Vermont Skiing and Maple Sugaring in the 21st Century:

How two of Vermont's leading environmentally dependent industries are responding to increasingly unpredictable natural conditions

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1. Introduction

Vermont is notable for the strong land use planning and development controls in place at the state level. Keen forethought in the late 1960s into the 1970s allowed Vermont to control urban growth and sprawl, and preserve its primarily rural character. In 1965, two National Forests were established covering over a quarter of Vermont's total land acreage, and the amount of land under protection has only increased since. By recognizing the impact that increasing development pressures were having on Vermont and adjoining states, as well as acknowledging increased tourism and its impact to the region, planners and development officials were able to take effective steps to regulate growth and retain their heritage (NPS 2013). Put into the context of rural America as a whole, Vermont is a small area with relatively small-scale agriculture and forestry, unable to seriously compete in most national or global commodities markets. In many ways, rural Vermont is delicate, struggling with aging populations and the loss of the commerce or industries that built its downtowns and iconic New England communities. There are two industries dependent on Vermont's natural features in which the state excels, however: maple sugaring and skiing.

Snow and cold temperatures bring in a lot of money for Vermont. Vermont ski areas offer recreation for residents and visitors along with thousands of jobs, contributing more than $1.1 billion annually to the state's economy during the 2010 – 2011 season, approximately 4.2 percent of Vermont's gross state product of $26 billion (GA 2011). Beginning with the country's first alpine ski tow built on a Woodstock farm in 1934, as well as the nation's first ever chairlift used on Mount Mansfield in 1940, Vermont has been the prominent skiing and winter sport destination on the east coast. Vermont has approximately twenty alpine ski resorts and thirty cross-country touring centers throughout the state, complete with 6,052 acres of alpine terrain, 1,269 trails, 179 lifts, and 885 miles of Nordic trails. Averaging individual resorts' reports, average annual mountain snowfall is roughly 225 inches (VDTM 2012). Vermont winter recreation, from skiing to snowboarding to snowmobiling, got so popular in part because the terrain is capable of accommodating every skill level, from beginning children to advanced professionals, and the wide range of terrain available to each skill set, from wooded glades to steep fields.

Vermont is the skiing stronghold of the east, but it is not regarded as the best state for skiing in the country. Where Vermont is number one, though, is in maple syrup. Vermont is the largest producer in the United States, generating about 5.5 percent of the global supply. The state takes a great deal of pride in the quality of its syrup, enough so that it chose a maple-sugaring scene to put on the back of its commemorative state quarter. About one of every four trees in Vermont is a maple, with the sugar maple designated as the state tree of Vermont in 1949. All in all, the maple industry in Vermont yields about fifteen million dollars in direct sales each year, with the economic impact of maple in Vermont hitting over $226 million annually. This is a relatively small percentage of Vermont's overall economy, but maple sugaring is a crucial iconic industry for the state, being one of the few things Vermont is number one in the nation for.

Climate change would obviously appear to present a challenge to these natural assets and well-preserved ecosystems which make Vermont unique and upon which it thrives. Both skiing and maple sugaring would seem to be fairly dependent on Vermont's natural features and climate, and too much change could be potentially damaging. Since 1970, the average temperature in New England has increased by two degrees Fahrenheit, with average winter temperatures rising twice as fast, four degrees between 1970 and 2000. It may not seem like much, but it is a significant increase. Precipitation in Vermont has also gone up by as much as twenty percent, with more of it arriving as rain and less as snow. Overall, Vermont has seen hotter summers, longer and more persistent droughts, heavier, more frequent and torrential extreme weather events such as Tropical Storm Irene in 2011, rainier winters, and earlier springs (NECIA 2006).

The climate of Vermont has been shifting quickly in recent decades as amplified concentrations of greenhouse gases in the atmosphere push changes in the global climate. These changes in regional climate have and will continue to affect Vermont's landscape, including agriculture, forests, streams, lakes and wildlife. Furthermore, a lot of the relevant societal infrastructure of Vermont, such as the water and wastewater treatment systems upon which the ski resorts rely heavily, was designed under the assumption that its climate would vary little as time went on. This is not true any longer, meaning a more adaptive approach is needed for the rest of this century if the state is to preserve profitable management of a changing environment and continue enjoying the outdoor activities upon which it thrives.

I set out to research the current state of Vermont's maple sugaring and skiing industries in the face of climate change and the more random and unpredictable weather patterns that have occurred in the last decade. I set my focus on the years 2000 to the present, giving me the opportunity to look at the last approximately thirteen years of each industry. How are these industries performing? How have they changed their practices due to climate changes that have already occurred? How are they planning on further adapting for the future? Will these industries even still be viable in Vermont in one hundred years?

To piece together the last thirteen years of maple sugaring and skiing in Vermont, I examined Internet and print sources and reached out to many individuals and organizations throughout the state in order to compile all relevant data I could. Because of the time-scale involved, and the wide range of maple sugarers and ski resorts scattered throughout the state, I felt as though tracking down and pulling in diverse, unconnected data from across the state was the most efficient and most informative method. To gain a better understanding of climate and current weather trends, I reached out to the Vermont State Climatologist and used data gathered from the National Weather Service. A majority of data regarding maple syrup production and sales was acquired from the United States Department of Agriculture and studies done by the Proctor Maple Research Center, while skiing information largely came from The Vermont Ski Areas Association. These data were collated with information from local and national newspapers, scholarly journals, radio, the University of Vermont, and various branches of the Vermont state government, from the Agency of Natural Resources to the Department of Tourism and Marketing.

2. Maple Sugar in Vermont: Pre-Colonial to Present

Maple sugaring has been prevalent in the Vermont region since before Europeans had begun to move in and settle (Albers 2000). Native Americans are believed to have made maple sugar prior to the year 1673, although the exact timing or manner of the discovery is unknown (Crockett 1915). Some historical records indicate Native Americans tapping maple trees over a hundred years before that, in 1540, with written observations of Native Americans actually transforming sap into maple sugar existing from as early as 1557 (UVM 2013). The Native American method of tapping trees was to make a diagonal incision in the trunk of the maple, insert a reed or concave piece of bark into the lower end, and convey the sap into a bark trough or other receptacle. To boil it, they would drop hot stones repeatedly into the clay or bark vessels containing the sap. The 1755 journals of a prisoner captured by Native Americans, most likely the Abenaki, the most widespread tribe in Vermont, relates the fact that the native population stored sap in large troughs made of elm bark, often with a capacity of a hundred gallons (Crockett 1915).

Upon their arrival, early European settlers continued the practice of tapping maple trees in the spring, turning a majority of the sap produced into maple sugar instead of syrup (Albers 2000). These early white settlers largely followed the Native American methods of sugar making, but with a few of their own twists, substituting wood spikes or spouts for the reed or bark spouts, and using iron or copper kettles for boiling. For these early settlers, it was important to be able to produce most of the food or clothing needed by the family, and maple sugar was the only sugar most of them could obtain.

Unfortunately for early pioneers, comfortable settlement was not possible without cultivating the land and eliminating much of the forest. Early settlers, in order to clear the land and to produce a fine grade of potash salts from the ashes, burned thousands of great, old sugar maples. It was only once the pioneer stage of Vermont's history had subsided somewhat that Vermonters were ready and able to take full advantage of their maples (Crockett 1915).

Early European settlers typically found much of Vermont to be frightening and difficult to settle, but they eventually found a truly bright side in, and learned the immense value of, the maple tree. Beginning at the start of the nineteenth century, European settlers were more fully utilizing and being impressed with the natural productivity of the maple trees and of its growth as a commercial endeavor. In the 1809 account *The Natural and Civil History of Vermont*, author Samuel Williams wrote:

> "A man much employed in making maple sugar, found that for twenty one days together, one of the maple trees which he tended, discharged seven gallons and an half each day ... These accounts serve to show, what a quantity of fluid, is naturally contained in some of our trees" (p. 91).

A little over thirty years later, in 1842, Burlington resident Zadoch Thompson released his *History of Vermont, Natural, Civil, and Statistical*, in which he devoted pages to the merits of the maple. Even more interestingly, he directly pinpointed, way back in the 1840s, a strong preservation ethic being formed directed towards the maple:

> "The Sugar Maple is one of our most common and valuable forest trees ... Valuable as this tree is on account of its wood, and for being one of our most beautiful and flourishing ornamental shade trees, its value is greatly increased on account of the sugar extracted from it. When the country was new, nearly all the sweetening consumed in the state was obtained from the sugar maple, and although the proportional quantity has been diminished by the destruction of the maple forests, our people have become so sensible of its value, both for fuel and for

> its sugar, that they are taking much pains to preserve groves of the second growth. It is a tree which grows rapidly, and considerable quantities of sugar are now made from trees which sprung from the seed since the settlement of the state was commenced" (p. 209).

The state was indeed producing a considerable amount of sugar: Zadoch Thompson reports over 4,600,000 pounds were manufactured in the state in 1840. The maple was now regarded as the most useful tree in the region. Farmers were said to take as much pains keeping and preserving an orchard of maple as they would of apple trees, from which each could manufacture between fifty to two-thousand pounds of sugar annually, mostly for their own use, but which would become an item of commerce if plentiful.

The quality of the sugar made in the state during this time, however, was very unequal. Much of the sugar was indeed was of great quality, but some of it was black, dirty and "disagreeable", leading to the first studies in Vermont on the proper manner and care with which maple sugar should be manufactured. It did not take long for settlers to realize that the dark color of much of their maple syrup, along with the sliminess and disagreeable taste, was primarily the result of three factors: negligence to scald the buckets used for catching the sap and to keep the sap clear from all impurities, allowing the kettles to become overly heated causing the syrup to burn and elements from the kettle to be dissolved and mixed in with the syrup, and allowing syrup to remain too long in iron kettles. The aforementioned Zadoch Thompson reached the conclusion that if these things were to be prevented, allowing the syrup to be well settled, well cleansed, and done down without being burnt, there could be no doubt that there would be good maple sugar in Vermont.

Farmers in Vermont more commonly began to not only supply themselves with maple sugar for domestic use and comfort, but also have a portion to spare for their neighbors. While the expense of fuel wood to boil away the sap had previously prevented many people from engaging in the process, new inventions and technologies in the mid-1800s such as sheet iron boilers, the heater, and the evaporator removed these barriers (Beckley 1846). More people were able to and began to get involved, further solidifying the connection between the maple and Vermont identity. There was a strong pride in Vermont syrup, which Thompson's closing remarks on the sugar maple make well clear:

> "The sugar made from this tree, in addition to its excellent qualities, has two important recommendations. It is the production of our own state, and it is never tinctured with the sweat, and the groans, and the tears, and the blood of the poor slave" (p. 210).

By 1890, Vermont was making over fourteen million pounds of syrup annually, becoming the leader in the nation in maple syrup production (Albers 2000).

Vermont's maple domination in relation to the rest of the country only continued to grow as the twentieth century rolled in. In 1909, Vermont produced 7,726,817 pounds of maple sugar, almost 55 percent of the nation's total. The United States census report for 1910 shows that 5,585,632 maple trees were tapped in Vermont that year, 29.5 percent of the total number of maple trees tapped in the United States, and the largest number reported by any state. While these numbers are nowhere near the 14,123,921 pounds of maple sugar Vermont had produced in 1889, the maple worm, a saturniide moth larva that defoliates trees, and the increasing value of maple wood for timber purposes had decreased production everywhere. Vermont was continuing to be number one in the country (Crockett 1915).

Laws and Regulations

Demand for Vermont maple products actually grew greater than the supply. Manufacturers leaped on this opportunity by purchasing low-grade maple sugar and using it to flavor glucose or cane sugar. Regardless of whether Vermont had a good sugar season in any given year, and whether quality sugar was widely available or not, new manufacturers producing goods only partially comprised of maple sugar were able to churn out their product and make quite a profit. Many Vermonters did not approve of this practice, however, as they had such pride in the quality of their maple sugar. They felt as though the buying public were entitled to know whether they were buying pure or impure maple products. Some of the so-called maple products did not even contain a fraction of maple sugar or syrup, but were flavored with an extract made from hickory bark, and it was not unheard of for fictitious names of towns to be used on "Vermont" labels. This practice led to the beginning of the strengthening of Vermont's pure food laws and the Vermont brand, which strictly prohibits the adulteration and misbranding of Vermont food products, with particular emphasis on maple sugar and syrup (Crockett 1915).

An important aspect of the Vermont maple industry is how regulated it has become in the law. Vermont's long history regarding maple sugar led to an intense pride in the quality of the syrup it produces, which appears to be well founded, or at least successfully played up. A survey by the Center for Rural Studies at the University of Vermont found that an association with Vermont could boost sales of a product by fifteen percent, likely a combination of genuinely good syrup and successful marketing (AP 2005). The trademark, "State of Vermont Pure Maple Syrup" is registered with the Secretary of State, and its use is restricted to very specific terms, involving fairly strict grade and density standards. Vermont passed a statute in 1981 governing maple products, edited many times since in 1985, 1989, 1991, 1997, 2003, and 2009. Maple syrup which is produced, packaged, handled, or sold in Vermont cannot be bleached or lightened in color by artificial means except by simple filtration through cloth or paper, through a filter press, or through food grade diatomaceous earth with a filter press in order to remove suspended solids. Every shipment, package or container of maple syrup that is packed, sold, offered or exposed to sale or distribution has to be strictly labeled with the name, address and zip code of the packer, the true name of the product, the grade, and the volume of the contents at 68 degrees Fahrenheit. Any labeling on bulk or packaged maple syrup which indicates "State of Vermont pure maple syrup", Vermont maple syrup, Vermont syrup, or any other words that even imply that the syrup was produced in Vermont can only be used if the product is 100 percent maple syrup that was entirely produced within the state of Vermont.

It is against Vermont's maple laws to use the term "maple syrup" or "maple sugar," however altered, to describe any product, flavoring, sweetener or food additive unless the product, flavoring, sweetener or food additive being described meets the state's definition of "maple syrup" or "maple sugar." Terms such as "artificial maple syrup" or "artificial maple sugar" are said to be misleading and deceptive and can only be used to describe a product flavored or sweetened with a substance which attempts to duplicate real maple flavor if words such as "artificial," "flavor," and other modifiers of the word "maple" are stated in equal prominence to the word "maple" on the label and in all advertising of the product. The laws get fairly specific and strict. All advertisements of maple syrup displayed, circulated, broadcast by radio or telecast within Vermont which quote a price have to specify the grade and volume of maple syrup in equal prominence with the stated price, and there are entire sections of the law devoted to what types of containers it is acceptable to put Vermont syrup into, or what types of hydrometers are appropriate for testing sugar content.

In order to ensure no one misuses the Vermont brand, any dealer or processor who wants to do business and buy syrup in bulk for resale in Vermont has to be licensed with the Secretary for the Vermont Agency of Agriculture, Food and Markets. All licensed dealers and processors have to keep meticulous records of their purchase and sale of maple products, which must be made available to the Secretary or an inspector upon request. The Agriculture, Food and Markets Secretary or an appointed inspector is routinely allowed upon any licensed dealer or processor's operation in order to check up on their premises, records, equipment, and inventory to make sure all rules are being followed. If they are not, the license may be suspended. Anybody who intentionally produces, packages, labels, sells, holds, stores, transports, offers, exposes, advertises, or possesses maple products, maple-flavored products, or artificial maple-flavored products in any manner that violates these rules could also be subject to a fine of up to $5,000 and/or one year in prison (VAAFM 2006).

In one memorable 2011 incident, the food chain McDonald's released a new product, their Fruit and Maple oatmeal. For a majority of the country, this was a rather mundane moment. In Vermont, it was a controversy. Under Vermont law, in order to use the word "maple" in a product's name or advertising, it has to be 100% pure Vermont maple syrup, and McDonalds was using "natural maple flavoring" in their oatmeal. The Vermont Agency of Agriculture got involved, as state law required McDonald's to either add real maple syrup to their product in Vermont locations, or remove the word maple from the product's name and advertising (Davenport 2011). McDonald's ended up reaching a resolution and complying with state laws, allowing customers in Vermont to request Vermont maple syrup or sugar to be added to their oatmeal (Allen 2011). If no request is made, however, they still receive the sweetener using maple flavor extracted from the bark of a bush related to the maple tree. Similar incidents have occurred with products such as Dannon's Activia yogurt and Pinnacle Foods' "all natural" Log Cabin pancake syrup over the years (Warner 2011).

