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Disaster and risk management in outdoor recreation and tourism in the context of climate change

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Abstract

Purpose – The increasing frequency and intensity of the extreme weather events could cause devastating consequences in tourism. Climate change–related extreme weather events and their relation to tourism is an emerging field for education and research. The purpose of this study is to categorize the impact of climate change on tourist destinations with regard to extreme weather-related risks in outdoor recreation and tourism. Managerial implications for policymakers and stakeholders are discussed.

Design/methodology/approach – To outline the risks from climate change associated with tourism, this study uses the Prisma analysis for identification, screening, checking for eligibility and finding relevant literature for further categorization.

Findings – Based on a thoroughly examination of relevant literature, risks and threats posed by climate change could be categorized into following four areas: reduced experiential value in outdoor winter recreation; reduced value in beach scenery and comfort; land degradation and reduced biodiversity; and reduced value in personal safety and comfort in tourism. It also focuses on the significance of using big data applications in catastrophic disaster management and risk reduction. Recommendations with technology and data analytics to continuously improve the disaster management process in tourism education are provided based on findings of this study.

Originality/value – Primary contributions of this study include the following: providing a summarized overview of the risks associated with climate change in terms of tourist experiential value for educational implications; and revealing the role of data analytics in disaster management in the context of tourism and climate change for tourism education.

Keywords Climate change, Outdoor recreation, Disaster risk management, Tourism education

Paper type Research paper

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1. Introduction

The tourism industry has been the fastest growing industry in the modern era. It had grown 56-fold between 1950 and 2018 (Roser, 2020). Even during the COVID-19 pandemic, the direct contribution of travel and tourism to global GDP was US$4.7tn (Lock, 2020). In the aftermath of the pandemic, the growth of the industry is expected to increase even further (Abbas *et al.*, 2021). Its global impact on economic, social and sustainable development is gaining widespread recognition (Scheyvens and Biddulph, 2018). To keep pace with the rapid growth of tourism and the flow of tourists, strategic plans are developed to mitigate risks at certain destinations (Goh, 2012).

One major impact on the global tourism industry is the occurrences of extreme weather events due to climate change (van Putten *et al.*, 2014). This particular risk is set to accelerate with the increase in the global warming, along with the frequency and intensity of extreme weather in the past few decades. Extreme weather events, such as typhoons, floods, heat waves and wildfires have caused tourist destinations to face uncertainties and risks. Prediction and preparation against these events are crucial for the tourism industries. From tourism businesses to local, regional and national governments, the ability to successfully adapt to new climatic conditions – regardless of whether those conditions offer opportunities or pose potential threats – will depend heavily upon the recognition of and adaptation to climate change (Amelung and Nicholls, 2014).

Climate change in consequence of human activities affects the environment and biological systems through various ways, such as global warming, rising sea level and extreme weather events (Manolas, 2011). The recent report issued by the Intergovernmental Panel on Climate Change (IPCC) explained that climate drivers such as burning fossil fuels, cutting down forests and farming livestock disrupt the natural balance between the amount of energy that the earth receives from the sun and the amount of energy that is lost to space via reflected sunlight and heat (Atwoli *et al.*, 2021; Masson-Delmotte *et al.*, 2021). The Special Report on Extreme Events and Disasters of IPCC has further predicted an increasing number of incidences and growing severity of extreme wet and dry events in the 21st century due to climate change and further emphasized that urgent actions need to be taken to reduce these effects (Zommers and Singh, 2014).

A rise in average global temperatures of 1.5°C would increase the chance of reaching a tipping point of crossing planetary boundaries in natural systems that would result in acute instability (Atwoli *et al.*, 2021; Masson-Delmotte *et al.*, 2021; Rockström *et al.*, 2009). The increasing frequency and intensity of the extreme weather events can have devastating consequences for tourism. In the tourism industry, negative impacts, even small ones, can be accompanied by a large financial loss in addition to human loss. There are several recorded examples of economic damages resulting from climate change. For example, winter outdoor recreation industries, such as skiing, may suffer severely from global warming, as an increase in average global temperatures may reduce the snow cover necessary for these events to occur (Masson-Delmotte *et al.*, 2021). Tourist-catering businesses in Delani National Park, AK, home of the highest peak in North America, experienced US$250,000 loss in revenue in one year after rising temperatures thawed out permafrost and resulted in landslides (Patton *et al.*, 2021). The forecasted reduction of winter snow would inevitably lead to a decrease in tourist arrivals and revenues, as well as a in tourism-related jobs (Scott *et al.*, 2019, 2021; Willibald *et al.*, 2021). In the case of the Victoria falls in Zimbabwe, reduced water levels due to droughts (Nhamo *et al.*, 2021) and the covering news reports (Mushawemhuka *et al.*, 2021) led to a massive decrease in tourist arrivals. Reduced tourist arrivals due to adverse weather changes will be extremely detrimental to local economies and communities that depend on tourism, including dramatic reductions in employment and cash flows based on tourism activities.

Not only does climate change influence the tourism industries, but tourists themselves can also be subjected to its impact. In 2021, heatwaves in Greece caused forest fires, which resulted in thousands of entangled tourists being evacuated (Arabadzhyan, 2021). When catastrophic circumstances occur at outdoor tourist sites, tourists are often the most vulnerable. Although tourists may have a general understanding of the extreme weather in their regions of residency, they are less aware of the potential risks of disastrous weather at their travel destinations (Yu *et al.*, 2018). During disastrous conditions, where the electricity supply, internet accessibility, transportation and rescue operations are limited, tourists are less likely to find help or resources. Educational awareness of potentially extreme weather caused by climate change is imperative for self-preparation, even with comprehensive and advanced weather forecasting.

As an example, sea level rise due to climate change can worsen tsunami-induced flooding (Li *et al.*, 2018). Such an extreme coastal hazard has proven to be disastrous for tourists at coastal destinations. In August 2018, Typhoon Jebi, the strongest typhoon to have landed in Japan since 1993, caused at least 13 deaths and 741 injuries. A tanker was blown into the bridge connecting Kansai International Airport, leaving 3,000 tourists stranded at the airport overnight (Takabatake *et al.*, 2018). In December 2018, a strong tsunami hit the Sunda Strait in Indonesia, causing runups of up to 13 meters on the adjacent coasts of Sumatra and more than 437 people, mostly tourists, were confirmed dead (Grilli *et al.*, 2019).

The need for prediction and preparation against extreme weather in tourism has therefore become even more evident with climate change. Whether located along coastal lines or up on the mountains, the tourist destinations are vulnerable in the face of extreme weather events. Climate change heavily affects regions that depend economically on tourism or areas in which the importance of the tourism industry is expected to grow in the future (Scott *et al.*, 2019). The use of big data analytics and artificial intelligence (AI) applications can benefit the development of forecasting and preparedness of disastrous weather events in outdoor recreation and tourism.

Climate change–related extreme weather events and their relation to tourism is an emerging field of education and research. Several studies have mentioned the risk of climate change to various tourism sectors, such as snow tourism (Elsasser and Bürki, 2002; Steiger *et al.*, 2019) and coastal and ocean tourism (Arabadzhyan *et al.*, 2021; Wolf *et al.*, 2021). The objective of this study is to categorize the impact of climate change on tourist destinations with regard to extreme weather-related risks in outdoor recreation and tourism. Managerial implications for policymakers and stakeholders are discussed.

