USING TIME-LAPSE PHOTOGRAPHY TO MONITOR AVALANCHE TERRAIN

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ABSTRACT: On January 14, 2016 an avalanche occurred on the Football Field of Saddle Peak in Southwest Montana. Saddle Peak is a backcountry slope, located immediately adjacent to the Bridger Bowl Ski Area boundary and accessed from the Bridger Bowl Schlassmans Lift. A time-lapse digital SLR camera mounted on an unused gun platform with a clear view of Saddle Peak captured the avalanche. Diana Saly (researcher) and Doug Richmond (Bridger Bowl Patrol Director) met at the gun platform where Richmond was initiating and coordinating the response. The team reviewed the images and assessed skier involvement within minutes of the event. Two skiers were photographed in close proximity to the avalanche during release and resulting avalanche. Both skiers were photographed returning to the ski area boundary following the avalanche and confirmed as not involved. A short video (2 min) was developed to document the January 2016 event and demonstrate the value of this technology for rescue and emergency situations. The data also provides an opportunity to document terrain use in different snowpack and avalanche conditions by travelers in easily accessed back country terrain.

KEY WORDS: time-lapse photography, backcountry, case study, terrain use

I. INTRODUCTION

Saddle Peak is located in southwest Montana, USA, in the Gallatin National Forest. Saddle Peak is directly south of the Bridger Bowl Ski Area which operates with an open boundary policy. The skiable slope below the ridge line to Saddle Peak is complex avalanche terrain with several start zones, mid-track cliffs, and frequent wind-loading. Saddle Peak is also easily accessed from the ski area and a compacted snowpack is common. With a favorable camera vantage point, Saddle Peak provides the opportunity to sample skier use of a backcountry environment.

On February 16, 2010 a large avalanche occurred on Saddle Peak. A storm the weekend prior to the avalanche brought 75 cm of snow with strong westerly winds to the Bridger Range. The avalanche hazard was rated Considerable by Gallatin National Forest Avalanche Center (GNFAC). The Schlassmans Lift had been closed for the storm and reopened Monday morning, February 16, 2010. Around 11:00 am a chunk of cornice fell from the ridge of Saddle Peak onto the slope. It rolled downslope 30 m, where it initiated an avalanche approx. 300 m wide and 600 m long (Fig. 1). Reports estimated that 20-30 people were hiking the ridge at the time and several people had already skied the slope (Chabot, et al., 2010). Many personal cameras captured the avalanche. Several skiers were on slope performing transceiver searches immediately after the avalanche. Bridger Bowl Ski Patrol and Gallatin Country Search and Rescue responded with personnel and dog teams. No one was reported missing by 3:00 pm. Half of the feature did not run, putting the runout zone at risk. New snow was rapidly re-loading the slope throughout the day. The search was called off; no one was involved or injured. The response utilized a large number of responders in a high risk environment (Chabot, et al., 2010). Had the event been captured by a purpose specific camera, involvement could have been quickly determined and adding more people to the slope and subsequent search would have been deemed unnecessary. Search and rescue efforts could have been reduced and placing responders in hazardous terrain could have been avoided.

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Fig. 1: Picture of 2010 Saddle Peak Avalanche

Winter recreation in mountainous terrain has noticeably increased in recent years. Avalanches are one of the deadliest hazards threatening both recreationalists and professionals (Techel, et al., 2015). Backcountry terrain adjacent to ski area boundaries, referred to as sidecountry, provides easy access to complex avalanche terrain. From a snowpack perspective, there is little difference between sidecountry and backcountry; the most important factor is that neither is controlled avalanche terrain (Shockey, et al., 2014). Such areas can see high skier usage and avalanche occurrences. The adjacent resort is typically not obligated to respond to incidents which occur outside their boundaries. Placing personnel on slope can be hazardous and careful consideration is required when planning a rescue. Unwitnessed avalanches can be extremely hazardous as rescue efforts depend on fast response.

