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Research Article

Climbing the Alps in a warming world: Perspective of climate change impacts on high mountain areas influences alpinists' behavioural adaptations

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ABSTRACT

Climate change is having a major impact on high mountain areas, with glacier retreat and permafrost warming. Alpinism is deeply affected by this changing environment, which increases the technicality of the routes, their dangers, and the uncertainty of the periods of suitable climbing conditions during the summer. This raises the question of how recreational alpinists perceive and adapt to changing conditions. To answer this question, this paper reports the results of a quantitative social media survey of European alpinists based on the substitutability theory. The results from the 1071 completed questionnaires show that climate change and its impacts are clearly observed and identified by recreational alpinists; the higher the awareness of the changes, the more likely they are to engage in adaptation behaviours such as temporal, activity and spatial substitution, and informational coping. Furthermore, the more respondents perceive that climate change is affecting their practice in terms of degraded routes, increased risk, or increased frequency and magnitude of rockfalls, the more they engage in adaptation behaviours. Although adaptation seems to be sufficient to ensure satisfactory practice conditions, the development of communication for less informed alpinists, as well as the development of climate services, could be valuable to ensure sustainable and safe practices.

Management implications: Recreational alpinists' awareness of the impacts of climate change on alpinism increases their adoption of substitution and coping behaviours. The results highlight the importance for alpine organisations to communicate research on high mountain changes, especially to novice or occasional alpinists who may be less informed. The results also suggest the importance of high mountain climate services to support decision making. This could include proposing maps and topographical guides that specifically show how climate change will affect the most frequently used routes, or developing indicators such as the Rockfall Susceptibility Index.

1. Introduction

In 1787, the Geneva Naturalist Horace-Benedict de Saussure reached the summit of the Mont Blanc, the highest point in the European Alps (4808m). The previous year, Jacques Balmat and Gabriel Paccard discovered and opened the first route to the summit from the Chamonix Valley. These events are often regarded as the birth of alpinism (Joutard, 1986). This first ascent was motivated by scientific reasons. Soon after, the practice of alpinism grew with the idea of sport and the aim of reaching summits for themselves (Hoibian, 2008). In the decade 1854–1865, almost all peaks over 4000m in the Alps were reached (Hoibian et al., 2002). This paved the way for contemporary alpinism, which is now on the UNESCO Intangible Heritage List (Debarbieux, 2020).

Alpinism is often confused in the literature with mountaineering. However, we distinguish between alpinism, which is defined as "the art of climbing summits and walls in high mountains, in all seasons, in rocky or icy terrain, using one's own physical, technical and intellectual abilities, and using appropriate techniques, equipment and highly specific tools" (UNESCO, 2019, p. 4) from mountaineering activities, which can include guided treks or high-altitude hikes (Pomfret, 2006). In this paper, alpinism refers to the first definition. Alpinists constitute an informal community, although many of them are structured into associations and clubs, the exact number of which is difficult to determine.

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Some practitioners are members of an Alpine Club, but this is not mandatory. UNESCO (2019) estimates that in 2019, alpinists in France, Italy, and Switzerland–the three countries that applied for UNESCO inscription–represent around 700 000 practitioners, including around 5000 mountain guides.

The pursuit of Alpinism activities is based on a common body of knowledge linked to the history of ascents and routes to the summits. These routes are documented in guidebooks, some of which are cultural and historical references for alpinists (*e.g.*, Rébuffat, 1973; Labande, 1991). More recently, the use of social media platforms has led to the development of community sites (e.g. camptocamp.org, gulliver.it, hikr.org), where route information is updated by users. Alpinism is pursued in high mountain areas, peaks and route (Salim, Mourey, Ravanel, Picco, & Gauchon, 2019). Accordingly, the activity is highly dependent on environmental conditions.

However, because of the severity of climate change in high mountain areas (IPCC, 2019), these environments are changing rapidly, particularly owing to glacier retreat (Rounce et al., 2023) and permafrost degradation (Etzelmüller et al., 2020). For example, access to mountain huts has become increasingly difficult because of the geomorphological processes associated with deglaciation (Mourey, Ravanel, Lambiel, Strecker, & Piccardi, 2019). Historic alpinism routes can also be more difficult, and some have disappeared from the Mont Blanc massif (France, Italy, and Switzerland; Mourey, Marcuzzi, Ravanel, & Pallandre, 2019) and Valais (Switzerland; Mourey et al., 2022 a) because of glacier retreat and permafrost degradation. These impacts already influence mountain guide activities (Salim et al., 2019) and mountain recreationists (Pröbstl-Haider, Hödl, Ginner, & Borgwardt, 2020). In the context of these changes, substitution behaviour is important for alpinists to ensure that they do not undertake routes in poor conditions, which would substantially increase their exposure to risk (Mourey, Ravanel, & Lambiel, 2022 b).

Although no link has yet been established between the effects of climate change on mountain environments and accident rates in mountain sports such as alpinism (Vanpoulle, Soulé, Boutroy, & Lefèvre, 2021), previous studies have shown that clients of mountain guides can be reluctant to change their behaviour according to the local environmental conditions, leading to increased difficulties and risks for clients and guides (Mourey, Perrin-Malterre, & Ravanel, 2020; Salim et al., 2019). Accordingly, it seems important to understand how the substitution behaviours of alpinists are driven by the way they perceive changes in their environment in order to increase the dissemination of knowledge in favour of safety. Therefore, the aim of this paper is to propose a first approach to understand the perspectives of recreational alpinists on the impact of climate change on their practice environment and how it influences their behaviour. The research is based on an online survey disseminated through social media platforms, targeting recreational alpinists practising in the European Alps.

2. Literature review

This section reviews the literature on the practice of alpinism facing climate change and substitution behaviour.

2.1. Alpinism and climate change

High mountain environments are rapidly evolving due to climate change (Beniston et al., 2018; IPCC, 2019). Permafrost degradation (Etzelmüller et al., 2020), glaciers retreat (Hugonnet et al., 2021) and ice aprons melt (Kaushik et al., 2022) involve numerous processes that affect alpinism routes and modify their climbing parameters. For the Austrian Alps, Ritter, Fiebig, and Muhar (2012), through a questionnaire sent to mountaineering professionals, identified 22 processes related to climate change that affect mountaineering, which can lead to an increase in their danger, technical difficulty, and a change in the periods when they can be climbed in relatively good conditions. For the Bernese Alps (Switzerland), Temme (2015) showed, by comparing guidebooks, that there is an increase in rockfall frequency. For the Southern Alps of New Zealand, Purdie and Kerr (2018) have shown that glacier melt has made the classic route up Mt. Cook (3724 m a.s.l.) technically more difficult and the favourable period for its ascent shorter.

For the Mont Blanc massif, Mourey, Marcuzzi et al. (2019) studied the evolution of the routes described in Rébuffat's iconic guidebook *The Mont-Blanc massif: the 100 finest routes* (1973). The authors identified 25 geomorphological or glaciological processes caused by climate change that affect and modify alpinism routes and their climbing parameters, such as glacial retreat and the appearance of bedrock, tills or moraines, glacier surfaces more often in bare ice, an increase in the frequency of rock destabilisation in unglaciated rockwalls, or an increase in the slope angle of ice aprons. On average, each of the 95 routes studied was affected by nine different processes, leading to an increase in technical difficulty, danger, and a shift in the period of good climbing conditions from summer to spring and autumn. In 27.0% of the routes studied, the level of difficulty and/or danger increased to such an extent that they were no longer accessible in summer. In the Valais Alps, Mourey et al., 2022b mapped climate change-related processes affecting alpinism routes and found similar results to those for the Mont Blanc massif, with an average of nine processes affecting each route, 25.0% of which are no longer accessible in summer.

