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# Winter tourism and climate change: Exploring local and non-local snowmobilers' perceptions of climate change and adaptation behaviors

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ABSTRACT

Climate change poses great risks to winter tourism, and snowmobiling is one of the most vulnerable recreation activities under changing climate conditions. Research on climate change and winter tourism primarily focuses on how the winter season changes in different emission scenarios. Little is known about tourists' demands of winter tourism activities under climate change and related adaptation behaviors, especially for snowmobilers. This study collects data from snowmobilers in Vermont Association of Snow Travelers (VAST), and compares local and non-local snowmobilers' preferences for snowmobiling conditions, perceptions about climate change on VAST trails, and adaptation behaviors to varying scenarios of climate change. Results indicate that the quality of snowmobiling is influenced by four factors (i.e., trail encounters, trail scenic views, trail accessibility/connectivity, and trail feature diversity). Whereas non-local snowmobilers have a higher desirability for the diversity of trail features than local snowmobilers, local snowmobilers are more sensitive to climate change conditions than non-local snowmobilers. Moreover, study results suggest that local snowmobiling markets are more vulnerable than non-local snowmobiling markets to future climate change scenarios. Study findings provide land managers guidance for maintaining high quality snowmobiling experiences and adaptation planning strategies for local and non-local snowmobiling markets under future climate change scenarios.

## Management Implications

- Local and non-local snowmobilers in Vermont have different use patterns of snowmobiling. Local snowmobilers have a higher use level of Vermont snowmobiling trail system than non-local snowmobilers.
- Trail encounters, trail scenic views, trail accessibility/connectivity, and trail feature diversity are the important factors for the quality of snowmobiling experiences in Vermont.
- Local snowmobilers are more sensitive than non-local snowmobilers to perceive the declining snowmobiling conditions in Vermont due to climate change.
- Local snowmobiling markets are more vulnerable than non-local snowmobiling markets to future climate change scenarios.

## 1. Introduction

Climate change poses great risks for winter recreation and related tourism industries (Amelung, Nicholls, & Viner, 2007; Lemieux & Scott, 2011; Perry, Manning, Xiao, Valliere, & Reigner, 2018). Snowmobiling has been identified as one of the most vulnerable winter recreation activities under the projected impacts of climate change (Wobus et al., 2017). For instance, evidence suggests that under the high emission scenario, the demand for snowmobiling in the Northeast US might decrease more than 65% or even cease to exist in some traditionally snowmobiling-rich areas in Pennsylvania and New York (Frumhoff, McCarthy, Melillo, Moser, & Wuebbles, 2007). Moreover, because winter recreation activities are highly associated with localized economic benefits (Dawson & Scott, 2013; Marco et al., 2011; Scott & McBoyle, 2007), the projected future warming and decrease in

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snowpack and snow season length might reduce revenue from the winter tourism industry because of insufficient days of snow supply for snowmobiling and displacement of snowmobiling experiences (Hoy, Hänsel, & Matschullat, 2011; Morrison & Pickering, 2012).

Although most managers of parks and protected areas (Archie, Dilling, Milford, & Pampel, 2012; Sharp, Lemieux, Thompson, & Dawson, 2014) and stakeholders in winter tourism are aware that climate change is happening (Behringer, Buerki, & Fuhrer, 2000), there is limited evidence about visitors' perceptions about climate change and how it might affect the demand for winter recreation activities. Given the fact that snowmobiling is highly dependent on the natural snow supply and the quality of snowmobiling facilities, it is important to examine snowmobilers' general perceptions about climate change. Also, because of different preferences for snowmobiling conditions between local and non-local snowmobiling markets, it is essential to understand how local and non-local snowmobilers may respond to different climate change scenarios.

Given the increasing risk of climate change on snowmobiling conditions (Xiao et al., 2019), the salience of climate change to snowmobilers' recreation experience, and the uncertainty of adaptation behaviors from snowmobiling segments (Perry, Manning, Xiao, & Valliere, 2018), this study aims to investigate local and non-local snowmobilers' (1) patterns of snowmobiling activities and preferences for related conditions; (2) perceptions about climate change impacts on snowmobiling and related coping behaviors; and (3) adaptation behaviors to changing snowmobiling conditions. Our general hypothesis is that local and non-local snowmobilers would differ in their patterns of snowmobiling participation, preferences for related conditions, perceptions about climate change impact on snowmobiling, and adaptation behaviors under changing snowmobiling conditions. We chose to collect data in Vermont, because the snowmobiling segment in Vermont consists of both local and non-local recreationists. Our survey integrates a number of climate change manifestations that might influence the demands and experiences of snowmobilers in Vermont and measures snowmobilers' coping and adaptation behaviors to a wide range of snowmobiling conditions for each manifestation of climate change. Comparing local and non-local snowmobilers' perceptions about climate change and adaptation behaviors would help managers and stakeholders in the snowmobiling industry modify and develop potential adaptation plans and marketing strategies. In addition, understanding different groups of snowmobilers could help industry professionals provide better service and maximize the positive experience of snowmobilers, thus increasing health benefits from snowmobiling.

