6-2014

Changes in Spring Arrival and Fall Departure Dates of Migratory Birds as an Indication of Local Climate Change: A phenological study of New York State's Capital Region using citizen science

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A phenological study of New York State's Capital Region using citizen science

by

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Submitted in partial fulfillment

of the requirements for

Honors in the Department of Biology

UNION COLLEGE

June 2014

ABSTRACT

Climate change is becoming an increasingly important topic of scientific research, and studies commonly analyze biological indicators. Migratory birds are responsive to environmental changes because life cycles depend on finding proper seasonal locations. *eBird* is a citizen science database launched by the Cornell Lab of Ornithology and National Audubon Society in 2002, and this study focused on *eBird* data to analyze migratory shifts over the past two decades for the Green-winged Teal (*Anas crecca*), Northern Pintail (*Anas acuta*), Bufflehead (*Bucephala albeola*), Common Goldeneye (*Bucephala clangula*), Common Merganser (*Mergus merganser*), Red-breasted Merganser (*Mergus serrator*), Canada Goose (*Branta canadensis*), Snow Goose (*Chen caerulescens*), Barn Swallow (*Hirundo rustica*), and Tree Swallow (*Tachycineta bicolor*) in the Capital Region of New York State. Historical data sets from the early and mid-1900's were also used to make qualitative comparisons to past observations. Small changes in temperature and ice dynamics are already taking place in New York State, and observations of bird abundance and timing of migration may be reflecting climate change on a local scale. Plots were made using abundance data from *eBird* for Albany, Rensselaer, Saratoga, Schenectady, and Washington counties and evaluated in five-year time slices and decadal slices between 1995-2013. Overall, there has been advancement and delay in spring and fall migrations. The Barn Swallow and Tree Swallow show roughly a two-week advancement in spring arrival since the earlier decade. The Barn Swallow appeared to linger two weeks longer in the fall in the last decade, but sufficient data were not available for the Tree Swallow to make comparisons. The Green-winged Teal and Northern Pintail showed similar spring arrival dates between the two decades and an earlier fall departure by about two weeks in the later decade. The Common Goldeneye, Common Merganser, and Canada Goose displayed an opposite trend with a two- to three-week earlier spring arrival in the later decade and comparable fall departures between decades. The Bufflehead appeared to be arriving in the Capital Region approximately a month later in the more recent decade with a similar fall departure for both. Data were relatively sparse for the Snow Goose, and therefore migration dates for the two decades could not be compared. However, with the data available it appeared the Snow Goose decreased its length of time in the region. The Red-breasted Merganser is uncommon in this area, and there were essentially no sightings in the earlier decade. Thus, the slight increase may reflect a change in distribution. Avian migration is a complex behavior undoubtedly influenced by climatic conditions. These can either have direct impacts by affecting open water availability or indirect impacts by altering plant activity and insect abundance. Other factors like photoperiod, territorial competition, and risk of pre-breeding mortality must be recognized as affecting migration in addition to climate.

ACKNOWLEDGEMENTS

I would like to thank my advisor Professor Garver for his guidance and support during this project and for inspiring my deeper interest in this topic; Professor Emeritus Carl George for contributing his valuable insight and experience in ornithological research; Dr. Bob Yunick and his colleagues for their helpful suggestions and the wonderful learning experience joining their fall bird banding expeditions; Alison van Keuren for informing me of the Dayton Stoner records and Dr. Jeremy Kirchman at the NYS Museum who helped me access them; and the Union College Special Collections Department for their assistance in locating the historic *Birds of New York* volumes. Without the collaboration of these individuals, this project would not have been possible.

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INTRODUCTION

In today's world, climate change is a topic of daily conversation. A phenomenon that at one time was irrelevant is now dominating the scientific community as significant changes are expected to occur within our lifetime—and as evidence shows, human activity is escalating the process (IPCC AR5, 2013). Large-scale indications such as the melting of the polar ice caps and the degradation of the Great Barrier Reef are easier to document, but transformation driven by climate change occurs on a much more local scale at country, state and even county levels. Studying alterations in the local environment is crucial to our overall understanding of climate change, and in supporting the notion that it is a very proximate concern.

Biological indicators are organisms whose changes in physiology or behavior reveal transformations in the environment, and birds prove to be among some of the most telltale species (Crick, 2004). Migratory birds follow a schedule that is very sensitive to climatic conditions. Birds breed in northern areas during warmer months and journey to southern regions for the non-breeding wintering months and are highly responsive to environmental cues such as photoperiod, temperature, and water availability (Lincoln, 1999). For instance, in anticipation of shorter days, temperature decreasing, and water freezing, avian migrants molt, begin accumulating excess fat, and prepare for migration (Gill, 2006). However, if temperatures remain higher and open water is accessible for a longer period, birds may delay their migration due to the fact that conditions are not yet harsh and resources are still available (Lincoln, 1999). Likewise, if springtime is advanced, birds may arrive early to take advantage of resources. Because temperature and ice dynamics are factors of climate change, studying the phenology of birds in terms of spring arrival and fall

departure dates in correlation with these factors can provide evidence of climate change occurring within a given region.

A flyway is a route used for a large number of migrants, and the Atlantic (or Eastern) Flyway follows the Atlantic coast of North America directly through the Capital Region of New York State (U.S. Fish and Wildlife Service, 2013). Birds follow topographic features, prevailing winds, waterways, and foraging areas, and the Hudson River is a major channel in the Atlantic Flyway used for navigation (McColl, 2005). In addition to the Hudson River's influence on migrant activity in the area, the Mohawk River serves as a corridor to and from the flyway, causing movement in the western part of the state as well. To establish a concentrated region within this Hudson-Mohawk system, this phenological study focuses on Albany, Rensselaer, Saratoga, Schenectady, and Washington counties (Figure 1). This area is not only representative of an important region to migrant birds, but also to a relatively large population in the Capital District of New York State. Thus, there are a number of recorded observations of birds through time.

Using such records, this study seeks to find any significant changes in bird migrations over the last two decades that may reflect Capital Region climate change. The records used for this study are a compilation of citizen science data, which are based on bird observations made by the public. Citizen science is emerging as a tool for ecological research, because it increases the range of data available to researchers and allows for public contribution to science (Dickinson, 2012). The major data set used for this study comes from the online database, *eBird*, which contains public bird sightings dating back several decades that can be categorized by species, date, and location. To evaluate a group

of species representative of both waterfowl and passerines, the ten bird species under analysis are: Canada Goose (*Branta canadensis*), Snow Goose (*Chen caerulescens*), Common Goldeneye (*Bucephala clangula*), Bufflehead (*Bucephala albeola*), Common Merganser (*Mergus merganser*), Red-breasted Merganser (*Mergus serrator*), Northern Pintail (*Anas acuta*), Green-winged Teal (*Anas crecca*), Tree Swallow (*Tachycineta bicolor*), and Barn Swallow (*Hirundo rustica*). By using public observation data, this study investigates if birds are responding to local climate change, and also if citizen science has the potential to detect such change.

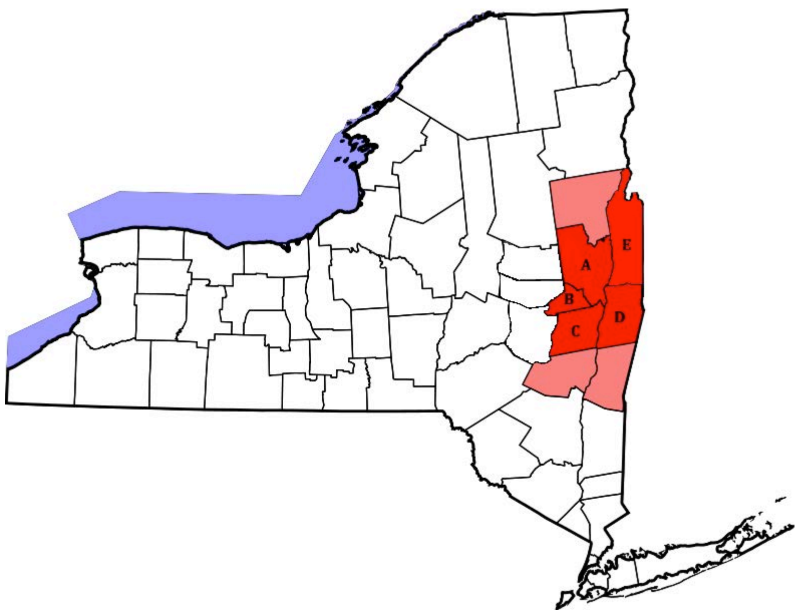


Figure 1**.** County map of New York State. The highlighted area (pink and red) represents the Capital District and the red counties are those used for this study. **A.** Saratoga **B.** Schenectady **C.** Albany **D.** Rensselaer **E.** Washington.

CLIMATE CHANGE BACKGROUND

New York State

It is widely appreciated that New York State is already experiencing noticeable impacts of climate change, which are projected to increase in the near future (Rosenzweig et al., 2011). These effects include higher temperatures and increases in number of heat waves, higher annual precipitation and frequency of heavy rainfall, and decreases in snow season and average snowfall. Also included are important changes in the timing of ice formation and ice breakup on rivers and lakes (see Rosenzweig et al., 2011).

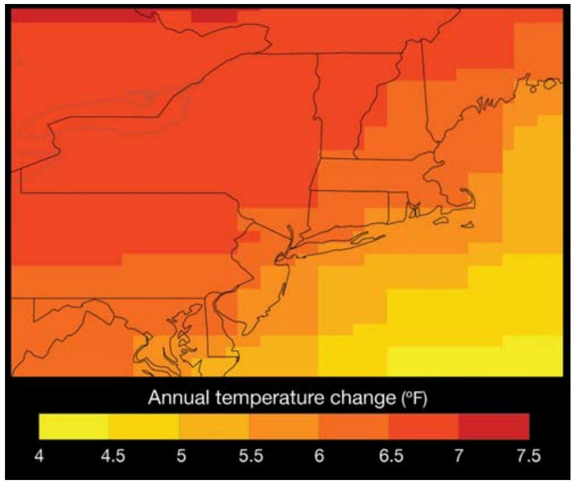
Average annual temperatures in New York State vary from 40-55°F depending on the region and have increased approximately 0.6°F per decade since 1970 with the greatest seasonal warming occurring in the winter at an increase of around 1.1°F per decade (Rosenzweig et al., 2011). With the use of global climate models, temperatures in NY State are projected to increase 1.5-3.0°F by 2020s, 3.0-5.5°F by 2050s, and 4.0-9.0°F by 2080s (Figure 2). Perhaps more important, however, is the change in extreme events and their effects on lake and river ice (Magnuson et al., 2000). The number of extreme heat events such as droughts and heat waves are expected to increase whereas extreme cold events are expected to decrease in frequency. By the end of the century, the greatest temperature increase may be in the northern part of the state and will have consequences such as more intense summers, milder winters, and lengthening the State's growing season by approximately a month (see Rosenzweig et al., 2011).

According to global climate models, there is no apparent trend in annual precipitation in New York State since 1900 due to the continuous fluctuation in average

rainfall and the large decade-to-decade variability. Yet, Rosenzweig et al. (2011) claim that a small increase in annual precipitation is predicted for the future. By 2020s, there is an anticipated annual precipitation increase of 0-5%, 0-10% by 2050s, and 5-15% by 2080s (Figure 3) with the largest seasonal increases during the winter. The frequency and severity of extreme precipitation (heavy rainfall) events undoubtedly increased in recent decades and are expected to continue increasing in future years (see Rosenzweig et al., 2011).

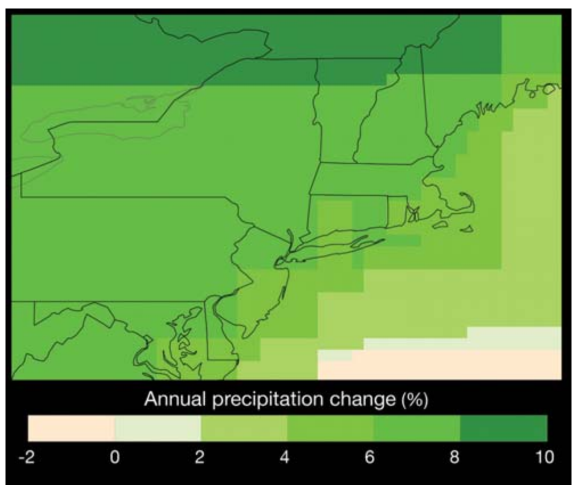
A rise in winter temperatures may play an important role in changing the biosphere. The length of the snow season in New York State is expected to decrease, and thus far the seasonal ice cover on the Great Lakes has decreased 8% per decade over the past 35 years. Models from Rosenzweig et al. (2011) also suggest that there is a decreasing trend in the number of days with a minimum temperature at or below 32°F.

As overall temperatures increase, especially winter temperatures, migratory birds are likely to respond as open water occurs earlier in the spring and persists later into early winter. With an increase in the spring temperature causing earlier spring blooms, the earlier availability of resources such as warmth and nourishment may hasten the migration and breeding schedule. With temperature increases also causing ice break-up events, the accessibility to open water may be particularly inviting to waterfowl, causing their earlier migration. Also, warmer fall temperatures may mean the waterfowl linger later in the season as water remains open.



Source: Columbia University Center for Climate Systems Research. Data are from WCRP and PCMDI

Figure 2. Projected change in annual temperature in the Northeast for the 2080s. Note that for the mid-Hudson and Mohawk Valley, this projection is for a 6.5 to 7°F change. Taken directly from ClimAID.



Source: Columbia University Center for Climate Systems Research. Data are from WCRP and PCMDI

Figure 3. Projected change in annual precipitation in the Northeast for the 2080s. Note that for the mid-Hudson and Mohawk Valley, this projection is for a 6 to 8% change. Locally in the Watershed the average annual precipitation is about 35-40 inches a year, thus this change translates to about 2.5 inches per year. Taken directly from ClimAID.

The Mohawk

The Mohawk Watershed has entered a wet phase in its history due to increases in precipitation and discharge in the basin (Garver and Cockburn, 2011). While total annual rainfall in the region continues to fluctuate, it has experienced an overall rising trend in the past ~40 years (Figure 4). Average winter temperatures in the area show a similar trend with a general increase since ~1980 (Figure 5). Due to warmer winter temperatures, earlier ice-out dates have occurred along with the number of mid-winter break up events, changing the availability of open water on rivers and lakes in the watershed (Cockburn et al., 2009).

This combination of a wetter watershed and change in ice dynamics may directly impact specifically the migratory waterfowl in the region (Garver, 2013). These birds are attracted to open water and with its availability increasing, they may be present more frequently during the winter and earlier in the spring.

