CONSERVATION STATUS OF THE CHIHUAHUAN GREEN TOAD, *ANAXYRUS DEBILIS*, IN WESTERN KANSAS RANGE

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ABSTRACT

Amphibians remain an important model organism closely associated with environmental conditions and ecological processes. They are considered critical bioindicators of the relative health of ecosystems providing insights into levels of pollution, such as agricultural and industrial runoff, effects of UVB increases, ecosystem service functionality and much more (Rohman et al. 2021). Amphibians are an essential food source to organisms at higher trophic levels and to humans in developing countries (Schleich et al. 1996). Amphibians also provide pest control for agricultural and urban landscapes (Warkentin et al. 2009). Amphibians provide novel medicinal treatments for a wide variety of human ailments and have facilitated our understanding of the processes of human growth and development (Alves et al. 2013). Unfortunately, there are increasing concerns that amphibians may lack adaptability to ongoing global change in temperature, precipitation, and other large-scale anthropogenic modifications to the biosphere (Stuart et al. 2005). Chihuahuan Green Toads, *Anaxyrus debilis*, are an arid-adapted anuran native to the southwestern USA and a restricted portion of western Kansas. The objective of this research was to monitor small-scale movements, population health, distribution, and habitat preference. This information and subsequent analysis will be provided to the KDWP for future recovery planning of this Kansas Threatened species. Understanding the current population trends of arid-adapted anurans provides better insight of the potential limitations on the distribution of these populations in Kansas.

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INTRODUCTION

Amphibian Physiology

Ectothermy is a primary influence on the behavior of all herpetofauna and is responsible for many adaptations not shared with mammals or birds (endotherms). Amphibians and reptiles behaviorally modify body temperature and subsequent activity levels (sunning/shading), therefore requiring less energetic resources than endotherms (Pough, 1983). As a result, some of the primary benefits of ectothermy include diversification at smaller body sizes, decreased competitive interactions for small food items, and higher rates of body mass assimilation from the uptake of resources (Pough, 1980). Understanding the physiology and ecology of herpetofauna can help us determine a species' movements, distributions, and behaviors within any given environment.

Most amphibians are relatively small and intrinsically tied to water for one or more life stages and are sensitive to environmental changes. Accordingly, amphibians have become a group of model-organisms used to evaluate a variety of anthropogenic influences on the environment. They provide a unique movement of energy, nutrients, and biomolecules from their aquatic larval stage to their more terrestrial-adapted adult forms (Capps et al. 2015). Even as some amphibian species transition towards terrestrial lifestyles after metamorphosing, they may remain highly associated with aquatic habitats. This is because many adult amphibian species conduct a significant amount of gas exchange through moist, permeable skin (Tattersall, 2007). The high permeability of their skin makes amphibians exceedingly susceptible to environmental pollutants (Brühl et al. 2011).

Dependency on aquatic habitats for larval growth and development also makes amphibians highly susceptible to the increased rates of UVB as climate change alters the atmosphere

(Bancroft et al. 2008). Larval amphibians depend on the solar radiation that enters pools to regulate their body temperature and therefore, their growth rate. As rates of solar radiation increase, these larval amphibians may be unable to adapt quickly enough to persist, especially in habitats at higher elevations that receive increased amounts of UVB (Blaustein & Bancroft, 2007). The sensitivity of amphibians to environmental factors and their reliance on multiple habitat types make them important bioindicators for environmental health and water quality within a system (Sumanasekara et al. 2015).

Amphibian Ecology

Anurans are a contemporary group of amphibians that include frogs and toads. The distinction between these two groups is relative and, in many cases, subtle. Frogs spend a larger proportion of their lifetime in or around a permanent water source and opportunistically use several differing water sources for breeding activities. Toads tend to be more arid-adapted, or terrestrial, and favor ephemeral pools; natural depressions in the landscape where water accumulates after a rain event (Hedges & Kumar, 2009).

Ephemeral pools are required by many amphibians to complete reproductive cycles (Semlitsch et al. 2015). Ephemeral pools often do not contain pre-established predatory populations of fish or larger invertebrates, like crayfish. The lack of predators increases the likelihood that larvae will survive until metamorphosis and reproductive maturity (Semlitsch & Skelly, 2007). Anuran larvae in ephemeral pools exhibit phenotypic plasticity while living and growing within a constantly shrinking resource. For example, some species of anuran larvae, such as *Scaphiopus couchii*, Couch's Spadefoot, will cannibalize conspecifics as pools desiccate and resources become scarce (Newman, 1988).

Anurans play vital roles in the movement of nutrients within ecosystem food webs. Aquatic eggs provide a dense resource for many aquatic invertebrates and deposit nutrients into the surrounding environment (Axelsson et al. 1997 & Henrikson, 1990). Tadpoles primarily eat aquatic vegetation which is assimilated into body mass during metamorphosis. This creates a unique flow of aquatic resources into terrestrial environments once metamorphosis has occurred, because it allows terrestrial predators to ingest nutrients otherwise restricted to aquatic systems (Register et al. 2006). Anurans are primarily categorized as “active foragers”, those that actively hunt for prey, or “sit-and-wait predators”, those that remain stationary and wait for prey to cross their paths (Blanco-Torres et al. 2020). Adult terrestrial amphibians tend to be sit-and-wait predators, primarily ingesting terrestrial invertebrates that are used in the creation of gametes and deposited back into an aquatic environment (Solé & Rödder, 2010).

Special Interest: Chihuahuan Green Toads

The Chihuahuan Green Toad, *Anaxyrus debilis*, is the smallest of the eight native Kansas toads, measuring 32-50 mm snout-vent length (SVL). The Chihuahuan Green Toad (CGT) was listed as a Threatened Species by the Kansas Department of Wildlife and Parks in 1987 (Simmons, 1988). This small, arid-adapted toad has a historical range that extends from the Chihuahuan Desert of Mexico north through the eastern portions of Arizona and Colorado, and the western portions of New Mexico, Texas, Oklahoma, and Kansas. Historically, the range in Kansas included Logan, Wallace, Greeley, Wichita, Grant, Hamilton, and Morton counties (Rundquist, 1979). Currently, the range of CGTs in Kansas is restricted to the Smoky Hill River Drainage primarily within Logan and Wallace counties and the species is considered extirpated from Grant, Hamilton, and Morton counties. Localized extirpation has been attributed to the dramatic changes in land use predicated by the Dust Bowl of the 1930’s that presumably left the landscape inhospitable for CGTs (Burnette & Stahle, 2013). The 1990s repatriation efforts in the

Cimarron National Grassland, located in Morton County, resulted in no established population (Collins et al. 2009).

In Kansas, the largest population(s) of CGTs in Logan and Wallace counties seem to be restricted to the Smoky Hill River and Ladder Creek drainage basins (Taggart, 1997). This area is predominately short-grass prairie with low annual rainfall. Land use is dominated by rangeland, used primarily to produce livestock, and cropland, to produce corn, wheat, and milo (Bell, 1964). However, this habitat is also comprised of a Rangeland-Prairie-Canyon system with multiple out-croppings of Upper Cretaceous Niobrara chalks that fragments the landscape (Bass, 1926). These outcrops potentially provide CGTs with refuge from disturbances caused by agricultural production.

CGTs are small, highly cryptic and have a short season of activity which makes them difficult to locate through traditional surveying methods. Their morphology suggests alternate adaptations to evading desiccation and predators compared to other common burrowing *Anaxyrus* species that possess a keratinized "spade" on their hind feet. Instead, CGTs are dorso-ventrally flattened, and their parotid glands are located laterally on the side of the head. These adaptations might aid in wedging into tight rock crevasses, fibrous or taproot structures, or premade mammal burrows as a means of protection against predation and desiccation (Simioni et al. 2014).

CGTs are stimulated into activity by rainfall events that occur from mid-June to mid-August (Sullivan, 1985). Observations of CGTs in their western Kansas range often occur after rainfall. Light rain events might stimulate foraging behavior, while larger rain events stimulate breeding aggregations (Sullivan et al. 1996). Breeding aggregations occur at ephemeral pools for two-to-three days after a rainfall event. An individual female deposits 1,000-2,000 eggs on aquatic vegetation. Eggs hatch and tadpoles emerge in 8-25 days. Gestation time depends on rainfall accumulation, relative humidity, dissolved oxygen concentration, and ambient temperature (Goldberg & College, 2019). The soil composition of western Kansas also plays a large role in this species' persistence in the region. The soil has a high composition of clay and helps retain surface water by decreasing infiltration rates (Zedler, 1987). Soil with a high clay content can contract into prismatic columns creating large fissures in the soil when desiccated. When more water enters the system, these columns expand but the fissures remain (Morin, 1959). These fissures are hypothesized to be important to newly metamorphosed CGT toadlets by minimizing desiccation and increasing escape cover from predators. (Schwarzkopf & Alford, 1996).

Since the early 2000s, the distribution of documented observations suggests that CGTs occur within Logan and Wallace counties. However, there has been no dedicated effort to empirically evaluate their life history characteristics and habitat use in the current range. The purpose of this study is to define the life history characteristics and range of CGTs in Kansas by manually surveying for CGTs in Logan and Wallace counties. This research will focus primarily on their movement, distribution, and habitat use.

METHODS

Permissions and Study Area

I obtained IACUC certification and permits from KDWP prior to the start of each research season. The two research seasons ran from late May to late July in 2022 and from late May to mid-July in 2023. I used OnX Hunt Maps coupled with historical observations from the Kansas Herpetological Atlas (Collins et al. 1999) to determine potential suitable survey sites. Potential survey sites were identified based on proximity to historical observations of CGTs (<250 m buffer), type of water source on the property and land use. Properties that are predominantly used to produce row crops were excluded. Both survey seasons included an array of water sources: permanent bodies of water from the Smoky Hill River, dried tributaries of the Smoky Hill watershed, ephemeral pools, man-made pools, and cattle tanks. I used the information from OnX to contact landowners and receive permission to conduct surveys at ten different locations in 2022: nine in Logan County and one in Wallace County. In 2023 I received permission to survey seven locations in Logan County but permission to survey in Wallace County could not be obtained. Only two properties were surveyed both years. The first property (DRF1 – Dewayne Repshire Farm) was a historical location of CGTs presence dated from 1979, comprised primarily of Niobrara Chalk outcroppings. The second property (CHT – Carl Hanson Trust) was considered a "hotspot" of activity, because it provided most of the CGT detections during the 2022 season (Figure 1). Sites were surveyed to establish areas with higher potential for the formation of ephemeral pools, clay-based soil with no or minimal vegetation, and to monitor the occurrence and distribution of CGTs.

Automatic Recording Devices

Automatic Recording Devices (ARDs) (Song Meter Micros from Wildlife Acoustics) were deployed to aid in the detection of CGT calling or chorusing behavior and document presence. I placed one ARD per site along the boundaries where ephemeral pools were likely to form. I set the ARDs to record for five minutes every half-hour from sunset to sunrise. We replaced Micro-SD cards and AA batteries in all ARDs every ten days to ensure constant detection throughout the survey season. I analyzed the audio files from the ARDs in Kaleidoscope Pro (KPro) after training the software (Appendix A) to identify calls from anurans likely to occur in the region.