Collection and Production of Maple Sugar

Of the over one hundred varieties of maple tree existing in the world, the sugar maple (*Acer saccharum*) is the species most frequently tapped, with a high enough concentration of natural sugar to allow for relatively easy maple syrup production. Other species, including the black maple, silver maple, and red maple, also get tapped, although not too frequently in Vermont. Sugar maples are pretty easy to identify in the autumn even to a casual observer. They display flashy red and orange hues, preferring and thus typically found in at least moderately well drained soils. The sugar is produced in the tree's leaves during photosynthesis. It is transported to and stored for the winter in the living wood tissue, typically in the form of carbohydrates, before being converted into sucrose and dissolved into the sap. The sugaring season is traditionally known to begin in late February, when temperatures begin to first rise above freezing, triggering a physiological reaction inside maple trees that begins sap flow. The length of the sugaring season is dependent on temperature, and varies annually, but averages around six weeks. By mid April, night temperatures are often above freezing, leaf and flower buds begin to swell, and the majority of sugarers are done boiling. During a single season, each tree will produce anywhere from ten to twenty gallons of sap, or maybe one-third of a gallon of maple syrup, depending on sugar content (UVM 2013).

Sap flows in maples through a portion of the outer trunk known as sapwood. Inside sapwood are cells that conduct water and nutrients, dissolved in the sap, from the roots of the tree out to the branches. Throughout the day, these cells respire and produce carbon dioxide that is released into the intercellular spaces in the sapwood. Carbon dioxide that was dissolved in the cool sap is also released into the spaces between the cells. These two sources of carbon dioxide result in pressure building up in the cells. A third source of pressure, osmotic pressure, is added by the presence of sugar and other substances dissolved in the sap. When the tree is wounded, as when a maple producer taps it, the pressure pushes the sap out of the tree. When temperatures go below freezing, typically at night, the carbon dioxide cools and contracts, forcing the sap out of the tree. Some of the carbon dioxide also becomes dissolved in the cooled sap, and some of the sap freezes. All three of these factors create suction in the tree, causing water from the soil to be drawn up into the roots and up through the sapwood. The next day, when temperatures rise above freezing, sap flow once again commences (UVM 2013). Sap only flows while these conditions are all correct, and stops when they are not met.

Sap is collected through buckets or tubing. Sap flow through tubing can be accomplished through gravity, depending on the geographical layout of the sugarbush in relation to the sugarhouse, or through the use of a vacuum to create suction in the tubing. Often, a plastic tubing system is set up to bring sap directly from the trees, with smaller lines joining into half inch to two inch main lines and bringing it to a central location. Many producers use a process called reverse osmosis to remove water from the sap before it is boiled. This allows up to ninety percent of the water to be removed from the sap, reducing energy consumption of boiling (UVM 2013). By one estimate, as much as ninety percent of the syrup sold passes through reverse osmosis (Scott 2013). Whether this step is taken or not, the sap is typically then served into an evaporator unit and heated. During evaporation, sap is concentrated to the desired sugar content and the color and flavor of the maple syrup develops as a result of the chemical changes that occur during the heating process. The sap moves up and down channels in the evaporator unit, becoming darker as it becomes more concentrated. Syrup darkens with boiling time and microorganisms in the sap. Reducing boiling time and killing microorganisms through UV treatment thus helps produce lighter colored syrup. It eventually passes to a flat pan, is drawn off, and gets passed through a filter. The pans have covers on them with stacks to take the steam away through the sugarhouse roof, leaving the air clean in the building and preventing contaminants from falling into the boiling sap. A small evaporator may boil about 25 gallons of sap per hour, while a large evaporator might boil up to 380 gallons per hour (UVM 2013). At this stage, while the majority of it remains as syrup, many producers go on to produce other products. Maple cream, for example, is made from maple syrup that has been heated to around 23 degrees Fahrenheit or so above the boiling point of water. It is then cooled rapidly to around 50 degrees Fahrenheit and stirred until it becomes smooth with a creamy texture (UVM 2013).

3. Erratic Weather and Maple Syrup Production

As was stated before, Vermont became the largest producer of maple syrup in the United States fairly early, and has held on to the title ever since. Vermont has an ideal climate for growing sugar maple trees, great conditions for sap flow, and a long history of syrup production. In the years between 2000 and 2012, overall maple syrup production has increased by over 56%, from 480,000 gallons to 750,000 gallons twelve years later (Figure 3.1). The lowest production the state saw in that period was in 2001, with just

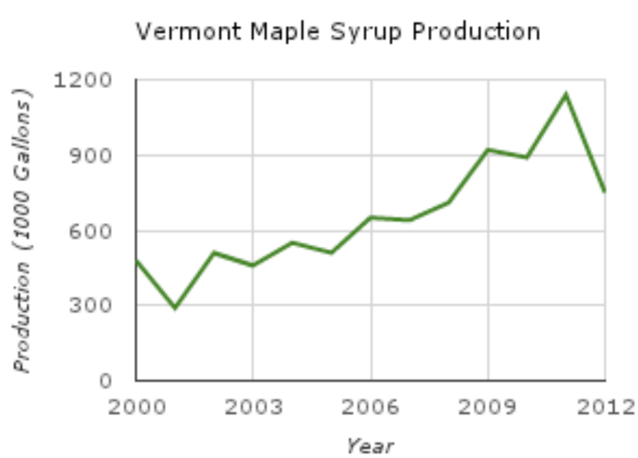


Figure 3.1 : Data from USDA National Agricultural Statistics Service

290,000 gallons produced, while its peak year was in 2011, with a whopping 1,140,000 gallons, nearly a 300% difference. 2011 was a 28% increase from 2010, and was the first year to surpass one million gallons since the 1940s. Overall United States maple syrup production has been on the general decline since the early 1900s, with only small spikes in production in occasional years (Weissmann 2012).

This recent upward trend in production is notable for being one of the strongest surges in maple syrup production in nearly one hundred years, beginning relatively recently in the past twenty years or so. The years in the middle of the 2000s are largely characterized by an increase in production one year, followed by a slight decline the following, with another increase the next year, and so forth, with production ultimately climbing higher.

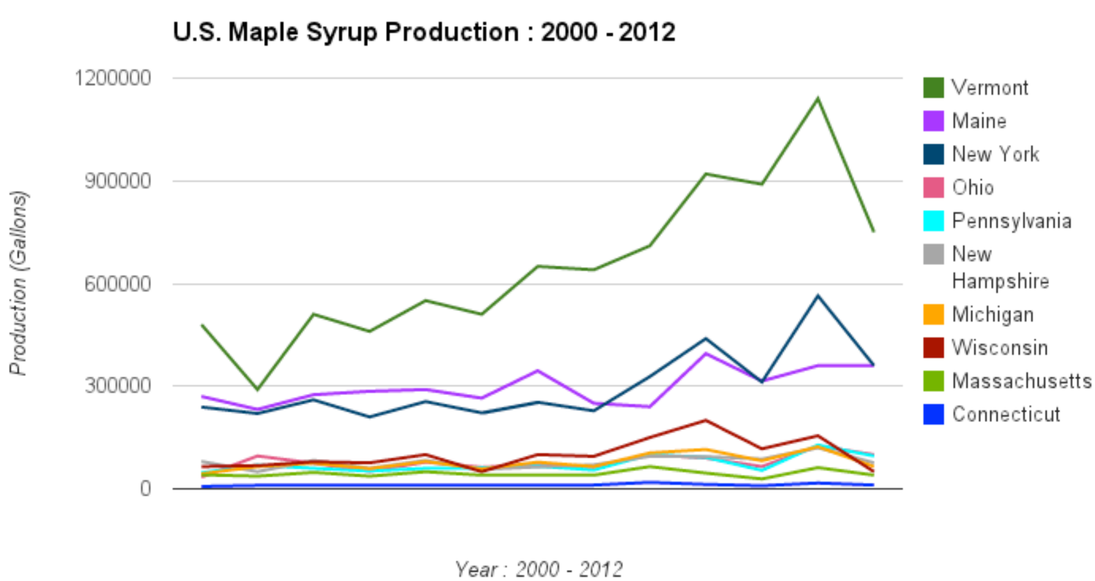


Figure 3.2 : Data from USDA National Agricultural Statistics Service

Vermont seems to have no problem staying ahead of the rest of the United States in terms of overall production. Its closest competitor during the peak year of 2011, New York, only produced 564,000 gallons, slightly less than half of what Vermont was able to produce. Even Vermont's lowest year of production during this time, 2001, saw the state maintain its status as the number one producer of maple syrup in the country, still producing more than Maine or New York despite those two states not experiencing nearly as heavy a decline in production as Vermont did.

We have seen the natural and historical factors that allowed Vermont to become the top producer of maple syrup in the country, but what has been driving its dramatic increase in production since the year 2000? Vermont has seen a much more drastic growth in maple syrup production than any other state. The most obvious answer would be that more people are getting involved with the maple sugaring process in the state, or that the people that are involved are expanding their operations and tapping more trees.

The number of tapped trees in Vermont has increased, from 2,150,000 taps in 2000 to 3,500,000 in 2012, an increase of over 62 percent. The trend of the number of taps in the state does not correspond with the state's overall production, however. The general trend of an increase over time is evident, with Vermont having over sixty-two percent more taps in 2012 than in 2000, but the number of taps does not waver up and down on its progression upwards in the same way that production does. Furthermore, despite the twenty-seven percent increase in the number of taps between 2002 and 2007, the number of actual operations in Vermont with taps went down in those years.

Between 2002 and 2007, the number of Vermont operations with taps decreased about twenty-four percent, from 1723 in 2002 to 1310 in 2007, a loss of 413 sugaring operations in just five years.

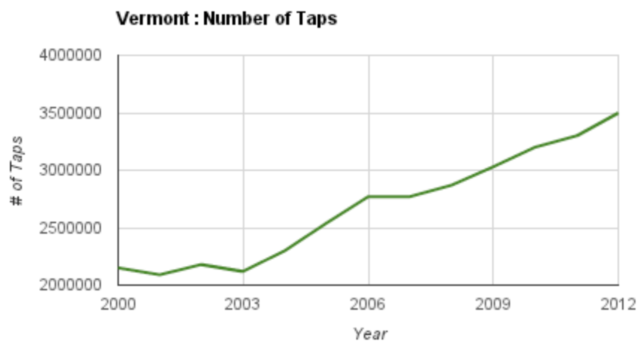


Figure 3.7 : Data from USDA National Agricultural Statistics Service

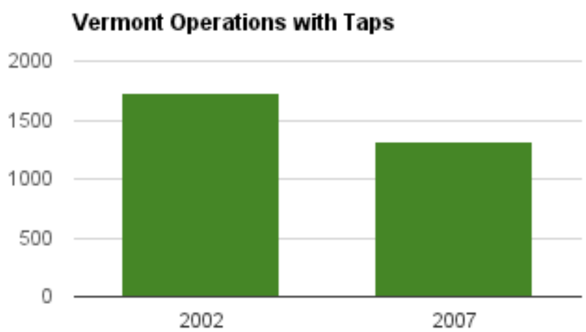


Figure 3.8 : Data from USDA National Agricultural Statistics Service

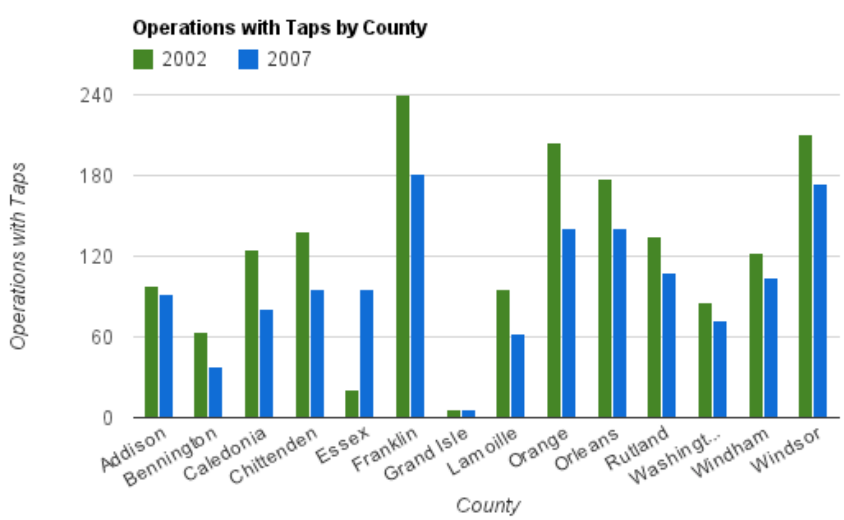


Figure 3.9 : Data from USDA National Agricultural Statistics Service

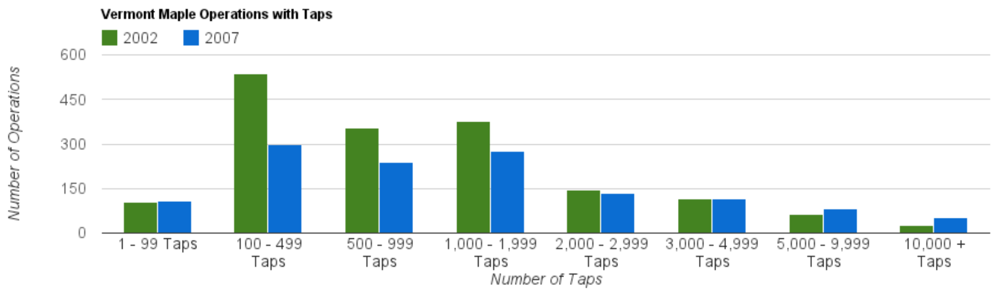


Figure 3.10 : Data from USDA National Agricultural Statistics Service

Only Essex County experienced an increase in the amount of sugaring operations with taps between 2002 and 2007 (Figure 3.9). Twelve of the remaining counties experienced a decline, with Grand Isle County staying steady with six. Caledonia experienced the greatest percentage decline in operations, losing slightly over thirty-five percent of its operations with taps. Production and the number of taps are increasing, but the amount of sugaring operations showed a notable decline during the middle of the 2000s. The only possible explanation for the link between the numbers of taps increasing but the number of operations decreasing is that the fewer operations began tapping more trees.

In the five-year span between 2002 and 2007, the number of operations with between 100 - 499 taps decreased forty-four percent from 537 to 300, the number of operations with between 500 - 999 taps decreased thirty-two percent from 354 to 240, and the number of operations with 1,000 - 1,999 taps decreased almost twenty-seven percent from 377 to 276. Meanwhile, the number of operations with between 5,000-9,999 taps increased by almost forty percent, and operations with more than 10,000 taps exactly doubled, from 26 to 52. This data supports there being fewer sugarers in the state, but with more intensive operations. It does not, however, explain the variations in production. Even if some of the smaller sugarers are being put out of business by larger operations, the fact remains that the number of taps in operation in Vermont has steadily gone up. Thus, the variations in production, particularly the years that experience declines, have to be explained by natural variations of sap production by the maples themselves.

