# A Comparative Analysis of the Commensal Diversity of Two Gopher Tortoise (*Gopherus polyphemus*) Populations in Central Florida

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## Abstract

Gopher tortoises (*Gopherus polyphemus*) are extremely important to Florida's environments and have been called a keystone species. Gopher tortoises have earned this distinction because their burrows serve as shelter and foraging space for a plethora of different animals, also known as commensals, including invertebrates, reptiles, amphibians, mammals, and birds. Interestingly, the commensals that live in different areas may be different depending on the location and age of the gopher tortoise community. To determine the difference in commensal diversity between gopher tortoise populations, this study surveyed the commensals present in Circle B Bar Reserve, which has a relocated gopher tortoise population, and Lakeland Highland Scrubs, which has a natural, undisturbed population. Pit fall traps, motion-activated field cameras, and a burrow camera were used to survey the commensals that live among the gopher tortoises in both sites, and the diversity of each site's commensals was analyzed. The two sites ultimately did not have significantly different commensal diversity, even though their gopher tortoise populations were present in their environments for very different lengths of time.

## Introduction

One of Florida's most notable characteristics is the incredible diversity of its invertebrates. In fact, some of Florida's arthropods are only found in this state. A large number of these endemic species are found in the natural areas of central Florida because of the Lakeland Ridge and Lake Wales Ridge (Deyrup, 1989). During the prehistoric eras, Florida was just a series of islands, which became the ridges we know today once the sea retreated from Florida's lowlands (Neill, 1957). Once Florida's lowlands became exposed, the ridges still retained their unique biodiversity because their drained sands were unsuitable for many lowland species, and the lowlands were too wet and unsuitable for ridge species (Deyrup, 1989). These invertebrates are hardy, but they still occasionally need protection from the harsh Florida heat. In these sandy ridges and other scrub habitats in Florida, the gopher tortoise (*Gopherus polyphemus*) provides an essential service to these invertebrates and other animals.

The gopher tortoise is native to the southeastern United States (Alabama, Florida, Georgia, Louisiana, Mississippi, and South Carolina) and is federally or state listed in its range (US Fish & Wildlife Service, 2017). Gopher tortoises primarily create burrows to serve as shelter for weather extremes, predators, and other potential threats (Auffenberg and Franz, 1982). These burrows are also used by over 300 species of animals for food and shelter, which makes the gopher tortoise an important animal to protect because it indirectly allows for the survival of many other animals that share this relationship, known as a commensal relationship, with the gopher tortoise (Jackson and Milstrey, 1989). These species include approximately 60 vertebrates, and the remaining diversity is composed of invertebrates (Jackson and Milstrey, 1989). Because gopher tortoise burrows harbor hundreds of other species, it is known as a keystone species, which is a species that is paramount to the environment in which it lives because of the services it provides (Eisenberg, 1983). Keystone species must be protected because their environment would be drastically altered without them. Gopher tortoises live in a variety of habitats in Florida, including longleaf pine-oak uplands, xeric hammocks, sand pine-oak ridges, and ruderal lands, which results in a variety of commensals that live in each habitat (Auffenberg and Franz, 1982). Because gopher tortoise populations are so widespread across Florida, humans are bound to cross paths with them. Unfortunately, human development imperils gopher tortoises, which also imperils the hundreds of species that depend on gopher tortoise burrows for survival.

