Climate change impact chains across the environment and the economy in coastal and marine destinations

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ABSTRACT

Climate change has important effects on the tourism industry, since both the supply and the demand of tourism services depend upon the quality and management of a set of environmental attributes. Within this framework, this paper has two main goals. It firstly proposes a conceptual framework for defining the channels of influence of climate change on tourism. This pivots around the notion of Impact Chains: a tool representing and summarizing the complex relationships between hazards, direct physical impacts, exposure and vulnerability. Secondly, empirical evidence for marine and coastal tourism is provided through a critical review of the available literature and applying a value transfer approach. Results show a great heterogeneity of findings and that available data do not deal with all the potential impacts of climate change in tourism, hence being unsuitable for an integrated approach to risk assessment. Among the potential available impacts, those for which there is empirical evidence which can be utilized in a value transfer context are the impacts due to loss of attractiveness of marine environments (species or landscapes), loss of comfort due to beach availability reduction, and loss of comfort due to thermal stress and heat waves. Nevertheless, the economic impacts for these three environmental threats are significant, and would imply large reductions in the number of tourists visiting tourist destinations and relevant amount of monetary damages.

Keywords
Climate change, Impact chains, Risk, Tourism, Value transfer, Literature review

1. INTRODUCTION

The tourism industry is subject to potential impacts of climate change that are likely to have significant economic effects. The identification and the study of these impacts is key to decide upon the appropriate policy measures to be undertaken by tourism destinations in order to adapt and mitigate the socioeconomic damages and losses. This paper identifies and analyses the most relevant economic impact chains leading to climate change risks in tourism, by taking into account the hazards, vulnerability and exposure indicators that affect the activity of the tourism sector.

This paper has two main goals. It firstly presents a comprehensive assessment of climate change impact chains on tourism, building under the conceptual architecture provided by IPCC (2012, 2014.). It is underpinned on the central term of risk, referring to the potential (when the outcome is uncertain) for adverse consequences on life, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructures derived from climate hazards. The complex relationships between hazards and risks are mediated by the exposition of natural and social subsystems to climate hazards and by the degree of their resilience in coping with climate shocks. It allows for a consistent design of the assessment studies of climate-related impacts and thus for the comparison and aggregated treatment of the associated social costs. As a result, mitigation and adaptation efforts may be prioritised for the sake of minimizing social costs of the transition to a decarbonized and more secure society.

Following this systematic approach, various risks faced by coastal and marine tourism due to climate change hazards are identified and classified attending to their nature and effects: i) risks related to health, safety and comfort of tourists; ii) risks related to natural habitats, marine and terrestrial, that sustain the attractiveness of destinations; and iii) risks associated to negative impacts on infrastructures and facilities that provide basic services to tourists. Overall, nine risks are identified through an expert-assisted process. It is presumed that all these risks, if borne to a certain degree, affect the value of the recreational experience and the decision-making process of tourists when choosing destinations. Such a framework also allows to evaluate the economic impact of climate change on tourism activity through a range of indicators that, when fed with local data, will provide a useful policy tool for the destination management. Secondly, empirical evidence of the impact of climate change for marine and coastal tourism is provided through a review of the available literature, which is classified and critically assessed according to the impact chains framework previously introduced. We hence apply a value transfer approach, which is based on the available information provided from past scientific research (Smith, 1992; Bergstrom and Taylor, 2006). Value transfer is a method for assessing the potential economic outcome of environmental impacts utilizing findings from previous research for which estimates are available. That is, values or data from a study site are applied or transferred to a site where no data are available. The value transfer method has been utilized in many applications to assess the costs and benefits related with environmental impacts and policies (Smith and Pattanayak, 2002; Johnston and Rosenberger, 2010). It dates back to the 1980s, although is not until the 1990s that the method became scientifically formalized and supported by academic scholars (Brookshire and Neill, 1992; Boyle and Bergstrom, 1992.).

Although there are different approaches to the benefit transfer method (e.g. unit value, expert judgment and transfer function (Loomis, 1992; Ready and Navrud, 2005; Rosenberger and Phipps, 2007), in this paper we apply a simple unit value transfer approach (Luken et al. 1992), which essentially consists in the transfer of the results from past research to the policy context under study without any structural adjustment. This approximation may be considered as valid in the context of our objective, since we are dealing with multiple effects arising from the analysis and evaluation of the climate change impact chain risks in tourism.

Many studies of the socioeconomic impacts of climate change on tourism have been conducted over the last decade but the methodological heterogeneity in previous studies makes it hard to achieve a synthetic picture of the complex relationship between climate change and tourism (Amelung et al. 2007; Ciscar et al. 2011; Hall et al. 2012). Researchers from different fields bring their own conceptual models to the study of vulnerability and adaptation of tourism to climate change, models which often address similar problems but using different languages. It is still lacking a "common language so that climate change research can move forward in a way that integrates these different traditions in a coherent yet flexible fashion, allowing researchers to assess vulnerability and the potential for adaptation in a wide variety of different contexts" (Brooks, 2003, p.2).

The main contribution of this paper is hence to provide a methodological framework for investigating and interpreting the impact of climate change on tourism, thus building a bridge between academic research and practical climate risk assessment policies. In this way, and this is our second major contribution, it is possible to critically assess the recent literature in order to estimate the economic impact of climate change on tourism through a transfer value approach and to identify gaps to fill with future research. At present, a few reviews of the literature exist (Becken, 2010; Kaján & Saarinen, 2013; Fang et al., 2018 among the others), but with a general focus, and they are not linked to risk assessment policies. In a nutshell, the main novelty of this paper is to critically classify and assess recent findings and contributions, in light of the methodological approach provided by Impact Chains. Given the extensive literature and the heterogeneous impacts that climate can have on different destinations, the focus of this paper is on coastal and marine tourism only[1].

1 / A whole strand of literature investigates the impact of climate change on mountain destinations, with particular reference to winter tourism. We refer to Steiger et al. (2019) for a review on the topic.

The paper is structured as follows. Section 2 outlines the conceptual framework for the assessment of climate change impact risks, considering its application to the impacts which are most likely to be encountered in the tourism industry. Section 3 presents the value transfer methodology. Section 4 assesses the climate change impact chain risks in tourism based on the available evidence of the literature, focusing on the biophysical and socioeconomic impacts of climate change on coastal and marine destinations. Finally, Section 5 presents and discusses the concluding remarks following from the paper's methodology and findings.

2. Conceptual Framework

Tourism long-term sustainability depends on preservation and enhancement of its environment. Climate change affects several services that ecosystems provide to tourism (Kaján et al. 2015; Franzoni, 2015; Cheer and Lew, 2017). For example, more frequent and severe heatwaves or beaches reduction due to sea level rise and coastal erosion influence the value of the recreational experience at the destination and hence its demand. The systematic assessment of the complex relationship between climate hazards and tourism experience value and demand requires an accurate identification of the sequential links, the proper indicators to represent them, the nature of link-to-link relationships and the functional forms that better fit those relationships.

To deal with it, this section first briefly depicts the IPCC's conceptual framework that summarizes the hazard-risk relationship, introducing the key concepts underpinning it. Vulnerability and risk assessment encompass various approaches and techniques, ranging from indicator-based global or national assessments to qualitative participatory approaches of vulnerability and risk assessment at the local level. Several participatory risk assessment methods, often based on participatory rural appraisal methods, have been adjusted to explicitly address changing risks in a changing climate. Examples of guidance on how to assess climate vulnerability at the community level are available from several sources (Willows and Connell, 2003; Moench and Dixit, 2007; van Aalst et al., 2007; CARE, 2009; IISD et al., 2009; Tearfund, 2009). In our context, experts' assessment has been used to approach the particular impact chains linking hazards and risks with the mediation of factors of exposure and vulnerability, and the indicators to measure them.

