Research Article

Climate Resiliency Strategies for New Hampshire Ski Areas

—August Murray

Outdoor recreation has been an integral part of New Hampshire's identity for over 100 years. As the state has grown and changed, the outdoor industry and its significance have changed as well. With this heritage comes many "firsts." The cable chairlift, downhill race courses, and the aerial tramway are just a few of the firsts that our state can lay claim to (Allen).

August Murray

There are currently nineteen ski areas that operate in New Hampshire. Each of these contribute their own unique personalities, characteristics, and offerings to residents and visitors across New England. From a financial standpoint, the ski industry and its supporting industries are estimated to contribute roughly $1.3 billion (as of 2019) to New Hampshire's annual economy (Stroka). This revenue helps stimulate employment and development throughout the state, providing nearly 10,000 jobs to New Hampshire residents (Stroka). In rural areas, ski mountains have helped facilitate and strengthen economic growth in regions that may otherwise lack industry and infrastructure.

Climate change and its anticipated impacts pose a significant threat to the current and future stability of the ski industry across New England. Climate models from the Environmental Protection Agency (EPA) suggest that, in the next 25 years, rainfall and average temperatures are expected to increase during the winter and spring months (US GCRP). Given a ski area's dependency on low temperatures and natural snowfall, these changes will be especially detrimental to ski area operations in New Hampshire. In order to persist through seasons of less snowfall, quicker snowmelt, and a shorter ski season altogether, adaptation measures must be communicated and implemented statewide.

Snowmaking has become one of the most common ways to adapt to unpredictable snowfall and warmer winters. Through the artificial creation of snow, a ski area's dependency on natural

snowfall is reduced, and base depth can remain more consistent throughout the season. Studies have found that ski areas with snowmaking infrastructure are far more likely to survive future climates when considering climate change (Steiger).

While this adaptation strategy has great benefits, there are shortfalls that will be exacerbated due to climate change and its specific impacts to the state. As Elizabeth Burakowski, a research assistant professor at the University of New Hampshire, has discussed, "We are going to see a threshold crossed where making snow is not even going to be an option." Higher average winter temperatures across the state will result in less available snowmaking days. Even without the challenges caused by climate change, snowmaking is very energy- and water-intensive, making it a costly solution (Damm). As snowmaking's efficacy decreases from these effects, additional measures must be explored to ensure ski areas can continue operating.

Figure 1. Tuckerman's Ravine on Mount. Washington in late spring. A 'rite of passage' for New England skiers and an integral part of the state's ski identity.

I initially conducted this research for an independent study surrounding the ski industry and have since revised and expanded it for publication in *Inquiry*. Skiing has been a part of my family for over three generations, and each generation's ski career began on the same mountains here in New Hampshire. Performing this research is a way to combine a passion of mine with skills and fundamentals I learned throughout my undergraduate career.

I feel news about climate change, when discussing the outdoor industry, has an underlying theme of anticipatory doom. My intention in writing this article is to discuss positive and real changes that can be made with the hopes of people realizing that all is not lost. There is work to be done, but successful adaptation and resiliency are well within reach to save what many of us in the state care so much about.

Methods

I began the research and analysis process by gathering information about worldwide climate resiliency practices pertaining to ski area operation and preservation. This was done to cast as wide a net as possible for potential practices, studies, or general information that could then be adapted or applied to New Hampshire. To gather this information, I performed a literature review. I used Google Scholar as the primary search engine to identify published reports and studies in topics pertaining to this project. This website searches published and peer-reviewed databases and was used to ensure a high quality of information for use in this report.

I used a keyword-based search approach to find publications in areas such as climate change, ski area management, climate resiliency, and ski industry adaptation. Articles identified through

the search engine were then reviewed while considering the overall project goal and relevant subject areas. I also considered the data presented, strategy types, dates of publications, and the overall quality of each article during the review process.

