VERMONT

ENVIRONMENTAL TRENDS REPORT: THE POPULATION CONNECTION

By: George Plumb

December 6, 2011

Cover
Three digitalized aerial photographs show the development pattern seen at and around Taft Corners, in Williston, Vermont. The uppermost image, taken in 1937, shows a largely agricultural area. The second image, taken in 1962, shows I-89 as a dirt road during its construction. Aside from the beginning of the I-89 construction project, little had changed in the area. At this time Burlington International Airport, which is located just outside of the presented images to the upper left, was still a municipal airport and had not grown nearly to the size and level of business it has today. The bottom image, taken in 2007, shows the dramatic changes in development in the Taft Corners region over the 45 years between the photographs. During this time I-89 was completed, Burlington Municipal Airport became Burlington International Airport, and Vermont's population increased by nearly 50%. Although the aerial photographs illustrate Taft Corners, many cities and towns in Vermont are suffering from similar degrees of development and sprawl.

Special thanks to William Gill of the University of Vermont's Government Documents and Maps section for making the digital aerial photographs so readily accessible.

About the author
George Plumb is the volunteer executive director of the grassroots environmental organization Vermonters for Sustainable Population. He is also the author of the *Disappearing Vermont?* report published in 2008. If you have questions about the report or suggestions regarding how it could be improved you may reach him at
plumb.george@gmail.com

Table of Contents

EXECUTIVE SUMMARY

Vermont's rural landscape is a source of cultural pride within the state, but development and population pressures are threatening the state's natural and cultural heritage. In 2008, the state environmental organization Vermonters for a Sustainable Population released the *Disappearing Vermont?* report which focused on natural and cultural changes within the state. This *Vermont Environmental Trends Report*: *The Population Connection* adopts a similar goal, although its focus is on quantifying and presenting key environmental trends within the state. The goal of the report is to further a statewide dialog on the impacts of a rising population and increasing development pressure on the state's cultural and environmental heritage.

Unlike the previous report which included both objective and subjective indicators, this report focuses on measurable indicators related to different elements of the state's environmental health. A wealth of potential indicators could be chosen to quantify Vermont's environmental health; those presented in this report fall into the categories of land use, water quality, air quality, climate change and ecological health. The author has chosen what he and Vermonters for a Sustainable Population (VSP) deem to be the most important of dozens of indicators available as the best reflection of what is happening with each aspect of Vermont's environment.

The first indicator is land-use change. While earlier trends showed the state losing cropland and pasture to forest and development, current trends suggest a loss of cropland, pasture and forest to development. Given the higher environmental values of forests and even cropland and pasture, this trend shows a decline in the state's environmental health and a risk to its environmental and cultural heritage. Although there are no data yet available, certainly this year’s floods added to environmental impacts.

Indicators that focus on water quality within the state, including Environmental Protection Agency Toxics Release Inventory data focusing on all chemical releases as well as carcinogens and persistent bioaccumulative toxins (PBTs) show improving trends. Some lake pH monitoring stations throughout the state also show improvements, albeit more gradual ones. Estimates of stressed, altered and impaired river miles in the state of Vermont are declining, although estimates of altered and impaired lake acreage are increasing, partly due to eutrophication caused by non-point source pollution from storm water and agricultural runoff.

Although Vermont's air quality appears to be improving, with fewer days of unhealthy air measured at data collection stations throughout the state and declining emissions of carcinogens and PBT compounds, the state's average annual temperature is rising. This trend towards increasing average temperature represents climate change within the state, and may foretell of shifting agricultural seasons and risks of new, potentially destructive or invasive species migrating into the state from further south.

The number of threatened and endangered species in the state could not readily be followed over time. This report catalogs the total numbers of threatened and endangered species as of the current time, both those that are state-listed and those that are federally-listed. Future reports may update these numbers. Forest health, as gauged by changes in the health of the sugar maple canopy relative to baseline, has trended downward; more years in the previous decade have shown declines relative to baseline than have shown increases. Estimates of two invasive pest species, tent caterpillars and gypsy moths, show declines in abundances in study plots, although these declines must be viewed with caution as their continuation is not guaranteed. It is absolutely necessary for Vermont foresters and land owners to be ever vigilant for invasive pests, as their immigration and establishment could have severely detrimental impacts on Vermont's environmental health and its cultural heritage.

In summary, there are thirteen indicators of environmental health being measured. Of these, seven are showing improvement: stressed, altered and impaired rivers; toxic water releases; lake water pH; rain pH; toxic air releases; the number of unhealthy air quality index days and harmful forest pests. Four show declining environmental trends: land use; stressed, altered and impaired inland lakes; average annual temperature and maple tree canopy cover. Two trends are difficult to interpret at this point: greenhouse gas emissions which have declined since 2004 but have not yet reached the 1990 level which was still very high, and threatened or endangered species, because of a lack of good historical data. These indicators are not all equal in terms of their importance. Land use and average annual temperature, for instance, will substantially impact all other indicators over time and must be watched closely.

Vermonters for a Sustainable Population recommends that this report be expanded and updated every 3-5 years by a larger environmental organization to keep the state's environmental trends in the public eye. It also recommends that the state legislature appoint a commission to study what a truly sustainable population would be in the state, that the state move towards a sustainable steady-state economy instead of a growth-based economy, that all environmental organizations and state environmental agencies acknowledge the connection between population growth and the health of the natural and cultural environment, and that because of the urgency Vermont take immediate and bold action to address climate change.

INTRODUCTION

In 2008, Vermonters for a Sustainable Population published *Disappearing Vermont?* That report focused on assessing environmental and social trends in the state, and drew parallels between these trends and the development path that the state continues to embark on, a development path that tends to replace Vermont's rural land uses such as forest, pasture and cropland with suburban development. The report asked the question 'Is Vermont's development path sustainable?', and generally concluded it was not.

This report, *Vermont Environmental Trends*, approaches the same question while focusing on a smaller number of environmental health indicators and presenting more complete trends and commentary. No list of indicators can completely encompass such a broad notion as environmental health, but hopefully this report and the data it presents can further a meaningful state-wide discussion on Vermont's environmental trajectory and whether the state is heading in a sustainable and socially acceptable direction. Although there have been other reports that have included some environmental indicators, including *Disappearing Vermont?* and *Vermont in Transition*, this is the first and most comprehensive environmental trends report published since the Agency of Natural Resources (ANR) last published *Environment 2003*[1]. Our *Environmental Trends* report is meant to be more readily understandable by the general public, and ties in critical elements not addressed in the ANR report.

BACKGROUND

Historical

What would eventually become the state of Vermont was covered by glaciers as recently as 10,000 years ago, when Lake Champlain was far larger than it currently is and was a salt water sea[2]. Lake Champlain's water level receded between 10,000-9,000 years ago, and as the water level fell indigenous peoples began exploring and hunting the maturing forests. Vermont grew to become a largely forested landscape, although the forest was more or less managed by indigenous peoples who also settled in and farmed the western part of the state.

In 1535 French explorer Jacques Cartier was the first European to reach Vermont, and in 1609 Samuel de Champlain "discovered" Lake Champlain. European colonization of Vermont began through the mid to late 1600s, with the first permanent British settlement established in 1724. Estimates of Vermont's population in 1763 put it at roughly 300 Europeans, which rose to roughly 85,000 by the time Vermont became the 14th state in the United States in 1791. Sheep were introduced to the state in 1812, leading to the first Great Deforestation as Vermonters cleared over 2/3rds of the land for sheep grazing[3]. During this period of intensive agricultural use, Vermont's topsoil suffered a great deal of erosion and its biological diversity fell as well. By 1837 there were over 1,000,000 sheep in the state, leading to a glut of wool and falling wool prices. The raising of sheep – and farming more generally – became far less lucrative, and around the mid 1800s the total acreage devoted to pasture and cropland reached its zenith. Abandoned farmland gradually regrew into forest, albeit a much less mature and less diverse forest, leading to the largely forested landscape familiar to modern Vermonters.

