem. Collaboration with the Hahn laboratory has led to several significant findings including documenting the fungus in Houston toads in Bastrop County.
4. *Captive Assurance Colony* - There are many factors that are uncontrollable in the current situation, particularly the drought pattern and consequent increased risks of catastrophic wildfire(s) in the habitat. The population is already suffering from the effects of the drought and there is little evidence that the situation is improving overall. With endangered species we must plan recovery but insure survival. In the spring of 2006 we detected only 31 toads on the Griffith League Ranch (a key conservation property under HCP) the fewest toads recorded for any full season on the GLR during the past seven years. Thus, it was both prudent to assure survival and valuable by assisting with the ongoing recovery effort, to create a captive assurance colony for the Houston toad. The Houston Zoo took this project as part of their continuing efforts with the Houston toad and a nascent assurance colony is now in place.

INTRODUCTION

The Houston toad is endemic to south-central Texas. John C. Wottring first noted the toad near Houston, Texas in the late 1940s. In 1953 Ottys Sanders described it as a distinct species. On-going habitat destruction and a severe drought in the 1950s raised concerns for the future of the species (Seal 1994). The Houston toad was first listed as endangered in 1970 under the Endangered Species Conservation Act of 1969 (35 FR 16047). The endangered classification was continued with passage of the Endangered Species Act of 1973. The Service designated critical habitat for the Houston toad in Bastrop and Burleson counties in 1978 (43 FR 4022).

The species is most often described as occurring in only nine Texas counties: Austin, Bastrop, Burleson, Colorado, Lavaca, Lee, Leon, Milam and Robertson (Seal 1994). But this information is badly out of date. The Bastrop County population is considered to be the most robust and sustainable of the remaining populations (Seal 1994; U.S. Fish and Wildlife Service 1995). The Houston toad was extirpated from Fort Bend, Harris and Liberty counties during the late 1950s (Price 1990). Primary threats to survival of the Houston toad are most often depicted as habitat destruction and degradation, fragmentation of habitat, predation, inter-specific competition and hybridization, contamination by chemical herbicides, pesticides and fertilizers and prolonged drought. To that list we need to add the possibility of Chytrid fungus, an emerging amphibian pathogen worldwide, now known to be in Austin, TX populations of the Barton Creek Salamander (another endangered species).

From this context we can begin to evaluate the current situation in the wild for the Houston toad. Central Texas has just emerged from a very severe drought (Fig. 1) and the drought is as severe as any in historic times (Fig. 2). The current extreme drought is really a continuation of the very dry period in the mid-1990s which caused a serious reduction in the Houston toad population monitored at Bastrop State Park (Price 2003). Thus, at the landscape scale, the Houston toad is under drought related stressors which have been often argued to have resulted in its extirpation from Harris, Liberty, and Austin Counties during the drought of the 1950s. However, there are additional points which have come from our research efforts during the past seven years that also increase the category of risk for the Houston toad population that remains.

There are several aspects of the existing data for the Houston toad that are often cited, repeated, and relied upon, but under scrutiny may not be reliable in a situation as serious as extinction. They can be summarized by addressing two questions, “where do Houston toads still occur today?” and “what is the current size and reproductive trend of the remaining population?”. In answering these two questions, potential solutions to Houston toad stewardship and recovery become self-evident.

STATUS OF THE HOUSTON TOAD IN 2007

Current occupied range

Effectively all working information on the distribution, habitat occupancy, and current range of the Houston toad is more than a decade out of date. In the 1984 Recovery Plan, one goal was a range-wide survey to assess the toad. Jim Yantis, working with TPWD, completed those surveys and reported them in a series of technical reviews (1989-1992). It was from these reports, primarily, that occupied range for the Houston toad was conceptually created. So far as we are aware, aside from our own surveys, no work has been completed to evaluate counties outside of Bastrop, since that time. It is important to reiterate that many of those locations reported by Yantis have not been revisited, particularly since the decline during the mid-1990s (Price 2003) immediately following the range-wide survey work of Yantis (1989-1992).

As an example of why current knowledge is so critical, we can review the case of the Houston toad in Lee County, which borders Bastrop County to the North. Beginning in 2000, we began surveys in Lee County (Forstner and Dixon 2000, 2001) and other Houston toad counties outside of Bastrop County itself. While John Kuhl had reported Houston toads to occur in Lee County, we eventually published the first confirmatory record for Lee County (Gaston et al. 2001). By the end of 2001, significant choruses of the Houston toad were known to occur in Lee County, some of those choruses as large as those heard during those same years in Bastrop County. Unfortunately, by the end of 2001, significant clearing of forested habitat creating pasturage, manipulations of known breeding ponds, and other impacts were obvious. This forest conversion has continued and was ongoing through the first week of October 2006. In preparation for a population genetic survey of the Houston toad under proposal to Section 6, we undertook surveys of the historical chorusing sites in Lee County during the spring of 2006. No Houston toads were heard in chorus at any of the previous positive locations. Similarly, during the past three years, including 2005, Drs Dixon, Forstner, and Swannack have sought Houston toads in counties outside of Bastrop, particularly the area of Hilltop Lakes in Leon County. We have encountered 3 (total) male Houston toads outside of Bastrop and Lee Counties since 2000.

We hesitate to put strong emphasis on this, as we have not performed surveys at the level of intensity we feel are required to substantiate the negative (no toads). However, it is very likely that if you examine the nine counties listed as having Houston toads, only three of those have any record of Houston toads since 2000 (Bastrop, Lee, and Leon). In fact, the 46 subdivision HCP (TE-025965-1X and TE-025997-1X) specifically acknowledged that no toads have been documented in Lavaca County since 1991, none in Burleson (designated Critical Habitat) since 1983, and that numbers in Bastrop County are declining (USFWS 2001). To summarize, in 2006 Houston toads were actually heard in chorus in two counties out of nine theoretically occupied counties. In one of those counties (Leon) a single male toad was located.

One conclusion here is that more than 15 years after the last range-wide surveys were completed, we have little evidence that contradict continued extirpation of the Houston toad from its range. The Houston toad was described in 1953, first discovered in the late 1940s (see above), and by 1960 it was gone from the three original counties from which it was known. Rediscovered in Bastrop in 1967, it was listed as an endangered species in 1970 and had critical habitat designated in 1978. The Houston toad occurred historically in just 12 counties in Texas. Applying the data presented here, in the 14 years from 1946 to 1960, it was reduced by 25% to 9 counties occupied. By 1983 it was gone from another (Burleson) a 10% loss in the two decade period, then another area went quiet by 1991 (Lavaca) for a further 10% reduction in just ten additional years. We have no real data to extrapolate to a trend for any of the remaining counties except Bastrop and Lee. In Lee County the trend is downward, it seems safe to assume a similar overall pattern in the remaining remnants in Austin, Colorado, Leon, Milam, and Robertson. We (Forstner, Dixon and Swannack) did perform limited surveys in 2005-2006 in Leon, Milam and Robertson and again in 2006 in Austin and Colorado without locating any Houston toad choruses at historical locations. In summary, it is often erroneously stated that the toad remains in 9 counties in Texas; we know this to be false. By the most hopeful guess in 2006, it was thought to remain in 6 counties, but the pragmatist would argue that only two or maybe three counties will have breeding populations in 2007. This is a 75% reduction in 50 years, and 33% of that reduction in range since ESA listing in 1970.

