ASSESSING THE RANGE OF HOUSTON TOAD (*BUFO [ANAXYRUS] HOUSTONENSIS*) RELATIVE TO SOIL, GEOLOGY AND VEGETATION OVER THREE DECADES IN BASTROP COUNTY, TX

by

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A directed research report submitted to the Geography Department of

Texas State University in partial fulfillment

of the requirements for the degree of

Master of Applied Geography

with a specialization in Geography Resource and Environmental Studies

May 2021

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INTRODUCTION

Identifying the habitat and spatial patterns of endangered species is important for research and management of the species and can also be helpful for identifying the geographical and anthropogenic factors that influence their distributions.

The Houston toad (*Bufo [Anaxyrus] houstonensis*) is an endangered species that is endemic to east-central Texas and is currently only found in nine counties, one of which contains federally recognized critical habitat. The Houston toad's habitat is extremely susceptible to a variety of threats that currently affect the region, including urbanization, wildfire, drought, agricultural practices, and invasive species. These threats and their impacts on habitat availability and quality may cause changes in population distributions. This research uses a GIS to analyze and compare historical and modern Houston toad detection records for Bastrop County, Texas, in relation to soil, geology, and vegetation classification maps to determine if the species distribution has adjusted to occupy different types of soil, geology and vegetation over time. This proposed investigation aims to quantify if, and how, the patterns of Houston toad detection has changed over the observation period. This research is important because it can help elucidate what environmental and anthropogenic factors may be influencing changes to their habitat use.

The results of the study will add to existing knowledge on Houston toad habitat and potentially provide novel information to help explain changes in the distribution of their populations over time. This information can be useful for identifying factors that may be causing changes to Houston toad distributions and that can help inform the conservation and management of the species.

LITERATURE REVIEW

Species information/habitat requirements

The Houston toad relies on a very specific habitat that is only found in a limited range within the state of Texas (Dixon 2000; Swanack, Grant and Forstner 2009). First discovered in the 1940's and later described in 1953, the Houston toad is an amphibian averaging around 2.5 inches in size. Other physiological characteristics include a light grey-brown, sometimes purplish skin color with dark brown and light-colored blotches in the skin pattern. Male individuals are characterized by blue-green throats that expand when calling (Sanders 1953). The Houston toad was listed federally as an endangered species in 1970 and was the first amphibian to be added to the United States list of endangered native fish and wildlife (Gottschalk 1970).

The peak breeding period of the Houston toad falls between late January and early May, during which large clusters of males begin to call at ponds within the habitat. The breeding activity of the Houston toad is sensitive to the daily weather conditions in the area (MacLaren, McCracken, and Forstner 2018; Swannack 2007).

Because of their reclusive nature, the primary method used to detect Houston toads within their habitat is by conducting audio surveys. Conducting audio surveys during suitable season and weather conditions is very important in ensuring maximum detection of populations in the survey area and is necessary for the management of the Houston toad, as non-suitable weather can lead to a potentially false result of absence (Jackson et al. 2006). For the purposes of this study, "detection" refers to a call heard in an audio survey. The point dataset used in this study are derived from audio surveys conducted by various organizations and individuals during the Houston toad breeding season (Buzo 2008).

The Houston toad is currently known to exist in nine Texas counties, including Austin, Bastrop, Burleson, Colorado, Lee, Leon, Lavaca, Milam and Robertson counties (Dixon 2000; Swanack, Grant and Forstner 2009). Federally designated critical habitat for the Houston toad falls within Bastrop County and Burleson County, however there are no enforced restrictions in Burleson County. Two major breeding populations are found within the Lost Pines ecoregion in Bastrop County. These habitats are considered critical because they contain essential features that are important in the conservation and recovery of the Houston toad (Swannack, Grant and Forstner 2009; Brown, Swannack, and Forstner 2013). Suitable habitat for the Houston toad includes deep, sandy soils and a thick canopy cover mainly consisting of the Loblolly pine (*Pinus teada*) and the Post Oak (*Quercus stellate*), as well as a standing or flowing body of water (Wallace 2015).

Habitat suitability models using soil type, canopy cover and distance to water to predict viable habitat locations for the Houston toad have been created and provide important information regarding the locations within the counties known to contain Houston toad populations (Buzo 2008). Buzo (2008) constructed a table of Houston toad points based on detections that were heard or observed to evaluate with the habitat suitability models to confirm accuracy, and not all locations contain modeled as suitable habitat are occupied by the species through known detections. Predictive suitability models are very useful for the selection of future reintroduction and recovery sites for the species (Buzo 2008).

Habitat disruption:

There are many anthropogenic and environmental factors that have a role in the spatiotemporal dynamic of Houston toad populations. These factors include, but are not limited to, urbanization, roadways, agricultural practices, drought, fire/fire prevention, and invasive species.

Urbanization, including land cover changes, the leveling of property and construction of impervious surfaces, as well as the introduction of domestic predators and the use of pesticides in the management of introduced plant species has played a major role in the habitat disturbance and degradation of the Houston toad. Roads directly impact the Houston toad populations. They increase the probability of death due to automobile interference and alter drainage patterns, causing nearby ephemeral ponds and streams to dry forcing individuals to migrate to drainage ditches closer to the roadway. As urbanization and road networks continue to spread, they will continue to impact the Houston toad unless alternative practices are set in place (Seal 1994; Wallace 2015).

Agricultural practices such as growing crops and livestock production also causes disturbance in the Houston toad habitat. Livestock production usually includes the elimination of native prairie lands and the introduction of exotic grasses. Management requirements of lands for growing crops and livestock production that negatively affect Houston toad include, but are not limited to, mowing, pesticide-use, and fertilizer-use, which can all have detrimental impacts on Houston toad populations (Seal 1994).

There have been two severe drought occurrences within the range of the Houston toad habitat since its discovery. The first drought lasted from 1950 to 1957 and the second from 2005 and 2015. This later drought contributed heavily to the 2011 Bastrop wildfire event (Raney 2013). The drying of habitats in drought periods causes a major reduction in suitable breeding areas, causing a decline in Houston toad reproduction rates (Seal 1994; Wallace 2015).

Lastly, invasive species such as the red imported fire ant and feral hogs also contribute to the habitat destruction and population decline of the Houston toad. The red imported fire ant has been observed in multiple studies to cause a decrease in biodiversity in the southern U.S. (Gotelli

and Arnett 2000; Cook 2003). Red imported fire ants were introduced into Bastrop county and the Lost Pines ecoregion in the 1970's and have been known to prey on juvenile Houston toads as they become terrestrial (Freed and Neitman 1988; Brown, DeVolld, and Forstner 2012). Feral hogs are also present in the Lost Pines ecoregion and can cause habitat destruction within the range of the Houston toad such as damage to pond structures and degradation of water quality (Brown et al. 2012).

Conservation efforts/regulations:

Since its listing, the Houston toad has been included under the implementation of the Lost Pines Habitat Conservation Plan, which is a widely implemented plan that accompanied the issuance of an U.S. Fish and Wildlife Service Incidental Take Permit to Bastrop County (Brown et al. 2011). Management strategies for the species are also included in the Houston toad Programmatic Safe Harbor Agreement, which provides habitat and threat assessment as well as a discussion of the conservation practices that landowners can implement and their benefits to the recovery of the species (Longoria 2017).

SITE DESCRIPTION

The known habitat of the Houston toad is currently situated in nine counties. These counties include Austin, Bastrop, Burleson, Colorado, Lee, Leon, Lavaca, Milam and Robertson counties (Dixon 2000; Swanack, Grant and Forstner 2009). Bastrop County will be the study area for this research as there are the most documented Houston toad detections in this county.

DATA

The data for this study includes soil classification shapefiles from the Soil Survey Geographic Database (SSURGO) managed by the U.S. Department of Agriculture Natural Resources Conservation Service, geological classification shapefiles from the U.S. Geological Survey, East Central Texas Plains vegetation shapefiles from the Texas Ecological Mapper provided by Texas Parks and Wildlife Department, and Houston toad observation point data that is compiled in the Buzo (2008) thesis from various sources for Bastrop County, Texas. The Houston toad point data was collected from Texas Parks and Wildlife Department, U. S. Fish and Wildlife Service, field notes, and surveys. The detection points for Bastrop County range from the 1980s to the 2000s (Figure 1, Appendix A). For the present study, the data was categorized into three decades for this study to ensure concise results with more detectable changes in spatial patterns. Other data used for the purpose of this study includes a publicly available ESRI topographic basemap for the for use in the cartographic figures.

METHODOLOGY

The soil, geology, vegetation, and species detection point data collected were analyzed through ArcGIS software. Houston toad point data with geographical coordinates was entered into an Excel spreadsheet and converted into a point feature class in ArcGIS software and combined with the feature classes for soils, geology, and vegetation. Detailed descriptions for these feature classes can be found in Appendix. The “dissolve” tool was used to simplify the polygons per classification of each feature class. The feature classes were clipped to the Bastrop County boundary. Visual inspection and calculations of point counts using the “summarize within” tool in

each of the polygons within the three classification feature classes was quantified and tables were created from the tool output to represent the data numerically. Only the soil units containing points were included in the tables.

RESULTS

There were 76 Houston toad observation points available for the years 1980-1989, 220 points available for the years 1990-1999, and 97 points available for the years 2000-2009. After entering the data into GIS software and performing analyses and quantifying the extent of point aggregations within the soil, vegetation, and geology classification polygons for Bastrop County, maps and tables were created to represent the associations visually and numerically between Houston toad observation locations and the various classifications for each decade.

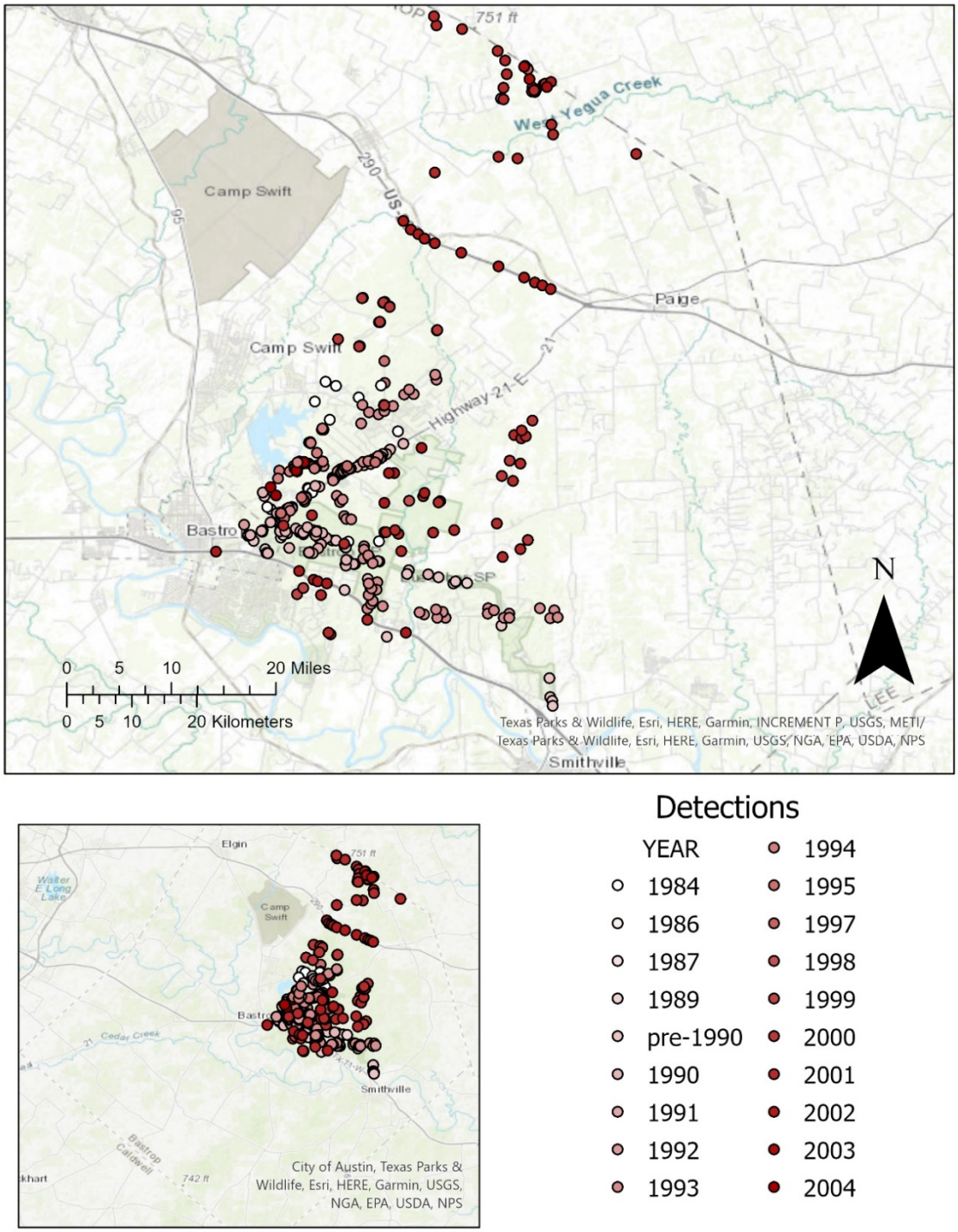


Figure 1. Map representing Houston toad (*Anaxyrus houstonensis*) detections in Bastrop County, TX symbolized by year with light-colored points representing earlier years (1980s) to dark red representing later, more recent years (2000s). A list of Houston toad detection points can be found in Appendix A.