Overall, climate change makes alpinism route more difficult because of increasing slope angle in ice-based and glacier routes (Mourey, Marcuzzi, et al., 2019; Purdie & Kerr, 2018), or rock-based routes where glacier thickness lead to the appearance of new extensions of high difficulty level (Mourey, Marcuzzi, et al., 2019). The timing of the practice is also changing due to inadequate route conditions in summer caused by lack of snow on ice-based and mixed routes (Salim et al., 2019; Temme, 2015), or because of an increase in the frequency and magnitude of rockfalls in summer and especially during heat waves (Ravanel, Magnin, & Deline, 2016). These changes in the practical conditions of alpinism make it more difficult for mountain guides to deal with uncertainty (Mourey et al., 2020; Rushton & Rutty, 2023), but may also increase the way in which recreational alpinists are exposed to risk.

In this context, alpinists must consider these increasingly restrictive changes and adapt their behaviour (Mourey et al., 2020; Pröbstl-Haider, Dabrowska, & Haider, 2016). This is particularly true when considering the different types of summer alpinism that exist: 'rock alpinism', which consists mainly of climbing rock routes; 'snow/ice alpinism', which consists of climbing routes such as snow couloirs, ice gullies or long glacier walks; and 'mixed alpinism', which combines the two previous configurations in a single route. We also use the terms 'sport climbing' to describe outdoor climbing with belaying equipment in place, and 'traditional climbing' to describe outdoor climbing without belaying equipment and where climbers provide their own protection.

2.2. Substitution behaviour

Research on outdoor recreation has sought to understand what happens when recreationists are unable to engage in activities that satisfy them because of various constraints (Brunson & Shelby, 1993; Gentner & Sutton, 2008). Constrained recreationists choose to find alternatives to achieve the desired outcomes (Brunson & Shelby, 1993). First development of the substitutability theory by Iso-Ahola (1986) suggests that substitution occurs in the short term and not in the preparation of the activity. In other words, the author suggests that the substitutability theory be applied after the recreationist has chosen an activity and is informed that the activity is not available. Substitutability theory also suggests that when a recreationist is unable to participate in the planned activity, he/she will adapt by choosing a substitution activity (changing the activity), a temporal substitution (doing the same activity at a different time) or a spatial substitution (doing the same activity elsewhere) (Iso-Ahola, 1986). Recreation substitution is a concept used to understand how people adapt or cope with changes in

their recreational landscapes (Aas & Onstad, 2013).

Different factors influence the adoption of substitution behaviour. For example, Propst and Koesler (1998) found that women are more intuitive than men and adopt more recreational coping than men in long-term outdoor practices. Ditton and Sutton (2004) found the opposite regarding activity substitution in the specific case of recreational fishing. They also found that age had a positive influence on the adoption of activity substitution. Furthermore, Miller and McCool (2003) have demonstrated the existence of a relationship between stress levels and coping responses, with low levels of stress corresponding to cognitive adaptation rather than substitution when stress levels are higher.

Individual characteristics are also considered in the literature to explain substitution behaviour. In the context of ski in the U.S Northeast ski region, Dawson, Havitz, and Scott (2011) concludes that high involved skiers are more likely to substitute than low involved skiers. Moreover, in the context of ski in Ontario (Canada), Rutty et al. (2015) found that beginners and infrequent skiers are more likely to ski less, while core skiers are more likely to engage in spatial substitution when their favourite resort cannot open due to snow conditions. McCreary, Seekamp, Larson, Smith, and Davenport (2019), studied summer and winter nature-based recreationists in the North Shore region of Lake Superior in Minnesota, USA, and found that the younger recreationists are, the more likely they are to use informal coping, spatial, and activity substitution in response to climate-related impacts.

Substitution behaviours can be chosen in the longer term when considering the impact of climate change on a particular activity, such as the reliability of snow at a particular ski resort (Rutty et al., 2015). Concern about climate change is also considered effective because it is perceived as posing a personal risk to practitioners (De Urioste-Stone, Le, Scaccia, & Wilkins, 2016). This leads recreationists to adapt their practice not only by substitutions, but also by using strategic (or tactical) adaptation that consists of recreationists using different gears, equipment, or methods to overcome constraints (Aas & Onstad, 2013), and informational coping, which consists of changing the channels used to inform themselves about the activity carried out (*e.g.* weather forecast apps, social media, etc.). This last behaviour has mainly been discussed regarding climate-related constraints (*e.g.* Moreno, Amelung, & Santamarta, 2008; Rutty & Andrey, 2014). Accordingly, it can be hypothesised that the greater the perceived risk - in the sense of the degree of uncertainty combined with the potential severity of the consequences (Riesch, 2013) –, the greater the substitution behaviour.

The substitution behaviour of recreational alpinists has never been studied. The constraints associated with climate change in alpinism are very specific. As shown by Salim et al. (2019), mountain guides may adapt their behaviour because of routes that are no longer accessible due to glacial retreat, routes (especially snow or mixed routes) that suffer from a lack of snow, or routes that become more dangerous due to rockfalls caused by warming permafrost. Mourey et al. (2020) showed that adaptation behaviour of French mountain guides can also be related to a perceived higher risk taking due to the conditions at the time of the decision. Salim et al. (2019) and Mourey et al. (2020) found that mountain guides develop different adaptation strategies to cope with these impacts. More recently, Rushton and Rutty (2023) showed that mountain guides are required to develop a toolbox of adaptation strategies and that adaptation is a basic component of a guiding job.

Although they did not mobilise the theory of substitutability, the strategies mentioned could be related to activity substitution (when the guide chooses other activities, e.g. rock climbing instead of mixed routes), temporal (when the guide chooses a particular route earlier in the season), spatial (when the guide chooses another route because the first choice is no longer suitable; in this case, the spatial substitution can be at these two scales: choosing another route in the same mountain or choosing another route on another mountain), or strategic (when the guide decides, for example, to reduce the number of clients on a particular route because of current conditions).

Accordingly, and assuming that recreational alpinist experiment approximately the same constraints and adopt the substitution behaviours described in the literature (see McCreary et al., 2019), this study seeks to answer the following two research questions:

- Does recreational alpinists' perception of the impact of climate change on alpinism influence their substitution behaviour?
- Do individual characteristics influence the adoption of substitution behaviour?

3. Material and methods

A quantitative methodology targeting alpinists in the European Alps was designed to answer these research questions.