Current population size and reproductive success of the Houston toad

Science is an endeavor that proceeds cyclically, with subsequent research cycles providing new insights and observations to supplement or supplant previous ones. We have been very active with students and collaborators during the past seven years in just such a research cycle for the Houston toad. The most relevant findings relate directly to both our interpretation of what we know and do not know about the Houston toad in the wild and which management strategies are most likely to assist with its eventual recovery.

Detection
Houston toads are rare. Houston toads are difficult to find not only because they are rare, but also because they are fairly secretive in their nocturnal lives. The only time that Houston toads are obvious is during the one or two nights that they are present in breeding aggregations during the spring. Quite obviously, most of the information we have on Houston toad occurrence is thus directly related to chorusing, with surveys designed to "hear" the toad and thus deduce its presence or absence. In a particularly relevant coincidence, the amateur herpetologist (Wottring) who first brought the Houston toad to the attention of biologists was also the first person to have used chorus surveys in detecting and describing a regional amphibian fauna.

The USFWS has developed and required Houston toad surveys to meet a set of predescribed conditions of weather, timing, duration, and replicates. Current evaluations of Houston toad detection, taking advantage of new applications of advanced power analyses, allowed us (Jackson et al. 2006) to clearly show that a minimum of 16 audio surveys are required in order to detect Houston toads when they are present at a given pond. This is nearly three times the number of required surveys under current guidelines as they exist for Houston toad surveys today. Worse, many of the original surveys describing the range for the Houston toad (Yantis 1989-1992) also would not have met these criteria of detection. Thus, we have an issue of missing Houston toads when they are present, determining they are not there when they are, and need to revise the current guidelines given this new information.

All of the work performed by Dixon and his students (of which Forstner is one) has relied on 20 survey nights. This is advantageous in the current discussion because the majority of the results described that clarify what we know about Houston toad population size and reproductive success are able to clearly meet the, now known, criteria for effective detection of Houston toads in chorus. It is important to note that the work of Price (2003) in Bastrop State Park also meets or exceeds the threshold required for effective detection, making his and our datasets statistically defensible for determining presence of the toad during our survey efforts.

Size of the population
The bottom line in determining the size of any animal population across its range is that all answers are at best, very good guesses. In the case of the Houston toad, the Hatfield et al. (2004) PVA required an adult population size of 5,000 in order to stabilize the model without extinction within 10 years. Importantly, this is 5000 adult female Houston toads, not 5000 total Houston toads. The USFWS estimated the population of Houston toads in their 1978 news release regarding critical habitat to be 1,000-1,500 Houston toads on the planet. By liberal estimate, subsequent work may have doubled that number (Yantis 1989-1992). We (Forstner and colleagues 2002, 2003) conducted surveys of all of Bastrop County with the hint of being likely toad habitat (Fig. 3) including sections south of the Colorado River (Forstner 2002, 2003). We concluded that there could be as many as 200 Houston toads in chorus across the entirety of Bastrop County in 2003 (Forstner 2003). Even if there were an equal number of Houston toad females as males (see below) that would imply that there were, by the most liberal estimate, 400 Houston toads in Bastrop County. Bastrop County is acknowledged by everyone involved to have the largest remaining choruses and with the results from Lee County in 2007 (this report) that would mean that the situation may be optimistic in estimating between 1,000 and 1,500 total Houston toad adults alive in the fall of 2007. We had a previous, exceptionally liberal estimate from data up to 2004 of between 2373-2764 individuals (Forstner and Swannack 2004 p.53).

Effective population size

Complicating that very small population size is another issue. It relates to the operational sex ratio generally applied in the study of amphibian life histories. The operational sex ratio assumes that we

observe a bias in the sex ratio (more males than females) in many amphibians as a consequence of it being easier to find males (they chorus and are easily found) than females. However, using data from a trap array (Forstner and Swannack 2004) on Griffith League Ranch (GLR) in Bastrop County, we detected a biased sex ratio with approximately 5 males for every adult reproductive female. Our publication (Swannack and Forstner 2007) concludes that the biased sex ratio sex ratio in the population, while not as skewed as what is seen at the ponds, is significantly male biased. The basic cause for this biased ratio is that female Houston toads take one year longer to mature than do males (Quinn and Mengden 1984) and that requires the females to remain away from the breeding ponds an extra year. That extra year of growth required for female maturity also increases the probability that a given female will die before reproduction. When modeled, this results in a skewed male biased sex ratio where there are approximately 7 males for every adult reproductive female. Not only does this help to explain the results we have collected on annual reproductive success (below), it also means that the effective population size (N_e) for the population is only slightly more than half its number of individuals.

To put this in perspective, we detected 40 Houston toads on the GLR in 2003 (Forstner et al. 2003). For the remaining county-wide surveys we documented 122 males (Forstner 2003). Thus, the most liberal number of Houston toads in all of Bastrop County in 2003 excepting Bastrop state park would be 162 males. With the biased sex ratio implying only 23 reproductive females across the County for 2003, one consequence is an unequal representation in the next generation (only 23 females reproducing, so only 23 males of the total contribute to the next generation). But critically, it is obvious that with the most robust population of Houston toads that remains, in an average year (2003) its future success is reliant upon just more than 20 adult females. In summary, the Bastrop County population of Houston toads for our most comprehensive survey year (2003) represented less than 100 individuals in effective population size with recovery of the species dependent on very few adult female Houston toads, nowhere near the 5000 females required for population stability under the latest PVA (Hatfield et al. 2004).

Annual reproductive success

The situation is even more grim than it would appear from that summary. So far as paradigms go, if one heard Houston toads in chorus, then it was assumed that hearing males meant that reproduction occurred in that location for that year. This is not the case. All of our evidence, now inclusive of surveys of all the ponds in Bastrop State Park (Greg Creacy et al. work in 2006), intense work on the Griffith League Ranch, Welsh Tract, Jim Small property, and Long family properties in Bastrop County, reveals a very different reality (Forstner and Swannack 2004, Forstner and Jackson 2006a-d). Chorusing of Houston toads only results in reproduction in less than half of all chorusing ponds, and actually getting recruitment (juvenile toads coming out of the pond) occurs in only 1 in 10 chorusing ponds (Swannack and Forstner 2004, Forstner and Jackson 2006c). This aspect is among the most troubling results from our work with the species during the past eight years evaluting the actual reproductive success of the Houston toad. This means that out of 36 locations heard in chorus in 2003 (Fig. 3) only four of them on average produced any future generations of Houston toads.

After an intense effort by one of my former graduate students, we are able to report on direct measures of survivorship for the juvenile stages of the Houston toad (Forstner and Swannack 2004). This is critical, as the Hatfield et al. (2004) evaluation relied on an estimate of juvenile survivorship of 1% in order to stabilize the model against extinction within 10 years (see Fig. 4). Please be certain when examining Figure 4, the population size modeled is only the number of adult female toads not the total toad population.

