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Cover Photograph: A sampling of the vertebrate species encountered on the Georgia Southern University campus, including (from top to bottom) the Southern Leopard Frog, the Wood Stork, the Northern Raccoon, the Banded Pygmy Sunfish, and the Common Garter Snake. All photos © John David Curlis.

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John David Curlis[*1,2,3], Rebecca Scott[1,4], Emily Evans[1,5], Michelle Cawthorn[1], C. Ray Chandler[1], James Roberts[1], and Lance McBrayer[1]

Abstract - As urbanization increases worldwide, areas that possess both urbanized spaces and natural or semi-natural greenspaces, such as university campuses, present ideal settings in which to measure biodiversity in the modern era. From 2015 to 2017, we documented the vertebrate species that occurred on the main campus of Georgia Southern University (GSU) in the southeastern United States. To maximize the number of species encountered, we sampled using a broad array of surveying and trapping techniques and engaged citizen scientists for assistance. In total, we recorded 206 vertebrate species, representing 46% of the species documented in the surrounding county and 58% of the county species that we would realistically expect to encounter on campus due to species-specific habitat requirements or rarity. While this biodiversity was generally concentrated in the less-intensely urbanized regions of campus, our findings suggest that even partially developed and highly fragmented landscapes can support a relatively high richness of species. Our results underscore the importance and benefits of greenspaces in urban planning and species conservation. We further emphasize that spaces like university campuses should be better leveraged to document contemporary patterns of biodiversity and can serve as ideal study sites for long-term monitoring of species assemblages in an ever-changing world.

Introduction

Biodiversity loss is one of the most pressing environmental issues facing the world today (Cardinale et al. 2012). Many biologists consider the earth to be undergoing a sixth mass extinction event (Barnosky et al. 2011, Ceballos et al. 2020), and it is clear that recent and current extinction rates are significantly higher than "background" extinction rates inferred from the fossil record (Ceballos et al. 2015). One of the driving factors of today's biodiversity loss is the degradation, fragmentation, and destruction of natural habitats by human activities (Díaz et al. 2019, Fahrig 2003). In particular, anthropogenic land development and urbanization play a major role in the decline of native species and populations (Aronson et al. 2014). Because of this, developed and urbanized areas have not received as much conservation or research attention as designated natural areas (Soanes et al. 2019). However, in a world where biodiversity is declining and urbanization is spreading, it is increasingly important to document urban biodiversity in order to better understand where and how to deploy contemporary means of conservation (Mitchell et al. 2015, Ziter 2015). Moreover, a

[1]Department of Biology, Georgia Southern University, 4324 Old Register Road, Statesboro, GA 30458, USA. [2]Department of Ecology and Evolutionary Biology, University of Michigan, 1105 North University Avenue, Ann Arbor, MI 48109, USA. [3]University of Michigan Museum of Zoology, 3600 Varsity Drive, Ann Arbor, MI 48108, USA. [4]College of Marine Science, University of South Florida, 140 7th Avenue South, St. Petersburg, FL 33701, USA. [5]Florida Fish and Wildlife Conservation Commission, 3911 Highway 2321, Panama City, FL 32409, USA. *Corresponding author: curlisjd@umich.edu.

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number of studies support the idea that urban areas can actually support a surprisingly high amount of biodiversity (Derby Lewis et al. 2019, Ives et al. 2016, Kühn et al. 2004, Soanes et al. 2019).

"Urbanization" broadly refers to the anthropogenic conversion of natural and semi-natural land-cover types (e.g., forest, grassland, agricultural fields) via construction of buildings, neighborhoods, parking lots, and roads. However, the effects of urbanization on biodiversity may vary drastically depending on the intensity of the land-cover change (Alberti et al. 2003, Ziter 2015). For example, the conversion of a natural area into a botanical garden or park would likely have markedly different effects on local wildlife than would the conversion of a natural area into a parking lot or office building. One way to minimize the negative impacts of urbanization on biodiversity is via the creation of "greenspaces," areas within an urbanized patchwork that contain natural vegetation, both managed and unmanaged. Such greenspaces can serve as refugia, nesting sites, corridors, stopover points, and hunting/foraging sites for a wide range of animals (González-García et al. 2009, Hutto and Barrett 2021, Partridge and Clark 2018, Partridge et al. 2020, Rutz 2006), which might otherwise avoid an urban area entirely if no greenspaces are present (Lepczyk et al. 2017, Streicher et al. 2021). In addition, the maintenance of greenspaces can provide financial incentives for businesses and institutions that wish to meet certain sustainability goals and/or properly manage natural resources (Aronson et al. 2017). Because a key metric of sustainable practice is the maintenance or enhancement of native biological diversity (reviewed in Niesenbaum 2019, Verma et al. 2020), one must have detailed baseline biodiversity data for future assessment of sustainability practices or future environmental impacts. The various benefits provided by greenspaces have proven to be highly attractive to landowners and urban planners, such that many development projects are being intentionally designed with ample greenspaces in mind (Aronson et al. 2017).

Numerous, large greenspaces are often a hallmark of university and college campuses. These campuses have long recognized greenspace utility not only for the psychological benefits to students and faculty, but also for recreation, outdoor classrooms, and/or ecological study sites. As such, college and university campuses often balance heavily and partially urbanized areas with greenspaces, making them ideal sites to measure biodiversity (Liu et al. 2017). As noted by Liu et al. (2021), colleges and universities often have faculty, staff, and students who are trained in biology, environmental science, wildlife management, and/or forestry, making them (presumably) motivated and well-equipped to accurately identify groups of organisms. Moreover, campuses often harbor nature enthusiasts who may not necessarily be trained in such fields, but who may serve as valuable citizen scientists in biodiversity surveys (Colding and Barthel 2017, Silvertown 2009). Finally, many urban areas, especially colleges and universities, are undergoing a rapid transition to increase awareness and application of sustainable practices, promotion of more sustainable development, and reduction of environmental impacts (Colding and Barthel 2017). In short, college and university campuses are ideal sites to measure biodiversity, preserve biodiversity, and engage the public about the environment, conservation, and the benefits of sustainable practices. While the number of campus biodiversity surveys has indeed increased since 2000, only about 1.2% of universities worldwide have taken advantage of this largely untapped potential (Liu et al. 2021).

In this study, we leveraged the collective knowledge and surveying efforts of citizen scientists, undergraduates, graduate students, and university professors to inventory the vertebrate biodiversity on the campus of Georgia Southern University (GSU). The central goal of our study was to quantify the total number of species of fishes, birds, reptiles, am-

phibians, and mammals observed on campus over two years. We combined standardized sampling methods (e.g., encounter surveying, electrofishing, live trapping), opportunistic encounters, and citizen science data to generate a species inventory and demonstrate the utility of campuses in harboring vertebrate diversity. In addition, we wanted to develop a framework whereby survey and monitoring efforts could be continued and expanded upon in the future. Thus, we developed an on-going iNaturalist project that involves researchers and citizen scientists alike. To provide broad context to the vertebrate biodiversity data on the GSU campus, we compared our findings with known species records for the surrounding region (Bulloch County), and we considered these comparisons in light of differences in habitat availability between campus and county. Ultimately, the results of our comprehensive and systematic survey serve as a reliable assessment of how well campus biodiversity reflects the regional biodiversity, as well as a reference for future monitoring or assessment of future environmental impacts to the campus or region.

Materials and Methods

Study Site

Our vertebrate survey took place on the main campus of Georgia Southern University (GSU), in Statesboro, Bulloch County, Georgia, U.S.A. Statesboro is located in the Southeastern Plains ecoregion (Omernik 1987), an area dominated by pine/oak forest, scrub, sandhill, and wetland habitats. Much of the land surrounding Statesboro has been developed or converted to farmland for row crops (cotton, peanuts, and soybeans) or pasture, but some large patches and corridors of relatively natural bottomland forest, upland scrub, and free-flowing blackwater rivers and streams are present. The main campus of GSU is comprised of 365 contiguous hectares and hosts roughly 21,000 students, faculty, and staff (Georgia Southern University Office of Institutional Research 2018). Our survey area was bounded by Fair Road (Georgia State Highway 67) to the northeast, South Main Street (United States Highway 301) to the northwest, Veterans Memorial Parkway (United States Highway 25 Bypass) to the southwest, and Lanier Drive to the southeast (Fig. 1). Like many university campuses, the area is a heterogeneous patchwork of habitats with varying degrees of anthropogenic alteration, ranging from paved parking lots to mature forests and from constructed ponds with fountains to natural and degraded wetlands.

Standardized Surveying and Trapping

From 1 July 2015 to 1 July 2017, we surveyed for fishes, birds, reptiles, amphibians, and mammals on the campus of GSU. Because these different taxa can have highly dissimilar behaviors, life history strategies, habitat requirements, and degrees of rarity, we determined that a multifaceted surveying approach would be critical to documenting a high proportion of the vertebrates found in the area. Accordingly, we utilized both generalized and taxon-specific techniques when sampling (Fig. 2). All methods were approved under Georgia Southern University IACUC protocols and Georgia Department of Natural Resources Scientific Collecting Permits (see Acknowledgments).

Our most heavily relied-upon method of sampling was the encounter survey. This consisted of actively searching for vertebrates, which were identified by sight (and possibly by sound, if the animals were calling or singing). Encounter surveys mostly involved scanning the sky, vegetation, substrate, and ponds for animals out in the open, yet they also included overturning rocks, logs, and debris to locate reclusive species. We were able to identify many taxa from a distance (especially birds and large mammals), but reptiles and amphib-

ians were caught by hand to allow for close observation and counts of meristic traits like scales and costal grooves, which can be diagnostic. We conducted encounter surveys in all seasons both during the day and the night (using flashlights), as well as in a variety of weather conditions, to maximize the potential species encountered. Photographs were taken whenever possible to aid or confirm species identification.

To capture aquatic amphibians, turtles, and fishes, we used dipnets, seines, gill-nets, minnow traps, rod-and-reel, and Halltech direct-current backpack electrofishers (Halltech Environmental Inc., Guelph, Ontario, Canada). In contrast to non-electrofishing methods that rely heavily on the user's skill/speed, electrofishers allow for broader, more effective sampling by delivering a low-voltage charge that immobilizes fishes long enough for collection and identification (Vaux et al. 2000). Electrofishers were set at 60 Hz for all sampling, and voltage was adjusted as needed according to measured conductivity (ranging from 450–650 V). Aquatic vertebrates were identified in the hand or in a small holding aquarium and then immediately released at the site of capture.