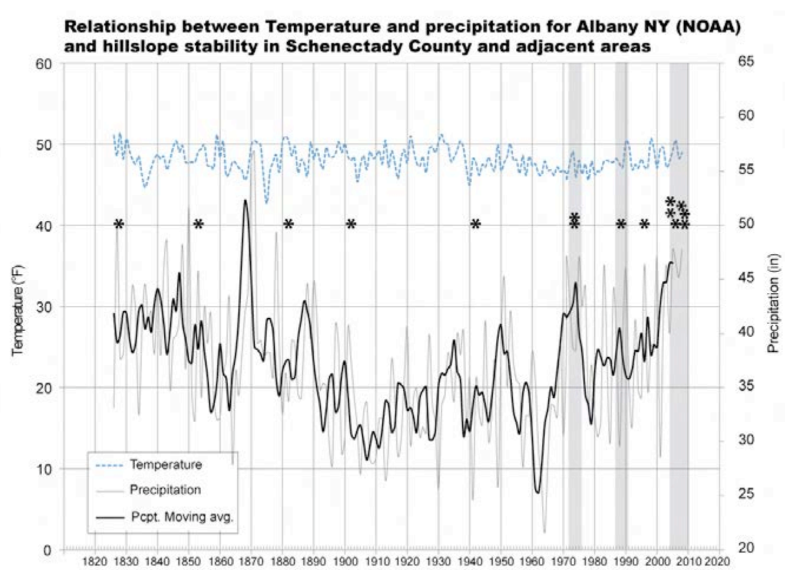


Figure 4. Precipitation and temperature for Albany since 1820. (the longest record in the Capital District). Taken directly from Garver, et al., 2010 Mohawk Watershed Symposium.

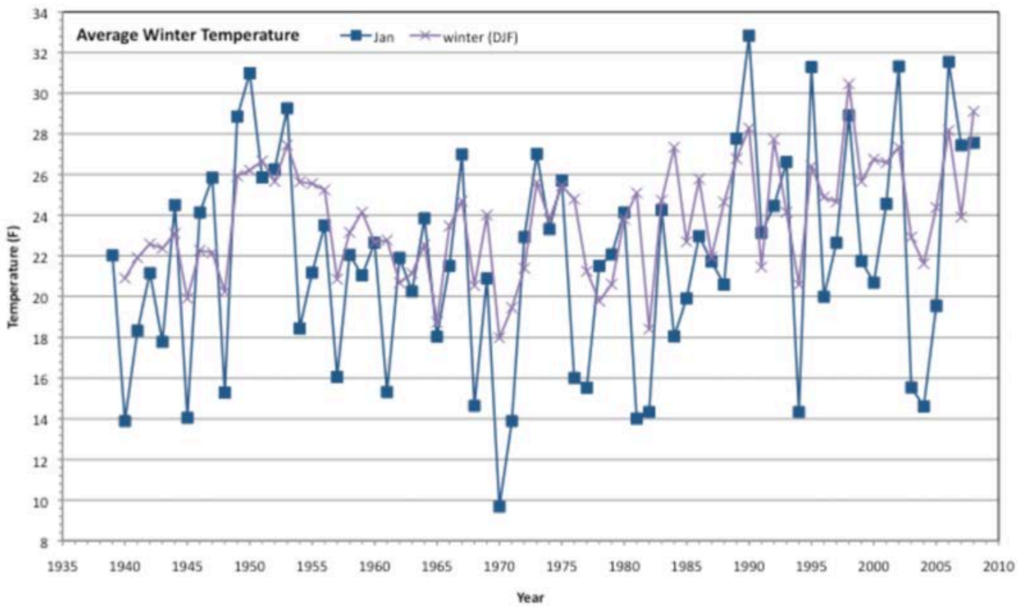


Figure 5. Average winter (purple line) and average January (blue line) temperatures in Albany from 1935-2010 determined by daily observations. Taken directly from Cockburn et al., 2009 Mohawk Watershed Symposium.

<u>The Flyway (Arctic Sea Ice)</u>

The Arctic sea ice is full and complete in the winter, but during the summer thawing of sea ice and warming of adjacent land provides one of the most productive breeding grounds for birds on the planet. The cycle of the Arctic sea ice extent is defined by the months of September, where extent is at the summer minimum, and March, where the extent is at the winter maximum. The minimum extent for each year between 2007-2013 is lower than any other year in the period of record and has been declining at an average rate of 13.7% per decade. The maximum extent has also been declining but at a smaller rate of 2.6% per decade (Figure 6). These declines in minimum and maximum sea ice extent result

in more open water for an extended period of time, for example, the southern part of the Northwest Passage is now open in September (see Arctic Report Card, 2013).

Arctic sea ice is composed of ice types that differ in age, and the age of ice is an indicator of thickness; oldest ice is the thickest and first-year ice is the thinnest. Since the 1980s, there has been an extensive loss of older ice, and thus the system is more fragile (Figure 7). According to the Arctic Report Card (2013), in 1988, oldest ice comprised 26% of total ice cover and this number dropped to 7% in 2013. First-year ice made up 58% of total cover in 1988 and became 78% in 2013. This increase in first-year ice cover is leading to thinner overall Arctic sea ice, which means faster thawing and loss of volume.

Changes in Arctic sea ice have direct effects on some migratory waterfowl, such as the Snow Goose, that reside in the Arctic tundra during the breeding season. Because minimum and maximum extent are declining and younger, thinner ice is taking over, there is not only a greater amount of open water, but open water present for longer periods of time. Migrant waterfowl will remain in their Arctic home as long as open water is available, and therefore may be extending their stay.

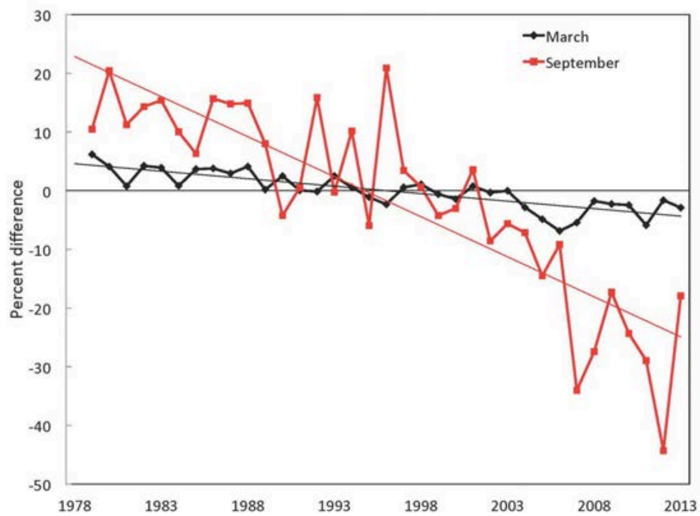


Figure 6. Time series of maximum (March) and minimum (September) ice extent showing percent difference relative to the mean values from 1981-2010. Taken directly from the Arctic Report Card. (http://www.arctic.noaa.gov/reportcard/index.html)

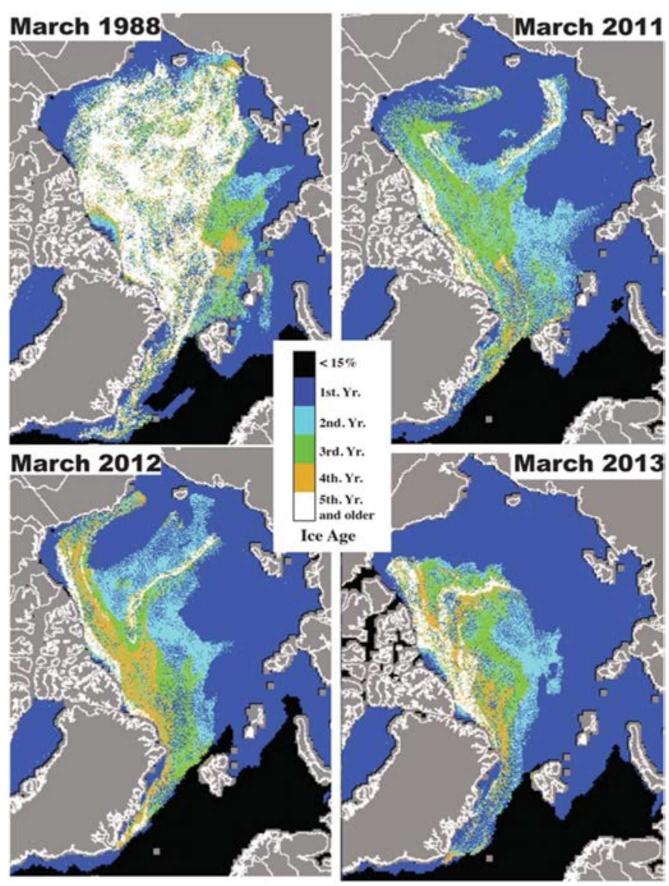


Figure 7. Satellite-derived ice coverage in March 1988, 2011, 2012, and 2013. Taken directly from the Arctic Report Card. (http://www.arctic.noaa.gov/reportcard/index.html)

DATA SOURCES

To confirm trends, the arrival and departure dates of migratory birds must be reviewed over a substantial period of time. The goal of this study is to use citizen science to observe more recent changes in comparison to historic data sets. The bulk of data under analysis is from the past two decades and historical data comes from 1905-1907 and 1920's-1940's. Without data sets that provide a continuous record of sightings, there are inevitable gaps within the referenced time frame, but the data still produce a general timeline that is significant for evaluation of migration changes. The pool of current observational data is substantial given the Internet and other technologies. However, for the data set to reflect relevant change and be of value to future generations, this pool must be connected to the past. Mining unique historical data may establish connections with great potential.

Birds of New York by Elon Howard Eaton

Birds of New York is a two-volume publication (published in 1910 and 1914) by the New York State Museum written by Elon Howard Eaton, a New York State native and naturalist. John Mason Clark, the director of the NYS Museum at the time, commissioned Eaton to write the work to provide the most recent ornithological research in the state accessible to the public. To write *Birds of New York*, Eaton compiled distribution maps, migration surveys, and detailed observations, and enlisted Ithaca artist Louis Agassiz Fuertes to paint illustrations. Credited for sparking ornithological interest across the state, these volumes prove to be of value to researchers over 100 years later. Volume I contains a vast table of county schedules that provides knowledge of birds in every county in New

York State, including arrival and departure dates. The information was gathered from bulletins and schedules returned to the museum by observers between 1905 and 1907 (New York State Education Department, Research Library).

Dayton Stoner Records, NYS Museum

Dayton Stoner (1883-1944) was originally from Iowa and became the State Zoologist at the New York State Museum in 1932. Stoner expressed many interests from general zoology, entomology, mammology, to ornithology, and his expertise in all of these areas is reflected in his over 160 published works (University of Iowa, Department of Geoscience). In addition to his publications available at the New York State Museum, the ornithology department also houses his personal notes and observations, including first and last sightings of birds in this region of New York State. These records, which also include remarks from other observers, date from the 1920's to the 1940's.

These two data sets are not in a digitized format like current observations, and thus can be used for qualitative comparisons.

eBird

eBird is an online database of bird observations launched in 2002 by the Cornell Lab of Ornithology and the National Audubon Society. This real-time data source is a premier example of citizen science with mass amounts of observations submitted daily by the public. *eBird* allows for retrospective data entry and provides information on abundance, distribution, and schedules of birds all over the world with some observations ranging as

far back as the 1950's. The success of *eBird* has allowed these vast numbers of observations to become accessible to scientists, researchers, and the average birdwatcher.

SPECIES OF STUDY

The ten avian species used in this study are comprised of waterfowl and songbirds, or passerines (Figure 8). Waterfowl, which include ducks, geese, and swans, are adapted for swimming, floating, and diving, and their breeding and diet center around aquatic habitats. Water is a defining part of their overall ecology and therefore makes them highly susceptible to changes in the local hydrology induced by climate change, such as freezing and thawing of ice.

Passerine species, typically regarded as the perching songbirds, are included in this study as a possible interesting comparison to waterfowl. With different ecology that does not directly focus on water, any observed change in their migration dates has potential to reflect something different about the environment. In many instances, these birds are affected by food and temperature, both of which can be related to the bloom of flowers and the occurrence of insects.

Waterfowl (Anseriformes):

Northern Pintail (*Anas acuta*)

This distinctly shaped duck is slim and long-necked. The male has prominent markings, including a white neck-stripe, and a long tail that makes this species unmistakable to spot. The female is duller in color and lacks the distinctive tail, but still

exhibits the graceful, long-necked shape. Pintails inhabit low vegetation and shallow wetlands in open country and are classified as dabbling ducks due to their behavior of picking food off the surface of the water and tipping up. The breeding range extends into northern Canada and Alaska and non-breeding grounds include the southern United States, Mexico, the Caribbean, and parts of Central and South America. The Northern Pintail is one of the earliest nesters in North America appearing shortly after ice begins to melt, and although it is not endangered, its population is still lower than ideal (*All About Birds* and Sibley, 2003).

Green-winged Teal (*Anas crecca*)

A very small, stocky duck, the Green-winged Teal is brightly patterned with an iridescent green patch on its wings from which it derives its name. This species is common in marshes, flooded fields, and mudflats, and like the Northern Pintail is considered a dabbler feeding mainly on seeds picked from the surface of the water. Its breeding and non-breeding grounds are similar to the Northern Pintail, but the wintering range barely extends into Central America (*All About Birds* and Sibley, 2003).

Bufflehead (*Bucephala albeola*)

Buffleheads are small, large-headed ducks with short, wide bills. Males have strikingly white bodies, black backs, and dark iridescent heads with a large white patch that wraps around the back. Females are gray-brown overall with an oval white cheek patch. These ducks are common on lakes, harbors, and bays and dive for mollusks, crustaceans, and insect larvae. They nest only in cavities, primarily those made by Northern Flickers, whose distribution therefore limits their breeding range (*All About Birds*, 2014). In

winter, the Bufflehead occurs mainly near coastlines in most of the United States and in the summer breeds near lakes in Canada and Alaska. During their spring migration, they spend much time on rivers and valley lakes, often the first spots to become free of ice. In the early twentieth century, the Bufflehead was scarce due to overshooting, but under protection from the U.S. and Canada the population began to recover. While duck hunting is still carefully managed to protect the Bufflehead population, about a quarter of a million are still shot per year, and nest sites are being lost as loggers cut boreal forest (*All About Birds* and Sibley, 2003).

