Section 6 (Texas Traditional) Report Review

Form emailed to FWS S6 coordinator (mm/dd/yyyy): 6/21/2011

TPWD signature date on report: 5/9/2011

Project Title: Houston Toad (*Bufo houstonensis*) 5-Year Review: Summary and Evaluation

Final or Interim Report? Final

Grant #: E-101

Reviewer Station: Austin ESFO

Lead station concurs with the following comments: NA (reviewer from lead station)

Interim Report (check one):

- ☐ Acceptable (no comments)
- ☐ Needs revision prior to final report (see comments below)
- ☐ Incomplete (see comments below)

Final Report (check one):

- ☒ Acceptable (no comments)
- ☐ Needs revision (see comments below)
- ☐ Incomplete (see comments below)

Comments:

FINAL REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. TX E-101-R

Endangered and Threatened Species Conservation

Five-year Status Review: Houston Toad

Prepared by:

Michael Forstner

TEXAS PARKS & WILDLIFE

Carter Smith
Executive Director

Clayton Wolf
Director, Wildlife

30 March 2010

FINAL REPORT

STATE: ____Texas_______________ **GRANT NUMBER:** ___TX E-101-R___

GRANT TITLE: Five-year Status Review: Houston Toad

REPORTING PERIOD: ____1 Oct 08 to 31 Mar 2010_

OBJECTIVE(S):

To conduct in one year a status review of the Houston Toad.

Segment Objectives:

Task 1. **Updated information and current species status.**_ Summarize new information, citing detailed information and analyses and provide an updated status of the species, citing new information about the species and its breeding, wintering, and migratory range.

Task 2. **Electronic GIS layers** (shapefiles or geodatabases).

Task 3. **An annotated bibliography** using Reference Manager, ProCite or some other form of bibliographic software that can export to an RIS format, and copies (pdfs) of all literature (not already in FWS files) pertaining to the species since the time of listing.

Significant Deviations:

None.

Summary Of Progress:

Attached files contain:

Attachment A – the Five-year Status Review document (pdf)
Attachment B – set of reviews and responses generated from with the status review panel (pdf)
.zip file containing EndNote files for literature references

Electronic files: "All points, maps, and other materials were delivered to the USFWS on July 21, 2009" – email from Dr. Forstner, 30 Mar 2010 (10:38 am; on file).

Location: Texas State University, San Marcos, Texas.

Cost: ___Costs were not available at time of this report, they will be available upon completion of the Final Report and conclusion of the project.__

Prepared by: _Craig Farquhar_____________ **Date:** _30 Mar 2010

Approved by: ____________________________ **Date:**_____30 Mar 2010___
C. Craig Farquhar

Houston Toad

(Bufo houstonensis)

5-Year Review:

Summary and Evaluation

M.R.J. Forstner and J.R. Dixon

Texas State University and Texas A&M University (Emeritus)

submitted to

U.S. Fish and Wildlife Service

Austin Ecological Service

Austin, TX

5-YEAR REVIEW
Species reviewed: Houston toad (*Bufo houstonensis*)

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5-YEAR REVIEW

Houston toad/*Bufo houstonensis*

1.0 GENERAL INFORMATION

1.1 External Reviewers *(Paul Crump, Jeff Hatfield, Ray Semlitsch Todd Swannack)*

Internal Reviewers (James Bell, Donald Brown, Dittmar Hahn, Jake Jackson, Diana McHenry, Shawn McCracken)

Lead Regional or Headquarters Office: Region 2, PO Box 1306 Albuquerque, NM 87103 (505) 248-6282

Lead Field Office: Austin ES Field Office, Region 2, (512) 490-0057

Cooperating Field Office: Clear Lake ES Field Office, Region 2, (281) 286-8262

Cooperating Regional Office: N/A

Cooperating Science Center (NMFS only): N/A

1.2 Methodology used to complete the review:

It is safe to assume that neither the authors of the 1984 Houston toad Recovery Plan (Potter et al. 1984) nor the workgroup completing its population and habitat viability assessment (PHVA) (Seal 1994) could have foreseen the magnitude of work completed on amphibian declines in the last two decades. We began by reviewing both of those Houston toad summary documents, choosing to begin with revisions since the 1984 Recovery Plan and specifically evaluating its goals and objectives. In overview, there have been three distinct research "cycles" of information collected for the Houston toad since its discovery and eventual scientific description. The first of those cycles was primarily discovery and investigations from the original description by Sanders (1953) up through petition and listing as an Endangered Species under the Endangered Species Act (ESA) in 1973, but inclusive of the group of researchers leading the development of the Recovery Plan in 1984. That same group of authorities was actively involved in the 1994 viability analyses (Seal 1994) and bridge into the latter two research cycles. The second cycle of Houston toad research included significant contributions to the scientific literature of the species (e.g. Hillis et al. 1984), population monitoring at Bastrop State Park (Price 2004), experimental propagation and reintroductions (Quinn 1980; Quinn & Mengden 1984; Quinn et al. 1987) and changes to the knowledge of its distribution (Yantis 1989; 1990; 1991; 1992; Yantis & Price 1993). The authors here represent authorities from the second and third cycles. Michael R.J. Forstner (Texas State University) and James R. Dixon (Texas A&M

University & Texas Cooperative Wildlife Collection, *Professor emeritus*, retired) collaboratively reviewed existing literature, books, and their own field experience with the species. Dixon has been actively conducting field research on the species from the 1980s (Dixon 1982; 1983) to the present. Forstner began work in 1993 and intensified his collaborative investigations since 2000. We were advantaged to be able to rely on the recent work of student researchers and soon to be colleagues whose work on habitat modeling (Buzo 2008), ecological monitoring (Swannack et al. 2009), and genetics of the species (McHenry & Forstner 2009) were particularly timely additions to this review. As no prior 5-year status review has been found, despite some indications that one had been initiated at least once before, we have chosen to regard the 1984 final Recovery Plan for this species as the most recent review in our assessments of changes in status or relevant information.

1.3 Background:

1.3.1 FR Notice citation announcing initiation of this review:

1.3.2 Listing history

Original Listing
FR notice: 35 FR 16047 16048
Date listed: 10/13/1970
Entity listed: *species*
Classification: *endangered*

Revised Listing, if applicable (N/A)
FR notice (*Federal Register Volume and page number*):
Date listed:
Entity listed (*species, subspecies, DPS*):
Classification (*threatened or endangered*):

1.3.3 Associated rulemakings
FR Notice: 43 FR 4022 4026
Date listed: 1/31/1978
Name of Plan or outline: Final determination of Critical Habitat for the Houston Toad

1.3.4 Review History:
FR notice: 71 FR 20714 20716
Date listed: 4/21/2006

Name of Review: announces a 5-year review, but no document appears to exist for the Houston toad

1.3.5 Species' Recovery Priority Number at start of 5-year review: 2c

1.3.6 Recovery Plan or Outline
Name of plan or outline: Houston toad recovery plan
Date issued: Sept 17, 1984
Dates of previous revisions, if applicable: N/A

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate? | ***Yes***
2.1.2 Is the species under review listed as a DPS? | ***No****, go to section 2.1.4*
2.1.3 Was the DPS listed prior to 1996? | ***N/A***
2.1.3.1 Prior to this 5-year review, was the DPS classification reviewed to ensure it meets the 1996 policy standards? | ***N/A***

2.1.3.2 Does the DPS listing meet the discreteness and significance elements of the 1996 DPS policy? | ***N/A***

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy? | ***No***

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

___ ***Yes***

_X_ ***No***

As 1) a Recovery team is in place, 2) a revised Recovery Plan for this species has been divided among members for development, and 3) we are all members of that team, we have chosen not to supercede the team by making such recommendations unilaterally and potentially prematurely, here.

2.2.2 Adequacy of recovery criteria.

As was current in 1984, the Recovery Plan does not articulate clear recovery criteria and as such, we have indicated that they are not adequate and do not conform to current standards, we do evaluate the criteria in the context of the recovery outline (see section 2.2.3) from the 1984 Recovery Plan for this species.

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?

____ *Yes, go to section 2.2.2.2.*
_X_ *No, go to section 2.2.3.*

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

____ *Yes, go to section 2.2.3.*
____ *No, go to section 2.2.3,*

As 1) a Recovery team is in place, 2) a revised Recovery Plan for this species has been divided among members for development, and 3) we are both members of that team, we have chosen not to supercede the team by making such recommendations unilaterally and potentially prematurely, here.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information.

The following are the listed recovery goals as proposed in 1984, obviously these are dated in comparison with modern recovery plans where objective, verifiable criteria are applied to enable judgment of the status (recovered or not) for a given taxon at a given review period. We address these here as if they were explicit criteria for judgment of recovery.

Recovery Plan Goal 1.0 Maintain and enhance existing Houston toad populations in their present habitats.

Review for 1984 Recovery Plan Goal 1: Progress toward these achievements in the years since 1984 has been narrow in scope and uneven in annual progress. However, the past 26 years have provided significant advances in our understanding of the Houston toad, its distribution, ecology, and stewardship. There have also been mistakes and outright stewardship failures during this period as well. Taken as a whole, many of these goals have seen progress. It is useful to learn from the evidence of past mistakes so as to prevent future repetitions both here with the Houston toad, but with similar efforts for other taxa.

Recovery Plan Goal 1.1 Monitor existing populations and habitats.

Monitoring of the Houston toad on a range-wide basis, or even on a rotating basis among known locations has not been consistently conducted during the period of time following the Recovery Plan. Refer to section 2.3.1.2 for a review of trends, surveys, and approaches over time, but synthetically no monitoring of Houston toad populations on any realistically representative range-wide scale has ever been conducted. It may not be practical to complete range-wide surveys regularly as a consequence of both scale and required intensity (Scott et al. 2002; Williams et al. 2002), but habitat assessment using aerial survey photos is achievable. Buzo (2008) utilized a geographical information system (GIS) to model the habitat suitability for the Houston toad, and her work revealed significant losses of high suitability habitat in the period from 1999 to 2005 in both Lee and Bastrop counties. This two-county region has the greatest data depth for toad population monitoring of any regional scale, historical or current, and also the most regulatory and stakeholder attention to development projects or changes to the landscape. We feel comfortable stating that while not specifically compiled or analyzed, detrimental habitat changes noted as resulting in the extirpation of the species from the Houston area in the 1984 Recovery Plan have continued unabated across the occupied habitats of the Houston toad (see 2.3.2.1).

Recovery Plan Goal 1.2 Identify population needs and habitat requirements.

There have been relatively few studies that have sought to examine the broad population level needs and habitat requirements for the Houston toad. There is an intractable conflict between the early depictions and summaries of Houston toad habitat (Kennedy 1962) and those from current survey and population monitoring results. Kennedy (1962) appears to be the published basis for placing the Houston toad within the Gulf Coastal Prairie ecosystem as primarily a grassland species. Subsequent survey work has not found any current populations of Houston toads to be strongly associated with nor particularly abundant within any modern grassland communities. This conflict may simply be a consequence of radical anthropogenic influences on the landscape over time resulting in the collapse of whatever was the original habitat for the Houston toad. It may also be that the original conclusions of the species' association in coastal prairie were confounded by ongoing changes to the landscape of the Houston area consequent of both extensive sand mining and clearing of forested habitats. We note the forceful way with which the 1984 Recovery Plan makes the case for occupancy by the Houston toad in prairie habitats.

Range-wide surveys completed by Yantis and colleagues from 1989-1992 (Yantis 1989;

1990; 1991; 1992; Yantis & Price 1993), resulted in the detection of new localities for the Houston toad. These new locations included 5 counties unknown to the authors of the 1984 Recovery Plan (Freestone, Lavaca, Leon, Milam, and Robertson counties). Yantis & Price (1993) also predicted the likely occurrence of the species in Caldwell and Lee counties, which was subsequently substantiated for Lee County (Gaston et al. 2001). John Kuhl may have been the first biologist to detect the Houston toad at the boundary of northern Bastrop County and into Lee County during work in the late 1990s (Kuhl 1997). The occurrence of the Houston toad was subsequently validated as a county record with a road killed voucher in 2001 (Gaston et al. 2001). Using the findings of Yantis as the basis for a GIS model, Buzo (2008) completed a habitat suitability assessment for the Houston toad. Recent range-wide surveys conducted by the coauthors and our graduate students have sought to validate the underlying assumptions of the habitat model developed by Buzo (2008), which predicted a soil and canopy-vegetation structure to represent high suitability Houston toad *breeding* habitat. The results indicate that the probability of hearing a Houston toad chorus on otherwise suitable deep sandy soils is significantly higher when concurrent with vegetation characterized as woodland or forest than for existing grasslands (Buzo et al. unpublished data). Integrating the habitat suitability model results with fine-scale genetic data (McHenry & Forstner 2009) supports the conceptual framework of three useful management and regulatory Houston toad habitat types. *Breeding* habitat is a body of water supporting the reproductive and larval Houston toad lifestages. The adjacent uplands outward to 1.6 km enclose the *occupied* habitat for the breeding site, supporting adults year round, and *dispersal* habitats provide the patch connectivity landscape outward 5km from the ponds (See section 2.3.1.6 below).

Given the modern association of the Houston toad with forested habitats, management approaches have shifted accordingly, with emphasis on reestablishing healthy forest ecosystems. It is not clear how prescribed fire or its application was tied to major negative impacts on the Houston toad, but it is clear that Seal (1994) perceived more negatives than positives from the use of fire in management of Houston toad habitat. While the erroneous conclusions that resulted in strong enforcement of fire prevention in fire-managed ecosystems has passed, the results of more than 60 years under this mandate has left badly fire suppressed forests occupied by the Houston toad. Three large scale restoration projects are now underway. Bastrop State Park (BSP) began fire management and restoration efforts for its forest ecosystem in 2002 (Jones 2006; Taber et al. 2008). In 2005 that effort was expanded to include a group of private properties and their owners/stakeholders adjacent to BSP under the collaborative research supervision of David Wolfe of the Environmental Defense Fund (EDF) and MRJF. In 2009, they also began the direction of a landscape scale reforestation and restoration effort within the greater Alum Creek watershed of Bastrop and Lee Counties. This project is a watershed restoration effort lead by Mr. Wolfe and EDF to reforest habitats cleared for pasture and to reestablish continuity among the drainages of the greater Alum creek watershed. Finally, MRJF is supervising a research test of the linkage between prescribed fires and the aquatic ecosystems in the forests of Bastrop County. These projects are generating information directly useful to understanding the needs and habitat of the Houston toad, but outcomes thus far have been confounded by a severe drought period spanning 2005-2009.

Recovery Plan Goal 1.21 Study existing populations and habitats, including human uses of land, pesticides, and herbicides.

One obvious conflict with the guidance from the 1984 Recovery Plan is simply the narrow geographic scope of all ongoing work with the Houston toad. Nearly every project investigating aspects of its habitat and interactions with human uses of that land has been done in Bastrop County. It does appear to be evident in the conclusions of the 1984 Recovery Plan and from the recent habitat analysis by Buzo (2008) that human conversion of forests to pasture results in the catastrophic decline of even significant chorusing populations of the Houston toad. Compilation volumes exist which provide insight into the effects of several hundred chemicals on amphibians with limited reference to the genus *Bufo* (Devillers & Exbrayat 1992). No progress has been made to evaluate the consequences of pesticides or herbicides specifically on the Houston toad.

Recovery Plan Goal 1.22 Study ecological relationships between the Houston toad, and other species of Bufo, predators, and competitors.

A number of publications have examined the indirect evidence of interactions with other members of the genus *Bufo*, using hybridization data. In fact, the majority of those studies were completed prior to the Recovery Plan (Brown 1971; Hillis et al. 1984). The current state of hybrid frequency, direction of mating, and overall distribution among available samples has just been completed and is summarized below under new information for the species' genetics (2.3.1.3). However, there have not been studies completed that examine the competitive displacement of the species by other toad species, nor any such effects at the larval stage. Studies have substantiated the latter type of competition and are known to have relevance in toads (Petranka et al. 1994; Alford & Wilbur 1985) including endangered bufonids (Griffiths et al. 1991). Other than a few observations (Price pers. comm. to MRJF 2002; Forstner & Swannack 2004; Ferguson 2005), the ecological context of the toad, its relevant competitors, consequences of watersnake prevalence (Swannack 2007), anthropogenically enhanced predators (e.g. feral hogs, raccoons, cats, etc.) have not been provided in the literature.

Recovery Plan Goal 1.23 Monitor study progress and evaluate results.

It is not clear whether the Recovery team had an explicit set of experiments or if they intended a subsequent review of particular projects when they drafted this objective. We are not aware of an overview or summative review of 1.23 in the years between 1984 and today.

