WHAT WOULD A WATERBIRD DO? AN ANNUAL STUDY OF 13 URBAN WETLANDS IN FRISCO, TEXAS

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By

Jayce Alan Proctor

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LIST OF ABBREVIATIONS

HC	Hackberry Creek
HL	Heritage Lakes
IUCN	International Union for Conservation of Nature
LAERF	Lewisville Aquatic Ecosystem Research Facility
LSR	Lone Star Ranch
MCA	Multiple correspondence analysis
NAIP	National Agricultural Imagery Program
NDWI	Normalized difference water index
NRCS	Natural Resource Conservation Service
PCA	Principal component analysis
RF	Random forest model
SC	Stewart Creek
TPW	Texas Parks and Wildlife
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USACE	US Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	US Fish and Wildlife Service
USGS	United States Geological Survey

CHAPTER 1

INTRODUCTION

Over 50% of the worlds' wetlands have been lost in the past century (Ma et al., 2010; Dahl, 1990). During the time of European settlement in the 1600s, what was to become the United States of America had approximately 221 million acres of wetlands, which had shrunk to 103 million existing in the mid-1980s. In this case, six states lost 85% or more of their wetlands, California being the most significant, losing 91% of its original wetlands (Dahl, 1990). Texas has lost 50-80% of its wetlands from the 1780s to mid-1980s (Dahl, 1990).

These facts are paramount when considering waterbirds since they sustain their survival off of wetlands, and a devaluation of wetlands invariably contributes to a devaluation of not just waterbirds, but all life that draws sustenance off of wetland interactions. I urge the reader to extend their sense of ecology and ecosystem boundaries, understanding that all the different ecosystems throughout earth (and earth itself) are hugely interdependent, and interact with one another as a lump sum called 'nature' (Whatmore, 2002). We must broaden our sense of relationships within the environment, and value the influences that they have on each other and other creatures, to a point where we understand how what's happening at a wetland can help or harm us, and how we may be able to positively or negatively impact the dealings of a wetland territory. Furthermore, how do other forms of nature other than humans affect each other and their surroundings? Nature can be viewed and experienced as hybrid geographies in this since.

My study aims at understanding how urban wetlands affect waterbird diversity and abundance. Or, from another perspective, what would a waterbird do? Within the modern urban scene, wetlands have become increasingly more created, and regulated in different ways than what has occurred in the recent past. Prominently managed by humans, these new ways of operating wetland systems are not fully understood yet in terms of providing value to waterbirds, as that was not a prime intention for building them. A majority of these ‘human managed’ wetlands have taken on a different look, and operate under new parameters of equilibrium states, or in other terms, new consistencies. What this may mean for wetlands is that possibilities are abstracted and limited in certain ways, such as rich and diverse, thriving biota of a given species. Considering environmental ethics, and the fact that there are institutional structures within our society that uphold beliefs and initiatives concerning the importance of biodiversity at these geographies, these matters deserve to be looked at further, especially within a local context (McKenney & Kiesecker, 2010; O’Toole et al., 2009; McKinstry & Anderson, 2002).

1.1 Wetlands, Waterbirds and Biodiversity

Waterbirds are wetland bird species that have evolved to flourish within a wetland habitat, and that rely on wetland habitats for their survival. Within this array, arises stark differences as well as similarities, including appearance, movement patterns, feeding patters, and landscape preferences. These patterns have resulted in some common nomenclature for collapsing together species into classes. White and Main (2005, 2004) have applied a version in their study of 183 golf course ponds in Florida that extends this idea of collapsing the waterbird species into 6 classes: (1) open water waders, (2) dip dabblers, (3) diving birds, (4) moist soil birds, (5) aerial piscivores, and (6) dense vegetation waders. Notice that the differentiating factor for grouping different species together is related to food/eating behavior and landscape. Open water waders have long legs, and wade into the water, stalking their pray, and striking quickly when taking a bite, feasting on crayfish, fish, insects, frogs, snakes, and even baby turtles. Dabbling ducks favor vegetation, and forage for food by dabbling at the water surface and shoreline area, and are even known to consume berries and acorns from fruiting trees. Diving ducks in North America can go beneath the water's surface for 10-30 seconds approximately. These diving bird species are also mainly carnivorous, with a diet that consists largely of fish, and macro-invertebrates (Hoppe et al., 1986).

There are then the moist soil class, who hang around the water's edge, and dig through mud, sand, and rocks for their food, which is mainly insects and crustaceans (macro-invertebrates), and few seeds (Baldassarre & Fischer, 1984). Aerial piscivores often swoop down to the water and scoop their food up by skimming the top of the water. Dense vegetation waders lurk through thick vegetation, are similar to open water waders with the caveat of being more secretive, and are often left unnoticed, having a diet that is much akin to that of an open water wader. Indeed, food patterns is perhaps the most important factor when considering presence or absence of a waterbird.

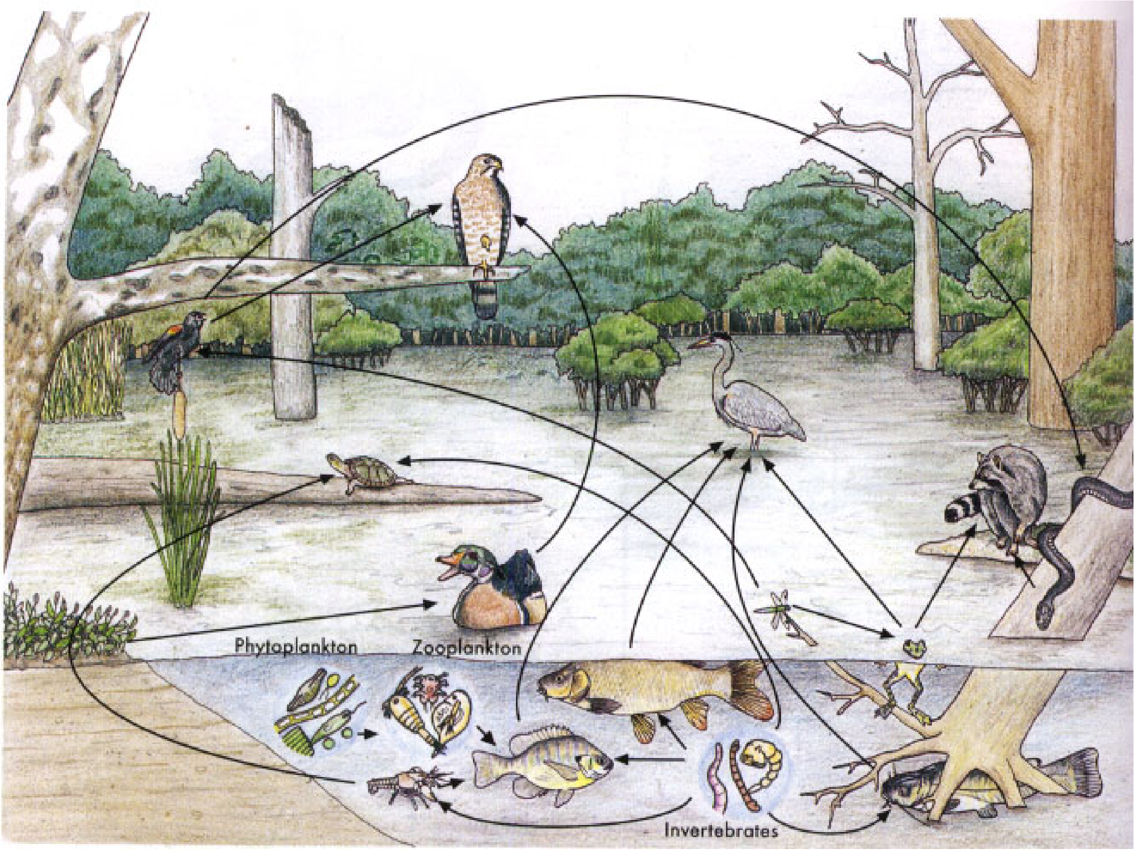


Figure 1.1: Wetland food web rendering (Farmer, 2011).

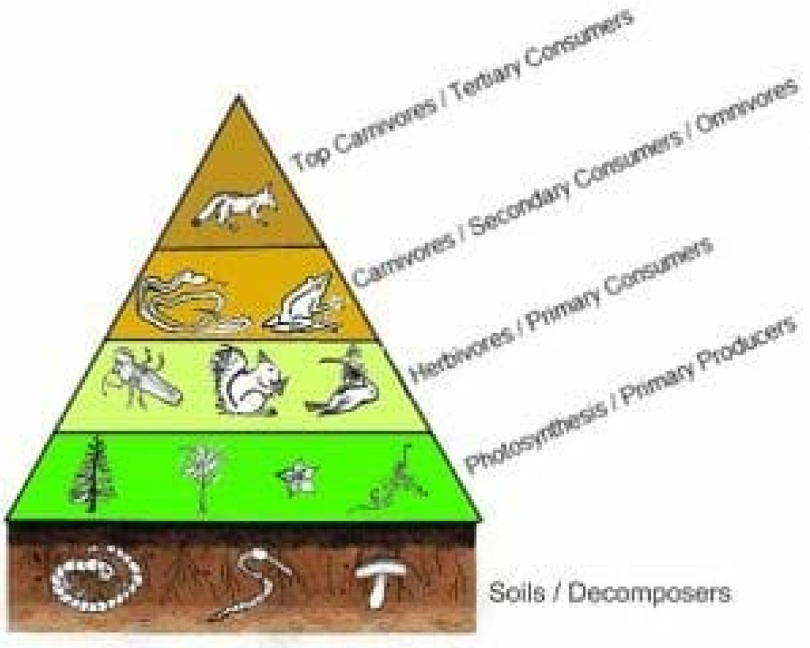


Figure 1.2: Trophic scale rendering of production and consumption roles (Biology Dictionary, 2019).

This can be put into focus by referring to the food web (Figure 1.1); waterbirds are considered secondary consumers. The idea of the food web can relate a cascading effect through the trophic scale, to interact with other species; in terms of waterbirds affecting humans, they may be understood through environmental, economic, cultural, and health concerns (Figure 1.2; Green & Elmberg, 2014). Such examples show the interrelated aspect of wetland and waterbird health on our surroundings. Consequently, the anthropogenic degradation of our worlds' wetlands has had, and still continues to have a significant direct, and also indirect effect on many different waterbird populations.

Characteristic of many waterbird species is that populations can vary immensely, from region to region, year to year, hence waterbirds (especially those that migrate) are inherently geographically fresh if you will, as they not only move-fly-but they can easily fluctuate in count by orders of magnitude within just a year, be it because of community collapse, change in preference of regions and sites, or the observer just happens to arrive 10 minutes before they flew away, (or for that matter 10 minutes after). This is why organizations like Texas Parks and Wildlife monitor population patterns regionally, and annually.

Policy and government sanctions operate within what is called *biodiversity*, dealing with "the diversity of all living forms at different levels of complexity: genes, species, ecosystems and even landscapes and seascapes," where it has officially became an international effort in 2010; being geared towards maximizing the functioning of services from and to the worlds' ecosystems and inhabitants (United Nations Educational, Scientific, and Cultural Organization (UNESCO), 2011).

In linkage with these efforts, this research involved looking at targeted sub-urban (urban) wetlands, and the use of them by wetland birds. Observations made of urban wetlands has peaked recognition of there being variation within them and their makeup, but with an increasingly large amount of homogeneity across urban wetland sprawl due to urban development patterns taking precedence. This kind of homogeneity can be attributed to urban and economic processes, where wetlands are constructed and managed primarily for storm water mitigation, recreation and aesthetic purposes, while other types of wetlands that resemble the more 'natural' wetlands of the past are becoming less, and less prevalent in the urban landscape.

1.2 Research Question

This research lies in the question, does the local urban environment support abundant and diverse populations of waterbirds that reflect the expected observations of this region? If the urban environment does or does not support these population estimates, why might that be, is there variation within the urban context?

To better understand these relationships, I refer to what is called *life-history* theory, commonly known within the scientific community, and refers to the concept that by looking at the different stages within the life cycle of an organism, you gather information on how it has evolved to live in certain environmental contexts, adapting uniquely to certain circumstances, and through this, has developed particular behavior patterns, skills, habitat needs, and phenotypes. By understanding the life history of a species, one can assign relative importance of variables to a given waterbird classification group (White & Main, 2004). Findings from this can then be compared to accepted theory of waterbirds in association with the real world, i.e., how I observed it. The goal for this study is to understand what waterbirds need to flourish, and the conditions they need to make that happen, and even further, is it happening in a given local context?

1.3 Purpose of the Study

Intention for this study is driven by finding patterns that may be shown to reveal primary factors of influence for the abundance and diversity of wetland birds. These correlations may be used to promote wetland management strategies for the benefit of waterbird species, and help illuminate current local wetland conditions for waterbirds, respectively. The idea is to help enliven individuals to become a more conscious steward and manipulator of our environment through incorporating structural and biological components into wetland development and management strategies, and broadly speaking, urban development practices.

Destruction of wetland habitats can be generalized to fit into several different categories: agricultural, silviculture, urban developmental/industrial, and the impoundment of reservoirs (Dahl, 1990). These have relationships to policy making as well as other social, political, and economic aspects; although here in this study, I focus specifically on conducting an ecological study of waterbird populations at urban wetlands. In order to gain understanding into the current situation of waterbirds, the history of this topic was investigated further.

CHAPTER 2

BACKGROUND AND CONTEXT

2.1 History of Declines and Attempts at Pursuing Recourse

At the ‘onset’ early factors related to waterbird declines were attributed to the improper hunting and handling practices of waterbirds leading into the 1900s, which then preceded with the monumental Migratory Bird Treaty Act of 1918, regulating bird handling practices. Later adaptions and amendments to this treaty have encompassed land management practices as well, marking a realization and recognition of the important link between structure and biological use of a habitat based on its physical, chemical, and biological components. Eventually these matters, in association with other species declines around the world, led to the creation and standardized implementation of the International Union for Conservation of Nature (IUCN) in 1948, which catalogs and measures the status of the natural world, and from this, species are labeled under a criterion of their abundance, or scarcity. This standardized approach of understanding and monitoring wetland bird populations has helped curb radical population declines. Under the auspices of the Endangered Species Act, the IUCN has kept 99% of the endangered species it comes into contact with from being extinct (Palmer, 2017).

Unfortunately in the 1970s notice was given to significant declines in waterbird populations, despite prior awareness of the ecological trends that indicated wetland birds were at risk. The 1970s era in the US marked a major shift in government involvement and regulation of protecting the environment and its’ natural resources through the creation of government ran organizations that regulate, and through legislature and law, enforce and mandate environmental concerns.

There now exists multiple active, helpful, and influential organizations, some non-profit and others government ran, who play a heavy hand in the indexing of wetland bird populations, the creation of habitat structure for such species, and in general take part in the preservation and conservation of wetland areas found to be of paramount importance to waterbird populations. Organizations such as the Audubon Society, Ramsar, Ducks Unlimited, BirdLife International, and Wetlands International are examples of such non-profit organizations, while the US Environmental Protection Agency (USEPA), Natural Resource Conservation Service (NRCS), US Army Corps of Engineers (USACE), US Fish and Wildlife Service (USFWS), US Geological Survey (USGS), and Texas Parks and Wildlife (TPW) serve as examples for government ran organizations that deal into these matters.

Given this, the past two decades have marked a shift in waterbird and wetland conservation tactics, where in the Blackland Prairie region of Texas only 4 out of 18 observed species (byTPW) have negatively slopped linear trends, *Anas fulvigula* (mottled duck), *Anas acuta* (pintail), *Anas discors* (blue winged teal), and *Aythya valisineria* (canvasback), amounting to a combined positive linear trend from 1997 to 2018 for total duck estimates (Figure 2.1), an order of 1 million total estimates (TPW, 2018). The trend for dip dabble ducks, as well as diving birds is steadily increasing (Figures 2.2, & 2.3; TPW, 2018).

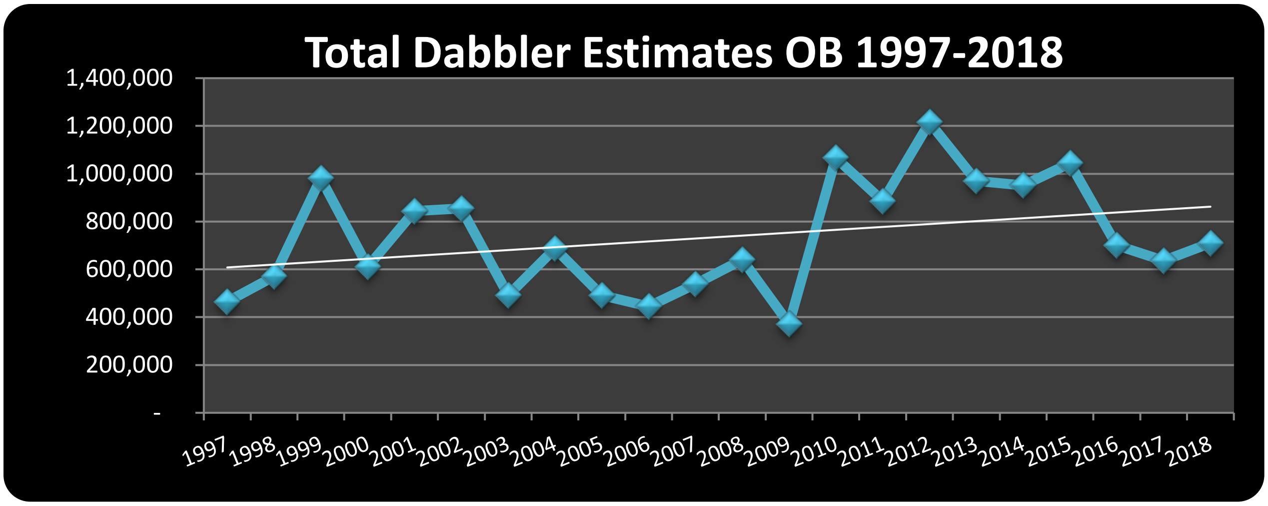


Figure 2.1: Total dip dabbler estimate (TPW, 2018).

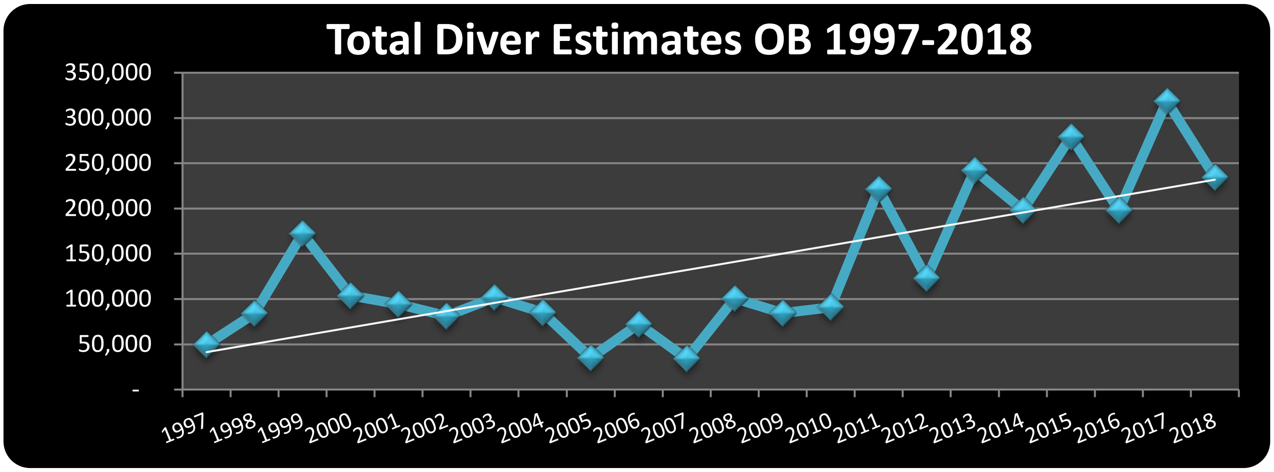


Figure 2.2: Total diving bird estimate (TPW, 2018).

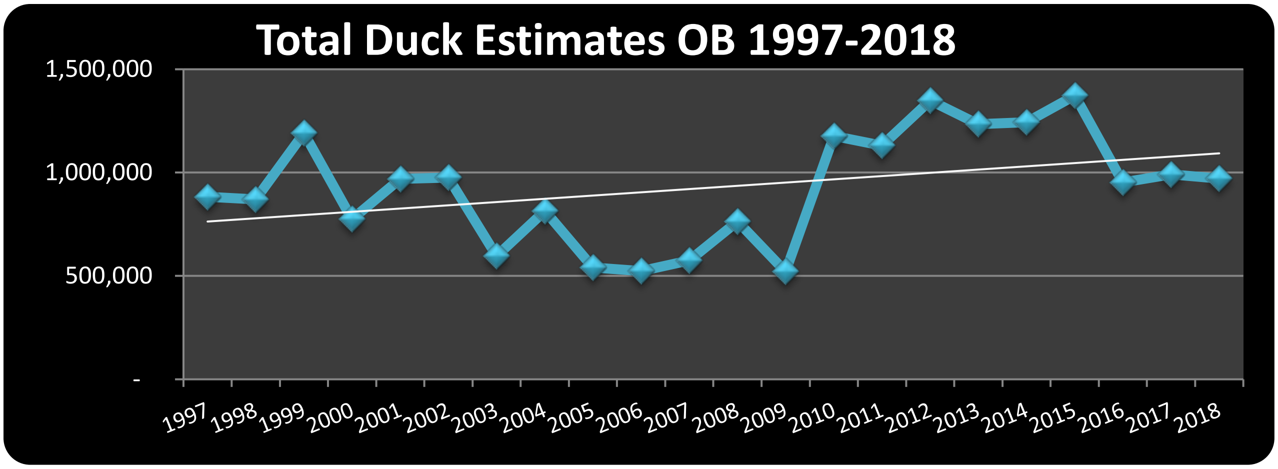


Figure 2.3: Total duck estimates (TPW, 2018).

Keep in mind, different regions of Texas have different results, with some doing worse than others. As for other species in families such as Rallidae (53% of the population with no estimates), Ardeidae (16%), and Laridae (8%) [which are inherently more elusive and harder to find than other wetland birds (excluding *Fulica americana* (American coots), due to their behavior and life history], a growth in population has not been documented (Wetlands International 2012). Rallidae make up 28% (the largest portion) of wetland birds who are globally threatened, but again, the American coot species within the Rallidae family shouldn't be confused with being sparse, as they in particular are quite abundant (Wetlands International, 2012). Due to the lack of data that's been collected for species within the family Rallidae, more uncertainty is derived from the percentage values given. These species are not common to see in the Blackland Prairie region (except for American coots of course).

Anas platyrhynchos (mallards) and *Mareca strepera* (gadwalls) are amongst the most common, and highest estimated populations of dip dabble ducks for the Blackland Prairie region, followed by *Anas carolinensis* (green winged teal), *Mareca americana* (American widgeons) and *Anas clypeata* (northern shovelers); for diving ducks it is the *Aythya collaris* (ringed-necked ducks) and *Aythya americana* (red head ducks), followed by the *Aythya affinis* (lesser scaup), canvasback and *Bucephala albeola* (bufflehead) that are the most common (TPW, 2019).

Again, waterbird populations are quite dynamic, and frequent monitoring of populations is of great value (Morrison et al., 2006). In 2008, Kirby et al. stated that IUCN Red list indices revealed an 11% value for the global migratory land and waterbird species that were classified as threatened, and pointed out that it marked an increase in threat to endangered species from the time of 1988, with 33 species deteriorating and six improving in status (2008). Amongst these and other similar findings, a strong emphasis on regional declines, and the need for regional surveying is affirmed, making it practical to study waterbird populations frequently, especially in different geo-spatial contexts, which are always changing.

2.2 Wetland Loss and Creation

In 2005, global wetland losses have been estimated to be more than a shocking 50%, mostly due to vestiges of past agricultural abuse which dealt with the draining of wetlands (these were government supported)(Dahl, 2011; Finlayson et al., 2005; Hassan et al., 2005). However, from 2004-2009 in the US, the biggest cause to wetland loss was due to silviculture, followed by deep water flooding of coastal regions or reservoir inundation occurrences (Figure 2.4).

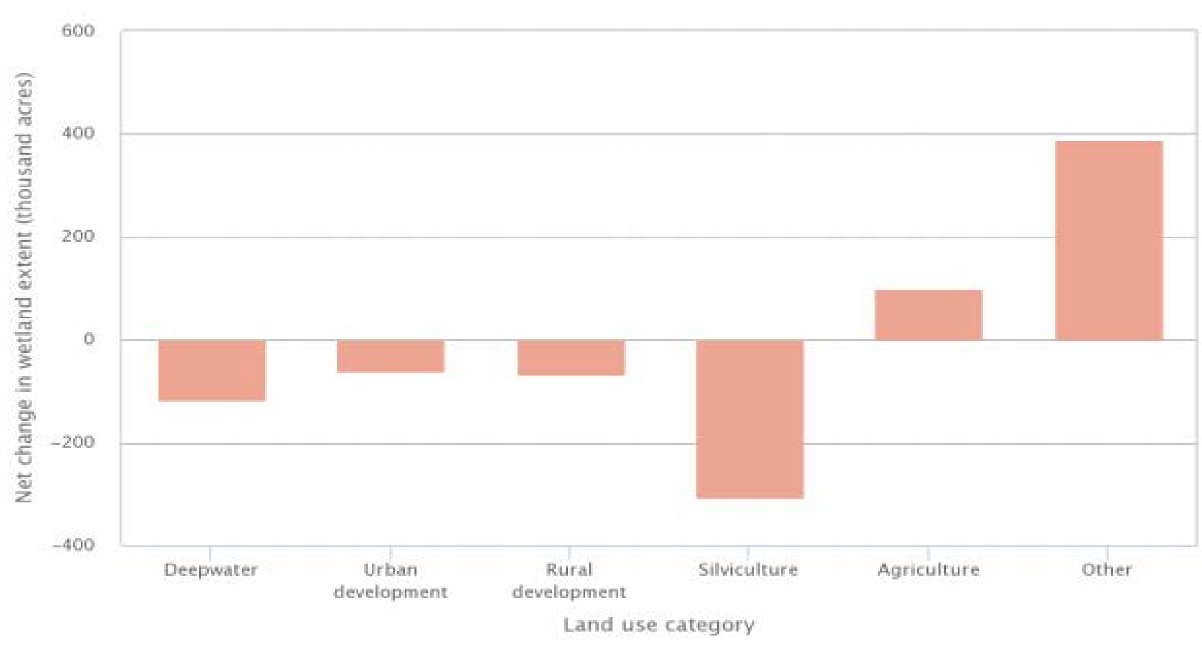


Figure 2.4: 2004-2009 sources of wetland gain or loss (Dahl, 2011).

In 2005, a projection was estimated for food products humans would need 25 years into the future, finding that it's likely to increase by 50% (Hassan et al., 2005). That study considered the addition of growth for energy crops for bio-fuel production. This perspective speaks on the need for an increase in spread of agriculture land to meet production needs, and indirect effects of urban population rise on wetlands and waterbirds (Smeets et al., 2007).

Now at this point in history, agriculture in the US can somewhat be thought of, at least in some cases due to legislature, as preservations, and protective landscape buffers from urban encroachment. In another sense, agriculture operations may be helpful because of organizations such as the USFWS and the Fish and Wildlife Act of 2006, where what is called a Nation Wide Permit 27 now allows land-owners, often farmers and ranchers to only be required to pay at least 50% of the cost, and the USFWS will construct a wetland on their property. One note to add, when landowners construct these wetlands on their properties, often times in these circumstances it is to provide a water source for cattle. In the case of cattle ponds, if not managed correctly, the edges and littoral zones can get trampled by the movement of cows. These ponds often have extremely muddy edges and water, and sparse vegetation present.

Other organizations such as Ducks Unlimited also partake in wetland creation in rural areas, in their instance, it’s often to promote hunting. Keep in mind, the quality of a wetland is important, where purely large quantities of wetland presence is not the only concern. The ‘other’ category in Figure 2.4 reflects wetland restoration and construction efforts, and areas of transition, which includes the activity of the USACE operating under legislation of the Clean Water Act of 1972 (amended 1982). The activities of the USACE incorporate a focus on native ecosystem restoration and habitat engineering.

Although urban growth isn’t the main cause to wetland loss, the activities of urban areas still impacts wetlands and waterfowl both directly and indirectly by shear growth and population expansion, and then also by the compounding need for extraction of earths vital resources to support the functions of a growing population, i.e. silviculture for example, or seemingly essential activities, such as damning native landscape for lake impoundments to provide a fresh water supply to human populations.

Urban environments often create, or convert pre-existing wetlands into storm-water management wetlands, which often do not offer the same functional ecosystem resources as they once did, this happening may not be seen as wetland destruction, as the wetland is still there (Price et al., 2013).

This raises the question: what kind of habitat structure does the urban area offer waterbirds, and what specific habitat variables are associated with high numbers of abundance, and diversity of waterbirds? Although urban growth wouldn’t be thought of as contributing to wetland loss, as a function of wetland area coverage, perhaps in cases it is a cause of loss in wetland value, and or function, potentially curbing, or slowly dwindling down local and migratory waterbirds, or other biota.

If these questions are asked and answered, then they may give us information about not only the geography and frequency distribution amongst waterbird assemblages across urban wetlands within a local context, but also illuminates the geography of waterbirds in relationship to other factors present at a given urban wetland, highlighting important variables to be mindful of, providing for the prediction of, and potential management and conservation/preservation of waterbirds (McKinstry & Anderson, 2002).

Wetland destruction and waterbird decline are related to the encroachment of urban land sprawl, and with 54% of the world living in urban populations since 2014, urbanization has become a major component to waterbird populations globally, and if not directly, then indirectly through other means of human expansion (Figure 2.4; Dahl, 2011; Anon, 2014).

Awareness brought about by initiatives such as the ‘no net loss’ policy of the 1988 Wetlands Conservation Act, and the Biological Diversity initiative of the United Nations Environment Program, would assert that it’s not worth leaving ambiguous the effect of common land management practices of wetland areas on the habitat value for waterbirds (McKenny & Kiesecker, 2010; UNESCO, 2011) . This is especially true within areas that experience rapid urban development, and produce more often than not urban wetlands that have un-planned biological functions, but rather more planned hydro-physical and recreational functions incorporated.

In a land cover context, urban development can be associated with the destruction of natural surface cover, and the take-over of human built surfaces, often summarized as cement, asphalt, and buildings, of which have less biological value, and create harmful effects within our local, regional, and global geo-chemical processes (McDonald et al., 2013).

In the context of wetlands, the rapid appearance of these types of land cover surfaces in our environment means that there is an increased rate of surface water run-off and ground flow from rain events due to the increased amount of impervious surfaces (cement, asphalt, buildings), where infiltration of water into the ground is limited; therefore, wetlands that exist within a dense urban context, and exist relative to a given topographical layout (elevation and location to a stream or lake), become more specific in terms of their purpose and design. This design is often to accommodate this in-flux of surface water in the event of a flood, as per measure of flood protection from damage to property, and to regulate human safety.

With these motivations being central in the design and implementation of many wetlands found in neighborhoods and other urban areas, other potential functions are not occurring. Governmental agencies such as the USACE and USFWS are vested in the biological diversity initiative, as well as other non-profit agencies. However many urban wetlands are built by home developers in compliance with city level government regulations, and in many cases, these outcomes develop into the storm-water mitigation ponds discussed.

With a continuation of processes related to globalization and urban land sprawl, provoked by the pressures of capital gain, activities that determine how the geography of urban wetlands are shaped and the biota it houses are unfortunately not always congruent with policy initiatives such as biodiversity. This is in the sense that many wetlands within the urban context are rarely built and managed in a way that fosters a high level of biodynamic action amongst different species along the aquatic food chain. Local studies of urban wetland landscapes, conducted within the prose of the scientific method, are much needed to better understand the role that humans are having on waterfowl assemblages, especially within an environment that experiences rapid land change and degradation (McKenny & Kiesecker, 2010).

The USEPA has delineated core guidelines to follow when restoring aquatic resources, where amongst the many things dictated is that the natural and original function of the wetland should be replicated, or added on to, where the original geography may still cater to local biota (USEPA, 2000). This tactic doesn't seem to often be implemented within the urban context of ponds, posing questions relating to the usage of these ponds by waterbirds, and other ponds that have been altered significantly from their previous geographical attributes, and set on a new course primed towards storm water mitigation and recreation. Wetlands worked with by the USACE do however receive the treatment recommended by the USEPA.

Consequences of not answering questions related to habitat suitability for waterbirds in a local context may lead only to speculation about wetland habitat value and use for waterbirds within a given local-urban context. Epistemologically, the purpose of this study is to empirically discover a relative truth about waterbird use of urban ponds through using the scientific method, which is bound in the effort to objectively discover truth (while at the same time doing your best to realize bias and relativity)(Inkpen & Wilson, 2013).

Wetland policy, status and history have been discussed heavily up to this point, which helps make sense out of how wetlands are valued differently, and essentially destroyed, created, and maintained based off of these differences. To establish a more complete understanding of the importance, and potential benefits that can be provided by wetlands and waterbirds, and routes of interaction, one last theory must be explained, ecosystem services.

2.3 Ecosystem Services and Wetland Value

Ecosystem services, which are benefits that organisms derive from an ecosystem, are branched into four categories, provisional, cultural, regulating, and supporting, and it is a key concept that needs to be well understood when learning about the importance of any ecosystem, and in this case, waterbirds and wetlands. Albeit, ecosystem services can easily become a human-centered perspective, we must instead consider many other living creatures benefit in different ways under the same model of connection through these ecosystem services (Hudson, 2011).

Provisioning services provided by waterbirds include down feathers, hunting, and the providing of eggs. Waterbirds provide cultural services through iconography and eco-tourism, regulating services through disease outbreak location, and supporting services through decomposition and bio-turbation (Green & Elmberg, 2014). Bio-turbation is where waterbirds mix and turn up the sediment and substrate when feeding, be it feeding on invertebrates, or tubers of aquatic plants, which in turn helps the spread and ratio of nutrients and minerals in the substrate and water column, and in reference to plants, encourages the spread of aquatic propagules and seed pods, helping with improved germination rates.

The ecosystem services of wetland birds spans to direct and indirect economic effects. These include provisions for food, eco-tourism, and multiple uses as a bio-indicator, such as use for tracking disease outbreaks-for example influenza- as well as use for being a proxy indicator of health and status of a wetland (Green & Elmberg, 2014). Considering these benefits along with many more, and the establishment of governmental policies related, in addition to any other social or economic factors that may be at play, waterbirds deserve to be studied. This is even more prevalent given the threat of destruction to their homes (wetlands), and subsequent population numbers reflected globally. Ecosystem services are not only provided by waterbirds, but also must be provided *for* waterbirds.

Wetland value is a concept that describes all the avenues of value attributed to a wetland, where often a wetland is seen as being more valuable when it has a higher level of integration with its surrounding landscape, where it can offer habitat structure for biodiversity, mitigation from storm water and pollution, and aspects of recreation for humans (Mitsch & Gosselink 2000). For instance, some urban wetlands include trails, bird watching blinds, boardwalks, fountains, and golf courses (or golf courses include wetlands), which are implemented into their function and use. Wetlands that have significantly dense and diverse riparian and littoral zones help offer other functions as well, such as providing food and shelter for organisms, as well as providing for water quality control, where through phyto-remediation tactics, plants such as *Vallisneria spiralis L.*, and *Juncus effesus* to name a few, allow for extraction of harmful chemicals into the plants biomass (Zhang et al., 2010).

Slowly decomposing, anaerobic soils sequester approximately half of the pollutants entering wetlands (Weis & Weis, 2004). Pollutants enter these wetland systems through the mobilization of elements in weathering processes (often ground flow of water into an aquatic system) and to a lesser degree, stream influx from creeks, and atmospheric deposition of volatile compounds.

Vegetation within an aquatic system also helps the cooling of ambient air temperatures via evapotranspiration, where latent heat energy from the surrounding atmosphere is absorbed by the vaporization of water molecules from a plant; being transpiration when dealing with water transfer from the inside of a plant, and evaporation when dealing with surface water and through-fall accumulated on the surface of a plant, the combined effect being evapotranspiration. The surface water of a pond is also a major culprit for cooling off ambient temperatures, as evaporation happens within a similar context. The larger the surface area of water there is, the more water there is to be transferred to the atmosphere in this process. Surface water and vegetation in general are land cover surfaces which have an effect on surface albedo, being able to absorb heat, yet emit it slowly back into the atmosphere, while at the same time, through the processes previously mentioned, cool off the atmosphere (McDonald et al., 2013). High temperatures are also controlled by plants through capturing CO_2 from the atmosphere, using it in the processes of photosynthesis, and through doing so, they sequester and transform CO_2 that would otherwise be deposited in a more environmentally deleterious location.

In continuation of the concept of wetland value, wetlands are responsible for 20-30% of the Earth’s estimated soil pool of 2,500 Pg of carbon (Lal, 2008), which is in light of wetlands covering close to 5-8% of earths land cover (Mitsch & Gosselink, 2007). Urban wetlands can be nestled in neighborhoods, located near major roadways, or isolated within the urban environment on nature preserves, airports, and research facilities, or can be found out of the urban environment, in rural areas and spaces of wilderness. In this study I am associating some of the possible geographies of urban ponds, and am seeking to understand them not only individually, but also within relation to each other, and their spatial relationships within proximity of their surrounding ecosystems, documenting the resident and migratory waterbirds, and associated wetland vegetation.

2.4 Past Research within the Field

Similar to my approach, many studies that I have come across in my review of the literature looked at habitat variables and pond characteristics to determine those that are most closely correlated with the presence of waterbirds. Amongst these, some of the more prevalent variables include proximity to human activity, proximity to other wetlands, size of wetland, percent cover of open water, vegetation communities and plant species, macro invertebrate and vertebrate communities, water depth, water transparency, and other water quality measures

(McKinstry & Anderson, 2002; Paton et al., 2009; Lewis et al., 2015; Sebastián-González & Green, 2014; Cizzily, 1992; Pickens & King, 2014; White & Main, 2004).

Research methods that have been used to address questions regarding waterbirds and their habitat viability, commonly involve survey data that is statistically modeled using univariate and multivariate methods. Observations of waterbirds obtained during field visits, or the use of a priori data is often used in these models. Although the use of a priori data is less common, one research study used a priori data to answer questions relating to intrinsic or extrinsic factors of population decline, which involved making comparison across regions, using different pre-existing data sets (Tomankova et al., 2013).

Once wetland characteristics are measured and bounded, these are used as independent variables that are seen as potentially being explanatory variables for the response or outcome variable. In this situation, the outcome variable (also called a dependent variable) is the presence or absence of certain species. The goal is to understand the relationship of the dependent variables to the corresponding features (explanatory variables) in the landscape. In this situation, mixed model regressions can be used, and are typically used to model variables which have linear relations with one another. Additionally, variable selection methods can be used in conjunction with the mixed model methods, to remove noisy or unrelated variables to increase model precision and decrease model complexity. Non-linear models and non-parametric models are also sometimes used, as species data can be sparse, and vary away from simpler linear relationship (e.g. generalized additive mixed models with splines). Multivariate methods are also an important tool commonly used in analyzing waterbirds and associated habitats. These multivariate methods are sometimes referred to as ordination methods. Ordination methods are a class of exploratory techniques (i.e. principal components analysis, non-metric multidimensional scaling, or multiple correspondence analysis and its derivatives), are used to order objects (e.g. rows or columns of a data matrix) on multiple attributes, so that similar objects are situated near each other and dissimilar objects, farther from each other.

These multivariate methods include principal components analysis (in the case of linear relationships) and multiple correspondence analysis (in the case of mixed variables with nonlinear relationships). These exploratory multivariate methods have been used to cluster variables on the basis of correlations, linking groups of variables with certain groups of waterbirds by order of correlation, and discovering classes of imposing constraints of interest between the groups (Bellio et al., 2009). Multidimensional scaling has also been used to show presence at a specific location relative to other locations, looking at colonial nesting of *Ardea herodias* (great blue herons) in relation to surrounding habitat variables, such as marshes, emergent wetlands, or forest edges (Kirsch et al., 2008).

Since different waterbirds have different life-history requirements, different habitat variables can be shown to have more importance than others when considering the management of different waterbirds (the reason why “wetland mosaics” that have different characteristics and habitat variables are encouraged), and a multiple correspondence analysis or a principal components analysis can group these variables with specific waterbird species, and or feeding guilds (Hamer et al., 2011; McKinstry & Anderson, 2002; Reynaud & Thioulouse, 2000). For instance, one may expect a grouping with habitat variables that correspond to strong predictions of species presence, hinting at significant wetland characteristics.

Pickens and King (2014) showed that water depth was the most important variable in their study when considering waterbird attraction to ponds. In this instance, Pickens and King translated the importance of depth to the mere necessity of having a permanently impounded wetland, else if the wetland had dried up, it was of only seasonal importance (2014). The importance of inter-annual lowering of depth, which supports the propagation of aquatic seeds, was also stressed; lowering attracts different abundances of waterbirds, mainly dip dabble ducks who feed on plant seeds. McKinstry and Anderson (2002) also suggests that waterbird abundance and diversity is increased by inter-annual lowering of depth, which mimics tendencies of an ephemeral wetland.

Wetlands often dry up or are managed and lowered in early spring, and then flooded late summer, which helps the propagation of grasses and other aquatic plants. It is also helpful (when managing for the propagation of vegetation and waterbirds) to leave the pond partially impounded, which may help in attracting marsh birds who have been found to be correlated with more shallow, emergent dominated wetlands on the edge of open water (Pickens & King, 2014). Ponds of this kind need to be left lower in the winter to allow emergent vegetation to proliferate later in the season for these conditions to occur, and then the flooding should incur before the migratory dip dabblers and other migratory birds start to arrive (Pickens & King, 2014). When these ponds are managed and lowered, the wetland manager must realize that they are releasing stored CO_2 and methane, contributing to atmospheric pollution and green-house gases in the troposphere, and so caution, strategy, and minimization are all considered when engaging in the process of inner-annual lowering of depth.

Often espoused is that there tends to be more diverse and abundant waterbirds in areas with multiple wetlands in proximity to each other “wetland mosaics” (McKinstry & Anderson, 2002; Williams et al., 1997; Ma et al., 2010; Linz et al., 1997; Weller, 1998; Hamer et al., 2011). This ‘mosaic’ of wetlands is espoused by many researchers, as different depths, and plant species are associated with different species of waterbirds; for instance, diving waterbirds such as the pie-billed grebe's (*Podilymbus podiceps*) , are considered as marsh birds, but are associated with deeper depths, as they often feed off of fish while diving and remaining under water for a period of time, but marsh birds in general, as I have discussed, and other waterbirds, such as dip dabble ducks, are negatively associated with deeper depths, favoring wetlands that are more moderate and shallow, with dip dabble ducks favoring an abundance of submersed vegetation (Baschuk et al., 2012). In other studies, depth relations have been cross validated, where *Fulica americana* (American coots), *Gallinula galeata* (gallinules), pie-billed grebes, and interestingly *Botaurus lentiginosus* (American bitterns) were associated with deeper wetlands compared to those that experienced inner-annual lowering of depth, and *Porzana carolina* (soras), *Rallus elegans* (king rails), and *Ixobrychus exilis* (least bitterns) were associated with more shallow depths, and vegetation dense areas, with king rails also showing an affinity for inner-annual lowering of depth levels at wetlands (Baschuk et al., 2012).

Depth in relation to waterbirds is a function of food association, as depth level has strong bearing on food availability. This is expounded by Johnson et al. (1984), where depth was a good indicator of plant communities, but showed mixed data for correlation with waterfowl like scaup, whistling ducks, and blue-winged teal showing no relation to depth, while ringed-necked ducks, American wigeons, and mottled ducks did show some correlation with depth, although out of this, only a small variation in duck use was accounted for by variations of depth. Another example links diving ducks with deeper water, especially during non-breeding times throughout the wintering period, where seed propagules have fallen to the bottom of a wetland (Green et al., 2002).

For further elaboration of these nuances, although deeper depths can be associated with piscivorous fish, like pie-billed grebes, who can be seen often in the deeper parts of a pond, you also see that wading birds and that some of the marsh birds can be found at these ponds too, but are feeding at more shallow areas of the pond, and are associated with more shallow depths relative to their location within the wetland (Lantz et al.. 2010). Other studies show how depth is more specifically related to the ability of certain plants to grow, demonstrating the mechanisms for controlling food resources for waterbirds, finding that from 2m to 4m is the threshold range for depth of emergent plants to grow (*Valissenria*), and 1.45m for submerged plants (*Typha*, cattails), 1.45 being the point at which the emergent biomass is observed emerging from the water at the deepest depth (Hudon et al., 2000).

Lastly, wetland size is also identified as a key factor in understanding waterbird presence at wetland sites, as the larger the area of a wetland there is, the higher degree of variability there exist to support different species, as there are greater levels of varying depth for littoral zones, and a greater opportunity for plant diversity and abundance to occur (Telleria, 2004). In a supporting study, wetland size was seen as the primary variable for waterbird attraction, along with shallow slopes for a littoral shelf, which is a common feature for natural wetlands, while storm water mitigation ponds can often have steep sloping contours (White & Main, 2005).

Urban wetlands in general have been discussed to be valuable for their ecosystem services, offering a broad variation of benefits to different species, including those of the macroinvertebrate families (Noble & Hassall, 2015), although other studies conflict and find urban ponds to offer little biodiversity, with respect to certain species (Price et al., 2013).

As made evident by digging into the research, as well as commonalities, there are contradictions and nuanced differences amongst the findings across different studies. Waterbirds seem to be flexible when it comes to certain factors such as depth, and urban influence, perhaps out of necessity, but the importance of vegetation, and need for overall variation in wetland-habitat connectivity schemes remain important themes throughout. Conducting different studies based within the scientific method, across time and place can better help objectify and validate findings (Inkpen & Wilson, 2013). The point of concern with learning about the relative importance of variables associated with a given waterbird is so that you can interpret the relative results of a study that was done, as replication is always the true challenge in science (Inkpen & Wilson, 2013). The goal is to better make practical inferences about waterbird species so that we can plan for the future, and better project a desired outcome.

2.5 Research Objective

The research problem lies in the ambiguity of whether or not wetland value initiatives are being fostered by modern and conventional practices of urban development. My questions are: (1) whether or not the wetland sites included in the study offer viable habitat for waterbirds, and at what degree of abundance and diversity are they observed at a given wetland location and (2) what about a given urban wetland draws the waterbirds in, what specific habitat variables are responsible for which waterbird species, or absence thereof. This research is important for addressing research questions about the production of space in urban aquatic wetland ecosystems to better understand whether or not urban environments are providing suitable, and valuable habitats for migrating and resident waterbirds. Once again, if these questions are not answered, we risk that city planners, government organizations and affiliates, policy makers and non-profit organizations, and citizens may continue to allow for such urban spaces to be built in a way that fails to support the agenda outlined within the Convention on Biological Diversity, and that does not follow the recommendations outlined by the EPA for constructing wetlands (UNESCO, 2011; USEPA, 2000). My study objectives include:

> Objective 1: Conduct data collection at multiple different kinds of urban ponds within a similar locality, sampling for pertinent habitat variables related to waterbirds.

Objective 2: Conduct bird surveys at these ponds once a week, for a year.

Objective 3: Apply multi-variate statistics, geospatial technologies such as ArcGIS and digital remote sensing, and ecological methods of identification and analysis to understand, and explain the presence, or absence of waterbirds at these urban wetland sites.

CHAPTER 3

LOCATION

3.1 Study Area

My study area consist of 13 urban ponds in the Eastern Cross Timbers region of North, Central, Texas, Denton, County, in the city of Frisco (Figures 3.1 & 3.2). Stewart Creek (SC) runs adjacent to three of the sites in this study, while a second order of the stream runs with Heritage Lakes (HL) and its five lakes (ponds), as well as Lone Star Ranch (LSR) and its three ponds, while Hackberry Creek (HC) runs adjacent to two other ponds in this study, with a total of 13 ponds studied (Figure 3.2). LSR sites are positioned on what was once a literal ranch, and these are the only group of ponds that are not created, and which hold their original shape, albeit have undergone some engineering. Near the year of 2001, housing developments began popping up in the area, with scarce urban development being present. SC-3 and SC-4 are upon what were once natural wetlands, but since 2015 have been re-shaped and enlarged by the USACE. SC-5 was an ephemeral wetland at certain points of the year largely due to the inundation of Lake Lewisville. Lake Lewisville, a human created lake built in 1927 and expanded in the 40s and 50s, hugs the western portion of the study area. Natural wetlands also occupied the area where HL-2 and HL-5 are, but since 2001 (as Google Earth allows one to view), these have been enlarged as well. Bottom land hardwood forests surround SC, while grasslands, or what were once grasslands, occupy the rest of the now heavily urbanized area.

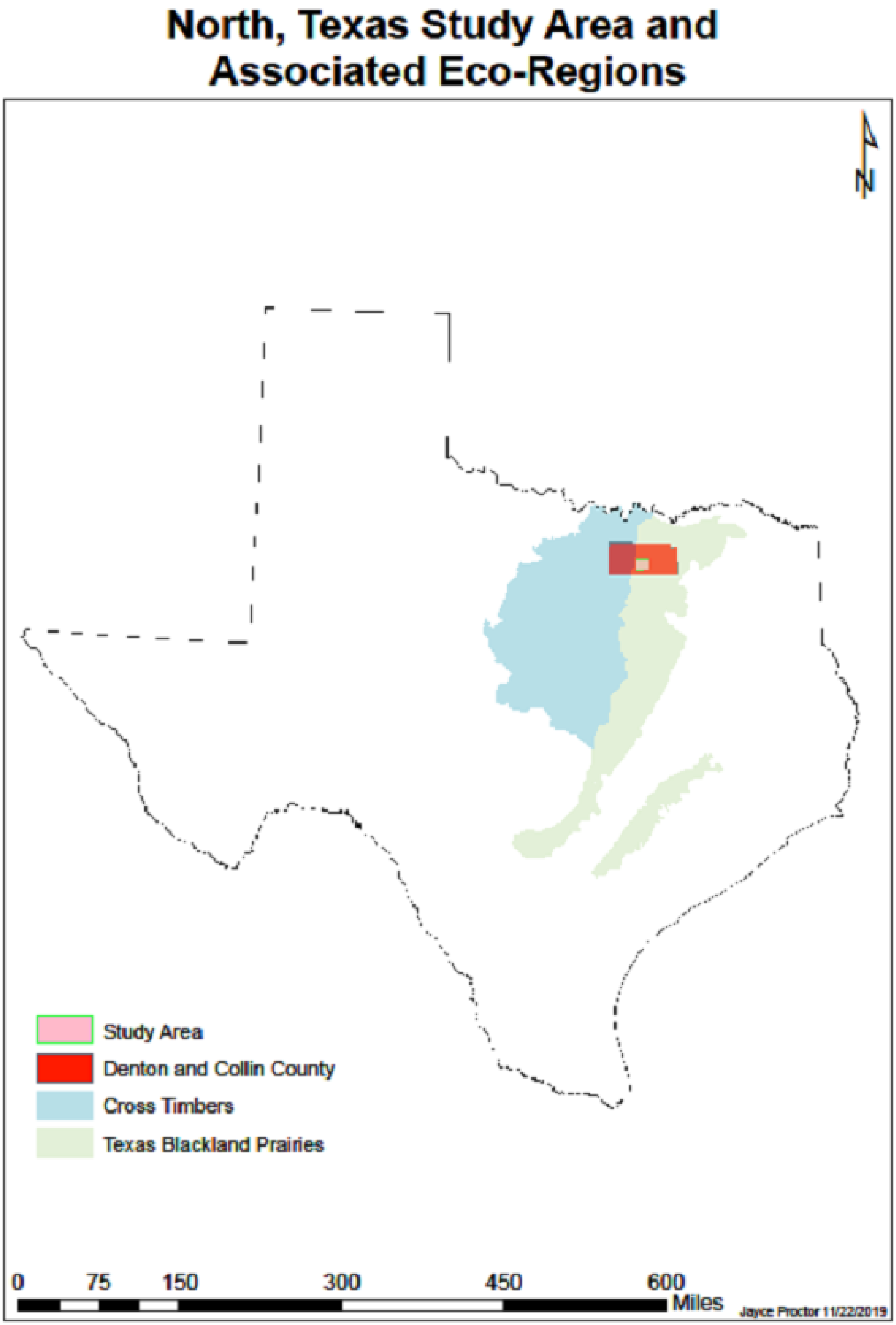


Figure 3.1: Scaled out map of study area and associated eco-regions.

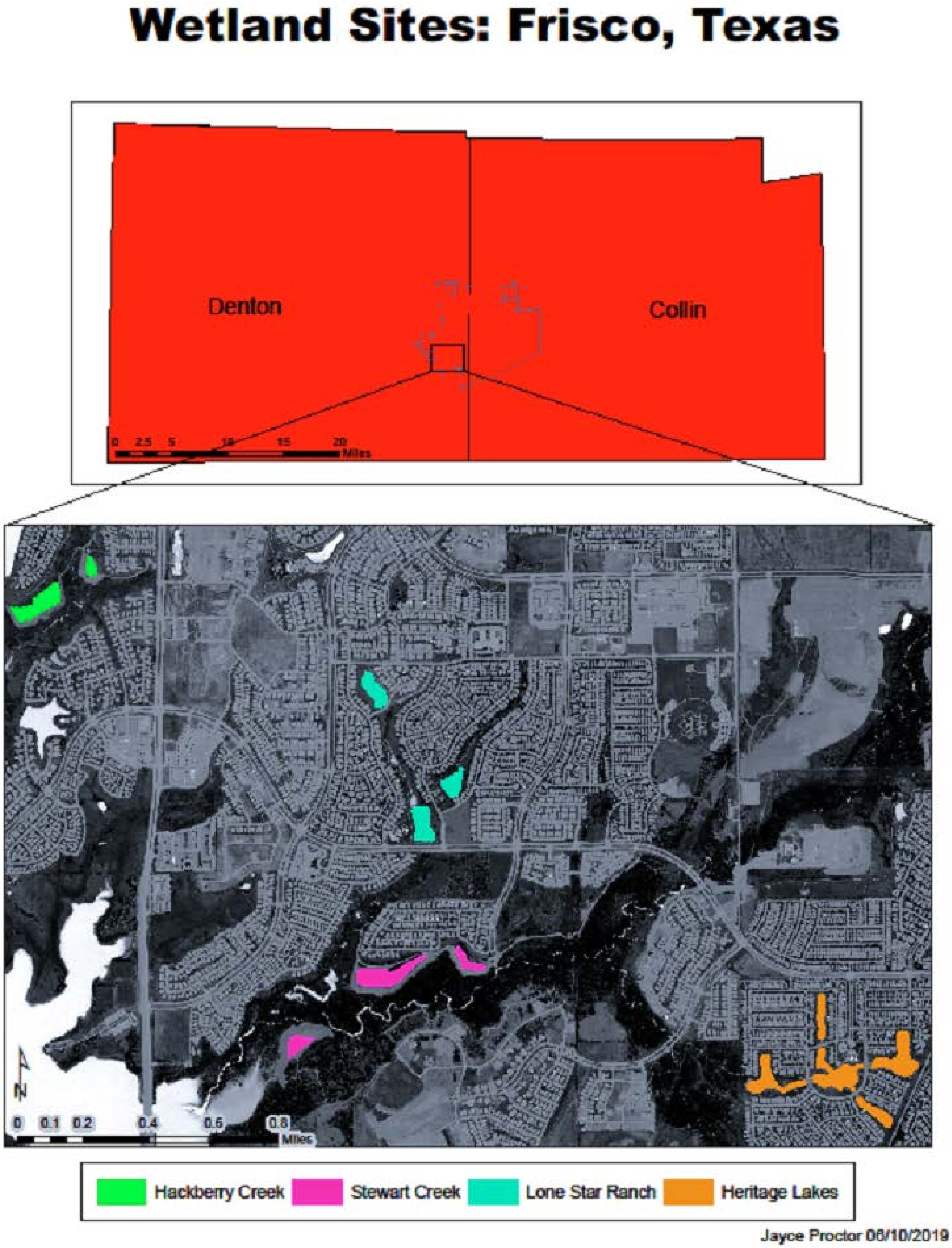


Figure 3.2: Zoomed in map of study sites.

3.2 Site Description

This study includes five restoration ponds referred to as SC and HC cells, and have been created by the USACE (Figures 3.3 & 3.4). These constructed wetland cells are grouped into two different locations, two of them located at HC and three located at SC sites. HC sites are sized for surface area at 196458 sq. (HC-1), and 84126 sq. at (HC-2). SC site area sized for surface area at 286336 sq. (SC-4), 79619 sq. (SC-3), and 53542 sq. (SC-5). All of the constructed cells have been planted with native aquatic plants by the USACE, and have been managed to foster a native and natural wetland habitat structure.

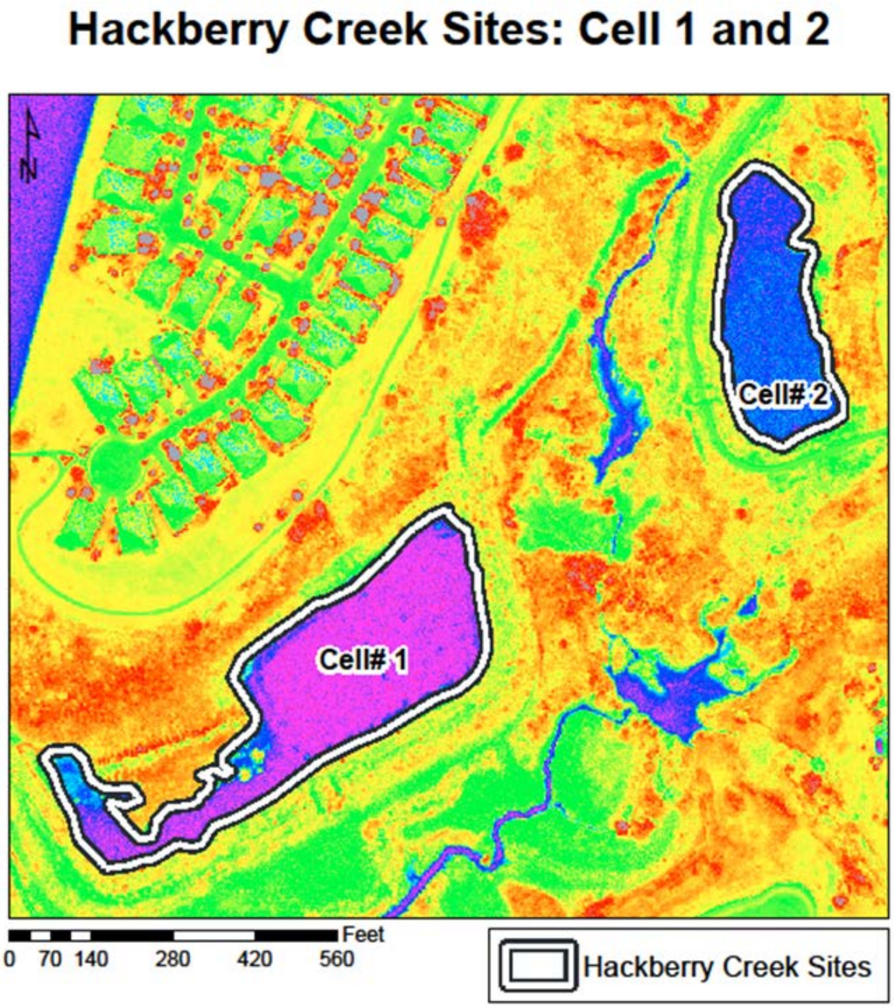


Figure 3.3: Hackberry Creek NDVI map.

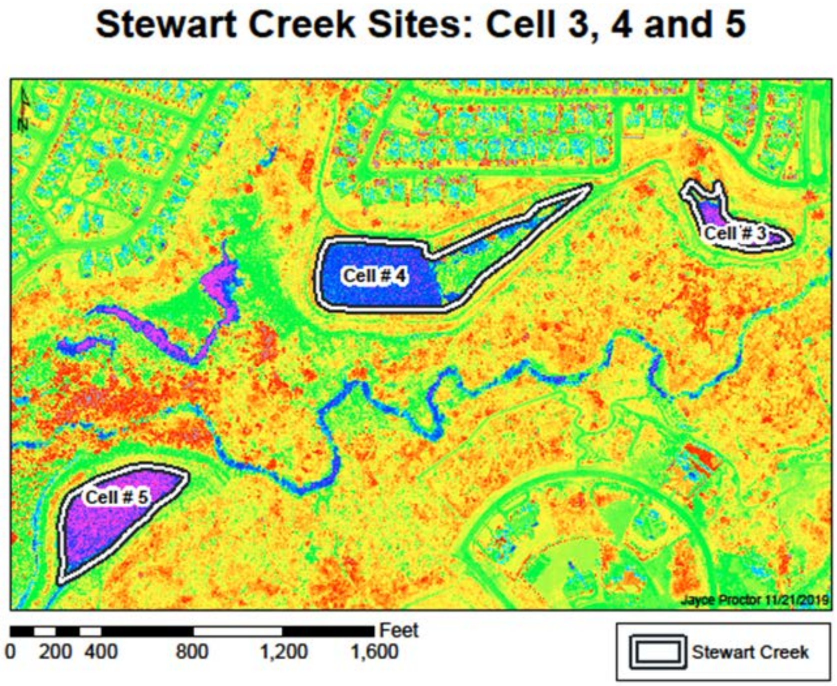


Figure 3.4: Stewart Creek NDVI map.

These constructed cells are nestled within a 183.6 acre area buffer zone, which is nestled within residential neighborhoods. These cells are accompanied with recreation trails that lead close to the shore, and are made out of gravel. Out of these five restoration ponds, one is not associated with public access (SC Cell 5), while the rest are, making this pond more isolated.

SC Cell 5 is also the shallowest of the five, having a deepest depth of nearly 2 feet, and hosts a considerable mud flat adjacent to it during large portions of the year (Figure 3.5). SC Cell 5 is more dynamic than most of the ponds in my study, experiencing inner-annual flooding and inner-annual depth fluctuations (see Appendix B). This area's entire pond surface area is its littoral zone, as it is very shallow most of the year. SC Cell 5 is also the most isolated out of all of the study sites. SC Cell 4 has a high degree of flooded terrestrial vegetation on the eastern end (Figure 3.6). Starting in 2016 this site has been undergoing restoration from the Lewisville Aquatic Ecosystem Research Facility (LAERF), a division of USACE.

Figure 3.5: ***Ardea alba*** **(great white egrets) flying overhead eastern mudflat portion of SC-5.**

Figure 3.6: May 2017 eastern end of SC-4.

The LAERF has focused on aquatic plant restoration (Figures 3.7 & 3.8), grass-swell drill seeding and planting, and terrestrial planting of native species. Since initial efforts, SC Cell 4 has filled in with vegetation most quickly in the aquatic landscape of the site (Figure 3.9), which is where this wetland cell had been principally expanded by the USACE. This pond experiences a more significant inner-annual fluctiation of depth on the eastern flooded terrestrial section, while maintaining its rectangular shape on the western end year around.

Figure 3.7: April 2016: LAERF begins aquatic restoration at SC-3.

Figure 3.8: April 2016: LAERF begins aquatic restoration at SC-4.

Figure 3.9: May 2018: Vegetation renewal at SC-4.

HC cells also experience significant inner-annual depth fluctuations, with Cell 1 being the most notable, as close to 50% approximate of its surface area is lost during the tail end of summer (see Appendix B). These site locations are on either side of each other, while another wetland area exists in between the two HC sites. One of the wetlands in the middle has areas of dense flooded terrestrial vegetation, and both are shallow, with a high degree of depth variation caused by *Myocastor coypus* (nutria) activity and flooding events, which draws in all of the different classes of waterbirds throughout different times of the year, although these observations were not included in my descriptive analysis or modeling (see Figure 3.3). These areas served as a reference wetland, as I was able to make observations while walking past to visit Cell 1, noting that it was prime for dense vegetation waders, open water waders, moist soil, and green winged teal for dip dabblers.

The HC sites rest within a retirement community, and are not obviously available to the public, where no one except for those who live near the neighborhood would be privy to its recreation intent, similar to SC sites. Both groups of HC ponds are located in fringe areas, connecting residential and the conserved natural landscape. These sites, also like SC sites, have more prominent mud cover around the riparian edge of the ponds due to recent construction activities by the USACE, but are quickly being recruited by plants. Some of these include *Bothriochloa saccharoides* (silver bluestem), *Schizachyrium scoparium* (little bluestem), *Bouteloua dactyloides* (buffalo grass), and wild flowers like *Dakota mockvervain* (prairie verbena), *Gaillardia pulchella* (firewheel), *Monarda citriodora* (lemon bee-balm), *Oenothera speciosa* (pink evening primrose), and *Achillea millefolium* (yarrow) to name a few. During the summer months, much of the sites shift into having more dense areas of grass with pockets of *Sorghum halepense* (Johnson grass), *Desmanthus illinoensis* (bundle flowers), *Ambrosia* (ragweed), *Helianthus* (sunflowers), *Iva annua* (sumpweed), *Eragrostis cilianensis* (stink grass), and then cattails closer to the water's edge (Figure 3.10).

Figure 3.10: HC-1, facing southwest during late summer.

The three LSR ponds included in this study are managed primarily for aesthetics and storm water mitigation, with the presence of water fountains, a monoculture of grass grown right to the edge of the shore, dyed water to prevent plant and algae growth, and a resin-rocked shoreline at all three of the ponds to help mitigate erosion incidents (Figures 3.11 & 3.12). There are a group of channel wetlands in between Ponds 1 and 2 at the LSR sites, which flow south from a human-created waterfall into Pond 2.

Figure 3.11: LSR-1 resin rocked beach.

These wetlands are fed by what is either a localized perched groundwater source, or a sand and gravel deposit. This site was also once part of a cattle ranch, where these wetlands existed in a more natural state than they do now, where they have since undoubtedly been re-contoured, and re-shaped to accommodate for more storm water (dredging was observed before the study period started). The surface area for these ponds are 114465 sq. (LSR-1), 145723 sq. (LSR-2) and 86875 sq. (LSR-3). The installment of resin-rock beaches (Figure 3.11) not only prevents erosion, but also miffs aquatic vegetation, where the general theme is to have smoothly sloped-in certain cases steep- shorelines made of short green grass, aiding in accessibility and visual openness.

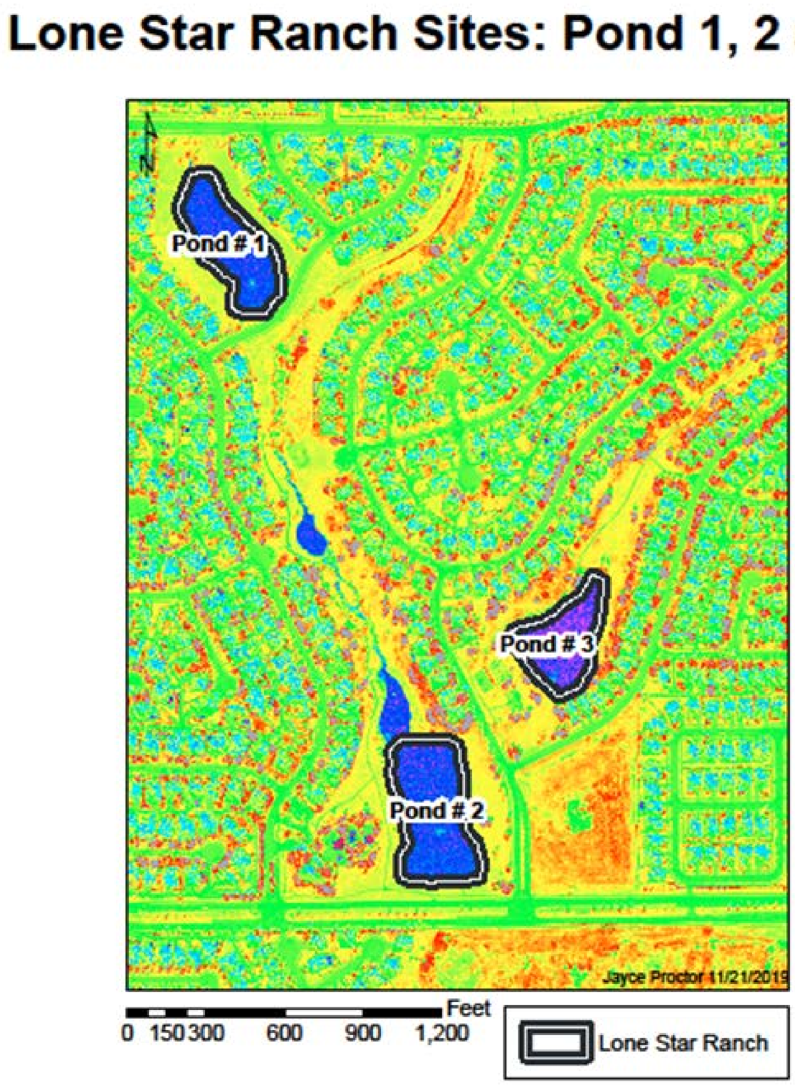


Figure 3.12: LSR NDVI map.

The LSR sites have rather large fresh water muscles inside of them, particularly Pond 2, and simply by walking alongside it they are noticeable (Figure 3.13). Muscles and other macro-invertebrates are considerable food species for diving birds, such as bufflehead and canvasback, shown to have positive correlations with abundance and count on one another (Phelps, 1994; Johnsgard, 1987).

Figure 3.13: Large fresh water muscles at LSR-2.

All of the LSR ponds are sparse with aquatic vegetation due to contracted pond management and landscaping companies who are paid to come out and mechanically, as well as chemically remove aquatic vegetation, and control for algae on a regular basis, especially during summer months when growth rates are at their highest and algae growth is common. This is done not just for aesthetics, but also so fisherman/women can more easily abate vegetation while fishing, via getting their lure caught, or having to fight with an open spot on the edge. What's somewhat contradicting about this practice is that if there were more plants, they would have less algal growth because the plants would be taking in those nutrients instead, and also presumably fish populations would increase due to improvement of habitat structure and foraging habitat for fish (Slade et al., 2005; Goertzen & Suhling, 2013). People fish here at Lone Star Ranch, as the ponds are stocked with common sport species such as *Micropterus salmoides* (largemouth bass) and *Lepomis macrochirus* (blue-gill). These sites also have *Quercus virginiana* (live oak), *Taxodium distichum* (bald cypress), and *Quercus shumardii* (red oaks) trees near the shorelines, which offer fruiting bodies and acorns as a food sources for dip dabbler foragers (Miller et al., 2003; Martin et al., 1961; Garden, 2010).

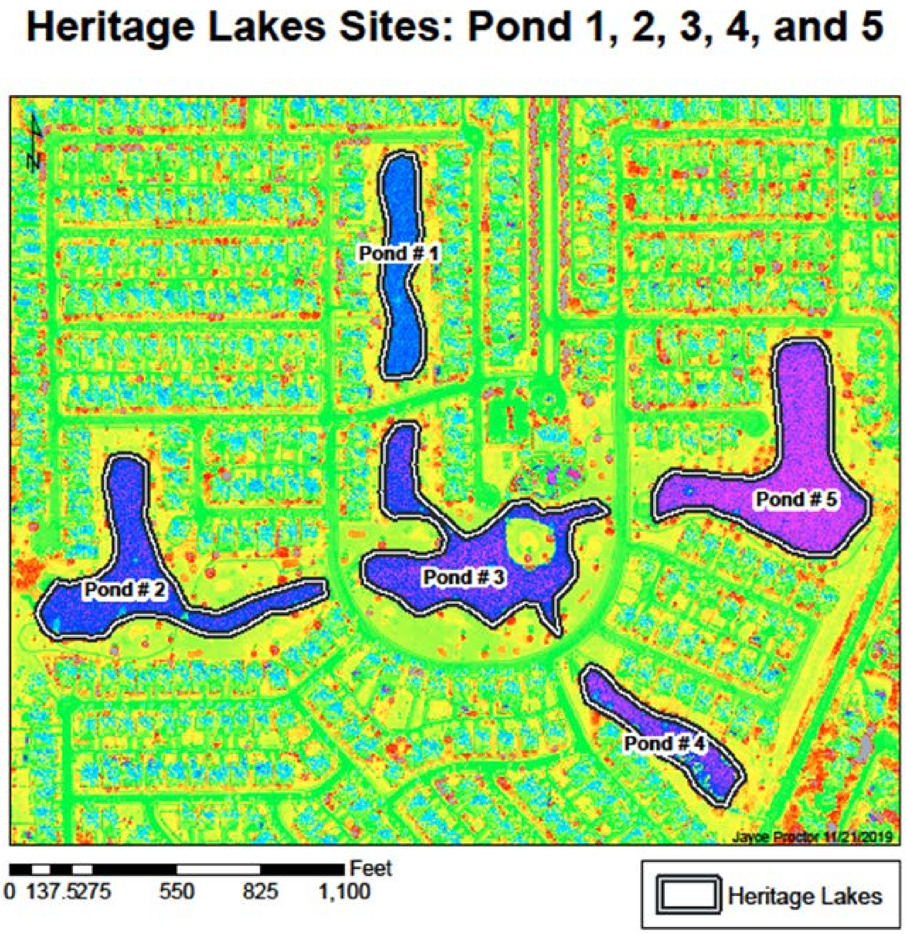


Figure 3.14: HL NDVI map.

I included in this study five other urban wetland sites that are in a gated community called Heritage Lakes (HL), where a golf course exists, with fountains and concrete spillways that manage the water level within the ponds (Figure 3.14). The HL site is part of a US Federal Emergency Management Agency (FEMA) floodplain, and also a part of SC, as it runs through the neighborhood, and is channeled into and out of it by the ponds. At least two of these wetlands existed before the creation of the residential neighborhood, but they now however have been expanded hugely to accommodate for flood risk. Surface area for these ponds are at 90210 sq. (HL-1), 172605 sq. (HL-2), 211532 sq. (HL-3), 83853 sq. (HL-4), and 221132 sq. (HL-5).

Some of these ponds have fountains, and all are treated with dyes to prevent growth of unwanted plant and algae species. More aquatic vegetation is present here than at the LSR sites, mainly because they contract a different company to manage their wetlands, who most likely use different chemicals and strategies. In Figure 3.15, I was able to capture the company in the process of spraying a chemical solution to manage aquatic vegetation, and then with Figure 3.16 I captured the result just minutes after it was sprayed.

Figure 3.15: HL-3 during chemical removal of vegetation.

Figure 3.16: HL-3 after being treated with chemical herbicide.

The HL sites also have fish feeders at HL-2 and 5, indicative of these ponds being stocked with fish. Like LSR, people fish at these ponds. HL and LSR sites are heavily human managed aquatic wetland ecosystems, which means they require the intervention of humans to continue to exist and function as they do, whereas if they were left alone, in time the pond areas would look more like a ‘natural’ pond having aquatic vegetation along the sides and perhaps even clearer water. Ponds such as these share similar spatial features, such as deep depths and steep contours, incorporation of fountains for ornament, the use of dyes, and the related controlled growth of native plants and algae, all characteristics associated with less biodiversity and more contaminated waters (O’Toole et al., 2009).

With the absence of aquatic and riparian vegetation, there are few root systems that can help stabilize and bind together the soil, so erosion problems are likely to occur and worsen over time, hence the implementation of resin-rocked beaches at the LSR sites. HL sites do not have the resin-rocked shoreline, but they do house more aquatic vegetation in some of the sections of the ponds such as *Ludwigia peploides* (water primrose) and *Potamogeton nodosus* (American pondweed). The spillways that channel into each other at HL offers wide concrete shoreline areas within the ponds where birds gather (Figure 3.17). Cut banking erosion is occurring at all of the sites and in some sections are quite extreme. This occurs where vegetation is sparse, and limited to turf grass on the pond edge, in combination with steeply sloped shorelines for the channeling of storm water runoff into a pond. Erosion issues are becoming more apparent and problematic at the HL sites. Both HL and LSR sites practice management strategies that limit the growth of native aquatic vegetation, and riparian vegetation, but both sites do however have the presence of fruit bearing and acorn producing trees near the shoreline, and are stocked with sport fish, which offers viable hunting and foraging possibilities for waterbirds.

Figure 3.17: HL-4 spillway at west side of pond, showing a female mallard, 4 of her young, and 1 *Charadrius vociferous* (killdeer).

3.3 Site Selection

The first sites that were chosen were the HC and SC sites due to my affiliation with the USACE. I was involved with early restoration efforts of these two different site locations, and the original question was on how to monitor the progress of restoration occurring at these wetlands, but the issue was that I was not there before they were created and enlarged, so I did not have a baseline. This led me to incorporate other nearby wetlands so that I could have a comparison for the HC and SC sites. I first chose the closest group of wetlands near the SC sites; these are the LSR grouping of ponds. After some time, I had given a presentation on my plan for this study to a chapter of the Texas Master Naturalists, and from the crowd came forward an individual who wanted to help me incorporate the ponds in their neighborhood, which was nearby, hence the inclusion of Heritage Lakes happened! There was a 14th wetland originally included in my plans, but due to logistics, and its location being farther away from the others, and in another city all together, I dropped the site, with a resulting 13 wetlands to be studied.

The initial idea was to choose, apart from the restoration wetlands of Stewart and Hackberry Creeks, wetlands that were completely different in structure, hoping to capture a bigger picture of what the particular urban area has to offer in terms of wetlands. This would then lead to gaining insight about the differences and how those differences affect waterbird population presence. In the end, considering time and distance, 13 wetlands were almost too much to handle, and inclusion of any more than that would have been very taxing to do by oneself.

CHAPTER 4

MATERIALS AND METHODS

4.1 Data Requirements

Obtainment of the data in Table 4.1 results in completion of the 1st and 2nd objectives outlined in this study, helping to connect the explanatory variables [all of the variables from Table 4.1, and those produced from it – barring bird species – to the response variable (bird species count and class prediction)].

> Objective 1: Conduct data collection at multiple different kinds of urban ponds within a similar locality, sampling for pertinent habitat variables related to waterbirds.
>
> Objective 2: Conduct bird surveys at these ponds once a week, for a year.

This then sequences the ability to model predictions, and understand the complex, interactive relationships that have been observed in this study. As alluded to in the second chapter when talking about other referenced studies within the field of wetland sciences that are similar to mine, the above variables signify a collective of approaches. What is unique about this chosen collective of variables is that an effort was made to conduct a geospatial analysis of wetland variables, with the inclusion of vegetation used for habitat structure and foraging tendencies of waterbirds. These results were modeled using both modeled predictions for bird class and species count, predicting useful wetland attributes for different waterbird classes.

Table 4.1: Baseline Data Needed to Conduct Study

Required Variables	Description
Date	Logged dates for which sites are surveyed
Site	A given local pond within a group of other local ponds
Section	Specific area within a site
Wind Speed	Logged daily wind speed for bird survey visits
Bird Species Count	Surveyed bird species respective to section within a pond

(table continues)

Required Variables	Description
X, Y Coordinate	Absolute location of the middle point for each pond
X Section, Y Section	Absolute location of the middle of a section
Fence Post	Fence line and post within a pond
Fish Feeder	Presence of a fish feeder at a pond
Deepest Depth	Deepest point found within each pond
Perimeter	Distance around the edge of a pond
Surface Area	Total cover of pond
Aquatic Species	Aquatic plants found within a pond
Tree Species	Trees found within a pond, or within a 100 ft.
Grass	Percent cover of grass within a 100 ft.
Bare soil	Percent cover of bare soil within a 100 ft.
Water	Percent cover of water within a 100 ft.
Distance to Urban Built Environment	Length from pond edge to nearest road, building, or backyard fence within 100 ft.
Urban Built Environment	Percent cover of urban built environment within n 100 ft.
People	Surveyed number of people at a pond respective to section
Distance to Nearest Wetland	Length from pond edge to nearest wetland within 3300 ft.
Distance to Creek	Length from pond edge to nearest creek within 3300 ft.
Distance to Nearest Ephemeral Wetland	Length from pond edge to nearest seasonal wetland
Distance to Lake	Length from pond edge to nearest lake within 3300 ft.
Number of Wetlands	Number of wetlands within 3300 ft.

Amongst the most important variables that I have left out are those relating to the niche in the food web that fits in between waterbirds and plants, with plants representing a lower level in the trophic scale, and waterbirds representing a higher level on the scale (Figure 1.2). This middle ground is that of macro-invertebrate and vertebrate taxa, including insects, mollusks, amphibians, fish, and reptiles. Exclusion of these variables was considered carefully, based again on logistics and workload, and to focus the relationship between the primary producers as plants, and the primary and secondary producers as waterbirds, all within a geo-spatio-temporal context.

The LAERF has its’ main role with the HC and SC sites positioned around providing viable habitat through means of introduction and colonization of native vegetation (primary producers). The belief is again based on the trophic scale theory in that presence, richness and diversity of vegetation can lead to more diverse and healthy ecological relationships further up the food web.

4.2 Data Collection

Bird surveys were collected once a week approximate, with 45 date periods surveyed for bird species count. All sites were visited during a survey repetition, and were visited near the end of the day, usually starting when there was at least 3-4 hours of sunlight left, approximate, as it took nearly that to survey all the sites. I would always start from west to east, with the HC sites to HL. HC Cell 2 was the pond I always started with. The sampling method was based on convenience, preventing extra miles driving in alternating sequences constantly, what would have been going back and forth, re-tracing mileage. Bird species were recorded within respect to section of pond (Figure 4.1).

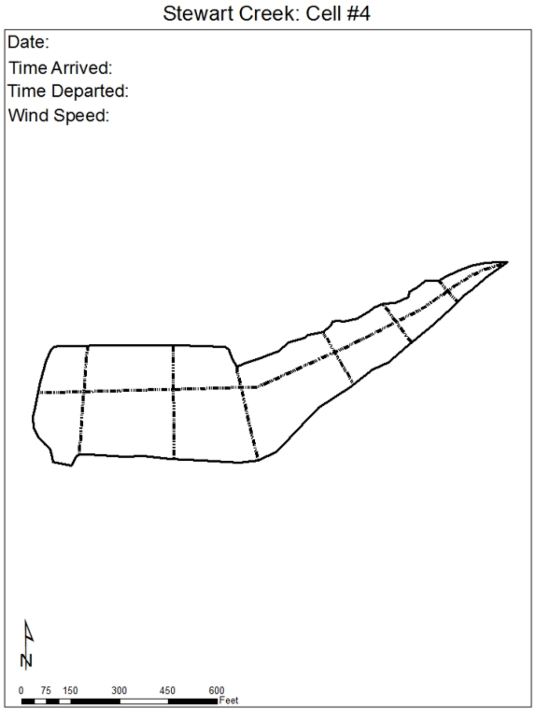


Figure 4.1: Sample of maps used to log bird species count within section.

