AVALANCHE RISK FOR RECREATIONISTS IN BACKCOUNTRY AND IN OFF-PISTE AREA: SURVEYING METHODS AND PILOT STUDY AT DAVOS, SWITZERLAND

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ABSTRACT: In the field of avalanche warning and avalanche protection, the usage of free area (non-avalanche-secured terrain) is of high importance and was hardly estimated so far. During the winter 2004-05 different methods to survey and to count people in the free area were tested in the Davos area. Two methods prove to be rather efficient surveys: the light barriers and the voluntary registration boards. During the winter 2005-06, two light barriers and three voluntary registration boards were operated at four different sites in Davos, Switzerland. These surveys provided a good dataset, the first of this type for the Alps. They are the basis of our investigations regarding the behavior of backcountry and off-piste recreationists. This study showed a high sensitivity of the backcountry recreationists to the avalanche danger level. Off-piste recreationists were more sensitive to good snow conditions than backcountry recreationists. Our surveys about the usage of free area enable us to calculate the risk of an avalanche accident more precisely. The individual risk of an avalanche accident for off-piste snow sport was calculated as 7×10^{-5} and for backcountry snow sport as 3×10^{-5} per year, which is both slightly smaller than the risk of driving by car. The surveys will be continued in the future to study the variability between different years.

KEYWORDS: avalanche risk, avalanche warning, avalanche accident, backcountry area, off-piste area, individual risk

1. INTRODUCTION

Backcountry snow sport is known since the end of the 19th century (Perfahl, 1984) and is nowadays a very popular sport in Switzerland. Many first ascents of high alpine peaks by ski had been made in the beginning of the 20th century. Backcountry skiing has experienced many booms, often due to technical improvements. From lodging statistics of the mountain huts of the Swiss Alpine Club (SAC) we found a prominent increase of winter overnight stays since the late 1970's, which is also an evidence for increasing backcountry activity.

In contrast, off-piste snow sport (skiing and snowboarding) is a younger sport. The start of some legendary mountain railways such as Corviglia in St. Moritz (built 1928) and Parsenn in Davos (built in 1931) can be marked as an important mile stone in the history of winter sport. Off-piste snow sport became popular much later and has gained popularity in the last 10 to 20 years, whereby off-piste avalanche fatalities were slightly increasing (Harvey, 2003).

A good data set about recreationists in backcountry and off-piste areas is necessary to calculate the avalanche risk and to get better information of the recreationists behavior. With better knowledge about the behavior of backcountry and off-piste recreationists the products of the avalanche warning can be focused on their needs.

Neither for backcountry snow sport nor for off-piste snow sport the whole population of practicing people are known. Scientific studies about this theme are very rare. Mosimann (2004) made a study for mountain sports in Switzerland, where the usage of terrain by mountaineers was roughly estimated. The most detailed study including the usage of terrain has been made with a large heli-skiing operator at British Columbia, Canada by Grímsdóttir and McClung (2006).

In winter 2004-05 we tested many different methods to count people in the free area. The best

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of these methods were used again in winter 2005-06. The main goal of this study is to show methods for counting people in the free area and to discuss them. With this values of usage in free area we studied the behavior of backcountry and off-piste recreationists. We expected, that both groups are more active due to good weather conditions and on the weekends. From avalanche accident statistics we also expected that backcountry recreationists are more sensitive on avalanche danger level than off-piste recreationists (Harvey, 2002). Furthermore, a first attempt to assess the individual risk of an avalanche accident in the free area is made and compared to other activities.

2. STUDY SITE

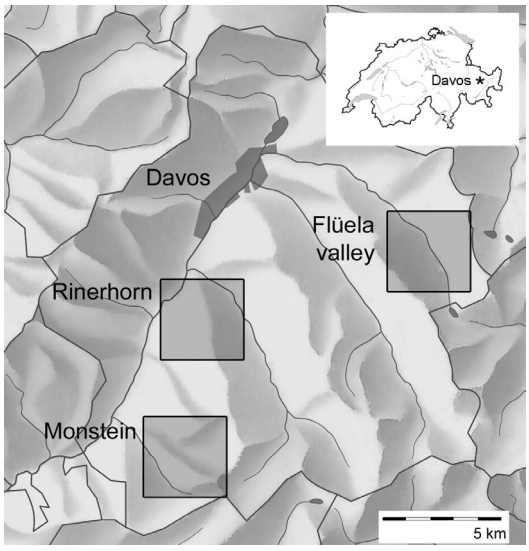

Figure 1: Community of Davos with the study sites of Monstein, Flüela valley and Rinerhorn ski resort.

