Climate Resilience in Carlisle and Cumberland County: Ecosystems

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1. Introduction

The Earth's ecosystems, including those in Cumberland County, have long been stressed by a variety of pressures such as nutrient loads, erosion, conversion of natural areas to human uses, periods of drought, periods of excessive rain, and flooding. Climate change is modifying and adding to the stressors. As global temperatures continue to rise, these stressors will be magnified, further burdening our local ecosystems. The climate stressors that are beginning to affect Cumberland County are predicted to worsen if action is not taken some time in the immediate future. In order to work towards establishing borough and county-wide resilience to climate change, it's important to identify the different stressors that are currently a threat to the local ecosystems. Additionally, it is important to point out current strengths and weaknesses that are either helping or hindering Cumberland County's progress toward healthy and resilient ecosystems as well as overall climate resilience. This report will identify these strengths and weaknesses both on a borough and county level. It will also identify some strategies and indicators of resiliency that should be considered throughout the process of increasing the area's overall capacity to limit harms from climate change. This report will focus specifically on the following planning areas: Streams, wetlands, and lakes, forests, wildlife, pollinators, and biodiversity, and recreation (Lipton et al., 2018).

2. Climate Stressors

The climate stressors that currently pose a threat to Cumberland County have been identified as more frequent extreme weather events, droughts, increased air temperature, and changes in regular weather patterns (Leary, 2023). This means there will likely be more frequent and intense rain events taking place in Carlisle and Cumberland County. It is very likely that these climate stressors will have adverse effects on the county's aquatic ecosystems (e.g. streams, wetlands, and lakes), forests, recreational opportunities, and pollinators, wildlife, and biodiversity (Lipton et al., 2018). These stressors can directly harm or jeopardize the health of our local ecosystems as well as the infrastructure that is necessary to facilitate the community's connection to these ecosystems. For example, recreational outdoor activities like trails could be subject to damage from climate change related issues. Stressors like increased air temperature can also make it less accessible and enjoyable for people to go outdoors and participate in outdoor recreation.

3. Streams, wetlands, and lakes

3.1. Additional Stressors

In addition to the known stressors that are being driven by climate change, there are other stressors at play that can interact with the climate stressors, creating the potential to exacerbate the effects of either stressor. In the case of the county's streams, wetlands, and lakes, an additional stressor is that most of the soil that is in Cumberland County is very well-drained, which allows runoff that carries nutrients to pass through and enter these aquatic systems (H. Slear, personal communication, October 18, 2023). Aquatic ecosystems that are in poor condition due to nutrient loads are less resilient to harm from climate change

due to overall poor ecosystem health. At present, 30 percent of stream miles in Cumberland County are notably degraded and don't meet the current water quality standards. In addition to the effects of the county's well-drained soil, the nutrient load in the county's water is also affected heavily by the county's agricultural land. It is estimated that 63 percent of nutrients and sediment in Cumberland County streams comes from agricultural sources. The second greatest source of nutrients and sediment is developed or urban areas, which is estimated at approximately 17 percent. (Cumberland County, 2019). Continued development in the County acts as an additional stressor as more development generally increases impervious areas and decreases green spaces. These effects cause an increase in stormwater runoff (PA DCNR, 2018)

3.2. Vulnerabilities

Climate stressors working in tandem with other stressors has led to an abundance of vulnerabilities within Carlisle and all of Cumberland County. These vulnerabilities represent the potential impacts that the climate stressors and additional stressors will have on the County's aquatic ecosystems. More frequent and intense rain and more flooding events will lead to vulnerabilities such as more erosion and an increased nutrient load in the county's rivers and streams (H. Slear, personal communication, October 18, 2023). This is due to increased stormwater runoff which erodes soil and carries nutrients from that soil and deposits them in the nearest body of water. Erosion poses many risks to aquatic ecosystems as increased sediment in the water is harmful to many aquatic plant and animal species. Additionally, large deposits of sediment caused by erosion can disrupt the natural flow of rivers and streams, thus increasing the likelihood of flooding events near that waterway.

Increased nutrient loading is also a threat to aquatic ecosystems as it causes the process of eutrophication. This leads to extreme algal growth and low levels of dissolved oxygen which can cause die-offs of fish and other aquatic organisms. Algal growth also limits the amount of light that is able to reach species like aquatic grasses, causing them to die off as well, overall decreasing the biodiversity of that ecosystem. This vulnerability will also be intensified by the stressor of increased air temperature as warmer air and water will worsen the oxygen depleting effects of nutrient loads, further harming the biodiversity and general health of these aquatic ecosystem (Chang, 2004).