Vegetation surveys of the aquatic plants growing at each site were conducted 4 times throughout the research period, and logged respective to section as well (see Appendix C). Individual species were assigned a rank cover, and what was aquatic was determined by if it was in the water or the littoral zone (Tables 4.2 & 4.3).

Table 4.2: Percent Rank Cover (Daubenmire, 1959)

Cover Class	Range of Cover	Mid Point of Range
0	0	0
1	1-5%	2.50%
2	6-25%	15.00%
3	26-50%	37.50%
4	51-75%	62.50%
5	76-95%	85.00%
6	96-100%	97.50%

Table 4.3: Percent Aquatic Rank Cover of LSR

Site:	Section:	AVG Emergent	AVG Submerged	AVG Floating Leaf	AVG Terrestrial
LSR-1	A	1.25	1.75	0	0
LSR-1	B	1.25	1.75	0	0
LSR-1	C	1.25	1.75	0	0
LSR-1	D	1.25	1.75	0	0
LSR-1	E	1.25	1.75	0	0
LSR-1	F	1.25	1.75	0	0
LSR-1	G	1.25	1.75	0	0
LSR-1	H	1.25	1.75	0	0
LSR-2	A	1.25	1.75	0	0
LSR-2	B	1.25	1.75	0	0
LSR-2	C	1.25	1.75	0	0
LSR-2	D	1.25	1.75	0	0
LSR-2	E	1.25	1.75	0	0
LSR-2	F	1.25	1.75	0	0

(table continues)

Site:	Section:	AVG Emergent	AVG Submerged	AVG Floating Leaf	AVG Terrestrial
LSR-3	A	1.25	1.75	0	0
LSR-3	B	1.25	1.75	0	0
LSR-3	C	1.25	1.75	0	0
LSR-3	D	1.25	1.75	0	1
LSR-3	E	1.25	1.75	0	0
LSR-3	F	1.25	1.75	0	0

Individual tree species on the shoreline were surveyed up to a 100 ft. buffer, still respective to each pond section. Ponds that had sharp bends of perimeter, such as HL Ponds 2, and 5, would have the out of water section boundaries eventually transect due to curves within the pond, and in these instances, such as with Section C at HL Pond 5 (Figure 4.2). With this section, I shared its tree coverage ranking with the section to the left of it, Section B due to the angle. I used the same Daubenmire ranking scheme for collecting data on land cover near a pond (Table 4.4).

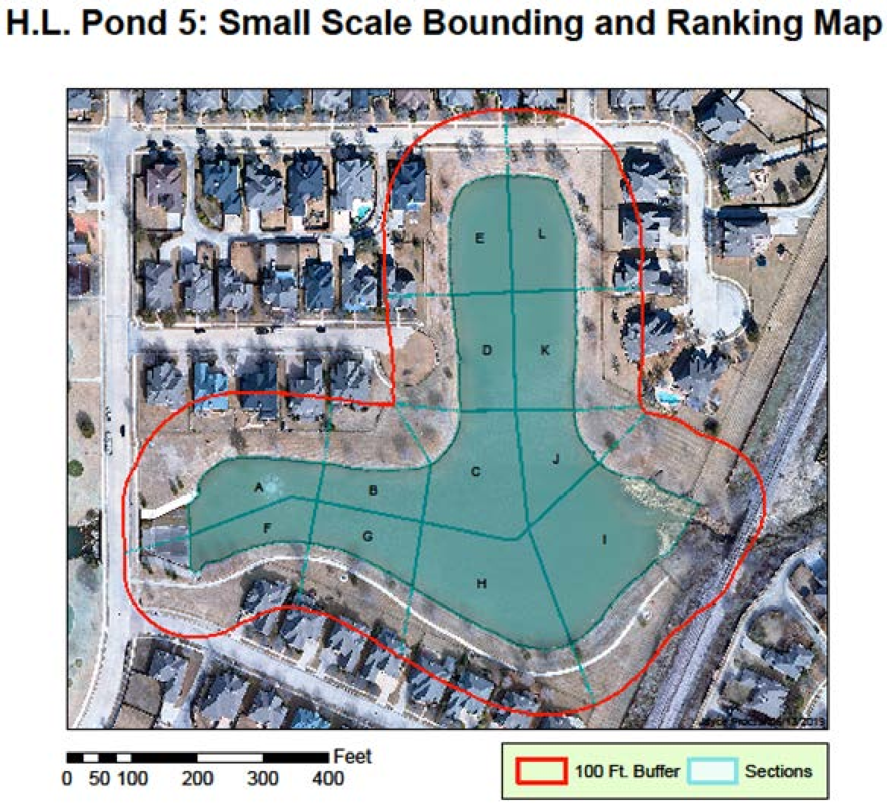


Figure 4.2: Map used to assign cover class rankings within 100 ft.

Table 4.4: Percent Rank Cover of Land Cover within 100 ft. (Daubenmire, 1959)

Trees (Rank Cover Within 100 ft)	Grass (Rank Cover Within 100 ft)	Bare Soil (Rank Cover Within 100 ft)	Water (Rank Cover Within 100 ft)	Urban Built Env (Rank Cover Within 100 ft)

The depth data was gathered by first marking two parallel points on either end of the pond that align with the furthest edge of the pond, and then measuring from these points 100 ft. down the shoreline edge (Figure 4.3).

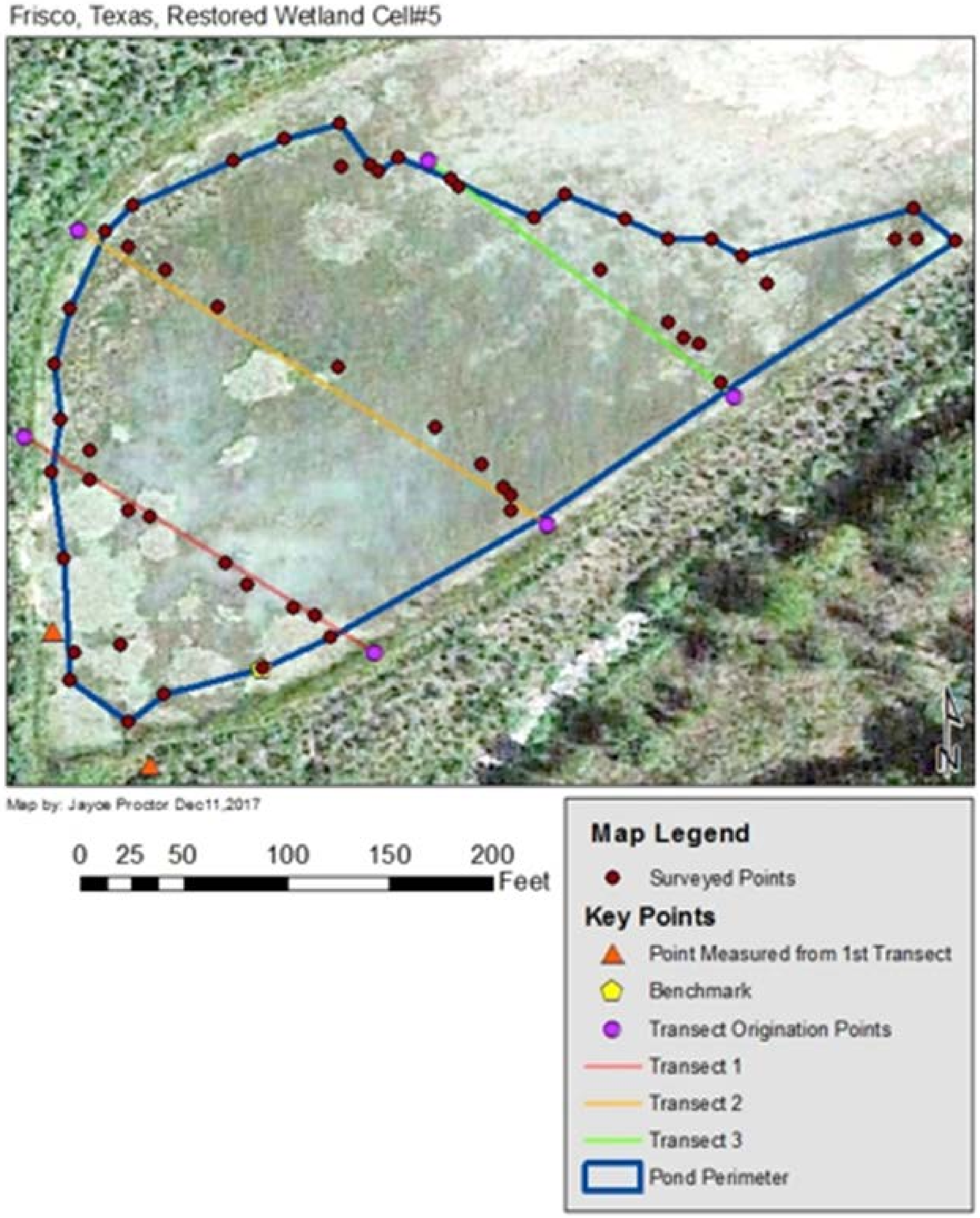


Figure 4.3: SC-5 diagnostic of how depth is surveyed.

Figure 4.4: Depth survey of LSR-1. (Photos courtesy of Duong Nguyen.)

Once the first 100 ft. marker point was found, it was staked with rebar on either side of the pond, and a 1000 ft. long piece of 550 Para cord was strung across the pond with help from a kayak, and then tied to the rebar stake on the other end, and wound taught. This it helps stabilize and anchor the water craft from wind and waves, and also offers a physical reference for the transec; both are necessary for collection of X, Y coordinates at the relative depth value. Coordinates were gathered using a Garmin edge 100 GPS. Every 0.5 ft. change in depth was paired with and X and Y coordinate, allowing for modelling of 3-dimenssional space, with the Z coordinate being depth. Lastly the physical transect allows for minimal paddle use in the kayak, which is important because observation of the change in depth while traversing along a transect is needed (Figure 4.4). This is done with submersion of a 10 ft. long piece of PVC pipe that had a transposed scale written measured in feet. X and Y coordinates were gathered for the pond perimeter as well, with the input recorded as 0 ft. deep. Also random points were gathered in areas of the pond that needed more representation, I used my best judgment, as all the ponds were different. In situations where the water was too deep (deeper than 10 ft.) I used a Deeper Sonar device that connects to my iPhone wirelessly via Bluetooth. The end result of this process can be seen in Figure 4.5, and was done once for all ponds in the study.

Figure 4.5: Depth contour map for LSR-1.

Once the deepest depth was known, a benchmark point could be created for each site where you measure the distance from the top of the surface of the water to a given height, adding or subtracting from the original height depending on depth fluctuation, and then adding or subtracting that number from the deepest recorded depth point during the depth contour survey. Prior scoping however revealed that LSR and HL sites do not experience inner-annual lowering of depth due to weather patterns, thus I did not monitor change in depth for these ponds, but for SC and HC sites I did, conducting 4 surveys during the same time depths were surveyed.

I used ArcGIS to conduct spatial analysis on the variables listed in (Table 4.5) so that I could collect the necessary spatial variables to use in the statistical modeling. All of these variables with the exception of *Distance to Urban Built Environment* were done using the point to nearest distance tool in ArcGIS. Using 2017 high resolution multi-spectral National Agricultural Imagery Program (NAIP) imagery made available from the USGS, I located nearby wetlands within the buffer area. This imagery uses Bands 1, 2, 3, and 4 (Figure 4.6).

Table 4.5: Variables Collected in ArcGIS Analysis

- Dist to Nearest Wetland (ft)
- AVG Dist to wetland (ft)
- # of Wetlands (Within 3300 ft)
- Dist to Urban Built Env (ft)
- Dist to Creek (Within 3300 ft)
- Dist to Ephem Wetland (Within 3300 ft)
- Dist to Lake (Within 3300 ft)
- Surface Area (sq. ft.)
- Perimeter (ft)

With additional comparison of historical google earth images, I classified ephemeral wetlands as those in which only hold water for a brief part of the year, and those that only had water in it during the year that I surveyed it. Sentinel-2 Landsat Imagery from (viewer.remotepixel.ca) was also used to understand changes in water depths across wetlands, as the ephemeral marshland indicates, Hackberry Creek backed up at the meeting between it and Lake Lewisville, but had significantly dried up within the span of two months (see Figure 4.6).

Surface area and perimeter of each site were also collected in square feet and feet through use of ArcGIS. Fence post was simply collected as either being present or not within a section, and presence of fish feeders were treated the same way. People were treated the same way as bird counts, I recorded the number of people I would see within a 100 ft. buffer of a pond, in relation to section.

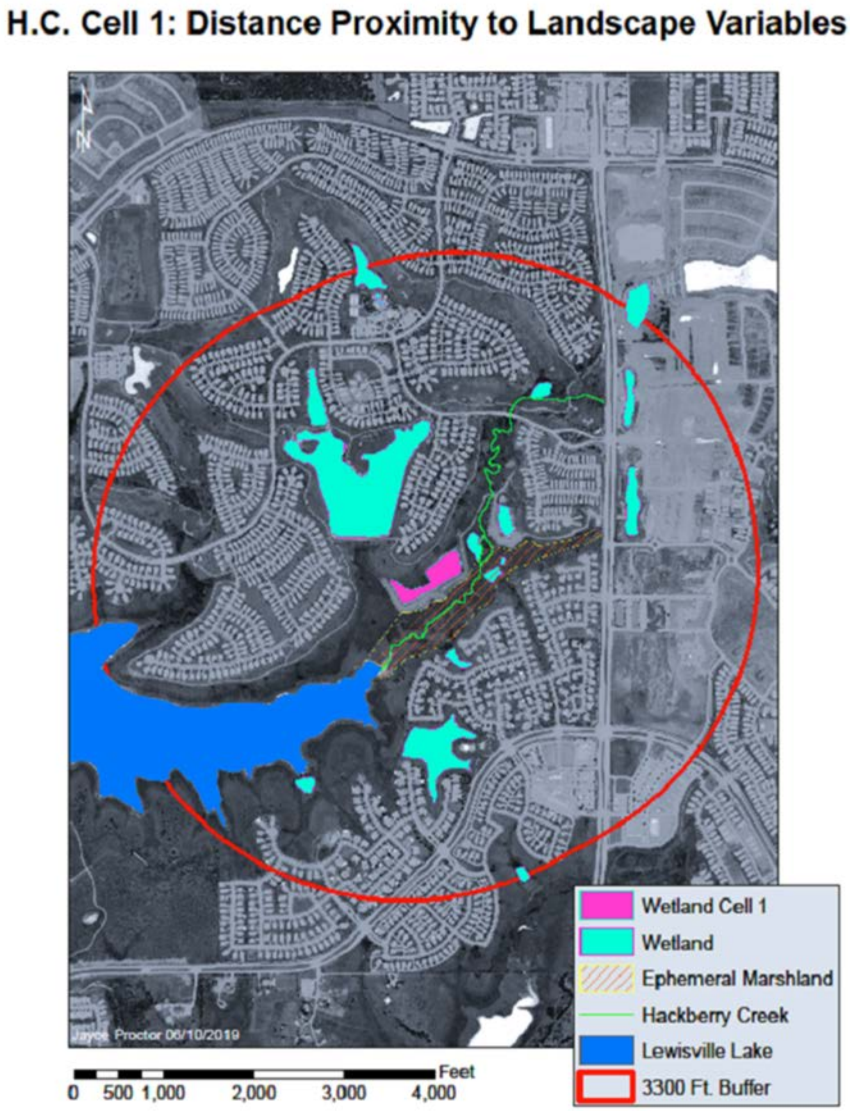


Figure 4.6: Variables influencing waterbirds within buffer regions of a wetland.

4.3 Data Organization

Bird species counts were collapsed across bird classes (White, 2004), and zero counts were removed from the analysis to cut down on the size of data. Individual bird species information will remain intact through descriptive statistics. By grouping together the variables, fitting a model becomes more convenient and useful, especially in situations with large scale dependent data, that has lots of zeros and low counts that actually have a value and mean something.

Modeling was tried on the data without grouping it together, but the sparse data was overshadowed by the larger species count. When not accounting for zero-inflation correctly in ecological observation data, bias and other false parameter estimates can lend themselves to creating uncertainty (MacKenzie et al., 2002). Aerial piscivores and unknown bird species (observations I was unable to identify during the survey period) were left out of the modeled data because they accounted for so little of the data. Out of the aerial piscivores, only 3 *Megaceryle alcyon* (belted kingfishers) were observed, and observations were spread across sites. Observations made of bird species that were at one pond during an observation visit, which then hopped over to the next pond I was observing were counted and included in the data (despite some birds potentially being counted twice).

Plants were also collapsed across class, including emergent, submerged, floating leaf, and terrestrial. These were then averaged across the 4 sampling periods, and an average rank cover class was ascribed per section, per pond. Individual tree species were not used in the statistical analysis for the 100 ft. buffer areas either, and were rather represented by Daubenmire’s rank cover class scheme (1959). The section variables were transformed into a single variable by using a principal components analysis (PCA), which constructs a distance matrix between the two different continuous variables X and Y coordinate, assigning a value to them that accounts for the maximum amount of variance possible, and in this case, 95.5% was achieved. Then a principal component value was given which represents this 95.5% variance, and this component value represents the combination of these two variables. When rendering data pertinent to a given section, the X and Y PCA score can be linked back to the original two coordinates and mapped back to the geographical coordinate.

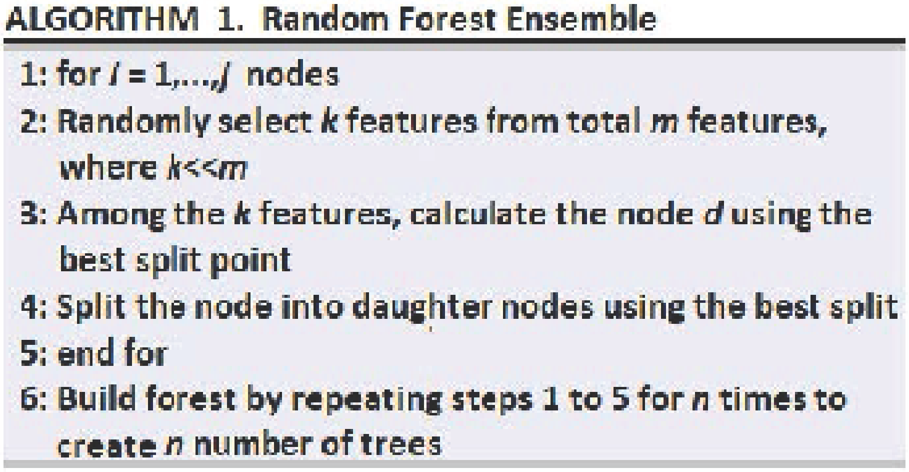
For the distance buffer variable maps, I transformed the multispectral imagery using a normalized difference water index (NDWI), which focuses the green and near-infra red bands to better render water bodies (McFeeters, 1996).

4.4 Data Analysis

ArcGIS was used to analyze landscape variables within a buffered distance of each pond. R statistical package software was used to conduct the rest of the data analysis. R is a free software package that is well supported with many free package installs, allowing for it to essentially be an open source data analysis program. A random forest (RF) decision tree regression model was fit with species counts as the outcome variable, and then a second classification model predicting probability of bird class was ran as well (Table 4.6). For both of the regression models, tuning packages were used to assess optimal fitting, and prevent over fitting of the model. Although I gathered data for a year, once a week approximate, my data is still considered as a small sample size.

Decision trees were used in this study because they can handle non-linear, non-parametric data which makes no distributional assumptions, and that involve complex relationships. A potential downside to using decision trees is that they can be weak in predictive power when compared to other approaches, unless that is you pair said approach with something like a random forest, or an out of bag sampling method that combines different sets of decision tree models, and ensembles them together in a way that accounts for maximum variance (James et al., 2013). The random forest model is a machine learning technique that helps identify non-intuitive relationships, and can pick up on marginal effects that may defy expectations. This ability of the random forest allows it to find interactions, and assign importance values to individual variables in a straight forward fashion, while at the same time, finding significance in what may otherwise remain hidden (Evans et al., 2011).

Table 4.6: Random Forest Algorithm



ALGORITHM 1. Random Forest Ensemble

```
1: for i = 1,...,j nodes
2: Randomly select k features from total m features,
   where k<<m
3: Among the k features, calculate the node d using the
   best split point
4: Split the node into daughter nodes using the best split
5: end for
6: Build forest by repeating steps 1 to 5 for n times to
   create n number of trees
```

In the past few decades, advances in machine learning and artificial intelligence have shown that non-parametric and semi-parametric method regression methods are viable alternates to linear and generalized linear regression methods. Notable examples of these methods are the generalized additive model (GAM), and classification and regression tree models - the so called CART method (Evans et al., 2011). Germane to this study are the CART methods, which require few statistical assumptions, while automatically handling interactions, multi-collinearity and nonlinear effects. Furthermore, classification and regression tree approaches can handle datasets that have large numbers of predictors with mixed data types (e.g. nominal, ordinal, and numeric data types). Variations on CART methods (e.g. random forests), dispense with the need for variable selection, and have a built in out-of-sample validation step (the so-called *out-of-bag OOB error estimation*), prediction averaging (bootstrap aggregation or bagging) that shrink outcome prediction estimates towards less biased prediction estimates, while providing useful variable importance metrics that are insensitive to the presence of noisy variables that are unrelated to the outcome variable (Palacio, 2018).

A drawback of individual trees can be high variance in predictions, with small changes in the data distributions yielding different final trees. Ensemble based versions of CART methods (e.g. Breiman’s RF algorithm), uses a number of algorithmic features to reduce this bias and variance. Two notable features of Breiman’s RF algorithm are the random sub-space method, and the boostrap aggregation (bagging) of prediction estimates. The random sub-space method uses smaller sets of variables, chosen at random from the larger set of available variables – the mtry parameter – to recursively partition the data space, using binary splits on the chosen variables, into smaller sets of homogeneous records of data. Repeated resampling from the observed data with either sampling with replacement (bootstrap) or sampling without replacement (sub-sampling), combined with repeated random selection of subsets of variables gives an ensemble of regression trees.

Bagging or bootstrap-aggregation then combines the predicted values of the outcome, across the ensemble of trees. Essentially, Breiman’s RF algorithm is a kind of model averaging with resampled features (variables) and resampled data. Single trees from the ensemble base their model performance and prediction error on data values that were not chosen during resampling from the original data (i.e. R-squared and OOB prediction error). That is, every tree that is built from resampled data predicts the remaining data that was not chosen for that sample, the so-called out-of-bag prediction estimates. In this way, the RF algorithm has a built in safeguard against having the RF model over-fit the data. Over fitting the data can occur when the model is estimated on all the available data, after which the performance of that model (e.g. R-squared) is assessed on all the same data that was used to estimate the model.

Additionally, best-practice RF modelling suggest that a grid-search across the primary tuning constants be done prior to a final model fit using the RF algorithm. This grid search identifies the best set of tuning constants that maximize the out-of-sample prediction errors. Therefore, the criterion is a simple way of imposing constraints on model fitting, such that out of sample errors (for future samples) are small as possible, given that a given number of trees must be chosen; a given minimal node size must be chosen, and a suitably chosen random subset of variables for building the random trees must be found.

Breiman's RF algorithm is the main regression algorithm used in the present study. More specifically, in the first phase of the data analysis, the RF algorithm is used in two separate RF models, whereby the bird class count variable serves as an outcome variable; then, a RF classification regression is performed, using the bird class labels as an outcome variable to be predicted by the other explanatory variables. The first RF regression looks at modeling counts as a function of class labels and other explanatory variables. The second classification regression models predicted probabilities of class membership as a function of the explanatory variables. Good fitting RF regression models are usually tuned on specific settings, prior to the final model fit, to ensure models that generalize well with unseen data.

The primary tuning constants optimized prior to fitting the final RF model fitting were the *mtry*, *ntree,* and *node.size* – the minimum terminal node size. The terminal node size is the minimum number of cases that are required in a node, before terminating further binary splits on other variables, from the current node (variable). Using these optimally chosen tuning constants, the RF algorithm methodology builds a large number of independent decision trees (*ntree*=5000 for the present study), using a random subset of varying explanatory variables (*mtry*=24), for each decision tree.

Although each decision tree varies somewhat for the predictor variables (e.g. 27 choose 24), each decision tree predicts the same outcome variable of interest. In addition, sampling with replacement (SWR) is used to select subsamples of the original data, when building each decision tree. In this study, the bird class count variable *Species Count* is used as an outcome variable with the variables listed in Table 4.1 as the explanatory variables. Specifically, the following variables were used to predict the bird class counts: *BirdSpecies* (class counts), *x.y.sect.pc1* (PCA derived weighted composite of the GIS sectioned pond coordinates), *DstToUrbBltENV* (distance to built environment), *Baresoil*, *Water*, *DeepestDepth* (deepest depth of pond), *Perimeter* (pond perimeter), *DstToLake* (distance to lake), *FishFeeder* (presence/absence of fish feeder), *AvgDstToNearWet* (average distance to the nearest wetland), *Site* (pond site abbreviations), *People*, *AVGEmergent*, *FencePost* (presence/absence of a fence post), *DistToCreek*, *UrbBltENV*, *DistToNearEphem*, *Trees*, *NumberofWet*, *SurfaceArea* (surface area of the pond), *DstToNearWet* (distance to a nearest wetland), *AVGFloatingLeaf*, *AVGTerrestrial*, *AverageDeepestDepth* (the average deepest depth of the pond), *Grass*, *AVGSubmerged,* and *WindSpD* (windspeed at the pond site when pond was visited).

Also, an explanatory variable was coded - *Date.Season* – that collapses 45 pond visit dates, into 4 levels that code for the seasonal periods – spring, summer, autumn, and winter. Specifically, dates 4/3-7/17 code for spring; dates 7/22-9/16 code for summer; dates 9/23-12/15 code for autumn; and dates 12/30-3/28 code for winter. In all, the bird class counts are predicted by 27 predictor’s total. The original data matrix before collapsing counts across date and bird class strata and removing zero counts was n = 192,960 records. The total sample size, after (i) recoding the date variable into a 4 level period variable; (ii) recoding the original bird species labels into 5 bird classes; and (iii) removing all zero counts to produce a presence-only data matrix, was n = 7396 records.

In the present study, the decision was made to use presence-only data as opposed to presence/absence data. To make this point clear, the total number of absent bird species recorded on each visit, for all sites and sections equaled 0 for 191,184 records. There were a total of 5724 non-zero counts recorded during the study – approximately 1% of the total values recorded. While modeling presence-only data is a valid approach to modeling habitat populations, there are some drawbacks. Obtaining presence/absence data can be difficult to obtain, or may be obtained at a substantial cost. However obtaining only species presence data is usually much easier to obtain than the corresponding absence information. Sample locations with observed presences, with a corresponding sample of background locations in the surrounding landscape is often referred to as presence only data (Zaniewski et al., 2002). Despite these background locations possibly lacking presence/absence data, these locations can increase prediction accuracy.

However, presence-only data samples are often biased, with records of species collected possibly being biased toward more accessible locations (Reese et al., 2005). Bias in the observed presences may be counteracted by sampling background data with the same bias. Ecologists often use presence-only data for different species in the same region to build statistical models for sampling rates, given environmental covariates. The predicted probabilities for the sampling rate bias are then used as weights in sampling the background data. In the present study, after removing zero count data to produce presence-only data, two approaches were taken with regard to the unbalanced bird class size distributions. Firstly, during the resampling phase of the RF model fitting, weighted sampling with replacement was used to draw records from the pool of available data. Weights were calculated as the inverse of the class frequencies such that some random down-weighting of high frequency classes and some random up-weighting of low frequency classes occurs (Nahorniak et al., 2015). Nahorniak et al. demonstrate through simulation and field data the effectiveness of this approach in removing bias in estimating ecological populations. Moreover, they demonstrate how ignoring inclusion probabilities in data obtained from unequal probability samples results in biased model estimates. Secondly, the study uses a very simple variation of a scheme described in Howard et al. (2014).

RF regression can accommodate a wide variety of explanatory variables - the manner in which the RF identify important variables are based on maximizing predictive capacity while using a non-parametric data partitioning method-and do-not maximize a log-likelihood function. By including the count variable as a predictor of class label, combined with inverse probability weighted resampling of the class labels, we are able to hold constant (and co-vary out to some degree) the overall effect of count on the class probabilities, while still assessing the independent relationship of the other covariates on the class probabilities.

The primary outputs for the two RF regressions (regression and classification) are two sets of predicted values for Y: 1) *SpeciesCountPred* – the predicted bird class count values; and 2) 5 predicted probabilities outcomes - one for each of the classes, e.g. *DenseVegWadersPred*, *DipDabblePred*, *DivingBirdsPred*, *MoistSoilPred*, and *OpenWaterWadersPred*.

RF also produced a set of relative importance values that rank each of the predictors in terms of their importance in accounting for the outcome variable. The scaling of these importance values aren't interpretable; however, their relative ranks do give information about relevance and importance. Lastly, graphing utilities exist for most RF software implementations, and give the user the ability to graph what are known as partial dependence plots. Partial dependence plots attempt to convey the qualitative information regarding the input variables influence on the outcome variable, when holding all the inputs constant at their conditional means, other than the variable that is of interest. By way of comparison, partial plots in linear regression communicate the functional form of the input variable on the outcome variable – the slope of this partial plot corresponding to a beta coefficient in the regression table. Likewise, a partial dependence plot attempts to display the functional relationship of a single (or a pairwise interacting relationship) on the outcome variable, averaging over (or marginalizing over) the other variables. Unusually these plots are nonlinear (curvilinear) in nature, and one does not get coefficients from this approach.

The second phase of the data analysis in this study builds an augmented data matrix with the predicted outcome variables (for both RF models) in the data matrix with the explanatory variables as part of that data matrix. An ordination method – specifically multiple correspondence analysis (MCA) – is used to model the relationships of the optimally linearly scaled data columns (all RF predicted variables and all the original explanatory variables), in a classical linear model, with the goal of discovering which optimally scaled predictors significantly predict (in a univariate linear model) the optimally scaled predicted values for the 6 predicted outcome variables - 1 for the bird class count variable, *SpeciesCount* , and the other 5 corresponding to the predicted probabilities of class membership for the 5 bird classes. MCA is essentially a nonlinear principal component analyses that imposes presumed measurement scaling information on the variables, while extracting the eigenvalues of the main components of variation in the data (Reynaud & Thioulouse, 2000). For our purposes, two components were extracted while estimating the optimally scaled scores for the data matrix.

The goal of the MCA analysis in the present study was to produce a final variable importance matrix with explanatory variables as rows and bird classes as columns. The entries in this matrix show a positive value for positively associative variables with bird class; show a negative value for negatively associative variables with class; showing an empty entry for variables that did not reach a critical threshold of alpha = .05. It is an interesting side note, that the t-values, for the variables, of these univariate regressions, all had a positive spearman rank correlation. Essentially, the larger idea behind using the MCA step, was to use the MCA as a meta-organizing tool - to organize the output from the two RF models, while gaining insight on the directions of the associations that related the optimally scaled predictors to the optimally scaled predicted values.

CHAPTER 5

RESULTS

5.1 Summary Statistics

From Apr/03/2018 to Mar/28/2019 a total of 5724 observations were made during the study period, with a total of 30 species observed (Tables 5.1 & 5.2). There were 45 survey samples logged for bird species across the 13 wetland sites. Across time, autumn and winter had the largest numbers of waterbirds, comprised mostly of dip dabbler ducks and diving birds, while in the spring and summer dense vegetation waders increase, relatively. Moist soil species largely increasing in the spring with killdeer, but more so in the autumn for *Gallinago delicate* (Wilson snipe), and the frequency itself of the class remains more or less consistent with a slight drop in the dead of winter. Dip dabble birds occupy the area year around too, as does open water waders and moist soil birds.

Out of all of the sites, HL-3 had the highest sums, but SC-4 had the highest mean value of 38, followed by HL-3 at 36, and then HC-1 at an average of 33 waterbirds (Figure 5.1). Within the top ranked sites for average, those same three also represent those with the highest sums.

All sites are represented strongest by dip dabbler species, with few exceptions regarding diving species, largely due to the degree of sociality enacted by moist soil birds, open water waders, and dense vegetation waders; these species are often alone or in small groups *Bubulcus ibis* ((cattle egrets) and great blue herons are exceptions, amongst other special circumstances involving pooling of food source (Krebs, 1974)). SC-4 had the highest amount of dip dabbler species, followed by HC-1, and then HL-3. HL-4 and LSR-3 have amongst the lowest counts for dip dabbler waterbirds.

Table 5.1: Total Number of Species Observed and Distribution of Species across Bird Class

Dip Dabblers	Diving	Open Water Waders	Dense Vegetation Waders	Moist Soil
• American coot • Mallard • Gadwall • Amerian widgeon • Northen shoveler • Pintail • Green winged teal • Canadian geese • Blue winged Teal	• Lesser scaup • Ringed-necked duck • Pie-billed grebe • Double-crested cormorant • Redhead • Goldeneye • Bufflehead • Canvasback	• Great blue heron • Little blue heron • Great white egret • Snowy egret • Cattle egret	• American bitten • Green heron • Night heron	• Wilson snipe • Killdeer • Franklins gull • Snowy plover • Yellowlegs

Total # of species observed = 30

Table 5.2: Total Observation Count over All Sites

Site	Species Class Count Sum	X	Y (-)
HC-1	720	33.132085	-96.897207
HC-2	461	33.13386	-96.894534
HL-1	205	33.113121	-96.856294
HL-2	501	33.110224	-96.858815
HL-3	1080	33.110375	-96.855209
HL-4	64	33.108875	-96.853438
HL-5	641	33.111026	-96.851934
LSR-1	220	33.128049	-96.879612
LSR-2	279	33.122105	-96.877185
LSR-3	39	33.123909	-96.875453
SC-3	262	33.115731	-96.874754
SC-4	877	33.115295	-96.879302
SC-5	375	33.11253	-96.883779

5724 = Total species class observations over survey period (April 2018-2019).

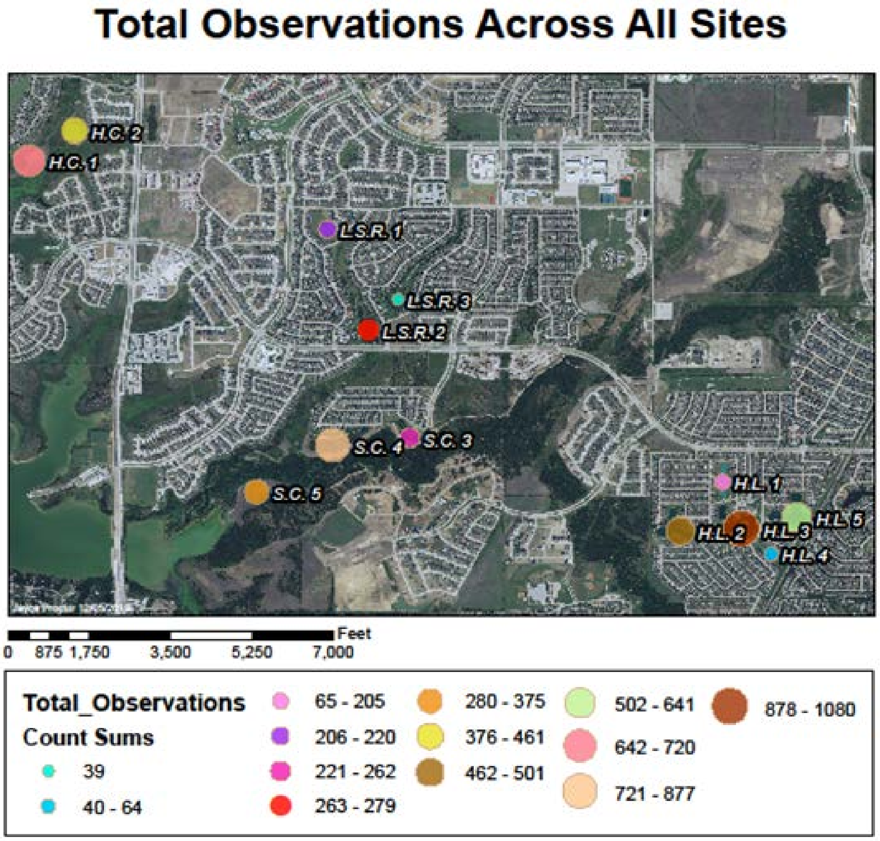


Figure 5.1: Geographic visualization of total sum distribution across site.

Diving birds are most greatly represented by HL-3, followed by SC-4. HL-4 and LSR-3 sites are the lowest site representations for diving species. Moist soil birds were sparse amongst counts, but were most notably represented by HL-4 and HC-2 sites. HC-1 also had the highest amount of open water waders, closely followed by SC-5. Dense vegetation waders are most prominent at HC-1 and SC-4, and only 7 of the 13 sites even had any birds within this class observed. Aerial piscivores were dropped from the data due to low counts (only 3 were observed), and were seen at different sites throughout the period.

Bird class count by site by section was compared descriptively for each site using grouped, stacked bar charts, and heat-bar graphs were generated for section within site (see Figures 5.16-5.33). Dip dabblers were most abundant at SC-4 and HC-1 restoration sites, followed by HL residential golf course ponds (Figure 5.16). Mallards and gadwalls dominated the dip dabbler counts (Figure 5.16). Diving birds were most prominent at HL-3, specifically, followed by SC-4, HL-5, HC-1 and HL-2 (Figure 5.17). Ringed necked duck and scaup were the most abundant diving birds (Figure 5.17). Open water waders were most abundant at HC-1 and SC-5, followed by HL-1 (Figure 5.17). Of the open water waders, great white egrets and great blue herons were seen the most, followed by cattle egrets and *Egretta caerulea* (little blue herons) (Figure 5.18). The dense vegetation waders were prominent at SC-4 and HC-1 sites, with *Butorides virescens* (green herons) and *Nyctanassa violacea* (night herons) observed most frequently (Figure 5.19), and moist soil's highest counts are from killdeer at HL-4 and HC-2 (Figure 5.20).

When looking at sections across the ponds, a common theme is to see dip dabblers across all areas of a pond, while diving birds often favor deeper areas, and open water and dense vegetation waders, as well as moist soil birds prefer more shallow depths for foraging (Figures

5.21-5.33). There are exceptions, such as grebes who will dive in more shallow waters, and *Phalacrocorax auritus* (double crested cormorants) who use features like fence posts to perch in shallow areas (Figure 5.21). Also, in ponds that experience inner-annual flooding periods such as HC and SC sites, diving ducks can be seen favoring ponds and sections that are on average deeper throughout the year (Figures 5.21-5.25). For open water waders, dense vegetation waders and moist soil, although they are observed at ponds or sections that do not always represent a shallow depth, they are using the shallow areas of that particular section, such as the shoreline in such cases. A good example of this can be seen for open water waders and dense vegetation waders observed at HL sites (Figures 5.29-5.33). Open water waders and dense vegetation waders such as the green heron and the night heron also showed an affinity for flooded terrestrial habitats, or wetlands near those habitats (Figures 5.21 & 5.23).

5.2 Random Forest Regression and Classification

In the first random forest regression model species counts were predicted, ranking the importance's for each variable (see Table 5.3). Three radar charts were ran on this data set to ascertain interactions amongst these importance's (Figures 5.2, 5.3, & 5.4).

Table 5.3: Random Forest Model 1: Fit and Importances for Variables Predicting Species Count

Regression Fit	
Sample size	7369
Number of trees	5000
Forest terminal node size	1
Avg number of terminal nodes	2105.208
Number of variable tried at each split	24
Total number of variables	27
Resampling used to grow trees	swr
Resample size used to grow trees	7369
Analysis	RF-R

(table continues)

Regression Fit	
Family	regr
Splitting rule	mse *random*
Number of random split points	200
% variance explained	35.69
Error rate	238.43
Importances	
Predictor	Importances
BirdSpecies	221.920993
x.y.z.sect.pc1	106.437173
DstToUrbBltENV	21.067872
Baresoil	20.119823
Water	19.56037
DeepestDepth	15.374841
Perimeter	14.868054
DstToLake	13.864758
FishFeeder	13.857926
AvgDstToNearWet	13.704549
Site	13.592416
People	12.452694
AVGEmergent	12.102126
FencePost	11.726006
DistToCreek	11.548576
UrbBltENV	11.41769
DistToNearEphem	11.320076
Trees	10.938897
NumberofWet	10.736838
SurfaceArea	10.24129
DstToNearWet	9.189881
AVGFloatingLeaf	8.600414
AverageDeepestDepth	6.905256
Grass	6.345153
AVGSubmerged	5.899422
WindSpD	-50.875583

Figure 5.2 shows how dip dabblers and diving birds account for most of the waterbird counts, outlining which sites are modeled to more strongly account for the variance of explaining predicted counts being in a given bird class. Dense vegetation waders variance are better predicted by Sites HL-4 and SC-4, and open water waders are more prominently explained at HL-1 and SC-4, marginally. Moist soil is hard to see because it is amongst the hardest to predict (due to low counts).

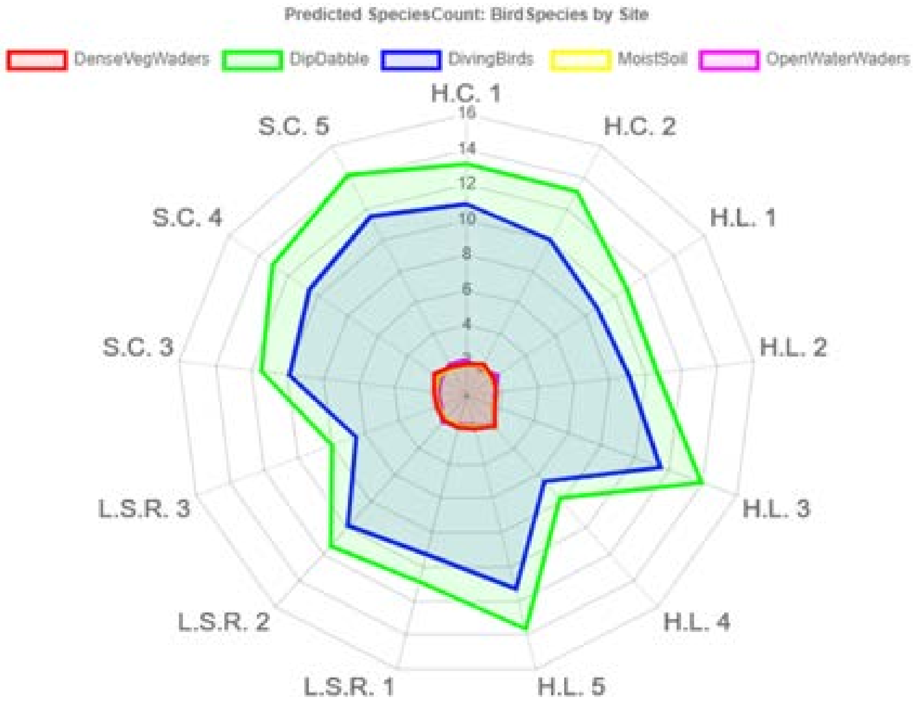


Figure 5.2: Radar chart predicting count: bird class by site.

The interaction shown with species count by surface area reveals 3 tiers of surface area, where count prediction goes up by about 4 for both dip dabblers and diving birds when you have a surface area of 179639 sq. ft. (Figure 5.3). When a surface area of 228138 sq. is present, the dip dabble ducks' ability to predict increases by a rate of a full count more than that of diving ducks. Figure 5.3 shows the marginal interaction with surface area of HC-1 and SC-4 sites, where they show a greater rate of increase than other sites in ability to predict bird species when surface area goes up.

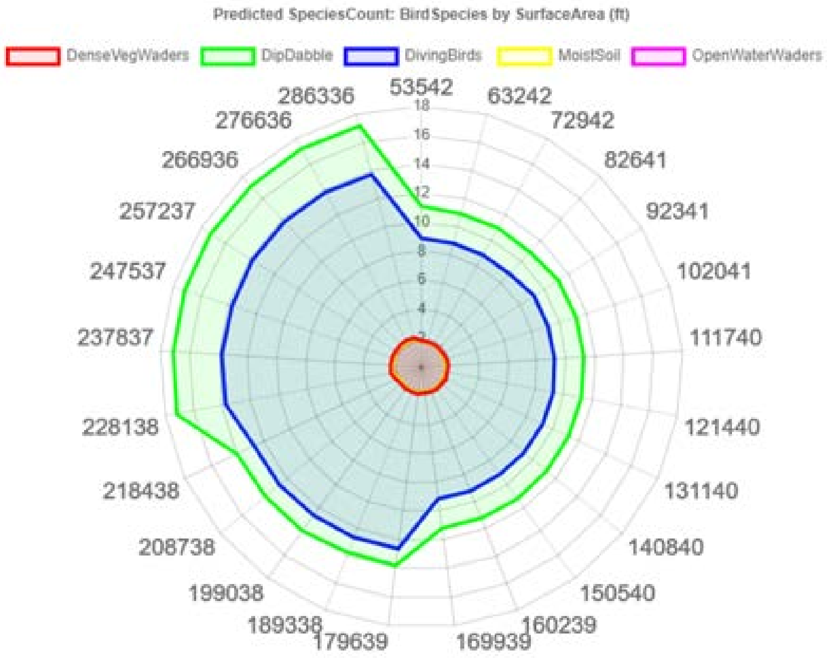


Figure 5.3: Radar chart predicting count: bird class by surface area sq.

Species class by bird count by average floating leaf shows a significant interaction (Figure 5.4). When average floating leaf vegetation increases from 0.44 to 0.51 the ability to predict diving birds increases by 4 counts, and this lasts until you reach 0.80, where it's more even with prediction of surface area values to that of dip dabblers. When looking at average emergent vegetation's interaction with predicting bird class counts, the big take away is that sites interaction with average emergent vegetation and predicted species count shows that SC-5, if it were to have more emergent vegetation present, would be a prime place for waterbirds. What's interesting about Figure 5.5 is that SC-4 starts out just above a prediction of 9, but then drops down to 1.5 average emergent vegetation, and then goes back up by 2 and evens out. HC-2 drops down like SC-4 does, and increases sharply as emergent vegetation increases. The heat-bar graph in Figure 5.6 shows that there is a positive interaction between average floating leaf and average emergent vegetation, they both increase the ability for prediction when found together in higher values. Figure 5.6 shows the correlation that floating leaf and aquatic vegetation have on prediction of species counts, where the HC and SC sites are the only ones that had floating leaf cover, and that had much more emergent and submerged vegetation, whereas LSR and HL sites were more comparable with submerged vegetation only.

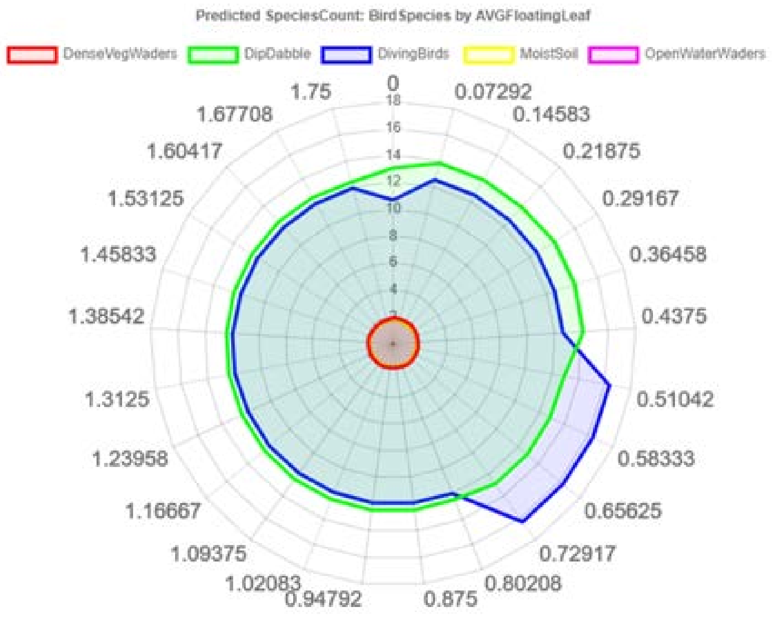


Figure 5.4: Radar chart predicting count: bird class by AVG floating leaf.

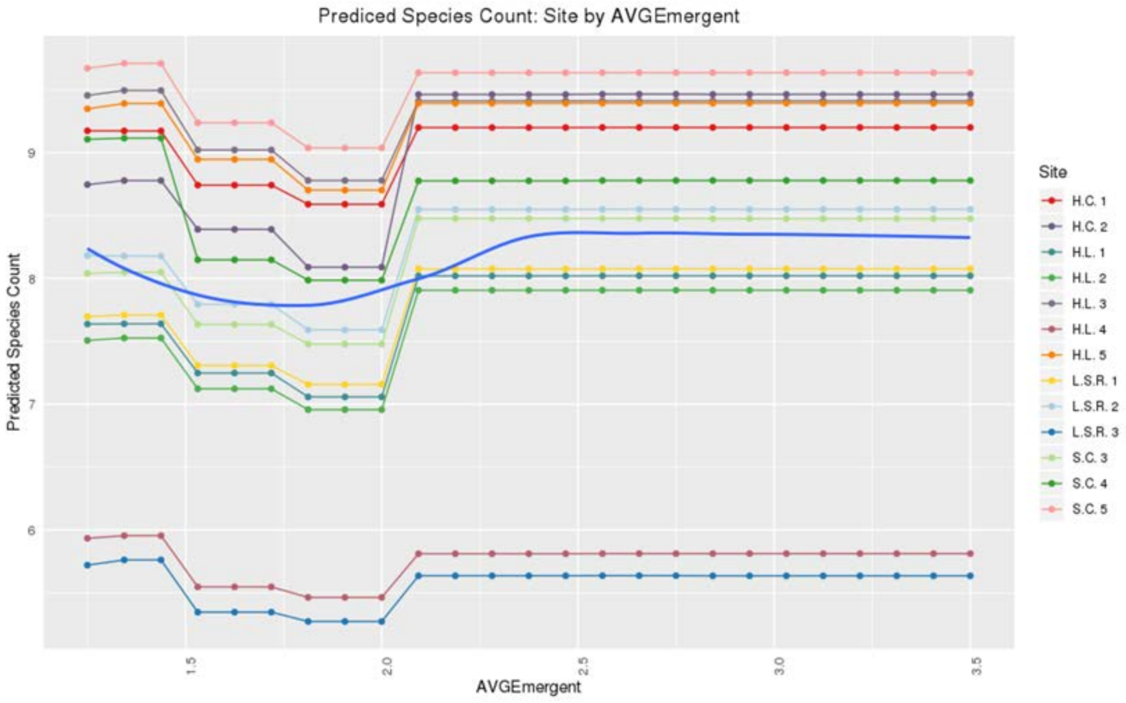


Figure 5.5: Stacked line chart predicting count: bird class by AVG emergent.

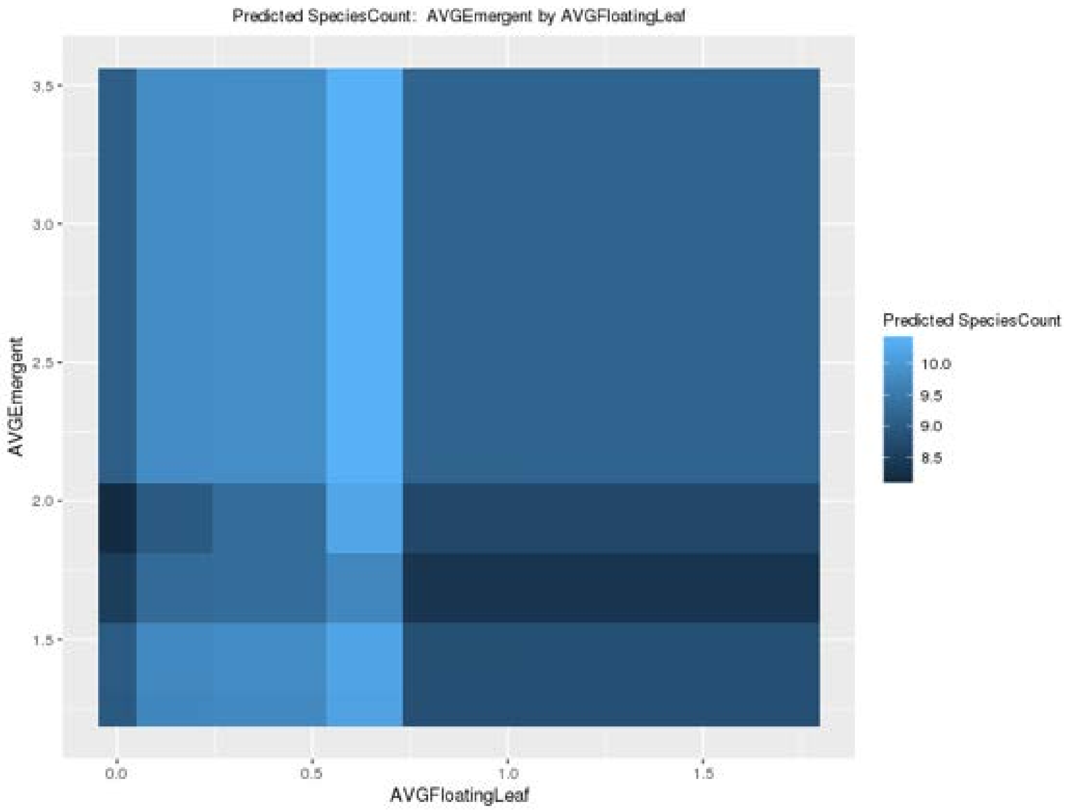


Figure 5.6: Heat-bar graph predicting count: AVG emergent by AVG floating leaf.

For the classification regression, the variable date, along with average floating leaf and emergent jumped up in importance from what it was in the first model using species count (Tables 5.4 & 5.5). There are other differences but for the most part they complement each other nicely.

Table 5.4: Random Forest Model 2: Fit and Importances for Variables Predicting Bird Class

Regression Fit	
Sample size	7369
Frequency of class labels	337, 2968, 1838, 362, 1864
Number of trees	5000
Forest terminal node size	15
Average number of terminal nodes	314.2634
Number of variables tried at each split	25
Total number of variables	28

(table continues)

Regression Fit	
Resampling used to grow trees	swr
Resample size used to grow trees	7369
Analysis	RF-C
Family	class
Splitting rule	gini *random*
Number of random split points	200
Normalized brier score	21.52
AUC	98.89
Error rate	0.1, 0.13, 0.11, 0.1, 0.15, 0.06
Importances	
Predictor	Importances
SpeciesCount	0.43919398
x.y.z.sect.pc1	0.125179406
Date.Season	0.096654818
AVGFloatingLeaf	0.008903568
DstToUrbBltENV	0.00786617
AVGEmergent	0.007422542
DeepestDepth	0.007158492
Baresoil	0.007027382
FencePost	0.006780997
DistToNearEphem	0.006601998
Perimeter	0.006278298
DstToNearWet	0.005840911
Site	0.005239609
People	0.004544118
DstToLake	0.004462459
AVGTerrestrial	0.004297219
AvgDstToNearWet	0.004040381
AVGSubmerged	0.004028481
Water	0.003916358
DistToCreek	0.002848848
UrbBltENV	0.002605858

(table continues)

Importances	
Predictor	Importances
Trees	0.002440347
SurfaceArea	0.002310054
NumberofWet	0.001571845
FishFeeder	0.001302874
Grass	0.00072269
AverageDeepestDepth	0.000396537
WindSpD	-0.005646173

Table 5.5: Statistics for Random Forest Model 2

Confusion Matrix and Statistics					
Prediction	DenseVeg Waders	DipDabblers	DivingBirds	MoistSoil	OpenWater Waders
DenseVegWaders	337	13	0	39	47
DipDabblers	0	2673	36	0	0
DivingBirds	0	128	1685	0	23
MoistSoil	0	24	59	323	37
OpenWaterWaders	0	130	58	0	1757
Overall Statistics					
Accuracy	0.9194				
95% CI	(0.9129, 0.9255)				
No information rate	0.4028				
P-value [Acc > NIR]	<0.00000000000000022				
Kappa	0.8876				
McNemer’s test P-value	N/A				
Statistics by Class					
	DenseVeg Waders	DipDabblers	DivingBirds	MoistSoil	OpenWater Waders
Sensitivity	1	0.9006	0.9168	0.89227	0.9426
Specificity	0.98592	0.9918	0.9727	0.98287	0.9658
Pos Pred Value	0.77294	0.9867	0.9178	0.72912	0.9033
Neg Pred Value	1	0.9367	0.9723	0.99437	0.9803
Prevalence	0.04573	0.4028	0.2494	0.04912	0.253

(table continues)

Statistics by Class					
	DenseVeg Waders	DipDabblers	DivingBirds	MoistSoil	OpenWater Waders
Detection Rate	0.04573	0.3627	0.2287	0.04383	0.2384
Detection Prevalence	0.05917	0.3676	0.2492	0.06012	0.2639
Balanced Accuracy	0.99296	0.9462	0.9447	0.93757	0.9542

The classification regression in Figures 5.7, 5.8, and 5.9 show the relationship between bird class, season, and site. Figures 5.7 and 5.8 show that the relationship between species count and dense vegetation waders are more prominent in the spring and summer, at HC-1, HL-1, HL-2, and SC-4 sites. Dip dabblers, present year long, decrease in numbers as winter arrives. At certain sites the open water waders increases above dip dabblers during the summer, and at SC-5 it is even high than dip dabblers before summer arrives. Diving birds increase in general as autumn is entering, and then into winter, being more accurately predicted than dip dabblers during winter at HL-1, LSR-2, and SC-5. Moist soil is the highest at HL-3 and HL-4, and in general observation sightings of the class slow down over winter.

In Figure 5.10, spring time suggest that there is a strong probability of predicting a large number of dip dabblers, which is the same in summer, with more fluctuations in autumn and winter. Dense vegetation waders are more active in spring and summer, and have a higher prediction than diving ducks or moist soil foragers. Diving ducks have a higher probability of prediction in autumn at low counts, but decrease as counts ‘theoretically’ go up.

The classification model shows a positive relationship with emergent vegetation with spring and summer seasons, with slight increase in power of prediction at intermediate levels, and then a drop and re-stabilization (Figure 5.11). Average floating leaf shows a positive relationship with dip dabble birds, and a slight bump in lower values with diving birds (Figure 5.12).

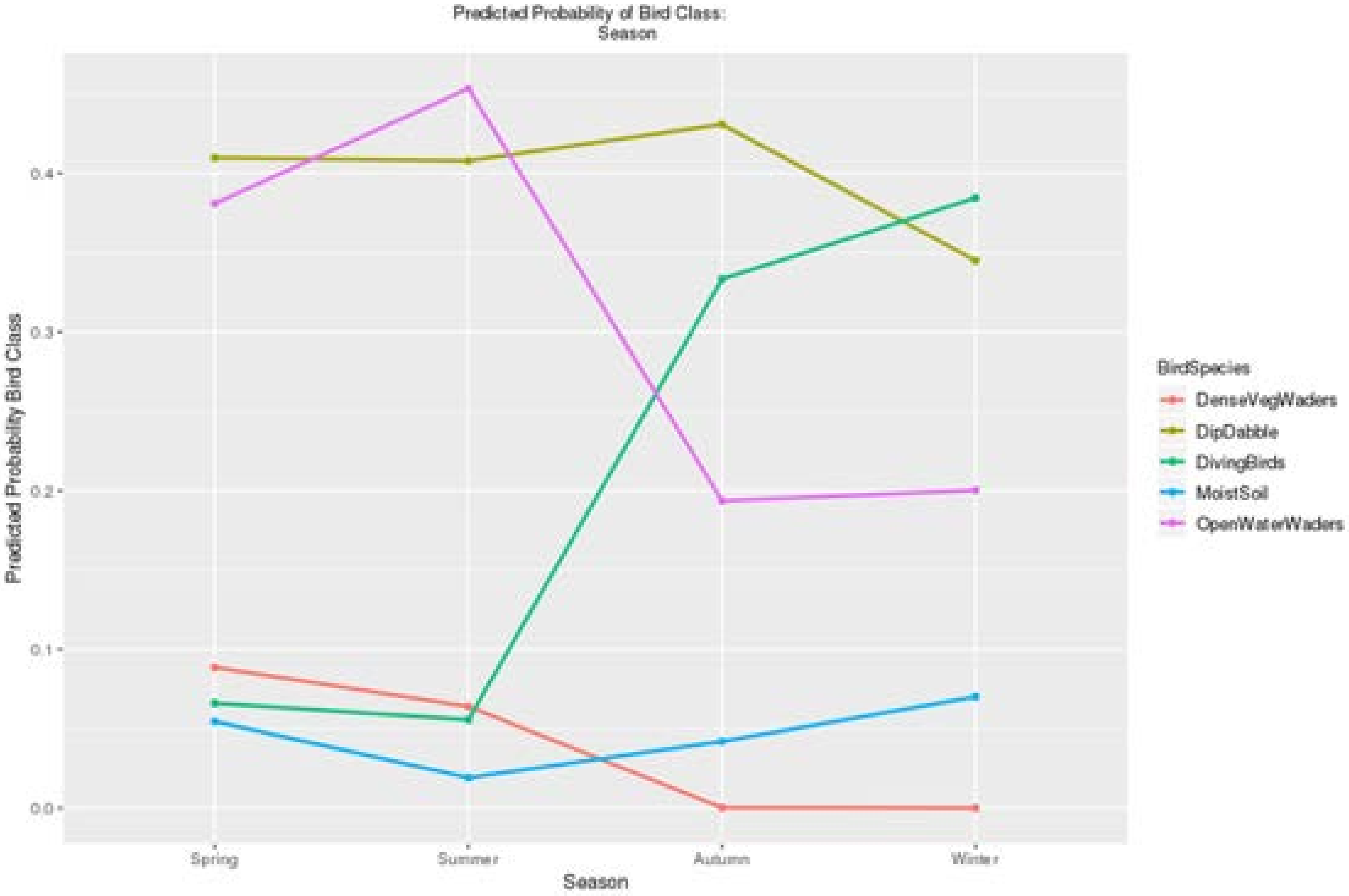


Figure 5.7: Predicted probability of bird class: season.

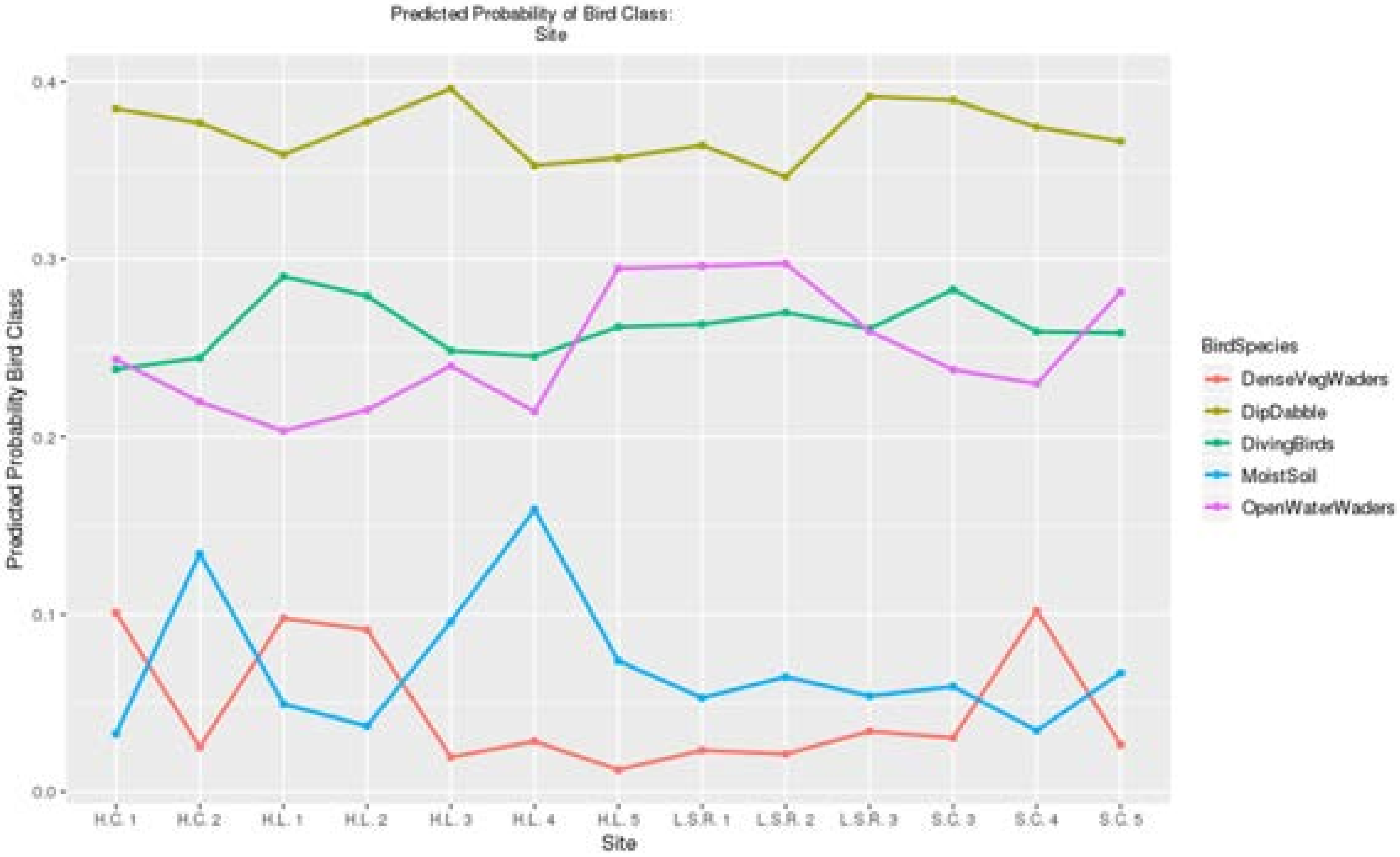


Figure 5.8: Predicted probability of bird class: site.

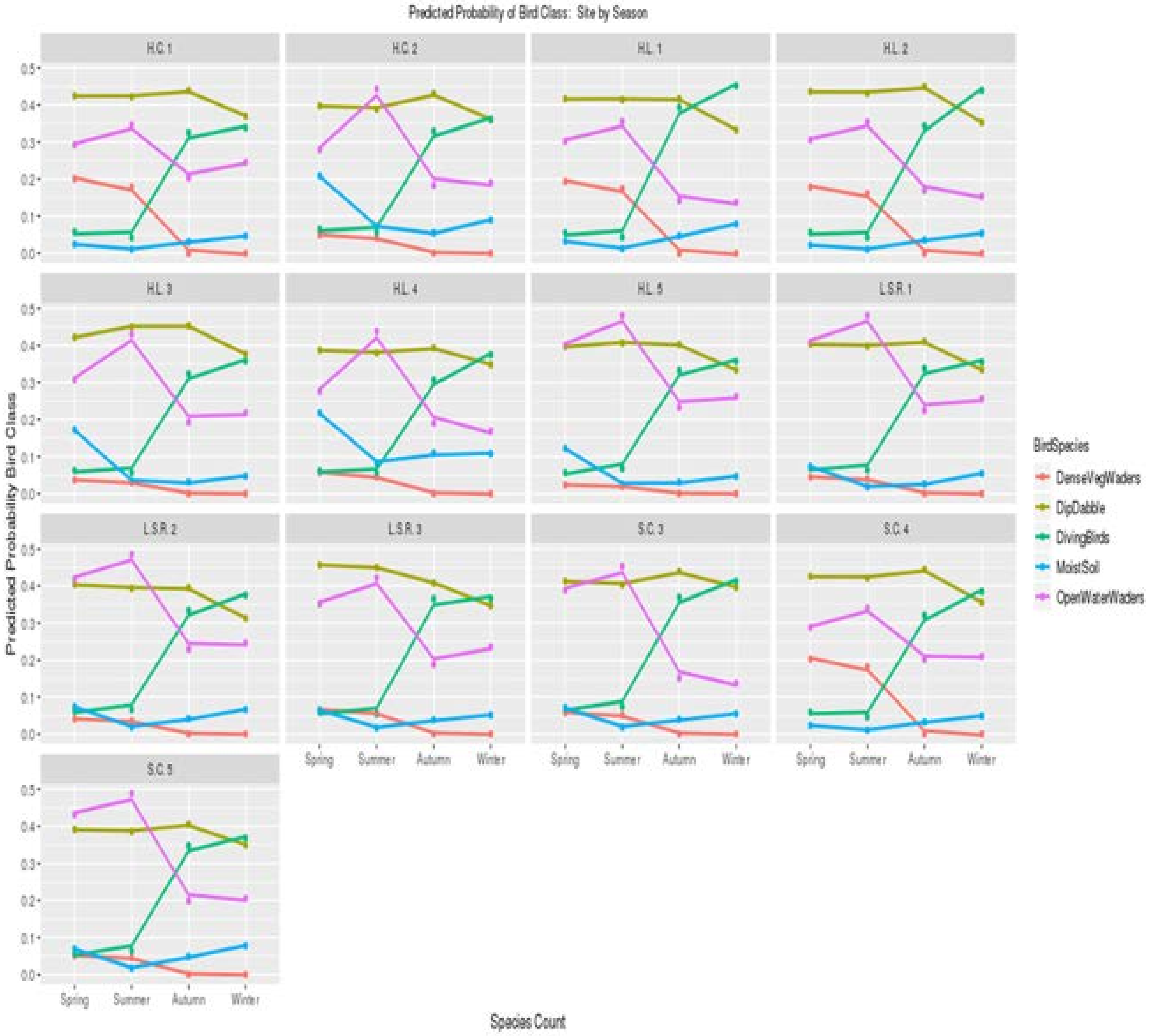


Figure 5.9: Predicted probability of bird class: site by season.

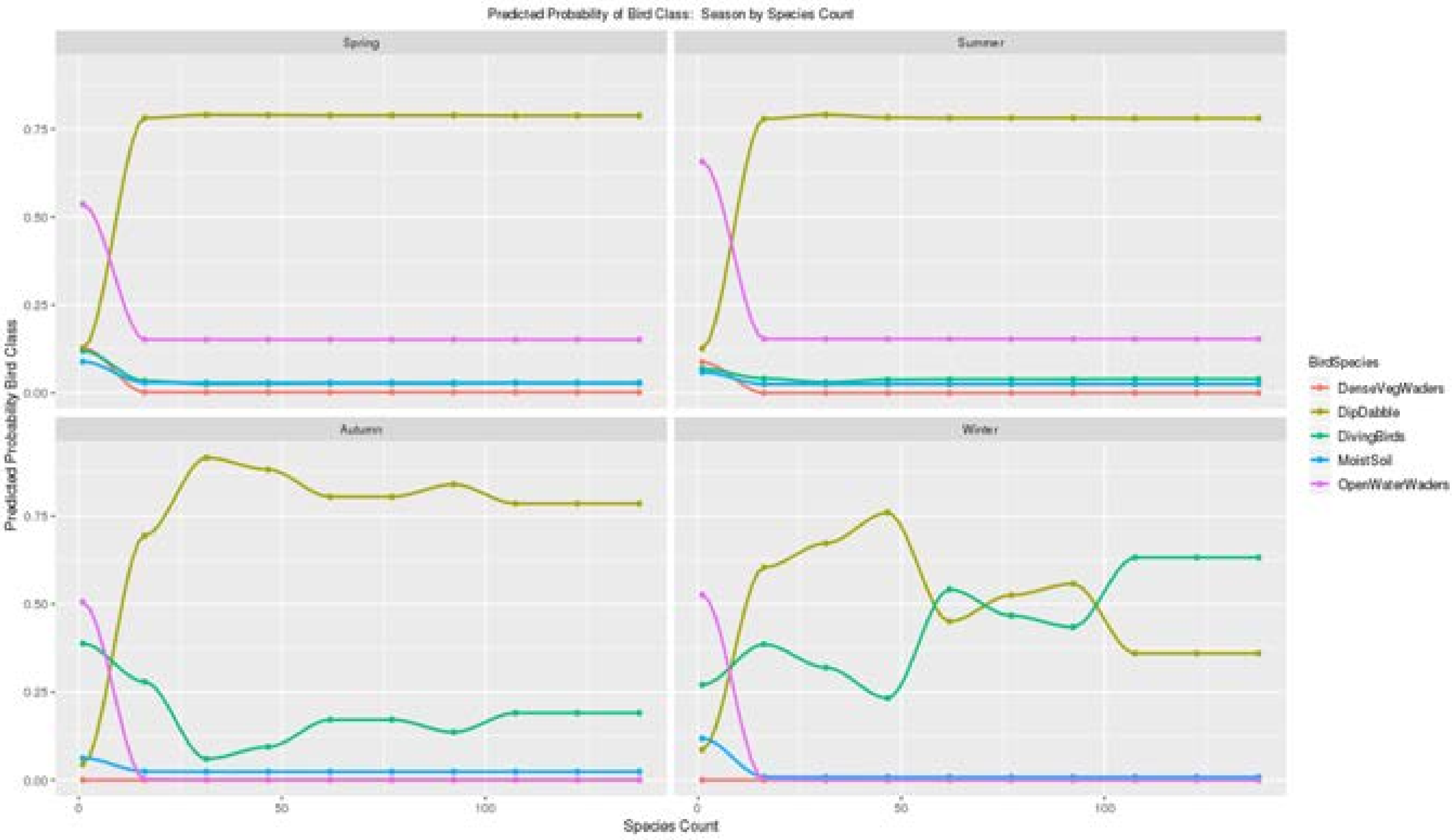


Figure 5.10: Predicted probability of bird class: season by species count.

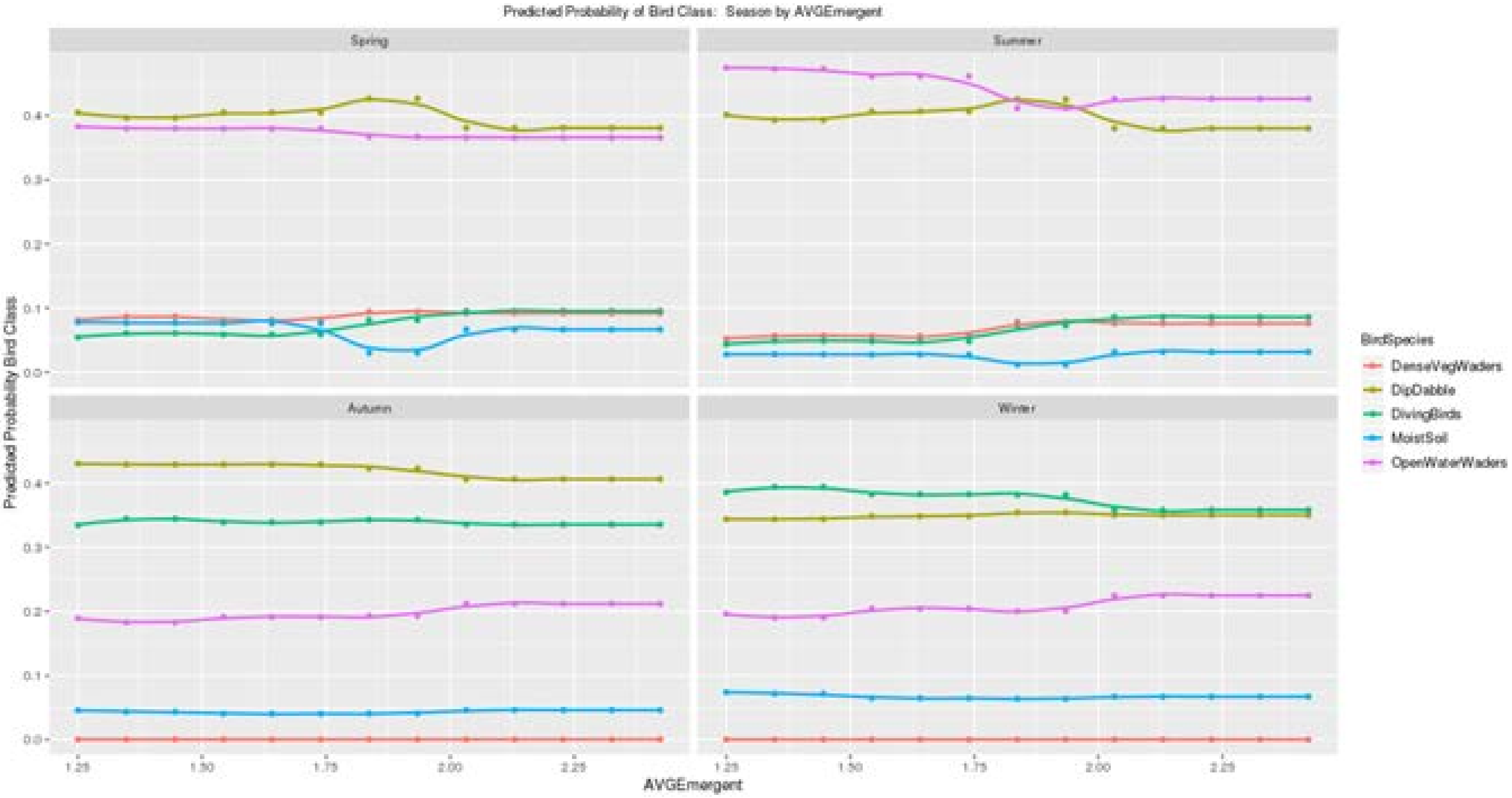


Figure 5.11: Predicted probability of bird class: season by AVG emergent.

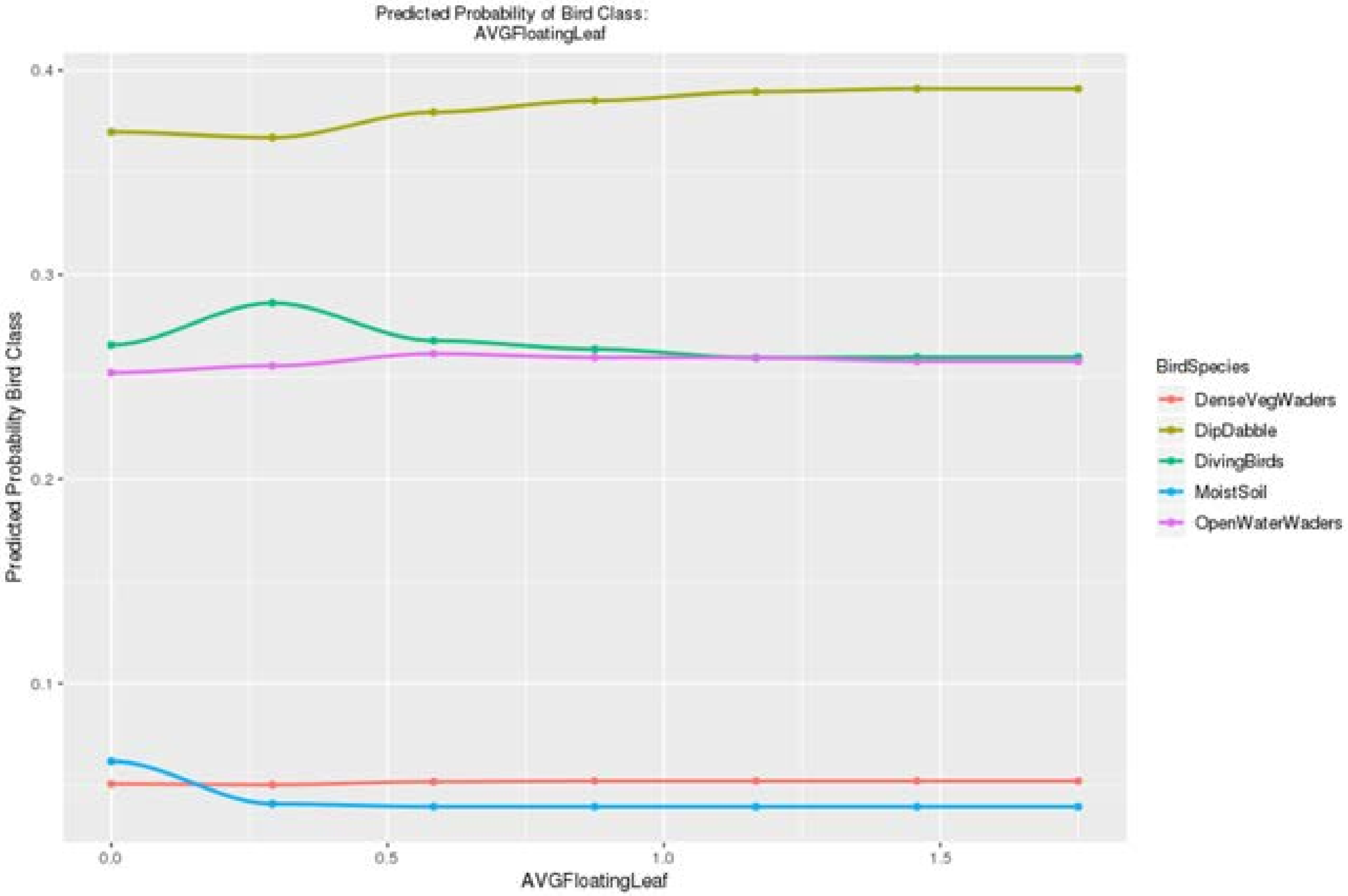


Figure 5.12: Predicted probability of bird class: season by AVG floating leaf.

The model also shows an interaction between diving birds, depth and site (Figures 5.13 & 5.14). Diving birds have a positive correlation with deepest depth, and moist soil with lower depths (Figure 5.13). Open water waders slightly increase with an increase in depth, and dense vegetation waders and dip dabblers have no correlation. Average distance to nearest wetland most interacts with dip dabblers and dense vegetation waders, primarily in spring and summer (Figure 5.15). The closer a wetland is to other wetlands, it increases the probability of observing those species.

