Climate Change vs. Warblers: The Phenological Phenomenon of BMIs

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Context

The rising climate is causing irreversible damage across the globe. We are in the sixth mass extinction, and the biggest one to date (1). Large keystone species facing extinction, such as Polar bears, Pandas, Koalas, and Emperor Penguins, garner most of the public attention and sympathy, due to major organizations searching for support, such as the WWF. However, every species has a vital role in its ecosystem, so the extinction of any organism has the potential to lead to the collapse of its surrounding environment.

On average, the earth has warmed 0.72 degrees Fahrenheit from 1979-2008 (2); but has been warming at different rates across the globe. Across the United States, five states have been warming at rates higher than the rest of the nation; therefore, these states should be at the forefront of concern about changing ecosystems. Vermont is ranked third with Minnesota and Wisconsin, with winters warming at about 1.3 degrees per decade (3). Warmer and shorter winters are throwing off the balance of Vermont seasons, causing flowers to bloom sooner, allowing some populations to become overpopulated, while others shrink due to lack of food, and increasing range and population of invasive species (4).

Among other species, bird populations have been severely affected by climate change. This is critical as bird populations play a vital role in keeping forests healthy and promoting biodiversity by pollinating plants, eating harmful insects, and spreading seeds (5). A recent field study conducted by the Vermont Center for Ecostudies (VCE) counted birds over the course of 25 years. In 2013, at the completion of their study, they discovered that Vermont bird populations had declined by 14.2 percent (5). Additionally, the Vermont Audubon chapter is pushing for 32 Vermont bird species to be put on the national threatened species list; more than a quarter of Vermont's 125 bird species (5). The disappearing bird populations in Vermont, make

it extremely important to find what is causing these declines and to then find ways to combat them.

Reasons behind declining populations include increased fragmentation of habitat, invasive species, acid rain depleting nutrients, and climate change changing their habitats and food supply (5). All of these have led to declining bird populations, and damaged ecosystems; however, it is debated as to which cause has led to the most damage for bird populations.

Ken Rosenberg, from the Cornell Lab of Ornithology, conducted a meta-analysis of pre-gathered bird population data and argued that decreasing bird populations may be the fault of food availability, especially with birds whose main diet revolves around insects (6). Some species of birds have already changed migration times, or even stopped migrating altogether, due to a warmer climate. Others, such as the blackpoll warbler, whose population has decreased by 80% in the past 40 years (7), are severely declining due to changing food availability. This underscores the importance of researching warblers (small insectivorous songbirds) to discover if with the rise in global warming, warblers BMIs are decreasing late summer. In particular, narrowing the focus to Vermont, since it is a leading state for climbing temperatures. If food isn't available for birds pre-migration, or if the warmer temperatures prevent the warblers from increasing their fat and protein stores, this would be detrimental to their ability to successfully migrate. Thus creating a chain reaction that would affect the entire ecosystem of Vermont and every area they have historically migrated through. Without these species, the insects they ate would overpopulate, plant diversity would decrease without the spreading of seeds, and thus, affect countless other species with this offset of balance.

The Professional Conversation

Climate Change

As stated above, the rising climate has been a major factor in shifting and depleting warbler's food sources. Therefore, looking at warbler's body mass indexes (BMIs) is important. When researching how warblers BMIs are affected by climate change in Vermont, it is important to see how fast climate change is affecting Vermont and the species of birds living there. A map produced by Climate Central in 2013, showed that temperatures are warming nationwide; furthermore, five states show faster and higher winter temperature changes than anywhere else (3). Winter temperatures in Vermont are rising at an average rate of 1.3 degrees per decade, garnering it a spot as one of these top five states. Research from the Fairbanks Museum and Planetarium, a weather station in St. Johnsbury, Vermont, show a slower, but still significant rate of change year round, gaining by a half degree in 18 years (8). Although this data is only gathered from one town in Vermont, the town has experienced little in the way of human industrialization and change since the weather station began collecting data, leaving it as a good climate control for the rest of Vermont, over other more industrialized locations (9).

Other places in the world have already noticed the effects of climate change on warblers. As A.L. Tsvey and L.V. Sokolov, found in 2014, climate change negatively impacted the warblers they documented, and they found a correlation between decreasing BMIs and a warmer climate (10). This study, conducted in Russia over the course of 28 years, looked at six different common species of warblers during the spring migration. Using banding, or ringing (a form of capturing birds and tagging them with a small band, or ring, around their leg, to further record them if recaptured) to document these birds, Tsvey and Sokolov found that fat stores were decreasing, along with general mass (10). They also noted that fat and protein are the two largest sources of energy for birds, both of which can only be measured by body mass (10). In essence,

with the passing years, birds' energy stores were becoming significantly depleted, at the same time as climate temperatures have risen. This can be seen with the blackpoll warbler, a species which has recently been added to the endangered species list by the U.S. Fish and Wildlife. Due to their habitual timing, their young are hatching at the same time each year; however, due to the rising climate, their main food supply of insects, are hatching and dying off earlier, all before the blackpoll warblers' young have hatched. This is leaving the birds with sparse amounts of food, causing their ecosystem not to be able to support them anymore, and in turn are dying due to starvation, causing their numbers to quickly decline by 80% in only 40 years (1).

However, it is also possible that bird species have been declining in numbers due to other factors, such as habitat fragmentation or changing habitats, rather than food availability. As well, it can be argued that climate change hasn't been negatively affecting warblers BMIs. Some warblers have been able to keep up with the shifting seasons, and others, have been able to stop their migrations all together (11), thus rendering the question of pre-migration BMIs obsolete.

Food and Plants Being Affected

With the depletion of birds' energy stores, finding out what is causing this drop is imperative, making it important to study warbler's diets. Research published in 2013 by Samuel Caro et al. from *PLos Biology* found a growing disparity between plants growing seasons and warblers internal clocks (11). Caro found that birds tend to migrate and molt according to the amount of daylight, while plants flower and live phenologically. He then discovered through seasonal research, that due to global warming, plants' seasons are shifting later, while most birds are still migrating and molting at the same time. However, he observed that bird's diets and mating seasons are affected by the temperature; therefore this phenomenon doesn't always occur, and some birds have managed to shift their migrations later or earlier to match the availability of

their food supply (11). This may cause issues, because, as Les Line described in "Migration Songbirds Switch Their Diet For Long Trips South," many warblers switch their diet from insects to include more fatty fall berries when preparing for their fall migration (12). If, due to a changing temperature, these berries are not available during the critical fat building time pre-migration, the warblers are still needing to molt and migrate without their BMIs at a higher level. This not only affects the warblers but the plants too, since the warblers are critical in spreading the seeds from the berries they eat.

Bird Populations Being Affected

Research from the Vermont Center for Ecostudies found that as of 2017, the general bird population in Vermont has decreased by 14.2 per cent in the past 25 years (6). This study also found that some bird populations, such as the American robin, have actually increased in the past 25 years, but aerial insectivores have decreased by around 45% (5). Ken Rosenberg, from the Cornell Lab of Ornithology, analyzed the data collected and found that while many of the decreasing bird species managed to stabilize their populations after the initial drop, birds which eat insects as their main diet, or aerial insectivores, were unable to stabilize and continued to decline (6). This trend affects warblers, as most warblers belong to the aerial insectivore family.

Madhusudan Katti and Trevor Price from the *Journal of Animal Ecology,* conducted a study in India, wanting to see whether or not rainstorms would affect the greenish leaf warblers fat scores on a day to day basis, and what caused warblers to seek out fat (13). This research found that even on a weekly or day to day basis, the warblers' fat stores were fluctuating with daily temperatures, gaining fat when it was cold or when food was scarce, but losing their fat stores when the temperature increased and there was ample food (13). They also observed on the greenish leaf warblers they caught and banded each day, that increased fat storages delayed their

molting time, and had bad health effects, including inefficient flight and a rapid damage rate of the primary and secondary coverts (wing feathers that cover the flight feathers and help with efficient air flow), along with the rectrices (tail feathers) (13). This information is supported by Scott R. McWilliams, Shannon B. Kearney, and William H. Karasov, from the *Journal of Avian Biology*, who researched in 2002, which types of fat warblers prefer, saturated or unsaturated, and complex versus simple fats. This study found that warblers preferred long chain unsaturated fatty acids as these were the fats that would last longest in colder temperatures (14). They also discovered that warblers tended to eat more food in the cold, but they ate less pre-migration and post-migration (14).

While some researchers say that birds molt and migrate according to the time of day, others argue that birds can't molt if they are too fat; however, both agree that food availability pre-migration is affecting birds, whether there is not enough food, or if the climate is too warm for them to stress eat. Additionally, Scott R. McWilliams et al., argued that although birds ate more in the cold, they were actually eating less pre-migration, which contrasts Madhusudan Katti and Trevor Price, who argued that keeping increased fat stores when they weren't preparing to migrate, would actually have detrimental health effects.

Hypothesis

This study hypothesizes that as the climate warms, there will be a positive correlation between declining BMIs in Vermont warblers and increasing temperatures. This would show that pre-migration temperatures affect birds' ability to gain needed migration fat and protein stores, and it also suggests that increasing temperatures contribute to the decreasing warbler populations.