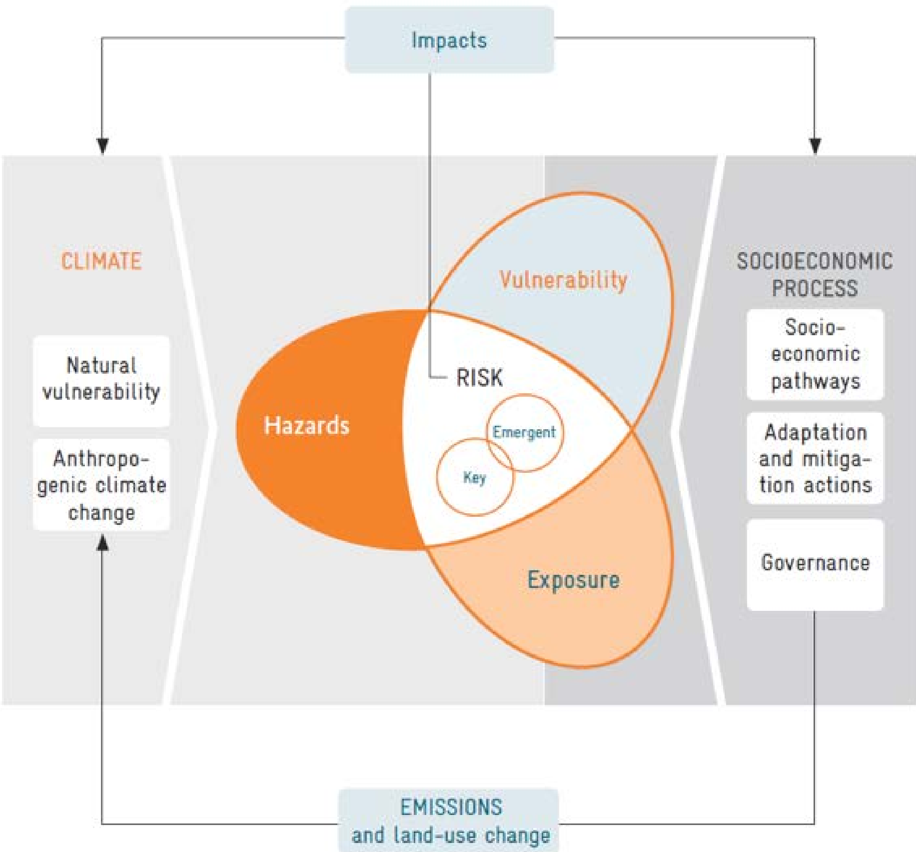
Secondly, the economic modelling of changes in ecosystem services due to climate change can be addressed following the Lancaster approach of the demand of characteristics (Lancaster, 1971). That is, climate induced changes in ecosystems services can be considered as attributes of the tourism experience, thus affecting its value and subsequently the behaviour of tourists towards and in the destination. As a result, a systematic assessment of the differential effects of climate change on different destinations can be used to estimate changes in flows of tourists.

2.1. The concept of Risk Assessment and Impact Chains

To ensure that risk and vulnerability assessments are understood in the context of climate change, the key challenges for future vulnerability and risk assessments are, in particular, i) the promotion of more integrative and holistic approaches; ii) the improvement of assessment methodologies that also account for dynamic changes in vulnerability, exposure, and risk; and iii) the need to address the requirements of decision-makers and the general public. The IPCC (AR5) report (2012) on vulnerability and risk assessments is essential and relevant to inform both disaster risk management and climate change adaptation. Therefore, it is required the use of reliable methodologies that allow an adequate estimation and quantification of potential losses and consequences to the human system in a given exposure time. According to the last IPCC report (2014, pp. 127), the risk is defined as "the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure". Thus, the risk assessment concerns the interaction of climatic, environmental, and human factors that can lead to impacts and disasters, options for managing the risks posed by impacts and disasters, and the important role that non-climatic factors play in determining impacts.

The IPCC AR5 risk concept has been developed around the central term 'risk'. In this concept, risk is a result of the interaction of vulnerability, exposure, and hazard, as shown in Figure 1.

Fig. 1 / SREX concept of risk (source: the authors)



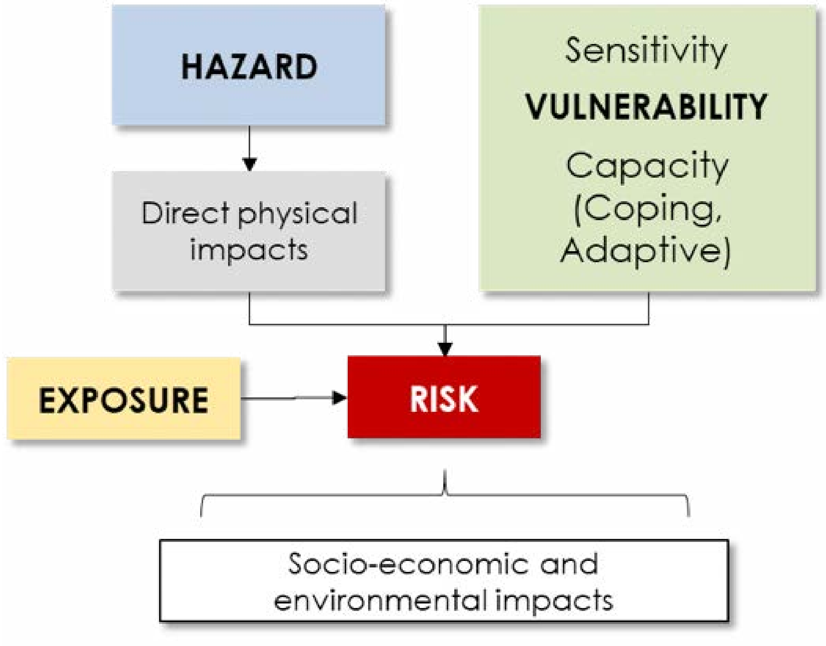


Fig. 2 / Complex System Flowchart for Risk Assessment following the IPCC AR5 Report (source: the authors)

Assessment frameworks with integrative and holistic perspectives have been developed by Turner et al. (2003a), Birkmann (2006b), and Cardona (2001). Key elements of these holistic views are the identification of causal linkages between factors of vulnerability and risk and the interventions (structural, non-structural) that nations, societies, and communities or individuals make to reduce their vulnerability or exposure to hazards.

In the context of this research, we have adopted the concept of climate-driven impact chain (Schneiderbauer et al. 2013, Fritzsche et al., 2014), that in turn build on the IPCC risk concept depicted above. The impact chain looks like a diagram tool, which synthetizes the relationships between different climate shocks, ecosystem services and economic activities under study, taking into account exposure (to climate parameters), sensitivity (related to physical and socio-economic features of the destination), and adaptive capacity.

The definitions of the components are the following:
- A climate socio-economical risk is the potential for climate - related consequences (climate impacts) for something of value (= assets, people, ecosystem, culture, etc.).
- The hazard is the potential occurrence of a climate-related physical event or trends or their physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.
- The exposure is the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
• Exposure is related to specific exposed elements (or elements at risk), e.g. people, infrastructure, ecosystems.

• The degree of exposure can be expressed by absolute numbers, densities or proportions etc. of the elements at risk (e.g. population density in an area affected by drought)
- The vulnerability is the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
• Sensitivity may include physical attributes of a system (e.g. building material of houses, type of soil on agriculture fields), social, economic and cultural attributes (e.g. age structure, income structure).
• Capacity refers to the ability of societies and communities to prepare for and respond to current and future climate impacts.
The Impacts are the effects on natural and human systems, on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system.

2.2. Climate Change and the Tourism Sector: The Tourist Experience Value

The Impact Chains (IC) in the tourism sector have been constructed considering the concept of tourist experience value. This concept has been analyzed in detail in Prebensen et al (2014). As the authors remark, the tourist's experience is an individual perception generated in the context of interactions and resource integrations, and which has a value-in-use for the consumer. Therefore, climate changes potentially affect the tourist's choice of the destination (since they could affect ecosystems services, basic services, infrastructures and facilities, weather comfort, etc.), and impacts his/her perception of the destination image, which depends on several attributes or variables. This framework allows us to ultimately analyze the economic impact of climate change by looking at the interaction between demand and supply. We should observe a change (decrease) in both tourists' arrivals and receipts.

