AVALANCHE EDUCATION IN NORTHERN ARIZONA: IDENTIFYING WINTER BACKCOUNTRY DEMOGRAPHICS TO FOCUS EDUCATION EFFORTS OF THE KACHINA PEAKS AVALANCHE CENTER

By Derik Dmitri Spice

A Practicum

Submitted in Partial Fulfillment

of the Requirements for the Degree of

Master of Science

in Applied Geospatial Sciences

Northern Arizona University

May 2016

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ABSTRACT

AVALANCHE EDUCATION IN NORTHERN ARIZONA:

IDENTIFYING WINTER BACKCOUNTRY DEMOGRAPHICS TO FOCUS

EDUCATION EFFORTS OF THE KACHINA PEAKS AVALANCHE CENTER

By Derik Dmitri Spice

Winter recreation is a growing trend in the United States, especially skier, snowmobile, and snowboard visits to backcountry terrain. These visits involve potentially dangerous travel in avalanche prone areas, often adjacent to ski areas situated in National Forests. Avalanches are the most common cause of death on National Forest land, with an average of 30 fatalities each year. Avalanche terrain is often monitored by professional avalanche forecasters employed by Avalanche Centers throughout the western United States, which provide backcountry snow stability forecasts and avalanche education for the safety of winter recreationists. Despite these efforts, avalanche fatalities continue to increase, and the National Avalanche Center believes that avalanche education is the best method to avoid future avalanche accidents and fatalities. Locally, avalanches on the San Francisco Peaks in Northern Arizona are a winter hazard, including a fatal avalanche accident in 1995. This practicum project utilizes a survey method of identifying the unique demographics of winter recreationists in Northern Arizona in terms of current safety habits of backcountry travelers, their level of avalanche education and rescue preparedness. This research seeks to focus the avalanche education strategies of the Kachina Peaks Avalanche Center (KPAC) to prevent further winter backcountry fatalities. Survey results indicate potential to improve overall levels of avalanche education; increase proper safety practices; and foster greater awareness of the resources of the Kachina Peaks Avalanche Center.

Keywords: avalanche; avalanche center; avalanche education; backcountry terrain; backcountry travel; Kachina Peaks Avalanche Center; snow stability; snow study; US Forest Service; winter recreation.

Prescott College

FOR THE LIBERAL ARTS AND THE ENVIRONMENT

April 11, 2016

Graduate Committee
Northern Arizona University
Flagstaff. AZ 86001

Dear Committee:

This letter is written in behalf of Derik Spice to demonstrate his significant support to Kachina Peaks Avalanche Center, Inc. (KPAC). As education coordinator and founding member of KPAC, I am familiar with his contributions.

When Derik relocated to Flagstaff in almost a decade ago to become a member of the Snowbowl Professional Ski Patrol he soon became involved with KPAC, bringing expertise gained through prior employment with The Canyons Ski Patrol in Park City, UT and by working with the Utah Avalanche Center, one of the most prestigious organizations of its type. In no time at all, he became a KPAC board member, and in 2010 was elected president of the board of directors.

Derik's background in avalanche mitigation practices, prudent travel procedures, snowpack stability evaluation, and avalanche education has influenced local perspectives. This has significantly benefited both the Arizona Snowbowl Resort's ski patrol and KPAC's operations and professionalism. He has devoted tremendous energy to KPAC on many levels, but particularly in a leadership role. As president he has organized and chaired all of the board of directors meetings, been the point person in fundraising events, and spokesperson while interacting with the media. He has been a member of our educational team, working as a co-instructor in many free "Introduction to Avalanche" clinics at local sport stores and at the Coconino County Sherriff's Department, and co-instructing the American Avalanche Association's level 1 courses.

Derik has been instrumental in providing communication and coordination between a number of local agencies involved in emergency management and winter recreation safety. Specifically, he has helped to facilitate productive and integrated relations between Coconino County Search and Rescue, Coconino National Forest, AZ Snowbowl Resort, and Kachina Peaks Avalanche Center, Inc. As a valued expert, his advice has critically influenced decisions related to public safety and wilderness access when prevailing conditions have reached the extreme and warranted restrictions.

Social/behavioral research, as well as, professional standard field observations have enabled Derik and the KPAC team to understand unique characteristic of the regional snowpack and population we serve. Derik's analysis of survey data have allowed him to better understand and relate to local winter recreationists, and more accurately describe our avalanche problems and give advice of precautionary measures. Since 2012, KPAC has issued weekly summaries characterizing backcountry conditions in the Kachina Peaks Wilderness. These have been posted to KPAC's website www.kachinapeaks.org as a public service. Derik has either written or edited almost all of these.

Derik's dedication and commitment to avalanche education and safety have been essential to the success of Kachina Peaks Avalanche Center's award willing success. His passion, tenacity, and commitment have had a pivotal influence on KPAC's success.

Sincerely,

David W. Lovejoy
Faculty, Winter Program Director
Adventure Education Program
Prescott College

ACKNOWLEDGEMENTS

I would like to, first and foremost, thank my committee chair, Pam Foti, and committee members Aaron Divine and Marieke Taney, for their enthusiasm, encouragement, friendship, patience, humor and guidance in my efforts to complete this project. Also, many thanks to the faculty and staff of the Geography, Planning and Recreation Department who have hosted me in their midst for three years, consistently welcoming and encouraging me to explore the academic realm of possibilitites.

Thank you to Professors Amanda Stan, Erik Schiefer, Mark Manone and Dawn Hawley, who have proven themselves as brilliant colleages, mentors and advisors. Nicole Harris, Dana Mandino, and Kayla Hare provided indispensable support in my attempts to navigate the labyrinth of University procedures and policies, as well as securing crucial office space in a competitive market.

Nate Moody and Jenifer Zanoni are recognized as the best office mates and real world neighbors possible. Thank you for your constant encouragement and assistance with my coursework and practicum challenges.

United States Forest Service Ranger Patrick McGervey, Forest Service volunteers, and Coconino County Search and Rescue Coordinators Aaron Dick and Art Pundt deserve praise for their assistance and dedication to public safety and avalanche education. Many thanks to Utah Avalanche Center ‘Know Before You Go’ Program Coordinator Craig Gordon for his expertise and enthusiasm.

The founding members of the Kachina Peaks Avalanche Center, BJ Boyle, Angelo Kokenakis, David Pederson, and David Lovejoy have provided the motivation to pursue the mission of the Avalanche Center. Current board members Troy Marino, James Foulks, and Blair Foust are steadfast supporters, friends and collaborators.

Most of all I would like to thank David Lovejoy, Prescott College Adventure Education Coordinator, for his immense dedication and inspiration.

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DEDICATION

I would like to dedicate this project to the array of avalanche professionals who work for the safety and benefit of winter recreationists : avalanche researchers ; avalanche control workers, ski patrollers, avalanche dog handlers and transportation workers ; ski guides ; avalanche educators and avalanche forecasters . Collectively, this group comprise many of the finest individuals I have had the pleasure of association. A combination of outstanding work ethic, tenacity, compasison, physical rigor, keen intellect and abundant humor are hallmarks of avalanche professionals.

Specifically, I honor the memory of Brian Roust, and all avalanche professionals who have perished. Additionally, the members of the Canyons Professional Ski Patrol Association, the Arizona Snowbowl Professional Ski Patrol, and Kachina Peaks Avalanche Center as colleagues, collaborators and great friends. Safe travels.

Chapter 1: INTRODUCTION

An avalanche is defined as “a mass of snow, ice, or rocks in swift motion down a mountainside or over a precipice” (Merriam-Webster, 2016). Avalanches are a natural phenomenon, triggered by wind, additional snow load, warming temperatures, rain or solar gain.

However, when humans become engulfed in an avalanche, survival is unlikely, and tragedy unfolds; especially since over 90% of avalanche accidents are triggered by the victim or a member of their group (McCammon, 2000). Victims completely buried by avalanche debris typically have less than fifteen minutes to be rescued alive. Otherwise, asphyxia or trauma take their toll on 73% of those caught in an avalanche after 35 minutes. (Tremper, p. 11, 2008).

Avalanches account for the highest number of fatalities on National Forest land in the United States, eclipsing deaths from any other natural or human hazard (Abromeit, 2008). Current averages hover at 30 fatalities a year in the United States, and 15 a year in Canada (Atkins, 2013; Uttl, 2009). Fortunately, avalanches can be studied and accidents prevented by practicing decision making and observational skills. Combining elements of weather, snowpack, terrain and human factors, winter recreationists can safely travel in avalanche terrain for a lifetime of enjoyment.

This practicum will strive to describe avalanches from a human perspective through time, eventually focusing on the modern era of winter recreation and an increase in avalanche fatalities. To combat this trend, Avalanche Centers have been established throughout western North America to provide avalanche education and publish daily or weekly avalanche advisories.

In Northern Arizona, the Kachina Peaks Avalanche Center was established in 2005 as a response to a Northern Arizona University student who perished in an avalanche within view of Flagstaff. The Center’s mission is: to provide support for and to engage in avalanche education, safety training and information exchange specific to the San Francisco Peaks in Northern Arizona.

The research component of this project attempts to define winter backcountry demographics in Northern Arizona through a survey administered in conjunction with the Coconino National Forest. This information will help focus the educational efforts of the Kachina Peaks Avalanche Center to reduce the likelihood of avalanche accidents, fatalities and costly rescues.

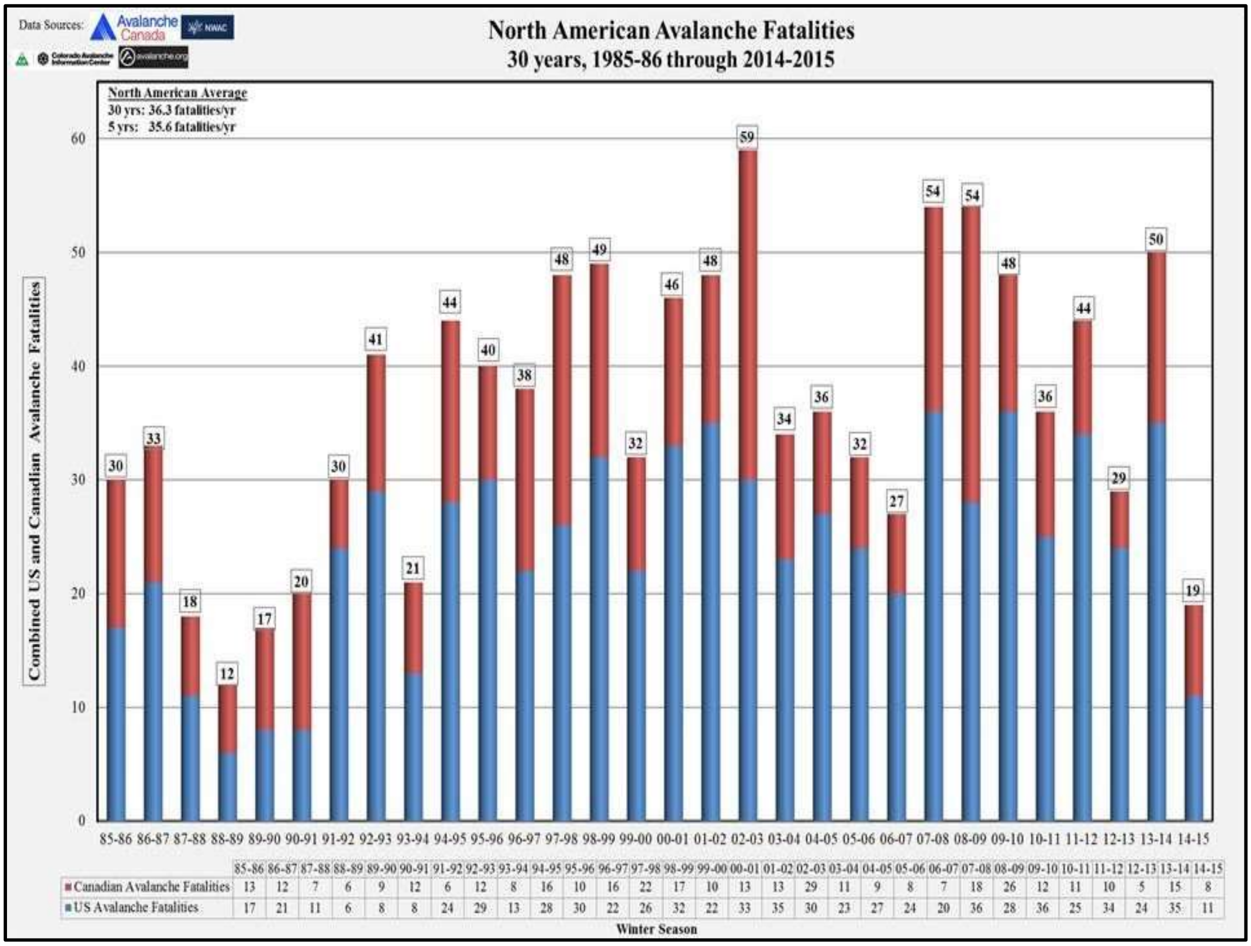

Figure 1.1: North American Combined Canada and U.S. Avalanche Fatalities 1985-2015. This figure illustrates the overall trend in avalanche fatalities for North America since 1985.

1.1: *AVALANCHES IN HUMAN HISTORY*

Societies in mountainous terrain have grappled with the poorly understood and erratic behavior of avalanches for millennia. Accounts of avalanches are recorded from as early as the 2nd century B.C., when Hannibal lost thousands of troops while crossing the Italian Alps, recorded in an epic poem by Silius Italicus "There where the path is intercepted by a glistening slope, [Hannibal] pierces the resistant ice with his lance. Detached snow drags the men into the abyss and snow falling rapidly from the high summits engulfs the living squadrons" (Jenkins, 2001).

Figure 1.2: Hannibal crossing the Alps 218 BC.

Accounts of natural avalanches affecting the inhabitants of mountainous areas in Europe have been documented throughout the Middle Ages, including 100 fatalities at Great St. Bernard Pass in 1499; along with major avalanches in Davos, Switzerland in 1569; 1689 in the Montafon Valley; and in 1808 in Trun, Switzerland. Avalanches were defined as "the greatest and most resistless of catastrophes which can overtake the Alpine pedestrian", according to an account from an 1843 journal titled "*Travels Through the Alps of Savoy"* (Jenkins, 2001).

1.2: *SNOWPACK STABILITY*

Snow has many characteristics and metamorphoses from the moment it forms in the atmosphere. Once on the ground, snow continues to evolve and is in a state of constant change. Temperature, moisture content, aspect, exposure to wind or sun, underlying strata or vegetation, compaction by settlement or human traffic, all conspire to transform the initial form of snow into a myriad of crystals, which may or may not bond well to each other.

Each snow storm or wind event deposits added weight on existing layers of the snowpack, potentially affecting the fragile cohesion which bonds each layer to the next. Depending upon the moisture content of the snow and volume of a storm, the added weight may decrease the ability of lower layers in the snowpack to maintain their bonds thus initiating a failure. On steeper terrain, between 30-45 degrees, this failure of individual grains to maintain cohesion produces a fracture which propagates across a slope, creating an avalanche due to the force of gravity propelling the released layers of snow downhill (Tremper, 2001).

Avalanche initiation and propagation are not clearly understood, and "introduce uncertainty into avalanche forecasts: uncertainty in timing the potential for an avalanche, and uncertainty as to the spatial distribution of strong and weak areas of snow" (Atkins, Young, 2002).

The type of avalanche released is of importance in understanding the risk to winter travelers. Loose snow, or point and release, and icefall avalanches account for a small portion of avalanche accidents. Slab avalanches, also known as "the White Death", are the most unpredictable and destructive type of avalanche, resulting in the vast majority of avalanche fatalities. Slabs are individual or several layers of snow in the snowpack with enough cohesion to maintain integrity up to a certain failure point, where the shear strength is exceeded by stress on the snowpack. Subsequently, a weak layer of poorly bonded faceted grains fails, propagating a fracture, resulting in the slab sliding on a bed surface of snow, rock or vegetation underneath (Stethem, 2003).

Slabs often support the weight of a human, enticing a recreationist onto a snowfield due to it's cohesive properties until a failure occurs on a weak layer within the snowpack. This fracture travels up to 220 mph through the slab which shatters like a pane of glass into a myriad of blocks, engulfing the victim as the avalanche cascades down the slope. These slabs typically measure two feet in depth and 60-100 yards across, initially accelerating to 80 mph within the first 6 seconds (Tremper, 2008).   Figures 1.3 – 1.5 address this phenomena.

Figure 1.3: Slab avalanche fracture. Photographer Garret Grove.

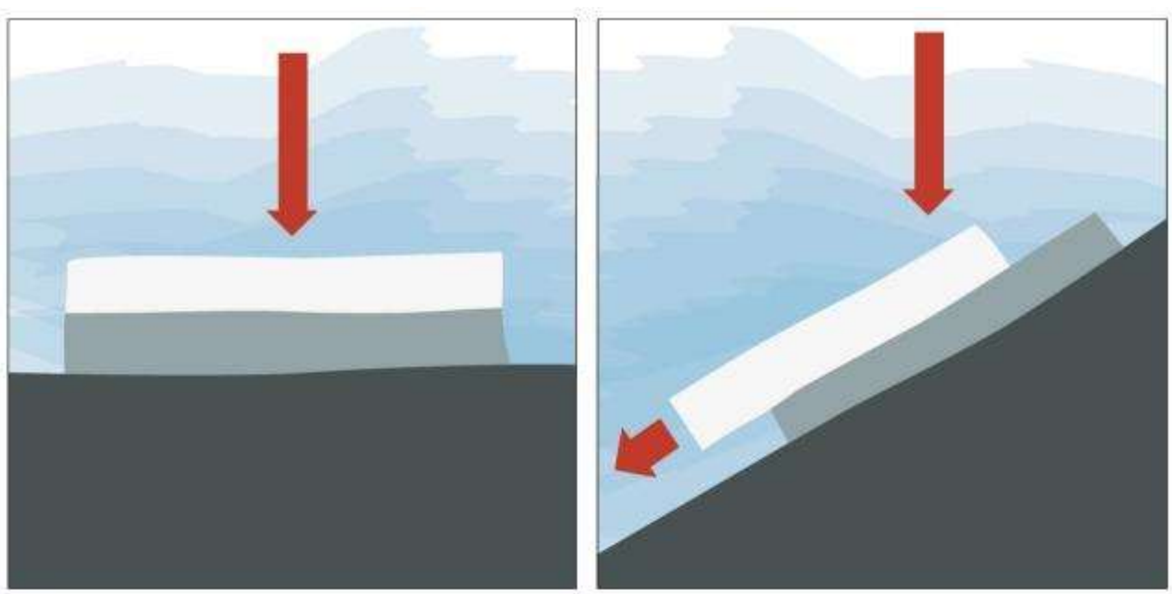

Figure 1.4: Ingredients for trouble: the slab, the weak layer, bed surface and a steep angle.

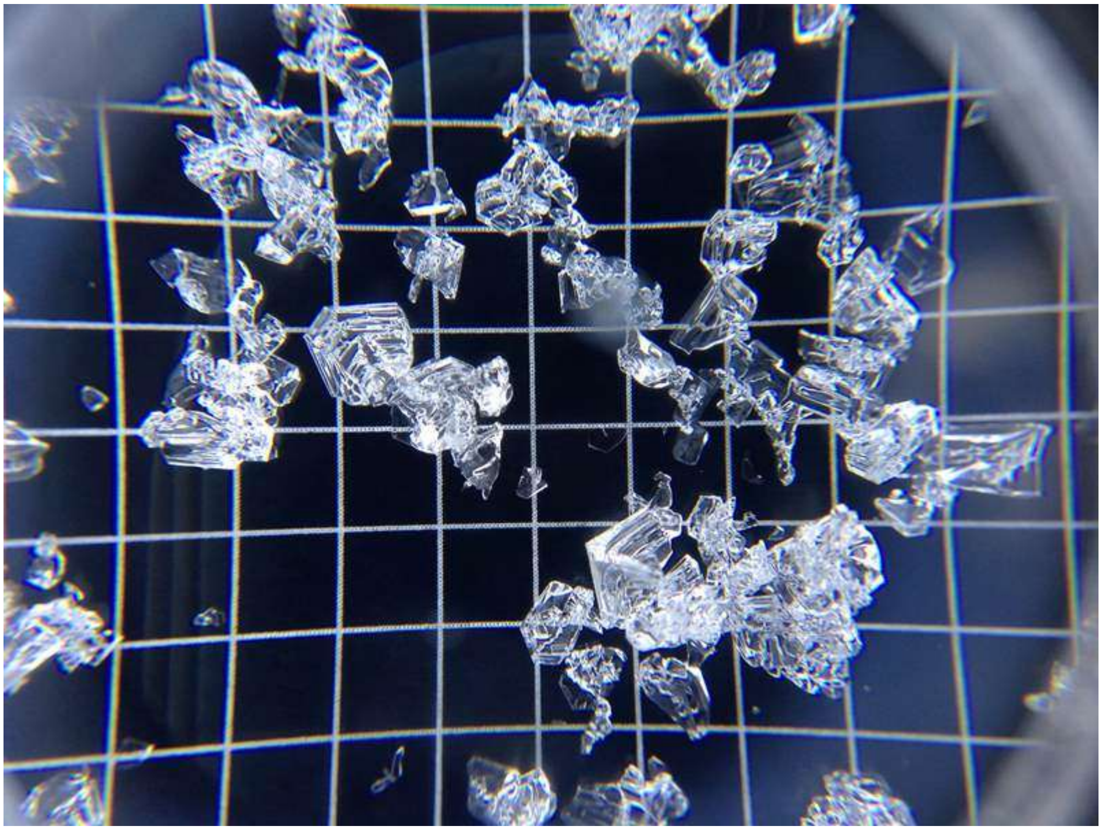

Figure 1.5: Faceted grains which lack cohesion are weak layers in the snowpack. The angular nature of theses 2-3 mm grains reduce their ability to bond together.

