KU LEUVEN

FACULTY OF SCIENCE

HOW DO PEOPLE PERCEIVE THE IMPACT OF CLIMATE CHANGE ON MOUNTAINEERING IN THE SWISS ALPS?

Cristiana PEDRAZZINI

Supervisor: Prof. H. Jacquemyn

Thesis presented in
fulfillment of the requirements
for the degree of Master of Science
in Sustainable Territorial Development

Academic year 2022-2023

COPYRIGHT NOTE

At the bottom of the first page the following text should be written concerning copyright, in the same language as the rest of the master's thesis:

Acknowledgement

I sincerely thank my supervisor Hans Jacquemyn, my family, my friends and my fellow master students who helped me during the writing of my master thesis. And of course a special thank you to all the mountaineers and alpinists who strenuously fight to climb their peaks, even though their beloved mountain is becoming more and more hostile.

Abstract

The aim of this work was to find out whether mountaineers and ski mountaineers perceive the effects of climate change during their tours in Switzerland, what changes they notice, how these affect the way they practise these sports, how they adapt and what their sensitivity is on this issue, and thus to answer the main question "How do people perceive the impact of climate change on mountaineering and ski mountaineering in the Swiss Alps, in particular in the Bernese Oberland, Graubünden, Valais and Ticino?". To get to the bottom of this research, an online questionnaire was conducted using Microsoft Forms to collect the answers of mountain enthusiasts and semi-structured qualitative interviews to collect the answers of the professions and mountain guides. From the 61 responses to the online questionnaire and the 15 semi-structured qualitative interviews, it appears that melting glaciers, thawing permafrost and decreasing snow and ice cover have an effect on mountaineering and ski touring. They increase the danger and technical difficulty and alter certain characteristics such as the optimal time to practice, the length of routes and the routes themselves.

French Summary

L'objectif principal de cette recherche est de comprendre comment le changement climatique, un phénomène étudié et discuté au niveau mondial, affecte l'alpinisme et le ski de randonnée dans les Alpes suisses. Il s'agit notamment de tenter de répondre aux questions suivantes : "Comment les gens perçoivent-ils l'impact du changement climatique sur l'alpinisme et le ski-alpinisme dans les Alpes suisses, en particulier dans l'Oberland bernois, les Grisons, le Valais et le Tessin ?", "Quelles sont les conséquences du changement climatique sur l'alpinisme et le ski-alpinisme de manière directe et indirecte ?", "Les alpinistes perçoivent-ils le changement climatique et qu'en savent-ils ?" et "Comment s'adaptent-ils à ces changements ?".

Pour répondre à ces questions, un questionnaire en ligne et un questionnaire qualitatif semi-structuré ont été réalisés. Le questionnaire en ligne a été conçu en anglais et en italien avec Microsoft Forms pour recueillir les réponses des "amoureux de la montagne", c'est-à-dire des personnes qui vont à la montagne comme passe-temps pendant leur temps libre, et 61 réponses ont été recueillies. Le questionnaire qualitatif semi-structuré visait à recueillir les réponses de professionnels et de guides de montagne, c'est-à-dire de personnes qui ne vont pas seulement à la montagne pour le plaisir, mais aussi pour des raisons professionnelles. 15 entretiens ont été réalisés : 7 avec des guides de montagne, 2 avec des experts, 2 avec des gardiens de sentiers et 4 avec des sportifs de montagne expérimentés.

L'analyse des données recueillies a permis d'identifier trois éléments principaux, à savoir la fonte des glaciers, le dégel du pergélisol et la diminution de la couverture de neige et de glace, qui ont une influence directe sur l'alpinisme et le ski-alpinisme.

La fonte des glaciers en Suisse est évidente et entraîne des conséquences négatives importantes. On a observé une augmentation de la rupture des séracs, un allongement temporel des accès aux glaciers, un terrain morainique légèrement plus raide avec beaucoup de débris non consolidés et de roches abruptes en raison de la régression des masses de glace, et une diminution de la pression du glacier contre la montagne entraînant la chute de blocs instables.

Le dégel du permafrost entraîne une augmentation des chutes de pierres et des conditions de terrain instables, particulièrement évidentes pendant la période estivale, ainsi qu'une diminution et une concentration de la période pendant laquelle les faces nord de l'Eiger (Oberland bernois) et du Cervin (Valais) peuvent être escaladées, en hiver et au printemps.

La diminution de la couverture de neige et de glace a une grande influence sur les itinéraires, de glace et mixtes. En effet, certaines voies faciles à gravir en présence de neige deviennent particulièrement difficiles, voire impossibles, en présence de roche ou de glace uniquement. L'état du manteau neigeux est particulièrement dégradé pendant la période chaude. Les périodes favorables et stables pour les alpinistes passent de l'été au printemps, à l'automne et à l'hiver. En outre, l'altitude et la taille des crevasses augmentent, surtout en période estivale. Les crevasses représentent un grand danger pour les alpinistes.

Il ressort clairement de ces recherches que les alpinistes et les guides de montagne doivent s'adapter aux effets du réchauffement climatique afin de réduire leur exposition aux dangers mortels. Six stratégies d'adaptation ont été mises en évidence : choisir un itinéraire plus précis et exact, anticiper et raccourcir la période des excursions, développer un niveau de connaissance et de préparation plus élevé, mettre en œuvre l'équipement technique à transporter en montagne., équiper les sentiers avec des matériels techniques artificiels, et pratiquer d'autres sports.

Il a été noté que le sujet abordé dans cette recherche gagne de plus en plus d` importance, notamment après l'accident de la Marmolada du 3 juillet 2022 dû à une chaleur trop importante. Cependant, le fossé à combler par des recherches sur ce sujet est encore énorme. Les recherches futures dans ce domaine permettront de limiter et de prévenir les dangers pour les pratiquants de ces sports.

Table of Contents

1. Introduction

My great sensitivity to climate change and my strong passion for mountain sports led me to combine them in this Master thesis in the attempt to understand how they are related.

Climate change is a globally studied, known and discussed phenomenon. Its scientifically established effects are, for example, the average increase in temperatures, the progressive melting of glaciers and the rise in sea levels (Mitchell, 1989). Since the end of the 20th century, these effects have captured the attention of the international community, the media and scientists. Every 5/6 years, the Intergovernmental Panel on Climate Change (IPCC) publishes a report that formulates scenarios -over a time horizon of 20, 50, 80 years- on the effects of climate change on the Earth's entire ecosystem. If we do nothing to improve the situation by 2100, the concentration of carbon dioxide would reach 957 parts per million (530 ppm more than the current concentration) (Sitch, 2005). This, together with the increase in other greenhouse gases, would lead to a 4°C rise in global atmospheric temperatures. According to Kohler & Maselli (2009), mountains are one of the most affected and sensitive regions to global warming. Several changes are evident, ranging from the retreat of glaciers, thawing of permafrost, altitude shifts of animals and plants (CREA Mont-Blanc, n.d.), etc. However, the effects of climate change are not only concentrated on mountains, but have instead an influence from a global point of view. Mountains are an important source of water for 50% of the world's population. Climate change will have enormous implications for irrigation, urbanisation, industrialisation and hydropower production (Kohler & Maselli, 2009).

The effects of climate change are progressively evident around the world also as far as mountaineering and ski mountaineering are concerned, making these sports all the more dangerous and difficult (Khadka, 2019). Fatal accidents, such as the breaking of the Marmolada glacier in the Dolomites on the 3rd of July 2022, which led to a death toll of 11 (Bonnel, 2022), are increasingly frequent. The effect of climate change on mountaineering and ski mountaineering is a topic that has been addressed very late (2005s) and very slowly through scientific literature. Perhaps this is because the urgency and importance of this issue has not been perceived before. So far, most studies have focused on the Mont Blanc region, and only an exiguous minority on the Swiss region. The aim of this research is to contribute to fill this gap by trying to understand what changes mountaineers perceive and by what means

Using a quantitative approach based on a 61-response survey and 15 semi-qualitative interviews, this research seeks an answer to several questions. The main research question is the following:

How do people perceive the impact of climate change on mountaineering and ski mountaineering in the Swiss Alps, in particular in the Bernese Oberland, Graubünden, Valais and Ticino?.

This leading question is complemented by the following secondary questions:

What are the consequences of climate change on mountaineering and ski mountaineering directly and indirectly?

Do mountaineering perceive the changes related to climate change and what do they know about them?

How are they adapting to these changes?

The research is divided into nine main chapters: introduction, background, main objective and research questions, materials and methods, results, discussion, conclusions, bibliography and appendices. The chapter “Background” is divided in two main parts and it introduces the essential elements necessary to understand the section reporting the results and the discussion. The first part is devoted to a description of mountaineering and ski mountaineering, starting with their history, equipment, degrees of difficulty, risks, tourism aspect and environmental and social impact. The second part focuses on climate change, starting with an explanation of what it is and then delving into its effects on the mountain environment. In the second chapter “Main Objective and Research Questions” I first describe the reasons that motivated me to conduct this research, and I list the main questions that I wish to answer with this research. The chapter “Materials and Method” is divided into three main parts. The first one focuses on the introduction of the case study, a description of the Swiss territory and of the four main regions taken into consideration (Ticino, Valais, Bernese Oberland and Grisons), whilst the remaining two parts describe the methods and materials used to collect data, namely an online questionnaire and a semi-structured qualitative questionnaire. The section dedicated to the “results” is divided into two main parts. The first part analyses the 61 answers to the online questionnaire, and the second one -adopting a categorical and descriptive perspective- those to the semi-structured qualitative questionnaires. In the section dedicated to the “discussion”, which is organised in four subchapters -glacier retreat, permafrost thaw, snow cover and adaptation strategies-, the results are compared and supported by the existing scientific literature on the topic. The “conclusion” reports the most important results of the discussion, and suggests a reflection on what could be tackled differently. The paper ends with the complete “bibliography” and the “appendices”, which contain selected questions used for the interviews and an excel table showing the main data from the interviews.

2. Background

A mountain is a “landform that rises prominently out of its surroundings, usually with steep slopes, a relatively limited summit area and considerable local relief” (Apollo & Wengel, 2022). Their formation is often, but not always, the result of plate tectonics or the collision of different land masses, more precisely of continent-continent and continent-ocean collisions (Dewey & Burke, 1973). Five types of mountains have been distinguished: volcanic, fold, plateau, fault block and dome mountains (Goudie, 2004). Due to the inhospitable climate of mountains, mountain ranges were not colonised by humans in ancient times. In the mountains, compared to the plains, it is colder (-1° for every 300 m of altitude difference), it is more windy (air currents are intercepted by the mass of the mountain) and, as the air is colder, rain and snow precipitation are more frequent (Douglas, 2011)

Nevertheless, mountains are an essential resource for our planet and for human beings. For the 1.1. billion people living in the mountains, this particular landform supports their livelihood and well-being, and indirectly it benefits the billions of people living outside its are by fournishing tangible and intangible resources. (Apollo & Wengel, 2022). Mountains provide 60-80% of the world's freshwater resources and host 25% of the world's biodiversity (Palomo, 2017). Mountains are also home to 15% of the world's population, 90% of which is in developing countries, and host 15-20% of global tourism (Debarbieux et al., 2014). It is estimated that more than two billion people live in the surrounding of mountains and plains and that this number is set to increase (Meybeck et al., 2001).

Mountains are also a favourite place to practice sports. Depending on the time of year, various sports can be practiced in the mountains. On the one hand, ski touring, downhill skiing, snowboarding and snowshoeing are among the most popular sports practiced during the winter season in the mountains. They are practiced on snow-covered surfaces using gliding equipment, such as skis. In summer, on the other hand, the most popular sports include trekking, mountain biking and trail running, which take advantage of mountains’ slopes. Contrary to all these sports, mountaineering and climbing can be practiced all year round.

2.1. Mountaineering and Ski Mountaineering

2.1.1. Mountaineering

Mountaineering, also called “climbing” or “alpinism”, consists of a set of actions leading to the ascent to a peak. The term and meaning of mountaineering have changed over the decades, leading to its redefinition several times, and it is a sport that has evolved a great deal over the last two centuries since its inception.

2.1.1.1. History

From the Mountains to the Birth of Mountaineering

This chapter examines the relationship between mankind and mountain and explores how this bond has changed over the centuries and how it has led to the birth of mountaineering. Mountaineering developed mainly in the Mont Blanc region at the end of the 18th century and has evolved ever since technically, culturally and ideologically (Mourey et al., 2019).

Since the earliest times, mankind has been intrigued by mountains and what they conceal from the eyes of the larger population. From prehistoric times until the 18th century, according to myths and legends, mountains were inhabited by gods, monsters and supernatural and evil beings. Over the centuries, various local populations developed a culture of worship, adoration, respect and awe for the mountains as a result of these mysterious and supernatural characteristics associated with them (Apollo & Wengel, 2022). According to Greek culture, the gods lived on Mount Olympus, at 2 918 m, and therefore it was a place of veneration (Apollo & Wengel, 2022). In Asia, various mountains, including Mount Fuji and some Himalayan peaks are considered holy and sacred (Langdon, 2000; Macfarlane, 2009). In 1492, Charles VIII of France, ordered his chamberlain and military engineer to climb the mountain “mont Anguille” at a height of 2 087 m, once considered unattainable, with the aim of seeking divinity on top of it (History Cooperative, 2019). As late as 1600, Jacob Scheuchzer wrote a catalogue with all the dragon species that populated the Alps. These legends were born precisely with the aim of explaining and understanding natural phenomena occurring in the high mountains, such as blizzards and storms (Macfarlane, 2003).

Religions, through their beliefs, had a great influence on the relationship between mankind and mountain, leading to the construction of monasteries at high altitudes and to the increasing presence of pilgrims.

Christianity (which spread in the 1st century A.D.) was greatly influenced by the value that previous religions associated to mountains. As we can read in the book “Mountaineers. Great Tales of Bravery and Conquest”,”Christianity emerged from old religious traditions in which certain mountains were considered sacred. The new faith continued to treat mountains with reverence, seeing them as places close to God in which to receive extraordinary revelations. For Christianity, the mountain is a symbol of closeness and elevation to God, of purification and sanctification” (Douglas et al., 2011).

Many of the narratives told in the Old Testament also take place on mountains. In Genesis, it is told that Noah's ark stranded on Mount Ararat, a high mountain in Turkey. Also in Genesis, it is told that Abraham, having heard the word of God, is about to sacrifice his first-born son Isaac on top of a mountain. Another important reference concerns Mount Sinai in Egypt at 2 285 m (now called Mount Jebel Musa). It was at the foot of this mountain that Moses received the tablets with the Ten Commandments from God in 550 AD. Later, the monastery of St. Catherine was built on that site

(Douglas et al., 2011). Dante Alighieri, in his famous work "The Divine Comedy", uses the image of the insurmountable hill as a metaphor for the soul that tries to go from hell to heaven via the steep path of purgatory (Douglas et al., 2011). The summit is a symbol of the goal to God.

For the Buddhist religion, the ascent of an arduous mountain symbolically represents the elevation of the soul to the highest spheres until reaching Nirvana. Various peaks are venerated in Asia by this religion, such as Mount Fuji and Mount Kailas in Tibet, where several temples have been built (Douglas et al, 2011). For example, in 818, the Buddhist monk Kukai built a monastic hut on top of Mount Koya, a 1 000 m high peak. For Kukai, it was an ideal place of meditation and peace because “the mountains are high, the clouds pour much rain nourishing the vegetation and that water allows many species of fish and dragons to feed and multiply” (Douglas et al., 2011).

In general, however, with a few exceptions, mountains had a strong negative connotation until the 18th century. That is because the wilderness they belong to, was seen as infertile and hideous (Macfarlane, 2003).

Nevertheless, from the 18th century onwards this negative view on mountains started to change and people began to perceive mountains as something beautiful. Various elements helped driving away the idea that mountains were inhabited by dragons and witches, which gave rise to the connotation of the beauty of mountains: the development of the Enlightenment, the doctrine of natural theology, the interest in science (from a glaciological, cartographical and botanical level), the pleasure of risk, the secular pleasure in altitude, romanticism, and the birth of the spirit of adventure (Macfarlane, 2003).

The geological revolution played an important role. According to the Christian Orthodox view, the mountains had been created by God on the third day of creation and had not changed since then. Thomas Burnet's theory (1681) brought to light that the surface of the globe had changed over the centuries and was therefore an “immense ruin”. From the smooth surface of the Earth, mountains, oceans, and so on were created over the years. This new perception of the Earth led to a great focus on science and Earth history. Mountains gained in interest and fascination and looking at mountains meant looking at the past for the first time and how it was created (Macfarlane, 2003).

Although the idea of risk has always existed in human history, its meaning has been changing since the 18th century. Whereas before it was accepted in the name of another end such as scientific development, personal glory, economic gain, from the 18th century risk is sought as an end in itself, for the pure pleasure of fear in and of itself, without taking on secondary ends. As David Harley wrote in 1749, at the sight of an element such as a precipice, a waterfall, they provoke feelings of fear and dismay that go on to exalt all the other emotions felt until they are transformed into an emotion of pleasure at the sight of these elements.

Over time, the idea of reaching a peak and getting to the top of a mountain became a symbol of success and achievement. Just think of the dual meaning of “to peak”. On

the one hand it means to make it to the summit, whilst on the other hand it means to reach the pinnacle of a challenge.

The peak also took on a meaning of sensory experience: the awe, admiration and emotions one feels in front of a panorama of the alpine landscape. This is an element of novelty if one considers that up until the 1700s, those who crossed the mountains had their eyes covered so as not to be frightened by the sight of ravines and precipices.

If before, the summit and the ascent to the heights were purely a spiritual sentiment linked to religion and a metaphor for getting closer to God, in the 1700s we witness a secular sentiment of altitude, the height to find pleasure and excitement in itself, without any other purpose. We see a feeling of veneration for the summit from the 1700s onwards, reaching its peak in the early 1800s.

Romanticism, which developed in the late 18th century, led to an appreciation of the mountains, to which the idea of the sublime ("the grandiose spectacle that generates fear and dismay but, at the same time, pleasure") was associated. Among the great figures who carried forward this idea of the beauty of the mountains was Johann Von Goethe. In his book “Sturm und drang”, written following one of his trips to Switzerland, he speaks of the beauty and sublimity of the winter landscape. Various artists and writers sought out the mountains at that time (Varotti, 2021; Douglas et al., 2011).

From the end of the 1700s, people in Western culture began to appreciate and to be attracted to the unknown, and thus to discovery as an end in itself. There was a spreading yearning to find the unexpected, the unknown, the beauty and novelty of unexplored places. And as Baudelaire said, “Au fond de l'inconnu pour trouver du nouveau” ("in the depths of the unknown to find something new”). The mountains, due to their proximity and ease of access, offered a valid alternative to those who wanted to go into the unknown but had neither the time nor the means to leave and discover distant and unknown lands.

The Birth of Mountaineering

According to Apollo & Wengel (2022) there are six stages to be discerned that brought mountaineering to be what it’s today:

1. Pre-mountaineering: Before 1786
2. Early mountaineering: 1786-1864
3. Classic mountaineering: 1864-1899
4. Modern mountaineering: 1900-1964
5. Contemporary mountaineering:1964-2021
6. Commercial mass mountaineering: 2021 onwards

Pre-Mountaineering: Before 1786

This period is characterized by the first interactions between mankind and mountain that lasted until the ascent of Mont Blanc in 1786. The birth of alpinism is attributed to Horace Bénédict de Saussure, a young scientist from Geneva. Horance Charmonix was deeply impressed by the majesty of Mont Blanc during one of his visits to the area

and decided that he wanted to make measurements of temperature and pressure at high altitude (Luperini, n.d.). Saussure decided to offer a monetary reward to whoever would succeed in climbing its 4 807 m in height. It was Michel-Gabriel Paccard who fulfilled his dream in 1786 (Guest Contribution, 2019; Apollo & Wengel, 2022).

Early Mountaineering: 1786-1864

The “Golden Age” of mountaineering, lasting from 1855 to 1865, was the period where most of the Alps peaks have been scaled. The peaks were reached by the easiest and most accessible routes. From 1800 to 1870, all the main Alpine peaks were climbed. Among the various major ascents there are: Mont Blanc in 1789, Ortles in 1804, the Jungfrau in 1811, Pelvouy in 1828, Finsteraarhorn in 1829, the Bernina in 1829, the Gnifetti peak in 1842, Marmolada in 1864, the Matterhorn in 1865, etc. (Apollo & Wengel, 2022). Regarding the latter, the first person to attempt to climb the Matterhorn was Jonathan Carré in 1856. It is said that Carré, after reaching the summit, descended from the summit, carried his clients to safety and, exhausted by fatigue, died just below the summit. After several attempts from 1857 to 1865, on the 14th of July 1865 the Matterhorn, with its 4 478 m height, was climbed by Edward Whymper from the Swiss side (Matterhorn Documentary)

At this time, climbing mountains was primarily an activity reserved for the English aristocratic elite. By 1850, the English and German elite (young people from good families making the Grand Tour of Europe) together with Swiss, Italian and French guides climbed all the Swiss peaks. This phenomenon led to the development of alpine tourism, the writing of the alpine guide and the creation of alpine clubs (Apollo & Wengel, 2022).

Classic mountaineering: 1864-1899

This period witnessed a high development of mountaineering, mostly in Europe. From 1879, people began to look for more challenging and difficult routes to climb previously conquered peaks (Hansen, 2013). This led to a growth in the sporting character of mountaineering. First ascents were also made by climbers without a guide (Apollo & Wengel, 2022).

