How Temperature Rise Effects Migratory Patterns in the Atlantic Flyway

Photo: Peter Ahl

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Internship at Back Bay National Wildlife Refuge
Conservation Leadership Old Dominion University

Undergraduate
Peter Ahl
Parks, Recreation and Tourism Major
Conservation Leadership Minor

Professors
Dr. Eddie Hill
Ph. D. in Recreation and Tourism Studies, University of Utah (2004), M.S.Ed. in Special Education, Old Dominion University (1998), and B.S. in Outdoor Recreation, Old Dominion University (1995).

Dr. Hans-Peter Plag
Ph.D. in Natural Science, Free University of Berlin (1988), Professor of Ocean, Earth, & Atmospheric Sciences

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Abstract

Temperature rise due to increased amount of CO_2 concentration is an increasingly important issue. The effects that it has on waterfowl ecosystems plays a crucial role in the survivability of the migration system. With more cold temperature snaps, severe weather, and droughts waterfowl could face low resource habitats that were once suitable for massive numbers of migrating bird species. Data from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey and Weather underground was collected to see the relationship of temperature rise and waterfowl population numbers. The time period that was focused on was 1955 - 2016 and forecasted to 2050. Research was done to see how temperature rise effects the Atlantic flyway shifting north due to increased temperature effects waterfowl, how waterfowl adjust to weather conditions at their breeding grounds, en-route resting sites and at wintering grounds and how increased temperatures affect the respiratory system of migration waterfowl. Adapting refuges ecosystems to maintain habitable resting sites and wintering grounds is paramount for waterfowl survivability.

1. Introduction

The Atlantic flyway extends from the Arctic to the Caribbean following the Atlantic coast line. Within this vast migratory route, birds need areas to rest during their migration south, or back north to the breeding grounds of Canada (Schummer et al., 2010). Long range migration requires a massive amount of food intake, at the point of origin, almost doubling the birds body weight (Klaassen, 1996). National wildlife refuges (NWR) have been established providing stop over sites around the main resting areas for migratory birds. During this resting period the bird will consume food to provide enough energy to finish migration. The amount of food intake is crucial, too much and the bird will be too heavy and burn energy too fast, not enough food, and the bird will have to stop short of its destination to re-energize, delaying destination arrival (Klaassen, 1996). Food is not the only important resource the bird needs during migration; water is the other key component. Birds lose most of their body water through their lungs, and temperature plays a significant role in the rate of water loss (Klaassen, 1996).

The three areas that the bird population data, collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey, was focused on were New Jersey (N.J.), Virginia(Va.) and South Carolina (S.C.). All three of these states have wildlife refuges which share a relationship in bird species. The three species included are the tundra swan (TDSW), American black duck (ABDU) and the American wigeon (AMWI). These species inhabit the Atlantic flyway and have multiple stopover sites.

Tundra Swan

The tundra swan, or Cygnus columbianus (Fig. 1), has a wingspan of 167 cm, can weigh up to 10 kg and mostly has an omnivorous diet (Bart et al., 1991). Breeding takes place in wetlands, including lakes, ponds and pools. Migrating from these breeding grounds in Northern Canada and Alaska they fly roughly 5,995 km one way to their destinations on the Atlantic and Pacific coasts, during the winter season (Limpert and Earnst, 1994). These destination coast lines consist of lakes, ponds and pools that are similar to their breeding grounds. Tundra swans spend their winter on the water, sleeping and immersing their heads into the water to grasp plants, tubers and roots. During the winter months tundra swan dabble in the water to feed on clams when they are not fighting off greater black back, ring billed or herring gulls, for their catch (Bart et al., 1991)

Figure 1: A tundra swan, Cygnus columbianus, settling on the water.

American Black Duck

Often confused with a female mallard (MALL) the American black duck, Anas rubripes (Fig. 2), has an overall length about 58 cm and their weight varies depending on the season (Stotts, 1963). The black ducks habitat consists of bogs, shallow lakes, and tree lined swamps. Wildlife refuges offer a safe habitat for the black duck during hunting season (Coulter and Mendall, 1968). Classified as a dabbling duck they feed on mostly aquatic insects, mollusks and crustaceans. During their migration from their Canadian breeding ground the black duck re-energizes from eating fruits, seeds, aquatic plants and invertebrates (Longcore, 2000). The black ducks migration distance during their annual migration ranges from 1,100 to 1,300 km

(Longcore, 2000). Typically black ducks migrate in flocks at night stopping enroute at open water or inland wetlands (Palmer, 1976).

Figure 2: American black duck, Anas rubripes, male in front of female.

American Wigeon

With a breeding area from northern Alaska to the north western part of the United States the American wigeon, Mareca Americana (Fig. 3), has one of the largest breeding grounds of all waterfowl (Mini et al., 2014). The American wigeon mostly occupies freshwater marshes, impoundments, and agricultural lands and sometimes will be found in brackish wetlands and estuaries (Turnbull and Baldassarre, 1987). As dabbling ducks like the American black duck, the American wigeon has a diet that consists of aquatic plants, clovers, seeds and fruits. During breeding season the wigeon focuses more on insects, mollusks and crustaceans (Mini et al., 2014). In mid-February through the beginning of March the wigeon depart their wintering habitats from New Jersey through Florida and arrive in their northern breeding grounds by mid-May (Bellrose, 1980). The timing of the wigeon migration is dependent on multiple factors. Weather plays a critical role when the small flocks decide to depart, along with water levels and the food conditions of the departing habitat.

Figure 3: American wigeon, Mareca americana, Male forward of female.

Temperature Rise

Anthropogenic emissions have increased the amount of CO_2 in the atmosphere (Cox et al., 2000). The amount of CO_2 that remains in the atmosphere yearly is roughly 57% (Cole et al., 1993). Earth's oceans and lands absorb the remaining CO_2, creating warmer ecosystems. As figure 4 illustrates, the more CO_2 concentration, parts per million (ppm), that is present in the atmosphere the higher the mean temperature will be over land.

High and low pressures along with the polar vortex and the Arctic oscillation work together forming temperature variability (Kennedy et al, 2014). As CO_2 levels increase so does temperature, which melts more ice and snow in the Arctic. Cohen et al. (2014) explains this phenomenon as the Arctic amplification. Recent research has linked the Arctic amplification to the extreme weather occurrences in the mid-latitude region.

Three distinct pathways have been exposed, changes in storm tracks, the jet stream, and planetary waves and their associated energy propagation (Cohen et al., 2014). These pathways have two different phases the North Atlantic Oscillation/Arctic Oscillation can enter, a positive and negative phase. During the positive phase winters are usually mild in northern Eurasia and eastern United States, resulting from storm tracks shifting pole ward. When storm tracks shift toward the equator, winters are typically more severe in northern Eurasia and eastern United States, the North Atlantic Oscillation/Arctic Oscillation are in a negative phase (Cohen et al., 2014). Recently temperature trends through the Northern hemisphere have shown that the North

Atlantic Oscillation/Arctic Oscillation have been in negative phases over the past two-decades (Cohen et al., 2014). These phases create multiple hazards for the migrating waterfowl in the Atlantic flyway which will be explained in the next section.

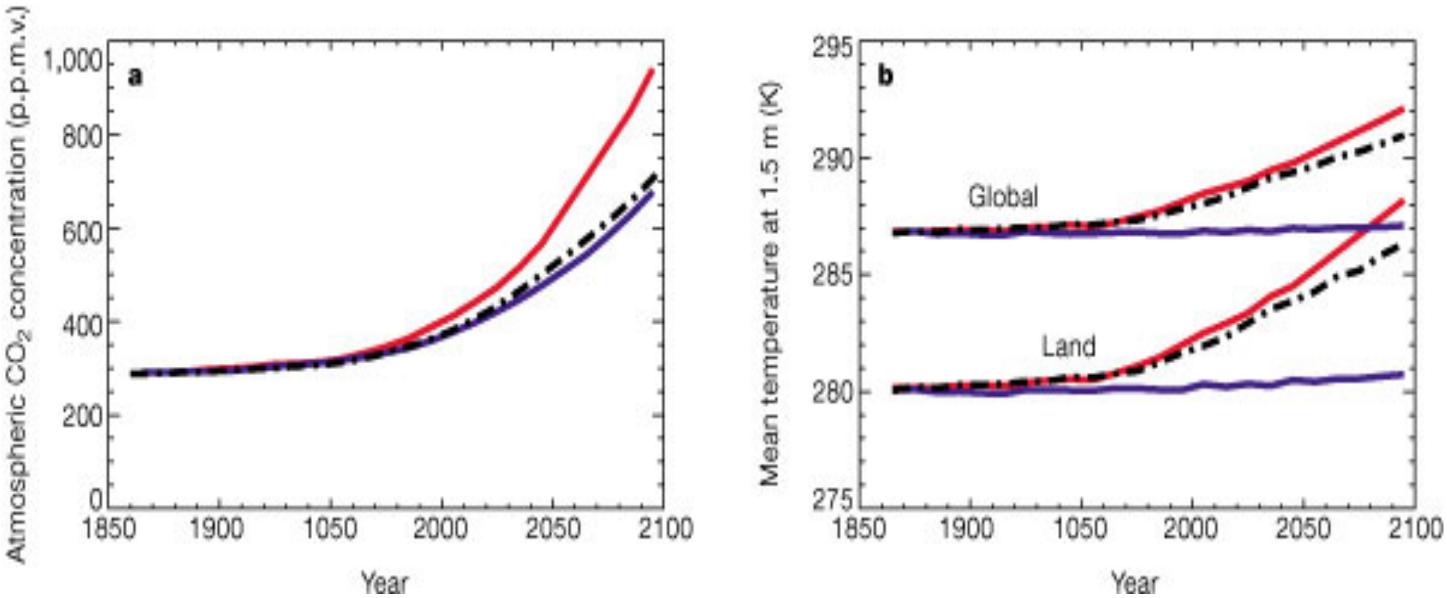

Figure 4: a. Atmospheric increase in CO2 ppm from 1850 to 2100. b. Mean temperature increase at a global level and at land level per year from 1850 to 2100 (Cox et al. 2000).