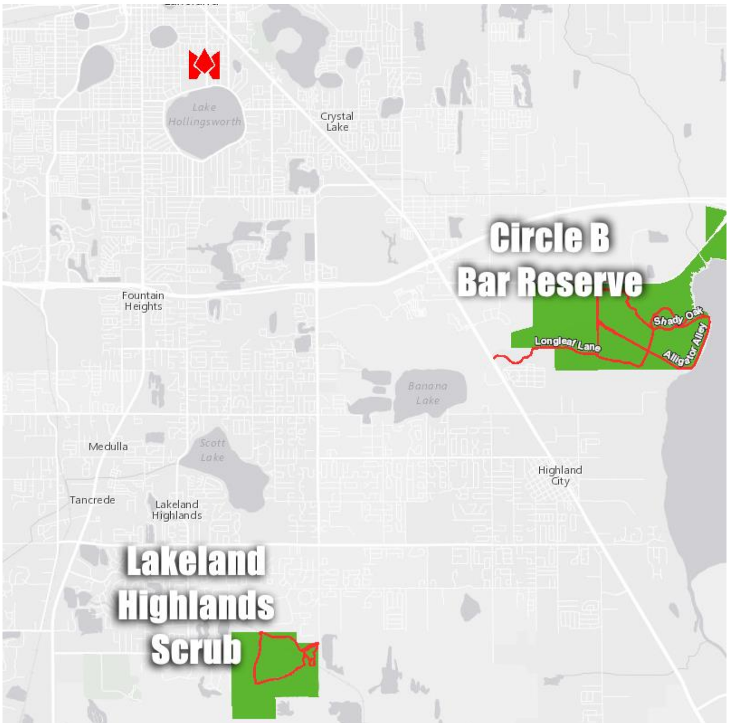
Land modification such as agricultural clearing and urban expansion has dramatically reduced the number of gopher tortoises in Florida, as tens of thousands of hectares of original gopher tortoise habitat have been altered or destroyed (Auffenberg and Franz, 1982). Given the gopher tortoise's expansive range in Florida and the growing human population, construction is invariably proposed for areas in which the tortoises live, which results in tortoises being relocated. Specifically, relocation will occur whenever a contractor cannot continue development on a property without killing tortoises or destroying their burrows (FFWCC, 2017). The Florida Fish and Wildlife Conservation Commission requires those with permits to completely document all impacted burrows, along with paying various fees related to the proper relocation of the tortoises. Gopher tortoises in this situation are usually relocated to appropriate reserves that are closely managed (Ashton and Ashton, 2008). Between 1989 and 1998, more than 25,000 tortoises were relocated, indicating the importance of relocation for the conservation of the species (Enge et al., 2002). In central Florida, one of the only reserves that accepts relocated tortoises is Circle B Bar Reserve (CBR), which has a restored uplands scrubs area in which CBR began specific gopher tortoise management practices in 2013. While reserves with relocation programs, such as CBR, are managed for gopher tortoise survival and health, no studies have been conducted on the animals that live in CBR's gopher tortoise burrows.

Commensal relationships are commonly described as obligate, which indicates that commensals require the burrows to survive, and facultative, which indicates that they are not entirely dependent on burrows (Jackson and Milstrey, 1989, Ashton and Ashton, 2008). Beyond obligate and facultative relationships, commensals may also only use burrows in specific seasons or during specific situations (Eisenberg, 1983). An example of seasonal use of the burrows is the indigo snake (*Drymarchon couperi*) in Georgia, which uses gopher tortoise burrows in the winter to stay sheltered from the colder weather, but then stops using them as frequently in the spring in favor of sheltering under roots and stump openings (Hyslop et. al., 2009). Though *D.couperi* does not use gopher tortoise burrows all year, the burrows play an extremely important role in their survival, and other animals that frequent these burrows likely have a similar relationship with them. Gopher tortoise burrows are deep enough in the ground that they create a unique temperature gradient that provides thermally distinct microhabitats that commensals can use to protect themselves from the temperatures on the surface (Pike and Mitchell, 2013). Hundreds of invertebrates utilize gopher tortoise burrows as shelter, which results in a diverse community of prey items for larger animals. Small mammals, birds, amphibians, and reptiles all frequent gopher tortoise burrows to find an excellent source of food in these burrow mouth microhabitats (Dziadzio and Smith, 2016).

These commensal relationships are extensively studied, so they are generally assumed to exist wherever there are burrows. One cannot assume, however, that every habitat is home to every commensal that has been recorded. For example, compared to a natural population that has existed for thousands of years, the commensal population may be less diverse in an area where gopher tortoises are newly reintroduced after they were absent for at least one hundred years. To understand the difference between the burrow commensal diversity in relocated and natural, long-term populations, a burrow commensal survey was conducted at two different locations. One location has been kept almost entirely natural, so the gopher tortoise burrows are more established. Because the burrows are more established, the commensal populations at this location have been interacting with gopher tortoises and their burrows for much longer than the relocated population, which could lead to a more diverse burrow commensal population. At CBR, the other location, species that are commonly associated with gopher tortoise burrows may not be established because they did not have gopher tortoise burrows to use to increase survival. CBR does have pocket gopher burrows and nine-banded armadillo burrows that could harbor similar commensals, but further studies need to be conducted on those commensals to arrive at any conclusions. Consequently, we hypothesize that the commensals at the natural location will have a greater diversity than those at the relocated location. Examining the difference between the commensal populations in these areas will allow for a greater understanding of the ecology of these commensal communities and their ability to thrive.