3.1. Quantitative instrument

A 53-question survey (Appendix 1) was designed to understand the factors that influence the substitution behaviours of recreational alpinists. Based on the theory of recreational substitution (Iso-Ahola, 1986) and previous studies (McCreary et al., 2019; Rutty et al., 2015), 11 questions were included to measure spatial, temporal, informational, and activity substitutions. The questions were based on current behaviour that alpinists consider engaging due to climate change. The selected behaviours were based on the findings of Salim et al. (2019) and Mourey et al. (2020) for alpine guides and adapted to recreational alpinists based on the authors' knowledge. To measure the alpinist perspective of the impact of climate change on the practice of alpinism, 16 questions were included, based on the work by Mourey et al., 2022b and Mourey, Marcuzzi, et al. (2019) on the processes that affect alpinism routes. Previous questions were 5-point Likert-Scale ranging from 1 = Never to 5 = Very often, and 1 = Not agree at all to 5 = Totally agree, respectively.

Concerns about climate change and perspectives were measured using four questions proposed by Howe, Mildenberger, Marlon, and Leiserowitz (2015). Finally, five questions about socio-demographic characteristics and 17 questions about alpinism practice and experience were included. The latest category was based on Salim et al. (2019) and Mourey et al. (2020) about the practice of alpinism and the job of mountain guides. It includes six questions about the frequency of practice of summer activities (rock-based alpinism, snow/ice-based alpinism, mixed-alpinism, traditional climbing, and sport climbing), four on the frequency of practice of winter activities (alpine skiing, ski touring, ice climbing, and winter alpinism). All were measure using 5-point scale ranging from 1 = Never to 5 = Very often. Experience was measured using one question regarding the number of years since the beginning of practice, one question regarding the number of days of practice every year, and five questions related to the frequency of practice for each difficulty level (Easy to Extremely difficult, ranging from 1 = Never to 5 = Very often). Limesurvey software was used to create and host the survey.

3.2. Distribution of the survey

As response rates to academic surveys used in quantitative research decline over time, more innovative and relevant data collection methods, such as social media, are being tested to survey hard-to-reach populations (Dusek, Yurova, & P.Ruppel, 2015). This study used social media to conduct an online survey. As recreational alpinists in the European Alps are an informal community, the self-administered survey was distributed in German, French, English and Italian on general and specific social media platforms. Facebook was used as the primary platform. A search using the keywords "alpinism", OR "alpinist", OR "climb", OR "climbing", OR "climber", in each language available for the survey, was carried out to identify Facebook groups related to alpinism. This resulted in 39 groups of 498 127 users. A request for inclusion was

sent to each group along with a brief explanation of the purpose of the study and inviting participation via a link. This resulted in 33 of the 39 identified groups agreeing to inclusion and sending the request. The administrators of the six remaining groups refused to share the survey.

In parallel, the survey was sent to specific websites, including the main alpinism community platforms in France (camptocamp.org), Italy (gulliver.it), and the German-speaking part of the Alps (Germany, Alemannic Switzerland, and Austria; hikr.org). A message similar to the previous one was sent to the discussion spaces to introduce the study and invite the members to participate. The survey was available between August and December of 2022. A reminder was sent to each group two months after the initial invitation to participate. Finally, the message was posted on the first author's personal pages on Facebook, Instagram, Twitter, and LinkedIn.

The distribution resulted in 3157 questionnaires. For the analyses, we only considered questionnaires that were completed up to the thank you page and excluded those in which the participant stopped before the end. This resulted in the suppression of 552 incomplete questionnaires from participants who did not go to the last page (17.5%) and 1534 questionnaires where participants stopped on the first page (48.6%). The final sample consisted of 1071 completed questionnaires. Facebook represented 616 questionnaires (57.5%), specific websites 265 (24.7%), LinkedIn 67 (6.3%), and Twitter 1 (0.1%). The origin of the remaining 122 questionnaires (11.4%) was unknown, probably due to direct exchange between respondents.

3.3. Analysis

The valid sample was analysed using SPSS v.28. In addition to descriptive statistics, exploratory factor analyses (EFA) were conducted to explore patterns of activity practiced, perception of changes in alpinism, and substitution behaviour. Based on the observed patterns, we calculated the average score for the different themes, based on the included variables and used this average score for the following analyses. The core of the analysis is a series of three multiple linear regressions aimed at understanding the factors influencing adaptation behaviours. There is controversy about whether the use of Likert scales (ordinal variables) in parametric analyses such as linear regression, which should be done with continuous variables, is appropriate (e.g. Kuzon, Urbanchek, & McCabe, 1996). However, its power and reported robustness when used with Likert scales (see for examples Carifio & Perla, 2007 and Norman, 2010) leads us to choose this method.

4. Results

4.1. Description of the sample

Characteristics of the respondents are summarised in Table 1. Males represent 73.9% of the respondents while female 25.0%. Regarding country of residence, most of the respondents live in France (57.1%) and Switzerland (25.0%), followed by Italy (5.0%), Germany (3.6%), Austria (2.1%) and Slovenia (0.1%). The remaining non-Alpine countries represent 6.9% of respondents. Respondents between 30 and 39 years old are the largest class (29.8%), followed by < 29 (23.5%), 40–49 (19.5%), 50–59 (16.3%), and more than 60 (10.6%). Most of the respondents are university graduate or PhD (59.5%). Only 1.6% of the respondents are mountain guides and 6.5% are belonging to other mountain professionals (mountain leader, climbing leader, etc.).

In terms of experience, the largest group is made up of alpinists who have been practising for less than five years (32.9%), followed by those who have been practising for more than 20 years (28.6%). The largest group practices less than 11 days per year (45.3%), followed by 11–30 days (41.3%) and more than 30 days (13.3%). Respondents were asked to indicate how often they practise at different levels of difficulty (D1 to D5[1]). A difficulty index was calculated using the following equation:

$$Dindex = (D1 * 1) + (D2 * 2) + (D3 * 3) + (D4 * 4) + (D5 * 5)$$

The results were divided into three categories: easy (17.4%), moderate (62.5%) and difficult (13.7%). Among summer activities, rock alpinism is the most common (practiced by 51.3% of respondents), followed by sport climbing (48.8%), snow/ice alpinism (38.1%), traditional climbing (32.7%), and mixed alpinism (29.8%). In terms of winter activities, ski touring is practised frequently by 64.4% of respondents, followed by downhill skiing (41.9%), winter alpinism (20.6%) and ice climbing (12.6%). Detailed results of the respondents' experiences are presented in Table 2.

To reduce the number of variables for regression analyses, EFA was conducted with nine previous items related to the frequency of practice for each mountain sport. After removing two cross-loaded items, EFA (Table 3) produced three factors with an acceptable Kaiser-Mayer-Olkin (KMO) of 0.718 and a significant Bartlett's test of sphericity of 0.000 (Andy, 2013). Factor 1 includes rock-based activities and was labelled "Rock-based". Factor 2 includes snow/ice-based activities was labelled "Snow/ice-based". Factor 3 includes ski activity and was labelled "Ski". Factors 1 and 2 provided acceptable reliability scores of >0.600 (Nunnally & Bernstein, 1994). However, Factor 3 provided a reliability score of 0.477 and was excluded from further analysis.

Table 1
Socio-demographic statistics.