Soil

Houston toad detection points and soils data showed some interesting patterns (Table 1; Figure 2). In the 1980s, the largest number of points, 18%, was found in Axtell-Tabor complex (AtD) and 17% occurred with the Jedd stony (JeF) soil units. Tabor fine sandy loam (TfB) and Patilo complex (PaE) each contained 16 percent of points for the decade (Table 1; Figure 2). There is a large difference in the association of species detection and soil type between the 1980s and 1990s, with PaE containing about 41 percent of the points for the 1990s decade, which is over twice the number of points found in PaE in the 1980s. Soil unit Silstid loamy fine sand (SkC) also contains a higher proportion of points in the 1990s than in the 1980s (Table 1; Figure 2). In the 2000s, soil units PaE and SkC remained the two soil units with the highest proportion of points within them for that decade (Table 1; Figure 2)(Appendix B).

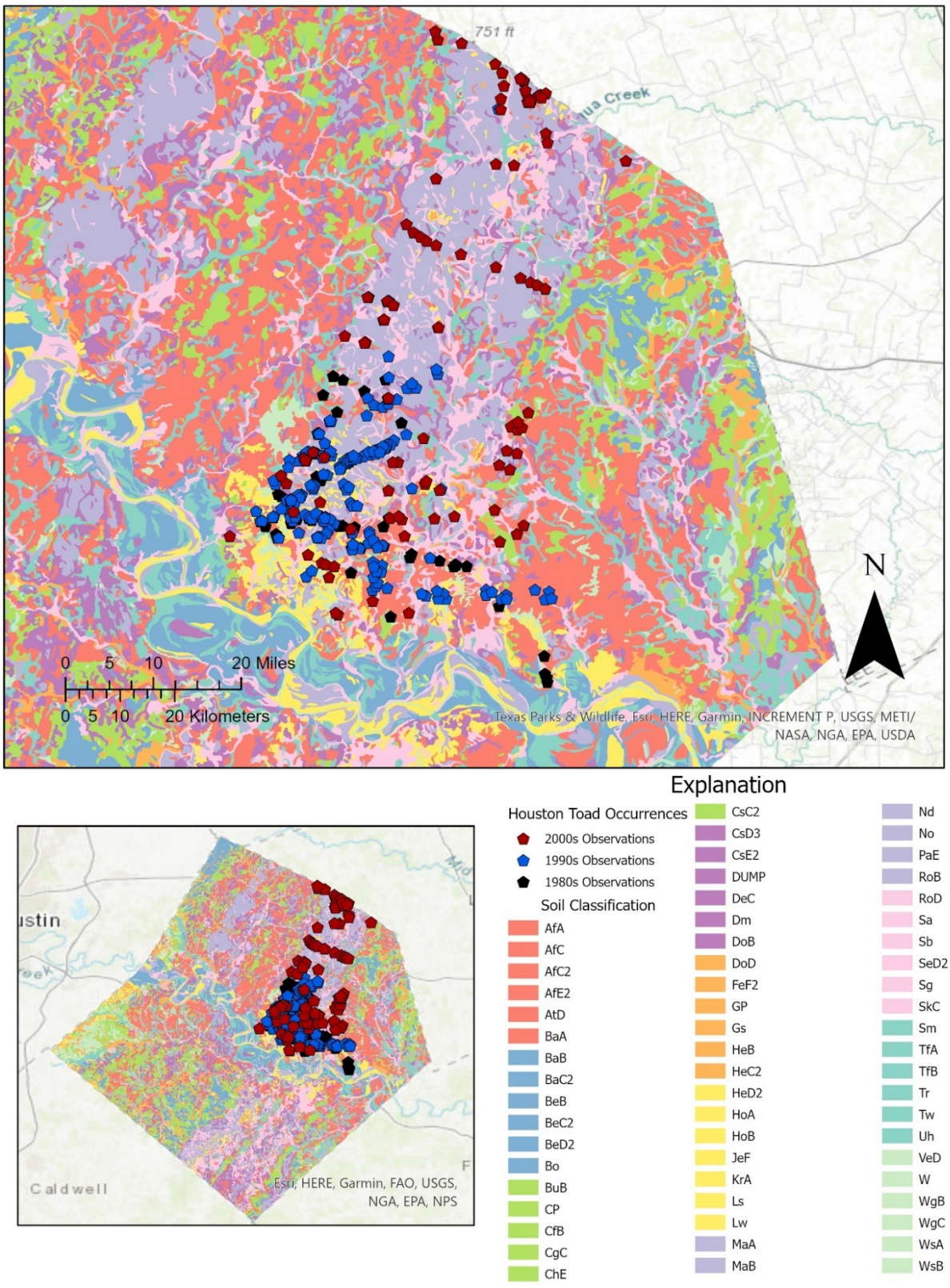


Figure 2. Houston toad (*Anaxyrus houstonensis*) detection points from 1980s, 1990s, and 2000s on a soil classification map of Bastrop County, TX. 1980s points are represented in black, 1990s points are blue, and 2000s points are red. A detailed table describing the soil units in the explanation can be found in Appendix B.

Table 1. Count of points per soil unit in Bastrop County for the three decades with a percent calculation for each decade. Soil abbreviations are standard abbreviations as documented in USDA (1979) (Appendix B).

Soil Unit	Number of Detections 1980	% of total 1980	Number of Detections 1990	% of total 1990	Number of Detections 2000	% of total 2000
AfC	1	1.32	1	0.45	4	4.12
AfC2	1	1.32	1	0.45	4	4.12
AtD	14	18.42	20	9.09	3	3.09
Bo	1	1.32	0	0.00	0	0.00
CsC2	0	0.00	0	0.00	1	1.03
CsE2	0	0.00	0	0.00	1	1.03
DeC	3	3.95	9	4.09	9	9.28
DoB	0	0.00	0	0.00	1	1.03
GP	0	0.00	1	0.45	0	0.00
JeF	13	17.11	28	12.73	7	7.22
MaA	2	2.63	1	0.45	2	2.06
PaE	12	15.79	91	41.36	29	29.90
Sa	3	3.95	10	4.55	6	6.19
SkC	10	13.16	34	15.45	15	15.46
TfA	0	0.00	0	0.00	3	3.09
TfB	12	15.79	20	9.09	8	8.25
VeD	1	1.32	1	0.45	0	0.00
W	3	3.95	3	1.36	4	4.12

Vegetation

Houston toad detection data and vegetation/ecological systems classification data showed changes in species distribution patterns across vegetation cover over time (Table 2; Figure 3). In the 1980s, the vegetation unit that contained the most points was the Loblolly Pine Forest in the Bastrop Lost Pines, equating to about 38 percent of points from that decade. Riparian Evergreen Forest had a proportion of about 14 percent of the points, and Young Post Oak Woodlands and Loblolly Pine-Oak Forest consisted of about 11 percent and 9 percent of points respectively for the 1980s. A small proportion of points were in areas of Urban Low Intensity (Table 2; Figure 3). In the 1990s, the Loblolly Pine Forest in the Bastrop Lost Pines and the Central Texas Riparian Evergreen Forest held the largest percentage of points, similarly to the 1980s. There was a major change to the proportion of points located in an area of Urban Low Intensity, as they more than doubled compared to the percentage of points observed in this area since the 1980s (Table 2; Figure 3). The largest change occurs from the 1990s to the 2000s. In the 2000s, the highest proportion of points was found in areas of Urban Low Intensity, at almost 19 percent of all points from the decade. The next highest percentages of points are found in Post Oak Savanna, specifically Post Oak/Yaupon Motte and Woodland as well as Savanna Grassland (Table 2; Figure 3)(Appendix C).

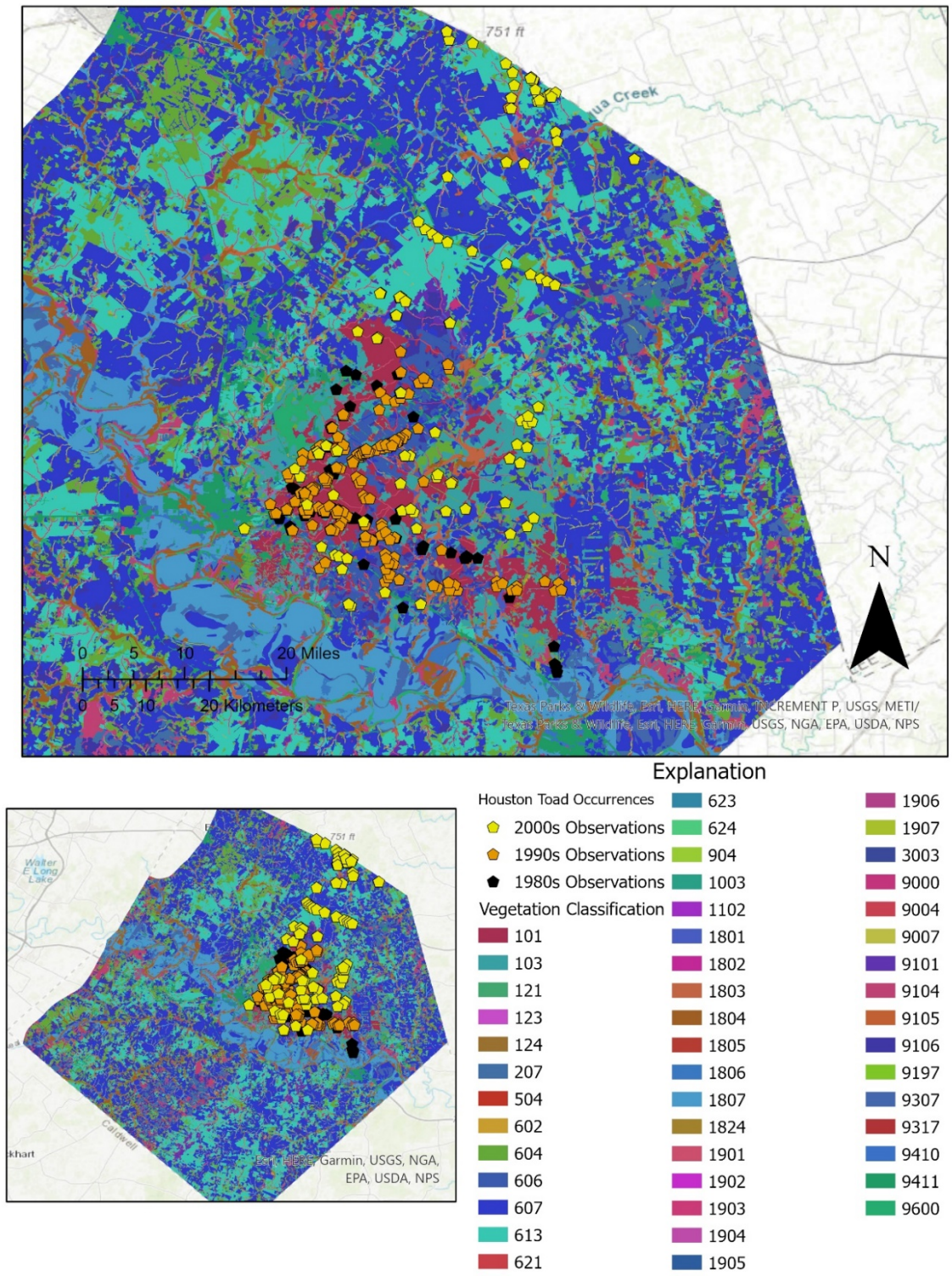


Figure 3. Houston toad (*Anaxyrus houstonensis*) detection points from 1980s, 1990s, and 2000s on a vegetation classification map of Bastrop County, TX. 1980s points are represented in black, 1990s points are in orange, and 2000s points are in yellow. A detailed table describing the vegetation units in the explanation can be found in Appendix C.

Table 2. Count of points per vegetation unit in Bastrop County for the three decades with a percent calculation for each decade. Vegetation units are standard as provided by TPWD (2014) (Appendix C).

