

# CLIMATE CHANGE AND THE VISITOR INDUSTRY

People, Place, Culture, and the  
Hawai'i Experience

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A report for the Hawai'i Tourism Authority





# The Center for Sustainable Coastal Tourism

The University of Hawai‘i Sea Grant Center for Sustainable Coastal Tourism (Center), established in 2009, is a university collaboration between the School of Ocean and Earth Science and Technology, the College of Social Sciences, School of Travel Industry Management, Hawai‘inuiākea School of Hawaiian Knowledge, and the School of Architecture. In partnership with local businesses, government, and the community, the Center conducts research, education, and outreach on sustainable coastal tourism in Hawai‘i and the various economic, cultural, and environmental impacts of the visitor sector. The Center acknowledges tourism as a central driver of the economy in Hawai‘i and recognizes the inseparable link between the environment and the economy. The Center’s primary focus is improve the quality of Hawai‘i’s natural environment, maintain habitats and ecosystems, and reduce the energy and water needed to support the tourism sector resulting in positive impacts for Hawai‘i’s economy and quality of life for local residents. For more information on the Center, please visit <http://sct.seagrant.soest.hawaii.edu/>.

## Acknowledgements

This study was funded by the Hawai‘i Tourism Authority by contract HTA-L-11-77 “Climate change impacts to Hawai‘i visitor industry and coastal communities: Benchmark analysis and outreach” with the University of Hawai‘i Sea Grant College Program.

The authors are grateful to Matthew Gonser (University of Hawai‘i Sea Grant College Program) for his review and for producing the maps in this report.

A large mahalo goes to Darren Lerner and Darren Okimoto (University of Hawai‘i Sea Grant College Program) for their reviews and suggestions.

The authors would also like to thank the following external reviewers for their valuable comments: Pao-Shin Chu (University of Hawai‘i, School of Ocean and Earth Science and Technology), Lee Endress (University of Hawai‘i, Department of Economics), Juanita Liu (University of Hawai‘i, School of Travel Industry Management), James Mak (University of Hawai‘i, Department of Economics), John Marra (National Oceanic and Atmospheric Administration), Toufiq Siddiqi (East-West Center), and Oliver Timm (University of Hawai‘i, School of Ocean and Earth Science and Technology).

Finally, appreciation is extended to Cindy Knapman and Heather Dudock (University of Hawai‘i Sea Grant College Program) for their assistance in editing and publishing the report.

This paper is funded in part by a grant/cooperative agreement from the National Oceanic and Atmospheric Administration, which is sponsored by the University of Hawai‘i Sea Grant College Program, SOEST, under Institutional Grant No. NA09OAR4171060 from NOAA Office of Sea Grant, Department of Commerce. The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its subagencies. UNIHI-SEAGRANT-TT-12-06

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# Executive summary

Over the next couple of decades climate change is expected to have an increasingly negative impact on Hawai‘i’s tourism sector, the state’s primary economic engine. Understanding the magnitude of this impact is necessary to develop targeted adaptation strategies. Using an analytical approach, we identify climate processes, their effects on ecosystems and human activities, the impacts on tourism resources, and feasible adaptation strategies. This report also suggests priority sectors that should be involved in adaptation in support of tourism, identifies regions potentially vulnerable to the effects of climate change, and compiles the available information about the economic value of tourism resources in Hawai‘i.

The processes triggered by the increase in global atmospheric greenhouse gases concentration on Hawai‘i’s environment include:

- Increase in air and sea surface temperature
- Acidification of the ocean
- Rise in sea level
- Change in rainfall and stream flow pattern and variability
- Increase in drought frequency and duration
- Change in storm frequency
- Intensity and decrease in trade winds

All these processes have multiple impacts on both ecosystem and human dimension that affect tourism directly and indirectly. Priority adaptation sectors include public health, tourism-related businesses, transportation assets, and recreational activities and facilities. Tourism resources and assets jeopardized by climate change are found in all the Hawaiian Islands making adaptation applicable to the entire state. The available data shows that the market price for Hawai‘i’s natural resources, tourism infrastructure and facilities, and tourism-related businesses in 2010 had a value of 8.245 billion USD.

Given the great importance of tourism resources to Hawai‘i’s economy, adaptation strategies that tackle the challenges that climate change brings to each sector include:

- Energy and water
- Health
- Natural resources and outdoor recreation
- Coastal facilities and infrastructure
- Competition with other tropical destinations

These strategies have the potential to provide Hawai‘i’s tourism sector with environmental, economic and educational opportunities.

This work constitutes the first analysis of the vulnerability of tourism resources and their economic value. Further research on climate and economics developed from this fundamental investigation will allow for a deeper comprehension of the implications of a changing climate on Hawai‘i’s tourism industry.

# Introduction

## Climate change and tourism in Hawai‘i

Climate change is an issue of global concern, particularly for islands and coastal regions. The Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report (AR4) released in 2007 concluded that the current climate change is human-induced, and identifies the increase in the concentration of atmospheric greenhouse gases (GHGs), especially carbon dioxide (CO<sub>2</sub>), as its primary driver (Solomon et al., 2007). Globally, coastal marine ecosystems provide more than 14 trillion USD in ecosystem goods and services annually, which accounts for 43% of the world’s total (Harley et al., 2006), while per capita Gross National Product (GNP) in coastal areas of the world tends to be four times higher than inland areas (Brown et al., 2006). Given that coastal regions play such a key role in sustaining the world’s economy, the effect of climate change in these areas is of particular concern.

The IPCC, together with other international institutions, indicates that climate change adaptation and mitigation policies must be implemented soon to avoid the increased economic, social, and environmental costs that will be incurred if nothing is done. The consequences of climate change will differ greatly depending on the region, meaning that targeted mitigation, adaptation, and development policies, specifically designed for the economic, social, and environmental conditions of the region, are necessary (Parry et al., 2007). The threat of climate change provides an opportunity to consider our state’s vulnerability to natural hazards that is exacerbated by climate change and adopt a more comprehensive and holistic “no regrets” approach to climate adaptation and hazard mitigation.

The state of Hawai‘i is a geographically isolated chain of islands in the middle of the Pacific Ocean’s Ring of Fire (an area with a large number of earthquakes and volcanic eruptions surrounding the ocean basin) and is at risk from many natural hazards, including non-climatic hazards (e.g., earthquakes, volcanic eruptions, and tsunamis) and extreme weather events (e.g., tropical storms, drought, and flooding). The intensity and frequency of extreme weather events is likely to be exacerbated by climate change. The effects of climate change include an increase in air and ocean temperature, ocean acidification, sea-level rise, increased drought frequency, and changes in the frequency and intensity of tropical storms (e.g., Fletcher, 2010 and references therein). Climate change can have a potentially disastrous impact on Hawai‘i’s natural resources and, in turn, on its economy.

Hawai‘i, like many coastal economies and particularly tropical islands, relies on the tourism sector as the primary private source of GNP and employment. The U.S. Department of Commerce, Office of Travel & Tourism Industries (OTTI) defines travel and tourism as a sector made up of “...a diverse group of industries that supply goods and services purchased by businesses, and other travelers.” (Mak, 2004). Cai et al. (2005) report that, among the 131 industries in the Hawai‘i 1997 Input-Output table that measures the size of the relationships between the state’s industries, only 14 have no relationship to tourism, either as direct vendors to tourists or as intermediate suppliers. Industries that sell the majority share of their output to visitors are classified as tourism industries, and their revenues and profits would be substantially affected if tourism ceased to exist. In 1997, hotels, sightseeing transportation, automobile rental, amusement services, air transportation, ground transportation, golf courses, general merchandise stores, apparel and accessories stores, and recreation constituted Hawai‘i’s top ten tourism related industries in terms of total revenue.

The state of Hawai‘i is inherently rich in natural resources. Ravago et al. (2008) explained that tourism manifests the demand for these natural attributes because it converts non-market goods and services into market goods and services as tourists consume them. Thus, Hawai‘i tourism is an “export” in the sense that it generates an inflow of dollars and foreign currency from external demand. When tourists visit Hawai‘i, they consume non-traded goods and services (e.g., hotel services, restaurant meals, retail services, heritage and cultural

activities) as well as unpriced and underpriced environmental amenities (e.g., beaches, mountains, volcanoes, rock formations, tropical weather, etc). A rapid increase in tourism demand is the economic equivalent of a resource boom. The tourism boom stimulated demands for the non-traded goods, increasing their prices relative to traded goods. It also opened new markets that were nonexistent before (e.g., sightseeing tours). The income received by the service sector captures both value added in these industries as well as the value of non-market environmental amenities (Copeland, 1991).

In general, island economies like Hawai‘i show tendencies to be highly oil and tourism-dependent (UHERO, 2008). Hawai‘i’s primary private industries are tourism and residential services (health, financial, education, etc.). Few manufacturing activities exist and the agricultural sector is small (Konan, 2009). Thus, tourism continues to be Hawai‘i’s dominant economic sector and no other economic sector can now generate similar income levels and standard of living (DBEDT, 2006; Shea et al., 2001). Tourism is also an integral part of communities across the state and an important source of employment (Hawai‘i Tourism Authority, 2005). The income of nearly all Hawai‘i residents is tied to the visitor sector since it supports about 22% of all jobs in the state, directly and indirectly (DBEDT, 2006). Hawai‘i’s tourism sector also includes military and second home tourism. Battlefields and other military landmarks are major attractions for tourists. The tropical weather also convinces residents of other U.S. states and foreign countries to buy a second home or condominium in Hawai‘i (Ravago et al., 2008).

Climate change is expected to negatively impact coastal regions and their natural resources; the tourism sector will also be in need of particular adaptation strategies. At the same time, many tourism-related activities have been found to be greenhouse gas (GHG) intensive (Konan, 2009; Konan and Chan, 2010). Air transportation, sightseeing, and ground and maritime transportation services generate significant GHGs. Hotel, restaurant, and retail services also tend to be intensive in their use of electricity, utility gasoline, and water. As Hawai‘i’s visitors are heavy users of energy and transportation services, efforts to modernize tourism infrastructure and move to more sustainable practices that include conservation and efficiency can play an important role in relation to climate change mitigation, especially in regard to their ability to reduce GHGs emissions (Scott and Becken, 2010).

The first step in adapting Hawai‘i’s tourism sector to climate change is to understand the potential consequences of climate change for the natural resources and visitors upon which tourism relies. Climate change is a global issue and Hawai‘i is tied in with the rest of the globe. Therefore, climate change has the potential to affect Hawai‘i through its impact on the tourists who constitute the demand side of the tourism sector and the businesses that supply these goods and services, along with non-governmental organizations, government agencies, and residents who strive to protect tourism’s assets. The demand of tourists is affected by their income, by the price of getting to the destination, the prices at the destination, and by the attributes of the “package” tourists experience. Climate change also affects both the quantity and quality of Hawai‘i’s tourism assets, degrading them to the point that businesses supplying goods and services to visitors face bigger challenges, and those striving to protect these assets are also facing increased difficulty. These supply challenges make Hawai‘i less attractive. This will in turn affect the demand for tourism (Mak, pers. comm.)

The connection between climate change and tourism is widely recognized and investigated (e.g., Berrittella et al., 2006; UNWTO, 2009). However, modeling studies relating climate and tourism usually only consider temperature as proxy for climate (Gössling et al., 2012) and do not examine the effects of climate change other than increased temperature. Little has been done to develop a general approach to examine any other effect that global climate change could have on tourism and to develop specific adaptation strategies. In this report, a five-step sequential approach is used to assess the understanding of climate change impacts on Hawai‘i and its environment to link the driver of climate change to the local resources. From that, feasible strategies for sustaining the resources can be developed.

## Scope of the report

The overall scope of this research is to examine the current and potential impacts of climate change on Hawai‘i’s visitor industry, and to identify opportunities for adapting and sustaining the tourism sector.