Recovery Plan Goal 1.3 Protect existing populations.

In 1953, Houston toads were known to occur in Austin (Sealy), Burleson (Lake Woodrow), Colorado (E of Columbus), Harris (Houston), and Liberty (Liberty) counties (Sanders 1953). By 1984, Houston toads had been additionally detected in Fort Bend (Fresno) and Bastrop (Bastrop State Park) counties (Brown 1971). Critical habitat for the species was designated in 1978 (43 FR 4022 4026). By 1990 the populations of Houston toads in Burleson, Fort Bend, Harris, and Liberty counties were effectively or completely extirpated (Seal 1994). The 1984 Recovery Plan recommendation to locate additional populations (see 2.0 below) resulted in work by Yantis and colleagues that identified new locations for the Houston toad. The new locations were in five counties (Freestone, Lavaca, Leon, Milam, and Robertson counties). In 1993 Yantis & Price conclude the extirpation of Fort Bend, Harris, and Liberty counties consequent of habitat destruction. Recent surveys of Lavaca County have failed to detect the Houston toad at the original location or any other potentially suitable locations that remain (McHenry & Forstner 2009). Most recently, the extensive choruses of Houston toads detected in Lee County (Forstner & Dixon 2000) have diminished to only a single toad detected each year since 2005 (McHenry & Forstner 2009). The trend is fairly clear for existing populations of the Houston toad. Assuming that in 1953 the Houston toad occurred in all the counties from which it has been detected and no more, there were thirteen counties with populations in Texas (but see 2.3.1.5 regarding Freestone County). Currently there are five confirmed within the last 5 years (Austin, Bastrop, Colorado, Leon, and Milam). We consider it likely that Houston toads also persist in Robertson, but given the historical optimism for situations like this, coupled to dramatic, extensive oil and gas exploration expansion in the past 5 years in Robertson County, without confirmation of presence we will not conclude them to persist there. Notably we have been unable to obtain evidence of take permits issued for this species in habitats within Robertson County since 2000; this mimics the situation we observed for Lee County between 2000 and today (see 2.3.1.2). Consistent incremental habitat loss, including forest clearing to pasture conversion has been observed during active chorusing months and during active chorusing periods alongside such loss at other times of the year. It is our conclusion that adequate protection for the existing populations since 1984 has not been achieved, inclusive of even Bastrop County.

Recovery Plan Goal 1.31 Seek cooperation of landowners (private or public) and provide them with conservation information.

Attitudes and conflicts between private landowners and endangered species stewardship are well known, well characterized, and often negative (Shogren & Tschirhart 2001). Little has changed in any practical way for these attitudes or their general context. As Texas is a state dominated by private lands, integrating these landowners as stewards to the Houston toad recovery effort has always been critical. This need has long been recognized and efforts by Texas

Parks and Wildlife Department and most recently Bastrop County as part of the Lost Pines Habitat Conservation Plan have met this objective. The continuing efforts of both these groups and those of the Environmental Defense Fund and USFWS have become increasingly open to finding common ground between landowner needs and those of the Houston toad. These objectives remain as critical today as they were in 1984. More important today is increasing the scope of the outreach and breadth of landowners, particularly for those landowners outside of Bastrop County.

Recovery Plan Goal 1.32 Review and comment on all projects which might affect the Houston toads or their habitat.

The objectives of this goal have certainly been the case for projects brought to the USFWS for review. As mentioned above regulatory oversight and enforcement has been inadequate for the majority of the changes to the landscape that have impacted persistence of the Houston toad. Ultimately the constraints are often more political than biological (Shogren & Tschirhart 2001). Examples of the consistent success of political expedients over biological or conservation priorities for the species have been extensively documented elsewhere (Brown & Mesrobian 2005). It is our conclusion that the system is as unlikely to allow the successful achievement of this 1984 Recovery Plan goal today as it was during the years just prior to the Recovery Plan or those immediately afterward.

Recovery Plan Goal 1.33 Prepare habitat management plans.
Recovery Plan Goal 1.34 Enhance habitat for Houston toad.

Both of these objectives have become more critical as the historically fire managed ecosystems occupied by the Houston toad have been fire suppressed and increasingly fragmented. A key difficulty underlying the successful implementation of both these objectives is the conflict between early statements of prairie habitats supporting the Houston toad (Kennedy 1962) and recent studies showing that breeding sites separated from forested habitat by a few meters of non-native pasture represent reproductive sinks for the species (Forstner & Swannack 2004). Currently, restoring the perceived historical fire regime and reforestation of agricultural pastures remain the only viable strategies for those populations we have documented in current years. New pond construction as a conservation strategy for this species appears to be strongly contraindicated based on our analysis of component Allee effects (Gaston et al. *in press*). Several ongoing studies including that of the prescribed fires east of Highway 21 and now those west of that roadway should begin to provide results in the absence of other exacerbatory stressors (i.e. extreme drought conditions) for the next several years. Similarly, recently initiated projects seeking to restore watershed level connectivity for the greater Alum Creek watershed and further detailed examinations of the outcomes from prescribed fire will also provide relevant management data for the species in the coming years.

Recovery Plan Goal 1.35 Obtain management rights to habitat, if necessary, to protect continued existence of a county's Houston toad population.

This option has not been implemented in any counties historically or currently occupied by Houston toads other than Bastrop County. Achievements toward this goal have been difficult to assess. In the last few years several biologically relevant Safe Harbor Agreements and one HCP (5,000 acre Griffith League Ranch [GLR]) have been completed. Using funds from mitigation fees, a tract bordering the GLR (i.e. the Welsh Tract) was purchased and the remaining funds used to add acreage to Bastrop State Park. The Welsh Tract (454 acres) remains the only tract of land whose primary goal is Houston toad stewardship; all other tracts have other primary goals. Significant data relevant to species management and recovery goals have been gathered from the tracts mentioned here, thus outlining successes on this goal. There have also been missed opportunities. A legal settlement (1.75 million USD) established the Pines and Prairies Land Trust (PPLT) to "extend and protect the clean air and existing Houston toad habitat of the "Lost Pines" and Post Oak Savannah areas of Bastrop and Lee Counties in Central Texas" (US District Court 2003). These funds represented the single largest resource for use in obtaining and managing Houston toads in the area. Unfortunately, despite significant acquisitions of both deeds and conservation easements from these funds, no occupied Houston toad lands have been purchased from the funds out of that settlement nor are any currently under management by PPLT. While the situation in Bastrop County has improved since 2003 from the previously mentioned biologically relevant safe harbor and HCPs, Lee County has continued to lose habitat. Among the truly significant missed opportunities for Houston toad conservation in recent years has been the purchase of habitat or habitat rights by PPLT for tracts not representing currently or potentially future, biologically relevant tracts for Houston toad recovery in Lee and Bastrop counties.

Recovery Plan Goal 2.0 Locate additional natural populations of Houston toad.
2.1 Design a systematic search for additional populations.
2.2 Monitor and evaluate study progress.

As outlined above in section 1.3, the status of the Houston toad in 1984 was unclear to the authors of the Recovery Plan (Potter et al. 1984), particularly for the original habitats near Houston. By the time the Recovery Plan was completed, the toad was already extirpated from Fort Bend, Harris, and Liberty. The toad was also effectively extirpated from Burleson by 1984, despite the designation of Critical Habitat in that county. The range-wide efforts of Yantis (Yantis 1989; 1990; 1991; 1992) and Yantis & Price (1993), along with their collaborators' extensive fieldwork, provided data for the first comprehensive knowledge base on the distribution of the Houston toad in Texas. Yantis utilized soil maps to locate deep sands (>40 inches depth) and then designed routes to survey for the species within and across those soil types throughout the eastern part of the state. These wide ranging audio survey routes were designed to detect the species across the state, but were not designed to determine the presence or absence of the Houston toad at a particular pond. The data were gathered as audio chorus surveys of routes within or across a group of surveyed counties using short interval stops placed approximately 0.4km part along the survey route. Optimum weather conditions were deduced during the study and warm humid nights associated with prefrontal boundaries guided surveys (Seal 1994). The scale of this effort remains a remarkable achievement by any standard.

Audio surveys have become a standard method for the detection of amphibians (Heyer et al. 1994). There are also important issues related to the probability of detecting Houston toads, or more specifically failing to detect Houston toads when they are actually present using audio chorus surveys (Jackson et al. 2006). The surveys conducted by Yantis and colleagues were designed to detect the Houston toad on a landscape scale. Those surveys were obviously successful in this endeavor with the Houston toad detected in new counties detected and historical localities confirmed (Yantis & Price 1993). Regional detection of the Houston toad is very different from determining the presence of the species at a given pond. The guidelines used by Yantis to detect toads on a broad scale were erroneously applied by the USFWS as suitable for presence/absence detection for all subsequently reviewed projects potentially affecting Houston toad habitat. The required characteristics for acceptable audio chorus detection surveys for the Houston toad in the period from 1993 to 2007 were six survey nights with temperatures greater than 50°F during the months of January through May. These guidelines were drawn almost entirely from the surveys of Yantis and colleagues but applied for a very different purpose, presence or absence at a given pond. In an alternative approach Dixon and colleagues surveyed a large number of sites across the range of the species using 20 survey nights in a given season for a listening post. Our analysis of the probability that a survey will fail to detect Houston toads when they are actually present at a given pond concludes that with six survey nights, 20% of the time a survey would result in a false negative. The standard USFWS guidelines have now been changed to reflect this and 12 survey nights are required, providing an ~5% probability of false negatives. Our recent range-wide efforts focused on ponds, not entire habitat patches, and we continue to utilize 20 survey nights for presence/absence detection of the Houston toad (~1% probability of false negative) (Jackson et al. 2006).

Recovery Plan Goal 3.0 Determine the systematic status of the Bufo houstonensis.

3.1 Design and conduct a study of the taxonomic relationships of the Houston toad to other Bufo.

3.2 Consult with systematic herpetologists and evaluate taxonomic data.

We discuss the taxonomic and systematic revisions to the species in section 2.3.1.4 below. Pragmatically we believe that systematic or phylogenetic evaluations of this species since 1984 have been rare. While recent taxonomic chaos is ongoing for North American amphibians, that process will run its course and has little direct bearing on this species. What is relevant is that modern appreciation for rampant hybridization in the genus *Bufo* has become increasingly apparent (Masta et al. 2002), but was also recognized by Sanders (1987). Notably the arguments made by Sanders (1987) have been largely ignored and even censured (Collins 1989) despite that same author accepting just as dramatic a set of changes by Frost et al. (2006). While we likely concur with errors evident in Sanders (1987) we are less inclined to discount his appreciation for the nature of hybridization and its extent for the genus (Blair 1972a; Hillis et al. 1984). In any case, it is apparent that the scientific review of *Bufo houstonensis* agrees on its specific status, and future genetic evidence will likely review a confounding history among what may well be a large and complex genetic swarm among the bufonids of northeastern Texas. The most recent evaluation of this area and its toads does not provide any additional information on the Houston toad (Fontenot 2009) but it would be logical to conclude that incorporating *B. houstonensis* is the next step in that evaluation in a genomic context (Malone & Fontenot 2008). What was key to the authors of the 1984 Recovery Plan was the contention by some authorities (e.g. Blair) that this organism was more properly a subspecies or isolated form of the American toad (*Bufo americanus*). The most recently published comprehensive phylogeny (Pauly et al. 2004) reveals that the situation is not well explained by subspecific status and the evolutionary history of the currently described *B. americanus* is also more complicated than was recognized in 1984. In any case Houston toads are maintaining genetic continuity that is discrete from sympatric congeners within the remaining occupied habitat fragments, despite infrequent hybridization events (McHenry & Forstner 2009; McHenry et al. unpublished data). From an applied phylogenetics standpoint, the situation will not be completely resolved until we have a more complete view of the underlying genetics of *Bufo americanus*, but in general the question has been reasonably addressed by currently published works.

Recovery Plan Goal 4.0 Restore and manage populations of Houston toads in suitable areas of former range.

- *4.1 Select suitable habitat in former range occupied by Houston toad.*
- *4.11 Identify and enhance suitable habitat.*
- *4.12 Develop management plans.*
- *4.2 Introduce Houston toads.*
- *4.3 Monitor introduced toads and habitat.*
- *4.4 Continue introductions.*
- *4.5 Manage restored habitat and populations.*
- *4.51 Seek cooperation of owners of Houston toad habitat, including owners of adjoining properties.*
- *4.52 Review and comment on all projects which might affect Houston toads and their habitats.*

It can be difficult to fully appreciate that, at the time of the 1984 Recovery Plan, efforts were ongoing to reintroduce the Houston toad into the southern sand-band counties (Table 1), including re-establishment of the toad in the coastal prairie fragments. Strangely enough, we are unaware of any surveys of Austin and Colorado counties during this period of time, but the belief was simply that the toad had been extirpated from the areas surrounding Harris County. Despite that historical missed opportunity, this set of goals is as relevant today as it was in 1984, only today the list of counties from which *B. houstonensis* appears extirpated has grown longer. It is doubly unfortunate that the authors of the 1984 Recovery Plan did not have recent survey data for Colorado and Austin counties and that the reintroduction efforts were also focused on a type of habitat (Attwater Prairie Chicken National Wildlife Refuge) that we would consider to be unsuitable for the Houston toad based on current knowledge of occupied habitats. Nevertheless, this goal from the 1984 Recovery Plan represents the entire modern suite of goals for the species in a general sense, but even today it is not clear if reintroductions to extirpated habitat fragments is warranted, or if the conditions required to assist in the success of those introductions can be provided. What is clear is that despite conclusions to the contrary (Dodd et al. 1991) the reintroductions of the Houston toad during the 1980s very likely worked. It is our conclusion from the recently completed genetic work (McHenry & Forstner 2009) that a self-sustaining population of Houston toads resulted from the introductions despite those introductions being made into otherwise unsuitable habitats. In itself this is a noteworthy achievement and worthy of broad attention in the amphibian conservation community:

> Individuals from Colorado County (COLS) do not assign to the same genetic cluster as many from Austin County sites despite those two collections areas being ~13 km apart. Unexpectedly, individuals from COLS were assigned to the same genetic cluster as individuals from Bastrop County. One possible explanation for these results involves the translocation program conducted by the Houston Zoo in the 1980s as part of the Houston Toad Recovery Plan (Quinn 1980; Potter et al. 1984; Quinn et al. 1984; Quinn et al. 1987). *Bufo houstonensis* was collected from Bastrop County, reared at the Houston Zoo, and then translocated to the Attwater Prairie Chicken National Wildlife Refuge (APCNWR, ~30 km SE of the 2007 sample site used in this study) in Colorado County. Over five years, ~400,000 eggs, ~7,000 metamorphs, and 62 adults were released at APCNWR. Measuring success of the program has been difficult because budgetary constraints allowed few return visits to survey APCNWR from 1987 onward (Quinn et al. 1987) but Dodd & Seigel (1991) cite that no new populations had been successfully established as of 1991. Yet, it is known that *B. houstonensis* bred in 1985 (a developing egg string was found) and called in two years (one male in 1984 and seven in 1986) at sites near the San Bernard River which abuts the refuge (Quinn et al. 1984; 1987). The original Bastrop County collection sites for the translocation program are identical to or are <2 km from sites to which the extant samples from Colorado County genetically assign. Since the San Bernard River is close to both APCNWR and the 2007 sample site in Colorado County (~3 km from the river), it is feasible that toads and their descendants traveled along the river northward from APCNWR over the past 20 years and the results presented here characterize that movement. An alternative hypothesis requires the San Bernard River to represent a barrier for the species and that Houston toads have maintained close

genetic continuity with genetic exchange between Bastrop and Colorado counties in recent years, to the exclusion of similar exchanges with Austin County. — McHenry & Forstner 2009

Taken as a whole these recent genetic results appear to confirm the success of the reintroduction efforts. This should be taken as a strong motivation to include population supplementation as part of the recovery efforts for the Houston toad. It should also be a strong cautionary tale. If the Houston toads currently detected in Colorado County are, indeed, the self-sustaining population from the reintroduction efforts, then that success is bittersweet. Houston toads were thought extirpated from the Colorado/Austin County area in 1984 (Potter et al., pg. 6). That assumption was clearly wrong. Worse, those authors acknowledge their assumption was not based on survey data or out of any systematic attempts to locate the Houston toad in that area. Consequently the 1980s reintroduction effort has placed northern sand-band genotypes (Bastrop County) into the southern sand-band remnants (Colorado County) (Table 1; Figure 1). The consequences of this may be minor or substantial but as they have only recently been determined it will take additional research to make an informed assessment.