Our field estimate for juvenile survival (=0.03%). is more than two orders of magnitude less than what was used for the low estimate in the PVA (0.01). What is notable in this vast difference of the model integrated value of 1% and our field determination is what the intuitive reality must be. We began by tracking 7018 eggs and conclude that a 0.03% survivorship to 1 year leads to a result of replacement of

the adults (0.03% of 7018 is ~2). Whereas, using 1%, 7018 eggs would result in 70 replacement toads from each pair, which would cause the population to increase exponentially and reach unrealistic levels in a short time. Further, juvenile survival of 2% also would generate unrealistic survival values, even if spatial distribution and dispersal patterns are taken into account (Swannack, 2007). So the number of ponds successfully producing Houston toads is much lower than what almost anyone would have thought prior to collecting the data, the survivorship numbers are greatly lower than modeled, and Houston toads have a lower numerical population size and the potential for representation at half that size in genetic terms (effective population size). To clarify this, examine the graph from Hatfield et al. (2004) ignore that the probabilities collapse the population immediately at our measured juvenile survivorship (0.03% vs. 1% as modeled) and simply examine the probability of extinction with less than 500 individuals in only 1 population (their Figure 26.2). This is likely the relevant case for the Houston toad in Bastrop County, implying a probability of extinction based on existing PVA and field data at greater than 70%. If the Bastrop County population is on that trend what must we expect given the data in Lee County and the trends from previous years/decades in other counties?

This situation has become worse with the continuing drought. For the first year since we began monitoring in 2000, our primary study pond (Pond 2) on the GLR failed to produce offspring in 2006 (Forstner and Jackson 2006c). Normally two ponds on average produce juvenile toads out of 20 ponds monitored on the GLR (Forstner and Swannack 2004). In 2006 only one pond produced offspring on the GLR, a reduction in future recruitment of 50% (Forstner and Jackson 2006c). Given the severity of the situation and the number of ponds dry (for the first time since 2000) on the GLR (60% of total ponds), it seems prudent to assume similar issues across the County and even the range of the toad. I note that Bastrop State Park also has a majority of chorusing locations at either very reduced water levels or dry currently.

Methods and Materials

Audio surveys

During 2007 we had several cohesively structured objectives. We continue to monitor many locations in Bastrop County for Houston toad activity. Our audio survey methods for that work follow our recent publication (Jackson et al. 2006). We completed such "presence" surveys for as many counties as we were able to schedule personnel to cover. We also completed surveys not meeting that standard (i.e., fewer survey nights with shorter stops) in other counties within or adjacent to known Houston toad localities. These "range" stops were generally completed on nights where Houston toad activity was occurring in Bastrop County, and were used to assess if any Houston toads were in chorus across as much of those counties as we could cover in one night. All surveys outside of Bastrop County included historically known Houston toad locations where habitat remained present to support them. We will seek to combine both of these approaches during the 2008 surveys, which will be the last year of range-wide survey work we have scheduled to complete in this cycle.

Field surveys

As we have previously noted (Forstner and Swannack 2004), Houston toads chorus at ponds where breeding does not subsequently occur. Thus, using chorusing data as a proxy for reproduction is both misleading and biased toward a liberal interpretation of status. Consequently, we normally visit and individually mark, measure, and document individuals at each pond in chorus. Then, whenever possible, we have included daylight surveys of ponds after nights of chorusing. These daylight surveys allow us to examine if eggs were laid and how many egg strings were deposited. Once a pond is known to have eggs, the natal pond is evaluated in subsequent weeks up through the eventual emergence, if any, of juvenile toads. Finally, at one location on the GLR, juveniles are followed subsequent to emergence. We have emphasized the period after emergence, as it appears to be among the most critical periods for affecting the population trend if habitat is healthy and secure from fragmentation.

Headstarting
Beginning in 2007, we have collected subsets of eggstrings (less than 50% of any given string) from natal ponds. Those eggs are transported to the Houston Zoo for headstarting. This type of work has been previously attempted *in situ* on the GLR using artificial ponds but with very little success. In captivity, absent of predators, the survivorship is quite high and enables the release of many more juveniles back into the upland adjacent to their natal ponds. During 2007, we were able to locate and harvest portions of three egg strings. The releases were completed in three cycles, roughly correspondent to 1, 3, and 6 months of age. A final release is scheduled for the first warm period of 2008.

Habitat recovery/restoration
Work on habitat recovery continued on the Jim Small and Bob Long properties, alongside additional applications to funding agencies for the funds required for more work. We were successful in LIP funding for work on the GLR and associated properties. This is critical and a welcome achievement, but will also only provide the funds necessary to begin. We estimate a decade of habitat management to remove the immediate danger of catastrophic wildfire, with the work of the 2020s creating a stable and natural regime of fire and forest ecology in these systems for Bastrop County. Work must begin in other counties, within and without occupied Houston toad habitat, but representing historical localities or suitable habitat if recovered or involved in Houston toad conservation.

Chytrid fungus
We have completed much more extensive work evaluating and documenting Chytrid fungus in central Texas during 2007. This work is overseen by Dr. Hahn and his students in collaboration with Forstner. The methods and approach are fairly standard for microbiology and utilize molecular techniques to evaluate the potential pathogen from samples of either skin swabs or toe clips.

Captive assurance colony
The necessity of a captive assurance colony is conceptually a strong indication of a precarious future in the wild. The Houston toad represents a unique Texas endemic with real potential for recovery but also currently persists at low population levels with evidence of continued declines. Consequently, Houston toads have been retained from the headstarting effort as the nascent portion of the captive assurance colony held at the Houston Zoo.

Results

Field surveys
We completed such "presence" surveys for Austin, Bastrop, Colorado, Lavaca, Lee, Milam, and Liberty counties in 2007. We also completed surveys not meeting that standard (i.e., fewer survey nights with shorter stops) in Burleson, Leon, Limestone, and Robertson counties. We believe that we have visited all historical localities for the Houston toad across those counties during our 2007 work. For many of the NE counties, Forstner traveled with Dr. Yantis to revisit the sites. All of the localities and explicit georeferences are being compiled into a single GIS for the toad. The routes chosen optimized forested cover, encounters along historically documented occupied habitat, within suitable soils or assumed suitable habitats. Minimally, all audio-only "presence" surveys include 12 visits and had a minimum of 11 listening posts along the route.

Southeastern routes: **Austin, Colorado, & Liberty counties**
Routes replicated known localities (to the best of our abilities for Liberty County record). No Houston toads were located in Austin or Liberty counties. In Colorado County, Houston toads were heard (n=5) and 2 males were sampled at roadside pond.

Southwestern route: **Lavaca County**
The route visited the historical localities including areas bounding those locations with potential habitat. No Houston toads were heard or otherwise detected.

Northerneast route: **Leon, Limestone, & Robertson counties**
A single route of 11 stops inclusive of historical Houston toad locations, and including an area of Limestone County with both suitable soils and potential habitat were surveyed. A single Houston toad male was found in Leon County and three others were heard in chorus.

Northwest route: **Milam County**
A single route detected multiple locations on several nights with Houston toads in chorus. A single Houston toad female and 3 males were located and sampled at roadside. The data from Milam County indicates that the largest remaining chorusing events (multiple individuals and at multiple locations) detected outside of Bastrop County during the past two years have been in Milam County.