Methods

To test the hypothesis, a meta-analysis study was conducted of research collected from eight banding stations in Vermont: North Branch Nature Center (Montpelier) (15), Dead Creek WMA (Addison) (16), Green Mountain Audubon (Huntington) (17), Vermont Institute of Natural Science (Woodstock) (18), Black Branch Nulhegan Basin (Bloomfield) (19), Mount Mansfield (Underhill Center) (20), Missisquoi NWR (Swanton) (21), and Knight Island (North Hero) (22). For a banding station to be included, it had to fulfill the following parameters: it had to have been in existence for at least two years, to have had its research conducted anytime between the years of 1996-2016, it had be located in Vermont, and it had to have reported its data to MAPS (Monitoring Avian Productivity and Survivorship). After considering those parameters, only the eight banding stations above met the listed criteria. These stations were located in a mixture of habitats, from hardwood and softwood forests, to fields, pond edges, and more.

To begin to narrow down the data, all data points were deleted that were not found between the years of 1996-2016, all birds that were not insectivores, all warblers that don't migrate, and, as this paper looks at fall migration, birds that were caught in months other than

July and August (banding only going through August each year). Additionally, all birds whose weight or wing chord hadn't been recorded and a few data points that had been recorded incorrectly, were deleted. To test the hypothesis, BMIs were isolated to prove their relevance against climate trends. BMIs were chosen in particular, instead of fat scores, as BMIs offer a more precise and accurate number, rather than fat scores which are rated on a scale of 0-7. Additionally, protein stores (which are part of a birds BMI) are the second most important thing, aside from fat, for a migrating bird to have (10). Based on Tsvey and Sokolov's research, the data was split into hatch year birds (ones who haven't experienced a migration yet), and post hatch year birds (ones who have experienced at least one migration). Additionally, each species group was looked at with two different time parameters. One looked at the birds through the months of July and August (late summer) while the other only looked at the two weeks prior to the start of their migration. The BMIs were then solved for by multiplying the overall weight by 100 and then dividing by the wing chord (wing chord being the length of the wing from the shoulder to the tip) (23). Data was collected on wing chord, weight, and age, as they are all variables which affect the warbler's BMI, and which can be found on the MAPS data sheet that is required to be filled out and submitted to The Institute for Bird Populations (IBP) for every bird collected (24). Time of capture and time of migration were excluded due to time constraints on the research. Sex was also excluded, as over half of the birds' sex was undetermined, not allowing for adequate research to be conducted including sex as a filter. After the unusable data points had been filtered out, four separate wood warbler species were focused on, the ovenbird, American redstart, chestnut-sided warbler, and common yellowthroat. The t-interval for the slope of a regression line was then calculated, to find if the confidence interval was significant, then scatterplots and lines of best fit were created for each grouping, and a t-test for the slope of a

regression line to find the significance of the line of best fit was conducted. Lastly, two sets of t-tests for the difference of means were run with the BMIs from each grouping of birds, to find the difference in five year and ten year sets.

Once the BMIs were isolated, warblers' BMIs were then compared to Vermont's warming trend over the past twenty years, with data received from the Fairbanks Museum *Eye on the Sky* weather database in St. Johnsbury, Vermont. From there, it was determinable whether it shows a significant rate of change with birds' BMIs as the climate rises, if as the climate rises the BMIs are staying consistent, or if the time span of twenty years fails to show a significant rate of change.

Warbler Profiles

The four species of warblers chosen, were selected for their commonality in banding stations across Vermont. Allowing for the groups to have more data points, therefore giving more accurate results.

American Redstart

The American redstart is not on the threatened species list due to its widespread population (25). However, in 48 years, this species has declined up to 47% across the United States. As it is a warbler, insects are the main part of its diet; however, it begins to eat berries pre-migration (26). American redstarts are considered long-distance migrators, departing at the end of July to winter in Central America.

Chestnut-sided Warbler

The chestnut-sided warbler is on the threatened species list for Vermont, which can be shown by its decreasing populations across the United States by around 44% in 49 years. According to the Cornell Lab of Ornithology, "numbers have declined in part, due to loss of habitat" (27). It mainly consumes insects living underneath leaves, though, like the American redstart, it will also eat fruit pre-migration. This bird also winters in Central and South America, departing its breeding grounds in late August.

Common Yellowthroat

The common yellowthroat has declined about 38% in the past 48 years (28), with some populations down south, decreasing as much as over 90%. However, this warbler is not considered a threatened species due to its widespread range (29). This particular type of insectivore, prefers to find and eat insects from the forest floor. Another long-distance migrator, this warbler departs around the same time as the ovenbird and chestnut-sided warbler.

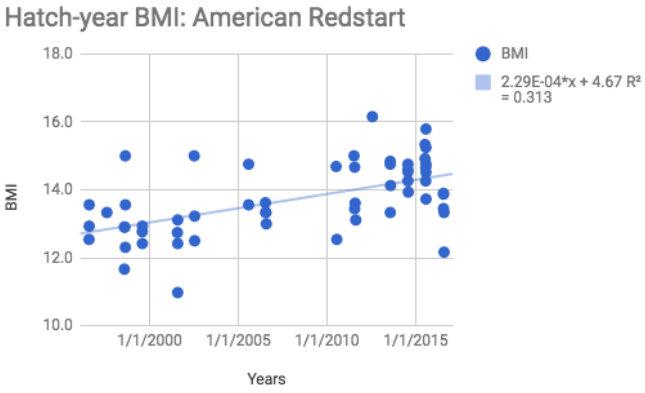
Ovenbird

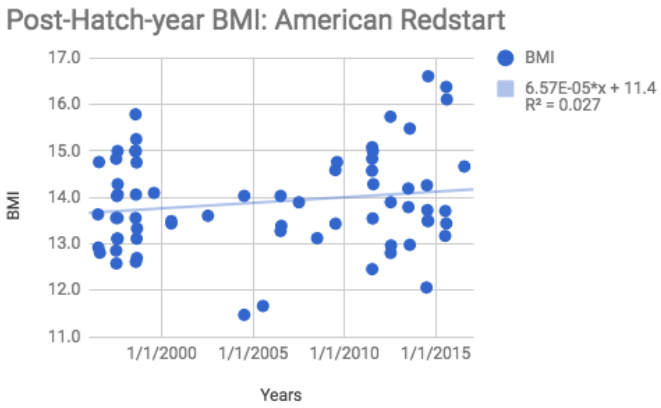
The ovenbirds' populations have not experienced a drastic change over the past 48 years. They are a bush and floor dwelling bird, and their diet includes insects from the forest floor, and some seeds (30). Likewise to the other species studied, they begin their fall migration late August to travel to their wintering grounds in Central America.

Results

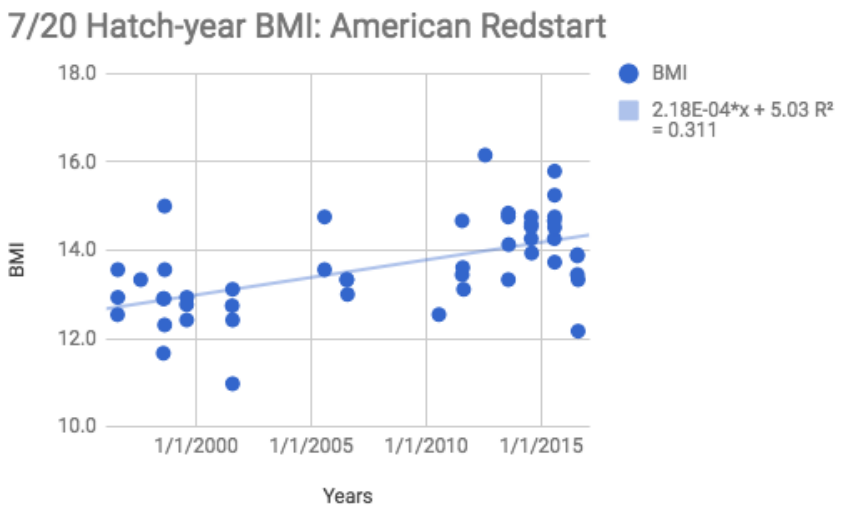
In determining the results, the data was analyzed with eight different filters. Again, each of the four chosen species of birds, American redstart, chestnut-sided warbler, common yellowthroat, and the ovenbird, were split into post hatch year birds or hatch year birds. As well, each species was studied in the two weeks prior to their migration, and during the late summer (July and August). Each species had four groups of data, and each group was then looked at three times.