Survey Protocol

Surveys for both seasons began near sundown (8PM-9PM, CDT) and continued for three hours, or until 12AM, whichever came first. I used a Kestrel 5000 to estimate relative humidity (%), temperature (°C), wind speed (MPH) and wind direction before each survey. I noted the latest rainfall event and the amount of rain produced in millimeters. Rainfall data was obtained using CoCoRaHS (Community Collaborative Rain, Hail & Snow Network), reports from landowners, and the Weather Channel. Surveys consisted of searching all distinct habitat types within a site with emphasis on dried stream beds, permanent bodies of water, and ephemeral pools. Along chalk outcroppings we manually manipulated surface rocks to search for herpetofauna as part of the effort. Throughout these nightly surveys, any amphibian or reptile encountered was identified and their locations recorded using a Garmin Rhino 650t Series GPS unit (+/- 4.88 m accuracy). When we encountered a CGT, we recorded the sex, weight (g), SVL (cm), and GPS location of the individual. We also recorded the activity exhibited by the individual including breeding, chorusing, or foraging behaviors. All GPS locations of amphibians and reptiles observed during surveys were used for mapping and distribution analysis.

Call surveys were conducted three times during each site survey; at the start of the survey, one hour into the survey, and two hours into the survey. Call surveys consisted of a five-minute period of listening for any anuran calls and helped us determine areas to focus our search effort. Calls were categorized on a scale of 1-3: 1 there are distinct gaps between calls and individuals can be counted; 2 individual calls can be distinguished but there is some overlap; 3 full chorusing, calls are continuous, constant, and overlapping (Eastern Ecological Science Center, 2016).

Rainfall

Three relatively "large" (greater than 8 mm) rain events covered the survey sites during the 2022 survey season but were not inclusive of all ten sites in any single event. All rain events that produced less than 5 mm were not recorded because they seldom stimulated even the more abundant toad species, such as Woodhouse Toads, *Anaxyrus woodhousii*, Great Plains Toad, *Anaxyrus cognatus*, to activity.

The 2023 sites received 18 distinct rain events, six of which resulted in 25 mm or more, and were inclusive of the seven sites in May, June, July, and August. Any rain event that produced less than 8 mm was excluded from the data.

Radio Telemetry

I fitted 14 CGTs with PowerTags, weighing approximately 1.2 g, in June of 2023 (manufactured by Cellular Tracking Technologies (CTT)). CGTs are small in stature, making tag weight an important consideration to reduce the influence of the tag on an individual's movement and breeding capabilities. PowerTags are battery operated and send radio signals that are converted to a digital display of the unique tag ID and signal strength. The signal strength varies from zero to -140dB; zero located at the tag, and -140 at maximum distance the locator can detect (Appendix B). The PowerTags had a pre-determined signal rate with differing intervals. Signal intervals were as follows: 5 tags every 60 seconds (lifespan of 1.5 months), 5 tags every 20 seconds (lifespan of 1 month), and 5 tags every 10 seconds (lifespan of 2 weeks). We created harnesses using Stretch Magic 0.05 mm diameter cord and JB Weld Fiberfix Total Repair UV adhesive. One end of the Stretch Magic cord was attached to the right side of the tag and cured in place using the UV adhesive. The other end of cord was left unattached to allow for accurate fitting of CGTs in the field.

Eight males and six females were collected from two adjacent ponds on LAM during a breeding aggregation on June 18; females laying eggs were not disturbed or used in this study. Tags had to be manually activated and tested for signal detection before deployment; only one tag could not be activated and was excluded from this study. We attached tags to the posterior region of CGT individuals by wrapping the Stretch Magic cord around the hips, while extending hindlimbs posteriorly, and gluing cord in place on a tag with the same UV adhesive. Plastic sandwich bags were used as a barrier when affixing harnesses to prevent adhesive getting on permeable skin (Figure 2). The fit-of-harness was tested by placing newly tagged individuals in short grass to determine if tags would remain fastened during intense physical movement. Once tagging harnesses were confidently secured and excess Stretch Magic cord was clipped, CGT individuals were released back into breeding pools.

Manual relocation was attempted every other day after deployment using a CTT Manual Locator. The Manual Locator is a hand-held Yagi antenna that is Wi-Fi enabled and can interface with a cellphone. The cellular interface provides real time tag ID and signal strength. The general protocol for manually relocating tags was to start directly East of the breeding pool, connect the locator to a cellphone, and point the antenna in each cardinal direction. Once a tag was identified and selected, we moved 3 m in any direction and repeated. The direction that produced the highest signal strength (nearest to zero) was followed until we either observed the individual or maximized signal strength.

An array of telemetry receivers, or nodes, (CTT) was deployed on the telemetry site (LAM – Jason Lamb Property) on June 21 and consisted of 13 nodes mounted on galvanized pipe approximately 2 m above the ground (Appendix C). Nodes act as mini base-stations that receive tag signals and send updates including node health, date and time, GPS coordinates, and tag detections to the SensorStation every five minutes. Twelve nodes were placed approximately 120 m apart in a 3x4 grid running North to South, with a 13th node placed approximately 700 m to the southeast of the array near another water source (Figure 3). A SensorStation (CTT) was deployed approximately 300 m from the northeast corner of the node array to record the telemetry information sent from nodes (Figure 4).

Imaging

Drone flights were conducted over the telemetry site June 21, 2023 (Figure 5). The drone imaging was stitched together in ArcGIS Pro to create a 2D map of the telemetry site. This provided a higher resolution map with topographical relief and aided in defining habitat types where tagged individuals were located.

RESULTS

2022 Season Encounters

Across two field seasons, 680 person hours were spent surveying CGTs across 15 sites. Forty-two CGTs were encountered in total, resulting in 6.17 CGTs for every 100 hours surveyed. 414 hours were spent manually surveying, 234 hours running ARD circuits, and 32 hours manually relocating tagged individuals (2023). Over two years, ARDs recorded 1,277 hours (Table 1) but chorusing was only recorded in 2023. These results support the perception that CGTs are extremely cryptic and exhibit narrow windows of temporal activity.

During the 2022 survey season, 28 different surveys were conducted across ten sites, averaging two surveys per site. Light and highly variable rainfall during the drought in 2022, defined as <75% of the average annual rainfall (The National Integrated Drought Information System (NIDIS)), resulted in few CGT encounters (Figure 6). Six CGTs (+1 Dead on Road or

DOR) were encountered in 2022. The low occurrence of CGTs in 2022 is attributed to the compounding effects of extended periods of intense heat between little and isolated rainfall throughout the season.

On June 6, 2022, I observed 2 (+1 DOR) CGTs on an asphalt roadway during a road cruise survey in Wallace County. Road cruise surveys were conducted during the three rain events that occurred in 2022 in an attempt to increase the probability of observing CGTs. These surveys followed a route created for managing the ARDs, and enabled monitoring of sites during rain events (Wallace County site excluded due to remoteness). The first of the three rain events produced 20 mm of rain on June 6, the next event produced 9 mm of rain on July 7, and the last event produced 24 mm of rain on July 29 (Table 2).

The other 4 CGTs observed were located on a single property in Logan County (CHT) under rocks on and around chalk outcrops after the last rain event on July 29. The CGTs encountered in 2022 consisted of 3 females, 3 males, and 1 unknown (DOR). Unfortunately, no detections of CGTs calling or chorusing were recorded on ARDs in 2022. Lack of breeding aggregations and chorusing is attributed to intense periods of heat between rain events, that quickly evaporated any ephemeral pools that were produced.

Great Plains Toads, *Anaxyrus cognatus*, and Plains Spadefoots, *Spea bombifrons,* are arid-adapted anurans that are commonly encountered in western Kansas. These two species were only encountered during the road cruise survey on June 6.

The American Bullfrog, *Lithobates catesbeianus*, and the Plains Leopard Frog, *Lithobates blairi*, were excluded from the May 29, June 28, and July 19 surveys. These surveys were conducted around permanent bodies of water and disproportionally increased the rate of occurrence of these two species. 120 Plains Leopard Frogs were encountered on May 29, 110 encountered on June 28, and over 300 encountered on July 19 as well as 30 American Bullfrogs (Figure 7). We observed a higher diversity of reptiles and encountered them on a more consistent basis than amphibians (Figure 8). In 2022, 101 reptiles of 11 species (Figure 9) and 166 amphibians of 8 species (Figure 10) were encountered.

2023 Season Encounters

In 2023, 20 surveys were conducted across seven sites resulting in nearly three surveys per site. Moderate to frequent rain events occurred during the summer and increased the number of encounters of CGTs by 2 times; although western Kansas remained in a drought, it was downlisted from Extreme/Severe in 2022 to Severe/Moderate in 2023. Total rain amounts for the 2023 season was 355 mm and averaged 118 mm of rain accumulation per month (Table 3). In 2023, 300+ amphibians of 7 species and 91 reptiles of 15 species were encountered.

On June 18, 50-60 CGTs formed a breeding aggregation in a clay-based ephemeral pool on LAM and I deployed 14 radio telemetry tags. In total, 35 CGTs were encountered across five of seven sites during the 2023 season. Most of the occurrences (21) were on the telemetry site, LAM. The remaining observations occurred on differing sites as follows: two CGTs on JLH, nine on CHT, two on DRF1, and one on BDS2 (Appendix D). These 35 CGTs were composed of 15 males, 15 females, and 5 juveniles (Table 4).

2023 Calling

In 2023, calling and chorusing was detected by ARDs on five of seven sites; calls were detected on June 3 – 4 and July 3 – 4 on JLH and CHT, and July 8 on LAM. Calling behavior is defined as one-to-several individuals calling with distinct gaps between calls. Full chorusing was detected on June 13 – 17, following two storms that accumulated 101 mm of precipitation, on BDS2 and LAM, and July 4 – 6 on LAM. Full chorusing occurred on the telemetry site, LAM, as well as JLH and BDS2. BDS2 proved difficult to access after rainfall due to unmaintained county roads. The only CGT calls detected in person occurred on June 18, during the breeding aggregation on LAM, and later, July 7, in the same pools where breeding occurred. The July 7 detections consisted of two-to-four CGT males calling after a rain event deposited 25.40 mm of precipitation on July 4.

Sexual Dimorphism

Males and females were observed in equal proportions in 2022 and 2023. Females tend to be larger than males in length and weight (Table 5). The results of a two-sample t-test indicate that female weight (g) and snout-vent length (cm) are statistically significant. The statistics derived for female weight when compared to males was $t = -3.59$, $df = 34$, and $p = 0.001019$ ($p<0.05$). The SVL of females compared to males was $t = -4.44$, $df = 34$, and $p = 8.995e^{-5}$ ($p<0.05$).

2023 Telemetry

In total, 14 tags were deployed on June 18 on eight males and six females (Table 6). The following day we observed one tagged male deceased in a pool. It was later determined that the deceased male was one of two males with 60-second tags that were not detected during that survey. No tagged individuals were encountered again on the surface, even when using the manual locator.

Three males and five females were detected using the manual locator (Figure 11). The manual locator detected tag signals for two days, June 19 and 20. All three males were located both days, two females were located on June 19, and the other three tagged females were located on June 20. Five females and five males were detected by either the node array or manual location in this study and three males and one female were not detected by any technology. On average, females appeared to move farther from the breeding aggregation compared to males.

Two males, T2A07 (10), and T614B (60) and one female, T071E (20) were detected by the manual locator for two days following tag deployment near pool edges, but were never re-encountered above ground. I observed CGT individuals emerge from clay borders and the bottom of the northern breeding pool. This might suggest that some individuals will burrow back into the bank after breeding and might overwinter in the thick clay. One male, T5566 (20) moved approximately 40 m to the east of the breeding pools over a two-day period. T5566 had the strongest signal strength reading above a tarantula burrow, suggesting use of pre-established burrows or dens.