In the simplest scenario, this change in tourists' perception will translate into reductions from the demand-side (less arrivals in the destination, lower demand of services, etc.). Nevertheless, climate changes could also affect the supply-side: think about the different managerial and policy actions that should be implemented to keep the demand curve unaffected (i.e., keep the tourist experience value at the initial level). These actions will likely imply higher productions costs and will therefore affect the supply curve.

The ICs considered for this sector can be summarized in three main categories:

1. Loss of tourist experience value in the destination due to changes in environmental attributes[2].
2. Loss of tourist experience value in the destination due to changes in human being comfort (or health).
3. Loss of tourist experience value in the destination due to changes in the quality of infrastructure and facilities.

2 / A distinction between the biotic degradation (species and forest) and abiotic environment (beach) has been made.

These categories try to summarize all the interactions the tourist can experiment in the destination. Firstly, the environmental attributes could serve as service them-selves (ecosystem service) in the case of tourism devoted to nature observation. However, in most of the cases, the interaction with nature (marine environment, land environment, forests or beaches) will come in the form of activities: sports, hiking, pleasure, etc. Secondly, the comfort or health of tourists is important in the decision of visiting the destination. Higher temperatures, frequent precipitations or even the emergence of new diseases due to climate changes or new species, will lower the comfort, and therefore, the tourist experience value. Finally, the quality of infrastructures and facilities available will also affect the perception and comfort of the incoming tourists. The three main IC categories have been divided into 9 subcategories. These subcategories aim at defining particular and measurable risks that could take place within the general categories. These individual risks have been defined as follows:

1. Loss of tourist experience value in the destination due to changes in environmental attributes.
    - 1.1. Loss of attractiveness of marine environments (due to loss of species and/or increase of exotic invasive species; or degradation of landscape)
    - 1.2. Loss of attractiveness and comfort due to beach availability reduction
    - 1.3. Loss of attractiveness due to increased danger of forest fire in tourism areas
    - 1.4. Loss of attractiveness of land environments (due to loss of species and/or increase of exotic invasive species; or degradation of landscape)

2. Loss of tourist experience value in the destination due to changes in human being comfort (or health).
    - 2.1. Loss of comfort due to increase of thermal stress
    - 2.2. Increase of health issues due to emergent diseases

3. Loss of tourist experience value in the destination due to the change in the quality of infrastructure and facilities.
    - 3.1. Increase of damages to infrastructures and facilities (accommodation, promenades, water treatment system, etc.) due to sea level rise and extreme weather conditions
    - 3.2. Decrease of available domestic water for the tourism industry
    - 3.3. Loss of attractiveness due to loss of cultural heritage (monuments, gastronomy, etc.)

The economic modelling of the effects of climate impacts on tourism can be addressed with a lancasterian approach (Lancaster, 1971), in which the environmental impacts would act as attributes of the tourism products on offer in the market of tourism destinations (Seddighi and Theocharous, 2002; Hua et al. 2018). That is, while conventional demand theory postulates that individuals derive utility directly from the consumption of goods, Lancaster's assumption is based on the idea that marketed products are defined by combinations of characteristics which attract consumers. Thus tourists, by traveling to destinations for tourism reasons, purchase goods and services in order to acquire these characteristics in desired quantities and combinations. It is not the goods themselves but rather their underlying characteristics that confer satisfaction to the buyer. Therefore, the environmental impacts following climate change would modify the attributes that tourists experience at destinations, thereby inducing changes in the traveling and expenditure decisions with consequent economic impacts. The latter can be observed either as market or non-market impacts, which can be evaluated utilizing non-market valuation methods. Demand modeling of these decisions can be approached utilizing discrete choice models (Ben-Akiva and Lerman 1985; Louviere et al., 2000; Papatheodorou, 2001).

3. Transferable Values

In this section, the complex system flowchart for risk assessment is presented. Disaggregated flowcharts for each of the 9 specific risks identified in the Section 2 are in Appendix A, and the specific evidence of their transferable values are available from authors upon request. Figure 3 presents the interaction between hazards, exposure and vulnerability factors that affect the potential risk, as explained above. We have identified three main types of potential risks that, if damaged, could affect the attractiveness of a tourism destination, and the tourist experience value as consequence. These categories refer to ecosystem services, comfort and health, and infrastructure and services. Moreover, specific risks can be identified inside each category.

In the case of ecosystem services, potential climate hazards could affect the marine or land environment, the availability of beaches or the risk of forest fires. Regarding comfort and health, it has been identified the potential risks of thermal stress and changes in the likelihood of being affected by emergent diseases. With respect to infrastructures and services, apart from damages to infrastructures and cultural heritage, the availability of water supply has been identified as an important risk.

A set of climatic hazards have been identified in line with the existing literature and the IPCC reports. In particular, it should be emphasized the occurrence of heat waves, droughts, floods, storms and other extreme atmospheric and oceanic conditions. These events usually have a sharp and important impact on biodiversity, society and infrastructures, due to their strength. However, other climate hazards such as increase of temperature, changes in precipitation and wind patterns, sea level rise and ocean acidification are not so noticeable due to their progressive effect. Still they are very relevant, not only because of their influence on extreme hazards, but also on their effect on ecosystems and habitats.

