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A Prospective Analysis on the Sustainability of the Great Smoky Mountains National Park

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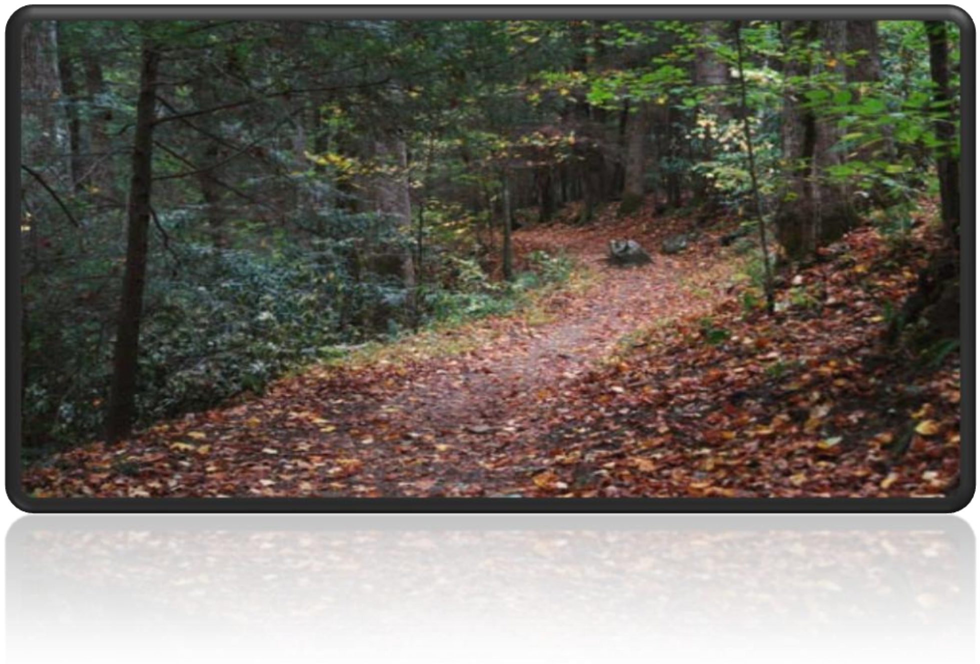

A PROSPECTIVE ANALYSIS ON THE SUSTAINABILITY OF THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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A Prospective Analysis on the Sustainability of Recreational Activities in The Great Smoky Mountains National Park

Consequences of large-scale climate change are felt by all corners of society ranging from international relations, political positioning, weather patterns, and business relationships. Many professional sports franchises and leagues are continuing to make strides in marketing and employing energy-saving programs in efforts to cut costs and project an image of environmental efficiency to the public. In large part, the sports industry has been immune to the critiques of environmentalists calling for emission standards many other types of industries. The large amount of energy consumed at any given sporting event has often been overlooked. Emissions at a sporting event include travel, electricity costs, pollution, and, in the case of motorsports, participant emissions. That being said, one particular aspect of sport is of the utmost importance in terms of environmental influence and that is recreation. Based on a survey from 2003, 97.6 % of individuals sixteen or older participated in some form of recreation at least once per year ("USDA American's Participation in Outdoor Recreation 2"). A more specific definition including examples of different types of recreation will be defined more precisely later but recreation generally is characterized by an outdoor activity in which a human is interacting in some fashion with the natural environment. The high percentage of humans who participate yearly in recreational activities carries two very important results. First, a highly detectable connection between the sports industry and the preservation of natural environment is paramount in the continued enjoyment of recreation. Therefore, an incentive for sports executives, including those in the recreational sector, clearly exists and requires that issues of sustainability surrounding nature be addressed presently and in the future for the sports industry as a whole to survive. Secondly, the high percentage of participants in recreation creates a large burden on the natural environments in which recreation takes place and consequently calls for an efficient management of environmental resources to ensure the long-term sustainability of these opportunities to partake in these activities. Taking note of the importance of recreation as a societal norm, the significance of the preservation recreation along with the protection of the needed resources to perform these activities outdoors simply cannot be understated. Many questions remain, however. At what lengths are individuals willing to go to in order to keep recreation as a viable activity? What costs are to be incurred in order to maintain the natural resources in recreational areas? How willing are people to believe in the long-term, large-scale effects of recreation in national parks? While these questions are yet to be answered there is a significant amount of data available that provides insight into the long-term sustainability of recreation in national parks. Raw scientific data along with visitation trends and statistics reveal that recreation in national parks is a viable, long-term possibility. However, this will not be possible without concessions by people along with creative solutions and policies that need to be implemented. Long-term sustainability of recreation in the Great Smoky Mountains National Park is feasible given the data obtained regarding the three main problems surrounding the activities in the park: ground level ozone, global climate change, and resistance to changes in policy. Analyzing the causes, sources, contributing factors, characteristics, and most importantly solutions this essay will review these three issues and describe reasons why recreation long-term sustainability of recreation in the Great Smoky Mountains National Park is a feasible outcome based on data and trends.

