TRAVEL BEHAVIOR OF LIFT ACCESS BACKCOUNTRY SKIERS ADJACENT TO BRIDGER BOWL SKI AREA, MONTANA, USA

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ABSTRACT: Our research expands existing knowledge of travel behavior and decision-making in avalanche terrain. We utilize GPS tracking to observe the travel behavior of lift access backcountry (LABC) skiers and in person survey data to investigate the human factors that influence their terrain choices. Our study area is the southern boundary of Bridger Bowl Ski Area, Southwest Montana, USA (N=139). We analyze travel behavior by avalanche hazard rating, and identify human factors that affect avalanche terrain choices. A subset of our results are presented here, which illustrate the demographics of our sample and highlight their travel behavior through heat maps. Our results provide a case study example of the terrain preferences and avalanche awareness of LABC skiers, and highlight specific human factors that are correlated with terrain selection. Two practical applications of this research are: 1) targeted avalanche education outreach based on our results, and 2) designing new signage to illustrate the avalanche terrain near the ski area boundary for skiers who are inexperienced in the backcountry or unfamiliar with the area.

KEYWORDS: GPS tracking, Human factor, Lift access backcountry, Heat map.

1. INTRODUCTION

Human factors have been recognized as contributing to avalanche accidents and fatalities for almost 40 years (Fesler, 1980). The methods for analyzing human factors have shifted from subjective descriptions of behavior patterns, to empirical analysis of accident data, to hypothetical survey responses, to field observations and intercept surveys, and finally GPS tracking of travel behavior (Furman et al., 2010; Haegeli and Atkins, 2016; Hendrikx et al., 2016; Mannberg et al., 2017; Marengo et al., 2017; McCammon, 2004; Procter et al., 2014; Thumlert and Haegeli, 2017).

This paper uses GPS tracking and field surveys to analyze the travel behavior of Lift Access Backcountry (LABC) skiers on Saddle Peak, Bridger Mountains, Montana, USA. LABC recreationists merge resort skiing and backcountry skiing, by utilizing ski lifts before exiting ski resort boundaries and recreating in adjacent uncontrolled backcountry terrain.

Exit signs erected by ski areas typically indicate the area boundary is being crossed, that the snowpack is not controlled for avalanches, and that rescue is the responsibility of the skiers leaving the ski area so ski parties should adopt backcountry ski and avalanche practices. Between 2007 and 2016, lift access backcountry recreationists (LABC) comprised 10% (29 of 278) of all avalanche fatalities in the United States. This paper examines the behavior of LABC skiers who recreate at Saddle Peak, Bridger Mountains, Montana, USA.

GPS tracking provides us with a decision footprint for our actions in the backcountry. When combined with a Geographic Information System (GIS) we can analyze detailed terrain metrics as well as positions in space and time along the route. Field based surveys, administered immediately after participants travel in avalanche terrain, provide us with a set of responses to characterize the participants in terms of demographics, preparedness, and their self-rated influence of human factors.

1.1 *Previous work*

GPS tracking of winter recreationists has been shown to be an effective method for understanding travel in hazardous terrain (Haegeli and Atkins, 2016; Hendrikx et al., 2014; Hendrikx and Johnson, 2016; Techel et al., 2015; Thumlert and Haegeli, 2017).

Carrying essential rescue equipment (avalanche transceiver, probe, and shovel) and knowledge of the public avalanche forecast are considered fundamental to preparedness and objective decision-making in backcountry skiing. Fitzgerald et al., (2016) found LABC skiers are less prepared with

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rescue equipment and more poorly informed on avalanche hazard compared to traditional back-country skiers in the same region. Procter et al. (2014) found only 52.5% of ski groups knew the avalanche danger level.

Prior research on LABC skiers utilized online and intercept survey data (Gunn, 2010; Haegeli et al., 2012; Silverton et al., 2009) and have investigated the preparedness of LABC users for avalanche rescue and their level of avalanche education (Silverton et al., 2009), skier's terrain preferences under various avalanche danger levels and their understanding of the ski resort avalanche mitigation and rescue policies (Gunn, 2010).

2. METHODS

We collected data from the area around Saddle Peak (2,791 m) (45.791314˚N, 110.937614˚W), in the southern Bridger Mountains, Montana, USA. Saddle Peak terrain is accessible via a short hike from a ski lift and skiers can easily return the base of the ski lift (Figure 1). Skiable terrain has a vertical drop of 644 m from the peak back to the base of the lift.

