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Abstract

Birds are ubiquitous, intricately connected to habitat, sensitive to environmental changes and their presence can indicate ecosystem function. Situated along a major bird migration route, the University of Pennsylvania (Penn) provides important stop-over habitat for migrating birds and foraging and nesting habitat for resident birds. Analysis of diversity, abundance and behavior reveals how the campus landscape provides essential habitat. Point-count surveys and area searches at representative habitat typologies on campus were conducted during migration and breeding seasons in 2018 and 2019. Systematic and incidental data collection resulted in 84 species from 34 families, with a total of 3,777 detections of birds recorded. As Penn's Landscape Planner, I play a pivotal role in furthering the university's sustainability goals and influencing landscape design and management on campus. This research establishes quantitative data that can define best practices and inform future landscape standards. Enhancing bird-friendly design guidelines and improving campus habitat and management strategies could have a broad impact on landscape connectivity and bird species richness. Future monitoring studies are recommended in order to quantify trends linking campus environmental health with bird species richness.

Disciplines

Environmental Sciences | Physical Sciences and Mathematics

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ABSTRACT

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Birds are ubiquitous, intricately connected to habitat, sensitive to environmental changes and their presence can indicate ecosystem function. Situated along a major bird migration route, the University of Pennsylvania (Penn) provides important stop-over habitat for migrating birds and foraging and nesting habitat for resident birds. Analysis of diversity, abundance and behavior reveals how the campus landscape provides essential habitat. Point-count surveys and area searches at representative habitat typologies on campus were conducted during migration and breeding seasons in 2018 and 2019. Systematic and incidental data collection resulted in 84 species from 34 families, with a total of 3,777 detections of birds recorded. As Penn's Landscape Planner, I play a pivotal role in furthering the university's sustainability goals and influencing landscape design and management on campus. This research establishes quantitative data that can define best practices and inform future landscape standards. Enhancing bird-friendly design guidelines and improving campus habitat and management strategies could have a broad impact on landscape connectivity and bird species richness. Future monitoring studies are recommended in order to quantify trends linking campus environmental health with bird species richness.

INTRODUCTION

Birds disperse seeds, pollinate plants, control pests, dispose of animal carcasses and contribute large amounts of money to global economies through bird-watching (Whelan et al., 2015). They are of cultural, economic, scientific, environmental and artistic importance. They are incredibly diverse; worldwide 11,000 species of birds have been described, with around 1,000 of those species in North America (E360 Digest, 2018). Birds and humans have co-existed together for thousands of years. Similar to humans, many birds live in urban environments. Though cities only cover 3% of the earth's land mass, over 50% of humans and 20% of bird species live in cities (Alfano, 2014). Are cities ecological traps or do they provide the food, shelter, habitat and water necessary for birds to thrive? I will explore the intimate relationships that birds have with the existing landscape typologies and will recommend improved planting, monitoring and maintenance of the existing landscapes to increase the diversity and abundance of birds. I will review applicable scientific literature and analyze my own empirical data to examine what birds were observed at Penn and how connectivity can inform landscape planning. As Penn's Landscape Planner working with the University Landscape Architect at Facilities and Real Estate Services, I play a pivotal role in influencing landscape ecology, design and management on the campus landscape, and this research will provide scientific data to inform campus landscape decisions.

Birds as Ecosystem Indicators -- Birds are found in almost every habitat type throughout most of the world, are generally easy to observe and have been well-studied by humans. They are sensitive to environmental changes making them ideal indicator species. Rather than studying every minute aspect of an environment, which could be prohibitively expensive and time consuming, one can look to the presence of birds to better understand the health of a habitat. "Birds serve as flagships for imperiled habitats and ecosystems, and as early warning systems for environmental toxins or other destructive forces" (Lovett & Fitzpatrick, 2016).

Penn Landscape -- Penn, a private institution of higher learning, has been located on the West Philadelphia campus since 1871. An arboretum and a large urban forest, with 18.8% tree canopy coverage (representing trees 8' high and taller, O'Neil Dunne, 2019), it encompasses 300 acres of land (extending from 30th St to 40th St, east to west, and Chestnut St to the Schuylkill River, north to south, Fig. 3). It includes 100 acres of open space, 6,200 trees and multiple urban parks, gardens, green roofs, and green stormwater infrastructure in West Philadelphia. Urban forests comprise "all the trees within our urban lands" that are "defined by their proximity to human populations and include numerous physical elements that constitute urban development" (Nowak, 2016). Today's campus is built on a legacy of long-term open space planning that began burying trolleys underground and pedestrianizing streets in the 1950's and created a holistic vision for the campus landscape in the 1970's (CED, 1977). Within its core campus, Penn increased canopy coverage from 8.7% in 1970 to 20.5% in 2012, representing trees and shrubs based on aerial photo interpretation (Roman et al., 2017). Using 2018 LiDAR-derived data that captured trees 8' high and taller, the same core campus area increased to 23.94% canopy coverage (O'Neil Dunne, 2019). This figure is likely a low estimate because any vegetation below 8' was not included in the calculation. Penn continues its ambitious greening goals through curation and management of "a diverse collection of trees, focused on preserving and sustaining the urban forest for the well-being of the community, environmental benefits, research and educational opportunities" (Penn Campus Arboretum).

Development and Sustainability at Penn -- As in many cities across the country, development regularly occurs in Philadelphia, threatening open space and natural lands. The University of Pennsylvania (Penn), the largest private employer in Philadelphia, has developed almost 50 acres over the last decade and plans to continue expanding and re-developing its urban campus (Penn, 2006; Penn, 2012; Penn, 2018). In 2007, Penn became the first Ivy-League school to sign on to the American College and University Presidents' Climate Commitment to address climate change and further sustainability goals across the entire university, launching the Climate Action Plan (CAP) in 2009, Climate Action Plan 2.0 (CAP 2.0) in 2014 (Penn, 2014) and the Climate & Sustainability Action Plan 3.0 in 2019 (Penn, 2019). The Physical Environment section of CSAP 3.0 prioritized ecological landscapes, recommending the implementation of Penn's *Ecological Landscape Stewardship Plan,* guidelines that "will build on landscape best practices and will articulate improved ecological design and management of landscape and open space across campus" (Penn, 2019). It also proposes reducing the number of bird strikes on campus. Penn Connects 2.0, a campus development roadmap launched in 2012, directs Penn to "Employ University sustainability goals and objectives to inform future development" (Penn, 2013). Penn

Connects 3.0 emphasizes similar priorities, highlighting the 30.25 ac. of open space added since 2006, and outlines the following physical environment goal to "Create and maintain a sustainable campus by increasing green space, decreasing building energy consumption, and increasing education and awareness of sustainable design" (Penn, 2018). It also proposes future development opportunities, including a new South Street parking garage with an athletic field on the roof, to be constructed in Penn Park, north of the South Street Bridge (Penn, 2018). Penn is poised to develop spaces thoughtfully and intentionally, limiting ecological damage in the process.

BACKGROUND/LITERATURE

General Decline of Birds -- Many birds are in danger of extinction as a result of multiple human induced causes. A recent study found that forty percent (40%) of the world's bird species are in decline due to agriculture, deforestation, invasive species, hunting, development and climate change (E360 Digest, 2018). One third of North American bird species are in decline as a result of habitat loss and degradation, often caused by urbanization, pesticide use and outdoor cat predation (State of NA's Birds, 2016). A recent study analyzed widespread bird monitoring networks over 50 years and found substantial declines that indicate a net loss of nearly 3 billion birds (29%) since 1970. "Population loss is not restricted to rare and threatened species, but includes many widespread and common species that may be disproportionately influential components of food webs and ecosystem function" (Rosenberg et al., 2019). While habitat destruction remains one of the top threats to birds, glass windows, building lighting and outdoor cats also represent a substantial potential danger to birds. Unlike other threats to birds, "glass is an indiscriminate killer that takes the fit as well as the unfit of a species population" (Klem, n.d.). After habitat destruction and domestic cats, bird building collisions are the next biggest threat to birds (Sheppard & Phillips, 2015). Researchers estimate that buildings kill between 365 and 988 million birds annually in the United States (Loss et al., 2014). The more glass on a building, the larger the risk of bird window collisions. "…Both the proportion and absolute amount of glass on a building façade best predict mortality rates; … every increase of 10% in the expanse of glass correlates to a 19% increase in bird mortality in spring and 32% in fall" (Sheppard & Phillips, 2015). As glass structures continue to grow in popularity, bird window collisions will likely increase. Birds often do not recognize glass as a barrier; they see reflections or see through to sky and/or vegetation. Bird window collisions are a direct and immediate risk of city living, but other threats are indirect, making them more difficult to fully understand. At the same time that cities represent potential risks to birds through building collisions and other factors, they also can provide refuge. Though cities have been completely altered by humans, they appear to offer opportunities to many generalist species of birds that are flocking to urban environments.

Birds in Philadelphia -- Philadelphia is an important area for birds, supporting at least 104 species in the winter (Phila Mid-Winter Bird Census Report, 2019), and 42 breeding species in the summer (Halley & Croasdale, 2018). In 2002, Philadelphia and the U.S. Fish and Wildlife Service (USFWS) created the Urban Conservation Treaty for Migratory Birds partnership. "Millions of birds, representing 300 species, migrate through this city, some from as far away as South America," said Tom Melius, the Service's Assistant Director for Migratory Birds and State Programs. "Yet many Philadelphians see a scarlet tanager or an indigo bunting and take this amazing phenomenon for granted. They don't realize that Philadelphia is at the center of the Atlantic flyway and is as important to birds as I-95 is to traffic" (USFWS, 2002). In a recent study looking at fall migration stopover sites, researchers obtained radar data from 16 locations around the northeastern United States. The Pine Barrens hosted a radar tower that covered an 80 kilometer radius extending to Philadelphia and determined that "Philadelphia had the highest bird densities within the area sampled" and was therefore found to have locally and regionally important stopover sites (Buler & Dawson, 2014). Situated in the heart of the Atlantic Flyway, one of 4 major migration routes through North America, Penn provides important stop-over habitat for migrating birds and foraging and nesting habitat for resident birds. Since February 2018, Penn has collected data from its Motus antenna, a radio telemetry wildlife tracking system that detects radio-tagged and banded migrating birds and other small animals that fly within 15 km of the receiver. Motus antennae exist across 28 countries, with most receiver stations focused in North and South America.

E-Bird, a citizen science project of the Cornell Lab of Ornithology that collects bird sightings from millions of birders worldwide, recorded 327 species from nearly 44,000 checklists in Philadelphia, while 89 species from 185 checklists have been counted in Kaskey Memorial Park, otherwise known as the BioPond (eBird). A longtime birder provided a bird list containing 85 bird species based on 30 years of informal observations in the BioPond (Faust, 2019). There were 39 species documented historically in the BioPond that were not documented during recent systematic bird counts (Table 7 in Appendix). This list includes species that are rare in our region, some have steeply declined over the past 2 decades, and others are still common in the region but just happened to not be observed during our data collection events. Beginning in 1904, and more recently in 2006 and 2016, adjacent development has reduced the garden size from its original 5 ac. to 3 ac. Many of the birds historically observed in the BioPond could be encouraged to return to the garden through minor adjustments to the landscape management practices, described herein. If attracting birds to Penn's landscape, bird-friendly infrastructure guidelines should be implemented.

Bird Building Collisions -- Bird strikes have been documented in Philadelphia since the late 1890's, when over 450 birds were killed during one migration season at City Hall Tower (Frank, 2015, Stone, 1900). With taller buildings and more glass in the city, today there are increased building threats, and many of the same species continue to be killed. Some birds are more at risk than others; many species of conservation concern are frequently killed by building collisions, such as golden-winged warbler, painted bunting, Canada warbler, wood thrush, Kentucky warbler, and worm-eating warbler. "Species such as the white-throated sparrow, ovenbird, and common yellowthroat appear consistently on top 10 lists from urban areas" (Sheppard, 2011). These same three (3) bird species were documented as the most frequent bird strikes at Penn. From April 2018 – October 2019, 90 bird strikes comprising 30 species of birds, were documented on Penn's campus (See Fig. 1, Penn Bird Strikes). Blackpoll warblers, listed as endangered in Pennsylvania by the Pennsylvania Game Commission, were found dead three (3) times on campus. The following birds were only observed dead on campus: Eastern Whip-Poor-Will (on watch list), Grasshopper Sparrow, Least Flycatcher, Northern Waterthrush and Swamp Sparrow.

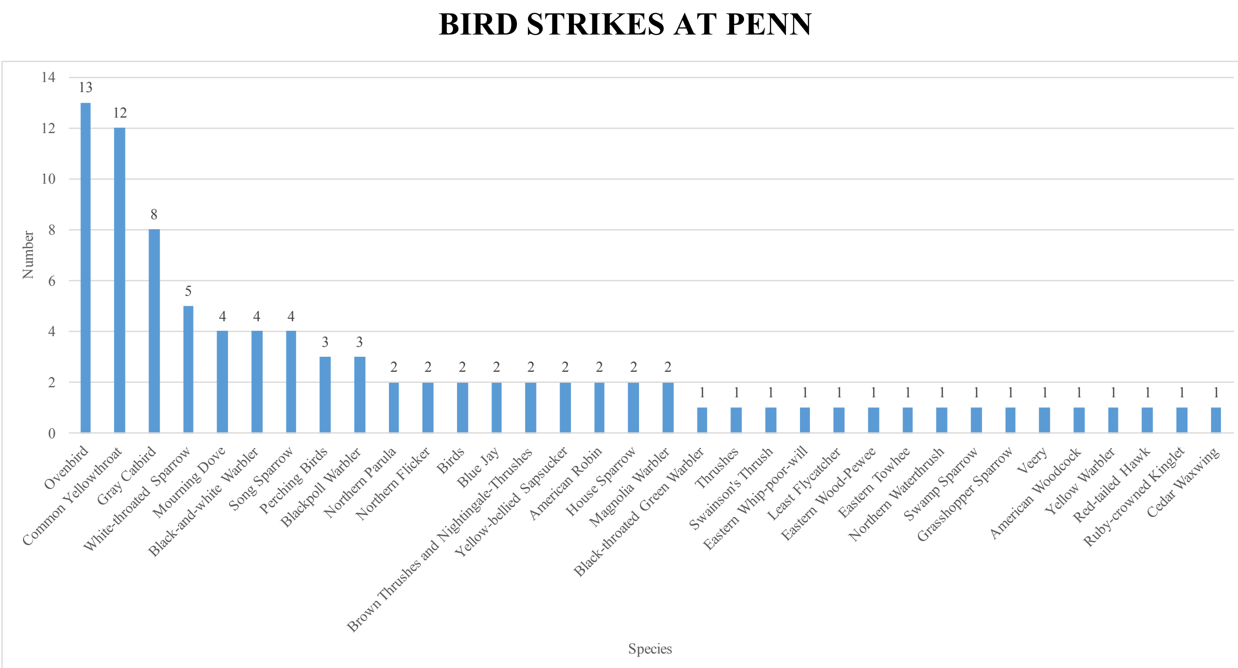

Fig. 1. Birds documented dead on Penn's campus between April 2018- October 2019, (Penn Bird Strikes).

