Bird of Prey Migration in the Greater Toronto Area

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Abstract

Topography is known to factor into the migration patterns of birds of prey. As topography changes to reflect changing land use and urbanization, it becomes important to assess migrating species biodiversity. In this paper I attempt to evaluate how Lake Ontario, as a topographic barrier for the southbound autumn migrating birds of prey, impacts local bird of prey biodiversity. Using data collected by volunteers from four Hawk Watch groups in the Greater Toronto Area I evaluated species richness and diversity for each of the sites. In this, I found that Cranberry Marsh had the greatest Shannon-Weiner diversity index values among the four groups. It is therefore the site with the greatest biodiversity, a result contrary to my hypothesis. I followed this analysis with a comparison of species between three sites: High Park, Cranberry Marsh, and Iroquois Shoreline. Overall, I found a great amount of consistency between all sites, rather than High Park reporting the greatest numbers which was expected. Given the proximity of each study site to each other this result suggests a strong tendency for successful repeatability using the conventional Hawk Watch methodology. Further studies on methodological accuracy, as well as integration of citizen science generated knowledge for use in ecological studies are possible points of investigation to build upon for future research.

Keywords: Migration, Birds of Prey, biodiversity, topography, citizen science, Hawk Watch

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Foreword

My aim in pursuing a Master in Environmental Studies was to explore conservation biology and urban ecology from a multifaceted perspective. I wanted to investigate the many factors influencing conservation. More specifically, I wanted to focus my studies on Urban Ecology with the goal of including human behaviour in a study of ecology and conservation. As such, this paper applies itself to my learning objectives as they pertain to section 1.1 Conservation and Urban Ecology, and sections 2.1, 2.2, and 2.3 Ecological Field Methods and Data Analysis.

As per my Plan of Study, I developed an understanding of the different lenses through which conservation and applied ecology may be viewed. Citizen Science is an avenue through which Urban Ecology can be studied, and this form of environmental education can present itself as a mobilizing force for the conservation of species. In this paper, I apply statistical analysis to the data gathered by volunteer citizen scientists to evaluate the diversity of migrating bird of prey species in the urban region of Toronto and nearby municipality of Whitby. This area, known as the Greater Toronto Area, is a known migration corridor for birds of prey. It is also the most rapidly urbanizing area in the country. As habitat loss, climate change, and land use patterns change and act as stressors on migrating species, the work done by citizen scientists such as the Hawk Watch groups become of value for understanding species population movements, and conservation planning.

Acronyms

HMANA = Hawk Migration Association of North America

BV	Black Vulture	*Coragyps atratus*
TV	Turkey Vulture	*Cathartes aura*
SS	Sharp-shinned Hawk	*Accipiter striatus*
BW	Broad-winged Hawk	*Buteo platypterus*
RT	Red-tailed Hawk	*Buteo jamaicensis*
AK	American Kestral	*Falco sparverius*
CH	Cooper's Hawk	*Accipiter cooperii*
NG	Northern Goshawk	*Accipiter gentilis*
RS	Red-shouldered Hawk	*Buteo lineatus*
RL	Rough-legged Hawk	*Buteo lagopus*
GE	Golden Eagle	*Aquila chrysaetos*
OS	Osprey	*Pandion haliaetus*
BE	Bald Eagle	*Haliaeetus leucocephalus*
NH	Northern Harrier	*Circus cyaneus*
ML	Merlin	*Falco columbarius*
PG	Peregrine Falcon	*Falco peregrinus*
UA	Unknown Accipiter	
UB	Unknown Buteo	
UF	Unknown Falcon	
UE	Unknown Eagle	
UR	Unknown Raptor	

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Chapter 1: Introduction to Hawk Watch and Environmental Education

Environmental Education, through citizen science, is the cornerstone of the success of the Hawk Watch community. For centuries humans have been fascinated by birds in our attraction to their beauty, diversity, and usefulness to our livelihood. Birds refuse to be bound to the line humans draw between "nature" and our cities, and their migrations act as testament to this fact. Choosing instead to infiltrate our daily lives in spite of these imaginary boundaries, birds are ubiquitous. As a result, an encounter between human and bird-kind is inevitable and it can act as a pathway to interest in the other non-human life that exists on the shared planet. Birds can provide a path towards environmental awareness, and scientific understanding, and multiple successful citizen science projects have shown this to be the case (Bonney et al., 2009). Hawk Watch exists as one of many such environmental encounters. In this way, citizen science acts through environmental education as a means towards meeting greater conservation goals and protecting species worldwide.

Maurice Broun, one of the key figures in the establishment of Hawk Mountain Bird of Prey sanctuary, attributes his fascination with birds in an encounter with birders from when he was thirteen years old. From there, he speaks about binoculars and books he borrowed, and the friendly experts and amateurs who helped coach this interest, despite hailing from "the heart of Boston – a poor environment, perhaps, for anyone to cultivate a love for wild birds" (Broun, 2000). Hawk Mountain stands as the world's first refuge for birds of prey, where it once was a location for the hunting of birds of prey. Hundreds of migrating hawks were shot from the Blue Mountains for sport and because of the perception of birds of prey as a threat to game life and other birds (Broun, 2000).

This shift from a prime hunting location to a bird of prey sanctuary can be attributed to the efforts initiated by Mrs. Rosalie Edge of the Emergency Conservation Committee (ECC). Mrs. Edge similarly began her interest in birding with a local birding group in Central Park, New York City (Furmansky, 2009). In 1934 Mrs. Edge leased the property on top of Blue Mountain (newly coined "Hawk Mountain") and installed Maurice Broun as warden of the hawk refuge (Hawk Mountain Sanctuary, 2019). As warden, Broun maintained the site as a sanctuary, and he also began to collect data on hawk migration by observation. Rachel Carson, author of *Silent Spring*, in her book referred to the data from this very site when speaking of population declines of birds of prey due to exposure to the chemical DDT (Furmansky, 2009). Hawk Mountain continues its outreach program in a similar vein; to educate the public on the nature of birds of prey and their role in the local ecosystem. Interest in Hawk Watching has grown and had expanded beyond the border into Canada. Informal groups sprang up into existence throughout the country. In 1993 The Greater Toronto Raptor Watch (GTRW) was organized between the Cranberry Marsh and High Park groups (Toronto Ornithological Club, n.d.). A third group, Iroquois Shoreline was added to the GTRW. These groups with the efforts of volunteers continue to compile data on bird of prey migration.

Involving laypeople in collecting data relevant to scientific studies is a practice that has been on the rise. As questions involving a grander scale are asked, and technology improves and becomes more accessible, so too does the application of citizen science present as a cost effective and increasingly viable methodological option. Ornithology is one of a few scientific disciplines in which amateurs can make significant contributions (Trumbull et al., 2000). The Cornell Lab of Ornithology is one such case study that exemplifies this form of experiential learning. Citizen Science can act as a pivotal component towards helping foster understanding of the scientific method and understanding the importance of conservation for the preservation of species. Depending on the structure of the project, citizen scientists can be found formulating their own hypotheses about the subject, critically thinking about the methodology, and in the case with ornithology, learning about bird biology. These goals are lofty but achievable, and were viewed in one project, the bird seed preference test, conducted in 1993. In it, researchers sifted through hundreds of letters sent by participants to find evidence of scientific thinking. What they found was that nearly 80% revealed “thinking processes similar to those that are part of science investigations” (Trumbull et al., 2000) including formulating hypotheses, and considering alternative methodologies to attain results. Other projects in progress at the Cornell lab include eBird, Project FeederWatch, NestWatch, among others (Bonney et al., 2009). How does watching hawks migrate relate to this case? Indeed naturalists from observation alone have hypothesized that the hawks are best viewed when there is a north or north west wind (Pittaway, 1999). Hawk watchers have also noted that the birds of prey follow the coastline of the Great Lakes, a topic which I will explore in the following chapter.

Dissociation of environmental issues from the local environment has been flagged as a worrying trend in traditional educational curricula. Children are increasingly aware of deforestation of the rainforests, but lack the knowledge of the destruction of local habitats (Louv, 2005). In his book *Last Child of the Woods*, Louv quotes a friend of his, biologist Elaine Brooks who says, “humans seldom value what they cannot name” (Louv, 2005). Hawk watch groups utilize greenspace and are reliant on identification of birds of prey. It is a form of place-based education that utilizes nearby natural areas for observation and identification of migrating raptors. Place-based education is known to have positive effects in increasing knowledge of local natural history, and connecting to the local community. Much like the case with

Rosalie Edge and Maurice Broun, perhaps learning about the local fauna will inspire learners to preserve the natural spaces and protect the species around them.

Attitudes towards birds of prey have changed (Broun, 2000; Furmansky, 2009). Once believed to be pests for their behaviour in frightening game animals, they are now a respected part of the ecosystem. Today, with habitat loss and climate change acting as stressors to populations worldwide, education which enriches the perspectives of individuals becomes fundamental to igniting the interest in maintaining and preserving ecosystems for these charismatic animals to continue to thrive. Hawk Watch groups support this form of environmental education. In the following chapter I will present a research article which makes use of the Hawk Count data gathered by volunteer citizen scientists. My source will be the data compiled by the Greater Toronto Raptor Watch groups, as well as data from a fourth group, Rosetta McClain Gardens, located within Scarborough, in the city of Toronto. Together, these data should serve as a portrait of the species diversity within this region.

Chapter 2: Bird of Prey Migration in the Greater Toronto Area

1. Introduction

Long distance migration can be considered to be the most spectacular movement of animals to be witnessed, and among land-based predators the migration of birds of prey may be among the most prolific (Zalles & Bildstein, 2000). Birds of prey, as top tier predators on food webs, may be particularly sensitive indicators of environmental change or how human alterations to the landscape are impacting local and regional ecosystems (Hoffman & Smith, 2003). Population monitoring of birds of prey provide a unique opportunity for monitoring changes on the regional or broad scale (Bednarz et al., 1990). Population trends can also be used to inform ecologists of the life history of the species investigated.