During the winter of 2015-2016, a time-lapse camera was installed at an unused gun platform to photograph skiers on Saddle Peak. A digital camera in weatherproof housing is a relatively low cost, low maintenance tool used to monitor high-use avalanche terrain. Once programmed and correctly mounted, the only limiting factors are power supply and image storage capacity, and visibility. This technology could be useful to first responders in avalanche emergencies in order to determine the number of people involved and their relative location with respect to an avalanche. Cameras could also be used to study terrain use by backcountry users, natural avalanche cycles in remote terrain, and start zones of frequent-flier avalanches to determine potential trigger spots.

2. STUDY AREA

Saddle Peak is located in the Bridger Range of Southwest Montana. The Bridger Range runs north-south; Bridger Bowl Ski Area (BB) utilizes the east side of the ridge. Saddle Peak is a short hike (approx. 30 min) up the ridge from the BB south boundary line. The Football Field is the northern (and closer) half of the east bowl of Saddle Peak, easily accessed from Bridger Bowl by riding the Schlassmans Lift and a shorter hike (10 min) along the ridge.

The east face of Saddle Peak is visible from the ski area; the face is divided in the middle by a sparsely treed rib feature. The large complex start zones are frequently wind-loaded. The entire feature is broken mid-track by large cliffs upwards of 60 m (Fig. 2). The run out features low angle terrain that runs adjacent to the ski area. A trail out leads back to the ski area.

Fig. 2: Annotated photo of Saddle Peak, February, 2016

Saddle Peak is an ideal slope to observe avalanche terrain usage. Accessible only via the ski area, use is dependent on when the BB Schlassmans Lift is open. Multiple groups hiking the ridge and skiers simultaneously on slope is common. The start zone slope angles (35-38 degrees) of Saddle Peak are stubborn to avalanche when steeper slopes are running. As well, constant wind-loading produces a notoriously a hard slab which further lowers the frequency of avalanching. The lack of frequent avalanching contributes to the lack of caution when skiing the terrain. The February 2010 avalanche incident highlighted the challenge of skiing avalanche terrain when there are numerous parties choosing to access the same area with limited regard for one another. Even with its complex start zones, constant wind loading, and close-out cliffs, Saddle

Peak is skied often and in a variety of snowpack conditions.

A gun platform, once used to control inbounds terrain along the ridge, provides a great view of Saddle Peak. A Canon Rebel EOS Digital SLR camera was installed on the gun platform in a weather-proof housing unit and programed to take one photo every 10 seconds between the hours of 10:00 am – 4:00 pm during the 2015-2016 winter season. An off-the-shelf time-lapse product made by Harbortronics was used (https://www.harbortronics.com/Products/TimeLapsePackage/). The camera captured a large portion of the east side of Saddle Peak from the ridgetop to the lowest traverse back into the boundary. The resolution of the images made tracking and identifying individual skiers possible, but was not detailed enough to pick up any distinguishing characteristics of skiers.

The easy access provided by Bridger Bowl allows users of varying ski/winter travel ability and avalanche knowledge to quickly find themselves in complex avalanche terrain with little effort. When an incident occurs on Saddle Peak, BB Ski Patrol are the first to be informed and closest response. However, as Saddle Peak is outside the ski area, the sheriff must first be informed and delegate ski patrol to become the Search and Rescue Team. Responder safety is a major concern in rescue response and efforts are made to minimize the number of people on slope.

Two unique case studies are presented where this time-lapse camera provided useful information for both operational safety and research applications.

3. CASE STUDY 1, OPERATIONAL

On January 14, 2016, the GNFAC reported 7-13 cm of new snow overnight with a forecasted 3-5 cm throughout the day. The GNFAC avalanche advisory rated all wind-loaded slopes at Considerable. A 15 cm basal depth hoar layer was topped by a 60-120 cm wind slab that had become increasingly harder to trigger in the days prior. The new snow did not produce a substantial load and was not forecasted to trigger a natural avalanche cycle. “New snow and wind overnight will make human triggered avalanches likely near ridgelines, and a poor snowpack structure make it possible to trigger a larger avalanche,” wrote Alex Marienthal of the GNFAC January 14, 2016 (GNFAC, 2016).

