NEW TRENDS OF RECREATIONAL AVALANCHE ACCIDENTS IN SWITZERLAND

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ABSTRACT: In the last 10 years equipment and knowledge of recreationists and organised rescue teams in avalanche terrain has developed. More and more people are travelling in off-piste terrain or on skitours. Avalanche prevention and rescue training as well as avalanche warning and the possibilities to get good information have improved. Time to look back 30 years (1977 - 2006) to analyse trends of recreational avalanche accidents. Although more people recreate in avalanche prone terrain, the number of fatalities has decreased. Though the amount of complete burials has not changed, burial time and mortality rate of completely buried persons developed into a positive direction. Companion rescue and organised rescue teams recovered more often survivors in recent years. Further the development of fatalities in guided groups is decreasing and shows higher professionalism. Over the years avalanche warning has also changed. We compared avalanche accidents with predicted avalanche danger degrees to find out, if the proportion of accidents to danger levels has changed and found out, that people do not tend to take higher risk. Comparison of accidents with danger levels did not show particular differences for specific climatologic regions. The avalanche accident risk at a certain danger level is not influenced by a regional factor.

KEYWORDS: avalanche accident, avalanche accident statistics, avalanche forecast, avalanche danger degree, avalanche rescue, backcountry

1. INTRODUCTION

Reports and analysis of avalanche accidents have always been of interest for educators in avalanche prevention and rescue. Therefore the Swiss Federal Institute for Snow and Avalanche Research publishes annual reports of avalanche accidents since 1941 (e.g. Zweifel, 2006). All known natural avalanches which caused any damage to people and/or property in approximately the last 120 years, as well as all recreational avalanche accidents since winter 1970/71 are stored in a electronic data base. It contains totally around 12700 datasets of avalanches and about 6500 datasets of people caught by avalanches.

Latest analysis of avalanche accidents of different time periods before year 2000 in Switzerland have been published e.g. by Tschirky et al. (2000), Schweizer et al. (2000), Harvey (2002) and Harvey et al. (2002). In the last 10 years more and more people recreate in backcountry terrain. Their behaviour as well as the equipment has changed. Avalanche safety and rescue equipment for recreationists and for rescue teams has improved. Brugger et al. (2007) showed based on avalanche data (1990-2004) from Austria and Switzerland, that avalanche rescue devices reduce mortality. Further, avalanche prevention, safety and rescue training as well as avalanche warning and information service have improved (Etter et al., 2008).

To show how all these developments effected avalanche accidents in recent years is the purpose of this paper. Based on a 30 year dataset (1977-2006) trends of recreational accidents were analysed. Further accidents were compared to predicted avalanche danger degrees (19 year dataset). Additionally some well known statistics have been updated based on new data.

2. TRENDS 1977 – 2006 (30 YEARS)

A 30-year dataset of recreational avalanche accidents from 1977 to 2006 has been used for analysing trends. The dataset contains 6156 avalanches, whereof 1619 datasets are recreational avalanche accidents. In these 1619 avalanches, 3434 people have been caught, whereas 703 were fatalities. A linear model has been used to determine trends. A trend has been called significant when the

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level of significance was smaller than 0.05 (p-value).

Due to more information of "harmless" avalanche accidents, the recorded number of incidents and caught persons has increased. Even so the trend of fatalities is decreasing over 30 years (Fig. 1; p=0.019).

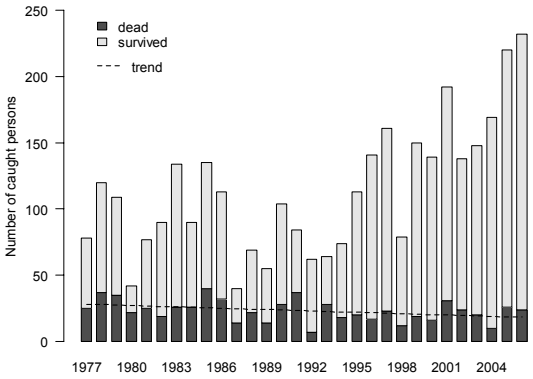

Figure 1: Number of people caught by avalanches. The dotted line shows the linear trend of fatalities. It indicates a significant decreasing trend over the last 30 years.

