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Special Issue

Social Climate Change: The Advancing Extirpation of Snowmobilers in Vermont

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Abstract

Climate change has potential to substantially affect the availability and quality of snow and thus has potential to affect snow-dependent winter recreation activities. Research has shown that participants in these recreation activities are adapting to climatically changed conditions and are likely to continue to adapt in the future. This study explores these issues as they apply to snowmobiling in Vermont, identifying a suite of climate change manifestations, investigating their salience to the snowmobiler recreation experience, and assessing how these manifestations may impact the snowmobile participation rate and quality of experience. Climate change manifestations are informed by climate change models, helping to define the future conditions and supply of snowmobiling opportunities. Social science research on how snowmobilers may adapt to these changing conditions helps define the future demand for snowmobiling. We conducted an online survey of snowmobilers in Vermont, asking respondents if and how they would change the amount of snowmobiling they do in response to climate change manifestations that may impact snowmobiling

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conditions. Study findings suggest that the amount of snowmobiling in Vermont is already declining and that these declines are likely to become more substantial. For example, 44.7% of respondents have noticed declines in the length of the winter season during which there is enough snow to snowmobile, and 30.7% of respondents have decreased their amount of snowmobiling in response. Moreover, study data define the future relationship between climate-related changes in snowmobiling conditions and changes in amount of snowmobiling. For example, with 150 days of adequate snow cover, the amount of snowmobiling will increase 36.9%, but with 25 days of adequate snow cover, the amount of snowmobiling will decrease 44%. The length of season threshold for participation in snowmobiling is estimated at 79 days; more than 79 days will cause snowmobiling to increase from current levels, and fewer than 79 days will cause a decrease. Given the climate change sensitivity of snowmobiling found in this study, along with the predictions of climate models for Vermont, snowmobiling may ultimately be unsustainable. This will decrease the benefits of snowmobiling, including the enjoyment of locals and tourists who participate in the sport, the economic contributions, and the culture of the state. Substitution of other winter season recreation activities is a potential adaptation to declining opportunities for snowmobiling.

Keywords

Climate change, adaptations, snowmobiling, outdoor recreation, Vermont

Introduction

Winter recreation is often dependent on the availability and quality of a specific natural resource—snow. As climate change alters the consistent availability and quality of snow, recreationists will need to adapt their snow-dependent activities and behaviors. Indeed, research suggests that participants in outdoor winter recreation activities are adapting their behavior (e.g., altering the recreation activities in which they participate as well as the amount, location, and timing of recreation activity) in response to climate change and are likely to continue to do so in the future. One study estimated the effects of climate change on participation in selected outdoor recreation activities and found that a 2.5°C increase in temperature and a 7% increase in precipitation were both associated with significant decreases in downhill and cross-country skiing days (52%) (Loomis & Crespi, 1999). A review paper on climate change-related adaptations in outdoor recreation found that climate change would have a negative effect on snow- and ice-based activities in Ontario (Browne & Hunt, 2007). In Europe, changes have already been detected in the "snow security" for and participation patterns in winter tourism activities such as downhill and cross-country skiing, and participation has declined as well (e.g., Agrawala, 2007; Landauer, Sievänen, & Neuvonen, 2015; Tranos & Davoudi, 2014). Beyond downhill, cross-country, and alpine skiing, participation is expected to decrease in all winter sports, including ice fishing, snowmobiling, and skating, due to reduced opportunities (Browne & Hunt, 2007). Reductions are expected to vary by region and by activity and will depend on the length of the initial season and the length of the new season (Browne et al., 2007). For example, across the Alps and northern reaches of Europe, the change in snow-cover days to fewer than 100 per season has already limited opportunities for participation in winter sport tourism (Tranos & Davoudi, 2014). In the same area, snowfall models suggest that a 1°C increase in global air temperature would render 10% of alpine ski resorts "snow unreliable," with increases to 33% with a 2°C increase (Agrawala, 2007), further limiting opportunities for snow-dependent winter recreation. In the U.S., models of climate change under higher and lower emission scenarios, coupled with anticipated population growths, suggest that downhill skiing and snowmobiling may lose 12-20% and 4-11% of their current visits, respectively, by 2050, while cross-country skiing participation may fluctuate between a 6% gain to 2% loss in visits (Wobus et al., 2017). By 2090, there is more uncertainty in the models but the anticipated changes are greater: 6-45% reduction in downhill skiing visits, 17% gain to 31% loss in cross-country skiing visits, and 3% gain to 43% loss in snowmobiling visits (Wobus et al., 2017). Beyond the dependence of these activities on sufficient snow resource conditions, factors influencing these demand levels in climate change modeling may include tourist sociodemographic characteristics (e.g., age, culture) and the holiday type (Gössling, Scott, Hall, Ceron, & Dubois, 2012).

The climate-related character of the northeastern United States, in part defined by its pronounced seasonal variations, is also undergoing noticeable changes. The percentage of precipitation in New England (defined by the National Ski Area Association as the six northeastern U.S. states bordered by New York on the west, plus New York) that falls as snow has declined significantly throughout the region between 1949 and 2000 (Huntington, Hodgkins, Keim, & Dudley, 2004). While the rate of projected future warming in the Northeast is lower than in other regions of the U.S., winter minimum temperatures are still expected to increase 2-5°C by 2100 (National Assessment Synthesis Team, 2001). Warmer temperatures in New York and New England are projected to reduce average number of days with snow cover 50% under a low emissions scenario and 75% under a higher emissions scenario (Burakowski & Magnusson, 2012). The anticipated related reductions in downhill skiing visits in the Northeast are among the most significant in the country (Wobus et al., 2017). Current trends in wintertime climate in the northeastern United States already show a reduction in the number of snow-covered days in the winter. Changes in Vermont winter temperatures have been following this regional pattern. In the past 50 years, the mean winter temperature in Vermont has risen about 2.5°C and freeze periods have become shorter by about 3.7 days per decade (Betts, 2011a). Even under low carbon emission scenarios, climate models predict increases in temperatures will continue into the future (Frumhoff, McCarthy, Melillo, Moser, & Wuebbles, 2007; Hayhoe et al., 2008). Such changes in climate could have dramatic effects on the amount and types of outdoor recreation in which Vermont visitors and residents participate.

For some recreation activities, temporary technological "fixes" may help to stave off the impacts of climate change. Snowmaking technology, for example, is widely used to adapt to a growing lack of natural snow cover. Use of snowmaking will mean most of the alpine skiing industry is likely to remain viable into at least the 2050s under all but the warmest climate change scenarios in the southern Canadian provinces of Ontario (Scott, McBoyle, & Mills, 2003), Quebec (Scott, McBoyle, & Minogue, 2007), and the state of Vermont (Dawson & Scott, 2007). Other winter recreation activities are potentially more vulnerable to the effects of climate change. Negative effects on ice-fishing, skating, Nordic skiing, and snowmobiling will occur due to reductions in, and unreliability of, natural ice and snow cover (Lofgren et al., 2002; Scott & Jones, 2006; Scott, Jones, & Khaled, 2005). This highlights the vulnerability of these sports and their ancillary economic and other benefits to communities (Pachauri et al., 2014).