Late Summer Trends





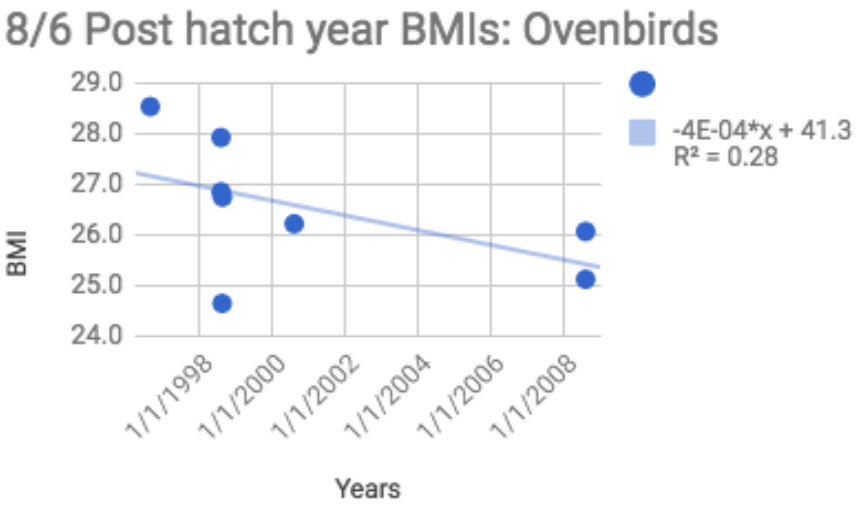
When looked at this way, all of the hatch year birds experienced a BMI increase over the span of twenty years of between .2 to 2. Only two out of the four, the American redstart and the chestnut-sided warbler, post hatch year, saw a BMI increase of .3 and .2 respectively. Meanwhile, the common yellowthroat decreased slightly in average BMI by .1, and the ovenbird decreased by .9. (See Appendix A/B for full set of graphs exhibiting all species studied)



Pre-Migration Trends

After that, the filter was narrowed for each species, now examining only the two weeks prior to the start of their migration, again keeping each species split into their hatch year and post hatch year groups. Here, the hatch year American redstart, chestnut-sided warbler, and ovenbird, still showed signs of a BMI increase of between .6-1.1, while the common yellowthroat showed a slight loss of .2 over the twenty years. (See Appendix C for full set of graphs exhibiting all species studied)

This was concurrent for the post hatch year American redstart and the common

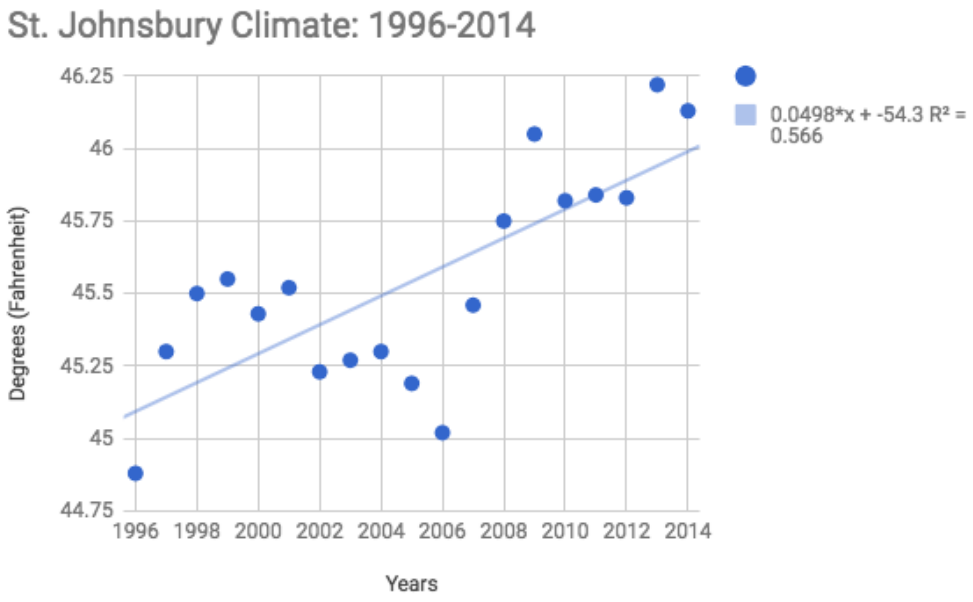


yellowthroat who showed a 1.2 and .3 increase respectively; however, the chestnut-sided warbler showed no change, and the ovenbird's BMI decreased by 1.3 points. (See Appendix D for full set of graphs exhibiting all species studied)

Species Trends

Within species, other species specific trends were visible. American redstart hatch year birds increased at a similar rate during the late summer, and two weeks prior to migration, while pre-migration post hatch year American redstarts increased by around .9 over their late summer counterparts. The common yellowthroat groups switched slopes with pre-migration and late summer. The late summer hatch years, increased by 2 points while weeks later, pre-migration, their BMI dropped by .2. Meanwhile, the exact opposite occurred with the adults, with the post hatch years decreasing BMIs by .1, only for their yearly average to increase by .3, in the two weeks before migration. The hatch year chestnut-sided warblers, experienced .7 (a little over double) increase over the pre-migration hatch year, group, and the summer post hatch years had a small increase over the twenty years, of .2, while the pre-migration post hatch years, stayed stagnant, showing no change. Lastly, late summer hatch year ovenbirds, increased by two, with the pre-migratory group increasing by 1.1. As well, both groups of post hatch year ovenbirds experienced a decrease in average BMIs, with the late summer group decreasing by .9, and the pre-migratory group decreasing by 1.3.

Vermont Climate Change



Meanwhile, the climate in Vermont, has shown a slow, but consistent increase of about .5 degrees Fahrenheit per decade, in the past eighteen years of available data. (See Appendix E for original graph)

Discussion

As can be shown by the results section, there was not shown to be a significant rate of change. This was especially apparent as some of the graphed trend lines, for example the pre-migration, common yellowthroat, hatch year, group's BMIs showed a positive slope while the t-tests for the difference of means, showed a decrease. This contrasts the research conducted by A.L. Tsvey and Sokolov, who found significant rates of change between bird's fat scores and a rising climate in Russia, over a 28 year time span. This could be due to a different location, as climate change affects separate regions around the globe differently. As well, although the climate has shown a significant rising trend, the climate also goes through fluctuations, where

some sets of years are colder than others; however, this isn't likely, as the study overlapped years with the Vermont study outlined in this paper.

Since bird populations are decreasing, including the species analyzed in this study, it can then be concluded that although bird populations are decreasing, and as studies by Andrew Friedland et al., the Vermont Center for Ecostudies, and Wilson Ring, suggest, are quite possibly due to food availability, in this instance it is not proven to be significantly tied to climate change. This research has shown that in Vermont, warming climates are not significantly affecting warbler's ability to gain fat and protein late summer and pre-migration, and can be conjectured that there is not a visible correlation over 20 years, as of now, of warbler species in Vermont.

However, some trends, though insignificant, came to light, which should be noted and watched in the future. Even though changes in BMIs were slight, it could be possible, that the reason some of these changes occurred, was due to their food supply, with maybe an increasing availability for those species whose BMIs went up, a decreasing pre-migration supply for some, such as the ovenbird, which was surprising due to their historically stagnant population, or even that for species such as the American redstart, it is possible that they are having to switch over to their pre-migration berries sooner, allowing for adult birds to feed, but possibly proving to be more of a challenge for hatch year birds who have fledged, but aren't used to an abrupt change of food source.

Limitations

Unfortunately, there are many limitations to this study. First and foremost, scientific studies usually include at least thirty data points and thirty years. However, due to the time span of the banding stations studied, only twenty out of twenty-six possible years were studied. If this study was redone in another ten years or so, trends may become more evident as more research is

collected. As well, when filtering groups, some birds had exceptionally low numbers, sometimes fewer than nine in a group, with many years missing in between, thus causing for a very small sampling. Additionally, many birds were recaptures, not allowing for a perfect random sample, and possibly skewing the data collected. Because of the low numbers of birds in some groups, and gaps in years, all recaptures were kept to keep the study as close the the thirty point minimum as possible, and to keep the study consistent throughout. If recaptures were excluded from the data, along with having a more consistent data set per year, more trends may have appeared, and the results may have been altered. As well, due to the nature of the study, it is quite possible that the birds collected were not a part of a perfect random sample. It was assumed that the birds captured in the mist nets were randomly caught; however, it is quite possible that only birds from a certain territory were caught, recaptures, who consistently forgot where the net was located, and birds from only a certain level in the forest where these nets could reach. Lastly, one must assume that climate change is a real, and a threat to the environment.

Implications

The implications of these results, show that the meta-analysis conducted in Vermont contrasts much of the hypotheses and research in this field. Even though it is undoubted that warbler populations are declining, the correlation between rising temperatures and body mass indexes pre-migration didn't show any significance. Thus bringing to light the possibility that the assumptions made to explain these species rapidly declining populations must be rethought, and more research must be conducted concerning other aspects that could affect a warbler's mortality.

Further research

From conducting this study, it was evident that there is still much more to learn from this field and set of data. First, the ovenbird populations should be monitored and studied more closely in the future, as even though they were the one species with a stagnant population, their BMIs decreased the most across the filters. Since it is still evident that Vermont bird populations are still declining rapidly, another quantitative study looking at the number of birds per year, would be wise. Another direction for research could look into molting times for Vermont warblers, and looking to see if they are molting, and thereby migrating, at a later time, as the study by Madhusudan Katti and Trevor Price suggested. As well, analyzing the data and trends found with this study, then researching the four birds diets, and looking at the population trends of those insects, and then comparing that to the downward or upward trend that these birds experienced, would be another important area to research. Lastly, another noticed trend, was that almost no birds of any species were caught in the years surrounding 2005; therefore, research should be conducted to find what occured in those years that resulted in a severely decreased bird population.