Common Goldeneye (*Bucephala clangula*)

A medium-sized diving duck, the Common Goldeneye male is mostly white with black wings, back, and tail. It has a greenish-black head, round white patch on the side of the face, and golden yellow eyes. Females have brown heads and mostly slaty gray bodies. These ducks are common on lakes, rivers, and bays and their diet includes crustaceans, small fish, and mollusks. The Common Goldeneye breeds in most of Canada and Alaska along lakes and rivers bordered by forests where they nest in tree cavities. This is one of the last ducks to migrate south in the fall and winters in almost the entire United States usually as far north as open water admits (*All About Birds* and Sibley, 2003).

Common Merganser (*Mergus merganser*)

The Common Merganser is a large, streamlined duck with a very narrow bill. Males are particularly striking with clean white bodies and dark green iridescent heads. Females are gray-bodied with cinnamon-colored crested heads, and both sexes exhibit a red bill. This species lives mainly on freshwater rivers and lakes, nests in tree cavities, and is

classified as a diving duck because it forages underwater for fish. Its breeding grounds consist of southern and central Canada, and it winters in the central and southwestern United States. The Common Merganser population has been very stable for the past fifty years, but due to its position at the top of the aquatic food chain, it is particularly susceptible to environmental effects (*All About Birds* and Sibley, 2003).

Red-breasted Merganser (*Mergus serrator*)

Also a large slender diving duck, the Red-breasted Merganser has a narrow red bill and distinctive shaggy crest on the back of the head. Males have iridescent green heads with red eyes, dark rusty-colored chests, gray sides, and black backs with a long white patch on the wings. Females have slaty gray bodies, orange-brown heads, and a white patch on the wings that is visible during flight. These ducks are found in large lakes, rivers, and the ocean, but they prefer salt water to fresh water. They dive mostly for fish, sometimes feeding on crustaceans and insects, and nest in depressions made in the ground close to water. The Red-breasted Merganser breeds farther north and winters farther south than any other species of merganser, breeding in all of Canada and Alaska and wintering in the entire United States (*All About Birds* and Sibley, 2003).

Snow Goose (*Chen caerulescens*)

The medium-sized white-bodied Snow Goose has black primary feathers barely visible when on the ground but noticeable in flight. The pink bill has a dark line often called a “grinning patch”, and dark-colored morphs exist as well. Snow geese are a spectacle in flocks, with numbers sometimes reaching into the hundreds of thousands. They are commonly found grazing on marshy vegetation and agricultural fields, also foraging in

large numbers. These birds breed in the Arctic tundra and winter in the southern United States. The Snow Goose population has escalated since the mid-twentieth century, now making it one of the most abundant waterfowl species on the continent. This drastic population increase could possibly be the result of the adapted exploitation of agricultural fields or the warming conditions in the Arctic breeding grounds (*All About Birds* and Sibley, 2003).

Canada Goose (*Branta canadensis*)

This familiar waterbird is monomorphic with a brown back, pale chest, black neck and head, and white cheek. Canada Geese are found just about everywhere near lakes, ponds, and other bodies of water and on agricultural land and lawns. Their diet consists of grass, berries, and seeds, and they feed by dabbling in water or grazing in fields. These birds have "resident" populations that dwell in some areas all year round in addition to migrant populations, which breed in Canada and winter in the southern United States. Migrating flocks of family groups and individuals fly in the well-known V formation and are known to stay in northern areas even in very cold temperatures as long as open water and resources are available. Canada Geese are very common, and their numbers are increasing in North America despite the large number being harvested by hunters (*All About Birds* and Sibley, 2003).

Songbirds (Passeriformes):

Among songbirds, swallows are of particular interest due to the abundance of data and their adherence to strict migratory patterns (e.g. arriving on the same date at the same tree year after year).

Tree Swallow (*Tachycineta bicolor*)

These aerial acrobats are streamlined with long, pointed wings. Males display metallic blue-green backs and clean white fronts, while females are duller with more brown on their backs. They are found in open fields and wetlands, nesting in birdboxes and tree cavities. Tree swallows swiftly chase after insects and are highly social birds. They form large migratory flocks into the hundreds of thousands and roost in large numbers as well. Breeding in the northern United States and Canada and wintering in Florida, Mexico, and Central America, tree swallows winter farther north than any other American swallow and are the first to return to nesting grounds. Among the best-studied birds in North America, this species has helped researchers make major advancements in several branches of ecology (*All About Birds* and Sibley, 2003).

Barn Swallow (*Hirundo rustica*)

This sparrow-sized, agile flyer is often seen cruising low, just above the surface of the ground or water. Barn swallows display a deeply forked tail, which sets them apart from other swallows. They are steely, cobalt blue above with a rufous throat and tawny underside. These birds feed on the wing, foraging in open areas such as fields and large ponds and build their muddy nests almost exclusively on man-made structures. As the most abundant and widely distributed swallow species, barn swallows breed in practically all of North America and winter in the entirety of South America. Due to nesting benefits afforded by man-made structures and their appeal to people, barn swallows have greatly expanded their breeding range and numbers as a result of human settlement (*All About Birds* and Sibley, 2003).

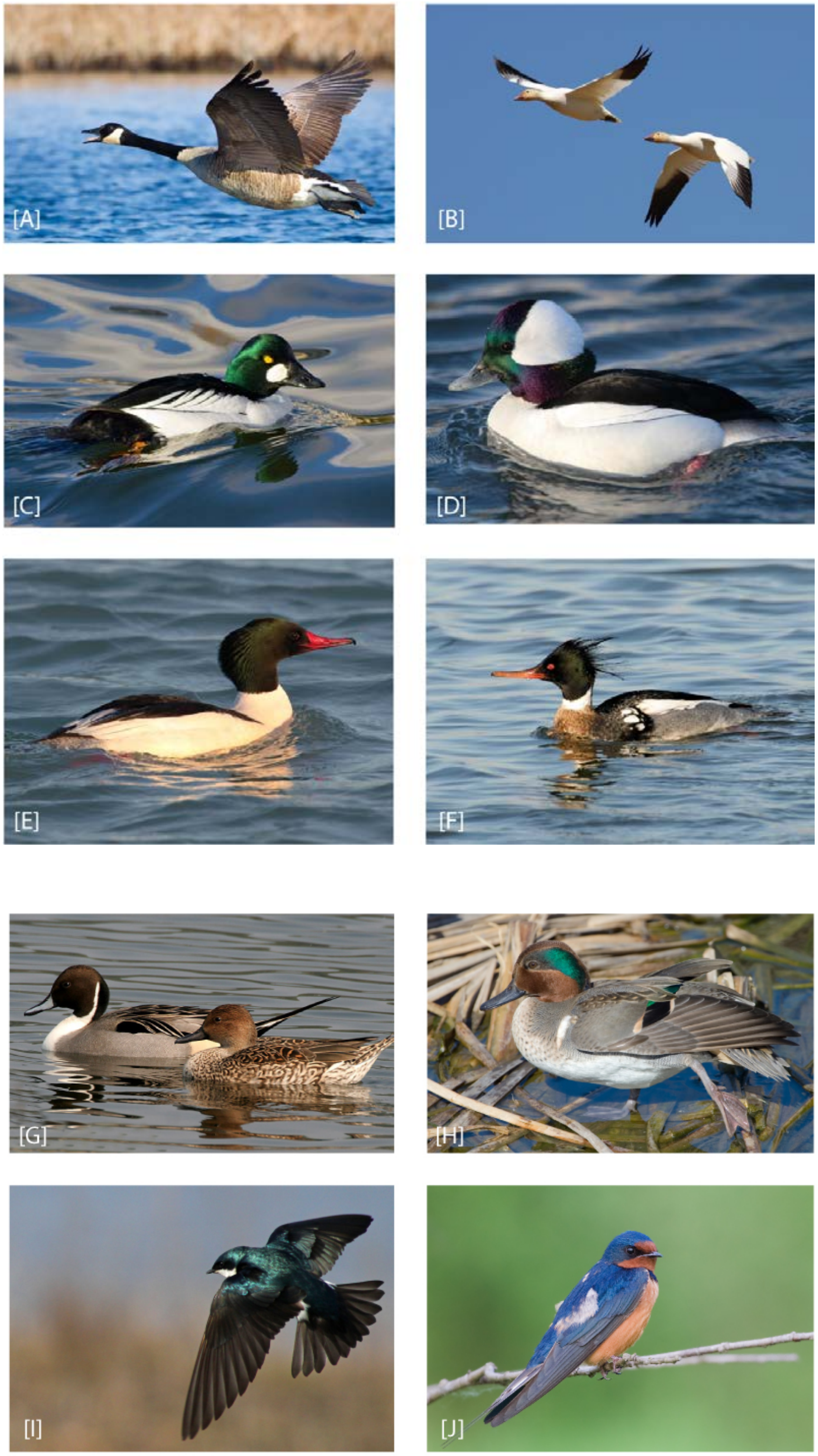
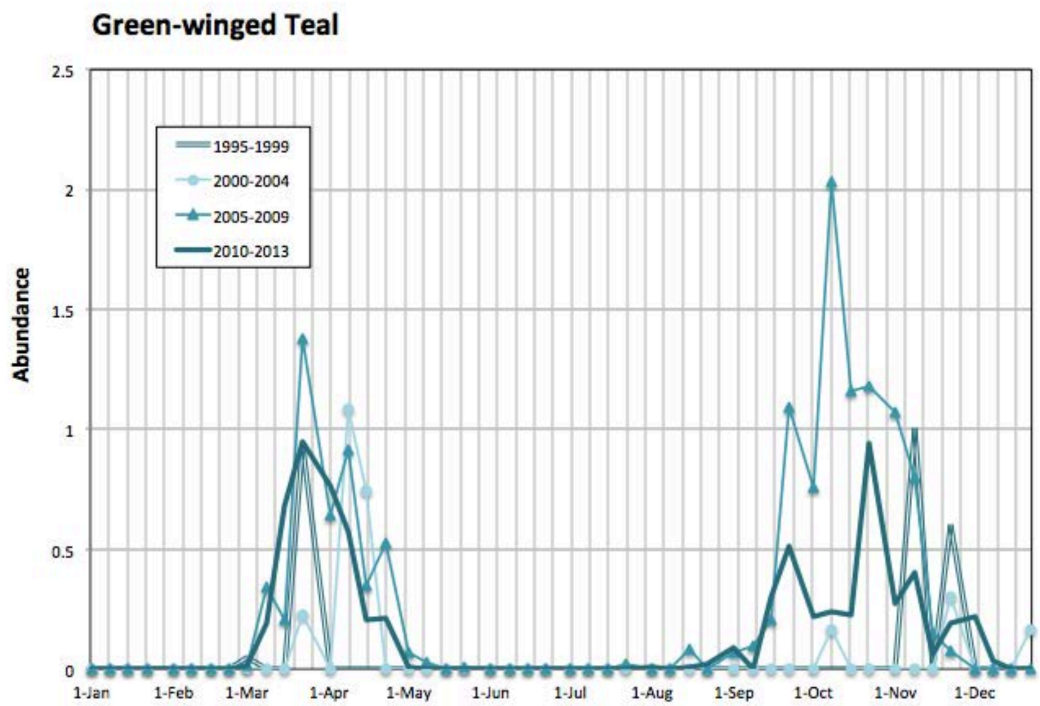


Figure 8. [A]. Canada Goose (*Branta canadensis*) [B]. Snow Goose (*Chen caerulescens*) [C]. Common Goldeneye (*Bucephala clangula*) [D]. Bufflehead (*Bucephala albeola*) [E]. Common Merganser (*Mergus merganser*) [F]. Red-breasted Merganser (*Mergus serrator*) [G]. Northern Pintail (*Anas acuta*) [H]. Green-winged Teal (*Anas crecca*) [I]. Tree Swallow (*Tachycineta bicolor*) [J]. Barn Swallow (*Hirundo rustica*)

RESULTS

The following data are summary plots of when key birds are seen and reported on *eBird* in our five counties of interest. For each species, the general trend is reviewed between 1995-2013 for 5-year time slices and then decadal intervals. The point of this review is to highlight major changes seen in bird migration.

The plots were made using *eBird*'s abundance data specified by county, species, and date. *eBird* describes abundance as "the average number of birds on all checklists" for that indicated region and time frame, and therefore these data can also be considered to represent the probability of seeing that bird on a given day in that location. For each species, weekly abundance was recorded for each year between 1995 and 2013, and the average was taken for each five-year increment and plotted. In order to display broader trends, the averages for each decade were then calculated and graphed. For birds that were observed continuously through the winter, the decadal graphs were plotted beginning with July 1 in order to present an unbroken trend during the winter months.