Prior to examining raw data and drawing conclusions, there are first many issues that need to be addressed and defined. An important term that will be referred to numerous times throughout this paper is *long-term sustainability*. First, the definition of the word *sustainability* must be brought to light in order to make more clear the goal of this project. A general definition of *sustainability* as provided by Merriam-Webster is as such: “of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged (Merriam-Webster Online)”. Simply put, given current use of a resource, will the resource last for the foreseeable future barring the appearance of other unknown factors. As defined by the Environmental Protection Agency, *sustainability* “calls for policies and strategies that meet society’s present needs without compromising the ability of future generations to meet their own needs (Environmental Protection Agency). A similar concept is the idea of a renewable resource. Trees, for example, are renewable resources that as long as steps are taken to replenish the resource the resource will last forever. Similarly, so long as precautions are taken to ensure the sustainability of the Great Smoky Mountains National Park, the resources will last and people will continue to enjoy the resources. However, the solution is not that simple. The climate is dynamic. The economy is dynamic. People are dynamic. What may look sustainable now may not be years or decades from now due to changes in the status quo. Thus, solutions must be as flexible as the problems that demanded them. The other word in the term “long-term sustainability” that must be clarified is *long-term*. How much time is being referred to when long-term is brought up? Years? Decades? Centuries? This brings the issue to the idea of timescale and changes in climate change. According to the table published in the Edmund Mathez text Climate Change, there are different timescales of weather phenomena (Mathez 5). A short-sighted example of scale would be a weekly occurrence such as the passage of a weather front (Mathez 5). A decadal example would be events such as El Niño or changes in storm paths based on alterations in the North Atlantic Oscillation (Mathez 5). Scale even reaches to the

10,000 to 100,000 to million year range in which glacial ice ages can occur and entire continents can shift (Mathez 5). As far as the *long-term sustainability* of the Great Smoky Mountains is concerned, the appropriate definition of long-term is directly related to foreseeable results of climate change due to natural causes and anthropogenic causes. Thanks to climate proxies, regional variations in climate change are predictable over decades and centuries based on climate alterations researched from the past. Examples of geologic scale proxies include but are not limited to tree rings, ice cores, foraminiferers, and varves (Finkelstein Notes). Scientists can take samples and analyze ages, compositions, and life cycles to come to a decent conclusion about the climate of the atmosphere during a given time period and thus project future climate variations. Thus, over decades and centuries, regional changes can be predicted. The problem is whether individuals are willing to adjust current habits for the sake of expected changes a century from now. Scale is critical to finding a solution to many environmental issues. Will the amount of traffic entering the Great Smoky Mountains have an impact on the health of salamanders within park parameters tomorrow? Certainly not. However, decades from now the salamander population could be very adversely affected by changes in climate and composition of rivers within the park. Therefore, any solution to long-term sustainability requires a willingness to understand the long-term repercussions of actions and a willingness to adjust present habits in order to result in improvements years and years from present day. Another term that requires clarification is recreation and the activities that are involved, specifically in the Great Smoky Mountains National Park. The most popular recreational activities that attract park visitors to the Great Smoky Mountains National Park are hiking, biking, sightseeing, camping, fishing, horse riding, picnicking, wildlife viewing, photography, and related activities. For the purpose of this essay, any activity that occurs within the Great Smoky Mountains National Park and is classified as a leisure activity that requires visitors to travel to the park and enjoy is classified as recreation. A third issue to consider and one that is paramount to many policy debates is point of view. From the point of view of present-day citizens who visit parks, the prospect of a depleted experience centuries from now for tourists is likely less than important compared to the point of view of the people who will inherent the park resources from their ancestors. Other points of view that need to be kept in mind are those of the wildlife, policy implementers, policy enforcers, people who do not visit the park, taxpayers, and many more. The object of this project is not to persuade the reader to decide on the validity of anthropogenic responsibility for climate change. The objective is to objectively analyze raw data and conclude whether the current rate of visitation combined with potential policy changes will result in a long-term sustainable national park. That being said, the points of view of many perspectives are important to consider when creating and implementing solutions to problems in the Great Smoky Mountains National Park. Finally, before delving into the data and taking a deeper look into the science behind the possible degradation of park resources, consider one last perspective. Is the delegation of the over 814 square miles of lands that comprise the Great Smoky Mountains National Park as protected lands actually the most effective way of preserving the wildlife on the lands or does it actually do more damage than if the lands were unprotected? And, is recreation to blame for attracting high traffic and consequently high pollution amounts directly into the park? These are questions to keep in mind while taking a closer look at the mechanics behind recreation in the Great Smoky Mountains National Park.