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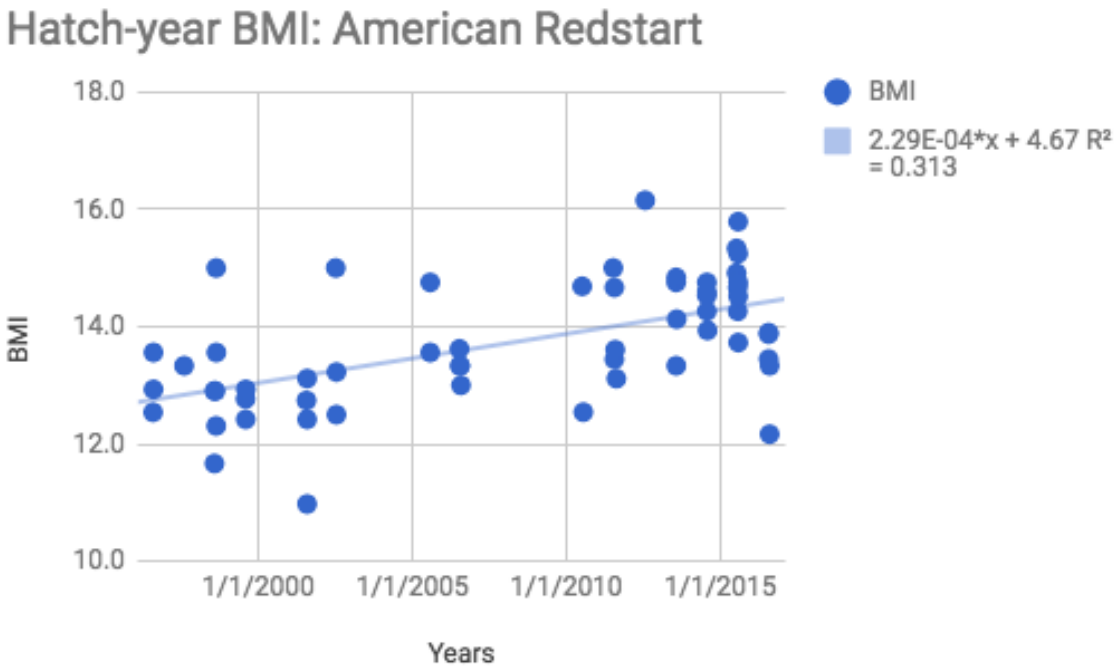
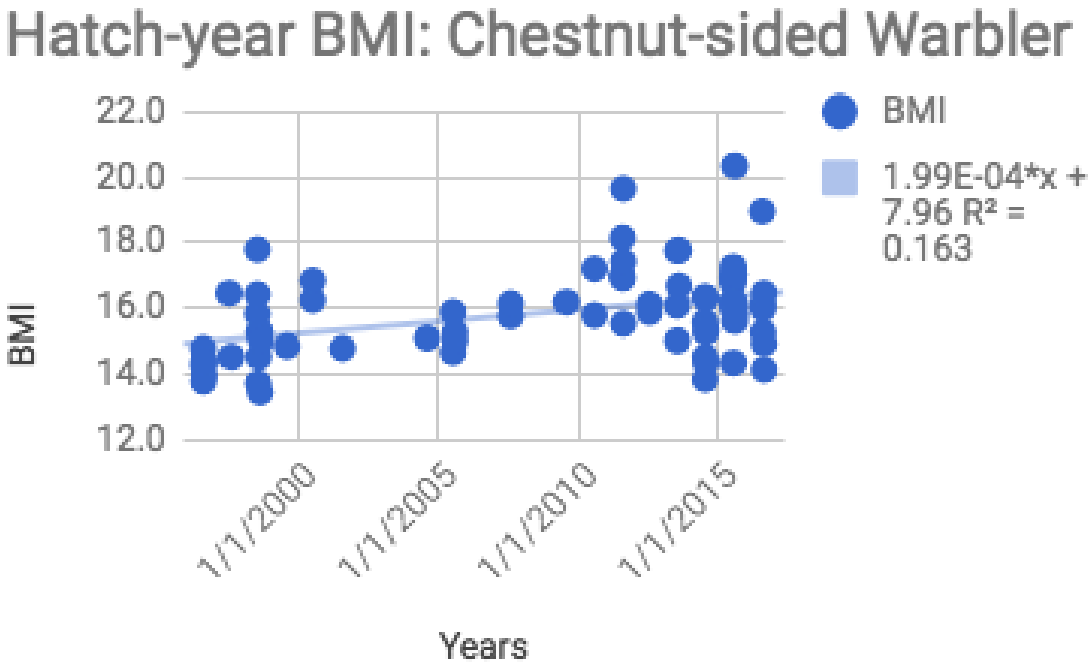
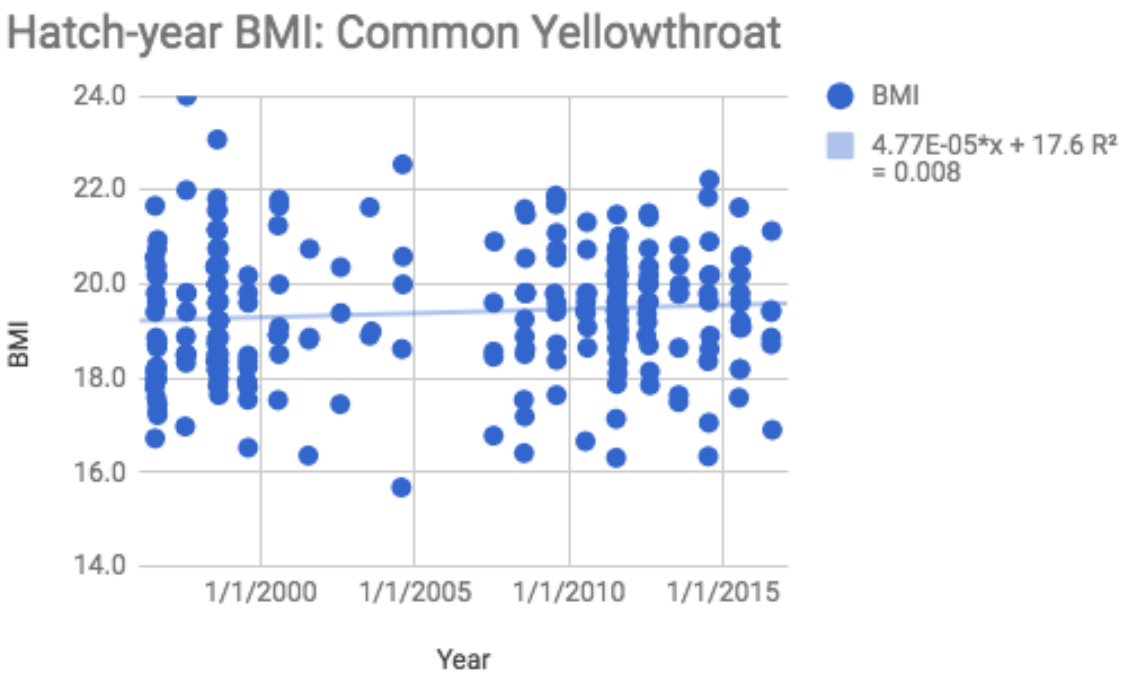
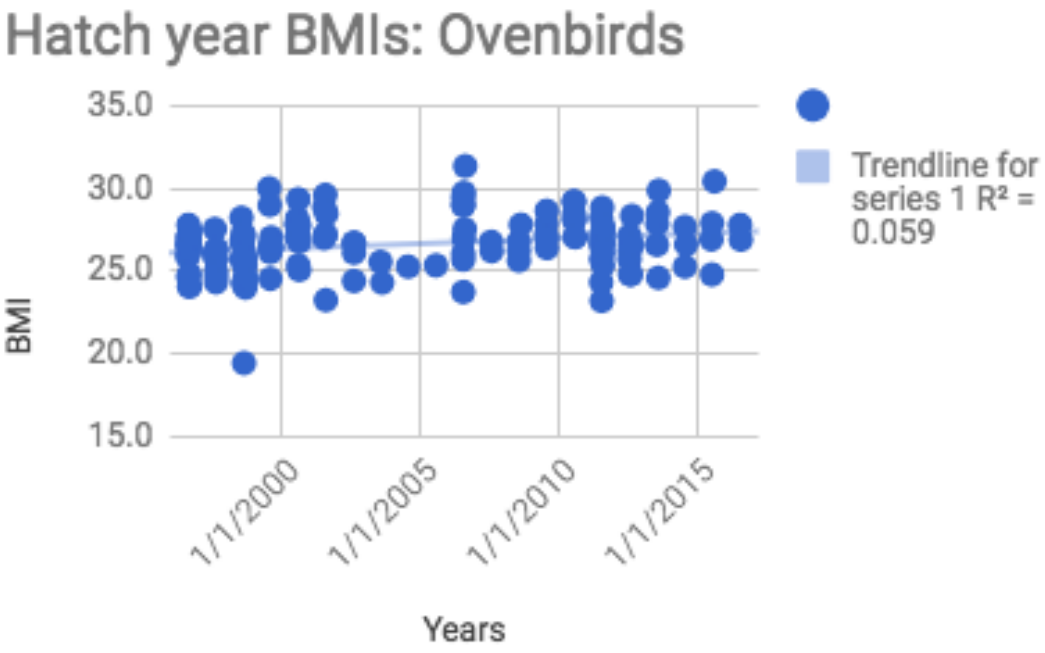