It is thought that landscape morphology impacts the route migrating raptors take. Landscape features such as cliffs and water bodies can direct migrating birds along a specific path, causing migrants to concentrate in certain areas (Ydenberg, Butler, & Lank, 2007). There may be energetic preferences for flying in relation to certain landscape features. Cliffs and ridges provide orographic lift, which provides a means of energy efficient soaring favoured by larger raptors, such as the Golden Eagle (*Aquila chrysaetos*) (Bohrer et al., 2012). Turkey Vultures (*Cathartes aura*) by contrast use almost exclusively thermal lift, which is generated in areas of flatter terrain or gentle slopes (Bohrer, et al., 2012), whereas accipiters and kestrels are more prone to powered flight (Ydenberg, Butler, & Lank, 2007).

Most raptors avoid crossing bodies of water wider than 25km (Zalles & Bildstein, 2000). This would suggest that raptors migrating in Eastern North America would follow the shoreline of the Great Lakes on their migration route (Goodrich & Smith, 2008; Pittaway, 1999). Naturalists suggest that Southern Ontario provides some of the best sites in North America to watch migrating hawks and other birds of prey, due to the funnelling effect created by the topography between Lakes Huron, Ontario and Erie, with most hawks exiting the province across the Detroit River south of Windsor (Pittaway, 1999). Being situated on the northern coast of Lake Ontario, the city of Toronto is therefore en route for many migratory raptors (*Birds of Toronto: A Guide to Their Remarkable World*, 2011).

Bird populations are ubiquitous on every continent on Earth, and as a popular and charismatic group, the development of citizen science monitoring groups with an interest in bird populations holds the potential to improve monitoring and conservation efforts. “Hawk Watch” is a volunteer-led initiative with the goal to watch for and count migrating birds of prey. Hawk Watch groups originally established themselves independently and these groups can be found all across the North American continent. The Hawk Migration Association of North America (HMANA) was established in 1974, and over 300 hawk watchers from North America first gathered for its inaugural meeting, where HMANA became established as a volunteer non-profit organization with the goal of creating a formal network of observers in North America, and to standardize empirical data (Hawk Migration Association of North America, 2017). Utilizing this interest for the purposes of population monitoring can benefit ecologists. The benefits in cost saving, and data collection effort makes the study of these data collected in citizen science projects a worthwhile endeavour (Svensson, 1978).

The city of Toronto and the surrounding area is an important region for predatory bird migration (City of Toronto, 2011). Due to the barrier effect of the Great Lakes, many species fly through the Toronto area, as the lakes act to funnel southbound migrants (Pittaway, 1999). Through observational efforts such as the collection of Hawk Watch Citizen Science data, naturalists have noted variations in species composition at different sites in the Greater Toronto Area. These observations provide an opportunity to investigate this variation.

Hawk Watch sites are typically situated along topographic features that funnel or divert large numbers of raptor migrants (Kerlinger, Flight Strategies of Migrating Hawks, 1989). In the case for this study, Lake Ontario is thought to provide the greatest barrier for bird of prey species in their migration path. Certain migrating bird of prey species are thought to be more water evading than others, which may influence species variation among different sites along Lake Ontario. Therefore, in this study I investigate the diversity of species within each of the four study sites. Specifically, I sample four sites in the Greater Toronto Area and examine species abundance, richness, and evenness. I also examine individual species trends for the five most common species among the four study sites (Turkey Vulture, Broad-winged Hawk, *Buteo platypterus*, Sharp-shinned Hawk, *Accipiter striatus*, Red-tailed Hawk, *Buteo jamaicensis*, and the American Kestrel, *Falco sparverius*). For both datasets I predicted that the site furthest west along the lake shore and closest to a crossing point should show highest species richness and diversity as well as abundance of the five species considered.

2. Methods

Study Sites

Records from four sites from west to east on or near Lake Ontario (High Park, N 43° 38' 46.9",W -79° 27' 56.2"; Rosetta McClain Gardens, N 43° 41' 23.739",W -79° 15' 32.061"; Cranberry Marsh, N 43° 50' 24.9",W -78° 57' 57.7"; and Iroquois Shoreline, N 43° 56' 6.3",W -78° 58' 8.7") were gathered from Hawk Migration Association of North America (HMANA) Hawk Count online database (hawkcount.org). High Park and Rosetta McClain Gardens border Lake Ontario in the city of Toronto. Cranberry Marsh (Lynde Shores Conservation Area) and Iroquois Shoreline (Herber Down Consevation Area) are both in Whitby, ON. Cranberry Marsh is on Lake Ontario while Iroquois Shoreline Hawkwatch is approximately 9km from Lake Ontario. High Park and Rosetta McClain Gardens are mixed habitat sites and Cranberry Marsh and Iroquois Shoreline hawk watch efforts were conducted in wetland habitats.

Data collection for all sites followed a standardized format using the Hawk Count online database (Hawk Migration Association of North America, 2016) (see below “Hawk Watch Data”). Volunteers submitted their observation data to the Hawk Count website. The amount of data available for each site varied: High Park and Cranberry Marsh, had 23 years (1994-2016), Iroquois Shoreline Hawk Watch location had 8 years (2007-2014) and Rosetta McClain Gardens had 2 years (2013-2014).

Hawk Watch Data

The goal of Hawk Watch in North America is to count migrating birds of prey during the migration season (Bednarz et al., 1990). Standardized observations were recorded on site by a seasoned volunteer on a single paper record with a checklist of species from the area. This seasoned volunteer is considered the “qualified observer”, and they have developed the skill of identifying all bird of prey species which migrate overhead (Hawk Migration Association of North America, 2018b). The volunteer recording the numbers was typically the one who verified the bird species identification. These records were then transcribed to digital format and made available from the HMANA Hawk Count online database.

Volunteers identify raptors by the naked eye, binoculars, and sometimes through photography (Bednarz et al., 1990). Volunteers were therefore limited to seeing raptors within their line of sight. The data set used in this study contained observations made during the fall migration period. The fall migration period included data from the months of August, September, October, November and December. Alongside count data, volunteers also recorded the amount of hours spent in the day where there had been an observer present to count birds of prey. In this study, this value was called the volunteer "effort", or volunteer hours.

Annual Species Abundance, Richness and Diversity

For each site by year species richness was measured, as well as the total abundance per species. I used the raw data to calculate annual species diversity for each site and calculated the average and standard deviation across years. The measure for biodiversity used was the Shannon-Wiener Index (Spellerberg & Fedor, 2003) which generates a value for biodiversity using proportional abundances of species included in the dataset. I used a paired t-test to compare High Park and Cranberry Marsh for the 23 year datasets.

Standardizing the Sampling Effort from Hawk Watch Datasets

The sampling effort differed from location to location, and year to year. To correct for the variation of sampling effort across the four sites, the data was standardized by an average of every 10 sampling hours, following Bednardz *et al* (1990) and Hoffman and Smith (2003). The total hours of sampling effort were summed on a yearly basis for each site. The total hours of sampling effort was divided by 10 to determine the coefficient for a year. The total number of birds counted in a year was divided by the yearly coefficient, to calculate the number of birds across all species per 10 hours of sampling effort.

Table 1: Table of *p* values resulting from the Shapiro-Wilk test for normality. In each case, the data appears non-normal. Data was run through the R program.

Species	**High Park**	**Cranberry**	**Iroquois**
Turkey Vulture	$<2.2e^{-16}$	$<2.2e^{-16}$	$<2.2e^{-16}$
Sharp-shinned Hawk	$<2.2e^{-16}$	$<2.2e^{-16}$	$<2.2e^{-16}$
Broad-winged Hawk	$<2.2e^{-16}$	$<2.2e^{-16}$	$1.065e^{-14}$
Red-tailed Hawk	$<2.2e^{-16}$	$<2.2e^{-16}$	$<2.2e^{-16}$
American Kestrel	$<2.2e^{-16}$	$<2.2e^{-16}$	$5.639e^{-14}$

The Shapiro-Wilk test is a function which is used to determine if a set of data is normally distributed. It does this by testing against a null hypothesis of normal distribution, and a *p* value below 0.05 rejects this null hypothesis. The annual abundance trends for the five most common species data was found not to have a normal distribution (Shapiro-Wilk test; Table 1). Therefore, I used a non-parametric test (paired Wilcoxon) to compare the standardized sampling effort for the five most common species across three sites (High Park, Cranberry Marsh and Iroquois Shoreline) with overlapping sampling periods from 2007-2014.

Peak Population Comparisons

The total number of hawks varied across time at each site. Therefore, I used a second approach which considered annual "peak values", comparing the day with the total highest bird count for each of the 5 most common species. The "peak value" is the greatest single value generated within the total year of population count sampling effort within a study site. In order to compare the three sites, eight years (2007-2014) of collected data for High Park, Cranberry Marsh and Iroquois Shoreline were used, due to the data in Iroquois Shoreline being limited to this range.

3. Results

Annual Species Abundance, Richness and Diversity

The number of species among the four sites did not greatly vary (Table 2). Cranberry Marsh consistently has the greatest Shannon-Wiener index values among the four groups (*H'* averages ± SD: High Park 0.15±0.20; Cranberry Marsh 1.71±0.23; Iroquois Shoreline 1.36±0.15; and Rosetta McClain Gardens 1.27±0.73; see Tables 3, 4). Cranberry Marsh and High Park were significantly different in their diversity scores (paired t-test: $t=-3.8$, $df= 22$, $p = <0.001$).