The region of Davos is situated in the eastern Alps of Switzerland. With four different ski areas and a large backcountry area it offers an ideal setting for a study of the usage of the free area. The best locations to count people in the free area are bottle necks like parking lots at the starting points for popular backcountry routes as well as short ascents for off-piste runs or forest tracks, where off-piste recreationists have no choice of route. We chose the location of Monstein and the Flüela valley to observe backcountry activity and the ski resort of Rinerhorn to have a closer look at off-piste activity (Figure 1).

Rinerhorn is a small ski resort with one aerial tramway and three T-bar lifts. The area offers attractive off-piste terrain between the T-bar lifts and beyond. We can define three main runs, which all lead down to the valley bottom. “Bäbi” and “Hubel” runs are going to the Sertig valley, “Leidbach” run leads to Leidbach valley (Figure 2).

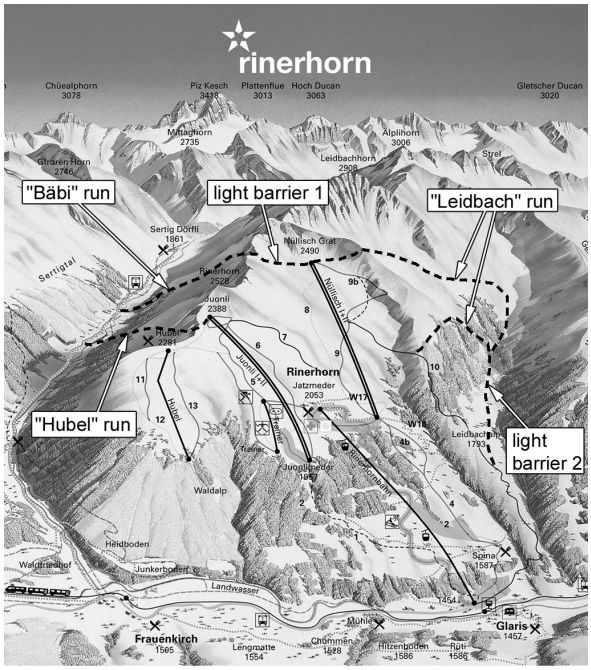

Figure 2: Rinerhorn ski resort. The dashed lines mark the main off-piste routes. People were counted at two locations using light barriers.

3. METHODS

3.1 Light barriers

We used light barriers of the type ALGE RLS 1 which are conceived for alpine ski sports. A ray of light between a sender and a reflector is controlled on interruptions. When a person crosses the ray of light the light barrier registers one interruption. The signals are saved on a data logger in a two minute interval.

The main advantage of the light barrier is the ability of counting people continuously and in all weather conditions. The most important and

challenging fact using this method, is to find an optimal location for the light barrier. The light barrier 2 ("Leidbach" run), which was placed beside a narrow forest track, where all skiers and snowboarders have to pass, achieved the best results (Figure 3).

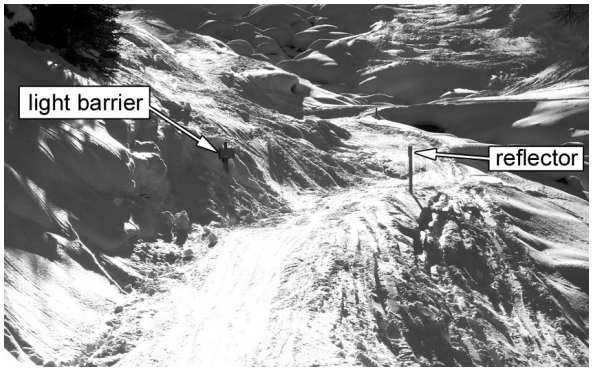

Figure 3: Light barrier 2 at the forest track in Leidbach valley. This is the only way out of the valley and therefore every recreationist has to pass the light barrier (Photo: SLF/A. Raez).