Veg ID	Vegetation Type	Number of Detections 1980	% of total 1980	Number of Detections 1990	% of total 1990	Number of Detections 2000	% of total 2000
101	Bastrop Lost Pines: Loblolly Pine Forest	29	38.16	59	26.82	10	10.31
103	Bastrop Lost Pines: Loblolly Pine-Oak Forest	7	9.21	15	6.82	6	6.19
121	Bastrop Lost Pines: Loblolly Pine Slope Forest	0	0.00	1	0.45	0	0.00
602	Post Oak Savanna: Live Oak Motte and Woodland	0	0.00	1	0.45	1	1.03
604	Post Oak Savanna: Post Oak Motte and Woodland	0	0.00	0	0.00	4	4.12
606	Post Oak Savanna: Young Post Oak Woodland	8	10.53	29	13.18	1	1.03
607	Post Oak Savanna: Savanna Grassland	2	2.63	13	5.91	12	12.37
613	Post Oak Savanna: Post Oak / Yaupon Motte and Woodland	0	0.00	3	1.36	15	15.46
1801	Central Texas: Floodplain Evergreen Forest	0	0.00	2	0.91	1	1.03
1803	Central Texas: Floodplain Hardwood / Evergreen Forest	0	0.00	2	0.91	1	1.03
1804	Central Texas: Floodplain Hardwood Forest	3	3.95	2	0.91	4	4.12
1806	Central Texas: Floodplain Deciduous Shrubland	1	1.32	3	1.36	1	1.03

Veg ID	Vegetation Type	Number of Detections 1980	% of total 1980	Number of Detections 1990	% of total 1990	Number of Detections 2000	% of total 2000
1807	Central Texas: Floodplain Herbaceous Vegetation	1	1.32	2	0.91	0	0.00
1901	Central Texas: Riparian Evergreen Forest	11	14.47	31	14.09	7	7.22
1903	Central Texas: Riparian Hardwood / Evergreen Forest	1	1.32	6	2.73	3	3.09
1904	Central Texas: Riparian Hardwood Forest	0	0.00	1	0.45	3	3.09
1906	Central Texas: Riparian Deciduous Shrubland	3	3.95	5	2.27	2	2.06
1907	Central Texas: Riparian Herbaceous Vegetation	0	0.00	3	1.36	0	0.00
9101	Native Invasive: Juniper Woodland	1	1.32	2	0.91	5	5.15
9105	Native Invasive: Juniper Shrubland	1	1.32	2	0.91	0	0.00
9106	Native Invasive: Mesquite Shrubland	2	2.63	4	1.82	1	1.03
9410	Urban High Intensity	1	1.32	1	0.45	18	18.56
9411	Urban Low Intensity	5	6.58	30	13.64	0	0.00
9600	Open Water	0	0.00	3	1.36	2	2.06

Geology

The geology is less diverse in this region than the soil and vegetation classifications, however Houston toad detections occurred across different geologic units over time (Table 3; Figure 4). The Houston toad points were observed on two types of geology, Claiborne group (2eT) and Wilcox group (1eT), both found within the U.S. Atlantic and Great Coastal Plains. For the 1980s-decade, Claiborne group contained most observation points, at about 87 percent (Table 3; Figure 4). This percentage is much higher in the 1990s with the Claiborne group containing 94 percent of points from the decade (Table 3; Figure 4). For the 2000s, this percentage fell back down to 80 percent of points in the Claiborne group (Table 3; Figure 4) (Appendix D).

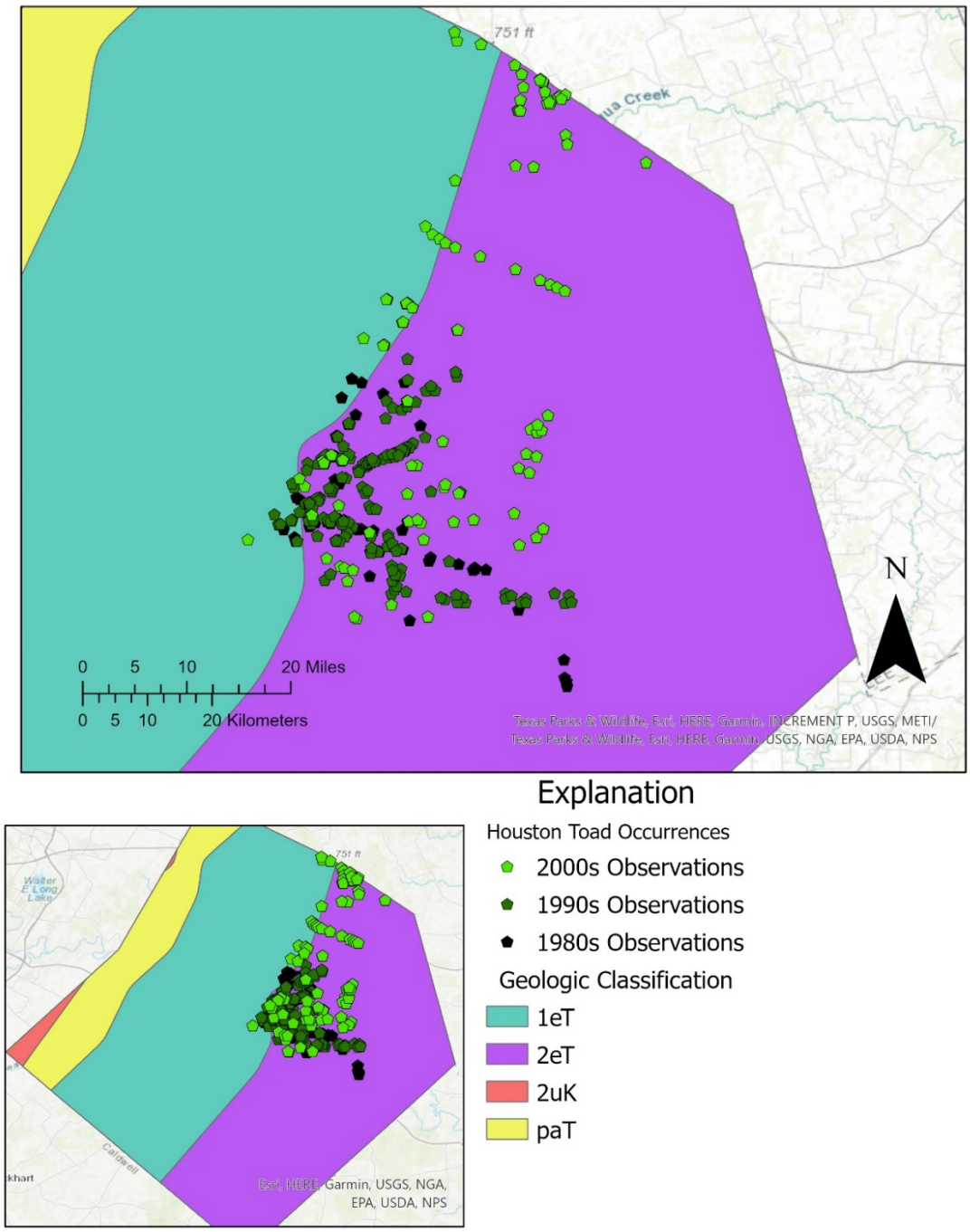


Figure 4. Houston toad detection points from 1980s, 1990s, and 2000s on a geology classification map of Bastrop County, TX. 1980s points are represented in black, 1990s points are in dark green and 2000s points are in light green. A detailed table describing the geology units in the explanation can be found in Appendix D.

Table 3. Count of points per geologic unit in Bastrop County for the three decades with a percent calculation for each decade. Geologic units are standard as provided by USGS et al. (2020) (Appendix D).

Geologic Unit	Rock Type	Age	Number of Detections 1980	% of total 1980	Number of Detections 1990	% of total 1990	Number of Detections 2000	% of total 2000
Claiborne Group (2eT)	Sedimentary	Middle Eocene	66	86.84	207	94.09	78	80.41
Wilcox Group (1eT)	Sedimentary	Lower Eocene	10	13.16	13	5.91	19	19.59

DISCUSSION

The detection of the Houston toad across soil, vegetation and geologic landscapes were examined in this study. Overall, the Houston toad detections remained mostly within moderate to deep sandy, clayey and gravelly soils. Detections also tended to be situated in areas with canopy cover, mostly consisting of the Loblolly Pine Forest and Post Oak Savanna, with an increase of detections within the urban realm. Houston toads were detected within two types of geology for the 3 decades examined, to include the Wilcox and Claiborne groups.

The preference of the Houston toad populations to deep, sandy soils is well-known (Seal et al. 1994; Wallace 2015). Most early surveys relied heavily on the Seal et al. (1994) diagnosis of likely habitat (deeps sands and canopy) despite the data from Yantis and Price (1993) being available to the recovery group. Yantis and Price (1993) demonstrated Houston toads occurred in a wide array of habitat associations over moderate depth to deep sands in Texas. Therefore, the spatial position of Houston toad detections on soils such as AtD, JeF, TfB, PaE, and SkC was expected. AtD is the soil unit that most Houston toad detections were located on in the 1980s. AtD is classified as an Axtell-Tabor complex, which is a gently sloping and is generally characterized as a gravelly-sandy soil surface with a sandy, clay base underneath. AtD soils are present in wooded areas. JeF had almost as many detections in the 1980s as there were on the AtD soils. JeF is classified as Jedd stony soils, which are moderately sloped and are characterized by a gravelly-sandy soil surface with a presence of small gravel to stones. JeF soils are used to support wildlife habitat and wooded areas as they are too erosive for crop-growing. TfB is classified as Tabor fine sandy loam and has characteristics such as gentle slopes and a fine, sandy loam soil structure. TfB soil is commonly found in pastures and ranges. TfB and PaE soils were the next highest regarding Houston toad detections in the 1980s. Houston toad detections on PaE soil more than doubled in

proportion to the total collected points between the 1980's and 1990s observations. PaE soil is classified as Patilo complex soil. PaE sloping can vary from gentle to strong and is structured with a thick, sandy, billowy surface and a sandy clay that begins about 30 inches down. This soil type is mostly present in wooded ranges. Lastly, Houston toad detections in soil class SkC had increased steadily between the 1980s and 1990s and remained the second highest in detections through the 2000s. SkC is classified as Silstid loamy fine sand and is a gently sloping soil. It is characterized as a fine sandy loam soil and is found mostly in ranges and woodland habitats (USDA 1979)(Appendix B). From the predominant detection of the Houston toad on these soil types over three decades, it can be inferred that soil preference weighs heavily in the spatial patterns of species detection. It also can be inferred that because most of the soil types listed occur in wooded areas that the preference of habitat with a canopy cover is also heavily accounted for in the change in detection locations of the Houston toad over three different decades. Additional map documents representing the data by decade can be found in Appendixes E, F, and G.

Suitable habitat requirements for the Houston toad also include substantial canopy cover (Seal et al. 1994; Wallace 2015). Vegetation analysis with the Houston toad detection data shows that the Houston toad wooded range tends to mainly include the Loblolly Pine Forest in the Bastrop Lost Pines, Post Oak Savanna Woodlands as well as Central Texas Riparian Evergreen Forest and even areas of Urban Low Intensity. The 1980s analysis showed most significance in the Loblolly Pine Forest in the Bastrop Lost Pines. Areas of lesser significance that still had a substantial number of detection points included the Riparian Evergreen Forest, Young Post Oak Woodlands, and the Loblolly Pine-Oak Forest. Urban Low Intensity, characterized by areas that have been developed but not fully covered by impervious surface to include the non-industrial areas within a city or town, has a small number of detections within it in the 1980s but is not nearly as much as

the wooded areas. In the 1990s, the Loblolly Pine Forest in the Bastrop Lost Pines remained the highest in Houston toad detections, with the Riparian Evergreen Forest next in significance. While these two proportions are like those found in the 1980s analysis, there was a major increase in detections within areas of Urban Low Intensity, which was over twice the detections in these areas in the 1980s. The 2000s data showed the most dramatic changes with the greatest number of detections now found in areas of Urban Low Intensity and Post Oak Savanna, and Savanna Grasslands contained the second highest number of detections (Appendix C). The detection of populations from areas of canopy cover increasing into areas where there have been moderate anthropogenic impacts is an important pattern found in this analysis. These changes could be due to several reasons. Increasing urbanization within the wooded habitat of the Houston toad, including transportation and residential development can have a major impact on the distribution of the species. This result is not to imply that the Houston toad populations are moving into areas of urbanization, but that the Houston toads have already existed in these areas and are being increasingly detected in areas of urbanization as the human population continues to develop within the habitat. Land-use practices and small developments within land parcels such as ponds built by landowners can also affect the breeding and spatial patterns of the Houston toad. For instance, the increase in ponds, livestock tanks and other water bodies by landowners in the past century have presented new complications for the Houston toad in that there is a decrease in toad density at each pond, lowering the chorus attendance by males and therefore negatively impacting the reproductive success of Houston toad populations (Gaston et al. 2010). Additional map documents representing the data by decade can be found in Appendixes H, I, and J.

