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Impact of Climate Change on Tourism on the Qinghai-Tibetan Plateau: Research Based on a Literature Review

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Abstract: Irrespective of insights gained from previous studies on the impacts and adaptions associated with climate change; little consideration has been given to the effect of climate change on tourism on the Qinghai-Tibetan Plateau (QTP). Based on a conceptual framework of the impact of climate change on tourism in high-altitude regions; this paper reviews the literature pertaining to the effects of climate change on the natural characteristics of the QTP and it discusses the corresponding implications for tourism within the region. The findings show that the features of the QTP affected most by climate change comprise wetlands, glaciers, and the vegetation, wildlife, and climate resources. Accordingly, such effects could have considerable implications for related tourism activities. Climate change poses both challenges and opportunities for tourism development on the QTP. The information presented in this paper offers insight for tourism management on the QTP. Comprehensive measures involving all stakeholders should be taken to promote the sustainable development of tourism on the QTP, and to both mitigate the threats and exploit the opportunities related to climate change.

Keywords: tourism; climate change; impact; Qinghai-Tibetan Plateau

1. Introduction

It is argued that human-induced climate change has intensified increasingly since the start of industrialized civilization [1]. Global climate change has resulted in a series of profound changes in earth's ecological system, which has affected the political and socioeconomic aspects of countries globally. In June 1992, Agenda 21 was promulgated in Rio de Janeiro to resolve the threat of climate change through human effort [2]. It described a blueprint for a plan of global action for the 21st century. Since then, the climate change issue has become an increasingly important agenda of international politics. Despite the withdrawal of the U.S. from the Paris Agreement, it remains undeniable that climate change constitutes one of the biggest threats facing humankind. David King, the Chief Scientific Advisor to the U.K. government [3], has even argued that climate change poses a greater security threat than terrorism. As the world's largest industry, tourism will be affected dramatically by climate change [4] because of its reliance on the attractiveness of the environment in many destinations, especially in coastal and high-altitude regions [5].

Known as "the third pole" of the earth or as "Asia's water tower", the Qinghai-Tibetan Plateau (QTP) has an average elevation of 4000 m. Its ecological environment is important not only to the sustainable development of the whole of East Asia but also to the rest of the world. The cold temperatures, low levels of oxygen, unique topography, and natural features make the ecological environment of the QTP extremely sensitive and fragile and thus, perhaps more susceptible than low-altitude areas to the effects of climate change [6,7]. In the overall scheme of regional development envisaged by the Chinese central government, the QTP region is considered a zone in which high-intensity human development is either restricted or strictly forbidden. In fact, the QTP has 155 nature reserves covering a total area of 82.24 million km^2, which accounts for 32.35% of the QTP and 57.38% of the protected areas in China [8]. In these protected areas, high-intensity industrial development activities are restricted. However, the ecosystems and natural resources of these conservation areas constitute unique attractions of global significance that offer great potential for the development of regional tourism. Following improvements to transport links, most notably the opening of the Qinghai-Tibet Railway in 2006, tourism on the QTP has gained impetus. The QTP has become one of the most popular destinations in China, and tourism now plays an important role in its economic development. For example, the income derived from tourism in the Tibet Autonomous Region reached 34.4 billion Yuan in 2016, accounting for 29.9% of its GDP [9]. Consistent with its geographical features, the natural environment is the focus of tourism activities in this area, including wildlife sightseeing, glacier sightseeing, alpine adventuring, and river source exploration. These tourism activities are highly dependent on the natural environment and the landscape, both of which are susceptible to the effects of climate change [10]. Therefore, the impact of global climate change on tourism on the QTP is likely to be more significant compared with other areas.

While various insights can be gained from extant climate change impact and adaptation studies, little is currently known about the impact on tourism on the QTP. The potential impacts of climate change on the tourism activities of the QTP have not yet been identified systematically. Specifically, the core issues surrounding the sustainable development of tourism on the QTP need to be addressed. Given the current tourism boom within the region and, more importantly, its great vulnerability to the effects of climate change, relevant studies are of considerable importance. By systematically analyzing the conceptual framework of the impacts of climate change on tourism, this paper investigates the potential changes in tourism activities on the QTP pertaining to climate change. Based on this, countermeasures and suggestions are proposed that could act as references for the study of related fields and for the promotion of the sustainable development of QTP tourism.

2. Materials and Methods

2.1. Compiling the Database

The database used for this study comprised Chinese and English peer-reviewed journal articles, and it was built in June 2017 via a three-step keyword search (Table 1) using the extensive online databases of the Web of Science^{TM} (WOS) and China National Knowledge Infrastructure (CNKI).