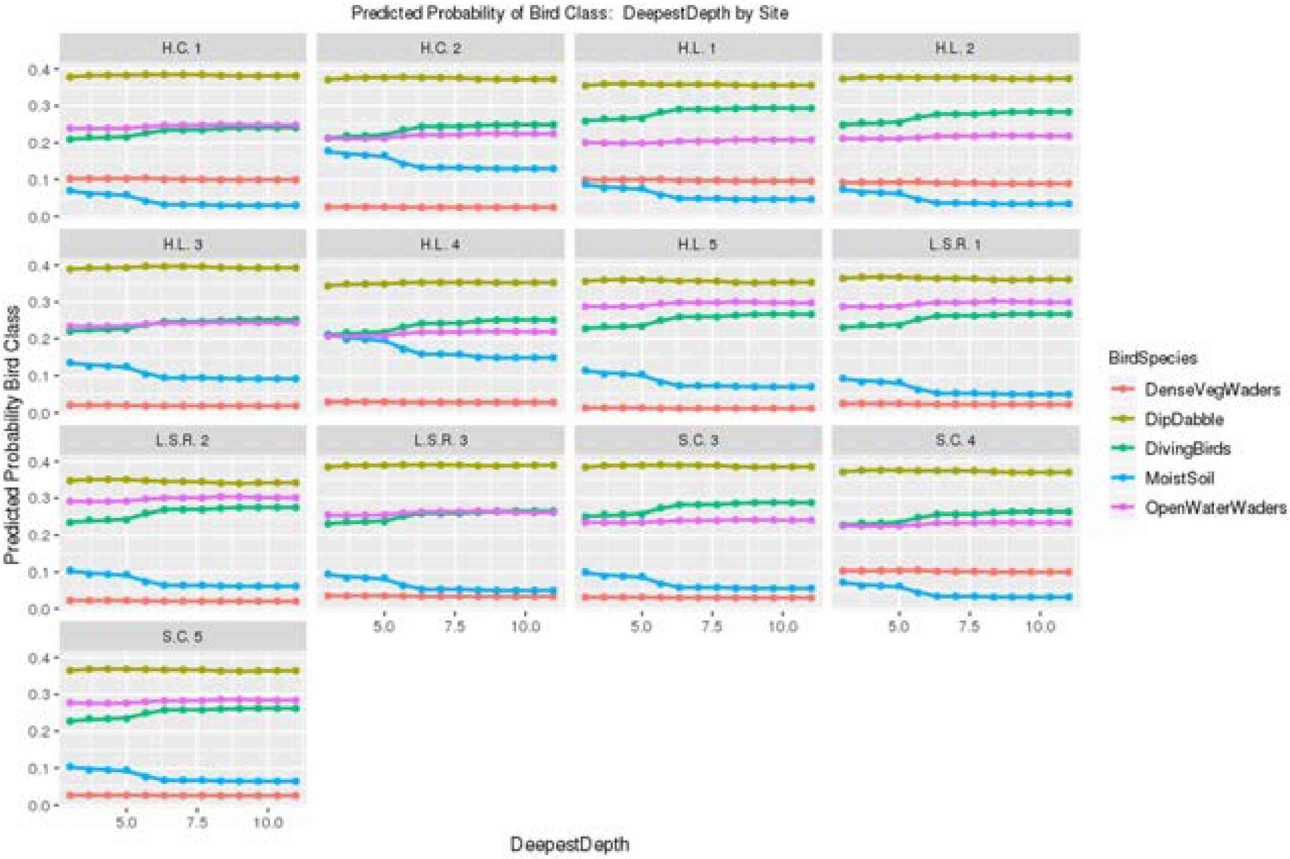


Figure 5.13: Predicted probability of bird class: deepest depth by site.

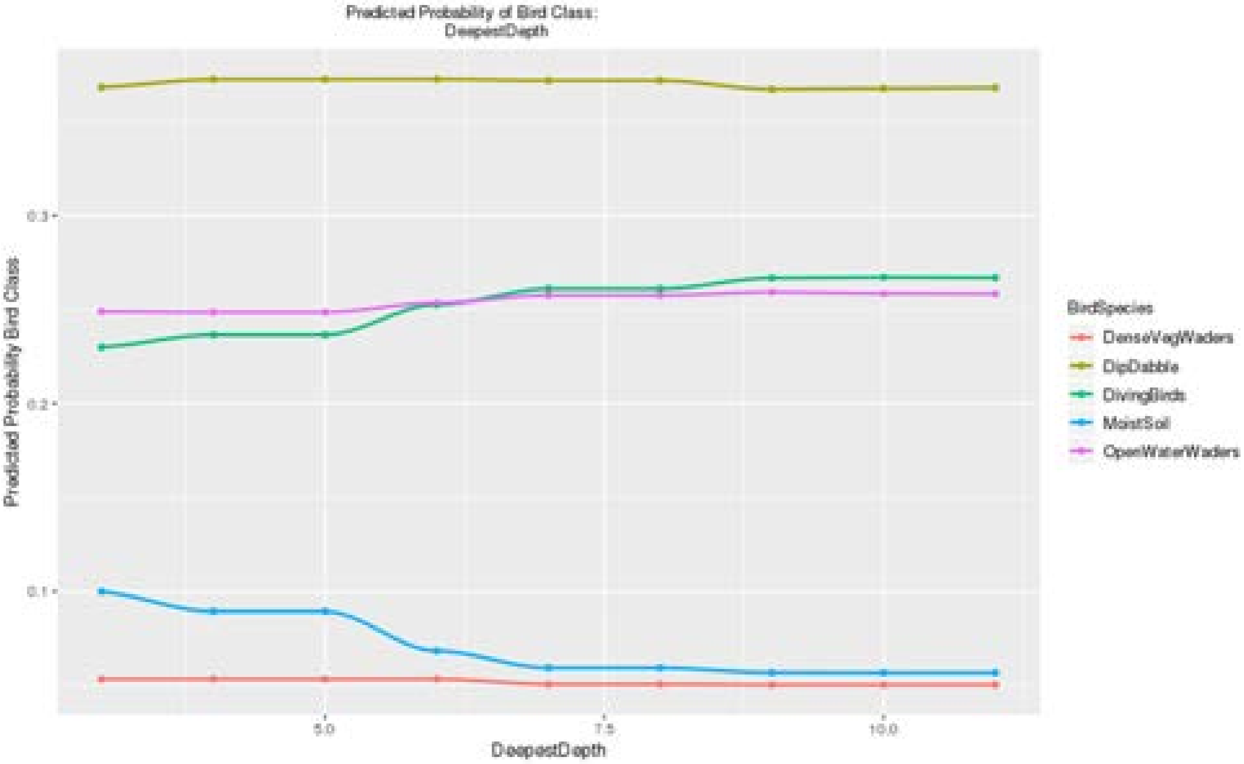


Figure 5.14: Predicted probability of bird class: deepest depth.

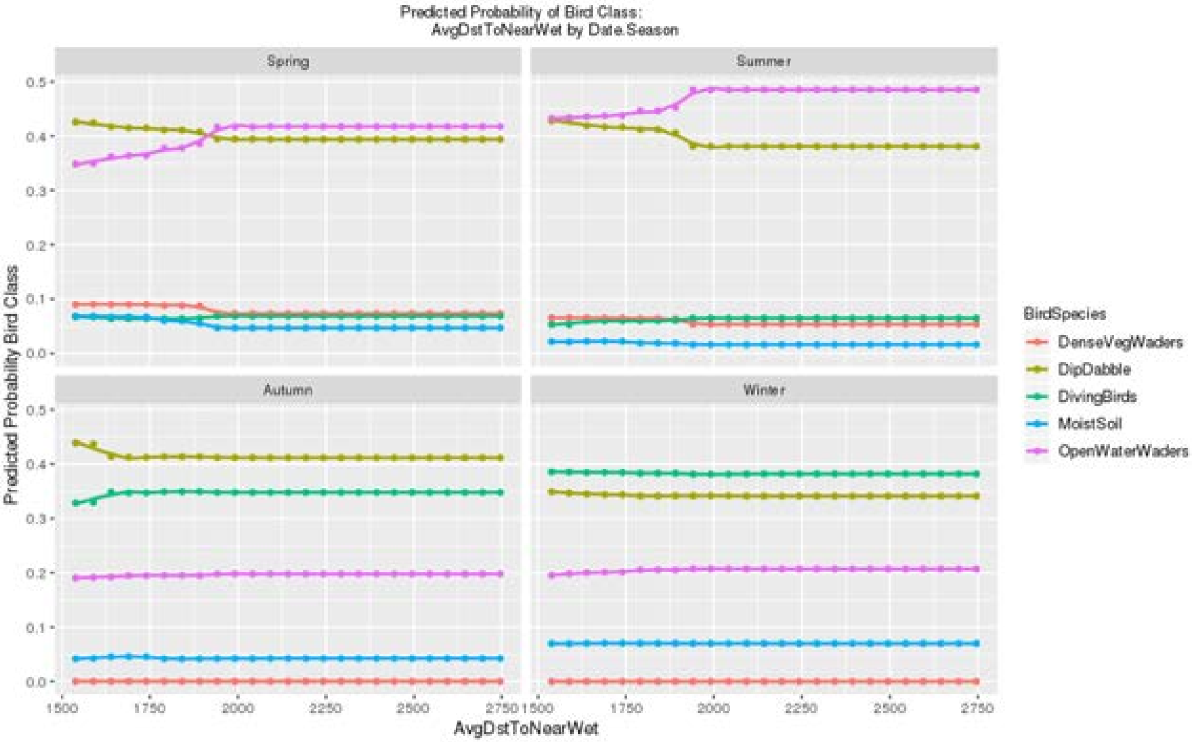


Figure 5.15: Predicted probability of bird class: average distance to nearest wetland by season.

Taking the importance values for the two random forest models, inferences and interaction effects were shown, gaining understanding about the interaction of site and time in relation to bird class and count, but the second question of this study is still yet to be answered straightforwardly, which is, what are the most significant wetland characteristics for attracting certain waterbird species? To help answer this empirically using statistical modeling, the MCA was essentially used to render those causes for (or characteristics of) a wetland to a table of importance values relative to waterbird class (Table 5.6).

Table 5.6: Multiple Correspondence Analysis of Predictions for Bird Class

	DenseVeg Waders	DipDabblers	DivingBirds	MoistSoil	OpenWater Waders
Site	+	-		-	-
x.y.sect.pc1	+	+		-	-
Date.Season	-	-	+		-
WindSpD			+		
Trees	+	+	-		-
Grass	-	+	-	+	+
Baresoil	+	-		+	-
Water	+	-	-		-
UrbBltENV			-		-
DstToNearWet	+		+		+
NumberofWet	-		-		
DstToUrbBltENV	-	+			+
DistToCreek	-	+	-	+	
DistToNearEphem		-	-		-
DstToLake	-	+		-	+
DeepestDepth	-	+		+	+
FencePost	+		-	-	+
FishFeeder			-		
AVGEmergent		+			
AVGSubmerged	+	-	+	-	

(table continues)

	DenseVeg Waders	DipDabblers	DivingBirds	MoistSoil	OpenWater Waders
AVGFloatingLeaf		+	+	+	
AVGTerrestrial	+	-	+		-
People					
SpeciesCountPred	-	-	+	+	-

Entries are the sign of the linear partial correlation coefficient for each bird class's predicted probability predicted by each predictor variable. Blank entries are deemed practically unimportant. A positive sign represents a positive relationship, and a negative sign represents a negative relationship. The variable SpeciesCountPred is the Random Forest Regression models predicted counts. All variables were optimally scaled using multiple correspondence analysis (MCA).

5.3 Multiple Correspondence Analysis

Keeping in mind that ecological data can be affected by endogenous, and exogenous effects, as well as inevitable sampling bias, results must be interpreted critically, and claims of direct causation should be met not only with theoretical understanding, but subjective experience. Interpreting the results of the MCA can be more straightforward than the interaction plots generated from the RF regressions, those do however reflect the results from the MCA, so the two can be used to substantiate one another.

The MCA has discovered that for dense vegetation waders, flooded terrestrial habitat, submerged vegetation, fence posts, distance to nearest wetland, water, bare soil, trees, and date and season are the most important circumstances. Number of wetlands within the buffer area did not seem to matter as much for dense vegetation waders as I would have thought it would, but then again I don't know the quality of those 'other' wetlands. This is perhaps the most surprising result as the HC-1 and SC-4 sites had high numbers of dense vegetation waders and both having 16 wetlands near them, which were amongst the highest amount when compared to the other sites. The MCA produced this because some green herons were seen at HL-1, which has the least amount of wetlands near it. This affects the results of the class at large, but not necessarily in a bad way, as it allows you to understand the data in a new way. Seeing that these creatures can fly, it shouldn’t be that surprising to see them at another nearby local wetland. After all, it was only one count of one species of dense vegetation waders that affected the MCA results. Baresoil is important because it is an ecosystem for certain insects that dense vegetation waders could eat, as I observed at HL-1 with a green heron.

Dip dabblers are related to x.y.pc1, trees, grass, and distance to urban built environment, distance to creek, distance to lake, deepest depth, emergent vegetation, and floating leaf. This makes since as dip dabblers are distributed across many sites, but with section in a pond it does become important, such as in the case of trees near the shoreline, or aquatic plants that they can feed on. Dip dabblers favor deeper depth and ponds that are larger, and seem to be very comfortable within an urban environment, which comes to reason since many of the counts come from mallards who stay here year around and were observed to visit HL sites a good amount. The year around aspect of mallards would easily throw off the sensitivity to date when compared to other migrating dip dabblers like American widgeons.

Diving birds have significance with date, wind speed, distance to near ephemeral wetland, submerged, floating leaf, average terrestrial, and species count. Diving birds are the best predicted by date, and with an increase in wind speed. It seems more possible that it is just a coincidence of poor and windy weather conditions accompanying the come of winter. Species count being important points to how when they arrive, they arrive in large numbers, or counts. Distance to nearest wetlands makes some sense, considering they were often seen at ponds with close distances to each other. Those sites that have the lowest number of wetlands near them are the LSR sites, which had canvasback and bufflehead, as well as grebes; therefore, the results of the MCA coincide with what was observed geographically.

Moist soil has grass, bare soil, and distance to creek, deepest depth, average floating leaf, and species count associated with it. In this instance of species counts, the moist soil foragers makes sense because they were always found in similar numbers. Often seen near areas with both mud and turf grass, like at HL-4, it is not surprising that both variables help predict moist soil classes. Wilson snipe, and killdeer were sighted in muddy areas. Deepest depth is perhaps misleading, as I’m not sure a deeper depth would help predict the bird class in my observation, they were most commonly seen at shallow ponds.

Open water waders were seen distributed in fairly moderate quantities all throughout the urban area over all ponds, mostly in HC and SC sites, but with condensed intermediary counts consistently. Associated with grass, deep depth, and urban areas, the open water waders enjoy scenes all over the urban environment.

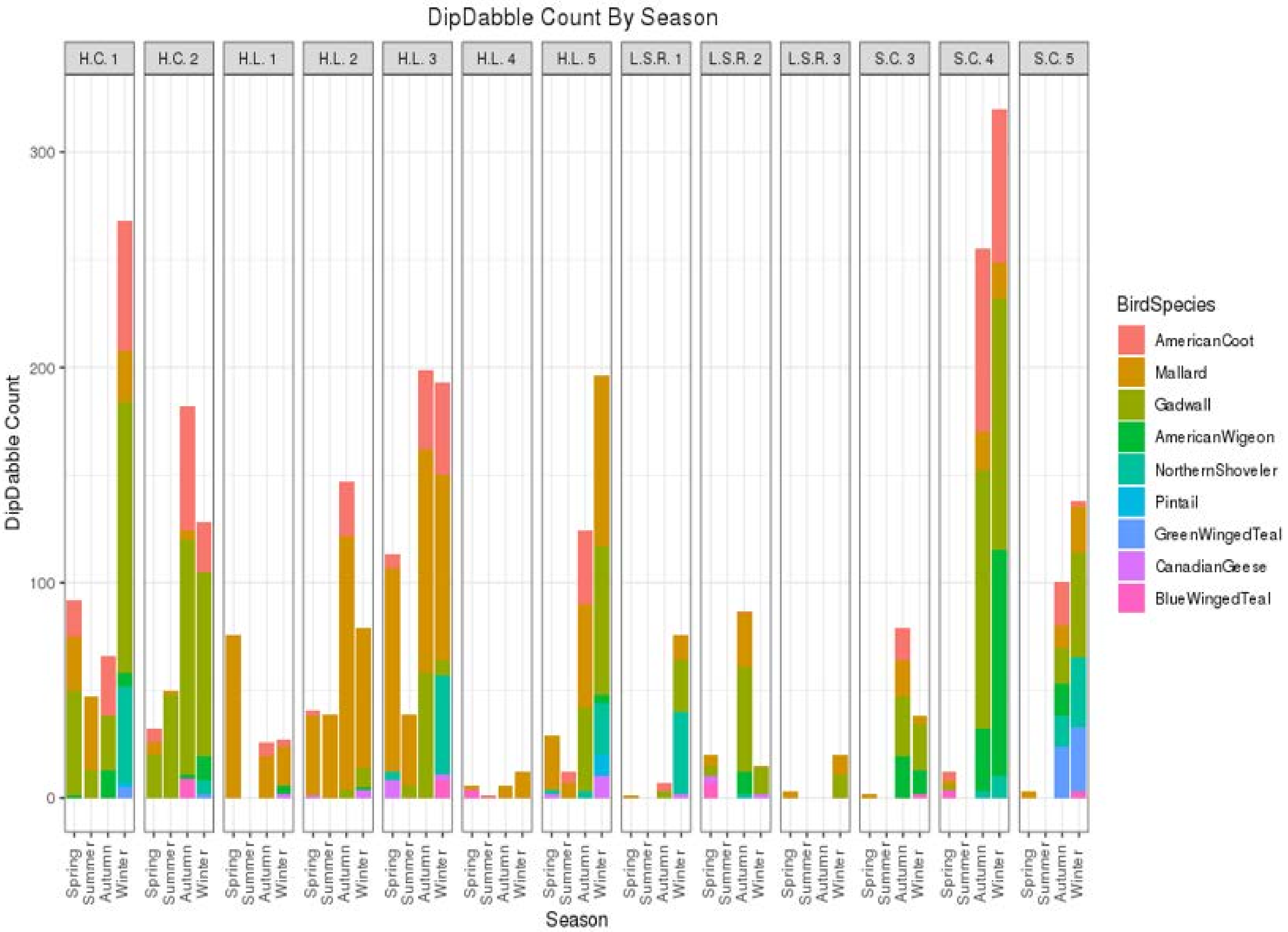


Figure 5.16: Observed dip dabble species by season by site.

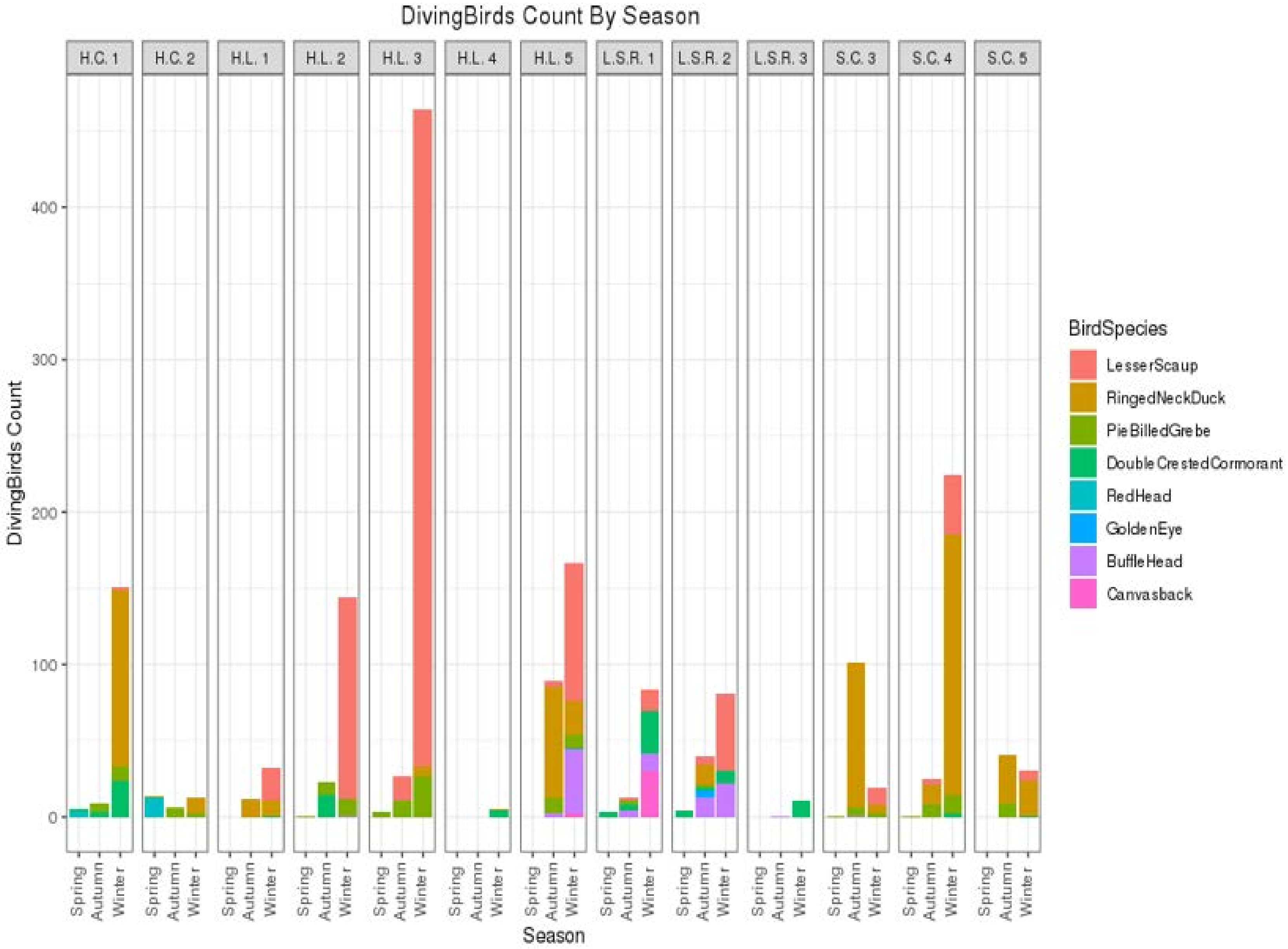


Figure 5.17: Observed diving bird species by season by site.

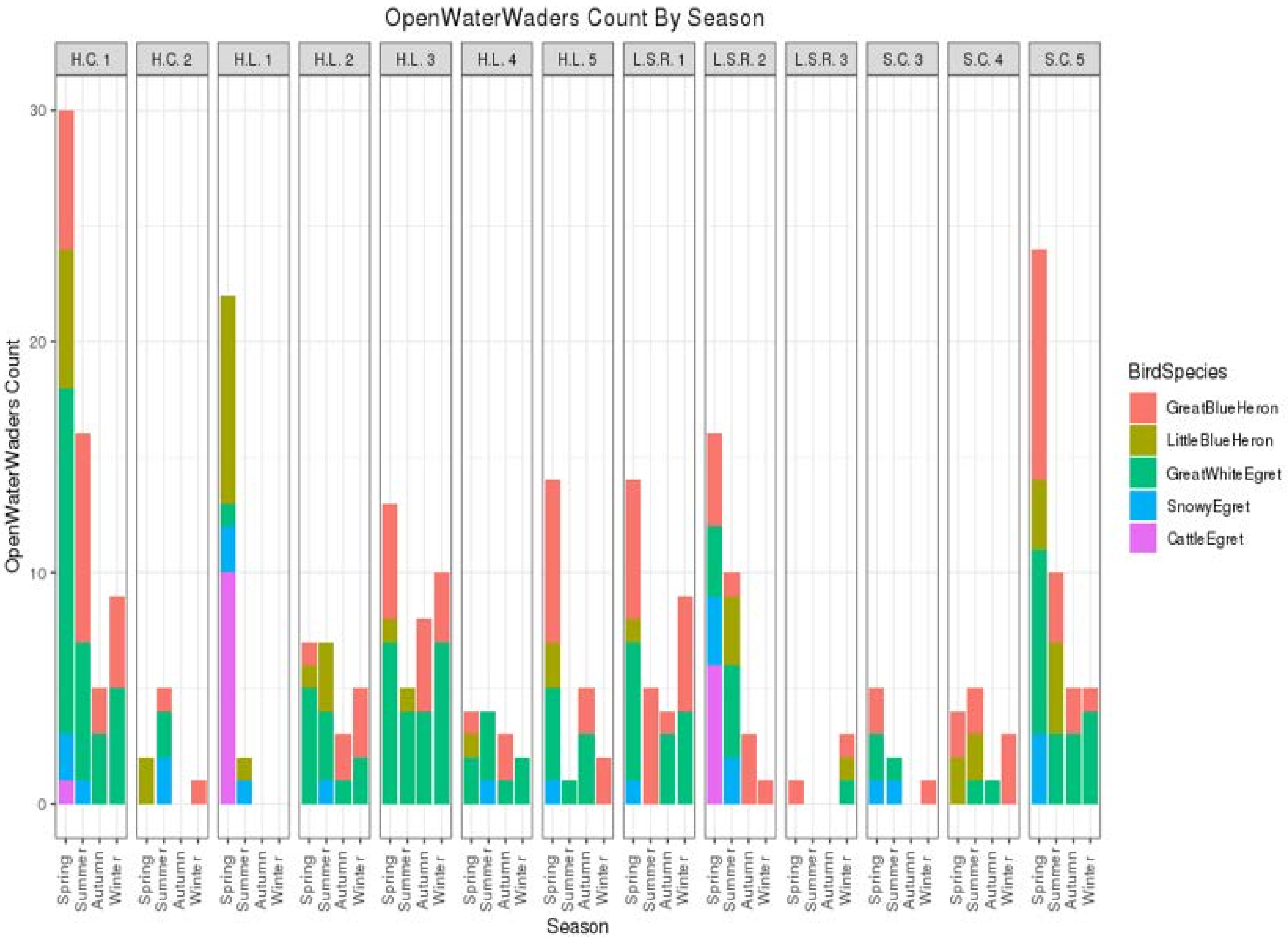


Figure 5.18: Observed open water wader species by site by season.

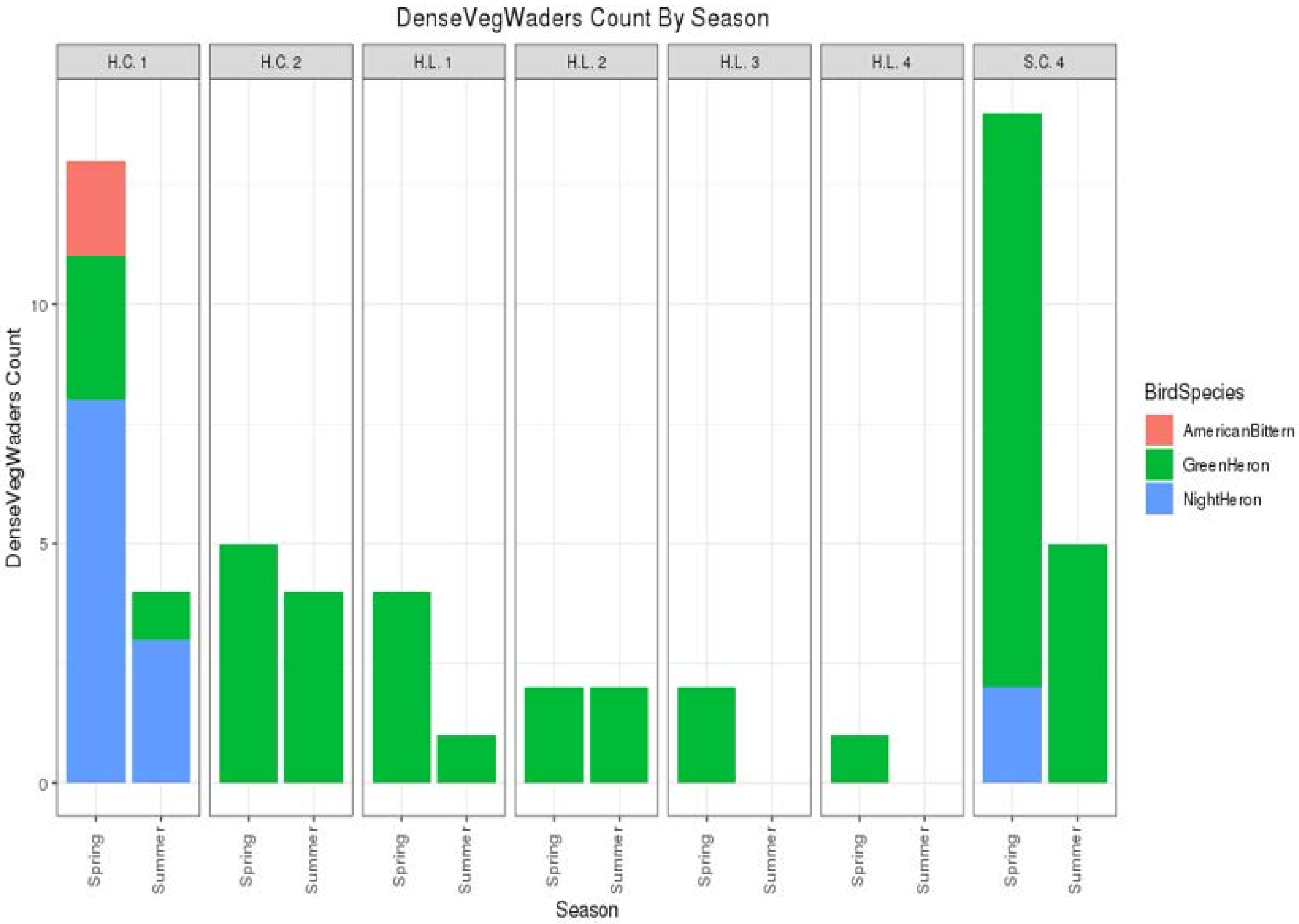


Figure 5.19: Observed dense vegetation wader species by site by season.

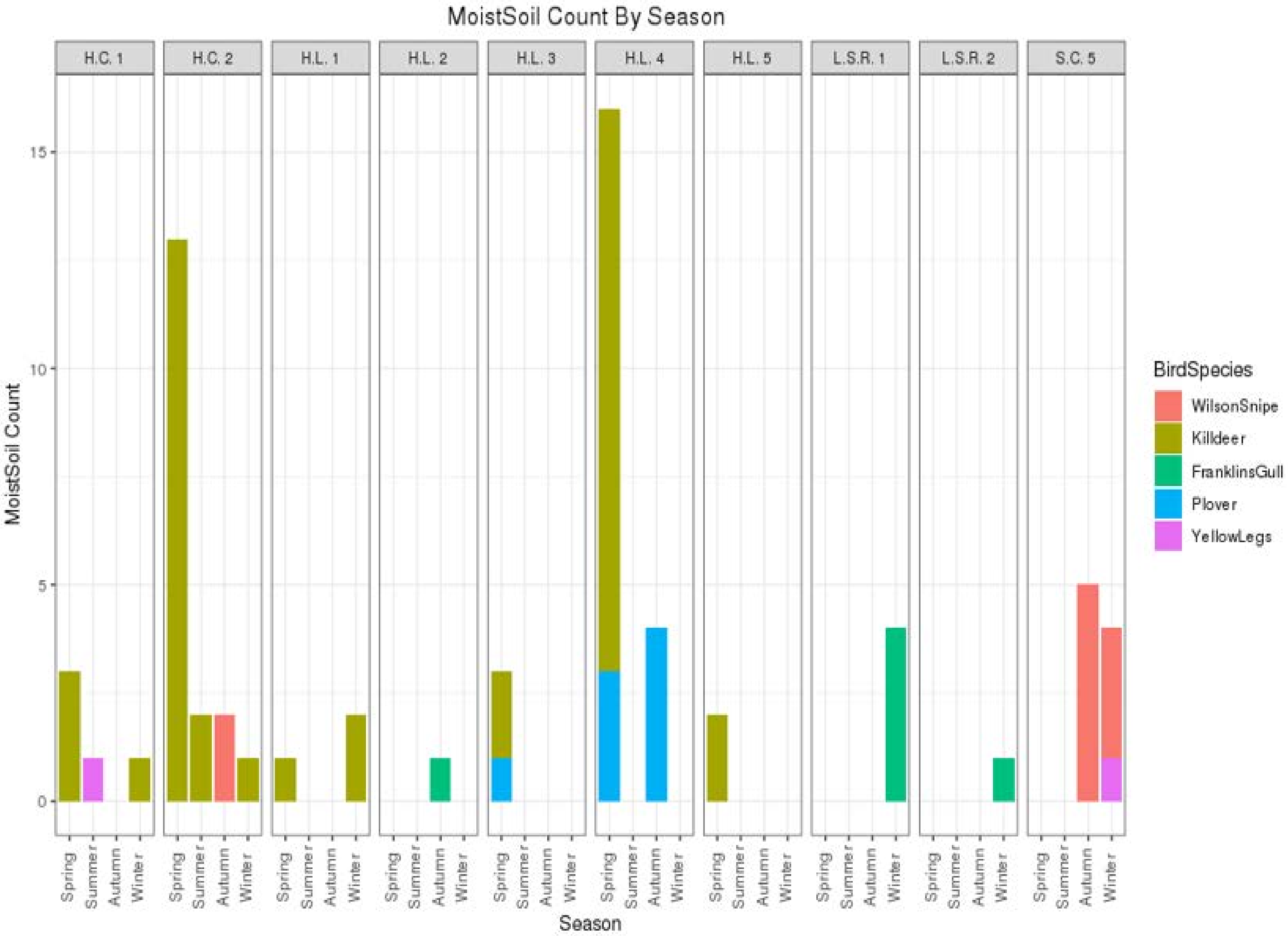


Figure 5.20: Observed moist soil species by site by season.

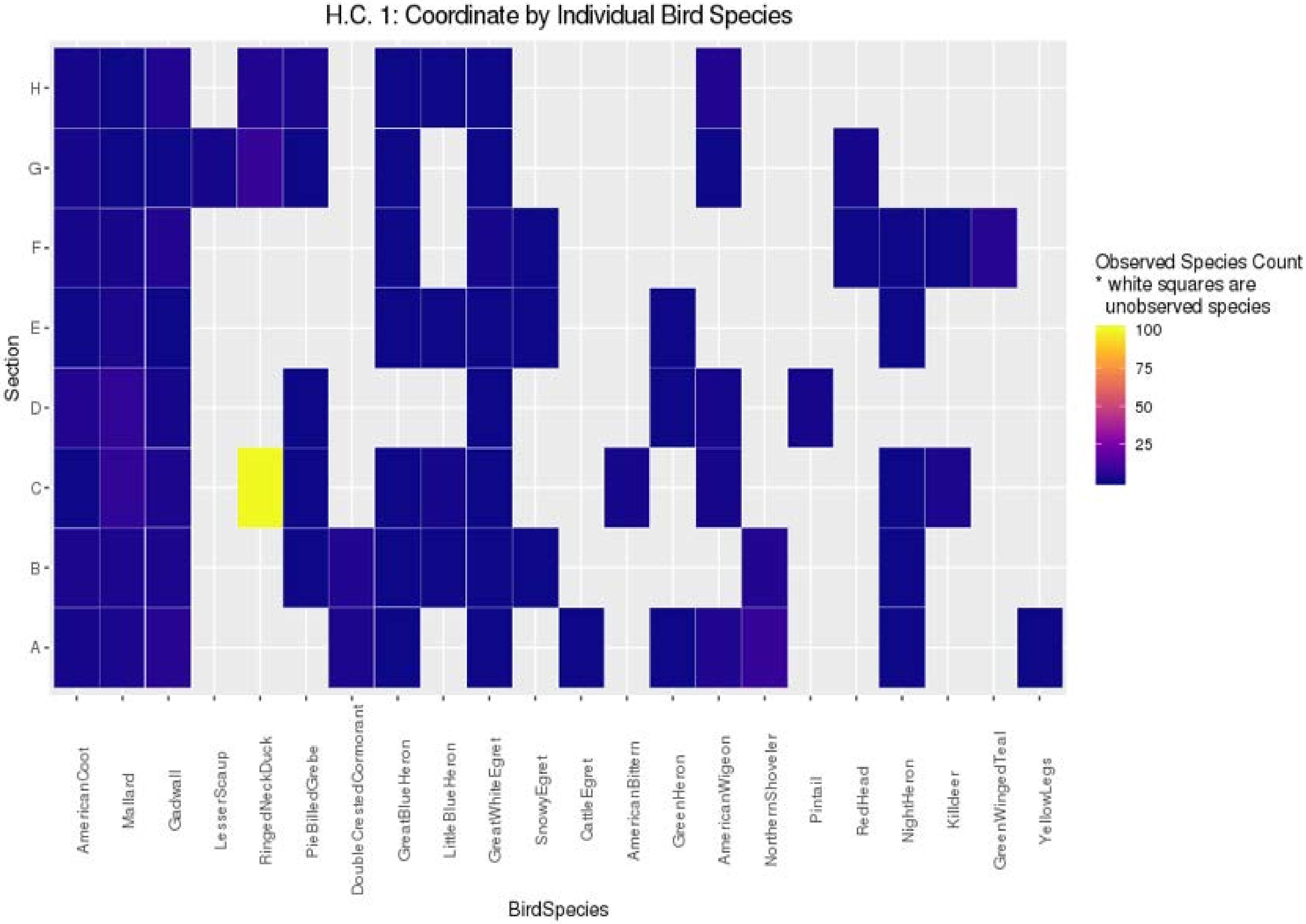


Figure 5.21: Heat-bar graph of species by section, HC-1.

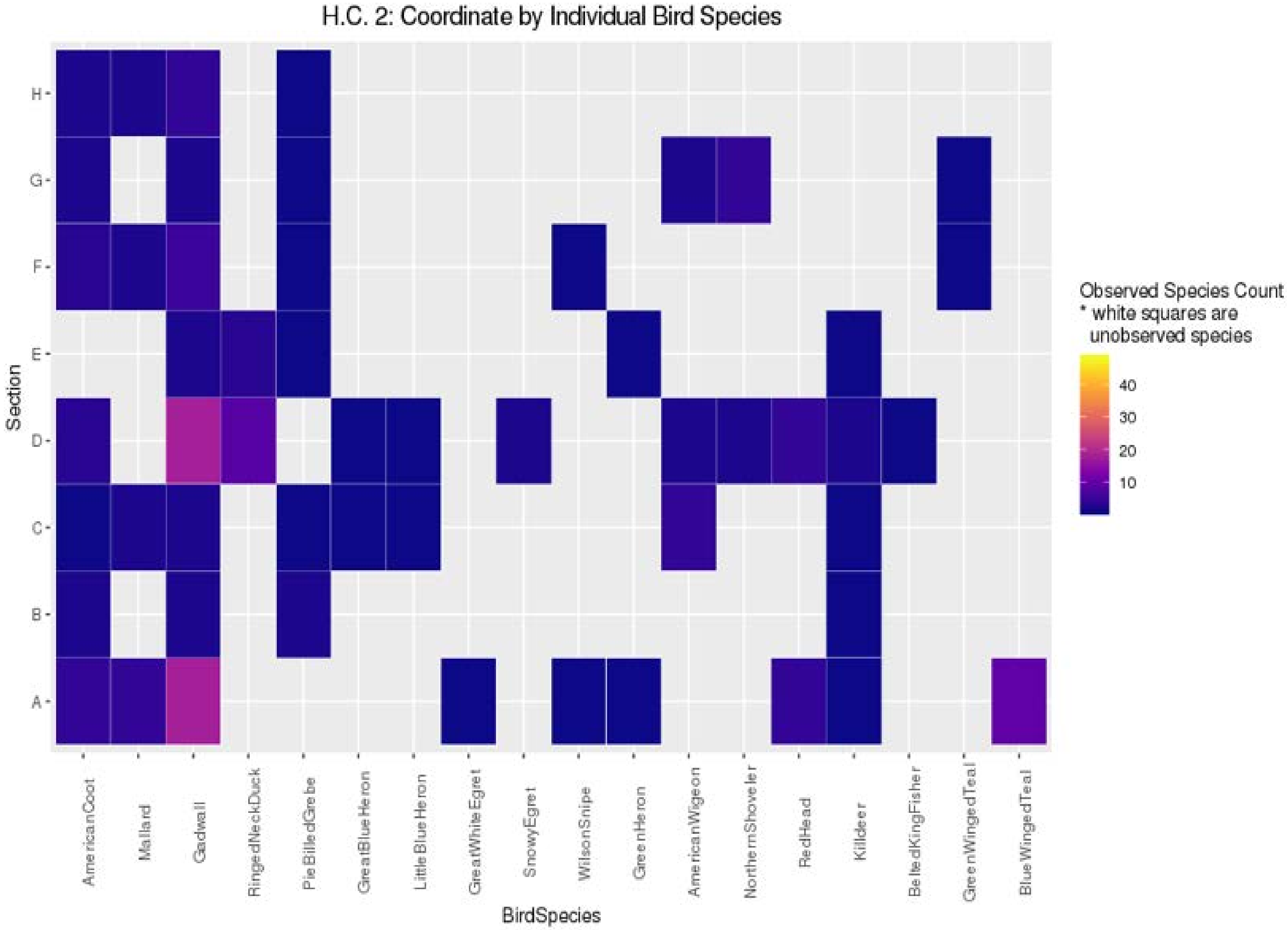


Figure 5.22: Heat-bar graph of species by section, HC-2.

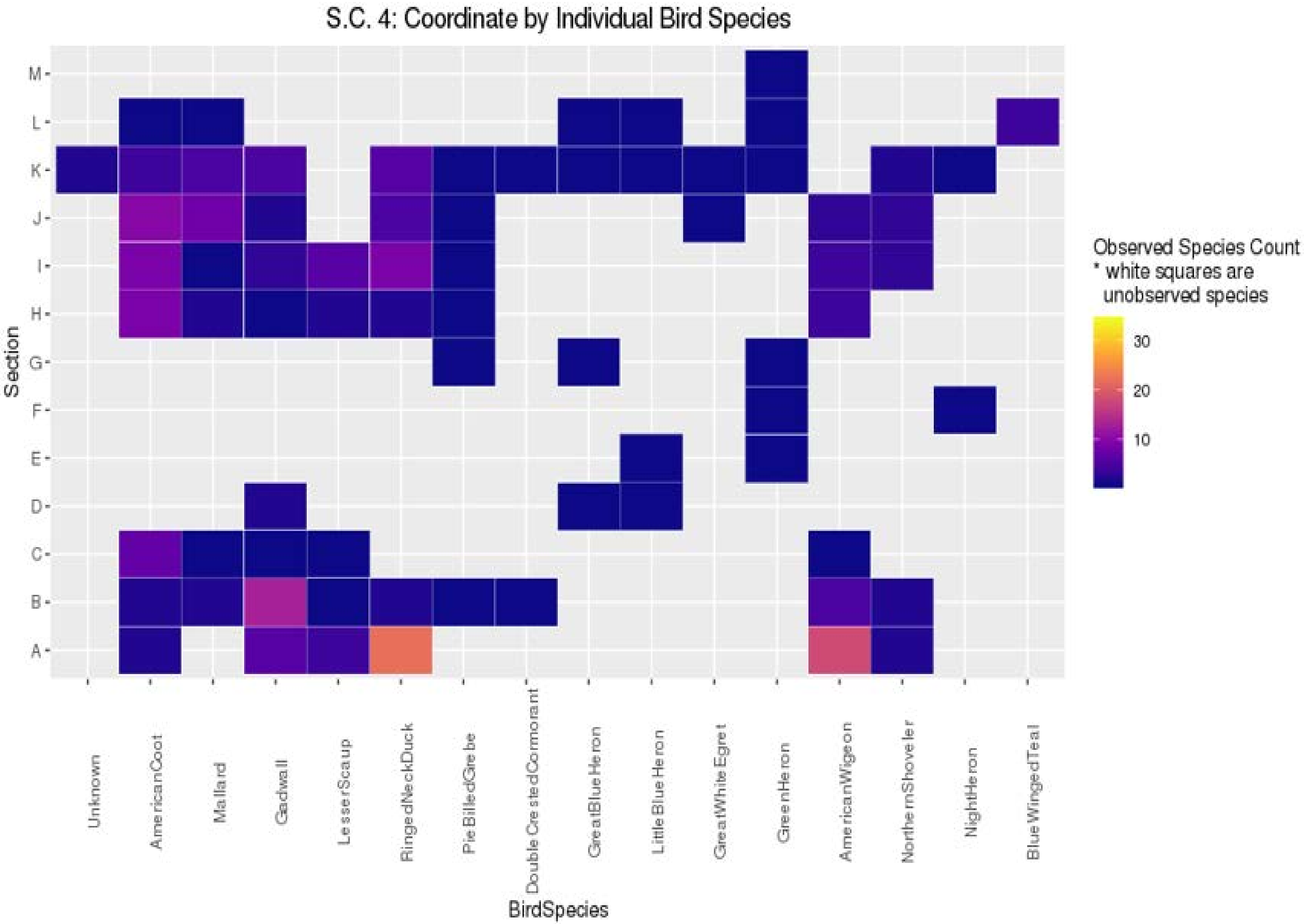


Figure 5.23: Heat-bar graph of species by section, SC-4.

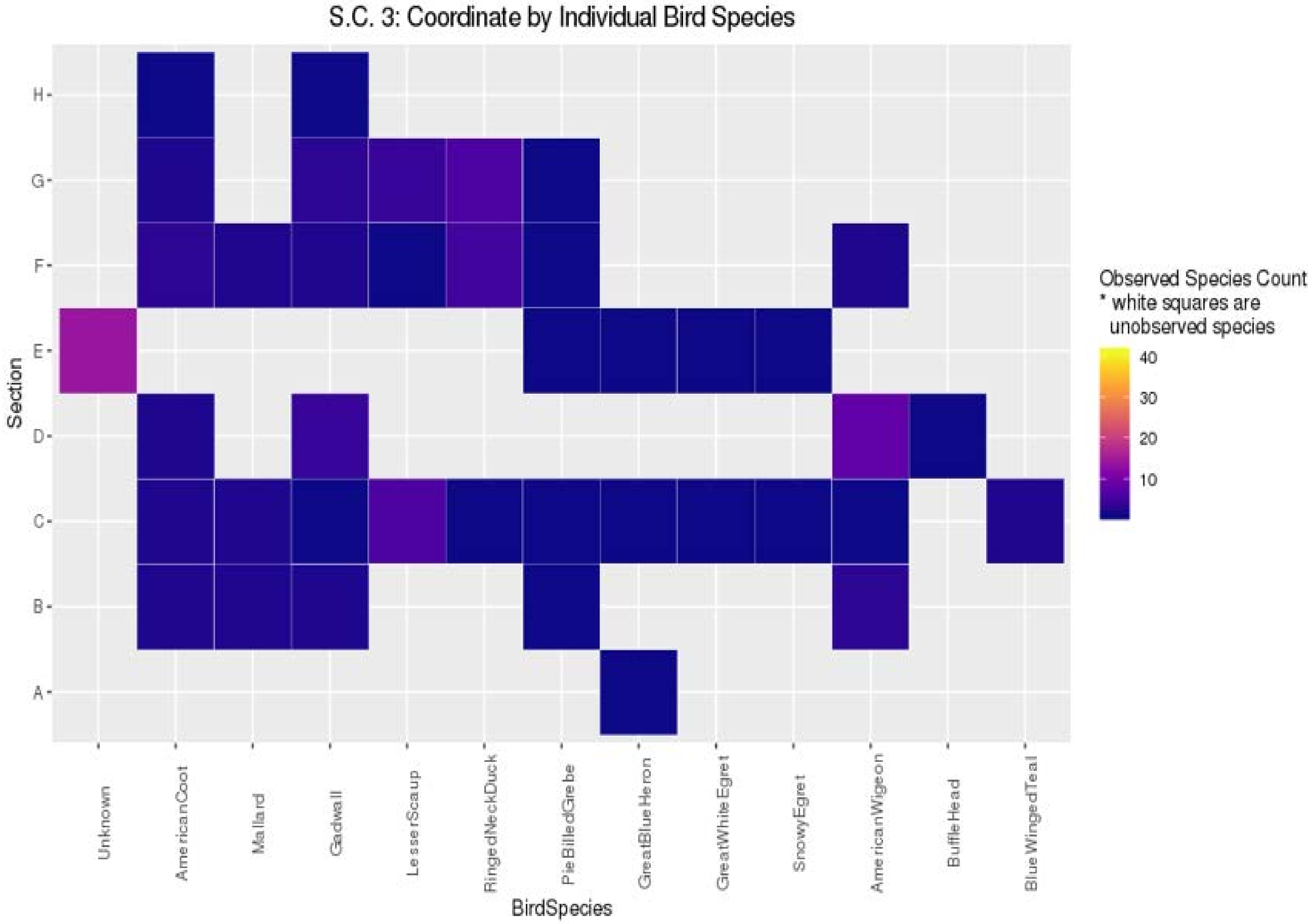


Figure 5.24: Heat-bar graph of species by section, SC-3.

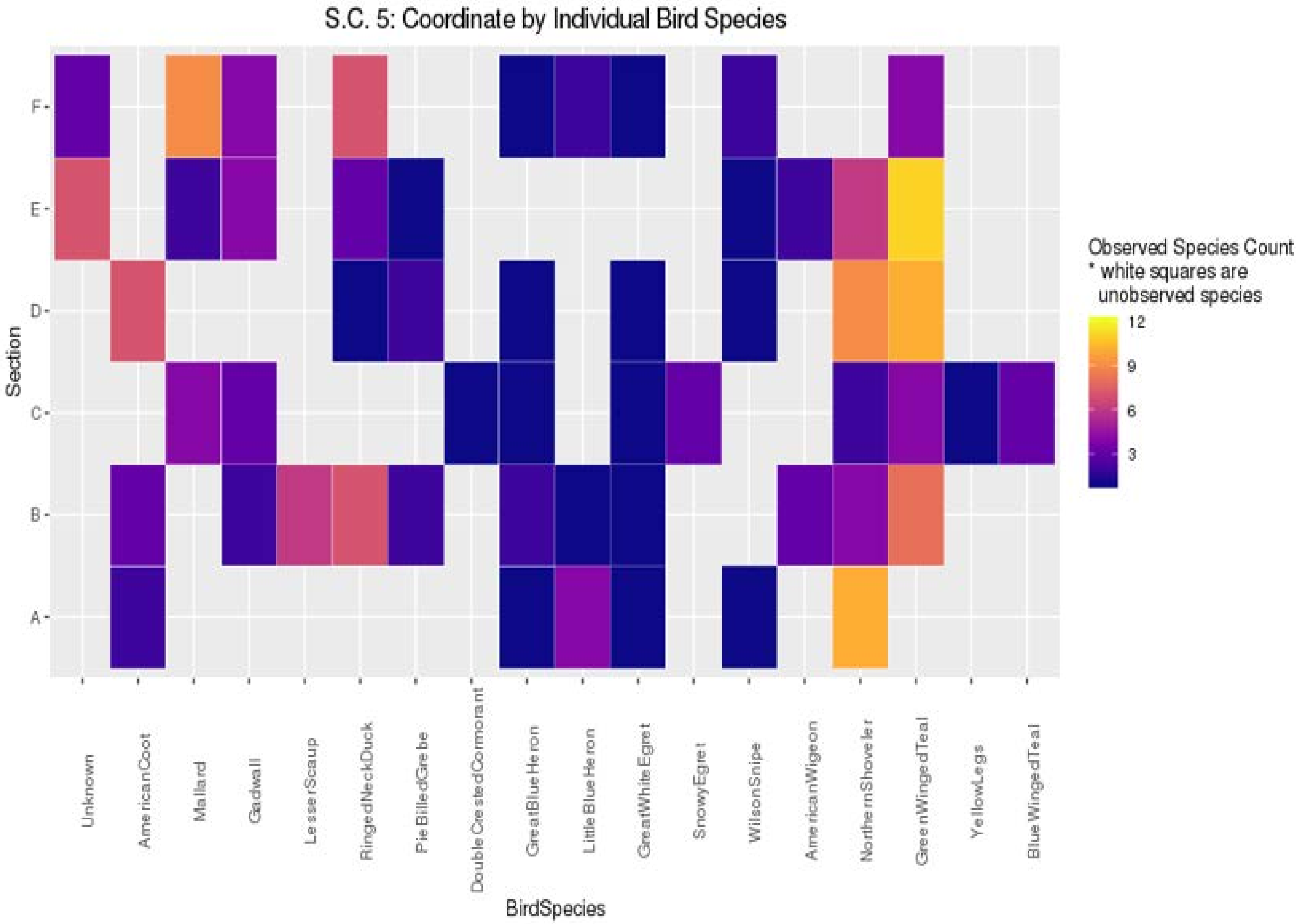


Figure 5.25: Heat-bar graph of species by section, SC-5.

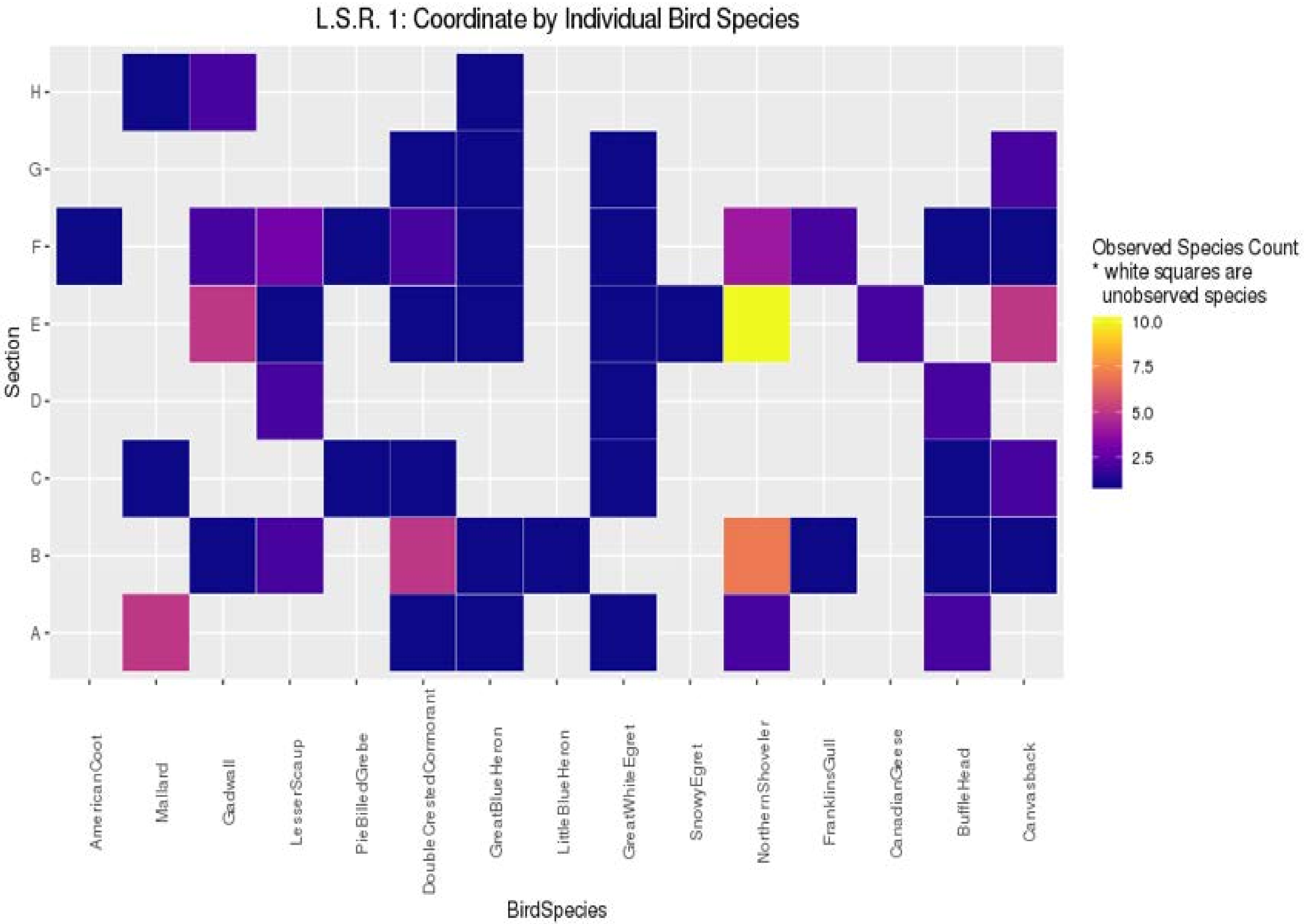


Figure 5.26: Heat-bar graph of species by section, LSR-1.

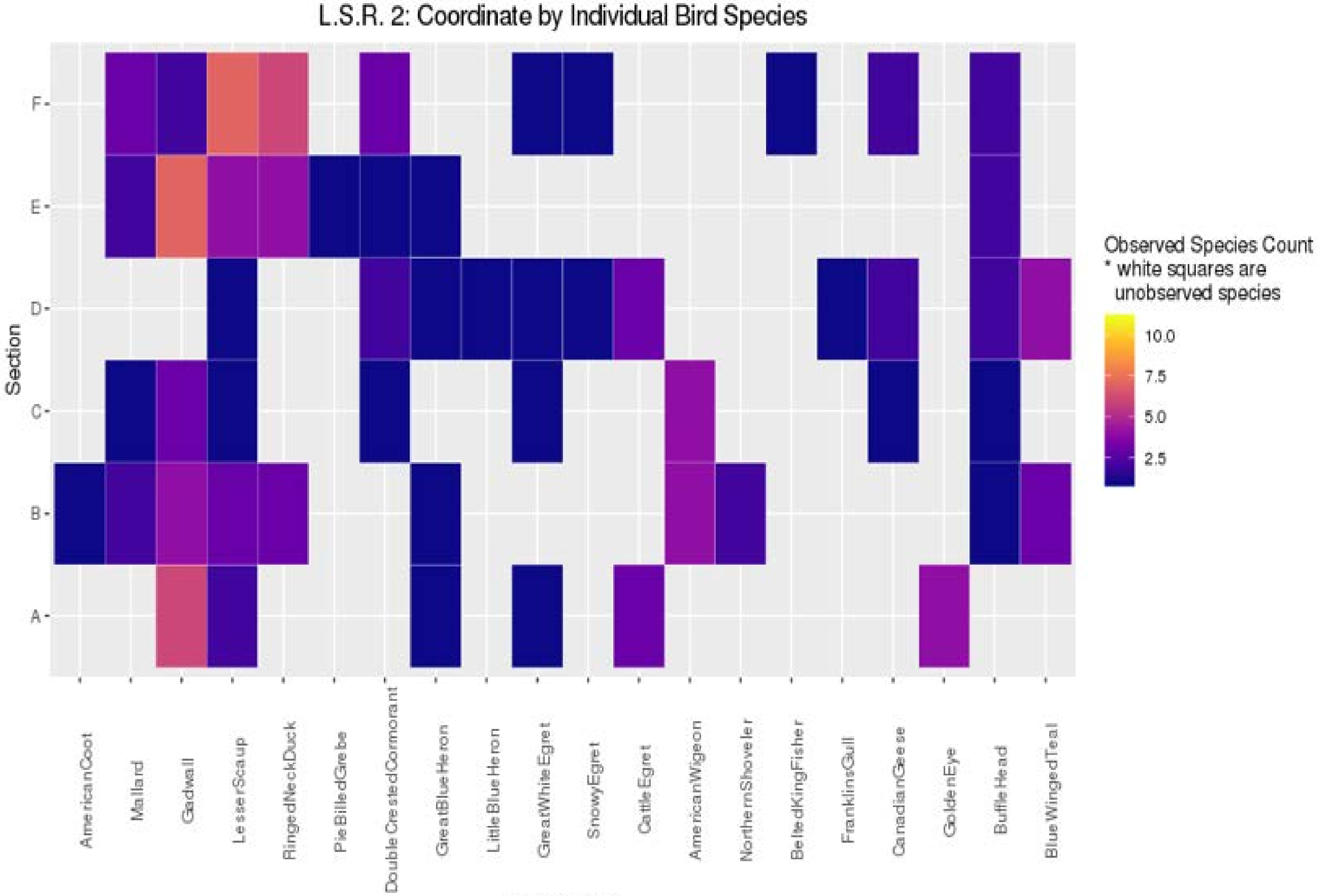


Figure 5.27: Heat-bar graph of species by section, LSR-2.

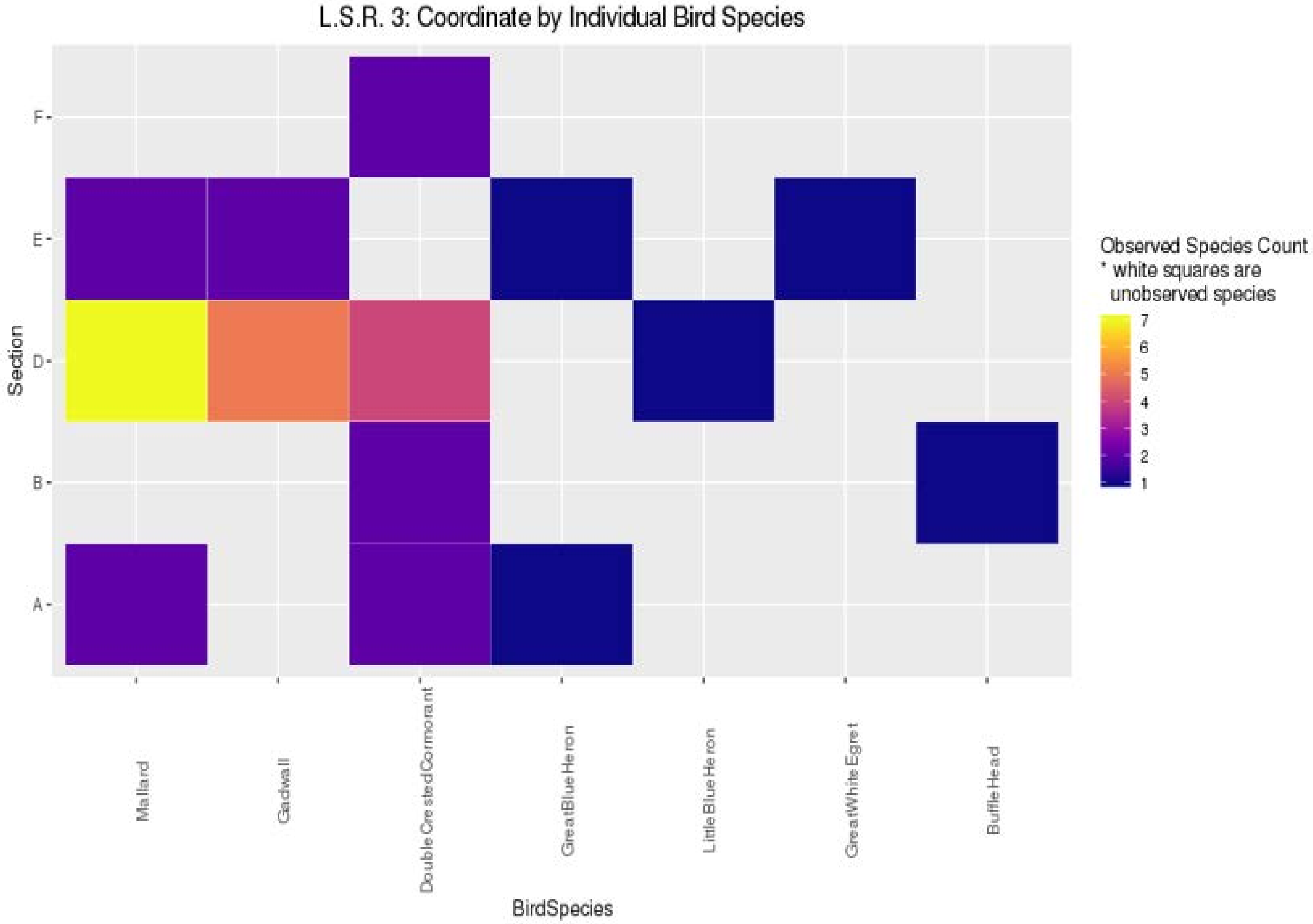


Figure 5.28: Heat-bar graph of species by section, LSR-3.

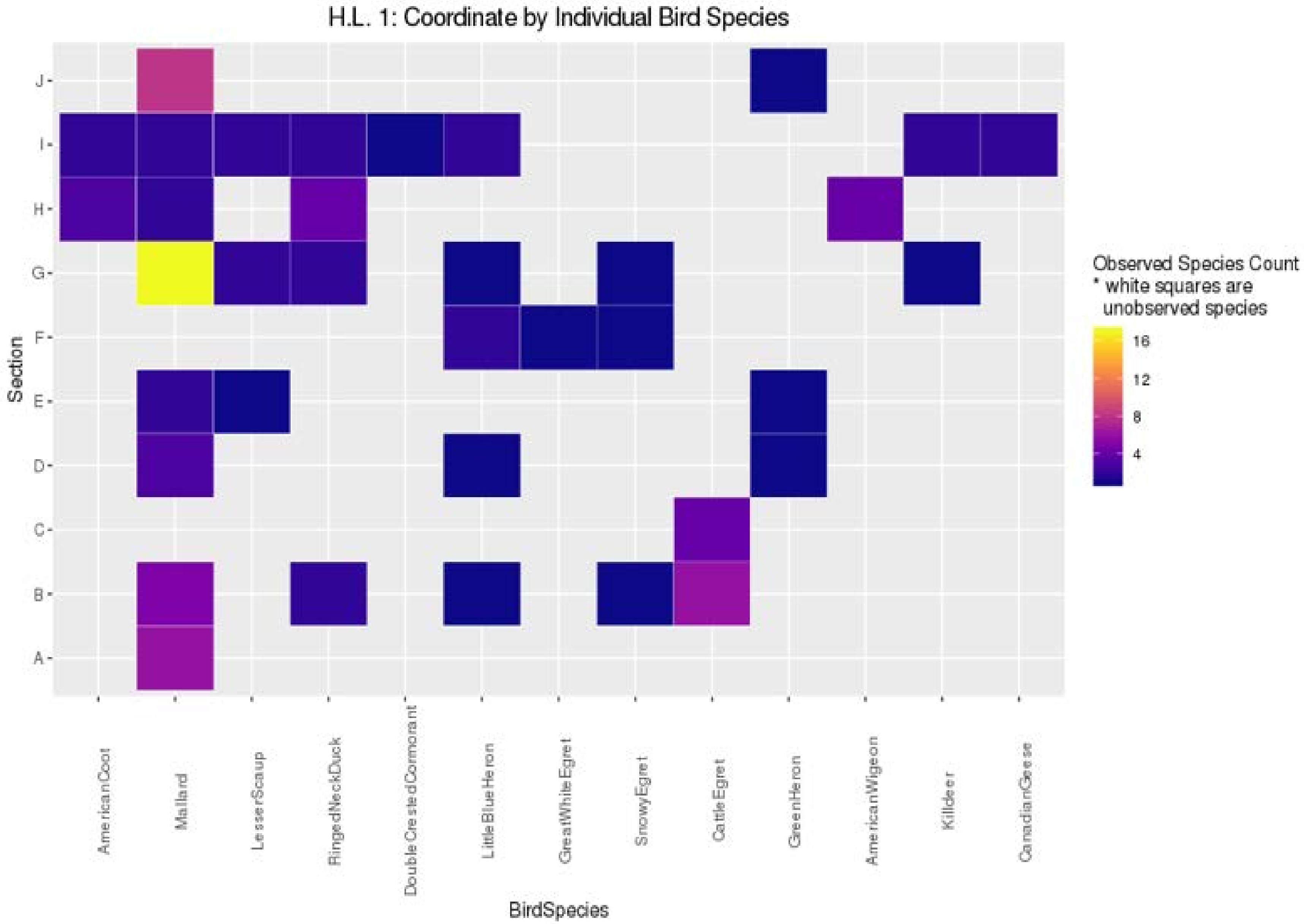


Figure 5.29: Heat-bar graph of species by section, HL-1.

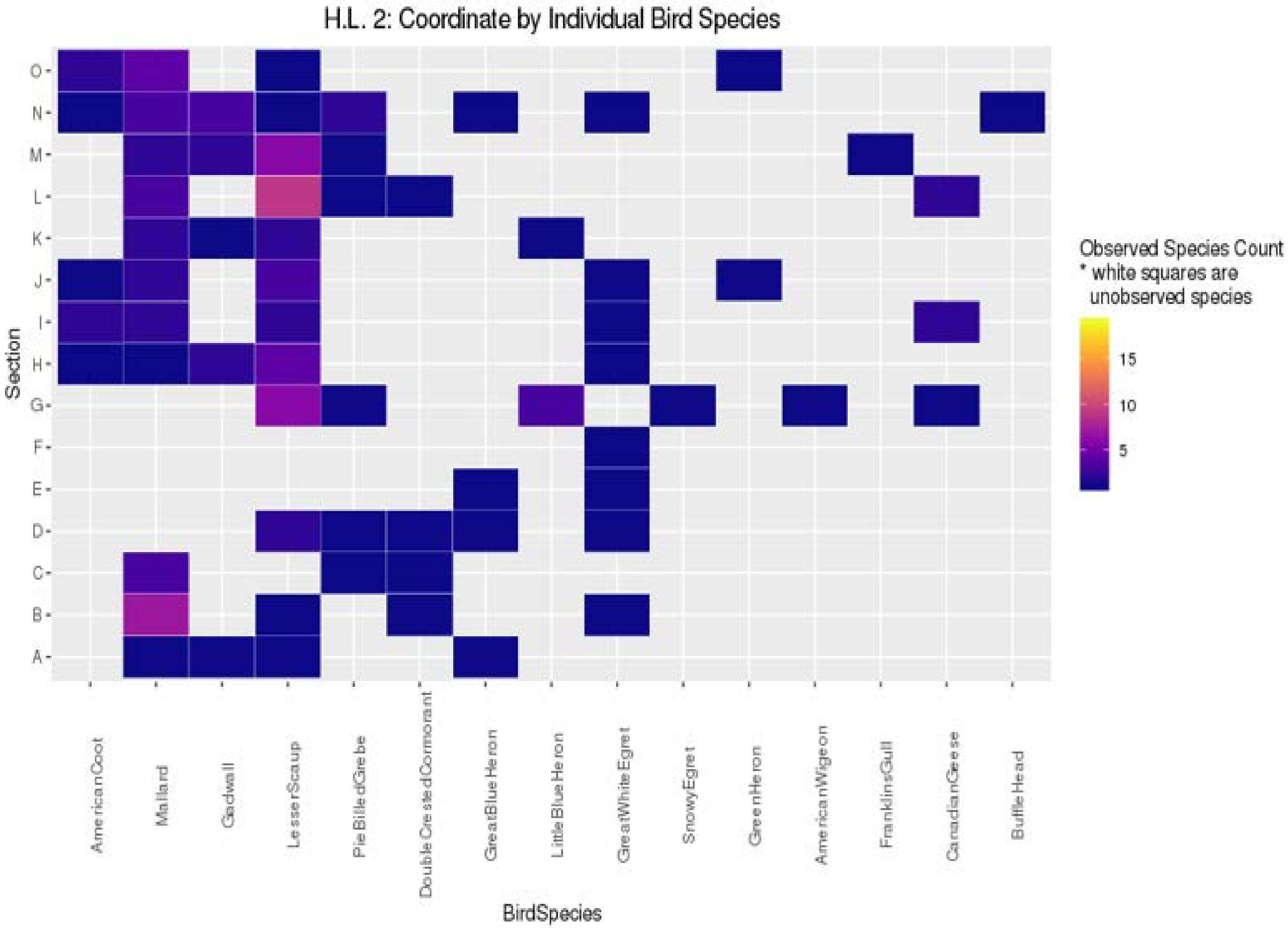


Figure 5.30: Heat-bar graph of species by section, HL-2.

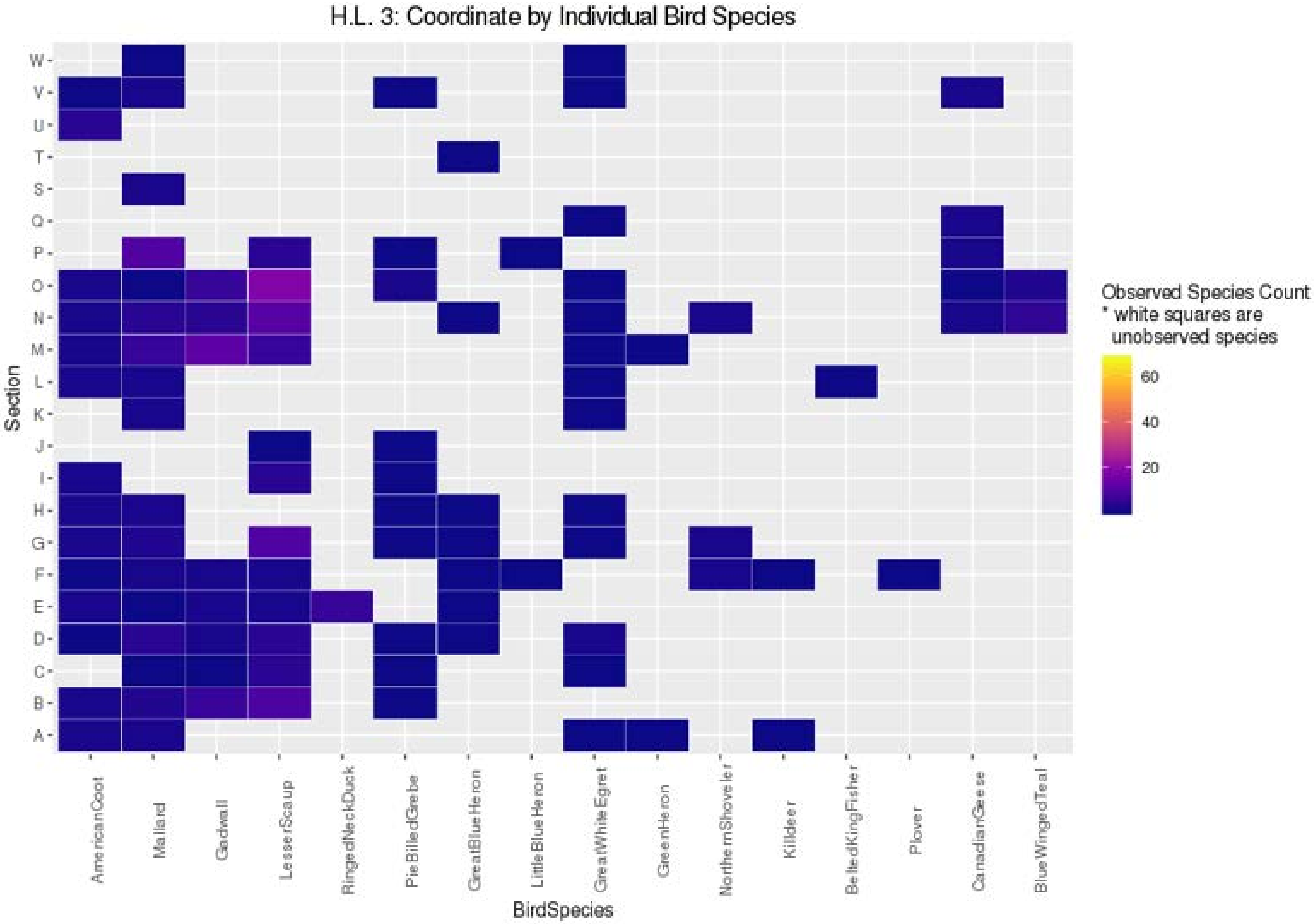


Figure 5.31: Heat-bar graph of species by section, HL-3.

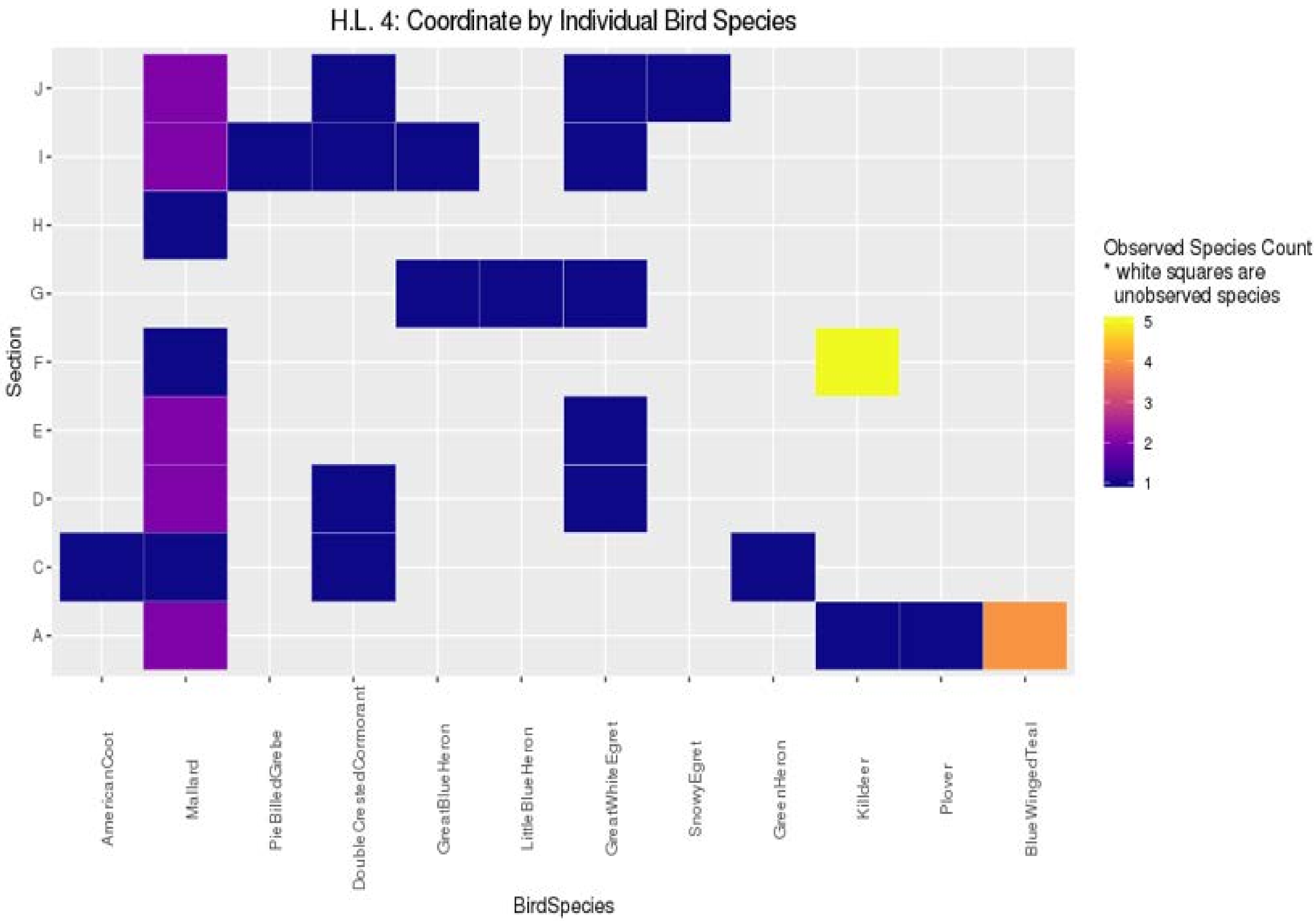


Figure 5.32: Heat-bar graph of species by section by site, HL-4.

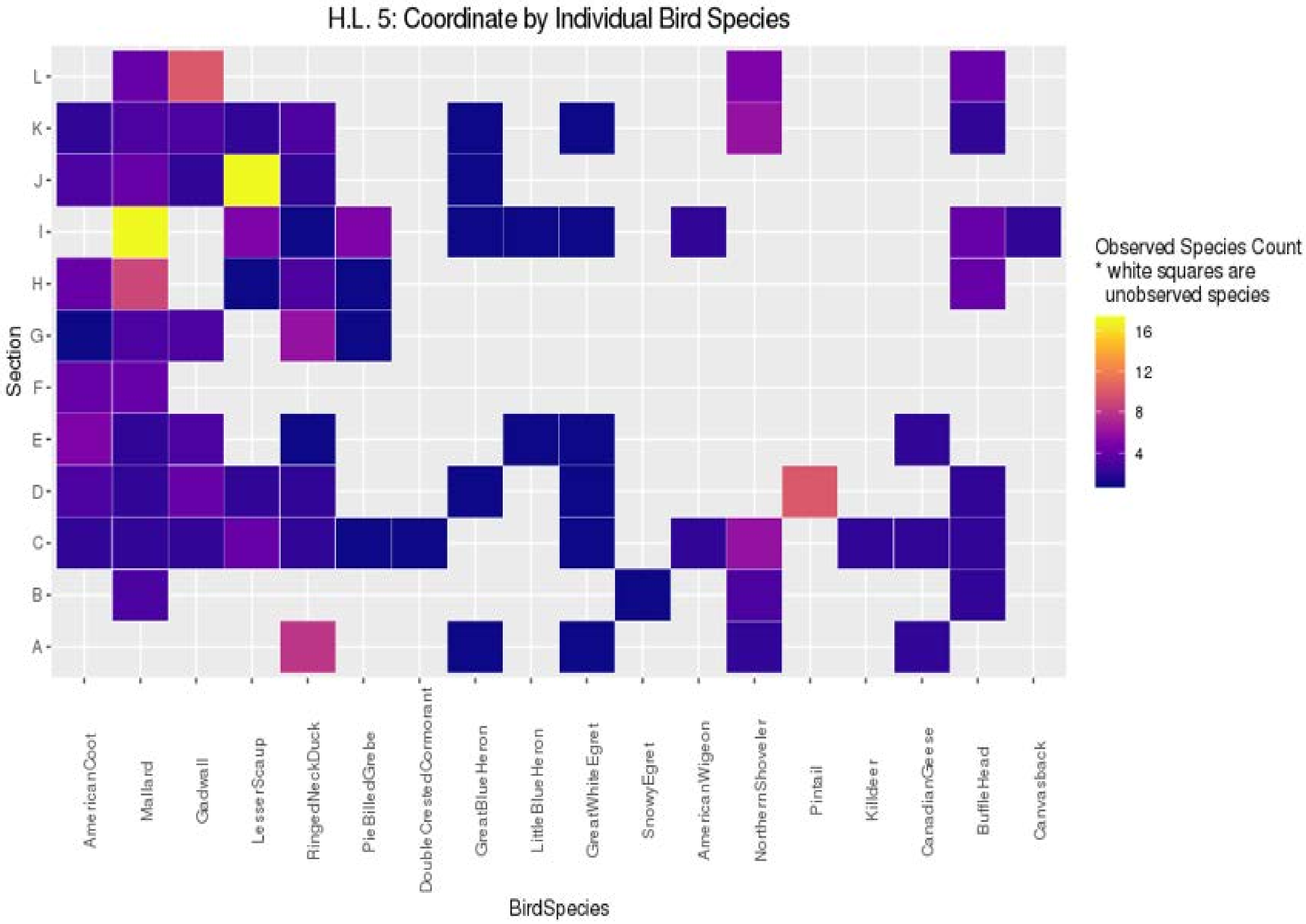


Figure 5.33: Heat-bar graph of species by section, HL-5.