The remaining four females detected with the manual locator, T1934 (60), T2D52 (10), T614C (20), and T7852 (10), all moved across the telemetry site. T7852 and T614C were detected once, and their distances were calculated as a straight-line value from the center between the two pools where breeding took place. T7852 moved approximately 208 m to the northeast of the pools and was detected within a burrow of unknown origin surrounded by shortgrass. T614C moved approximately 208 m southeast of the pools and was detected in a burrow under the base of a Yucca. The remaining two females, T2D52 and T1934, were detected in burrows at the base of chalk out-croppings surrounded by rocky terrain.

Because the tags were detected for a brief period, in relation to their projected lifespans, CGT movement could not be estimated using the nodes to triangulate precise locations and movement patterns within the node array. Figure 12 illustrates the node locations where CGT signals were recorded (Figure 12).

Eight tags were detected by the node array; three females, two detected by the manual locator, and one solely detected by the node array, and five males, three detected by the manual locator and the remaining two detected by the node array. One individual female, T071E (20), was detected by five nodes for a total of 11 days. This female had the longest period of detection and was detected by more nodes than any of the other tagged individuals.

DISCUSSION

The purpose of this study was to determine preferential habitat and burrow use along with breeding dynamics of CGTs for future conservation efforts. The 2022, CGT encounters provided little novel life history insight. Although it was encouraging to encounter two individuals (+1 DOR) on the Wallace County blacktop, the location was far from our survey sites and in a previously documented area. The rain event that occurred on June 6 deposited 9 mm of rain and might tentatively be considered a threshold to stimulate surface foraging and replenishing internal water stores. However, without regular, sequential rainfall, it is difficult to ascribe a defining pattern from the few encounters in 2022. No calls from CGTs were detected in 2022, however, the recordings detected in 2023 contained calling and chorusing behaviors from CGTs, Plains Spadefoots, *Spea bombifrons*, Woodhouse Toads, *Anaxyrus woodhousii,* Great Plains Toads, *Anaxyrus cognatus*, and Plains Leopard Frogs, *Lithobates blairi*.

Great Plains Toads and Plains Spadefoots are behaviorally similar to CGTs; highly adapted to arid environments, stimulated by rain events to breed, and obligatorily use ephemeral pools for reproduction. Although the precipitation was light, finding these two species during rain events reinforces the hypothesis that the drought spanning 2021-2022 in western Kansas had negative effects on the occurrence and distribution of arid-adapted anurans native to the area. Through the entirety of the 2022 survey season, Logan and Wallace counties were in Severe and Extreme levels of drought, as defined by the National Integrated Drought Information System (NIDIS) and amphibian encounters were few.

Reptiles were encountered more consistently (29 survey days) than amphibians (19 survey days) in 2022 and might be a result of less precipitation and more search time away from water sources. In 2023, amphibians were encountered more consistently than reptiles and might be a result of higher water accumulation and more mesic focused search effort. In 2022, 166 amphibians were encountered and 101 reptiles, but amphibian detection was inflated by large groups of Plains Leopard Frogs. In 2023, 300+ amphibians and 91 reptiles were encountered, amphibian detection was inflated instead by large breeding aggregations of CGTs and Plains Spadefoots.

One Western Tiger Salamander, *Ambystoma mavortium,* was encountered both years and surprisingly in larval form in the extreme drought year of 2022. A Western Milksnake, *Lampropeltis gentilis*, was observed both years and immediately following a rain event when humidity was high (60-70%) and temperatures were moderate (75-80°F). In 2023 two Plains Black-headed Snakes, *Tantilla nigriceps,* were encountered on two separate surveys on the same site (CHT) and on the same chalk outcrop. These two individuals had radically different body sizes that helped us determine them as different individuals. This species was not observed in 2022.

Twice as many CGTs were encountered in 2023 compared to 2022 and likely as the result of more frequent and intense rain events. In 2022, surface stimulation was tentatively attributed to rain events that deposit 9 mm or more and I observed more of these “threshold-like” events in 2023. Throughout the central range of CGTs in Southwestern USA, monsoon season dictates breeding opportunity, but in their Kansas range CGTs might be adapted to resurface with less rain accumulation because of differences in climate. This species has a short period of temporal activity in Kansas and stimulation by less rain might benefit their ability to forage, balance osmolality of the blood, and replenish lost nutrient stores after long periods of brumation. However, CGT surface stimulation might be an adaptation to monsoons, where rain continues to be deposited throughout the season, ensuring enough water for offspring metamorphosis.

CGTs were observed breeding in two adjacent and relatively similar ephemeral pools on June 18. The main difference between the two pools is the northern pool had less than 1% aquatic vegetation while the southern pool was comprised of nearly 95% aquatic vegetation. The two pools were less than 10 m apart and CGTs were observed showing preferential behavior to the pool with less aquatic vegetation. Ten CGTs were obtained from the northern pool, and only five were obtained from the southern pool. CGT preference of pools with less aquatic vegetation might be because the more abundant amounts of aquatic vegetation quickly deplete the water in an ephemeral pool. Selecting a pool with less vegetation might benefit the success of CGT offspring by reducing the risk of desiccation. Aquatic vegetation also provides food and habitat for aquatic invertebrates that consume anuran eggs and larvae. Selection of a pool without excessive vegetation might reduce the risk of predation.

CGTs were stimulated into breeding activity following a rain event that deposited 20.32 mm on June 17 and CGTs were tagged on June 18. Upon returning to the telemetry site on June 19, the breeding aggregation had dispersed, and no individuals were encountered on the surface. Short periods of breeding activity and quick dispersal might decrease the likelihood of adult CGT predation or desiccation. The turnaround from breeding to dispersal occurred over a period of 48 hours and is highly suggestive of sporadic temporal activity by CGTs following breeding aggregations.

Manual relocation of tagged individuals was conducted every other day for eight days, however after two days of searching, signals were no longer detected by the manual locator. Signal detection ranged from -72dB to -42dB and is attributed to the thick clay of the pasture that diminishes signal strength and reduced our ability to receive stronger signals. Deployed tags were designed to have lifespans ranging from two weeks to two months. When tags were undetectable after June 20, it was initially hypothesized that the manual locator had failed. However, after downloading data from the node array, I discovered that most of the tags detected, excluding one (T071E), signaled for three to five days following deployment. However, nearly half of the tagged CGTs were not detected by the node array or during personal surveys. This suggests that CGTs are highly associated with large rainfall events and quickly retreat after breeding. The tagged individuals that were not detected by the telemetry equipment included males T5244 (10), T1933 (60), T554C (60), and female T5519 (20). The data suggests that females move greater distances after breeding. Females might be replenishing resources lost to gamete production but given their small size it seems unlikely they would attempt multiple clutches. Males remained closer to the breeding pools. It seems likely that males are positioned to take advantage of multiple breeding opportunities.

Although radio telemetry was not effective in localized triangulation, that would provide small-scale movement patterns, some new understandings of life history characteristics were gained. Five tagged individuals were manually relocated nearest to burrows around chalk out-croppings (two) or in shortgrass (three). Many anuran species use burrows for shelter and it is likely the case with CGTs. Signal strength was strongest near tarantula and mammal burrows and around the roots of Yucca for relocations where individuals were not observed on the surface. The central distribution of CGTs in Southwestern USA is primarily dominated by drought-tolerant plants such as Mesquite, which is physically like Yucca; both having deep penetrating taproots and expansive fibrous root systems. Burrows supported by root systems provide structural integrity, coverage, defense against predators, and supplies moisture to the inhabitants (Nobbs, 2003). Yucca might support the persistence of CGTs in their Kansas range in place of Mesquite by providing sufficient dens for hibernation.

Large (greater than 12.70 mm) and sequential (occurring over consecutive days) precipitation events stimulated reproduction. No tagged toads were encountered on neighboring properties and given the relatively short activity period observed among breeding CGTs, I was not surprised. Once breeding is complete, CGTs might forage for a brief period before returning to burrows or under rocks. Interestingly, in 2023 several large rain events occurred in late summer and early August that refilled ephemeral pools, but I observed no breeding activity other than one or two males calling. Chorusing at two other sites produced no CGT eggs, tadpoles, or juveniles. Pool size and composition on JLH was similar to the northern pool where breeding occurred on LAM, and no pools were identified on BDS2. Twenty individuals were encountered throughout the 2023 season foraging near chalk-outcroppings in sparsely vegetated or short-grass areas following rain events. Presumably these individuals are taking advantage of moist ground to forage and prepare for brumation.

The drought during the 2022 field season caused many challenges, most importantly, it further restricted our access to CGTs. Climate change might be an increasingly critical factor in the distribution and vagility of this species because CGTs are desert amphibians and depend on rainfall to stimulate resurfacing and breeding. One hypothesis of climate change suggests that higher amounts of accumulation will be produced by rain events, but there will be increased variability in the timing and intensity of these events (Thorton et al. 2014). Less frequent water accumulation and extended time periods of intense heat between rain events will result in fewer breeding opportunities for species that depend on ephemeral pools to complete necessary lifecycle stages (Tuytens et al. 2014). This shift in climactic variability might also reduce the time available for amphibian larvae to metamorphose (Brooks, 2004). Additionally, increased aridity in western Kansas could dramatically decrease detections of this species, because CGT breeding aggregations occur over two-to-three days.

The ability of a species to persist is largely a function of the genetic variability within the population, which increases the populations' ability to survive demographic or environmental stochastic events (Jamieson et al. 2008). Decreased availability for recombination of genes could result in lower overall fitness and population decline. As climate change accelerates, the effects of global warming might alter a system faster than a species can adapt, leading to increased rates of extinction or local extirpation (Frankham et al., 2002).

The soil in western Kansas has a high composition of clay that can be advantageous for water accumulation and, subsequently, to the formation of ephemeral pools. However, clay reacts to changes in temperature and relative humidity. When the environment is dry with little rainfall, clay-based soils will constrict into prismatic columns. When rainfall is variable and arid conditions persist, clay will continue to constrict creating larger fissures. Fissures increase the rate of water infiltration, but without regularly occurring rain events, fissures reduce the ability of ephemeral pools to become saturated and retain water (Whitford & Duval, 2020). As global warming continues to increase in severity and duration, arid-adapted anurans might be more highly impacted by the effects of the changes occurring in the global hydrologic cycle (Griffis-Kyle, 2016).

Many of the clay-based ephemeral pools we encountered were near or around chalk outcrops or other large, rocky ravines. Rocky areas are difficult to convert to agricultural land in western Kansas and most often are used in cattle production. These intact rangelands provide refuge for CGTs.

All sites surveyed throughout this study contained cattle, and it was observed that cattle prefer to use recently filled ephemeral pools rather than cattle tanks. The pools where breeding was observed were quickly depleted of water, and eggs observed deposited on aquatic vegetation were destroyed due to cattle trampling. Cattle trampling through ephemeral pools can disrupt and diminish CGTs' effort to reproduce. Cattle production in western Kansas is a lucrative business, and efforts to mitigate the effects of cattle on ephemeral habitats need not be incompatible with cattle production. Construction of temporary fencing around clay-based ephemeral pools with sparse vegetation is an easy solution. T-posts and electric fencing around an ephemeral pool would benefit CGT reproduction. A 50 mm clearance from the ground to the bottom of the fence would allow amphibians and reptiles access to the pool. The gap reduces the risk of amphibians and reptiles becoming ensnared in fencing but restricts access to larger animals. Electrical fencing powered by solar panels is an effective option to deter cattle trampling of ephemeral pools and can be turned off or removed outside of the breeding season.