Population Growth

US Census Bureau Data

Vermont is the least populous state in New England and among the least populous states in the United States, although its population density, the number of people per square mile, is higher than some New England states. Figure 1 shows the population of Vermont based on data from the US Census Bureau illustrating the prolonged period of relatively stable population from 1850 to 1950 and the rapid population increase from 1950 to 2000. 2010 census results suggest this period's rapid population growth trend has slowed, and the state may be nearing another period of stable population. There is also the slight possibility that rising temperatures and increasing risk of severe weather associated with climate change may force those living in southern states to migrate north and augment Vermont's current rate of population growth. Data from the US Census Bureau indicate that Vermont has among the lowest birth rates in the nation at roughly 42 births per 1000 women per year, and roughly half of its population growth since the 2000 census is attributable to migration into the state. A higher population generally has more of an impact on Vermont's environment and natural resources, although the precise relationship between population and population growth and environmental impact depends on how Vermonters are relating to their landscape.

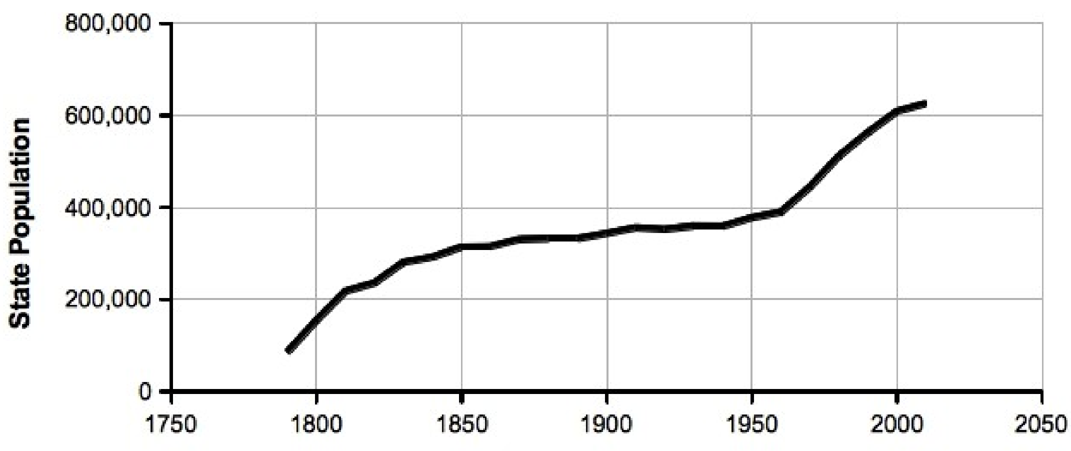

Figure 1. Vermont's population, 1790-2010 (data from US Census Bureau)

This historical information offers a useful starting point from which to begin exploring Vermont's environmental health. The following section will introduce the idea of environmental indicators, which are quantitative measures useful in following specific aspects of the state's environmental quality over time.

Interconnections

Although Vermont's population of just over 625,000 is only a tiny fraction of the world's population of 7 billion, we are very much interconnected with the rest of the world. What Vermonters do impacts the earth beyond Vermont's borders and what people outside of our state do has a major impact on Vermont. We import 100 percent of our fossil fuels, helping to contribute to the air pollution caused by the extraction, refining, and shipping of these fuels. We import approximately 95 percent of our food, most of which is grown on massive industrial "farms" causing soil loss and degradation and the inhumane treatment of animals. We import an estimated 95 percent of all material resources we use, from clothing to computers, again causing a decline in renewable resources and unsustainable use of renewable resources in other parts of the world.

On the other hand, seven billion people in the rest of the world cause the major fraction of the air pollution resulting in most of the global warming and the acid rain that affects our land and surface water. Our global population and its high per-capita resource consumption rate is resulting in the 6th great mass species extinction. Vermonters in general are reluctant to acknowledge that population size and growth are of concern because we do have a relatively small population and our state is still fairly rural, but the connection between population, consumption rates and environmental impact is very real.

ENVIRONMENTAL INDICATORS

What is a healthy environment? This question has challenged environmental scientists, ecologists and activists for decades. It is fairly easy to arrive at a qualitative definition of a healthy environment: one that offers all its inhabitants clean air, clean water, healthy and abundant food, and is diverse enough to be resilient when faced with unexpected events such as severe weather or natural disasters. This definition, however, doesn't offer either objective criteria of what constitutes adequate 'clean' or 'healthy' levels, nor a means by which to follow trends in an objective, quantitative manner. Quantitative indicators take some of the subjectivity out of following environmental trends, and can be useful as benchmarks in making environmental policy.

In an ideal world, environmental health could be summed up by a single environmental indicator that is relatively inexpensive to measure accurately. There have been a couple of attempts at developing a single metric that can accurately judge environmental health. One is ecological footprint. The idea behind calculating ecological footprint is to estimate the area of land associated with different consumption aspects of a person or population's lifestyle. The total area of land associated with meeting a population's consumptive needs is then compared with available land, and if the population requires more land than they have, the population is thought of as 'unsustainable', or living beyond their means.

Estimates of the ecological footprint done on a few online calculators put the ecological footprint of the average Vermonter at around 15 acres per person. Given Vermont's current population and its surface area, the state can offer at most 9 acres per person, suggesting that the lifestyle of the average Vermont resident is probably not sustainable and that, from an environmental standpoint, Vermonters are living beyond their means.

The challenge of ecological footprint, however, is translating the full spectrum of activities that make up a lifestyle into land area. How does one translate fossil fuel consumption to land area, for instance? One idea involves estimating the amount of forested land required to sequester the carbon (in the form of carbon dioxide, or CO_2) associated with fossil fuel combustion. This is much more challenging than it sounds since the dynamics of forest carbon sequestration are anything but clear and there are a wealth of other negatives associated with fossil fuel dependence aside from just CO_2 emissions, making the typical treatment of fossil fuel use at best inadequate in the context of estimating ecological footprint. One can raise similar objections to the way ecological footprint calculators translate many other lifestyle elements to land areas, such as material usage and waste disposal, among other things.

A related indicator of environmental health is biocapacity, or carrying capacity. The idea of carrying capacity is simple enough; carrying capacity means the total number of individuals of a given species that an area can support over an extended period of time. If resource managers, for instance, had a perfect understanding of the total available resources in the state of Vermont, they could estimate the total number of people that the state can support and call this number the state's carrying capacity. If one used the ecological footprint of 15 acres per person noted above, for instance, one can back-calculate that the state's carrying capacity is about 400,000 people.

In practice accurate data on resources are challenging and costly to obtain, and Vermont imports many resources from outside of the state and even outside of the country to maintain Vermonters' lifestyles, adding yet another layer of complexity to estimating carrying capacity. Finally, carrying capacity is a dynamic concept, meaning that the number of individuals that an area can support doesn't remain the same in perpetuity. In years of drought the carrying capacity goes down, in years of abundance it rises. In the aftermath of tropical storm Irene, given observed destruction of housing, agricultural areas and infrastructure, the state's carrying capacity has certainly fallen, although it remains unclear how long this temporary decline will persist. Does one assume a worst case scenario and use the worst of the bad years of resource availability to estimate carrying capacity? Or use an average year? These questions are challenging, and illustrate the difficulty in using carrying capacity as a quantitative indicator in policy decision making.