## Methods

Commensal sampling was conducted at two scrub habitats in Central Florida: Circle B Bar Reserve (CBR) and Lakeland Highlands Scrub (LHS). Both of these areas are managed by Polk County's Environmental Lands program and are located in Lakeland, FL (Figure 1). Sampling occurred during June and July 2017 (for a total of 60 trap days) and was conducted using pit fall traps made with 2-liter bottles. The top of the 2-liter bottle was cut off, then inverted inside the bottle so that animals could not crawl out of them (Figure 2). Pit fall traps were chosen as the main sampling technique instead of the popular technique of digging up the entire burrow apron and sifting through the sand to find commensals because the tortoises were nesting during the time of this study, and we did not want to disturb the nests that are also in the burrow apron (Jackson and Milstrey, 1989, Ashton and Ashton, 2008).




(**Figure 1**. Map of sampling locations. Edited from http://gisapps.polk-county.net/elp/)


(**Figure 2**. Diagram of 2-liter bottle pit fall trap set-up)

Ten active (established through visible evidence of tortoise tracks and a clear burrow opening) gopher tortoise burrows in each location were selected and four pit fall traps were placed within the apron with two burrows on either side of the burrow opening. Care was taken to ensure that the traps were not blocking the path that the tortoise used to get to the burrow or the site where eggs were laid in the case of nesting females. Each trap was covered with a piece of cardboard that was raised two to three centimeters above the opening of the trap so that animals that walked into the traps would not desiccate in the sun or drown from rain (Figure 3). Traps were checked three times per week and specimens of each new invertebrate was preserved in 70% ethanol so that more thorough inspection could be conducted in the lab for identification purposes. Class *Insecta* was identified using Choate, P.M., 2001, Evans, A.V., 2008, and Evans, A.V., 2014. Class *Arachnida* was identified using Comstock, J.H., 1912, Emerton, J.H., 1961, Evans, A.V. 2008, and Kaston, B.J., 1972.

(**Figure 3**. Trap set-up by gopher tortoise burrow)

In addition to the pit fall traps, motion-activated field cameras (tasco 3 megapixel trail camera) were placed at six random burrows in each location to survey any larger animals frequenting the burrows. Mammals, birds, amphibians, and reptiles are known to visit gopher tortoise aprons specifically for foraging (Dziadzio and Smith 2016). The SD cards in the motion-activated field cameras were checked once a week and any animals found in the images were recorded. In order to survey any commensals that preferred to live within the burrow itself, a burrow camera was used. A conventional burrow camera was not available for use, so a burrow camera rig was created using an action camera (Akaso EK5000 Action Camera), 20-foot long corrugated tubing, and a small LED flashlight attached to a plastic toy car as a base (Figure 4). The burrow camera was used once a week at each burrow being surveyed by pit fall traps. The camera would be slowly inserted into the burrow and pushed down until the camera hit the end of the burrow, an impassible blockage, or a tortoise blocking the way. In all of the sampling methods used, each animal seen was counted as new data, instead of attempting to identify the frequency of specific individuals visiting the burrows.


(**Figure 4**. Burrow camera rig)

Dominant plant species were determined by creating a 10m x 10m ($100m^2$) plot in each burrow site with the gopher tortoise burrow at the center. Plants within that $100m^2$ plot were identified with the help of a botanist (E. Kjellmark) and the USF Plant Atlas by Wunderlin et al., 2017, and the percentage cover of each species was visually estimated. These plants were then separated into categories based on how they took up space in the plots (trees, ground cover, and vines). The dominant plant species for each category had the overall largest average percent cover in each location (Table 1).

**Table 1**. Dominant tree, ground cover, and vines found in the transects around burrows in each location

| Circle B | Scientific name | Percentage cover |
|---|---|---|
| | Dominant tree (Percentage of total number of trees) | |
| | *Prunus serotina* | 66.67 |
| | *Callicarpa americana* | 16.67 |
| | *Quercus laurifolia* | 16.67 |
| | Ground cover | |
| | *Cynodon dactylon* | 39.94 |
| | *Paspalum notatum* | 16.68 |
| | *Melinis repens* | 8.39 |
| | *Eupatorium capillifolium* | 6.57 |
| Lakeland Highland Scrubs | Dominant tree (Percentage of total number of trees) | |
| | *Quercus inopina* | 56.52 |
| | *Prunus serotina* | 19.57 |
| | *Pinus clausa* | 15.22 |
| | *Quercus nigra* | 8.70 |
| | Ground cover | |
| | *Paspalum notatum* | 40.73 |
| | *Cynodon dactylon* | 18.13 |
| | *Melinis repens* | 12.44 |
| | *Licania michauxii* | 10.36 |
| | Vine | |
| | *Vitus rotundifolia* | 94.74 on trees |
| | | 5.26 on the ground |