1.3: *AVALANCHES IN NORTH AMERICA*

In North America, the earliest accounts of avalanche activity occurred in a mythology recorded by Smithsonian ethnologist Frank Boas in 1910: an account of a group of Alaskan Tsimshian Indians being chased up a mountainside: "they began to work with their staffs, and dug out the snow; and when the many people who pursued them were near, they broke off a large piece of snow, which fell down over the pursuers and they all perished in the avalanche" (Boas, 1916).

The winter of 1781-82 was the first westerner's account of avalanches in the New World, in Nain, Newfoundland Labrador, Canada: "a monstrous body of snow which shot all at once down and pressed the winter hauss even with the ground, with all the people in it excepting one man who was buried in the snow without. Out of 31 only 9 got out alive".

However, it was the call of the western frontier that truly placed humans in the path of avalanches in North America. ‘Manifest Destiny’ brought thousands of settlers to the Rocky Mountains, Sierra Nevada and Cascade mountain ranges in the 1800’s, following the doctrine that “there was order in American nature, and that God put it there for Americans [and Canadians] to profit by” (Fresonke, 2003).

As the western United States was settled, railroads and roadways made travel possible, often through numerous avalanche zones in steep mountainous terrain. The worst avalanche accident in U.S. history occurred in 1910 near Stevens Pass along the Great Northern Railroad. This route traversed the Cascade mountains in Washington state from Spokane to Seattle. An eight day storm from February 21-28 deposited up to 20 feet of snow, stranding a five car passenger train and a mail train near Wellington, Washington. The trains were parked at the base of a slide path which had been logged and burned, eliminating possible anchors for the deepening snowpack. On March 1, at “0120 hours, the white death made it’s call”, the slope avalanched, sweeping both trains in their entirety into the gulch below, resulting in 96 fatalities. This event instigated a realignment of the tracks through an 8 mile tunnel, and relocation of 40 miles of railway to avoid avalanche hazard along the route (Gallagher, 1967).

A few days later, Canada’s worst avalanche accident occurred on March 4, 1910. The same winter storm system which created the avalanches in the Cascades, resulted in a massive avalanche along the Canadian Pacific Railway, killing 62 men clearing snow from the railway at Rogers Pass, British Columbia. This event also resulted in a realignment of the tracks, through a 4 mile tunnel (Backler, 1981). Figure 1.5 consists of photographs of the aftermath of this tragedy.

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Figure 1.6: *The scene of the 1910 Rogers Pass avalanche in B.C.(Revelstoke Museum and Archives)*

Canadian records indicate 884 avalanche fatalities since the 1782 account in Nain, N.L.. and over 1600 in the United States since the mid 1800's, though no definitive number is available (Woods, et. al 2014; Atkins, 2010). Three phases of North American human encounters with avalanches have occurred: the Mining era (1848 – 1920); Inter War era (1920 – 1949); and the Modern era (1950 – present) (Atkins, 2006).

1.4: *MODERN WINTER RECREATION SINCE 1950*

The 'modern era' of avalanches begins in 1950 and continues to the present. Post World War II, winter recreation blossomed and avalanches involving winter recreationists increased accordingly to 83% of the 976 avalanche fatalities from 1950 to 2014. Since 2000, winter recreation has accounted for 92% of avalanche fatalities in Canada, and 100% of avalanche victims in Colorado from 2000-2006 (Atkins, 2006; Perkins, 2002). Of those 976 fatalities, over 40% have occurred since 1990, and 30% from 2004-2013. Snowmobilers currently account for the highest death rate, followed by backcountry skiers and snowboarders (Atkins, 2014).

This trend reflects the transition in the Modern era (since 1950) from an industrial and extractive economy to a service, technology and tourism based economy, especially with an emphasis on winter recreation (Atkins, 2006). Ski areas have proliferated in the Modern era, obtaining permits to operate on National Forest land at the rate of one of more a year from 1960 through 1975. Iconic ski areas established in this phase of expansion include: Alpine Meadows, Heavenly, Kirkwood and Northstar in California; Copper Mountain, Crested Butte, Keystone, Snowmass, Telluride, Steamboat and Vail in Colorado; Jackson Hole, Wyoming; and Snowbird and Park City Resort, Utah (McKinzie, 1992).

Members of the U.S. Army 10th Mountain Division, originally trained as ski soldiers in the mountains of Colorado to engage in combat in the Italian Alps, returned to the western United States after World War II. These veteran soldierskiers were instrumental in establishing many ski areas and pioneering the use of explosives to conduct avalanche control work (Baumgardner, 1998).

An increase in leisure time, income, interest in the outdoors and improved ski technology allowed Americans to investigate skiing as never before. The United States had 240 ski areas in 1960, 600 ski areas by 1968 and 700 ski areas by 1978 (Goeldner, 1980). As of 2014, ski areas have declined in number to 480, and skier visits have flattened to an average of 55 million visits per year since 2000 (Vanat, 2014).

Since 1980, no new major ski areas have been opened as permitting and environmental concerns have made opening a ski resort much more difficult. Thus, existing areas experienced continued expansion in an effort to diversify their offerings and cater to an aging, more affluent ski and snowboard demographic. Ski areas and associated towns now offer ski in/out real estate to entice visitors to invest in second homes, timeshares and condominiums.

Ski ‘areas’ have transformed into ski ‘resorts’; with year round accommodations, restaurants and a core ‘village’. Summer operations at ski resorts now routinely include lift accessed mountain biking, alpine slides, mini golf, disc golf, and concerts in an effort to host visitors year round. The two largest ski areas in North America: Vail, CO, and Whistler, BC now derive only 50% of revenue from lift ticket sales, with an increasing proportion of operating income from services, lodging, and real estate (Thompson, 2012).

With this focus on real estate and resort services, the actual activity of skiing became secondary at some ski areas: "Ski resorts for years sterilized the ski experience. They essentially dumbed down skiing. Backcountry touring offers fun and adventure that you can't necessarily get at a ski resort. You feel like you can get a little adrenaline pumping” (Cox, 2013.)

1.5: *BACKCOUNTRY VISITATION*

‘Backcountry touring’ is usually associated with the use of climbing skins on the base of skis or split boards to ascend, then removing the skins to ski or ride down. Backcountry terrain refers to “mountainous terrain where avalanche hazard is not actively controlled by professional avalanche technicians before recreationists enter the area” (Furman, 2010; Haegli et al., 2009).

Access to backcountry terrain from ski areas simplifies this process, allowing enthusiasts to ride lifts and then leave the ski area through designated access points. This practice is referred to as the ’side country', or ‘near country’ segment of ski touring, and responsible for 40% of all avalanche fatalities in the most recent decade (Atkins, 2014).

The growth of backcountry, side country, and uphill travel at ski areas can be partially attributed to improvements in alpine touring (AT) boots and bindings, “which allows alpine skiers to lift their heels and ascend a slope, an ability previously enjoyed by telemark skiers alone” (Cox, 2013).

The Outdoor Foundation’s 2013 Outdoor Recreation Participation Report found that over the previous five years national participation in telemark and AT skiing increased by 87%,with a 13% increase in the past 3 years. Of all forms of active outdoor recreation studied, telemark/AT skiing had the third highest rates of growth. The number of participants in undeveloped [backcountry] skiing, according to Forest Service research, is projected to increase by 55% – 106% by 2060 (Winter Wildlands, 2014).

Furman, et al. suggest several factors at play to explain this increase in visits to backcountry terrain, including an overall increase in high risk recreation activities; modern AT equipment; convenient access to side country terrain from ski areas; and a response to rising costs of skiing at ski resorts (Furman, 2010).

Quantifying actual numbers of winter enthusiasts entering the backcountry is difficult to determine, but increased sales of touring and backcountry ski gear is a growth indicator. Reports from the 2015 Snow Industries of America fact sheet indicate that “Alpine/AT boots, defined as alpine boots that can be converted to AT/Touring…may be one of hottest items in the alpine market. Sales of alpine/AT boots are up 27 percent in units sold. Backcountry accessories sales including beacons, probes and shovels increased 12 percent in units and dollars sold. Ski touring has been growing at lower double-digit rates for some years now” (Snowsports Industries of America, 2015).

According to the 2011 Annual report of Snowsports Industries of America (SIA):

> “human-powered snowsports is the fastest growing segment of winter recreation. This segment includes backcountry skiing, alpine touring (AT), snowshoeing and cross-country skiing. SIA reports on equipment sales show that alpine touring equipment sales are growing by more than 50 percent year to year while other equipment segments are declining or flat” (Snowsports Industries of America, 2015).

A sales report from retailer Backcountry.com confirms the growth in backcountry travel: “In the U.S., online gear-seller Backcountry.com reported a 43 per cent bump in categories such as touring bindings, boots and avalanche beacons. The number of people skiing in the backcountry now is shocking***, the question is, are they going more or less informed than they used to?"*** (Mitsui, 2013; emphasis added).

A newspaper headline from February 2012, Seattle Times, reads:

> **Deaths highlight boom in backcountry skiing “**The skiers killed by an avalanche at Stevens Pass on Sunday were part of an exploding trend in skiing — skiing on backcountry slopes adjacent to ski resorts. The growing number of out-of-bounds skiers worries avalanche experts” (Welch, 2012).

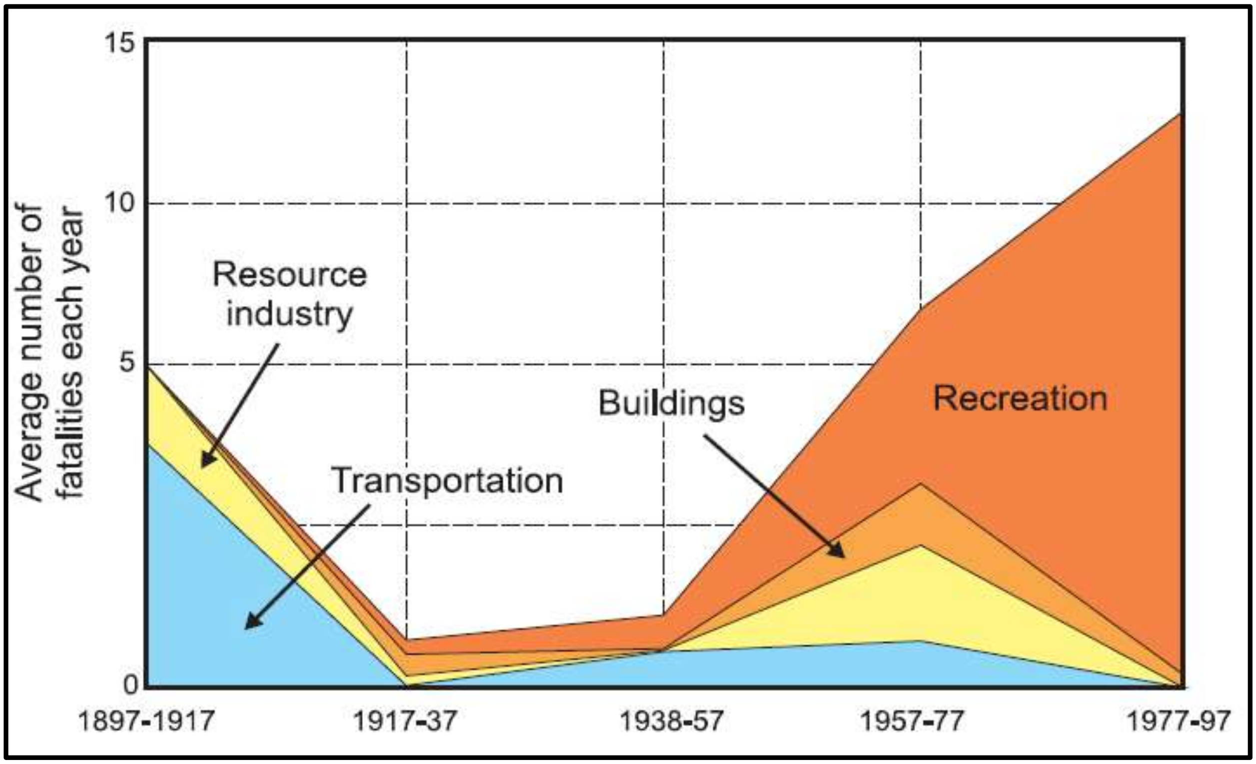


Figure 1.7: Increase in Recreation based avalanche fatalities 1897-1997, Canada.

Figure 1.8: Backcountry access point, Wasatch Range, Canyons Ski Resort, Utah.

The unfortunate trend of increasing fatalities in 'near country, or side country' skiing is illustrated in the following 'Accident Summary' from the Utah Avalanche Center, page 15, which describes a fatality of a snowboarder passing through the gate in Figure 1.8 on February 23, 2012:

Accident and Rescue Summary Dutch Draw: Killed: 1

“Timothy Robert Baker, 24, died in an avalanche he triggered under the cliffs in Dutch Draw February 23, 2012. The accident occurred in Dutch Draw, a backcountry area south of the Canyons Resort.

Timothy and his partner were on snowboards. They left through the well marked boundary gate at the top of 9990 Lift and traversed south It is believed both the victim and his partner descended about 150 or 200’ below the ridgeline and stopped near the cliffs. Then Timothy descended the next section first, triggered a slab avalanche. He was caught, carried and buried. Neither he nor his partner were wearing a beacon or had rescue gear.

Rescue: Timothy’s partner immediately headed down to the debris and started searching. As other backcountry travelers in adjacent area came into view, he called out for help, and a total of 8 people arrived. One was sent for help. The other 7 people searched the debris. None of the parties were equipped with beacons or rescue gear. Some skiers popped the baskets off their poles and probed. One struck the victim’s snowboard and they started digging just as 2 Canyons ski patrollers arrived on the scene. Timothy was dug out, and a ski patroller and Timothy’s partner started CPR. They transported the victim to a nearby flat area where a medical helicopter could land and transport the victim to the hospital. The victim was buried about 40 minutes. It is unknown if he died from trauma or asphyxiation.

The victim was carried about 600 vertical feet, strained through small trees, and buried near the toe of the slide. He was buried head first downhill, face down, with his head approximately 3 feet below the snow surface in debris that was about 6 to 8 feet deep. The snowboard was broken in half, but held together by some of the material” (Utah Avalanche Center, 2012).

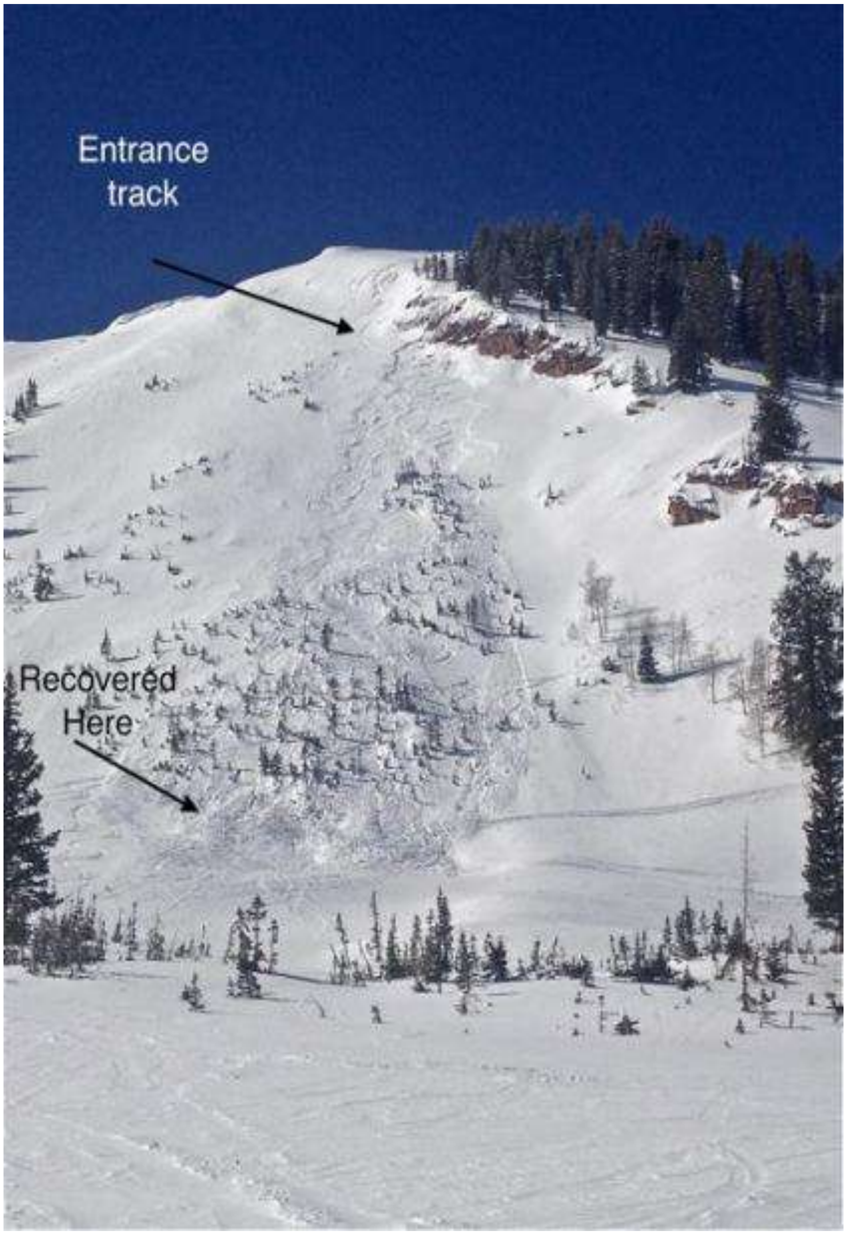


Figure 1.9: Avalanche in Dutch Draw fatality, February 23, 2012

The above accident report is a too often repeated reality of modern backcountry skiing, snowboarding and snowmobiling. The same slope in the photograph above avalanched in 2005, killing a snowboarder in similar fashion. None of the victim's party in either event was equipped with rescue gear, and all ignored the posted avalanche advisory from the Utah Avalanche Center.

1.6: *AVALANCHE ACCIDENT STATISTICS*

Compiled each season from reports submitted to the Colorado Avalanche Information Center, the average trend in avalanche fatalities has continued to increase. Figures 1.10-1.12 attest to this trend, as well as the increase in snow mobile related fatalities.

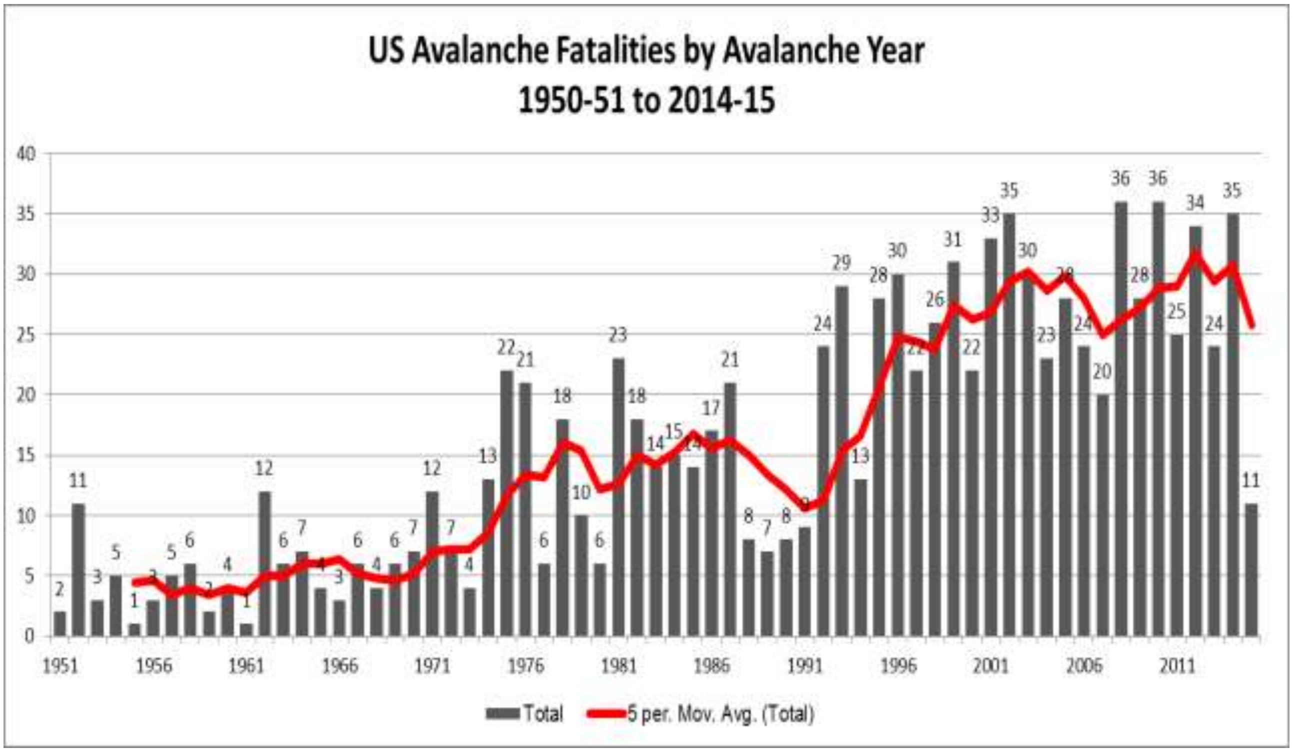


Figure 1.10: US Annual Avalanche fatalities 1950-2015.