Increasing the number of ephemeral pools on the property is another option. Excavation of clay-based pools overrun with vegetation creates accessible and enticing pools for CGT reproduction. Aquatic vegetation should remain in small quantities, around 1% of total pool surface area, for the attachment of aquatic eggs. Properties with several ephemeral pools could fence off half of the pools, and leave the remaining pools open for cattle use. Construction of fencing during the breeding season, or year-round, in addition to statically excavated shallow basins might provide cost effective habitat improvements for arid adapted amphibians like CGTs. Cost share programs, like EQIP from the NRCS, might be a useful source for landowners to access the resources and financial support necessary for implementing these basic conservation efforts.

CONCLUSION

Natural History

Chihuahuan Green Toads are small, arid-adapted, cryptic anurans that originate in the Southwestern United States and Chihuahuan Desert of Mexico. Kansas has the northern-most extent of the CGT range, that has likely been isolated from the main distribution since the 1930's. The drought of 2022 and sequent, heavy, rainfall the following year support suggestions that CGTs have evolved to take advantage of the monsoon season in its central range of the southwest. Twice as many CGTs were encountered during the 2023 season, which had substantially more rainfall than the previous survey season. It was observed that CGTs will emerge from underground following a large rainfall, and if water has accumulated in ephemeral pools, are stimulated into breeding. Subsequent rainfall following breeding may bring a few CGT individuals to the surface, but multiple breeding aggregations within a season were not detected during visual surveys or in audio recordings.

A single breeding event might be adaptive for females given their small size and the reproductive investment in egg production. That coupled with the stochastic availability of breeding habitat might explain the brief period of observations and limited evidence of breeding (eggs and tadpoles). Males calling towards the end of the reproductive window might have emerged late or is variation to ensure late emerging females can reproduce. No breeding events were observed after June 17 in 2023, even though rain events occurred on July 4 (25.40 mm), July 8 (17.78 mm), and August 9 (25.40 mm) that refilled the breeding pool. Late season observations were predominately juveniles near chalk outcrops and under rocks rather than around pools. Unfortunately, these observations are based on one good season of activity observed visually and in audio recordings.

Technology

Tagged CGT individuals detected by the manual locator indicated that they inhabit a variety of burrows or dens, that may or may not have other inhabitants. Visual observation along with manual relocation documented that some likely burrow into the soft clay in the ephemeral pool banks. Overall, the functionality of CTT PowerTags coupled with a node array and manual locator was not effective in elucidating fine-scale movement of this species. Although it is highly sought after technology for more vagile animals, such as birds, turtles, bats, and other mammals, it provided insufficient data in terms of algorithm-based localization techniques, and therefore was not effective in tracking small, cryptic species such as CGTs. The thick clay that makes up the region and tracking species around pools of water both disperses and diminishes tag signals. The cryptic life characteristics of CGTs also reduced our ability to detect tagged individuals after deployment.

Conservation

CGTs are a Kansas Threatened Species; consequently, conservation and recovery planning are critical to their survival in its restricted Kansas range. Understanding the behaviors, habitat preference, pool selection, and stimuli thresholds associated with CGTs will aid in making conservation-based decisions. The population(s) of CGTs cannot be confirmed to have increased or decreased since their listing in 1987, however, CGT's dependence on their environment, coupled with their specific life history characteristics, make CGTs increasingly vulnerable to global climate shifts. The recommendation for the conservation of CGTs is to continue monitoring the movement, distribution, and breeding success in western Kansas. Many questions remain unanswered in terms of burrow and habitat preference, burrow sharing, diet, pool association characteristics, average lifespan, mate selection, and length of brumation period. It remains unknown whether CGTs can survive years without resurfacing or breeding if drought persists and the environment is unsuitable. Genetic sampling might determine relatedness at breeding aggregations and potentially pool associations. Using eDNA to test for CGT occurrence in pools might uncover a new understanding of pool preference and population size. Finally, the creation of a habitat suitability model would aid in determining beneficial habitat characteristics and areas that are suitable in their Kansas range for future repatriation efforts.

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TABLES

Table 1. Total Efforts Spent Searching for CGTs in Western Kansas.

Research Effort	2022	2023	Total for both years
Number of Surveys	28	20	48
Survey Hours	252	162	414
Manual Location Hours	0	32	32
ARD Circuits	7	7	14
ARD Circuit Hours	126	108	234
ARD Recording Hours	542	735	1,277
Hours Searching for CGTs	378	302	680
Number of CGTs found	7	35	42
CGTs per Unit Effort	1.85/100 hours	11.59/100 hours	6.17/100 hours

Table 2. Rainfall Accumulation Amounts for Storms that Occurred During the 2022 Survey Season.

Date	Rainfall (mm)
5/25/22	17.27
6/3/22	2.54
6/6/22	20.32
6/22/22	2.54
7/2/22	4.83
7/7/22	7.62
7/29/22	24.13

Gray highlights indicate road-cruise survey dates.

Table 3. Rainfall Accumulation Amounts for Storms that Occurred During the 2023 Survey Season.

Date	Rainfall (mm)
5/25/23	7.62
5/28/23	13.46
5/30/23	17.78
6/2/23	16.51
6/3/23	25.40
6/4/23	12.70
6/13/23	17.78
6/16/23	43.18
6/17/23	20.32
6/30/23	12.70
7/4/23	25.40
7/8/23	17.78
7/20/23	27.94
8/2/23	10.16
8/4/23	12.70
8/6/23	17.78
8/8/23	12.70
8/9/23	25.40

Table 4. Number of CGT Individuals Found During the 2022 Versus the 2023 Season.

CGT Sex	Total Observed in 2022	Total Observed in 2023
Male	3	15
Female	3	15
Unknown	1	5

Table 5. Sexual Dimorphism Characteristics of CGT Males and Females.

CGT Sex	Average Weight (g)	Average SVL (cm)
Male	4.24	3.73
Female	5.96	4.13
p-value (F vs. M)	p = 0.001019	p = 8.995e^{-5}
t-value (F vs. M)	t = -3.59	t = -4.44
df (F vs. M)	df = 34	df = 34

Table 6. Data of Tagged CGT Individuals.

Date	Sex	Weight (g)	SVL (cm)	Tag ID	Tag Signal Rate
6/18/23	M	3.5g	3.5cm	4B2D2A07	10 seconds
6/18/23	M	4.0g	3.5cm	34615234	10 seconds
6/18/23	M	4.75g	3.9cm	33554C66	10 seconds
6/18/23	M	4.0g	3.5cm	342D6634	20 seconds
6/18/23	M	4.5g	3.9cm	34525566	20 seconds
6/18/23	M	3.0g	3.6cm	4B4C614B	60 seconds
6/18/23	M	4.5g	3.9cm	33341933	60 seconds
6/18/23	M	5.25g	4.1cm	4B1E554C	60 seconds
6/18/23	F	5.0g	3.9cm	78347852	10 seconds
6/18/23	F	6.5g	4.5cm	78342D52	10 seconds
6/18/23	F	4.75g	4.2cm	6633614C	20 seconds
6/18/23	F	5.75g	4.3cm	2A1E071E	20 seconds
6/18/23	F	6.0g	4.6cm	34075519	20 seconds
6/18/23	F	4.75g	4.1cm	66661934	60 seconds

Gray highlights represent tags detected by manual location and the node array, teal highlights represent tags detected only by the node array, and yellow highlights represent tags detected only by manual location.

FIGURES

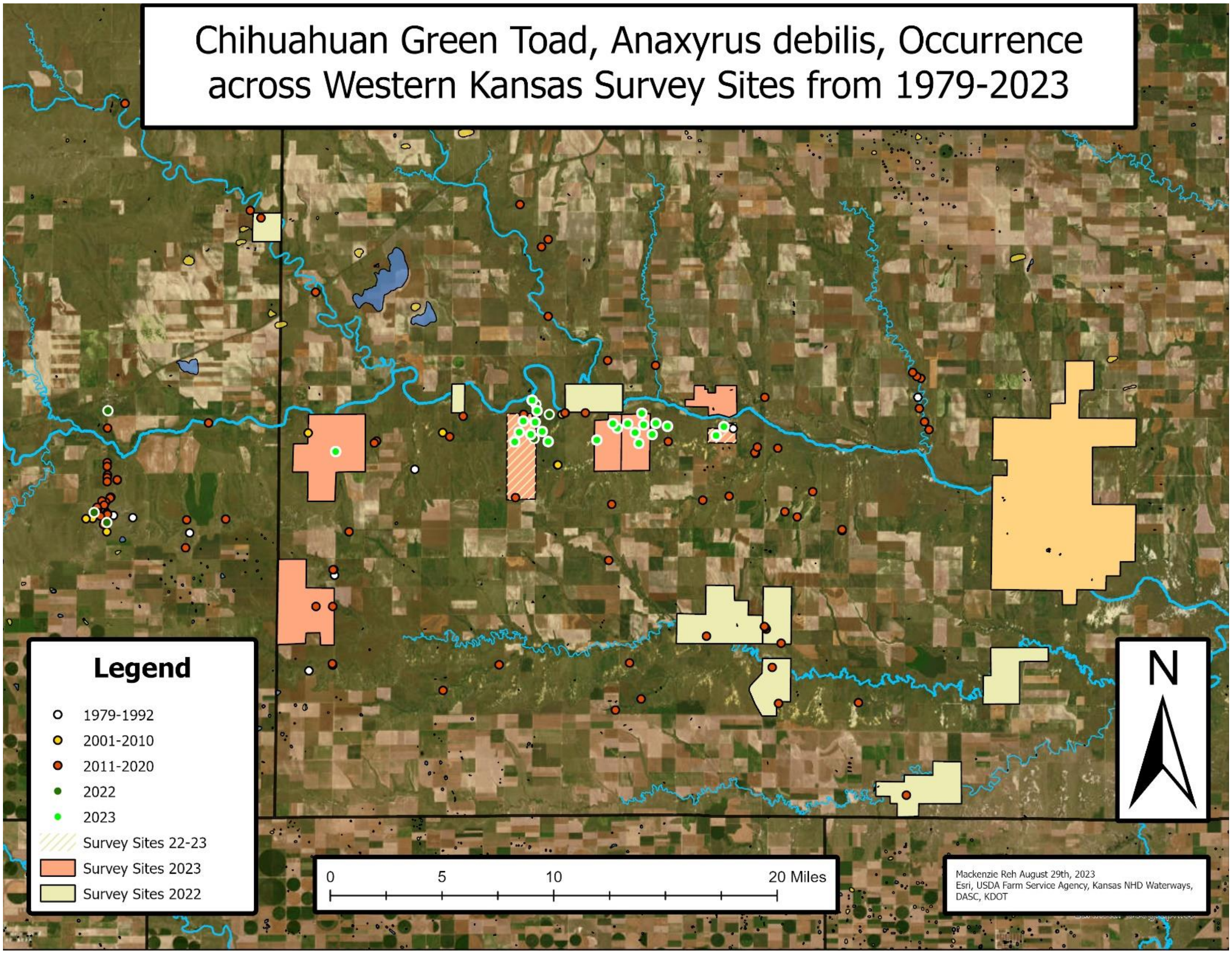

Figure 1. Survey Sites Across Logan and Wallace Counties, Kansas. This map depicts the 10 sites surveyed in 2022 (yellow) and the 8 sites surveyed in 2023 (orange). Two sites were surveyed both years (orange with yellow stripes). The tan outline on the right side of the map is TNC Smoky Valley Ranch where this study was based out of. The dark green dots with white borders represent the distribution of CGTs observed in 2022, and the light green dots with white borders represent the distribution of CGTs observed in 2023.