Modern Mountaineering: 1900-1964

From the end of the 1800s, non-European explorations began with the Andes Mountains of South America, the North American Rocky Mountains, the Caucasus at the western edge of Asia, Africa's peaks, and finally the vastness of the Himalayas. In the 20th century, everyone wants to climb the Himalayan mountains (Kiesinger, 2020; Apollo & Wengel, 2022). In 1907, a British expedition reached the summit of Mount Trisul I at 7 120 m in 1950, a French expedition with Maurice Herzog and Louis Lachenal climbed the summit of Annapurna (8 091 m). In 1953, the Mount Everest, the highest mountain in the world at (8848 m), was reached by a British expedition consisting of John Hunt, New Zealander Edmund Hillary, and Sherpa Tenzing Norgay. In 1954, a team of Italian mountaineers conquered K2. This period experienced a

break in mountaineering during the 1st and 2nd World Wars and lasted until all the 8 000 m peaks had been climbed.

The 20th century brought big technical evolutions. Thanks to the creation of new tools and materials, mountains with increased technical difficulty were climbed and grades of difficulty increased up to V/VI on the UIAA classification scale. The official birth of grade VI is due to Solleder and Lettenbauer, who climbed the North West Face of the Civetta (1925). Reinhold Messner christened the grade VII with the ascent of the Mezzo Pillar of Sass della Crusca in 1968 (Apollo & Wengel, 2022).

Contemporary Mountaineering: 1964-2021

This period lasted until the last 8 000 m had been climbed in wintertime. In the world there are 14 mountains higher than 8 000 m, also known as the eight-thousands, distributed between Himalayas and Karakoram. Two of the most important feats took place during this period. The first was in 1980, when Reinhold Messner was the first to climb the Mount Everest without oxygen cylinders (Douglas et al, 2011). The second was in 1985, when Richard Bass first conquered all the highest peaks of the seven continents, the 'Seven Summits'.

This period is characterized by a huge popularization of mountaineering in the press and media and the creation of so-called peak-bagging challenges, such as the Seven Summits for example (Chu et al., 2018; Lew & Han, 2015). Mount Everest is no longer seen as an extreme and unreachable peak. With the development of commercial Everest expeditions, anyone with basic mountaineering experience can climb Mount Everest, leading to the development of mass mountaineering.

In 2019, mountaineering was inscribed on the UNESCO Representative List of the Intangible Cultural Heritage of Humanity. There are several aspects that allowed mountaineering to enter this list. First and foremost, the traditional and cultural aspect of the sport. In addition, knowledge of the natural environment in which mountaineering is practised, the weather elements and natural hazards. Another essential element is the importance of aesthetics between the mountaineer's movements in harmony with its environment (Unesco, n.d.).

Commercial Mass mountaineering: 2021 Onwards

For two hundred years, mountaineering was a sport practised only by the elite, but with the development of interest in the mountain area and improved accessibility to mountaineering background and stakeholders, such as the International Climbing and Mountaineering Federation (Apollo, 2017), today virtually everyone can practice mountaineering in the mountains.

2.1.1.2. What is mountaineering

Mountaineering refers to high mountain climbing, which ranges from high mountain hiking to alpinism. Over the years, it has undergone specialisation and today mountaineering consists of 3 main activities (Apollo, 2021): hiking, trekking and climbing (Apollo & Wengel, 2022). Hiking is the fundamental element of mountain

climbing and consists of putting one foot after the other on well-prepared routes. In hiking, one does not use one's hands to overcome obstacles, but only one's legs. Participants are exposed to subjective and objective dangers (Kiesinger, 2020; Apollo & Wengel, 2022). The term trekking refers to a middle way between hiking and climbing. Unlike hiking, it involves the occasional use of the hands to overcome obstacles. Trekking usually takes place in alpine terrain without any tourist infrastructure (ladders, ropes, etc.) (Apollo & Wengel, 2022). Climbing is the most dangerous and demanding of the three activities. It is practised in high mountains, above the forest line. The use of hands and legs during the activity is essential to overcome obstacles (Apollo & Wengel, 2022). Mountaineering techniques vary depending on various factors such as location, season, terrain (earth, rock, snow or ice) and the route chosen (Kiesinger, 2020).

Climbing consists of various disciplines that can be practiced both indoors and outdoors (Gatterer et al., 2019; Aubel et al., 2021). Mountain climbing consists of climbing at high altitude and low ice exposure, protective equipment must be placed by climbers (if not already present). *Traditional/alpine climbing* is practiced at low and moderate altitudes and on several pitches (multi-pitch). *Sport climbing* is made outdoors and consists of rope climbing, top rope and bouldering. *Indoor climbing* is like sport climbing, but on artificial walls. Finally, *ice climbing* is done on ice formations, such as frozen waterfalls and ice-covered mountain walls, with the help of crampons and ice axes. For the Olympic Games in Tokyo (2020), climbing was entered as on official sport. This consists of progression, speed and bouldering. Depending on the type of terrain, climbing season and climbing techniques, different types of climbing can be discerned.

Type of Terrain

Based on the type of terrain, different types of climbing can be distinguished. The first type is *Rock climbing* which according to Apollo & Wengel (2022) means "moving in rocky terrain not covered with ice or snow". The safety elements are the rope, the artificial anchor and the carabiner. They are used discreetly and are not used as handholds for climbers. *Rock climbing* requires good use of the hands for balance, and of the feet for support. An upright position allows the climber to observe the holds he or she needs for subsequent holds. There are always three points of contact on the rock depending on the situation, they can be 2 hands and a foot or 2 feet and a hand. The descent is done by abseiling, i.e. one person belays from above by lowering the partner slowly (Kiesinger, 2020). Secondly there is *Ice Climbing* which refers to "moving (climbing) in an area covered with ice and fern - steep snow corners, icefalls (frozen waterfalls), and various icicle formations, for example" (Apollo & Wengel, 2022). *Snow Climbing* involves moving (climbing) in glacier mountains and engaging in mountaineering during the winter season (Apollo & Wengel, 2022). The last type is *Mixed Climbing*, which is a climbing style that requires the use of both rock and ice techniques (Eng, 2010; Hattingh, 2000).

Season

it is important to distinguish between summer mountaineering and winter mountaineering. The summer season is preferred by most mountaineers, because the weather and snow conditions are better for mountaineering activities. Compared to the summer season, winter mountaineering is more challenging and requires a considerable physical and mental effort and a bigger need of technical knowledge (Apollo & Wengel, 2022).

Technique

Traditional climbing involves climbing only using natural holds and the additional climbing equipment is only for the climber's safety. Climbing with supplementary tools involves the use of artificial facilities to climb and move around more easily and thus not only for safety reasons (Eng, 2014; Hattingh, 2000). An example is the use of oxygen cylinders for high mountain climbing (Apollo & Wengel, 2022).

2.1.2. Ski Mountaineering

Ski mountaineering, also called “skimo”, is a winter sport that involves climbing mountains with skis on one's feet, or carrying them on the way up and wearing them on the way down. Skimo can be seen as a combination of ski mountaineering, Telemark, cross-country skiing and mountaineering (Volken et al., 2007). The fundamental characteristics of this sport are: the endurance exercise associated with ascents, the thrill of descents on largely unprepared slopes (“off-piste” skiing) and the spectacular closeness to nature (Bortolan, 2021). Ski mountaineering is a sport that is becoming increasingly popular, both for simple creative purposes and in a more competitive manner. While it was once practised only by specialists, with the development of modern equipment, wealth and the idea of using one's quality leisure time with healthy, ski mountaineering has been discovered and increasingly practiced by the masses (Branigan & Jenns, 2013, p. 38). Today, skimo can be a competitive or recreational sport. According to the official website of the Olympics, "competitors ski uphill and downhill and use mountaineering skills to compete in the snowy mountains” (Olympics, n.d.).

2.1.2.1. History

Based on drawings found on the Scandinavian peninsula, it is believed that cavemen used something of similar shape to the modern skis to gather food and hunt as early as 7 000 thousand years ago. One of the oldest skis that has been found dates back 4 500 years and was discovered in Sweden (Dawson, 1997). For a long time, skis were very rudimentary objects, consisting of simple pieces of wood tied around the tip of the boot where animal skins were placed under the ski to enable people to walk uphill on snow. They were used by the Scandinavian people for fun, to hunt, to move around and as a means of military travel. It is said that in 1564, the Swedish army had an army of 4 000 skiers to fight the war against Denmark (Luperini,

n.d.). From 1880 onwards, skiing spread as a sport mainly practised by wealthy citizens purely for fun (Luperini, n.d.). The following years saw a second conquest of the Alps, this time on skis. In 1888, the Norwegian explorer, intellectual and scientist Fridtjof Nansen made the first east-west crossing of South Greenland, covering around 500 km in 40 days. The book he wrote describing his journey was translated into several languages and triggered interest in skiing. Ski mountaineering begin with an expedition in the Swiss Alps with the ascent of the Pragel Pass in Glarus in 1893 and was organised by the Swiss Christoph Iselin and the German Wilhelm Paulcke (Ski-si-snowboard, 2014). In 1886, the first ski ascent of the Oberalpstock (at 3 330 m) took place, followed by the crossing of the Oberland in 1897, the Monte Rosa at 4 200 m in 1898, etc. (Luperini, n.d.). Marcel Kurz, a Swiss engineer, cartographer and mountaineer born in 1887, was the first to use skis in the Alps and to describe the technique of ski mountaineering and ski tours. Luis Trenker (1892-1990), born in Ortisei, was the first to obtain a licence as an alpine guide and ski instructor. Ski Mountaineering spread especially during the 1st World War in Romania thanks to the establishment of schools and specialised military troops to fight in the mountains. "Ski-mountaineering combines a range of techniques that will actively contribute to the formation of capable soldiers to overcome the limits imposed by the alpine and arctic environment, motivating them to reach the top regardless of its physiognomy" (Martinescu-Badalan et Stanciulescu, 2019). From 1930 there is a diversification of skiing into various disciplines such as cross-country skiing, ski touring, Nordic skiing, (Bortolan, 2021) which are still practised today. Moreover, for the first time ever, in 2026 ski mountaineering will be included in the Winter Olympics to be held in Milan-Cortina (Bortolan, 2021; Luperini, n.d).

2.1.3. The Figure of the Mountain Guide

Today there are more than 6 000 official mountain guides. A mountain guide is an experienced mountaineer certified by local authorities or mountain guide associations. Among other competences, a guide must have basic knowledge of the terrain (on a historical, morphological and biological level), know how to accompany clients by giving them motivation, have technical knowledge during the hike and be able to keep clients safe throughout the hike minimizing risks (IFMGA, n.d.)

One of the main factors that contributed to the development of the appreciation of the mountains was the appearance of the guide. it is precisely at the time that the exploration of mountains and glaciers started to plummet, the role and importance of mountain guides became more and more appreciated. Wealthy English aristocrats were accompanied by locals to discover the unexplored mountains. A mutualistic relationship developed, in which the tourists could get to difficult places and the villagers could increase their income and financial situation. The ascent of the summit of Mont Blanc in 1786 encouraged the development of alpine tourism in the Chamonix area. In the 19th century there were between two and three thousand tourists annually. The increase in alpine tourism led to the creation in 1821 of the Compagnie des Guides de Chamonix, the first association of alpine guides in the world. After a series of

accidents, a more professional approach to mountain guiding was introduced in 1850 through the institution of stricter rules. However, the guides did this work in their spare time in addition to their main job and their technical and practical knowledge was limited (Summitpost, n.d.)

From 1850 onwards, there was an occupation of British mountaineers in the Alps. They were by far the most technically proficient and conquered all the unexplored mountains. Between 1854 and 1 865, they climbed 31 4000 m peaks for the first time. Mountain guides who accompanied the English on difficult and demanding climbs learnt from them and greatly improved mountaineering skills. The British created the Alpine club in 1857, which was an exemplary model for the Alpine clubs that were founded in the following years. The various mountaineering associations that were founded in the Alps in the following years took care of the technical and physical training of mountain guides (increased quality of the guiding profession), worked with an official certification system, created rules of conduct for guides and clients and insurance for guides. The creation of the British Alpine club made mountaineering

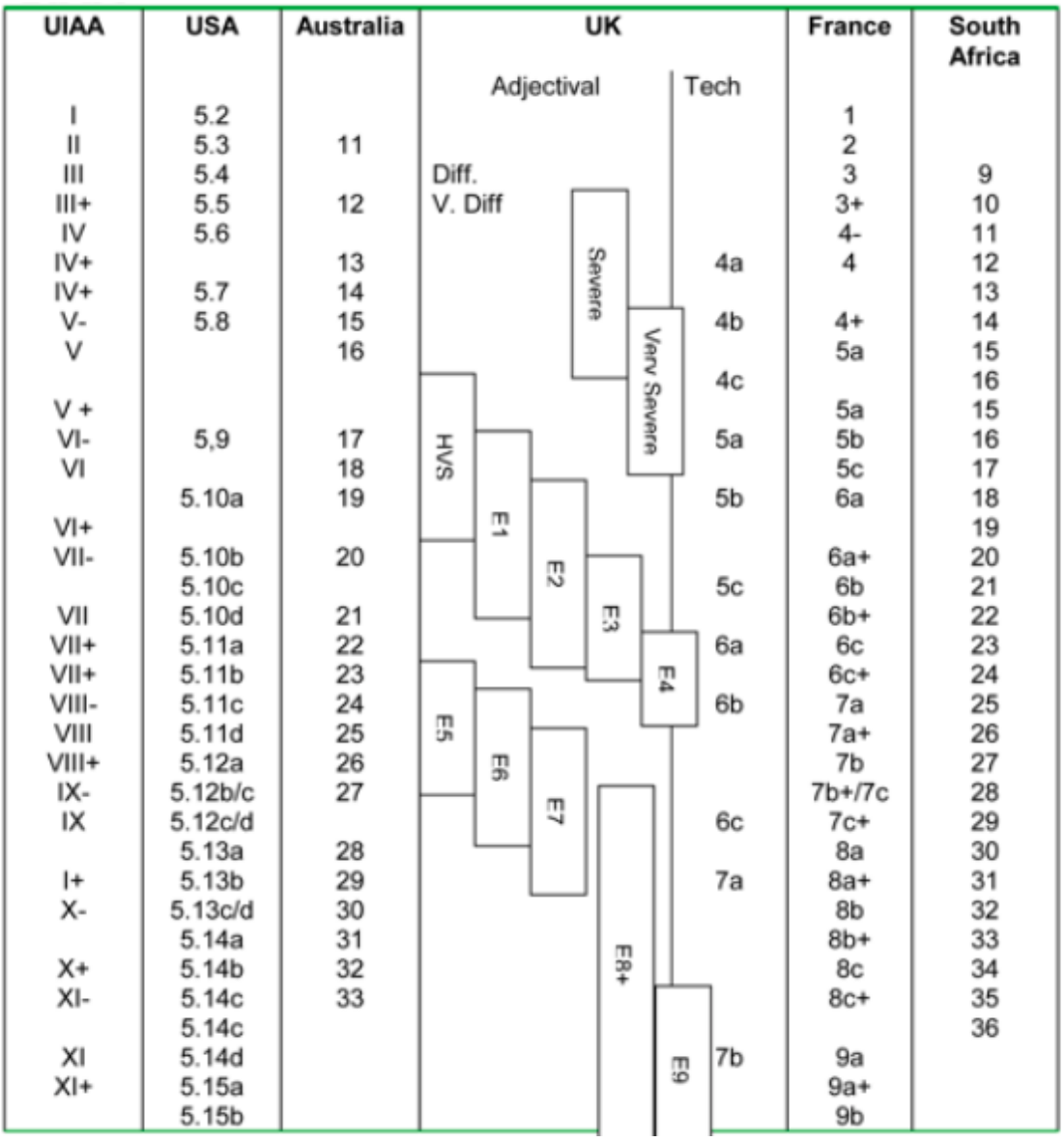

Figure1: various scales to classify mountaineering and climbing (UIAA, 2008)

known to the rest of the world. The members of the club were talented writers who published books and articles on mountaineering in the following years. This caused the number of tourists to rise from 1 500 in 1 830 to 12 000 in 1865. Tourism in the Alps increased rapidly and so did the number of mountain guides. In Chamonix, the number of guides rose from 46 in 1821, to 156 in 1845, to 298 in 1898.

There are three important elements that changed the work of mountain guides at the end of the 19th century: 1) the increasing number of climbers without a guide, 2) the number of long engagements decreased sharply compared to the Golden Age when nobles hired one or more mountain guides for long periods of time, and 3) the start of ski mountaineering, which meant that mountain guides could work all year round.

2.1.4. Grades

Various grades have been created to classify the technical difficulties of mountaineering trails. This allows the hiker to choose a route that will be feasible according to his knowledge and limitations and thus reduce possible dangers. There are scales for each activity practiced in the mountains: via ferrata, rock climbing (classic), bouldering, ice, snow or mixed climbing, hook climbing, rafting on mountain rivers, downhill skiing, etc. Each discipline is classified differently: with adjectives, letters, numbers or a mix of numbers and letters. A single discipline can be classified by several scales (Figure 1). For all scales, the rule applies that the first element (like I for UIAA scale) equals the easiest level and the last element the most difficult. Above UIAA Grade I, it's required to have proper climbing preparation and specialist equipment (Radwańska-Paryska & Paryski, 1995). However, in recent years, in some cases even for the higher grades, artificial elements such as ladders and ropes have been added, which allow even those without special equipment to do the route. It is important to know that the difficulty rating of any route is subject to and influenced by other factors such as weather conditions and equipment. If, during an excursion, the weather conditions are poor and the climbing equipment of low quality, the trip will be more complicated and demanding than expected.

The classification of ice and snow trails is more complex. This is because snow and ice conditions change constantly, from season to season but also within 24 hours. On a very warm day, the ice may melt, leading to an increase in difficulty. The difficulties are defined based on the complications of climbing, the thickness of the ice, and the elements of its sculpture in the form of icicles, cauliflowers, and slings (Eng, 2010).

2.1.5. Risk and Safety

Mountaineering and ski mountaineering are sports with a high degree of risk. These risks are caused by various factors (Table 1). Depending on the decisions made by the mountaineer, the risks can be limited, but never completely avoided. In the mountains, the dangers are of two types: subjective and objective. The two cannot always be distinguished in a clear and easy way (orthvox, n.d.).

Table 1: Main causes and risk factors in different mountain sports activities (adapted from Gatterer et al, 2019)

Mountain sports activity	Main causes	Main risk factors
Mountain hiking	Non-traumatic (mostly cardiac death) Trauma-related death (falls)	Male sex Higher age Pre-existing diseases Insufficient physcial fitness Inappropriate equipment
Mountain biking	Trauma-related death (falls, crashes) Non-traumatic (mostly cardiac death)	Lack of familiarity with the terrain Lack of skill Risky behavior Pre-existing diseases
Paragliding	Trauma-related death (falls) Non-traumatic (mostly cardiac death)	Collapse of the paraglider Incorrect use of break lines Strong wind Lack of skill
Trekking	Trauma-related death (falls) Non-traumatic (mostly cardiac death)	Higher age Pre-existing diseases High-altitude illness Insufficient physical fitness
Mountain, rock and ice climbing	Trauma-related death (falls, rock/ice fall) Avalanche burial Non-traumatic (mostly cardiac death)	Lack of skill Insufficient physical fitness Inappropriate equipment
High-altitude climbing	Trauma-related death (falls, rock/ice fall) Hypothermia Avalanche burial High-altitude illness	Exposure Lack of skill Insufficient physical fitness Inappropriate equipment Pre-existing disease

Subjective: subjective dangers are caused by human beings themselves, also called human error. Self-reflection, caution and training can help minimize the danger slice (Apollo & Wengel, 2022). The main types of subjective errors are overestimation of one's own abilities, misjudgement of situations, fear and panic situations. Subjective risks are influenced by three main factors. The first one is the experience, frequency of participation and commitment of the mountaineer, the second is his or her the perception of risky environmental conditions, and the third the individual trade-off between risk and information, the desired experience and other constraints, such as time management or weather conditions (orthvox, n.d.).

Objective: "Objective risk is the absolute form of uncertainty, which is linked to the impossibility of predicting the development of certain phenomena such as earthquakes or floods" (Apollo & Wengel, 2022). Objective risk refers to hazards posed by nature and the natural environment such as weather conditions that change very rapidly and unpredictably, falling rocks and ice, avalanches, etc. (Orthvox, n.d.).

In the mountains, the probability and intensity of encountering accidents increases. The mountaineer has no influence on it, however, the risk can be reduced by making the right decision, observing the weather and environment, and climbing with the appropriate equipment. Proper preparation, planning and performance, and safety measures are key elements in reducing the probability of risk (Beedie, 2003). In the event of hazards, four are the fundamental elements for mountain climbers to consider

in order to reduce the impact of the disaster (Ziegler et al., 2021). First of all there is *preparedness*, and therefore the readiness to take action in case of any emergency situation. Then there is *mitigation*, which stands for minimizing the likelihood of the development of the disaster. This is followed by the third element, which is *response* in the event of an accident and casualties, namely the ability to act as quickly as possible to assist the injured. And finally there is *recovery*, i.e. the ability to recover from an accident (Apollo & Wengel, 2022). However, there is no such thing as zero risk in the mountains. “Those who engage in alpine climbing accept the fact that they might die in the process” (National Geographic, 2011).

Summer Mountain Sports and Summer Risk

According to Gatterer et al. (2019), the mortality risk varies greatly depending on the type of mountain sport practiced. For those practiced in the summer season, such as hiking, trekking and mountain biking, the mortality rate is lower than for paragliding, rock and ice climbing and especially those practiced in high mountains, i.e. mountaineering. For rock, ice and mountain climbing, deaths are mainly caused by falling rocks, falling roped up, hitting rock/ice, broken holds, avalanches, falling into crevasses and sudden climatic changes. Deaths occur as a result of head injuries, avalanche burials, hypothermia and sudden cardiac arrest.