Lastly, increased air temperature creates the vulnerability of increased water temperature. This poses a large threat to local aquatic ecosystems as many of the county's cold-water streams will no longer be able to support the current cold-water fish species, even if warmed by only a few degrees (J. Vastine, personal communication, October 4, 2023). These adverse impacts not only affect fish populations and, subsequently, the entire aquatic ecosystem, but they also will negatively impact the local recreation opportunities. Fishing for cold-water species like trout will no longer be an option if the streams and other bodies of water get too warm.

3.3. Strengths and weaknesses

In the face of these stressors and vulnerabilities, Cumberland County is responsible for developing ways to manage these harms. Despite the vulnerabilities that the aquatic ecosystems of both Carlisle and Cumberland County are facing due to climate change, many strengths already exist in the area. These

efforts are considered strengths. Strengths include assets, organizations, and activities that provide capacities for responding effectively to limit harms from climate and other stressors. Some current strengths for improving the resilience of aquatic ecosystems in Carlisle include organizations such as the Central PA Conservancy, the Conodoguinet Creek Watershed Association, the Letort Regional Authority, Yellow Breeches Watershed Organization, Capitol RC&D, Alliance for Aquatic Resource Monitoring (ALLARM) as well as the Chesapeake Bay Foundation which works at a larger scale protecting Cumberland County's watershed and encouraging the use of best management practices by people and organizations. (A. Bowling, personal communication, October 23, 2023, H. Campbell, personal communication, October 10, 2023).

Another strength of the borough and county is that local interest in water quality seems to be increasing as the rise of water temperature is beginning to threaten local fishing practices, so people are becoming more interested in preserving the ecosystem (J. Vastine, personal communication, October 4, 2023). There are also many initiatives and plans that are on their way to being created and implemented in the county. For example, the Countywide Action Plan Overview for Cumberland County includes goals of creating a water quality communication plan, which would develop messages and solutions to better communicate issues of water quality. The Countywide Action Plan also mentions an agriculture erosion and sediment/nutrient management plan, which would allow each municipality to develop and implement their own unique plan to eliminate excess sediment and nutrient loading. (Cumberland County, 2021). Lastly, a final strength of Carlisle and Cumberland County is their connection to Penn State Extension as well as other academic institutions like Dickinson College and Shippensburg University which offer opportunities for environmental and sustainability improvement projects through entities such as Dickinson's Center for Sustainability Education and Shippensburg's Center for Land Use and Sustainability (J. Chain, personal communication, November 17, 2023).

In addition to strengths, Cumberland County also has a few weaknesses. These weaknesses are factors that can obstruct effective responses for limiting harms from climate and other stressors in any of the county's ecosystems. One of these weaknesses is an overall lack of public awareness concerning the health and resilience of the local aquatic ecosystems, in other words, an "education gap" (E. Letavic, personal communication, October 10, 2023). People who lack knowledge of the importance of the local aquatic ecosystems and the value that they provide to the area are less likely to make sustainable choices and work toward the preservation of these ecosystems. A large piece of this "education gap" is that oftentimes issues like climate science and the complex effects that it is having on our ecosystems are described using jargon and other inaccessible language. It is important to be able to convey these issues in a way that the general public can understand and engage with, thus helping eliminate barriers to public engagement (Stephanie Williams, personal communication, November 1, 2023)

3.4. Resilience strategies

Considering the county's current stressors, strengths, and weaknesses, there are several identified resilience strategies. The following resilience strategies represent ways to build resilience to some of the identified vulnerabilities in Carlisle and Cumberland County. Two examples of resilience strategies that can be used to address the resilience of aquatic ecosystems in Cumberland County are implementing more public engagement initiatives as well as providing more education opportunities. These strategies will help create awareness, which is the first step in generating public interest which can then lead to

more people taking action, putting pressure on political representatives, and personal investment in long-term climate resilience measures. Another climate resilience strategy that is specific to establishing resilience in the county's streams, lakes, and wetlands is implementing more cover crops and riparian buffers to help filter sediment from stormwater runoff and increase soil capacity (Cumberland County, 2019). According to South Mountain Partnership's report card on the environment and health of the South Mountain region, riparian buffer miles have not increased, making this one of the more critical issues of the County as it has not yet begun to be addressed (South Mountain Partnership, 2023).