This study seeks to help bridge this gap and its primary contributions includes the following:

- providing a summarized overview of the risks associated with climate change in terms of tourist experiential value for educational implications; and
- revealing the role of data analytics in disaster management in the context of tourism and climate change for tourism education.

2. Methodology

In the tourism industry, disaster and risk management is defined as the planning and implementation of the processes aimed to manage disasters and risks on tourism destinations (Robertson *et al.*, 2006). To provide proper process, knowledge of risk and disaster assessments is needed. To outline the risks from climate change associated with tourism, this study uses the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Prisma) (Moher *et al.*, 2009) for identification, screening, checking for eligibility and finding relevant literature for further categorization.

Robertson *et al.* (2006) provided an overview of generic risk management process. The framework included five steps:

(1) establish the context;
(2) identify risks;
(3) analyze risks;
(4) evaluate risks; and
(5) treat risks.

According to the United Nations Environment Program Handbook for Disaster Risk Management for Coastal Tourism, disaster risk management includes a five-step process:

(1) identifying hazard risks;
(2) assessing a community's vulnerability to the risk;
(3) developing a preparedness and mitigation plan;
(4) implementing the plan; and
(5) monitoring, evaluating, revising and updating the plan for continuous improvement Shurland and de Jong (2008).

On the topic of risk management, Mikulić *et al.* (2018) stated that integrated risk management is still a new approach. To bridge that gap they provided an integrated risk management approach with a framework including seven steps:

(1) define destination objectives;
(2) analyze of external and internal environment;
(3) risk identification;
(4) risk assessment;
(5) risk mapping;
(6) risk management decisions; and
(7) monitor and review continuously.

In this study, a metadata of literature review was first conducted to examine the issues associated with climate change risks and factors and how they affect the tourism industry with educational implications. Based on this literature review, the various risks and threats posed by climate change were identified and explained. A framework was designed to illustrate how policymakers and other stakeholders (e.g. residents, local businesses, tourists and local government) in the tourism industry could better understand, consider and react to the risks posed by climate change. Prisma procedure is applied in this study to extract findings in the literature relevant to climate change risks in tourism. The importance of big data analytics and AI applications to help enhance disaster management systems concerning climate change risks is also discussed. The full content of the resulting eligible studies has been thoroughly examined and discussed in terms of two important issues:

(1) impact of climate change on experiential and recreational value in tourism; and
(2) educational implications for prediction and preparation in disaster prevention.

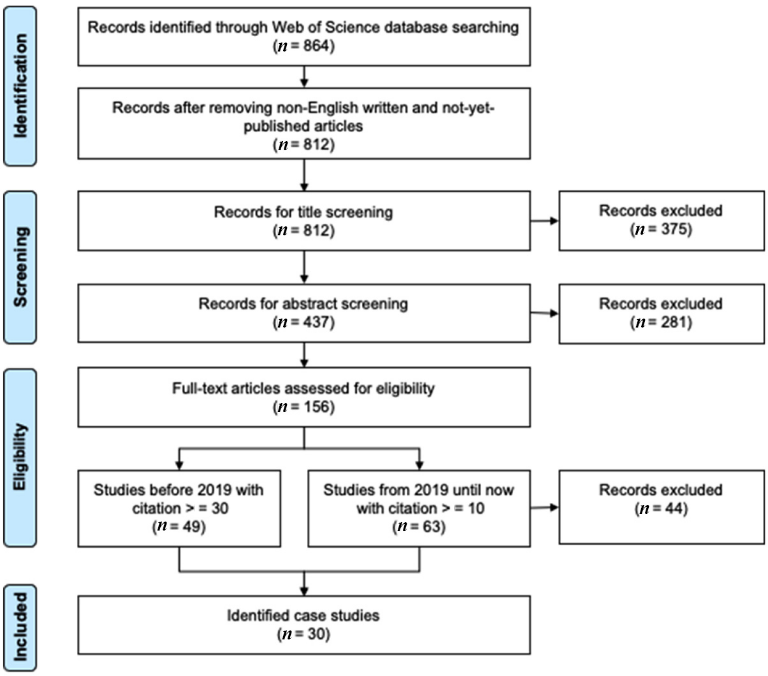
3. Results

The Prisma process includes identification, screening, checking for eligibility and locating relevant literature. Only articles with main keywords climate change risks in tourism from 2000 to 2021 were selected for further process. There was a total of 864 results from Web of Science database searching in the first step. By the last step, to determine the articles to be included, measure of individual article quality which is based on the frequency of citations was used to apply (Caon *et al.*, 2020; Moed, 2005; Sendhilkumar *et al.*, 2013). Articles published during the period 2000–2018 were included only if their citations are equal to or above 30, while those published during the 2019–2021 period with at least 10 citations were included. Articles with significant findings were summarized. The methodological treatment for literature review following Prisma analysis (Moher *et al.*, 2009) is illustrated in Figure 1.

A survey of the literature was administered to identify the present and potential risks posed by climate change to modern tourist destinations. Table 1 provides a list of the literature examining the risks associated with climate change for tourist destinations, and Table 2 summaries the findings in relevant articles.

Based on a thoroughly examination of relevant literature, risks and threats posed by climate change could be categorized into following four areas:

(1) reduced experiential value in outdoor winter recreation;
(2) reduced value in beach scenery and comfort;
(3) land degradation and reduced biodiversity; and
(4) reduced value in personal safety and comfort in tourism.



Source: From this research

Figure 1.
A flowchart of data generation based on Prisma analysis

Risk associated with climate change for tourist destinations	Related literature from 2000 to 2021
Reduced experiential value in outdoor winter recreation	(Burakowski and Magnusson, 2012; Gilaberte-Búrdalo *et al.*, 2014; Moen and Fredman, 2007; Neuvonen *et al.*, 2015; Rutty *et al.*, 2017; Scott *et al.*, 2019; Smith *et al.*, 2016; Steiger *et al.*, 2021; Steiger and Scott, 2020; Tervo-Kankare *et al.*, 2013; Wilkins *et al.*, 2018)
Reduced value in beach scenery and comfort	(Abuodha and Woodroffe, 2006; Johnson *et al.*, 2015; Masselink *et al.*, 2020; Mullin *et al.*, 2019; Ranasinghe, 2016; Saurí *et al.*, 2013; Scott *et al.*, 2012; Toimil *et al.*, 2018; Vitousek *et al.*, 2017)
Land degradation and reduced biodiversity	(Aukema *et al.*, 2017; Bellard et al., 2012, 2014; Bhuiyan *et al.*, 2018; Chen *et al.*, 2015; Dube and Nhamo, 2020; Rinawati *et al.*, 2013)
Reduced value in personal safety and comfort in tourism	(Lau *et al.*, 2015; Lhotka *et al.*, 2018; Rutty and Scott, 2010)

Source: Created by authors

Table 1. The impact of climate change on tourist destinations

These are elaborated below.