Upon gathering this preliminary information, I filtered out practices and adaptation measures based on their implementation potential within the state of New Hampshire. The key considerations in filtering these measures centered around the state's unique environmental, economic, and societal characteristics. These characteristics surrounded topic areas such as the historical significance of ski areas, relative funding available for each type of implementation strategy, annual snowfall totals, and changes in skier interests (such as the growth of backcountry skiing in the state). By studying these characteristics, implementation feasibility became much clearer. Instead of looking purely at the physical sciences or economics of each proposed solution, I viewed them from a wholistic perspective. This allowed me to consider how a change may impact a resort, and the rider, as well as what it would mean for communities in the region, as they are all interconnected.

Figure 2. Bare slopes from a particularly hot spring season.

As important as these adaptation measures are, they would not be feasible without considering the stakeholders that would be implementing them. The stakeholders I considered when analyzing implementation feasibility consisted of public, private, and municipal entities that were identified from personal experiences and stakeholder groups named in other studies. The end goal in doing so was to create adaptation measures that were feasible for operators, while ensuring these changes wouldn't take away from the experience and amenities riders typically seek while skiing and snowboarding in the state. Given my personal history with skiing in New Hampshire, I was able to combine these factors with my physical experiences at resorts across the state. Additionally, completing courses such as RMP 603, Ski Industry Management, gave me a strong understanding of resort operations surrounding topics such as development, financial management, staffing, and day-to-day operating considerations. Considering stakeholders during the strategy development process greatly aided me in creating feasible solutions. I ensured that for each adaptation measure developed, an industry stakeholder could be linked to each role involved for a given strategy.

While I found a multitude of adaptation strategies in publications and studies, many seemed less effective after considering the location, political atmosphere, and estimated available resources of resorts and ski areas within New Hampshire. For each strategy found, I reviewed the strengths and shortfalls of prior study or performance reports to determine what could be improved or changed. My intention in doing so was to increase that adaptation measure's potential benefit to better mitigate the effects of climate change if implemented in the state.

After filtering these adaptation measures and identifying the best practices in various studies, I developed adaptation strategies that are unique to New Hampshire. To best discuss these strategies, I grouped them by the type of change performed to the ski area: physical, operational, and public. These preliminary strategies are supplemented with additional recommendations surrounding ways to locate or generate funding to make implementation appear more feasible to ski area operators.

Physical Adaptation Measures

Several physical adaptation measures were identified and developed for implementation across New Hampshire. Physical changes describe tangible, observable changes that can be made to a ski area to support overall climate resiliency. These include practices such as snowmaking, snow farming, and geophysical adaptations.

A common example of a physical change already seen at many ski areas across the state is snowmaking capability. As previously discussed, artificial snowmaking currently serves as one of the strongest and most popular methods of climate adaptation in the ski industry (Scott). By reducing its dependency on natural snowfall, a ski area can open earlier in the season, provide consistent base depths, and remain open well into the spring (Damm). At the time of writing this report, snowmaking is the most effective method of combatting the effects of climate change (Damm). Given its high implementation and usage costs, as well as its temperature dependencies, this measure would be far more effective if operating costs could be reduced.

Figure 3. Snowmaking is an important adaptation measure that helps mountains compensate for less natural snow due to climate change. *Source: Wikimedia Commons.*

Water reservoirs are a common way for a ski area to reduce snowmaking costs. Given the high water demand for snowmaking, having a water source that naturally replenishes can reduce operating costs, and ideally would allow a ski area to run snowmaking systems more frequently. One potential strategy to address the financial burden of snowmaking is creating partnerships with a town or county to share the development and upkeep costs of the reservoir. Because their usage periods would be in opposite seasons of the year, the town could use the reservoir in the summer to alleviate drought, and the ski resort could use it in the winter for snowmaking. Recharge of the reservoir could then occur in the spring and fall

Figure 4. Ragged Mountain expanded their snowmaking reservoir by nearly 20 million gallons in 2016 to increase snowmaking capability. *Courtesy of the Concord Monitor.*

months, which are high in snowmelt and precipitation in New Hampshire. In rural areas, or with smaller ski areas, this method may be especially beneficial as the two entities may not be able to fund such a project individually.