The same morning Bridger Bowl Ski Patrol recorded 12 cm of new snow overnight (9% water content). Light south winds had resulted in small cornice growth and new snow was bonding well (Maleki, 2016).

At 11:39 am, skiers remotely triggered an avalanche on the Football Field of Saddle Peak. The time-lapse camera located at the BB gun platform photographed a pair of skiers skiing just outside the boundary appear to remotely trigger the avalanche from approx. 50 m away. It failed on a basal facet layer 15 cm above the ground, a layer that had previously run that season. The avalanche was 300-400 m wide with a crown depth of 30-60 cm. It flushed over the cliffs and left an impressive powder cloud over the valley (Fig. 3). The size 2.5 avalanche terminated far into the run out. Fortunately, the pair of skiers were not caught in the avalanche.

Fig. 3: Remotely triggered avalanche captured January 14, 2016.

However, the avalanche was not reported by the party triggered. The avalanche was observed by other members of the public and by the BB Ski Patrol, who then initiated their avalanche response plan. Ski Patrollers moved towards the south boundary line and top of the Football Field, the Schalassmans Lift was closed, and the GNFAC and search and rescue were alerted. Richmond (Bridger Bowl Ski Patrol) made his way to the gun platform to coordinate the response via radio. The gun platform provided an excellent view of Saddle Peak, the Football Field, and the run out. From his vantage point at the gun platform Richmond could see the crown line, but was unable to determine skier involvement.

Saly (Researcher) coincidentally arrived to perform camera maintenance and swap the data cards. Upon arrival, the memory card was pulled from the camera and the photos reviewed. Although clouds hid the crown line, the majority of the avalanche was still visible. The camera photographed a pair of skiers in close proximity to the fracture line prior to and during the avalanche initiation. As the avalanche released and moved past them, the pair of skiers were documented moving away from the Football Field and back to the ski area. Richmond and Saly were able to determine the avalanche had moved past the pair without involvement and that the pair had safely returned to the ski area.

With the information provided by the camera, BB Ski Patrol was able to reduce their level of avalanche rescue response. There was still significant hang-fire left in the Football Field and responder personnel were hesitant to enter the terrain without some level of avalanche mitigation.

A video of the avalanche can be viewed at https://youtu.be/cipDJANpp-A.

4. CASE STUDY 2, RESEARCH

In this second case study we review the terrain use of a groups in the backcountry environment as captured with our camera. On Sunday, February 14, 2016 the GNFAC rated the avalanche hazard Considerable for slopes steeper than 35 degrees. In the 24 hours prior, 15-20 cm of snow had fallen in the Bridger Range. The snowfall overnight had a high moisture content (20 mm SWE) and was accompanied by moderate southerly winds. During the day, more snow was expected and winds forecasted to shift north-westerly. A dense and stubborn wind slab was the primary avalanche concern.

On February 14, 2016 several skiers were captured departing BB and hiking the ridge to Saddle Peak. A variety of lines were captured, two common areas were identified: (1) The BB boundary line and the skiers left of the Football Field, and (2) The east running ridgeline from Saddle Peak. Skiers also accessed the terrain by traversing low into the Football Field or skiing the low angle run out below the cliffs (Fig. 4).

Even under considerable hazard, solo skiers hiking and skiing Saddle Peak are common. Groups act chaotically, with limited backcountry disciple and etiquette, initially skiing one at a time, then together stopping mid-slope. In large groups, the skiers at the back tend to drop on slope sooner than the initial skiers.