2.1 Activity of caught people

Although we do not know the number of persons recreating in avalanche terrain, we can say, due to qualitative observations that the amount of people has increased. New winter sports as snowboarding and snowshoeing came up and were affected by avalanche accidents in the last 10 years (Fig. 2).

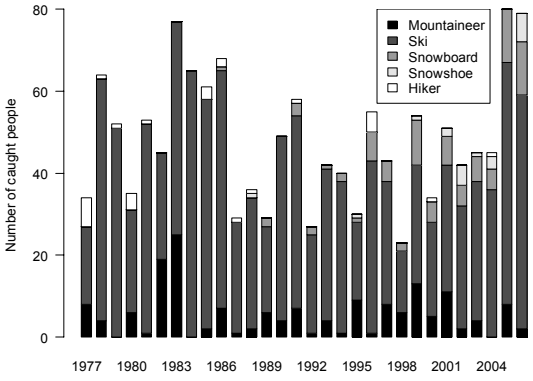

Figure 2: Injured people and fatalities, caused by recreational avalanche accidents. In recent winters avalanches caught fewer hikers. On the other hand injured respectively killed snowboarders or snowshoers came up.

Media often mention an increase of avalanche accidents in off-piste terrain. Analysis of data of avalanche accidents shows, that 60% of recreational accidents occur on backcountry tours and 40% off-piste. There is no significant trend. The ratio of the number of caught recreationists on tours and off-piste fluctuates every year quite strongly and lies constantly at around 70:30 over the last 30 years, without a significant trend (Fig. 3).

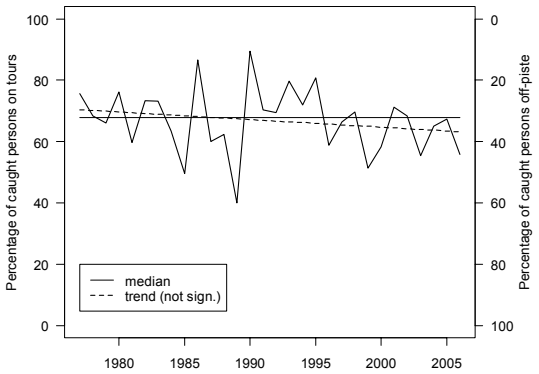

Figure 3: Ratio of people caught on ski tours to people caught in off-piste terrain. There is a marginal trend to more off-piste accidents, which is not significant.

2.2 Guided groups

From the 1619 recreational avalanche accidents in the investigation period, 278 involved guided groups. We defined guided groups as groups led by a professional mountain guide, an official tour leader of an association (like Swiss Alpine Club or Youth and Sports, etc.), the army, a school or any other groups of recreationists, where one or several persons were responsible for avalanche safety. 193 fatalities out of 1020 caught persons in guided groups are recorded. In the last 30 years the number of fatalities has decreased significantly (Fig. 4). A linear model computes the following numbers of fatalities per year in guided groups:
1978: 10 fatalities; 1989: 7 fatalities; 2006: 3 fatalities.

The ratio of fatalities in guided and non-guided activities dropped significantly from 40:60 to under 20:80. In other words, guided groups were less involved in severe avalanche accidents in recent years. One reason may be better avalanche knowledge and higher professionalism of guides and leaders. Although this trend

looks promising, still every 5th recreational avalanche fatality occurs in a guided group nowadays with experienced guide or leader. These accidents usually have legal consequences with no increasing prosecution in recent years (Schweizer et al., 2006).

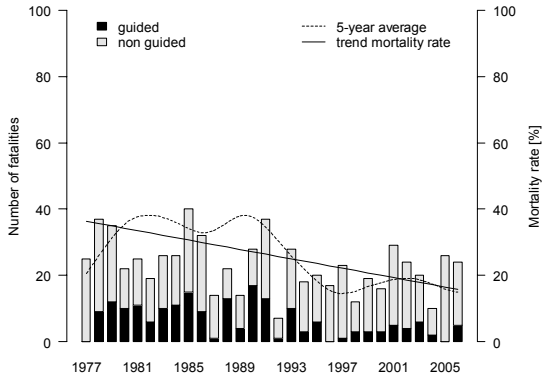

Figure 4: Fatalities in guided and non-guided groups. The mortality rate in guided groups has decreased significantly (continuous line, right y-axis), where in non-guided groups no trend can be figured out.