The higher the altitude, the greater the probability of death. Of all deaths in the Austrian Alps, 6.6% occurred during rock and ice climbing. However, over the past 25 years, the number of accidents in the Austrian Alps has decreased considerably. For climbing at higher altitudes (i.e. above 5 500 m), the probability of death is considerably higher. Mortality rates are 0.03%, meaning 3 deaths per 10 000 climbers, for the Kilimanjaro. This figure increases to 4%, meaning 40 deaths per 1 000 climbers, for the Annapurna. Among the most common causes are falls, high-altitude illness, hypothermia, and sudden cardiac death (Gatterer et al., 2019). Between 2001 and 2012, 42 731 climbers have tried to climb the summit of Aconcagua, at 6 961 m in the Andes mountain range. 33 (0.08%) of them died due to falls (24%), high-altitude illness (21%), hypothermia (15%), sudden cardiac death (12%) and other causes (28%) (Westensee et al., 2013).

For peaks higher than 8 000 m, death risk increases even more. This is due to the fact that rescue interventions are more difficult and may not arrive in time. The mortality rate is 0.64% for Cho Oyu (8 188 m), 1.56% for Mount Everest (8 848 m) and 4.5% for Annapurna I (8 091 m), which is considered the most dangerous mountains on Earth. Most alpinists died on the Mount Everest, since this is the most frequently climbed mountain (Amstrong, 2021). Nonetheless, mortality rates have decreased in the last decades, probably thanks to a selection of low-risk 8 000 m mountains, improvement of logistics services, acclimatization strategy and medical support, modern equipment and a better weather forecast (Gatterer et al., 2019).

Winter Mountain Sports Risks

According to the writer Winkler, out of 100 000 persons who participate in mountain sports in winter, 7.4 persons die. This is equivalent to one and a half times the risk of having a fatal car accident in one year. Avalanches are the leading cause of death. It has also been observed that men have a 3.5 times higher risk than women, ski mountaineers have a risk 6 times higher compared to people who go with snowshoes (Winkler, 2018). The main causes of death in winter mountain sport (2018) are avalanches (66%) and falls (25%). Falls are more dangerous in case of hard and slippery soil, if there are crevasses and rock walls, and if there are obstacles like trees and stones. Other causes include falling into the crevasses of unstrung people, storm, cold, crossing (stuck to the wall with no possibility of climbing up and down), and exhaustion, frames breaking, seracs and selective strikes.

Avalanches

Depending on the type of snow, various types of avalanches have been identified. There are slab avalanches, which are the cause of 90% of all deaths, cohesionless snow avalanches, respiration avalanches and ice avalanches. The occurrence of avalanches is influenced by wind, fresh snow, snowpack, slope inclination, exposure, altitude and shape of the land (Winkler, 2018). Since 1936, there have been 24 fatalities per year in Switzerland. 90% of these occurred off-piste and most of them were in the Valais and Graubünden (SLF, n.d.).

2.1.6. Altitude Adaptation Problems

In addition to the risks associated with the natural environment of mountains, there are a vast number of physiological problems related to the adaptation of the body to the conditions of the mountain environment. The severity of these problems depends on the type of mountain where a person is situated. Three distinct mountain types have been defined (Gallagher & Hackett, 2004; Wilson et al., 2009). High altitude mountains (altitude between 1 500 and 3 500 m), very high altitude mountains (between 3 500 and 5 500 m) and extremely high altitude mountains (above 5500 m).

The probability of developing acute altitude-related diseases and thus of suffering functional damage increases exponentially with altitude above 2 500 m (Luks et al., 2010). However, these can be limited by the body's adaptation and acclimatisation mechanisms (Kiełkowska & Kiełkowski, 2013).

According to Kowalewski and Kurczab (1983), the harmful factors affecting the human body at altitude are the reduction in atmospheric pressure and the consequent decrease (with increasing altitude) in the partial pressure of oxygen. This can lead to chronic hypoxia, i.e. a "condition in which the body or a region of the body is deprived of adequate oxygen supply at the tissue level" (Apollo & Wengel, 2022). This leads to a deterioration that manifests itself in lack of appetite, weight loss, loss of sleep quality, lowered mood, etc..

Above 5 500 m, i.e. at extremely high altitudes, inhaled oxygen pressure drops by 50% compared to sea level and on Mount Everest it can drop by up to 70%. This makes it impossible to live at an altitude above 5 500 m (without oxygen cylinders) and only a short stay is possible (Gatterer et al., 2019). Besides, there is a decrease in air humidity air temperature, which can also be harmful to the human body. In high mountains, temperature decreases with 6.5 ° C per km of altitude difference. In addition, weather conditions can change very suddenly, often within a few hours (Gatterer et al., 2019). Finally, increased radiation at high altitudes leads to sunburns or sunstrokes. These four factors can be further influenced by dehydration, hunger and fatigue.

The most common altitude-related diseases include acute altitude sickness, altitude lung oedema, altitude brain oedema, altitude peripheral oedema, fluid in the alveoli and retinal haemorrhage. Moreover, extreme climate factors like snowstorms can cause frostbite, hypothermia or blindness and an overstated sun exposure at high altitude can cause heat exhaustion, sunstroke, and sunburns. Acclimatization consists of an adaptation on a physiological and morphological level, a fundamental process that must be performed every time one is in the high mountains (Szymczak, 2009). Following physical exertion, an automatic response to increased gas exchange in the body occurs in high mountains. This response consists of intensified lung ventilation, accelerated heart rate and increased blood pressure. Acclimatization increases the pressure in the pulmonary blood vessels, which means that blood enters the parts of the lungs that are usually not used at low altitude (West et al., 2012). This process varies from person to person. Some adapt faster than others. The body spends a lot of energy adapting to the low oxygen pressure in high mountains. This leads to an average weight loss of 0.5-1.5 kg in one week (at an altitude of 5,800m; see Pugh, 1962). However, if acclimatization is not carried out correctly, it can lead to chronic hypoxia. Above an altitude of 5 300 m the limit at which complete acclimatization can take place is reached, after which a “partial” acclimatization takes place (Kowalewski & Kurczab, 1983). Unfortunately, knowledge about how to practice the right acclimatization is still very undervalued and overlooked. Very frequently, acclimatization is done incorrectly, climbing too quickly and not resting enough. In general, the following rules for proper acclimatization are advised (Apollo & Wengel, 2022). Above 3 000 m, do not climb more than 3003 m of altitude difference per day and stay in one place at the same altitude for 2/3 days. These preventative measures lead to a much longer trip. With proper acclimatization, to climb an 8 000 m the trip can take up to 2 months (Apollo & Wengel, 2022).

2.1.7. Tourism

More and more people are going to the mountains (Marek & Wieczorek, 2015; Nepal, 2000; Zurick, 1992) and it is in fact one of the fastest growing leisure activities worldwide. We are now in an era of commodification of high-mountain-climbing tourism, a tourism present at every level of the sport in the mountains, from trekking to hiking and climbing (Mountaineering Tourism). According to UNEP (United Nations

Environment Programme) and ICIMOD (International Centre for Integrated Mountain Development), approximately 120 to 170 million people are visiting mountain regions around the world each year, taking up 15 to 20% of the global tourism market, and their number is still growing. In America alone, 10 million people practice mountaineering and hiking. More than six thousand official mountain guides are leading many of these people on the mountains. However, it is impossible to ascertain the exact number of people mountaineering, ski touring, hiking, etc. The sale of products and services related to outdoor activities reaches an annual turnover of USD 10 billion (Macfarlane, 2003). According to Apollo (2014), the swelling number of people going to the mountains is related to three main reasons: the increase in the level of physical skills of people in high-altitude-climbing tourism, the evolution of mountaineering techniques including climbing equipment, acclimatization, belaying, and climbing style, and the accessibility due to commercialisation (commodification) of high-mountain-climbing tourism and the popularity of bucket lists (i.e. a list of unmissable experiences to live before death) (Thurnell-Read, 2017).

With the process of commodification and commercialisation of mountain activities, mountaineering and ski mountaineering have undergone a mutation from an “elite sports activity” to “mass tourism” in recent years (Beedie & Hudson, 2003; Johnston & Edwards, 1994). However, more and more people nowadays venture into “challenging” climbs without sufficient experience and knowledge in this regard (Elmes & Barry, 1999; Messerli & Ives, 1997; Mu et al., 2019). Alpine tourism is a sub-category of that comprising mountain tourism, a tourism activity in a mountain environment (Apollo & Wengel, 2022). There are various reasons why people venture into mountain activities. Ewert (1985) concluded that those with a higher professional level are motivated to go into the mountains for reasons mainly related to thrill, personal challenge and control, while the inexperienced ones are motivated by recognition and socialization. In broad terms, mountaineering tourists can be divided into two categories based on the motivations and aims that drive them to go into the mountains. One category is referred to as the “Adventurers”, namely those who go for adventure-related motives, in search of strong emotions and sensations. Several are the motivations related to the self for participating in mountaineering, and among these one can count seeking contact with a better self, the assertion or conquest of the self or even the escape from it, and the goal of enhancing a sense of integration (Lester, 2004). The second category refers to pilgrims who go to the countryside for spiritual/religious reasons. They trek and hike to reach holy places and do not engage in overly dangerous adventures such as climbing. Pilgrims, for example, aim at apologizing for sins or at praying and getting closer to the religious deity (e.g. see Barber, 1993). Pilgrimages are the oldest form of tourism. Already the Greeks paid homage to the gods on Mount Olympus and so did the Incas on the peaks of the Andes (Gawlik et al., 2021; Shinde & Olsen, 2020). Today, among the most frequently visited mountains for religious myths are the Kailash in China, the Kii mountains and Mount Fuji in Japan, Mount Sinai in Egypt, etc. The behaviour of pilgrims depends very much on their religion and cultural background.

Apollo and Wengel (2022) identified three types of contemporary mountaineers. The first type is *True mountaineers* and refers to mountaineers who are interested in exploring challenging, off-the-beaten-path mountain destinations. They have the same technical knowledge as professional and elite mountaineers, and they organize their trips independently being also able to lead a small group of friends and spend a long time in mountain destinations. *True Mountaineers* are familiar with the mountaineering environment, technical equipment, trails, weather conditions, etc., and they are ready in case of emergency and able to face potentially life-threatening challenges. The second type is *Recreational mountaineer*, and it refers to "semi-professional mountaineers who occasionally climb in high-altitude environments for recreational purposes" (mountaineering tourism). They have good technical knowledge and are willing to improve their knowledge in this regard, they are able to prepare their own trips independently, but unlike the *True Mountaineers*, they are not able to lead a group. They are ready to respond in case of challenging and emergency situations and their expeditions are often organized by mountaineering clubs or their more experienced peers. Finally, the third type are the *Novice Mountaineers*. Often, *novice mountaineers* visit high-altitude mountain environments just once to experience the "adventure of a lifetime". Of the three categories, they are those with the least mountaineering experience and knowledge. They rely on (commercial) expedition companies and guides to go into the high mountains. The increase in this category in recent years is leading to an increase in demand for commodified mountaineering adventures. They often have limited time to complete their mountain adventures, even if short expedition times, without extra days in case of bad weather or emergencies, can lead to dangerous situations.

Mountaineering and ski touring are considered "transformational tourism". This term was coined by Willig in 2008 referring to extreme sports that "provide a physical challenge, a therapeutic experience, psychological balance and facilitate opportunities to test, play and possibly transcend the boundaries of the self". Elements present in mountaineering such as physical and mental challenges, stepping outside one's comfort zone and usual routine, has a great influence on personal growth and development (Harper and Webster, 2017). This was clearly articulated by Apollo & Wengel (2022) when they wrote that "mountaineering impacts the personality and allows us to learn about self, life, and the world around us and enhance our ability to adapt and grow".

Mountaineering, unlike other sports, has no formal, official rules or regulations. Instead, it is governed by philosophies, ethics and techniques that have never been formalised (Hoibian, 2016) and that take into account safety, equipment and techniques. In recent years, the mountaineering community has also developed a great sense of concern about the impact of mountaineering on the environment and mountain communities. Two codes have been written regarding the ethics of mountaineering, namely 'The Code of High Mountain Tourism', which was written in 1937, and "The UIAA Mountain Ethics Declaration", written by the International Mountaineering and Climbing Federation at the General Assembly of the Union Internationale des Associations d'Alpinisme (UIAA) in 2009.

2.1.8. Environmental and Social Consequences

Positive Consequences

The development of mountaineering produced both positive and negative consequences for our planet and our society. Focusing on the positive ones first, mountaineering has facilitated the economic, infrastructural, transport and connection development of many mountain regions in the world (World Tourism Organisation, 2018). Without mountaineering, these areas would have remained isolated from the rest of the world. Furthermore, with the development of a tourism sector related to these sports, mountain communities have transitioned from an economy primarily linked to agriculture to one of offering services related to mountaineering tourism (Apollo & Wengel, 2022).

Environmental Impact

Despite these positive consequences, mountaineering can also have a negative impact. Natural areas such as alpine ones have an extremely fragile and precarious environment (Buckley, 2000) and are consequently very susceptible to human presence, and especially to mass tourism. It is therefore essential to remain within set limits, such as a limit on the number of people who can go up a particular mountain, in order not to damage the ecosystem. However, economic profit often leads to a failure in respecting these limits, which has negative consequences for the environment. One example concerns the most frequently used road to Kilimanjaro, Marangu Route. For it, a capacity of 15 000 persons per year was calculated, but instead there was a recorded 60 000 persons in 2015 (Apollo & Wengel, 2022).

As far as *soil cover and vegetation* are concerned, various changes have been observed. Among these there is the compaction of the soil due to trampling that affects the composition of the soil and its temperature. This leads to a reduction in the biological activity of the soil and a reduction in the absorption of water in the soil and thus to a swamping of the path. It has been noticed a changes in vegetation too, with the introduction of non-native species and the disappearance of native ones. This depends on trampling intensity, frequency, distribution, weight of broken biomass, the season, the weather, the habitat, the species, soil type, altitude, etc. (Pescott and Stewart, 2014). Another change is the damage to vegetation resulting in the loss of vegetation (seeds in shoes and plant size change, etc.), in soil degradation and -in the worst case scenario- soil erosion (Fidelus, 2016). Climbing can lead to the removal of lichens, mosses, rock prairie and damage to the vegetation at the foot of the wall.

Regarding *Faunistic changes*, the presence of humans in the mountains can have an impact on animals living in the area as animals become frightened by the presence of climbers. Their pulse speeds up for fleeing animals or slows down for those that camouflage themselves and stress hormones are secreted. Since animals in winter reduce their metabolism to conserve energy, too much escape and thus too high an

expenditure of energy has a negative impact on the animal, leading to a possibility of less displacement, illness, or death by exhaustion (Winkler et al., 2018). Disturbances from humans are exceptionally dangerous during the winter months when animals need more nourishment but there are fewer resources in the surrounding environment (Cole, 1993; Dorrance et al, 1975; Formenti et al., 2015; Rehnus et al., 2014). The presence of humans also affects the habitats and migration of fauna and repeated disturbances can lead to a species abandoning its habitat and migrating to other places and in the worst cases to their extinction. For example, chamois move from mountain grasslands to wooded areas if they are continually disturbed (Winkler, 2018). Decrease in population size can lead local extinction of the animal. Finally, animals may lose their ability to forage for food independently when tourists feed the animals and consequently health problems may arise because the food is not suitable for their diet (Apollo & Wengel, 2022).

Considering *environmental pollution*, one of the biggest problems concerns solid waste. Waste management is more difficult and costly in the mountains due to its slope and isolation. In addition, the presence of waste scattered around has a great negative impact on aesthetics and prejudice for tourists, who may decide not to come any more (Noe et al., 1997, Godde, 1999), which consequently causes a negative impact on the local economy. Another major problem concerns the immense amount of waste released by mountaineers and tourists in remote areas such as food and its packaging, fuel containers, ropes, used climbing equipment and clothes, batteries, broken glass, 35-mm film packaging, oxygen cylinders, and cooking equipment, including dishes and cutlery. These remote areas, as in Asia, do not have an adequate system to collect and dispose of waste. In the last 60 years in the Everest area, 40 000 kilograms of solid waste have been estimated to remain in the area following all expeditions (Kelliher, 2014). The Government of Nepal works together with the Nepal Mountaineering Association and expedition teams to create regular clean-up campaigns aiming to remove rubbish from mountain slopes (Dangi et al., 2021). In addition, human waste and refuse have a negative and harmful impact on water quality such as the presence of pathogens. High concentrations of nitrate, phosphorous, and algal species have been observed in the glacial lakes near popular mountaineering sites such as the Everest, Aconcagua, and Kilimanjaro base camps (Apollo, 2017; Ells, 1997). Some measures to limit this problem are bring-your-waste-back, charge fees to finance an effective waste sorting system, introduce a waste monitoring programme and educational programs to raise awareness.

Sociocultural Impacts

The establishment of mountain-based tourism has had an enourmous influence on mountain regions and the culture of the communities inhabiting them. For example, some alpine regions in the European alps have been overbuilt and overdeveloped, losing their cultural attractiveness (Price et al., 1999). Moreover, increased tourism may lead to degradation of socio-cultural traditions and heritage (Lama & Sattar, 2004) and negative socio-economic changes, including pollution, increased traffic, noise and

increased living costs (Apollo & Andreychouk, 2022). Finally, tourists influence the customs of local communities by creating a “plethora of cultures” and local people may adopt new ways of dressing, passing their time and speaking. On the other hand, mountain tourism can be a means of preserving and making known the cultural identity of an ethnic mountain community and resisting the influence of tourists (Apollo & Wengel, 2022).

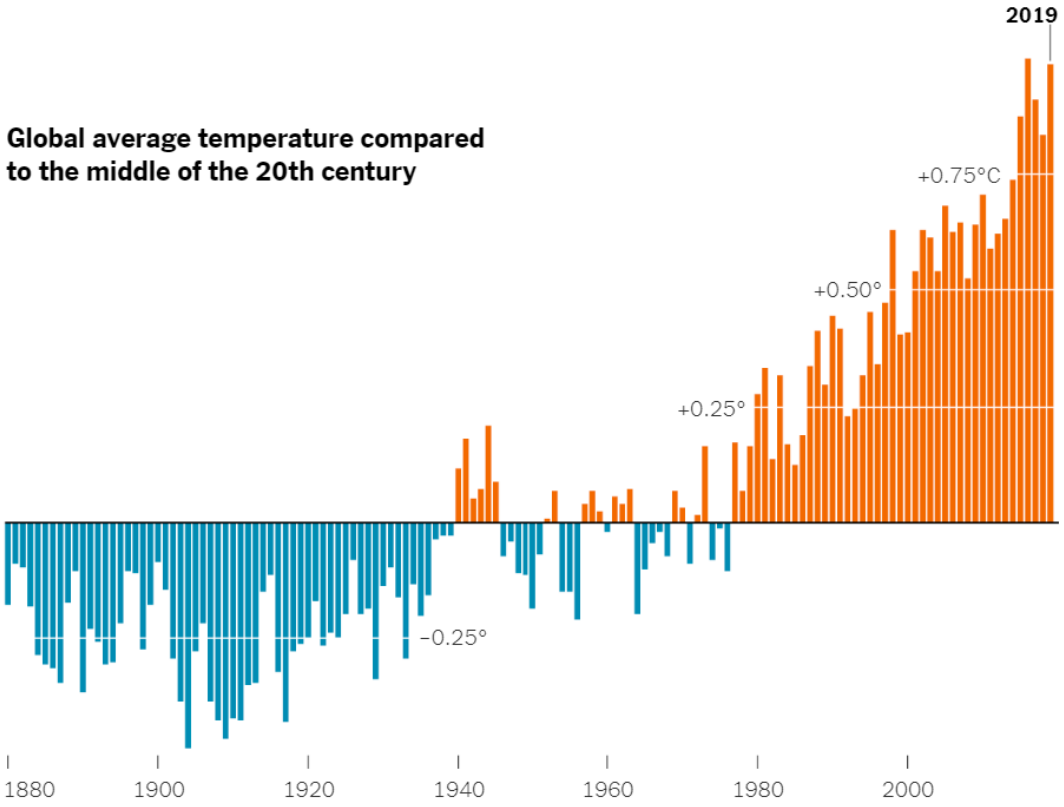

Figure 2: Changes in global surface temperature relative from 1880 to 2019 (Learning Network, 2020)

2.2. Climate Change

When we talk about climate, we refer to the result of a set of interactions between the energy emanating from the sun, the atmosphere, the oceans, the clouds, the soils, the biosphere and the nature of the earth's surface.

Looking at the geological history of planet Earth, the climate has changed greatly due to natural causes such as periodic variations in solar activity or the distance between the Earth and the sun. Depending on the amount of energy received from the sun, there have been phases of cooling or warming of the Earth's crust. However, the global warming observed over the last 150 years is unprecedented (Figure 2). In 2019, the CO_2 concentration was the highest one in the last 2 million years (IPCC 2021). The greenhouse effect is a natural phenomenon that allows greenhouse gases to retain part of the solar thermal radiation re-emitted by the planet in the form of infrared rays in the atmosphere. This mechanism ensures that on the planet, instead of -18 °C,

there is an average temperature of 15 °C, producing thus ideal conditions for life. However, as a result of humanity's use of fossil fuels, the concentration of greenhouse gases (such as water vapor, carbon dioxide, methane, nitrous oxide) has reached unprecedented levels. According to the IPCC (2021), in 2019 carbon dioxide concentration was 410 ppm, 1866 ppb for methane (CH4), and 332 ppm for nitrous oxide (N2O). High Green House Gases (henceforth GHG) concentrations bring about knock-on and potentially catastrophic consequences, primarily the increase in the planet's global temperature measured in recent decades (Reinhard, 2005; Beniston 1994). In the last 2000 years, the global surface temperature has increased faster since 1970 than in any other 50-year period (IPCC 2021). This, in turn, leads to retreat of glaciers and permafrost thawing. In 2011-2020, the annual average Arctic Sea ice area reached its lowest level since at least 1850 (IPCC 2021). Increased temperatures will also lead to increased sea levels. According to the IPCC (2021), the global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3000 years. It is further predicted that the intensity and frequency of extreme weather events, such heavy precipitation and drought heatwaves, will increase and changes in the snowline (i.e. the height at which precipitation falls as snow instead of rain) will occur.