It is an advantage to place a light barrier on a descent route, because people are not tempted to stop which could lead to multiple countings from one person.

The light barrier 1, which was installed at a short ascent for the popular off-piste run "Bäbi" (Figure 2) delivered suitable measurements as well. The light barrier 1 was installed on a narrow shoulder, where it is most convenient to cross a steep slope (Figure 4). The ascent track followed this path in 95 % of all counted cases.

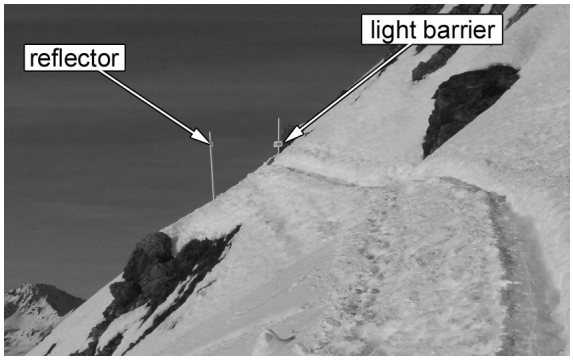

Figure 4: Location of the light barrier 1 on the short ascent to the "Bäbi" run (Photo: SFL/A. Raez).

3.2 Voluntary registration board

To count people in the backcountry area we used voluntary registration boards, where people were asked to write down the date, their route and their ascent style (touring ski, telemark ski or snowshoes). As with the light barriers, it is difficult yet essential to choose a good location to place the boards. We chose two parking lots, one at Tschuggen (Figure 5) in the Flüela valley and one at Monstein. Both are popular starting points for backcountry routes. The big disadvantage of this method is obvious: it is voluntary to register on the boards and not all recreationists were willing to fill in their data.

Figure 5: Registration board at Tschuggen parking lot in Flüela valley, which is an important starting point for several popular backcountry routes (Photo: SLF/A. Raez).

3.3 Observations from ski patrollers

Ski patrollers often have a good overview and are observing the ski area most of the time. They also oversee off-piste and backcountry recreationists or can count them or count their fresh tracks. It is easy for them to register people by a simple tally sheet. This method is good with fresh snow and good visibility. Ski patrollers from the Jakobshorn ski resort have an excellent view to the off-piste runs going down from the neighboring Rinerhorn ski resort into the Sertig valley. They registered the activity in two sectors, the "Bäbi" run and the "Hubel" run.

4. DATA

4.1 Data filtering for the light barriers

One of the first problems of the use of light barriers were multiple countings from people who stopped to have a detailed look at the barrier. This occurred especially on ascent tracks (light barrier 1), rather than on descent tracks (light barrier 2). In both cases, the excess countings lead to characteristic clusters in the signal which could be filtered.

A second phenomenon was the signal disturbance due to snow drift. Light barrier 2 had some periods where snow drift was measured. The counting signal showed extremely high values which were filtered as well (Figure 6).

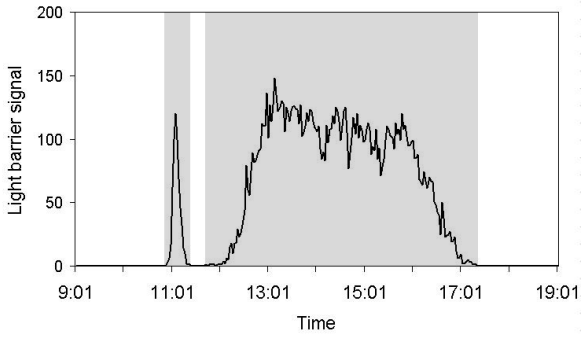

Figure 6: Signals caused by heavy snow drifts at the light barrier 2 on January 16, 2006. The grey ranges were filtered.

Unfortunately it is not possible to count people during snow drift time, because their signals are superposed by the extreme values of the snow drift. However, the snow drift phenomenon occurred only during 1.7 % of the measured time and only at light barrier 2. At light barrier 1 no snow drift occurred most probably because it is placed on a southern slope where the snow had a crust most of the time.