Maple yield per tap varies quite a bit year to year. The lowest average yield per tap came in 2001, while the highest was in 2011, which corresponds with the lowest and highest years of total production. This fluctuation represents a substantial 150% change in yield per tap. As discussed before, ideal conditions for the maple-sugaring season of March to mid-April is traditionally temperatures in the mid-twenties during the night, followed by temperatures of around forty degrees Fahrenheit in the daytime. Conditions too much warmer or cooler than this can result in a delayed beginning of the season or a

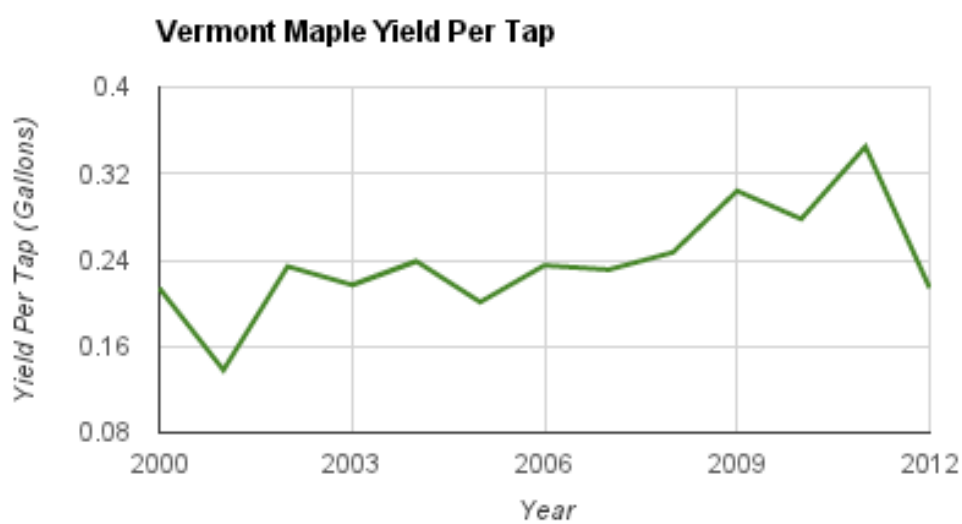


Figure 3.11 : Data from USDA National Agricultural Statistics Service

premature end. Figure 3.12 compiles average maximum and minimum temperatures for all sugaring seasons in the years 2000 to 2012, based on temperatures in Burlington, Vermont, where much of the state's most thorough meteorological data is collected. Lines representing the ideal day and night temperatures for sap production have been imposed on the graph. Theoretically, the closer the bars are to their respective ideal temperature line, the better conditions are for maple sugaring, and the higher the yield per tap would be. The bars for average April temperatures are going to be consistently high, as the data takes into account the full month when the maple sugaring season is typically finished by mid April, so generally the lower those bars are the better off the season should have been. Based on temperature alone, it would appear as though 2001 would have been quite a bad year, with a much too cold March, the most crucial month. Average March minimum temperatures were over twenty-five percent colder than is ideal.

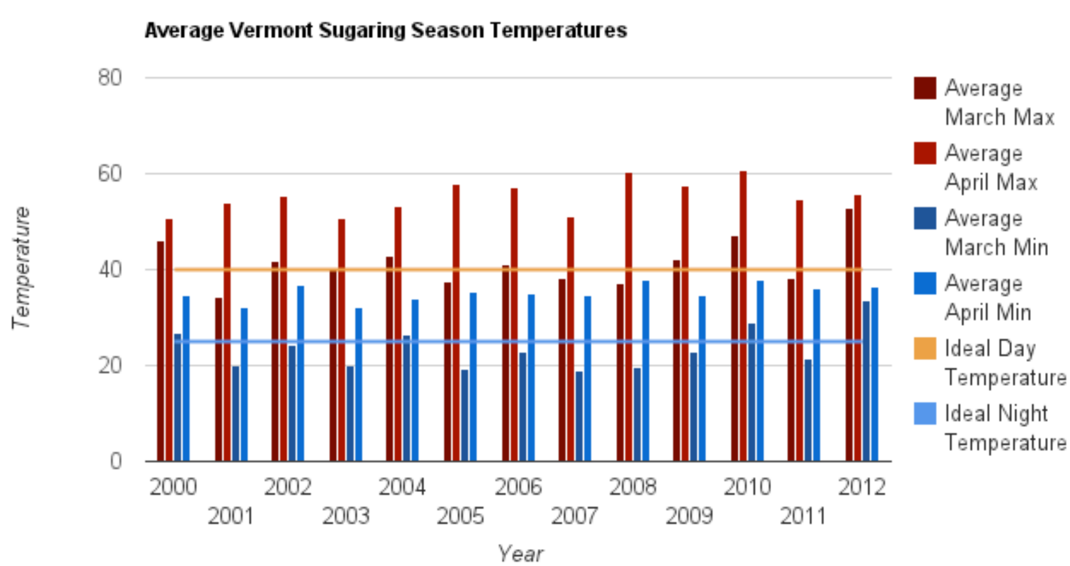


Figure 3.12 : Data from USDA National Agricultural Statistics Service

2003 also might have had a problem with too-cold March nights, although good daytime temperatures may have stabilized the season. 2005, 2007, and 2008 might likewise have been a bit on the colder side, while 2010 looks a bit too warm. 2012 appears as though conditions were far too warm for adequate sugaring, with average March maximums being over twenty-four percent higher than ideal, and average March minimums being over twenty-five percent warmer. By layering the relative average maple tree yield per tap onto the sugaring season temperatures graph as in Figure 3.13, it is possible to observe how closely yields correspond to these expected results. Indeed, 2001 saw a very low yield per tap, declining roughly 35.5% from the average 2000 yield, corresponding with the overly cold March. There are likewise dips in many, though not all, of the years that are predicted to be affected by temperature conditions, including 2003, 2005, 2007, and 2010.

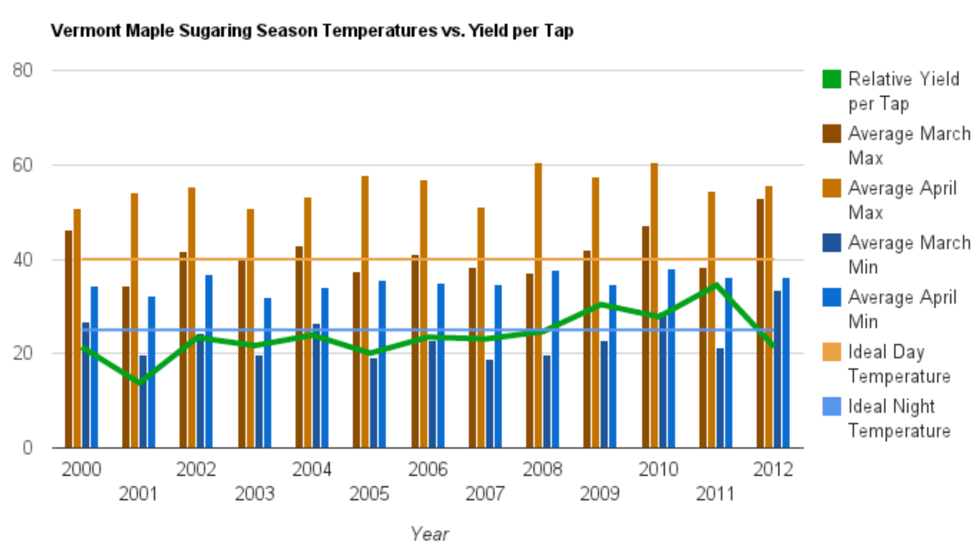


Figure 3.13 : Data from USDA National Agricultural Statistics Service

Nationwide, 2004 maple syrup production was up twenty percent from 2003, totaling 1.51 million gallons across the country, its highest level since 1996. Vermont had a nineteen percent increase from the previous season with 500,000 gallons. This production increase is largely a result of increased yield per tap combined with more taps set, but temperatures were generally favorable enough for good sap flow and syrup production.

Producers in the southern counties of Bennington, Windham and Windsor reported fluctuating weather alongside short but productive sugaring seasons, starting late, ending early, interrupted in the middle by periods of warm days with little to no sap flow, but with the quality of the syrup produced being of very high quality. Rutland and Addison Counties on the western New York border of the state were able to extend their seasons a bit due to a cold snap at the end of March, but also reported sporadic conditions throughout March that slowed or completely halted sap flow. The northern half of the state experienced similarly sporadic conditions: too cold in the beginning of the season, followed by a period of heavy flow, followed by a cold burst that would halt production, followed by another period of flow, followed by a few days of it being too warm, and so forth. Some operations were able to benefit from this scenario, as the freezing bursts prevented tree budding extended the season. Wind played a detrimental effect on several producers, with the cold winds blowing in after storms hurting sap flow. The south wind combined with high pressure resulted in lower yields than could be expected. The 2004 sugaring season was almost split in two for many of the state's producers, but the quality of the syrup was not impacted (NASS 2004).

In 2005, Vermont was able to produce 33 percent of the nation's maple syrup, but overall production and yield was down. Overall, the 2005 maple season was too cool in temperature, resulting in production decreases across all of New England. The season began too cold and then warmed up too fast, resulting in a late start to the season (NASS 2006). As of mid-March, sugaring operations were still dealing with the effects of thick snow pack, unfavorably cold temperatures, and strong wind (Hirschfeld 2005).

The 2006 sugaring season was largely split between the northern and southern halves of the state. Southern counties Bennington, Windham, Windsor, and Rutland reported difficult or short seasons. In Bennington, it got warm early on, but most producers did not want to tap early and have the taps dry out before the March flow, ultimately resulting in a short season. Windsor experienced a period of warm days in the middle of the season that was difficult to recover from, while Windham noted very dry conditions, most likely resulting in part from the lack of snowfall that year. Rutland'a short season resulted from temperatures getting cold early and warming early, leaving only the middle section of the traditional season. Central counties such as Addison, Orange and Washington also reported poor sap flow. It was typically just too cold in the beginning of the season and remained too warm once it got warm. In between, it was just too cool in the day and not cold enough at night. Sugar content was also very low, and the syrup not as sweet as usual. One operation in Orange County reported the quality of the syrup decreasing over the course of the season, starting out light but quickly turning to medium and dark grade B. Recalling that the amount of sap needed to produce one gallon of syrup is dependent on sugar content, at the beginning of the season it was taking them thirty-three gallons of sap to produce one gallon of syrup, while by the end it was taking fifty gallons (NASS 2006).

Meanwhile, in the very northern region of the state, Franklin County reported an exceptional year with good conditions, quality and quantity. They also reported syrup starting out light and getting darker through the season, but in a much more manageable fashion. Sap flow, sugar content, and taste were all reported as favorable. There is a report from a Franklin County operator that installed their first vacuum in this year, which found that "the vacuum lines did well; buckets not so well, which proves the difference." Orleans County next door certainly did not have a perfect season, but had a much more favorable time than the southern half of the state.

It is interesting to note that one operator in Orleans County reported poor sap runs but good quality, while another reported great sap runs and a long season, but not as good sap, highlighting the sometimes incredibly variable local conditions. A similar variation between neighboring counties is seen in Bennington and Windham in this year, with one operation in Bennington that typically makes fancy grade syrup unable to do so at all in 2006, while a producer in Windham noted that the lighter than usual syrup had a strong flavor perfect for fancy grade (NASS 2006).

Overall, reports from the majority of the state were not favorable for 2006, but production was up that year. The winter and spring was largely characterized by several bursts of ideal sugaring weather in January and February, with March temperatures that began too low and quickly got too high for sustained sap flow (Wilmot 2008). 2006 is an important year in beginning to notice the contrasts between what sugaring operators report and the numbers that result (NASS 2006).

2004 production went up, 2005 went down, 2006 went up, and 2007 went back down again. New England had its lowest production since 2001, though Vermont obviously still had the highest production in the nation, with 450,000 gallons, just a two percent decline from 2006 compared to a fourteen percent nationwide decline. Sugar content of the sap was down from the previous year, an average of approximately forty-five gallons of sap required to produce one gallon of syrup, compared with forty-four gallons in 2006 and forty gallons in 2005. The majority of the syrup produced was medium to dark. The production declines had to have been mostly a result of decreased yields, this time stemming from a once again too cool season (NASS 2007). There were a few days of favorable sugaring weather in early January, but cold temperatures until mid-March followed (Wilmot 2008).

In the southern part of the state, the season started late, staying cold for too long. When it did get warm, it stayed warm for too long. In Bennington County there were problems with tent caterpillars having a really detrimental effect on the trees, while many operators in Windham County experienced high buildup of bacteria in the pipeline in late March. Throughout central Vermont, operations were producing unusually dark syrup. One Rutland County operation reported no light syrup in that year. In Addison County, a producer reported making more medium than usual, with the season starting with dark syrup and production turning to fancy and medium amber after a week of cold temperatures in mid-March, with a small amount of dark amber at the end of the season.

Orange County also had extensive problems with a continued Eastern Tent Caterpillar infestation, cold temperatures in the middle of the season, and darker than normal syrup. Caledonia and Chittenden Counties both reported difficulties in producing fancy grade, while a producer in Washington County was able to produce some light syrup at the end of the season, although the sap had low sugar content. In the very north, both Franklin and Orleans Counties experienced darker syrup than usual. Too much snow and too-cold temperatures in the beginning and middle of the season resulted in a shortened and interrupted season, and a lower sugar content than average. In Franklin County, temperatures were adequate, but the wind was a problem, with one operator reporting the trees drying out and halting sap flow almost every time there was a storm. All things considered, a two percent decrease in production from the prior year was not too bad an outcome (NASS 2007).

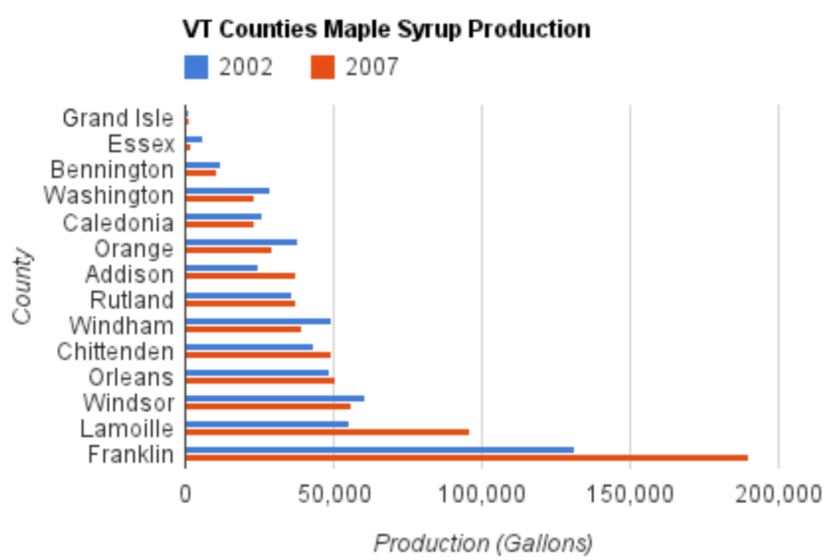
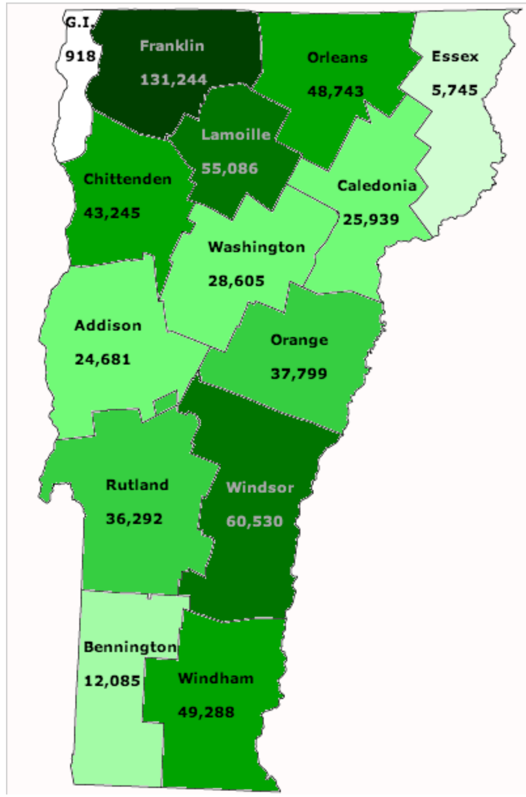


Figure 3.14 : Data from USDA National Agricultural Statistics Service

Franklin County has by far the greatest maple syrup production in the state. It approximately doubled the production of the second-highest producer in 2007, Lamoille County, and had almost sixty percent more gallons produced in 2002 than the then second-highest producer, Windsor County. Franklin County is located in the very northernmost part of the state, bordering the Canadian province of Quebec, where the weather is generally much more favorable for maple sugaring. Canada is able to produce more than eighty percent of the world's maple syrup, and Franklin County benefits from its bordering location. Many of Vermont's largest sugaring operations are located in Franklin County, with several having more than sixty thousand taps (McLean 2010). In 2007, Franklin County produced 29.4% of total Vermont maple syrup, with 25.8% of the state's taps on 13.8% of the state's farms. The top three producing counties in the state in 2007 (Franklin, Lamoille, and Windsor) possessed approximately fifty percent of the Vermont's total maple taps, and produced about fifty-three percent of the state's syrup.

