Glacier tourism and climate change adaptation in Iceland

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Dissertation submitted in partial fulfillment of a
Philosophiae Doctor degree in Tourism Studies

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Abstract

Climate change constitutes one of the most pressing challenges faced by tourism today. Tourism research on climate-induced environmental changes has contributed to an increase in knowledge about adaptation during the last decade. Despite a general recognition of the urgent need to adapt, as well as a large-scale scientific effort in this field underlining evidence of potential risk, the impacts of adaptation research on practices and policies in tourism appear to be relatively low.

To reduce the gap between adaptation research and practitioner action this thesis aims to increase the understanding of adaptation to climate-induced changes in nature-based tourism, by analyzing the adaptation processes and practices of tourism actors involved in glacier tourism. Glacier tourism is a highly relevant example of a type of tourism which needs to adapt to climate-induced environmental changes. Therefore, this thesis examines: what is the state-of-the-field knowledge concerning relationships among tourism, the glacial environment, and climate change; how do glacier tourism actors adapt to the current and future impacts of climate change; and how can glacier tourism actors' engagement with science contribute to proactive adaptation.

The research conducted in this thesis uses a combination of two analytical approaches. An actor-oriented approach is employed to investigate tourism actors' experiences and perceptions of climate change and their adaptation behavior. The other approach draws on transdisciplinary research, involving an active engagement of local stakeholders and scientists to form dialogues to combine knowledge bases, and to verify the social relevance of research on climate change adaptation. An embedded case study design was chosen due to its potential to integrate an actor-oriented approach with transdisciplinary research. The glacier sites of southeast Iceland form the case-study area wherein the adaptation processes of glacier tourism actors were examined. The case study constitutes the setting for the collection of empirical data by means of quantitative methods, such as literature review and visitor surveys, as well as qualitative methods, such as interviews and participatory scenario workshops.

The results reveal a limited but growing body of scholarly work that examines the relationships between tourism, glaciers, and climate change impacts and responses. The existing work lacks however important data concerning the motives, preferences, experiences, and behaviors of actors in glacier tourism in general and specifically in the context of climate change. The results of the analysis of tourism actors' adaptation practices furthermore show that climate change has already resulted in several impacts on glacier sites and that operators have responded to these implications in the form of a wait-and-see strategy combined with ad-hoc reactive adaptation. On the other hand, the results also show that visitors to glacier sites are more heterogeneous in their responses to future climate change–induced impacts. Furthermore that adaptation processes of glacier tourism actors are shaped by the interaction of actors' attributes of agency, such as risk perception, concerns, motivations and interests, with structural elements of the glacier destination

systems, such as type of visitation implication, prevailing economic rationale or lack of effective climate change institutions. Lastly, the results stress the development and application of a participatory scenario planning process, as a form of science-practitioner engagement, to be a valuable tool to support the adaptation planning of glacier sites through sharing knowledge, elaborating on long-term changes and associated uncertainties, and exploring proactive adaptation options.

Climate is only one of the drivers of change that determine the development of glacier tourism. It is thus concluded that climate change implications cannot be understood as isolated factors; rather, they should be viewed as constituting interconnected and cumulative effects on socioeconomic and natural environments. Mainstreaming climate change adaptation into current destination planning and management or integrating climate change adaptation with related science fields, such hazard reduction research or sustainability science, would thus provide more promising approaches than studying climate change adaptation in isolation.

Útdráttur

Loftslagsbreytingar eru ein stærsta áskorun sem ferðaþjónusta heimsins stendur frammi fyrir í dag. Síðastliðinn áratug hafa rannsóknir innan ferðamálafræði á breyttum umhverfisaðstæðum vegna loftlagsbreytinga stuðlað að aukningu rannsókna á aðlögum að loftslagsbreytingum. Þrátt fyrir almenna viðurkenningu á þörfinni fyrir aðlögun að breyttum aðstæðum, og umfangsmiklar rannsóknir sem sýna fram á mögulega áhættu sem fylgir slíkum breytingum, virðast áhrif aukinnar þekkingar um aðlögun á starfsemi og stefnu í ferðaþjónustu enn vera tiltölulega lítil.

Með það að leiðarljósi að minnka bilið á milli rannsókna á aðlögun að loftslagsbreytingum og aðgerða ferðaþjónustunnar, leggur þessi doktorsritgerð áherslu á að auka skilning á aðlögun að breyttum umhverfisaðstæðum vegna loftlagsbreytinga í náttúrutengdri ferðaþjónustu, með því að greina aðlögunarferli og starfshætti ferðaþjónustuaðila sem stunda jöklaferðamennsku. Jöklaferðamennska er mjög skýrt dæmi um ferðaþjónustu sem þarf að aðlaga sig að breyttu umhverfi vegna áhrifa loftslagsbreytinga. Meginmarkmið þessarar ritgerðar eru að meta: hver er staða þekkingar á sambandi ferðamennsku, jökulumhverfis og loftslagsbreytinga; hvernig ferðaþjónustuaðilar sem stunda jöklaferðamennsku aðlagist að núverandi og framtíðar áhrifum loftslagsbreytinga; og hvernig tengsl ferðaþjónustuaðila við vísindi geti stuðlað að framvirkri aðlögun.

Rannsóknirnar í þessari doktorsritgerð nota sambland af tveimur greiningaraðferðum. Annars vegar gerendanálgun til að rannsaka reynslu og viðhorf ferðaþjónustuaðila til loftslagsbreytinga sem og aðlögunarhegðun þeirra. Hins vegar aðferð sem byggir á þverfaglegri nálgun sem felur í sér gagnvirka þátttöku hagaðila í héraði og sérfræðinga til að ræða saman og mynda sameiginlegan þekkingargrunn, og til að sannreyna félagslegt mikilvægi rannsókna á aðlögun að loftslagsbreytingum. Til að samþætta þessar tvær aðferðir, þ.e. gerendanálgun og þverfaglega nálgun, var ákveðið að styðjast við tilviksrannsókn. Nokkrir áfangastaðir við sunnanverðan Vatnajökul voru valdir sem rannsóknarsvæði, þar sem söfnun gagna fór fram. Stuðst var við bæði megindlega aðferðafræði, svo sem spurningakannanir til ferðamanna, og eigindlega aðferðafræði, svo sem viðtöl, þátttökuathuganir og sviðsmyndagreiningu.

Niðurstöður sýna takmarkaða en vaxandi rannsóknavirkni sem beinir sjónum að tengslum ferðamennsku, jökla, áhrifum loftslagsbreytinga og viðbrögðum við slíkum áhrifum. Jafnframt, að enn vanti töluvert af rannsóknum sem beini sjónum að reynslu, hegðun og óskum gerenda í jöklaferðamennsku, bæði almennt en sérstaklega þó í tengslum við loftslagsbreytingar. Niðurstöður sýna enn fremur að loftslagsbreytingar hafa þegar haft töluverð áhrif á jöklasvæðin við sunnanverðan Vatnajökul og að ferðaþjónustuaðilar hafa brugðist við þessum afleiðingum í formi ”bíða-og-sjá-til” afstöðu, ásamt samsvarandi afturvirkum aðgerðum. Á hinn bóginn sýna niðurstöðurnar einnig að ferðafólk sem heimsækir jökulsvæðin er innbyrðis breytilegt varðandi viðbrögð við framtíðar áhrifum loftslagsbreytinga. Enn fremur að aðlögunarferli gerenda í jöklaferðamennsku mótist af gagnvirku samspili gerendahæfni þeirra, varðandi þætti eins og áhættuskynjun, hugsjónir, hvata, og áhugasvið, við skipulagningu ferðaþjónustunnar og innviði á einstökum áfangastöðum, svo sem varðandi þau áhrif sem ferðamennskan hefur, viðhorf til

hagþróunar og hvort til staðar séu skilvirkar stofnanir sem sinna loftlagsmálum. Síðast en ekki síst, leggja niðurstöður rannsóknanna áherslu á mikilvægi þróunar og beitingu þátttökusviðsmynda til að samtvinna viðhorf hagsmunaaðila í héraði og vísindamanna í skipulagsferli. Slíkar þátttökusviðsmyndir eru mikilvægt verkfæri til að styðja við skipulega aðlögun áfangastaða jöklaferðamennsku að breyttum umhverfisaðstæðum vegna loftlagsbreytinga, í gegnum gagnkvæma miðlun þekkingar, íhugunar um langtíma breytingar og þá óvissu sem þeim fylgir, og skoðunar á mögulegum framvirkum aðlögunaraðgerðum til að mæta slíkum breytingum

Loftslagsbreytingar eru aðeins einn þeirra drifkrafta sem stýra þróun jöklaferðamennsku. Ekki er hægt að horfa á áhrif loftslagsbreytinga sem einangraða þætti; heldur verður að horfa heildrænt á alla áhrifaþætti til að skilja betur hin flóknu og gagnvirku tengsl á milli hinna samfélagslegu, hagrænu og umhverfislegu sviða. Með því að setja aðlögun að loftslagsbreytingum í forgrunn í núverandi áfangsstaðaáætlunum og stýringaraðgerðum, eða með því að samþætta aðlögun að loftslagsbreytingum við ákveðin vísindasvið eins og áhætturannsóknir eða sjálfbærnirannsóknir, væri hægt að leiða fram mun betri nálgun en með því að horfa á aðlögun að loftslagsbreytingum sem einangrað fyrirbæri.

To Ingibjörg

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Paper II Welling, J. & Árnason, Þ. (2016). External and Internal Challenges of Glacier Tourism Development in Iceland. In H. Richins and J.S Hull (Eds.), *Mountain Tourism: Experiences, Communities, Environments and Sustainable Futures* (pp. 186-195). Wallingford: CAB International.

Paper III Welling, J. & Abegg B. (2019). Following the ice: adaptation processes of glacier tour operators in Southeast Iceland. *International journal of biometeorology*; doi.org/10.1007/s00484-019-01779-x

Paper IV Welling, J., Ólafsdóttír, R. & Árnason, Þ. (2020). Implications of climate change on nature-based tourism demand: a segmentation analysis of glacier site visitors in southeast Iceland. *Sustainability* 12(13), 5338; doi:10.3390/su12135338.

Paper V Welling J., Ólafsdóttir R, Árnason Þ & Guðmundsson S. (2019). Participatory Planning Under Scenarios of Glacier Retreat and Tourism Growth in Southeast Iceland. *Mountain Research and Development* 39(2), D1-D13; doi.org/10.1659/MRD-JOURNAL-D-18-00090.1

Co-authored articles

In Paper I, the author was mainly responsible for developing and writing the paper. The co-authors reviewed the paper and contributed to the editing of the paper.

In Paper II, the author was mainly responsible for the developing and writing the paper. The co-author reviewed the paper and contributed to the editing of the paper.

In Paper III, the author was mainly responsible for the developing and writing the paper. The co-author reviewed the paper and contributed to the editing of the paper.

In Paper IV, the author was mainly responsible for developing and writing the paper. The co-authors reviewed the paper and contributed to the editing of the paper.

In paper V, the author was mainly responsible for the analysis and for writing the paper. Snævarr Guðmundsson conducted the glacial land-cover modeling. Þorvarður Árnason and Rannveig Ólafsdottír reviewed the paper and contributed to the editing of the paper.

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Abbreviations

IMO	Icelandic Meteorological Office
ITB	Icelandic Tourism Board
NGO	Non-Governmental Organization
PSP	Participatory Scenario Planning
VNP	Vatnajökull National Park

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PART ONE
SYNOPSIS

1 Introduction

A ceremonial funeral was held for a glacier lost to climate change in Iceland on August 18, 2019. The glacier Ok had lost its status as a glacier few years previously due to its loss of ice mass and the forces of gravity that subsequently acted upon it (Iceland Review, 2019). The disappearance of this particular glacier sparked worldwide attention, in part because bringing the natural change into a social context (that of a funeral) focused attention on the physical changes caused by climate change.

Glacial recession is one of the clearest visual examples of the effects of climate change. Since the 1990s, glaciers worldwide have been receding and thinning at an accelerated rate Vaughan et al., 2013). According to Hock et al. (2019), glaciers around the world outside Greenland and Antarctica lost mass at an average rate of 220 ± 30 Gt yr–1 from 2006 to 2015. During the same period, many glaciers worldwide have become popular tourist destinations, some visited by over a hundred thousand tourists per year for a broad range of outdoor recreation- or adventure-based activities (Paper I; Purdie, 2013). The rapid global recession of glaciers has resulted in increased attention to the glaciers that remain and has brought about an increase in their perceived value (e.g., Carey, 2007; Gagné, Rasmussen, & Orlove, 2014; Haeberli, 2008).

The interconnection between increased visitation to glaciers sites and the shrinkage in glacier volume underlines the necessity of nature-based tourism in the cryosphere to adapt to the consequences of a changing climate. Therefore, it is of vital importance to gain an in depth understanding of how adaptation in dynamic glacier environments occurs.

In tourism research, climate-induced environmental changes have led to an increase in adaptation research during the last decade (Kaján & Saarinen, 2013). However, despite a general recognition of the urgent need to adapt and a large scientific effort in this field underlining evidences of potential risk, the impacts of adaptation research on practices and policies in tourism seems to be relatively low (Scott et al., 2012). According to Klein and Juhola (2014), the traditional adaptation research model does not appear sufficient to facilitate adaptation action by all relevant public and private stakeholders, because either adaptation research fails to demonstrate to stakeholders the relevance of its findings, or stakeholders base their views and decisions on other kinds of information.

Despite the considerable amount of scholarship on climate change adaptation in the tourism sector that has been produced in the last decade, most of this research has been highly theoretical in nature and system oriented, largely focusing on climate change risk and vulnerability assessments, theoretical conceptualizations, or classifying options, rather than on existing adaptation actions or whether and how adaptation is actually occurring (Becken & Hay, 2012; Kaján & Saarinen, 2013). In particular, research on the adaptation practices of tourists (Scott et al. 2016) and small-sized private companies remains lacking (Hoffmann et al., 2009; Linnenluecke et al., 2013).

The gap between adaptation research and practitioner action is further widened by a profound difference in the perception of climate change–induced risks, concerns, and feelings of urgency to act and adapt between science and tourism practitioners (Abegg et al., 2017). Empirically examining adaptation practices provides valuable insights into

conditions and factors that shape the adaptation processes and practices of various actors. Such insights into adaptation action enable decision- and policymakers to support favorable conditions for entrepreneurial adaptation and can provide valuable information to assist destinations in designing appropriate adaptive strategies and destination planning. This gap demonstrates that climate change adaptation is a transdisciplinary problem that must be addressed both inside and outside the scientific community.

In addition, knowledge remains limited regarding the social dimensions of glacier recession in Iceland. Glacier recession research in Iceland has been conducted almost entirely in the domain of natural science. Recent research on the attitudes of community members towards glacier retreat in Iceland (i.e., Jackson, 2019) provides valuable insights into the various perceptions of glacier recession of people who live in the direct vicinity of glaciers. However, knowledge about the perceptions and adaptive behaviors of actors in tourism towards glacial environmental change remains lacking in Iceland. Therefore, this thesis provides an opportunity to study climate change as it is embedded in society.

To increase the understanding of adaptation to climate-induced changes in nature-based tourism, this thesis analyzes adaptation processes and practices of tourism actors involved in glacier tourism in Iceland.

1.1 Aim and research objectives

The aim of this thesis is to increase the knowledge and understanding of the causal relations between glacier tourism, climate change, and adaptation. To accomplish this aim, three research objectives are addressed:

(a) to examine the state-of-the-field knowledge concerning relationships among tourism, glacial environments, and climate change;

(b) to examine how glacier tourism actors adapt to the current and future impacts of climate change;

(c) to examine how science-practitioner engagement can contribute to proactive adaptation action.

1.2 Outline of the thesis

This thesis consists of two parts: the first part presents a detailed theoretical grounding and methodological framework, summarizes five published research papers that present projects that have been carried out as part of this PhD project, and provides an encompassing discussion and conclusion. The second part includes a collection of the five original research papers.

This introductory chapter is followed by Chapter 2, which describes the main concepts used in the thesis and the research approach. The study area in southeastern Iceland is outlined in Chapter 3. Chapter 4 describes the methodological approach and introduces the manner in which the research process was carried out. In Chapter 5, the main results of Papers I–V are discussed in relation to the three research objectives. Finally, Chapter 6, summarizes the conclusions of the thesis and provides recommendations for future work.

2 Concepts and research approach

2.1 Adaptation

Adaptation to climate change is a rapidly developing research field that has a long and multidisciplinary history of research. As a result, the term "adaptation" is used in a variety of ways by scholars and practitioners (Moser & Ekstrom, 2010). The Intergovernmental Panel on Climate Change (IPCC, 2013, p.23) defines adaptation as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities." This simple and frequently used definition is useful for this thesis. However, some issues in this definition must be better clarified for the purpose of this thesis research. The *adjustment* mentioned in the definition can range widely, from short-term coping in order to return to the status quo to long-term system transformation in which whole economic sectors or communities develop into new trajectories. In this thesis, *adaptation* relates to short-term (< 10 year) incremental adjustments. Another aspect to consider is that adaptation rarely occurs in response to climate drivers alone. Numerous researchers (e.g., Adger et al., 2007; Tompkins et al., 2009) have thus found that many if not most adaptation actions are not taken for climate-related reasons alone. Moser and Ekstrom (2010) further point out that while the IPCC's definition assumes effectiveness, well-intended adaptations can fail, proving to be maladaptive at a later stage. They propose a more detailed definition that better fits with this thesis. According to them,

> Adaptation involves changes in social-ecological systems in response to actual and expected impacts of climate change in the context of interacting non-climatic changes. Adaptation strategies and actions can range from short-term coping strategies to longer-term, deeper transformations, aim to meet more than climate change goals alone, and may or may not be successful in moderating harm or exploiting beneficial opportunities. (Moser & Ekstrom, 2010, p.22026)

2.2 Adaptation practices

In practice, adaptation can involve a wide range of activities and options. Different classifications of adaptation practices can be discerned in climate change literature, reflecting the various underlying logics driving adaptation behavior (Gasbarro & Pinkse, 2016). Adaptation can be classified on the basis of the actors involved (public or private), its timing (anticipatory or reactive), and the intention behind it (incidental, implicit [autonomous] and explicit [planned]). This thesis focuses on the private adaptation of tour operators (Paper III &V) and tourists (Paper IV), as well as the public adaptation of glacier site planning and management (Paper V), which in this thesis is the public actor Vatnajökull National Park (VNP). Furthermore, the thesis considers both anticipatory and reactive adaptation, as well as implicit and explicit adaptation in its analysis.

Preston et al. (2011) propose a classification framework that is useful in structuring the broad range of adaptation practices in glacier tourism. Their framework is used in this thesis. It classifies adaptation options on the basis of two broad categories of adaptation

strategies: facilitating adaptation by building up actors' adaptive capacity and implementing adaptive means by delivering adaptation action. The first category consists of adaptation strategies gathering information and developing research, raising awareness, and changing organizational and institutional structures. The second category comprises various strategies to reduce, prevent, or spread climate risks or to exploit new opportunities. Table 1 shows a classification of different examples of climate change adaptation options by the glacier tourism actors.

Table 1 Typology of adaptation strategies to structure adaptation options of tour companies and tourists (adapted from McCreary et al., 2019; Preston et al., 2011; Papers III–IV)

Adaptation strategies	Examples of adaptation options of tourism entrepreneurs	Examples of adaptation options of tourists	Examples of adaptation options of glacier site management
Building Adaptive Capacity			
Gathering and sharing information	Monitoring equipment and site attributes, training and education of staff	Gathering information on destination, local climate, and weather, improving one's skill and physical capacity	Monitoring infrastructure, undertaking research, training and educating staff
Creating a supportive institutional framework	Changing standards, best guidance practices		Adjusting legislation, developing management and planning strategies
Creating supportive social structures	Changing internal organization systems, working in partnership or establishing network	Purchasing organized holiday, participating in travel group.	Collaboration with research institutions and rescue teams.
Delivering adaptation action			
Bearing the risks	Accepting impacts and bearing the losses, cancelation	Cognitive coping through rationalization (e.g., justifying the problem or reevaluating situation in a more favorable light)	Passive nature conservation
Sharing or spreading the risks	Taking an insurance, diversification of products, sites and income sources	Purchasing insurance	Establishing calamity fund, purchasing insurance
Avoiding or reducing the risks	Improving transportation, relocating and rerouting tour activities, bolstering safety measures	Strategic substitution (using different gear, equipment, or guidance), temporal and site substitution	Improving and extending infrastructure, implementing safety zoning, putting up safety signs
Exploiting new opportunities	Engaging in new activities, adjusting behavior to take advantage of changing climate conditions	Activity substitution	Establishing facilities (e.g., camping site, biking routes), climate change education

2.3 Adaptation processes

The literature on individual (e.g., Grothmann & Patt, 2005; Miller & McCool, 2003) and organizational (e.g., Berkhout et al., 2012; Moser & Ekstrom, 2010) adaptation reveals a measure of consensus about the general steps that comprise an adaptation process: detecting climate-induced signals, appraising the signals' risk and available adaptation options, taking action, and monitoring feedback. Although the framework presents adaptation as a linear process comprised of consequential steps, Berkhout (2012) points out

that in reality, the process stages operate continuously and in parallel with each other, periodically reinforcing or constraining one another. The following four stages describe the process.

The first stage, signal detection, refers to an actor's perception and awareness of climate change signals. This stage involves deciding what is to be adapted to and what is to be ignored. Actors can perceive climate change signals directly, through experiences of climate-induced implications, or indirectly, through changes in regulations or adaptation strategies. The second stage concerns evaluation, in which the signal is interpreted, foreseeable consequences are evaluated, and response options are assessed. There are considerable differences among the actors involved here depending on their goals, interests, and liability decisions. The third stage, action, concerns the enactment of options and integrating them into organization routines. Finally, feedback involves monitoring the outcomes of decisions to assess whether they are as expected, adjusting organizational routines accordingly, and recording the experiences of individuals.

The different stages are shaped and constrained by physical, ecological, technological, financial, informational, socio-cultural, and cognitive factors that arise from the actor's agency, the system of concern (e.g., glacier destinations) and the socio-institutional context in which the actor operates (Adger et al., 2007; Moser & Ekstrom, 2010). These factors are often represented as capacities to adapt.

2.4 Adaptive capacity

In the climate change literature, adaptive capacity is generally defined as the ability of a system to mobilize resources to anticipate or adjust and respond to the effects of changes (Engle 2011). In this sense, adaptive capacity determines whether adaptation can occur (Adger et al., 2011). Lereboullet et al. (2013) argue that adaptive capacity is conceptualized in the literature as a latent characteristic of individuals and groups that constitutes the preconditions for adaptation. While these preconditions are often conceptualized as different forms of capital, it has been pointed out (i.e., Grothmann & Patt, 2005; Nelson, 2011) that people's capacities to adapt often depend on characteristics beyond those generally understood to be "capitals."

Recent adaptive capacity research (i.e., Mortreux & Barnett, 2017; O'Neill & Graham, 2016; Parson et al., 2018) includes a focus that is expanded to include the ways in which psycho-social factors shape the ways in which assets are used to influence adaptation action, including personal experiences, expectations of institutions, trust, place attachments, and risk attitudes.

In the context of organizations, adaptive capacity can also be shaped by internal factors in the form of organizational structure, hierarchy, and culture, as well as by external factors such as the market and regulatory regime (Berkhout, 2012; Burch, 2010).

According to Smit & Wandel (2006), the capacity to adapt depends on the specific context and therefore varies between and within regions, sectors, social groups, and individuals. These different scales of adaptive capacity are nevertheless interrelated, and in studies of adaptation, it is thus important to consider the interaction among societal levels and how they influence each other's abilities to adapt (André, 2013).

This thesis takes as its starting point the perceptions, attitudes, and important structural factors of various glacier tourism actors that affect their abilities to adapt. I thus aim to gain insight into how and to what extent different factors affect adaptive capacity.

2.5 Actor-oriented approach to adaptation

Smit & Wandel (2006) distinguish between two main types of adaptation scholarship. A more system-oriented view is taken by studies that aim to investigate system properties that might enable action, to estimate the modeled impacts of climate change, or to compare the vulnerability of countries, regions, or communities. Action-oriented studies, by contrast, aim to provide practical adaptation initiatives or to assess specific adaptation measures for specific exposure units. This thesis contributes to the latter body of literature, in which "adaptation is concerned with actors, actions and agency" (Nelson et al., 2007, p. 398). The main focus of this study is on the type of adaptation research that looks at practical adaptation initiatives and processes from a bottom-up perspective. Hence, this research aims to produce a better understanding of tourism actors' experiences and perceptions of climate change and of opportunities to adapt.

A great deal of adaptation research appears to be largely detached from the reality of stakeholders, focusing predominantly on conceptualizing and assessing vulnerabilities and resilience, rather than on actual adaptation practices or action (Smit & Wandel, 2006; Arnell, 2010; Eisenack & Stecker, 2012). According to Klein & Juhola (2014), much of the adaptation literature stresses systems over actors and processes over actions – and hence fails to consider stakeholders and the contexts in which they operate. To overcome these limitations, the research conducted in this thesis uses an actor-oriented approach to research climate change adaptation, an approach that is particularly salient to investigating inter-actor influences and is based on Long's (1992) "actor-oriented" theory of social interfaces. The theory posits that actors' decisions are conditioned by factors such as knowledge and consideration of the social, cultural, and economic outcomes of taking particular decisions (McDonald & Macken-Walsh, 2016). The actor-oriented approach focuses on the "human agency" of the actors involved, while also recognizing the importance of the interplay and mutual determination of contexts, relationships, and structures, including the natural environment and social and political networks (Bramwel, 2006). Rather than conceiving of socio-economic structures and the natural environment as stable features, the actor-oriented approach regards them as emergent properties that are the products of the interlocking of the projects and practices of specific actors (Bramwel, 2006).

In the context of tourism adaptation research, actor-oriented adaptation research could advance knowledge on the process of adaptation and the role of tourism actors in glacial environments. It is likely to provide new insights into the strategies regarding the implications of climate change adopted by actors in glacier tourism and into what leads these actors to take adaptation action and what prevents them from acting (Klein & Juhola, 2014).

2.6 Transdisciplinary research

Tourism studies is inherently interdisciplinary, involving researchers from a broad range of disciplines, and examining a variety of subjects, for example, tourism actors, destinations,

developments, and impacts. Researching tourism in the context of climate change adds complexity to this varied scholarship. Climate impacts and responses are intertwined with their socio-political context, as well as with environmental variables (Carew & Wickson, 2010). Due to the incremental, irreversible, and complex character of these issues, the contested nature of concepts (such as climate change itself), and the major uncertainties involved, it is increasingly claimed that new types of knowledge and new means of knowledge production are needed (e.g., Gibbons et al., 1994; Funtowicz and Ravetz, 1993).

For example, Gibbons coined the term 'knowledge generation' as a shift from mode 1 to mode 2 science (Gibbons et al., 1994). Mode 1 science refers to traditional knowledge production processes, which focus on hierarchical mechanisms and processes executed by a set of homogenous actors from a common disciplinary background. On the other hand, Mode 2 science produces knowledge that is distributed, organizationally diverse, application-oriented, and trans-disciplinary. Funtowicz and Ravetz (1993) have called this contemporary scientific practice 'post-normal science'. According to them traditional science no longer fits its purpose when "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz and Ravetz, 1993, p. 744). Post-normal science can better address these new realities because it proposes a style of scientific research and practice that is reflexive, inclusive and transparent in regards to scientific uncertainty and is moving into a direction of the democratization of expertise (Strand, 2017).

Transdisciplinary approaches are critical for research that deals with complex, ill-defined problems concerning human–environment interactions such as climate change and that require "collective leadership, complex collaborations, and significant exchanges among scientists, decision makers and knowledge users" (Gosselin, Belanger, Lapaige, & Labbé, 2010, p.337). In this research context, transdisciplinary refers to a research approach that deals with real-world problems for which solutions cannot be found in knowledge derived from existing disciplines, but that instead require links across specific knowledge domains in order to meet inherent problem complexity and devise appropriate responses (Alvargonzález, 2011).

Transdisciplinary research entails the active engagement of stakeholders representing different interests and worldviews in the processes of problem identification, knowledge production, and learning (Serrao-Neumann et al., 2015). Science-based stakeholder dialogues are forms of transdisciplinary research that are initiated and driven by the research community in order to contribute to a deeper understanding, to combine knowledge bases, and to verify the social relevance of research on a particular issue (Welp et al., 2006). Participants in such dialogues are selected based on their specific knowledge base on and experience with a given subject, and not necessarily with the aim of achieving representativeness (e.g., public participation; Welp et al., 2006). Numerous studies (e.g., Bhave et al., 2016; Carlsen et al., 2013; Mobjörk, 2010; Welp et al., 2006) underline that in practice, methods such as integrated assessments and participatory research embody science-based stakeholder dialogues.

However, varying views of what constitutes salient and credible knowledge spur tension and challenge the exchange of knowledge between diverse knowledge bases. Boundary work, a mean that creates permeable knowledge boundaries by promoting research which facilitates meaningful participation of relevant stakeholders in knowledge co-production, can manage those tensions (Clark et al., 2011; Cook et al., 2013; Nel et al., 2015).

Important elements in these knowledge promotion activities are the use of boundary objects: “coproduced outputs that are adaptable to different viewpoints yet robust enough to maintain identity across them” (Nel et al., 2015, p. 178). These objects include, for example, maps, models, and tools, through which different actors can engage with each other, thereby promoting corporation among stakeholders.

3 Study area

The thesis research focusses on the southeastern part of Iceland (Figure X). The region is largely characterized by the large ice cap Vatnajökull. The region's sparce population, of 2,434 inhabitants as of January 1, 2020 (Statistics Iceland, 2020), is mainly scattered in the lowlands along the coastline; 1,750 inhabitants live in the area's only town, Höfn. The area is made up of one municipality, the Hornafjörður municipality. The region has a subpolar oceanic climate and contains the southeast part of the largest ice cap in Europe (by volume), the Vatnajökull ice cap. The Vatnajökull ice cap plays a central role in the tourism sector in southeast Iceland (Árnason & Welling, 2019). The ice cap contains multiple outlet glaciers and pro-glacial lakes, of which several have been developed into sites suitable for glacier tourism and recreational activities.

Southeast Iceland (Figure 1) was selected as the subject of a case study because it plays a central role in the Icelandic glacier tourism sector, and because the glacial landscapes that attract many tourists to the region are heavily impacted by climate change (Björnsson, 2017).

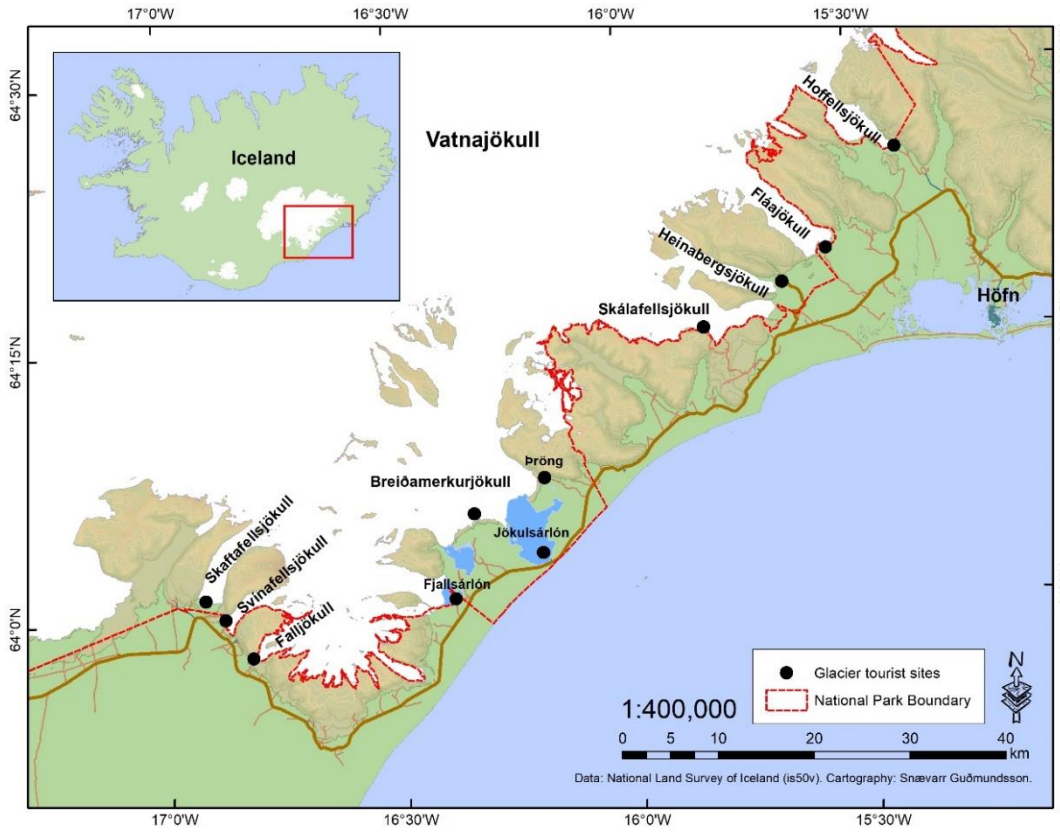

Figure 1 Southeast Iceland

In the last two decades, this sparsely populated rural part of Iceland has developed from being mostly based on agriculture and fishing to become an important tourism area. Since 2011, Iceland has faced an exceptionally strong growth of inbound tourism. The foreign

visitor numbers have increased by 251% in the past decade alone, from 565,611 visitors in 2011 to 1,986,153 visitors in 2019 (ITB, 2020). This rapid growth in the number of visitors to Iceland is reflected by an increase in site visitations of several glaciers in the Vatnajökull region. However, as Table 2 reveals, some glacier sites have experienced a faster visitor growth rate during the summer than others.

The southeast glaciers of Vatnajokull are located in one of the warmest and wettest areas of Iceland (Hannesdóttir et al., 2010) and therefore respond quickly to changes in temperature and precipitation. The recession of the outlet glaciers in the southeast part of Vatnajökull has been especially pronounced since the 1990s, with all monitored ice caps retreating and thinning at an unprecedented pace (Hannesdóttir et al., 2015; IMO, 2018; Schmidt et al., 2019).

Table 2 Visitor numbers at popular glacier sites in southeast Iceland during the month July (2013–2019)

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Jökulsárlón	No data	84,186	87,871	107,154	114,520	117,886	114,441
Svínafellsjökull	No data	No data	16,208	19,741	23,926	27,455	24,741
Jökulstígur	13,494	13,016	12,920	15,825	18,312	18,445	17,516
Fjallsárlón	No data	No data	37,580	No data	52,658	51,916	46,956
Heinaberg	1,186	1,480	1,434	2,180	2,449	2,536	2,547
Hoffell	3,306	3,281	4,177	2,869	4,474	6,409	5,237

Source: Þórhallsdóttir & Ólafsson, 2020

The Vatnajökull ice cap is part of the Vatnajökull National Park (VNP), established in 2008 (Alþingi, 2007). Most of these glacier sites are part of VNP, which means that all tour activities are subject to the management guidelines and regulations of VNP and, conversely, that the tour companies are stakeholders of the park. However, despite the fact the Vatnajökull ice cap is designated as a national park, there is an absence of any formal strategic plans, policies, or other formal institutions related to climate change adaptation at the corporate, tourism-sectoral, or public-governance levels in Iceland (Landauer et al., 2017).

4 Research design and methodology

4.1 Research process

The research process of this thesis consists of three sequential stages that each address a specific research objective (Figure 4.1). Stage I establishes the context of the thesis research. The focus of this stage was to investigate what has been researched on the topic of glaciers, tourism, and climate change both on a global level and in Iceland. The two papers (I and II) of this stage are closely linked, as Paper II is the continuation at a national level of the more general study conducted in Paper I. Both papers build a foundation for Stage II by providing literature for Papers III and IV and describing the case-study area. In Stage II, the data collected in Paper III was used to develop visitor implication scenario statements for Paper IV. The results obtained from Stage II formed the basis for Paper V in Stage III. Papers III and IV provided empirical evidence that supports findings of Paper I and led to the development of assumptions about how proactive adaptation for glacier tourism, based on relevant information, could be stimulated. Science-practitioner interaction in the form of participatory scenario development was assumed to support current adaptation planning for glacier sites in southeast Iceland. These assumptions were tested in Paper V.