What might this mean for snowmobiling in Vermont? The snowmobiling and cross-country skiing season across Vermont is currently estimated at 5-14 weeks (Wobus et al., 2017). Most snowmobile trails are located at lower elevations, and snowmobiling relies entirely on natural snowfall due to the linear nature and long distances of snowmobile trails, making widespread implementation of snowmaking impractical (Burakowski & Magnusson, 2012). This means that climate trends in the northeastern United States and elsewhere have the potential to substantially impact snowmobiling in the region. Burakowski and Magnusson (2012) posit that consecutive years of insufficient snow may have already altered snowmobile participation in the U.S.; national snowmobile registrations have been fairly flat to decreasing since 2000. Mcboyle, Scott, and Jones (2007) used a model on future snow depth estimates to examine the potential impact of two climate change scenarios on the length of snowmobiling seasons in the 2020s and 2050s at 13 non-mountainous sites in Canada. In the Provinces of Ontario and Québec, average length of snowmobile seasons in the 2020s are projected to be reduced between 11% and 44% under the low emission climate change scenario, and between 39% and 68% under the high emission climate change scenario. Under the high emission scenario for the 2050s, a reliable snowmobiling season would be essentially eliminated from Canada's non-mountainous region. Similarly, Scott, Dawson, and Jones (2008) found that as early as the 2020s, some regions in the northeastern United States (including Vermont) are projected to lose more than half of the current snowmobile season, and that reliable snowmobile seasons of greater than 50 days will be all but eliminated by the end of the century. Under current climate projections, this trend is expected to continue. Considering the estimated 32,251 registrations and 310,900 snowmobile days in Vermont in 2009-2010, the 13th highest rates in the nation (Burakowski & Magnusson, 2012), effects on the recreation experience and related economic impacts may be large. These studies suggest that many winter outdoor recreation activities may be highly climate dependent and, therefore, especially vulnerable to climate change. Although this vulnerability has been noted, the winter tourism industry of skiing and snowmobiling are often reported together (Burakowski & Magnusson, 2012) or with primary focus on the skiers (Dawson & Scott, 2013; Pütz et al., 2011). The salience of particular manifestations of climate change to the snowmobiler recreation experience and the ways in which snowmobilers are adapting or may adapt their recreation behavior in response to these changes has received less attention.

Study Objectives

The objective of this study was to explore adaptations to multiple manifestations of climate change by snowmobilers in Vermont. Climate models developed in the physical/natural sciences suggest a number of manifestations of climate change that may influence the quality of snowmobiling (Betts, 2011; Pontius & Duncan, In review). These manifestations of climate change were integrated into a survey questionnaire administered to snowmobilers in Vermont to help estimate the effects of climate change —in the recent past, and into the future—on snowmobiling in Vermont. Rather than specify a single climate scenario or narrow range of conditions for each manifestation, this study was intended to provide managers with insight into current and potential snowmobiler behavioral adaptations for a number of different climate change manifestations and large ranges of each. In this way, climate change manifestations salient to the snowmobiling experience and thresholds for snowmobiling participation for each can be determined. Our general hypothesis is that many snowmobilers are already adapting their participation in the sport (e.g., reducing snowmobiling activity) as a function of changing climatic conditions and that these adaptations will become more extreme (e.g., further reducing snowmobiling activity) as climate change progresses.

Study Methods

Survey Administration

The primary study method was an online survey of members of the Vermont Association of Snow Travelers (VAST). Online surveys have potential advantages over conventional mail surveys, including faster speed of responses and lower cost. VAST is the primary organization of snowmobilers in Vermont and the organization maintains and grooms a network of over 5,000 miles of snowmobile trails in the state. Snowmobilers who wish to use this system of trails must join VAST and purchase a Trail Maintenance Assessment (TMA) pass. At the time of the survey, there were 23,565 snowmobiles registered for a 2014-2015 TMA pass on the VAST trails. VAST's membership list at the time of survey administration encompassed 10,292 email addresses; the number of members who did not have or did not provide an email address was not provided to the researchers. The survey was administered to all TMA pass holders with an email address (10,292); 2,195 addresses were returned as undeliverable, and thus the viable population for this study totaled 8,097 members. The survey was conducted between November 17 and December 14, 2015. The VAST TMA pass holders received an email message from VAST, which was signed by both the principle investigator at the University of Vermont and the VAST Executive Director on November 17, requesting their participation in the survey with a hyperlink to the study questionnaire. Those who had not completed the online questionnaire by November 30, 2015, received a reminder email with the link to the questionnaire, requesting again that they participate. The online survey was closed at noon on December 14, 2015. A total of 1,450 responses were received, yielding a response rate of 17.9%. Detailed online surveys tend to receive response rates averaging 10%–25% (Sauermann & Roach, 2013); this study's response rate was within this range.

Online surveys can be designed in ways that are interactive with respondents (Pan, 2010). In this survey, the online questionnaire provided visual information about changes to snowmobile trail networks, which were designed to help respondents understand the question more clearly. In addition, links to four videos were embedded in the questionnaire that more fully explained some of the most challenging questions and illustrated how the response scales worked. Video links were provided to respondents to explain questions and response options in this alternative form of media. In these videos, a narrator described the questions and illustrated use of the response scales. The four videos were accessed a total of 620 times, suggesting that many respondents used this additional feature, that they may have found it helpful, and that the videos may have contributed to the quality of resulting data.

Non-Respondent Bias

Although non-response biases can vary across online surveying efforts, research suggests that data collected via online approaches may contain only relatively small errors in reflecting tourism patterns (Choe & Fesenmaier, 2016). The methods incorporated efforts to improve response rates and representativeness of the resulting sample, such as email reminders to non-respondents (Dolnicar, Laesser, & Matus, 2009). To examine non-respondent bias, Vermont versus non-Vermont respondent proportions were compared to their respective proportions in the VAST membership database. When compared to overall VAST membership, members from outside of Vermont were oversampled in the current study. VAST membership at the time of the study consisted of approximately 67% Vermont residents and 33% out-of-state residents. Our sample had roughly a 50%–50% mix of Vermont and out-of-state residents. However, there were few significant differences between the two subsamples on relevant variables, indicating that oversampling of out-of-state residents did not substantially alter study findings.