2.3 Complete burials, rescue trends

Although the number of caught recreationist has increased in the last years (Fig. 1) due to more reported avalanche accidents, the amount of completely buried persons has not changed (p=0.787). This indicates that especially "harmless" avalanche incidents were communicated more often. Further complete burials have been recorded as thorough as possible in the past. As in Tschirky et al. (2000) mortality rate of complete burials has decreased further in recent years and reaches a level of 40% nowadays (Fig. 5). This reduction has been achieved especially through a significant higher success in rescue in the last years (Tab. 1).

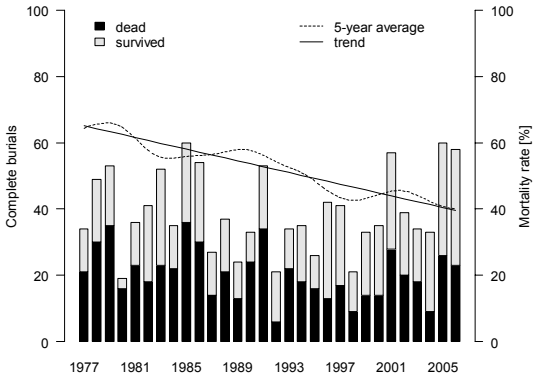

Figure 5: Trend of mortality rate of completely buried persons on tours and off-piste (continuous line, right y-axis). The bars show the number of survived and not survived of complete burials (left y-axis).

The effectiveness of rescue increased. Mortality of complete burials has decreased significantly for companion rescue as well as for organised rescue teams (Tab. 1).

	77-86 (10 yrs)	87-96 (10 yrs)	97-06 (10 yrs)	linear trend
companion rescue	34%	32%	20%	p=0.006
organised rescue	88%	79%	70%	p=0.001

Table 1: Mean mortality rate for companion rescue and organised rescue teams in three 10-year periods (1977-86, 1987-96 and 1997-2006). A linear trend model is decreasing for both rescue groups significantly over 30 years.

Burial time of complete burials decreased significantly in the last 30 years (p= 7.4e-06). Median burial time was in the late 70s at around 120 minutes, at the beginning of the 90s at around 80 minutes, nowadays at 20 to 30 minutes (Fig. 6). Modern equipment and good rescue education led to faster recovery, which finally reduced mortality rate of complete burials. Burial depth of completely buried persons, not found due to visible parts, has not changed and lies at 120 cm for fatalities, 70 cm for survivors with a total median at 100 cm (Harvey et al., 2002).

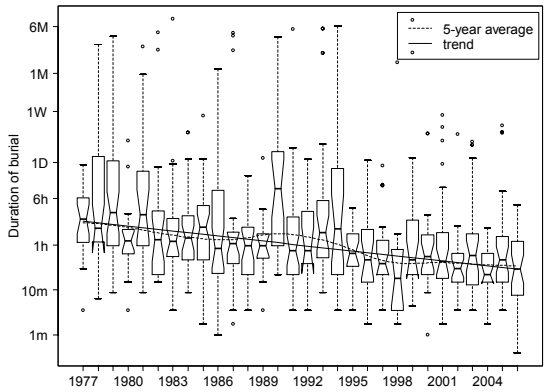

Figure 6: Burial time of completely buried persons found without visible parts.

Better training with avalanche transceivers and/or digital transceivers may have reduced mortality rate of completely buried found with transceivers to 30% in recent years (Tab. 2).

	77-86 (10 yrs)	87-96 (10 yrs)	97-06 (10 yrs)	linear trend
transceiver	49%	59%	29%	p=0.024
vis. parts	21%	8%	10%	p=0.111

Table 2: Mortality rate of completely buried recovered through companion rescue and discovered by transceiver or visible parts.