We sampled reptiles and amphibians by creating, deploying, and monitoring artificial refugia and drift fence arrays, both of which are common tools in herpetofaunal surveys (Curlis et al. 2020, Willson and Gibbons 2009). Artificial refugia included coverboards, which are pieces of sheet metal laid on the ground, and frog tubes, which are pieces of PVC pipe with a rubber cap on one end that are oriented vertically and strapped to trees (Willson and Gibbons 2009). In total, we put out and regularly checked 73 coverboards and 11 frog tubes. In addition, we

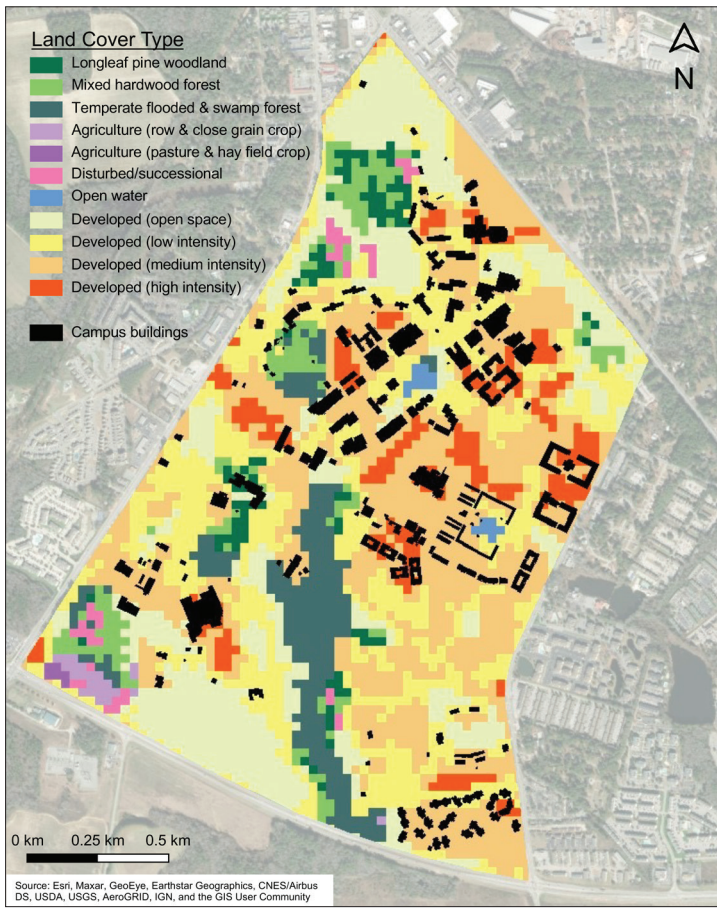

Figure 1. Map of the 365-ha contiguous survey area of Georgia Southern University in Statesboro, Georgia, U.S.A. showing 11 different habitat types.

deployed seven drift fence arrays, which prevent the natural movement of animals across an area and redirect them into traps from which they cannot escape (Willson and Gibbons 2009). Drift fences were made of 10m-long, 0.5m-high (~30 ft-long, ~1.5-ft high) aluminum flashing positioned between two five-gallon buckets (the pitfall traps) buried in the ground on each end. Pitfall trap buckets had tiny holes drilled into their bottoms so that they would not fill with rainwater. Foldable funnel traps (Terrestrial Ecosystems, Mt. Claremont, Washington, USA) made of nylon mesh were placed on either side of each drift fence arm to maximize species sampling at drift fences (Greenberg et al. 1994). Drift fence arrays were operational only when pitfall and funnel traps could be checked twice daily to ensure that animals did not overheat, become hypothermic, starve, and/or die. During any periods in which traps could not be checked so frequently, buckets were covered with tight-fitting lids and funnel traps were removed, preventing captures. All animals captured in any kind of trap or found in any artificial refuge were released immediately after identification.

Figure 2. Equipment and techniques used to survey for vertebrates, including a) a PVC-style track tube, b) a Sherman trap, c) backpack electrofishing, d) a cover board, e) a frog tube, and f) a drift fence with buckets. Photograph of Sherman trap © C. Ray Chandler, all other photographs © John David Curlis.

We sampled mammals through the use of live-trapping, camera-trapping, and track-detection techniques. Rodents were captured by Sherman live-traps baited with sunflower seeds and placed throughout various habitats on GSU's campus. We set Sherman traps two hours before dusk and checked each within four hours of sunrise the following day to reduce the amount of time animals were in traps. We used camera traps (a combination of Reconyx [Reconyx, Holmen, Wisconsin, USA] and Browning [Browning Trail Cameras, Birmingham, Alabama, USA]) to passively survey for larger mammals that might be using game trails or otherwise moving through the forests. We placed cameras traps in four locations around campus at a height of 0.5–1.0m (~1.5–3.3ft) above the ground and did not bait them. Cameras were set to automatically trigger when motion was detected, and the sensitivity was set to take three to five pictures per trigger. Lastly, we surveyed for small mammals using modified track plates that allowed us to detect footprints (Loggins et al. 2010, Wilkinson et al. 2012). We used two styles of these "track tubes" for sampling both arboreal and semi-fossorial mammals: PVC tubes and gutter tubes. PVC tubes of 30cm x 5cm (11.81in x 1.96in) were outfitted with a downward facing 90° elbow on one end (the opening) and an end cap on the other. Tubes were placed on small stilts that kept the opening 8–12cm (3.15–4.72in) from the ground. On the inside of the tube, an inkpad was placed towards the opening and sunflower seeds were placed as bait towards the opposite end. In between the inkpad and bait, a strip of cardstock paper was placed. As animals crawled from the entrance of the tube to the bait, they would leave a trail of ink footprints on the cardstock, which was later brought back to the lab for footprint identification. In a similar manner, we constructed gutter tubes to obtain tracks from animals that were too large to fit in the PVC tubes (Drennan et al. 1998). These gutter tubes consisted of two sections of 12cm x 60 cm (4.72in x 23.6in) K-style gutters taped together along their long edges to create an enclosed tube. Rather than having only one open end, we positioned the bait in the center of the gutter tube and placed an inkpad at both ends, with cardstock in between. These tubes were placed on tree limbs and secured with bungee cords. In total, we surveyed 46 locations with 35 PVC tubes and 11 gutter tubes and checked them on a weekly basis.

Opportunistic Encounters, Reports, and Citizen Science

In order to document as much diversity as possible, we did not want to risk excluding unique or important observations simply because they occurred outside of a standardized survey effort or were obtained by someone not directly affiliated with the overall survey. To address this, we documented opportunistic encounters in which a vertebrate was encountered outside of an official survey (e.g., when walking between buildings, driving through campus, etc.). In addition, we utilized information from GSU students and the general public as a way to increase our likelihood of recording species that we might not have observed ourselves. We generated an online and a hard-copy data form that asked observers to report the species, time, location, behavior, and any other relevant information regarding any animal they encountered on campus. We also created a group project in the mobile application and online website iNaturalist (https://www.inaturalist.org/projects/georgia-southern-biological-survey), which allowed users to upload information about their sightings directly from a mobile phone or computer. All observations that came from data forms and iNaturalist were vetted by at least one member of the survey team before being included in the dataset. For most observations, a photograph or video was required for approval.

Variation in Survey Intensity

The number of people who took part in each sampling effort varied widely, but we estimate that more than 100 individuals were involved in sampling in some capacity throughout

the course of our two-year survey. The most experienced individual surveyors conducted encounter surveys and checked traps on a near daily basis. Every few months, we conducted "Bioblitzes" in which a large group of surveyors (both experienced and inexperienced) was split into smaller taxon-focused teams that each attempted to find as many species as possible in a day. Information about the overall project, Bioblitzes, data forms, and the iNaturalist project were disseminated to multiple biology classes at GSU, including General Biology, Environmental Biology, Field Biology, Fisheries Biology, Ichthyology, Ornithology, Herpetology, and Mammalogy. We also presented our progress and goals at a poster session to the public, hosted by the Georgia Southern Center for Sustainability, to garner interest in our study. In this manner, we had researchers, students, and citizen-scientist students engaged in both formal and informal surveys nearly continuously throughout 2015–2017.

Determining Expected Species

One of our main objectives was to assess the extent to which biodiversity (measured as species richness) on the GSU campus reflects regional diversity. For our purposes, we considered Bulloch County the region of interest. Bulloch County is characterized by an area of approximately 178,450 hectares, a human population size of 79,608 (United States Census Bureau 2019), and a similar mix of natural and anthropogenically modified habitat conditions as those described above for Statesboro. We tabulated vertebrate species collection records for Bulloch County by searching the scientific literature and Georgia Department of Natural Resources databases. However, even in the absence of anthropogenic influences, we would not expect the GSU campus species list to perfectly match the Bulloch County species list simply due to species-specific preferences for habitat or diet. For example, the GSU campus does not contain any large rivers, nor does it contain any scrub or natural sandhill habitats, yet these are found in Bulloch County. Moreover, some species are so exceedingly rare in (or have even been extirpated from) Bulloch County that their likelihood of appearing in an area as small as the GSU campus would be extremely low. We therefore created a list of "expected species" by taking the Bulloch County list and removing certain species, as determined from expert opinion (the authors of this study include research professors, each of whom have over 20 years of experience working with their respective taxonomic group), and a number of printed reference materials (Dunn and Alderfer 2011, Jensen et al. 2008, Page and Burr 2011, Powell et al. 2016, Reid 2006), as well as online databases (eBird 2020, Fishes of Georgia [Straight et al. 2009]). We used these same resources to designate each species recorded for Bulloch County and for the GSU campus as either native or non-native.

Land Cover and Habitat Analysis

Habitat classification for both the GSU campus and Bulloch County was performed using ArcMap v.10.5.1 (ESRI, Redlands, California, USA). Land cover data was compiled from the GAP/LANDFIRE National Terrestrial Ecosystems 2011 Dataset (USGS Gap Analysis Project 2016) and clipped to the geographic extent of both areas of interest. We used a raster analysis to determine and compare the land cover composition of the GSU campus and Bulloch County. We also overlayed our vertebrate observations onto the survey area, allowing us to assess campus biodiversity within each habitat type.

Results

During our two-year survey on the GSU campus, we encountered a total of 206 vertebrate species, including 20 fishes, 126 birds, 22 reptiles, 20 amphibians, and 18 mammals

(Fig. 3, Appendix 1). These 206 species represent 58.4% of all vertebrates that we would expect to encounter on the GSU campus and 46.0% of all vertebrates recorded from Bulloch County. Representation by taxon is as follows: 37.7% of the fish species we would expect to encounter on campus and 32.3% of all fishes recorded from Bulloch County; 64.0% and 49.8% for birds; 51.2% and 40.0% for reptiles; 60.6% and 54.1% for amphibians; and 66.7% and 43.9% for mammals (Fig. 3, Appendix 2). Of the total 206 species, nine were non-native: *Carassius auratus* (Goldfish), *Cyprinus carpio* (Common Carp), *Columba livia* (Rock Dove), *Streptopelia decaocto* (Eurasian Collard-Dove), *Phasianus colchicus* (Ring-necked Pheasant), *Passer domesticus* (House Sparrow), *Sturnus vulgaris* (European Starling), *Rattus norvegicus* (Brown Rat), and *Sus scrofa* (Wild Boar). Seven species were listed on the IUCN Red List as species of conservation concern as of 2017: *Chaetura pelagica* (Chimney Swift), *Passerina ciris* (Painted Bunting), *Lanius ludovicianus* (Loggerhead Shrike), *Hylocichla mustelina* (Wood Thrush), and *Melanerpes erythrocephalus* (Red-headed Woodpecker) were listed as Near Threatened; *Terrapene carolina* (Eastern Box Turtle) was listed as Vulnerable; and *Anguilla rostrata (*American Eel) was listed as Endangered. In addition, *Plethodon ocmulgee* (Ocmulgee Slimy Salamander) has not yet been assessed by the IUCN but has an extremely restricted range in southeastern Georgia.