2. Factors that Affect the Atlantic Flyway System

There are many hazards that waterfowl face within the multiple ecosystems they inhabit annually. According to Green (1996) among the 7 threats to waterfowl, habitat loss ranks the highest at 73% , while hunting 48% and introductions 31%, rank second and third. Habitats can be negatively affected by a number of factors. Alterations to habitat include agriculture and construction, pollution poisoning from pesticides and other chemicals and changes in climate (Green, 1996). The Atlantic flyway system (Fig. 5) relies heavily on climate condition variables which directly affect survival of bird species (Richardson, 1978). There are three elements within the bird migration system that could contain hazards which the migrating birds would have to adapt to. These three elements are conditions at the point of origin, en route and at the migration destination (Richardson, 1978).

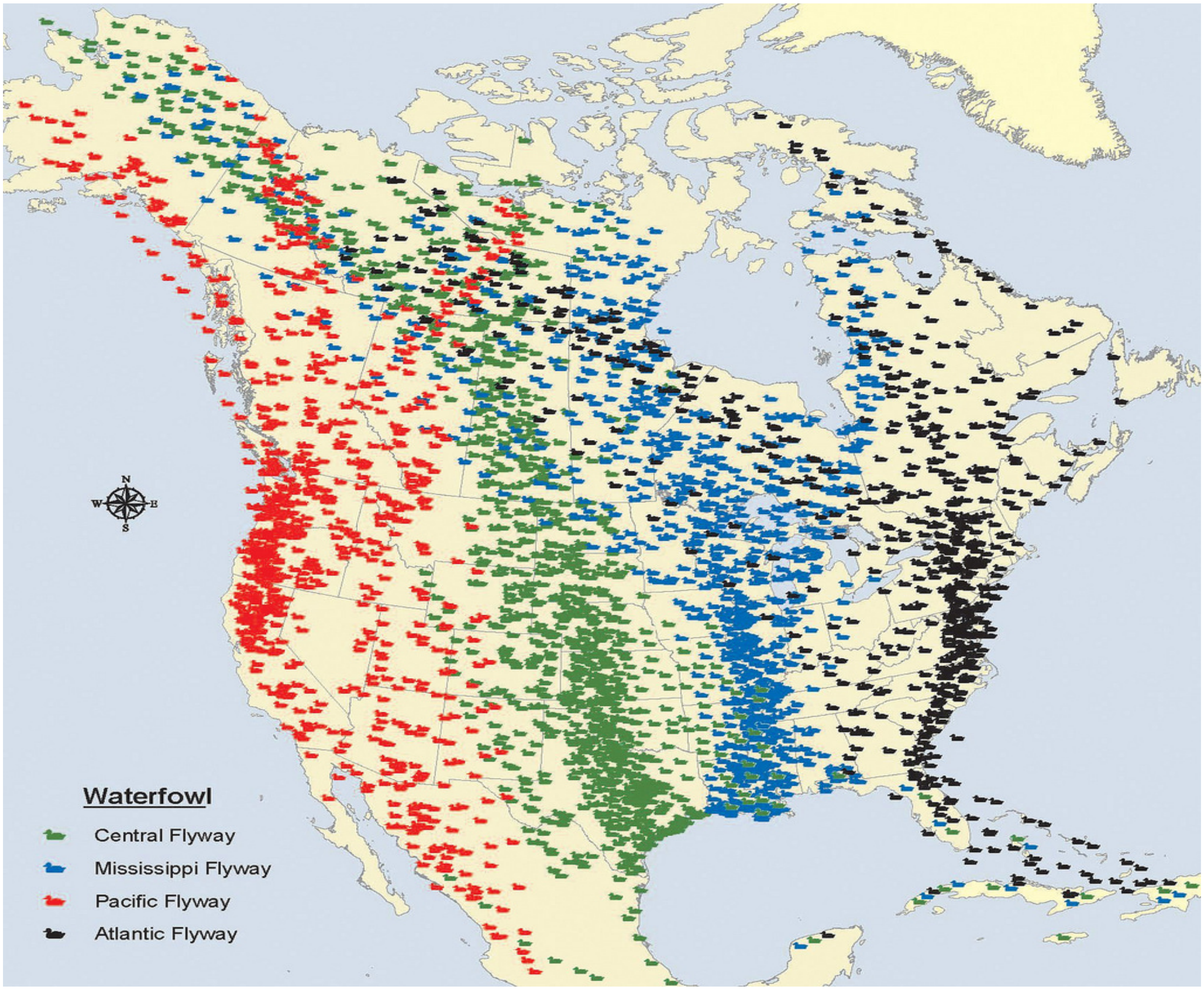

Figure 5: Waterfowl flyways of North America. The Atlantic flyway is depicted by black birds on the map.

Weather is the main driving factor that changes these climate conditions. Wind direction and velocity, precipitation, and temperature are the main climate condition variables (Richardson, 1978). If temperature is rising due to increasing CO2 levels, then arctic amplification could directly affect the weather that the waterfowl in the Atlantic flyway rely on (Cohen et al., 2014).

Temperature Rise Along the Atlantic Flyway

The three locations that were used for this study, were selected due to their relationship in waterfowl and the geographical locations along the Atlantic flyway. Mean temperature data was gathered from Weather Underground's temperature log from December to January, 1955 to 2016 (Fig. 6). The data shows that in all three states the mean temperature has been increasing. This time frame was chosen to correlate to the U.S. Fish and Wildlife's mid-winter survey dates.

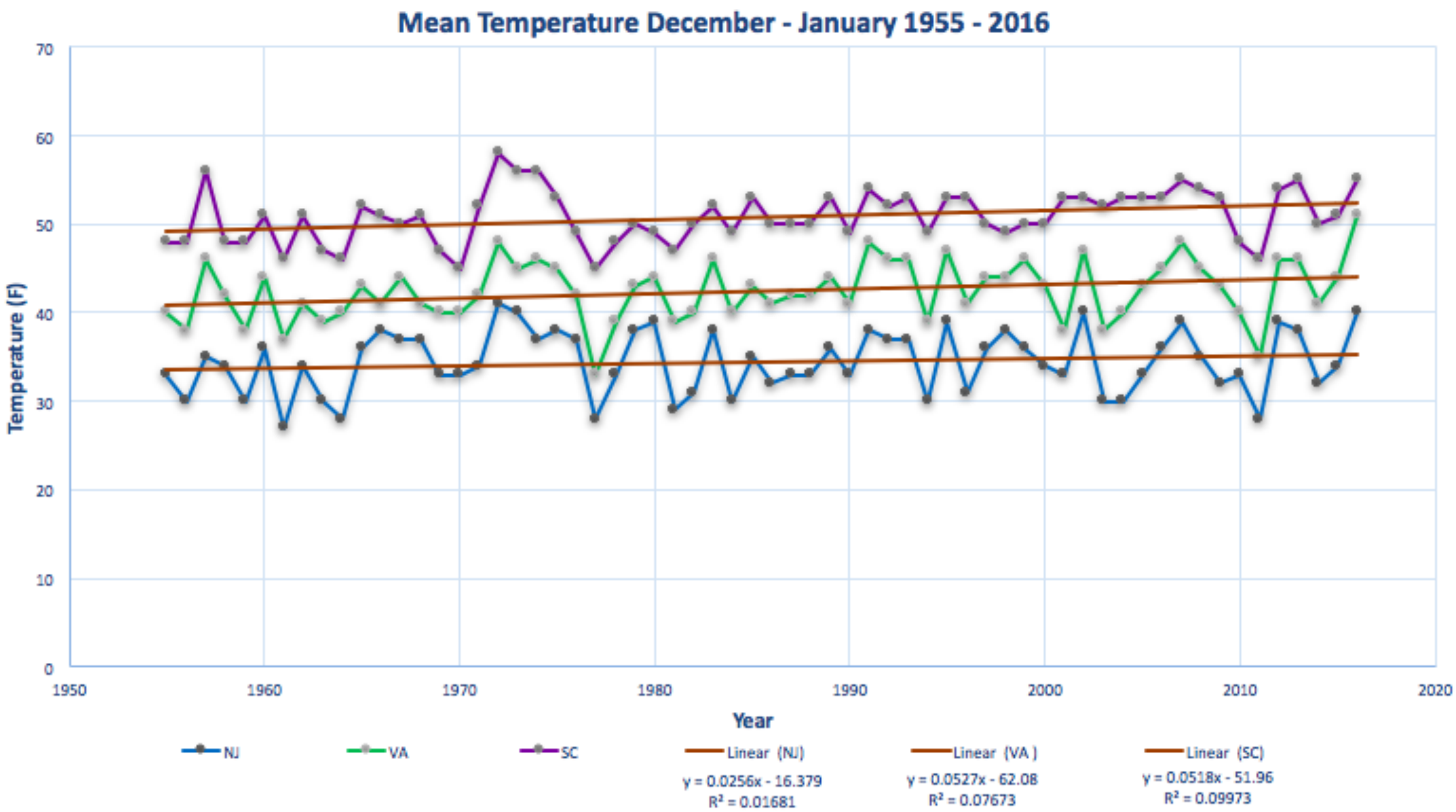

Figure 6: Temperature (F) data from Weather Underground ranging from 1955-2016 for New Jersey (NJ), Virginia (VA) and South Carolina (SC).

Within the next century temperatures could rise 5.8C (McCarthy, 2001). Temperature and humidity increase can lead to higher rates of disease due to wet vegetation growing more bacteria (Rosenzweig et al., 2001). Waterfowl depend on wetlands for sustainable habitats and increased disease in these wetlands could have devastating effects on species populations (Sorenson,1998).

3. How Migrating Waterfowl Respond to Changing Climatic Conditions

Waterfowl migration is dependent on many variables throughout the Atlantic flyway system and can be influenced by minor shifts in climate (Richardson, 1978). Atmosphere stability and turbulence can also play significant roles in determining when and where migrating species migrate. Shifts in weather patterns can create more hazards causing cold snaps producing freezing temperatures and hail can increase mortality rates during en-route migration at stop over sites (Sorenson, 1998). Precipitation during the Springtime has shown a negative effect on the amount of long distance migrating waterfowl (Lemoine et al. 2003). Long term and short term migration require different amount of food intake due to energy output which can shorten or lengthen the stop over period that certain species have (Richardson, 1978). When heat-stressed, birds use water for evaporative cooling. As temperature increases the time of wetland recovery is increased (Fig. 7). Longer wetland recovery time could decrease the amount of water migrating waterfowl have to cool. Under such circumstances, a bird may rapidly dehydrate. Migrants locate air layers where both favorable winds and meteorological conditions that conserve water prevail (Richardson, 1978).