3.5. Indicators and metrics

In order to track climate resilience in Carlisle and Cumberland County and to make sure we are headed in the direction of our sustainability goals; it is important to have established indicators of climate resilience as well as metrics to properly track and quantify how resilient certain ecosystems are. For stream, lake, and wetland ecosystems, a strong indicator of resilience is water quality. This indicator can be measured using the following metrics: Dissolved oxygen levels, water temperature, nutrient levels (N, P, etc.) as well as estimates of nutrient loads, turbidity, and salinity. Current monitoring practices already indicate that the streams in Cumberland County have elevated amounts of nitrogen, phosphorus, and sediment. In addition, out of approximately 100 groundwater samples that were taken throughout Cumberland County, ten samples had nitrate levels that exceeded the EPA's safe drinking water threshold of 10 mg/L (Cumberland County, 2019). Other metrics for measuring water quality include estimates of nutrient loads entering surface waters in the county, the number of "best management practices" (BMPs) that are being implemented in a given area as well as amount of land, in acres, which use BMPs. These indicators and metrics should continue to be monitored as resilience efforts are increased to track their efficacy.

4. Forests

4.1. Additional Stressors

Another stressor that poses a threat to the County's forest ecosystems that is outside of the identified climate stressors is urban development. This is an especially pressing issue for Cumberland County as it is one of the fastest growing counties in the state (U.S. Census Bureau, 2022). Urban development is a threat to forest ecosystems as it can lead to deforestation, habitat loss, habitat fragmentation, etc. Development is a pressing issue as forested land in the South Mountain region has already decreased by 1,400 acres (South Mountain Partnership, 2023). In Cumberland County specifically, between the years 2001 and 2016, the county lost approximately 1,467 hectares (3,625 acres) of land annually. For context, the total amount of forested land in Cumberland County is approximately 107,500 acres (Cumberland County, 2022). The vast majority of this loss is attributed to the conversion of forested land to settlement (Shippensburg University, 2021).

4.2. Vulnerabilities

Climate stressors combined with additional stressors such as urban development leave forest ecosystems vulnerable to many harmful issues. Among these include changes to the leaves' natural color change and fall patterns, increased harmful invasive species, increased vulnerability to harmful insects, and increased likelihood of forest fires (H. Campbell, personal communication, October 10, 2023, National Fish Wildlife and Plants Climate Adaptation Partnership, 2012). Changes in color change and fall patterns of leaves have the potential to offset other ecological patterns as well as disrupt tourism patterns and decrease outdoor recreation opportunities that are centered around viewing the changing colors of the fall leaves.

Due to the warming climate, plant species such as some shrubs and trees that were once only found in states south of Pennsylvania are beginning to be found in Cumberland County (A. Basehore, personal communication, October 13, 2023). In addition to enabling the spread of new invasive species, climate change is also perpetuating the spread of invasive species that already pose an existing problem. Invasive species compete with native ones for resources and have the capacity to cause extinctions of native plants if they are outcompeted. This is an especially important vulnerability for species that have already been identified as at risk. Some species that have been identified as at risk include trees such as Eastern hemlock, chokecherry, yellow birch, quaking aspen, bigtooth aspen, and American beech (PA DCNR, 2018).

In addition to overall higher average air temperatures, climate-derived changes may also cause an increase in aridity. These changing conditions will increase the likelihood of forest fires. This vulnerability may also be aggravated by other potential vulnerabilities. For example, as the number of wildfires and severe weather events increases, the County's ability to respond will be challenged, particularly when multiple events occur at once (PA DCNR, 2018). Additionally, when fires do occur, they remove the organic matter from the forest floor and expose mineral soil, a condition that may be favored by invasive species, leading to them colonizing the newly cleared area (Zouhar et al., 2008).

These vulnerabilities jeopardize the overall health of forest ecosystems and their surroundings. For example, the trees in forested areas play a key role in improving local air quality (Kittatinny Ridge, 2015). Forested land also plays a key role in carbon sequestration, a process that is becoming more and more vital as the adverse effects of climate change become more prevalent. Annual carbon dioxide removals between 2001 and 2016 were approximately -375, 345 tons CO2e per year (Shippensburg University 2021). Trees in urban areas are also of extreme importance as they play a key role in limiting the harmful effects of urban heat islands as well as help to manage storm water runoff (Rosenzweig et al., 2006).