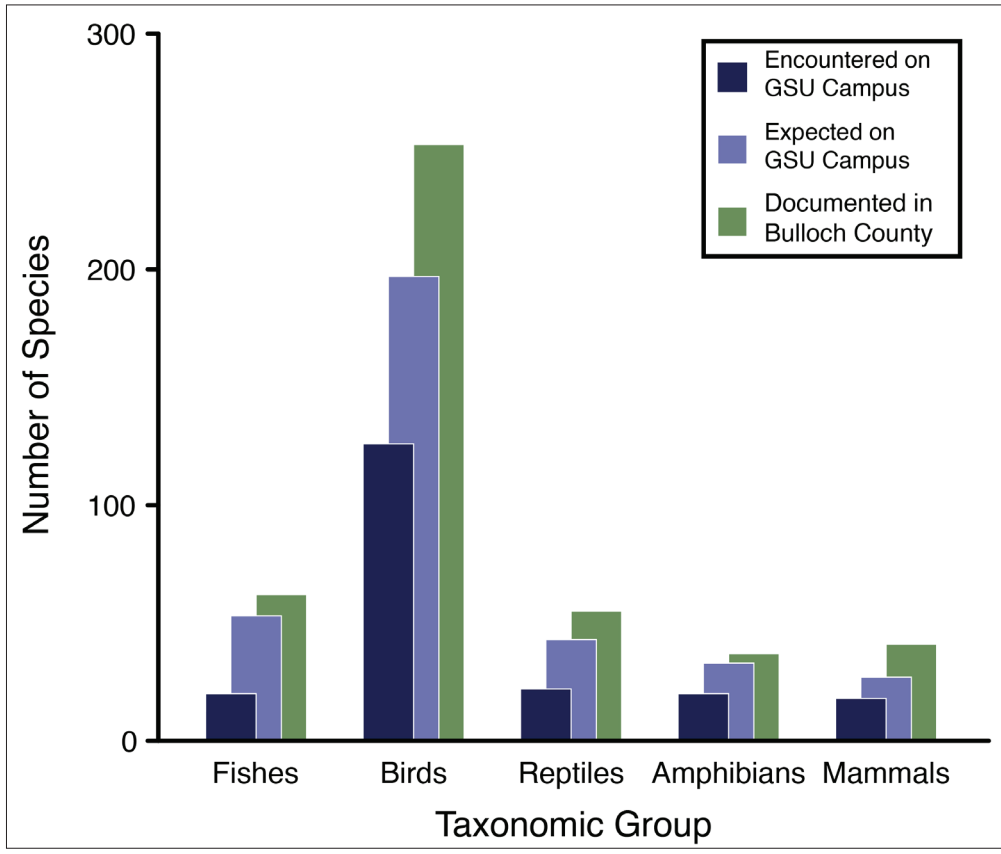

Figure 3. Results of the vertebrate survey on the campus of Georgia Southern University (GSU), showing the number of species encountered on campus, the number of expected species on campus based on available habitats and rarity, and the number of species documented in Bulloch County. Species observed on the GSU campus outside of the two-year survey period are not included. For a full list of observed, expected, and county species, see Appendices 1 and 2.

Outside of the two-year survey, but less than two years before the start or after the end, we encountered an additional 14 species, including one fish, nine birds, one mammal, and three reptiles (Appendix 1). If added to the 206 species from our survey period, this represents 62.3% of all vertebrate species that we would expect to encounter on campus and 49.1% of all vertebrate species documented for Bulloch County. Of these additional 14 species, one reptile was non-native, *Hemidactylus turcicus* (Mediterranean Gecko). One bird, *Colinus virginianus* (Northern Bobwhite), was listed as Near Threatened by the IUCN Red List in 2017.

The proportions and types of habitats differ substantially between the GSU campus and Bulloch County (Fig. 4). Almost 85% of the university's campus can be classified as developed or disturbed land, with dominant subcategories including open developed land (33.7%), followed by low intensity (23.6%) and medium intensity (18.9%) developed land. With respect to non-developed land, GSU contains 6.8% flooded and swamp forest and 4.6% mixed hardwood forest. In contrast, only 15.1% of Bulloch County is classified as developed or disturbed, and the county contains much higher proportions of flooded and swamp forest (29.7%), mixed hardwood forest (17.7%), and pasture or hay fields (27.7%).

As expected, the number of species we documented during our survey was highly variable across habitat types on the GSU campus (Fig. 5a). The least biodiversity (19 species) was observed in agricultural habitat areas, while a total of 180 species were observed in forested/woodland zones, and 135 species were observed in temperate flooded/open water zones. The greatest number of unique species was documented in developed and disturbed land cover types, with a total of 183 species encountered. However, when accounting for land area covered by each habitat type on the campus of GSU, the patterns change (Fig. 5b): 6.5 species/ha were observed in agricultural areas, 0.6 species/ha were observed in developed/disturbed areas, 4.7 species/ha were observed in forested/woodland areas, and 4.4 species/ha were observed in temperate flooded/open water areas. Breaking these habitat types down into sub-categories showed substantial variation within habitat types as well (Fig. 6).

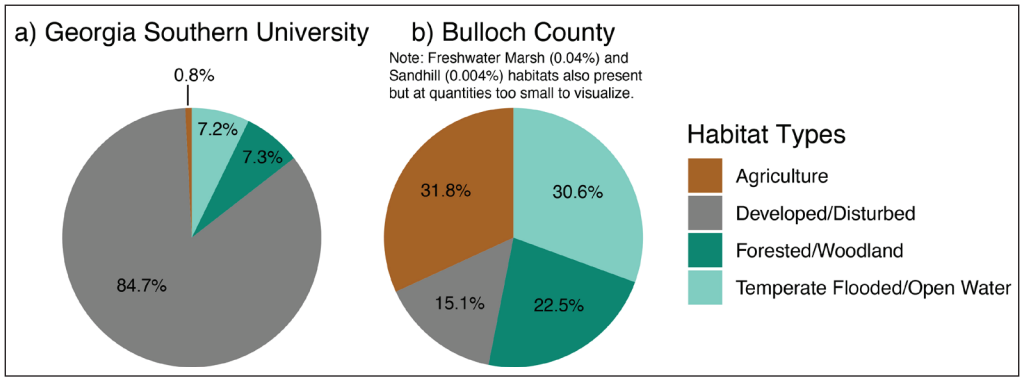

Figure 4. A comparison of relative proportions of habitat types on the campus of Georgia Southern University a) and in Bulloch County b). Habitat type "Agriculture" includes land cover categories "Agriculture (Row & Close Grain Crop)" and "Agriculture (Pasture & Hay Field Crop)." Habitat type "Developed/Disturbed" includes land cover categories "Disturbed/Successional" and all "Developed" classifications. Habitat type "Forested/Wetland" includes land cover categories "Longleaf Pine Woodland" and "Mixed Hardwood Forest." Habitat type "Temperate Flooded/Open Water" includes land cover categories "Temperate Flooded & Swamp Forest" and "Open Water."

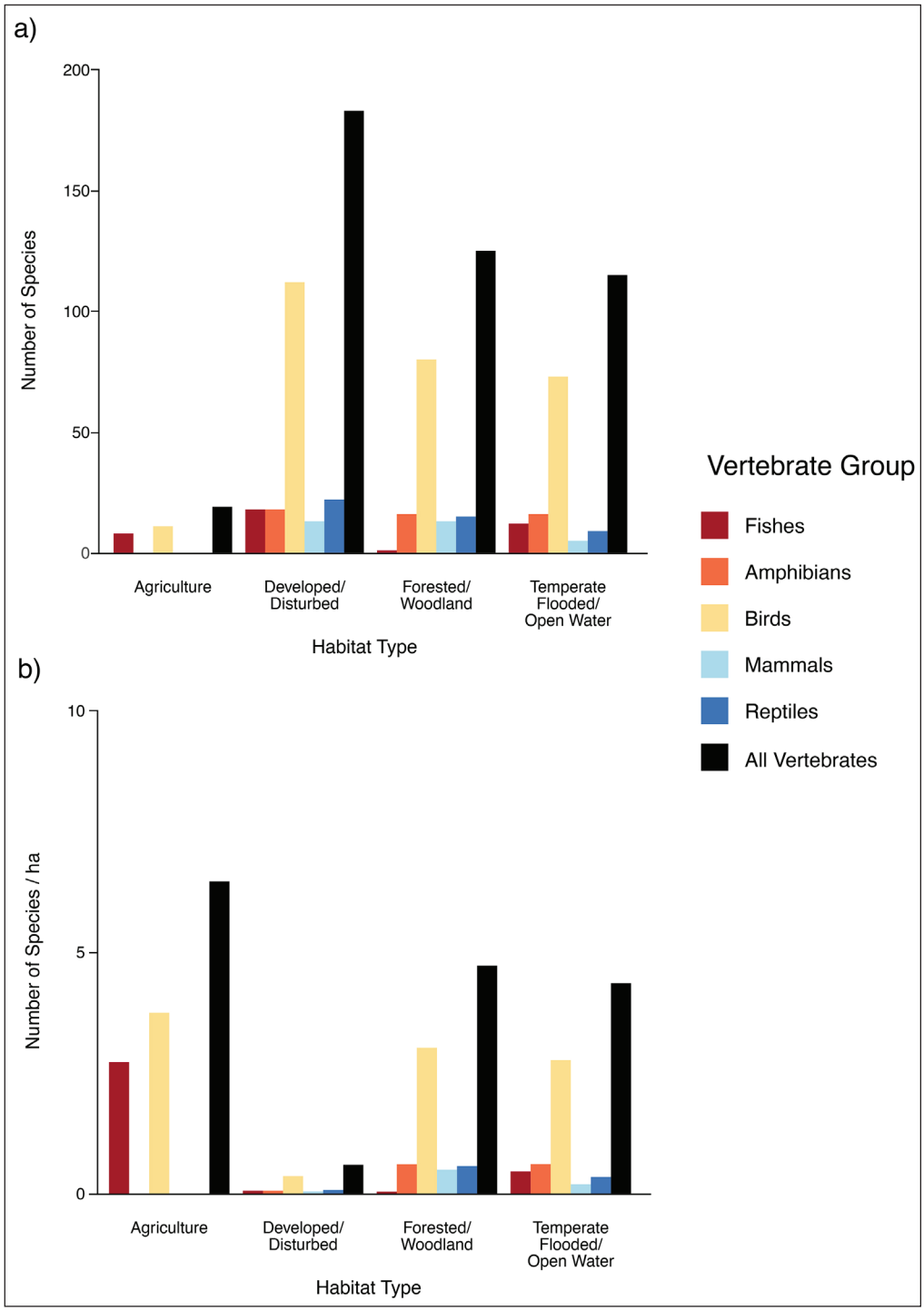

Figure 5. The total number of species a) and the total number of species per hectare b) documented in each broad habitat type on the Georgia Southern University campus.