Regarding geology, very few changes existed for the observation numbers over the course of three decades. The Claiborne group (2eT) was the unit that most Houston toad detection points

were in across all decades. Wilcox group (1eT) had points present in each decade, but only a very small amount. This is most likely because the geology in the region is not nearly as complex as the soil and vegetation attributes of the same study area. Claiborne group covered most of the area immediately around the point locations while Wilcox group was only present for a small part of the eastern portion of the point aggregation. Both Claiborne and Wilcox groups are classified as sedimentary in structure, but there is a difference in that age- Claiborne group is aged to the Middle Eocene and Wilcox group is aged to the Lower Eocene (USGS et al. 2020)(Appendix D). Additional map documents representing the data by decade can be found in Appendixes K, L, and M.

There are many environmental factors that could directly impact the Houston toad habitat and cause these changes in detection patterns over time. These factors include development and urbanization, agricultural practices, drought and wildfire, and invasive species (Seal 1994; Wallace 2015; Raney 2013; Gotelli and Arnett 2000; Cook 2003; Freed and Neitman 1988, Brown, Devolld, and Forstner 2012; Brown et al. 2012). If these environmental factors continue to impact the Houston toad environment at the same or increasing rate, we can expect substantial changes in the detection patterns to continue over future decades, possibly into further changed habitats not necessarily within the preference or tolerance of the Houston toad populations.

Limitations of the data include the inconsistent spatial nature of gathering species detections in the field, especially for a species that can be moderately reclusive such as the Houston toad. The study was limited to the areas where field notes were taken so it can be assumed that the range of the Houston toad populations is greater than what was observed within the study area. Other limitations include results that may not present as meaningful of patterns at a 10-year scale as they would at a 5- or 1-year scale of analysis. A 5-year scale may portray more

continuity in spatial patterns and may provide results more directly related to certain human and environmental factors that occur in shorter periods of time, such as inter-annual weather patterns (wet, dry, and normal years) and urbanization or development that could lead to habitat destruction or new road access to detections sites. This time frame also follows the lifespan of the Houston toad more closely and can provide more accurate results from a biological perspective.

Some improvements and other studies in the future could include a higher temporal resolution of analysis, the use of more point data as it becomes available, expansion of the study into other counties that are known to contain Houston toad habitat, road density data corresponding to the survey dates, and the use of multiple landcover data sets spanning the detection sampling time frame. Future analysis could also include the use of thiessen polygons to provide a buffer of 500m to account for the distance that Houston toads can be detected via audio survey, this would help remove false positives for multiple detection of the same individual. This can help to standardize the data to reduce the impact of inequalities in detection numbers per time interval. The road density could provide a good proxy for patterns of encroaching rural-urban development on Houston toad habitat and land cover data could be used to detect changes in pond density and sizes over time. It is hypothesized that as urbanization increases so do the number of small pond and stock tanks. These likely influence breeding behavior and success by creating more dispersed populations among males and females.

CONCLUSION

The purpose of this research was to examine the spatial distribution patterns of Houston toad detections over the span of three decades to determine whether the patterns of species detections has changed across soil, geologic and vegetation landscapes in the 1980s, 1990s, and

2000s. Over the course of three decades, the detections of Houston toads were generally situated upon sandy, gravelly, and clayey soils, areas with moderate to heavy canopy cover consisting of the Loblolly Pine Forest and Bastrop Lost pines, and sedimentary-type Middle and Lower Eocene-aged geologic structures. An increase in detection was observed in low-intensity urban areas as well, which could be due to continuous development within the habitat range in Bastrop County over the past few decades. This study provides important insight in understanding the soil, geologic and vegetation types preferred in the habitat of the Houston toad and the spatial patterns associated with how the species is navigating the landscape over time.

APPENDIX

Appendix A: Houston toad detection data acquired from Buzo 2008.

ID	YEAR	CITATION	SOURCE
BAS_1	1990	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_2	1990	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_3	1990	Dixon & Price	Buzo 2008 (Tannika's 2001 Files)
BAS_4	1990	Dixon & Price	Buzo 2008 (Tannika's 2001 Files)
BAS_5	1990	Dixon & Price	Buzo 2008 (Tannika's 2001 Files)
BAS_6	1990	Dixon & Price	Buzo 2008 (Tannika's 2001 Files)
BAS_7	1990	Dixon & Price	Buzo 2008 (Tannika's 2001 Files)
BAS_8	1990	Dixon & Price	Buzo 2008 (Tannika's 2001 Files)
BAS_9	1990	Dixon & Price	Buzo 2008 (Tannika's 2001 Files)
BAS_10	1990	Dixon & Price	Buzo 2008 (Tannika's 2001 Files)
BAS_11	1990	Dixon & Price	Buzo 2008 (Tannika's 2001 Files)
BAS_12	1990	Dixon & Price	Buzo 2008 (Tannika's 2001 Files)
BAS_13	1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_14	1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_15	1990	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_16	1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_17	1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_18	1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_19	1990	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_20	1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_21	1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_22	1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_23	1991	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_24	1992	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_25	1992	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_26	1995	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_27	1995	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_28	1995	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_29	1995	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_30	1995	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_31	1995	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_32	1998	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_33	1998	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_34	2000	Michael Forstner	Buzo 2008 (Tannika's 2001 Files)
BAS_35	2000	Michael Forstner	Buzo 2008 (Tannika's 2001 Files)
BAS_36	2000	Michael Forstner	Buzo 2008 (Tannika's 2001 Files)
BAS_37	2000	Michael Forstner	Buzo 2008 (Tannika's 2001 Files)
BAS_38	2000	Michael Forstner	Buzo 2008 (Tannika's 2001 Files)
BAS_39	2000	Michael Forstner	Buzo 2008 (Tannika's 2001 Files)
BAS_40	2000	Michael Forstner	Buzo 2008 (Tannika's 2001 Files)
BAS_41	2000	Michael Forstner	Buzo 2008 (Tannika's 2001 Files)
BAS_42	2001	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_43	2001	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_44	2001	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_45	2001	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_46	2001	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_47	2001	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_48	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_49	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_50	pre-1990	Martin et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_51	pre-1990	Martin et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_52	pre-1990	Martin et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_53	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_54	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_55	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_56	pre-1990	Martin et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_57	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_58	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_59	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_60	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_61	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_62	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_63	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_64	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_65	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_66	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_67	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_68	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_69	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_70	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_71	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_72	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_73	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_74	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_75	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_76	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_77	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_78	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_79	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_80	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_81	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_82	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_83	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_84	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_85	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_86	pre-1990	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_87	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_88	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_89	pre-1990	James R. Dixon	Buzo 2008 (Tannika's 2001 Files)
BAS_90	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_91	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_92	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_93	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_94	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_95	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_96	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_97	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_98	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_99	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_100	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_101	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_102	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_103	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_104	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_105	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_106	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_107	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_108	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_109	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_110	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_111	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_112	1984	Hillis et al.	Buzo 2008 (Tannika's 2001 Files)
BAS_113	1986	Houston Zoo	Buzo 2008 (Tannika's 2001 Files)
BAS_114	1987	Houston Zoo	Buzo 2008 (Tannika's 2001 Files)
BAS_115	1989	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_116	1989	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_117	1989	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)

ID	YEAR	CITATION	SOURCE
BAS_118	1989	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_119	1989	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_120	1989	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_121	1989	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_122	1989	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_123	1989	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_124	1990	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_125	1990	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_126	1990	Dixon et al.-Texas A&M for TPWD	Buzo 2008 (Toad's Files)
BAS_127	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_128	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_129	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_130	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_131	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_132	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_133	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_134	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_135	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_136	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_137	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_138	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_139	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_140	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_141	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_142	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_143	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_144	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_145	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_146	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_147	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_148	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_149	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_150	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_151	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_152	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_153	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_154	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_155	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_156	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_157	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_158	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_159	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_160	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_161	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_162	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_163	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_164	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_165	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_166	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_167	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_168	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_169	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_170	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_171	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_172	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_173	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_174	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_175	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_176	1990	Horizon Environmental Services, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_177	1990	Price	Buzo 2008 (Toad's Files)
BAS_178	1991	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_179	1991	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_180	1991	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_181	1991	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_182	1991	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_183	1991	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_184	1992	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_185	1992	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_186	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_187	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_188	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_189	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_190	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_191	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_192	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_193	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_194	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_195	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_196	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_197	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_198	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_199	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_200	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_201	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_202	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_203	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_204	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_205	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_206	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_207	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_208	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_209	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_210	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_211	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_212	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_213	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_214	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_215	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_216	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_217	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_218	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_219	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_220	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_221	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_222	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_223	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_224	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_225	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_226	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_227	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_228	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_229	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_230	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_231	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_232	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_233	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_234	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_235	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_236	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)
BAS_237	1993	Espey, Huston, and Associates, Inc.	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_238	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_239	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_240	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_241	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_242	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_243	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_244	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_245	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_246	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_247	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_248	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_249	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_250	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_251	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_252	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_253	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_254	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_255	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_256	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_257	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_258	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_259	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_260	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_261	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_262	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_263	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_264	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_265	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_266	1993	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_267	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_268	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_269	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_270	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_271	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_272	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_273	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_274	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_275	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_276	1994	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_277	1994	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_278	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_279	1994	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_280	1994	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_281	1994	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_282	1994	LCRA	Buzo 2008 (Tannika's 2001 Files)
BAS_283	1994	Espey, Huston, and Associates, Inc.	Buzo 2008 (Toad's Files)
BAS_284	1995	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_285	1995	TxDOT	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_286	1995	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_287	1995	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_288	1995	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_289	1995	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_290	1995	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_291	1995	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_292	1995	TxDOT	Buzo 2008 (Tannika's 2001 Files)
BAS_293	1995	Espey, Huston, and Associates, Inc.	Buzo 2008 (Toad's Files)
BAS_294	1995	Espey, Huston, and Associates, Inc.	Buzo 2008 (Toad's Files)
BAS_295	1995	Espey, Huston, and Associates, Inc.	Buzo 2008 (Toad's Files)
BAS_296	1995	Espey, Huston, and Associates, Inc.	Buzo 2008 (Toad's Files)
BAS_297	1995	Espey, Huston, and Associates, Inc.	Buzo 2008 (Toad's Files)
BAS_298	1997	Hicks & Company	Buzo 2008 (Tannika's 2001 Files)
BAS_299	1997	Hicks & Company	Buzo 2008 (Tannika's 2001 Files)
BAS_300	1997	Hicks & Company	Buzo 2008 (Tannika's 2001 Files)
BAS_301	1997	Hicks & Company	Buzo 2008 (Tannika's 2001 Files)
BAS_302	1999	PBS&J	Buzo 2008 (Toad's Files)
BAS_303	1999	PBS&J	Buzo 2008 (Toad's Files)
BAS_304	1999	PBS&J	Buzo 2008 (Toad's Files)
BAS_305	1999	PBS&J	Buzo 2008 (Toad's Files)
BAS_306	1999	PBS&J	Buzo 2008 (Toad's Files)
BAS_307	2000	Michael Forstner	Buzo 2008 (Toad's Files)
BAS_308	2000	Michael Forstner	Buzo 2008 (Toad's Files)
BAS_309	2000	Michael Forstner	Buzo 2008 (Toad's Files)

ID	YEAR	CITATION	SOURCE
BAS_310	2000	Michael Forstner	Buzo 2008 (Toad's Files)
BAS_311	2000	Michael Forstner	Buzo 2008 (Toad's Files)
BAS_312	2000	Michael Forstner	Buzo 2008 (Toad's Files)
BAS_313	2000	Michael Forstner	Buzo 2008 (Toad's Files)
BAS_314	2000	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_315	2000	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_316	2000	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_317	2000	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_318	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_319	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_320	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_321	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_322	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_323	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_324	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_325	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_326	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_327	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_328	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_329	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_330	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_331	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_332	2001	USFWS	Buzo 2008 (Tannika's 2001 Files)
BAS_333	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)

ID	YEAR	CITATION	SOURCE
BAS_334	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_335	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_336	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_337	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_338	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_339	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_340	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_341	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_342	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_343	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_344	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_345	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_346	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_347	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_348	2001	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_349	2001	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_350	2001	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_351	2001	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_352	2001	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_353	2001	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_354	2001	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_355	2001	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_356	2001	Price	Buzo 2008 (Tannika's 2001 Files)
BAS_357	2001	Price	Buzo 2008 (Tannika's 2001 Files)