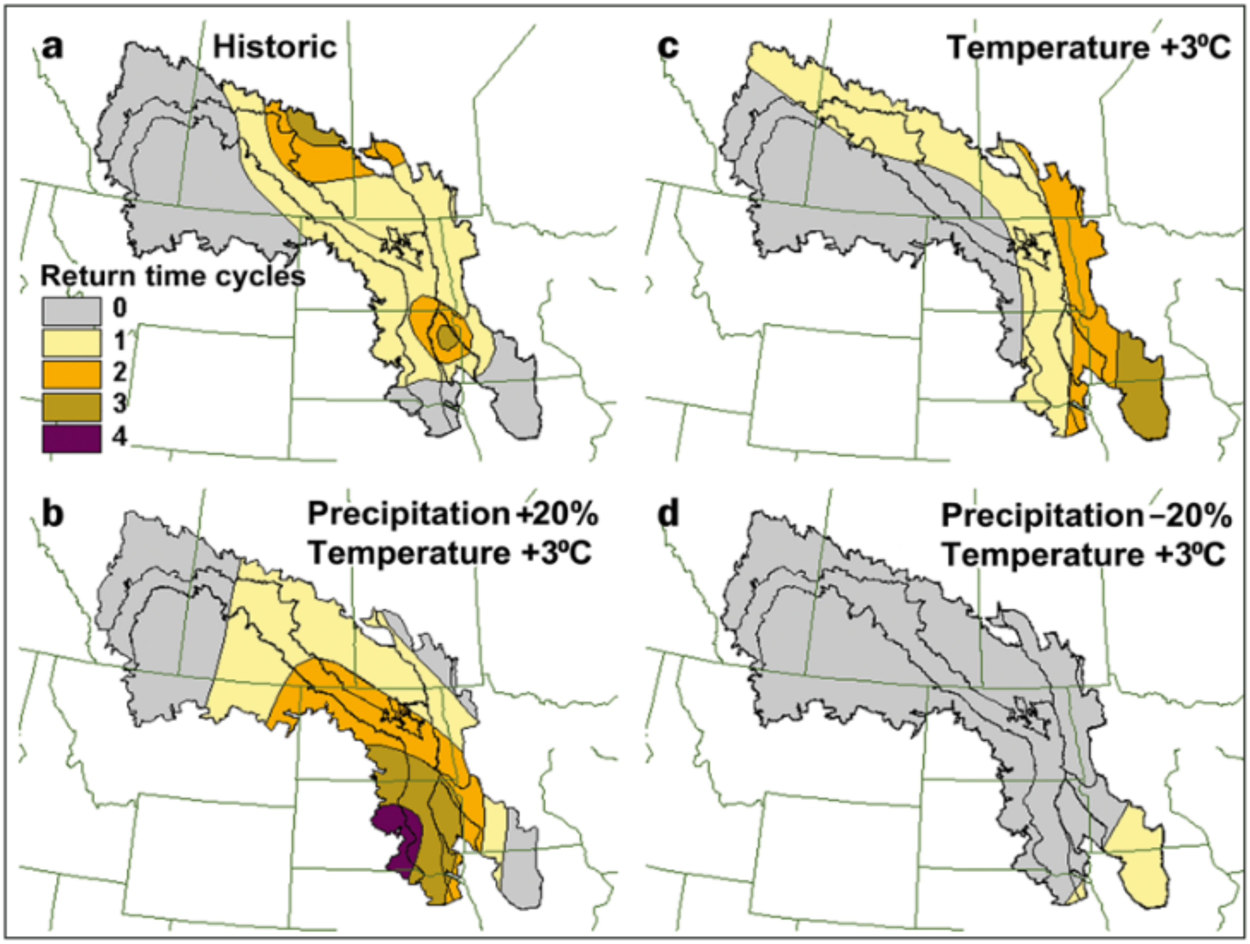

Figure 7: Geographic patterns of the speed of the wetland cover cycle, simulated for the prairie pothole region under historic (a) and alternative future (b, c, and d) climatic conditions (Johnson et al., 2005).

Varying season temperatures have also been produced by temperature rise. Long distance and short distance migrating species are affected by different climate changes. Long distance migrants seem to increase when temperatures decrease. Lemoine et al. (2003) also explains that long distance migrants increase with an increasing temperature difference between the coldest winter month and Spring. Short distance migrants have been recorded to increase as temperatures increase (Lemoine et al. 2003).

4. Future Outlook of Rising Temperatures Affecting Waterfowl

The waterfowl data that was collected from the 3 locations along the Atlantic flyway was from 1955 through 2016. The linear line projects the data into 2050. The three species were selected due to all three being species that inhabit the locations include the tundra swan (TDSW), the American black duck (ABDU) and the American wigeon (AMWI). The first three graphs represent the population for each species for all three states (Fig. 8, 9 and 10).

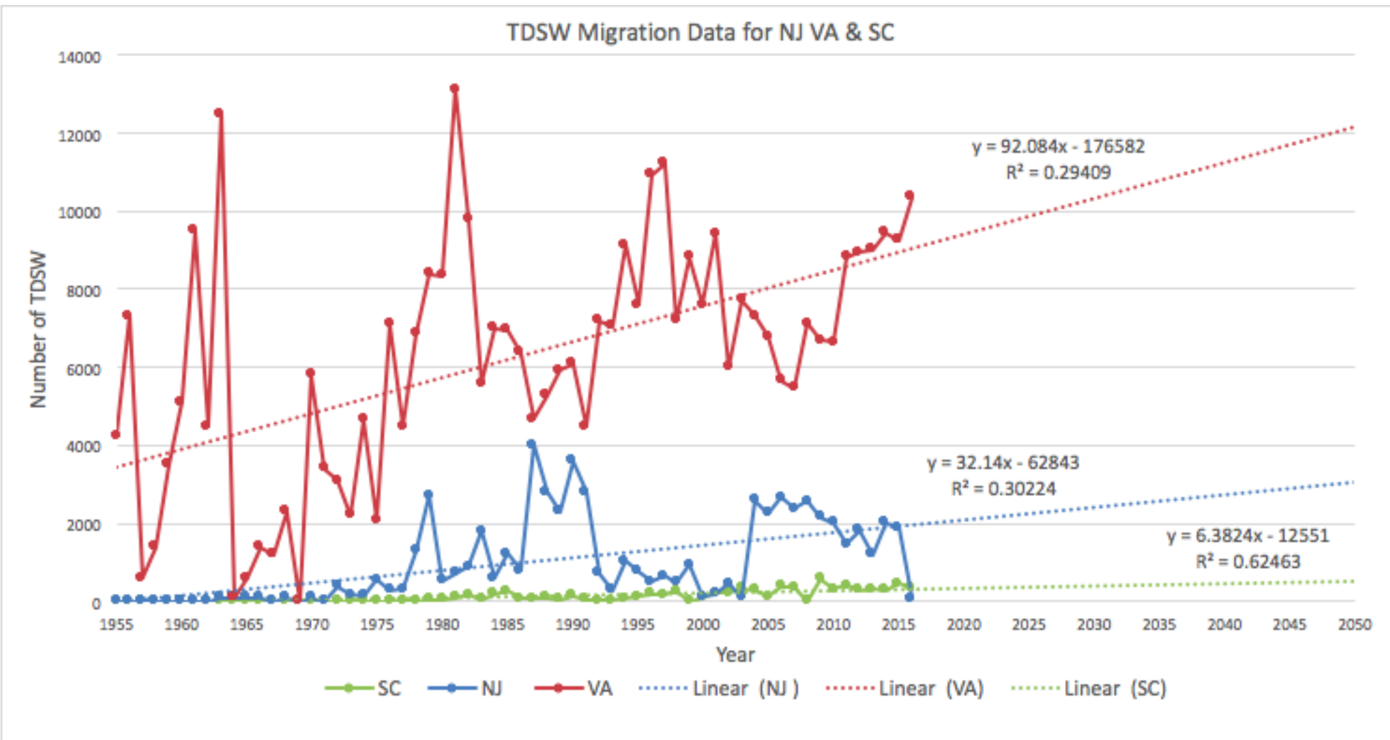

Figure 8: TDSW population for New Jersey, Virginia, and South Carolina from 1955 - 2016. Linear line displays an increase of TDSW in Virginia and New Jersey and South Carolina staying consistent, through 2050. All population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey.