No. of burials	No. of accidents	affected people	% no. of accidents	% affected people
Backcountry touring				
1	126	126	80%	63%
2	24	48	15%	24%
3	5	15	3%	7%
4	3	12	2%	6%
Off-piste				
1	63	63	89%	74%
2	4	8	5%	9%
3	2	6	3%	7%
4	2	8	3%	10%

Table 3: number of accidents and number of affected people (completely buried people found without visible parts from 2000 to 2006).

In recent years there were hardly any accidents with more than 7 people caught. The mean size of groups recreating in backcountry terrain involved in an avalanche accident has decreased significantly from 3.6 to 2.8 persons. There were less multiple burials recorded since 2000. From 2000 to 2006 only around 5% of all the accidents had more than two burials (Tab. 3), whereas between 1970 and 1999 (Harvey et al., 2002) the number was more than 10%.

3. ACCIDENTS AND DANGER DEGREE 1988-2006 (19 YEARS)

The predicted avalanche danger level of the avalanche warning reports is stored in a database since winter 1987/88. Therefore analysis of accidents with the danger scale rating could only be done during the time period of winter 1987/88 until 2005/06 (19 years). Degrees from the elderly seven-scaled danger scale before 1993 have been converted into the European avalanche danger scale with 5 levels (Stoffel et al., 2004).

During the investigation period danger level 'low' decreased marginally (p=0.067) for the benefit of 'considerable' and 'moderate', which both increased marginally ('considerable' p=0.132, 'moderate' p=0.06). As in Stoffel et al. (2004), where mean danger scores were compared, there is also no significant trend for each danger level itself.

3.1 Characteristics over time

The number of recorded recreational avalanche accidents increased in recent years especially at danger level 'moderate' and 'considerable'. To compare characteristics over time, independent of number of avalanche accidents, we looked at the ratio of avalanche accidents occurring at each danger level (Fig. 7). The ratio decreased at danger level 'high' (p=0.007), where as for danger level 'considerable' it increased marginally (p=0.052). Danger levels 'moderate' and 'low' do not show any trend.

The division of the number of accidents per danger level by the frequency of each danger level for every year resulted in an index of avalanche risk per danger level and year. The frequency of the danger levels was calculated by the sums of danger levels for each of 117 static, spatial units (Stoffel et al., 2004). Fig. 8 shows the percentage of this index for each year and danger level. From 1988 to 2006 no trend is recognisable, which means that within the danger levels 'low', 'moderate' or 'considerable the proportion of avalanche accidents has not

changed. Due to sparse data, danger levels 'high' and 'very high' could not be considered for this analysis.

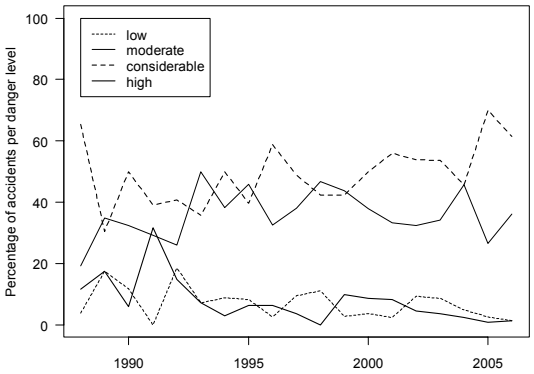

Figure 7: Percentage frequency of avalanche accidents per danger degree.

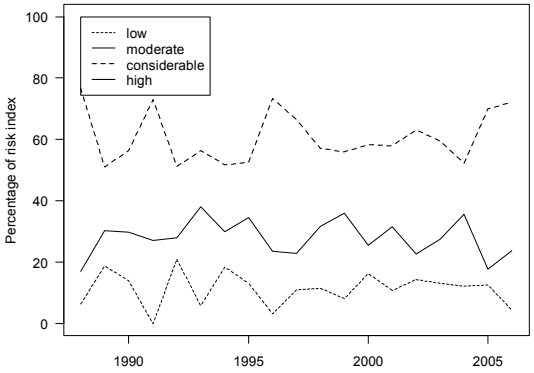

Figure 8: Proportion of avalanche accident risk for danger levels 'low', 'moderate' and 'considerable'. The risk for an avalanche at 'considerable' is nearly double as high than for 'moderate'.