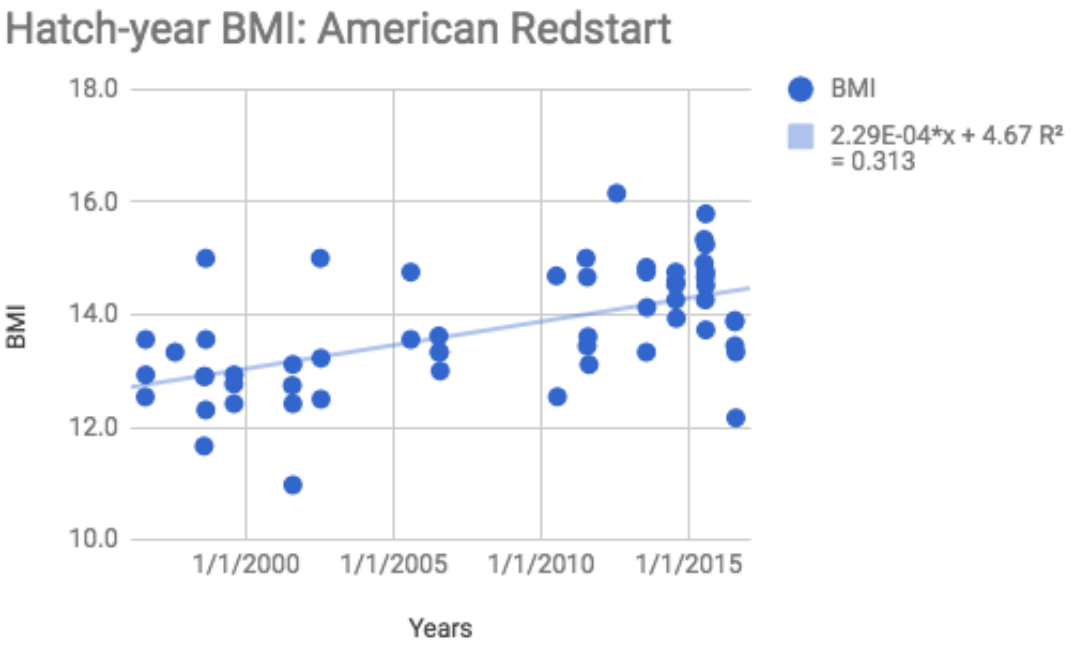
Appendix A: *Late summer, hatch year.*

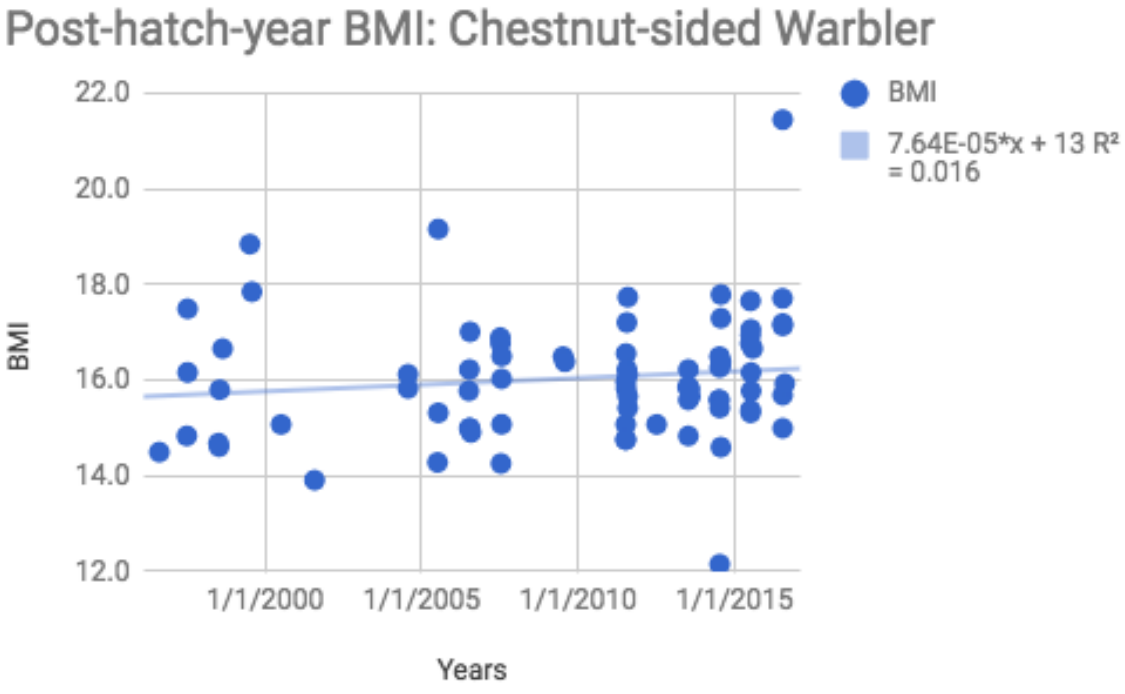


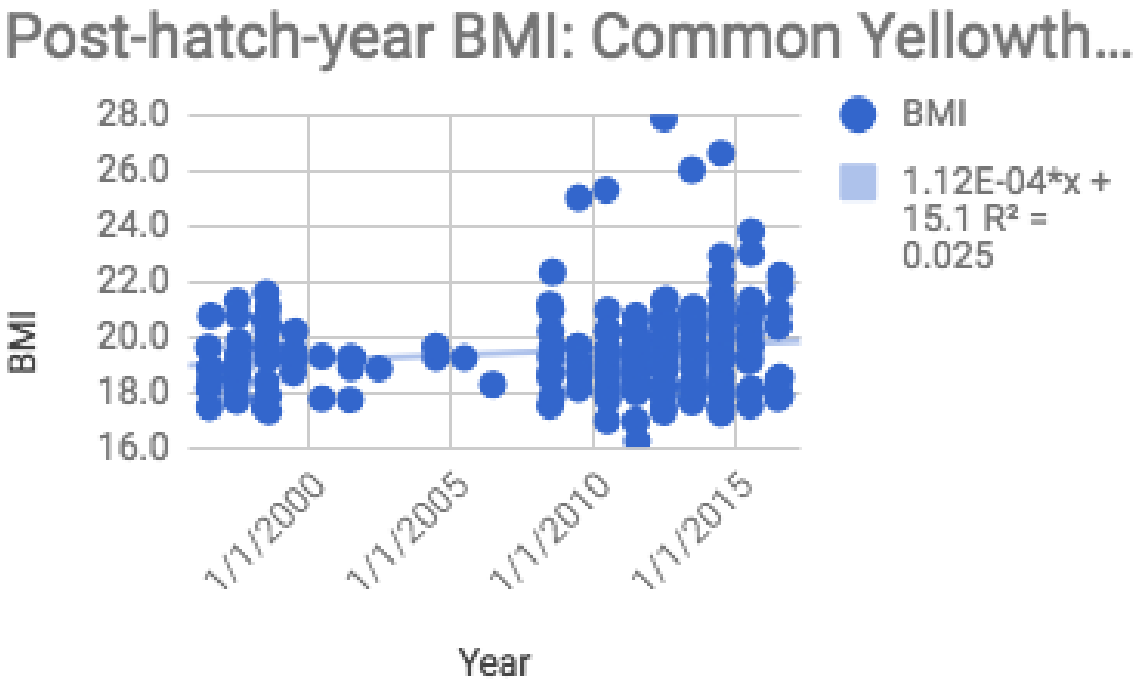

Hatch-year BMI: Common Yellowthroat
24.0
22.0
20.0
18.0
16.0
14.0
BMI
1/1/2000
1/1/2005
1/1/2010
1/1/2015
Year
BMI
4.77E-05*x + 17.6 R² = 0.008