*Data Analysis*

Commensal biodiversity was estimated using the Shannon Diversity Index, which is a more accurate representation of biodiversity when comparing two sites than the other frequently used Menhinick's index of species richness. The Shannon Diversity Index was compared between CBR and LHS using Hutcheson's t-test in Microsoft Excel 2013 with a significance level of $\alpha < 0.05$. Hutcheson's t-test was used for determining the difference between the diversity indices because Shannon's Diversity Index is not linear, so Hutcheson's t-test accounts for the inability for two of these indices to be compared fractionally (Hutcheson, 1970).

# Results

*Pit fall traps*

The following tables detail the animals, separated by class, found in the pit fall traps at CBR and LHS. The Shannon diversity index for CBR was 2.934, while the index for LHS was 2.831. After taking a Hutcheson t-test between the two indices, the difference between the two was not statistically significant (p-value of 0.303 and $\alpha$ of 0.05). There were 31 total different species found at CBR, while there were 35 different species found at LHS.

**Table 2.** Animals Found in Pit Fall Traps at CBR

| Class | Scientific name |
|---|---|
| Amphibia | *Gastrophryne carolinensis* |
| Reptilia | *Aspidoscelis sexlineata* |
| Gastropoda | *Zonitoides arboreus* |
| Arachnida | *Dictyna spp.* |
| | *Plexippus payleulli* |
| | *Hogna carolinensis* |
| | *Zelotes florodes* |
| | *Latrodectus mactans* |
| | *Geolycosa xera* |
| | *Vonones ornatus* |
| | *Pardosa milvina* |
| | *Rabidosa rabida* |
| Insecta | *Gryllus rubens* |
| | *Gryllodes sigillatus* |
| | *Acupalpus spp.* |
| | *Stenolophus spp.* |
| | *Cicindela hirtilabris* |
| | *Hemiopsida robusta* |
| | *Cicindela punctulata* |
| | *Odontotaenius floridanus* |
| | *Hypoponera opacior* |
| | *Madarellus undulatus* |
| | *Calosoma sayi* |
| | *Scarites subterraneus* |
| | *Camponotus floridanus* |
| | *Camponotus tortuganus* |

**Table 3.** Animals Found in Pit Fall Traps at LHS

| Class | Scientific name |
|---|---|
| Reptilia | *Aspidoscelis sexlineata* |
| Gastropoda | *Zonitoides arboreus* |
| | *Praticolella bakeri* |
| Clitellata | *Amynthas corticis* |
| Arachnida | *Dictyna spp.* |
| | *Rabidosa rabida* |
| | *Geolycosa xera* |
| | *Hogna carolinensis* |
| | *Latrodectus mactans* |
| | *Zelotes ocala* |
| | *Zelotes florodes* |
| | *Plexippus paykulli* |
| | *Centruroides hentzi* |
| | *Pardosa milvina* |
| | *Trachelas spp.* |
| Chilopoda | *Hemiscolopendra marginata* |
| Insecta | *Ceuthophilus maculatus* |
| | *Gryllus rubens* |
| | *Gryllodes sigillatus* |
| | *Acupalpus spp.* |
| | *Stenolophus spp.* |
| | *Eurycotis floridana* |
| | *Cincidela hirilabris* |
| | *Cicindela scabrosa* |
| | *Arenivaga floridensis* |
| | *Calathus opaculus* |
| | *Cicindela punctulata* |
| | *Strategus splendens* |
| | *Pheidole adrianoi* |
| | *Hypoponera opacior* |
| | *Camponotus floridanus* |
| | *Camponotus tortuganus* |

*Trail cameras*

The following tables detail the animals, separated by class, found using the trail cameras at each location.

**Table 4.** Animals Found in Trail Camera Photographs at CBR

| Class | Scientific name |
|---|---|
| Mammalia | *Dasypus novemcinctus* |
| | *Procyon lotor* |
| | *Canis latrans* |
| Aves | *Meleagris gallopavo* |

**Table 5.** Animals Found in Trail Camera Photographs at LHS

| Class | Scientific name |
|---|---|
| Mammalia | *Dasypus novemcinctus* |
| | *Sciurus carolinensis* |
| | *Didelphis virginiana* |

*Burrow camera*

The burrow camera did not catch any animals on video at either site, other than the gopher tortoises that lived in the burrows.