Moreover, there are the so-called “feedback loops”, i.e. processes that can either amplify or diminish the effects of climate forcings. Positive feedback is a process that increases an initial warming, while a negative feedback is a feedback that reduces an initial warming. An example of positive feedback concerns permafrost, which is a large deposit of methane and carbon dioxide and is present in 25% of the land in the northern hemisphere. When permafrost thaws, these greenhouse gases are released back into the atmosphere as temperatures rise (IPCC, 2021; Vaks et al., 2013).

The severity of the situation in the future will depend primarily on future GHG emissions. Depending on how we decide to act on GHG emissions, the IPCC has come up with three possible future scenarios (Alley 2007). Compared to the situation in 1850-1900, the global surface temperature for the period 2081-2100 could be: 1.0 °C to 1.8 °C higher under the ultra-low greenhouse gas scenario, 2.1 °C to 3.5 °C higher under the intermediate scenario, and 3.3 °C to 5.7 °C higher under the ultra-high greenhouse gas scenario (IPCC 2021). Rising temperatures can have several negative consequences that are prone to touch many domains. Human health is likely to be affected by this phenomenon for example, and more frequent and prolonged droughts lead to agricultural crop losses and an increased risk of forest fires. A rise in the snowline has serious consequences for winter tourism, and there could be a deterioration in soil, air and water quality. Moreover, the habitat of present and passing species could change and harmful organisms, diseases and exotic species will more easily spread (UFAM, 2017).

2.2.1. Impact of Climate Change in Mountain Environments

Mountains offer an incredibly wide palette of eco-systemic benefits and services to the human population. According to Molden & Sharma (2013), mountains cover 24% of the Earth's surface and are home to 12% of the human population. They provide 40% of global goods and services, including water, hydropower, timber, biodiversity, minerals, recreation and flood protection. However, these benefits are threatened by the intensifying effects of climate change. According to Beniston (2003), high mountain areas are the most affected by climate change. This is due to the fact that, as snow and ice melt (reflecting the sun's rays), dark rocks, previously hidden underneath, rise to the surface absorbing more solar heat (Stretton, 2019; Brown, 2001) and heating up much more the surroundings. Climate change in the mountains refers mainly to changes in temperature and precipitation (Stretton, 2019).

Precipitation

From a global point of view, rainfall has not changed much. Instead, the changes are different from region to region. Climate models show that on the French side of Mont Blanc there will be no significant change in the amount of precipitation, while the Italian side will experience a decrease (Stretton, 2019) in it. In any case, trends of dry periods and lower snow cover in the Alps are evident (Stretton, 2019). In 2018, Switzerland experienced a severe drought and the Swiss Mountain Aid Organization had to transport large quantities of water by truck and helicopter to water the cows on the alpine pastures (Swissinfo, 2018).

Temperature

The temperature of the globe has increased by 1°C over the last 100 years (Hartmann et al., 2013). However, this has not been a uniform warming, as continents have warmed more than oceans and countries at higher latitudes have warmed faster than those at lower latitudes. For mountains, atmospheric warming depends on latitude. Looking at projected temperature changes in the future, the predictions are as follows: a stronger temperature increase on land than in the ocean, and a stronger increase at high latitudes than in the tropics, where temperatures will increase more at high altitudes than at low altitudes (Collins et al, 2013). Temperatures above 4 000 m increased at the same rate as those in the lowlands (Gilbert et al, 2013). In addition, the frequency of warm days has increased, while that of cold nights have decreased. Above 700 m, winter snow is extremely sensitive to temperature changes (Hantel & Hirtl-Wielke, 2007). Since 1980, the Alpine snowpack has decreased and the snow season has shortened. The ice mass balance is greatly influenced by summer temperatures. In summer, the zero degree level has been raised by 75 m every decade since 1959. Glaciers have been retreating since 1980 (Brocard et al., 2013). As a consequence of the increase in temperature, changes in the distribution of vegetation have been observed as well (Lenoir et al., 2010).

Mountain Water

Mountains play an essential role in the water we need and use. For example, the Himalayan Hindu Kush mountains provide water to about 1.3 billion people. More than 50% of the water we drink comes from rivers and reservoirs fed by rivers. And mountains play an essential role in the outflow of these rivers, ranging from 40 to 95%, depending on the region. Runoff from mountain reservoirs is influenced by air temperature (influences the seasonal behaviour of runoff by controlling snowfall and snowmelt) and precipitation (influences annual and seasonal runoff volumes).

As the temperature rises, there will be an increasing amount of runoff in the winter period, earlier snowmelt in the winter and, therefore, a decrease in runoff in the summer. This represents a major challenge, since the demand for water is greatest in summer. Moreover, as the temperatures rise, the snowline will also increases. Warmer winter temperatures mean that the mid-mountains will receive more rain, rather than snow, during the winter. As a result of the reduced snowfall and warmer spring temperatures, the period of snow cover at mid-altitudes has decreased by one month since 1979 (Stretton, 2019). For example, in the Mont Blanc massif, the snow cover period at medium altitudes has decreased by almost one month since 1970 (Figure 3). At higher altitudes (>2,500 m) although winter precipitation levels have remained stable in recent decades, higher temperatures in spring and summer have led to faster melting and a reduction of the snow cover period (CREA Mont-Blanc, n.d.). As far as the Mont Blanc massif is concerned, the snow-free period increased by 25% at 2 500 m by 21% at 2 300 m and by 12% at 1 500 m.

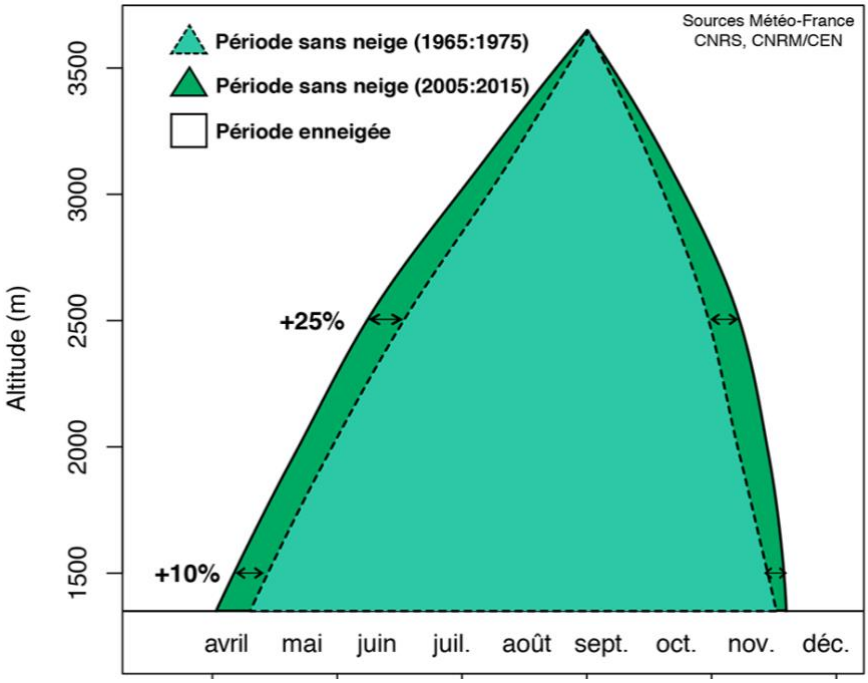

Figure 3: Periods without snow in function of altitude (1965-2015) (Météo – France - CNRS, CNRM/CEN, n.d.)

Snow, compared to glaciers, is a more significant source of water due to its large spatial extent. For example, in Switzerland, snow melt provides 40% of the total runoff, while ice melt only accounts for 2%. Currently, 1 billion people in Asia, North and South America and Central and Southern Europe depend on water from snow and glacier melt in the dry season. In the Himalayan region, it has been calculated that the freshwater resources stored in the region in the form of ice and snow would be enough

to supply water to the entire world for two years (Sharma et al., 2014). The problems arising in warm periods due to runoff from the mountains include decreased water supplies, longer minimum outflows, periods of low flow in rivers, lowered lake and groundwater levels, increased water temperatures, disruption of aquatic systems and decreased hydropower production. In addition, pressure on mountain waters in summer is increasing due to population growth, mass tourist urbanization, industrialisation, irrigation, hydropower production and firefighting (Kohler et al., 2014).

Mountains Glaciers

Worldwide, there are 170 000 glaciers covering an area of 730 000 km^2 (Vaughan et al., 2013), 80% of which are located in the Canadian Arctic, Alaska, the Asian Highlands, Antarctica and Greenland. It has been calculated that if these glaciers were to melt, sea levels would rise by about 0.5 m (Huss & Farinotti, 2012). The glaciers are melting because they are very sensitive to changes in atmospheric temperatures and are therefore a reliable indicator of climate change (Haeberli et al., 2000). An increase in temperature of a tenth of a degree for 10 years can cause the retreat of a glacier's tongue by a hundred metres. The retreat of a glacier's tongue length depends on its size. Thus, smaller ones such as the Pizol glacier (Graubünden) react quickly to an increase in temperature, while larger ones such as the Aletsch glacier (Valais) react much more slowly (UFAM, 2017). The rate of thickness loss has tripled since 1980 (Kohler et al., 2014). Furthermore, it has been observed that ice loss is occurring at a higher rate than that caused by the presence of GHG in the atmosphere alone. This means that, in addition to the effect of greenhouse gasses, positive feedback processes -an interaction in which a perturbation in one climate magnitude causes a change in a second, leading to a further change in the first magnitude-, are playing an important role. What is the fate of glaciers? Unfortunately, even if the human population makes an enormous effort to remain within the best possible scenarios, by 2100 most of the glaciers in the Alps will have melted (European Geosciences Union, 2019). The two main problems related to the melting of glaciers are the rise in sea level and the change in seasonal runoff capacity. Furthermore, the disappearance of glaciers could have a negative impact on the culture and identity of the communities living in the mountains (Kohler et al., 2014)

Snow Cover

The snow cover plays a really important role since it is a resource of winter tourism, has a function of water storage, insulates the soil and thus also safeguards the permafrost and the habitat for some species. Snow cover is influenced by air temperature and precipitation (ONERC, 2008).

Permafrost Thawing

According to Stretton (2019), permafrost is permanently frozen ground (soil, rock and ice) that has been below freezing temperature for more than two years. It is widespread in the Arctic and in high mountain environments. Permafrost is the 'glue'

that holds the mountains of the Alps together and rising temperatures cause it to thaw, often with dramatic consequences. Among its various functions is to stop the percolation of groundwater. In the Mont Blanc massif, permafrost is present in 65% of the rock faces above 2 300 m (CREA Mont-Blanc, n.d.). The loss of permafrost has increased in recent years due to rising temperatures. In fact, it reacts directly to changes in the energy balance on the surface (PERMOS, 2005). Researchers from the PACE (Permafrost and Climate in Europe) project (Observatoire national sur les effets du réchauffement climatique, 2008) have observed a temperature increase between 0.5 and 2.0°C in permafrost soils in European mountain regions over the past 80 years. In the last 20 years, permafrost has disappeared below the 3 300 m of the south-facing rock faces of Mont Blanc (CREA Mont-Blanc, n.d.). Snow cover also plays an important role in the permafrost setting: early snowmelt exposes permafrost to long summer warming (Observatoire national sur les effets du réchauffement climatique, 2008). The loss of permafrost, even if we cannot see it and if it is less visible than glacier retreat (Haeberli et al., 2011), is a huge problem for rock stability. This leads to unstable soils, landslides and rockfalls (also called rock avalanches), especially in the warm period of spring (Arnaud, 2015).

In general, there are four major types of ground movement (Bommer, 2012):

a) sliding of slopes, rock glaciers (increased production of mobilizable materials);

b) subsidence due to melting of interstitial or fissural ice;

c) landslides and landslips due to meltwater pressure in permafrost;

d) erosion of thawed permafrost bodies due to an unstable structure.

With excessive temperature rise, perennial permafrost will thaw giving way to continuous periods of frost and thaw (Amitrano et al., 2012). During freezing periods, cooling will generate ice crystallization leading to rock expansion and widening of ice-filled crevices that weaken the rocks, leading to rock destabilization. When ice melts, the water will subject the rock to pressures that can lead to a sudden loss of stability (Bommer, 2012). This phenomenon will contribute to the damage of the rock and finally to its collapse. This phenomenon has a particularly intense effect on rock faces that are not protected by a debris cover (Hoelzle et al., 2002), which is able to buffer temperature fluctuations, a typical condition for steep rock faces in high mountains. Several studies have already shown that increasing temperatures and thawing permafrost have led to the increase in rock falls in the European Alps (Arnaud, 2015).

Mountain Hazards

Mountains are naturally exposed to a multitude of natural hazards. With climate change, natural hazards are predicted to become more frequent and increasingly serious. Floods, debris flows, landslides and avalanches are among the mountain hazards most sensitive to climate change. Moreover, as more and more people move to the mountains, this puts more people at risk (Kohler et al., 2014).

Biodiversity in Mountains

About half of the world's biodiversity hotspots can be found in mountain areas. This is possible due to the geological and climatic variations found in the mountains (Kohler et al., 2014). Mountains are also a center of agrobiodiversity, meaning that they are home to a wide variety of ancient local species of plants and livestock. These species are an important resource of genetic diversity. Thanks to their genetic diversity, compared to commercial species, they are able to adapt and survive in conditions of climate change, thus ensuring food security. However, climate change is a clear threat to mountain biodiversity. An example of this could be the case of the ptarmigan, a bird that is at risk of losing up to 60% of its habitat by 2050 and, in the worst case scenario, could become extinct by 2090 (Carlson, 2018).

Due to rising temperatures, animals and plants have to flee and adapt to the changed conditions (Figure 4). For animals (it has been observed that most animal species rise between 30 and 100 m per decade) (CREA Mont-Blanc, n.d.), moving to higher altitudes or northwards is easier and faster than for plants. Glacier buttercup (*Ranunculus glacialis*), which is specifically adapted to growing in high mountain environments, will need to climb 1 200 m (3 937 ft) by 2100 to find favorable climatic conditions (Carlson, 2018). Mountains also have a secret weapon, a mosaic of neighboring microhabitats with different temperatures. Thus, a plant only has to

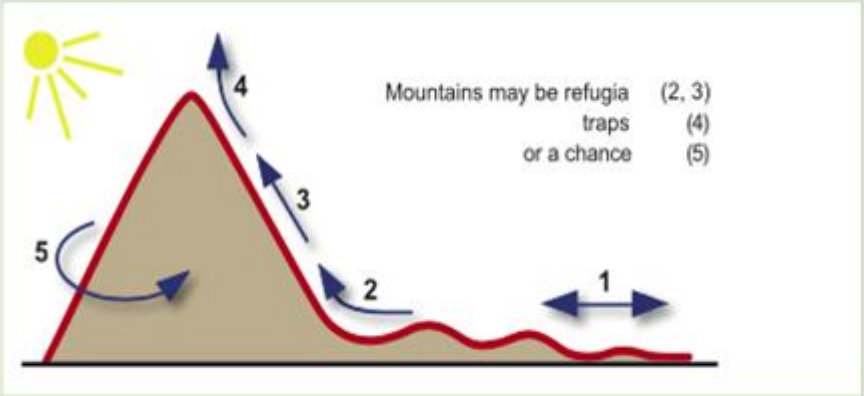

Figure 4: Species responses to global warming (Kohler et al, 2014)

migrate around the corner to find a suitable habitat for it. With an increase of 2 °C, colder habitats will shrink, leading to competition between inhabitants (and in the worst case some will disappear) and an increase in other habitats and plants (Scherrer & Körner, 2011). We must expect a change in the vegetative structure in the mountains, a 'greening' of the Alps even at higher altitudes.

Forests provide great protection against natural hazards, but they have also become threatened by forest fires and insect epidemics, events that are expected to become increasingly frequent with climate change. Furthermore, the resilience of forest ecosystems depends on biodiversity at several levels. At the tree species level, pure stands of spruce in the same area are more susceptible to bark beetle outbreaks than mixed stands that are more resistant to outbreaks (Stadelmann et al., 2013). More root types are also more resistant to soil erosion and landslides. Moreover, forest

represent a favorable habitat for a multitude of animals and plants and as a result show more resilience against insect damage. Finally, heterogeneous landscapes are less sensitive to disturbing elements, such as forest fires, due to the structure of the forest (Kulakowski & Bebi, 2004).

Food Security

Producing food in the mountains is more difficult than in the plains. Mountainous terrains have steep slopes and a harsh climate, which makes growing food more difficult and challenging. Moreover, at high altitudes, crop growth is slower, and farmers can only harvest once a year. According to the FAO (2003), about 45% of the world's mountain area is unsuitable, or only marginally so, for cultivation, livestock or forestry activities (FAO, 2003). Due to the lack of dietary diversity, people living in mountains are more likely to have micronutrient deficiencies, such as iodine deficiency. Climate change, with rising temperatures and more frequent extreme weather events, will negatively affect the food production of crops and livestock (Field et al., 2014). The most affected will be mountain people and farmers who depend on agriculture and are already vulnerable and food insecure. On the other hand, mountains could benefit from the new climatic conditions. Crops could start growing earlier at high altitudes, at least where there is enough water and the soil is suitable, leading to higher food productivity.

Mountain Economy

Mountains offer a multitude of ecological services for the human population. Unfortunately, our politics and our economy are based on a system whereby raw materials are extracted in the mountains and then brought to the city on the valley

	Human Development Index		Per capita gross national income	
	High-income countries	Low-income countries	High-income countries in US$	Low-income countries in US$
All regions	0.890	0.493	40 046	2 904
Mountains	0.872	0.462	35 621	2 227

Figure 5: Comparison of the Human Development Index and per capita gross national income in high-income and low-income countries between mountain regions and all regions (UNDP, 2014)

floor. There, due to the economic infrastructure and market system, the opportunities for profit and gain are greater. This causes many social problems, such as conflicts, tensions, poverty, injustice and insecurity of livelihood. Today, in both high- and low-income countries, the poverty rate is highest in mountain villages (Figure 5). Climate change further accelerates and intensifies these dynamics in the valley bottom.

3. Major Goal and Research Questions

There are two main reasons to conduct this research on the relationship between mountaineering, ski mountaineering (or (ski)mountaineering) and climate change in Switzerland. Firstly, these sports are highly practiced in Switzerland and are of great importance from an economic, cultural and social point of view. Secondly, Switzerland is already experiencing the effects of climate change. At the moment, Switzerland has experienced an increase of 2°C since 1864, an increase in the zero degree line of 300/400 m, and a 12% increase in heavy precipitation. Moreover, snow days have decreased by 50% below 800 meters and 20% below 2000 meters, the vegetation period has increased by 2 to 4 weeks and the volume of glaciers has decreased by 60% since 1850 (FOEN, 2020). By 2050, an increase of at least 2°C is expected in autumn, winter and summer, and at least 3°C in spring. Rainfall is expected to increase by 10% in winter and decrease by 20% in summer. Floods (especially in winter), landslides, heat waves and droughts are expected to increase. The aim of this research is to understand how people involved -like mountain guide, mountain lovers and researchers- perceive and live this situation.

The main question of the research is the following:

“How do people perceive the impact of climate change on mountaineering and ski mountaineering in the Swiss Alps, particularly in the Bernese Oberland, Graubünden, Valais and Ticino?”

To this first general research question, I add the following -more precise- ones:

- What consequences of climate change affect mountaineering and ski mountaineering directly and indirectly?

- Do mountain guides and mountaineering/ski mountaineering enthusiasts perceive the changes related to climate change and what is their knowledge of them?

- How are they adapting to these changes?

4. Materials and Methods

4.1. Study Area

Switzerland has an area of 41 285 km^2 and borders five countries: Italy, France, Germany, Austria and the Principality of Liechtenstein. The Swiss population has increased from 6.8 million in 1990 to 8.7 million in 2020. 74.5% of the population is Swiss, while 25,5% are of foreign origin (FSO, 2020). There are four official languages in this country: German (spoken by 70% of the population), French (22.9%), Italian (8.2%) and Romansh (0.5%) (UFAM[3], n.d.). One of the main characteristics of Switzerland is the enormous diversity of landscapes, which can be divided into three main geographical regions: the Alps, which cover most of the country (58%) but where only 11% of the population lives, the Central Plateau, which covers an area of 31% of the country, and the Jura, which occupies the 11% of the Swiss territory. Switzerland has 1 500 lakes covering almost 4% of the country, it has 6% of Europe's freshwater reserves and supplies most of its water resources to major European rivers such as the Rhone, Rhine and Inn. It is also home to 12 UNESCO World Heritage sites, such as the Jungfrau-Aletsch region and the Bernina lines of the Rhaetian Railway.