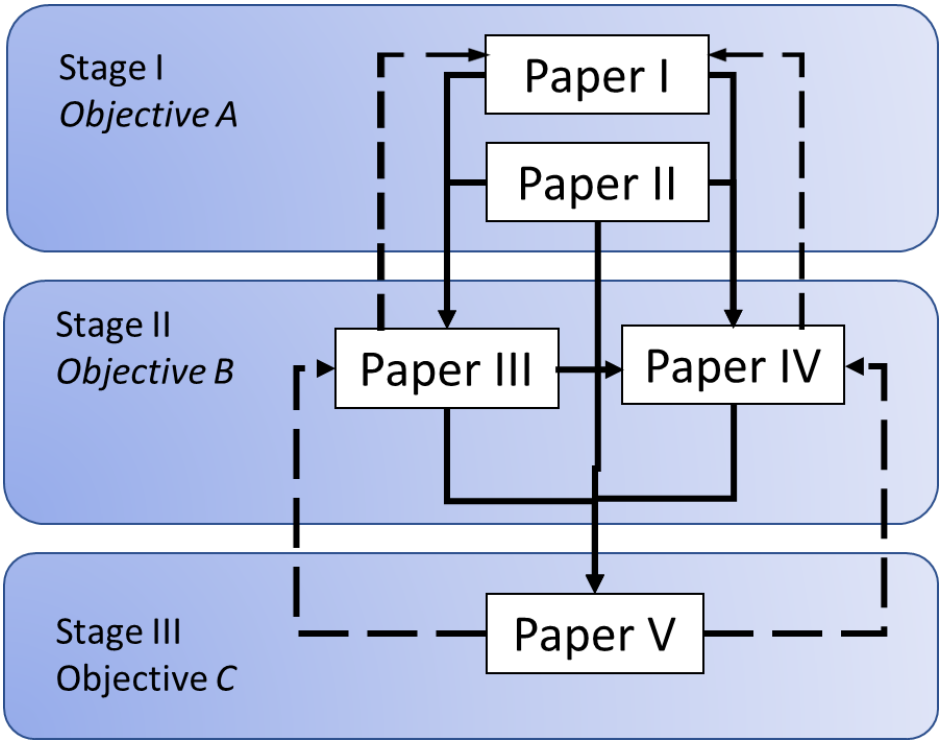

Figure 2 A flow chart of the research process. Arrows indicate the relationships between the papers. Straight lines indicate that the results of one research paper led to the design of the other. Dashed lines indicate that the results of one research paper support findings or validate assumptions developed in the previous papers.

4.2 Pragmatic viewpoint

This thesis adopts a pragmatic viewpoint to underpin its methodology. Pragmatism is rooted in the work of American philosophers of the late nineteenth and early twentieth century (e.g., Charles Pierce, William James, and John Dewey). Their ideas provided a 'third' way in the ontological debate of the nature of human mind's relationship to reality and truth between positivistic and constructionistic perspectives, by valuing knowledge for its practical extrinsic usefulness for daily life questions (Talisse & Aikin, 2008).

In adopting a pragmatic worldview, knowledge is understood as being constructed based on the reality of the world we experience and believe in (Morgan, 2014). This means that pragmatism accepts that there are single or multiple realities that are open to empirical inquiry (Creswell & Clark, 2011). Therefore, knowing in a complex reality, such as climate change adaptation in glacier tourism, requires multiple perspectives of different tourism actors to be considered, where knowledge might be convergent, varied, or even contradictory.

Pragmatism advocates transferability of research results as the way to infer knowledge from data. According to Morgan (2007), we need to investigate the factors that affect whether the knowledge we gain can be transferred to other settings, instead of assuming that our methods and our approach to research makes our results either context-bound or generalizable. Therefore, the usefulness of knowledge in new circumstances should be advocated above argumentation about whether data is generalizable or not (Morgan, 2007). Furthermore, a pragmatic worldview offers epistemological justification for the use of a transdisciplinary approach that brings together multiple sources of knowledge with the goal of finding workable solutions, and gaining a greater understanding of (tourism) actors and their world in which they live and practice (Johnson & Onwuegbuzie, 2004). By primarily reflecting a pragmatic standpoint, this thesis values a study design that maximizes whatever sources of and methods for collecting and analyzing data that might be best for reaching the thesis's central aim (Creswell & Plano Clark, 2011). Therefore, this thesis uses both quantitative and qualitative modes of inquiry and prioritises the assessment of their usefulness in light of an existing problem and the need to compensate for the biases and weakness of each method. It thus provides the opportunity to change disciplinary methodological lenses in order to serve the project's needs.

4.3 Embedded single case study

This thesis is an example of an embedded case study, in which one case (glacier tourism in Southeast Iceland) involves more than one object of analysis (tour operators, visitors, glacier site stakeholders) and that furthermore focuses on different salient aspects of the case using a variety of qualitative and quantitative methods and multiple sources of information, such as interviews, focus groups, surveys, and documents (Scholz & Tietje, 2002). A carefully established rationale guided the selection of the embedded single case study design, including the fact that this study required a holistic case study, enabled the study of adaptation processes and practices among different tourism actors in the same institutional and geographical contexts and, in the context of transdisciplinary production of knowledge, enabled this study to link researchers and stakeholders for knowledge exchange, dialogue, and communication. The embedded case study design is an empirical form of inquiry appropriate for explorative research, in which the goal is to explore the

features, context, and process of a phenomenon. Embedded case studies explore the phenomenon in terms of subunits, each of which focuses on different aspects. The data obtained from the cases is interpreted in a transformational process that relies on various methods to arrive at a perception, judgement, or evaluation (Scholtz and Tietje, 2002). The multiple data sources and the methodological triangulation lend breadth and depth to data collection, decreasing the weaknesses of any individual method and thus strengthening the outcome of the study.

The use of an explorative embedded case study design does not preclude the use of other types of research, nor does it mean that data can be collected only concurrently. The first paper (Paper I) reviews research that focuses on glacier tourism outside the study area of this thesis. Furthermore, the papers of this thesis inform other papers conducted at a later stage; for example, several references obtained in the literature review (Paper I) were used in other papers (Paper III–V), while the findings of the in-depth interview study (Paper III) were used to develop questions and hypotheses for the questionnaire in the visitor survey (Paper IV).

4.4 Methods

Although there is no agreed-upon design for embedded case studies, in general, research identifies problems, poses questions, and gathers data and analyzes it (Creswell, 2007). This research is no exception. Data collection methods included a scoping literature review, semi-structured interviews, questionnaires, observations, and workshops. Data-analysis methods included content analysis, document analysis, cluster analysis, and modelling (Table 3).

Table 3 Methods, data sources, unit of analysis and spatial and temporal scales used in this thesis

Paper	Data collection/ analyses methods	Source of data	Unit of analysis	Spatial scale	Temporal scale
I	Scoping literature review	Academic literature	Glacier tourism in general	Global	Past
II	In-depth interviews and document analysis	Tour operators, websites, statistics	Icelandic glacier tourism sector	National	Present
III	In-depth interviews and participant observation	Tour operators	Tour operators	Local	Present
IV	Visitor survey, cluster analysis	Glacier site visitors	Tourists	Local	Present and future
V	Participatory scenario workshops	Local stakeholders, land survey	Glacier site stakeholder (tour operators, park managers, NGOs, municipality planner)	Site	Future

4.4.1 Scoping literature review

This research project began with a scoping literature review of glacier tourism literature (Paper I). The review consisted of English-language academic literature including peer-reviewed articles, reports, and academic book chapters and aimed to synthesize what is currently known about glacier tourism. This is the first review on glacier tourism literature in academic literature and aimed to familiarize the researcher with the object of the research and to assess the state of existing knowledge, clarify concepts, and identify knowledge gaps. A scoping review is comparable to a systematic literature review; however, its aim is not to produce a critically appraised and synthesized result/answer to a particular question, but rather to provide an overview of current knowledge on a specific topic (Munn et al., 2018). The literature was collected through various online academic databases and reference list searches of selected literature. This literature review functioned as an important baseline study, identifying concepts, research gaps, and opportunities, as well as references for academic literature used in the other studies (Papers III–V) of this thesis.

4.4.2 Document analysis

Document analysis is a method used to explore the social world through diverse forms of text in written, audial, visual, or electronic forms and can either support a complete research project in its own right or provide supplementary data for other research methods (Botterill & Platenkamp, 2012). The research in this thesis used documents both as a main data source (Paper II) and as additional evidence to support other forms of research (Paper III). Distinct from the literature review, document analysis adds new data to the analysis. Tour companies' websites, tourism statistics, and policy documents regarding adaptation and glacier site management were the main documents analyzed in this thesis.

4.4.3 In-depth interviews and content analysis

To obtain insights from tour operators regarding their business development (Paper II) and adaptation process towards climate change impacts (Paper III), a series of interviews were conducted with nine local tour operators during the period April–June 2015. All interviews were conducted in English. The length of the interviews ranged from 45 to 90 minutes, and in most instances they were conducted at the residence or workspace of the respondents. The interviews were semi-structured, using a basic interview framework for all interviews (Creswell, 2007), but the order in which individual core questions were asked (and answered) varied, depending on the flow of conversation. All interviews were recorded, transcribed verbatim, and analyzed through the search for repeated themes and topics. To validate the interview data, a triangulation technique was applied that examined both the interview findings and the participant observation data to build a coherent justification for the emerging themes. To ensure methodological reliability, an interview guide was developed, discussed and tested (Appendix A), and the interview transcripts were then evaluated to make sure that obvious mistakes were not being made.

4.4.4 Participant observation

In addition to the interviews, tour participation and glacier site observation took place, respectively, in June and August 2015 (Paper III). Four different glacier sites were visited

(Skaftafellsjökull, Svínafellsjökull, Falljökull and Jökulsárlón) and the behavior of guided tour participants and guides was observed, as was that of non-guided visitors at the glacier sites. To further observe guides, tourists, and site managers, participant observation was conducted in three scheduled glacier hiking tours. Observations were written down and complemented by photographs of the sites, particular tour activities, equipment, and infrastructure. To validate the observation results, thick and rich descriptions (Creswell, 2014) were made and detailed fieldnotes were taken during the observations.

4.4.5 Visitor survey and segmentation analysis

To collect data concerning the coping behavior of glacier tourists regarding climate change–induced impacts (Paper IV), a visitor survey was conducted at two popular tourist sites within the study area (Jökulsárlón and Skaftafell). The procedure of the design, administration, processing, and analysis of a visitor questionnaire of Veal (2006) was followed for this part of the study. The survey was administered to visitors around the visitor center in Skaftafell and the cafeteria and parking lot at Jökulsárlón glacier lagoon, where most visitors gather, and consisted of self-completion questionnaires that were distributed randomly to visitors. The questionnaires were available in three languages (English, German, and French), because visitors speaking these languages constituted the largest groups of foreign visitors at the time at which the questionnaires were administered (ITB, 2016). A segmentation analysis of the glacier site visitors' behavior was conducted to examine the extent of variation in visitor behavior towards climate-induced environmental changes of glacier sites. Following the recommendation of Hair et al. (2014) a standard two-stage clustering sequence was applied in which a hierarchical cluster analysis was run, followed by clustering through K-means cluster techniques on the decided optimum number of clusters. The validity of the results was checked through statistical tests such as reliability measurement and discriminant analysis. To enhance the reliability of the survey, a pilot study was conducted on a smaller sample in order to test the questionnaire before running the full study. Furthermore, the subsamples from the summer and winter data collection were compared to evaluate the stability of the results.

4.4.6 Participatory scenario workshops

The transdisciplinary approach adopted in this research project was implemented through a series of participatory scenario workshops (Paper V). Practitioner and expert knowledge of current and future development of recreational land use at the glacier site Þröng in southeast Iceland (see Figure 3) were yielded from three stakeholder workshops held in Höfn (November 2016, June and October 2017) to which tour operators, park managers, municipality planners, NGO representatives, and tourism experts were invited. During the three stakeholder workshops, a participatory scenario planning (PSP) exercise was conducted that consisted of three main phases. The first workshop involved analyzing the recreational land uses of the study area as a socio-ecological system and exploring how drivers of change may influence this system through a collective cognitive mapping exercise. The workshop participants designed alternative future scenarios in the form of narratives and recreational landscape maps of the study area. The future land-use changes were assessed by comparing the development of the land-use variables described in the story lines with the spatial distribution of current land uses of the study area. Finally, the future land-use story lines were converted into a spatial representation and added to a projected glacial landcover map of the Þröng site for 2026 using a glacial land cover

modelling technique (Guðmundsson et al., 2017) and Geographic Information System (GIS). The result of this science practitioner engagement were three scenario landscape maps. In the second workshop, the scenario story lines and maps were presented and discussed with the local stakeholder group to identify the most important opportunities and threats for each scenario. Finally, in the third and final workshop, the stakeholders identified a set of options to adapt to the main threats and opportunities identified earlier and assessed the practicality of implementing these options, including the availability and sufficiency of land-use governance and management products and services. The scenario story lines and maps were validated through discussion in the stakeholder workshops and through triangulation in which the scenarios were compared to other scenarios of future tourism development in Iceland.

5 Summary of papers

5.1 Paper I

Paper I set out the foundation for understanding glacier tourism as a niche sector in its own right. The paper aims to provide a state-of-the-field of current knowledge on glacier tourism and identifies gaps in knowledge in this relatively new field of research. The scoping literature review conducted initially identified 166 sources, from which 53 sources were ultimately included for review. The paper results reveal that research on glacier tourism is limited but growing (Paper I, Figure 2). The results further indicate that current literature on glacier tourism conceptualizes it as tourism activities in which the glacial environment functions as the main attraction or setting for various leisure activities based on three elements: adventure, recreation (based on specific geomorphology) and education. Glacier tourism does not solely consist of activities that take place on the glacier itself; many activities take place in adjacent pro-glacial areas such as moraine areas and pro-glacial lakes.

The literature review identified three central themes: perceptions and values of glaciers, the effects of glacier tourism on the social and ecological environment in which it takes place, and climate change and variability. The majority of the reviewed studies addressed the last theme. Results indicate that the impacts of local climate change on glacier tourism concern changes in both weather conditions and weather patterns (Paper I, Figure 4). Changes in weather conditions affect glacier tourism directly by changing the visibility, safety, and comfort level at glacier sites. Changes in weather conditions and patterns affect glacier tourism indirectly through the alteration of glacial landscapes, for example, by glacier shrinkage, glacier river run-off, and permafrost thawing. In turn, these glacial landscape changes have already led to significant impacts on tourism activities and operations in glacier landscapes in the form of increased occurrence of natural hazards, reduced accessibility to glaciers or within glacier sites, limited tour activities, and changes in landscape scenery.

Furthermore, the results show that responses to the climate-induced impacts varied widely depending on the type of climate-induced impact (e.g., glacier hazards or destination accessibility), the glacier tourism activities impacted (e.g., skiing or hiking) and the geographical area, and the actors or institutions that implement these adaptation or mitigation measures (e.g., entrepreneurs or area managers). The few studies that analyzed the demand for glacier tourism with respect to the impacts of climate change show a significant decrease in demand as a consequence of considerable changes in glacier scenery or glacier disappearance.

Studies concerning tourist perceptions of glacier recession reveal that glacier visitors have good knowledge of the processes involved in glacial recession, but this knowledge is more a result of preconceived ideas disseminated within society, most probably originating from the media, rather than of direct observations of the glacial landscape. Studies of tourism operators, by contrast, indicate some indifference to climate change among entrepreneurs,

as they consider recent glacier recession more as a product of local precipitation and summer temperatures than of global climate change.

The paper constitutes the foundation on which the research in the other papers is developed and provides an overview of what research has been carried out on glacier tourism up to the present. The state-of-the-art knowledge did not prevent me from looking into research that was published after 2014. The papers of this thesis that follow after this first paper analyzed several more recent researches about glacier tourism (e.g., Stewart et al., 2016; Groulx et al., 2017; Weber et al., 2019; Purdie et al., 2020).

Paper contribution

The contribution of the scoping review is that it was the first study to synthesize and analyze glacier tourism research, thereby placing this tourism niche on the agenda for further research. An important research gap identified in the scientific field of glacier tourism is the lack of data concerning the motives, preferences, experiences, and behaviors of glacier tourism actors in general and specifically in the context of climate change. This thesis is one step towards filling this gap.

The review furthermore demonstrates that glacier tourism encompasses lived, valuable experiences of climate change–induced phenomena, such as glacier recession and fragmentation. Research on how such localized lay knowledge, perception, and understanding is formed during the interaction of glacier tourism actors with their changing environment provides an important opportunity to study climate change as embedded in society. This paper therefore constitutes an answer to a clear call (e.g., Orlove et al., 2008; Gagné et al., 2014) to focus on the human dimension of climate change, particularly in the context of glacial environmental change.

5.2 Paper II

The findings of Paper I motivated a more extended exploration of the impact of climate change on glacier tourism at the national level. To this end, Paper II examined the development of glacier tourism in Iceland and explored the challenges that this form of niche tourism are facing as a result of gradual and sudden changes in the natural environment, as well as of the development of mountain tourism in Iceland more generally. The findings show that glacier tourism in Iceland has grown quickly from being a fairly small, niche-oriented sector to becoming one of the largest and most diverse adventure-tourism sectors in the country. These developments are largely due to the general increase recently in annual tourist arrivals to Iceland, but also to a considerable extent to the entrepreneurial activities of tour operators. The results reveal, furthermore, that the challenges facing glacier tourism in Iceland can be divided into two basic types. The first is external challenges, which constitute direct or indirect changes in the natural environment that affect glacier tourism but on which the tourism sector has no influence. Catastrophic but short-lived volcanic activity and especially small-scale but cumulative impacts of climate change are examples of such challenges. Second, glacier tourism also faces internal challenges, which result from the changes in the demand for and supply of glacier tourism activities themselves.

Paper contribution

Paper II delved deeper into the glacier tourism sector on a national level and explored the diverse factors that shape the development of glacier tourism. This paper sets the stage for the embedded case study approach by describing the area, its characteristics, and the main actors and developments. An important contribution of the paper is that it reveals that climate change is one of many challenges faced by the glacier tourism sector in Iceland.

5.3 Paper III

This study aims to examine how adaptation to the impacts of climate change is practiced by small- and middle-scale glacier tour operators at the destination level. Data was collected by means of a set of semi-structured interviews with the managers or owners of a total of nine small- or middle-scale tour companies operating in VNP in southeast Iceland and observations of glacier sites in which the respondents' companies were operating. This set of nine glacier tour companies constituted a sound representation of the glacier tour operator sector in Iceland (n = 61 in 2015, Paper II) in terms of size (number of employees and customers) and tour specializations.

The results show that most operators experienced more than one signal of the impact of climate change during their daily operations, and several impacts occurred in a combination of changes in the glacial environment and extreme weather events. Climate change has already resulted in several impacts on glacier tour operators' current operations in the study area, which are mostly related to accessibility issues to and within glacier sites and changes in the occurrence of natural hazards (Paper III: Table 3). However, the results reveal that although all entrepreneurs consider climate change to be a real phenomenon that affects their present daily operations, they perceive these implications as not being significant threats to their business. The operators have responded to these implications by implementing multiple but almost entirely short-term reactive or implicit adaptation measures (Paper III: Table 4 and 5) that lack an anticipatory planned strategy to cope with future climate-induced implications.

The results, furthermore, reveal that the interaction of operator's attributes of agency such as firsthand experiences, risk perceptions, and abilities to self-organize, with structural elements of the glacier destination system, such as economic rationales and hazard reduction institutions, has shaped and consolidated operators' adaptation processes in the form of a wait-and-see strategy combined with ad hoc reactive adaptation measures. This has postponed or prevented proactive long-term adaptation strategies.

Paper contribution

An important contribution of this paper is that it empirically examines how glacier tour operators enact climate change adaptation by framing adaptation as a decision-making process consisting of four main interactive aspects: perception, evaluation, action, and feedback. As a result, a thorough understanding of these processes is obtained by examining how the agency of individual decision-makers of the tour companies and the structural components of the system in which those decision-makers operate interact to create locally specific adaptation processes. Such insights can enable decision and policy makers in the glacier tourism sector to support favorable conditions for entrepreneurial climate change adaptation.

5.4 Paper IV

Paper IV continues the task of understanding the impacts of climate change on glacier tourism and the adaptation responses of glacier tourism actors. This paper provides insight into how the demand for glacier tourism responds to the implications of climate change. This research, therefore, assesses how the visitation implications of climate change affect the intended behavior of glacier site visitors and examines the extent of variation in visitor behaviors as a result of these implications. Data obtained from a quantitative survey of 565 tourists who visited several glacier sites (see Figure 1) during the first week of August 2015 and the second week of February 2016 was generated, processed, and analyzed.

Based on the findings of Paper III, eight hypothetical but plausible statements were developed to gain insight into the adaptive response behavior of glacier site visitors. The statements represent the implications of climate change for visitors to glacier sites in the near future (2–4 years). They represent practical implications, caused by a combination of climate change impacts and managerial adaptations that visitors can encounter, such as increased walking time to a glacier margin, reduced proximity to the glacier, or mandatory use of commercial guides or transportation (Paper III: Figure 2)

The results demonstrate that climate change–induced environmental changes greatly affect the demand for glacier tourism, but to what extent glacier visitors are affected varies across visitation implications. Changes in glacier scenery and especially management measures, such as mandatory transportation and guiding to adapt to changed environmental conditions, have a negative effect on the intended visitation behavior of considerably more visitors than other implications such increased walking time or reduced proximity to a glacier margin.

Further analysis of the survey results using cluster analysis shows that the responses of glacier visitors to those changes differ considerably across visitor segments. Three more or less evenly divided, but significantly distinct visitor segments (Resistant, Susceptible and Adaptive visitors) were discerned on the basis of the intended behavior of glacier site visitors towards the visitation implications. One visitor segment (the Resistant visitor) is characterized by the intension to visit a glacier site under all visitation implications; another segment (the Adaptive visitor) is willing to visit a site given some of the implications; a third segment (the Susceptible visitor) will not visit a glacier site given almost any implication. The results demonstrate furthermore that these three visitor segments differ significantly in demographic and cross-cultural characteristics, length of stay, activity interests and performance, motivation, and climate change perception.

The results indicate that there is a significant difference between visitor segments in the way these visitors appraise the changed condition (desirable/undesirable) and response (continue to visit; substitute activity, timing, or site by doing something else; or accept technical coping, i.e., using vehicles or expert skills/knowledge, in order to overcome visitation implications). Furthermore, the findings offer new insights into visitor attributes such as gender, recreation activity interests, and travel motivation that constitute underlying variables that can explain differences across the visitor segments' adaptation behaviors.

Paper contribution

This paper contributes to the vast need for studies to examine tourists' responses to climate change impacts. It is the first study that segments glacier tourists on the basis of their intended behavior in response to climate change–induced environmental change. Insight into the heterogeneity of the climate change adaptive behavior of glacier site visitors is of vital importance to planning and managing the dynamic glacier destinations. For example, the visitor segmentation revealed potential trade-offs between strategies to increase the number of glacier site visitors under conditions of environmental change in the near future. Disclosure of these trade-offs underlines the necessity to consider climate change adaptation as an integral part of an organization's sustainable development strategies.

5.5 Paper V

This research explores how participatory scenario planning (PSP) can support adaptation planning for glacier sites. The PSP involved three local stakeholder workshops in which the stakeholders generated maps reflecting plausible glacial land cover and land use in the near future. This process took place in four stages from the autumn 2016 to the winter of 2017–18, including different activities such as the identification of potential drivers of land-use change, the development of multiple land-use scenarios, and the examination of the potential consequences of these scenarios and options for adapting to them.

The PSP approach combined science and practitioner knowledge into the exploratory scenario development of recreational land uses at the glacier site Þröng (see Figure 1). The science contribution took the form of future landcover maps based on a glacial landcover modeling technique (see the methodology chapter), while the local stakeholder group brought in their practitioner knowledge regarding recreation, land-use, and management.

The results demonstrate that PSP is a valuable tool to support recreational land-use planning in glacial landscapes and to improve anticipatory adaptation to potential future changes. The results reveal important barriers to implementing adaptive actions. Of the addressed adaptation options, more than half were considered difficult or impossible to implement under current decision-making and governance conditions, because important resources such as knowledge, education, vision, regulations, and financial means required to implement the options were absent or insufficient (Paper V: Table 5). However, factors such as the presence of an informal stakeholder network and the inclusion of local knowledge of the natural environment and recreation possibilities can enhance the adaptive capacity of recreational management to respond to climate change impacts.

Paper contribution

The contribution of this paper concerns enhancing the adaptation planning of glacier sites by a) developing tailor-made scenarios on the basis of the stakeholders' concerns and perceptions (i.e., their identification and prioritization of drivers of change of recreational land uses and their development pathways); b) addressing the co-created knowledge at relevant spatial (glacier site level) and temporal scales (10 years) for the stakeholders; and c) visualizing this knowledge in the form of maps to add a spatial dimension to the process.

An advantage of the proposed PSP process is the creation of scenario maps of recreational land-use that allowed the diverse stakeholders to work together; facilitate their

communication and understanding across different concerns, interests, and knowledge; and build consensus regarding the main potential impacts and adaptive measures to take in response to these. Results showed that the scenarios clearly enabled the stakeholders to share knowledge, elaborate on long-term changes and associated uncertainties, and explore proactive adaptation options. The analysis also showed that the local stakeholder workshops played an important role in the sense-making of scientific knowledge (i.e., glacial landcover modelling results) and how this process can facilitate proactive adaptation planning.

This research also demonstrates that the applied PSP approach empowered the stakeholders through their contributions to the creation and application of the different scenarios. All participants had a stake in the final outcome; they all contributed their own knowledge and expertise to the development of the scenarios. During the scenario development process, greater mutual understanding was further attained within a diverse group, whose members would otherwise be less likely to have the opportunity to meet and discuss these issues.

In addition, the research also provides insight into the capacity of current recreational management and planning systems to adapt to potential combined climate and non-climate impacts. Next to the presence or lack of resources as factors that enable or constrain adaptation planning, the study also provides insight into how stakeholders' interests and concerns shape proactive adaptation. Stakeholders prioritized short-term issues, such as the current rapid growth of tourism in Iceland and the governance of public lands, above incremental and long-term changes, such as glacier recession, as important drivers of land-use change. This supports the findings of Paper III, in which tour operators perceived the recession and thinning of glaciers as entailing limited risk or being controllable.

6 Conclusion and future work

6.1 Conclusion

Climate change constitutes one of the most pressing challenges faced by current and future tourism. In particular, tourism that takes place in those environments that are most susceptible to global climate change is extremely vulnerable to such challenges. Glacier tourism is a highly relevant example of a type of nature-based tourism which needs to adapt to climate-induced environmental changes. However, despite a general recognition of the urgent need to adapt, as well as a large-scale scientific effort in this field underlining evidence of potential risks, the impacts of adaptation research on practices and policies in tourism appear to be relatively low. This thesis aims to increase the knowledge and understanding of the relations among glacier tourism, climate change, and adaptation and by doing so to attempt to build a bridge between academic knowledge production, on the one hand, and policy-making and site management, on the other.

The first objective of this thesis was to provide state-of-the-field knowledge concerning relationships among tourism, glacial environments, and climate change. A scoping review of English-language literature on glacier tourism revealed a limited but growing body of scholarship that examines the relationship between tourism and glaciers, of which studies on climate change impacts and adaptive responses of glacier tourism constitute a key emphasis. However, the majority of the identified studies consists of general descriptions of existing measures and policies, or a summary of suggestions for what measures might be implemented in the future. An important research gap identified is lack of data concerning the motives, preferences, experiences, and behaviors of actors in glacier tourism in general and specifically in the context of climate change, building the foundation for this thesis second study.

The second objective was to examine how glacier tourism actors adapt to the current and future impacts of climate change. The results show that operators consider impacts related to accessibility problems to and within glacier sites, as well as changes in the occurrence of natural hazards, to be the main implications induced by climate change on their tour operations, but they do not perceive these impacts to be a serious threat to the continuation of these operations, due to a combination of low risk perception and high adaptation efficacy. The operators responded to these implications by implementing multiple but almost entirely short-term reactive or implicit adaptation measures that lack an anticipatory planned strategy to cope with future climate-induced implications.

These results are in line with findings from other studies on climate change adaptation of tour operators in glacier tourism (e.g., Paper I; Stewart et al., 2016; Purdie et al., 2020) as well as in other tourism sectors where the entrepreneurs' operational environments are heavily impacted by climate change such as downhill skiing (e.g., Haanpää et al., 2014; Trawöger, 2014) or the coral reef diving sector (e.g.; Evans et al., 2016). Such similarities in findings confirm that studying glacier tourism constitutes a relevant and valuable contribution to climate change research in tourism.

The results also indicate that there is a significant difference between glacier site visitor segments concerning the ways in which they appraise potential climate change induced changed conditions and subsequently respond to these changes. Depending on the type of implications at the glacier site as well as on visitor attributes such as place of residence, motivation, or activities of interest, visitors either accept potential impacts, employ technical adaptation, or substitute the particular glacier site. Hence, the visitors differ on many aspects, and subsequently their sensitivity to climate change implications. Such information is of vital importance for site managers and in particular tour operators, in light of their confidence in being able to overcome climate change implications by continuing their current reactive adaptation strategy. Therefore, a crucial element for the understanding of the vulnerability of glacier tourism destinations to climate change is to integrate supply- and demand side perceptions about climate change impacts and adaptive responses to these.

The thesis concludes that the interaction of the agency attributes of individual tour operators (in form of firsthand experiences, risk perceptions and abilities to self-organize) and tourists (in form of travel motivation and activity interests) with the structural elements of the glacier destination system (in form of economic rationales of area management, competing interests, hazard reduction institutions, visitation implications and lack of effective climate change institutions) results in the creation of locally specific adaptation processes. Through these empirical results, this thesis contributes to previous research on adaptation processes by providing insight into the complexity of adaptation processes in practice and by revealing that these processes of glacier tourism actors are determined by the integration of cognitive, socio-ecological and institutional factors. A thorough and holistic understanding of these interactions is crucial to gauging the adaption capacities of glacier tourism actors.

The third objective was to examine how science-practitioner engagement can contribute to future-orientated, proactive adaptation. This engagement, in form of a PSP process with local stakeholders, proved to be a valuable tool to support the adaptation planning of glacier sites. The PSP method developed in this thesis provide salient and usable knowledge for local stakeholders, and to stimulate stakeholders to elaborate on the long-term changes and associated uncertainties that can encourage a more future-oriented mentality by applying boundary objects such as scenario and cognitive maps of recreational land uses of the examined glacier site Þröng. The results stress that the importance of the PSP process lies in the fact that it places the adaptation planning of glacier sites in a wider network involving more than just glacier tourism actors. The engagement of representatives of VNP, local environmental NGOs and the planning department of Hornafjörður municipality linked the tourism system to a broader regional system in which not only future impacts on the economic viability of the glacier tourism were addressed but also the social and environmental implications of glacier tourism itself on a regional scale. The implications of glacier tourism previously addressed in other glacier tourism studies were synthesized in the scoping review paper of this thesis (Paper I).

It may be concluded that climate is only one of many drivers of change that determine the development of glacier tourism in the case study area. This finding strongly suggests that climate change implications cannot be understood as isolated factors; rather, they should be viewed as constituting interconnected and cumulative effects on the socioeconomic and natural environments where glacier tourism takes place. This is supported by Ólafsdóttir and Haraldsson (2019), stressing the importance of holistic understanding when it comes to tourism development and planning. Climate change interacts – and competes – with other natural and socio-economic impacts that glacier tourism actors have to cope with in their local environments. Therefore, climate change adaptation needs to be embedded in responses to multiple stresses and connect to broader network than just tourism actors in order to avoid trade-offs between adaptation to climate change and other developments. Mainstreaming climate change adaptation into current destination planning and management (Mogelgaard et al., 2018) and/or integrating climate change adaptation with related fields of science, such as hazard reduction research or sustainability science (Abegg et al., 2017), thus provide more promising approaches than studying or dealing with climate change adaptation in isolation.

6.2 Further research

Further research is needed to increase the understanding of climate change adaptation in the context of glacier tourism, a form of tourism that is, arguably, highly susceptible to climate change impacts and thus able to provide valuable insights into the potential, as well as constraints, of climate change adaptation within tourism in general. In particular, new research should deepen and widen the knowledge obtained in this thesis which attempted to study climate change adaptation broadly in a transdisciplinary and holistic manner, within an embedded (and thus geographically limited) case study area. First, I suggest extending the geographic coverage of research on glacier tourism adaptation to popular glacier destinations that are sparsely studied, such as glacier destinations in Argentina and Scandinavia. Second, the PSP approach developed for the adaptation planning of glacier sites in this study should be applied to other glacier sites in Iceland, or other popular glacier destinations worldwide, to increase the validity and usability of the approach.

To widen the knowledge obtained in this thesis, I suggest conducting cross-area comparative analyses of the perceptions of climate change impacts and the adaptation strategies and practices of glacier tourism actors. Such studies would allow for the analysis of the full range of potential climate change impacts and their interactions with other drivers of change, and would furthermore transcend the regional context of many adaptation studies and thus also provide more general insights about climate change adaptation within glacier tourism. In particular, as encouraged by other tourism studies, it is necessary to continue and increase research into how and to what extent visitors' attributes determine their adaptive behaviors towards climate-induced environmental changes (e.g., Gössling et al., 2012; Scott et al., 2016).

Finally, the PSP approach developed in this thesis for adaptation planning concerning glacier tourism sites should be improved by complementing local stakeholders with a diverse group of experts and by using exploratory landcover projections to reframe local

stakeholders' guiding assumptions regarding changing glacial environments. The presentation of future glacier landscape scenarios could be improved and made more realistic by using two-dimensional visualization techniques (Weber et al., 2019) or immersive virtual environments (Fauville et al., 2020) which would allow participants to perceive future landscape scenarios using multiple senses.

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PART TWO
PAPERS

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RESEARCH FRONTIERS

Glacier tourism: a scoping review

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Many glaciers worldwide have become popular tourist destinations where a broad range of outdoor recreation- or adventure-based activities, such as glacier hiking, ice climbing or snowmobiling, can be conducted. Despite the growing popularity of glaciers as tourist destinations, up to now only very limited research has been undertaken into this form of tourism. The purpose of this paper is to systematically assess the nature and scope of research into glacier tourism in academic literature and to identify gaps in knowledge in this relatively new field of research. A scoping literature review was conducted of English language academic literature including peer-reviewed articles, reports and academic book chapters, in order to synthesize what is currently known about glacier tourism. From the initially identified 166 sources, 53 sources were ultimately included for review. The greater part of the reviewed literature consists of descriptive empirical studies. The review identified three central themes: perceptions and values of glaciers; the effects of glacier tourism on the social and ecological environment in which it takes place; and climate change and variability. The majority of reviewed studies address the last theme ($n = 25$). Research on glacier tourism is limited but growing. It deals with a broad scope of topics and addresses glacier tourism in a variety of ways. The literature review demonstrates the need for additional research into several issues, including: (1) designing a coherent conceptual framework that incorporates the main elements of glacier tourism; (2) examining the motives, preferences, experiences and behaviours of glacier tourists, as well as of the motivational push and pull factors of glacier tourism; and (3) conducting cross-area or sub-sector comparative analyses of existing or potential climate-induced impacts on glacier tourism or adaptation strategies and measures. The present study provides a basis for further research in a young and growing research field.

世界范围内的很多冰川已成为广受欢迎的旅游目的地，在那里可以开展一系列户外游憩或者探险活动，像冰川徒步、冰川攀登或者雪地机动车运动。尽管冰川旅游目的地广受欢迎，但是直至现今有关这种旅游形式的研究仍非常有限。本文目的是系统地评估学术文献中冰川旅游研究的范围与特点，识别这个较新研究领域的知识缺口。为系统了解当前冰川旅游研究的现状，对包括同行评审论文、研究报告和学术书籍章节等英文文献进行了概览性综述。最初收集到166份文献，最终把其中的53份纳入文献综述范围。绝大部分文献是描述性的经验研究。本综述识别出3个中心议题□冰川的认知及价值研究；冰川旅游对当地的社会及生态环境影响；气候变化与异动。绝大部分文献研究的最后一个议题□文献篇数 = 25）冰川旅游研究数量有限但是在逐渐增加。它涉及议题广泛并且从不同方面关注冰川旅游。文献综述表明，在一些议题方面需要进一步研究，包括；1）设计一个融合冰川旅游主要要素的概念框架；2）考察冰川旅游者的动机、偏好、体验与行为以及冰川旅游动机的推拉因素；3）开展现有及潜在的气候引发的冰川旅游影响及调适措施的跨区域、跨部门比较研究。本研究提供了一个基础，进一步研究这一年轻、增长的研究领域。

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Keywords: glacier tourism; glacial landscapes; scoping review; climate change glacier sites; perceptions and values

关键词**:** 冰川旅游；冰川景观；概览性综述；气候变化；冰川场址；认知与价值

Introduction

Research into tourism in glaciated landscapes is a fairly recent phenomenon. In the past decades, many glaciers worldwide have become popular tourist attractions. These majestic, intimidating and fairly uncommon landscapes now form the basis for a broad array of tourist activities, services and products in many different countries. Glaciers are found on all continents except Australia and currently cover 0.5% of the Earth's terrestrial surface (Arendt et al., 2014). Due to global climate change, glaciers all over the world have been retreating rapidly over the past decades (IPCC, 2013), resulting in increased attention being paid to the glaciers that remain and an increase in their perceived value (Carey, 2007; Gagné, Rasmussen, & Orlove, 2014; Haeberli, 2008). Glacial recession is one of the clearest visual examples of the effects of climate change and images of glaciers are thus commonly found in climate change news and documentaries, which may in turn have stimulated increased general interest in them (e.g. Aronson, DuPré-Pesman, Orlowski, & Balog, 2012). Glaciers are the foundation of many spectacular landscape types and landforms, such as glacial valleys, moraines, eskers, and drumlins. Such areas are often characterized by highly dynamic landscapes which in turn attract tourists. Glaciers and glacial environments furthermore form the centrepiece of several World Heritage sites (Wang & Jiao, 2012) and national parks, attracting millions of tourists each year (Table 1).