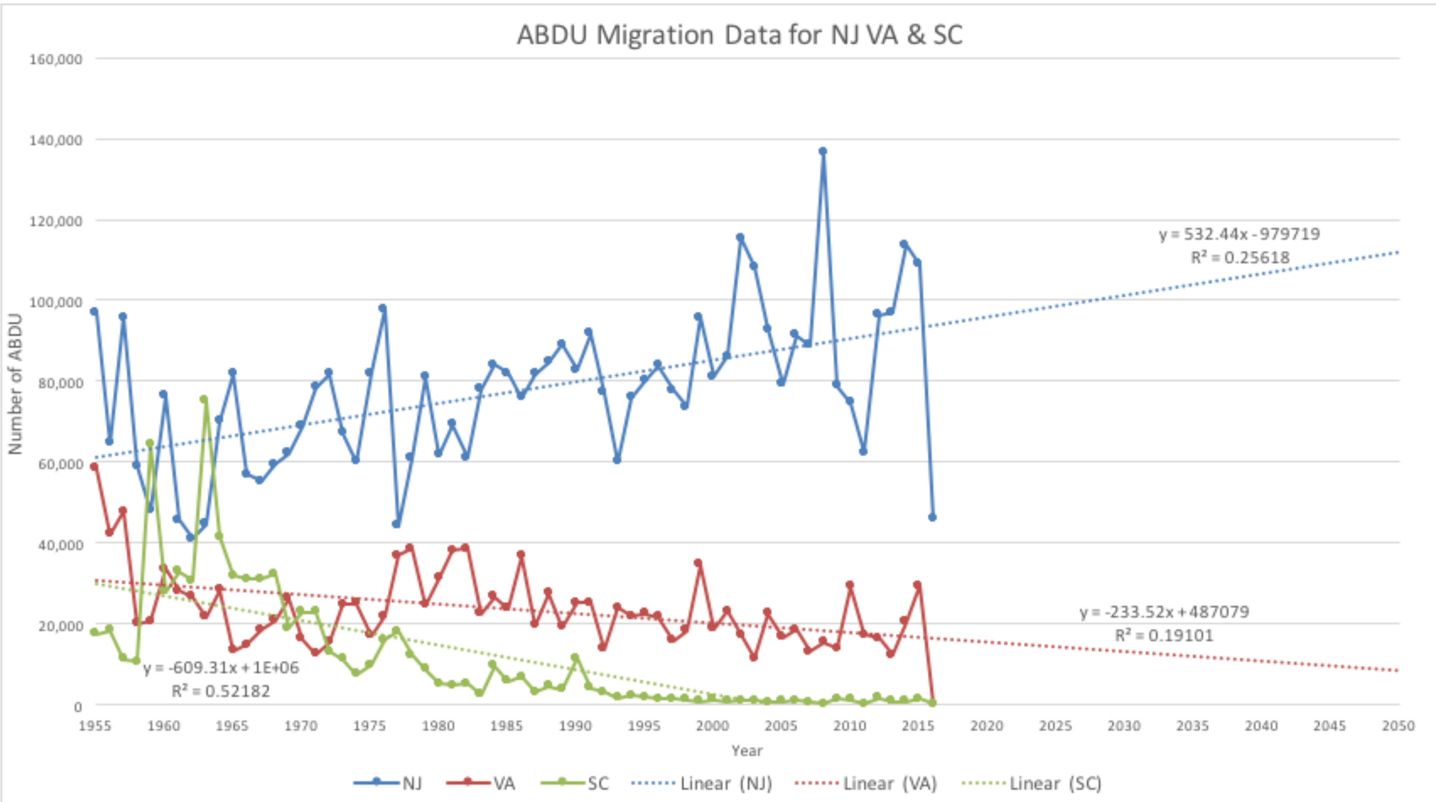

Figure 9: ABDU population for New Jersey, Virginia, and South Carolina from 1955 - 2016. Linear line displays an decrease of ABDU population in Virginia and South Carolina and New Jersey shows an increase in population through 2050. All population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey.

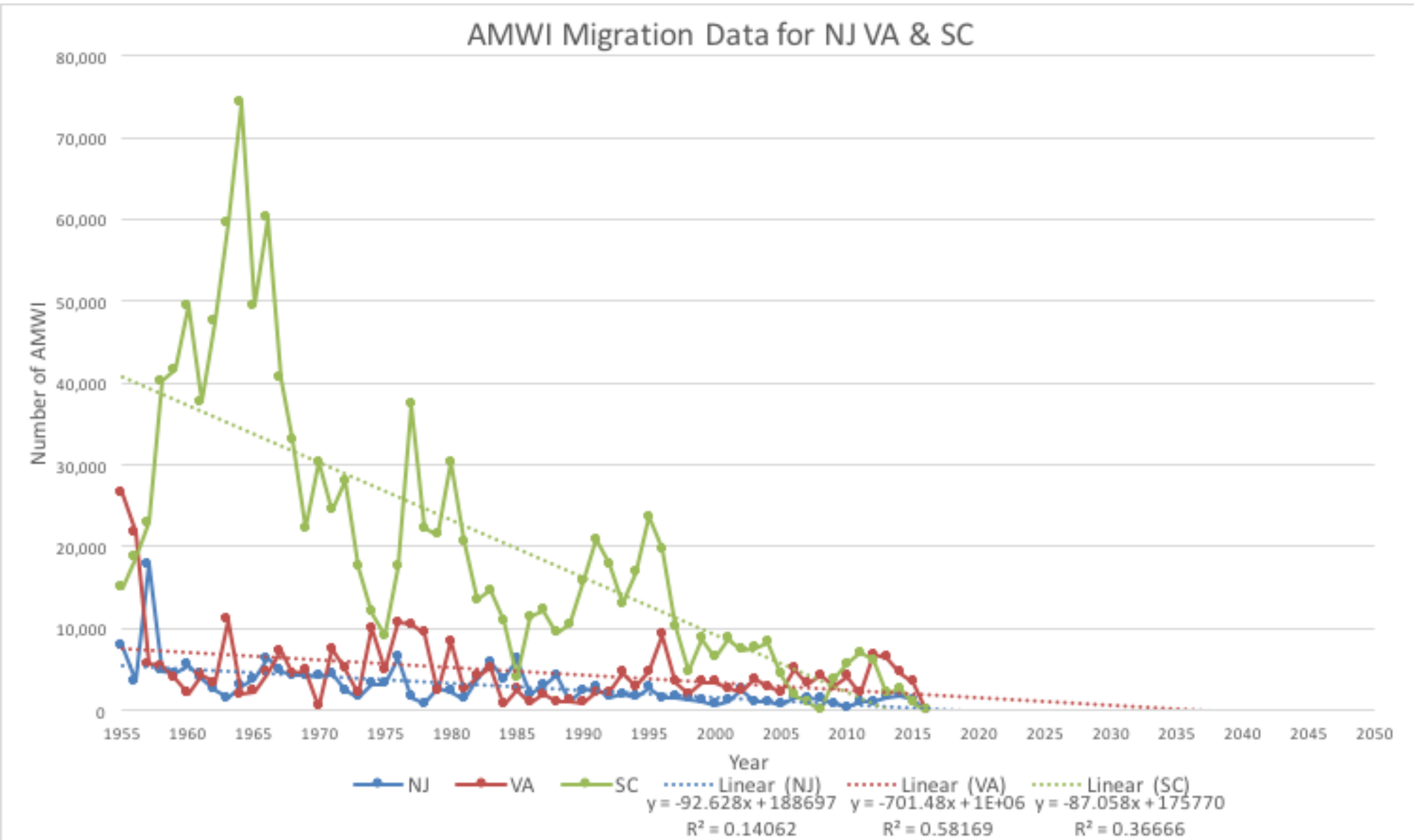

Figure 10: AMWI population for New Jersey, Virginia, and South Carolina from 1955 - 2016. Linear line displays an decrease of ABDU population in all three states through 2050. All population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey.

TDSW have shown an increase in New Jersey and continue to increase through 2050 (Fig. 11). This could show a relationship between temperature rise and the migration of TDSW in the Atlantic flyway. As temperature increases in New Jersey the climate could become more habitable within the conditions that the species prefers. Virginia TDSW data (Fig. 12) revealed a significant increase, almost tripling the amount of TDSW, that were present in 1955 to 2016. South Carolina had very minimal TDSW from 1955 to 1979, then in 1980 the migratory population tripled (Fig. 13). In 1999 and in 2008 there were not any TDSW in the area that was reported, which could have been a lapse in record keeping or TDSW weren't in the area where the migratory bird managements data was taken. TDSW seem to be increasing in population numbers in the midpoint of the Atlantic flyway. This could mean that while the TDSW are at stop over sites, the migrating flocks are finding the climate more habitable and staying for the winter.

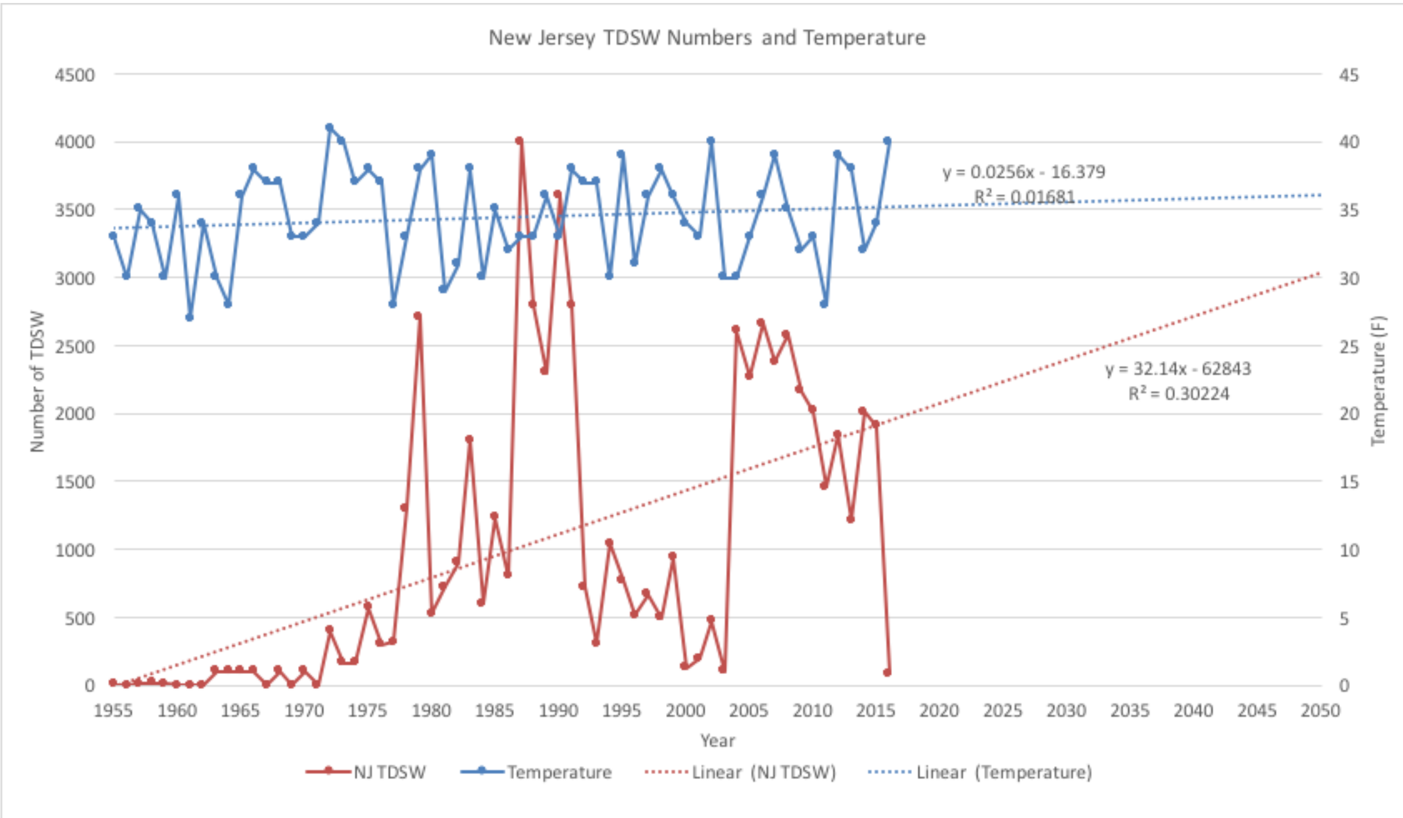

Figure 11: TDSW population and mean temperature (F) from December - January for New Jersey from 1955 - 2016. Linear line displays TDSW population and mean temperature to 2050. TDSW population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey. Temperature data collected from weather underground.