To fulfill this goal, the study focused on the following objectives:

1. Derive the impacts of climate change on Hawai‘i’s tourism sector through an analytical review of the current knowledge
2. Determine the major vulnerabilities to climate change impacts for the tourism sector
3. Identify the priority geographic areas most frequented by visitors that are potentially at risk to climate change impacts
4. Present existing secondary data on the value of the tourism resources at risk, based on available visitor counts, preferences, and expenditure data
5. Explore feasible climate adaptation strategies

The report summarizes the current understanding of the consequences that climate change can have on Hawai‘i’s tourism industry in an analytical and interpretative way. It is directed to decision-makers, community leaders, local administrators, and tourism entrepreneurs in order to inform and provide guidance on the critical problems that climate change presents for tourism, the economy, and the community in general. The purpose of the report is to raise awareness and suggest strategies as a first step in adapting Hawai‘i’s society to a changing environment.

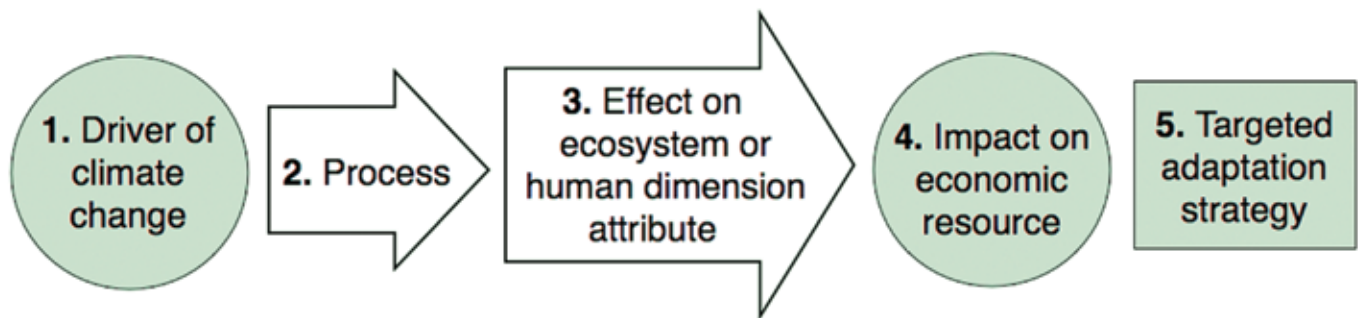
In the next section, an overview of the five-step process to link climate change impacts in Hawai‘i and the tourism resources is presented. The following section applies the analytical approach using a review of the published literature on climate sciences to derive the meaning of the observed and projected changes for tourism. The fourth section identifies the vulnerabilities and attempts an initial estimation for the economic value of the resources at risk, based on the available economic data. Adaptation challenges and opportunities for sustainable development of tourism in Hawai‘i are explored in the fifth section. The report closes with conclusions, an outlook for future research and policy needs, and a summary of considerations relative to Hawai‘i’s place in the Pacific Islands region.



# Identifying local impacts of global change

## An analytical approach

Although climate change will likely have repercussions for all sectors of Hawai‘i’s economy, isolating each consequence is difficult. A five-step sequential approach (Fig. 1) is used here to review, analyze, and interpret existing data and material. They were then combined in order to link the cause of global climate change to its impact on the tourism sector and to suggest potential, targeted adaptation strategies. This analytical and interpretative approach is advantageous as it establishes a framework for the review of the available information and guides the reader with a visual of the changes in global climate that concern Hawai‘i.



*Figure 1: Sequential analytical approach to identify the impact of climate change on a specific economic sector (tourism). The first step is the driver of climate change. This change will induce various processes, which are identified in the second step. Each process will have specific effect(s) on the specific ecosystem or human dimension attributes, representing a third step of the approach. In the fourth stage, the actual impact(s) on the tourism resources are identified. Finally, based on the impacts found, adaptation, and development strategies can be explored (Step 5).*

The starting point in this sequential approach is the drivers of climate change, primarily the increase in the concentration of greenhouse gases (GHGs) in the atmosphere. These changes induce various processes, both globally and regionally (e.g., an increase in ocean and air temperature), which are identified in the second step. Each process has specific effect(s) on the specified ecosystem (e.g., degradation of marine life) or human dimension attributes (e.g., discomfort), representing a third step of the model. In the last stage, the actual impact(s) on the economic resources are identified (e.g., loss in touristic attraction of particular areas), to recognize the specific feature, service, and/or infrastructure being most affected by climate change and in need of mitigation, adaptation, and/or development strategies. These can be developed in an additional fifth step.

In Table 1, a five-step methodology is explained in detail, from the drivers of climate change to the impact on the economic sector (e.g., tourism, agriculture, fisheries, energy) together with guiding questions that helped analyze the system.

The first step of the approach is the identification of the driver of climate change. This is ultimately the increase in greenhouse gases (GHGs) in the atmosphere, in particular, the increase in the partial pressure of carbon dioxide ( $p\text{CO}_2$ ). In Hawai‘i, the combustion of fossil fuels for electricity and transportation is the most significant driver of climate change.



Table 1. Description of the five steps in the analytical approach used in this report to derive impacts of climate change on a specific economic sector (tourism) and to develop targeted adaptation strategies.

<b>Step 1</b>	<b>Identification of the driver of climate change</b> <ul style="list-style-type: none"> <li>• What drives climate change in the area or region under study?</li> </ul>
<b>Step 2</b>	<b>Identification of the processes driven in the location of interest</b> <ul style="list-style-type: none"> <li>• What processes will most likely follow in the system?</li> <li>• What are the observations and the future climate projections for the area or region under study?</li> </ul>
<b>Step 3</b>	<b>Determination of the effects on the ecosystem and on human dimension attributes</b> <ul style="list-style-type: none"> <li>• What consequences will these processes bring to the natural ecosystem upon which the economic sector being investigated depends?</li> <li>• What consequences are expected for the human population in the area or region under study?</li> <li>• What are the most vulnerable attributes of the system and what are the risks for them?</li> </ul>
<b>Step 4</b>	<b>Assessment of the impacts on the sector of interest</b> <ul style="list-style-type: none"> <li>• What are the sectorial vulnerabilities related to the effects of climate change?</li> <li>• What are the direct impacts on the economic resource?</li> </ul>
<b>Step 5</b>	<b>Development of possible adaptation and development strategies</b> <ul style="list-style-type: none"> <li>• Based on the vulnerability assessment (Step 4), what solutions can be implemented for each impact?</li> <li>• Can common adaptation strategies be found for different impacts?</li> <li>• How can the sector be developed in a more sustainable way?</li> </ul>

The second step of the procedure consists of identifying the main processes driven by climate change in the specific region of interest, in this case, Hawai‘i. Observation of past and current changes as well as future climate projections have been considered at this stage of the analysis.

The third step of the approach is the determination of the effects that the processes analyzed previously can have on both the ecosystem and the human dimension attributes. This means considering all the possible outcomes (i.e., positive, negative, and neutral) that the processes will bring to the natural resources of the area and on the local population. This step helps identify the most vulnerable resources upon which tourism depends, and determine the concrete risks those resources are likely to face.

The fourth step represents the last stage in the analysis of the impacts climate change can have on Hawai‘i’s tourism. All potential increase and/or decrease in revenues and/or costs associated with changes in the

environment can be distinguished and analyzed. These are the resources that will be impacted by climate change and will necessitate adaptation strategies.

The fifth and final step includes analyzing the impacts of climate change on the economic sector of interest and identifying the most vulnerable resources through the first four steps of the procedure, then targeted adaptation strategies can be developed. The analysis covered feasible solutions that could be implemented for the specific resources needed in order to allow adjustments of the system and to favor a proper reaction to the expected changes. The same adaptation strategy could be applicable for multiple impacts and sectors. The implementation of targeted strategies can result in economic benefits and efficiencies, thereby contributing to sustainable development of the tourism sector.

# Impacts of climate change on Hawai'i tourism

## Climate change drivers, processes, effects, and impacts

The analytical approach for climate change impact assessment explained in the previous section was applied to the Hawaiian context with consideration of the observed climate trends as well as those projected for the future. We evaluate how changes in climate alter the ecosystems and affect the tourism sector. However, we did not investigate the local relationship between the natural resources and the tourism sector (non-climatic stressors) that may also have consequences for these ecosystems.

As the IPCC concluded, the driver of global climate change is ultimately the increase in greenhouse gases (GHGs) concentration in the atmosphere with carbon dioxide (CO<sub>2</sub>) being the most important among the long-living greenhouse gases (Solomon et al., 2007). Global atmospheric concentrations of CO<sub>2</sub>, methane, and nitrous oxide have increased markedly as a result of human activities since the Industrial Revolution, and now far exceed pre-industrial values inferred from ice cores spanning hundreds of thousand years. In 2008, global CO<sub>2</sub> emissions continued to rise, reaching 30.1 billion metric tons, an increase of 1.7% from the previous year (United Nations, 2011). The global increase in carbon dioxide concentration is primarily due to fossil fuel burning and land use changes, while the increase of methane and nitrous oxide is primarily due to agriculture.

In Table 2, we compiled the main processes driven by climate change in Hawai'i. The processes are linked to their effects on the ecosystems and attributes that affect humans (hereafter referred to as human dimension attributes), as well as to their corresponding impacts on the local tourism sector, including both natural resources and infrastructure upon which the visitor industry relies.

The increase in global GHGs concentration causes, directly or indirectly, a variety of changes in the Hawaiian environment. The scientific literature documents that the effects include:

1. An increase in air temperature (Giambelluca et al., 2008; Shea et al., 2001; Solomon et al., 2007)
2. An increase in ocean temperature (Bindoff et al., 2007; Casey and Cornillon, 2001; Shea et al., 2001)
3. An increase in ocean acidification (Byrne et al., 2010; Dore et al., 2009)
4. An increase in sea level (Pew Center on Global Climate Change, 2009; Vermeer and Rahmstorf, 2009)
5. A change in precipitation (Chu and Chen, 2005; Chu et al., 2010) and a decrease in stream flow (Oki, 2004)
6. An increase in drought frequency and duration (Chu et al., 2010; Karl et al., 2009; Loope and Giambelluca, 2004)

7. The change in frequency and intensity of tropical storms (Chu 2002; Emanuel, 2008; Gualdi et al., 2008; Knutson et al., 2010)
8. A decrease in frequency of northeast trade winds (Garza et al., 2012)

Table 2. Main processes driven by climate change in Hawai'i and their effects on environmental and human dimension attributes with correspondent impacts on the tourism resource.

Driver	Processes	Effects on ecosystem or human dimension attribute	Impacts on tourism resource
Increase in greenhouse gases concentration in the atmosphere	Increase in air temperature	Increase in discomfort especially during nighttime and at high elevations	Increase in energy use for cooling
		Spread of those pathogens responding positively to increased temperature	Impact on public health concerns
		Degradation of sensitive terrestrial flora and fauna	Loss in landscape amenities for land-based activities
		Enlargement of tropical areas	Change in the competitive advantage of the local tourism sector
	Increase in ocean temperature	Coral bleaching	Loss of amenities for marine-based activities
		Migration of non-native and invasive species	
	Ocean acidification	Degradation of marine flora and fauna	
		Loss in both quantity and diversity of species	
	Increase in sea level	Flooding of low-lying areas during high tides and heavy rainfall events	Deterioration of coastal recreational facilities
			Inundation of critical infrastructure
		Increased coastal erosion	Decrease in beach and shorelines areas
	Change in rainfall and stream flow pattern and variability	Decrease in freshwater supply	Decrease in water supply and increase in water prices
		Dryness/aridity of soil	Increase in the demand for irrigation water
	Change in storm frequency and intensity	Damage to environment and to private and public infrastructure	Increase in insurance costs
Decrease in tourist numbers as visitors react to the increased uncertainty of storm events			
Increase in death, injuries and suffering for visitor as a result of storm events			
High costs for repair			
Change in precipitation rate and pattern	Decrease in freshwater supply and increase in water prices		
Change in surface ocean circulation	Degradation of marine environment for marine-based activities		

The effect of each process on various ecosystem and human dimensions attributes and the consequences for the tourism sector are addressed below.