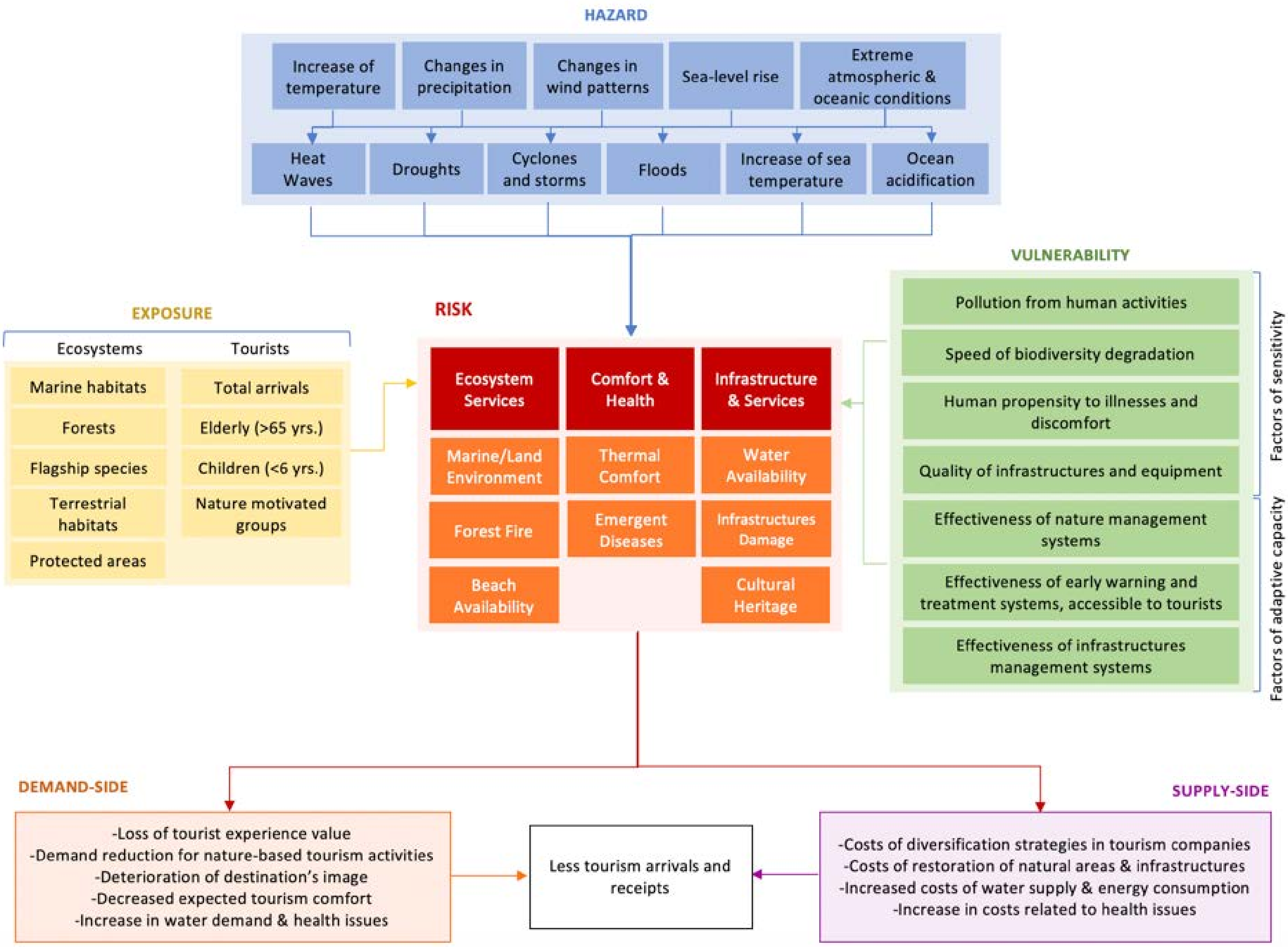


Fig. 3 / Generic System Flowchart for Risk Assessment (source: the authors)

The impact of hazards on the identified risks may be exacerbated given the exposure and vulnerability factors. These elements take into consideration the potential sample at risk, on the one hand (exposure), and the factors that could either influence the extent of the risk (factors of sensitivity), or the tools available to overcome the potential impacts (adaptive capacity).

In order to identify and summarize the economic impact of the potential risks, effects from the demand or the supply side have been considered. With respect to the demand, tourists would face a decrease in their experience value, affecting their economic valuation and their behaviour regarding the destination or activity choice. Similarly, the destination's image could be damaged, producing a similar effect on tourists' behaviour and valuation. In addition, depending on the risk considered, they could produce increases in water demand from tourists and also increases in health issues. As for the supply side, costs of restoration of natural areas and infrastructures are considered, together with costs of increased water supply, increased energy consumption and increases in costs related to health issues.

4. A literature review of impact chains

A systematic assessment of the climate change impact chains risks outlined in the previous section for tourism does not exist. In most of the cases, the available evidence in the literature focus either on the impacts of the different hazards on ecosystem services and infrastructures, or on tourists' behaviour and valuation of changes in ecosystem services and infrastructures. Only a few studies follow an integrated approach to determine the economic impact of the hazard on the risks. This section systematically reviews the available evidence on the different aspects of the climate change impact chains in tourism, focusing on the socioeconomic impacts. The results will be presented for the specific risks defined in Section 2, according to the availability of research. The identification of potential gaps in the existing literature will be pointed in order to identify research gaps and the future agenda. Values emerging from this analysis will be considered for the general assessment of the risks of climate change impacts in tourism.

4.1. Loss of tourist experience value in the destination due to changes in environmental attributes

4.1.1. Loss of attractiveness of marine environments (due to loss of species and/ or increase of exotic invasive species or degradation of landscape)

Shifts in climatic attributes may result in spreading of invasive and dangerous species, affecting tourists' well-being and their destination choice (Nilsson & Gössling, 2013), but also in losses of marine and coastal habitat, which are amongst the indirect environmental effects of climate change and may have profound implications on the destination's attractiveness, especially if wildlife is the main reason for travel.

Special attention has been paid to coral reefs (Hall, 2001; Marshall et al., 2011; Coghlan & Prideaux, 2009), as they represent an important attraction for tourists but are also very delicate ecosystems that can be deeply affected by climate change. Indeed, the increase of oceanic waters temperature causes mass coral bleaching that damages the reefs, while acidification of the oceans endangers their flora and fauna (Marshall et al., 2011). Coral bleaching refers to '(…) the whitening of corals due to stress-induced expulsion or death of their symbiotic protozoa, or to loss of pigmentation within the protozoa' (Scott et al., 2012b, p. 220) and is mainly due to temperature change and ocean acidification. This last phenomenon is due to the presence of high percentages (about 30%) of total emitted anthropogenic CO2 in the ocean waters (IPCC, 2014), thus impacting the reproductive and physiological activity of numerous marine creatures (Scott et al., 2012b) and increasing their vulnerability. With high confidence, IPCC AR5 (2014) states that numerous species may extinguish because of climate change and the other modifications that are affecting their environment. Coral reefs are also at risk because of the increased intensity and frequency of extreme events. Although it is acknowledged that corals are endowed with high level of resilience and can naturally recover successfully from cyclones, hurricanes or typhoons (Bythell et al., 2000), when these extreme events become more frequent, the reefs are not able to fully rebuild themselves, especially if other climatic changes are at place, making the environment less favourable for the corals. Furthermore, destruction of corals due to the storms may trigger the succession of algae (Welsh, 1983), which may affect tourist demand, as shown in Nilsson & Gössling (2013). Note also that coral reefs are not only an important part of marine ecosystem and a tourist attraction, but also a shield that protects the beaches and coasts from erosion (Cuttler et al., 2018). A study by Hongo et al. (2018) has incorporated projections of both SLR and tropical cyclones to simulate impacts on beach erosion under two scenarios: a degraded reef and a healthy reef. Results show that healthy reefs can reduce the significant wave heights by up to 0.44 m, while a reduction by only 0.1 m would already be sufficient to decrease the risks of coastal and infrastructural damages. Therefore, these studies show that there is also a tight interconnection between different physical impacts.

Other species of marine and coastal habitat are also at risk. Assuming 2°C global warming and consequent inundation of low-lying coasts for shorebirds in the US, the projected loss of habitat ranges from 20 to 70%, with most vulnerable sites being those where the current coastline is unable to move inland because of steep topography or coastal defence structures such as sea walls. (Galbraith et al., 2002). For certain species, however, the impact may be both positive and negative depending on the exact climate change scenario and on specific physical impacts: SLR and increased intensity of storms would have a negative impact on turtle nesting beaches, while seawater temperature rise may result in increased food availability for the same animals (Poloczanska et al., 2009).

Such changes would have impacts on tourism industries, particularly for the islands where these natural features are of high value for tourists. Regarding coral reefs, the literature generally finds that biodiversity loss results in a lower probability of revisiting the destination (Uyarra et al., 2005; Parsons & Thur, 2008), with consequent economic losses. Payet & Obura (2004, in Scott et al. 2012b, p.246) estimate that in the western Indian Ocean, where 30% of corals loss led to a considerable decrease in visitors, economic losses amount to almost US$18 million; Parsons & Thur (2008) claim that the drop in the quality of the reefs in Bonaire results in per-capita spending decrease of $45-$192. At the same time, this result is also case-specific: Cheablam et al. (2013) study the case of massive coral bleaching in Mu Ko Surin National Park, Thailand. Despite the surveyed tourists strongly agreeing that coral has been severely degraded, more than a half of respondents were willing to revisit the park, and two-thirds of the respondents were satisfied with the overall quality of tourism activities. It follows that climate change results in a need to increase awareness of both tourists and businesses (Zeppel, 2012), and leads to increased costs of preservation and restoration of marine and coastal flora and fauna from

Table 1: Summary of Impacts found in the literature corresponding to *Loss of attractiveness of touristic marine environments (due to loss of species and/or increase of exotic invasive species; or degradation of landscape)*