Variable	Sub-category	Respondents (%)
Gender		
	Male	73,9
	Female	25,0
	Prefer not to answer	1,1
Country of residence		
	France	57,1
	Switzerland	25,0
	Other	6,9
	Italy	5,0
	Germany	3,6
	Austria	2,1
	Slovenia	0,1
Age		
	<29	23,5
	30–39	29,8
	40–49	19,5
	50–59	16,3
	>60	10,6
Diploma		
	No diploma	1,2
	Professional degree	4,6
	High school	9,6
	Technician degree	9,0
	Bachelor	15,7
	Master	47,6
	PhD	11,9
Mountain professional		
	No	91,9
	Yes, mountain guide	1,6
	Yes, other (*e.g.*, mountain leader)	6,5

4.2. Climate change concern and perspective on its impact on the practice

Climate change is considered a real phenomenon by 97.6% of respondents, 1.6% say they do not know, and only 0.8% (8 respondents) think it is not real. The human origin of climate change is recognised by 88.5% of respondents, while 7.1% say they do not know, and 4.4%

[1] Based on the *High Mountain Group* cotation system with D1 = F + PD; D2 = AD; D3 = D; D4 = TD; D5 = ED.

Table 2
Experience statistics.

Variable	Sub-category	Respondents (%)
Years of practice		
	Less than 5 years	32,9
	6–10 years	19,4
	11–20 years	18,7
	More than 20 years	28,6
Day of practice per year (summer alpinism only)		
	Less than 5 days	16,6
	5–10 days	28,7
	11–20 days	25,6
	21–30 days	15,7
	31–40 days	6,1
	More than 40 days	7,2
Difficulty index		
	Easy	17,4
	Moderate	62,5
	Difficult	13,7
Summer activity	*% of respondent practicing "often" and "very often"*	
	Rock alpinism	51,3
	Snow/ice alpinism	38,1
	Mixed alpinism	29,8
	Traditional climbing	32,7
	Sport climbing	48,8
Winter activity	*% of respondent practicing "often" and "very often"*	
	Alpine ski	41,9
	Ski touring	64,4
	Winter alpinism	20,6
	Ice climbing	12,6

Table 3
EFA of activity items.

KMO=718 Bartlett's test of sphericity=0.000	Factor		
	Rock-based	Snow/ice-based	Ski-based
Cronbach Alpha	*0.746*	*0.804*	*0.477*
Mean score	*3,20*	*3,11*	*unreliable*
Traditional climbing	0,756		
Sport climbing	0,749		
Rock-based alpinism	0,537		
Mixed alpinism		−0,841	
Snow/ice-based alpinism		−0,801	
Alpine ski			0,568
Ski touring			0,545

Extraction Method: Principal Axis Factoring. Rotation Method: Oblimin with Kaiser Normalisation.[a].

[a] Rotation converged in 8 iterations.

replied that it is mainly a natural phenomenon. When asked if they are worried about climate change, 56.5% say they are "very worried", 33.0% "worried" and 10.5% "not worried" or "not very worried".

Climate change affects high mountain areas and alpinism for 97.9% and 95.6% of respondents, respectively. Respondents also broadly agree that climate change will affect their own practice of alpinism (82.6%), degrade high mountain environments (79.3%), and make alpinism more difficult (77.0%). Although more divided, most respondents agree that climate change is reducing the beauty of high mountain landscapes (59.0%). Respondents were asked to indicate whether or not specific changes associated with climate change are intense in the practice of alpinism. The results show that the frequency and volume of rockfalls, seasonality of routes, and feasibility of climbing snow and ice routes are considered to be intensively affected by more than 75.0% of respondents. Although less prominent, most respondents consider that climate change is increasing the disappearance of routes (64.8%), the risk on routes (66.4%), their accessibility (53.8%), and the overall danger of the practice (60.8%). Conversely, 38.4% and 39.5% of respondents consider that the climate increases the severity of accidents and reduces the opening of refuges. Detailed results for this point are shown in Fig. 1.

As a result, 74.5% of respondents consider that certain routes are now too dangerous due to climate change. The way they inform themselves is also changing: 29.7 and 29.4% of respondents think that paper guides and paper maps are outdated, respectively, and 82.0% think that climate change influences the way they prepare their alpinism activities. Similarly, 46.9% of respondents say that climate change influences the way they practise alpinism. In addition, 68.3% of respondents consider that climate change has a slight (15.3%), moderate (24.1%) or strong (29.0%) influence on their motivation to practice. Of these, 53.5% consider that it reduces their motivation to practise alpinism.

To reduce the number of variables for regression analyses, an EFA was conducted with 10 items related to the perception of the impacts of climate change on alpinism. After removing one cross-load item, EFA (Table 4) produced three factors with an excellent KMO of 0.920 and a significant Bartlett's test of sphericity of 0.000 (Andy, 2013). Factor 1 includes changes related to the route and was labelled "Route feasibility". Factor 2 includes changes related to risks and dangerousness of the practice and was labelled "Risk increase". Factor 3 includes changes related to rockfall frequency and volume and was labelled "Rockfall increase". All factors provided acceptable reliability scores of >0.600 (Nunnally & Bernstein, 1994).

4.3. Substitution behaviour

Fig. 2 shows the descriptive results for each item measuring substitution and coping behaviours. The most common behaviours are temporal and spatial substitutions. The results show that only 8.2% of respondents agree with the variable 'Because of the effects of climate change, I sometimes think about stopping alpinism'.

To reduce the number of variables for regression analyses, EFA was conducted with 12 items related to substitution behaviours. After removing two cross-load items, EFA (Table 5) produced three factors with an acceptable KMO of 0.894 and a significant Bartlett's test of sphericity of 0.000 (Andy, 2013). Factor 1 includes temporal substitution items and was labelled "Temporal". Factor 2 includes informational substitution items and was labelled "Informational". Factor 3 includes activity and spatial substitution items and was labelled "Activity/Spatial". All factors provided acceptable reliability scores of >0.600 (Nunnally & Bernstein, 1994).

4.4. Regression analyses

To identify the variables that influence engagement in adaptation behaviour, three linear regression analyses were conducted with activity/spatial, temporal substitution, and informational coping as dependent variables. The three multiple linear regressions (Table 6) significantly predict activity/spatial substitution ($F=46.07$; $p<0.001$; $R^2 = 0.39$, adjusted $R^2 = 0.38$), temporal substitution ($F=35.05$; $p<0.001$; $R^2 = 0.34$, adj. $R^2 = 0.33$), and informational coping ($F=29.80$; $p<0.001$; $R^2 = 0.37$, ad. $R^2 = 0.35$). Multicollinearity problems can be rejected as, for the three models, all predictors have a variance inflation factor (VIF) < 10, and a tolerance >0.3 (Andy, 2013). The effect-size of each predictor are summarised in Fig. 3. It should be noted that the predictor variables are 5-point Likert scales, except for the number of days practised (6-point Likert scale) and the difficulty index (continuous variable from 15 to 75), which may influence the magnitude of the effect described.