Table 1. Procedure of compiling the database.

Database	Keywords	Number of Articles	Number of Available Articles
WOS	climate change; impacts; tourism	801	386
	climate change; impact; tourism; QTP	1	1
	tourism; QTP	10	8
	climate change; QTP	401	287
CNKI	climate change; impacts; tourism	23	6
	climate change; impact; tourism; QTP	1	1
	tourism; QTP	139	107
	climate change; QTP	600	317
	Total number of available articles		1113

Step one: To outline the conceptual framework for analyzing the implications of climate change for high-altitude tourist destinations, a keyword search on 'climate change, impacts, and tourism' was performed in both WOS and CNKI. To narrow the focus of the topic, the database only included literature that mentioned 'high-altitude destination' directly.

Step two: To examine the impacts of climate change on tourism on the QTP, a keyword search on 'climate change, impact, tourism, and the QTP' was performed, although only two articles were found.

Step three: To broadly examine the potential impact of climate change on tourism on the QTP, two inventories were established via a keyword search on 'climate change and the QTP' and on 'tourism and the QTP.' Based on these inventories, literature that focused on landscape attributes or environmental features relevant to both climate change and tourism were identified and selected. Those works deemed irrelevant to tourism or climate change were excluded, such as the paper by Wang et al. on the response of soil microbes on the QTP to climate change [11] and the paper by Liu et al. on the cultural tourism attraction of the QTP [12].

The final database included 1113 publications (see Table 1), which suggests a lack of research on the impact of climate change on tourism on the QTP (i.e., only two articles found, one in English and the other in Chinese). It is acknowledged that the process of selecting relevant papers from the literature (especially non-core publications) involved some subjectivity; hence, it is possible that some relevant publications were not included in the database.

2.2. Conceptual Framework

According to Gössling et al., there are four major types of climate change impact on tourism demand: (1) direct impact of changed climate conditions and weather; (2) indirect impact of climate-induced environmental changes; (3) mitigation policy and tourist mobility; and (4) societal change related to reduced economic growth, consumer culture, and sociopolitical stability [13]. Based on this classification, the following section provides a conceptual framework for examining the potential implications of climate change for high-altitude tourist destinations.

2.2.1. Direct Impact of Changed Climate Conditions and Weather

Climate conditions and weather are important for almost all outdoor recreational activities in high-altitude destinations because they can determine when and/or where tourism activities are appropriate. Changes, induced by global warming, in the spatiotemporal distribution of these climate resources are expected to exert profound impact on high-altitude destinations. While the influences of meteorological factors on specific outdoor recreational activities vary, certain factors can affect tourism activities in general. Climate suitability in high-altitude destinations is determined by several key meteorological variables, including temperature, precipitation, humidity, and cloud cover. In addition, climate indices, e.g., the Physiologically Equivalent Temperature index, are also valid proxies with which to measure climate suitability. Such indices are developed according to the human energy balance, and they are expected to influence the tourist experience more directly than meteorological variables alone. They have been widely adopted in recent studies on climate suitability, especially in high-altitude regions [14–16]. Meteorological variables and climate indices are likely to change both temporally and spatially under the effects of climate change scenarios, as indicated by the Special Report on Emissions Scenarios or Representative Concentration Pathway projections proposed by the Intergovernmental Panel on Climate Change, in which various groups of meteorological variables were simulated with different emission scenarios. Such changes, in turn, would lead to modification of tourism suitability both in time and in space.

It appears that high-altitude regions would reap some benefits if only the direct impacts of changes in climate conditions and weather were taken into account [17]. The climate conditions in current high-altitude regions are projected to improve during summer, and even in spring and autumn, because of an increasing number of warm days [18]. Consequently, tourism hotspots will shift to regions of higher altitude. In addition, the frequency of cold spells is also expected to decrease. However, a number of studies have shown that tourists might respond to these changes in nonlinear ways, with an increase in visitations under moderate warming scenarios but a decline in an 'extreme heat wave' scenario [19]. For example, in the highest parts of mountain areas, a distinct decrease in visitor numbers is projected in summer under the A1B and RCP8.5 scenarios because of higher frequency of heat stress [20].

2.2.2. Indirect Impact of Climate-Induced Environmental Changes

There is considerable evidence demonstrating the important role of the natural environment in the decision-making process of tourists when selecting tourism locations [21]. In high-altitude destinations, most natural environmental elements such as wetlands, glaciers, the vegetation, and wildlife are sensitive to climate change. Consequently, alterations in these aspects induced by climate change might result in either an increase or a decline in visitations.