Impact Studied	Reference	Results
Impact of climate on biodiversity	Marshall et al. (2011)	Increase of oceanic waters temperature causes mass coral bleaching that damages the reefs; ocean acidification endangers their flora and fauna.
	Scott et al. (2012b)	Coral bleaching is mainly due to temperature change and ocean acidification.
	Scott et al. (2012b)	Temperature change and ocean acidification, due to 30% of total emitted anthropogenic CO_2 in ocean waters (IPCC, 2014), impact the reproductive and physiological activity of marine creatures and increase their vulnerability.
	Bythell et al. (2000)	Higher frequency of extreme events (cyclones, hurricanes or typhoons) due to climate change does not allow the natural recovery of reefs (even if their level of resilience is high)
	IPCC AR5 (2014)	Numerous species may extinguish because of climate change and the other modifications that are affecting their environment.
	Galbraith et al. (2002)	2°C global warming and inundation of low-lying coasts could cause loss of 20-70% shorebirds habitats (US)
	Poloczanska et al. (2009)	SLR and increased intensity of storms would have a negative impact on turtle nesting beaches. However, seawater temperature rise may result in increased food availability for them.
Importance of biodiversity	Cuttler et al. (2018)	Coral reefs are not only an important part of marine ecosystem and a tourist attraction, but also a shield that protects beaches and coasts from erosion.
	Welsh (1983)	Destruction of corals due to storms may trigger the succession of algae
	Hongo et al. (2018)	Impact of projections of SLR and tropical cyclones on beach erosion: healthy reefs can reduce wave heights by up to 0.44m. A reduction by 0.1m would be sufficient to decrease risk of coastal and infrastructural damages.
Tourists' valuation and behaviour	Uyarra et al. (2005)	>80% of tourists unwilling to return same holiday price in the event of coral bleaching as result of elevated sea surface temperatures and reduced beach area as result of sea level rise. (Bonaire and Barbados)
	Cheablam et al. (2013)	Although coral has been severely degraded, >50% of tourists willing to revisit the park; and 2/3 were satisfied with overall quality of tourism activities (Mu Ko Surin National Park)
	Parsons & Thur (2008)	Drop in quality of reefs results in per-capita spending decrease of \$45-\$192 from modest to larger losses (Bonaire)
Economic Impact	Payet & Obura (2004)	30% of coral loss led to a considerable decrease in visitors, and economic losses of \$18 million (Western Indian Ocean).
	Zeppel (2012)	Climate change results in a need to increase awareness of both tourists and business, and leads to increased costs of preservation and restoration of marine coastal flora and fauna.
	Bayraktarov et al. (2016)	Cost of restoration or rehabilitation projects vary significantly, depending on location, type of ecosystem and executing actor. Projects in developing countries are 30 times less expensive; coral reefs and seagrass are among the most expensive ecosystems to restore. Median and average cost for restoration of one hectare of marine coastal habitat were between \$80,000-\$1,600,000 (Europe, US, Australia)

the supply-side. Bayraktarov et al. (2016) have constructed a comprehensive database of restoration or rehabilitation projects of the last 40 years for five main marine coastal ecosystems: coral reefs, seagrass, mangroves, saltmarshes, and oyster reefs, mostly in Europe, US and Australia. The results suggest that the cost vary significantly over many dimensions: depending on the location, type of ecosystem to restore and executing actor: projects in developing countries were found to be up to 30 times less expensive, while coral reefs and seagrass were among the most expensive ecosystems to restore, and community- or volunteer-based projects usually associated with lower costs. Regarding costs estimates, the median and average reported costs for restoration of one hectare of marine coastal habitat were between US$80,000 and US$1,600,000 (2010), respectively, while the authors suggest that the real median cost was about two times higher.

4.1.2. Loss of attractiveness and comfort due to beach availability reduction
The most important effects of climate change on coastal and maritime areas are the sea level rise (SLR), the changes in water and air temperatures, the increased frequency of extreme events (rainstorms, heat waves, etc.) and other climatic features. They all have both direct and indirect effects, contributing to environmental physical impacts, such as shifts in biodiversity, beach surface reduction, increased risks of forest fires, which would affect marine environments from both demand and supply sides.

An obvious and immediate consequence of SLR is beach erosion and damage to related infrastructure. On the demand side, beach surface reduction was found to negatively impact the destination image in various locations, for example in Martinique, where 25cm SLR was estimated to pose at risk 87% of beaches used for tourism (Schleupner, 2008). In Barbados, where 77% of tourists declared unwillingness to return in case of beach surface reduction, tourism revenues could decrease by as much as 46% (Uyarra et al., 2005). In Australia, where under different beach erosion scenarios the share of tourists opting for alternative destinations is estimated to be 17-23%, the drop of revenues would be as large as $20-$56 million per year (Raybould, 2013). However, many tourists claim to reconsider their choice if coastal protection measures were taken (Atzori et al., 2018). Buzinde et al. (2010) investigate the case of Playacar, Mexico, that was hit by severe beach erosion and undertook some protective measures, which were expected to have a strictly negative impact on tourists' perception. The analysis revealed that tourists adapt their views and attitudes: some express positive sentiment towards the changed image of the beaches while others, although expressing concerns from aesthetical points of view, are still aware of the necessity of protection measures, and are willing to accept them in the light of climate change. In this respect, Rulleau & Rey-Valette (2013) find that the willingness to pay for beach protection measures in the French Mediterranean area is, on average, €36.4 per household per year. Similarly, Castaño-Isaza et al. (2015) estimate that the experience value that tourists place on the beaches of San Andres Island implies an annual willingness to pay of US$ 997,468.

On the supply side, beach erosion affects properties, infrastructure, and, consequently, contribute to increased costs. A vulnerability assessment on the consequences of SLR and flooding on the Moroccan coasts (Snoussi et al., 2008), estimates 24% land loss in "best case" scenario of 2m inundation, and 59% of land loss in "worst case" scenario of 7m inundation, with severe damage to housing, leisure and agricultural sectors as well as to the natural environment. A recent study by Antonioli et al., (2017) on climate change-induced SLR in the Italian regions of North Adriatic, the Gulf of Taranto and Sardinia (Oristano and Cagliari) reports that the expected projections of SLR by 2100 (516-1010 mm for the IPCC scenarios and up to about 1430 cm for the Rahmstorf scenario) will have a dramatic impact on the Italian coastal plains, with about 5500 km2 inundated, resulting in land loss, damage to environment and infrastructures, as well as inland migration. In Sardinia, the maximum sea-level rise by 2100 is estimated to be about 1.35 m, leading to partial flooding of several areas located at 1 m a.s.l. Such changes cannot leave intact tourist facilities and infrastructures. Sagoe-Addy & Addo (2013), having studied the enhanced sea level rise (ESLR) impacts on tourism infrastructure on coastal Accra (Ghana), indicate that 13 tourism facilities may suffer from SLR impacts, with 31% likely to be fully damaged. Scott et al., (2012a) studied potential impacts of one metre SLR in the Caribbean islands, suggesting that 29% of the resort properties would be partially or fully inundated, whereas indirectly, through causing beach erosion, a one-metre sea level rise would affect 60% of resort properties. The projected losses are estimated to halve tourism receipts and are expected to be spread unevenly across the Caribbean region, with 50% of the loss burden lying on 5 countries.

While most of the studies tend to project severe consequences of SLR on coastal infrastructures, some suggest that the overall impact on the tourism industry would be moderate. Bigano et al. (2008) estimate the impacts of SLR on tourists flows and on the world economy through a Computable General Equilibrium (CGE). The results suggest that 25 cm. of sea level rise projected by 2050 would lead to a GDP loss ranging from 0.1% in South East Asia to almost no loss in Canada, while redistribution of tourist flows would correspond to GDP losses ranging from 0.5% in Small Island States to 0.0004% in Canada. Therefore, the study also highlights that both SLR and the redistribution of tourism flows would have different impacts in different parts of the world.