Central counties: (Bastrop and Lee counties)
Bastrop County (multiple routes, properties, and intensities)

Griffith League Ranch- More than 25 surveys were conducted on the GLR during 2007. Approximately 30 Houston toads were detected on the GLR during 2007. Emergence was detected at two ponds and one of those ponds had at least two eggstrings successfully emerge in 2007. This is excluding the daily activity surrounding juvenile research which tracked juveniles surrounding Pond 2 from May 11, 2007 and continued through August 1, 2007. Notable events for this year included Houston toads detected very late in the year (chorus heard in the first week of June by a single male) and a female Houston toad found injured (assumed predation wounds) at the pondside on May 28, 2007. This female was transported to a qualified veterinarian, treated by amputation of a forelimb, and recovered. The female was then transported to the Houston Zoo where she remains at the current time. The last Houston toad juvenile was located on July 14, 2007 demonstrating proof of concept for following this life stage longer than ever previously by us in the field.

Lost Pines Scout Reserve- No Houston toads were detected on the LPSR during 2007, nor were any heard calling from areas adjacent to the tract.

Welsh tract- Houston toads were detected in limited numbers on the Welsh Tract during 2007. No evidence of reproduction was detected at the pond. It is noted that only limited (positive nights elsewhere) surveys were conducted for this location.

BlueBonnet Headquarters- Surveys detected chorusing on several nights and found many (10+) eggstrings during the season in combination among the 3 main ponds on the site. Emergence was successful in two of those ponds in 2007. More than 50 male Houston toads were detected on the property in 2007, nonconsumptive sampling did occur for a number of these males allowing DNA to be archived. These were the largest chorus groups we detected during 2007 and the ponds had the highest reproductive output of any location we surveyed.

Jim Small- Surveys detected chorusing on several nights and found an eggstring in one pond. Emergence was not detected but late stage tadpoles believed to be Houston toads were located just prior to their absence. We believe that emergence did occur but we did not locate juveniles at the natal pond. More than 30 total Houston toads were heard in chorus across the property in 2007 with many of those individuals marked and sampled for DNA.

Bob Long family tract- Only three male Houston toads were heard in chorus on the Long family property in 2007 and no evidence of reproduction was detected. Importantly, no Houston toads were heard on adjacent properties during 2007 which had been the case in previous years.

290 Corridor and Musgrave Family- Several "new" locations for Houston toads were documented along and south of Highway 290 between FM2336 and the Highway 21 junction during 2007. More than 30 males were heard in chorus across the season for this route. Seldom were any actually encountered as all were heard on private lands from the roadways. One location had Houston toads call south of the Highway and then be detected afterward on the north side of the same drainage. Only a single Houston toad was detected (April 4, 2007) on the Musgrave tract by us (the Musgrave family documented several others by photograph and provided the only activity evidence for Houston toads during the "mystery" months of Sept-Nov. We did not detect evidence of successful reproduction of Houston toads on the Musgrave property in 2007, nor did we find any evidence of successful emergence for Houston toads. No Houston toads were collected in any of the pitfall arrays deployed to evaluate both toads and arthropods in the area.

South Shore Woods- Audio surveys did not detect any Houston toad activity on the property. We did detect Gulf Coast toads at the pond on the powerline edge and also encountered juvenile Gulf Coast toads at this location in the fall. At this time we do not believe that Houston toads are currently utilizing the property for reproduction, but the site does support the other sympatric toad.

Lee County

A single route which includes areas just north of Highway 290, north into Lee County and encompasses all of the localities documented by Forstner and Dixon during the surveys of 2000-2002 were visited. There were no significant choruses of Houston toads. A faint, single call, of a male Houston toad was believed to have been detected on a single occasion.

Headstarting/Captive assurance colony

Three partial eggstrings were moved to the Houston Zoo on March 15, 2007 (supplemental notes already provided to USFWS by P. Crump and S. Mays). Releases back to the natal ponds occurred on May 27 (n=452; >1g) , July 09 (n=373; <2g), and September 11, 2007 (n=227; <20g). Approximately 250 headstarted toads remain at the Zoo today with an intended release in the spring of 2008. We must make general estimates on the number of eggs collected but our working guess is that 3,300 eggs were collected in total with ~1,300 releases or currently housed toads resulting (~40% survivorship overall). This represents roughly 4 orders of magnitude greater survivorship than our field estimates for the wild at one of the natal ponds.

We recognize that the indiscriminant movement of amphibians could have contributed, on some level, to the current global disease problem. Of even more concern is the movement of amphibians in and out of cosmopolitan amphibian collections like that at the Houston Zoo. To eliminate the chance of transmission of any novel or known pathogens to or from the Houston Toads housed at the Zoo we followed the recommendations of Zippel *et al*., (2006) by partitioning the Toad colony in a separate physical location from the exhibit collection at the zoo and by working the area in a manner that prevented the transmission of pathogens into the collection. We also performed pre-release screening as recommended by Daszak *et al*., (2001) by bi-weekly fecal collection and analysis on all toad enclosures, molecular chytrid testing pre-releases, and by submitting a subset of deceased Toads to two separate veterinary pathology labs (Texas Veterinary Medical Diagnostic Laboratory System at Texas A&M University and to Allan Pessier at the Wildlife Disease Laboratory at the San Diego Zoological Society) for comprehensive histopathology.

Habitat recovery/restoration
In 2000-2002 several projects on the GLR incorporated Boy Scouts and other volunteers in an effort to replant drainages for dispersal by Houston toads and to transplant vegetation to surround and improve the quality of several ponds. These efforts are now beginning to pay off with several groups of the transplants now above a meter in height and few are now reasonably categorized as small trees. We had a setback for management on the GLR as cattle were not excluded during the breeding and emergence season from the ponds. We excluded cattle from the ponds in 2001, with fairly immediate success at several of the most heavily cattle impacted locations improving in water quality and eventually in having reproduction by Houston toads (Pond 5 and Pond 9). Without cattle exclusion many ponds show impacts by cattle today. Pond 5 is the most proximal to the areas where cattle are supplementally fed and it shows the most significant impacts with nearly complete edge destruction by hoof traffic, eutrophication, and near complete loss of the natural vegetation.

Chytrid fungus
The potential pathogen has now been confirmed in Houston toads. Interestingly, the fungus was not detected among samples from 2000-2005, appearing only among samples taken in 2006. The impact(s), if any, of this is not clear. Work continues to identify and clarify what these data imply for the Houston toad.

Discussion

The situation for the Houston toad is grim. It has been critical for more than 20 years with the loss of the species in the only critical habitat (Burleson) outside of Bastrop County. In light of this and our findings during the past seven field seasons, most would see only the inevitable extinction of the toad as a consequence. We remain more optimistic than that simply because the toad has survived bad droughts, even catastrophic droughts, before this one (Lowry 1959) and even more impossible to imagine megadroughts deeper backward in time (Grimm and Clark 1999; Grissino-Mayer 1996). One might ask if the toad has survived these climatic events before, what factors are different this time?