Discussion

Throughout two years of surveying the main campus of Georgia Southern University (GSU), we documented almost half of all vertebrate species found in Bulloch County, as well as nearly 60% of the vertebrate species that we would expect to encounter based on habitat availability and rarity. Consistent with previous research (Aronson et al. 2014), we found that developed and disturbed areas of campus exhibited a small fraction (roughly 9–14%) of the vertebrate biodiversity found in more natural areas. However, the fact that the 365-ha GSU campus could harbor such a high proportion of regional diversity despite being considered nearly 85% developed underscores the notion that biodiversity can remain present in relatively urbanized areas, especially when ample greenspaces are present (reviewed in Liu et al. 2021). Although our results were likely impacted by sampling bias—more people spent more time surveying (at least opportunistically) in developed/disturbed areas than in forested areas—and a higher likelihood of edge/disturbed habitat species on campus than in the county, it is likely that our findings are typical of university campuses that possess a mixture of developed and natural areas.

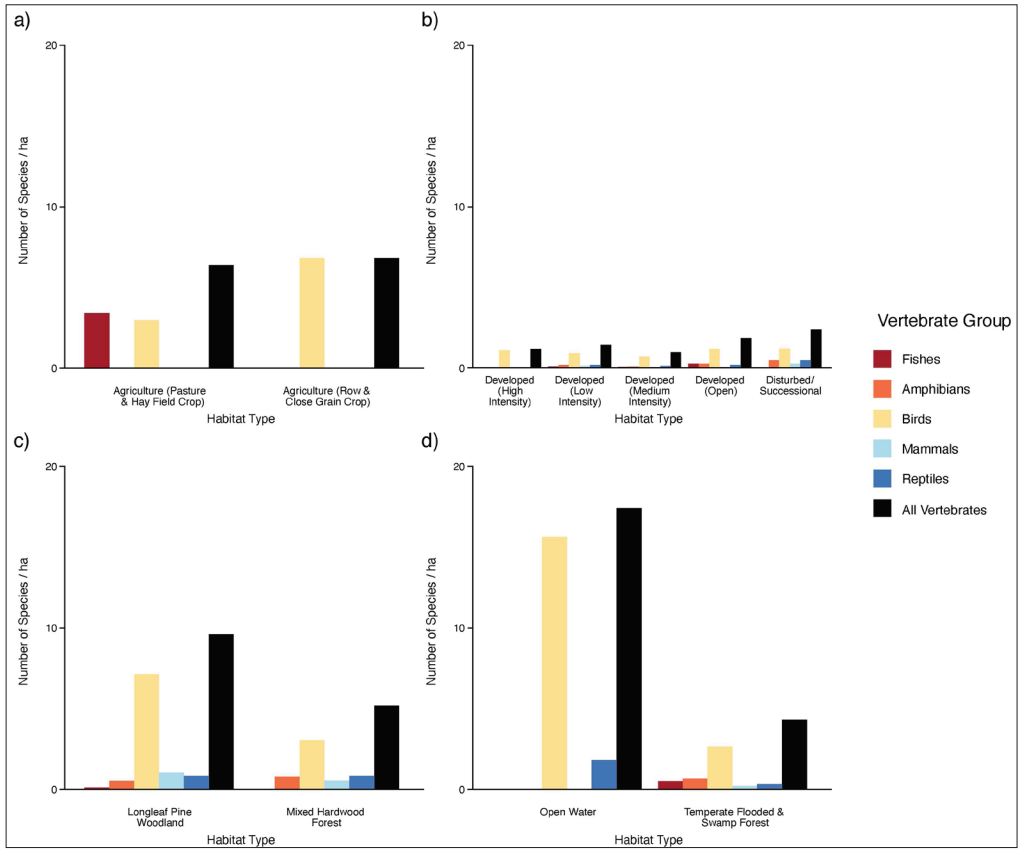

Figure 6. The number of species from each vertebrate group documented in each subcategory of a) Agriculture, b) Developed/Disturbed, c) Forested/Wetland, and d) Temperate Flooded/Open Water habitat types on the Georgia Southern University campus. Note that the "Open Water" habitat type included ponds too deep to effectively sample without the use of watercraft (thus we were unable to record any fish species in these areas), but some non-fish species were documented flying above or swimming at the surface of such ponds.

A number of the species encountered during our survey were species of conservation concern, suggesting that the campus (and other urbanized areas more generally; Casanelles-Abella et al. 2021) may be suitable for even some sensitive species. Our survey documented one endangered fish species, one vulnerable reptile, five near-threatened bird, and an amphibian with a highly restricted range. Moreover, we documented several notable species that are not necessarily of conservation concern but are not particularly abundant in semi-urbanized areas of southeastern Georgia, including *Mycteria americana* (Wood Stork), *Rallus limicola* (Virginia Rail), *Piranga ludoviciana* (Western Tanager), *Ophisaurus ventralis* (Eastern Glass Lizard), *Scaphiopus holbrookii* (Eastern Spadefoot), and *Castor canadensis* (American Beaver). *Masticophis flagellum* (Coachwhip) and *Lontra canadensis* (North American River Otter) were also rather surprising, though they were encountered outside the timeframe of the official survey. The presence of these uncommon and sensitive species, coupled with the scarcity of non-native species (approximately 4% of the species encountered during our survey, a relatively low proportion; Guénard 2015), is likely indicative of a healthy, intact ecosystem on the GSU campus.

Finding such a high diversity of species, especially species of conservation concern and rare species, on a busy university campus also suggests that such areas may serve as refugia for animals facing intense habitat loss or disturbance. Although the GSU campus and Bulloch County show no overlap in the predominant habitat types today (Fig. 4), both the campus and the county would have been dominated by xeric longleaf pine and mesic mixed hardwood forests prior to colonial settlement (Frost 1993). Such an ecosystem was historically maintained by anthropogenic and lightning-induced fire regimes (Van Lear et al. 2005) and therefore would have been characterized by both mature stands and forests at various stages of succession. The fact that the GSU campus still contains longleaf pine stands, mixed hardwood forest, wetlands, and successional areas as "greenspaces" is one of the likely mechanisms that allows a high proportion of the county's biodiversity to persist on the campus. Furthermore, the GSU campus is managed by a single landowner, which has and should continue to provide opportunities for habitat and biodiversity conservation that would be more challenging on much of the privately owned land elsewhere in Bulloch County.

The success of our survey not only shows the utility of university campuses as ideal study sites for measuring and preserving biodiversity (Colding and Barthel 2017), but it also demonstrates the usefulness of leveraging iNaturalist for conducting such surveys. Users of the application can easily view and access all data, as well as contribute observations to the dataset in the form of photographs. Although iNaturalist generally relies upon crowdsourcing to identify a species in a photograph (an observation is considered "research grade" if two thirds or more of the identifiers, who can be any users, agree upon a taxon), the program can be made to further ensure the veracity of user submissions by requiring approval from a qualified project leader (in this case, the authors) before being included. The accumulation of large, verified datasets is thus relatively straightforward using iNaturalist, and the long-term ease of continued data collection cannot be overstated; our iNaturalist project for the GSU campus continues to add vertebrate observations and now includes 92 species of arthropods, coleopterans, and odonates as well. As we and others have found, undergraduate students became particularly interested in the iNaturalist project (Niemiller et al. 2021), making it an ideal tool to develop further teaching (e.g., Course-based Undergraduate Research Experiences, Dolan 2016) and outreach to local communities and/or K–12 schools.

Here, we demonstrate that university campuses and other semi-urbanized areas with greenspaces are important sites for assessing, monitoring, and maintaining biodiversity. We found a degree of species richness on campus that reflects nearly 60% of what we might

expect to find based upon the available habitat types, including several rare species and species of concern for which habitat availability is likely limiting. We show that university campuses can leverage existing expertise of professors and graduate students and the availability of willing and able undergraduate surveyors to quantify and curate biodiversity data. While we recognize that GSU represents a particularly favorable campus for a vertebrate survey due to the rich biodiversity of the region and the easy access to a great number of local scientists and citizens (which may limit GSU's broad representation of other campuses), we strongly encourage universities around the world to conduct similar biodiversity inventories so that broad comparisons and generalizations can be made in the future. Moreover, the long history and probable future permanence of universities make these institutions ideal settings in which to begin or continue long-term biodiversity studies, the results of which can be used to assess species and population trends through time in an ever-changing, increasingly urbanized world.

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Appendix 1. List of all vertebrate species observed on the campus of Georgia Southern University. Non-native species are indicated with an asterisk, and species observed outside of the survey period (but within two years of the start or end) are indicated by a dagger. The values in the column "No. recorded" indicate the number of individuals documented during the survey period (for individuals only documented before/after the survey period, this value is "N/A") and are included for a rough measure of relative abundances, but these values do not account for individuals encountered multiple times nor for discrepancies in sampling effort across taxa (e.g., fishes were sampled less often than birds). The IUCN status column lists the conservation classification of each species as of 2017, with LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, and N/A = Not Applicable (for non-native species or species not assessed by IUCN).

Class	Order	Family	Species	Common Name	No. Recorded	IUCN Status (2017)	Species Authority
Actinopterygii	Amiiformes	Amiidae	*Amia calva*	Bowfin	2	LC	Linnaeus
	Anguilliformes	Anguillidae	*Anguilla rostrata*	American Eel	3	EN	(Lesueur)
	Cypriniformes	Catostomidae	*Erimyzon sucetta*	Lake Chubsucker	84	LC	(Lacépède)
		Cyprinidae	*Carassius auratus* *	Goldfish	1	N/A	(Linnaeus)
			Cyprinus carpio *	Common Carp	1	N/A	Linnaeus
			Notemigonus crysoleucas	Golden Shiner	191	LC	(Mitchill)
	Cyprinodontiformes	Poeciliidae	*Gambusia holbrooki*	Eastern Mosquitofish	395	LC	Girard
	Esociformes	Esocidae	*Esox americanus*	Redfin Pickerel	29	LC	Gmelin
	Lepisosteiformes	Lepisosteidae	*Lepisosteus platyrhincus* †	Florida Gar	N/A	LC	DeKay
	Perciformes	Centrarchidae	*Centrarchus macropterus*	Flier Sunfish	31	LC	Lacépède
			Lepomis auritus	Redbreast Sunfish	393	LC	(Linnaeus)
			Lepomis gulosus	Warmouth	84	LC	(Cuvier)
			Lepomis macrochirus	Bluegill	46	LC	Rafinesque
			Lepomis marginatus	Dollar Sunfish	5	LC	(Holbrook)
			Lepomis microlophus	Redear Sunfish	5	LC	(Günther)
			Lepomis punctatus	Spotted Sunfish	6	LC	(Valenciennes)
			Micropterus salmoides	Largemouth Bass	37	LC	(Lacépède)
		Elassomatidae	*Elassoma zonatum*	Banded Pygmy Sunfish	37	LC	Jordan