## 2. Literature review

### 2.1. Climate change and winter tourism

Since 2000, an increasing amount of research has focused on assessing the impacts of climate change on winter recreation activities. The primary impacts of climate change on winter tourism include the warming temperature in the winter season (Burakowski, Wake, Braswell, & Brown, 2008), reduced length of snow season and depth of snowpack (Dawson & Scott, 2007), and increased vulnerability and volatility of natural snow conditions (Landauer, Sievänen, & Neuvonen, 2015). For example, one study assessed the climate change impacts in the Northeast US using IPCC SRES emission scenarios and found that a higher temperature was expected in the higher latitudes of the Northeastern US (Hayhoe et al., 2008). The rising temperatures have also been recognized as one of the most important factors that challenges winter recreation activities, such as snowmobiling, skiing, and snowboarding (Pröbstl-Haider, Richins, & Türk, 2019).

Studies across geographical scales consistently indicate that the length of snow season will decline based on climate change projections. For instance, a study simulating natural snow accumulation at 247 winter recreation areas across the US found that the length of the winter recreation season was expected to decline in all recreation areas, with some locations even expected to reduce by as much as 80% by 2090 (Wobus et al., 2017). A regional study examined the impact of climate change on 29 winter recreation areas in the Northeastern US using two different emission scenarios (Scott, Dawson, & Jones, 2008). The results indicated that the length of the snowmobiling season would significantly decrease and might not even exist in some areas during starting in 2040. At the state level, one study examined the vulnerability of the Vermont ski industry based on the Global Climate Models and found the average length of ski season would decrease 4%–14% during the time period of 2010–2039 (Dawson & Scott, 2007). Huntington, Hodgkins, Keim, and Dudley (2004) used the ratio of snowfall to total annual precipitation as an indicator of vulnerability of snow conditions to assess climate change impacts in New England (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut) and found that the vulnerability of snow has increased in one-third of the historical climatology network sites in these six states.

Going abroad, a study of winter recreation in Finland developed a vulnerability index for winter recreation activities that consisted of exposure, sensitivity, and adaptive capacity indicators, and found that the vulnerability of cross-country skiing varied greatly across different Finland's regions (Landauer et al., 2015). Another study about winter tourism in Mittenwald, Austria found that the declined conditions of natural snow cover and reduced snow security were primary threats for winter tourism in the region (Bausch, 2019, pp. 92–102). In general, current evidence on climate change impacts to winter recreation activities have primarily focused on projections of climate change on snow conditions, and most studies have focused on the change of snow conditions for skiing. Very few studies have examined climate change impacts on other winter recreation activities (e.g., snowmobiling, ice-fishing, skating) and these rarely address how recreationists perceive climate change and respond to the changing conditions of winter recreation.

### 2.2. Snowmobiling and climate change

Snowmobiling is very sensitive to climate change and highly dependent on natural snow conditions. One study estimated the lengths of snowmobiling seasons based on RCP 4.5 and RCP 8.5 emission scenarios across different regions in the US. Results showed that the snowmobiling seasons in the Midwest and Northeast would decline by more than 80% in 2050 under the RCP 4.5 emission scenario (Wobus et al., 2017). Another study assessed climate change impacts on snowmobiling in non-mountainous regions of Canada. Results suggested that the average snowmobiling seasons in the provinces of Ontario and Quebec would reduce by 11%–44% in 2010–2039 under the low emission scenario (McBoyle, Scott, & Jones, 2007). Tercek and Rodman (2016) modeled the expected number of days with adequate snow coverage in Yellowstone National Park and found that the length of the snowmobiling season there would decrease more than 70% by the end of this century. One regional study assessed the impacts of climate change on the Vermont snowmobiling industry and found that the average snowmobiling season in southern Vermont was projected to decline by 60% in 2050 under the high emission scenario (Frumhoff et al., 2007). In addition, research on climate change impacts to snowmobiling found that the mechanical snowmaking strategy, the traditional poor weather and climate adaptation strategy for skiing, was generally not applicable to snowmobiling because snowmobiling relied on natural snowpack and across long trails and varied terrains rather than a concentrated ski slope (Frumhoff et al., 2007; Tercek & Rodman, 2016).

Although research has primarily focused on changes to resource conditions of winter recreation under climate change, a few studies have started to examine how winter recreationists perceive climate change and how their demands for winter recreation activities may respond to climate change (Marco et al., 2011; Pickering, 2011). For example, one study examined the ski recreation demands in a 10-year time horizon

(1997–2007) with varying natural snow conditions in six ski resorts in Austria. Study results indicated that the ski demand declined by 14%–48% in 2006, which was a year with comparatively poor natural snow cover (Pickering, 2011). The study also identified a significant relationship between natural snow cover and visitation rates to ski resorts (Pickering, 2011). Multiple studies have examined skiers' behavioral adaptations to climatic variability and climate change and identified three types of adaptation behaviors: temporal substitution (participating in the activity at different time), spatial substitution (changing destination), and activity substitution (one activity replaces another activity), with proportions of three types of adaptation behaviors varying greatly among ski resorts across different regions and countries (Behringer et al., 2000; Dawson & Scott, 2013; Pickering, Castley, & Burtt, 2010; Rutty et al., 2015). Moreover, research has found that the adaptation behaviors of skiers for changing winter recreation conditions vary among skiers with different levels of leisure involvement. Highly involved skiers were more likely to alter skiing behavior than less involved skiers when snow conditions were poor (Dawson, Havitz, & Scott, 2011). However, research is limited on how local and non-local recreationists respond to the changing conditions of winter tourism. One review study of climate change impacts on ski tourism indicated that skiers from different geographic areas may vary in their climate change-related adaptation behaviors (Steiger, Scott, Abegg, Pons, & Aall, 2017), and that the spatial dimension is a needed addition to the adaptation framework of winter recreation planning under climate change (Tranos & Davoudi, 2014).