Table 2: Species richness values over the entire population count data set for each location.

Study Site	**Species Richness over total sampling period**[a]
High Park	n = 16
Cranberry Marsh	n = 16
Iroquois Shoreline	n = 15
Rosetta McClain Gardens	n = 17

[a]Only identified species included (i.e., not unidentified category).

Table 3: High Park and Cranberry Marsh annual species diversity indices (Shannon-Wiener's *H'* values).

High Park		**Cranberry**	
YEAR	*H'*	YEAR	*H'*
1994	1.407363	1994	1.130456
1995	1.596463	1995	1.982458
1996	1.646179	1996	1.677131
1997	1.680084	1997	1.811338
1998	1.483549	1998	1.643811
1999	1.639852	1999	1.832638
2000	1.172151	2000	1.551512
2001	1.484625	2001	1.706033
2002	1.886549	2002	1.897079
2003	1.737476	2003	1.948487
2004	1.78287	2004	2.141815
2005	1.705993	2005	1.784508
2006	1.769861	2006	1.945503
2007	1.672841	2007	1.871659
2008	1.69657	2008	1.805573
2009	1.659033	2009	1.658417
2010	1.715693	2010	1.80464
2011	1.188244	2011	1.533095
2012	1.680465	2012	1.613614
2013	1.650672	2013	1.671268
2014	1.595043	2014	1.536432
2015	1.164043	2015	1.304114

2016	1.449842	2016	1.521076

Table 4: Iroquois Shoreline and Rosetta McClain Gardens annual species diversity indices (Shannon-Wiener's *H'* values).

Iroquois		**Rosetta**	
YEAR	*H'*	YEAR	*H'*
2007	1.464852		
2008	1.196486		
2009	1.590935		
2010	1.448604		
2011	1.461623		
2012	1.136792		
2013	1.29132	2013	1.786951
2014	1.316237	2014	0.759547

Standardized Hawk Watch datasets

From 2007-2014, the top five species Broad-winged Hawk, Turkey Vulture, Sharp-shinned Hawk, Red-tailed Hawk, and American Kestrel, made up more than 90% of the standardized count data at three sites (Table 5). The top five species represents 95.7% of the population counts in High Park, 94.3% in Cranberry Marsh, and 96.2% in Iroquois Shoreline. For three of the five species (Broad-winged Hawk, Turkey Vulture and Red-tailed Hawk), there was a trend where Iroquois Shoreline had higher value counts compared to Cranberry Marsh and High Park (Table 5).

Table 5: Averaged (±SD) standardized population count totals per 10 hours of sampling effort between the years 2007-2014 for High Park, Cranberry Marsh and Iroquois Shoreline.

Species	**Iroquois**	**Cranberry Marsh**	**High Park**
Broad-winged Hawk	348.09 ± 169.66	72.97 ± 36.85	108.82 ± 97.47
Turkey Vulture	136.56 ± 48.52	108.84 ± 49.20	106.59 ± 31.77
Sharp-shinned Hawk	47.77 ± 16.01	45.30 ± 16.20	51.77 ± 12.60
Red-tailed Hawk	74.90 ± 35.77	32.42 ± 7.61	46.51 ± 13.61
American Kestrel	4.84 ± 2.03	14.35 ± 2.58	7.22 ± 1.94
Red-Shouldered Hawk	6.51 ± 2.84	1.04 ± 0.39	3.22 ± 4.14
Cooper’s Hawk	3.96 ± 1.13	3.00 ± 1.00	3.08 ± 1.25
Northern Harrier	3.45 ± 1.02	3.64 ± 1.53	2.03 ± 0.82
Bald Eagle	2.80 ± 1.43	2.06 ± 0.67	1.81 ± 0.43
Osprey	1.89 ± 0.76	2.78 ± 1.00	1.63 ± 1.31
Peregrine Falcon	0.56 ± 0.28	0.93 ± 0.30	0.74 ± 0.21
Merlin	0.65 ± 0.36	1.04 ± 0.41	0.68 ± 0.28
Golden Eagle	2.89 ± 1.18	0.34 ± 0.28	0.56 ± 0.30
Rough-legged Hawk	1.23 ± 0.49	1.18 ± 1.25	0.37 ± 0.25
Northern Goshawk	0.32 ± 0.19	0.38 ± 0.19	0.30 ± 0.20

The standardized population count total for Broad-winged Hawks in the Iroquois Shoreline counts differed from both High Park and Cranberry Marsh. American Kestrel counts also differed between two out of the three sites (Table 6). Although the Wilcoxon test can be used to determine which sites are significantly different, it does not determine in what way those sites differ. The nature of the differences in species presence, which I called “directionality”, can be determined by considering the total values standardized for 10 hours from which the Wilcoxon test results were generated. From here, I concluded that the populations of Broad-winged Hawks were significantly greater in the Iroquois Shoreline location when compared with the Cranberry Marsh population count (Table 6). Red-tailed Hawk population counts were significantly greater in the Iroquois Shoreline site in comparison to Cranberry Marsh and

High Park; The High Park population count of Red-tailed Hawks was significantly greater than the population count from Cranberry Marsh (Table 6). The American Kestrel population count was significantly greater in Cranberry Marsh, in comparison to the High Park study site and the Iroquois Shoreline study site, whereas the standardized population count values for this species did not differ significantly between High Park and Iroquois Shoreline data sets.

Table 6: P values from paired Wilcoxon tests for the top five most common species using the standardized 10 hour data.

Species	**High Park: Cranberry Marsh**	**Cranberry Marsh: Iroquois Shoreline**	**High Park: Iroquois Shoreline**
Turkey Vulture	0.8438	0.07813	0.05469
Broad-winged Hawk	0.3828	**0.007813**	**0.02344**
Sharp-shinned Hawk	0.1953	0.3828	0.7422
Red-tailed Hawk	**0.007813**	**0.02344**	**0.0309**
American Kestrel	**0.007183**	**0.007813**	0.1484

Peak Population Comparisons

Overall, the highest peak values were Cranberry Marsh, High Park, and Iroquois Shoreline respectively (Table 7).This can be explained in part due to the sampling effort in each location: High Park and Cranberry Marsh had more than double the volunteer hourly sampling effort (2206.02 and 2980 cumulative hours respectively) compared to Iroquois Shoreline (979.5 total hours). The peak days were very similar across sites and provided no trend in a particular direction across species (e.g., Iroquois Shoreline, then High Park a day or two later; Figure 1; remaining species see Appendix C).

Table 7: The average of the peak values, peak day (Julian date), and migration season length (“range” in days), for the five most common species between 2007-2014 for High Park, Cranberry Marsh and Iroquois Shoreline.

Location	**Averages**	**TV**	**SS**	**BW**	**RT**	**AK**
High Park	Peak Value	1028.125	246.125	2023.5	320.875	47.625
	Peak Day	283.75	267.125	257.25	301.625	264.25
	Range	69.625	80.5	38	85	67.25
Cranberry	Peak Value	872.375	269.5	1864.625	339.125	131.625
	Peak Day	282.875	261.125	258.625	302.625	264.625
	Range	74.125	89.875	45.375	92.5	81.25
Iroquois	Peak Value	494.5	89.5	2014.125	266.25	15.375
	Peak Day	288.25	267.5	258.5	305.375	262.5
	Range	57.625	84.75	33.875	84.875	49.875

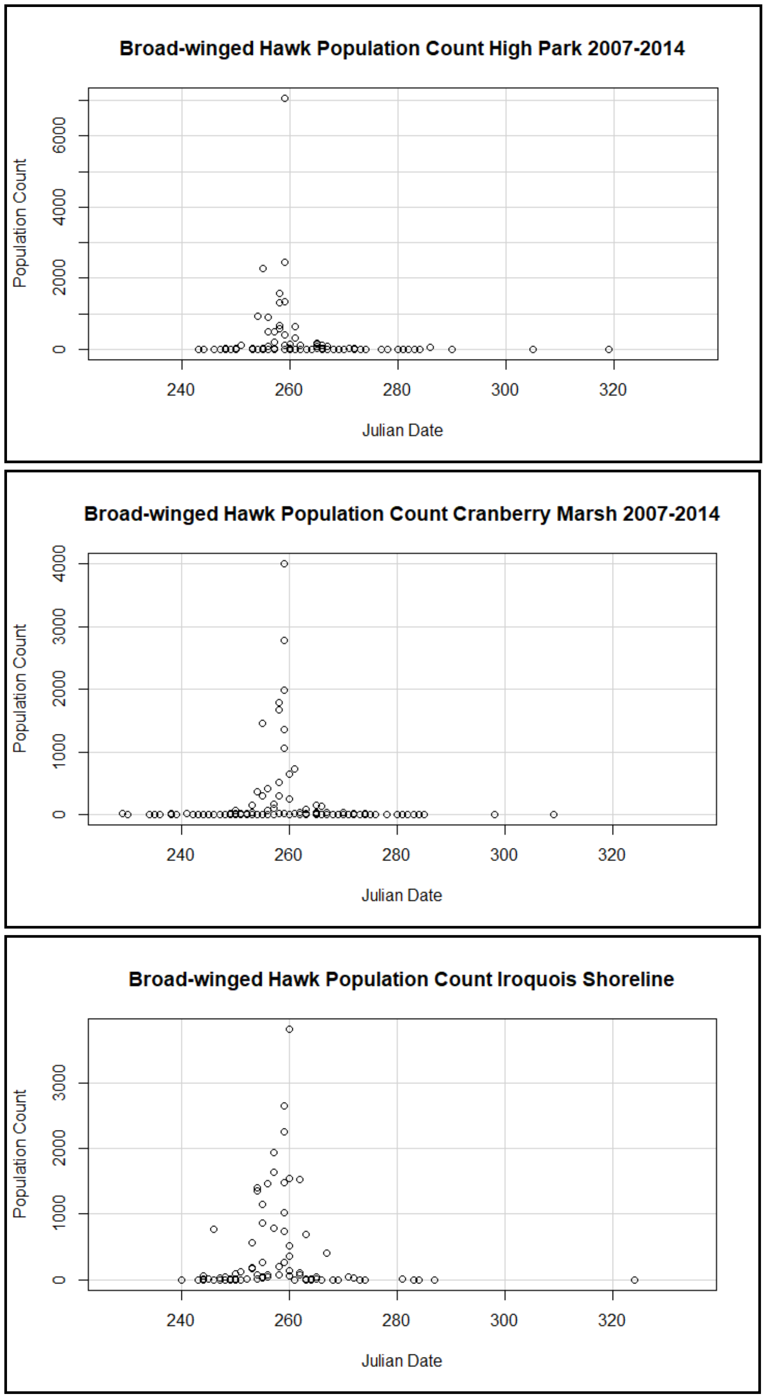

Figure 1: Numbers of Broad-winged Hawks in relation to Julian date for High Park, Cranberry Marsh, Iroquois Shoreline between the years 2007-2014.