Production and yield both saw modest increased in 2008. That year, elevation appeared to play a key role in sap production. Along the western border of the state, operators in both Addison and Rutland Counties reported trees at higher elevation did worse, and started slow, while trees at lower elevations did much better. Producers in Caledonia and Franklin Counties likewise reported difficulties relating to elevation. Heavy amounts of snow across the state, remaining too deep for too long, halted sap flow. Weather conditions appear to get more and more chaotic every year. Once the snow disappeared, operations across the state once again reported it getting much too warm, too quickly. More and more, weather and conditions are inconsistent. Across the



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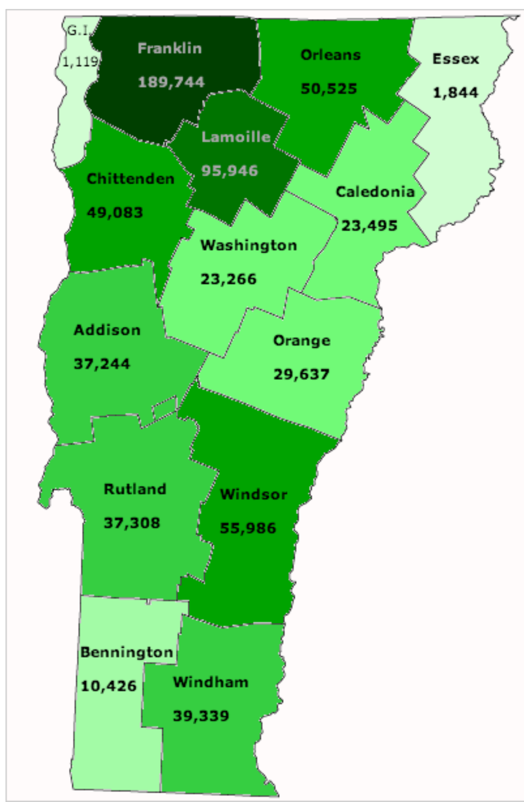

2007

Figure 3.15 : Data from USDA National Agricultural Statistics Service

state, 2008 was simultaneously the "best season in many years" in Addison and "one of the worst seasons we have ever had" in Lamoille, while conditions ranged from "the weather was not favorable" in Franklin to "weather conditions were about normal" in Windham to "weather conditions were perfect this year" in Washington (NASS 2008). Another sugarbush operator in Washington County noted that while the quality was very good, his quantity was down. According to him, "The sugarmakers that are on vacuum are doing better, as they always do, because they're sucking it out of the tree and through the lines and I must rely on gravity" (Sneyd 2008). A producer in Chittenden County felt the same, but from the other side: "It was a very good year! ... Most sap runs influenced by stormy weather and low atmospheric pressure. We had very few classic cold nights and sunny warm days. It started cool until April 1 and then it warmed up too quickly and did not freeze again. It was a cold season. Sap didn't start flowing until the afternoons and without vacuum we wouldn't have made as much as we did" (NASS 2008).

2009 was another big year. Production in Vermont went up thirty percent to 920,000 gallons, and average yields per tap increased as well. Moving up the state, from the south northwards, reports from operations speak for themselves. In Bennington, they had a "bad year this year; only made 80 percent of what they should have made", while in Windham someone reported, "the weather was not good for sap. All the grades were off this year." A producer in Rutland "only had two good runs; didn't make what they would have liked. It got cold and stayed cold then it got warm and stayed warm—to much of everything! It was a horrible year." In Windsor, "Without vacuum would have made none ... Started out too cold and season went to fast", Addison County reported, "the season was short", and in Orange County, they "never got enough cold nights." Some operations did manage to do well, while others in the same county floundered. For example, in Chittenden County it was a "long, hard season" for one producer and a "very good year" with sap running "as fast as ever seen in seven years" for another, and the "best year ever had" for yet another. In Caledonia County, one operation noted, "the weather was too dry. Not a good season this year. Used a vacuum system, which helped during a week with warm nights", while another saw "the highest production year ever ... overall a very good season with no surprises" (NASS 2009). Natural conditions are either incredibly variable within a very small region, or the conditions themselves are much less relevant to the trees and more relevant to the collection system in place. Although average yields per tap fluctuate a bit annually, sugar makers have ultimately been able to diminish their dependence on natural conditions and to maintain perfectly satisfactory yields even in years when temperatures would have traditionally made it much more difficult.

2012, the warmest year of the time period presented, saw the greatest percentage decline in yield from the prior year at almost thirty-eight percent. Looking closely, however, 2012 appears to have been a much worse year in terms of temperature than 2001. Averaged together, maximum temperatures during the sugaring season in 2001 were 9.6% removed from the ideal, while minimum temperatures were just 4.2% removed. Average maximum temperatures in 2012, however, were over twenty-six percent higher than ideal, and minimum temperatures were over twenty-eight percent removed. Based off of this, it would be reasonable to expect that yield per tap should have been higher in 2001 than in 2012, but this is not the case. 2012 averaged .214 gallons per tap, while 2001 averaged .138, a 35.5% difference. Indeed, 2012 had the exact same yield as 2000, when average temperatures were much more favorable for the sugaring process. If external factors beyond weather had remained the same, 2012 should have had a much lower yield per tap than 2000. This, however, is not the case, meaning that in this twelve-year period Vermont sugaring operations did one of maybe three possible things; they either somehow increased the natural productivity of the trees themselves, increased the productivity of the trees through advanced technological means, or they increased the range of temperatures at which sap is capable of flowing. Through some method, maple trees were able to produce the same yield per tap in an overly warm 2012 as a much more appropriately conditioned 2000.

4. Coping with Nature: Technological Adaptations in Sugaring

The Proctor Maple Research Center collected information from a survey of 163 maple sugar producers, of which approximately ninety percent were located in Vermont, with the remainder coming from immediately surrounding states. The survey compares the number of producers surveyed using a given method, and the average yield for each method. The lowest yield per tap seemingly comes from gravity tubing, the third most popular method of production. The next step up in terms of yield is the more old-fashioned bucket system, which is still utilized by a number of assumedly smaller-time producers. From here, yield for the most part increases with increased vacuum level at the pump. The majority of producers appear to be using fairly large vacuum systems. There are more producers using a twenty-three to twenty-five inch vacuum than any other

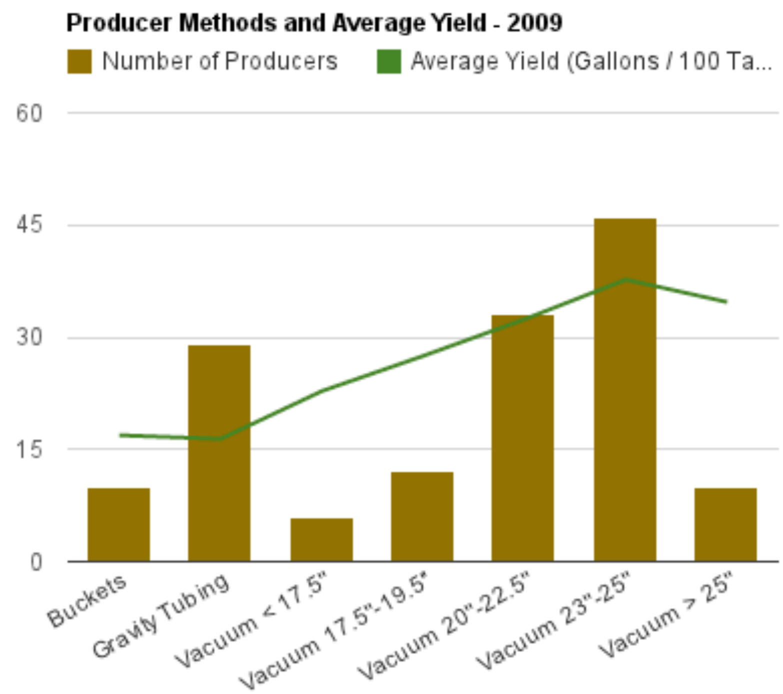

Figure 4.1 : Data from USDA & Proctor Maple Research Center

method, with this method producing the highest yield. Average yield per tap for this type of vacuum is .377 gallons, a 56.5% increase over the average gravity tubing yield of .164 gallons. Surprisingly, the ten sampled producers with the largest vacuums see a decrease in average yield, whereas the trend up until that point had been the larger the vacuum the larger the yield. There are either outside factors at work, such as a lot of the largest vacuums maybe being in a part of the state with less favorable season conditions that year, or there comes a point where increased pressure on the tree begins to hurt yield again instead of boost it. Regardless, as of 2009 the majority of taps in Vermont were on vacuum.

Of the 627,414 total taps of the sugaring operations surveyed, 569,270 were on vacuum, 41,062 were on gravity tubing, and 17,082 were on buckets. Needless to say, the large majority of taps in Vermont are attached to vacuum, which is unsurprising given

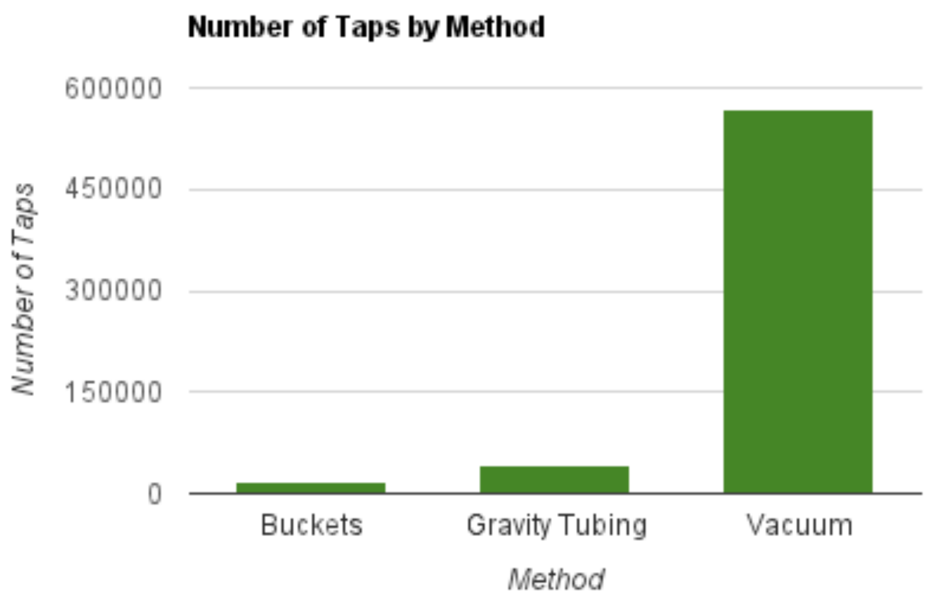

Figure 4.2 : Data from Proctor Maple Research Center

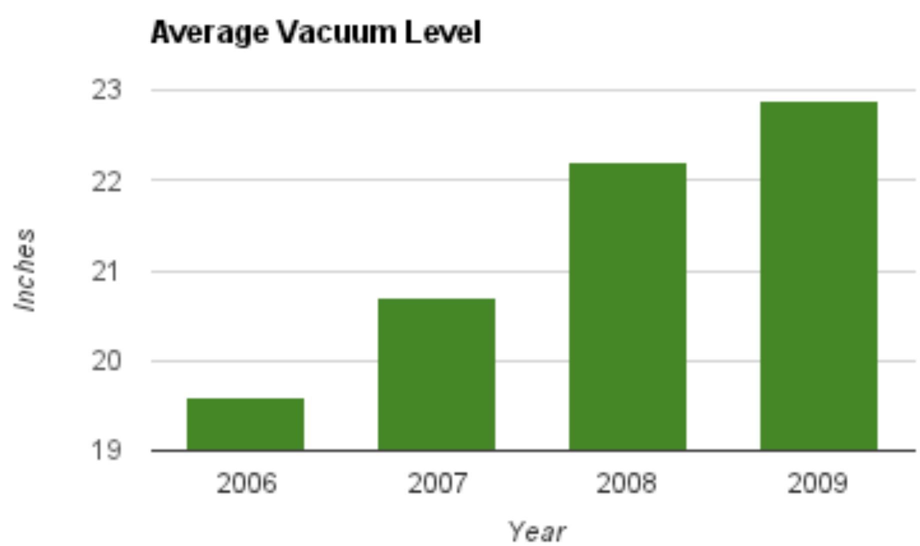

Figure 4.3 : Data from Proctor Maple Research Center

that vacuum operations have the highest average yield. Between the years 2006 and 2009, average vacuum level at the pump increased from 19.6 inches to 22.9 inches. Generally across the state, producers are using higher vacuum for sap collection.

The 2010 sugaring season was notable for how much producers largely fared the same across the board. A majority of counties in Vermont reported both an early beginning to the season, and an early end. Whoever wasn't ready for the early start to the season really suffered, and this is largely responsible for the decline in production from the year prior (NASS 2010). There were a few more trees being tapped in 2010; a 2009 agreement between the state and the Vermont Maple Sugarmakers Association expanded the number of state forests and parks where sugarmakers could tap trees for maple syrup production, a total area of approximately seven-hundred acres (Sneyd 2009). The season began in late February, and a lot of producers missed at least a week of ideal sap flow by getting set up for the beginning of March. By mid-March or so, the weather had warmed too much, resulting in the decreased yield (NASS 2010). The quick increase in temperature switched the sugar maples from producing sap to popping out buds (VPR 2010).

The other factor producers across the state reported as being the same was the importance of vacuum. In the south, "those with vacuum fared better" in Bennington County, "those using vacuum systems had a better season than those using buckets" in Rutland, and "vacuum systems were essential for production this year. Taps not on vacuum did very poorly" in Windsor. Central Vermont reported the same thing. "Vacuum made the difference" in Addison County, "vacuum systems overcame the poor weather conditions" in Washington County, and in Orange County, "without a vacuum, production would have been drastically lower". In the maple stronghold of the Vermont north, "high vacuums saved the season" in Orleans County, "buckets were hurt by long spells without a good freeze" in Chittenden, "vacuum helped to continue sap flow despite the poor conditions" in Lamoille, and "sap flowed steadily every day on vacuum, while buckets only ran for about 2 weeks" in Franklin County (NASS 2010). The mild percent decrease in Vermont production from 2009 to 2010 was not nearly as high as declines in maple production across the rest of the nation (VPR 2010).

Following this year that was buoyed almost entirely by vacuum, Vermont saw its greatest production year in recent memory in 2011. Across the state, the season seemed to start late, remaining cold and snowy. There were few large runs during any given time, but more of a steady flow once temperatures picked up a bit before getting too warm. Conditions were not perfect by any means, much less than the production numbers would imply. A lot of the state was hit with a fairly heavy snow and ice storm in the beginning of March, largely responsible for the delay to the start of the season, and in mid- to late- March, many producers across the state reported a cold snap that drastically reduced production (NASS 2011). This cold snap effectively shut down many sugaring operations for about ten days (Keese 2011). Weather and temperatures were certainly better than in the couple of years prior, but to experience the huge production increase that the state did, up 28 percent from 2010 and the highest production level since 1945, shows the ability of more modernized maple sugaring methods when conditions do indeed more resemble what is traditionally known to be favorable sugaring weather.

Really one of the few things the 2011 season had going for it was the fact that it did not get warm too fast, as in the year prior (Keese 2011).

One of the most interesting years for maple sugaring in terms of the data presented was 2012, when Vermont producers were able to obtain above-average overall production, and an equal average yield as in 2000, despite a maple syrup season across all of New England that was considered to be far too warm. There were a series of heat waves in March that ended the season very early for many operations (NASS 2012). The earliest date in the year to ever hit eighty degrees or higher in Burlington was in fact in 2012, on March 22nd (NWS 2012). Historically, the sugaring season does not end until mid-April, so eighty plus degree temperatures on March 22 would certainly put an early end to the season. The average start date for sap collection in Vermont was February 25, and the average closing date was March 22, a little less than four weeks. The lower elevations of the state were hit especially hard by the warm weather (Pellett 2012). Some regions of the state experienced a week of the abnormally warm temperatures, and some two weeks. The prolonged period of warm days accelerated the budding of the maples, affecting sap flow and quality. The sap was continuing to flow, but most producers were finding that the sap had decreased sugar content, diminished flavor, contained bacteria levels that meant it ultimately had to be dumped, or was just outright rancid. A majority of the syrup produced in the second half of March, in other words, was completely unmarketable (NASS 2012).

Even in a year that had eighty-degree days in March in Vermont, however, sugarers were able to produce more syrup than in many years prior. It is no secret that there have been many advances in technology over recent years in all fields, maple-sugaring being no exception, but I feel as though there is something particularly significant to be said for the extent of technical innovation in sugaring as it relates to removing reliance on natural conditions. Several of these changes over the last ten or so years may seem relatively minor or unimportant with respect to yield; smaller spouts being introduced, switching to polyethylene tubing from polyvinyl chloride tubing, and general improvements in fitting. Many of these new sugaring methods and devices that have been gaining in popularity in Vermont in recent years, along with modifications in tubing system design, installation, and maintenance, and alterations in vacuum systems and their operations, allowed producers to experience significant improvements in sap yields (Perkins 2009). New taps would soon be developed that would prevent the holes in the tapped maples from closing up, allowing operators to withdraw sap for a longer period of time (Bodette 2013).