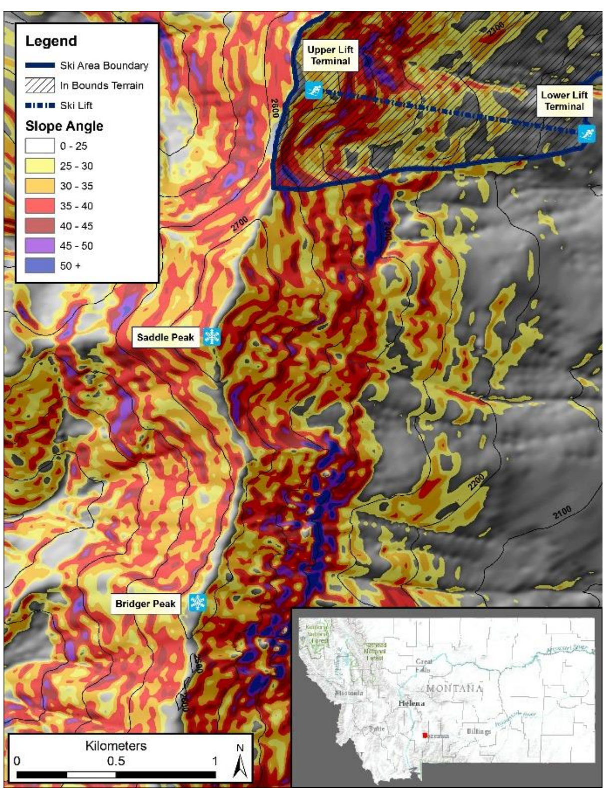

Figure 1: Slope angle map of Saddle Peak LABC zone. GPS units were handed out on the ridgeline at the ski area boundary and collected at the lower lift terminal.

The Saddle Peak LABC terrain is complex, with steep wind loaded slopes above cliff bands in many areas. A variety of ski runs are accessible by hiking from the ski lift, but all options involve travelling in avalanche terrain with angles of 30˚ or higher. The regional snowpack is categorized as intermountain, with some seasons more characteristic of a continental climate (Mock and Birkeland, 2000). Wind direction is predominantly westerly, resulting in frequent wind loading on the eastern aspect. Large cornices hang over the eastern aspect, creating an additional hazard to skiers entering the terrain from the ridgeline. Numerous avalanche events have occurred on the LABC terrain around Saddle Peak, with notable events in 2010 and 2018 (GNFAC web page). Chabot et al. (2010) have identified poor travel practices, misjudgment of the effect of skier compaction, and overreliance on familiarity with the terrain as critical issues in the use of the terrain.

2.1 *Data Collection*

We collected 139 useable GPS tracks and survey responses from February 2017 through February 2018. Participants carried a GPS unit when they exited the ski area boundary and returned it after their backcountry run, at the base of the ski lift. They were then asked to fill out a survey while riding the lift back up and place the completed survey in a drop box at the upper lift terminal (Sykes et al., 2018).

Our research design aimed to minimize the time required for participation and maximize participation. Several skiers provided repeat tracks/surveys. Only one GPS track and survey were collected from each participant for each day of data collection. Groups of skiers who travelled together were limited to carrying one GPS unit and filling out one survey. Surveys were anonymous. Tracks and surveys were paired for each participant.

Survey design follows (Fitzgerald et al., 2016 and Hendrikx & Johnson, 2016) and is composed of four sections: demographics, preparedness, LABC biases, and heuristic traps.

Avalanche forecast (avalanche danger level and the primary avalanche problem) and daily weather data were compiled from online archives at the Gallatin National Forest Avalanche Center (GNFAC) and Bridger Bowl Ski Area. Sampling days were selected to maximize participation, but were not biased by specific weather and avalanche conditions except when conditions were too extreme to open the lift.

2.2 *Data Analysis*

We created heat maps to illustrate the changes in travel behavior based on participant's survey responses. GPS track density is calculated using raster analysis, where the length of the GPS tracks within a 30m radius of each raster cell are divided by the area of the cell neighborhood. We use stretched classification symbology to color code the heat maps, specifying 'standard deviation' as the stretch type with 'n=5'.

3. RESULTS

Of the 139 participants who provided GPS and survey data, 119 of them were sampled on moderate hazard days, 20 were sampled on considerable hazard days, and none were sampled on low hazard days. We collected an average of 7.3 tracks/ day, with 10 tracks/day on moderate hazard days and 3.3 tracks/day on considerable hazard days. Total sample rates were approximately 75% of LABC skiers under both moderate and considerable avalanche hazard. Partial survey responses were included in the final dataset, therefore sample sizes vary depending on survey question.