3.2 Spatial characteristics

In a similar way as above we analysed if there were differences of avalanche accidents within a danger level in different climatologic regions of Switzerland. Laternser (2002) suggested new climatologic regions based on spatial grouping of snow stations. We adapted these 14 regions from an avalanche forecasters point of view to 16 climatologic regions (Fig. 9). We wanted to find out if the proportion of risk for a recreational avalanche accident at danger levels 'low', 'moderate' and 'considerable' varies among the climatologic regions.

Fig. 9. Adapted climatologic regions.

Therefore we calculated the ratio of avalanche accidents for danger levels 'low', 'moderate' and 'considerable' in each region to avoid unbalanced avalanche frequencies in each region and to normalise the data (Fig.10). Danger level 'high' and 'very high' were ignored due to sparse data of recreational avalanche accidents. Therefore all avalanches causing damage would have to be taken into consideration.

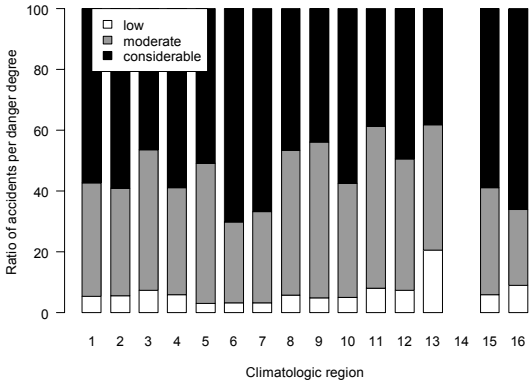

Figure 10: Ratio of recreational avalanche accidents for danger level 'low', 'moderate' and considerable' in 16 climatologic regions.

Because of missing data the climatologic region No. 14 was not considered in the analysis.

The ratio of accidents per climatologic region and danger degree was divided by the frequency of each danger level in every region, which resulted in an index of avalanche accident risk per danger level for each climatologic region. Fig. 11 shows the percentage of this risk index for danger levels 'low', 'moderate' and considerable' in each region. It shows, that if an avalanche accident occurs on a specific day, to which percentage the avalanche danger level is 'low', 'moderate' or 'considerable' for 16 regions.

This under the assumption, that the percentage of people who recreate in avalanche terrain at danger level 'low', 'moderate' or 'considerable' is more or less the same in all regions. Obvious different frequencies of recreationist in specific regions did not affect this analysis.

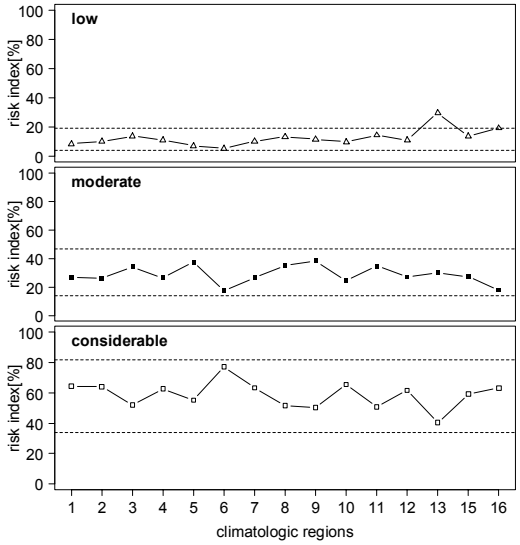

Figure 11: Proportion of avalanche accident risk for danger levels 'low', 'moderate' and 'considerable' in 16 climatologic regions. Days with danger degree 'high' or 'very high' were excluded due to sparse data. The dashed lines show the thresholds we used to detect outliers.