Recovery Plan Goal 5.0 Enforce all Federal and State laws protecting populations and habitats of the Houston toad.

5.1 Inform agencies.

5.2 Consult with agencies on their proposed projects and their responsibilities under the law.

In the very negative portrayal of the political intrusions impacting stewardship and conservation efforts for the Houston toad, Brown & Mesrobian (2005) highlight the complex and often contradictory efforts that have acted to the detriment of the Houston toad. In our own experience, enforcement has not been the active noun that best represents what we have observed since 1984. In two pertinent examples, it is easy to see that the laws protecting the toad from harm are ignored by viewing the name LUECKE tauntingly left on aerial imagery (see 2.3.2 and Figure 4 below) after habitat destruction in Bastrop County. Second, the authors notified the USFWS to ongoing habitat destruction during chorusing of Houston toads in Lee County without apparent changes to the process. In the latter example, the areas of Lee County where we had detected large choruses (dozens to hundreds of individuals), are now quiet, with no Houston toads detected at that site since 2003. While we acknowledge the difficulties facing law enforcement and we understand their decisions, we would be misrepresenting the issue across the range if we concluded that this goal of the 1984 Recovery Plan had been met.

Recovery Plan Goal 6.0 Produce and disseminate information.

Within a collaborative partnership of agencies (e.g. TPWD) significant information has been made available to the public on the Houston toad. The authors of the Recovery Plan could not have realized how dramatically access to information would be transformed by the 1990s with the presence of web browsers and the internet. We now live in a transformed world, where information is widely available, easily accessible, and increasingly detailed. Ongoing efforts to reach stakeholders remain focused in Bastrop County, with very little effort or realized outreach in any of the other occupied counties.

2.3 Updated Information and Current Species Status

Since 1984 (Potter et al. 1984) significant efforts by a wide range of field and laboratory investigators have allowed us to improve our understanding of amphibian population biology and global declines (Lannoo 2005; Stuart et al. 2008) Often these studies have information that is likely relevant to the Houston toad and its ecology (Shepard & Brown 2005). We seek to update the information since the previous Recovery Plan. We do not seek to provide an exhaustive treatment of the advances in our general understanding of amphibians nor of all the potentially useful data that may be usefully extrapolated to the Houston toad (Stuart et al. 2008). We have preferentially chosen information from closest congeners or studies on the Houston toad or its occupied habitats, to the exclusion of assuming seemingly related work is likely to be comparable for this species.

A significant amount of scientific work useful to Houston toad stewardship has been accomplished during the more than 26 years since completion of the Recovery Plan for this species. For a broad review of Houston toad relevant literature published up through 2000, please see Allison & Wilkins (2001). We did not have access to the reports of other surveys completed by other teams in the years since 2000, making our listing of such survey work almost exclusive to those completed by the coauthors and colleagues. At the same time we did search the literature extensively for Houston toad specific peer reviewed publications since Allison & Wilkins (2001) We will seek to update the literature on the Houston toad since that time, replicating the divisions used in the Allison & Wilkins (2001) in a revised literature summary subsequent to this report.

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history

In the sections below we seek to provide updates to the status of the Houston toad, trends for its subpopulations, and to update what is known of its biology and life history including ecological aspects such as habitat. We have often relied on recently completed work with other bufonids, generally relying on work reported from its close congener, *Bufo americanus*.

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

Introduction—Endangered species can be difficult to assess as a direct consequence of their scarcity (Thompson 2004). The Houston toad is both rare and elusive. The species is rare within remaining habitats, encountered almost exclusively in the breeding season, and breeding choruses are unpredictable to a large degree while limited to less than five nights on average for a given pond in a given spring season (Swannack 2007; Swannack et al. 2009; Forstner et al. unpublished). These factors may well have contributed to the delay in its description until Sanders (1953). Those same factors have complicated and will most likely continue to complicate short-term assessments of population trends for the Houston toad. When sampling such rare species, two related recommendations have emerged which include conducting statistically adequate survey work and determining the detection probabilities for a given species (Thompson 2004). These can assist in clarifying whether a species is simply rare because it is elusive or if both rarity and low detection act to increase the difficulties to making accurate population estimates. For the data that we have, summary population trends are down in all counties, with very similar general themes in each county examined. Field data useful in comparison with both historical and recent population viability analyses reveal that these trends are logically consequent of several known threats but may also be exacerbated by several newly detected biological aspects of the Houston toad itself.

Several recent publications have revealed that the analysis of the demographics of the Houston toad further substantiate serious issues facing the species particularly in the face of continued direct habitat losses, consequent fragmentation, and the results of long term habitat degradation. These include Hatfield et al. (2004) revisions to the 1994 PHVA (Seal 1994) concluding that a minimum of three sustaining subpopulations with connectivity are required. Field data have also provided direct measurements of juvenile survivorship (Greuter 2004), juvenile growth in the wild (Greuter & Forstner 2003), and sex ratio bias with consequences to the effective population size (Swannack et al. 2006). While Seal (1994) concluded the population in Bastrop County to be stable over time, the data do not support that conclusion in the years since then. Bastrop County has long been considered the largest population of Houston toads remaining (Brown 1967; Seal 1994), but the most recent data indicate the declines observed elsewhere are now occurring in Bastrop as well.

Estimates of population size and trends in subpopulations to the present—Authorities have provided a wide range of numerical estimates for the Houston toad's subpopulation sizes, or species census size, published over the years. Importantly, the majority of these speculative extrapolations have been limited to only the population in Bastrop County. However, even for just the single county the disparities among estimates are dramatic. One of the earliest estimates (Brown 1967) put the species at less than 300 individuals. By the 1970s, this was revised to 1,500 individuals (Thomas et al. 1975). A decade later Hillis et al. (1984) and Jacobson (1983) extrapolated 30-1,000 toads per pond. Thereafter estimates of 2,000 toads in Bastrop County were reported (Seal 1994). We have also fallen to making extrapolations with Forstner (2003) estimating 100-200 Houston toads detected across Bastrop County in that year. While all of these authors acknowledge the inadequacy of their data to make statistically relevant estimates, the numbers are repeated without those caveats, particularly in the popular press.

It is possible that the variation in counts reflect detection rather than population trends. Several recent studies have sought to clarify the issues associated with making estimates for this species. Jackson et al. (2006) sought to define the probability of nondetection for the species. The authors conclude that twice the number of survey nights (n=12) than historically applied (n=6) were required to provide a reliable detection of the species at a given pond. The regulatory guidelines for Houston toad detection surveys were adapted from Yantis (1989) by the USFWS. Prior to that time a wide range of survey approaches, number of visits, and criteria were used (Seal 1994). The range-wide detection surveys of Yantis (1989-1993) and his colleagues operated on a landscape scale seeking detection across a county or multiple county area. Those methods were then applied to the evaluation of a given pond or single site as the general requirement for detecting Houston toads. Unfortunately the majority of surveys we have reviewed are typically single properties smaller than 10,000 acres and not suitable for landscape scale survey design methods. The consequences of this are straightforward, surveys that were relied upon to define presence of the Houston toad failed to detect the toad, when it was actually present, 20% of the time. The situation is exacerbated by a regulatory rather than biological evaluation of habitat (see 2.3.1.6 below).

Another issue with abundance estimates for the Houston toad is the inconsistency of field assessments on a local, much less regional, scale (Brown & Mesrobian 2005). Only Bastrop County has seen relatively consistent surveys in a given year (Table 1). Surveys designed to evaluate chorusing on a large scale within the county were conducted in 2002 (Forstner 2002), 2003 (Forstner 2003), and again in 2009 (Forstner 2009). Where chorusing was relatively consistent between 2002 and 2003 with 100-200 Houston toad males detected, by 2009 the total number of Houston toads detected on the county-wide scale did not exceed 28 individuals for a similar survey route. More toads were detected within Bastrop County during 2009 as that value does not include isolated large tracts which are individually surveyed in the county, inclusive of Bastrop State Park. However, the GLR dataset is now a decade in depth and shows a decline in toads detected since 2002-2003 as well.

Elsewhere, the dearth of consistent or coordinated survey efforts outside of Bastrop County has led to several very poor outcomes for this species. First among those is the inadequacy of existing data for any of the occupied counties, except Bastrop County, noted by Seal (1994) but remaining almost as inadequate today. In our recently completed range-wide surveys for the species we conclude that Houston toads are now likely to be extirpated from Lavaca County, but we do not have any idea when that may have first become true (McHenry & Forstner 2009). We do not have trend data for the extirpation event as only the first detection years and three subsequent years of nondetection are available (Table 1). A second issue would be the release of Houston toads into the Attwater Prairie Chicken National Wildlife Refuge, when remnant populations of Houston toads persisted just north of the refuge and could have been detected had they been surveyed. Finally, the documentation of losses for several counties would be more clear had any of those counties (e.g. Burleson, Fort Bend, Harris, Lavaca, and Liberty) been surveyed with any reasonable consistency or effort.

In hindsight a relatively consistent trend appears to be present for the counties in which extirpation appears to be complete. We summarize the data by county in our recent report of the results from three years of range-wide surveys (McHenry & Forstner 2009). What emerges when reviewing the historical survey database (Table 1) is what may be an overall trend for an extirpation event. At least it is the case for two or possibly three instances for which we have at least some level of trend data (Table 1). If we begin with the data from Burleson County, we find that toads are detected there very early (1950s) and continue to be detected in numbers into the 1970s (Table 1). Then, despite this area being designated as Critical Habitat in 1978, the Houston toad was last detected there in 1990 (Table 1). The detections during the 1980s were all of a single or few individuals.

The other two counties have relatively more annual information than most where collapses have been documented. Harris County was the first where Houston toads were considered extirpated (Yantis & Price 1993) and remains so today. In Harris County there were relatively large numbers of toads detected from 1949 to 1952 with a gap of data into the 1950s drought years (Table 1). Thereafter came many years (1958-1965) with one or a few toads detected prior to the last report in 1976. Very often the 1950s drought is credited with the losses, but given the actual reporting, it is simply not a very supportable claim. This is particularly true when we examine the recent events in Lee County. We (MRJF and JRD) detected large choruses in Lee County and extreme northern Bastrop County in 2000 and 2001. Simultaneously we reported ongoing clearing of forested habitat during the breeding season including active chorusing sites (Forstner and Dixon, 2001 letter to USFWS). Importantly, we have continued to survey these sites in the years since that time (Table 1). With continuity across years we were able to document the collapse of chorusing in Lee County between 2000 and 2005 (prior to the onset of the exceptional drought of 2005-2009) (Buzo 2008).

Several things are nearly identical to what was seen in Harris County, large choruses of Houston toads were detected in Lee County in 1997 (Kuhl 1997) and again in 2000-2001, then one or a few toads detected after the onset of the collapse in chorusing. In the case of Lee County there has not been urbanization nor did the drought lead to the collapse in chorusing numbers. One factor was present in all of these cases though, unpermitted habitat losses (Figure 4). In what we find to be the best documented example, between 1999 and 2005, Lee County lost 13% of its canopy cover (Buzo 2008). When canopy habitats on deep sandy soils are taken into account, Lee County lost 16% of its high suitability habitat in that same period (Buzo 2008). This period covers the collapse of chorusing and while correlation is not causation, Forstner and Dixon directly observed the effects within the region of Houston toad chorusing in Lee County from 2000 up to the present (Table 1). After clearing of the Houston toad area to pastures, Houston toads were no longer detected there (McHenry & Forstner 2009). In this same period Bastrop County lost 11% of high suitability habitat (Buzo 2008). It may be that there is a fundamental habitat availability "cliff" beyond which the toad can no longer persist in the face of fragmentation, edge effects, or the direct consequences of habitat loss.

Survivorship estimates and population demographic modeling—One way to approach questions of persistence is to model the species survival using viability analyses. The first Houston toad population viability analysis was completed in 1994 (Seal 1994), the conclusions were straightforward and have not been dramatically contradicted by evidence since then. Foremost the toad exists within a metapopulation dynamic of small occupied habitats that are widely separated from other such fragments. The workshop contributors (Seal 1994) also concluded that one of the most damaging issues was the lack of consistent survey data, particularly survey results from outside Bastrop, and they describe a need to clarify optimal Houston toad habitat. Hatfield et al. (2004) took advantage of both the advances in population modeling and the data from the long term mark recapture study of the Houston toad in Bastrop State Park (Price 2004). The more recent viability analysis corroborated the need for management of the species as a metapopulation, emphasizing the need to maintain several self-sustaining subpopulations in order to reasonably prevent imminent extinction (Hatfield et al. 2004). One piece of the modeling effort that was lacking in 2004 was juvenile survivorship, which is critical to formulate effective estimates. The results published in 2004 used 1-2% juvenile survivorship with 1% or less resulting in a high probability of extinction. This emphasized the need for refined estimates of juvenile survivorship.

Given the difficulties with field research on adult Houston toads, data on juveniles are expectedly less prevalent in the literature. Several publications have described the dispersal of juveniles away from the natal ponds (Hillis et al. 1984; Swannack et al. 2006; Thomas & Allen 1997) alongside growth of this life stage in the wild (Greuter & Forstner 2003). The most recent publications emphasize the critical nature of the immediate edges of the natal ponds. Juveniles tend to emerge, concentrate at the pond edge, and then disperse (Greuter 2004; Taigen & Pough 1981). One consequence of this emergence strategy is that for a period of nearly a week all of the juveniles are crowded into a remarkably narrow zone at the water's edge. This is also the case in *Bufo americanus* and other toad species as an adaptive strategy of metamorphosis to the terrestrial form (Taigen & Pough 1981). At no time are as many Houston toads in one location as this immediate post emergence period, providing a critical point in which very significant losses can occur. Survivorship of the Houston toad is obviously life stage dependent, and truly high concentrations of individuals accessible to predators or other losses are only present during the egg, larval, and then immediate post emergent stages. Even historical breeding choruses (100s of individuals) did not provide such high concentrations of individuals in a small area.

Greuter (2004) calculated juvenile survivorship by direct observation of an eggstrand in a natal pond. She estimated replacement survival (2 individuals from egg to one-year old to be 0.0003. Given that the strand from which those measures were developed was directly counted as 7018 tadpoles hatched, such a survivorship results in ~2 adults or replacement of the breeding pair. In that same strand 1% survivorship would result in 70 returning adults, a seemingly obvious overestimate. As Greuter (2004) is the only field measurement of juvenile survival, but represents only a single strand we can likely assume a value somewhere between her estimate of 0.0003 and 0.01 to define a starting point for juvenile survivorship. Subsequent work by Swannack et al. (2009) refined model estimates and they concluded that a range of 0.0075-0.0105 is likely appropriate. Applying these values within the Hatfield et al. (2004) model would result in outcomes more likely to lead to extinction of this species in near time.

Swannack & Forstner (2007) conducted an analysis of the sex ratio disparity seen in the Houston toad. Amphibians are commonly detected with a male biased sex ratio which is generally assumed to be artificially biased consequent of ease of male detection (chorusing) in comparison with females at a pond. Swannack & Forstner (2007) demonstrated that male biased sex ratios that are not a result of differential detection, but biologically consequent of differential mortality of female Houston toads. The direct consequence of this result is the populations of Houston toads are male biased and the uneven sex ratio results in a lower effective population size (N_e) than the census size. This increases the necessity of conservation measures that influence stability or increased female Houston toad survivorship. Very recently we have directly measured the sex ratio of Houston toads reared to maturity at the Houston zoo and verified that the sex ratio is indeed 1:1 from egg to adult in the absence of predation or differential mortality (Forstner et al. unpublished data).

In a recent publication Gaston et al. (*in press*) examine another potentially exacerbating effect of the strong downward trend in chorus sizes detected across Bastrop County since the 1980s. Houston toads are aggregative breeders, with chorusing acting as the means by which females find males and reproduce. Allee effects are phenomena that act within small populations and are influenced by the population density. From the work of MRJF and colleagues on the Griffith League Ranch in Bastrop County, we have observed that it is inappropriate to view the detection of chorusing as a proxy of reproduction, much less recruitment by the Houston toad. Restated, the Houston toad is routinely found in chorus at ponds that do not have females detected (Chorusing ponds), and eggstrands are found without juvenile emergence (Breeding ponds), but ponds having actual recruitment (Emergence ponds) are rare. It has been an integrated effort to seek an underlying reason for these observed results, presumptively examining habitat. However, the Gaston et al. (*in press*) paper concludes that the relative success of chorusing is tied to chorus magnitude. Larger choruses lead to recruitment significantly more often. Thus, as the subpopulations of the Houston toad have collapsed, the declines have likely been compounded by Allee effects on the species. On a purely pragmatic basis this strongly contradicts the conclusions voiced in Seal (1994) in which an increased number of ponds is considered an enhancement of population size. In fact, with habitat degradation (e.g. fire suppression, edge effects) the decrease in population size is inevitable and more water bodies (>1700 in the Critical Habitat area of Bastrop; Mahato & Forstner unpublished data) could only have exacerbated Allee effects leading to a spiral of lessened recruitment and worsening effects.