3.1 *Demographics*

The median age of participants is 36 years old, with median years of skiing 27 years. The sample is composed of 90% males (n=123) and 10% females (n=13). Participants using alpine ski equipment comprise 51% (n=70) of the sample, with 33% (n=45) using backcountry ski equipment, and 16% (n=22) percent using a snowboard. Group sizes ranged from 39% (n=50) solo skiers, 40% (n=52) groups of two, 14% (n=18) groups of three, and 7% (n=9) in groups of four or more.

Participant's avalanche education varied from 16% (n=22) with no avalanche education, 35% (n=48) with awareness level, 34% (n=47) with a U.S. recreational level one avalanche course, and 15% (n=20) with U.S. level two or higher education. Self-rated backcountry experience is 6% (n=8) novice, 16% (n=22) intermediate, and 78% (n=107) expert.

While in backcountry terrain, 72% (n=97) of participants had an avalanche transceiver, probe, and shovel; 13% (n=18) of participants carried either an airbag or Avalung™ as an additional safety measure. Our results indicate that 40% (n=19) of solo skiers do not carry a beacon, probe, and shovel compared to 22% (n=17) of skiers who travel with partners. Fishers Exact Test revealed a significant association between solo skiers and not carrying basic rescue equipment (Odds Ratio 2.4, p-value 0.04).

While traveling in backcountry terrain, 61% (n=78) of participants carried out some kind of instability test. Traveling tests (37%, n=47) and ski cuts (33%, n=42) were the most common form of instability test, with 17% (n=22) performing cornice tests and 3% (n=4) performing a compression or beam instability test. Despite Bridger Bowl Ski Patrol posting the public avalanche forecast at the upper terminal of the ski lift, only 64% (n=89) of participants accurately reported the current avalanche hazard.

3.2 GPS Mapping

To visualize changes in travel behavior we created heat maps for survey questions that had significant results from our statistical models: gender, backcountry experience, and avalanche mitigation (Figure 2). Male, expert, and participants who did not assume avalanche mitigation in the LABC area all show similar widespread travel with a concentration along the central ridge. These are interpreted as positive attributes, because the central ridge is the safest descent option in terms of slope angle and terrain traps. Females show a very high concentration of tracks along the central ridge, indicating a conservative terrain selection. However, the sample size of female skiers is small (n=13) and it is unknown whether they were travelling in mixed gender groups. Non-experts and participants who assume avalanche control in the LABC area show a high concentration of travel adjacent to the ski area boundary. This line choice exposes skiers to large cliff bands and is generally considered a high risk option, albeit convenient due to the proximity to the ski area.

4. DISCUSSION

The demographics of the wider LABC population is not well documented, so our demographic data add detail to the limited available data. Compared to prior research, the mean age of participants in this study (late 30s) is notably older than survey research on LABC skiers in western Canada and Utah (late 20s) (Gunn, 2010; Silverton et al., 2009). This difference may be due to the tendency for younger skiers to participate in social media outlets that would utilize online surveys. Chabot et al. (2010) also described Saddle Peak as having a large contingent of longtime local skiers who represent an older demographic than the typical backcountry ski population (Chabot et al., 2010). While the younger population of LABC skiers do travel on Saddle Peak, the generally older 'regulars' were there every day we collected data, regardless of avalanche or weather conditions. This could be due to the younger population being less confident in their