Some counts at light barrier 2 may be caused by animals, usually at night and therefore could be filtered.

4.2 Data extrapolation for the entries on the voluntary registration boards

To verify the data quality of the voluntary registration boards we personally observed the number of recreationists on selected days and compared this number with the number of registrations (Table 1).

Table 1: Registration rate on registration board of Tschuggen parking lot according to spot checks.

Date	*number of people observed*	*number of registra-tions*	*registration rate [%]*
2006/2/15	13	8	62
2006/2/19	34	6	18
2006/4/1	15	4	27
2006/4/7	108	16	15
2006/4/20	72	16	22
Total	242	50	21

The comparison indicated, that only one fifth of all recreationists used the voluntary registration board. Therefore the method has to be improved. For the following analyses the values were corrected with the factor of the registration rate of 21 %. But one has to keep in mind that the uncertainty of this data especially for single day comparisons is quite high.

4.3 Data correction for ski patroller countings

Ski patroller countings became difficult in bad weather due to bad visibility and after a long time with good weather and good snow conditions. Once all slopes are heavily tracked the patroller would have to observe continuously to miss no one. Hence, ski patroller countings may underestimate the true usage. To prove this aspect we compared registrations from light barrier 1 (“Bäbi” run) with the ski patroller countings from Jakobshorn ski resort for the same run. For the time period of 2006/01/12 to 2006/4/2 barrier 1 counted 498 people and ski patrollers counted 473 people. The countings by the ski patrollers differ only about 5 % from the light barriers. The values for “Bäbi” and “Hubel” run were corrected by this error of 5 %.

4.4 Total values for winter 2005-06

Analyses with the total activity of the whole winter are more certain than statistics based on single days, because errors from day to day do

not preponderate. The light barrier 1 measured from January 12, 2006 to April 2, 2006. So it failed the beginning of the ski season from December 23, 2005 to January 12. 2006. For this time period we can take the values of ski patroller countings for the same run ("Bäbi"). The light barrier 2 failed the last nine days of the ski season from March 25, 2006 to April 2, 2006 and had to be corrected. This was done by 50 % of the mean value of 15 people per day. We calculated with 50 % because it was during low season. The voluntary registration boards were operating the whole ski season. The total numbers of backcountry and off-piste recreationists as of winter 2005-06 are listed in Table 2.

Table 2: Number of total of registrations and corrected values for total usage in winter 2005-06

	Measured time period	*Number of registrations*	*Corrected values*
Light barrier 1	06/1/12 - 06/4/2	498	729
Light barrier 2	05/12/23 - 06/3/24	1370	1437
Ski patrollers counting "Bäbi" run	05/12/23 - 06/4/2	623	654
Ski patrollers counting "Hubel" run	05/12/22 - 06/4/1	720	756
Voluntary registration board Flüela	05/12/10 - 06/4/21	955	4548
Voluntary registration board Monstein	05/12/23 - 06/4/22	1171	5576

4.5. Comparisons

Comparisons of the usage of backcountry or off-piste terrain and different weather and snow conditions have been made for the time period from December 23, 2005 to March 23, 2006, when we had best data quality. Data from the winter 2004-05 was not used because it is not a continuous record of the whole ski season. Parameters we used are defined as follows:

Usage of backcountry terrain (U_{bc}): U_{bc} is the sum of the values from the voluntary registration boards at Flüela valley and at Monstein corrected with the mean registrations rate of 21 % (Table 1).

Usage of off-piste terrain (U_{op}): U_{op} is a value for the Rinerhorn ski resort and calculated from the three main off-piste runs. It is the sum of the values from the light barrier 1 ("Bäbi" run) and 2 ("Leidbach" run) and the countings from the ski patrollers for "Hubel" run.

Total usage of free area (U_{total}): U_{total} is the sum of U_{bc} and U_{op}. All usage values are given in number of people per day.

Relative sunshine duration (S_{rel}): S_{rel} is the percentage of possible sunshine on a day. This value was taken to describe weather conditions.

Avalanche danger level: For all calculations the danger level for the region of Davos was taken from the regional avalanche bulletin of the warning service of the SLF (Brabec et al., 2001).