## 1. Air temperature

Weather data show a rapid increase in the surface air temperature (SAT) in Hawai'i over the last 30 years. Over the last century the SAT has varied as a result of the Pacific Decadal Oscillation (PDO), however, in the recent



decades the surface warming has dominated the cooling trend associated with the PDO (Giambelluca et al., 2008). According to the IPCC climate projections, North and South Pacific islands are very likely to warm during this century (Solomon et al., 2007). Other model-based climate change scenarios also highlight a general warming trend across the Pacific (Shea et al., 2001).

In Hawai‘i, nighttime temperatures and temperatures at high elevations have increased more relative to the average daily temperature (Giambelluca et al., 2008). Visitors, who are likely to be more sensitive to the increases in temperature since they often live in more temperate areas, are expected to find these increases uncomfortable and seek relief. This need for relief from the heat is expected to increase the use of cooling systems and, accordingly, in the increase in energy need for the tourist infrastructure used by the tourism sector.

Pathogens that respond positively to the rise in SAT could spread more quickly. This would bring an increase in the incidence of diseases affecting both people and animals, such as the reported spread of avian malaria in Hawai‘i to higher elevations. Additionally, the increased air temperature would increase the probability that visitors would suffer from extreme weather events such as heat waves.

An increase in SAT would change the characteristics of the terrestrial ecosystem, potentially leading to a general degradation of the terrestrial flora and fauna. Eventually, this could result in a general loss of the landscape amenities for land-based activities, such as hiking, biking, camping, and picnicking, which rely on the unique beauty of the Hawaiian environment.

Finally, a possible outcome of the rise in global atmospheric and oceanic temperature could be the enlargement of the tropical zones around the world, which increases the number of tropical coastal areas that visitors might consider rather than Hawai‘i. In the U.S., destinations in Texas, Louisiana, and Florida (also called the “3S states” for sun, sand, and sea) could become more competitive with Hawai‘i as they are able to offer tropical coastal environments at lower travel costs for visitors. On the other hand, other destinations that are currently competitive with Hawai‘i (e.g., the Caribbean Islands) will face similar problems due to global warming.

## **2. Ocean temperature**

Various studies conclude that the ocean surface temperature is rising globally, including the Pacific region (Casey and Cornillon, 2001; Shea et al., 2001). As assessed by the IPCC fourth Assessment Report (AR4), the global sea surface temperature (SST) has risen 1°C (1.8°F) in the last forty years and the warming trend is very likely to continue during this century (Bindoff et al., 2007).

The rise in SST can affect sensitive resources like coral reefs and fisheries. Bleaching occurs when corals are stressed by changes in temperature and other environmental conditions. The warming of the ocean is the fundamental cause of the increase in the frequency and severity of coral bleaching events (Jokiel and Brown, 2004; Keller et al., 2009). Additionally, if stressed by temperature and bleaching, corals are more vulnerable to pathogens and algal overgrowth (Harvell et al., 2002). Finally, increasing SST could expand the depth and range of invasive coral and fish species (Keller et al., 2009).

In terms of the visitor sector, these perturbations in the natural marine ecosystems could result in a general deterioration of the ocean coastal environment and, therefore, in a loss of highly valued amenities accessed by tourists using marine activities such as snorkeling, fishing, and scuba diving.

## **3. Ocean acidification**

Carbon dioxide is partially absorbed by the oceans and reacts with seawater. As levels of atmospheric carbon dioxide increase due to anthropogenic forcing, the concentration of CO<sub>2</sub> in ocean waters also increases, causing the oceans to become more acidic (Dore et al., 2009). Some marine organisms with calcium carbonate shells or

skeletons are adversely affected by decreases in pH and carbonate saturation state (Kuffner et al., 2008; Ries et al., 2009; Zeebe et al., 2008) as they would become unable to grow in an acidic environment.

As a consequence of the ocean acidification, the marine ecosystem will undergo a slow degradation, especially in shallow-water environments along the coasts and the coral reefs, where the marine fauna is more sensitive. As for the increase in ocean temperature, the ultimate consequence in terms of tourism would be a general loss in amenities for marine-based tourist activities (e.g., snorkeling or scuba diving).

#### **4. Sea-level rise**

Over the past century the relative sea level in Hawai‘i has been rising at different rates on each of the main islands due to isostatic rebound (vertical movements of the Earth’s crust) and wind-driven changes (Merrifield, 2011; Timmermann et al., 2010). Sea-level rise rates range from 1.5 mm/year (0.06 in/year) on Kaua‘i to 3.3 mm/year (0.13 in/year) on Hawai‘i Island (Fletcher, 2010). Global mean sea level could rise by more than one meter (3.3 ft) by 2100 (Pew Center on Global Climate Change, 2009; Vermeer and Rahmstorf, 2009). As a consequence, the flooding of low-lying areas during high tides and heavy rainfall events and enhanced coastal erosion is expected in Hawai‘i.

Storm surge and the inundation of low elevation regions would have a strong impact on recreational facilities, such as beaches and parks, as well as on accommodation, critical infrastructure such as power generation and communication, and transportation assets such as roads, airports, and harbors. This infrastructure would become unusable during severe weather events and, if damage occurred as a result of the event, the infrastructure could be unusable for a longer time period. These weather events and the interruptions pose challenges for the tourism sector as entrepreneurs attempt to deal with managing the issues that current visitors face, and convincing potential visitors that the increased probability of such events occurring should not deter them from visiting.

Additionally, sea-level rise accelerates and expands the natural process of coastal erosion, decreasing the area of beaches and shorelines (Fletcher, 2010). The University of Hawai‘i’s Coastal Geology Group<sup>1</sup> has already documented shoreline retreat due to erosion occurring now along Hawai‘i’s coasts. Moreover, the shoreline response to sea-level rise is likely to be non-linear. This means that there could be a threshold in the ocean elevation beyond which the coral reefs surrounding Hawai‘i are no longer an effective barrier to incoming waves. As a result, once this elevation is regularly reached, the shoreline would experience a sudden and substantial change in flood and erosion potential (Marra, pers. comm.).

Since beaches are one of Hawai‘i’s major tourist attractions, the loss of beaches due to sea-level rise and erosion would have a dramatic economic impact on the visitor sector. Other tourism-related businesses such as restaurants, land-ocean activities, and other retail operations would also be impacted. A major tourism-related activity that would indirectly suffer from sea-level rise is surfing. Hawai‘i is a worldwide known destination for practitioners and professionals, and surfing represents a huge generator of income through contests, lessons, and related businesses such as the apparel industry. Famous locations could become unsuitable with the increase in water level if the waves could no longer break regularly on the reef, while new spots could become more suitable.

#### **5. Rainfall and stream flow**

Rainfall in Hawai‘i depends on the trade winds and is influenced by terrain, mid-latitude weather systems, subtropical storms, and tropical cyclones. Furthermore, the El Niño-Southern Oscillation (ENSO) and the PDO affect Hawai‘i’s rainfall and stream flow through internal climate variability (Chu, 1995). Both rainfall (Chu and Chen, 2005) and stream flow (Oki, 2004) records in Hawai‘i show a decreasing trend over the last century, and modeling studies suggest that this trend will continue in the future (Timm and Diaz, 2009). Although some studies have attempted to estimate changes in precipitation extremes (Norton et al., 2011; Timm et al., 2011), the estimates

<sup>1</sup> <http://www.soest.Hawaii.edu/coasts/erosion/index.php>

are qualitative overall rather than quantitative. Increasing rainfall intensity is projected for the island of Hawai‘i and parts of Maui, but decreasing intensity is expected for O‘ahu and Kaua‘i (Chu et al., 2010). For southern O‘ahu, however, an increase in the frequency of heavy rainfall events is projected for the next 30 years (Norton et al., 2011).

A decrease in rainfall in Hawai‘i could mean a decrease in the supply of freshwater, which would eventually lead to a water shortage affecting all economic sectors, including tourism. Furthermore, a decrease in the stream flow could decrease the opportunities for visitors to enjoy rafting, the viewing of waterfalls, and other terrestrial water activities. The projections of heavy rainfall in southern O‘ahu could represent a major concern for the tourism sector, as most of the accommodation infrastructures are located there.

## **6. Droughts**

Droughts are extended periods in which a region undergoes a prolonged decrease in the water supply. In Hawai‘i, droughts are related to El Niño events associated with dryer-than-normal winters and have become more frequent in recent decades (Chu, 1995). Over the last 60 years, Hawai‘i also experienced a longer duration of droughts (Chu et al., 2010). Due to the change in climate variability as a result of global warming this trend is expected to continue, and Hawai‘i will likely experience prolonged drought conditions during the six-month wet season from October to March when El Niño occurs (Karl et al., 2009). However, the current state of modeling projections for El Niño-Southern Oscillation (ENSO) is not totally conclusive (Vecchi et al., 2010).

Increased drought frequency will decrease the water supply and drive up water prices. Visitors generally pay for water as part of a bundle of services they purchase from an accommodation, attraction, or food service provider. Thus, visitors are expected to experience an overall increase in the prices they pay for many goods and services.

Drought can also have a dramatic impact on the agricultural sector, which indirectly affects the visitor sector. Furthermore, droughts decrease the supply of rainwater for the soil and therefore more water would be needed to irrigate the hotel and resort landscapes. This would increase the demand for water by the tourism sector.

## **7. Tropical storms**

The development of tropical cyclones depends on SST, water vapor content, and wind-shear. Examples of rapid storm intensification are associated with storms passing over deep, warm ocean pools, and through regions of low wind shear (Shay et al., 2000). Therefore, maximum tropical cyclone potential intensities could increase in response to increased SST, atmospheric temperature, and wind shear changes (Emanuel, 2008; Knutson, 1998). A reduction in the frequency and an increase in rainfall associated with the tropical cyclones are projected for the future (Gualdi et al., 2008). However, not many studies have explored the changes in tropical cyclones in Hawai‘i due to global warming and extrapolation must come from either the Eastern or Western Tropical Pacific, even though the Central Pacific storm track can have its own dynamical constraints from the wind-shear and changes in the preferred storm tracks approaching from the Eastern Pacific (Norton, 2011; Yokoi and Takayabu, 2009; Yu et al., 2010). In Hawai‘i, tropical storms appeared to occur more frequently during the El Niño events (Chu and Wang, 1997). On the longer time scale, hurricane activity in the vicinity of Hawai‘i has undergone decadal variations (Chu 2002). While a large degree of uncertainty exists about how climate change will affect storm patterns, experts generally agree that a warmer surface ocean is likely to lead to more intense storm activity in the future.

Increased intensity of tropical storms would cause damage to infrastructure, like communication, recreation areas, roads, and airports, as well as to energy and the local food supply, which would indirectly affect tourism. These events are expected to increase the chances of visitors experiencing death, injury, and suffering. As visitors react to the news of current storms, they are likely to assume that storm events are more common and therefore consider other destinations in the future. At the same time, the destruction from and clean-up of storm events often causes

environmental damage as people rush to restore normalcy. Businesses and the public sector would face high costs for repairs, an increase in insurance/program costs, and pass these costs on to visitors.

## 8. Trade winds

Recent studies show that the frequency of the northeast trade winds has decreased, while the east trade winds have increased in frequency (Garza et al., 2012). A change in the atmospheric circulation over Hawai‘i can modify the local precipitation rate and pattern as well as the surface ocean circulation. The effect of changes in precipitation and its impact on tourism resources was discussed above. Changes in local surface ocean circulation have the potential to affect marine recreational activities such as scuba diving, sailing, surfing, swimming, and snorkeling.

# Vulnerabilities and value

## Priority adaptation sectors

The analysis carried out in the previous section detailed the consequences Hawai‘i’s tourism sector is expected to face because of climate change (last column of Table 2). They can be summarized as follows:

- An increase in energy usage for cooling systems because of increased atmospheric temperature;
- An increase in public health concerns because of the possible spread of pathogens; the increased probability of accidents and visitors sufferings due to rain storms and heat waves;
- A decrease in attractiveness of land-based activities because of degradation of terrestrial flora and fauna and subsequent loss of landscape amenities;
- An increase in the competition of other destinations because of enlarged tropical zones and damages from tropical storms;
- A decrease in attractiveness of marine-based tourist activities because of increased ocean temperature and acidification, and subsequent loss of marine amenities;
- A deterioration of the coastal recreational facilities, inundation of accommodation and public infrastructure, and a decrease in beach areas and shorelines because of sea-level rise and enhanced coastal erosion;
- A decrease in the freshwater supply and an increase in water prices because of decreased rainfall and stream flow, and increased probability and length of droughts; and
- An increase in cost of infrastructure repair and insurance costs and a decrease in tourist numbers because of increased intensity of extreme weather events.