4.4.1. Activity/spatial substitution

The p-value and regression coefficients (β) indicate that the variables "Rock-based activity" ($\beta = 0.333$, $p < 0.001$), "I sometimes think about stopping alpinism" ($\beta = 0.251$, $p < 0.001$), "Route feasibility" ($\beta = 0.237$, $p < 0.001$), "Are you worried about climate change?" ($\beta = 0.127$, $p = 0.002$), "Risks increase" ($\beta = 0.110$, $p < 0.012$), and difficulty index ($\beta = 0.009$, $p < 0.001$) have a positive effect on spatial/activity substitution,

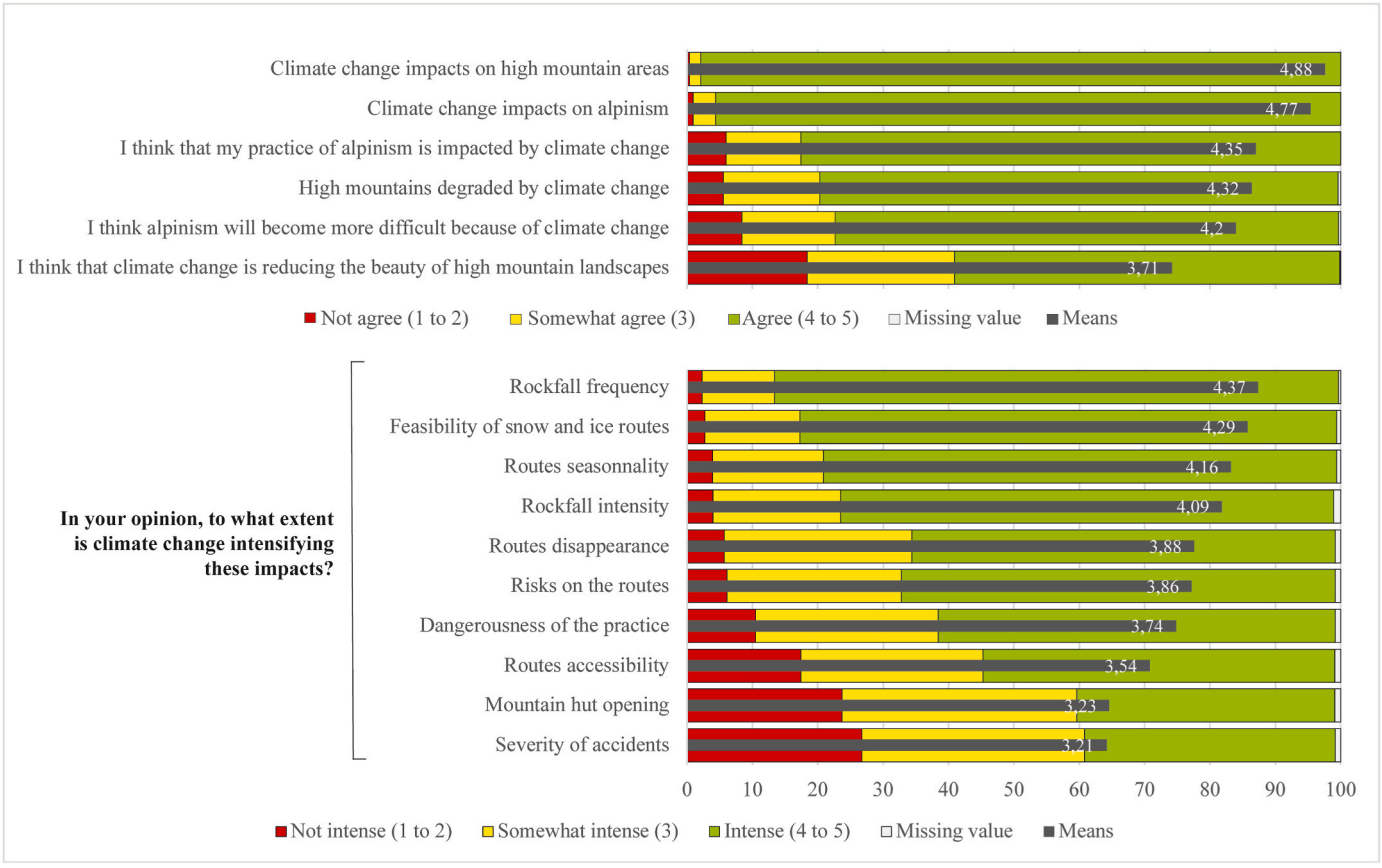

Fig. 1. Descriptive statistics concerning the perception of climate change impacts on high mountain areas and the intensification of issues due to climate change.

Table 4
EFA of perception items.

KMO=920 Bartlett's test of sphericity=0.000	Factors		
	Route	Risk	Rockfall
Cronbach Alpha	*0,761*	*0800*	*0,781*
Mean score	*3,97*	*3,61*	*4,23*
Route seasonality	0,701		
Feasibility of snow/ice routes	0,634		
Route disappearance	0,607		
Route accessibility	0,458		
Severity of accidents		−0,718	
Dangerousness of the practice		−0,633	
Risks on the routes		−0,553	
Rockfall frequency			−0,837
Rockfall intensity			−0,485

"Extraction method: Factorisation into principal axes.Rotation method: Oblimin with Kaiser.a normalisation".
a. Rotation converge in 10 iterations.

while the variables "Ice/snow-based activity" ($\beta = -0.131$, $p < 0.001$) and "Day of practice per year (alpinism only)" ($\beta = -0.064$, $p = 0.003$) have a negative effect.

4.4.2. *Temporal substitution*

The results showed that "Route feasibility" had the strongest positive effect on temporal substitution ($\beta = 0.337$, $p < 0.001$), followed by "Are you worried about climate change?" ($\beta = 0.193$, $p < 0.001$) and "Ice/snow-based activity" ($\beta = 0.186$, $p < 0.001$). "I sometimes think about stopping alpinism" has a weaker positive effect on temporal substitution ($\beta = 0.139$, $p < 0.001$), as does "difficulty index" ($\beta = 0.012$, $p < 0.001$), while "days of practice per year (alpinism only)" has a small negative effect ($\beta = -0.075$, $p < 0.001$).

4.4.3. *Informational coping*

For informational coping, "Risks increase" has the strongest positive effect ($\beta = 0.257$, $p < 0.001$), followed by "Climate change human-induced" ($\beta = 0.234$, $p = 0.049$), and "Are you worried about climate change?" ($\beta = 0.229$, $p < 0.001$). Other factors that have positive effects on informational coping are "Rockfall increase" ($\beta = 0.122$, $p = 0.005$), "I sometimes think about stopping alpinism" ($\beta = 0.113$, $p < 0.001$), "Ice/snow-based activity" ($\beta = 0.099$, $p < 0.001$), and "I think that climate change is reducing the beauty of high mountain landscapes" ($\beta = 0.055$, $p = 0.016$).