CHAPTER 6

DISCUSSION

6.1 Waterbird Community Structure over Time

Within the four seasons, there are visible differences within respect to the observed waterbird species across site, making clear that local wetlands host a variety of niches within their services, and these serve to benefit different waterbird species relations undoubtedly. In this study it's shown that the spring season is the time for which open water waders and dense vegetation waders show their highest counts. There are a couple of contradictions for this statement though, more open water waders were seen in winter at LSR-3, and in summer for HC-2. Dense vegetation waders start coming in spring and taper off until about mid-August. Out of the dense vegetation waders, secretive American bitterns and night herons were mostly observed during spring time observations, with less observations in the summer. Little blue herons were more prominent during this time as well, and cattle egrets were only observed during this season alone.

Diving ducks are sparse during spring, to where only a few grebes and 1 red head was documented at HC-1. The moist soil birds documented within my study have different migrating patterns, so killdeer are more prominent in the spring, with Wilson snipe during autumn, and the *Charadrius nivosus* (plover) not around during winter. Dip dabble ducks are still the most frequent class during spring time. Mallards and American coots make up the other large part of dip dabblers during spring time. Early spring blue winged teal can still be seen occupying HL-3, a rare case in my data structure. During late spring, mallards were amongst the only dip dabble species still local. Spring is mating time for mallards, and presence of nesting mallards was noticed at HL and HC sites during the end of this time period. Where counts are fairly high for mallards at HC-1, HL-1, HL-2, HL-3 and HL-5, these patterns can be seen.

Open water waders are more active also during summer, with great white egrets, and great blue herons taking the majority, followed by little blue herons to a lesser amount. To another degree, dense vegetation waders remain present during the summer time, but with fading numbers as summer progresses, where green herons and night herons make up this activity during the summer, and where green herons are the last to leave.

Open water waders in the summer take advantage of the ephemerality of wetlands, picking off prey that become easy targets due to decreasing volume and area of the wetland habitat. These events are described earlier when I noted how open water waders (or dense vegetation waders, for that matter) were not social or not often seen in large groups; however, they can be social in advantageous situations of focused in-flux of food into the environment (Krebs, 1974).

Autumn is best represented by dip dabble species, being mainly that of gadwall, mallards and American coots who start to come in, with American widgeons coming in towards the tail of autumn. Diving birds are now starting to show up during this time, prominently grebes, double crested cormorants and ringed necked ducks. During autumn, heavy rains persisted during late October and early November, causing raises in water depth, significantly at SC and HC sites, most notably SC-5, and HC-1. This seems to have an interaction with the presence of green winged teal, where they are observed. Diving birds, such as the pie billed grebe, double crested cormorant, and ringed necked ducks become actively present. Open water wader activity slows down during this point, limited to great blue herons, and great white egrets. As mentioned, Wilson snipe were seen in highest numbers at SC-5 during this time period. Plovers at HL-4 were seen in their highest amounts during this time too.

Winter is where the most ‘action’ happens so to speak, as migrating waterfowl have made their journey to the region, in what sparks hobbyists to occupy their time with bird watching at ponds, and hunters to go on trips. During this time, dib dabblers still have amongst the highest common frequencies, but diving duck species observations for lesser scaup had sky rocketed, particularly at HL-3, in Section O (see Figure 5.3).

The random forest classification regression shows that with larger counts, the power of predicting a class for season goes up for diving birds, while it goes down for dip dabblers, but at lower counts, dip dabble ducks can be more confidently predicted. In comparison with other sites, dip dabble species at HL-3 are high in counts for mallards, American widgeons, and American coots, although HC-1 has the most dip dabblers during this time of year. Out of the dip dabblers for winter, the least seen was pintail, only seen twice, once at HC-1 and once at HL-5.

Diving birds who constitute the largest population out of the class are lesser scaup and ringed necked ducks. Lesser scaup had the highest survey count of 68 total at one pond (HL-3). Bufflehead were sparse, but seen in steady numbers at LSR-1 and 2, and HL-5. Bufflehead and canvasback together were only observed at attending these same 3 ponds. Pie-bill grebe were most common during winter at Site HL-3. Wilson snipe are seen during winter only at SC-5.

6.2 Waterbird Community Structure over Site

Sites HC and SC are built and modeled off of more native ecosystems, and have more diverse and rich aquatic vegetation present than the other sites do, both consisting primarily of *Potamogeton nodosus* (American pond weed), *Najas guadalupensis* (southern naiaid), and *Chara* (muskgrass), with pockets of *Ludwigia peploides* (water primrose) and *Typha* (cattails). These are the only groups of sites to have floating leaf plants. Also, SC-4 and HC-1 are rather big with larger surface areas. These two groups of sites have the highest amount of dip dabble ducks. They also have the most ringed necked ducks, able to cater to diving birds as well.

Following in line, these two site areas have the highest amount of open water waders (not to mention dense vegetation waders). These sites experience seasonal fluctuations in depth as well, which create new temporary aquatic habitats near the area, as much of the water is coming from the interaction between the creeks and the lakes hydrography. For dense vegetation waders, MCA reveals increases in distance to near ephemeral wetlands (Table 5.6). The wetland restoration sites also have more terrestrial vegetation around them, and experience flooded terrestrial conditions. HC sites have fence posts in them, which served as hot spots for birds like double crested cormorants during winter, other wading birds throughout the year, and night herons during spring and summer months. All of the mentioned species like to perch and dry off after getting wet, and also use said vantage point for a better view of their prey.

LSR sites provided habitat for buffleheads and canvasbacks uniquely well. Two of them are larger, and all three are deep. Large fresh water muscles were observed at these sites, particularly LSR-2, which has a human-made water fall flowing into it, adding extra carbon into the environment, a potential factor for more muscles being present. People fish these sites as well, and they were originally wetlands before the urban area encroached. These wetlands are fed by an aquafer, so it’s likely that there are other biological or geo-physiochemical processes going on I did not sample for that could be responsible for these presences. Also, there were dip dabble species that were seen eating live oak acorns at the LSR-2 site.

HL sites are channelized wetlands which for the most part, excluding HL-4, are deep and big. This is the biggest wetland complex in the study. HL-5 of the area did cater to bufflehead and canvasback too. Oddly enough that used to be a smaller wetland area, too, like LSR was.

HL-3 is significant for catering to many ringed neck duck species during the winter. The HL ponds are also unique for catering to the few Canadian geese observed, perhaps due to large green grass swells around the area (a golf course), where they forage on grass. HL sites seem to be beneficial for diving ducks, especially Section O, which is the deepest area of the pond and where many of the lesser scaup counts were. Fish feeders are at HL-2 and HL-5, as well, which was however shown to have little effect size as a variable for any bird classes. The *Pistacia chinensis* (Chinese pistache trees), red oak trees, and live oak trees at HL are helpful for dip dabble ducks too.

Dense vegetation waders is the only class that is positively correlated with site, indicating that the variable site is what is most important in being able to explain the variation in different species and counts of species of this class. HC-1 had the most activity from this species group, with all species observed (night heron, green heron, American bitter), and multiple other observations seen at the sight throughout the survey period. The species grouped together in this class are showing huge mutual relation on few loadings, especially since they were only observed for two out of four seasons of the year. The negative correlation with the rest applies variations amongst species and how data was classified.

HC-1 was only positive with dense vegetation waders and dip dabblers, which indicates consistency in returning to the same section. In the instance of dense vegetation waders, they were at times seen in small groups in a single section feasting on biota from HC-1 drying up, and in other instances, classes re-appeared within the same sections for the next survey visit. The sections that they appeared in are most closely related with natural weather based inner-annual lowering of depth during warmer, dryer summer months, and flooded terrestrial areas with dense vegetation cover. The exception was at the HL sites where a green heron was observed, eating bugs near the shoreline.

Dip dabble birds also have positive associations with section, which is interesting because they have a negative association with site. This looks at how within bird classes a species may be able to find value in many different wetland types, but that's because of specific things localized within that wetland, perhaps vegetation, or depth variables. Negative associations with section for moist soil and open water waders suggests that within the class of moist soil and open water waders, the group of species as a whole are more parsimonious throughout sections of a wetland. This was not the case for the plover and the killdeer, however, as I always saw them occupying certain areas of one pond in particular (HL-4) where they hung out on a concrete spillway, drinking water and feeding, using it as a platform for enhanced foraging tactics (Section F).

For bird class predictions paired across site, it showed moist soil to best be predicted by HL-4. As spoken of, there are structural components at HL-4 that make it unique, as it's the only shallow pond that has a structure like these built into it, and it has crushed rock and boulders near the shoreline, being typical of killdeer habitat. Plover also frequented the same spot, never seeing them anywhere else other than that location with an associated spillway structure. *Leucophaeus pipixcan* (Franklin's gulls) were seen at deeper ponds, and the *Tringa melanoleuca* (yellow legs) were seen at different ponds in different contexts, thus contributing to some fuzziness. The yellow legs were observed at SC-5 and HC-1 only, the two ponds that experience the most significant inner-annual lowering of depth, and have significant mudflats during periods of the year (see Appendix B). Open water waders also show a negative correlation to section, which makes more sense, as they were regularly varied over site and section, as great white egrets and great blue herons (the most abundant) are year round residents, and so must be able to better forage for food in the local area than other species.

6.3 Waterbird Resource Management Strategies

The data and information collected from this study can help with making recommendations to better orient strategists for improving local, to international populations of waterbirds. Within this, site must be carefully considered, especially in the case of wetland destruction and manipulation and/or restoration. The idea of wetland heterogeneity needs to be impressed, which compels the idea that wetlands are all different, and areas within wetlands are different, and help different species in different ways. I recommend future land planners to treat all wetlands as potentially worth preserving, or at least, conserving. Certain sites are irreplaceable ecosystems, and the catering to local biota is what matters most in this context, so if a site is manipulated, it should be done so in a way that aims at making the site do what it was doing before, for other living organisms in the area, but even better and more inclusively, factoring in hybrid geographies and potentially new species. The HC and SC sites are along such ethics of manipulation and creation from the USACE. These sites were pre-existing wetland areas, and were expanded and bounded to serve a more permanent and directed function. These functions included, but are not limited to containing storm water runoff and ephemeral wetland integrity, public recreation and integration with the urban environment, restoration and conservation of native wetland and bottom land hardwood plant communities and habitat, and sequentially other secondary producers and consumer recruitments.

The landscape interactions that can proceed within and around these systems can be dynamic, including but not limited to depth fluctuation, ephemeral flooded terrestrial and marshland and wetland habitat change, surface cover of the riparian area, seasonal vegetation community shifts, and seasonal waterbird population shifts. Aquatic vegetation is important, where in this study the ponds with the most aquatic vegetation and species richness had more dip dabblers and diving ducks overall than those that had less. Although vegetation species were collapsed, it's believed that the presence of not only more vegetation, but specifically *Sagittaria platyphylla* (delta arrowhead or duck potato) was thought to have significant impact on observations, as only the USACE ponds had this plant present. The USACE ponds were also the only ponds to have floating leaf vegetation.

Large wetlands that are deep enough to not completely dry up in the summer, but shallow enough that they can experience inner-annual lowering of depth in areas over the late spring and summer months for open water waders, dense vegetation waders, and moist soil foragers like yellow legs are recommended. These ponds would ideally have deeper areas for year-round dip dabble species like mallards, but also more shallow areas, where in cases shallow areas are surround by dense terrestrial and aquatic vegetation, while in others it's around open mudflat areas catering to moist soil foragers and the like. Subsequently, then a wetland would need to fill back in to cater to migrating bird populations, who start to arrive in autumn. The presence of rocky surfaces near mudflats and shallow depths is also recommended for moist soil species like killdeer. The plover, who is near threated (BirdLife International, 2017) was only seen at constructed spillways at HL sites where there was water flowing over the spillways slowly, indicating importance of this unique structuring.

Wetlands that are near other wetlands, situated near creeks and that are incorporating other landscape geographies have more value, as they are able to serve more beings, and service more purposes. Purpose could include, but are not limited to, fostering native aquatic ecology through the introduction of plants as primary producers, serving as food and shelter for other biota. Introduction of native sporting fish species, or fish like *Gambusia affinis* (western mosquito fish) are helpful, as they can control localized mosquito populations, while contributing in many other ways through mobilizing nutrients down and up the food web. Wood duck boxes can also be incorporated in wetland resource management projects, which service as nesting habitat for bird species. Tree species are important as well, such as red oak, and live oak, and the fruiting tree Chinese pistache specifically, as these were observed as forage material for dip dabble birds such as mallards, American widgeons, and American coots.

Common practices for urban wetlands include chemical removal of vegetation, which causes bio-accumulation of harmful chemicals by organisms within the food web, causing potentially fatal, or sub-lethal effects on primary and secondary consumers (O'Toole et al., 2009; (Sewalk et al., 2000; Pérez et al., 2011; & Annett et al., 2014). I argue that it is not necessary to control algae in such ways, and that it is more costly to do so, and that it's inputting synthetic chemicals into our water resources, limiting the amount of biodiversity that can occur, becoming an exclusive ecosystem in regards. Aquatic plants, if left intact, or were planted at a wetland, would be able to cycle nutrients back through the ecosystem, helping to curb algal blooms. At the same time, these plants can provide food and habitat structure for all sorts of aquatic and terrestrial life. Rather than manage for waterbird resource management strategies, perhaps we should manage with waterbirds the resources that we share. As bio-indicators, waterbirds in this study overall have shown to favor wetlands that have more vegetation, and that are not treated with chemical herbicides.

6.4 Conclusions

The urban wetland landscape in Frisco, Texas, offers variable habitat value for waterbird populations, arising mainly from variation in how the wetland habitats are constructed. This variation can be seen, to a degree, as a dichotomy between private interests and public interests, with the 5 wetlands of HC and SC sites on the public side built by government entities, and the HL and LSR on the side of private interests. To a degree, the lines between the two are blurred, but simply understood, these four different urban wetland sites can be separated into these two categories. This phenomenon seen in the development of space can be described as 'uneven development,' where differentiation is ascribed to the physical and social structures of a system because of a difference in supported values within society (Smith, 2010). The main difference between these two categories is the (1) management, presence and absence of aquatic vegetation communities; (2) inner-annual lowering of depth and depth fluctuations; (3) surrounding riparian buffer regions (golf courses, forests, grasslands, buildings, fruiting trees); and (4) input of sport fish into the system, sometimes fed using automatic fish feeders.

Overall, more abundant and diverse waterbird populations on average visited the USACE restoration wetlands, although diving ducks in particular seem to draw more value from the more common urban storm water management/golf course ponds than other species do, with additional variation given to some open water wader species. Common urban methods of wetland landscaping involves the planting of acorn and fruit producing trees that offer food sources to dip dabblers, which the USACE wetlands lacked. Depth, surface area, and specific areas within wetlands are also very important characteristics that help contribute to waterbird foraging possibilities, leading to a call for increased focus on the interaction happening between species and area within a given section of a wetland.

6.5 Difficulties and Recommendations

The challenges behind this study, as with any of this sort, was sampling bias, as I conducted convenience sampling of a large population for a year. Distance, and location of sites made surveying them more difficult to schedule, and access during certain times of the year.

Sections for ponds were drafted based off of known landscape features that were permanent, serving as a constant reference point, but even within this fine grained strata of location, it could have been pushed even further, where outer shoreline, shoreline edge, inner shoreline, and open water could have been distinguished as tiers within the wetland, helping to further solidify findings on depth as a variable (where a finer grain of depth could be given to each species per observation within section). An extenuation of the modelling approach with the random forest algorithm and MCA could have been done in such a way to where species were not collapsed, and the importance's could have been generated for each individual species, and then the MCA could ascribe importance's for each species, and a cluster analysis could have grouped the species together into a modeled classification set, rather than a supervised one as I had done with the 5 bird classes. By taking the approach I did, I made assumptions about birds within each bird class that were not congruent with all of the birds found within a given class.

There are of course even more variables I could have sampled for, such as macro-vertebrates, or different ways to sample the data that may have been better, let alone statistically analyze it with modern and cool new techniques, rendered with modern graph types, but the biggest difficulty was learning how to think like a waterbird. It wasn't until I had observed these beings for some time that I had come to realize they have their own behaviors, tendencies and preferences, which are displayed in such subtle ways that even if you were looking, you could miss something. Comparing the results with the MCA, the descriptive statistics, and use of my memory, I was able to put the whole picture together as a solid trail. Also, the time that was spent at the wetlands observing the waterfowl for more than just a count is what offered the most insight.

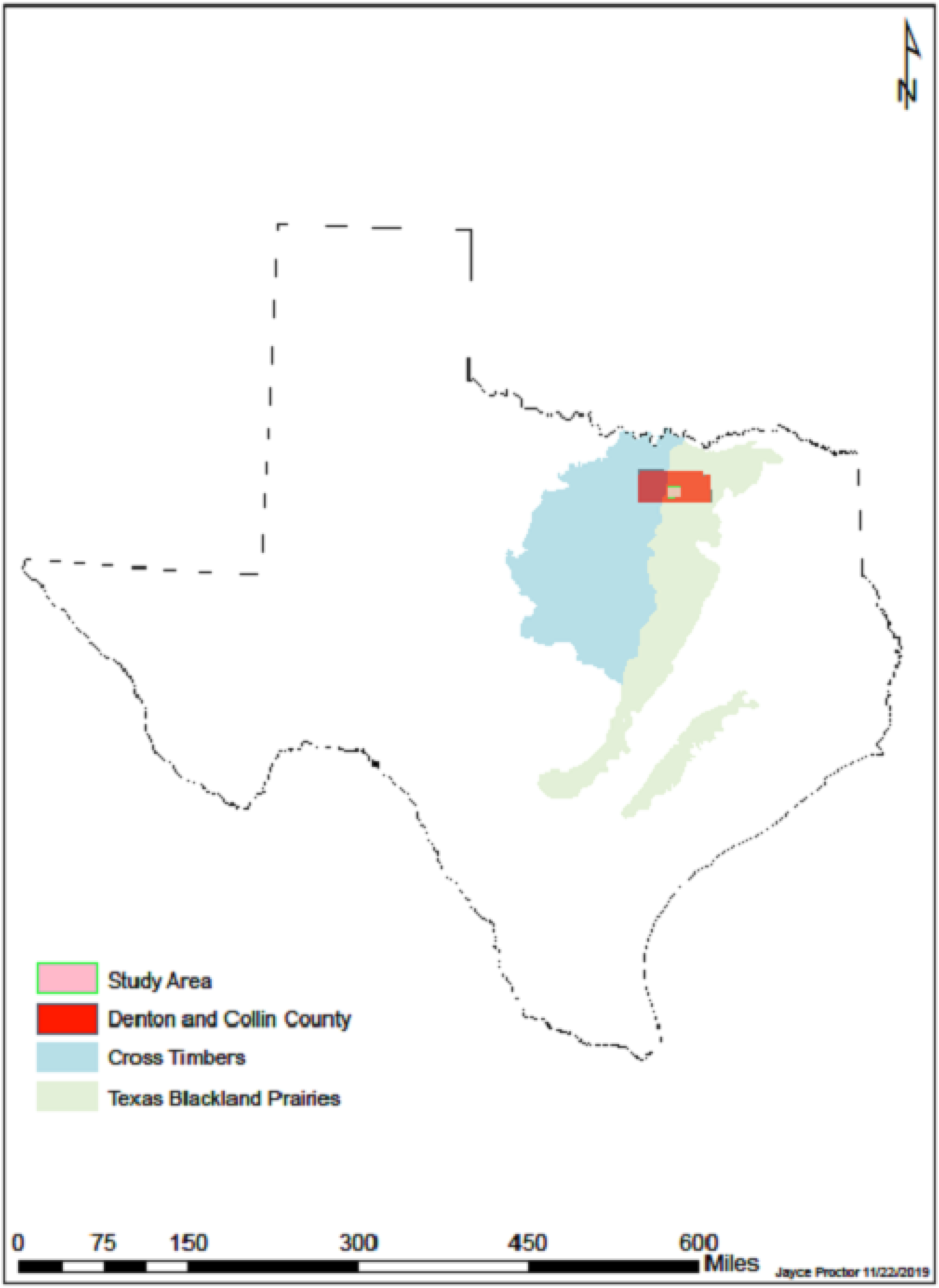
For data collection, I recommend the use of high-tech, remote control boats with GPS and sonar devices to conduct depth surveys. These are used by local urban pond managers because they are extremely efficient; it can take only 5 minutes to complete a survey, versus 5 hours. In addition, drone technology for landscape mapping and multi-spectral imagery is already in use in some locations, and would be very helpful performing this kind of research. Lastly, motion-sensor and/or long range in situ cameras would provide better photographs for improved data collection. Regarding data analysis, I recommend that whoever is interested in doing this type of work become well versed in using R statistical software. The data analysis included in this thesis is advanced even for those who are data scientists, so knowledge of the software beforehand will save much time later.

6.6 Future Research

Taking this study one step further would involve sampling for macro-invertebrates, and other primary and secondary producers than just plants. What is most challenging is making sure to get enough of the sample to represent the population, so in this since, further research and increased sample rates at these sites and other sites would help improve confidence. This study could flex in scale quite a bit, and become even more localized, or more spread-out. I could use my data to compare it against other sets of data, and model larger population trends regionally. Fecundity modeling could be applied in this sense, helping to answer different but substantiating questions about waterbirds. As long as there are urban-scapes and human built environments being erected, maintained, and re-worked, wetlands will be in danger, and so will waterbirds.

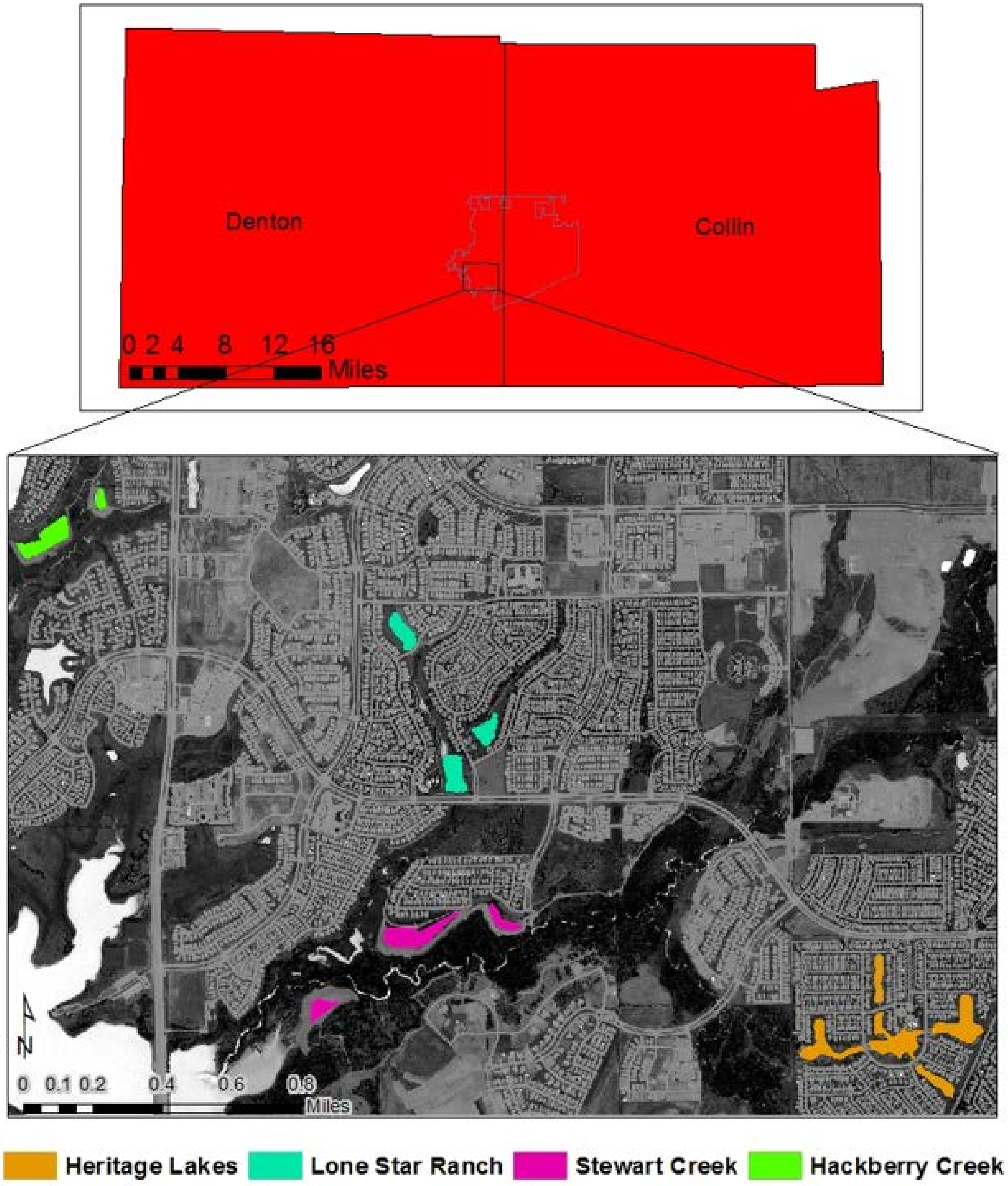
APPENDIX A

LOCATION MAPS, SURVEY MAPS, SECTIONS MAPS, DEPTH MAPS, BUFFER MAPS



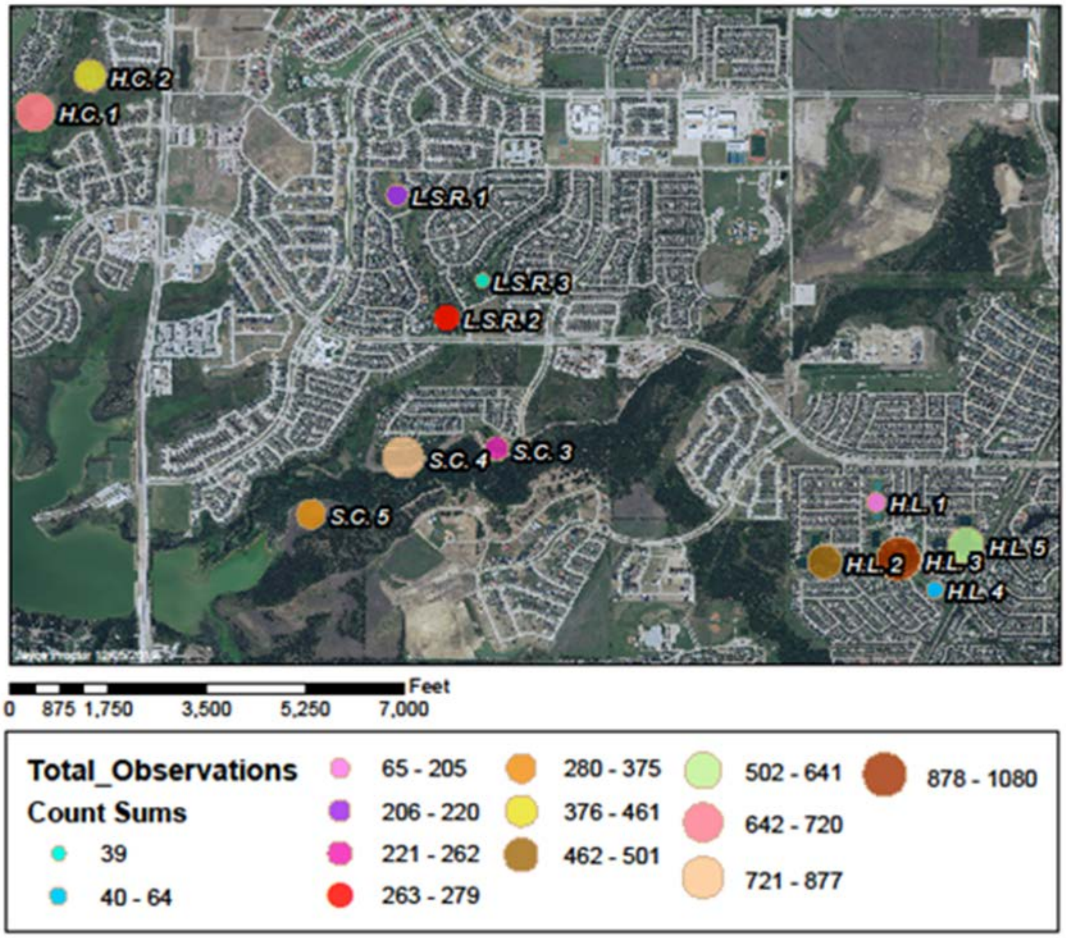
North Texas Study Area and Associated Eco-Regions

Wetland Sites: Frisco, Texas



Jayce Proctor 06/10/2019

Total Observations Across All Sites



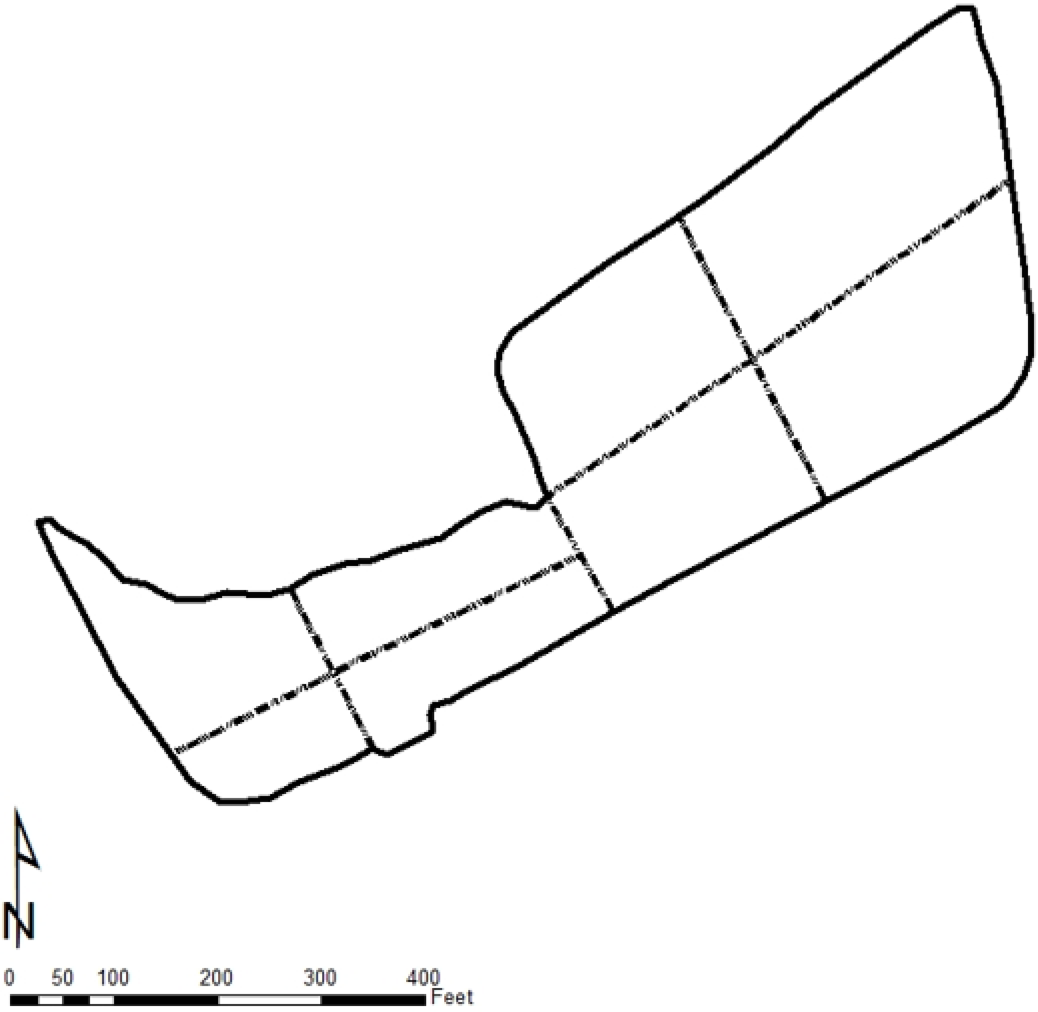
Hackberry Creek: Cell # 1

Date:

Arrival Time:

Departure Time:

Wind Speed:



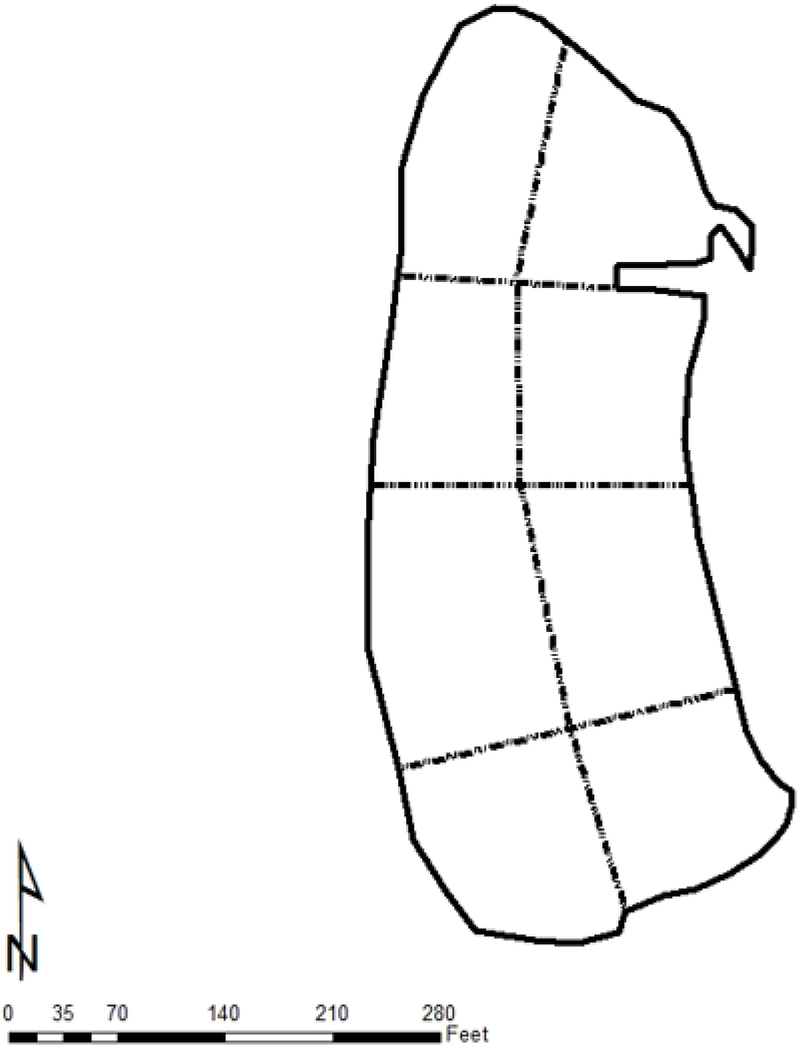
Hackberry Creek: Cell # 2

Date:

Arrival Time:

Departure Time:

Wind Speed:



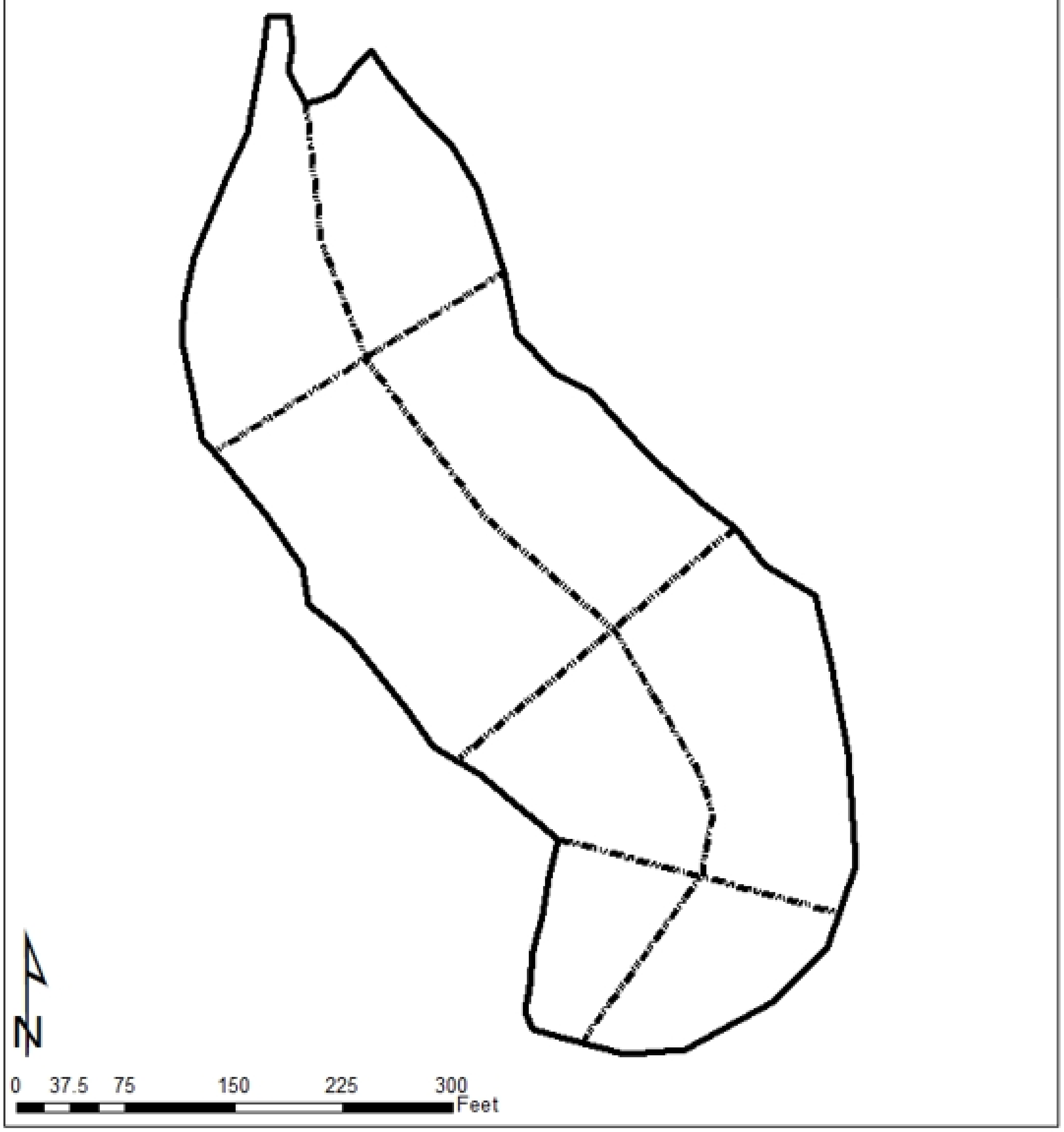
Lone Star Ranch: Cell #1

Date:

Time of Arrival:

Time of Departure:

Wind Speed:



Lone Star Ranch: Cell #2

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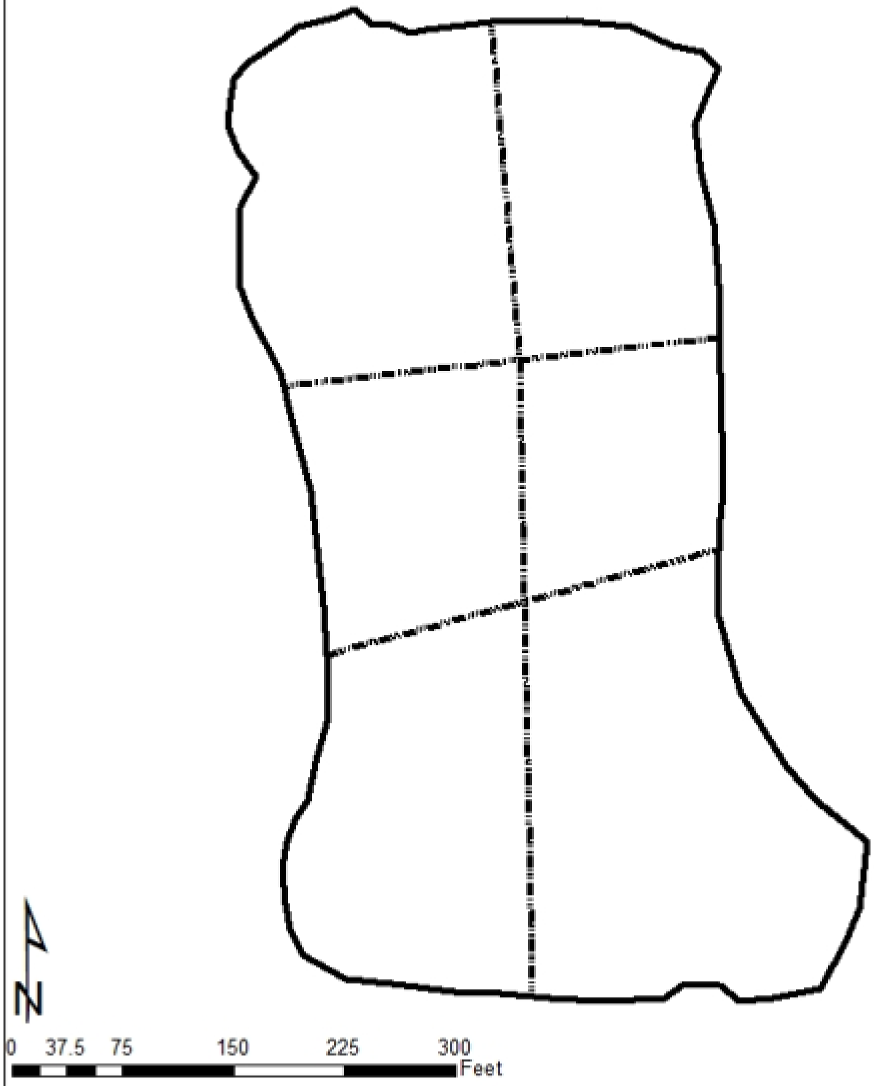
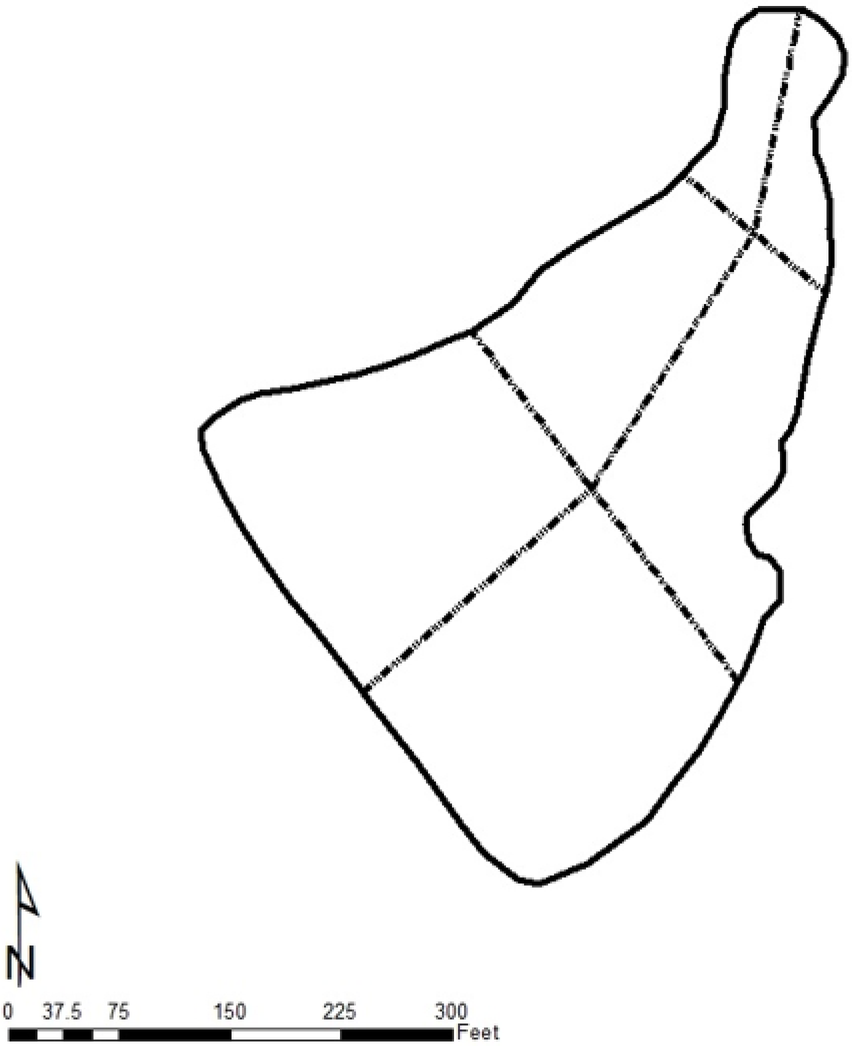


Lone Star Ranch: Cell #3

Date:
Time of Arrival:
Time of Departure:
Wind Speed:



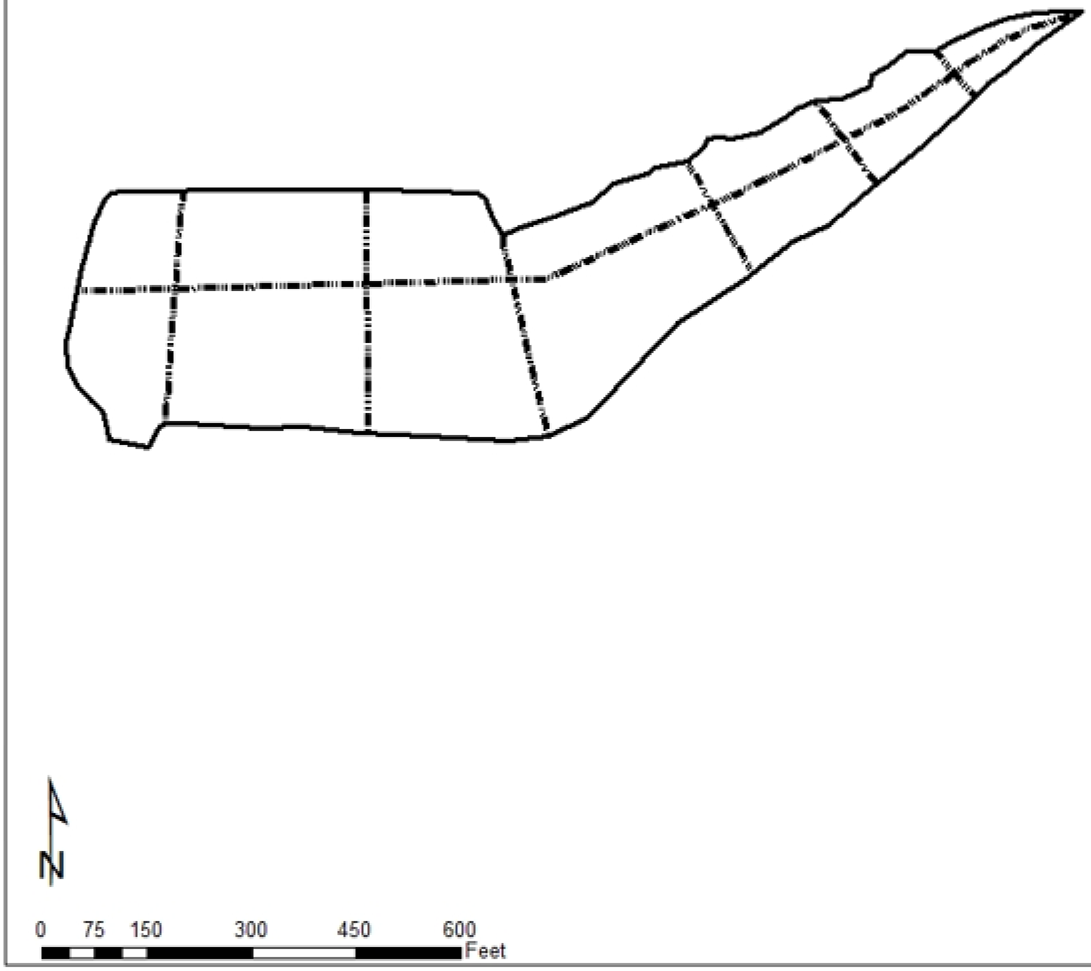
Stewart Creek: Cell #4

Date:

Time Arrived:

Time Departed:

Wind Speed:



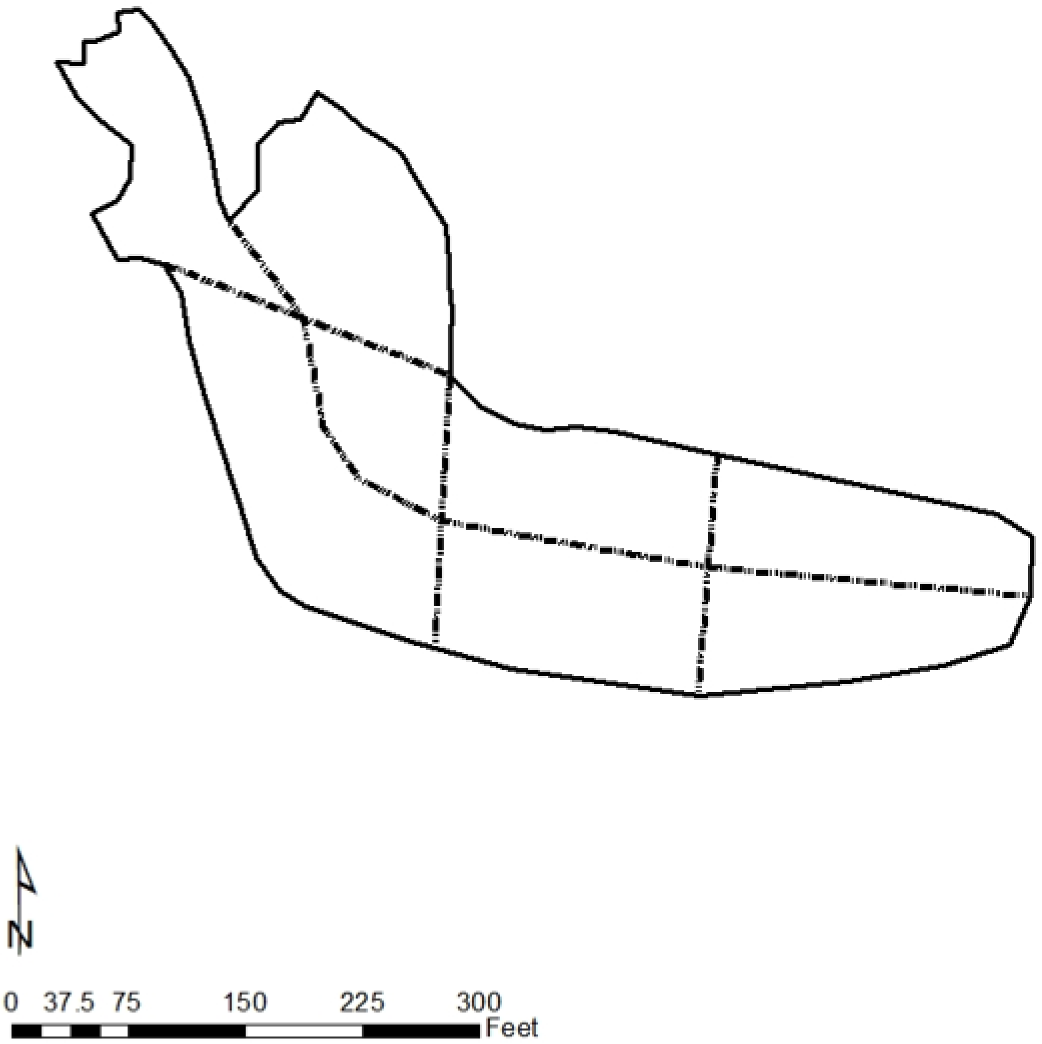
Stewart Creek: Cell #3

Date:

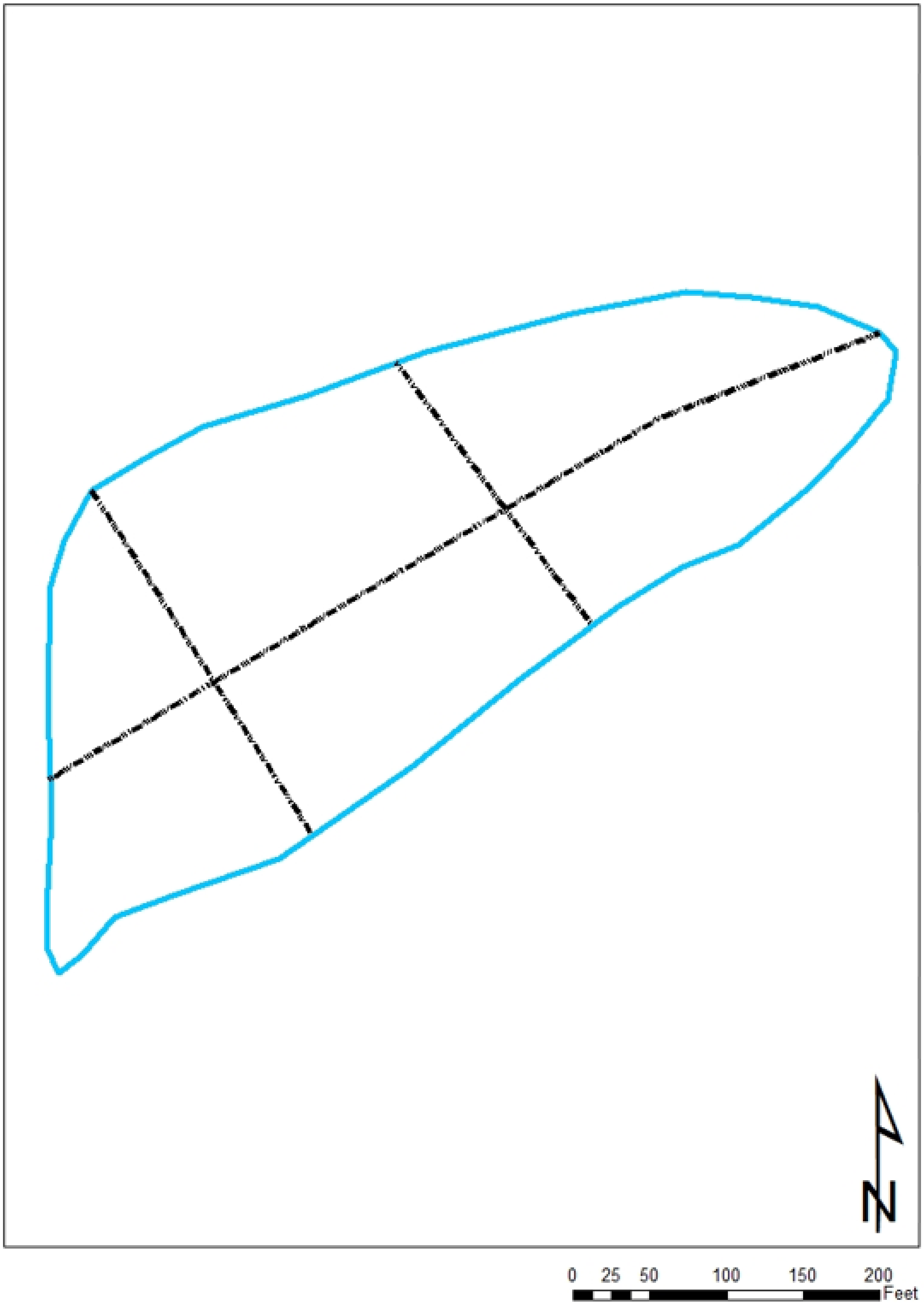
Time Arrived:

Time Departed:

Wind Speed:

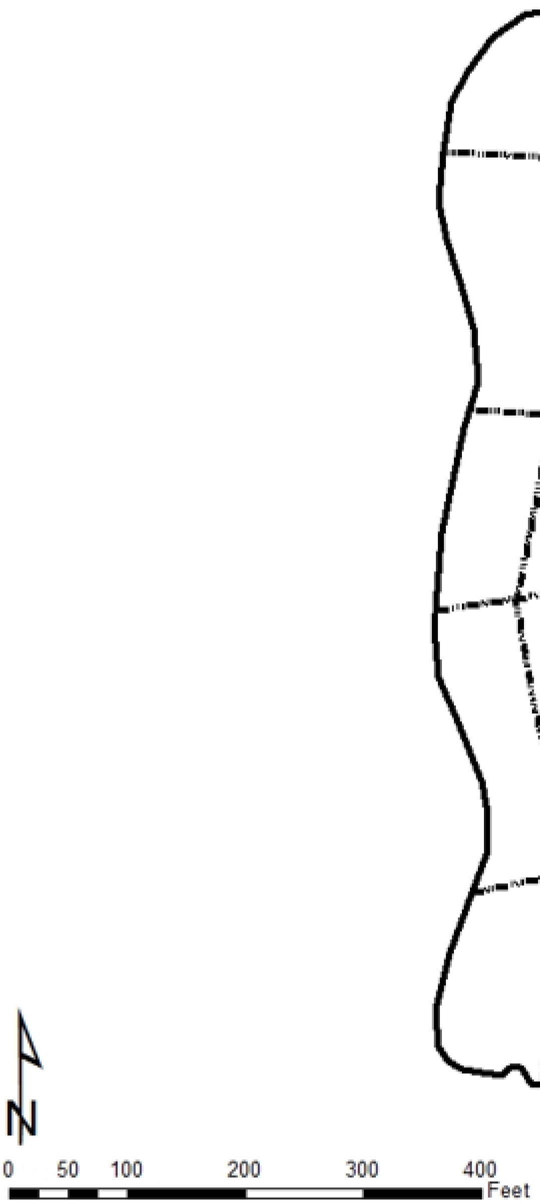


Cell 5

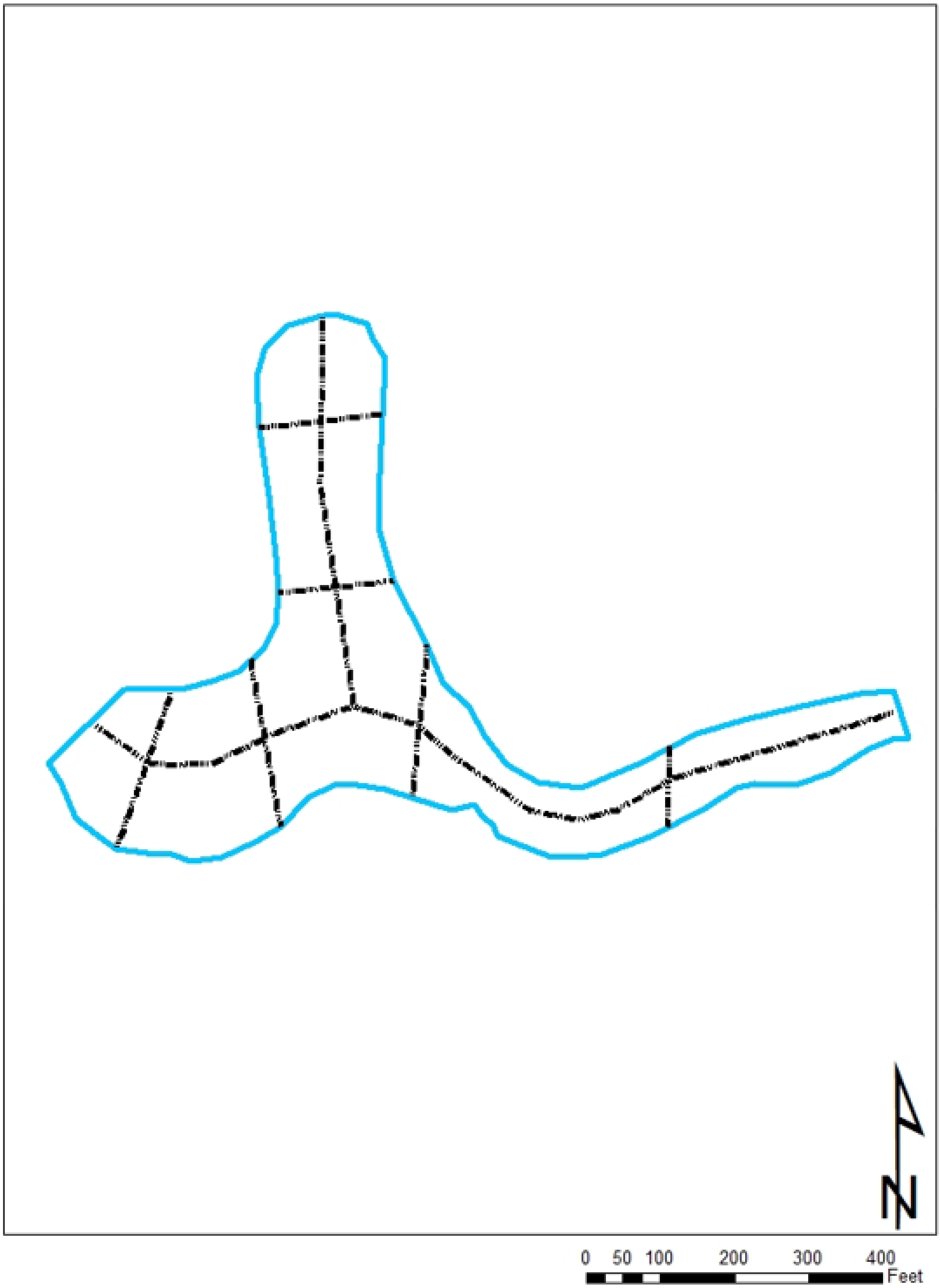


Heritage Lakes: Cell #1

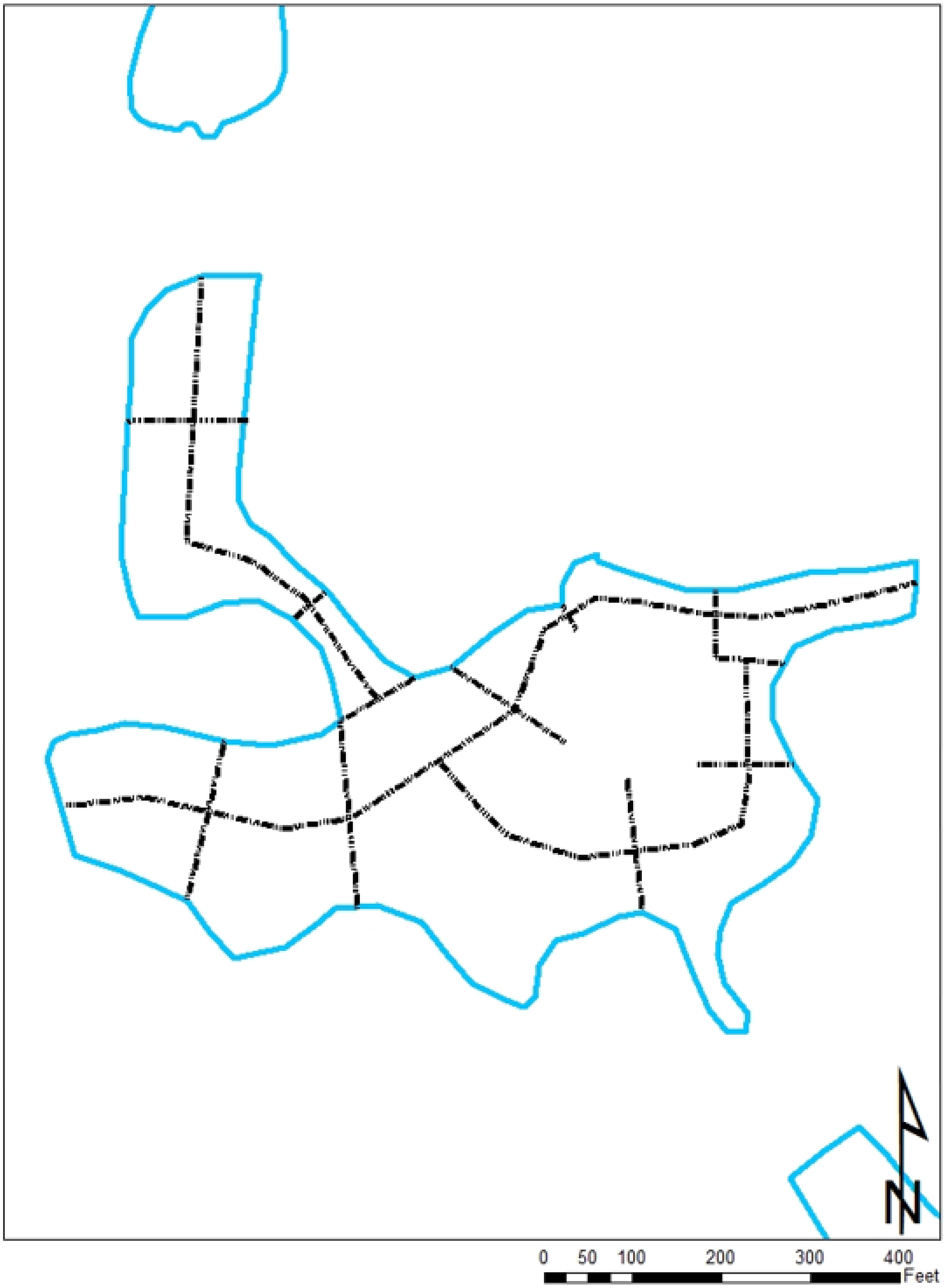
Date:
Arrival Time:
Departure Time:
Wind Speed:



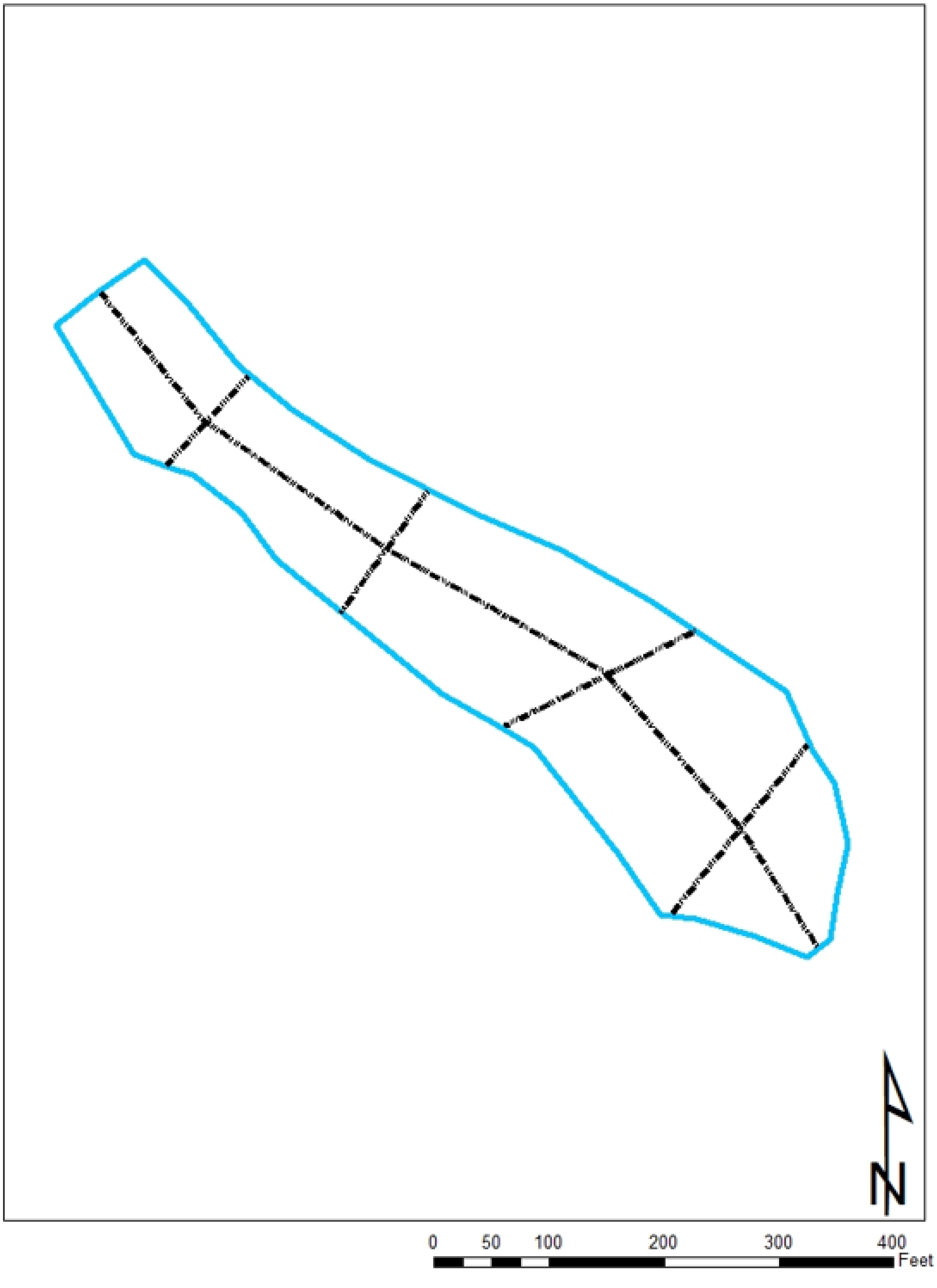
Heritage Lakes: Pond 2



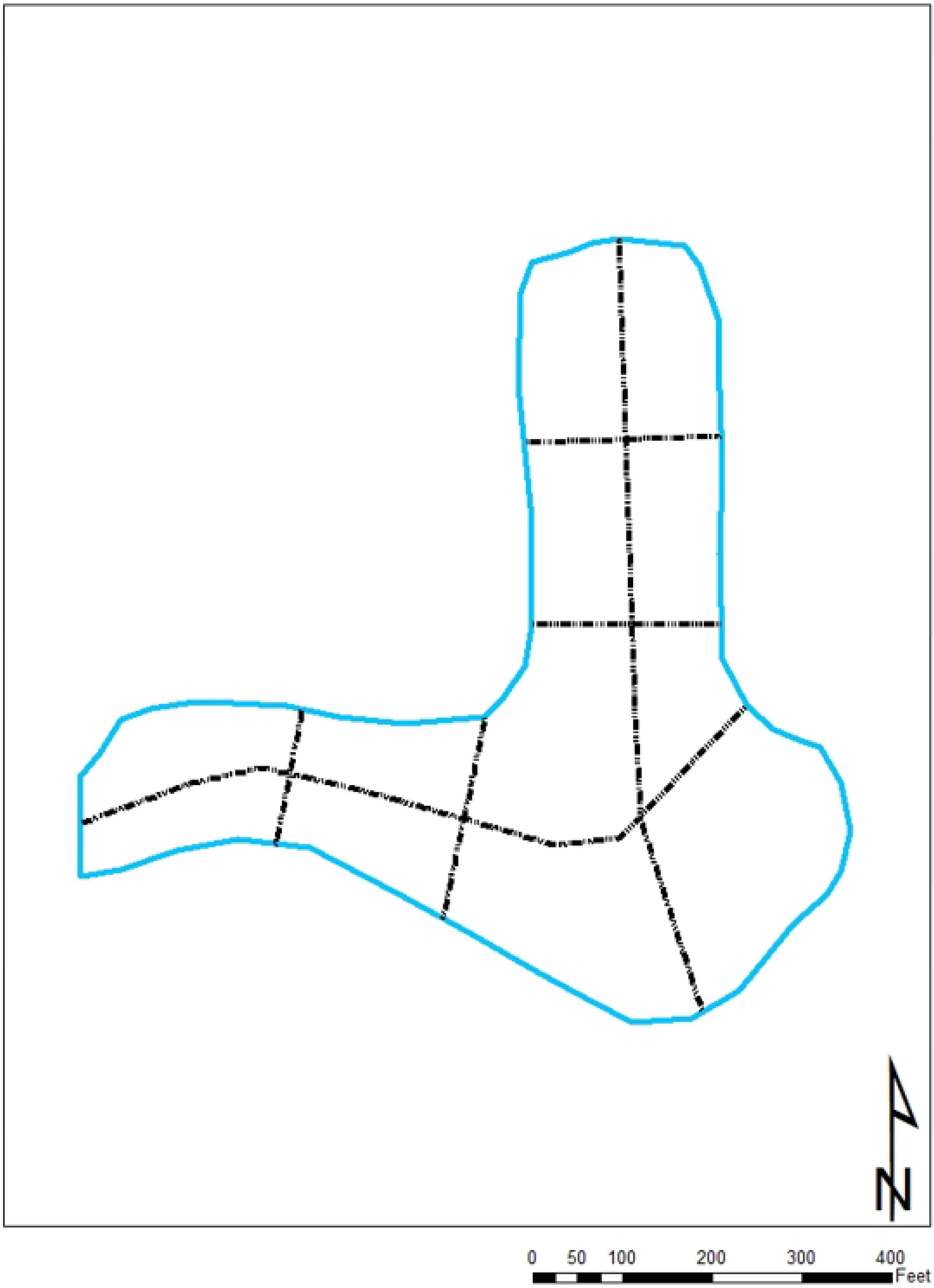
Heritage Lakes: Pond 3



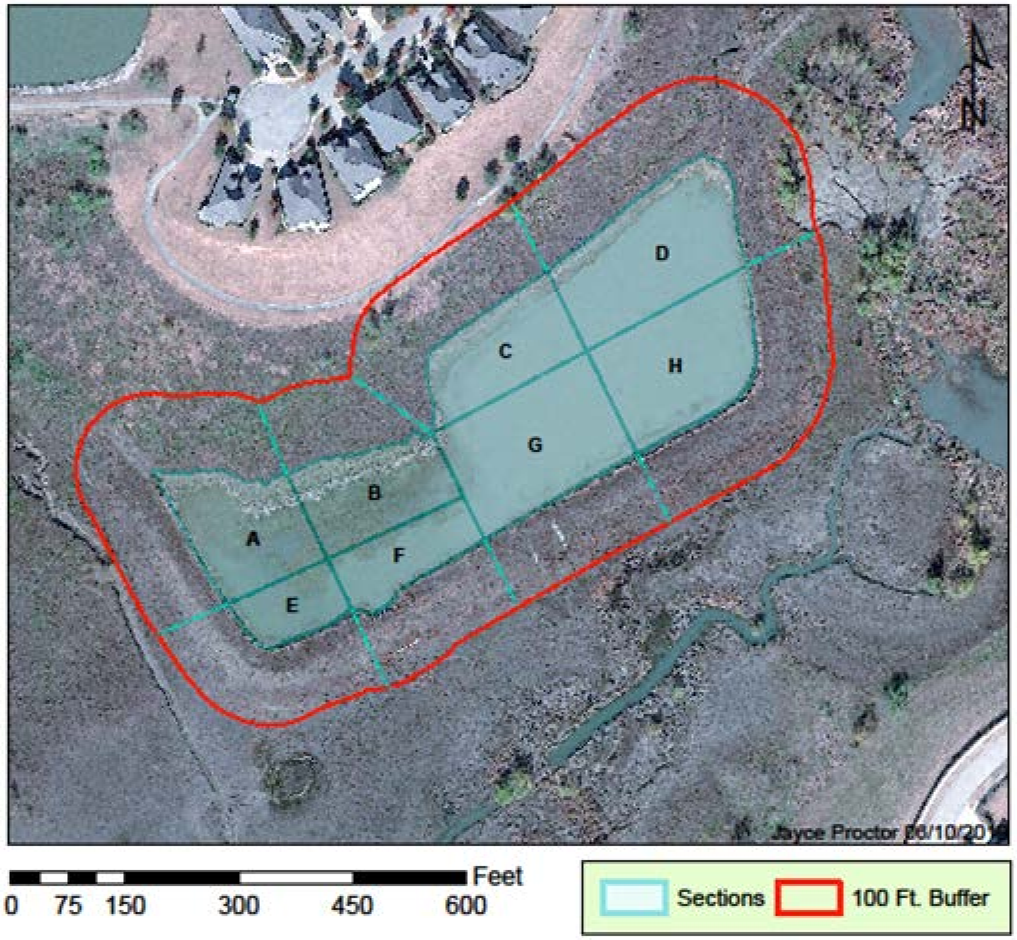
Heritage Lakes: Pond 4



Heritage Lakes: Pond 5



H.C. Cell 1: Small Scale Bounding and Ranking Map



H.C. Cell 2: Small Scale Bounding and Ranking Map

L.S.R Pond 1: Small Scale Bounding and Ranking Map

L.S.R. Pond 2: Small Scale Bounding and Ranking Map

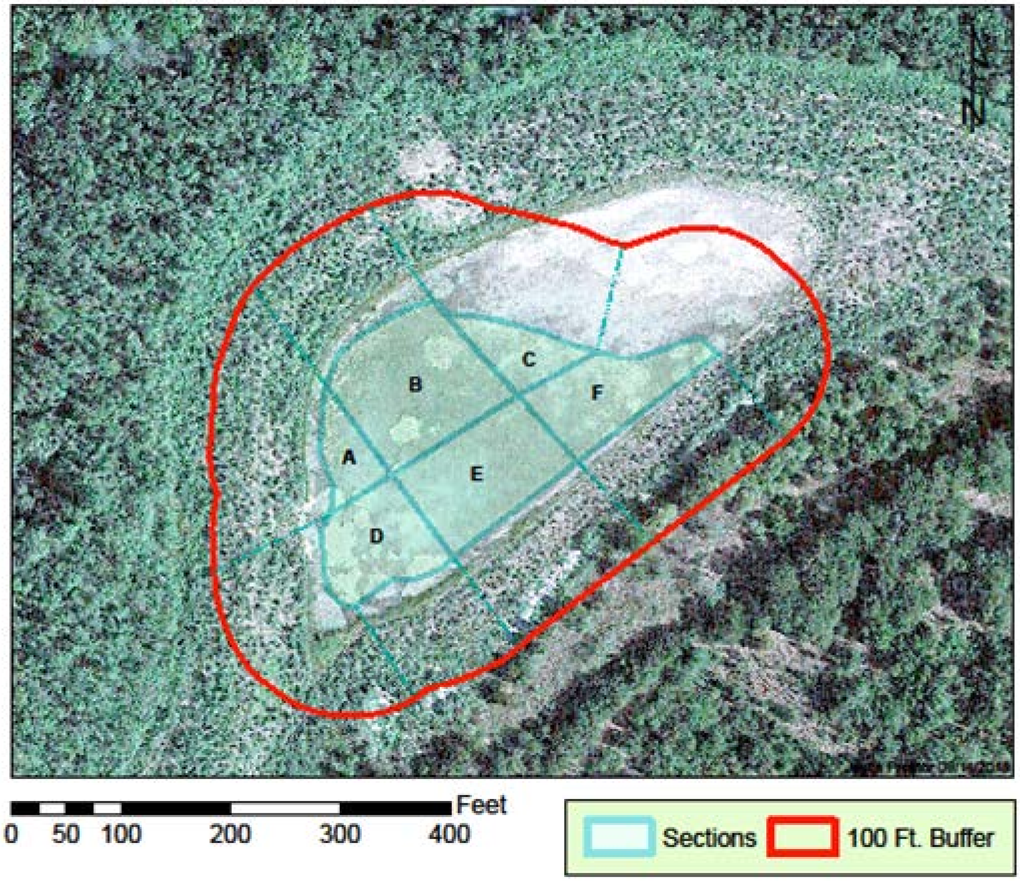
Jayce Proctor 06/13/2015

L.S.R. Pond 3: Small Scale Bounding and Ranking Map

S.C. Cell 4: Small Scale Bounding and Ranking

S.C. Cell 3: Small Scale Bounding and Ranking Map

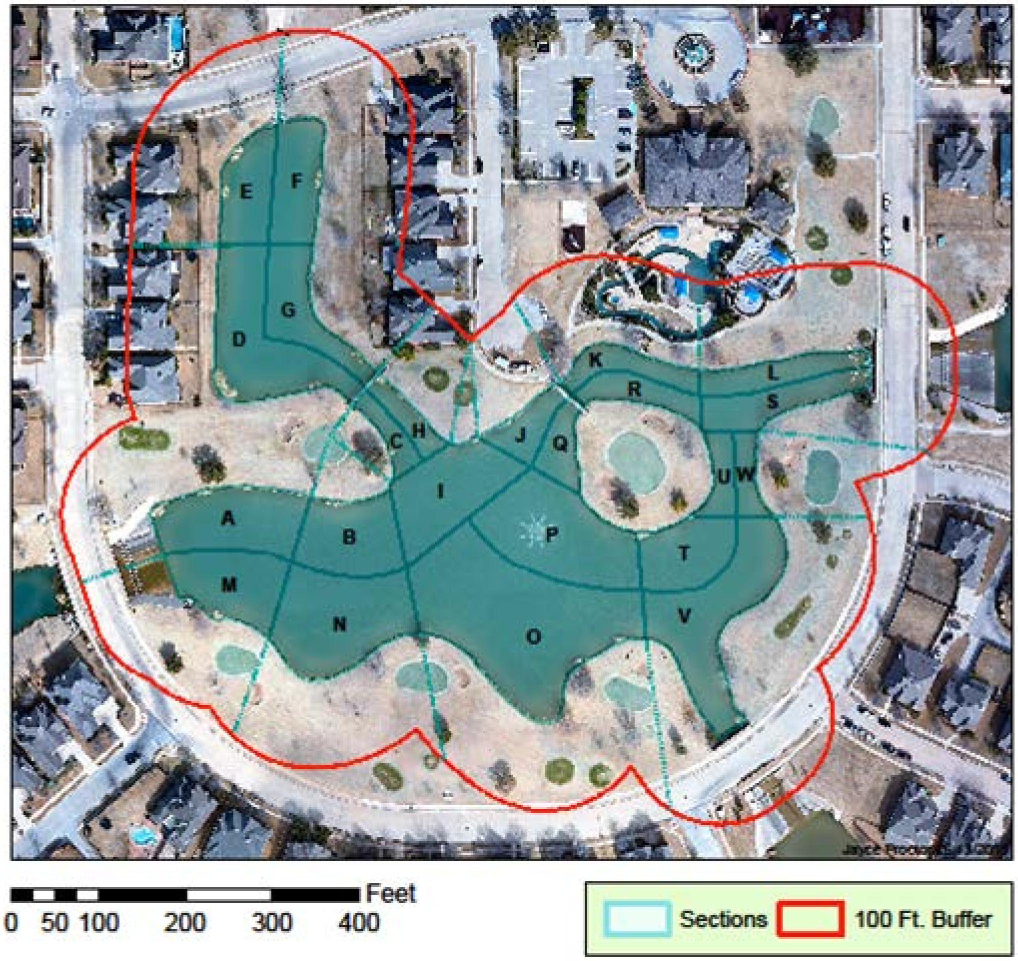
S.C. Cell 5: Small Scale Bounding and Ranking Map



H.L. Pond 1: Small Scale Bounding and Ranking Map

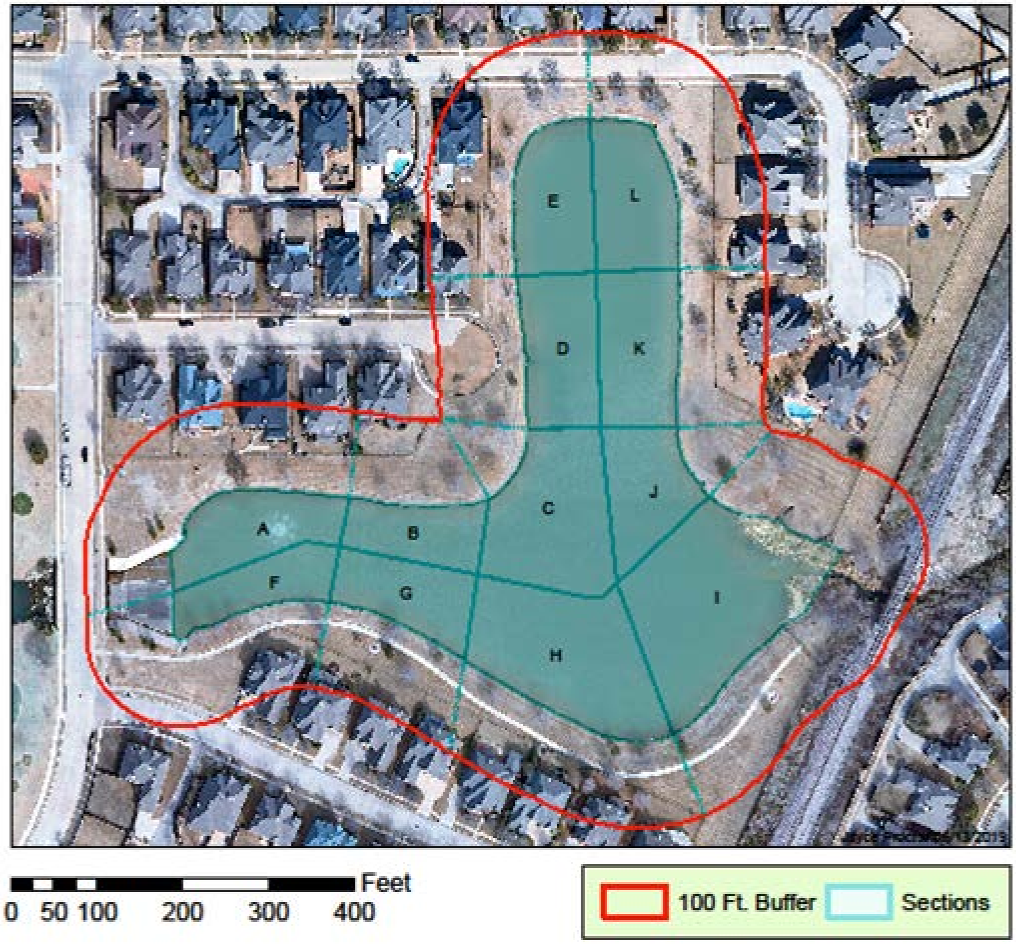
H.L. Pond 2: Small Scale Bounding and Ranking Map

H.L. Pond 3: Small Scale Bounding and Ranking Map

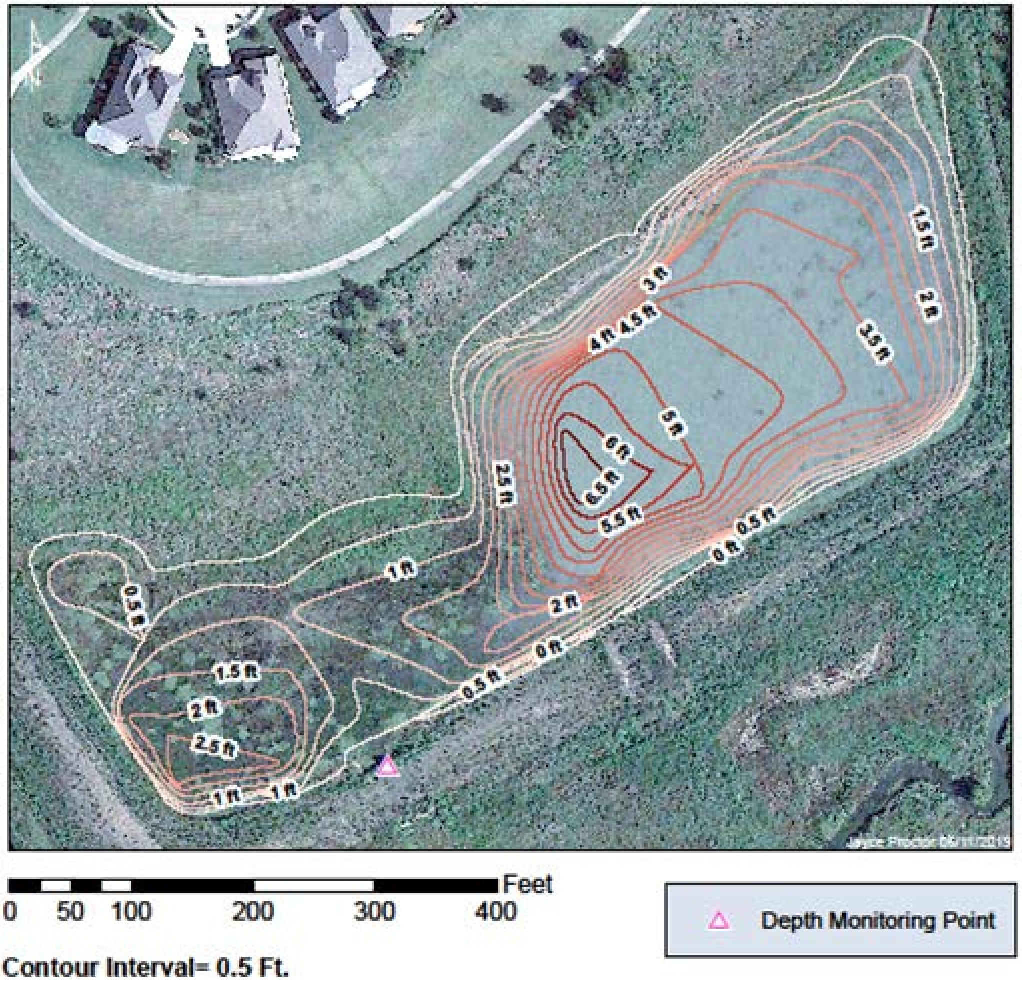


H.L. Pond 4: Small Scale Bounding and Ranking Map

H.L. Pond 5: Small Scale Bounding and Ranking Map



H.C. Cell 1: Depth Contours



Jaycee Proctor 05/11/2019

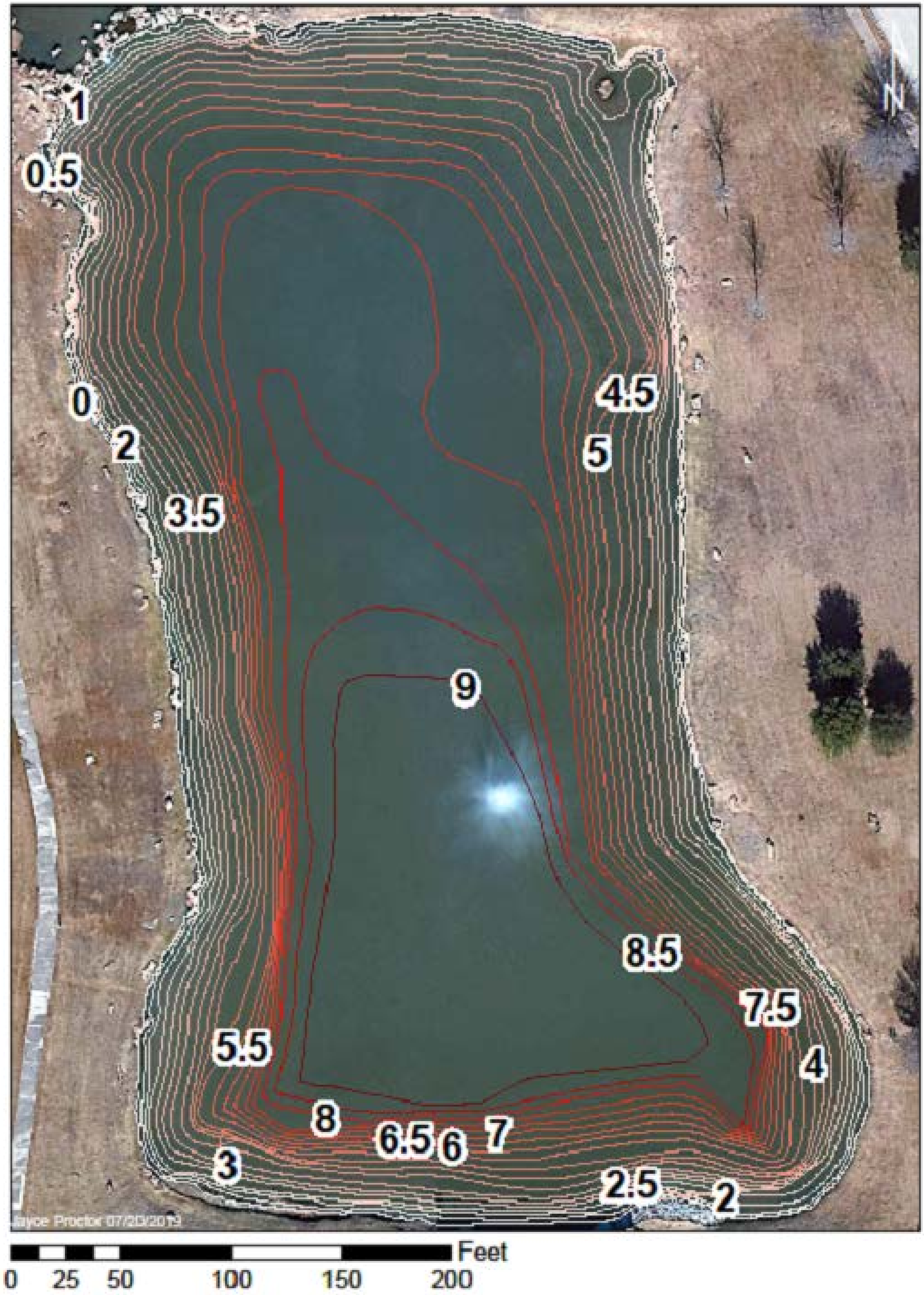
Contour Interval= 0.5 Ft.