Snow conditions: For an evaluation of the snow conditions we developed a simple classification where we subjectively divided into good, medium and poor conditions, independent of the avalanche danger. "Good" means powder snow or spring snow conditions. "Poor" means hard conditions for snow sport like a breakable or a wind crust. The class "medium" stays for a few days old snow which is still good for snow sport but not powder.

5. RESULTS

5.1 Different behavior of off-piste and backcountry recreationists

The total usage of free area increases with better weather conditions (Figure 7).

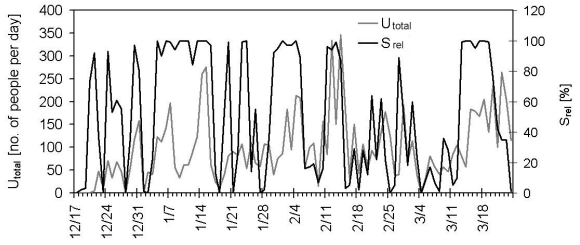

Figure 7: Comparison of total usage of free area U_{total} with the relative sunshine duration S_{rel} at the ANETZ weather station (MeteoSchweiz) at Weissfluhjoch Davos, 2690 m a.s.l. in winter 2005-06. High U_{total} correlates positively with high S_{rel}.

The total usage of free area decreases with higher avalanche danger levels. However, backcountry recreationists are more sensitive to the avalanche danger level than off-piste recreationists. Data of winter 2005-06 showed that 96.8 % of the usage of backcountry terrain is on days with avalanche danger levels 2 and 3 and only 3.2 % on days with danger level 4 whereas off-piste activity is 18.5 % at danger level 4 (Figure 8). Avalanche danger levels 1 and 5 did not occur during the survey period.

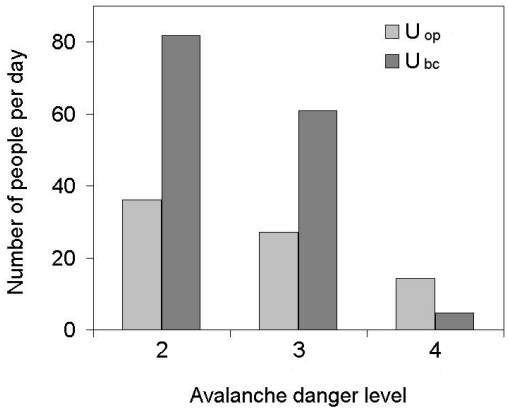

Figure 8: Comparison of the usage of backcountry U_{bc} and off-piste terrain U_{op} with the avalanche danger level in winter 2005-06. Backcountry recreationists are more sensitive to the avalanche danger level than are off-piste recreationists.

The comparison of the snow conditions with the usage of backcountry and off-piste terrain showed a higher sensitivity of the off-piste recreationists for “good” snow conditions, while the activity of backcountry recreationists was higher in “medium” and “poor” snow conditions (Figure 9). The snow conditions can be related to the avalanche danger level, whereby “good” snow conditions appear more often during higher avalanche danger levels.

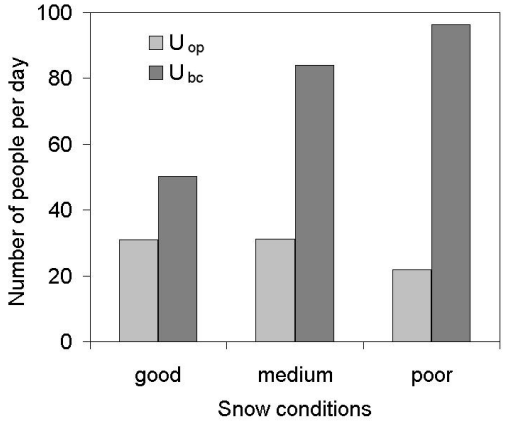

Figure 9: Usage of backcountry U_{bc} and off-piste terrain U_{op} in comparison with the snow conditions in winter 2005-06. U_{op} was higher for “good” snow conditions, while U_{bc} was higher in “medium” and “poor” snow conditions.