## 3. Methods

### 3.1. Data collection

We conducted an online survey of the Vermont Association of Snow Travelers (VAST) trail maintenance assessment (TMA) pass holders with viable email addresses from November 17 to December 14, 2015. We distributed surveys to 8097 VAST TMA pass holders via emails on November 17, inviting their participation. For those who had not completed the survey by November 30, we sent an email reminder to complete the survey with a link to the questionnaire. A total of 1450 completed questionnaires were collected, yielding an overall response rate of 17.9%.

The primary reason to conduct an online survey for VAST TMA pass holders was the ability to use interactive platforms to display information to respondents. In this survey, we provided visual information about changes in snowmobile networks to help respondents contextualize the questions (Manning, 2011; Xiao, Lu, Manning, & Reigner, 2019). Three videos were also included in the questionnaire to illustrate response strategies to the complex questions, including: 1) Introduction of survey purpose, scale for each question, and response options for different sets of questions; 2) The visual maps of VAST snowmobiling trails with different percentage of trail network open; 3) The visual maps of VAST snowmobiling trails with different connectivity of trail network. Research has indicated that videos can be useful for participants to recall their experiences or serve as a reference point for participants' responses (Wright, 2017). Moreover, the video in the survey can deliver information more adequately than text illustrations (Hoffmann, Winter, Caro, & Gottlieb, 2014). The videos were accessed 620 times, indicating a relatively high rate of use by respondents, which may help improve the quality of survey data.

### 3.2. Study instrument

The online survey of VAST members included five sets of questions. The first set was basic socio-economic information of snowmobilers, including gender, age, education background, and residential state. The second set included the use of snowmobile trails in Vermont, such as the number of days snowmobiled, the mileage ridden, and the spatial extent of trails used.

The third set of questions asked respondents to rate the desirability of conditions related to high quality snowmobiling. There were 18 variables related to snowmobile conditions; respondents were asked to report how these conditions would detract from or add to the quality of snowmobiling in Vermont. The measurement scale ranged from -2 (detracts a great deal) to 2 (adds a great deal).

The fourth set of questions measured snowmobilers' perceptions about climate change. The respondents were asked to report whether they had noticed the change in six snowmobiling-related climate variables: 1) the frequency of snow, 2) the length of the snow season, 3) the depth of snow, 4) the number of snowmobile trails, 5) forest quality on the snowmobile trails, and 6) the variability of snow depth. The measurement scale for these was 1 (decrease), 2 (no change), or 3 (increase).

The last set of questions measured respondents' change in snowmobiling participation in Vermont under a series of climate change scenarios. The climate change variables for snowmobiling were: 1) days with adequate snow cover (150-, 125-, 100-, 75-, 50-, and 25-day), 2) the percentage of open snowmobiling trail network (100%, 80%, 60%, 40%, 20% and 10%), 3) characteristics of snowmobiling trail network (high connectivity, medium-high connectivity, medium-low connectivity, and low-connectivity), 4) wildlife on snowmobile trips (all trips, 75% trips, 50% trips, 25% trips, and not seeing wildlife), 5) landscape types on snowmobiling trails (all open fields, 75% open field and 25% forested, 50% open field and 50% forested, 25% open field and 75% forest, and all forested), and 6) encounters on snowmobiling trails (0-, 5-, 10-, 25-, 50-, 75-, 100-encounter, and more than 100 encounters). The range of snowmobiling conditions varied from better than current conditions to worse than current conditions. The respondents were asked how their frequency of snowmobiling would change, if at all, under these ranges of different conditions.

### 3.3. Data analysis

A series of statistical tests were conducted to examine the research objectives. Chi-square tests were employed to identify differences in socio-economic factors (e.g., gender, education). To examine factors impacting the quality of snowmobiling experiences, an exploratory factor analysis (EFA) with varimax rotation was conducted for 18 variables of snowmobiling conditions with a reliability test of measuring scales. To examine differences in preferences about snowmobiling conditions and perceptions about changes to snowmobiling conditions on VAST trails related to climate change, two series of one-way analysis of variance (ANOVA) procedures were conducted. Finally, ANOVA tests were employed to compare adaptation behaviors under six climate change manifestations between local and non-local snowmobilers. The norms of participation rates under different climate change manifestations for local and non-local snowmobilers were also calculated in R programming.