Figure 2. CGT Radio Telemetry Tag Fitting. This photo illustrates the process of tagging CGTs. The Stretch Magic Cord harness was preattached before depolyment. Individuals were held uder plastic sandwich bags while extending their legs posteriorly to ensure tight fitting of harnesses. The cord was then wrapped around the hips of the individual and glued back to the top of the tag using UV cured adhesive.

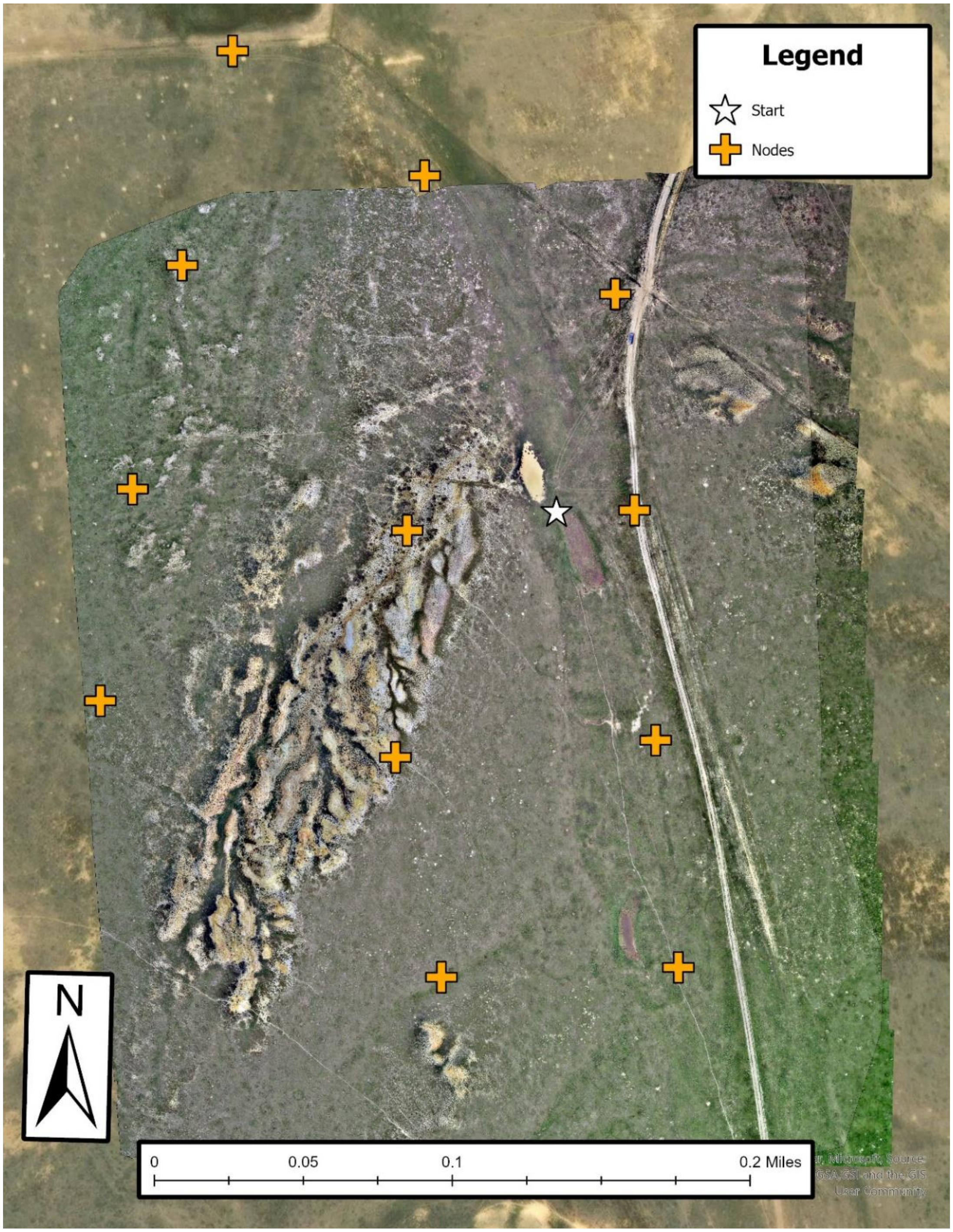

Figure 3. Node Array Distribution. Map illustrates the high-resolution map created from the drone flight. Orange crosses indicate node placement in the Node Array, excluding the 13th node, placed SE of the main array.

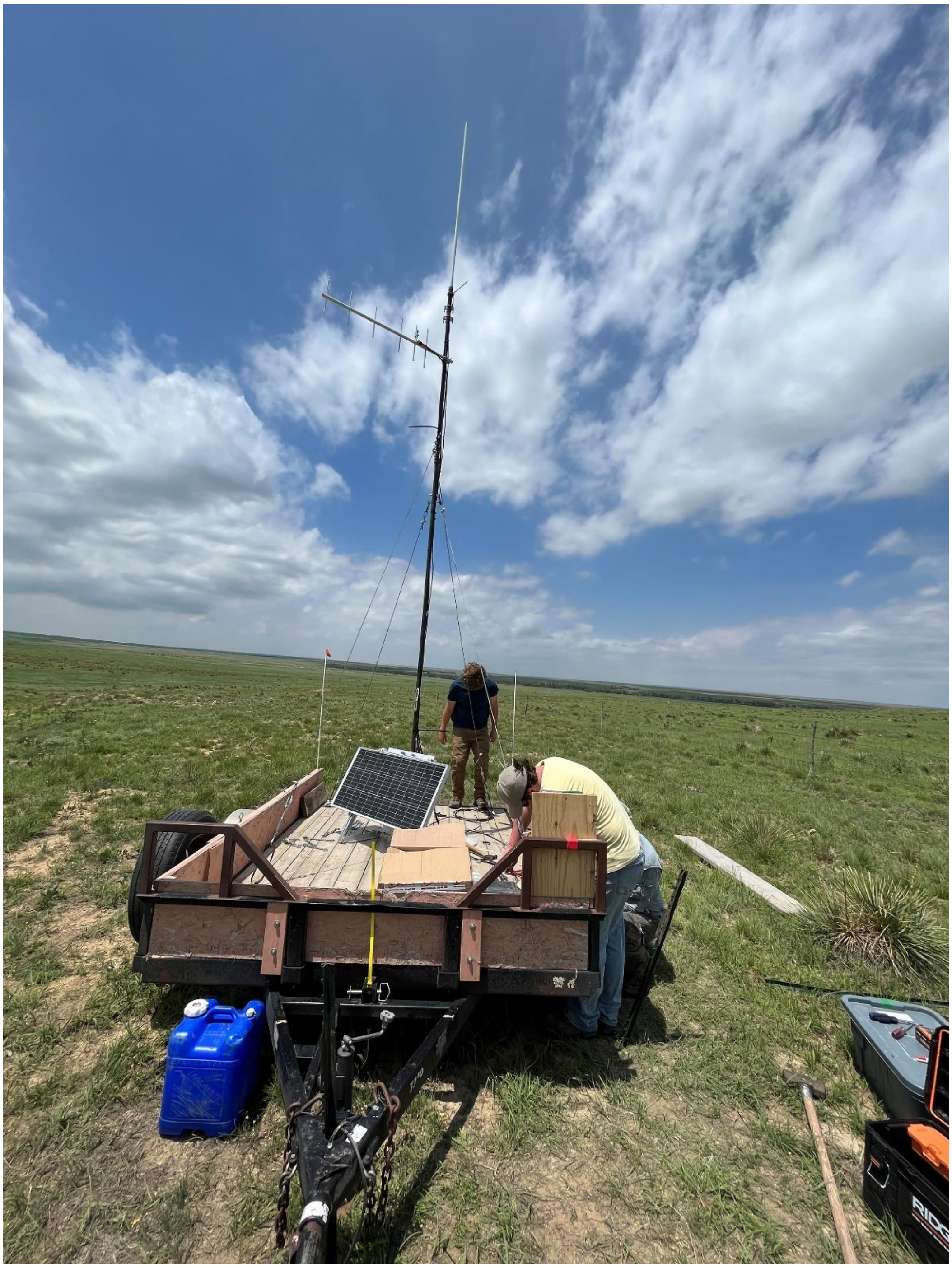

Figure 4. SensorStation Deployment. This photo shows the SensorStation mounted on an open trailer during initial set up on the telemetry site. Solar panels ensured constant power and T-posts around the computer box helped reduce damage from cattle.

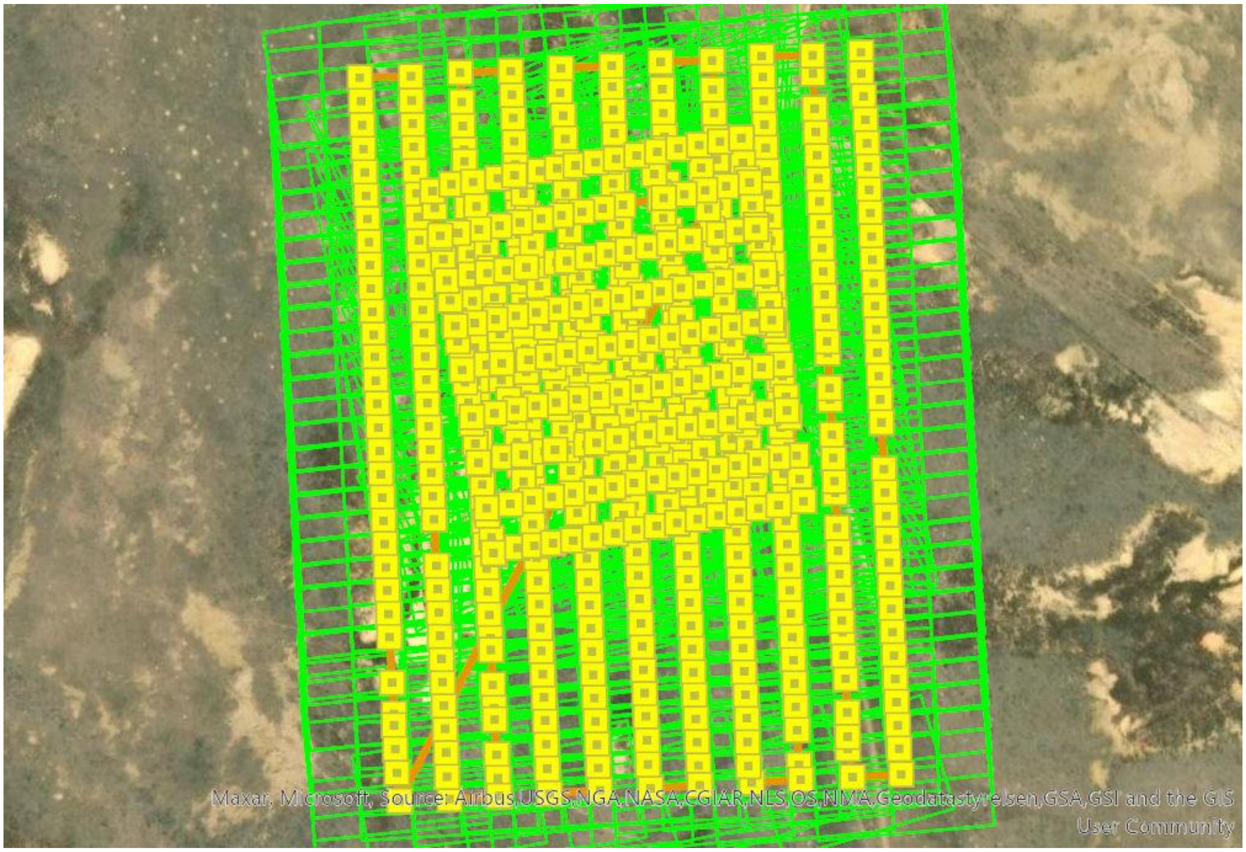

Figure 5. Drone Flight. Map illustrates the flight path of the drone used to capture imagery of the telemetry site. Green lines indicate the path of the drone and yellow squares represent photos taken. Photos were then stitched together in ArcGIS Pro to create a high-resolution map of the telemetry site.