4. Discussion

I predicted the Hawk Watch site furthest west would have higher species richness, diversity and population counts as a result of the funnelling effect the Great Lakes has on southbound migrating birds of prey. Overall, the results do not support these predictions. Species richness was similar among sites; species diversity measures indicated Cranberry Marsh, the site positioned in the middle along Lake Ontario, had the highest values. Standardized abundance counts for the top five species showed no particular east-west trends. This was unexpected because it is known that as the birds are migrating south, there is a funnelling effect in the region due to the Great Lakes. Naturalists have long noted such an effect (Pittaway, 1999).

Peak days for the top five species also indicated that the three sites experienced similar numbers simultaneously for some species. If birds of prey were being funnelled westward due to the presence of Lake Ontario, High Park should have had the highest species diversity. Yet, Cranberry Marsh consistently showed the higher values and was significantly different from High Park. Three species had different population counts between sites; the Broad-winged Hawk, which was counted as more prevalent in Iroquois Shoreline, the Red-tailed Hawk had greater count numbers in Iroquois Shoreline, and the American Kestrel had greater count numbers in Cranberry Marsh.

One of the shortcomings in this study was in the data used from the Rosetta McClain Gardens Hawk Watch. The 2 years submitted to the HMANA website was used for this analysis. Rosetta McClain Garden Hawk Watch has a long history of observation data, compiled since 2004, therefore amassing information for over 14 years, however much of the data has been omitted from the HMANA database (Hawk Migration Association of North America, 2018a; "Rosetta McClain Gardens Raptor Watch," 2018) . A potential reason for this omission may be due to proximity to another Hawk Watch location. As part of the data submission policy guidelines, HMANA may choose to omit data from a new site if it is thought that these data collected from the two sites "could overlap substantially" (Hawk Migration Association of North America, 2018a). Another factor to consider is species richness values. Species richness values are influenced by the species accounted for on the volunteer checklist used on site (see Appendix A for checklist by site). As an example, Iroquois Shoreline omits Black Vultures (BV) while Rosetta McClain Gardens added Gyrfalcon (GY) in the list for their 2013 surveys (see Table 2). The resulting species richness values may reflect the addition or removal of the species on the list. The different checklists may have been a factor in affecting the species richness and diversity measures.

One of the reasons why the funnelling effect did not have the expected effect in this study may be because the effect might not have been captured among the study sites used. The region investigated was only a portion in relation to the topography affected by the Great Lakes. Naturalists have noted that most migrating hawks exit Southern Ontario across the Detroit River, between Lake Erie and Lake Huron (Pittaway, 1999). The Holiday Beach Hawk Watch site, located in Windsor, Ontario tallies the highest hawk numbers in Canada. For future work, it will be beneficial to include a site further west to detect bird of prey funnelling.

Yet, not all birds of prey may avoid water. Most birds of prey use gliding from thermal to thermal as a flight strategy during migration (Kerlinger, 1989; Pittaway, 1999). Of the top 5 species investigated, the American Kestrel and Sharp-shinned Hawk appear to be water adverse than the Turkey Vulture, Red-tailed Hawk and Broad-winged hawk (Kerlinger, 1985). The latter three species are known to rely more heavily on thermal to thermal migration. The Great Lakes not only provide a leading line topographically for migrants to follow, but onshore winds play a part in the migrants' journey, and strong winds can keep migrants inland (Pittaway, 1999).

Weather conditions are considered to be an important factor in the migration of birds of prey (Seeland, Niemi, Regal, Peterson, & Lapin, 2012) and may perhaps be the predominant factor in directing migrants on their migratory pathway (Hawk Migration Association of North America, 2018c). This study omits weather as a factor in analysis, and can benefit with its inclusion in the future. The many factors pertaining to the migration of birds of prey are of research interest within the field. Kerlinger (1989) critiques using Hawk Count data for analysis of population predictions by identifying choice of location of Hawk Watch groups as a potential source of bias. He states that "a topographic map of North America shows that long continuous ridges or coastlines...occupy only a small portion of the continent" (pg 33) and therefore, if hawks and other birds of prey use leading lines or are more visible during specific weather conditions, then the results of some studies are questionable or of limited value.

An important characteristic in this study was the choice to investigate sites within an increasingly urbanizing region. Changes in ecosystem type as well as continued habitat fragmentation would reduce species heterogeneity. A study from New Jersey looked at the species richness in a forest raptor community and found that of the species investigated, a generalist predator, the Red-tailed Hawk, benefited from increased fragmentation (Bosakowski & Smith, 1997). Broad-winged Hawks were similarly less sensitive to urbanization in this particular case. The Red-tailed Hawk has a preference for edge, and open habitat such as agricultural areas (Bednarz et al., 1990; Kerlinger, 1989). However other studies contrast this with counts showing decreasing trends for the raptor (Bednarz et al., 1990).

5. Conclusion

Birds of prey, as top tier predators, have a unique position within the food chain that can allow them to act as indicator species for the state of the local environment. The underlying impetus for migration is as an adaptation to resources, particularly food sources for birds of prey, which fluctuate over time and space (Dingle & Drake, 2007; Goodrich & Smith, 2008). As the climate changes and the environment becomes urbanized, different factors impact the behaviour of raptors in their migratory decisions – including the continued presence of food sources beyond their preferred seasonal environment. Urbanization presents unique changes in the local ecosystem which raptors adapt to. Birds of prey can extend their range beyond the urban centre (Chace & Walsh, 2006). They may also increasingly become resident species in urban areas due to an abundance of food sources. An example of this would be the increased presence of prey bird species in urban areas, as a result of bird feeders (Goodrich & Smith, 2008).

This increased human and bird of prey interaction no doubt contributes to the curiosity and fascination which builds the citizen science and naturalist movements aimed at education and conservation of these species. Urban ecology provides a unique vantage point for public engagement and inclusion of the public in the conservation practice. As interest for Hawk Watch and similar citizen science groups increase, information regarding the state of our urban ecosystems become increasingly more accessible to policy makers and the public.

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Appendix A

Surveyed Species based on Site Location. Information accessed from open data provided on the Hawk Count website (Hawk Migration Association of North America, 2016).

High Park Hawk Watch (City of Toronto) 16 Species	**Rosetta McClains Gardens Raptor Watch (City of Toronto; Scarborough)** 15 species	**Cranberry Marsh Hawk Watch (Whitby)** 16 species	**Iroquois Shoreline Hawk Watch (Whitby)** 16 species
Black Vulture *(C.atratus)*–**BV**	Turkey Vulture *(C. aura)* – **TV**	Black Vulture *(C.atratus)* – **BV**	Black Vulture *(C.atratus)* – **BV**
Turkey Vulture *(C. aura)*–**TV**	Osprey *(P.haliaetus)* – **OS**	Turkey Vulture *(C. aura)* – **TV**	Turkey Vulture *(C. aura)* – **TV**
Osprey *(P.haliaetus)*– **OS**	Bald Eagle *(H. leucocephalus)* – **BE**	Osprey *(P.haliaetus)* – **OS**	Osprey *(P.haliaetus)* – **OS**
Bald Eagle *(H. leucocephalus)*–**BE**	Northern Harrier *(C.cyaneus)* – **NH**	Bald Eagle *(H. leucocephalus)* – **BE**	Bald Eagle *(H. leucocephalus)* – **BE**
Northern Harrier *(C.cyaneus)*–**NH**	Sharp-shinned Hawk *(A.striatus)* – **SS**	Northern Harrier *(C.cyaneus)* – **NH**	Northern Harrier *(C.cyaneus)* – **NH**
Sharp-shinned Hawk *(A.striatus)*–**SS**	Cooper's Hawk *(A.cooperii)* – **CH**	Sharp-shinned Hawk *(A.striatus)* – **SS**	Sharp-shinned Hawk *(A.striatus)* – **SS**
Cooper's Hawk *(A.cooperii)*–**CH**	Northern Goshawk *(A.gentilis)* – **NG**	Cooper's Hawk *(A.cooperii)* – **CH**	Cooper's Hawk *(A.cooperii)* – **CH**