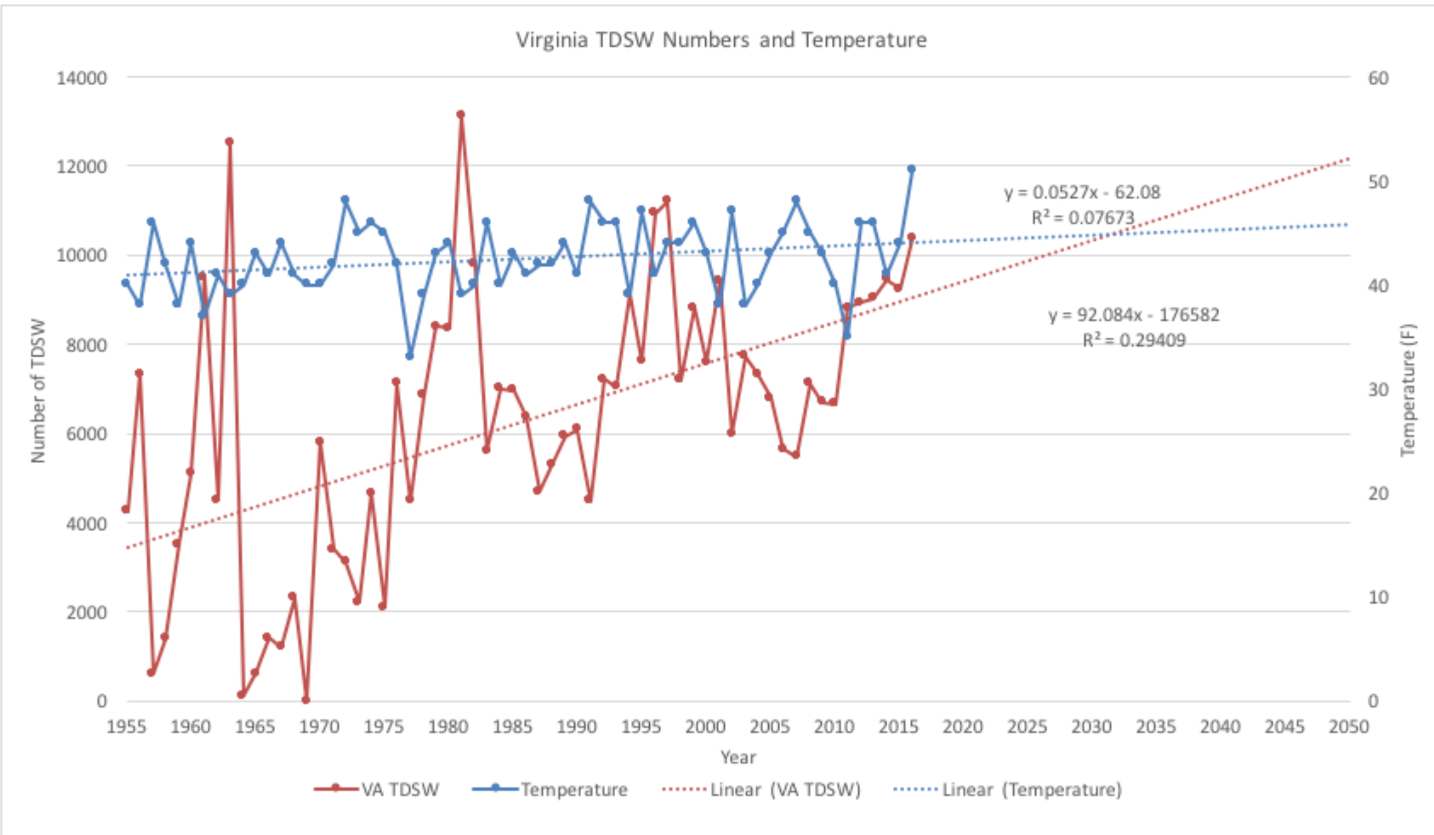

Figure 12: TDSW population and mean temperature (F) from December - January for Virginia from 1955 - 2016. Linear line displays TDSW population and mean temperature to 2050. TDSW population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey. Temperature data collected from weather underground.

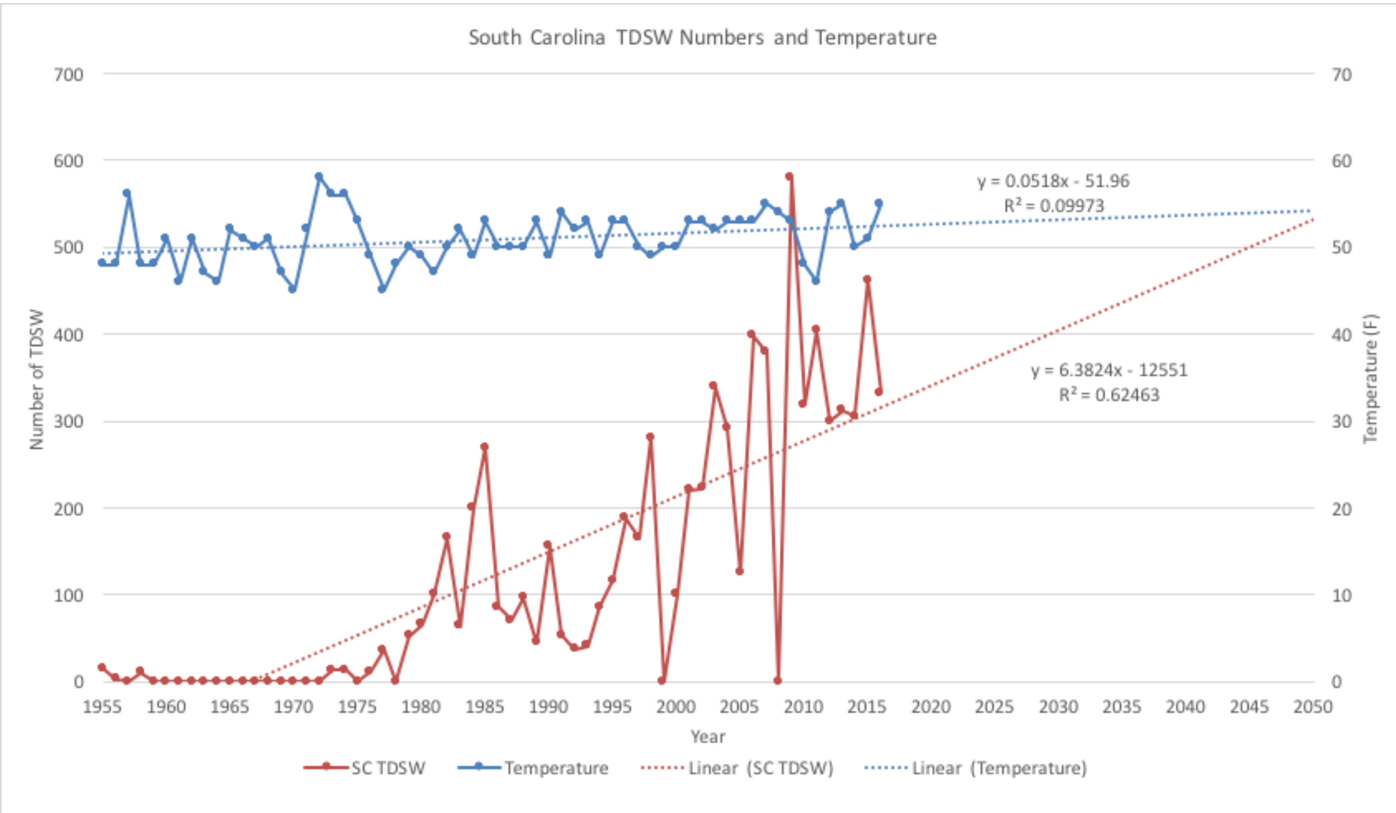

Figure 13: TDSW population and mean temperature (F) from December - January for South Carolina from 1955 - 2016. Linear line displays TDSW population and mean temperature to 2050. TDSW population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey. Temperature data collected from weather underground.

The ABDU population numbers for Virginia and South Carolina showed decreasing numbers (Fig. 15 and 16). In New Jersey the amount of ABDU has shown a steady increase as the temperature increases (Fig. 14). Again, all three states are having increasing temperatures from 1955-2016 and continue to rise through 2050. Between 1950 and 1960 ABDU populations have shown a decline in numbers along the Atlantic flyway. Reasoning for this is due to a habitat struggle in breeding grounds with Mall (Longcore, 2000). It is common for ABDU to migrate to their wintering grounds as far south as mid South Carolina. For an ABDU to winter south of that area is typically uncommon (Longcore, 2000). A reason for ABDU population increase in New Jersey and a decrease in South Carolina and Virginia could be because the uncommon wintering area is increasing in size. With temperatures rising due to an increase of CO2 there could be a shift in the system that ABDU are responding to. As the ABDU population influxes in New Jersey the ecosystem might become overloaded, bringing the system close to its carrying capacity. If this happens the migration pattern could shift again or ABDU population numbers could start to decline in northern Atlantic flyway states.