Rather than developing a single metric to express Vermont's environmental health, this report instead gathers data on several indicators the author and sponsors deem the most important and that explore the state's environmental trends in land, water, air, climate and ecology. The following sections will explore the importance of each series of indicators and data trends that are apparent.

Land Use

Vermont is one of the United States' most rural states, and Vermonter takes pride in its rural landscape and character. The dominant land feature in the state is forest, although cropland and pasture areas are sizable and contribute importantly to the state's character. While studying changes in land use over time can't paint a perfectly informative portrait about Vermont's environmental health, noting changes in land use can suggest changes in the state's character that might be of concern. For instance, natural environments such as forest and meadows are far more diverse and contribute far more to a healthy state-wide ecosystem than do croplands and pasture, both of which are far less diverse. On the other hand, croplands and pasture do offer a range of habitat and food sources to many species and contribute positively to the aesthetic appeal of landscapes in the eyes of most Vermonters, so they too are valuable. Croplands and pasture are certainly more environmentally valuable than land developed into housing, shopping centers and parking lots, which contribute habitat and food to a relatively few species and have other environmental drawbacks.

Since a natural hierarchy is present in terms of the value of different types of land use to environmental health, tracking land use over time is an important part of assessing the state's environmental trends. Land that is developed from forest or wild meadow to cropland or pasture loses biological diversity and often primary productivity - its ability to turn incident sunlight into plant material. As diversity falls, carrying capacity also tends to fall. Further, when land is paved and buildings constructed, the paved area prevents rainwater from percolating into the soil, thus increasing over-land runoff to nearby streams and increasing the risks of flash flooding. Constructed buildings also demand energy to heat and cool and to provide whatever commercial, residential or industrial services they were designed for, adding yet another environmental burden. Development, while a useful indicator in and of itself, also indirectly affects many other indicators investigated in this report.

One vital indicator influenced by development pressure is threatened and endangered species. Many species that end up listed at either the state or federal level become listed due to habitat loss. Habitat loss is often caused by the development of key wild habitat into either agricultural land or - increasingly - suburban or urban development. Land use change from wild habitat to either agricultural uses or to suburban or urban development are often driven by population growth and the desire of that growing population to expand their rates of resource consumption. Expanding developed land also increases stormwater runoff, which negatively impacts the water quality in receiving waters, particularly lakes. This is a continuing issue, for instance, in Lake Champlain with respect to phosphorus loading.

Table 1 shows the total acreage in Vermont associated with developed land, cropland, pasture, and forest from 1982 through 2007, which are the most recent data available[4]. Although changes are small in percentage terms (Vermont's total area is 6,153,600 acres, of which roughly 262,000 acres is water), trends are clear. Vermont had been losing cropland and pasture to development and 'other' land uses since the 1980s and likely earlier. Since 2002 this trend has shifted to one where the state is losing cropland, pasture *and* forests to development and 'other' land uses, which include fields not actively planted in crops or grazed, among other land uses. In fact, from 1997 to 2007 Vermont developed nearly 48,000 acres of previously undeveloped land, or roughly *75 square miles*. Vermont's largest city, Burlington, has a land area of just under 11 square miles, illustrating that during the period 1997-2007 Vermont developed a land area equivalent to roughly 7 new cities the size of Burlington. The data also shows that for the first time in decades instead of increasing forest coverage the forest cover is now in decline.

Table 1. Land-use in Vermont, 1982-2007. All land areas reported in acres.

Year	Developed	Crop	Pasture	Forest	Other
1982	261,900	643,500	444,900	4,459,700	82,400
1987	303,800	641,000	378,400	4,489,100	79,600
1992	332,200	627,200	347,300	4,502,700	82,100
1997	345,400	596,000	343,000	4,521,700	86,300
2002	372,900	558,000	320,700	4,550,600	89,600
2007	393,200	540,600	308,100	4,536,000	113,800

Water Quality

Water is not only vital for a healthy environment, it is also necessary for human health. Water quality is thus a natural general criterion by which to judge Vermont's environmental health. Given this, the question emerges of how best to assess water quality and how to track trends in water quality over time that are relevant statewide. The author and report sponsors lean towards three particular indicators of water quality, each based on data gathered independently.

Impaired Water Bodies

The first indicator is a listing of stressed, altered and impaired water bodies in the state of Vermont. These data are gathered from the 305 (b) series of reports published every two years by the Vermont Department of Environmental Conservation (DEC), as required by the United States Environmental Protection Agency (EPA)[5]. These reports assess inland lakes, rivers and streams, wetlands, and Lake Champlain. A variety of metrics are assessed, including aesthetics, capacity to support aquatic life and other wildlife, recreational uses, fish consumption, and others. Since this report focuses on environmental quality, only the capacity of water bodies to support aquatic life and other wildlife will be tracked over time. The DEC assesses each water body and makes a judgement on whether it is able to fully support the various uses listed above, whether the water body shows signs of stress, whether its ability to support the various uses has been altered and finally whether its ability to support the listed uses is impaired. Table 2 presents stressed, altered and impaired waters acreage (for lakes) and river miles (for streams) in Vermont. While these data are available as far back as 1996, only beginning in 2004 were the methods consistent enough year-to-year to allow for meaningful cross-year comparisons.

Table 2. Stressed, altered and impaired water bodies in Vermont, 2004-2010. Percentages show fractions of total assessed acres or miles.

Year	Lakes			Streams		
	Stressed	Altered	Impaired	Stressed	Altered	Impaired
2004	16,933 (30.5%)	8,916 (16.1%)	6,979 (12.6%)	836 (15.3%)	317 (5.8%)	227 (4.1%)
2006	17,455 (31.5%)	7,389 (13.3%)	6.979 (12.6%)	835 (15.2%)	295 (5.4%)	218 (4.0%)
2008	17,708 (32.4%)	7,527 (13.8%)	12,394 (22.7%)	860 (15.2%)	300 (5.3%)	209 (3.7%)
2010	16,260 (29.8%)	8,317 (15.2%)	12,442 (22.8%)	872 (15.1%)	290 (5.0%)	191 (3.3%)

The data show a trend towards rising acreage of altered and impaired inland lakes within the state, but a slight decline in acreage of stressed lakes from 2008-2010. It's not clear whether this decline in stressed lakes is due to real improvements, or is just statistical noise introduced by the fact that the state cannot assess all lakes every year and does not follow all lakes over successive years. At the same time that altered and impaired lake acreage is increasing, stressed, altered and impaired stream miles are decreasing in Vermont. One possible reason for the contradictory trend is that impacts on lakes are caused primarily by non-point sources of pollution such as agricultural runoff and storm water discharges, while point sources of pollution such as effluents from industrial and manufacturing facilities may play the most important role in causing rivers to be listed. Vermont's water regulations have done a decent job controlling point-source pollution, but non-point source pollution, particularly nutrient enrichment as popularized by the recent documentary *Bloom*[6], has proven more challenging for the state to control. It is also necessary to realize that the rationale behind each water body's inclusion in the altered or impaired categories varies so it's impossible to claim a single factor as the overarching cause of these trends. As noted above, not all water bodies are assessed in each report cycle so these data do not necessarily trace the level of impact on all water bodies in the state. Water bodies assessed in one year may not have been assessed the year previously or the year after. The DEC began assessing the water quality of Lake Champlain in 2006, and has consistently found that roughly 12% of the lake area, or 21,000 acres, has had its ability to serve as aquatic habitat degraded.