5. Discussion

An important result of this study is that recreational alpinists are well aware of climate change and its consequences in high mountain areas. Only 4.1% of the respondents believe that climate change is mostly a natural phenomenon; this result is well under the percentage for the OCDE report on high-income countries (30.0%), France (43.0%), Germany (29.0%), and Italy (16.0%) (Decherleprêtre, Fabre, Planterose, Chico, & Stantcheva, 2022). In a recent report in France, 81.0% of respondents considered climate change to be mainly human-induced (ADEME & Daniel Boy RCB Conseil, 2022). The effects of climate change on high mountains and alpinism are clearly perceived and are in line with findings from studies dedicated to mountain guides (Mourey et al., 2020; Salim et al., 2019); however, they differ from other studies regarding ski stakeholders' perceptions that mainly perceive and acknowledge climate change as a global phenomenon (Rice, Cohen, & Scott, 2022; Trawöger, 2014). This could be explained by the fact that climate change directly impacts alpinism routes by increasing risks, rockfalls and declining feasibility (Mourey et al., 2022b); these impacts are clearly observed by practitioners and form three independent factors resulting from the EFA. Conversely, an important part of the respondents

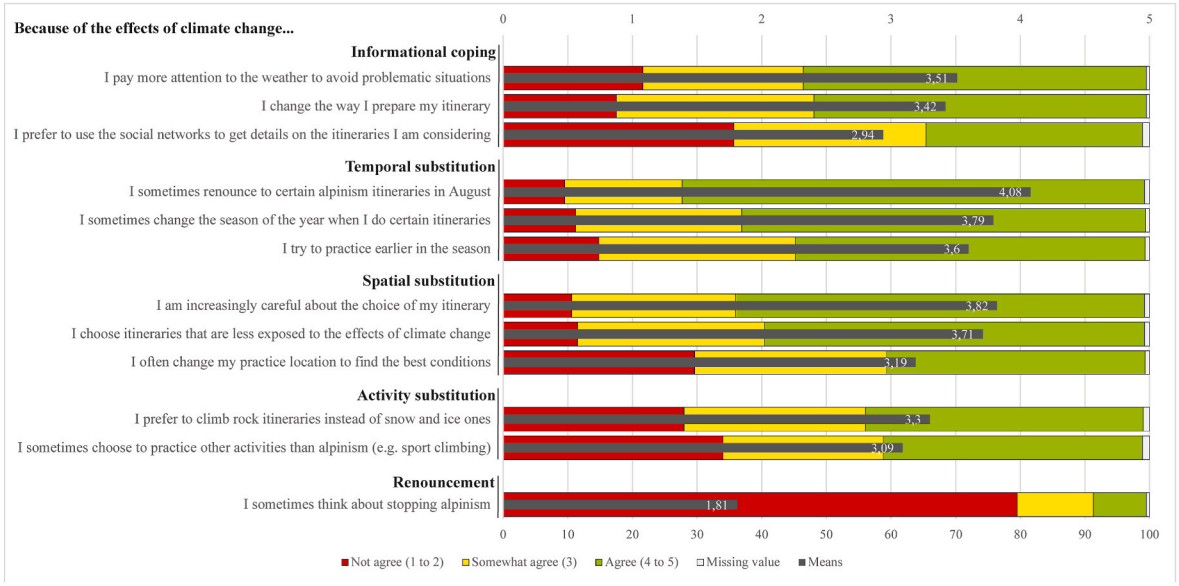

Fig. 2. Descriptive statistics of respondents' substitution behaviours.

Table 5
EFA of substitution behaviours.

KMO=894 Bartlett's test of sphericity=0.000	Factors		
	Temporal	Informational	Activity/ Spatial
Cronbach Alpha	*0,800*	*0668*	*0,683*
Mean score	*3,83*	*3,37*	*3,43*
I sometimes change the season of the year when I do certain itineraries	0,795		
I try to practice earlier in the season	0,775		
I sometimes renounce to certain alpinism itineraries in August	0,649		
I pay more attention to the weather to avoid problematic situations		0,766	
I am increasingly careful about the choice of my itinerary		0,470	
I change the way I prepare my itinerary		0,436	
I prefer to use the social networks to get details of the itineraries I am considering		0,295	
I prefer to do rock itineraries instead of snow and ice ones			0,734
I sometimes choose to practice other activities than alpinism (*e.g.* sport climbing)			0,399
I choose itineraries that are less exposed to the effects of climate change			0,372

"Extraction method: Factorisation into principal axes.Rotation method: Oblimin with Kaiser.a normalisation".
a. Rotation converge in 7 iterations.

Table 6
Results of the regression models.

		ß	*P*
Activity/spatial substitution *R=0.625 R-square=391 Adj R-square=382*	Rock-based activity (1 = Rarely; 5 = Very often)	0,333	**0000**
	I sometimes think about stopping alpinism (1 = No; 5 = Yes)	0,251	**0000**
	Route feasibility	0,237	**0000**
	Ice/snow-based activity (1 = Rarely; 5 = Very often)	−0,131	**0000**
	Are you worried about climate change? (No = 1; Yes = 5)	0,127	**0002**
	Risks increase	0,110	**0012**
	Day of practice per year (alpinism only)	−0,064	**0003**
	Difficulty Index	0,009	**0012**
Temporal substitution *R=0.588 R-square=346 Adj R-square=336*	Route feasibility	0,337	**0000**
	Are you worried about climate change? (No = 1; Yes = 5)	0,193	**0000**
	Ice/snow-based activity (1 = Rarely; 5 = Very often)	0,186	**0000**
	I sometimes think about stopping alpinism (1 = No; 5 = Yes)	0,139	**0000**
	Day of practice per year (alpinism only)	−0,075	**0000**
	Difficulty Index	0,012	**0000**
Informational coping *R=0.610 R-square=372 Adj R-square=359*	Risks increase	0,257	**0000**
	Climate change human-induced (0 = Yes; 1 = No)	0,234	**0049**
	Are you worried about climate change? (No = 1; Yes = 5)	0,229	**0000**
	Rockfall increase	0,122	**0005**
	I sometimes think about stopping alpinism (1 = No; 5 = Yes)	0,113	**0000**
	Ice/snow-based activity (1 = Rarely; 5 = Very often)	0,099	**0000**
	I think that climate change is reducing the beauty of high mountain landscapes (1 = No; 5 = Yes)	0,055	**0016**

does not agree that climate change will reduce the beauty of high mountain areas. This is in line with findings from Salim, Ravanel, and Gauchon (2021), showing that despite stakeholders' perceptions, tourists in glacier tourism destinations are still satisfied with the beauty of the landscape.

Another interesting finding is the fact that alpinists have indicated that they are already adopting substitution behaviours to cope with the effects of climate change. Among the three factors produced by the EFA, temporal substitution is the most adopted behaviour, which is consistent with the results of Mourey et al. (2020) on French mountain guides. Moreover, the most common behaviour is the avoidance of routes in August, which is also acknowledged by French and Italian mountain guides; it becomes the worst season for alpinism because of poor snow and ice conditions and increasing rockfall activity (Salim et al., 2019). In