In order to connect these issues to the raw data, there are some scientific concepts that are necessary in order to provide a foundation for the observation of the facts at hand. Many of the following geologic concepts are derived from scientific theories and models that help to put into perspective many of the climate change issues at hand. Many of the concepts were brought to my attention through various lectures and texts that I obtained during my undergraduate studies but are very helpful in setting the table for any discussion surrounding climate change. One concept that reverts back to the importance of timescale is the notion of *lag time*. *Lag time* is the amount of time it takes for a system or process to respond to changes in compositional amounts or parts in the system. For example, it takes about ten years for the atmosphere to respond to alterations in rates of carbon in and out of the biosphere (Mathez 65). The ten years would represent the *lag time* it takes for the atmospheric system to respond to changes in composition due to changes in flows of carbon (natural or anthropogenic) to and out of the biosphere. This is relevant to the Great Smoky Mountains National Park due to carbon dioxide emissions from vehicles entering, touring, and exiting the park. Effects from the extra anthropogenic carbon input may not be noticeable for up to a decade and given the notion that vehicles continually travel in and out the effects can be difficult to predict. A second example that involves longer lag times is sea level rise due to glacial melting. It will likely take a long period of time for the entire globe to feel the effects of glacial melting in the Northern Hemisphere. Sea level rise has a relatively high lag time when compared to other consequences of climate change. Ocean water processes tend to take long periods of time to cycle through relative to changes in carbon input throughout the atmosphere. In terms of time and scale, the magnitude of changes in a system can be hard to evaluate on a short-term time scale due to lag time. However, on a larger scale time period, lag time is taken into account and therefore results from changes can be accurately calculated. A common hurdle that inhibits constructive progress in the area of limiting air pollution is the “free rider” concept. The *free rider* concept was brought to my attention during a lecture in an upper level Geology course by Dr. Michael McKinney, professor of Geology. Essentially a *free rider* is, generally speaking, when an individual or group receives privileges from an activity without having to account for an equally proportionate amount of costs. The *free rider* concept represents a significant obstacle in relation to finding an answer to human causes of climate change, particularly policy-based issues. An ideal example is the Great Smoky Mountains National Park. Visitors can drive and perform the majority of recreational activities without paying a dime. Thus, whatever harm is inflicted upon park resources during this time is done so without costs to the polluter. More importantly, *free riders* are reluctant to waive the status quo voluntarily in order to make the use of resources more efficient. Thus, policies designed to encourage citizens or “free riders” to change their energy usage will inevitably fall short of its goals. This is especially true considering that *free-riders* make up most of the population in an industrialized nation such as the United States. Those individuals willing to sacrifice their usage for the good of the environment are in such small numbers that they could never come close to offsetting the impacts associated with “free riders.” The result is that policies will have to be enforced as regulatory policies, or command and control, in order to force “free riders” to cooperate (McKinney Notes). This concept creates more issues such as cost inefficiencies due to increased enforcement and costly monitoring. Thus, park managers have a tall task in balancing the extra costs associated with increased policy restrictions against the prospect of doing nothing at all and potentially sacrificing the health of the park. This prospect transitions into the idea of *feedback effect*. Similar to cause and effect, when something changes in a dynamic system such as the climate system, an affected result will occur. For example, if more policies are enacted in the Great Smoky Mountains National Park, more costs will be incurred to enforce the laws and consequently a higher admissions fee will likely be needed to compensate for the additional costs. This exemplifies a positive feedback effect. A negative feedback example would be if emissions decreased in the park, effects of pollution would decrease and therefore affected wildlife would also decrease. Feedback effects coincide with changes in input/output. Referring back to the carbon cycle for a moment, suppose an increased amount of carbon entered the atmosphere due to an increase in fossil fuel emissions surrounding the Great Smoky Mountains National Park. The increased carbon represents a change in input. Thus, a change in the output, or result, is expected. Some of the increased carbon likely would be stored in the lithosphere, hydrosphere, or biosphere by natural processes (Mathez 57). Below are examples of residence times for carbon storage for different carbon storage locations:

Atmospheric Carbon Dioxide- 12.7 Years

Primary Producers- 10 Years

Consumers- .16 Years

Terrestrial Soil and Marine Sediments- 53.3 Years

Methane- 5 Years

Sedimentary Rocks- 200,000,000 Years

Oceanic Bicarbonates -81,489.4 Years

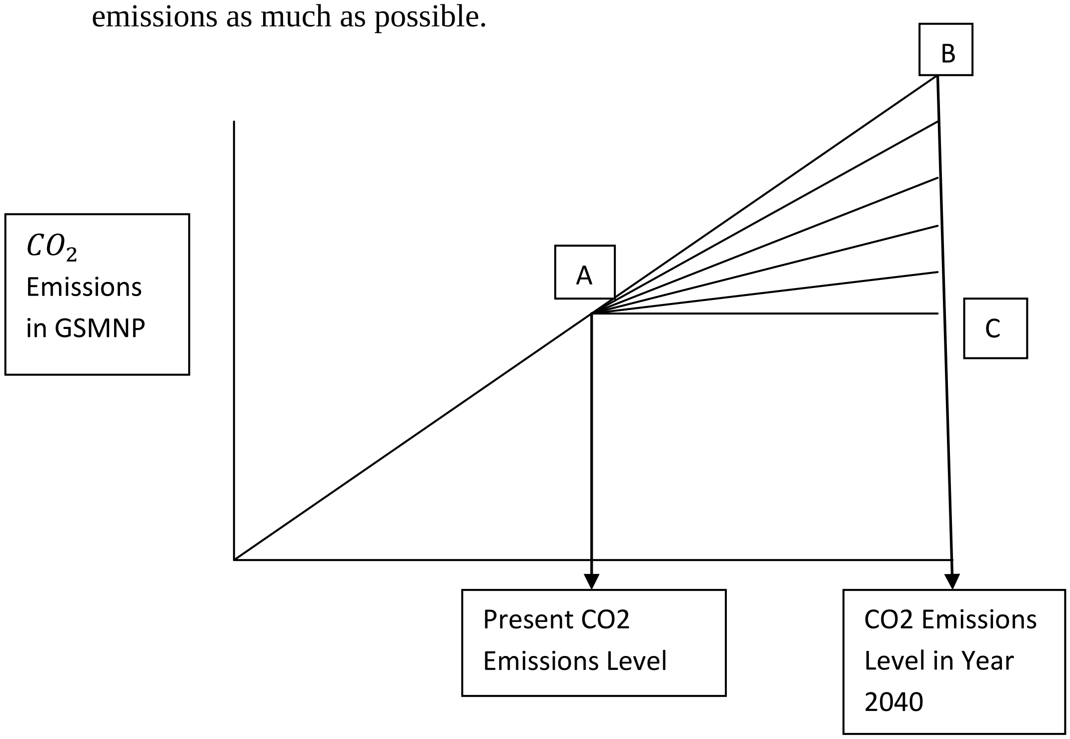
Oceanic CO_2 (Carbonic Acid) -12.3 Years