Consequently, some countries have begun to invest in a variety of adaptation initiatives such as beach protection and artificial beach nourishment (Mycoo & Chadwick, 2012). Such measures are obviously costly, but ignoring mitigation and adaptation strategies may lead to much higher losses. Darwin & Tol (2001) estimate that if no protection measures take place, a 0.5 meters SLR in 2100 would have the annualised total cost of about US$43 billions, with severe differences across regions: US$7 billions in Europe and US$36 billions in the Asian region. However, adopting an optimal protection package would reduce total cost, thus resulting in US$10.5 billions for the whole world. Importantly, the

Table 2: Summary of Impacts found in the literature corresponding to *Loss of attractiveness and comfort due to beach availability reduction*

Impact Studied	**Reference**	**Results**
Impact of Sea Level Rise (SLR) on beach erosion and damage to coastal infrastructure	Schleupner (2008)	25cm SLR poses a risk on 87% of beaches used for tourism (Martinique)
	Snoussi et al. (2008)	24% of land loss in the case of 2m inundation (*best case*); 59% of land loss if 7m inundation (*worst case*) (Moroccan coasts)
	Antonioli et al. (2017)	Projections of SLR by 2100, of 526-1010mm for IPCC scenario and 1430cm for Rahmstorf scenario, will result in 5500 km² inundated (Italian coastal regions)
	Sagoe-Addy & Addo (2013)	13 tourism facilities may suffer from SLR impacts; 31% likely to be fully damaged (Accra, Ghana)
	Scott et al. (2012a)	1m of SLR will result in 29% of resort properties partially or fully affected; indirectly affected 60% of resort properties. Uneven spread: 50% of loss burden lying on 5 countries. (Caribbean islands)
Tourists' valuation and behavior	Uyarra et al. (2005)	77% of tourists unwilling to return in case of beach surface reduction (Barbados)
	Raybould (2013)	17-23% tourists opting for alternative destinations under different beach erosion scenarios (Australia)
	Nilsson & Gössling (2013)	Algae bloom affects tourist demand: >75% consider algal bloom as something negative (health hazard, threat to bathing, aesthetic problem) and reduce visitor satisfaction. <25% have been affected by the algae: 81% could not take a swim and changed activities (40%); 17% shortened their stay and moved to another holiday area; 8% cancelled their holiday.
	Rulleau and Rey-Valette (2013)	WTP for beach protection measures is, on average, €36.4 per household per year. (French Mediterranean)
	Castaño-Isaza et al. (2015)	Tourists' experience and the value they placed on SAI's (San Andres Island) beaches is estimated as WTP of US$ 13,414 for the whole sample. Given the estimated expansion factor of 74.4, the extrapolated WTP for all tourists to SAI annually is US$ 997,468.
Economic Impact	Uyarra et al. (2005)	Tourism revenues decreased by 46% because of less tourists arrivals from beach reduction (Barbados)
	Raybould (2013)	Drop of revenues around $20-$56million p.a. because of less tourists arrivals from beach reduction (Australia)
Impact of SLR on tourists flows and world economy	Bigano et al. (2008)	25cm of SLR projected by 2050 would lead to GDP loss of 0.1% in South East Asia; no loss in Canada. Redistribution of tourist flows would mean GDP losses from 0.5% in Small Island States to 0.0004% in Canada
	Darwin & Tol (2001)	If no protection measure takes place, 0.5m of SLR in 2100 would have an annual cost of $7billions in Europe and $36billions in Asian regions. However, adopting an optimal protection package would cost $10.5billions for the whole world.

authors find that international trade is going to smoothen disparities in losses by redistributing from regions with relatively high to regions with low damages. Extreme weather events, such as storms and hurricanes, can produce immediate detrimental impacts, which could be even more profound that those from SLR, although the literature is biased towards the latter. A recent study of the 2015-2016 El Niño events (Barnard et al., 2017) revealed that the shoreline retreat among the six regions of the US West Coast in the winter of 2015-2016 was 76% above the normal winter erosion rates. Similarly, the stormy winter of 2013-2014 along the Atlantic coast of Europe was found to have changed dramatically the equilibrium state (beach gradient, coastal alignment, and nearshore bar position) of the beaches (Masselink et al., 2016). The effects were found to vary depending on obliqueness of the waves, and lead not only to beach erosion, but also to beach rotation (Burvingt et al., 2016). The immediate economic impacts of events such as El Niño can be quite considerable, reaching US$11.5 billion globally (NOAA, 2016).

Regarding the impacts of extreme events on the demand side, the literature consistently finds a negative impact on tourist arrivals. Results from a study in Jamaica show that increased number of hurricanes may cause a fall in the exchange rate and a decrease in tourism arrivals in the short term, and a negative impact on tourists' expenditures in the long-run (Ghartey, 2013). Increased greenhouse gases may change the frequency and intensity of events such as heat waves, drought and fire in the Mediterranean region, leading to a less economically and environmentally sustainable tourism with criticalities for tourists' safety and adaptability (Perry 2006).

The literature that studies the past dynamics of different types of extreme events generally finds that their frequency and intensity has been increasing. Wave height and other parameters of storminess, which are found to have risen over the last decades, are of particular interest for marine sector. Specifically, for the Atlantic coast of Europe an increasing trend in significant wave height of up to 0.02 m yr-1 was documented (Bertin et al., 2013), and elevated levels of storminess measures have also been observed since 1871 in many parts of central, western and northern Europe (Donat et al., 2011). However, regarding projections of extreme events occurrence, intensity and frequency, there is little consensus in the literature. An extensive review by Seneviratne et al. (2012) reveals that there is low confidence for the abovementioned wave height projections, as well as for the El Niño episodes, while high confidence in projections of heat waves and temperature extremes in general. Therefore, it is crucial to account for occurrence and intensity of extreme events and for the uncertainty in their projections when modelling and measuring the socio-economic impacts of climate change.

4.1.3. Forest fires

Climate change may also impact destinations through the probability of wildfire occurrence. Wildfire outbreaks are particularly likely when humidity is extremely (unusually) low while the temperatures are extremely high. For example, extreme summer heat in Moscow in 2010 fuelled wildfires in vast areas around the city, resulting not only in physical damage to the forests, but also to severe increase in pollution, leading to 11.000 excess deaths over only 6 weeks (Shaposhnikov et al., 2014).

The impact chains analysis highlights the importance of wildlife fires in affecting the attractiveness of the destination for tourist purposes. Despite the fact that wildfires often result in large losses of forests and even human lives, this chain is among the least represented in the current literature, with much more emphasis on losses and recovery strategies (Lynch, 2004), than on tourists' behaviour. Concerning the demand side, there is mixed evidence on the attitudes of tourists towards fires. While the immediate effects of fires can be negative, in the long-run tourist behaviour does not alter (Hystad & Keller, 2008). Moreover, a considerable share of tourists can be completely insensitive to fire risks and do not intend to change their travel plans even when informed about wildfires present in the destination. For instance, in Florida, where wildfires happen almost on a yearly basis, about 33% of tourists are not at all discouraged by this risk factor, while 42% would change their behaviour only if the risk is very high (Thapa et al., 2013). Regarding the supply side, a somehow similar picture appears: businesses report being affected in the short-run, but not in the long-run (Hystad & Keller, 2008). However, in some cases indirect impacts of increased probability of wildfires, such as increase in insurance costs, can be even more considerable than the direct ones, especially for small businesses (Cioccio & Michael, 2007).

4.1.4. Loss of attractiveness of land environments (due to loss of species and/or increase of exotic invasive species or degradation of landscape)

This impact chain is the least investigated by scientific research. To the best of our knowledge, there is only one paper (Hakim et al., 2005) which studies the impact of changing land environments on tourism demand, while no papers investigate the supply-side. However, there are a few contributions on the reverse impact: how tourism contributes to the invasive species diffusion (Anderson et al., 2015) and to biodiversity loss (Steven & Castley, 2013). The lack of research on land environments sums to the scattered evidence on the impact of forest fires recalled in the previous sub-section, and suggests that marine tourism is really facing the sea: everything that happens behind, on the land, in the forests have little importance for tourists and hence for research.