## 4. Results

### 4.1. Socio-demographic profile of snowmobilers

Respondents were almost evenly split between Vermonters (local snowmobilers; 50.2%) and non-Vermonters (non-local snowmobilers; 49.8%). The majority of snowmobilers were male (89.6%). The average age of respondents was 53 years, and local snowmobilers were slightly older than non-local snowmobilers. About one-third (37.9%) of respondents reported obtaining a bachelor's degree or higher. Non-local snowmobilers reported a significantly higher education level than local snowmobilers (44.1% versus 31.8%, respectively). Respondents' socio-demographic information is listed in Table 1.

**Table 1**
Socio-demographic profile of snowmobilers.

| Variables | Categories | Local | Non-local | Total | Chi-square | F value | p value |
|---|---|---|---|---|---|---|---|
| **Gender** | **Female** | 13% | 8% | 10% | 5.651 | NA | 0.017 |
| | **Male** | 87% | 92% | 90% | 5.651 | NA | 0.017 |
| **Education** | **High school or lower** | 24% | 16% | 20% | 9.030 | NA | 0.003 |
| | **Some college** | 45% | 40% | 42% | 2.428 | NA | 0.129 |
| | **Bachelor's degree** | 21% | 31% | 26% | 12.208 | NA | <0.001 |
| | **Graduate degree or professional degree** | 11% | 13% | 12% | 1.823 | NA | 0.177 |
| **Age** | **Mean** | 54.7 | 52.7 | 53.7 | NA | 9.296 | 9.296 |
| **Participation history** | **Years snowmobiling** | 27.4 | 21.9 | 24.6 | NA | 42.509 | 42.509 |
| | **Days/year snowmobiling in Vermont** | 24.7 | 17.5 | 21.1 | NA | 56.070 | 56.070 |
| | **Miles/year snowmobiling in Vermont** | 1171.2 | 994.1 | 1038.9 | NA | 12.410 | 12.410 |
| | **Trail variety: Stay on same trails** | 39% | 51% | 45% | 14.783 | NA | <0.001 |
| | **Trail variety: Ride on different trails** | 61% | 49% | 55% | 14.783 | NA | <0.001 |

### *4.2. Patterns of snowmobiling of local and non-local snowmobilers*

Overall, local snowmobilers reported a significantly longer participation history than did non-local snowmobilers ($p < 0.001$): 27.4 versus 21.9 years participating in snowmobiling. Local snowmobilers also reported higher use levels in terms of days and miles ridden in Vermont. This translated to Vermont snowmobile riding for 24.7 days and 1171.2 miles in a typical winter season for locals and 17.5 days and 994.1 miles for non-locals. In addition, local snowmobilers were significantly more likely to ride on varied trails than non-local snowmobilers ($p < 0.001$). More than 60% of local snowmobilers ride their snowmobiles on different trails, while less than half of non-local snowmobilers do.

### *4.3. Local and non-local snowmobilers' preferences about facilities, conditions, and snowmobiling designs*

To assess the importance of factors associated with high quality of snowmobiling, we asked respondents to rate the desirability of facilities, conditions, and snowmobiling design elements. With these different elements, we conducted an EFA to extract the primary components of desirable snowmobiling conditions. Factors with EFA factor loadings less than 0.40 were removed. We assessed the EFA results as reliable, as the Kaiser-Meyer-Olkin (KMO) was 0.802, Barlett's test of sphericity was $p < 0.001$, rotated factor loadings were 0.456–0.946 for within-factor items, and Cronbach's α's were 0.822–0.890 for each factor (Table 2). Four primary components were extracted: 1) trail encounters, 2) trail scenic views, 3) trail accessibility/connectivity, and 4) trail feature diversity (Table 2), explaining 68.1% of the variance among responses.

**Table 2**
Exploratory Factor Analysis of snowmobiling conditions, resulting in four factors each containing three to six items.

| Factor and items | Factor loading* | Cronbach's α |
|---|---|---|
| **Trail encounters** | | 0.890 |
| Encountering cross-country skiers along the trail | 0.941 | |
| Encountering snowshoers along the trail | 0.946 | |
| Encountering bikers along the trails | 0.782 | |
| Encountering dog sleds along the trails | 0.825 | |
| **Trail scenic views** | | 0.822 |
| Seeing wildlife | 0.724 | |
| Visiting natural features | 0.827 | |
| Visiting historic/cultural features | 0.742 | |
| Getting away to remote places | 0.615 | |
| High quality scenery along the trail | 0.670 | |
| **Trail accessibility/connectivity** | | 0.830 |
| Easy access to services & facilities | 0.566 | |
| Interconnectivity of trails for making loops and tours | 0.579 | |
| Ability to travel great distances | 0.477 | |
| Regular grooming of trails | 0.830 | |
| Consistent snow cover along the trail | 0.808 | |
| Being able to begin your ride at home | 0.456 | |
| **Trail feature diversity** | | 0.850 |
| Challenging trail features | 0.773 | |
| Ability to travel fast on trails | 0.673 | |
| Deep snow | 0.631 | |

*KMO value = 0.802, and Barlett's test $p < 0.001$.