Prompted by a growing body of research into nature-based tourism more generally (Balmford et al., 2009; Hall & Boyd, 2005; Kuenzi & McNeely, 2008; Newsome, Moor, & Dowling, 2002) and climate change research in the context of tourism (Scott, Hall, & Gössling, 2012), glaciers have recently attracted greater attention from tourism researchers (Furunes & Mykletun, 2012; Wang & Jiao, 2012). Initially, tourism in glaciated areas was primarily viewed as a sub-set of mountain tourism and/or nature-based tourism, rather than a tourism niche in itself (Wang & Jiao, 2012). In addition, the relationship between tourism and glacial landscapes has received increased attention in the context of research into the human dimensions of climate change (e.g. McDowell, Stephenson, & Ford, 2014). Glacial environments are extremely dynamic and sensitive to climate change and variability (e.g. UNEP & WGMS, 2008) and are thus considered to be among the most visible and reliable indicators of global warming (IPCC, 2013). Climate-induced environmental change has been documented in several mountain regions worldwide that are also key tourist destinations, including sites in the European Alps, the Rockies, the Andes, and the Himalayas. During the past 40 years, an estimated 7000 km^2 of ice cover has been lost from glaciers in these mountain regions (UNEP & WGMS, 2008). Although climate research has long been the domain of the natural sciences, more recently social scientists and humanistic scholars have entered the fray, focusing on the human dimensions of climate change, and attempting, for example, to describe and analyse perceptions of climate change, public understanding of risk, and the construction of climate change policies (Brace & Geoghegan, 2010).

The present study attempts to contribute to the literature on nature-based tourism and on the human dimensions of climate change by systematically reviewing academic literature on the relationship between glaciers and tourism. This relationship will henceforth be referred to as 'glacier tourism'. This study aims to provide a state-of-the-field of current knowledge on glacier tourism and critically detect gaps in knowledge in the existing

Table 1. Examples of popular glacial tourist destinations.

Park name and location	Glacial attraction(s)	Number of visitors/year	Tourist activities provided
Banff NP, Canada	Columbia Ice Fields, Athabasca Glacier	600,000	Glacier coach tours, glacier hiking, exhibitions
Los Glacier NP, Argentina	Perito Moreno glacier, Lake Argentino	167,000	Glacier hiking, ice-climbing, ice cave tours, glacier boat tours
Huascarán NP, Peru	Pastoruri Glacier	109,000	Sightseeing, hiking
Westland Tai Poutini NP, New Zealand	Franz Jozef glacier and Fox glacier	346,000	Glacier walking, ice-climbing, heli-hiking
Ilulissat Icefjord, Greenland	Sermeq Kujalleq Glacier	12,000	Cross-country skiing, dogsled tours, cruise ships, heli-hiking
Jostedal glacier NP, Norway	Brikdals glacier	40,000	Glacier hiking, glacier lake kayak/boat, skiing, cross-country skiing, exhibition
Vatnajökull NP, Iceland	Vatnajökull glacier	343,000	Glacier hiking, ice-climbing, ice cave tours, glacier boat tours, snowmobiling, superjeep tours

Source: UNWTO, UNEP, and WMO (2008), Purdie (2013), Guðmundsson (2013), and IUCN and UNEP-WCMC (2014).

research into the relationship between glacial landscapes and tourism by (1) assessing the nature and scope of the body of research literature that addresses glacier tourism; (2) defining glacier tourism based on current knowledge; and (3) identifying central themes that characterize glacier tourism within the academic literature.

Methodological approach

Scoping review

In this study a scoping review was employed in an attempt to explore the conceptualizations and characteristics of glacier tourism within the academic literature. Scoping in this kind of literature review involves 'a synthesis and analysis of a wide range of both research and non-research generated material to provide greater conceptual clarity about a specific topic or field of evidence' (Davis, Drey, & Gould, 2009, p. 1386). Scoping reviews are used in a number of ways, such as to examine the scope and nature of a particular area of research, summarize the findings of existing research and identify research gaps (Arksey & O'Malley, 2005), and are according to Mays, Roberts, and Popay (2001) and McKinstry, Brown, and Gustafsson (2014) especially suitable for use in less-explored research fields or where prior synthesis is unavailable. A scoping literature review can be carried out using systematic or non-systematic approaches (Davis et al., 2009). The present study employs a systematic scoping review using a structured and explicit predetermined methodology so as to ensure consistency and replicability (McKinstry et al., 2014). A scoping review differs from other forms of review, such as systematic reviews and narrative or literature reviews, through its use of broad research questions. The synthesis is qualitative, the author does not typically assess the quality of the included studies and the scoping process requires analytical reinterpretation of literature (Armstrong, Hall, Doyle, & Water, 2011; Levac, Colquhoun, & O'Brien, 2010). At present only a handful of scoping reviews appear to have been conducted in the field of tourism research (e.g. Crooks, Kingsbury, Snyder, & Johnston, 2010; Snyder, Crooks, Johnston, & Kingsbury, 2011; Tremblay, 2006).

Selection criteria

The present study employs the seminal framework for conducting a scoping review designed by Arksey and OMalley (2005), which consists of the following five steps:

(1) identifying the research question;
(2) identifying relevant studies;
(3) selecting identified studies;
(4) charting selected data;
(5) collating, summarizing and reporting the results.

The first step was to formulate a research question to guide the structure of the review strategy. The question used was: 'what knowledge does the existing academic literature concerning the nature and scope of glacier tourism present?' In the second step online academic databases were searched until no new sources could be identified. These databases were as follows: ISI Web of Knowledge, Bielefeld Academic Search Engine (BASE), BioOne, Directory of Open Access Journals (DOAJ), EconBiz, CABI leisure-tourism, DirectScience, Taylor and Francis online, JSTOR, SAGE and the Library

Table 2. Prioritization criteria used in the study.

	Glacier site specific	Not glacier site specific
Focus on tourism/recreation	*High*	*Medium*
No focus on tourism/recreation	*Medium*	*Low*

Source: Adapted from Smith (2004).

Catalogue of the authors' university. The database search period for this review ranged from January 1981 to December 2014. The terms used to search in each database were as follows: 'glacier tourism', 'glacier tourist', 'glacier recreation', and 'tourism' AND 'glacier'. These search terms were applied in the search fields: title, abstract, subject heading and keywords.

For the selection of relevant studies a set of inclusion criteria was employed. As the focus of this paper is to provide an overview of current knowledge on glacier tourism in academic literature, only peer-reviewed articles, chapters from academic books, proceedings from scientific conferences and reports from academic institutions were included in the final review. Other criteria used were that the literature: (1) was published after 1980, as research prior to this date was deemed unlikely to reflect current research developments; (2) was written in English; (3) did not constitute the main content of another publication (identified book chapters and reports formed the basis of articles subsequently published); and (4) had a significant focus on the relationship between tourism and glaciers. The significance of literature was defined with regard to the method developed by Smith (2004) to prioritize papers in a literature review on the basis of their appropriateness as high, medium or low priority articles (cf. Table 2). High priority was given to papers and other documents which focused jointly on tourism/recreation *and* glacier sites. A glacier site refers here to a spatially defined tourist attraction that contains a glacier – either totally or in part – and its adjacent glacial landforms and waterways such as moraines, fjords and glacier lakes. Medium priority was given to papers concerned with tourism/recreation in a non-specific glacier region *or* papers that dealt with glacier sites but did not focus exclusively on tourism or the recreational use of those sites. Papers given low priority lacked both a focus on tourism/recreation *and* were not glacier site-specific. Only the high and medium priority documents were considered to provide a substantial focus on glacier tourism and therefore these documents were included in the final synthesis of this research.

Selection procedure

The selection procedure can be divided into three steps (Figure 1). The first step included an initial search through the electronic databases that resulted in an identification of 241 potentially relevant studies. After removing duplicate records, the remaining 166 publication titles and abstracts were screened on the basis of the inclusion criteria to guarantee their suitability for a full text review. The initial search found 69 candidates for full review. In the second step, reference lists from reviewed studies were used to identify further studies of potential interest, based on the inclusion criteria, and this process was then repeated until no new relevant publications presented themselves. This process resulted in 17 additional publications for full review. Altogether, a total of 86 studies were identified. The third and final step included further screening of the 86 identified studies on the basis of the inclusion procedure, resulting in a total of 53 studies that form the subject

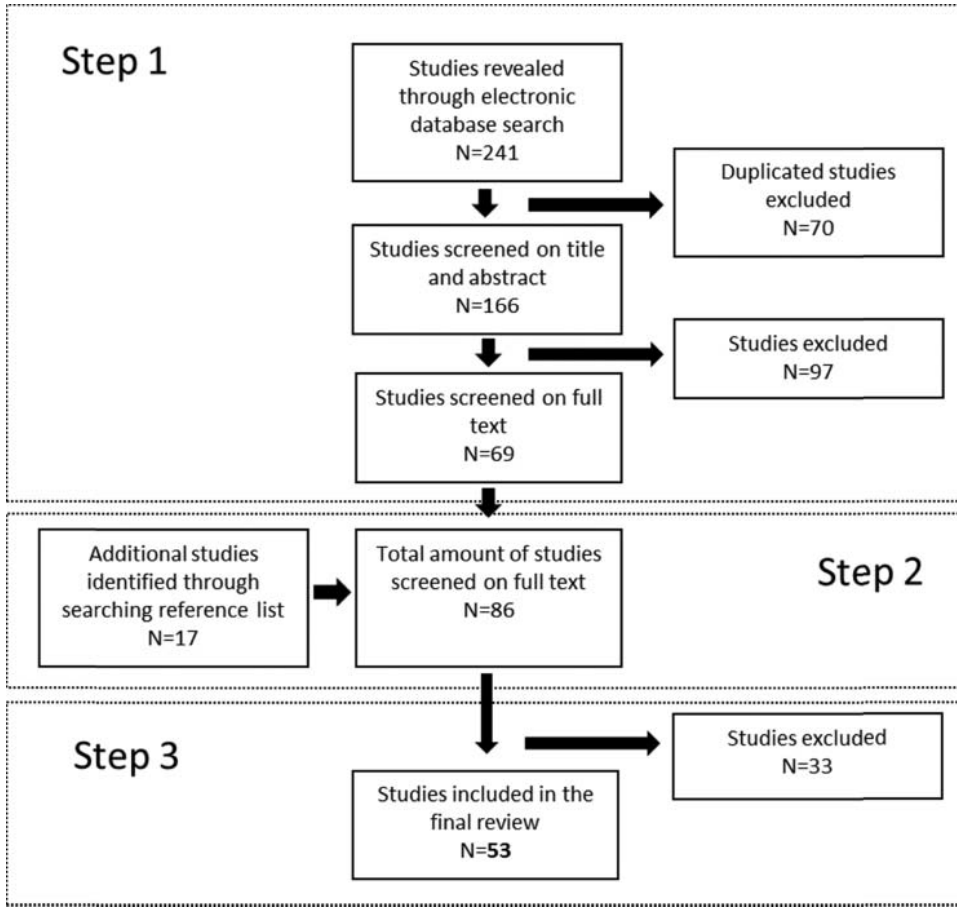

Figure 1. A flow chart illustrating the three steps in the study's selection process.

matter of this scoping review (a list of all publications included in the review is provided in Appendix 1).

The selected papers were then categorized and entered into a spreadsheet according to data including author(s), year of publication, aims of the study, methodology, data sources, results, themes, and study location. Finally, a content analysis was performed to identify recurrent research themes as well as gaps in the literature.

Results

Nature and scope of the existing research literature on glacier tourism

Most of the resulting 53 studies were of fairly recent origin; only two of these studies were published before 1995 while 43 studies were published after 2005 (Figure 2).

This clearly indicates that glacier tourism is a relatively new academic topic and one that is receiving increasing attention, even if the total number of studies is still quite small. The final literature set consisted of 43 peer-reviewed articles, 4 book chapters and 6 scientific reports. The articles were published in 34 different journals – of these, only 6 journals published more than one article related to glacier tourism (Table 3).

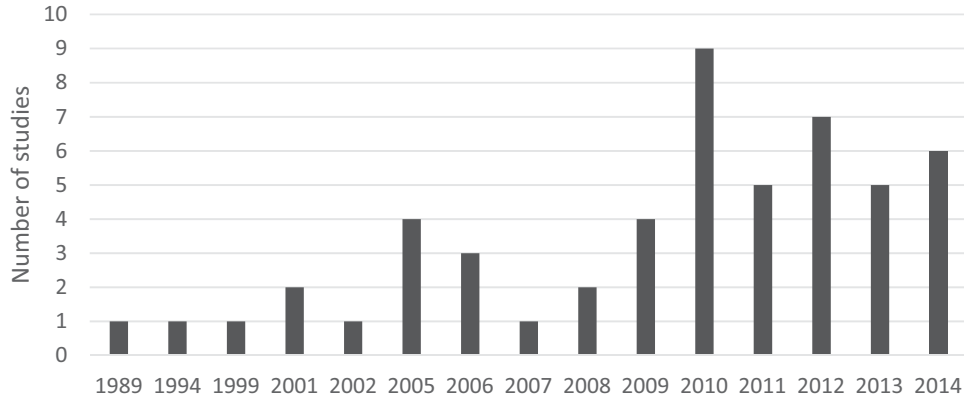

Figure 2. Number of reviewed studies per year of publication (1989–2014).

The disciplinary focus of the journals in question is tourism (23%), geology (21%), multi-disciplinary mountain/arctic research (21%), environmental/climate science (19%), geography (7%) and other disciplines (9%). Both the broad range and diverse disciplinary background of these journals underlines the multi-disciplinary scope of glacier tourism in the academic literature. The studies were produced by 116 authors, of which 30 papers (75%) were written by a single author or a two-author team. The scoping review furthermore identified a broad scope of focal research subjects (Table 4). The majority of studies focused on tourists, glacier areas or sites, area management and tour operators or other tourism entrepreneurs. This indicates glacier tourism goes beyond the supply-and-demand dichotomy and involves a plurality of socio-economic and natural actors and entities at multiple scales.

A diverse and broad array of glacier tourism activities were furthermore addressed (Table 5) with only six studies that did not address tourist activities specifically. Hiking/sightseeing, guided glacier walking and glacier skiing are the most prominent among these activities, which is not surprising given the research that supports their popularity and economic significance for many local communities in mountain areas (e.g. Bury et al., 2011; Haimayer 1989; Smiraglia et al., 2008; Wilson, Stewart, Espiner, & Purdie, 2014b).

The results show a broad range of geographical regions where glacier tourism has been researched. Only one article discussed glacier tourism on a global scale, four studies were conducted on a national scale whilst the remainder – the vast majority – addressed

Table 3. Distribution of journals that published more than one study on glacier tourism.

Journal name	Number of articles
Mountain Research and Development	4
Géomorphologie: Relief, processus, environnement	3
Cold Regions Science and Technology	2
Environmental Management	2
Journal of Earth Science	2
Tourist Studies	2
Other journals publishing only one paper each	28

Table 4. Central research topics of the reviewed studies*.

Topics of research focus	No. of topics	Topics of research focus	No. of topics
Tourists	18	Local communities	5
Area/landscape	14	Biodiversity	2
Area management	12	Other	2
Operators	10		

Note: *Some studies have more than one central research topic.

Table 5. Types of glacier tourism activity addressed in the reviewed studies*.

Tourism activity	No. of activities	Tourism activity	No. of activities
Hiking/sightseeing	21	Trekking	5
Glacier walking/ ice climbing	9	Geo-tourism	5
Glacier skiing	8	Boat/kayak	4
Mountaineering	7	Pilgrimage	1
Scenic flight (helicopter/plane)	7	Glacier museum	1

Note: *Some studies address more than one activity.

Table 6. Geographical location of site-specific case studies in the reviewed studies.

Case studies	No. of studies	Case studies	No. of studies
New Zealand	10	France	3
Italy	7	USA	3
China	5	Nepal	2
Iceland	4	Tanzania	2
Austria	4	Peru	1
Norway	3	India	1
Canada	3	Iran	1

glacier tourism on a regional or local scale. Most reviewed studies consisted of single case-studies that were site-specific within 14 different countries around the world (Table 6).

Most of the reviewed documents adopted a descriptive research approach (38 studies) or an explanatory approach (9), while only three studies employed a predictive approach and three an exploratory research approach (Table 7). The majority of the studies (40) furthermore adopted an empirical approach, presenting primary research data either through quantitative methods (25), qualitative methods (12) or mixed methods (3). Just 13 studies present secondary data or a combination of primary and secondary data. The empirical research data originate from a variety of sources including tourists, tour operators, academic experts and local community members.

Definitions and conceptualizations of glacier tourism

It is noteworthy that only four of the studies reviewed attempted to define the concept of glacier tourism as such and that these definitions differed considerably between authors.

Table 7. Methodology of reviewed studies.

Research approach	*N*	Collected data	*N*	Methods of data collection (in primary studies, $N = 40$)	*N*
Descriptive	38	Primary	40	Quantitative	25
Explanatory	9	Secondary	12	Qualitative	12
Predictive	3	Primary/secondary	1	Mixed	3
Exploratory	3				

Liu et al. (2006, p. 365) described glacier tourism simply as 'tourism activities in glacier areas', but they also pointed out that this form of tourism differs from conventional tourism in several ways: the resources used (i.e. glaciers and icecaps) are scarce and fragile, the activities are heavily localized, its connotation is scientific, and it is multifunctional with a high recreational, aesthetic and scientific value. Wang and Jiao (2012, p. 401) extended the definition of Liu et al. (2006) by referring to glacier tourism as an '…activity or event whereby glaciers and ancient glacier relics serve as main attractions…' Furunes and Mykletun (2012, p. 324) on the other hand presented a narrower concept of glacier tourism in their study on glacier adventure tourism in Norway. They defined glacier tourism as mainly 'walking and climbing on glaciated areas for the unique experience'. All these descriptions apply a geographical perspective to typify glacier tourism, where the site of the glacier functions as the main attraction or setting for various leisure activities. In this respect, glacier tourism resonates with general descriptions of nature-based tourism, such as those of Hall and Boyd (2005, p. 3) who described nature-based tourism as forms of tourism that take place in a natural setting, tourism that focuses on specific elements of the natural environment, and tourism that is developed in order to conserve or protect natural areas. Thus, while it may seem logical to classify glacier tourism as a subcategory of nature-based tourism there are several critical issues which need to be further addressed before this step can be taken, e.g. regarding what kinds of activities should be included as typical elements of glacier tourism and how to demarcate glacier areas in spatial and morphological terms, as has been stressed by Mehmetoglu (2007) and Fredman and Tyrväinen (2010).

Concerning the latter point, the results show that glacier tourism does not solely consist of activities that take place on the glacier itself but also in adjacent areas. This is consistent with Purdie (2013) who accounted for both activities that take place on the glacier and activities in pro-glacial areas, such as kayak or boat tours on glacial lakes, inlets or fjords (Young, Gende, & Harvey, 2014). Pro-glacial zones or areas are the dynamic forefields immediately in front of or just beyond the outer limits of a glacier, icecap or ice sheet formed by or derived from glacier ice. These areas often contain spectacular landforms and features such as giant boulders, dead ice, kettle holes, moraines and pro-glacial lakes with icebergs that often reflect a magnificent blue colour, attracting tourists. This is further supported by Wang, He, and Song (2010) and Wang and Jiao (2012) who considered ancient glacier relics such as cirques, hanging valleys and horns as a source of attraction for glacier tourism. Purdie (2013) and Smiraglia et al. (2008) also note how glacier lakes in the New Zealand and Italian Alps attract tourists for differing reasons, such as the opportunity to watch the calving process of glacier ice into the lakes. The pro-glacial zones furthermore form attractive areas for hiking, as demonstrated by Brandolini and Pelfini (2010), and are the sites from which most glacier tourists view the different glacier

features and processes. More importantly, as landscape features formed by glaciers advance and recede, the pro-glacial zones illustrate the dynamics and power of glaciers. Pro-glacial zones have a high educational value, providing geological and climatological information (Bollati et al., 2013; Moreau, 2010). These are the places where tangible evidence of global warming can actually be perceived. Thus, tourist activities conducted in pro-glacial zones are part and parcel of glacier tourism. However, none of the reviewed literature defined the extent of the pro-glacial area or zone, either in quantitative or qualitative terms.

The literature review underlines that glacier sites offer a suitable arena for various nature-related activities based on three elements: (1) adventure, (2) recreation (based on specific geomorphology) and (3) education. Furunes and Mykletun (2012, p. 329) supported this view when describing glacier tourism as a hybrid of nature- and adventure-tourism where 'glaciers can be considered a playground for tourists seeking different levels of challenges in strange and potentially hazardous environments'. They further emphasized that in order to reduce the risk of accidents and increase access to glaciers for tourists, most tourism activities are performed under guided supervision where clients rely on guides' expertise to find their way through the glacial landscape. This is in line with the general description of adventure tourism by Buckley (2007, p. 1428) who considered glacier adventure tourism to encompass mostly guided commercial tours where the principal attraction is an outdoor activity that: relies on features of the natural terrain (e.g. a glacier ice wall to climb or a glacier tongue to traverse), requires specialized equipment (e.g. crampons and ice axes), and is exciting for the tour clients (Figure 3). Typical activities in glacier adventure tours currently include glacier hiking, ice climbing, traverse glacier on skies, snowmobiling and glacier lake kayaking. However, Wilson (2012) points out that a considerable number of the tourists that visit glacier sites come there solely to observe glacier attributes and adjacent landforms, often without setting foot on the glaciers themselves. She further notes that in contrast to adventure tourism, these sightseeing

Figure 3. A guided glacier walking tour (Photo by Þorvarður Árnason).

activities are often conducted in an unorganized manner. Many glacier sites are furthermore gradually becoming an object for educational trips because of their educational value as examples of spectacular landscapes, geo-diversity and given their status as representatives of the environmental response to global climate change (e.g. Bollati et al., 2013; Feuillet & Sourp, 2011; Mahabadi & Soleimanifakhr, 2014).

Pralong and Reynard (2005) framed glacier tourism as a form of geomorphological tourism by proposing a framework highlighting the multiple relationships between geomorphology and tourism, e.g. natural and socio-cultural land features, services, infrastructure, impacts, vulnerabilities, risk and exploitation. Glacier geomorphosites are undoubtedly tangible evidence that our planet's climate is changing and the accelerated pace of worldwide glacier retreat makes visitors more aware of the consequences of this change. This educational aspect has already been put into practice at the renowned Norwegian Glacier Museum, one of three glacier visitor centres situated around the Jostedalen glacier (Aal & Hoye, 2005), as well as in various interpretive trails in glacier areas in the Alps (Bolatti et al., 2013; Cayla, 2009; Martin, 2010).

Central themes characterizing glacier tourism

Three recurrent themes were identified in the literature on glacier tourism (Table 8): (1) climate change and variability, (2) effects of glacier tourism on social and ecological environments, and (3) perceptions and values of glacier tourism actors. These three themes represent the most discussed issues concerning the relationship between glaciers and tourism in the English-language academic literature (an overview of all reviewed studies by theme is provided in Appendix 2).

Climate change and variability

The worldwide recession of icecaps and glaciers is often considered to be one of the most tangible and reliable indicators of global climate change (Brugger, Dunbar, Jurt, & Orlove, 2012). It is therefore not surprising that the impacts of climate variations and conditions on glacier tourism should prove to be the central issue in 25 studies of the reviewed literature. Three central issues discussed with respect to climate change and variability were as follows: (1) impacts of climate change and climate variability; (2) responses to climate change; and (3) perceptions of climate change.

Impacts of climate change and variability

The results indicate that the impacts of local climate on glacier tourism concern changes in weather conditions and changes in weather patterns (Figure 4). In general, climate influences tourism directly by determining weather conditions at a tourist destination and

Table 8. Identified themes in the reviewed studies.

Theme	Number of studies	Percentage (%)
Climate change and variability	25	47
Effects of glacier tourism	15	28
Perceptions and values	15	28

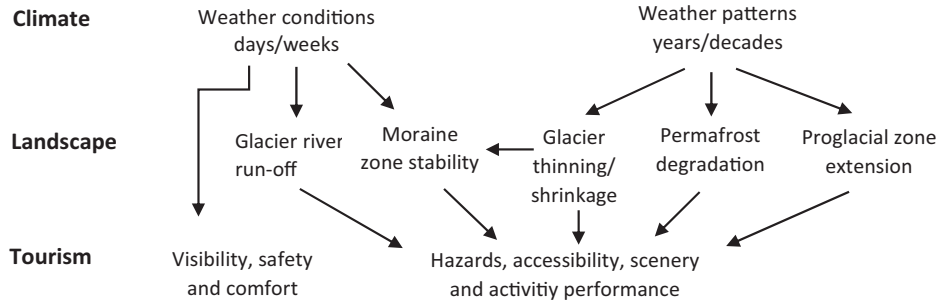

Figure 4. Impact of climate change and variability on glacial landscapes and tourism.

at the tourists' place of residence (UNWTO et al., 2008). Weather also directly affects key aspects of tourist operations, including activity programming and infrastructure (Scott, Jones, & Konopek, 2007). Cloudiness and fog reduce visibility at and access to glacier sites and thus affect various glacier-based tourist activities such as sightseeing flights and heli-hikes (Becken, 2012; Espiner & Becken, 2014). Furthermore, weather conditions such as heavy rain can indirectly affect tourism by triggering unexpectedly large ice block calving (Tinti et al., 1999), destabilizing ground moraine areas, or enhancing glacier river run-off, which increases the risk of hazardous events, hampers terrain accessibility and can even lead to the closure of entire sites (Wilson, 2012). The impacts of climate change, as evidenced by gradually changing weather patterns on glacierized landscapes, can be divided into three main phenomena: (1) glacier shrinkage, (2) permafrost degradation and (3) pro-glacial area extension (Haeberli & Beniston, 1998; Kääb, Reynolds, & Haeberli, 2005).

Some of the studies which focused on the impacts of glacier recession on tourism provided a general descriptive analysis of the existing or potential impacts on glacier tourism from the accelerated recession of glaciers worldwide, as well as a description of optional adaptation strategies and measures (e.g. Liu et al., 2006; Purdie, 2013; Wang & Jiao, 2012; Wang et al., 2010). The majority of studies, however, focused on the analysis of the risks and hazards associated with glacier recession and its impact on tourist activities in glacial areas, such as mountaineering (Ritter et al., 2012), summer skiing (Diolaiuti et al., 2006; Smiraglia et al., 2008; Fisher et al., 2011), pro-glacial lake tourist activities (Smiraglia et al., 2008; Tinti et al., 1999) and geo-tourism (Brandolini & Pelfini, 2010). Based on expert and stakeholder opinions, Ritter et al. (2012) distinguished two areas of impact on glacier mountain tourism due to glacier recession and permafrost degradation: (1) changes in the occurrence of natural hazards (i.e. intensity, frequency and spatial distribution) and (2) changes in terrain accessibility. Thus, glacier shrinking and permafrost degradation cause substantial threats to tourists and recreationists who visit a glacier or its foreland, such as debris slope and rock wall instability, as well as increased rock fall, landslides and debris flows (Blair, 1994; Ritter et al., 2012). Furthermore, the calving of icebergs and ice blocks into pro-glacial lakes or waters adjacent to tidewater glaciers can cause huge waves which pose a threat to sightseeing tourists on the lake shore and destabilize tour boats (Purdie, 2013; Smiraglia et al., 2008; Tinti et al., 1999).

Recent research (i.e. Furunes & Mykletun, 2012; Ritter et al., 2012; Wilson et al., 2014b) pointed out that glacier retreat can reduce accessibility to glaciers or within glacier sites by increasing supraglacial debris cover, changing the access route to the glacier

and increasing the steepness of ice slopes at the glacier terminus. This can result in increased costs for entrepreneurs who as a result require different modes of transportation to and through the site such as helicopters and or fast motor boats to ensure tourists reach the glacier (Espiner & Becken, 2014; Purdie, 2013). Conversely, inaccessibility may contribute to the appeal of some glacier activities, such as glacier mountaineering and trekking, and thus generate employment and other economic opportunities, e.g. through the rental of special equipment or need for local guides (Nyaupane & Chetri, 2009; Wilson, 2012; Wilson et al., 2014b). In addition, glacier recession can lead to the formation of sub-glacial caves and pro-glacial lakes, providing opportunities for new forms of sightseeing tourist activities (Diolaiuti & Smiraglia, 2010; Purdie, 2013; Smiraglia et al., 2008). However, climate change is not the only driver of hazards to glacier tourism. Bird et al. (2010) revealed that sub-glacial volcanic and seismic activities cause a range of glacier hazards which negatively affect tourism.

Another important potential impact of glacier retreat is the change to scenery it brings about (Diolaiuti & Smiraglia, 2010; Garavaglia, Diolaiuti, Smiraglia, Pasquale, & Pelfini, 2012). Despite repeated warnings about the potential negative effects of environmental change on the attractiveness of mountain landscapes (UNWTO et al., 2008), the question of how changes to glacial landscapes will affect the demand for tourism at glacier sites is a central issue in three studies (i.e. Scott et al., 2007; Wilson, Stewart, Espiner, & Purdie, 2014a; Yuan, Lu, Ning, & He, 2006). These studies examined tourists' stated future landscape preferences in hypothetical scenarios with natural areas impacted by climate change. Their results showed a decrease in tourists' demand for glacier site visitation resulting from the partial or total disappearance of glaciers in the visited area.

On the other hand, some authors have argued that the dissemination of information about worldwide glacier recession and disappearance may increase the number of glacier visits as a form of last-chance tourism (Purdie, 2013) or climate change tourism (Aal & Hoye, 2005). To what extent climate-induced changes to the natural environment such as glacier recession, permafrost thawing and changing pro-glacier areas will impact tourism actors, depends also on geological and geomorphological factors (Ritter et al., 2012) and the ability of tourism actors to adapt to the changing environment, as well as their differing perceptions of environmental and climate-induced changes (Espiner & Becken, 2014; Gössling, Scott, Hall, Ceron, & Dubois, 2012).

Responses to climate change

Responses to climate change in the form of adaptation or mitigation measures were addressed in 19 studies. Responses varied widely depending on the climate-induced impact type (e.g. glacier hazards or destination accessibility), glacier tourism activities impacted (e.g. skiing or hiking) and geographical area, and the actors or institutions that implement these adaptation or mitigation measures (e.g. entrepreneurs or area managers). Adaptation measures towards glacier hazards included expanding scientific knowledge on the monitoring of moraine relief (Blair, 1994), the calculation of safe distances for visitors (Kohler, 2009), distribution and location of hazard signs or panels (Espiner, 2001), development of map symbols (Brandolini & Pelfini, 2010), the wearing of special safety gear (Furunes & Mykletun, 2012; Schindera et al., 2005) and the demarcation of safety zones and closure of areas (Bury et al., 2011; Wilson, 2012). The adaptation initiatives proposed to address climate-induced impacts on accessibility to glacier sites included reducing ice ablation through the employment of chemicals, additives or physical protection covers (Fisher et al., 2011), as well as the use of new modes of transportation such as

helicopters (Purdie, 2013) or new trail routes or infrastructure (Ritter et al., 2012). However, in addition to the availability of physical measures, a key factor in successful adaption by glacier tourism entrepreneurs concerns their social capabilities such as flexibility and the capacity to react quickly to any glacier change (Wilson et al., 2014b). In more general terms, Wang et al. (2010) developed a taxonomy of glacier tourism adaptation that consists of seven adaptation and mitigation strategies to deal with global climate warming: (1) optimize the spatial layout of glacier tourism areas; (2) improve glacier tourism and environmental protection planning; (3) adopt multidimensional protective measures; (4) strengthen scientific research into glacier and environment protection; (5) develop multi-directional glacier tourism products; (6) integrate regional tourism resources; and (7) reinforce public environmental education.

The majority of studies that addressed climate change mitigation or adaptation responses consist of general descriptions of existing measures and policies or a summary of suggestions for what measures might be implemented in the future. Only two studies evaluated the effectiveness of climate change responses (Fisher et al., 2011; Olefs & Fisher, 2008). Both studies evaluated technical mitigation measures to reduce snow and ice ablation in Alpine glacier ski resorts.

Perceptions of climate change

Three studies have examined tourists' awareness, perceptions and knowledge of glacier landscape changes (Garavaglia et al., 2012; Moreau, 2010; Wilson et al., 2014a). An onsite visitor survey study by Wilson et al. (2014a) revealed that most glacier site visitors thought climate change was happening and would result in ongoing glacier retreat in the visited areas. The studies of Moreau (2010) and Garavaglia et al. (2012) also found that visitors have a good knowledge of the processes involved in glacial recession but this was often not perceived in the actual landscape. Visitors' knowledge of glacier retreat depended more on preconceived ideas disseminated within society, most probably ultimately originating from the media, than on direct observations of the glacial landscape (Moreau, 2010). These studies furthermore show that visitors' knowledge of glacier recession differs greatly according to what types of glacier recreation they participate in. Moreau's study (2010) points out that the difference in perception and understanding of glacial landscapes between hiker and mountaineers is affected by their different length of stay at the glacier site and the different activities they engage in. Mountaineers stay on average longer at the glacier site, have a better knowledge of the geomorphology of the area and have a more accurate view of the glacier's recession. Hikers on the other hand spend less time at the site, primarily seek out aesthetic scenery, have a poor knowledge of geomorphological terms, and have difficulties in seeing the glacial retreat in the landscape (Moreau, 2010). According to Garavaglia et al. (2012), the viewpoint from which visitors can observe and understand the landscape seems to have a significant influence on how they perceive glacial landscape changes. Studies of tourism operators on the other hand indicated some indifference to climate change among entrepreneurs, as they consider recent glacier recession more as a product of local precipitation and summer temperatures than global climate change (Espiner & Becken, 2014; Furunes & Mykletun, 2012). Operators linked the issue of climate change to global, high-profile examples (e.g. floods in Bangladesh and the melting ice shelf) rather than changes in local weather patterns (Wilson, 2012).

Effects of glacier tourism on social and ecological environments

A considerable number of the studies (14) focused on the third and last theme identified within the literature, namely the effects of glacier tourism on its socio-economic and ecological environment. Three issues regarding these effects can be discerned: (1) impacts of glacier tourism on local communities, (2) impacts on the natural environment, and (3) impacts of tourist activities on other tourists at glacier sites.

According to Haimayer (1989) and Espiner and Becken (2014), glacier tourism constitutes an important source of income and employment for local communities adjacent to glacier tourist sites. A household survey among the residents of the Catac region, a gateway community through which visits to the Pastoruri glacier in Peru pass, likewise indicated that a quarter of the surveyed households were engaged in some forms of tourism-based activity (Bury et al., 2011). Indirect economic gains in the form of amenities necessary for the construction of glacier tourism related infrastructure can have positive effects on a local community's economic situation (Haimayer, 1989). However, Aspinall, Cukier, and Doberstein (2011) showed that local people's quality of life can also be negatively influenced by growing tourism development.

A few studies investigated the environmental impacts of glacier tourism. Hoover-Miller et al. (2013) assessed visits by kayak and other watercraft to tidewater glaciers and the resulting impact on harbour seals in the Kenai Fjords National Park in Alaska. The study revealed that boat and kayak-based tourism causes significant disturbance to seal populations and voluntary changes to tourist operations can lead to a significant reduction in this disturbance. Other studies analysed the effect of glacier tourism on air quality (Zhang, He, Theakstone, & Pang, 2010) or biodiversity (Dhaulakhandi, Rajwar, & Kumar, 2010). The effects of waste produced by tourists in glacier areas were the subject of three studies (Goodwin et al., 2012; Kaseva & Moraina, 2009; Kuniyal, 2002). These studies highlighted the negative effects of waste produced by tourism on the natural environment and human health, and argued that with the projected growth of tourism in the regions examined, pollution levels could increase significantly without effective waste management. Furthermore, the growing discussion around the extension of tourism activities into fragile environments, both in natural and cultural terms, was the focus of several studies (Frömming, 2009; Stoddart, 2011). These studies underline the detrimental effects of different forms of glacier tourism on biodiversity and ancient cultural customs, as well as perceptions and evaluations of glaciers among local stakeholders or indigenous communities.

Two studies in this review examined the impacts of glacier tourism activities on tourists themselves. The studies of Sutton (1998) and Corbett (2001) investigated the issue of crowding by visitors to the Fox and Franz Josef glaciers in New Zealand. Both studies indicated that crowding occurs only during the periods of highest visitor numbers in the main valley and is concentrated at the front of the glacier.