## Discussion

Though LHS had a larger total number of organisms found through the pit fall traps and field cameras (254 for LHS versus 210 for CBR), CBR still had a larger Shannon diversity index (2.934 for CBR and 2.831 for LHS). The result of the Hutcheson's t-test indicated that the two values were not statistically significantly different, which does not support the original hypothesis that LHS would have a more diverse population of commensals. The actual calculation of the Shannon diversity indices greatly depends on how many equally common species there are. Depending on how many individuals of each species were found, the Shannon diversity index can drastically change. Even between areas that have the same number of species, the Shannon diversity index can be different depending on the distribution of species. CBR had fewer total species than LHS, but the distribution of individuals in those species resulted in a more diverse community of organisms overall because of how the Shannon diversity index is calculated.

Even though CBR's gopher tortoise population and their burrows are recently established, they still provide shelter for a diverse collection of commensals. The exact year when gopher tortoises were taken out of CBR is unknown; we only know that the tortoises were not present when CBR was purchased by Polk County's Environmental Lands Program. Commensals do not spontaneously appear whenever tortoises arrive, so CBR's commensal population must have been thriving among other burrow-creating organisms at the reserve. One such organism is the pocket gopher, which has been spotted in the same habitat in which the gopher tortoises live at CBR. The plains pocket gopher burrow systems of Kankakee Sands in Indiana are home to 26 unique species of beetles alone, so burrow systems in Florida are also likely to host a plethora of invertebrates (Powell et al., 2017). These invertebrates could have moved to the gopher tortoise burrows in CBR once they became available because they seemed more attractive for shelter, or because there was less competition for resources. Another organism that could have contributed shelter for the commensals in the gopher tortoise habitat at CBR is the nine-banded armadillo. The nine-banded armadillo arrived in Florida's environment after a small population was released from a personal zoo in Titusville in 1924 (Taulman and Robbins, 1996). Titusville is close to Lakeland, so CBR's armadillo population likely stemmed from this original release. This timeframe indicates that armadillos were in the current gopher tortoise habitat in CBR before the gopher tortoises were re-established, which could mean that commensals were thriving in armadillo burrows before the tortoises arrived. A study in Belize on the armadillo commensals in scrub habitats indicated that various fleas and reptiles lived among nine-banded armadillos, but the methodology was not conducive for finding more invertebrates (no passive traps in the ground) so further studies need to be conducted to draw more conclusions (Platt et al., 2003).

The plant cover around the burrows at each location was extremely similar, which could indicate another reason why the diversity indices were close to each other. Three of the top four plants that covered the $100m^2$ area around the burrow in the ground cover category in each site were the same. Plants serve as additional shelter, breeding grounds, and food for many invertebrates, so the fact that the plants closest to ground near the burrows in each site were almost the same indicates that the same invertebrates could find their preferred habitats among the burrows in both sites, creating similar diversity indices. This ground cover is also important for mammals, birds, amphibians, and reptiles, as they may need a place to hide from predators that may spot them while they are foraging for food in the sand around the burrow opening.

Over thirty different species were found at each location, but the lack of snakes was surprising. The indigo snake and the pine snake are frequently cited as commensals in gopher tortoise burrows, so we assumed that we would find some individuals during this study (Eisenberg, 1983, Jackson and Milstrey, 1989, Ashton and Ashton, 2008, and Hyslop et al., 2009). One of the main reasons why a burrow camera was constructed was so that snakes could be spotted while they were hiding in the burrows, as they would never be trapped in a two-liter bottle pit fall trap, or show up on a field camera photograph. Perhaps each burrow should have been inspected every time the pit fall traps were checked to increase the chance of spotting a snake, but each time burrow cameras were used, the inspection would result in making the tortoises inside the burrows hiss at us for disturbing them, so we tried to keep burrow camera usage to once a week to prevent the tortoises from becoming stressed. Even with this frequency of using the burrow camera, we still expected to see at least one snake in or around the burrows during this study. Data was collected during June and July, two of the hottest months of the year, so it is possible that the pine and indigo snakes that usually share burrows with the gopher tortoises at CBR and LHS did not feel the need to shelter from the elements like they do during the winter (Hyslop, 2009). The burrow camera also did not catch any invertebrates in its path. This lack of recorded invertebrates may have occurred because invertebrates are accustomed to moving out of the way of anything that moves down the burrow, as tortoises may step on them while walking down. The light from the camera rig may have also scared invertebrates, and by the time they would have been in focus, they already moved away from it.