Human Alterations to Landscape -- Humans represent most known threats to birds and biodiversity, and the human population continues to grow at unsustainable rates. Clearing land for agriculture and development destroys entire ecosystems, while urbanization intensifies light, noise and air pollution, as well as invasive species. Feral and outdoor cats predate birds at alarming rates and glass buildings cause unnecessary fatal bird collisions. In addition, we are beginning to better understand the adverse effects of climate change on birds, which will likely continue to expand as temperatures increase and weather becomes more extreme. "The impacts of global climate change on avian populations are widely recognized yet the underlying mechanisms are not well established. Several studies have demonstrated that the effects of changing temperature or precipitation can be indirect. Examples include the contraction or expansion of current bioclimatic envelopes that can limit habitat availability or help establish novel communities; phenological shifts in the timing of breeding in relation to peak prey availability (the ''mismatch hypothesis''); and the amount of overlap in the activity of breeding birds and their predators" (Becker & Weisberg, 2015). Birds may be forced to adapt to new landscapes if their old home no longer exists. They may alter their breeding time based on a new environment, but then determine that this trait is no longer beneficial. For instance, birds may breed earlier in the season due to warmer winters, but that may not guarantee ample insects to feed their young. Climate change may force birds into unfamiliar situations where they no longer understand the threats. Many consequences remain unknown. Habitat loss continues to grow, as development around the world increases. Both migrating and resident birds rely on healthy habitat in order to thrive. Almost half of known birds migrate during the winter to access improved weather and food sources, then return to their breeding grounds when weather allows. Migratory birds need healthy stopover habitat across various flyways in order to refuel and rest before flying thousands of miles on a risky journey. All birds need habitat that provides nutritional food, water, and opportunities to nest and find shelter. As critical habitat disappears, the remaining landscapes become more fragmented, putting additional strain on the birds who rely on these sites.

Humans have disturbed natural landscapes for at least 10,000 years, but as the human population expands exponentially, the resulting habitat destruction grows worse. A recent study looked at the impacts of development on birds in cloud forests, coffee plantations, peri-urban forests and urban greenspaces within Veracruz, Mexico. "Our results highlight the overall negative effect of urbanization on breeding bird species richness and composition, as well as the importance of large patches of well-preserved cloud forests in sheltering high bird diversity. Similar numbers of bird species were found in all of the habitats throughout the year, however, more bird species were found in the cloud forest during breeding season. … During the nonbreeding season, when habitat requirements are less strict, species distribute homogeneously across the landscape, whereas species tend to be more selective and concentrated in original forests during the breeding season" (MacGregor-Fors et al., 2018). Cities generally have high density, with a lot of people, buildings and impervious surfaces, as well as simplified plants and animals in smaller, more fragmented landscapes. These habitats with fewer numbers and species of plants and animals mean fewer prey and predators and overall homogenization of an environment. Within an ecosystem, there is often a cascading effect. However, when adjacent undisturbed environments remain, these can provide critical shelter and nutrition to birds when it matters most during the breeding season. Consequently, whether a city supports diverse species of birds may depend not only on the availability and quality of the habitat within its borders but also on the health of landscapes in the surrounding region.

The majority of people worldwide live in cities (UN Population Fund, 2007), which often have simplified ecosystems and are generally not associated with biodiversity. "Although urbanization does threaten and impair certain biological elements (e.g., direct loss and fragmentation of vegetation) contributing to habitat for organisms, many studies document the persistence of native species within cities" (Pennington & Blair, 2011). Cities often contain birds, though, they "generally support only a few abundant species that are often the same among different urban locations" (Ferenc et al., 2014). Some birds exploit the urban environment, while others do not have the flexibility to adjust their needs. "… High food density and low predation risk in urban environments will result in a few species becoming superabundant" (Fuller, Tratalos & Gaston, 2009). This simplification is exemplified by five cosmopolitan birds (European Starling (*Sturnus vulgaris*), House Sparrow (*Passer domesticus*), Rock Pigeon (*Columba livia*), Mallard (*Anas platyrhynchos*) and Canada Goose (*Branta Canadensis*)) that are commonly found in many cities across the world (Marzluff, 2014). "Many resident species increase with urbanization, whereas many migratory species tend to decrease" (Leston & Rodewald, 2006). Though not all urban habitat is of equal value. Habitat with diverse structure often supports more critical interactions amongst species. "Habitat structure is one of the fundamental environmental factors that contribute to the survival of avian fauna in urban gradients determining the availability of food and nest-sites" (Magudu & Downs, 2015). Depending on the type and quality of the available habitat, cities can either support more diverse bird species or large numbers of limited species.

Adaptations of Birds to Urbanization -- With so many health and environmental factors, what are the consequences of more birds being found in urban areas? "Urban areas seem to impose so many constraints on birds (e.g., landscape fragmentation, isolation of habitat patches, noise, pollution, type and availability of food resources, human activities, and vegetation quality in habitat patches) that only species that have (pre-) adapted biological traits are able to tolerate them. In that sense, we can really consider urbanization to filter bird species on the basis of their traits" (Croci, Butet, & Clergeau, 2008). Certain species of birds are better adapted to live in urban settings. In one Swiss and 11 French cities, the traits of tolerant and intolerant species of birds were compared in a scientific study. "Regional analysis revealed that urban adapters prefer forest environments, are sedentary, omnivorous, widely distributed, high-nesters with large wingspans. Urban avoiders seem to allocate more energy to reproduction than do urban adapters, to the detriment of adaptation to new environments such as urban areas" (Croci, Butet, & Clergeau, 2008). Another study revealed "Bird species that adapted to urban habitats were characterized by large breeding ranges, high propensity for dispersal, high rates of feeding innovation (novel ways of acquiring food), short flight distances when approached by a human, and a life history characterized by high annual fecundity and high adult survival rate. … Species that have successfully invaded urban areas were, through their short flight distances, pre-adapted to urban environments with close proximity to humans" (Møller, 2009). Urban adapted birds generally have higher population densities, better immune response and appear to be pre-adapted to thriving in cities. "Ecologically successful species are more likely to invade urban areas than less successful species" (Møller, 2009). For a bird species to survive and thrive in an urban setting, it would likely already need to be thriving in its natural habitat. Often the urban adaptors are generalists or opportunists, while the urban avoiders are specialists. "… Avian species that respond negatively to increased levels of urbanization include habitat specialists and species with narrow environmental tolerance" (Magudu & Downs, 2015). Specialist birds often require specific habitat types, foods and breeding grounds and cannot tolerate noise, air or light pollution, while generalist birds can adapt to different habitats, can often tolerate different types of pollution and are quite prolific. As land is developed, ecosystems are altered and cities expand, generalist birds will be the most able to adapt and exploit these growing resources.

Cities as Ecological Traps or Opportunities? -- If cities generally have simplified flora and fauna, then one might assume that they would provide limited value to birds. A common misperception is that cities are ecological traps, however, such sweeping generalizations are not always true. Urban settings can provide immense benefits to certain species of birds. "Cardinals were 1.7x (in the breeding season) to nearly 4x (in non-breeding season) more abundant in urban than rural forests, and the results suggest that these differences in abundance stemmed from urban-associated changes in habitat and microclimate features used by cardinals to select habitats. Most notably, cardinals were strongly associated with dense understory vegetation and warmer minimum January temperatures, both of which were promoted as urban development increased within the landscapes surrounding riparian forests" (Leston & Rodewald, 2006). Cities often provide ample dense understory vegetation where birds can seek shelter and build nests. "Northern cardinals strongly selected for complex understory vegetation that was positively associated with survivorship" (Ausprey & Rodewald, 2011). The benefits of nesting in invasive shrubs may be species-specific and context-dependent. "In Pennsylvania, more non-native honeysuckles mean more native bird species" (Davis et al., 2011). Though non-native honeysuckle may attract native birds, their berries do not contain high nutritional content, creating an ecological sink in the city. Unfortunately, non-native invasive plants are prevalent in cities across the world, due to large amounts of human disturbance and increasing temperatures, creating opportunities for invasive plants to take over.

The urban heat island effect, a phenomenon whereby temperatures in a large city can be up to 5° Fahrenheit warmer during the day, or up to 22° Fahrenheit warmer at night than the surrounding area (EPA, n.d.), may attract birds to cities. Spring temperatures warm up faster, giving birds an advantage by allowing them to build their nests and begin their breeding season earlier. Early arrivals can incite competition between species that have otherwise not been in the same space before, threatening successful breeding and increasing resource competition. Extreme temperatures during early nesting periods could harm birds (Becker & Weisberg, 2015), particularly as climate change intensifies, warmer temperatures could help some species of birds succeed. "Nest survival increased at slight temperature increases during the nestling stage, which suggests that in a climate-change context, moderate warming in spring temperatures may be beneficial for some breeding birds" (Becker & Weisberg, 2014). Moderate temperature increases may be the critical variable, since there is likely a tipping point where warmer temperatures are no longer beneficial, becoming detrimental to nestling survival. Cities can offer copious opportunities to generalist bird species who are able to adapt, but the benefits may come with costs.

Genetic Change versus Phenotypic Plasticity -- Why do certain birds flourish in cities? Have they adapted to certain environmental traits or have their genes evolved over time? Crows are known to be intelligent birds and examples abound of their smarts, from carrion crows in Sendai, Japan who leave walnuts in the road so vehicles will drive over them, giving the crows easy access to the food inside, to crows in Paris, France who have been trained to pick up trash for a food reward (Chazan, 2018). These birds seem to be exploiting humans to gain advantage. Is this just an example of their innate brainpower or does this reveal a behavioral adaptation? Phenotypic plasticity occurs when an environment alters the behavior, morphology and physiology of a bird species. “The environment in which animals live, communicate, and reproduce can have a major impact on their phenotype” (Slabbekoorn & den Boer-Visser, 2006). Could living in close proximity with humans affect crow behavior? How can one tell the difference between phenotypic plasticity vs. long-term genetic changes? “Urban-living individuals develop specific adaptations to the novel urban habitat – either as the result of (long-term) genetic changes or through the expression of phenotypic plasticity” (Rutz, 2008). Genome sequencing can highlight changes in a bird’s DNA over time and growing interest in urban ecology has prompted more scientific studies comparing urban and rural conspecifics. Some scientists refer to cities as “powerhouses of evolution” (Worrall, 2018), due to strong natural selection resulting in quick evolution, instead of a gradual change over time (Darwin, 1859). “The birds’ DNA, after 200 years or less of adaptation, has diverged from that of their rural ancestors” (Schilthuizen, 2016). The blackbird (*Turdus merula*), a city dweller that was formerly a shy forest species, epitomizes the city as a force of rapid change. “City blackbirds have shorter beaks; don’t migrate anymore; have different stress responses; start breeding much earlier in the year; and sing at a different pitch” (Worrall, 2018). An urban environment offers different food availability, has warmer temperatures earlier in the year, is noisy and full of humans. “… Successful colonisation of urban areas may … require local adaptation and phenotypic/genetic divergence from ancestral populations. Such a process would be facilitated by limited dispersal to and from the novel habitat. This former forest specialist is now amongst the most abundant urban birds across most of its range” (Evans et al., 2012). All of these ecological pressures interact to change these birds, allowing blackbirds to not only survive but flourish in cities. Cities are quickly altering the landscape of the world, and birds need to exploit these novel ecosystems or perish in the process. Some successful adaptations have been surprising, revealing that you cannot always predict which species will adapt well.

Similar to the blackbird, northern goshawk (*Accipiter gentilis*), the formerly shy forest species, is now commonly found in cities. In the past, goshawks were sensitive to disturbance and preferred interior forest, but now they thrive in diverse metropolitan areas. They first appeared in Hamburg, Germany in the 1940's, but didn't begin breeding there until the 1980's. In examining data across 7 decades from 1946 – 2003, a scientist described how goshawks were both pushed from adjacent areas and pulled into the German City of Hamburg (Rutz, 2008). "Pioneer settlement in urban Hamburg coincided with: (i) an increase in (legal) hunting pressure on goshawks in adjacent rural areas; (ii) an increase in prey abundance in the city; and (iii) severe winter-weather conditions in the Greater Hamburg area" (Rutz, 2008). Rutz revealed that when complex environmental factors occurred simultaneously, they could interact causing the goshawks to learn how to adapt, and fairly quickly flourish in a novel urban environment. "Different factors vary in their importance across species, but abundant food supplies and release from predation risk and/or interspecific competition in the urban habitat emerge as key correlates of successful city-colonization events" (Rutz, 2008). The goshawks learned to avoid rural environments that were no longer safe from hunters, finding abundant food and protection in the nearby city.

Around the same time that northern goshawks began nesting in Hamburg, raptors began flocking to cities all over the world. Since the 1970's, raptors in general and Cooper's hawks (*Accipiter cooperii*) in particular have been nesting successfully in urban settings. "Three elements support the premise that nesting areas in the metropolitan Milwaukee area were not marginal or inferior habitats and that this urban Cooper's hawk population was probably not a sink: 1) our long-term, consistent, and comparatively high indices of reproductive success, 2) repeated re-occupancy of nest sites suggesting at least a stable nesting density, and 3) documented recruitment from within the population" (Stout et al., 2005). Birds may also choose to live in cities in order to avoid parasites and predators and to gain access to supplemental food (Yong, 2016). Research shows that urban environments support many species of birds and can increase their overall fitness.