Perceptions and values of glacier tourism actors

The last theme identified as characterizing the reviewed literature focuses on the attitudes, values and experiences of glacier tourism actors. Different studies attempted to assess the valuation of glacier areas in the context of tourism utilization. These studies can be divided into *expert design approaches*, which involve the evaluation of landscape quality by trained experts, and *scientist and public perception based approaches*, which involve the subjective assessment of landscape-based perceptions by participants (Daniel, 2001). Several studies in this review employed a landscape quality assessment, involving the

evaluation of landscape qualities by experts using numerical assessment frameworks that assign scores to landscapes on the basis of quantitative criteria in order to assess the value of a site (i.e. Bollati et al., 2013; Feuillet & Sourp, 2011; Pralong, 2005; Pralong & Reynard, 2005). Other studies employed subjectivist approaches using qualitative methods, such as participant observation, to explore the values tourists attach to glacier landscapes (e.g. Jóhannesdóttir, 2010; Lund, 2013; Olafsdottir, 2013). Beza (2010) found that visitors' aesthetic evaluation of landscapes along the Mt. Everest trek comprised a structured mix of bio-physical characteristics together with concepts such as wilderness, and emotions such as beauty and thrill. Similar observations were obtained by Jóhannesdóttir (2010), arguing that glacial landscapes create an atmosphere of wonder and awe through the perception and experience of the physical qualities of the glacier: e.g. colours, forms, textures and sounds. Corbett (2001) and Garavaglia et al. (2012) find that scenery and encounters with glaciers are the two most common motivations to visit a glacier site. These results correspond to the findings of Wilson et al. (2014a) which revealed that viewing a glacier and seeing a natural feature that may disappear in the future were among the most important reasons for tourists to visit a glacier site in New Zealand's Westland Tai Poutini National Park. The opportunity to touch a glacier can be a major impetus in getting tourists to book glacier tours despite bad weather or low visibility (Espiner & Becken, 2014). At the same time glaciers seem to invoke a sense of unpredictability, exoticism, uncertainty or even hostility towards visitors, making glacier tours an exciting adventure (Olafsdottir, 2013). According to Furunes and Mykletun (2012, p. 327) glaciers can be seen as an 'accelerated sublime' attraction, a destination that offers the opportunity to have a close encounter with a rare and sublime natural phenomena and at the same time fuels a spirit of adventure, with opportunities for play, tension, insight, increased self-understanding, identity formation, and risk-taking.

Factors that bring about differences in perceptions or evaluations of glaciers among tourism actors were the main focus of several studies. Identified factors are: the socio-cultural background of tourism actors (Beza, 2010), the extent of tourism actors' experience with the visited area (Moreau, 2010), the viewpoint from which glacial landscapes were perceived (Zhang et al., 2010) and underlying local−global power relations (Frömming, 2009). Frömming (2009) e.g. argues that the current prevailing perceptions and valuations of the Kilimanjaro glacier as a beautiful or sublime site are grounded in the Western-based hegemony of aesthetic modernity, which suppresses the ancient cultural values of native tribes who have lived for centuries in the vicinity of the glacier.

Discussion and conclusions

Current state-of-knowledge on glacier tourism

This literature review indicates that there are a limited but growing number of studies examining the relationship between tourism and glaciers. The majority of the studies provide data from single case studies that investigate glacier tourism in a particular context. While this has advanced the general knowledge of glacier tourism to some extent, such studies are grounded in specific local or regional contexts and are based on diverse interpretations of glacier tourism concepts and attributes. As a result, there is a lack of consistency in the conceptualizations and principles that underpin research on glacier tourism, which in turn leads to a corpus of literature that is broad in scope but at the same time lacking in cohesion. Glacier tourism as a research topic hovers at the interface between the established tourism research fields of mountain tourism, geo-tourism and outdoor

adventure tourism. Each of these sub-fields has established conceptual and theoretical groundings (e.g. Nepal & Chipeniuk, 2005; Pomfret, 2006; Reynard, 2008) that collectively can provide valuable input for the conceptual and theoretical basis of glacier tourism research. A future and more comprehensive research agenda might aim at the development of a coherent conceptual framework that incorporates the main elements of glacier tourism brought up in this review.

Taken as a whole, the reviewed literature provides indications of the main social, economic and environmental dimensions of impacts of glacier tourism which need to be addressed to find sustainable trajectories for the development of the glacier tourism niche. From a socio-cultural perspective, a central issue concerns the emergence of modern tourism in mostly remote rural areas which can lead to a severing of the bond between the glacier and its local communities, which then in turn may result in the deprivation or degradation of the locals' sense of place (e.g. Frömming, 2009). From an environmental perspective there are two major issues that can be highlighted. First, glacier tourism operates in highly fragile and fairly inaccessible environments that require specific infrastructure which easily leads to negative effects on the natural environment, as well as on the aesthetic value of glacial landscape and its image as wild and untamed nature. Second, the tourism sector as a whole is responsible for significant contributions to the increasing emission of greenhouse gasses, the primary cause of enhanced global climate change (IPCC, 2013; UNWTO et al., 2008), which is gradually leading to the disappearance of glaciers, the primary attraction of glacier tourism, while paradoxically at the same time stimulating visits to glacial landscapes as 'last chance tourism' (Purdie, 2013; Wilson et al., 2014b).

Gaps in knowledge on the relation between glacial landscapes and tourism

We realize that the relatively small corpus of academic literature identified in this review is bound to raise questions about the existence and legitimacy of glacier tourism as a *stand-alone* research topic. Despite such doubts, there remain two main reasons to put this tourism niche on the agenda for further scientific research. Firstly, a pragmatic reason: as stated in the beginning of this review, glaciers worldwide attract millions of visitors every year, affecting multiple actors in varying socio-economic, cultural, and/or environmental circumstances in many different countries around the world. Seen in this light, glacier tourism is certainly a real tourism phenomenon. The activities, interactions, impacts, attitudes and perceptions of tourism actors in this sector need to be guided by scientific research. The other reason is the recent call for more social science and humanistic approaches to climate change research, a field that has until now been dominated by natural science paradigms (Hulme, 2009; Palsson et al., 2013). According to Brace and Geoghegan (2010), climate change has to be addressed in a relational context that blends physical spaces with human daily practices, values and history. This study clearly reveals that glacier tourism encompasses lived, valuable experiences of climate change induced phenomena, such as glacier recession and fragmentation. Research on how such localized lay knowledge and understanding is formed during glacier tour activities provides an important opportunity to study climate change as embedded in society. In sum, what is clearly called for here is an integrated approach, involving and combining perspectives from the humanities/social sciences and natural sciences (e.g. Holm et al., 2013). The relevance of sound physical data about site-specific glacier geomorphology and recession, as well as on global processes of climate change, should not be diminished by the engagement of scholars from other disciplines, but rather serve as an important foundation for humanistic and social science research as these disciplines begin to take on a more active

role in researching the complex sphere of human responses to climate change (Hulme, 2009; Norgaard, 2011).

In addition to the above-named limitations and potential research benefits, the results of this review also point out a lack of in-depth knowledge about the following basic elements of the glacier tourism niche:

(1) Uneven geographical coverage in the existing literature; there were no studies dealing with countries such as Switzerland, Sweden or Argentina where a significant glacier tourism market exists.
(2) Data concerning the motives, preferences, experiences and behaviours of glacier tourists, as well as of the motivational push and pull factors of glacier tourism.
(3) Cross-area or sub-sector comparative analyses of tourists' perceptions and experiences of glacier site visits and of existing or potential climate-induced impacts on glacier tourism or adaptation strategies and measures.

Moreover, the focus on English language academic studies as the data source for this review can be considered a limitation, since a number of relevant studies published in other languages are likely to have been overlooked. It is therefore important that future research on glacier tourism includes non-English language literature, as well as publications from grey literature. Despite such limitations, this review constitutes a baseline for the understanding of glacier tourism and provides a foundation to guide the development of future glacier tourism research.

The present study investigated concepts, themes, topics and concerns relating to the nexus of tourism and glaciers. By employing a scoping review method this study was able to specify the state-of-the-art knowledge on glacier tourism in English language academic literature and reveal a number of pressing knowledge gaps that can inform the development of future research agendas. It may be concluded that literature on glacier tourism deals with a broad scope of topics and addresses glacier tourism in a variety of different ways. Within this diversity of research disciplines, core concepts, methodologies and focal research topics, three relatively distinctive research themes have been discerned (namely: climate change and variability, effects of glacier tourism, and perceptions and values of glacier tourism actors). Moreover, a significant lack of comprehensive conceptual and theoretical understanding of glacier tourism is evident. Such understanding is critical in order to tie together the diverse research interests, subjects and methodologies found in the literature review, and subsequently ground a more coherent and consistent research field.

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Appendix 1. List of studies in final review

Author	Document type	Name of Journal	Nationality first author	Focal research topic	Research design	Data[1]	Type of tourism	Case study
Haimayer (1989)	Article	*Mountain Research and Development*	Austria	Local communities	Descriptive	P	Skiing	Diverse glaciers in Austria
Blair (1994)	Article	*Mountain Research and Development*	New Zealand	Glacier area	Explanatory	P	Not specified	Tasman glacier, New Zealand
Sutton (1998)	Report	NA	New Zealand	Tourists	Descriptive	P	Hiking, scenic flights	Franz Josef and Fox glacier, New Zealand
Tinti, Maramai and Cerutti (1999)	Article	*Phys. Chem. Earth (A)*	Italy	Area management	Descriptive	S	Sightseeing	Miage glacier lake, Italy
Corbett (2001)	Report	NA	New Zealand	Tourists	Explanatory	P	Hiking, glacier walk, scenic flights	Franz Josef glacier, New Zealand
Espiner (2001)	Article	*Pacific Tourism Review*	New Zealand	Tourists	Descriptive	P	Hiking, sightseeing	Franz Josef and Fox glacier, New Zealand
Kuniyal (2002)	Article	*Environmental impact assessment review*	India	Glacier area	Descriptive	S	Not specified	Pindari Valley, India
Pralong (2005)	Article	*Géomorphologie*	Switzerland	Glacier Area	Descriptive	S	Geo-tourism	Not specified
Pralong and Reynard (2005)	Article	*Il Quaternario, Italian Journal of Quaternary Science*	France	Glacier Area	Exploratory	P	Geo-tourism	Bossons glacier, Mer de Glace glacier, Chamonix-Mont Blanc region
Aal and Hoye (2005)	Book Chapter	NA	Norway	Operators	Descriptive	S	Glacier museum tourism	Jostedalen glacier, Norway
Schindera et al. (2005)	Article	*Wilderness and Environmental Medicine*	Switzerland and USA	Tourists	Descriptive	P	Not specified	Not specified
Liu, Yang and Xie (2006)	Article	*Chinese Geographical Science*	China	Area management	Descriptive	S	Not specified	Bogda Glacier Park, China
Diolaiuti et al. (2006)	Article	*Cold Regions Science and Technology*	Italy	Glacier area	Explanatory	P	Skiing	Vedretta Piana glacier, Italy
Yuan et al. (2006)	Article	*Journal of Mountain Science*	China	Tourists	Predictive	P	Sightseeing	Yulong Mountain glacier, China
Scott, Jones and Konopek (2007)	Article	*Tourism Management*	Canada	Tourists	Predictive	P	Hiking/sightseeing	Waterton Lakes National Park, Canada
Olefs and Fischer (2008)	Article	*Cold Regions Science and Technology*	Austria	Area management	Explanatory	P	Skiing	Schaufelferner and Gaiβkarferner glaciers, Austria

(*continued*)

Author	Document type	Name of Journal	Nationality first author	Focal research topic	Research design	Data[1]	Type of tourism	Case study
Smiraglia et al. (2008)	Book Chapter	NA	Italy	Tourists, glacier area and area management	Descriptive	P	Skiing, sightseeing	Vedretta Piana Glacier and Miage lake, Italian Alps
Nyaupane and Chetri (2009)	Article	*Tourism Geographies*	Nepal	Glacier area	Descriptive	S	Mountaineering, hiking	Mt. Everest National Park, Annapurna Conservation Area and Chitwan National Park
Kohler (2009)	Report	NA	Norway	Glacier area	Descriptive	P	Glacier boat tours	Hornsund area of Svalbard
Frömming (2009)	Article	*Etnográphic*	Germany	Local communities	Descriptive	P	Trekking	Kilimanjaro glaciers, Tanzania
Kaseva and Moraina (2009)	Article	*Waste Management and Research*	Tanzania	Management	Descriptive	P	Trekking	Kilimanjaro glaciers, Tanzania
Wang, He and Song (2010)	Article	*Journal of Earth Science*	China	Area management	Descriptive	S	Miscellaneous	Baishui Glacier No. 1, China
Zhang, He, Theakstone, & Pang (2010)	Article	*Journal of Earth Science*	China	Atmosphere	Descriptive	P	Not specified	Baishui Glacier No. 1, China
Dhaulakhandi, Rajwar and Kumar (2010)	Article	*Journal of Plant Development*	India	Biodiversity	Explanatory	P	Pilgrimage, mountaineering, hiking	Gangotri glacier, India
Brandolini and Pelfini (2010)	Book Chapter	NA	Italy	Glacier area	Descriptive	P	Hiking	Solda Valley, Stelvio National Park, Italian Alps
Diolaiuti and Smiraglia (2010)	Article	*Géomorphologie*	Italy	Glacier area	Descriptive	S	Geo-tourism	Forni glacier, Val Viola glacierized basin
Jóhannesdóttir (2010)	Book Chapter	NA	Iceland	Tourists	Discriptive	P	Glacier walking	Sólheimajökull glacier, Iceland
Moreau (2010)	Article	*Géomorphologie*	France	Tourists	Descriptive	P	Hiking and mountaineering	Évettes glacier Cirque, French Alps
Beza (2010)	Article	*Landscape and Urban Planning*	Australia	Tourists and operators	Descriptive	P	Trekking	Mount Everest region, Nepal
Bird, Gisladottir and Dominey-Howes (2010)	Article	*Journal of Vocanology and Geothermal Research*	Iceland	Tourists and management and operators	Descriptive	P	Not specified	Myrdalsjökull glacier, Iceland

(*continued*)

Author	Document type	Name of Journal	Nationality first author	Focal research topic	Research design	Data[1]	Type of tourism	Case study
Fisher, Olefs and Abermann (2011)	Article	*Annals of Glaciology*	Austria	Area management	Explanatory	P	Skiing	Mittelbergferner, Austria
Feuillet and Sourp (2011)	Article	*Geoheritage*	France	Glacier areas	Descriptive	P	Geo-tourism	Pyrenees National Park, France
Bury et al. (2011)	Article	*Climatic Change*	USA, Canada, Peru	Local communities, operators and area management	Descriptive	S	Not specified	Pastoruri glacier, Peru
Aspinall, Cukier and Doberstein (2011)	Article	*Journal of Environmental Assessment Policy and Management*	Canada	Local community	Predictive	P	Skiing	Jumbo glacier, Canada
Stoddart (2011)	Article	*Leisure Studies*	Canada	Media	Descriptive	P	Skiing	Jumbo glacier, Canada
Wang and Jiao (2012)	Article	*Sciences in Cold and Arid Regions*	China	Area management	Descriptive	S	Not specified	Mt. Yulong Snow scenic area, China
Ritter, Fiebig and Muhar (2012)	Article	*Mountain Research and Development*	Austria	Glacier area	Descriptive	P/S	Mountaineering	Glaciated mountain ranges in Austrian Alps
Furunes and Mykletun (2012)	Article	*Scandinavian Journal of Hospitality and Tourism*	Norway	Operators	Descriptive	P	Ice-climbing, glacier walks	Different glacier sites in Norway
Wilson (2012)	Report	NA	New Zealand	Operators	Descriptive	P	Hiking, glacier walks, scenic flights	Frans Jozef and Fox Glacier, New Zealand
Becken (2012)	Article	*Journal of Travel Research*	New Zealand	Tourists	Explanatory	P	Scenic flights	Franz Josef Glacier, New Zealand
Garavaglia et al. (2012)	Article	*Environmental Management*	Italy	Tourists	Descriptive	P	Mountaineering, hiking	Forni Valley in Stelvio National Park, Italy
Goodwin, Loso and Braun (2012)	Article	*Arctic, Antarctic, and Alpine Research*	USA	Tourists	Explanatory	P	Mountaineering	Kahiltna Glacier in Denali National Park and Preserve, USA
Hoover-Miller et al. (2013)	Article	*The Journal of Wildlife Management*	USA	Biodiversity	Explanatory	P	Kayaking, boat tours	Kenai Fjords National Park, USA
Bollati, Smiraglia and Pelfini (2013)	Article	*Environmental Management*	Italy	Glacier area	Descriptive	P	Hiking	Miage Glacier Area, Italy
Lund (2013)	Article	*Tourist Studies*	Iceland	Tourists	Descriptive	P	Hiking	Snæfelljökull glacier, Iceland
Olafsdottir (2013)	Article	*Tourist Studies*	Luxembourg	Tourists	Descriptive	P	Trekking	Vatnajökull glacier, Iceland

(*continued*)

Author	Document type	Name of Journal	Nationality first author	Focal research topic	Research design	Data[1]	Type of tourism	Case study
Purdie (2013)	Article	*Mountain Research and Development*	New Zealand	Tourists and operators	Descriptive	S	Glacier walking, sightseeing and glacier boat tours	Franz Josef and Fox glaciers, New Zealand
Espiner and Becken (2014)	Article	*Journal of Sustainable sTourism*	New Zealand	Operators	Exploratory	P	Hiking, glacier walks	Fox and Franz Josef Glaciers, New Zealand
Wilson et al. (2014a)	Report	NA	New Zealand	Tourists	Descriptive	P	Glacier walking, scenic flights, hiking	Fox and Franz Josef Glaciers, New Zealand
Wilson et al. (2014b)	Report	NA	New Zealand	Operators and area management	Descriptive	P	Glacier walking, scenic flights, hiking	Fox and Franz Josef Glaciers, New Zealand
Young, Gende and Harvey (2014)	Article	*Tourism in Marine Environments*	USA	Area management	Descriptive	P	Boat tourism	Glacier Bay NP, USA
Mahabadi and Soleimanifakhr (2014)	Article	*Current World Environment*	Iran	Glacier area	Descriptive	P	Geo-tourism	Tale-Tange Valley, Iran
Gagné et al. (2014)	Article	*Wiley Interdisciplinary Reviews: Climate Change*	Canada	Operators, local communities	Exploratory	S	Miscellaneous	Different glacier sites in the world

[1] Data type: P= primary data, S= secondary data, P/S= equal mix of primary and secondary data.

Appendix 2. Overview of reviewed studies per theme

Themes/issues	Studies
Climate change	
Types of climate impacts	Blair (1994), Tinti et al. (1999), Aal and Hoye (2005), Diolaiuti et al. (2006), Yuan et al. (2006), Scott et al. (2007), Kohler (2009), Smiraglia et al. (2008), Nyaupane (2009), Moreau (2010), Diolaiuti and Smiraglia (2010), Brandolini and Pelfini (2010), Bury et al. (2011), Becken (2012), Wilson (2012), Ritter et al. (2012), Purdie (2013), Espiner and Becken (2014), and Wilson et al. (2014b)
Actors perceptions	Bird et al. (2010), Moreau (2010), Wilson (2012), Garavaglia et al. (2012), Furunes and Mykletun (2013), Espiner and Becken (2014), Wilson et al. (2014a), Wilson et al. (2014b)
Adaptation and mitigation	Blair (1994), Tinti et al. (1999), Espiner (2001), Aal and Hoye (2005), Schindera et al. (2005), Diolaiuti et al. (2006), Olefs and Fisher (2008), Smiraglia et al. (2008), Kohler (2009), Wang et al. (2010), Diolaiuti and Smiraglia (2010), Brandolini and Pelfini (2010), Bury et al. (2011), Fisher et al. (2011), Wilson (2012), Wang and Jiao (2012), Purdie (2013), Espiner and Becken (2014), Wilson et al. (2014b)
Tourism impacts	
Economic effects	Haimayer (1989), Bury et al. (2011), Wilson (2012), Furunes and Mykletun (2013)
Social cultural effects	Haimayer (1989), Sutton (1998), Corbett (2001), Frömming (2009), Stoddart (2011), Aspinall et al. (2011), Goodwin et al. (2012)
Environmental effects	Kuniyal (2002), Diolaiuti et al. (2006), Kaseva and Moraina (2009), Ningning and Yuanquing (2010); Dhaulakhandi et al. (2010), Fisher et al. (2011), Hoover-Miller et al. (2013), Young et al. (2014)
Perception and values	
Assessment approach	Pralong (2005), Pralong and Reynard (2005), Beza (2010), Jóhannesdóttir (2010), Feuillet and Sourp (2011); Olafsdottir (2013), Bollati et al. (2013), Lund (2013)
Type of value	Espiner (2001), Pralong (2005), Pralong and Reynard (2005), Beza (2010), Jóhannesdóttir (2010), Feuillet and Sourp (2012), Wilson (2012), Furunes and Mykletun (2012), Olafsdottir (2013), Bollati et al. (2013), Espiner and Becken (2014), Wilson et al. (2014a), Mahabadi and Soleimanifakhr (2014), Gagné et al. (2014)
Perception differences	Corbett (2001), Frömming (2009), Moreau (2010), Beza (2010), Gagné et al. (2014)

Paper II

18 External and Internal Challenges of Glacier Tourism Development in Iceland

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Introduction

Glaciers in Iceland have been visited by foreign guests for centuries, but it is only in the last few decades that some of these have become highly popular tourist destinations on which a broad array of guided tour activities, ranging from soft to hard adventure, are now performed. Interest in these forms of tourist activities has grown rapidly in recent years, which has in turn led to the formation of many new tour companies specializing in this field, as well as increased overall product diversity. This chapter will examine the development of glacier tourism in Iceland and explore the challenges that this form of niche tourism is facing through gradual and sudden changes of the natural environment, as well as through the development of mountain tourism in Iceland more generally. The findings are based on data collected through a mix of quantitative and qualitative methods. Information concerning glacier tourism for this chapter was obtained by means of a literature study, analysis of tourist enterprises' websites, participant observations during two commercial glacier tours, and in-depth interviews with eight entrepreneurs specialized in glacier tour activities.

Historical Development of Glacier Tourism in Iceland

Due to its geographical isolation and fairly harsh climatic conditions, Iceland did not become a significant destination for foreign travellers until the end of the 18th century. Most foreign visitors in these early times were European scientists who came to Iceland to study its geological phenomena, later followed by upper-middle-class travellers and adventurers motivated to explore the wild and unfamiliar landscapes of volcanoes, lava field and glaciers, and experience untamed and sublime nature (Sæþórsdóttir *et al.*, 2011; Karlsdóttir, 2013). With the arrival of steamships in the late 1870s, Iceland became more accessible to foreign visitors, which led to a transition from the mostly scientist-explorer form of travel to a more touristic or pleasure-based form (Ísleifsson, 1996). It was not until after the Second World War, however, that the tourism industry in Iceland as such started to develop, taking advantage of the transportation infrastructure introduced and developed by the British and American occupation forces during the war.

The first international passenger flights from Iceland to Europe began in 1944, flying

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 Mountain Tourism: Experiences, Communities, Environments and Sustainable Futures (eds H. Richins and J.S. Hull)

Table 18.1. Types of Glacier-Based Tourism Activities Provided by Icelandic Tour Companies (*Source: Icelandic Tourism Board, 2014b)*.

Types of tours provided	Number of companies	Types of tours provided	Number of companies
Super jeep / Truck	16	Photography tours	4
Snowmobile	12	Ice cave tours	4
Glacier walks	9	Glacier hiking (> 1 day)	3
Glacier lake Zodiac / boats	5	Glacier training	1
Ice climbing	5	Other (e.g. scenic flights, dog sledding)	2

out of the US Air Force base in Keflavík, situated about 50 km from Reykjavík, the capital of Iceland. Soon afterwards a route network connecting mainland Europe and North America, using Iceland as a hub, was established, thus creating transport links that provided a major impetus to tourism development on the island (Johannesson *et al.*, 2010). In addition, after the end of the war, Icelanders obtained many of the large army trucks and jeeps with front-wheel drives which had been brought over by the occupation forces (Huijbens and Benediktsson, 2007). These vehicles opened up motorized access to the Central Highland (an uninhabited, largely pristine wilderness that covers about half of the island) and thus enabled travel to various icecaps and glaciers that had previously only been accessible on foot or by horseback. From then on, nature-based tourism in Iceland gradually expanded, mountaineer clubs and travel agencies started to organize tours across the Highlands for both domestic and foreign tourists, lodging cabins were built and travel routes laid out over the wilderness (Sæþórsdóttir *et al.*, 2011).

Because of the limited accessibility and dangerous terrain of glaciers, travelling on or across them was for a long time mainly limited to experienced alpinists and well-equipped scientific expeditions (Guðmundsson, 1995). It was not until the 1990s that local entrepreneurs started to develop commercial adventure and motorized tour activities on glaciers, which catered to less-experienced travellers. Tours taking place on glaciated terrain require specialized equipment (e.g. crampons or full-body harnesses) or modified vehicles (e.g. super-jeeps or snow-scooters), as well as experienced guides who can lead the tour groups safely through the glacial landscape (Buckley, 2007; Furunes and Mykletun, 2012). Several types of activities also take place on the margin of the glaciers (e.g. hiking and boat trips). In the last decade or so, a broad assortment of guided tour activities that take place on or in the near vicinity of glaciers have been developed in Iceland (Table 18.1).

More recently, smaller or emerging Icelandic tour companies have attempted to explore new niche markets, such as ice cave tours, to differentiate themselves from the now fairly mainstream 'blue-ice' walking tours provided by the bigger companies. Another novel tourism initiative involves drilling a 300-m tunnel for sightseeing purposes in Langjökull, an icecap situated fairly close to the capital area and Keflavík International Airport (Icelandic Tourism Board, 2014a).

Development of Glacier Tourism in Iceland

Iceland has 269 glaciers, including 16 major icecaps, covering in total roughly 11% of Iceland's terrestrial surface (Sigurðsson and Williams Jr, 2008). The large majority of glacier tourism activities, however, take place on just four of these glaciated areas, most of which are situated along the south coast of Iceland. Figure 18.1 shows a map of Iceland with the glaciated areas (in orange) where most glacier tourism occurs. The Mýrdalsjökull and Vatnajökull icecaps, along with some of their outlet glaciers, are particularly important for glacier-based tourism services, both motorized and non-motorized, due to their easy and safe accessibility, as well as their proximity to highway nr 1, the ring road which connects the capital to the rest

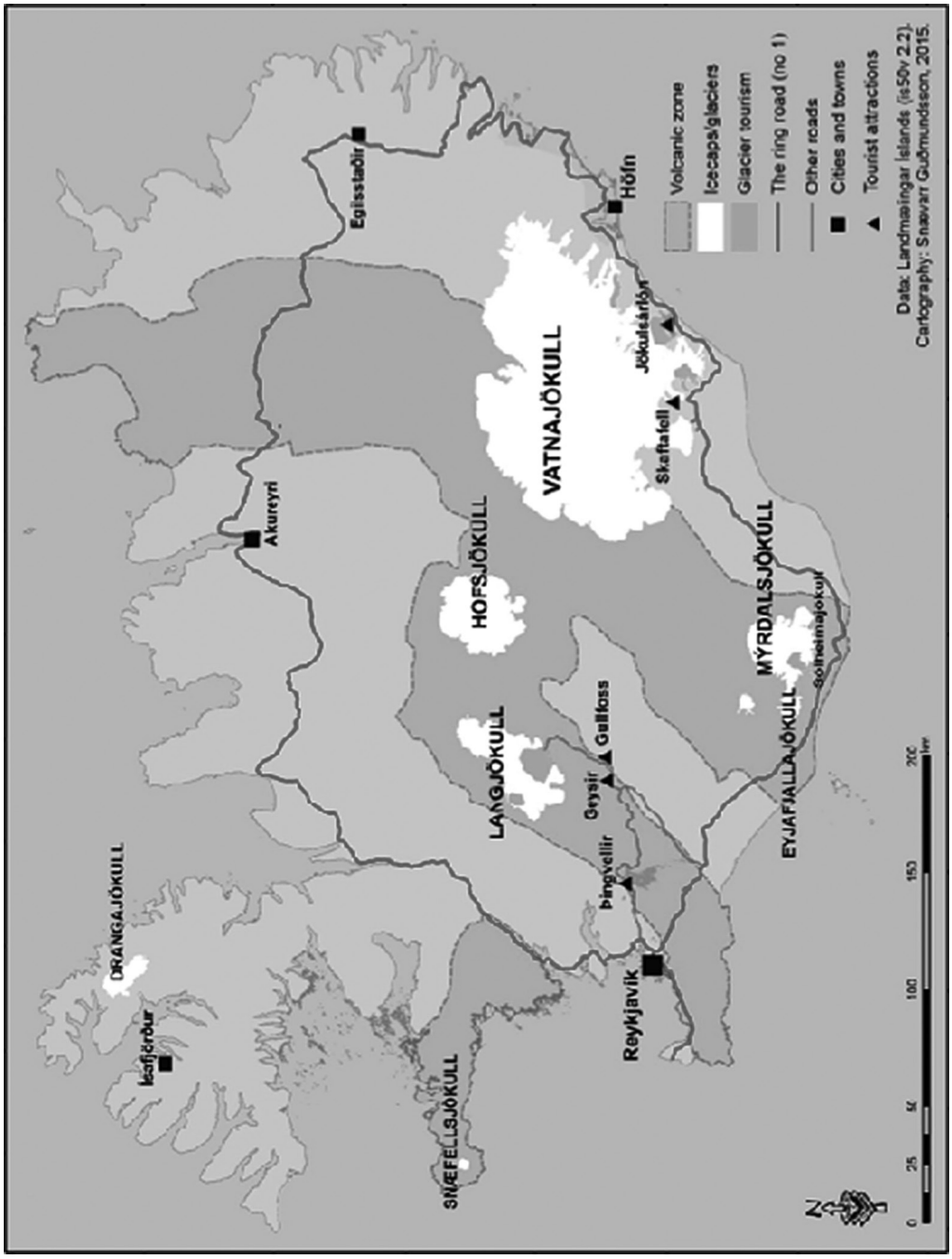

Fig. 18.1. Map of Iceland with the Glaciated Areas (in Orange) Where the Large Majority of Glacier Tourism Activities Take Place (*Figure courtesy of Snævarr Guðmundsson, Johannes Welling and Thorvardur Arnason*).

of the island. Langjökull icecap, on the western rim of the Central Highland, is also a popular site for motorized glacier tours, as is the outlet glacier Skálafellsjökull, on the southeast side of Vatnajökull. Many companies that offer jeep or snowmobile tours furthermore select their sites with regard to combining a glacier tour with visits to other popular nature destinations in the nearby vicinity, (e.g. colourful geothermal sites or spectacular waterfalls). Tours may also go to pro-glacial lakes such as Jökulsárlón on Breiðamerkursandur, which has in recent years become one of the best-known tourist attractions in Iceland. Amphibious boat tours have been available on the lake for roughly three decades and longer-lasting Zodiac tours were recently introduced. The latter type of tour is now also available on the nearby Fjallsárlón pro-glacial lake on the south-east margin of Vatnajökull.

Despite the increasing number and diversity of tour options, specialist outdoor activity companies who focus their product assortment entirely on glaciers or glacial landscapes still constitute a relatively small segment of the total tourism and leisure market in Iceland. As things currently stand, only about 40 companies (approximately 4% of all tour operators in Iceland) are specialized in providing glacier tours (Icelandic Tourism Board, 2014b). Glacier tourism in Iceland is furthermore characterized by the presence of a few relatively large companies with a diverse product range and a fairly large number of smaller and more specialized companies. The large companies have 30–50 full-time employees and a seasonal staff in the summer of more than 150 people. The majority of glacier tourism companies are middle-scale enterprises with between 10 and 30 employees, mostly based in the capital area and with operations on one or more glaciers. Businesses operating solely on Vatnajökull or its outlet glaciers are micro-companies, run by individuals or families, with only 1–5 employees. The number of the latter has increased considerably in the last few years, primarily due to the increase in winter tourism around Jökulsárlón and growing interest in ice cave tours.

Although the glacier tourism market in Iceland is relatively small, the demand for glacier tourism products grew rapidly in the last decade. In 2009 only around 2% of all recreation activities purchased by foreign tourists in Iceland were glacier or snowmobile trips, while by 2012 this had grown to 15% (Icelandic Tourism Board, 2014c). A number of different factors lie behind this strong increase. Glacial landscapes offer opportunities for nature-based recreation and tourism, in response to the ever-growing demand from foreign visitors for activity tours which explore Iceland's 'wild and untamed' nature (Sæþórsdóttir, 2010). Annual tourism surveys have repeatedly shown that the main motivation for travel to Iceland is to experience the island's nature. In the most recent survey, 80% of respondents cited this as the main reason for their trip (Icelandic Tourism Board, 2014c). Glaciers consist of physical features such as moraines, crevasses, moulins and especially the blue ice itself, which stimulate in their visitors feelings of wonder and amazement, as well as thrill, fear and the recognition of the glacier's dangerous power (Jóhannesdóttir, 2010). An encounter with a glacial landscape allows visitors to experience a unique and novel environment, which provides them with escape from their everyday life (Furunes and Mykletun, 2012). Glacier landscapes thus offer elements and attributes that meet the main travel goals of tourists in Iceland (i.e. to experience the pristine and sublime 'land of ice and fire', the last remaining wilderness of Europe). In addition to this, most tourists will not have experienced a glacier previously to their visit. For such tourists, glaciers have an iconic status which creates a 'must see or touch' feeling (Espiner and Becken, 2014). Glaciers furthermore open up opportunities for the provision of a wide range of soft and hard adventure tourism services (Pomfret, 2006; Buckley, 2007), which use the glacier as the setting or backdrop for their activities. Glaciers fulfil the desire of visitors to find something unique or different during their travels, as well as to take on adventurous challenges in a strange and potentially dangerous environment (Furunes and Mykletun, 2012).

Similar to the situation in Norway (Furunes and Mykletun, 2012), glacier tourism in Iceland is mainly the result of entrepreneurial activity by tour companies, which market and sell glacier-based activities as a tourist product. The increase of glacier tourism in Iceland is therefore also a result of the diversification of tour

activities over the last ten years. During this period, glacier tourism expanded from a fairly limited glacier mountaineering niche to a much more general nature-based or outdoor recreation sector, offering a broad activity assortment.

Glacier activities now include guided glacier walks, hikes and glacier traversing; ice-climbing; motorized tours with super-jeeps, trucks or snowmobiles on icecaps; boat and kayak tours on glacier lakes; photography tours in ice caves; training sessions for climbers; and scenic flights by plane or helicopter. The majority of these activities are available throughout the year, whereas some are only possible during the winter season, making glacier tourism in addition an important stimulus for reducing the pronounced seasonality of tourism in Iceland. Furthermore, tour operators often provide tailor-made products for their customers, ranging from short and easy glacier walking trips for families to multi-day glacier tours intended for experienced mountaineers or scientific expeditions, which further diversifies their product range. Some of the larger glacier tour operators have extended their tour assortment enormously, providing more than 100 different kinds of organized trips on glaciers. The majority of glacier tour products consist of single or half-day tours which fit well into one-day tour packages that are in high demand from tourists residing in the capital area and/or are easily combined with other tour activities taking place on that same day.

The large glacier tour companies have recently established strong networks with other tour operators, as well as transport and hotel chains, for cooperation and coordinated activities and have through this enhanced their marketing position vis-à-vis their competitors in other adventure tourism sectors. The majority of their employees consist of part-time contractors who are hired during the high season (June to August). Such contractors have a relatively easy entrance to the market due to the use of privately owned four-wheel-drive vehicles and often have basic mountain and glacier experiences and skills obtained through their membership of local search and rescue (SAR) teams which operate in every municipality in Iceland or through taking training courses for glacier guides, which are offered on a regular basis by the large glacier tour companies.

Challenges

The challenges facing glacier tourism in Iceland are of two basic kinds. First, external challenges constituting direct or indirect changes in the natural environment that affect glacier tourism but on which the tourism sector has no influence. Volcanic activity and climate change are examples of such challenges. Second, glacier tourism also faces internal challenges, which result from the changes in demand for and supply of glacier tourism activities themselves. The rapid growth of tourism in Iceland is an example of such a challenge.

Volcanic and Geothermal Activity

Iceland is one of the most active terrestrial volcanic regions, with a frequency of one eruption every four to five years (Gudmundsson *et al*., 2008). Approximately 60% of the Icelandic glaciers and icecaps are located on top of a volcanic zone (Fig. 18.1), the most extreme case being Vatnajökull, which covers nine major volcanic or geothermal areas. Since the time of settlement in Iceland (c. 870 AD) at least 80 sub-glacial volcanic eruptions have taken place in Vatnajökull (Hannesdottír, *et al*., 2010), the latest in Grímsvötn in 2011. The challenges facing glacier tourism mainly concern the indirect consequences of sub-glacial volcanic and geothermal processes. The three main impacts are glacier floods (jökulhlaups), tephra dispersion and diffusion of toxic gases through melt water.