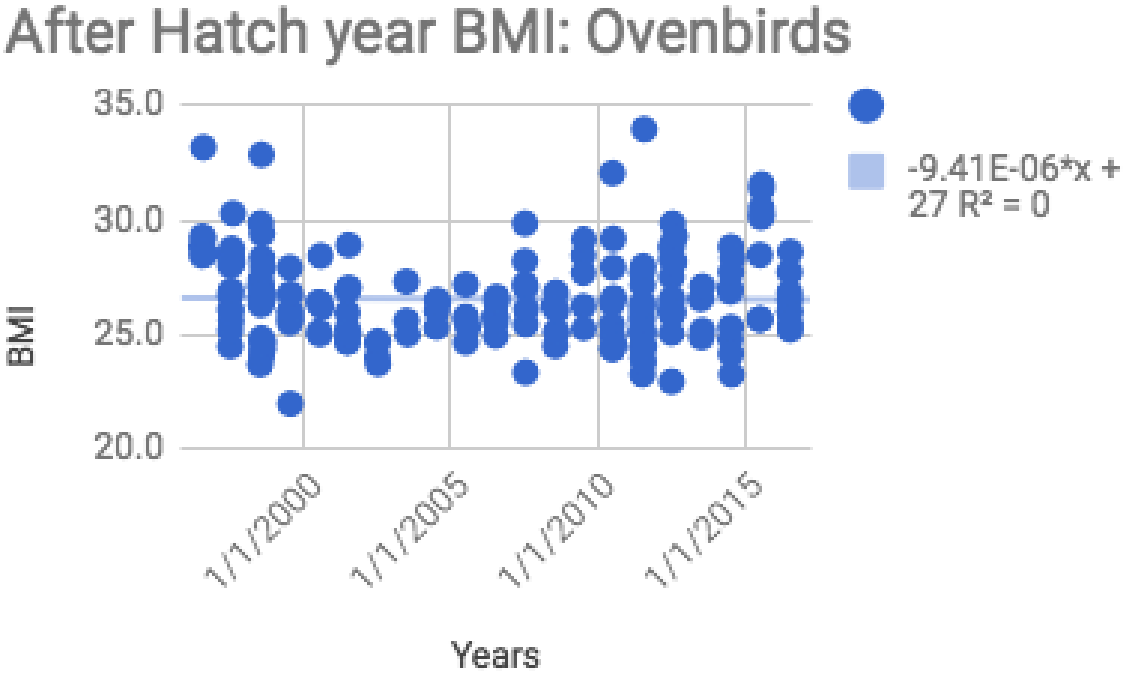

Hatch year BMIs: Ovenbirds
35.0
30.0
25.0
20.0
15.0
BMI
1/1/2000
1/1/2005
1/1/2010
1/1/2015
Years
Trendline for series 1 R² = 0.059

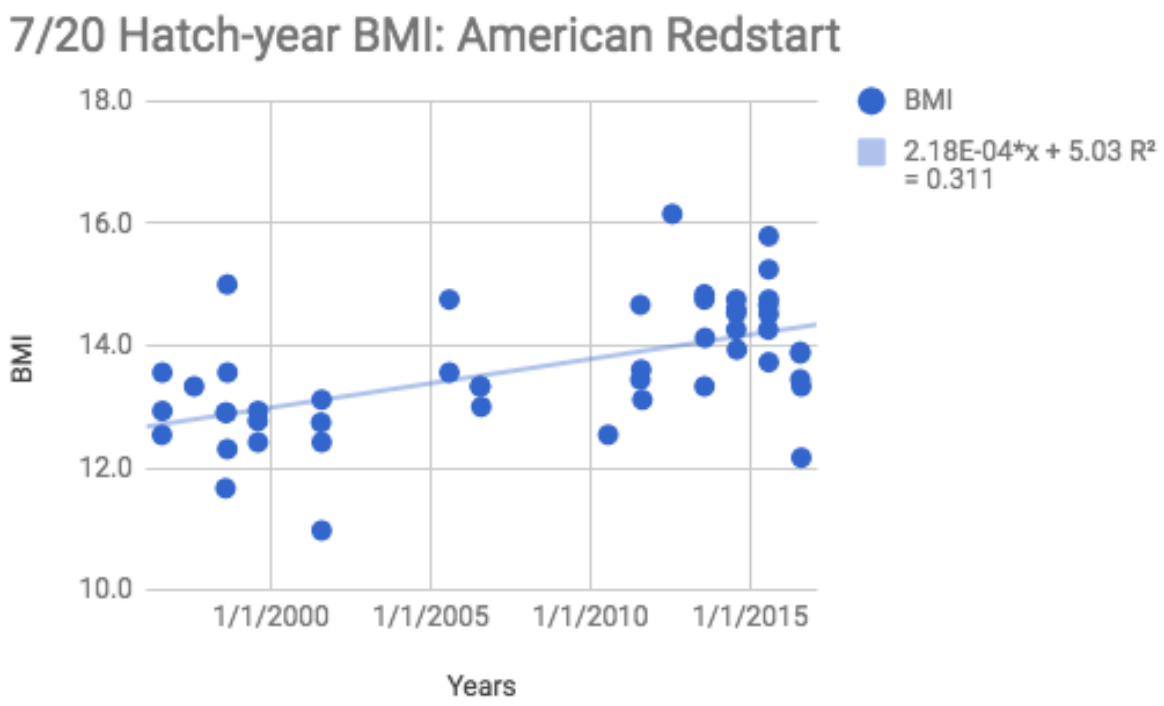
Appendix B: *Late summer, post hatch year.*

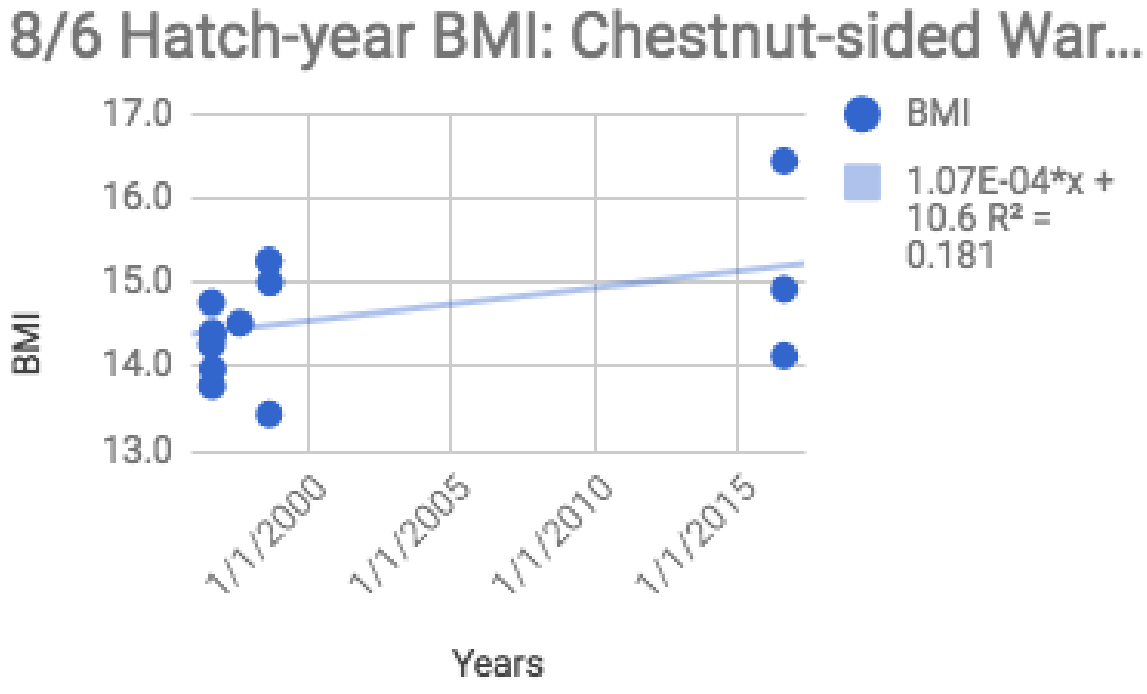

Hatch-year BMI: American Redstart
18.0
16.0
14.0
12.0
10.0
BMI
1/1/2000
1/1/2005
1/1/2010
1/1/2015
Years
BMI
2.29E-04*x + 4.67 R² = 0.313


Post-hatch-year BMI: Chestnut-sided Warbler
22.0
20.0
18.0
16.0
14.0
12.0
BMI
1/1/2000
1/1/2005
1/1/2010
1/1/2015
Years
BMI
7.64E-05*x + 13 R² = 0.016

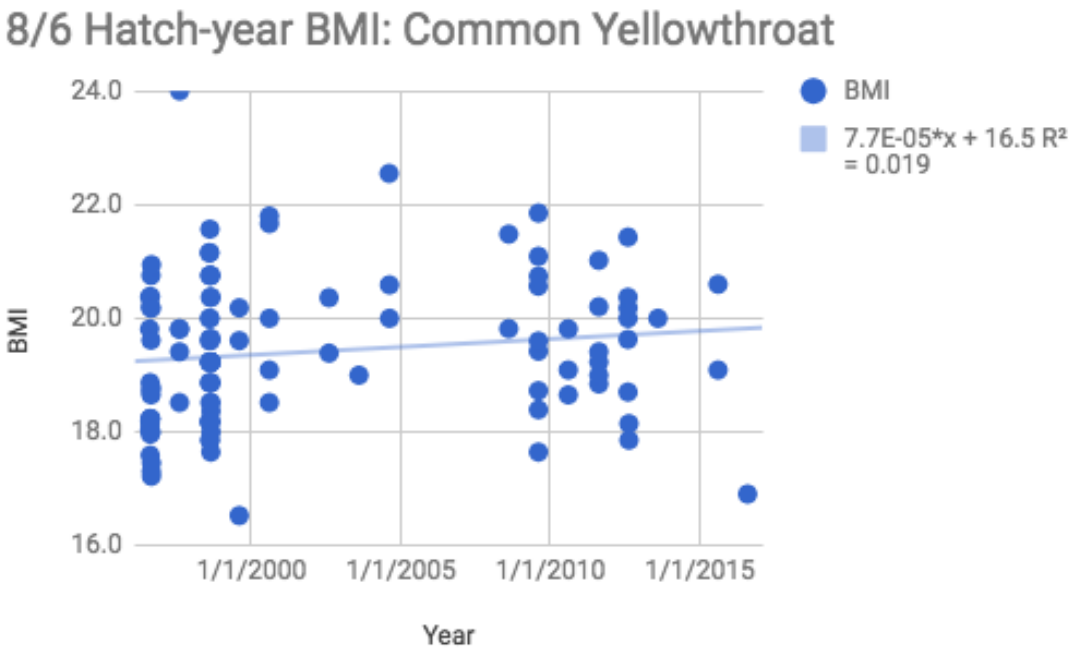

Post-hatch-year BMI: Common Yellowth...
28.0
26.0
24.0
22.0
20.0
18.0
16.0
BMI
1/1/2000
1/1/2005
1/1/2010
1/1/2015
Year
BMI
1.12E-04*x + 15.1 R² = 0.025