The barrier to sustained high sap yields in tubing systems before these new taps were invented was related to contamination with various microorganisms. Microbial contamination of tap holes resulting in tap hole drying was one of the primary causes of sap flow reductions and an earlier end to the season. As sap collection tubing systems age, microbial biofilms develop inside, and all previously attempted methods of decontamination to return tubing to an unused level of sanitation were unsuccessful. To deal with the problem, maple researchers introduced annually replaceable spouts and spout adapters, allowing for a clean spout-tree interaction. The new adapters still did not provide an adequate barrier against the migration of microorganisms from the spout or line back into the tap hole, however, and thus did not completely fix the issue of microbial induced tap hole drying. This problem is made a lot worse by the use of vacuum in tubing operations, as it creates a substantial negative pressure within the tap hole region, causing the sap to briefly surge backward in the tubing system towards the tree and carrying microbes into the tap hole when a leak occurs or the system is shut down quickly. As more microbes reach the tap hole as more of this sap backflow occurs, the tap hole drying response strengthens until sap will eventually stop flowing due to the blockage of vessels. The sugaring season would then be finished for that operator (Perkins 2009).

It is starting to become clearer how Vermont sugaring operations have managed to increase their yields. In terms of obtaining the best yield possible once an operation had vacuum, it has been largely a piece-by-piece maneuver, with operations adapting small technologies, upgrades, or methods as they became available that allowed them to minimize one problem at a time they may have had that was cutting their production off. By 2007, researchers at the Proctor Maple Research Center were focused on finding alternative ways to reduce microbial contamination of tap holes. The solution was relatively simple, using a check-valve to prevent backward movement of sap from the tubing systems into the tap hole. A small rubber ball is placed between the spout adapter and the spout stub with a groove cut on the lower internal part. The groove prevents the ball from moving away from the tree, allowing sap to pass through the spout into the drop line, but prevents sap from moving from the drop line back towards the tree by pressing against the forward inner ring of the spout adapter if it is moved towards the tree. When this relatively simple valve prototype was tested in 2008, it produced 18 gallons of sap per tap over the season, 26.1% more than the control spout with 14.3 gallons. In the 2009 season, check-valve chambers yielded 1 gallon per tap, 23.5% higher than the sap yield in control spout chambers of .81 gallons. Most of this change in check-valves comes from late in the season, as the new valves extends the sap collection period, preventing the holes in the tapped maples from closing up, but they also have a benefit in allowing operations to tap earlier. By reducing tap hole contamination, the check-valve spout adapter reduces the amount of drying and keeps sap flowing better throughout the season, even if tapped early (Perkins 2009).

Again, it has been a series of small steps such as the check-valve that has allowed yield to rise the way it has. Vermont benefits from being a small state with a central, very active, and very engaged maple research center. As reports come in annually, problems are able to be noted and research can be undergone to determine solutions in a rather quick manner, allowing for a relatively rapid increase in yield. Not only are problems able to be categorized and addressed, but information can also be disseminated easily to the state's sugarers. New research and knowledge has been just as important as new technologies or system components. For example, maple producers have also been able to double, or even triple, the number of taps they are able to put in the maple trees as it has been learned that it is quite difficult to over-tap a tree if certain guidelines are met. Trees between ten to twenty inches in diameter should have no more than one tap per tree, a second tap can be added if the tree has up to a 25 inch diameter, and trees larger than that can safely sustain up to three taps. The dramatic increase in the number of taps since the year 2000 highlighted earlier is not merely a sign of more producers, or larger operations tapping more trees, it is also an effect of producers getting more comfortable with putting more taps in a tree. The vacuum pumps that research showed have been gaining in popularity and result in substantially higher yields allow sap to flow even as spring weather becomes more unpredictable (Bodette 2013). Obviously, climate change and weather will always be an important factor in sugaring, but 2012 was an important year in highlighting just how much has changed in such a relatively short period of time. One producer believed in 2012 that "without vacuum, production would be little or none", while another noted that "the season was short, but sap flow was plentiful during that brief window thanks to high vacuum".

Vacuum sap collection is not particularly new, but it has spread rapidly and become common in recent years, attracting a fair share of controversy about how vacuum affects maple sap, syrup and trees alongside the use of collection systems capable of achieving very high levels of vacuum. Early systems used pumps designed for milking or other non-maple applications, resulting in vacuum output that was relatively low, as the pumps were not suitable for sustained operation beyond about thirteen to fifteen inches of mercury, a means to measure pressure. Available tubing and fittings were also difficult or impossible to make leak-free, and the vacuum level at the tap hole was seldom close to the vacuum level at the pump. Despite the constraints and the difficulties of maintaining a working system, many producers with these early vacuum systems were encouraged by enhanced collection, especially during periods of slow sap flow, and researchers studying the relationship between the vacuum level at the tap hole and the amount of sap collected started to realize that increasing vacuum levels lead to increased sap yields. Despite evidence of a positive relationship between enhanced vacuum and improved yield, until fifteen to twenty years ago, equipment limitations prevented an examination of what is considered today to be high vacuum. Recent technological improvements in vacuum system design and equipment, including oil flood or liquid ring pumps, polyethylene tubing, improved fittings and spouts, and wet and dry line arrangements, made it possible for maple producers to achieve a vacuum level close to the maximums experienced today.

However, reports of the benefits of vacuum in terms of sap yield have long been accompanied by concerns about effects on sap and syrup quality. Studies showed that at moderate vacuum levels, no abnormal cellular constituents, the presence of which might indicate rupture of living wood cells, were added to the sap, but vacuum levels are far past that now. The Proctor Maple Research Center tested just this in 2007. First, they found that there was no significant trend in the relationship between sap sugar content and vacuum level. Sap was not diluted at higher vacuum levels. Mineral composition of the sap also showed no particular trends related to vacuum level. While there was some variability in sap composition among different vacuum levels compared to the control sap, there was no indication that increasing vacuum was either supplementing or depleting sap nutrients. Vacuum level also had no effect on the amount of visible internal damage to trees. Issues surrounding the use of high vacuum sap collection that the researchers did not address included the possibility of perhaps removing too much of the tree's carbohydrate reserves by removing too much sugar from the tree, and resulting syrup quality (Wilmot et al 2007).

These technological changes are easy to see on an individual level, as provided in the example of a sugar making operation located in the state capital of Montpelier. Forty years ago, the farm would collect the sap into buckets and load them onto a tractor before bringing it back to be boiled. Nowadays, there is five miles of pressurized tubing weaving along the farm, drawing sap from the trees and depositing it into large tubs, allowing for twice as much sap intake as before. As the operator of the farm said, "You can make it run when nature wouldn't have it run." Once obtained, it is first processed in a reverse-osmosis machine that concentrates the sap and increases the sugar content even before it gets boiled (Scott 2013). Another operation in Franklin County started off their sugaring operation in the mid-1980s using horses and buckets. Nowadays, they have gone with a mainline tubing system with vacuum pumps to allow sap to flow as weather becomes less predictable, switching to the new taps that prevent the holes in trees from healing up, and tap over 66,000 trees. The operator expresses a level of regret, missing the horses and the sense of tradition, but ultimately needed to upgrade in order to make it. This example also highlights the barrier that many operators face in keeping up with this new maple sugaring world: the total cost to invest in the high-tech equipment to handle large volumes of sap totaled more than $100,000 (Bodette 2013).

What kinds of operations are still using buckets and traditional methods, then? Are these operations able to survive against the new standard for Vermont maple? There is one such operation in Washington County that serves as an interesting example of how these methods are faring. A team of siblings, tapping approximately five hundred trees on a hilltop grove, runs the operation. They largely resist the technology that has enabled the large-scale sugarers to mass-produce their product. They use metal buckets to catch the sap, and an old tractor to transport it from the tree to the sugarhouse. Their methods are largely the same as their father's, over fifty years ago. The most they ever made in a season with their five hundred trees was a bit over one hundred gallons. During the sugaring season, it is normal for them to put in twelve to fifteen hour workdays, but they are not making a lot of money off of this endeavor. All of them have other day jobs, and are lucky to break even with their sugaring. They use traditional methods of sugaring as a hobby and because they enjoy it, but would be unable to make a living off of it continuing in the style that they do; one of them joked that if they had to charge based on the work that's required, it would cost more like $200 per gallon (Hirschfeld 2005).

One of the main factors influencing syrup production moving forward is going to be figuring out when the ideal time to tap will be. Vermont operations have long tapped their trees on a certain date, around March 1, in order to encompass what are traditionally the best four to six weeks of sugaring conditions. If one tapped too early, it was believed the holes may run poorly later on in the season when conditions are favorable for sap flow, while tapping too late would result in missing out on some of the crucial early season weather. The Proctor Maple Research Center has done a couple of studies regarding this, focusing on tapping date impacts on gravity collection in 2000 to 2002, and on vacuum collection in 2006 and 2007.

All of the trees they studied were located at the University of Vermont Proctor Maple Research Center at an elevation of 1300 - 1500 feet. Between the years 2000 and 2002, sap yields from trees tapped on different dates were studied using gravity collection. Sixty trees were divided into three groups of twenty, with each group tapped three to four weeks apart. All trees had a single tap hole and to reduce variability, all tap holes were located on the same side of the trees. Trees were mostly in forest stands, with some open grown, and had an average diameter of sixteen inches. Sap and sugar content were measured whenever the sap ran, from the time of tapping until all taps had ceased running. Although they measured sap sugar content, they were primarily focused on sap volume was of primary importance in this study because it was directly affected by tap hole drying. Sap sugar content is unlikely to be affected by the tapping date, with the exception that sap collected in January or early February may be less sweet. The dates chosen for tapping were selected to be about a month early, near the traditional date of March 1, and about two weeks late.

They were able to pick up three trends from the results. The overall yields for the first two tapping dates were very similar, even though the tap holes in the first group were a month older than those in the second group. The sap did flow less as the holes became older, but for the most part this did not occur until the last week or two of the season. Tapping well past the start of the season resulted in tap holes that out-produced all others, though production from these tap holes could not make up for the earlier lost sap runs. During these three years there was very little sap flow weather in February, so the advantage of tapping on February 1 was negligible in terms of yield. 2002 was the only year in which a significant amount of sap was collected before the traditional date. Thus, these experiments showed that while tapping early did not appear to hurt overall sap yields, neither did it supplement them.

During the years 2006 and 2007, sap yields from different tapping dates were studied using collection by high vacuum. The study trees, growing in a forest stand and ranging from ten to sixteen inches in diameter, were divided into three groups of ten trees, with each group tapped on a different date. All trees had one tap hole located on the south side of the trunk. Sap was collected in 3.2 gallon vacuum chambers. These chambers allowed collection of sap from individual tap holes under vacuum; the sap remained in the chamber for volume measurement and sampling for sugar content until it was manually emptied. Vacuum was supplied by an oil-cooled liquid ring pump. The three groups of trees were tapped at widely spaced intervals, beginning in January. The difference in age from the newest to the oldest tap holes was thus considerable; 61 days in 2006 and 76 days in 2007.

Overall yields for the trees were very large, illustrating the superior performance of both high vacuum, and the collection method which essentially eliminates any lateral line restriction by using only a 5/16"dropline connected directly to the chamber. These experiments were testing the efficacy of tapping very early and in both years a fairly large amount of sap was collected in January and February. It is important to note the yields during the sap run of 3/24 in 2006 and 3/28 in 2007; in both cases, the earliest tap holes, which were 9 and 11 weeks old, respectively, equaled or nearly equaled the performance of tap holes that were much newer. As was true with gravity collection, during the last week or two of the season the average sap flow declined in the older holes relative to the newest holes. During this time, some tap holes stopped flowing altogether, while others continued at a rate nearly comparable to earlier weeks. Warmer weather, particularly after the end of March 2006, was strongly correlated with the decline in flow from both the January and February tap holes.

Sap sugar content in January, particularly in 2006, was low compared to sugar content in March. During the first runs in 2006, the sap averaged 1.3% brix, compared to 2.1% by mid-March. In 2007, the January sap run averaged 1.8% compared to 2% in March. Low sweetness translates to greater fuel consumption in order to make syrup, although for producers using reverse osmosis the difference in fuel consumption would not be large. Despite the differences in sap sugar between the earliest tapped trees and those tapped in March, syrup yield (sweetness x volume) was still much higher for the January tapped trees.

If tap holes can run well for as long as fourteen weeks, as many did in 2007 under vacuum, then the traditional wisdom that they will run for only four to six weeks needs to be re-examined. The similarity of the vacuum collection results with those from the gravity tubing experiments suggests that an open spout does not dry up sooner than a spout in a closed system. The two tapping dates were separated by seven weeks, and no sap was collected from the January tapped trees for the first six weeks. Despite the difference in age, there was no indication that the yield from the older tap holes declined relative to the newer tap holes, despite being open to the air for a total of twelve weeks. Under both gravity and vacuum, sap flow from tap holes drilled in January and February was comparable to sap flow from much fresher holes during the cooler part of the sap flow season. Toward the end of the season, when temperatures had exceeded fifty degrees Fahrenheit on several days, January and February tap holes yielded less sap than newer tap holes. In years when many of the sap flow periods involve relatively low temperatures, around forty degrees or below, the additional yield from early tapping may provide a significant advantage compared to tapping on March 1 (Wilmot 2008).

Naturally, immediate concerns regarding advanced means of tapping and pulling sap out of trees would involve harming the tree, possibly sucking it dry, or at the very least diminishing the flavor of the resulting syrup. The Proctor Maple Research Center responsible for the special plastic spout that prevents tap holes from drying up or collecting bacteria, says that this is not a worry. They have done studies where they purposefully attempt to kill a tree by over-tapping it, and have found it to be difficult (Scott 2013). A chemical analysis of maple syrup processed both with and without reverse osmosis revealed a change in certain flavor compounds, but a Proctor Maple Research Center study concluded that taste-wise, no one could tell the difference. Indeed, the Proctor center believes that as much as ninety percent of syrup now sold passes through reverse osmosis (Scott 2013). As worries about new technological innovations fall by the wayside, the Vermont flavor of maple syrup has adapted itself for the twenty-first century.

5. Skiing in Vermont

History

Skiing in Vermont can technically be traced back to the very beginning of the twentieth century, when the inn manager at the Woodstock Inn in Vermont would push guests to hike up the hill, strap wooden boards to their feet, and ski back down. In 1909, Dartmouth College student Fred Harris started the Dartmouth Outing Club, and two years later, as a senior, inaugurated the first Dartmouth Winter Carnival. By 1922, a Dartmouth College student had built a ski jump on a Brattleboro hillside, to go with an annual jumping competition that started in February of that year which still continues to this day. Crowds of up to 10,000 spectators were not uncommon at these competitions during the 20s and 30s, as the public's interest in skiing, and visiting Vermont, really began to take off.

By 1933, skiing in Vermont had become much more established. The first uphill ski tow in the country, a rope tow, was opened on Gilbert's Hill in Woodstock on January 28th, 1934. With that first ski lift on the hill in the town of Woodstock in 1934, Vermont skiing was put on the map in a big way, the beginning of what was to become a major industry for the state. Every guest room in town would often be filled as visitors came from near and far to try out the new ski lift. Woodstock was the origin of American skiing. Once the ski lift had been introduced into Vermont, it did not take long for skiing to spread throughout the state. Skiers were already scaling and descending the highest peak in the state, Mount Mansfield, within just a few short years. Within the next three years, there were four ski areas in the vicinity, with seven tows in operation.

Throughout the rest of the 1930s, state forester Perry Merrill and his appointed band of Civilian Conservation Corps cut ski trails on Mount Mansfield, Burke, Okemo and Ascutney. The first was the Bruce Trail on Mount Mansfield. Local skiers had hiked up the Toll Road and skied down for a few years, but Merrill and his twenty-five-man crew created a network of trails that would eventually be the genesis of today's Stowe Mountain Resort. After the Bruce trail was finished, they cut the Nose Dive, Chin Clip, Perry Merrill, Teardrop, and Lord trails, rounding out the first six trails that make up Stowe. It was at Stowe's Mount Mansfield, that Charles Minot Dole fell and broke his ankle while skiing with friends on the Toll Road in 1936. The lack of any organized rescue gave him the idea to start what would become the National Ski Patrol in 1938. The state's first chairlift was installed at Stowe for the 1940 - 1941 ski season, the same year the first T-bar lift was installed at Pico Peak.