Jökulhlaups

Jökulhlaups are outburst floods from glaciers caused either by sub-glacial volcanic eruptions or the draining of sub-glacial geothermal lakes, both types of floods occur quite frequently in Iceland. Jökulhlaups can change glacial landscapes dramatically: deposit fluvial and glacial sediments, flush away vegetation, endanger humans and livestock, and make large regions inaccessible by destroying bridges and roads (Björnsson and Pálsson, 2008). The most dramatic example of this in recent times is the

1996 Gjálp eruption underneath Vatnajökull, which destroyed two major bridges on the ring road. Most jökulhlaups caused by the draining of sub-glacial geothermal lakes are relatively minor and occur at fairly regular intervals but outburst floods caused by volcanic activity, in contrast, tend to drain without delay towards the glacier margin (Björnsson, 2002). A recent example of the latter is the volcanically generated jökulhlaup from Sólheimajökull, one of the most popular glacier tourism sites in Iceland, in the summer of 1999. This flood was unexpected and characterized by an unusually rapid rise of the melt water peak discharge draining into two former ice-dammed lake basins, which rapidly filled and drained catastrophically, filling the adjacent valley (Russell *et al.*, 2010).

Tephra Dispersion

Another consequence of sub-glacial volcanic activity is the widespread dispersion of tephra (volcanic ash) during and following an eruption. Icelandic eruptions are often characterized by the production of large volumes of volcanic ash (Thordarson and Höskuldsson, 2008). The airborne dispersion of tephra can cover extensive parts of the glacier surface near the volcano. The tephra dispersion and disposition from sub-glacial eruptions in Eyafjallajökull in 2010 and Grimsvötn in 2011 affected the surface of almost all icecaps in Iceland. This can result not only in negative effects on the perceived glacial scenery but can also have major impacts on the accessibility of the area, whether by land or air.

Poisonous Gas from Floodwater

Sub-glacial geothermal activity can release poisonous gases into floodwater underneath an outlet glacier or icecap. A common volcanic gas that diffuses from melt water generated by the geothermal areas underneath Icelandic glaciers is hydrogen sulphide (H_2S; Lawler *et al.*, 1996). Hydrogen sulphide has a malodorous smell and can irritate and eventually burn mucous membranes in both eyes and the respiratory system. The glacier river that drains from Sólheimajökull often contains high concentrations of sulphur, which can reach poisonous levels by the glacier margin. In July 2014, high concentrations of H_2S in the floodwater emerging from the glacier required local authorities to advise travellers and tour companies to avoid going close to the glacier margin (Civil Protection in Iceland, 2014).

Responses to such events concerning tourists are mostly aimed at preventive measures and information dispersal. Local authorities, in cooperation with Search and Rescue (SAR) teams and regional tourism associations, have developed regional volcanic risk management strategies that consist of information meetings, onsite training sessions, distribution of information brochures to tourists, and the placing of hazard and emergency response information panels in mountain huts and in prominent positions along hiking trails (Bird and Gisladóttir, 2014). However, a recent study by Bird *et al.* (2010) showed that tourists in Iceland lacked knowledge of volcanic hazards, such as jökulhlaups, and that both tourists and tourism employees lacked knowledge of the early warning system and emergency response procedures.

Climate Change

Icelandic icecaps and glaciers are all categorized as being temperate or warm-based, i.e. they have a high annual mass turnover where considerable melting is compensated for by high precipitation and, in turn, high rates of accumulation (Aðalgeirsdóttir *et al.*, 2011). Such glaciers are highly dynamic and sensitive to climate variation, resulting in rapid responses (advance or retreat) to changes in temperature and precipitation (Björnsson and Pálsson, 2008; Guðmundsson *et al.*, 2011). The recorded changes in the volume and area of Icelandic glaciers are thus excellent indicators of global climate change. The first records of glacier volume in Iceland date back to the first centuries of settlement in Iceland (Aðalgeirsdóttir et al, 2011). After the onset of the Little Ice Age in the 13th century, glaciers started to advance and continued to do this until the late 19th century, when most of them had reached their

maximum postglacial extent (Hannesdóttir *et al.*, 2014). Around the beginning of the 20th century this trend was reversed, and since then all glaciers in Iceland have on the whole been receding. Glacier recession has been especially pronounced since the 1990s, with all monitored icecaps retreating and thinning at an unprecedented pace (Björnsson and Pálsson, 2008, Hannesdottír *et al.*, 2010). Langjökull, for example, diminished by about 7% in area from 1997 to 2006, and the outlet glaciers Virkisjökull–Falljökull, south of the Vatnajökull icecap, have shown an exceptionally fast retreat since 2007 (Guðmundsson *et al.*, 2011; Bradwell *et al.*, 2013). Dynamic glacier models coupled with future climate scenarios predict that the largest icecaps in Iceland – Vatnajökull, Langjökull and Hofsjökull – will lose 25–35% of their 1990 volume before 2040 and disappear almost totally within 150–200 years (Björnsson and Pálsson, 2008).

The recession of Icelandic glaciers, in particular, the upwards shift of the margins of outlet glaciers where most tourism activities take place, has already resulted in a number of negative impacts for glacier tourism, primarily concerning the maintenance of accessibility for tourism operations to popular glacier sites. As an example, the recession of the glacier terminus of Skálafellsjökull, south-east of the Vatnajökull icecap, to a higher elevation level made the glacier access point too steep for access by inexperienced tourists. A more wide-reaching concern of glacier tour companies is the extension of the distance between the parking place for their vehicles to the retreating glacier margin, which increases the time and walking distance that tour groups need to travel before they reach the glacier. In some cases, distances from the parking lot to the glacier have doubled in less than 20 years, resulting in the cessation of tours on such glaciers. Climate change in Iceland is also causing an earlier onset of the melting season, as well as enhanced late summer melting, resulting in an increase of glacier runoff and changes in the courses of glacial rivers, which can affect accessibility of different glacier sites (Björnsson *et al.*, 2011).

Glacier recession also results in the emergence of pro-glacial lakes in front of most of the southern outlet glaciers of Vatnajökull, due to the uncovering of deep sub-glacial troughs carved out by the ice-age glaciers, which then fill up with melt-water runoff (Magnusson *et al.*, 2012). This can restrict access for walking tours to the glacier margins but, in turn, provides opportunities for new types of activities, especially boat tours of various kinds. Future projections of glacier recession indicate that glacier lakes will become longer and wider and gradually replace the outlet glaciers totally (Magnússon *et al.*, 2012). In the short run, this is likely to provide opportunities for more tourism activities on or around those lakes. However, the extension of glacier lakes may form serious barriers for tours on the glacier, as they can block access to the valley completely (Ritter *et al.*, 2012). Glacier retreat also triggers the calving of ice-blocks from the termini of the glacier into lagoons, causing tidal waves, which can be hazardous to nearby visitors. Due to increased risk of calving at the margin of Sólheimajökull in August 2014, the nearby parking area was closed for weeks and the trail to the glacier had to be re-routed (Robert, 2014). This extended the walking time to the glacier by almost one hour, which in turn made the tour too difficult for less mobile visitor groups, such as families with young children and older people.

Increased Tourism

The number of foreign visitors to Iceland tripled between 2002 and 2013 to reach 781,000 (Icelandic Tourist Board, 2014c). The long-term average of increase in tourist arrivals was around 6–7% per year until 2011, when a new and much faster phase of increase started, with annual growth of 15–20% per year, which shows no signs of abating. This strong increase places growing pressure on fragile ecosystems and on local ways of life and traditions (OECD, 2014) and also has effects on glacier tourism. The number of glacier tours is thus rapidly growing while the number of glaciers accessible for such tours remains more or less the same. This results in increased tension between different tourist groups and between different tour companies. An example of this are ice-cave tours in south-east Iceland, which have recently become very popular, following an increase in winter tourism in Iceland. The

number of easily accessible caves is very limited and tensions can thus arise between specialized tours for photographers, which involve small groups staying for fairly long durations, and larger groups of general tourists seeking the thrill of experiencing an ice cave.

Tensions have also risen between local tour operators who largely depend on such trips for their livelihood and the larger and more diversified adventure tour companies based in Reykjavik that offer day-tours to the ice caves from the capital area. The fact that these activities take place within the borders of Vatnajökull National Park suggests a possible solution in the form of specific management guidelines, which could limit the number of companies operating in such areas, but no such guidelines currently exist and, even if they were developed, they might prove difficult to enforce.

Conclusion

Glacier tourism in Iceland has grown from being a fairly small, niche-orientated sector to becoming one of the largest and most diverse adventure tourism sectors in the country in a relatively short period of time. These developments are largely due to the general increase in annual tourist arrivals to Iceland, which has been much intensified in recent years, but also to a considerable extent by the entrepreneurial activities of tour operators, who have both extended and diversified their operations. Glacier tourism faces several different types of external challenges, some catastrophic but short-lived (such as volcanic eruptions), some recurrent but localized (such as emission of poisonous gases) and some which are small-scale but cumulative and thus likely to have a significant long-term effect (such as global climate change).

The internal challenges facing this sector stem mainly from an unusually high rate of increase in tourist arrivals, which has been going on for a much longer period than any previous tourist boom and is putting large strains on the tourism infrastructure in Iceland. In some cases tensions have arisen between tourism companies due to competition for a limited resource (such as ice caves). Such tensions can be at least partly abated through increased cooperation or, in the case of protected areas, more stringent management guidelines.

The future development of glacier tourism in Iceland will mainly depend on the ability of tourism entrepreneurs to respond to the growing demand for distinctive glacier-based tour products that maintain the atmosphere of being in a sublime and untouched glacial landscape, while simultaneously coping with changes in the environment, both physical and perceived.

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Paper III

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SPECIAL ISSUE: CLIMATE, TOURISM AND RECREATION

Following the ice: adaptation processes of glacier tour operators in Southeast Iceland

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Abstract
The growing recognition that global climatic change is a pressing reality and that its impacts on humans and ecological systems are inevitable makes adaptation a core topic in climate change research and policymaking. The glacier tourism sector that is highly sensitive towards changing climatic conditions is among the most relevant in this respect. This study aims to examine empirically how adaptation to climate change impacts is practiced by small- and middle-scale glacier tour operators. Data was collected by means of a set of semi-structured interviews with the managers or owners of nine small- or middle-scale tour companies operating in the Vatnajökull National Park in Southeast Iceland and observations of glacier sites where the respondents' companies are operating. The results indicate that all entrepreneurs consider climate change to be a real phenomenon that affects their present daily operations, but they perceive these implications not as significant threats to their business. The interaction of operator's attributes of agency such as firsthand experiences, risk perceptions, and abilities to self-organize, with structural elements of the glacier destination system such as economic rationales and hazard reduction institutions, has shaped and consolidated operators' adaptation processes in the form of a wait-and-see strategy combined with ad hoc reactive adaptation measures and postponed or prevented proactive long-term adaptation strategies.

Keywords Adaptation · Climate change · Glacier tourism · Iceland · Tour operators · Adaptation · Decision-making

Introduction

There is a growing recognition that global climatic change is a pressing reality and that its impacts on humans and ecological systems are inevitable (IPCC 2014). Glacier environments are among the most affected natural landscapes due to their sensitivity towards changes in regional temperature and precipitation levels. Past, present, and future projections from various studies (see Vaughan et al. 2013) give a picture of retreating glaciers, thinning glaciers, and permafrost thawing. Nature-based tourism is a fast-growing sector in glacial environments (Welling et al. 2015) but is also seen as a highly affected industry, both at present and in the future (Palomo 2017). A few extant studies point out that the climate change–induced thinning and recession of glaciers have already led to significant impacts on tourism operations in glacier landscapes such as increased occurrence of natural hazards (Smiraglia et al. 2008; Brandolini and Pelfini 2010), the reduction of the accessibility to glaciers or within glacier sites (Ritter et al. 2012; Purdie 2013), and change of landscape scenery (Purdie et al. 2015; Groulx et al. 2017). In addition, different studies that analyzed glacier tourism demand under the impacts of climate change show a significant decrease in demand as a consequence of considerable changes in glacier scenery or glacier disappearance (Scott et al. 2007; Stewart et al. 2016; Groulx et al. 2017).

The vulnerability of the glacier tourism sector towards climate change depends considerably on the capacity of individual actors to adapt to these implications (Espiner and Becken 2014). Hence, adaptation, an action that aims to moderate, cope with, and benefit from the consequences of climate change in order to manage risk and reduce vulnerability (Jopp et al. 2010), is crucial in this regard. In the last decade, a considerable amount of scholarship on adaptation in the

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tourism sector has evolved; however, most of this research has been quite theoretical in nature and system oriented, focusing, e.g., on climate change risk and vulnerability assessments, theoretical conceptualizations or intended adaptation, but not on existing adaptation actions or whether and how adaptation is actually occurring (Becken and Hay 2012; Kaján and Saarinen 2013). In particular, research on adaptations of private companies is lacking (Hoffmann et al. 2009; Linnenluecke et al. 2013). Existing empirical research on tourism entrepreneur's adaptation suggests that most of them implement short-term reactive adaptation and are reluctant to engage in longer-term adaptation processes (Scott et al. 2012; Haanpää et al. 2014; Steiger et al. 2017).

Such research has shown that the adaptive action of tourism entrepreneurs depends on different factors not only related to the availability of resources but also to awareness of climate change, perception of risk, media attention, entitlements, presence of relevant information, or governance institutions (e.g., Evans et al. 2016; Tervo-Kankare 2011; Trawöger 2014). These factors may constitute different barriers or constraints for the allocation and implementation of adaptation strategies (Eisenack et al. 2014). Knowledge about these determinants enables decision- and policymakers to support favorable conditions for entrepreneurial adaptation.

The research aim of this study at hand responds to these research findings by examining empirically how adaptation to climate change impacts is practiced by small- and medium-scale tour operators. We use a case study from Southeast Iceland where glacier tourism constitutes the most popular commercial outdoor adventure activity (Árnason and Welling 2019). Given their past, current, and possible future exposure to a fast-changing environment and their dependence on these environments for offering their products, Icelandic glacier tour operators present a suitable case to study empirically climate change adaptation in tourism.

Literature review

Adaptation process

The climate change literature discerns various approaches towards adaptation, reflecting different underlying logics driving adaptation behavior (Gasbarro and Pinkse 2016). Adaptation can be classified on the basis of the actors (public or private), timing (anticipatory or reactive), and intention (planned or autonomous) (Smit et al. 2000). With regard to intention, Eisenack and Stecker (2012) suggested to distinguish between incidental adaptation that is adaptation action without an intention to adapt, implicit adaptation that is purposeful adaptation but without the intention to adjust to climate change–induced implications, and explicit adaptation which ultimate purpose refers to an impact of climate change. Other studies made adaptation classification related to companies. For example, Hoffmann et al. (2009), focusing on corporate climate change adaptation by ski area operators, distinguished three types of adaptation on the basis of a company's strategic objectives: strategies that protect affected business such as technical and procedural means, strategies that expand beyond the affected business such as exploration of additional business activities that are not affected by climate change, and strategies that share risks of financial impacts such as collaboration or insurances.

A central concept in corporate adaptation are operational routines (Nelson and Winter 1982), that are means (e.g., operational procedures, organization rules, technologies, or business culture and beliefs) by which companies exert their ongoing activities by matching appropriate procedures to conventional and non-conventional situations (Berkhout et al. 2006). When facing novel situations such as climate change–induced environmental changes, companies can modify or adapt routines depending on their dynamic capabilities, organizational competences (e.g., knowledge, skills, and technology) that allow organizations to integrate, develop, and configure internal and external resources (Teece et al. 1997).

The literature on organizational adaptation (e.g., Arnell and Delaney 2006; Berkhout et al. 2006; Moser and Ekstrom 2010) agrees on the general steps that comprise an adaptation process: perception of the problem, evaluation of adaptation option, enactment, and feedback (Berkhout 2012). For example, Risbey et al. (1999) identified four stages in the adaptation process: signal detection, where it is decided what is adapted to and what is ignored; evaluation, where the signal is interpreted and foreseeable consequences are evaluated; decision and response, which results in an observable change in the behavior and performance of the system; and feedback, which involves monitoring of the outcomes of decisions to assess whether they are as expected. Although these normative frameworks are useful to show how adaptation *should* be conducted, they fall short in explaining how adaptation is actually performed. Therefore, a starting point for our research is to understand how decisions in the adaptation process are made by exploring the broader perspectives on adaptation decision-making.

Perspectives on adaptation decision-making

Berkhout (2012) distinguished three broad perspectives on organizational adaptation decision-making: a rational (utility maximizing), behavioral, and structural perspective. The rational perspective, based on the utility theory, assumes that organizations act as rational and self-interested agents that compare the prospects of alternative adaptation options in terms of the expected utility and the probability of each option (Eiser et al. 2012). The rational perspective has been criticized for making unrealistic assumptions about how decision-makers act, assuming that actors or organizations have full

information about the costs and benefits of different adaptation options and their preferences are stable and continuous. However, factors such as time pressure, uncertainty, and complexity, and the ill-defined nature of many problems make a rational and systematic analysis virtually impossible (Daft et al. 2014). The behavioral perspective, which draws on psychological theories, eases the assumptions of utility maximization by explaining adaptation decision-making on the basis of bounded cognitive abilities (Selten 2002). It does not assume that decision-makers act irrationally, but that their rationality is bounded by their cognitive abilities. In a complex or uncertain situation, decision-makers in organizations often fall back on heuristics or use "rule of thumb" strategies based on their own experiences, easy retrievable and available data, or intuition, rather than on an assessment of the optimal response from a set of adaptation options (Marx and Weber 2012).

The structural perspective stresses the role of societal structures and the institutional context in which organizations are embedded. Social environments shape the adaptation behavior of actors indirectly through the continuous reformulation or reproduction of value, norm, and knowledge systems that define the role of the decision-maker and whether his or her decisions and actions are effective and legitimate (Gorddard et al. 2016). The decision-maker's choice of action is shaped and constrained by external socio-cultural, economic, and political structures and processes such as entitlements to resources, kinship networks, technical expertise or prevailing economic ideologies (Hogarth and Wójcik 2016). For example, Tervo-Kankare (2018) found that adaptation-related decision-making of nature-based tourism companies is related to their entrepreneurial lifestyle characteristics in which high confidence in own survival may add to reactive behavior rather than pro-active adaptation.

On the basis of the previous, we frame adaptation in this study as a decision-making process consisting of four main interactive aspects: perception, evaluation, action, and feedback. This process is driven by human agency—the perceptions, attitudes, awareness, or creativity of individuals and organizations—but the agent's decision-making is structured by socio-cultural, economic, and political factors (Hogarth and Wójcik 2016). Therefore, a thorough understanding of an organizations' adaptation process requires an examination of how the agency of individual decision-makers and the structural components of the system in which those decision-makers operate interact to create locally specific adaptation processes (Wyss 2013; Abegg et al. 2017).

Adaptation by glacier tour operators

Empirical studies on glacier tourism operators' adaptation towards climate change are very few in number (Welling et al. 2015). Different studies on glacier tour operators in Norway and New Zealand come to similar findings with regard to the companies' awareness of climate change, risk perceptions regarding climate change implications, and implemented adaptation responses. To cope with different climate change–induced implications for glacier tourism, i.e., reduced accessibility to and within glacier sites, increased occurrence of hazards, and degraded scenery, several adaptation measures have been implemented. In their study on glacier tour operators in Norway, Furunes and Mykletun (2012) found that the entrepreneurs mostly used operational adaptation means such as rerouting or product diversification (e.g., different adventures or nature-based activities to complement the general sightseeing tour on the glacier). However, they found that half of the interviewed operators expressed no worries regarding the recent recession of the glaciers. Furunes and Mykletun argued that an important reason why Norwegian glacier tourism operators do not feel that climate change is a threat is because the impacts they have experienced were framed as secondary effects, i.e., caused by changing natural conditions which are less obvious and more dependent upon local weather variabilities in the form of precipitation and summer temperatures fluctuations than anthropogenic climate change.

Research by Wilson (2012) on entrepreneurs in Glacier Country in New Zealand showed similar results regarding the entrepreneurs' risk perceptions. Here, several operators were worried about the attraction of the region for tourists if the glaciers continued to recede significantly; however, for the majority of the interviewed entrepreneurs, the potential further recession of the glaciers did not feature as a significant challenge. Most respondents believed the glacier would remain a tourist attraction for a long time. Wilson argued that the long history of glacier tourism reinforces the perception that tourism companies will be able to adapt to physical changes of the glacier destinations in the coming decades.

Wilson et al. (2014), using interviews with glacier tour operators in New Zealand, revealed that most of the businesses' adaptive responses were reactive, rather than proactive, with tourism operators being focused on maintaining the "status quo and waiting to see what happens" (Wilson et al. 2014, p. 35). Furthermore, Purdie (2013) found that the retreat of the glaciers in New Zealand was perceived in some cases as benefits by tour operators because the recession makes access to some glaciers easier and due to the expanding pro-glacial lakes, which the entrepreneurs exploit in form of organized boat tours.

According to Wilson et al. (2014), flexibility with respect to preparedness to change products and norms about what is acceptable at the glaciers and the ability to react quickly to any glacier change are keys to successful adaptation. This confirms results of the study by Espiner and Becken (2014) who found that the local glacier tourism industry in Glacier Country in New Zealand displayed remarkable levels of resilience to climate change implications due to its acquired ability to organize itself around continuously changing glacier

conditions. Stewart et al. (2016) point out that especially structural or contextual aspects such as legal constraints with respect to area governance, business concerns related to financial risk, and visitor preferences and demand were perceived as limitations to adaptation by entrepreneurs operating at glacier destinations in New Zealand.

Materials and methods

Study area

The study area of this research is the southeast part of the Vatnajökull icecap (Fig. 1), which has been marketed as the Vatnajökull region (www.visitvatnajokull.is). In the last two decades, this sparsely populated rural part of Iceland has developed from being mostly agricultural to become an important tourism area. We choose the southeast part of the Vatnajökull icecap as a study area because it plays a central role in the Icelandic glacier tourism sector. Approximately a quarter of all glacier tour enterprises in Iceland provide tours on or in the direct vicinity of the different outlet glaciers of the Vatnajökull icecap (Icelandic Tourist Board 2016). These tours constitute a broad array of glacier-based outdoor activities including guided glacier walks, hikes and glacier traversing, ice-climbing, motorized tours with super-jeeps or snowmobiles on icecaps, boat and kayak tours on glacier lakes, photography tours in ice caves, training sessions for climbers, and scenic flights by plane.

The Vatnajökull region contains several outlet glaciers of which eight glaciers and two glacier lakes (Fig. 1) have so far been exploited for recreational purposes on a regular basis. Table 1 shows the diverse recreation activities undertaken on the different glacier sites within the Vatnajökull region. Commercial tours are offered at most glacier sites, but these vary depending on the conditions and opportunities there. In addition, unguided sightseeing is taking place at the margin of outlet glaciers or the banks of glacier lakes.

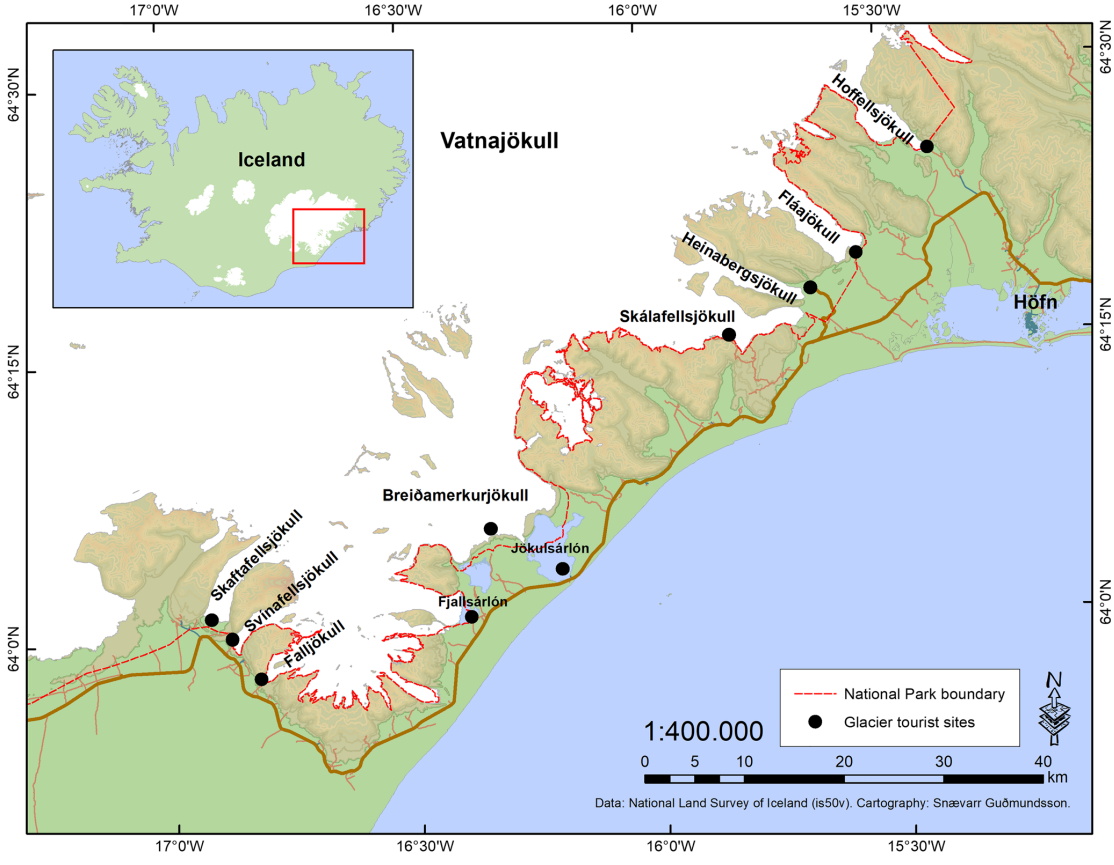

Fig. 1 Map of the Vatnajökull region showing the different glacier sites (courtesy of Snævarr Guðmundsson)

Table 1 Visitor numbers and main activities at glacier sites in the Vatnajökull region in 2017. Source of visitor numbers: Þórhallsdóttir and Ólafsson 2018

Glacier sites	Main recreation activities	Visitor numbers
Skaftafellsjökull	Sightseeing, educational hikes	91,920
Svínafellsjökull	Sightseeing, glacier hikes, ice-climbing	195,358
Fjallsárlón	Sightseeing, boat tours	281,936
Jökulsárlón	Sightseeing, boat tours	770,801
Heinabergsjökull	Sightseeing, glacier hikes, kayak tours	12,934
Hoffellsjökull	Sightseeing, ATV tours	25,562

Most of these glacier sites are part of Vatnajökull National Park (VNP) which means that all tour activities are subject to the management guidelines and regulations of VNP and, conversely, that the tour companies are stakeholders of the park. However, promoting outdoor recreation and in particular the stimulation of nature-based tourism initiatives as an instrument of rural development constitute two of the main goals of the park (VNP 2013), which result in a rather "liberal" policy regarding tour operations at glacier sites in the VNP.

The southeast glaciers of Vatnajökull respond rapidly to temperature and precipitation changes because they are located in the warmest and wettest part of Iceland (Hannesdóttir and Baldursson 2017). By the end of the previous millennium, the southeast outlet glaciers of Vatnajökull have retreated at an accelerated pace, ranging from an average of 22 to 55 m^{-1} per year between 1995 and 2016 (Einarsson 2017). Recent glacier models (e.g., Aðalgeirsdóttir et al. 2011) indicate that several outlet glaciers of Vatnajökull will vanish by the end of the twenty-first century.

Data collection and analysis

A purposive sampling method (Patton 2002) was conducted to select a set of nine glacier tour companies which constitute a sound representation of the glacier tour operator sector in Iceland ($n = 61$ in 2015, Welling and Árnason 2016) regarding size (number of employees and customers) and tour specialization (Table 2). A large majority of the companies are local and only operate in this part of Iceland. The staff of the smaller companies all live in the Vatnajökull region, while most of the staff of the larger companies are from Reykjavík or abroad. To explore perceptions of change (both regarding glaciers and tourism) and to gain information from respondents that have significant overview of the company's operations, this study interviewed the owners or general managers or, in the case of one company, senior employee[1] who had been more than 5 years with the company (Table 2).

The interviews were conducted during the period of April–June 2015. All interviews were conducted in English, which hampered to some extent the non-native English speaking respondents in the expression of their answers and comments. The length of the interviews was between 45 and 90 min, and these took place in most instances at the residence or workspace of the respondents. The interviews were semi-structured (Patton 2002), using a basic interview framework in all interviews, but where the order in which individual core questions were asked (and answered) varied, depending on the flow of conversation. Information from the interviews was supplemented with data gathered through glacier site observations, on-site tour participation, analysis of glacier tour operators' websites, statistical records, and a narrative literature review of national and regional land use policy papers. This last source was used to investigate the structural perspective on the adaptation processes of the tour companies. All interviews were recorded, transcribed verbatim, and analyzed through the search for repeated themes and topics.

[1] This company had just changed ownership, so it was better for the research to interview a senior employee.

Results

Perception of climate change signals and impacts on tour operations

The empirical results show that all operators ($n = 9$) consider climate change to be a real phenomenon that is taking place in present times. The respondents all mentioned the physical alterations of the glacial environment as a direct signal of regional climate change (Fig. 2). All operators also mentioned the shrinkage of outlet glaciers in the region, the retreat of the ice margin, the submergence of the glacier surface, or all three. Additional perceived physical changes were the extension of the moraine area adjacent to the snout of the glaciers and the emergence or enlargement of glacier streams, river and lakes, and glacier fragmentation and permafrost degradation. Operators had also perceived non-glacier-related signals of climate change such as the extension of the summer season and the occurrence of extreme weather events such as heavy rain and strong wind. The occurrence of extreme weather events was actually mentioned by a majority of the operators; however, most of them did not discern this as a climate change–induced phenomenon but as a general attribute of the regional climate which has "always been known for its extreme variability of weather conditions" (respondent A).

Table 2 List of interviewees

	Interviewee	Tour specialization	Year of establishment	Number of employees[1]	Number of tour customers 2014–2015[2]
1	Owner	Super jeep tours	2009	3–2	1.500–2.000
2	Owner	Glacier walking, ice cave tours	1994	4–3	2.000–2.500
3	Owner	Ice cave tours, glacier lake kayaking	2011	2–1	3.000–4.000
4	Owner	Glacier walking, ice cave tours	2011	1–1	4.000–5.000
5	Owner	Glacier walking, ice cave tours	2013	2–3	5.000–6.000
6	Owner	Snowmobiles, super jeep tours	1996	7–2	17.000–20.000
7	Senior employee	Glacier walking, ice climbing	2006	80–30	20.000–25.000
8	Manager	Glacier walking, ice climbing	1993	150–70	35.000–40.000
9	Manager	Amphibian boat and zodiac tours	1989	50–3	100.000–110.000

These perceived signals are largely based on the operators' first-hand experiences while conducting business. Direct observation, such as monitoring glacier retreat, is important because it is unambiguous and salient to the operator's performance and makes them aware of the significance of a changing climate. Next to personal observations, two operators mentioned media coverage as an information source that grounds their perception of climate change, although this information was only brought up to support their personal experiences with climate-induced impacts. Climate change information obtained through formal channels is almost nonexistent due to the absence of any formal strategic plans, policies, or other formal institutions related to climate change adaptation at the corporate, tourism sectoral, or public governance levels in Iceland (Landauer et al. 2017).

All interviewed companies stated that their tour operations have already been affected by changes in the glacier environment and/or the occurrence of extreme weather events. Table 3 gives an overview of the various impacts caused by two general categories of perceived climate change signals: extreme weather events (heavy rain and strong wind) and changes in glacial environments (glacier shrinkage, pro-glacial zone extension, permafrost degradation). Most operators experienced more than one impact of climate change signals during their daily operations, and several impacts occur in a combination of changes in the glacial environment and extreme weather events. For example, the increased occurrence of rockfall and landslides take place at moraines that are recently exposed to by glacier retreat but are often triggered by heavy rain and strong winds. Reduced accessibility to and within glacier sites and the increased occurrence of hazards were the most frequently mentioned impacts both as a result from the signals changing glacier environment and extreme weather events.

Evaluation of impacts and potential responses

Even though all operators mentioned that their business operations were already exposed to different climate change signals, the majority of the respondents did not consider the signals' related impacts as a significant risk to their current business, which they furthermore believe could continue without major alterations for the next decades. The optimistic attitude

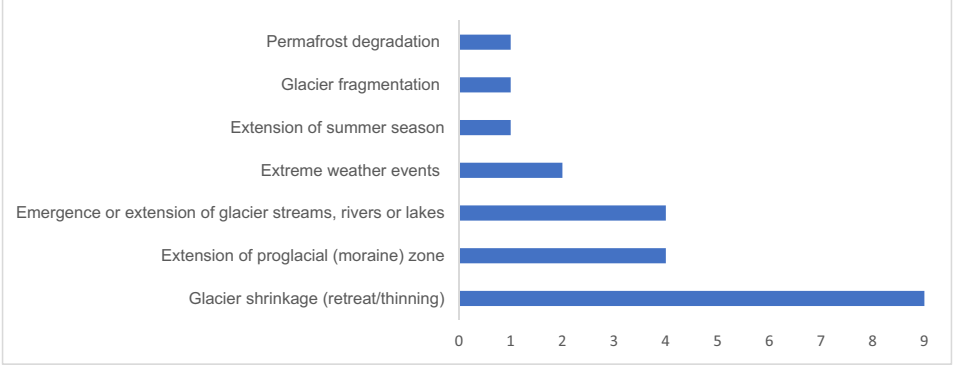

Fig. 2 Perceived climate change signals by the interviewed operators

Table 3 Experienced impacts on glacier tour activities (most often mentioned impact first)

Climate change signals	Experienced impacts on tour activities
Changing glacier environment	• Reduced accessibility to and at a glacier site: extension of route from parking to glacier, difficult road/driving conditions, blocking/disconnecting routes, more complicated terrain (steeper, slippery, rough) for less mobile and/or experienced customers
	• Increased occurrence of hazards: rockfall, landslides, tidal waves in lagoons, falling into crevasses
	• Glacier site disappearance: glacier cave meltdown
	• Tour quality degradation: decreased time on the glacier
	• Tour opportunity/improvement: glacier lake tour opportunities, climate change phenomena used as an educational tour attribute to inform customers
Extreme weather events	• Reduced accessibility to the region: difficult road/driving conditions
	• Reduced accessibility to and at a glacier site: difficult road/driving conditions, flowing water in ice caves
	• Increased occurrence of hazards: slipping on the glacier due to wet surface
	• Tour quality degradation: decreased visibility, decreased comfort

may be a result of different reasons. First, some operators downplayed the effects of climate change or regarded climate change impacts as a benefit, as, e.g., can be seen from the following words by one operator: "Climate change [does] not really affect[s] the company operations, I mean the lagoon is getting bigger of course…. but the cold affects us more than the warm" (operator C). Second, many operators perceive these impacts as "just another" environmental implication that their business has to cope with when operating in a highly dynamic environment such as a glacier destination. Rapidly changing weather conditions, the inherently hazardous working situation on and around glaciers, and especially the rapid growth of visitors to the region are impacts that absorb the attention and efforts of the operators.

More importantly, most operators consider the observed impacts as not being an immediate threat for their glacier tours based on their own experience of a relatively gradual retreat of the glacier margin without surpassing a natural or managerial threshold that would force the company to radical business changes or transformations. In addition, according to some operators, the esthetic and recreational value of the glacier sites in the Vatnajökull region creates a "must see or touch" feeling among tourists (Espiner and Becken 2014), or as one operator mentioned: "Usually, for the general tourist they only want to experience, touching the ice, just stepping on the ice" (operator B). This notion of the tourists' preferences, in tandem with the ever-increasing numbers of tourist visiting Iceland, strengthen several operators' perception that the demand for glacier tours will continue in the near future regardless the changing conditions of the sites.

The relatively successful and inexpensive ways through which operators have adapted to changing natural conditions until now made them confident to carry out adaptation responses in the future and cope with the implications of the potential changes in the glacial landscape, as stated by an operator: "Yes, climate change does affect my work, mainly of course during the glacier trips, but it is not a problem for me as long as we follow the glacier" (operator H).

These interpretations led to reactive adaptation but not to anticipatory adaptation or the formulation of an adaptation strategy. When asked what kind of formal strategy they have developed to cope with future impacts of climate change, all operators replied that they lack a future climate change strategy mainly because of the uncertainty related to physical changes of the glacier sites: "No, we have no future scenarios for planning, because the glacier is constantly moving. I think we cannot predict precisely because the movement is irregular even if the general thinning is the same" (operator F) or "No, we do not have a real planning, it is too hard to predict, your guesses are as good as mine about what is going to be happening in 10 years" (operator C).