The Alpine region covers an area of approximately 190 700 km² spread over eight regions: Austria, France, Germany, Italy, Liechtenstein, Monaco, Slovenia and Switzerland (EEA, n.d.) and 20% of the entire Alpine region is located in Switzerland. The highest mountain in the Alps is Mont Blanc, located on the border between Italy and France. The countries that are part of the Alpine region have signed the Alpine Convention. Today, the Convention has 43 regions, 5 800 local authorities and a population of around 13 million inhabitants (UFAM[2], n.d.). The objective of this treaty is to ensure the preservation and sustainable development of the Alpine space. Mountains play an essential role in Switzerland's identity, tradition and economy and Switzerland is one of the most mountainous countries in Europe. Of the 824 000 m peaks, 49 are located in the Swiss territory (UFAM, 2017). The highest is the Dufourspitze in the Monte Rosa region (in the canton of Valais) at 4 634 m The Grisons region is characterized by 1 200 mountains with a height of between 2 000 and 3 000 m. The canton of Uri has the highest density of mountains (UFAM[1], n.d.).

50% of the total area of glaciers in the Alpine region is located in Switzerland (ONERC, 2008) and covers an area of 1 000 km^2. The largest in Switzerland and Europe is the Aletsch Glacier, which stretches 23 km (UFAM, 2017). The highest concentration of glaciers is found in the Jungfrau region of the Bernese Alps (AlpenWild, n.d.).

As Graubünden, Valais, the Bernese Oberland, and somewhat less Ticino are the most interesting and important Swiss regions in terms of mountain sports and mountain sports-related tourism, I selected these four cantons as settings for my research. In 2018 and 2019, according to the Federal Statistical Office, 54% of total hotel nights were booked in Valais, Graubünden, and the Bern region. For Valais and

Graubünden, winter tourism accounts for more than 10% of their GDP (Turuban, 2020).

Ticino

The Canton of Ticino is located South of the Alps and differs from the rest of Switzerland in its typical subtropical vegetation, its mild and sunny climate, and in being the only canton where Italian is the only official language. Ticino, whose capital is Bellinzona, has an area of 2812 km^2, which corresponds to 6.8% of Switzerland's surface area, and has a population of 354 375 inhabitants. This canton is mainly composed of two very different geographical areas in terms of morphology: 1) the Sopraceneri, characterized by a mountainous and alpine conformation, and 2) the Sottoceneri, with a prealpine and hilly vegetation and lower mountains than the Sopraceneri. The two areas are separated by the mountain Monte Ceneri (Iperpaesaggi, 2016). Eighty per cent of the canton is made up of mountains and about half of the territory is located above 1 500 m, 54% in the Sopraceneri and 5% in the Sottoceneri (Iperpaesaggi, 2016). The highest peak is called Adula, located in the Blenio valley at 3 402 m.

Valais

Valais has an area of 5 224,8 km^2 of which 3,5% is settlement area, 19% is agricultural area, 24% is wooded area and 53,5% is unproductive area (including mountains) (OFS, 2021). It borders Italy and France and counts 345 525 inhabitants in 2019. The official languages are (Swiss) German and French, though the latter is the most present on the cantonal territory as it is spoken by the 67.8% of the population of Valais (OFS, 2021). This region is home to the highest mountains in Switzerland, such as the Monte Rosa, the Finsteraarhorn and the Cervino. In fact, there are 51 mountains with a height of over 4 000 m and 27 glaciers. Among the best known alpine villages there are Crans montana, Saas fee, Verbier and Zermatt, whilst the most famous glaciers are Adula and Gorner Glacier. Together with Canton Bern and Graubünden, Canton Valais is the canton with peaks above 4000 m (Britannica, 2013).

Bernese Oberland

The name “Bernese Oberland” refers to the alpine region of the canton of Berne around the lakes of Thun and Brienz. Its area extends from the Jungfrau chain to the southern border of Canton Bern. In terms of mountaineering, it is known for the Finsteraarhorn (at 4 274 m), the Jungfrau (4 158 m) and the Aletschhorn (4 194 m), as well as for the famous North Face of the Eiger at 3 970 m (Britannica, 2019)

Grisons

The canton of the Grisons has an area of 71 050 km^2, 2% of which is for settlement, 28% for agriculture, 27.6% is forest and 41.6% is unproductive. With 199 021 inhabitants spread over its large surface, it is the least densely populated canton. There are three official languages in the Grisons: Italian, Romansh and (Swiss)

German, which the most widely spoken language (SFO, 2021). The highest mountain is the Pizzo Bernina (at 4 049 m), which is the only 4 000 m high mountain in the Maloja region (Britannica, 2016)

4.2. Online Questionnaire

An online questionnaire was designed both in English and Italian with Microsoft Forms to collect the answers from “mountain lovers”, namely people who go in the mountains as a hobby, during their free time. The respondents were reached through Facebook alpinism Suisse groups, Alpine club like UTOE and CAS (Swiss Alpine Club) Switzerland, regional subdivisions (Bellinzona, Locarno, Lugano), friends and associates.

The questionnaire consisted of four main parts and a total of 44 questions (the majority were closed ones). Questions 1 to 6 collect the participants’ personal information, namely their name, surname, age, gender, profession, and country of living. The second part **(**questions 7 to 15) focuses on the relation of the interviewees with the mountains through questions investigating the reasons why participants go in the mountains, since how many years, which sport they practice there, and where they most preferably go. The third part (questions 16 to 37) explores the climate knowledge of the interviewees and which changes linked to climate change they have noticed during their excursion of alpinism and ski alpinism. The fourth and last part (questions 36 to 44) assesses whether and how the respondents are adapting to these changes and what are their opinions on what should be done to limit this problem.

For the online questionnaire, a categorical analysis was made in which each of the four parts were examined individually. Graphs and tables were created to represent the data collected.

4.3. Qualitative Semi-Structured Interviews

This semi-structured qualitative questionnaire had the objective to collect answers from professionals and mountain guides, therefore from people who do not just go in the mountains for pleasure, but also for professional reasons. 15 interviews have been conducted: 7 with mountain guides and 2 with experts, 2 with hit keepers and 4 with expert mountain sportsmen. The interviewees have been reached through alpine club, friends and word-of-mouth.

The interview guidelines counted 25 questions, which were adapted from the online survey in order to produce open answers. The aim of this part was to get to the bottom of the various questions, gathering more detailed and nuanced responses, which is not possible for the online survey. The interviews were conducted face to face, through zoom and phone calls, in Italian, French and English. They have all been recorded with the informed consent of the participants and they normally lasted between 25 minutes to max 1 hour for a total of 9 hours interviews.

The data collected from the interviews were grouped together in a table. Subsequently, the analysis of the qualitative semi-structured interviews was divided

into two parts. In the first part, a table was created to collect some categorical data (i.e. data that can be grouped into various categories) from the interviewees such as gender, mountain sports practised, climate sensitivity etc.. In the second part, a descriptive analysis was carried out in which an attempt was made to answer two main questions:

1) How climate change influences mountaineering and ski mountaineering. The answers to this question are divided into three broad categories corresponding to glaciers melting, permafrost thawing and less snow and ice cover.

2) How are the interviewees adapting to changes? The answer here was organised in five categories of adaptation.

The places most affected by the influence of climate change according to the participants were represented on a map of Switzerland. They were divided into three colours according to whether they were glaciers melting (blue), permafrost melting (green) or less snow and ice cover (orange).

5. Results

The section dedicated to the “results” is divided into two main parts. The first part analyses the 61 answers to the online questionnaire, and the second analyses the 15 semi-structured qualitative questionnaires.

5.1. Questionnaire

In Chapter 5.1, the online questionnaire is analysed in four parts - Personal information, their relationship with the mountains, their knowledge of the climate and whether and how they are adapting to the observed changes.

Analysis First Part: Personal Information

Between March and April 2022, 61 mountaineers and ski mountaineers filled in the questionnaire. The average time to answer the questionnaire was 13 min. In total, 57% of the respondents are between 26 and 50 years old, 18% are younger (i.e. <26) and 24% older (i.e. <50). As far as gender is concerned, the majority of respondents are male (62%) (Figure 6). Of the total of participants, 46% come from the canton of Ticino, 11% from canton of Zurich, 10% from canton of Berne, 6% from the canton of Valais, 6% from outside Switzerland and the rest 21% from the rest of Switzerland.

93% of the participants practices sport in their free time and not for work reasons. As it can be seen in the graph below, in response to the multiple choice question "What motivates you to go to the mountains?", 90% chose the option to be in nature, 65% to feel pleasure, 62% to challenge myself, 52% to keep fit and feel alive, 50% to be with friends, 42% to be alone, 39% to escape the hustle and bustle of the city, 31% to reflect and 10% to improve my sporting skills (Figure 7). In total, 55% of the participants have been practicing mountain sports for more than 20 years, 16% for 15 to 20

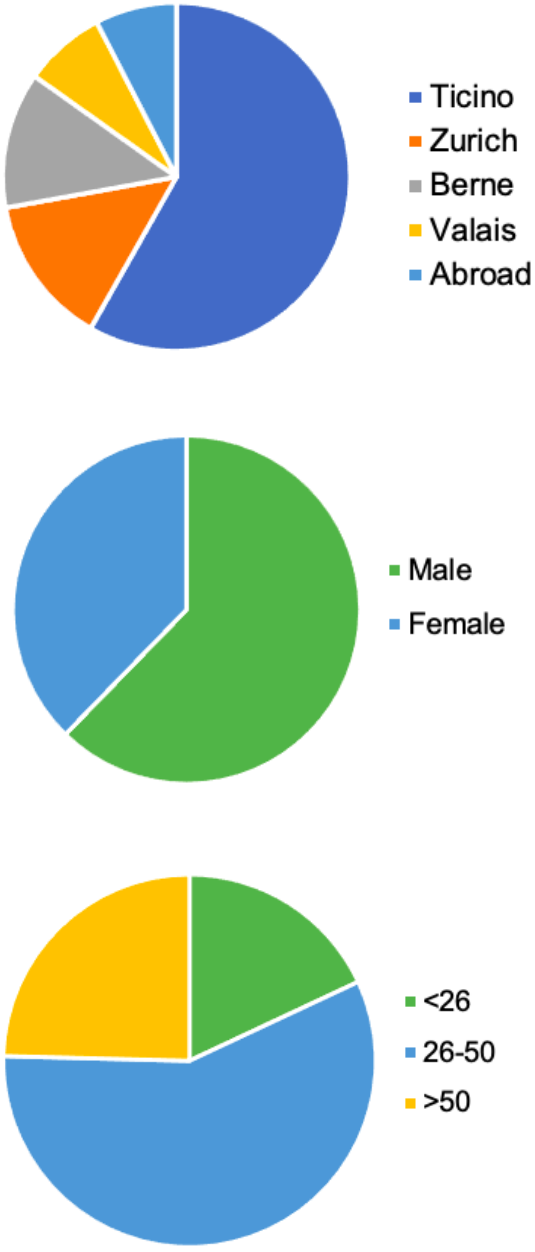

Figure 6: Age, gender and province of the people that hve contributed to the questionnaire. In total 61 people responded to the questionnaire.

years, 8% for 10 to 15 years and 20% for 0 to 10 years.

Figure 7: Reasons for people to go into the mountains. Values represent percentages of the people choosing a particular option

To the multiple-choice question "What sports do you practice in the mountains?", 100% of the participants answered that they practice mountaineering, 85% ski touring/split boarding, 73% ski/snowboard, 80% hiking, 51% mountain biking, 20% climbing/bouldering and 11% trail running.

For mountaineering, 62% of the people go to Ticino, 46% to Valais, 36% to Canton Uri and 26% to Canton Bern. For ski mountaineering, 60% go to Ticino, 41% to Valais, 41% to Canton Uri and 40% to Graubünden.

Analysis Second Part: Their Relation with the Mountains

To the question "Do you think mountain sports are in danger?", 51% think they are, 34% answered maybe and 16% think they are not. Of those who answered yes and maybe, 94% think mountaineering is under threat, 88% think so for ski mountaineering and splitboarding and 58% for skiing and snowboarding. Climate change is recognized as the main threat by 92% of respondents, while risks and hazards are the second option, chosen by 88%. When asked "How do you rate your knowledge of climate change from 1 to 6?", 4 is the average answer and 92% of the respondents agree that climate change influences mountaineering and ski mountaineering.

Analysis Third Part: Their Climate Knowledge

The main question of the third part is: “In the last year, have you experienced the following change during your mountaineering and ski mountaineering excursions in the region of Bernese Oberland, Graubünden and Valais/Ticino due to altered climatic conditions?”. The results are showed in Table 2.

Table 2: Changes observed by respondents in recent years during their mountaineering and ski mountaineering excursions

	Change	Increase in the change	Decrease in the change	No change
Change of itinerary	72% a change of itinerary in the last years			28% no change
Distance of the itineraries		42% longer excursions	17% shorter excursions	38% no change
Technical difficulty of itineraries		58% technical difficulty of itineraries has increased		38% no change
Snow cover			95% less snow cover	
Optimal periods for making an ascent for mountaineering		17% longer period	60% shorter period	23% no difference
Stability of the soil			79% less stable	21% didn't notice any change
Avalanche		41% an increase		53% no change
Incident and danger		58% increase of incident and dangers		41% no change
Number of mountaineering and ski mountaineering excursions		32% have increased	24% have decreased	44% excursion numbers haven't changed

To the open question if they have noticed any other change, two respondents noticed an increase of crevasses, two an increase of rock fall, one noticed that there is less snow powder, and one noticed, as a result of less snow, an increase of incidents with the ski. 65% have noticed these changes in Ticino, mostly in Val Bedretto, 56%

in Valais while the majority did not observe them in Graubünden (54%) and Bernese Oberland (66%)

Analysis Fourth Part: Whether and How They Are Adapting to the Observed Changes

To the question “Do you think you are already adapting to these changes during your mountaineering and ski mountaineering trips?”, 56% answered that they are adapting to these changes when mountaineering and ski touring, 32% do not know and 12% are not adapting. When asked how they do it, 7 people said they modify and adapt their hikes according to the conditions, such as not going where there are rock fall hazards.

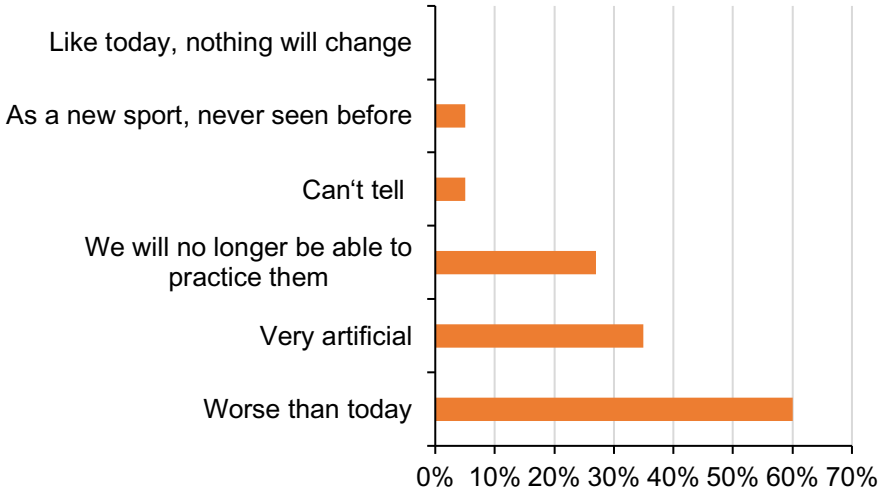

Figure 8: Answers to the question "What will mountaineering and ski mountaineering look like in 2050?. Values are represented in percentage.

To the multiple question "What kind of emotions do you feel when you realize that mountaineering and ski mountaineering are suffering from the effects of climate change?", the feeling that was most often selected is *sadness*, 32% feel that there is not enough knowledge about the effects of climate change on mountaineering and ski mountaineering and 61% think there could be more knowledge and prevention about the effect of climate change on mountaineering and ski mountaineering. When asked the open question "What measures do you think should be taken to limit these changes?", 10 people suggested the need to stop fossil fuel emissions and 8 people suggested raising awareness and consciousness on this issue. 60% imagine that mountaineering and ski mountaineering in 2050 will be worse than today, 35% think they will be very artificial and 27% think it will no longer be possible to practice them (Figure 8).

A total of 83% of respondents are already doing something to reduce their impact on the climate, 87% of whom reach their starting point by public transport or bicycle, 58% buy environmentally friendly/sustainable sports equipment and 58% try to reduce their meat consumption, while 17% do nothing.

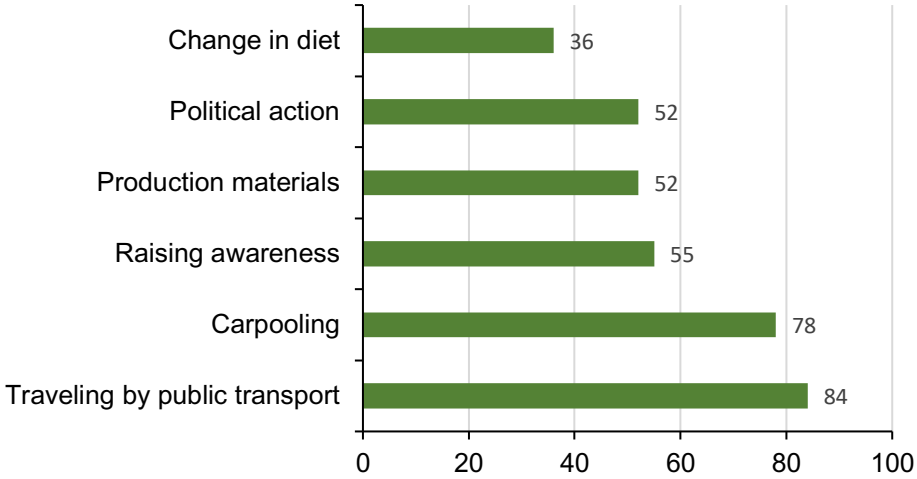

Figure 9: What people think can be done to practice mountaineering and ski mountaineering in a sustainable way. Values represent percentages of the people choosing a particular option.

To the final multiple-choice question, “How can mountaineering and ski mountaineering be done more sustainably?”, 84% answered by traveling by public transport, 78% by carpooling, 55% by raising awareness of climate change among fellow travellers, 52% by paying attention to the production materials of sports equipment, 42% by political action and 36% by a vegetarian/vegan diet. These results are reported in the graph (Figure 9) above

5.2. Semi-Structured Interviews

Chapter 5.2 is divided into a 'categorical part' and a 'descriptive part'. The latter is subdivided into two main parts - How does climate change affect mountaineering and ski mountaineering? and How do respondents adapt to change -.

5.2.1. Categorical Part

Table 4: representation of categorical data from semi-structured interviews

	Category	Number of respondents
Age	<25	1
	25 – 50	7
	>50	6
Sex	Male	14
	Female	1
Where they come from	Ticino	7
	Grisons	2
	Bern	1
	Valais	1
	Fribourg	1
	Zurich	1
	outside Switzerland	2
Job	Mountain guide	7
	Research	2
	Hut	2
	Others:	4
How long have they been practising mountain sports (years)	<10	3
	from 10 to 30	5
	>30	7
Connection with the mountains	Professional and amateur	13
	Only amateur	2
Mountaineering and/or ski mountaineering	Both	12
	Only ski Moutaineering	3
Where they practice mountaineering and ski touring.	Valais	10
	Ticino	8
	Grisons	12
	Oberland Bernese	8
Climate change sensitivity	Particularly sensible	6
	Sensible	6
	Not so sensible	3
They consider climate change to be a major threat to mountain sport	Yes	11
	No	4
Their self-evaluation on their knowledge of climate change from 1 (=I know nothing) to 6 (=I am an expert)	2	1
	4	4
	5	8
	6	1
They observed the effects of climate change during their tours	Yes	11
	No	4
They are adapting to climate change effects	Yes	15
	No	0

Table 4 summarises the categorical data collected from the 15 semi-structured interviews. 93% of the respondents are over 25 years old and male. Almost half come from Ticino and the other half from the rest of Switzerland. As for their profession, 46% are mountain guides, 13% work in research, 13% work in mountain huts and the remaining 26% fall under the "other" category (which can include Doctor of Electrical Engineering, teacher, forest engineer, ecc). 80% have been mountaineering and ski touring for more than 10 years. Regarding the data more related to climate change, 40% of the respondents are very sensitive to climate change, 40% are sensitive and the remaining 20% are not particularly sensitive to this topic. 73% of the respondents consider climate change to be a threat to mountain sports, and 73% have observed the effects of climate change during their outings. 100% of respondents stated that they are adapting to the effects of climate change.

5.2.2. Descriptive Part

How does climate change influence mountaineering and ski mountaineering?

In the following part, descriptive data are analysed in three main categories: glacier melting, permafrost thawing and reduction in snow and ice cover. Figure 10 represents geographically across Switzerland the changes reported by respondents as a consequence of climate change in their mountaineering and ski touring practices. The three categories are represented by three different colours, as described in the legend. There is a high concentration of geographical references in the Bernese Oberland area.

Glacier Melting

The melting of glaciers brings a variety of negative consequences. One of the first changes reported by interviewee No. 8 concerns the fact that in some places where the glacier has receded a moraine has formed. Instead of crossing the glacier through the path, one now has to cross the moraine, a terrain formed by stones and sand that makes crossing more difficult. Furthermore, as the glaciers become softer, due to temperature increase, the risk of falling ice increases (nr 8). It was observed by interviewees 10 and 15 that while one could cross the glacier before without too many problems, since the glacier has melted and thus lowered, one has to descend in altitude to cross and ascend once again afterwards. This makes the route more complicated and longer. Respondent no. 14 reported that, as at Aletschhorn (Valais), the melting of the glaciers causes the paths to pass over moraines. The paths are steeper and characterized by many unstable stones that are in danger of falling at any time. The route to the Adula summit (Ticino), which passes over the glacier, has become steeper over the years due to the lack of snow (no. 11). Consequently, if the danger is too great, other paths have to be found. One example concerns the Campo Tencia glacier (Ticino). Since it has melted, the path now passes over the ridge (no. 10).