3.1 Reduced experiential value in outdoor winter recreation

Winter- and snow-related recreational or sporting activities represent a large and prosperous industry. These activities include snow skiing, winter hiking, snowboarding, fat biking, snow climbing and so on – activities that are expanding in popularity, especially in countries with cold winter climates, such as Scandinavian countries (Vanat, 2014). Several reports have shown that climate change risks the sustainability and expansion of the snow tourism industry (Scott *et al.*, 2021, 2019; Steiger *et al.*, 2019; Willibald *et al.*, 2021). Owing to global warming, higher temperatures could potentially lead to poorer snow quality, shorter and shifting skiing seasons, and less snow cover (Wilkins *et al.*, 2021). Although it has been pointed out that many climate risk studies associated with snow tourism overestimate risks as they do not consider artificial snowmaking (Scott *et al.*, 2021), there are still limits to the compensating effects of snowmaking (Scott *et al.*, 2019; Wilkins *et al.*, 2021). Also, snow making uses high amount of energy and water. Less snow cover and other adverse circumstances may lead to undesired effects on tourists that negatively impact the industry, such as “activity substitution,” where tourist replace snow-related leisure with other activities (Steiger *et al.*, 2019).

3.2 Reduced value in beach scenery and comfort

In tropical climate, tourism relies on the attraction and quality of coastal and marine environment. The rise of sea-level induced by climate change could lead to severe beach erosions, storm surges, reduced coastal areas and flooding, which can consequently negatively affect tourists’ experiences of the destination and decrease the desire of revisiting the site (Abuodha and Woodroffe, 2006; Uyarra *et al.*, 2005; van Putten *et al.*, 2014). Coral reefs may be damaged by warming waters (McManus *et al.*, 2021), which further reduce the quality of these coastal tourist sites and the corresponding flow of visiting tourists.

3.3 Land degradation and reduced biodiversity

Climate change may inflict great harm on landscapes through increase in frequency and intensity of extreme weather events such as floods and storms. Studies have suggested that climate change can lead to loss of habitats and negatively influence the migrations of species (Pallarés *et al.*, 2021; Worm and Lotze, 2021). These can further lead to extinction of species,

Impact study	Summary
Reduced experiential value in outdoor winter recreation	
Gilaberte-Búrdalo *et al.* (2014)	Climate change poses severe risk to the snow tourism industry through reduced snowfall, especially at low altitudes
Rutty *et al.* (2017)	Supply-side operations for the ski industry are more likely to be negatively affected by climate change than skiing demand
Scott *et al.* (2019)	Snowmaking adaptation may not be sufficient to meet the negative consequences of climate change for the snow tourism industry in Ontario, Canada
Scott *et al.* (2021)	Climate change will lead to significant regional shifts in demand in snow tourism in Austria
Reduced value in beach scenery and comfort	
Abuodha and Woodroffe (2006)	Coastal vulnerability index was used to evaluated 24.8 km of beaches in Illawarra and Moruya areas, Australia. The result indicated that 40.6% of the selected shoreline is identified from extreme to high vulnerability because of future sea-level rise
Scott *et al.* (2012)	A scenario analysis of a one-meter rise in sea levels for the Caribbean suggested that 29% of resort properties would be at risk of being completely flooded and that 49% and 60% would be at risk of beach erosion
Toimil *et al.* (2018)	Fifty-seven beaches in Asturias (Spain) were monitored to study the effects of erosion on the values of beach recreation. The study showed that by 2100, disappearance of beaches would happen due to climate change even with a 5-year retreat. The median value of expected cumulative damage would value up to 237.81m EUR
Land degradation and reduced biodiversity	
Bellard *et al.* (2012)	A review of influences of climate change on biodiversity revealed severe risk of species loss and diversity, and further extinction
Bhuiyan *et al.* (2018)	Climate change significantly caused biodiversity loss in Asia
Dube and Nhamo (2020)	A study investigating the evidence and impact of climate variability and climate change on Kruger National Park, South Africa, revealed that climate change significantly affected wildlife in a negative manner
Reduced value in personal safety and comfort in tourism	
Lau *et al.* (2015)	The study used a climate change model to determine that three European cities (i.e. Gothenburg in Sweden, Frankfurt in Germany and Porto in Portugal) would experience relatively warmer urban temperatures due to climate change
Rutty and Scott (2010)	This study measures tourist perceptions of "unacceptably hot" and measures them against future predictions of increases in temperature for tourist spots in the Mediterranean region and found that in the long-term several destinations would be unacceptably hot
Lhotka *et al.* (2018)	This study used a large ensemble of regional climate model simulations to predict that in the near future (2020–2049), heat waves would double in frequency compared to past periods

Source: Created by authors

Table 2.
A Summary of studies on the impact of climate change on tourist destinations

especially in ecologically vulnerable systems such as wetlands (Estrela-Segrelles *et al.*, 2021), a disaster that is not always properly recorded by governments (Chiba *et al.*, 2017). Further example revealed that climate change could explain the patterns of loss of species in Concord, Massachusetts (Willis *et al.*, 2008). Román-Palacios and Wiens (2020) reported that increases in the mean annual and hottest yearly temperatures may lead to the extinction of roughly 57%–70% of the examined plant and animal species worldwide. In addition to this, the land degradation resulted from climate change may also affect the tourism industry. For instance, the increased incidences of forest fires, as recently happened in Australia and California (USA), led to extensive areas of damaged and disrupted ecosystems, as well as significant losses of biodiversity (Rein and Huang, 2021). The severe changes to the landscapes would also reduce tourist flow and damage the economy of tourist industries.

3.4 Reduced value in personal safety and comfort in tourism

Climate change may also result in reduced tourist comfort and safety. The increased incidence of typhoons or tropical storms due to climate change in coastal destinations obviously puts tourists at risk. Research has shown that cruise ships and airplanes were both negatively affected by the incidence of hurricanes at popular tourist destinations, such as the Caribbean and the Canary Islands (Carballo Chanfón *et al.*, 2021; Yanes Luque *et al.*, 2021). In addition, changes in climate, for instance increased temperature, may also result in conditions like intense heat waves that reduce comfort for tourists (Matzarakis *et al.*, 2013). These conditions may reduce the likelihood of tourists returning to visit or they may stay for shorter periods at these destinations.

4. Discussion and proposing a risk management framework

The risks associated with climate change are often described and analyzed through the impact chain (IC) as defined by the IPCC (Arabadzhyan *et al.*, 2021; Masson-Delmotte *et al.*, 2021). Risk is categorized based on the interactions between hazards, natural vulnerability and socioeconomic vulnerability (Arabadzhyan *et al.*, 2021; Brooks, 2003). While particular areas are susceptible to natural hazards because of their geographic location, the ability to respond and adapt to climate change can be critical in tourism with essential educational implications.

A framework incorporating technology and data analytics into the disaster management is illustrated in Figure 2. Risks associated with climate change on outdoor and recreation tourism need to be further analyzed to better understand in reducing potential damage caused by catastrophic occurrences.

Implications to big data analytics, early warning systems and communication challenges are discussed below.

4.1 Big data, artificial intelligence, machine learning and quantum computing opportunities in outdoor recreation and tourism

Big data analytics are beneficial in improving the efficiency and effectiveness of disaster management. Big data analytics have been used in industry and academia for market intelligence (Dolnicar and Ring, 2014). In the future, disasters could be tracked rapidly, accurately and precisely in real time in saving lives and reducing damages during evacuation or recovery. Big data modeling/simulation tools and combining data from drones, sensors or robots can assist tourists and first responders in mitigating risks to reduce damage and loss caused by climate-related disasters.