Effluents

Another series of criteria worth studying are the effluents released into waterways and waterbodies within the state of Vermont. One source for effluent data is the EPA's Toxics Release Inventory (TRI)[7]. This database catalogs all releases for all target chemicals released by all businesses in a state, provided the level of releases is greater than minimums established by law for each chemical. Thousands of chemicals are released into Vermont's waters, so to simplify the presentation of data I sum chemical releases in three ways: total chemical releases, chemicals known to be carcinogenic, and chemicals known to be persistent, bioaccumulative and toxic (PBT). Persistent chemicals resist degradation and last a long time in the environment, while bioaccumulative compounds tend to enter the food chain and accumulate in higher predators such as large fish or in certain species of plants. EPA's TRI program began in the 1980s, yielding a relatively long dataset with which to see trends over time. Figure 2 shows total TRI water releases in Vermont as well as carcinogens and PBTs.

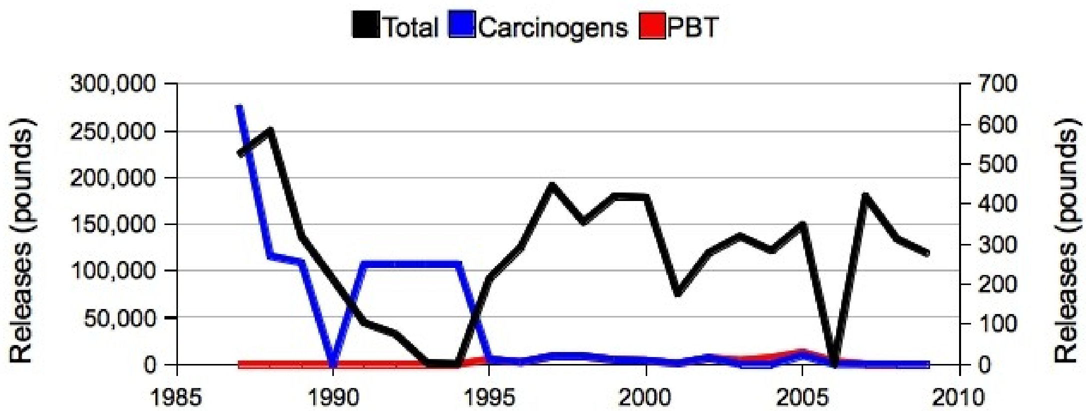

Figure 2. Total water releases (left axis), and carcinogens and persistent, bioaccumulative toxins (PBTs) (right axis) released into Vermont waters, 1987-2009.

Total water releases fluctuate wildly, and show no clear signs of trending upwards or downwards. While total mass is modestly high, many of these compounds are of far lesser concern than carcinogens and PBTs. One reassuring trend is that since the mid-1990s water releases of carcinogens plummeted, and releases of PBT compounds have always been very low in the Green Mountain state since EPA's TRI reporting program began.

Water pH

A final water quality metric that will be presented is lake pH. Historically, Vermont received a great deal of acid deposition from midwest coal-fired power plants, leading to the acidification of many of the state's water bodies. Some lakes were more sensitive to this acidification than others. The Vermont DEC has collected water pH values from several lakes throughout Vermont for decades, and provided data on three water bodies to illustrate water pH trends within the state[8].

Figure 3 shows pH trends from three lakes within the state of Vermont: Bourn, Haystack and Grout. Grout Lake is the only lake that the state assesses with declining pH, and this is partly due to the lake's high humic acid content and its inability to regenerate its buffering capacity (alkalinity) after acidification. Haystack Lake is representative of a few other monitored lakes in that its pH rose after the introduction of EPA's allowance program to control acid rain but have since remained at a moderately acidic pH. Finally, Bourn Lake is representative of other Vermont lakes where, following the start of EPA's acid rain program, their pH has continued to increase. Increasing pH effectively means that the impacts of acid deposition are slowly 'healing', or being reversed. Overall, federal programs aimed at curbing acid rain seem to be having an impact, albeit slowly, and some of Vermont's sensitive lakes are showing slow recovery. It remains unclear whether these lakes can recover fully however, and over what time frame that recovery could occur, assuming continued reductions in sulfur and nitrogen deposition.

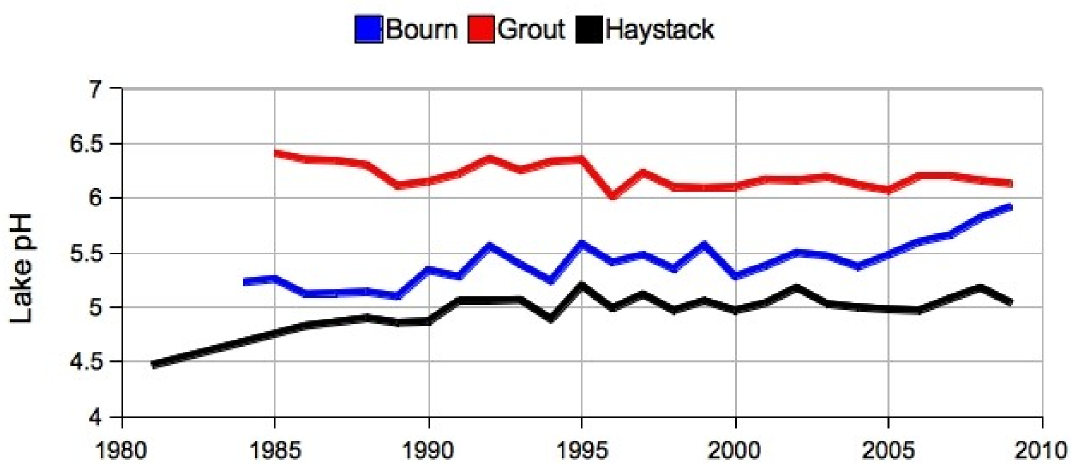

Figure 3. Long-term trends in lake pH in three Vermont lakes.

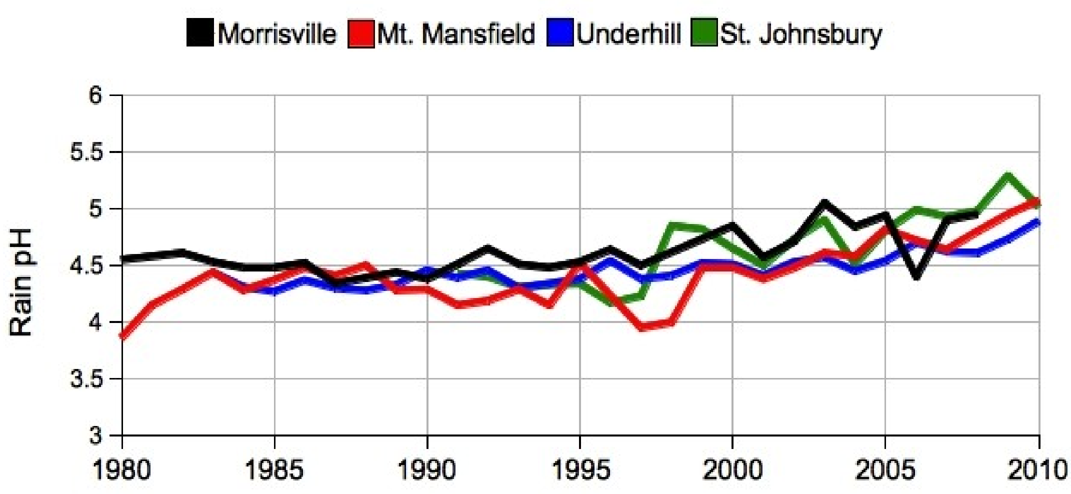

Figure 4. Rain pH data for four monitoring stations in Vermont.