4.3. Strengths and weaknesses

Some strengths for establishing climate resilience in the forest ecosystems of Carlisle and Cumberland County include many nonprofit and government organizations working towards persevering nearby forested land. Among these organizations are the Appalachian Trail Conservancy, South Mountain Partnership, the Cumberland County Conservation District, the Cumberland County Farmland Preservation, the Central Pennsylvania Conservancy, and the Department of Conservation and Natural Resources. Another strength of Carlisle and Cumberland County is academic institutions like Dickinson College and Shippensburg University which offer opportunities for environmental and sustainability

improvement projects through entities such as Dickinson's Center for Sustainability Education and Shippensburg's Center for Land Use and Sustainability (J. Chain, personal communication, November 17, 2023).

Cumberland County is also strengthened through its connections to state parks such as Kings Gap Environmental Education Center, Colonel Denning State Park, Pine Grove Furnace State Park, and state forests like Michaux State Forest, and Tuscarora State Forest. Cumberland County is also home to four different state game lands (Kittatinny Ridge, 2015). These protected lands are a critical tool for safeguarding biodiversity, maintaining ecosystem health, preserving important habitats, and building resilience to climate change.

Despite many organizations working towards persevering and caring for these forested environments, the county still faces some barriers to the development of climate resilience. For example, there are very few small accessible grants available for local environmental organizations to use for their different conservation projects. There are some grants available such as the Cumberland County Planning Department's land partnership grant, the South Mountain Partnership's flex grant program, and funding from the Department of Conservation and Natural Resources. However, despite increased federal funding for these types of projects, these funds are inaccessible to many organizations working in Cumberland County due to the size requirement that the projects must meet in order to receive funding.

Another weakness that limits public participation in conservation efforts is that many public engagement opportunities are based on volunteers. This limits public participation as not everyone has the time to volunteer (J. Chain, personal communication, November 17, 2023). This is especially true of younger people who may be working or in school during hours when there may be opportunities to volunteer.

4.4. Resilience strategies

Some resilience strategies that can be used to address the resilience of forest ecosystems in Cumberland County are implementing more public engagement initiatives as well as providing more education opportunities. These strategies will help create awareness, which is the first step in generating public interest which can then lead to more people taking action, putting pressure on political representatives, and personal investment in long-term climate resilience measures. With more public buy-in, organizations that are already working on forest preservation can hopefully receive more funding to magnify their efforts especially as forest ecosystems are becoming more vulnerable due to climate change.

Additionally, in order to establish resilient forest ecosystems in Cumberland County, organizations with similarly aligned missions like preservation should work together instead of separately. For example, the Cumberland County Historical Society has a historic preservation program that also offers environmental benefits by preserving historic land and preventing new and expansive development. There is some collaboration happening already among organizations in the county, however, small organizations could still benefit from expanding their projects to include other non-profits.

The Pennsylvania Department of Conservation and Natural Resources has identified a series of adaptation strategies in their Climate Change Adaptation and Mitigation plan to help establish resilience in the state. Among these strategies, some that could be useful for forest ecosystems include to manage herbivory to promote regeneration of desired species and evaluate whether manipulating the density, structure, or species composition of a forest may improve its resilience when faced with climate stressors or other biological stressors. This refers to monitoring activities such as the grazing of deer and other herbivorous species to ensure that certain desired plant species are not being eliminated. The DCNR also mentions strategies such as increasing use of prescribed burns throughout the state as well as developing new ways to communicate wildfire risk to the public (PA DCNR, 2018). The recommended actions in the DCNR's Climate Change Adaptation and Mitigation Plan are directed broadly at the state level, however they could also be adjusted so that they are more suitable for being prioritized at the county and borough level.