As higher the danger degree, as wider the range of avalanche risk gets among the regions. By looking only at ski touring accidents, the width of the range at 'considerable' and 'moderate' danger level was more or less the same (Tab 4). Outliers were detected as values more than 1.5 times the interquartile range above the third quartile or below the first quartile. Except region No. 13 and 16 at danger degree 'low', there were no regions with significant different avalanche accident risk. Further we could not find a significant effect of inner alpine, southern or northern regions on the avalanche accident risk index. By comparing pairs of regions some interesting differences could be detected. For example the risk index of an avalanche accident at 'moderate' or 'considerable' danger degree is significant different from region No. 6 to No. 8, which both are inner alpine regions. Region No. 6 has more off-piste activity than region No. 8, where more ski tourers recreate. Zweifel et al. (2006) showed, that the proportion of the usage of ski touring and off-piste terrain is slightly different for danger level 'moderate' and 'considerable'. This may have an influence on the high risk in region No. 6 at danger level 'considerable'. Therefore we did the same calculation only with ski touring accidents. However, these results did not show any difference.

Not to forget is, that these comparisons were done with predicted avalanche danger degrees, which were not verified. For a more realistic risk calculation the number of persons recreating in the different regions at a certain danger level should be known, as well as a verified danger level for each region.

Danger degree	All: range 1.-3. Qu.	Tour: range 1.-3. Qu.	Off-piste: range 1.-3. Qu.
1	10-14%	14-19%	0-4%
2	26-34%	31-41%	12-20%
3	52-66%	42-52%	78-82%

Tab. 4: Range between first and third quartile of avalanche accident risk at danger level 'low', 'moderate' or 'considerable'.

4 DISCUSSION AND CONCLUSION

From 1977 to 2006 recreational avalanche fatalities have decreased although there is more backcountry activity. This simple comparison shows, that the avalanche awareness of recreationists improved in the last years, that avalanche knowledge and information got better and rescue techniques and equipment advanced. Especially the percentage of fatalities in guided groups has decreased from nearly 40% to less than 20%, which indicates better avalanche knowledge and higher professionalism of guides and leaders.

Mortality rate of complete burials has decreased, influenced by a significant shorter burial time, which lies on an average between 20 and 30 minutes nowadays. Companion rescue and organised rescue both could decrease mortality rate. Despite of this tendency, companion rescue, with 20% mortality rate nowadays still is more promising than organised rescue teams (70% mortality rate) due to the time factor. In the last 7 years 16% of recreational avalanche accidents with complete burials - not found due to visible parts - were multiple burials. Only in 5% of the cases more than 2 complete buried persons had to be found. This percentage may have decreased in recent years due to smaller groups, which move in

avalanche terrain and maybe also due to behaviour measures for risk reduction (e.g. maintaining safety distances between the single skiers when traversing avalanche prone slopes). Avalanche rescue training should therefore be better focused on reducing burial time for cases with one or two burials than on complicated multiple burial scenarios.

Although frequency of avalanche accidents and danger levels has partially changed over time, the proportion of avalanche accident risk on days with danger levels 'low', 'moderate' or 'considerable' has not changed. This means that in general the interpretation of the danger degrees has not changed and that recreationists have not taken higher or lower risk between 1988 and 2006. The risk of avalanche accidents for danger degrees 'low', 'moderate' or 'considerable' in 16 climatologic regions varies partly, without any logic pattern. The greatest outlier region is No. 13 (Fig. 9) with a relative high proportion of avalanche accident risk at danger level low. For danger level 'moderate' and 'considerable' all regions lie between the defined thresholds. Region No.6 seems to have a higher risk of avalanche accidents for danger level 'considerable'. This cannot be explained through high frequencies of off-piste activity. For better spatial risk calculation behaviour of recreationists, accessibility, topography and verified danger degrees would have to be considered.

Despite the positive tendency of recreational avalanche accidents, avalanche awareness has to be further developed to minimise injuries and fatalities as much as possible.

5. ACKNOWLEDGEMENTS

Without reports of avalanche accidents from involved recreationist, guides, ski patrollers, police, rescuers, etc. we would not be able to archive and describe interesting accident examples. The more avalanche data we get, the more solid analyses are possible. We would like to thank every one who contributed avalanche data in one or the other way.

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