Machine/Deep learning (M/D/L) and AI tools have evolved to provide timely analysis (Ford *et al.*, 2016; Guo *et al.*, 2015; Hassani *et al.*, 2019). For example, an AI program was used to classify social media messages posted during disasters in real time (Imran *et al.*, 2014). A deep learning framework was used to extract information from YouTube videos in the context of flood damage, fire, landslide, tornado and lightning (Pouyanfar and Chen, 2017). Using social media mining, facial recognition technology can help in connecting missing people with their families (Charalabidis *et al.*, 2014). In addition, AI and M/D/L tools assist in predicting and detecting extreme weather events and provide help in conducting rescue operations. For example, using AI to analyze satellite imageries, Descartes Labs launched its

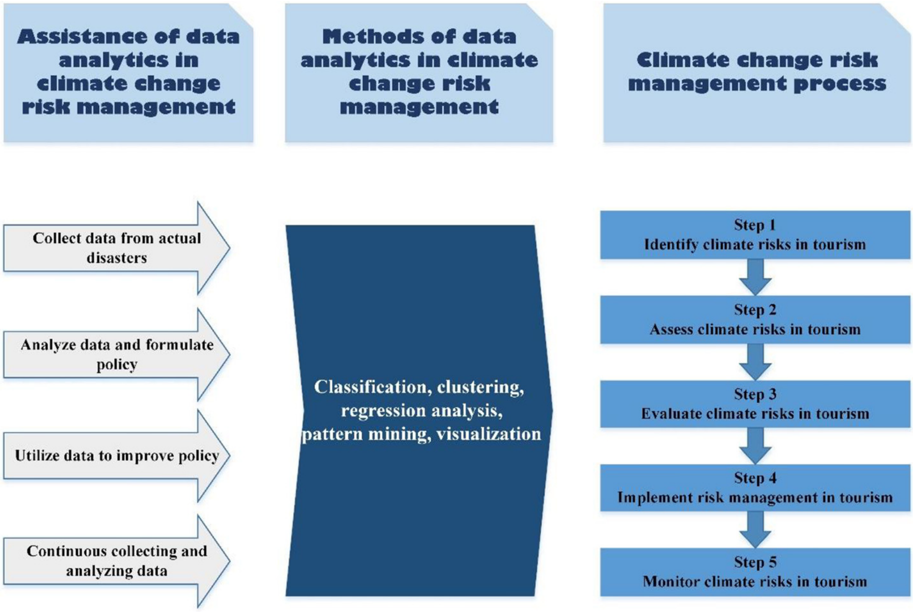


Figure 2.
The integrated framework of risk management in response to climate change in tourism

Source: From this research

US wildfire detector in July 2019 (Padron-Hidalgo *et al.*, 2019). Moreover, M/D/L tools can automatically identify texts and tweets related to a particular crisis, which helps first responders and rescue workers save the lives of trapped victims and make rescue efforts safer, better coordinated and less time-consuming. Big data analytics have been used to monitor and detect natural hazards, mitigate their effects, assist in relief efforts and contribute to recovery and reconstruction processes (Yu *et al.*, 2018). AI and M/D/L can provide enhanced warnings about extreme events (Huntingford *et al.*, 2019). Convolutional neutral networks, a deep learning technique, have been used for weather prediction up to 5 days ahead of time with 94% accuracy in mitigating climate-related risks (Chattopadhyay *et al.*, 2020).

Disaster management related to climate change risks can be more efficient once all the data acquired from heterogeneous sources is available in real time. This poses an enormous challenge in integrating cyberphysical infrastructure (e.g. data storage and associated energy usage and security and privacy). Current and future advances in quantum computing will provide an opportunity for large-scale storage to allow faster than real-time analyses to mitigate climate change–related risks.

Recent works that apply big data in outdoor recreation and tourism with climate change considerations is listed in Table 1. Although big data has been largely applied in climate change and weather forecasting, catastrophic disaster management in outdoor recreation and tourism has been overlooked in the tourism education literature. In catastrophic disaster management in outdoor recreation and tourism, protocols are inconsistent and incomprehensively implemented in various tourist sites. In the future, the importance of catastrophic disaster management in outdoor recreation and tourism cannot be overemphasized. Researchers and stakeholders are encouraged to examine climate changes with big data applications in catastrophic disaster management and to develop sustainable evaluation protocols that can be implemented for outdoor and recreation tourism education.

4.2 Adequate warning systems

Safety alarms for extreme weather are crucial in outdoor recreation and tourism. Early warning systems are critical tools for earthquakes, floods, droughts, storms and other hazards. Many systems are in operation worldwide; however, there are still high-risk areas that remain without these systems (Zommers and Singh, 2014), and these regions are usually where the outdoor recreation and tourism industry contributes a large proportion to economic development. Advances in data storage and structured analytical modeling have made forecasting of devastating weather more accurate (Boult and Evans, 2021). Technology-enhanced warning systems reduce human losses, economic losses, emotional stresses and partial travel caused by weather disasters.

4.3 Communication challenges in catastrophic disaster management in outdoor recreation and tourism

Evacuation protocols for catastrophic circumstances at tourist destinations are often neglected. Air travel provides an example of a reinforced evacuation protocol. Before taking off, each passenger is informed of the emergency procedure, even though the possibility of an emergency is extremely low. Hotels are another example, with regulated fire evacuation procedures in place in case of fire. It is especially critical in places vulnerable to extreme weather-related events, such as tsunami events or heat waves, for evacuation procedures to be in place and communicated clearly to tourists prior to their travel or visit.

A new generation of mobile broadband networks that provide wireless communication is spurring the development of more sophisticated location-based services using the global positioning system (MacKay and Vogt, 2012). Tourists rely heavily on technology-driven devices to connect to the outside world, but when a catastrophic disaster affects a location, within a short time, electricity and Wi-Fi connections go down. Tourists become disconnected. It is imperative to inform all potential or expected tourists of the escape plans or fail-safe protections that can be offered to them when extreme weather or no-escape natural disasters (e.g. landslides, or avalanches) occur (Huan *et al.*, 2004). Additionally, tourists may not be proficient enough in the local language to communicate with the locals if there are special needs.

5. Policy implications

Disaster management in the context of climate change in the tourism industry provides opportunities to improve the tourist experience. The various threats posed by climate change include:

- reduced experiential value in outdoor winter recreation (Rutty *et al.*, 2017; Scott *et al.*, 2019);
- reduced value in beach scenery and comfort (Abuodha and Woodroffe, 2006; Dube and Nhamo, 2020; Scott *et al.*, 2012);
- land degradation and reduced biodiversity (Bellard *et al.*, 2012; Dube and Nhamo, 2020); and
- reduced value in personal safety and comfort in tourism (Lau *et al.*, 2015; Lhotka *et al.*, 2018).