Most wetlands in high-altitude destinations are interior wetlands, which might be disrupted by climate-induced changes in precipitation, snowmelt, and vaporization. For instance, water levels in lakes might be reduced through increased evapotranspiration [22], diminishing the aesthetic value and recreational opportunities they offer.

The unprecedented rapid rates of recession and thinning of glaciers are another major concern within the context of global warming. In most cases, glaciers in high-altitude regions would retreat under the effects of global warming [23], influencing access and reducing their aesthetic value. Moreover, changes induced in glacier surface morphology might result in increased risk of rockfall, posing a potential hazard to visitors [24].

Vegetation represents an attraction for tourists as well forming the basic element of the biological chain in high-altitude regions. The impacts of climate change on vegetation include changes in the phenological period, type of dominant plant species, and structure of the plant community. These changes would affect the prime season for enjoying certain flowers and/or leaves [25], and the scenic beauty would also change in other seasons.

With regard to wildlife in high-altitude destinations, the variety of species and their numbers, as well as the occurrence of wildlife migration, will be influenced by climate change. For instance, increased frequencies of fire risk and of extreme climate incidents have the potential to be adverse influences on wildlife [26]. The extreme droughts, expected in many high-altitude regions because of climate change, would limit the sizes of the breeding populations of mammals, and severely reduce many sports fisheries [27].

2.2.3. Complexity of Overall Effects of Climate Change

The combination of the various potential direct and indirect effects of climate change discussed above makes it difficult to determine whether the status of tourism development in high-altitude destinations is deteriorating or improving. For any specific tourist destination, the impact of climate change on tourism is usually superimposed. This means the climate conditions, weather, and different natural environmental elements of the destination could all be affected by climate change simultaneously, while the role and relative importance of each element varies. Hence, the analysis of the overall effects of climate change on tourism is complex. At the same time, the expected changes in the climate suitability of high-altitude regions might lead to substantial increases in visitations and economic benefits; however, such benefits could also result in increased environmental pressures.

2.3. Study Region

2.3.1. Geographic Environments of the QTP

The QTP lies in southwestern China (Figure 1), covering an area of around 250×10^4 km^2 within 25°–40°N, 74°–104°E. The QTP is separated by the Tanggula Mountains into two zones, along a rainfall gradient from 50–200 mm in the western Tibet Autonomous Region (Tibet) to 200–500 mm in the east, including Qinghai Province [28]. The QTP is a typical high-altitude tourist destination with an average elevation of >4000 m. Many high mountain ranges, including the Himalayas, Pamir, Kunlun Shan, and Qilian Shan, surround the plateau and together they constitute a unique geomorphic and climatic environment. The effects of global climate change have been reported to be more obvious in regions of high altitude [29], and the QTP is regarded as one of the regions of the world most sensitive to climate change [6].

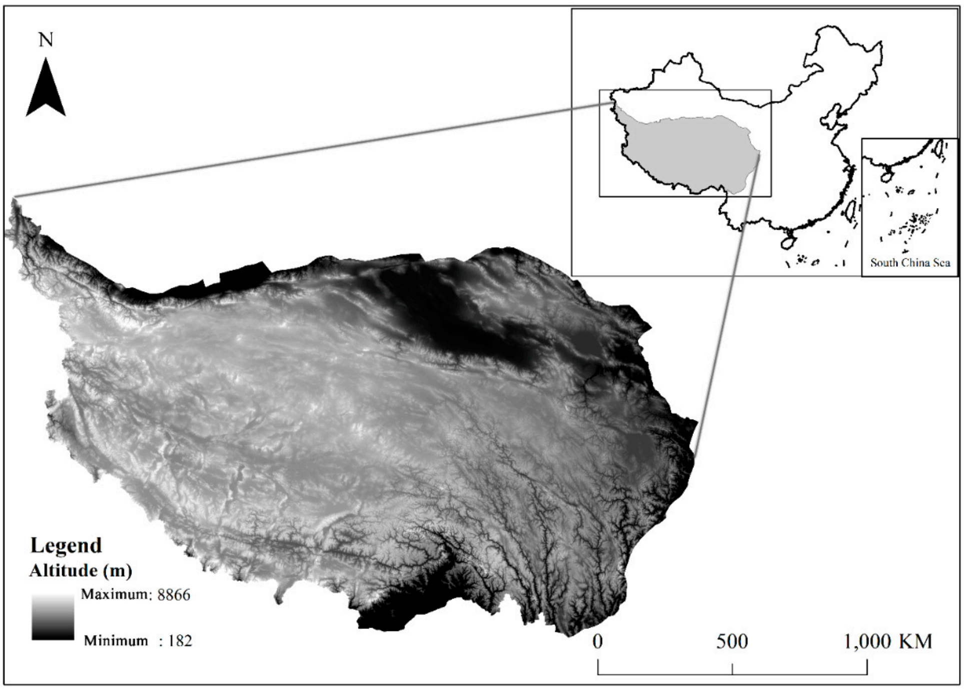

Figure 1. Location of the Qinghai-Tibetan Plateau.