In addition to measuring lake water pH, Vermont also has a volunteer program that measures precipitation pH throughout the state. Figure 4 shows general increases in precipitation pH at four monitoring stations throughout the state, with most of the increases due to reduced sulfur deposition. Nitrogen deposition, unlike sulfur deposition, has not yet shown signs of decline. To put these numbers in context, the ideal rain pH in the absence of acidifying pollution would be roughly 5.6. So while Vermont's precipitation pH is trending upwards, it has a ways to go before it returns to a range that can be considered normal.

Air Quality

EPA Toxics Release Inventory

Vermont air quality is generally quite good, but trends are still worth noting. Two indicators were used to assess air quality trends in Vermont: EPA Toxics Release Inventory (TRI) air releases, and the Air Quality Index (AQI) developed by EPA. As with TRI water releases, TRI air release data cannot speak directly to human exposures resulting from toxics released into the air, but nonetheless show trends in releases by industry throughout the state[7]. Figure 5 illustrates these trends, showing that total releases and carcinogens have fallen in the years since EPA began keeping track of data, and PBT releases have remained low since the TRI program's inception.

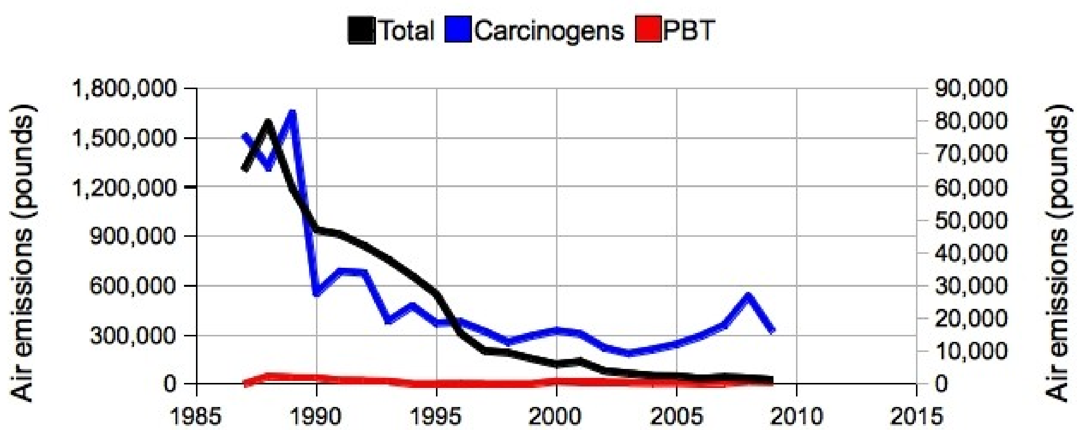

Figure 5. EPA TRI total air releases (left axis) and carcinogens and PBT compounds (right axis), 1987-2009

EPA Air Quality Index

The second metric, the number of days with unhealthy air, comes from datasets on a series of air pollutants that are far more common than those tabulated in EPA's TRI database[9]. The Air Quality Index (AQI) is a composite score built on information about the air concentration of several common air pollutants, including particulate matter, carbon monoxide (CO), sulfur dioxide (SO_2), ozone (O_3), and nitrogen dioxide (NO_2). Air concentrations of these compounds are combined so as to yield a single indicator that offers a sense of the risk posed to those who breathe the air over an extended time period, such as over a workday. EPA and the state of Vermont divide AQI scores into ranges of good, moderate, unhealthy for sensitive groups (such as children, asthmatics, the elderly), unhealthy, very unhealthy, and hazardous. AQI indices are calculated at several monitoring locations throughout the state of Vermont, but the author choose to report three stations in Burlington, Bennington and Underhill since these stations offer the best data continuity. Figure 6 reports the number of days when AQI scores fell in the ranges of unhealthy for sensitive groups, unhealthy, very unhealthy, and hazardous, although it was exceedingly rare for any of the air sampling stations to record a day that was worse than unhealthy for sensitive groups. While the stations reporting in Burlington show the city has good air quality, the other two stations in Bennington and Underhill have both shown improvement since data collection began, and particularly in the last decade.

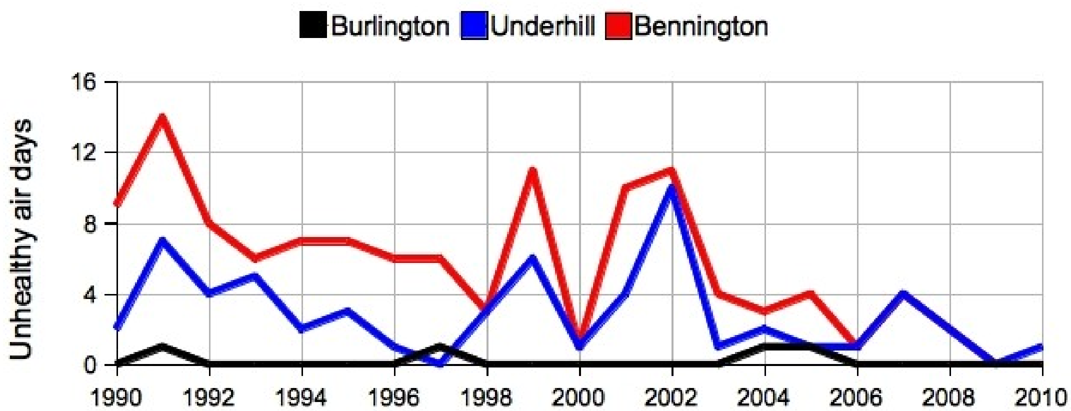

Figure 6. The number of days rated as 'unhealthy for sensitive individuals' (or worse) on the AQI scale recorded at three air monitoring stations in Vermont.

Climate Change

Climate change will have a profound impact on Vermont's environment in many ways, including shifting agricultural seasons, allowing new species to migrate into the state, and potentially by impacting season-specific activities such as winter sports[10]. The goal of this section is to trace trends in Vermont's greenhouse gas emissions and to study trends in average annual temperature.

Greenhouse Gas Emissions

Figure 7 shows greenhouse gas emissions in CO_2 equivalents in the state, noting an increase to 2004 and thereafter a modest decline[11]. Falling CO_2 emissions are partly due to Vermont's continued trend towards a service economy, but are also due to the state's reduced dependence on fossil fuels for its electricity generation sector and other efficiency gains in the economic sectors that depend on fossil fuel combustion for energy generation. One must be cautious when interpreting this graph though, as the state acquires a large share of its electricity from the Vermont Yankee nuclear power facility in the southern part of the state as well as from hydroelectricity imported from HydroQuebec's facilities in Canada. Not reflected in Vermont's current greenhouse gas emissions are the negative impacts associated with nuclear power, including minor tritium contamination of the groundwater and Connecticut river near the plant. Hydroelectricity, particularly when done on a large scale, has severe environmental and cultural impacts on surrounding landscapes and communities, so it is also necessary to acknowledge that while electricity from HydroQuebec's hydroelectric plants have low associated CO_2 emissions, they do not have a low environmental impact overall. By relying on this source of imported electricity, the state of Vermont effectively exports its environmental impact north, as it does to the west by importing coal-generated electricity.