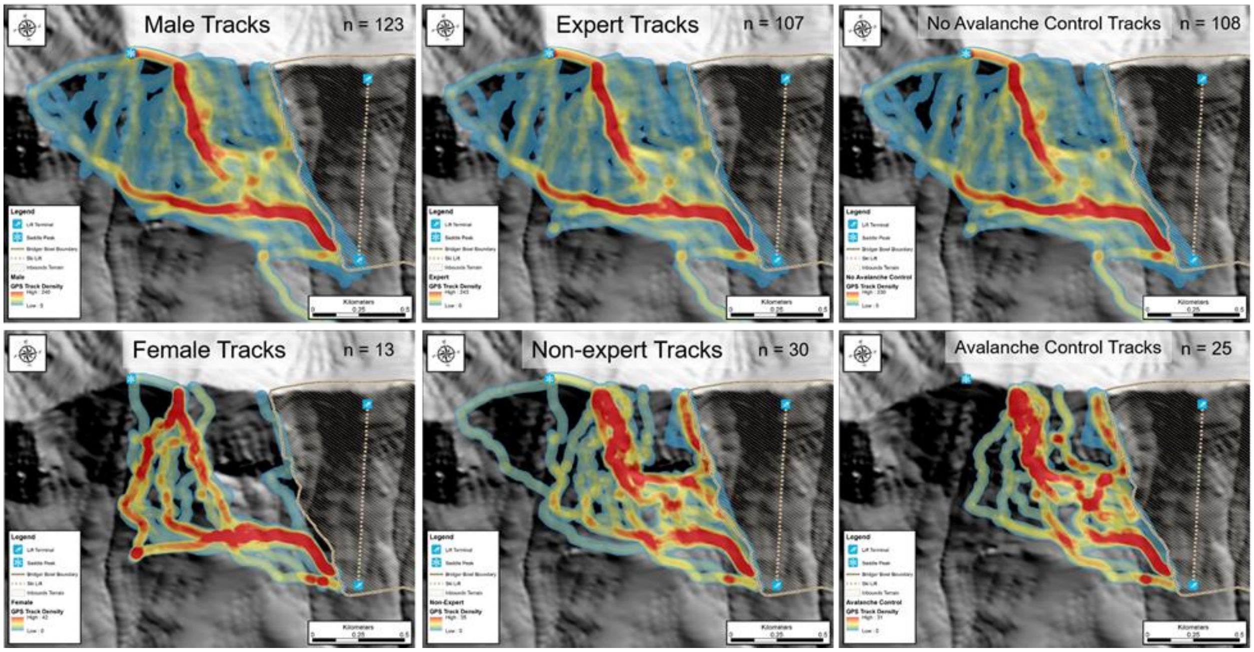

Figure 2: Heat maps of GPS tracks separated by survey response variables. Note the increased travel adjacent to the resort boundary for non-experts and participants who assume avalanche control in the LABC area ("Avalanche Control Tracks"). This line choice is exposed to large cliffs despite being easy to access.

ability to manage the Saddle Peak terrain under adverse weather and avalanche conditions. The proportion of male to female participants in this sample is consistent with prior LABC skier re-search (Gunn 2010; Hendrikx & Johnson 2016; Mannberg et al. 2017; Procter et al. 2014).

Group sizes on Saddle Peak were generally smaller than those found in non-lift accessed backcountry research, with 81% of participants travelling in groups of one or two. In contrast, (Zweifel et al., 2016) reports 60% of participants travelling in groups of one or two. Solo skiers represented 38% of the sample while Fitzgerald et al. (2016) reports 30% on Saddle Peak. Hendrikx & Johnson (2016) report similar percentages of solo skiers in their data.

The high incidence of solo skiers in LABC terrain may be due to the close proximity of the ski area and that nearly 80% of participants consider themselves expert level backcountry skiers.

The proportion of participants who knew the forecasted avalanche hazard level was 64.0% in our sample, similar to the 67% found by Fitzgerald et al. (2016). These numbers are higher than the 52.5% of European skiers who knew the avalanche danger in previous work (Procter et al., 2014). The relatively low rate of forecast knowledge is surprising since the avalanche forecast is posted at the top of the lift.

In our sample 71.8% of participants had necessary rescue equipment compared to 80% in previous studies on Saddle Peak and 80.6% of skiers in the European sample (Fitzgerald et al., 2016; Procter et al., 2014). By comparison, a study of LABC skiers in the Wasatch Mountains of Utah USA in 2007, had far lower adherence to carrying avalanche rescue equipment (36% Transceiver, 31% Shovel, 32% Probe) (Silverton et al., 2007). This could be due to increased communication about the hazards of LABC skiing since the earlier research was carried out (11 years ago), and concentrated community outreach from the local avalanche forecasting and education network at Bridger Bowl Ski Area (Chabot et al., 2010). Bridger Bowl's policy of requiring all skiers on the ridge terrain and Schlasmans lift to wear avalanche transceivers could also influence skier's likelihood of including shovel and probe in their equipment.

4.1 *Limitations*

Despite limitations, this study provides a case study of the travel behavior and decision-making tendencies of LABC skiers. All survey data collected for this research focused on individual participants, not group dynamics, with the exception of questions about group size and group terrain management. GPS tracks submitted by the same user on different days are not identifiable within the data set and could introduce cluster biases into the data. Environmental variables such as wind, temperature, precipitation, new snow, and ski quality were not included as variables in this research. The scope of inference for this research is limited to Bridger Bowl Ski Area LABC skiers.

5. CONCLUSION

By collecting GPS tracks and survey responses via intercepting LABC skiers in the field, we have broadened the scope of GPS tracking research in avalanche terrain to include participants who may not volunteer their time and energy to submit GPS tracks online or via social media or web-based platforms.

On a practical level, our research points to the need for further, targeted education and outreach regarding the nature of LABC and the dangers therein. This could be facilitated through increased signage with clear imagery showing where they are relative to the terrain around them, and the hazards to which they are exposed. Finally, the continued development of easy to use GPS tools and online mapping platforms for the public to track their travel in avalanche terrain could help backcountry recreationists objectively analyze their own travel and learn to more carefully manage terrain.

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