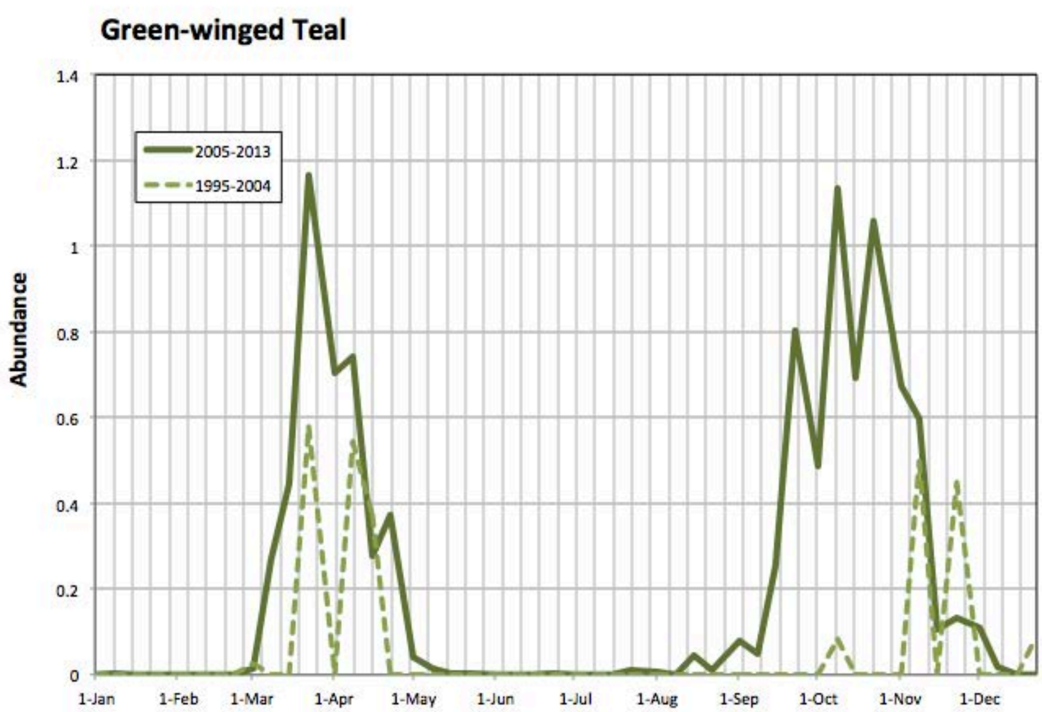
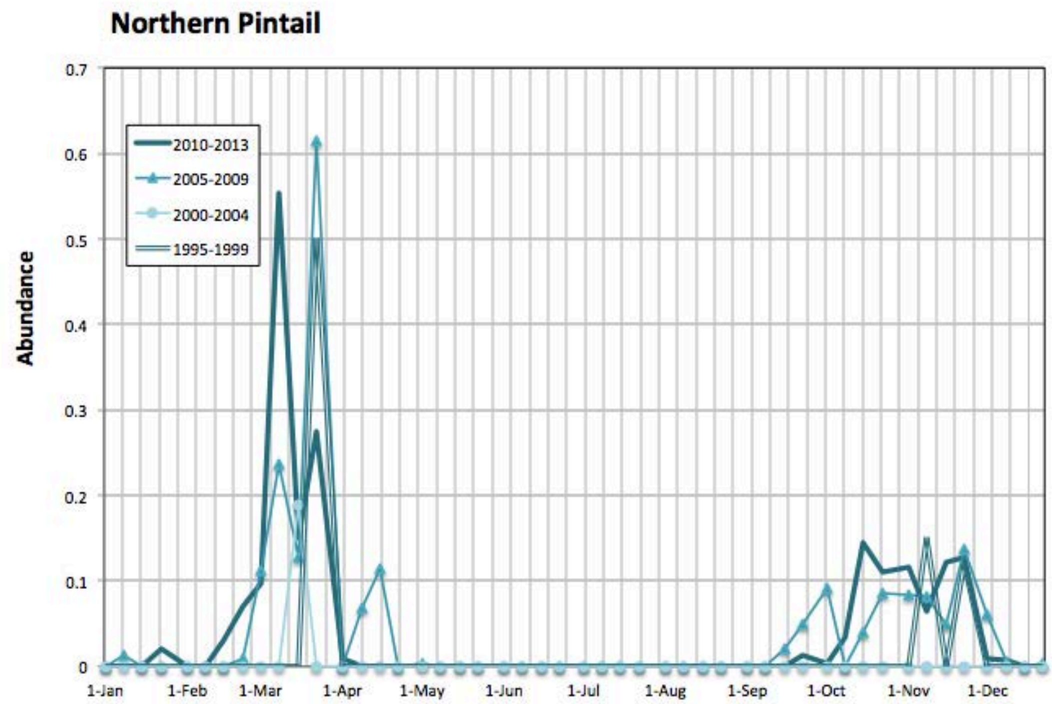


Figure 9. Plots showing the annual distribution of the Green Winged Teal (*Anas carolinensis*). Upper graph shows data in 5-year time slices, and the lower graph in decadal slices. See text for discussion.



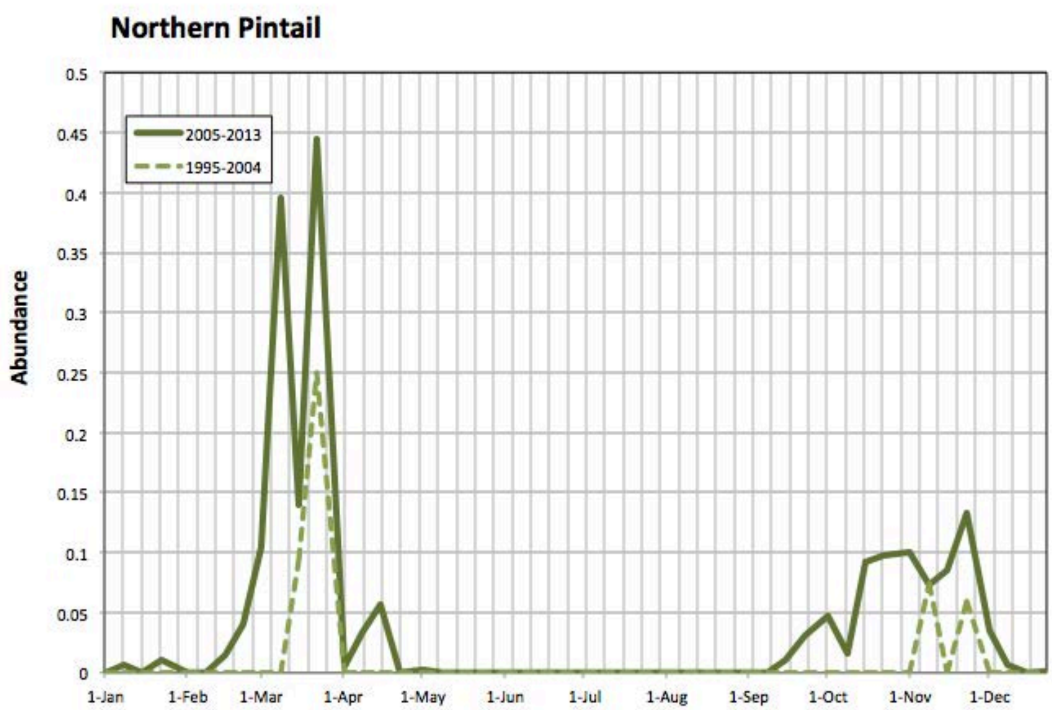
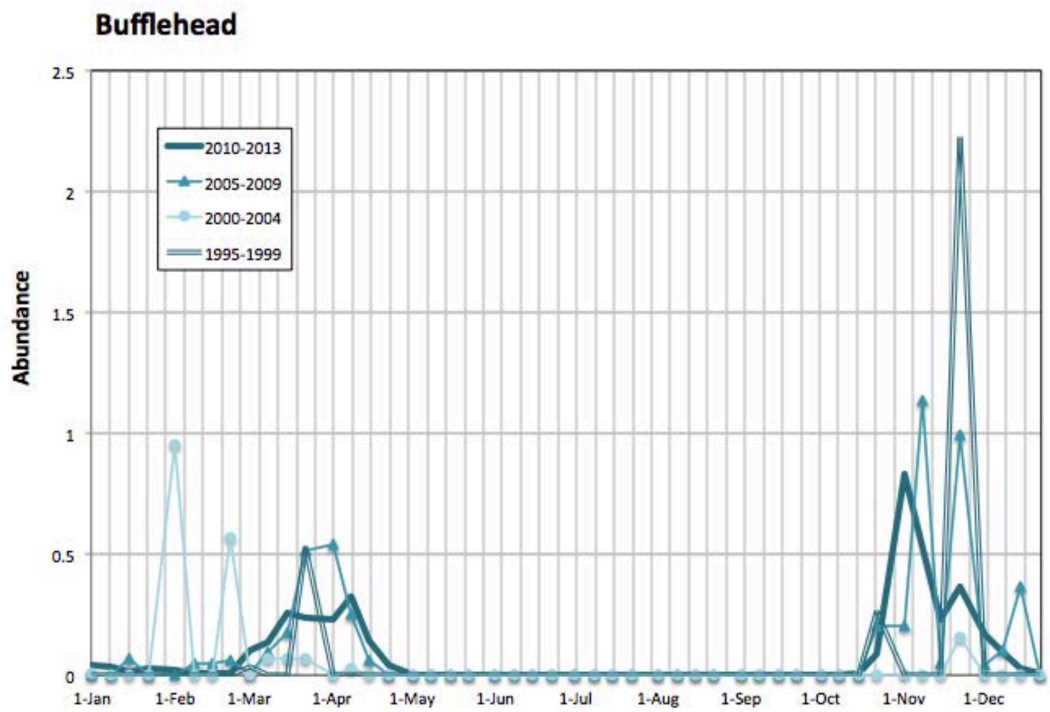


Figure 10. Plots showing the annual distribution of the Northern Pintail (*Anas acuta*). Upper graph shows data in 5-year time slices, and the lower graph in decadal slices. See text for discussion.



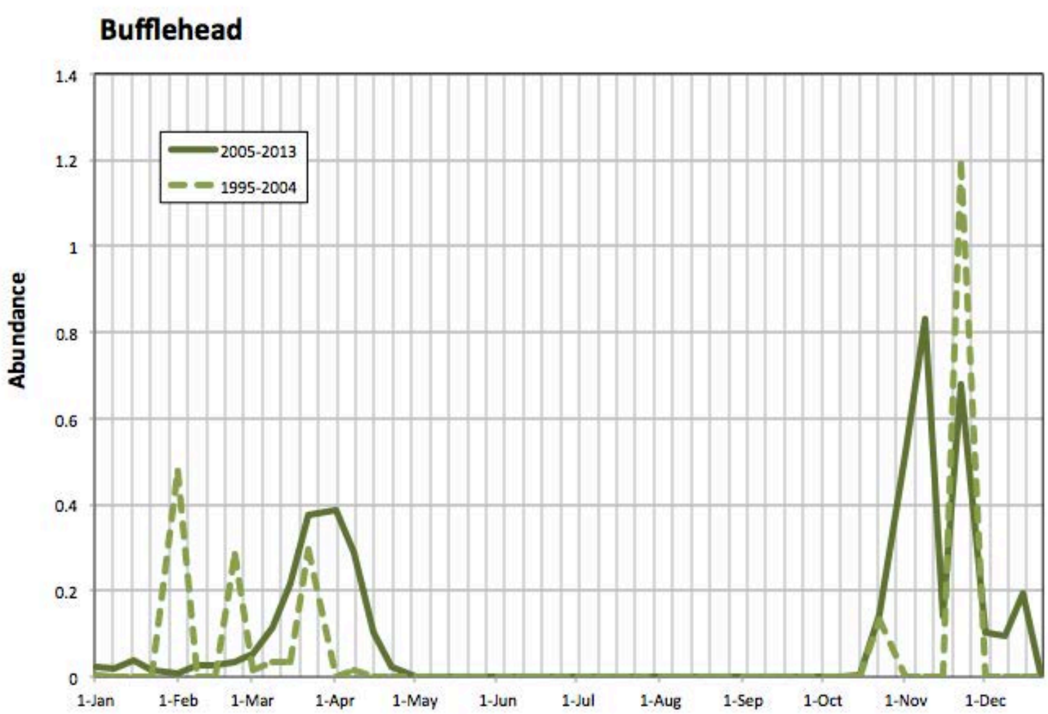
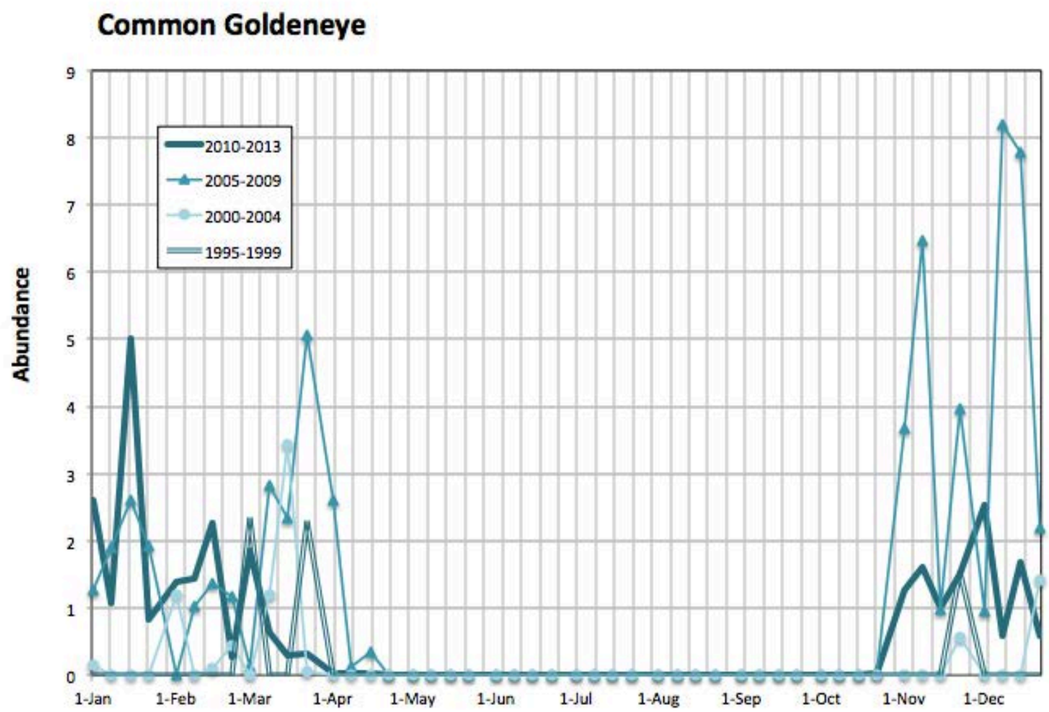


Figure 11. Plots showing the annual distribution of the Bufflehead (*Bucephala albeola*). Upper graph shows data in 5-year time slices, and the lower graph in decadal slices. See text for discussion.