H.C. Cell 2: Depth Contours

L.S.R Pond 1: Depth Contours

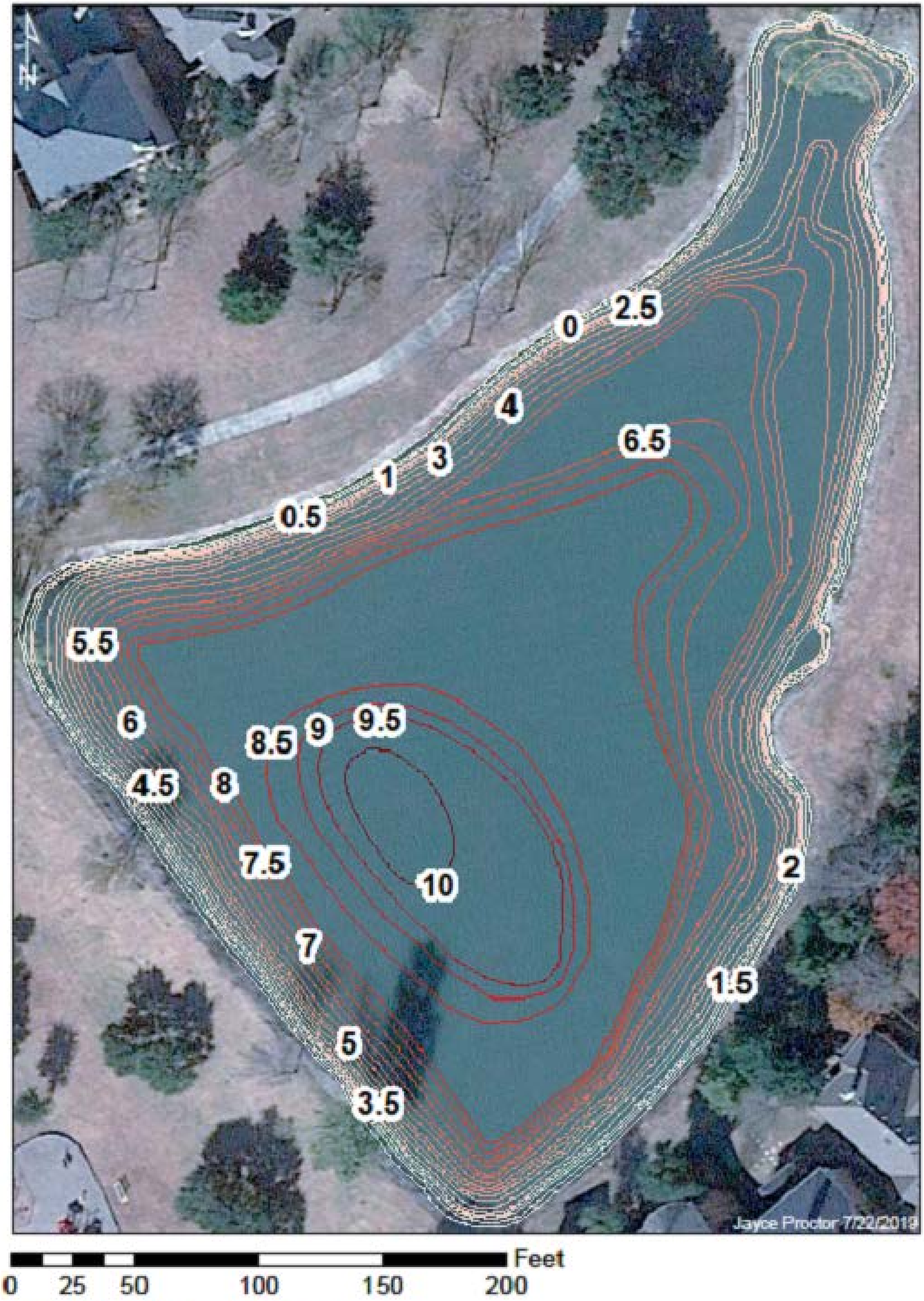
Contour Interval= 0.5 Ft.

L.S.R Pond 2: Depth Contours



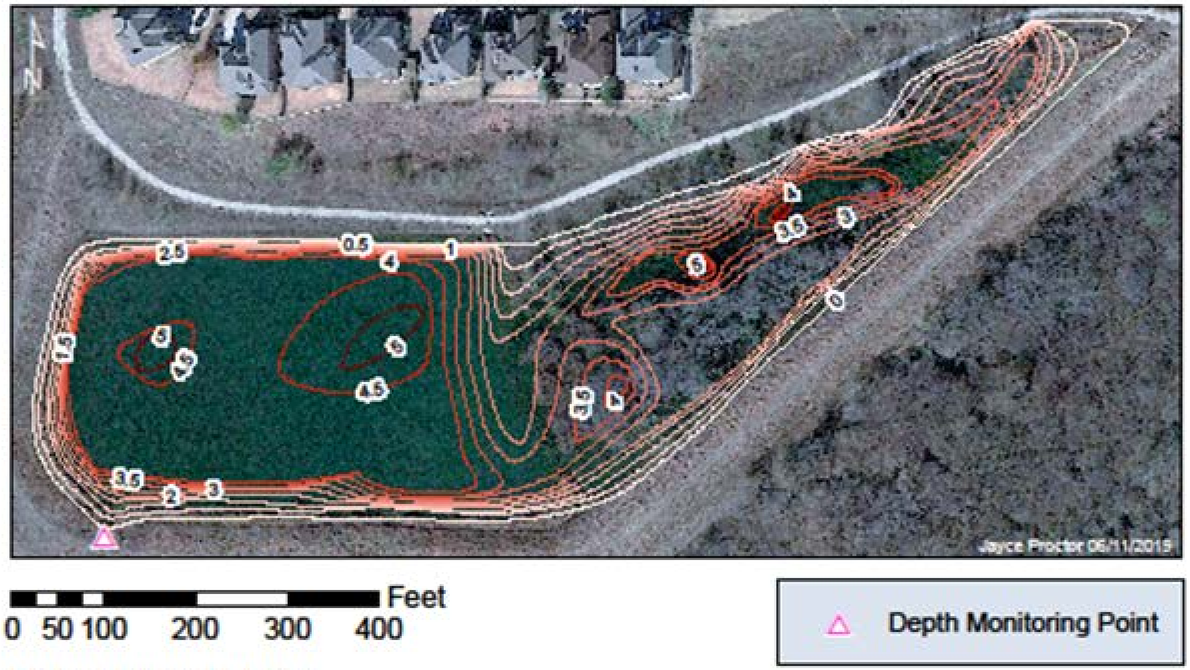
Contour Interval= 0.5 Ft.

L.S.R Pond 3: Depth Contours



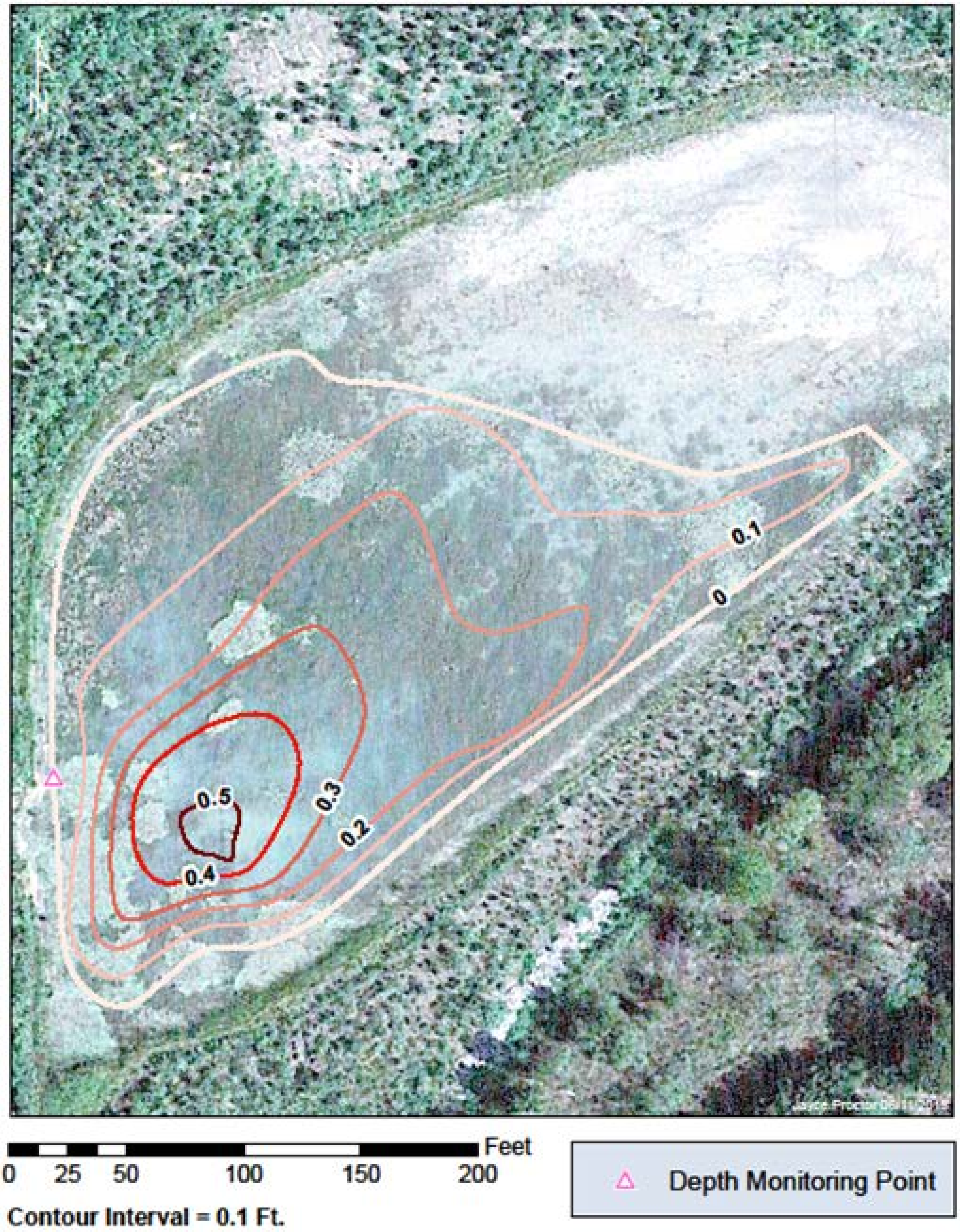
Contour Interval= 0.5 Ft.

S.C. Cell 4: Depth Contours

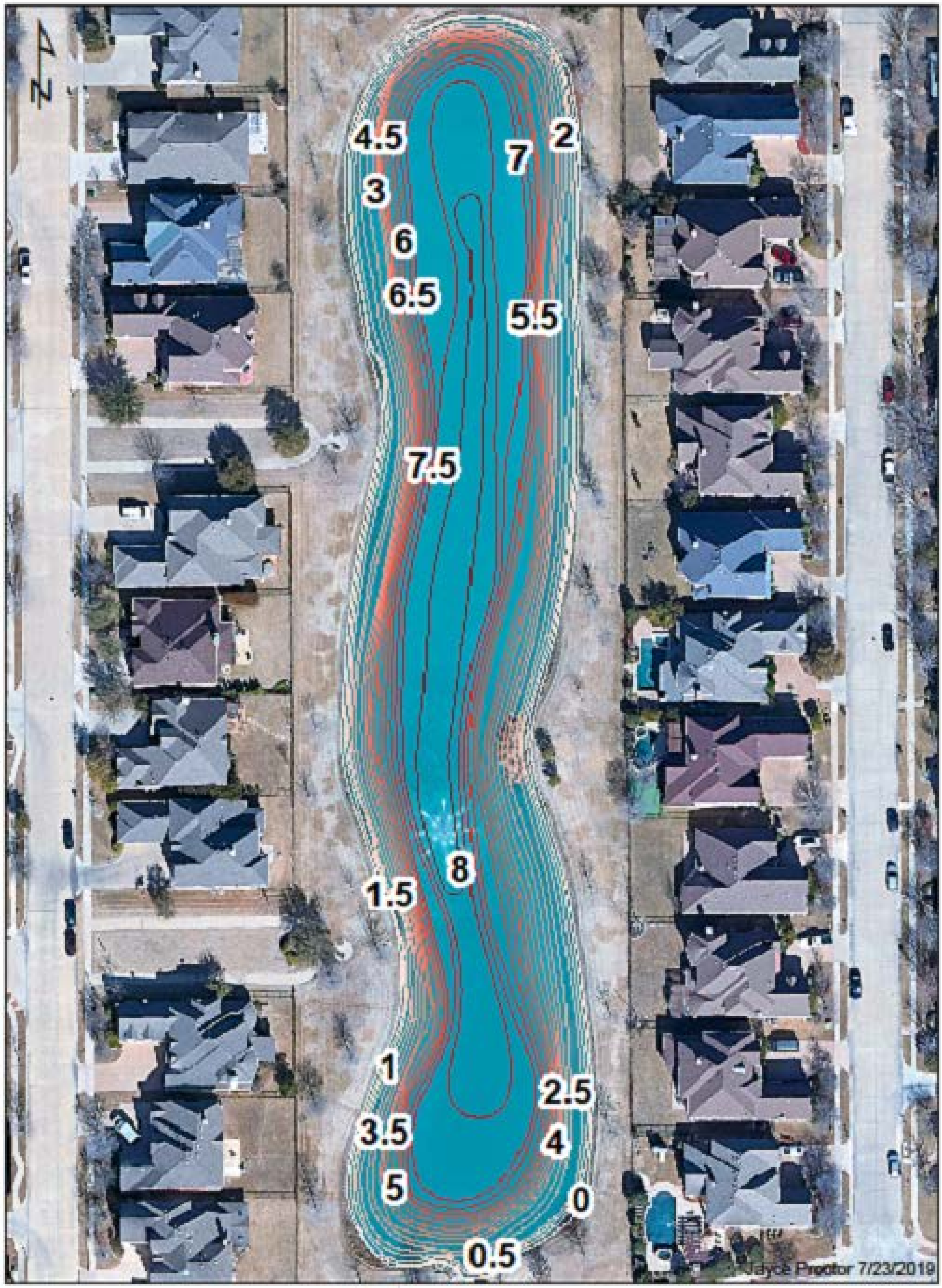


Contour Interval = 0.5 Ft.

S.C. Cell 5: Depth Contours



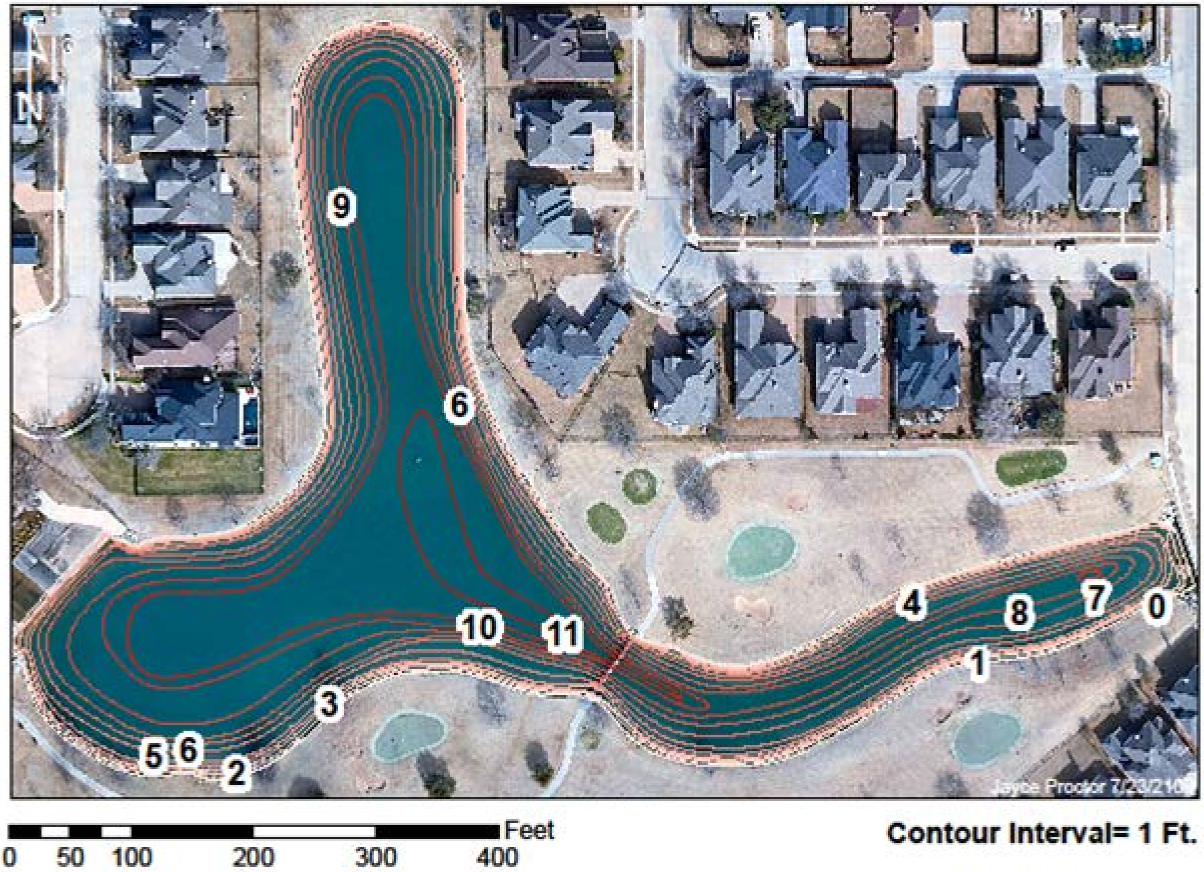
H.L. Pond 1: Depth Contours



Jayce Proctor 7/23/2019

Contour Interval= 0.5 Ft.

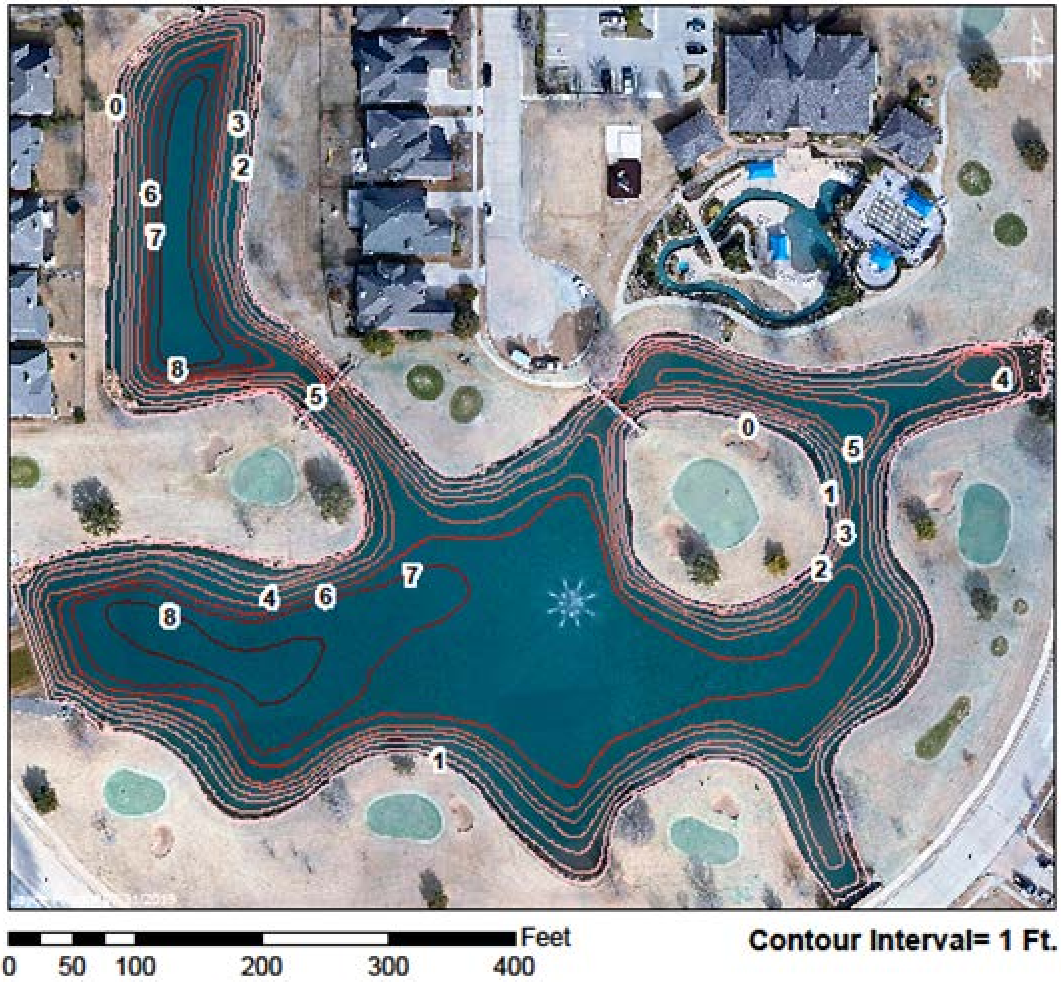
H.L. Pond 2: Depth Contours



Jayce Proctor 7/23/210

Contour Interval= 1 Ft.

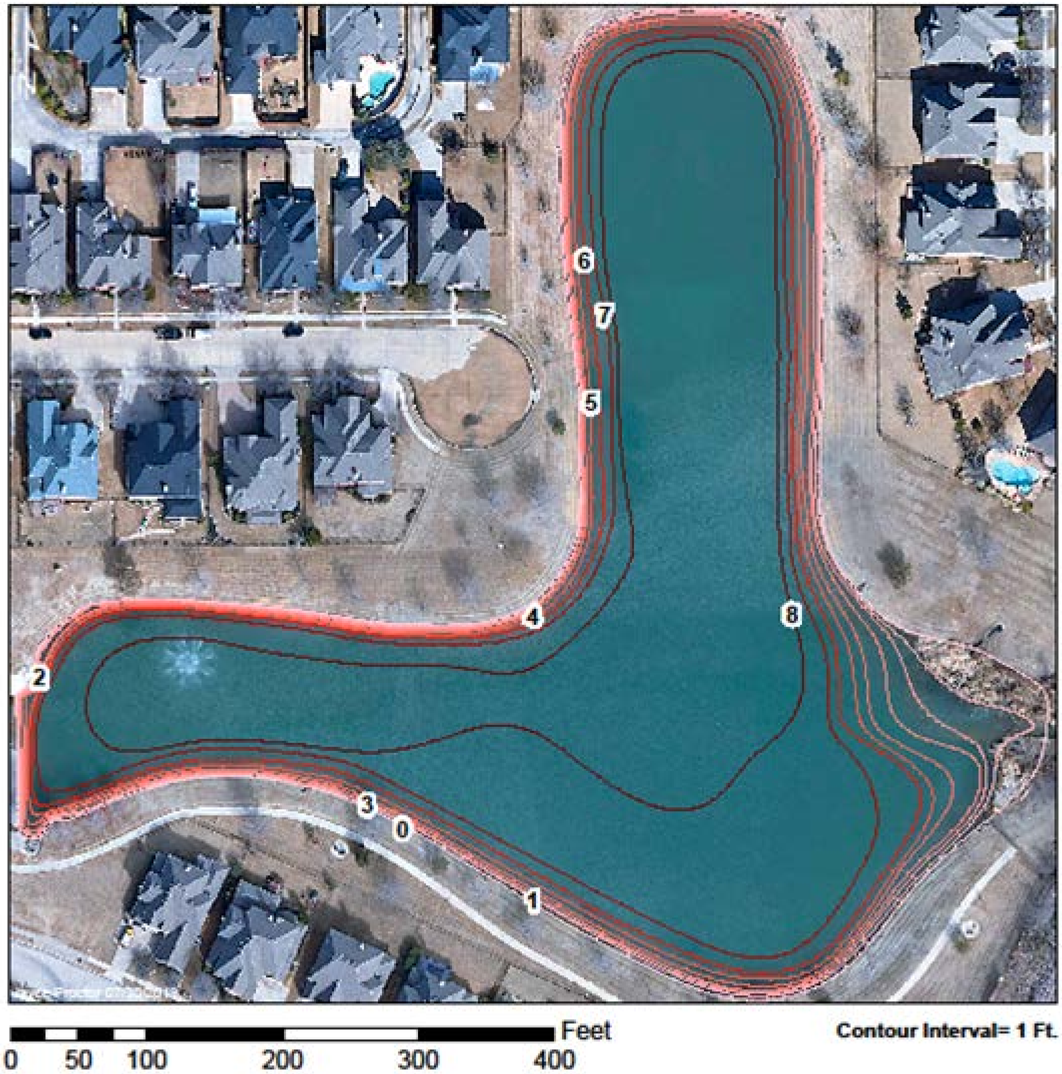
H.L. Pond 3: Depth Contours



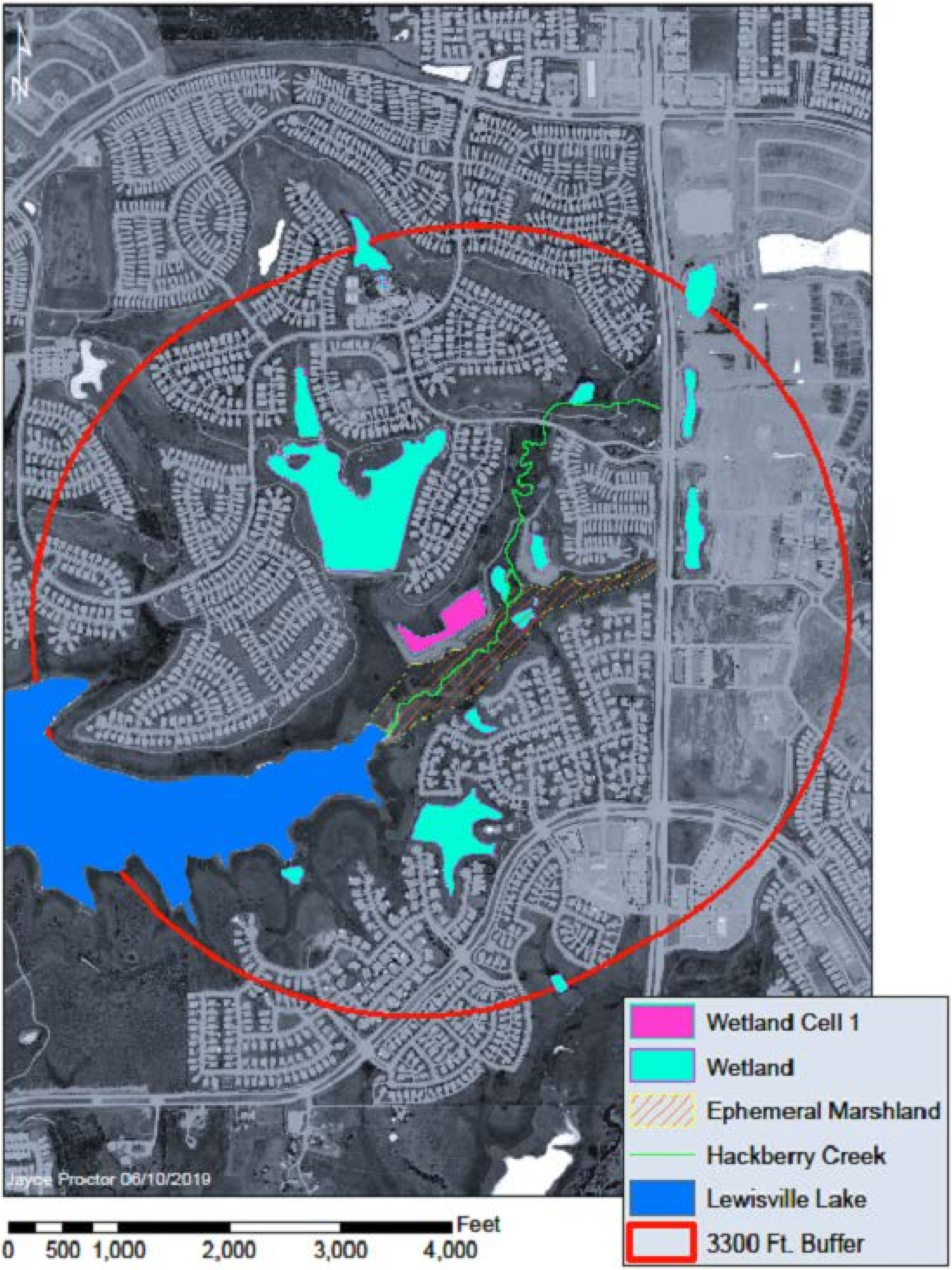
Contour Interval= 1 Ft.

H.L. Pond 4: Depth Contours

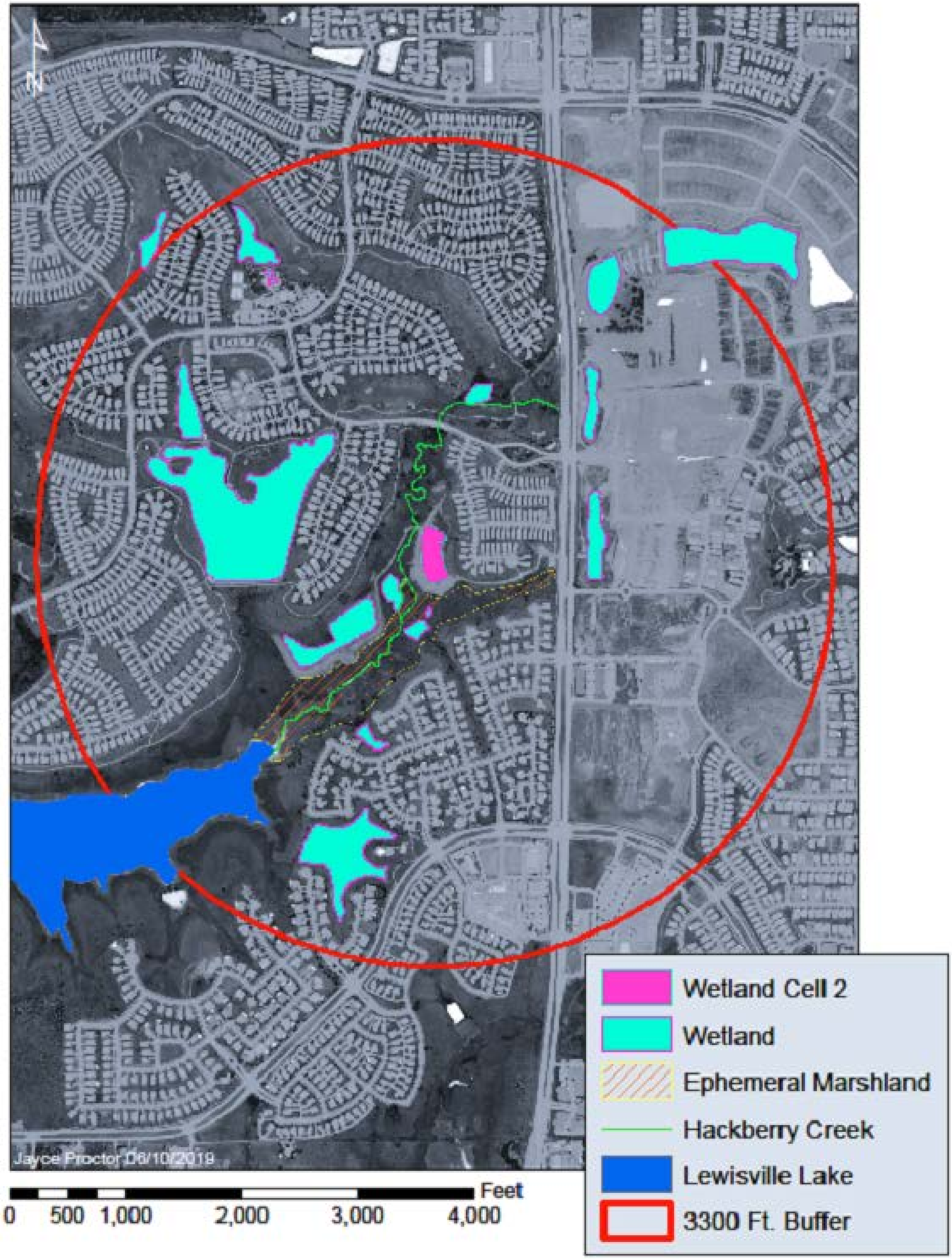
H.L. Pond 5: Depth Contours



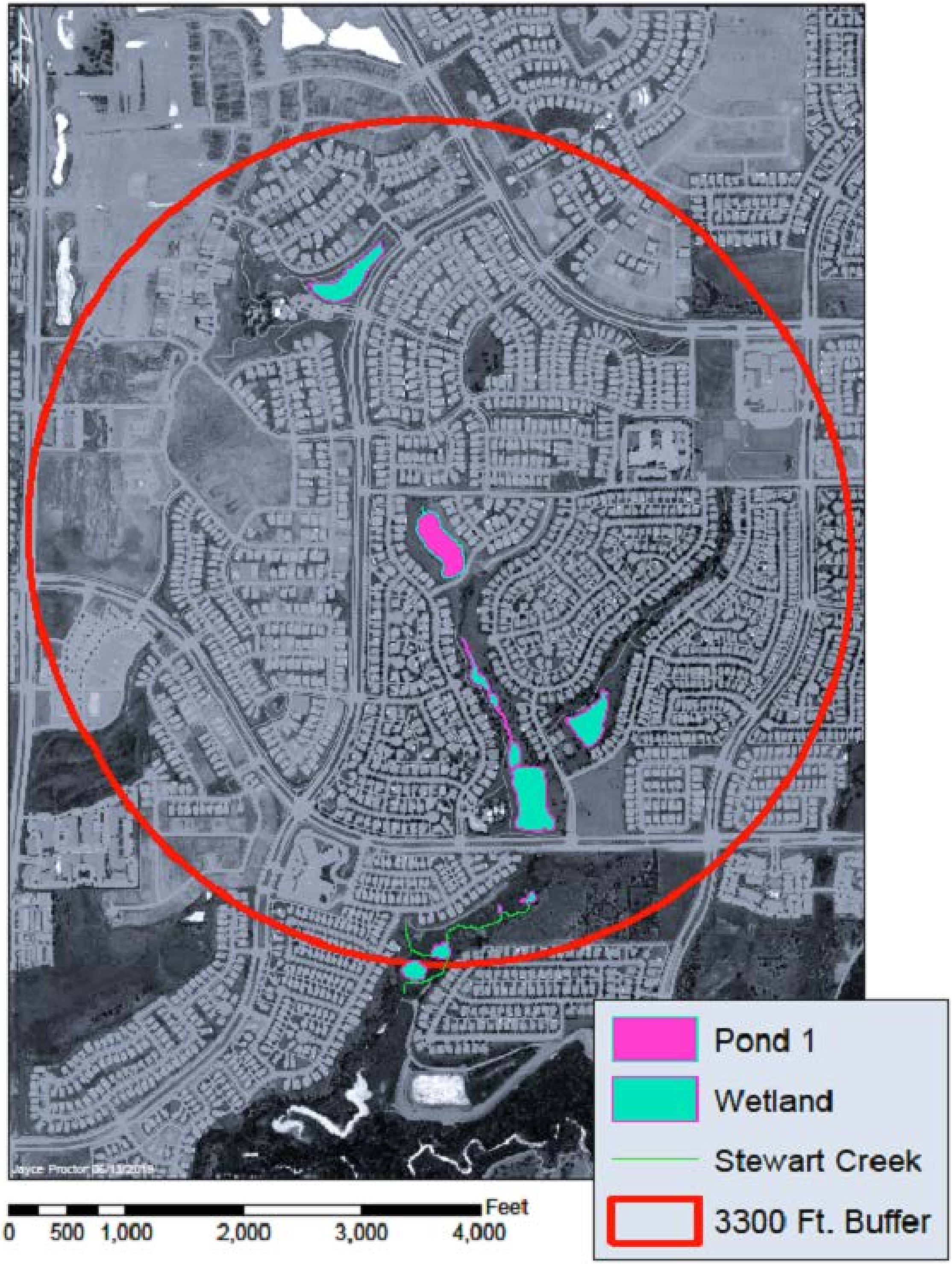
H.C. Cell 1: Distance Proximity to Landscape Variables



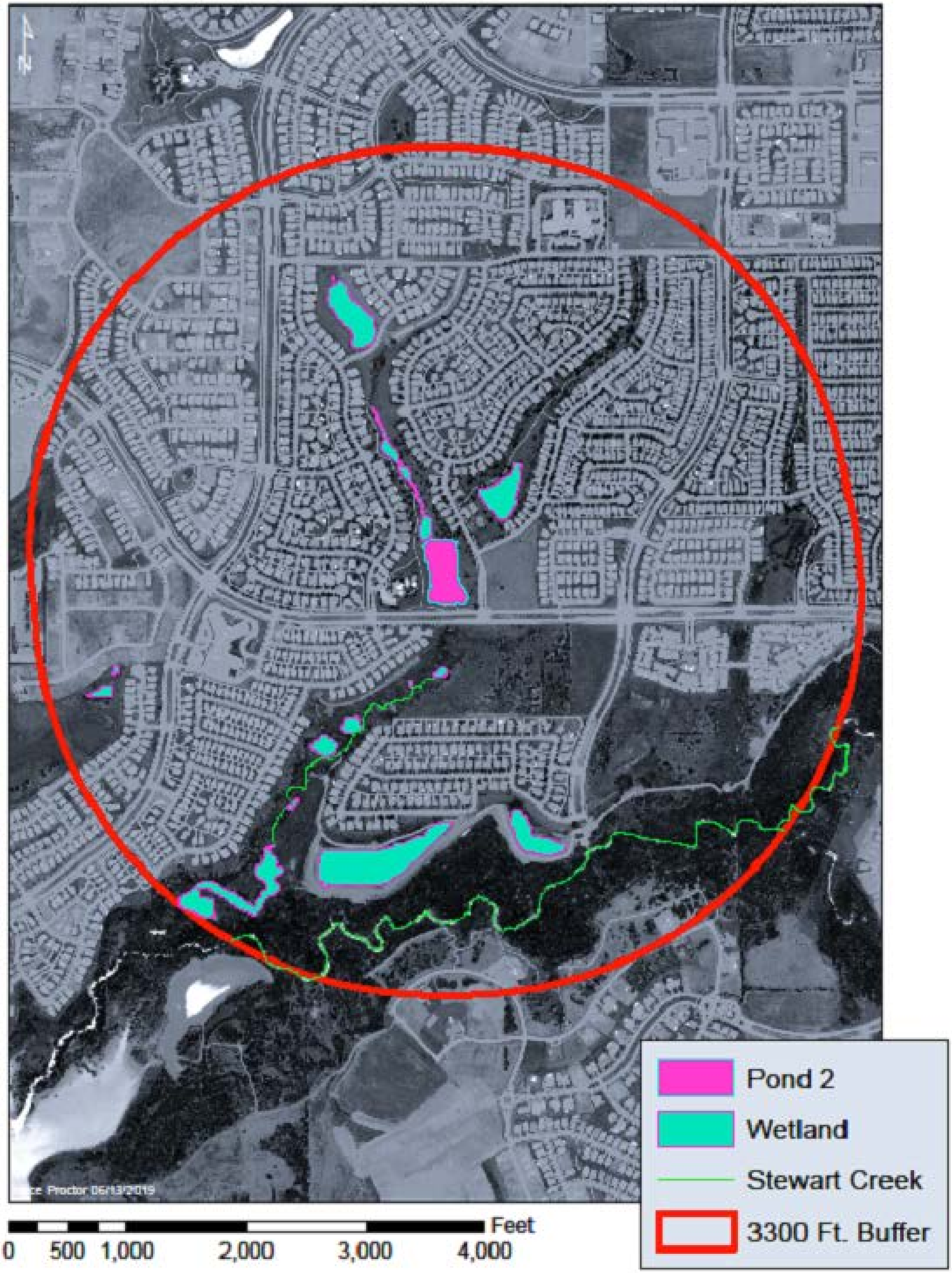
H.C. Cell 2: Distance Proximity to Landscape Variables



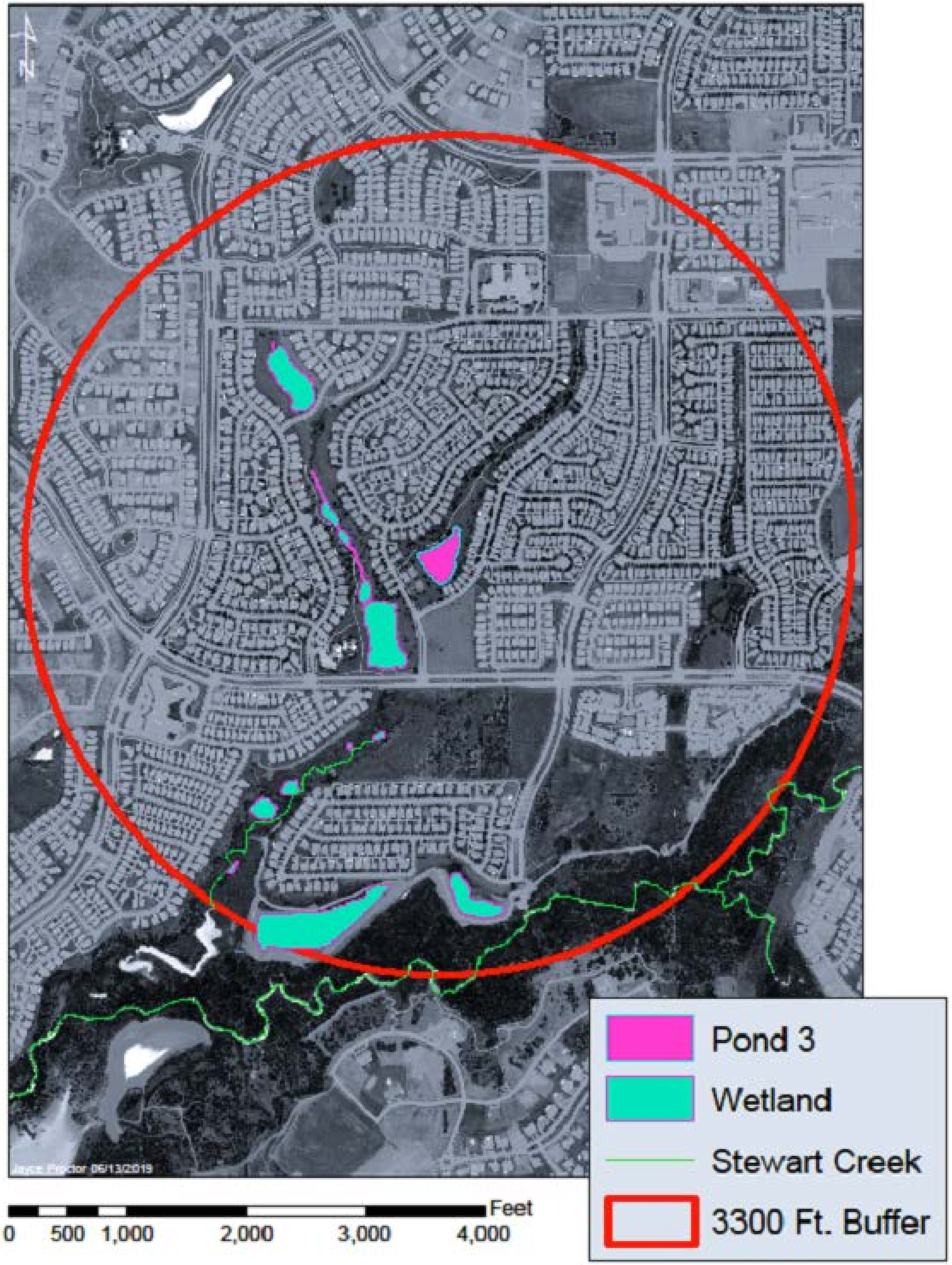
L.S.R. Pond 1: Distance Proximity to Landscape Variables



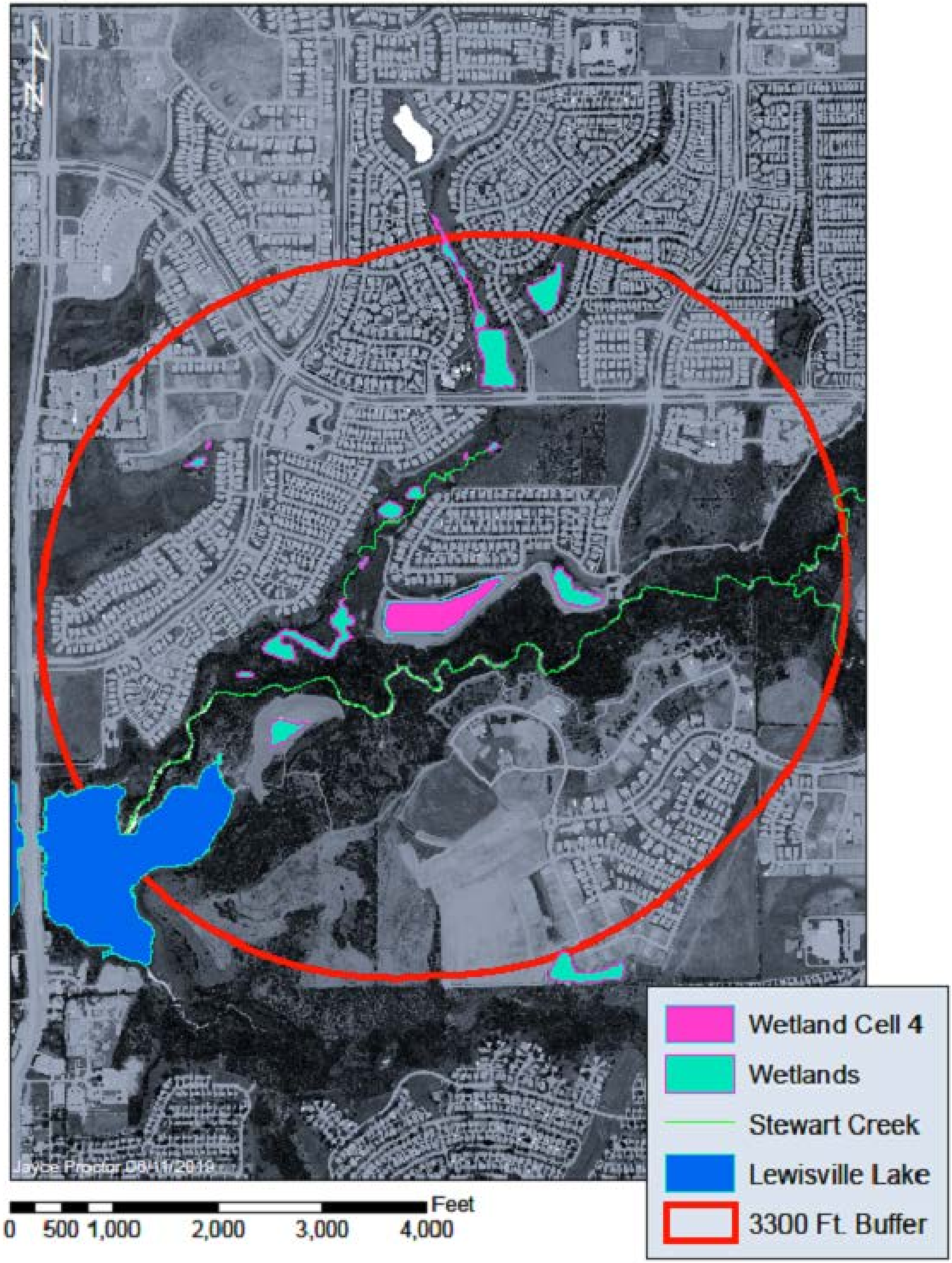
L.S.R. Pond 2: Distance Proximity to Landscape Variables



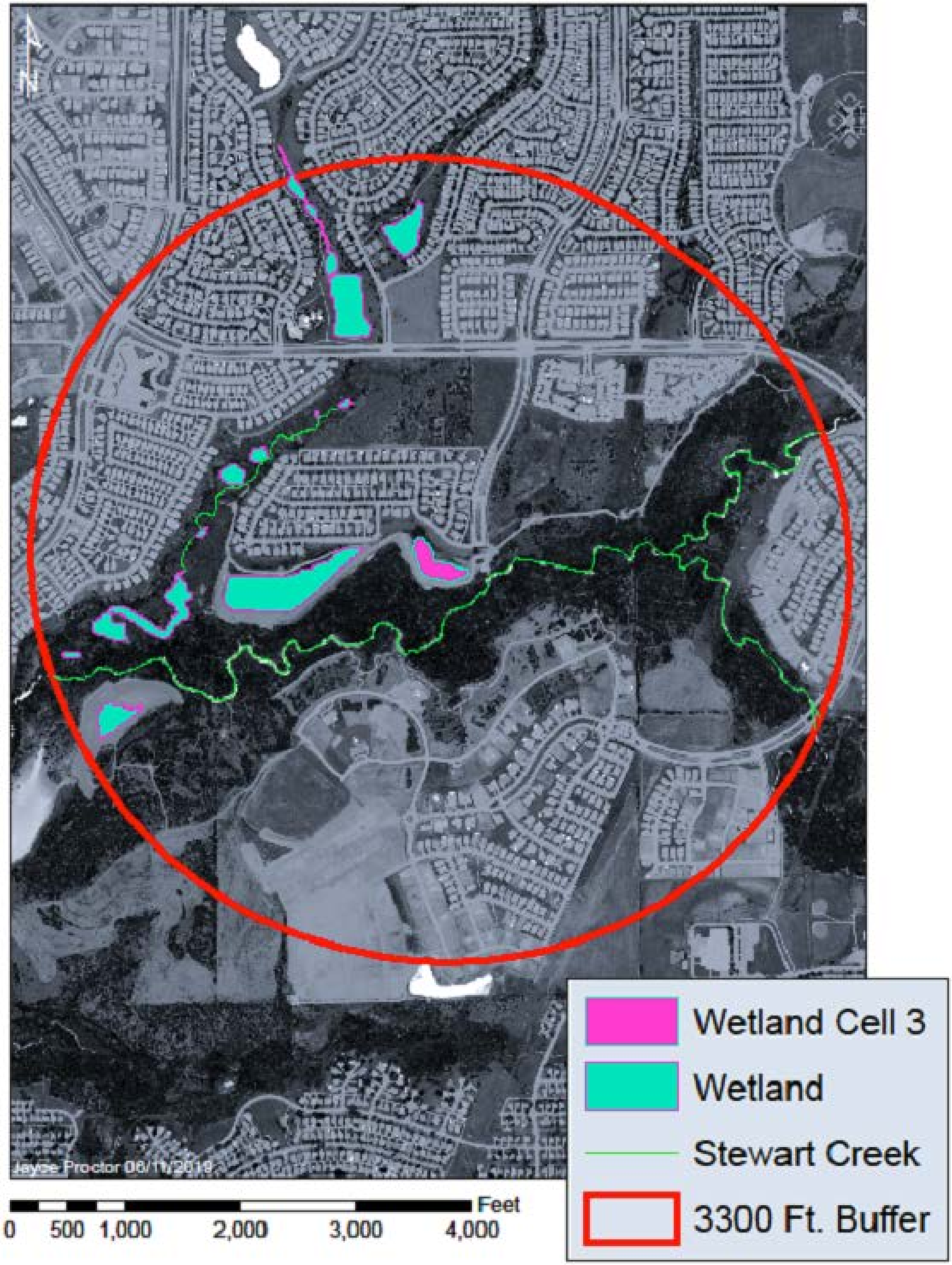
L.S.R. Pond 3: Distance Proximity to Landscape Variables



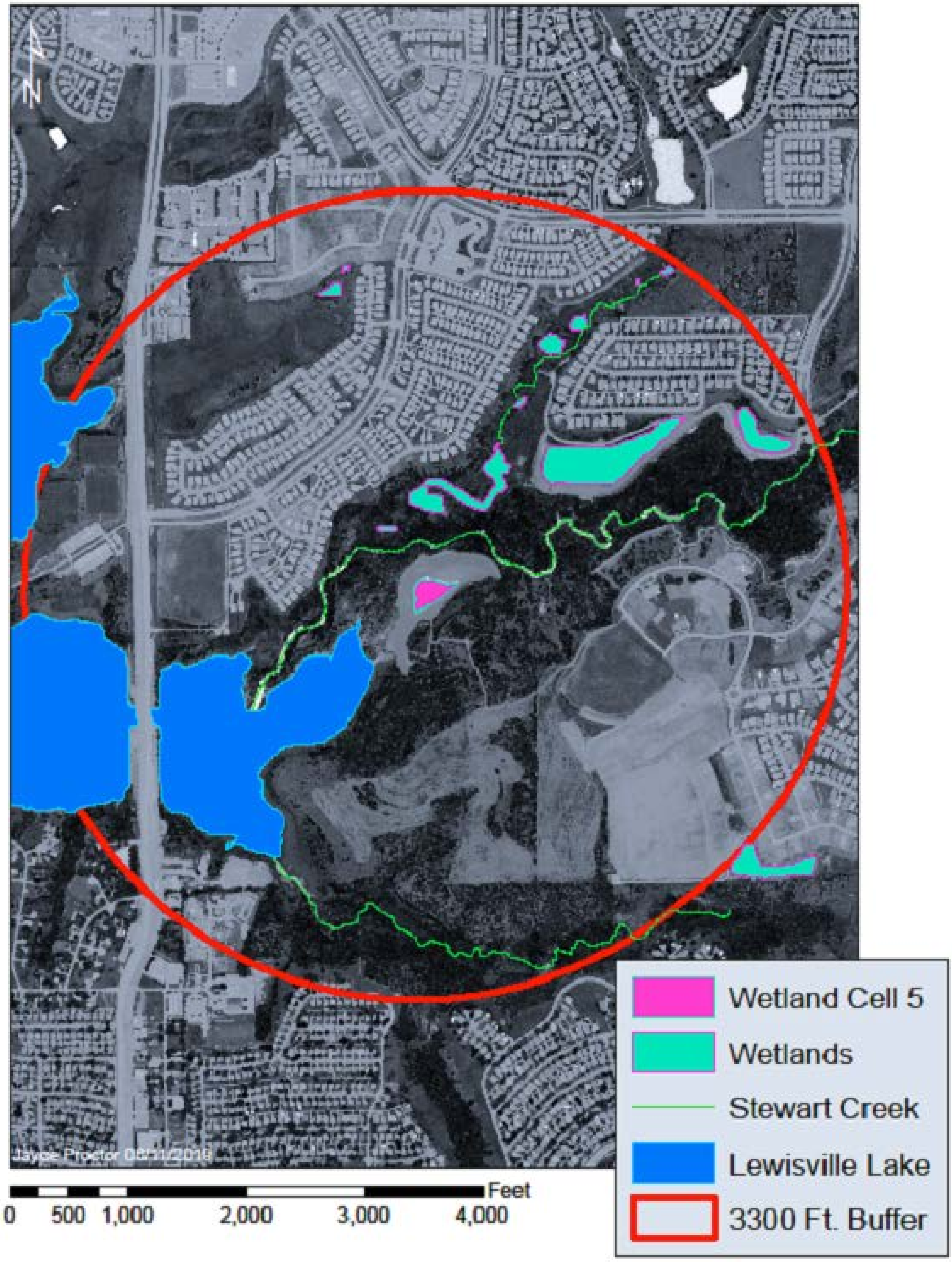
S.C. Cell 4: Distance Proximity to Landscape Variables



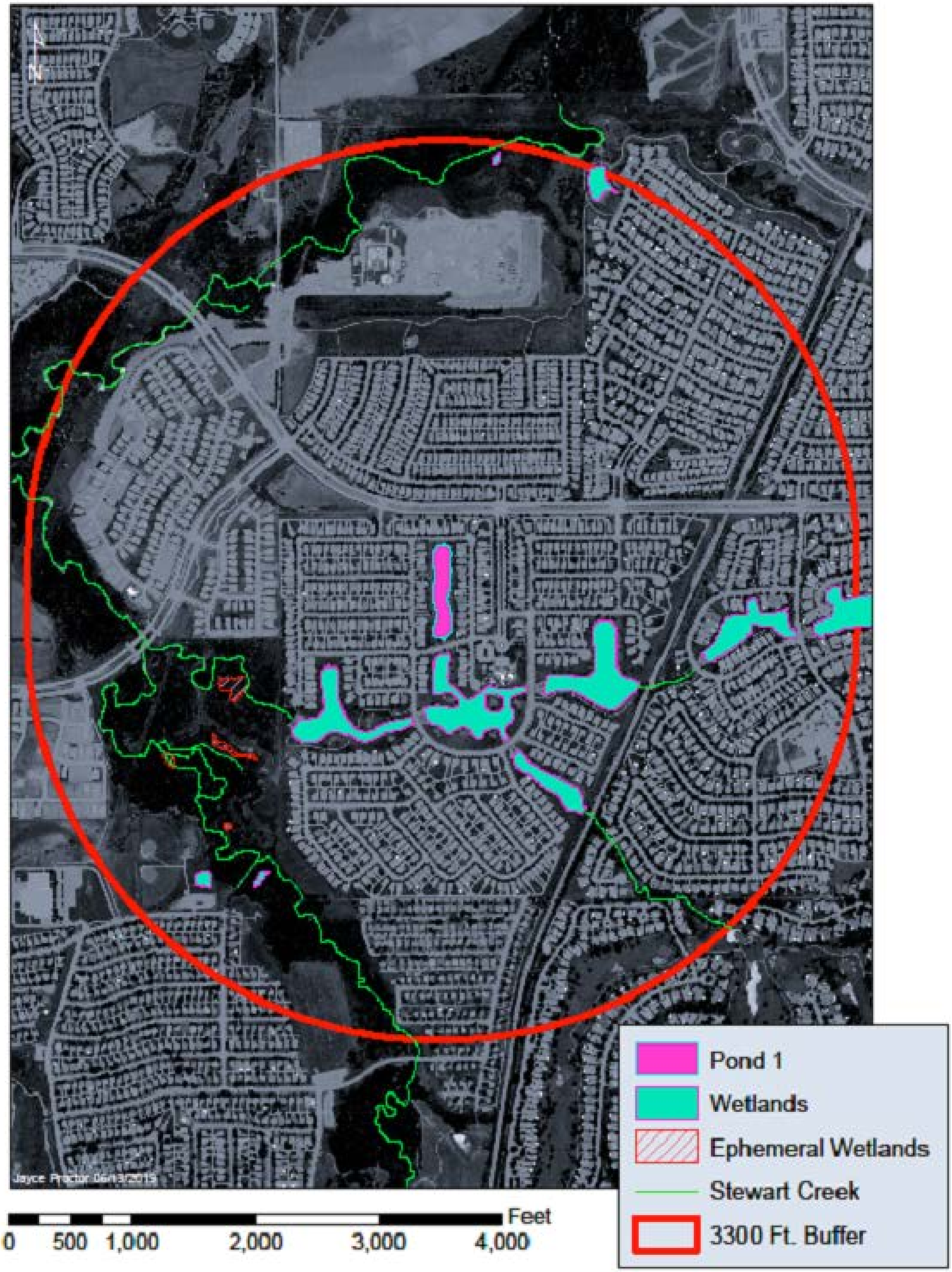
S.C. Cell 3: Distance Proximity to Landscape Variables



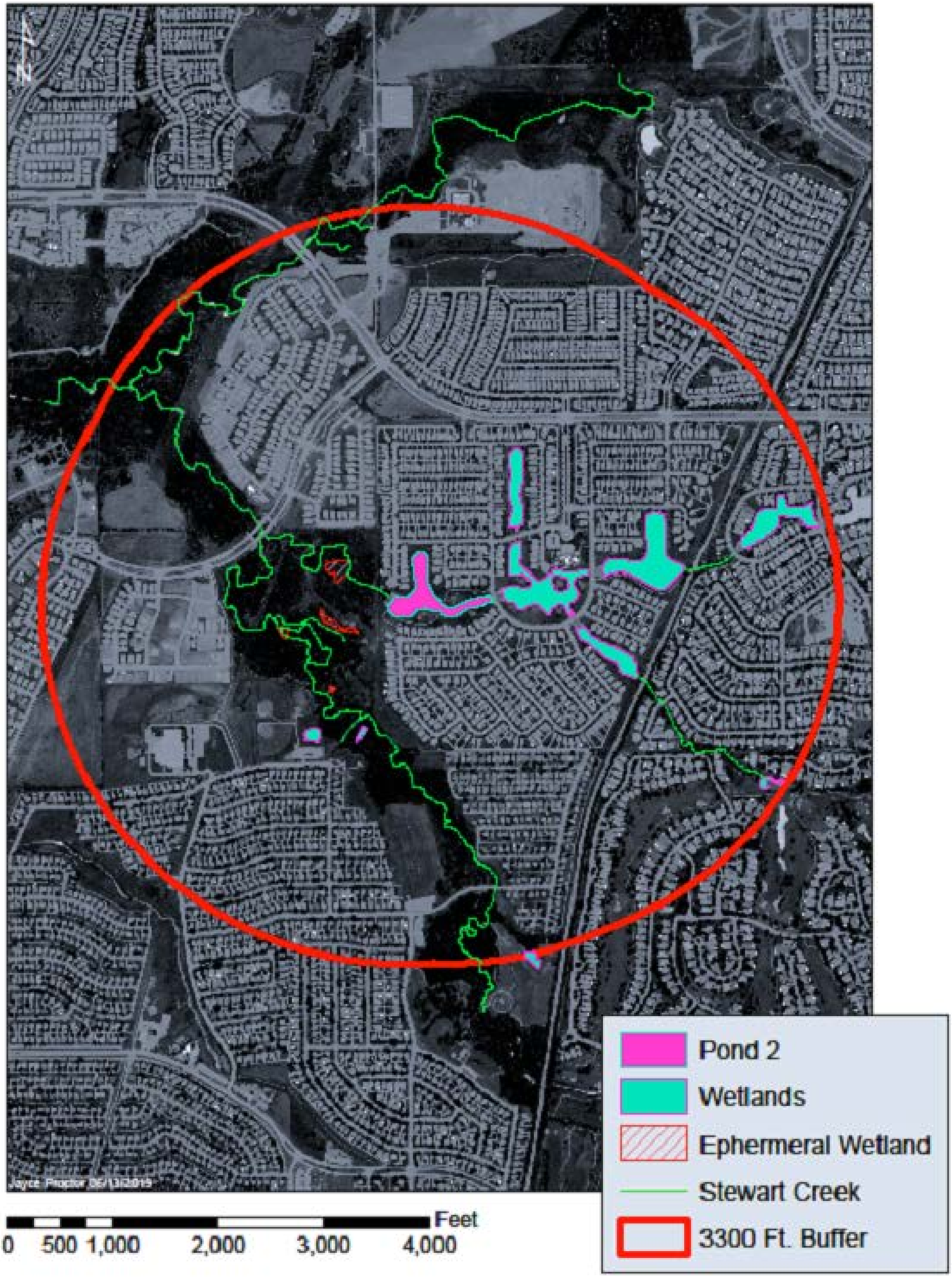
S.C. Cell 5: Distance Proximity to Landscape Variables



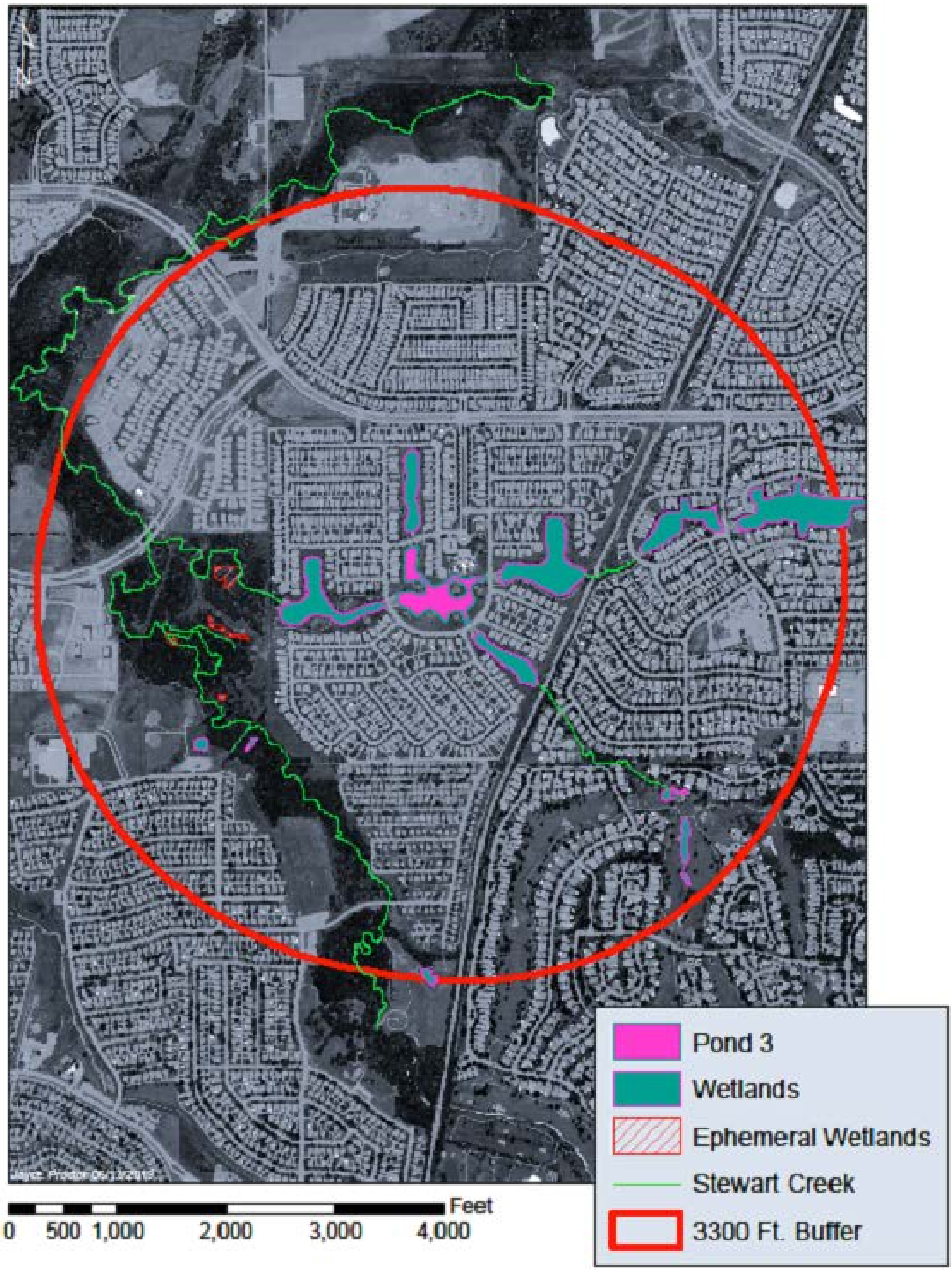
H.L. Pond 1: Distance Proximity to Landscape Variables



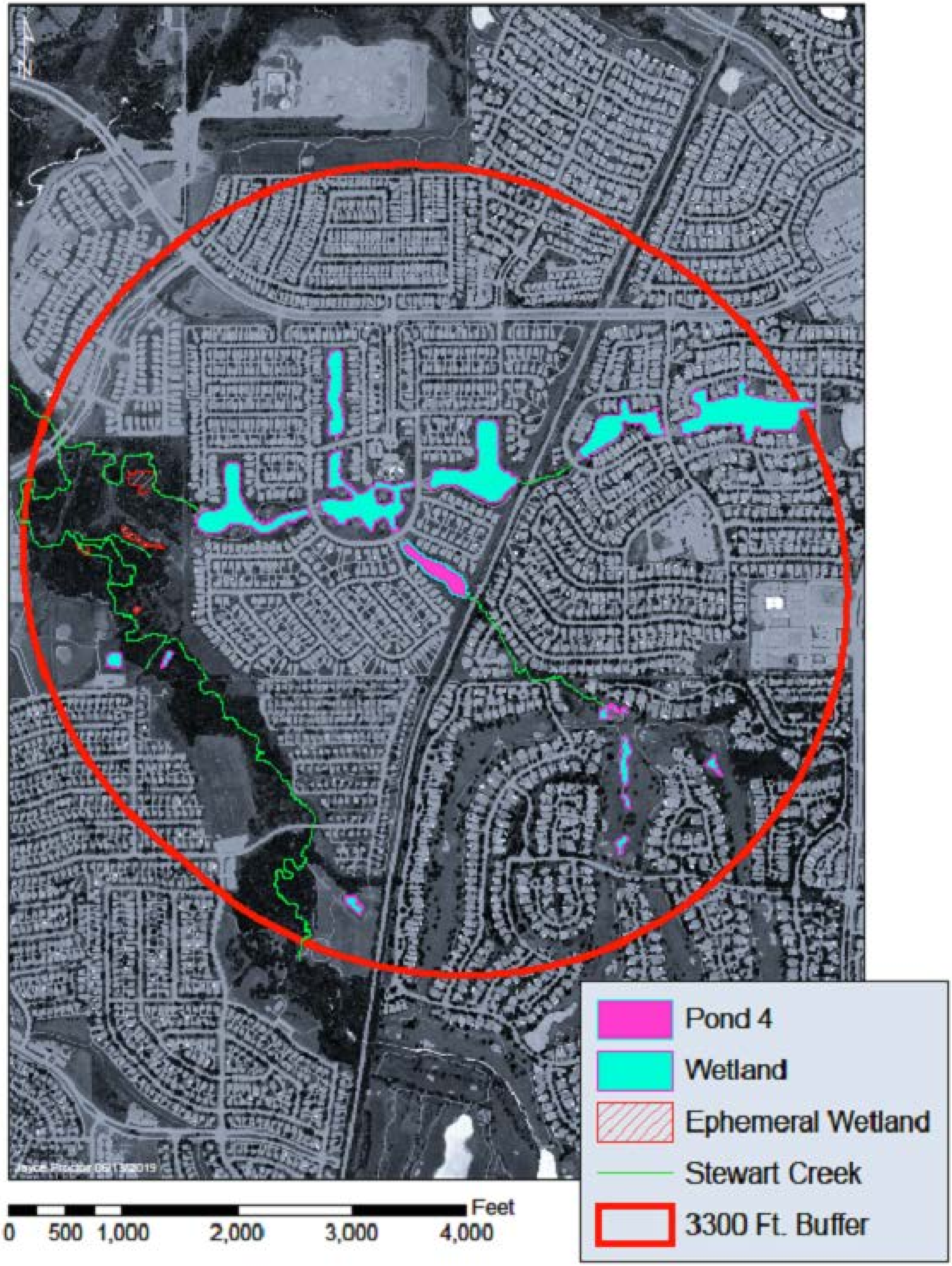
H.L. Pond 2: Distance Proximity to Landscape Variables



