Advanced Review

International tourism and climate change

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Tourism is a major global economic sector that is undergoing tremendous growth in emerging economies and is often touted as salient for development and poverty alleviation in developing countries. Tourism is recognized as a highly climate-sensitive sector, one that is also strongly influenced by environmental and socioeconomic change influenced by climate change, and is also a growing contributor to anthropogenic climate change. This article outlines the complex interrelationships between climate change and the multiple components of the international tourism system. Five focal themes that have developed within the literature on the consequences of climate change for tourism are then critically reviewed: climatic change and temporal and geographic shifts in tourism demand, climate-induced environmental change and destination competitiveness within three major market segments (winter sports tourism, coastal tourism, and nature-based tourism), and mitigation policy developments and future tourist mobility. The review highlights the differential vulnerability of tourism destinations and that the resultant changes in competitiveness and sustainability will transform some international tourism markets. Feedbacks throughout the tourism system mean that all destinations will need to adapt to the risks and opportunities posed by climate change and climate policy. While notable progress has been made in the last decade, a number of important knowledge gaps in each of the major impact areas, key regional knowledge gaps, and both tourist and tourism operator perceptions of climate change risks and adaptive capacity indicate that the tourism sector is not currently well prepared for the challenges of climate change.

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INTRODUCTION

Tourism is a concept that is easy to visualize, yet more complex than most consider it to be. Most people think of tourism in terms of travel for leisure and holidays, but the United Nations (UN)[1] also includes travel related to education, health, religion, conventions, business, and visiting friends and relatives in its official tourism statistics. As a field of analysis, tourism therefore refers to the social and economic phenomenon of tourism, including tourists, the tourism industry, government and nongovernment organizations, and the people and places that comprise tourism destinations.[2]

International tourism has grown rapidly over the past 60 years to become one of the largest global economic sectors and a significant contributor to many national and local economies. From 1950 to 2005, international arrivals increased by 6.5% per year, from an estimated 25 million in 1950 to 940 million in 2010.[3] Importantly, international tourism trips are estimated to represent only 15% of all tourist trips.[4] With strong growth in emerging economies, the UN World Tourism Organisation (UNWTO) forecasts

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that international tourism will exceed 1.8 billion arrivals by 2030 and four times as many tourists traveling domestically.[5] The economic importance of the sector is further demonstrated by estimates from the World Travel and Tourism Council (WTTC),[6] an international association of tourism-related corporations, that tourism contributed between 5 and 9.6% of global gross domestic product (GDP) and 7.9% of worldwide employment in 2008.

Tourism is a significant source of foreign exchange earnings in the majority of the least developed countries (LDCs).[7] Between 1995 and 2007, it is estimated that international tourism in emerging and developing markets grew at twice the rate of industrialized countries.[8] The UNWTO, WTTC, World Economic Forum, and international development organizations promote international tourism as a means of poverty reduction and contribute to the UN Millennium Development Goals.[7] However, there have also been substantive criticisms of international tourism as a development strategy.[2,9–14] Consideration of the tourism development–climate change nexus is extremely important for developing countries that are potentially both highly vulnerable to climate change and highly economically dependent on tourism.

This review is organized into three sections. The first outlines a conceptual overview of the four main pathways by which climate change will impact the international tourism system and the adaptive capacity of key tourism stakeholders. It is beyond the scope of this article to comprehensively examine the multiple interrelationships between tourism and climate change. Consequently, the second section provides a critical review of five key themes that have developed within the literature on the consequences of climate change for tourism: climatic change and temporal and geographic shifts in tourism demand, climate-induced environmental change and destination competitiveness within three major market segments (winter sports tourism, coastal tourism, and nature-based tourism), and mitigation policy developments and future tourist mobility. The article concludes with a discussion of the preparedness of the tourism sector for the challenges of climate change.

CLIMATE CHANGE, TOURISM SCHOLARSHIP, AND INDUSTRY ENGAGEMENT

Scholarship on the interactions between tourism and climate change first appeared in the mid-1980s.[15–17] The early focus of the field was on the impact of climatic change on tourism destinations and high-risk sectors such as winter sports and coastal tourism. The contribution of tourism to climate change through greenhouse gas (GHG) emissions was first discussed in 1996, identifying aviation as a major contributor to per tourist emissions.[18] This was subsequently shown to be a salient problem for long-haul destinations, particularly island destinations.[19] The volume of research doubled in the 1990s and again in the 2000s,[20,21] with the diversity of disciplinary contributions increasing substantially. The multidisciplinary nature of the field is both a strength, infusing new ideas and research techniques, and a challenge, with differing disciplinary perspectives on the validity of assumptions and findings.[22–25]

The engagement of the tourism sector (international and national tourism government agencies, nongovernmental organizations, tourism industry) followed a different timeline than academic interests.[26,27] The science and policy momentum generated by the release of the IPCC TAR and the Kyoto Protocol entering into force as an international treaty were instrumental in stimulating high-level involvement of the tourism sector. In 2003, the UN coordinated the *First International Conference on Climate Change and Tourism* in Djerba, Tunisia,[28] which recognized the interrelationships between tourism and climate change, the need to better understand the implications of climate change for the sustainability of tourism, and highlighted the obligations of the sector to reduce its GHG emissions and accede to all relevant international agreements to mitigate climate change. The scientific assessment commissioned[29] for the *Second International Conference on Climate Change and Tourism* (Davos, Switzerland, 2007) addressed some of the information priorities, identified regional tourism vulnerability 'hotspots', reviewed the state of adaptation within the sector, provided an estimate of the contribution of global tourism to climate change (roughly 5% of CO_2 emissions in 2005; later refined to 5.2–12.5% of radiative forcing),[30] and set out options for decoupling future growth in the tourism sector from GHG emissions. The conference concluded that '[climate change] must be considered the greatest challenge to the sustainability of tourism in the twenty-first century'.[6] Prior to the COP-15 conference in Copenhagen, Denmark, the WTTC[5] issued its first position paper on climate change, which included 'aspirational' carbon emissions reduction targets of 25% by 2020 and 50% by 2035 (both from 2005 levels).