Given the infrequency of spotting larger animals like armadillos, squirrels, and birds, the trail cameras also did not perform as well as they could have. The cameras were reliable for catching most movement during the day, but it took longer for them to register movement at night it seems, as night-time photographs always only featured the back end of the animal. Delayed reactions to taking photographs during the night could explain why there were fewer than ten pictures in each site of nocturnal animals such as opossums and armadillos even though they are extremely common in CBR and LHS. Birds were also not seen on camera, except for slow-moving turkeys at CBR. This lack of smaller birds could indicate a better foraging area close to the trees in which they live, or the potential that the trail cameras did not take pictures quickly enough to capture the movement of swift birds.

Each animal seen was counted as new data because attempting to mark individual invertebrates would have been a large challenge. Because of this limitation, it is possible that certain individuals came back into the pit fall traps after being put back in their environment once they were recorded. For example, *Latrodectus mactans* in CBR were repeatedly found at the same burrows, which could indicate that individuals that lived in and around those burrows were simply falling into the traps more than once. Additionally, some days resulted in no animals in the pit fall traps. These days were usually right after a rain, which likely means that the commensals did not move around the burrow mouth as much and instead hid inside while the rain was falling.

Because of the nature of pit fall traps, no flying invertebrates were caught in these traps. Flies and wasps are cited as commensals in gopher tortoise burrows and their aprons, but none were caught during this project because we did not set out sticky traps or another type of trap that is meant to capture flying invertebrates (Jackson and Milstrey, 1989). Additionally, no soil mites or fleas were caught in the pit fall traps, likely because these animals prefer to stay farther below the surface of the ground and closer to the end chamber of the burrow (Jackson and Milstrey, 1989, Ashton and Ashton, 2008).

In a future study that expands upon the concepts explored in this study, a wider variety of commensals could be sampled if trapping methods are slightly altered, and if the timeframe of the study is extended. To account for flying invertebrates that may have a commensal relationship with gopher tortoises, sticky traps could be placed near the burrows to capture specimens of these species. Sampling armadillo burrows for their commensals and comparing those to the gopher tortoise burrow commensals would also be an interesting addition to the project. If nine-banded armadillo and gopher tortoise commensals were compared, we could more accurately say whether or not the current gopher tortoise commensals at CBR moved in from existing nine-banded armadillo burrows. Additionally, the types of commensals found over the course of this study may have been restricted by the months during which the commensals were trapped. If this study extended into the winter months, it is possible that more commensals would be captured because colder weather entices commensals to spend more time in the warmer burrows. Surveying commensal populations in the winter could potentially increase the chances of seeing snakes as well, which would nicely contrast the data found in this study that indicated a lack of snakes in the burrows.

Gopher tortoise burrows are safe havens for many different species from many different classes of the animal kingdom, which is an important characteristic that classifies gopher tortoises as keystone species (Eisenberg, 1983). These burrows may become even more important as climate change continues to alter our planet, as they can provide thermal gradients that are cooler than the ambient temperature outside (Pike and Mitchell, 2013). As the climate changes, the cool, safe burrows may attract more animals as temperatures rise and extreme weather events become more common. This element of protection that they provide from changing climate serves as another reason to protect gopher tortoises. All keystone species should be at the forefront of our conservation efforts, as they ensure that the communities around them are thriving. If we protect the gopher tortoise, we also protect over 300 species of animals that provide irreplaceable services for our environment.

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## Appendix

Further tables to illustrate the number of each animal found and the calculation of Shannon indices.