Among the four factors associated with snowmobiling quality, trail accessibility/connectivity was rated as the most important (Table 3). The items within trail accessibility/connectivity, such as consistent snow cover along the trails, interconnectivity, and ability to begin ride at home can greatly improve the quality of snowmobiling. Trail scenic views ($m = 1.22$) and trail feature diversity ($m = 0.55$) can also improve the quality of snowmobiling, though to a lesser extent. However, trail encounters (i.e., meeting cross-country skiers, snowshowers, bikes, dog sleds, etc. along the trail) can decrease the quality of snowmobiling ($m = -0.63$). ANOVA tests indicate that local and non-local snowmobilers' assessments of desirable snowmobiling conditions were generally similar for snowmobile trail encounters, scenic views, and accessibility/connectivity. However, non-local snowmobilers assessed trail feature diversity as significantly more desirable ($p = 0.020$) than did local snowmobilers.

### *4.4. Local and non-local snowmobilers' perceptions about climate change and coping behaviors*

To identify snowmobilers' perception about climate change, respondents were asked whether they have noticed changes in snowmobiling conditions related to climate change. Among ten measured conditions related to climate change (Table 4), respondents noted observing decreased conditions for the frequency of snowfall greater than 6 inches, the depth of snow throughout the winter, and the length of the winter during which there is enough snow to snowmobile. Respondents also noticed a slight increase in the variability of snow coverage, snow depth, and winter temperature. ANOVA tests indicated that local snowmobilers were more likely to notice worsened conditions for snowmobiling. For instance, more than 40% of local snowmobilers noticed a downward trend in the frequency of snowfall greater than 6 inches and the depth of snow throughout the winter, whereas about 30% of non-local snowmobilers noticed this trend. Additionally, the majority of local snowmobilers have noticed a shorter length of the winter for snowmobiling, compared to 37.5% of non-local snowmobilers. Local

**Table 3**
Comparison of factors for high quality snowmobiling between local and non-local snowmobilers.

| | Local[a] | Non-local[a] | Total[a] | F value | p-value |
|---|---|---|---|---|---|
| Trail encounters | -0.6262 | -0.6557 | -0.6409 | 0.371 | 0.543 |
| Trail scenic views | 1.2184 | 1.2166 | 1.2175 | 0.003 | 0.960 |
| Trail accessibility/ connectivity | 1.5531 | 1.551 | 1.5521 | 0.006 | 0.940 |
| Trail feature diversity | 0.5518 | 0.660 | 0.6056 | 5.451 | 0.020 |

[a] Cells reported in means on a scale from -2 to 2.

**Table 4**
Frequency and mean response of local and non-local snowmobilers' perceptions about changes, if any, to climate change-related conditions for snowmobiling in Vermont.

| | Decrease (-1) | | No change (0) | | Increase (1) | | Mean (-1 to 1) | | | F value | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate change related conditions for snowmobiling | Local | Non-local | Local | Non-local | Local | Non-local | Local | Non-local | Total | | |
| Frequency of snowfall greater than 6 inches | 44% | 27% | 41% | 54% | 15% | 19% | -0.31 | -0.08 | -0.21 | 19.622 | <0.001 |
| Depth of snow throughout the winter | 44% | 31% | 39% | 45% | 18% | 24% | -0.28 | -0.05 | -0.18 | 14.178 | <0.001 |
| Length of the winter during which there is enough snow to snowmobile | 52% | 37% | 34% | 44% | 15% | 19% | -0.40 | -0.17 | -0.29 | 17.446 | <0.001 |
| The number of snowmobile trails | 23% | 18% | 60% | 63% | 17% | 19% | -0.07 | 0.01 | 0.03 | 2.646 | 0.104 |
| The extent of snowmobile trails throughout the state | 18% | 14% | 68% | 69% | 14% | 18% | -0.04 | 0.06 | 0.00 | 5.368 | 0.021 |
| Forest health or quality along snowmobile trails | 6% | 7% | 84% | 82% | 10% | 11% | 0.04 | 0.04 | 0.04 | 0.029 | 0.866 |
| The variability of snow depth from year to year | 28% | 24% | 46% | 53% | 25% | 23% | 0.02 | 0.05 | 0.03 | 0.338 | 0.561 |
| The variability of snow coverage along the trails from year to year | 28% | 23% | 48% | 56% | 24% | 21% | -0.01 | 0.01 | 0.00 | 0.318 | 0.573 |
| The variability of winter temperatures from year to year | 16% | 13% | 53% | 66% | 31% | 22% | 0.19 | 0.14 | 0.16 | 2.124 | 0.145 |
| The average coldness of winters | 21% | 17% | 57% | 65% | 22% | 18% | 0.01 | 0.02 | 0.01 | 0.09 | 0.924 |

snowmobilers are also more likely than non-local snowmobilers to notice the decreasing extent of snowmobile trails throughout Vermont.