Conclusions of the trends of the abundance of the Houston toad—Overall trends for abundance are down across the occupied habitats of the Houston toad. Often the drought of the 1950s is portrayed as the likely cause of extirpation around Houston. Concurrent with that drought were the anthropogenic changes to habitat that may well have been more influential given the correlated results seen for the Houston toad subpopulations in Burleson, Lavaca, and Lee counties in subsequent decades. There is little doubt that the drought has had significant impacts on Houston toads. Recent years have seen a drought that may have exceeded that of the 1950s for sheer intensity in Bastrop County (Nielsen-Gammon & McRoberts 2009). The next few years will allow a more clear examination of the consequences of such a drought in habitats that remain intact, potentially clarifying the impacts of drought in comparison with habitat loss.

Both Potter et al. (1984) and Seal (1994) note only the extirpations of Houston toads as presumed in Fort Bend, Harris, and Liberty counties. We concur that while a detection of the species in those counties might be possible, it is very unlikely. Unknown to those authors, the toad was already gone from Burleson County by 1994. Since then we conducted extensive surveys in Lavaca and have concluded it is either at levels too low for practicable detection or extirpated (McHenry & Forstner 2009). Simply using the county level occupancy as a rough measure, by 1984 of twelve historically occupied counties (Austin, Bastrop, Burleson, Colorado, Fort Bend, Harris, Lavaca, Lee, Leon, Liberty, Milam, and Robertson) Houston toads were extirpated from three by the 1970s, from another by the 1990s, and with both Lavaca and Lee counties now included based on zero or single individuals detected in recent years. This translates to a loss of 25% of the occupied counties by 1984, 33% by 2000, and 50% by 2009. Notably Lee County still has had a single Houston toad detected annually since 2005 and might be recoverable with effort, but if the past is any guide it is not particularly likely. It seems clear that Houston toad extirpation events have continued unabated in the years since it was listed as an endangered species, after the designations of Critical Habitat, and after the Recovery Plan was completed.

Table 1 Number of *Bufo houstonensis* recorded per year by county (McHenry & Forstner 2009).

	Northern sand-band counties						Reference
	Bastrop	Lee	Burleson	Milam	Robertson	Leon	
1949							
1950			2*				Sanders 1953
1951	1*						
1952							
1956							
1958							
1959							
1960							
1963-4	42*						Brown 1971
1965-7	<300*		3				Brown 1971
1968	1*						
1971	3*						
1974-8							
1974	10s		2 (≥1)				Brown 1975; Thomas 1977
1975	50 (≥1)		10-20 (≥1)		2*		Thomas 1977
1976	100s (≥1)		<20 (≥1)				Thomas 1977; Potter et al. 1984
1977	>1 (≥1)	0 (≥1)	>1 (≥1)				Thomas 1977
1978	83*		0 (1)				Dixon 1983
1979	81*		0 (1)				Dixon 1983
1980	52*		0 (1)				Dixon 1983
1981	>1500*		0 (1)				Dixon 1983; Hillis et al. 1984
1982	≥215*		0 (≥1)				Dixon 1983; Jacobson 1989
1983	25*		4 (≥38)				Dixon 1983
1987	1*			1*			
1988	24*						
1989	8* (4)[a]		5* (20)	1 (≥4)	1* (≥4)	43* (≥3)	Yantis 1989
1990[b]	>300*		1 (90)	0 (30)		≥40* (35)	Price 1990b; Yantis 1990; Price 2003

Table 1 continued

	Northern sand-band counties						Reference
	Bastrop	Lee	Burleson	Milam	Robertson	Leon	
1991	>400*		0 (≥1)			≥11*	Yantis 1991; Price 2003
1992	292*		0 (≥1)		>in 1991 (≥1)	>11 (≥1)	Yantis 1992; Yantis & Price 1993; Price 2003
1993	>250*						Thomas & Allen 1997; Price 2003
1994	>200						Price 2003
1995	>400						Price 2003
1996	>150	>5					Kuhl 1997; Price 2003
1997	>175	>30					Kuhl 1997; Price 2003
1998	>100						Price 2003
1999	>175						Price 2003
2000	>50 (22)	>100 (25)			1*		Forstner & Dixon 2000; Price 2003
2001	>100 (20)	>100* (>100)					Forstner & Dixon 2001; Price 2003
2002	>100 (92)	<15 (>100)					Forstner 2002; Price 2003
2003	≥200* (92)	0 (2)					Forstner 2003
2004	>45 (24)	1 (5)					Forstner & Swannack 2004
2005	127* (24)	1 (4)				0 (6)	Forstner 2006
2006	55 (39)	0 (18)				1 (5)	Forstner 2006
2007	118 (39)	1 (26)	0 (9)	>30(22)	0 (12)	1 (9)	Forstner et al. 2007
2008	94 (38)	0 (19)	0 (3)	2 (21)	0 (2)	>10(9)	Forstner et al. 2008

Values resulting from surveys are followed by number of sites surveyed in parentheses. * indicates vouchers exist.
[a] Only south of Colorado River was surveyed this year in Bastrop County
[b] Number of sites surveyed is number of listening stops

Table 1 continued

	Southern sand-band counties						Reference
	Lavaca	Colorado	Austin	Fort Bend	Harris	Liberty	
1949					66		Potter et al. 1984
1950					3*		Sanders 1953
1951					2*		
1952		9*	9*		≥40*	1	Sanders 1953
1956		1					Blair 1956
1958					5*		
1959					8*		Bragg 1960
1960					2		Kennedy 1962
1963-4					3		Sanders & Cross 1964
1965-7		0		1	3		Brown 1971
1968							
1971							
1974-8					2		Pottter et al. 1984
1974							
1975							
1976					1 (≥2)		Thomas 1977; Potter et al. 1984
1977							
1978							
1979							
1980							
1981							
1982		1*					
1983							
1987							
1988							
1989		0 (9)	0 (3)		0 (3)	0 (10)	Yantis 1989
1990[b]		≥2* (468)	7* (41)	0 (415)	0 (15)		Yantis 1990
1991	7* (≥1)						Yantis 1991
1992	0 (≥1)				0 (≥1)		Yantis 1992; Yantis & Price 1993
1993							
1994							
1995							
1996							
1997							
1998							
1999							
2000							

Table 1 continued

	Southern sand-band counties						Reference
	Lavaca	Colorado	Austin	Fort Bend	Harris	Liberty	
2001							
2002							
2003							
2004							
2005							
2006							
2007	0 (19)	5 (11)	0 (17)	0 (5)	0 (3)	0 (11)	Forstner et al. 2007
2008	0 (37)	0 (19)	5 (19)				Forstner et al. 2008

Values resulting from surveys are followed by number of sites surveyed in parentheses. * indicates vouchers exist.
[a] Only south of Colorado River was surveyed this year in Bastrop County
[b] Number of sites surveyed is number of listening stops

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

The Houston toad has had surprisingly few genetic evaluations completed although recent work is very comprehensive for Bastrop County. It may be that its inherent rarity alongside unpredictable chorusing acted as an obstacle to more generalized nonconsumptive collecting. In our recent range-wide sampling effort only one or a few samples were available from counties other than Bastrop, even after extensive sampling efforts. This is not a necessarily recent trend however, as it is apparent that relatively few wild collected samples have been placed as vouchers into museum collections. Fewer still of those vouchers were collected recently enough for genetic materials to have been part of that effort. To the best of our knowledge viable materials suitable for genetic investigations are currently held at the Texas Natural History Collection (University of Texas) and the Forstner Tissue Collection (currently held at Texas State University). The genetic materials from Sanders (i.e. Sanders & Cross 1964) do not appear to have been retained.

As noted below (2.3.1.4) Sanders & Cross (1964) utilized karyotype analyses in an effort to discern the relationships of several toads including *Bufo houstonensis*. Kennedy (1962) and others (Brown 1971; Hillis et al. 1984) have reported on hybridization between Houston toads and congeners. Only one of those studies (Hillis et al. 1984) directly examined wild hybrids validated by genetic data. The Hillis lab also recently completed a phylogenetic investigation of toads including *Bufo houstonensis* (Pauly et al. 2004). McHenry & Forstner (2009) report the results of a large scale population genetics investigation of the species, and McHenry (2010) has also completed an evaluation of hybridization from an expansion of that same dataset to include congeners in sympatry. Recent evaluations of hybridization in bufonids indicate that rare forms may be negatively impacted by hybridization with more common forms (Vogel & Johnson 2008). This in contradiction to the strong opinion of Brown with regard to hybridization in the Houston toad (Seal 1994). It is also different from the conclusions of an examination of thirty years of hybridization between *Bufo americanus* and *Bufo woodhousei fowleri* (Jones 1973). Hybridization has long been considered a nonissue for the Houston toad. This likely requires careful reevaluation in the light of the much more modern context of both analyses and data available.

In keeping with his long held position, Blair summarizes the position of *Bufo houstonensis* as a Pleistocene isolate from the southern populations of *Bufo americanus* (Blair 1972b). McHenry & Forstner (2009) utilize a fairly conservative molecular clock for the control region of the mitochondrial DNA (i.e. D-loop) and place the divergence of these two species at more than 300,000 years ago, minimally. Those authors accept and agree with the contested nature of molecular clocks, but retain the conclusion that Houston toads diverged from American toads long before the last glacial maximum.

McHenry & Forstner (2009) echo the findings of Pauly et al. (2004) in discerning large genetic differences within American toads, with samples from the northeastern USA diverging significantly from those collected in Oklahoma. The situation is much more complicated than this as reproductive isolation among toad species is not consistent and species tend to maintain discrete evolutionary continuity in light of hybridization (Malone & Fontenot 2008). Evidence of a much earlier divergence for the species (McHenry & Forstner 2009) has other implications including its persistence through megadrought periods (2.3.1.7) and the dramatic climatic shift of the last 30,000 years (Bryant & Holloway 1985).

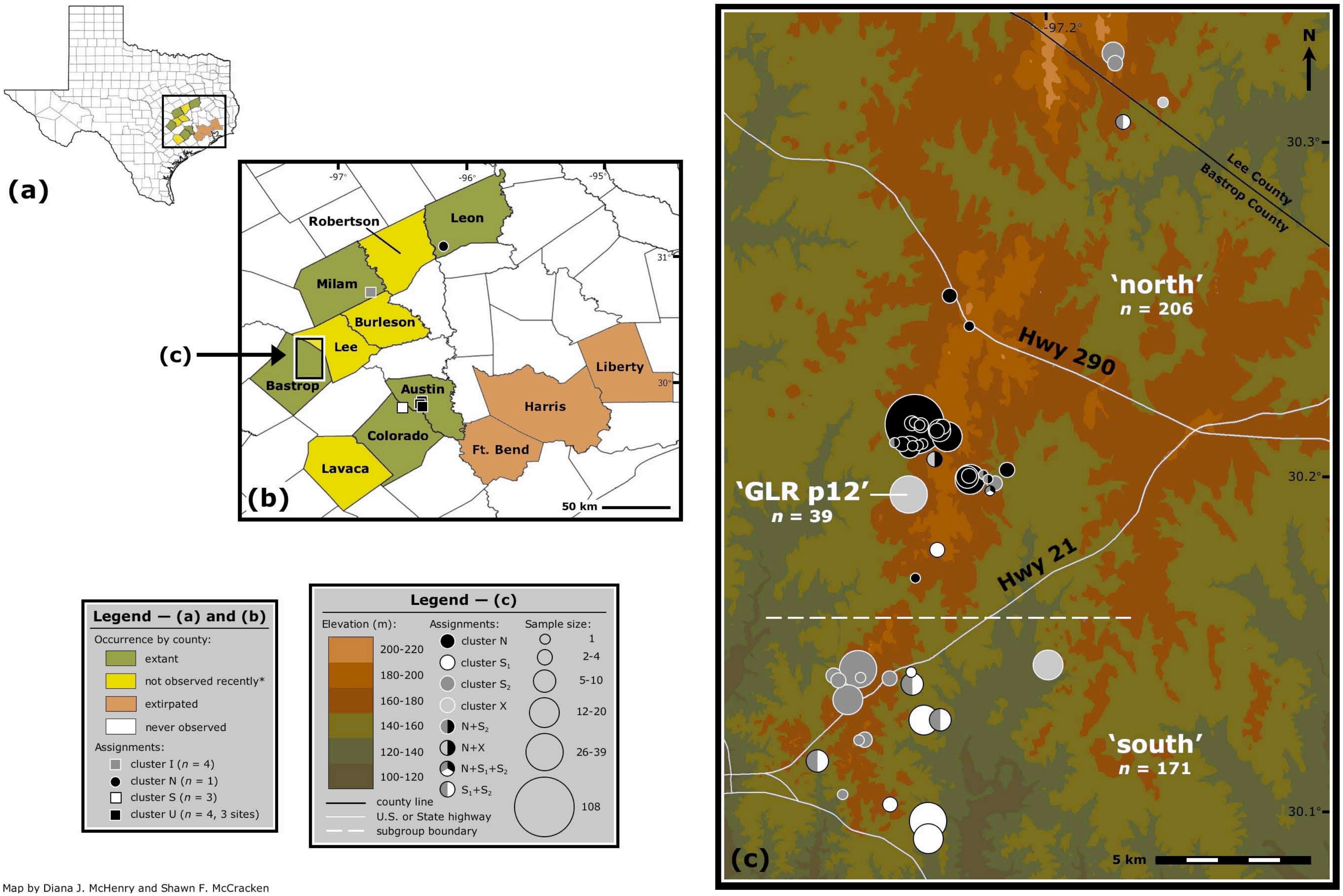
The recent population genetic analysis results also reveal that mtDNA evidence shows strong relatively recent connectivity among populations (McHenry & Forstner 2009), with microsatellite data providing evidence of subdivisions even within Bastrop County (Figure 1). A key finding is that significant genetic variation remains in the Bastrop area, but without additional sampling the detailed genetics of the other subpopulations remain generally unknown. As an example of how sampling changes conclusions, our genetic data indicate that the Houston toads sampled in Colorado County are genetically identical to those from Bastrop County. Prior to our finding, sampling, and analyzing samples from Austin County in 2008, our conclusions from this result would have been very different. Just across the San Bernard River in Austin County, the toads have some mtDNA haplotype differences and strong nuDNA microsatellite differences. The addition of the Houston toad samples from Austin County were critical to this determination as no genetic samples are available from any other historical southern sand-band county. We conclude that the specimens we sampled in Colorado County are the descendants of the headstarting efforts at Attwater Prairie Chicken National Wildlife Refuge and the Austin County samples from just a few kilometers away are remnants of the "natural" subpopulation in the region. Unfortunately this hypothesis is difficult to unambiguously defend as no other genetic samples from the original headstarting efforts exist, and not a single Houston toad genetic sample for the southern sand-band tier of counties exists from prior to the headstart releases (Table 1). It is more likely, particularly given the density of sampling in Bastrop County over much larger distances, that the explanation above is correct, than to assume that a small drainage (San Bernard River) would act as a strong isolating barrier over significant time.

The population genetic results offer good and bad news. The good news is that significant genetic variation remains and that success with ongoing management efforts can be directed to retain that variation. The bad news may be that the Houston toad did not adapt over evolutionary time as small, isolated subpopulations. The mtDNA data would support a large, generally well connected population of Houston toads spanning Bastrop to Milam counties and onward northwest toward Leon County. Assuming that the Colorado County specimens are introduced success stories, then the southern tier of counties would have been less connected or unconnected to those in the northern tier.

Today the remaining populations are all widely scattered, small, and disconnected. Similarly, the southern tier of counties had survivors, with Austin County representing a distinct subpopulation which is assumed to represent the group once widespread from Lavaca to Liberty counties (McHenry & Forstner 2009). This is good news and indicates persistence through the losses of the 1950-1990s, but also bad news as now northern tier (i.e. Bastrop County was the source of the headstarting efforts) Houston toads are established in the southern tier of counties (i.e. Colorado County). We can defend the success of the headstarting efforts, but also wish it had either different original parental stock or had happened elsewhere (e.g. Burleson County).