As the chart above attests, the average trend in United States avalanche fatalities is, on average, increasing. These accidents occur primarily in the backcountry, often on public land adjacent to ski areas. Winter recreation participants most likely to be involved in an avalanche accident are snowmobilers, skiers and snowboarders, in respective order (Tremper, 2008).

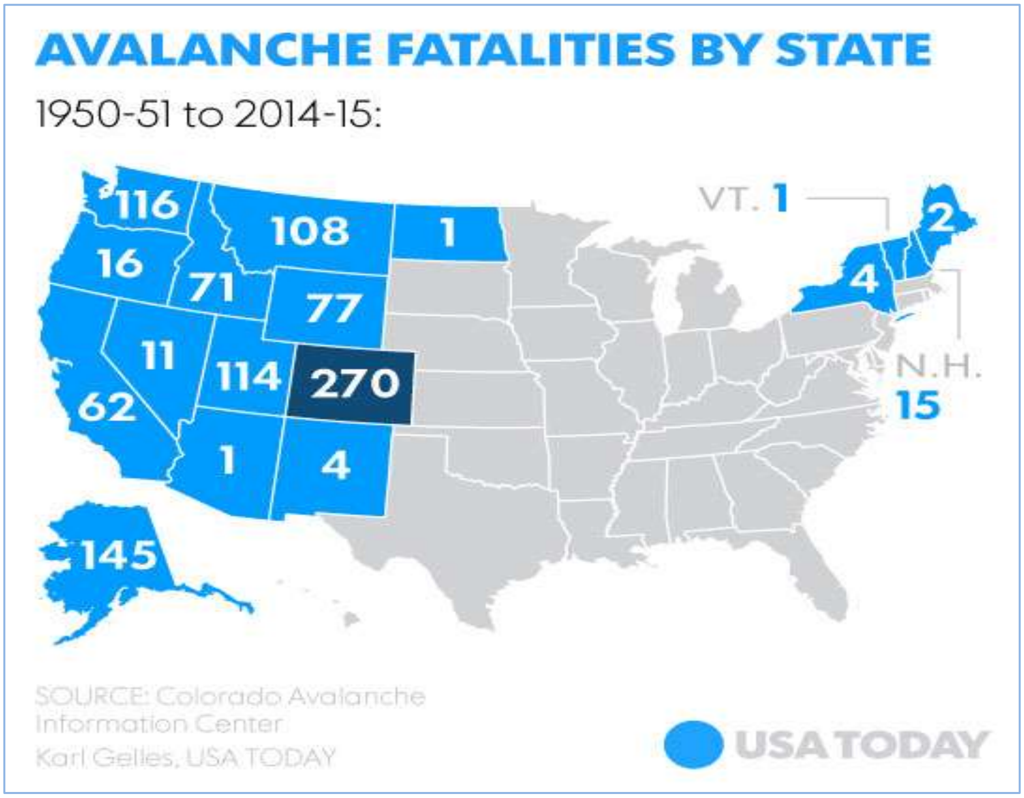


Figure 1.11: Avalanche Fatalities by State 1950-2015.

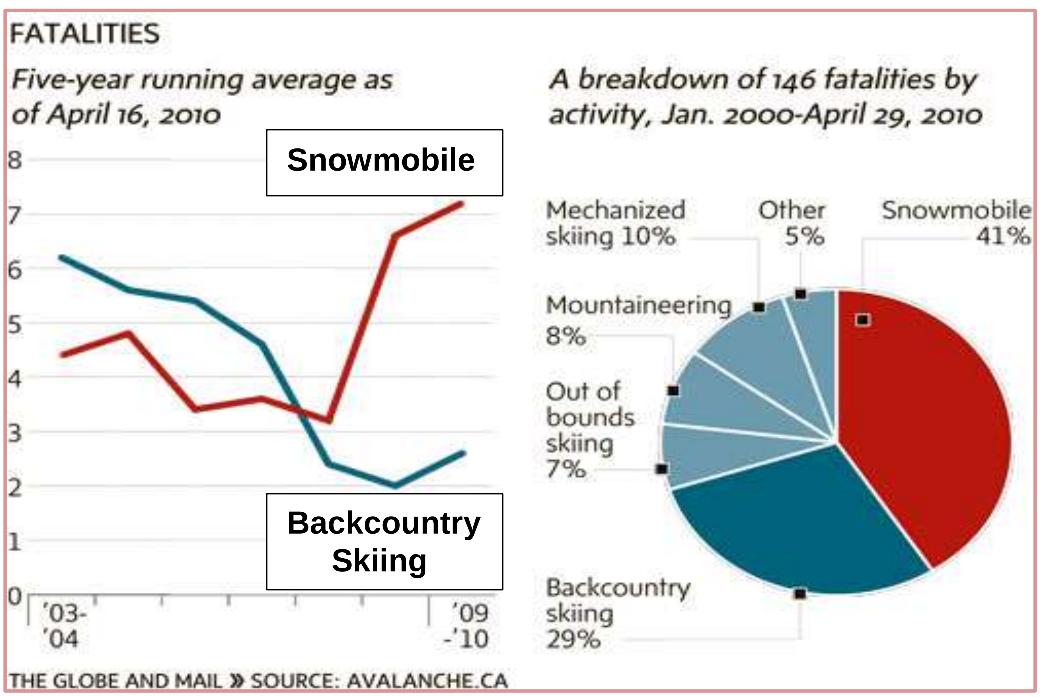


Figure 1.12: Canadian Skier/Snowboard vs. Snowmobile Fatalities 2000-2010.

Researcher Dale Atkins' (2013) analysis of avalanche accidents in the United States from 2004-2013 include the following statistics:

- 350 individuals are caught in an avalanche each winter
- 976 fatalities since 1950; 281 (29%) since 2003
- On average, 28 are killed each year in the United States: 15 annually in Canada (Uttl, 2009).
- 281 individuals died in 237 avalanche accidents
- 92% of avalanche victims are male
- 94% of avalanche accidents are caused by the victim or someone in their group
- Average age of male victims is 36, though age 25-29 has the most victims
- 96% of victims were engaged in outdoor recreation
- 40% of skier/snowboarder accidents are within 2 miles of ski areas in the 'side country' or 'near country'
- 93% of fatalities are due to slab avalanches
- 90% of buried victims survive if recovered within 15 minutes; only 50% survive after 30 minutes of burial; and only 25% survive a burial of 45 minutes. Average burial depth is 3.8 feet.
- Of fatalities, 25% of buried victims die of traumatic injuries; 75% from asphyxiation.
- Companion rescue resulted in a 49% survival rate.
- Beacons are the most successful search method, though with only a 34% survival rate.

- Organized rescue probe lines recover the most victims, but 91% are dead.
- Avalanche dogs have found only 1 of 19 victims alive in the last decade.
- The majority of victims choose to visit hazardous slopes during periods of avalanche and snowpack instability.
- ***72% of victims had some level of avalanche education; with 33% of this group with advanced training*** (emphasis added).

The last bullet point regarding avalanche education has frustrated educators and researchers, and led to increased efforts to adapt avalanche courses to address the 'Human Factor' in avalanche accidents and decision making (Furman, 2010).

Figure 1.13: Rope and sign closure of 'side country' in Fernie, B.C.. Areas adjacent to ski areas are not patrolled nor have avalanche control work performed. Crossing the ropeline can be deadly.

1.7: *ROLE OF AVALANCHE CENTERS AND EDUCATION*

"The National Avalanche Center believes that avalanche education is the best method to prevent avalanche accidents" (Abromeit, 2008). To help achieve this goal, 23 avalanche centers throughout the western United States disseminate avalanche advisories, safety information, links to educational resources and daily updates on avalanche conditions, all accessible at www.avalanche.org.

Avalanche forecasting began in North America in 1962 with the opening of the Snow Research and Avalanche Warning Section of Parks Canada at Rogers Pass, British Columbia (Williams, 1996). The goal of the program was to protect road travelers by forecasting avalanche hazard along the Trans-Canada Highway. In the United States, the first program to address avalanche safety for backcountry recreationists began in 1973 as the US Forest Service Colorado Avalanche Warning Program. Other programs followed suit, and by 1981, eight western states had established avalanche forecasting programs to inform the public of avalanche activity and hazards (Williams, 1996).

As of 2016, a network of 23 Avalanche Centers in the United States employ professional avalanche forecasters and observers to study the snowpack daily and publish advisories based on their observations. Avalanche forecasting can be defined as "…an art based on experience, intuition, and process-oriented reasoning that is difficult to learn, to teach, and to transfer from one region to another" (Atkins, Young, 2002).

Figure 1.14: Avalanche Triangle: Weather, Terrain, Snowpack and Humans

This network of Avalanche Centers operates under the auspices of the National Avalanche Center, which explains the intent of the organization as follows:

> "The purpose of listing agency and non-agency avalanche centers on this website is as a public service to promote avalanche safety and education by providing a critical link for the recreating public to increase their knowledge and awareness of avalanche hazards" (National Avalanche Center, 2016).

Avalanche Centers utilize standard snowpack stability assessment guidelines established in the publication: 'Snow, Weather, and Avalanches: Observation Guidelines for Avalanche Programs in the United States' (American Avalanche Association, 2010). Addressing the fact that avalanches are responsible for more deaths on National Forests than any other natural hazard, Avalanche Centers provide crucial information and education resources to the public "including danger advisories and basic awareness skills that significantly reduce avalanche risk to US Forest Land visitors" (Abromeit, 2008).

North American Public Avalanche Danger Scale
Avalanche danger is determined by the likelihood, size and distribution of avalanches.

Danger Level	Travel Advice	Likelihood of Avalanches	Avalanche Size and Distribution
5 Extreme	Avoid all avalanche terrain.	Natural and human-triggered avalanches certain.	Large to very large avalanches in many areas.
4 High	Very dangerous avalanche conditions. Travel in avalanche terrain not recommended.	Natural avalanches likely; human-triggered avalanches very likely.	Large avalanches in many areas; or very large avalanches in specific areas.
3 Considerable	Dangerous avalanche conditions. Careful snowpack evaluation, cautious route-finding and conservative decision-making essential.	Natural avalanches possible; human-triggered avalanches likely.	Small avalanches in many areas; or large avalanches in specific areas; or very large avalanches in isolated areas.
2 Moderate	Heightened avalanche conditions on specific terrain features. Evaluate snow and terrain carefully; identify features of concern.	Natural avalanches unlikely; human-triggered avalanches possible.	Small avalanches in specific areas; or large avalanches in isolated areas.
1 Low	Generally safe avalanche conditions. Watch for unstable snow on isolated terrain features.	Natural and human-triggered avalanches unlikely.	Small avalanches in isolated areas or extreme terrain.

Safe backcountry travel requires training and experience. You control your own risk by choosing where, when and how you travel.

Figure 1.15: North American Public Avalanche Danger Scale. Danger levels are reported daily in advisories from most avalanche centers.

To supplement the knowledge and information of the various avalanche centers, numerous avalanche textbooks and publications began to appear in the 1980's to educate backcountry users on the hazards of travel in avalanche terrain. Along with these instructional texts, a series of publications which chronicle and summarize all avalanche accidents in the United States since 1910, *The Snowy Torrents,* has been published periodically for use as a resource in investigating the continuing trend of avalanches impacting winter enthusiasts, roadways and towns. Currently, the Colorado Avalanche Information Center is the repository for avalanche accident information in the United States.

Over 100 avalanche education schools have been established to offer basic and advanced knowledge and techniques to travel safely in avalanche terrain and assess snow pack stability (Silverton, 2007). Despite a plethora of resources designed to educate winter recreationists, avalanche fatalities have on average continued to rise steadily. Bruce Tremper, Director of the Utah Avalanche Center, shares advice from helicopter ski guide Roger Atkins: "staying alive in avalanche terrain probably has more to do with mastering yourself than mastering knowledge of avalanches" (Tremper, 2008).

1.8: *THE HUMAN FACTOR*

Successful strategies "to decrease the number of avalanche fatalities has eluded researchers and educators" (Furman et al, 2010). Researcher Ian McCammon (2000) ponders "does avalanche education really make a difference?", noting that avalanche victims with basic formal training exposed themselves to more hazard than any other group, including those with no awareness of avalanches.

Research into this trend has begun to assess the human factor, or 'heuristic traps' in avalanche accidents: as to why well informed recreationists with access to avalanche forecasts in the form of internet advisories, text alerts, and daily news updates continue to suffer in avoidable avalanche accidents (McCammon, 2004). Researcher Keith Robine (2014) observes that although there is a general agreement among educators regarding the most important physical elements of evaluating avalanche danger: weather, snowpack, and terrain factors; “the human factors remain somewhat of an enigma in avalanche education”.

First recognized as a major contributor to avalanche accidents by educators Doug Fesler and Jill Fredston in the late 1970’s, the ‘human factor’ has become a key component of current avalanche education (McCammon, 2009).

Fesler, Fredston and Tremper co authored a paper in 1994, *THE HUMAN FACTOR-LESSONS FOR AVALANCHE EDUCATION;* specifically elaborating on the fact that “victims tend to make critical decisions based on human desires and assumptions rather than upon the integration of key pieces of physical data. Victims sometimes see and understand the danger signs but ignore them anyway, adding to the increasing number of avalanche accidents in which the victims have some level of avalanche training” (Fesler, et al, 1994).

Fesler, et al.(1994), identified eight human factors which contributed to poor decision making in avalanche accidents:

- ***Incorrect assumptions***: believing and desiring the snowpack to be stable, instead of objectively seeking signs of instability
- ***Herding instinct:*** safety in numbers; more people allows more comfort and confidence in a group than if the skier was solo. As group size increases, hazard increases due to more individuals at risk, greater weight on the snowpack, less effective communication, and the erroneous shift in perceived safety. Actual snowpack instabilities have not changed.
- ***Attitude:*** Pride, ego, hubris. Unrealistic optimism and goal orientation create a form of tunnel vision which obscures the big picture.
- ***Testosterone:*** Most avalanche victims are males age 16-35. Females make up only 5% of avalanche victims.

- ***Weather and Perception:*** Most avalanche accidents occur during blue sky days after a storm…sunny days make us feel good, though the snowpack may not share our optimism. Perception of hazard is out of sync with the actual hazard. Foul weather travel creates gloomy emotions, cutting corners and making hasty decisions, resulting in the 'horse syndrome' a rush to get back to the barn.

- ***City vs mountain thinking:*** Bringing human culture and concerns into a dynamic mountain environment. Think like a mountain and perceive the mountain on it's own terms and adjust our behavior accordingly.

- ***Avalanche skills vs travel skills:*** Expert skiers and snowboarders invariably over estimate their avalanche assessment skills.

- ***Communication:*** Open and effective dialogue among all group members is essential to address questions of avalanche hazard. Quiet individuals may not speak up if there is a dominant personality among the group, thus signs of instability or opinions may not be communicated.

Other researchers have listed various human factors influencing sound judgement in avalanche terrain: Tremper, 2008, 11 factors; McClung and Shearer, 2006, 15 factors; Volken et al, 2007, 25 factors, and McCammon managed to distill them into six factors, 2004 (McCammon, 2009).

1.8 A: Heuristic traps:

Feslers' observations of the human condition and foibles in avalanche accidents prompted further research into the topic. Notably, Ian McCammon's research into heuristics, or 'rules of thumb', has expanded inquiry and debate into how to recognize decision making processes and when they may not serve recreationists well in recognizing avalanche hazards, thus becoming 'heuristic traps' "where decisions are based on familiar but inappropriate cues" (McCammon 2000, 2002, 2004).

Heuristics: involving or serving as an aid to learning, discovery, or problem-solving by experimental and especially trial-and error methods <heuristic techniques> <a heuristic assumption>

(Merriam Webster, 2016).

McCammon (2004) reviewed 715 avalanche accidents from 1972 to 2003, using data from the Colorado Avalanche Information Center, assigning each incident a hazard exposure score based on evidence of up to seven common indicators of avalanche hazard:

1. Obvious Path: 82% of 715 accidents
2. Recent loading: 66% of 715 accidents
3. Terrain trap: 58% of 715 accidents
4. Posted Hazard: 55% of 715 accidents
5. Recent Avalanches: 35% of 715 accidents
6. Thaw instability: 20% of 715 accidents
7. Snowpack instability: 17% of 715 accidents

> "The distribution of exposure scores shows that most victims proceeded into an avalanche path with ample evidence of danger: almost three quarters of all accidents occurred when there were three or more obvious indicators of hazard."

> "The blatancy of the hazard in avalanche accidents would be understandable if most victims had little understanding of avalanches. Unfortunately, this does not seem to be the case: almost half of the parties contained at least one person (often the leader) who had formal avalanche training. Almost two thirds of the parties were aware of the avalanche hazard and proceeded into the path anyway."

> "Even more telling, is the fact that exposure to hazards did not significantly decrease with the level of avalanche training. All four levels of training: None, Aware, Basic, and Advanced; appeared susceptible to heuristic traps" (McCammon 2004).

McCammon (2004) concludes that formal avalanche training did not make victims in the study less likely to be in accidents; nor did formal training equip victims with effective tools for decision making. For avalanche educators, the task is to empower students with practical alternatives to heuristic traps, such as easily applied decision making tools to encode the knowledge and observations readily available.

In an effort to provide an "easily applied decision making tool", McCammon (2004) suggests ***F.A.C.E.T.S.:***

- ***Familiarity trap***: Past experiences guide decisions on familiar terrain. 'This slope has never slid, so it must be safe.' This particular heuristic is most pronounced in parties with the highest level of training, exposing themselves to significantly more hazard in familiar terrain.

- ***Acceptance trap:*** The tendency to engage in activities that we think will result in positive feedback and acceptance by individuals we want to liked and respected by.

- ***Commitment trap:*** Maintaining a commitment to a predetermined plan, without altering the decision process when confronted with contrary evidence of obvious hazards.

- ***Expert Halo trap:*** Assuming that an individual in the group possesses a certain level of avalanche assessment skill and not questioning their goals or behavior. A positive personal impression of a leader within the party may impart avalanche skills upon them that they do not possess.

- ***Tracks trap:*** Referring to the absence of tracks on a slope, and the relative scarcity of an untracked slope for 'powder fever' purposes, especially if it has not snowed for some time; individuals take greater risks to access untracked snow.

- ***Social Facilitation trap:*** In the presence of other parties, accident victims with greater levels of training exposed themselves to greater hazards after meeting others on their tour. Groups with no formal training exhibited a decrease in their level of exposure to hazards.

McCammon's seminal research is perhaps the most frequently referenced work in avalanche academia in the previous decade, with 72 citations. Since 2004, much research has been focused on the 'human factor', with recommendations and refinement of McCammon's original research.

1.8 B: An Avalanche of Acronyms for decision making tools:

In the wake of McCammon's **F.A.C.E.T.S.** acronym to combat heuristic traps, several researchers have created alternatives. Nick DiGiacomo (2006) recommends **F.I.N.D**.; "when faced with a choice, FIND the answer", using Bayes Rule. Bayesian methods view probability of an event as a subjective expression of belief as opposed to an objective property of the environment.

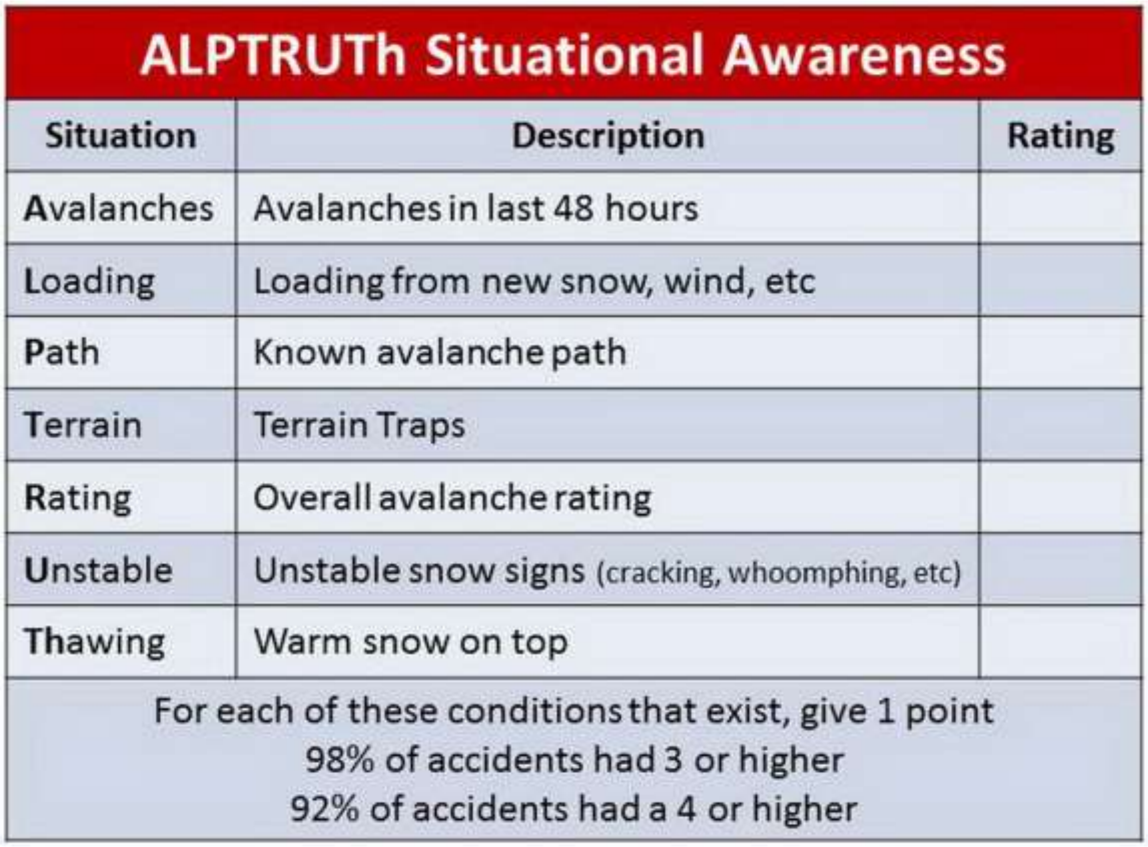
- **Frame:** Look at the choice from a Bayesian perspective by focusing first on your general beliefs about the choices without considering evidence, and then preparing yourself to consider each relevant piece of evidence in turn.