The differences in activity between workdays and weekends was small. Off-piste recreationists do not show any preference of day. Backcountry activity is a little higher on weekends (Figure 10).

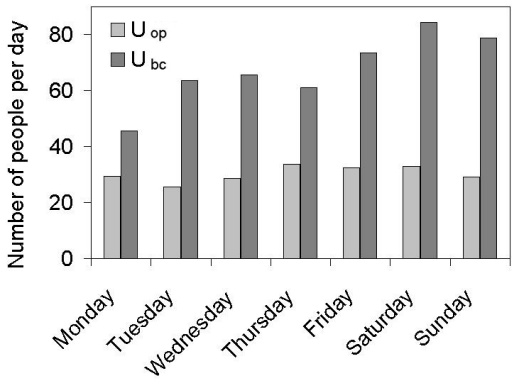

Figure 10: Usage of backcountry U_{bc} and off-piste terrain U_{op} related to weekdays in winter 2005-06. U_{bc} was little higher on weekends. U_{op} does not show any preference of day.

5.2 Individual risk for off-piste and backcountry snow sport

The individual risk is the probability to suffer a certain damage during a certain time (Fritzsche, 1986). To calculate this risk we need numbers about victims as well as numbers about the total population of practicing people.

If we look to Rinerhorn ski resort we can calculate the sum of the corrected usage values of the three main off-piste runs ("Bäbi" counted by light barrier 1, "Hubel" counted by ski patrollers and "Leidbach" counted by light barrier 2) and get a total amount of 2922 runs for ski season 2005-06 (Table 2). Avalanche observation data from the Rinerhorn ski resort (regarding the same perimeter as for the usage values) showed 19 avalanches triggered by snow sports: one avalanche of size 4, 13 avalanches of size 3, four avalanches of size 2 and one avalanche of size 1, according to the Canadian avalanche classification (McClung and Schaerer, 1993). Two people have been caught and one person died in an avalanche on the "Leidbach" run on March 13, 2006. Within the last 20 years (winter 1984-85 to winter 2003-04) there were four avalanche fatalities on off-piste runs at Rinerhorn. Assuming a constant total population which is the number of the 2005-06 survey, we can calculate the individual risk which is defined as the number of victims per year divided by the number of people being at risk (Fritzsche, 1986). This leads to an individual risk of 7×10^{-5} per year.

The same calculation has been done for backcountry area of Flüela valley and Monstein but the uncertainty of the number of recreationists is higher because of the low registration rate (Table 1). The total of the corrected usage values are 4548 for Flüela valley and 5576 for Monstein. In the last 20 years there were three avalanche fatalities at Monstein and no fatalities at Flüela valley in the backcountry area. With the previous assumption of the constant total population, this amounts to an individual risk per year of 3×10^{-5} for Monstein. For the Flüela valley the individual risk cannot be calculated.

We compared the values of individual risks for different sports and activities. A study in Switzerland estimates individual risks for alpine climbing, rock climbing and for mountain hiking (Mosimann, 2004). Individual risk for driving by car was calculated by Proske (2004). Figure 11 shows a comparison of the individual risks of the different activities.

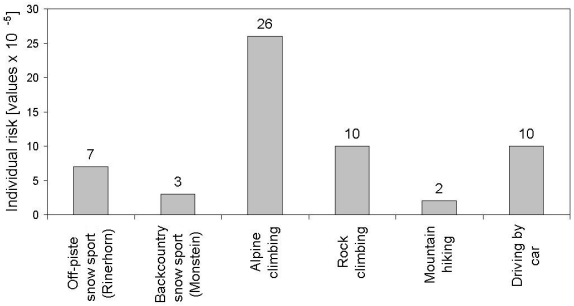

Figure 11: Different individual risks per year from the literature in comparison to the risk of off-piste and backcountry snow sport, determined from our surveys during winter 2005-06.

6. DISCUSSION

Additional methods to count people in the free area have been tested in winter 2004-05, but were not applied further on. Nevertheless, some of them are worth to follow up.

Photographs: To count fresh tracks, photographs were taken from the opposite slopes. Due to light problems because of bad weather or shadowed parts in the slopes it was more difficult to differ the individual tracks on the pictures than assumed.