Migration among distinguishable units within Bastrop County appears to be among definable forested habitat patches in the county (Figure 1). There may be evidence of connectivity along drainage systems, and current habitat restoration efforts (Wolfe et al. 2009 NRCS funding) seek to restore habitat along the drainages of the greater Alum Creek watershed. What is less unambiguous is whether the current genetic similarities found among all northern tier counties from current mtDNA analyses are simply an artifact of very low sample size from counties other than Bastrop or if the overall habitat connectivity was historically that extensive. The genetic evaluations for the Houston toad have not yet included a comprehensive evaluation inclusive of the complicated hybrid swarm of bufonids in Texas (Fontenot 2009; Vogel & Johnson 2008). These hybrid dynamics will complicate large scale evaluations if samples are eventually available. We note that in Leon County, recently collected samples are rare (n=3), but include hybrids with mismatched (non Houston toad) mtDNA from audibly and morphologically consistent Houston toad phenotype individuals (n=2) (McHenry 2010). We speculate that as Houston toad abundance decreases in an area or breeding pond, the impacts of hybridization exacerbate the declines. We also note that while earlier studies often emphasized hybridization issues with *Bufo woodhousei*, in the past ten years of surveys for Bastrop County we have encountered a total of less than 20 *Bufo woodhousei*. This may differ from historical abundance and could be relevant to the situation in the Houston toad as well. Given that, among all samples from ten years of sampling, hybridization in the Houston toad occurs at a genetically detectable rate of approximately 10% (McHenry 2010), this is not an issue that can be easily solved without significant attention to the underlying forces driving it and an consequent assessment of the impacts to the Houston toad populations in the future.

NEXT PAGE — **Figure 1. (a)** Occurrence of Houston toads in the state of Texas by county. Inset is Fig. 1(b). **(b)** Sites sampled outside of Bastrop and Lee counties; symbols show population assignments from GENELAND analysis of all individuals. Inset is Fig. 1(c). **(c)** Sites sampled in Bastrop and Lee counties; symbols show population assignments from GENELAND analysis of only Bastrop and Lee counties and sample sizes. The three geographic subgroups within Bastrop County (north, south, and GLR p12; white dashed line is the approximate boundary between subgroups north and south) and their sample sizes are also indicated. From McHenry & Forstner (2009).



Map by Diana J. McHenry and Shawn F. McCracken

2.3.1.4 Taxonomic classification or changes in nomenclature:

The Houston toad (*Bufo houstonensis*) was relatively recently described (Sanders 1953). Both before and since that time, considerable debate has been evident with regard to what toads have historically been recognized from the Houston, Texas area and the appropriate taxonomic status for the Houston toad. Obviously the existence of toads representing what we now recognize as the Houston toad were likely known prior to that official species description. Similarly, since that designation there have been differing opinions or taxonomic treatments of the species, culminating in broad changes at the genus level during recent years. We provide an overview of that history and our conclusion regarding currently proposed changes to the genus.

Several early publications provide information on the toads of Texas (Cope 1880; Strecker 1915; Wright & Wright 1949). However, as a theme, those early authorities do not recognize or describe toads in the areas we now know to represent Houston toad habitat in a form that would provide evidence of the Houston toad within those early accounts. As an example, Wright & Wright (1949) provide range maps depicting only *Bufo woodhousii*, *B*. *w*. *fowleri*, and *B*. *valliceps* in the areas known to historically include the Houston toad. Those authors also do not depict *B*. *americanus* occurring within Texas, terminating north of the border with Oklahoma. In contradiction, Strecker (1915) does include *Bufo americanus* in Texas but relates it as inclusive of a much wider range than we consider to have been likely today (e.g. reported from the cities of Austin, Burnet, and San Antonio, pg. 53). Cope (1880) refers to *B. americanus* in Dallas, but also as occurring in New Orleans, LA. Harwood (1933) is often erroneously cited as reporting on the Houston toad from Harris County. Previous authors have attributed Harwood (1933) to having referred to what would become Houston toads as *Bufo terrestris.* This makes some sense as Wright & Wright (1949) depict that species as occurring into far eastern Louisiana. Yet in our examination of both his doctoral thesis (Harwood 1931) and the often incorrectly cited subsequent publication (Harwood 1933) he provides no clear descriptions of these animals nor their origin, locality, or collection date.

The taxonomic situation does not become immediately clear even after description by Sanders (1953). Sanders (1953) makes a strenuous morphological argument for the unique structural aspects distinguishing his new Houston toad from other toad species. Interestingly, we can read into his conclusions that he felt the closest relative was likely to have been the Southern toad (*Bufo terrestris*), potentially linking subsequent references to Harwood (1933) into the literature for these species. What is remarkable is how little attention has been paid to a subsequent paper (Sanders & Cross 1964) in which he again presents a very forceful argument against any close relationship with *Bufo americanus* based on whole genome karyotype comparisons. In that paper (Sanders & Cross 1964) the authors place Houston toads in a group distinct from both *B. terrestris* and *B. americanus* based on karyotype differences. Indeed those authors conclude “The concept of subspecific relationship between *Bufo houstonensis* and *Bufo americanus* or between *Bufo w. velatus* and *Bufo fowleri* is not acceptable.” Thus, Sanders, who worked directly with Wottring and described the species, clearly disagreed with the conclusions of earlier authors placing Houston toads as a subspecies of *B. americanus* (Blair et al. 1957). Obviously, based on the comments of Sanders & Cross (1964) they also did not agree with the subsequent conclusions of Blair's (1963) characterization of *B. houstonensis* as a Pleistocene relict of the American toad. Notably, Kennedy (1962) incorrectly attributes Sanders (1953) as naming an "*americanus*-like" or "*terrestris*-like" toad, which Sanders clearly did not conclude in his diagnosis. Kennedy (1962) then reiterates Blair's established position on the relationship of the Houston toad to other species.

Little additional taxonomic commentary was made in the years leading up to the species' Recovery Plan, beyond reiteration of the above conclusions in one form or another (Potter et al. 1984). In recent years, the species status has become widely accepted (Dixon 2000) with the USFWS listing the taxonomic clarification specifically requested in the 1984 Recovery Plan as completed prior to 1995 (USFWS Recovery Plan Implementation Status, accessed online June 19, 2009). Interestingly we are not aware of when, or from which publication(s) that determination was originally concluded or by whom, even if it seems appropriate today. However, this does not mean that changes beyond the specific status have not occurred. Without making any taxonomic changes relevant to the Houston toad, Pauly et al. (2004) completed the most extensive DNA phylogeny for the North American *Bufo*. Interestingly, they recovered a relationship placing Houston toads as part of a group of taxa including the southernmost American toad (*Bufo americanus charlesmithi*) and East Texas toad (*Bufo velatus*), specifically to the exclusion of more northern *Bufo americanus*. This result supports the conclusions of Sanders & Cross (1964) that while close in similarity to *B. velatus*, Houston toads differed strongly from *B. americanus*. Sanders & Cross (1964) made their comparison between Houston toads and an American toad from Massachusetts.

The situation becomes complicated from 2008 onward, not because of interspecific or even intraspecific taxonomic evaluations, but consequent of higher systematic changes. In an attempt seeking to clarify common names, a list of accepted reptile and amphibian names was originally compiled by a group of prominent authorities (Conant et al. 1956). This was expanded in an attempt to include scientific names (Collins et al. 1978). In recent years the revisions to this list of names and the application of those names as standards, have become increasingly controversial (Pauly et al. 2009). For the Houston toad, the most relevant changes stem from a single, if large, publication (Frost et al. 2006). With that publication have come a series of taxonomic changes to the genus *Bufo*, wherein Frost et al. (2006) elevate historical subgeneric names to full generic status. Thus, under that proposed taxonomy, *Bufo houstonensis* would most likely become *Anaxyrus houstonensis*. Pauly et al. (2009) have very efficiently and effectively portrayed our own position on this matter and it is our conclusion that pending significant additional data, analyses, and interpretation, the appropriate nomenclatural combination for this species remains *Bufo houstonensis*. Obviously the systematic arguments remain unresolved (Frost et al. 2009) and we conclude these serve to reinforce the necessity of taking a conservative, stable approach to the taxonomy in general use, pending authoritative and durable conclusions from the systematists.

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

The origin of the Houston toad provides some key information on overall trends in spatial data for this species and its historical range. Holman (2003) concludes that no fossil evidence for *Bufo americanus* currently exists from periods prior to the Pleistocene. The early authorities (Blair 1963; Sanders 1953) disagreed on the relationship of the Houston toad to the American toad. It appears clear that Blair (1963) considered the species as a merely southern isolate of the American toad (*Bufo americanus*). Conversely, it is particularly clear in Sanders & Cross (1964) that the authors dismiss any potential subspecific relationship of the Houston toad with the American toad. Recent phylogenetic work (McHenry & Forstner 2009; Pauly et al. 2004) reveal that the American toad likely comprises at least two genetically distinct populations, one in the southern plains distinct from that in the northeastern USA. The Houston toad is related to both, but much closer to American toads from Oklahoma and the central plains than further north or east. This reveals part of the issue, as previous authors comparing calls, genetics, or other intrinsic features do not typically distinguish among localities for the American toad. Many conclusions or inferences made about the Houston toad may have been different had the genetic evidence supporting a much deeper separation with the American toad (McHenry & Forstner 2009) been available. Many conceptual extrapolations may well have been tied to the accepted tradition of the species as a peripheral, recent, southern isolate of the American toad.

In line with decades of authorities more often following the conclusions of Blair (1963) the species is depicted as a coastal prairie entity (Kennedy 1962). Only after the efforts of Yantis and colleagues (Yantis 1989; 1990; 1991; 1992; Yantis & Price 1993) does the broader range for the species emerge. Since 1993 only one new area has been documented, with Lee County reported (Kuhl 1997) and subsequently vouchered (Gaston et al. 2001). The list of counties from which Houston toads have been reported by authorities includes Austin, Bastrop, Burleson, Colorado, Fort Bend, Harris, Lavaca, Lee, Leon, Liberty, Milam, and Robertson (Table 1). The last Houston toads reported from Liberty County were in the 1950s, Fort Bend in the 1960s, Harris in the mid 1970s, Burleson in 1990, and Lavaca in 1991. Range-wide surveys have just been repeated (McHenry & Forstner 2009) with Houston toads not detected in Lavaca or Liberty counties. The efforts in Lavaca County were extensive, less so in Liberty County, and only very limited (~ several nights in 2007) efforts were expended in Fort Bend and Harris counties in our recent efforts. Historical localities were examined in Burleson County but the efforts were not extensive, being coupled to surveys in Milam and Leon counties during the period, without detecting any Houston toads. Importantly, the recent range-wide efforts "rediscovered" Houston toads in both Austin and Colorado counties after a hiatus of nearly 20 years (Table 1) providing several important genetic results (see 2.3.1.3 above). Our efforts were guided by the results of

Buzo (2008) and it appears the Houston toad is likely now extirpated from Lavaca County in addition to Fort Bend, Harris, and Liberty counties. We consider Houston toads to be extirpated in Burleson based on the trend seen for the species during the surveys leading up to the 1990s (Table 1) and we expect that Lee County will soon follow these counties given the trends observed there (see below). After careful review, it is our conclusion that the single, juvenile toad collected at roadside in daylight from Freestone County (Yantis 1990) cannot be concluded to be a Houston toad at this time. Thus, we consider the often cited Freestone subpopulation as unsubstantiated at this time, although suitable habitat fragments do exist there today (Buzo 2008). We have been unable to locate that specimen nor others collected by Yantis during his surveys which were believed to have been transferred to the University of Texas in Austin. In a similar situation we surveyed Limestone County sites with suitable habitat several times during 2006-2008 without detecting Houston toads, but our efforts should not be considered conclusive. Further we consider Robertson County to be data deficient to make a determination at the end of 2009, but no chorusing has been detected there during our intermittent survey efforts of the last decade. Milam County has now been surveyed across several recent years with multiple chorusing areas detected in 2007-08 and toads found at roadside for sampling in 2007.

The Houston toad subpopulation in Leon County was also detected in 2007-08 but the results from toads sampled for DNA are not good for the Hilltop Lakes site. Hilltop Lakes is a historic locality and one from which dozens of males were commonly found in chorus in the 1990s. This is one of the few locations outside of Bastrop County from which relatively large choruses were frequently detected (Table 1). One individual was heard in chorus in 2006 at Hilltop Lakes, it was recaptured again in 2007 at the same location. A single additional male was found in 2007 at the site, and both toads had blood drawn for DNA analyses. Both of these sampled toads were morphological and audibly Houston toads (MRJF and T Swannack collectors). Both of these toads show a background of genetic admixture (= part of a toad's genome is from a species other than *Bufo houstonensis*, i.e. a descendant of a hybridization event) with other sympatric toads species (see 2.3.1.3 above). In 2008 near this locality, Houston toad chorusing was detected at two locations. A chorus of two males and then a second chorus of 10 or more Houston toads were at sites adjacent to Hilltop Lakes.

Finally Lee County provides what may represent the closest thing we have to a real time dataset for Houston toad extirpation events. In 2000-2001 MRJF and JRD conducted extensive surveys of the county. Chorusing was common across the area depicted by Kuhl (1997), which, had we known then had been mapped, would have been very useful to our efforts. However we were able to independently arrive at the same general conclusions for distribution of the species in Lee County (Forstner & Dixon 2001). MRJF has continued to survey Lee County each year at a less intense scale but on nights during which Houston toad chorusing activity is high for sites in Bastrop County. The results are straightforward: Houston toads have dropped from hundreds of individuals detected during 2001 to one male detected every other year on average since 2005. In her habitat suitability analysis, Buzo (2008) utilized aerial imagery to calculate the change in canopy for Lee County from 1999 to 2005 as having lost 13% of its canopy cover (Figure 2).

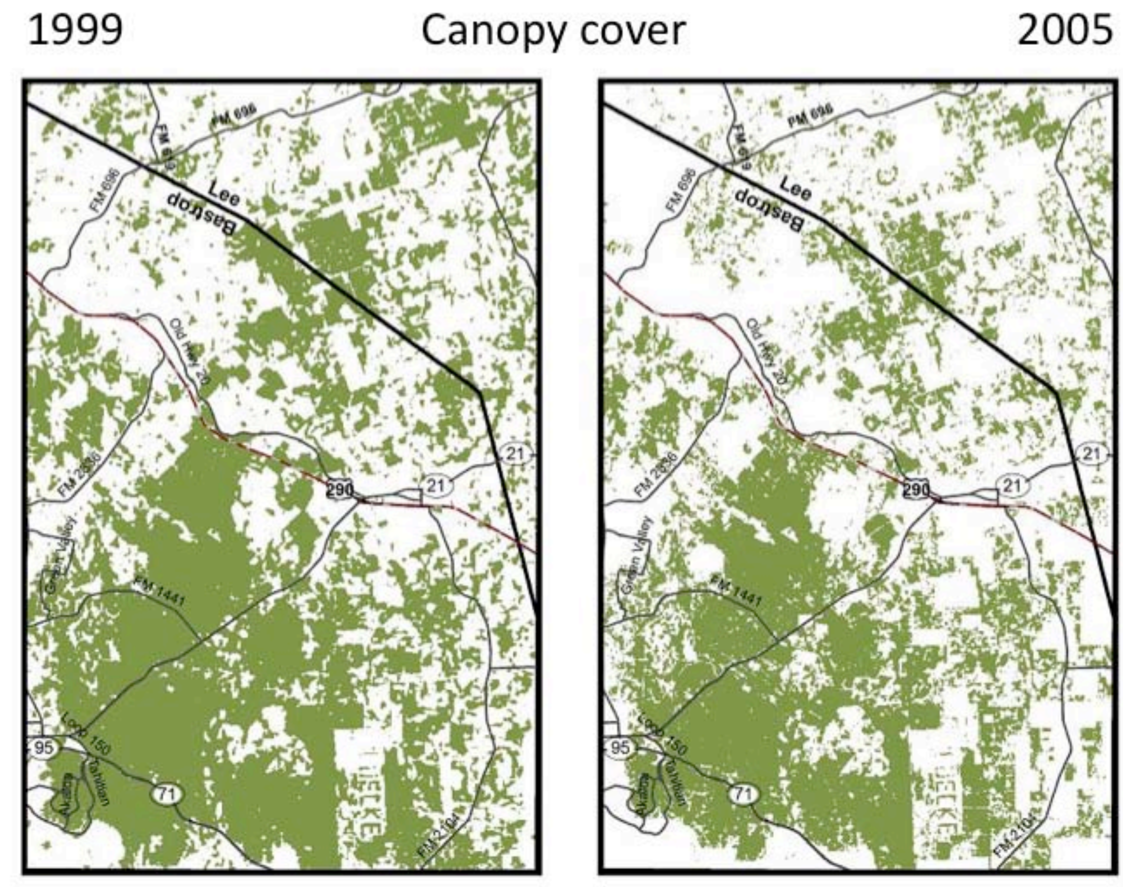


Figure 2. Changes to canopy cover for an area (as depicted in Figure 1c) of Bastrop and Lee counties, Texas (after Buzo 2008). A decrease in canopy of 13% occurred for the region in Lee County and Bastrop County experienced a decrease of 9% for the period between 1999 and 2005.