Sectors that have priority for the development of adaptation strategies can be associated to one or more of the identified impacts. These sectors (not ranked by importance) are listed below:

1. Public health will be affected by the possible spread of pathogens as well as by increased frequency of heat waves and accidents due to storms;
2. Tourism-related businesses, such as hotels, resorts, restaurants, and retail establishments, will be affected by rising energy and water costs, as well as extreme weather events, inundation, and lack of availability and attractiveness for tourism;
3. Transportation assets, such as roads, airports, and harbors, will be affected by extreme weather events and inundation;
4. Freshwater supply and recreation, such as stream kayaking and waterfall viewing, will be affected by the decrease in stream flow;
5. Golf courses will be impacted by the decrease in water supply for irrigation and a projected increase in heavy rainfall events;

6. Beaches will be affected by sea-level rise and enhanced coastal erosion;
7. Land-based recreation, such as hiking, biking, camping, picnicking, horseback riding, and bird watching, will be affected by the degradation of terrestrial ecosystems and the loss in quantity and diversity of plant and animal species;
8. Marine-based recreation, such as snorkeling, scuba diving, fishing, surfing, and swimming, as activities, will be affected by the degradation of the marine and coastal ecosystems and the loss in quantity and diversity of plant and animal species, as well as the missing protection of shallow waters given by coral reefs.

## High vulnerability areas

The identified priority adaptation sectors (also summarized in Table 3, but not ranked by importance), was used as the basis for the compilation of a preliminary list of the vulnerable areas in the state of Hawai‘i expected to be impacted the most by climate change. The list has been compiled based on highly recommended destinations and activities given by various travel guides, including the Hawai‘i Tourism Authority (HTA) Visitor’s Guide 2012-2013 and the Lonely Planet Travel Guide for Hawai‘i (2009), as well as on information derived from the State of Hawai‘i Department of Transportation (DOT), the State of Hawai‘i Department of Business, Economic Development, and Tourism (DBEDT), the Healthcare Association of Hawai‘i, and various online resources for travelers (e.g., TripAdvisor, Expedia, and the websites of major resorts, parks, and villages). As a preliminary assessment, this list is useful to identify the primary resources and infrastructure that have a high priority for the development of adaptation strategies. Table 4 shows the most vulnerable visitor attractions per sector of concern in each of the major Hawaiian Islands. The list is not ranked by priority, as its aim is purely informative. Prioritization efforts are very complex and require consideration across a wide variety of factors that is beyond the scope of this report and are left for the administrators and stakeholders of each sector.

*Table 3. Priority adaptation sectors.*

Public health	Hospitals, medical centers
Tourism-related businesses	Hotels, resorts, restaurants, retail establishments
Transportation assets	Roads, airports, harbors
Freshwater supply and recreation	Stream kayaking, waterfall viewing
Golf courses	Golf clubs, resorts, public courses
Beaches	Large, well-known beach parks
Land-based recreation	Hiking, biking, camping, picnicking, horseback riding, birdwatching
Marine-based recreation	Snorkeling, scuba diving, fishing, swimming, surfing

### 1. Public health

Increased occurrences of pathogen- and heat-related conditions are expected to increase the number of visitors who require medical services. Visitors are most likely to access larger hospitals because they are better known and easier to locate. In addition, secondary information about small, private clinics is more difficult to locate. Therefore, only the largest hospitals are included in the list, which tourists as well as residents are most likely to use.

### 2. Tourism related businesses

Tourists are expected to stay in hotels, frequent food service operations, and shop. Only the areas with the highest number of establishments are listed, not single hotels or shopping centers, unless they are large resorts occupying significant portions of land.



### **3. Transportation assets**

Visitors rely on transportation infrastructure (e.g., roads, airports) to get to the various attractions. The island of O‘ahu has a public bus system and a short freeway running along its eastern corridor. The other islands do not have as efficient public transportation systems. All islands have at least one major coastal road linking locations. The highest volume of coastal roads and highways are included in the list, as their interruption is more likely to cause major transportation problems. However, smaller, lower volume roads are vulnerable as they are often not well maintained, and therefore more at risk of damage from extreme weather events. In addition to the major highways and freeways, harbors and airports are also included in the list for each island.

### **4. Freshwater recreation**

Tourists are very interested in water activities and water views. The waterfalls and pools with the high volume of visitor traffic are listed. Many streams are highly dependent on the rainfall variability and do not exist in times of low rainfall regime.

### **5. Golf courses**

Golfing is a common activity for visitors. Golf clubs and resorts that include golf courses are listed here, as customers who are not hotel guests can also use the courses. The most popular public courses are also included.

### **6. Beaches**

Hawai‘i has many beaches which draw many visitors and residents on a daily basis. The beaches that have the highest volume of visitors are included. However, due to the large number of beaches all around the state, small beach parks and accessible shoreline areas are not listed.

### **7. Land-based recreation**

While ocean-based activities are most popular among visitors, land-based activities do provide a variety of recreational opportunities. The locations, where one or more of these land-based recreational activities are popular, are listed together. However, single ranches offering horseback riding tours are not listed.

### **8. Marine-based recreation**

Water activities are very popular for visitors. The most popular locations for these marine-based recreational activities are listed together. Some of the beaches are also included.

The vulnerable assets in the main Hawaiian Islands are also indicated in the maps in Figure 2 (Hawai‘i Island), Figure 3 (Maui), Figure 4 (Lāna‘i and Moloka‘i), Figure 5 (O‘ahu), and Figure 6 (Kaua‘i). The maps summarize visually the vulnerabilities with icons to indicate the priority adaptation sectors for sections of the various island.



Table 4. Tourism resources and areas at high vulnerability to climate change in the Hawaiian Islands.

Priority adaptation sectors	High vulnerability areas					
	Hawai'i	Mau	Lāna'i	Moloka'i	O'ahu	Kaua'i
Public health	Kona Community Hospital; Hilo Medical Center	Urgent Care Maui Physicians	Lāna'i Community Hospital	Moloka'i General Hospital	Queen's Medical Center; Straub Clinic & Hospital	Wilcox Memorial Hospital
Tourism-related businesses	Kailua-Kona; Hilo; North and South Kona coast; North and South Kohala; Waimea (Kamuela); Mauna Lani Resort; Mauna Kea Resort; Puna	Ka'anapali coast, Kihei; Lahaina; Kahului; Kapalua; Wailea; Makena; Hana; Upcountry	Lāna'i City	Kaunakakai	Waikiki, Kailua, Mānoa, Ala Moana Center, Ward Center; Hawai'i Kai; Hale'iwa; Turtle Bay Resort; Ko 'Olina Resort;	Līhu'e; Wailua; Kapa'a; Kilauea; Princeville; Hanalei; Kōloa; Po'ipū; Waimea
Transportation assets	Hawai'i Belt Rd; Māmalahoa Hwy; Queen Ka'ahumanu Hwy; Akoni Pule Hwy; Kona Int'l. Airport; Hilo Int'l. Airport; Waimea-Kohala Airport; Upper Pā'auau Airport; Kona Harbor; Hilo Harbor; Kawaihae Harbor	Hana Hwy; Kahekili Hwy; Honoapi'āni Hwy; Mokulele Hwy; Kuihelani Hwy; Haleakalā hwy; Kula Hwy; Pr'ilani Hwy; Kahului Airport; Kapalua-West Maui Airport; Hana Airport; Kahului harbor; Mā'alaea harbor	Keōmuku Road; Mānele Rd; Kaumalapa'u Hwy; Lāna'i Airport	Kamehameha Hwy; Kala'e Hwy; Maunaloa Hwy; Moloka'i Airport; Kaunakakai Harbor	Kamehameha Hwy; Farrington Hwy; Kalaniana'ole Hwy; Pali Hwy; Likelike Hwy; Honolulu Int'l Airport; Barbers Point Airport; Kalaeloa Barbers Point Harbor	Kūhiō Hwy; Kaumuali'i Hwy; Līhu'e Airport; Princeville Airport; Port Allen Airport; Līhu'e Harbor
Freshwater recreation	'Akaka Falls	Waikamoi Falls; Wailua Falls	N/A	Hālawala Valley Falls	Waimea Valley; Mānoa Falls; Maunawili Falls	Wailua River; Hanalei River; Kalihiwai Stream; Hule'ia River
Golf courses	Waikoloa Beach & King's Courses; Francis I'i Brown North and South Courses; Mauna Kea & Hapuna Golf Courses; Mauna Lani; Four Season Hualālai Course; Hilo Municipal Golf Course; Volcano Golf & Country Club	Plantation Course; Wailea Golf Course; Ka'anapali Coast; Waiehu Municipal Golf Course	Experience at Kohele; Challenge at Mānele	Ironwood Hills Golf Club; Kaluakoi Golf Course	Ala Wai Golf Course; Kāne'ohe Pali Golf Course; Ko 'Olina Resort and Golf Club; Mākaha Resort and Golf Club; Moanalua Golf Club; Olomana Golf Links	Prince Course; Kaua'i Lagoons' Kiele Course; Po'ipu Bay Golf Course; Wailua Municipal Golf Course
Beaches	White Sands Beach Park; Hāpuna Beach; Kauna'oa Bay; Beach 69; Waipi'o Valley; Manini'ōwali Beach; Makalawena Beach; Kūki'o Bay Beaches; Honokōhau Beach; Kekaha Kai State Park; Kiholo Bay; 'Anaeho'omalu Beach Park; Hoholohokai Beach Park; Mau'umae Beach; Green Sands Beach	Mākena State Park; Ulua Beach; Ho'okipa Beach; Kite Beach; Honolua Bay; Kā'anapali Beach; Kapalua Beach; Keawakapu Beach; Charley Young Beach; Big Beach; Malu'aka Beach; Little Beach; Pa'iloa Beach	Hulopo'e Beach; Shipwreck Beach; Polihua Beach	Dixie Maru Beach; Kawaiku'i Beach; Twenty Mile Beach; Pūko'o; Hālawala Beach; Mo'omomi Beach	Mālaekahana State Recreational Area; Sunset Beach; Waimānalo Beach Park; Wa'ānae Coast; Waikiki Beach; Ala Moana Beach; Kailua Beach; Lanikai Beach; Hanauma Bay; Makapu'u Beach; Mākaha Beach; Popo'i'a Island; Mokulua Islands; Diamond Head Beach Park; Sandy Beach; Kuilima Cove; Turtle Bay; 'Ehukai Beach Park; Nānākuli Beach Park; Mā'ili Beach Park; Pōka'i Bay Beach Park; Waimea Bay Beach Park	Po'ipū Beach Park; Kē'e Beach; Makua (Tunnels) Beach; Salt Pond Beach Park; Lydgate Beach Park; 'Anini Beach Park
Land-based recreation	Hawai'i Volcanoes National Park; Waipi'o Valley; 1871 Trail; Mt Hualālai; Kona cloud forest sanctuary; Pololu Valley; Kohala Forest Reserve; Mauna Kea and Mauna Loa; Hāmākua Coast; 'Akaka Falls State Park; Waimanu Valley; Waimea; North Kohala	Upcountry; Skyline Trail; Haleakalā National Park; Polipoli Spring State Recreational Area; Waihe'e Ridge Trail; Lahaina Pali Trail; Waikamoi Nature Trail; Wai'ānanapapa State Park; Hoapili Trail; Kanahā Pond Bird Sanctuary; Maui Nui Botanical Gardens; Tropical Gardens of Maui; Keālia Pond National Wildlife Refuge; 'Iao Valley State Park; 'Ahihi-Kina'u Natural Area Reserve; Kahanu Garden and Pi'ilanihale Heiau	Koloiki Ridge Trail; Kanepu'u Preserve; Munro Trail	Kamakou Preserve; Kalaupapa Peninsula; Halawa Valley; Moloka'i Forest Reserve	Mālaekahana State Recreational Area; Mt Tantalus; Mānoa Valley; Mānoa Cliffs; Makiki Forest Recreation Area; Kuli'ou'ou Ridge; Keaiwa Heiau State Recreational Area; Maunawili Trail System; Ahupua'a o Kahana State Park; Kaipapa'u Valley; Ka'ena Point State Park; Keālia and Kuaokala Trails; Wa'ānae Range; Kualoa Ranch; Kualoa Regional Park; Lyon Arboretum; Wa'ahila Ridge; Koko Head Regional Park; Popo'i'a Island; Mokulua Islands; Kawainui Marsh; Hāmākua Marsh Wildlife Sanctuary; Foster Botanical Garden; Ho'omaluhia Botanical Garden; James Campbell National Wildlife Refuge; Waimea Valley; Wahiawa Botanical Garden; Honouliuli Forest Reserve	Kōke'e State Park; Waimea Canyon State Park; Pihea Trail; Alaka'i Swamp Trail; Noalolo Trail; Awa'awapuhi Trail; Kalalau Trail; Nounou Mountain Trail; Haena State Park; Na Pali Coast State Park
Marine-based recreation	White Sands Beach Park; Kealakekua Bay; Kahalu'u Bay; Two-Step; Mahukona; Red Hill; Ka'awaloa Cove; Turtle Pinnacle; Kaiwi Point; Kaloko Fishpond; 'Aimakapa Fishpond; 'Ai'opio Fishtrap; Makaiwa Bay; Honoka'ope Bay; Pauoa Bay; Kalahuipua'a Fishpond; Puako; Kapa'a Beach Park; Kapoho Tide Pools; Ahalanui Beach Park; Kekaha Kai; Kapoho Tide Pools; Hapuna Beach; Manini'owali; Kauna'oa Bay	Molokini Crater; Turtle Beach; 'Ahihi-Kina'u Natural Area Reserve; Ulua Beach, Pu'u Keka'a; Kapalua Beach; Slaughterhouse Beach; Honolua Bay; Kā'anapali Coast; Kihei; Wailea; Mākena State Park	Hulopo'e Beach; Shipwreck Beach; Cathedrals	Pala'au barrier reef; Dixie Maru Beach; Kawaiku Beach; Twenty Mile Beach; Pūko'o; Halawa Beach	Hanauma Bay; Mālaekahana State Recreational Area; Pūpūkea Beach; Three Tables; Shark's Cove; Ala Moana Beach Park; Waikiki; Diamond Head Beach Park; Hālonā Blowhole; Popo'i'a Island; Mokulua Islands; Kualoa Regional Park; Kahana Bay Beach Park; Punalu'u Beach Park; Pūpūkea Beach Park; Waimea Bay Beach Park; Hale'iwa Beach Park; Hale'iwa Ali'i Beach Park; Mā'ili Beach Park; Pōka'i Bay Beach Park; Kuilima Cove	Kōloa Landing; Pō'ipu Beach Park; Kē'e Beach; Makua (Tunnels) Beach; Ahukini Landing; Salt Pond Beach Park; Lydgate Beach Park; Na Pali Coast; 'Anini Beach Park