Field surveys
Primarily, as seen in all the evidence thus far, the danger to Houston toads remains the current drought cycle, coupled to a very reduced population size and nowhere to hide (refuge) during the current dry cycle. It seems reasonable to believe that the urban expansion of the Houston area, coupled to the drought of 1950s, extirpated the toad from 25% of the historical range, it persisted in the remaining counties and survived the drought. Today, however, those counties are now fragmented, fire suppressed and urbanized in a radical shift from the 1950s and 60s. The populations are much lower than at any prior period of monitoring (Price 2003, Forstner and Jackson 2006c). Furthermore, we now have data that suggest that what populations remain are not able to produce at the reproductive capacity normally self evident in species with a life history like that of the Houston toad (Forstner and Swannack 2004). Previous to our work, the presence of chorusing was considered equivalent to evidence of reproduction, we know today that is not a good assumption. We had a respite with rainfall reaching Central Texas during 2002-2003, but we are back to drought severity for 2005-2006. One immediate consequence of those two years of beneficial rains was the increase in toad populations (reaching 91 individuals found on the GLR in 2005) (Forstner 2006). However, the rains stopped, the populations have not come back to the breeding ponds in 2006 with the fewest toads recorded for any full season on the GLR in 2006 (n=31) (Forstner and Jackson 2006c) and only marginally more (~35) in 2007. The change from 2005-2006 represents the most severe decline between any two years of the study on the GLR since we began work there in 2000 (~70%). We had hoped that another of the underlying assumptions often repeated for Houston toads would be shown true here, where after a year with no chorusing the toads reappear in numbers with the rains. This was not the case in 2007, with the same low numbers returning in 2007 as seen in the very low year 2006 for the GLR. Results across Bastrop County were less consistent than the pattern seen in 2006 (Forstner and

Jackson 2006a-d). Several sites (Jim Small, BlueBonnet Headquarters, & the Highway 290 corridor) had significantly more chorusing activity than seen in 2006 and one had very successful reproductive output (BlueBonnet Headquarters). Indeed, the pond on the BlueBonnet Headquarters had more eggstrings in a single pond than we saw elsewhere in the County, in total. It is important to remember that while 2007 was a spectacularly wet year, the rain totals for even this exceptional amount of rain, summed, only bring the 3 year total up to just below average for Bastrop County.

Headstarting/ Captive assurance colony
One method has proven to be remarkably successful for endangered species recovery, population stabilization, and growth: headstarting. The Houston toad is an *r* strategist which means that is has tremendous reproductive potential with low overall survivorship of eggs, larva, and juveniles. Eggs removed from the natal ponds and hatched, tadpoles reared, and juveniles allowed us to achieve several months of growth in captivity and was successful up to the headstared releases. We will be monitoring the release sites and adjacent sites to those locations in the coming years to document the relative success or failure of the releases themselves by following the headstarted genotypes and cohort marked individuals among the recaptured toads from 2008 and beyond.

Habitat recovery/restoration
A key component of recovery is simply to insure that habitat capable of supporting the Houston toad in the wild exists and is itself recovered to a healthy (and municipally safe) forest ecosystem. The current situation for much of the habitat in Bastrop County is extreme fire suppression. Indeed the situation is not actually likely to be safely solved using prescribed fire, it is simply too heavy a fuel load, in too dry a forest. We continue to help establish a comprehensive program of stakeholder involved, federally assisted understory brush reduction and prescribed fire following that, as soon as safe fuel loads and moisture levels are attained.

We have worked with Environmental Defense and the National Fish and Wildlife Foundation to develop an effective, toad friendly means of reducing brush and improving the critical upland habitat. Landowners have been and will continue to be active collaborators and assist with further outreach to meet goals for habitat recovery and fuel load reductions across the habitat in Bastrop County. However, it is critical that efforts outside of Bastrop County begin in earnest. We cannot recover the toad without recovery in Bastrop County, but recovery within Bastrop County alone will not achieve recovery of the species. Inattention to this has potentially led to the extirpation of a large subpopulation in Lee County within just the last seven years. So went the population of Burleson County two decades ago.

Chytrid fungus
We also need to ascertain dangers that have been proposed but not evaluated for the Houston toad. Recently, we detected Chytrid fungus on endangered Barton Spring salamanders (endemic to Austin, TX) using molecular techniques (i.e., polymerase chain reaction based detection techniques that amplify DNA fragments specific for the fungus), confirming analyses of Dr. Lisa O'Donnell (City of Austin). Sequence analysis of the fragments confirmed the detection of Chytrid fungus (Annis et al. 2004), and thus demonstrated the presence of this pathogen in Central Texas for the first time. We have now documented the fungus in Houston toads, but only from a recent subset of the samples collected at the GLR. Only recent samples provide positive results for its presence among Houston toads, none of the samples prior to 2006 were positive.

During the last 20 years significant declines in populations of amphibians or even total disappearance of species have been observed worldwide. For most of the time, human activities and the resulting environmental changes and problems have been blamed as major causes for these declines (Daszak and Cunningham 2003). Recent studies on suddenly declining and disappearing populations of frogs, however, revealed an additional culprit, a newly emerging infectious disease (Bell et al. 2004). This

disease, chytridiomycosis, is caused by the fungus *Batrachochytrium dendrobatidis* (or Chytrid fungus), an aquatic organism with two life stages: a sessile, reproductive zoosporangium and a motile, uniflagellated zoospore released from the zoosporangium. Frogs can be infected by zoospores, or through skin contact with infected animals. Since the fungus does not survive under dry conditions, contaminated water or sediments containing zoospores or infected amphibians have been hypothesized as the major means for its rapid spread from an emergence site as an epidemic wave. The exact reasons for death are unknown, and similarly little is known about the epidemiology of the fungus (Davidson et al. 2003).

Knowing that the fungal pathogen has been detected in Houston toads, immediately suggests that we need to assay the population of amphibians in Bastrop County and the remaining range of the Houston toad. The fungus is not generally considered to be a threat to North American (temperate) amphibian populations, yet it is primary suspect in the decline of Californian amphibians. We need to solve this seeming contradiction and quickly.

CONCLUSIONS

The Houston toad has been critically endangered since it was rediscovered in 1967 in Bastrop County. Likely never exceeding a few thousand individuals in Bastrop County at any recent time, that population has now declined. We have little reliable data on populations outside of Bastrop County, but what data we do have show alarming downward trends for those populations as well. Finally, the drought that really began in 1993 and has continued through today is not normalizing despite several recent years of near average rainfall respite (Fig. 3) and a remarkably wet 2007 (not depicted). We know that drought played a role in the extirpation of the Houston toad from 25% of its former range during the 1950s, the current situation threatens to do the same in the remaining counties. As this report was completed, the situation has again cycled to a very dry beginning to 2008 and little relief is seen in the long range forecasts for central Texas.

It is not all bad news, as the Houston toad has remarkable resiliency and intrinsic capacity for population increase. It is currently seeing a very bad time, one that we are in a position to partially alleviate by immediate conscientious efforts in headstarting, habitat improvement, and assessing novel threats to the taxon as we help it to recover by active rather than passive stewardship. This necessitates a change in stance, from simply monitoring and research to involved stewardship. Considerable effort and funding has been applied and succeeded in obtaining information that is directly relevant to reversing the decline in this species in the coming years. We argue that not only is the current situation and its trend toward imminent extinction clear, so are the solutions. Indeed conscientious action and positive attitudes among stakeholders and management authorities during the past seven years have positioned us to make such an effort feasible. The stewardship efforts are the solution and must move to include remaining populations and stakeholders outside of Bastrop County.