When canopy habitats on deep sandy soils are taken into account, Lee County lost 16% of its high suitability Houston toad habitat in that same period (Buzo 2008). This period covers the collapse of chorusing and while correlation is not causation, we (MRJF and JRD) directly observed the effects within the region of Houston toad chorusing in Lee County. After clearing of the Houston toad area to pastures, Houston toads were no longer detected there (McHenry & Forstner 2009). In this same period Bastrop County lost 11% of these high suitability habitats (Buzo 2008). It may be that there is a fundamental habitat “cliff” beyond which the toad can no longer persist in the face of fragmentation, edge effects, or the more direct consequences of habitat loss. On a broader scale the loss of forests and woodlands to agriculture or housing development is a common theme across the historic range of the species. During the 2008 oil price boom, MRJF noted the increased oil and gas exploration in Bastrop, Leon, and Robertson counties resulting in direct take of otherwise suitable habitat. This included not only direct habitat take during the breeding season, but also dramatic increases in heavy vehicle traffic on otherwise seldom used rural roadways all day and night. This appears to have diminished with oil prices, but we would safely predict that it will return with rising prices.

In the Houston toad's highly fragmented landscapes, key to preventing extinction of the Houston toad will be the intrinsic properties affecting the occupancy of the habitat patches. Those primary factors influencing persistence within habitat patches are likely a function of patch size and quality, and then their context to other such patches. That context defines the dispersal or migration factors interconnecting occupied patches. Buzo (2008) did not calculate losses of overstory or canopy habitats on deep sandy soils across the range of the species, but it seems prudent to conservatively assume losses similar to that seen in Lee and Bastrop counties for the recent decade across the range. Since the 1984 Recovery Plan, as others have noted (Brown & Mesrobian 2005), even the most prominent occupied and studied Houston toad locality (Bastrop State Park) has lost and degraded Houston toad habitat for a golf course expansion. While this was contentious at the time, and questionable in hindsight, it was nevertheless completed. This is the trend today, has been the trend since 1950 in Texas, and will probably be the trend in the future. Simply stated, the Houston toad cannot persist in the face of unplanned developments in the absence of useful compensatory mitigation. The Houston toad occurs only in Texas and within a triangle bounded by the largest cities in the state. Despite this, it has zero acres of primary conservation land reserved for its stewardship. In 2002, the ~450 acre Welsh Tract was purchased as part of a mitigation funded land acquisition grant for the species. This is the only tract whose primary agenda is Houston toad stewardship. All other tracts stewarding the species have other agendas that probably will always take precedence over recovery or enhancement efforts for this species.

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

One of the issues (1.2 above) that has been seemingly intractable over the years is an accurate, consistent characterization of Houston toad habitat. In hindsight the core of the conflict is a simple consequence of the early reports putting the Houston toad into coastal prairies, while all subsequent reports have found them on deep sandy soils with a tree overstory of variable densities. While Sanders (1953) himself makes no statements as to habitat(s) associated with the species, subsequent authors effectively summarized the species as historically associated with coastal prairies (Potter et al. 1984), but they also predicate this on a likely wide habitat range like that of the American toad. By 1994, that general belief had been modified, emphasizing deep sandy soils, but retaining continuity with historical associations with grasslands (Seal 1994). It is our interpretation that the workshop participants in 1994 (Seal 1994) recognized the general preeminence of deep sandy soils, but also began to include woodlands or savannah associations as defining the habitat (pgs. 32-33). That change was likely a direct consequence of the newly completed range-wide surveys of Yantis and colleagues (Yantis 1989; 1990; 1991; 1992; Yantis

& Price 1993). We began reviewing the issue of Houston toad habitat among historical sites in 2000, concluding that it is at least likely that the original sites in Harris County were either not typical of occupied habitats, or were modified from wooded sites recently enough that toads moved to and persisted at ponds in open sandy exposures described by Kennedy (1962).

We began by examining early accounts describing the general areas representing Houston toad occupied habitats. For Harris County the descriptions of the Houston area from the 1930s was one of "splendid forest… opposite Buffalo Bayou" (Raines 2007 (1900)). An earlier account also describes pine forests bordering the bayou and drainages of the San Jacinto River (Moore 1965 (1840)), which is corroborated by reports from Roemer in the 1840s, describing Houston as an area where sandy areas were overgrown with pine trees (Roemer 1995 (1935)). Roemer also traveled into the Bastrop area and into Burleson County near Caldwell, Texas relating pine forests covering sandy hills (Roemer 1995 (1935)). However, we also have a remarkable biologic history from the pollen records of several Central Texas bogs. In the landscape of central Texas during the last 16,000 years the habitat of the Houston toad (Bryant 1977; Bousman 1998) modified from the almost unimaginable spruce forests of the full glacial period to increasingly less mesic conditions to the present. One additional point from the ancient pollen data is that the Lost Pines of Bastrop did not simply expand into the less sandy areas of the Post Oak Savannah to the north during the late Quaternary (Bryant 1977). This changes the underlying premise that today's Lost Pines ecoregion is a remnant of a once vast pine forest coincidently supporting Houston toads. Given that all authors concur that one of the diagnostics for the Houston toad is deep sandy soils, deducing the vegetation on those sandy outcrops is a key component in defining its habitat.

Taking advantage of improved digital soil layer information, high quality aerial imagery, and modern software analyses, Buzo (2008) utilized GIS in a cautious approach (Roloff et al. 2009) to using the existing Houston toad occurrence database toward a view of Houston toad habitat (Figure 3). The model was subsequently validated by surveys designed to test the validity of the model predictions (Buzo et al. unpublished data). It is apparent from the effort that most, but not all, Houston toad locations are in, or very near, forested patches of habitat. Those locations not in this relationship are historical and likely were within woodland or forest at the time of record. It may well be that the species is adaptable to a wide range of overstory vegetation, since it is clearly not restricted to pine forests. The percent canopy cover is a larger question as we have observed the species in areas with relatively low overstory, grading from an open woodland with considerable herbaceous plant growth (i.e. forbs) into closed canopy gallery forests. The modern state of the majority of these habitats is as unnatural as were the changes to the Houston area from 1840 to the 1950s were. Fire suppression, pasture conversion, and artificial impoundments, have all contributed to a very different ecosystem and landscape than was present a century ago.

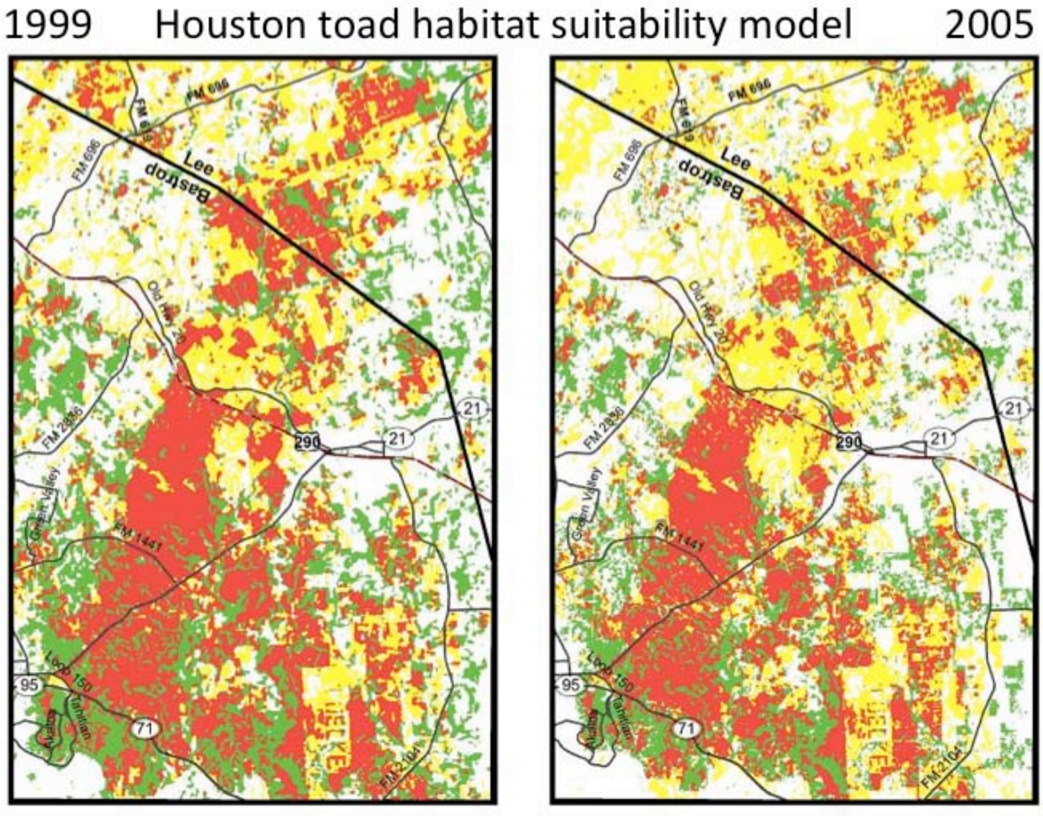


Figure 3. Houston toad (*Bufo houstonensis*) habitat suitability models for an area (as depicted in Figure 1c) of Bastrop and Lee counties, Texas (after Buzo 2008). Red areas are highest suitability decreasing to yellow and finally green, low suitability areas. White areas are considered to be very low suitability for the Houston toad. A decrease in high suitability habitat of 13% occurred for the region with Lee County decreasing by 16%, correspondent to a loss of Houston toad chorusing in the County. In the same period Bastrop County had a loss of 11% of high suitability habitat for this area, which contains all of the designated Critical Habitat for the species.

Thematically, the majority of data for this species centers on its Bastrop County subpopulation. In Bastrop County, the Griffith League Ranch is a large tract of land (5,000 acres) owned and managed by the Capitol Area Council, Boy Scouts of America. The site has been the primary field site for Houston toad research by MRJF and colleagues from February 2000 to the present. One of the projects was a very large scale drift fence trapping effort that sought to test habitat use by Houston toads (Forstner & Swannack & 2004). The results were very clear: with more linear feet of drift fence present in mixed pastures (i.e. mixed nonnative grasses and native forbs), no Houston toad was ever trapped further than 50 m from the forested edge. Effectively all movement detected by trapping, nocturnal surveys, and telemetry was characterized as within overstory or forests. Notably, telemetry revealed that Houston toads would move along drainages within pastures, provided some overstory was present along the drainages. It is unclear if these restrictions are simply a consequence of the pastures inhibiting movement. Out of an array of studies, Forstner & Swannack (2004) report on extensions to previously reported pond characteristics (Forstner & Ahlbrandt 2003) and note that no juvenile Houston toad was detected to have successfully crossed a five meter mixed pasture corridor surrounding the artificial pond arrays.

Other authors have clarified the necessity to address multiple life stages in seeking to steward amphibian populations (Cushman 2006; Semlitsch 2000; Semlitsch & Bodie 2003). For the Houston toad several aspects have been discerned recently that are useful in considering these aspects. Buzo (2008) revealed areas of occupied habitat mosaics east of Highway 21 in Bastrop County, comprised of mixed overstory with and without deep sandy soils and deep sandy soils with and without overstory. In subsequent surveys of these areas (Forstner 2009) it becomes apparent that either Houston toads persist in tiny habitat fragments (<100 acres) over untenably long periods (decades or longer) or they meet the criteria outlined by others for metapopulation dynamics (Seal 1994). The consequences of the persistence of Houston toads in isolated forested or woodland patches, mapped as deep sandy patches within otherwise "unsuitable" soils leads to a necessary change in the general description of the habitats suitable for the Houston toad. A successful description must take into account the metamorphic life of the species. Previous depictions of habitat have noted that clarifications for habitat by juveniles and adults outside the breeding season are necessary for any useful discussion of habitat requirements (Seal 1994). Similarly recent publications (e.g. Semlitsch & Bodie 2003) argue the necessity of linkages between aquatic and terrestrial habitats in considering management efforts. We propose that sufficient data now exist to clarify these issues for the Houston toad.

Here, we delineate three types of habitat used by Houston toads: *breeding*, *occupied*, and *dispersal*. What we consider *breeding* and *occupied* habitats are together termed 'core habitat' in other studies (Semlitsch & Jensen 2001; Harper et al. 2008). Due to the different management regimes required for each of the three habitats for Houston toads and our interpretation that 'core habitat' may or may not include *dispersal* habitat, we feel the delineation and use of three habitat types is essential in understanding and managing for Houston toads. These habitats should not be confused with buffer zones which protect habitats from surrounding land-use practices (Semlitsch 1998; Semlitsch & Jensen 2001). Inadequate buffer zones around core habitats may result in local extirpations (Harper et al. 2008).

A primary change from past depictions is differentiation among habitats required for each of the life stages. Three habitat zones clarify the lifestage dependent correlation to Houston toad use: *breeding*, *occupied* and *dispersal* habitats. Defining *breeding* habitat is likely the most straightforward in its requirements. Adult Houston toads require fully aquatic habitats in order to breed. These *breeding* habitats may or may not be ephemeral, may or may not contain fish (introduced or otherwise, see also Threats 2.3.2 below), and are almost always lentic. The context of Houston toad breeding ponds in prehistoric times were very different from that of today (Bryant 1977) creating the backdrop for controversy regarding optimal *breeding* habitat. For this reason it is important to discuss the *breeding* habitat today despite it being less than ideal from an evolutionary standpoint. What were once ephemeral pools fed by winter rains and widely scattered on the landscape have become adjacent, permanent water with strong anthropogenic influences. Likewise the sheer intensity of agricultural or recreational impoundments present on the landscape today are also nearly as dramatic a change as any changes to the average hydroperiods. Today nearly all Houston toad breeding ponds in Bastrop County are within audible proximity of other potential ponds, this is certainly a change from the prehistoric situation and even a significant change from what was present on the landscape of only a century ago.

Directly adjacent to the breeding ponds is a buffer zone of *occupied* habitat. *Occupied* habitat supports adult Houston toads after the breeding season and represents a boundary of suitable soils within a 1.6 km radius of the breeding ponds. A 1.6 km buffer surrounding the ponds may be less than the actual annual dispersal distance of Houston toads (Price 2003) and likely underestimates the potential use by the species given that toads are routinely recaptured at distances of 800 to 1600 m between breeding seasons (Forstner et al. GLR dataset 2000-2009; Price 2003). A 1.6 km periphery also encloses the one year dispersal distances reported for female American toads (*Bufo americanus*) (Forester et al. 2006) without extrapolating to the obviously greater potential dispersals detected of 34 km in just 18 months (Smith & Green 2006), supporting this boundary as a useful management unit for the adult *occupied* habitat boundaries. These are the uplands immediately adjacent to the *breeding* habitat and provide the area within which adult toads persist after the breeding season. Given the dispersal results from Bastrop State Park (Price 2003) and the GLR (Forstner & Swannack 2004) it is likely that this zone encompasses suitable soils surrounding the breeding ponds outward to approximately 1.6 km.

Finally, *dispersal* habitat is currently the least protected and least understood, yet remains just as critical to the persistence of the Houston toad subpopulations as either of the first two habitat zones. The key to metapopulation connectivity is dispersal capacity, providing the linkages among population and subpopulation fragments (Revilla et al. 2004). No factor has been more consistently ignored in regulatory oversight of Houston toad habitat loss than the dispersal of the juvenile life stage. Amphibian juvenile dispersal (Bull 2009; Funk et al. 2005) provides the majority of connectivity among ponds. In Houston toads this has been most likely observed in recent headstarting efforts with the movement of a single juvenile Houston toad over a distance of 3.7 km (minimum straightline distance) in a three week (April-May 2008) period (Forstner & Jackson 2009). So far as we are aware, this is the longest dispersal documented thus far for an individual of this species and represents more than 170 m/day. Such dispersals in juveniles have also been reported for *Bufo boreas* at 87 m per day for newly metamorphosed juveniles (Bull 2009). We also have genetic evidence that Houston toads show a general level of connectivity in a broad overall historical sense among subpopulations (McHenry & Forstner 2009) with distinguishable groups also seen within Bastrop County (see also 2.3.1.3 above). It is notable that the assumptions of the juveniles moving the longest distances is contradicted for toads in several published works, notably by the data from Funk et al. (2005). It may well be that *dispersal* habitat is as appropriate for adults as it is for juveniles even if the density and abundance of juveniles moving is likely higher. At least in the case of the Houston toad, genetic evidence detected adults to be resident in *occupied* habitat adjacent to *breeding* habitat significantly more often than was the case for juveniles (McHenry & Forstner 2009).