Implementation of adaptation measures

Table 4 gives an overview of the implemented adaptation measures relating to each perceived climate change–induced implication. We categorized the adaptation measures into six adaptation types: (1) application of technical means, (2) reorganization of itinerary and services, (3) diversification of product and services, (4) obtaining or communicating knowledge, (5) monitoring and maintenance of routes and sites, and (6) cooperation and networking.

Several adaptation measures responded to multiple implications. For example, the relocation of tours to another glacier site was a response to the site cessation as well as to the reduction of glacier site accessibility and the increased hazards of glacier sites. Almost half of all named adaptive responses were implicit adaptation measures and have been implemented primarily as a reaction to non-climate change–induced natural regional phenomena (Table 5). Glacier tourism in the

Table 4 Overview of the implemented adaption measures mentioned by the respondents per adaptation category and impact type

	Accessibility reduction	Hazard increase	Tour quality degradation	Site cessation/disappearance	Tour opportunities
1. Technical means	Infrastructure, special terrain vehicles	Safety gear, safety signs, infrastructure, communication devices	Special terrain vehicles		Tour equipment
2. Diversification	Diversifying period, diversifying tours, diversifying income, diversifying sites			Diversifying sites, diversifying tours, diversifying income	Combining existing tours with tours in new areas
3. Reorganizing itinerary and services	Rerouting tours, relocation, changing tour duration	Rerouting, relocation	Cancellation	Relocation, cancellation	
4. Knowledge obtaining/communication	Training program	Training program, information gathering	Informing customers	Informing customers	Include climate change info in tours
5. Monitoring and maintenance	Monitoring glacier margins and routes, maintaining paths, scouting out new sites	Risk assessments, monitoring routes		Monitoring, scouting new sites	Scouting new sites
6. Cooperation and networking	Sharing equipment, exchange site and weather info	Exchange site and weather info		Sharing site information	

Vatnajökull region has been forced to adapt to various impediments caused by natural conditions such as the volcanic and seismic activity beneath the Vatnajökull icecap and general glacier processes (Welling and Árnason 2016); hence, all tour operators had already implemented several implicit adaptation measures and strategies that can also be applied to deal with the impacts of climate change; these include training programs, monitoring of the sites, and purchase of special safety equipment. In addition, several implicit adaptations, such as the diversification of tour products and operation period and the acquisition of transport vehicles, were a direct response to experienced or anticipated developments in the Icelandic tourism market. Since 2011, Iceland has experienced an unprecedented growth of visitor numbers with an annual growth rate from 29% between 2014 and 2015 and a 39% rate between 2015 and 2016 (ITB 2018) which resulted in a strong increase of different tour companies offering a wide range of tour activities in the rural areas of Iceland.

Almost all mentioned explicit adaptation measures were reactive; they are implemented or envisioned after the climate change–induced impacts have been observed. The implemented explicit adaptations that were mentioned by the entrepreneurs were in most cases relatively inexpensive and easy conductible technical measures such as employment of removable bridges to cross emerging or diverging glacier rivers or the extension of existing tracks or construction of new trails to make glacier sites accessible and the reorganization of itineraries in form of rerouting at the site or relocation of tours to neighboring sites. Only one entrepreneur mentioned a single anticipatory adaptive measure that has been implemented.

Feedback of adaptation effectiveness

Several operators mentioned a form of feedback to estimate the effectiveness of the implemented adaptation measures, i.e., whether the measures contributed to companies' operation goals. In most cases, the feedback comprised a brief assessment by the tour guides of the implemented adaptation measures as part of overall safety evaluation of the tour conditions at the start and end of a tour day. This was mostly feedback related to measures that are relatively easy and inexpensive to adjust such as removable infrastructure or rerouted itineraries. Feedback regarding more inflexible or relatively expensive measures such as transport vehicles or training schemes were evaluated on a seasonal basis. Only limited information is stored in long-term organization memory. Most small-scale companies only store information regarding the implemented adaptation means in personal memory which will be lost when these employees would leave the company. The middle-scale companies used logbooks in which the guides report salient information regarding the use and efficacy of implemented adaptation measures. However, there was limited evidence

Table 5 Overview of implemented adaptive responses by the tour companies

	Implicit (autonomous)	Explicit planned	
		Reactive	Anticipated
Implemented	Terrain vehicles (4); safety gear (4); communication devices (2); diversifying period (1), income (2), and tours (5); training program (3); monitoring site (4); sharing weather and site information (2); route maintenance (1)	Infrastructure (4); safety signs (1); diversifying sites (2); rerouting (3); relocation (3); cancellation (4); include CC info in tours (2); combining tours (2); informing customers (2); information gathering (3); scouting new sites (4); sharing equipment, site information, and access points (3)	Diversifying tour or site (1)
Total number (%)	28 (46.5%)	31 (52%)	1 (1.5%)

of the translation of this information into official work procedures or business strategies.

Discussion

Adaptation behavior of the tour operators

On the basis of the results of this study regarding the operators' awareness of risks, adaptation appraisal, and the amount, type, and category of adaptive responses which the operators exhibit, two different types of organizational adaptation behavior could be discerned here. First, three companies adopted an adaptation strategy, where the implementation of adaptation measures is postponed or has not been envisioned (Berkhout et al. 2006). The entrepreneurs' attitude is to "wait and see" what will happen in the future and until then either do not undertake an action or postpone decisions. The entrepreneurs in question lacked appropriate competences and resources (such as knowledge, skills, technologies) and therefore lacked belief in their ability to carry out adaptation effectively, as this operator stated: "But I don't know how the company will be [in the future']. I am just a farmer. I don't think about it. You have today and that is more than enough" (operator A).

Another reason for the operators' deferred adaptation behavior was that some entrepreneurs considered adaptation action unnecessary. Their direct access to implicit adaptation means, such as conducted safety training and purchased transport vehicles, allowed these entrepreneurs to incorporate the implications of physical glacier conditions without any significant changes in current operational routines.

The other adaptation behavior type comprises managing reactively risks and opportunities that arise from climate change. The companies that apply this approach respond with short-term action to implications caused by glacier site change when these occur. These operators attempt to provide the same standards of products and services but cannot endure all the experienced impacts without changing their business operation routines or internal organization. Their tailor-made competences for particular impacts cannot cope with the changing environmental conditions of the glacier sites. This type of adaptation behavior among tourism entrepreneurs has been identified in other studies (e.g., Saarinen and Tervo 2006; Haanpää et al. 2014; Trawöger 2014).

Furthermore, the companies have difficulty to forecast the timeline of the occurrence of the impacts rather than the occurrence itself. Therefore, several entrepreneurs continue to apply their established adaptation measures, or they invest in more resources such as staff or equipment that enhance these reactive adaptation measures. An important factor of the reactive adaptation behavior is the feedback in the form of lessons learned from previous experiences. However, the experience with gradual changing glacier conditions can implicitly result in maladaptation when the direct observations of gradual changing glacier conditions consolidate current operation routines that can not sufficiently cope with situations where thresholds in the glacial environment are passed or novel situations emerge.

Determining variables of operators' adaptation process

This study shows how adaptation decision-making is subject to both agency and structural factors that shape the glacier tour operators' adaptation process to climate change implications in deferred and reactive adaptation.

An important attribute that determines the operators' adaptation process is the first hand or direct observation of events that they connect to climate change, which in turn makes them aware of the risk and benefits and thus stimulates them to realize adaptation. However, the results show that direct experiences and observation also function as their primary source of information. This form of availability heuristic (Tversky and Kahneman 1974), which allows people to make likelihood predictions based on what they remember, how easily these memories are retrieved, and how readily available those memories are (Marx and Weber 2012), can lead to

different biases. First, the operators' experience with the relatively erratic but gradual retreat of the glaciers convinced several operators that this will continue in the future, an underlying assumption of relative environmental stability that is identified as an important limitation of organizational learning (Winn et al. 2011).

Second, a common identified bias in the adaptation processes (Bazerman 2006; Grothmann and Patt 2005) is optimistic bias or unrealistic optimism (Weinstein 1980) in which people often perceive their personal risk of being harmed by a certain threat as smaller than the average risk and people generally tend to be unrealistically positive about the future rather than the current situation. The experience of the relatively successful use of adaptation measures in the recent past (e.g., changing access routes to the glacier margin, extending roads, or place removable bridges) fueled many operators' optimism about their ability to cope with future implications by using the same strategies. Several tour operators showed a strong belief in their current capacity to cope with future impacts by employing the tools and strategies that they have been using in the past. This is in line with Trawöger (2014), who found that several ski operators in the Austrian Alps exhibit very optimistic views about ski tourism in a warmer climate, and perceived controllability over future events. On the other hand, the glacier tour operators' direct observation of the unpredictability of glacier changes on a year to year base creates a weak belief in anticipatory adaptation.

From a structural perspective, two key sets of institutions that mediate the interaction between the tour operators and the natural operating environment can be discerned that shape the adaptation process of the tour operators. First is the importance of hazard reduction institutions, sets of rules, norms, and shared strategies that govern choices that reduce the societal and corporate impacts of natural hazards (Chapin et al. 2006). The dynamic character of the region with a long history of climate variability but also volcanic and seismic activity has stimulated the availability of hazard reduction infrastructure, equipment, or devices (e.g., safety chains, helmets, or GPS), or the development of diverse hazard reduction institutions, such as local search and rescue teams (SARs). For example, a majority of the operators were present or former members of such local rescue teams which enabled them to obtain valuable knowledge about the terrain, natural processes, and how to prepare for and cope with hazards. Entrepreneurs who live and operate in those areas have learnt to self-organize around the continuously changing natural conditions and to develop an attitude that is open to uncertainty. However, most hazard reduction institutions in Iceland are centralized and top-down, giving hardly any space for local interpretation and salient regional-based information (Van Well et al. 2018). This lack of regional embedding has enhanced the operators' reliance on their own observations and regional-based memory as a primary source to interpret and assess potential risks.

Second is the neoliberal rational of natural area governance in which natural areas are managed increasingly to provide direct economic benefits, often by means of the facilitation of tourism activities, to justify public investment or tap into additional financial sources (Job et al. 2017; Slocum 2017). In Iceland, protected areas are promoted as an important resource base for tourism to stimulate rural development (Huijbens et al. 2014; Petursson et al. 2016), providing potential business opportunities for local entrepreneurs and employment possibilities for particular young local community members. This policy contributes to the promotion of outdoor recreation businesses by limiting recreational land use regulations which gives entrepreneurs a lot of operational freedom in the use of transport means, chosen routes, and types of activities. More importantly, the unprecedented growth of visitors to the Vatnajökull region constitutes a competing interest (Mortreux and Barnett 2017) that suppresses attention and consideration of structural strategies to cope with future climate change impacts. Behavioral decision research has shown that people have a limited capacity for worrying about issues in such a way that an increase of concerns about a risk or opportunity can result in a decrease in concern about other issues (Marx et al. 2007). For example, Evans et al. (2016) revealed that the concern of reef operator in Australia of future climate change–related biophysical changes to the Great Barrier Reef was compromised by the many other challenges that these operators need to deal with.

The operators' economic interest in extending or changing their business to profit maximally from the short-term benefits that the sudden increase of inbound tourism in Iceland is providing conflicts with long-term climate considerations within their business model. Furthermore, the absence of local and regional climate change policies that can incentivize, guide, or compel anticipatory adaptation in the tourism sector makes adaptation processes dependent on short-term mostly technical measures that explicitly deal with tourism-related issues and only implicitly with climate change–induced impacts. In addition, the lack of climate change adaptation institutions prioritizes operators' direct observations of recent changes and successful responses as the only salient source of information which in turn fuels their risk and adaptation appraisals.

Conclusion

This study has attempted to provide insight into how adaptation to climate change occurs by exploring the glacier tour operators' decision-making process of adaptation from their perception of a problem signal to the feedback on the implementation of adaptation measures. The results show that climate change has already resulted in several impacts on glacier tour operators' current operations in the Vatnajökull region, which are mostly related to accessibility problems to and

within glacier sites and changes in the occurrence of natural hazards. The operators have responded to these implications by implementing multiple but almost entirely short-term reactive or implicit adaptation measures that lack an anticipatory planned strategy to cope with future climate-induced implications.

Our findings indicate that the interaction of operator's attributes of agency such as firsthand experiences, risk perceptions, and abilities to self-organize, with structural elements of the glacier destination system such as economic rationales and hazard institutions have shaped and consolidated operators' adaptation processes in form of a wait-and-see strategy combined with ad hoc reactive adaptation measures and postponed or prevented pro-active long-term adaptation strategies.

To improve decision-making about future climate change responses of glacier tourism in Iceland, cooperation between the tourism sector, the land-use management, and the scientific community needs to be established. Future glacier length and thickness have been the topic of several regional modelling studies (e.g., Aðalgeirsdóttir et al. 2011). However, these future glacial landscape scenarios have a multi-decadal timescale, lack a social-cultural perspective, and are developed through a top-down approach without the involvement of local stakeholders. Therefore, new research should address this mismatch between industry and science by focusing on short-term process–oriented participatory scenario studies (Reed et al. 2013). This kind of mismatch has also been identified in other parts of the world where glacial tourism is operated (Purdie 2013).

Furthermore, considering the absence of collective reflection on climate change impacts and adaptation for the whole tourism sector and the lack of communication and participation mechanisms to frame adaptation, established institutions such as the Vatnajökull NP could function as a platform to discuss current and future implications of climate change at a local level. In addition, such governmental institutions can catalyze integrative and forward-looking climate change–based policies and regional plans.

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Paper IV

sustainability

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Article

Implications of Climate Change on Nature-Based Tourism Demand: A Segmentation Analysis of Glacier Site Visitors in Southeast Iceland

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Abstract: Since the end of the 20th century, glaciers are shrinking at an accelerated pace worldwide. This fuels the concern that increased glacier recession will lead to changes in the accessibility, safety, and amenity of many popular glacier tourist destinations—which may, in turn, affect the number of tourists visiting these areas. However, tourist responses to climate-induced environmental changes are still not well understood. Therefore, this study assesses the effects of the implications of glacier recession for glacier site visitation demand and examines the heterogeneity of tourists' responses to these implications for visitation, combining a contingent behavior approach with multivariate cluster analysis. Data were generated from a quantitative survey of 565 visitors to Vatnajökull National Park in southeast Iceland. The results show that climate change induced environmental changes greatly affect nature-based tourism demand, and that the responses of glacier visitors to those changes vary considerably across visitation implications and visitor segments. In order to facilitate future glacier site visitation demand in a sustainable manner, decision-makers and practitioners need to act more proactively and incorporate visitor segment differences into their planning, education, communication efforts and product development.

Keywords: glacier tourism; climate change; tourism demand; sustainable tourism; Iceland; visitor segmentation

1. Introduction

Climate change has been identified as global tourism's greatest challenge with respect to sustainability [1]. Due to its influence on key travel motivations, such as travel costs, infrastructure and landscape quality, climate change already has a considerable impact on tourists' destination choices [2]. Tourist destinations in glacial environments are particularly vulnerable to climate change, due to their dependency on ice for their attractiveness [3,4]. However, since the end of the 20th century, glaciers worldwide have receded in size and volume at an accelerated pace [5–7]. According to the Intergovernmental Panel on Climate Change [8], glaciers worldwide, outside Greenland and Antarctica, lost mass at an average rate of 220 ± 30 Gt yr–1 from 2006–2015. Recent studies [9–11] show that climate change forms a serious challenge for nature-based tourism in glacial environments because it triggers glacier hazards, hampers glacier accessibility and affects the aesthetic value of the scenery. Such implications can lead to a reduction of glacier-based tour operations and in the number of visitors. Furunes and Mykletun [3] show that in Jostedalsbreen National Park in Norway the number of participants in glacier tourism went down by 38% between 2003–2009, mainly due to changes in the morphology of the glaciers and their accessibility. Conversely, other studies argue that the prospect of

vanishing glaciers constitutes an important motivation for tourists to visit glacier destinations as a form of 'last chance tourism' [12,13], or that even a total glacier disappearance at a destination does not automatically lead to a structural reduction in demand [14].

In order to secure the sustainability of the glacier tourism sector, the sector needs to understand climate change impacts in terms of the markets' behavior responses to changing natural conditions under future outlooks of climate change. However, tourist responses to environmental change are still not well understood, and even less so in the context of climate change [15,16]. Kaján and Saarinen [17] and Pröbstl-Haider et al. [16] stress that knowledge concerning tourists' reactions to (bio)physical changes in destinations can be an effective way of assisting destinations in designing appropriate adaptive strategies and destination planning. Landauer et al. [18] furthermore point out that due to variable responses to climate-induced implications by different visitors, it is crucial for destination planners and tour operators to better understand the heterogeneity of visitors by defining different visitor segments and examining the variation in the behavior of such segments. In this context, this study attempts to gain insight into how glacier tourism demand responds to climate change induced implications. Therefore, this paper aims to a) examine how climate change induced environmental changes affect the intended behavior of glacier site visitors, and b) examine the extent of variation in visitors' behavior towards these implications.

2. Literature Background

2.1. Visitors' Coping Behavior Towards Climate Change Impacts

How individuals respond to changing conditions induced by climate change has been scrutinized in several studies [19–21]. In the context of outdoor recreation, Miller and McCool [22] argue that recreationists cope with changing conditions through a tiered process. First, recreationists appraise whether changed conditions of a natural area are relevant, benign-positive, or undesirable (i.e., harmful, a threat or a challenge). Then, when confronted with undesirable conditions, recreationists are likely to change their behavior by substituting the visited site, the timing, or activities at the sites, using technical means, such as specific gear, equipment or specialists to overcome the situation, or otherwise reevaluate the situation in a more favorable light.

Such cooping behaviors can be viewed as 'adaptive responses' in a broad sense, as they involve adjustments that tourists make when faced with undesirable conditions. Perceptions play a key role in these adjustment choices by influencing the actual result of the individual tourist's personal appraisal of reported or experienced change, as well as their judgement of the effectiveness of response options, or their ability to perform them [15,21]. However, such perceptions vary considerably among visitors depending on a broad scale of personal attributes, such as age, gender, preferences, lifestyle, travel motivations, or the visitors' type of vacation and experiences of previous travels [15,23,24]. The actual choices that tourists make can both (directly and indirectly) influence the responses of other actors, in particular those of tour operators and site managers. Directly by deciding not to visit destinations or sites which are impacted by climate change, changing the demand for these destinations; and indirectly by inciting product development as tour operators and site managers try to anticipate changes in demand and respond to these by implementing different adaptation measures [25–28].

2.2. Glacier Tourists' Responses to Climate Change

Several studies show that climate change induced thinning and recession of glaciers has led to significant impacts on tourism operations and activities in glacier landscapes, such as an increase in the occurrence of natural hazards [29,30], the reduction of the accessibility to glaciers or within glacier sites [10,31], and a change in the landscape due to increased debris coverage [11] or a reduction in glacier size [32]. To alleviate or eliminate such implications, several glacier destination managers and tours operators have implemented a broad range of adaptation measures [33]. Numerous studies [3,30,31,34,35] show that adaptive responses to climate-induced changes in a glacier landscape

are relatively easily incorporated by the glacier tourism supply side into daily management, or operation practices, until a certain threshold is passed. When such a threshold is passed, the actions applied seem to lead to a more radical change in adaptation, such as closing off areas, changing destinations, or introducing new transportation means, which can have considerable implications for the visitor in this regard.

A limited number of studies have, on the other hand, examined how potential climate-induced changes in glacial landscapes might affect their future visitation. Existing studies suggest that demand for glacier destination visitation would be affected considerably by such changes. Using a visitor survey with visitors of Lijing region in China, Yuan et al. [36] reveal that a substantial part (19,6%) of the visitors would not have visited the area if its famous Yulong glacier had melted away completely. Similar results were found in Canada by Scott et al. [37], where 25% of the respondents indicated that they would not be willing to visit two Canadian national parks once all the glaciers in these parks would disappear. Focusing on the effects of glacier landscape changes on potential visitations to the Westland Tai Poutini National Park in New Zealand, which includes two popular glacier sites (Fox glacier and Franz Josef glacier), Steward et al. [38] found that 46% of all respondents indicated that they would not have visited the park if it were not for the glacier view. Exploring the potential influence of climate-induced environmental change on visitation to the Athabasca Glacier in Jasper National Park in Canada using a visitor's survey with photorealistic environmental visualizations of an impacted glacier site in 2050, Groulx et al. [32] revealed that 23% of the respondents would not like to visit the site if they were to experience changed glacial environmental conditions. Groulx et al. [32] further investigated the impacts of adaptation responses to changing environmental conditions in the form of motorized tours (snow-coach and helicopters tours), walking paths, bridges and fences by destination managers or tour operators. Their results show that a large proportion of the current visitors (41%) stated that they would likely not have made the journey if the conditions at the site included both potential impacts and potential adaptations. The percentage of visitors who were unwilling to visit was considerably higher when the scenery had been changed by both environmental conditions and adaptations (47%), than when it was altered only by natural changes (23%). Weber et al. [39] explored visitor satisfaction among visitors of the Athabasca Glacier sites using combined tourism development and glacial landscape change scenarios. Their results reveal that visitor satisfaction with changed landscape features in the future scenarios decreases compared to the visitors' current satisfaction with their experience. In particular, future landscape scenarios that showed more commercialized recreation activities were considered less satisfying in comparison with future landscapes with hardly any signs of such activities. These studies suggest that there are underlying variables that influence visitors' perceptions and consequently determine the differences in the degree of willingness to (re)visit a glacier destination. For example, Scott et al. [37] conclude that it is the first-time visitors and the ones who have to travel a long distance that are most likely to be negatively affected by climate-induced environmental changes. This is further supported by Steward et al. [38], who demonstrate that the willingness to visit glacial destinations under changed environmental conditions is significantly higher among local visitors (65%) in comparison to international visitors (51%). In addition, Groulx et al. [32] show that visitors' landscape preferences and perceived naturalness of the glacier landscape has a moderate to strong correlation to the likelihood of a return visit to a glacier site.

The existing studies provide valuable information for future planning and management of glacier destinations. They do, however, have some limitations, such as a lack of multiple implications. Some studies address only a single implication for future visitation, namely, changes in the current scenery. In contrast, several studies have revealed e.g., that changes in accessibility to and within glacier sites, or alterations in the occurrence of hazard [3,10,31], are also important implications for glacier destination visitation. Furthermore, the time scale of the future scenarios employed in most studies is multidecadal—which, thus, relates to environmental conditions that future generations of visitors will encounter, rather than contemporary visitors [37]. In addition, some studies do not take into account adaptive responses by destination managers or tour operators to the long-term landscape

changes. Implemented adaptation measures, such as the establishment of a safety zone or the rerouting of trails, can decrease the climate change induced risk of hazards to a minimum for mainstream glacier site visitors [10,40]. However, as stressed by Groulx et al. [32] and Weber et al. [39], these types of measures can, in turn, lead to negative consideration of future visitation and experiences.

3. Materials and Methods

3.1. Study Area

Iceland has numerous glaciers—of which only a few are exploited for recreational purposes (Welling and Árnason, 2016). The largest share of glacier sites is located in southeast Iceland, around the edge of the Vatnajökull icecap, which makes up the study area for this research (Figure 1).

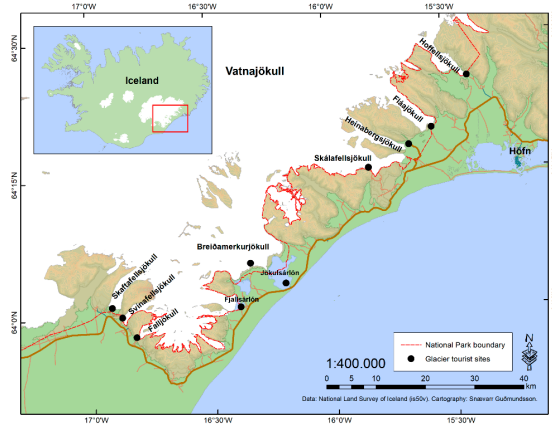

Figure 1. Map of the study area encompassing the southeast part of the Vatnajökull icecap. The black dots refer to the main glacier sites of the study area.

Vatnajökull ice cap, the largest glacier in Europe (by volume), plays a central role in the regional tourism sector in southeast Iceland [41]. The ice cap contains multiple outlet glaciers and pro-glacial lakes, of which several have been developed into glacier tourism sites suitable for tourism and recreational activities. The total ice cap is part of Vatnajökull National Park (VNP) which was established in 2008 [42]. All the glaciers in Iceland are temperate or warm-based, meaning that their ice temperature is close to 0 °C throughout the year, and they are therefore highly dynamic and sensitive to climate variations, resulting in rapid responses (advance or retreat) to changes in temperature and precipitation [43]. The recession of the outlet glaciers in the southeast part of Vatnajökull has been especially pronounced since the 1990s, with all monitored ice caps retreating and thinning at an unprecedented pace [44–46].

There are 10 glacier sites within the study area, where different outdoor recreation activities can be conducted, from sightseeing to motorized activities. Some of these glacier sites are easily accessible for all tourists, such as the well-known pro-glacial lake, Jökulsárlon, which was visited by 770,800 visitors in 2017 [47]. Glacier tourism in Iceland is still highly seasonal with the large majority of guided glacier tours being provided in the summer months, i.e., June to August. However, the exceptional increase in tourist numbers in Iceland in the off-season in the past few years, as well as the enhanced effects of climate change on glacier sites, have prompted the extension of existing and new glacier-based products to the shoulder and winter seasons [48].

3.2. Data Collection

Data were collected by means of a visitor survey conducted at two popular tourist sites within the study area, i.e., Skaftafell and Jökulsárlón (Figure 1). The survey was administered to visitors around the visitor center in Skaftafell and the cafeteria at Jökulsárlón. These two sites were selected as they are the most visited destinations in southeast Iceland during the whole year [47]. The survey was implemented during the first week of August 2015 and the second week of February 2016 to obtain data from both summer and winter visitors. A total of 631 visitors were approached and asked to fill in a questionnaire; of these, 574 (91%) agreed to take part in the survey. Of this sample, 96.9% of the respondents (N = 556) completed the questionnaire and visited one or more glacier sites during their trip to southeast Iceland. The survey consisted of self-completion questionnaires that were distributed randomly to visitors. The questionnaire was available in three languages (English, German and French) because visitors of these language groups constituted the largest groups of foreign visitors at the time the questionnaires were administered [49].

3.3. Survey Design

The questionnaire was composed of 17 closed-ended questions concerning: Visitors' personal and visitation characteristics, their motivation and experience of glacier sites, and their perception of climate change (the English version of the questionnaire is provided as Supplementary Material). To examine the effects of climate change induced environmental changes on glacier visitors' behavior, a contingent travel behavior (CTB) method was applied. This method uses hypothetical questions to obtain knowledge about travel behavior in constructed scenarios by asking visitors directly for the changes in their intended behavior contingent to changed conditions [50]. Different studies [51,52] have demonstrated the validity of the CTB method to examine visitor behavior in response to qualitative changes of recreational sites, indicating that CTB is an appropriate indicator of actual behavior. The method is directly linked to the theory of Planned Behavior [53], that posits that most social behavior is under the volitional control of the individual actor. As a result, the intention or willingness to engage in a particular behavior constitutes the best direct predictor of that behavior [54,55]. Therefore, one of the survey questions consisted of eight statements presenting hypothetical, but plausible, implications for visitors to glacier sites in the near future (2–4 years), using a 5-point Likert scale to understand respondents' willingness to visit a site under each statement. These statements were based on findings from different studies [3,10,11,28,56], and emphasize that the impacts of climate change for glacier site visitors are mostly caused by a combination of changes to glacier landscape attributes (e.g., glacier recession and surface debris cover) and managerial adaptation means (e.g., close-off access or rerouting trails). Nevertheless, they manifest themselves mostly in practical implications for the visitors, such as increased walking time to a glacier margin, reduced proximity to the glacier, or mandatory use of commercial guides or transportation to travel to or within glacier sites (Figure 2).

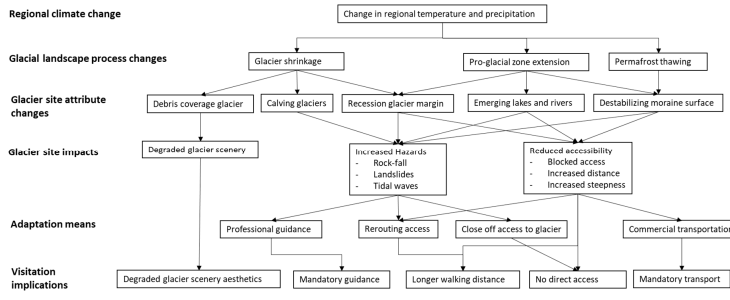

Figure 2. Relations between (regional) climate change, glacier site attribute change and impacts, and visitation implications highlighted in the questionnaire, modified from [3,10,11,28,56].

3.4. Data Analysis

In order to examine the extent of variation in visitor behavior towards climate-induced environmental changes of glacier sites, a segmentation analysis of the glacier site visitors' behavior was conducted considering the results of visitation implication statements. Instead of using a pre-processed segmentation method, a data-driven segmentation by means of cluster analysis, as is recommended by different scholars [57–59], was employed. To examine the internal consistency of the variables, and to avoid the problem of multicollinearity, a reliability measurement analysis using Cronbach alpha reliability coefficients [60] was further conducted for the eight visitation implication statements in the second stage of the analysis (Table 1). An alpha coefficient greater than or equal to 0.65 and that item total correlations greater than or equal to 0.40 indicate variables that are reliably measuring the same concept, and thus, justifies combining them in further analyses was used [61]. The reliability measurement revealed that several statements (three times two statements) were measuring the same concept, and were therefore, on the basis of their mean value, combined for further analysis.

Table 1. Reliability measurement of the visitation implication statements.

Willing to Visit a Glacier Site When . . . [1]	Mean	Std. Dev.	Item-Total Correlation	Cronb. Alpha	Implication Variables
The walking to the glacier edge is 45 min	3.79	1.178	0.731	0.84	Walking time
The walking time to glacier edge is 1.5 hrs.	3.44	1.267	0.731		
It is not possible to come within 150 m of the glacier	3.20	1.237	0.767	0.87	Proximity
It is not possible to touch or stand on the glacier	3.18	1.259	0.767		
It is necessary to use motorized (jeep/truck) transport	2.53	1.219	0.653	0.79	Commercial Transportation
It is necessary to take a boat for crossing a lake	2.74	1.261	0.653		
The glacier is considerably covered with debris and mud [2]	2.68	1.11	<0.4	n.a.	Scenery
It is necessary to take a guided tour for a safe passage [2]	3.06	1.31	<0.4	n.a.	Safety Guidance

[1] All statements measured on a five-point Likert scale of 1 "not willing at all" to 5 "very willing; [2] The statement variables 'Willing to visit when the glacier is considerably covered with debris' and 'Willing to visit when it is necessary to take a guided tour for safe passage' did not inter-correlate with any of the other statements, hence, were retained and not combined with other variables in a further analysis.

The measurement resulted in the following five visitation implication variables: Walking time, proximity, scenery, commercial transportation and safety guidance (Table 1). The visitors (respondents) were finally clustered based on the five visitor implication variables. Following the recommendation of Hair et al. [62], this study conducted a two-stage clustering sequence method on the five visitor implication variables using the IBM SPSS statistical software package. In the first stage, a hierarchical cluster analysis using Ward's method with squared Euclidian distance was applied to identify the number of clusters by an agglomeration schedule on the cluster analysis. A range of a possible three to six cluster solutions was examined from which the three-cluster solution was considered the most meaningful and interpretable result.

In the second stage, a K-means clustering analysis to classify the samples according to the intended adaptation behavior that best discerns them was applied. To validate the results of the cluster analysis, a multivariable discriminant analysis obtained from Hair et al. [62] was applied. This analysis examines the differences among the identified clusters, determines discriminant functions that differentiate them and assesses the accuracy level of classification of segment membership.

In the last part of the analysis, cross-tabulation with chi-square analysis and post hoc testing, using the adjusted residual method [63] and Analysis of Variance (ANOVA) with Tukey's post hoc testing, were applied. This was to explore the difference between the clusters in terms of categorical

variables (such as socioeconomic background), travel behavior, and continuous variables (such as visitors' motivation to visit regional glacier sites and their perception of climate change).

4. Results

4.1. Descriptive Overview of Glacier Site Visitor Characteristics and Their Travel Pattern

The gender division of the sample is fairly equal, 50.9% male and 49.1% female. Nearly two-thirds (65.4%) of the respondents are under 35 years old, and the average age is 34.1 years. Almost all respondents (98.5%) are non-residents of Iceland, and most reside in West Europe (France, Germany and Benelux countries) (46.1%) and North America (20.2%). Most respondents are staying between two and four days in the region (49.6%), travelling in couples (36.3%), and interested in sightseeing (71.9%), hiking (71.4%), and/or a guided glacier tour (61%) (Table 2). Almost half of the respondents (49.5%) had never visited a glacier site before. Most of them stayed between 5–10 h at each glacier site they visited (47.8%).

Table 2. Glacier site visitors' personal characteristic and conducted activities (N = 556).

Variables	Categories	N	%	Variables	Categories	N	%
Gender	Female	273	49.1	Country of residence	Iceland	8	1.5
	Male	283	50.9		Western Europe	256	46.6
Age	Under 25 years	123	22.1		UK	53	9.7
	25–34 years	241	43.3		Eastern Europe	42	7.7
	35–44 years	78	14.0		Southern Europe	46	8.4
	45–55 years	61	11.1		USA/Canada	111	20.2
	66 years and older	53	9.5		Asia/Oceania	25	4.6
					Rest of the world	8	1.5
Length of stay in region	1 day	72	16.6	Travel party	Individual	41	7.4
	2–4 days	276	49.6		Couple	202	36.3
	5–10 days	122	21.9		Family	59	10.6
	11 days or more	21	3.8		Small group	181	32.6
					Big group	61	11.0
Previous times at a glacier site	First time	275	49.5		Other	12	2.2
	1–3 times before	195	35.1				
	4–10 times before	59	10.6	Activities interested in doing in the region [#]	Sightseeing	400	71.9
	11 times or more before	27	4.9		Hiking	397	71.4
					Glacier tour	339	61.0
Hours spent at glacier sites	1 h or less	29	5.2		Swimming/bathing	189	34.0
	2–4 h	215	38.7		Camping [1]	175	31.5
	5–10 h	266	47.8				
	11 h or longer	44	7.9	Activities done at glacier sites [#]	View glacier from distance	421	75.7
					Guided walk	204	36.7
					Glacier lake boat tour [1]	84	15.1
					Ice cave tour [2]	63	11.3

Multiple responses were possible, [1] only included in the summer version of the questionnaire; [2] only included in the winter version of the questionnaire.

Regarding the conducted activities of the respondents, the results show that a large majority had viewed glaciers from a short distance (75.7%), while guided glacier hikes (36.7%), boat tours on glacier lakes (15.1%) and ice cave tours (11.3%) constitute the most popular guided glacier tours (Table 2).

On average, the respondents have a neutral stance regarding the importance of glaciers for their visit to Iceland (mean = 3.5) and for visiting southeast Iceland (3.8). The most important motivations to visit the glacier sites of the southeast part of Vatnajökull are 'Experiencing new things' (mean = 4.45), 'See a glacier in real-life' (mean = 4.34) and 'Be close to nature' (mean = 4.31). The least important motivations are 'Develop personal and spiritual values' (mean = 2.79), 'A story to tell' (mean = 3.26) and 'Visit a glacier before it disappears' (mean = 3.46) (Table 3).

Table 3. Visitor motivations and aspects important for their experience (N = 556).

Variables	Categories	Mean	SD	Variables	Categories	Mean	SD
Important motivation for glacier visit #	Experience new and different things	4.45	0.84	Importance aspects for visit experience #	Scenery	4.31	0.83
	See a glacier in real-life	4.33	0.93		Unique environment	4.29	0.83
	Be close to nature	4.31	0.90		Being in an untouched natural environment	4.16	0.94
	Thrilling Experience	3.94	1.14		Come close to glacier	3.99	1.05
	Have a change from everyday life	3.87	1.19		Seeing glacier attributes	3.95	1.08
	Experience peace and calm	3.80	1.19		Being in a challenging environment	3.68	1.15
	Friends and Family	3.51	1.36		Learning about glaciers	3.55	1.13
	Visit a glacier before it disappears	3.46	1.27		Seeing real-life impacts of climate change	3.45	1.17
	A story to tell	3.19	1.31		Weather conditions	3.43	1.17
	Develop personal. spiritual values	2.78	1.39		Size of the glacier	3.23	1.05
The importance of a glacier for #	A visit to Iceland	3.46	1.17	Climate change perception *	Climate change is happening now	4.56	0.76
	A visit to the region	3.79	1.16		Climate change is the result of human activity	4.26	0.94
					Climate change is the result of natural causes	2.99	1.17
					I am concerned about climate change	3.97	1.02

Based on Likert-scale (1 = not important at all—5 = very important); * Based on Likert-scale (1 = totally disagree at all—5 = totally agree).