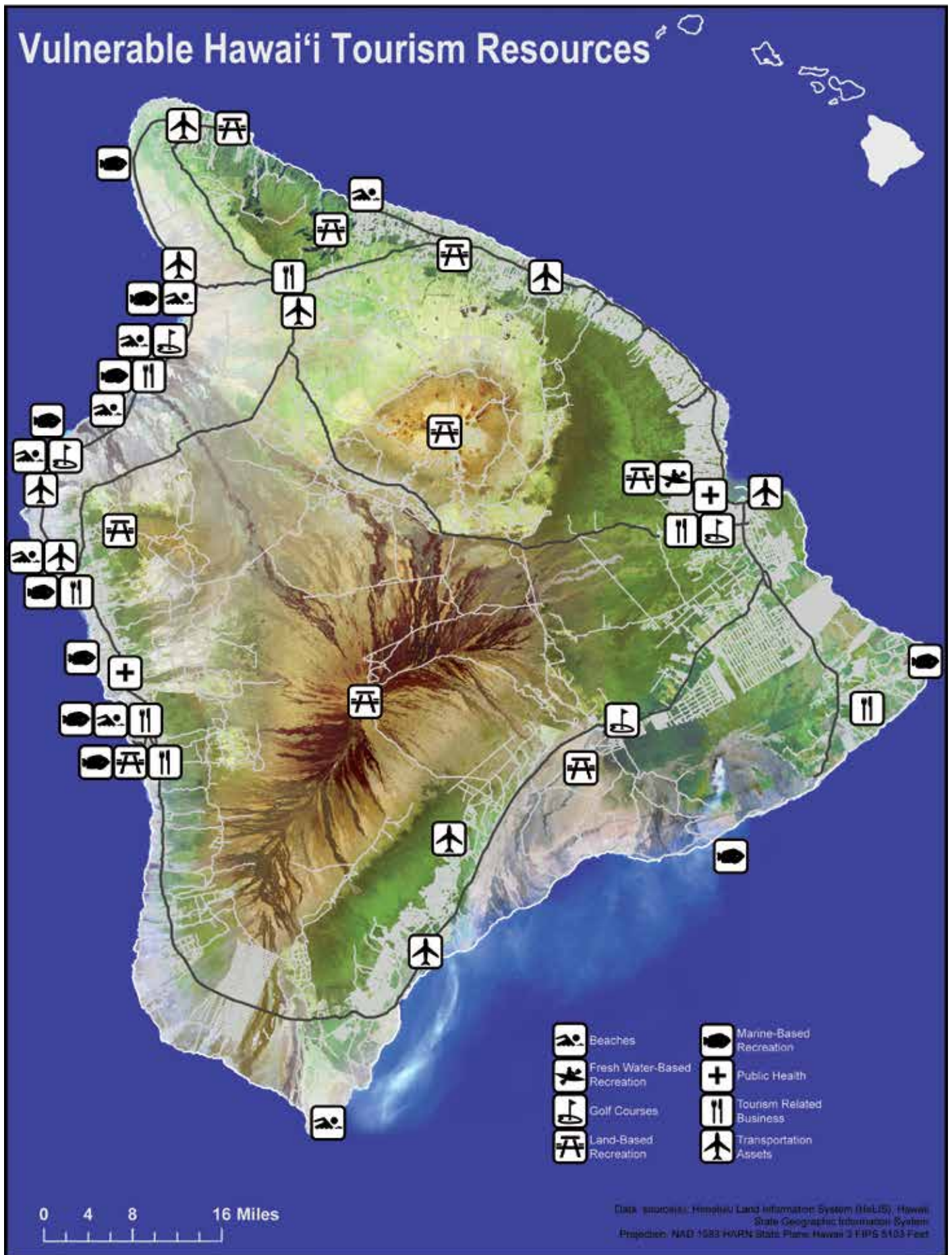


Figure 2: Map of the tourism-related high vulnerability areas on Hawai'i Island. Map by Matthew Gonser.

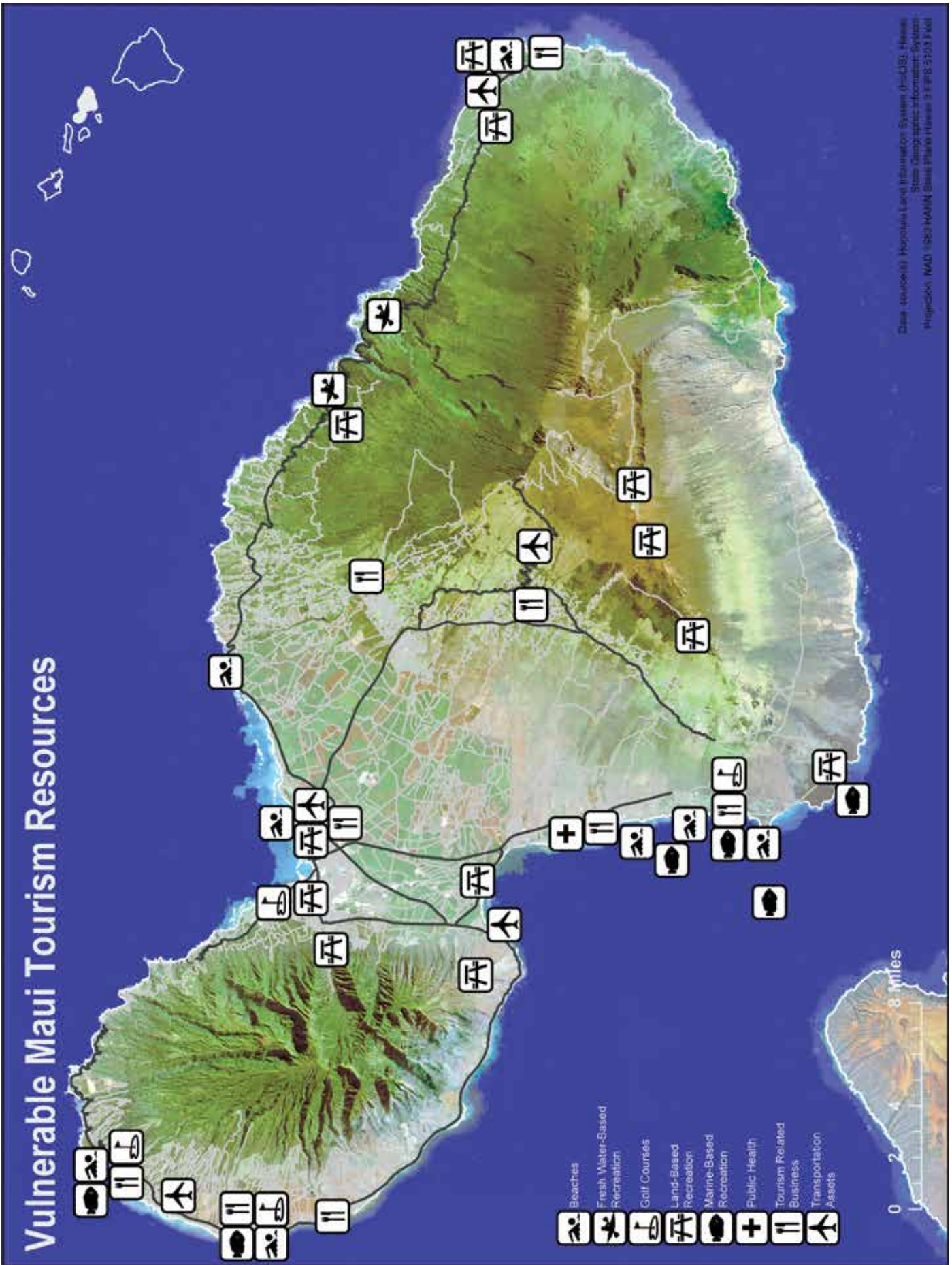


Figure 3: Map of the tourism-related high vulnerability areas on Maui. Map by Matthew Gonser.