Dispersal habitats are large and do not require deep sandy soils, but may well require some overstory components as shown for *Bufo americanus* (Rothermel & Semlitsch 2002). The most influential dataset that is available today for these estimates are genetic (McHenry & Forstner 2009). We summarize these results above (2.3.1.3) concluding that the Houston toad had historically and in prehistoric time maintained broad connectivity among subpopulations across the subpopulations. This must have been consequent of dispersal among patches on the scale of tens of kilometers. Funk et al. (2005) find that nearly 2% of *Bufo fowleri* completed long distance dispersals and the results predict as many as 0.15% of individuals would move at least 15 km. We consider these results to be largely inadequate in general application to Houston toad habitat and constrain our definition of *dispersal* habitat to lie within the outer boundaries of the deep sandy habitat "bands" in the northern and southern tiers of counties. It is critical that dispersal among deep sand patches be maintained and that the boundaries of occupied soil layers (Buzo 2008) coupled to adjacent suitable *breeding* or *occupied* habitats be used as *dispersal* habitat limits. Providing an absolute figure is an extrapolation from other species (Funk et al. 2005) but judging from the Bastrop County deep sandy mosaics of *breeding* habitat east of Highway 21, west of FM2104 a radius outward from *breeding* habitats of 5 km is likely practicable for *dispersal* habitat. This outer ring of subpopulation connectivity does not explicitly have to have the deep sandy soils, nor continuous overstory conditions found for *breeding* and *occupied* habitats, but it must lie within the broad outer boundaries of suitable soils (Buzo 2008).

The integrity of connectivity among these habitat patches relies heavily on Houston toad abundance. The more individuals recruited each year, the more likely that dispersal will result in migration, defined explicitly as dispersal inclusive of subsequent reproduction. Toward that end the net productivity of *occupied* habitats and their contained *breeding* habitats is strongly influenced by the carrying capacity of those habitats. Carrying capacity in *occupied* and *dispersal* habitats is unlikely to be influenced by the availability of suitable daytime retreats but is likely influenced by available prey. It is logical to deduce that increased herbaceous diversity will correlate with increased arthropod diversity. Increased herbaceous diversity is one result from understory reduction and prescribed fire, although arthropods have not been shown to increase on the short term (Taber et al. 2008). In any case the diversity of the modern *occupied* habitats is likely lower than that of historical habitats.

No single factor seems as obviously influencing this today as fire suppression. The effects of prescribed fire on the Houston toad have created considerable debate (Seal 1994). The workshop participants (Seal 1994) strike a strong cautionary note of the application of prescribed fire in occupied Houston toad habitats. At the same time, the same authors note that fire suppression is at best a negative pressure leading to habitat degradation and at worst a catastrophe with the increased probability of stand-replacing wildfires. The consequences of that seeming contradiction were no prescribed fires, experimental or otherwise, examining the effects on the Houston toad until 2000. One of our students (Jones 2006) conducted small mammal trapping in burned and unburned units of Bastrop State Park. Her results are far from conclusive, but she captured an equal number of juvenile Houston toads in units burned more than 12 months prior, with no detection of juvenile Houston toads in units burned more recently. Given the nature of these fire managed ecosystems, it is obvious that due diligence is necessary when conducting prescribed fires.

However, fire suppression has consequences that are more dire as we observed with the Wilderness Ridge fire of 2009, on the eastern edge of Bastrop State Park (Texas Forest Service 2009). As more information has become available it is apparent that fire is a tool useful in ecosystem management, but can be misused or misapplied like any other manipulative treatment. Studies of the response of the Houston toad to prescribed fire and the influences of prescribed fire on the aquatic habitat on which it relies are ongoing today. It is our conclusion that prescribed fire is a necessary mechanism for habitat restoration and fuel reduction, making a strong contribution to increased forest floor herbaceous diversity, the supported arthropod community, and Houston toad abundance. Indeed in at least two studies, the number of toads detected increased in burned tracts (Moseley et al. 2003), with significantly more *Bufo americanus* (twice as many) found in winter burned forests than the unburned controls (Kirkland et al. 1996). We consider it ironic that this study was completed by 1992 in similar forested habitats to those of Bastrop County, and provides results from a closely related species to the Houston toad, given the controversy toward prescribed fire that was articulated in Seal (1994).

2.3.1.7 Other:

Drought has been routinely cited as a primary cause of the loss of the Houston toad from Fort Bend, Harris and Liberty counties during the 1950s. We ourselves have included this reiterated viewpoint in our own summaries for this species. Unfortunately reiteration doesn't create fact out of fiction. Drought has been an unwelcome routine, but erratic, additional stressor on Houston toads for thousands of years. Drought undoubtedly impacts wildlife species directly and indirectly. Direct effects of drought on the Houston toad include desiccation, loss of breeding sites, and loss of eggs or tadpoles consequent of pond evaporation. During the most recent severe drought (2005-2009) we observed loss of egg strands, tadpoles, and juveniles through desiccation during the spring 2009 breeding season in Bastrop County. Price (2003) documents a decrease in Houston toad abundance following the 1993 drought in central Texas. Our own survey datasets for Bastrop County indicated dramatic reductions in the number of chorusing groups, chorus size, and the length of the chorusing season between 2002-2003 and the 2009 survey results (Forstner 2009).

Indirect effects of drought on the Houston toad, or wildlife in general, are less well understood. It seems clear that decreased food abundance impacts the species as the food web of plants and insects collapses in the drought. As drought severity increases, surface water abundance, predators, and livestock concentrate at the remaining water bodies each providing impacts to different life stages of the species. We documented a rise in the prevalence of chytrid fungus and first detections of bullfrogs at breeding sites within large forested habitat patches as the drought intensified in 2006. Finally, the Wilderness Ridge fire in Bastrop County eliminated hundreds of acres of habitat in just a few days (Texas Forest Service 2009) at a severity of intensity that could result in juvenile and adult toad mortality directly in addition to removing habitat until decades of regrowth can recover it. The Reese Lane fire on the Austin and Colorado county line also burned 1,950 acres beginning on July 4, 2009 very near to the only remaining chorusing detections for those counties.

Obviously drought has impacts on the Houston toad, wildlife, and can be a very potent effect on persistence within a given habitat fragment or region. The most recent drought affected nearly all of the remaining occupied counties (Nielsen-Gammon & McRoberts 2009). Thus, it would seem that the introduction to this section is in error, as of course drought badly affects the Houston toad. Yet, the drought of the 1950s and even the most recent droughts for the area (e.g. 1993 and 2005-2009) are quite simply not even on the same scale as historical droughts for the region (Cook et al. 2007; Herweijer et al. 2007), much less those of the more distant past (Cook et al. 2009). Similarly, reconstructions of the past 30,000 years of climate (Bryant & Holloway 1985) in Texas indicated that the climatic shifts successfully faced by this species on any relevant timescale far exceed those faced by it during the 1950s or recently. It is unreasonable to predicate the extirpation event for a taxon that has faced civilization-ending drought intensities (Benson et al. 2007) on an intense, even notable, drought during the 1950s, but not a drought on the intensities it has faced just hundreds of years prior. Drought may be a significant issue for the Houston toad, but only in the context of badly fragmented and degraded habitats in which they cannot rebound after the drought stress ends. The species has persisted in the face of unimaginably intense droughts, even by the standard of the 1950s (Cook et al. 2007). Drought impacts are more a consequence of dramatically reduced subpopulations, ruptured connectivity, and the related consequences to all small populations.

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms) - *For each of the five listing factors outlined below, provide a brief summary and citation(s) of any relevant new information, including conservation measures, regarding the magnitude (scope and severity) and imminence of previously identified threats to the species or new threats to the species. Note if any of the factors are not relevant to the species. Upon completion, go to 2.4., Synthesis.*

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

The core explanation of the historical and ongoing declines toward extinction for the Houston toad is habitat loss exacerbated by the degradation of the fragments of habitat remaining. That loss is most often seen as direct habitat destruction in the conversion to housing, agriculture or other unsuitable landscapes. Most often these losses to occupied habitat are small, just acres in size, but taken together they cumulatively result in extirpation (see Lee County example above 2.3.1.5). Sometimes they are dramatic and flagrant, as is the case for hundreds of acres of highly suitable habitat for the species eradicated by a landowner in Bastrop County who has left that indelibly irrefutable in aerial photographs coincident with the extra effort of providing a name (Figure 4). We wonder if the person(s) responsible for that event are aware that Luecke is German for "gap" and the inherent implications to conservation and recovery of the Houston toad.

The continuing process of habitat loss, fragmentation, and degradation will conclusively result in the extinction of the Houston toad. This can be no more evident than in the dramatic reduction in chorusing detected for Lee County between 2000 and the present. It may well be that, in unambiguous correlation with other extirpation events for the species, habitat loss reaches a final boundary beyond which the species is unable to persist. Knowing that chorusing of hundreds of Houston toads across multiple choruses could be reduced to effectively zero in just five years should be a final warning to managers and regulatory agencies. The best explanation we can offer is that the loss of suitable habitat, defined by deep sandy soils and overstory vegetation declined by 16% from 1999 to 2005 in Lee County. Worse, in the same period Bastrop County lost 11% and chorusing has now been additionally impacted by drought, with chorusing collapsing to only a few dozen individuals at Bastrop State Park for 2009.

The entirety of the Houston toad's current range is bounded by the largest cities in Texas. Texas remains a high growth state within the USA, meaning development within Houston toad habitat is assured. In a continuing trend of subpopulation level extirpation events, habitat losses have provided the primary mechanism by which other negative impacts (e.g. subsidized predators, disease, or drought) have abnormally large consequences to persistence within a given habitat patch. Without dramatic changes to these trends additional conservation efforts for the species are doomed to fail.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

In the historical overview of the species in Seal (1994), Brown states that considerable collecting of this species occurred by both amateur and professional for private and museum collections (pg. 23). We are unable to substantiate this based on nationwide requests for Houston toad specimen holdings, with wild collected vouchers of the species comprising only a few specimens or being absent from the majority of scientific collections. We cannot evaluate the private collection of the species for captive "pets" prior to listing as an endangered species but we do not consider overutilization to be a current threat to the taxon.

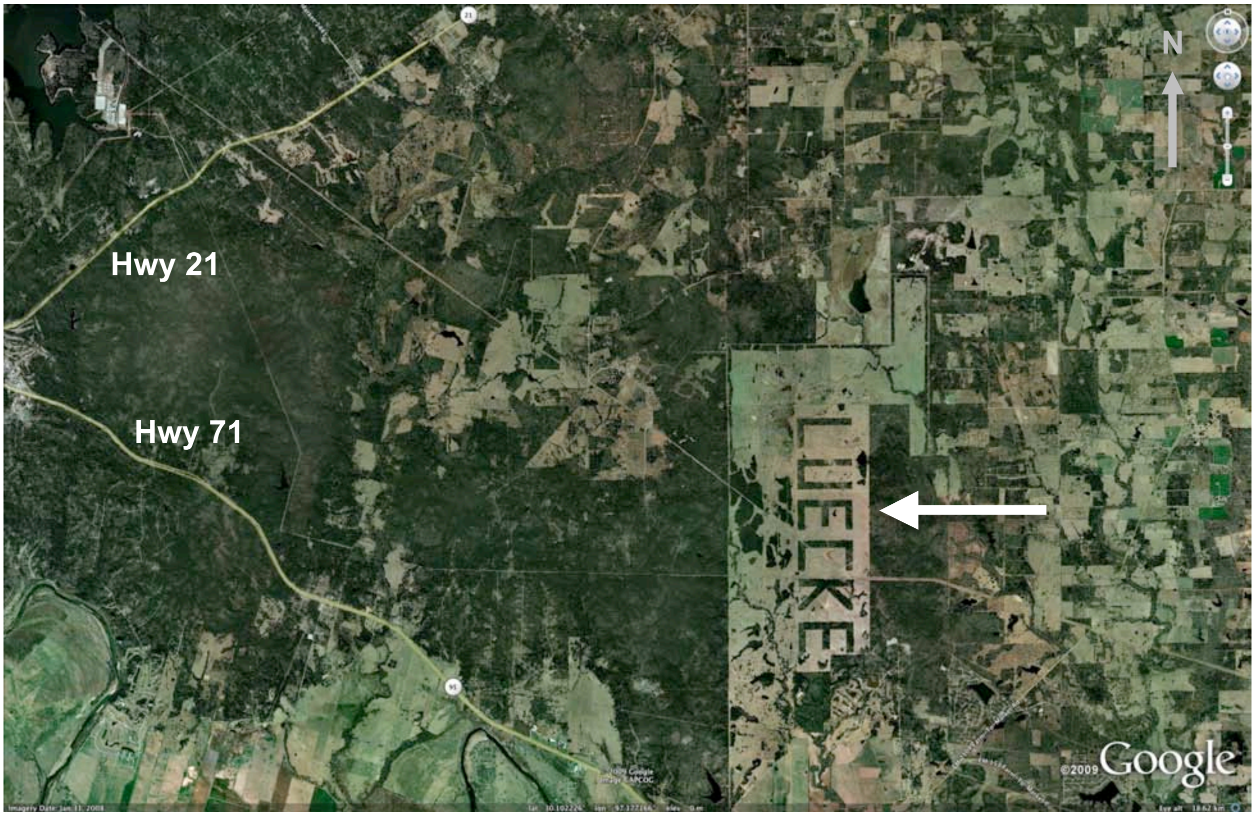


Figure 4. Unpermitted habitat destruction of a large tract of Houston toad habitat adjacent to Bastrop and Buescher State Parks, Bastrop, Texas (indicated by white arrow). The disturbance area encompasses more than 1,250 ha, with each letter of the word "Luecke" more than 750 m tall and 450 m wide.

2.3.2.3 Disease or predation:

Both disease and predation are likely issues for the species consequent of unnatural changes to its ecological context. Since 1999 chytrid fungus has been a recognized, often cited, causative factor in amphibian declines or extinction (Berger et al. 1999). It has been argued (Weldon et al. 2004) that the origin of modern chytrid fungal infections affecting amphibians worldwide originated from *Xenopus laevis* out of South Africa. Truly enormous numbers of the African clawed frog (*Xenopus laevis*) were exported from its wild populations for use in human pregnancy tests starting in the 1930s. The appearance of this fungal pathogen suddenly, on a cosmopolitan scale, corroborated with genetic data, argues for an emerging disease (Morehouse et al. 2003; Weldon et al. 2004). Chytrid fungus has been detected in Houston toads (Gaertner et al. unpublished data) and in other amphibians occurring sympatrically in central Texas (Gaertner et al. 2009) but thus far the specimens appear to be asymptomatic for the disease. What we observed among Houston toad samples tested thus far was intriguing, with samples having a low overall incidence of infection or absence until the onset of drought conditions which correlated with the first appearance of bullfrogs (*Rana catesbeiana*) at breeding ponds within forested habitat. American bullfrogs are a documented chytrid fungus vector (Garner et al. 2006) and on the short list of the organisms that are potentially responsible for the global expansion (James et al. 2009; Goka et al. 2009). It is not yet clear what the effects on the Houston toad have been or will be. It is often assumed that the pathogen is less problematic for North American species (Ouellet et al. 2005) potentially as the epidemic wave has already passed. Its impact appears to be variable among taxa with some showing population stabilization with a now endemic infection of the pathogen (Retallick et al. 2004), and others dramatically declining (Lips 1999). Lips (1999) also reports this same type of species specific outcome among different bufonid species in Panama, so the effects on the Houston toad remain unclear at present. It is certainly a newly documented disease and stressor for the Houston toad and one likely to act as a negative influence on the remaining populations.