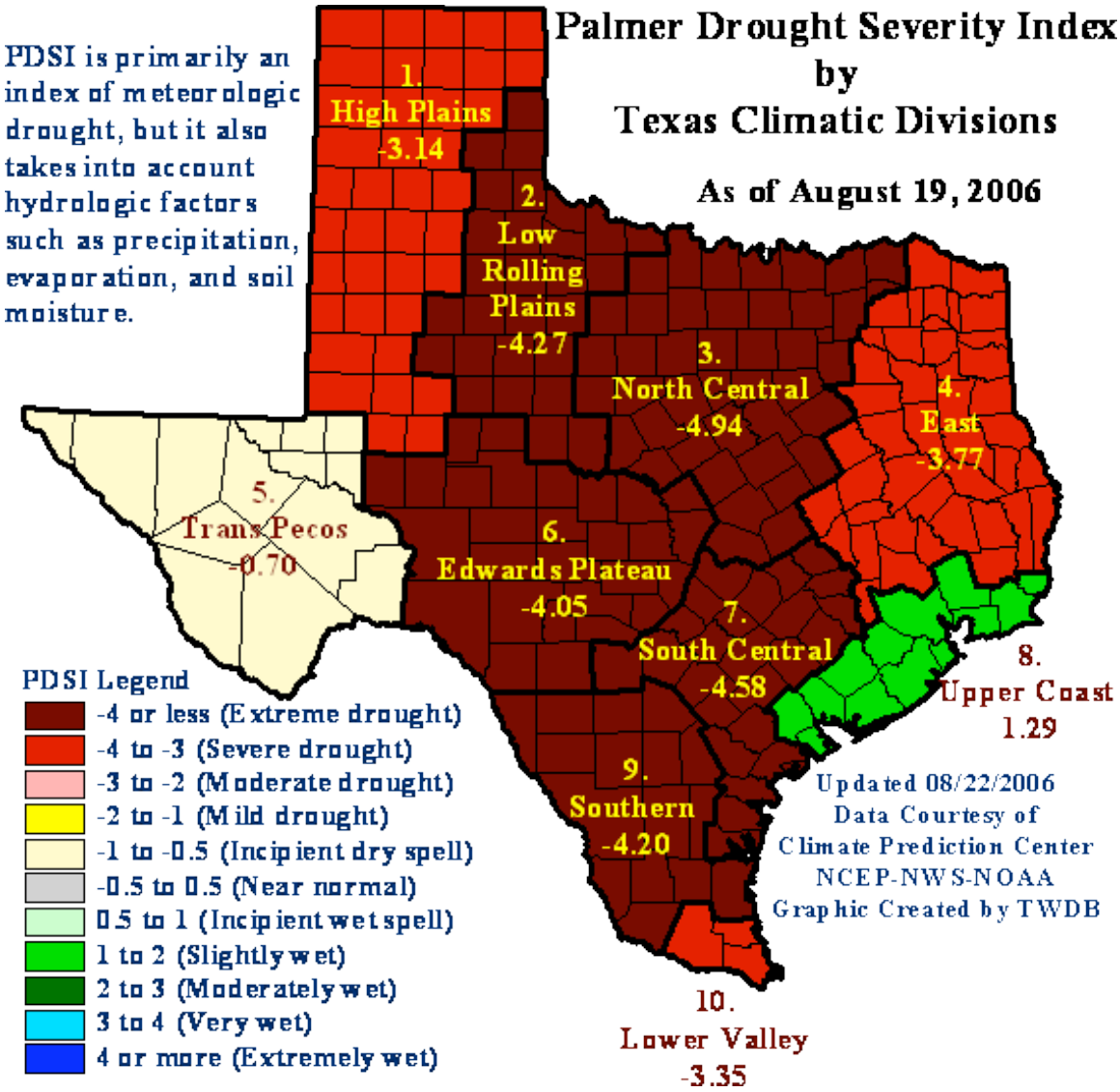

Figure 1. Drought conditions for Texas for August 2006. The South Central region contains nearly all known chorusing populations of Houston toads.

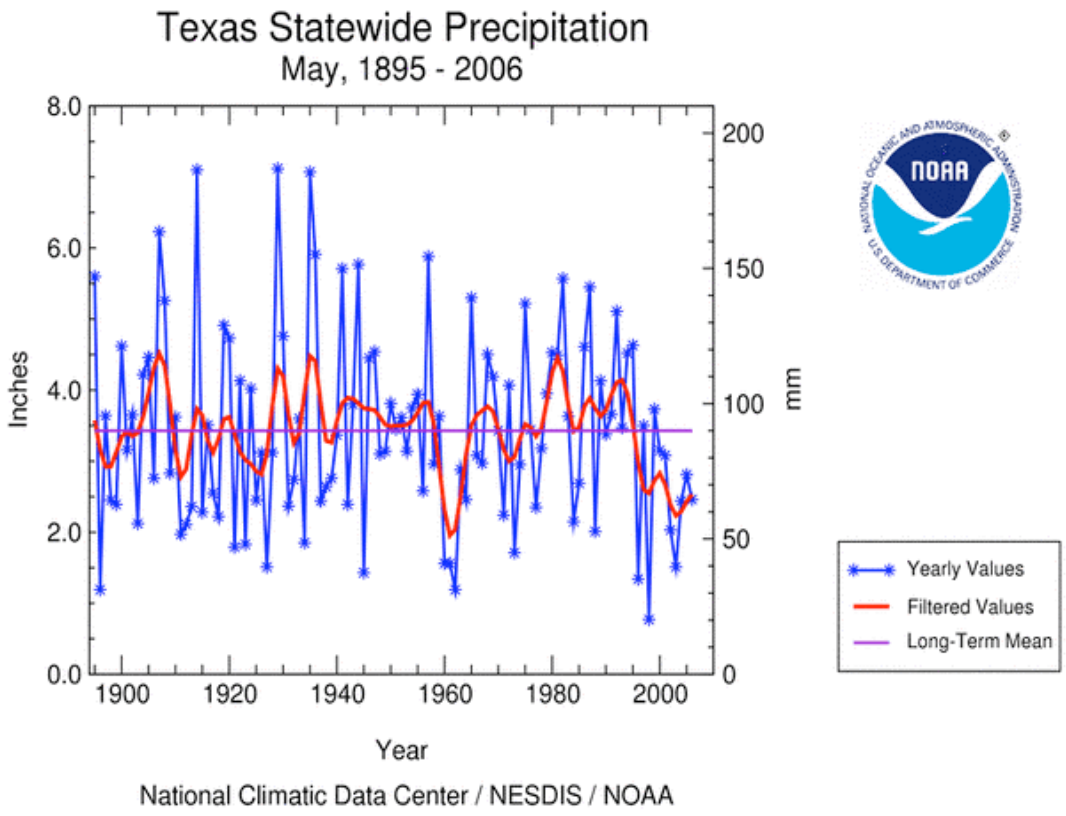

Figure 2. Historical records for precipitation in Texas, emphasizing the severity of the 2005-2006 drought period for the state. During 2007, one of the wettest years on record occurred bringing the three year total back to near average yearly values for the period.