2.3.2. Tourism on the QTP

The natural ecosystem plays a vital role in tourism development on the QTP. Owing to the unique natural attractions of the special geographic environment, nature-based tourism is regarded as the most attractive type of tourism on the QTP. The principal natural attractions of the QTP are its wetlands, glaciers, vegetation, and wildlife. In addition, the cultural landscape, which has been created by ethnic minorities such as Tibetan, Qiang, and Yi, is another important element of tourism on the QTP that has largely been shaped by the natural ecosystem through history. Based on the recreational ecosystem services, the popular recreational activities that are offered to visitors include wetland tourism, viewing of glaciers and fall foliage, camping, hiking, and hunting. In fact, the tourism industry of the QTP has experienced rapid development during the previous decade (Figure 2), and it has become an important source of income for local residents, especially those living in zones of forbidden development [30].

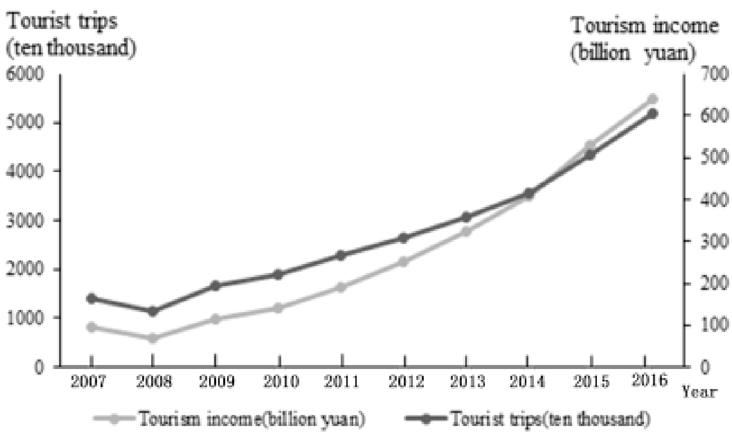

Figure 2. Total income and numbers of trips associated with tourism in Qinghai Province and the Tibet Autonomous Region during 2007–2016 (Data source: national economy and society developed statistical bulletin of Qinghai Province and the Tibet Autonomous Region 2008–2017).

In summary, tourism on the QTP has great importance for the local population, and because of its susceptibility to the effects of climate change, any climate-induced alteration in the ecosystems of the QTP could either threaten or provide opportunities for further tourism development [31]. Thus, the potential impacts posed by climate change are of major concern for the tourism sector of the QTP economy.

3. Implications of Climate Change on Tourism on the QTP

According to the conceptual framework proposed above and the natural elements related to tourism on the QTP, the direct impact of climate change on tourism is mainly in terms of climate suitability, and the indirect impact of climate change is mainly on the wetlands, glaciers, vegetation, and wildlife (Figure 3) [32–34]. Specifically, climate change largely improves climate suitability for tourism, but it exerts mainly negative effects on glaciers, and it is considered a double-edged sword for the wetlands, vegetation, and wildlife of the region. Based on the analysis of the impacts of climate change on tourism attractions of the QTP, this paper discusses the implications of these impacts on several tourism activities: wetland tourism, glacier tourism, plant-based tourism, and wildlife-based tourism.

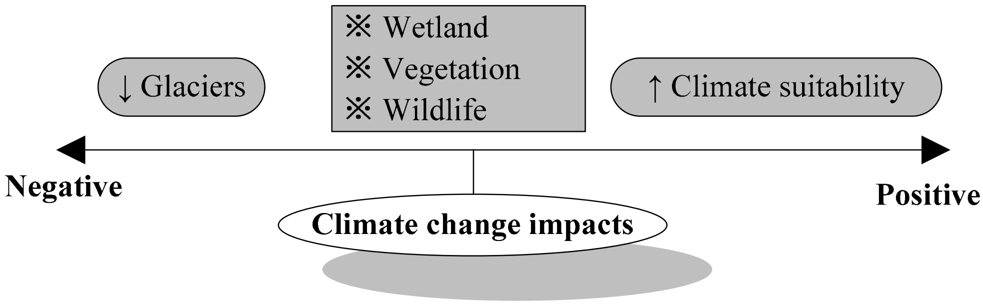

Figure 3. Impact of climate change on tourism attractions of the Qinghai-Tibetan Plateau.