Aside from a single publication (Freed & Neitman 1988), predation events on the Houston toad have been seldom published. We have recently submitted a report of predation on the species by a bullfrog (McHenry et al. *accepted*), directly documented the predation of a Houston toad by a water snake (Forstner & Swannack 2004) and indirectly documented predation by mesocarnivores by recovery of chewed or passed telemeters (Forstner & Swannack 2004; Swannack 2007). From our observations in the field (Ferguson 2005; Ferguson et al. 2008) mesocarnivores are a consistent influence on Houston toad populations in Bastrop County. While this is likely expected as a native predator web on amphibians we highlight the potential for several of the predators being strongly anthropogenically influenced. As the habitat for the Houston toad has become fragmented, increasingly urbanized, and comprising more stock tanks, all or most of those changes have subsidized predators. Raccoons, skunks, even house cats are all positively impacted by the changes to the landscape and all are negative pressures on the toad. Another change noted by Yantis (pers. comm. to MRJF Dec 2009) is the increase in watersnakes at Houston toad sites, with the implication that increased water body density and proximity has elevated watersnake numbers and interactions to the Houston toad. We have encountered *Nerodia erythrogaster* (Blotched watersnake) engulfing toads at Houston toad breeding ponds and manipulated the prey out of the snake to find it was *Bufo valliceps* (Gulf Coast toad), but doubt the snake would have distinguished between to the two toad species. There seem to be few solutions to this situation aside from noting the increased pressure on the species by anthropogenically subsidized predators. Scheinder (2001) notes that control of the predators did not lessen the impacts on the endangered prey species and the primary determinants of prey persistence was a direct function of landscape configurations. Thus the effects of landscape fragmentation are primary with secondary exacerbation impacts including increased predators (Schnieder 2001). This is likely the same for all predators and useful mitigation strategies necessitate reduction of the access or amount of resources (i.e. garbage) available to the predators (Boarman et al. 2006) or by testing habitat manipulations or predator removal to gauge effects (Sinclair et al. 1998).

2.3.2.4 Inadequacy of existing regulatory mechanisms:

It is apparent now and has been apparent for some time (see review by Brown & Mesrobian 2005) that even when legal aspects of Houston toad protection seem obvious, they are not obviously implemented. Willful take of Houston toad habitat (Figure 4) illustrates the impotence of active regulatory protection of the species in what is the best studied and most documented habitat fragment remaining. Given the controversy and outcomes of the golf course expansion in Bastrop State Park (Brown & Mesrobian 2005), the lack of consequences to such actions like that shown in Figure 4 has become altogether too apparent. Yet, in stark contrast to these negative outcomes both regulatory and private, in the last decade the Houston toad has gained more involved stakeholders, more consistent annual increases in acres under stewardship within Bastrop County, than at any time since its description. The lessons from Bastrop County in the Houston toad spotlight are clear, but so are the more damaging lessons from the neglected counties like Lee or Lavaca. We suggest that the potential economic consequences of the seldom used determination of Jeopardy may be a motivation for additional stewardship efforts, particularly as the decline toward imminent extinction appears to be substantiated by all available data for this species.

Definitions for what conditions made a species endangered, much less their management or recovery, were still ambiguous topics by the mid 1980s. While recognized endangered species have increased numerically, the success stories have not increased in any meaningful correlation of those dramatic increases in listings. The political agendas and attitudes of many landowners in Texas have changed little from the summary provided in Brown & Mesrobian (2005). What has happened with consistent efforts by a wide range of organizations and individuals, is the citizens of Bastrop County have grown to recognize the advantages alongside the potential disadvantages that coexisting with this species brings to their community. Real incentives are now available in Bastrop County for Houston toad habitat stewardship and conservation activities with property tax decreases available for participation. Nothing has happened anywhere else in the range of the species, until 2008 when the first landowners with Houston toad breeding ponds were actively involved in Austin County. Similar efforts have now been made for Colorado and Milam counties and in both cases these are fragile first efforts. Conservation stewardship for this species has been an inactive process, assuming an attitude of benign neglect. Unfortunately, the reality is that without efforts in the counties outside Bastrop, extirpations have continued and the hope for any eventual recovery diminished. The conclusions in the latest viability analysis (Hatfield et al. 2004) and from population genetics (McHenry & Forstner 2009) are clear, the Houston toad meets the criteria of a metapopulation and that requires multiple, viable subpopulations *with* connectivity. This reality has been and continues to be effectively ignored in the sporadic efforts toward recovery of this species. This is ironic as unlike other priority species (i.e. Whooping crane) the Houston toad has an extraordinary reproductive capacity providing an innate potential for rapid and significant population recovery.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

One feature of the Houston toad landscape that has not been adequately addressed is the concomitant increases in roadways, traffic, and the consequences to exacerbating all of the threats articulated above that come with these activities. Roadway mortality is a strong negative pressure on amphibian dispersal (Carr & Fahrig 2001) and has been documented in the direct take of Houston toads both historically (Price 1990a) and in recent mortalities found in Austin County (Forstner unpublished data). There have been attempts at mitigation of these impacts, with efforts on Highway 21 adjacent to core habitat areas near Bastrop State Park in the early 1990s (Brown & Mesrobian 2005). It remains unclear today whether the placement of barrier fencing to guide toads into existing culverts under Highway 21 in this area have been of any assistance to the species. What is clear is that the comprehensive study of roadways and wildlife connectivity has advanced significantly since 1984 (Sherwood et al. 2002). Likewise the management of the rights-of-way (ROWs) adjacent to the roadways has been examined and many recommendations provided to enhance the utility of these ROWs for wildlife (Goodrich-Mahoney et al. 2008). For the Houston toad, connectivity studies are limited but an examination of the expansion of Highway 290 is underway (Forstner unpublished data). Implementation of wildlife crossings suitable for the Houston toad can be significantly expensive additions or marginal increases to total cost depending on the planning and roadway construction. Key to understanding maximum benefits to such crossing are the utilization by wildlife of key landscape corridors more prevalently than other areas and providing suitable underpass or overpass facilities for wildlife use (Sherwood et al. 2002). For the Houston toad dispersal is likely to conform to drainage systems and will be underpass not overpass features. The key components to such systems have been explored (Woltz et al. 2008) but not specifically for the Houston toad. Maximizing dispersal while minimizing mortality is best achieved by maintaining as natural a drainage under the roadways as possible. Culvert pipes are likely to create temperature and humidity changes that mimic caves and these are not likely to be readily accepted by toads as the environmental shift could signal caves or other evolutionary proscribed habitats. Broad gentle drainages mimicking that seen in *dispersal* habitat near ponds will best assist the species. At the same time, impoundments adjacent to the roadway can lead to direct mortality and should be avoided as well. Ultimately, Texas Department of Transportation is aware of the constraints to construction timing, and is a likely partner toward innovations in roadway crossings for wildlife. These features are a national priority and directly mitigate motorist injuries or damage coincident with larger faunal collisions.

Climate change is an uncertain variable and a threat that potentially exacerbates other ongoing impacts (as mentioned above). NatureServe has produced a “climate change vulnerability index” that allows species to be objectively ranked by their sensitivity to predicted changes in temperature and rainfall patterns. Preliminary use of the index categorized Houston toads as “extremely vulnerable” meaning that the “abundance and/or range extent within geographic area assessed extremely likely to substantially decrease or disappear by 2050”

(NatureServe 2010). Much attention has been paid to species that have restricted specialized habitat requirements such as the America Pika or the Polar bear. Houston toads, due to their reliance upon the deep sandy soils for persistence, are effectively isolated in this same manner. Alteration of rainfall patterns concomitant with habitat loss might also decrease the phenological partitioning in place between Houston toads and other toad species and increase the likelihood of hybridization events. Climate models should be analyzed and used for determination of locations for future conservation action.

2.4 Synthesis - *Provide a synthesis of the information discussed in sections 2.1., 2.2., and 2.3, to provide an updated assessment of the status of the species and its threats. Please note any significant changes in the species' status or its associated threats since the last review, and explain why the species meets the definition of threatened or endangered, as appropriate. This section should conclude with a recommended classification (downlist, uplist, delist, remain the same). See guidance and 50 CFR 424.11 (the factors considered for delisting are the same factors considered for listing; species may be delisted due to extinction, recovery, and/or data error). This synthesis will provide a basis for the results provided in section 3.0, Results, and the baseline by which to measure changes in status for the next review.*

It is safe to conclude that the authors of the 1984 Recovery Plan would have been overwhelmed, even amazed, by the changes to scientific emphasis on amphibian decline since they completed their work. At that time, relatively few amphibians were on the endangered species list and the global amphibian decline data had not been assembled, nor synthesized as it has today (Sparling et al. 2003). It is just as likely that they would have been less than surprised by the continued decline of the Houston toad. Virtually every main threat to the species was known and articulated by the authors of the 1984 Recovery Plan. Indeed most of these were re-emphasized by the 1994 PHVA authors (Seal 1994). It may be that the only change since then is the increased pace of habitat loss and more clear temporal correlation with extirpation level events (Buzo 2008).

There have not been a large number of studies completed for this species in the years since 1984. Recent data collection has accelerated coincident with increased publication of those results. Alongside the increased pace of scientific inquiry is the scale of stakeholder involvement for the Houston toad habitat within Bastrop County. Together these resources provide a more substantial context for actions suitable to offset the continued declines in the past decades and a model for extrapolation to the other remaining subpopulation areas. Each major review of the Houston toad has shifted conclusions based on the most recent analytical or investigative results. Today it is less clear why prescribed fire was seen as more potential harm than good, similarly, at that time building breeding ponds was an easily embraced landowner practice. Now we believe fire to be a critical missing element in Houston toad habitats and that more ponds on the landscape contribute to decreased reproductive success in the species. These changes to perspective are within a context of much smaller overall populations detected than was true for 1984. At very small sizes, populations are influenced by a variety of forces (e.g. genetic drift, Allee effects) that are not as relevant for reasonable population sizes.

The Houston toad can be considered a specialist in a comparison to its sympatric congener the Gulf Coast toad (*Bufo valliceps*). It has more generally restricted habitat requirements and a more narrow breeding season. While not explicit to one type of woodland, or a particular dominant tree species, it occupies habitats with trees on deep sandy soils. The conversion of these habitat types to agriculture grasslands is the most likely contributor to its continued declines range-wide. The result is a fragmented landscape very different from what the species may have historically occupied given the close genetic relationships seen across relatively large distances. This reinforces that habitat and patch occupancy are critical, necessitating connectivity as the next priority. Landscape configurations allowing persistence and enhancing juvenile dispersal represent a real challenge to all stakeholders, but unpermitted unmanaged habitat losses, continuing the trend of the last three decades, will lead inevitably to extinction. Importantly the time frame for that may be radically shorter than we might have supposed in the absence of the dramatic decreases in chorusing seen for Lee County.

In the decades since the last review (Potter et al. 1984) the Houston toad has continued to experience subpopulation extirpation events, reductions to available habitat, and detectable declines within even large habitat patches (i.e. Bastrop County). The trend in abundance and distribution for this species remains nearly the same as that noted in the 1960s when listing efforts for the species were first undertaken. There are significantly more data available for trends in the species over time, but only for a very narrow subset of the remaining habitat patches. In the absence of trend data it has often been assumed that the species persist in those patches. Recently, this has been shown to be most likely incorrect for Lavaca County and highlights the need for more consistent collection of data for the areas outside of Bastrop County. Clearly the situation across the remaining habitat was negatively impacted by the recent very severe drought. That drought is an additional stressor is unquestioned, but what is questionable is how influential it would be were the populations intact or if they retained more reasonable abundance generally. In the current situation, drought is likely a strong pressure on the subpopulations, with a real potential as an extirpation force on isolated habitat fragments or even entire subpopulational patches. Drought should not, however, be seen as the primary stressor leading to extirpation events, merely the catastrophe that provides the final impacts.

In 2004 (Hatfield et al. 2004) best available data population viability analysis concluded that a minimum of three connected, self-sustaining populations were required to prevent imminent extinction. In 2007 the situation in the field was severe enough that the expert analysis required establishing captive assurance colonies as insurance against extinction. Headstarting efforts have proven to be a suitable successful method for offsetting population declines in other endangered species, and in the Houston toad. Today it is critical that the populations rebound quickly off their lows, enabling a more substantial trend toward annual increases. The species has remarkable reproductive potential and significant stakeholder momentum toward stewardship. So while the Houston toad has not moved toward recovery during the period of the last 26 years and has, in fact, moved further away from that goal, it may have finally garnered enough attention to begin reversing that trend. We conclude that the species should not change in classification, but may warrant a higher overall priority than it has had during the past three decades.

3.0 RESULTS

3.1 Recommended Classification: *Given your responses to previous sections, particularly section 2.4. Synthesis, make a recommendation with regard to the listing classification of the species*

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (*Indicate reasons for delisting per 50 CFR 424.11):*
____ *Extinction*
____ *Recovery*
____ *Original data for classification in error*
__X_ No change is needed

3.2 New Recovery Priority Number *(indicate if no change; see Appendix E)*:

Brief Rationale:

These appear to be a regulatory decision and we believe are best left to the agencies involved. It is our conclusion that the species is at more risk of extinction today than it was in 1984 when the prioritization was set. If the prioritization influences attention, funding priority, or regulatory oversight actions, then that priority should increase to the maximum extent possible.

3.3 Listing and Reclassification Priority Number, if reclassification is recommended *(see Appendix E)*

Reclassification (from Threatened to Endangered) Priority Number: ____
Reclassification (from Endangered to Threatened) Priority Number: _N/A__
Delisting (Removal from list regardless of current classification) Priority Number: ____

Brief Rationale:

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS - *Provide recommendations for future actions that stem from this review and that focus on the highest priority actions needed prior to the next 5-year review. Recommendations may address, but are not limited to, data needs for future 5-year reviews, implementation of high priority recovery actions, actions on DPS-related issues identified in section 2.1., revisions or updates of recovery plans, or development or modification of special rules.*

Somehow a country dies, right under people's eyes….
Epilogue (Sanders & Sanders 1988)

Responses to habitat losses:

a. Utilize Regional HCPs or other legal frameworks for the remaining occupied counties where chorusing groups have been detected in recent years
    i. Goal should be to immediately prevent extirpation and implement stewardship within Austin, Colorado, Milam, and Leon counties
b. Priority should be given to assessment of Robertson County for inclusion on the above list
c. Fund and support annual monitoring of the subpopulations or minimally triennial monitoring by subpopulation on a rotating basis
d. Directly assess trends in habitat losses using analyses of aerial photography
    i. Utilize existing data (Buzo 2008) but supplement every 5 years to establish trends
e. Notify, engage, and enforce permitting beginning with utilities companies, appraisal districts, agricultural extension offices, and other direct lines of information on habitat changes within the affected counties
f. We will attract more stewards with incentives than with prosecution, but some level of enforcement of federal laws protecting the species must become a reality
    i. Aggressively prevent continued habitat losses without mitigation
    ii. Integrate enforcement with interagency notifications (prior bullet "e")

Disease, predation, or other population stressors, natural or manmade:

g. Assessment of Austin County
    i. Examine the population genetic issues
    ii. Utilize these data in the evaluation of a potential DSP for the next 5-year review
h. Headstart the remaining subpopulations efficiently to positively influence change in abundance
    i. Determine most efficient and cost effective methods
    ii. Obtain a judgment on captive propagation from the Recovery team
    iii. Seek a critical assessment of reintroductions from captive lineages and the potential localities for those reintroductions
    iv. Assess Allee effects on the populations and the existing habitats
i. Assess impacts of supplemented predators and means to mitigate them
j. Establish best management practices for roadway crossing connectivity

i. Conduct cost-benefit analyses for significantly increased roadway permeability

Inadequacy of existing regulatory mechanisms:

k. We reiterate: Notify, engage, and enforce permitting beginning with utilities companies, appraisal districts, agricultural extension offices, and other direct lines of information from landowners for habitat changes within the affected counties
l. We reiterate: We will attract more stewards with incentives than with prosecution, but some level of enforcement of federal laws protecting the species must become a reality
    i. Aggressively prevent continued habitat losses without mitigation
    ii. Integrate enforcement with interagency notifications (prior bullet "e")
m. Efficient productive stakeholder involvement and stewardship outside of Bastrop County must become as accessible and common as is now the case in Bastrop County

5.0 ACKNOWLEDGEMENTS

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *Bufo houstonensis*

Current Classification:

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
____ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By:

FIELD OFFICE APPROVAL:
Lead Field Supervisor, Fish and Wildlife Service

Approve ____ Date _________
The lead Field Office must ensure that other offices within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion.

REGIONAL OFFICE APPROVAL:
The Regional Director or the Assistant Regional Director, if authority has been delegated to the Assistant Regional Director, must sign all 5-year reviews.

Lead Regional Director, Fish and Wildlife Service

Approve ____ Date _________

The Lead Region must ensure that other regions within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. Written concurrence from other regions is required.

Cooperating Regional Director, Fish and Wildlife Service

_____Concur _____ Do Not Concur

Signature____ Date_______