Class	Order	Family	Species	Common Name	No. Recorded	IUCN Status (2017)	Species Authority
		Percidae	*Etheostoma fusiforme*	Swamp Darter	1	LC	(Girard)
	Siluriformes	Ictaluridae	*Ameiurus natalis*	Yellow Bullhead	20	LC	(Lesueur)
			Ameiurus nebulosus	Brown Bullhead	1	LC	(Lesueur)
Amphibia	Anura	Bufonidae	*Anaxyrus terrestris*	Southern Toad	81	LC	(Bonnaterre)
		Hylidae	*Acris gryllus*	Southern Cricket Frog	23	LC	(LeConte)
			Hyla chrysoscelis	Cope's Gray Treefrog	11	LC	Cope
			Hyla cinerea	Green Treefrog	40	LC	(Schneider)
			Hyla femoralis	Pine Woods Treefrog	32	LC	(Bosc)
			Hyla gratiosa	Barking Treefrog	2	LC	(LeConte)
			Hyla squirella	Squirrel Treefrog	15	LC	(Bosc)
			Pseudacris crucifer	Spring Peeper	36	LC	(Wied-Neuwied)
			Pseudacris ocularis	Little Grass Frog	1	LC	(Holbrook)
		Microhylidae	*Gastrophryne carolinensis*	Eastern Narrow-mouthed Frog	67	LC	(Holbrook)
		Ranidae	*Rana catesbeiana*	American Bullfrog	60	LC	(Shaw)
			Rana clamitans	Green Frog	29	LC	(Latreille)
			Rana sphenocephala	Southern Leopard Frog	56	LC	(Cope)
		Scaphiopodidae	*Scaphiopus holbrookii*	Eastern Spadefoot	1	LC	(Harlan)
	Caudata	Amphiumidae	*Amphiuma means*	Two-toed Amphiuma	8	LC	Garden
		Plethodontidae	*Eurycea cirrigera*	Southern Two-lined Salamander	6	LC	(Green)
			Eurycea quadridigitata	Dwarf Salamander	33	LC	(Holbrook)
			Plethodon ocmulgee	Ocmulgee Slimy Salamander	17	N/A	Highton
		Sirenidae	*Siren intermedia*	Lesser Siren	10	LC	Barnes
			Siren lacertina	Greater Siren	9	LC	Österdam

Class	Order	Family	Species	Common Name	No. Recorded	IUCN Status (2017)	Species Authority
Aves	Accipitriformes	Accipitridae	*Accipiter cooperii*	Cooper's Hawk	9	LC	(Bonaparte)
			Accipiter striatus	Sharp-shinned Hawk	1	LC	Vieillot
			Buteo jamaicensis	Red-tailed Hawk	14	LC	(Gmelin)
			Buteo lineatus	Red-shouldered Hawk	22	LC	(Gmelin)
			Buteo platypterus	Broad-winged Hawk	1	LC	(Vieillot)
			Elanoides forficatus	Swallow-tailed Kite	1	LC	(Linnaeus)
			Haliaeetus leucocephalus	Bald Eagle	1	LC	(Linnaeus)
			Ictinia mississippiensis	Mississippi Kite	4	LC	(Wilson)
		Pandionidae	*Pandion haliaetus*	Osprey	10	LC	(Linnaeus)
	Anseriformes	Anatidae	*Aix sponsa*	Wood Duck	38	LC	(Linnaeus)
			Anas platyrhynchos	Mallard	31	LC	Linnaeus
			Aythya americana	Redhead	6	LC	(Eyton)
			Branta canadensis	Canada Goose	493	LC	(Linnaeus)
			Dendrocygna autumnalis †	Black-bellied Whistling-duck	N/A	LC	(Linnaeus)
			Lophodytes cucullatus	Hooded Merganser	2	LC	(Linnaeus)
	Caprimulgiformes	Apodidae	*Chaetura pelagica*	Chimney Swift	31	NT	(Linnaeus)
		Caprimulgidae	*Antrostomus carolinensis* †	Chuck-will's-widow	N/A	LC	(Gmelin)
			Chordeiles minor	Common Nighthawk	18	LC	(Forster)
		Trochilidae	*Archilochus colubris*	Ruby-throated Hummingbird	13	LC	(Linnaeus)
	Cathartiformes	Cathartidae	*Cathartes aura*	Turkey Vulture	52	LC	(Linnaeus)
			Coragyps atratus	Black Vulture	18	LC	(Bechstein)
	Charadriiformes	Charadriidae	*Charadrius vociferus*	Killdeer	14	LC	Linnaeus
		Scolopacidae	*Actitis macularius*	Spotted Sandpiper	8	LC	Linnaeus
			Scolopax minor	American Woodcock	1	LC	Gmelin

Class	Order	Family	Species	Common Name	No. Recorded	IUCN Status (2017)	Species Authority
			Tringa solitaria	Solitary Sandpiper	2	LC	Wilson
	Ciconiiformes	Ciconiidae	*Mycteria americana*	Wood Stork	12	LC	Linnaeus
	Columbiformes	Columbidae	*Columba livia* *	Rock Dove	9	N/A	Gmelin
			Streptopelia decaocto *	Eurasian Collared-Dove	14	N/A	Frivaldszky
			Zenaida macroura	Mourning Dove	275	LC	(Linnaeus)
	Coraciiformes	Alcedinidae	*Megaceryle alcyon*	Belted Kingfisher	10	LC	(Linnaeus)
	Cuculiformes	Cuculidae	*Coccyzus americanus*	Yellow-billed Cuckoo	3	LC	(Linnaeus)
	Falconiformes	Falconidae	*Falco sparverius*	American Kestrel	1	LC	Linnaeus
	Galliformes	Odontophoridae	*Colinus virginianus* †	Northern Bobwhite	N/A	NT	(Linnaeus)
		Phasianidae	*Phasianus colchicus* *	Ring-necked Pheasant	1	N/A	(Linnaeus)
	Gruiformes	Rallidae	*Rallus limicola*	Virginia Rail	1	LC	Vieillot
	Passeriformes	Bombycillidae	*Bombycilla cedrorum*	Cedar Waxwing	271	LC	Vieillot
		Cardinalidae	*Cardinalis cardinalis*	Northern Cardinal	282	LC	(Linnaeus)
			Passerina caerulea †	Blue Grosbeak	N/A	LC	(Linnaeus)
			Passerina ciris	Painted Bunting	9	NT	(Linnaeus)
			Passerina cyanea	Indigo Bunting	4	LC	(Linnaeus)
			Piranga ludoviciana	Western Tanager	1	LC	(Wilson)
			Piranga olivacea	Scarlet Tanager	1	LC	(Gmelin)
			Piranga rubra	Summer Tanager	4	LC	(Linnaeus)
		Corvidae	*Corvus brachyrhynchos*	American Crow	31	LC	Brehm
			Corvus ossifragus	Fish Crow	33	LC	Wilson
			Cyanocitta cristata	Blue Jay	124	LC	(Linnaeus)
		Fringillidae	*Haemorhous mexicanus*	House Finch	226	LC	(Müller)
			Haemorhous purpureus †	Purple Finch	N/A	LC	(Gmelin)

Class	Order	Family	Species	Common Name	No. Recorded	IUCN Status (2017)	Species Authority
			Spinus pinus	Pine Siskin	52	LC	(Wilson)
			Spinus tristis	American Goldfinch	30	LC	(Linnaeus)
		Hirundinidae	*Hirundo rustica*	Barn Swallow	22	LC	Linnaeus
			Progne subis	Purple Martin	3	LC	(Linnaeus)
			Stelgidopteryx serripennis	Northern Rough-winged Swallow	3	LC	(Audubon)
			Tachycineta bicolor	Tree Swallow	7	LC	(Vieillot)
		Icteridae	*Agelaius phoeniceus*	Red-winged Blackbird	230	LC	(Linnaeus)
			Icterus galbula	Baltimore Oriole	3	LC	(Linnaeus)
			Icterus spurius	Orchard Oriole	2	LC	(Linnaeus)
			Molothrus ater	Brown-headed Cowbird	410	LC	(Boddaert)
			Quiscalus quiscula	Common Grackle	236	LC	(Linnaeus)
		Laniidae	*Lanius ludovicianus*	Loggerhead Shrike	25	NT	Linnaeus
		Mimidae	*Dumetella carolinensis*	Gray Catbird	39	LC	(Linnaeus)
			Mimus polyglottos	Northern Mockingbird	218	LC	(Linnaeus)
			Toxostoma rufum	Brown Thrasher	57	LC	(Linnaeus)
		Paridae	*Baeolophus bicolor*	Tufted Titmouse	143	LC	Linnaeus
			Poecile carolinensis	Carolina Chickadee	87	LC	(Audubon)
		Parulidae	*Geothlypis trichas*	Common Yellowthroat	20	LC	(Linnaeus)
			Helmitheros vermivorum	Worm-eating Warbler	1	LC	(Gmelin)
			Leiothlypis celata	Orange-crowned Warbler	4	LC	(Say)
			Mniotilta varia	Black-and-white Warbler	8	LC	(Linnaeus)
			Parkesia noveboracensis	Northern Waterthrush	4	LC	(Gmelin)

Class	Order	Family	Species	Common Name	No. Recorded	IUCN Status (2017)	Species Authority
			Seiurus aurocapilla	Ovenbird	5	LC	(Linnaeus)
			Setophaga americana	Northern Parula	5	LC	(Linnaeus)
			Setophaga caerulescens	Black-throated Blue Warbler	3	LC	(Gmelin)
			Setophaga citrina †	Hooded Warbler	N/A	LC	(Boddaert)
			Setophaga coronata	Yellow-rumped Warbler	446	LC	(Linnaeus)
			Setophaga dominica	Yellow-throated Warbler	5	LC	(Linnaeus)
			Setophaga fusca	Blackburnian Warbler	1	LC	(Müller)
			Setophaga palmarum	Palm Warbler	6	LC	(Gmelin)
			Setophaga pensylvanica †	Chestnut-sided Warbler	N/A	LC	(Linnaeus)
			Setophaga pinus	Pine Warbler	38	LC	(Linnaeus)
			Setophaga ruticilla	American Redstart	7	LC	(Linnaeus)
			Setophaga striata	Blackpoll Warbler	4	LC	(Forster)
			Setophaga tigrina	Cape May Warbler	5	LC	(Gmelin)
		Passerellidae	*Ammodramus savannarum*	Grasshopper Sparrow	1	LC	(Gmelin)
			Junco hyemalis	Dark-eyed Junco	8	LC	(Linnaeus)
			Melospiza georgiana	Swamp Sparrow	6	LC	(Latham)
			Melospiza melodia	Song Sparrow	5	LC	(Wilson)
			Passerculus sandwichensis †	Savannah Sparrow	N/A	LC	(Gmelin)
			Pipilo erythrophthalmus	Eastern Towhee	30	LC	(Linnaeus)
			Spizella passerina	Chipping Sparrow	549	LC	(Bechstein)
			Spizella pusilla	Field Sparrow	1	LC	(Wilson)
			Zonotrichia albicollis	White-throated Sparrow	111	LC	(Gmelin)
		Passeridae	*Passer domesticus* *	House Sparrow	2	N/A	(Linnaeus)
		Polioptilidae	*Polioptila caerulea*	Blue-gray Gnatcatcher	13	LC	(Linnaeus)