4.2. Loss of tourist experience value in the destination due to changes in human being comfort

4.2.1. Loss of comfort due to thermal stress and heat waves

The relationship between weather and climate variables and tourists' comfort is complex and is the focus of numerous studies. To measure the suitability of climate for tourism sector the literature resorts to different variations of the Tourism Climatic Index (TCI), originally proposed by Mieczkowski (1985), which allows incorporating several weather dimensions (e.g. mean temperature, humidity, precipitation, etc) and has an easy interpretation. Mieczkowski's original index has been modified and adapted, leading to alternative versions (de Freitas et al., 2008), creation of indices for specific types of tourism (Moreno & Amelung, 2009), or area-specific modifications, with a focus on Europe and the Mediterranean region (Amelung & Viner, 2006; Moreno & Amelung, 2009;

Perch-Nielsen et al., 2010), Australia (Amelung & Nicholls, 2014), or at global scale (Amelung et al., 2007). This unified tourist comfort measure is then used to obtain projections of seasonality changes in various regions. Amelung & Viner (2006) and Amelung et al. (2007) use TCI to predict shifts in seasonality for the Mediterranean region for IPCC-2000 climate change scenarios. The results suggest that climate change will lead to the Mediterranean becoming too hot in summer but a more pleasant destination in the shoulder seasons. For the case of Balearic Islands the studies predict that, while these changes may be even favourable from resource management and biodiversity point of view, effects from an economic and social perspective are likely to be detrimental. Abundant literature provides evidence of tourism being a highly weather-sensitive activity (Maddison, 2001; Scott et al., 2008; Becken, 2010). This relationship stems, in particular, from the effect on human being comfort. On the extensive margin, weather and climate directly affect tourism industry through tourists' destination choice (Gössling et al., 2006); on the intensive margin, they change the type of available activities and their timing (Cavallaro et al., 2017; Gómez-Martín et al., 2014), generating changes in tourists flows within destinations. Additionally, tourists' comfort may be indirectly affected when climate changes result in a decrease of water availability (itself also a consequence of extra-demand of water generated by tourism), or an increase in health risks. These indirect effects receive less attention in the literature. Gómez-Martín et al. (2014) study the case of a heat wave in Spain in 2003 and inquire respondents on their perceptions of the extreme weather they had to face and on the changes in their habits and activities. According to the results, many tourists switched to indoor activities and 25% reported a substantial increase in water consumption. The study also highlights that perceptions are heterogeneous across respondents of different age: younger generations are less susceptible to extreme weather conditions than the elderly. Indeed, while high temperatures are generally associated with higher risks of dying from cardiovascular, respiratory, and cerebrovascular diseases, these risks are substantially more pronounced for young children and people older than 65 (Basu, 2009).

Climate and weather change will, therefore, inevitably lead to increased health costs. As shown in Toloo et al. (2015) for the case of Brisbane, Australia, projected increased temperatures can have a considerable impact on Emergency Department admissions: the excess number of visits in 2030 is estimated to range between 98–336 and 42–127 for younger and older groups, respectively, with the associated costs of AU$51,000–184,000 and AU$27,000–84,000. By 2060, these projections reach 229–2300 and 145–1188 at a cost of between AU$120,000–1,200,000 and AU$96,000–786,000 for the respective age groups.

4.2.2. Increase of health issues due to emergent diseases

Apart from the direct effect on health outcomes, climate change is expected to have pronounced indirect effects via disease spreading. In light of globalization and increased population mobility, the geography of certain diseases is changing rapidly, urging to be seriously considered in the process of diagnosing. Tourists are a particularly vulnerable population subgroup, especially when they choose a destination with environmental features which are drastically different from those of their country of origin. The health and medical literature, however, generally does not focus on tourists, and more often considers increased risk for various demographic groups of the indigenous population. One of the exceptions is the analysis of Lau et al. (2010a) and Lau et al. (2010b). The authors examine potential effects of climate change on the spread of leptospirosis and conclude that increased temperatures, extreme weather events and particularly flooding will result in increased incidence and magnitude of the outbreaks of this disease. Results reveal that travellers are at particularly high risk even if initially they are in good health because the disease is often under-diagnosed in their home countries. Importantly, the paper highlights adventure-seeking tourism activities as most susceptible to leptospirosis. Therefore, it should be noted that different types of tourism exhibit different exposure to health risks (e.g. cruise tourism is one of the most vulnerable (Liu & Pennington-Gray, (2017).

From an economic perspective, disease spreading can have significant economic impacts, both directly and through affecting tourism arrivals, on the destination. Developing countries are likely to be the most vulnerable to these impacts, since they are often highly dependent on the tourism industry, but also have lower levels of health care services and hygienic conditions. Mavalankar et al. (2009) estimate the potential losses for the tourism industry in a hypothetical scenario of the chikungunya and dengue epidemics in Gujarat (an economically important state of India), Malaysia, and Thailand. Under the assumption of 4% annual decline in the number of international tourists from non-endemic countries, the estimated losses of tourism revenues are at least US$ 8 million for Gujarat, US$ 65 million for Malaysia, and US$ 363 million for Thailand. To have an idea of the relative importance of these values, the authors provide comparison with the estimated immediate annual cost of chikungunya and dengue to these economies: US$ 90 million, US$ 133 million, and approximately US$ 127 million respectively, thus revealing that highly tourism-dependent Thailand would incur extremely high losses.

4.3. Loss of tourist experience value in the destination due to the change in the quality of infrastructures and facilities

4.3.1. Increase of damages to infrastructures and facilities (accommodation, promenades, water treatment system, etc.) due to sea level rise and extreme weather conditions

Infrastructure and facilities play an important role in providing tourism services. Apart from accommodation per se, a wide range of amenities contributes to the attractiveness of a destination: transportation (Della Corte et al., 2015), restaurant services (Szende et al., 2018), recreation facilities and amusement parks (Zopiatis et al., 2017), etc. Climate change can have both direct and indirect effect on these features.

Table 3: Summary of Impacts found in the literature corresponding to *Loss of comfort due to thermal stress and heat waves*		
Impact Studied	**Reference**	**Results**
Relationship between climate and tourists' comfort	Amelung et al. (2007)	Climate change will lead to Mediterranean becoming too hot in summer, but a more pleasant destination in shoulder season.
Tourists' behaviour	Gössling et al. (2006)	Weather and climate directly affect tourism industry through tourists' destination choice (extensive margin)
	Cavallaro et al. (2017)	Climate changes the type of available activities and their timing (intensive margin), generating changes in tourists flows within destinations.
	Gómez-Martín et al. (2014)	Due to a heat wave, many tourists switched to indoor activities; 25% reported substantial increase in water consumption. Younger people are less susceptible to extreme weather conditions than the elderly (Spain)
Impact of climate on health	Basu (2009)	High temperatures associated with risk of dying from cardiovascular, respiratory and cerebrovascular diseases; risks substantially more pronounced for young children and people older than 65.
Health costs	Toloo et al. (2015)	Increased temperatures impact Emergency Department admissions: excess number of visits in 2030 estimated to be 98-336 for younger group and 42-127 for older, with associated costs of AU$51,000-184,000 and AU$27,000-84,00. By 2060, higher projections (Brisbane, Australia)

The quantity and intensity of precipitation was found to have an effect on transport demand through its influence on the choice of transportation mode, trip postponement or cancellation (Koetse & Rietveld, 2007, Koetse & Rietveld, 2009). For the aviation sector the crucial factors are wind speed and direction; however, the potential impacts of climate change are viewed as ambiguous, since the impacts may affect transport infrastructure in different directions (Koetse & Rietveld, 2009). A study of climate change impacts on road and railway systems at EU27 aggregated level by Nemry & Demirel (2012) suggests that normal degradation rates of road transport infrastructures will only slightly increase in the future (according to A1B scenarios for 2040-2100). However, more frequent extreme weather events may induce additional cost of 50-192 million €/yr. In contrast, softer winter conditions are projected to reduce the costs by 170-508 million €/yr.