ID	YEAR	CITATION	SOURCE
BAS_358	2002	USFWS	Buzo 2008 (Toad's Files)
BAS_359	2002	USFWS	Buzo 2008 (Toad's Files)
BAS_360	2002	USFWS	Buzo 2008 (Toad's Files)
BAS_361	2002	USFWS	Buzo 2008 (Toad's Files)
BAS_362	2002	USFWS	Buzo 2008 (Toad's Files)
BAS_363	2002	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_364	2003	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_365	2003	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_366	2003	Horizon Environmental Services, Inc.	Buzo 2008 (TxDOT Toads)
BAS_367	2004	SWCA	Buzo 2008 (Field Surveys- Lost Pines)
BAS_368	2004	SWCA	Buzo 2008 (Field Surveys- Lost Pines)
BAS_369	2004	SWCA	Buzo 2008 (Field Surveys- Lost Pines)
BAS_370	2004	SWCA	Buzo 2008 (Field Surveys- Lost Pines)
BAS_371	2004	SWCA	Buzo 2008 (Field Surveys- Lost Pines)
BAS_372	2004	SWCA	Buzo 2008 (Field Surveys- Lost Pines)
BAS_373	1994	Espey, Huston, and Associates, Inc.	Buzo 2008 (TxDOT's Points)
BAS_374	1994	Espey, Huston, and Associates, Inc.	Buzo 2008 (TxDOT's Points)
BAS_375	1994	Espey, Huston, and Associates, Inc.	Buzo 2008 (TxDOT's Points)
BAS_376	1994	Espey, Huston, and Associates, Inc.	Buzo 2008 (TxDOT's Points)
BAS_377	1994	Espey, Huston, and Associates, Inc.	Buzo 2008 (TxDOT's Points)
BAS_378	1994	Espey, Huston, and Associates, Inc.	Buzo 2008 (TxDOT's Points)
BAS_379	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_380	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_381	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)

ID	YEAR	CITATION	SOURCE
BAS_382	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_383	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_384	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_385	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_386	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_387	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_388	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_389	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_390	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_391	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_392	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_393	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_394	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)
BAS_395	2002	SWCA, Environmental Consultants	Buzo 2008 (TxDOT's Points)

Appendix B. Table with soil types and descriptions (USDA 1979).

SOIL TYPE	DESCRIPTION
AfC: Axtell fine sandy loam	1-5% slopes, located on ridgetops and side slopes. Suitable for improved pasture and wooded pasture
AfC2: Axtell fine sandy loam	2-5% slopes, surface layer of fine sandy loam 6 inches thick with a 36-inch subsoil layer of mottled clay and mottled sandy clay underneath to about 64 inches. Suitable for improved pasture and wooded range.
AtD: Axtell-Tabor complex	1-8% slopes, surface layer of gravelly sandy loam about 14 inches deep with mottled clay underneath to about 28 inches and mottled sandy clay to 60 incles. Suitable for wooded range.
Bo: Bosque Loam	Less than 0.5% slopes. Suitable for cultivated crops and improved pasture.
CsC2: Crockett soils	2-5% slopes, surface layer ranging from loam to fine sandy loam. Suitable for crops.
CsE2: Crockett soils	5-10% slopes, surface layer of dark greyish-brown loam or fine sandy loam to 4 inches, with mottled clay subsoil to 56 inches deep. Suitable for pasture, wildlife habitat, and range.

SOIL TYPE	DESCRIPTION
DeC: Demona loamy fine sand	1-5% slopes, located on ridgetops and side slopes. Suitable for range and wildlife habitat, some crops.
DoB: Dougherty loamy fine sand	0-3% slopes, located on high terraces and ridgetops. Suitable for pasture, some crops.
GP: Gowen soils	Less than 0.5% slopes. Suitable for improved pasture or hay.
JeF: Jedd stony soils	5-20% slopes, surface layer made of gravelly sandy loam to gravelly loamy sand with siliceous pebbles. Suitable for wildlife habitat and wooded range.
MaA: Mabank loam	0-1% slopes, surface layer is grayish-broan loam about 6 inches deep with a clay subsoil to 48 inches. Suitable for crops, some pasture.
PaE: Patilo complex	1-12% slopes, surface layer is thick, billowy, sandy surface layer to 30 inches deep with mottled clay underneath. Suitable for woodland, range and crops.
Sa: Sayers fine sandy loam	Less than 1% slopes, located on bottom lands. Suitable for pasture and wooded range.
SkC: Silstid loamy fine sand	1-5% slopes, located on uplands. Suitable for range and wildlife habitat.

SOIL TYPE	DESCRIPTION
TfA: Tabor fine sandy loam	0-1% slopes, surface layer of fine sandy loam about 16 inches deep with a mottled clay subsoil to 52 inches and a mottled clay loam to 70 inches. Suitable for pasture and range.
TfB: Tabor fine sandy loam	1-3% slopes, found on ridgetops, foot slopes and in drainageways. Suitable for pasture and range.
VeD: Vernia complex	1-8% slopes, located on uplands. Suitable for range.
W: Wilson series	Nearly level, surface layer of grey clay loam to 6 inches deep, clay to 42 inches and mottled, calcareous clay to 65 inches deep. Suitable for crops, pasture and range.

Appendix C. Table with vegetation types and descriptions (TPWD 2014).

VEGETATION TYPE	DESCRIPTION
Bastrop Lost Pines: Loblolly Pine Forest	Loblolly Pine (*Pinus taeda*) is dominant, understory mainly consists of Farkleberry (*Vaccinium arboreum*), and Little Bluestem (*Schizachyrium scoparium*).
Bastrop Lost Pines: Loblolly Pine-Oak Forest	Transition from a Loblolly Pine (*Pinus taeda*) dominated forest to a post oak savanna. Post Oak (*Quercus stellata*) and Blackjack Oak (*Quercus marilandica*) are prominent, however the Loblolly Pine continues to dominate.
Bastrop Lost Pines: Loblolly Pine Slope Forest	Loblolly Pine (*Pinus taeda*) dominated forest with minor presence of Post Oak (*Quercus stellata*) and Blackjack Oak (*Quercus marilandica*), however the Loblolly Pine continues to dominate. This area is characterized by slopes greater than twenty percent.
Post Oak Savanna: Live Oak Motte and Woodland	Plateau Live Oak (*Quercus fusiformis*) or Coastal Live Oak (*Quervus virginiana*) dominate. Post Oak (*Quercus stellata*) may be present, however minor.
Post Oak Savanna: Post Oak Motte and Woodland	Post Oak (*Quercus stellata*), Plateau Live Oak (*Quercus fusiformis*) and Blackjack Oak (*Quercus marilandica*) are dominant.
Post Oak Savanna: Young Post Oak Woodland	Post Oak (*Quercus stellata*) dominant.
Post Oak Savanna: Savanna Grassland	Grasslands dominated by mid- and tallgrass species such as Little Bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*) and Switchgrass

VEGETATION TYPE	DESCRIPTION
Post Oak Savanna: Post Oak / Yaupon Motte and Woodland	Post Oak (*Quercus stellata*) dominant. Dense layer of Yaupon (*Ilex vomitoria*) present.
Central Texas: Floodplain Evergreen Forest	Eastern Redcedar (*Juniperous virginiana*) dominant. Sometimes Loblolly Pine (*Pinus taeda*) is dominant.
Central Texas: Floodplain Hardwood / Evergreen Forest	Plateau Live Oak (*Quercus fusiformis*) most common. Characterized as a mix of evergreen and deciduous canopy species.
Central Texas: Floodplain Hardwood Forest	Deciduous species dominant in the canopy.
Central Texas: Floodplain Deciduous Shrubland	Deciduous shrubs such as Possumhaw (*Ilex decidua*), Honey Mesquite (*Prosopis glandulosa*), Black Willow (*Salix nigra*), Roughleaf Dogwood (*Cornus drummondii*), and Common Buttonbush (*Cephalanthus occidentalis*) dominant.
Central Texas: Floodplain Herbaceous Vegetation	No significant overstory. Non-native grass species such as Bermudagrass (*Cynodon dactylon*), King Ranch Bluestem (*Bothriochloa ischaemum var. songarica*), and Johnsongrass (*Sorghum halepense*) dominant.
Central Texas: Riparian Evergreen Forest	Eastern Redcedar (*Juniperous virginiana*) dominant. Sometimes Loblolly Pine (*Pinus taeda*) or Shortleaf Pine (*Pinus echinata*) is dominant.

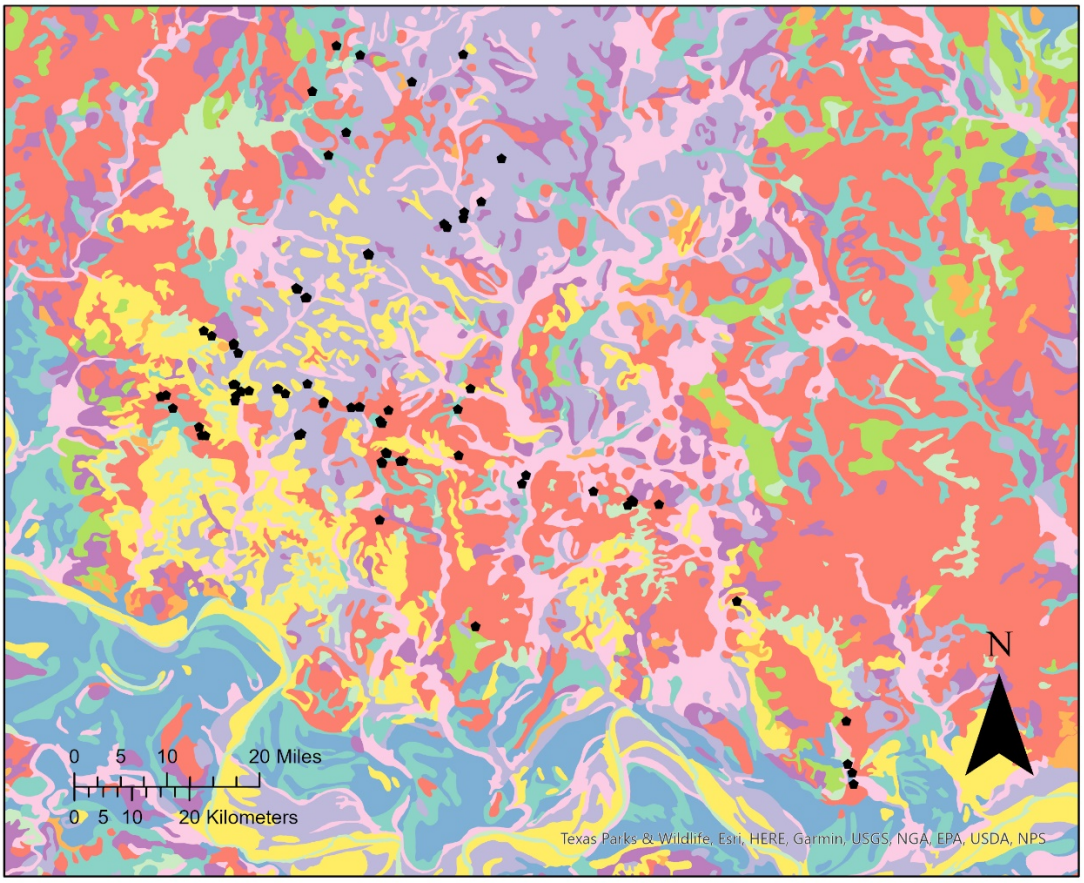
VEGETATION TYPE	DESCRIPTION
Central Texas: Riparian Hardwood / Evergreen Forest	Mix of evergreen species such as Eastern Redcedar (*Juniperus virginiana*), various Pines (*Pinus sp.*) Plateau Live Oak (*Quercus fusiformis*) and/or Coastal Live Oak (*Quercus virginiana*) dominant.
Central Texas: Riparian Hardwood Forest	Deciduous species dominant in the canopy.
Central Texas: Riparian Deciduous Shrubland	Deciduous shrubs such as Possumhaw (*Ilex decidua)*, Honey Mesquite (*Prosopis glandulosa*), Black Willow (*Salix nigra*), Roughleaf Dogwood (*Cornus drummondii*), Swamp Privet (*Forestiera acuminata*) and Common Buttonbush (*Cephalanthus occidentalis*) dominant.
Central Texas: Riparian Herbaceous Vegetation	Lacks canopy, but herbaceous cover is dominated by Little Bluestem (*Schizachyrium scoparium*) and Indiangrass (*Sorghastrum nutans*).
Native Invasive: Juniper Woodland	Ashe Juniper (*Juniperus ashei*) dominant in the Northwest, Eastern Redcedar (*Juniperus virginiana*) dominant in the Northeast and East, Redberry Juniper (*Juniperus pinchotii*) dominant in the Northwest and Plateau Live Oak (*Quercus fusiformis*) common.
Native Invasive: Juniper Shrubland	Various Juniper (*Juniperus sp.*) dominate, primarily Eastern Redcedar (*Juniperus virginiana*).
Native Invasive: Mesquite Shrubland	Honey Mesquite (*Prosopis glandulosa*) dominant.