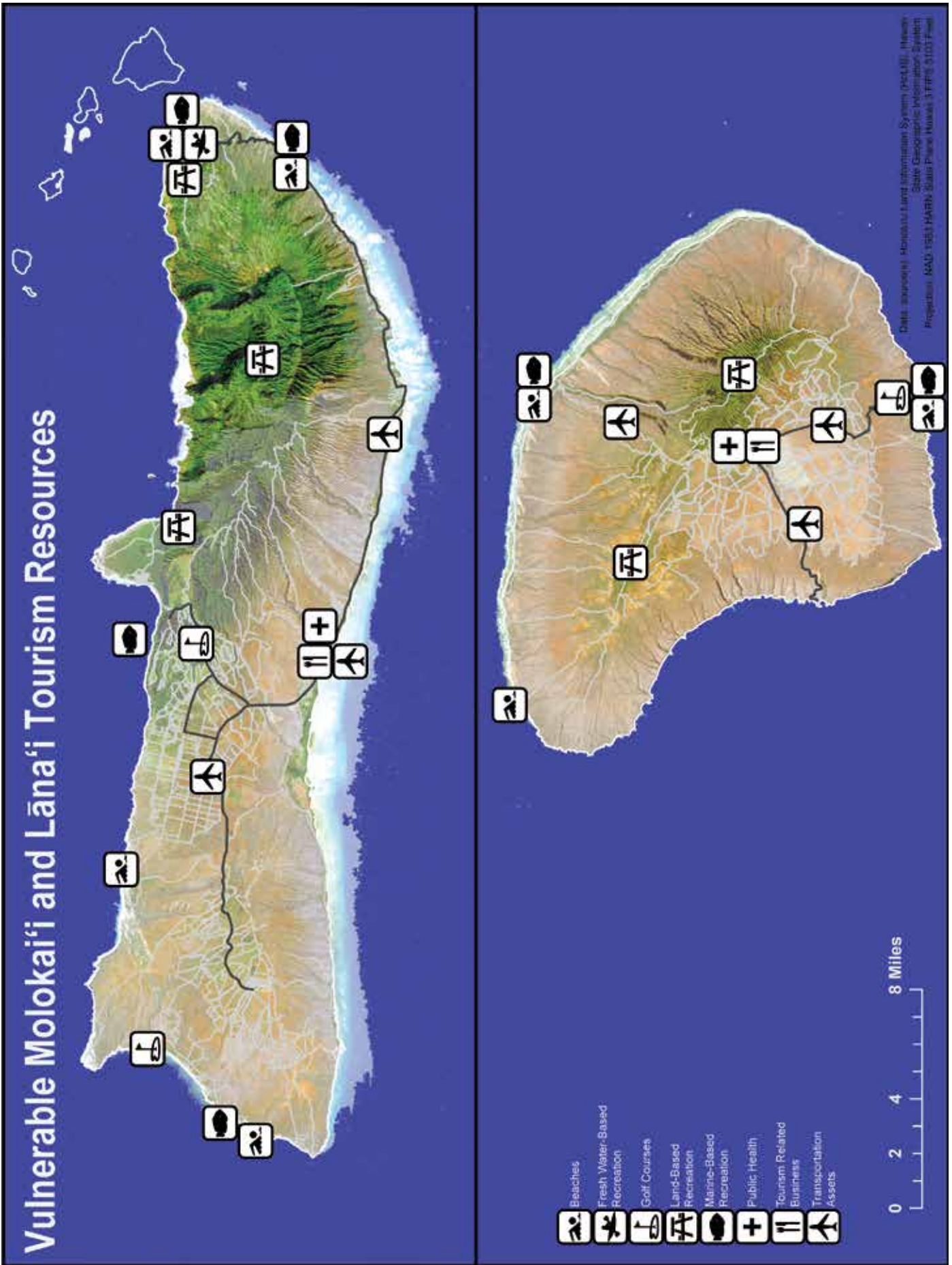


Figure 4. Map of the tourism-related high vulnerability areas on Lāna'i and Molokai'i. Map by Matthew Gonser.

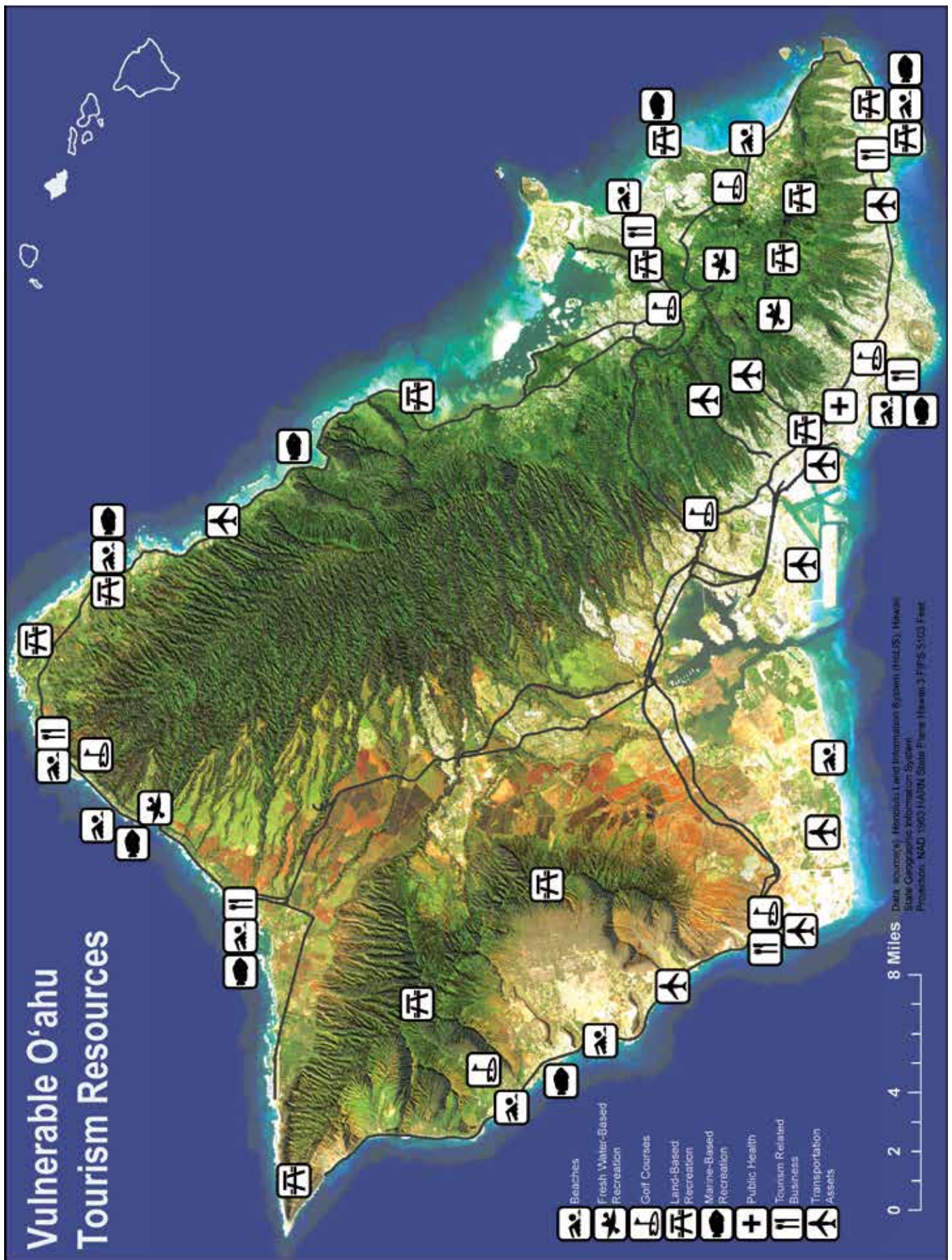


Figure 5: Map of the tourism-related high vulnerability areas on O'ahu. Map by Matthew Gonser.

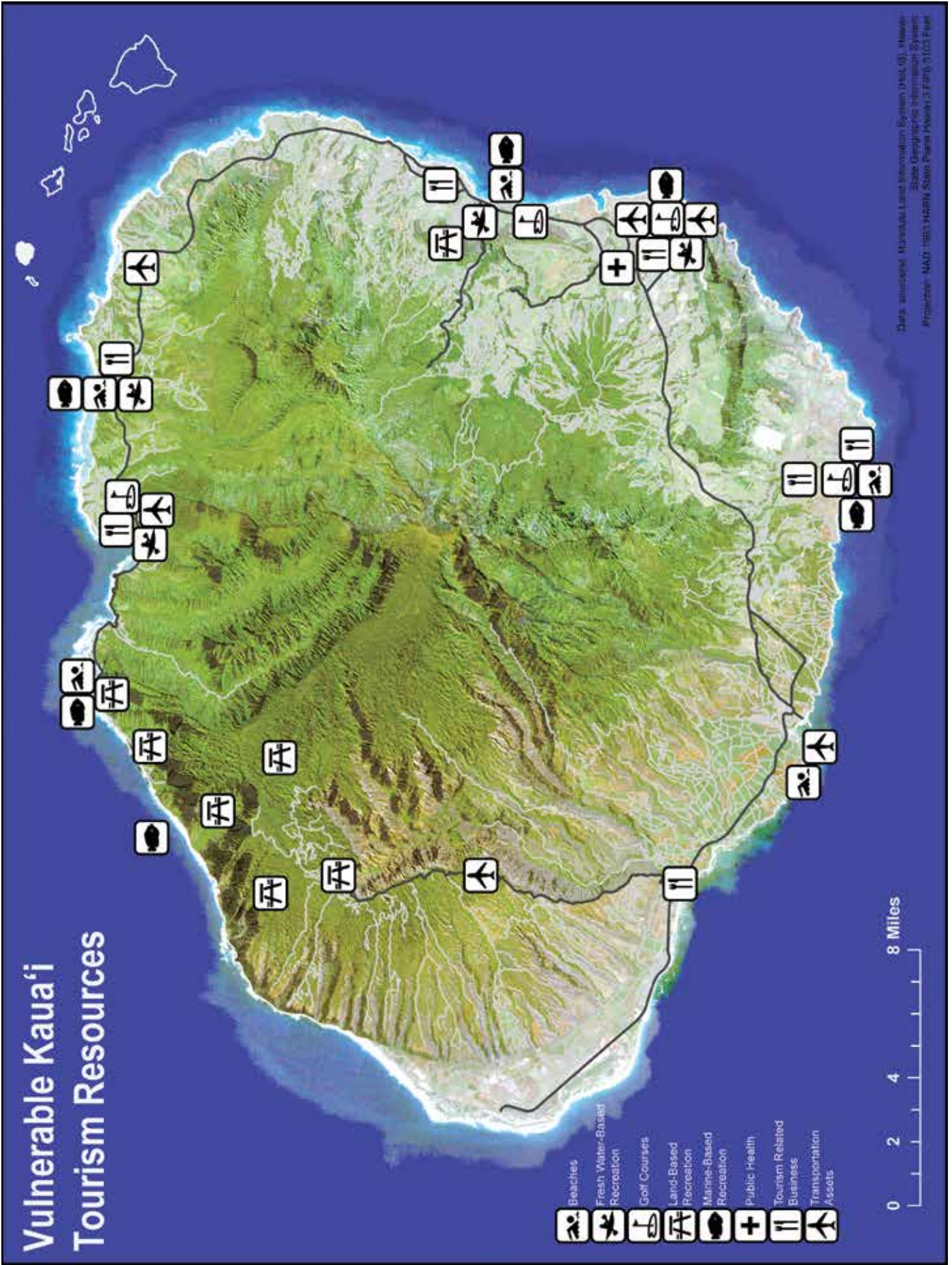


Figure 6: Map of the tourism-related high vulnerability areas on Kaua'i. Map by Matthew Gonser.

## Valuing resources at risk

Due to the numerous options offered, exact visitor counts at all beaches, parks, or other facilities are not available. However, the HTA provides data on tourist arrivals, activities, preferences, and expenditures for the major Hawaiian Islands that can be used to value certain resources for tourism. To estimate the economic value of Hawai‘i’s assets and resources, we collected, reviewed, and analyzed the available data on tourists’ arrivals on the various islands, preferred activities, and total expenditures per category, adding information from existing published literature.

According to the latest, most complete report on tourism (Hawai‘i Tourism Authority, 2010a), in the year 2010 over seven million tourists visited one of the Hawaiian Islands for a total visitor expenditure of over 11 billion USD. Counts for each island are summarized in Table 5.