INTERACTIONS BETWEEN CLIMATE CHANGE AND THE TOURISM SYSTEM

Figure 1 illustrates the multifaceted interface between climate change and the tourism system. The notion

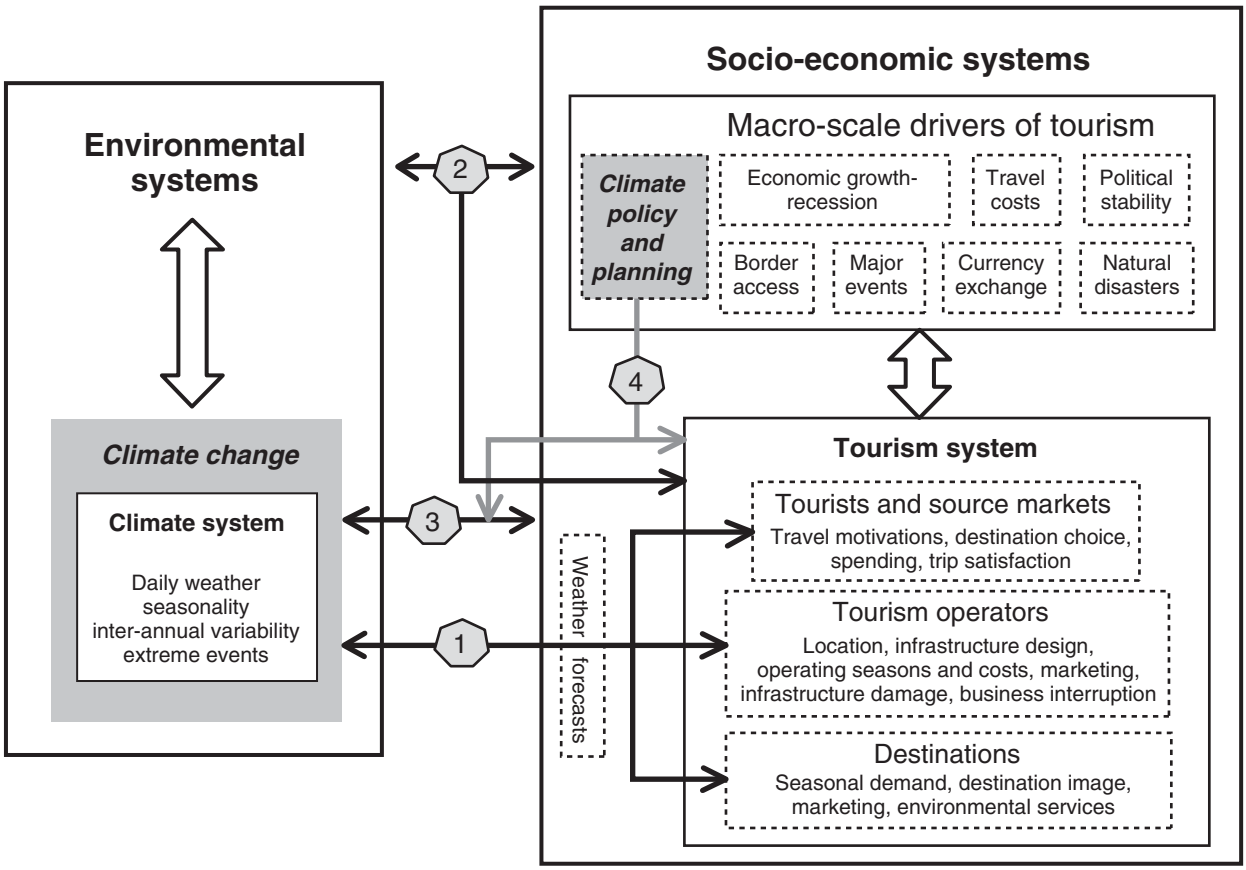

FIGURE 1 | Climate change impact pathways on international tourism. (Adapted with permission from Ref 27. Copyright 2012 Routledge)

of a tourism system is extremely important when considering the impacts of climate change. One of the limitations of the literature is that studies have tended to examine potential climate change impacts only in terms of one element of the tourism system, usually a destination or market segment, rather than considering the broader tourism system.[2,22,31–36] If a meaningful proportion of competing tourism operators or destinations are impacted, these changes and the demand-side response of tourists will have repercussions for competitors and other parts of the tourism system so that a negative impact in one part of the tourism system may have a knock-on negative effect or constitute an opportunity elsewhere in this competitive global system. Furthermore, as Figure 1 shows, climate change is only one of several macroscale drivers of future tourism development and there has been limited analysis of the potential interactions with other major drivers.

Figure 1 also sets out the four broad pathways (arrows 1–4) by which climate change will affect the future prospects of international tourism:[27] (1) direct climatic impacts that alter the length and quality of climate-dependent tourism seasons, operating costs, location decisions and design, infrastructure damage and business interruptions, destination attractiveness, and tourist demand and destination choice; (2) indirect climate-induced environmental change that affects natural assets that define destination image and are critical attractions for tourists, environmental conditions that can deter tourists, operating costs and the capacity of tourism firms to do business sustainably; (3) indirect climate-induced socioeconomic change such as decreased economic growth and discretionary wealth, increased political instability and security risks, or changing attitudes toward travel; and (4) policy responses of other sectors, such as mitigation policy, that could alter transport cost structures and destination or modal choices as well as adaptation policies related to water rights or insurance costs, which have important implications for tourism development and operating costs.