Another promising physical adaptation measure is snow farming, which is the process of covering or storing snow to preserve existing snowpack. This process entails stockpiling snow for times of high temperature or low snowfall (Grünewald). This practice is typically seen on glaciers in Europe; however, studies have shown it can be effective with lower elevation resorts as well (Steiger). In other regions, slope faces and glaciers are covered with geotextiles or woodchips to shield snowpack from the sun. One study found snowmelt can be reduced by as much as 60 percent on high heat days with the use of geotextiles (Grünewald).

Geophysical adaptation is another physical change that is less commonly used but may provide particular benefit in New Hampshire. This process describes the combination of two existing measures, land contouring and rock removal, that were merged into a broader category for discussion within this report. The geophysical adaptation process involves physically modifying a ski slope to better support and maintain snow accumulation. By doing so, snowmaking demand is reduced, and terrain quality is improved (Scott).

Removing rocks from ski slopes can help maintain snowpack by reducing the frequency of hotspots, commonly seen as small areas on a ski slope where snow has melted and exposed a rock. Rocks reflect the sun's heat and are poor insulators against the heat that radiates from the Earth's core, known as terrestrial radiation (Marshall). Soil is far more porous, and acts as a better insulator from terrestrial radiation, meaning it will accumulate snow quicker and easier than rock faces.

Slope contouring is a strategy performed to smoothen slopes, because uniform surfaces without ruts or pits will accumulate more snow and will create a more even base depth (Scott). As these two measures are carried out in similar areas, during similar time periods, with similar tools and staff, they are better presented as a combined process. These geophysical adaptation measures would reduce trail maintenance costs, better support snow accumulation, and simplify climate adaptation planning if performed together.

Future development or current maintenance of ski slopes provides an opportunity to perform geophysical optimization. As New Hampshire is known as the "Granite State," the removal of rocks and the balancing of uneven slope surfaces may be especially beneficial for ski areas within the state. By combining these changes with existing projects, such as those that occur over the summer, the cost to improve these slopes would be greatly reduced in comparison to performing trail maintenance and development separate from climate strategies.

Operational Adaptation Measures

Operational adaptation measures center around changes to the way a ski area operates on a daily and seasonal basis. This could be seen in the formation of a conglomerate or partnership, or in changes to operating procedures through a winter season.

For smaller ski areas in the state, or those that lack snowmaking infrastructure, changing its operating structure is one of the best ways to reduce costs and preserve snowpack. On low turnout days, such as midweek, a ski area could close to reduce energy, staffing, and upkeep costs. During times of inactive lift operation, the ski area could be opened for uphill access. Many ski areas across the state already have existing uphill policies, marked trails, and legal documentation which would reduce the work required to implement these changes. Ski areas could also partner with organizations such as Ski the Whites, Granite Backcountry Alliance, or local ski shops to offer reduced rental rates of uphill equipment or educational courses to ease public image issues surrounding the new closures. Should resources be available, geotextiles could be laid on inactive slopes during inactive days to increase snowpack preservation. This could also help with employee retention, as snowmakers or groomers could instead be tasked with geotextile management on days of temporary closure.

Public Adaptation Measures

Public strategies are those that engage public and political stakeholders to enact change and generate support toward causes that support resort operation, such as funding for climate resiliency planning. Collaborating with key stakeholders, such as municipalities, the public, local businesses, and other industry stakeholders, is an important step when attempting to engage the public on an issue. While multi-stakeholder efforts can present as a challenge, there is opportunity for independent and sister resorts to work together to address these challenges. By doing so, audiences would be diversified, and the impact of these collaborative efforts would likely be far more significant than if they were done individually.