As regards restaurants, hotels and other facilities, they are also directly influenced by weather and climate change. In particular, extreme events are the most damaging and may have severe consequences, especially for small and less productive businesses that face financial constraints. These effects can be even more pronounced in the long-run, if the area is characterized by high levels of competition (Basker & Miranda, 2014), which is often the case for coastal areas. It is important to note that infrastructural damages resulting from the increased probability of extreme events are often much higher than those from gradual climate change processes. Using the case of Barbados and scenarios for land loss, inundation and flooding due to SLR and hurricanes until 2100, Moore et al. (2010) have shown that when only SLR is accounted for, the projected losses in revenues are $15.6-$150.3 mln, while if hurricanes scenarios are also incorporated, the projected losses rocket up to $267-$1477 mln. On the demand side, damages to different infrastructures were found to have a negative impact on the destination image, especially for tourists who have never visited the destination before (Pearlman & Melnik, 2008).

4.3.2. Decrease of available domestic water for the tourism industry
Climate change can also impact the quality of the facilities indirectly, for instance, by affecting water availability, and this aspect receives plenty of attention from the literature. While globally tourism-related direct water consumption was estimated to be less than 1% and is expected to remain marginal even taking into account tourism growth projections (Gössling et al., 2012), in fact, for heavily tourism-dependent countries tourism sector is one of the major water consumers. In Barbados, for instance, the average per capita consumption associated with tourism is three times higher than the one of domestic consumers, and water demand by the tourism sector is projected to rise from the current 12% to 18% of total consumption by 2050 (Cashman et al., 2012). Given that most of the climate change projections predict a decrease of precipitation levels for Barbados (Cashman et al., 2010), freshwater scarcity is expected to be a serious issue affecting all economic sectors, including tourism, resulting in increased operating costs, and consequently, increased prices (Cashman et al., 2012). This may lead to significant changes in the market, giving a comparative advantage to larger hotels and resorts, since they are more efficient in water consumption due to economies of scale (Gabarda-Mallorquí et al., 2017). Furthermore, for countries where tourism is a major sector providing jobs and generating revenues, needs of tourists might be prioritised over the needs of local population, creating potential for local conflicts, instability and marginalization (LaVanchy, 2017). It is important to note that developing countries are not the only focus of the literature: in the context of the Mediterranean region, for instance, it addresses concerns about the impacts of decreasing rainfall on water supply availability (Philandras et al., 2011) and costs (Martínez-Ibarra, 2015). The literature also tackles important methodological aspects of measuring the water footprints, such as taking into account both direct and indirect water consumption: although the latter is often overlooked, it may account for much larger share of water consumption by tourists than its direct counterpart (Hadjikakou et al., 2013).

4.3.3. Loss of attractiveness due to loss of cultural heritage (monuments, gastronomy, etc.)
Finally, climate change may also have an impact on those segments of a destination's infrastructure that are the very purpose of the trip: monuments, architecture, and other cultural heritage. Existing studies provide evidence that climate change will lead to damage of different types of cultural heritage (Hall et al., 2016), and result in increased conservation-restoration costs (Grøntoft, 2017). While the literature on the impacts of tourism on the cultural sites is very vast, there is very scarce research investigating the reverse relationship. A

notable exception is the study of Alberini & Longo (2009), who apply contingent valuation to investigate the cost-efficiency of a hypothetical conservation program for heritage sites in Armenia. Their analysis revealed that uncertainty about what would happen to monuments in the absence of the program results in decreased willingness to pay. However, the study was conducted using data from surveying local population rather than tourists.

5. Conclusions

Climate change is susceptible of having important effects on the tourism industry, since both the supply and the demand of tourism services depend upon the quality and management of a set of environmental attributes which are under threat of modification by climate change. This paper has provided a working specification of the methodological framework for investigating and interpreting the impact of climate change on tourism. Given the diversity of destinations and the heterogeneous impacts that climate can have, the focus of this paper is on coastal and marine tourism only, where three main channels of transmission and nine impact chains have been identified and analysed.
In order to make risk assessment operational there is the need to evaluate the various linkages associated within the impact chains of climate change. This paper has critically assessed the recent literature in order to estimate the economic impact of climate change on tourism based on the available evidence. Thus, a value transfer approach is applied, which is commonly utilized in many scientific fields and in environmental economics to estimate the value of unknown variables or parameters based on available empirical evidence.
In short, this paper aimed at critically classify and assess recent findings and contributions in light of the methodological approach provided by Impact Chains, thus building a bridge between academic research and practical climate risk assessment policies and identifying gaps to fill with future research.

To summarize, there is abundant literature on the effects of climate change on tourism flows. However, a wide range of empirical methodologies and approaches are applied to diverse case studies, and relatively few studies aim to pin down particular channels of transmission: in fact, they focus on either the environmental (intermediate) impacts of climate change, or on the effects of these intermediate impacts on the tourism industry, but not on the full chain of interconnections (physical and economic impacts). Results show the lack of sufficient evidence to cover all the potential impacts of climate change in coastal and marine tourism. Physical impacts of climate change are very well studied, although the degree of consensus varies across the literature: there is more confidence about projections of impacts of sea level rise, less confidence in the projection of extreme events occurrence and intensity.

Secondly, economic impacts focus in general on the demand side, looking at the effect on the number of tourists arriving at the destination and on their expenditure pattern, while only a few contributions investigate the supply side. A relevant exception is the impact on infrastructures and facilities, specially stemming from sea level rise and increase intensity and frequency of storms. Thirdly, we identified some impact chains that are particularly overlooked by the literature (impact of changes in land environment and for cultural heritage degradation on the destination image, where academic research focusses instead on the reverse link (that is, how tourism impacts land environment and cultural heritage). It is hence in these subfields of research that there is room for future contribution.

As regards the empirical evidence that can be used in a value transfer context, the impacts due to loss of attractiveness of marine environments (species or landscapes), loss of comfort due to beach availability reduction, and loss of comfort due to thermal stress and heat waves are the most promising. However, although the economic impacts for these three environmental threats are significant, implying large reductions in the number of tourists and relevant amount of monetary damages, the range of estimates is too large to provide punctual and feasible values to be transferred. Just to recall a few of the most striking results, Parsons and Thur (2008) estimate that the decrease in tourists' spending due to biodiversity loss in Thailand would range between $45 and $190; Raybould et al. (2013) estimate that tourism expenditure in Australia would drop between $20 and $56 million because of beach reduction; Bayraktarov et al (2016) estimate that rehabilitation projects of marine environments would cost between $80,000 and $1.6 million per marine hectare in five marine areas. The range of estimates is so large that the transfer of these results to specific destinations then becomes feasible only if adjusted by informed expert judgment and by on site information to complement prior assessments based on the unit value transfer approach.

Finally, the paper is not free of limitations, which also constitute the avenue for future research. One, the present work only focuses on coastal and marine tourism, and the application of our methodological approach based on the identification of impact chains to other types of tourism (mainly mountain, cultural and business tourism) is of paramount importance. Two, someone might be interested to work on a meta-analysis, although the diversity of methodologies and approach used in the literature, and the wide range of available estimates cast a serious doubt on the feasibility of such analysis.

Acknowledgements
Research for this paper has been supported by European Union's Horizon 2020 research and innovation programme under grant agreement No 776661, project "SOCLIMPACT - DownScaling CLImate imPACTs and decarbonisation pathways in EU islands and enhancing socioeconomic and non-market evaluation of Climate Change for Europe, for 2050 and beyond". A previous version of the paper has been included in the SOCLIMPACT material as Deliverable 5.1 "Report on the Bibliography". We thank participants to the 7th IATE Conference (La Plata, Argentina) and to the 11th TEM Workshop (Colonia, Uruguay) for comments and suggestions. The usual disclaimers apply.

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