All throughout the late 1930s and 40s, rope tows were being constructed on nearly every local hillside and pasture, and the proliferation of ski areas seemed to have no end. But soon larger ski areas began to squeeze out the smaller tow areas. Larger and more lifts continued to come into existence, and lifts became increasingly more sophisticated, until by 1948 there were seven ski areas in the state large enough to have cable-type chair lifts. These seven original ski areas brought in about a million dollars per year, and the overall industry only continued to grow. Between 1943 and 1958, Vermont saw the rise and growth of Big Bromley, Mad River Glen, Mount Snow, Okemo, Smugglers' Notch, Jay Peak, Sugarbush, Killington, Burke and Ascutney. All the while, the rope tow areas fell by the wayside until only a handful of small, community ski areas were left. There was another expansion of larger ski mountains in the 1960s as Magic Mountain, Stratton, Glen Ellen (now Sugarbush's Mount Ellen) and Bolton Valley sprung up. By 1961 it was up to twenty-one major ski areas in Vermont, bringing in roughly seventy-two million dollars, and by 1997 there were twenty-six areas bringing in approximately a half billion

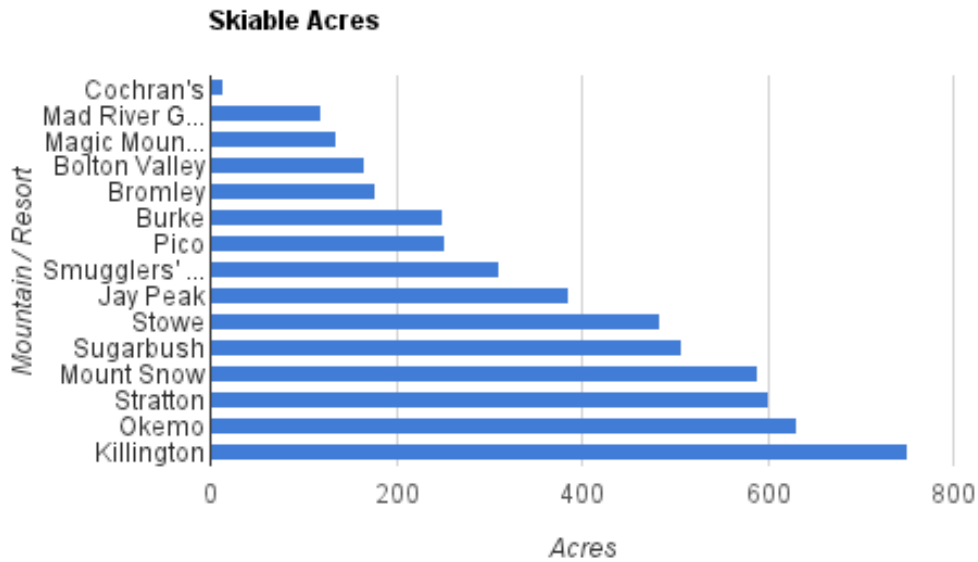

Figure 5.1 : Data from Vermont Ski Areas Association

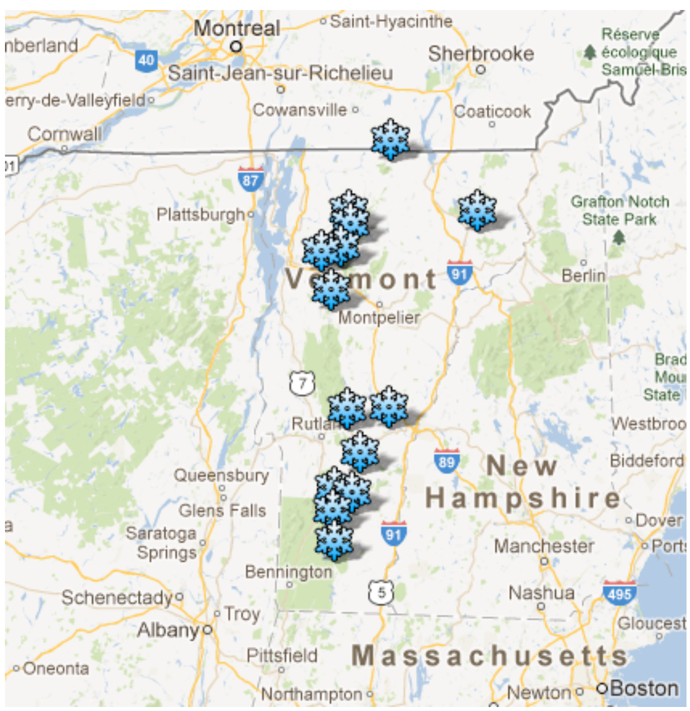

Figure 5.2: Ski Mountains in Vermont

dollars (Albers 2000). By current estimates, 116 Vermont ski areas have existed but failed and collapsed, leaving barely two dozen still in operation.

The backbone of Vermont's large winter recreation sector is still the skiing industry, though. Figure 5.2 lays out many of Vermont's larger ski resorts by total skiable acres. The four largest ski areas in terms of skiable acres, Killington, Okemo, Stratton, and Mount Snow are all located in the lower cluster of ski areas. Overall, ski areas cover the state, appearing in equal amounts in the southern and northern parts of the state. This map also makes evident how many of the ski areas are located directly off of the major highways, an example of the importance of skiing to Vermont. When the most recent highway system was being planned, easy access to ski areas was near the top of the priority list. This was one step in the state's attempt to facilitate a bustling ski industry. Figure 5.3 tracks how successful efforts over the years have been, in annual skier visits to Vermont from the 2000 - 2001 ski season to the 2011 - 2012 ski season.

Figure 5.3 : Data from Vermont Ski Areas Association

Annual skier visits to the state fluctuate year to year around an average of about 4,216,462, with a total range of nearly 760,000 visits. In this twelve-year period, Vermont has never managed to again attract as many skiers as it did in 2000-2001, when it brought in 4,579,719 visits to the state. The worst year for skier visits was the 2006-2007 season, with 3,820,431 visits, a 16.6% decline from 2000, while the second-worst year was just last season, 2011-2012, with 3,903,171 visits.

Following a 2003 - 2004 season largely regarded as disappointing due to frigid weather in January and much of February that kept skiers away, hopes were high for the 2004 – 2005 season (Edwards 2004). There was plenty of snow going into the 2004 holiday season. Jay Peak saw eighteen inches in the week leading up to Christmas, and Sugarbush and Stowe received several additional inches as well (Gorlick 2004). By the Christmas holiday, the northern half of the state was nicely blanketed (Basch 2004). However, it may have been too little to late, as the first half of December was characterized as experiencing heavy rains (Gorlick 2004). The 2004 Christmas season was ultimately average, and January of 2005 only saw sporadic snow. Between February and March, however, some Vermont ski areas saw as much as nine feet (AP 2005).

Faced with challenging weather, skier visits in Vermont fell 6 percent in 2005 – 2006. Vermont's seventeen downhill ski areas reported a bit more than 4.1 million skier visits for the season, compared to the previous year's 4.4 million visits (Edwards 2006). Several resorts were still trying to lure visitors through the end of March in hopes of bringing in visitors (Kost 2006). Despite the decline, Vermont was able to remain the third ranked state for skiing in the country, behind Colorado and California. The current president of the Vermont Ski Areas Association, Parker Riehle, wrote, "The past season was certainly a challenging one for the industry. With our resorts' ever-improving snowmaking and grooming capabilities, we were able to survive the wildly variable weather patterns that seemed to hit hardest during our key holiday periods and finish the season stronger than many had predicted." Some resorts fared significantly worse than the overall, such Mount Snow, dropping almost eighteen percent, Mad River Glen, projecting visits to fall by twenty percent and Killington and Pico, which saw declines in skier visits of nineteen percent. Killington reported numerous freeze/thaw cycles and rain on important dates, like Martin Luther King and Presidents Day weekends, that hurt visits (Edwards 2006).

Warm weather meant a rough start to the ski season for 2006 - 2007. Warmer-than-usual temperatures in November prevented resorts from making snow, and delayed resort openings across the state, with many hoping that they could open by the end of November, hopefully scoring a Thanksgiving crowd, or at the very least early December. Snowfall for the month in Burlington was 2.3 inches below average (AP 2006). December was also simply too warm and wet. In Burlington, temperatures averaged thirty-three degrees Fahrenheit, compared to an average in the mid-twenties (Dentch 2007). The precipitation that did fall was largely in the form of rain, and temperatures reaching into the high thirties and low forties hindered snowmaking efforts (Curran 2007). As of December 10th, only fourteen percent of the state's trails were open (AP 2007). For some areas in the state, the season really did not begin until mid-February (Zezima 2007). Stowe got forty-eight inches of snow in one mid-February week, and

February 14th set the record in Burlington for most snow in a twenty-four hour period, at twenty-five inches, compared with the old record of twenty-three inches in 1934 (Dentch 2007). Vermont's 3.8 million skier visits were a seven percent drop from the previous season (VPR 2008). There were still people on the slopes in April, but the snowless November and uneventful holiday season could not make up for the more favorable spring skiing (Ring 2007).

By mid-December of 2007, Vermont ski resorts were buried in snow, with more on the way. Burlington got 13.3 inches of snow in the first thirteen days of the month, compared with 4.2 in 2006 (Edwards 2008). By Christmas, it had accumulated thirty-four inches, compared to an average of 15.7 inches (Zezima 2007). According to the National Weather Service in Burlington, December was Burlington's then fourth-snowiest month on record (Edwards 2008). By mid-December, almost sixty percent of Vermont's trails were open (AP 2007). In the same time span, there were only two days in which the temperature dipped below freezing in 2006, compared with the first thirteen days of December in 2007, when only three days were above freezing. The Mad Riven Glen ski cooperative reported about six feet of snow by Christmas (Zezima 2007). Okemo Resort also reported favorable business levels, with more terrain open than they've had in past years at the same time, projecting for the first time that they would be 100% open by the December holiday week (Curran 2007). By the end of the season, their visits were up by almost twenty-five percent from the year prior (VPR 2008). Sugarbush was close to being one hundred percent booked for Christmas, a record for them, and expected one hundred percent of their terrain to be open. At Smugglers' Notch, they had thirty-two trails open on Black Friday, compared to having only four trails open two weeks after Black Friday in 2006. Approximately fifty-nine percent of Vermont's 1,242 ski trails were open as of December 10th 2007, compared with fourteen percent at the same time last year (Curran 2007). The season continued to be quite favorable, with fresh snowing happening to fall on most weekends and holiday periods. February became a record month, the National Weather Service reporting 42.3 inches of snow in Burlington, far surpassing the previous 1958 record of 34.3 inches. Three ski resorts in the state, Jay Peak, Mount Snow, and Sugarbush, were still open in the last week of April (Edwards 2008).

Overall, Vermont resorts saw business grow during the beginning part of the 2008 – 2009 season (Parsons 2009). There was a fifteen to seventeen percent increase in sales of season tickets (Economist 2008). Mount Snow reported that while the Christmas 2008 holiday was rather slow, January 2 2009 was their biggest day since 2004, benefitting from falling on a Friday and seeing great snow (Parsons 2009).

The 2009 – 2010 season started off well. Temperatures were cold, dipping into the twenties in the first week of November. With a couple natural inches of snow and ninety hours of snowmaking, Killington had expert trails open by early November. The favorable temperatures allowed them preserve about sixty percent of the snow the resort made during that time in preparation for their official season open. In the second week of November, they closed for a day stating, "Over the next 24 hours, snowmaking operations will continue and snow cats will being working the snow surface to provide guests the possible opening day conditions" (Kumka 2009).

2010-2011, the third-snowiest season on record, was a big year for Vermont's ski resorts, pulling in more than 4.3 million visits. The season started off slow, but had strong numbers coming in through Christmas, New Year, and Martin Luther King weekend. It was the state's best ski year since 2004-2005 (AP 2011).

The 2011 holiday season was disappointing, though. Christmas holiday visits to Sugarbush were down seven to eight percent from the year prior, while skier visits to Okemo Ski Resort were down twenty-eight percent over Christmas (Keck 2012). Several ski areas were also dealing with repairs after Tropical Storm Irene hit the state. Killington sustained the most damage, with a portion of its base lodge collapsing, along with structural damage to conveyer lifts and roads (Wilbur 2011). Mid-January snowfall was a welcome relief. Sugarbush reported five to seven inches right before Martin Luther King weekend, before which conditions were merely cold, forcing them be less than sixty percent open as they made the snow (Keck 2012). Overall, however, the 2011 - 2012 was fairly disappointing, suffering from a lack of snow and high temperatures (Canfield 2013). A warm spell arrived in March with almost summer-like temperatures, ending the season for most Vermont resorts (Edwards 2013).

This past winter of 2012 - 2013, though, was a snowy one. Although official numbers will not be released until June, the Vermont Ski Areas Association estimates approximately 13.3 million slope visits, up twenty percent from the year prior. There was snow during all of the big holiday periods. Sugarbush Resort was able to beat their previous record for one-day skier visits by nine percent on December 29, during the week nestled right between Christmas and New Year (Canfield 2013). Across the state, good weather and high-tech snowmaking equipment helped extend the ski season and keep resorts open later (Varricchio 2013). As of the beginning of May, Sugarbush and Killington resorts were still open (Canfield 2013). Indeed, Killington's plan was to stay open through the beginning of June (Bradley 2013). Vermont skiing in June? Such a scenario would have been practically impossible not too long ago.

Unlike with maple sugaring, where overall production, sales, and yield have been increasing, annual skier visits in Vermont have overall been on the decline. The most immediately obvious explanation for this, given the nature of skiing, would be diminishing snowfall.

6. Snowfall and Snowmaking on the Ski Mountains

Figure 6.1 shows two different datasets regarding snowfall to show the general snowfall trend: annual state average snowfall from the Vermont Ski Areas Association, and meteorological Burlington total snowfall data.

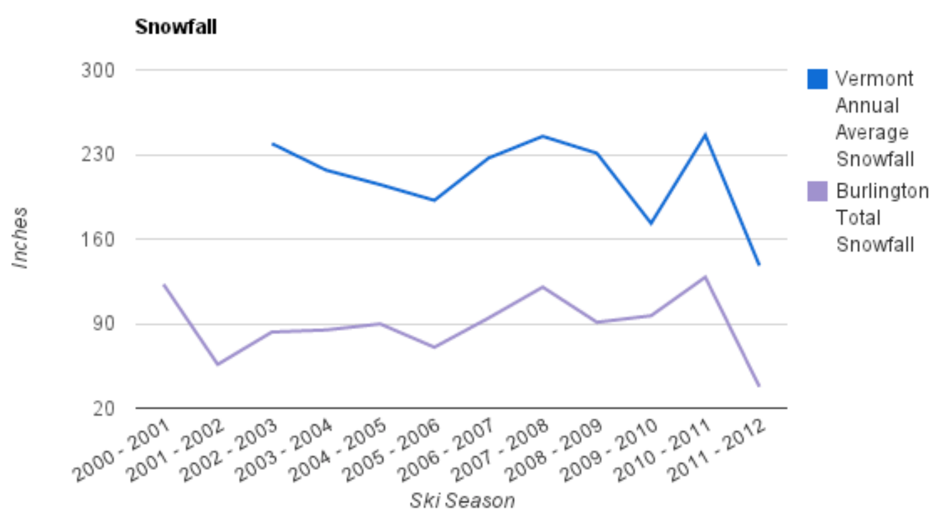

Figure 6.1 : Data from National Weather Service and Vermont Ski Areas Association

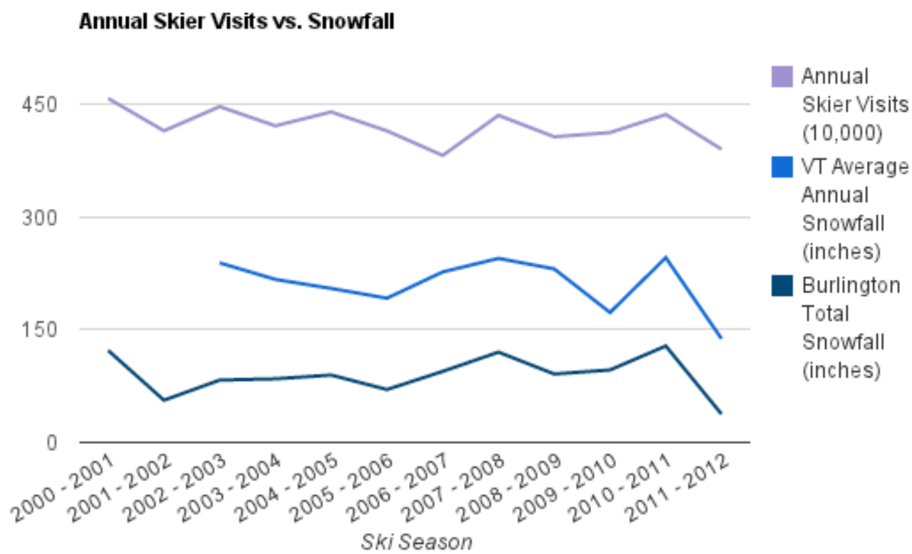

Figure 6.2 : Data from National Weather Service and Vermont Ski Areas Association

Like annual ski visits, Vermont snowfall over the same period has no clear trend, but rather fluctuates up and down. Given the lack of ski visits in the 2006-2007 and 2011-2012, it would be reasonable to expect those years to have among the lowest snowfall totals. This is certainly true of the 2011 - 2012 season, which has the lowest values for both snowfall datasets. However, the 2006-2007 season actually saw an increase in snowfall over the prior year, and thus does not provide an explanation as to the low amount of visits for that year. In addition, average statewide snowfall in the 2009-2010 season, the second lowest year, should potentially suggest a dip in skier visits for that year, but this again is not true. Thus, while there is certainly some correlation between snowfall and skier visits, such as the 2007-2008 and 2011-2012 seasons, it is not a total correlation.