One of the most effective and important things a ski area can do to adapt to climate change is to inform and educate the public on the issues they are facing (Scott). Educating and helping the public understand why problems such as poor conditions or unexpected closures are occurring can change the narrative from anger to action. A great example of this is Wildcat Mountain and their lift issues in the 2021-2022 season. Due to the funding structure of their conglomerate, lift maintenance could not be performed in a timely manner, and eventually caused the lift to stop running during peak dates of the ski season. Wildcat explained this issue to the public, which resultingly instigated a change in funding allocations so the lift could be repaired. By communicating these issues, the public's irritation was shifted toward the root cause of the issue, instead of toward the mountain.

The same approach can be applied to climate change. Working to educate and engage the public across the state can institute the development of additional resources and methods to adapt to climate change (Stone). Educating the public about the issues a ski area is facing, especially those outside of its control (such as a reduction in snowfall), could help increase public understanding and engagement. The unique cultural and economic role the ski industry plays in New Hampshire makes our state a great place for these types of efforts to begin. Organizations such as SkiNH are already taking this type of action, by taking on projects such as EV charger implementation, education surrounding these issues, and policy work to enact change at the state and federal levels.

Funding Strategies

New Hampshire is home to many small and independently operated ski areas, which are more likely to close due to climate change because of their lack of financial stability compared to larger conglomerates. If a smaller ski area is facing closure, they may be able to change their operating structure to a 501(c)(3) nonprofit. This would allow access to federal and state subsidies, as well as reduced operating costs. Crowdsourcing, volunteering, and angel investments are more common with nonprofit operations, and given the historical significance of many ski areas across the state, they may be especially viable candidates for such charitable contributions (Scott). Additionally, a town or county may be able and willing to "adopt" the ski area to continue its operation as an asset of a municipality. As an example, Whaleback Mountain currently operates under the 501(c)(3) designation with support through a nonprofit foundation.

Increasing lift ticket prices is an easy way to gain additional revenue for funding adaptation strategies (Scott). While the increase in prices may dissuade skiers and snowboarders, communicating the reason for the increased cost would likely reduce the dissatisfaction of riders. It would also provide a great opportunity to begin identifying climate change as the growing culprit of common operating challenges.

Year-round operation to increase revenue is a growing practice in the industry. By offering services and attractions such as weddings, special events, mountain biking, and year-round resort reservations, a ski area can diversify its income and reduce its dependency on the quality and duration of a winter season (Scott). Furthermore, utilizing existing infrastructure such as chairlifts, lodging, and event areas can greatly reduce the startup cost of year-round operations. This can also help a ski area gain awareness by attracting visitors who are not solely skiers and snowboarders. Employee retention may also increase as seasonal workers would have the opportunity to work for the ski area yearround. Overall, this practice has shown to be very promising, as seen at nearby mountains such as Loon Mountain, Killington, and Mt. Abram.

While reducing operating costs is important in itself, the financial surplus it can create could be allocated toward climate adaptation. To reduce some of these costs, a ski area could partner with town managers to jointly invest in sustainable and renewable energy, such as solar or wind systems. Combining financial resources would make it more feasible to implement these systems and would benefit both parties. A ski area would save money on energy costs, and by partnering with a municipality, the project may qualify for government subsidies or loans that are typically unavailable to a private entity. With these reduced costs, more revenue could be applied toward adaptation measures.

Town and city managers in New Hampshire are typically supportive of these types of partnerships. Waterville Valley Resort and their community's town manager are a great example of a public-private partnership being mutually beneficial to each stakeholder (in the context of ski area operation and municipal management). By working together, the town and resort have developed plans that support sustainability, economic growth, and responsible

development. By considering climate change in that planning process, both the town and resort will be better prepared for changes to their climate and region.