3.1. Direct Impact of Changed Climatic Conditions and Weather of the QTP

A number of reasons have been proposed supporting the argument that the overall climate suitability of the QTP will be upgraded by climate change. On the one hand, cold stress, which is regarded as a constraint on the development of tourism on the QTP, will decline. Temperature is a key determinant of climate suitability for tourism on the QTP. During the previous 50 years, the rate of temperature increase on the QTP has been higher than the global average [35]. The annual mean surface temperature of the QTP has increased by about 1.8 °C, with a rate of change of 0.36 °C/decade during 1960–2007 [36] (the global rate of change was 0.12 °C/decade during 1951–2012 [37]). On the other hand, the climate condition shaped by the combined function of air temperature, vapor pressure, wind velocity, and global radiation has become more suitable for tourism in the context of global warming. Li and Chi evaluated the climate-change-induced alterations in climate suitability of the QTP using a Physiologically Equivalent Temperature model that included variables such as air temperature, vapor pressure, wind velocity, and global radiation [38]. They found that with global warming, annual cumulative number of thermally favorable days has been increasing, and that of cold stress has been reducing.

In the case of precipitation, it is difficult to discern whether climate-change-induced alterations present threats or opportunities. While rainy days are often regarded as negative for tourists [39], moderate precipitation would contribute to a more comfortable climatic environment. Yin et al. showed that the change of precipitation on the QTP has been characterized by a slight increase over the previous 30 years [40]. However, the change in the spatiotemporal pattern of precipitation on the QTP has been found considerably heterogenetic. Jiang et al. studied the interannual variations of available annual precipitation. Their study revealed differences among the subregions of the QTP; however, an overall trend of humidification was found in the Qaidam region and eastern parts of the South Qiangtang Plateau in northern Tibet [41].

3.2. Indirect Impact of Climate-Change-Induced Environmental Changes on the QTP

3.2.1. Wetland-Based Tourism

The QTP has the largest high-altitude wetlands in China, which provide a resource for many types of recreational activity [42]. Some activities depend strictly on water condition (i.e., quantity and quality), such as freshwater fishing. Other activities, such as camping and hiking, are often located near wetlands with only indirect contact with water resources; however, the appeal of such activities might be enhanced by the presence and the condition of the water. Changes experienced by the wetlands are attributed primarily to natural causes rather than to human intervention [41]. In recent years, these changes have been exacerbated by the effects of climate change [43]. In short, it appears that climate change affects the quantity and quality of the water of the QTP wetlands, which subsequently affects wetland-based tourism.

The variations in temperature and precipitation induced by climate change are projected to generate an asymmetric response in the seasonal pattern of water levels, alter flooding and aquifer levels, and cause perturbation in the hydrological equilibria of the QTP wetlands [37]. Given that wetlands depend on water condition, climate-induced impacts will further accentuate the alterations of these sensitive ecosystems on the QTP, especially those related to water quantity and quality [44].

The total area of wetlands on the QTP has expanded because of increased melting of snow and ice resulting from global warming. For example, Yan et al. examined lakes on the QTP with areas >0.5 km^2. They found the total areas of these lakes expanded by 13.42%, 4.86%, and 13.04% during 1970–1990, 1990–2000, and 2000–2010, respectively [45]. Xin et al. examined lakes on the QTP with areas >0.1 km^2. They found the total areas of these lakes increased by 5238.66 km^2 during 1962–2009 [46].

The pattern of change of QTP wetlands in response to climate change exhibits strong spatial heterogeneity. For instance, Yan et al. showed that during 1970–1990, lakes on the QTP generally expanded, with the exception of those in northern Tibet, central southern Tibet, the Qiangtang Basin and eastern Qinghai Province; during 1990–2000, almost all the lakes on the QTP increased in area, except in northern parts of Qinghai Province; and during 2000–2010, reduction in lake area occurred only in southern Tibet [45]. This heterogeneity is dependent on the different recharge patterns of wetland landscapes. Compared with wetland landscapes at low altitudes, the high-altitude wetlands of the QTP generally receive most water from runoff associated with melting glaciers and thus, they tend to expand, e.g., Siling Co and Chibuzhang Co. For wetlands depending on both precipitation and surface runoff, the effects of climate change are more complex. For instance, Li and Wang found that the areas of Bam Co, Pung Co, Dung Co, and Nuripung Co in the Nagqu District have increased steadily since 2005 because of a wetter QTP climate [33]. Huang et al. concluded that most lakes in the Nagqu District have seen an increase in surface area over the previous 40 years [47]. Yao et al. found that lake areas in the Hoh Xil region shrank prior to 2005 but then expanded subsequently [48]. In addition, evaporation is another vital factor. When increased evaporation surpasses increased precipitation and surface runoff, wetland landscapes will shrink, as has occurred in the Yamzhog Yumco Basin.