Certain peaks and valleys are obvious in Figure 6.2, such as the peaks in 2007-2008 and 2010-2011, and the drop in 2011-2012, although that decline in annual skier visits is not nearly as steep as the decline in snowfall would suggest. However, no explanation is provided for either the fluctuations between 2002 and 2005 or the low in the 2006 - 2007 season.

The hottest winters were in 2001-2002 and 2011-2012, averaging 26.5 degrees Fahrenheit, corresponding to decreases in skier visits. In fact, 2002 was the warmest year on record, while 2012 was the second warmest, so the relatively mild decrease in visitors in the 2001-2002 season especially is noteworthy. Otherwise, though, there appears to be little correlation between winter temperatures and precipitation and skier visits. Precipitation, especially, appears to have little to no effect. The 2007-2008 winter was the second wettest on record, but skier visits for that year only differ roughly three percent from the average of the time period. Snowfall still appears to be the most relevant factor, although it provides an incomplete explanation.

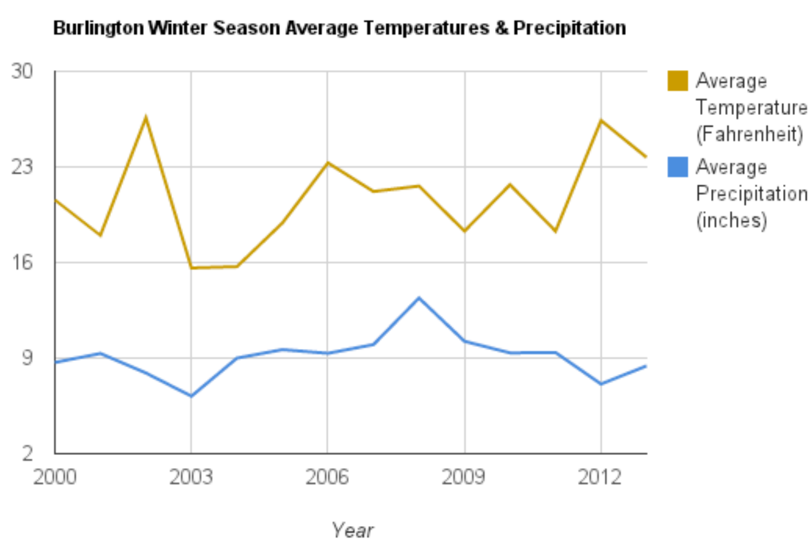

Figure 6.3 : Data from National Weather Service

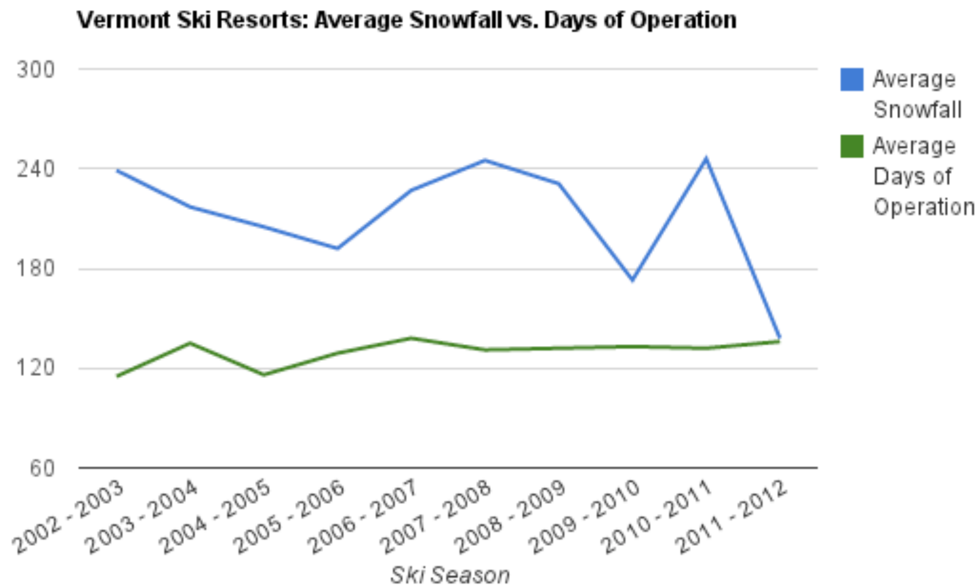

Figure 6.4 : Data from National Weather Service and Vermont Ski Areas Association

Figure 6.4 again shows Vermont average annual snowfall, but this time with the average number of days of operation of the state's ski areas. The dips and peaks of the annual snowfall are there, but their affect on the number of days the ski areas are able to be open is seemingly non-existent. The average days of operation centers around 129.7, with no noticeable impact by snowfall. Indeed, the worst year in terms of snowfall, the 2011 - 2012 season, saw operations open for an above average amount of days, and the same is true with the second-least snowy winter of 2009-2010. It of course makes sense that ski areas might need to remain open for an extended period of time during winters with low amounts of snowfall, in order to try to recoup as much as money as possible. However, if already snowless winters drive ski areas to stay open for a bit longer than they might otherwise, artificial snowmaking operations would have to be quite expansive and powerful, if they are responsible for both elongating and supplying much of the season.

The complete lack of correlation between average snowfall and average days of operation provide further evidence for the heavy use of artificial snowmaking. Figure 6.5 begins to explore the extent of snowmaking by laying out the percentage of terrain per ski resort that is covered by artificial snowmaking as of the 2010 - 2011 ski season. It shows that three resorts have over 90% of their terrain covered by artificial snowmaking, half of them have at least 75% coverage, and all but one of them have at least 50% coverage. Okemo Mountain Resort is capable of covering the highest percentage of its terrain at almost 96%, while Mad River Glen, a smaller ski area located in Washington County, still chooses to maintain a more traditional way of skiing, relying more on natural snow. Figure 6.6 breaks down the number of acres possible to be covered by snowmaking compared to total remaining skiable acres that are reportedly uncovered.

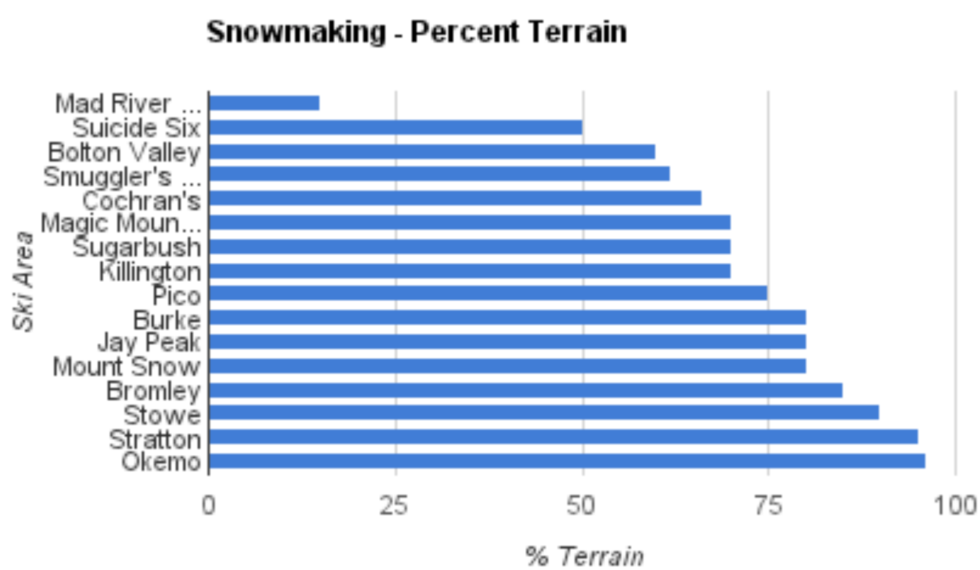

Figure 6.5 : Data from Vermont Ski Areas Association

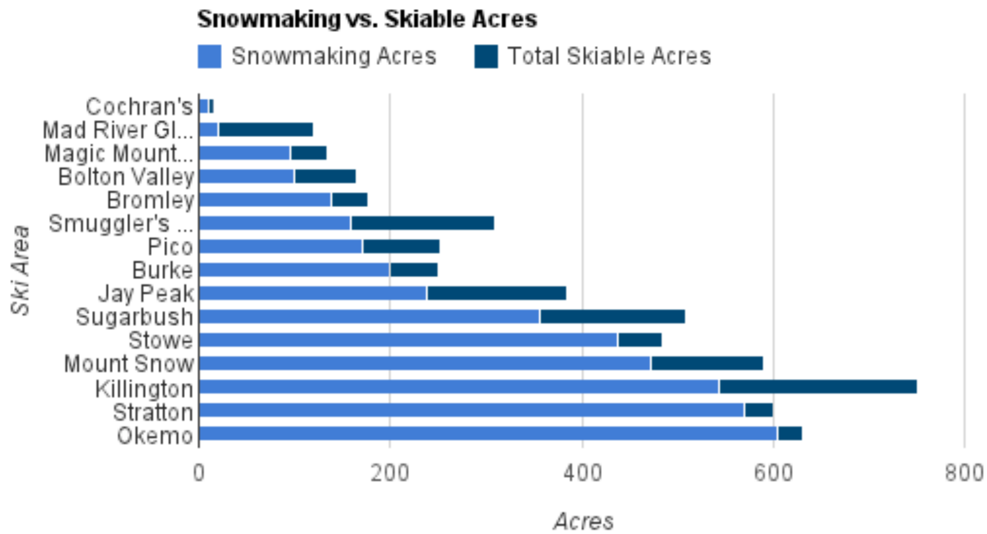

Figure 6.6 : Data from Vermont Ski Areas Association

As this graph makes clear, even some ski areas that percentage-wise may not appear to produce among the most artificial snow in the state, such as Killington, are in fact just larger and employ more powerful snowmaking operations than other ski areas that may use a higher percentage of artificial snow, such as Bromley. Okemo and Stratton top both lists, with Okemo capable of covering approximately 605 of its 632 acres, and Stratton capable of covering around 570 of its 700 acres. It becomes apparent why such disconnect between snowfall, skier visits, and days of operation is capable of existing; most of the larger ski areas attempt to gloss over unfavorable conditions with increasingly more powerful snowmaking.

Technological improvements in ski resorts are constant, and completely necessary for their continued existence. Jay Peak spent over $500,000 in 2006 alone on snowmaking and grooming equipment (AP 2006). New England Business Journals reported that ski resorts in Vermont and New Hampshire combined spent more than thirty million dollars in improvements for the 2007 – 2008 season (AP 2007). The following are just improvements various ski resorts were undertaking before the 2009 – 2010 season. Bolton Valley was extending snowmaking on their popular Cobrass trail and retrofitting their snow guns to improve efficiency. Bromley had just completed a two-year, over $1 million upgrade to its snowmaking system, increasing capacity by thirty percent. Okemo Mountain Resort added a second Prinoth BR500 grooming machine, nicknamed "The Beast", featuring a twenty-four foot wide tiller and a twenty food wide blade, in addition to reconfiguring their snowmaking system to enhance resurfacing response time. Magic Mountain repaired and upgraded its snowmaking for more efficiency, while Mount Snow, Pico and Killington also made miscellaneous upgrade, improvements, and repairs to their systems. Stowe Mountain Resort did not make any improvements in this year, only because they had just finished a project in which they entirely redid their Spruce Mountain area complete with new snowmaking (Jones 2009).

Before the 2011 – 2012 season, there were just as many improvements being made. Bromley introduced 60 new HKD energy efficient tower guns spread out over five different trails and the top of the mountain, investing $200,000 in snow. Burke Mountain completed a major snowmaking project, installing over 100 high efficiency snow and fan guns, increasing snowmaking capacity by over fifty percent. Smugglers' Notch invested over one million dollars in snowmaking enhancements, adding additional high efficiency tower guns and a new electric compressor, allowing more snow to be made at a wider temperature range, improving early and late season coverage, as well as strengthening in-season coverage and reducing energy costs. Stowe Mountain Resort continued to invest in snowmaking operations with an additional 4.7 million dollars in new equipment and upgrades, including 325 HKD tower guns, 150 energy efficient land guns, 16 Super Pole Cat fan guns and seven miles of new snowmaking pipe. In addition to supplementing its snowmaking, the improvements allowed Stowe to operate with greater energy efficiency and eliminate 100,000 gallons of diesel storage, use and emissions. Killington Resort, on the heels of investing twenty million dollars in the last five years on improvements including snowmaking, was continuing to upgrade their snowmaking systems, and Stratton as well added more snowmaking coverage on some of their more beloved trails (VBM 2012).

What is coming up next in 2013? After receiving positive comments from guests about last season's improvements, Magic Mountain is continuing its revamp of its snowmaking process by improving snowmaking capacity and efficiency in order to shoot snow on the mountain sooner and faster. Mount Snow also has some enhancement plans for their snowmaking process, planning to replace about three miles of snowmaking pipe to improve both production and efficiency. Killington Resort and Pico Mountain are excited for their largest capital investment under their new ownership, with total expenditures for 2013-2014 expected to come out at just less than ten million dollars at Killington and $1.3 million at Pico (White 2013).

Ski areas being forced to make more snow and groom more intensely results in much more intensive energy and water usage. As of 2006, the Vermont Ski Areas Association estimated that Vermont's ski resorts spent about twenty million dollars on energy a year, the second largest operations expense besides employee compensation.

Okemo Mountain Resort, averaging approximately 600,000 visitors a season, had to pump 450 million gallons of water to generate snow, roughly 100 million gallons more than in previous years. As of the end of March, they were still creating snow, hoping to lure more visitors. Buoyed by the need for snow and heating oil and increasing fuel prices, the expense of all this was only expected to increase. Mad River Glen ended the 2006 season with a deficit, largely because of increased fuel costs that ended up being higher than they anticipated.

Ski resorts are not perfect. In 2008, Sugarbush Ski Resort was fined close to $20,000 for violating the federal Emergency Planning and Community-Right-to-Know Act. The settlement followed earlier enforcement against Sugarbush for violations of the Clean Water Act and federal hazard regulations. Sugarbush is subject to federal facility inspection conducted at the resort because it is located on federally owned National Forest land. An Environmental Protection Agency inspection in February 2007 revealed that Sugarbush had failed to identify propane, diesel fuel, gasoline, sodium hypochlorite, aluminum sulfate and other hazardous chemicals present at the facility. The hazardous waste and Clean Water Act violations were discovered in the same visit, to which Sugarbush agreed to an expedited settlement of $3,000 (Ballentine 2008). There was nothing malicious about this incident in any way, it was merely an oversight, but it highlights that despite best efforts, the full impact ski resorts have on their local environment are perhaps underreported, or not fully understood. Going forward, as ski resorts need to increase their snowmaking and other technologies to keep the Vermont ski season feeling alive, these will only strengthen.