Considering that climate, the natural environment, personal security, and travel costs are primary factors in travel decisions, and each is projected to be significantly impacted by global climate change and climate policy, the integrated effect on international

tourism is anticipated to be far-reaching in the decades ahead.[6,22,34,37,38]

CRITICAL REVIEW OF KEY CLIMATE CHANGE RISKS FOR INTERNATIONAL TOURISM

With a rapidly expanding literature on climate change and tourism throughout the 2000s, a number of scholars have stressed the need for critical reflection and synthesis of knowledge in key focal areas.[22,31,39,40] Within the space limitations of this advanced review, we offer a multidisciplinary perspective on key findings, limitations, and knowledge gaps within the five specified areas. Other research themes where substantive literature exists (e.g., estimating GHG emissions from tourism) but that do not focus on the consequences of climate change on international tourism are not reviewed here.

Climatic Change and Altered Geographic and Seasonal Tourism Demand

Climate has direct and salient effects on tourism operators, destinations, and tourists alike[41] and understanding the implications of climatic change for destination competitiveness and tourist demand patterns have been identified as a research priority in this field.[39,41–48] Varied approaches used to examine the potential geographic and seasonal redistribution of climatic resources for tourism and how tourist demand might respond tend to support some common broad-scale patterns of influence on international tourism, but the contrasts also reveal some important areas for future research.

A number of studies have utilized a 'Tourism Climate Index',[49] which integrates multiple climate variables relevant to tourism, to examine how the distribution of climate resources for tourism could be altered over the 21st century.[46,50,51] These studies reveal generally consistent geographic and temporal patterns, with conditions ideal for tourism activity expanding in higher latitudes throughout the spring–summer–fall tourism seasons and improving in most mountain regions in the peak summer season, while conditions degrade in many subtropical and tropical destinations, particularly in the peak summer tourism season, but even in some shoulder seasons.[46,51] The impacts are particularly pronounced under warmer scenarios and in the later decades of the century. By altering the push-pull climatic factors influencing tourist destination choice, destination competitiveness was broadly projected to improve in Canada, Northern Europe, and Russia and decline in most subtropical and tropical countries, including many small island developing states. Increased competition was also projected among major winter sun–sand–sea (3S) destinations.

This approach is not without criticism. Climate indices for tourism have been subject to a range of critiques,[33,50,52–54] with the most utilized indices not empirically tested against the climate preferences of tourists or accounting for the overriding behavioural importance of physical parameters (i.e., rain and wind) under certain conditions. The generalizability of indices to the varied climate requirements of major tourism market segments (e.g., 3S versus urban tourism) has also been questioned[33,55–57]. A better understanding of the role of climate in tourism decision-making and the varied climate preferences of tourism markets and cultural groups is needed to further validate tourism climate indices and provide a more accurate assessment of how the future redistribution of climate resources for tourism will affect destination competitiveness.

Speculation on the impacts of climatic change on tourism in the Mediterranean basin exemplifies some of these limitations. With climate as one of its principal attractions and projections for hotter and drier summer conditions in the decades ahead,[47,58] it has been repeatedly asserted by academics,[59–61] governments,[58,62–65] the business sector,[66–68] and the media[69–72] that Mediterranean summers will become 'too hot' for tourism, even as early as the 2020s. However, at no point was 'too hot for tourists' defined by these assessments[33,55] or coastal microclimates and urban heat islands that are critical to tourism destinations in the region considered.[27] One analysis that utilized tourist surveys to determine perceptions of 'ideal' conditions as well as thresholds of 'too hot' for 3S and urban cultural sightseeing holidays found that the average summer temperatures at some of the Mediterranean destinations examined were already in the range considered to be 'too hot' and that some others entered this range, but only in the warmest scenarios for mid- to late 21st century.[55] Furthermore, tourist surveys[55,56] and tourist visitation and spending patterns during the 2003 European heat wave[73,74] reveal that tourists seek relief from the heat of large cities by going to the coast, and that higher summer temperatures may not dissuade tourism in the region to the extent that some have assumed.

Changes in the geographic and seasonal distribution of climate resources are anticipated to have important consequences for tourism demand from the global to destination scale. Studies using statistical and econometric approaches and temperature as a proxy for climate change have projected a gradual shift

in international tourism demand to higher latitude countries, with the shift in demand becoming much more pronounced under warmer scenarios and in the mid- to later decades of the 21st century.[48,75,76] It is anticipated that tourists from temperate nations that currently dominate international travel (e.g., Northern Europe, Japan, USA, and Canada) would adapt their travel patterns to take advantage of new climatic opportunities closer to home. Demand for international travel to subtropical, tropical, and some Middle Eastern countries is projected to decline, with fewer arrivals from temperate nations and increased outbound travel from these nations. Notable subregional differences were observable in some studies, such as the projected positive impact for Scandinavian nations versus the negative impact for Mediterranean nations of Europe,[47] the much more positive impacts projected for countries like Canada and Russia compared to other nations in their groups (e.g., Australia, Eastern Europe), or that China and India were expected to be largely unaffected.[48,75,76]

National-scale studies in the UK, Ireland, and Germany have concluded that tourists from all three nations would spend more holidays in their home country, increasing domestic tourism at the expense of destinations like Greece or Spain.[45,77–79] There is some support for this pattern from anomalously warm summers in the UK,[80,81] where domestic tourism increased, while outbound tourism decreased, as well as in mountain areas with nearby major cities.[82,83]

Global-scale simulation models of tourism demand under climatic change are necessarily highly simplified and have important limitations.[22,23,25,48,75,84,85] Macroscale models utilize constructs of climate that have no meaning to tourist decision-making (e.g., annual average temperature for a country). Therefore, integrating microscale tourist behavioral research into global-scale analyses of the influence of climate on tourism demand patterns remains an important area of future research.