Some wetland-based tourism activities performed in certain wetlands might be threatened by water shortages, while others might benefit from the increasing levels of humidity and precipitation. The lack of water in southern Tibet and the Yamzhog Yumco Basin will have implications for the character and carrying capacity of the wetland ecosystems. For example, in naturally confined marshes, lowered lake levels will result in the marsh reverting to marsh meadow and, eventually, to dry land. In time, sport fishing could become affected by reduced quality of the shoreline marshes where fish feed and spawn [49]. Furthermore, the frequency of fires is expected to increase in some areas where increasing evaporation caused by climate change occurs [50]. In such cases, marshes might lose their wetland characteristics, which could result in changes to waterfowl migration routes and even to the disappearance of hunting or birdwatching activities under some extreme conditions. Furthermore, some non-consumptive activities, such as canoeing, will be constrained by the lack of open water. However, the expanding area of the wetlands in the Nagqu District will enhance the tourist sightseeing experience and provide greater recreational opportunities.

3.2.2. Glacier-Based Tourism

There are 46,377 glaciers on the QTP with a total area and total volume of 59,425 km^2 and 5600 km^3, respectively [51]. Glacier-based tourism has become very popular on the QTP, although it is the activity most sensitive to weather because it mainly includes walking, climbing, and flying onto or over these ice formations. Glacier tourism in the QTP often provides rich experiences for visitors, as well as socioeconomic opportunities for the local communities [52]. Glaciers rely on the accumulation of snow and ice but global warming has accelerated the rates at which snow and ice melt [53]. The major impact of climate change on the glaciers of the QTP is the loss of mass due to melting, calving, and other processes [54]. Nonetheless, there might be some mass gain through increased snowfall in a warmer climate in some areas, e.g., the glaciers of the Karakorams [55], and while this could lead to increased opportunities for adventurous travel, there is currently little evidence to support this.

Overall, the QTP is currently experiencing rapid glacier retreat within the context of global warming, which has the potential to undermine the viability of its glaciers as tourist attractions. For instance, Ke et al. found the glaciers of the QTP have experienced notable shrinkage at a linear rate of -0.31 ± 0.04 km^2/year during 1976–2013 [34]. Li et al. found 27 of the glaciers in the Luozha region of the QTP disappeared during 1980–2007 [56]. Apparent spatial variability in the climate-induced alterations of glaciers has been reported in many studies [57]. It has been argued that the speed of glacier retreat at the periphery of the QTP has been faster than in the middle [58]. Retreat speed has also been found to exhibit strong spatial heterogeneity throughout southeastern and northwestern regions of the QTP. Marked glacier thinning and retreat have been found widely on the southeastern QTP, while many glaciers in northwestern parts have retained a state of equilibrium or have even advanced slightly during recent decades [59]. Area shrinkage of glaciers has been substantial (i.e., >15% during the recent several decades) in peripheral areas of the QTP and its surroundings, such as in the Tian Shan, Altai, Altun, Qilian, Amne Machin, Hengduan, Nyainqêntanglha, Gangdisê, and Himalaya mountains [60]. The glaciers in interior areas of the QTP, such as the Kunlun and Tanggula mountains and the Qiangtang Plateau, have remained relatively stable over the previous several decades with shrinkage rates of <10% [61]. The glaciers in the eastern Tanggula Mountains have shrunk by 23.7% in terms of glacier area and by 15.1% in terms of glacier reserve [62].

The glaciers of the QTP have become narrower, thinner, and dirtier. This not only undermines their aesthetic value but it also reduces the overall number of accessible glaciers. Glaciers are the primary reason for people to visit the QTP [63]; if the glaciers were not there, the glacier-based source of income for the local communities would disappear. Moreover, rapid recession and thinning of the glaciers have caused changes to their surface morphology, resulting in steep, slippery terrain, crevasses, rockfalls, and river crossings. Such changes could increase the safety hazards associated with glacier tourism on the QTP, which might disrupt recreational and tourism activities [24].

It must be noted that the so-called 'last-chance' tourism linked to climate-sensitive glacier tourism activities could be seen as a challenge. Last-chance tourism often leads to substantial increases in visitations to the 'area in danger' in a short period. The publicly documented crisis of the QTP glaciers has led to them becoming labeled a last-chance tourism destination, which has encouraged more tourists to visit seeking to experience the glaciers before their disappearance [64]. Although extra tourists mean greater economic benefits in the short term, they can in turn increase pressure on the local environment. The greater frequency of long-distance travel means enhanced levels of carbon emissions through tourism-related energy consumption, which exacerbate global warming.