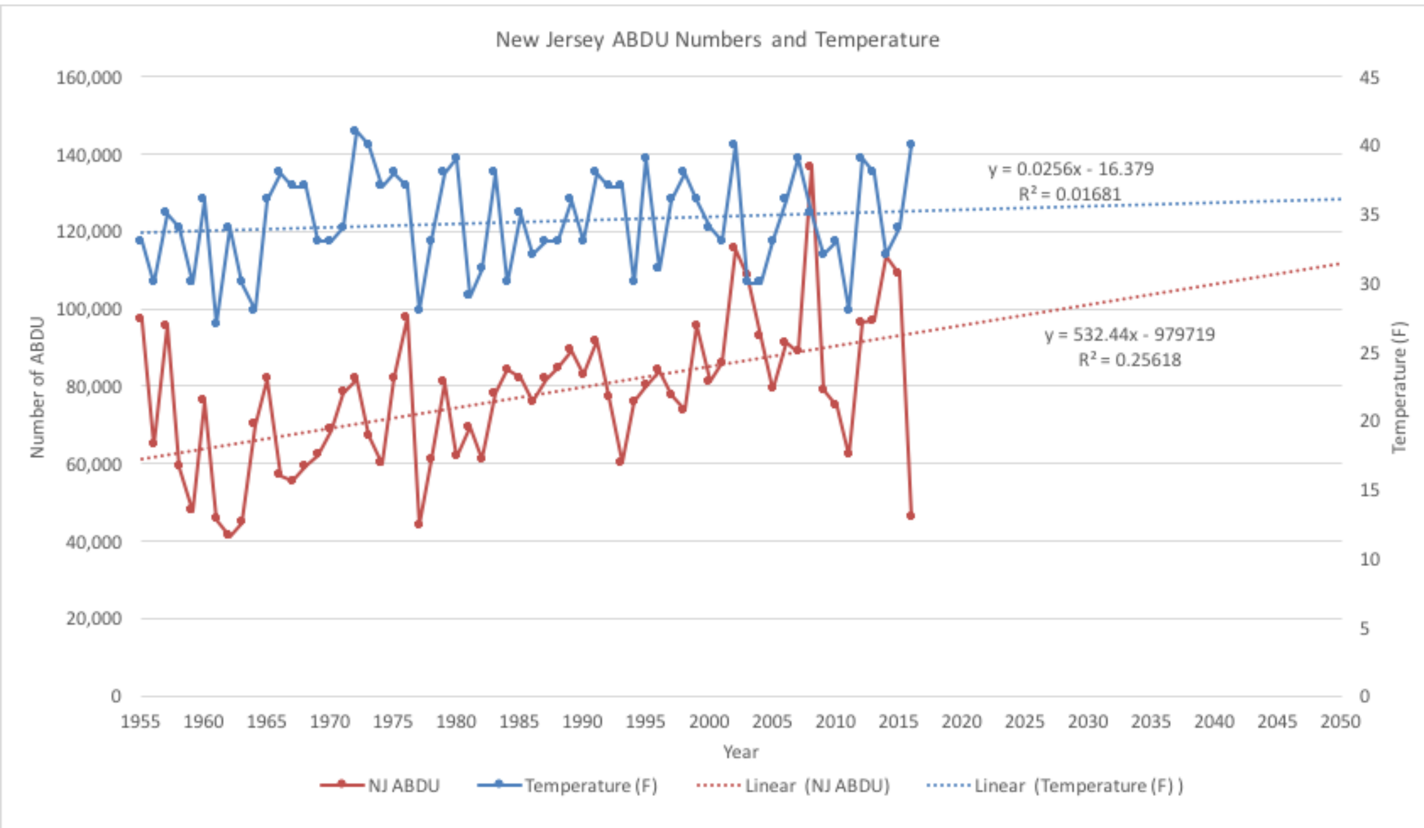

Figure 14: ABDU population and mean temperature (F) from December - January for New Jersey from 1955 - 2016. Linear line displays ABDU population and mean temperature to 2050. ABDU population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey. Temperature data collected from weather underground.

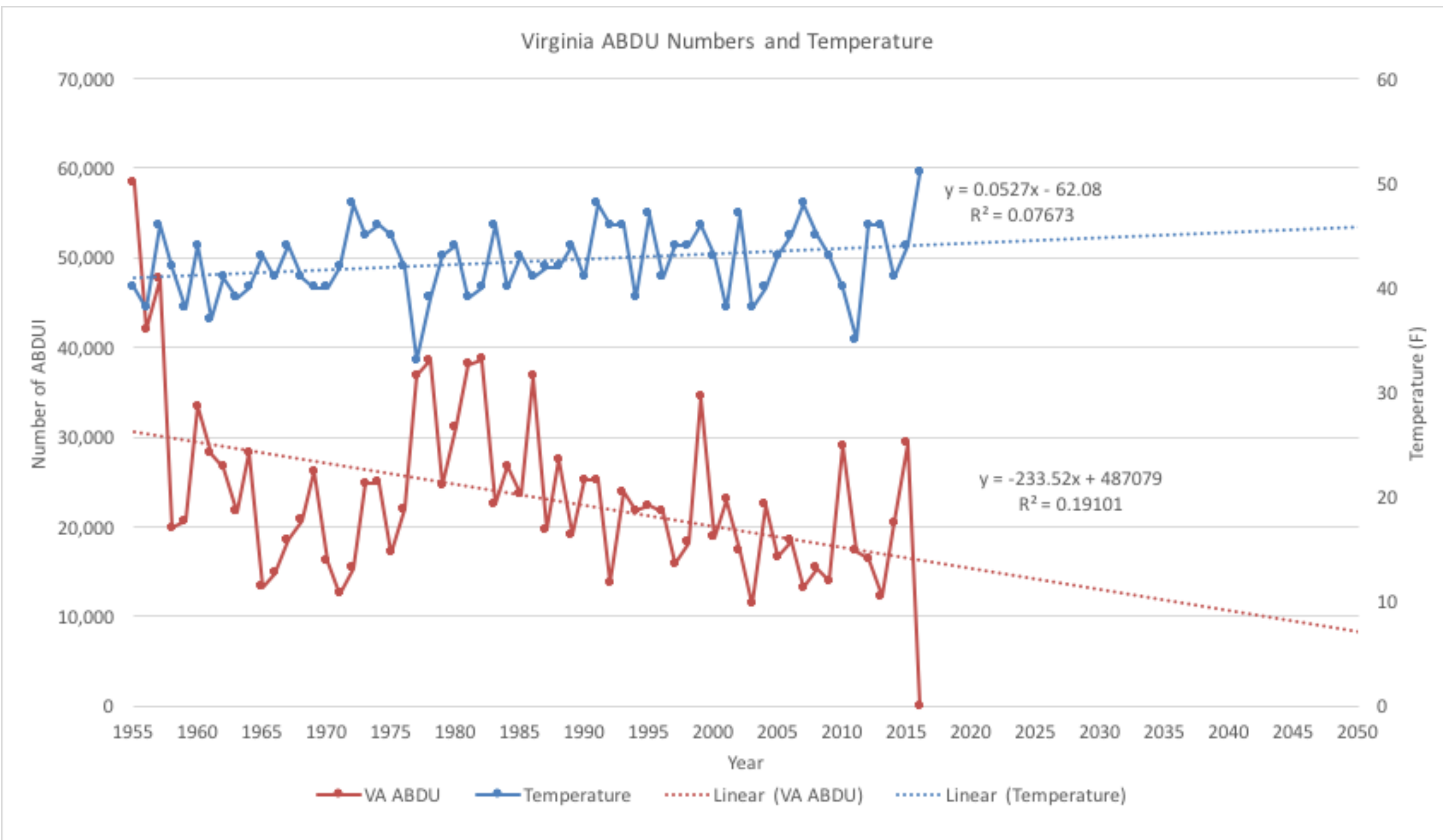

Figure 15: ABDU population and mean temperature (F) from December - January for Virginia from 1955 - 2016. Linear line displays ABDU population and mean temperature to 2050. ABDU population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey. Temperature data collected from weather underground

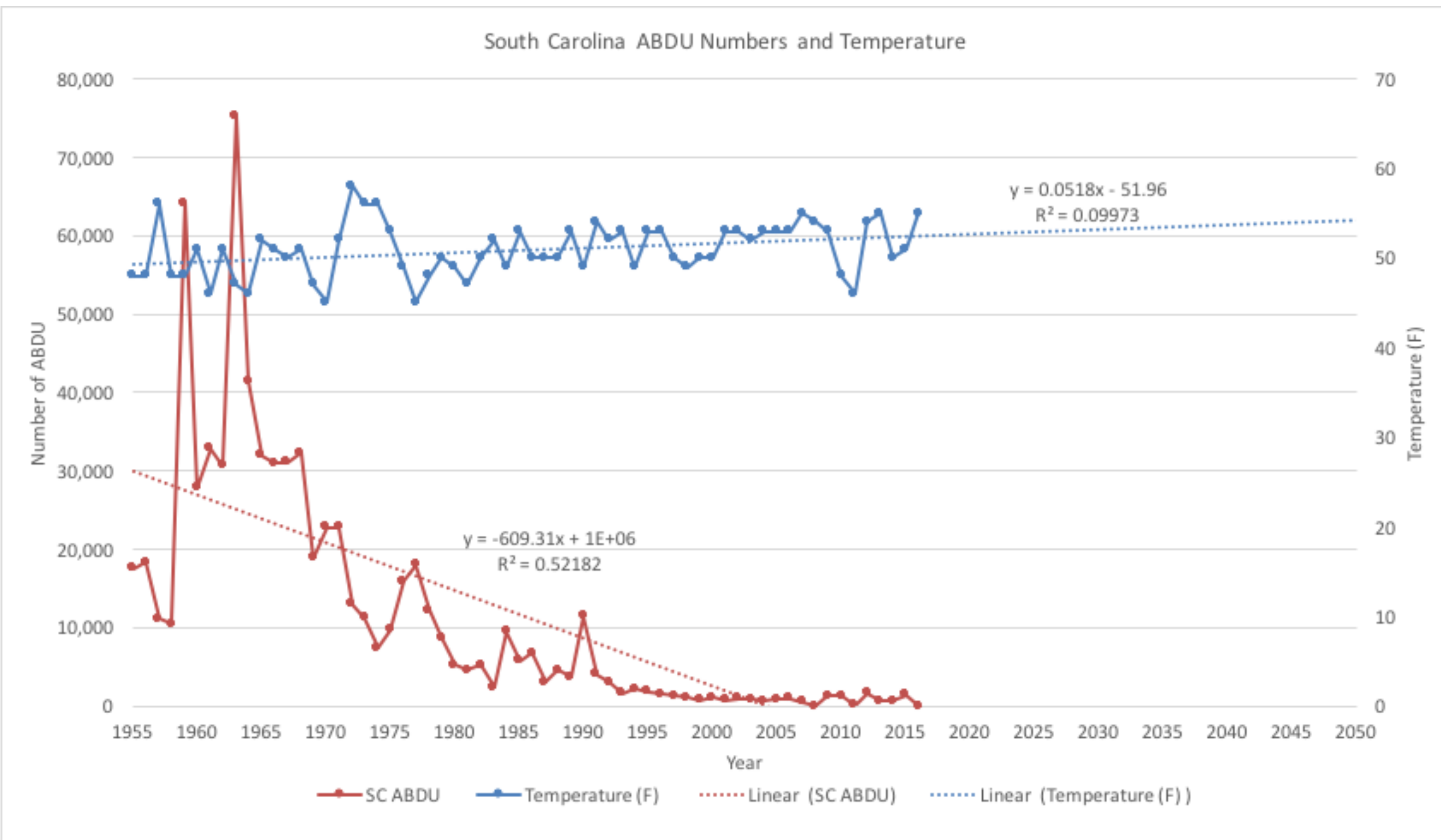

Figure 16: ABDU population and mean temperature (F) from December - January for South Carolina from 1955 - 2016. Linear line displays ABDU population and mean temperature to 2050. ABDU population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey. Temperature data collected from weather underground