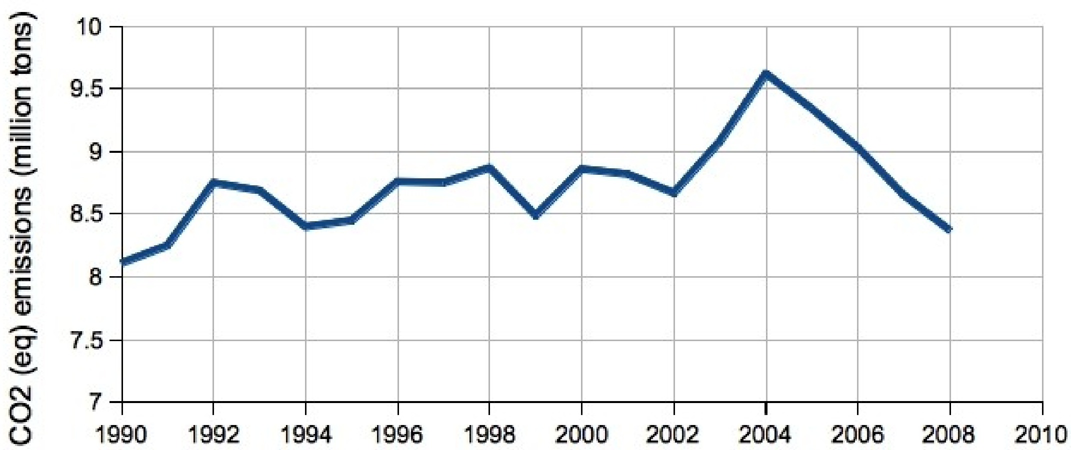

Figure 7. Greenhouse gas emissions as CO_2 equivalents in Vermont, 1990-2008

Average Annual Temperature

As Vermont struggles to contain its greenhouse gas emissions, climatic trends within the state are already emerging. Figure 8 shows average annual temperatures as recorded at the Burlington International Airport weather station, showing a slow but clear trend upwards since the 1960s despite substantial year-to-year variability[12]. Data already suggest that Vermont's climate is changing, and predictions suggest that the state's climate may become more like that of southern New York state in the coming decades if current trends continue[9]. Although the trend towards increasing annual average temperature is fairly clear, no clear trends in average annual snow depth or annual precipitation were evident from data collected from this weather station.

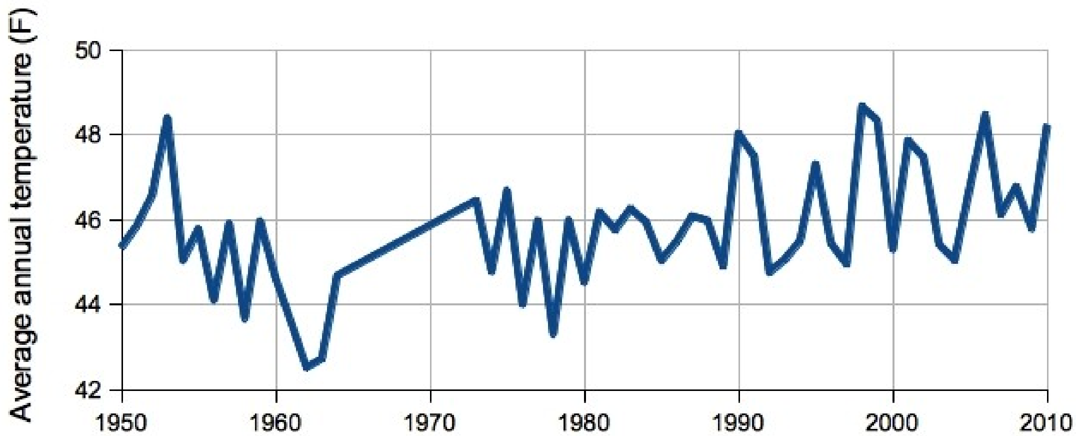

Figure 8. Average annual temperature, in degrees Fahrenheit, as measured at the Burlington International Airport weather station, 1950-2010.

Ecological Health

Studying trends in ecological health is challenging. While valuable, the above indicators themselves don't represent the complex web of interrelationships that constitutes ecological health. In judging ecological health, we are caught looking for the impacts of all of the trends on plant and animal communities. There are ways we might attempt to do this, but none offers datasets readily followed over time, and some important indicators such as invasive and noxious species are difficult to define and quantify. Here the author has chosen to quantify three indicators of ecological health. The first is state and federally threatened and endangered species that exist in the state of Vermont. Since Sugar Maples (*Acer saccharum*) represent such an important component of Vermont's forests and contribute so heavily to the aesthetics of the state, the second indicator examined is the percent change in Sugar Maple canopy health. Finally, trends in the prevalence of two insect pests are also illustrated.

Threatened and Endangered Species

Table 3 lists federally threatened and endangered species that live within Vermont. All data in Table 3 are drawn from a pair of reports summarizing work done on the Vermont National Heritage Information Project by the Vermont Fish & Wildlife Department[13]. Listing dates were taken from the appropriate fact sheets from the U. S. Fish & Wildlife Service. The total number of species listed by the state of Vermont as threatened or endangered is much larger than those listed federally and is summarized in Table 4. The larger number of threatened and endangered species at the state level is often due to species found in Vermont being near the edge of their range and therefore uncommon within the state, but common more generally. The reports from which these data were gathered[13] list the Eastern Mountain Lion (*Puma concolor*) as endangered by both the state of Vermont and the Federal Government, but because it was declared extinct by the U.S. Fish & Wildlife Service earlier this year this species was not included in Table 3[14].

Species become threatened and endangered for many reasons, and most of the species shown in Tables 3 and 4 are listed due to habitat loss. The addition of new listed species may prove useful as a benchmark to gauge the collective impact of development and possibly climate change on native flora and fauna.

Table 3. Federally threatened and endangered species in the state of Vermont, as of 2011

Species	Status
Jesup's Milk-vetch (*Astragalus robbinsii* var. *jesupii*	Endangered (1987)
Small Whorled Pogonia (*Isotria medeoloides*)	Threatened* (1994)
Barbed-bristle Bulrush (*Scirpus ancistrochaetus*)	Endangered (1991)
Puritan Tiger Beetle (*Cicindela puritana*)	Threatened (1990)
Dwarf Wedgemussel (*Alasmidonta heterodon*)	Endangered (1990)
Indiana Bat (*Myotis sodalis*)	Endangered (1967)
Canadian Lynx (*Lynx canadensis*)	Threatened (2000)

*The Small Whorled Pogonia was originally listed as Endangered in 1982, and was reclassified to Threatened in 1994.

Table 4. Threatened and endangered species in the state of Vermont, as of 2011.

Classification	Threatened	Endangered
Vascular plants	93	62
Insects	3	0
Amphipods	0	1
Freshwater mussels	3	7
Fishes	2	4
Amphibians	0	1
Reptiles	3	3
Birds	1	8
Mammals	1	6

Forest Health

Although many tree species are important to Vermont's forested landscape, Sugar Maples (*Acer saccharum*) are particularly important. They are abundant, contribute importantly to Vermont's forests as a source of food for wildlife, and contribute importantly to the state's economy by providing maple syrup, vibrant fall foliage colors and timber. Figure 9 shows changes in the health of Sugar Maple canopy cover relative to a baseline[15]. Although much of the 1990s showed positive changes in canopy health, the years 2004-2007 showed reduced canopy health. No long-term trends are discernible from available data, although maple trees are important enough to Vermont's forests that this trend should be watched.