Class	Order	Family	Species	Common Name	No. Recorded	IUCN Status (2017)	Species Authority
		Regulidae	*Regulus calendula*	Ruby-crowned Kinglet	38	LC	(Linnaeus)
			Regulus satrapa	Golden-crowned Kinglet	5	LC	Lichtenstein
		Sittidae	*Sitta canadensis*	Red-breasted Nuthatch	1	LC	Linnaeus
			Sitta pusilla	Brown-headed Nuthatch	76	LC	Latham
		Sturnidae	*Sturnus vulgaris* *	European Starling	206	N/A	Linnaeus
		Troglodytidae	*Thryothorus ludovicianus*	Carolina Wren	102	LC	(Latham)
			Troglodytes aedon	House Wren	1	LC	Vieillot
		Turdidae	*Catharus fuscescens*	Veery	1	LC	(Stephens)
			Catharus guttatus	Hermit Thrush	10	LC	(Pallas)
			Catharus ustulatus	Swainson's Thrush	2	LC	(Nuttall)
			Hylocichla mustelina	Wood Thrush	2	NT	(Gmelin)
			Sialia sialis	Eastern Bluebird	31	LC	(Linnaeus)
			Turdus migratorius	American Robin	219	LC	Linnaeus
		Tyrannidae	*Contopus virens*	Eastern Wood-pewee	8	LC	(Linnaeus)
			Empidonax virescens	Acadian Flycatcher	2	LC	(Vieillot)
			Myiarchus crinitus	Great Crested Flycatcher	30	LC	(Linnaeus)
			Sayornis phoebe	Eastern Phoebe	22	LC	(Latham)
			Tyrannus tyrannus	Eastern Kingbird	19	LC	(Linnaeus)
		Vireonidae	*Vireo flavifrons*	Yellow-throated Vireo	2	LC	Vieillot
			Vireo griseus	White-eyed Vireo	4	LC	(Boddaert)
			Vireo olivaceus	Red-eyed Vireo	16	LC	(Linnaeus)
			Vireo solitarius	Blue-headed Vireo	6	LC	(Wilson)
	Pelecaniformes	Ardeidae	*Ardea alba*	Great Egret	17	LC	Linnaeus
			Ardea herodias	Great Blue Heron	12	LC	Linnaeus
			Butorides virescens	Green Heron	5	LC	(Linnaeus)

Class	Order	Family	Species	Common Name	No. Recorded	IUCN Status (2017)	Species Authority
			Egretta caerulea	Little Blue Heron	3	LC	(Linnaeus)
			Egretta thula	Snowy Egret	2	LC	(Molina)
			Egretta tricolor †	Tricolored Heron	N/A	LC	(Müller)
		Threskiornithidae	*Eudocimus albus*	White Ibis	3	LC	(Linnaeus)
	Piciformes	Picidae	*Colaptes auratus*	Northern Flicker	41	LC	(Linnaeus)
			Dryobates pubescens	Downy Woodpecker	20	LC	(Linnaeus)
			Dryobates villosus	Hairy Woodpecker	1	LC	(Linnaeus)
			Dryocopus pileatus	Pileated Woodpecker	2	LC	(Linnaeus)
			Melanerpes carolinus	Red-bellied Woodpecker	31	LC	(Linnaeus)
			Melanerpes erythrocephalus	Red-headed Woodpecker	39	NT	(Linnaeus)
			Sphyrapicus varius	Yellow-bellied Sapsucker	12	LC	(Linnaeus)
	Podicipediformes	Podicipedidae	*Podilymbus podiceps*	Pied-billed Grebe	7	LC	(Linnaeus)
	Strigiformes	Strigidae	*Bubo virginianus*	Great Horned Owl	4	LC	(Gmelin)
			Strix varia	Barred Owl	2	LC	Barton
	Suliformes	Anhingidae	*Anhinga anhinga*	Anhinga	1	LC	(Linnaeus)
		Phalacrocoracidae	*Phalacrocorax auritus*	Double-crested Cormorant	6	LC	(Lesson)
Mammalia	Artiodactyla	Cervidae	*Odocoileus virginianus*	White-tailed Deer	37	LC	(Zimmermann)
		Suidae	*Sus scrofa* *	Wild Boar	1	N/A	Linnaeus
	Carnivora	Canidae	*Urocyon cinereoargenteus*	Gray Fox	19	LC	(Schreber)
		Mustelidae	*Lontra canadensis* †	North American River Otter	N/A	LC	(Schreber)
		Procyonidae	*Procyon lotor*	Northern Raccoon	15	LC	(Linnaeus)
	Chiroptera	Molossidae	*Tadarida brasiliensis*	Mexican Free-tailed Bat	1	LC	(I. Geoffroy)

Class	Order	Family	Species	Common Name	No. Recorded	IUCN Status (2017)	Species Authority
		Vespertilionidae	*Lasiurus seminolus*	Seminole Bat	1	LC	(Rhoads)
	Cingulata	Dasypodidae	*Dasypus novemcinctus*	Nine-banded Armadillo	3	LC	Linnaeus
	Didelphimorphia	Didelphidae	*Didelphis virginiana*	Virginia Opossum	27	LC	Kerr
	Eulipotyphla	Soricidae	*Blarina carolinensis*	Southern Short-tailed Shrew	1	LC	(Bachman)
		Talpidae	*Scalopus aquaticus*	Eastern Mole	2	LC	(Linnaeus)
	Lagomorpha	Leporidae	*Sylvilagus floridanus*	Eastern Cottontail	5	LC	(J.A. Allen)
	Rodentia	Castoridae	*Castor canadensis*	American Beaver	3	LC	Kuhl
		Cricetidae	*Sigmodon hispidus*	Hispid Cotton Rat	6	LC	Say & Ord
			Peromyscus gossypinus	Cotton Mouse	1	LC	(Le Conte)
		Muridae	*Rattus norvegicus* *	Brown Rat	1	N/A	(Berkenhout)
		Sciuridae	*Glaucomys volans*	Southern Flying Squirrel	1	LC	(Linnaeus)
			Sciurus carolinensis	Eastern Gray Squirrel	180	LC	Gmelin
			Sciurus niger	Fox Squirrel	1	LC	Linnaeus
Reptilia	Squamata	Anguidae	*Ophisaurus ventralis*	Eastern Glass Lizard	1	LC	(Linnaeus)
		Colubridae	*Coluber constrictor*	North American Racer	6	LC	Linnaeus
			Masticophis flagellum †	Coachwhip	N/A	LC	(Shaw)
			Diadophis punctatus	Ringneck Snake	2	LC	(Linnaeus)
			Nerodia erythrogaster	Plainbelly Watersnake	3	LC	(Forster)
			Nerodia fasciata	Southern Watersnake	8	LC	(Linnaeus)
			Opheodrys aestivus	Rough Greensnake	3	LC	(Linnaeus)
			Pantherophis alleghaniensis	Eastern Ratsnake	6	LC	(Holbrook)
			Pantherophis guttatus	Red Cornsnake	1	LC	(Linnaeus)
			Storeria dekayi †	Dekay's Brownsnake	N/A	LC	(Holbrook)
			Storeria occipitomaculata	Redbelly Snake	10	LC	(Storer)

Class	Order	Family	Species	Common Name	No. Recorded	IUCN Status (2017)	Species Authority
			Thamnophis sauritus	Eastern Ribbonsnake	1	LC	(Linnaeus)
			Thamnophis sirtalis	Common Garter Snake	9	LC	(Linnaeus)
		Dactyloidae	*Anolis carolinensis*	Green Anole	20	LC	(Voigt)
		Gekkonidae	*Hemidactylus turcicus* *†	Mediterranean House Gecko	N/A	N/A	(Linnaeus)
		Scincidae	*Plestiodon fasciatus*	Common Five-lined Skink	3	LC	(Linnaeus)
			Plestiodon laticeps	Broadhead Skink	4	LC	(Schneider)
			Scincella lateralis	Ground Skink	39	LC	(Say)
		Teiidae	*Aspidoscelis sexlineata*	Six-lined Racerunner	3	LC	(Linnaeus)
	Testudines	Chelydridae	*Chelydra serpentina*	Common Snapping Turtle	6	LC	(Linnaeus)
		Emydidae	*Terrapene carolina*	Eastern Box Turtle	21	VU	(Linnaeus)
			Trachemys scripta	Yellow-bellied Slider	80	LC	(Schoepff)
		Kinosternidae	*Kinosternon subrubrum*	Eastern Mud Turtle	1	LC	(Lacépède)
			Sternotherus odoratus	Eastern Musk Turtle	6	LC	(Sonnini & Latreille)
		Trionychidae	*Apalone ferox*	Florida Softshell	6	LC	(Schneider)

Appendix 2. List of all vertebrate species documented in Bulloch County but *not* documented on the campus of Georgia Southern University during the two-year survey. All species were "expected" to occur on the campus Georgia Southern University unless they had specific habitat/dietary requirements that would preclude them from doing so or if they were exceedingly rare in the county. Non-native species are indicated with an asterisk, and species observed outside of the survey period (but within two years of the start or end) are indicated by a dagger. The IUCN status column lists the conservation classification of each species as of 2017, with LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, and N/A = Not Applicable (for non-native species or species not assessed by IUCN).