By considering these various risks and threats, policymakers and stakeholders involved in the tourism and recreational industry may apply big data analytics and technology to forecast adverse weather events, both for the short- and long-terms in mitigating climate-change risks. The process involves the IPCC approach in ICs, considering the complex relationships between hazards, natural vulnerability, climate change and socioeconomic vulnerability (Arabadzhyan *et al.*, 2021; Brooks, 2003; Masson-Delmotte *et al.*, 2021). Contingency plans should be drafted to respond a disaster, as well as a framework to learn from disaster events stemming from climate change.

A properly designed disaster management system allows stakeholders to improve the process continually. Data collected during actual disasters can be used to ensure that response times are faster and more efficient. For example, data analytics can be used to determine which channels of communication people relied on the most to spread information or even misinformation during disasters, with the government taking measures to take advantage of such information. The process of continual data collection, policy making and improvement that could result from a disaster management system to prevent catastrophic circumstances in tourism education.

6. Conclusions

The role of big data analytics in risk management in the context of climate-change related disaster is not widely discussed, as big data and climate change effects on tourism education in general are relatively new topics. We sought to bridge this gap by discussing and presenting a preliminary framework that incorporates data analytics and that allows policymakers and stakeholders to reduce and react to risks in the tourism industry in a proactive manner with educational implications.

The purpose of this article is to urge researchers and stakeholders to further examine the risks associated with climate change on outdoor and recreation tourism by considering the ICs associated with the consequences and effects of climate change. It also focuses on the importance of using big data applications in catastrophic disaster management and risk reduction. Recommendations for improvement in disaster management in the context of climate change for tourism education include the following:

- Sharing outdoor and recreation tourism data to the public so analytics can be applied to model the impacts of climate change on outdoor and recreation tourism.
- Improving the speed, reliability and accuracy of forecasting models using big data analytics specifically for outdoor and recreation tourists to enhance understanding of possible weather-related disasters and escape procedures.
- Developing AI and M/D/L tools for specific aspects of weather-related disasters that impact tourism and stakeholders for tourism education.
- Emphasizing prevention and mitigation strategies over evacuation strategies.
- Disseminating readiness and accurate information to stakeholders in mitigating risks. An example is the use of remote sensing technology and combining it with AI/ML to classify wildfires, hurricanes, flood events and subsequently running simulations faster than real time to predict economic/human impact and to mitigate climate change risks.

In conclusion, in the era of climate change, risk management should incorporate big data analytics to enhance forecast accuracy, efficiency and effectiveness in disaster management in tourism education. Such an approach can benefit tourism education research and stakeholders who manage resources related to weather-related disaster rescue. Moreover, policymakers and stakeholders should properly understand the nature of the risks posed by climate change. The development of protocols and tools to enhance the welfare of tourists visiting destinations vulnerable to climate change is imperative and advantageous in future tourism educational research.

References

Abbas, J., Mubeen, R., Iorember, P.T., Raza, S. and Mamirkulova, G. (2021), "Exploring the impact of COVID-19 on tourism: transformational potential and implications for a sustainable recovery of the travel and leisure industry", *Current Research in Behavioral Sciences*, Vol. 2, p. 100033, doi: 10.1016/j.crbeha.2021.100033.

Abuodha, P.A. and Woodroffe, C.D. (2006), "Assessing vulnerability of coasts to climate change: a review of approaches and their application to the Australian Coast", *GIS for the Coastal Zone: A Selection of Papers from CoastGIS 2006*.

Amelung, B. and Nicholls, S. (2014), "Implications of climate change for tourism in Australia", *Tourism Management*, Vol. 41, pp. 228-244, doi: 10.1016/j.tourman.2013.10.002.

Arabadzhyan, A., Figini, P., García, C., González, M.M., Lam-González, Y.E. and León, C.J. (2021), "Climate change, coastal tourism, and impact chains – a literature review", *Current Issues in Tourism*, Vol. 24 No. 16, pp. 2233-2268, doi: 10.1080/13683500.2020.1825351.

Atwoli, L., Baqui, A.H., Benfield, T., Bosurgi, R., Godlee, F., Hancocks, S., Horton, R., Laybourn-Langton, L., Monteiro, C.A., Norman, I., Patrick, K., Praities, N., Rikkert, M.G.O., Rubin, E.J., Sahni, P., Smith, R., Talley, N., Turale, S. and Vazquez, D. (2021), "#healthyclimate: call for emergency action to limit global temperature increases, restore biodiversity, and protect health", *JMIR Public Health and Surveillance*, Vol. 7 No. 9, p. e32958, doi: 10.2196/32958.

Aukema, J.E., Pricope, N.G., Husak, G.J. and Lopez-Carr, D. (2017), "Biodiversity areas under threat: overlap of climate change and population pressures on the world's biodiversity priorities", *Plos One*, Vol. 12 No. 1, p. e0170615, doi: 10.1371/journal.pone.0170615.

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W. and Courchamp, F. (2012), "Impacts of climate change on the future of biodiversity", *Ecology Letters*, Vol. 15 No. 4, pp. 365-377, doi: 10.1111/j.1461-0248.2011.01736.x.

Bellard, C., Leclerc, C., Leroy, B., Bakkenes, M., Veloz, S., Thuiller, W. and Courchamp, F. (2014), "Vulnerability of biodiversity hotspots to global change", *Global Ecology and Biogeography*, Vol. 23 No. 12, pp. 1376-1386, doi: 10.1111/geb.12228.

Bhuiyan, M.A., Jabeen, M., Zaman, K., Khan, A., Ahmad, J. and Hishan, S.S. (2018), "The impact of climate change and energy resources on biodiversity loss: evidence from a panel of selected Asian countries", *Renewable Energy*, Vol. 117, pp. 324-340, doi: 10.1016/j.renene.2017.10.054.

Boult, V.L. and Evans, L.C. (2021), "Mechanisms matter: predicting the ecological impacts of global change", *Global Change Biology*, Vol. 27 No. 9, pp. 1689-1691, doi: 10.1111/gcb.15527.

Brooks, N. (2003), "Vulnerability, risk and adaptation: a conceptual framework", Tyndall Centre for Climate Change Research. Tyndall Centre for Climate Change Research, February.

Burakowski, E. and Magnusson, M. (2012), "Climate impacts on the winter tourism economy in the United States", *Prepared for Protect Our Winters (POW) and Natural Resources Defense Council (NRDC)*, December.

Caon, M., Trapp, J. and Baldock, C. (2020), "Citations are a good way to determine the quality of research", *Physical and Engineering Sciences in Medicine*, Vol. 43 No. 4, pp. 1145-1148, doi: 10.1007/s13246-020-00941-9.

Carballo Chanfón, P., Mohan, P., Strobl, E. and Tveit, T. (2021), "The impact of hurricane strikes on cruise ship and airplane tourist arrivals in the Caribbean", *Tourism Economics*, Vol. 29 No. 1, pp. 68-91, doi: 10.1177/13548166211037406.

Charalabidis, Y., Loukis, E.N., Androutsopoulou, A., Karkaletsis, V. and Triantafillou, A. (2014), "Passive crowdsourcing in government using social media", *Transforming Government: People, Process and Policy*, Vol. 8 No. 2, pp. 283-308, doi: 10.1108/TG-09-2013-0035.