- **Inventory:** Catalog your beliefs about the choices into categories of personal belief; vicarious belief, and inherent beliefs to get started

- **Negotiate:** See how your initial beliefs hold up to the evidence. With more evidence, does your feeling about the choice change?

- **Decide:** Did your initial beliefs survive the evidence, or did the evidence overwhelm them?

In an attempt to facilitate consideration of physical signs of avalanche hazard, McCammon suggests **A.L.P.T.R.U.T.H.,** illustrated in Figure 1.16, below.



ALPTRUTh Situational Awareness		
Situation	**Description**	**Rating**
Avalanches	Avalanches in last 48 hours	
Loading	Loading from new snow, wind, etc	
Path	Known avalanche path	
Terrain	Terrain Traps	
Rating	Overall avalanche rating	
Unstable	Unstable snow signs (cracking, whoomphing, etc)	
Thawing	Warm snow on top	
For each of these conditions that exist, give 1 point 98% of accidents had 3 or higher 92% of accidents had a 4 or higher		

Figure 1.16: ALPTRUTH, or 'obvious clues' decision making aid (McCammon, Hageli, 2007).

Keith Robine (2014) presents three decision making aid acronyms: **P.E.A.C.E.; B.L.T.S.;** and **A.L.S.O.D.T.** PEACE addresses the human factor; BLTS addresses avalanche hazard; and ALSODT deals with the consequences of skiing the slope. The author elaborates that "Some find PEACE in the backcountry. Food often tastes good, like the old standard, BLTS (bacon, lettuce, tomato sandwich). Sweets are also fun, so don't forget ALSO DT, for 'also dessert'".

Human Factor:

- **Patience**

- **Experience**
- **Attitude**
- **Communication**
- **Euphoria**

Avalanche Hazard:

- **Bulletin:** avalanche hazard rating
- **Loading:** wind or precipitation loading
- **Temperature:** thaw instabilities
- **Signs of instability:** other avalanches on similar slopes and aspects, cracking, collapsing or whumpfing.

Consequences:

- **Angle:** slope angle between 35-40 degrees
- **Length:** size of slope and potential length of run out zone
- **Shape:** convex slopes are particularly hazardous, with increased tensile stresses.
- **Obstacles:** hazardous terrain features such as rocks, cliffs, trees, gullies.
- **Depth:** thickness of the slab will influence severity of an avalanche.
- **Travel practices:** safe travel practices in the group, such as skiing one at a time, travelling from safe zone to safe zone, and staying within sight of each other are essential for groups travelling in avalanche terrain.

1.9: *REFINING ANALYSIS OF BEHAVIOR IN AVALANCHE TERRAIN*

To improve the effectiveness of avalanche education, DiGiacomo (2006) suggests that avalanche education may be better served by learning from the behavior of "experienced practitioners who ***don't*** have accidents, as opposed to comparing the apparent risk tolerance of groups of victims" (emphasis added). The challenge with this approach is the lack of documentation of backcountry tours which did not suffer from an avalanche accident. Without data from the majority of tours in avalanche terrain which occur without incident, extending conclusions from avalanche accident victims behavior to the general backcountry community is problematic.

In defense of avalanche training and education as a successful deterrent to being involved in an avalanche accident, Jessica Tase's (2004) research incorporates each groups frequency of exposure to avalanche hazard for the four levels of avalanche education: none, aware, basic and advanced. McCammon's (2004) research into the level of training of avalanche victims does not quantify the rate that each group travels in hazardous terrain, thus raising questions about his assertion that "remarkably, parties with advanced training that were travelling in familiar terrain exposed their parties to about the same hazards as parties with little or no training. In some respects, familiarity seems to have negated some of the benefits of avalanche training".

Tase (2004) reports that those with advanced avalanche training travel in the backcountry 68% of the time 'very often', vs 21% of backcountry travelers with a training level of 'none' who travel in the backcountry 'very often'. Thus, backcountry travelers with advanced training are exposing themselves to avalanche danger with a much greater frequency. Overall, advanced avalanche training resulted in two thirds, or 66% more safe tours in avalanche terrain than recreationists with no training.

Efforts to refine and adopt consistent decision making aids are the focus of ongoing research and debate in avalanche academia. Analysis of 751 avalanche accidents in the United States reveal that “between 60 and 92% of historical accidents would have been prevented using a decision aid” (McCammon, Hageli, 2007).

A powerful element to consider when assessing the rationality of decisions in avalanche terrain is ‘desire’. Desire can be an underestimated emotion, and does not lend itself to logical analysis, hazard evaluation scorecards, or danger ratings. The emotive desire to experience euphoria associated with backcountry travel, regardless of apparent contradictory evidence, can be recognized in research results from Furman, et al (2010):

> “Skiing untracked powder is among the greatest of backcountry rewards and appears to be highly influential.   The behavioral activation system (BAS) suggests that individuals are motivated to behave in a way that maximizes reward, hope and elation; and may play a role in backcountry skiers choosing to ski a rewarding slope despite avalanche conditions”.

In an observation from McCammon’s 2009 paper, ‘Human factors in avalanche accidents: Evolution and interventions’, McCammon confides “it is worth a reminder that there is nothing inherently safe about recreating on steep, avalanche prone slopes”.

CHAPTER 2 : AVALANCHES IN ARIZONA?

Figure 2.1 : ‘Avalanches in Arizona ?’ sign, with view of Monte Vista slide path ; the site of an avalanche fatality in 1995.

2.1: *SAN FRANCISCO PEAKS, FLAGSTAFF, AZ*

The San Francisco Peaks, located in the Coconino National Forest of Northern Arizona, rise from the Colorado Plateau, at 7,000’, to a height of 12,633’. Along its flanks are well defined avalanche slide paths which are visited by an increasing number of winter recreationists, based on winter backcountry permit statistics since 1998, Table 2.1.

The Peaks are the remainder of a conical volcano which erupted approximately 750,000 years ago. Prior to the eruption, it is estimated that the volcano was 15,000’ high, with a single summit, instead of the various summits today, which are the high points on the rim of the current caldera.

Figure 2.2: Arizona physical topography map, with San Francisco Peaks bracketed in black.

Figure 2.3: Inner Basin of San Francisco Peaks

The Peaks were surveyed from 1977-1980 to ascertain the frequency of avalanche activity by volunteer members of the San Francisco Peaks Mountain Avalanche Project. Dr. Lee Dexter, Emeritus Professor in Geography at Northern Arizona University, integrated this research as a component in his Masters Degree.

Dr. Dexter's efforts resulted in the publication of a comprehensive avalanche slide path map in 1981, shown below in Figure 2.4. However, the community lacked an organization to disseminate current avalanche conditions and educational resources to the winter backcountry community.

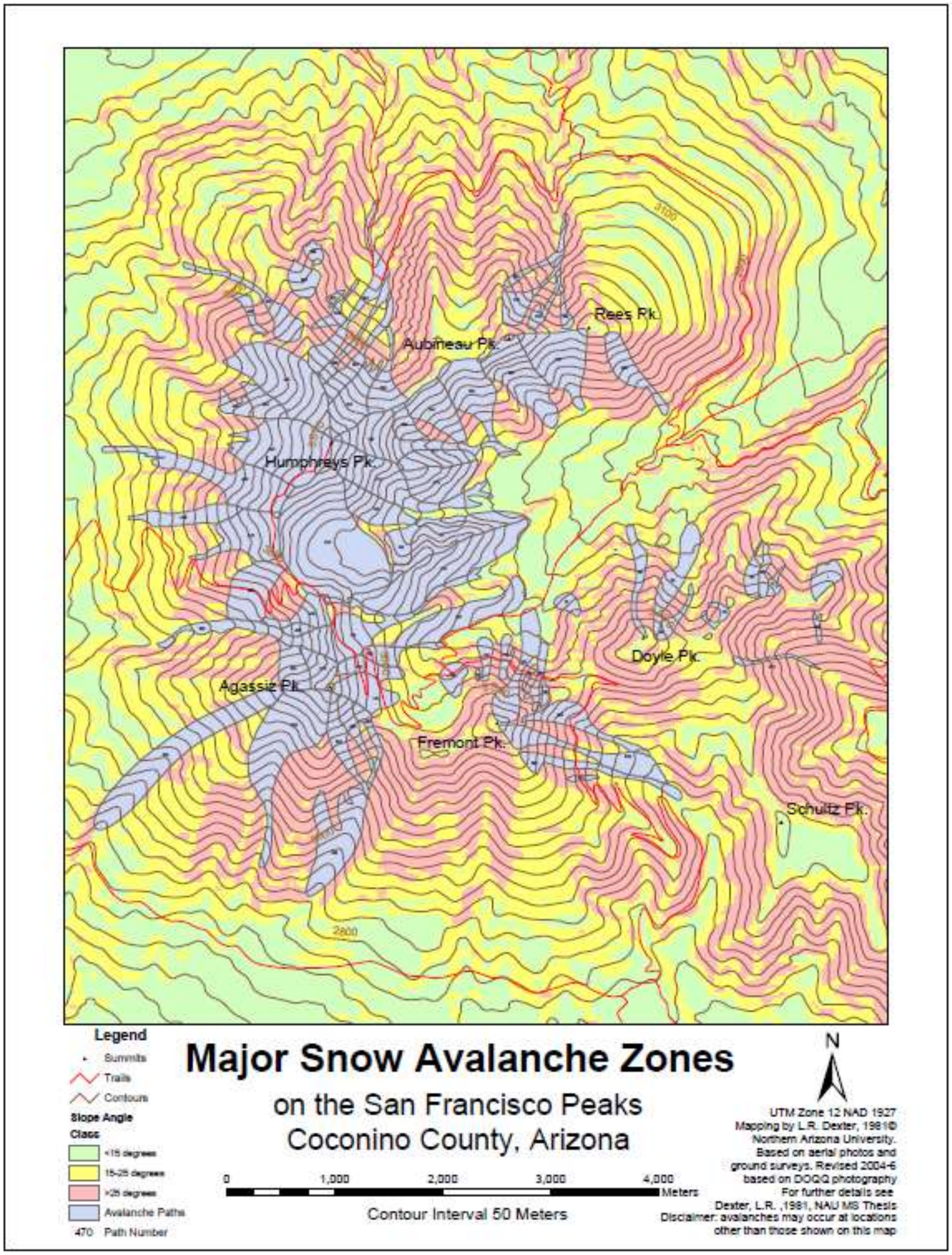


Figure 2.4: Major Snow Avalanche Zones of the San Francisco Peaks

2.2: *NECESSITY FOR AN AVALANCHE CENTER IN NORTHERN ARIZONA*

Several factors conspire to necessitate avalanche education in Northern Arizona. The Peaks are blanketed by active slide paths, with avalanche frequency associated with consistent winter precipitation. Historically, naturally occurring avalanches posed little hazard to humans on the Peaks, but an increase in winter recreation has resulted in more visitation to the once lonely and majestic avalanche terrain.

2.2 A : Geography:

The southern edge of the Colorado Plateau bisects Arizona from northwest to southeast, rising from the Basin and Range topography of Phoenix (1500') and the Verde Valley (4000') to an average elevation of 7000' in Flagstaff. This elevation change creates substantial orographic lifting of moisture laden Pacific storm systems as they move across Arizona, creating conditions for precipitation in the form of snow throughout the winter months.

Rising a vertical mile above the Colorado Plateau and containing the highest peaks in the desert Southwest, the San Francisco Peaks are the remains of a stratovolcano with 77 identified avalanche paths (Dexter, 1981). Humphreys Peak, at 12,633', is the highest, with Agassiz Peak, at 12,326', a close second. Average snow totals on the Peaks at a 10,000' elevation are 260" per year.

Flagstaff, AZ elevation 7000', receives an average of 103" of snow per year, making it the sixth snowiest incorporated city in the U.S.

2.2 B: Avalanche Activity:

An average of 15 avalanche events occur on the San Francisco Peaks per year, with a return period of large events of 4.25 years per avalanche path (Dexter, 1981). Many events occur naturally and may not be observed or recorded. Varying snow totals result in significant fluctuations of avalanche activity from year to year. During the winter of 2009-2010, the most recent above average snowfall winter, a local skier triggered a potentially fatal avalanche in the Telemark Slide Path and was rescued uninjured by helicopter.

In 2005 a climax avalanche event occurred in Abineau Canyon on the north side of Humphrey's Summit. This area has numerous slide paths with multiple starting zones which feed into a single runout, displayed in Figure 2.5. Thousands of logs are strewn in the runout of this massive avalanche, as seen in Figure 2.6.

Figure 2.5: Abineau Canyon looking from the north. Humphreys Summit is the prominent peak in this view, 12,633'. Courtesy Southwest Aerial Photography.

Figure 2.6: Abineau Canyon avalanche runout zone with mature timber removed by a climax avalanche event in 2005.

Prior to the opening of the Flagstaff City Watershed to recreational use in the early 1970's, there was little possibility of human triggered avalanches. The Flagstaff watershed encompasses the Inner Basin of the San Francisco Peaks, an area which includes the majority of the 77 named slide paths on the Peaks. According to Dexter (1981), a result of opening of the watershed to recreation, "for the first time in history, the chance for man-avalanche encounters on the Peaks has become significant".

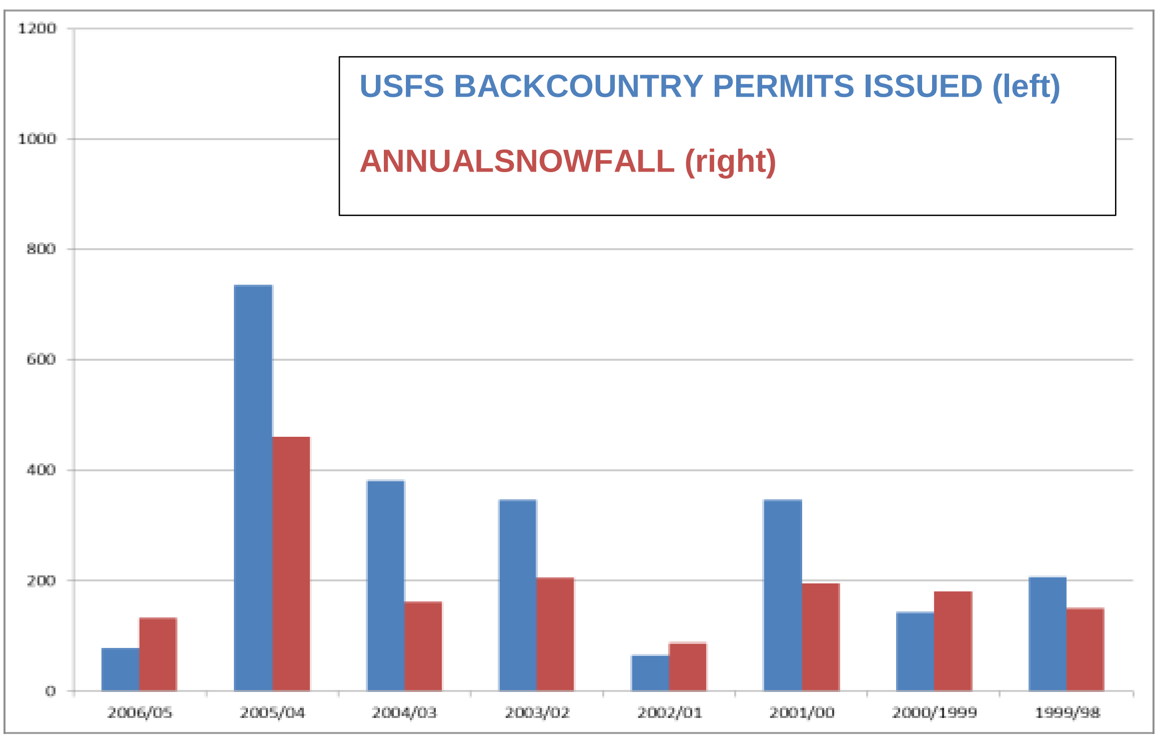
Numerous reports of avalanches are recorded on the Kachina Peaks Avalanche Center website each season as more winter recreationists visit the Kachina Peaks Wilderness. Though it is difficult to determine exact use in the backcountry, data from total USFS backcountry permits and from a USFS installed laser counter affixed to the backcountry gate at the Arizona Snowbowl attests to an increase in backcountry travel. Increased user visits to the Kachina

Peaks Avalanche Center website also provides evidence of additional backcountry interest. See Table 2.1 and Appendix 2 and 3.

2.2 C: Increase in Winter Recreation on the San Francisco Peaks

Winter recreation on the San Francisco Peaks can be correlated to annual snowfall and an increase in the popularity of backcountry skiing and snowboarding. The two graphs in Table 2.1 illustrate this trend with the total number of USFS Backcountry permits issued in relation to snowfall per year. Despite varying snowfall totals, permits on average are on the rise with the increased popularity of 'side country' skiing: leaving the ski area to access adjacent terrain.

1,110 backcountry permits were issued in the 2009-2010 season, the highest number in the 18 years of the program, which also had the highest snowfall recorded during this period, with 321". Permits have remained on an upward trend throughout, with on average, nearly 700 permits issued each season since 2007.



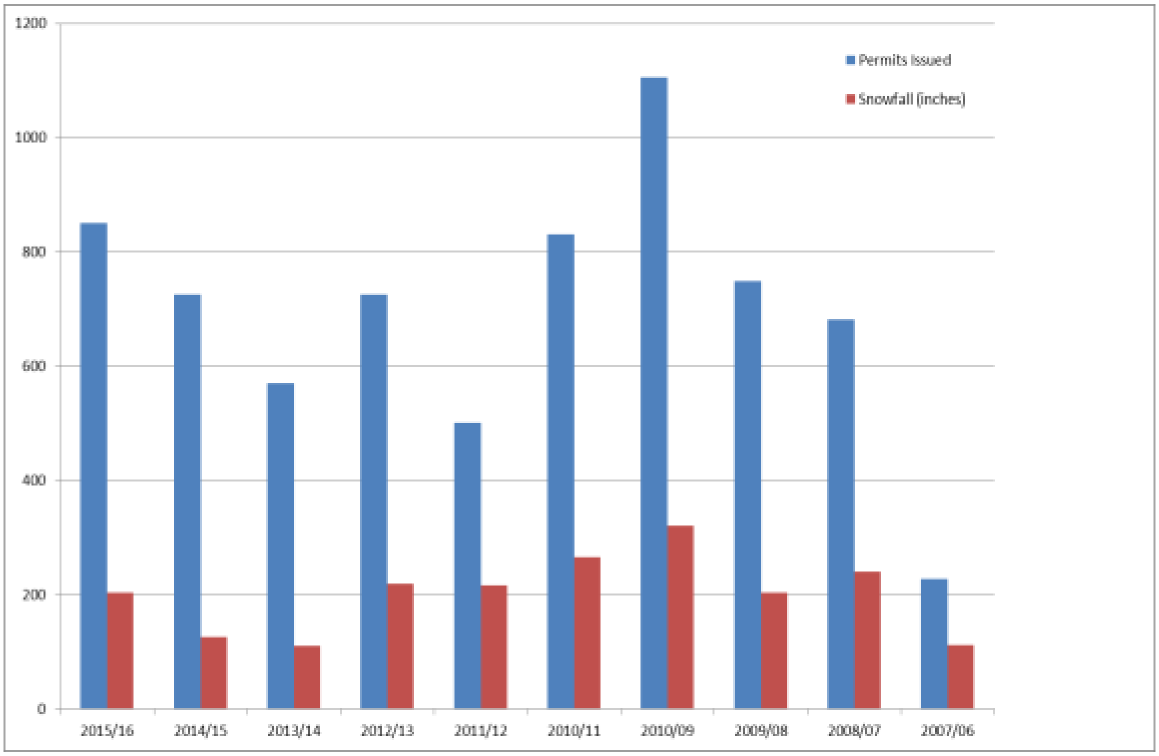


Table 2.1: Winter Backcountry permits issued on the San Francisco Peaks from 1998- 2016. Blue bars are Permits Issued, Red bars are snowfall for the season. (Source: USFS Coconino County).

Many ski areas, including the Arizona Snowbowl, provide access to adjacent backcountry terrain through gates near the top of ski lifts. On the San Francisco Peaks, this access gate is at 11,500', and within reach of several avalanche starting zones off of Agassiz Peak, outside of the ski area boundary.

To reduce the risk of avalanches within ski area boundaries, avalanche control work is performed by Professional Ski Patrollers with explosives, attempting to mitigate potential avalanche hazard prior to opening avalanche terrain to the public. These efforts do not guarantee total immunity from avalanches within ski areas, but it greatly reduces the chances of an inbounds accident to "less than 1%" (Tremper, 2008). Defining avalanche hazard mitigation as 'control work' has become less common in the industry, as practitioners grapple with the reality that 'controlling' avalanches is not foolproof. Numerous 'post control' avalanches have occurred in the last decade, several resulting in fatalities within ski area boundaries (Ferrari, 2010).