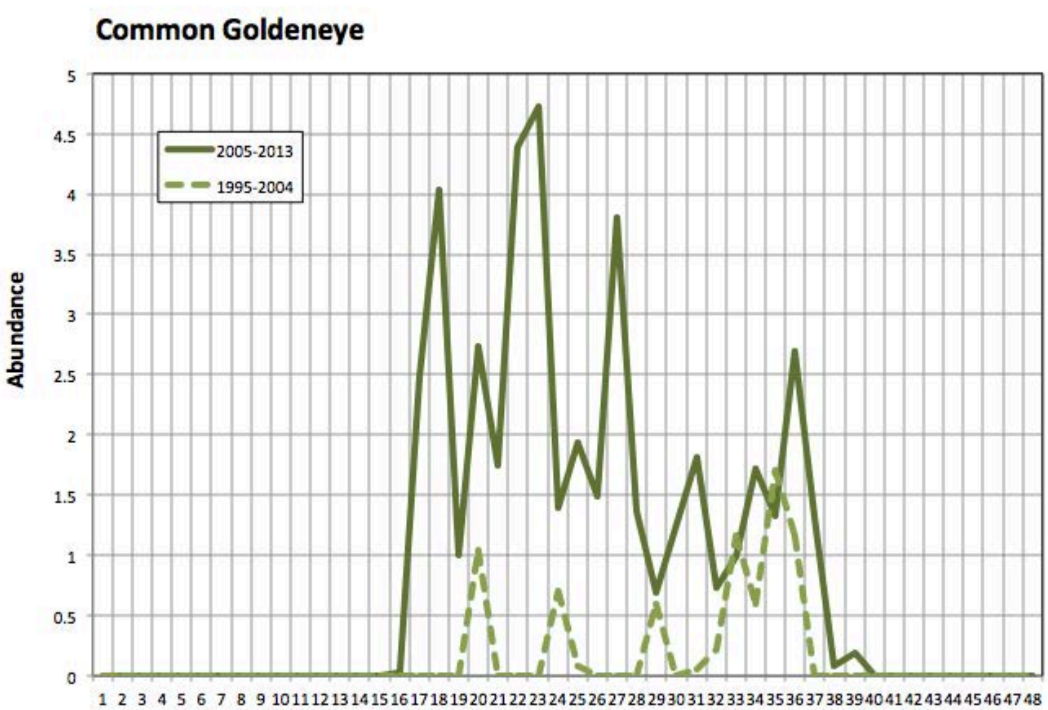
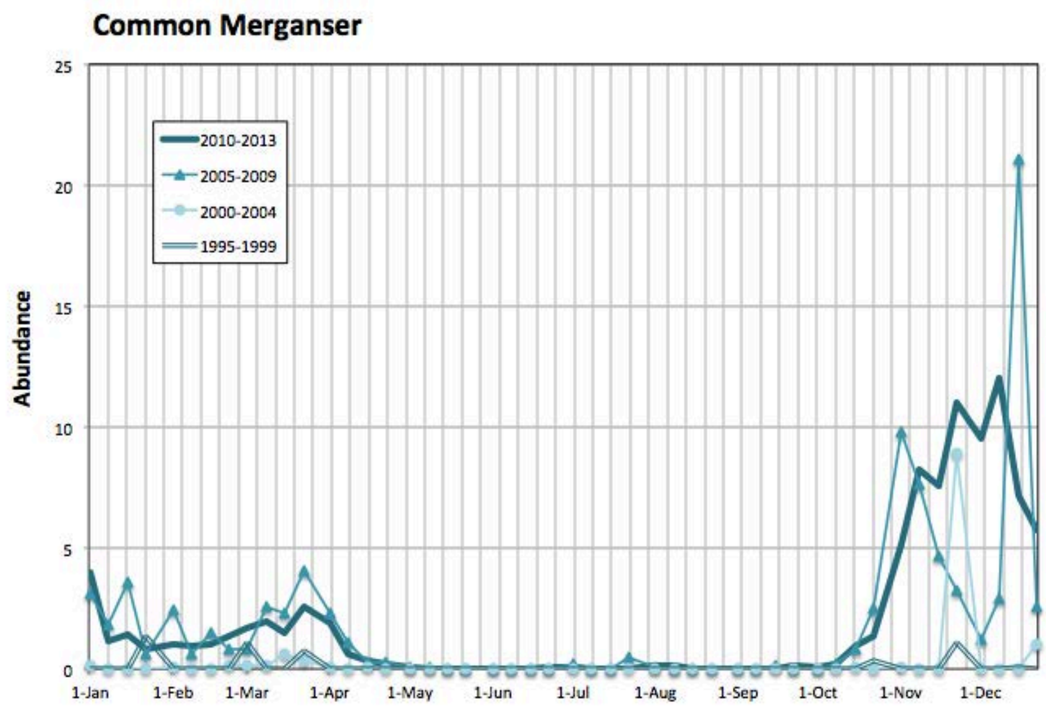


Figure 12. Plots showing the annual distribution of the Common Goldeneye (*Bucephala clangula*). Upper graph shows data in 5-year time slices, and the lower graph in decadal slices. Weeks are numbered in decadal graph (1= July 1; 25= January 1). See text for discussion.



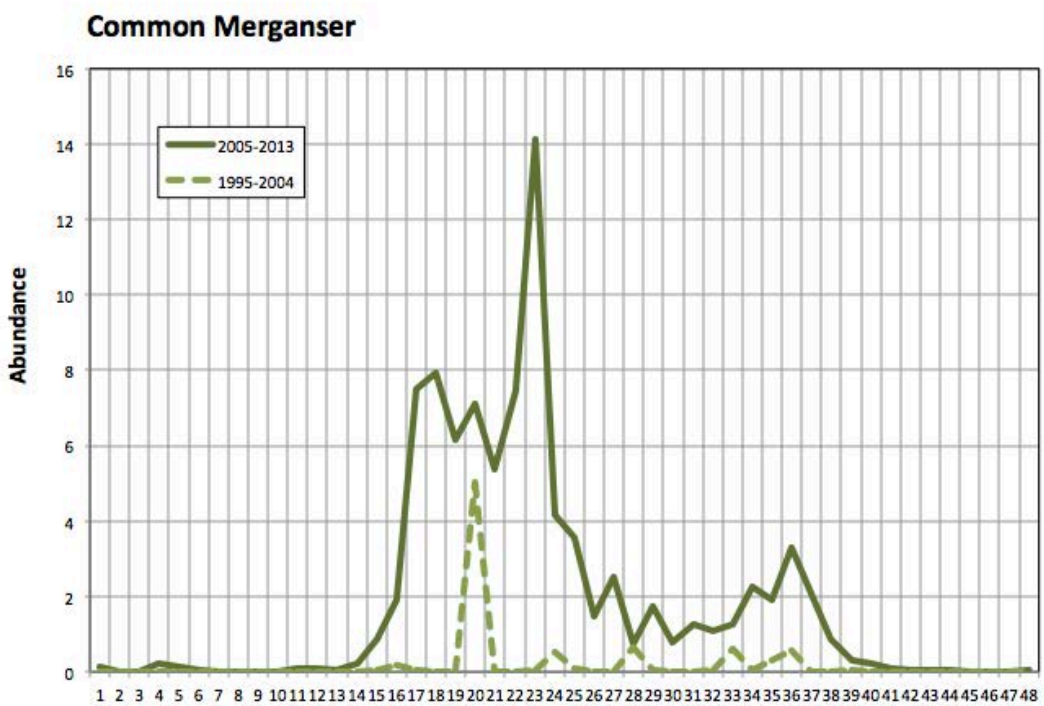
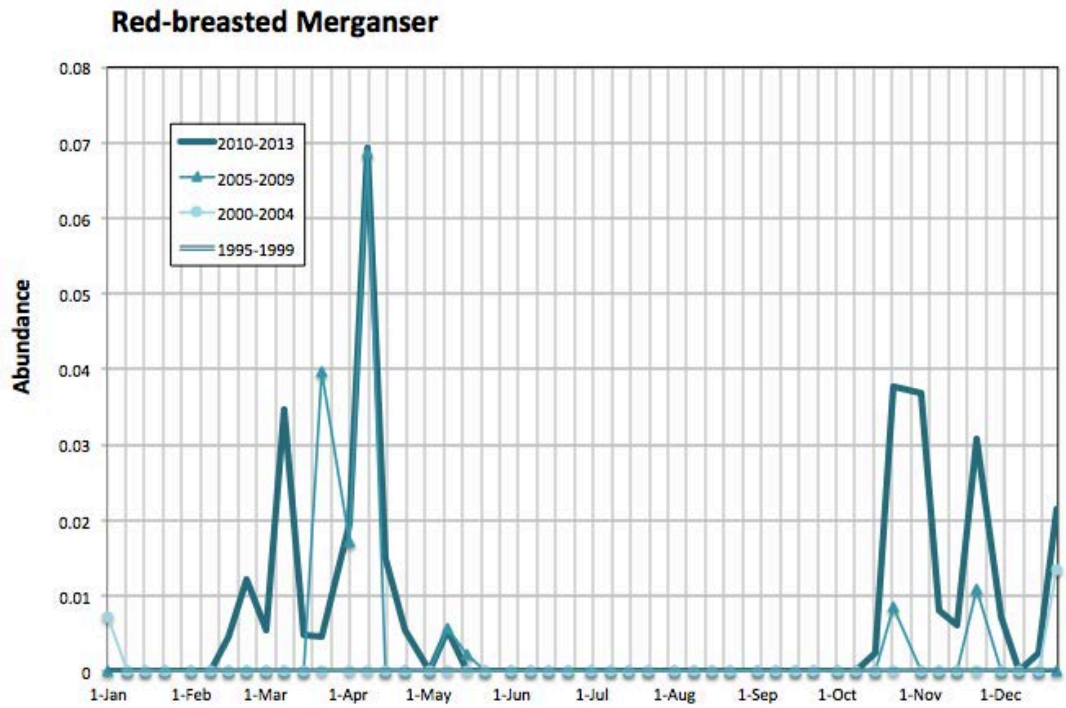


Figure 13. Plots showing the annual distribution of the Common Merganser (*Mergus merganser*). Upper graph shows data in 5-year time slices, and the lower graph in decadal slices. Weeks are numbered in decadal graph (1= July 1; 25= January 1). See text for discussion.



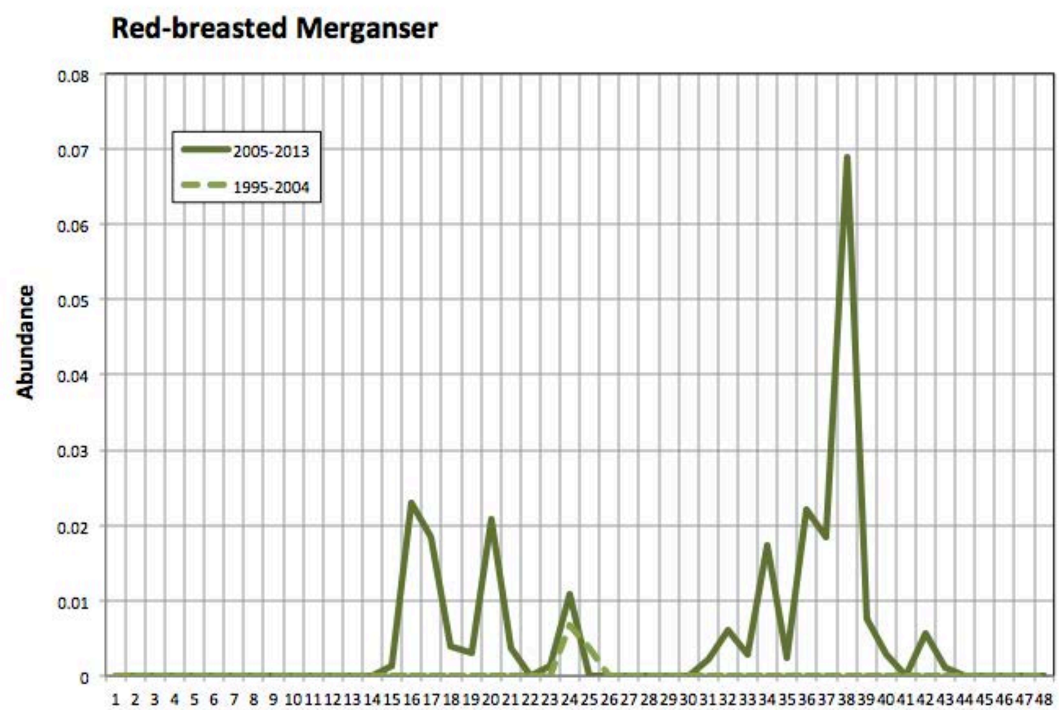
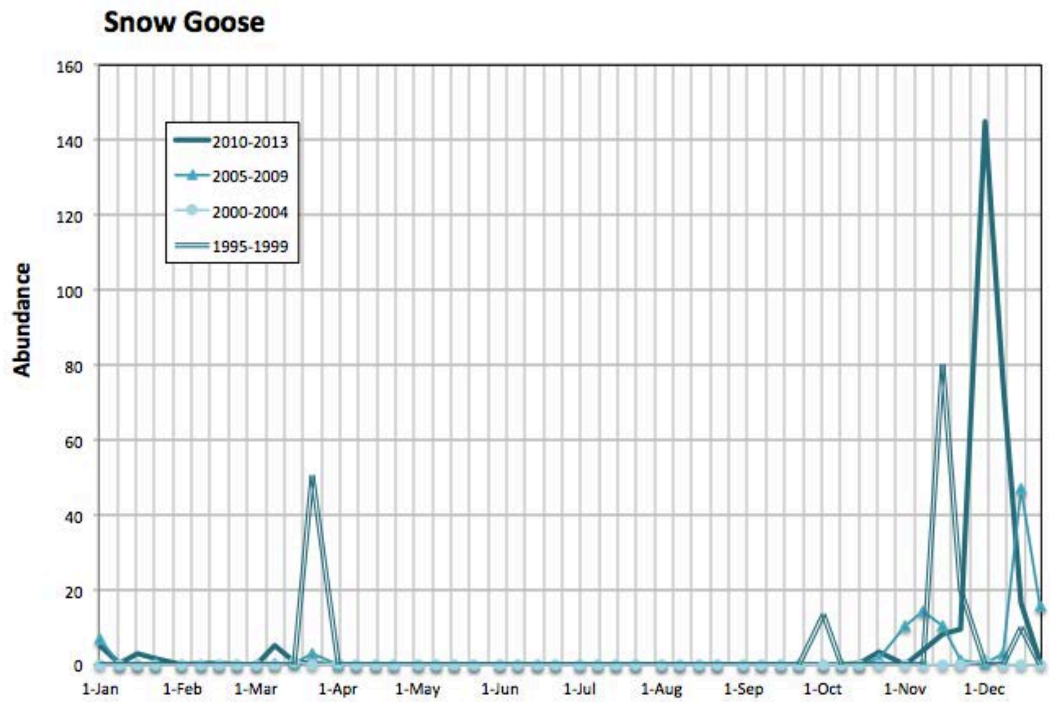


Figure 14**.** Plots showing the annual distribution of the Red-breasted Merganser (*Mergus serrator*). Upper graph shows data in 5-year time slices, and the lower graph in decadal slices. Weeks are numbered in decadal graph (1= July 1; 25= January 1). See text for discussion.