### 4.5. Snowmobilers' adaptation behaviors to climate change

To examine differences in adaptation behaviors to climate change between local and non-local snowmobilers, we asked respondents to

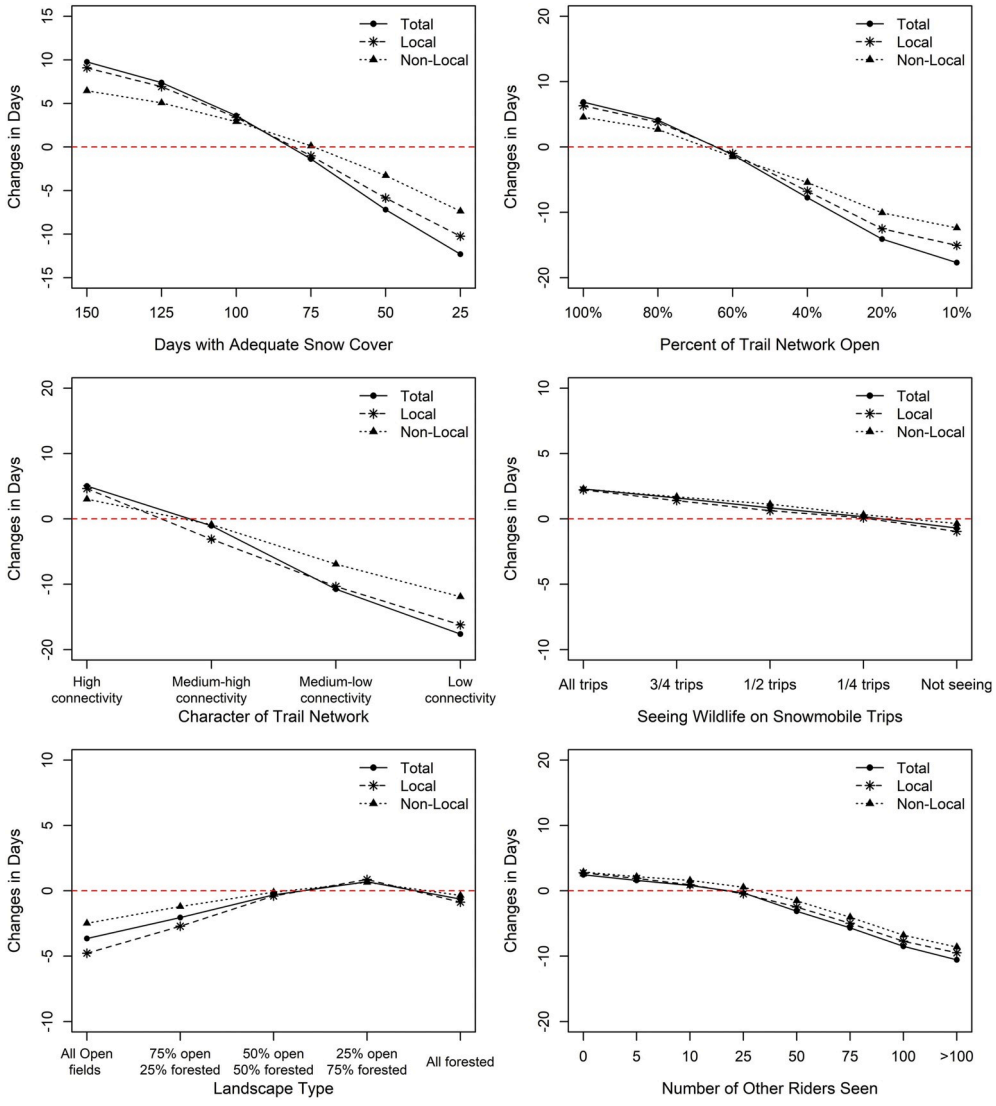


**Fig. 1.** Acceptability and norms of participation in snowmobiling in Vermont by local and non-local snowmobilers given changes in six categories of climate change impacts on the recreation experience.

report how their amount of snowmobiling in Vermont would change from their current levels, if at all, under a range of probable climate change-related scenarios (Fig. 1). Overall, local snowmobilers were more sensitive to climate change, with local snowmobilers generally reporting larger decreases in snowmobiling in each climate change scenario.

For days with adequate snow cover, the thresholds of current use levels for local and non-local snowmobilers were 85 and 75, respectively. With fewer days with adequate snow cover than these thresholds, snowmobilers will reduce their days of snowmobiling in Vermont. Local snowmobilers were significantly more sensitive to the change in days with adequate snow cover. For instance, when adequate snow cover drops to 50 days per year, local snowmobilers will reduce their snowmobiling in Vermont by almost a week (6.7 days), which is more than double the reduction by non-locals (3.2 days) ($p < 0.001$). When adequate snow cover drops further, to only 25 days per year, local snowmobilers will reduce their snowmobiling in Vermont by 11.7 days, versus 7.2 days by non-locals ($p < 0.001$).

Local snowmobilers are also more likely to alter their amount of snowmobiling when trail network conditions change. For instance, when 100% of the trail network is open, local snowmobilers will increase their snowmobiling by almost a week (6.6 days) versus 4.2 days by non-locals. The acceptability thresholds of the percentage of open trail network for local and non-local snowmobilers are the same (62% of open trail network). However, when the percentage of open trail network is less than the threshold, local snowmobilers report a significantly greater reduction in snowmobiling frequency than do non-locals. When only 20% of the trail network is open, locals would reduce their Vermont snowmobiling by two weeks (13.9 days) versus the non-locals' 9 days (8.8 days) ($p < 0.001$).