Furthermore, most important for the respondents' experience during their visit to a glacier site are 'scenery' (mean = 4.31), 'unique environment (mean = 4.29) and 'being in an untouched natural environment' (mean = 4.16). These general nature values were perceived of greater importance for the respondents' experience than glacier specific aspects, such as 'Seeing glacier attributes' (mean = 3.95) or 'Come close to a glacier' (mean = 3.99). The aspects 'Weather conditions' (mean = 3.43) and 'Size of the glacier" (mean = 3.23) were perceived as being the least important.

All respondents express high levels of agreement with the statements that climate change is happening now (mean = 4.56) and that it is the result of human activity (mean = 4.26). However, they also have a neutral stance regarding the statement that climate change is a result of natural causes

(mean = 2.99), revealing some uncertainty among the respondents regarding the anthropogenic source of climate change (Table 3).

4.2. Visitors' Behavioral Response to Visitation Implication Statements

The respondents were asked how willing they would be to visit a glacier site in the area that has different potential future visitation implications. The results show that a substantial part of the respondents (46.7%) would not be willing to visit any glacier site if it was covered largely with debris (Figure 3), which supports the previously mentioned results from this study that scenery is the highest valued aspect for the visitor experience of glacier sites. The results further reveal that a considerable part of the respondents would not be willing to visit a glacier site if they would not be able to come within 150 m of the margin of the glacier (27.2%), or would not able to touch or stand on a glacier (28.2%). These results are supported by the fact that almost 76% of the respondents' activity at a regional glacier site was to view a glacier from a short distance. The implication that constrains the respondents' intended visitation the least is the amount of walking time to the glacier margin. Only a small proportion of the respondents (22.5%) were not willing to visit a glacier site if they had to walk 1.5 hrs to the glacier margin. In addition, a large part of the respondents were not willing to visit glacier sites if it was necessary to take a commercial jeep or truck to access the glacier sites (52.2%), cross a glacier lake with a commercial boat (41.9%), or take a guided tour for a safe passage to and on the glacier (31.3%) (Figure 3).

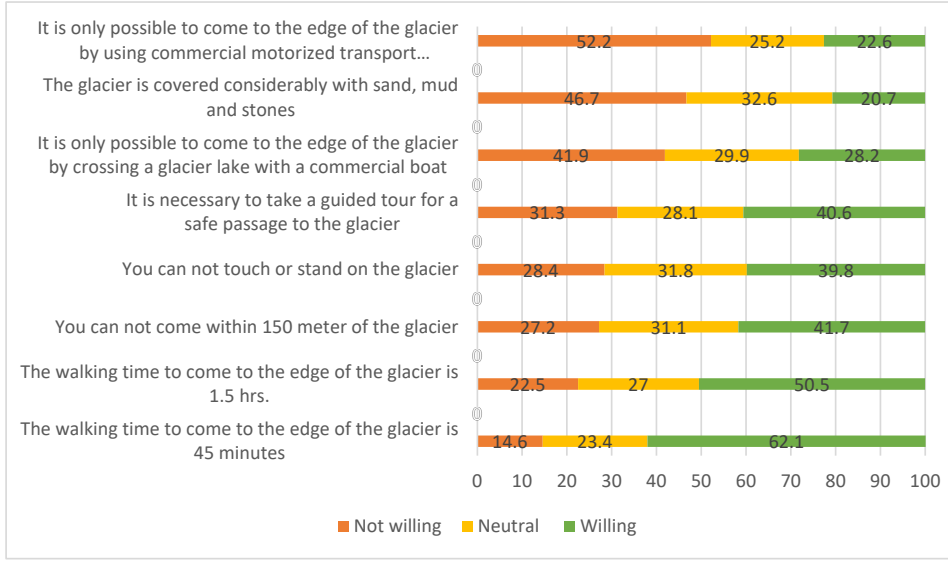

Figure 3. Respondents' willingness (in %) to visit a regional glacier site under climate-induced landscape visitation implications (N = 556). Based on a 5-point Likert scale: Not willing includes "not willing" + "not willing at all"; Neutral; Willing includes "willing" + "very willing").

4.3. Glacier Site Visitor Segments on Their Intended Visitation Behavior

The cluster analysis used to classify the visitors' responses according to the visitation implication variables that best described them, resulted in a three-cluster solution (Table 4). The results of the ANOVA tests further revealed that all five visitation implication variables contributed to differentiating the three clusters ($p < 0.001$) which were named: *Susceptible visitor*, *Resistant visitor* and *Adaptive visitor*.

Table 4. Non-hierarchical cluster analysis of visitation implications variables based on K-means clustering (N = 556).

Visitation Implication Variables	Cluster 1 (N = 169)	Cluster 2 (N = 186)	Cluster 3 (N = 201)	F	Sig.
	Susceptible visitor	Resistant visitor	Adaptive visitor		
Walking-Time	3.49	4.42	2.99	109.040	<0.001
Proximity	2.89	4.12	2.58	135.304	<0.001
Scenery	2.26	3.32	2.28	64.362	<0.001
Com.-Transportation	1.62	3.13	3.02	153.209	<0.001
Safety-Guidance	1.61	3.9	3.68	368.879	<0.001

The multivariate discriminant analysis extracted two statistically significant discriminant functions. Function 1 explained 73.7% of the variance (eigenvalue = 2.11, Wilks' Lambda = 0.183, $\chi 2$ = 934,962, Sig. = 0.000). Function 2 explained 26.3% of the variance (eigenvalue = 0.75, Wilks' Lambda = 0.57, $\chi 2$ = 309,758, Sig. = < 0.001). The classification results showed that almost all (97.2%) the 556 grouped cases were correctly classified, representing a very high rate of accuracy and reliability.

The *Susceptible visitors* constitute the smallest cluster segment (30.4%), and is the most susceptible visitor type to the climate-induced visitation implications. This segment exhibits a relatively low willingness to visit a glacier site regarding all visitation implications except walking time (mean = 3.49, 25% were unwilling to visit). This segment is inclined to avoid a glacier site when they are obliged to take a guided tour for safety reasons (mean = 1.62, 86% were unwilling to visit) or has to use motorized transport to come to the glacier margin (mean = 1.62, 92% were unwilling to visit). In addition, this type of visitor will avoid a glacier site where the scenery is degraded, due to a considerable mud and debris coverage of the glacier (mean = 2.26, 62% were unwilling to visit) or can only be viewed from a considerable distance (mean = 2.89, 38% were unwilling to visit) (Table 4).

The second cluster, the *Resistant visitor*, comprises a third of the respondents (33.5%). This segment represents the least vulnerable visitors as regards climate-induced visitation implications. These visitors are tempted to visit a glacier site without the possibility to physically encounter the glacier (mean = 4.12, 3% unwilling to visit), has an enlarged walking distance to its margin (mean = 4.42, 1% unwilling to visit), or requires professional guidance (mean = 3.9, 9% unwilling to visit). Furthermore, the resistant visitor shows a more neutral stance regarding the use of commercial transport to access a glacier site (mean = 3.13, 35% unwilling to visit) (Table 4).

The third and last cluster, the *Adaptive visitor*, is the largest (36.1%) segment and consists of visitors that are on average not willing to visit a glacier site where scenery has been considerably degraded (mean = 2.28, 57% unwilling to visit), direct access to the glacier itself is impassible (mean = 2.58, 50%unwilling to visit) and has a long walking distance to reach the glacier (mean = 2.99, 35% unwilling to visit). However, the adaptive visitor is moderately willing to visit a glacier site when they had to take commercial guidance (mean = 3.68, 6% unwilling to visit) and has a neutral stance regarding the use of commercial transportation (3.02, 34% unwilling to visit) to adapt to climate-induced safety and accessibility implications outlined in the scenario statements (Table 4).

4.4. Profiling the Segments with External Variables

The differences between the segments were further examined in terms of personal and travel behavioral attributes of glacier site visitors. The results show significant differences ($p < 0.01$) between the visitor segments in terms of socio-demographic characteristics, activity performance, visitation motives and experiences, as well as climate change perceptions.

4.4.1. Visitor Segments' Socio-Demographic Characteristics

Cross-tabulation with t-testing revealed a significant difference ($p < 0.01$) between the clusters regarding gender (Table 5). Chi-square post hoc analysis indicated that there are significantly more male respondents among the *Susceptible visitors* (59%) and significantly more female ($p < 0.008$) respondents among the *Resistant visitors* (59%).

Visitor segments also differ significantly in terms of the visitors' residence. Chi-square post hoc analysis revealed the *Susceptible visitors* group contains a significantly higher proportion of visitors ($p < 0.002$) that live in North and Western Europe (61%) in comparison with the *Resistant visitors* (49%) and the *Adaptive visitors* (33%). The *Adaptive visitor* cluster has a relatively low proportion ($p < 0.002$) of visitors from North and Western Europe (33%), but a significantly high proportion of visitors from Eastern Europe (12%). In comparison, the *Resistant visitor* cluster consists of the largest proportions of visitors from the UK (15%) and Asia (8%).

Table 5. Socio-demographics of visitor segments (N = 556).

Visitor cluster Profile (*Variable*/Categories)	Susceptible Visitor	Resistant Visitor	Adaptive Visitor	χ2	*p*-Value	Cramer's V
Gender				11.15	0.01	0.142
Female	70 (41%) *	109 (59%) *	94 (47%)			
Male	99 (59%) *	77 (41%) *	107 (53%)			
Country of residence				52.02	<0.001	0.231
N-Western Europe	101 (61%) **	89 (49%)	66 (33%) **			
USA/Canada	29 (17%)	32 (18%)	50 (25%)			
UK	7 (4%) **	27 (15%) **	19 (10%)			
Southern Europe	15 (9%)	15 (8%)	16 (8%)			
Eastern Europe	6 (4%)	13 (7%)	23 (12%) **			
Asia/Oceania	3 (2%)	6 (3%)	16 (8%) **			
Iceland	3 (2%)	0 (0%)	5 (3%)			
Rest of the world	2 (1%)	1 (1%)	5 (3%)			

* Significant at the adjust Bonferroni corrected significance level ($\propto = 0.008$); ** Significant at the adjust Bonferroni corrected significance level ($\propto = 0.002$).

4.4.2. Visitor Segments' Regional Travel Characteristics

Interests in recreational activities differ significantly between the three cluster segments. That also applies to the number of days the different visitor segments stayed in southeast Iceland (Table 6). A significantly higher percentage of visitors in the *Adaptive visitor* segment were one-day visitors (33%) of the region in comparison with the other two visitor segments, while the visitors of the *Resistant visitor* segment consist of a significantly larger proportion of visitors that stay five days or more in southeast Iceland (31%).

Visitors that are most interested in non-guided recreation activities, such as to camp and visit a museum, are significantly more numerous in the *Susceptible* and *Resistant visitor* segments than in the *Adaptive visitor* segment. Furthermore, a relatively smaller proportion of the *Susceptible visitors* is interested in different guided nature-based outdoor recreation activities, such as glacier hiking tours and snowmobile tours, in comparison with the other two segments. Furthermore, statistical tests did not reveal a significant difference between visitor segments regarding respondents' number of previous visits to glacier sites and their visitation period (summer or winter).

Results from the one way ANOVA test (Table 6) suggest that the *Susceptible visitors* spent on average significantly more time at the glacier sites (6.9 h) than *Adaptive visitors* (5 h), which is not surprising considering the significantly longer period the Susceptible visitors spends in the region compared to the *Adaptive visitor*.

The significant differences in activity interest in southeast Iceland between the visitor segments have an effect on their activity participation at glacier sites in the study area. The test results show, e.g., that *Susceptible visitors* have the largest proportion of visitors that did not take any guided tours at

a regional glacier site (63%), while this proportion was significantly smaller among *Resistant visitors* (45%) and *Adaptive visitors* (43%). Looking at the five recreational activities that most of the respondents participate in the results reveal a significantly higher percentage of *Susceptible visitors* taking part in non-guided activities, such as viewing glaciers from a distance and hiking, than the other two segments. There is a significant difference between the visitor segments with regards to their participation in guided glacier tours and viewing glaciers from a short distance. Half of the *Adaptive visitors* participated in a guided walk, compared to only 15% of the *Susceptible visitors*. On the other hand, a non-guided activity, such as viewing a glacier from a short distance, was significantly more often undertaken by *Susceptible visitors* (86%) than by the other segments.

Table 6. Visitor segments' travel characteristics (N = 556).

Visitor Cluster Profile (*Variable*/Categories)	Susceptible Visitor	Resistant Visitor	Adaptive Visitor	$\chi 2$	*p*-Value	Cramer's V
Number of days respondent stays in region				25.116	<0.001	0.150
1 day	37 (22%)	33 (18%)	67 (33%) *			
2–4 days	88 (52%)	96 (52%)	92 (46%)			
5–10 days	34 (20%)	55 (30%) *	33 (16%)			
11 days or more	10 (6%)	2 (1%)	9 (4%)			
Regional activities interested in						
Interested in camping #	53%	44%	33%	12.636	0.002	0.139
Interested in glacier tour	47%	61%	73%	29.996	<0.001	0.216
Interested in snowmobiling	11%	25%	27%	7.611	0.001	0.162
Interested in museum visit	12%	21%	10%	9.485	0.009	0.131
Tour participation				17.213	<0.001	0.240
Did not participate in guided tour	106 (63%)	83 (45%)	86 (43%)			
Did participate in guided tour	63 (37%)	103 (55%)	115 (57%)			
Activities done at glacier sites						
View glacier from a short distance	145 (86%)	142 (76%)	134 (66%)	18.338	<0.001	0.182
Guided glacier walk	25 (15%)	78 (42%)	101 (50%)	52.996	<0.001	0.309
Hiking (non-guided)	29 (17%)	22 (12%)	12 (6%)	12.573	0.003	0.144
				F-value	Sig.	Eta
Amount of time spent at glacier site(s) in the region (on average)	6.9 h [a]	6.4 h	5.0 h [a]	4.602	0.01	0.128

* Significant at the adjust Bonferroni corrected significance level ($\propto$ = 0.003); [a] Means with the same letter are significantly different on Turkey's Post Hoc test ($p < 0.05$); # Only included in the summer version of the questionnaire.

4.4.3. Motivation, Experience Aspects and Climate Change Perception

Based on the one-way ANOVA, followed by Tukey's post-hoc test, the results show significant differences in glacier visit motives between the visitor segments, as well as in aspects that contribute to the visitors' glacier site experiences (Table 7). *Adaptive visitors* find glaciers significantly more important for their visit to southeast Iceland than the visitors of other segments. They also value the motive 'A story to tell' significantly higher and the motive 'Be close to nature' significantly lower than the other visitor segments. On the other hand, *Susceptible visitors* find the motive a 'Thrilling experience' and 'Have a change from everyday life' significantly less important in comparison to the other visitor clusters. Regarding their experiences, the *Resistant visitors* found the aspects 'Scenery', 'Learning about glaciers' and 'Seeing real-life impacts of climate change' significantly more important than the other two segments.

Table 7. Visitors' cluster differences based on visitation motivation and climate change perception (N = 556).

Visitor Cluster Profile (*Variable*/Categories)	Susceptible Visitor	Resistant Visitor	Adaptive Visitor	*F*-Value	Sig.	Eta
Importance of visiting a glacier when visiting the region [1]	3.60 [a]	3.73 [b]	4.00 [ab]	5.709	0.004	0.142
Motivation to visit glacier site [1]						
Be close to nature	4.35 [a]	4.50 [b]	4.09 [ab]	5.472	<0.001	0.192
Thrilling experience	3.67 [ab]	3.96 [a]	4.14 [b]	7.967	<0.001	0.168
Have a change from everyday life	3.62 [ab]	4.02 [a]	3.93 [b]	5.472	0.004	0.140
A story to tell	2.87 [a]	3.17 [b]	3.49 [ab]	10.437	<0.001	0.192
Aspect for experience on a glacier site [1]						
Scenery	4.23 [a]	4.47 [ab]	4.24 [b]	4.811	0.008	0.132
Learning about glaciers	3.40 [a]	3.79 [ab]	3.46 [b]	6.474	0.002	0.152
Seeing real-life impacts of climate change	3.17 [a]	3.73 [ab]	3.42 [b]	10.581	<0.001	0.194
Perception of climate change [2]						
Climate change is happening now	4.57	4.70 [a]	4.41 [a]	6.983	0.001	0.157
Climate change is the result of human activity	4.28	4.40 [a]	4.11 [a]	4.533	0.01	0.127
I am concerned about climate change	3.87 [a]	4.19 [ab]	3.86 [b]	6.5	0.002	0.152
Climate change is the result of natural causes	2.73 [ab]	3.08 [a]	3.12 [b]	6.02	0.003	0.146

[1] Variables measured on five-point Likert scale of 1 "not important at all" to 5 "very important"; [2] Variable measured on five-point Likert scale of 1" totally disagree" to 5 "totally agree"; [ab] Means with the same letters are significantly different on Tukey's Post Hoc test ($p < 0.05$).

Comparisons of the segments with respect to the respondents' general perceptions towards climate change show that the *Resistant visitors* express significantly more concern regarding climate change than those in the other two segments (Table 7). On the other hand, *Susceptible visitors* agree significantly less with the statement that climate change is the result of natural causes than the other two segments.

5. Discussion

5.1. Glacier Tourism Demand Responds to Climate Change Induced Implications

The results of this study reveal that glacier site visitation demand is highly impacted by climate change. By examining multiple practical implications for the visitors on a site scale in the foreseeable future, this study goes beyond previous research on glacier visitor behavior under climate change [36–38]. This approach provides a relevant and necessary complement to the often top-down and abstract impact assessments based on multidecadal timescales, which often do not take into account the heterogeneity of visitor demand [31,64]. By translating climate change induced environmental change into various practical implications for the visitor, this study furthermore reveals that glacier site visitors' responses differ considerably between implications. These range from a limited number of visitors (27%) not being willing to visit a glacier with an increase in walking time, to a considerable number of visitor (52%) not being willing to visit a glacier when commercial transportation to reach the glacier is needed. The latter result is in line with recent studies [32,39], which indicate that management measures (such as an increase in transportation modes to adapt to changed conditions) are evenly, or more detrimental, to visitation demand than the implications that these measure attempt to abate. These studies showed that many visitors perceive the degradation of a glacier site's naturalness more negatively than the natural changes of a glacier site. An aspect highly relevant in the context of management of the glacier sites in southeast Iceland, considering the relatively high importance of the aspects 'Scenery' and 'Being in an untouched natural environment' for visitors' experience observed in this study. This corresponds with studies concerning visitor experiences in

natural areas in Iceland [65,66], supporting the importance of naturalness and limited anthropogenic impacts for visitors.

5.2. Variation in Glacier Tourists' Intended Behavior

The results furthermore show significant differences between the glacier site visitor intended behavior. This study discerned three more or less evenly divided, but significantly distinct visitor segments, i.e., *Resistant visitors*, *Susceptible visitors* and *Adaptive visitors*, that can be interpreted on the basis of Miller and McCool's [22] recreationist appraise and response framework to changed conditions. *Resistant visitors* may seem to appraise the perceived visitation implications not as undesirable or otherwise, however, when confronted with these implications they might change their perception of the implications in a more favorable manner (cognitive coping). The *susceptible visitor,* on the other hand, appears to appraise most visitation implications as undesirable, and therefore, will presumably substitute the site by conducting the same or other planned activities somewhere else, or plan their visit at a different time when conditions have improved. *The adaptive visitor* seems to appraise implications as undesirable if they include reduced proximity, lengthened walking time, or scenery degradation, but is willing to exert technical coping, i.e., using vehicles or expert skills/knowledge, in order to overcome the accessibility and safety implications of glacier sites. The results demonstrate furthermore that these three visitor segments differ significantly in demographic and cross-cultural characteristics, length of stay, activity interests and performance, motivation and climate change perception. These visitor attributes constitute underlying variables that can explain differences between the segments' intended climate-related coping behaviors. Several studies [23,24,36,67–71] support that these variables determine differences in tourist climate change adaptation behavior. On the other hand, the results also show that some attributes (i.e., previous glacier visits, period of visitation) did not significantly differ among the segments, and therefore, cannot explain glacier tourist climate-related coping behaviors that are contrary to findings in other studies, such as [24,37]. In addition, finding regarding the attribute *country of residence* reveal a significantly lower percentage of national visitors (1.5%) than similar studies that investigate glacier tourism demand [36,38]. Place of residence can have a profound influence on the visitor's perception of climate change impacts at a destination level [15]. Therefore, more research is needed to clarify how, and to what extent, these visitor attributes influence visitor adaptation behavior at glacier sites. By doing this, adaptation measures that are tailored to the type of visitors that come to those sites can be developed.

5.3. Management Implications

The results of this study will benefit both site managers and tour operators when it comes to the organization of their practices under the impacts of climate change. Being aware of the heterogeneity of glacier site visitors is important to be able to plan and manage the dynamic glacier destinations and better meet environmental, as well as visitors' demands. The results from this study indicate that visitor segmentation can reveal potential trade-offs between strategies to facilitate glacier site visitors under environmental changes in the near future. For example, to overcome visitor implications, such as safety and accessibility, measures like monitoring, extending, and adjusting walking paths to the glacier margin would be acceptable management options to accommodate the *Susceptible* and *Resistant visitors*. However, such measures can have negative consequences for the *Adaptive visitors*, who are (on average) less willing to walk long distances. Moreover, such measures are both time-consuming and labor-intensive, and hence, can absorb a considerable part of area management's financial and labor capacity. On the other hand, the permittance and build-up of road transportation or aircraft carrier infrastructure instead of walking path networks are likely to keep the *Susceptible visitor* away and can have negative consequences for both visitors' visitation satisfaction and the natural environment [39,72]. Disclosure of these trade-offs underlines the necessity to consider climate change adaptation as an integral part of the organization's sustainable development strategies. Nevertheless, Welling and Abegg [28] point out that the current climate change strategies of glacier tour operators and area

management to cope with changing environmental conditions in southeast Iceland are a combination of wait-and-see and reactive adaptation. These reactions are likely to be common at other glacier sites. Such a strategy most probably falls short to accommodate *Susceptible* and *Adaptive visitors* under rapidly emerging environmental changes when pro-active adaptation is needed to achieve safe direct access to a glacier margin in the future.

Pro-active strategies, such as the implementation of a recreational zoning system based on recreational preferences to accommodate different visitor types and prevent land-use conflicts can overcome potential trade-offs, as described above. This is supported by several studies [73–75]. However, in a dynamic environment, such as rapidly changing glacier sites, a more effective solution is to stimulate the diversification of tour products. Considering visitors' diverse interest in non-glacier-based activities, such as hiking, sightseeing and camping, tour product diversification is a sound adaptation in dynamic glacier sites. In addition, the results indicate that receding glaciers present an opportunity to educate visitors about the realities of climate change considering that almost half of the respondents found the aspects learning about glaciers and seeing real-life impacts of climate change important for their experience at glacier sites. Stewart et al. [38] came to a similar conclusion based on comparable results of their visitor survey. In addition, Lemieux et al. [13] argue that tourists' interest in visiting climate change impacted destinations and their desire to learn about environmental change can be used in planned communication and education strategies at glacier sites to promote climate change awareness. Similar to findings in [32,38,72], the results in this study show that a relatively high percentage of the respondents agree that climate change is caused by natural sources (33%). This indicates that explaining the link between glacier recession and the anthropogenic emission of greenhouse gases is necessary information in visitor communication strategies. Tour operators should attempt to fuse this growing interest in 'last chance tourism' and learning about glaciers into new recreational products that will inform visitors about climate change, in order to broaden their understanding of the topic, while enhancing their stewardship towards glaciers or the cryosphere in general. *Resistant visitors*, in particular, consider educational aspects significantly more important for their glacier site experience than the other two segments, proving to be a market segment for such educational tour products.

This study is determined by its regional context as it only includes glacier site activities conducted in southeast Iceland. The limited scope of the glacier activities makes generalization of glacier site visitors' behavior under climate change on a global level challenging. A comparative study between visitors of glacier destinations worldwide is therefore recommended to draw general conclusions on the impacts and responses of glacier site demand towards climate change induced changes of glacier destinations. This study is furthermore based on a limited number of questions of an in-situ visitor survey, as suggested by Veal [76]. This caused a certain limitation as the scenario statements were not composed of multiple visitor implications, or implications that arise from socioeconomic change, such as crowding or an increase in visitor facilities. Hence, an integration of multiple socioeconomic and natural environmental changes into future outlooks is a more effective and realistic way to analyze the impacts of climate change on, and responses from, recreational demand than examining these in isolation [77,78]. This study stresses the critical importance that glacier site stakeholders need to be alerted about how to best manage and organize glacier destinations. It supports that further research on the impacts of climate change on glacier visitation should implement choice experiments methods [79] or participatory scenarios planning methods [80] to address multiple natural and socio-economic implications.

6. Conclusions

Over the last decades, climate change has led to widespread shrinking of the cryosphere, which has affected many glacier destinations around the world. Despite the urgency for glacier destinations to adapt to climate change, so far, only limited research has examined the responses of glacier site visitors to climate change impacts. This study is one step towards filling that knowledge gap. It demonstrates

that climate change induced environmental changes greatly affect nature-based tourism demand, and furthermore that the responses of glacier visitors to those changes vary considerably across visitation implications and visitor segments. This study benefits both site managers and tour operators when it comes to organizing their practices under the impacts of climate change. It may be concluded that potential shifts in tourism demand can be abated by the implementation of adaptation measures that are in line with visitor segments' behavior. This study demonstrates that visitors are critical actors in socio-ecological systems, such as glacier destinations. Therefore, to facilitate future glacier visitation, sustainability should be continually considered by decision-makers and practitioners, and thus should incorporate visitor segment differences into their planning, education, communication efforts, and product development.

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Paper V

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Participatory Planning Under Scenarios of Glacier Retreat and Tourism Growth in Southeast Iceland

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Glacial mountain environments are changing rapidly as a result of climate change and the expansion of nature-based recreation. Anticipatory planning to adapt to such changes is a key management challenge. The aim of this study was to explore how adaptation planning for recreation sites in these areas can be supported using participatory scenario planning (PSP). For this purpose, a study area in southeast Iceland was chosen where management is likely to be heavily impacted in the near future. PSP involves local stakeholder workshops in which participants generate maps reflecting plausible glacial land cover and land use in the near future. This process takes place in stages, including the identification of potential drivers of land-use change, development of multiple land-use scenarios, and examination of the potential consequences of these scenarios and options for adapting to them. The study demonstrates that PSP can be a valuable tool to support recreational land-use planning in glacial landscapes, and to improve anticipatory adaptation to potentially undesirable future changes. PSP also has the potential to provide salient and usable knowledge for local stakeholders, stimulate stakeholders to elaborate on long-term changes and associated uncertainties through scenario construction and visualization, provide insight into the adaptive capacity of current recreational planning systems, and reframe stakeholders' guiding assumptions to encourage a more future-oriented mentality. This approach could be valuable in other glaciated mountain areas and in recreation areas where there are multiple significant future changes in landscape attributes, processes, and uses at play simultaneously.

Keywords: *Participatory scenario planning; glacial land-cover mapping; land-use mapping; outdoor recreation; climate change adaptation; local stakeholders; Vatnajökull National Park; Iceland.*

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Introduction

Glacial mountain environments are changing rapidly as a result of climate change (eg Vaughan et al 2013; Huss et al 2017) and the expansion of nature-based recreation (Welling et al 2015). Numerous studies (Furunes and Mykletun 2012; Ritter et al 2012; Purdie et al 2015) have shown that the overlap of these 2 trends has diverse implications for the visitors and managers of glacier recreation sites—for example, the increased risk of visitor accidents due to landslides and rockfall, scenic landscape changes, and reduced accessibility to and within glacier recreation sites.

Empirical research has been conducted to project future demand for glacier site visits, revealing a considerable reduction in demand as a result of the deterioration of glacier scenery (Stewart et al 2016; Groulx et al 2017) or complete disappearance of glaciers (Yuan et al 2006; Scott et al 2008). Conversely, the disappearance of glaciers is also viewed by some as a reason to visit them in a form of "last chance tourism" (Dawson et al 2011; Stewart et al 2016), which paradoxically can increase glacier shrinkage due to the heat released by large-scale tourism activities at glacier sites (Wang et al 2019). Despite these projected changes in demand, empirical studies on the behavior of glacier tourism entrepreneurs (eg Furunes and Mykletun 2012; Wilson 2012; Espiner and Becken 2014; Wilson et al 2014) reveal that a majority do not consider the potential further recession of the glaciers to be a significant challenge to their business success and that most respond reactively rather than proactively to these environmental changes, focused on maintaining the "status quo and waiting to see what happens" (Wilson et al 2014: 35).

Many of the most popular glacier recreation sites are located in protected mountain areas (Wang and Jiao 2012; Lemieux et al 2018). Although such areas have management plans, management of protected areas is often hampered by the lack of proactive climate change

adaptation planning and implementation by conservation and recreation practitioners (West et al 2009; Lemieux and Scott 2011). Proactive, adaptive land-use planning for glacier recreation sites is critical to address current and future challenges in a sustainable and cost-effective manner.

Lemieux and Scott (2011) argue that an important reason for the current lack of anticipatory adaptation is the high degree of uncertainty about the effects of climate change. This uncertainty is especially relevant in glacial landscapes, which undergo continuous and unpredictable change, such as the erratic retreat of glacier margins, the emergence of glacier lakes and streams, and the continuous and often large-scale course alterations of glacier rivers (Benn and Evans 2010; Björnsson 2017). Other researchers (eg Shaw et al 2009; Hagerman et al 2010; Mastrandrea et al 2010) assert that scientific research for adaptation planning often falls short of providing information that can be directly useful in practical decision-making.

New approaches are therefore needed to more effectively support recreational land-use planning and management for climate change adaptation in glacial mountain environments (McDowell et al 2014; Rannow et al 2014). Such approaches need to address the high uncertainty inherent in glacier recreation sites and to produce information that can be used in practical decision-making.

Participatory scenario planning (PSP) can support decision-making in unpredictable environments by (1) describing plausible future conditions with a range of potential implications (Peterson et al 2003; Mott Lacroix et al 2015) and (2) engaging stakeholders in the development and application of scenarios, thus cocreating understanding and knowledge and enhancing the relevance, credibility, and legitimacy of the resulting information (Bizikova et al 2015). PSP has been applied to different issues in glacial and nonglacial mountain environments, including tourism planning (Malek and Boerboom 2015), management of natural parks (Daconto and Sherpa 2010), risk management (Nussbaumer et al 2014), and development of collective local adaptive capacity (Christmann and Aw-Hassan 2015).

Scenarios can be descriptive, exploring what could happen, or normative, exploring what ideally should happen (Borjeson et al 2006). Descriptive scenarios are more suitable for projecting future trends through the exploration of diverse drivers of change based on existing trends or stakeholders' estimations, while normative scenarios are more suitable for developing strategies to reach a desirable future condition (Houet et al 2010). Several PSP approaches use visualization techniques to increase a topic's understandability and relevance to local stakeholders (eg Hoyer and Chang 2014; Malek and Boerboom 2015; Brewington et al 2017). For example, maps have been used effectively to visualize climate change impacts across time and space, and to enhance understanding of complex environmental issues, increase stakeholder engagement, and promote behavioral change and learning (Sheppard 2005; Becken et al 2015). However, other studies (eg Reed et al 2013; Newell and Canessa 2018) point out that visualization techniques pose the risk of visual bias—by which aspects of scenarios that, for example, are easily represented visually or evoke a sense of place receive more attention from focus group participants than other aspects.

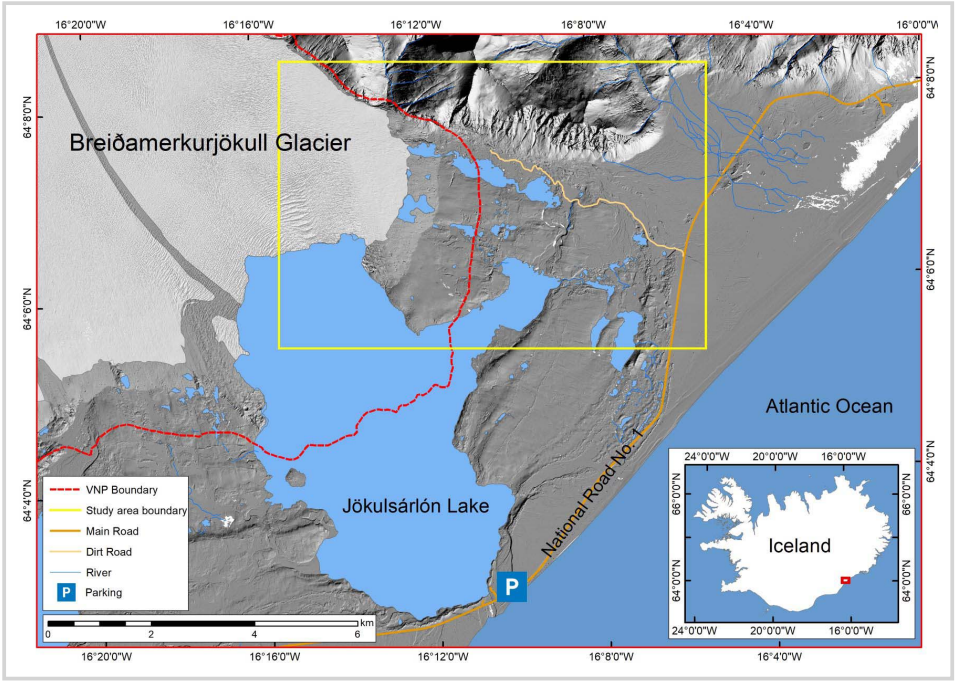
This study explored ways that PSP can support recreational land-use planning and decision-making in glacial landscapes and how it can improve anticipatory adaptation to potential undesirable future changes. To this end, a PSP process was developed, grounded on a combination of scientific expertise and local stakeholders' engagement, and a popular glacier recreation site in southeast Iceland was chosen as a case study.

Study area

Europe's largest glaciers are in Iceland, where they cover about 10% of the landmass (Björnsson 2017). Since the 1990s, glaciers in Iceland have been the setting of increasing outdoor recreation and adventure activities, which have created a substantial niche tourist market, on which some regions of Iceland have become economically dependent (Welling and Árnason 2016). The case study area, called Þröng, is on the southern edge of the Vatnajökull ice cap and has become a glacier recreation site over the past decade (Figure 1). It is approximately 16.5 km^2 in area and includes the eastern snout (terminus) of the outlet glacier Breiðamerkurjökull, where glacier recreation has been gradually increasing during the past 5 years. The study area borders the west side of the proglacial lake (a moraine-dammed lake that emerges adjacent to the frontal margin of a glacier) Jökulsárlón, one of the most popular tourist destinations in Iceland, which received around 800,000 visitors in 2017 (Þórhallsdóttir and Ólafsson 2019). In July 2017, the area became a part of Vatnajökull National Park, but the management plan for this area remains to be developed.

Currently, the Þröng site has no visitor infrastructure or facilities, and it can only be accessed by an unmarked and unmaintained track, only passable by a four-wheel-drive vehicle. Recreation activities include guided glacier hikes during the summer and ice-cave tours during the winter (Árnason and Welling 2019). Around 27,000 people visited the Þröng site in 2018 (Þórhallsdóttir and Ólafsson 2019), most of them on guided tours. Nonguided visitors are currently rare due to the site's limited accessibility. A recent economic impact study of Vatnajökull National Park (Siltanen 2018) stressed the importance of park visitation to the regional economy, showing that the park's direct economic impacts are US$88.3 million, with

FIGURE 1 Location of Þröng recreation site, showing the glacier margin as of 2010. (Map by S. Guðmundsson)



an economic impact-to-cost ratio of 15:1 and the creation of 71 full-time jobs.

The study area is characterized by a dynamic landscape. The southeast glaciers of Vatnajökull are located in the warmest and wettest area of Iceland (Hannesdóttir et al 2010) and therefore respond quickly to changes in temperature and precipitation. The terminus of Breiðamerkurjökull has retreated >5 km, losing 11.2% (114 km^2) of its volume from the late 19th century to 2010 (Guðmundsson et al 2017). Since the start of this millennium, the southeast outlet glaciers of Vatnajökull have retreated rapidly; according to Hannesdóttir and Baldursson (2017), their mass loss per unit area is among the highest in the world. In line with global climate change trends (IPCC 2013), climate projections for southeast Iceland show an increase in annual temperature of 2–2.4°C under Representation Concentration Pathway 4.5 and 3.4–4°C under Representation Concentration Pathway 8.5 by 2081–2100 (Icelandic Meteorological Office 2017). Glacier models (based on Intergovernmental Panel on Climate Change Special Report on Emission Scenarios A2 and B2; IPCC 2000) indicate that southern Vatnajökull could lose around 25% of its current volume within the next 50 years (Björnsson and Pálsson 2008).