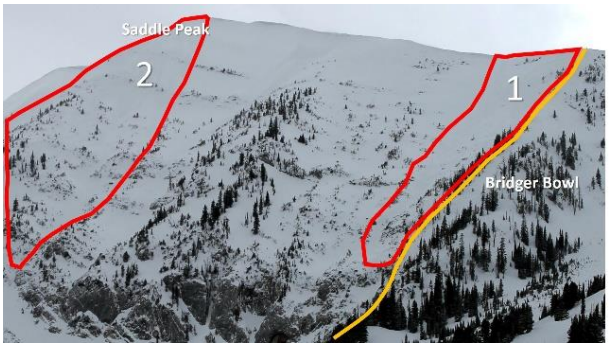

Fig. 4: The backcountry terrain immediately adjacent to Bridger Bowl, highlighting common terrain use above the cliffs: (1) the BB boundary line and Football field; and (2) the east running ridge line from Saddle Peak.

In particular, at 11:48 am on February 14, at least 15 skiers were captured along the Saddle Peak ridge. Two skiers were positioned atop Saddle Peak. Another skier was positioned directly above the middle of the Football Field and a group of five was positioned above the southernmost line still within BB Ski Area.

In this example, we observe as the first skier (BB1) on slope descends from the group above the in-bounds line. BB1 skis the gully feature and stops at the tree line still in bounds. The skier centered above the Football Field (FF1) follows. FF1 center-punches the bowl, skiing the center fast and aggressively. FF1 pauses above the cliffs then negotiates the edge of the cliffs along the BB boundary line and skis the runout below the Football Field (Fig. 5). The full line takes approx. 4 min. Shortly after FF1 drops into the Bowl, the large group on the in-bound line skis the terrain fast, meets up with BB1 and departs.

At the same time the first skier (SP1) from the pair on Saddle Peak drops in. SP1 skis the ridge line and stops at the tree line. SP2 skies a more exposed line towards the center of the bowl. The line is fast and aggressive line to the first set of rocks, SP2 then traverses right to meet SP1. The pair pauses mid-track, then moves together downslope through the rocks and trees and back to the ski hill (Fig. 5). Interestingly, FF1 drops in