AMWI numbers in all three states have had decreasing migration numbers with some decreases being very drastic (Fig, 17, 18 and 19). In 1957 New Jersey and South Carolina had increase in AMWI, with New Jersey seeing an increase of approx. 14,000 AMWI and South Carolina saw a 2,000 AMWI increase. Virginia in 1957 saw a decrease of approx. 16,000 AMWI. This could account for the 16,000 AMWI that either stopped in New Jersey, or continued their migration to South Carolina. Virginia in the two prior years had steady numbers of AMWI, in 1955 there were 26,450 and 21,800 in 1956. New Jersey and Virginia did not see migration numbers of AMWI in that capacity again. South Carolina saw record numbers of 74,200 and 60,200 in 1964 and 1966. After these spikes the population numbers started to decline steadily just as New Jersey and Virginia had. During 1957 and 1958 one of the strongest El Niño occurred. During an El Niño winter months are typically warmer (NOAA, 2017). This proves true with the temperature data from weather underground reporting higher than average temperatures in all three states during that time. AMWI population numbers are now in the low thousands in the past 10 years. It is forecasted that AMWI migration will continue to trend southward as AMWI tend to winter in the southern part of the United States and Mexico (Mini et al., 2014). As temperatures continue to rise AMWI could start to re-energize at stop over sites for longer periods in more northern parts of the Atlantic flyway.

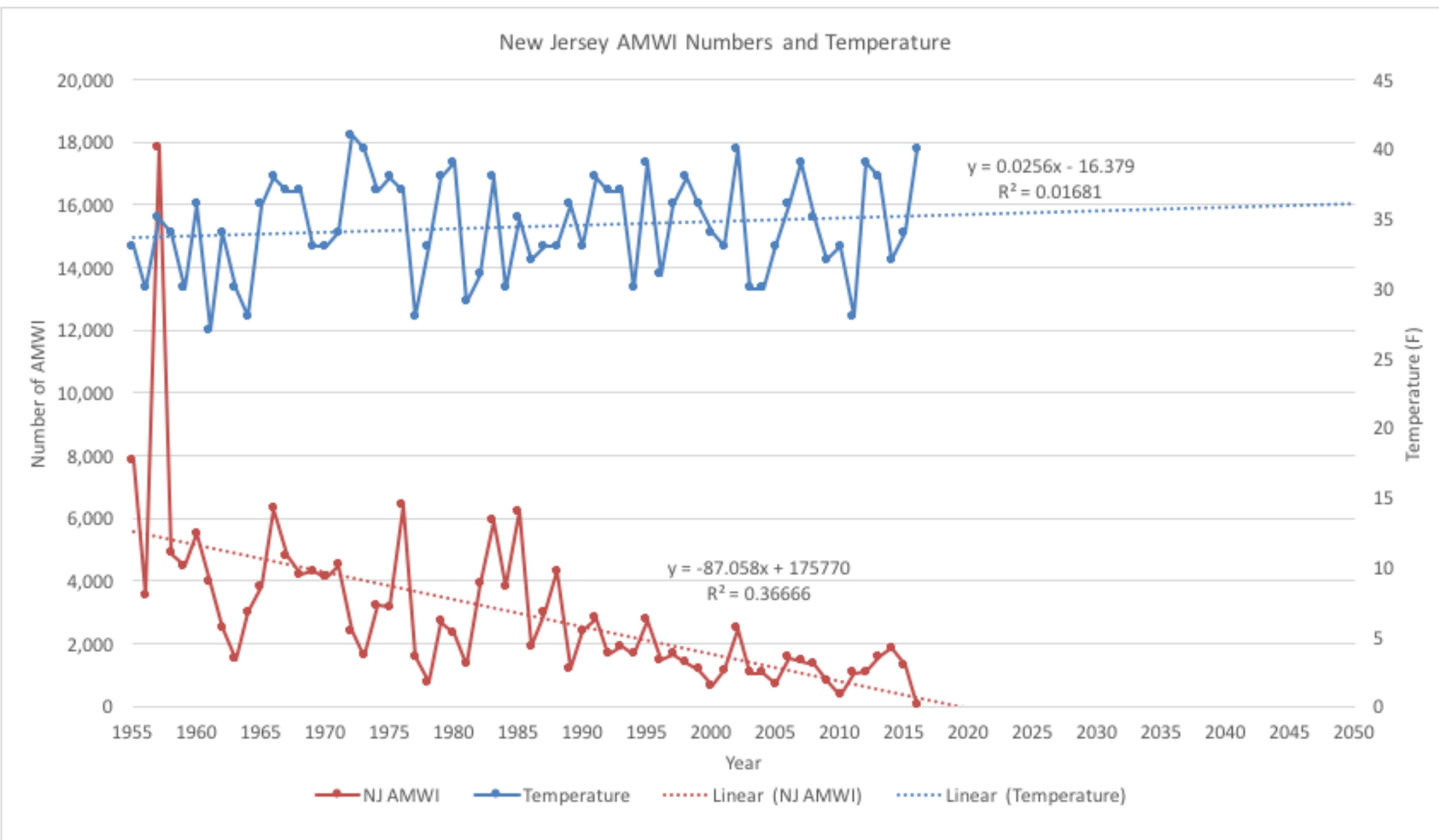

Figure 17: AMWI population and mean temperature (F) from December - January for New Jersey from 1955 - 2016. Linear line displays AMWI population and mean temperature to 2050. AMWI population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey. Temperature data collected from weather underground.

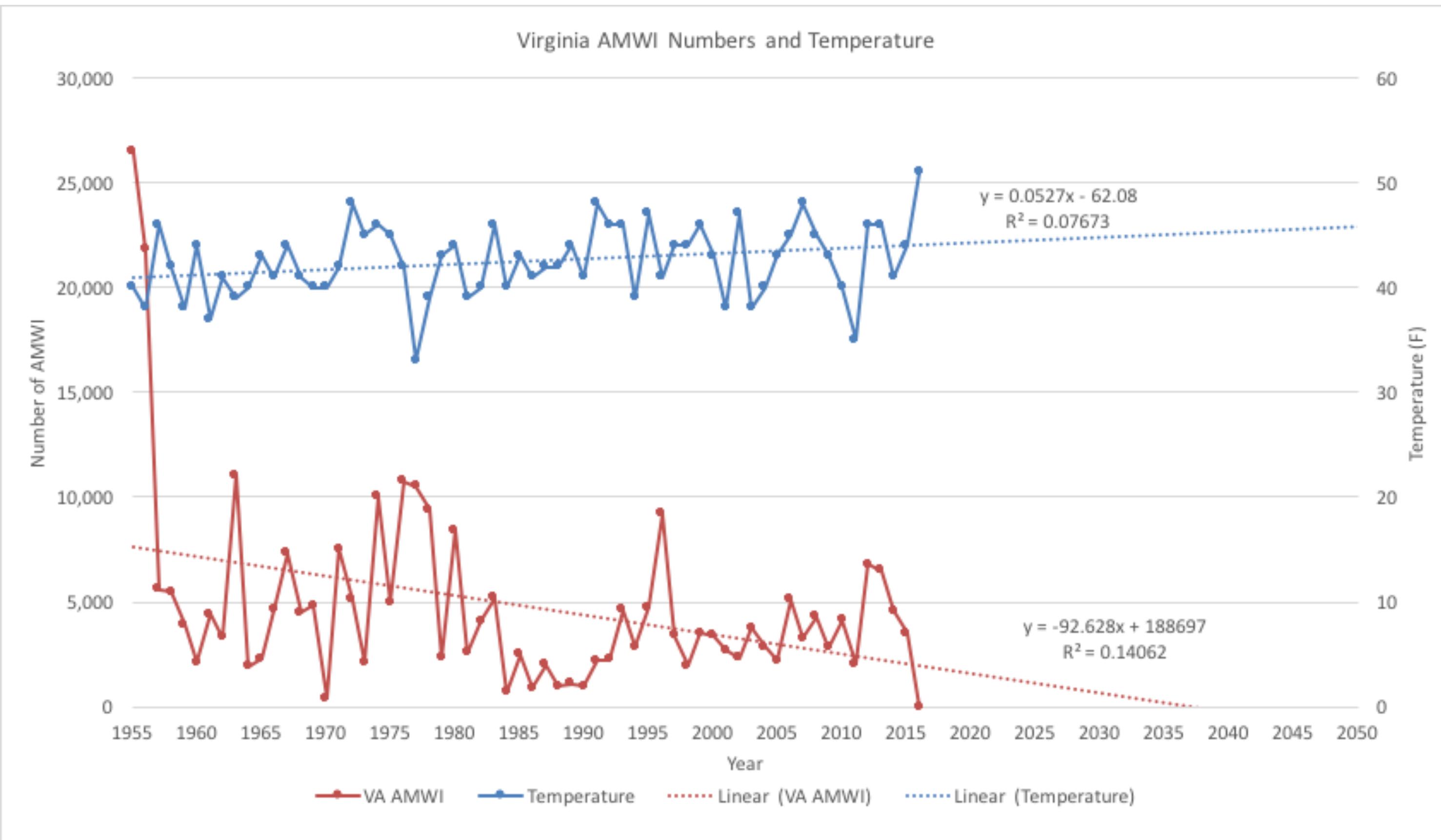

Figure 18: AMWI population and mean temperature (F) from December - January for Virginia from 1955 - 2016. Linear line displays AMWI population and mean temperature to 2050. AMWI population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey. Temperature data collected from weather underground.