Furthermore, physical damage to ice formations appears intensified by increased numbers of visitors, e.g., intense trampling on the glaciers [65].

3.2.3. Plant-Based Tourism

The vegetation on the QTP is not only part of the environment but it is also part of the tourism attractions of the region. The QTP constitutes the largest and highest grassland area on the Eurasian continent. Its land-cover vegetation is dominated by alpine grassland, which covers an area of approximately 2.5 million km^2 [66,67]. The alpine grassland covers more than 50% of the entire plateau area, most of which is $\geq$3500 m above sea level [68]. Since the 1980s, the alpine grassland has been changing because of increasing temperatures and variation in precipitation [7,69]. Prior to and following 2000, the climate conditions on the QTP have displayed different trends. During 1986–2000, a wetter and warmer climate enhanced alpine grassland growth in most parts of the QTP. However, during 2000–2011, a drier and hotter climate undermined alpine grassland growth, especially in the arid regions across Tibet [70].

The flower blossom and fruit-bearing seasons have become popular times for tourists to visit the QTP because of various plant-based tourism activities. Such activities include fruit picking, the viewing of flowers and leaf color, and local festivals and events. For example, flower blossom festivals are held in Menyuan County in the north of the QTP, and the Peach Festival is held in Chengguan District, Lhasa. Plant-based tourism will be affected by changes in the phenological phases of plants (e.g., flowering and changes in leaf coloration), which are determined by the temperature and precipitation in a specific period. Phenological studies indicate that plants are more sensitive to temperature during the flowering and fruiting periods [71]. In general, rising temperatures mean the promotion of bud sprouting and flowering. Many studies have shown that the forage phenological phase of the QTP became extended during 1965–2013, and that the re-greening stage of forage was delayed from the southeast to the northeast [72]. Zhao et al. attributed such phenomena to the advanced periods of re-greening, heading, and blossoming of forage, while the onsets of yellowing and withering were delayed [72].

Although consensus over the impact of climate change on plant phenology has yet to be reached, the responses of forage phenological period to warming and cooling might be different because of heterogeneity in plant community compositions and soil physicochemical properties along the slopes of mountains. Some plants might even show abnormal patterns and thus, the spatiotemporal pattern of plant-based tourism demand can be expected to vary because of this.

3.2.4. Wildlife-Based Tourism

The QTP provides habitat for a unique assemblage of wildlife, including Chiru, Tibetan gazelle, Kiang or Tibetan wild ass, Tibetan argali, blue sheep, and wild yak [73], which are regarded as a valuable sightseeing resource for tourism. The distributions and abundances of these species are expected to alter following climate change because numerous species change their habits, characteristics, and activity ranges in response to rising temperature [74]. Furthermore, changes in the distributions of certain species on the QTP have been linked with variation in precipitation [75]. Wu studied eight types of animal species living on the QTP, including snow leopard (*Panthera uncia*), Tibetan ass (*Equus kiang*), and Alpine musk deer (*Moschus chrysogaster*). In response to climate change, the northern distribution limit of most species was predicted to shift northward, although it was predicted to shift southward for a small number of species. Moreover, the southern distribution limit was predicted to shift northward for all species; the western limit was predicted to shift westward for a few species but eastward for the majority; and the eastern limit was predicted to shift eastward for most species and westward for a few [75].

Population decline caused by climate change threatens species diversity and the delivery of critical ecosystem services [76]. Climate-change-induced decline in plant habitats and species diversity pose severe challenges to large wildlife in terms of food availability. For instance, Forrest et al. found that a steady increase in greenhouse gas emissions would lead to a shift in the Himalayan treeline, resulting in a 30% reduction in the habitat of the snow leopard [77]. Wildlife tourism activities on the QTP consist mainly of watching migratory species [78]. Consequently, this type of activity is likely to experience change as wildlife occurrences, abundances, and community compositions alter. Climate change is expected to affect the presence and frequency of species targeted by wildlife tourism operators. Hence, wildlife tourism seasons might need to be shortened, lengthened, or shifted to coincide with changing migration patterns.

Figure 4 presents some of the implications of climate change predicted for wildlife tourism on the QTP. Because of climate change, opportunities for wildlife tourism have improved in parts of the QTP, where the abundance of wildlife has increased through altered migration patterns [79]. Such areas are expected to benefit from changes in the timing of wildlife migrations, with wildlife arriving earlier and staying longer. However, research demonstrating such a relationship between climate change and recreational wildlife remains lacking, and there is little empirical evidence for the predicted implications presented in Figure 3. Consequently, climate-change-induced alterations could lead to some regions benefitting from the effects of global warming, albeit at the expense of other regions where the opportunity or attraction of wildlife tourism activities decreases because of substantial decline in the occurrence of wildlife.