Survey Instrument

The survey questionnaire collected information on four main topical areas. First, characteristics of snowmobilers (e.g., age, years of snowmobiling participation, participation in other winter activities [Table 1]) and second, snowmobile use (e.g., number of days per year snowmobiling, length of rides) were collected for insight into who is currently snowmobiling and what are their basic patterns of use.

The third and fourth areas of questioning regarded perceptions of the snowmobile experience and any current or future climate-related adaptations. For these, a diversity of climate change manifestations and wide range of conditions for those manifestations were selected for inclusion. In this way, the instrument design attempts to account for the uncertainty inherent in the climate change model (Pontius & Duncan, In review) and provide a spectrum of climate-influenced conditions sensitive enough to detect physical and/or social change. Because conditions for each of the metrics vary across the topography of Vermont and VAST's trail network, the options provided for current and potential conditions are relative percentages rather than fixed quantities of snow, wildlife, etc. This deliberate framing allowed for questions to be applicable to wherever the respondent snowmobiles in Vermont.

The third main topical area regarded adaptations to climate change (e.g., altered snowmobiling behaviors). This portion of the questionnaire included two batteries of questions on climate-related changes and manifestations of climate change, which were gleaned from the climate change literature, models noted above (e.g., Betts, 2011; Pontius & Duncan, In review), and project scoping discussions with VAST staff.

- The first battery asked respondents if they had noticed any of nine potential manifestations of climate change and, if so, how they have altered the amount of snowmobiling they do in Vermont, if at all, to address these climate-related changes. These included variability of winter temperatures from year to year, forest health along the snowmobile trails, average coldness of winters, extent of snowmobile trails throughout the state, variability of snow depth from year to year, variability of snow coverage along trails from year to year, depth of snow throughout the winter, frequency of snowfall greater than six inches, and length of

Table 1

Other Winter-Based Recreation Activities in which Respondents Participate

Activities	Frequency	Percent*
Snowshoeing	446	30.8
Alpine/downhill skiing	433	29.9
Hunting	293	20.2
Viewing sporting events	234	16.1
Sledding	232	16.0
Ice fishing	213	14.7
Ice skating	187	12.9
Nordic/cross-country skiing	142	9.8
Snowboarding	100	6.9
Other	94	6.5
Pond hockey	82	5.7
Indoor hockey	57	3.9
Horseback riding/Horse drawn sleigh riding	31	2.1
Ice climbing	6	0.4
Trapping	6	0.4
Dog sledding	1	0.1

*Respondents could choose more than one response, so percentages total more than 100%.

the winter during which there is enough snow to snowmobile. The response scale for the first part of the question was "increased," "stayed the same," and "decreased," while the response scale for the second part of the question was "increased my snowmobile riding," "snowmobile riding stayed the same," and "decreased my snowmobile riding" (see Tables 2 and 3 for exact question wording).

- The second of battery asked respondents how they would alter the amount of snowmobile riding they do in Vermont in response to seven potential manifestations of climate change: number of days per year with adequate snow cover, percent of the VAST trail network open, integrity of the VAST trail network (i.e., the degree of connectivity within the trail network, seee Figure 1), wildlife seen, type of landscape represented in the trail network (i.e., open versus forested lands), number of snowmobilers encountered per day along trails, and increases in driving distance required to reach trailheads. In this battery of questions, respondents were presented with a range of changing conditions in these seven manifestations of climate change, including both improvements and declines. Because "amount" of snowmobiling may have different connotations, the question was specified as "percent change you would expect in the number of days" from current behavior. Thus, respondents were asked the degree to which each resulting condition would alter the number of days of snowmobiling they would do in Vermont. The range of conditions in the integrity of the VAST trail network was represented in the four trail system maps shown in Figure 1. The nine response scale options included 1) "decrease participation by 100% (you would no longer snowmobile in Vermont)," "decrease participation by 75%," "decrease participation by 50%," "decrease participation by 25%," "no change in participation (you would ride the same number of days you do now)," "increase participation by 25%,"" increase participation by 50%", "increase participation by 75%", and "increase participation by 100% (you would double the number of days you snowmobile in Vermont)" (see Table 4 for exact question wording).

Finally, the fourth main topical area of questioning regarded characteristics of high-quality snowmobiling. Based on the literature on snowmobiling and consultation with VAST staff, a list of variables was presented to respondents that might affect the quality of snowmobiling. Respondents were asked to rate the degree to which each variable adds to or detracts from the quality of snowmobiling. The five-point response scale ranged from "detracts a great deal" to "adds a great deal" (see Table 5).

Analysis centered on examining frequency data for all questions included in this survey. Additionally, the responses of snowmobilers who had noticed declines in conditions were examined separately (Table 3). Where appropriate, standard deviations and Vander Eijk's A are reported. Vander Eijk's A is a measure of consensus levels among respondents, ranging from -1 to 1; values approaching -1 indicate higher levels of disagreement and values approaching 1 indicate higher levels of agreement within the sample (Krymkowski, Manning, & Valliere, 2009).

Table 2

Changes Noticed in Climatic Conditions and their Effect on Snowmobile Activity

	Notice change %			Change in snowmobiling %		
	Decrease (-1)	Same (0)	Increase (1)	Decrease (-1)	Same (0)	Increase (1)
Length of the winter during which there is enough snow to snowmobile	44.7	38.7	16.6	30.7	43.2	26.1
Depth of snow throughout the winter	37.6	41.6	20.8	22.3	50.1	27.7
Frequency of snowfall greater than 6 inches	35.9	47.3	16.8	19.2	54.0	26.8
The variability of snow depth from year to year	26.1	49.5	24.4	25.1	64.7	10.2
The variability of snow coverage along the trails from year to year	25.9	51.5	22.5	25.6	64.9	9.5
The average coldness of winters	19.3	60.9	19.8	15.5	74.0	10.5
The extent of snowmobile trails throughout the state	16.3	68.0	15.6	5.8	75.6	18.6
The variability of winter temperatures from year to year	14.6	58.7	26.7	22.2	69.8	8.0
Forest health or quality along snowmobile trails	6.4	83.3	10.3	1.8	87.2	11.0

Table 3

Adaptations to Recent Declines in Climate-Related Snowmobile Conditions

	Notice change %	**Change in snowmobiling when noticing declining climate related conditions for snowmobiling %**		
	Decrease (-1)	**Decrease (-1)**	**Same (0)**	**Increase (1)**
Length of the winter during which there is enough snow to snowmobile	44.7	73.8	23.0	3.2
Depth of snow throughout the winter	37.6	61.9	34.3	3.8
Frequency of snowfall greater than 6 inches	35.9	57.3	39.3	3.3
The variability of snow depth from year to year	26.1	59.7	37.8	2.6
The variability of snow coverage along the trails from year to year	25.9	62.6	35.4	2.1
The extent of snowmobile trails throughout the state	16.3	37.1	61.4	1.5
The average coldness of winters	19.3	51.9	40.3	7.8
The variability of winter temperatures from year to year	14.6	63.4	29.7	6.9
Forest health or quality along snowmobile trails	6.4	23.1	75.0	1.9