Marine Carbonate Sediments- 5,000 Years

Carbonate sedimentary Rocks- 200,000,000 Years

*Sources: Mathez Text, Finkelstein and McKinney Notes

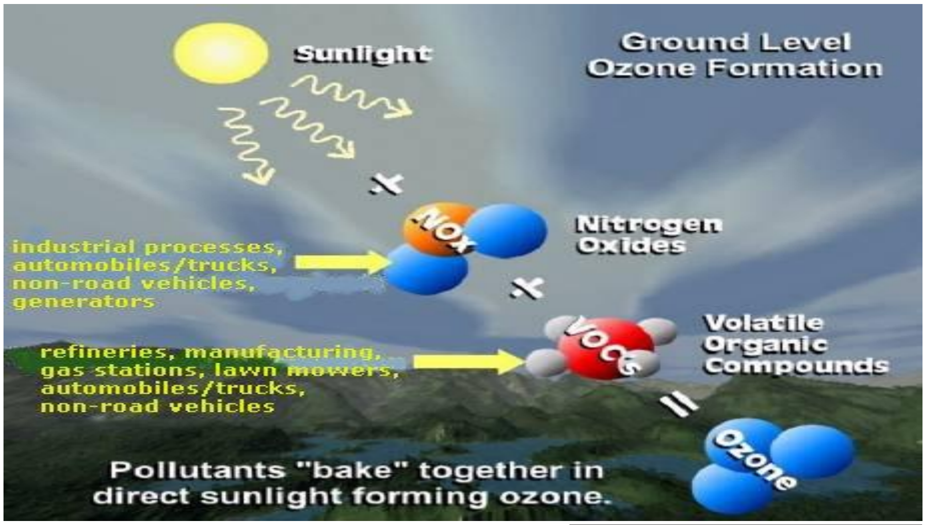
To clarify, carbon inputs can be stored for an average of 53.3 years by terrestrial soil and marine sediments and so on and so forth for the remaining examples. The remaining extra carbon represents the unknown results and symbolizes the heart of the climate change issue. There are more inputs into the atmosphere in the form of carbon than there are outputs. Human-induced activity exponentially increases these inputs. The main culprit from human activity is the burning of fossil fuels. Also, deforestation, waste removal, and farming can contribute. Other inputs of carbon include respiration from consumers, decomposition from terrestrial soil and marine sediments, weathering, and gases emitted from volcanism. Outputs of carbon from atmospheric carbon dioxide include carbon taken from the atmosphere by photosynthesis from plants, exchange of carbon with the oceans, and small portions from silicate and carbonate weathering. There is no output capable of getting rid of the large amounts of carbon emitted by humans. Also, the aforementioned lag time forces carbon to be built up into the atmosphere until the system can react to the increased amounts of carbon. According to Dr. McKinney, human-induced carbon into the atmosphere will last anywhere from 60 to 120 years (McKinney Slide 12). A popular model for solutions to increased emissions is the climate stabilization wedge. A climate stabilization wedge is part of a series of equally divided wedges making up a triangle that represents, given current technologies, potential reductions in CO_2 emissions by a specific year (Mathez 215). Each wedge reduces emissions by an equal amount and represents an action that can be taken to reduce emissions. The wedges are separated from point A as labeled in the diagram below and represent the current level of emissions. The wedges fan out to form projected levels of CO_2 given the wedge scenarios. At point B, none of the wedges would be implemented and no change in emissions would be shown. Point C would occur if all actions in each wedge were implemented and would represent the ideal scenario. Different types of wedge options would include different plans for reductions in emissions. General examples would include conservation, nuclear energy, fossil fuel based solutions, and clean energy solutions (McKinney Notes). Of course, each wedge would have positives and negatives. An example of a positive is that clean energy emits no CO_2. A negative is that clean energy can be a diffuse resource. In a precursor to his lecture on "Geological Storage as a Carbon Mitigation Option," Dr. Michael Celia gave a few examples of wedges that his research came up with. Given that 1 wedge=25 Gigatons of Carbon, doubling the amount of nuclear power plants would fill one wedge (Celia Lecture). Also, driving 2 billion cars using ethanol would fill one wedge (Celia Lecture). These are just some examples of how each wedge is quantified to be equally effective in reducing carbon. The key behind the climate stabilization triangle along with the individual wedges is that it requires a variety of technologies to attain the ideal result of limiting carbon emissions as much as possible.