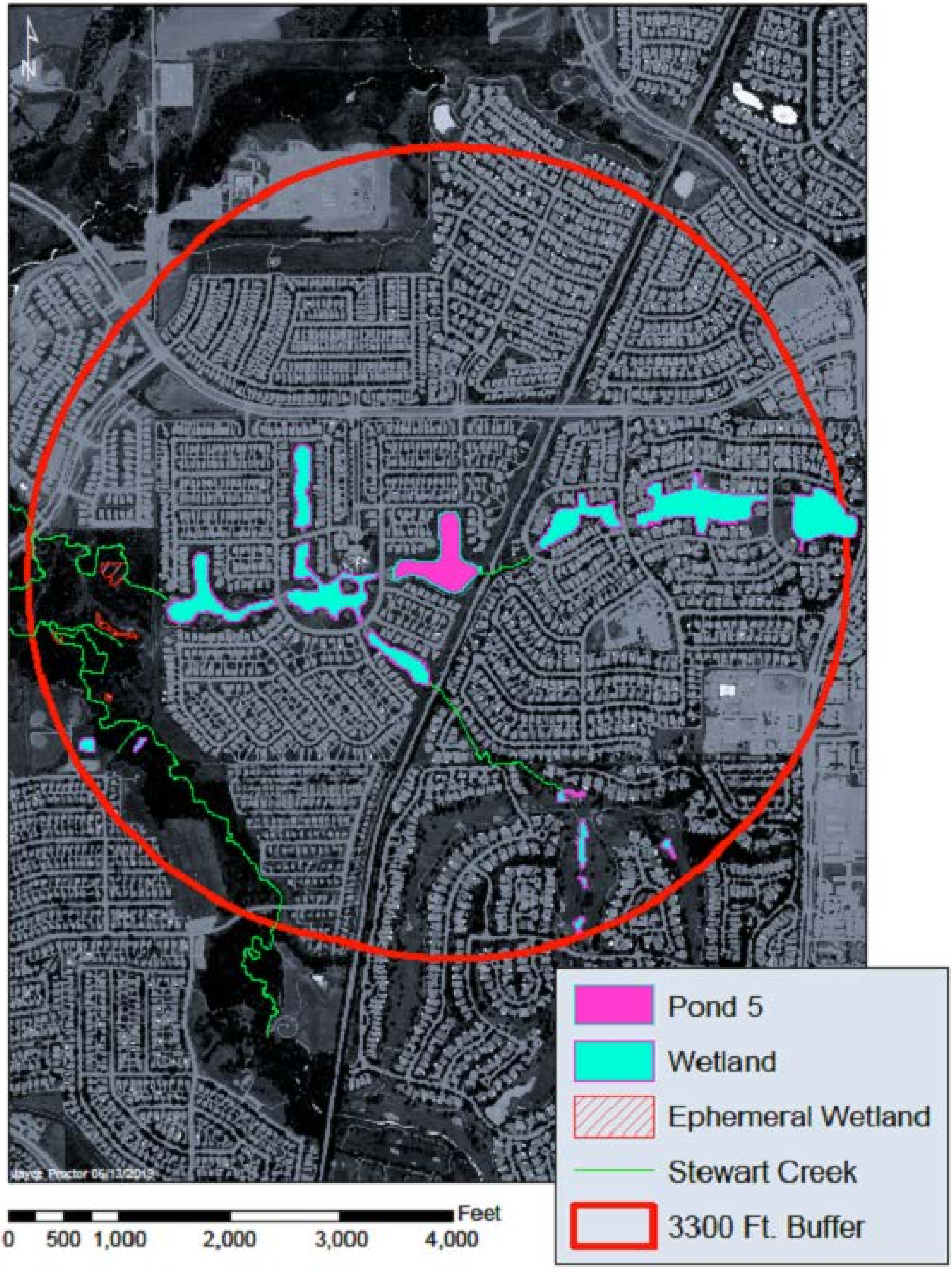
H.L. Pond 3: Distance Proximity to Landscape Variables



H.L. Pond 4: Distance Proximity to Landscape Variables



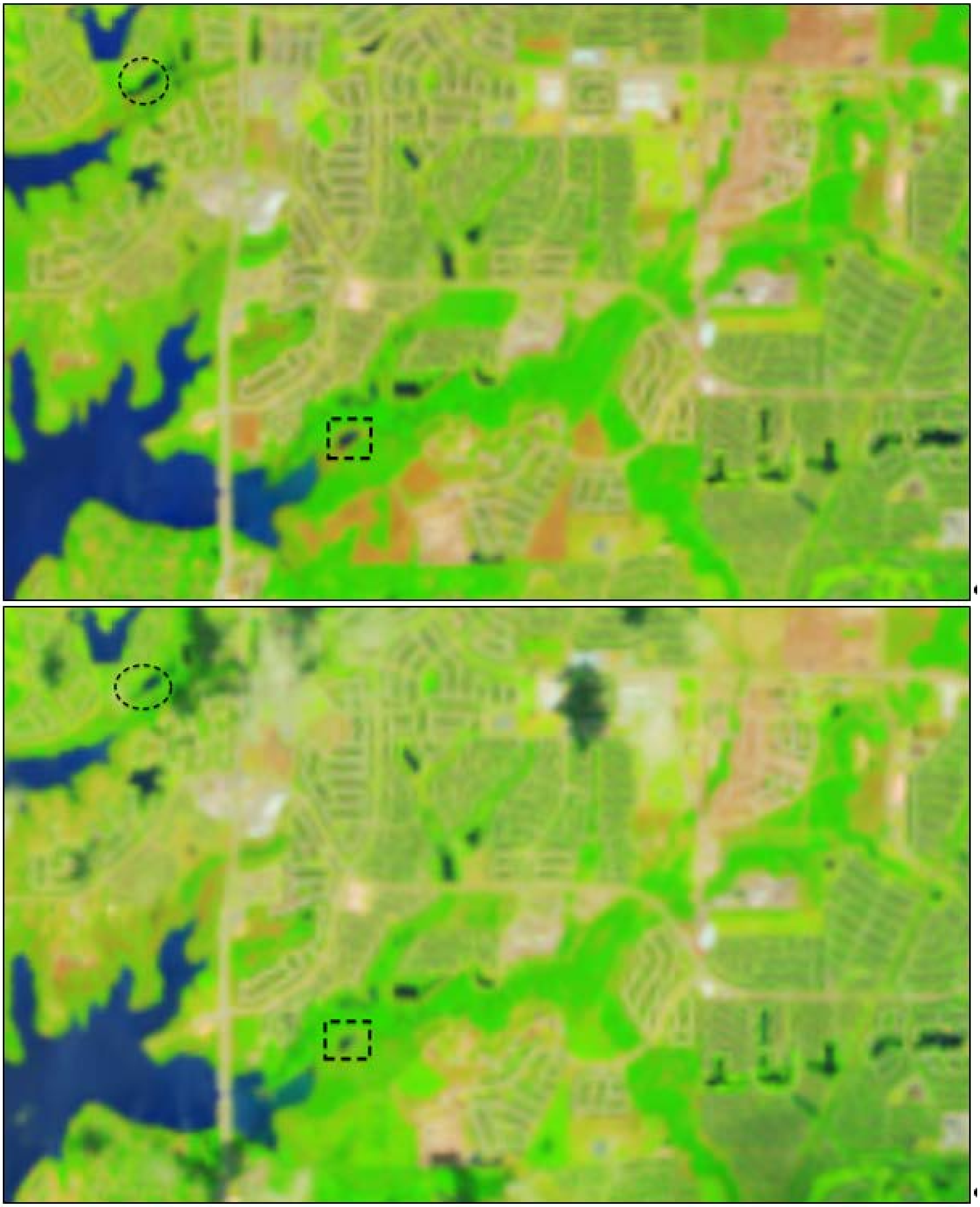
H.L. Pond 5: Distance Proximity to Landscape Variables



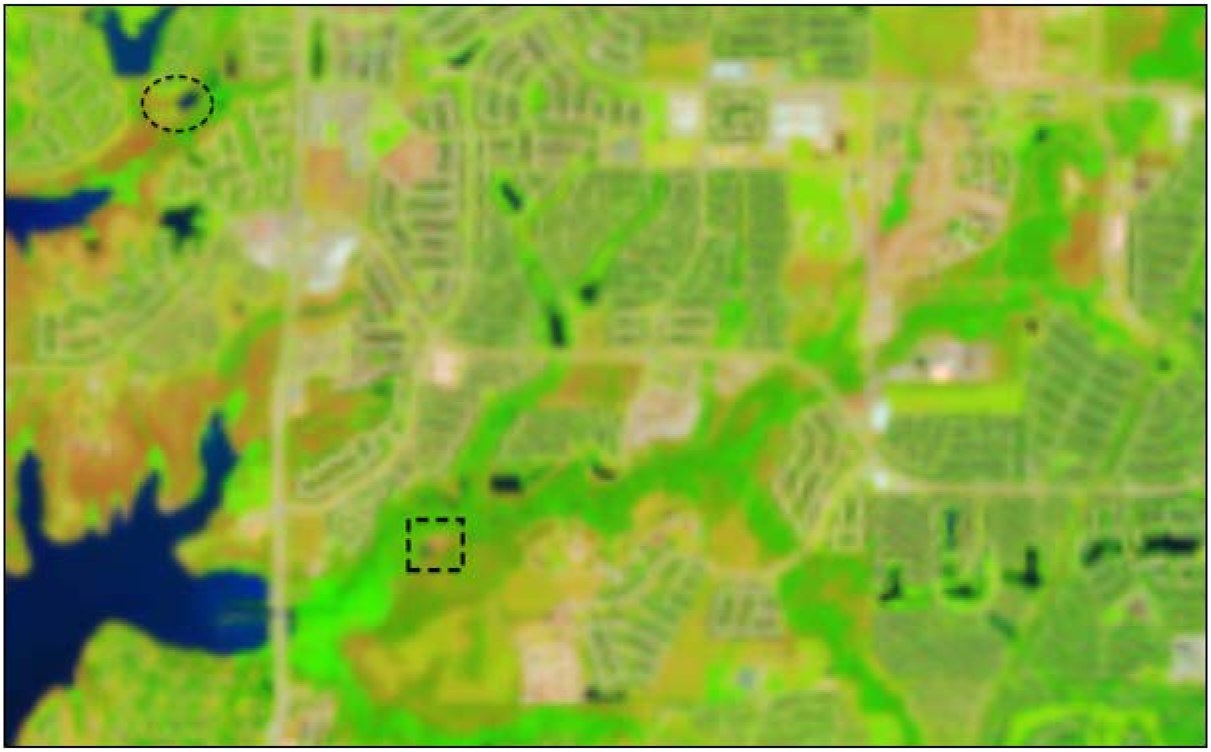
APPENDIX B

IMAGE ANALYSIS OF WETLAND CHANGE OVER TIME: FRISCO, TEXAS. EOX SENTIENIEL 2 CLOUDLESS (VEGETATION ANALYSIS BANDS 6, 5, 4)

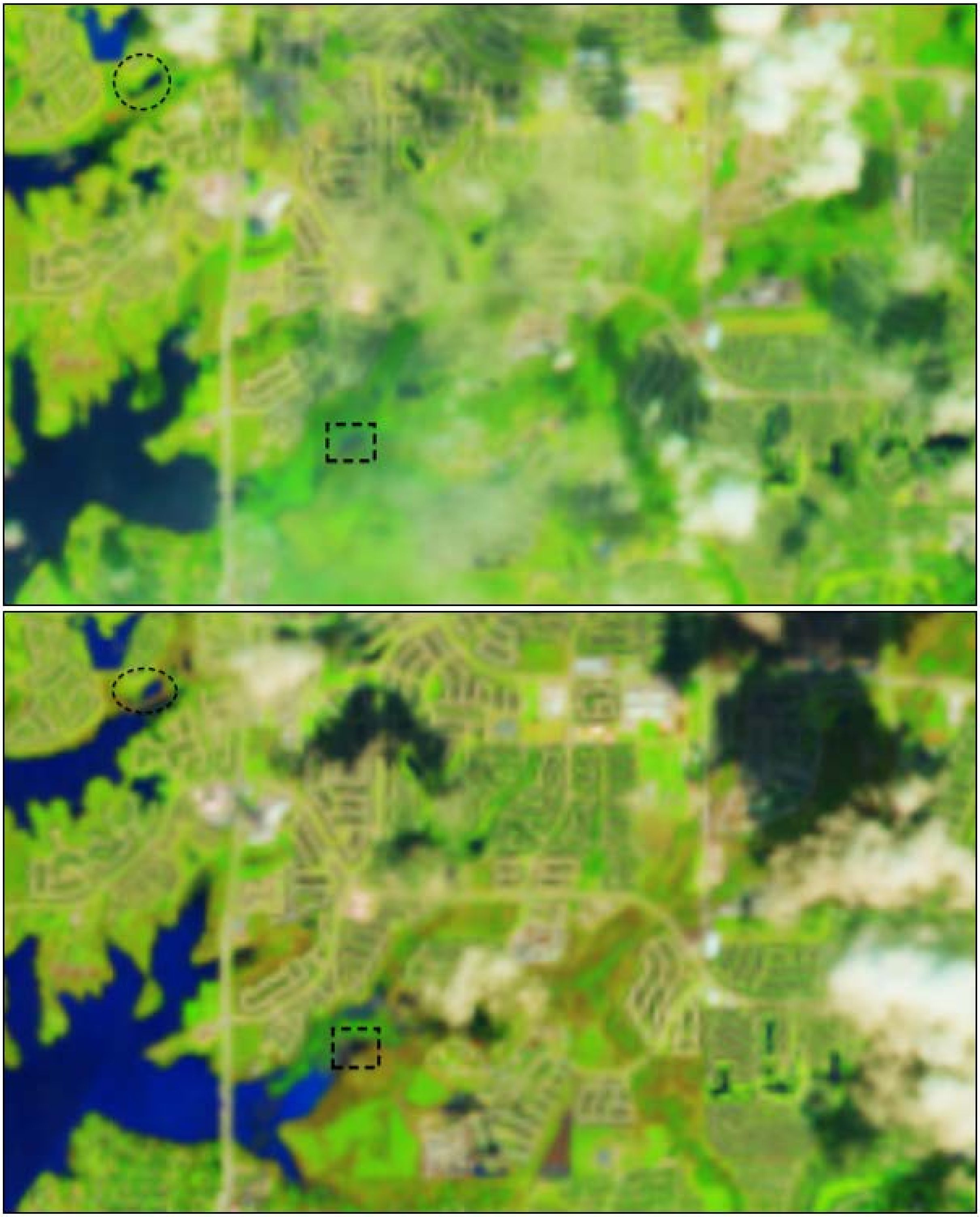
2018/05/09-2018/06/10



2018/07/12-2018/08/29



2018/09/30-2018/11/01



2018/11/17-2019/01/04

2019/03/09-2019/03/25

APPENDIX C

RAW DATA COLLECTION AND DESCRIPTIVES

3300 and 100 ft Buffer Variables

Site	Dist to Nearest Wetland (ft)	AVG Dist to wetland (ft)	# of Wetlands (Within 3300 ft)	Dist to Urban Built Env (ft)	Dist to Creek (Within 3300 ft)	Dist to Ephem Wetland (Within 3300 ft)	Dist to Lake (Within 3300 ft)	Trees* (Rank Cover Within 100 ft)	Grass* (Rank Cover Within 100 ft)	Bare Soil* (Rank Cover Within 100 ft)	Water* (Rank Cover Within 100 ft)	Urban Built Env* (Rank Cover Within 100 ft)
HC-1	116	1622	16	239	165	86	727	1	5	3	1	0
HC-2	210	1565	16	129	55	113	1966	1	5	2	1	1
SC-3	424	1940	13	119	177	0	0	2	6	1	0	0
SC-4	294	1588	16	56	276	0	1979	2	5	2	0	2
SC-5	478	2127	12	839	282	0	475	2	3	4	0	0
LSR-1	520	2077	9	14	0	0	0	1	5	1	0	2
LSR-2	11	2746	14	65	622	0	0	2	5	1	2	1
LSR-3	387	1654	11	29	1441	0	0	3	5	0	0	2
HL-1	130	1893	10	42	1331	1545	0	1	3	1	0	5
HL-2	119	1539	9	37	55	350	0	1	3	1	0	2
HL-3	119	1633	12	20	841	1410	0	1	5	1	0	3
HL-4	134	1752	14	14	0	2066	0	1	3	2	1	3
HL-5	144	1881	14	35	0	2383	0	1	4	1	1	3

*Ranking cover scheme (0= not present, 1= .01-5%, 2= 6-25%, 3= 25-50%, 4= 51-75%, 5= 76-95%, 6=96-100%)

Depth (ft) and Other Variables

Site:	Depth 1 01/10/2018	Depth 2 08/26/2018	Depth 3 12/07/2018	Depth 4 03/18/2019	Deepest Depth (Contour Survey)	AVG Depth	Fish Feeder	Fence Post
HC-1	6.5	4.1	6.5	6.6	6	6.5	No	Yes
HC-2	5.5	3.1	4.9	5	5	4	No	Yes
SC-3	6.5	5.9	6.5	6.6	6	6	No	No
SC-4	5.5	4.2	7	7.2	6	6.5	No	No
SC-5	1.8	0.8	4.5	1.9	0.5	0.5	No	No
LSR-1	-	-	-	-	8.5	8.5	No	No
LSR-2	-	-	-	-	9.5	9.5	No	No
LSR-3	-	-	-	-	10	10	No	No
HL-1	-	-	-	-	8	8	No	No
HL-2	-	-	-	-	11	11	Yes	No
HL-3	-	-	-	-	8.5	8.5	No	No
HL-4	-	-	-	-	3.5	3.5	No	No
HL-5	-	-	-	-	8.5	8.5	Yes	No

Tree Species Rank Cover within 100 ft Buffer

Site	Sect.	Tree Species														
		Black Willow	Bald Cypress	Cedar Elm	Green Ash	Red Oak	Live Oak	Pistache	Honey Locust	Mesquite	Cotton Wood	Southern Magnolia	Eastern Red Cedar	Hawthorn	Sugar Berry	Osage Orange
HC-1	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HC-1	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HC-1	C	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
HC-1	D	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
HC-1	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HC-1	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HC-1	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HC-1	H	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
HC-2	A	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
HC-2	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HC-2	C	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
HC-2	D	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
HC-2	E	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
HC-2	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HC-2	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HC-2	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	A	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
SC-4	B	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	D	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	E	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	F	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	G	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	H	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

(table continues)

Site	Sect.	Tree Species														
		Black Willow	Bald Cypress	Cedar Elm	Green Ash	Red Oak	Live Oak	Pistache	Honey Locust	Mesquite	Cotton Wood	Southern Magnolia	Eastern Red Cedar	Hawthorn	Sugar Berry	Osage Orange
SC-4	I	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	J	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	K	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	L	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	M	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-4	N	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-3	A	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
SC-3	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC-3	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC-3	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC-3	E	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-3	F	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-3	G	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-3	H	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-5	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC-5	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC-5	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC-5	D	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-5	E	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SC-5	F	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
LSR-1	A	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0
LSR-1	B	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
LSR-1	C	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
LSR-1	D	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
LSR-1	E	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
LSR-1	F	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0

(table continues)

Site	Sect.	Tree Species														
		Black Willow	Bald Cypress	Cedar Elm	Green Ash	Red Oak	Live Oak	Pistache	Honey Locust	Mesquite	Cotton Wood	Southern Magnolia	Eastern Red Cedar	Hawthorn	Sugar Berry	Osage Orange
LSR-1	G	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
LSR-1	H	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0
LSR-2	A	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
LSR-2	B	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
LSR-2	C	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0
LSR-2	D	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
LSR-2	E	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
LSR-2	F	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
LSR-3	A	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0
LSR-3	B	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
LSR-3	C	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
LSR-3	D	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0
LSR-3	E	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
LSR-3	F	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
HL-1	A	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0
HL-1	B	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
HL-1	C	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
HL-1	D	0	1	1	0	0	0	1	0	0	0	1	0	0	0	0
HL-1	E	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0
HL-1	F	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
HL-1	G	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
HL-1	H	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
HL-1	I	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
HL-1	J	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
HL-2	A	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
HL-2	B	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0

(table continues)

Site	Sect.	Tree Species														
		Black Willow	Bald Cypress	Cedar Elm	Green Ash	Red Oak	Live Oak	Pistache	Honey Locust	Mesquite	Cotton Wood	Southern Magnolia	Eastern Red Cedar	Hawthorn	Sugar Berry	Osage Orange
HL-2	C	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
HL-2	D	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0
HL-2	E	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0
HL-2	F	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0
HL-2	G	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0
HL-2	H	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
HL-2	I	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
HL-2	J	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0
HL-2	K	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
HL-2	L	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0
HL-2	M	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0
HL-2	N	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0
HL-2	O	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0
HL-3	A	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
HL-3	B	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
HL-3	C	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
HL-3	D	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
HL-3	E	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0
HL-3	F	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
HL-3	G	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
HL-3	H	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
HL-3	I	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
HL-3	J	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HL-3	K	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
HL-3	L	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
HL-3	M	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0

(table continues)

Site	Sect.	Tree Species														
		Black Willow	Bald Cypress	Cedar Elm	Green Ash	Red Oak	Live Oak	Pistache	Honey Locust	Mesquite	Cotton Wood	Southern Magnolia	Eastern Red Cedar	Hawthorn	Sugar Berry	Osage Orange
HL-3	N	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
HL-3	O	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
HL-3	P	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
HL-3	Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HL-3	R	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
HL-3	S	0	1	0	0	1	0	1	0	0	0	0	1	0	0	0
HL-3	T	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
HL-3	U	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
HL-3	V	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0
HL-3	W	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0
HL-4	A	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
HL-4	B	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
HL-4	C	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
HL-4	D	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
HL-4	E	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
HL-4	F	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
HL-4	G	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
HL-4	H	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0
HL-4	I	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
HL-4	J	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
HL-5	A	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0
HL-5	B	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
HL-5	C	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
HL-5	D	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
HL-5	E	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
HL-5	F	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0

(table continues)

Site	Sect.	Tree Species														
		Black Willow	Bald Cypress	Cedar Elm	Green Ash	Red Oak	Live Oak	Pistache	Honey Locust	Mesquite	Cotton Wood	Southern Magnolia	Eastern Red Cedar	Hawthorn	Sugar Berry	Osage Orange
HL-5	G	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0
HL-5	H	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0
HL-5	I	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
HL-5	J	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
HL-5	K	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0
HL-5	L	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0

Site Over Species Class Count Sum

Site	Species Class Count Sum	X	Y (-)
HC-1	720	33.132085	-96.897207
HC-2	461	33.13386	-96.894534
HL-1	205	33.113121	-96.856294
HL-2	501	33.110224	-96.858815
HL-3	1080	33.110375	-96.855209
HL-4	64	33.108875	-96.853438
HL-5	641	33.111026	-96.851934
LSR-1	220	33.128049	-96.879612
LSR-2	279	33.122105	-96.877185
LSR-3	39	33.123909	-96.875453
SC-3	262	33.115731	-96.874754
SC-4	877	33.115295	-96.879302
SC-5	375	33.11253	-96.883779

5724 = Total Species Class Observations Over Survey Period (April 2018-2019)

Site	Perimeter (ft)	Surface Area (sq)
HC-1	2309	196458
HC-2	1400	84126
SC-4	2956	286336
SC-3	1399	79619
SC-5	1040	53542
LSR-1	10644	114465
LSR-2	1735	145723
LSR-3	1352	86875
HL-1	1724	90210
HL-2	3075	172605
HL-3	4014	211532
HL-4	1770	83853
HL-5	2690	221132

Season Dates

Spring	Summer	Autumn	Fall
March/01-May/31	June/01-Aug/31	Sept/01-Nov/30	Dec/01-Feb 28

Aquatic Vegetation Ranking: HC

Date Series: Date 1: 04/13/2018

Site	Sect.	Vegetation Species														
		Flatstem Spike Rush	Needle Spike Rush	Cattail	American Bullrush	Fiddle dock	Curly Dock	Brittons Sedge	Rusty Sedge	Delta Arrowhead	Coontail	Muskgrass	Southern Naiad	American Pond Weed	Water Primrose	Water Lilly
HC-1	A	1	1	0	0	1	1	0	0	0	0	0	0	3	2	0
HC-1	B	1	1	1	1	1	1	1	1	0	0	0	0	0	3	0
HC-1	C	1	1	1	0	1	1	0	0	0	0	0	0	2	0	0
HC-1	D	1	1	1	0	1	1	0	0	1	2	2	3	4	2	1
HC-1	E	1	1	1	0	1	1	0	0	0	0	0	0	3	0	0
HC-1	F	1	1	0	0	1	1	0	0	0	0	0	0	3	0	0
HC-1	G	1	1	0	0	1	1	0	0	0	0	0	0	3	2	1
HC-1	H	1	1	0	0	1	1	0	0	0	0	0	0	3	0	1
HC-2	A	1	1	2	0	1	1	0	0	0	0	2	3	3	2	0
HC-2	B	1	2	1	0	0	0	0	0	0	0	1	2	3	0	0
HC-2	C	1	1	0	0	0	0	0	0	0	0	1	2	2	0	0
HC-2	D	1	1	1	0	0	0	0	0	0	0	2	3	2	0	0
HC-2	E	1	1	2	0	0	0	0	0	0	0	3	4	3	1	0
HC-2	F	1	1	2	0	0	0	0	0	0	0	2	3	3	1	0
HC-2	G	1	1	2	0	0	0	0	0	0	0	2	3	3	1	0
HC-2	H	1	1	2	0	0	0	0	0	0	0	2	3	3	1	0

Date Series: Date 2: 08/26/2018

Site	**Sect.**	**Vegetation Species**																
		Flatstem Spike Rush	**Needle Spike Rush**	**Cattail**	**American Bullrush**	**Fiddle dock**	**Curly Dock**	**Britons Sedge**	**Rusty Sedge**	**Amaranth**	**Delta Arrowhead**	**Coontail**	**Southern Naiad**	**American Pond Weed**	**Water Primrose**	**Water Lilly**	**Water Willow**	**Black Willow**
HC-1	A	1	1	1	0	1	1	0	1	0	0	3	6	3	5	0	0	0
HC-1	B	1	1	1	1	1	1	1	1	1	0	3	6	0	6	0	0	0
HC-1	C	1	1	1	0	1	1	0	1	0	0	3	6	2	3	0	1	1
HC-1	D	1	1	2	0	1	1	0	1	0	1	3	6	5	3	1	2	1
HC-1	E	1	1	1	0	1	1	0	1	1	0	3	6	4	3	0	1	1
HC-1	F	1	1	1	0	1	1	0	1	0	0	3	6	4	3	0	1	1
HC-1	G	1	1	1	0	1	1	0	1	1	1	3	6	4	3	1	1	1
HC-1	H	1	1	2	0	1	1	0	1	0	1	3	6	5	3	1	2	1
HC-2	A	1	1	2	0	1	1	0	1	0	0	3	6	6	2	0	0	1
HC-2	B	1	2	1	0	0	0	0	1	0	0	3	6	6	0	0	0	0
HC-2	C	1	1	1	0	0	0	0	1	0	0	3	6	6	0	0	0	0
HC-2	D	1	1	1	0	0	0	0	1	0	0	3	6	6	0	0	0	1
HC-2	E	1	1	2	0	0	0	0	1	0	0	3	6	6	1	0	0	1
HC-2	F	1	1	2	0	0	0	0	1	0	0	3	6	6	1	0	0	1
HC-2	G	1	1	2	0	0	0	0	1	0	0	3	6	6	1	0	0	1
HC-2	H	1	1	2	0	0	0	0	1	0	0	3	6	6	1	0	0	1

Date Series: Date 3: 12/07/2018

Site	Sect.	Vegetation Species																
		Flatstem Spike Rush	Needle Spike Rush	Cattail	American Bullrush	Fiddle dock	Curly Dock	Brittons Sedge	Rusty Sedge	Water Star Grass	Delta Arrowhead	Coontail	Muskgrass	Southern Naiad	American Pond Weed	Water Primrose	Water Lilly	Black Willow
HC-1	A	1	1	0	0	1	1	0	0	0	0	0	0	0	3	2	0	0
HC-1	B	1	1	1	1	1	1	1	1	0	0	0	0	0	0	3	0	0
HC-1	C	1	1	1	0	1	1	0	0	0	0	0	0	0	2	0	0	1
HC-1	D	1	1	1	0	1	1	0	0	0	1	2	2	3	4	2	1	1
HC-1	E	1	1	1	0	1	1	0	0	0	0	0	0	0	3	0	0	1
HC-1	F	1	1	0	0	1	1	0	0	0	0	0	0	0	3	0	0	1
HC-1	G	1	1	0	0	1	1	0	0	0	0	0	0	0	3	2	1	1
HC-1	H	1	1	0	0	1	1	0	0	0	0	0	0	0	3	0	1	1
HC-2	A	1	1	2	0	1	1	0	0	0	0	0	2	3	3	2	0	1
HC-2	B	1	2	1	0	0	0	0	0	0	0	0	1	2	3	0	0	0
HC-2	C	1	1	0	0	0	0	0	0	0	0	0	1	2	2	0	0	0
HC-2	D	1	1	1	0	0	0	0	0	0	0	0	2	3	2	0	0	1
HC-2	E	1	1	2	0	0	0	0	0	0	0	0	3	4	3	1	0	1
HC-2	F	1	1	2	0	0	0	0	0	0	0	0	2	3	3	1	0	1
HC-2	G	1	1	2	0	0	0	0	0	0	0	0	2	3	3	1	0	1
HC-2	H	1	1	2	0	0	0	0	0	0	0	0	2	3	3	1	0	1

Date Series: Date 4: 02/23/2019

Site	Sect.	Vegetation Species															
		Flatstem Spike Rush	Needle Spike Rush	Cattail	American Bullrush	Fiddle dock	Curly Dock	Brittons Sedge	Rusty Sedge	Amaranth	Delta Arrowhead	Coontail	Southern Naiad	American Pond Weed	Water Primrose	Water Lilly	Black Willow
HC-1	A	1	1	0	0	1	1	0	0	0	0	0	0	3	2	0	0
HC-1	B	1	1	1	1	1	1	1	1	1	0	0	0	0	3	0	0
HC-1	C	1	1	1	0	1	1	0	0	0	0	0	0	2	0	0	1
HC-1	D	1	1	1	0	1	1	0	0	0	1	2	3	4	2	1	1
HC-1	E	1	1	1	0	1	1	0	0	1	0	0	0	3	0	0	1
HC-1	F	1	1	0	0	1	1	0	0	0	0	0	0	3	0	0	1
HC-1	G	1	1	0	0	1	1	0	0	1	0	0	0	3	2	1	1
HC-1	H	1	1	0	0	1	1	0	0	0	0	0	0	3	0	1	1
HC-2	A	1	1	2	0	1	1	0	0	0	0	0	3	3	2	0	1
HC-2	B	1	2	1	0	0	0	0	0	0	0	0	2	3	0	0	0
HC-2	C	1	1	0	0	0	0	0	0	0	0	0	2	2	0	0	0
HC-2	D	1	1	1	0	0	0	0	0	0	0	0	3	2	0	0	1
HC-2	E	1	1	2	0	0	0	0	0	0	0	0	4	3	1	0	1
HC-2	F	1	1	2	0	0	0	0	0	0	0	0	3	3	1	0	1
HC-2	G	1	1	2	0	0	0	0	0	0	0	0	3	3	1	0	1
HC-2	H	1	1	2	0	0	0	0	0	0	0	0	3	3	1	0	1

Aquatic Rank Cover Class Averages: HC

Site	Section	AVG Emergent	AVG Submerged	AVG Floating Leaf	AVG Terrestrial
HC-1	A	2	2.5	0	0
HC-1	B	2	3	0	0
HC-1	C	1.5	2.5	0.5	0
HC-1	D	1.5	3	0.75	0
HC-1	E	2	2.5	0	0
HC-1	F	1.5	2.5	0.5	0
HC-1	G	1.5	2.75	0.75	0
HC-1	H	2	3	0.75	0
HC-2	A	2.75	2.75	0	0
HC-2	B	1.75	2.75	0	0
HC-2	C	1.75	2.75	0	0
HC-2	D	1.75	2.75	0	0
HC-2	E	2	2.75	0	0
HC-2	F	2	2.75	0.25	0
HC-2	G	2	2.75	0.5	0
HC-2	H	2	2.75	0	0

Aquatic Vegetation Ranking: SC

Date Series: Date 1: 04/13/2018

Site	Sect.	Vegetation Species																												
		Flatstem Spike Rush	**Needle Spike Rush**	**Soft Stem Rush**	**Cattail**	**Pickeral Weed**	**American Bullrush**	**Pennywart**	**Fiddle dock**	**Curly Dock**	**Brittons Sedge**	**Rusty Sedge**	**Button Bush**	**Johnson Grass**	**Switch Grass**	**Bushy Bluestem**	**Delta Arrowhead**	**Coontail**	**Muskgrass**	**Southern Naiad**	**American Pond Weed**	**Water Primrose**	**Water Lilly**	**Water Willow**	**Azola**	**Black Willow**	**Cedar Elm**	**Green Ash**	**Boxelder**	**Honey Locust**
SC-4	A	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
SC-4	B	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	1	0	0	0	0
SC-4	C	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0
SC-4	D	1	1	0	0	0	0	1	1	0	1	0	1	1	0	0	0	0	0	0	3	0	0	0	1	0	2	0	0	0
SC-4	E	1	1	0	0	0	0	0	1	1	1	0	2	0	1	0	0	0	0	0	3	1	0	0	1	0	2	0	1	0
SC-4	F	1	1	0	2	0	1	0	0	0	1	1	2	1	0	0	0	0	0	0	3	1	0	0	2	0	5	0	0	1
SC-4	G	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
SC-4	H	1	1	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
SC-4	I	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
SC-4	J	1	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0	1	1	0	0	0	0
SC-4	K	1	1	0	1	0	0	0	0	0	1	1	2	2	1	0	0	0	0	0	2	0	0	0	1	1	4	1	1	0
SC-4	L	1	1	0	2	0	1	0	0	0	1	1	2	1	1	0	0	0	0	0	2	1	1	0	2	1	1	0	1	0
SC-4	M	1	1	0	4	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2	1	1	0	2	1	2	0	0	0
SC-4	N	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(table continues)

Site	Sect.	Vegetation Species																												
		Flatstem Spike Rush	Needle Spike Rush	Soft Stem Rush	Cattail	Pickeral Weed	American Bullrush	Pennywart	Fiddle dock	Curly Dock	Brittons Sedge	Rusty Sedge	Button Bush	Johnson Grass	Switch Grass	Bushy Bluestem	Delta Arrowhead	Coontail	Muskgrass	Southern Naiad	American Pond Weed	Water Primrose	Water Lilly	Water Willow	Azola	Black Willow	Cedar Elm	Green Ash	Boxelder	Honey Locust
SC-3	A	1	1	0	4	0	0	1	0	0	0	0	1	0	0	1	1	2	2	3	3	2	1	1	0	2	0	0	0	0
SC-3	B	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3	3	0	0	1	0	0	0	0	0	0
SC-3	C	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	0	0	0	0	1	0	0	0	0
SC-3	D	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2	2	3	3	2	1	0	0	1	0	0	0	0
SC-3	E	1	1	1	2	1	0	1	0	0	0	0	0	0	0	0	0	2	2	3	3	0	0	0	0	3	0	0	0	0
SC-3	F	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	2	3	3	0	0	0	0	1	0	0	0	0
SC-3	G	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	0	1	1	0	1	0	0	0	0
SC-3	H	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	0	1	1	0	1	0	0	0	0
SC-5	A	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	B	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	C	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	D	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	E	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0
SC-5	F	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

Date Series: Date 2: 08/26/2018

Site	Sect.	Vegetation Species																												
		Flatstem Spike Rush	Needle Spike Rush	Soft Stem Rush	Cattail	Pickeral Weed	American Bullrush	Pennywart	Fiddle dock	Curly Dock	Brittons Sedge	Rusty Sedge	Button Bush	Johnson Grass	Switch Grass	Bushy Bluestem	Bacopa	Delta Arrowhead	Coontail	Southern Naiad	American Pond Weed	Water Primrose	Water Lilly	Water Willow	Azola	Black Willow	Cedar Elm	Green Ash	Boxelder	Honey Locust
SC-4	A	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	6	6	0	0	0	0	0	0	0	0	0
SC-4	B	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	6	6	0	1	0	0	1	0	0	0	0
SC-4	C	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	3	6	6	0	0	0	0	1	0	0	0	0
SC-4	D	1	1	0	0	0	0	1	1	0	1	0	1	1	0	0	0	0	3	6	6	0	0	0	1	0	2	0	0	0
SC-4	E	1	1	0	0	0	0	0	1	1	1	0	2	0	1	0	0	0	3	6	5	1	0	0	1	0	2	0	1	0
SC-4	F	1	1	0	2	0	1	0	0	0	1	1	2	1	0	0	0	0	3	5	3	1	0	0	2	0	5	0	0	1
SC-4	G	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0
SC-4	H	1	1	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	3	6	3	0	0	0	0	0	0	0	0	0
SC-4	I	1	1	0	2	0	0	0	1	1	0	0	0	0	0	0	0	0	3	6	6	1	0	0	0	0	0	0	0	0
SC-4	J	1	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	3	6	6	0	1	0	1	1	0	0	0	0
SC-4	K	1	1	0	1	0	0	0	0	0	1	1	2	2	1	0	0	0	3	6	5	0	0	0	1	1	4	1	1	0
SC-4	L	1	1	0	2	0	1	0	0	0	1	1	2	1	1	0	0	0	3	6	3	1	1	0	2	1	1	0	1	0
SC-4	M	1	1	0	4	0	0	0	0	0	1	1	0	0	0	0	0	0	3	6	3	1	1	0	2	1	2	0	0	0
SC-4	N	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
SC-3	A	1	1	0	4	0	0	1	0	0	0	0	1	0	0	1	0	1	3	4	4	2	1	1	0	2	0	0	0	0

(table continues)

Site	Sect.	Vegetation Species																												
		Flatstem Spike Rush	Needle Spike Rush	Soft Stem Rush	Cattail	Pickeral Weed	American Bullrush	Pennywart	Fiddle dock	Curly Dock	Brittons Sedge	Rusty Sedge	Button Bush	Johnson Grass	Switch Grass	Bushy Bluestem	Bacopa	Delta Arrowhead	Coontail	Southern Naiad	American Pond Weed	Water Primrose	Water Lilly	Water Willow	Azola	Black Willow	Cedar Elm	Green Ash	Boxelder	Honey Locust
SC-3	B	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	6	0	0	1	0	0	0	0	0	0
SC-3	C	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3	6	6	0	0	0	0	1	0	0	0	0
SC-3	D	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3	6	6	2	1	0	0	1	0	0	0	0
SC-3	E	1	1	1	2	1	0	1	0	0	0	0	0	0	0	0	0	0	3	6	5	0	0	0	0	3	0	0	0	0
SC-3	F	1	1	0	2	0	1	0	0	0	0	0	0	0	0	0	0	1	3	6	6	0	0	0	0	1	0	0	0	0
SC-3	G	1	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	3	6	6	0	1	1	0	1	0	0	0	0
SC-3	H	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	3	6	6	0	1	1	0	1	0	0	0	0
SC-5	A	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	B	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	C	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	D	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	E	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0
SC-5	F	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

Date Series: Date 3: 12/07/2018

Site	Sect.	Vegetation Species																												
		Flatstem Spike Rush	Needle Spike Rush	Soft Stem Rush	Cattail	Pickeral Weed	American Bullrush	Pennywart	Fiddle dock	Curly Dock	Brittons Sedge	Rusty Sedge	Button Bush	Johnson Grass	Switch Grass	Bushy Bluestem	Delta Arrowhead	Coontail	Muskgrass	Southern Naiad	American Pond Weed	Water Primrose	Water Lilly	Water Willow	Azola	Black Willow	Cedar Elm	Green Ash	Boxelder	Honey Locust
SC-4	A	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
SC-4	B	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	1	0	0	0	0
SC-4	C	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0
SC-4	D	1	1	0	0	0	0	1	1	0	1	0	1	1	0	0	0	0	0	0	3	0	0	0	1	0	2	0	0	0
SC-4	E	1	1	0	0	0	0	0	1	1	1	0	2	0	1	0	0	0	0	0	3	1	0	0	1	0	2	0	1	0
SC-4	F	1	1	0	2	0	1	0	0	0	1	1	2	1	0	0	0	0	0	0	3	1	0	0	2	0	5	0	0	1
SC-4	G	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
SC-4	H	1	1	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
SC-4	I	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
SC-4	J	1	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0	1	1	0	0	0	0
SC-4	K	1	1	0	1	0	0	0	0	0	1	1	2	2	1	0	0	0	0	0	2	0	0	0	1	1	4	1	1	0
SC-4	L	1	1	0	2	0	1	0	0	0	1	1	2	1	1	0	0	0	0	0	2	1	1	0	2	1	1	0	1	0
SC-4	M	1	1	0	4	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2	1	1	0	2	1	2	0	0	0
SC-4	N	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC-3	A	1	1	0	4	0	0	1	0	0	0	0	1	0	0	1	1	2	2	3	3	2	1	1	0	2	0	0	0	0

(table continues)

Site	Sect.	Vegetation Species																												
		Flatstem Spike Rush	Needle Spike Rush	Soft Stem Rush	Cattail	Pickeral Weed	American Bullrush	Pennywart	Fiddle dock	Curly Dock	Brittons Sedge	Rusty Sedge	Button Bush	Johnson Grass	Switch Grass	Bushy Bluestem	Delta Arrowhead	Coontail	Muskgrass	Southern Naiad	American Pond Weed	Water Primrose	Water Lilly	Water Willow	Azola	Black Willow	Cedar Elm	Green Ash	Boxelder	Honey Locust
SC-3	B	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3	3	0	0	1	0	0	0	0	0	0
SC-3	C	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	0	0	0	0	1	0	0	0	0
SC-3	D	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2	2	3	3	2	1	0	0	1	0	0	0	0
SC-3	E	1	1	1	2	1	0	1	0	0	0	0	0	0	0	0	0	2	2	3	3	0	0	0	0	3	0	0	0	0
SC-3	F	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	2	3	3	0	0	0	0	1	0	0	0	0
SC-3	G	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	0	1	1	0	1	0	0	0	0
SC-3	H	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	0	1	1	0	1	0	0	0	0
SC-5	A	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	B	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	C	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	D	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	E	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0
SC-5	F	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

Date Series: Date 4: 02/23/2019

Site	Sect.	Vegetation Species																												
		Flatstem Spike Rush	Needle Spike Rush	Soft Stem Rush	Cattail	Pickeral Weed	American Bullrush	Pennywart	Fiddle dock	Curly Dock	Brittons Sedge	Rusty Sedge	Button Bush	Johnson Grass	Switch Grass	Bushy Bluestem	Delta Arrowhead	Coontail	Muskgrass	Southern Naiad	American Pond Weed	Water Primrose	Water Lilly	Water Willow	Azola	Black Willow	Cedar Elm	Green Ash	Boxelder	Honey Locust
SC-4	A	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
SC-4	B	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	1	0	0	0	0
SC-4	C	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0
SC-4	D	1	1	0	0	0	0	1	1	0	1	0	1	1	0	0	0	0	0	0	3	0	0	0	1	0	2	0	0	0
SC-4	E	1	1	0	0	0	0	0	1	1	1	0	2	0	1	0	0	0	0	0	3	1	0	0	1	0	2	0	1	0
SC-4	F	1	1	0	2	0	1	0	0	0	1	1	2	1	0	0	0	0	0	0	3	1	0	0	2	0	5	0	0	1
SC-4	G	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
SC-4	H	1	1	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
SC-4	I	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
SC-4	J	1	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0	1	1	0	0	0	0
SC-4	K	1	1	0	1	0	0	0	0	0	1	1	2	2	1	0	0	0	0	0	2	0	0	0	1	1	4	1	1	0
SC-4	L	1	1	0	2	0	1	0	0	0	1	1	2	1	1	0	0	0	0	0	2	1	1	0	2	1	1	0	1	0
SC-4	M	1	1	0	4	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2	1	1	0	2	1	2	0	0	0
SC-4	N	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SC-3	A	1	1	0	4	0	0	1	0	0	0	0	1	0	0	1	1	2	1	3	3	2	1	1	0	2	0	0	0	0

(table continues)

Site	Sect.	Vegetation Species																												
		Flatstem Spike Rush	Needle Spike Rush	Soft Stem Rush	Cattail	Pickeral Weed	American Bullrush	Pennywart	Fiddle dock	Curly Dock	Brittons Sedge	Rusty Sedge	Button Bush	Johnson Grass	Switch Grass	Bushy Bluestem	Delta Arrowhead	Coontail	Muskgrass	Southern Naiad	American Pond Weed	Water Primrose	Water Lilly	Water Willow	Azola	Black Willow	Cedar Elm	Green Ash	Boxelder	Honey Locust
SC-3	B	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3	3	0	0	1	0	0	0	0	0	0
SC-3	C	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3	0	0	0	0	1	0	0	0	0
SC-3	D	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2	1	3	3	2	1	0	0	1	0	0	0	0
SC-3	E	1	1	1	2	1	0	1	0	0	0	0	0	0	0	0	0	2	1	3	3	0	0	0	0	3	0	0	0	0
SC-3	F	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1	3	3	0	0	0	0	1	0	0	0	0
SC-3	G	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3	0	1	1	0	1	0	0	0	0
SC-3	H	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3	0	1	1	0	1	0	0	0	0
SC-5	A	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	B	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	C	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	D	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
SC-5	E	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0
SC-5	F	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

Aquatic Rank Cover Class Averages: SC

Site	Section	AVG Emergent	AVG Submerged	AVG Floating Leaf	AVG Terrestrial
SC-4	A	1.5	2.75	0.5	0
SC-4	B	1.5	2.75	0.5	0
SC-4	C	1.5	2.75	0.5	0
SC-4	D	1.75	2.75	0.75	3
SC-4	E	1.5	2.75	0.75	3
SC-4	F	1.5	2.75	1	3.75
SC-4	G	2.5	2.75	0.25	0
SC-4	H	1.5	2.75	0.5	0
SC-4	I	1.5	2.75	0.5	0
SC-4	J	1.5	2.75	0.5	0
SC-4	K	1.5	2.75	1	3.75
SC-4	L	1.75	2.75	1	3.75
SC-4	M	2	2.75	1	1.5
SC-4	N	2.5	2.75	0.25	0
SC-3	A	3.5	2.75	1.25	3
SC-3	B	1.25	2.75	0	0
SC-3	C	1.25	2.75	0.5	0
SC-3	D	1.75	2.75	1.75	0
SC-3	E	2	2.5	0	3
SC-3	F	2	2.75	0	0
SC-3	G	2	2.75	0.75	0
SC-3	H	2	2.75	1.75	0
SC-5	A	2	2	0	0
SC-5	B	1.75	2	0.25	0
SC-5	C	1.75	2	0	0
SC-5	D	2	2	0	0
SC-5	E	1.75	2	0	0
SC-5	F	1.75	2	0	0

Aquatic Vegetation Ranking: LSR

Date Series: Date 1: 04/13/2018

Site	**Sect.**	**Vegetation Species**									
		Flatstem Spike Rush	**Needle Spike Rush**	**Cattail**	**Pennywart**	**Curly Dock**	**Bacopa**	**Southern Naiad**	**American Pond Weed**	**Water Primrose**	**Black Willow**
LSR-1	A	1	1	0	1	1	1	0	0	2	0
LSR-1	B	1	1	0	1	0	1	0	0	0	0
LSR-1	C	1	1	0	1	1	2	0	0	2	0
LSR-1	D	1	1	0	1	0	1	0	0	2	0
LSR-1	E	1	1	0	1	1	0	0	0	0	0
LSR-1	F	1	1	0	1	1	1	0	0	0	1
LSR-1	G	1	1	0	1	1	1	0	0	1	0
LSR-1	H	1	1	0	1	1	1	0	0	2	0
LSR-2	A	1	1	1	0	0	1	3	0	0	0
LSR-2	B	1	1	0	0	0	1	3	0	0	0
LSR-2	C	1	1	0	0	0	1	3	0	1	0
LSR-2	D	1	1	0	0	0	1	3	0	1	0
LSR-2	E	1	1	0	0	0	1	3	0	0	0
LSR-2	F	1	1	0	0	0	1	3	0	0	0
LSR-3	A	1	1	0	1	0	0	0	0	0	2
LSR-3	B	1	1	0	1	0	0	0	0	2	0
LSR-3	C	1	1	1	1	0	1	0	0	2	1
LSR-3	D	1	1	0	1	0	1	0	2	2	1
LSR-3	E	1	1	0	1	0	0	0	2	2	1
LSR-3	F	1	1	0	1	0	0	0	2	2	1

Date Series: Date 2: 08/26/2018

Site	Sect.	Vegetation Species										
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pennywart	Curly Dock	Bacopa	Coontail	American Pond Weed	Water Primrose	Black Willow	Cotton Wood
LSR-1	A	1	1	0	1	1	2	2	0	2	0	0
LSR-1	B	1	1	0	1	0	2	2	0	2	0	0
LSR-1	C	1	1	0	1	1	2	2	0	2	0	0
LSR-1	D	1	1	0	1	0	2	2	0	2	0	0
LSR-1	E	1	1	0	1	1	2	2	0	2	0	0
LSR-1	F	1	1	0	1	1	2	2	0	2	1	0
LSR-1	G	1	1	0	1	1	2	2	0	2	0	0
LSR-1	H	1	1	0	1	1	2	2	0	2	0	0
LSR-2	A	1	1	1	0	0	1	1	1	1	0	0
LSR-2	B	1	1	0	0	0	1	1	1	1	0	0
LSR-2	C	1	1	0	0	0	1	1	1	1	0	0
LSR-2	D	1	1	0	0	0	1	1	1	1	0	0
LSR-2	E	1	1	0	0	0	1	1	1	1	0	0
LSR-2	F	1	1	0	0	0	1	1	1	1	0	0
LSR-3	A	1	1	0	1	0	1	0	1	1	2	0
LSR-3	B	1	1	0	1	0	1	0	1	1	0	0
LSR-3	C	1	1	1	1	0	1	0	1	1	1	0
LSR-3	D	1	1	0	1	0	1	0	1	1	1	1
LSR-3	E	1	1	0	1	0	1	0	1	1	1	0
LSR-3	F	1	1	0	1	0	1	0	1	1	1	0

Date Series: Date 3: 12/07/2018

Site	Sect.	Vegetation Species													
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pennywart	Curly Dock	Bacopa	Water Star Grass	Delta Arrowhead	Coontail	Southern Naiad	American Pond Weed	Water Primrose	Black Willow	Cotton Wood
LSR-1	A	1	1	0	1	1	1	0	0	0	0	0	2	0	0
LSR-1	B	1	1	0	1	0	1	0	0	0	0	0	0	0	0
LSR-1	C	1	1	0	1	1	2	0	0	0	0	0	2	0	0
LSR-1	D	1	1	0	1	0	1	0	0	0	0	0	2	0	0
LSR-1	E	1	1	0	1	1	0	0	0	0	0	0	0	0	0
LSR-1	F	1	1	0	1	1	1	0	0	0	0	0	0	1	0
LSR-1	G	1	1	0	1	1	1	0	0	0	0	0	1	0	0
LSR-1	H	1	1	0	1	1	1	0	0	0	0	0	2	0	0
LSR-2	A	1	1	1	0	0	1	0	0	0	3	0	0	0	0
LSR-2	B	1	1	0	0	0	1	0	0	0	3	0	0	0	0
LSR-2	C	1	1	0	0	0	1	0	0	0	3	0	1	0	0
LSR-2	D	1	1	0	0	0	1	0	0	0	3	0	1	0	0
LSR-2	E	1	1	0	0	0	1	0	0	0	3	0	0	0	0
LSR-2	F	1	1	0	0	0	1	0	0	0	3	0	0	0	0
LSR-3	A	1	1	0	1	0	0	0	0	0	0	0	0	2	0
LSR-3	B	1	1	0	1	0	0	0	0	0	0	0	2	0	0
LSR-3	C	1	1	1	1	0	1	0	0	0	0	0	2	1	0
LSR-3	D	1	1	0	1	0	1	0	0	0	0	2	2	1	1
LSR-3	E	1	1	0	1	0	0	0	0	0	0	2	2	1	0
LSR-3	F	1	1	0	1	0	0	0	0	0	0	2	2	1	0

Date Series: Date 4: 02/23/2019

Site	Sect.	Vegetation Species													
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pennywart	Curly Dock	Bacopa	Water Star Grass	Delta Arrowhead	Coontail	Southern Naiad	American Pond Weed	Water Primrose	Black Willow	Cotton Wood
LSR-1	A	1	1	0	1	1	1	0	0	0	0	0	2	0	0
LSR-1	B	1	1	0	1	0	1	0	0	0	0	0	0	0	0
LSR-1	C	1	1	0	1	1	2	0	0	0	0	0	2	0	0
LSR-1	D	1	1	0	1	0	1	0	0	0	0	0	2	0	0
LSR-1	E	1	1	0	1	1	0	0	0	0	0	0	0	0	0
LSR-1	F	1	1	0	1	1	1	0	0	0	0	0	0	1	0
LSR-1	G	1	1	0	1	1	1	0	0	0	0	0	1	0	0
LSR-1	H	1	1	0	1	1	1	0	0	0	0	0	2	0	0
LSR-2	A	1	1	1	0	0	1	0	0	0	3	0	0	0	0
LSR-2	B	1	1	0	0	0	1	0	0	0	3	0	0	0	0
LSR-2	C	1	1	0	0	0	1	0	0	0	3	0	1	0	0
LSR-2	D	1	1	0	0	0	1	0	0	0	3	0	1	0	0
LSR-2	E	1	1	0	0	0	1	0	0	0	3	0	0	0	0
LSR-2	F	1	1	0	0	0	1	0	0	0	3	0	0	0	0
LSR-3	A	1	1	0	1	0	0	0	0	0	0	0	0	2	0
LSR-3	B	1	1	0	1	0	0	0	0	0	0	0	2	0	0
LSR-3	C	1	1	1	1	0	1	0	0	0	0	0	2	1	0
LSR-3	D	1	1	0	1	0	1	0	0	0	0	2	2	1	1
LSR-3	E	1	1	0	1	0	0	0	0	0	0	2	2	1	0
LSR-3	F	1	1	0	1	0	0	0	0	0	0	2	2	1	0

Aquatic Rank Cover Class Averages: LSR

Site	Section	AVG Emergent	AVG Submerged	AVG Floating Leaf	AVG Terrestrial
LSR-1	A	1.25	1.75	0	0
LSR-1	B	1.25	1.75	0	0
LSR-1	C	1.25	1.75	0	0
LSR-1	D	1.25	1.75	0	0
LSR-1	E	1.25	1.75	0	0
LSR-1	F	1.25	1.75	0	0
LSR-1	G	1.25	1.75	0	0
LSR-1	H	1.25	1.75	0	0
LSR-2	A	1.25	1.75	0	0
LSR-2	B	1.25	1.75	0	0
LSR-2	C	1.25	1.75	0	0
LSR-2	D	1.25	1.75	0	0
LSR-2	E	1.25	1.75	0	0
LSR-2	F	1.25	1.75	0	0
LSR-3	A	1.25	1.75	0	0
LSR-3	B	1.25	1.75	0	0
LSR-3	C	1.25	1.75	0	0
LSR-3	D	1.25	1.75	0	1
LSR-3	E	1.25	1.75	0	0
LSR-3	F	1.25	1.75	0	0

Aquatic Vegetation Ranking: HL

Date Series: Date 1: 04/13/2018

Site	Sect.	Vegetation Species										
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pickeral Weed	Pennywart	Elephants Ear	Johnson Grass	Bacopa	American Pond Weed	Water Primrose	Black Willow
HL-1	A	1	1	0	0	1	0	0	2	0	0	0
HL-1	B	1	1	0	0	1	0	0	1	0	0	0
HL-1	C	1	1	0	0	1	0	0	0	0	0	0
HL-1	D	1	1	0	0	1	0	1	0	0	0	0
HL-1	E	1	1	0	0	1	0	0	0	0	0	0
HL-1	F	1	1	0	0	1	0	0	1	0	0	0
HL-1	G	1	1	0	0	1	0	0	1	0	0	0
HL-1	H	1	1	0	0	1	0	0	1	0	0	0
HL-1	I	1	1	0	0	1	0	0	1	0	0	0
HL-1	J	1	1	0	0	1	0	0	1	0	0	0
HL-2	A	1	1	0	1	1	0	0	0	2	0	0
HL-2	B	1	1	0	0	1	0	0	0	2	0	0
HL-2	C	1	1	1	0	1	0	0	0	0	0	0
HL-2	D	1	1	0	0	1	0	0	0	2	0	0
HL-2	E	1	1	1	0	1	0	0	0	2	1	0
HL-2	F	1	1	1	0	1	0	0	0	2	0	0
HL-2	G	1	1	1	0	1	0	0	0	2	0	0
HL-2	H	1	1	1	0	1	0	0	0	2	1	0
HL-2	I	1	1	1	0	1	0	0	0	3	0	0
HL-2	J	1	1	1	0	1	0	0	0	3	0	0
HL-2	K	1	1	0	0	1	0	0	0	2	2	0
HL-2	L	1	1	1	0	1	0	0	0	2	2	0
HL-2	M	1	1	1	0	1	0	0	0	2	0	0
HL-2	N	1	1	1	0	1	0	0	0	3	0	0

(table continues)

Site	Sect.	Vegetation Species										
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pickeral Weed	Pennywart	Elephants Ear	Johnson Grass	Bacopa	American Pond Weed	Water Primrose	Black Willow
HL-2	O	1	1	1	0	1	0	0	0	3	2	0
HL-3	A	1	1	1	0	1	1	0	0	2	2	1
HL-3	B	1	1	1	0	1	0	0	0	0	2	0
HL-3	C	1	1	1	0	1	0	0	0	0	3	0
HL-3	D	1	1	1	0	1	0	0	0	2	0	0
HL-3	E	1	1	1	1	1	0	0	0	0	2	0
HL-3	F	1	1	1	1	1	0	0	0	0	2	0
HL-3	G	1	1	0	1	1	0	0	1	0	2	0
HL-3	H	1	1	0	0	1	0	0	0	0	3	0
HL-3	I	1	1	0	0	1	0	0	0	0	3	0
HL-3	J	1	1	1	0	1	0	0	0	1	1	0
HL-3	K	1	1	0	0	1	0	0	0	1	1	0
HL-3	L	1	1	0	0	1	1	0	0	0	0	0
HL-3	M	1	1	1	0	1	0	0	0	0	2	0
HL-3	N	1	1	1	0	1	0	0	0	2	2	0
HL-3	O	1	1	1	0	1	0	0	0	2	2	0
HL-3	P	1	1	0	0	1	0	0	0	2	2	0
HL-3	Q	1	1	0	0	1	0	0	0	2	2	0
HL-3	R	1	1	0	0	1	0	0	0	2	2	0
HL-3	S	1	1	0	0	1	1	0	0	0	2	0
HL-3	T	1	1	1	0	1	0	0	0	0	2	0
HL-3	U	1	1	1	0	1	0	0	0	0	0	0
HL-3	V	1	1	0	0	1	0	0	0	0	2	0
HL-3	W	1	1	0	0	1	0	0	0	0	2	0
HL-4	A	1	1	0	0	1	0	0	0	2	2	0
HL-4	B	1	1	0	0	1	0	0	0	2	2	0

(table continues)

Site	Sect.	Vegetation Species										
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pickeral Weed	Pennywart	Elephants Ear	Johnson Grass	Bacopa	American Pond Weed	Water Primrose	Black Willow
HL-4	C	1	1	0	0	1	0	0	0	0	2	0
HL-4	D	1	1	0	0	1	0	0	0	0	3	0
HL-4	E	1	1	4	0	1	0	0	0	0	2	0
HL-4	F	1	1	1	0	1	0	0	0	2	0	0
HL-4	G	1	1	0	0	1	0	0	0	0	0	0
HL-4	H	1	1	0	0	1	0	0	0	0	0	0
HL-4	I	1	1	0	0	1	0	0	0	2	2	0
HL-4	J	1	1	4	0	1	0	0	0	0	0	0
HL-5	A	1	1	1	0	1	0	0	0	0	2	0
HL-5	B	1	1	0	0	1	0	0	0	0	2	0
HL-5	C	1	1	0	0	1	0	0	0	0	1	0
HL-5	D	1	1	0	0	1	0	0	0	2	2	0
HL-5	E	1	1	0	0	1	0	0	0	2	2	0
HL-5	F	1	1	0	0	1	0	0	0	0	2	1
HL-5	G	1	1	0	0	1	0	0	0	0	0	0
HL-5	H	1	1	0	0	1	0	0	0	0	2	0
HL-5	I	1	1	3	0	1	0	0	0	0	0	0
HL-5	J	1	1	0	0	1	0	0	0	0	0	0
HL-5	K	1	1	0	0	1	0	0	0	2	2	0
HL-5	L	1	1	0	0	1	0	0	0	2	2	0

Date Series: Date 3: 12/07/2018

Site	Sect.	Vegetation Species										
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pickeral Weed	Pennywart	Elephants Ear	Johnson Grass	Bacopa	American Pond Weed	Water Primrose	Black Willow
HL-1	A	1	1	0	0	1	0	0	2	0	0	0
HL-1	B	1	1	0	0	1	0	0	1	0	0	0
HL-1	C	1	1	0	0	1	0	0	0	0	0	0
HL-1	D	1	1	0	0	1	0	1	0	0	0	0
HL-1	E	1	1	0	0	1	0	0	0	0	0	0
HL-1	F	1	1	0	0	1	0	0	1	0	0	0
HL-1	G	1	1	0	0	1	0	0	1	0	0	0
HL-1	H	1	1	0	0	1	0	0	1	0	0	0
HL-1	I	1	1	0	0	1	0	0	1	0	0	0
HL-1	J	1	1	0	0	1	0	0	1	0	0	0
HL-2	A	1	1	0	1	1	0	0	0	2	0	0
HL-2	B	1	1	0	0	1	0	0	0	2	0	0
HL-2	C	1	1	1	0	1	0	0	0	0	0	0
HL-2	D	1	1	0	0	1	0	0	0	2	0	0
HL-2	E	1	1	1	0	1	0	0	0	2	1	0
HL-2	F	1	1	1	0	1	0	0	0	2	0	0
HL-2	G	1	1	1	0	1	0	0	0	2	0	0
HL-2	H	1	1	1	0	1	0	0	0	2	1	0
HL-2	I	1	1	1	0	1	0	0	0	3	0	0
HL-2	J	1	1	1	0	1	0	0	0	3	0	0
HL-2	K	1	1	0	0	1	0	0	0	2	2	0
HL-2	L	1	1	1	0	1	0	0	0	2	2	0
HL-2	M	1	1	1	0	1	0	0	0	2	0	0
HL-2	N	1	1	1	0	1	0	0	0	3	0	0
HL-2	O	1	1	1	0	1	0	0	0	3	2	0

(table continues)

Site	Sect.	Vegetation Species										
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pickeral Weed	Pennywart	Elephants Ear	Johnson Grass	Bacopa	American Pond Weed	Water Primrose	Black Willow
HL-3	A	1	1	1	0	1	1	0	0	2	2	1
HL-3	B	1	1	1	0	1	0	0	0	0	2	0
HL-3	C	1	1	1	0	1	0	0	0	0	3	0
HL-3	D	1	1	1	0	1	0	0	0	2	0	0
HL-3	E	1	1	1	1	1	0	0	0	0	2	0
HL-3	F	1	1	1	1	1	0	0	0	0	2	0
HL-3	G	1	1	0	1	1	0	0	1	0	2	0
HL-3	H	1	1	0	0	1	0	0	0	0	3	0
HL-3	I	1	1	0	0	1	0	0	0	0	3	0
HL-3	J	1	1	1	0	1	0	0	0	1	1	0
HL-3	K	1	1	0	0	1	0	0	0	1	1	0
HL-3	L	1	1	0	0	1	1	0	0	0	0	0
HL-3	M	1	1	1	0	1	0	0	0	0	2	0
HL-3	N	1	1	1	0	1	0	0	0	2	2	0
HL-3	O	1	1	1	0	1	0	0	0	2	2	0
HL-3	P	1	1	0	0	1	0	0	0	2	2	0
HL-3	Q	1	1	0	0	1	0	0	0	2	2	0
HL-3	R	1	1	0	0	1	0	0	0	2	2	0
HL-3	S	1	1	0	0	1	1	0	0	0	2	0
HL-3	T	1	1	1	0	1	0	0	0	0	2	0
HL-3	U	1	1	1	0	1	0	0	0	0	0	0
HL-3	V	1	1	0	0	1	0	0	0	0	2	0
HL-3	W	1	1	0	0	1	0	0	0	0	2	0
HL-4	A	1	1	0	0	1	0	0	0	2	2	0
HL-4	B	1	1	0	0	1	0	0	0	2	2	0
HL-4	C	1	1	0	0	1	0	0	0	0	2	0

(table continues)

Site	Sect.	Vegetation Species										
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pickeral Weed	Pennywart	Elephants Ear	Johnson Grass	Bacopa	American Pond Weed	Water Primrose	Black Willow
HL-4	D	1	1	0	0	1	0	0	0	0	3	0
HL-4	E	1	1	4	0	1	0	0	0	0	2	0
HL-4	F	1	1	1	0	1	0	0	0	2	0	0
HL-4	G	1	1	0	0	1	0	0	0	0	0	0
HL-4	H	1	1	0	0	1	0	0	0	0	0	0
HL-4	I	1	1	0	0	1	0	0	0	2	2	0
HL-4	J	1	1	4	0	1	0	0	0	0	0	0
HL-5	A	1	1	1	0	1	0	0	0	0	2	0
HL-5	B	1	1	0	0	1	0	0	0	0	2	0
HL-5	C	1	1	0	0	1	0	0	0	0	1	0
HL-5	D	1	1	0	0	1	0	0	0	2	2	0
HL-5	E	1	1	0	0	1	0	0	0	2	2	0
HL-5	F	1	1	0	0	1	0	0	0	0	2	1
HL-5	G	1	1	0	0	1	0	0	0	0	0	0
HL-5	H	1	1	0	0	1	0	0	0	0	2	0
HL-5	I	1	1	3	0	1	0	0	0	0	0	0
HL-5	J	1	1	0	0	1	0	0	0	0	0	0
HL-5	K	1	1	0	0	1	0	0	0	2	2	0
HL-5	L	1	1	0	0	1	0	0	0	2	2	0

Date Series: Date 4: 02/23/2019

Site	Sect.	Vegetation Species										
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pickeral Weed	Pennywart	Elephants Ear	Johnson Grass	Bacopa	American Pond Weed	Water Primrose	Black Willow
HL-1	A	1	1	0	0	1	0	0	2	0	0	0
HL-1	B	1	1	0	0	1	0	0	1	0	0	0
HL-1	C	1	1	0	0	1	0	0	0	0	0	0
HL-1	D	1	1	0	0	1	0	1	0	0	0	0
HL-1	E	1	1	0	0	1	0	0	0	0	0	0
HL-1	F	1	1	0	0	1	0	0	1	0	0	0
HL-1	G	1	1	0	0	1	0	0	1	0	0	0
HL-1	H	1	1	0	0	1	0	0	1	0	0	0
HL-1	I	1	1	0	0	1	0	0	1	0	0	0
HL-1	J	1	1	0	0	1	0	0	1	0	0	0
HL-2	A	1	1	0	1	1	0	0	0	2	0	0
HL-2	B	1	1	0	0	1	0	0	0	2	0	0
HL-2	C	1	1	1	0	1	0	0	0	0	0	0
HL-2	D	1	1	0	0	1	0	0	0	2	0	0
HL-2	E	1	1	1	0	1	0	0	0	2	1	0
HL-2	F	1	1	1	0	1	0	0	0	2	0	0
HL-2	G	1	1	1	0	1	0	0	0	2	0	0
HL-2	H	1	1	1	0	1	0	0	0	2	1	0
HL-2	I	1	1	1	0	1	0	0	0	3	0	0
HL-2	J	1	1	1	0	1	0	0	0	3	0	0
HL-2	K	1	1	0	0	1	0	0	0	2	2	0
HL-2	L	1	1	1	0	1	0	0	0	2	2	0
HL-2	M	1	1	1	0	1	0	0	0	2	0	0
HL-2	N	1	1	1	0	1	0	0	0	3	0	0
HL-2	O	1	1	1	0	1	0	0	0	3	2	0

(table continues)

Site	Sect.	Vegetation Species										
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pickeral Weed	Pennywart	Elephants Ear	Johnson Grass	Bacopa	American Pond Weed	Water Primrose	Black Willow
HL-3	A	1	1	1	0	1	1	0	0	2	2	1
HL-3	B	1	1	1	0	1	0	0	0	0	2	0
HL-3	C	1	1	1	0	1	0	0	0	0	3	0
HL-3	D	1	1	1	0	1	0	0	0	2	0	0
HL-3	E	1	1	1	1	1	0	0	0	0	2	0
HL-3	F	1	1	1	1	1	0	0	0	0	2	0
HL-3	G	1	1	0	1	1	0	0	1	0	2	0
HL-3	H	1	1	0	0	1	0	0	0	0	3	0
HL-3	I	1	1	0	0	1	0	0	0	0	3	0
HL-3	J	1	1	1	0	1	0	0	0	1	1	0
HL-3	K	1	1	0	0	1	0	0	0	1	1	0
HL-3	L	1	1	0	0	1	1	0	0	0	0	0
HL-3	M	1	1	1	0	1	0	0	0	0	2	0
HL-3	N	1	1	1	0	1	0	0	0	2	2	0
HL-3	O	1	1	1	0	1	0	0	0	2	2	0
HL-3	P	1	1	0	0	1	0	0	0	2	2	0
HL-3	Q	1	1	0	0	1	0	0	0	2	2	0
HL-3	R	1	1	0	0	1	0	0	0	2	2	0
HL-3	S	1	1	0	0	1	1	0	0	0	2	0
HL-3	T	1	1	1	0	1	0	0	0	0	2	0
HL-3	U	1	1	1	0	1	0	0	0	0	0	0
HL-3	V	1	1	0	0	1	0	0	0	0	2	0
HL-3	W	1	1	0	0	1	0	0	0	0	2	0
HL-4	A	1	1	0	0	1	0	0	0	2	2	0
HL-4	B	1	1	0	0	1	0	0	0	2	2	0
HL-4	C	1	1	0	0	1	0	0	0	0	2	0

(table continues)

Site	Sect.	Vegetation Species										
		Flatstem Spike Rush	Needle Spike Rush	Cattail	Pickeral Weed	Pennywart	Elephants Ear	Johnson Grass	Bacopa	American Pond Weed	Water Primrose	Black Willow
HL-4	D	1	1	0	0	1	0	0	0	0	3	0
HL-4	E	1	1	4	0	1	0	0	0	0	2	0
HL-4	F	1	1	1	0	1	0	0	0	2	0	0
HL-4	G	1	1	0	0	1	0	0	0	0	0	0
HL-4	H	1	1	0	0	1	0	0	0	0	0	0
HL-4	I	1	1	0	0	1	0	0	0	2	2	0
HL-4	J	1	1	4	0	1	0	0	0	0	0	0
HL-5	A	1	1	1	0	1	0	0	0	0	2	0
HL-5	B	1	1	0	0	1	0	0	0	0	2	0
HL-5	C	1	1	0	0	1	0	0	0	0	1	0
HL-5	D	1	1	0	0	1	0	0	0	2	2	0
HL-5	E	1	1	0	0	1	0	0	0	2	2	0
HL-5	F	1	1	0	0	1	0	0	0	0	2	1
HL-5	G	1	1	0	0	1	0	0	0	0	0	0
HL-5	H	1	1	0	0	1	0	0	0	0	2	0
HL-5	I	1	1	3	0	1	0	0	0	0	0	0
HL-5	J	1	1	0	0	1	0	0	0	0	0	0
HL-5	K	1	1	0	0	1	0	0	0	2	2	0
HL-5	L	1	1	0	0	1	0	0	0	2	2	0

Aquatic Rank Cover Class Averages: HL

Site	Section	AVG Emergent	AVG Submerged	AVG Floating Leaf	AVG Terrestrial
HL-1	A	1.25	1.75	0	0
HL-1	B	1.25	1.75	0	0
HL-1	C	1.25	1.75	0	0
HL-1	D	2	1.75	0	0
HL-1	E	1.25	1.75	0	0
HL-1	F	1.25	1.75	0	0
HL-1	G	1.25	1.75	0	0
HL-1	H	1.25	1.75	0	0
HL-1	I	1.25	1.75	0	0
HL-1	J	1.25	1.75	0	0
HL-2	A	1.25	1.75	0	0
HL-2	B	1.25	1.75	0	0
HL-2	C	1.25	1.75	0	0
HL-2	D	1.25	1.75	0	0
HL-2	E	1.25	1.75	0	0
HL-2	F	1.25	1.75	0	0
HL-2	G	1.25	1.75	0	0
HL-2	H	1.25	1.75	0	0
HL-2	I	1.25	2	0	0
HL-2	J	1.25	2	0	0
HL-2	K	1.25	1.75	0	0
HL-2	L	1.25	1.75	0	0
HL-2	M	1.25	1.75	0	0
HL-2	N	1.25	2	0	0
HL-2	O	1.25	2	0	0
HL-3	A	1.25	1.75	0	0
HL-3	B	1.25	1.75	0	0
HL-3	C	1.25	1.75	0	0
HL-3	D	1.25	1.75	0	0
HL-3	E	1.25	1.75	0	0

(table continues)

Site	Section	AVG Emergent	AVG Submerged	AVG Floating Leaf	AVG Terrestrial
HL-3	F	1.25	1.75	0	0
HL-3	G	1.25	1.75	0	0
HL-3	H	1.25	1.75	0	0
HL-3	I	1.25	1.75	0	0
HL-3	J	1.25	1.75	0	0
HL-3	K	1.25	1.75	0	0
HL-3	L	1.25	1.75	0	0
HL-3	M	1.25	1.75	0	0
HL-3	N	1.25	1.75	0	0
HL-3	O	1.25	1.75	0	0
HL-3	P	1.25	1.75	0	0
HL-3	Q	1.25	1.75	0	0
HL-3	R	1.25	1.75	0	0
HL-3	S	1.25	1.75	0	0
HL-3	T	1.25	1.75	0	0
HL-3	U	1.25	1.75	0	0
HL-3	V	1.25	1.75	0	0
HL-3	W	1.25	1.75	0	0
HL-4	A	1.25	1.75	0	0
HL-4	B	1.25	1.75	0	0
HL-4	C	1.25	1.75	0	0
HL-4	D	1.25	2	0	0
HL-4	E	2	1.75	0	0
HL-4	F	1.25	1.75	0	0
HL-4	G	1.25	1.75	0	0
HL-4	H	1.25	1.75	0	0
HL-4	I	1.25	1.75	0	0
HL-4	J	2	1.75	0	0
HL-5	A	1.25	1.75	0	0
HL-5	B	1.25	1.75	0	0
HL-5	C	1.25	1.75	0	0

(table continues)

Site	Section	AVG Emergent	AVG Submerged	AVG Floating Leaf	AVG Terrestrial
HL-5	D	1.25	1.75	0	0
HL-5	E	1.25	1.75	0	0
HL-5	F	1.25	1.75	0	0
HL-5	G	1.25	1.75	0	0
HL-5	H	1.25	1.75	0	0
HL-5	I	2	1.75	0	0
HL-5	J	1.25	1.75	0	0
HL-5	K	1.25	1.75	0	0
HL-5	L	1.25	1.75	0	0

Descriptives for Observed Counts: Site by Season by Bird Class

Site	Season	BirdSpecies	Mean	Sum	SD	Max
HC-1	Spring	DenseVegWaders	2.600	169.000	1.367	5.000
HC-1	Spring	DipDabblers	11.125	1157.000	10.710	38.000
HC-1	Spring	DivingBirds	1.667	65.000	0.478	2.000
HC-1	Spring	MoistSoil	3.000	39.000	0.000	3.000
HC-1	Spring	OpenWaterWaders	4.143	377.000	0.995	6.000
HC-1	Summer	DenseVegWaders	1.333	28.000	0.483	2.000
HC-1	Summer	DipDabblers	11.750	329.000	6.958	20.000
HC-1	Summer	MoistSoil	1.000	7.000	0.000	1.000
HC-1	Summer	OpenWaterWaders	2.143	105.000	1.568	5.000
HC-1	Autumn	DipDabblers	8.571	660.000	5.322	20.000
HC-1	Autumn	DivingBirds	1.800	99.000	0.755	3.000
HC-1	Autumn	OpenWaterWaders	1.667	55.000	0.957	3.000
HC-1	Winter	DipDabblers	33.000	3168.000	29.252	97.000
HC-1	Winter	DivingBirds	25.167	1812.000	34.896	101.000
HC-1	Winter	MoistSoil	1.000	12.000	0.000	1.000
HC-1	Winter	OpenWaterWaders	1.500	108.000	0.769	3.000
HC-2	Spring	DenseVegWaders	2.500	65.000	0.510	3.000
HC-2	Spring	DipDabblers	5.333	416.000	4.257	13.000
HC-2	Spring	DivingBirds	4.667	182.000	3.343	9.000
HC-2	Spring	MoistSoil	2.600	169.000	0.806	4.000
HC-2	Spring	OpenWaterWaders	1.000	26.000	0.000	1.000
HC-2	Summer	DenseVegWaders	4.000	28.000	0.000	4.000
HC-2	Summer	DipDabblers	25.000	350.000	23.868	48.000
HC-2	Summer	MoistSoil	1.000	14.000	0.000	1.000
HC-2	Summer	OpenWaterWaders	2.500	35.000	0.519	3.000
HC-2	Autumn	DipDabblers	22.125	1947.000	15.064	44.000
HC-2	Autumn	DivingBirds	1.200	66.000	0.404	2.000
HC-2	Autumn	MoistSoil	1.000	22.000	0.000	1.000
HC-2	Winter	DipDabblers	15.250	1464.000	15.457	54.000
HC-2	Winter	DivingBirds	4.333	156.000	2.662	8.000
HC-2	Winter	MoistSoil	1.000	12.000	0.000	1.000

(table continues)

Site	Season	BirdSpecies	Mean	Sum	SD	Max
HC-2	Winter	OpenWaterWaders	1.000	12.000	0.000	1.000
HL-1	Spring	DenseVegWaders	1.333	52.000	0.478	2.000
HL-1	Spring	DipDabblers	12.667	988.000	6.514	19.000
HL-1	Spring	MoistSoil	1.000	13.000	0.000	1.000
HL-1	Spring	OpenWaterWaders	3.667	286.000	2.225	8.000
HL-1	Summer	DenseVegWaders	1.000	7.000	0.000	1.000
HL-1	Summer	OpenWaterWaders	1.000	14.000	0.000	1.000
HL-1	Autumn	DipDabblers	6.500	286.000	1.677	8.000
HL-1	Autumn	DivingBirds	4.000	132.000	2.990	8.000
HL-1	Winter	DipDabblers	5.400	324.000	3.032	11.000
HL-1	Winter	DivingBirds	6.400	384.000	5.321	16.000
HL-1	Winter	MoistSoil	2.000	24.000	0.000	2.000
HL-2	Spring	DenseVegWaders	1.000	26.000	0.000	1.000
HL-2	Spring	DipDabblers	5.857	533.000	10.742	32.000
HL-2	Spring	DivingBirds	1.000	13.000	0.000	1.000
HL-2	Spring	OpenWaterWaders	1.000	91.000	0.000	1.000
HL-2	Summer	DenseVegWaders	1.000	15.000	0.000	1.000
HL-2	Summer	DipDabblers	6.500	273.000	3.730	11.000
HL-2	Summer	OpenWaterWaders	1.750	49.000	1.323	4.000
HL-2	Autumn	DipDabblers	13.182	1595.000	9.630	34.000
HL-2	Autumn	DivingBirds	3.286	253.000	2.620	9.000
HL-2	Autumn	MoistSoil	1.000	11.000	0.000	1.000
HL-2	Autumn	OpenWaterWaders	1.000	33.000	0.000	1.000
HL-2	Winter	DipDabblers	7.900	948.000	8.736	30.000
HL-2	Winter	DivingBirds	11.077	1728.000	11.028	41.000
HL-2	Winter	OpenWaterWaders	2.500	60.000	1.532	4.000
HL-3	Spring	DenseVegWaders	1.000	26.000	0.000	1.000
HL-3	Spring	DipDabblers	11.300	1469.000	11.070	39.000
HL-3	Spring	DivingBirds	1.500	39.000	0.510	2.000
HL-3	Spring	MoistSoil	1.000	26.000	0.000	1.000
HL-3	Spring	OpenWaterWaders	1.300	169.000	0.643	3.000
HL-3	Summer	DipDabblers	5.571	273.000	3.410	12.000

(table continues)