Remote sensing: Satellite images like IKONOS with a one-meter resolution can show tracks during optimal visibility. From an archive image from Pilatus peak (central Switzerland) on a clear spring day it was possible to recognize fresh tracks on the snow cover. However, difficulties occur in distinguishing the individual tracks to count them. Satellite images are costly, which is a disadvantage of this method. Air photographs have a better resolution and would be a good source to count fresh tracks on snow. These photographs would have to be ordered individual for a specific area and time period to ensure a temporal continuity, which is also costly.

Questionnaires: In winter 2004-05 we collected data from different hotels at Davos. This is a good method to get a better idea of the activity of guests in winter sport resorts. The main difficulty is to get a high return rate of

questionnaires and to find a good segment of hotels. One should also check the customs of guests who stay only one day.

Tourism statistics: Lodging statistics of mountain huts or selling statistics of mountain equipment like beacons or shovels gave a possibility to analyze historical evolution of snow sport in free area.

The analyses of the behavior of backcountry and off-piste recreationists are based on single day values, because most data as the avalanche danger level, the snow conditions and the avalanche activity exists in a single day resolution. Therefore, the counting methods have to be very exact, allowing only small errors in the single day counts. Data from the light barriers with an estimated error of maximally 10 % are very suitable for these analyses. Data from the voluntary registration boards with its high variation from day to day are more problematic. The method could be improved perhaps by an automatic camera system.

The accuracy of the values for the individual risk is normally in the area of one order of magnitude. So accuracy of the calculated individual risk for off-piste snow sport on Rinerhorn of 7×10^{-5} is probably the best present estimation. Even the value of individual risk for backcountry snow sport at Monstein of 3×10^{-5} per year which is based on the voluntary registration boards give the correct order of magnitude.

7. CONCLUSION

This study was based on the first data set of usage in the free area in the Alps. With a unique data set of the winter 2005-06 we showed how the usage of free area depends on weather and snow conditions, avalanche danger level and weekday. As expected the total usage of free area increases with better weather conditions. As expected a higher sensitivity of backcountry recreationists on avalanche danger level in comparison to off-piste recreationists was observed. The differences in usage between the workdays and the weekends was surprisingly small, especially for off-piste recreationists. Furthermore we found that off-piste recreationists are highly sensitive to good snow conditions. The calculated individual risk of an avalanche accident was 3×10^{-5} for backcountry snow sport at Monstein and 7×10^{-5} for off-piste snow sport at the Rinerhorn ski resort in winter 2005-06. It is on average a factor 5 smaller than the risk during Alpine climbing. The chance to die in a car accident is slightly higher, while mountain hiking slightly smaller. This knowledge will enhance avalanche prevention efforts and may later flow into avalanche warning products in Switzerland.

We will continue the measurements with the light barriers and the registration boards at least for the winter 2006-07. The method of the voluntary registration boards has to be improved in future. A good idea would be to control or to substitute them by an automatic camera system. After further winters it will be interesting to compare the activity of different winters with different snow cover conditions. One future goal should also be to develop sound up scaling methods. In this context it would be helpful to establish a classification for off-piste runs and backcountry routes concerning the avalanche risk, the degree of difficulty and the accessibility.

8. ACKNOWLEDGEMENTS

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10. GLOSSARY

Snow sport: All recreational activity on snow like alpine skiing, snowboarding, telemark skiing and many more. Snow sport can be practiced both in controlled areas and in free areas.

Controlled area: Avalanche controlled area for snow sport (as done by security service and ski patrollers).

Free area: All non-avalanche-secured terrain, both backcountry and off-piste area. People go there on their own risk.

Backcountry: Non-avalanche-secured terrain apart of the controlled areas. People need ascent aids like touring skis or snow boots to get into backcountry terrain.

Off-piste: Non-avalanche-secured terrain with the controlled ski areas as starting point. Only short ascents are done in off-piste terrain. People don't need ascent aids to get into off-piste terrain (including helicopter skiing).

Individual risk: Probability to suffer a certain damage during a certain time (normally one year). The individual risk is calculated from the number of victims per year divided by number of people being at risk (Fritzsche, 1986).