Infrastructure -- Urban infrastructure can both increase and decrease fitness of birds. Roads, railways and related infrastructure can have positive benefits, "(1) roads: providing foraging habitat; reducing the predation pressures; and providing a warm surface assists in conserving metabolic energy; (2) lights of streets: prolonging diurnal activity; (3) powerlines, fences, etc. along roads: providing perches for hunting activities; and (4) bridges, pylons, tree lines along roadsides, bases of powerline pylons: providing nesting sites and cover from predators" (Morelli et al., 2014). Opportunistic birds exploit urban environments they encounter, creating successful urban niches for themselves. Roads and powerlines may reduce biodiversity by their close association with development and habitat loss, but they can also provide better access to food and increased protection from predators. Road surfaces warm up faster than natural ground, attracting birds earlier in the season and day. Urban habitat was commonly assumed to be an ecosystem sink, though this research shows it can also be a source, particularly in allowing birds to conserve critical energy that they may have otherwise expended by trying to stay warm or protecting themselves from predators. Not all urban habitat is high-quality, but it is not all low-quality either. Birds may choose to nest in a natural area or on a human-made structure in a city, such as a building, bridge, telephone pole, or nest box. Future research could investigate the nesting success of these common urban birds.

Nesting Locations -- Nest boxes, infrastructure and warmer temperatures may benefit birds, though some species are more suited to nesting in urban locations than others. In cities, nest boxes can be set up in an attempt to increase the abundance of certain bird species, who may not have enough ideal nesting sites. Birds will often nest on top of or inside infrastructure, such as buildings, bridges and fences. This can be advantageous to birds, by expanding their nesting sites, but may be detrimental to the structures. Nesting boxes should be used "more widely as a conservation tool for conserving endangered birds" (Mainwaring, 2015). Nest boxes should be carefully sized and placed, making sure that the adjacent habitat can support the birds one is trying to attract. Within reason, birds should be allowed to nest on human-made structures without disturbance, particularly to allow endangered birds to increase abundance. Though many common birds find homes in cities without direct human assistance. In 2009, two Red-Tailed Hawks (*Buteo jamaicensis*) began nesting on a window ledge at The Franklin Institute in Philadelphia, Pennsylvania. Over 2,600 people have since joined the Facebook group that anxiously awaits photographs documenting the hawks' latest behavior (Franklin Hawkaholics, 2019). Nesting birds may be attracted to urban life by the profuse availability of prey, safety and warmer temperatures. The Red-Tailed Hawk was only observed four (4) times on Penn's campus during systematic counts, though it was observed seven (7) additional times during incidentals (Fig. 2). Many of the incidental sightings came from other people who were aware of my project. With an average wingspan of 123.5 cm, these adaptable and enigmatic birds are a ubiquitous reminder of nature within the city. It is unknown how many juvenile and adult Red-Tailed Hawks have been detected on campus and whether they are nesting on-site or in nearby locations.

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Fig. 2. Representative photographs of Red-Tailed Hawks at Penn. 1) College Green, courtesy of Joe Durrance, 8/25/2019, 2) Woodland Walk, courtesy of Joe Durrance, 11/11/2018, 3) Shoemaker Green, courtesy of Gahl Shottan, 8/13/2019 4) 37th and Locust Walk security camera, courtesy of Thomas Messner, 1/29/2018.

Behavior -- A recent scientific study showed that reproduction timing varied in European blackbirds depending on whether they lived in an urban setting or a forest. Gonad development in both sexes of urban blackbirds began 3 weeks earlier in the spring. "The extended breeding season of urban birds may either be the result of micro-evolutionary changes that have evolved during the urbanization process (e.g. different photoperiod thresholds), or of phenotypic flexibility of individuals exposed to the different environmental conditions of town or forest" (Partecke et al., 2004). Several factors could impact reproduction timing in urban environments, including artificial light, microclimate, anthropogenic food, and increased natural food in early spring due to warm temperatures. Artificial light may trigger early breeding by imitating daylight and impacting the photoperiod, one of the main environmental cues (Dawson & Sharp, 2007). Due to the urban heat island effect, cities are generally warmer than forests and warm up earlier in the spring. Ample food is available at bird feeders through the winter for urban birds, giving them a head start over their forest peers. Increased temperatures mean increased natural food availability as well. Urban European blackbirds thrive in urban settings as revealed by their density and reduced migration. The urban environment appears to affect not only when birds have babies, but also how many babies they have. Likely due to better rates of survivability, urban birds tend to take better care of themselves and have smaller clutch sizes. Researchers reviewed 116 case studies and "found support for a global trend towards a slower pace of life in urban bird populations when compared to their rural counterparts, since urban birds have higher survival and smaller annual clutch sizes" (Sepp et al., 2018). Many urban birds have been found to breed earlier and migrate less frequently than rural ones which "can promote further ecological divergence … and in some cases may contribute to their previously documented genetic divergence" (Evans et al., 2011). Assuming there is ample high quality food, shelter, water and habitat available, those birds who begin breeding earlier would have the advantage over birds who breed later. "Migratory populations and individuals tend to breed later than more sedentary ones, and this can limit reproductive success. The reduced migratory behavior of urban blackbirds may thus facilitate the earlier breeding that has been documented in urban populations of many bird species including blackbirds" (Evans et al., 2011). Migration is a long and dangerous journey that birds undertake out of necessity to find abundant insects, plants and nesting locations. If migration is no longer necessary because those insects, plants and nesting locations are already available in their current location, then birds can "enjoy reduced fitness costs of migratory deaths" (Møller et al., 2014).

From 1959 – 2012, Finnish wintering birds have been monitored in regards to their migratory strategy, urbanity and thermal niche. "Among landbirds, forest species have suffered severe declines, whereas urban species have considerably increased in their wintering numbers. … Trends of landbirds have been mainly driven by human-induced land-use changes. While urban species have likely benefited from the increase of supplementary feeding, forest species have probably suffered from the loss of native habitats" (Fraixedas, Lehikoinen & Lindén, 2014). Specialist forest birds appear more vulnerable to habitat loss and are less able to adapt to decreased food, shelter and nesting opportunities. Urban birds gain many benefits from choosing to live around humans, while also increasing risks associated with development and artificial lights.

Impacts of Light Pollution -- Excessive, inefficient and conspicuous anthropogenic lights continue to negatively impact all living creatures and the natural environment. Light pollution is "one of the fastest growing and most pervasive forms of environmental pollution. …Light pollution can alter behaviors, foraging areas, and breeding cycles" (Chepesiuk, 2009). Artificial lighting disrupts ecosystems and wildlife with measureable negative impacts. Birds use the stars to help navigate during migration, but can become disoriented by bright artificial lighting in cities, and may even be killed by exhaustion or resulting collisions with buildings. "Night skies across nearly half the United States are polluted by light. Many of America's metropolises lie along rivers, coastlines and ridges that concentrate large numbers of migratory birds" (Farnsworth & Horton, 2018). People expect their cities to be brightly lit but lighting can create big problems for birds in cities. "Bright electric lights can … disrupt the behavior of birds. About 200 species of birds fly their migration patterns at night over North America, and especially during inclement weather with low cloud cover, they routinely are confused during passage by brightly lit buildings, communication towers, and other structures" (Chepesiuk, 2009). Many community programs exist, such as FLAP and Audubon Lights Out Programs, to develop policy, perform research and educate people about the risks of unnecessary artificial light to birds, particularly during fall and spring migration seasons. As many migrating birds are guided in part by stars at night, building lights attract them, sometimes resulting in building collisions. Many cities throughout North America have developed Lights Out Programs, initiatives that recommend businesses and residents turn off their building lights at night during spring and fall migration in order to reduce bird window collisions. Turning off the lights offers a potential strategy for cities to help birds safely migrate through large metropolitan areas along major flyways.

Impacts of Noise Pollution -- Not only do cities contain significant artificial light, they also contain more noise than adjacent suburban and rural settings. "Human-created environmental noise has changed considerably in volume, acoustic structure, and global distribution as a result of industrialization and urbanization" (Wood & Yezerinac, 2006). Recommended noise levels should be below 55 decibels in the day and 40 at night, though a recent study in Boston found that urban noises tended to be much louder and that noise ordinances were rarely enforced (Baggaley, 2018). Recent studies show that 21 million US residents experienced hearing loss from everyday sounds that include leaf blowers (JAMA, 2017). "Noise is tricky to deal with because, unlike water or air pollution, it leaves no traces behind in the environment" (Baggaley, 2018). Noise pollution has implications for the short- and long-term health of humans and animals, causing sleep problems, increased risk for heart disease, hypertension, hearing problems and interrupting critical communication.

Birds need to communicate with each other, in order to find good mates, protect territory and send out warning calls. Researchers evaluated the ambient noise while studying the responses of Great Tits (*Parus major*) in The Netherlands and Song Sparrows (*Melospiza melodia*) in Portland, Oregon. Most anthropogenic noise, such as traffic, leaf blowers and industry, exists at low frequencies. "In urban environments, anthropogenic noise may mask bird song, especially the notes occurring at lower frequencies (1-2 kHz). Birds living in urban environments may modify their songs, particularly the low-frequency portions, to minimize masking by anthropogenic noise" (Wood & Yezerinac, 2006). In noisy areas, birds, such as Common Nightingales (*Luscinia megarhinchos*), intensified the frequency and amplitude of their songs so that the receiver could better hear and understand their message (Wood & Yezerinac, 2006). Besides camouflaging bird song, urban noise likely alters the song length, speed, style and frequency level. In Great Tits (*Parus major*) "Urban songs were shorter and sung faster than songs in forests, and often concerned atypical song types" (Slabbekoorn & den Boer-Visser, 2006). Besides interrupting and altering bird communication, environmental noise can have a negative effect on bird physiology, behavior and overall fitness. Traffic noise can alter the reproductive behavior of birds who nest close to roadways. "…Although our study suggests that sensitivity to noise can vary across, and possibly within, species, it adds to the growing evidence suggesting that exposure to traffic noise has negative consequences for avian reproduction" (Mulholland et al., 2018). Another study looked at the role that persistent environmental noise can play on overall health, finding that "…disturbed nestlings had overall lower metabolic rates and mass-adjusted metabolic rates than undisturbed birds" (Brischoux et al., 2017). This biological shift was likely caused directly by noise pollution, which can cause "higher stress levels, sleep perturbations, cognitive deficits, physiological pathologies or indeed a combination thereof" (Brischoux et al., 2017). Many generalist birds appear to be able to modify their behavior and physiology to shifting environmental conditions, however, we do not fully understand the consequences of these adaptations over time. Finally, air pollution is the most well-known form of urban pollution and is prevalent throughout the world, particularly within large cities.

Impacts of Air Pollution -- Some birds have adapted to air pollution, while others suffer the consequences. Pigeons (*Columba livia*) are one of the most well-adapted urban bird species in the world. Urban pigeons tend to have darker coloration, which helps protect them within polluted environments. "In cities, dark pigeons' melanin might give them an edge, performing double-duty by helping the birds rid themselves of chemical toxins" (Nuwer, 2014). The darker colored feathers are better able to absorb toxins, keeping toxins out of the pigeon's blood stream. The pigeon detoxes while shedding old feathers and growing new ones during each annual molt. Over time, darker feathered birds and their offspring are better able to survive in cities. It is unclear whether these birds developed darker feathers after relocating to an urban setting, or if they were better able to adapt to city living because of their darker feathers. "Research hints that darker birds are bolder and more aggressive—traits that could equally well explain their relative success in a competitive urban environment" (Perkins, 2014). Many different factors including appearance, personality and behavior come together to make certain birds more likely to thrive in urban settings. Though considered invasive in North America, House Sparrows (*Passer domesticus*), are in decline through their native range in Europe. In order for house sparrows to be successful, they must have access to enough food and nest sites (often man-made structures) to provide for their offspring. According to recent research in London, house sparrow colonies have declined due to nitrogen dioxide pollution (Fuller, 2014). When the strongest and most successful birds start to suffer health effects from air pollution, it is hard to imagine how more vulnerable species will adapt.

BIRD FRIENDLY DESIGN

Architectural Strategies -- There are many strategies that designers, planners and policy makers can undertake to improve the long-term health and viability of birds in the city. Clients and designers prefer large transparent panes of glass, which will remain architecture's biggest threat. The bigger the pane of glass, the more likely it will cause bird window collisions. Organizations such as the American Bird Conservancy (ABC), National Audubon Society (NAS) and Fatal Light Awareness Program (FLAP) work on advocacy and community engagement solutions. This will require a long-term multi-faceted approach that includes outreach and education, regulation, legislation enforcement and ongoing research for new materials and strategies. Until protecting birds becomes a cultural and moral priority, bird window collisions will only get resolved on a case-by-case basis. Clients and designers can create a bird-friendly building by "using minimal glass, placing glass behind some type of screening and using glass with inherent properties that reduce collisions" (Sheppard & Powers, 2015). Birds cannot recognize glass as a barrier and will often die from bird window collisions. Testing has shown that most songbirds will not fly through spaces that are 2" high and 4" wide, approximately the size of an average songbird in flight. Glass that contains a 2" x 4" pattern (the 2x4 rule) will be the most effective in reducing bird window collisions. Energy efficient buildings can often provide important bird-friendly co-benefits, since many energy reduction strategies are also bird-friendly. Since 2009, the US Green Building Council which manages LEED certification, a comprehensive ratings program for green building standards, has encouraged bird friendly design by offering a point for projects that create "bird collision deterrence". This LEED point remains difficult to obtain due to complicated design strategies, required lights off at night and post-construction monitoring plans. Aesthetically pleasing and bird-friendly designs are not mutually exclusive. New York City's all-glass Javits Convention Center used to be one of the biggest bird killers in the city until its recent renovation solved the problem by using fritted glass. Bird deaths have been reduced by 90%. The building contains a 6-acre green roof, attracting many species of birds to its food, shelter and nesting ground. By creating both bird-friendly landscape and infrastructure, birds can take advantage of the habitat without risk of crashing into the windows (Foderaro, 2015). The Discovery Center, the city's first completely bird-friendly building was recently completed in Philadelphia. As champions of environmental education, the clients, Audubon Pennsylvania and Outward Bound, demanded bird-friendly design and the results are a beautiful work of architecture. "The reason the etched, or fritted, glass isn't used more often is that it interferes with the fantasy that there is nothing between the viewer and the great outdoors. But once the eye adapts, the views are still magnificent. The momentary adjustment is a small price to pay for saving millions of birds" (Saffron, 2018).