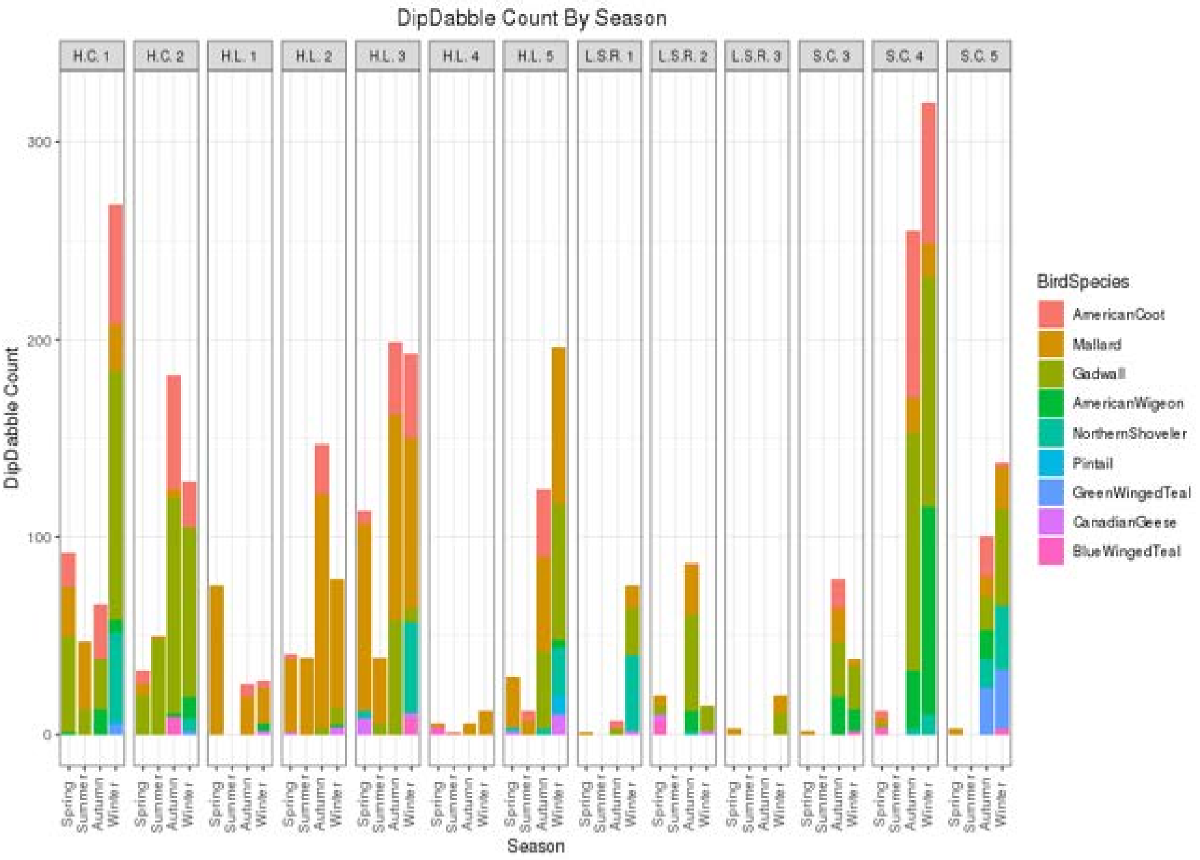
Site	Season	BirdSpecies	Mean	Sum	SD	Max
HL-3	Summer	OpenWaterWaders	1.000	35.000	0.000	1.000
HL-3	Autumn	DipDabblers	12.312	2167.000	12.286	50.000
HL-3	Autumn	DivingBirds	3.375	297.000	5.224	17.000
HL-3	Autumn	OpenWaterWaders	1.600	88.000	0.807	3.000
HL-3	Winter	DipDabblers	11.500	2208.000	13.391	50.000
HL-3	Winter	DivingBirds	35.692	5568.000	95.747	366.000
HL-3	Winter	OpenWaterWaders	1.250	120.000	0.665	3.000
HL-4	Spring	DenseVegWaders	1.000	13.000	0.000	1.000
HL-4	Spring	DipDabblers	3.000	78.000	2.040	5.000
HL-4	Spring	MoistSoil	7.000	182.000	2.040	9.000
HL-4	Spring	OpenWaterWaders	1.000	39.000	0.000	1.000
HL-4	Summer	DipDabblers	1.000	7.000	0.000	1.000
HL-4	Summer	OpenWaterWaders	1.000	21.000	0.000	1.000
HL-4	Autumn	DipDabblers	3.000	66.000	1.024	4.000
HL-4	Autumn	MoistSoil	4.000	44.000	0.000	4.000
HL-4	Autumn	OpenWaterWaders	1.000	33.000	0.000	1.000
HL-4	Winter	DipDabblers	2.000	144.000	0.581	3.000
HL-4	Winter	DivingBirds	1.250	60.000	0.438	2.000
HL-4	Winter	OpenWaterWaders	2.000	24.000	0.000	2.000
HL-5	Spring	DipDabblers	4.141	381.000	2.474	9.000
HL-5	Spring	MoistSoil	2.000	26.000	0.000	2.000
HL-5	Spring	OpenWaterWaders	2.011	185.000	1.074	4.000
HL-5	Summer	DipDabblers	4.000	84.000	1.449	5.000
HL-5	Summer	OpenWaterWaders	1.000	7.000	0.000	1.000
HL-5	Autumn	DipDabblers	12.400	1364.000	6.388	22.000
HL-5	Autumn	DivingBirds	9.667	957.000	5.014	16.000
HL-5	Autumn	OpenWaterWaders	1.000	44.000	0.000	1.000
HL-5	Winter	DipDabblers	23.500	2256.000	9.964	35.000
HL-5	Winter	DivingBirds	19.625	1884.000	11.137	34.000
HL-5	Winter	OpenWaterWaders	1.000	24.000	0.000	1.000
LSR-1	Spring	DipDabblers	1.000	13.000	0.000	1.000
LSR-1	Spring	DivingBirds	3.000	39.000	0.000	3.000

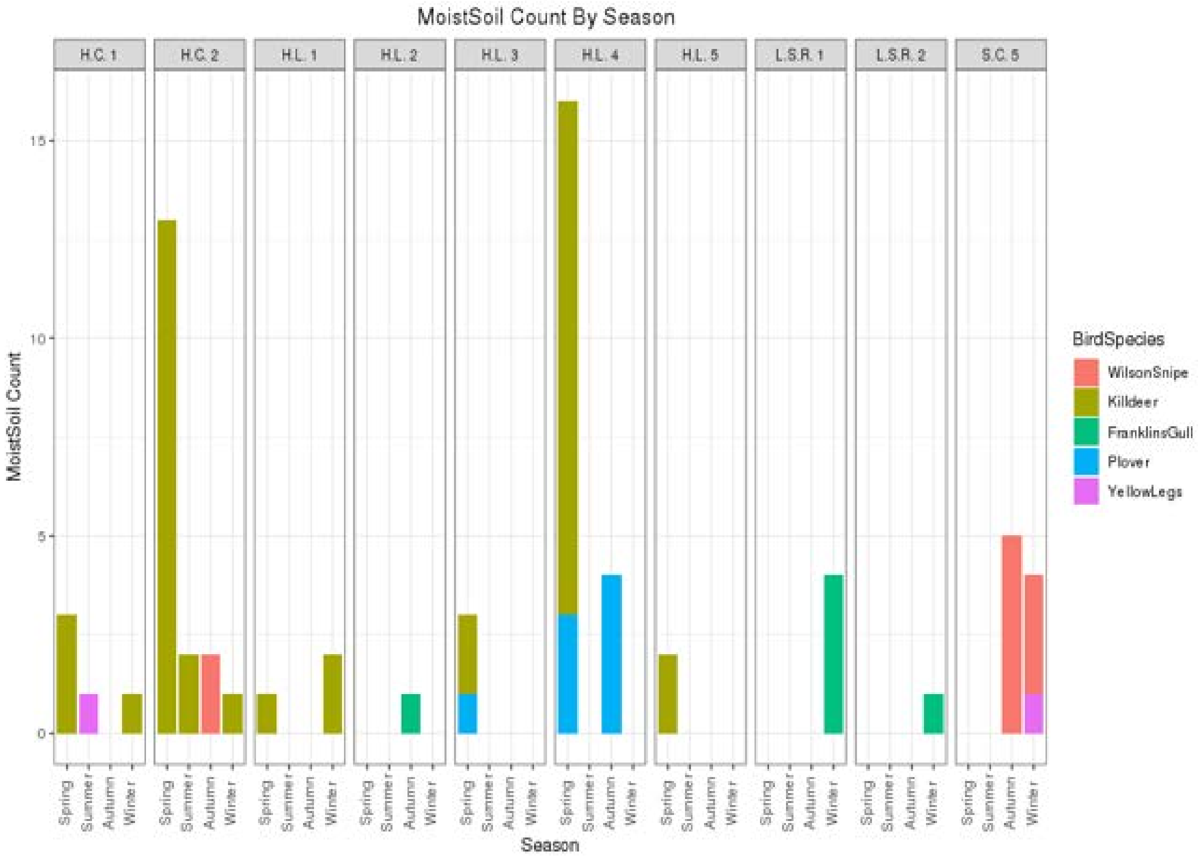
(table continues)

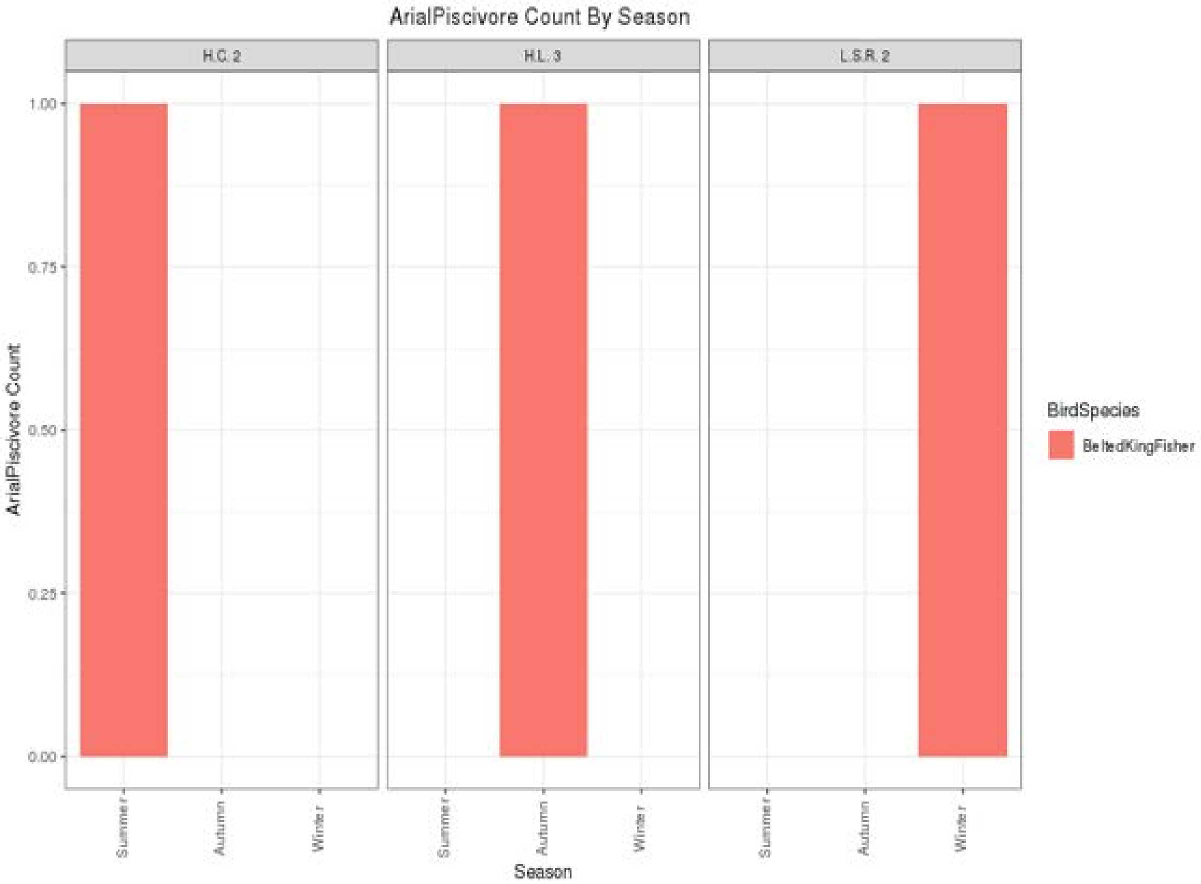
Site	Season	BirdSpecies	Mean	Sum	SD	Max
LSR-1	Spring	OpenWaterWaders	2.800	182.000	1.481	5.000
LSR-1	Summer	OpenWaterWaders	1.241	36.000	0.435	2.000
LSR-1	Autumn	DipDabblers	3.500	77.000	0.512	4.000
LSR-1	Autumn	DivingBirds	2.200	121.000	1.177	4.000
LSR-1	Autumn	OpenWaterWaders	1.000	44.000	0.000	1.000
LSR-1	Winter	DipDabblers	12.667	912.000	8.944	25.000
LSR-1	Winter	DivingBirds	11.286	948.000	6.901	19.000
LSR-1	Winter	MoistSoil	2.000	48.000	0.000	2.000
LSR-1	Winter	OpenWaterWaders	1.286	108.000	0.704	3.000
LSR-2	Spring	DipDabblers	5.000	260.000	0.714	6.000
LSR-2	Spring	DivingBirds	4.000	52.000	0.000	4.000
LSR-2	Spring	OpenWaterWaders	3.000	195.000	2.114	6.000
LSR-2	Summer	OpenWaterWaders	2.000	56.000	1.764	5.000
LSR-2	Autumn	DipDabblers	15.800	869.000	13.858	41.000
LSR-2	Autumn	DivingBirds	6.667	440.000	3.844	13.000
LSR-2	Autumn	OpenWaterWaders	1.500	33.000	0.512	2.000
LSR-2	Winter	DipDabblers	5.000	180.000	2.191	7.000
LSR-2	Winter	DivingBirds	12.667	912.000	6.944	25.000
LSR-2	Winter	MoistSoil	1.000	12.000	0.000	1.000
LSR-2	Winter	OpenWaterWaders	1.000	12.000	0.000	1.000
LSR-3	Spring	DipDabblers	1.500	39.000	0.510	2.000
LSR-3	Spring	OpenWaterWaders	1.000	13.000	0.000	1.000
LSR-3	Autumn	DivingBirds	1.000	11.000	0.000	1.000
LSR-3	Winter	DipDabblers	9.000	216.000	3.065	12.000
LSR-3	Winter	DivingBirds	2.750	132.000	0.838	4.000
LSR-3	Winter	OpenWaterWaders	1.000	24.000	0.000	1.000
SC-3	Spring	DipDabblers	2.000	28.000	0.000	2.000
SC-3	Spring	DivingBirds	1.000	13.000	0.000	1.000
SC-3	Spring	OpenWaterWaders	1.481	40.000	0.509	2.000
SC-3	Summer	OpenWaterWaders	1.000	7.000	0.000	1.000
SC-3	Autumn	DipDabblers	12.833	847.000	10.446	33.000
SC-3	Autumn	DivingBirds	20.200	1111.000	30.056	79.000

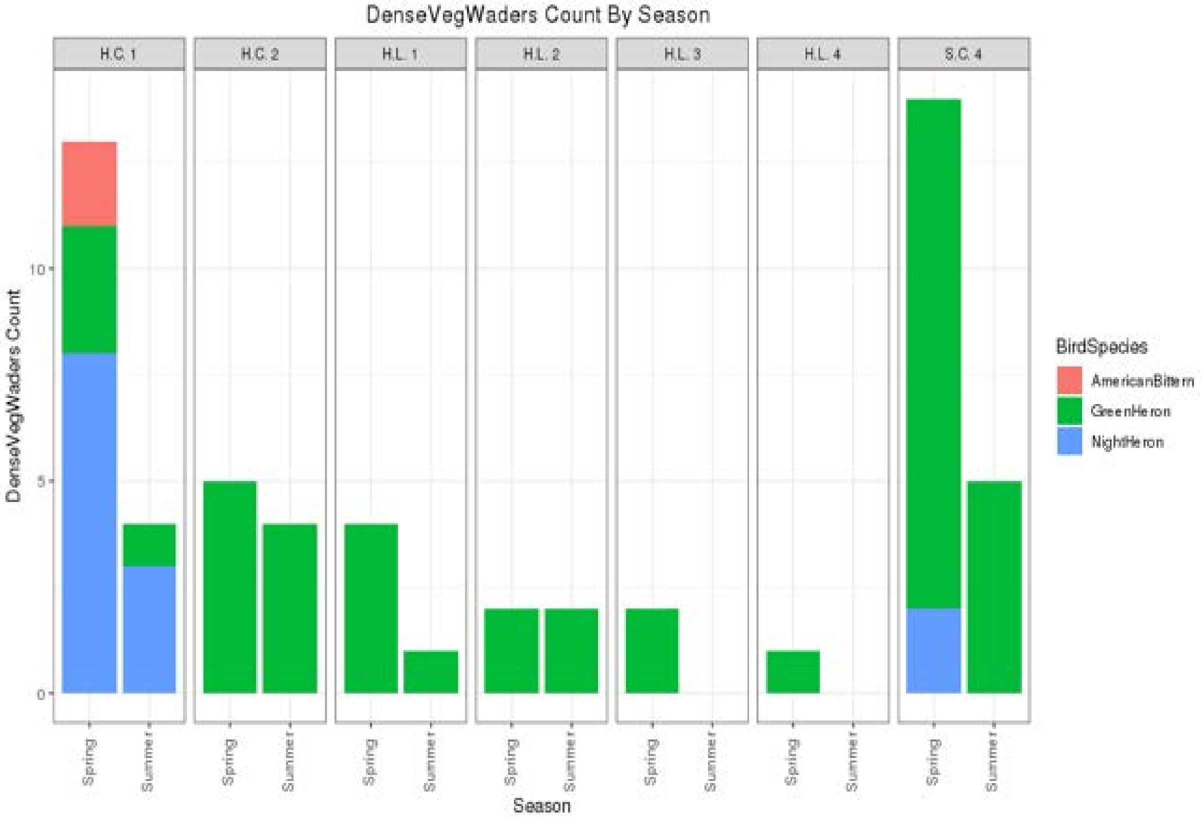
(table continues)

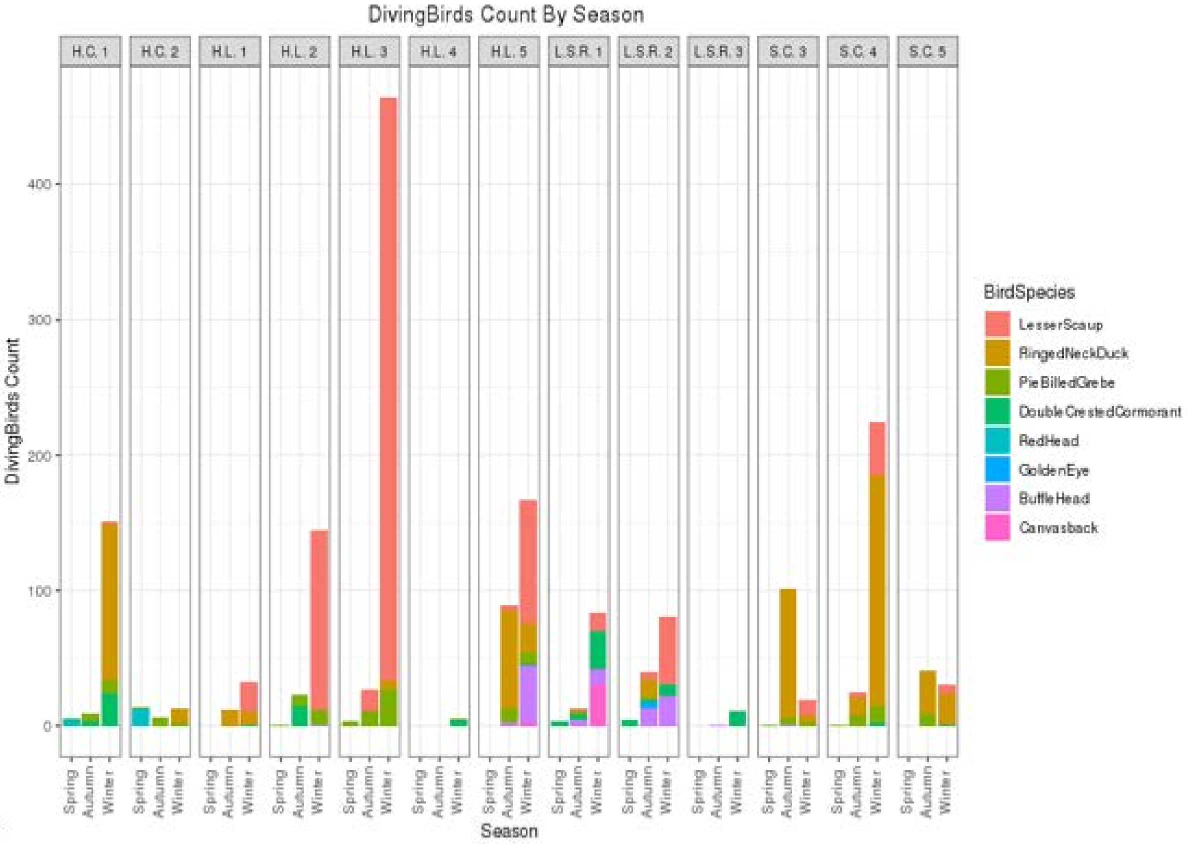
Site	Season	BirdSpecies	Mean	Sum	SD	Max
SC-3	Winter	DipDabblers	6.000	432.000	3.537	12.000
SC-3	Winter	DivingBirds	4.750	228.000	4.190	11.000
SC-3	Winter	OpenWaterWaders	1.000	12.000	0.000	1.000
SC-4	Spring	DenseVegWaders	2.333	182.000	1.383	4.000
SC-4	Spring	DipDabblers	3.000	156.000	1.749	6.000
SC-4	Spring	DivingBirds	1.000	13.000	0.000	1.000
SC-4	Spring	OpenWaterWaders	2.000	52.000	1.020	3.000
SC-4	Summer	DenseVegWaders	2.500	35.000	1.557	4.000
SC-4	Summer	OpenWaterWaders	1.250	35.000	0.441	2.000
SC-4	Autumn	DipDabblers	26.667	2640.000	26.486	90.000
SC-4	Autumn	DivingBirds	12.500	275.000	9.724	22.000
SC-4	Autumn	OpenWaterWaders	1.000	11.000	0.000	1.000
SC-4	Winter	DipDabblers	37.500	3600.000	23.430	84.000
SC-4	Winter	DivingBirds	28.000	2688.000	26.107	77.000
SC-4	Winter	OpenWaterWaders	1.000	36.000	0.000	1.000
SC-5	Spring	DipDabblers	3.000	39.000	0.000	3.000
SC-5	Spring	OpenWaterWaders	4.400	286.000	2.351	8.000
SC-5	Summer	OpenWaterWaders	3.333	70.000	1.278	5.000
SC-5	Autumn	DipDabblers	15.500	1023.000	13.109	36.000
SC-5	Autumn	DivingBirds	13.667	451.000	11.010	29.000
SC-5	Autumn	MoistSoil	1.667	55.000	0.479	2.000
SC-5	Autumn	OpenWaterWaders	1.250	55.000	0.438	2.000
SC-5	Winter	DipDabblers	26.400	1584.000	12.971	46.000
SC-5	Winter	DivingBirds	7.500	360.000	8.257	21.000
SC-5	Winter	MoistSoil	1.333	48.000	0.478	2.000
SC-5	Winter	OpenWaterWaders	1.250	60.000	0.438	2.000

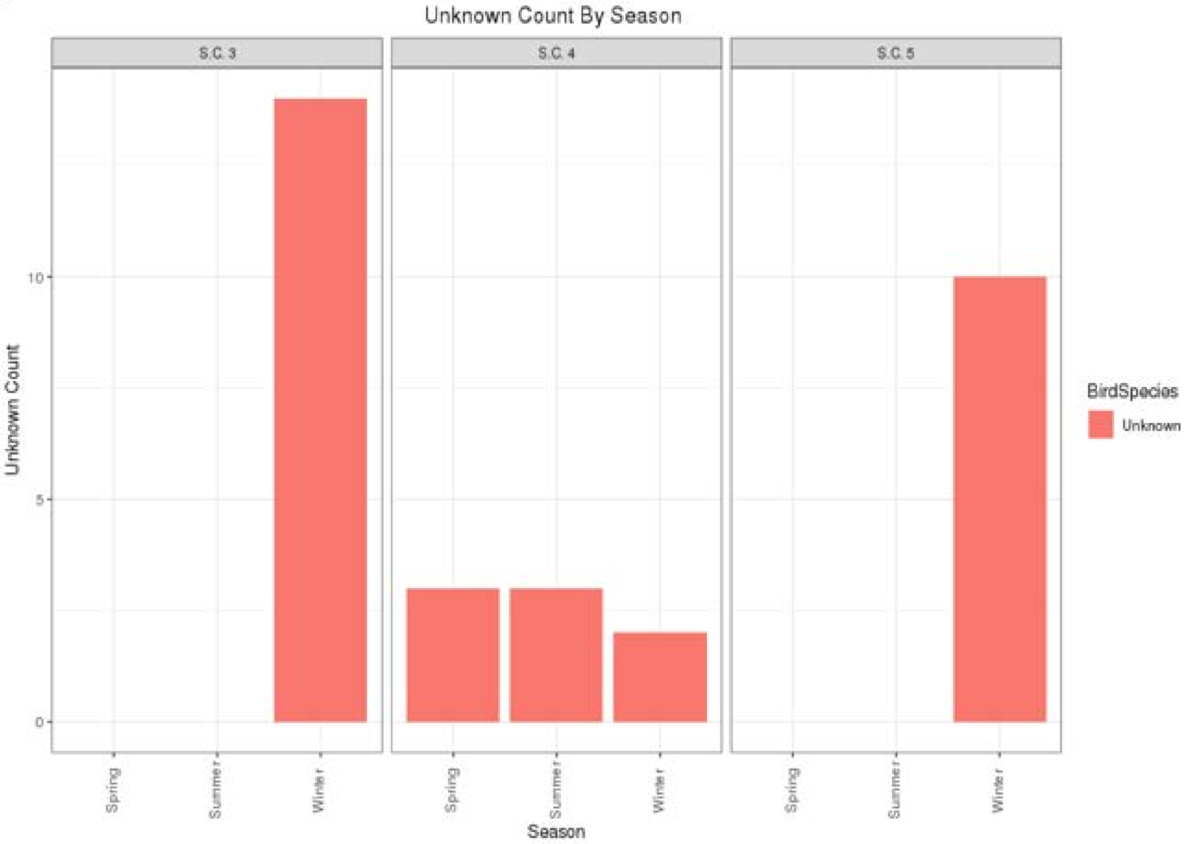

DipDabble Count By Season
H.C. 1
H.C. 2
H.L. 1
H.L. 2
H.L. 3
H.L. 4
H.L. 5
L.S.R. 1
L.S.R. 2
L.S.R. 3
S.C. 3
S.C. 4
S.C. 5
DipDabble Count
0
100
200
300
Spring
Summer
Autumn
Winter
Season
BirdSpecies
AmericanCoot
Mallard
Gadwall
AmericanWigeon
NorthernShoveler
Pintail
GreenWingedTeal
CanadianGeese
BlueWingedTeal

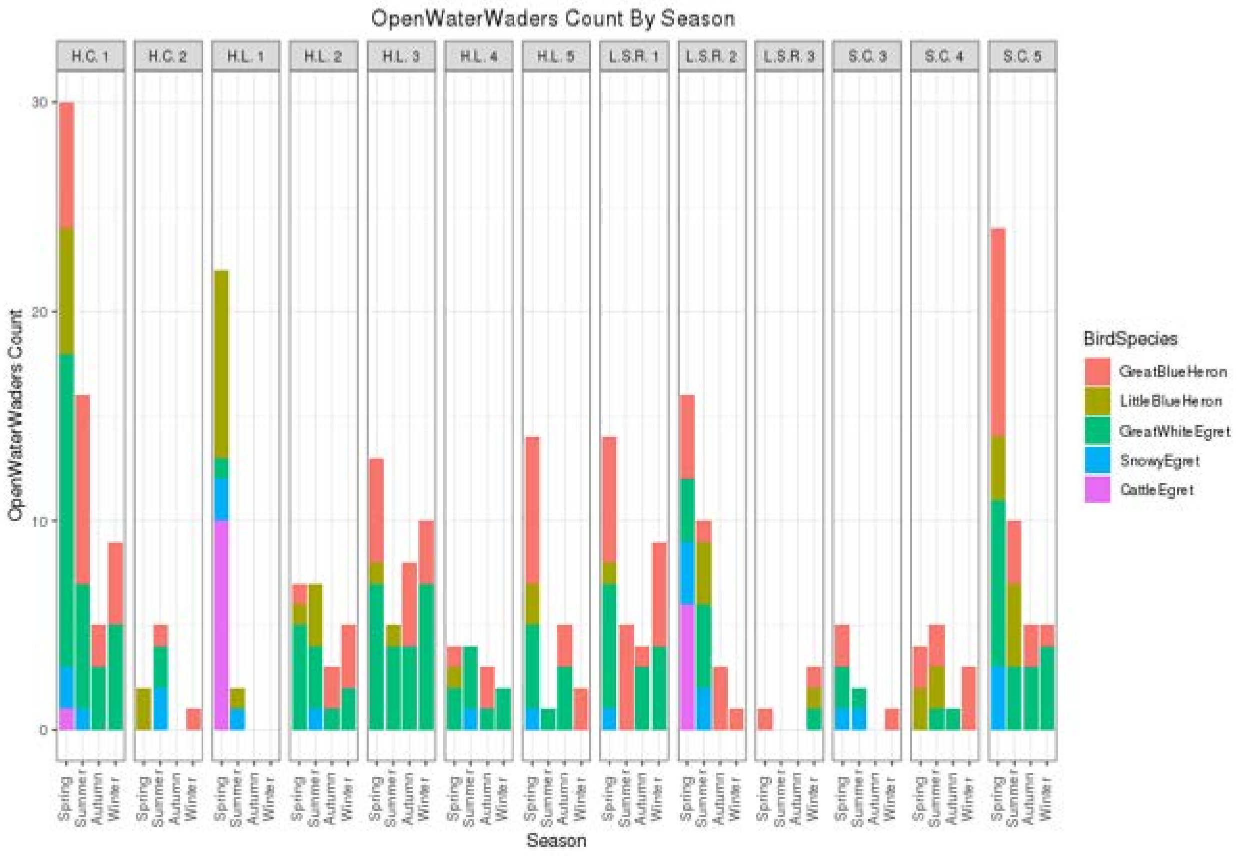

MoistSoil Count By Season
H.C. 1
H.C. 2
H.L. 1
H.L. 2
H.L. 3
H.L. 4
H.L. 5
L.S.R. 1
L.S.R. 2
S.C. 5
MoistSoil Count
0
5
10
15
Spring
Summer
Autumn
Winter
Season
BirdSpecies
WilsonSnipe
Killdeer
FranklinsGull
Plover
YellowLegs

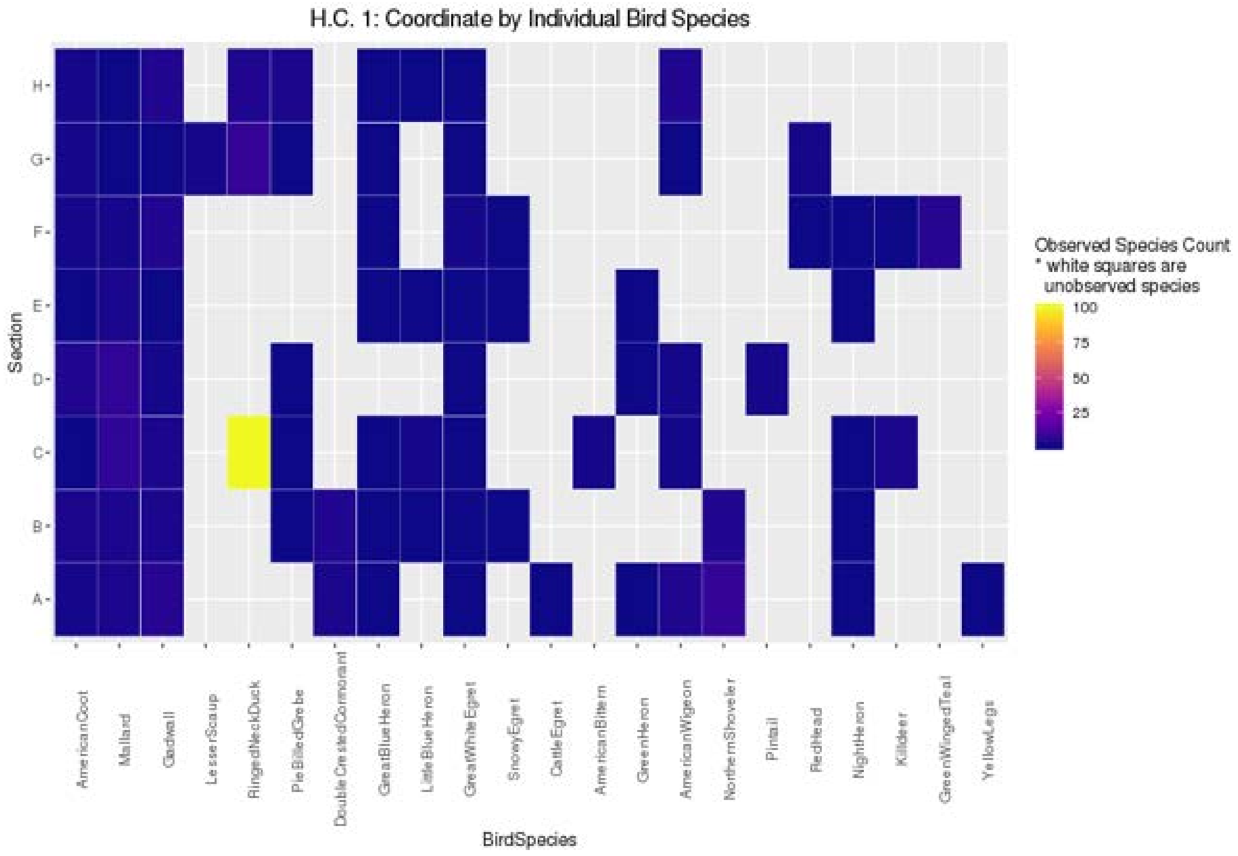

ArialPiscivore Count By Season
H.C. 2
H.L. 3
L.S.R. 2
1.00
0.75
0.50
0.25
0.00
ArialPiscivore Count
Summer
Autumn
Winter
Summer
Autumn
Winter
Summer
Autumn
Winter
Season
BirdSpecies
BeltedKingFisher

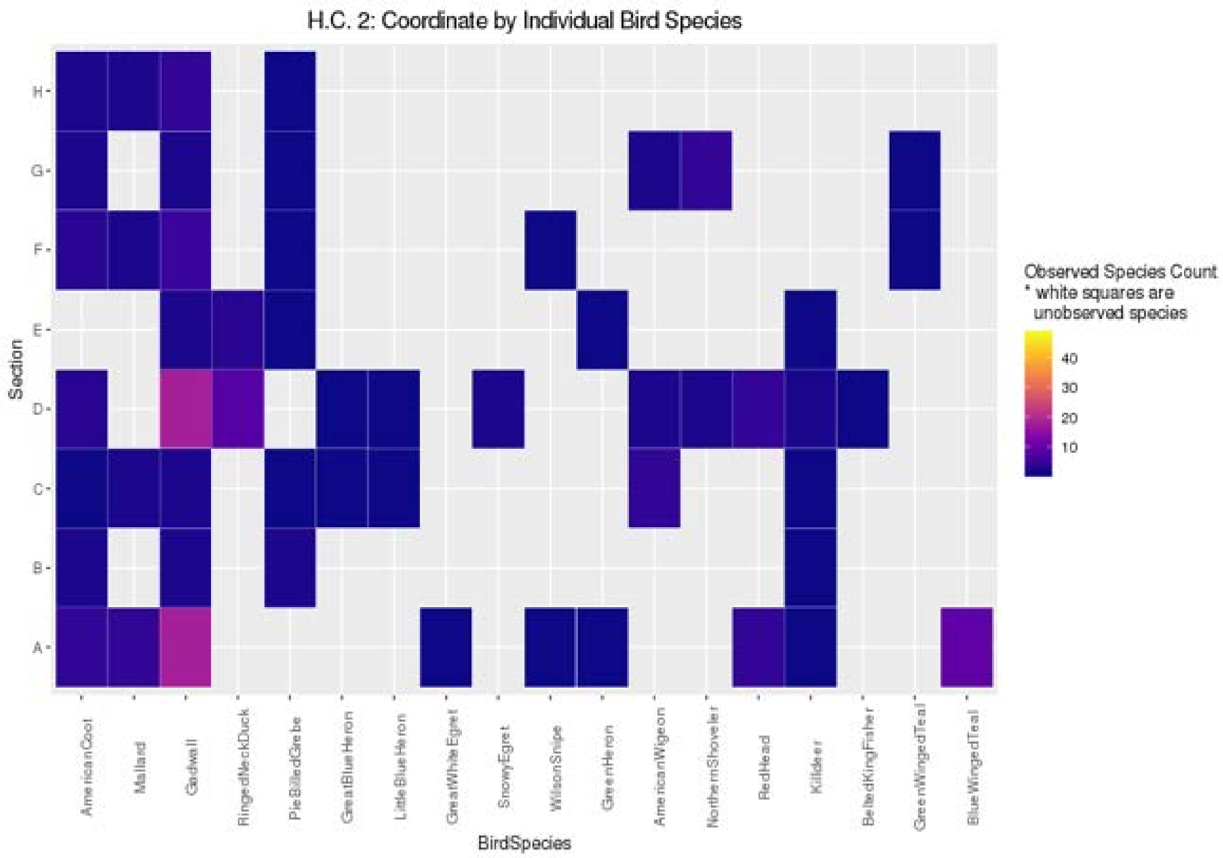

DenseVegWaders Count By Season
H.C. 1
H.C. 2
H.L. 1
H.L. 2
H.L. 3
H.L. 4
S.C. 4
10
5
0
DenseVegWaders Count
Spring
Summer
Spring
Summer
Spring
Summer
Spring
Summer
Spring
Summer
Spring
Summer
Spring
Summer
Season
BirdSpecies
AmericanBittern
GreenHeron
NightHeron

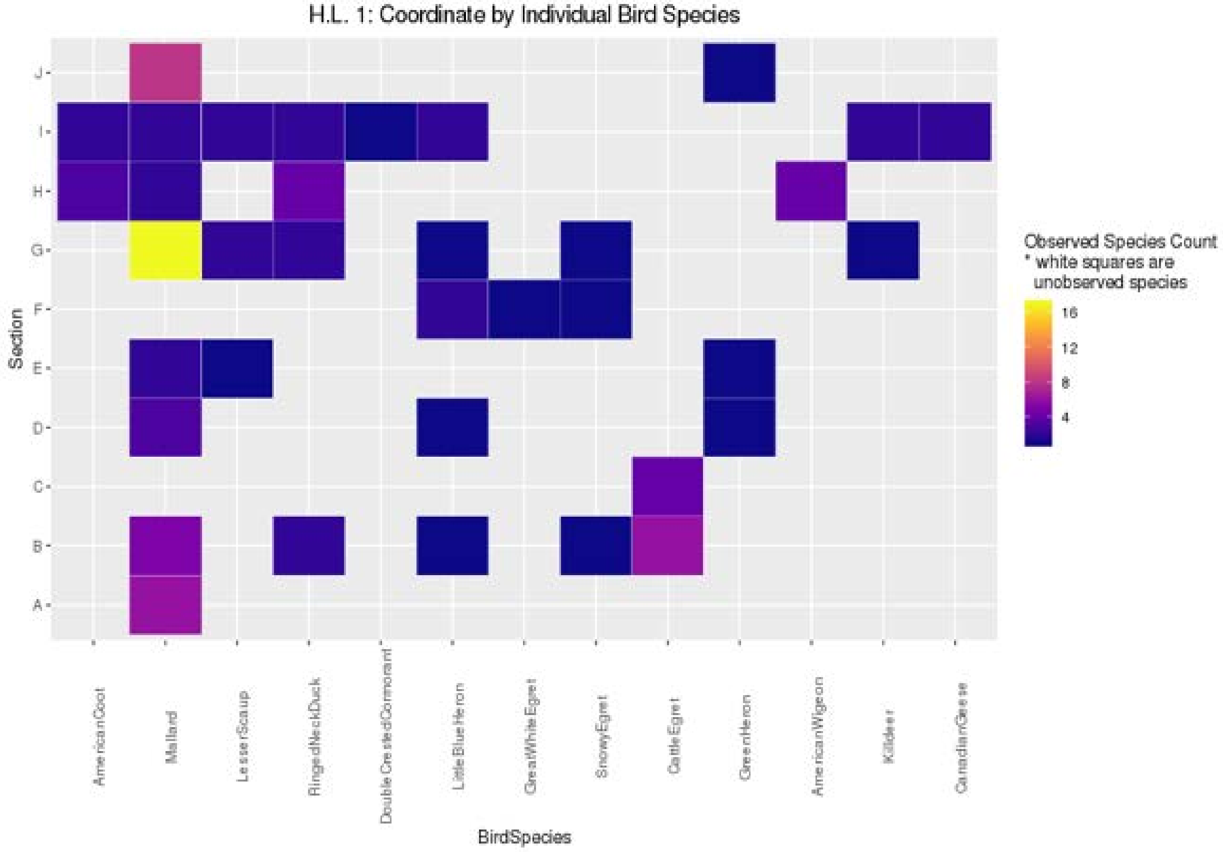

DivingBirds Count By Season
H.C. 1
H.C. 2
H.L. 1
H.L. 2
H.L. 3
H.L. 4
H.L. 5
L.S.R. 1
L.S.R. 2
L.S.R. 3
S.C. 3
S.C. 4
S.C. 5
DivingBirds Count
0
100
200
300
400
Spring
Autumn
Winter
Season
BirdSpecies
LesserScaup
RingedNeckDuck
PieBilledGrebe
DoubleCrestedCormorant
RedHead
GoldenEye
BuffleHead
Canvasback

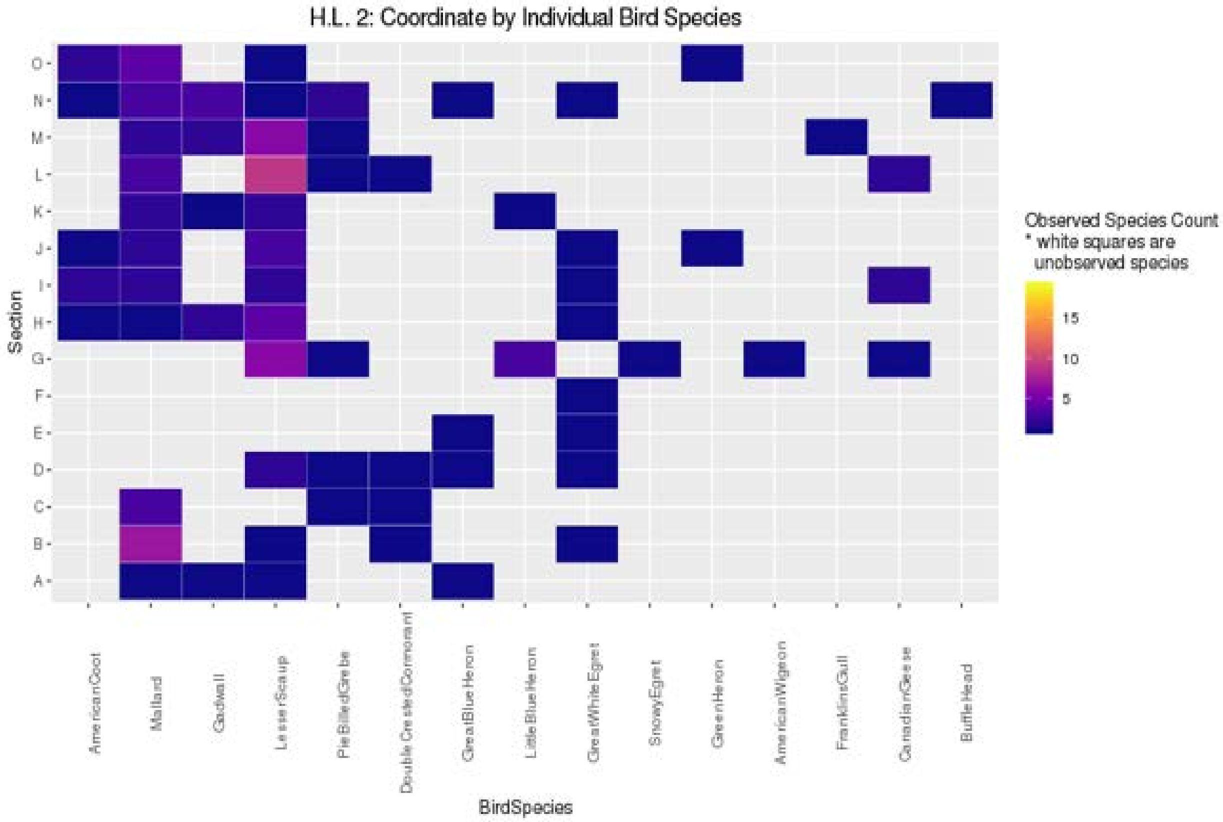

Unknown Count By Season
S.C. 3
S.C. 4
S.C. 5
Unknown Count
0
5
10
Spring
Summer
Winter
Season
BirdSpecies
Unknown

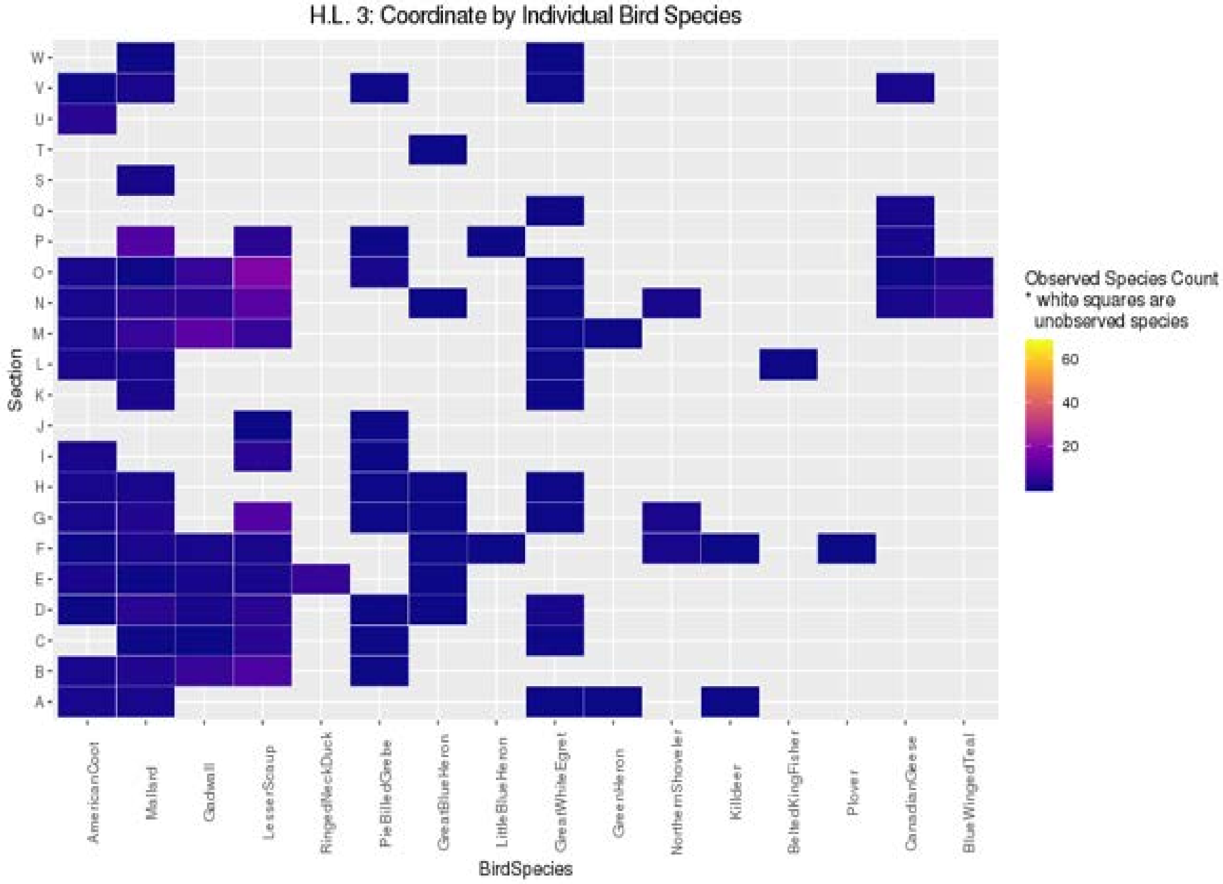

OpenWaterWaders Count By Season
H.C. 1
H.C. 2
H.L. 1
H.L. 2
H.L. 3
H.L. 4
H.L. 5
L.S.R. 1
L.S.R. 2
L.S.R. 3
S.C. 3
S.C. 4
S.C. 5
OpenWaterWaders Count
0
10
20
30
Spring
Summer
Autumn
Winter
Season
BirdSpecies
GreatBlueHeron
LittleBlueHeron
GreatWhiteEgret
SnowyEgret
CattleEgret

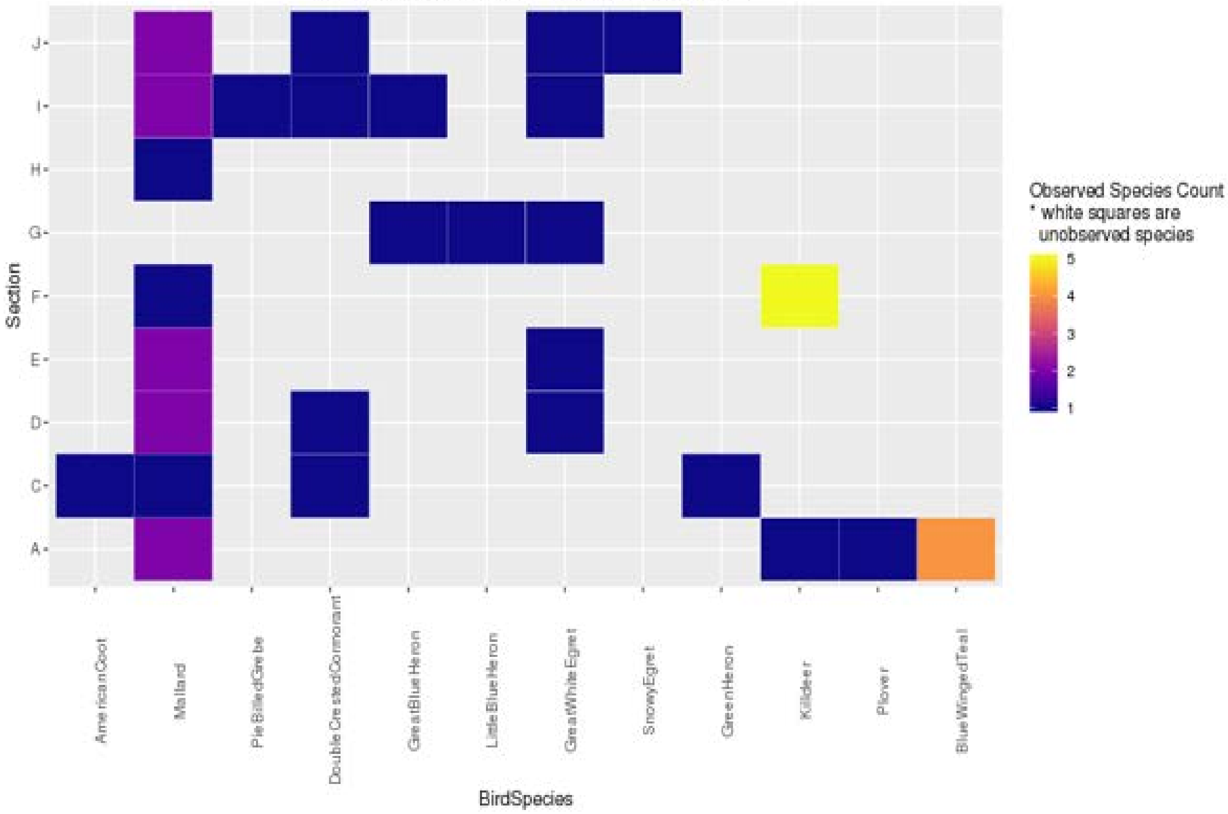

H.C. 1: Coordinate by Individual Bird Species
Section
H
G
F
E
D
C
B
A
AmericanCoot
Mallard
Gadwall
LesserScaup
RingedNeckDuck
PieBilledGrebe
DoubleCrestedCormorant
GreatBlueHeron
LittleBlueHeron
GreatWhiteEgret
SnowyEgret
CattleEgret
AmericanBittern
GreenHeron
AmericanWigeon
NorthernShoveler
Pintail
RedHead
NightHeron
Killdeer
GreenWingedTeal
YellowLegs
BirdSpecies
Observed Species Count
* white squares are
unobserved species
100
75
50
25


H.C. 2: Coordinate by Individual Bird Species

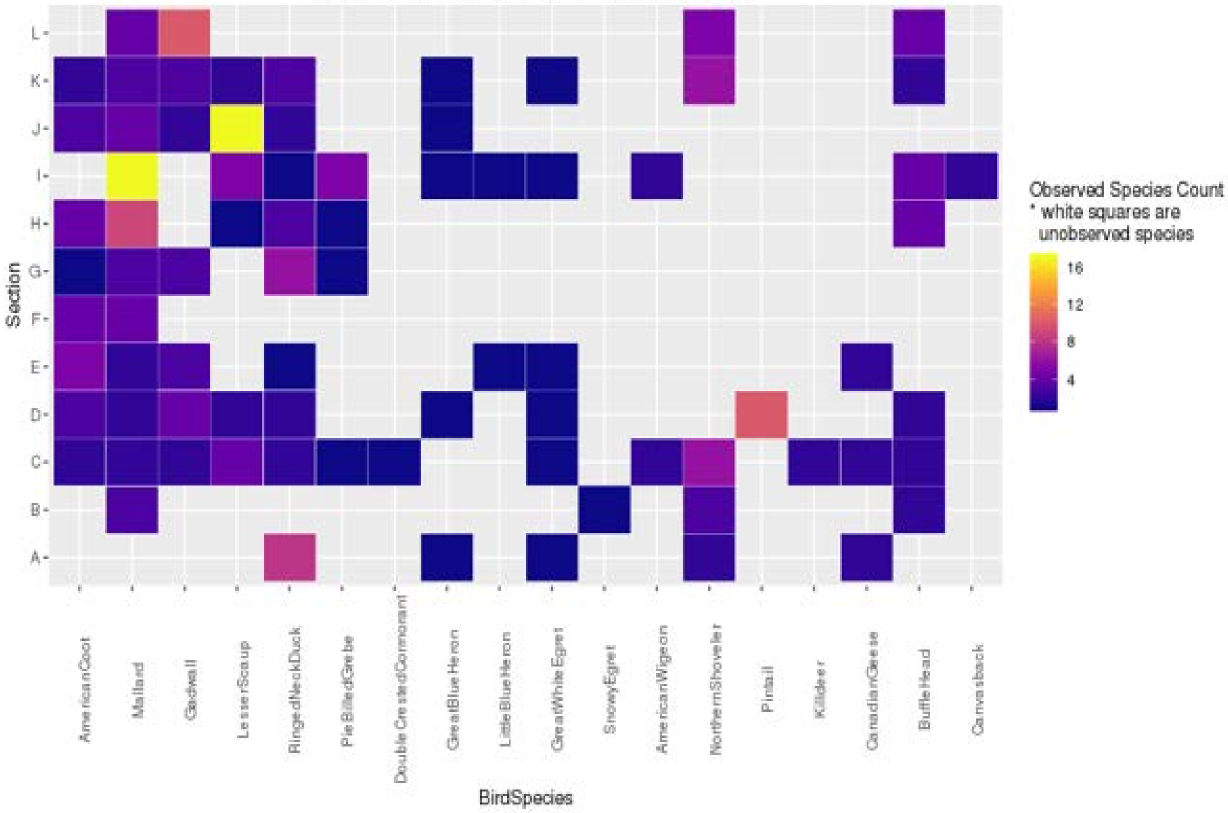

H.L. 1: Coordinate by Individual Bird Species


H.L. 2: Coordinate by Individual Bird Species

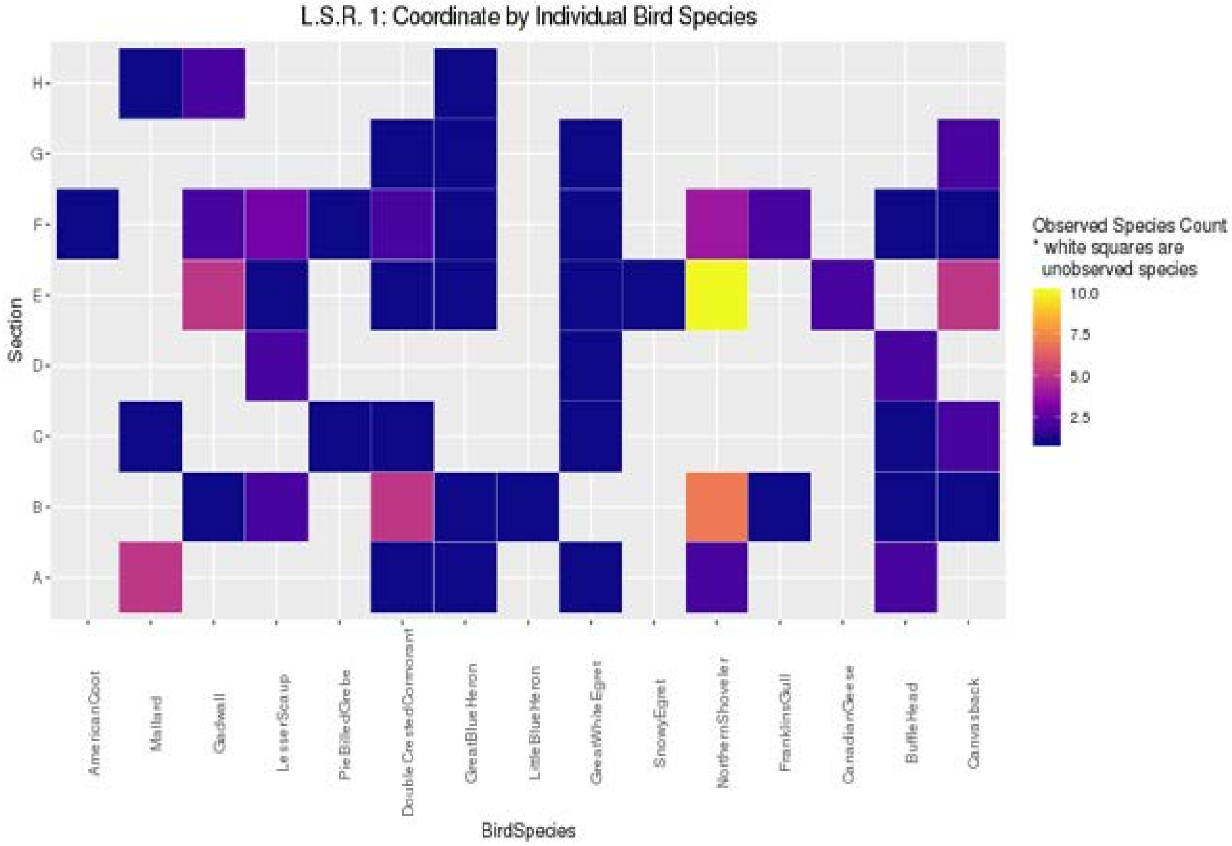

H.L. 3: Coordinate by Individual Bird Species

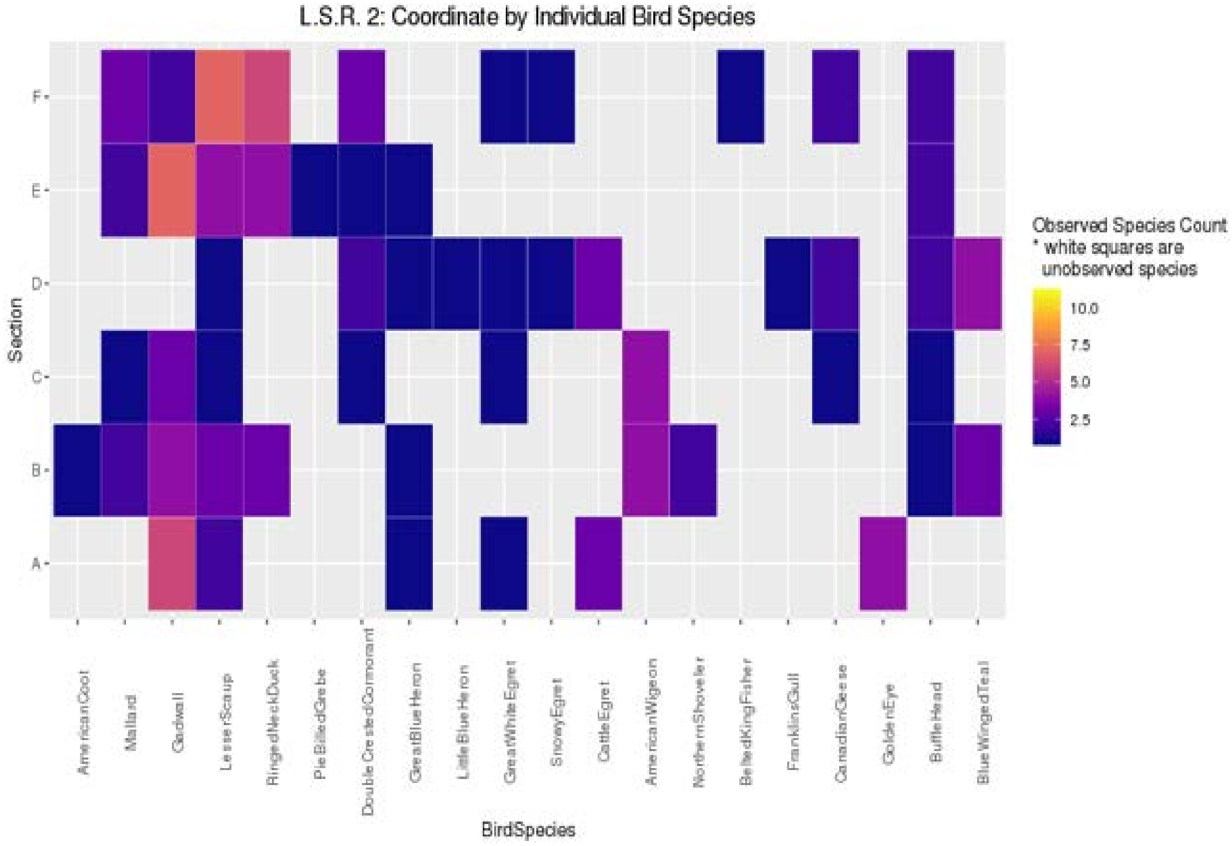


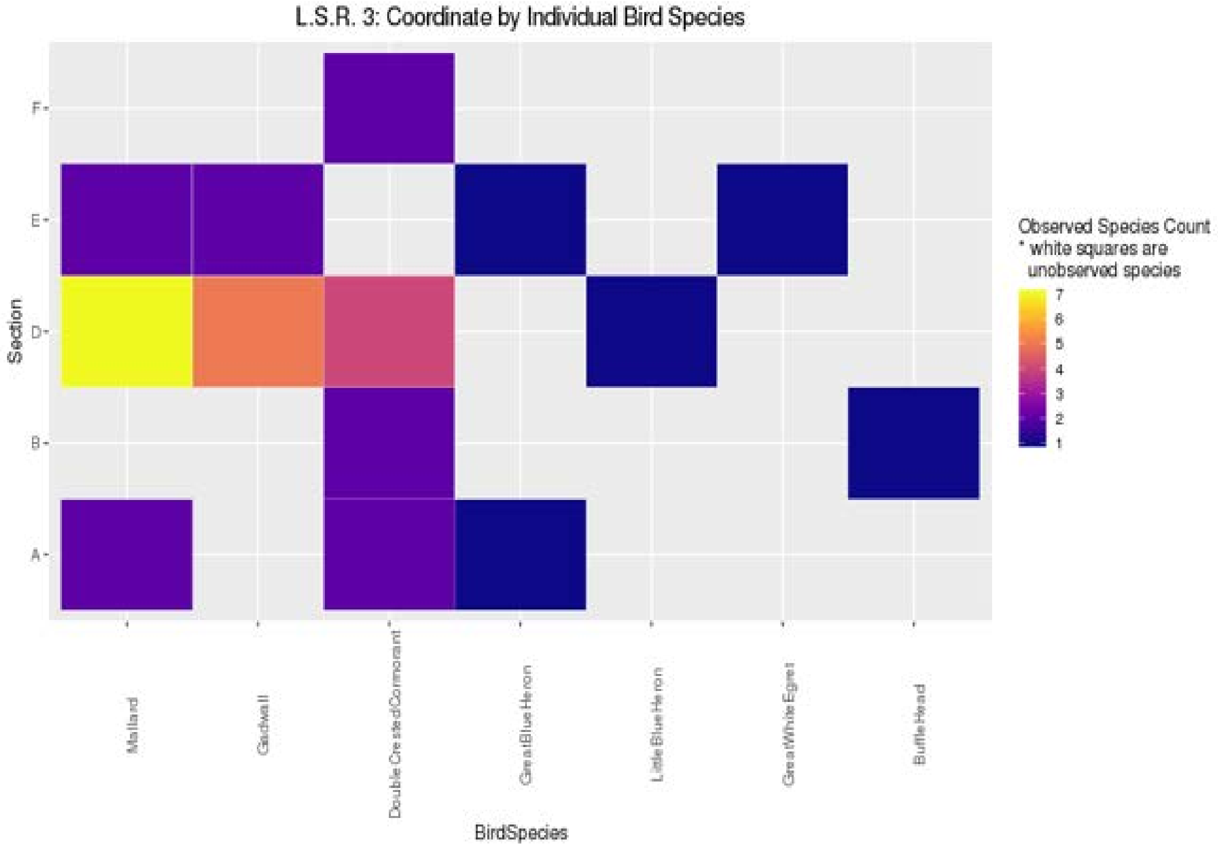
H.L. 4: Coordinate by Individual Bird Species

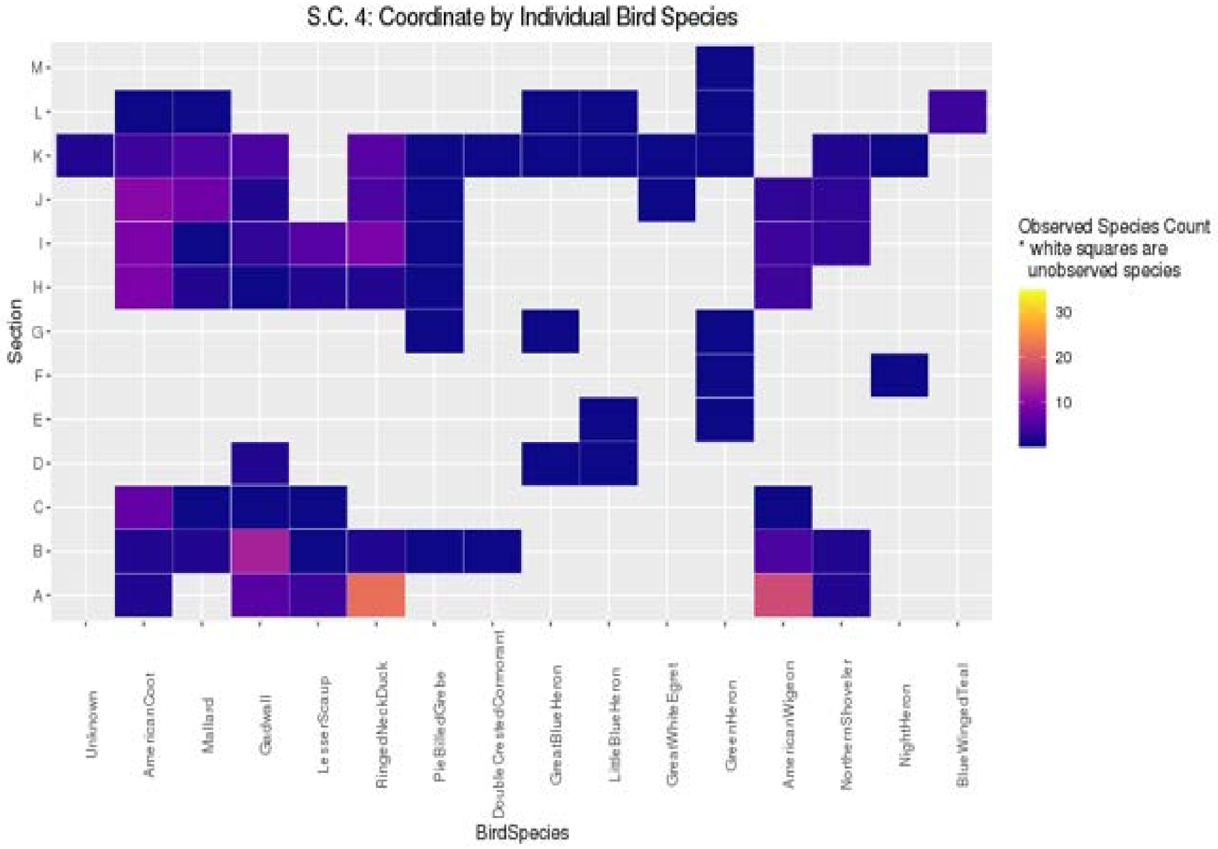


H.L. 5: Coordinate by Individual Bird Species

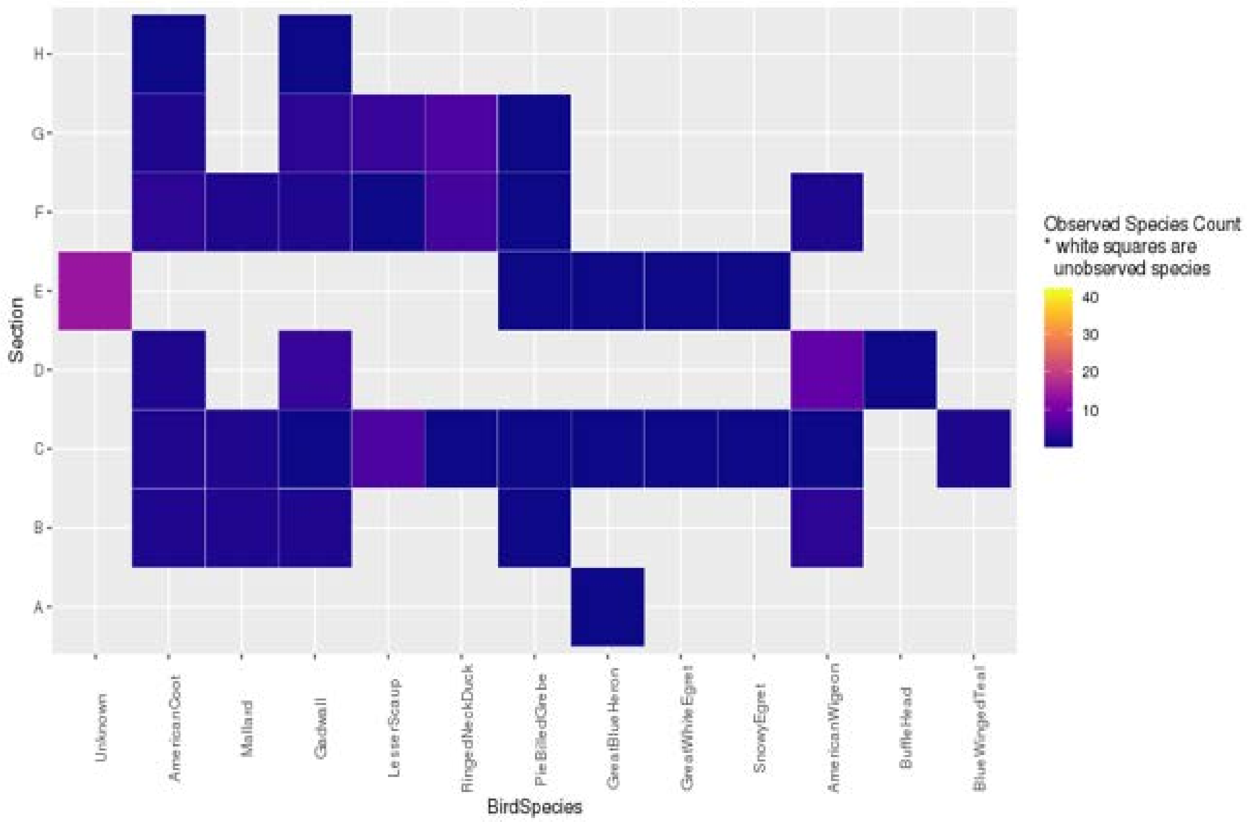

L.S.R. 1: Coordinate by Individual Bird Species


L.S.R. 2: Coordinate by Individual Bird Species

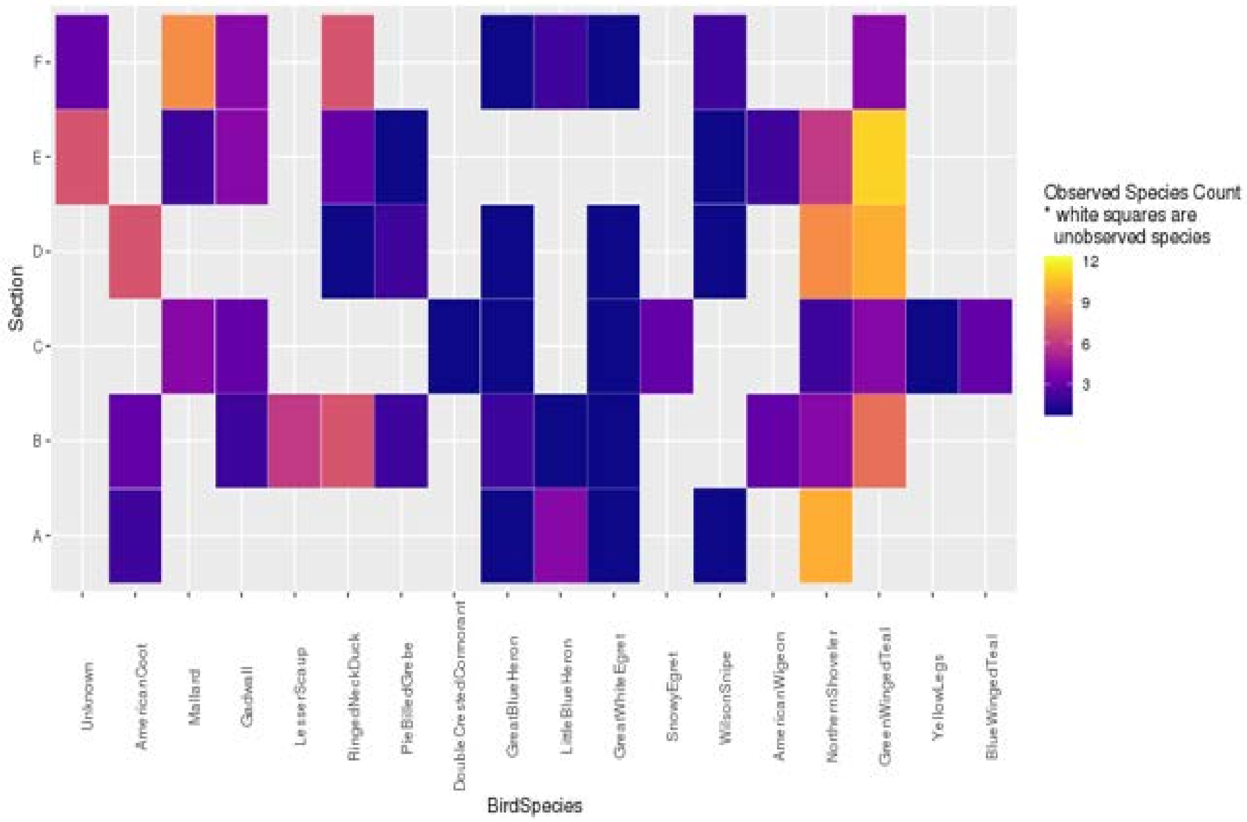

L.S.R. 3: Coordinate by Individual Bird Species
Section
F
E
D
B
A
Mallard
Gadwall
DoubleCrestedCormorant
GreatBlueHeron
LittleBlueHeron
GreatWhiteEgret
BuffleHead
BirdSpecies
Observed Species Count
* white squares are
unobserved species
7
6
5
4
3
2
1


S.C. 4: Coordinate by Individual Bird Species
Section
M
L
K
J
I
H
G
F
E
D
C
B
A
Unknown
AmericanCoot
Mallard
Gadwall
LesserScaup
RingedNeckDuck
PieBilledGrebe
DoubleCrestedCormorant
GreatBlueHeron
LittleBlueHeron
GreatWhiteEgret
GreenHeron
AmericanWigeon
NorthernShoveler
NightHeron
BlueWingedTeal
BirdSpecies
Observed Species Count
* white squares are
unobserved species
30
20
10

S.C. 3: Coordinate by Individual Bird Species

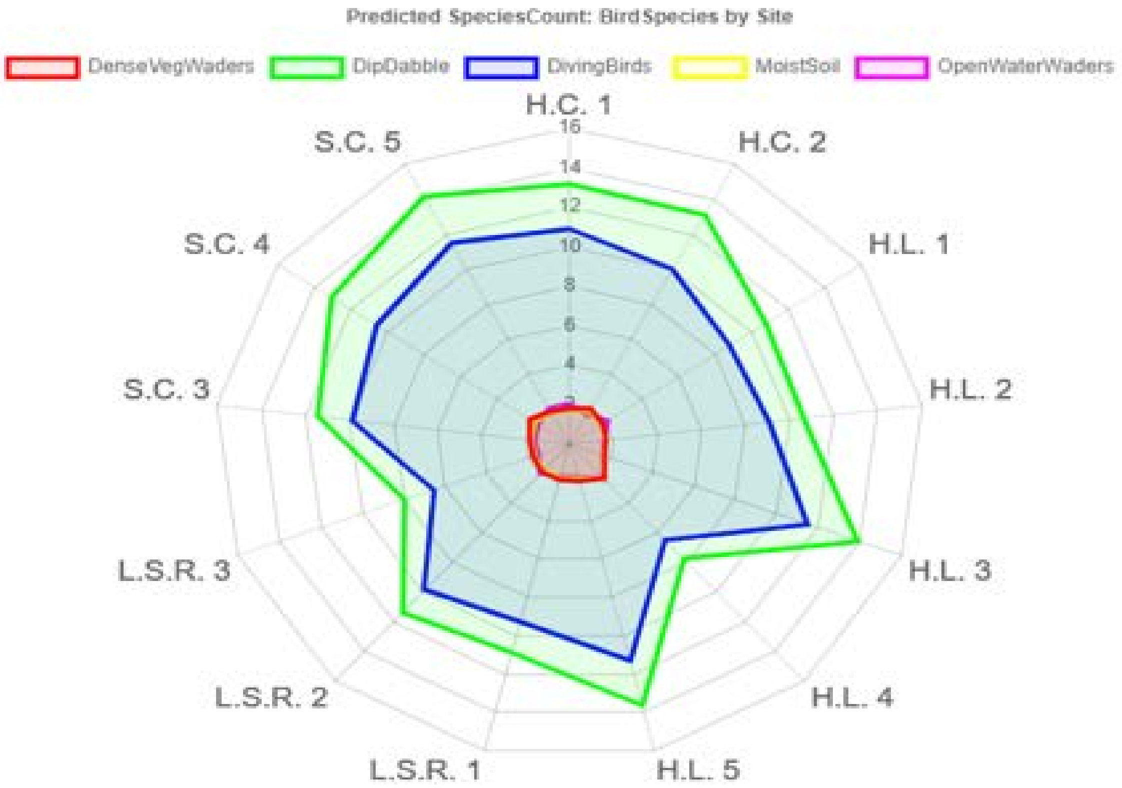


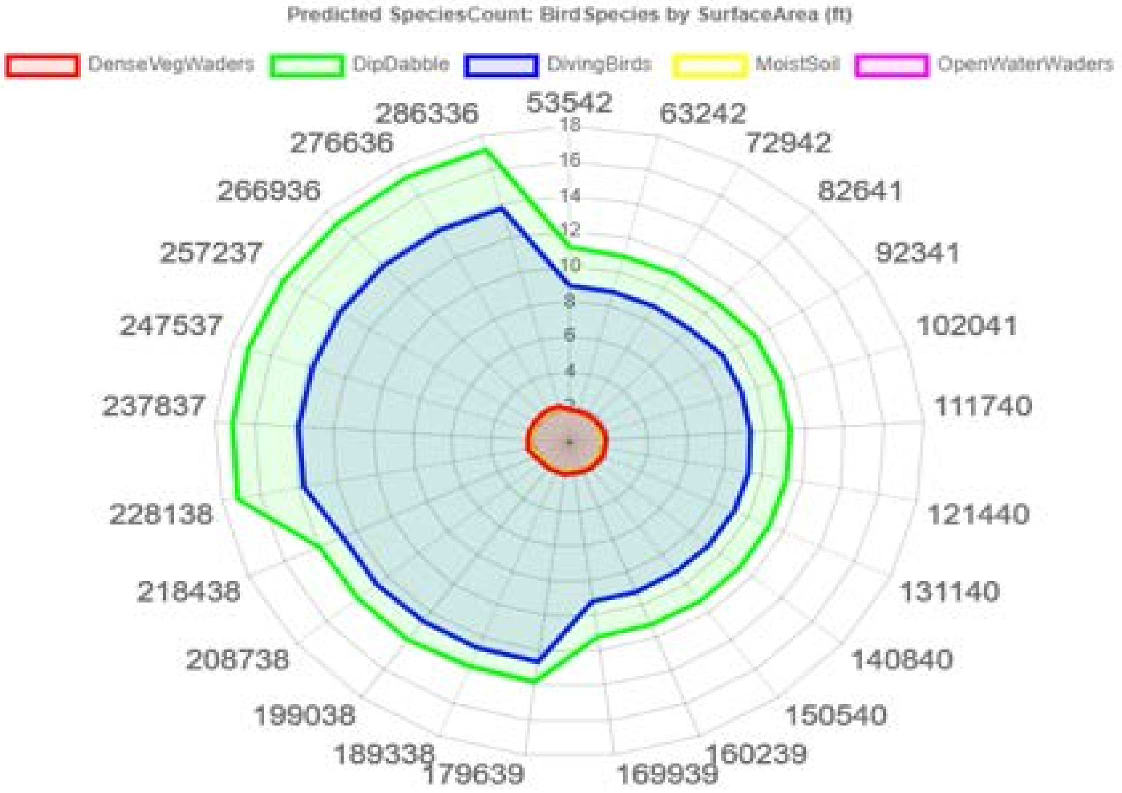
S.C. 5: Coordinate by Individual Bird Species