In regards to trail network characteristics, local snowmobilers are significantly more likely to decrease their snowmobiling with decreased trail connectivity (i.e., increased fragmentation). Under the lowest network connectivity (i.e., highest network fragmentation), local snowmobilers would decrease their participation by 17.5 days whereas non-locals would decrease theirs by 12.1 days ($p < 0.001$).

Unlike the significant differences seen between local and non-local snowmobilers' adaptation behaviors given variations in snow cover, open snowmobile trail network, and network connectivity, their adaptation behaviors were similar for wildlife prevalence and landscape types. For both groups, the thresholds to maintain current rates of snowmobiling are seeing wildlife on at least a quarter of the trips and having a trail experience that is 25% open and 75% forested landscape.

Local and non-local snowmobilers would maintain their current rates of snowmobiling in Vermont with 25 or fewer encounters on the trail per trip. When encounters range from 0 to 75, local and non-local snowmobilers reported similar levels of change for snowmobiling amount. However, with more than 75 encounters on snowmobile trails, local snowmobilers reported significantly greater declines in participation. For example, with 100 encounters, local snowmobilers would reduce their snowmobiling by 8.4 days, whereas non-locals would reduce theirs by 5.9 days ($p < 0.001$).

## 5. Discussion

This study identified that quality snowmobiling conditions are important to all snowmobilers in Vermont, regardless of whether they are Vermonters or not. Locals, however, are significantly more attuned to current deteriorations in snowmobiling conditions and more sensitive to a variety of likely future conditions. These are valuable findings for land managers and tourism advocates, and they lend nuance to discussions about the place of snowmobiling in the character of Vermont and as a recreation sport in general enjoyed by locals and non-locals alike. The following are a few key areas of observation from our findings.

First, study findings support our general hypothesis that local and non-local snowmobilers in Vermont have different use patterns of snowmobiling, preferences of snowmobiling conditions, perceptions about climate change impact on snowmobiling, and adaptation behaviors for changing climatic conditions. These findings align with the trend of an expected decline in participation of snowmobiling under projected climate change scenarios (Dawson & Scott, 2013; Scott et al., 2008; Wobus et al., 2017). Study results provide important insights on previously unreported factors that may affect the quality of snowmobiling experiences and potential coping and adaptation behaviors from both local and non-local snowmobilers' perspectives.

Second, local snowmobilers were found to have a higher use level of Vermont snowmobiling trail system, riding for 17.6 days in the state, or almost 1.5 times more days than non-locals do. Certainly, ease of spatial accessibility may be a factor (Lindberg & Veisten, 2012; Weber & Sultana, 2013; Xiao, Aultman-Hall, Manning, & Voigt, 2018). Local snowmobilers do not need to travel for as long of a distance to access the Vermont snowmobile trail system, assuming that locals ride local trails. More interestingly, our research indicates that local snowmobilers are more likely to ride on different trails than non-local snowmobilers. This implies that locals seek out diverse trails, perhaps lesser known to non-locals, and may relate to the intimate knowledge locals have of place and their longer recreation use history (Palso, Ivy, & Clemons, 2009) with snowmobiling. Vermonters will want to seriously consider if and how to advertise these "hidden gems" to outsiders if climate conditions worsen on known/advertised trails but the state still wants to promote (and economically benefit from) snowmobile tourism.

Through EFA, we identified four primary factors that may influence the quality of snowmobiling experiences: trail encounters, trail scenic views, trail accessibility/connectivity, and trail feature diversity. Supporting previous research, our study also shows that trail accessibility/connectivity is the most important factor to enhance the experience of snowmobiling for everyone (Pröbstl-Haider et al., 2019). This highlights the importance of consistent snow coverage along VAST's trail system, to maintain high quality experiences for locals and non-locals alike (McBoyle et al., 2007). Unlike the findings from previous studies that local and non-local visitors have significant differences in preferences for facilities development in nature tourism (Lindberg & Veisten, 2012), our study found only marginal differences in locals' and non-locals' preferences about facilities and conditions for snowmobiling. This may indicate that snowmobiling is a more self-sufficient form of recreation than other nature tourism endeavors and that further facility development/enhancement is neither a required nor sound investment for Vermont.

In addition, the diversity of trail features was significantly more desirable for non-local snowmobilers. This suggests that elements of trail diversity (challenging, fast, and snow-rich trails) are important quality considerations for non-Vermonters recreating in the state and that these attributes may be particular draws for non-locals to travel to Vermont for snowmobiling. These findings echo with the results from previous research that the diversity of terrain is a key factor for non-local skiers to Canada (Godfrey, 1999). Vermont holds appeal as a sparsely-populated bucolic destination with varied, mountainous terrain. This image may be heightened with those who are from out-of-state and thus travel to Vermont to engage with diverse trail features. Maintaining the exact conditions of trail feature diversity may not be possible under a changing climate. However, two of the three items in this factor, challenge and speed, are more climatically stable. The relative nature of the third (snow depth) compared to conditions in visitors' home states may still offer Vermont as a desirable recreation location. If and when changes occur to the feature diversity, Vermont may still want to market itself as still having relatively more challenging, faster, and more snow-abundant trails, especially in tourism advertisements and VAST communications with tourists from farther flung locations.