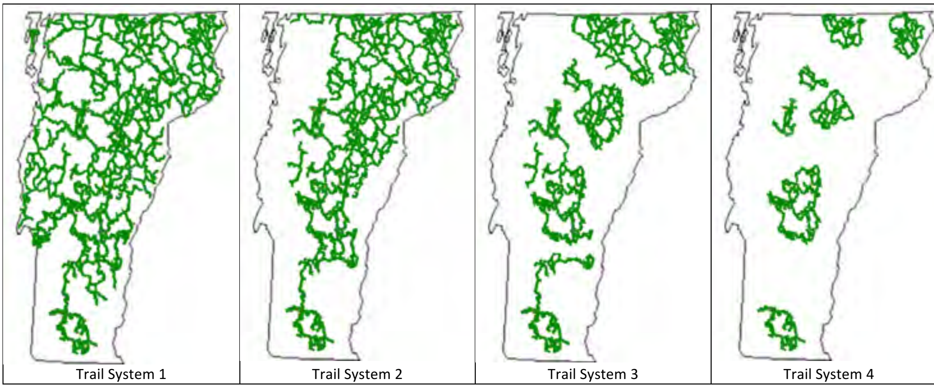

Figure 1. Maps illustrating changes in the integrity of the VAST trail network.

Table 4

Reported Future Adaptation to Seven Manifestations of Climate Change

	Change in snowmobile activity %									Statistics		
	Decrease				No change	Increase						
	100%	75%	50%	25%	0%	25%	50%	75%	100%	Mean Change	SD	A
Days with adequate snow – Threshold = 79 days with adequate snow												
150	0.6	0.4	0.9	1.2	30.3	19.1	23.5	9.4	14.7	36.9	38.1	0.55
125	0.4	0.3	0.7	2.7	37.5	24.7	16.9	8.7	8.2	27.9	34.6	0.65
100	0.5	0.1	1.7	7.2	52.8	17.7	10.3	4.3	5.3	15.1	32.4	0.70
75	1.7	1.7	7.1	24.2	45.8	9.3	4.9	2.4	3.0	-2.9	34.1	0.66
50	4.7	9.5	23.8	21.5	28.8	4.8	2.8	1.8	2.2	-23.0	40.2	0.52
25	17.0	27.0	19.6	8.5	19.5	2.7	1.3	1.3	3.1	-44.0	47.5	0.44
Percent trail network open – Threshold = 66 percent of trail network open												
100	0.6	0.6	0.2	0.7	48.5	16.6	17.3	5.7	9.8	25.9	35.5	0.68
80	0.7	0.4	0.8	3.7	61.2	13.0	10.5	5.2	4.6	14.7	31.8	0.75
60	1.6	1.3	7.9	24.9	49.9	7.1	4.3	1.6	1.7	-6.1	30.6	0.71
40	6.7	8.8	24.8	26.9	26.2	3.1	1.8	0.9	0.9	-29.7	36.0	0.58
20	22.3	26.9	24.0	8.3	15.3	1.1	0.5	0.8	1.0	-54.6	39.6	0.55
10	44.6	27.1	7.8	3.9	13.6	0.7	0.4	0.5	1.5	-67.9	42.4	0.63
Trail System Integrity (see Figure 1) – Threshold = Trail System 1.7												
Trail System 1	0.2	0.3	0.8	1.2	60.3	13.0	11.6	5.7	7.0	19.3	32.8	0.76
Trail System 2	1.7	3.0	9.9	16.9	58.1	4.7	2.8	1.5	1.4	-8.1	30.8	0.73
Trail System 3	12.6	19.7	25.1	18.7	20.5	1.3	0.9	0.5	0.7	-42.9	36.9	0.53
Trail System 4	43.6	26.2	14.5	6.2	7.5	0.3	0.4	0.7	0.6	-70.7	35.5	0.71
Wildlife viewing – Threshold = Seeing wildlife on approximately 20 percent of trips												
Seeing wildlife on all trips	0.3	0.1	0.5	0.8	71.0	13.5	7.1	3.6	3.1	12.1	26.0	0.85
Seeing wildlife on 3/4 trips	0.2	0.3	0.4	1.0	77.7	10.6	5.2	3.0	1.7	8.5	22.4	0.88
Seeing wildlife on half of trips	0.3	0.3	0.3	2.1	83.7	7.0	3.4	1.8	1.1	4.8	19.5	0.90
Seeing wildlife on 1/4 trips	0.3	0.8	1.4	3.8	85.8	4.4	1.6	1.4	0.6	1.1	18.1	0.90
Not seeing wildlife on trips	1.3	1.5	3.7	4.7	86.3	1.0	0.4	0.7	0.5	-3.8	20.3	0.91

cont.

Table 4 (cont.)

Landscape type – Mixed landscapes are preferred											
100% open fields	2.5	8.0	17.9	18.4	44.7	3.9	2.3	1.0	1.3	-17.9	34.7	0.66
75% open/25% forested	1.2	3.5	9.8	19.9	55.6	6.0	2.2	1.4	0.5	-9.5	28.2	0.75
50% open/50% forested	0.6	1.2	4.1	7.8	74.9	7.2	2.6	1.1	0.5	-1.0	22.1	0.84
25% open/75% forested	0.5	0.7	1.8	7.1	73.9	10.1	4.1	1.2	0.7	2.4	21.7	0.85
100% forested	1.6	2.5	6.4	14.2	61.8	6.3	4.5	1.6	1.2	-4.1	29.9	0.73
Number of Snowmobilers seen/encountered – Threshold = 23 snowmobilers seen/encountered											
0	0.4	0.3	1.7	4.1	63.6	10.9	9.8	4.0	5.2	13.4	31.6	0.75
5	0.3	0.2	.6	1.8	73.2	11.7	6.5	3.7	2.0	9.8	24.9	0.85
10	0.2	0.0	.6	1.9	81.3	8.5	4.1	2.1	1.3	6.1	20.4	0.89
25	0.3	0.6	2.6	9.1	79.1	4.2	3.1	0.6	0.5	-0.9	19.1	0.88
50	1.5	3.1	9.7	24.6	57.5	2.0	1.3	0.1	0.3	-13.4	24.6	0.80
75	4.3	7.8	18.8	27.1	39.5	1.6	0.7	0.1	0.1	-25.5	29.7	0.71
100	10.6	14.7	22.6	20.6	29.8	1.3	0.2	0.2	0.1	-37.5	34.6	0.59
More than 100	19.4	18.8	20.2	15.7	24.8	0.4	0.4	0.1	0.2	-47.0	37.8	0.51
Extra distance travelled to get to trails – Threshold = Any extra distance travelled											
10%	2.2	1.4	3.7	16.1	74.8	0.9	0.6	0.1	0.3	-8.2	22.0	0.88
20%	4.3	2.0	11.2	26.4	54.6	0.6	0.8	0.0	0.2	-17.3	27.0	0.79
30%	6.7	7.3	19.0	34.8	30.5	1.0	0.2	0.3	0.2	-29.7	30.3	0.69
50%	13.0	16.3	29.2	22.1	18.1	0.5	0.2	0.1	0.4	-44.6	33.5	0.59
100%	23.5	23.1	24.3	13.6	14.5	0.4	0.2	0.2	0.3	-55.7	35.5	0.56
300%	39.8	24.2	16.0	7.7	11.1	0.6	0.3	0.1	0.3	-67.2	35.9	0.66
400%	51.4	21.7	11.6	3.4	10.7	0.2	0.3	0.2	0.4	-73.6	35.8	0.72