While the specific projections of models of any social system 50–75 years in the future are highly uncertain, if even remotely accurate, then these studies indicate the implications of climatic change for the geographic redistribution of tourism demand are significant and will impose adaptation challenges for destinations expected to lose tourism (e.g., property values, employment, foreign exchange earnings) as well as those expected to gain future tourism development (e.g., transport and water capacity, sustainable environmental attractions). The implications for poverty alleviation objectives through tourism development in small island developing states deserve particular attention.[7,29]

Winter Sports Tourism

With its highly visible sensitivity to climate variability, the risks posed by climate change to the large international ski tourism industry have received considerable attention. The ski industry was the first and the most studied aspect of climate change impacts on tourism, with more than 30 known studies in 13 countries. Diverse methodologies have been used to examine both supply- and demand-side impacts of climate change as well as the adaptive capacity of the ski industry. Overviews of this geographically and methodologically diverse literature are available.[86–88]

Supply-side analyses have used two main methodologies to examine the future sustainability of ski operations, models, and climate change analogs. Modeling-based approaches are the more common. Many of these studies suffer from important limitations that reduce their validity and restrict the relevance for decision makers. The use of inappropriate impact indicators is a first limitation. Some studies simply model natural snow conditions near ski areas without any specific indicators relevant to ski operations, such as the length of the ski season or opening–closing dates.[89–92] Other studies utilize indicators that are not relevant to ski area operations, such as snow cover (which is a meteorological variable defined as 2.5 cm of snow, when ski operators require 30–100 cm of snow to open a ski run depending on terrain)[93–95] or snow water equivalent on the first day of April (which is a widely used hydrological indicator for summer water supply in mountainous regions, but one that provides no insight into snow accumulation in the vital start of the ski season or the number of days with necessary operational snow depth).[96] Yet others estimate ski season length solely on the basis of temperatures and rainfall, disregarding any measurement of snow depth and thus whether there is a snow product to ski on.[97]

A second limitation common to most of this literature[91,98–100] has been the omission of snowmaking in regions where snowmaking has been an integral adaptation to climate variability. Analyses that do not account for snowmaking, including the widely cited Organisation for Economic Cooperation and Development (OECD) report on the ski industry of the European Alps,[98] do not reflect the current operating realities of many ski operations, let alone their adaptive capacity[101–105] and are of little use to the tourism industry.

State of the art studies in Canada,[86,102,106,107] the United States,[36] Australia,[108] and Austria–Italy[88,109] that have utilized physically based snow models to fully account for snowmaking as an adaptation have consistently found that the impact of climate change

on ski areas was substantially lower than reported in studies that did not include snowmaking. However, from an operations perspective, by mid-century the ski tourism industry is at risk of decreased reliability of natural snow cover ('natural snow reliability'), greatly increased snowmaking requirements and decreasing snowmaking opportunities ('technical snow reliability'), shortened and more variable ski seasons, and an eventual contraction in the number of ski areas. Lower elevation ski areas and the early portion of the ski season (including the economically important Christmas–New year holiday period) are at greater risk. The importance of increased snowmaking necessitates greater scrutiny of its sustainability in terms of costs and water and energy usage.[98,102,106,109–111] The extent and timing of impacts are highly dependent on the magnitude of climate change, with the technical limits of snowmaking and larger season losses occurring in some ski areas in late mid-century under higher emission scenarios.

The second approach used to examine the impact of climate change on ski industry operations has been climate change analogs. Analyses of the impacts of record warm winters, typically serving as analogs for mid- to high-emission scenarios for the 2050s, in North America[27,36,106] and the Tyrol region of Europe[109] found ski seasons were shortened on average by 4–10%, while snowmaking requirements increased. When examining the differential vulnerability of ski businesses, lower-lying ski areas and smaller resorts consistently experienced the greatest loss in season length.[36,109] As lower elevations are often used for beginner ski runs, the implications for the development of skiing demand remain a notable uncertainty.[87,112–114] Importantly, analog studies also consistently found smaller losses in season length than modeling studies in the same regions. The differences can be explained by the inability of ski operations modeling to account for business decisions (i.e., opening under even very marginal conditions because of staffing inflexibility and to provide some level of skiing to guests staying in the resort), which can lead to the overestimation of season length losses. Despite the 'natural experiments' offered by a number of record warm winters in the past decade, the analog approach remains underutilized.[86] Future analog studies provide opportunities to gain insight into adaptive responses (from ski area operators, ski tourists, communities, and marketing organizations), identify key impact thresholds, understand the relative vulnerability of different ski destinations and ski operators, and validate modeling studies.

Collectively, modeling and analog studies highlight that the wide range of adaptations available to the ski tourism industry[115] provide substantive adaptive capacity to some ski tourism operators so that with the possible exception of the Australian, Scottish, and southern African ski industries, it is not the entire ski tourism market that is at risk to climate change, but rather specific ski businesses and communities that rely on ski tourism. The probable consequence of climate change will be a contraction in the number of ski operators in most regional markets. Determining where the ski industry is most likely to contract and where it will remain sustainable or even increase market share due to changed competition will be of interest to the ski industry, investors, real estate developers, insurers, governments, and communities, and examining the socioeconomic implications at the community level (e.g., employment, real estate prices, destination branding, development strategies, and visitation levels) should be a focus of future adaptation studies.[87] For example, over half of ski lodge/condo owners in the New England region of the United States indicated that if the ski area that their property was near closed as a result of consecutive poor winter conditions, they would use the property a lot less often or sell it, with attendant implications for property values.[27]

Critically, there exists a wide gap between the climate change risk perceptions of the ski industry and impending doom that is typically portrayed in the media. With advanced snowmaking in place, most ski area managers in North America, Australia, and Austria are highly confident in their capacity to negate the impacts of future climate change.[87,101–104,115,116] For example, almost half of Austrian ski area managers felt that with further adaptation of snowmaking their businesses would continue to be viable for at least another 75 years.[103] There are real dangers to media misinformation and flawed studies. Some European banks imposed financing restrictions on low-lying ski areas based partially on the findings of early studies, which did not account for snowmaking. Travel magazines and international real estate investment web sites have discussed where to buy ski properties to avoid global warming, with readers unaware that the statements were scientifically baseless.[27]