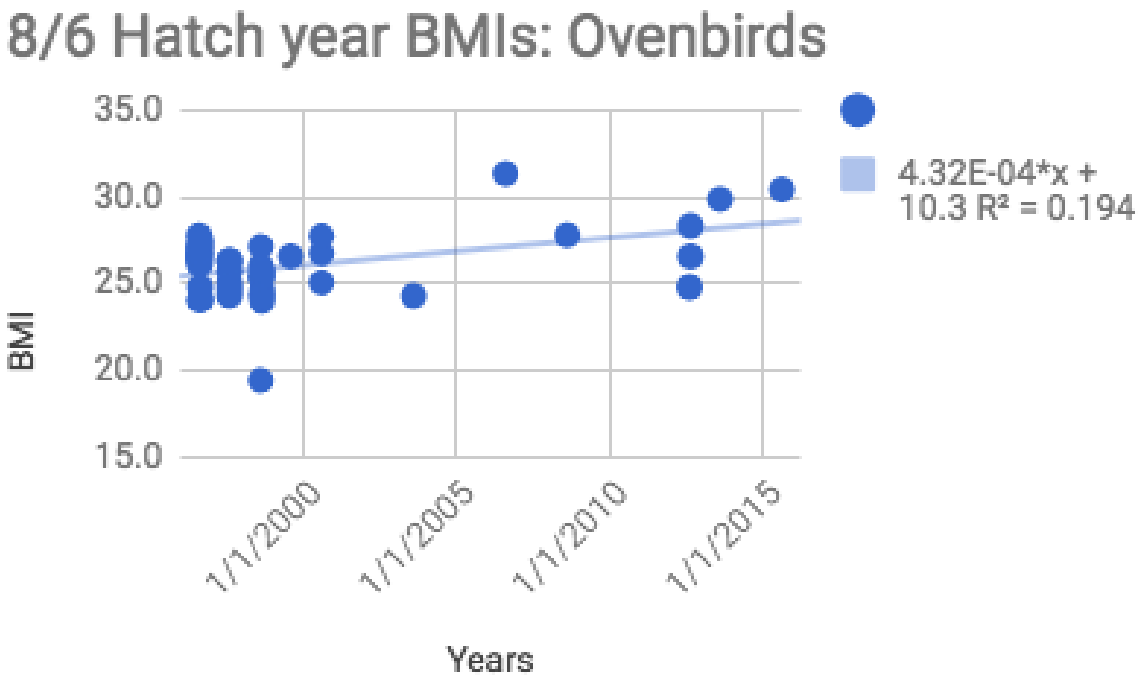

After Hatch year BMI: Ovenbirds
35.0
30.0
25.0
20.0
BMI
1/1/2000
1/1/2005
1/1/2010
1/1/2015
Years
-9.41E-06*x + 27 R² = 0