Study Findings

Characteristics of Snowmobilers

Characteristics of respondents. Snowmobilers in Vermont are generally an aging, male-dominated, and active population. Respondents ranged in age from under 20 years to over 80; nearly 40% are in the age category of 51–60. Nearly 90% of respondents were male. Just over half of respondents are Vermont residents, with the other half of respondents hailing from other New England states, New York, New Jersey, Pennsylvania, and seven other states. This suggests the importance of Vermont as a snowmobiling destination in New England for Vermont residents and non-residents alike. Just over a third of respondents have earned a college or advanced degree.

Characteristics of respondents' winter recreation activities. Respondents were asked which of 15 additional winter-based recreation activities they participate in; they were also allowed to list other winter-based recreation activities not enumerated in the question (Table 1). Some respondents (31%) also participate in other winter recreation activities beyond snowmobiling. The findings are listed in Table 1. These data show that many snowmobilers participate in a wide variety of activities, led by snowshoeing, alpine/downhill skiing, and hunting.

Patterns of Snowmobiling

Respondents have participated in snowmobiling for an average of nearly 25 years and ride their snowmobiles an average of 25 days per year (21 of those days, or 84%, in Vermont). An average ride is just over 93 miles accounting for an average of about 1,300 miles per year (1,065 of those miles, or 81.9%, in Vermont). Although averaging 1,300 miles per year, more than one-third of respondents logged more miles per season, with

Table 5

Conditions Affecting the Quality of the Snowmobile Experience

	Response (%)				
	Detracts a great deal (-2)	Detracts a little (-1)	Neither adds nor detracts (0)	Adds a little (1)	Adds a great deal (2)
Consistent snow cover along the trail	0.0	0.6	4.8	14.0	80.6
Regular grooming of trails	0.1	0.5	5.7	16.3	77.4
Being able to begin your ride at home	0.5	0.4	9.9	11.3	78.0
Easy access to services & facilities	0.0	0.9	9.1	35.0	55.0
High quality scenery along the trail	0.1	0.1	10.3	35.8	53.6
Interconnectivity of trails for making loops and tours	0.8	1.4	12.5	28.3	56.9
Ability to travel great distances	0.3	1.9	15.1	30.4	52.4
Visiting natural features	0.0	0.6	13.1	43.7	42.6
Getting away to remote places	0.4	0.4	16.0	37.8	45.5
Seeing wildlife	0.1	1.2	17.1	39.4	42.1
Long stretches without development	0.2	2.8	27.3	38.9	30.8
Visiting historic/cultural features	0.2	1.7	32.4	42.7	23.0
Deep snow	2.7	10.2	29.6	27.9	29.6
Ability to travel fast on trails	2.7	4.5	35.6	35.1	22.0
Being able to use your snowmobile to run errands	2.2	2.6	44.6	30.1	20.5
Challenging trail features	3.7	13.5	35.1	33.6	14.0
Encountering other snowmobiles along the trail	1.1	21.3	58.7	16.6	2.3
Encountering dog sleds along the trails	17.3	28.1	40.7	10.9	3.0
Encountering snowshoers along the trail	14.0	30.3	50.7	4.4	0.6
Road crossings	6.3	45.6	44.7	3.1	0.3
Encountering cross-country skiers along the trail	15.5	29.7	49.3	4.8	0.7
Having to drive to snowmobile trails	31.2	38.9	26.3	1.6	2.0
Encountering bikers along the trails	37.4	30.5	29.4	2.0	0.7

a few in excess of 4,000. Most respondents (65.8%) typically access trails from their home; the remainder typically trailer their snowmobile an average of about 40 miles to trailheads. Snowmobiling appears to be a social sport; more than half (53.7%) ride in mixed groups of family and friends and only 5.2% of respondents typically ride alone.

Current Adaptations to Climate Change

Various proportions of respondents are noticing climate change and adapting their snowmobile behavior accordingly. These data are shown in Table 2. Respondents reported that they have noticed declining conditions for snowmobiling, the most pronounced of which are length of winter during which there is enough snow to snowmobile (44.7%), depth of snow throughout the winter (37.6%), and frequency of snowfalls greater than six inches (35.9%). However, other respondents (10.3% to 26.7%) reported that the condition of the nine variables included in the question had improved. The remainder of respondents (38.7% to 83.3%) reported that they had noticed no change in these conditions.

It may be more important to focus specifically on the adaptations of respondents who report having noticed changes in climate that may affect the amount of snowmobiling they do. Table 3 shows adaptations of only those who noticed climate-related declines in snowmobile conditions. The majority of these respondents have reduced the amount of snowmobiling they do in response to all of these climate-related changes, with the exception of forest health or quality along snowmobile trails. For instance, nearly three-quarters of respondents reported reducing their participation in snowmobiling in response to reductions they have noticed in the length of winter during which there is enough snow to snowmobile. Around two-thirds of respondents reported reductions in their participation after noticing either a decreased depth of snow throughout the winter, variability of snow coverage along trails from year to year, or variability in winter temperatures from year to year. In general, the most obvious and definitive climate-related changes predicted (Betts, 2011, Pontius & Duncan, In review) are the ones noticed by the highest percentages of snowmobilers. This relationship is important, as it may lead to a steep decline in snowmobiling as these climate-related changes become pronounced and obvious on the winter recreation landscape.

Future Adaptations to Climate Change

The second battery of questions described a range of conditions for the seven potentially important climate-related variables outlined earlier and listed in the first column of Table 4. For each of the seven variables, the range of conditions varied from better than existing conditions to worse than existing conditions. Respondents were asked to report how they would alter their amount of snowmobiling (percentage change in days of snowmobiling in Vermont) for each of the range of conditions described. Study data are shown in Table 4 and are graphed in Figure 2a-g.