Northern Goshawk *(A.gentilis)*–**NG** Red-shouldered Hawk *(B.lineatus)*–**RS** Broad-winged Hawk *(B.platypterus)*–**BW** Red-tailed Hawk *(B.jamaicensis)*–**RT** Rough-legged Hawk *(B.lagopus)*–**RL** Golden Eagle *(A.chrysaetos)*–**GE** American Kestrel *(F.sparverius)*–**AK** Merlin *(F.columbarius)*–**ML** Peregrine Falcon *(F.peregrinus)*–**PG**	Red-shouldered Hawk *(B.lineatus)* – **RS** Broad-winged Hawk *(B.platypterus)* – **BW** Red-tailed Hawk *(B.jamaicensis)* – **RT** Rough-legged Hawk *(B.lagopus)* – **RL** Golden Eagle *(A.chrysaetos)* – **GE** American Kestrel *(F.sparverius)* – **AK** Merlin *(F.columbarius)*– **ML** Peregrine Falcon *(F.peregrinus)* – **PG** Unknown Accipiter *(Accipiter sp.)* – **UA**	Northern Goshawk *(A.gentilis)* – **NG** Red-shouldered Hawk *(B.lineatus)* – **RS** Broad-winged Hawk *(B.platypterus)* – **BW** Red-tailed Hawk *(B.jamaicensis)* – **RT** Rough-legged Hawk *(B.lagopus)* – **RL** Golden Eagle *(A.chrysaetos)* – **GE** American Kestrel *(F.sparverius)* – **AK** Merlin *(F.columbarius)* – **ML** Peregrine Falcon *(F.peregrinus)* – **PG**	Northern Goshawk *(A.gentilis)* – **NG** Red-shouldered Hawk *(B.lineatus)* – **RS** Broad-winged Hawk *(B.platypterus)* – **BW** Red-tailed Hawk *(B.jamaicensis)* – **RT** Rough-legged Hawk *(B.lagopus)* – **RL** Golden Eagle *(A.chrysaetos)* – **GE** American Kestrel *(F.sparverius)* – **AK** Merlin *(F.columbarius)* – **ML** Peregrine Falcon *(F.peregrinus)* – **PG**

Unknown Accipiter *(Accipiter sp.)*–**UA** Unknown Buteo*(Buteo sp.)*–**UB** Unknown Falcon *(Falco sp.)*–**UF** Unknown Eagle *(eagle sp.)*–**UE** Unknown Raptor *(Accipitridae sp.)* - **UR**	Unknown Buteo *(Buteo sp.)* – **UB** Unknown Falcon *(Falco sp.)* – **UF** Unknown Eagle *(eagle sp.)* – **UE** Unknown Raptor *(Accipitridae sp.)* - **UR**	Unknown Accipiter *(Accipiter sp.)* – **UA** Unknown Buteo*(Buteo sp.)* – **UB** Unknown Falcon *(Falco sp.)* – **UF** Unknown Eagle *(eagle sp.)* – **UE** Unknown Raptor *(Accipitridae sp.)* - **UR**	Unknown Accipiter *(Accipiter sp.)* – **UA** Unknown Buteo*(Buteo sp.)* – **UB** Unknown Falcon *(Falco sp.)* – **UF** Unknown Eagle *(eagle sp.)* – **UE** Unknown Raptor *(Accipitridae sp.)* - **UR**

Table 1: Hawk Watch totals based off of publicly available information gathered from HawkCount (https://www.hawkcount.org/). Data for Rosetta McClain Gardens retrieved on the Rosetta McClain Gardens Raptor Watch blog (https://raptorwatch.blogspot.ca/). *Rosetta McClain data for 2013, and August of 2014 is available on HawkCount.

High Park Hawk Watch N 43.64636, W -79.46561	Data available from 1994 onwards (23 years of data)	Count Season: Sept 1 – Dec 1
Iroquois Shoreline Hawk Watch N 43.93508, W -78.96908	Data available from 2007-2014 (8 years of data)	Count Season: Sept 1 – Dec 1

Cranberry Marsh Hawk Watch N 43.84025, W -78.96603	Data available from 1994 onwards (23 years of data)	Count Season: Sept 1 – Dec 1
Rosetta McClain Gardens Raptor Watch N 43.68993, W -79.25891	Data available for 2004 – 2016* (12 years of data)	Count Season: Aug 1 – Dec 1

Raptor Species

Table 2: List of raptors commonly sighted in Southern Ontario, as recorded by the Ontario Ornithological Society (Pittaway, 1999). Landscape features which guide individual species migration routes are sourced primarily from Goodrich & Smith(2008), with additional sources listed within the table. The migratory birds of prey species of Southern Ontario are all listed with the status of "Least Concern" on the International Union for Conservation of Nature (IUCN)(International Union for Conservation of Nature and Natural Resources., 2017).

Species	**Landscape Features**
American Kestrel *Falco sparverius*	The Toronto Region acts as its summer breeding grounds. Migrates along coastlines more frequently than along inland pathways (Goodrich & Smith, 2008). May not be as dependent on thermal migration in comparison to larger migrants (Kerlinger, Bingman, & Able, 1985). STATUS (by IUCN): Least Concern
Bald Eagle *Haliaeetus leucocephalus*	Usually migrates coastward or to open water(Goodrich & Smith, 2008). STATUS (by IUCN): Least Concern
Broad-winged Hawk *Buteo platypterus*	Long distance migrant. Migrates in large flocks, often soaring on thermal air currents. (Kerlinger, Bingman, & Able, 1985). STATUS (by IUCN): Least Concern
Cooper's Hawk *Accipiter cooperii*	Uncommon to fairly commonSouthern Ontario migrant (Pittaway, 1999). Regular sight in developed areas with urban trees (Bielefeldt, Rosenfield, Stout, & Vos, 1998; Cornell University, 2015). STATUS (by IUCN): Least Concern
Golden Eagle *Aquila chrysaetos*	Makes use of cliffs and ridges for flight during migration more so than thermal lifts (Katzner, et al., 2012; Lanzone, et al., 2012). STATUS (by IUCN): Least Concern
Merlin *Falco columbarius*	Hunts along the shoreline and willing to fly over bodies of water (Kerlinger, Water-Crossing Behavior of Raptors during Migration, 1985). STATUS (by IUCN): Least Concern
Northern Goshawk *Accipiter gentilis*	Partial migrants with a tendency to follow forest corridors (Squires & Kennedy, 2006). Population is known to fluctuate drastically based on prey populations (Goodrich & Smith, 2008).

	STATUS (by IUCN): Least Concern
Northern Harrier *Circus cyaneus*	Lone migrants, hunting on route (Cornell University, 2015). STATUS (by IUCN): Least Concern
Osprey *Pandion haliaetus*	Long distance migrant, able to fly over large water bodies (Kerlinger , 1989). STATUS (by IUCN): Least Concern
Peregrine Falcon *Falco peregrinus*	Willing to fly over large bodies of water (Government of Canada, 2016) STATUS (by IUCN): Least Concern
Red-shouldered Hawk *Buteo lineatus*	Preference for low land, marsh or forest edge habitat features, and can tolerate moderate disturbance (Bosakowski, Smith, & Speiser, 1992) STATUS (by IUCN): Least Concern
Red-tailed Hawk *Buteo jamaicensis*	One of the most common hawks. Short distance migrant, thermals and topography less of a concern in comparison to longer distance migrants (Kerlinger, Bingman, & Able, 1985). STATUS (by IUCN): Least Concern
Rough-legged Hawk *Buteo lagopus*	Moderately willing to cross water bodies (Kerlinger, Water-Crossing Behavior of Raptors during Migration, 1985) STATUS (by IUCN): Least Concern
Sharp-shined Hawk *Accipiter striatus*	May not be as dependent on thermals as larger migrants, and can utilize smaller thermals, therefore it may fly at lower altitudes in greater proportion than other larger species (Kerlinger, Bingman, & Able, 1985). STATUS (by IUCN): Least Concern
Turkey Vulture *Cathartes aura*	During migration, the turkey vulture uses almost exclusively thermal lifts for flight (Bohrer, et al., 2012). This is consistent with the preferred topography of open land(Mandel, Bildstein, Bohrer, & Winkler, 2008; Cornell University, 2015). STATUS (by IUCN): Least Concern

Appendix B

Site Summaries

High Park Site Summary

Year	Sampling Season	Total Days Sampled	Total Hours Sampled	Month	Days Sampled by month	Hours by month
1994	August 26-November 14	36	101	August	4	10
				September	14	42
				October	12	34
				November	6	15
1995	August 31-November 27	39	238.5	August	1	7
				September	14	81
				October	12	79
				November	12	71.5
1996	August 31 - November 26	63	464	August	1	7
				September	23	174
				October	23	170
				November	16	113
1997	August 27 - November 26	74	455.5	August	10	48
				September	28	187
				October	27	178
				November	18	82.5
1998	August 18 - November 27	83	495.5	August	10	48
				September	28	187
				October	27	178
				November	18	82.5
1999	August 17 - November 27	71	415	August	7	39
				September	26	156
				October	28	165
				November	10	55
2000	August 15 - November 30	106	283.5	August	15	13.5
				September	30	122

				October	31	126
				November	30	22
2001	August 15 - November 30	108	336.5	August	17	11.5
				September	30	146.75
				October	31	123.25
				November	30	55
2002	August 20 - November 27	83	420	August	7	31.5
				September	39	226.5
				October	24	118
				November	12	44
2003	August 27 - November 29	61	295.5	August	4	16.5
				September	21	104
				October	24	124.5
				November	12	50.5
2004	August 21 - November 21	65	276	August	4	10.5
				September	27	117
				October	22	99.5
				November	12	49
2005	September 1 - November 30	91	300.5	September	30	126.5
				October	31	122
				November	30	52
2006	August 29 - November 25	64	274.75	August	3	7.75
				September	25	114.25
				October	20	91.75
				November	16	61
2007	August 15 - November 30	108	277	August	17	0
				September	30	129
				October	31	105
				November	30	43
2008	August 15 - November 30	108	276.5	August	17	18
				September	30	120
				October	31	105
				November	30	33.5