An important distinction is needed before analyzing the different issues in and around the Great Smoky Mountains National Park. Two types of ozone that both cause significant problems in the Great Smoky Mountains National Park will be discussed later in this analysis. The first type is ozone that exists in the troposphere. This type, called ground-level ozone or smog, represents ten percent of total ozone and directly impacts the surface and areas near the surface (Mathez 28).

This is not to be confused with the other type, stratospheric ozone, which occurs in the stratosphere and comprises the remaining ninety percent of the total ozone (Mathez 28). This type forms a thin layer that shields harmful ultraviolet radiation from breaching the Earth's atmosphere and causing large problems for living objects on Earth. However, too thick of a layer also creates problems and is what is happening due to increased levels of carbon dioxide emissions. However, these topics will be discussed further during the individual problems' case studies. Now that a foundation is laid for proper analysis of the ground-level and stratospheric ozone problems in the Great Smoky Mountains National Park, it is time to take a closer look at the science behind each issue as well as the data trends in order to most effectively determine the outcome of the analysis.

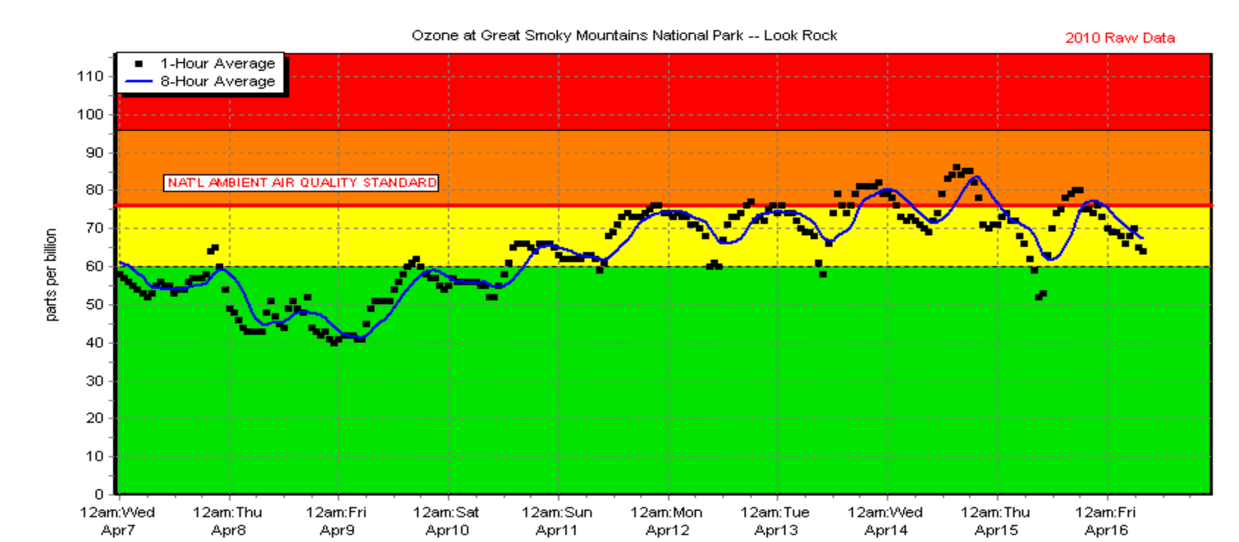
A look into the sustainability of recreation in the Great Smoky Mountains National Park based on the problem of ground-level ozone involves a look into causes, sources, characteristics, monitoring, effects, and solutions. Causes will include scientific reasons for the formation of smog in the park as well as other contributing factors that cause the Great Smoky Mountains National Park to be a hotbed for dangerous levels of ground-level ozone. The chemistry behind ground-level ozone, as previously mentioned, highlights an important distinction between ozone in the troposphere and ozone in the stratosphere. Ozone in the troposphere is formed from the reaction of nitrogen oxides and volatile organic compounds in the presence of sunlight (EPA Ozone Report). Stratospheric ozone is formed from the breakdown of oxygen atoms by ultraviolet radiation (EPA Ozone Report).The main issue in the Great Smoky Mountains is the prevalence of smog in the troposphere. The topography of the region contributes significantly to the problem of ozone in the Smoky Mountains. As the nitrogen oxides and volatile organic compounds are emitted, they are struck by sunlight and create smog. When the smog forms, air and wind patterns are unable to shift the smog out of the park because of the mountains blocking the wind's path. Therefore, the smog becomes stationary and directly hovers over the park and ecosystems within the park. Below is a diagram of how smog is formed:

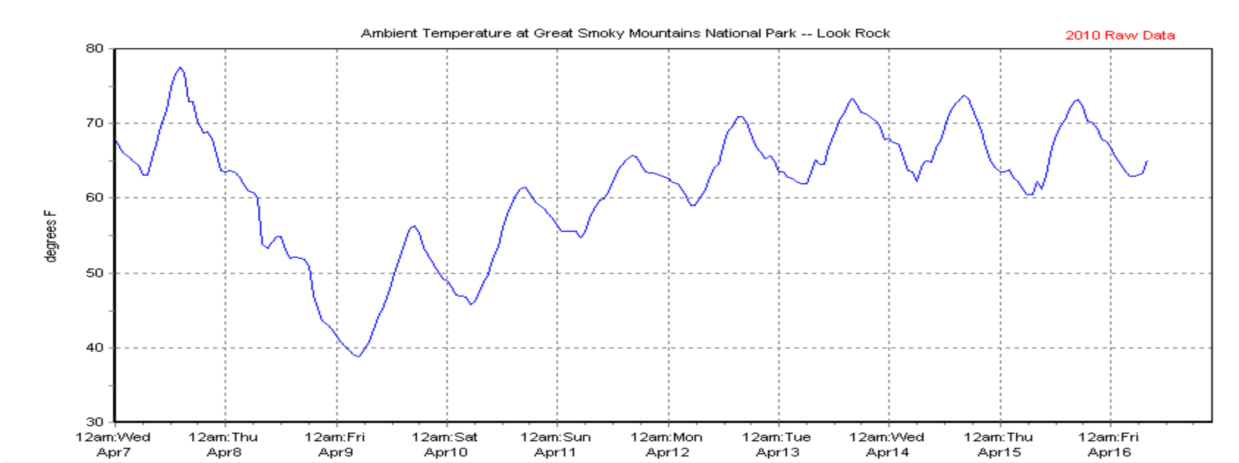


EPA Report on Ozone

The main sources of smog in all locations are emissions from power plants and vehicles. However, each component of ground-level ozone is emitted differently depending on its source. For example, 56% of nitrogen oxides are emitted from motor vehicles whereas half of volatile organic compounds stem from industrial processes (EPA Report on Ozone). These statistics have important implications for potential solutions to the problem of smog. In reference to the Great Smoky Mountains, the largest sources of smog are from the 3,931,606 million vehicles in the park on an annual basis as well as the numerous coal-fired power plants surrounding the region (National Park Service). The high number of vehicles is due to the increasing amount of tourism in the area. Also, the tourists are permitted to drive throughout the park and emit these harmful particulates directly into the park. In terms of the power plants, pollutants released from industrial processes often flow downwind into the park area and increasing the problem of smog.

Due to the increasing problem of smog in the park, sophisticated monitoring stations are located in two places to monitor ozone in parts per billion, temperature, wind speed, and take daily pictures to analyze changes in visibility. The locations of the monitoring stations are at Purchase Knob, on the east side of the park, and Look Rock, on the west side of the park. More importantly, it allows for specific analysis of trends in ground-level ozone on a daily, weekly, monthly, seasonally, and yearly basis. The daily cycles of ozone amounts are visible by looking at the raw data posted on the National Park Website. Interestingly, the daily ozone levels fluctuate up and down during the day which can be attributed to temperature changes and sunlight factors. Ground-level ozone levels typically peak during late afternoon hours when the sunlight and temperatures are the highest. Dips in ground-level ozone concentrations often occur overnight or in the early morning hours. Hourly measurements are also taken as a way to be prepared to warn the public about threatening levels of ozone in the atmosphere based upon the scale published in the EPA National Ambient Air Quality Standard (National Park Service). Below is a 10-day chart of raw data at Look Rock in the Great Smoky Mountains. This particular 10-day period is shown because it clearly displays a correlation between increasing temperatures and increased levels of ground-level ozone. The top graph displays ozone concentrations in parts per billion and is charted on top of the required levels of ozone according to the National Ambient Air Quality.





Referring back to the charts above, the peak ground-level ozone concentration occurs late in the afternoon on April 14, 2010. Below is a photo taken on that day by the National Park Service and statistics for that day revealed a visibility of less than 33 miles which is corroborated by visibly apparent increased levels of haze.

April 15, 2010

The ozone concentrations are superimposed upon the differing levels of ozone concentrations created to help warn individuals of harmful smog conditions. The green portion of the graph represents good levels of ozone. The yellow area of the graph represents moderate levels of ozone. The orange portion represents levels unhealthy for sensitive groups from 76 ppb to 96 ppb. The red area represents an area from 96 ppb to 116 ppb and means all people should reduce outdoor activity. Looking toward the future decades, as global and local temperatures increase it will be interesting to monitor the effects of those temperatures on ozone concentrations. Hot afternoons will likely occur with more frequency and will have longer durations during the day. Assuming that the number of nitrogen oxides and volatile organic compounds remain constant, the relationship between temperature and ozone will likely remain consistent. Thus, ozone problems and the consequences resulting thereafter will continue to be prevalent without policy changes that decrease the amount of nitrogen oxides and volatile organic compounds that are emitted into the atmosphere.

Smog can have significant implications for human health and of the overall enjoyment of the Great Smoky Mountains National Park. Dangerous ozone levels directly affect human health.

These levels increase rates of asthma, respiratory illnesses, and risks to communicable diseases. Specific symptoms are chest pains, coughing, and congestion (EPA Report on Ozone). An instant symptom of high ozone levels for humans is the difficulty of breathing when exposed to these high levels. Once concentration levels of ozone exceed 96 parts per billion, all humans are advised to avoid any outdoor activity. High ozone concentrations can affect humans in indirect ways in regards to the park. When ozone concentrations are high, visibility in the park and surrounding areas is limited significantly. An example is shown here to emphasize the difference smog can make in terms of the difference in visibility quality.