4.5. Indicators and metrics

Indicators of healthy and resilient forests include high biodiversity, which can be measured using species richness and species evenness indices. Particular species that have been identified as the most likely to decrease in numbers due to the changing climate should be monitored closely. Ensuring that the local forests have a high biodiversity means they will likely be less vulnerable to the stressors of climate change or otherwise, therefore making them more resilient. Other metrics that could be used to indicate and measure the health of the county's forest ecosystems include the percent change in forested area overtime. This metric may also account for the percent change in forested area that is lost due to converting forested land to other uses. These percentages be tracked to assess when and why deforestation occurs in Cumberland County. In addition, Cumberland County should assess the resilience of forest ecosystems using the actual acreage of forested land and protected forests. Approximately 30 percent of the county is covered by woodlands that are primarily located along its northern and southern ridgelines (Kittatinny Ridge, 2015). It is important to note that Cumberland County is developing rapidly, and preserving forested land is not meant to end development, however, the prioritization of these important forest ecosystems must be considered as areas in the County continue to develop.

5. Wildlife, pollinators, and biodiversity

5.1. Additional Stressors

Similarly, to the County's forest ecosystems, urban development also poses a threat to the County's wildlife, pollinators, and biodiversity. This is an especially pressing issue for Cumberland County as it is one of the fastest growing counties in the state (U.S. Census Bureau, 2022). Urban development is a threat to local wildlife and biodiversity as it can lead to deforestation, habitat loss, habitat fragmentation, etc. In addition to urban development, Cumberland County's agricultural industry also poses similar threats to local biodiversity. Some risks associated with the agricultural industry include habitat fragmentation, draining of wetlands, use of pesticides and herbicides, and runoff of nutrients and sediment, all of which can cause harm to local flora and fauna.

5.2. Vulnerabilities

Climate and additional stressors have caused the county's wildlife and biodiversity to become vulnerable to many harms. For example, changes in climate are leading to changes in natural patterns such as when the trees lose their leaves as well as when birds migrate (H. Campbell, personal communication, October 10, 2023). Changes in temporal patterns like these have the potential to offset whole ecosystems. New climate patterns are also altering the county's biodiversity in that invasive species that were once only found in states south of Pennsylvania are beginning to be found in Cumberland County (A. Basehore, personal communication, October 13, 2023). In addition to enabling the spread of new invasive species, climate change is also perpetuating the spread of invasive species that already pose an existing problem. For example, in the case of the spotted lantern fly, climate change has led to a shift in weather patterns which is causing it to be warmer for longer, offering this invasive species a longer period of time to reproduce and thus an opportunity for even faster population growth (A. Basehore, personal communication, October 13, 2023).

Another vulnerability that threatens the wildlife, pollinators, and biodiversity of Cumberland County is habitat fragmentation. As climate stressors and addition stressors like urban development and land use changes continue to put forests and other critical ecosystems at risk, habitats that many species rely on may become fragmented. This increases the distance between habitat patches which limits wildlife mobility and makes it more difficult fort species to access the resources they need such as food, water, shelter, mates, etc. (PA DCNR, 2018).

5.3. Strengths and weaknesses

A major strength of Cumberland County in establishing climate resilience is academic institutions such as Dickinson College and Shippensburg University which have programs through the Center for Sustainability Education and the Center for Land Use and Sustainability that help promote the importance of biodiversity (C. Weiser, personal communication, November 13, 2023). Having connections to other larger institutions like Penn State Extension is also a huge strength of the county as these educational resources can help inform community members about the importance of planting native and pollinator-friendly plants (A. Basehore, personal communication, October 13, 2023). Similarly, to other planning areas, the county is home to many organizations that are working to address issues concerning wildlife, pollinators, and biodiversity such as the Department of Conservation and Natural Resources, specifically the Michaux State Forest District Office, the Pennsylvania Game Commission, and the local chapter of the Audubon Society (A. Bowling, personal communication, October 23, 2023).

One significant weakness that prevents progress within this planning area is a lack of public knowledge on the importance of wildlife, pollinators, and biodiversity. There needs to be an effort made toward educating people on the importance of maintaining habitats for wildlife, especially pollinators as they play a key role in the success of the local agricultural industry as well as the health of the local ecosystems. These same sustainable practices that promote pollinator health and biodiversity also offer economic benefits as wild or native lawns require significantly less upkeep both physically and financially. This is a critical issue as people who lack knowledge of the importance of native plants and the benefits of native and wild gardens as opposed to green and fertilized lawns, are less likely to opt for the

more sustainable option, preventing these ecosystems from becoming truly resilient in the face of climate change.