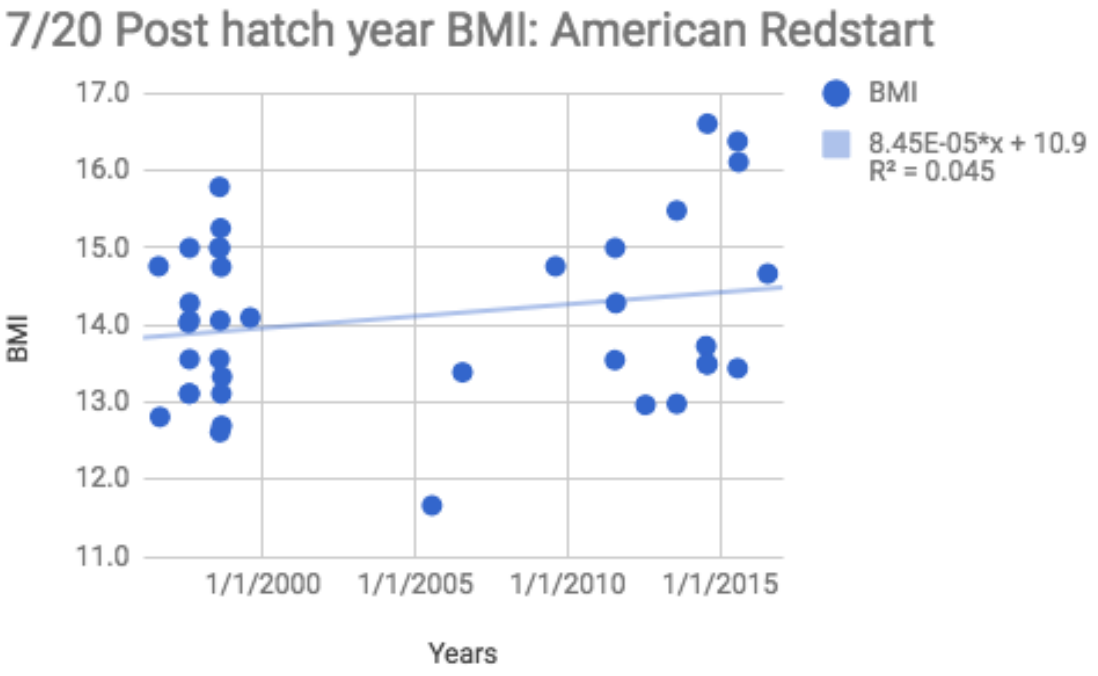


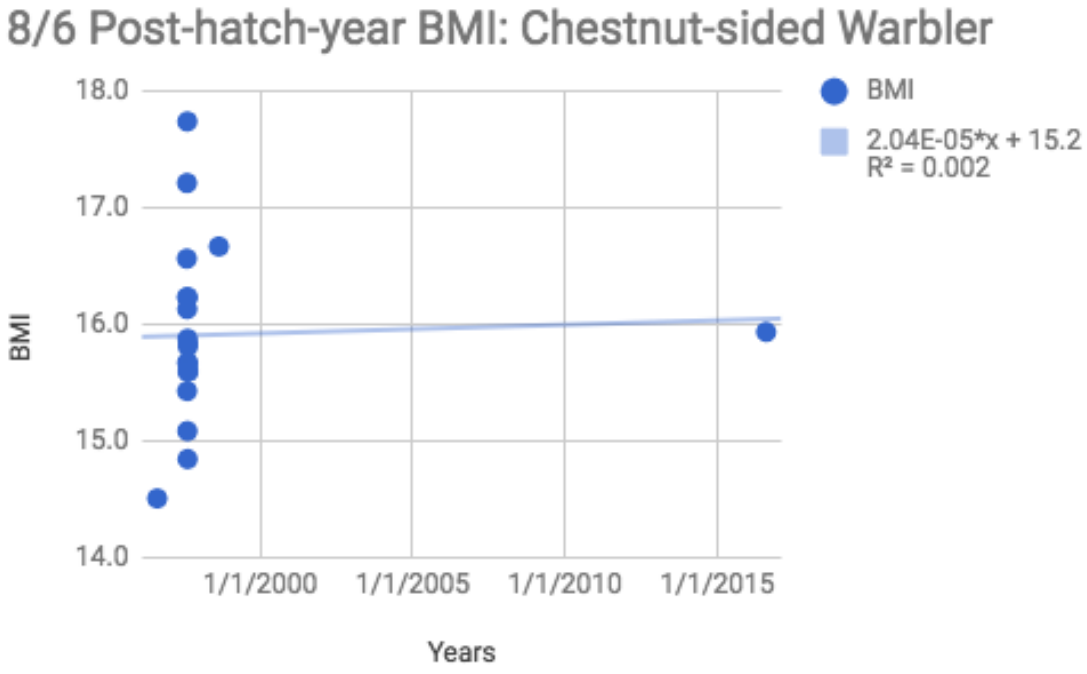


Appendix C: *Two weeks prior to start of migration: Hatch year.*

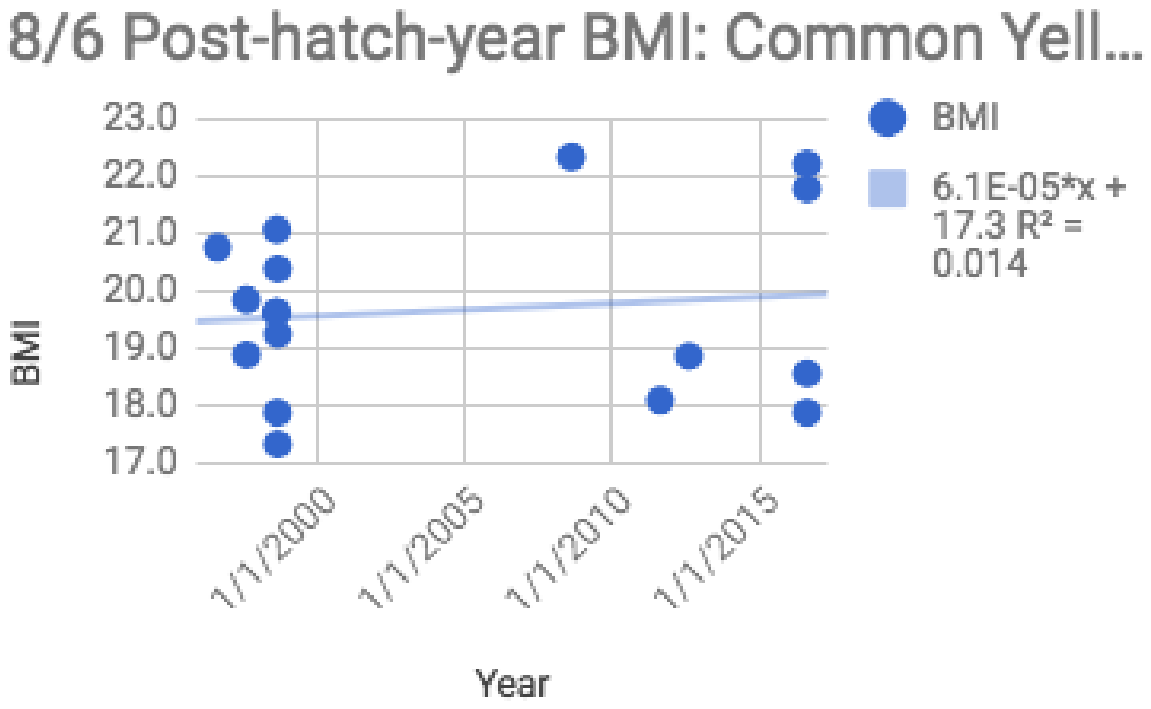

8/6 Hatch-year BMI: Common Yellowthroat
24.0
22.0
20.0
18.0
16.0
BMI
1/1/2000
1/1/2005
1/1/2010
1/1/2015
Year
BMI
7.7E-05*x + 16.5 R² = 0.019

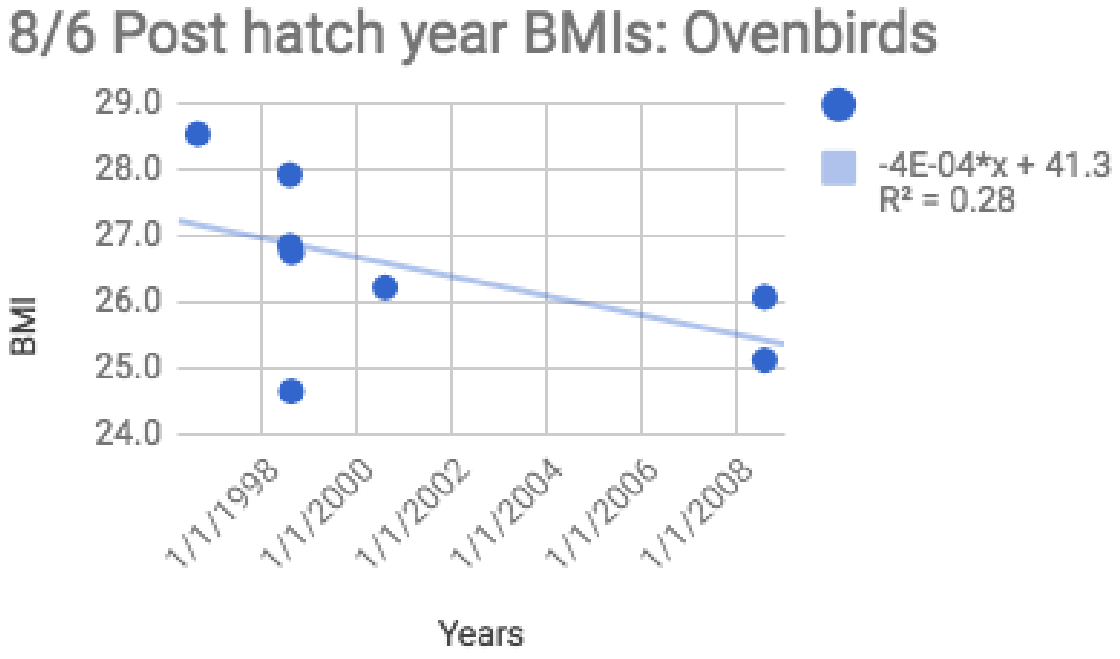

8/6 Hatch year BMIs: Ovenbirds
35.0
30.0
25.0
20.0
15.0
BMI
1/1/2000
1/1/2005
1/1/2010
1/1/2015
Years
4.32E-04*x + 10.3 R² = 0.194



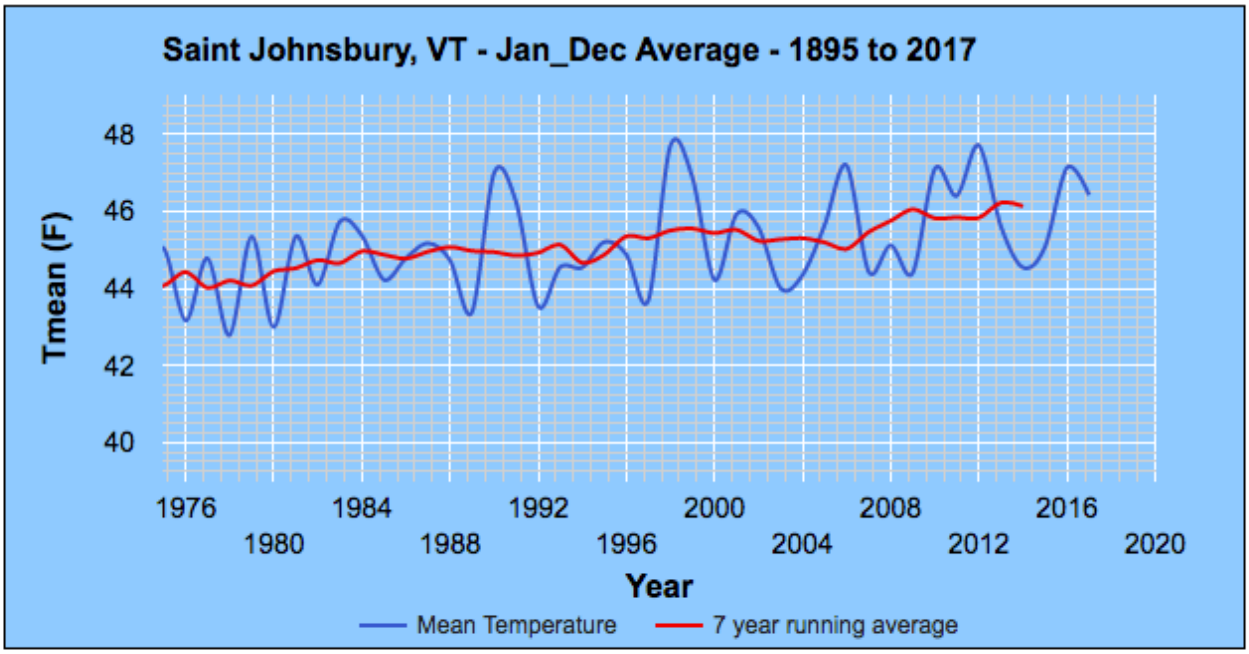


Appendix D: *Two weeks prior to start of migration: Post hatch year.*


8/6 Post-hatch-year BMI: Common Yell...
23.0
22.0
21.0
20.0
19.0
18.0
17.0
BMI
1/1/2000
1/1/2005
1/1/2010
1/1/2015
Year
BMI
6.1E-05*x + 17.3 R² = 0.014


8/6 Post hatch year BMIs: Ovenbirds
29.0
28.0
27.0
26.0
25.0
24.0
BMI
1/1/1998
1/1/2000
1/1/2002
1/1/2004
1/1/2006
1/1/2008
Years
-4E-04*x + 41.3 R² = 0.28

Appendix E: *Mean temperatures from 1975-2014 (8).*



The **Tmean chart** (immediately above) shows the average mean temperature for each calendar year.

Values often change a lot from one year to the next. In order to see the trend, a **7 year running average** is shown (thick red curve). For each year (except the first and last 3) the 3 previous years, the year, and the next 3 years are averaged.