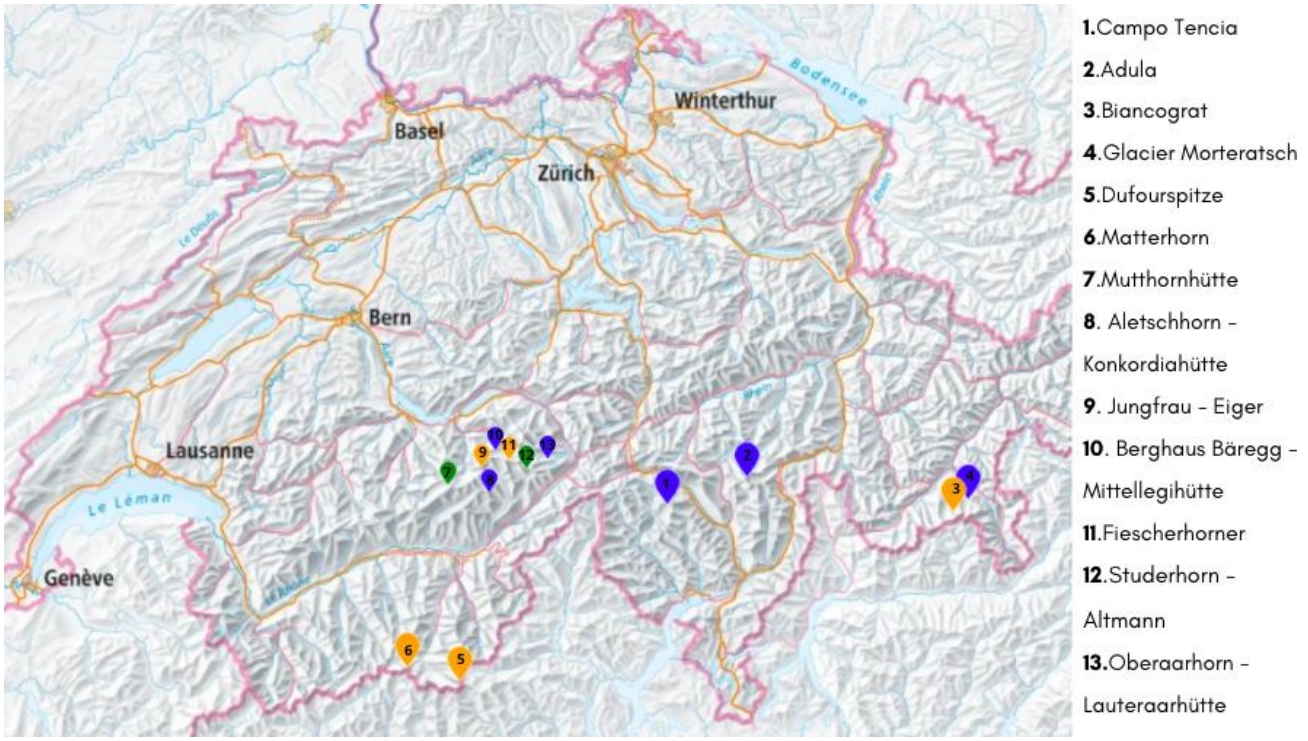

Figure 10: Geographical references divided into 3 categories of changes in mountaineering and ski mountaineering due to climate change, as answered by respondents

Reaching a glacier is becoming longer and more tiring. For example, the Morteratsch (Graubünden) glacier, which until 10 years ago could be reached in 30 minutes, now takes a good 1 hour (nr 15). The melting of the ice plays an essential role in stabilizing the terrain. Respondent no. 11 reported that since the rock has no more pressure, given by the melting of the glacier, it falls downhill due to gravity. A well-known example concerns the Berghaus Bäregg in the Grindelwald (Bernese Oberland) (Figure 11). The retreating glacier caused the sides of the mountain to collapse into the valley, leading to the destruction of the first Berghaus Bäregg hut (Bernese Oberland) (no. 14). Detachment of stones and landslides also increased in the summer in the Tencia field region (nr 10). Respondents 2, 4 and 14 reported that in the region of Mont Blanc, Altmann and Oberaarhorn in Chamonix and at the Mittellegi hut (Bernese Oberland), the retreat of the glacier has resulted in a very smooth and polished rock that is therefore technically more difficult to climb (higher grades) and also needs to be re-equipped with pitons.

Figure 11:Berghaus Bäregg in Grindelwald

While some huts, such as the Konkordia hut (Bernese Oberland), were originally built at the base of the glaciers, they are now found in the middle of the rocks. This makes the way to the huts more difficult and longer. The bell ringer at the Oberario hut (Bernese Oberland), said that if in 2013 it took 5 minutes to get to the hut from the moraine, in 2019 it will take 5 minutes longer (10 minutes) and as the moraine is less stable and safe, they have put a fixed chain to help with the ascent (nr 4). At the Konkordia hut, the approach is getting longer and longer as is the staircase, to which steps are added every year. For the Lauteraar hut (Bernese Oberland), the ladder is currently 230 meters long, whereas in the beginning it was 100/150 m long. More and more artificial technical tools, such as fixed ropes and ladders, are being added to reach the huts (no. 13)

Permafrost Thawing

An increase in rockfall in mountain areas due to thawing permafrost was noted by eight respondents (No. 4,6,7,8,9,11,13,14). In the Oberaahorn (Bernese Oberland) region and near Studerhorn and Altmann (Bernese Oberland), itineraries have become more difficult and dangerous due to the danger of danger of falling rocks some mountaineering routes have to be avoided and closed. This is, for example, the case with the Oberaarrothorn (Bernese Oberland), which can no longer be done. Others are being created as an alternative and the situation will get worse and worse in the future (Nos. 8, 13). One of the Swiss mountains that has been strongly affected by this phenomenon is the Matterhorn (Valais). One year in particular, due to great heat, was characterized by a large number of landslides and rock falls (nr 6). Some guides even decided to no longer take their clients up the Matterhorn as it is too dangerous (nr 7). This means that many of the routes that are considered too dangerous when it is hot, i.e. in summer, are done during the winter period. Some mountains can no longer be climbed in summer. Respondent no. 11 confirms that in Chamonix the mixed routes are no longer done in August since it is too hot and there are too many rock falls. Respondent no. 13 told about a tour in the Bernese Oberland starting from Lauteraar hut SAC to Oberaarjoch hut SAC via Scheuchzerjoch, and how during his ascent he noticed how unstable everything seemed, as everything could fall at any moment. He concluded that it's probably no longer safe to go there in summer but better to do it in winter. Permafrost thawing also negatively affects mountain huts built on frozen ground such as the Mutthorn hut (Bernese Oberland) (Figure 12). As temperatures rise, the ground melts and becomes unstable. The Mutthorn hut was closed because it was considered too dangerous.

The practice of climbing icefalls is also under threat from climate change. They melt much faster and as a result the period for climbing them is much shorter (nr 7, 11). A recurring change observed by the interviewees (nr 11, 5, 3, 14) concerns the ascent of north faces, whose period for climbing becomes increasingly shorter. Up until 40 years ago, the North Face of the Matterhorn (Bernese Oberland) and the Eiger (Bernese Oberland) were climbed during the summer months, because the winter months were too cold, whereas today the climbs are done in the winter and spring

Figure 12: The Mutthorn hut (Bernese Oberland) in the Swiss Alps.

months as doing them in summer is too dangerous. There are two main reasons for this: on the one hand, as the permafrost thaws, it makes the rock brittle and unstable, and on the other, as there is no more snow in summer, climbing wet rock is more difficult and dangerous (climbing on snow is easier).

Less Snow and Ice Cover

Respondent number 7 noticed two big changes regarding snowfall. First of all, it is happening more and more often that water is coming down in the form of rain instead of snow in the mountains, ruining the snowpack. Precipitation is reaching higher and higher areas. In 2022, 70% of the snowpack was lacking and interviewee no. 12 reported how for the first time he did not go seal-skiing because there was too little snow, while interviewee no. 7 was only able to go on two steep skiing trips. This means that the approaches on foot, before finding snow to go ski touring, are getting longer and you have to go higher and higher (nr 2), the descents down to the valley floor are getting rarer (nr 8) and the possibility of getting hurt because you fall on rocks and stones instead of snow is greater (nr 7).

Secondly, the snowfalls are getting increasingly inconstant. More and more frequently, there is a period of good weather and then a few days of heavy snowfall and great wind. From a period of avalanche of grade 2, it quickly goes to a grade 4 (nr 7). The lack of snow and ice in the high mountains means that some routes can no longer be climbed, especially in the summer and in shorter periods, such as the gully to Adula (nr 6) and the Fiescherhorn (Bernese Oberland), which forced interviewee nr 2 to turn back because there was only rock. If previously the ascent to Biancograt, a ridge of rock and snow leading to Piz Bernina (Bernese Oberland), was possible until the end of July because there was enough snow, now already in July there is only ice. This is because in winter there is less snow and the snow melts due to the high

temperatures. The ascent of Biancograt in July on ice alone is much more difficult and dangerous (no. 11). The material to be taken must therefore take these changes into account and be suitable also if there is only rock (no. 2).

Another major problem concerns crevasses. Since there is little snow and therefore less accumulation on the glaciers, they remain open and the bridges between one crevasse and the other are much finer and more fragile (nr 1, 2, 7). Respondent No. 1 reports how during a hike in the Jungfrau region, because of too many crevasses and too fine bridges, he had to give up several routes he had planned on doing because they were too dangerous. The seracs from the opening of the crevasses, being very dangerous because they can fall at any time, forced interviewee No. 2 to change route, to Silbersattel in the Dufour region (Valais) (No. 7).

How are the interviewees adapting to changes?

All respondents stated that they are adapting to the changes caused by climate change in their mountaineering and ski mountaineering practices and, as it can be seen in figure 13, they mentioned six strategies they adopt to do so. More specifically, respondents 1, 2, 6 and 14 are adapting by anticipating and shortening the period in which they go mountaineering and ski mountaineering. for example, if they used to go mountaineering till August in the high mountains, they now have to go in June.

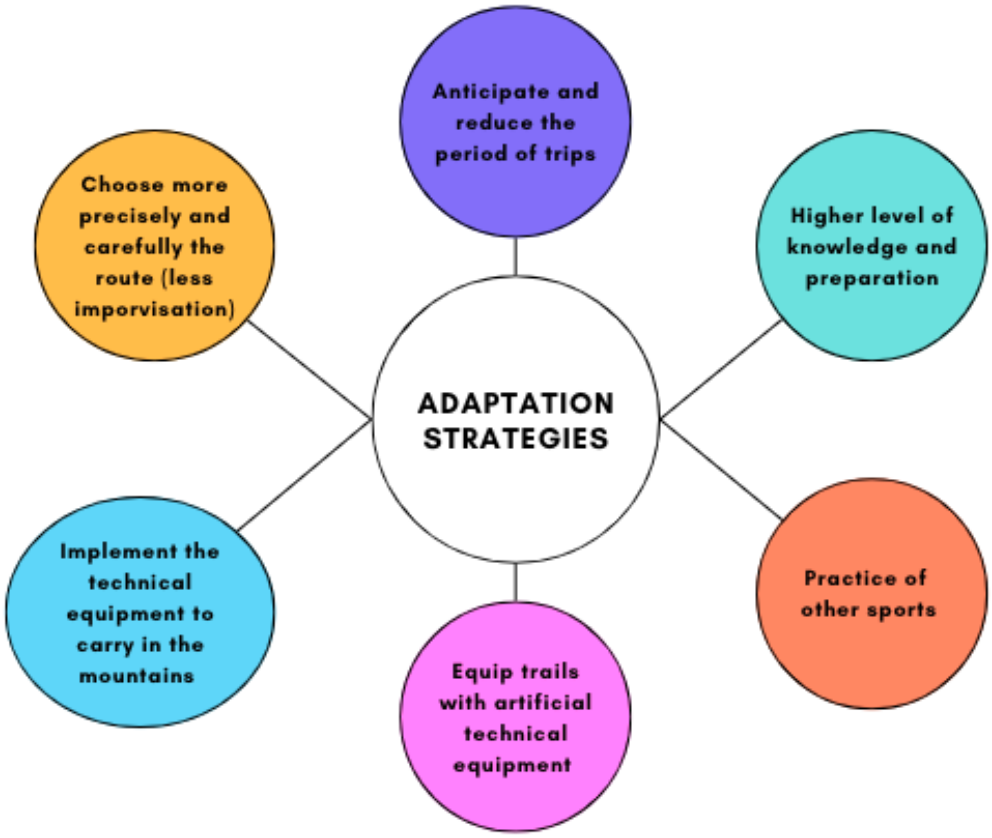

Figure 13: Adaptation strategies adopted from respondents

Another way of adapting, mentioned by interviewees 2 and 10, concerns the need to choose more precisely and carefully the route one wants to take, thus leaving less room for improvisation. For example, one needs to make sure to go to places where there is enough snow and not too many crevasses. According to respondents 1, 5, 7, 10, climate change imposes the need for a higher level of knowledge and preparation in order to respond to these changes. When the situation is not suitable for mountain sports, because for example there is no snow or the terrain is too unstable, respondents 7 and 9 practise other sports such as bouldering or running. Adapting also means implementing the technical equipment to carry in the mountains (2,11), e.g. plan to have the necessary equipment to climb a mountain in the absence of snow. Mountain trails also need to be increasingly equipped with artificial technical equipment such as ladders and fixed ropes to facilitate the ascent and arrival at the various huts as the ice level drops (No. 13). An example of this can be seen in the picture showing the ladder created to reach the Konkordiahutte (Figure 14).

Figure 14: Ladder to the Konkordiahutte (Bernese Oberland) (summitpost, 2007)

6. Discussion

Several are the studies that have investigated how climate change affects sports such as ski. Unfortunately, the same cannot be said for mountaineering and ski alpine, which still have received limited attention (Joly & Ungureanu, 2018). Most of the available literature focuses on the Mont Blanc region and they all agree that glaciological and geomorphological processes have a great impact on mountaineering and ski mountaineering and that as a result of melting glaciers and permafrost and poor snow and ice cover, mountaineering and ski mountaineering are becoming increasingly difficult and dangerous (Mourey et al, 2022). Angela Hawse, president of the American Mountain Guides Association, has stated that "the combination of crevasses becoming un-crossable, overhead icefall hazard increasing and rockfall events occurring regularly has made many classic routes more dangerous and less predictable". The results of our questionnaire and interviews point in the same direction.

From the analyses of the questionnaires and semi-structured interviews conducted in chapter 5 two key concepts emerge. Firstly, climate change is affecting mountaineering and ski mountaineering by altering various aspects of it. 92% of the online survey respondents and 73% of the interviewees agreed that climate change is impacting mountaineering and ski mountaineering. According to the survey results, 58% of the respondents observed an increase in accidents and dangers. This was also reported by respondents as a result of the increase in crevasses on glaciers, for example. 79% of the survey participants noted a decrease in soil stability, a feature reported by respondents with the increase in falling rocks as a result of thawing permafrost. 95% of the respondents noted a decrease in snow cover, which affects mountaineering as the early melting of snow leaves a terrain characterised only by ice or rock more difficult to traverse.

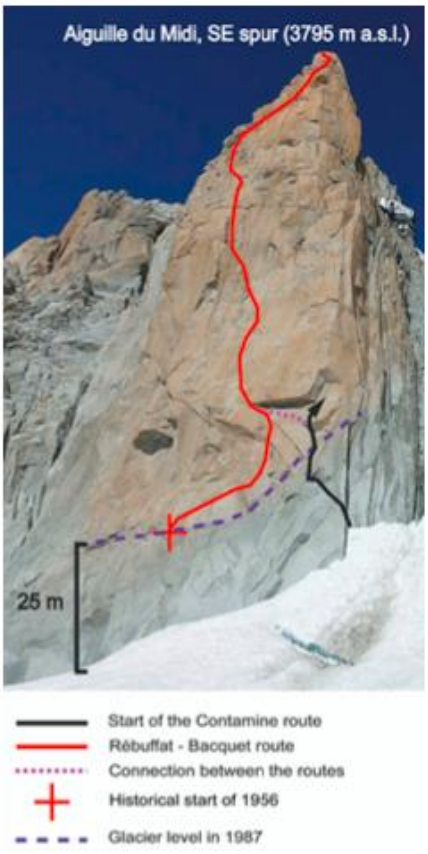

Figure 15: Aiguille du Midi south face, September 2018. The original start to the Rébuffat-Bacquet route (1956) is no longer accessible directly. The lower part of another route must be climbed to join it.

The survey shows that 58% of the participants believe that there is an increase in the technical difficulty of the routes, and this is, according to several respondents, a result of the formation of unstable moraines following the retreat of the glaciers. 72% of the respondents report that in recent years they have supported the alteration of routes, undertaking longer hikes to avoid dangers. Respondent No. 4 mentioned how, as a result of melting glaciers, the approach to the Konkordia hut

(Bernese Oberland), Oberario hut (Bernese Oberland) and Lauteraar hut (Bernese Oberland) is becoming longer.

Another change observed by 60% of the respondents to the survey concerns the shortening of the time to make an ascent for mountaineering and ski mountaineering. Respondents also confirmed that some ascents during summer, such as the ascent of the Mutthorn hut (Bernese Oberland), are too dangerous and are safer in winter.

Regarding both the survey and the interviews, no obvious changes were observed in the number of avalanches and the number of mountaineering and ski mountaineering excursions.

The results also showed that people who practice mountaineering and ski mountaineering are sensitive and informed about climate change (mountain guides and mountain enthusiasts) and that most are already adapting to these changes. From the questionnaire emerged that 56% of the participants are adapting to these changes when mountaineering and ski mountaineering, whilst the interviews. Shows that 100% of the respondents are doing so. The survey shows that 83% are already doing something to reduce their impact on the climate. 80% of respondents are sensitive to the issue of climate change.

6.1. Glacier Retreat

Glaciers in the Swiss Alps have decreased by 28% in 40 years (Fischer et al. 2014). The Great Aletsch Glacier (Valais), for example, has lost 28,000 m since 1870 (Stretton, 2019).

Increasingly Dangerous

Glacier retreat is considered as one of the most significant changes in mountainous areas (Salim et al, 2019). In Valais, 94% of the 36 routes were affected by glacier retreat and the appearance of bedrock (Mourey et al, 2022).

A critical element mentioned in the interviews concerns the presence of seracs. One example of the presence of seracs that was highlighted was the Silbersattel in the Dufour region, where hiking has become problematic. In fact, these seracs can even be fatal, as it has been on the Marmolada glacier, located just outside the Swiss border between the Trentino Alto Adige and Veneto regions. As already mentioned, on the 3rd of July 2022, the breaking of a serac, right where a popular route was passing, led to the death of 11 mountaineers. Mountaineer Reinhold Messner said, “With the warming, and especially the high temperatures of the last few weeks, the ice is becoming very thin in places, it's not the same glacier as it was fifty years ago” (Bonnel, 2022).

Increasingly Difficult

One of the elements reported in the results concerns the complicated and longer access to glaciers like the Morteratsch glacier (Graubünden). Various studies conducted outside the Alps (e.g. Norway, New Zealand, Everest) have observed how glacier retreat makes its approach more challenging (Purdie et al, 2015). Three

respondents mentioned the fact that the retreat of a glacier brings to the surface a smooth, polished rock that must be re-equipped for climbing like in the region of Bernese Oberland and that produces -as a result- higher climbing grades. This has also been observed in the Mont Blanc region, where the retreat of the ice in the Grand Capucin region since 1980 has resulted in 25 more meters of rock that must be climbed (Figure 15). To climb these 25 m, the grade of difficulty has changed from a 6c to a 7a (see Figure 1). This causes some routes to lose their attractiveness and interest because they are more difficult (Mourey et al., 2019). Furthermore, as the ice melts, the pressure of the ice against the mountain decreases, leading to the fall of unstable boulders, as was the case with Berghaus Bäregg (interviewee 11). Another example of this phenomenon occurred in 2006 on the east face of the Eiger (Bomio, 2007).

The interviews further confirm that the difficulty and the time to access huts such as the Konkordia hut (Bernese Oberland), Oberario hut (Bernese Oberland), and Lauteraar hut (Bernese Oberland), increase as the glacier subsides (Mourey and Ravanel, 2017). In 1880, it was possible to reach the glacier “the Mer de Glace “ (in Chamonix Valley) directly from the Montenvers Hotel in just a few meters. Today, however, one has to take a gondola and climb 367 steps (Mourey & Ravanel, 2017). The same has happened with the Coazh hut, a mountain hut in the Valley of Rosegg in Engadine that was once a bit just up the Bernina glaciers. Nowadays the hut is 100 m higher to the glaciers due to its melting (Stretton, 2019). A study in the Valais region showed that 15 of the huts taken into consideration, located at an average height of 3,000 m, are negatively affected by glacier retreat (Mourey et al, 2022). Furthermore, contrary to the results, in which the huts of Oberario (Bernese Oberland) and Campo Tencia hut (Ticino) interviewed confirmed that they are not economically affected by global warming, the situation is different for the Conscrits hut (2,602 m a.s.l.) (Graian Alps, France). A 25% decrease in overnight stays was observed in 2015, 2016 and 2017 due to the opening of a crevasse and falling rocks (Mourey et al, 2019).