**Table 6.** Total Counts and Shannon Indices of Commensals at CBR

| Class | Scientific name | Count | Shannon Index |
|---|---|---|---|
| Mammalia | *Dasypus novemcinctus* | 8 | -0.124482514 |
| | *Procyon lotor* | 5 | -0.088992134 |
| | *Canis latrans* | 2 | -0.044323432 |
| Aves | *Meleagris gallopavo* | 3 | -0.060692789 |
| Amphibia | *Gastrophryne carolinensis* | 2 | -0.047545294 |
| Reptilia | *Aspidoscelis sexlineata* | 12 | -0.173286795 |
| Gastropoda | *Zonitoides arboreus* | 7 | -0.120734878 |
| Arachnida | *Dictyna spp.* | 30 | -0.290046561 |
| | *Plexippus payleulli* | 6 | -0.108304247 |
| | *Hogna carolinensis* | 24 | -0.259930193 |
| | *Zelotes florodes* | 2 | -0.047545294 |
| | *Latrodectus mactans* | 21 | -0.242043915 |
| | *Geolycosa xera* | 5 | -0.088992134 |
| | *Vonones ornatus* | 3 | -0.060692789 |
| | *Pardosa milvina* | 2 | -0.044323432 |
| | *Rabidosa rabida* | 1 | -0.025462417 |
| Insecta | *Gryllus rubens* | 5 | -0.088992134 |
| | *Gryllodes sigillatus* | 4 | -0.07544406 |
| | *Acupalpus spp.* | 12 | -0.163554336 |
| | *Stenolophus spp.* | 5 | -0.088992134 |
| | *Cicindela hirtilabris* | 22 | -0.236349675 |
| | *Hemiopsida robusta* | 4 | -0.07544406 |
| | *Cicindela punctulata* | 1 | -0.025462417 |
| | *Odontotaenius floridanus* | 1 | -0.025462417 |
| | *Hypoponera opacior* | 3 | -0.060692789 |
| | *Madarellus undulatus* | 1 | -0.025462417 |
| | *Calosoma sayi* | 1 | -0.025462417 |
| | *Scarites subterraneus* | 1 | -0.025462417 |
| | *Camponotus floridanus* | 11 | -0.154482547 |
| | *Camponotus tortuganus* | 6 | -0.101581373 |
| | | Total: 210 | Total: 2.934100177 |

**Table 7.** Total Counts and Shannon Indices of Commensals at LHS

| Class | Scientific Name | Count | Shannon Index |
|---|---|---|---|
| Mammalia | *Dasypus novemcinctus* | 5 | -0.077320794 |
| | *Sciurus carolinensis* | 6 | -0.088478145 |
| | *Didelphis virginiana* | 1 | -0.021800529 |
| Reptilia | *Aspidoscelis sexlineata* | 19 | -0.193956734 |
| Gastropoda | *Zonitoides arboreus* | 5 | -0.077320794 |
| | *Praticolella bakeri* | 22 | -0.211883543 |
| Clitellata | *Amynthas corticis* | 1 | -0.021800529 |
| Arachnida | *Dictyna spp.* | 34 | -0.269185462 |
| | *Rabidosa rabida* | 2 | -0.038143205 |
| | *Geolycosa xera* | 5 | -0.077320794 |
| | *Hogna carolinensis* | 12 | -0.144209179 |
| | *Latrodectus mactans* | 3 | -0.05242585 |
| | *Zelotes ocala* | 2 | -0.038143205 |
| | *Zelotes florodes* | 3 | -0.05242585 |
| | *Plexippus paykulli* | 4 | -0.065370707 |
| | *Centruroides hentzi* | 1 | -0.021800529 |
| | *Pardosa milvina* | 2 | -0.038143205 |
| | *Trachelas spp.* | 2 | -0.038143205 |
| Chilopoda | *Hemiscolopendra marginata* | 6 | -0.088478145 |
| Insecta | *Ceuthophilus maculatus* | 3 | -0.05242585 |
| | *Gryllus rubens* | 3 | -0.05242585 |
| | *Gryllodes sigillatus* | 3 | -0.05242585 |
| | *Acupalpus spp.* | 9 | -0.118350343 |
| | *Stenolophus spp.* | 2 | -0.038143205 |
| | *Eurycotis floridana* | 5 | -0.077320794 |
| | *Cincidela hirilabris* | 8 | -0.108910007 |
| | *Cicindela scabrosa* | 3 | -0.05242585 |
| | *Arenivaga floridensis* | 3 | -0.05242585 |
| | *Calathus opaculus* | 1 | -0.021800529 |
| | *Cicindela punctulata* | 2 | -0.038143205 |
| | *Strategus splendens* | 1 | -0.021800529 |
| | *Pheidole adrianoi* | 3 | -0.05242585 |
| | *Hypoponera opacior* | 2 | -0.038143205 |
| | *Camponotus floridanus* | 65 | -0.348785649 |
| | *Camponotus tortuganus* | 6 | -0.088478145 |
| | | Total: 254 | Total: 2.830781118 |

# Works Cited

Ashton, R. E. & Ashton, P. S. (2008). *The Natural History and Management of the Gopher Tortoise Gopherus polyphemus*. Malabar, FL: Krieger Publishing Company.