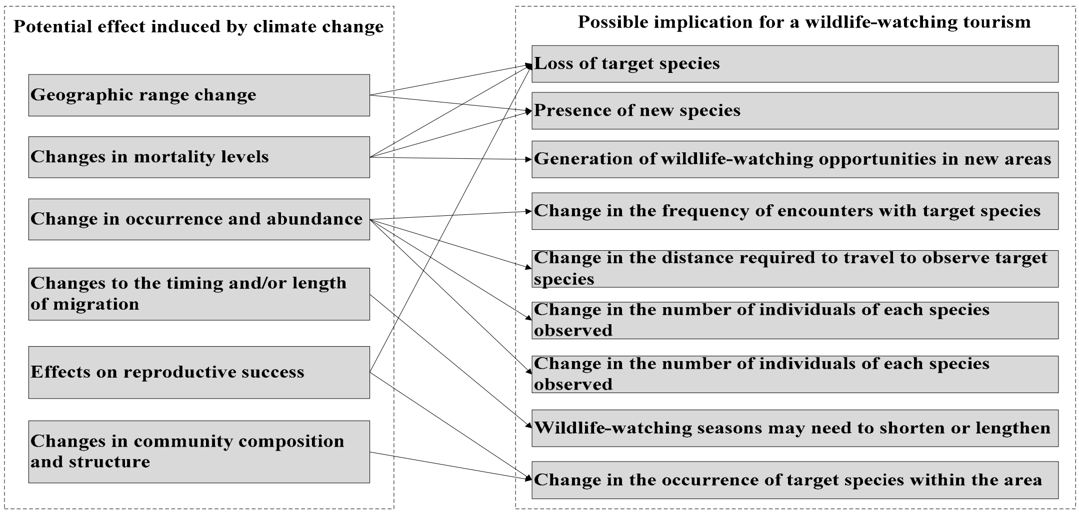

Figure 4. Possible implication for wildlife-based tourism.

4. Conclusions and Suggestions

Within the conceptual framework of the classification of climate change impacts, the implications of climate change for tourism attractions and tourism activities on the QTP were examined. Based on related literature, this study revealed that the impacts of climate change could be transferred to tourism activities through changes of environmental attributes and climate suitability. In the case of the QTP, the resources most sensitive to the effects of climate change are wetlands, glaciers, the vegetation, wildlife, and climate. Accordingly, the impacts of climate change could have implications for wetland-based tourism, ski-based tourism, glacier-based tourism, plant-based tourism, and wildlife-based tourism.

It should be noted that climate change brings both challenges and opportunities to tourism development on the QTP, and this work offers insight on the implications in relation to tourism management. Comprehensive measures should be taken by all stakeholders to promote the sustainable development of tourism, while mitigating the threats and taking advantage of the opportunities presented by climate change. From the perspective of government, it might be useful to make (potential) tourists aware of the extended period suitable for travel to/within the QTP, to focus on promoting travel in new seasons (e.g., spring, autumn), and to enhance the quality of the tourism service for the growing tourist market. Meanwhile, an environmental security monitoring system should be established, especially in glacier tourist areas, to safeguard against the frequent geological disasters caused by climate change. A dedicated website providing accurate forecasts of risk assessment of tourism-related climate should be established. It is also necessary for the government to provide financial support in the form of subsidies and interest-free loans to climate-change-sensitive small businesses. For example, some tourism enterprises promoting activities for the protection of Tibetan antelope should be subsidized by the government. In addition, research projects focusing on tourism vulnerability on the QTP should be given prioritized support.

As for the tourists, responsible tourism and low-carbon tourism activities should be advocated. Specific actions could include the following: (1) travelling to the QTP in spring or autumn instead of in summer to avoid tourism peaks and to reduce pressure on the resources and the environment of the QTP region; (2) consuming local food instead of foreign food with longer food miles, and reducing food waste; and (3) traveling by train instead of plane when visiting the QTP. For tourism enterprises, when designing tourism products and tourist routes or when building tourism infrastructure, they must fully consider all relevant meteorological disasters and geological hazards. For NGOs, public activities promoting rare animal protection and climate change adaptation for the QTP should be planned and implemented. Finally, empirical research based on first-hand fieldwork of climate change adaptation in the tourism sector of the QTP is greatly needed.

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