Avalanche hazard mitigation ceases at the ski area boundary and does not apply to adjacent slide paths, nor any other avalanche terrain outside the area. The benign conditions within ski areas may lull backcountry enthusiasts to assume that conditions outside of the boundary are similarly safe, contributing to unsafe travel practices and unfortunate consequences.

To assess backcountry use, the Coconino National Forest installed a laser counter on the backcountry gate at the Arizona Snowbowl to record traffic leaving the ski area. In the 2012-2013 season, there were 19 days with over 50 skiers or riders exiting through the gate. Eight of those days recorded over 100 visits to adjacent backcountry terrain, with the highest number being 340 backcountry visitor counts in one day (Coconino National Forest, 2013; appendix 2).

Arizona Snowbowl Southside Backcountry Access Point

Year	Exits Counts	Snow Totals Inches	Days Over 50 Count	Days with 3" or Greater Accumulation	Days in Operation
2012 - 2013 Season	3,146	219	19	7	90
2013 - 2014 Season	463	110	3	2	91
2014 - 2015 Season	1,392	126	6	7	76

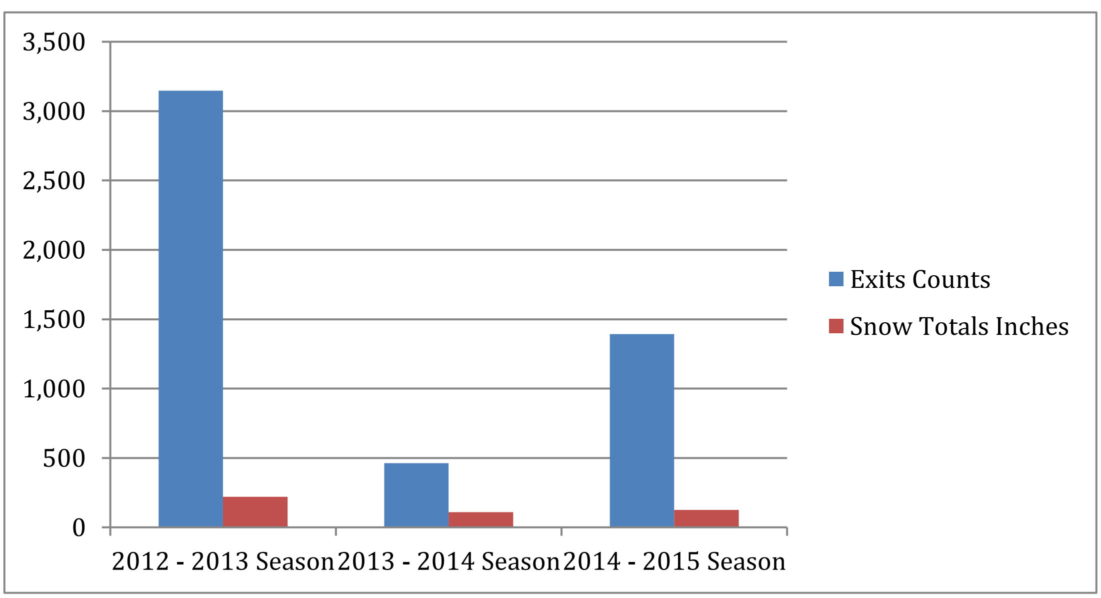


Table 2.2: Winter backcountry visits tracked with counter at access point.

The days of maximum backcountry visits corresponds with snowfall occurring on that day, or the previous day, correlating with the trend of snowfall attracting winter recreationists to backcountry terrain. Unfortunately, most avalanches occur either during a storm, or within 24 hours. ‘Loading’ is one of the danger signs explained in the ALPTRUTH acronym, indicative of recent loading of the snowpack by recent precipitation or wind. This evidence of winter enthusiasts flocking to uncontrolled avalanche terrain within 24 hours of a storm is proof of the power of desire to ski fresh powder versus the ability assess signs of potential avalanche danger.

Figure 2.6: Backcountry access point at the Arizona Snowbowl.

2.2 D: Avalanche fatality on the Peaks:

To date, one avalanche fatality has been recorded on the San Francisco Peaks. This was a human triggered avalanche which occurred in January 1995, after a storm and three days of intense wind loading of snow in the Monte Vista Slide Path, on the South aspect of Agassiz Peak (12,326').

The accident involved two NAU students who were expert snowboarders. They travelled out of the Arizona Snowbowl Ski Area and accessed the Agassiz Peak ridgeline above the Monte Vista Path. One of them triggered a hard slab, sweeping both snowboarders down the slope. One managed to grab a tree branch and avoid the violence of the slide, while the other suffered traumatic injuries. At the time, winter recreationists did not have easy access to avalanche education, snow stability assessments nor backcountry conditions information. Due to these limitations, and the perception that Arizona did not experience many avalanche events, "complacency and a lack of awareness played a role in human behavior on the San Francisco Peaks" (Lovejoy, 2006 p. 5).

2.3: *INITIAL AVALANCHE EDUCATION EFFORTS IN FLAGSTAFF, AZ*

After the Monte Vista Slide fatality, initial efforts to provide basic avalanche safety information consisted of members of the San Francisco Peaks Mountain Project (SFPMP) offering free Avalanche Awareness seminars in local outdoor gear stores. The SFPMP group was comprised of local Ski Patrol, US Forest Service, Search and Rescue, University researchers and other members of the community who were inspired to educate others to prevent future avalanche accidents (Lovejoy, 2006).

To complement these efforts, in 1998, the US Forest Service began requiring a free backcountry permit for anyone interested in accessing terrain in the Kachina Peaks Wilderness. The vast majority of avalanche terrain on the San Francisco Peaks lies within the Wilderness boundary, which, with one exception for the Snowbowl Ski Area, encircles the Peaks along a contour line from 8,000 to 9,000' in elevation.

The Avalanche Awareness seminars and USFS backcountry permit application process both provided backcountry travelers with a basic understanding of the potential hazards associated with travel in avalanche terrain. Unfortunately, the winter recreation community still lacked a centralized organization to collect and distribute avalanche conditions as they evolve throughout the winter.

2.4: *CHALLENGES TO AN AVALANCHE CENTER IN ARIZONA:*

2.4 A: Demographics: Arizona is typically perceived as a desert state, with Avalanches generally not considered as a factor in terms of natural hazards. As of 2016, the vast bulk of the 6.5 million state population inhabits the Phoenix and Tucson areas, which are true desert regions.

The population of Flagstaff, AZ, as of the 2014 census is 68,785, with up to 20,000 of those inhabitants temporary residents attending Northern Arizona University (Census Data).

2.4 B: Remote Avalanche Terrain: The San Francisco Peaks are a sky island of alpine avalanche terrain in a state whose core population has little exposure or experience with avalanche phenomena. The fact that the majority of avalanches occur within the remote Inner Basin of the Peaks also contributes to the lack of awareness of avalanches (Dexter, 1981).

Access to avalanche terrain on the San Francisco Peaks requires riding a chairlift at the Arizona Snowbowl, then hiking uphill for several hundred vertical feet, or simply hiking from a trailhead around the boundary of the Kachina Peaks Wilderness Area. Both approaches help to limit the ease of access to avalanche terrain, possibly reducing the frequency of avalanche accidents.

2.4 C: Weather factors: Precipitation in the form of winter snow varies greatly from year to year in Northern Arizona.

Average total snowfall and days with fresh snow in Flagstaff			
Days		**Inches**	**Centimetres**
7.2	January	22.5	57.2
6.9	February	22.2	56.4
6.5	March	21.9	55.6
2.8	April	6.7	17.0
0.7	May	0.6	1.5
0.5	October	1.2	3.0
2.9	November	10.6	26.9
6.2	December	17.9	45.5
33.7	Year	103.6	263.1

Table 2.3: Average total snowfall and number of days with snow, but the true variability is hidden in the statistics. Each December has an equal 25% chance of having either 27+ inches of snow or less than 10 inches for the month. January and February snow totals in Flagstaff range from 30" to about 10" per month (Weather, 2015).

Season	Total snowfall (cm)	Above/below avg. (cm)*	ENSO (+/-)
1988-89	431	- 229	La Niña
1989-90	610	- 50	Normal
1990-91	592	- 68	Normal
1991-92	914	+ 254	El Niño
1992-93	1168	+ 508	El Niño
1993-94	559	- 101	Normal
1994-95	658	- 2	El Niño
1995-96	287	- 373	La Niña

1996-97	686	+ 26	Normal
1997-98	838	+ 178	El Niño
1998-99	381	- 279	La Niña
1999-00	457	- 203	La Niña
2000-01	495	- 165	Normal
2001-02	221	- 439	Normal
2002-03	523	- 137	El Niño
2003-04	411	- 249	Normal
2004-05	1168	+ 508	El Niño
2005-06	338	- 322	La Niña
* Based on average snowfall of 660 cm/year			

Table 2.4: Total snow accumulation year to year from 1988 – 2006 at the Snowbowl Ski Area. Averages fluctuate erratically and greatly with two years at +508%, and one year at -439% of precipitation. 13 of the 18 recorded seasons experienced below average snowfall.

The wide range of precipitation received in Northern Arizona greatly affects the avalanche activity on the San Francisco Peaks. In low snowfall years, there may be little or no avalanches on the Peaks. However, large snowfall years can create numerous avalanches, such as the 2005 climax avalanche event in Abineau Canyon.

2.4 D: Lack of Agency Funding: The lack of stable funding for the Kachina Peaks Avalanche Center results in erratic resources to maintain operations. The vast majority of Avalanche Centers listed on www.avalanche.org receive USFS or some other agency funding. According to the 'USDA Forest Service Backcountry Avalanche Center Operational Guidelines' (2012) document, there are four types of Avalanche Centers:

- **Type 1 Regional Center:** Employs three or more Avalanche Specialists
    - Issues daily avalanche advisories.

- Provide public avalanche education.
- Provide relevant avalanche information to the local and national news media.
- Regularly collect snowpack stability data.
- Provides a platform for the exchange of snow, weather and avalanche information that benefits local avalanche safety programs and public users.

- **Type 2 Regional Centers:** Employs two or three Avalanche Specialists with the same duties as a Type 1 Center, though smaller in scale.
- **Type 3 Local Avalanche Information Centers:** Employs one or two full time Avalanche Specialists and/or Avalanche Coordinators, sometimes a Snow Ranger.
    - Issues weekly or twice weekly avalanche advisories or avalanche information bulletins.
    - Provides public avalanche education.
    - Acts as a local media contact.
    - Collects snowpack stability data.
    - Provides a platform for the exchange of snow, weather, and avalanche information that benefits local avalanche safety programs and public users.
    - Funding for Type 3 centers is variable. It may be included as a part of and an adjunct to other duties. **Additional total funding is necessary to assure that the avalanche related duties are given a high priority and accomplished.**

- **Type 4 Local Education Centers:** Usually employs one or more Avalanche Coordinators whose job description includes avalanche information duties. These avalanche centers do not issue avalanche advisories or warnings.
  - Provide public awareness classes.
  - Act as points of contact for local media
  - May help to coordinate and information exchange, where the public and others informally share information about snow stability.
  - Some Type 4 centers provide an online venue for the public and the center to post backcountry observations. Funding for Type 4 centers is included as a part of and an adjunct to other duties. Some Type 4 centers are run as non---profits and are staffed largely by volunteers**. Funding for this type of center should come from the field unit and the public.**

Though listed as a Type 4 Local Education Center, the Kachina Peaks Avalanche Center (KPAC) has performed tasks associated with a Type 3 Local Avalanche Information Center for the last three winters, including “issuing weekly or twice weekly avalanche advisories or avalanche information bulletins.” Recognizing KPAC as a Type 3 Center would qualify KPAC for “total funding of up to $30,000 and would assure that the avalanche related duties would be given a high priority and accomplished” (Abromeit, 2008).

The “GUIDELINES FOR STARTING AN AVALANCHE CENTER” section of the USDA (2012) document state:

> “A local avalanche education center may elect to expand its services after at least one year as a local avalanche education center and operate an avalanche information center (Type 3). An avalanche information center requires a substantial increase in commitment including additional funding

> for additional personnel and equipment in order to provide services that meet the industry standard."

Several factors unique to Arizona combine to create a challenging environment for a viable Avalanche Center: a majority desert population, remoteness of avalanche occurrences in Arizona, high variability in annual snowfall, and a lack of Agency funding for the Kachina Peaks Avalanche Center.

2.5: *CREATION OF KACHINA PEAKS AVALANCHE CENTER*

The Kachina Peaks Avalanche Center was formally incorporated on March 17, 2005 as a 501c3 non-profit organization. This official status created a foundation to address the need for an organization in Northern Arizona to provide a reliable forum for avalanche education and backcountry snow stability conditions.

The initial phase of the Avalanche Center consisted of a web based forum for observations and discussions with links to other avalanche related sites and education options. Free avalanche awareness seminars were expanded and held each month of the winter, as well as adding Level 1 and 2 avalanche courses following standard curriculum endorsed by the American Avalanche Association.

Another motivating factor to establish the avalanche center was that the 2004-2005 winter saw a 500% above average snow accumulation after six previous below average winters. Many of the major paths on the Peaks avalanched, with an especially large class 5 (climax) avalanche descending the Crossfire path in Abineau Canyon, wiping out a large swath of trees and substantially enlarging the former avalanche run out zone.

Numerous skier and snowboarder triggered avalanches were reported by backcountry enthusiasts and unofficial stories of other avalanches were shared within the community. An avalanche awareness clinic attracted over 50 participants with requests for more avalanche training and formal classes. Unfortunately, snow totals in the 2005-2006 winter were below average and interest temporarily waned as the Level 1 Avalanche course had to be cancelled due to lack of snow. (Lovejoy, 2006)

However, the founders of the Kachina Peaks Avalanche Center perceived a need "and potential for our vision", evidenced in the fact that the 2012-2013 winter saw enrollment in six Level 1 Avalanche courses (worth two credits at Northern Arizona University). Subsequent winters have shown increased enrollment in avalanche courses. Avalanche courses in the winter of 2015-2016 included 42 students in Level 1 and 2 courses; and approximately 80 participants in several 'Introduction to Avalanches' seminars.

Course offerings now include a multi day backcountry skiing course, and Level 1 and 2 avalanche courses utilizing a snow survey shelter in the Inner Basin of the San Francisco Peaks. This course is possible through a collaborative agreement and cooperation between the City of Flagstaff, USFS, Coconino County Search and Rescue, Arizona Snowbowl Ski Area, Northern Arizona University, Prescott College and the Kachina Peaks Avalanche Center to gain access to the Inner Basin Snow Survey Shelter.

Kachina Peaks Avalanche Advisory pilot study Survey form. Survey was performed in 2009-2010 winter, with over 90% of respondents indicating a 'benefit' from an avalanche advisory for the San Francisco Peaks.

2.6 *CURRENT AVALANCHE CENTER OPERATIONS*

The mission of Kachina Peaks Avalanche Center, Inc. is to provide support for and to engage in avalanche education, safety training and information exchange specific to the San Francisco Peaks in Northern Arizona.

Annual education efforts of the Kachina Peaks Avalanche Center include:

- Participation in community events to foster Avalanche Awareness: Science in the Park and STEM conference, among others
- Monthly, free, 'Introduction to Avalanches' two hour basic overview of Avalanches

- Level 1 and 2 Avalanche courses in conjunction with NAU and Prescott College
- Weekly Snow Summaries and Storm Updates with backcountry conditions
- Maintenance of KPAC website avalanche education information and observation discussion boards
- Annual free 'Field Day' of snowpack stability assessment methods
- Rescue training in conjunction with local Search and Rescue and Ski Patrol
- News segments explaining avalanche hazards of the San Francisco Peaks
- Annual Fundraisers for Level 1 Course scholarships and the General Fund

2.6 A: Snow Study and Snow Summary Bulletins:

The Kachina Peaks Avalanche Center regularly conducts snowpack assessment missions in the field to publish weekly or bi weekly 'Snowpack Summaries'. Snowpack Summaries include weather and snowpack stability information, specific information regarding backcountry conditions, and potential hazardous avalanche conditions.

Snowpack stability tests are performed and recorded according to standards set by the American Avalanche Association, "Snow, Weather, and Avalanches: Observation Guidelines for Avalanche Programs in the United States" (American Avalanche Association, 2010).

A published snow summary from www.kachinapeaks.org is presented in Appendix 1.

2.6 B: Future Potential of the Kachina Peaks Avalanche Center:

Currently listed with the National Avalanche Center as a Type 4 Local Education Center, KPAC is currently meeting the criteria for a Type 3 Local Avalanche Information Center by publishing weekly snow summaries . A Type 3 Center is eligible for up to $30,000 in funding which would "assure that the avalanche related duties would be given a high priority and accomplished" (Abromeit, 2008).

A change in designation to a Type 3 Avalanche Center would solidify funding for the staff and efforts to insure continued operation of the Avalanche Center as a community education and winter safety resource. Current operations are conducted by a group of dedicated volunteers.

However, without official funding, energy and motivation of the volunteer staff could dwindle and KPAC may not be a viable entity in the future for the safety and education of winter recreationists in Northern Arizona.

A draft of a cost sharing agreement, Figure 2.7, between KPAC and the Coconino National Forest is currently being negotiated and will possibly supply funding to continue Avalanche Center operations.

FS Agreement No. 12-CS-11030420-
Cooperator Agreement No. ____________

MASTER
CHALLENGE COST SHARE AGREEMENT
Between The
KACHINA PEAKS AVALANCHE CENTER, INC.
And The
USDA, FOREST SERVICE
COCONINO NATIONAL FOREST

This MASTER CHALLENGE COST SHARE AGREEMENT is hereby made and entered into by and between the Kachina Peaks Avalanche Center, Inc., hereinafter referred to as "KPAC," and the USDA, Forest Service, Coconino National Forest hereinafter referred to as the "U.S. Forest Service," under the authority of: Department of Interior and Related Agencies Appropriation Act of 1992, Pub. L. 102-154 and Cooperative Funds Act of June 30, 1914 (16 U.S.C. 498 as amended by Pub. L. 104-127).

Background: Winter recreation within the Kachina Peaks Wilderness has become increasingly popular because of opportunities found nearly nowhere else in Arizona. These activities often bring users into inherently dangerous situations involving avalanches and winter travel in extreme environments. The first avalanche fatality occurred in 1995, in response to this accident the Coconino National Forest struggled to find creative ways to provide the awareness and education to these recreationalists. In 1998 the Coconino National Forest began requiring a free recreational winter backcountry permit to increase awareness to winter recreationalist within the Kachina Peaks. This effort has help raised awareness, but the U.S. Forest Service had neither the skills nor budget to effectively provide technical avalanche education to the public nor monitor conditions and provide up to date information on the dangers of the Kachina Peaks. KPAC has helped to meet this need for increased education, awareness, and information sharing since 2005. For nearly a decade KPAC and the Coconino National Forest have worked together in partnership to promote safe backcountry winter travel and awareness in the Kachina Peaks Wilderness. This agreement is an opportunity to formalize this working relationship and expand our ability to jointly increase the education and safety of the winter recreating public on the Kachina Peaks.

Title: Master Cost Share Agreement for Avalanche Center, Forest-wide

Figure 2.7: Cost share agreement with Coconino National Forest

Chapter 3: PRACTICUM PROJECT

PROBLEM STATEMENT

In collaboration with the United States Forest Service, Coconino County Search and Rescue, Arizona Snowbowl Ski Patrol and the City of Flagstaff, Arizona, this research strives to analyze the demographics of backcountry skiers and riders in Northern Arizona to help focus the educational efforts and operational methods of the Kachina Peaks Avalanche Center (KPAC). Strategically targeting winter recreationists in need of avalanche education will hopefully improve the overall safety of the backcountry travelers and decrease the occurrence of avalanche fatalities, accidents and costly rescues.

3.1 *RESEARCH METHODS*:

To assess and quantify the demographics of winter backcountry users on the San Francisco Peaks, Arizona, a survey was conducted during the winter of 2015-2016. The target audience were winter recreationists applying for a free backcountry permit from the USFS Coconino National Forest.

USFS backcountry permits are available at local USFS offices in Flagstaff, AZ, or at the Arizona Snowbowl Ski area. Forest Service personnel and volunteers issue permits at the ski area on weekends. Permit applicants were encouraged to complete a brief survey, Figure 3.1., with explanatory text:

> "The Kachina Peaks Avalanche Center and Coconino National Forest are monitoring interest in backcountry travel and avalanche education. This information will help determine levels of funding and support for future avalanche education and rescue efforts."

Surveys were collected each week, assessed for accuracy and tabulated.

Of 368 backcountry permits issued at the Arizona Snowbowl during the winter of 2015-2016, 109 applicants completed the Kachina Peaks Recreation survey. Seven surveys were not filled out sufficiently for data purposes, leaving 102 of

109 surveys included in the results. Thus, 28% of backcountry permit applicants at Arizona Snowbowl completed a survey for this project.

KACHINA PEAKS RECREATION SURVEY

Thank you for taking a moment to complete this brief survey. The Kachina Peaks Avalanche Center and Coconino National Forest are monitoring interest in back country travel and avalanche education. This information will help determine levels of funding and support for future avalanche education and rescue efforts.