Table 4 reports standard deviations and Vander Eijk's A for the reported changes in snowmobile participation (Krymkowski et al., 2009). The generally low value of the standard deviation statistics suggests that there is substantial consensus about reported changes in participation among the sample. Vander Eijk's A values for six of the seven variables were higher than 0.5 and the average of all seven was 0.72, indicating strong agreement among respondents for each measure.

The mean change in amount of snowmobiling in Vermont to each condition for the seven climate-related variables is plotted in Figure 2. For five of the seven variables (number of days with adequate snow cover, percentage of the VAST snowmobile trail network open, character of the VAST snowmobile trail system, number of snowmobilers along the trail, and extra travel distance to trailheads), respondents reported that they would snowmobile more as climate-related conditions changed for the better and less as they changed for the worse. This sensitivity is illustrated by the amplitude of the data lines in Figure 2. For example, when asked about the percent of the trail network open (Figure 2b), respondents indicated that the number of days of snowmobile use will increase 25.9% from current levels as the percentage of the trail network open increases to 100%, but will decrease 67.9% as the percentage of the trail network open falls to 10%. The other two variables (seeing wildlife [Figure 2d] and landscape type [Figure 2e]) appear less salient to the quality of the experience. Of course, climate models suggest that the condition of all the climate-related snowmobile variables included in the study will decline or are already in decline (Burakowski et al., 2008; Keim & Rock, 2001).

Because we collected data on the average number of days respondents snowmobile in Vermont per year (21 days) and the average number of miles ridden in Vermont per year (1,065 miles), we are able to estimate the effects of percentage change in participation on these measures of use. Following the example above, a decline in the percentage of trail network open to 10% translates to a drop of 14.1 days of annual participation in the sport and a drop of 724 miles ridden per year, or about half of current use.

In addition to trends in participation, the graphs in Figure 2a-g and the associated data in Table 4 suggest thresholds at which the amount of snowmobiling in Vermont will change from increasing to decreasing levels. For example, this threshold is about 79 days per year for the number of days with adequate snow cover; with more than 79 days per year, snowmobiling will increase, but at fewer than 79 days per year, snowmobiling will decrease.

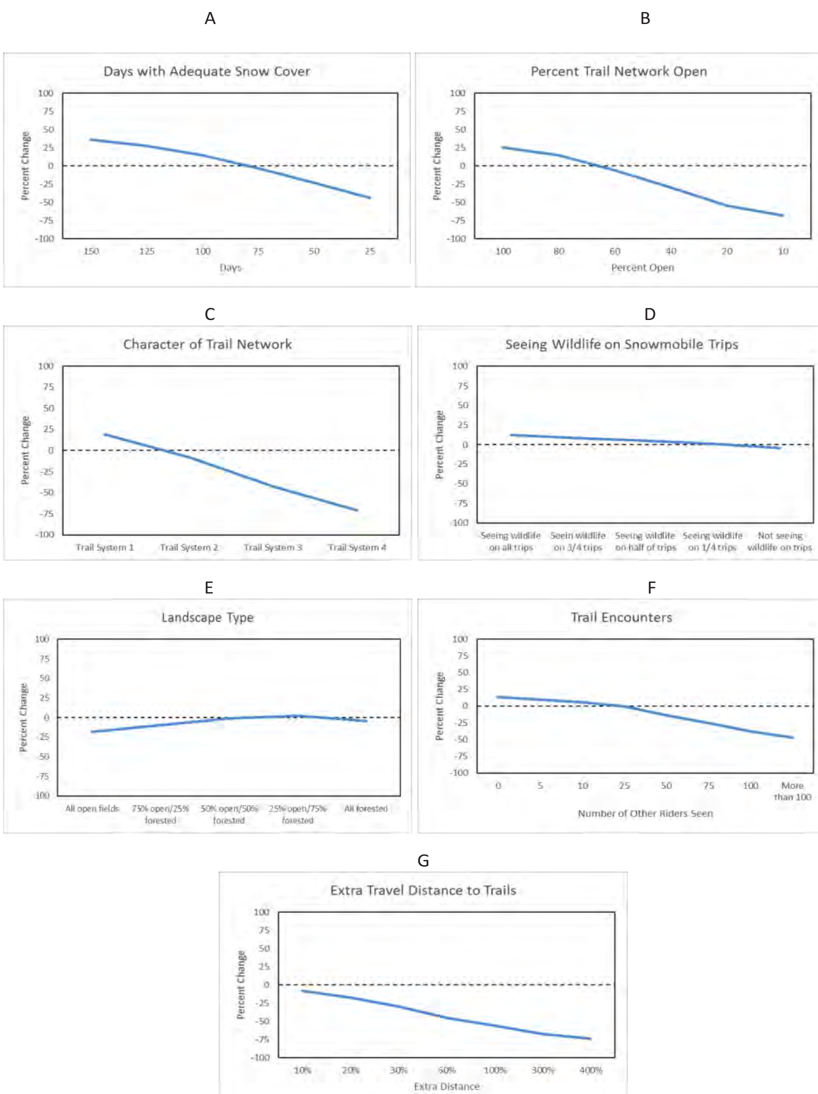

Figure 2. Future adaptations to a range of climate-related changes in snowmobile conditions.

Characteristics of High-Quality Snowmobiling

The final battery of questions explored the characteristics of snowmobiling opportunities that add to or detract from high-quality snowmobiling. A list of 23 variables that might affect the quality of snowmobiling was presented; respondents were asked to rate the degree to which each detracts from or adds to the quality of snowmobiling (Table 5). Five of the top 10 rated characteristics were climate-related: 1) consistent snow cover along the trail, 2) being able to begin your ride from home, 3) interconnectivity of trails for making loops and tours, 4) ability to travel great distances, and 5) seeing wildlife. Moreover, having to drive to snowmobile trails was the second most negatively rated characteristic of snowmobiling. Encounters with other user groups, including fellow snowmobilers, detracted from the quality of the experience for many respondents; as the extent of the trail network declines for climate-related reasons forcing snowmobilers on fewer miles of trails, encounters are likely to increase (thought this may be at least partially offset by fewer snowmobilers riding fewer miles). These findings suggest that many of the multiple manifestations of climate change are vitally important to the quality of snowmobiling, thus climate change is likely to have substantive effects on this outdoor recreation activity.