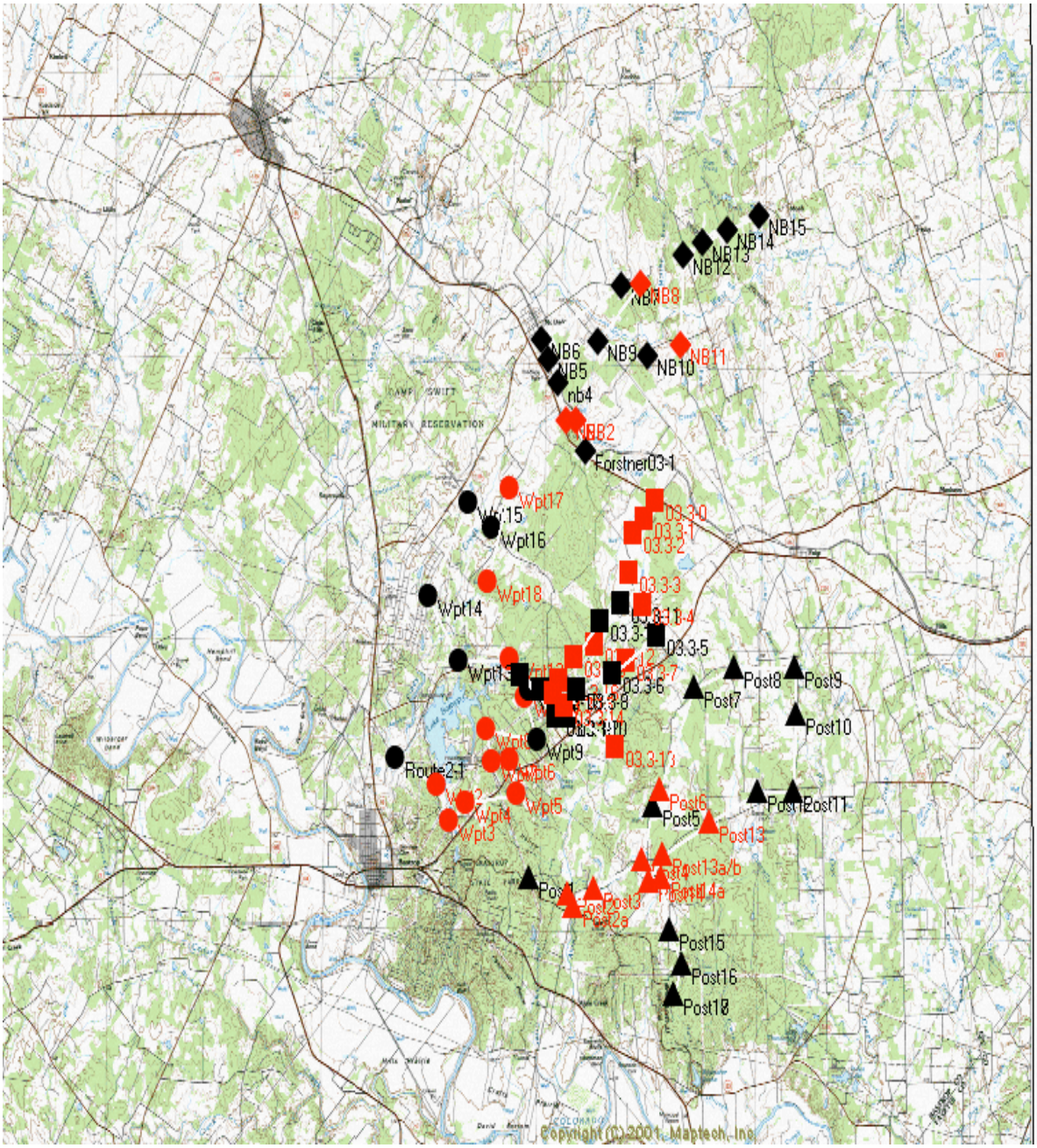

Figure 3. Geographic depiction of Houston toad audio survey listening post locations completed in 2003. The map represents the central and northern section of Bastrop County, Texas with the top of the map due North. Each different symbol shape represents a different individual survey route. Symbols in red indicate a listening post from which Houston toad chorusing could be heard. Route 1 is indicated by triangles, Route 2 by circles, Route 3 by squares, and Route 4 by diamonds. An additional set of 19 listening posts on Route 4 were completed in southern Bastrop County in the Pine Valley and Sandy Creek subdivisions. However, those locations are not depicted here nor were Houston toads heard at any of those locations.

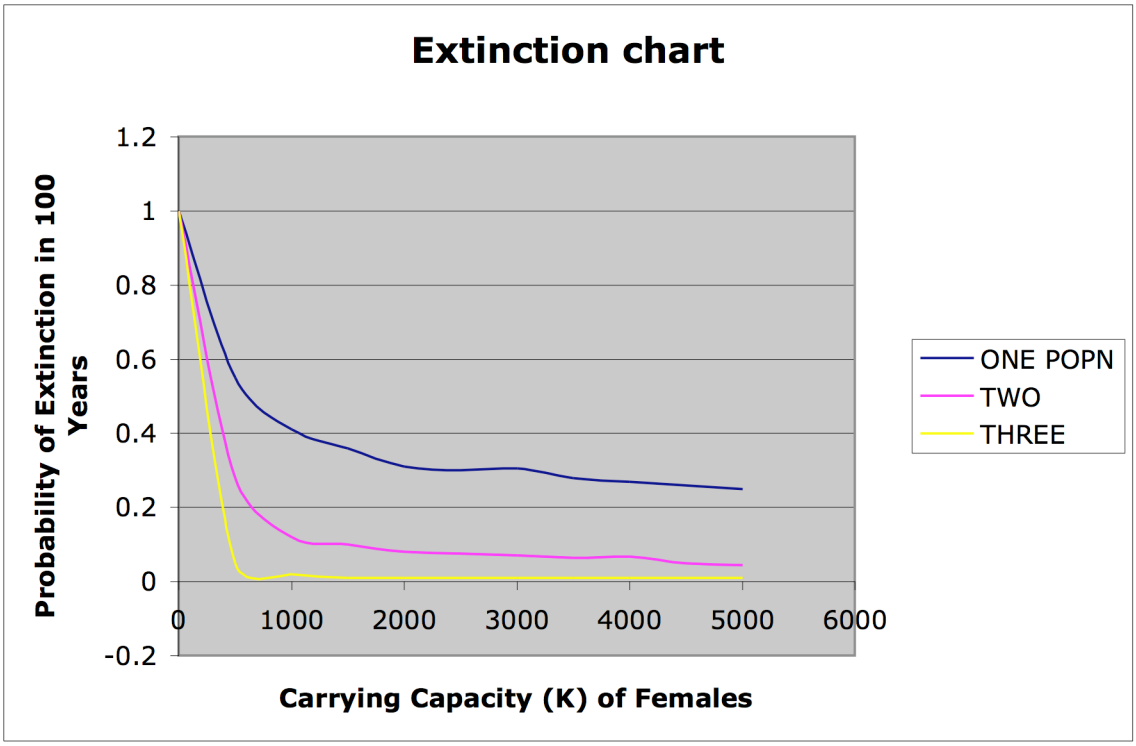

Figure 4. Extinction probability summary graph from Hatfield et al. (2004). Under this model the key conclusions are that more than one population is required to retain the population. Similarly, the larger the population size (overall) the better the chance to prevent extinction. This model used 1% survivorship for juveniles.

Literature Cited

Annis, S., F.P. Dastoor, H. Ziel, P. Daszak, and J.E. Longcore. 2004. A DNA-based assay identifies *Batrachochytrium dendrobatidis* in amphibians. J. Wildlife Dis. 40:420-428.

Bell, B.D., S. Carver, N.J. Mitchell, and S. Pledger. 2004. The recent decline of a New Zealand endemic: how and why did populations of Archey's frog *Leiopelma archeyi* crash over 1996-2001? Biol. Conserv. 120:189-199.