Results also highlighted that local snowmobilers are more sensitive to declining snowmobiling conditions due to climate change. Local snowmobilers reported significantly higher awareness about the reduced frequency of snowfall greater than 6 inches, depth of snow

throughout the winter, and length of winter season. It part, these observations are intuitive, as those who are local to an area generally have a more intimate awareness about its characteristics and more subtle changes than non-locals would. Also, locals had a longer participation history in snowmobiling and higher use of the VAST trail system, indicating a higher degree of specialization and related sensitivity to impacts (Manning, 2011). Following previous research that specialized skiers were more likely to alter their skiing behavior in deteriorated skiing conditions (Dawson et al., 2011), it is pertinent to examine how local and more highly invested snowmobilers would alter their snowmobiling in the local area given the probable climate change impacts. Because snowmobiling is snow-dependent, there are fewer options for temporal substitution (Pröbstl-Haider et al., 2019). Questions remain then about how spatial patterns of use may change and if the VAST trail network might see a shift from snowmobilers to other winter sports (cross--country skiing, snowshoeing, fat tire bicycling, etc.). Relatedly, the degree to which non-locals may also shift, and whether Vermont would remain a snowmobiling destination for them, warrants further study.

Lastly, the norms associated with six manifestations of climate change suggest that local snowmobilers have less tolerance for snowmobiling conditions that differ (unfavorably) from current conditions. For instance, while the threshold for days of adequate snow cover for non-locals to maintain their current use levels is 75 days, it is 85 days for locals. Vermont's current snowmobiling season ranges from 70 days to 102 days (Wobus et al., 2017), indicating some areas are already at risk of violating thresholds of local snowmobilers and have strong potential to violate the thresholds of non-local snowmobilers by the 2050s (Wobus et al., 2017). Based on the reported norms, we can estimate that use for local and non-local snowmobilers will decline 11.7 days and 7.2 days, respectively, assuming the snowmobiling season is 80% shorter under the high emission scenario (Frumhoff et al., 2007; Wobus et al., 2017). Beyond the length of snowmobiling season, local snowmobilers are more sensitive to trail closures and connectivity affecting their participation; under the most restrictive conditions for each, locals reported they would reduce their snowmobiling by 95%, compared to 70% for non-locals. These results suggest that under the future climate change scenarios, the non-local snowmobiling market might be less vulnerable to altered conditions and management strategies to expand the non-local snowmobiling market need to be developed to address the changing demands of snowmobiling under climate change impacts. Vermont is on the northern border of the US and may still have the best quality snowmobiling conditions in the Northeast, unless recreationists invest in a Canadian vacation (Hayhoe et al., 2008). Therefore, Vermont is still positioned to be "as good as it gets" in the area for these factors and may thus still draw recreationists because of this. However, any increases in non-local snowmobiling or increased local participation in the sport may be troubling for locals who are more sensitive to encounters (Manning, 2011; Xiao et al., 2019). It will be important to consider how patterns change and where exactly locals and non-locals are distributed across VAST's statewide trail network to identify potential hotspots of resource degradation and social conflict.

## 6. Conclusion

This study examined local and non-local snowmobilers' preferences for snowmobiling conditions, perceptions about climate change on VAST trails, and adaptation behaviors to varying scenarios of climate change. The results suggested that local snowmobilers have a higher use level of Vermont snowmobiling trail system than non-local snowmobilers. The non-local snowmobilers have a higher desirability of the diversity of trail features than local snowmobilers, whereas local snowmobilers are more sensitive to climate change conditions than non-local snowmobilers, e.g., the frequency of snowfall, the depth of snow, and the length of winter season. The study results also indicated that local snowmobiling markets are more vulnerable than non-local snowmobiling markets to future climate change scenarios. Our study findings provide land managers guidance for maintaining high quality of snowmobiling experiences and adaptation planning strategies for local and non-local snowmobiling market under future climate change scenarios.

While our study results have implications for existing and future research on climate change and winter tourism activities, the limitations of this study must be acknowledged. First, the climate related conditions for snowmobiling included in this study were primarily focused on the depth and variability of snow, the length of the winter, and the number of snowmobiling trails. The condition of snow (i.e., dry or wet snow) might also influence the quality of snowmobiling (Pröbstl-Haider et al., 2019), which will be worthwhile to examine in the future study to inform climate change adaptation for snowmobiling. Second, we collected data solely in Vermont, where there is a distinct composition of local and non-local recreationists. It is advisable that future research on climate change and winter tourism is carried out in other areas, to better capture a wider audience's perceptions and preferences on this topic, as well as account for other influencing factors (e.g., sport skill level, serious leisure) beyond tourists' localism. Given the fact that climate change is occurring worldwide, future studies should examine the topic of climate change in a wider context of tourism by examining additional tourism activities (e.g., skiing) and tourism markets (e.g., social tourism, volunteer tourism).

## CRediT authorship contribution statement

**Xiao Xiao:** Conceptualization, Investigation, Methodology, Writing - original draft. **Elizabeth E. Perry:** Writing - review & editing, Methodology. **Jie Gao:** Writing - review & editing, Validation, Software. **Junyu Lu:** Formal analysis, Visualization, Methodology. **Robert Manning:** Funding acquisition, Project administration.

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