Additional Considerations / Next Steps

Climate change is expected to cause an increase in average winter temperatures and a reduction in natural snowfall across the state of New Hampshire (Beaudin). With a higher amount of rainfall each winter, ski industries will have to shift their operating practices to survive these changes. Snowmaking and snow farming are two promising physical adaptations that can be made to a ski area to make it more climate resilient. These measures could be funded through new revenue sources generated by year-round operations, or by partnering with municipalities to reduce existing operating costs.

The next step in confronting these issues is to discuss climate adaptation measures with stakeholders such as industry professionals, university researchers, and ski area operators. By discussing these strategies with key stakeholders, adaptation measures can be improved while simultaneously making those with the ability to enact change aware of these solutions. Their experiences and input would greatly assist in furthering the adaptation strategies discussed in this report, with the end goal being implementation at ski areas across the state. Special care should be taken to work alongside stakeholders from ski areas of all sizes and locations throughout the state.

An institution, such as the University of New Hampshire, could collaborate with industry stakeholders to create more accurate climate models and adaptation strategies. Institutional partnerships like this could also help advance adaptation measures by combining the resources of university researchers with an optimal location, such as an active ski area, to perform these studies. Institutional participation will be crucial in facilitating the timely, effective, and successful development of these climate strategies. Snow farming in New Hampshire is one specific research area that would best be performed alongside an institution. There is a need for more accurate information about its potential benefits in the northeastern region of the United States. This practice has real potential to assist the industry with climate adaptation, however studies must be performed in this climate to best understand its implementation potential.

Future studies should account for inflation, advancements in technology (such as snowmaking efficiency), and improved climate models. Additionally, economic factors specific to the state such as material costs, labor rates, and ski area revenue streams should be considered to better understand the anticipated implementation costs of these resiliency strategies.

Ideally, the findings of this article will be made available to ski area operators and relevant stakeholders across the state and region to stimulate development and improvement of these important adaptation strategies. The public should also be educated on these issues, as they have the power to enact change at local, state, and federal levels. The New Hampshire ski industry can unify stakeholders, industries, and residents toward a common goal of reducing

the effects of climate change while simultaneously saving a major contributor to our state's economy, identity, and heritage.

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Author and Mentor Bios

Originally from Hampton, New Hampshire, **August Murray** took on this research project as an independent study to complete his minor in outdoor recreation management. He graduated in spring 2022 with a bachelor of science degree in civil engineering. With this project, August wanted to combine his passion for the ski industry and his engineering background. He learned how research on this topic and the resulting adaptation measures can differ between countries and even states. Some of August’s information was gathered from international sources, and he enjoyed learning about their methodologies toward climate adaptation as well as their research processes. For August, it was important to highlight climate change adaptation strategies that could potentially save the ski industry in New Hampshire. The topics his article discusses are pertinent, relevant, and significant, both to the UNH community, and to the region. August would like to build a career working with local and international communities on climate change adaptation, preparation, and mitigation.

Sean McLaughlin is a lecturer in the Recreation Management and Policy Department at the University of New Hampshire. Joining UNH in 2010, his work focuses on outdoor recreation, tourism, and event planning. The project that became August Murray’s research article gained traction when August was a student in one of McLaughlin’s classes: New Hampshire Ski Industry Management. A simple conversation about climate change and the ski industry led to a longer dialogue about studying this dilemma. The results of this study are not only evident in the publication for *Inquiry*, they have already made an impact within the New Hampshire ski industry. The regional backcountry ski organization, Granite Backcountry Alliance, is utilizing some of August’s work to inform new “glade” zones (managed backcountry ski areas). This is just one example of the potential for many of the regional ski areas to benefit from the results of August’s work, which McLaughlin says was fun and satisfying for both the researcher and mentor. Research on climate change is relevant to politics, recreation, energy, policy, and the future of the planet. August’s publication in *Inquiry* has universal impacts and framing his work for a greater audience is vital to its effectiveness.