Daszak, P. and A.A. Cunningham. 2003. Anthropogenic change, biodiversity loss, and a new agenda for emerging diseases. J. Parasitol. 89(Suppl):S37-S41.

Daszak, P., Cunningham, A.A., and Hyatt, A.D. Draft guidelines for international translocation of amphibians with respect to infectious diseases. Attachment 6. In: Speare, R. and Steering Committee of Getting the Jump of Amphibian Disease. Developing management strategies to control amphibian diseases: Decreasing the risks due to communicable diseases. School of Public Health and Tropical Medicine, James Cook University: Townsville. 2001: 150-156.

Davidson, E.W., M. Parris, J.P. Collins, J.E. Longcore, A.P. Pessier, and J. Brunner. 2003. Pathogenicity and transmission of chytridiomycosis in tiger salamanders (*Ambystoma tigrinum*). Copeia 3:601-607.

Forstner, M.R.J. 2002. The 2002 Houston toad surveys in Bastrop County. Final Technical Report. Bastrop County citizen's workgroup and Bastrop County Houston toad project. 20pgs.

Forstner, M.R.J. 2003. Final Technical Report. Final report of the 2003 Bastrop County coordinated Houston toad surveys. Bastrop County Citizen's Workgroup. 12pgs.

Forstner, M.R.J. 2006. Final Technical Report. Houston toad monitoring: 2005 data and final report for the CAC-Griffith League Ranch, Bastrop County, TX. Submitted to the CAC-BSA and United States Fish and Wildlife Service. 10pgs.

Forstner, M.R.J. and J.R. Dixon. 2000. Final Technical Report. An overview and genetic assessment of the occurrence of Houston toads on the Three Oaks lignite mine site. Jackson and Sjoberg, LLC. Austin, Texas. 19pgs.

Forstner, M.R.J. and J.R. Dixon. 2001. Final Technical Report. Report of Houston toads (*Bufo houstonensis*) surveys in Lee County, TX. David Jackson, Jackson and Sjoberg, LLC. Austin, TX. 7pgs.

Forstner, M.R.J. and J.T. Jackson. 2006a. Final Technical Report. Final Report of the Blue Bonnet Headquarters Tract, Bastrop County, TX Houston Toad Survey 2006. Submitted to Blue Bonnet Electric Co-op. 7pgs.

Forstner, M.R.J. and J.T. Jackson. 2006b. Final Technical Report. Final Report of the Small Property, Bastrop County, TX Houston Toad Survey 2006. Submitted to Jim Small and Environmental Defense. 5pgs.

Forstner, M.R.J. and J.T. Jackson. 2006c. Final Technical Report. Houston toad monitoring and 2006 data for the Griffith League Ranch and Lost Pines Scout Reservation, Bastrop County, TX Houston Toad Survey 2006. Submitted to the CAC-BSA and Environmental Defense. 13pgs.

Forstner, M.R.J. and J.T. Jackson. 2006d. Final Technical Report. Final Report of the Long Property, Bastrop County, TX Houston Toad Survey 2006. Submitted to Bob Long and Environmental Defense. 8pgs.

Forstner, M.R.J. and T.M. Swannack (eds.). 2004. The Houston toad in Context. Final Technical Report. Submitted to the Capitol Area Council, Boy Scouts of America and Texas Parks and Wildlife Department in completion of United State Fish and Wildlife Service Section 6 Grant "Habitat use of the Houston toad." 746pgs.

Forstner, M.R.J., J.T. Jackson, and T.M. Swannack. 2005. Final Technical Report. Final Report of the Long Property, Bastrop County, TX Houston Toad Survey 2005. Submitted to Bob Long and Environmental Defense. 13pgs.

Forstner, M.R.J., T.M. Swannack, K.L. Greuter, and S.R. Morris. 2003. Final Technical Report. Houston toad research and surveys: 2003 data and final report for the CAC-Griffith League Ranch, Bastrop County, TX. Texas Parks and Wildlife and United State Fish and Wildlife Service. 18pgs.

Gaston, M.A., J.R. Dixon, and M.R.J. Forstner. 2001. Geographic distribution. *Bufo houstonensis*. Herp. Rev. 32(3):189-190.

Grimm, E.C., and J.S. Clark. 1999. Fossil pollen and charcoal evidence for drought intensity and variability in the northern Great Plains. EOS, AGU Volume 80:46, F54.

Grissino-Mayer, H. 1996. A 2129-year reconstruction of precipitation for northwestern New Mexico, U.S.A. Pages 191-204 in J. S. Dean, D. M. Meko, and T. W. Swetnam, eds. Tree Rings, Environment and Humanity. Radiocarbon, Tucson, AZ.

Hatfield, J.S., A.H. Price, D.D. Diamond, and C.D. True. 2004. Houston toad (*Bufo houstonensis*) in Bastrop County, Texas: Need for protecting multiple subpopulations. Pages 292-298 in H.R. Akçakaya, M.A. Burgman, O. Kindvall, C.C. Wood, P. Sjögren-Gulve, J.S. Hatfield, and M.A. McCarthy (eds.), Species Conservation and Management: Case Studies. Oxford University Press.

Jackson, J.T., F.W. Weckerly, T.M. Swannack, M.R.J. Forstner. 2006. Imperfect detection and number of auditory surveys for Houston toads. J. Wildlife Management 70: 1461-1463.

Lowry, R.L. Jr. 1959. A study of droughts in Texas (B-5914). Texas Board of Water Engineers.

Price, A.H. 1990. Status of the Houston toad (*Bufo houstonensis*) along State Highway 21, Bastrop County, Texas. Submitted to the Texas Department of Highways and Public Transportation in fulfillment of Interagency Contract (90-91) 0860 330-0568. Texas Parks and Wildlife Department. Austin, Texas.

Price, A., 2003. The Houston toad in Bastrop State Park 1990 - 2002: a narrative. Open-file report 03-0401, Texas Parks & Wildlife Department.

Quinn, H.R. and Mengden, G., 1984. Reproduction and growth of *Bufo houstonensis* (Bufonidae). Southwestern Naturalist, 29:189-195

Swannack, T. M. 2007. Modeling aspects of the evolutionary and ecological dynamics of endangered Houston toads.

Swannack, T.M. and M.R.J. Forstner. 2007. Possible cause for the sex-ratio disparity of the endangered Houston toad (*Bufo houstonensis*). Southwestern Naturalist 52: 386-392.

USFWS. 2001. 46-Subdivisions Habitat Conservation Plan. 78pgs.

Yantis, J.H. 1989. Houston toad distribution and habitat status. Performance report, Job No. 76. Texas Parks and Wildlife Department. Austin, Texas.

Yantis, J.H. 1990. Houston toad distribution and habitat status. Performance report, Job No. 76. Texas Parks and Wildlife Department. Austin, Texas.

Yantis, J.H. 1991. Houston toad distribution and habitat status. Performance report, Job No. 76. Texas Parks and Wildlife Department. Austin, Texas.

Yantis, J.H. 1992. Houston toad distribution and habitat status. Performance report, Job No. 76. Texas Parks and Wildlife Department. Austin, Texas.

Zippel, K., Lacy, R., and Byers, O. (Eds.) (2006) CBSG/WAZA amphibian ex situ conservation planning workshop final report. Apple Valley, MN: IUCN/SSC Conservation Breeding Specialist Group.