Discussion

Our findings support our general hypothesis that many Vermont snowmobilers are already adapting their participation in the sport (e.g., reducing snowmobile activity) as a function of changing climatic conditions and that these adaptations will become more pronounced as the manifestations of climate change progress. These findings echo the trend of expected decreases in participation (days of snowmobiling per season) reported by others (Burakowski & Magnusson, 2012; Wobus et al., 2017), but provide important insights on factors that may influence the quality of the experience, and ultimately participation in the sport, beyond the number of snow cover days per season.

To examine how snowmobiler recreation behaviors would change in response to varying resource conditions, we selected relevant manifestations of climate change informed by our reading of climate models, particularly as they apply to Vermont (Betts, 2011; Pontius & Duncan, In review). The resource conditions centered on the recreationist's experience–percent change from current use levels rather than specific quantities of a manifestation. This approach allowed for the survey questionnaire to be relevant to the different users and locations of the VAST trail network as well as flexible to the estimates, but not certainties, in the climate models. As natural/physical science model parameters become more precise and/or specific manifestations of climate change become more pronounced ("supply"), our approach can aid in estimating social science-derived snowmobile "demand" in Vermont. For example, the thresholds noted in Figure 2 suggest the circumstances when the quality of snowmobiling, as defined by climate-related conditions, will be (or, in some cases, already has been) judged as unacceptable, leading to a decline in participation. There is substantial consensus among the sample regarding these relationships.

This study was initiated with the hypothesis that, because it requires specialized climatic conditions, snowmobiling may be an especially climate change-sensitive recreation activity and that snowmobilers are likely to adapt to climate change by increasing or decreasing their participation and employing other adaptations (e.g., switching their recreation activity to substitute activities). Study findings tend to support this hypothesis. First, relatively large percentages of respondents (between 14.6% and 44.7%) have already noticed declines in nine manifestations of climate change and for all of these declining conditions, 1.8% to 30.7% of respondents have already adapted by reducing their participation in snowmobiling. Second, the implications of these reductions in snowmobiling are magnified when examining the sub-group of snowmobilers who have already noticed climate-related declines in snowmobiling conditions; this group has made more remarkable reductions in their participation in snowmobiling. The majority of these respondents have reduced the amount of snowmobiling they do in response to all of these climate-related conditions with the exception of forest health or quality along snowmobile trails. Much more dramatic reductions in snowmobiling may be expected as the manifestations of climate change become more substantive and obvious to all. Third, most respondents reported that they would substantially reduce their participation in snowmobiling in the future in response to declining snowmobiling conditions caused by climate change. Finally, climate-related conditions are vital in defining high-quality snowmobiling; five of the top ten rated characteristics of high-quality snowmobiling conditions are climate-related. All of these findings suggest that snowmobiling is likely to decline considerably in both amount of activity and quality in response to climate change.

Snowmobilers in Vermont may be more sensitive to reduced snow conditions than previously estimated for the Northeast. Although Burakowski & Magnusson (2012) define a reliable snowmobile season in the Northeast as one that has 50 or more days of natural snow cover, our data suggest that Vermont snowmobilers define it as one of 79 or more days, or 58% longer, than this previous estimate. At that point, the reliability of the recreation resource begins to negatively affect the amount of snowmobiling. By the 50 day threshold, participation will decrease 23%. This suggests that snowmobilers may be more sensitive to deteriorating conditions than snowmobile tourism industry estimates, or that these industries have the capacity to absorb more loss than individual snowmobilers do. However, the Vander Eijk's A, although still positive, continually decreases with 100, 75, 50, and 25 days of snow cover, indicating that consensus wanes under these deteriorated conditions and sub-groups who are more or less sensitive to the shorter seasons may be present (Krymkowski et al., 2009). Further research is necessary on characteristics defining these sub-groups and how a high-quality experience can be maintained for each. This has implications for associations like VAST that rely on TMA permits, as they may need to expect declines in membership, or a shift in the composition of users, well before a reduced season of 50 days. Moreover, they may need to take actions such as concentrating on more snow-secure areas within the state, marketing to destination tourists who only require adequate snow cover for their stay, or expanding permitting to other trail users who may have lower thresholds for recreation participation (e.g., snowshoers, bicyclists, cross-country skiers). Because reliable ski seasons are considered to be 100 or more days of snow cover, and this threshold is poised to be imminently violated in the Northeast (Dawson & Scott, 2013), snowmobile associations and ski resorts should consider collaborative partnerships to diversify site use and thus increase the supply of snowmobiling locations. For example, opening ski trails to snowmobile use when conditions are unsuitable for skiing or hosting special events for snowmobiling at the reduced-snow times of the season may be options. Under higher emissions scenarios, reliable snowmobiling seasons of 50 or more days in the Northeast are expected to be completely eliminated by 2100 (Burakowski & Magnusson, 2012) and thus proactive management for this threshold or higher ones is necessary now.

Our research found that while some climate change manifestations are salient to the quality of the snowmobiler experience, other manifestations, no less unlikely to materialize, are not. Importantly, seeing wildlife on snowmobile trips and landscape type do not appear to be as salient (Figures 2d and e). In other words, projected decreases in the likelihood of viewing wildlife (i.e., less abundant wildlife in trail locations) and the shift away from forested landscapes (i.e., fewer trees and more open terrain) do not appear to influence the amount of snowmobiling by respondents. The lack of change in snowmobiling in response to these potential manifestations of climate change throughout the study may suggest that respondents do not understand the potential linkage between climate change, wildlife habitat, and forest health. Or it may be that wildlife and forest health are not central to the snowmobiling experience, that forest health conditions and the presence/absence of wildlife are less noticeable to recreationists during the snowmobiling season, or that conjuring declines in wildlife and forest health is more difficult for respondents. As wildlife and forest health are important focuses of research and related landowner engagement in Vermont (Pontius & Duncan, In review), academics and managers alike will need to consider ways to further probe this disconnection and appropriately tailor communications about climate change impacts and personal behaviors to lessen these impacts.

Some manifestations of climate change affect snowmobiling in unanticipated and indirect ways. For example, the large network of more than 5,000 miles of snowmobile trails in Vermont allows for extended trips throughout the state. This is a highly valued attribute of snowmobiling in Vermont. However, large portions of this trail network are at lower elevations and in the southern portion of the state where adequate snow cover is likely to be more substantially threatened by climate change. Study data suggest that loss of the integrity of this trail network is likely to lead to relatively steep declines in participation. Other examples of such indirect effects include concentration of snowmobilers on fewer miles of trail as the percentage of the state's snowmobile trail network declines and the need for many snowmobilers (e.g., those who live in the southern portions of the state, those who live in states south of Vermont, those who live at lower elevations) to travel farther from home to reach snowmobile trailheads. Furthermore, a decline in the trail network could concentrate use on the limited number of open trails for snowmobilers and other winter recreationists. Given that many respondents (ranging from 22.4% to 67.9% depending on type of encounter) noted that encounters with other snowmobilers and other types of winter trail users already detract from a high-quality experience, greater potential for crowding and conflict may exist in these truncated trail networks (Manning, 2011). All of these indirect and cascading effects of climate change are likely to exacerbate the negative impacts of climate change on snowmobiling in Vermont and elsewhere.