Auffenberg, W. & Franz, R. (1982). The Status and Distribution of the Gopher Tortoise (*Gopherus Polyphemus*). In R. B. Bury (Ed.), *North American Tortoises: Conservation and Ecology* (pp. 95-126). Washington D.C.: US Dept. of the Interior, Fish and Wildlife Service.

Choate, P.M. (2001). *Manual for the Identification of the Ground Beetles (Coleoptera: Carabidae) (including tiger beetles) of Florida*. Gainesville, FL: University of Florida.

Comstock, J.H. (1912). *The Spider Book: A Manual for the Study of the Spiders and Their Near Relatives, the Scorpions, Pseudoscorpions, Whip-Scorpions, Harvestmen, and Other Members of the Class Arachnida, Found in America North of Mexico, with Analytical Keys for their Classification and Popular Accounts of their Habits*. New York: Doubleday, Paige & Company.

Dziadzio, M.C. & Smith, L.L. (2016). Vertebrate Use of Gopher Tortoise Burrows and Aprons. *Southeastern Naturalist*, 15(4), 586-594.

Eisenberg, J. (1983). *The Gopher Tortoise as a keystone species*. Annual Meeting of the Gopher Tortoise Council Proceedings. pp. 1-4.

Emerton, J.H. (1961). *The Common Spiders of the United States*. London: Dover Publications, Inc.

Enge, K.M., Millsap, B.A., Doonan, T.J., Goore, J.A., Douglass, N.J., & Sprandel, G.L. (2002). *Conservation plans for biotic regions in Florida containing multiple rare or declining wildlife taxa*. Tallahassee, FL: Florida Fish and Wildlife Conservation Commission Technical Report 20.

Evans, A.V. (2008). *National Wildlife Federation Field Guide to Insects and Spiders of North America*. New York: Andrew Stuart Publishing, Inc.

Evans, A.V. (2014). *Beetles of Eastern North America*. Princeton, NJ: Princeton University Press.

Florida Fish and Wildlife Conservation Commission (FFWCC). (Rev. ed. 2017). *Gopher Tortoise Permitting Guidelines*. Tallahassee, FL: FFWCC.

Hutcheson, K. (1970). A test for comparing diversities based on the Shannon formula. *Journal of Theoretical Biology*, 29(1), 151-154.

Hyslop, N.L., Cooper, R. J., & Meyers, J. M. (2009). Seasonal Shifts in Shelter and Microhabitat Use of *Drymarchon couperi* (Eastern Indigo Snake) in Georgia. *Copeia*, 3, 458-464.

Jackson, D. R. & Milstrey, E. G. (1989). *The Fauna of Gopher Tortoise Burrows*. Gopher Tortoise Relocation Symposium Proceedings. pp. 86-98.

Kaston, B.J. (1972). *How to Know the Spiders* ($2^{nd}$ ed.). Dubuque, IA: WM C Brown Company Publishers.

Neill, W. T. (1957). *Historical biogeography of present-day Florida*. Gainesville: Florida State Museum, University of Florida.

Pike, D.A. & Mitchell, J.C. (2013). Burrow-dwelling ecosystem engineers provide thermal refugia throughout the landscape. *Animal Conservation*, 16, 694-703.

Platt, S.G., Rainwater, T.R., & Brewer, S.W. (2003). Aspects of the burrowing ecology of nine banded armadillos in northern Belize. *Mammalian Biology*, 69(4), 217-224.

Powell, G.S., Brattain, R.M., & Zaspel, J.M. (2017). Beetles (Insecta: Coleoptera) Associated With the Plains Pocket Gopher, *Geomys bursarius* (Mammalia: Rodentia: Geomyidae), in Indiana. *Annals of the Entomological Society of America*, 110(3), 269-275.

Taulman, J.F. & Robbins, L.W. (1996). Recent range expansion and distributional limits of the nine-banded armadillo (*Desypus novemcinctus*) in the United States. *Journal of Biogeography*, 23(5), 635-648.

US Fish & Wildlife Service. (2017). Species Profile for Gopher tortoise (Gopherus polyphemus). Retrieved from https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=C044

Wunderlin, R. P., B. F. Hansen, A. R. Franck, and F. B. Essig. (2017). Atlas of Florida Plants. Retrieved from http://florida.plantatlas.usf.edu/