Five respondents affirm that the lowering of glaciers gives way to steeper terrain, i.e. moraines, with a lot of unconsolidated debris and steep rocks smoothed by the ice that make crossing more complicated if not impossible ((Blair, 1994; Ritter et al, 2012). This is also the case with the Aletschhorn (Valais) and Campo Tencia (Ticino) glaciers (respondent 14). The lowering of the Tasman glacier in New Zealand nowadays requires a descent down an unstable and steep moraine to be reached and crossed, and then to be ascended back to the surface (Heather & Tim, 2022). The steeper terrain and more exposed rock extend the time of glacier ascents and require manoeuvres to be made with safety equipment (Heather & Tim, 2022)

6.2. Permafrost Thawing

About 5 to 6% of Switzerland's surface is formed by permafrost and its depth in the Alps varies from a few meters to several hundred meters (Figure 16). According to a study conducted at the Murtèl-Corvatsc rock glacier (Graubünden), the permafrost temperature at a depth of 23.6 meters has risen in recent years (PERMOS, 2007).

The results showed that thawing permafrost is negatively affecting mountaineering and alpine skiing. Falling rocks can also be a threat to the villages below. In fact, the village of Pontresina (Graubünden) built a dam in 2003 to protect itself from falling rocks and mud (MySwissAlps, n.d.).

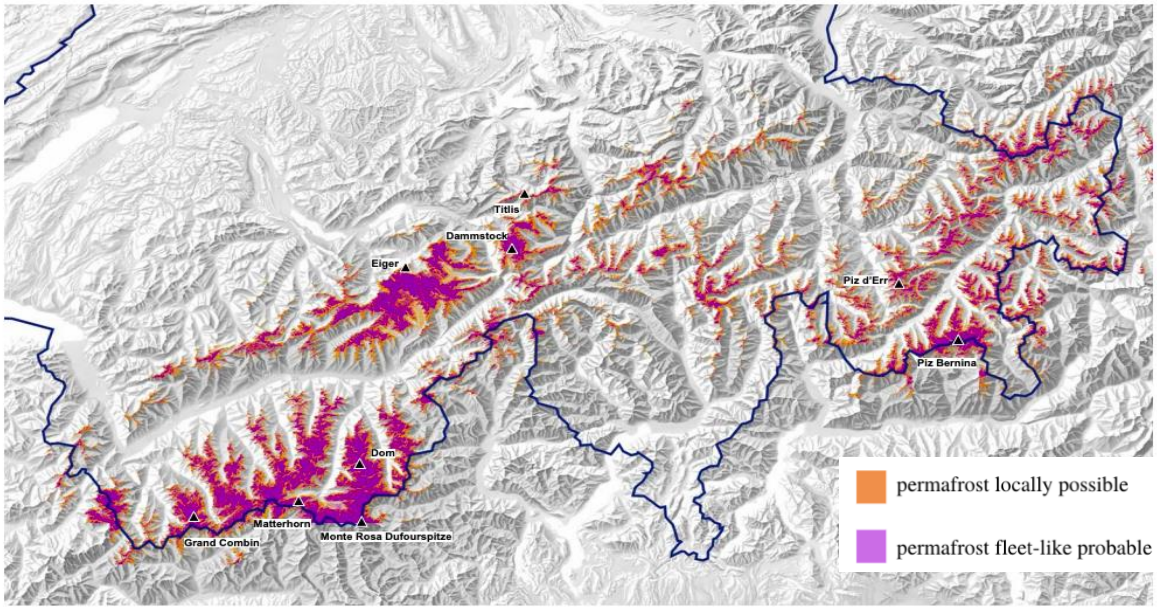

Figure 16: Permafrost mapping on Swiss territory (UFAM, n.d.)

Increasingly Dangerous

Eight interviewees noted that rock falls have become a major threat in the Bernese Oberland and Valais region, leading to an increase in the difficulty of climbs and, in the worst cases, their closure. This was also indicated by Christian Trommsdorff, president of the International Federation of Mountain Guides Associations (Khadka, 2019). According to Dr Charles Harris from the Earth Sciences department at Cardiff University moreover, the main areas in the alps at risk are Switzerland, Austria, France, Germany and Italy and according to guides and mountain rescue managers in Valle d'Aosta, accidents caused by rockfalls, as the terrain is increasingly unstable, have increased during the summer periods (Salim et al, 2019). Some routes that before were considered safe and easy to climb, are now considered too dangerous, mostly in the summer period as in the case of the Matterhorn (Valais) (interviewee 6 and 7). Following the fall of 1000 cubic meters of rock, 90 mountaineers were rescued (summitpost, n.d). This phenomenon has also increased in the Mont Blanc Massif. In the summer of 2003, the most famous route to reach the summit of Mont Blanc by the Grand Couloir du Goûter was closed to climbers due to the extreme heat and the high risk of rockfall (summitpost, n.d). In fact, in 2003, 2013, 2015, 2017 and 2018 it had to be closed due to dangerous rockfall (Kieran, 2018). From 1990 to 2017 an average of 3.7 deaths and 8.5 injuries per summer were registered in this area, the main causes being human error and rockfall (Mourey et al., 2022). According to a study in Valais, 72% of the analysed routes experienced an increase in rockfalls in non-glaciated rock

slopes and a 53% increase in rockfalls in recently deglaciated areas (Mourey et al., 2022).

Optimal Periods for Making an Ascent

The increased risk of rock falls during the summer months has important implications for mountain guides. Freddy Grossniklaus, an international mountain guide coming from the Bernese Oberland, had to change the way he practices his job. As he says “it’s not just the snow disappearing, it's the rocks; some standard routes or north faces, you just can't do safely anymore in the summer" (O'Neil, 2016).

Four respondents noted that the time for climbing north faces is getting shorter and shorter. The thawing of the permafrost is mainly affecting the north faces such as the Eiger’s and the Matterhorn’s. Landslides and rock falls have become increasingly frequent, mostly in summertime. This forces mountaineers to undertake their ascent in the winter and spring months and no longer in the summer months (Hermann, 2012).

Changes of Itineraries

In the worst case, when the situation is really too dangerous, some routes get closed like for example the Oberaarrothorn, reported by interviewees, which can no longer be done. A very interesting study conducted by Temme in 2015 showed how guides book have changed the description of the itineraries over the last 148 years. The study covered the alpine routes in the region Bernese Oberland, in particular the five mountains (Jungfrau, Mönch, Eiger, Finsteraarhorn and Schreckhorn), and focused on 63 routes in particular. The author found that the number of rockfall warnings in the guidebooks have increased over time. Rockfall warnings began to appear around 1960 and have been very prominent since 2000. Half of the 63 routes are considered prone to rock fall and 7 of them do no longer exist because they are considered too dangerous (Temme, 2015). Rockfall due to thawing permafrost is a problem that will increase in the following years and mountaineering routes will increasingly change because they are considered too dangerous and impracticable (Mourey et al, 2019).

6.3. Snow Cover

The analysis from the survey and the interviews indicated that the presence of snow is decreasing, affecting mountaineering and ski mountaineering. The increase in temperatures has led to a rise in the temperature of the zero degree isotherm (meaning the altitude where the temperature is zero degrees), in the last 50 years a rise of 67 meters of the isotherm has been observed every 10 years in the winter months (Scherrer et al., 2004). This causes, as observed by respondent 7, rain to arrive at higher and higher altitudes and ruin the snowpack. Since 1960, there has been a decrease in the amount of snow and the frequency of snowfall on the Plateau and in the Pre-Alps (Müller and Weber, 2007). From 1970 to 2015 m, the duration of snowfall decreased by 8.9 days per 10 years. The winter season starts 12 days later and ends 26 days earlier than in 1970 (Klein et al. 2016).

Snow, ice and mixed routes have been the elements more affected by global warming, whilst the rock routes have been affected to a lesser extent (Mourey et al., 2019). The summer "drying up", i.e. the lack of snow and ice during the summer period is a major issue for guides in the Mont Blanc region following the retreat of the glaciers (Salim et al, 2019). The presence of snow makes climbing some mountains easier and its absence makes rock climbing more difficult and challenging. According to a study conducted in the Mont Blanc area, snow and mixed routes, such as the Whymper couloir on the Aiguille Verte (4 122 m), cannot be climbed in summer anymore because snow and ice melt earlier. This characteristic was also observed by respondents for the gully to Adula, the Fiescherhorn (Bernese Oberland) and the Biancograt (Bernese Oberland), i.e. the ridge of the Piz Bernina, which are not too dangerous to climb in summer. With regard to this latter, there is less and less snow in recent years and its ascent is increasingly difficult and only recommended for experienced mountaineers and via ferrata routes have been installed to limit the number of accidents (Hermann, 2012). North faces, following the melting of the snowpack, are only characterized by bare ice that is more difficult to climb (Mourey et al, 2019).

One element mentioned both in the online questionnaire and during four interviews, concerns an increase in the appearance of crevasses, mostly in the Jungfrau (Valais and Bernese Oberland), and Dufur regions, which influences the difficulty and danger of excursions. According to a study conducted in New Zealand, crevasses appear earlier in summer and at increasingly higher altitudes due to climate change (Mourey, 2022). This is due to the thinning of the snowpack and the melting of the firm. Furthermore, less snow cover results in thinner corridors through crevasses and more open crevasses (Ritter et al, 2012). Given the dangerousness of crevasses during glacier excursions, the time window for making these ascents is reduced (Heather & Tim, 2022). Where crevasses were once rarely present, mountain guides in the Mont Blanc region are observing more and more of them (Mourey et al, 2019), which constitute a considerable danger for mountaineers.

Optimal Periods for Making an Ascent

Variations of the optimal periods for making an ascent due to climate change are less accentuated during the beginning of summer when winter cover is still present. Instead, the worst period is at the end of the summer season or during heat waves. Good and stable periods for alpinists are shifting from summer to spring and autumn (especially for snow, ice and mixed path) (Mourey et al, 2019). According to the mountain guides of the Mont Blanc region, the summer mountaineering season has shifted three weeks earlier than in the 1980s (Mourey et al, 2019). If routes are negotiated in this time window, the difficulty could be the same as always.

In the Mont Blanc region, due to the lack of snow and ice, some routes, such as the Whymper and Couturier couloirs at the Aiguille Verte, can no longer be climbed in summer (Salim et al, 2019).

6.4. How Are People Adapting?

When talking about adaptation to climate change in the mountains, one has to think that the protagonists of this adaptation are mainly mountain guides, mountain lovers and professional sportsmen. Unfortunately, the study of how mountain guides are adapting to changes is a topic that is still under-researched and poorly explored in literature (Salim et al, 2019).

From both the online survey (56%) and the interviews (100%), it becomes clear that respondents are adapting to climate change effects and six are the strategies of adaptation proposed in chapter 4.1.2 (Figure 13); 1) Choose more precisely and carefully the route; 2) Anticipate and reduce the period of trips; 3) Higher level of knowledge and preparation ; 4) Practice of other sports 5) Implement the technical equipment to carry in the mountains; 6) Equip trails with artificial technical equipment. With the term “adaptation” it is meant "a response to a problem whose objective is to reduce the vulnerability of the individuals exposed to profound and rapid disturbances (Simonet, 2015)". Adaptive capacity for an individual consists of both the ability to adopt mechanisms and strategies to deal with a threat (Adger, 2000). For mountain guides, adaptive strategies allow them to increase their resilience (Salim et al, 2019).

Three of the six main adaptation strategies reported by the interviews (anticipate and reduce the period of trips, choose more precisely and carefully the route and practise of other sports) corresponds to those found in a study carried out in the Mont Blanc region, whose aim is to analyse how guides are adapting to the changes brought about by climate change. Salim et al. (2019) also suggest three main strategies of adaptation. The first is called “omni-mobility” and corresponds to the result reported above “choose more precisely and carefully the route” and it consists of changing the route when conditions are not good and then moving to seek better conditions. This strategy was also mentioned by interviewees 2 and 10. According to Apollo and Wengel (2022), climate change can influence mountaineers' choice of destination and push them to choose destinations where conditions are better. The second strategy is called “omni-reactivity” and echoes the result of this study “anticipate and reduce the period of trips is to move activity in the winter period instead of summer”. It is thus becoming more and more classic to practice "summer" mountaineering in December. Respondents 1, 2, 6 and 14 anticipate and shorten their period in which they go mountaineering and ski mountaineering. This strategy is already adopted to a large extent by all those who go mountaineering. The third strategy suggested by Salim et al. (2019) is the "diversification of activity" strategy. In recent years, there has been an increase in other activities practised in the high mountains such as mountain bike, via ferrata, climbing, hiking and trail running, for the more athletic ones. An important element to consider concerns the flexibility of customers in adapting to these new "strategies".

The two other strategies mentioned by the respondents are implementing the technical equipment to carry in the mountains and equipping trails with artificial technical equipment. The latter consists of the use of more artificial technical equipment on the routes. Some examples cited by interviewees concerned the fixed chain to reach the Oberario hut (Bernese Oberland) and a ladder, to which steps are added every year, to reach the Lauteraar hut (Bernese Oberland) and the Konkordia

hut (Bernese Oberland). As a result of the lowering of the glacier, the couloir to reach the Aiguille de l'M (2 844 m a.s.l.) (Chamonix, France) is becoming steeper and more exposed due to rocks from the lateral moraine. To reduce the danger and difficulty caused by the melting of the glacier, abseiling ropes and ladders have been installed. In this way, the route can also be walked in the summer months (Mourey et al, 2019).

7. Conclusion

The aim of this work was to understand whether mountaineers and ski mountaineers perceive the effects of climate change during their excursions in Switzerland, what changes they notice, how these changes influence their way of practicing these sports, how they adapt and what their sensitivity is on this issue. (Ski)mountaineers are in fact the actors who have a first-hand experience of these changes and who can therefore actively contribute to research and discovery on this topic. It is therefore crucial to be able to interview them and understand their point of view.

The research showed that a large number of mountaineers are sensitive, informed and interested in this topic and that almost all those interviewed witness closely the effects of climate change on the Alps. All of them are adapting to the effects of climate change through various strategies.

Many of the numerous benefits that mountains offer to human beings are greatly threatened by climate change. Increases in temperature and changes in precipitation affect water resources through melting glaciers and decreasing snow cover, soil stability through thawing permafrost, increased natural hazards, biodiversity, food security and the mountain-related economic sector. Some of these effects have both a direct and indirect influence on mountaineering and ski touring.

It is scientifically proved that climate change has a direct influence on mountaineering and ski mountaineering. In fact, it increases the danger and technical difficulty related to these sports, and it alters some of their characteristics such as the optimal time to practice, the length of the routes and the routes themselves.

In this research, three main elements have been identified that are influenced by temperature increase and precipitation changes, which are glacier melting, permafrost thawing and decrease in snow and ice cover. These, in turn, lead to changes that directly affect mountaineering and ski mountaineering.

The melting of glaciers in Switzerland is evident and leads to major negative consequences. First of all, an increase in the breaking of seracs has been observed, following high temperatures over a prolonged period, which can be very dangerous and in the worst cases even fatal. Secondly, there is a temporal lengthening of accesses to glaciers, such as the Morteratsch glacier (Graubünden), and to huts, once located at the base of the glaciers, which are in fact negatively affected. Furthermore, the regression of ice masses brings to light steeper moraine terrain with a lot of unconsolidated debris and steep rocks, making the crossing more challenging and dangerous. The retreat of a glacier, as a result of its rock-binding action, in some cases brings to the surface a smooth, polished rock that must be re-equipped for climbing, and in some cases turns out to have higher climbing grades than the rest of the rock. Finally, it has been observed that the decrease in pressure of the glacier against the mountain, as a result of its subsidence, leads to an unstable boulders falling.

The thawing of permafrost in the Swiss Alps is undeniably causing an increase in dangers and accidents. One of the major negative consequences for

(ski)mountaineering concerns the increase in falling boulders and unstable ground conditions. It has been observed that this is particularly evident during the summer period. To limit the damage, for several years now, some routes have been undertaken in the winter months and avoided in the summer months. The thawing of the permafrost has an impact on the north faces. For example, the period for climbing the north faces of the Eiger (Bernese Oberland) and Matterhorn (Valais) is becoming increasingly shorter and concentrated in the winter and spring seasons. In the worst case, when the situation is really too dangerous, some routes are closed. This is the case with the ascent of the Mont Blanc and the Matterhorn, which have been closed in some years during the warmer months.

The increase in temperature and consequently the increase in altitude of the zero-degree isotherm cause a decrease in snow cover and the presence of ice. This has a great effect on the practice of mountain sports. First of all, mountaineering and ski mountaineering require increasingly higher altitudes to search for snow, and the period for finding good snow cover conditions is getting shorter and shorter. Snow, ice and mixed routes are affected the most. This is because some routes that are easy to navigate in the presence of snow, become particularly challenging, if not impossible, in the presence of rock or ice alone, as in the Mont Blanc region. In some cases, via ferrata routes have been installed to facilitate the ascent. The snowpack conditions are particularly deteriorated in the warmer period. Good and stable periods for alpinists are shifting from summer to spring, autumn and winter.

Another relevant factor is that the altitude and size of the crevasses are increasing, especially in the summer period. This is due to the thinning of the snowpack, the melting of the firm and the reduction in snowfall, which results in thinner corridors through crevasses and also more open crevasses. Crevasses pose a great danger to mountaineers.

In this research, it became clear that mountaineers and mountain guides need to adapt to the effects of global warming to reduce their exposure to fatal dangers. Six are the strategies of adaptation highlighted: choosing more precisely and carefully the route, anticipating and reducing the period of trips, developing a higher level of knowledge and preparation, implementing the technical equipment to carry in the mountains, equipping trails with artificial technical equipment and practicing of other sports.

It has been observed that the topic addressed in this research is gaining in importance over the last few years, especially after the Marmolada glacier calving incident on the 3rd of July 2022 due to too much heat. However, the gap to be filled with investigation on this topic is still enormous. Future research in this field would make it possible to limit and prevent damage and dangers to those who practice these sports.

There are several possible expedients, observed during the drafting of the work, that would have made it possible to address the topic more accurately and comprehensively. First of all, the selected research area was too large and dispersed in terms of data collection, making it difficult to get a complete and precise view of

what changes were observed by the interviewees. Instead of focusing on four cantons, i.e. Valais, Ticino, Graubünden and the Bernese Oberland, it would have been optimal to concentrate on just one canton, such as Valais or the Bernese Oberland, or -even better- on one of their sub-areas. This would have allowed to be more precise in the processes of data collection and analysis. Another expedient would have been to focus only on mountaineering and leave out ski mountaineering.

It would also be interesting to do a totally focused analysis on how climate change affects mountain huts in Switzerland. In this research, only two hut builders were interviewed, not enough to get an objective view of what is the effect of global warming on huts in Switzerland. Further research directions could therefore investigate this topic in more details.

30 July 2022

8. Bibliography

Adger W. N., (2000). *Social and ecological resilience: are they related*?. Progress in Human Geography 24(3) pp. 347–364

Alley R. et al. (2007). *Climate Change 2007: I Principi Fisici di Base*. IPCC.

Amitrano, D., Gruber, S. and Girard, L. (2012). *Evidence of frost-cracking inferred from acoustic emissions in a high- alpine rock-wall.* Earth and Planetary Science Letters, 341–344, 86–93.

Amstrong, M. (2021). *These are the world's most dangerous mountains.* https://www.weforum.org/agenda/2021/12/mountains-danerous-deadly-expedition-hiking/

Apollo, M. (2017). *The true accessibility of mountaineering: The case of the High Himalaya*. Journal of Outdoor Recreation and Tourism, 17, 29–43. https://doi.org/10.1016/j.jort.2016.12.001

Apollo, M. & Andreychouk, V. (2022). *Mountaineering Adventure tourism and local communities: Social, environmental and economic interactions*. Cheltenham: Edward Elgar Publishing.

Apollo, M. & Wengel, Y. (2022). *Mountaineering Tourism*. A critical perspective.

Aubel, O. et al. (2021). *Dati e statistiche*. I climber sotto la lente. Outdoor magazine.

Barber, R. (1993). *Pilgrimages*. The Boydell Press.

Beedie, P. & Hudson, S. (2003). *Emergence of mountain-based adventure tourism*. Annals of Tourism Research, 30(3), 625–643.

Beniston, M. (2003). *Climatic change in mountain regions: A review of possible impacts*. Climatic Change 59(1), 5–31.

Beniston, M. et al. (1994). *An analysis of regional climate change in Switzerland.* Theoretical and applied climatology, 49(3), 135-159

Blair, R. (1994). *Moraine and valley wall collapse due to rapid deglaciation in Mount Cook National Park, New Zealand*. Mountain Research and Development 14(4):347–358.

Bommer, C. et al. (2012). *Costruire sul permafrost.* Guida pratica.

Bortolan, L. et al. (2021). *Ski Mountaineering: Perspectives on a Novel Sport to Be Introduced at the 2026 Winter Olympic Games*.

Brocard, E. et al. (2013). *Upper air temperature trends above Switzerland 1959–2011*. J. Geophys. Res. Atmos., 118(10): 4303–4317. http:// dx.doi.org/10.1002/jgrd.50438.

Buckley, R. (2000). *Tourism in the most fragile environments.* Tourism Recreation Research, 25(1), 31–40.

Carlson, B. (2018). *Un avenir incertain pour le lagopède alpin*.

Chu, Q., Grühn, D., & Holland, A. M. (2018). *Life is short – Make a bucket list: How age and time horizon impact motivations.* Innovation in Aging, 2(1), 754.

Cole, D. N. (1993). *Minimizing conflict between recreation and nature conservation.* In D. S. H. P. C. Smith (Ed.), Ecology of greenways: Design and function of linear conservation areas (pp. 105–122). University of Minnesota Press.

Collins, M. et al. (2013). *Long-term climate change: Projections, commitments and irreversibility*. In T.F. Stocker, D. Qin et al. Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 1029–1136. Cambridge, UK, and New York, NY, USA, Cambridge University Press.

Dangi, T., Birendra, K. C., & Gautam, L. (2021). *History of tourism planning and development in Nepal: Achievements and challenges to sustainable future tourism*. In D. Stylidis & B. Seetanah (Eds.), Tourism planning and development in South Asia (pp. 42–62). CABI.