Knowledge of the response of ski tourists to the aforementioned changes in ski conditions and the ski tourism marketplace remains limited. Marketplace surveys have been conducted with skiers in several countries to examine how their travel behavior might change if climate change conditions were realized. Early surveys in Australia and Switzerland asked ski tourists how they would respond if 'the next five winters would have very little natural snow'.[111,117,118] In Australia, 90% stated that they would ski less often at Australian resorts, 69% would ski less often, 5%

would give up skiing, and 16% would ski at the same levels but overseas.[111] In Switzerland, 30% would not change their skiing behavior, 11% would ski at the same location but less often, 28% would ski at a more snow reliable resort at the same frequency, 21% would ski at a higher resort less often, and 4% would give up skiing altogether.[118] A similar survey in Austria found the majority were willing to travel further or pay more for a snow secure destination, but 25% would no longer ski.[119]

Three notable limitations with this literature restrict our understanding of demand-side response to a changing ski tourism marketplace. First, how are the climate change scenarios posed to ski tourists. How is 'Assuming that the next five winters had very little natural snow' to be interpreted? Different understandings could result in very different responses. More recent surveys that have based ski condition scenarios on climate change analogs or modeling results found stated behavioral changes to be much lower.[27]

Second, these studies did not examine how individuals have responded to marginal snow conditions in the past so that we do not know whether a behavioral change should be expected in the future. Importantly, analysis of ski tourism demand during climate change analog seasons in Canada,[106] the United States,[27,36,86] and Austria[109] found skier visits diminished between 7 and 15% compared to a climatically normal winter. This stands in sharp contrast to the stated responses found in many skier surveys. Also, while the impact of a single record warm winter on ski demand appears marginal, the impact of consecutive climate change analog winters remains uncertain.

Third, few surveys differentiated the stated behavioral responses among key market segments with those that found significant differences in behavioral adaptation.[27,120] Specialized (expert) skiers and those highly committed to skiing were more likely to ski more often than normal to make up for a shorter winter season. Skiers with high destination loyalty were more willing to wait until their usual resort opened to go skiing, and less likely to substitute place. Those with significant capital investment in ownership of a vacation property at or near a ski resort were also less likely to engage in place substitution. The capacity of tourism concepts such as substitution, specialization, and destination loyalty to enhance our understanding of climate-induced behavior change have not been adequately explored.[40,121]

Sea Level Rise and Coastal Tourism

As one of the most prominent impacts of global climate change, a considerable literature has developed over the past 20 years examining the potential impacts of sea level rise (SLR) on ecosystems, economies, and society, and even the physical existence of some sovereign nations.[122,123] Although coastal tourism has been identified as the largest tourism activity segment globally[124–126] and despite the massive ongoing investment in coastal tourism and vacation home properties, there has been remarkably little analysis of the implications for the tourism sector.[22,25,29,127] The lack of readily available geospatial data sets of coastal tourism assets (e.g., resorts, beaches, transport infrastructure) at the regional or global scale may partially explain the absence of tourism in global-scale SLR impact assessments.

The salience of SLR for the long-term future of burgeoning coastal tourism development was first observed in 1990.[128] Since then several publications have outlined the general types of impacts SLR would have on tourism in coastal areas (e.g., loss of high-value beaches, destruction of tourism infrastructure, altered biodiversity, increased need for shore protection, changed coastal aesthetics) and linkages to coastal zone management.[29,129–131]

A Computable General Equilibrium model of national-scale tourism, where the impacts of SLR are necessarily highly simplified and assume away the effect of SLR on the relative attractiveness of tourist destinations, concluded that SLR by 2050 (estimated at 0.25 m) had almost no impact on aggregate global tourism and very limited impact at the national level.[132]

In contrast, studies using engineering and geomatics-based techniques have begun to quantify the magnitude of impacts to tourism assets (beaches, cultural heritage resources) and tourism infrastructure (resorts, transportation networks) for specific tourism destinations under varied SLR projections and concluded the potential impacts to be much more salient. For example, large areas of the historical city of Alexandria, Egypt, are at risk to a 0.5 m SLR, including a series of high-value cultural sites and beach areas that are fundamental to tourism in this principal Mediterranean summer resort.[133] The cost of utilizing beach nourishment to stabilize major recreational beaches in 21 coastal states in the United States through to 2060 was estimated to range from US$6.5 billion under a 0.32 m SLR scenario to $20.4 billion under a 0.95 m scenario.[134] A subsequent study concluded that half of Florida's existing beaches, multiple airports, thousands of hotel rooms, and historic structures were deemed at risk to SLR.[135] Similar vulnerabilities were found in the nearby state of North Carolina, where 0.5 m SLR put US$1.2 billion of vacation properties at risk

in four counties alone, and the annual recreation benefits associated with beach and fishing trips in the state would decline by approximately US$4 billion.[136] Britain's coastal cultural heritage attractions are regarded as being at extreme risk to SLR,[137] although research on Britain's East Anglian coast suggests that climate change will result in a net increase in visitors, with the positive effects of warmer weather outweighing the negative influences of reductions in beach width due to SLR.[138] In the Caribbean island of Martinique, a large majority of tourist beaches (83%) and coastal infrastructure (62%) were estimated to be at risk to SLR-induced erosion.[139] A multinational study of the potential SLR impacts on major coastal tourism resorts in 22 nations of the Caribbean found roughly 25% would be vulnerable to partial or full inundation by a 1 m SLR, but a substantially higher proportion would be vulnerable to associated coastal erosion.[140] Far greater impacts occurred to resort front beaches, which would have essentially disappeared prior to damages to tourism resort infrastructure. If realized, such impacts would transform the region's destination competitiveness, with implications for property values, pricing structures, insurance, and promotion.