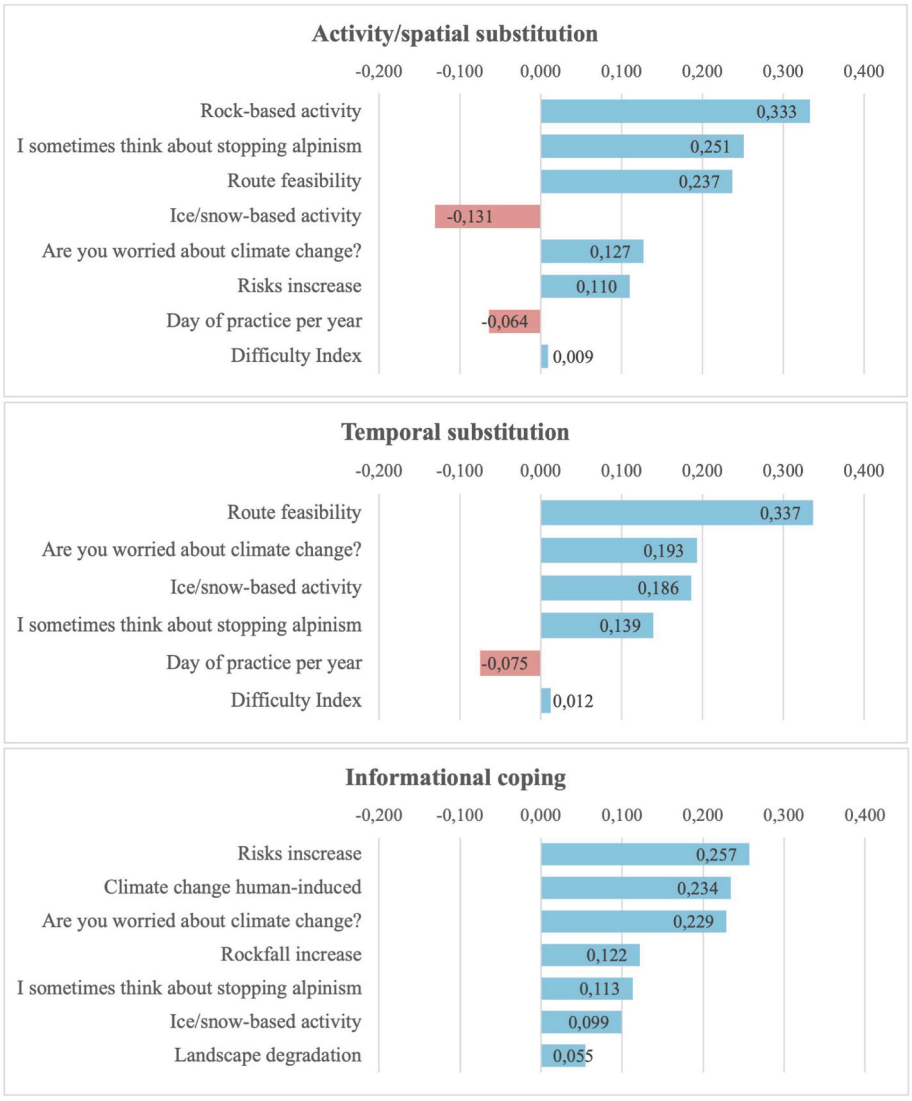

Fig. 3. Effect sizes of the predictor variables for each behaviour analysed.

this case, the route is rejected at a certain time and is performed at another moment. Conversely, even if respondents are aware of the impact of climate change on their practice and are adopting different behaviours to deal with it, few are considering stopping their practice accordingly. This suggests that coping behaviours are currently sufficient to maintain alpinists' satisfaction with their activities and perceived risk.

The EFA results showed that items measuring spatial and activity substitutions loaded on the same factor, suggesting that these two types of behaviour form a single construct. In the literature, these behaviours generally form two distinct categories (Dawson, Scott, & Havitz, 2013; McCreary et al., 2019; Rutty et al., 2015). This overlap of the two types of behaviours in our results can be explained by the specificities of alpinism. In alpinism, as Mourey et al. (2020) and Salim et al. (2019) have shown, changes in location for practice are mainly due to changing route conditions. Thus, in our survey, the items measuring spatial substitution mainly concerned changes in the routes and the behaviour of choosing another route in another location to substitute. As the activity practiced may differ according to the route chosen, it is likely that the overlap means that recreational alpinists consider these two types of substitution closely linked.

5.1. *Variables influencing the adoption of adaptation behaviours*

Overall, the results indicate that individual practices of alpinism and experience, as well as perspectives on the impact of climate change on high mountain environments and alpinism, influence the behaviour of recreational alpinists. However, our results do not reveal any significant explanation for socio-demographics on coping and substitution behaviours.

5.1.1. *Alpinism experience and practice mainly influence temporal and activity/spatial substitutions*

Even with a low effect-size, experience is significantly related to temporal and activity/spatial substitution in terms of the number of days of practice per year and the difficulty of the route followed. Interestingly, the fewer days climbers practice per year, the more likely they are to engage in substitution behaviours, suggesting that the less engaged practitioners are in the activity, the easier it is for them to plan something else or perform the activity at another time. This is partially consistent with Rutty et al. (2015), who found that beginner skiers in Ontario were more likely to ski less or engage in activities other than core skiers. However, the significance of the difficulty index in explaining temporal and activity/spatial substitution suggests that the higher the performance of alpinists, the more they engage in

substitution. Although this result seems contradictory, it could be explained by the fact that infrequent alpinists have more opportunities to substitute than frequent alpinists (in terms of available time slots or other activities to practice). At the same time, expert alpinists have a greater willingness to pursue the activity than beginners and are more open to substituting one activity or place for another. It should be noted that the effect-size of the result is relatively low and suggest a small, but significant explanatory effect.

Practising rock-based activities significantly and with a large effect-size explains the adoption of activity/spatial substitution. This can be explained by the fact that rock-based activities are diverse and can complement each other. For example, when conditions for rock-based alpinism are poor – e.g. in the case of a heat wave leading to high risks related to permafrost degradation – it is relatively easy to change location, by practising below the permafrost limit, or to change activity, by switching to sport or traditional climbing. This explanation has already been reported by Salim et al. (2019) and Mourey et al. (2020) for French and Italian mountain guides.

Practising more summer snow/ice-based activities significantly explains the three coping behaviours. For activity/spatial substitution, there is a negative, medium effect-size relationship: the more snow/ice-based activities are practiced, the less likely it is that this behaviour will be implemented. On the one hand, this can be explained by the fact that these activities are very specific, which means that it is less easy to substitute them with other activities based on the same element. On the other hand, as shown by interviews with French and Italian mountain guides (Salim et al., 2019), the most efficient way to continue summer snow/ice-based activities is to temporally substitute and to be more reactive and alert about information on the conditions, *i.e.* informational coping, which is most significantly and with medium effect-size explained by snow/ice-based activities. Snow/ice-based activities also require the most information to ensure a satisfying experience, especially in the context of climate change (Mourey et al., 2022b).

5.1.2. Climate concern as a key driver of adaptation behaviours

Concern about the effects of climate change significantly and positively predicts the three adaptation behaviours with a medium effect-size. As shown by McCreary et al. (2019), the more alpinists are concerned about climate change consequences for high mountain environments, the more they seek information. Other studies, such as Horne, De Urioste-Stone, Seekamp, Rahimzadeh-Bajgiran, and Rickard (2021), show that the more visitors to Acadia National Park believe in climate change, the more they perceive risks from climate change. Overall, the results are consistent with the literature showing that coping behaviours are implemented to reduce the risks or uncertainties of a particular activity or overcome constraints (Aas & Onstad, 2013).

5.1.3. Perspectives on the impacts of climate change on high mountain areas and on alpinism influence behaviours

Among the three main climate change impacts considered, the feasibility of routes significantly and positively explains substitution behaviour. In this sense, the more respondents are aware that alpinism routes are less often in good condition and sometimes disappear (Mourey, Marcuzzi, et al., 2019; Mourey et al., 2022b), the more likely they are to engage in activity/spatial and temporal substitution with a medium and large effect-size, respectively.