Age:___ Male or Female City:_____________ Zip Code:________

Circle all that apply: Skier Snowboarder Snowshoer Cross Country Skier Snowmobiler Hiker None

1. ***Would you benefit from an Avalanche Forecast Center for the San Francisco Peaks?*** Yes No
2. ***How often do you access backcountry terrain in the Coconino National Forest during winter?***
   Circle one: Never; or 'I ski/ride exclusively inbounds at Arizona Snowbowl';
   1 to 5 backcountry visits per season; 5-10 visits; 10-20 visits; 20 +
3. ***What do you bring with you on a backcountry tour?*** (circle all that apply):
   Nothing; or Partner; Backpack; Beacon; Probe; Shovel; Snow Saw; Snow Study Kit; GPS; Cell phone
4. ***Would you consider a donation to support an Avalanche Forecast Center?*** Yes No Maybe
5. ***Do you visit www.kachinapeaks.org for mountain conditions, avalanche, weather and educational information? (Circle one):***
   Every Day; A few times per week; 1 time per week; Never; I am not aware of this resource
6. ***What is your level of Avalanche Education? (circle one):***
   None__ Some basic knowledge___ Level 1 Avalanche Course__ Level II___ Level III or similar
7. ***Do you participate in uphill travel at the ski area?*** Yes: skins or hike; No

www.kachinapeaks.org

The Mission of the Kachina Peaks Avalanche Center, Inc. is to Provide Support for and Engage in Avalanche Education, Safety Training and Information Exchange Specific to the San Francisco Peaks in Northern Arizona.

Figure 3.1: Kachina Peaks Recreation Survey, 2015-2016.

3.2 *RESEARCH RESULTS:*

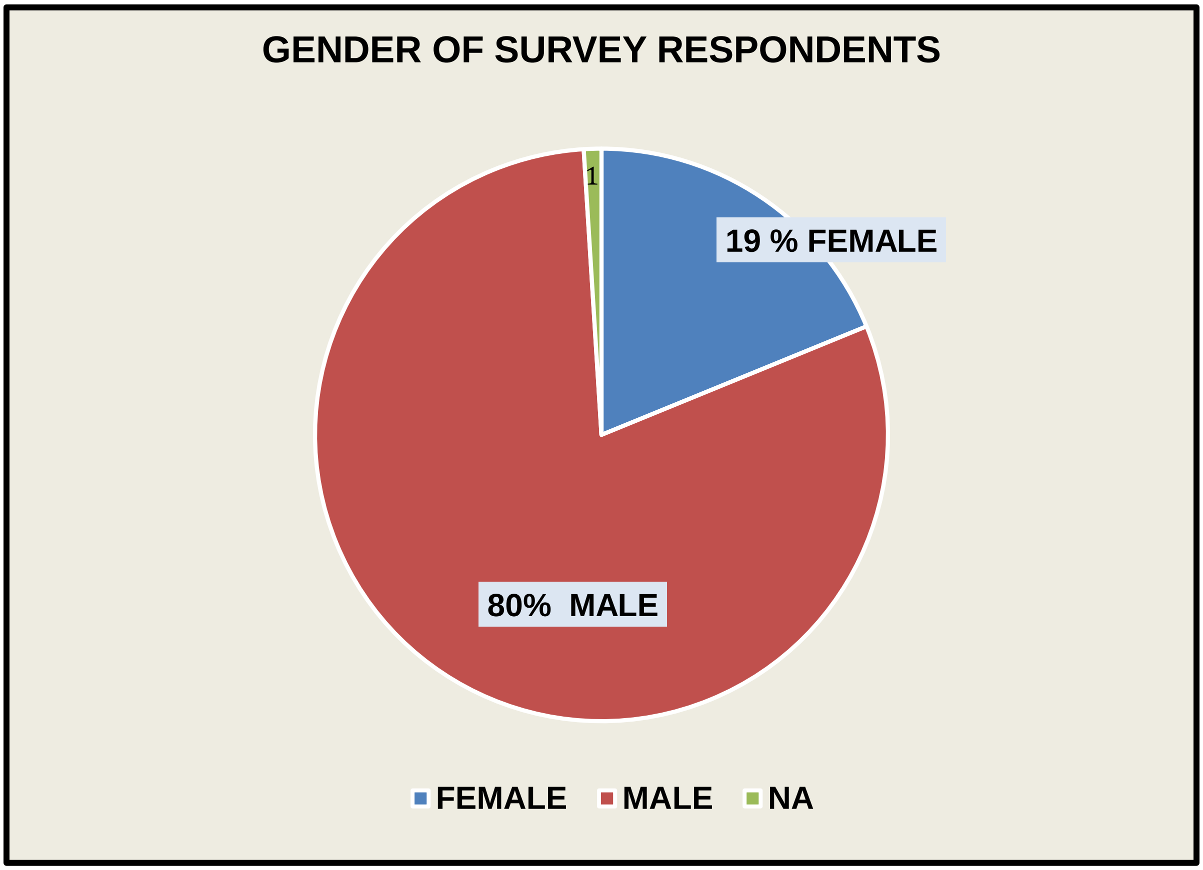


Chart 1: Gender of survey respondents

Results show that 80% of survey respondents were male, 19% female, and 1% not specifying. This data correlates with similar demographic studies conducted by Silverton, et al, in Utah (2007), but doubles the percentage of females compared to an international survey conducted by Tase (2004) which had 10% of survey respondents as females. Statistical analysis of avalanche accident data show that female's are proportionally involved in far fewer fatalities than males (Atkins, 2013). Thus, the nearly 20% of female survey respondents bode well for improved decision making in avalanche terrain for the San Francisco Peaks.

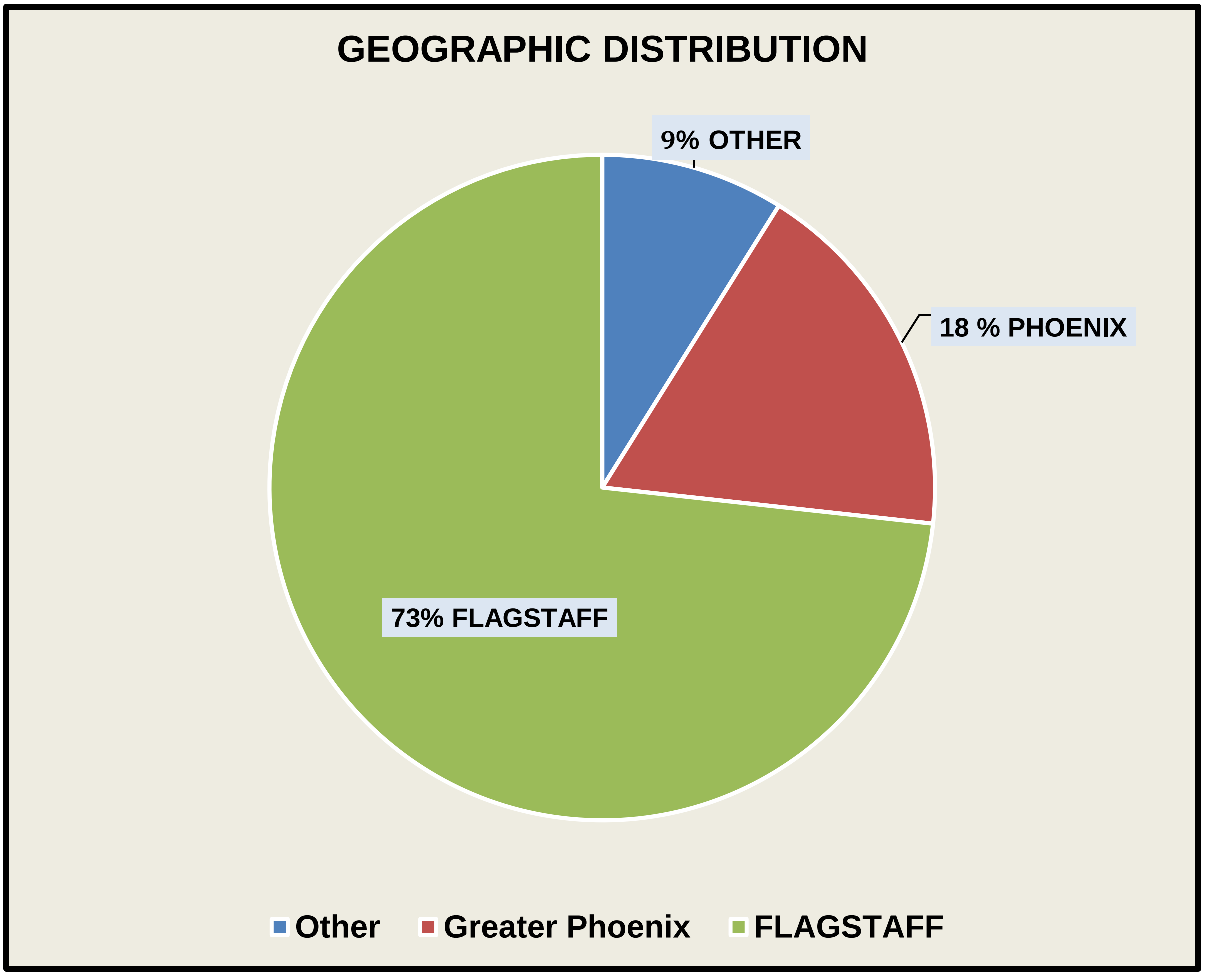


Chart 2: Geographic distribution of survey respondents

Geographically, 73% of the backcountry permit applicants who completed the survey designate Flagstaff, AZ as their home. 18% are from the greater Phoenix metropolitan area; with the remainder in the 'Other' category from as far afield as Haines, Alaska; Maine; and a few from Sedona, Williams, and Grand Canyon, AZ.

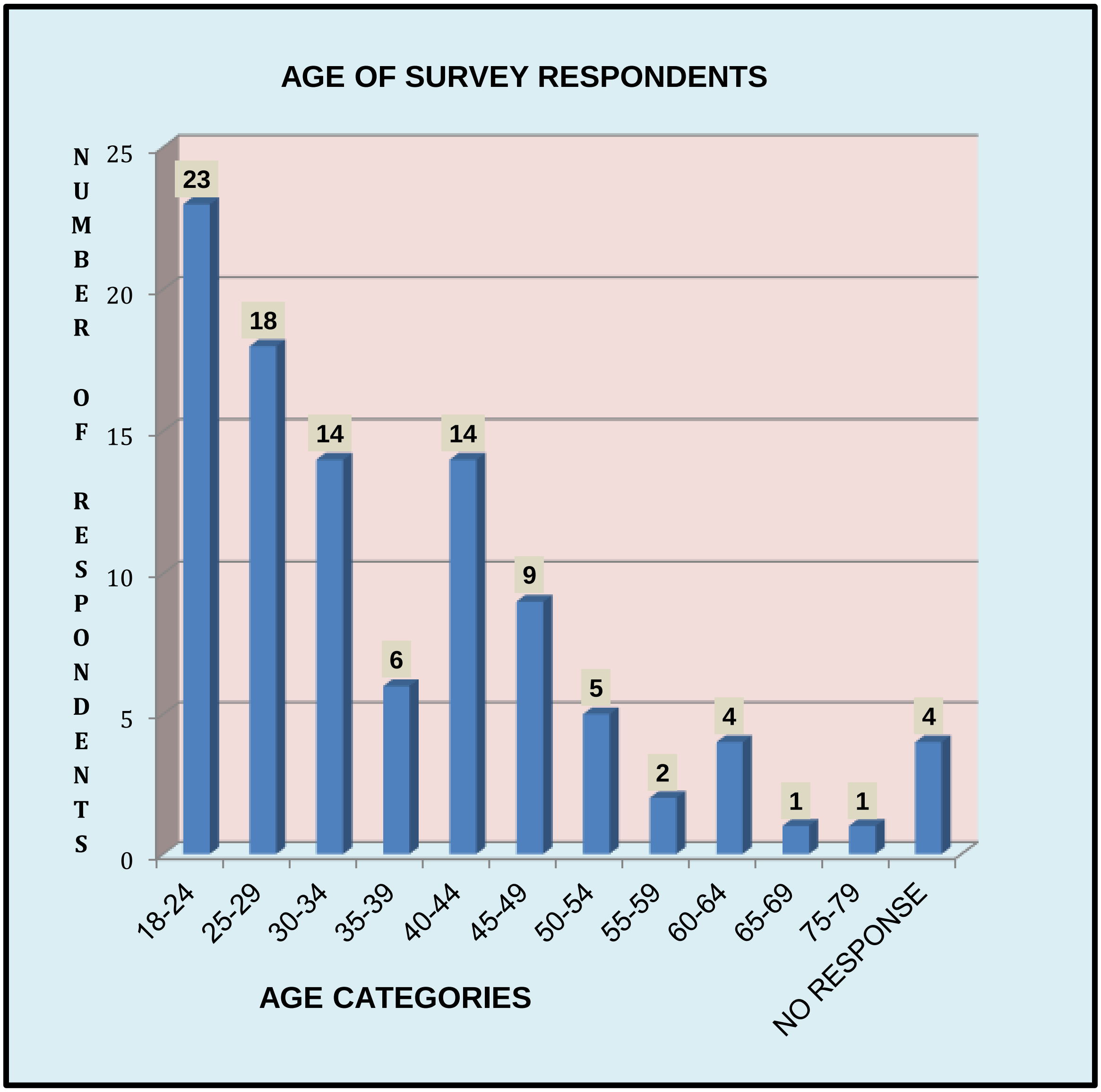


Chart 3: Age of respondents

Almost 25% of survey respondents are age 18-24, with another 18% of respondents in the age 25-29 category. These two age groups account for the majority of avalanche fatalities in the United States, and comprise 41% of survey respondents. The average age was 35.07, slightly higher than Tase's (2004) survey results, which had an average age of 34.5.

Interestingly, participants in the age groups 40-49 comprise almost 25% of survey respondents, indicating an aging group of backcountry enthusiasts.

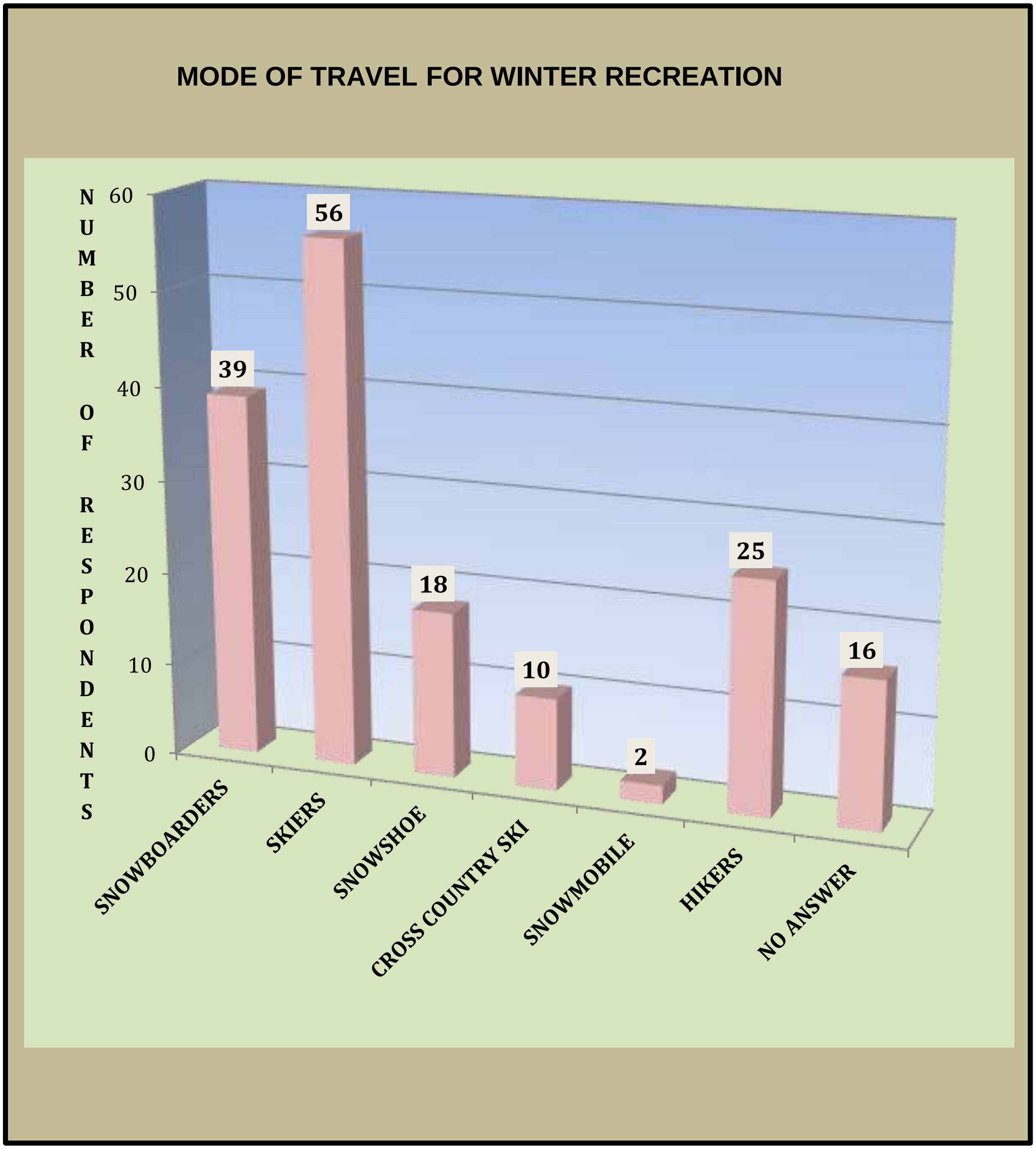


Chart 4: Mode of travel for survey respondents:

Over half of survey respondents were skiers, with 40% snowboarders, and 18% snowshoers. Participants could select more than one mode of winter travel for this question, thus numerous surveys indicated several choices. 16 participants failed to indicate their mode of travel.

Interesting results for Chart 4 are the very low number of snowmobilers, 2, in this survey. This is contrary to a trend throughout the majority of the west, where backcountry snowmobiling use has soared in the last few decades as a result of more powerful snowmobiles. In concert with the rise in use of snowmobiles has been a marked increase in snowmobile fatalities, with 40% of United States avalanche fatalities in 2005 (Silverton, 2007). This trend has now abated with combined skier and snowboarder fatalities as the majority.

This unique demographic feature of survey respondents can be attributed to the fact that the vast majority of avalanche starting zones on the San Francisco Peaks lie within the boundaries of the Kachina Peaks Wilderness, thus off limits to snowmobiles.

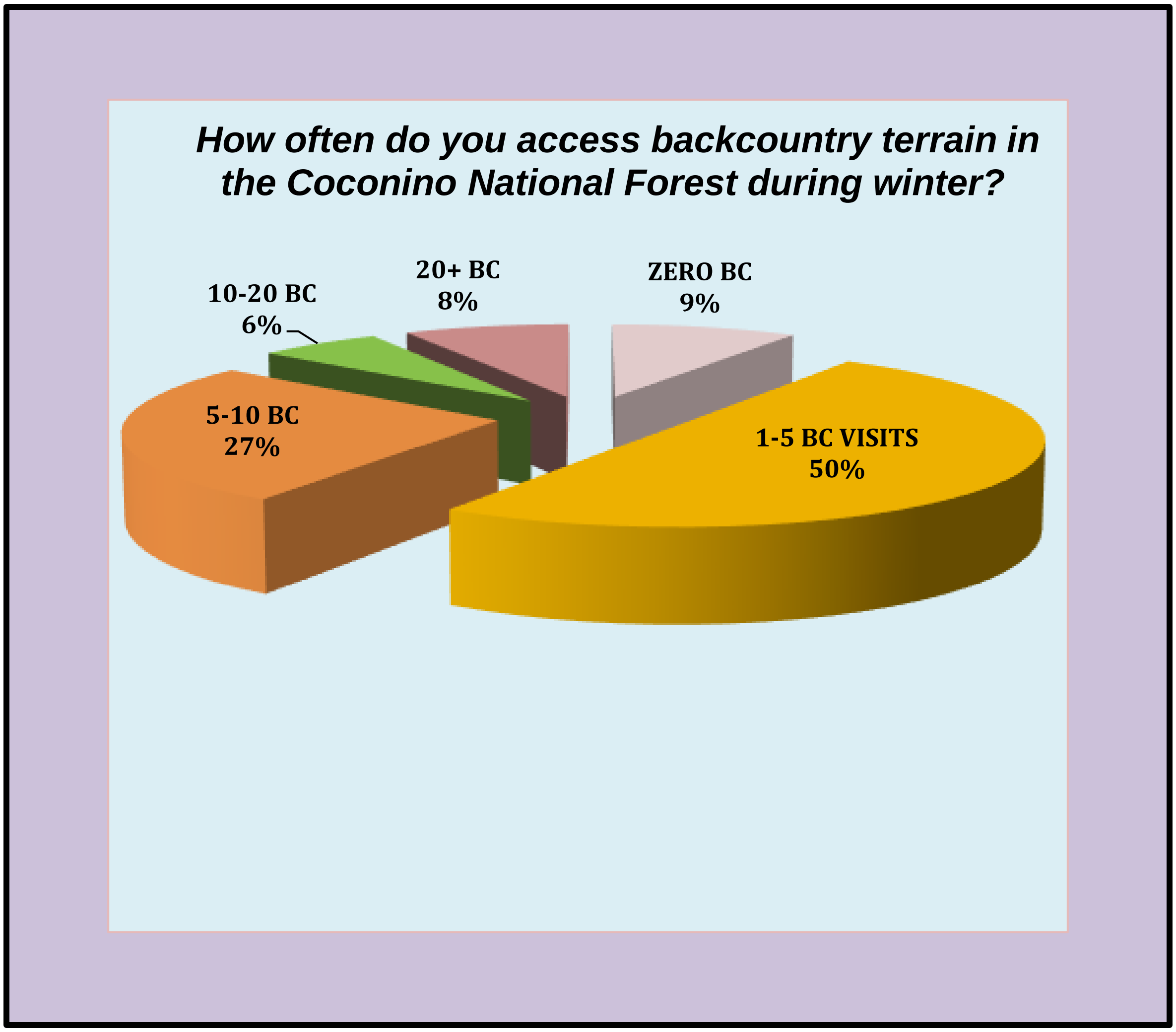


Chart 5: How often do you access backcountry terrain in the Coconino National Forest during winter?