*Table 5: Total tourist arrivals and expenditures in Hawai‘i in 2010. Source: Hawai‘i Tourism Authority.*

Island	Arrivals	Expenditures (million USD)
O‘ahu	4,427,372	5,683.40
Maui	2,186,279	2,953.30
Hawai‘i	1,378,921	1,345.70
Kaua‘i	1,042,633	1,086.90
Lāna‘i	72,152	72.40
Moloka‘i	52,258	24.40
TOTAL	7,083,663	11,166.30

Of the total, 5,231,129 or 73.84% of these visitors stated that they came to Hawai‘i for a vacation. This estimate is low, as the visitors coming to honeymoon, visit relatives and/or shop are not included. The expenditures for vacationers can be calculated as 73.84% of the total 11.1663 billion USD, yielding 8.245 billion USD. Therefore, in 2010, Hawai‘i’s natural resources, tourism infrastructure and facilities, and tourism-related businesses “used” by tourists coming for vacation had a market value of 8.245 billion USD. For the entire state, 2.3369 billion USD or 20% of the 11.1663 billion USD total expenditures accounted for restaurants, food and beverage expenses, 1.8724 billion USD or 17% for the purchases of retail goods, 1.1177 billion USD or 10% for transportation expenses and 995.4 million USD or 9% for recreation and entertainment expenses.

These data and additional information from the State of Hawai‘i Department of Business, Economic Development, and Tourism (DBEDT, 2006) indicate that tourism expenditures represent the single largest source of economic activity in Hawai‘i.

## Accommodation

In 2010, most tourists (62.5%) arrived by air and stayed in hotels paying an average of 186 USD per night for a room. The total visitor expenditures for lodging were 4.1723 billion USD (Hawai‘i Tourism Authority, 2010a). Nearly all hotels and resorts in Hawai‘i that target visitors are found in proximity of the ocean and will likely be affected by the projected increase in sea level and extreme weather events through inundation and storm surges, as discussed earlier.

Unfortunately, identification of the exact hotel and/or resort that will most likely be impacted is not possible as no precise map that shows the expected rise in Hawai‘i’s sea-level rise exists at this time. A more precise map would facilitate account of the affected rooms so that economic loss could be calculated. According to the research done by the Coastal Geology Group at the University of Hawai‘i at Mānoa,<sup>2</sup> an increase of about 30 cm (1 ft) in sea level is expected in Hawai‘i by 2050, and 90 cm (3 ft) by 2090, affecting properties at low elevation or fronting the beach. In addition to direct damages to the structures, these hotels will also be impacted by increased beach erosion which may eventually lead to the disappearance of the beaches fronting them, and to a visitor number and room value decrease. Hotels are expected to increase the room prices to cover increased

<sup>2</sup> <http://www.soest.hawaii.edu/coasts/>



energy and water costs as a result of climate change. The combination of increased hazards and prices will further discourage visitors, resulting in a decrease in occupancy and revenues.

## **Transportation**

The majority of visitors in O‘ahu at 86%, Maui at 87%, Kaua‘i at 85%, Kailua-Kona at 76% and Hilo at 51% make use of rental cars, trolleys, taxis, and public buses as transportation means (Hawai‘i Tourism Authority, 2010b). Specific data is available for the four major market areas (MMAs): Western U.S., Eastern U.S., Canada, and Japan. In 2010, on average, a visitor from these countries spent 15.70 USD for daily transportation in and within the various islands. In 2010, the total visitor expenditure for transportation was 1.1177 billion USD (Hawai‘i Tourism Authority, 2010a). Furthermore, tourists are contributing to the increased traffic congestion on Hawai‘i roads as demonstrated by the fact that over half of new car registrations each year are for the rental inventory (DBEDT, 2006).

Both transportation infrastructure and means of transportation will be affected by climate change in multiple ways. Damage to transportation assets can be caused by the combined effect of extreme weather events and sea-level rise through inundation, wave overtopping, drainage, wind velocity, rainfall, and slope instability (SSFM International, 2011). Increased oil prices will have indirect effects on ground transportation as well as on airfare ticket prices to and between the Hawaiian Islands.

Five of O‘ahu’s transportation assets were analyzed during a workshop organized by the O‘ahu Metropolitan Planning Organization (SSFM International, 2011): (1) Honolulu Harbor area; (2) Honolulu International Airport area; (3) Kalaeloa Airport, Kalaeloa Barbers Point Harbor, and Campbell Industrial Park; (4) Ala Moana Boulevard, Kalakaua Avenue, and McCully Street bridges to Waikīkī; and (5) Farrington Highway along the Wai‘anae Coast. The vulnerability of each asset with respect to climate change was evaluated by assigning a rank of low when repair of asset is needed, but can still be used; a rank of moderate when the asset is temporarily unusable and in need of repair; and a rank of high for total catastrophic loss. All the assets under consideration have been found highly vulnerable to sea-level rise and extreme weather events such as storm surges and high rainfall, as well as drought. In all cases, damage related to climate change effects would result in large replacement costs and large economic loss (cfr. Table 5 in SSFM International, 2011). However, the economic loss and repair costs have not been further analyzed.

## **Restaurants**

The vast majority of visitors eat in restaurants, although the percentage varies by island with O‘ahu at 94%, Maui at 91%, Kaua‘i at 90%, Kailua-Kona at 86%, Hilo at 61%, Moloka‘i at 62%, and Lāna‘i at 53%. The expenditures data for 2010 for the MMAs shows that tourists spend an average of \$36.10 a day for food, including dining, restaurant food, dinner-shows and cruises, and grocery snacks for a total of 1.1177 billion USD (Hawai‘i Tourism Authority, 2010a). Direct visitor expenditures for agricultural products in 1997 was 18.5 million USD (DBEDT, 2006).

Restaurants, like hotels, will be affected by climate change with a decrease in water supply and a rise in energy prices, exacerbated by climate change. This is expected to increase the prices that customers pay. At the same time, locally produced food could decrease due to the impacts of climate change on agriculture, such as drought or harvest ruined by extreme weather events. Imported food will become more expensive due to increased shipping rates as energy prices rise. As a result, tourist will have to pay higher prices for food and restaurants.

## **Shopping**

In 2010, virtually all tourists from the MMAs visiting O‘ahu (95%), Maui (92%), Kaua‘i (91%), most of those in Hawai‘i (88% of those staying in Kailua-Kona and 52% of those in Hilo), and Moloka‘i (63%), as well

as a big portion of those in Lāna‘i (46%) spent money shopping while staying in the state. The average daily expenditure for souvenirs, clothing, jewelry, cosmetics, food products, and other goods in 2010 amounted to \$36 per person for a total of 1.8724 billion USD (Hawai‘i Tourism Authority, 2010a).

Retail stores and shopping centers are normally found in proximity of hotels and resorts, and will face similar problems due to climate change. Establishments found in low-lying areas will most likely risk inundation and damage caused by the projected sea-level rise and extreme weather events. Additionally, rising energy prices are likely to cause retail prices to increase.

## Recreation

Table 6 shows the percentage of visitors engaging in various recreational activities for each of the major Hawaiian Islands. On average, each visitor from the MMAs spent 15.60 USD on a given day of 2010 for recreational activities. The total visitor expenditure was 995.4 million USD (Hawai‘i Tourism Authority, 2010a).

*Table 6: Preferred recreational activities in Hawai‘i in 2010 (percentage of the visitors in each island).  
Source: Hawai‘i Tourism Authority.*

Island		Sunbathing and swimming (%)	Snorkeling and scuba diving (%)	Surfing (%)	Golfing (%)	Running and walking (%)	Hiking and camping (%)
O‘ahu		72	27	65	6	32	16
Maui		83	52	80	12	41	19
Hawai‘i	Hilo	23	10	12	2	12	19
	Kailua-Kona	67	45	53	12	32	17
Kaua‘i		76	45	69	11	40	31
Lāna‘i		66	50	32	15	20	9
Moloka‘i		45	24	16	2	24	16

Clearly, marine- and land-based recreational activities are highly valued by tourists all around the state. Hawai‘i’s beaches and marine waters are famous worldwide, and a primary component of the state’s image as a desirable travel destination. Many visitors spend the majority of their vacation on Hawai‘i’s beaches and nearshore environments. Beach and water sports and recreational activities, such as sunbathing, swimming, surfing, snorkeling, and scuba diving, are by far the most popular among visitors. Beaches and coastal lookouts are also a major sightseeing attraction. As a result, coastal ecosystems are the most prevalent components of the overall environment involving visitor activity (DBEDT, 2006).

Erosion, pollution, loss of coral reefs, and loss of marine life are the greatest pressures on Hawai‘i’s beach and marine ecosystems, most of which are caused by climate change. The loss of beaches due to coastal erosion enhanced by sea-level rise in particular may lead a greater portion of visitors to choose other destinations. Over the last half century, nearly one-quarter of Hawai‘i’s beaches have been significantly degraded. Typical erosion rates throughout the state range between 0.5 and 1.0 ft per year. On O‘ahu, nearly 17.1 miles, 24% of the sandy shoreline has been narrowed (10.7 miles) or lost (6.4 miles) since the 1940s (DBEDT, 2006). Eventually, the absence of beaches would likely decrease the revenues from hotels, restaurants and businesses. For example, a study of the Waikīkī Improvement Association (Waikīkī Improvement Association, 2008) showed that the disappearance of Waikīkī Beach due to erosion could cost the tourism industry nearly 2 billion USD annually in lost visitor spending, trigger more than 6,000 job losses, and shrink state tax revenues by about 125 million USD a year.

The loss of marine flora and fauna due to increased ocean temperature and acidification would also lead to a loss of revenues for marine-based activities. Coral reefs, which protect beaches, serve as habitat to complex marine ecosystems, and create worldwide famous waves, are a particularly important feature of Hawai‘i’s underwater landscape. Climate change, pollution, alien and invasive species, nearshore recreation, and over-fishing represent the greatest threats to the health of reef ecosystems (DBEDT, 2006).

Much of the direct economic value of coral reefs is generated from nature-based and dive tourism, with net benefits estimated at nearly \$30 billion annually worldwide. In 2002, Hawai‘i’s coral reefs were valued by the National Oceanic and Atmospheric Administration (NOAA) at nearly \$10 billion when combining recreational, amenity, fishery, and biodiversity values (Fletcher et al. 2010). The annual recreational value of the coral reefs of each of six Marine Management Areas in the Hawaiian Islands (Hanauma Bay, Diamond Head, Honolulu, Molokini, Kahalu‘u, Waiopae) in 2003 has been estimated between 300,000 and 35 million USD (van Beukering and Cesar, 2004). In 2011 the number of tourists visiting the Hanauma Bay Nature Preserve alone was about 682,000, yielding 4.3 million USD in revenues (Hirohata, pers. comm.).

The total disappearance of marine amenities, such as coral reefs and fish, can result in a large economic loss for the tourism sector. For example, in Jamaica and Barbados, destruction of coral reefs has resulted in dramatic declines in visitor numbers, and the loss of revenue streams subsequently led to social unrest, which further reduces tourist arrivals (Brown, Corcoran, Herkenrath, and Thonell, 2006).

As coastal areas become increasingly overcrowded and urban, inland areas are gaining popularity with residents and visitors as a setting for recreational and sightseeing activities. Increasing numbers of people seek recreational opportunities such as picnicking, camping, hiking, horseback riding, mountain biking, and wildlife viewing within the state’s mountainous regions. Because of their large visitor numbers and prominence in tourism guides, many parks suffer from overcrowding and overuse as well as a corresponding growth of commercial group tours. To manage commercial demand, Nā Ala Hele (NAH), Hawai‘i Statewide Trails and Access Program, has established a regulatory system that allows authorized commercial trail tour operators to use certain trails and access roads determined appropriate for commercial use. The gross revenue from the fees collected in 2002 from commercial trail tour activity was 57,205 USD (DBEDT, 2006).

Furthermore, the market value for ecotourism of a single Hawaiian watershed has been estimated as high as 1-3 billion USD. In-stream uses, including kayaking, are worth 82-242 million USD (Timmons, 2003). In terrestrial areas, the deterioration of native forests and the loss of native flora and fauna due to the negative effects of climate change within these habitats are the most critical environmental concerns (DBEDT, 2006).