Landscape Strategies -- In addition to architectural strategies, there are communities and programs around the world working to create bird-friendly landscape design guidelines. Audubon North Carolina's Bird-Friendly Communities initiative establishes their vision, "Bird-friendly communities give birds the opportunity to succeed by providing connected habitat dominated by native plants, minimizing threats posed by the built environment, and engaging people of all ages and backgrounds in stewardship of nature" ("Bird Reward"). Vancouver focuses on the "protection and enhancement of large patches of habitat, increasing the overall size of biodiversity zones and establishing site-scale habitat features throughout the urban matrix. …the emphasis should be on habitat quantity, composition and structural complexity" (Campbell, 2013). The guidelines recommend using a 5-step process for anyone undertaking landscape design: survey, reduce threats, create, maintain and monitor. First, determine what bird species exist on the site and determine what existing features are important to maintain. Reduce any obvious threats to birds, from mitigating bird strikes at existing buildings to limiting other human-induced stressors. Create ecologically rich landscapes that enhance habitat for birds, providing them with food, shelter, nesting areas and water. Maintain the landscape in a more sensitive way than conventional landscape maintenance methods. Finally, monitor the landscape to understand what strategies are effective and what can be improved in order to attract more birds (Campbell, 2013).

Landscape guidelines need to consider multiple scales, from home gardens to city plans, and from perennials and shrubs to urban forests. Recent research shows that water features and native species of plants impact how breeding birds choose their nest sites. "…Native species were positively associated with the amount of vegetation in the landscape (percentage tree cover and percentage grass cover) and negatively with the amount of settlement intensity (building density)" (Pennington & Blair, 2011). Native plants support more diverse insects than introduced plants, and most bird species require insects to feed their young. "…Non-native plants reduce habitat suitability for chickadees by reducing insect food available for breeding. Improving human-dominated landscapes as wildlife habitat should include increasing native, and arthropod-producing, plant species to effectively support the life history needs of insectivorous birds" (Narango et al., 2017). Individual plants matter within the broader context of landscape connectivity. Wooded streets remain critical links for many species of birds to travel from one habitat fragment to another in big cities. While street trees can increase the abundance and richness of bird diversity in cities, human disturbance can negate positive results. "Wooded streets potentially could function as corridors, allowing certain species – particularly those feeding on the ground and breeding in trees or tree holes – to fare well by supporting alternative habitat for feeding and nesting. Local improvements in corridor quality, through increased vegetation complexity and reduced human disturbance, could exert a positive influence on the regional connectivity of the system" (Fernández-Juricic, 2000). Small improvements in landscape density, quality and abundance can have lasting effects on birds.

Landscape Planning -- Empirical data can inform landscape planning. A two-decade old study looked at bird density and distribution patterns in twenty-five wooded urban parks in Madrid varying from 1 to 100 ha in size and 8-367 years old, and located within 6km of Casa de Campo, a 1,722 ha forested urban park. "In this fragmented landscape composed of a set of urban parks with different ages, the main factors affecting species richness and community composition are park age and size" (Fernández-Juricic, 2000). The older and larger the park and the more complex the landscape structure, the more diversity of bird species were recorded. These habitat patches were scattered throughout the city and connected by tree-lined streets. "Wooded streets appear to function as corridors increasing the general connectivity of the landscape" (Fernández-Juricic, 2000). "Within a landscape, all habitat patches are potentially valuable (even the small and scattered ones) and policies that reflect this (instead of assigning higher values to large patches) could allow the conservation of more total habitat amount, and therefore more species, with a given investment" (De Camargo et al., 2018). Many larger landscapes already have protection, whereas smaller patches can be harder to protect, and may be more at risk of destruction (Buler & Dawson, 2014). Another study revealed that "groups of well placed small habitat patches can, together, be sufficient to attract birds in intensively developed areas" (Andersson & Bodin, 2009). They emphasize the need to look at a larger network, but assert that by understanding habitat requirements of target birds and using their landscape model, one can evaluate thresholds, patches and possible barriers for connectivity.

Comprehensive studies on stopover habitat in New York City "indicate that small and highly disturbed habitats that may otherwise be of little significance to wildlife have the potential to be valuable stopover sites for migrating birds" (Seewagen, 2010). Most urban bird studies look at nesting periods, but Seewagen's research shows that migration still needs to be carefully examined. Through capturing birds and using predictive models, he determined that migrating songbirds lost a lot of body mass either before or during stopover at the urban sites in New York City, and would therefore require high protein foods (Seewagen, 2010). Landscape planning and management practices should consider the needs of migrating birds in addition to resident birds.

Globally expanding urban areas and the resulting landscape fragmentation will continue to affect bird species richness and abundance. Using an urban gradient analysis, researchers investigated bird species richness using 285-point count stations at four roadside transects in and around Vancouver. The sites were characterized as impervious surface, grass, conifer trees and deciduous trees and the birds were grouped by nesting habitat guilds (building, deciduous tree, coniferous tree, ground, shrub, cavity, ledge/cliff, riparian). Environmental features such as streams, deciduous trees and extensive parkland and/or forest habitat were linked to sensitive bird species, such as ground and shrub nesters while impervious surfaces and fewer trees attracted more common bird species, many of which were non-native. Urban sites located close enough to fresh water, large conifer trees and berry-producing shrubs were associated with higher bird species richness. These findings suggest that development should minimize impervious cover, plant and preserve native trees and shrubs and create access to freshwater in order to restore native bird communities (Melles et al., 2003). Urban habitat islands and access to water can have a positive impact on biodiversity, particularly if there are regional connections to parkland and/or forest.

METHODS

Study Sites-- During 2018 and 2019, I conducted replicable bird surveys using the unlimited distance, single observer, point count method at Penn in the spring and summer and area searches in the fall of both years to determine comprehensive baseline bird data. I chose sites representative of four different habitat typologies with diverse habitation characteristics (Table 1, Fig. 4) that included a total of 9 bird survey plot points (Fig. 3): Kaskey Memorial Park (also known as the BioPond), 3 ac. mature diverse woodland comprised of native and non-native trees, shrubs and perennials, dating back to 1897, 74.8% canopy cover, with a .09 ac. man-made pond, .23 ac. impervious surfaces with approximately .18 ac. permeable paths, .25 ac. mowed lawn and .04 ac. rain garden on western edge of parcel (2 plot points); Blanche Levy Park (also known as College Green), 4.25 ac. mature urban forest comprised of native and non-native trees dominated by *Prunus* x *yedoensis*, *Acer saccharum*, *Ulmus parvifolia*, *Platanus* x *hispanica*, *Fraxinus pennsylvanica* and *Acer rubrum*, containing the oldest known tree on campus and a central open lawn, dating back to the 1890's, 70.69% canopy cover, 1.54 ac. mowed lawn, .85 ac. impervious surfaces, with shrub and herbaceous layers at edges (2 plot points); Shoemaker Green, 2.75 ac. urban park comprised of native trees, shrubs and perennials, dominated by *Quercus phellos*, *Magnolia virginiana* and *Cornus florida* 'Cherokee Chief', containing a central open lawn, surrounded by plantings of trees, shrubs and herbaceous plants, constructed in 2012, 45.29% canopy cover, a .11 ac. rain garden, .70 ac. mowed lawn, 1 ac. impervious surfaces, (1 plot point); and Penn Park, 24 ac. urban park comprised of native trees and grasses, dominated by *Celtis occidentalis*, *Platanus* x *hispanica*, *Quercus palustris*, *Metasequoia glyptostroboides*, *Liquidambar styraciflua*, *Quercus bicolor* and *Gleditsia triacanthos* var. *inermis*, constructed in

2011, 13.4% canopy cover, 7.43 ac. of sports fields, 5 ac. of mowed turf grass, 1.88 ac. impervious surfaces, .26 ac. orchard and 6 ac. of native grasses (4 plot points). (The 2018 results from an additional College Green site were included in the incidental section because it overlapped too closely with two (2) other plot points and did not provide enough additional information). These nine (9) plot points allowed coverage over the entirety of each parcel with the bird counts, considering density or openness of plantings, noise pollution, overall size of parcel, and unique features. I will examine how each site supports bird species as a lens to improve landscape management. Therefore, I consolidated the 9 plot points into 4 larger areas (BioPond, College Green, Shoemaker Green and Penn Park, Fig. 5) for purposes of data analysis. Tree and shrub data was downloaded from Penn's comprehensive tree database, BG-Base/BG-Map. The tree data accessed was comprehensive, whereas the shrub data was incomplete but offers a general description. Canopy coverage numbers represent trees 8' high and taller, (O'Neil Dunne, 2019). Any smaller tree, including most trees and shrubs within the Penn Park Orchard, did not get captured in this number.

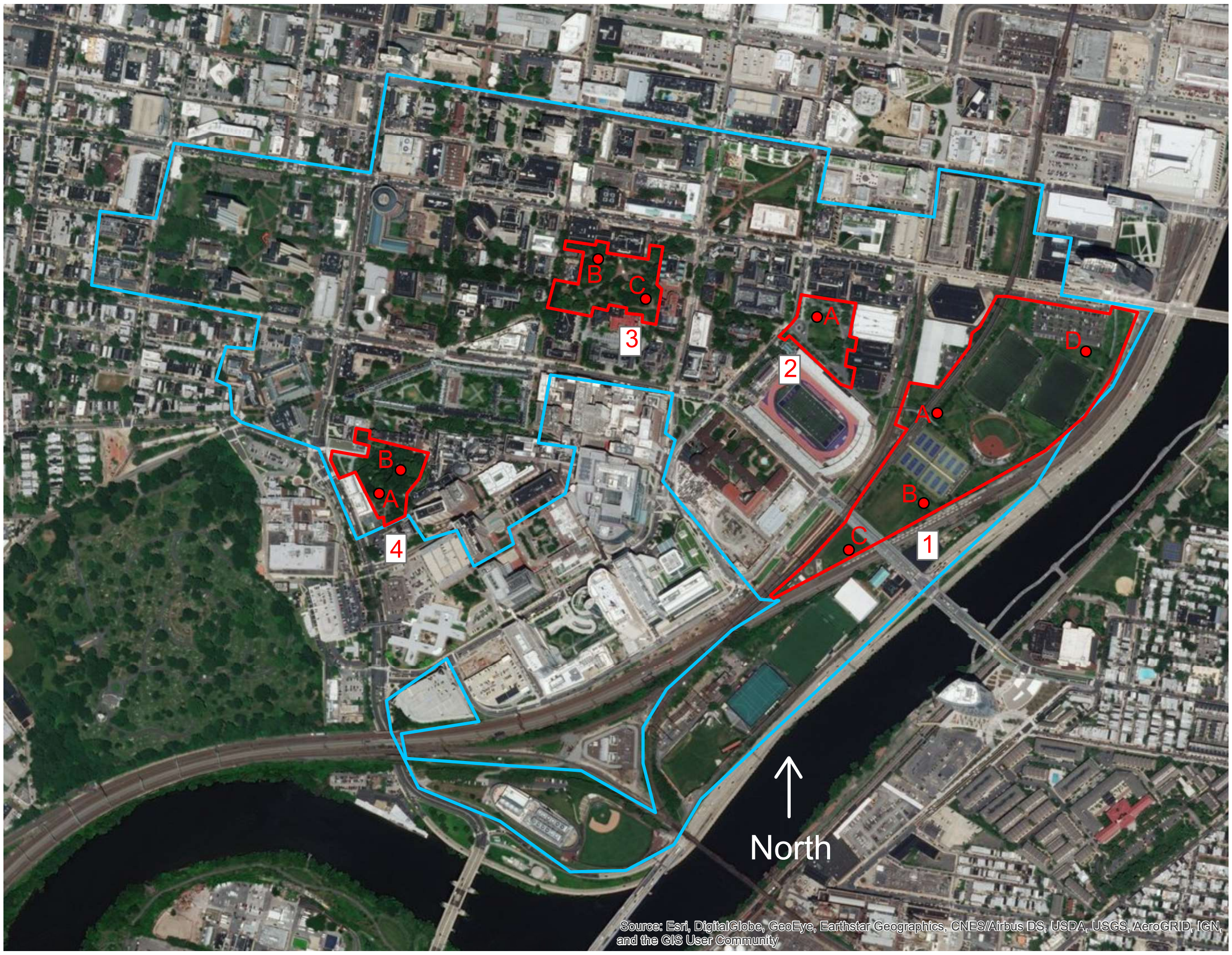

Fig. 3. GIS map of Penn showing campus boundary in blue with red dots representing 9 bird point locations, within 4 sites: (1) Penn Park (2) Shoemaker Green (3) Blanche Levy Park (also known as College Green) (4) Kaskey Memorial Park (also known as the BioPond).

Table 1. Vegetation characteristics at each site.

Site	Area (ac)	# of tree species	# of trees	% canopy cover	Avg.Canopy height (m)	Avg. Shrub height (m)
BioPond	3	105	257	74.8	8.8	3.6
College Green	4.25	77	325	70.69	8.8	2.8
Shoemaker Green	2.75	18	111	45.29	9.8	1.4
Penn Park	24	48	668	13.4	8.3	1.2

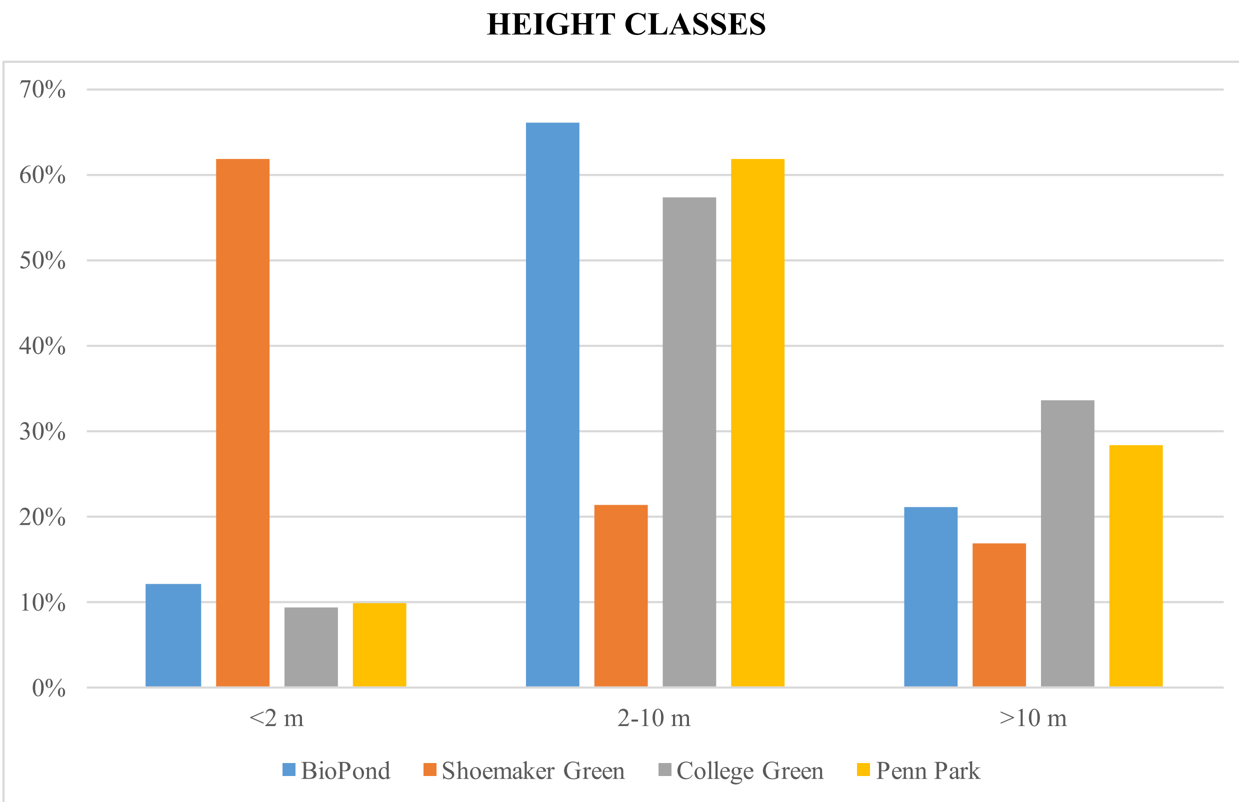

Fig. 4. Woody plant height classes (m) at survey sites.