Class	Order	Family	Species	Common Name	Expected on Campus?	IUCN Status (2017)	Species Authority
Actinopterygii	Acipenseriformes	Acipenseridae	*Acipenser oxyrhynchus*	Atlantic Sturgeon	No	NT	Mitchill
	Atheriniformes	Atherinopsidae	*Labidesthes sicculus*	Brook Silverside	Yes	LC	(Cope)
	Clupeiformes	Clupeidae	*Alosa mediocris*	Hickory Shad	No	LC	(Mitchill)
			Alosa sapidissima	American Shad	No	LC	(Wilson)
	Cypriniformes	Catostomidae	*Erimyzon oblongus*	Creek Chubsucker	Yes	LC	(Mitchill)
			Minytrema melanops	Spotted Sucker	Yes	LC	(Rafinesque)
		Cyprinidae	*Ctenopharyngodon idella**	Grass Carp	No	N/A	(Valenciennes)
			Cyprinella leedsi	Bannerfin Shiner	Yes	LC	(Fowler)
			Hybopsis rubrifrons	Rosyface Chub	Yes	LC	(Jordan)
			Notropis chalybaeus	Ironcolor Shiner	Yes	LC	(Cope)
			Notropis cummingsae	Dusky Shiner	Yes	LC	Myers
			Notropis maculatus	Taillight Shiner	Yes	LC	Hay
			Notropis petersoni	Coastal Shiner	Yes	LC	Fowler
			Opsopoeodus emiliae	Pugnose Minnow	Yes	LC	Hay
			Pimephales promelas	Fathead Minnow	Yes	LC	Rafinesque
			Pteronotropis stonei	Lowland Shiner	Yes	LC	(Fowler)
			Semotilus atromaculatus	Creek Chub	Yes	LC	(Mitchill)
	Cyprinodontiformes	Fundulidae	*Fundulus chrysotus*	Golden Topminnow	Yes	LC	(Günther)
			Fundulus lineolatus	Lined Topminnow	Yes	LC	(Agassiz)

Class	Order	Family	Species	Common Name	Expected on Campus?	IUCN Status (2017)	Species Authority
	Esociformes	Esocidae	*Esox niger*	Chain Pickerel	Yes	LC	Lesueur
		Umbridae	*Umbra pygmaea*	Eastern Mudminnow	Yes	LC	(DeKay)
	Lepisosteiformes	Lepisosteidae	*Lepisosteus osseus*	Longnose Gar	Yes	LC	(Linnaeus)
			Lepisosteus platyrhincus †	Florida Gar	Yes	LC	DeKay
	Perciformes	Centrarchidae	*Acantharchus pomotis*	Mud Sunfish	Yes	LC	(Baird)
			Enneacanthus gloriosus	Blue-spotted Sunfish	Yes	LC	(Holbrook)
			Enneacanthus obesus	Banded Sunfish	Yes	LC	(Girard)
			Pomoxis nigromaculatus	Black Crappie	Yes	LC	(Lesueur)
		Elassomatidae	*Elassoma evergladei*	Everglades Pygmy Sunfish	Yes	LC	Jordan
		Moronidae	*Morone saxatilis*	Striped Bass	No	LC	(Walbaum)
		Percidae	*Etheostoma hopkinsi*	Christmas Darter	Yes	LC	(Fowler)
			Etheostoma olmstedi	Tessellated Darter	Yes	LC	Storer
			Etheostoma serrifer	Sawcheek Darter	Yes	LC	(Hubbs & Cannon)
			Percina nigrofasciata	Blackbanded Darter	Yes	LC	(Agassiz)
	Percopsiformes	Amblyopsidae	*Chologaster cornuta*	Swampfish	Yes	LC	Agassiz
		Aphredoderidae	*Aphredoderus sayanus*	Pirate Perch	Yes	LC	(Gilliams)
	Siluriformes	Ictaluridae	*Ameiurus brunneus*	Snail Bullhead	Yes	LC	Jordan
			Ameiurus catus	White Bullhead	No	LC	(Linnaeus)
			Ameiurus melas	Black Bullhead	Yes	LC	(Rafinesque)
			Ameiurus platycephalus	Flat Bullhead	Yes	LC	(Girard)
			Ictalurus punctatus	Channel Catfish	No	LC	(Rafinesque)
			Noturus gyrinus	Tadpole Madtom	Yes	LC	(Mitchill)

Class	Order	Family	Species	Common Name	Expected on Campus?	IUCN Status (2017)	Species Authority
			Noturus leptacanthus	Speckled Madtom	Yes	LC	Jordan
Amphibia	Anura	Bufonidae	*Anaxyrus quercicus*	Oak Toad	Yes	LC	(Holbrook)
		Hylidae	*Hyla avivoca*	Bird-voiced Tree Frog	No	LC	Viosca
			Pseudacris nigrita	Southern Chorus Frog	Yes	LC	(LeConte)
			Pseudacris ornata	Ornate Chorus Frog	Yes	LC	(Holbrook)
		Ranidae	*Rana grylio*	Pig Frog	Yes	LC	Stejneger
			Rana heckscheri	River Frog	Yes	LC	Wright
	Caudata	Ambystomatidae	*Ambystoma opacum*	Marbled Salamander	Yes	LC	(Gravenhorst)
			Ambystoma talpoideum	Mole Salamander	Yes	LC	(Holbrook)
			Ambystoma tigrinum	Tiger Salamander	Yes	LC	(Green)
		Plethodontidae	*Desmognathus auriculatus*	Southern Dusky Salamander	No	LC	(Holbrook)
			Desmognathus conanti	Spotted Dusky Salamander	No	N/A	Rossman
			Eurycea guttolineata	Three-lined Salamander	Yes	LC	(Holbrook)
			Pseudotriton montanus	Mud Salamander	No	LC	Baird
			Pseudotriton ruber	Red Salamander	Yes	LC	(Sonnini de Manoncourt & Latreille)
			Stereochilus marginatus	Many-lined Salamander	Yes	LC	(Hallowell)
		Salamandridae	*Notophthalmus viridescens*	Eastern Newt	Yes	LC	(Rafinesque)
		Sirenidae	*Pseudobranchus striatus*	Northern Dwarf Siren	Yes	LC	(LeConte)
Aves	Accipitriformes	Accipitridae	*Circus hudsonius*	Northern Harrier	Yes	LC	(Linnaeus)

Class	Order	Family	Species	Common Name	Expected on Campus?	IUCN Status (2017)	Species Authority
	Anseriformes	Anatidae	*Alopochen aegyptiaca* *	Egyptian Goose	No	LC	(Linnaeus)
			Anas acuta	Northern Pintail	Yes	LC	Linnaeus
			Anas crecca	Green-winged Teal	Yes	LC	Gmelin
			Anser albifrons	Greater White-fronted Goose	No	LC	(Scopoli)
			Anser caerulescens	Snow Goose	No	LC	(Linnaeus)
			Aythya affinis	Lesser Scaup	Yes	LC	(Eyton)
			Aythya collaris	Ring-necked Duck	Yes	LC	(Donovan)
			Aythya valisineria	Canvasback	Yes	LC	(Wilson)
			Bucephala albeola	Bufflehead	Yes	LC	(Linnaeus)
			Bucephala clangula	Common Goldeneye	Yes	LC	(Linnaeus)
			Dendrocygna autumnalis †	Black-bellied Whistling Duck	Yes	LC	(Linnaeus)
			Mareca americana	American Wigeon	Yes	LC	(Gmelin)
			Mareca strepera	Gadwall	Yes	LC	(Linnaeus)
			Mergus serrator	Red-breasted Merganser	No	LC	Linnaeus
			Oxyura jamaicensis	Ruddy Duck	Yes	LC	(Gmelin)
			Spatula clypeata	Northern Shoveler	Yes	LC	(Linnaeus)
			Spatula discors	Blue-winged Teal	Yes	LC	(Linnaeus)
	Caprimulgiformes	Caprimulgidae	*Antrostomus carolinensis* †	Chuck-will's Widow	Yes	LC	(Gmelin)
			Antrostomus vociferus	Eastern Whip-poor-will	Yes	LC	(Wilson)
		Trochilidae	*Selasphorus rufus*	Rufous Hummingbird	No	LC	(Gmelin)
	Charadriiformes	Charadriidae	*Charadrius semipalmatus*	Semipalmated Plover	No	LC	Bonaparte

Class	Order	Family	Species	Common Name	Expected on Campus?	IUCN Status (2017)	Species Authority
			Pluvialis dominica	American Golden Plover	No	LC	Müller
			Pluvialis squatarola	Black-bellied Plover	No	LC	(Linnaeus)
			Vanellus vanellus	Northern Lapwing	No	NT	(Linnaeus)
		Laridae	*Chlidonias niger*	Black Tern	No	LC	(Linnaeus)
			Chroicocephalus philadelphia	Bonaparte's Gull	Yes	LC	(Ord)
			Hydroprogne caspia	Caspian Tern	No	LC	(Pallas)
			Larus argentatus	Herring Gull	No	LC	Pontoppidan
			Larus delawarensis	Ring-billed Gull	Yes	LC	Ord
			Leucophaeus atricilla	Laughing Gull	No	LC	Linnaeus
			Sterna forsteri	Forster's Tern	No	LC	Nuttall
			Sterna hirundo	Common Tern	No	LC	Linnaeus
		Recurvirostridae	*Himantopus mexicanus*	Black-necked Stilt	No	LC	(Müller)
			Recurvirostra americana	American Avocet	No	LC	Gmelin
		Scolopacidae	*Bartramia longicauda*	Upland Sandpiper	Yes	LC	(Bechstein)
			Calidris alpina	Dunlin	No	LC	(Linnaeus)
			Calidris bairdii	Baird's Sandpiper	No	LC	(Coues)
			Calidris fuscicollis	White-rumped Sandpiper	No	LC	(Vieillot)
			Calidris himantopus	Stilt Sandpiper	Yes	LC	(Bonaparte)
			Calidris mauri	Western Sandpiper	Yes	LC	(Cabanis)
			Calidris melanotos	Pectoral Sandpiper	Yes	LC	(Vieillot)
			Calidris minutilla	Least Sandpiper	Yes	LC	(Vieillot)
			Calidris pusilla	Semipalmated Sandpiper	Yes	NT	(Linnaeus)

Class	Order	Family	Species	Common Name	Expected on Campus?	IUCN Status (2017)	Species Authority
			Calidris subruficollis	Buff-breasted Sandpiper	Yes	NT	(Vieillot)
			Gallinago delicata	Wilson's Snipe	Yes	LC	(Ord)
			Limnodromus griseus	Short-billed Dowitcher	No	LC	(Gmelin)
			Limnodromus scolopaceus	Long-billed Dowitcher	No	LC	(Say)
			Tringa flavipes	Lesser Yellowlegs	Yes	LC	(Gmelin)
			Tringa melanoleuca	Greater Yellowlegs	Yes	LC	(Gmelin)
			Tringa semipalmata	Willet	No	LC	(Gmelin)
	Columbiformes	Columbidae	*Columbina passerina*	Common Ground-Dove	Yes	LC	(Linnaeus)
	Falconiformes	Falconidae	*Falco columbarius*	Merlin	Yes	LC	Linnaeus
			Falco peregrinus	Peregrine Falcon	No	LC	Tunstall
	Galliformes	Odontophoridae	*Colinus virginianus* †	Northern Bobwhite	Yes	NT	(Linnaeus)
		Phasianidae	*Meleagris gallopavo*	Wild Turkey	Yes	LC	Linnaeus
	Gaviiformes	Gaviidae	*Gavia immer*	Common Loon	No	LC	(Brünnich)
		Gruidae	*Antigone canadensis*	Sandhill Crane	Yes	LC	(Linnaeus)
		Rallidae	*Fulica americana*	American Coot	Yes	LC	Gmelin
			Gallinula galeata	Common Gallinule	Yes	LC	(Lichtenstein)
			Porzana carolina	Sora	Yes	LC	(Linnaeus)
			Rallus elegans	King Rail	No	NT	Audubon
	Passeriformes	Alaudidae	*Eremophila alpestris*	Horned Lark	Yes	LC	(Linnaeus)
		Cardinalidae	*Passerina caerulea* †	Blue Grosbeak	Yes	LC	(Linnaeus)
			Pheucticus ludovicianus	Rose-breasted Grosbeak	Yes	LC	(Linnaeus)