2009	August 15 - November 30	17	275.75	August	17	11.5
				September	30	128
				October	31	83.25
				November	30	53
2010	September 1 - November 30	60	309.75	September	23	119.25
				October	23	131
				November	14	59.5
2011	August 15 - November 30	108	255.52	August	17	0
				September	30	112.25
				October	31	98.77
				November	30	44.5
2012	August 12 - November 30	108	0	August	17	0
				September	30	153.5
				October	31	84.25
				November	30	37
2013	August 15 - November 30	108	233.5	August	17	0
				September	30	111.25
				October	31	94.75
				November	30	27.5
2014	September 1 - November 28	68	303.25	September	29	133
				October	23	103.25
				November	16	67
2015	September 1 - November 30	84	312	September	30	107
				October	30	123
				November	24	82
2016	September 1 - November 30	77	375.5	September	29	128.5
				October	27	160
				November	21	87

Cranberry Marsh Site Summary

Year	Sampling Season	Total Days Sampled	Total Hours Sampled	Month	Days Sampled by month	Hours by month
1994	August 27 - November 27	57	255.5	August	4	17
				September	20	107
				October	20	93.5
				November	13	38
1995	August 28 - November 30	80	387	August	2	7
				September	25	137.5
				October	30	142.5
				November	23	100
1996	September 1 - November 29	72	286.5	September	24	110
				October	28	116
				November	20	60.5
1997	August 30 - November 30	93	425	August	2	10
				September	30	150
				October	31	161
				November	30	104
1998	August 28 - November 30	95	435.5	August	4	26
				September	30	161.5
				October	31	151
				November	30	97
1999	August 18 - November 30	98	490	August	12	60
				September	30	150
				October	31	155
				November	25	125
2000	August 20 - November 30	103	444	August	12	50
				September	30	153
				October	31	148
				November	30	93
2001	August 15 - November 30	108	413	August	17	40
				September	30	145

				October	31	124.5
				November	30	103.5
2002	August 24 - November 29	98	362	August	8	22.5
				September	30	129.5
				October	31	124.5
				November	29	85.5
2003	August 21 - November 30	100	426	August	11	40
				September	29	138
				October	31	144
				November	29	104
2004	August 14 - November 30	109	428	August	18	49
				September	30	134
				October	31	123
				November	30	122
2005	August 21 - November 30	94	318.5	August	11	32
				September	30	109.5
				October	28	107
				November	25	70
2006	August 21 - November 30	99	364	August	11	30
				September	29	128
				October	29	113
				November	30	93
2007	August 18 - December 1	102	403.5	August	11	35
				September	30	133
				October	31	125
				November	29	105.5
				December	1	5
2008	August 14 - November 30	105	412	August	17	49
				September	30	124
				October	30	140
				November	28	99
2009	August 15 - November 30	108	405	August	17	40.5
				September	30	145
				October	31	122.5
				November	30	97

2010	August 23 - November 29	86	396	August	7	18.5
				September	30	139
				October	28	143.5
				November	21	95
2011	August 15 - November 30	108	60	August	17	8
				September	30	130
				October	31	157.5
				November	30	88
2012	August 15 - November 30	108	323	August	17	0
				September	30	134
				October	31	108.5
				November	30	80.5
2013	August 15 - November 30	108	374.5	August	17	4
				September	30	155
				October	31	136.5
				November	30	79
2014	August 15 - November 30	108	282.5	August	17	13
				September	30	112
				October	31	102.5
				November	30	55
2015	August 29 - November 30	67	293.5	August	2	8
				September	22	106.5
				October	23	117.75
				November	20	61.25
2016	August 21 - November 20	60	268.5	August	3	9
				September	22	105.75
				October	22	103.75
				November	13	50

Iroquois Shoreline Site Summary

Year	Sampling Season	Total Days Sampled	Total Hours Sampled	Month	Days Sampled by month	Hours by month
2007	August 15 - November 30	108	172.25	August	17	4.5
				September	30	61.75
				October	31	55.5
				November	30	50.5
2008	August 30 - November 30	93	238	August	2	8.5
				September	30	78.5
				October	31	98
				November	30	53
2009	August 15 - November 30	108	138.75	August	17	11.5
				September	30	76.25
				October	31	30
				November	30	21
2010	September 5 - November 29	30	94.75	September	10	34.5
				October	10	34.75
				November	10	25.5
2011	August 15 - November 30	108	105.75	August	17	0
				September	30	37
				October	31	45.25
				November	30	23.5
2012	September 1 - November 30	24	83	September	12	45
				October	5	15.5
				November	7	22.5
2013	August 15 - November 30	108	67	August	17	0
				September	30	37
				October	31	17.5
				November	30	12.5
2014	September 6 - November 29	22	80	September	9	35
				October	8	28.5

				November	5	16.5

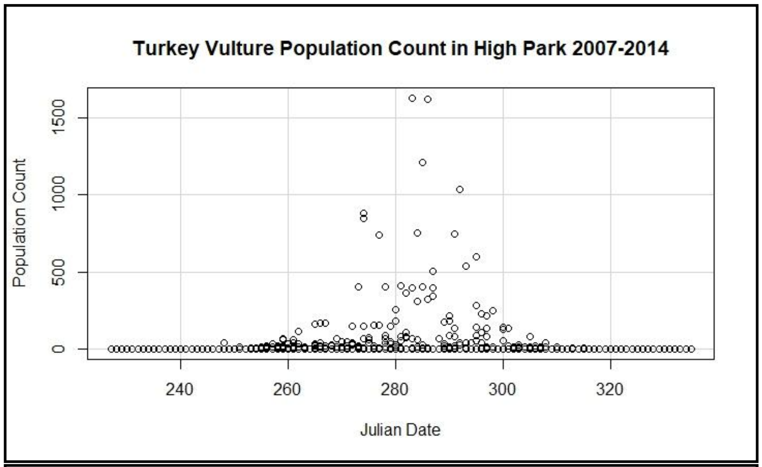
Rosetta McClain Gardens Site Summary

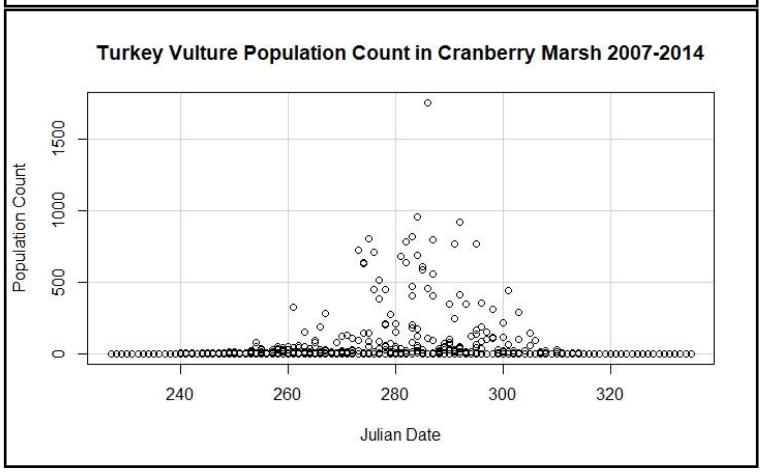
Year	Sampling Season	Total Days Sampled	Total Hours Sampled	Month	Days Sampled by month	Hours by month
2013	August 11 - November 28	76	450	August	14	66
				September	27	183
				October	24	148
				November	11	53
2014	August 9 - 17	8	43	August	8	43

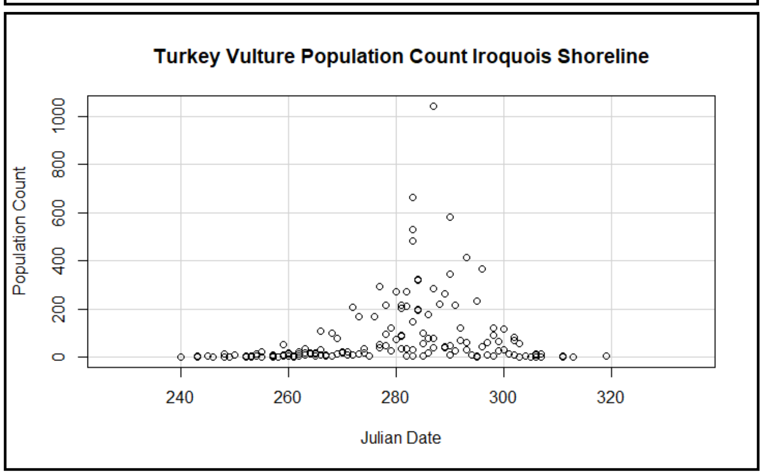
Appendix C

Population counts (2007-2014) from Cranberry Marsh, Iroquois Shoreline, and High Park.