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Fig. 5. Representative photographs of survey sites. 1) BioPond, 2) College Green, 3) Shoemaker Green, 4) Penn Park.

Data Collection-- I conducted twenty-four (24) replicable systematic bird counts during spring migration, breeding season and fall migration in order to estimate the populations and species of birds that Penn's campus supports. In spring and summer, I used the unlimited distance, single observer point count method, the most common method of bird monitoring, while in fall, I conducted area searches, since fewer birds are singing (Ralph, C. John et al., 1993). I collected bird data approximately every 2-3 weeks, beginning around sunrise and continuing for about 3 hours with at least 1 knowledgeable research assistant. One person recorded the bird data and each person used binoculars and listened for bird songs or calls in order to locate birds throughout the data collection period. I used a Bird Point Count Data Sheet (Fig.16 in Appendix), recording weather conditions, location, bird species, behaviors seen and/or heard and applicable notes during a 10-minute period from a specific plot point. Notable observations seen between bird survey plot points or outside of official count periods during 2018 and 2019 by the principal investigator and reputable 3rd parties were included as incidental sightings. Occasionally, no birds were observed during a point count. I digitized and analyzed the data in order to create comprehensive baseline data of bird species found on Penn's campus.

Collecting bird data in an urban setting was inherently complex. In addition to the difficulty of identifying birds through sight or sound in general, the weather, light conditions, noise pollution, people, special events and short data collection periods could affect what birds were present and could have impeded our ability to collect data. In particular, noise pollution was significant, and included vehicular and train traffic, generators, leaf blowers, power washers, and athletic events. I worked with research assistants who are knowledgeable about bird identification and we made every effort to identify each bird to the best of our abilities. Sometimes, we were only able to identify the bird order or genus, but not the species. This data provides a snapshot of what birds were observed on Penn's campus during the survey periods and is not a comprehensive census.

RESULTS AND DISCUSSION

Total Species Richness -- Over the course of systematic and incidental bird sightings spanning two years throughout Penn's campus, we documented 84 species of birds from 34 families, with a total of 3,777 detections of birds. (These detections do not equate to the number of individual birds, since we rarely knew whether we saw the same birds across multiple bird counts on different days). The bird collection data came from 24 bird counts (Table 2).

Table 2. Survey summary of dates, times, total species and counts.

Survey Date	*Survey Times*	*Total Species*	*Count*
4/24/18	6:35 AM - 9:50 AM	23	99
5/9/18	6:17 AM - 9:23 AM	19	78
5/30/18	5:34 AM - 8:44 AM	26	104
7/3/18	4:53 AM - 7:40 AM	18	99
7/20/18	5:33 AM - 8:53 AM	17	56
8/3/18	5:46 AM - 8:48 AM	19	56
8/17/18	5:40 AM - 8:49 AM	11	30
8/31/18	5:58 AM - 8:56 AM	11	41
9/15/18	6:18 AM - 9:24 AM	17	39
9/29/18	6:29 AM - 10:20 AM	17	51
10/21/18	7:00 AM - 10:09 AM	38	94
11/11/18	6:35 AM - 10:20 AM	18	39
4/12/19	6:36 AM - 9:10 AM	28	70
4/28/19	6:12 AM - 9:06 AM	16	38
5/19/19	5:45 AM - 8:47 AM	26	70
6/2/19	5:37 AM - 8:36 AM	22	52
6/15/19	5:32 AM - 8:33AM	16	55
7/14/19	5:45 AM - 8:27 AM	15	61
8/4/19	6:04 AM - 8:30 AM	17	44
8/25/19	6:26 AM - 9:33 AM	17	49
9/10/19	6:35 AM - 9:11 AM	20	50
9/24/19	6:44 AM - 9:23 AM	22	51
10/8/19	7:04 AM - 9:30 AM	12	28
10/22/19	7:09 AM - 9:42 AM	23	52
	Average:	19.5	58.58

During systematic counts, we documented 68 species from 30 families (not including flyovers, birds observed flying high overhead), with a total of 3,061 detections. 2,909 systematic detections (or 95%), including flyovers, were identified to species, while 2,837 detections, not including flyovers, were identified to species. The 4 campus areas (BioPond, College Green, Shoemaker Green and Penn Park) contained both overlapping and unique species. Each area supported the following numbers of species: 45 in the BioPond, 40 in Penn Park, 39 in College Green and 29 in Shoemaker Green (Fig. 6).

BIRD SPECIES DIVERSITY

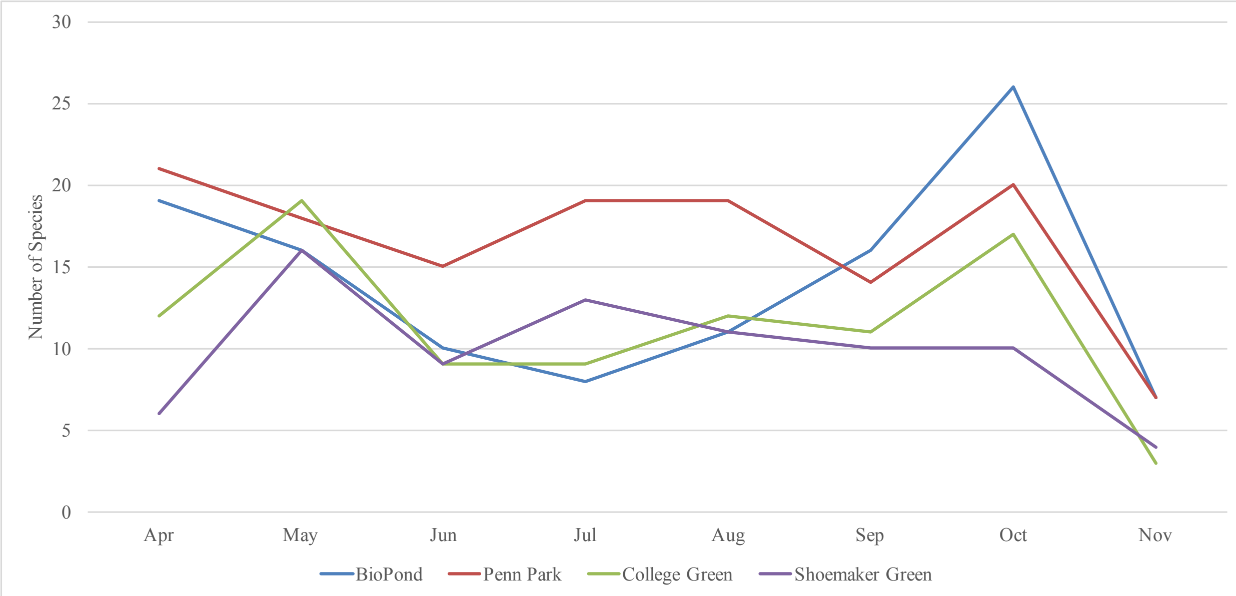

Fig. 6. Species richness across study sites, throughout the year.

Since I was most interested in determining which species of birds utilized the Penn landscape, I removed all flyover species (Gulls, Cormorants, Egrets, Herons and Canada Geese) and unidentified birds observed from my data analysis. Unidentified birds detected on campus included Unidentified Cormorant, Unidentified Crow, Unidentified Flycatcher, Unidentified Gull, Unidentified Poecile Chickadee, Unidentified Waterthrush, Unidentified Woodpecker, Unidentified Wren and Unidentified Passerine. Birds that were only observed as incidentals on campus included the American Woodcock, Cape May Warbler, Eastern Towhee, Fox Sparrow (Fig. 7), Laughing Gull, Louisiana Waterthrush, Rose-breasted Grosbeak, Sharp-shinned Hawk, Summer Tanager (Fig. 7) and Yellow-billed Cuckoo. The top 10 species of birds observed at Penn were as follows, in order of decreasing abundance: House Sparrow, European Starling, American Robin, Rock Pigeon, Chimney Swift, American Goldfinch, Gray Catbird, Northern Mockingbird, Mourning Dove and Northern Cardinal (Fig. 8).

1. 2.

Fig. 7. Photographs of species found as incidental sightings. 1) Summer Tanager, BioPond, Photo courtesy of Joe Durrance, 5/8/2018. 2) Fox Sparrow, BioPond, Photo courtesy of Joe Durrance, 4/18/2018.

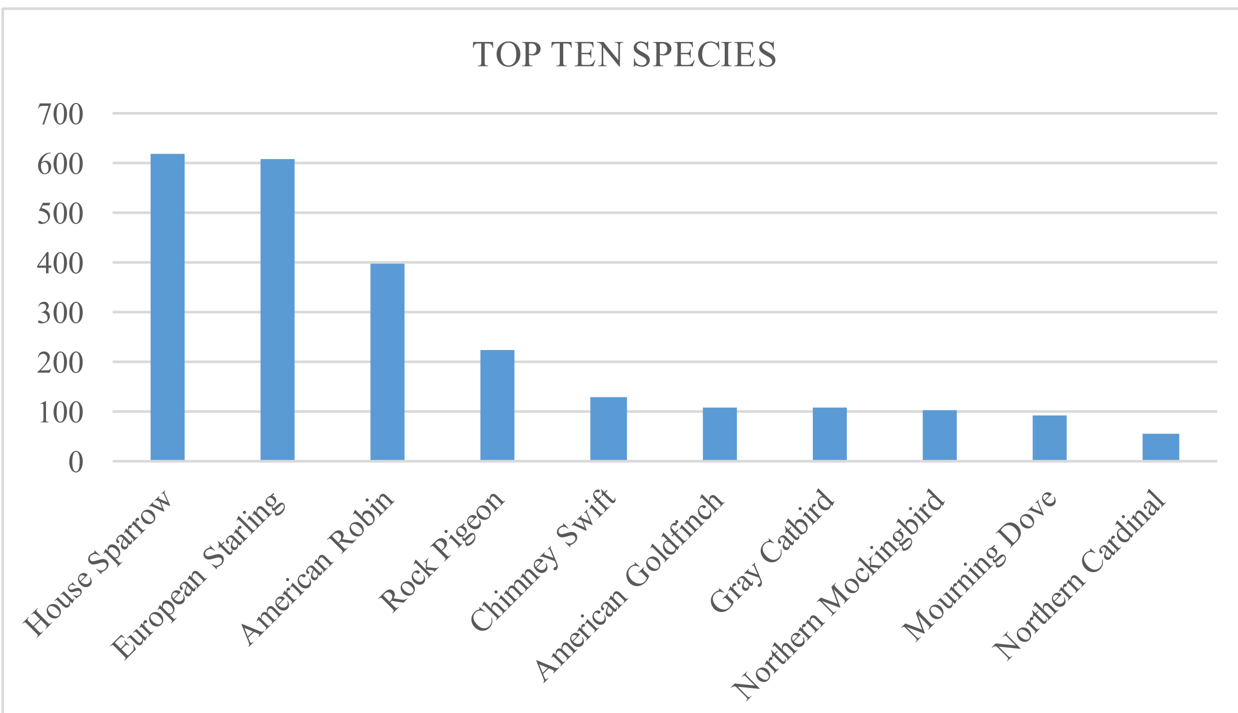

Fig. 8. Top ten bird species observed at survey sites. Numbers shown represent overall abundance based on individual detections during each bird count.

Twenty-four (24) species of birds (or 35.29%) were only documented at one site during the course of my study (Table 3). Penn Park supported the highest number of unique species and the highest number of species during the summer. This is understandable given the unique attributes of Penn Park's landscape, specifically the broad open space with extensive native meadows and young trees lining the edge. Penn Park provides a unique habitat type on campus offering significant wildlife value for birds in the region during breeding and migration.

Table 3. Bird species found at unique survey sites. Species shown with asterisks are represented in photographs below (Fig. 9).

PENN PARK	BIOPOND	COLLEGE GREEN	SHOEMAKER GREEN
Barn Swallow	Black-throated Blue Warbler	Black-capped Chickadee	American Crow
Belted Kingfisher	Blackpoll Warbler *	Golden-winged Warbler	Black-throated Green Warbler
Blue Jay	Brown Thrasher *	Hairy Woodpecker	
Brown-headed Cowbird	Eastern Wood-Pewee	Magnolia Warbler *	
Merlin	Green Heron *	Palm Warbler	
Red-eyed Vireo	Mallard		
Red-winged Blackbird	Swainson's Thrush		
Tree Swallow	Turkey Vulture		
Yellow Warbler			

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Fig. 9. Photographs of species found at unique survey sites. 1) Blackpoll Warbler, BioPond, Photo courtesy of Joe Durrance, 9/29/2018. 2) Brown Thrasher, BioPond, Photo courtesy of Joe Durrance, 4/12/2019. 3) Green Heron, BioPond, Photo courtesy of Joe Durrance, 4/28/2019. 4) Magnolia Warbler, College Green, Photo courtesy of Joe Durrance, 9/10/2019.