5.4. Resilience strategies

The main resilience strategy for this planning area is to increase public knowledge through education since the lack of knowledge is one of the county's key weaknesses in this specific area. This education would include initiatives that encourage people to plant more pollinator-friendly plants as well as participate in the active removal of harmful invasive species. Education initiatives would also inform local people about the harmful effects of using fertilizers and chemicals on lawns as well as the economic and ecological benefits of opting for wild or native gardens.

Many actions are mentioned in the Pennsylvania Department of Conservation and Natural Resources that may be implemented to address the vulnerability of habitat fragmentation. This includes developing stewardship plans to ensure habitat connectivity and potential migration corridors. This would help conserve key tracts of land, limiting wildlife vulnerability. Additionally, Pennsylvania's DCNR plans to prioritize grant funding that addresses climate change impacts on species and natural communities, such as connecting parcels that facilitate the movement of species (PA DCNR, 2018).

5.5. Indicators and metrics

The indicators and metrics that should be used to measure and keep track of the county's resilience in terms of wildlife, pollinators, and biodiversity include directly measuring biodiversity using species richness and evenness indices to evaluate how diverse the local ecosystems are. Another metric that should be used to quantify resilience in this area is the number of dedicated wildlife spaces and pollinator gardens that are in both the borough of Carlisle and all of Cumberland County. This is a clear way to quantify the efforts that are being made to establish strong pollinator and plant communities by dedicating spaces to be used as habitats. Invasive species like the spotted lanternfly should be tracked as well using resources like Penn State Extensions online Spotted Lanternfly Reporting Tool.

6. Recreation

6.1. Additional Stressors

Another stressor that may affect residents of Cumberland County's use of outdoor recreational space and involvement in other environmental activities and initiatives is the issue of accessibility. The South Mountain Partnership's Report Card on Environment and Health in the South Mountain region indicates that only 33 percent of people can walk to their local parks or trails (South Mountain Partnership, 2023). While this source is representative of a larger region, it is still a good indicator to assess and consider what these numbers look like in Carlisle in Cumberland County. Many factors may limit a person's access

to outdoor spaces. For example, many trails and outdoor spaces are not accessible to those who use wheelchairs or other mobility aids. Another long-standing accessibility issue in the outdoor and environmental space is the fact that many outdoor spaces are not equally welcoming to all groups of people. The outdoor social landscape is disparately white. This long-standing lack of inclusivity and proper representation has led to a disproportionate level of participation among black, Indigenous, or people of color in these outdoor spaces.

6.2. Vulnerabilities

Vulnerabilities that are affecting Carlisle and Cumberland County's outdoor recreation opportunities include many issues that jeopardize people's abilities to properly utilize these outdoor spaces. For example, as air temperatures and the frequency of extreme heat days in Carlisle and Cumberland County increase, contracting certain heat-related illnesses such as heat stroke or heat exhaustion may become more likely than in years past. Another vulnerability that affects the health and safety of people trying to participate in outdoor recreation is that the changing climate can make people more vulnerable to infectious insect borne diseases such as Lyme disease. Lyme disease is an especially pressing issue as Pennsylvania has the highest number of Lyme disease cases in the Unites States (Centers for Disease Control and Prevention, 2022). As air temperatures continue to rise, warmer seasons may last longer, allowing for longer breeding seasons and reproductive opportunities for the ticks that have the capacity to spread Lyme disease (Brownstein et al., 2005).

Another vulnerability that is caused by more frequent and intense rain is an increased likelihood of flooding, which would render trails and other recreational areas unusable. Climate change may also lead to overall milder winters which could potentially lead to fewer opportunities for winter activities such as ice fishing or snowshoeing. In addition to limiting the winter recreation season, climate change will likely elongate the spring and summer recreation season, causing more traffic on trails and outdoor areas. This is an issue for forests and other ecosystems that are used for recreational purposes as these spaces need a period of rest in between recreational seasons in order to recover from the stress of human use (e.g. trails being walked on which compacts the soil, etc.). Extending the summer and spring recreation seasons limits the ability of these ecosystems to recover from these stresses and therefore decreases its resilience as an ecosystem (PA DCNR, 2018).

6.3. Strengths and weaknesses

One of the county's strengths in this area is that interest in outdoor recreation and the use of outdoor spaces have also increased overall since COVID-19, which strengthens community members' likelihood of participation in initiatives to protect and address issues within their local ecosystems (A. Parker, personal communication, October 19, 2023). Cumberland County's Return on Environment notes that 39 percent of residents in south central Pennsylvania participate in outdoor recreation two or more times each week, noting that the most popular outdoor activities are kayaking, birding, wildlife watching, photography, running, and bicycling (Kittatinny Ridge, 2015). Another strength is that there are over 220 miles of trails

in Cumberland County, which provides ample opportunity for recreational use. However, more must be done in order to make these spaces more accessible and welcoming.