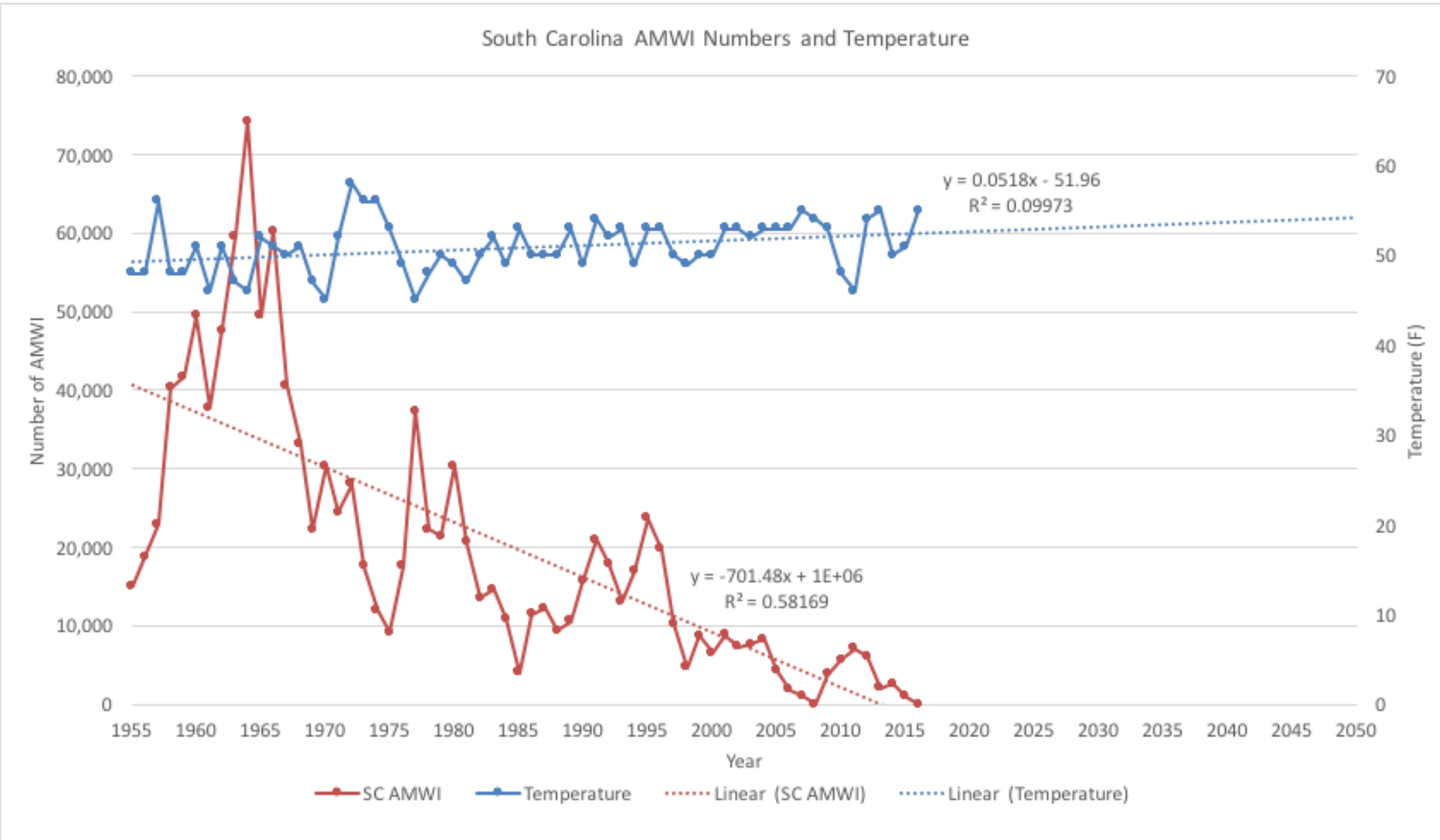

Figure 19: AMWI population and mean temperature (F) from December - January for South Carolina from 1955 - 2016. Linear line displays AMWI population and mean temperature to 2050. AMWI population data collected from U.S. Fish and Wildlife Service's division of migratory bird management's mid-winter waterfowl survey. Temperature data collected from weather underground.

As temperatures continue to increase and decrease in rapid trends, waterfowl migration could be affected. Temperature increase has brought numerous droughts around the globe (Smith Et al., 1989). Sorenson et al. (1998) ran multiple scenarios on how increasing temperature and increasing drought affect waterfowl and 11 out of the 12 tests resulted in declining numbers of wetlands and ducks. Due to greater amounts of evapotranspiration, because of higher temperatures, these droughts could get a lot worse by 2100. Also, the weakening of the gulf stream could have massive negative impacts to the world's flyway system. Based on the general circulation model (GCM) the long term mean population of migrating birds was forecasted to be

5.0 million. Now, due to rising temperatures, the 5.0 million mean population could fluctuate by 2.7 million by 2060 (Sorenson et al., 1998).

The time has come when it is no longer feasible to continue to manage the critical stop over and wintering sites as they have been the past 50 years. Now is the time to look forward and try to mitigate and adapt the refuge's established ecosystems, creating habitats for the vulnerable species, with the next 50 years in mind. Decisions that have to be made by national agencies will be reviewed next.

5. National Agency Partnership

Making decisions on managing NWR ecosystems with extreme varying temperatures that are trending up, is especially difficult. As CO2 rises U.S. Fish and Wildlife, Department of Natural Resources, Bureau of Land Management along with other agencies and organizations have the hard task to adapt the habitats to meet the needs of wildlife. Assessments of migrating waterfowl trends in each North American flyway would be beneficial. This assessment would provide more details than just population numbers. Providing earlier or late migration trends, and seasonal temperature variance, could help extend the agencies outlook. Temperature rise is going to continue to add more adverse weather, increase drought, and raise sea levels.

U.S. Fish and Wildlife could focus on each flyway within a region. The Atlantic flyway region could look at the last years surveys and discuss which refuge and stopover sites had what species of waterfowl. This would allow the upcoming years assessment plan to be made and shifted to what migrating waterfowl species is expected. If there are new stopover sites that are out of the bounds of U.S. Fish and Wildlife refuges then new protection habitats can be made through the National Parks Service or Bureau of Land Management. Migrating waterfowl are going to shift resting sites and wintering sites due to new climate conditions. It is the responsibility of these agencies to continue to produce new options to protect these new sites.

6. Multiple Agency Plan

There are many variables that are driving climate change and even more ecological impacts (McCarthy et al., 2001). Drought and resting spots are the two critical variables that could have a devastating impact on the migration system. There are three options that could help migrating waterfowl in the Atlantic flyway in the areas that were studied.

The very first step in creating this new assessment plan is to see which agencies will be included. Again, this should be looked at through the view of the waterfowl migrating species. Developing an outline of which agency will be responsible for each resting site will be decided on which agency owns the land, whether it be federal, state or local. The actual plan will be the same for each agency, to protect and adapt the areas that the migrating waterfowl are resting at. For an example, Back Bay NWR has ten impoundment pools that can be flooded or drained depending on which migrating species best suits the depth of water. Flood certain pools to provide habitats for diving ducks and maintain other pools at a shallow water depth for dabbling ducks. This option offers multiple mitigation benefits for migrating waterfowl. This could decrease the negative impact that droughts could have on the ecosystem. Providing plentiful amounts of food and rest area will keep Back Bays numbers stable in the varying migratory system.

The second option is to coordinate with other refuges around the Atlantic flyway and work together to adapt a coastal migratory plan. This plan will take into account various factors that temperature rise has on migration. For the TDSW, Va. numbers seem to be rising at a greater rate than the other two states, N.J. and S.C. Since the temperatures in the future could be too high for TDSW in S.C., N.J. could do what refuges like Back Bay are doing to keep their TDSW numbers increasing. By doing this N.J. ecosystem would be ready for the increase of TDSW. ABDU migration numbers are only increasing in N.J. and are forecasting to continue to do so. Va. and S.C. are seeing declines in ABDU which could be due to increase of MALL populations or due to better stop over sites in N.J. By coordinating between refuges and ensuring that at least a few pools are similar in water levels and vegetation could rule out those variables. Also, comparing ABDU to MALL numbers over the past 15 years could rule out that MALL are overpopulating the ABDU ecosystems. AMWI are in a steady decline in all three researched states. Further research with the Central and Mississippi flyway to see if AMWI migratory population numbers are increasing. Due to varying temperatures due to Arctic Amplification in the eastern part of the United States (Cohen et al. (2014), the stop over sites in these areas might be proving to be more consistent for the short distance migrating AMWI. This option focuses on the partnership of refuge's nationwide and the cooperation of multiple agencies.

The last step would be for the included agencies that are seeing shifts in migratory species is to accommodate to the most abundant species. This option is difficult due to changing ecosystems and species. As Va. is seeing a rise in TDSW then refuges like Back Bay could possibly keep more of the impoundment pools at high water levels to accommodate the TDSW and other diving waterfowl. N.J. is the only state of the three that is seeing a rise in ABDU. Wildlife refuges in N.J. could keep water levels lower to produce more habitats for the dabbling species.

7. Going Forward

Temperature rise is going to continue to be a global issue and continue to change the Atlantic flyway system. Communication between national, state and local agencies and organizations about how to adapt to temperature rise is crucial. Migrating waterfowl are going to breed, rest, and winter in the ecosystem that fits their needs (Schummer, 2010). This multi-step plan creates a foundation for the flyway system with temperature rise in mind. Adapting to the species that are abundant could help provide resources that other locations used to have, but are no longer available, due to higher temperatures changing the ecosystems. Looking forward to see what higher temperatures will do to local refuges' habitats by referencing southern refuges that currently have the temperatures, which are forecasted locally, could provide some insight. It is of utmost importance that there continues to be a changing plan to keep up with the earth's changing climate.

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