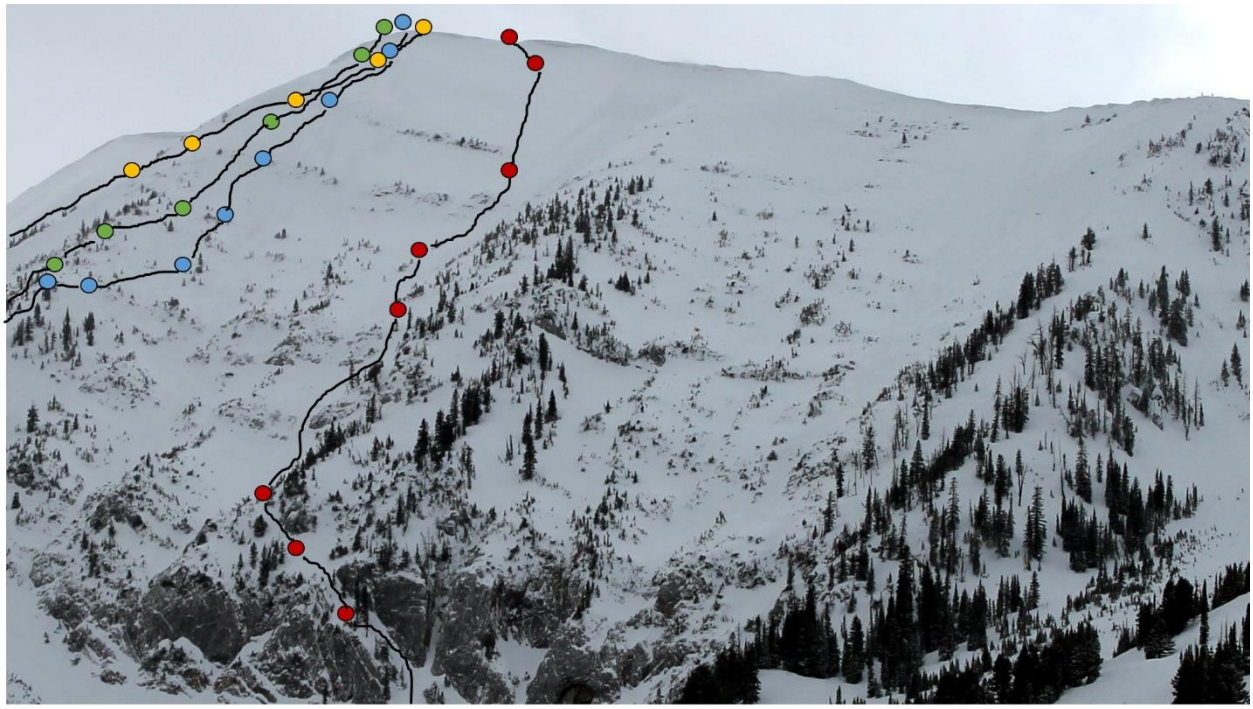

Fig. 5: The skier tracks of SP1 (blue), SP2 (orange), FF1 (green), BB1 (yellow). FF1 and SP1 ski the slope in unison.

almost exactly the same time as SP1, 450 m away; SP2 follows on slope 30 seconds later.

Approximately 12 minutes later as the skiers finish their lines, the camera captures more skiers on the ridge. A group of three (S1, S2, S3) positioned at the top of Saddle Peak; another skier (S4) approx. 100 m down the ridge next to the large cornice. The first skier (S1) drops from the peak and skis the southern ridge line stopping in some trees. The next skier (S2) descends from the peak and skis the first gully feature off the ridge line. As S2 and S1 regroup, both S3, positioned on the Peak, and S4, positioned down the ridge, drop in simultaneously. S3 follows the ridge, then skis right into the gully hidden from view away from S1 and S2 posted in the trees along the ridge. S4 skies an aggressive line down the center and out via the diagonal line through the middle of the cliff ban (Fig 6).

When S4 is still 100 m above the cliffs, another skier (S5) is captured descending from Saddle Peak. S1 and S2 are 300 m down slope of S5. S5 stops above the tree line and is then joined by another skier (S6) from Saddle Peak. The duo skis together into the gully which is hidden from the camera view. We note that simultaneous exposure of multiple skiers to the same avalanche path is frequent from Saddle Peak.

Overall, 145 people were captured skiing Saddle Peak on Sunday, February 14, 2016. The camera captured 34 solo skiers, 25 pairs, 11 groups of three and 6 groups larger than three. 81 people skied the terrain off Saddle Peak, 21 people skied the Football Field and 34 skied along the boundary line.

5. DISCUSSION/CONCLUSION

Time-lapse photography is a simple and inexpensive method to document usage in avalanche terrain. It is a beneficial way to study the snowpack for three reasons: aiding in avalanche rescue response, documenting backcountry usage, and documenting avalanche occurrences. We propose that well placed time-lapse cameras like the one presented here would aid avalanche rescuers and researchers in other locations with similar backcountry challenges.

Time-lapse photography can be a powerful tool in avalanche rescue response. A camera can document avalanches occurring in heavily used avalanche terrain, such as slopes easily accessed from a ski area or highway. The images can assist