Dawson, L.W. (1997). *Wild Snow*. Salt Lake City, UT, USA: AAC PRESS. House, S., & Johnston, S. (2014). Training for the New Alpinism: A Manual for the Climber as Athlete. Ventu, CA, USA: Patagonia Books.

Debarbieux, B. et al. (2014*). Tourism in mountain regions: Hopes, fears and realities Sustainable Mountain Development Series*. UNIGE, CDE, SDC.

Dewey, J. F., & Burke, K. (1973). *Tibetan, Variscan and Precambrian basement reactivation: Products of continental collision.* The Journal of Geology, 81,683–692.

Dorrance, M. J., Savage, P. J., & Huff, D. E. (1975*). Effects of snowmobiles on white-tailed deer.* The Journal of Wildlife Management, 39(3), 563–563. https://doi.org/10.2307/3800399

Douglas, E. et al. (2011). *Mountaineers*. Great Tales of Bravery and Conquest. Milano: Gribaudo

Ells, M. D. (1997). *Impact of Human Waste Disposal on Surface Water Runoff The Muir Snowfield, Mount Rainier*. Journal of Environmental Health, 59(8), 6–12. http://www.jstor.org/stable/44533135

Elmes, M., & Barry, D. (1999). *Deliverance, denial, and the death zone: A study of narcissism and regression in the May 1996 Everest climbing disaster*. Journal of Applied Behavioral Science, 35(2), 163–187. https://doiorg/10.1177/0021886399352003

Eng, R. C. (2010). *Mountaineering: The Freedom of the Hills*. Mountaineers Books. Engel, C. E. (1950). A history of mountaineering in the Alps. George Allen & Unwin

Ewert, A. (1985). *Why people climb: The relationship of participant motives and experience level to mountaineering.* Journal of Leisure Research, *17*(3), 241–250.

FAO. (2003). *Towards a GIS-based analysis of mountain environments and populations*. Environment and Natural Resources Working Paper, No. 10. Rome, Italy, FAO.

Federal Office For The Environment (FOEN). (2020). *Management summary: Climate change in Switzerland* - Indicators of driving forces, impact and response.

Federal Statistical Office (FSO). (2020). *Switzerland's population in 2020*

Fidelus, J. (2016). *Slope transformations within tourist footpaths in the northern and southern parts of the Western Tatra Mountains* (Poland, Slovakia). Zeitschrift fur Geomorphologie, 60, 139–152.

Formenti, N. et al. (2015). *Increased hormonal stress reactions induced in an alpine black Grouse (Tetrao tetrix) population by winter sports*. Journal of Ornithology, 156(1), 317–321.

Gallagher, S. A., & Hackett, P. H. (2004). *High-altitude illness*. Emergency Medicine Clinics of North America, 22(2), 329–355, viii. https://doi. org/10.1016/j.emc.2004.02.001

Gatterer. H. (2019). *Mortality in Different Mountain Sports Activities Primarily Practiced in the Summer Season—* A Narrative Review.

Gawlik, A. et al. (2021). *Pilgrimage tourism to sacred places of the high Himalaya*. In G. Nyaupane & D. Timothy (Eds.), Tourism and sustainable development in the Himalayas: Social environmental, and economic encounters. Routledge.

Gilbert, A. & Vincent, C. (2013). *Atmospheric temperature changes over the 20th century at very high elevations in the European Alps from englacial temperatures*. Geophys. Res. Lett., 40(10): 2102–2108.

Godde, P. M. (1999). *Tourism and development in mountain regions*. CABI.

Goudie, A. S. (2004). *Encyclopedia of geomorphology*. Routledge.

Haeberli W., Cihlar J., Barry R.G. (2000). *Glacier monitoring within the Global Climate Observing System*. Annals of Glaciology, 31: p. 241–246

Haeberli, W. et al. (2011). *Mountain permafrost: development and challenges of a young research field*. Journal of Glaciology, 56, 1043–1058.

Hansen, P. H. (2013). *The summits of modern man*. Harvard University Press.

Hantel, M. & Hirtl-Wielke, L.-M. (2007). *Sensitivity of Alpine snow cover to European temperature.* Int. J. Climatol., 27(10): 1265–1275.

Hartmann, D.L., et al. (2013). *Observations: Atmosphere and surface*. In T.F. Stocker et al. Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 159–254. Cambridge, UK, and New York, NY, USA, Cambridge University Press

Hattingh, G. (2000). *The climber's handbook*. New Holland Publishing. Heather, P. (2013). Glacier retreat and tourism: Insights from New Zealand. Mountain Research and Development, 33(4), 463–472.

Heather, P & Tim, K. (2022). *Aoraki Mount Cook: Environmental Change on an Iconic Mountaineering Route*. Mountain Research and Development, 38(4): 364-379. International Mountain Society.

Hoelzle, M., Vonder Mu¨hll, D.D. and Haeberli, W. (2002).*Thirty years of permafrost research in the Corvatsch-Furtschellas area*. Eastern Swiss Alps: a review. Norsk Geografisk Tidsskrift, 56, 137–145

Hoibian, O. (2016). *A cultural history of mountaineering and climbing*. In L. Seifert, P. Wolf, & A. Schweizer (Eds.), The Science of Climbing and Mountaineering. Routledge.Huss, M. & Farinotti, D. 2012. Distributed ice thickness and volume of all glaciers around the globe. J. Geophys. Res., 117(F4): 1–10.

IPCC. (2021). *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

Johnston, B. R., & Edwards, T. (1994). *The commodification of mountaineering*. Annals of Tourism Research, 21(3), 459–478.

Joly M., Ungureanu E. I. (2018). *Global warming and skiing: analysis of the future of skiing in the Aosta Valley. Worldwide* Hospitality and Tourism Themes

Kelliher, K. (2014). *An examination of governmental and nongovernmental organizations in Nepal: A partnership in managing and eliminating waste in the Solukhumbu.* Bates College

Kiełkowska, M., & Kiełkowsk, J. (Eds.). (2013). *Wielka encyklopedia gór i alpinizmu.* Wydawnictwo Stapis.

Kohler, T. & Maselli, D . (2009). *Mountains and Climate Change—From Understanding to Action*. Produced with an international team of contributors. Bern, Switzerland Geographica Bernensia and Swiss Agency for Development and Cooperation.

Kohler, T., Wehrli, A. & Jurek, M. (2014). *Mountains and climate change: A global concern. Sustainable Mountain Development Series*. Bern, Switzerland, Centre for Development and Environment (CDE), Swiss Agency for Development and Cooperation (SDC) and Geographica Bernensia. 136 pp.peration (SDC) and Geographica Bernensia. 136 pp.

Kowalewski, Z., & Kurczab, J. (1983). *Na szczytach Himalajów*. Sport i Turystyka.

Kulakowski, D. & Bebi, P. (2004). *Range of variability of unmanaged subalpine forests*. Forum für Wissen, 2004: 47–54. FOEN. c2005–2014. Nac

Lama, W. B., & Sattar, N. (2004). *Mountain tourism and the conservation of biological and cultural diversity*. In M. Price, L. Jansky, & A. Iatsenia (Eds.), Key issues for mountain areas (pp. 111–148). Tokyo: United Nations University Press

Langdon, M. K. (2000). *Mountains in Greek religion*. The Classical World, 93(5), 461–470.

Lenoir, J. et al. (2010). *Cross-scale analysis of the region effect on vascular plant species diversity in southern and northern European mountain ranges*. PLoS ONE, 5(12): 1–13.

Lester, J. (2004). *Spirit, identity, and self in mountaineering*. Journal of Humanistic Psychology, 44(1), 86–100.

Lew, A. A., & Han, G. (2015). *A world geography of mountain trekking*. In G. Musa, J. Higham, & A. Thompson-Carr (Eds.), Mountaineering tourism (pp. 19–39). Routledge.

Luks, A. M. et al. (2010*). Wilderness Medical Society consensus guidelines for the prevention and treatment of acute altitude illness.* Wilderness & Environmental Medicine, 21(2), 146–155.

Luperini, C. (n.d.). *Storia dell'alpinismo*.

Macfarlane, R. (2003). *Montagne della mente*. Storia di una passione. Torino:Einaudi

Macfarlane, R. (2009). *Mountains of the mind: Adventures in reaching the summit*. Knopf Doubleday Publishing Group.

Marek, A. & Wieczorek, M. (2015). *Tourist traffic in the Aconcagua massif area*. Quaestiones Geographicae, 34(3), 65–76.

Martinescu-Badalan, F. & Stanciulescu, R., (2019). *History and debut of the ski-mountaineering*. Scientific Bulletin. Vol. XXIV, No 1 (47).

Messerli, B., & Ives, J. (1997). *Mountains of the world: A global priority*. Parthenon Publishing.

Meybeck, M., Green, P. & Vörösmarty, C. (2001). A new typology for mountains and other relief classes. Mt. Res. Dev., 21(1): 34–45.

Mitchell, J. F., (1989). *"The "greenhouse" effect and climate change". Reviews of Geophysics*, *27*(1), 115-139.

Molden, D. & Sharma, E. 2013. ICIMOD's Strategy for delivering high-quality research and achieving impact for sustainable mountain development. Mt. Res. Dev., 33(2): 179–183.

Mourey, J. et al. (2018). *Accidentology of the normal route up Mont Blanc between 1990 and 2017*. Grenoble, France: Fondation Petzl.

Mourey, J. et al. (2019). *Effects of climate change on high Alpine mountain environments: Evolution of mountaineering routes in the Mont Blanc massif (Western Alps) over half a century*. Arctic, Antarctic, and Alpine Research, 51:1, 176-189, DOI: 10.1080/15230430.2019.1612216

Mourey J. & Ravanel L. (2017). *Évolution des itinéraires d'accès aux refuges du bassin de la Mer de Glace (massif du Mont Blanc, France).* Journal of Alpine Research | Revue de géographie alpine (105–4),

Mu, Y., Nepal, S. K., & Lai, P.-H. (2019). *Tourism and sacred landscape in Sagarmatha (Mt. Everest) National Park, Nepal*. Tourism Geographies, 1–18.

Müller H. e Weber F. (2007). *Klimaänderung und Tourismus: Szenarien für das Berner Oberland 2030*. Berna.

Nepal, S. K. (2000). Tourism in protected areas: The Nepalese Himalaya. Annals of Tourism Research, 27(3), 661–681.

Noe, F. P., Hammitt, W. E., & Bixler, R. D. (1997*). Park user perceptions of resource and use impacts under varied situations in three national parks*. Journal of Environmental Management, 49(3), 323–336.

Office fédéral de la statistique (OFS). (2021). *Dati chiave - Panoramiche cantonali 2021*. Atlante statistico della Svizzera

ONERC (Observatoire National sur les Effects du Réchauffement Climatique). (2008). *Climate change and resulting impacts in the Alps*. Paris: ONERC, 95 p.

Palomo, I. (2017). *Climate change impacts on ecosystem services in high mountain areas: A literature review*. Mountain Research and Development, 37(2), 179–187, 179.

Pescott, O. L., & Stewart, G. B. (2014). *Assessing the impact of human tram- pling on vegetation: A systematic review and meta-analysis of experimental evidence*.

Price, M., Wachs, T., & Byers, E. (1999). *Mountains of the world: Tourism and sustainable mountain development*. Institute of Geography, University of Berne.

Procter et al. (2016). *Burial duration, depth and air pocket explain avalanche survival patterns in Austria and Switzerland.*

Pugh, L. G. (1962). *Physiological and medical aspects of the Himalayan scientific and mountaineering expedition*, *1960–61*. British Medical Journal, 2(5305), 621–627.

Purdie H., Gomez C., Espiner S. (2015). *Glacier recession and the changing rockfall hazard: Implications for glacier tourism.* New Zealand Geographer 71(3) pp. 189–202 Purdie

Radwańska-Paryska, Z. & Paryski, H.W. (1995). *Wielka Encyklopedia Tatrzańska*. Wyd. Górskie.

Rehnus, M., Wehrle, M., & Palme, R. (2014). *Mountain hares Lepus timidus and tourism: Stress events and reactions. Journal of Applied Ecology,* 51(1), 6–12.

Reinhard, M., et al, (2005). *Recent climate change: Rethinking drought in the context of Forest Fire Research in Ticino, South of Switzerland*. Theoretical and Applied Climatology, 82(1-2), 17-25.

Ritter, F., Fiebig, M., and Muhar, A., S. (2012). *Impacts of Global Warming on Mountaineering: A Classification of Phenomena Affecting the Alpine Trail Network*. Mountain Research and Development, 32(1) : 4-15 Published By: International Mountain Society

Salim, E. et al. (2019). *Mountain guides facing the effects of climate change. What perceptions and adaptation strategies at the foot of Mont Blanc?.* Journal of Alpine Research | Revue de géographie alpine [Online], 107-4 | 2019, Online since 26 August 2019, connection on 21 September 2021. URL:

Scherrer S.C., Appenzeller C., Laternser M. (2004). *Trends in Swiss Alpine snow days: The role of local-and large-scale climate variability.* Geophys. Res. Lett., 31, L13215, doi:10.1029/2004GL020255.

Sharma, E. & Molden, D. (2014). *The Himalayas: A hotspot for climate change*. In S. Varadarajan, ed. The Hindu survey of the environment: Himalayas, the challenge, pp. 14–19. Chennai, Madras, India, The Hindu.

Shinde, A. K., Olsen, D. H. (2020). *Religious Tourism and the Environment.* Cabi.

Sitch, S. et al, (2005). *"Impacts of future land cover changes on atmospheric CO2 and climate". Global Biogeochemical Cycles*, *19*(2).

Stadelmann, G. et al. (2013). A predictive framework to assess spatio-temporal variability of infestations by the European spruce bark beetle. Ecograp., 36(11): 1208–1217. http://dx.doi.org/10.1111/j.1600-0587.2013.00177.x.

Stretton, J. (2019). How Climate Change is Affecting the Alps. https://runthealps.com/how-climate-change-is-affecting-the-alps/

Szymczak, R. (2009). Wpływ przewlekłej hipoksji wysokogórskiej na wybrane parametry życiowe organizmu człowieka. Uniwersytet Gdański. Gdańsk.

Temme, A. J. A. M. (2015). *Using climber's guidebooks to assess rock fall patterns over large spatial and decadal temporal scales: an example from the swiss alps*. Geografiska Annaler: Series A, Physical Geography, 97:4, 793-807, DOI: 10.1111/geoa.12116

Thurnell-Read, T. (2017). *'What's on your Bucket List?':Tourism, identity and imperative experiential discourse.* Annals of Tourism Research, 67, 58–66.

Vaks, A. et al. (2013*). "Speleotherms Reveal 500,000-Year History of Siberian Permafrost*," Science, April 12, 2013: Vol. 340 no. 6129 pp. 183-186, doi: 10.1126/science.1228729

Vaughan, D.G et al. (2013). *Observations: Cryosphere*. In T.F. Stocker, et al. Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 317–382. Cambridge, UK, and New York, NY, USA, Cambridge University Press.

Volken, M. et al (2007). *Backcountry Skiing: Skills for Ski Touring and Ski Mountaineering*. Outdoor Expert Series. The Mountaineers Books. p. 339. ISBN 978-1594850387.

West, J. et al. (2012). *High altitude medicine and physiology (5th ed.).* CRC Press.

Westensee, J. et al. (2013). *Mountaineering fatalities on Aconcagua: 2001–2012*. High Alt. Med. Biol. 14, 298–303

Willig, C. (2008). A phenomenological investigation of the experience of taking part in 'extreme sports'. *Journal of Health Psychology*, 13(5), 690–702.

Wilson, M. H., Newman, S., & Imray, C. H. (2009). *The cerebral effects of ascent to high altitudes*. Lancet Neurology, 8(2), 175–191.

Winkler et al. (2018). Sport di montagna in inverno. Bern: Edizioni del CAS

Ziegler, A. D. et al. (2021). *A call for reducing tourism risk to environmental hazards in the Himalaya*. Environmental Hazards.

Zurick, D. N. (1992). *Adventure Travel and sustainable tourism in the peripheral economy of Nepal*. Annals of the Association of American Geographers, 82(4), 608–628.

9. Webliography

AlpenWild. (n.d.). *Swiss Alps*. 4th August 2022 from https://www.alpenwild.com/staticpage/swiss-alps/

Bomio, M. (2007). *Climate Witness: Marco Bomio, Switzerland.* 4th August 2022 https://wwf.panda.org/wwf_news/?110300/Climate-Witness-Marco-Bomio-Switzerland

Britannica, T. (2013). *Valais*. *Encyclopedia Britannica*. 4th August 2022 from www.britannica.com

Britannica, T. (2016) *Graubünden*. *Encyclopedia Britannica*. 4th August 2022 from www.britannica.com

Britannica, T. (2019). *Bernese Alps*. *Encyclopedia Britannica*. 4th August 2022 from www.britannica.com

Brown, P. (2001). *Melting permafrost threatens Alps.* 4th August 2022 from www.theguardian.com

CREA Mont-Blanc. (n.d.). *Climate change and its impacts in the alps*. www.creamontblanc.org

EEA (European Environment Agency). (n.d.). *The Alpine region*. 4th August 2022 from www.eea.europa.eu/the

European Geosciences Union. (2019). *More than 90% of glacier volume in the Alps could be lost by 2100.* 4th August 2022 www.egu.eu

History Cooperative. (2019). *Reaching for the Heavens: The History of Mountaineering.* 4th August 2022 www.historycooperative. org

IFMGA (n.d.). *What is a professional Mountain guide.* 4th August 2022 www.ifmga.info

Iperpaesaggi. (2016). *Morfologia del Ticino*. 4th August 2022

Khadka, N., S. (2019). Climate change 'making mountaineering riskier'. 4th August 2022 https://www.bbc.com

Kieran. B. (2018). Mont Blanc's Gouter route at risk of closure: Heatwave increases risk of rockfall in Grand Couloir. 4th August 2022 https://www.seechamonix.com

Kiesinger, C., D. & Smith, G., A. (2020). *"mountaineering".* Encyclopedia Britannica. 4th August 2022 https://www.britannica.com

MySwissAlps. (n.d.). *Global warming in Switzerland.* WWW.MYSWISSALPS.COM

National Geographic. (2011). *Mountaineering: Height Doesn't Matter*. 4th August 2022 from www.youtube.com

Olympics. (n.d.). *Ski mountaineering*. 4th August 2022 from www.olympics.com

O'Neil, D. (2016). *How Climate Change Is Making Mountaineering More Dangerous: Rising temperatures are increasing rockfall danger, and alpinists are already starting to see the new risks.* 4th August 2022 from www.outsideonline.com

Ski-si-snowboard. (2014). *Istoria schiului. De la legende până azi.* 4th August 2022 from www.ski-si-snowboard.ro

SLF. (n.d). *Statistiche pluriennali*. 4th August 2022 from www.slf.ch

Summitpost. (n.d.) *A short introduction to the history of mountain guiding*. www.summitpost.org

Summitpost. (n.d.). *The fall of the alps*. www.summitpost.org

Swissinfo. (2018). *Drought-affected Alpine pastures get emergency help*. www.swissinfo.ch

Turuban, P. (2020). The importance of 'white gold' to the Alpine economy. 4th August 2022 from https://www.swissinfo.ch

UFAM (Ufficio federale dell'ambiente). (2017). *Rischi e opportunità legati al cambiamento climatico*. 4th August 2022 from www.bafu.admin.ch

UFAM[1] (Ufficio federale dell'ambiente). (n.d.). 4th August 2022 from *The Alps*. www.eda.admin.ch

UFAM[2] (Ufficio federale dell'ambiente). (n.d.). 4th August 2022 from *Alpine Convention*. www.eda.admin.ch

UFAM[3] (Ufficio federale dell'ambiente). (n.d.) *Language – facts and figures*. 4th August 2022 from www.eda.admin.ch

Unesco. (n.d.). *Alpinism*. 4th August 2022 from www.unesco.org

Varotti, C. (2021). *Vette sublimi e spazi selvaggi*. 4th August 2022 from www.site.unibo.it

10. Annexes

Annex 1

Question intewiev

1. First Name
2. Surname
3. Age
4. Sex
5. In Which country do you live?
6. Profession?
7. What is your connection with the mountains?
8. What motivates you to go to the mountains?
9. How many years have you been practicing sports in the mountains?
10. What sports do you practice in the mountains?
11. Mountaineering: in which region do you usually go?
12. Ski Mountaineering: in which region do you usually go?
13. Do you think mountain sports are under threat? Which sports? Which threat
14. How do you consider your knowledge about climate change? (0=no knowledge about climate change, 6=climate change expert)
15. Do you think climate change has an effect on mountaineering and ski mountaineering?
16. In the last year, have you experienced the following change during your mountaineering and ski mountaineering excursions in the region of Bernese Oberland, Graubünden and Valais/Ticino due to altered climatic conditions?
    a. Itineraries
    b. Distance of itineraries
    c. Technical difficulty of itineraries

d. Snow cover
e. Optimal periods for making an ascent for mountaineering
f. Stability of the soil
g. Avalanche
h. Incident and danger
i. Number of mountaineering and ski mountaineering excursions
j. Other ?

17. In Ticino ?
18. In Valais ?
19. In Graubünden ?
20. Oberland Bernese ?
21. Do you think you are already adapting to these changes during your mountaineering and ski mountaineering trips? How?
22. Do you think there is enough knowledge/information/awareness and prevention about the effect of climate change on mountaineering and ski mountaineering?
23. what will mountaineering and ski mountaineering look like in 2050?
24. What measures do you think should be taken to limit these changes?
25. How can mountaineering be done in a more sustainable way? And what you are already doing