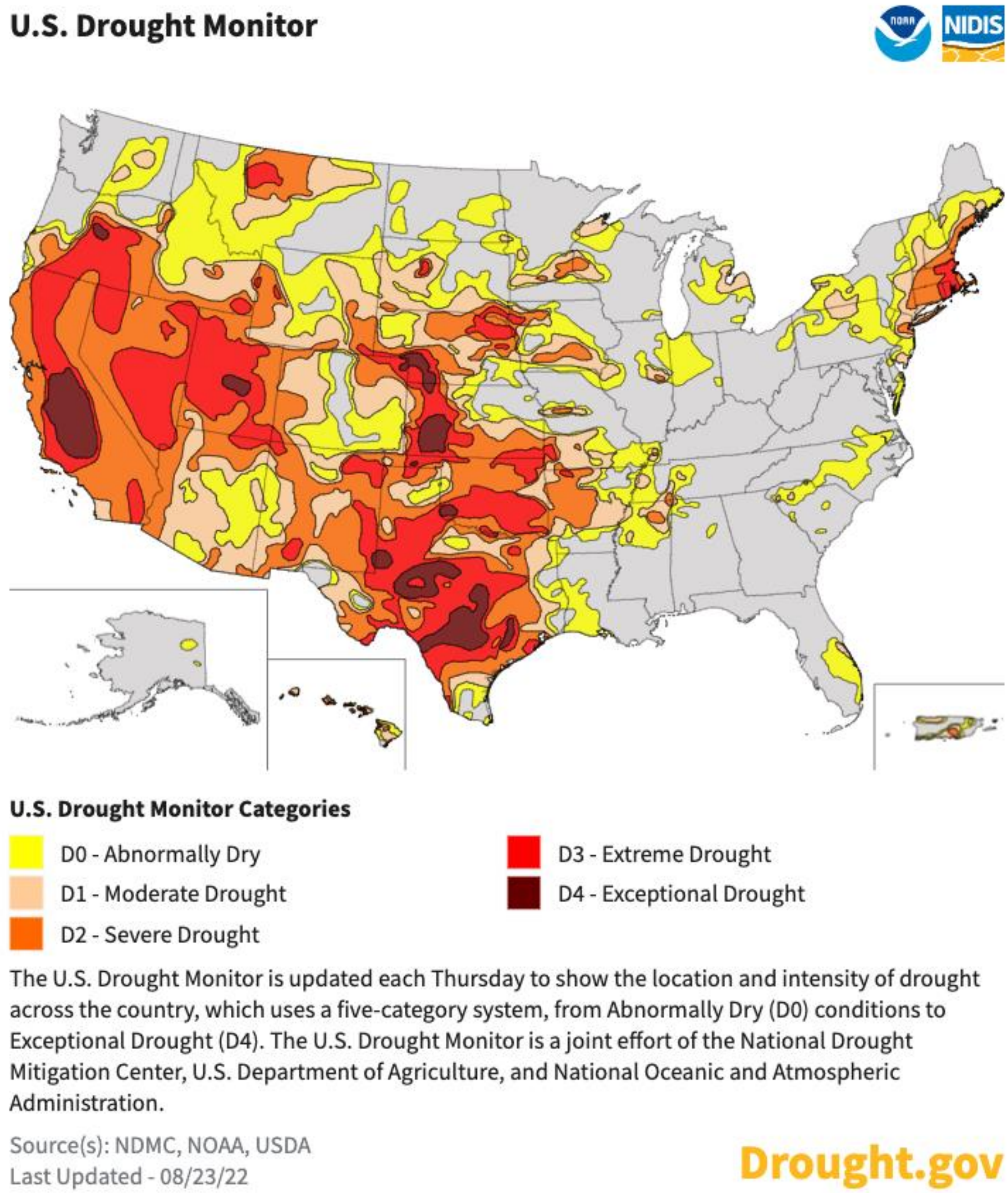

Figure 6. NIDIS Drought Monitor of 2022. This image shows that western Kansas was in Severe and Extreme drought through the 2022 survey season that resulted in few CGT encounters.

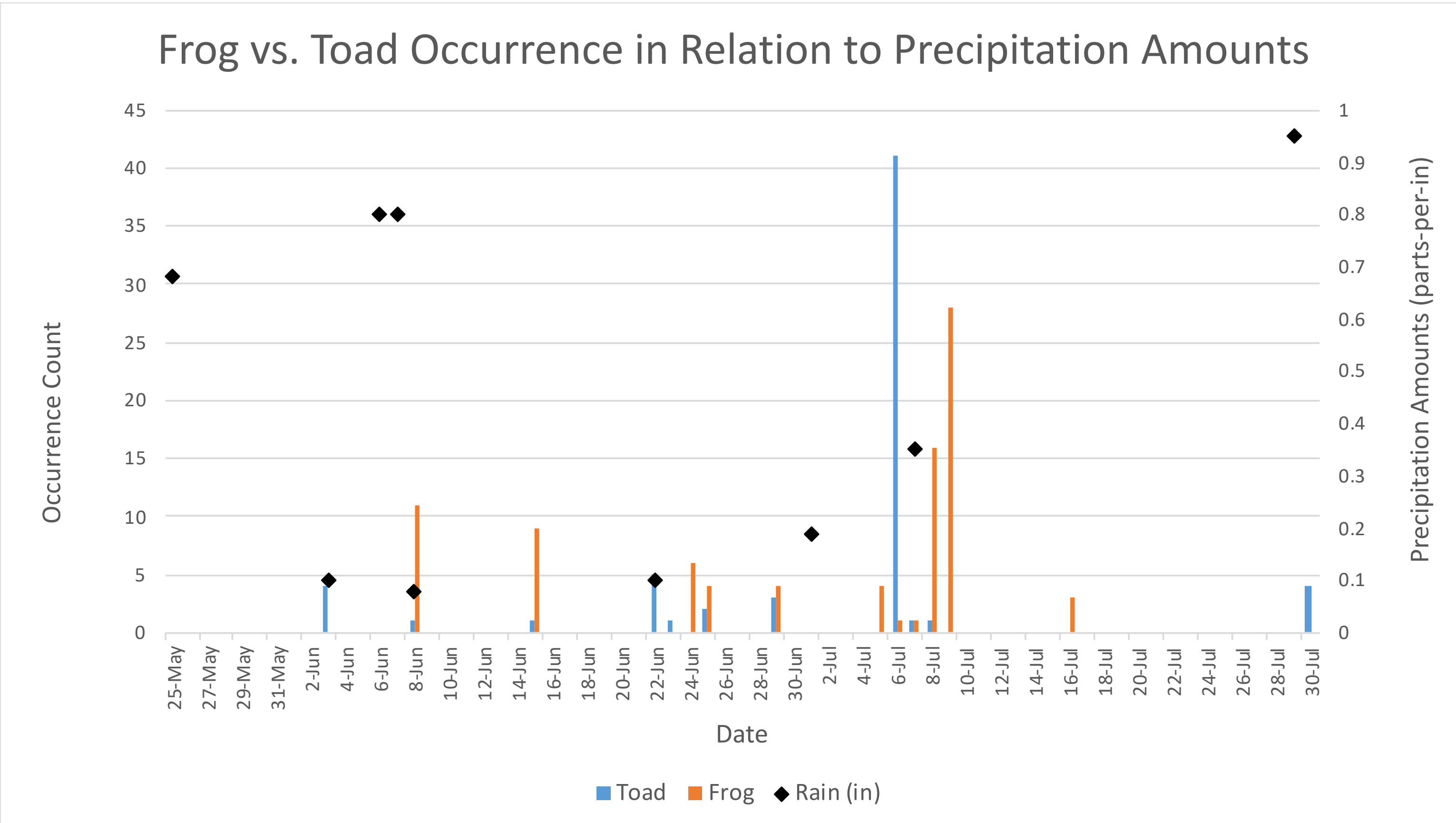

Figure 7. Frog vs. Toad Occurrence in Relation to Precipitation Amounts. Depiction of total anurans, categorized by toad and frog encounters, observed during the 2022 season. The x-axis shows dates, the primary y-axis shows number of anurans encountered, and the secondary y-axis shows precipitation amounts in inches. Toads are blue bars, frogs are orange bars, and precipitation is shown by black diamonds. Frogs were more evenly detected throughout the season regardless of recent precipitation because they opportunistically use any water source for reproduction. Toad observations were dependent on recent precipitation because they are arid-adapted anurans that rely on rain to fill ephemeral pools for reproduction.