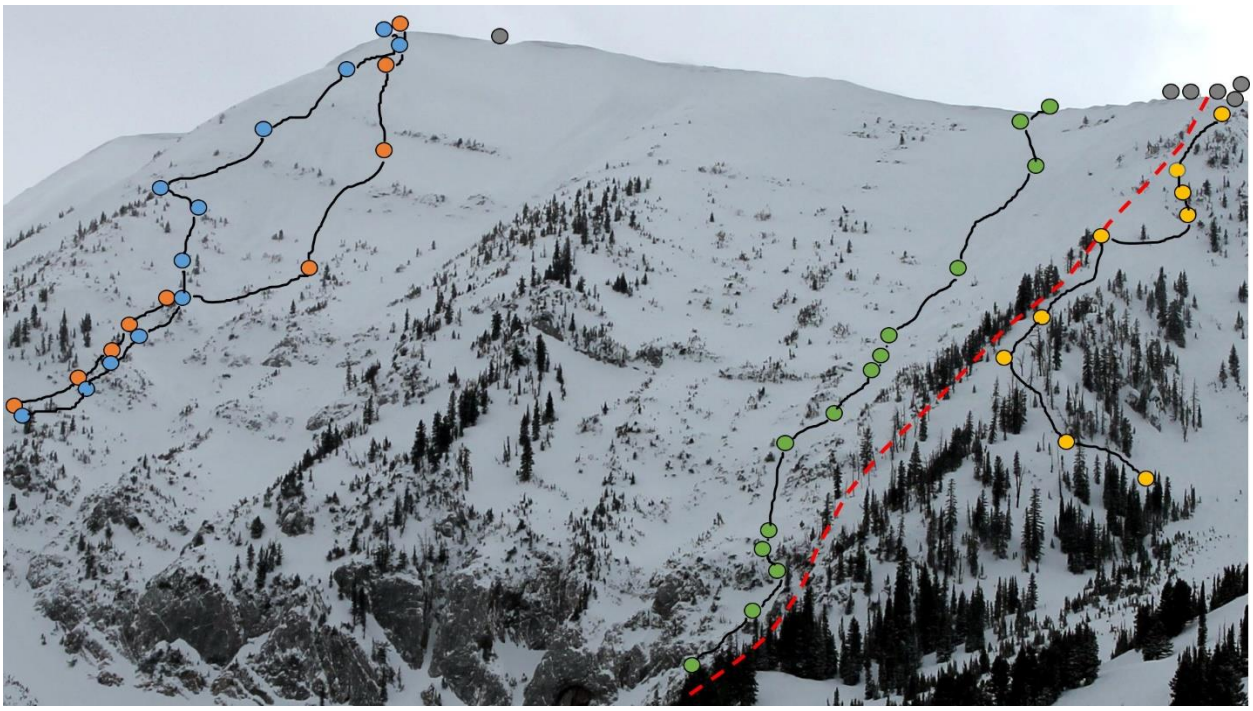

Fig. 6: The first four skier tracks of S1 (green), S2 (blue), S3 (red), and S4 (yellow). S1 and S2 act as a group, S3 and S4 ski the slope simultaneously following very different lines.

with determining the avalanche trigger and trigger location, the number of people involved and total group number, and provide a last seen point in the case of an avalanche involvement. Images can also provide a visual tool to determine residual hazards like hang fire. Well-placed cameras could assist in determining the amount of response needed in an avalanche event. This could be a critical factor when a rescue involves placing emergency responders in hazardous terrain. In heavily skied backcountry areas, a remotely accessed camera could quickly assist in rescue efforts. Cameras may also be helpful in the case of lost skiers.

A time-lapse camera monitoring avalanche terrain can also be beneficial outside of rescue efforts. From the gun platform, the Saddle Peak camera can document the total number of people who access Saddle Peak, what line they ski, and where they access the peak from (i.e. do they traverse on skis across South Bowl or hike the ridge to the peak?). Such information could provide insight into what factors affect a decision to leave a ski area boundary.

One concept of decision making by groups asserts the superiority of crowd averages over individual judgements (Surowiecki, 2004). However, this "wisdom of the crowd' effect is largely contingent on the lack of social influence which undermines decisions (Lorenz, et al., 2011). This requires members make decision independently. The high number of Saddle Peak users suggests that independent decision making is not possible due to the high visibility of current skiers and previous tracks. In the case of Saddle Peak, do tracks result in a rise in skier traffic? Would less people ski Saddle Peak (and the Football Field) if the terrain was not visible from Bridger Bowl?

A camera provides visual documentation of an avalanche. Rather than documenting that an avalanche has occurred due to visual clues, the camera provides a full account of the event including anything that occurs prior to propagation such as weather events and impact by people. As such, this also can identify avalanche triggers and timing of the avalanche. The camera is limited by visibility issues, so terrain must be viewable from the camera location and the weather and light conditions must allow for a clear, or mostly clear view. An infrared camera could be considered for locations where inclement weather would regularly reduce visibility.

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