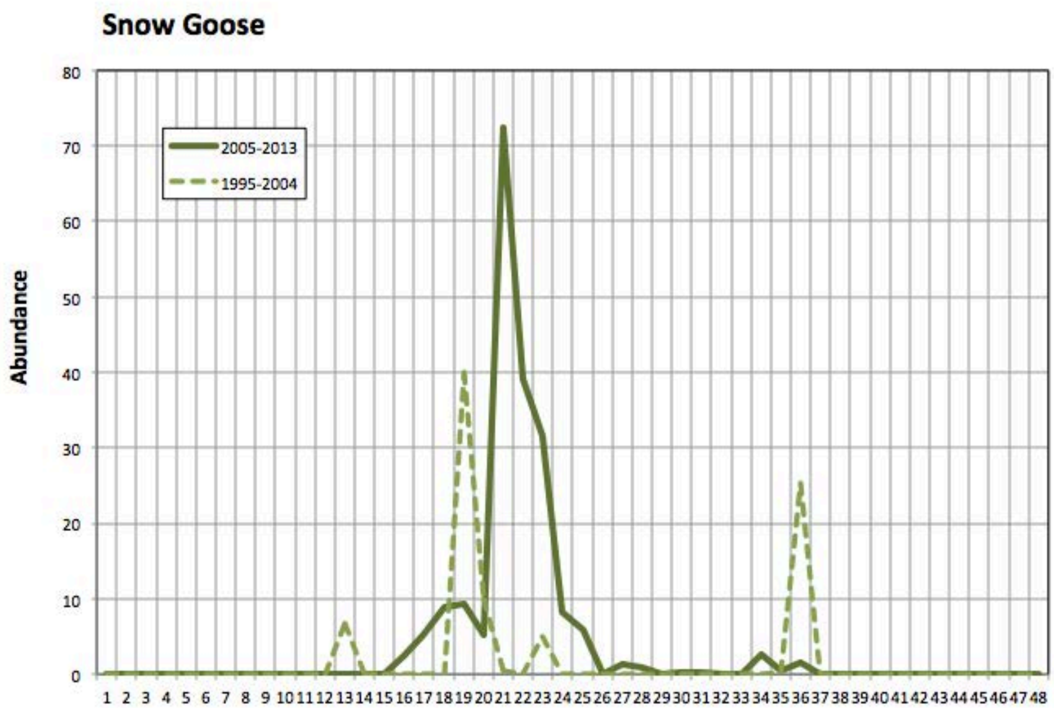
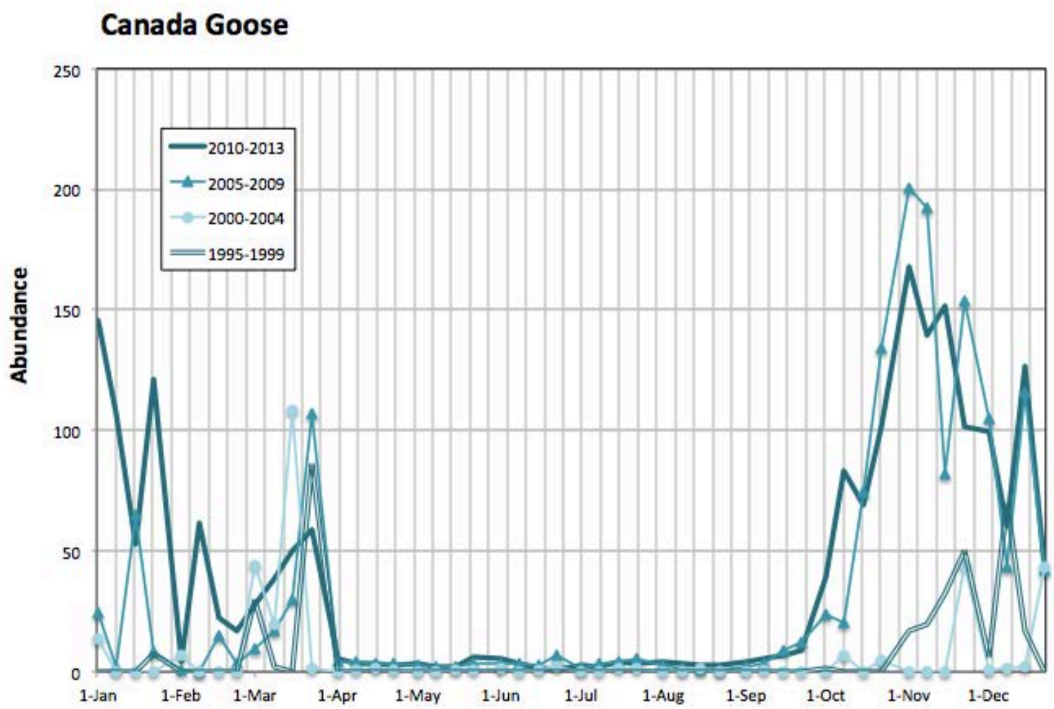


Figure 15. Plots showing the annual distribution of the Snow Goose (*Chen caerulescens*). Upper graph shows data in 5-year time slices, and the lower graph in decadal slices. Weeks are numbered in decadal graph (1= July 1; 25= January 1). See text for discussion.



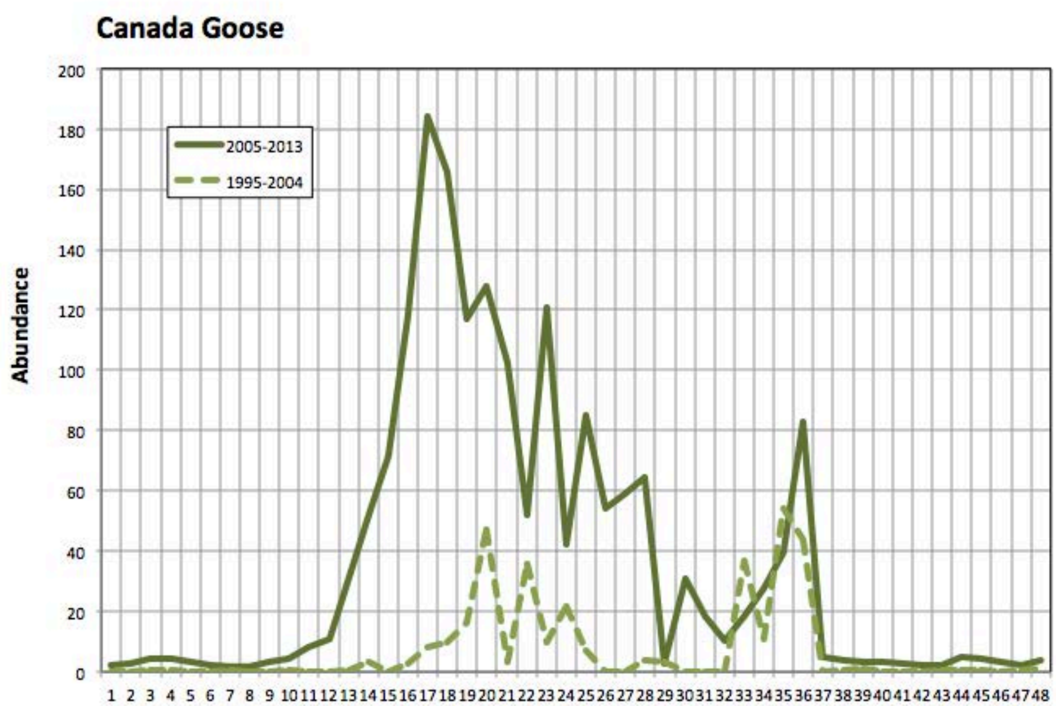
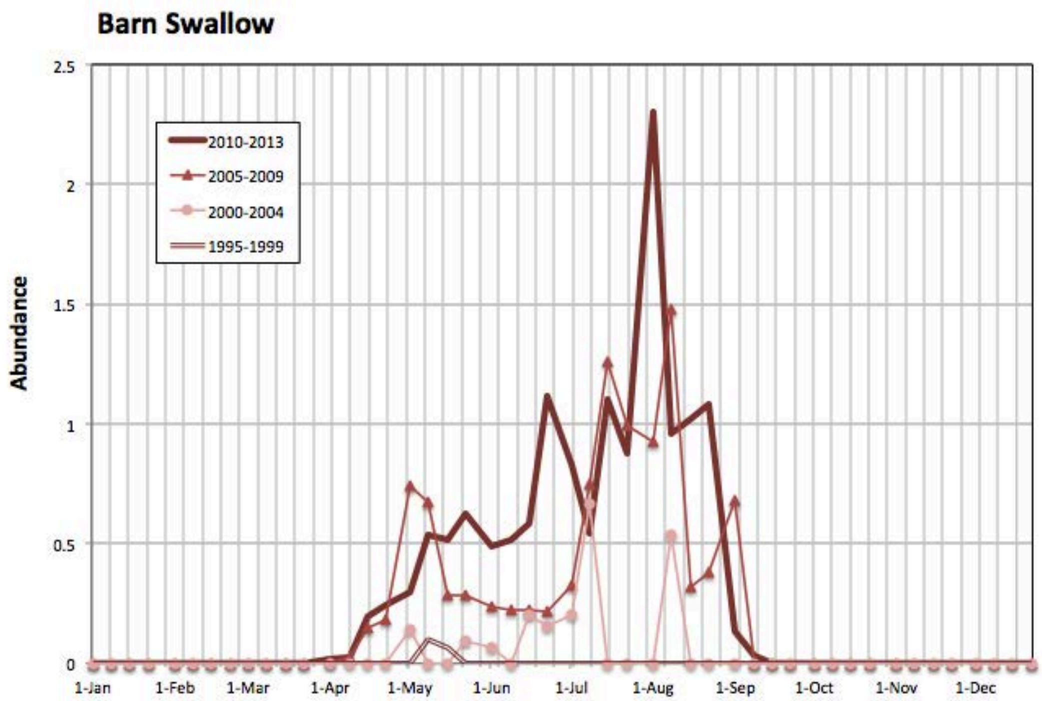


Figure 16. Plots showing the annual distribution of the Canada Goose (*Branta canadensis*). Upper graph shows data in 5-year time slices, and the lower graph in decadal slices. Weeks are numbered in decadal graph (1= July 1; 25= January 1). See text for discussion.



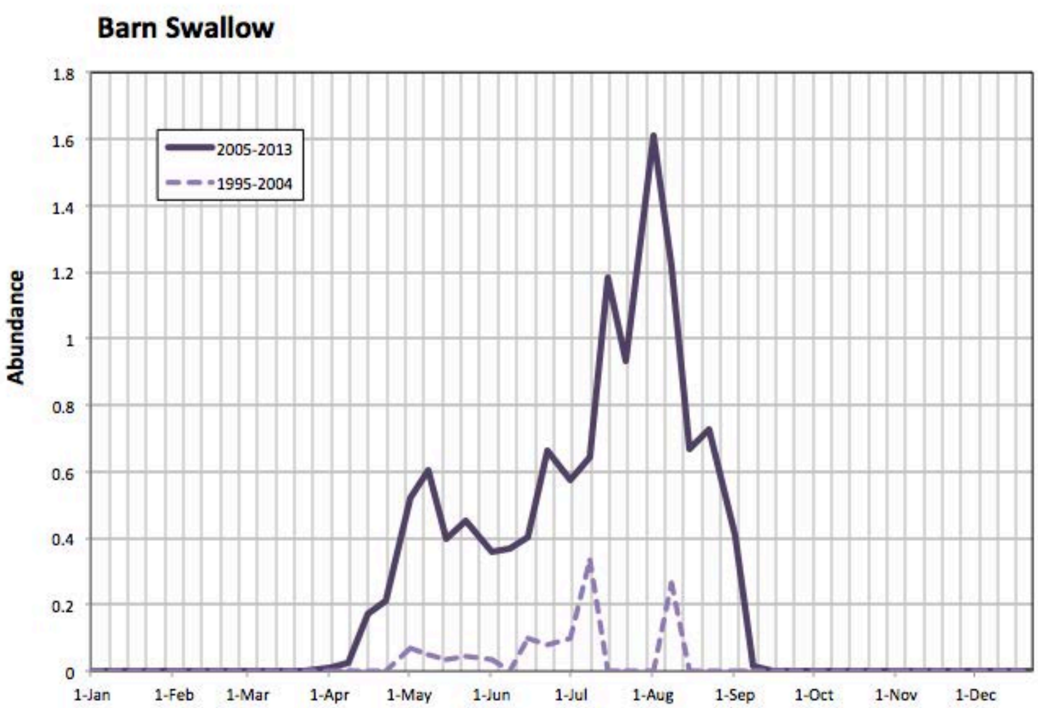
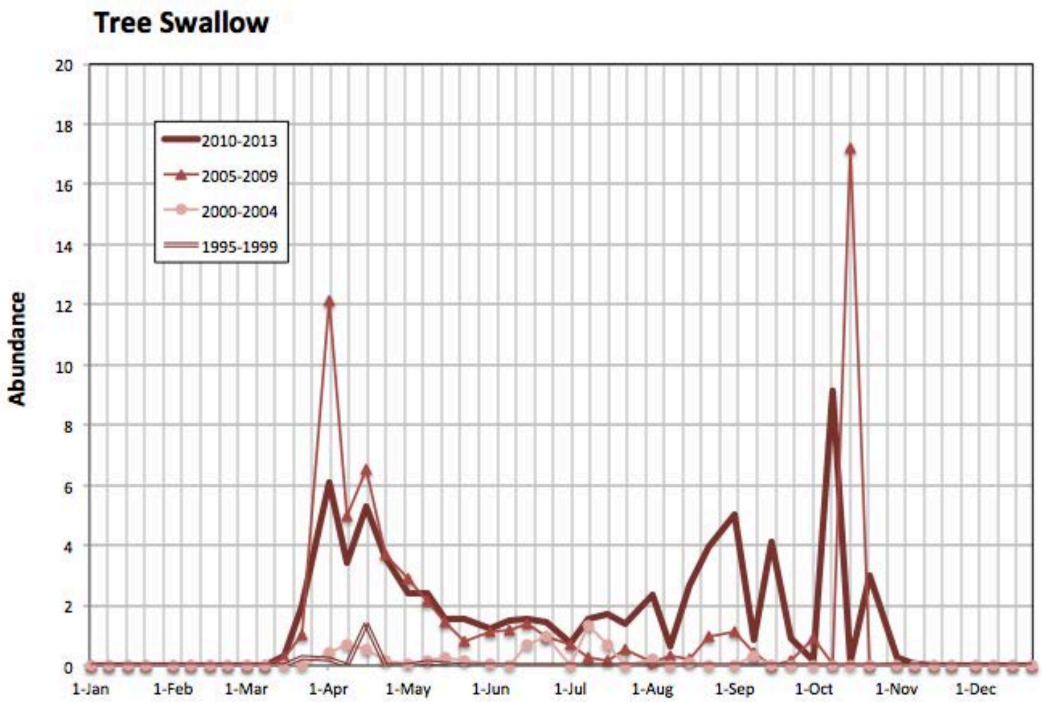


Figure 17. Plots showing the annual distribution of the Barn Swallow (*Hirundo rustica*). Upper graph shows data in 5-year time slices, and the lower graph in decadal slices. See text for discussion.