A common critique of engineering and geomatics-based SLR studies is that they represent potential impacts and have not adequately accounted for adaptation strategies, such as structural protection, which some contend would be a widespread economical response to avoid land loss and infrastructure damage from SLR.[123,141] This is a limitation common to studies of coastal tourism. However, the likelihood of coastal protection being successfully implemented varies substantially between regions. The capacity for coastal protection is estimated to be lowest in small island developing states generally, as well as LDCs in Africa and Asia where, although coastal tourism is highly important economically, there are substantial capital and policy constraints.[142] Furthermore, typical structural coastal protection works are not well suited to coastal resorts, which must maintain sea views, easy access to the beach and sea, and the aesthetic qualities of beach environments to attract international tourists. Although structural protection can be easily designed to protect resort buildings, 'coastal squeeze' means that resorts will lose their beaches unless there is significant investment in beach nourishment. Contemporary beach erosion illustrates the negative economic impact of beach loss on visitor perceptions, resort attractiveness, room rates, and property value[143–147] and serves as a useful analog for the impacts of SLR without beach nourishment. So while structural protection will be economically effective for certain tourism sector assets, such as airports, cruise ship terminals, and major urban areas with high concentrations of resort facilities, it remains uncertain whether structural protection is economical for low-density coastal resort areas.

Understanding tourist response to beach impacts is extremely important for coastal tourism destinations. A survey of tourists to the island of Barbados found that under a severe beach erosion scenario, 77% would be unwilling to return to this 3S destination for the same price.[148] Online tourist comments about destinations and trip experiences were used to examine tourist perceptions of beach erosion and attempts to restore the beach in Playcar, Mexico.[145,146] Tourist responses to erosion were classified into three categories: positive, negative, and reconciliatory. Those with negative reactions were unaware of the eroded beaches and felt deceived by beach images in destination marketing. Those with a positive view focused on additional recreational opportunities provided by the erosion control structures, while those in the reconciliatory group viewed the beach erosion control measures as aesthetically unpleasant but part of efforts to restore the beach through beach nourishment. It is unclear what proportion each group represented, which is important in order to understand the potential impact on destination reputation and future demand. It also remains unclear how prior knowledge of the degraded beaches or price discounts played in the varied interpretations or their respective intentions to return to this destination. These remain areas for future research.

Nature-Based Tourism

Climate-induced environmental change, both observed and projected, is well established for several environmental resources highly important to the growing nature-based tourism market (e.g., alpine glaciers, coral reefs, biodiversity, beaches, polar regions).[149–151] Tourist perceptions and responses to environmental change are not well understood broadly, and less so in the context of climate change, and remain an important knowledge gap.[22,40,152]

Evidence for potential tourist response to climate-induced environmental change comes from a range of landscapes. The potential effects of natural and cultural landscape change for mountain tourism have been noted in several alpine regions.[42,86,153–155] Studies of national park tourists in the Rocky Mountain region of North America found that specified change scenarios in the mountain environments, based on impacts projected for the early- to mid-21st century, would have a limited effect on tourist intention to

visit parks.[101,156,157] In scenarios representing greater environmental change by the end of the 21st century, an important threshold was reached for many visitors, and a substantial proportion indicated that they would no longer visit (19–31% in two parks) or would visit less often (36–38% in two parks).[156] For instance, the projected loss of glaciers in the region was noted as a significant heritage loss and the most important reason cited for no longer wanting to visit. This is consistent with findings related to the impact of glacier retreat in Lijiang, China, where 20–43% of tourists would not visit in the absence of the glacier.[158] In contrast, when the substantial damage from a category five tropical cyclone was used as a climate change proxy to explore tourist perceptions of landscape change in a tropical mountain rainforest landscape in Queensland, Australia, after 15 months only 6% of tourists reported seeing impacts and it was concluded that the scenic value would not change greatly once obvious physical damage to the forest was obscured by new growth.[159] However, the Queensland study may only be applicable to perceptions of sudden, as opposed to incremental, rainforest change.[160]

The widespread coral reef bleaching events of the late 1990s and 2000s have provided natural experiments to examine the potential future impact on the dive tourism market. After the 1998 bleaching event, general awareness of coral bleaching among tourists in El Nido, Philippines, was limited (44%) and there was no observed impact on 3S tourist arrivals.[161] Similar studies in Zanzibar, Tanzania, and Mombasa, Kenya also found low awareness of bleaching among tourists (28 and 45%, respectively).[162] When asked if they would be willing to dive on a bleached reef, a substantial proportion (40 and 33%, respectively) indicated they would, suggesting there may still be a market for degraded reefs for some time. This is consistent with a study in Mauritius that concluded that the state of coral reefs was of limited importance to dive tourists and snorkellers, as long as certain threshold levels of reduced species diversity, coral availability, and water visibility were not reached.[163] In the Caribbean, 76% of diver tourists in Bonaire indicated they would be unwilling to return for the same price in the event of severe bleaching.[148] However, a survey of dive tourism operators from across the Caribbean region found the widespread 2005 bleaching event had very limited impact on their business and the number of dive tourists.[164] When tourists in the Great Barrier Reef area were asked about bleaching, only a small proportion (13%) would not revisit the region, but a much larger group (41%) remained unsure of their intentions.[159] Another study of divers and snorkelers in North Queensland projected that degraded reef quality from bleaching would result in much larger changes in visitation in the region.[165] A general shortcoming of most studies is that they have not segmented between beginner and experienced divers, who have differential thresholds for tolerating coral bleaching.