7. Conclusion

Gentler, wetter winters are expected to decrease the length of the Vermont ski season; under high-emissions scenario, in which carbon dioxide emissions continue on the same path they are on now, many of the state's ski areas may no longer be sustainable by the end of the century. Under lower-emissions scenario more Vermont ski areas would be likely to persevere, and would likely end up benefitting economically as a result of less competition as the smaller resorts shut down. The long-term sustainability of these resorts will largely depend on skiers' willingness to travel greater distances to ski in some winters in which perhaps they do not see a single snowflake, and the resorts' access to the water needed for the substantial increases in snowmaking, as well as the money needed to pay for the larger operational costs.

Ascutney Mountain Resort, shut down for the past three winters now, is a good recent example of this. The resort operated fifty-seven trails and six lifts across two hundred square miles and 1800 vertical feet of skiable terrain, until it filed bankruptcy in 2010. It simply could not afford to operate. Ascutney is just one of the more recent additions to the number of closed ski areas scattered across the state. The Vermont ski industry arguably peaked in 1966 and has been on the steady decline ever since. At its height, Vermont had eighty-one ski areas in operation. Over the years, the number of ski areas open in a single season rose and fell with shifting economic and weather conditions, but as of today less than twenty ski resorts are in full operation.

Mad River Glen, a resort dedicated to resisting modern snowmaking technology as much as possible, shows what will increasingly happen to resorts who are unable to or simply do not blast their mountains with snow every year. The resort really suffered last year as a result of the inadequate snow buildup. The ski area uses snow blowers and groomers quite sparingly, with snowmaking technology covering fifteen percent of their terrain. Last year they could only be open for seventy-one days, when it needs to operate for at least a hundred days to actually see a profit. The resort lost money. Mad River Glen, alongside numerous other Vermont ski areas, is in trouble if current climatic trends continue. In coming years, one of the main challenges for the large ski areas capable of surviving will be convincing skiers to go to the slopes when there is very little snow actually falling to put the idea of skiing into their heads. If they can get them to the slopes, conditions are likely to remain favorable for snowmaking for a while and good skiing will be had, it will simply be a matter of pumping more and more money into it. Vermont will likely have less ski areas in the future, but those ski areas will be much larger in size and operation.

As for the syrup industry, as time goes on sugar maples will likely have to deal with increased competition from species of trees that are better suited to warm weather. Continued warming in the winter is expected to disrupt the pattern of freezing nights and warm days that is essential for good maple syrup production even more, posing further challenges to Vermont's maple sugaring industry. The changing climate has already been impacting the maple industry by altering the time schedule of when maple syrup is made to earlier in the spring and shortening the flow season. On average, sugaring now begins eight days earlier and ends eleven days sooner than it did forty years ago. This is a difference of just three days, but assuming an average season might be around thirty days, that is a full ten percent of the sugaring season gone. As we have seen, unusually warm temperatures can bring the sugaring season to a rather sudden stop, as they did in 2010, when temperatures quickly rose up to eighty degrees Fahrenheit in April.

Climate change, in addition to likely shortening the maple syrup season, will shift syrup production even more northward by the end of the century. Southern locations will see their maples start to disappear first, while the annual maple-sugaring season in the rest of the state will arrive sooner and last for fewer days. I believe that Vermont's maple habitat will remain viable in the next century, but the state's maple sugar producers will certainly need to adapt to maintain the levels of sap production that they currently see. New technology means that producers can count on a modestly good yield even in unfavorable years, when bad weather hurts the sap run. Although a number of factors affect maple sap flow in the now prevalent vacuum tubing systems, it has become increasingly evident that sap yields are largely more a function of vacuum level at the tap hole than any other single factor. Operations have benefitted greatly from the widespread incorporation of vacuum, but there is only so much further those sorts of technology can go. The maple trees are living things, after all. There is a limit to what they can produce, and I would argue that without altering the maple trees themselves, we are almost there. It is theoretically possible that perhaps in the future a high-yield maple variety could be genetically engineered that would boost production, but I do not think Vermont will go in that direction.

Warmer temperatures could potentially increase the productivity of maple groves in the short term, but under a high-emissions scenario, climate conditions suitable for these forests would decline substantially in large parts of Vermont in a hundred years or so. Under the lower emissions scenario, these suitable conditions would more likely continue throughout the state and the maple industry would be a lot better off. While the United States may lose even more of its overall maple syrup production to Canada, at the very least, Vermont will likely continue to be number one for maple in the country. If the traditional cycle of freezing nights and warmer days goes away, old-fashioned tap-and-bucket producers will simply become a complete thing of the past. It may be relegated below even the "hobby" standing it currently claims. Producers have been able to keep adapting to increasingly unpredictable weather, but further research is needed to comprehend the long-term effects of climate change on maple production, and to try and formulate appropriate strategies to minimize any detrimental impacts.

The traditional view of maple syrup largely involves sap flowing into buckets hanging from trees and getting boiled in a woodland sugarhouse. Modern maple syrup looks quite a bit different now, if we attempt to track it. An operator in the year 2000, looking to expand his operations, hooks up vacuum pumps and invests over $80,000 in a new evaporator and over $50,000 in reverse osmosis. These investments are heavy, but the operator is confident that they will ultimately pay off. Reverse osmosis, for example, will cut fuel costs significantly. Sap processing that used to take a couple hours can now be done in thirty minutes. All of this new equipment will allow for production on a much larger scale, allowing the operator to tap more trees over a larger distance. The operator sells his syrup at his farm stand, and to a few local stores, but by 2005 has reached a point where he is producing more than he can physically sell. He thus begins barreling up his syrup in bulk and selling it to a company acting as a middleman between maple producers and large-scale buyers. Vermont syrup is in high demand across the country. The bulk syrup is sent to a warehouse, sorted according to color and flavor specifications, piped into heating tanks, and filter pressed. The syrup is packaged and labeled, some to be sold at retail and grocery chains, some shipped to bread and cereal companies, some made into maple sugar, and so forth. For the most part, their customers' demands are larger than any individual producer could supply. It is a year-round business; the volume of syrup passing through the warehouse is enough to sell until the next season. It has become a yearlong business for the original producer as well. As his operation continues to expand, maintenance becomes a bigger issue. Taps need to be pulled, lines need to be cleaned, old tubing needs to be replaced, etcetera. He switches to the new taps that extend the season by keeping the tap holes open. By 2011, his operation has changed quite a bit. His sugarhouse now depends on sap from almost 100,000 taps, of which he only owns a little less than 20,000. The rest belong to other landowners who get paid for the sap their trees produce. He has a side company that people can hire to tap their trees. The sap is driven into trucks with tankers, brought to the sugarhouse, and pumped into underground pipes that lead to tanks in the basement. It gets tested, and then piped through a series of tubes to the reverse osmosis machines, eventually making its way to one of the sugarhouse's now two large evaporators. Maple syrup ends up bringing him enough money to make his living, but the investment required was substantial. He keeps a couple of buckets on trees in order to show people how it used to be done, and to help preserve his image. This is what maple syrup in Vermont more typically looks like now. For anyone trying to make a living off of maple sugaring, buckets on trees cannot compete with this. Buckets on trees are good for keeping tradition alive, and helping maple sugarers market their syrup.

A few more technical improvements could slightly lengthen the maple season, and enhanced snowmaking already meets blankets most of the state's ski areas, with more on the way. Eventually, though, tubing and vacuums will not be able to overcome the effects of winters with conditions too unpredictable to sufficiently prepare for, or with too few extended cold snaps, and no matter how much snow ski areas blast on their mountains, people will look elsewhere if Vermont does not get snowy winters. Who wants to ski in the rain? Who wants to eat maple syrup with a kind of bitter taste to it because it was eighty degrees in March? These two industries have hope, corresponding to how adequately we can prevent temperatures from going up by a few degrees, but quick adaptation will be key.

References

1. Albers, Jan. (2000). *Hands on the Land: A History of the Vermont Landscape.* Cambridge, Massachusetts: The MIT Press.

2. Allen, Susan. (2011). *Gov. Shumlin Announces Settlement With McDonald's USA Over Maple Claims.* Governor's Office, State of Vermont.
3. The Associated Press. (2011). *For Vermont, a banner ski year.* Bloomberg Businessweek.
4. The Associated Press. (2005). *Overall, U.S. ski season was decent.* The Spokesman Review.
5. The Associated Press. (2006). *Resorts Get Ready for Skiers.* Beaver County Times.
6. The Associated Press. (2004). *Ski areas eye bounce after 2 bad months.* Bangor Daily News.
7. The Associated Press. (2006). *Ski areas hope for cold, snow.* USA Today.
8. The Associated Press. (2007). *Snowfall giving ski resorts happy holidays.* USA Today.
9. The Associated Press. (2005). *Vermont defends its good name.* The Boston Globe.
10. Ballentine, Paula. (2008). *Vermont Ski Resort Fined for Failure to Report Hazardous Chemicals.* News Release. United States Environmental Protection Agency.
11. Basch, Marty. (2004). *Snowmaking heats up.* The Boston Globe.
12. Beckley, Hosea. (1846). *The History of Vermont; with Descriptions, Physical and Topographical.* Brattleboro, Vermont: George H. Salisbury.
13. Bellmare, C.; Guest, C.; Peterson, E.; Torkelson, L. (2006). *Maple Sugaring in Vermont: Prospects for a Changing Climate.* Middlebury College.
14. Bodette, Melody. (2013). *Vermont Finds High-Tech Ways to Sap More Money From Maple Trees.* Vermont Public Radio.
15. Bradley, Pat. (2013). *New England Ski Visits Up.* WAMC Northeast Public Radio.
16. Canfield, Clarke. (2013). *For local ski resorts, winter was a welcome bonanza.* The Boston Globe.
17. Crockett, Walter. (1915). *How Vermont Maple Sugar is Made.* Bulletin of the Vermont Department of Agriculture.
18. Curran, John. (2007). *Vermont ski resorts awash in snow.* The Associated Press.
19. Davenport, Melinda. (2011). *Vt. Takes on McDonald's over maple.* WCAX News.
20. Dawson, J. & Scott, D. (2007). *Climate Change Vulnerability of the Vermont Ski Tourism Industry.* Annals of Leisure Research, Volume 10, Issue 3-4.
21. Economist. (2008). *Skiers opt for New England instead of the Rockies.*

22. Edwards, Bruce. (2006). *Oddball winter weather hurts ski industry*. Rutland Herald.
23. Edwards, Bruce. (2004). *Ski resorts gear up for holiday*. The Barre Montpelier Times Argus.
24. Edwards, Bruce. (2008). *Well-timed snowstorms help ski resorts to rebound year*. Rutland Herald.
25. Gorlick, Adam. (2004). *New England ski resorts relish holiday snow*. Bangor Daily News.
26. Greyhill Advisors. (2011). *Gross State Product.*
27. Hirschfeld, Peter. (2005). *Sugarhouse draws visitors, but little sap.* The Barre Montpelier Times Argus.
28. Jones, Tim. (2009). *Many improvements at Vermont ski resorts*. Seacoast Media Group.
29. Keck, Nina. (2012). *Ski Areas Look to MLK Weekend For Boost*. Vermont Public Radio.
30. Keese, Susan. (2011). *Maple Season is Running Late, but Experts Expect Good Year*. Vermont Public Radio.
31. Kumka, Cristina. (2009). *All downhill from here*. Rutland Herald.
32. McLean, Dan. (2010). *Conditions get Vermont's maple syrup producers off to a sweet start*. Burlington Free Press. March 9.
33. National Climatic Data Center. (2005). *Climate of Vermont.*
34. National Park Service. (2013). *Vermont Landscapes*. U.S. Department of the Interior.
35. National Resources Defense Council. (2011). Climate Change Health Threats in Vermont.
36. National Weather Service. (2013). *Burlington, Vermont Temperature Extremes*. National Oceanic and Atmospheric Administration.
37. New Agricultural Statistics Service. (2004). *Maple Syrup 2004*. United States Department of Agriculture.
38. New Agricultural Statistics Service. (2006). *Maple Syrup 2006*. United States Department of Agriculture.
39. New Agricultural Statistics Service. (2007). *Maple Syrup 2007*. United States Department of Agriculture.
40. New Agricultural Statistics Service. (2008). *Maple Syrup 2008*. United States Department of Agriculture.
41. New Agricultural Statistics Service. (2009). *Maple Syrup 20089* United States Department of Agriculture.

42. New Agricultural Statistics Service. (2010). *Maple Syrup 2010*. United States Department of Agriculture.
43. New Agricultural Statistics Service. (2011). *Maple Syrup 2011*. United States Department of Agriculture.
44. New Agricultural Statistics Service. (2012). *Maple Syrup 2012*. United States Department of Agriculture.
45. Northeast Climate Impacts Assessment. (2006). *Climate Change in the U.S. Northeast*. Union of Concerned Scientists.
46. Parsons, Claudia. (2009). *If it snows, they will come, resorts find*. Reuters.
47. Pellett, Dorothy. (2012). *Warm weather shortens Vermont maple syrup season*. Burlington Free Press.
48. Perkins, Timothy. (2009). *Development and Testing of the Check-Valve Spout Adapter*. Maple Digest.
49. Perkins, Timothy & van den Berg, Abby. (2012). *Relationships Between Tubing System Component Age and Sap Yield*. Maple Syrup Digest.
50. Reed, Keith. (2003). *Resorts counting on plenty of white to put them in the black*. The Boston Globe.
51. Ring, Wilson. (2007). *Despite spring surge, ski season falls short*. The Associated Press.
52. Robinson, Jonathan. (2012). *Vermont Skiing: Making History*. Vermont Chamber of Commerce.
53. Scott, Julia. (2013). *High-Tech Means of Production Belies Nostalgic Image of Maple Syrup*. The New York Times.
54. Sneyd, Ross. (2008). *Maple sugaring season comes to a close*. Vermont Public Radio.
55. Sneyd, Ross. (2009). *State looks to expand maple syrup production*. Vermont Public Radio.
56. Thompson, Zadock. (1842). *History of Vermont, Natural, Civil, and Statistical*. Burlington, Vermont: Chauncey Goodrich.
57. University of Vermont. (2013). *Maple Syrup Frequently Asked Questions*. UVM Libraries and the Agriculture Network Information Center.
58. Varricchio, Louis. (2013). *Vermont skiing: bidding farewell to the white stuff*. The Addison Eagle.
59. Vermont Agency of Agriculture, Food & Markets. (2006). *Vermont Maple Products Law & Regulations*.
60. Vermont Agency of Natural Resources. (2012). *Tropical Storm Irene By the Numbers*.

61. Vermont Business Magazine. (2012). *Snowmaking investments continue as Vermont ski resorts prepare for 2012-2013 season.* September 26.
62. Vermont Department of Tourism and Marketing. (2012). *Skiing and Riding in Vermont.* The Official State of Vermont Tourism Site.
63. Vermont Natural Resources Council. (2006). *Vermont Maple Sugaring: Prospects for a Changing Climate.*
64. Vermont Public Radio. (2008). *Vermont ski resorts report good season.*
65. Vermont Public Radio. (2010). *VT Maple Crop Down.*
66. Vermont Ski Areas Association. (2007). *Alpine Ski Facts.*
67. Warner, Melanie. (2011). *McDonald's Fruit and Maple Oatmeal: Not Real Maple and Illegal in Vermont.* CBS News.
68. Weissmann, Jordan. (2012). *Why Does Canada Have a Strategic Maple Syrup Reserve?* The Atlantic.
69. White, Erin. (2013). *Vermont Resorts Summer 2013 Enhancements.* The Ski Channel.
70. Wilbur, Eric. (2011). *Irene causes Killington base lodge collapse.* Boston.com.
71. Wilmot, Timothy. (2008). *The Timing of Tapping for Maple Syrup Collection.* Maple Syrup Digest.
72. Wilmot Timothy, Perkins, Timothy & van den Berg, Abby. (2007). *Vacuum Sap Collection: How High or Low Should You Go*? Maple Syrup Digest.
73. Williams, Samuel. (1809). *The Natural and Civil History of Vermont.* Burlington, Vermont: Samuel Mills.
74. Wright, Zeke. (2013). *Sap is flowing – Open House Weekend coming.* Bennington Banner.
75. Zezima, Katie. (2007). *New England is Celebrating Season Filled With Snow.* The New York Times.