Chattopadhyay, A., Hassanzadeh, P. and Pasha, S. (2020), "Predicting clustered weather patterns: a test case for applications of convolutional neural networks to spatio-temporal climate data", *Scientific Reports*, Vol. 10 No. 1, p. 1317, doi: 10.1038/s41598-020-57897-9.

Chen, P.Y., Chen, C.C., Chu, L.F. and McCarl, B. (2015), "Evaluating the economic damage of climate change on global coral reefs", *Global Environmental Change*, Vol. 30, pp. 12-20, doi: 10.1016/j.gloenvcha.2014.10.011.

Chiba, Y., Shaw, R. and Prabhakar, S. (2017), "Climate change-related non-economic loss and damage in Bangladesh and Japan", *International Journal of Climate Change Strategies and Management*, Vol. 9 No. 2, pp. 166-183, doi: 10.1108/IJCCSM-05-2016-0065.

Dolnicar, S. and Ring, A. (2014), "Tourism marketing research: past, present and future", *Annals of Tourism Research*, Vol. 47, pp. 31-47, doi: 10.1016/j.annals.2014.03.008.

Dube, K. and Nhamo, G. (2020), "Evidence and impact of climate change on South African national parks: potential implications for tourism in the Kruger national park", *Environmental Development*, Vol. 33, p. 100485, doi: 10.1016/j.envdev.2019.100485.

Elsasser, H. and Bürki, R. (2002), "Climate change as a threat to tourism in the alps", *Climate Research*, Vol. 20 No. 3, pp. 253-257, doi: 10.3354/cr020253.

Estrela-Segrelles, C., Gómez-Martinez, G. and Pérez-Martín, M.Á. (2021), "Risk assessment of climate change impacts on mediterranean coastal wetlands: application in Júcar river basin district (Spain)", *Science of the Total Environment*, Vol. 790, p. 148032, doi: 10.1016/j.scitotenv.2021.148032.

Ford, J.D., Tilleard, S.E., Berrang-Ford, L., Araos, M., Biesbroek, R., Lesnikowski, A.C., MacDonald, G.K., Hsu, A., Chen, C. and Bizikova, L. (2016), "Big data has big potential for applications to climate change adaptation", *Proceedings of the National Academy of Sciences*, Vol. 113 No. 39, pp. 10729-10732, doi: 10.1073/pnas.1614023113.

Gilaberte-Búrdalo, M., López-Martín, F., Pino-Otín, M.R. and López-Moreno, J.I. (2014), "Impacts of climate change on ski industry", *Environmental Science and Policy*, Vol. 44, pp. 51-61, doi: 10.1016/j.envsci.2014.07.003.

Goh, C. (2012), "Exploring impact of climate on tourism demand", *Annals of Tourism Research*, Vol. 39 No. 4, pp. 1859-1883, doi: 10.1016/j.annals.2012.05.027.

Grilli, S.T., Tappin, D.R., Carey, S., Watt, S.F.L., Ward, S.N., Grilli, A.R., Engwell, S.L., Zhang, C., Kirby, J.T., Schambach, L. and Muin, M. (2019), "Modelling of the tsunami from the December 22, 2018 lateral collapse of Anak Krakatau volcano in the Sunda straits, Indonesia", *Scientific Reports*, Vol. 9 No. 1, p. 11946, doi: 10.1038/s41598-019-48327-6.

Guo, H.D., Zhang, L. and Zhu, L.W. (2015), "Earth observation big data for climate change research", *Advances in Climate Change Research*, Vol. 6 No. 2, pp. 108-117, doi: 10.1016/j.accre.2015.09.007.

Hassani, H., Huang, X. and Silva, A.E. (2019), "Big data and climate change", *Big Data and Cognitive Computing*, Vol. 3 No. 1, p. 12, doi: 10.3390/bdcc3010012.

Huan, T.C., Beaman, J. and Shelby, L. (2004), "No-escape natural disaster: mitigating impacts on tourism", *Tourism. Annals of Tourism Research*, Vol. 31 No. 2, pp. 255-273, doi: 10.1016/j.annals.2003.10.003.

Huntingford, C., Jeffers, E.S., Bonsall, M.B., Christensen, H.M., Lees, T. and Yang, H. (2019), "Machine learning and artificial intelligence to aid climate change research and preparedness", *Environmental Research Letters*, Vol. 14 No. 12, p. 124007, doi: 10.1088/1748-9326/ab4e55.

Imran, M., Castillo, C., Lucas, J., Meier, P. and Vieweg, S. (2014), "AIDR: artificial intelligence for disaster response", *WWW 2014 Companion – Proceedings of the 23rd International Conference on World Wide Web*, doi: 10.1145/2567948.2577034.

Johnson, J.M., Moore, L.J., Ells, K., Murray, A.B., Adams, P.N., Mackenzie, R.A. and Jaeger, J.M. (2015), "Recent shifts in coastline change and shoreline stabilization linked to storm climate change", *Earth Surface Processes and Landforms*, Vol. 40 No. 5, pp. 569-585, doi: 10.1002/esp.3650.

Lau, K.K.L., Lindberg, F., Rayner, D. and Thorsson, S. (2015), "The effect of urban geometry on mean radiant temperature under future climate change: a study of three European cities", *International Journal of Biometeorology*, Vol. 59 No. 7, pp. 799-814, doi: 10.1007/s00484-014-0898-1.

Lhotka, O., Kyselý, J. and Farda, A. (2018), "Climate change scenarios of heat waves in central Europe and their uncertainties", *Theoretical and Applied Climatology*, Vol. 131 Nos 3/4, pp. 1043-1054, doi: 10.1007/s00704-016-2031-3.

Li, L., Switzer, A.D., Wang, Y., Chan, C.H., Qiu, Q. and Weiss, R. (2018), "A modest 0.5-m rise in sea level will double the tsunami hazard in Macau", *Science Advances*, Vol. 4 No. 8, p. eaat1180, doi: 10.1126/sciadv.aat1180.

Lock, S. (2020), "Global tourism industry - statistics and facts | Statista", Statista.

McManus, L.C., Forrest, D.L., Tekwa, E.W., Schindler, D.E., Colton, M.A., Webster, M.M., Essington, T.E., Palumbi, S.R., Mumby, P.J. and Pinsky, M.L. (2021), "Evolution and connectivity influence the persistence and recovery of coral reefs under climate change in the Caribbean, southwest pacific, and coral triangle", *Global Change Biology*, Vol. 27 No. 18, pp. 4307-4321, doi: 10.1111/gcb.15725.

MacKay, K. and Vogt, C. (2012), "Information technology in everyday and vacation contexts", *Annals of Tourism Research*, Vol. 39 No. 3, pp. 1380-1401, doi: 10.1016/j.annals.2012.02.001.

Manolas, E. (2011), "Global warming: a very short introduction", *International Journal of Climate Change Strategies and Management*, Vol. 3 No. 1, pp. 109-110, doi: 10.1108/17568691111107961.

Masselink, G., Russell, P., Rennie, A., Brooks, S. and Spencer, T. (2020), "The impacts of climate change on coastal geomorphology and coastal erosion relevant to the coastal and marine environment around the UK", *Marine Climate Change Impacts Partnership (MCCIP) Science Review*, Vol. 2020, pp. 158-189.

Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R. and Zhou, B. (Eds) (2021), *IPCC, 2021: Climate Change 2021: The Physical Science Basis*, Cambridge University Press, New York, NY.

Matzarakis, A., Rammelberg, J. and Junk, J. (2013), "Assessment of thermal bioclimate and tourism climate potential for central Europe-the example of Luxembourg", *Theoretical and Applied Climatology*, Vol. 114 Nos 1/2, pp. 193-202, doi: 10.1007/s00704-013-0835-y.

Mikulić, J., Miloš Sprčić, D., Holiček, H. and Prebežac, D. (2018), "Strategic crisis management in tourism: an application of integrated risk management principles to the Croatian tourism industry", *Journal of Destination Marketing and Management*, Vol. 7, pp. 36-38, doi: 10.1016/j.jdmm.2016.08.001.

Moed, H.F. (2005), "Citation analysis in research evaluation", *Proceedings of ISSI 2005: 10th International Conference of the International Society for Scientometrics and Informetrics*, Vol. 2, Springer Science\& Business Media, doi: 10.5117/2006.019.002.007.

Moen, J. and Fredman, P. (2007), "Effects of climate change on alpine skiing in Sweden", *Journal of Sustainable Tourism*, Vol. 15 No. 4, pp. 418-437, doi: 10.2167/jost624.0.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G. and Prisma, Group. (2009), "Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement", *Annals of Internal Medicine*, Vol. 151 No. 4, pp. 264-269, doi: 10.7326/0003-4819-151-4-200908180-00135.

Mullin, M., Smith, M.D. and McNamara, D.E. (2019), "Paying to save the beach: effects of local finance decisions on coastal management", *Climatic Change*, Vol. 152 No. 2, pp. 275-289, doi: 10.1007/s10584-018-2191-5.

Mushawemhuka, W., Hoogendoorn, G. and Fitchett, J.M. (2021), "Implications of misleading news reporting on tourism at the Victoria falls, Zimbabwe", *Weather, Climate, and Society*, Vol. 13 No. 4, pp. 1015-1025, doi: 10.1175/WCAS-D-21-0013.1.

Neuvonen, M., Sievänen, T., Fronzek, S., Lahtinen, I., Veijalainen, N. and Carter, T.R. (2015), "Vulnerability of cross-country skiing to climate change in Finland – an interactive mapping tool", *Journal of Outdoor Recreation and Tourism*, Vol. 11, pp. 64-79, doi: 10.1016/j.jort.2015.06.010.

Nhamo, G., Dube, K. and Chikodzi, D. (2021), "Victoria falls water flow regimes: a tale of two half centuries", *The Increasing Risk of Floods and Tornadoes in Southern Africa*, Springer International Publishing, Switzerland, doi: 10.1007/978-3-030-74192-1_5.

Padron-Hidalgo, J.A., Laparra, V., Longbotham, N. and Camps-Valls, G. (2019), "Kernel anomalous change detection for remote sensing imagery", *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 57 No. 10, pp. 7743-7755, doi: 10.1109/TGRS.2019.2916212.

Pallarés, S., Colado, R., Botella-Cruz, M., Montes, A., Balart-García, P., Bilton, D.T., Millán, A., Ribera, I. and Sánchez-Fernández, D. (2021), "Loss of heat acclimation capacity could leave subterranean specialists highly sensitive to climate change", *Animal Conservation*, Vol. 24 No. 3, pp. 482-490, doi: 10.1111/acv.12654.

Patton, A.I., Rathburn, S.L., Capps, D.M., McGrath, D. and Brown, R.A. (2021), "Ongoing landslide deformation in thawing permafrost", *Geophysical Research Letters*, Vol. 48 No. 16, p. e2021GL092959, doi: 10.1029/2021GL092959.

Pouyanfar, S. and Chen, S.C. (2017), "Automatic video event detection for imbalance data using enhanced ensemble deep learning", *International Journal of Semantic Computing*, Vol. 11 No. 1, pp. 85-109, doi: 10.1142/S1793351X17400050.

Ranasinghe, R. (2016), "Assessing climate change impacts on open sandy coasts: a review", *Earth-Science Reviews*, Vol. 160, pp. 320-332, doi: 10.1016/j.earscirev.2016.07.011.

Rein, G. and Huang, X. (2021), "Smouldering wildfires in peatlands, forests and the arctic: challenges and perspectives", *Current Opinion in Environmental Science and Health*, Vol. 24, p. 100296, doi: 10.1016/j.coesh.2021.100296.

Rinawati, F., Stein, K. and Lindner, A. (2013), "Climate change impacts on biodiversity-the setting of a lingering global crisis", *Diversity*, Vol. 5 No. 1, pp. 114-123, doi: 10.3390/d5010114.

Robertson, D., Kean, I. and Moore, S. (2006), "Tourism risk management: an authoritative guide to managing crises in tourism", *APEC International Centre for Sustainable Tourism (AICST)* (Issue December).

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J.A. (2009), "A safe operating space for humanity", *Nature*, Vol. 461 No. 7263, pp. 472-475, doi: 10.1038/461472a.

Román-Palaciosa, C. and Wiens, J.J. (2020), "Recent responses to climate change reveal the drivers of species extinction and survival", *PNAS*, Vol. 117 No. 8, pp. 4211-4217, doi: 10.1073/pnas.1913007117.

Roser, M. (2020), "Tourism", available at: https://ourworldindata.org/tourism

Rutty, M. and Scott, D. (2010), "Will the Mediterranean become 'too hot' for tourism? A reassessment", *Tourism and Hospitality, Planning and Development*, Vol. 7 No. 3, pp. 267-281, doi: 10.1080/1479053X.2010.502386.

Rutty, M., Scott, D., Johnson, P., Pons, M., Steiger, R. and Vilella, M. (2017), "Using ski industry response to climatic variability to assess climate change risk: an analogue study in Eastern Canada", *Tourism Management*, Vol. 58, pp. 196-204, doi: 10.1016/j.tourman.2016.10.020.

Saurí, D., Olcina, J., Fernando Vera, J., Martín-Vide, J., March, H., Serra-Llobet, A. and Padilla, E. (2013), "Tourism, climate change and water resources: coastal Mediterranean Spain as an example", *European Climate Vulnerabilities and Adaptation: A Spatial Planning Perspective*, John Wiley and Sons, Oxford, doi: 10.1002/9781118474822.ch13.

Scheyvens, R. and Biddulph, R. (2018), "Inclusive tourism development", *Tourism Geographies*, Vol. 20 No. 4, pp. 589-609, doi: 10.1080/14616688.2017.1381985.

Scott, D., Hall, C.M. and Gössling, S. (2019), "Global tourism vulnerability to climate change", *Annals of Tourism Research*, Vol. 77, pp. 49-61, doi: 10.1016/j.annals.2019.05.007.

Scott, D., Simpson, M.C. and Sim, R. (2012), "The vulnerability of Caribbean coastal tourism to scenarios of climate change related sea level rise", *Journal of Sustainable Tourism*, Vol. 20 No. 6, pp. 883-898, doi: 10.1080/09669582.2012.699063.

Scott, D., Steiger, R., Rutty, M., Knowles, N. and Rushton, B. (2021), "Future climate change risk in the US Midwestern ski industry", *Tourism Management Perspectives*, Vol. 40, p. 100875, doi: 10.1016/j.tmp.2021.100875.