Data indicates 50% of respondents visit the backcountry 1-5 times per winter; followed by 27% with 5-10 visits; tapering to almost equal segments of use for 10-20 visits; 20+ visits and zero backcountry visits.

Expertise in avalanche terrain can be correlated with exposure to experiences in that environment (McCammon, 2000). Thus, backcountry users on the San Francisco Peaks who are exposed to avalanche terrain enough to gain direct knowledge and expertise comprise 14% of the survey respondents, while the 50% category of 1-5 visits would warrant a novice or basic avalanche awareness.

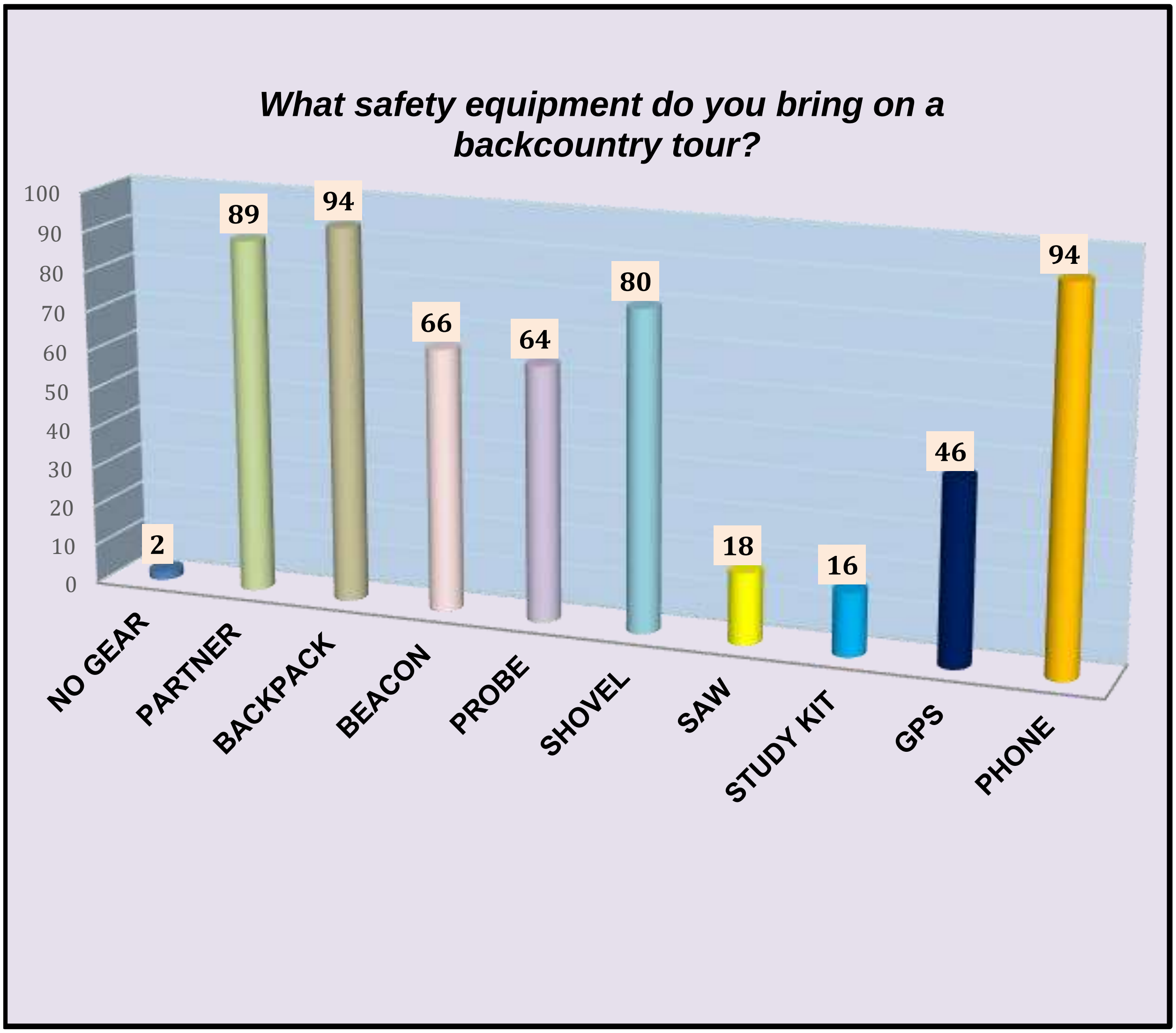


Chart 6: What safety equipment do you bring with you on a backcountry tour?

These results indicate an improvement can be made in the basic necessities of avalanche equipment, which include a beacon, probe and shovel. A beacon and shovel are the best means of a successful live recovery, though not a guarantee, as the mortality rate of the 10 years from 2003-2013 is at 66% of avalanche victims recovered with a beacon. However, mortality when searching for a victim without a beacon and shovel is over 90% (Atkins 2013).

Beacon, probe and shovel use were at 66, 64, and 80% of respondents. Cell phone and backpack use were the highest with 94% of respondents carrying these items on their tour, and 89% of participants travelled with a partner, also a mandatory component of a successful rescue.

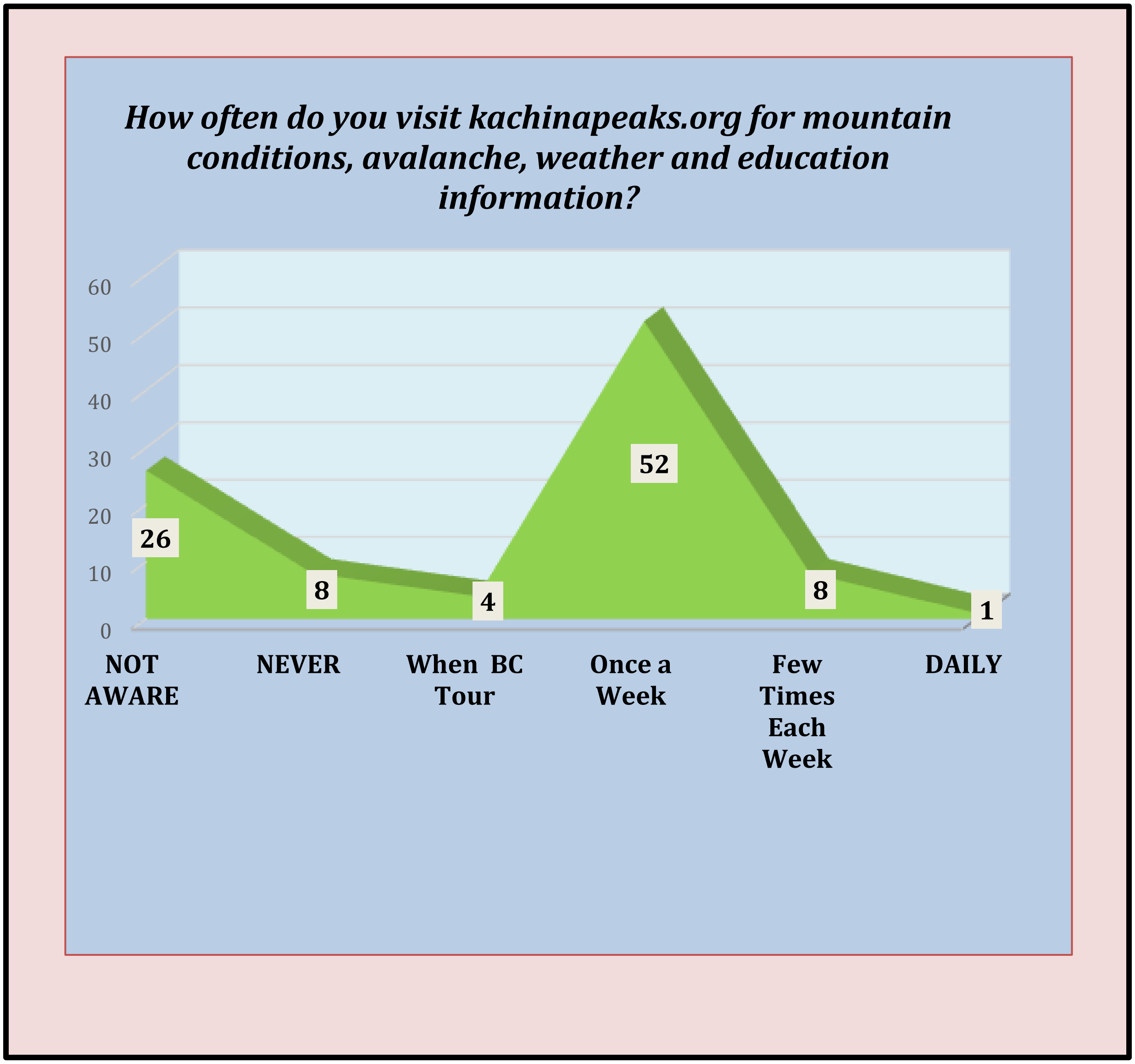


Chart 7: How often do you visit www.kachinapeaks.org for mountain conditions, avalanche, weather and education information?

Encouragingly, 52% of respondents signified they accessed the Kachina Peaks Avalanche Center website once a week to check on mountain conditions, avalanche, weather and education information.

Conversely, 34% of respondents indicated either never going to the Avalanche Center website, or not being aware of the resource.

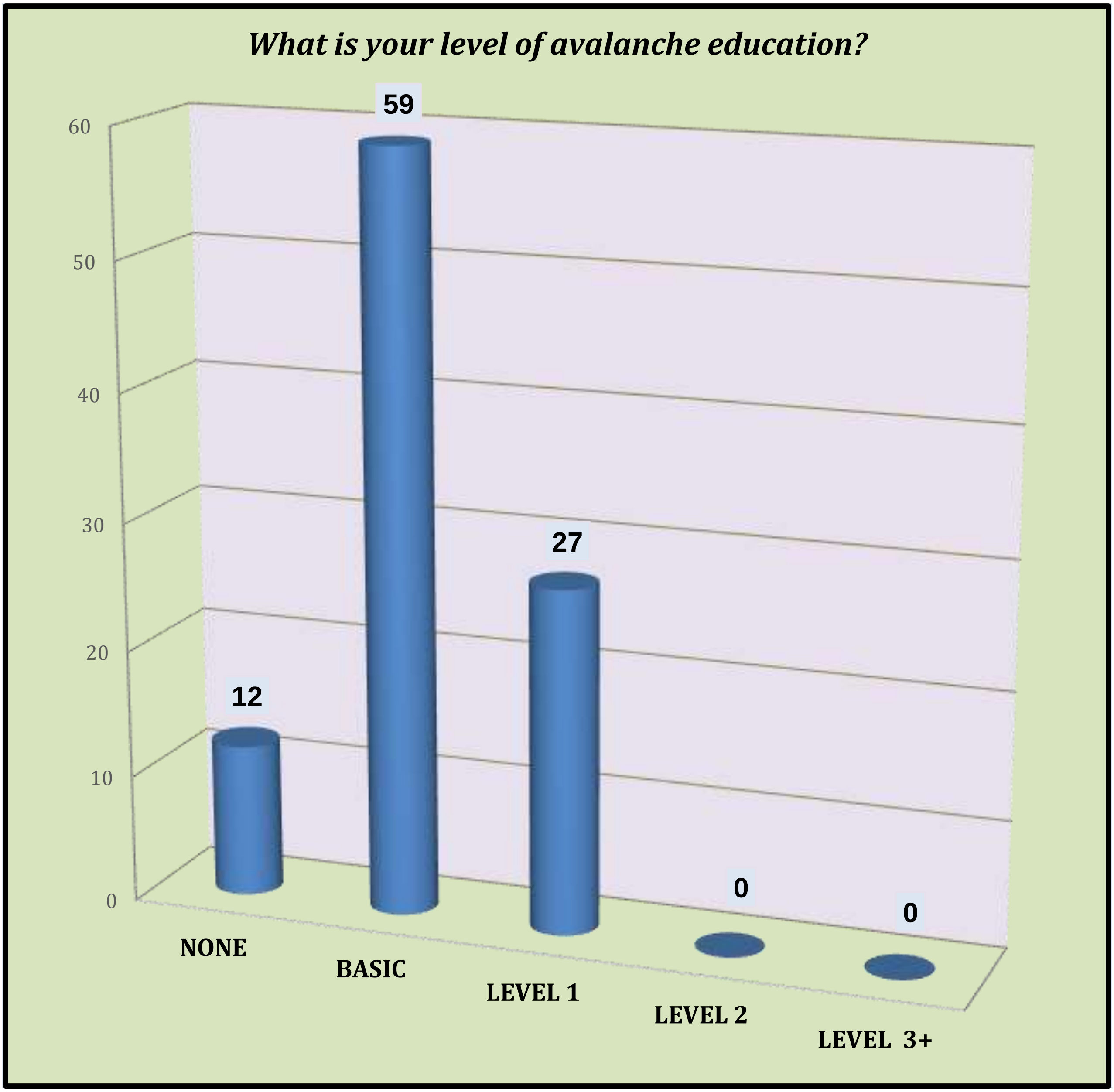


Chart 8: What is your level of avalanche education?

Results for level of Avalanche education indicate opportunities to provide continuing level 1 and level 2 courses to backcountry users on the San Francisco Peaks. Almost 60% of respondents indicated a 'Basic' level of avalanche education, lower than results from Utah, where 82% of respondents had a basic level of training (Silverton, 2007). Level 2 and 3 had a zero response rate.

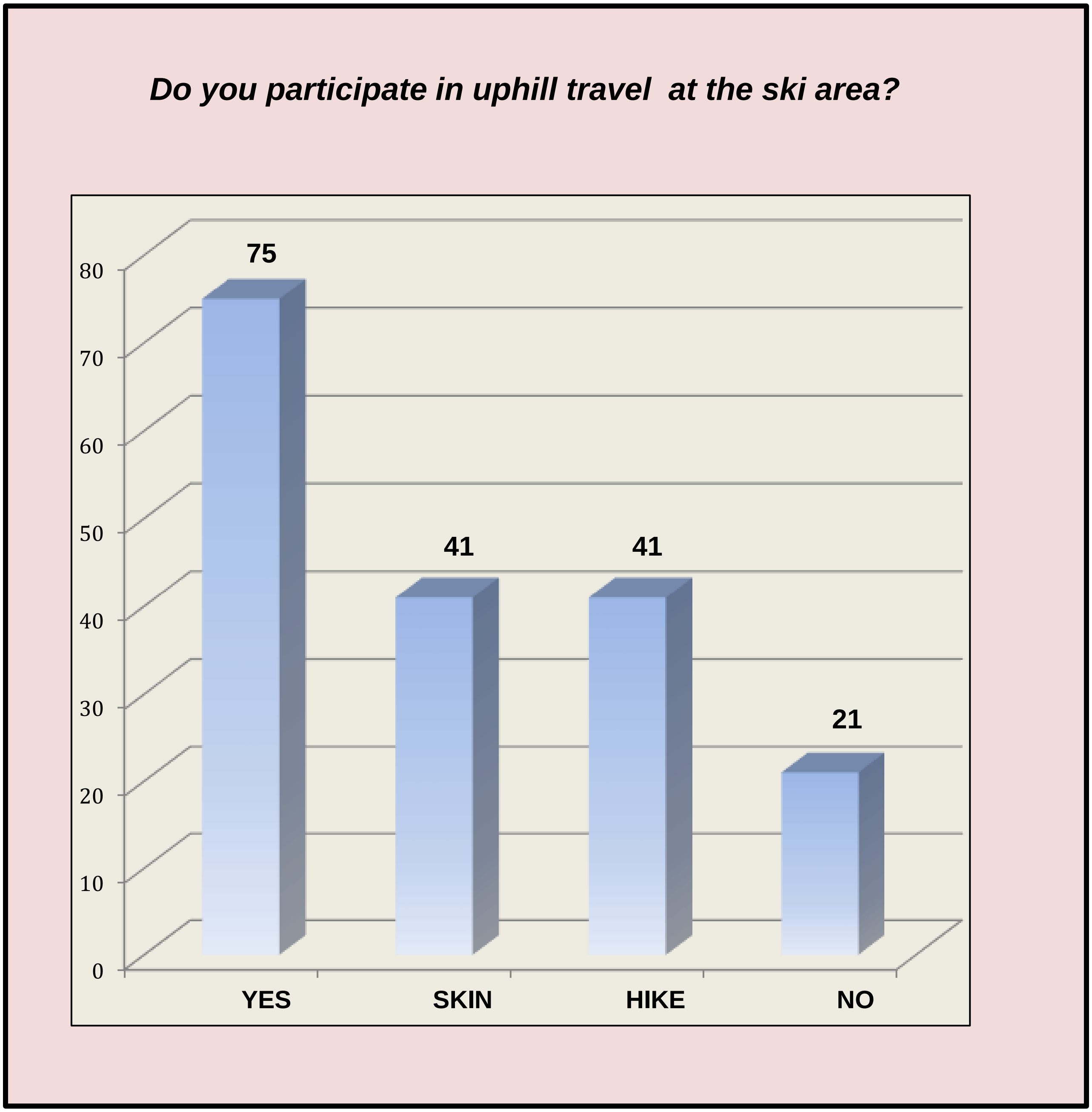


Chart 9: Do you participate in uphill travel at the ski area?

This data reveals a correlation with the surge in popularity of Alpine Touring gear and utilizing ski areas nationwide to recreate. Though not a direct correlation of backcountry travel, the 75% response rate indicates these users have the potential to travel beyond the ski area into avalanche terrain, since gear used for uphill travel on the ski area is the same used to access backcountry terrain.

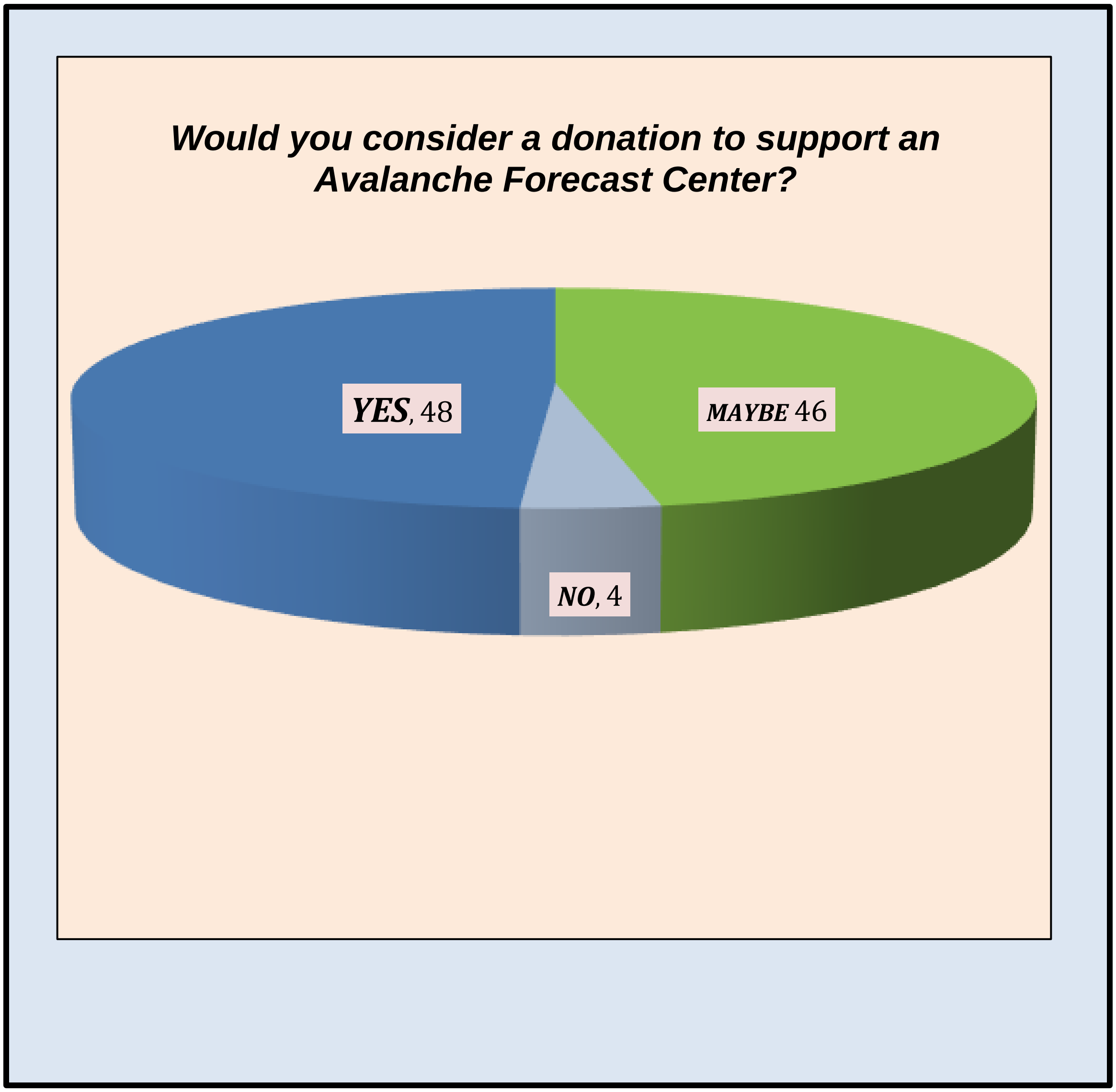


Chart 10: Would you consider a donation to support an Avalanche Forecast Center?