One weakness that prevents Cumberland County from establishing resilience in the planning area of recreation, specifically the Letort nature path, is a lack of public and available land along the lower Letort area (A. Parker, personal communication, October 19, 2023). This limits the county's ability to expand the current nature path and give more people in the lower Letort area access to this recreational resource.

6.4. Resilience strategies

One strategy to create resilience in this planning area is to encourage the participation of all people in recreational opportunities. This initiative could take place in the form of offering more free programs at local outdoor areas to encourage people to visit them. Another good way to encourage people to get outside and take advantage of local recreational resources is through education programs. Teaching local people about the benefits of spending more time outdoors will help them better appreciate the value that the outdoors adds to the community of Carlisle and Cumberland County (Kittatinny Ridge, 2015). In addition to teaching people about the benefits of outdoor recreation, another strategy to encourage participation and create resilience is by educating people on how to protect themselves from threats such as Lyme disease so that they are able to safely recreate outdoors. The Pennsylvania Department of Health currently provides some educational material on how to avoid and identify the signs and symptoms of Lyme disease (Pennsylvania Department of Health, 2024).

6.5. Indicators and metrics

An indicator that could be used to show climate resilience in the area of outdoor recreation is the maintenance and use of outdoor spaces. This could be measured by tracking the number of people who use different outdoor recreational spaces as well as by calculating and tracking the economic revenue that is generated by the county's outdoor recreation industry. Current indicators estimate that 521.5 million dollars are spent on outdoor recreation each year in Cumberland County and, as a result, up to 6,656 jobs have been created by this industry (Kittatinny Ridge, 2015). These metrics are important indicators of both how much recreational resources are being used as well as how much economic value they bring to the community. In addition to monitoring the number of people who use outdoor recreation spaces, it may be useful to collect some economic and demographic data, perhaps via surveys, on who is using these spaces. Additional metrics could include the number of Lyme disease cases in Cumberland County.

7. Conclusions

In summary, the climate stressors that pose the biggest threat to the borough of Carlisle and Cumberland County are as follows: more frequent extreme weather events, droughts, increased air temperature, and

changes in regular weather patterns (Leary, 2023). These stressors are likely to become more severe in the coming years unless immediate action is taken to reduce emissions and eliminate some of these stressors that are currently burdening the earth's ecosystems. In Cumberland County, the ecosystems and areas that are most at risk include streams, wetlands, and lakes, forests, wildlife, pollinators, and biodiversity as well as local outdoor recreation opportunities.

These climate stressors, combined with a variety of additional stressors such as urban development and increased nutrient input from the surrounding agricultural industry, have the potential to create many different vulnerabilities which will affect the county's ecosystems. Of these identifies vulnerabilities, there are a few that seem to be especially important based on written sources relating to climate resilience in Carlisle and Cumberland County as interviews with induvial who work locally in ecological conservation or other relevant fields. These specific vulnerabilities that are believed to be of utmost importance and should be prioritized as we move forward with efforts of establishing community resilience include increased water temperature and nutrient loads in the county's aquatic ecosystems, increased damage from harmful invasive plant and animal species, and increased likelihood of contracting insect-borne diseases.

Despite these stressors and vulnerabilities, Carlisle and Cumberland County have the opportunity to mitigate and adapt to many of these adverse effects. For example, using cover crops and riparian buffers along shorelines and in wetlands could help eliminate harmful erosion and nutrient loading by increasing the soil's filtration abilities and holding capacity. Additionally, implementing more public education and engagement opportunities, and building upon those that are already established, the county will be able to generate more interest and hopefully more public action in working towards solving these issues.