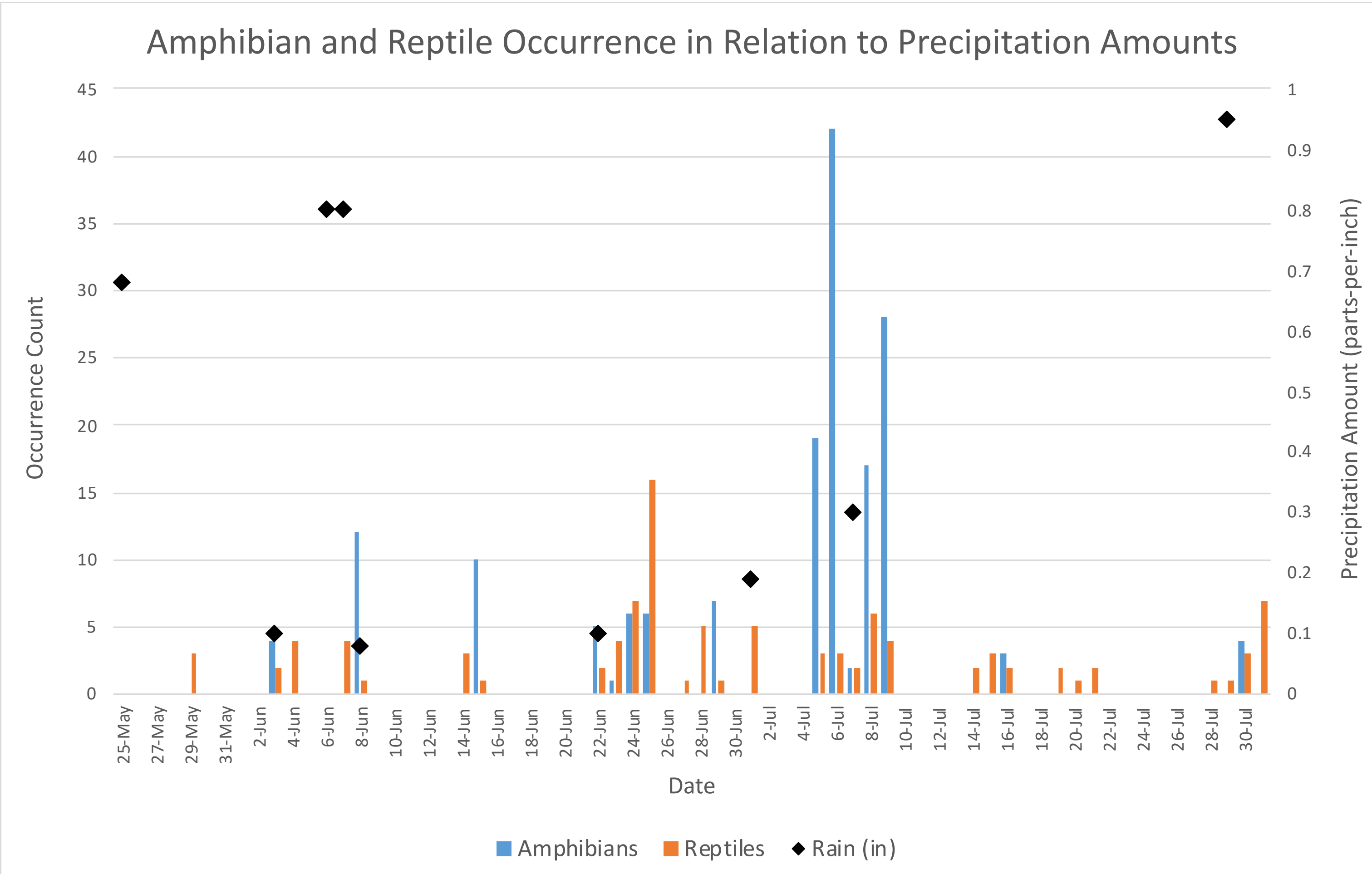

Figure 8. Amphibian and Reptile Occurrence in Relation to Precipitation Amounts. Illustrates the number of amphibians and reptiles encountered in the 2022 season in relation to precipitation amounts. Amphibians are blue bars, reptiles are orange bars, the x-axis represents dates, the primary y-axis represents number of individuals encountered, and the secondary y-axis represents precipitation amounts in inches. Reptiles were encountered consistently throughout the season, regardless of recent precipitation. Amphibian encounters were associated with precipitation and were observed in higher proportions after rainfall.

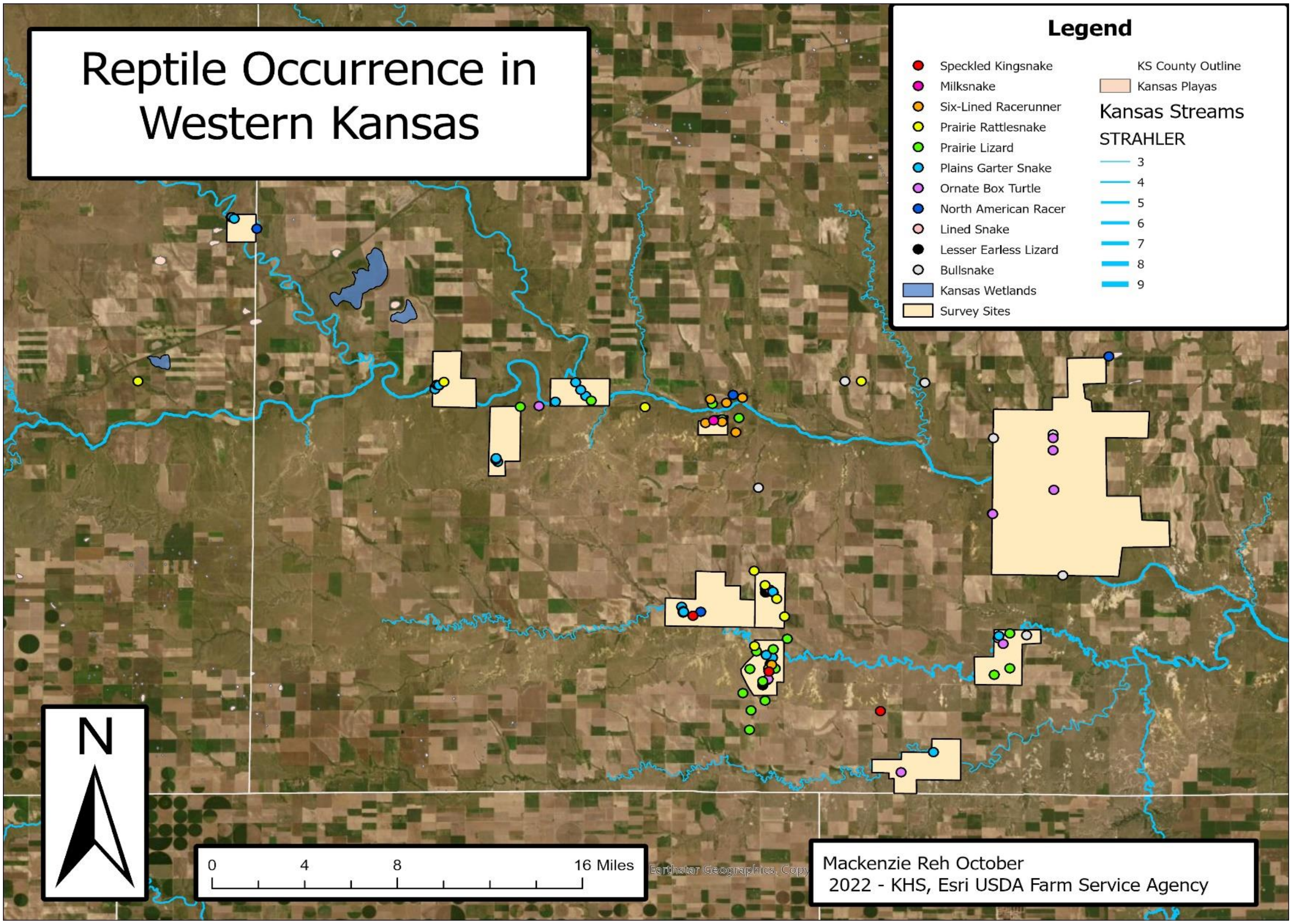

Figure 9. Reptile Occurrence and Distribution in 2022. This map depicts the number of observations of each reptile species encountered and their distribution during the 2022 survey season. 2022 had a higher rate of encountering reptiles than amphibians as a result of little rain accumulation.

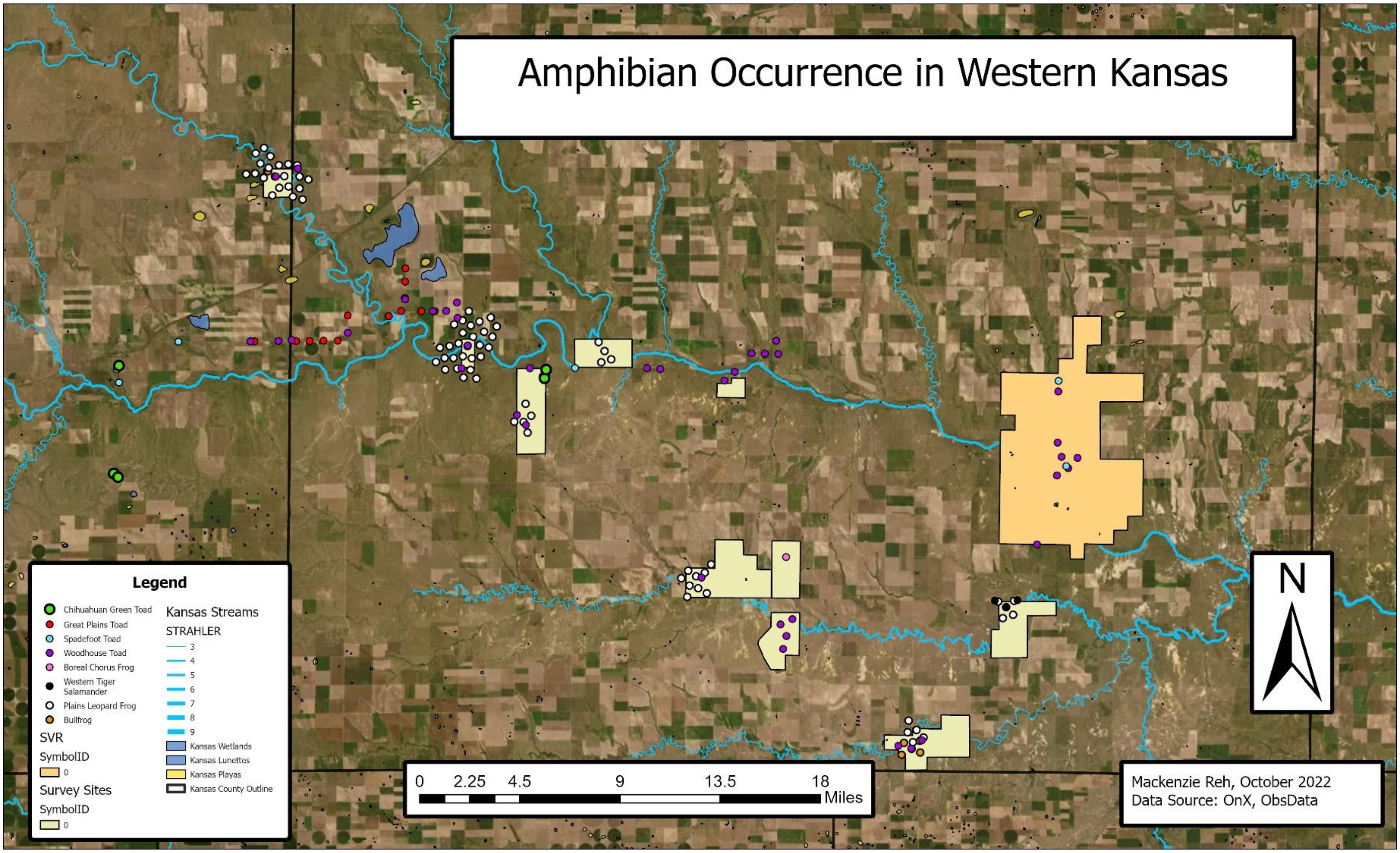

Figure 10. Amphibian Occurrence and Distribution in 2022. This map depicts the number of observations of each amphibian species encountered and their distribution during the 2022 survey season. High numbers of *L. blairi* required spatial readjustment of points using ArcGIS Disperse Tool.