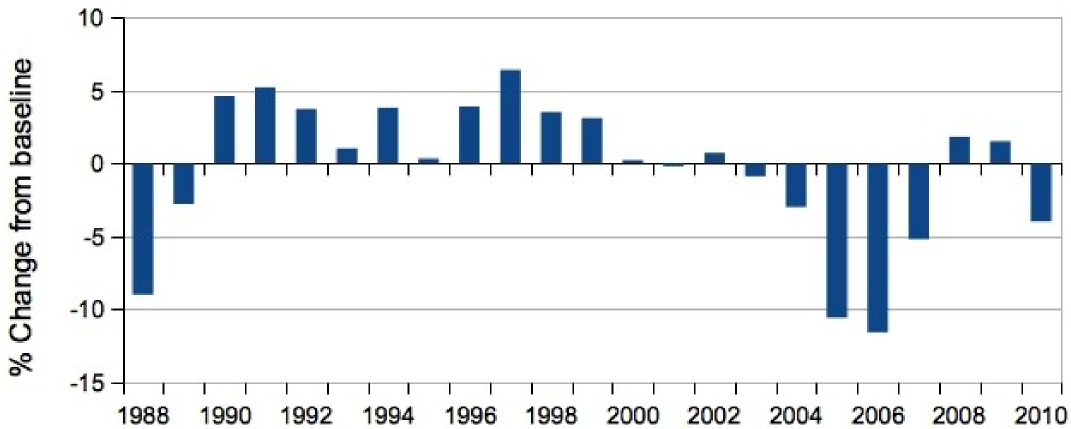

Figure 9. Changes in canopy health of Vermont sugar maples relative to baseline, 1988-2010.

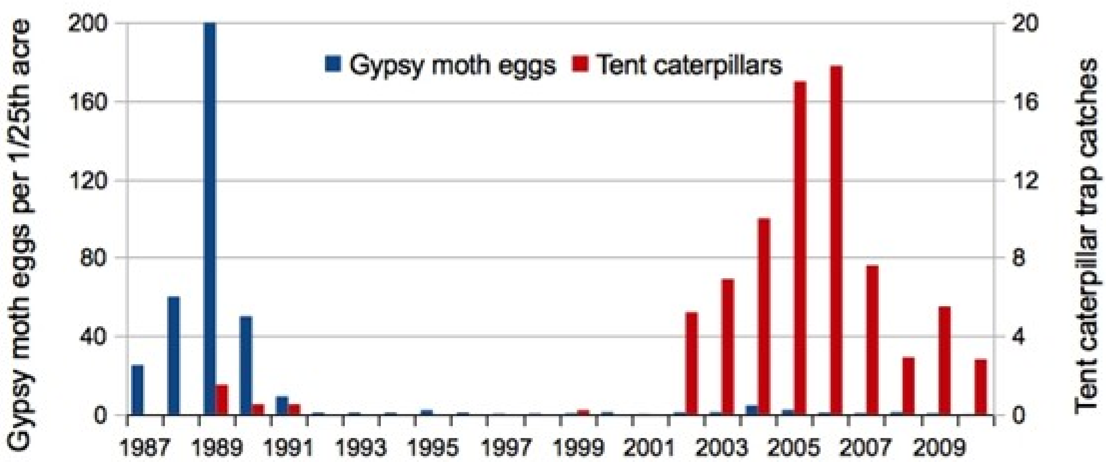

Figure 10. Gypsy moth egg masses per 1/25th acre monitoring plots (left axis), and tent caterpillar moth trap catches, 1987-2010.

Harmful Forest Pests

Finally, another stressor that may impact Vermont's ecological health is invasive or otherwise harmful pest species. Two pest species known to negatively impact Vermont's forests are the Gypsy Moth and the Tent Caterpillar. Figure 10 shows trapping rates of both of these species at selected sites in Vermont, showing that, for both species, abundances appear to be on the decline[15]. The highest densities of Gypsy Moth egg sacks occurred over two decades ago, while the highest incidence of trapping success for Tent Caterpillars occurred within this past decade. Other species, such as the Asiatic Long-horn Beetle and the Emerald Ash Borer, may migrate into the state.

Subjective Criteria

This *Environmental Trends* report covers environmental trend indicators that can be measured objectively. However, when it comes to Vermont's quality of life the subjective criteria are equally important. The 2008 *Disappearing Vermont?* report included a wide array of subjective criteria. They are subjective because they are either impossible or very difficult to measure. However, most Vermonters would agree that scenic beauty, a working agricultural landscape, limited noise and light pollution, relatively uncrowded recreation areas, and vibrant downtowns rather than suburban sprawl, are very important to their quality of life. The *Disappearing Vermont?* report quotes many experts in these fields, and most of these quotes attest to their observations that these indicators have worsened considerably as Vermont's population has increased since the 1950s. The *Disappearing Vermont?* report can be accessed at www.vspop.org.

ENVIRONMENTAL INDICATORS AND THE POPULATION CONNECTION

There is an obvious connection between population size and growth and changes in some of the environmental indicators considered in this report. This connection can be challenging to see from some of the graphs depicted herein, but most of the indicators discussed here have only been monitored for 20-30 years, if that, so true long-term trends for these indicators are elusive. This section will articulate the connection between measured indicators and Vermont's population size and growth rate with this longer-term view in mind. It is also important to realize that population growth does not, by itself, impact environmental indicators like those discussed here. Population growth works with consumption rates and rates of waste generation to define environmental impacts. In the case of Vermont, it is likely that both per capita consumption and waste generation rates are also increasing, so with population growth environmental impacts are even more challenging to avoid.

Land Use

There is a very close correlation between population size (and growth) with this indicator. From the initial clearing of Vermont's forests to the development of land for buildings and infrastructure, land use is directly tied to population growth. Most suburban sprawl in Vermont occurred since the 1960's when population began to grow after an extended period in a roughly steady state. Population growth outside of Vermont has resulted in land development in Vermont, such as the development of mountainsides for ski areas and the development of river banks and lake shores for vacation homes and camps. Many environmental organizations attribute at least half of sprawl to population growth, including NumbersUSA, Population Connection, and the Economic Policy Institute.

Impaired Water Bodies, Effluents, and pH

Water bodies were not widely or seriously impaired before so many people began to emit so much pollution that the aquatic ecosystems could not absorb the contaminants. A river can absorb the effluent from one home but cannot absorb the effluent from dozens and even thousands of homes, even with strong regulation. The trends towards improvement in impaired river miles, effluents and water body pH mask the longer-term declines in these indicators that were not caught during recent monitoring efforts.

EPA Toxics Release Inventory and EPA Air Quality Index

The same pollution principles apply for air contamination as for water contamination.

Greenhouse Gas Emissions

Many sources have shown the direct correlation between greenhouse gas emission and population growth. The highly respected climate scientist James Hansen in his book, *Storms of My Grandchildren,* talks strongly about this connection, as does Vermont's own Gus Speth in his acclaimed book, *The Bridge at the Edge of the World*. Vermont climate scientist Alan Betts authoritatively supports this connection as well.

Average Annual Temperature

While there have been changes in the average annual temperature in the past due to natural causes, approximately 98% of scientists now say that this increase is due to CO_2 levels rising as a result of greenhouse gas emissions. Increases in greenhouse gas emissions arise primarily from the combustion of fossil fuels, and the increased dependence on fossil fuels is tied directly to rising human population and rising standards of living.

Threatened and Endangered Species

Previous extinctions were caused by natural events but wildlife organizations such as the Center for Biological Diversity attribute the sixth great extinction to population growth and loss of habitat due to development.