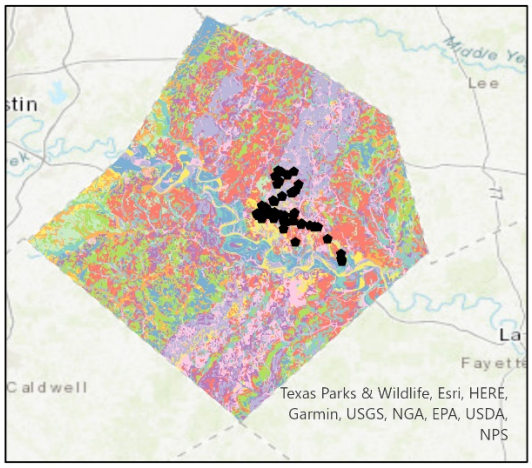
VEGETATION TYPE	DESCRIPTION
Urban High Intensity	Areas with high levels of development and large transportation networks with majority impervious cover; industrial areas within a city or town.
Urban Low Intensity	Areas that have been developed but are not fully covered by impervious surface; non-industrial areas within a city or town.
Open Water	Area characterized by a body of water.

Appendix D. Table with geology types and descriptions (USGS et al. 2020).

Geology Type	Description
1eT: Wilcox Group	Sedimentary-type geology aged from the Lower Eocene
2eT: Claiborne Group	Sedimentary-type geology aged from the Middle Eocene

Appendix E. Houston toad observation points from 1980-1989 on a soil classification map of Bastrop County, TX.



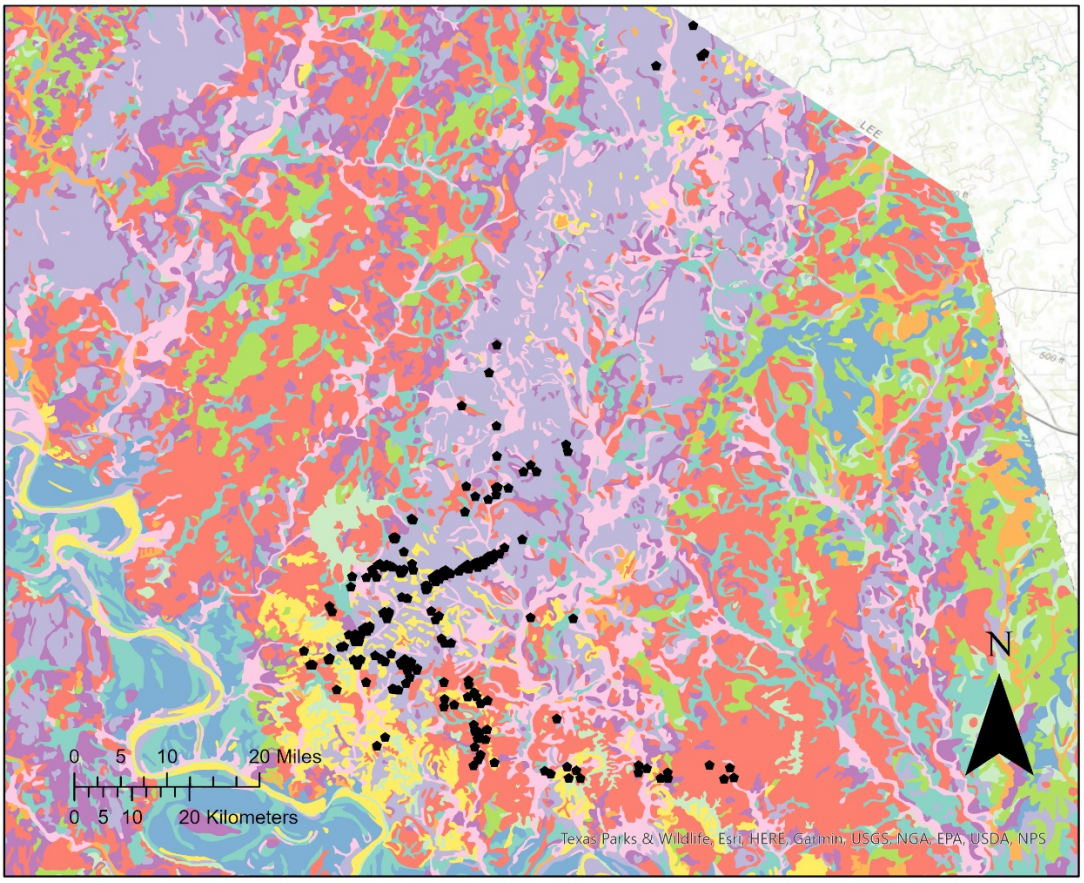


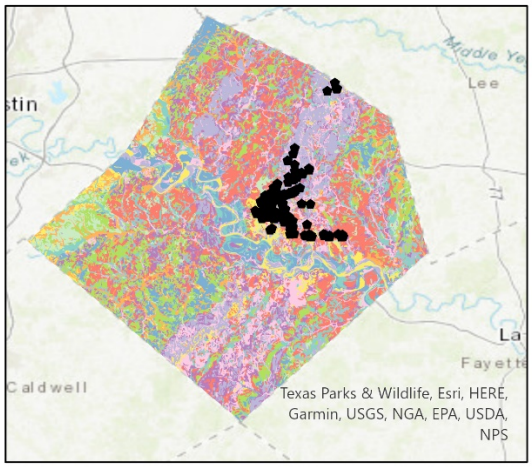
Explanation

Houston Toad Occurrences
- 1980s Observations

Soil Classification
- AfA
- AfC
- AfC2
- AfE2
- AtD
- BaA
- BaB
- BaC2
- BeB
- BeC2
- BeD2
- Bo
- BuB
- CP
- CfB
- CgC
- ChE
- CsC2
- CsD3
- CsE2
- DUMP
- DeC
- Dm
- DoB
- DoD
- FeF2
- GP
- Gs
- HeB
- HeC2
- HeD2
- HoA
- HoB
- JeF
- KrA
- Ls
- Lw
- MaA
- MaB
- Nd
- No
- PaE
- RoB
- RoD
- Sa
- Sb
- SeD2
- Sg
- SkC
- Sm
- TfA
- TfB
- Tr
- Tw
- Uh
- VeD
- W
- WgB
- WgC
- WsA
- WsB

Appendix F. Houston toad observation points from 1990-1999 on a soil classification map of Bastrop County, TX.





Explanation

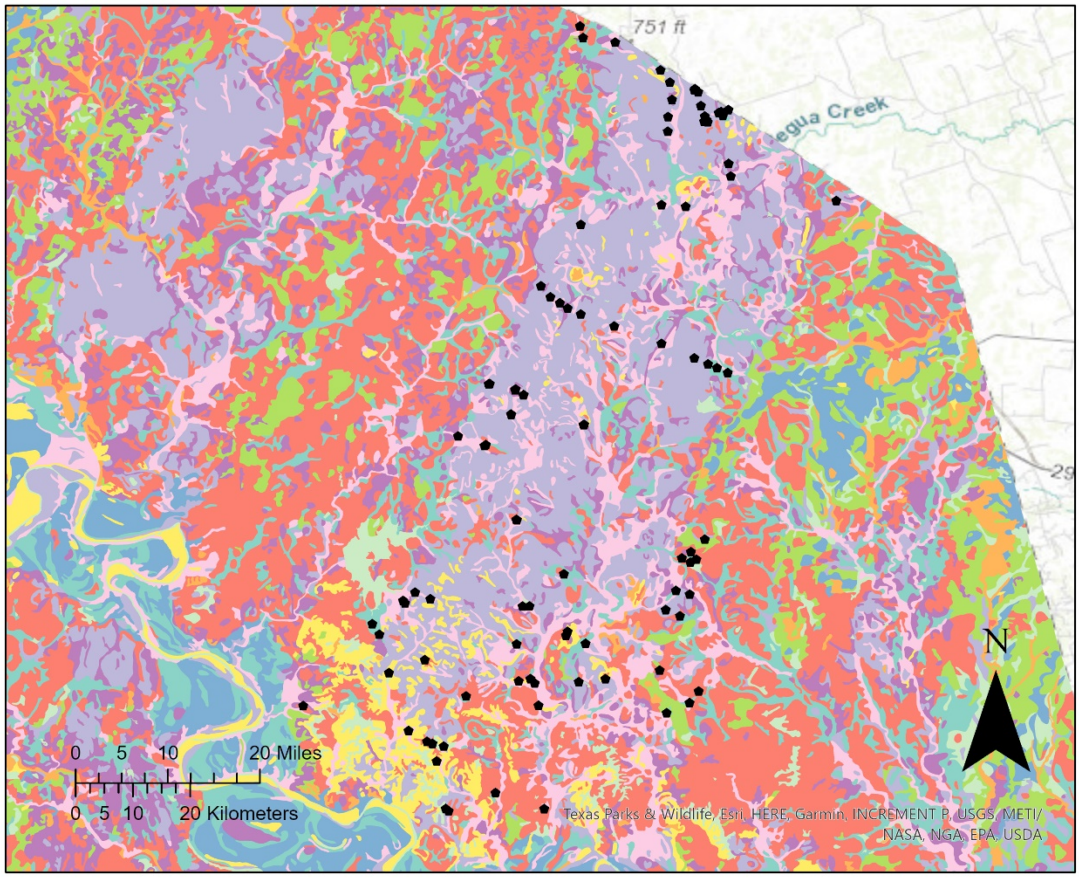
Houston Toad Occurrences

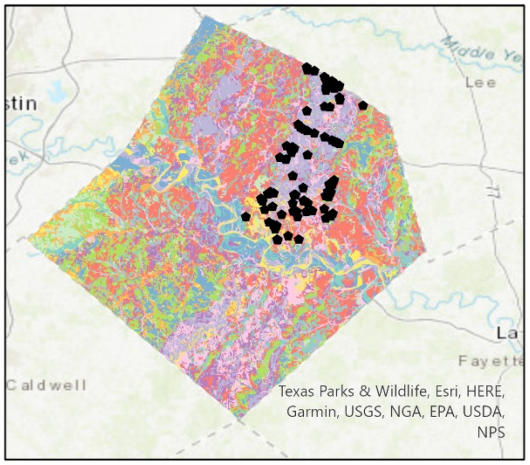
1990s Observations

Soil Classification

AfA
AfC
AfC2
AfE2
AtD
BaA
BaB
BaC2
BeB
BeC2
BeD2
Bo
BuB
CP
CfB
CgC
ChE
CsC2
CsD3
CsE2
DUMP
DeC
Dm
DoB
DoD
FeF2
GP
Gs
HeB
HeC2
HeD2
HoA
HoB
JeF
KrA
Ls
Lw
MaA
MaB
Nd
No
PaE
RoB
RoD
Sa
Sb
SeD2
Sg
SkC
Sm
TfA
TfB
Tr
Tw
Uh
VeD
W
WgB
WgC
WsA
WsB

Appendix G. Houston toad observation points from 2000-2009 on a soil classification map of Bastrop County, TX.