Another negative consequence is the potential harm to species within the park that people enjoy observing. The dying of trees due to direct exposure to ozone, along with invasive species, can change the aesthetic value of the Great Smoky Mountains National Park. In the coming years, if ozone concentrations increase proportionally with temperatures, humans will likely encounter more health problems. No one knows the extent of harm that increased exposure to smog can cause to humans. However, increased temperatures will likely increase the amount of time daily that humans are directly breathing in harmful ground-level ozone (Dr. Peine Lecture). Solutions will call for less harmful activity by humans in and around the park in order for humans to avoid the negative consequences of their own actions.

Biological impacts are very common due to complications with smog in the Great Smoky Mountains National Park. In the park since 1990, concentration levels have exceeded limits on

300 separate days (National Park Service). In other words, that is over 300 days of exposure of harmful pollutants to plants and wildlife during that time period. At around 6,000 feet in elevation, smog clouds directly contact plant and wildlife species in the mountains (Dr Peine Lecture). This is the most intensive type of air pollution in the Smoky Mountains because the species that exist at those elevation levels are directly and constantly draped in smog for hours upon hours during the warm months. For plant species in the park, high ground-level ozone exposure has been shown to cause plant damage that is noticeable by the changed appearance of the plant. Here is an example of damage done to a plant due to exposure to air pollution (National Park Service). The picture on the left is before and the picture on the right is after.


These complications can be attributed to interferences with photosynthesis and stunted plant growth. There are also some potential negative consequences to animal species that reside in the park. Lower air quality may lead to a long-term genetic adaptation of becoming smaller in size to compensate for poor air quality and to make breathing processes easier. This would lead to smaller population sizes as those unable to adapt would not be able to thrive. Should plant species become less plentiful and nutritious due to complications with photosynthesis, herbivores in the park will suffer from loss of energy and decreased food supply. The pending biological impacts that result from increased concentrations of ground-level ozone have important consequences for the vast biodiversity that exist in the Great Smoky Mountains National Park.

The park has a large variety of salamanders that are potentially threatened by air pollution along with fish due to increased acid rain occurrences. In order to preserve this biodiversity, changes will need to be implemented in order to preserve proper conditions for existing habitants in the park.

Recent policy changes in the last two decades lead to an optimistic forecast for improved ground-level ozone statistics in the future. The first effort was implemented in 1992 and was aimed at "identifying potential solutions to air quality problems in the southern Appalachians" (National Park Service). The Southern Appalachian Mountains Initiative (SAMI) created models that showed benefits from reductions in emissions and the positive outcomes from emissions standards. It would later lead to new policies that enacted actual emissions requirements rather than recommendations. The membership of the initiative is comprised of eight southern states in the Appalachian region. The negatives of the bill are that no requirements, regional or industrial-based, were implemented. The bill was centered on recommendations for improvement. The initiative represented some of the political biases that occur in "clean" legislation. The initiative may have projected some sort of progress being made toward cleaner air in the region, but actually only created voluntary recommendations. The Southern Appalachian Mountains Initiative did lead, however, to important state legislation that did result in emissions requirements. This legislation was called the North Carolina Clean Smokestacks Act and was created in 2002. It was devised around the models created in SAMI. Requirements were aimed at lowering haze-forming emissions by coal-fired power plants in North Carolina. The required emissions limits for the power plants included a 77% reduction in nitrogen oxides released and a 73% reduction in the amount of volatile organic compounds released over the next ten years retroactive to 2002 (National Park Service). Emissions were required to be reduced year-round and credits could not be sold to partner plants in other states (National Park Service). This would prohibit the ability of the plants in surrounding states to offset the progress made in North Carolina. The act was very forward-thinking and turned out to have very few loopholes. There were, however, a few negatives to the bill. This did not decrease all emissions in the park because Tennessee did not enact similar legislation. Therefore only emissions from North Carolina were decreased. This highlights an important issue regarding possible solutions to climate change in the future. States and countries alike need to cooperate in order to break ground and make significant reductions in the amount of emissions. Another complication with the act is that companies that do business in North Carolina may simply relocate to neighboring states in order to return to past emissions. The Tennessee Valley Authority also installed nitrogen oxide emissions controls on the two power plants closest to the park in 2004 (Dr. Peine Lecture). These examples of policies enacted in recent years show that progress has been made in the improvement of air quality in the Great Smoky Mountains. Future legislation similar to the North Carolina Clean Smokestacks Act will be needed in the future to force companies to comply and to significantly improve the local air quality.