Fourteen (14) species of birds (or 20.59%) were documented at all four (4) sites during the course of my study, including American Goldfinch, American Robin, Carolina Wren, Chimney Swift, Common Yellowthroat, European Starling, Gray Catbird, House Finch, House Sparrow, Mourning Dove, Northern Cardinal, Northern Mockingbird, Rock Pigeon and White-Throated Sparrow (Table 9 in Supplementary Materials). Generally, the most commonly detected birds were found at all sites. Common Yellowthroats and White-Throated Sparrows were found at all sites in lower numbers but were equally as adaptable as the more common species.

I consolidated the bird collection data into month periods, revealing distribution patterns and relative abundance variation throughout the seasons and sites (Table 8 in Supplementary Materials). We detected the following birds year-round: Mourning Dove, Rock Pigeon, Chimney Swift, European Starling, Gray Catbird, Northern Mockingbird, American Robin, Cedar Waxwing, House Sparrow, American Goldfinch, House Finch, Northern Cardinal and American Kestrel. We detected the following birds throughout most of the year: Downy Woodpecker, Barn Swallow, Carolina Wren and Common Yellowthroat. A wintering bird in this region, the Dark-eyed Junco was only observed in April and November. Migrants were detected during the spring and fall migration season, resulting in peak species diversity during those time periods.

Birds that eat insects and occur in forests, mature woods, open woodlands and woodland edges were more likely to be detected only in the BioPond and College Green. Those species included the Downy Woodpecker, Golden-Crowned Kinglet, Ruby-crowned Kinglet, White-breasted Nuthatch, Blue-gray Gnatcatcher, Hermit Thrush, Blue-winged Warbler and Chestnut-sided Warbler. Birds that occur in open areas with cliffs or grasslands were more likely to be detected only in Penn Park and Shoemaker Green, such as the Peregrine Falcon (seen perched on top of the adjacent 222.5 m tall FMC Tower) and American Kestrel. Birds that occur in grasslands, forests and their edges and open woodlands were more likely to be detected only in the BioPond and Penn Park, such as the Eastern Kingbird, Eastern Phoebe, Carolina Chickadee and Chipping Sparrow.

Migration and Breeding -- Penn's campus supported 29 residents, 19 migratory breeders, 14 migrants, 3 wintering and 3 introduced species of birds (Fig. 10). In order to determine the breeding status of birds observed on campus (Fig. 11, Table 9 in Supplementary Materials), I searched my data in order to obtain direct evidence: ON-On nest, CN-Constructing Nest, BY-begging young, FY-Feeding Young, PB-Pair Bonding, YOY-Young of year, FT-Food transfer, HY-Hatch Year, NM-Nest Material. I also searched for the following words in the Notes entry in order to obtain indirect evidence, including: parent, family, YOY, young, HY, hatch, juvenile, baby, babies, mom, nest, pair, male, female. Finally, I searched for any birds observed on campus during June or July. I sifted through the results to determine whether the behaviors or notes mentioned confirmed breeding on-site (Table 4). Without direct evidence, most of the birds found on campus during June or July were deemed probable breeders. For example, Chipping Sparrows were observed and heard in Penn Park during June and July and were likely breeding on-site. Some of the other resident birds we observed occasionally may be breeding on-site, such as the Peregrine Falcon, White-breasted Nuthatch, Common Grackle, Cooper's Hawk, Red-Tailed Hawk, Downy Woodpecker, Hairy Woodpecker, Northern Flicker, American Crow, Blue Jay, Black-capped Chickadee, Carolina Chickadee and Song Sparrow. Many factors encourage birds to breed on-site; additional food, water, shelter and nesting boxes, as appropriate, should be provided.

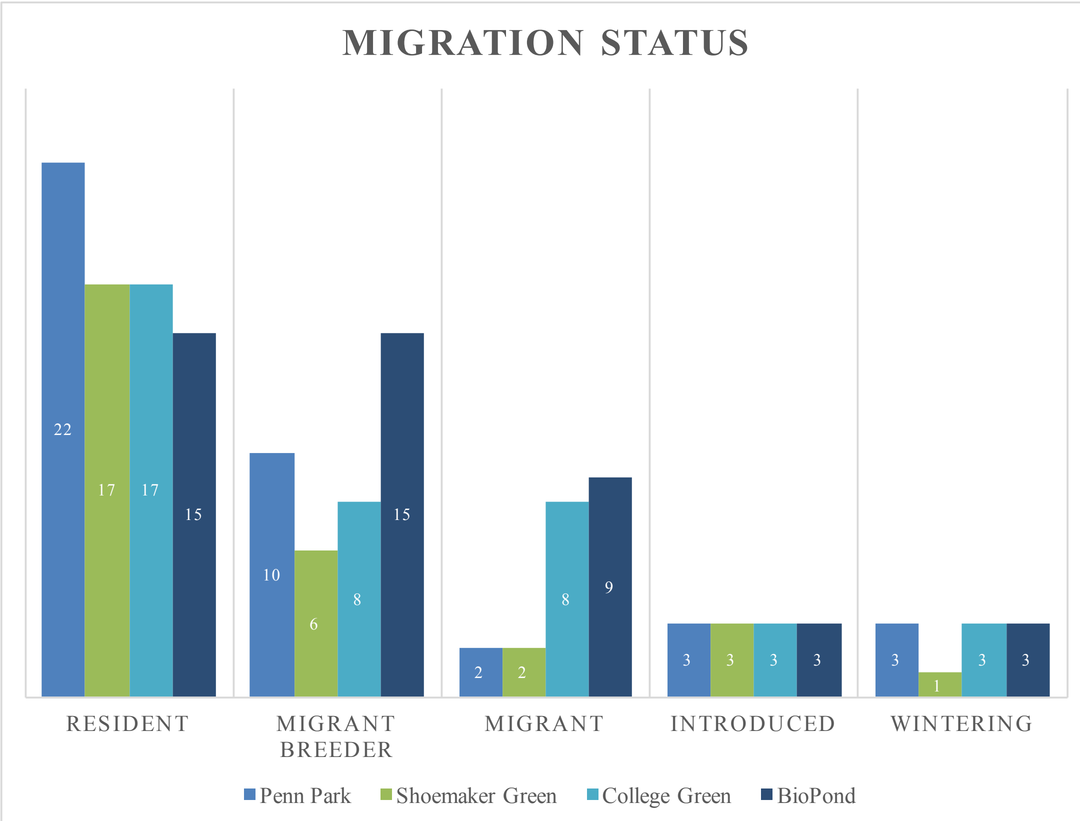


Fig. 10. Migration status of bird species found at survey sites.

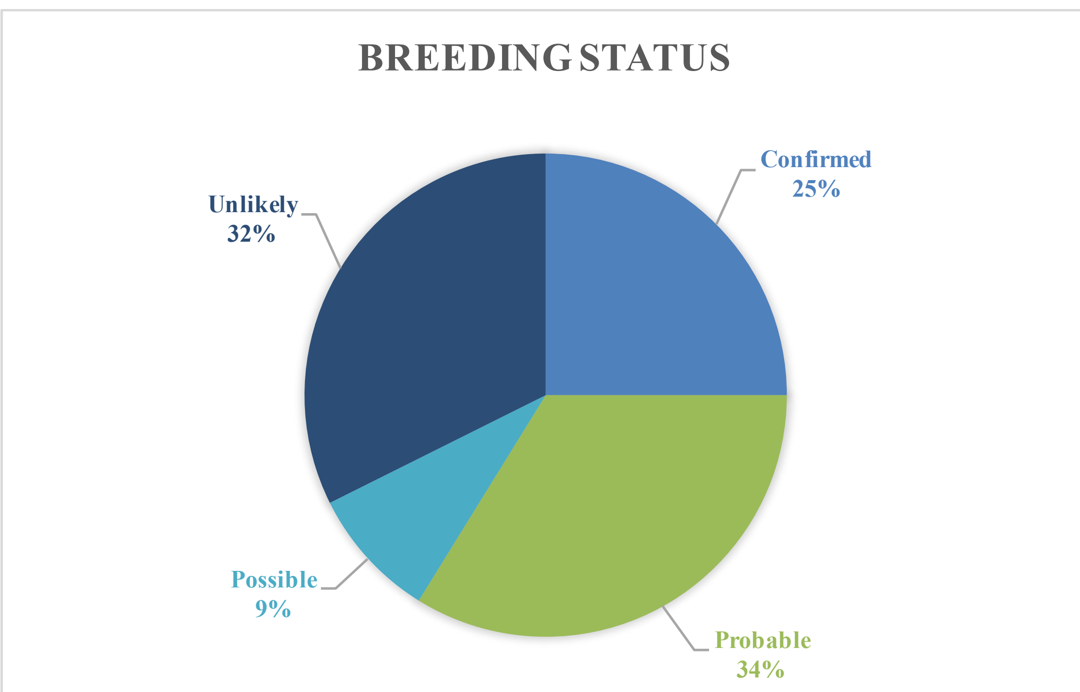


Fig. 11. Breeding status of 68 species of birds found in survey areas.

Table 4. Birds that were confirmed breeding on-site. * Indicates that no direct evidence was found, but it is believed that both are confirmed breeders on-site, likely on infrastructure.

CONFIRMED BREEDING ON SITE				
	Penn Park	Shoemaker Green	College Green	BioPond
American Goldfinch			•	
American Kestrel		•		
American Robin	•	•	•	•
Carolina Wren	•			
Cedar Waxwing	•			
Chimney Swift*				
Eastern Kingbird	•			
European Starling	•	•	•	
Fish Crow	•	•		
Gray Catbird	•	•	•	•
House Finch	•	•	•	
House Sparrow	•		•	•
Mallard				•
Mourning Dove	•			
Northern Cardinal				•
Northern Mockingbird	•			
Rock Pigeon*				

Conservation Values -- Penn's campus supports many birds in need of conservation. Determining species' conservation needs is a complex and evolving process; therefore, I consulted multiple conservation assessments to get a broader understanding of the birds observed throughout my project sites. All bird species native to North America have conservation scores based on their level of vulnerability, related to population size and trend, distribution and threats (State of NA's Birds, 2016). Scores vary from 0 to 20 with birds of low conservation concern scoring from 0-8, birds of moderate conservation concern scoring from 9-13 and birds of high conservation concern scoring from 14-20. I assigned introduced or invasive species a 0. Of the birds detected, only the golden-winged warbler warrants high conservation concern, while 37% of the birds observed have moderate conservation concerns (Fig. 12) and 62% have low conservation concerns. However, 22% of the birds observed scored an 8, which puts them close to levels of moderate concern. Thirteen (13) species of birds observed on Penn's campus are listed as Species of Concern, while the Blackpoll Warbler is Endangered and the Peregrine Falcon is Threatened in Pennsylvania (Table 9 in Supplementary Materials, PA Wildlife Action

Plan, 2015). While each area studied supported many birds of conservation concern, the BioPond nominally supported more of these species (Fig. 12).

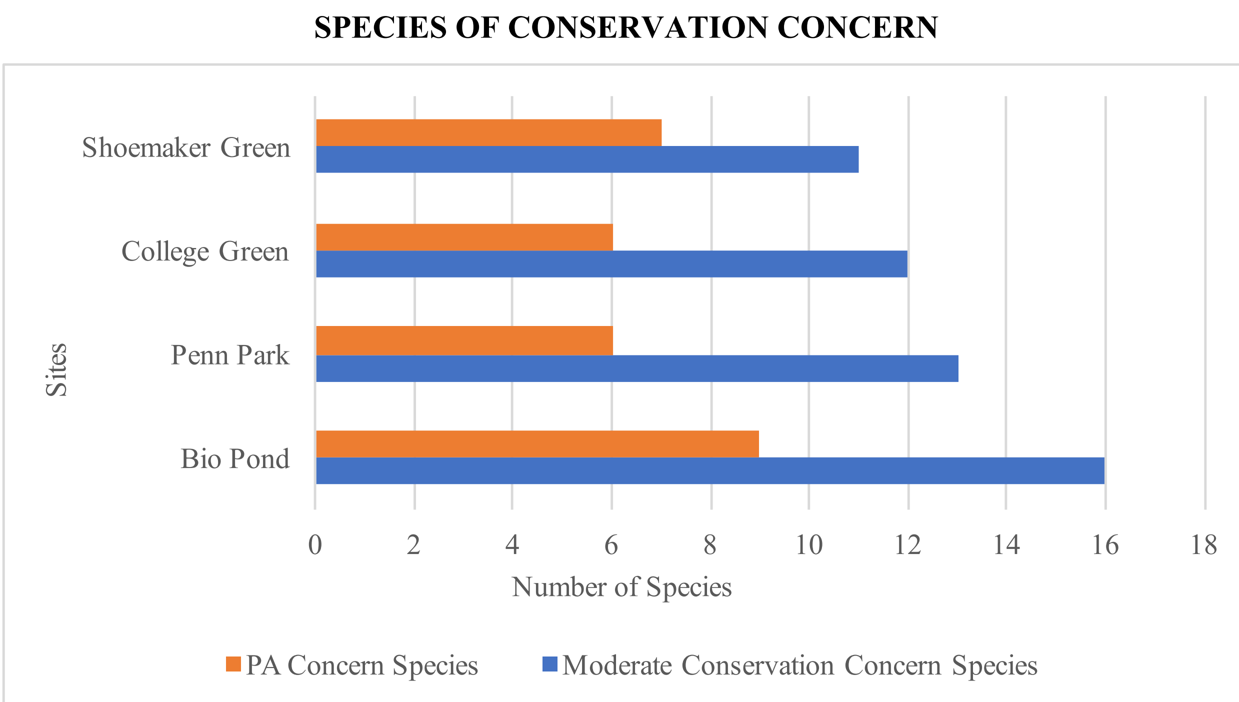


Fig. 12. Species of conservation concern mapped across survey sites.

Whereas, a recent study highlighted steep declines across many families of North American birds (Table 5, Rosenberg et al., 2019), Penn's campus supported 20 of the 21 declining North American bird families, comprising 67 species of birds (including incidentals). Penn is providing critical habitat for species that are in broad decline.

Table 5. Net change in abundance across North American bird families, 1970-2017 (Rosenberg et al., 2019).