Explanation

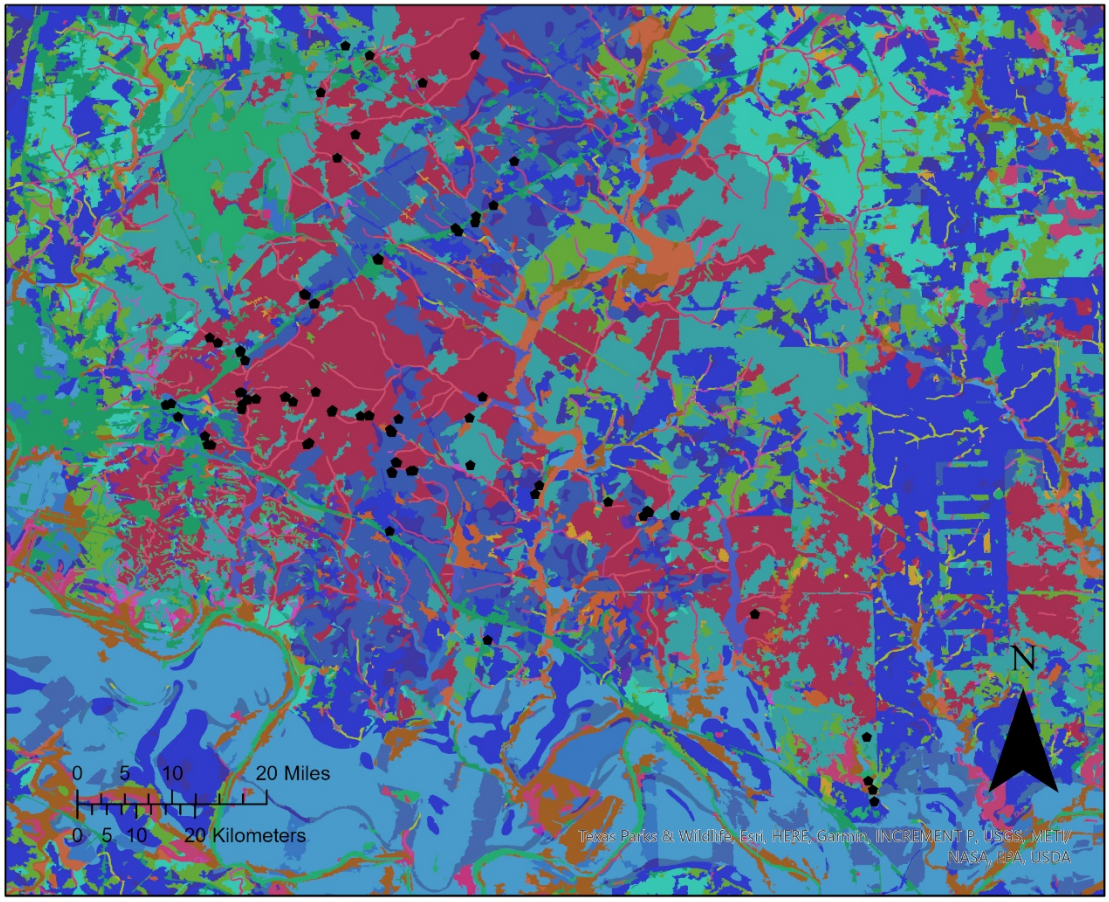
Houston Toad Occurrences

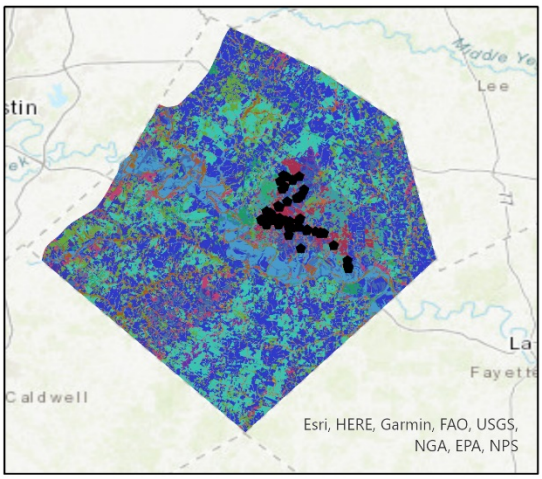
2000s Observations

Soil Classification

AfA
AfC
AfC2
AfE2
AtD
BaA
BaB
BaC2
BeB
BeC2
BeD2
Bo
BuB
CP
CfB
CgC
ChE
CsC2
CsD3
CsE2
DUMP
DeC
Dm
DoB
DoD
FeF2
GP
Gs
HeB
HeC2
HeD2
HoA
HoB
JeF
KrA
Ls
Lw
MaA
MaB
Nd
No
PaE
RoB
RoD
Sa
Sb
SeD2
Sg
SkC
Sm
TfA
TfB
Tr
Tw
Uh
VeD
W
WgB
WgC
WsA
WsB

Appendix H. Houston toad observation points from 1980-1989 on a vegetation classification map of Bastrop County, TX.





Explanation

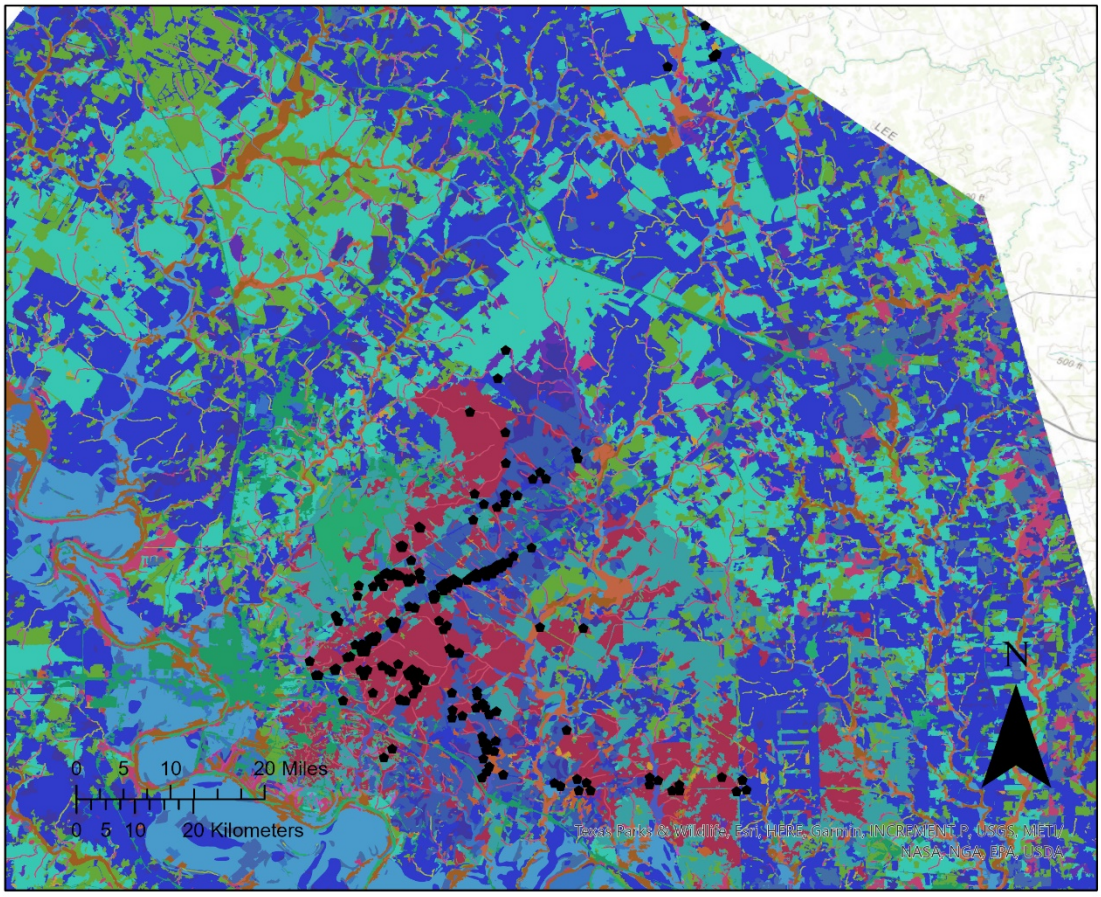
Houston Toad Occurrences

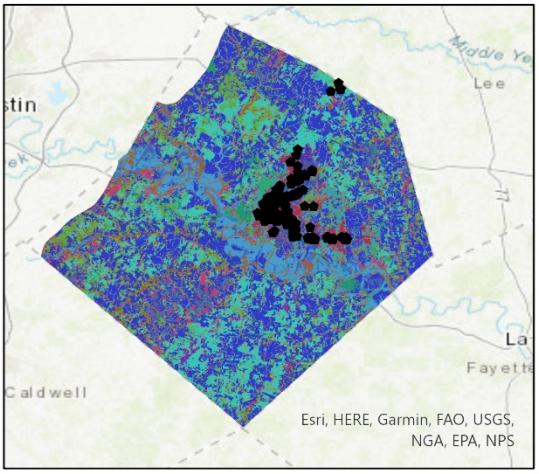
1980s Observations

Vegetation Classification

101
103
121
123
124
207
504
602
604
606
607
613
621
623
624
904
1003
1102
1801
1802
1803
1804
1805
1806
1807
1824
1901
1902
1903
1904
1905
1906
1907
3003
9000
9004
9007
9101
9104
9105
9106
9197
9307
9317
9410
9411
9600

Appendix I. Houston toad observation points from 1990-1999 on a vegetation classification map of Bastrop County, TX.





Explanation

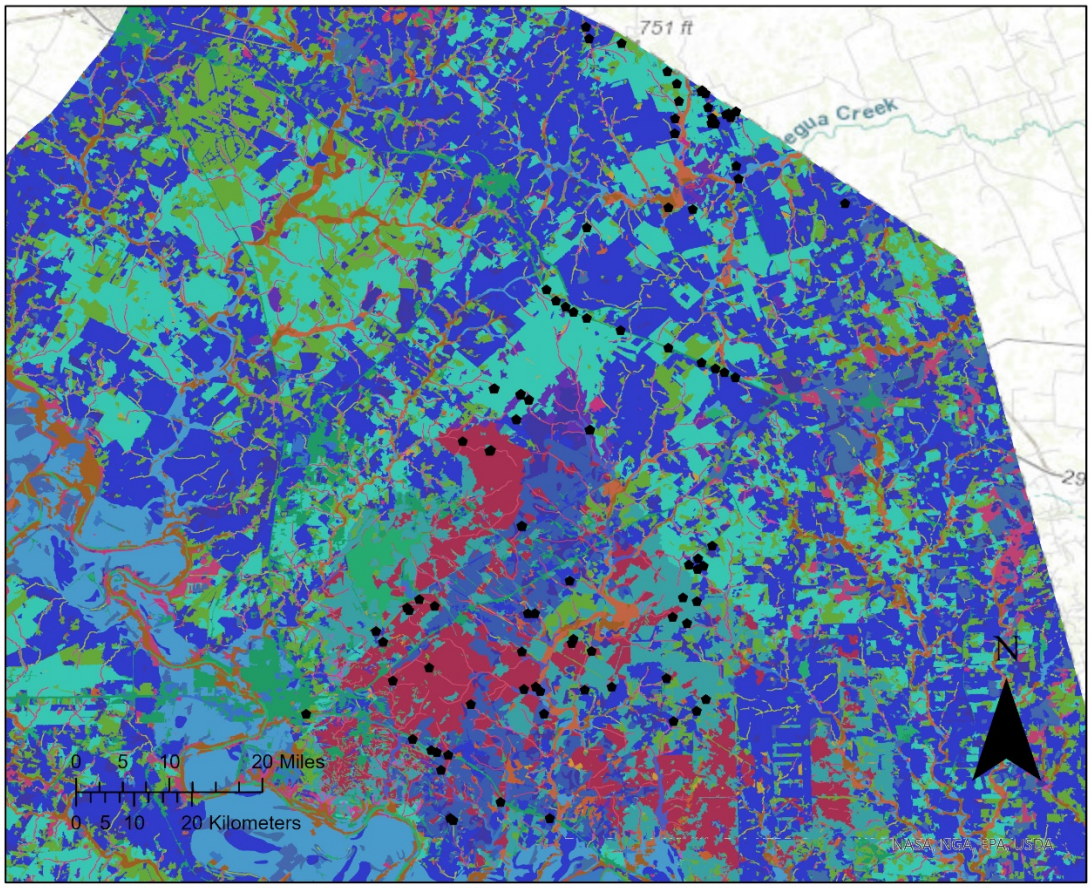
Houston Toad Occurrences

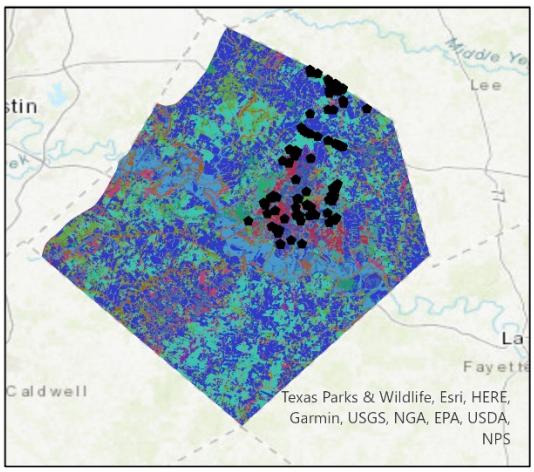
1990s Observations

Vegetation Classification

101
103
121
123
124
207
504
602
604
606
607
613
621
623
624
904
1003
1102
1801
1802
1803
1804
1805
1806
1807
1824
1901
1902
1903
1904
1905
1906
1907
3003
9000
9004
9007
9101
9104
9105
9106
9197
9307
9317
9410
9411
9600

Appendix J. Houston toad observation points from 2000-2009 on a vegetation classification map of Bastrop County, TX.