The more the respondents consider the activity to be risky, the more likely they engage in activity/spatial substitution and informational coping. On the one hand, the first result is consistent with Salim et al. (2019), who found that mountain guides often consider changing the activity, for example, by substituting alpinism with sport climbing, when they consider it to become too risky. On the other hand, this result is consistent with other studies from the risk reduction literature, showing that risk reduction strategies mainly consist of behaviour modification and information search (Adam, 2015; Hales & Shams, 1991). This fact is also pointed out by Mourey et al. (2020), who found that French mountain guides increased their attention to choose their route to cope with uncertainty.

Finally, in addition to the most perceived impact, the perception of increased rockfall frequency and volume significantly and positively explains the adoption of informational coping. Given that rockfalls in August are explained by strong temperature anomalies in the Alps (Viani et al., 2020) and that rockfalls are associated with exceptionally high bedrock temperatures (Legay, Magnin, & Ravanel, 2021), it is likely that such awareness among alpinists leads them to seek more information in the event of a heatwave and, more generally, during the summer. As a result, the perception of increased rockfalls is also likely to lead to a greater need for alpinists to access information, particularly in relation to temperature.

Finally, the more respondents indicated that they sometimes thought about quitting alpinism, the more they used all three adaptation strategies with a medium-sized effect. This suggests that substitution and coping strategies are used by alpinists to avoid stopping the activity. Furthermore, the limited number of respondents who indicated that they very often think about stopping alpinism suggests that the adoption of adaptation behaviours is still sufficient to guarantee satisfactory practice conditions for alpinists.

5.2. Management implications

The main finding of this study is that the more aware alpinists are of the consequences of climate change in the practice of alpinism - in terms of perceived increases in rockfall, risks, and route feasibility - the more they adapt their behaviour. Because of the potential risks that these changes pose to alpinists, it confirms the importance of Alpine organisations (e.g. La Chamoniarde in Chamonix in France or Fondazione Montagna Sicura in Courmayeur in Italy) to communicate scientific research that provides evidence of these changes in the high mountains, together with proposals for adaptation strategies. The findings also suggest that the less informed practitioners, *e.g.* casual or "one-shot" alpinists (foreign alpinists coming to Chamonix only to climb Mont Blanc, for example), are not necessarily aware of the risks exacerbated by climate change in the high mountains, and point to the importance of developing new information channels in collaboration with, for example, a reputable brand (*e.g.*, the *Alpine Academy* in Chamonix, “safety days”, etc.) or Alpine tourism destination. These new information channels should target less-informed practitioners to increase their awareness of changes in rockfall frequency, risk, and route conditions in a way that favours the adoption of substitution behaviour.

This question of information also raises the question of the tools available, and in particular climate services, which are defined as a means of "supporting decision-making process to better prepare for and adapt to the risks and opportunities of climate variability and change" (Boqué Ciurana & Aguilar, 2021, p. 1). In the case of alpinism, climate services could be developed to better identify the specific location at risk of rockfall or to propose real-time information or an index of the practical conditions of certain routes. These climate services could inform alpinists and raise their awareness of existing risks and conditions, helping them to adopt informed substitution behaviour. For example, a rockfall susceptibility index, as proposed by Legay et al. (2021), could facilitate the decision to substitute by choosing routes in locations where the index is lower. To this end, work has begun with the French National Union of Mountain Guides to propose maps and topographical guides that specifically show the effects of climate change on the most frequently used routes. As the map locates and characterises the processes affecting the routes (Mourey et al., 2022b), the distribution of this document to alpinists should increase their awareness of the processes affecting them and potentially help them to substitute. This is all the more necessary as the inclusion of alpinism on UNESCO’s Representative List of the Intangible Cultural Heritage of Humanity implies, as an example of conservation measures, the deepening of "the existing dialogue among alpinist communities, creating new platforms for

information-sharing" and "awareness-raising actions aimed at new audiences" (UNESCO, 2019).

5.3. Limits

The method described has limitations, mainly related to the mode of dissemination using social media. This introduces bias because people who do not use these networks could not respond. In addition, the composition of the sample shows an over-representation of French-speaking respondents, which is also the language of the authors, suggesting uncontrollable selection by algorithms, especially on Facebook. Unfortunately, there are very few studies on the use of social media to target hard-to-reach populations in tourism and leisure contexts. Exceptions outside the tourism context show that this technique can be effective (Bethel, Rainbow, & Dudding, 2021) and provide satisfactory response quality (Zhu, Shao, Fang, & Cao, 2013). In our case, despite its limitations, given the informal nature of the alpinist community, this type of dissemination was considered the most effective way to reach a large number of people.

Another limitation of this study is the lack of data on the composition of the alpinist population, making it impossible to determine the representativeness of the sample. However, studies on gender in alpinism practices have been carried out using Alpine Club statistics as a proxy. For example, they show that in 2010, women represented 36.4% of the members of the French Alpine Club and 25.8% of the members practising alpinism (Moraldo, 2013). In the Swiss Alpine Club, women represented 40% of members in 2018, but no data are available on the proportion of alpinism practitioners (Fink, 2018). Despite these limitations the composition of the sample, particularly in terms of gender, is in line with other studies: 25.0% of the respondents in our sample are women, compared with 25.8% of women practising alpinism in the French Alpine Club (Moraldo, 2013). In addition, alpinists are considered to be a highly educated population (Moraldo, 2021) and our results show that Masters and PhD graduates represent 59.5% of the sample.

6. Conclusions

Based on 1071 completed questionnaires, this paper assesses the perspectives and adaptation behaviours of recreational alpinists in the European Alps in the face of climate change. The results show that respondents are well aware of the consequences of climate change in high mountain areas and on alpinism, and they adapt their practices accordingly. Statistical analyses show that concern about climate change is a key predictor of both substitution and coping behaviours, indicating that alpinists who are concerned about climate change and those who sometimes think about stopping the activity are those who adapt the most. The results also suggest that having a high frequency of snow/ice-based activities in the summer increases the likelihood of engaging in temporal substitution and informational coping but reduces the likelihood of substituting this activity for another. Alpinists' perspective on the impact of climate change on alpinism is also a predictor of adaptation behaviour. The more the respondents perceive routes to be deteriorating, the more they engage activity/spatial and temporal substitution. The more they perceive an increase in the risks associated with the activity, the more they adopt information coping and change their activity. Finally, the more they perceive an increase in the likelihood of rockfall, the more they seek information. Overall, the more aware of the impact of climate change on the high mountains the alpinists are, the more likely they are to adapt their behaviours. The results support the importance of communication by Alpine organisations about the effects of climate change. The results also highlight the need for new information channels for less-informed practitioners who may not be aware of risks. The development of climate services, such as rockfall susceptibility index, could also help climbers make safer decisions and promote adaptation strategies to changing conditions.

CRediT authorship contribution statement

Emmanuel Salim: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration. **Jacques Mourey:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Anne-Sophie Crépeau:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Ludovic Ravanel:** Conceptualization, Writing - review & editing.

Declaration of competing interest

This manuscript has not been published or presented elsewhere in part or entirety and is not under consideration by another journal. All study participants provided informed consent, and the study design was approved by the appropriate ethics review board. We have read and understood your journal's policies and believe that neither the manuscript nor the study violates any of these. There are no conflicts of interest to declare.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jort.2023.100662.

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