Biodiversity is of critical importance for nature-based tourism, and the reduction of wildlife abundance or loss of species is anticipated to affect tourism visitation in many tourism destinations.[27,166] For example, the impact of altered geographic distribution of species and abundance of cold water sport fish was estimated to cause annual damages of US$320 million or more to the US sportfishing industry in the 2050s.[167] Other regional studies similarly project large changes in fish habitat, with implications for tourism,[167–171] but there has been no rigorous analysis of the potential adaptation strategies (e.g., lake stocking strategies, angler choice of species).

Few studies exist that examine the potential loss due to climate change of key species that serve as main tourist attractions. Analysis of the implications of a declining polar bear population in Churchill, Canada, is one exception.[172] If polar bear populations were to 'appear unhealthy', 62% of visitors would still visit the destination, but if populations declined such that visitors were 'not guaranteed to see any bears' only 50% indicated they would still visit. Importantly, a strong majority indicated that if they could not view polar bears at this destination, they would travel elsewhere to see them; signifying a loss for this destination could become an opportunity for another.

Evidence from these wide-ranging studies suggests that the impacts of environmental change will vary among tourist markets (i.e., expert versus beginners, regional versus higher yield international visitors, mass 3S versus nature-based segments, those with property or high place loyalty versus those without). There is also evidence that price discounts can substitute for degraded destination environments to some extent.[27] These remain important areas for future inquiry. Another important uncertainty regarding the potential impacts of long-range climate-induced environmental changes on tourism demand is whether future generational cohorts, who have no frame of reference of previous more pristine landscape or ecosystem conditions, would respond to degraded conditions in the same manner as contemporary visitors.[33,156]

Some argue that observed and anticipated climate-induced environmental change has also given rise to new tourism phenomena variously called 'disappearing destinations', 'last chance tourism', 'climate change voyeurism', 'climate disaster tourism', where

tourists visit a destination or attraction before it is 'lost' to climate change.[172–174] The ethics associated with additional travel-related GHG emissions that exacerbate the impacts of climate change on these attractions has been questioned.[172,173,175–179] Claims that such travel creates 'environmental ambassadors' who work to support the protection of these attractions and reduce travel-related GHG emissions are not supported by travellers surveys.[173] The cumulative evidence for this tourism trend remains scarce and further work is required to document if a meaningful trend exists.[27] Indeed, some question whether these terms are accurate, for while the environmental characteristics of destinations will change, with the exception of some very low-lying island destinations (e.g., Maldives, Kiribati, Tuvalu), tourism destinations will not physically 'disappear' as a result of climate change, and the tourism experiences sought at these locations will still be available elsewhere.[27]

Mitigation Policy, Consumer Attitudes, and the Future of Tourist Mobility

Discussions of the impact of mitigation policy on tourism have focused almost exclusively on the aviation sector (and bunker fuels more broadly). With carbon-justified levies on international flights (e.g., UK Air Passenger Duty), international aviation entering the EU Emission Trading System (ETS) in 2012, and a range of proposed policy frameworks to facilitate or require future emission reductions (see Refs 180–182 for a review of recent proposals), the prospective impact on air travel costs has become unsettling for destinations that have significant long-haul tourism markets (e.g., Caribbean, Australia, New Zealand, Indonesia have all voiced concerns).

However, studies that have examined the potential impact of aviation sector mitigation policies on international tourism demand have consistently found that policies as currently proposed would have little impact on overall tourism demand. Although all studies project a small decrease in the growth of international tourist arrivals versus a scenario with no emission reduction policies (typically less than 5% but regional differences are found due to proximity to primary international markets), in all cases demand for air travel and international tourism continues to increase.[183–188] Consequently, there is no evidence to suggest that current mitigation policies for international aviation would have even a moderate impact on tourism demand through 2020.

Nonetheless, it is clear that in order to achieve the large emission reductions needed to avoid 'dangerous' climate change, absolute emission reductions will eventually be required of the aviation sector[30] and aviation mitigation policies will therefore become increasingly relevant to international tourism.[30,189,190] Under more stringent global aviation mitigation policy scenarios, which could portend a post-2020 policy regime, more significant decreases in tourist arrivals were projected for small island developing states.[184,188] Related sensitivity analysis revealed that the range of air travel price elasticities in the economics literature had an equal impact on the results as uncertainties in future carbon or oil prices.[186,188] This suggests the need for fundamental research on air travel and holiday price elasticity if forecasts of the implications of carbon and/or fuel price increases in air travel and sea cruise travel are to be improved.

Additional research is needed to comprehensively assess the implications of proposed regulatory frameworks for aviation, to determine the effects for air travel demand, routing, modal shifts, and destination competitiveness, and to identify the most effective policies in achieving emission reductions without undermining tourism development (particularly in developing countries), if this is indeed possible. Policy modeling is also required in regions that have significant cruise tourism, which will also become subject to regulations of international marine transport GHG emissions in the years ahead.[191] Most cruise tourists fly to major ports of departure (e.g., Miami) before embarking on their cruise, and with GHG emissions from both flight and cruise segments, the price sensitivity of this tourism market to increased emissions regulations remains uncertain. Unfortunately, much of the tourism sector and international development agencies that promote tourism have not adequately considered the long-term implications of aviation and shipping mitigation policy for transforming international travel patterns and destination competitiveness.[27]

Tourist perceptions of the carbon footprint of travel could also influence future international tourism, with some long-haul destinations expressing concern that 'growing guilt over the impact of jet flights on global warming' could adversely impact the tourism economy.[192,193] With increased recognition of international tourism as a contributor to global GHG emissions, particularly the intensive media attention directed at air travel in some nations,[29,175,194] there is some evidence of growing awareness of the environmental impacts of air travel.[172,195–201] Other studies conclude a 'psychology of denial' exists in terms of awareness of the contributions of air travel to climate change.[199,202,203]