In addition to decreasing participation in snowmobiling, snowmobilers might substitute other winter-based recreation activities as an adaptation to climate-caused deteriorations in snowmobiling conditions. While we did not specifically question respondents on substitute activities, the findings on other activities they currently participate in (Table 1) suggest that these other activities are attractive to snowmobilers and might be substitutable to some degree. As other outdoor winter-based recreation activities are also dependent on climatic conditions, the substitutability of any one of them for a missed day or season of snowmobiling may be lessened. Additional issues may influence the substitutability of indoor winter-based recreation activities (i.e., viewing sporting events and indoor hockey). With different terrains and snow conditions across Vermont, those invested in the sport may already be substituting one snowmobiling experience for another when faced with climatically constrained choices. In a particular example, snowshoeing was the activity with the highest participation (Table 1) but almost half of respondents noted that encountering snowshoers detracts from the experience (Table 5). This implies that VAST members may use locations other than the VAST trails to snowshoe and thus if snowmobile conditions continued to deteriorate they may be spatially displaced off of this trail network to engage in their substitute recreation activity. Furthermore, given the reported social nature of snowmobiling (94.8% typically riding with others), it remains to be explored whether other winter sports fulfil this social experience benefit to a similar degree. Clearly, the issue of substitutability for snowmobiling is complex, however the fact that at least 31% of respondents participate in other winter-based recreation activities suggests that increased participation in these activities may be a potential adaptation to climate change. Switching to substitute recreation activities for snowmobiling is a potential adaptation to climate change-related declines in snowmobiling conditions, though this clearly warrants more research attention.

Limitations

A limitation of this study is that it focused primarily on the adaptation of increasing/decreasing amounts of snowmobiling. There are other potential dimensions of adaptations, including switching to substitute recreation activities. This issue was addressed only indirectly. The "direct question" approach asks respondents more directly about the degree to which recreation activities can be substituted satisfactorily (Manning, 2011). Substitutability, as well as other potential adaptations (e.g., spatial and temporal shifts in recreation activity, shifts in types of snowmobile equipment used) warrant more research attention. Furthermore, as this study was exploratory in the salience of individual manifestations of climate change and of realistic ranges of values for each, the collective impact of all of the manifestations on snowmobiling behavior was not addressed. One might expect that while each manifestation on its own has a certain amount of impact on the experience, the combination of some or all of the expected, concurrent impacts would likely further reduce recreation participation and the quality of the experience. This area will require focused study, potentially through the use of visuals illustrating varying levels of singular and collective impacts.

Conclusions

Snowmobilers' reported adaptations to multiple manifestations of climate change signal that a steep decline in snowmobiling in Vermont (and, by logical extension, elsewhere) has already started and is likely to intensify. It should be remembered that there was a substantial degree of consensus about these future adaptations (primarily in the form of reduced participation in snowmobiling) in this study. Although some people may be skeptical of climate change and its environmental and social effects, many snowmobilers report noticing several manifestations of climate change already and have reduced their participation in response. This study helps illuminate what climate change manifestations and have been noticed, are salient to the experience, and affect the amount of participation. Because snowmobiling is so climate-sensitive, it may well become unsustainable as climate change advances; the high expense of snowmobiling (equipment, travel, permits, etc.) may not be justifiable in the face of a drastically shortened season of relatively poor snowmobile conditions. Additionally, because snowmobiling is such a dispersed recreation activity, with snowmobilers often riding very long distances over very large areas of terrain, it is unlikely to benefit from snowmaking, a practice that has become indispensable to the more spatially concentrated recreation activity of alpine/downhill skiing in many geographic areas. Also, manufacturers may develop snowmobile models better equipped to handle lower quality snow conditions, it is unlikely that the average recreationist will invest in this equipment if the experience continues to degrade in response to climate change.

Like many outdoor recreation activities, snowmobiling is more than the sport itself. While it can provide great satisfaction to participants, it is also a part of Vermont culture, much like hunting (Boglioli, 2009). Snowmobiling provides family-oriented outdoor recreation to many Vermont residents and visitors during long winters in which other outdoor recreation activities are limited. Moreover, snowmobiling contributes substantially to the Vermont economy; nearly half of the respondents in our study traveled to Vermont to snowmobile. And, of course, climate change will alter the natural environment of the state. All of these changes are likely to have a dramatic effect on the environment, economy, and culture of Vermont (Burakowski & Magnusson, 2012; Dawson & Scott, 2007).

Undoubtedly, there will be some positive effects of climate change on outdoor recreation as well. For example, as snowmobiling declines, participation in other, substitute recreation activities is likely to grow, creating opportunities. Enterprising entrepreneurs are sure to respond and public park and outdoor recreation agencies should plan for this alternative future. But there may be some equity issues associated with recreation-oriented adaptations to climate change. For example, in the context of snowmobiling, longer travel to find good conditions will require greater wealth and may further limit the sport to those with the means to participate in more distant locations. All of these issues associated with adaptations to climate change in outdoor recreation warrant greater research attention.

In preparing and administering this study, we are impressed with the climate monitoring and modeling work conducted in the physical/natural sciences. The resulting body of scientific and professional literature has resulted in broad international agreement that the climate of the earth is changing, that scientists have isolated many of the potential manifestations of climate change, that these changes can be modeled with some degree of precision, and that human-caused emissions of greenhouse gases are contributing to climate change. Social science is now advancing this body of knowledge, including documenting and predicting how individuals and society will adapt to the many manifestations of climate change. In this way, the conventional science of climate change has been joined by an associated science of "social climate change": the manifold ways in which individuals and society at large are now and will increasingly continue to adapt to a changing physical and biological world. The study described in this paper is one, small, isolated example of this interdisciplinary and integrated approach to studying the nexus between climate change and society. However, the study has important implications, at least to those who will be vitally affected: snowmobilers and the ways in which they contribute to the vitality, economy, and culture of Vermont. It is apparent that the winter climate in Vermont is changing in ways that threaten the viability and sustainability of snowmobiling, and that these changes will continue to advance. This study confirms that snowmobiling is declining in response to these changes, and that these declines are likely to increase in magnitude. All of these physical, biological, and associated social trends suggest that snowmobilers face the probability of extirpation from Vermont in the undetermined but not-too-distant future. Of course, the greenhouse gas emissions of snowmobiling are an irony that cannot escape notice, and may offer an important lesson as we reexamine our conventional patterns of human behavior in light of the new realities presented by climate change and other environmental issues.

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