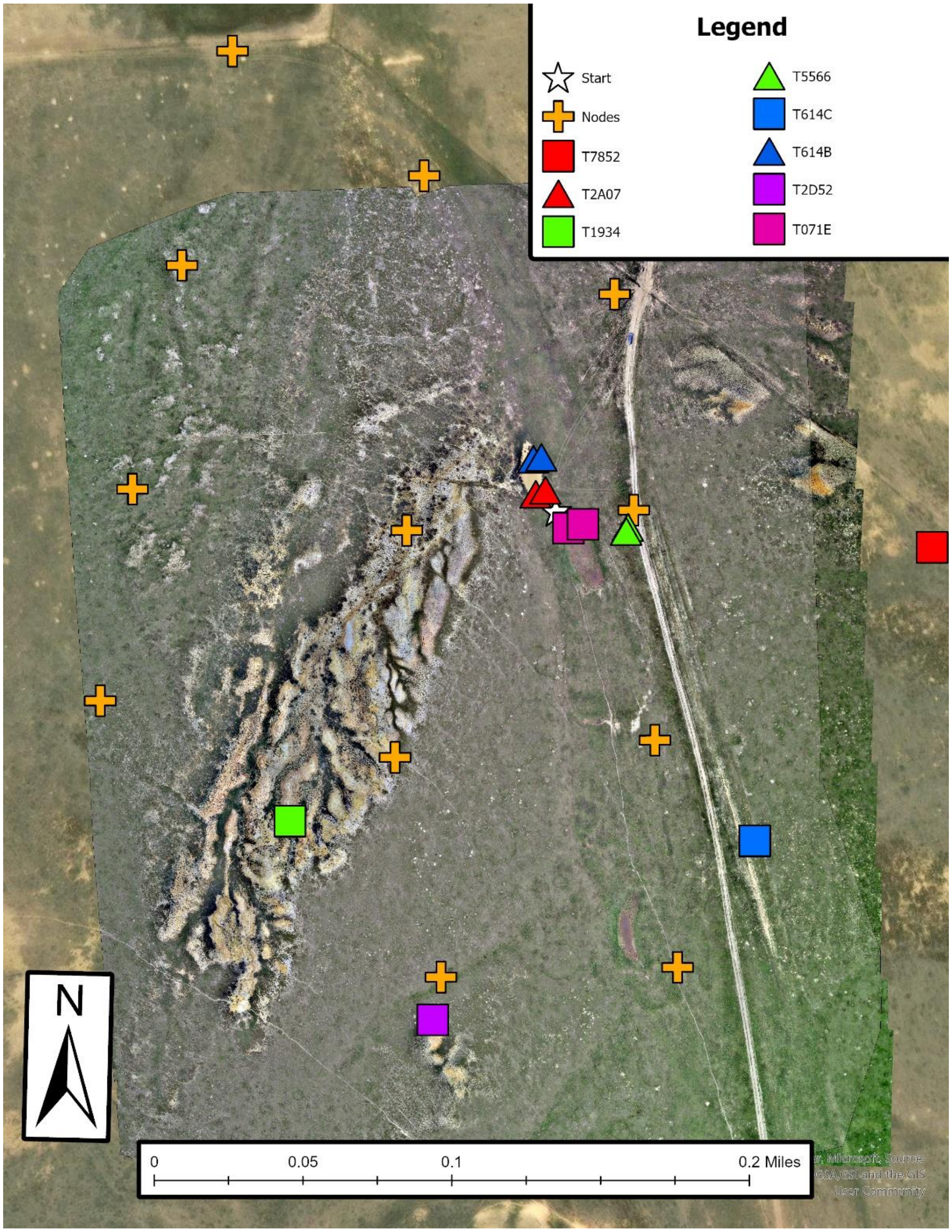

Figure 11. Manual Relocations of Tagged CGTs in Node Array. This map illustrates detections of radio telemetry tagged CGTs across telemetry site. Females are represented by squares and males are represented by triangles; color is only to distinguish individuality. The number of each shape depicts how many times the tags were detected using manual relocation.

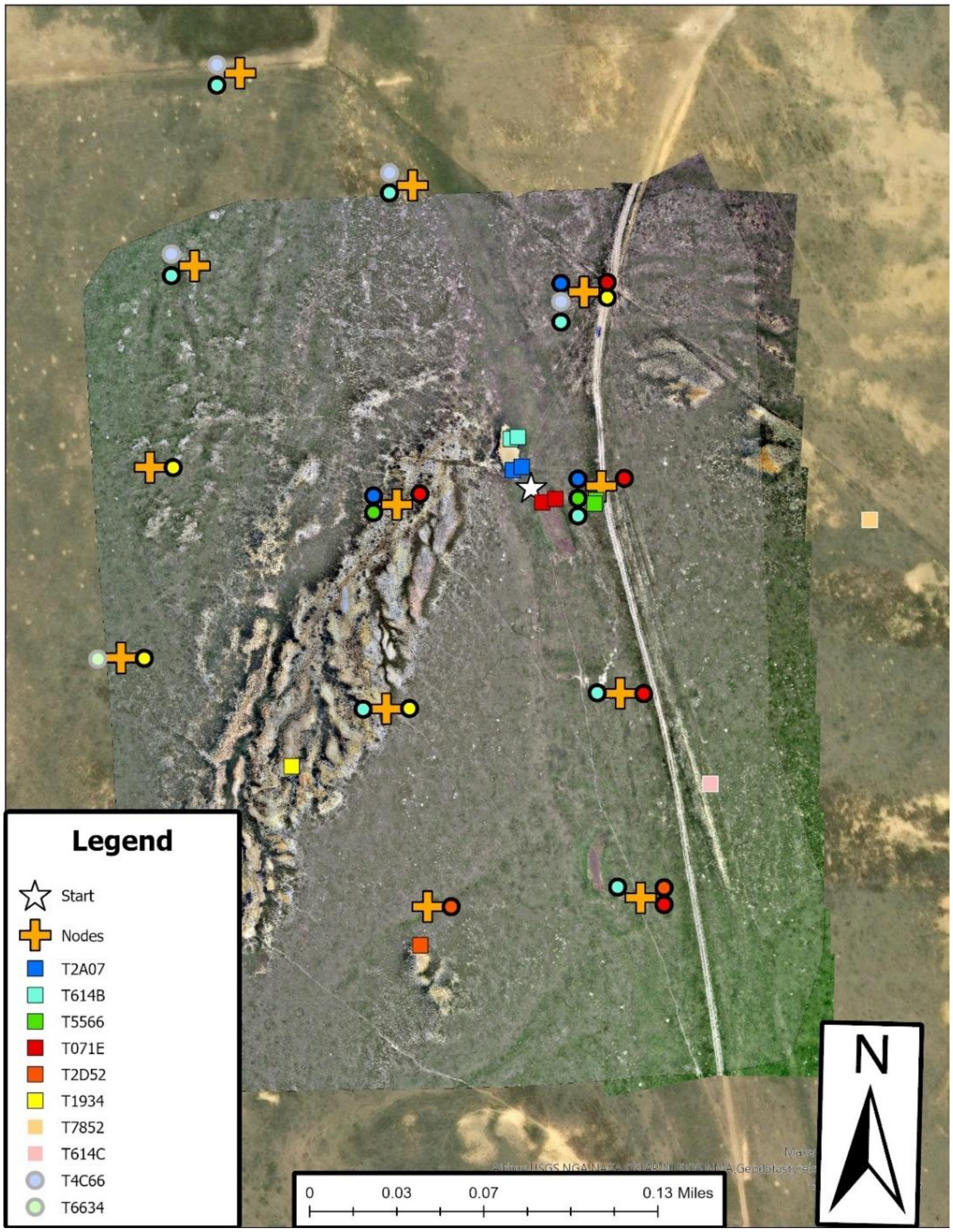

Figure 12. Total Tag Movement Across Node Array. Map illustrates radio telemetry tagged CGT detections by the Node Array. Males are represented by warm colors and females are represented by cool colors. Detections are illustrated by a colored dot corresponding to the individual's assigned color, males on the right of nodes and females on the left. Squares with white borders represent tags only detected by the manual locator and circles with white borders represent tags only detected by the node array.

APPENDICIES

Appendix A: Wildlife Acoustics Kaleidoscope Pro User Guide – Training the Software

Wildlife Acoustics. (2023, August 8). *Kaleidoscope Pro 5 User Guide*. Wildlife Acoustics – User Guides. https://www.wildlifeacoustics.com/uploads/user-guides/Kaleidoscope-Pro-User-Guide.pdf

KPro User Guide

This user manual published by Wildlife Acoustics for the training of Kaleidoscope Pro software to identify and recognize animal calls was used in this study. KPro has high proficiency in recording and identifying bat calls, however, the non-bat analysis was used for this study since the focal species was an anuran. KPro was trained to identify anurans that might be encountered in Western Kansas including Chihuahuan Green Toads, *Anaxyrus debilis*, Woodhouse Toads, *Anaxyrus woodhousii*, Great Plains Toads, *Anaxyrus cognatus*, Plains Spadefoot, *Spea bombifrons*, Plains Leopard Frogs, *Lithobates blairi*, and American Bullfrogs, *Lithobates catesbeinaus.*

Training KPro consisted of obtaining audio calls of the listed anurans, usually two or three per species, of varying lengths and converting the files into a .wav format using the application Tenacity. I ran all obtained calls through Cluster Analysis and manually identified individual calls detected by the software. Clusters were then renamed to represent the corresponding anuran. The analysis was saved and used as the cluster.kcs file which acted as the filter for audio recorded by the ARDs. The cluster.kcs file automatically identified calls that it recognized and further supplemented with manual identification.

Appendix B: CTT Locator User Manual

CTT. (2021, September 23). *CTT Locator User Manual*. Cellular Tracking Technologies User Guide Library. https://cellular-tracking-technologies.github.io/ctt_documentation/CTT_locator_user_guide.pdf

Manual Locator User Guide

This user manual published by Cellular Tracking Technologies was used to set up and run the CTT Manual Locator. The Manual Locator is a hand-help Yagi antenna used to aid in manual relocation of radio telemetry tags. This locator has Wi-Fi capabilities that allows interface between the antenna and a cellular device to identify unique tag ID and signal strength.

The Manual Locator must be fully charged, and tags must be activated prior to deployment for manual relocation. Turning on the Locator makes its Wi-Fi available to connect on a cellular device. Once connected to Wi-Fi, open a web browser, and go to https://locator.click/ to open the home screen. Six blue dots at the top right of the screen indicate functioning connection when spinning. Troubleshooting the Manual Locator includes turning the device on and off, turning Wi-Fi on and off, and refreshing the home screen when blue dots are not spinning.

Once connected, the Manual Locator was held parallel to the ground or at a 45-degree angle from the horizon to detect tags. PowerTags have differing signal rates and therefore changed the amount of time spent pointing the locator in each cardinal direction. When a tag was detected, we moved approximately 3m in the direction with the strongest signal and repeated pointing the locator in each direction. The direction that provided the strongest signal was then followed and the process was repeated until signal strength was believed to be maximized.

Appendix C: CTT Node User Guide

CTT. (2023, April 7). *CTT Node Version 2.0 with GPS*. Cellular Tracking Technologies User Guide Library. https://celltracktech.com/products/ctt-node%E2%84%A2-v-2-0

[Node User Guide]

This user manual published by Cellular Tracking Technologies was used as a reference for the set up and deployment of CTT nodes. Nodes are considered mini-base-stations that can record signals from a variety of radio telemetry tags produced by CTT and other companies. Solar panels are affixed to the top of the nodes which helps ensure battery life and even detection of tags. The solar panels require several days in full sun to fully charge before deployment. Node version 2.0 is equipped with GPS and sends health data to a SensorStation every five minutes including tag detections, GPS, date, time, and node health data.

Nodes are meant to be used in conjunction with SensorStations to effectively track telemetry tags across a study site. Nodes must stay within 1.5km of the SensorStation and localized triangulation can be used when nodes are placed 250-300m apart in an array. The nodes deployed for this study were set out in a 3x4 grid-oriented North to South with each node being approximately 120m apart. Once deployed the Node Array and SensorStation should not need regular maintenance unless they are being used as permanent fixtures.

Appendix D: 2023 Site Locations. 2023 property owner, code name, and location from East to West on Highway 25 out of Russell Springs. Aide for referencing spatial distribution of CGT encounters, breeding aggregation, and chorusing behavior.

Property Owner	Code Name	Latitude	Longitude
Dewayne Repshire	DRF1	38.89683	-101.19354
Dewayne Repshire	DRF2	38.9006	-101.19153
Jason Lamb	LAM	38.89506	-101.25172
John Haverfield	JLH	38.89939	-101.26476
Mark Hanson	CHT	38.90406	-101.32743
Bill & Dixie Surratt	BDS1	38.80914	-101.46204
Bill & Dixie Surratt	BDS2	38.88646	-101.44671

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