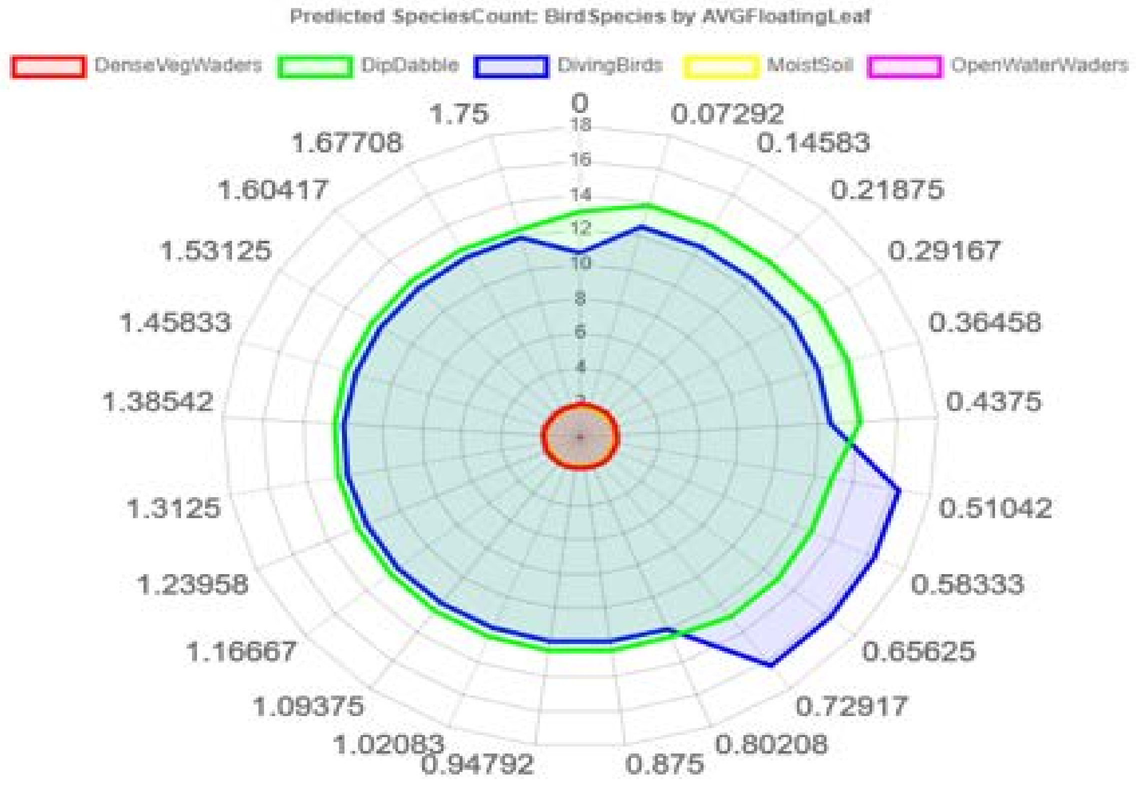


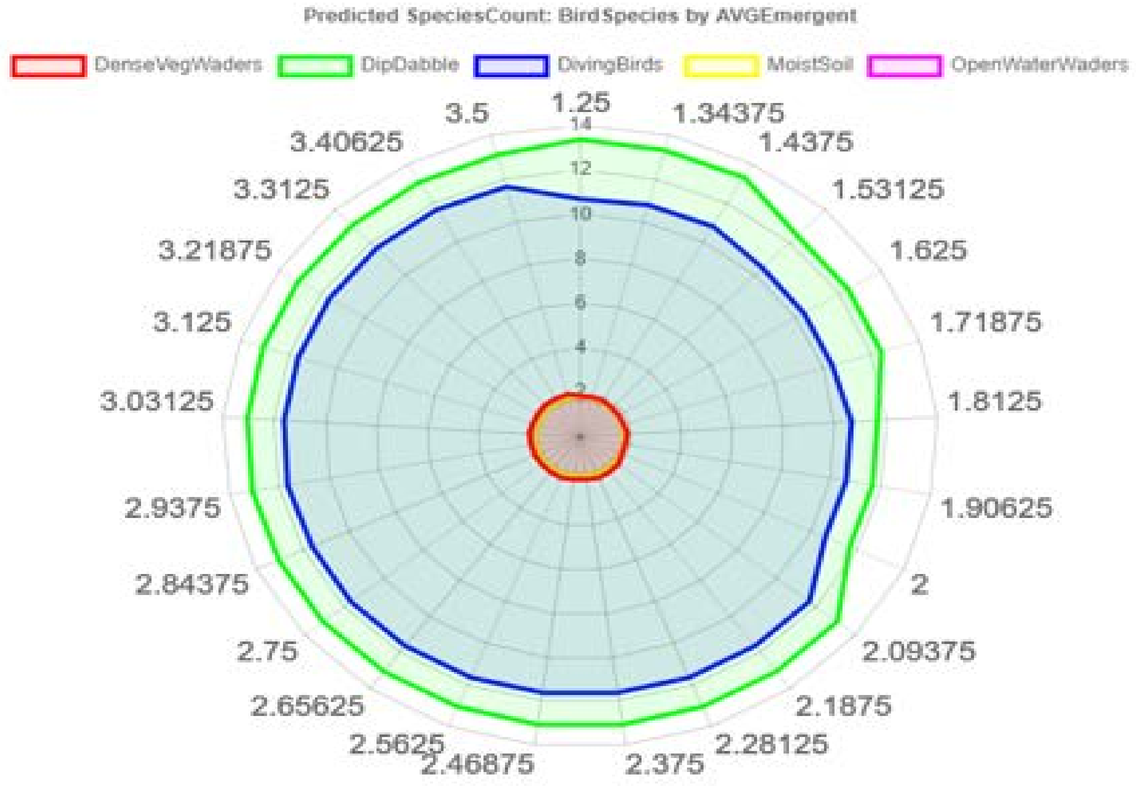
APPENDIX D

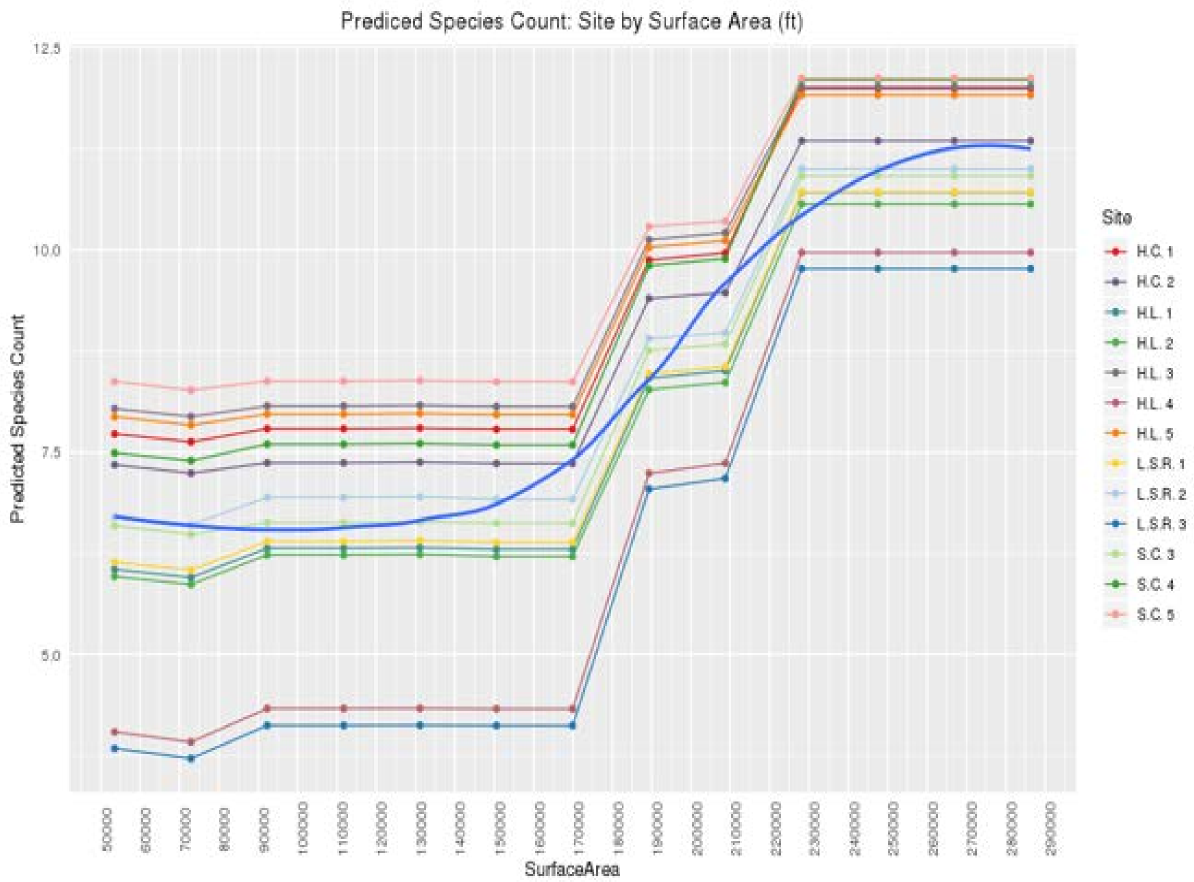
RANDOM FOREST MODEL FOR SPECIES COUNT, BIRD CLASS PREDICTION, AND MULTIPLE CORESPONDENCE ANALYSIS (PCA)


Predicted SpeciesCount: BirdSpecies by Site
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders
H.C. 1
H.C. 2
H.L. 1
H.L. 2
H.L. 3
H.L. 4
H.L. 5
L.S.R. 1
L.S.R. 2
L.S.R. 3
S.C. 3
S.C. 4
S.C. 5
16
14
12
10
8
6
4
2

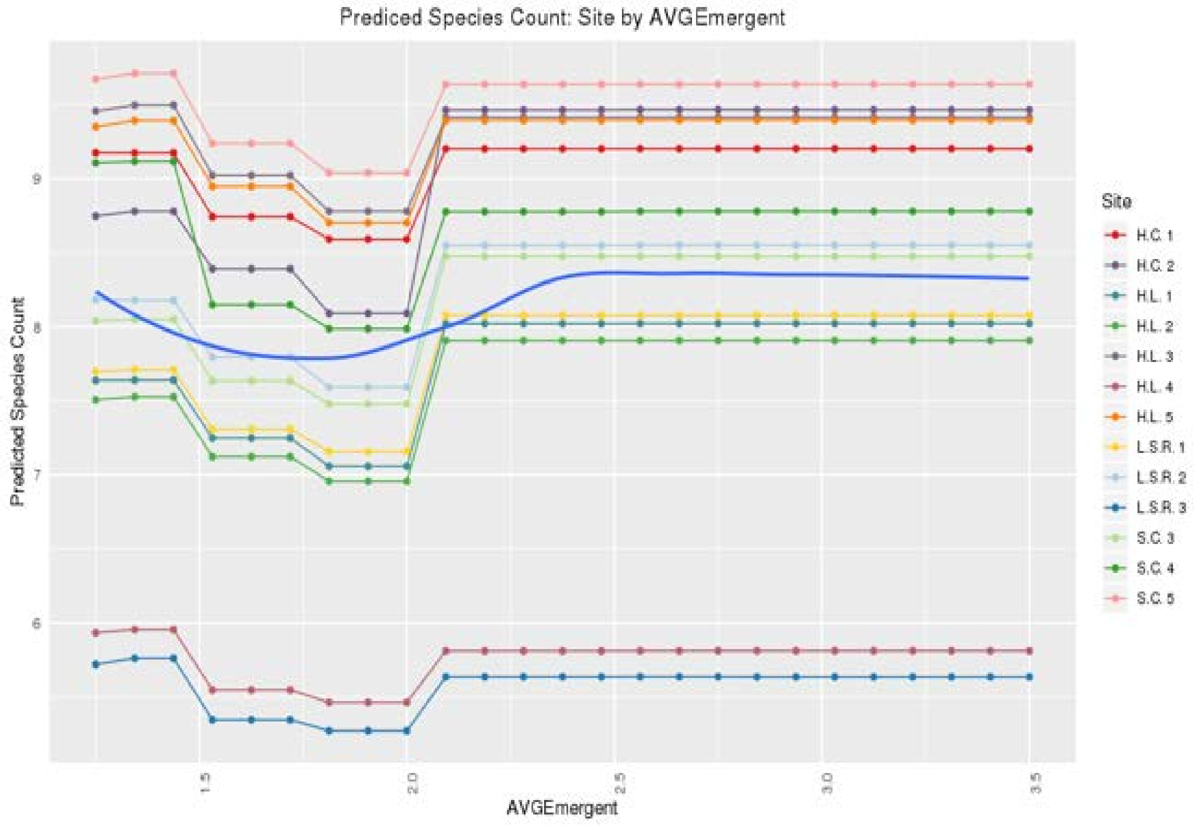

Predicted SpeciesCount: BirdSpecies by SurfaceArea (ft)
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders
53542
63242
72942
82641
92341
102041
111740
121440
131140
140840
150540
160239
169939
179639
189338
199038
208738
218438
228138
237837
247537
257237
266936
276636
286336
18
16
14
12
10
8
6
4
2


Predicted SpeciesCount: BirdSpecies by AVGFloatingLeaf
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders
0
0.07292
0.14583
0.21875
0.29167
0.36458
0.4375
0.51042
0.58333
0.65625
0.72917
0.80208
0.875
0.94792
1.02083
1.09375
1.16667
1.23958
1.3125
1.38542
1.45833
1.53125
1.60417
1.67708
1.75
18
16
14
12
10
8
6
4
2

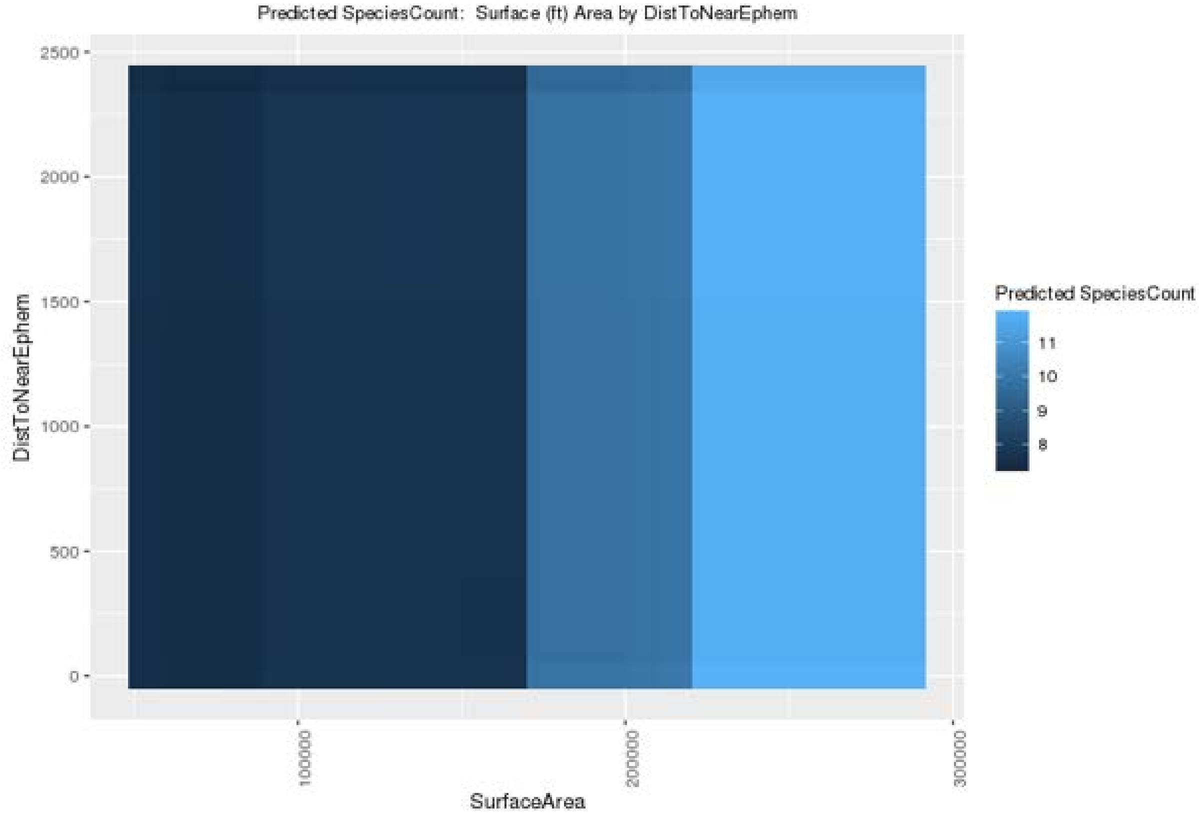

Predicted SpeciesCount: BirdSpecies by AVGEmergent
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders
1.25
1.34375
1.4375
1.53125
1.625
1.71875
1.8125
1.90625
2
2.09375
2.1875
2.28125
2.375
2.46875
2.5625
2.65625
2.75
2.84375
2.9375
3.03125
3.125
3.21875
3.3125
3.40625
3.5
14
12
10
8
6
4
2

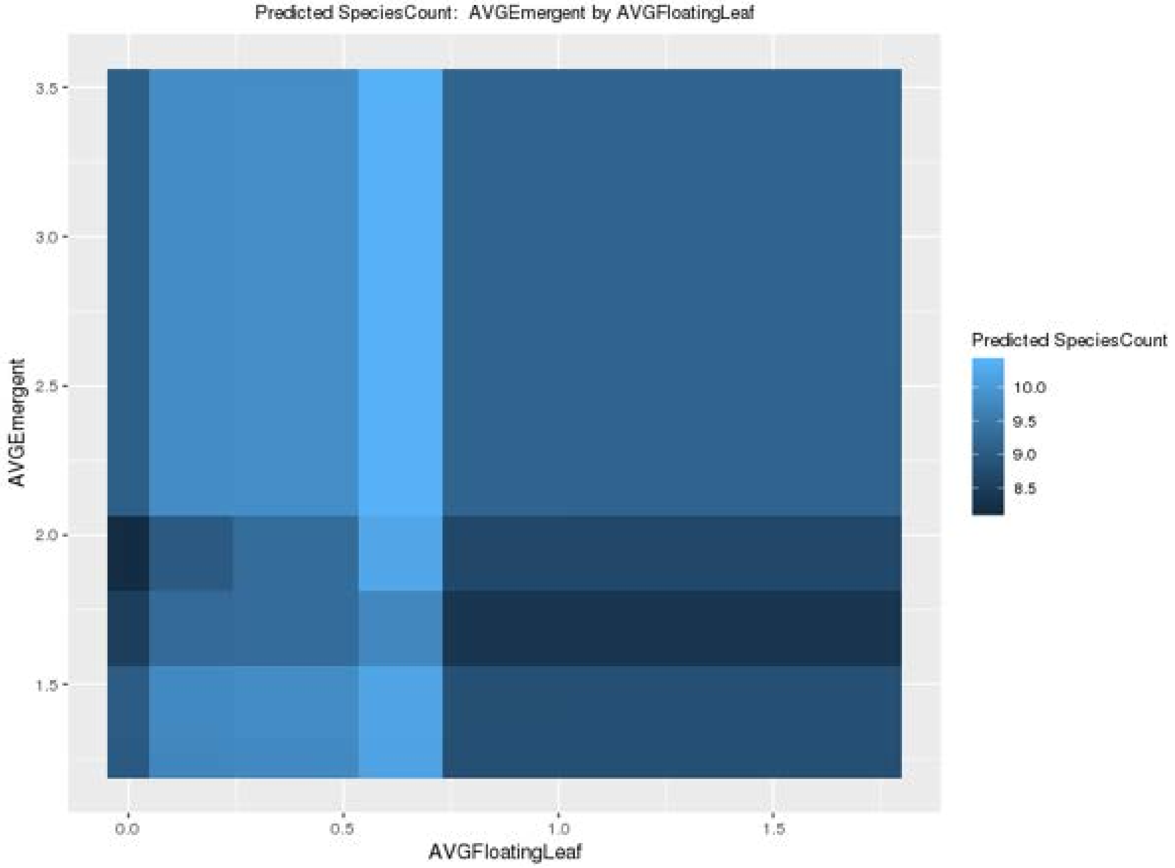


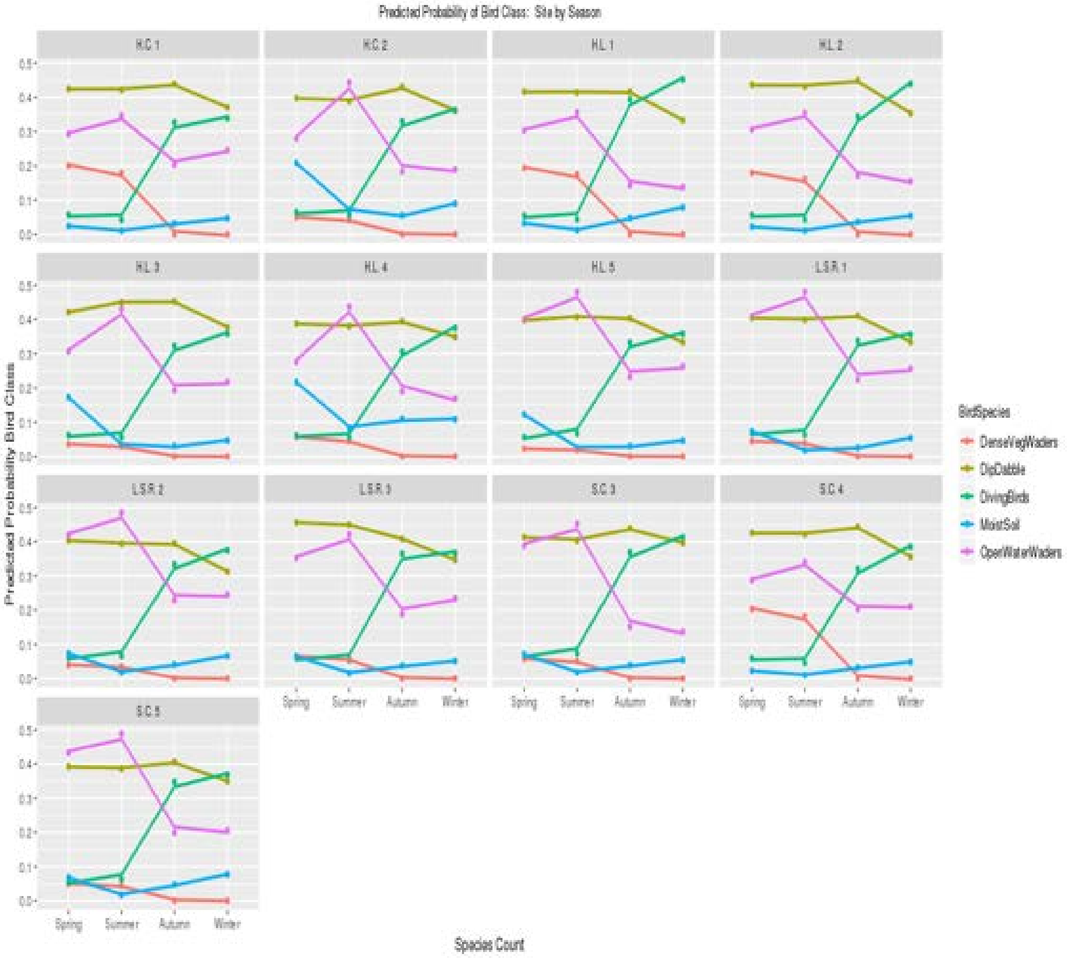
Prediced Species Count: Site by Surface Area (ft)

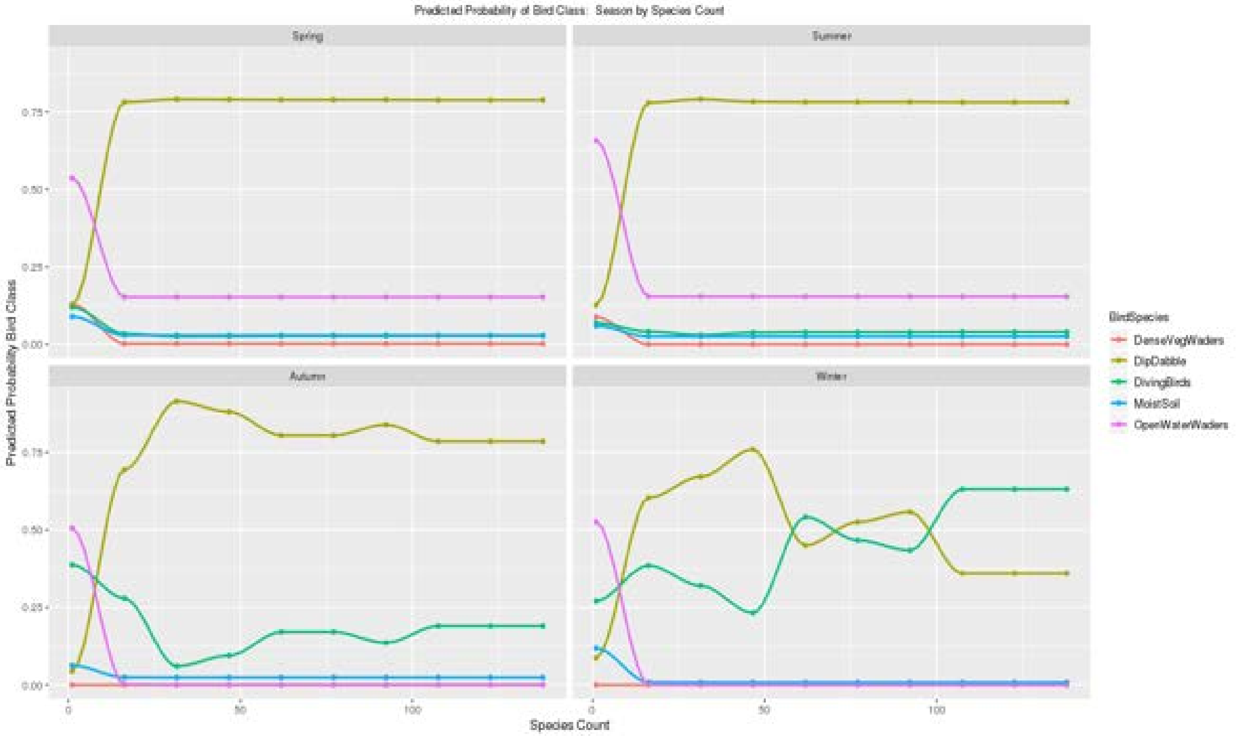


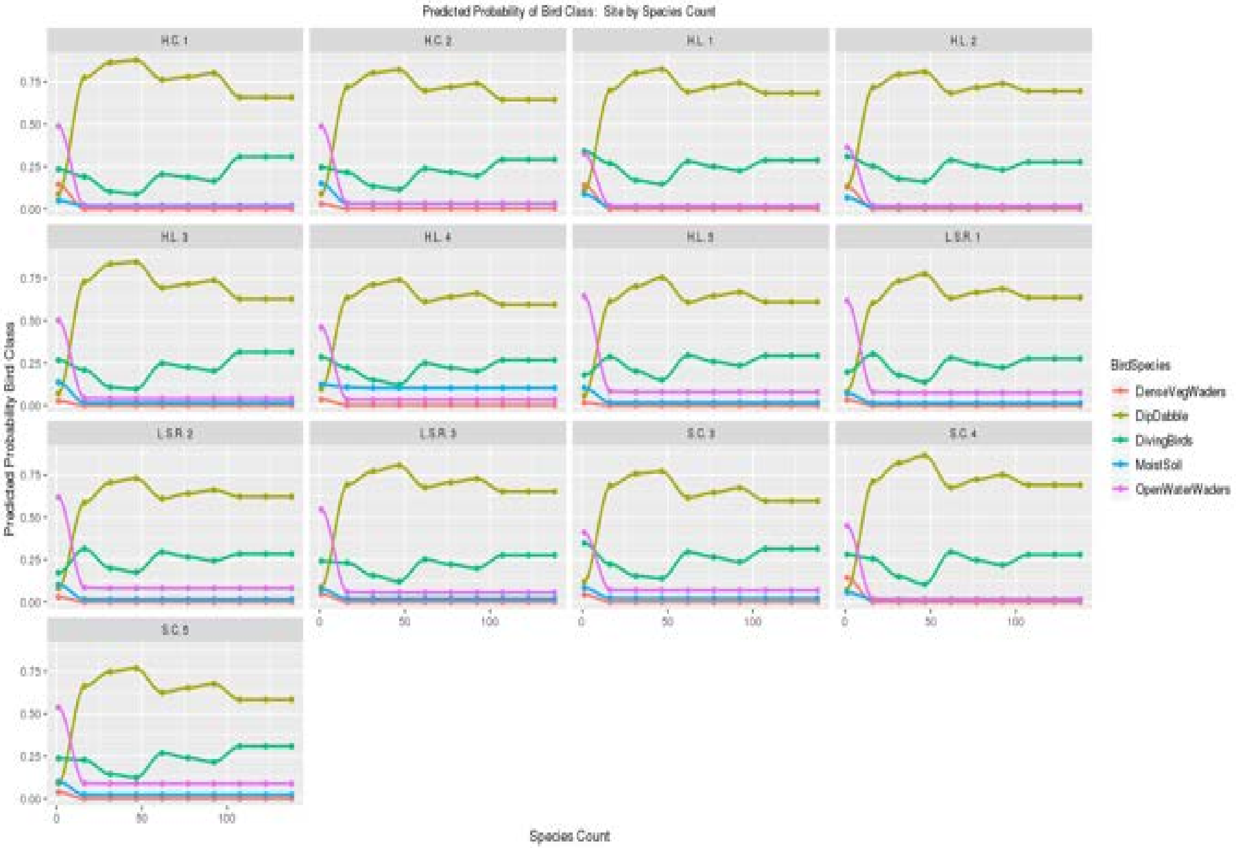
Prediced Species Count: Site by AVGEmergent

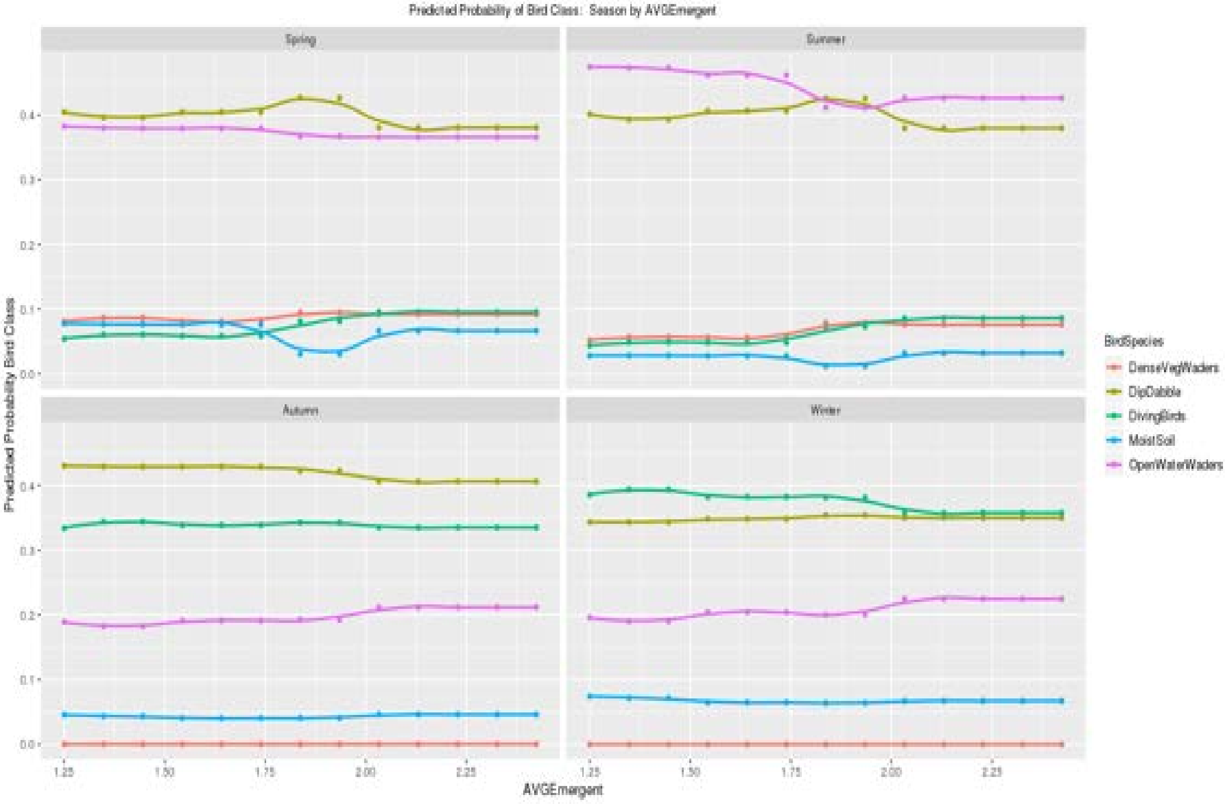

Predicted SpeciesCount: Surface (ft) Area by DistToNearEphem
2500
2000
1500
1000
500
0
DistToNearEphem
100000
200000
300000
SurfaceArea
Predicted SpeciesCount
11
10
9
8

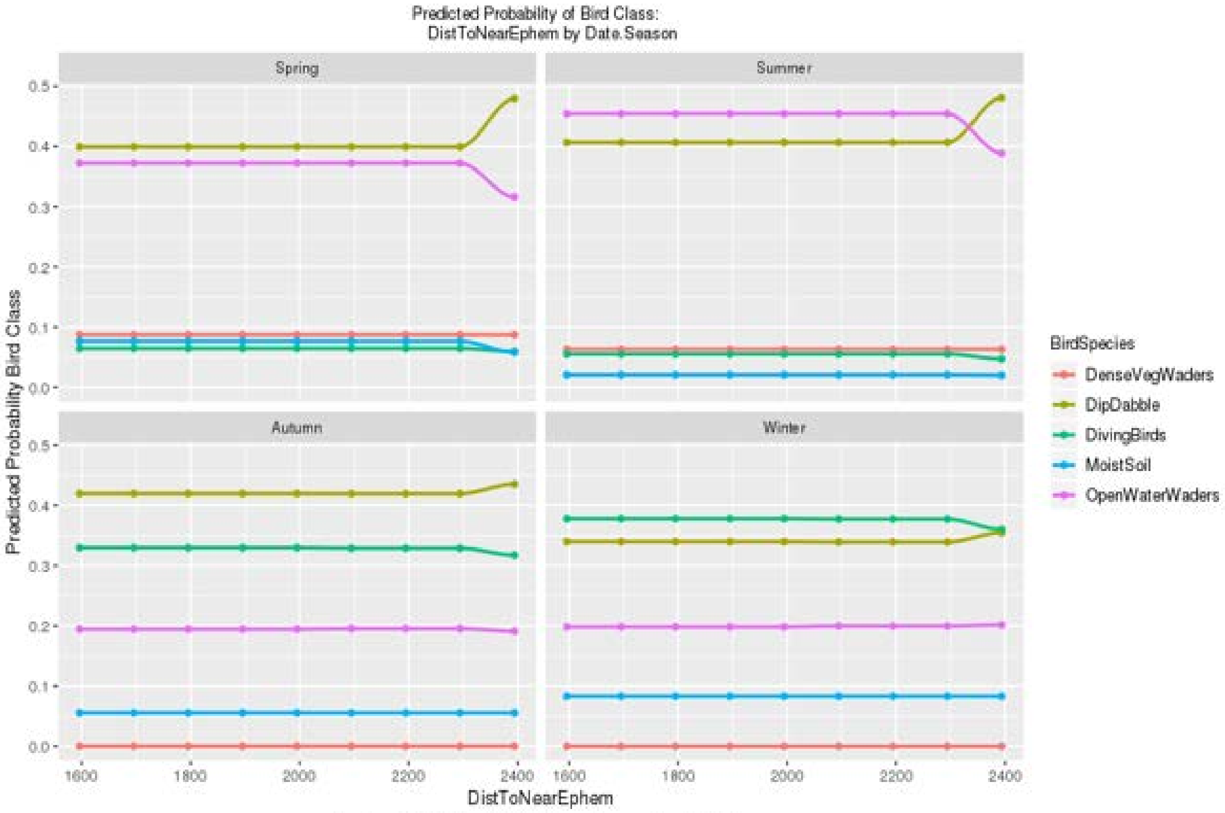

Predicted SpeciesCount: AVGEmergent by AVGFloatingLeaf
3.5
3.0
2.5
2.0
1.5
AVGEmergent
0.0
0.5
1.0
1.5
AVGFloatingLeaf
Predicted SpeciesCount
10.0
9.5
9.0
8.5

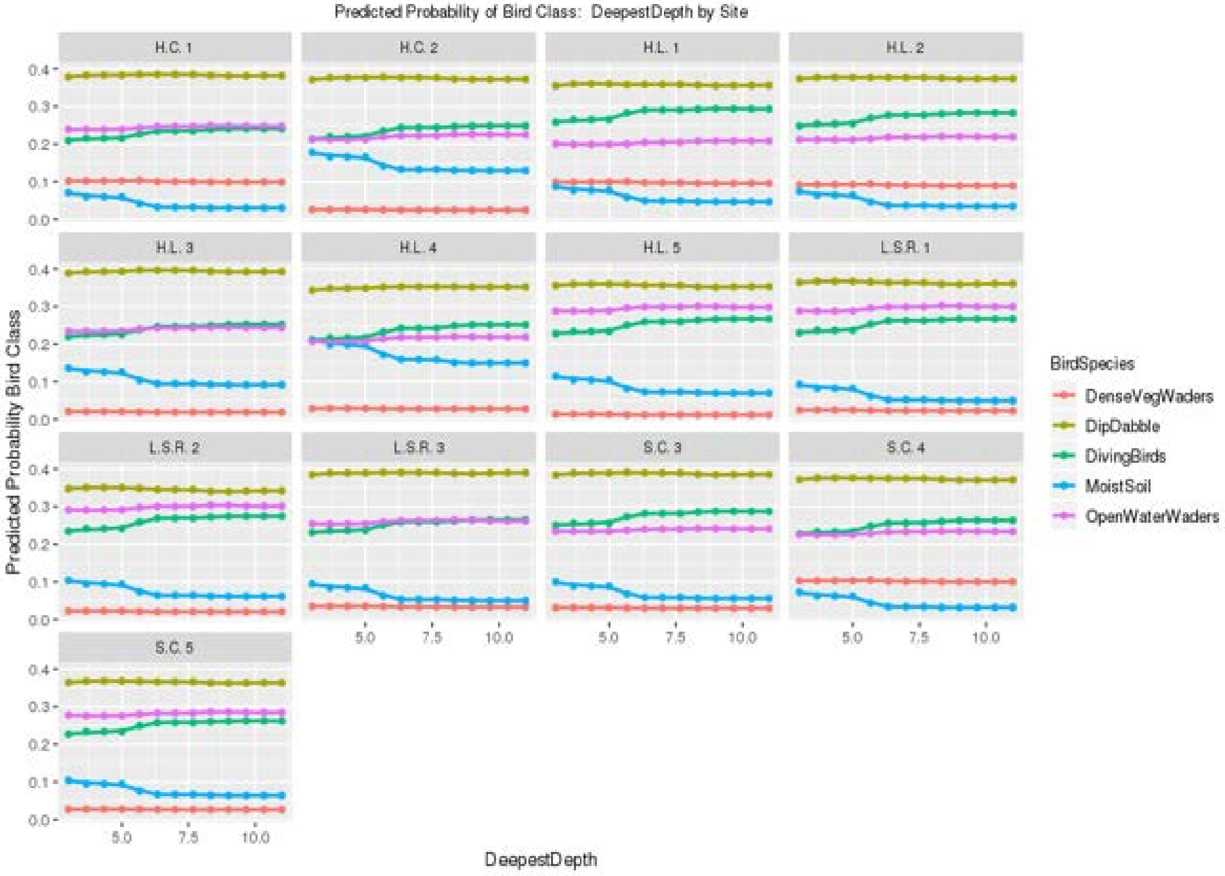

Predicted Probability of Bird Class: Site by Season
H.C 1
H.C 2
H.L 1
H.L 2
H.L 3
H.L 4
H.L 5
L.S.R 1
L.S.R 2
L.S.R 3
S.C 3
S.C 4
S.C 5
Predicted Probability Bird Class
0.0
0.1
0.2
0.3
0.4
0.5
Spring
Summer
Autumn
Winter
Species Count
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders

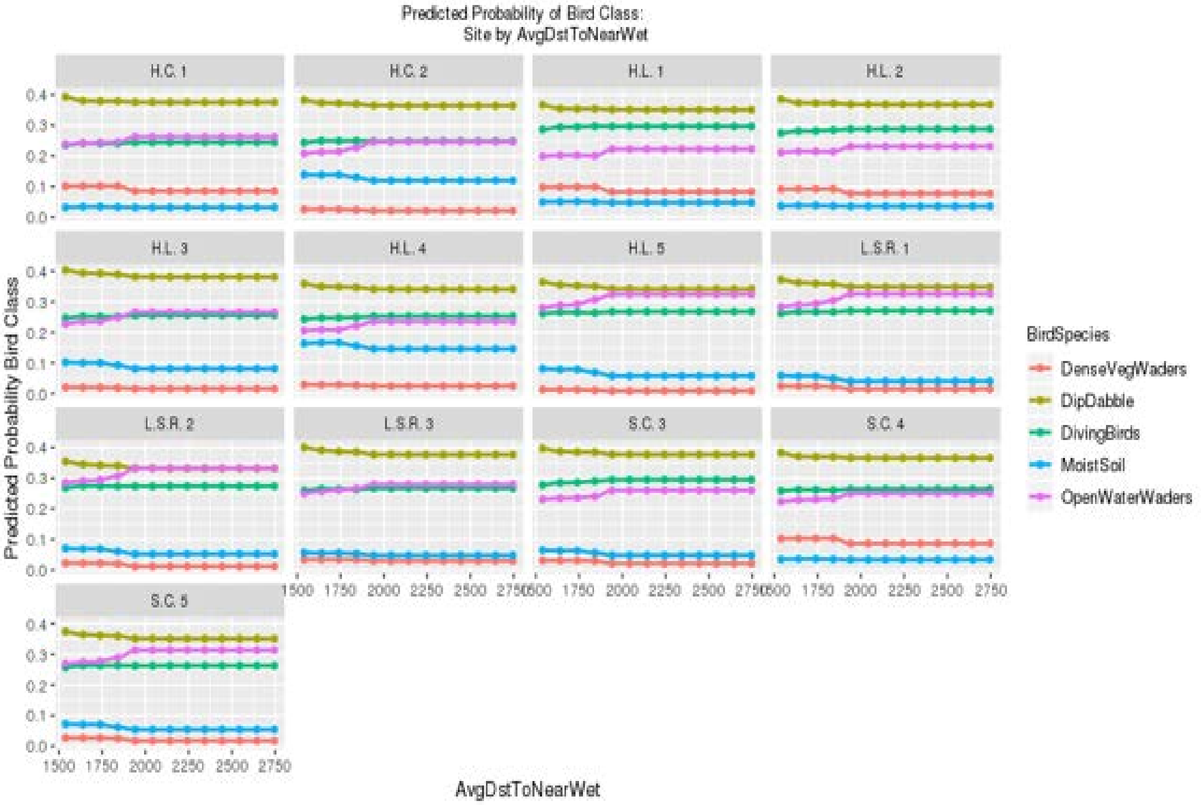

Predicted Probability of Bird Class: Season by Species Count
Spring
Summer
Autumn
Winter
Predicted Probability Bird Class
0.00
0.25
0.50
0.75
0
50
100
Species Count
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders

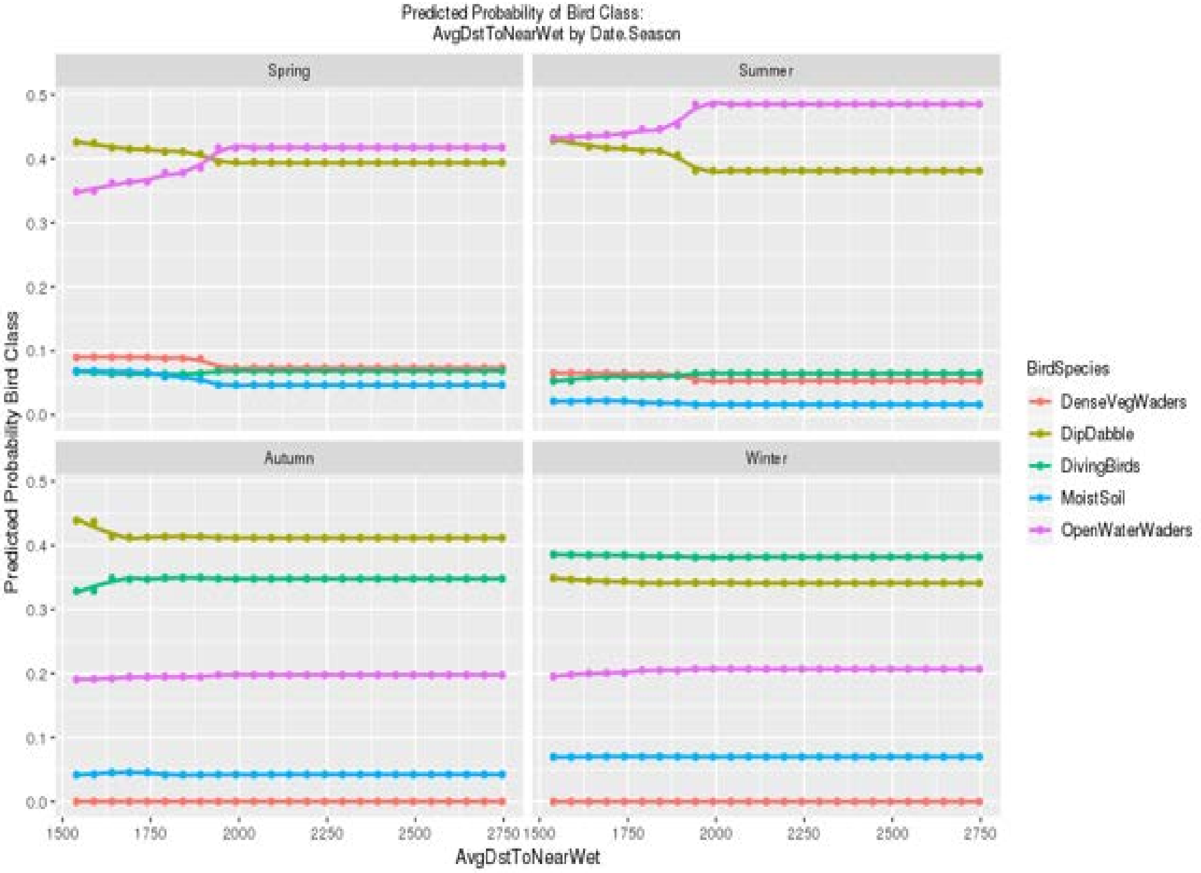

Predicted Probability of Bird Class: Site by Species Count
H.C.1
H.C.2
H.L.1
H.L.2
H.L.3
H.L.4
H.L.5
L.S.R.1
L.S.R.2
L.S.R.3
S.C.3
S.C.4
S.C.5
0.00
0.25
0.50
0.75
0
50
100
Predicted Probability Bird Class
Species Count
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders

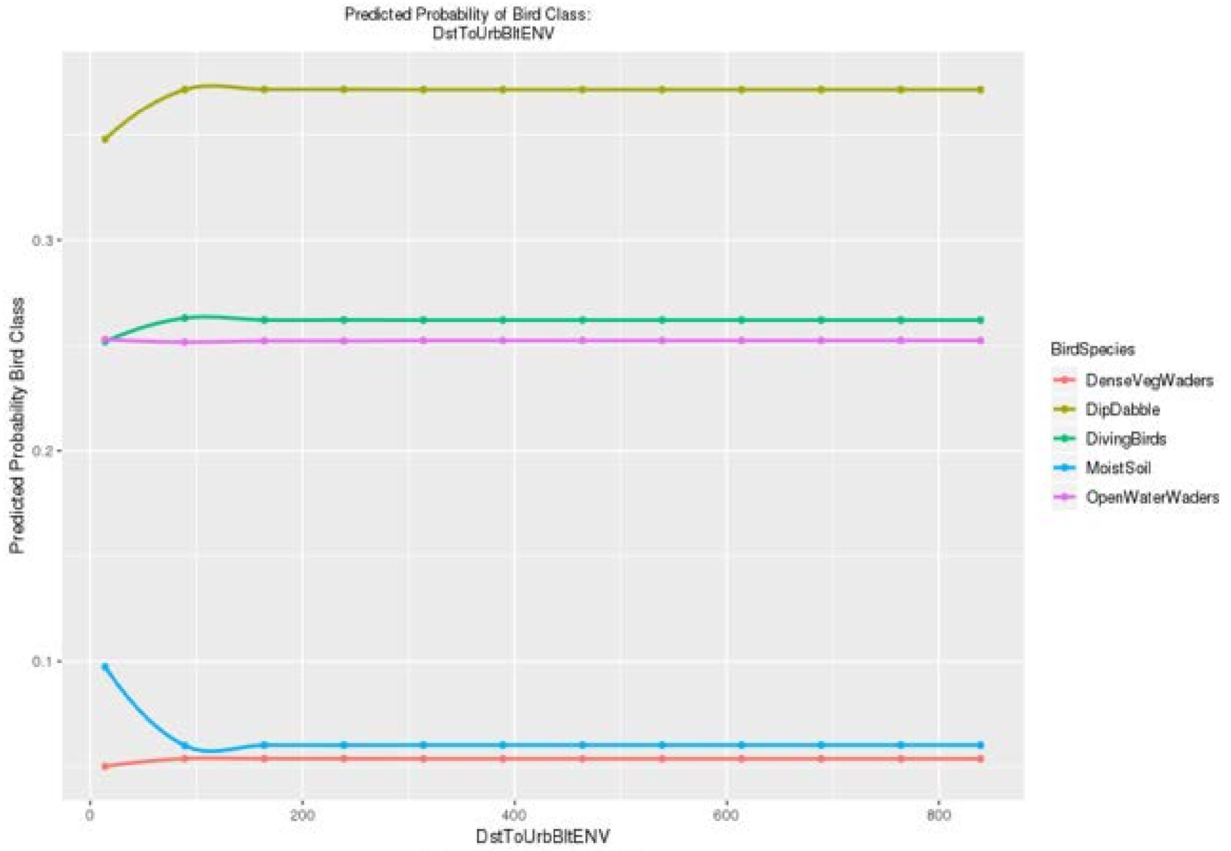

Predicted Probability of Bird Class: Season by AVGEmergent
Spring
Summer
Autumn
Winter
0.0
0.1
0.2
0.3
0.4
1.25
1.50
1.75
2.00
2.25
Predicted Probability Bird Class
AVGEmergent
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders


Predicted Probability of Bird Class:
DistToNearEphem by Date.Season
Spring
Summer
Autumn
Winter
Predicted Probability Bird Class
0.0
0.1
0.2
0.3
0.4
0.5
1600
1800
2000
2200
2400
DistToNearEphem
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders

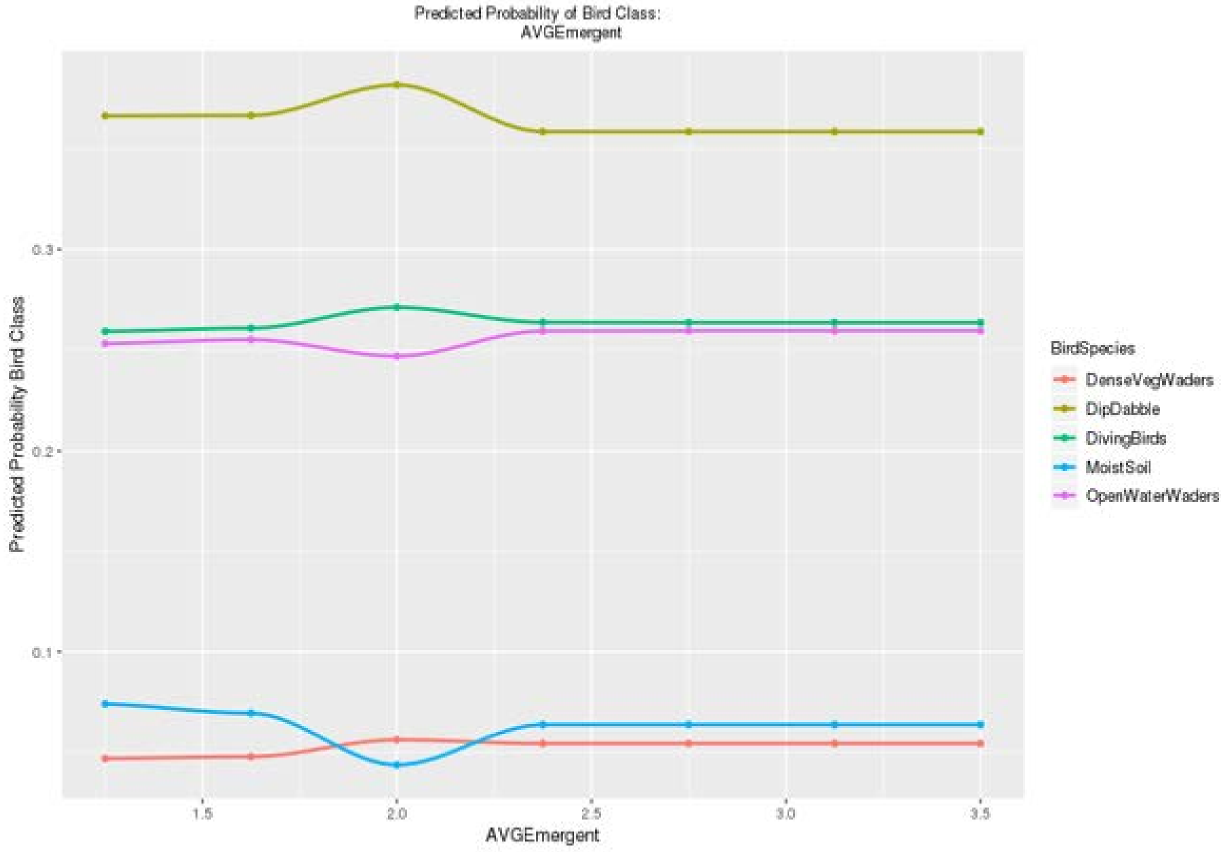

Predicted Probability of Bird Class: DeepestDepth by Site
H.C. 1
H.C. 2
H.L. 1
H.L. 2
H.L. 3
H.L. 4
H.L. 5
L.S.R. 1
L.S.R. 2
L.S.R. 3
S.C. 3
S.C. 4
S.C. 5
Predicted Probability Bird Class
0.0
0.1
0.2
0.3
0.4
5.0
7.5
10.0
DeepestDepth
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders


Predicted Probability of Bird Class:
Site by AvgDstToNearWet
H.C. 1
H.C. 2
H.L. 1
H.L. 2
H.L. 3
H.L. 4
H.L. 5
L.S.R. 1
L.S.R. 2
L.S.R. 3
S.C. 3
S.C. 4
S.C. 5
0.0
0.1
0.2
0.3
0.4
1500
1750
2000
2250
2500
2750
Predicted Probability Bird Class
AvgDstToNearWet
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders

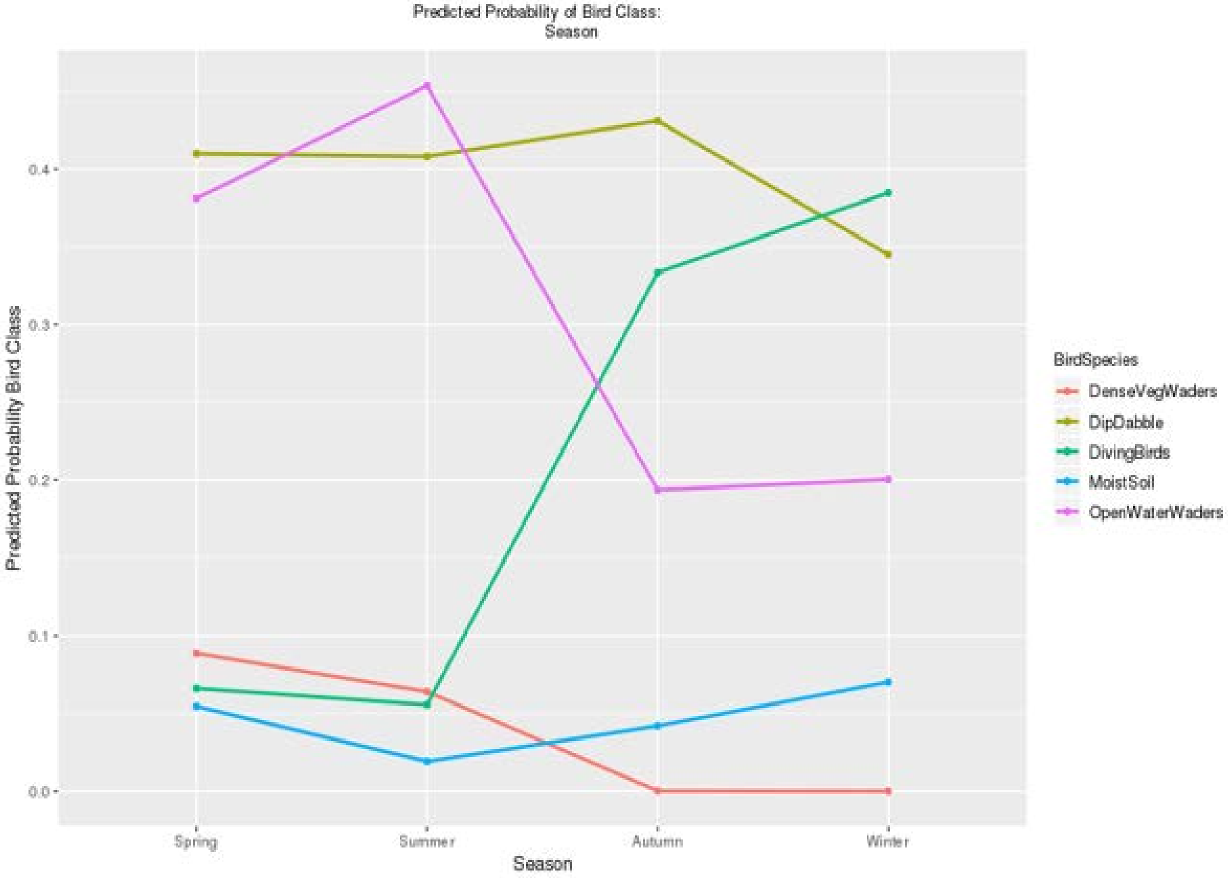

Predicted Probability of Bird Class:
AvgDstToNearWet by Date.Season
Spring
Summer
Autumn
Winter
0.0
0.1
0.2
0.3
0.4
0.5
1500
1750
2000
2250
2500
2750
Predicted Probability Bird Class
AvgDstToNearWet
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders

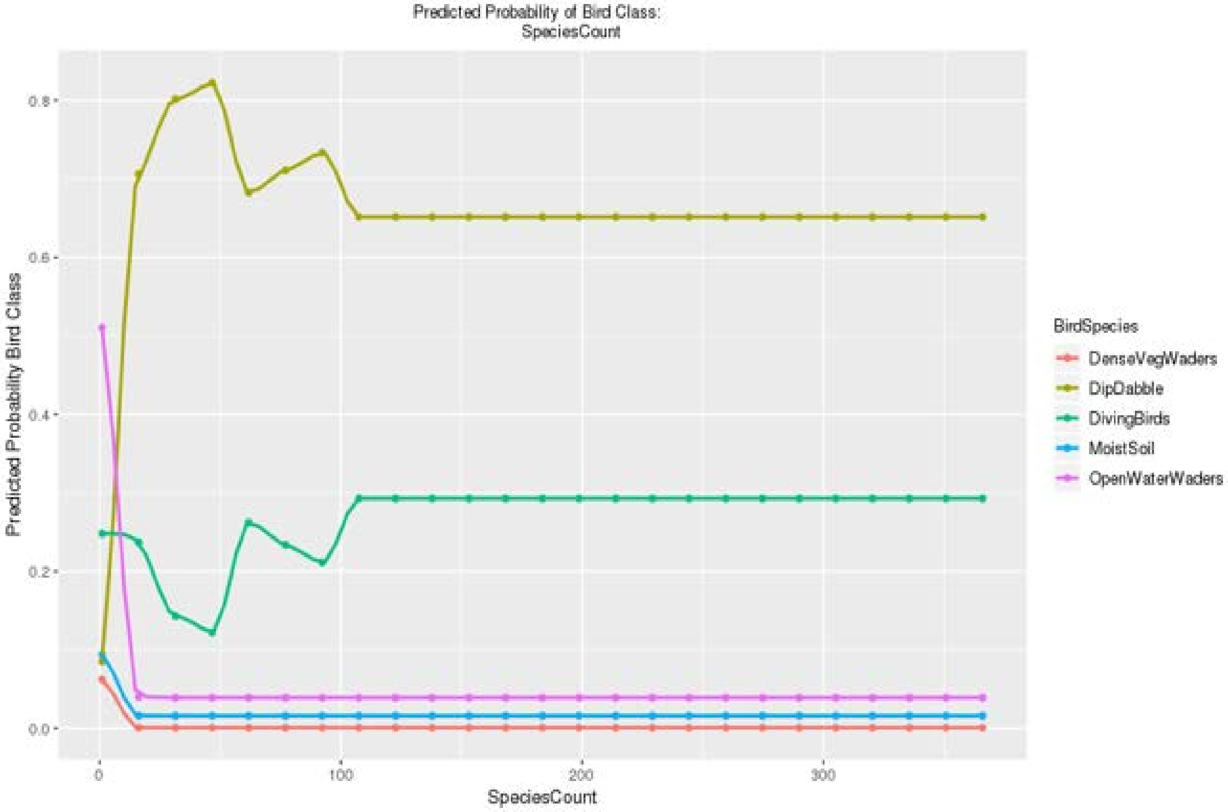


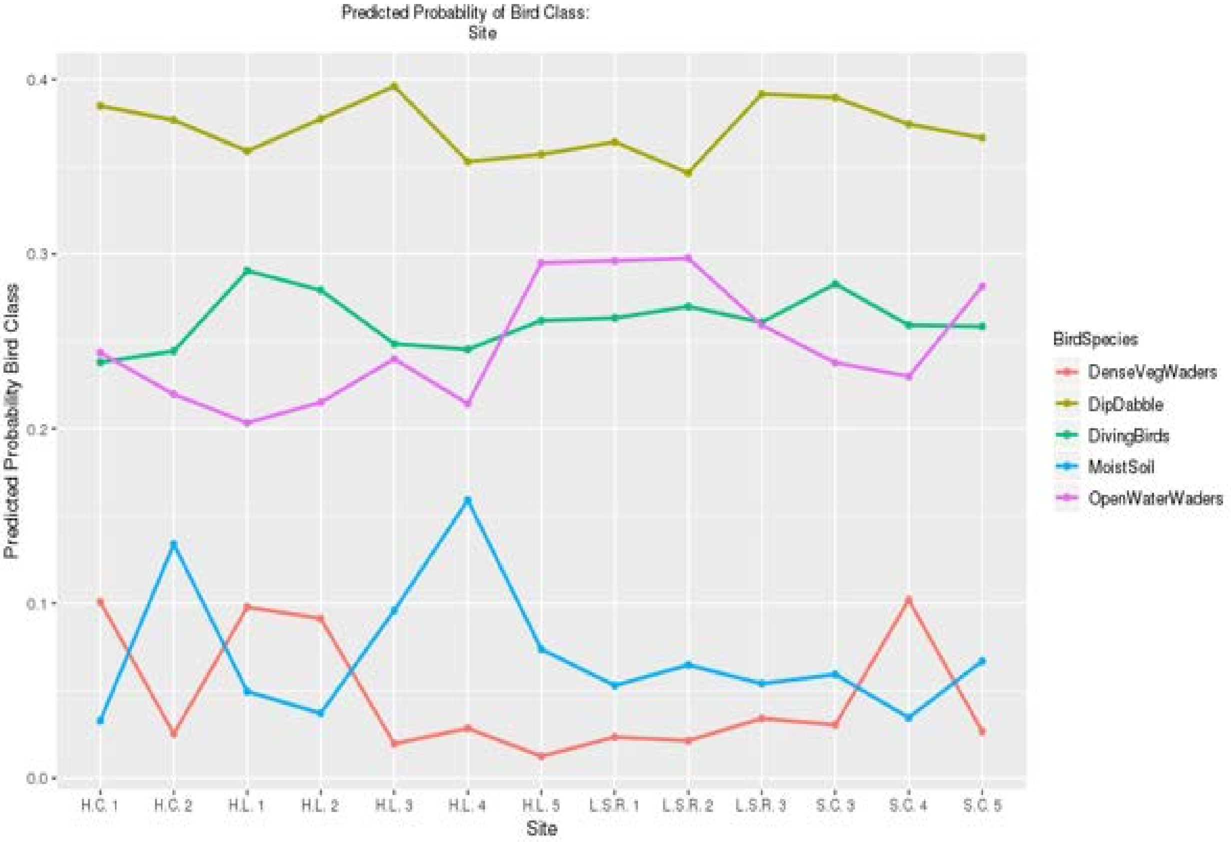
Predicted Probability of Bird Class:
DstToUrbBltENV

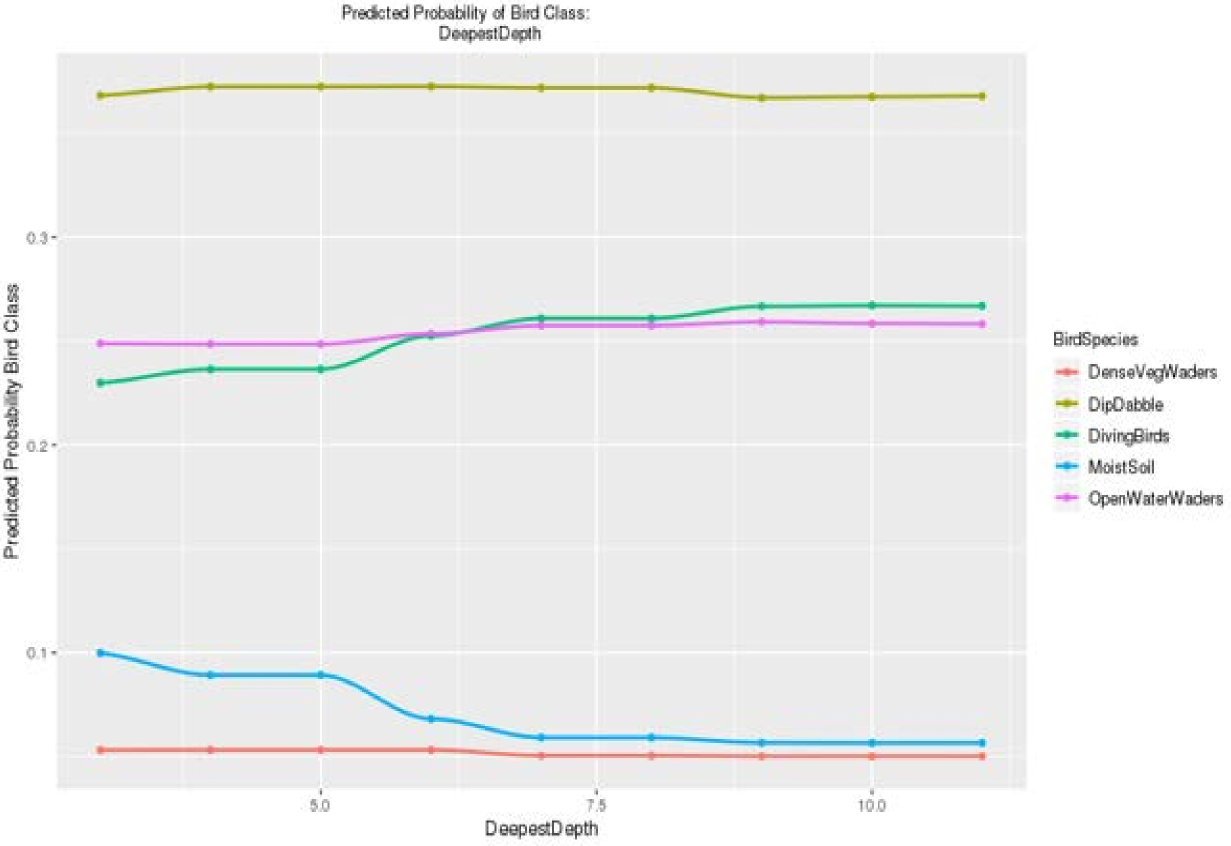


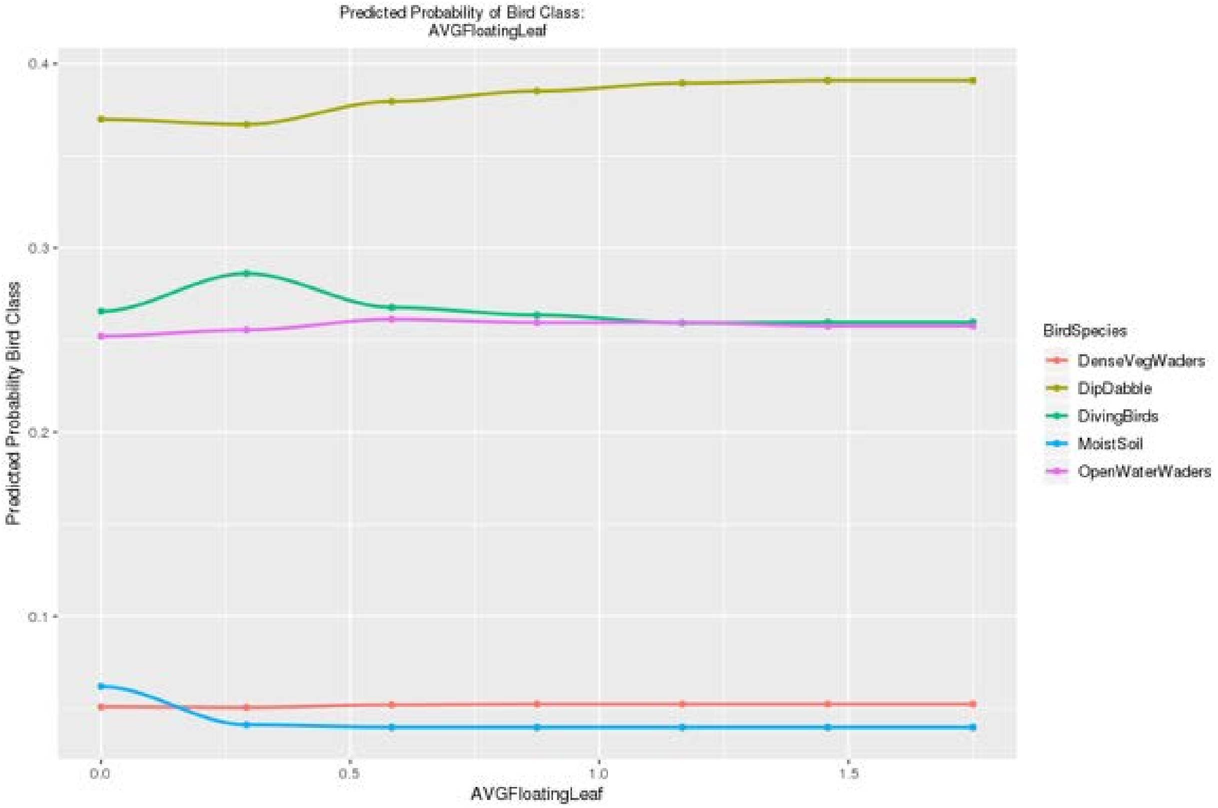
Predicted Probability of Bird Class:
AVGEmergent


Predicted Probability of Bird Class:
Season
Predicted Probability Bird Class
0.0
0.1
0.2
0.3
0.4
Spring
Summer
Autumn
Winter
Season
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders


Predicted Probability of Bird Class:
SpeciesCount
Predicted Probability Bird Class
0.0
0.2
0.4
0.6
0.8
0
100
200
300
SpeciesCount
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders


Predicted Probability of Bird Class:
Site
Predicted Probability Bird Class
0.0
0.1
0.2
0.3
0.4
H.C. 1
H.C. 2
H.L. 1
H.L. 2
H.L. 3
H.L. 4
H.L. 5
L.S.R. 1
L.S.R. 2
L.S.R. 3
S.C. 3
S.C. 4
S.C. 5
Site
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders


Predicted Probability of Bird Class:
DeepestDepth
Predicted Probability Bird Class
0.1
0.2
0.3
5.0
7.5
10.0
DeepestDepth
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders


Predicted Probability of Bird Class:
AVGFloatingLeaf
Predicted Probability Bird Class
0.4
0.3
0.2
0.1
0.0
0.5
1.0
1.5
AVGFloatingLeaf
BirdSpecies
DenseVegWaders
DipDabble
DivingBirds
MoistSoil
OpenWaterWaders

Optimally Linear Scaled Scores from a Multiple Correspondence Analysis: Predicting DenseVegWaders Probabilities from Predictors

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.000	0.000	0.000	1.000
Site.dim1	0.064	0.016	4.102	0.000***
x.y.sect.pc1.dim1	0.003	0.000	7.906	0.000***
Date.Season.dim1	-0.071	0.011	-6.727	0.000***
WindSpD.dim1	-0.007	0.009	-0.795	0.427
Trees.dim1	0.002	0.001	2.877	0.004**
Grass.dim1	-0.025	0.005	-4.541	0.000***
Baresoil.dim1	0.012	0.004	3.164	0.002**
Water.dim1	0.006	0.001	4.092	0.000***
UrbBltENV.dim1	0.002	0.001	1.146	0.252
DstToNearWet.dim1	0.024	0.007	3.617	0.000***
NumberofWet.dim1	-0.011	0.002	-5.769	0.000***
DstToUrbBltENV.dim1	-0.055	0.012	-4.658	0.000***
DistToCreek.dim1	-0.020	0.004	-4.471	0.000***
DistToNearEphem.dim1	-0.002	0.001	-1.847	0.065
DstToLake.dim1	-0.018	0.003	-5.105	0.000***
DeepestDepth.dim1	-0.008	0.003	-2.796	0.005**
FencePost.dim1	0.005	0.002	2.139	0.032*
FishFeeder.dim1	0.006	0.004	1.545	0.122
AVGEmergent.dim1	0.004	0.003	1.528	0.126
AVGSubmerged.dim1	0.002	0.000	5.275	0.000***
AVGFloatingLeaf.dim1	0.001	0.001	1.034	0.301
AVGTerrestrial.dim1	0.054	0.005	11.554	0.000***
People.dim1	0.007	0.010	0.739	0.460
SpeciesCountPred.dim1	-2.304	0.175	-13.151	0.000***

Highly Correlated with Outcome (removed from regression): AVGDistToNearWet.dim1, Perimeter.dim1, SurfaceArea, AverageDeepestDepth.dim1

Optimally Linear Scaled Scores from a Multiple Correspondence Analysis: Predicting DipDabblers Probabilities from Predictors

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.000	0.000	-0.000	1.000
Site.dim1	-0.428	0.045	-9.477	0.000***
x.y.sect.pc1.dim1	0.010	0.002	5.895	0.000***
Date.Season.dim1	-0.035	0.018	-1.989	0.047*
WindSpD.dim1	-0.019	0.017	-1.136	0.256
Trees.dim1	0.011	0.003	3.264	0.001**
Grass.dim1	0.080	0.013	5.964	0.000***
Baresoil.dim1	-0.072	0.011	-6.407	0.000***
Water.dim1	-0.024	0.007	-3.244	0.001**
UrbBltENV.dim1	0.004	0.007	0.506	0.613
DstToNearWet.dim1	-0.033	0.023	-1.460	0.144
NumberofWet.dim1	0.007	0.006	1.276	0.202
DstToUrbBltENV.dim1	0.336	0.038	8.835	0.000***
DistToCreek.dim1	0.078	0.010	7.556	0.000***
DistToNearEphem.dim1	-0.014	0.003	-4.040	0.000***
DstToLake.dim1	0.049	0.009	5.487	0.000***
DeepestDepth.dim1	0.062	0.007	9.506	0.000***
FencePost.dim1	-0.001	0.010	-0.104	0.918
FishFeeder.dim1	0.022	0.012	1.826	0.068
AVGEmergent.dim1	0.027	0.009	2.893	0.004**
AVGSubmerged.dim1	-0.011	0.002	-6.039	0.000***
AVGFloatingLeaf.dim1	0.019	0.003	5.830	0.000***
AVGTerrestrial.dim1	-0.039	0.007	-5.309	0.000***
People.dim1	-0.005	0.195	-0.026	0.979
SpeciesCountPred.dim1	-0.476	0.011	-41.865	0.000***

Highly Correlated with Outcome (removed from regression): AvgDstToNearWet.dim1, Perimeter.dim1, SurfaceArea, AverageDeepestDepth.dim1

Optimally Linear Scaled Scores from a Multiple Correspondence Analysis: redicting DivingBirds Probabilities from Predictors

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	-0.000	0.000	-0.000	1.000
Site.dim1	-0.105	0.151	-0.698	0.485
x.y.sect.pc1.dim1	-0.004	0.010	-0.359	0.720
Date.Season.dim1	0.967	0.069	14.123	0.000***
WindSpD.dim1	0.298	0.079	3.759	0.000***
Trees.dim1	-0.047	0.013	-3.642	0.000***
Grass.dim1	-0.207	0.092	-2.245	0.025*
Baresoil.dim1	-0.016	0.043	-0.370	0.711
Water.dim1	-0.079	0.035	-2.269	0.023*
UrbBltENV.dim1	-0.059	0.028	-2.103	0.036*
DstToNearWet.dim1	0.459	0.059	7.838	0.000***
NumberofWet.dim1	-0.115	0.024	-4.871	0.000***
DstToUrbBltENV.dim1	-0.034	0.097	-0.348	0.728
DistToCreek.dim1	-0.143	0.058	-2.481	0.013*
DistToNearEphem.dim1	-0.025	0.011	-2.233	0.026*
DstToLake.dim1	-0.051	0.030	-1.730	0.084
DeepestDepth.dim1	-0.032	0.043	-0.738	0.461
FencePost.dim1	-0.094	0.031	-2.987	0.003**
FishFeeder.dim1	-0.208	0.074	-2.812	0.005**
AVGEmergent.dim1	-0.065	0.044	-1.485	0.138
AVGSubmerged.dim1	0.032	0.005	6.088	0.000***
AVGFloatingLeaf.dim1	0.065	0.010	6.755	0.000***
AVGTerrestrial.dim1	0.123	0.028	4.408	0.000***
People.dim1	0.229	0.335	0.684	0.494
SpeciesCountPred.dim1	0.854	0.055	15.630	0.000***

Highly Correlated with Outcome (removed from regression): AvgDstToNearWet.dim1, Perimeter.dim1, SurfaceArea, AverageDeepestDepth.dim1

Optimally Linear Scaled Scores from a Multiple Correspondence Analysis: Predicting MoistSoil Probabilities from Predictors

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.000	0.000	-0.000	1.000
Site.dim1	-0.535	0.153	-3.502	0.000***
x.y.sect.pc1.dim1	-0.059	0.022	-2.719	0.007**
Date.Season.dim1	-0.084	0.079	-1.057	0.291
WindSpD.dim1	0.004	0.075	0.050	0.960
Trees.dim1	-0.003	0.014	-0.227	0.820
Grass.dim1	0.516	0.065	7.904	0.000***
Baresoil.dim1	0.111	0.043	2.613	0.009**
Water.dim1	0.034	0.038	0.877	0.380
UrbBltENV.dim1	0.010	0.036	0.283	0.777
DstToNearWet.dim1	0.064	0.073	0.869	0.385
NumberofWet.dim1	-0.013	0.025	-0.520	0.603
DstToUrbBltENV.dim1	-0.081	0.127	-0.638	0.524
DistToCreek.dim1	0.329	0.044	7.455	0.000***
DistToNearEphem.dim1	0.024	0.012	1.955	0.051
DstToLake.dim1	-0.161	0.032	-4.961	0.000***
DeepestDepth.dim1	0.271	0.031	8.858	0.000***
FencePost.dim1	-0.216	0.044	-4.922	0.000***
FishFeeder.dim1	-0.068	0.061	-1.115	0.265
AVGEmergent.dim1	-0.028	0.040	-0.692	0.489
AVGSubmerged.dim1	-0.018	0.006	-3.099	0.002**
AVGFloatingLeaf.dim1	0.074	0.011	6.597	0.000***
AVGTerrestrial.dim1	0.038	0.025	1.538	0.124
People.dim1	-0.034	0.280	-0.121	0.904
SpeciesCountPred.dim1	3.932	0.284	13.868	0.000***

Highly Correlated with Outcome (removed from regression): AvgDstToNearWet.dim1, Perimeter.dim1, SurfaceArea, AverageDeepestDepth.dim1

Optimally Linear Scaled Scores from a Multiple Correspondence Analysis: Predicting OpenWaterWaders Probabilities from Predictors

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.000	0.000	0.000	1.000
Site.dim1	-0.716	0.061	-11.807	0.000***
x.y.sect.pc1.dim1	-0.004	0.002	-2.550	0.011*
Date.Season.dim1	-0.130	0.023	-5.774	0.000***
WindSpD.dim1	-0.042	0.022	-1.920	0.055
Trees.dim1	-0.012	0.003	-3.602	0.000***
Grass.dim1	0.061	0.019	3.266	0.001**
Baresoil.dim1	-0.091	0.013	-7.283	0.000***
Water.dim1	-0.063	0.007	-8.980	0.000***
UrbBltENV.dim1	-0.019	0.007	-2.747	0.006**
DstToNearWet.dim1	0.107	0.027	3.901	0.000**
NumberofWet.dim1	0.001	0.007	0.190	0.849
DstToUrbBltENV.dim1	0.620	0.050	12.367	0.000***
DistToCreek.dim1	0.002	0.013	0.166	0.868
DistToNearEphem.dim1	-0.016	0.004	-4.065	0.000***
DstToLake.dim1	0.071	0.011	6.235	0.000***
DeepestDepth.dim1	0.023	0.009	2.662	0.008**
FencePost.dim1	0.038	0.012	3.203	0.001**
FishFeeder.dim1	-0.015	0.013	-1.144	0.252
AVGEmergent.dim1	0.010	0.012	0.883	0.377
AVGSubmerged.dim1	-0.003	0.002	-1.717	0.086
AVGFloatingLeaf.dim1	0.007	0.004	1.719	0.086
AVGTerrestrial.dim1	-0.032	0.008	-3.892	0.000***
People.dim1	-0.722	1.251	-0.577	0.564
SpeciesCountPred.dim1	-0.411	0.012	-33.731	0.000***

Important predictors for each bird class. Entries are the sign of the linear partial correlation coefficient for each bird class's predicted probability predicted by each predictor variable. Blank entries are deemed practically unimportant. A postive sign represents a positive relationship, and a negative sign represents a negative relationship. The variable SpeciesCountPred is the random forest regression model's predicted counts. All variables were optimally scaled using multiple correspondence analysis (MCA).

	DenseVeg Waders	**DipDabblers**	**DivingBirds**	**MoistSoil**	**OpenWater Waders**
Site	+	+		+	+
x.y.sect.pc1	+	+		+	+
Date.Season	-	-	-		-
WindSpD			+		
Trees	+	+	+		+
Grass	+	+	+	+	+
Baresoil	-	-		-	-
Water	+	+	+		+
UrbBltENV			+		+
DstToNearWet	-		-		-
NumberofWet	-		-		
DstToUrbBltENV	+	+			+
DistToCreek	+	+	+	+	
DistToNearEphem		-	-		-
DstToLake	+	+		+	+
DeepestDepth	-	-		-	-
FencePost	+		+	+	+
FishFeeder			-		
AVGEmergent		+			
AVGSubmerged	+	+	+	+	
AVGFloatingLeaf		+	+	+	
AVGTerrestrial	+	+	+		+
People					
SpeciesCountPred	+	+	+	+	+

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