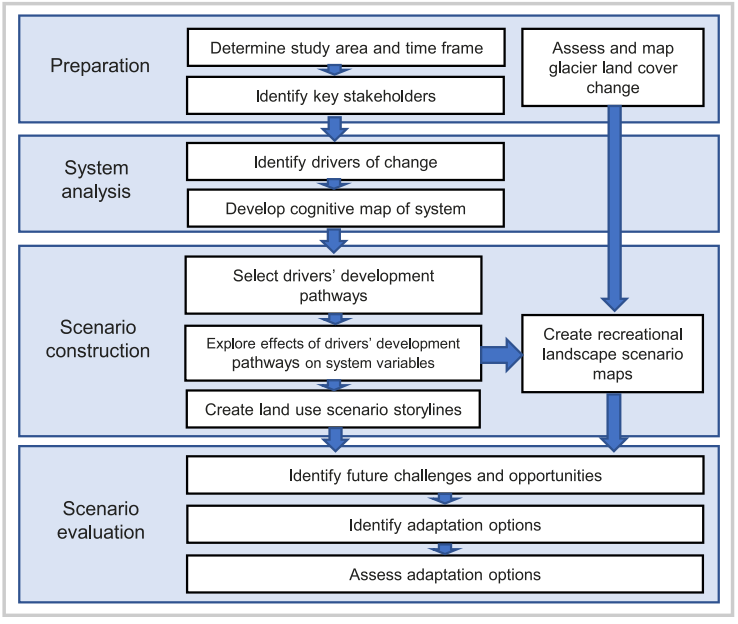
Applying PSP to the study area

We used PSP to explore future scenarios, their potential social and environmental consequences, and potential solutions to these consequences (Carlsen et al 2013). Our initial approach was primarily based on studies by Carlsen et al (2013), who created tailor-made scenarios engaging local stakeholders in their design and application, and Houet et al (2010), who combined landscape modeling and scenario-based approaches to map future land-use changes. These 2 studies provided a foundation for the PSP process used in this study, which consisted of 4 basic stages (the first carried out primarily by researchers and the others in cooperation with local stakeholders): preparation, system analysis, scenario construction, and scenario evaluation. Each stage contained multiple sequential steps, as shown in Figure 2.

Preparation

The first stage in the PSP process involved defining the study area, selecting a time frame, and identifying and selecting representative stakeholders. As a time frame for this study, we chose 2016–2026. According to Purdie (2013), this time span is short enough to encompass a foreseeable future, which entrepreneurs and tourism

FIGURE 2 Participatory scenario planning process used in this study.



planning and management actors ideally want to understand insofar as it pertains to changes in the accessibility of glacier sites and risk regimes. Moreover, management plans for recreation destinations typically cover no more than 10 years (Thomas and Middleton 2003).

Local stakeholders were the key data source in the development of the PSP process. However, power inequalities within stakeholder groups and differing levels of knowledge, worldviews, interests, and semantics can constrain meaningful engagement (Rounsevell and Metzger 2010; Reed et al 2013). Therefore, an important step was to convene a local stakeholder group in which the key interest groups concerned with recreational land use in the case study area were represented proportionally. It has been pointed out (eg Bizikova et al 2015) that connecting PSP with an existing stakeholder network can assist in identifying key stakeholders and can help to establish trust and mutual recognition among workshop participants. We therefore decided to connect the research approach of this study to an existing local stakeholder's network, a closed regional social media group that promotes nature-based tourism education. This was an important aspect of the study because it increased participants' willingness to share information and to speak freely during the workshops. Trust in the participatory process was further enhanced by appointing local workshop facilitators who were perceived by the stakeholders as neutral actors in recreational land-use planning.

A stakeholder group of 14 participants (of whom 8 were men), all local residents, was established. Three workshops were held, each with 8–10 participants drawn from this group, representing the main stakeholders in the area (Table 1). The workshops were held in Höfn, the only village in the municipality, in November 2016, June 2017, and October 2017. In each workshop, different nominal group techniques (ie structured face-to-face group session methods; Delbecq et al 1975) were employed—such as brainstorming, problem identification, group discussions, and solution generation—to obtain the necessary data.

To design future land-cover maps representing responses to future climate change in the case study area, a 2-step glacial land-cover modeling technique was applied, based on the work of Guðmundsson et al (2017). In the first step, 2 digital land-cover maps of the study area, for the years 2010 and 2016, were created using light detection and ranging (LiDAR) digital elevation models (DEMs) of the Vatnajökull ice cap (Jóhannesson et al 2011, 2013), Landsat 8 images, and the geographical database of the National Land Survey of Iceland. The 2016 ice-surface geometry was further constructed by studying the elevation changes between 2010 and 2016 near the terminus and its lateral margins and by using differential

TABLE 1 Focus group participants.

Stakeholder group	Details	Number
Entrepreneurs	Local glacier tour operators	5
National park	Manager and staff of Vatnajökull National Park	3
Municipality	Officials from planning and tourism departments	3
Nongovernmental organization	Nature conservation organization	1
Destination marketing organization	Regional tourism promotion and strategy development organization	1
Scientists	Experts in natural history	1

global positioning system elevation data collected on the glacier in 2016, also with the LiDAR DEM.

In the second step, a predictive land-cover map of the study area in 2026 was created by adding an extrapolation of the terminus position and the outlet's ice surface. The assumption was based on a continuation of the annual average retreat (about 96 ± 9 m) and surface lowering (3.5–6 m) of Breiamerkurj—kull during 2010–2016. The elevation contours of the assumed exposed foreland within the 2016 boundary were based on glacier subfloor uplift development derived from a radio-echometric survey of Breiðamerkurjökull in 1991 (Björnsson et al 1992).

System analysis

The second stage involved analyzing the recreational land uses of the study area as a socioecological system and exploring how drivers of change may influence this system through a collective cognitive mapping exercise. Cognitive mapping is a technique that captures a stakeholder's view of a particular issue in a graphical representation (Tegarden and Sheetz 2003). Through cognitive mapping, the qualitative knowledge of expert participants and local stakeholders is summarized to construct a simple systems model in which nodes represent concepts or ideas and arrows denote the interactions or linkages between these ideas (Mendoza and Prabhu 2006). This format gives participants the opportunity to investigate the complex interconnections between the elements of the system and to gain insights into the consequential relationships and feedbacks among different system issues, exogenous drivers, local variables, and outcomes (Goodier and Soetanto 2013).

During the first workshop, participants were asked to identify drivers of land-use change within the study area. After discussions, the stakeholders selected the drivers they considered most important and listed key local system variables that were directly connected to them. Based on these drivers and variables, the stakeholders developed a cognitive map of the recreation system in the study area.

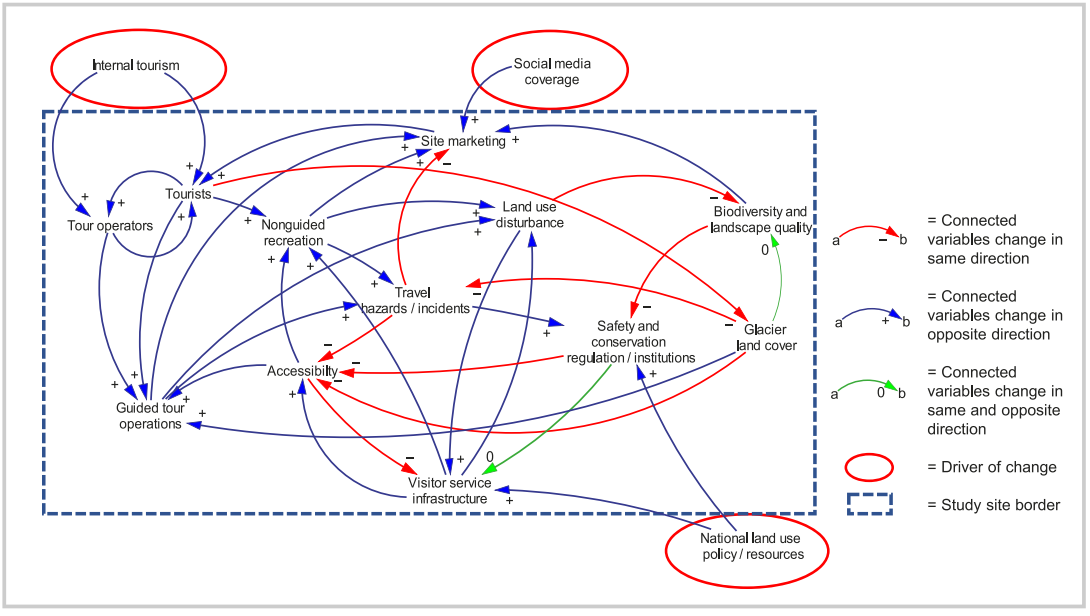
Scenario construction

In the third stage of the first workshop, participants designed alternative future scenarios in the form of narratives and recreational landscape maps of the study area. Participants were asked to imagine 2 to 3 contrasting but plausible pathways along which each identified driver of land-use change might develop by 2026 (their development pathways). Then, a simple scenario matrix (Carlsen et al 2013) was used to put together a relevant, important, and challenging combination of different driver development pathways and to construct and label significantly different plausible future scenarios based on "scenario logic," a simple method to structure potentially divergent issues and statements that underpin a story line to allow comparison and establish internal consistency (Rounsevell and Metzger 2010). Subsequently, based on the cognitive system map, the influence of the combinations of potential development pathways on key system variables in the study area were explored, and the development of the system variables for each scenario was translated into 1-page descriptive story lines.

During the last step in this stage, future land-use changes were assessed by comparing the development of the land-use variables described in the story lines with the spatial distribution of current land uses of the study area. The development pathways were translated into simple spatial rules to modify current land-use attributes based on Carter et al (2017) to convert the scenario narratives into spatial representations. Together with the outcomes of the 2026 land-cover mapping, the land-use attributes were processed using GIS (geographic information system technology) into landscape maps that consisted of a set of accumulated (overlaid) land-use and land-cover feature layers.

In general, it is problematic to validate exploratory scenario assumptions because they are derived from worlds that might happen in the future and have never happened in the past, which makes it impossible to test them against empirical data (Rounsevell and Metzger 2010). We validated all scenario story lines and maps through discussion in the stakeholder workshops. To evaluate the plausibility of the recreational land-use scenarios and land-

FIGURE 3 Cognitive map of the recreational system in the study area.



cover changes, we compared them to other scenarios of future tourism development in Iceland (eg KPMG 2015; Ministry of Industries and Innovation 2015) and simulations of the retreat of Breiðamerkurjökull glacier (Björnsson et al 2001; Nick et al 2007).

Scenario evaluation

The final stage of the process took place in subsequent workshops. In the second workshop, the scenario story lines and maps were presented and discussed with the local stakeholder group to identify the most important opportunities and threats for each scenario. In the third and last workshop, the stakeholders identified a set of options to adapt to the main threats and opportunities identified earlier, and they assessed the practicality of implementing the main options, including the availability and sufficiency of land-use governance and management products and services.

Results

Cognitive map of drivers of land-use change

During the first stakeholder workshop, the participants identified several drivers of change, that is, external variables of the Þröng site for the study period. Participants discussed these drivers and selected 3 for further discussion: (1) internal tourism development, (2) national land-use policies and resources, and (3) social media coverage. Next, they projected these drivers' likely development pathways (eg increase or decrease). During the second part of the workshop, participants identified, discussed, and selected 11 internal system variables on the basis of the 3 selected drivers of change. They then determined the connections between the variables and whether the connected variables changed in the same and/or opposite directions. Based on these findings, they developed a cognitive map of the recreation system in the study area (Figure 3).

Scenario matrix, story lines, and maps

The scenario matrix construction resulted in 3 plausible and challenging scenarios of recreational land use in the study area in 2026: business as usual, hot spot, and green tourism (Table 2). These scenarios differed in terms of development direction and the intensity of the local system variables, such as number of tourists and tour operators, demand for nonguided recreation, marketing, visitor regulation, and infrastructure development. The scenario maps are shown in Figure 4, and a summary of the corresponding story lines is given in Table 3. The comparison between the land-cover maps of 2016 and 2026 suggested glacier retreat of almost 1 km and surface lowering near the 2016 terminus of approximately 33–58 m. The estimated shrinkage of the Breiðamerkurjökull snout by 2026 also was expected to lead to the emergence of approximately 2.6 km^2 of deglaciated moraine,

TABLE 2 Scenario matrix.

Driver of change	Scenario		
	Business as usual	Hot spot	Green tourism
National land management policy	No change—limited regulation of recreation in protected areas	Slow extension	Fast extension
Tourism	Slow increase	Fast increase	Slow increase
Social media coverage	No change—low coverage	Fast increase	Fast increase

including 2 rivers, and to a shift of the glacier margin to an elevation 20 m higher.

Scenario evaluation

The story lines and maps of the 3 scenarios were validated through discussion with the local stakeholder group during the second workshop. Workshop participants identified 14 threats and 12 opportunities (Table 4). One opportunity and 2 threats were selected from each scenario to address in a third stakeholder workshop, where participants identified, discussed, and defined adaptation options to address the selected opportunities

FIGURE 4 Three scenarios for recreational land use in the study area in 2026.

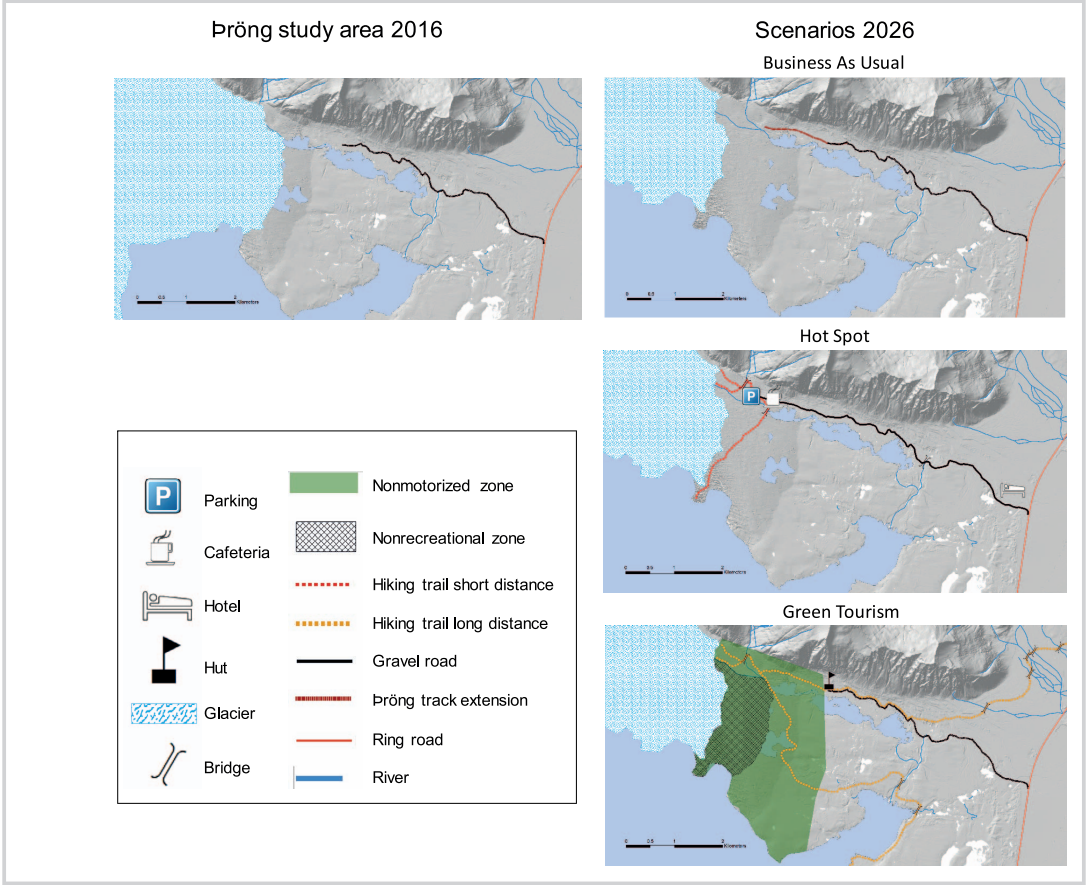


TABLE 3 Story lines for the 3 scenarios.

Variables	Scenario		
	Business as usual	Hot spot	Green tourism
Visitors per year	Around 50,000	Around 250,000	Around 50,000
Number of tour operators	Only a few companies offer guided hiking tours	About 25 companies offer transport to the area for sightseeing, and 10 companies offer special hiking or ice-climbing tours	No more than 5 companies receive a license to operate tours each year
Visitors pursuing nonguided recreation	Very few	Most	About half
Marketing	The site is not promoted as a tourist destination	The site is promoted as a tourist destination	The site is promoted as an ecotourism destination
Land-use restrictions	None for visitors or tour operators	None for tour operators	Nonrecreational and nonmotorized zones; ban on fossil-fuel-driven vehicles; restrictions on type and number of tour operators
Infrastructure	A single dirt road; no visitor facilities	Gravel road suitable for regular cars, parking area, toilet facilities, food shop, picnic tables, marked sight-seeing paths, hotel at the entrance	Small mountain hut and small campground with minimal services, marked geo-heritage educational walking trails, and connection to southern Iceland's network of hiking and biking routes

and threats. The options identified by workshop participants can be summarized as improving regulation/enforcement and planning/maintenance processes, stimulating research and education, promoting tourism, communication, and cooperation.

Due to the limited amount of time that was available during the workshop and maximum amount of time participants can be asked to devote to a focus group session, the workshop participants were asked to select 1–2 of the main adaptation options for addressing each threat selected in the previous workshop. After selecting adaptation options, participants assessed how each could be implemented in practice under current management

TABLE 4 Threats and opportunities identified for each scenario.

Scenario					
Business as usual		Hot spot		Green tourism	
Threats[a)]	Opportunities [a)]	Threats [a)]	Opportunities [a)]	Threats [a)]	Opportunities [a)]
Conflict and chaos	Research	**Increased pressure on nature and society**	Economic growth; increased income	Wishful thinking	Holistic planning
Poor access	**Passive nature conservation**	Diminished wilderness experience	Increased business opportunities	Conflicts due to changes	**Ecotourism**
Lack of planning	Tour diversity and availability	Risk of accidents	Increased accessibility	**Excessive management**	Wilderness experience
Risk of accidents	Experiencing untouched nature	**Increase in conflicts**	**Educating the public**	**Limited market**	Research
Lack of visitor planning or policy		Short-lived situation followed by a rapid socioeconomic and environmental downfall			

[a)] The threats and opportunities in bold were selected to be addressed in the third workshop.

TABLE 5 Assessment of adaptation options.

Threat	Adaptation option	Products and services needed	Available?	Sufficient?[a)]	Easy to acquire or change?[a)]	Possible to implement?
Poor access	Track repair and extension	Financing for infrastructure by tour operators	Yes	No	Yes	Yes
		Permits for commercial use	Yes	Yes	n/a	
		Visitor management plan	No	n/a	Yes	
Risk of accidents	Requirement to travel with guide	Specific regulation	No	n/a	No	No
		Enforcement of regulation	Yes	No	n/a	
Pressure on nature	Network of walking paths	Infrastructure fund financed by users (tour companies)	No	n/a	Yes	Yes
		Expert knowledge (eg concerning hiking trails)	Yes	No	Yes	
Stakeholder conflict	Proactive master planning and local planning	Holistic vision	No	n/a	No	No
		Stakeholders willing to cooperate	Yes	No	Yes	
Restrictive management	Cooperation platform between companies and park	Facilitation and maintenance of cooperation platform	Yes	No	Yes	Yes
	Promotion of changed attitudes to nature	Education, training, knowledge	Yes	No	No	No
Limited market	Promotion of tourism products	Marketing to increase awareness of the value of the area	Yes	No	Yes	No
		Grants for environmentally friendly tourism innovation and development	No	n/a	No	

[a)] n/a, not applicable.

and governance conditions, guided by the following questions:

- What kind of governance or management products and services are required to implement the particular adaptation option?
- Are those required products and services currently available?
- If the required products and services exist, are they available in sufficient quantity and quality?
- If the required products and services do not exist or are insufficient, are they easy to acquire, increase, or improve to allow implementation of the particular adaptation option?

Of the 7 selected adaptation options, 4 were considered difficult or impossible to implement under current decision-making and governance conditions, because at least 1 of the products and services required to implement the option was absent or insufficient (Table 5). Not one of the selected adaptation options was considered sufficiently available by the stakeholders. However, the options—repair and extend the current track, extend a network of walking paths in Þröng, and establish a cooperation platform between companies and park—required actions or products that were not all currently available but would be, according to workshop participants, relatively easy to acquire or increase or improve.

Discussion

The value of PSP in glacial recreation sites

Outdoor recreation is an interconnected activity that depends on the interplay of natural and socioeconomic services and goods. Glacier mountain environments have complex dynamics in which biological, geophysical, and socioeconomic trends and actors interact and are affected by climate change. An important strength of the

process developed in this study is the successful integration of socioeconomic and natural environmental changes into future scenarios. This is supported by Bonzanigo et al (2016), who concluded that such integration is a much more effective and realistic way to analyze the impacts of climate change on and responses to recreational land uses than examining these in isolation. The process furthermore enables the cocreation of future land-use scenarios by combining science-based knowledge in the form of land-cover dynamic modeling with local knowledge of land-use practices. Such approaches have been shown to provide effective ways to produce usable knowledge in support of adaptation-related decision-making (Dilling and Lemos 2011; Meadow et al 2015).

For the effective implementation of PSP, it is important that the process stimulates understanding and trust among stakeholders by using an existing regional network as the basis for stakeholder workshops, selecting workshop participants who represent a balanced mixture of local interest groups, and appointing as workshop mediators local residents who are perceived as neutral (in this study, the headmaster of a secondary school and director of a research center). Furthermore, the effectiveness of the stakeholder workshops is enhanced by developing tailor-made scenarios on the basis of the stakeholders' concerns and perceptions (ie their identification and prioritization of drivers of change of recreational land uses and their development pathways), developing and addressing cocreated knowledge at relevant spatial and temporal scales, and visualizing this knowledge in the form of maps to add a spatial dimension to the process. These last 2 aspects are supported by Purdie (2013), who stressed that the mismatch between glacier-based science and practitioners of glacier tourism can partly be addressed by focusing on short-term processes and site-specific studies.

In addition, the use of GIS techniques makes it possible to integrate plausible future recreational land-use attributes—such as roads, hiking trails, and restriction zones—into the land-cover maps, thus making the scenarios more in tune with stakeholders' immediate concerns and interests. Maps can also provide practical insights regarding the accessibility of a glacier site, such as in our case the nonemergence of a previously anticipated proglacial lake in front of the glacier terminus and the elevation of exposed moraine in the future, both of which were mentioned by entrepreneurs as important obstacles to business operations. Moreover, the maps' spatial and temporal scales make the derived information easier to integrate into the existing planning process.

To assess the future recession of the Breiðamerkurjökull glacier located at the Þröng site, this study used recession rate data from previous years to produce a map of projected future land cover. This approach provided accurate and robust results for the study area but did not generate varying plausible future outlooks other than the continuation of the current rate of glacier retreat. Regarding biophysical changes, the scenarios presented only limited changes from the current land-cover situation, resulting in the entrepreneurs' identification and selection of adaptation measures that did not differ from current practices. In addition, the glacier land-cover map may have confirmed many stakeholders' perception that the glacier is receding in an erratic but gradual way, without taking into consideration the crossing of possible natural thresholds that would force major transformations of business operations and site management. Therefore, an important future improvement of landscape maps for the PSP process would be to undertake more exploratory land-cover scenario development with varying landscape attributes.

Workshop participants were empowered by their contributions to the creation and application of the different scenarios. First, the cocreation of the scenarios ensured that all participants had a stake in the final outcome; they all contributed their own knowledge and expertise to the development of the scenarios, and they reached a consensus. According to Reed (2008), such an increase of participants' ownership of the scenario-planning process strengthens their sense of responsibility to act on what they have learned. During the scenario development process, greater mutual understanding is further attained within a diverse group, whose members would otherwise be less likely to have the opportunity to meet and discuss these issues. Individually, the participants tended to be caught up in their own immediate concerns, but when given a task to solve together, these private concerns faded into the background. Second, the future-oriented aspect of the exercise reduced latent tensions within the stakeholder group, as the problems and solutions did not affect the present-day situation, with its immediate conflicts and competition.

The construction and evaluation of the scenarios also provided insights into stakeholders' values, concerns, and interests. For example, workshop participants focused on short-term issues, such as the current rapid growth of tourism to protected areas in Iceland and the governance of public lands, both of which are debated and have a major impact on local conditions (Petursson et al 2016; Tverijonaite et al 2018). Such issues were prioritized above incremental and long-term changes, such as glacier recession, as important drivers of land-use change. This in line with findings, for example, by Evans et al (2013), which indicated that stakeholders in the Great Barrier Reef in Australia perceived future climate change scenarios that induce biophysical changes to the reef as being relative and only one of many challenges with which reef managers and industries needed to deal. Such

findings indicate that climate change implications cannot be understood as isolated factors; rather, they should be viewed as constituting interconnected and cumulative effects on the socioeconomic and natural environments. An improvement of our process would be to bring together experts (eg climate change scientists) with local stakeholders for the evaluation of the scenarios in order to address issues that transcend prevailing regional rationales and perceptions regarding incremental and long-term changes such as climate change.

General perceptions among stakeholders of the risk of glacier retreat also seem to have an impact on their level of concern about the physical changes to glacier landscapes. The framing of climate change as a global phenomenon that manifests itself in local impacts, such as glacier recession, could generate greater interest or action among those that experience such local impacts on a personal level (Shaw et al 2009). However, in cases where such manifestation is perceived as entailing limited risk or being controllable, this may actually lead to reduced concern. This is in line with findings from studies focusing on stakeholder perceptions of natural environments affected by climate change (eg Behringer et al 2000; Trawöger 2014; Lupp et al 2016). These studies show that due to climate change skepticism or due to personal experiences of limited impact severity or successful adaptation, climate change is not regarded as a significant risk. Such perceptions often result in a wait-and-see strategy for coping with future climate-induced changes (Berkhout 2012), and they can easily lead to maladaptation when natural or managerial thresholds (eg the situation when the margin of a glacier becomes impossible to reach on foot or by car) are crossed. In addition, it can be counterproductive to continue a business-as-usual strategy of increasing infrastructure and the number of transport vehicles in order to adapt to reduced accessibility of glacier sites; indeed, many visitors see these measures as a disturbance of wilderness and a degradation of the scenery, which in turn can lead to reduced visitation (Groulx et al 2017).

Anticipatory adaptation to climate-change-related challenges

PSP also provides insight into the capacity of the recreation planning system to adapt to potential future changes, such as glacier recession. The results of the scenario evaluation indicated that different factors can enhance the capacity of recreational land-use management to properly respond to potential future threats. One such factor is the presence of an informal network of major stakeholders, which can be mobilized to meet specific targets or to offer support for adaptation decision-making. Furthermore, the results show that the inclusion of local knowledge of the natural environment and recreational possibilities contributes to an awareness of the implications of climate change, which is an important requirement to increase adaptation action planning (Naess 2013).

However, the results also reveal barriers to implementing adaptive actions that reduce management's adaptive capacity. For example, the institutional planning and policy processes are inadequate and difficult to modify due to their rigidity and lack of transparency, both of which result from insufficient communication between policymakers and the people who are affected by the policies. The results further indicate that lack of funding for infrastructure, education, and maintenance may limit the adaptive capacity of recreational land-use managers. These results are in line with findings of other studies, which showed that limited financial resources and complex and rigid institutional structures significantly hinder anticipatory adaptation planning for protected areas (eg Jantarasami et al 2010; Lonsdale et al 2017).

Another crucial limitation to building adaptive capacity in protected area management in Iceland is the absence of policy for adaptation planning in general, a constraint that has been identified in other studies as well (eg Lemieux et al 2013).

Conclusion

The PSP process developed and applied in this study involves the identification of potential drivers of recreational land-use change in the context of climate change, the development of multiple scenarios for future recreational land use, and the examination of the potential consequences of these scenarios and adaptation measures to lessen or counter these consequences. The study results demonstrate that PSP is a valuable tool to support recreational land-use planning and decision-making in glacial landscapes, as well as to improve anticipatory adaptation to potentially undesirable future changes.

A similar process could be used in glacier regions worldwide and in other recreational areas where multiple simultaneous changes in landscape attributes, processes, and uses are anticipated. Glacier sites in mountain environments will continue to be impacted by climate change in future decades, resulting in multiple dimensions of dynamism (ie the interaction of biophysical, land-use, and governance changes in glacier sites at multiple temporal and spatial scales). Anticipatory management planning will thus need to address a constantly moving target, including the cumulative impacts of both natural and anthropogenic dynamics, and take into account both direct impacts (through tourism development) and indirect impacts (through climate change). Developing such an approach in Iceland is likely to involve a steep learning curve, as there has been only limited dialogue among the fields of outdoor recreation management, nature conservation, and climate change

adaptation. The process outlined in this paper could provide a prototype for more anticipatory and climate-conscious management of recreation in glacial mountain environments.

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Appendix A: Interview question scheme

A. Background of the tour operators' company

1. *Can you tell me something about your company?*
2. *How many employees does your company have in summer and winter season?*
3. *Which kind of tours does your company provide?*
4. *How many tours did you provide last year?*
5. *How many people took part on the tours you provided last year (estimation)?*

B. Characteristics of glacier tour operating

1. *Can you describe your tours?*
2. *Did you do any training to perform these glacier tourism activities?*
3. *Do you have procedures to follow during the tours?*
4. *What are the main dangers and hazards for walking and climbing on the glacier?*
5. *Are there any policies or regulations from the national park or other authorities concerning your tours?*
6. *On which glaciers do you provide the tours?*
7. *What were the important criteria to choose this glacier for your tours?*
8. *What do customers on the tours appreciate most?*

C. Perception of climate change

1. *Do you think climate change is happening today? How does this manifest?*
2. *How does climate change affect this region (the Vatnajökull region)?*
3. *How and where do you get your information about climate change?*

D. Climate change impacts and adaptation practices and strategies

1. *How does climate change influence your business today?*
2. *How do you deal with those impacts?*
3. *How does your company organize these activities?*
4. *Do you cooperate with other companies or authorities to deal with the impacts of climate change? If so, who and how?*
5. *What kind of regulations, policies or activities to deal with climate change are available from the national park, the municipality or other organizations?*
6. *How do you see the glacier sites develop in the future?*
7. *To what extent will climate change influence your business in the near future and in the next ten years?*
8. *How are you going to deal with those future impacts?*

Appendix B: Visitor survey questionnaire

To what extent do you agree with the following statements?

	Totally disagree				*Totally agree*
Climate change is happening right now	☐1	☐2	☐3	☐4	☐5
Climate change is the result of human activity	☐1	☐2	☐3	☐4	☐5
Climate change is the result of natural causes	☐1	☐2	☐3	☐4	☐5
I am very concerned about climate change	☐1	☐2	☐3	☐4	☐5

How willing are you to visit a regional glacier site when it had the following aspects?

	Not willing at all				*Very willing*
You cannot come within 150 meters of the glacier	☐1	☐2	☐3	☐4	☐5
You cannot touch or stand on the glacier	☐1	☐2	☐3	☐4	☐5
The amount of walking time to come to the edge of the glacier is 45 minutes	☐1	☐2	☐3	☐4	☐5
The amount of walking time to come to the edge of the glacier is 1,5 hours	☐1	☐2	☐3	☐4	☐5
The glacier is almost entirely covered with sand, mud and stones	☐1	☐2	☐3	☐4	☐5
It is only possible to come to the edge of the glacier by using commercial motorized transport (jeeps/truck)	☐1	☐2	☐3	☐4	☐5
It is only possible to come to the edge of the glacier by crossing a glacier lake with a commercial boat	☐1	☐2	☐3	☐4	☐5
It is necessary to take a guided tour for a safe passage to and on the glacier	☐1	☐2	☐3	☐4	☐5

i. **Who are you traveling with?** ☐1 Individual ☐2 Couple ☐3 Family ☐4 Small group (<10) ☐5 Big group (>10) ☐0 Other

ii. **What is your gender?** ☐1 Female ☐2 Male

iii. **What is your year of birth?** _____

iv. **In what country do you live?** _____

Thank you for your participation!

Glaciers and Tourism

Dear visitor, the University of Iceland currently seeks insight into the development of glacier tourism and the challenges it faces in Southeast Iceland. Such information is valuable both for a better understanding of tourist needs and in order to improve tourist services. All information will be handled confidentially and are anonymous. The questionnaire should take about *8* minutes to complete. Your participation is very valuable. Thank you!

1. How many days are you staying in the Southeast Iceland? ___ **days** (if less than 1 day write 0)

2. What kind of activities are you interested in participating in this area? (*mark all relevant activities)*

☐1 Sight-seeing ☐6 Glacier tour ☐10 Scenic plane flight
☐2 Camping ☐7 Horse riding ☐11 Mountaineering
☐3 Biking ☐8 Jeep tour ☐12 Swimming/ bathing
☐4 Fishing ☐8 Hiking ☐13 Museum visit
☐5 Photographing ☐9 Snowmobiling ☐14 Boat tour

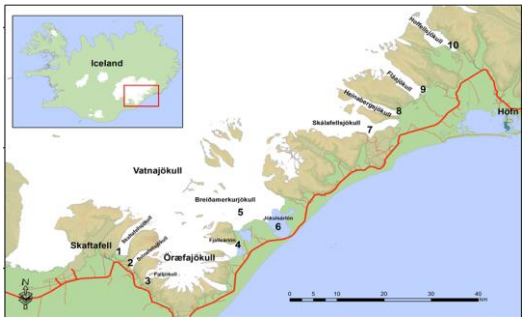
☐0 Other _____

3. How many times have you visited a glacier in your life? __ **time(s)** (if this was your first write 0)

4. How did you organize your trip to the glacier(s) you are visiting in Southeast Iceland? (*mark all relevant items)*

☐1 By myself
☐2 By travel agency in home country
☐3 By travel agency in Iceland
☐4 By local tour company (such as Mountain guides /Glacier Guides)
☐5 By tourist information cent
☐6 By my hotel/guesthouse
☐7 Do not know
☐0 Other, please describe:

_____



5. Which glaciers or glacier sites according to the map above did you visit in Southeast Iceland?

☐1 Skaftafellsjökull ☐5 Breiðamerkurjökull ☐9 Fláajökull
☐2 Svínafellsjökull ☐6 Jökulsárlón ☐10 Hoffellsjökull
☐3 Falljökull ☐7 Skálafellsjökull ☐11 Did not visit a glacier
☐4 Fjallsárlón ☐8 Heinabergsjökull ☐12 Do not know

☐0 Other _____

6. How important were the following motivations to you to visit a glacier site in Southeast Iceland?

	Not important at all				*Very important*
a. Do something with friends and family	☐1	☐2	☐3	☐4	☐5
b. Have a thrilling experience	☐1	☐2	☐3	☐4	☐5
c. To have a story to tell	☐1	☐2	☐3	☐4	☐5
d. Experience new and different things	☐1	☐2	☐3	☐4	☐5
e. See a glacier in real-life	☐1	☐2	☐3	☐4	☐5
f. Be close to nature	☐1	☐2	☐3	☐4	☐5
g. Develop personal, spiritual values	☐1	☐2	☐3	☐4	☐5
h. Visit a glacier before it disappears	☐1	☐2	☐3	☐4	☐5
i. Have a change from everyday life	☐1	☐2	☐3	☐4	☐5
j. Experience peace and calm	☐1	☐2	☐3	☐4	☐5

7. How much time did you spend at glacier sites in Southeast Iceland, all together? _____Hour(s)

8. What activities did you do at the glacier sites you visited in Southeast Iceland? (*mark all relevant activities)*

☐1 Guided walk on the glacier
☐2 Viewed the glacier from a short distance
☐3 Snow mobile tour
☐4 Super jeep tour
☐5 Photographing
☐6 Glacier lake boat tour
☐7 Ice climbing
☐8 Scenic flight (airplane)
☐9 Kayak tour in glacier lake
☐0 Other, please describe:

_____

9. How important was visiting a glacier for your decision to visit Iceland?

Not at all important ☐1 ☐2 ☐3 ☐4 ☐5 *Very important*

10. How important was visiting a glacier for your decision to visit Southeast Iceland?

Not important at all ☐1 ☐2 ☐3 ☐4 ☐5 *Very important*

11. How important were the following aspects for your experience during your last visit to a glacier site in Southeast Iceland?

	Not important at all				*Very impor*
a. The weather conditions	☐1	☐2	☐3	☐4	☐5
b. The scenery of the glacial landscape	☐1	☐2	☐3	☐4	☐5
c. Being in an unique environment	☐1	☐2	☐3	☐4	☐5
d. The size of the glacier	☐1	☐2	☐3	☐4	☐5
e. To come so close to a glacier	☐1	☐2	☐3	☐4	☐5
f. Seeing glacier attributes such as					