Order	Scientific Family	Common Family	Decline
Passeriformes	Passeridae	Old World Sparrows	-81.10%
Caprimulgiformes	Apodidae	Swifts	-65.30%
Charadriiformes	Laridae	Gulls and Terns	-50.50%
Passeriformes	Sturnidae	Starlings	-49.30%
Cuculiformes	Cuculidae	Cuckoos	-47.90%
Coraciiformes	Alcedinidae	Kingfishers	-47.80%
Passeriformes	Icteridae	Blackbirds	-44.20%
Charadriiformes	Scolopacidae	Shorebirds	-38.40%
Passeriformes	Passerellidae	New World Sparrows	-38.00%
Passeriformes	Parulidae	Wood Warblers	-37.60%
Passeriformes	Fringillidae	Finches and Allies	-36.70%
Pelecaniformes	Ardeidae	Herons	-28.00%
Passeriformes	Hirundinidae	Swallows	-22.10%
Passeriformes	Tyrannidae	Tyrant Flycatchers	-20.10%
Passeriformes	Mimidae	Thrashers and Allies	-19.40%
Caprimulgiformes	Trochilidae	Hummingbirds	-17.00%
Passeriformes	Turdidae	Thrushes	-10.10%
Passeriformes	Regulidae	Kinglets	-7.10%
Passeriformes	Corvidae	Jays and Crows	-6.50%
Passeriformes	Paridae	Chickadees and Titmice	-4.90%
Passeriformes	Cardinalidae	Cardinals and Allies	-3.30%

New World warblers (*Parulidae*) have declined 37.60% from 1970-2017 (Rosenberg et al., 2019, Table 5). We observed 15 species of warblers across the survey sites (Table 6), demonstrating the importance of Penn's campus to the livelihood of migrant warblers.

Table 6. New World warblers (*Parulidae*) species found at each survey site.

COLLEGE GREEN	BIOPOND	SHOEMAKER GREEN	PENN PARK
American Redstart	American Redstart	American Redstart	Black-and-white Warbler
Black-and-white Warbler	Black-and-white Warbler	Black-throated Green Warbler	Common Yellowthroat
Blue-winged Warbler	Black-throated Blue Warbler	Common Yellowthroat	Yellow Warbler

Chestnut-sided Warbler	Blackpoll Warbler	Northern Parula	Yellow-rumped Warbler
Common Yellowthroat	Blue-winged Warbler	Ovenbird	
Golden-winged Warbler	Chestnut-sided Warbler		
Magnolia Warbler	Common Yellowthroat		
Northern Parula	Northern Parula		
Ovenbird	Ovenbird		
Palm Warbler	Yellow-rumped Warbler		
Yellow-rumped Warbler			

Foraging Guilds -- Birds are grouped into foraging guilds that describe feeding behavior based on their major foods, substrate and technique (All About Birds, 2019). Penn's campus supports bird species that encompass eighteen (18) foraging guilds (Table 9 in Supplementary Materials), however most birds fall into 5 main guilds, as follows:

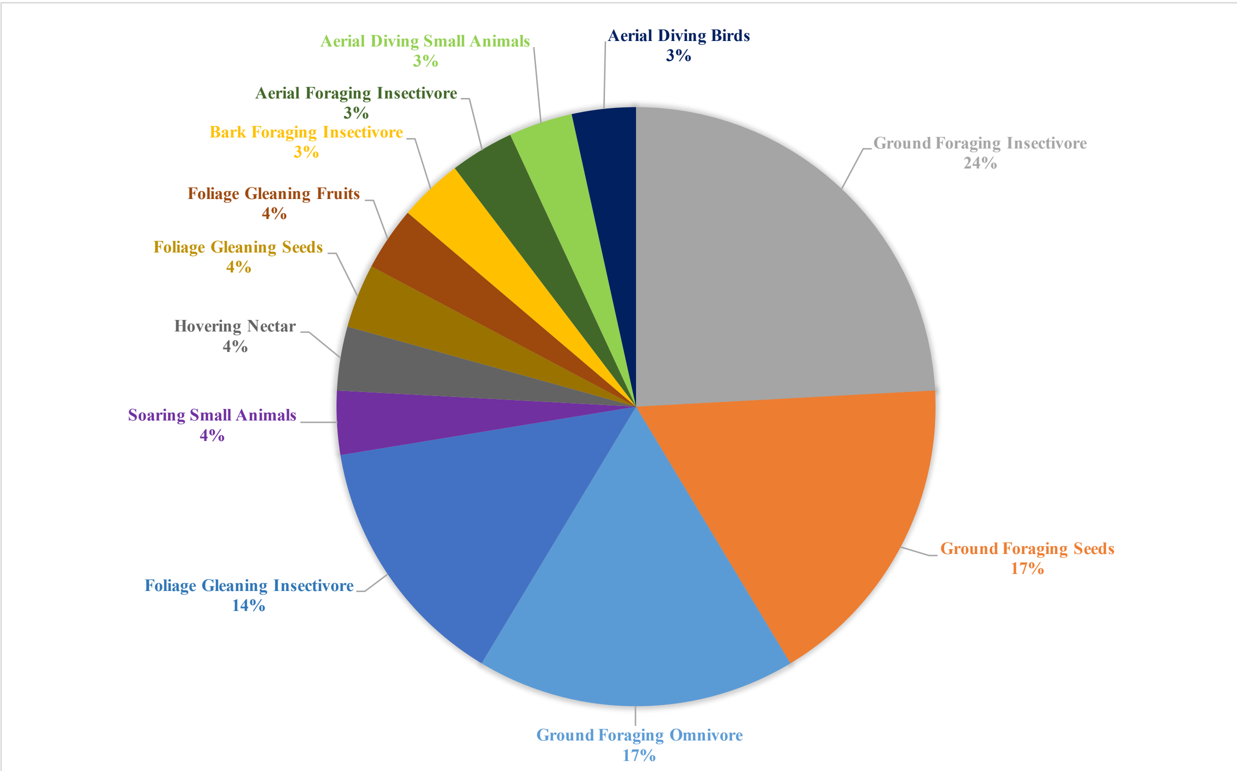
- 28% Foliage Gleaning Insectivore
- 15% Ground Foraging Insectivore
- 12% Ground Foraging Seeds
- 10% Ground Foraging Omnivore
- 9% Bark Foraging Insectivore

Fig. 13 shows the composition of foraging guilds at each of the four (4) survey sites. The largest guild, foliage gleaning insectivores, includes many PA species of concern, mostly migrants that are primarily warblers, as well as kinglets and chickadees. Of these birds, only Common Yellowthroat was found at all four (4) sites and several species were only found at one (1) site. Foliage gleaning insectivores were detected mainly in the BioPond and College Green. The Ground Foraging Insectivore guild encompasses mostly residents and some of the most widespread birds found on campus, including Carolina Wren, European Starling, Gray Catbird and American Robin, as well as the inconspicuous Ovenbird. The Ground Foraging Seeds guild includes many common birds, such as Mourning Dove, Rock Pigeon, House Finch and Northern Cardinal. Though it also includes Chipping Sparrow, and the following wintering birds, White-throated Sparrow and Dark-Eyed Junco. Most of these birds were found at all four (4) sites. One of the most adaptable of all foraging guilds, birds in the Ground Foraging Seeds guild rely on seeds of grasses and other plants, buds, fruits and trash. Ground foraging omnivores include mostly common birds, such as Northern Mockingbird and House Sparrow. Among the most adaptable foraging guilds, this group also encompasses many species that are prevalent in urban settings. Finally, bark foraging insectivores encompass White-Breasted Nuthatch, Brown Creeper, Black-and-White Warbler and Woodpeckers, mainly found in the BioPond and College Green that provide ample mature trees with furrowed bark.

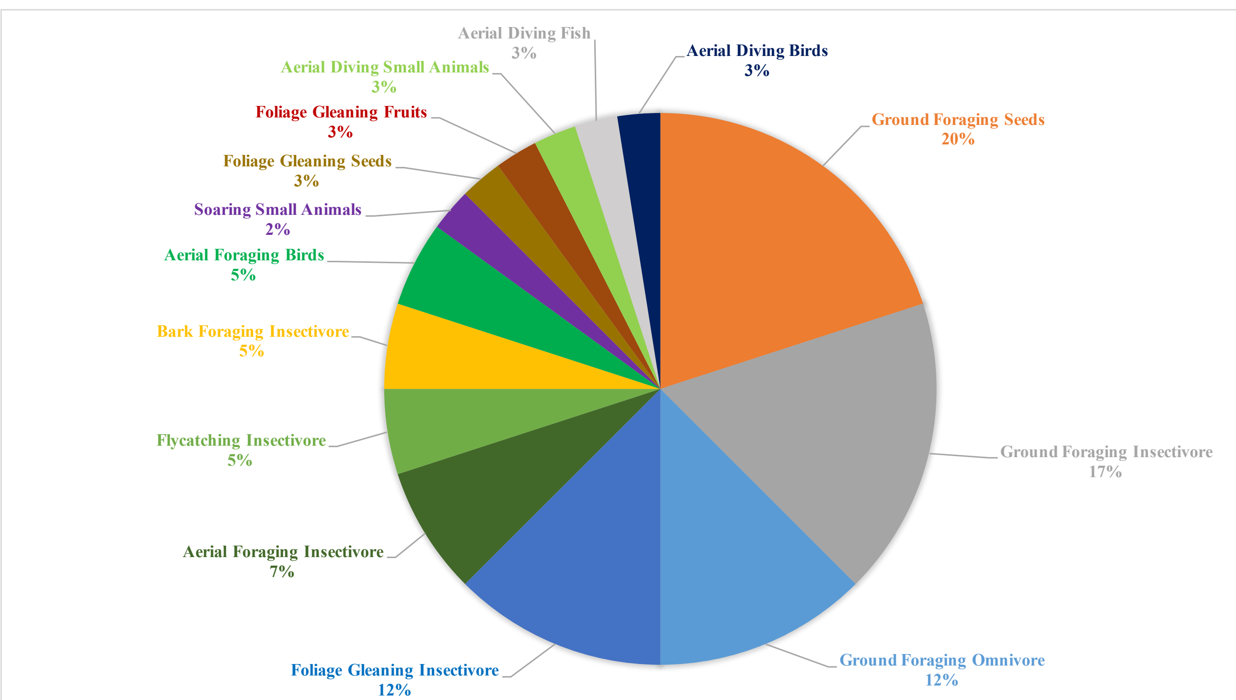
Due to their reliance on large open areas for catching insects on the wing, Penn Park supported the most aerial foraging insectivores (Chimney Swift, Tree Swallow and Barn Swallow) of any site. The BioPond provided urban forest habitat, albeit of a small scale, containing structural complexity with many mature trees and a water source. Foliage gleaning insectivores occurred mainly in the BioPond and College Green, as a result of the tree species diversity, including significant mature trees as well as ample upper and lower canopy structure. Birds in the flycatching insectivore guild were detected mainly at the BioPond and Penn Park, where they had access to abundant insects.

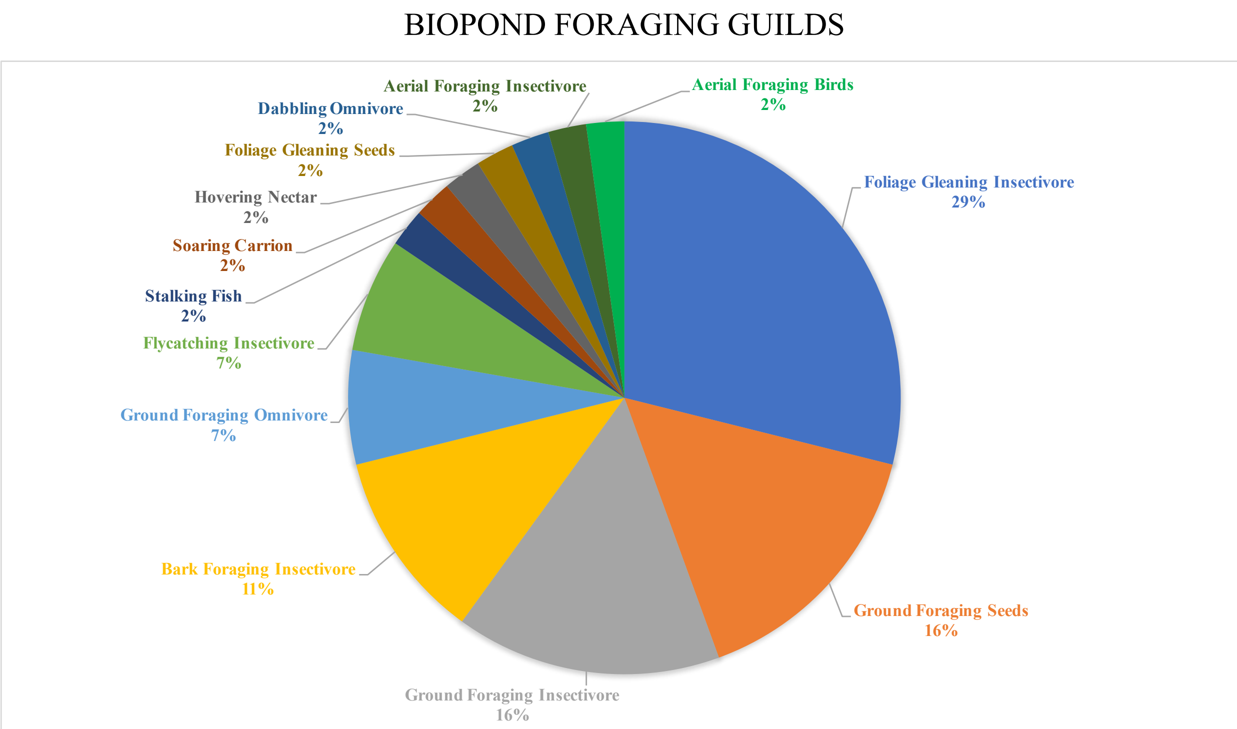
The ground foraging insectivore guild encompasses a number of birds from wide-ranging families that rely on invertebrate diversity and abundance. The most common species, such as American Robin or European Starling, will forage on open lawn. Many of the inconspicuous ground foraging insectivore bird species, such as the Ovenbird, were found in leaf litter within Shoemaker Green's rain garden, Memorial Garden on the northwest edge of College Green, and the entire BioPond. An essential part of the food web, leaf litter supports invertebrates, which in turn support insectivorous birds. In Australia, leaving leaf litter in landscapes increased the diversity of bird species by over 30% (Stagoll et al., 2010). Even though not all birds regularly eat insects, over 96% of land birds require insects for raising nestlings (Narango et al., 2017).