Explanation

Houston Toad Occurrences

2000s Observations

Vegetation Classification

101
103
121
123
124
207
504
602
604
606
607
613
621
623
624
904
1003
1102
1801
1802
1803
1804
1805
1806
1807
1824
1901
1902
1903
1904
1905
1906
1907
3003
9000
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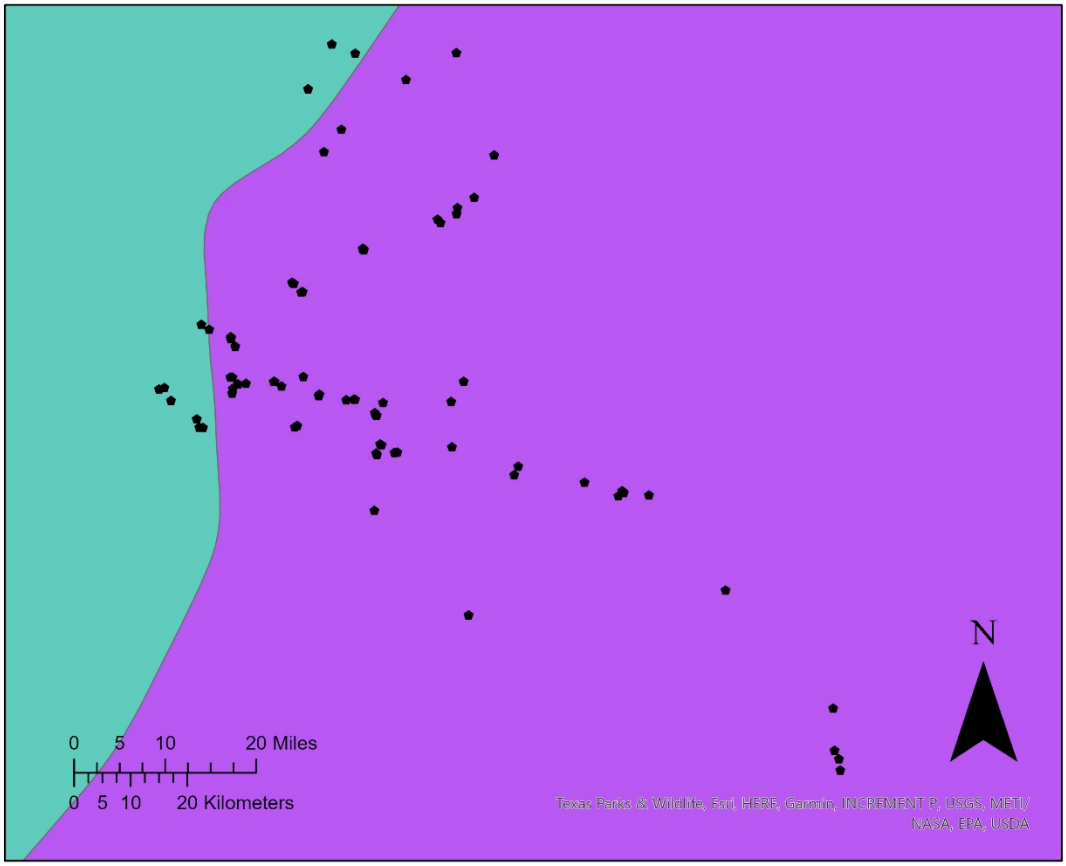
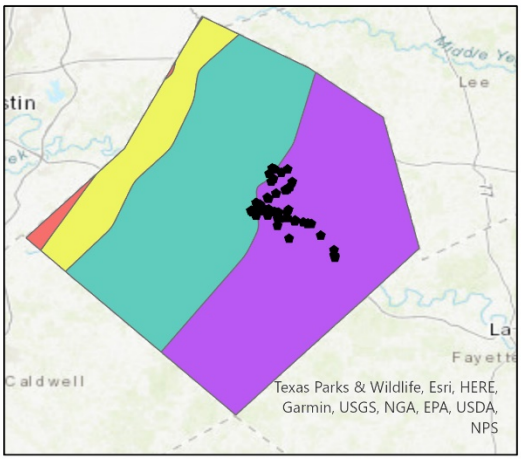
Appendix K. Houston toad observation points from 1980-1989 on a geology classification map of Bastrop County, TX.





Explanation

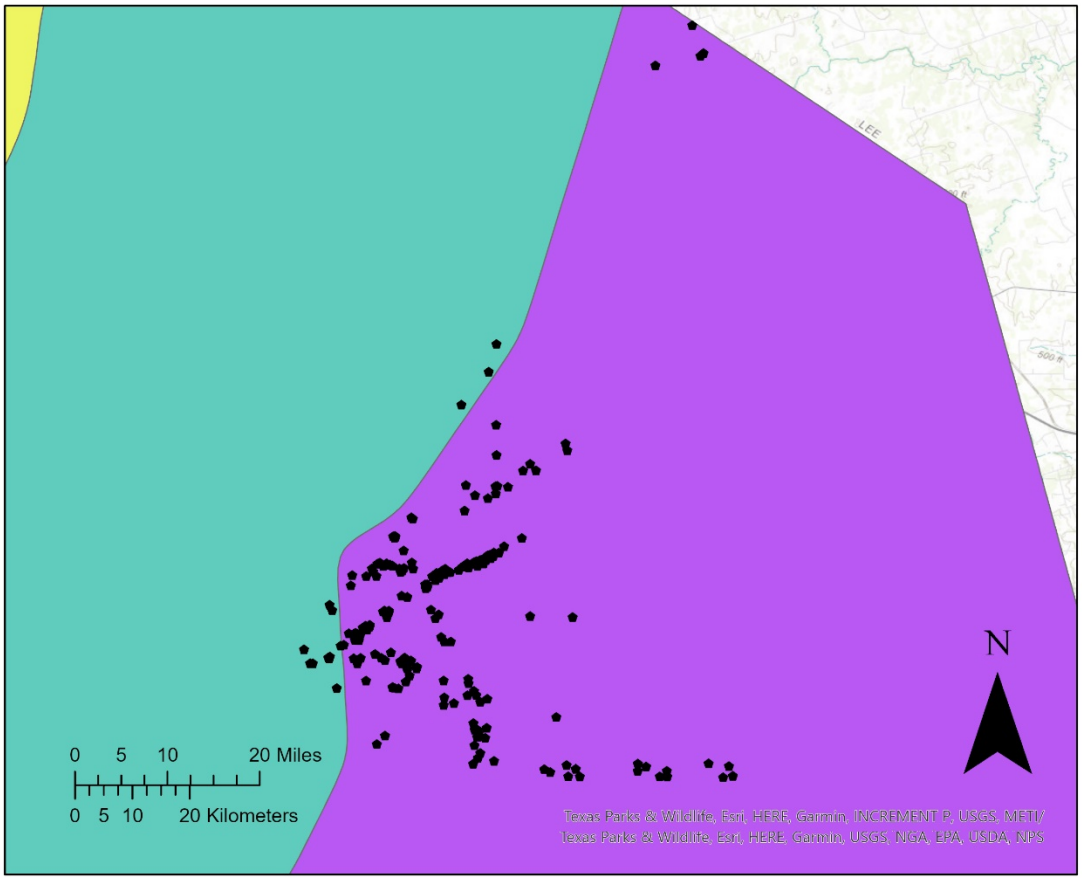
Houston Toad Occurrences

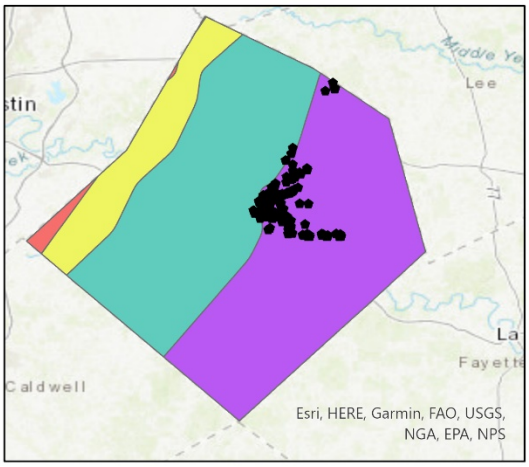
- 1980s Observations

Geologic Classification

- 1eT
- 2eT
- 2uK
- paT

Appendix L. Houston toad observation points from 1990-1999 on a geology classification map of Bastrop County, TX.





Explanation

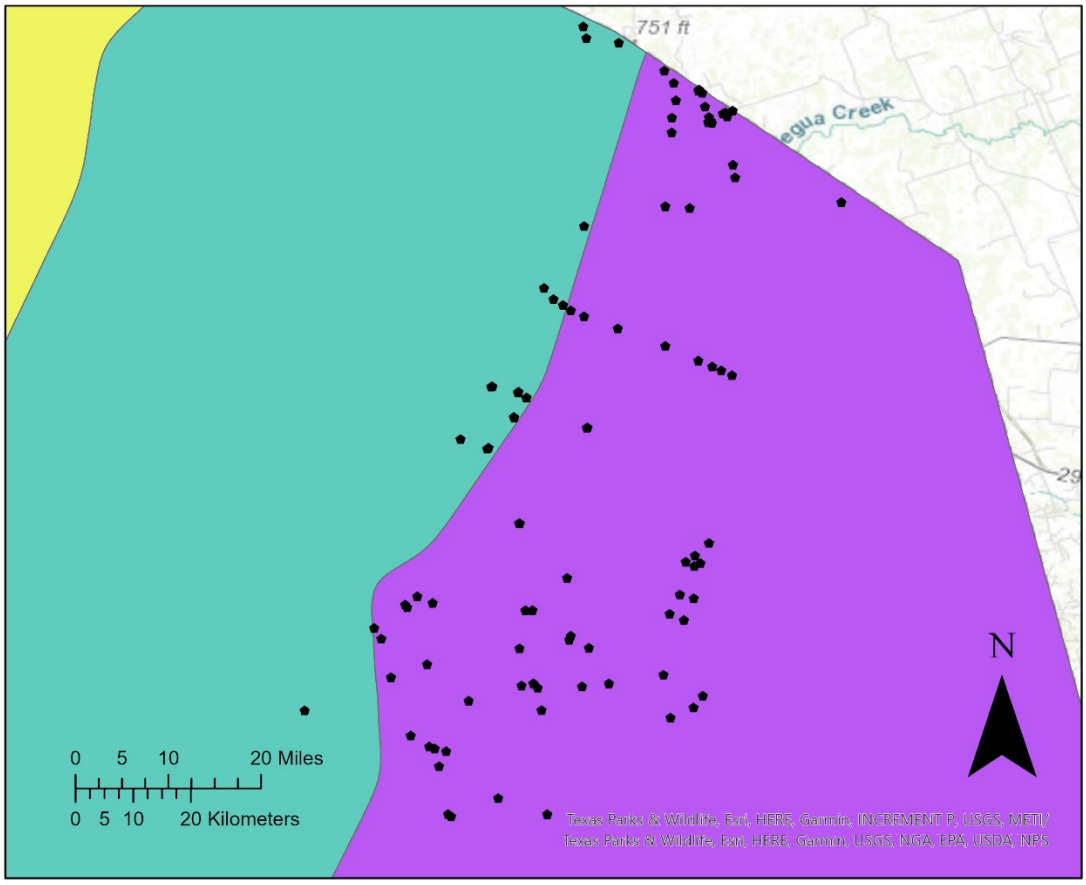
Houston Toad Occurrences

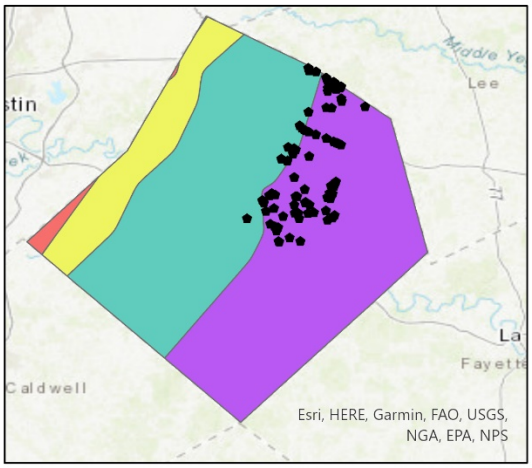
- 1990s Observations

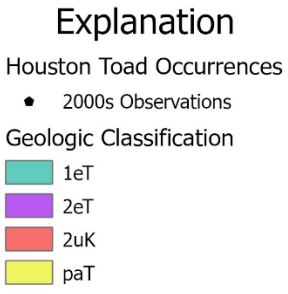
Geologic Classification

- 1eT
- 2eT
- 2uK
- paT

Appendix M. Houston toad observation points from 2000-2009 on a geology classification map of Bastrop County, TX.







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