Acknowledgements

Sources

Brownstein, J. S., Holford, T. R., & Fish, D. (2005). Effect of climate change on Lyme Disease Risk in North America. *EcoHealth*, *2*(1), 38–46. https://doi.org/10.1007/s10393-004-0139-x

Centers for Disease Control and Prevention. (2022, August 29). *Data and surveillance*. https://www.cdc.gov/lyme/datasurveillance/index.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Flyme%2Fstats%2Findex.html

Chang, H. (2004). Water quality impacts of climate and land use changes in southeastern Pennsylvania. *The Professional Geographer*, *56*(2), 240–257. https://doi.org/10.1111/j.0033-0124.2004.05602008.x

Cumberland County. (2022). *Chapter 6 natural - cumberlandcountypa.gov*. Chapter 6 Natural Resource Protection. https://www.cumberlandcountypa.gov/DocumentCenter/View/751/Chapter_6__Natural?bidId=

Cumberland County. (2021). *Countywide Action Plan Overview Cumberland County.*

Cumberland County. (2019). *Cumberland County Clean Water Technical Toolbox*.

Kittatinny Ridge. (2015). *2015 Cumberland County Return on Environment*. Audubon, PA.

Lipton, D., Carter, S. L., Peterson, J., Crozier, L. G., Fogarty, M., Gaichas, S., Hyde, K. J. W., Morelli, T. L., Morisette, J., Moustahfid, H., Muñoz, R., Poudel, R., Rubenstein, M., Staudinger, M. D., Stock, C. A., Thompson, L. M., Waples, R., Weiskopf, S. R., & Weltzin, J. F. (2018). *Chapter 7: Ecosystems, Ecosystem Services, and Biodiversity. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II*. https://doi.org/10.7930/nca4.2018.ch7

National Fish, Wildlife, and Plants Climate Adaptation Partnership. (2012). *National Fish, Wildlife and Plants Climate Adaptation Strategy*. https://doi.org/10.3996/082012-fwsreport-1

Neil Leary. (2023). *Changing Climate Hazards in Cumberland County, A Review of the Evidence*. Carlisle, PA.

Pennsylvania Department of Conservation and Natural Resources. (2018). *Climate Change Adaptation and Mitigation Plan*.

Pennsylvania Department of Health. (2024). Lyme disease - Pennsylvania Department of Health. https://www.health.pa.gov/topics/disease/Vectorborne%20Diseases/Pages/Lyme.aspx

Rosenzweig, Cynthia & Solecki, William & Parshall, Lily & Gaffin, Stuart & Lynn, Barry & Goldberg, Richard & Cox, Jennifer & Hodges, Sara. (2006). Mitigating New York City's heat island with urban forestry, living roofs, and light surfaces. 86th AMS Annual Meeting.

Shippensburg University. (2021). *GHG Inventory for Forests and Trees Outside Forests, 2001 to 2016 Cumberland County, Pennsylvania*. Shippensburg, PA.

South Mountain Partnership. (2023). *State of the Region Report Card*.

U.S. Census Bureau, Population Estimates Division. (2022). *County Population Estimates.*

Zouhar, K., Smith, J. K., Sutherland, S., & Brooks, M. L. (2008). *Wildland Fire in Ecosystems: Fire and Nonnative Invasive Plants*. https://doi.org/10.2737/rmrs-gtr-42-v6

Interviews:

Interviewee	Position/Organization	Date (2023)
Vastine, Julie	Director, ALLARM, Dickinson College	October 4th
Campbell, Harry	PA Science Policy and Advocacy Director, Chesapeake Bay Foundation	October 10th
Letavic, Erin	Civil Project Manager, Herbert, Rowland & Grubic (HRG).	October 10th
Basehore, Ann	Capital RC&D	October 13th
Slear, Hunter	Cumberland County Conservation District, Watershed Specialist	October 18th
Parker, Andy	Letort Regional Authority, Chair	October 19th
Bowling, Ali	Executive policy specialist, DCNR	October 23rd
Williams, Stephanie	Senior Planning Manager, Cumberland County Planning Department	November 1st
Franco, Ed	Member of Cumberland County Planning Commission, member of Lower Frankford Township Planning Commission, Friends of Possum Lake, and Conodoguinet Creek Watershed Association	November 2nd
Weiser, Cameron	Land Protection Coordinator, Central Pennsylvania Conservancy	November 13th
Chain, Julia	Program Manager, South Mountain Partnership	November 17th
Hartley, Suzanne	Environmental Education Specialist, PA Department of Conservation and Natural Resources	November 28th
Shull, Amy	Environmental Education Specialist, PA Department of Conservation and Natural Resources	November 28th
Beale, Jason Andrew	Executive Director, Central Pennsylvania Conservancy	December 1st