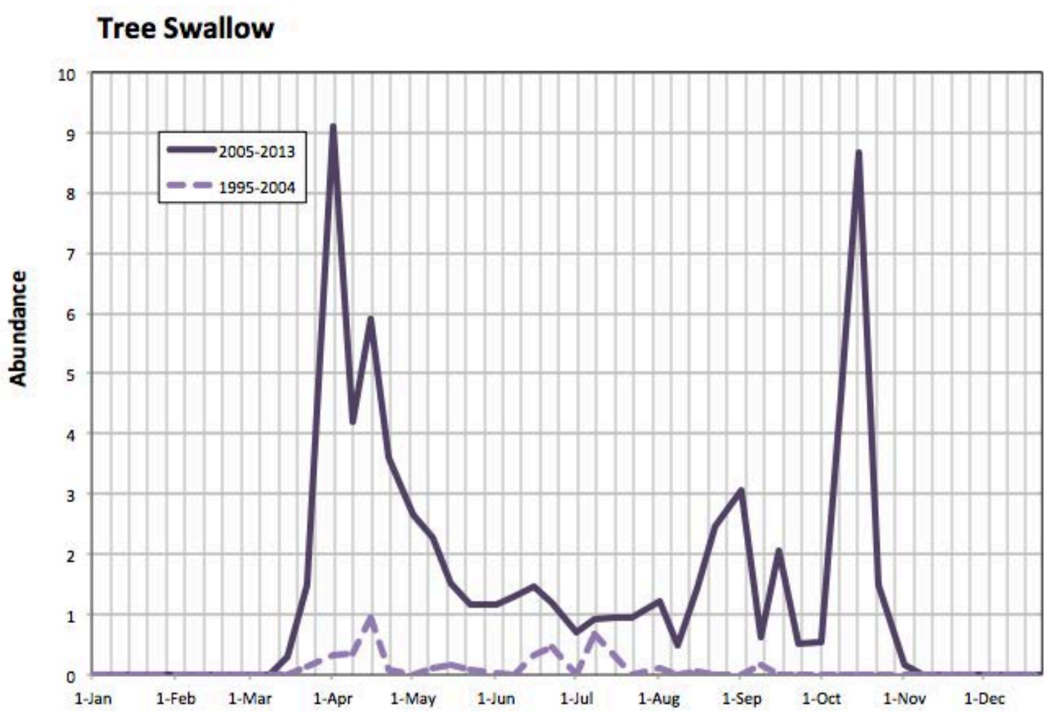


Figure 18. Plots showing the annual distribution of the Tree Swallow (*Tachycineta bicolor*). Upper graph shows data in 5-year time slices, and the lower graph in decadal slices. See text for discussion.

Green Winged Teal (*Anas carolinensis*) Spring arrivals for Green-winded teal for the two decades appear to be similar, occurring around the first week in April. In the more recent decade, fall departure may be taking place sooner at around the third week in October. In 1995-2004, fall departure is displayed approximately the second week in November; however, this data set is sparser and thus the reliability of only a few observations needs to be considered in the long-term analysis. Overall abundance for the Green-winged Teal has increased in the later decade as the average number of observations has increased by over 1400%.

Northern Pintail (*Anas* acuta) Spring arrivals of the Pintail between the two decades show no dramatic differences, both occurring between the third and fourth weeks of March. The slight difference in fall departures is more apparent, appearing to be earlier in 2005-2013. This decade displays a fall departure around the last week in October, while 1995-2004 shows departure in roughly the middle of November. The older data set is scant in comparison and shows lower abundance.

Bufflehead (*Bucephala* albeola) Spring arrival seems to be later in the last decade than 1995-2004, but the older data set has higher variability. It appears that in the last decade, the arrival of the Bufflehead occurs around the last week in March, whereas the 1995-2004 approximate arrival takes place the last week in February. There are no decipherable differences between the fall departures for the two decades, which appear to be around the end of November. The overall abundance remains similar between the two decades.

Common Goldeneye (*Bucephala clangula*) The Common Goldeneye seems to be arriving approximately two weeks earlier in the later decade, appearing in the second week in November as opposed to the last week in November in 1995-2004. The departures for both decades are roughly the same, occurring around the middle of March. The Common Goldeneye is observed in this region all winter and overall abundance has increased since the earlier decade. Both data sets display a substantial amount of variability.

Common Merganser (*Mergus merganser*) Although there is relatively little data for the earlier decade, it appears their arrival is occurring about three weeks earlier in 2005-2013, happening around the first week in November. The departure for both decades is taking place around the last week in March. This bird is present all winter and shows a greater abundance in the beginning months of its stay.

Red-breasted Merganser (*Mergus serrator*) With essentially no data for the earlier decade, conclusions cannot be made comparing arrival and departure dates. In regards to the later decade, abundance is low with high variability and no observations appear in the month of January, which is the middle of their wintering season. Arrival appears to be around the end of October and departure occurs in mid-April.

Canada Goose (*Branta canadensis*) The 2005-2013 arrival is taking place around the first week in November, approximately three weeks earlier than the previous decade. In both decades, the Canada Goose is departing in the middle of March. This species is present throughout the winter, and in the later decade, abundance never drops to zero for the entire year. There is an increase in overall abundance between the two decades with a significant peak in abundance in the beginning of November in 2005-2013.

Snow Goose (*Chen caerulescens*) Data are sparse in the earlier decade, but there are still peaks of considerable abundances. Observations occur between October and March, whereas presence in the later decade is primarily in November and December. Due to the variability of the earlier decade, arrival and departure dates cannot be discerned, however, it appears the time frame for the Snow Goose occurrence in the region is decreasing between the two decades.

Barn Swallow (*Hirundo rustica*) Spring arrival is approximately two weeks earlier in the later decade, occurring in the middle of April. It appears the Barn Swallow is also departing around two weeks later in the fall for 2005-2013. There is also a substantial increase in abundance between the two decades.

Tree Swallow (*Tachycineta bicolor*) Spring arrival appears to be in the beginning of April in 2005-2013 and mid-April in 1995-2004. There is not enough data from the earlier decade to determine fall departure differences. In the later decade, the Tree Swallow is leaving around the middle of October, and there are distinct spikes in abundance occurring at the beginning and end of the season. Within the middle of the season, between June and September, the difference in overall abundance between the two decades is not drastic.

DISCUSSION

Green-winged Teal and Northern Pintail

These two dabbling duck species share the same distribution, migration routes, habitat, and nesting types. Their similarities continue when observing the *eBird* data. Both species exhibit no shift in spring arrival between the two decades; however, the Teal's arrival is around the beginning of April whereas the arrival of the Pintail occurs sooner, typically at the end of March. This is expected, because the Northern Pintail is known for being one of the earliest nesters in North America appearing just after ice begins to melt (*All About Birds*, 2014). The Capital Region is a stopover site for these transient migrants, and it is possible observations of earlier spring arrival are occurring in other stopover sites rather than this area.

An interesting observation from the *eBird* data is the change in fall occurrence for both species, which appears to take place about three weeks earlier in the later decade. With warmer temperatures occurring in the region, birds are expected to linger longer before departing for their wintering grounds, but the Teal and Pintail display the opposite trend. A possible explanation for this shift is the change in wetland dynamics in their breeding grounds, rather than changes in the stopover region. Dabbling ducks such as the Green-winged Teal are very selective when choosing wetlands to breed near, and they tend to select those with the highest productivity and fertility (Paquette and Ankney, 1996). Egg-laying ducks have a high nutrient requirement for reproduction, especially those of smaller size like the Green-winged Teal that cannot deposit nutrients by means of fat reserves (Paquette and Ankney, 1996). Many ducks are therefore income breeders,

obtaining the energy required for reproduction after arriving at the breeding grounds (unlike capital breeders such as geese, which build up fat stores prior to migration for immediate reproduction upon arrival) (Houston et al., 2007). Because they are income breeders, dabbling ducks rely heavily on the productiveness of their wetland habitat to breed in a timely manner.

Freshwater wetlands are projected to be particularly vulnerable to climate change (Bethke and Nudds, 1995). The shallow depth of wetlands leads to high evaporation rates when temperatures are warmer (Drever and Clark, 2007), which puts them at high risk as a result of climate change. If temperatures continue to increase, the food supply for dabbling ducks in their breeding grounds may diminish earlier in the season. This could lead to greater nest abandonment rates and earlier departure from the breeding grounds, and consequently their earlier fall appearance in the stopover region. The long-term effects may include population decline if resources in the breeding grounds are starting to reduce, and the Northern Pintail specifically is losing numbers from pressures such as climate and agricultural expansion (Podruzny et al., 2002).

Sightings for the Green-winged Teal and Northern Pintail in *The Birds of New York* are too scattered to make decisive comparisons, but Dayton Stoner's records provide a substantial number of spring arrival dates for the two species. Between the 1920's-1940's, arrivals for the Green-winged Teal occur at the end of April, so it appears there is a steady trend into the most recent decade where the arrival is at the beginning of April. This gradual continuation is analogous to the Northern Pintail, except the Pintail's arrival is

occurring a couple weeks earlier. In the 1920's-1940's the appearance of the Pintail was taking place all over the month of April and is now at the end of March.

Bufflehead

The Bufflehead appears to be passing through the Capital District and departing for the north approximately a month later in the last decade. Buffleheads spend winters on coastlines, bays, reservoirs, and lakes—anywhere with open water. They are diving ducks that forage underwater for food, and thus rely on the availability of open water to feed (*All About Birds*, 2014). With projected earlier ice-out dates and number of winter break-up events in the Mohawk Watershed (Cockburn et al., 2009), it is possible the Buffleheads are merely lingering longer out of convenience and taking advantage of the open water to acquire energy on their way up north.

Complex relationships between species may complicate simple explanations between species. A potential explanation for the delay in spring migration of the Bufflehead involves its relationship with Northern Flickers. Buffleheads nest primarily in cavities made by Northern Flickers, one of the few North American woodpeckers that are strongly migratory (*All About Birds,* 2014). An interesting topic of future study could be looking at correlations between these two species' migrations and whether or not the Northern Flicker is influencing the Bufflehead's later departure.

The return sightings from the breeding grounds begin in early November for both decades. Buffleheads in particular show a high degree of phenological precision in their life cycle and are punctual fall migrants (Finley, 2007). During the 1970's, the estimated fall movement began around October 20th and peak migration was concentrated in the first

week of November, which is fairly consistent with the trend today, forty years later (Finley, 2007). This stable fall movement may suggest that the time of freeze-up for Canadian lakes and ponds has remained constant. It appears the increases in Canadian temperatures are occurring in the winter, therefore greater influencing break-up dates than freeze-up dates (Duguay et al., 2005). It may also suggest that the birds respond to diurnal cycles or some other external trigger besides climate that prompts migration.

Looking at historic data, the Bufflehead's spring appearance in the region occurs between the middle and end of April. The most recent decade's appearance is at the end of March and 1995-2004 is approximately the last week in February. These findings suggest that the Bufflehead is rather variable in regards to spring occurrence in the region. *The Birds of New York* and Dayton Stoner records show a fall migration taking place between the middle of October and end of November, which is consistent with the *eBird* data. The Bufflehead displays a stable fall movement even as far back as the early 1900's.

<u>Common Goldeneye</u>

Also a diving duck, the Common Goldeneye does not appear to show differences in spring migration between the two decades, departing for the breeding grounds around the middle of March in both. However, it is displaying a shift in fall migration, returning from the north approximately two weeks earlier in the last decade. The Goldeneye and Bufflehead share the same diet, range, habitat, and nesting type, so why would the Goldeneye leave for the Arctic earlier and also return from the Arctic sooner than the Bufflehead? In addition, their spring and fall appearances in the region were very similar from 1995-2004, so this divergence only took place within the last decade.

The deviation in migration schedules could simply be a method to reduce interspecies competition, especially between two birds that exploit precisely the same resources. It is also important to note that the Goldeneye shows overwintering in the region whereas the Bufflehead demonstrates transience, which is not surprising given the fact that the Capital Region is near the northern range of the Bufflehead's wintering distribution and migration range (see *All About Birds,* 2014). This slight dissimilarity in wintering grounds could influence the difference in their migration activity.

In general, the duration and timing of migrations vary among species, and even among conspecific individuals due to differences such as body condition, stopover activity, and breeding success (Arzel, et al., 2006). This overarching idea may simply be the explanation for the migration differences displayed between the Goldeneye and Bufflehead.

Spring sightings in *The Birds of New York* and Dayton Stoner records occur over a broad range from mid-March to mid-April. In the two most recent decades, spring appearance takes place in the middle of March, suggesting that there has not been much variability since the early 1900's. Likewise, historic Goldeneye fall sightings occur in the middle of November, which is also comparable to the *eBird* data.

<u>Common Merganser</u>

It appears the Common Merganser is returning through the Capital Region from its breeding grounds roughly three weeks earlier in the last decade. The departure time in the spring remains similar between the two decades, taking place at the end of March. Like the Bufflehead and Goldeneye, the Common Merganser is a diving duck (feeding mainly on fish) and nests in tree cavities in Canada and Alaska. The Common Merganser prefers

freshwater to saltwater, and forms resident populations wherever water remains open (National Audubon Society, 2014). By arriving three weeks earlier, this species may be starting to extend its stay in the region, which is already on the border of its resident/wintering boundary (see *All About Birds*, 2014). This is rather weak speculation, however, and interpretation is complicated by the fact that the abundance of the Common Merganser in the region is relatively low.

Historic data for the Common Merganser is quite scattered. Spring departure for the breeding grounds occurs all over the month of March in the early and mid-1900's. This is fairly consistent with the *eBird* data, however, where northward departure occurs at the end of March. Fall sightings are too dispersed to make any pivotal connections to the *eBird* data, showing instances in November and December.

<u>Red-breasted Merganser</u>

There are virtually no sightings of the Red-breasted Merganser in the region during the earlier decade. The later decade shows more evidence of sightings, but these are extremely variable with the highest abundance only reaching 0.07 birds/outing. Unlike other merganser species, the Red-breasted Merganser prefers saltwater and therefore winters mainly along coasts. In addition, its inland migratory flights typically occur at night (National Audubon Society, 2014). For these reasons, this species is not commonly seen in the Capital Region. However, the number of observations significantly increased between the two decades, so there may be interesting outcomes from continuing to monitor its presence in the region.

In the early and mid-1900's, spring and fall sightings in the region are limited and therefore rather variable. Sightings are scattered among the months of March, April, and May in the spring and September, October, and November in the fall.

Collectively, the merganser species are quite uncommon in the Capital District, yet they still exhibit interesting change between the last two decades in regards to abundance and timing. With the data available at this time, decisive conclusions cannot be made about the mergansers, but there is potential for ones to be made in the future.

Snow Goose

Although sightings of the Snow Goose were few in the earlier decade, there were still a large number of observations from October to March, whereas the majority of observations in the later decade occur in November and December. Therefore, the Snow Goose may be decreasing its wintering time in the region and increasing its breeding season in the Arctic between the two decades. Snow Geese nest on low, grassy tundra shortly after snow and ice melt away, and they graze on farmland and marshy vegetation (Sibley, 2003). The hastening of Arctic melting and decrease in ice cover due to warmer temperatures may consequently trigger the earlier arrival of the Snow Goose to its breeding grounds.