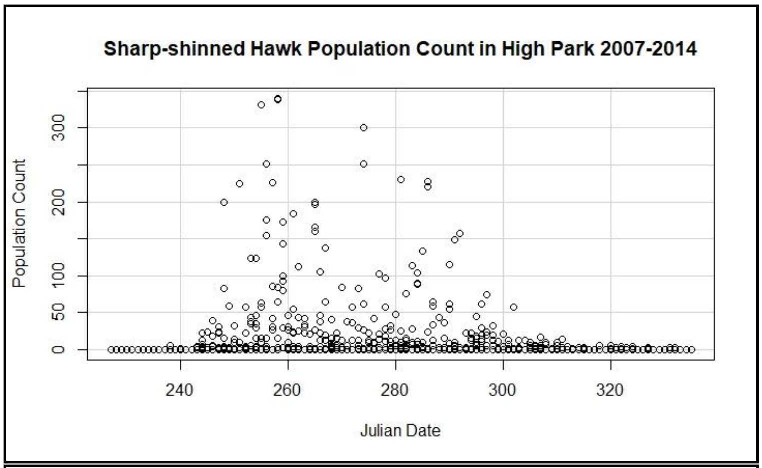
Turkey Vulture

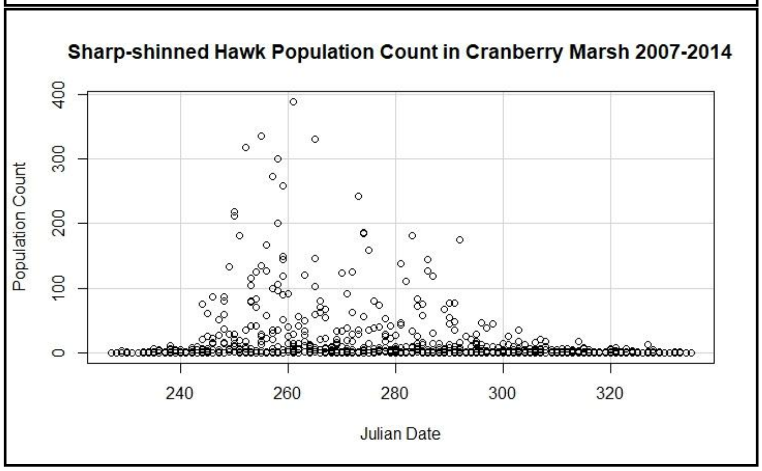


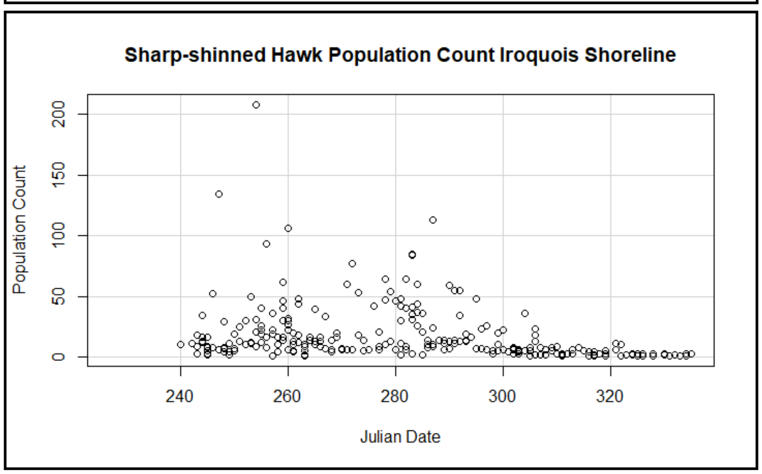




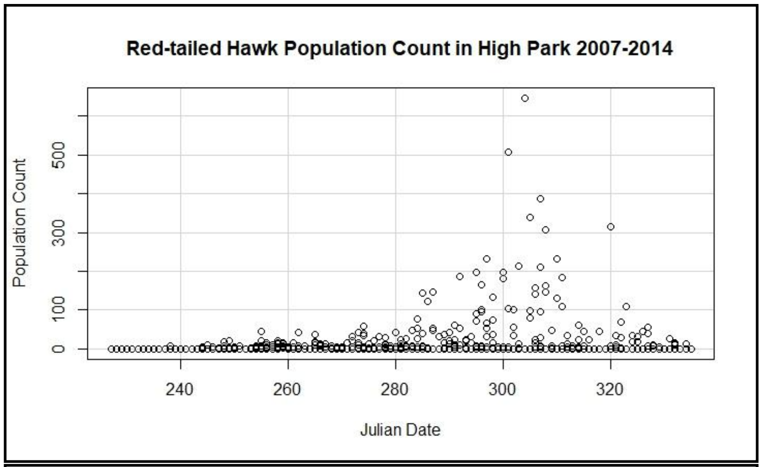
Sharp-shinned Hawk

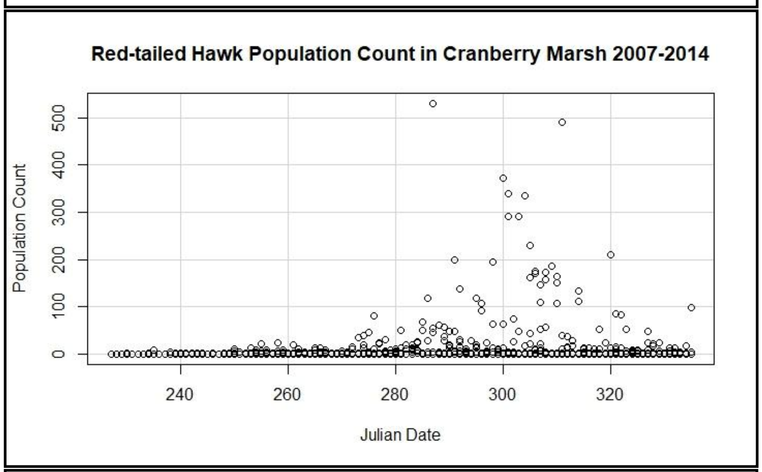


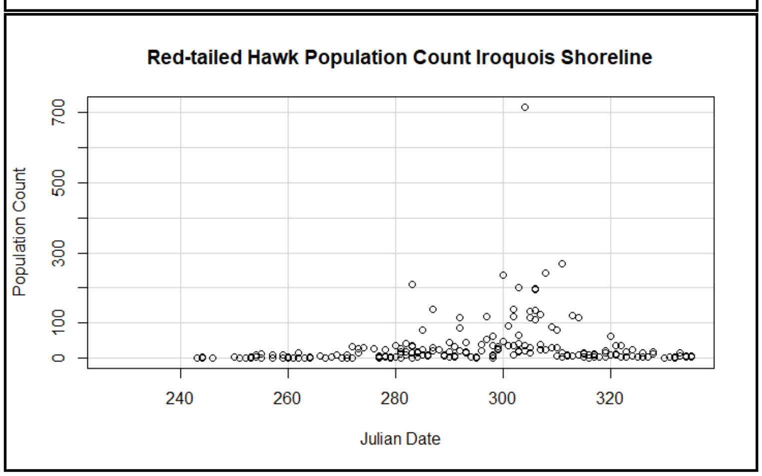




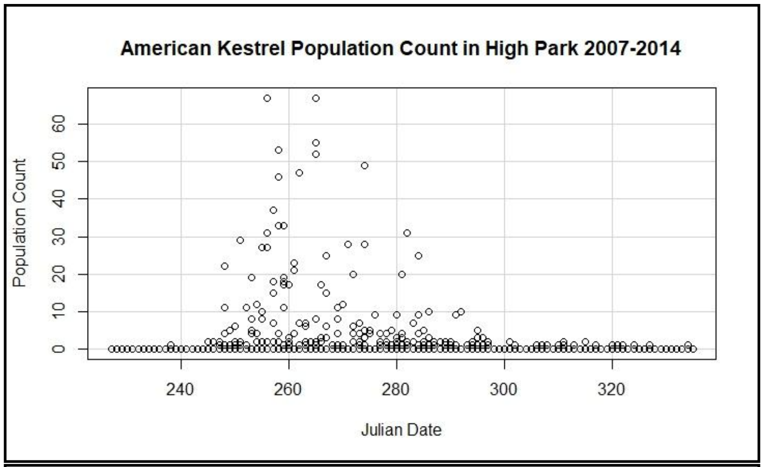
Red-tailed Hawk

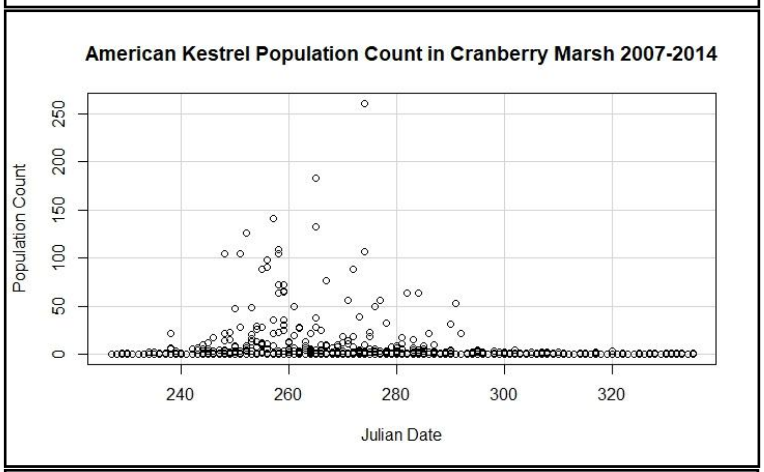


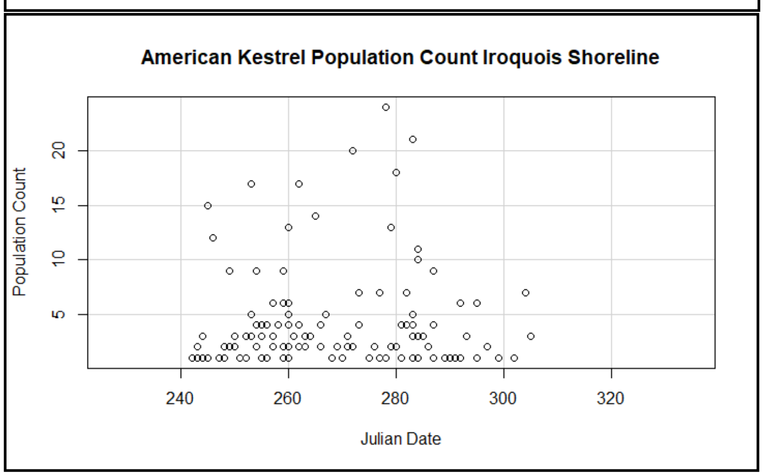




American Kestrel



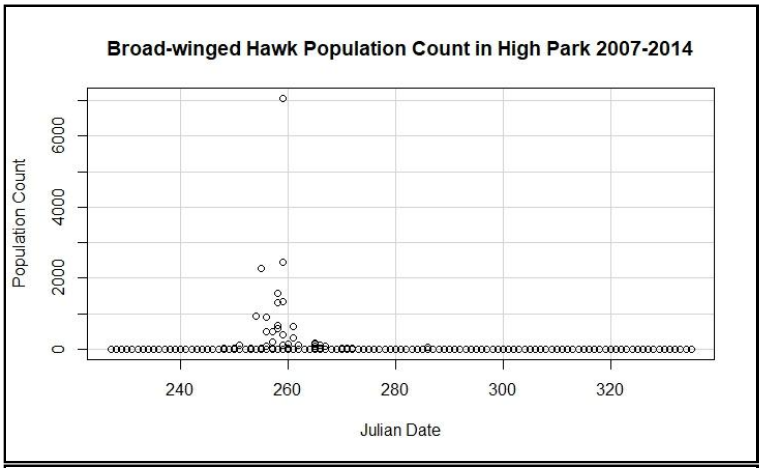