Survey results indicate a nearly 50/50 split in interest of personally donating to finance an Avalanche Forecast Center for Northern Arizona. While 48 respondents indicated 'yes', 46 indicated 'maybe' for a donation, with only 4 choosing 'no'. Providing a consistent Avalanche Forecast is considered a "critical factor in skier decision making" (Furman et al 2010).

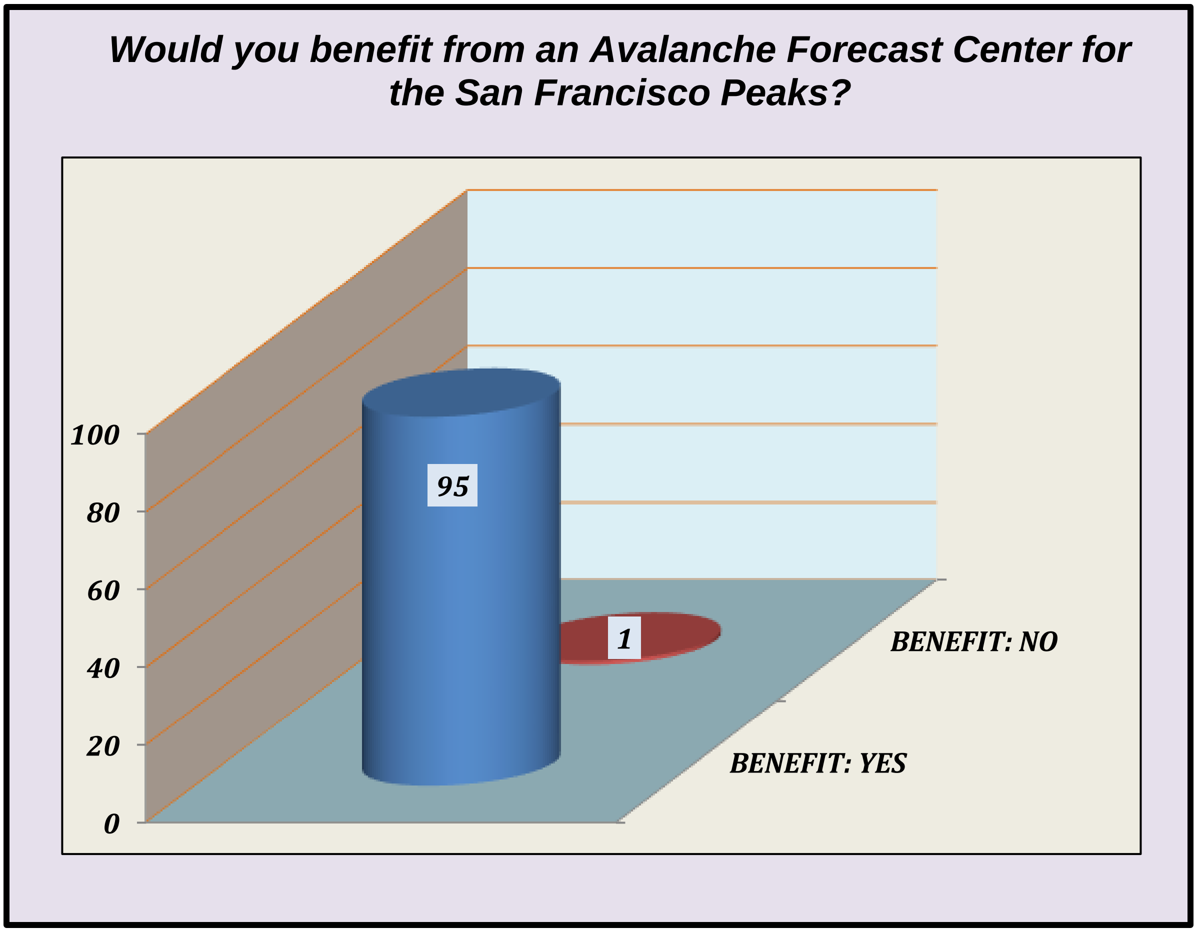


Chart 11: Would you benefit from an Avalanche Forecast Center for the San Francisco Peaks?

A resounding 'yes' in terms of benefitting from an Avalanche Forecast Center for the San Francisco Peaks, with 95 'yes' votes and one 'no' vote. When contrasted with Chart 10, 'Would you consider a donation to support and Avalanche Forecast Center?', which had only a 48% 'yes' rate, it would appear that though the vast majority of the public believe they would benefit from an Avalanche Forecast Center, 46% are not as inclined to provide personal funds to support an Avalanche Center.

These results indicate a gap in funding which could be filled by implementation of the USFS cost sharing agreement with the Kachina Peaks Avalanche Center.

Chapter 4 CONCLUSION:

4.1 *DISCUSSION*

The Kachina Peaks Recreation Survey quantified, for the first time, the unique winter backcountry demographics on the San Francisco Peaks. Since the Peaks comprise the bulk of active avalanche terrain in Arizona, and includes the site of the sole avalanche fatality in Arizona, it is imperative to understand the safety practices, rescue preparedness and level of avalanche education of winter backcountry travelers.

This data will assist in guiding future avalanche education programs of the Kachina Peaks Avalanche Center. Research results will also inform the United States Forest Service, Coconino County Search and Rescue, the Arizona Snowbowl and the City of Flagstaff in regards to increasing winter visitation and exposure to avalanche hazard of backcountry travelers on the San Francisco Peaks.

4.2 *RECOMMENDATIONS*

1. Establish funding for the Kachina Peaks Avalanche Center as a Type 3 Local Education Center in collaboration with the Coconino National Forest and National Avalanche Center:

- Survey results in Chart 11 indicate that 95% of respondents would benefit from an Avalanche Center on the San Francisco Peaks.
- KPAC has fulfilled the requirements of a Type 3 Center for three successive winters.
- KPAC has consistently fostered and demonstrated increasing use of it's website and avalanche education offerings, which directly "benefits local avalanche safety programs and public users" (USDA, 2012; Appendix 3).
- Furman, et al (2010) research indicates:

> "The information provided by avalanche forecast centers is a critical factor in skier decision making. This information should be as accurate and current as possible and that continued funding of these centers is critical as they provide a valuable public service."

2. Revisit Leland Dexter's 1981 Avalanche Mapping Program to update knowledge of the frequency, severity and location of avalanches on the San Francisco Peaks, particularly human triggered avalanches. Numerous avalanches have been reported on the KPAC discussion boards and by KPAC field researchers since 2005. Accurate mapping and analysis of these avalanche events will create a more definitive understanding of the avalanche hazard on the Peaks.

To further understand the physical dynamics of processes influencing avalanche initiation and propagation, additional research into the role of sublimation, a radiation influenced snow climate and the rugged basalt boulder substrate of the San Francisco Peaks is recommended. Do these factors individually or mutually help stabilize the snowpack or lead to greater instability?

3. Encourage the USFS, KPAC staff, Arizona Snowbowl Ski Patrol, and Coconino County Search and Rescue to proactively educate winter recreationists during and after significant snowfall events. The USFS installed counter at the backcountry access point recorded over 19 days of 50 + backcountry recreationists leaving the Arizona Snowbowl in the 2012-2013 season. On February 26, 2013; the counter recorded 340 backcountry visits after a significant snowfall (Appendix 2).

Expanding training of backcountry observers to provide accurate snowpack stability observations will assist in gathering avalanche hazard conditions and recent avalanche activity, informing the backcountry community in a timely manner of conditions and potential avalanche danger.

4. Survey results in Chart 8 indicate vast potential to improve the overall avalanche education and rescue readiness of backcountry practitioners on the

San Francisco Peaks. Compared to results from Silverton et al (2007) and McCammon (2004), low percentages of avalanche education on the San Francisco Peaks provide an opportunity to expand course offerings of Level 1, Level 2 and Basic avalanche education courses through the Kachina Peaks Avalanche Center. Sold out Level 1 courses and robust attendance at Avalanche Awareness Seminars in the 2015-2016 winter demonstrated the demand for avalanche education in Northern Arizona.

Regarding rescue readiness, Chart 6 displays relatively low percentages of recreationists who did not travel with a beacon, partner, probe and shovel, all essential equipment for a successful avalanche rescue.

5. 34% of respondents were not aware or had never visited www.kachinapeaks.org, according to Chart 7, indicating a need for better marketing of the resources available from the Kachina Peaks Avalanche Center. Stable funding of KPAC will result in paid staffing opportunities to improve consistent dissemination of KPAC educational opportunities.

6. Based on the numerous research initiatives focusing on the 'human factor', it is recommended to continue to incorporate and emphasize this area of research in KPAC avalanche education offerings. FACETS, ALPTRUTH, and other decision making aids, such as the FIND acronym, are available and should be implemented to help cater to different types of learners (McCammon, 2004; DiGiacomo, 2006).

Incorporating stories and real life scenarios of avalanche accidents into avalanche curriculum can provide real world context to the consequences of not recognizing signs of instability and avalanche hazard (Atkins, McCammon, 2004). Focusing as much of the course time as possible on field exercises is useful for novices to learn by touch, feel and experience, versus lecture and powerpoint style delivery.

7. Adapt the survey techniques used in this research to more accurately determine backcountry demographics on the Peaks. This practicum focused solely on individuals applying for a backcountry permit from the USFS at the Arizona Snowbowl.

Anecdotal evidence suggests there are many individuals who access backcountry terrain that may not have procured a permit, thus results may be skewed toward those that adhere to posted rules. 'Rule' followers may tend to be more prepared and educated overall than those not inclined to obtain a permit. Surveying backcountry travelers at local trailheads, such as the Humpheys Peak Trailhead, and the backcountry access point at the Arizona Snowbowl may more accurately define user demographics.

Offering the survey via the KPAC website could provide a greater response rate than in person interview techniques.

8. Utilize the "Uphill Travel Kiosk" at the Arizona Snowbowl parking area to inform the 75% of survey respondents (Chart 9) who participate in uphill travel at the ski area of KPAC resources, events and post Snow Summaries.

9. Offer more frequent "Introduction to Avalanches" seminars through partnerships with the Flagstaff Unified School District, Coconino Community College and Northern Arizona University. These efforts can be modeled on the successful "Know Before You Go" program of the Utah Avalanche Center. Survey results from Chart 3 indicate that 41% of respondents are between age 18-29. This corresponds to the age bracket with the majority of avalanche fatalities and should be a target audience for avalanche education (Atkins, 2013).

10. To assess the utility of avalanche education, interviewing participants who have completed a Level 1 avalanche course and recreated safely in the backcountry could prove insightful. A survey to determine which portion of the course proved most useful in avoiding avalanche accidents and examples of decision making in the field could illuminate successful strategies for avalanche educators.

In summary, the potential and need exists to improve winter public safety and education on the San Francisco Peaks. The goal of the National Avalanche Center is “to promote avalanche safety and education” (Abromeit, 2008). The Kachina Peaks Avalanche Center is poised to consistently fulfill this mission with adequate funding from the United States Forest Service.

KPAC has achieved the mandate of a Type 3 Avalanche Information Center for the winters of 2012-2016 as a volunteer non-profit entity, with a staff of dedicated educators and field researchers. Continued research and collaboration with local stakeholders will further insure the effectiveness of avalanche education and safe backcountry travel practices, preventing future avalanche accidents, fatalities and rescues on the San Francisco Peaks of Arizona.

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APPENDIX 1: SNOWPACK SUMMARY FROM WWW.KACHINAPEAKS.ORG:

Friday, December 6, 2013

The Weeks Weather in Review

The first week of December brought more snow, **very cold temperatures**, and wind to the Peaks.

3-6″ of **new snow** fell this Wednesday, December 4.   6″ of snow accumulated at higher elevations and as reported at the Snowslide Spring weather station in the Inner Basin (9730′). This has added up to 1″ of Snow Water Equivalent (SWE) weight to the snowpack.

Temperatures were moderate for the week until the onset of the storm, dropping abruptly on December 4 to single digits at 11,500′. This trend has continued with a maximum temperature of 13 degrees F and minimum of -2 this morning.

Wind was from the South and Southwest during the December 4 storm with periods of 30+ mph and significant snow transport and sublimation. The Agassiz Peak weather station at 11,500′, stopped recording during the storm, probably due to riming of the anemometer, so maximum wind speeds are not available for this time period. However, the Snowslide Spring station reported winds up to 27 mph.

Current forecasts call for continued low temperatures on the Peaks of near 0 degrees F, with high temperatures over the weekend of 13 degrees F. Winds will continue from the **West and Southwest gusting up to 55 mph** Saturday afternoon. **Wind chill values as low as -24 are possible.**

Snow accumulations are predicted to be **10+ inches** beginning Saturday with the bulk of precipitation Saturday evening and a chance of continued snow showers Sunday.

Summary

Above Treeline and Exposed Terrain:

Post storm observations from December 5 revealed that above treeline and exposed terrain has suffered scouring from the robust South and Southwest winds of December 4. A variety of wind hardened crusts and scattered pockets of wind slab remain, particularly along ridge lines.

The remaining snowpack above treeline is at most 3 feet deep in wind loaded areas, and generally thinner. The wind slabs have weak, poorly bonded snow underneath which is susceptible to accelerated faceting due to large temperature gradients in the snowpack.

Wind slabs are deceptive as they may support the weight of a rider initially, yet fail when a person is out in the center. Wind slabs can sound hollow. Be alert to any collapsing or cracking and always travel one at time in suspect terrain, on the way up and down.

Below Treeline and sheltered terrain:
Stability tests this week were conducted near 11,000′ and below. Results show the **primary concern** to be a failure between last weeks dense storm snow and weak basal facets, which make up the lower portion of the snowpack on North and Northwest aspects. Compression test and Extended Column test results of 11 and 13, with a sudden collapse initiated in the Extended Column test indicating increased energy and fracture propagation potential in the snowpack at this interface.

Potential Problem: Current below freezing temperatures will promote **more facet growth** in our shallow, early season snowpack. Temperature gradients recorded this week are double what is required for faceting to occur, which is a 1 degree Celcius per 10 cm gradient. Facets at the base of the snowpack are also known as **depth hoar** and are loose, angular grains which can grow to several millimeters.

These large faceted grains have very little cohesion and are a primary weak layer culprit in avalanche accidents. Temperature gradients throughout the snowpack can promote facet growth around crusts and near the surface. Facets can **persist** in the snowpack for some time, especially this time of year as temperatures remain low and hours of sunlight decreases.

Forecast accumulations for Saturday of 10+ inches of snow at higher elevations and strong South and Southwest winds may result in rapid wind loading and wind slab formation.

As a reminder, we have not had ample opportunity to thoroughly investigate all aspects and elevations – so please **treat this summary with appropriately guarded skepticism, make your own assessments**, and contribute to our body of knowledge by reporting your observations.

Please consider joining KPAC staff for:

'Introduction to Avalanches' free two hour seminar:
When: Wednesday December 11, 6:00 pm
Where: Leaf Auditorium, Coconino County Search and Rescue, 911 Sawmill Rd. (just south of New Frontiers Plaza) Flagstaff, AZ 86001
*USFS 2013-14 Backcountry permits are available at the presentation.

APPENDIX 2: USFS BACKCOUNTRY VISITS COUNT 2012-2013

Arizona Snowbowl Southside Gate Backcountry Access

2012 - 2013 Winter Season Count

December	
2012-12-26	
2012-12-27	10
2012-12-28	30
2012-12-29	37
2012-12-30	39
2012-12-31	34

Janurary	
2013-01-01	39
2013-01-02	39
2013-01-03	7
2013-01-04	15
2013-01-05	29
2013-01-06	30
2013-01-07	63
2013-01-08	6
2013-01-09	83
2013-01-10	14
2013-01-11	125
2013-01-12	52
2013-01-13	37
2013-01-14	12
2013-01-15	29
2013-01-16	3
2013-01-17	0
2013-01-18	2
2013-01-19	2
2013-01-20	30
2013-01-21	28
2013-01-22	14
2013-01-23	4
2013-01-24	0
2013-01-25	5
2013-01-26	0
2013-01-27	0
2013-01-28	2
2013-01-29	0
2013-01-30	136
2013-01-31	38

February	
2013-02-01	28
2013-02-02	51
2013-02-03	13
2013-02-04	10
2013-02-05	4
2013-02-06	3
2013-02-07	12
2013-02-08	3
2013-02-09	50
2013-02-10	61
2013-02-11	117
2013-02-12	109
2013-02-13	35
2013-02-14	50
2013-02-15	87
2013-02-16	80
2013-02-17	21
2013-02-18	22
2013-02-19	10
2013-02-20	106
2013-02-21	19
2013-02-22	139
2013-02-23	67
2013-02-24	31
2013-02-25	35
2013-02-26	340
2013-02-27	23
2013-02-28	22

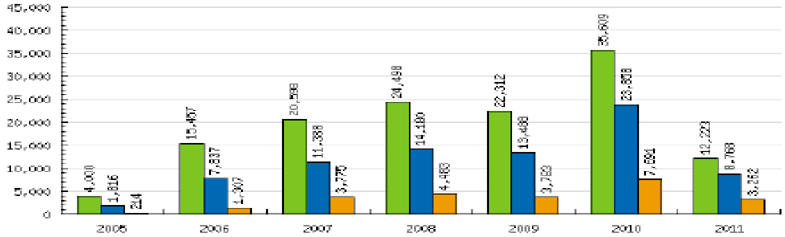
March	
2013-03-01	24
2013-03-02	17
2013-03-03	58
2013-03-04	24
2013-03-05	7
2013-03-06	6
2013-03-07	8
2013-03-08	61
2013-03-09	31
2013-03-10	175
2013-03-11	52
2013-03-12	27
2013-03-13	7
2013-03-14	9
2013-03-15	16
2013-03-16	10
2013-03-17	16
2013-03-18	4
2013-03-19	6
2013-03-20	0
2013-03-21	11
2013-03-22	8
2013-03-23	14
2013-03-24	14
2013-03-25	9
2013-03-26	17
2013-03-27	

Days over 50 counts

19 Days of over 50 Backcountry Skier Visits Last Winter ...maximum of 340 in one day!

APPENDIX 3: WEB DATA CAPTURE OF VISITATION TO KACHINA PEAKS AVALANCHE CENTER WEBITE 2005-2011 and 2011-2014

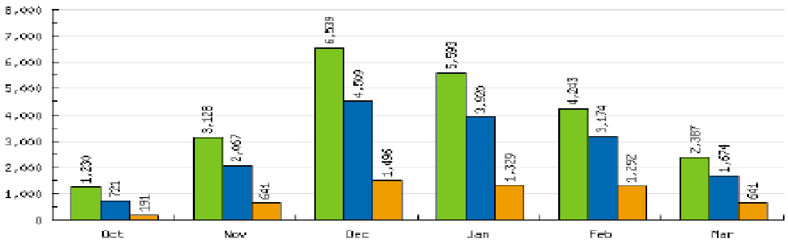
WEB DATA FROM 2005 THROUGH 24 MARCH 2011



	Page Loads	Unique Visitors	First Time Visitors	Returning Visitors
Total	**134,697**	**81,335**	**56,820**	**24,515**
Average	19,242	11,619	8,117	3,502

Year	Page Loads	Unique Visitors	First Time Visitors	Returning Visitors
2011	12,223	8,768	5,506	3,262
2010	35,609	23,858	16,167	7,691
2009	22,312	13,488	9,705	3,783
2008	24,498	14,180	9,697	4,483
2007	20,598	11,388	7,613	3,775
2006	15,457	7,837	6,530	1,307
2005	4,000	1,816	1,602	214

WEB DATA FROM OCT 2010 THROUGH 24 MARCH 2011



	Page Loads	Unique Visitors	First Time Visitors	Returning Visitors
Total	**23,120**	**16,065**	**10,475**	**5,590**
Average	3,853	2,678	1,746	932

Month	Page Loads	Unique Visitors	First Time Visitors	Returning Visitors
Mar 2011	2,387	1,674	1,033	641
Feb 2011	4,243	3,174	1,882	1,292
Jan 2011	5,593	3,920	2,591	1,329
Dec 2010	6,539	4,509	3,013	1,496
Nov 2010	3,128	2,067	1,426	641
Oct 2010	1,230	721	530	191

Returning Visitors - Based purely on a cookie, if this person is returning to your website for another visit an hour or more later
First Time Visitors - Based purely on a cookie, if this person has no cookie then this is considered their first time at your website.
Unique Visitor - Based purely on a cookie, this is the total of the returning visitors and first time visitors - all your visitors.
Page Load - The number of times your page has been visited.

2013/2014 Season Summary Stats for KachinaPeaks.org

Snowpack Summary Notification List

(We send out an email and phone text notifications to the lists when we update the summary)

	As of March 31, 2014
Email Subscriber count	80
Text Subscriber count	8

KachinaPeaks.org
Unique Visitors Dec. 1 – March 31

	2011-2012	2012-2013	2013-2014
All of Kachinapeaks.org	3822	3766	3198
Snowpack Summary	N/A	1395	1122
SnowPack Summary AZ only	N/A	908	666
Snowpack Summary Flagstaff only	N/A	308	257

KachinaPeaks.org/boards (public observation/discussion boards)
Unique Visitors Dec. 1 – March 31

	2011-2012	2012-2013	2013-2014
All	1211	1379	1025
AZ only	913	1018	775
Flagstaff only	292	402	433