Scott, D., Steiger, R., Rutty, M., Pons, M. and Johnson, P. (2019), "The differential futures of ski tourism in Ontario (Canada) under climate change: the limits of snowmaking adaptation", *Current Issues in Tourism*, Vol. 22 No. 11, pp. 1327-1342, doi: 10.1080/13683500.2017.1401984.

Sendhilkumar, S., Elakkiya, E. and Mahalakshmi, G.S. (2013), "Citation semantic based approaches to identify article quality", *Proceedings of international conference ICCSEA*, pp. 411-420, doi: 10.5121/csit.2013.3543.

Shurland, D. and de Jong, P. (2008), "Disaster risk management for coastal tourism destinations responding to climate change: a practical guide for decision makers", *United Nations Environment Programme*.

Smith, J.W., Seekamp, E., McCreary, A., Davenport, M., Kanazawa, M., Holmberg, K., Wilson, B. and Nieber, J. (2016), "Shifting demand for winter outdoor recreation along the North shore of lake superior under variable rates of climate change: a finite-mixture modeling approach", *Ecological Economics*, Vol. 123, pp. 1-13, doi: 10.1016/j.ecolecon.2015.12.010.

Steiger, R. and Scott, D. (2020), "Ski tourism in a warmer world: increased adaptation and regional economic impacts in Austria", *Tourism Management*, Vol. 77, p. 104032, doi: 10.1016/j.tourman.2019.104032.

Steiger, R., Damm, A., Prettenthaler, F. and Pröbstl-Haider, U. (2021), "Climate change and winter outdoor activities in Austria", *Journal of Outdoor Recreation and Tourism*, Vol. 34, p. 100330, doi: 10.1016/j.jort.2020.100330.

Steiger, R., Scott, D., Abegg, B., Pons, M. and Aall, C. (2019), "A critical review of climate change risk for ski tourism", *Current Issues in Tourism*, Vol. 22 No. 11, pp. 1343-1379, doi: 10.1080/13683500.2017.1410110.

Takabatake, T., Mäll, M., Esteban, M., Nakamura, R., Kyaw, T.O., Ishii, H., Valdez, J.J., Nishida, Y., Noya, F. and Shibayama, T. (2018), "Field survey of 2018 typhoon Jebi in Japan: lessons for disaster risk management", *Geosciences*, Vol. 8 No. 11, p. 412, doi: 10.3390/geosciences8110412.

Tervo-Kankare, K., Hall, C.M. and Saarinen, J. (2013), "Christmas tourists' perceptions to climate change in Rovaniemi, Finland", *Tourism Geographies*, Vol. 15 No. 2, pp. 292-317, doi: 10.1080/14616688.2012.726265.

Toimil, A., Díaz-Simal, P., Losada, I.J. and Camus, P. (2018), "Estimating the risk of loss of beach recreation value under climate change", *Tourism Management*, Vol. 68, pp. 387-400, doi: 10.1016/j.tourman.2018.03.024.

Uyarra, M.C., Côté, I.M., Gill, J.A., Tinch, R.R.T., Viner, D. and Watkinson, A.R. (2005), "Island-specific preferences of tourists for environmental features: implications of climate change for tourism-dependent states", *Environmental Conservation*, Vol. 32 No. 1, pp. 11-19, doi: 10.1017/S0376892904001808.

van Putten, I., Metcalf, S., Frusher, S., Marshall, N. and Tull, M. (2014), "Fishing for the impacts of climate change in the marine sector: a case study", *International Journal of Climate Change Strategies and Management*, Vol. 6 No. 4, pp. 421-441, doi: 10.1108/IJCCSM-01-2013-0002.

Vanat, L. (2014), 2014 international report on snow and mountain tourism: overview of the key industry figures for ski resorts, *RM World Reports*, Geneva, Switzerland.

Vitousek, S., Barnard, P.L. and Limber, P. (2017), "Can beaches survive climate change?", *Journal of Geophysical Research: Earth Surface*, Vol. 122 No. 4, pp. 1060-1067, doi: 10.1002/2017JF004308.

Wilkins, E.J., Akbar, H., Saley, T.C., Hager, R., Elkin, C.M., Belmont, P., Flint, C.G. and Smith, J.W. (2021), "Climate change and Utah ski resorts: impacts, perceptions, and adaptation strategies", *Mountain Research and Development*, Vol. 41 No. 3, p. R12, doi: 10.1659/MRD-JOURNAL-D-20-00065.1.

Wilkins, E., de Urioste-Stone, S., Weiskittel, A. and Gabe, T. (2018), "Effects of weather conditions on tourism spending: implications for future trends under climate change", *Journal of Travel Research*, Vol. 57 No. 8, pp. 1042-1053, doi: 10.1177/0047287517728591.

Willibald, F., Kotlarski, S., Ebner, P.P., Bavay, M., Marty, C., Trentini, F.V., Ludwig, R. and Grêt-Regamey, A. (2021), "Vulnerability of ski tourism towards internal climate variability and climate change in the Swiss Alps", *Science of the Total Environment*, Vol. 784, p. 147054, doi: 10.1016/j.scitotenv.2021.147054.

Willis, C.G., Ruhfel, B., Primack, R.B., Miller-Rushing, A.J. and Davis, C.C. (2008), "Phylogenetic patterns of species loss in Thoreau's woods are driven by climate change", *Proceedings of the National Academy of Sciences*, Vol. 105 No. 44, pp. 17029-17033, doi: 10.1073/pnas.0806446105.

Wolf, F., Filho, W.L., Singh, P., Scherle, N., Reiser, D., Telesford, J., Miljković, I.B., Havea, P.H., Li, C., Surroop, D. and Kovaleva, M. (2021), "Influences of climate change on tourism development in small Pacific island states", *Sustainability*, Vol. 13 No. 8, p. 4223, doi: 10.3390/su13084223.

Worm, B. and Lotze, H.K. (2021), "Marine biodiversity and climate change", *Climate Change: Observed Impacts on Planet Earth*, 3rd ed., Elsevier, Amsterdam, doi: 10.1016/B978-0-12-821575-3.00021-9.

Yanes Luque, A., Rodríguez-Báez, J.A., Máyer Suárez, P., Dorta Antequera, P., López-Díez, A., Díaz-Pacheco, J. and Pérez-Chacón, E. (2021), "Marine storms in coastal tourist areas of the canary islands", *Natural Hazards*, Vol. 109 No. 1, pp. 1297-1325, doi: 10.1007/s11069-021-04879-3.

Yu, M., Yang, C. and Li, Y. (2018), "Big data in natural disaster management: a review", *Geosciences (Switzerland)*, Vol. 8 No. 5, p. 165, doi: 10.3390/geosciences8050165.

Zommers, Z. and Singh, A. (2014), *Reducing Disaster: Early Warning Systems for Climate Change*, Springer Science+ Business Media, Berlin, p. 9789401785983, doi: 10.1007/978-94-017-8598-3.

Further reading

Analytica, O. (2021), "August wildfires will force Greek rethink on climate", *Emerald Expert Briefings*, doi: 10.1108/OXAN-DB263549.

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