In particular, the Arctic tundra is an environment with high seasonality and limited food availability, which puts restrictions on breeding. Earlier arrival leads to greater reproductive success in this variable environment because food availability will be at its peak, leading to optimal feeding conditions for young (Bêty et al., 2004). It was initially perceived that the availability of open water may be influencing this waterfowl's arrival,

however, it appears the melting of Arctic ice may have more important impacts on terrestrial nesting and feeding.

In addition to earlier arrival, the Snow Goose appears to be extending its stay in the Arctic. Fall departure is not as heavily studied, but it is possible the warming of the Arctic is increasing food availability later into the season and allowing the birds to stay longer. Also, winter Arctic ice formation is now occurring later in the season (Arctic Report Card, 2013), and this may drive exposure of nearby tundra for a longer period of time.

Abundance of the Snow Goose substantially increased between the past two decades, and the population growth of the Snow Goose in North America is a topic of growing concern. Over the past few decades, the Snow Goose population has increased dramatically and grew twice as fast in the last third of the 20th century than the first two thirds (Gauthier et al., 2005). It is suggested that the spike in population is attributed to a change in diet. Wintering geese now heavily feed on farmlands, particularly grazing on abundant spilled corn (Gauthier et al., 2005). This shift from marshland to farmland habitat was followed by a northward change in wintering distribution as well, and now Snow Geese are practically absent from southern states. Thus this shift in the numbers and temporal distribution may be related to farming practices as opposed to climate.

Pre-migratory condition heavily influences breeding success. Birds that arrive to breeding grounds with insufficient fat stores must adequately feed themselves before caring for young (Gauthier et al., 2005). The newfound abundance of food in the wintering grounds is likely increasing fat stores in geese, and they now arrive to their breeding grounds with improved body condition (Gauthier et al., 2005). This combination of earlier

arrival and enhanced body state is likely increasing the reproductive success of Snow Geese.

There are no historic records of Snow Goose sightings in the Capital Region in either *The Birds of New York* or Dayton Stoner's records. This result could either be due to the smaller or non-existent Snow Goose population at the time, a more southern wintering distribution, or a flyway that bypassed this part of NY State.

Canada Goose

The Canada Goose appears to be returning from the north roughly three weeks earlier in the last decade, unlike its Snow Goose relative that is remaining in the Arctic tundra longer in the fall. This observation is somewhat perplexing, but may be due to its overwhelming population size. Foraging conditions naturally decline later in the breeding season as the overall number of birds that need to eat increases with offspring and plant quality and abundance decrease with falling temperature (Sedinger and Raveling, 1986). The population of Canada Geese is so large and continuing to grow that foraging conditions may be declining more rapidly, thus driving an earlier departure. Also, Canada Geese are increasingly forming resident populations that remain in a region all-year round as long as open water and nutritional resources are available (*All About Birds*, 2014). If there are already residential areas with plenty of resources during the colder months, why not return earlier?

Spring departure appears to be similar between the two decades, taking place in the middle of March. Spring departure is particularly difficult to track due to over-wintering birds (*All About Birds,* 2014) and therefore the observations are likely skewed.

Like the Snow Goose, the Canada Goose population is dramatically increasing to the point where they are now regarded as a pest (*All About Birds,* 2014). In addition, its distribution is shifting northward (O'Connor et al., 2004). These changes are once again due to agricultural practices creating a shift in diet, allowing the geese to exploit abundant resources.

Also like the Snow Goose, there are essentially no records of sightings for the Canada Goose in *The Birds of New York* or Dayton Stoner records. This is rather surprising, considering the Canada Goose is known for being a common species in the region. However, due to its more current northward shift in wintering distribution, it is possible the wintering grounds were far enough south in the early 1900's to reduce the number of sightings during that time period.

Swallows

In eastern NY, the Barn Swallow appears to be arriving two weeks earlier and departing two weeks later, expanding its overall breeding season in the region by about one month in the last decade. Temperature most likely has an indirect effect on the Barn Swallow's migration by influencing the emergence and peak abundance of insects (Huin and Sparks, 1998). Food availability is the principle factor influencing the time of breeding season in birds, and they typically will not arrive until their food source is stable (Daan et al., 1988). With the decrease in mean winter temperatures (and mean low temperatures), projected decrease in the snow season, and increase in the growing season, insects are expected to appear earlier in the spring, thus hastening a reliable food source for the Swallow.

Likewise, the Tree Swallow's earlier arrival may be interpreted as a response to the advancement in the timing of insect abundance. In fact, studies show that Tree Swallows across North America started breeding nine days earlier between 1959-1991 in correlation with advanced vegetation and insect activity (Dunn and Winkler, 1999). These fellow insectivores rely on the availability of their prey to begin breeding and will be impacted by the change in plant phenology and air temperature affecting the timing of insect emergence.

Assessment cannot be made regarding the fall departure of the Tree Swallow because of lack of data. However, the Barn Swallow appears to be lingering in the region about two weeks longer. It is possible warmer temperatures are also lengthening the abundance of insects into the fall, delaying the need for birds to leave.

An important aspect of this finding is the possibility of an increase in offspring due to a longer season. The increase in food availability may lead to multiple broods. Swallows typically have two broods per breeding season, but earlier arrival and available resources may allocate time for a third brood that could postpone their departure (Grüebler and Naef-Daenzer, 2008). The time commitment from egg laying to fledging is approximately 45 days (Gill, 2006), and with the Barn Swallow's breeding season encompassing about five months in the later decade, this leaves enough time for three broods. Thus it is possible that the earlier arrival will correspond to an increase in productivity, and therefore abundance in the coming years.

When compared to *The Birds of New York* and Dayton Stoner data sets, it appears the major shift in migration of the Barn Swallow occurred within the past decade. Between

1900-mid 1940's, the Barn Swallow's arrival gradually changed from the beginning of May to the end of April, similar to the data from 1995-2004 (see *The Birds of New York* and New York State Education Dept. Research Library). This finding suggests spring arrival was on a slow, steady trend until the two-week jump that has been observed in the last decade.

The comparison between historic data sets and the *eBird* data for the Tree Swallow is similar, except it is arriving earlier than the Barn Swallow. From 1900-mid 1940's, spring arrival shifted from the end of April to the beginning of April, again analogous to 1995-2004 from *eBird*. In the last decade, the Tree Swallow's spring appearance appears to be at the end of March, suggesting a jump in arrival date.

CONCLUSION

Avian migration is a complex behavior, and there are several influential factors besides climatic conditions. Migration is still heavily controlled by photoperiod, which serves as an indicator for mating activity and molting time (Sokolov, 2006). Unlike temperature and precipitation, photoperiod is a constant feature unaffected by climate change. This must be recognized when studying this topic because in addition to food supply, photoperiod is a major trigger to begin migration. There is also a cost/benefit equation to early arrival in the breeding grounds. With increased temperatures, plant activity and food supply earlier in the season, it may be speculated that birds will migrate sooner. However, factoring in the potential costs of early migration makes the optimal response less obvious. These costs include competition for territories and risk of pre-breeding mortality (Jonzén et al., 2006). Climatic conditions undoubtedly influence birds'

phenology, but it is important to acknowledge the other elements that are going to influence migration.

Overall, shifts in trends in the Capital Region are not straightforward with delays and advances in both spring and fall migration in the last decade. Nonetheless, there are shifts. Temperature, precipitation, and ice changes in New York State are currently small in relation to climate change, but are projected to increase in the future. The birds in this study are showing potential responses to these changes, whether directly in regards to availability of open water or indirectly from alterations in abundance of food. Observational data were limited for this study and therefore resulted in trends that are not absolute. However, in hopes that the data pool continues to increase, there may be more notable migration changes in the future.

Climate change is becoming an increasingly important topic in scientific research. Relationships between the phenology of migratory species and climate change are heavily studied, but not on such a fine scale as this study. Typically assessed at large-scale perspectives, such as global or hemispheric standpoints, climate change in fact can have even finer impacts. The next step may therefore be further exploration into phenological changes on local levels. Public awareness may grow if there is evidence of significant change occurring in such a local domain.

What is the future for *eBird* and citizen science in general? Compiling data from *eBird* and other public observations was a key feature of this study to test citizen science's potential for detecting environmental change on a small scale. The purpose of citizen science is to engage non-professionals in authentic ecological research by tracking

biological changes, which can then be used by scientists and researchers (Havens and Henderson, 2013). Especially with increased interest in how climate change is affecting community structure, it is imperative to gather this type of data and mine older records to understand what changes are taking place. Strictly using *eBird* and other forms of observational data, this study confirmed the ability of citizen science to reveal environmental change. If public participation in scientific research continues to increase, it will substantially transform the range of data available to researchers on local and global scales (Newman et al., 2012). It will also hopefully provide a better level of understanding for professionals and the general public alike regarding transformations happening in the environment.

REFERENCES

Arctic Report Card. 2013. NOAA Arctic Research Program. http://www.arctic.noaa.gov/reportcard/index.html

Arzel, C. et al. 2006. Ecology of spring-migrating Anatidae: a review. Journal of Ornithology 147: 161-184.

Bethke, Raymond W. and Nudds, Thomas D. 1995. Effects of Climate Change and Land Use on Duck Abundance in Canadian Prairie-Parklands. Ecological Applications 5(3): 588-600.

Bêty, Joël et al. 2004. Individual variation in timing of migration: causes and reproductive consequences in greater snow geese (*Anser caerulescens atlanticus*). Behavioral Ecology and Sociobiology 57(1): 1-8.

Bird Guide, All About Birds. Cornell Lab of Ornithology.

Climate Extremes: Recent Trends with Implications for the National Security. October 2012. Harvard University Center for the Environment.

Cockburn, Jaclyn M.H. et al. Current Trends and Future Possibilities: Monitoring for the Future and How Watershed Dynamics May be Affected by Global Climate Change. 2009 Mohawk Watershed Symposium. 27 March 2009.

Crick, Humphrey Q.P. 2004. The impact of climate change on birds. Ibis 146: 48-56.

Daan, Serge et al. 1988. Food supply and the annual timing of avian reproduction. Proceedings of the International Ornithological Congress 19: 392-407.

Dickinson, Janis L. et al. 2012. The current state of citizen science as a tool for ecological research and public engagement. Frontiers in Ecology and the Environment 6(10): 291-297.

Drever, M. C. and Clark, R. G. 2007. Spring temperature, clutch initiation date and duck nest success: a test of the mismatch hypothesis. Journal of Animal Ecology 76(1): 139-148.

Duguay, C.R. et al. 2005. Recent trends in Canadian lake ice cover. Hydrological Processes 20: 781-801.

Dunn, P.O. and Winkler, D.W. 1999. Climate change has affected the breeding date of the tree swallows throughout North America. Proceedings of the Royal Society B 266: 2487-2490.

Finley, James K. 2007. The Punctual Bufflehead, *Bucephala albeola*: Autumn Arrivals in Shoal Harbour Sanctuary, Vancouver Island, in Relation to Freeze-up. The Canadian Field-Naturalist 121(4): 370-374.

Garver, John I. A Changing Flight Schedule for Ducks and Geese in the Mohawk Watershed, New York. 2013 Mohawk Watershed Symposium. 22 March 2013.

Garver et al. Historical Landslides and Precipitation Trends in Schenectady County, Mohawk River Watershed, NY. 2010 Mohawk Watershed Symposium. 19 March 2010.

Garver, John I. and Cockburn, Jaclyn. Changes in the Hydrology of the Mohawk Watershed and Implications for Watershed Management. 2011 Mohawk Watershed Symposium. 18 March 2011.

Gauthier, Gilles et al. 2005. Interactions between land use, habitat use, and population increase in greater snow geese: what are the consequences for natural wetlands? Global Change Biology 11(6): 856-868.

Gill, Frank. Ornithology, 3rd Edition. W.H. Freeman & Company, 2006.

Grüebler, M.U. and Naef-Daenzer, B. 2008. Postfledging parental effort in barn swallows: evidence for a trade-off in the allocation of time between broods. Animal Behavior 75(6): 1877-1884.

Havens, K. and Henderson, S. 2013. Citizen Science Takes Root American Scientist 100(5): 378-385.

Houston, A. I. et al. 2007. Capital or income breeding? A theoretical model of female reproductive strategies. Behavioral Ecology 18(1): 241-250.

Huin, N. and Sparks, T.H. 1998. Arrival and progression of the Swallow *Hirundo rustica* through Britain. *Bird Study* 45: 361-370.

IPCC Fifth Assessment Report. Climate Change 2013: The Physical Science Basis.

Jonzén, Niclas et al., 2006. Climate change and the optimal arrival of migratory birds. Proceedings of the Royal Society B 274: 269-274.

Lincoln, Frederick C. Migration of birds. No. 16. Government Printing Office, 1999.

Magnuson, J. J. et al., 2000. Historical trends in lake and river ice cover in the Northern Hemisphere. *Science,* 289: 1743–1746.

McColl, Robert W. Encyclopedia of world geography. Vol. 1. Infobase Publishing, 2005.

National Audubon Society, Inc. 2014. http://www.audubon.org

New York State Education Department, Research Library. http://www.nysl.nysed.gov/scandocs/birdsofny.htm

Newman, G. et al. 2012. The future of citizen science: emerging technologies and shifting paradigms. Frontiers in Ecology and the Environment 6(10): 298-304.

O'Connor, R. J. et al. 2004. Atlas of climate change effects in 150 bird species of the Eastern United States. USDA Forest Service.

Paquette, Gil A. and Ankney, C. Davidson. 1996. Wetland Selection by American Green-winged Teal Breeding in British Columbia. The Condor 98(1): 27-33.

Podruzny, K. M. et al. 2002. Long-term response of northern pintails to changes in wetlands and agriculture in the Canadian Prairie Pothole Region. The Journal of Wildlife Management 66(4): 993-1010.

Rosenzweig et al. November 2011. Response to Climate Change in New York State (ClimAID). Report 11-18. NYSERDA.

Sedinger, J. S. and Raveling, D. G. 1986. Timing of nesting by Canada Geese in relation to the phenology and availability of their food plants. The Journal of Animal Ecology 55(3): 1083-1102.

Sibley, David Allen. The Sibley Field Guide to Birds of Eastern North America. Andrew Stewart Publishing, 2003.

Sokolov, L.V. 2006. Effect of global warming on the timing of migration and breeding of passerine birds in the 20th century. Entomological Review 86(1): 59-81.

University of Iowa, Department of Geoscience.

U.S. Fish and Wildlife Service. Migratory Bird Program. 2013. http://www.fws.gov/migratorybirds/flyways.html