Class	Order	Family	Species	Common Name	Expected on Campus?	IUCN Status (2017)	Species Authority
			Spiza americana	Dickcissel	No	LC	(Gmelin)
		Certhiidae	*Certhia americana*	Brown Creeper	Yes	LC	Bonaparte
		Fringillidae	*Coccothraustes vespertinus*	Evening Grosbeak	No	LC	(Cooper)
			Haemorhous purpureus †	Purple Finch	Yes	LC	(Gmelin)
		Hirundinidae	*Petrochelidon pyrrhonota*	Cliff Swallow	Yes	LC	Vieillot
			Riparia riparia	Bank Swallow	No	LC	(Linnaeus)
		Icteridae	*Dolichonyx oryzivorus*	Bobolink	Yes	LC	(Linnaeus)
			Euphagus carolinus	Rusty Blackbird	Yes	VU	(Müller)
			Euphagus cyanocephalus	Brewer's Blackbird	Yes	LC	(Wagler)
			Icterus bullockii	Bullock's Oriole	No	LC	(Swainson)
			Quiscalus major	Boat-tailed Grackle	No	LC	Vieillot
			Sturnella magna	Eastern Meadowlark	Yes	LC	(Linnaeus)
			Xanthocephalus xantho-cephalus	Yellow-headed Blackbird	No	LC	(Bonaparte)
		Icteriidae	*Icteria virens*	Yellow-breasted Chat	Yes	LC	(Linnaeus)
		Motacillidae	*Anthus rubescens*	American Pipit	Yes	LC	(Tunstall)
		Parulidae	*Cardellina canadensis*	Canada Warbler	No	LC	(Linnaeus)
			Cardellina pusilla	Wilson's Warbler	No	LC	(Wilson)
			Geothlypis formosa	Kentucky Warbler	Yes	LC	(Wilson)
			Limnothlypis swainsonii	Swainson's Warbler	Yes	LC	(Audubon)
			Oreothlypis peregrina	Tennessee Warbler	Yes	LC	(Wilson)
			Parkesia motacilla	Louisiana Waterthrush	Yes	LC	(Vieillot)
			Protonotaria citrea	Prothonotary Warbler	Yes	LC	(Boddaert)

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			Setophaga castanea	Bay-breasted Warbler	Yes	LC	(Wilson)
			Setophaga cerulea	Cerulean Warbler	No	VU	(Wilson)
			Setophaga citrina †	Hooded Warbler	Yes	LC	(Boddaert)
			Setophaga discolor	Prairie Warbler	Yes	LC	(Vieillot)
			Setophaga magnolia	Magnolia Warbler	Yes	LC	(Wilson)
			Setophaga pensylvanica †	Chestnut-sided Warbler	Yes	LC	(Linnaeus)
			Setophaga petechia	Yellow Warbler	Yes	LC	(Linnaeus)
			Setophaga virens	Black-throated Green Warbler	Yes	LC	(Gmelin)
			Vermivora chrysoptera	Golden-winged Warbler	No	NT	(Linnaeus)
			Vermivora cyanoptera	Blue-winged Warbler	No	LC	(Linnaeus)
		Passerellidae	*Centronyx henslowii*	Henslow's Sparrow	Yes	NT	(Audubon)
			Chondestes grammacus	Lark Sparrow	No	LC	(Say)
			Melospiza lincolnii	Lincoln's Sparrow	Yes	LC	(Audubon)
			Passerculus sandwichensis †	Savannah Sparrow	Yes	LC	(Gmelin)
			Passerella iliaca	Fox Sparrow	Yes	LC	(Merrem)
			Peucaea aestivalis	Bachman's Sparrow	Yes	NT	(Lichtenstein)
			Pooecetes gramineus	Vesper Sparrow	Yes	LC	(Gmelin)
			Spizella pallida	Clay-colored Sparrow	No	LC	(Swainson)
			Zonotrichia leucophrys	White-crowned Sparrow	Yes	LC	(Forster)
		Sittidae	*Sitta carolinensis*	White-breasted Nuthatch	Yes	LC	Latham

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		Troglodytidae	*Cistothorus palustris*	Marsh Wren	No	LC	(Wilson)
			Cistothorus platensis	Sedge Wren	No	LC	(Naumann)
			Troglodytes hiemalis	Winter Wren	Yes	LC	Vieillot
		Turdidae	*Catharus minimus*	Gray-cheeked Thrush	No	LC	(Lafresnaye)
		Tyrannidae	*Empidonax flaviventris*	Yellow-bellied Flycatcher	No	LC	(Baird & Girard)
			Empidonax minimus	Least Flycatcher	No	LC	(Baird & Baird)
			Tyrannus verticalis	Western Kingbird	No	LC	Say
		Vireonidae	*Vireo gilvus*	Warbling Vireo	No	LC	(Vieillot)
			Vireo philadelphicus	Philadelphia Vireo	No	LC	(Cassin)
	Pelecaniformes	Ardeidae	*Botaurus lentiginosus*	American Bittern	No	LC	(Rackett)
			Bubulcus ibis	Cattle Egret	Yes	LC	(Linnaeus)
			Egretta tricolor †	Tricolored Heron	Yes	LC	(Müller)
			Ixobrychus exilis	Least Bittern	No	LC	(Gmelin)
			Nyctanassa violacea	Yellow-crowned Night-Heron	Yes	LC	(Linnaeus)
			Nycticorax nycticorax	Black-crowned Night-Heron	No	LC	(Linnaeus)
		Threskiornithidae	*Platalea ajaja*	Roseate Spoonbill	No	LC	(Linnaeus)
			Plegadis falcinellus	Glossy Ibis	No	LC	(Linnaeus)
	Podicipediformes	Podicipedidae	*Podiceps auritus*	Horned Grebe	No	VU	(Linnaeus)
	Strigiformes	Strigidae	*Megascops asio*	Eastern Screech-Owl	Yes	LC	(Linnaeus)
		Tytonidae	*Tyto alba*	Barn Owl	No	LC	(Scopoli)
Mammalia	Carnivora	Canidae	*Vulpes vulpes*	Red Fox	No	LC	(Linnaeus)

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		Felidae	*Lynx rufus*	Bobcat	No	LC	(Schreber)
		Mephitidae	*Mephitis mephitis*	Striped Skunk	No	LC	(Schreber)
		Mustelidae	*Lontra canadensis* †	North American River Otter	No	LC	(Schreber)
			Mustela frenata	Long-tailed Weasel	No	LC	Lichtenstein
			Neovison vison	American Mink	No	LC	(Schreber)
		Ursidae	*Ursus americanus*	Black Bear	No	LC	Pallas
	Chiroptera	Vespertilionidae	*Aeorestes cinereus*	Hoary Bat	Yes	LC	(Palisot de Beauvois)
			Myotis austroriparius	Southeastern Myotis	Yes	LC	(Rhoads)
			Lasionycteris noctivagans	Silver-haired Bat	Yes	LC	(LeConte)
			Lasiurus borealis	Eastern Red Bat	Yes	LC	(Müller)
			Nycticeius humeralis	Evening Bat	Yes	LC	(Rafinesque)
	Eulipotyphla	Soricidae	*Cryptotis parva*	Least Shrew	Yes	LC	(Say)
			Sorex longirostris	Southeastern Shrew	No	LC	Bachman
	Lagomorpha	Leporidae	*Sylvilagus palustris*	Marsh Rabbit	No	LC	(Bachman)
	Rodentia	Cricetidae	*Ondatra zibethicus*	Common Muskrat	No	LC	(Linnaeus)
			Ochrotomys nuttalli	Golden Mouse	Yes	LC	(Harlan)
			Microtus pinetorum	Woodland Vole	No	LC	(LeConte)
			Reithrodontomys humulis	Eastern Harvest Mouse	No	LC	(Audubon & Bachman)
			Neotoma floridana	Eastern Woodrat	Yes	LC	(Ord)
			Peromyscus polionotus	Oldfield Mouse	No	LC	(Wagner)
		Muridae	*Mus musculus*	House Mouse	Yes	LC	Linnaeus
			Rattus rattus	Roof Rat	Yes	LC	(Linnaeus)
Reptilia	Crocodilia	Alligatoridae	*Alligator mississippiensis*	American Alligator	No	LC	(Daudin)

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	Squamata	Anguidae	*Ophisaurus attenuatus*	Slender Glass Lizard	Yes	LC	Cope
		Colubridae	*Cemophora coccinea*	Scarlet Snake	Yes	LC	(Blumenbach)
			Drymarchon couperi	Indigo Snake	No	LC	(Holbrook)
			Farancia abacura	Mud Snake	No	LC	(Holbrook)
			Farancia erytrogramma	Rainbow Snake	No	LC	(Latreille)
			Haldea striatula	Rough Earthsnake	Yes	LC	(Linnaeus)
			Heterodon platirhinos	Eastern Hognose Snake	Yes	LC	Latreille
			Heterodon simus	Southern Hognose Snake	No	VU	(Linnaeus)
			Lampropeltis elapsoides	Scarlet Kingsnake	Yes	LC	(Holbrook)
			Lampropeltis getula	Eastern Kingsnake	Yes	LC	(Linnaeus)
			Liodytes rigida	Crayfish Snake	Yes	LC	(Say)
			Masticophis flagellum †	Coachwhip	Yes	LC	(Shaw)
			Nerodia taxispilota	Brown Watersnake	No	LC	(Holbrook)
			Pituophis melanoleucus	Pine Snake	No	LC	(Daudin)
			Storeria dekayi †	Dekay's Brown-snake	Yes	LC	(Holbrook)
			Tantilla coronata	Southeastern Crowned Snake	Yes	LC	Baird & Girard
		Elapidae	*Micrurus fulvius*	Eastern Coral Snake	Yes	LC	(Linnaeus)
		Gekkonidae	*Hemidactylus turcicus* *†	Mediterranean House Gecko	Yes	N/A	(Linnaeus)
		Phrynosomatidae	*Sceloporus undulatus*	Eastern Fence Lizard	Yes	LC	(Bosc & Daudin)
		Scincidae	*Plestiodon egregius*	Mole Skink	Yes	LC	Baird

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			Plestiodon inexpectatus	Southeastern Five-lined Skink	Yes	LC	(Taylor)
		Viperidae	*Agkistrodon contortrix*	Eastern Copperhead	Yes	LC	(Linnaeus)
			Agkistrodon piscivorus	Northern Cottonmouth	Yes	LC	(Lacépède)
			Crotalus adamanteus	Eastern Diamond-back Rattlesnake	No	LC	Beauvois
			Crotalus horridus	Timber Rattlesnake	No	LC	Linnaeus
	Testudines	Emydidae	*Clemmys guttata*	Spotted Turtle	No	EN	(Schneider)
			Deirochelys reticularia	Chicken Turtle	Yes	N/A	(Latreille)
			Pseudemys floridana	Coastal Plain Cooter	Yes	LC	(LeConte)
		Kinosternidae	*Kinosternon baurii*	Striped Mud Turtle	Yes	LC	(Garman)
			Sternotherus minor	Loggerhead Musk Turtle	Yes	LC	(Agassiz)
		Testudinidae	*Gopherus polyphemus*	Gopher Tortoise	No	VU	(Daudin)
		Trionychidae	*Apalone spinifera*	Spiny Softshell	No	LC	(Lesueur)