Other non-policy solutions in the future can be implemented as ways to complement the future policies. An example of such is the renovation of transportation procedures within the park. Cades Cove, a popular scenery loop within the park is currently characterized by slow-moving, gas burning vehicles emitting harmful haze-forming pollutants directly into the park's ecosystem. A system could be implemented in which clean transportation is provided once the tourists arrive at the park. In order to pay for the clean vehicles, a fee could be asked of all tourists that visit the park. Another helpful solution that would greatly help vehicle emissions is the enacting of a policy in which vehicles are required to be inspected to make sure they are emitting up to air quality standards. This practice is common in most places in the United States but not in the park and surrounding areas. In November of 2010, seven hybrid vehicles designed for park staff use were delivered to the Great Smoky Mountains National Park ("Great Smoky Mountains National Park Gets Hybrid Vehicles"). The new addition now gives the park sixteen hybrid vehicles to go along with an entire line of heavy equipment in the park equipped with bio-diesel fuels ("Great Smoky Mountains National Park Gets Hybrid Vehicles"). More creative ideas for improving air quality would be to improve accessibility and ease of use for pedestrians and cyclists. Similar to the global climate stabilization wedge, a similar concept could be localized specifically to the park.

A combination of the aforementioned policies and systems are necessary to be implemented to significantly reduce smog-forming emissions as a whole throughout the Great Smoky Mountains National Park and surrounding areas. Local park authorities are confident that the recent policy changes aiming to curb emissions are slowly turning back occurrences of dangerous levels of smog in and around the Great Smoky Mountains National Park. Again, lag time must be accounted for before a clear result of the policies is known. In addition, increasing temperatures due to climate change make fighting ground-level ozone an uphill battle due to the correlation between high temperatures and high smog. That being said, the progress that has been made along with the use of innovative solutions and technologies point toward a recreationally sustainable region assuming the current policy restrictions remain permanent and a reasonable use of technologies that limit emissions is implemented. After obtaining the 8-hour average ground-level ozone concentrations everyday for the years 2007-2009, I calculated the average yearly 8-hour average ozone concentration for each of those three years along with the number of occurrences within each ozone level according to the EPA standards. Below is a table summarizing the results. These measurements were taken at Cades Cove inside the Great Smoky Mountains National Park.

Year	Yearly Average 8-Hour Ozone Concentration (ppb)	# of Occurrences in Moderate (Yellow) Range	# Occurrences in Unhealthy(Orange) Range
2007	34.15	301(27.49%)	8(0.73%)
2008	32.12	202(18.45%)	4(0.37%)
2009	26.32	25(2.28%)	0(0%)

Source: U.S. Department of the Interior National Park Service: Air Quality Monitoring Site Reports

The numbers in the table are based on 8-hour averages of O3 in parts per billion (ppb). Therefore, each day there are three measurements. Thus, in 2007 there were 301 out of a possible 1,095 measurements that fell in the moderate range, or roughly a quarter of the measurements. The data in the table suggests a vast improvement over this three year range in ground-level ozone occurrences. The reasoning behind this improvement can be attributed to several factors. Weather patterns certainly play a role in various changes. Also, decreased tourism in and around the park due to a downtrodden economy may have played a minor role. However, mostly the improved figures are likely due to the effects of policies passed in the early 2000s that are now taking effect. Because of lag time, noticeable improvements due to policy changes may not be felt until years or decades after the new changes are implemented. The coming years will be critical in determining if the trend continues to improve based on these changes. Presently, however, all signs are pointing toward less frequent harmful ozone concentrations on a yearly basis. Thus, all of the aforementioned affected wildlife will be able to thrive in their natural environments and humans will be able to recreate more frequently without feeling harmful health effects. Eventually, in order to assure a long-term sustainable recreational area, the occurrences will need to be narrowed down to zero to ensure that further damage is not inflicted on the biodiversity of the area. Also, further improvements are necessary to counter the increasing global temperatures due to climate change. The increased temperatures will create more ideal conditions for ozone formation so more precautions are necessary to keep unsafe levels of smog down to a minimum.

Recreational managers face a difficult challenge in maintaining a balance between the natural resources at their disposal and the participants who enjoy those resources. Managers must keep the people interested in recreation while still ensuring that the same resources are available for future outdoor enthusiasts. From a geologic perspective, climate and climate change are extremely dynamic systems that are often unpredictable and must be analyzed from many different perspectives and timescales. To ensure long-term sustainability, officials must likewise be dynamic in their approach to maintaining the balance between the consumers and the producers of recreational opportunities. The Great Smoky Mountains National Park is characterized by its natural beauty and its habitat for numerous species within the park grounds. It is also a place of where people can enjoy the outdoors and avoid the noises and congestion of city life. Unfortunately, anthropogenic activities both by individuals and industries have brought the characteristics of the city such as smog and noise pollution to the park and it has severely damaged both the aesthetic value and the valuable ecosystem of the park. Polices enacted in recent years and the past decade have begun to make headway in the struggle for improving air quality but more changes are necessary for the park to remain a hotbed for biodiversity. Future impending temperature rises are surely going to increase the problem of ground-level ozone in the Great Smoky Mountains so solutions must not only offset current ozone levels, but also take into account future increases in ozone concentrations as well. Both the biological preservation of all species in the park and the health of residents in and around the park are at stake. Using the technologies already created and sophisticated monitoring devices, ozone concentrations can be monitored and analyzed in ways that can lead to more efficient solutions. The solutions to the air quality problems need to be proportionally efficient to the mechanisms that characterize the problems themselves. If the necessary solutions are created and successful, then the Great Smoky Mountains National Park can return to its government-protected state both in terms of on-land activities and in terms of air quality standards, thus ensuring long-term sustainability.

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