Sugar Maple Canopy Health and Harmful Forest Pests

It is perhaps difficult to show a direct correlation between Vermont's population size and growth and the declining health of our sugar maples and other important tree species, but the population-aggravated combination of acid rain from distant coal plants and the warming climate leading to invasive pest species, are certainly contributing factors.

THE 2011 FLOODS AND POPULATION

Because of the lack of trend data this report does not address the huge impact that the 2011 floods had on the Vermont environment. This damage resulted in tremendous erosion, silting, destruction of river ecosystems and pollution of our lakes. However, there is no doubt that the floods were the result of human population growth for two basic reasons. First the intense rains were almost certainly caused by global warming which is a result of human population growth. Second the damage done by the rains and flooding were the result of changes in the landscape that were caused by human population growth. If a person observes a brook in a heavily forested area, and not next to a road or trail, during intense rains there is very little erosion and very little silt in the brook. The brook still runs quite clear or at least runs clear soon after the rain stops. This is because the forest soils absorb much of the water and the stream banks are protected by the vegetation growing on the banks. However, once the brooks become rivers at the lower elevations the land is totally different with cleared and developed land, non-vegetated river banks, thousands of miles of dirt roads which add to the runoff, and of course bridges and culverts which constrain the water flow. The rivers now severely flood the surrounding landscape; have diminished fish and other aquatic communities; and run brown for weeks and even months.

RECOMMENDATIONS

Given the value of tracking trends in indicators of Vermont's environmental health, it is recommended that trends in the indicators shown here be continually monitored and the report be expanded and updated on a 3-5 year cycle. This will not only keep our understanding of these trends up to date, but it will also keep the trends in the public eye. Given the relatively small resources that Vermonters for a Sustainable Population can invest in continued updates of this report, the organization suggests that a larger environmental organization update the report in the future. A larger environmental organization would be able to do a more comprehensive report and do so without the political constraints of a government agency.

Vermonters for a Sustainable Population (VSP) acknowledges the very close links between population growth, development, and the environmental health both within the state boundaries and on the rest of the earth. It makes the following recommendations:

1. VSP recommends that the state legislature appoint a commission to study what a long-term sustainable population would be for the state. The US Congress and Presidents have appointed several commissions over the years and all of them

have essentially said there is nothing to be gained by continued population growth. Now with global warming and approaching peak oil having a major impact on Vermont it is time that we did our own study on what our resource capabilities are to meet our needs and what size population those resources can support in the long term.

2. VSP recommends that the state develop policies that would move Vermont towards a steady-state economy. A steady-state economy is one that does not have growth of economic production (measured by GDP) as a principal policy goal. This means that consumption levels are stabilized and do not continue growing. The most important component of a steady-state economy is that the economy relies primarily on renewable resources and only uses those resources at a rate at which they can naturally regenerate. The pollution generated by the use of those resources should also not exceed the capacity of the ecosystems to absorb that pollution. The use of non-renewable resources should be limited so that exhaustion rates do not exceed the rate at which renewable substitutes are developed to replace non-renewable resources. A steady-state economy could deliver a high quality of life to Vermont residents without putting additional burdens on the state's environment, and would provide Vermonters with the livelihoods they desire without forcing continued development at the expense of the state's forests and agricultural areas. Readers interested in learning more about a steady-state-economy should visit the Center for the Advancement of a Steady State Economy at its website: www.steadystate.org.

3. VSP recommends that all environmental organizations and state environmental agencies acknowledge the connection between population growth and the health of the environment. There is no question that there is a very strong connection. Almost every environmental indicator, both objective and subjective, is impacted by population size and growth. This connection was made very clear at the time of the first Earth Day in 1970. However, since then the environmental culture has evolved to the point where some now even deny that there is a connection. We are seeing the result with severe environmental problems from global warming to the coming disappearance of the first ecosystem, the coral reefs. With the world now at a population of over seven billion and headed towards nine billion or more, it is time for all who are concerned about the environment to again acknowledge the importance of the population factor in dealing with our environmental problems. Experts who study sustainability say that a sustainable world population ranges from 100 million to five billion.

4. VSP recommends that because climate change is already such a pressing issue in Vermont and around the world that Vermont take immediate and bold action to address the climate-related indicators. State and local governments should implement policies and programs of the six planks of www.350vt.org which include Green Jobs for All, Energy Efficient Homes and Buildings for All, 100% Renewable Energy for All, Local, Healthy Food for All, Green Transport for All, and Community Forests for All. It is also recommended that each and every adult

Vermonter commit to living more sustainably and that they personally commit to doing so by taking a very powerful ten point Living More Sustainably Pledge at www.vspop.org.

CONCLUSION

This report summarizes select trends in environmental health within the state of Vermont. While some trends, such as falling or consistently low emissions of carcinogenic and PBT compounds to the state's air and waters and rising precipitation pH owing to reduced sulfur emissions from midwest power plants, are improving, others are not. Given the importance of Vermont's environmental heritage to Vermonters, public discourse on these environmental trends is needed and this report will hopefully contribute to this discourse in a positive way.

ACKNOWLEDGMENTS

The author thanks Eric Garza, PhD for compiling the data used in this report as well as writing and editing many of its sections. The author also extends deep appreciation to Arthur H. Westing, PhD for his many suggestions on improving this report. Finally, the author extends gratitude to several individuals within various Vermont state agencies for providing support or advice regarding how best to present and interpret data on state environmental health. Specific individuals are listed in the *Notes* section.

NOTES

1. Vermont Council on Rural Development. 2008. *Vermont in Transition*. A report by St. Michael's College; Vermont Agency of Natural Resources Environmental Reports, accessible at http://www.vtenvironment.org/
2. Historical information on Vermont summarized from the Vermont State Historic Sites website (http://www.historicvermont.org/sites/html/timeline.html) and an article on the History of Vermont, accessible here: http://en.wikipedia.org/wiki/History_of_Vermont.
3. *Forests in the Green Mountain State: A Half Century of Change*. Vermont Department of Forests, Parks and Recreation. Brochure # NE-INF-142-01.
4. United States Department of Agriculture. 2009. *Natural Resources Inventory Summary Report*.
5. These reports are available through the Vermont Department of Environmental Conservation's website at: http://www.vtwaterquality.org/cfm/ref/ref_mapp.cfm
6. More information on the documentary *Bloom* can be found on the film's website: http://www.bloomthemovie.org/
7. Find the Environmental Protection Agency's Toxics Release Inventory website here: http://www.epa.gov/tri/
8. I thank Heather Pembrook of the Division of Water Quality for providing lake pH data in spreadsheet format for this report.

9. Find EPA's Air Quality Index website at: http://www.airnow.gov. I thank Ben Whitney of Vermont's Air Pollution Control Division for assisting in tabulating AQI scores for the three air monitoring sites presented here.
10. Union of Concerned Scientists and others. 2007. *Confronting Climate Change in the U. S. Northeast: Science, Impacts and Solutions*.
11. Vermont Agency of Natural Resources. 2010. *Vermont Greenhouse Gas Emissions Inventory Update*.
12. Data from National Climatic Data Center of the National Oceanographic and Atmospheric Administration, available from here: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~StnSrch~StnID~10012336
13. Vermont Department of Fish & Wildlife. 2011. *Rare and Uncommon Native Vascular Plants of Vermont*; Vermont Department of Fish & Wildlife. 2011. *Rare and Uncommon Animals of Vermont*.
14. See press release at: http://www.fws.gov/northeast/ecougar/newsreleasefinal.html
15. Vermont Department of Forests, Parks and Recreation. *Forest Insect and Disease Conditions in Vermont, 2010*. Agency of Natural Vermont *Natural* Heritage Inventory Resources.