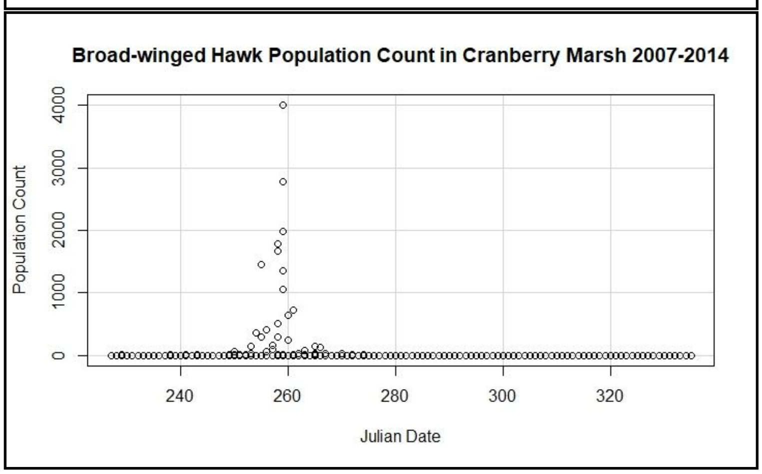


Appendix D

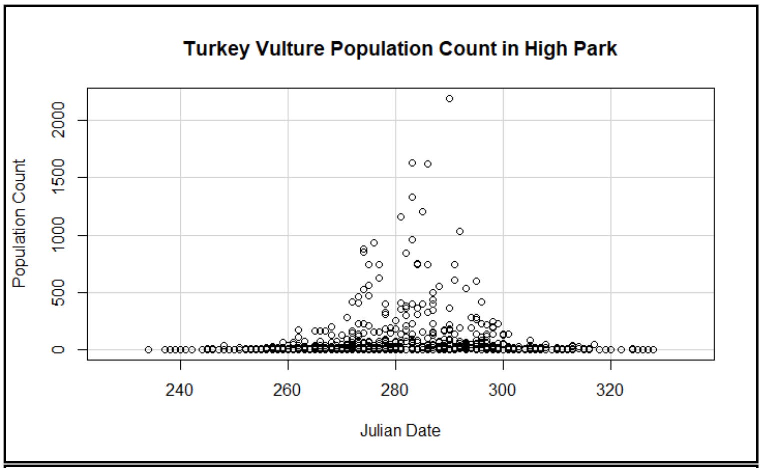
Total population counts (1994-2016) for High Park and Cranberry Marsh Hawkwatch sites.

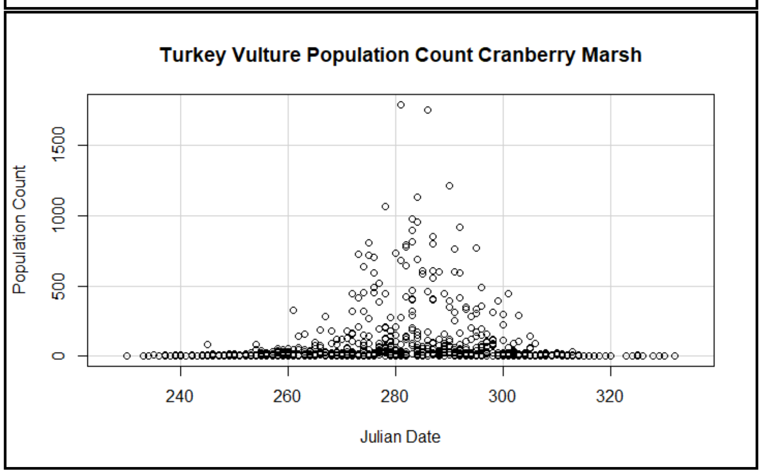
Broad-winged Hawk



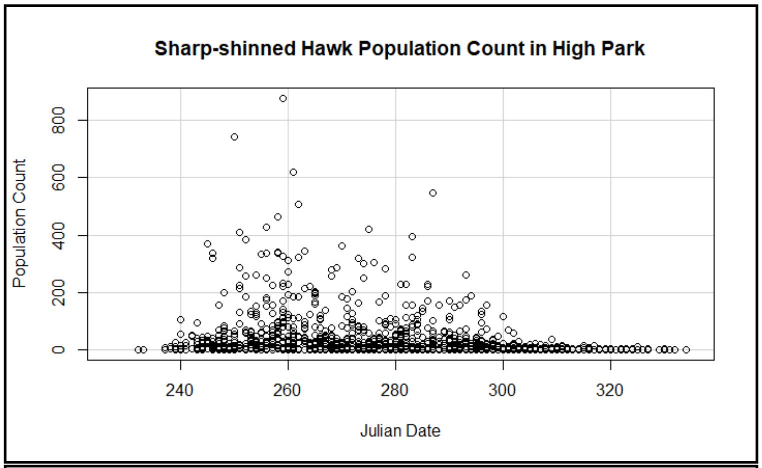


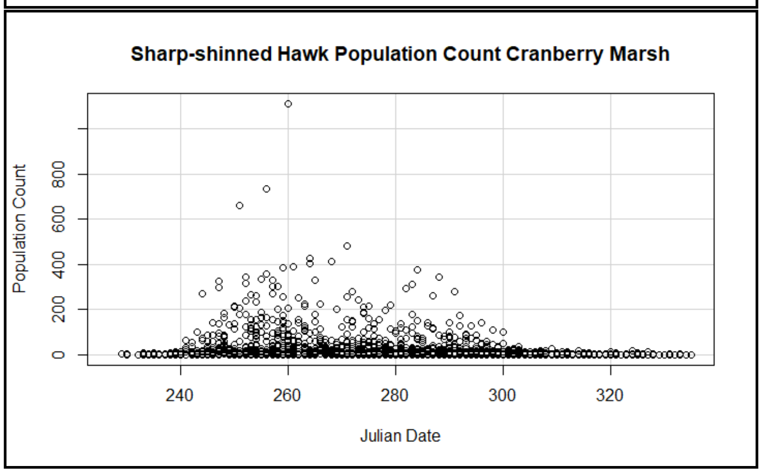
Turkey Vulture



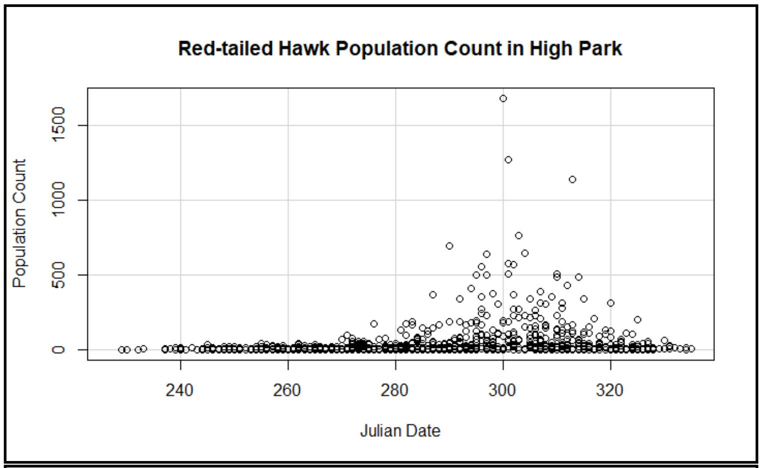


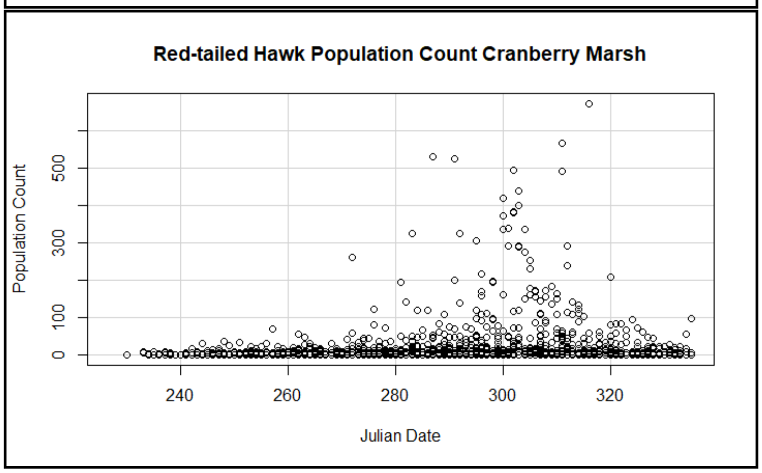
Sharp-shinned Hawk





Red-tailed Hawk





American Kestrel