This dichotomy of traveller perceptions is reflected in the very low inclination of tourists to voluntarily change their travel behavior (e.g., travel

less by air, substitute destinations) to reduce environmental impacts associated with flying, as the personal benefits of travel trump the social costs of climate change.[176,196,198,200,201,204–206] Furthermore, while a greater proportion of travelers have stated a willingness to pay some additional charge to reflect environmental costs (in the form of a levy or carbon offset),[197–199,206–212] the proportion of travellers who self-declare that they have purchased offsets or always purchase offsets is typically less than 5%.[199–201] Consequently, there is little evidence that customer attitudes toward flying are likely to have a meaningful impact on tourism demand in the near term. To better inform the development of mitigation measures, further research is needed to understand this attitude behavior gap and uncover the sociopsychological factors that influence tourist mobility behaviors. Existing studies also emphasize the role of policy in addressing this issue, with little evidence that such policy is actually emerging.[213]

ADAPTATION—IS TOURISM PREPARED?

Studies with a diverse range of tourism stakeholders in 11 countries have found they were reasonably well informed about the potential impacts of climate change on tourism, but not highly concerned that the impacts would significantly affect their businesses.[101,115,116,214–228] The large majority recognized the need for climate change adaptation and were highly optimistic about their capacity to overcome the challenges of climate change. The dynamic nature of the tourism industry and its ability to cope with a range of shocks, including SARS, terrorism attacks, natural disasters, the global financial crisis in 2008/2009, suggest a relatively high adaptive capacity within the tourism sector overall.[29,229] However, with very limited knowledge of the capacity of current climate adaptations of tourism operators and tourism-dependent communities to cope successfully with the major impacts of climate change,[27] tourism stakeholders may be overestimating their capacity to adapt under mid- to high-emission scenarios. Furthermore, because international tourists can hold different expectations for services and environmental conditions than destination residents, this can impose unique adaptation challenges in communities with visitor-based economies.[230]

Several key barriers to adaptation can be identified;[27,230] some common to other sectors. Uncertainty over climate change science is a major concern to some industry stakeholders, while overall there is low confidence in the current understanding of how climate change would impact tourism. The very long timeframes of climate change impacts are considered largely incompatible with business planning, restricting adaptation to low priority status. Inadequate technical, human resource and financial capacity are identified as critical barriers to climate change adaptation in all studies. Small- and medium-sized enterprises, which represent a high proportion of tourism businesses, have a more limited capacity for investment in infrastructure and integrating climate risks into business planning, and are therefore more vulnerable to climate change.[27,36,109,214,231] Most stakeholders indicate a clear need for government leadership on climate change, including financial support for early adaptation.

Tourism operators in several regions have expressed concern and intense frustration about media coverage of the climate change implications for their destinations.[116,217,225,232] The tourism industry is very image sensitive and cautious about even acknowledging concerns about climate change risks for fear of adversely affecting destination or business reputation.[27] Consequently, some resistance to engaging in public adaptation processes is expected to continue in some destinations. The need to counter misinformation about climate change impacts on tourism is an important rationale for further research.[24]

The highly competitive nature of the tourism sector means that for strategic business reasons climate change adaptation strategies by tourism operators are not usually made public.[24] Because there is no business advantage to recognizing or making known climate vulnerability, companies publically downplay any climate risk and quietly adapt or divest high-risk assets. Similarly, where a company sees potential competitive advantage, they will not broadcast this information to competitors, but use it like any other strategic business information to improve their position in the marketplace.

A recent assessment of 18 leading tourism countries revealed that in most cases national government has not undertaken a strategic review of the vulnerabilities and potential adaptation strategies within the tourism sector.[233] Only about a quarter of the countries have considered adaptation strategies for tourism, with two of these stating that no adaptation is necessary. Potential reasons for inaction included low awareness of the tourism sector's climate change adaptation needs and a lack of knowledge and research regarding the complexities of tourism–climate interrelationships.[233] Initiatives of international tourism organizations were also included in this analysis, but few specific examples of sectoral adaptation

strategies or plans for broader intersectoral collaboration on capacity building or adaptation financing were found.[233]

CONCLUSION

This article sets out a conceptual structure of four broad pathways by which climate change and climate policy will affect the future development of international tourism (Figure 1). Five focal areas that have emerged within the rapidly developing literature on the consequences of climate change for tourism were critically reviewed. Although large uncertainties remain within each area in regard to impacts on critical tourism resources and the demand-side response of tourists to destination-level impacts, the cumulative evidence indicates climate change will be a pivotal issue for the global tourism sector. Differential regional vulnerabilities are particularly noteworthy. Small island developing states and developing regions in Africa, Asia, and Oceania appear to be at greatest risk because of potential shifts in demand favoring higher latitude countries, large impacts on natural tourism assets, heightened security risks, relatively lower adaptive capacity, and greater distances to major markets.[27,29,34,35,67] This has significant implications for the many developing countries that look to tourism as a key future development strategy, and must be more thoroughly considered in national development plans, official development assistance programs, and international adaptation financing negotiations.[7,27,29]

Climate change will alter the competitiveness of tourism destinations as well as the sustainability of major tourism market segments (e.g., ski tourism). It is evident that all tourism destinations will need to adapt to climate change, whether to minimize risks or to capitalize on new opportunities associated with local impacts of climate change or impacts on competitors and the broader tourism system. Nonetheless, available evidence from the tourism industry and government agencies suggests the level of preparedness within the sector remains low.[27,29,68,233] The adaptation imperative that has emerged within the scientific literature and policy agendas over the last decade has yet to translate into discernible action within the tourism sector. Concerted research and capacity-building efforts by national governments, the tourism industry, and supranational tourism organizations will be required to advance adaptation mainstreaming and enhance the potential for this sector to contribute to green economy and poverty alleviation.[24,29,233]

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