SHOEMAKER GREEN FORAGING GUILDS



PENN PARK FORAGING GUILDS





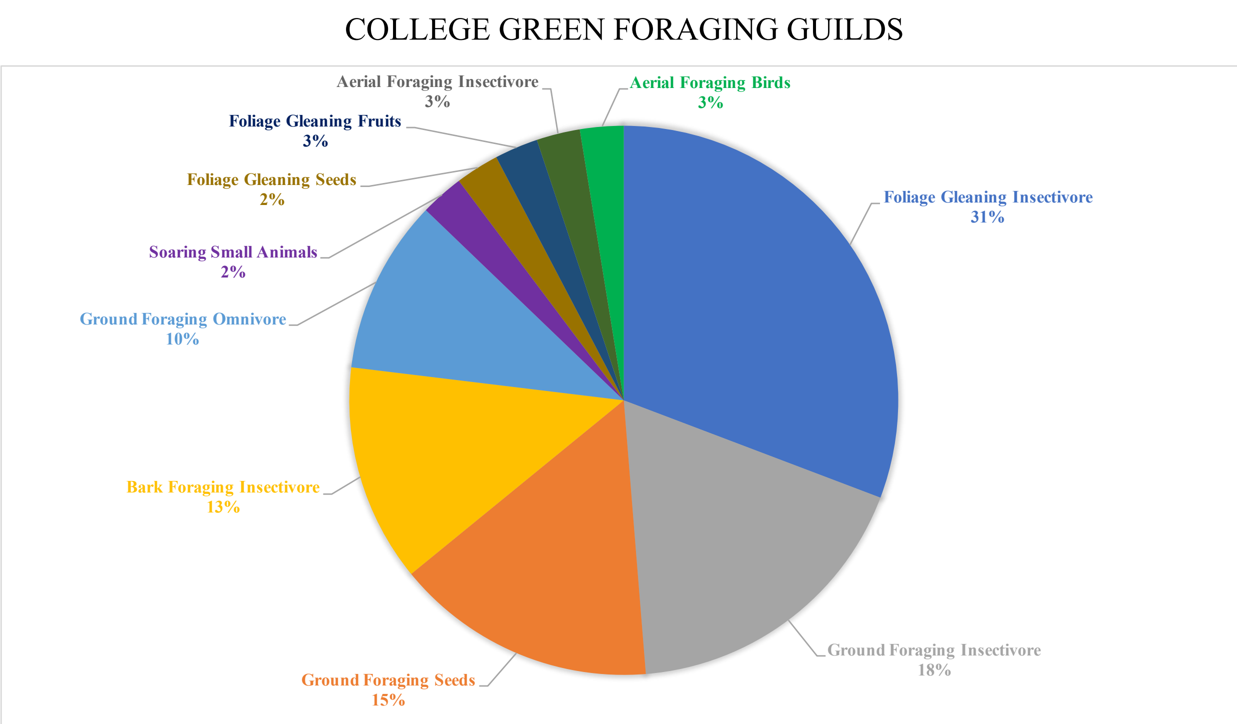
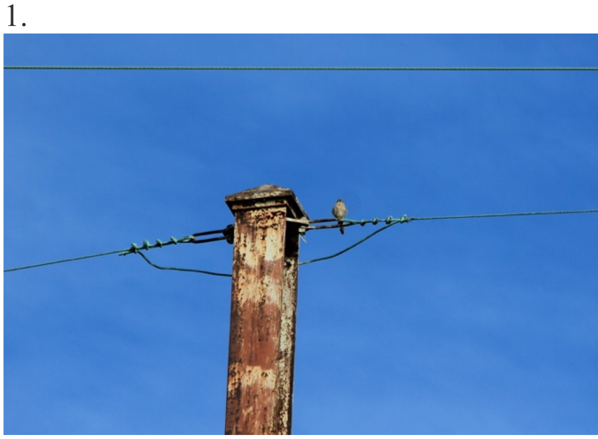


Fig. 13. Bird species foraging guilds for all four sites.

CASE STUDIES

American Kestrels -- In May 2019, we began regularly observing an American Kestrel, generally perched high on top of railroad wires above the elevated rail line (Fig. 14), and believed we saw the same bird on each count. Later, we frequently observed the male and female perched together, hunting for small animals in Penn Park's extensive open space. The male and female pair were confirmed breeding together in Shoemaker Green, though we did not see any juvenile birds during fledgling or dispersal season, so we suspect that the nesting failed. We anticipate the pair may return to nest in the same spot again next year. Penn Park provides critical habitat to American kestrels, as they rely on open fields for access to food. American Kestrels are in decline; they are of moderate conservation concern broadly, and are a Pennsylvania Species of Concern (PA Wildlife Action Plan, 2015). Generally, Falcons and Caracas (*Falconidae*) family populations are increasing (Rosenberg et al., 2019), however, American Kestrel populations are decreasing, representing widespread losses over many years. This decline is due mainly to habitat loss; agricultural fields and open space are being rampantly developed. "…Negative influences on populations are strongest in areas from which kestrels migrate near dense human populations along the Atlantic Coast" (Farmer, C.J. & Smith, J.P., 2009). In order to raise awareness and improve conservation of the American Kestrel, it is recommended to set up a nest camera at the nest site next year. Providing nesting boxes could also help increase the abundance of American Kestrels. Penn Park's 24 ac. of open space provides a unique urban habitat to a species of concern and should be preserved for conservation purposes.

1.



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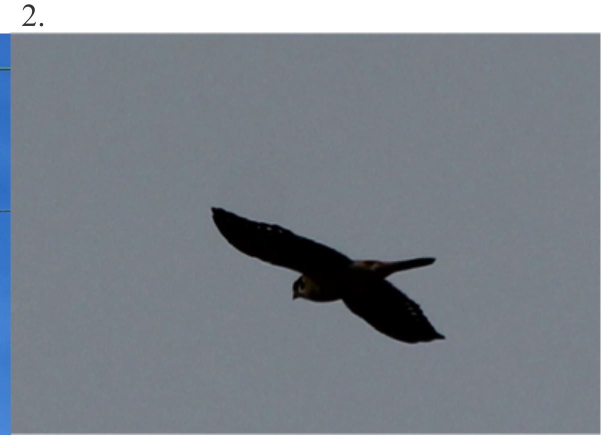

Fig. 14. Photographs of American Kestrels at Penn. 1) Penn Park, Photo courtesy of Joe Durrance, 6/15/2019. 2) Shoemaker Green, Photo courtesy of Joe Durrance, 5/1/2018.

Common Yellowthroat -- Common Yellowthroats are adaptable birds that were observed in low numbers in all four (4) habitat types across the study sites. As ground and lower-canopy foliage gleaning insectivores, they have access to diverse habitat structures on campus. They require dense vegetation and prefer wet areas. They were frequently observed foraging on the ground within the dense shrub layer in Shoemaker Green's rain garden, the thick shrub and herbaceous layer in Penn Park Orchard, the dense native perennials and shrubs in the BioPond, and in the tree canopy in College Green (Fig. 15). They are migrant breeders that are likely breeding on-site. Though we did not find direct evidence, we heard males calling for mates in May and we observed juveniles in September. A member of the *Parulidae* family, Common Yellowthroats are experiencing significant decline across their habitat range (Rosenberg et al., 2019). They are one of the most common birds to be killed from building-bird collisions, and in fact twelve (12) were found dead on Penn's campus between 2018-19. All of the study sites support Common Yellowthroats, and every effort should be made to continue planting and managing diverse habitats within Penn's existing open space in order to continue to support these declining birds.

1. 2.

Fig. 15. Photographs of Common Yellowthroats at Penn. 1) BioPond, Photo courtesy of Joe Durrance, 4/18/2018. 2) Shoemaker Green rain garden, Photo courtesy of Joe Durrance, 5/1/2018.

Chimney Swifts -- The fifth (5^{th}) most abundant bird found on campus, Chimney Swifts have been observed within all four (4) sites. They were often seen flying between 20-100 meters high, and within groups of up to twenty (20) individual birds. As these bird counts only provided a snapshot of birds observed within the study sites, we do not know if the abundance increased around dusk, when Chimney Swifts commonly forage for insects airborne. Chimney Swifts are migrant breeders that are confirmed breeders on-site, likely within the chimneys of old structures. Though they appear abundant on campus, the *Apodidae* family has declined 65.30% since 1970 (Rosenberg et al., 2019). Chimney Swifts are of moderate conservation concern broadly and are also listed as a Pennsylvania Species of Concern (PA Wildlife Action Plan, 2015). A recent study revealed that 40% of insect species are at risk of extinction, due mainly to habitat loss, agro-chemical pollutants, invasive species and climate change (Sánchez-Bayo et al., 2019). Conservation programs recommend building chimney swift towers since there are fewer suitable nesting locations in caves and hollow trees and in human infrastructure, due to chimneys getting capped.

CONCLUSION

North American birds, whose species richness can indicate the health of a broader ecosystem, are in steep decline. As cities become more developed and habitats more fragmented, urban landscapes need to contribute to biodiversity. Situated along the Schuylkill River and Atlantic Flyway, Penn is part of a broader region of green space in Philadelphia, and should continue to play an essential role in improving the ecological health of the area. "Natural habitat must not be viewed as an expendable luxury but as a crucial system that fosters human health and supports all life on the planet" (Fitzpatrick and Marra, 2019). Penn's urban forest provides critical habitat for resident and migratory birds, consisting of habitat patches that each play a vital role in conserving biodiversity (Aronson et al., 2017). These fragments include woodlands, urban parks, gardens, green roofs and transportation corridors, such as railroad tracks and streets planted with trees. Situated in the heart of Philadelphia, Penn is an urban sanctuary for birds, as demonstrated by the bird species richness observed in the baseline data collected. The BioPond supports the highest species richness at Penn, likely due to its age and diverse naturalized landscape strata. Penn Park and College Green support nearly the same number of species, with Shoemaker Green still supporting a considerable number of species. Adding more native shrubs to increase structural layers, in particular at Penn Park and College Green, will increase the ecological function of the landscape. Even incremental improvements in campus habitat and management could have a broad impact on landscape connectivity and bird species richness. Now that baseline data has been established, future monitoring studies are recommended in order to quantify trends linking campus environmental health with bird species richness. The

University has demonstrated a strong desire to create higher functioning and more bio-diverse landscapes and should continue to prioritize thoughtful development in partnership with open space preservation, landscape design and management.

Recommended planning and ecological management strategies include utilizing native plants with high protein value for birds (Seewagen, 2010), increasing hedgerow density (Gottschalk et al., 2010), structural complexity and street tree connectivity, creating access to water (Melles et al., 2003), letting leaves lay in situ, minimizing pesticide and herbicide use, decreasing turfgrass, improving turfgrass maintenance regimens (Aronson et al., 2017) and reducing bird strikes. High-quality and structurally diverse habitat provides nutritional food, water, and opportunities to nest and find shelter. Leaf litter sustains invertebrates that in turn provide an essential protein source for many birds. Intensive lawn management and chemical use negatively impact ecosystem health and should be reduced so that landscapes can provide enhanced ecological functions. "Cues to human care, expressions of neatness and tended nature, are inclusive symbols by which ecologically rich landscapes can be presented to people and can enter vernacular culture" (Nassauer, 1995). Finally, bird-friendly design efforts should be expanded, by bringing awareness to the issue and implementing design guidelines to reduce bird window collisions. Minimizing risks at glass facades by utilizing the 2x4 rule, limiting artificial light and monitoring buildings for bird strikes are essential strategies to protect birds. Establishing and maintaining resilient cities will be critical for the long-term health of birds and people.

ACKNOWLEDGEMENTS

I would like to acknowledge my deep gratitude towards the following people, who without which this project would not have been possible:

Michael McGraw's passion for and knowledge of birds inspired me to embark on a Master's Capstone about birds in a hyper-local environment. His advice and mentorship have been invaluable from the first brainstorm session through to the final draft. I am indebted to Dr. Sally Willig, whose guidance, support and encouragement from day one have brought my project to its full potential. I would like to acknowledge my appreciation of Joe Durrance, who assisted with data collection on nearly every bird count. His valuable photographs create a formal record of birds documented at Penn during my study and beyond. Finally, I cannot begin to express my endless thanks to my husband, Max Blaustein, who expertly assisted on many bird counts, provided indispensable advice, technical and emotional support, and helped me stay focused and clearheaded throughout the entire process.

APPENDIX

PASSERINE - Bird Point Count Data Sheet

Project Name ____________________ Sample Point ID # & Name ____________________

Date ________ Start Time ________ Stop Time ________ X coordinate, Y coordinate ____________________

Observer ______ Wind Spd. ______ Wind Dir. ______ Sky ______ Temp ______ Dominant (>50%) AES Habitat Type ____________________

Other Habitats____________________

N

W E

S

Wind	Sky	AES Habitat Type
0 = none	0 = <10% clouds	Developed
1 = 1-3mph	1 = partly cloudy	Cropland
2 = 4-7 mph	2 = mostly cloudy	Barren Land
3 = 8-12 mph	3 = overcast	Grassland
4 >12 mph	4 = rain	Upland Shrub-Scrub
	5 = fog	Upland Broadleaf Forest
Behavior		Upland Coniferous Forest
F = flying		Upland Mixed Forest
S = soaring		Wetland Forested
P = perching or on water		Wetland Shrub-Scrub
Fo = foraging		Wetland Emergent
MD = mating display		Open Water
O = other		

Notes:

Alpha Code	Behav. Code	Dir. from Point	Dist. from Point (m)	Flight Dir.	Ht. (ft or m)	0-3 min	3-5 min	5-10 min	10-15 min	15+ min	Notes

Fig. 16. Sample bird point count data collection sheet.

Table 7. Species historically documented in the Biopond, but not documented during these bird counts.

American Crow
American Kestrel
Bald Eagle
Baltimore Oriole
Bay-Breasted Warbler
Black-Throated Green Warbler
Blackburnian Warbler
Blue Jay
Blue-Headed Vireo
Brown-Headed Cowbird
Canada Warbler
Common Grackle
Connecticut Warbler
Eastern Towhee
Field Sparrow
Great Crested Flycatcher
House Wren
Kentucky Warbler
Mourning Warbler
Nashville Warbler
Northern Flicker
Northern Waterthrush
Osprey
Palm Warbler
Peregrine Falcon
Red-Bellied Woodpecker
Red-Eyed Vireo

Red-Tailed Hawk
Savannah Sparrow
Scarlet Tanager
Sharp-Shinned Hawk
Tufted Titmouse
Veery
White-Crowned Sparrow
Wilson's Warbler
Winter Wren
Wood Thrush
Worm-Eating Warbler
Yellow-Throated Vireo

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