## **Public health**

Global climate change currently contributes to disease and premature deaths worldwide, increasing the risk of adverse health impacts from more severe heat waves and other extreme weather events, reduced air quality, malnutrition, and infectious diseases (Balbus et al., 2008). Respondents to a nationwide survey-study conducted jointly by the National Association of County and City Health Officials, the Environmental Defense Fund, and the George Mason University generally recognize the reality of climate change impacts. Nearly 70% of the respondents believed that their jurisdiction has already experienced climate change in the past 20 years, and 78% believed that climate change would occur in the next 20 years. Roughly 60% thought that one or more serious public health problems could be expected in their jurisdiction in the next two decades as a result of climate change (Balbus et al., 2008). Although these numbers prove the expected impact of climate change in the U.S., a comprehensive study on the costs of medical care associated with it remains necessary.

# Challenges for adaptation and opportunities for sustainable growth

## Feasible adaptation strategies and opportunities for sustainable development of tourism in Hawai‘i

Summarizing the analysis described in the previous sections, climate change presents a challenge for many elements of Hawai‘i’s tourism sector including:

- Energy and water
- Health
- Natural resources and outdoor recreation
- Coastal facilities and infrastructure
- Competition

For each element at risk, risk mitigation and adaptation strategies can be explored using the application of the fifth step of the analytical methodology. The strategies discussed in the following section should be considered as general guidelines and suggestions. More specific solutions for each sector are needed as part of a more comprehensive plan to take action towards adaptation to climate change that includes all sectors of the economy in Hawai‘i. The implementation of these strategies by tourism operators and stakeholders, even if only on a voluntary basis, has the potential to bring opportunities for a sustainable development of the sector. In fact, the suggested strategies could improve Hawai‘i’s environment and benefit the tourism industry independently of what the consequences of climate change are.

The projected increase in **energy** use can be an incentive for the expansion of the renewable energy industry. In Hawai‘i, the potential for the production and use of solar and wind power is significant. Improvement in the energy management and efficiency of the hospitality industry will also generate large benefits through cost savings and support statewide efforts to reduce energy use. Improving the efficiency of energy use and climate control systems will generate the largest return on investment with immediate results. In general, the accommodation sector represents approximately 20% of emissions generated from tourism (UNWTO and UNEP, 2008). Using existing technologies and best practices, emissions could be reduced by 30–40%. Simple and effective strategies for adaptation of energy supply systems to climate change suggested by the UNWTO and the UNEP include: enhanced building siting and design; demand-based usage techniques such as cooling and lighting only when the room is occupied; use of energy-efficient appliances; frequent maintenance and cleaning of heating, cooling, and refrigeration equipment; use of alternative fuels and renewable energy sources; and capacity building and climate change environment-related education for managers of the accommodation establishments and in related sectors (e.g., architecture, construction, and engineering).

**Water** conservation techniques and the use of water-saving devices can be effective strategies to deal with water shortage due to climate change. Improvement in water supply planning and use is critical in destinations susceptible to drought such as Hawai‘i, and provides the opportunity to enhance local resource management. Other feasible solutions for the problem of reduced water supply in Hawai‘i is to decrease the tourism-related water use in accommodations, restaurants, activities, infrastructure, and in energy and food production.

According to Cooley et al. (2007), hotels could reduce indoor water consumption by 30% by installing water-efficient fixtures. Gössling et al. (2012) suggest that in large resorts, water can be saved in maintenance of gardens and pools. Restaurants' and hotels' kitchens could invest in efficient dishwashers and ice makers and apply flow control regulators at sinks and basins, which can significantly reduce water use while being highly economical (Smith et al., 2009). Among the activities that use the largest quantity of water is golf. Water can be saved in golf courses by monitoring soil moisture measurements to control and optimize water use (Rodriguez Diaz et al., 2007), reducing playing surfaces and excessive irrigation, or by changing turf species to less water demanding or salt tolerant ones. Overall, reducing water use will usually be economical and would therefore increase the revenues. Fortuny et al. (2008) show that many water-saving technologies have short payback times (between 0.1 and 9.6 years) making them economically attractive. Another effective way to reduce water overconsumption in Hawai'i (both from residential and commercial use) is to increase its delivery price. Efficiency pricing would result in a reduction of the quantity demanded by consumers and be an incentive for installing low flow fixtures (Endress, pers. comm.)

Public **health** concerns due to the potential spread of pathogens can be overcome through illness prevention, including inoculation, improvement of medical care (e.g., through targeted training), and national and international exchange programs. These strategies would benefit the local communities by promoting a general increase in knowledge, improvement of the service, and tightening of the cooperation between states. Investments in both prevention and preparedness to respond to crisis should be increased, given Hawai'i's volume of tourists and vulnerability to natural disasters. Investment in improved medical care is a crucial part of the effort towards disaster risk reduction and resilience (DR<sup>3</sup>).

Environmental and human pressures on **coral reefs** need to be reduced to help marine resources adapt to the effects of climate change. Decreasing non-climate stressors by protecting larger areas and supporting protected area management, promoting different kinds of water activities in different locations, tightening controls and regulations of the marine environment, and reducing or removing external stresses such as pollution and agricultural runoff can all contribute to the overall goal of reducing tourism pressures on coral reefs. The management of linked resources, such as fisheries and agriculture, would need to be improved. As a consequence, a healthier marine environment could be obtained, which is the fundamental resource for marine-based recreational activities in all the Hawaiian Islands.

Collaboration between local nature centers or organizations and tour operators can be strengthened in order to control the effects of climate change on **terrestrial resources** and protect the value of Hawai'i's watersheds. Nature centers are present in all Hawaiian Islands and strive to protect forests and to conserve terrestrial ecosystems. Local administration and community authorities could support nature centers' programs that control invasive species, reintroduce native plants, provide educational activities, and maintain trails. Engaging in these activities would improve the visitor experiences, such as hiking, as well as increase the visitors' knowledge of local ecosystems.

The adaptation of priority **shorelines** and developed coastal areas (e.g., Waikīkī) to climate change could be implemented by various forms of adaptation, accommodation, and retreat, as well as soft coastal protection like beach, dune, and vegetation restoration, to stem coastal erosion, and of the conservation of coastal ecosystems. Coastal land use management and policy should be enhanced by requiring hazard assessments in high-risk coastal zones and by strengthening the building codes and hazard avoidance techniques such as construction setbacks along the coasts. The management of drainage systems and watersheds should also be improved where necessary in order to reduce the risk of flooding, sedimentation, and nearshore pollution. Ultimately, the goal in addressing coastal erosion due to sea-level rise will require some form of managed retreat from the coast to maintain healthy sand beaches.

The adaptation of existing **infrastructure** to climate change could be implemented through regular maintenance, upgrades, prevention of damages from extreme weather events, investments in adaptation to projected hazards rather than repair, engineering research, and certification and legislation. The integration of climate change factors into regulatory frameworks for tourism development, such as Environmental Impact Assessment (EIA) for tourism infrastructure and establishments, may be an appropriate policy approach to address climate change. The benefits resulting from these initiatives would range from the improved safety of infrastructure and buildings to a general decrease in the costs associated with repair, which would in turn mean higher revenues.

In the long-term, climate change could enlarge tropical areas and increase the **competition** among tropical tourism destinations, both nationally and internationally, that will experience similar climate-related issues. Hawai‘i’s main tourist attraction will continue to be its natural beauty and culture which will need to be continually cultivated. Tourism marketing and diversification (e.g., health tourism, ecotourism, sports tourism and education tourism) in the promotion of Hawai‘i as a destination, together with strengthening the cooperation between the public and private sectors, could greatly improve the overall quality of Hawai‘i tourism, as well as enhance job training and education in this sector. One response to global competition in tourism is more competition in Hawai‘i to improve product, lower prices, and grow in a sustainable way while increasing resilience to risk (Endress, pers. comm.)

Opportunities linked to climate change adaptation in Hawai‘i extend to many sectors of the economy and the society, and can be grouped as:

1. Economic opportunities: Increased revenues from energy and water conservation and management; new energy and water sustainability business; and decreased costs of infrastructure repair due to extreme weather events.
2. Educational opportunities: Increased visitor awareness of local natural resources and of their sensitivity to external stressors such as climate change; promote local products, sustainability, and increased training and green-certification of tourism-related operators and managers.
3. Environmental opportunities: Enhanced beauty and resilience of land and marine flora and fauna, coasts and beaches.

## Developing a more resilient tourism industry

### Conclusions of the study

This study:

1. Assessed the impacts of climate change on Hawai‘i’s tourism industry through an analytical review of the current knowledge;
2. Determined the primary vulnerabilities of the tourism sector with respect to the projected climate change impacts;
3. Identified high vulnerability, high priority areas frequented by visitors potentially at risk;
4. Presented information on the market value of the tourism resources at risk, based on visitor counts, preferences and expenditure data, and the available information;
5. Explored feasible adaptation strategies that could bring economic, educational, and environmental opportunities for sustainable growth of tourism in Hawai‘i.

A review of the current knowledge on climate change impacts in Hawai‘i has been carried out linking climate processes, environmental effects, and impacts on tourism with the main driver of climate change, i.e., the increase in greenhouse gases (GHGs) concentration in the atmosphere. Once the main vulnerabilities are assessed, each impact can be addressed separately to explore possible adaptation strategies to climate change.

Climate change adaptation for communities around the world must be specifically designed for the needs of the region. An analytical approach to climate change impact assessment is functional to: distinguish climate change drivers, processes and effects in the region of interest; classify risks and vulnerabilities of specific economic sectors; and explore strategies for adaptation and sustainable development.

Through this approach we identified the different effects of climate change and the specific impacts on Hawai‘i’s tourism sector from the main processes forced by the increased atmospheric GHGs concentration (see Table 2).

Priority adaptation sectors for tourism that could be affected by climate change in Hawai‘i include (Table 3):

1. Public health
2. Tourism-related businesses
3. Transportation assets
4. Freshwater recreation
5. Golf courses
6. Beaches
7. Land-based recreation
8. Marine-based recreation

The list of the high vulnerable areas compiled here (Table 4) shows that all the main Hawaiian Islands contain sensitive areas and facilities linked to tourism’s priority adaptation areas, and include major popular beaches and parks as well as tourism establishments, hospitals, and transportation assets. Although preliminary, this is the first and most comprehensive compilation produced to date and constitutes an important review of the sites and resources at risk around the state from which planners and managers can start from towards adaptation to climate change.

The value of tourism resources jeopardized by climate change is based on the available literature and statistics on visitor arrivals, expenditures, activities, and preferences, and represents a first effort to estimate the potential economic impact of climate change in Hawai‘i. This evaluation demonstrates that natural resources in Hawai‘i are highly valued by tourists and constitute the primary basis for recreational activities and related businesses.

Once the primary consequences of climate change on the tourism sector in Hawai‘i had been identified, as well as the main vulnerabilities and the resources’ economic value, mitigation and adaptation strategies were explored for each impact. The challenges the tourism sector is facing due to climate change have the potential to be transformed into opportunities in order to facilitate the sustainable growth of the sector.

This research constitutes a first effort to understand the impact of climate change on tourism in Hawai‘i through a systematic review of the available literature and data. A knowledge assessment of what Hawai‘i has to expect is necessary to evaluate the resources in danger and to develop, strategies to react and adapt to climate change.

## **The next steps**

This report reveals that currently there is insufficient detailed and regionally specific information about how climate change will affect Hawai‘i’s economy in order to craft immediate adaptation measures. Additional

research in each of the economic sectors related or connected to tourism is needed in order to quantify the effects and prioritize adaptation strategies. Furthermore, this study highlights the need to integrate adaptation to climate change not only in tourism management, but also in policy and institutional efforts at all levels, from the federal to the community.

Finally, implementation of adaptation strategies is as important as their planning. Implementation can be done voluntarily by the individual stakeholders and tourism entrepreneurs or regulated by policymakers and legislators.

### *Research*

Hawai‘i’s tourist arrivals are expected to reach 10.8 million by 2030. Increasing visitor use of outdoor natural resources is expected (DBEDT, 2006). Therefore, Hawai‘i’s tourism and resource managers should consider the priority actions presented here on climate change in future planning and understand its economic implications in order to preserve those natural resources that are fundamental to the success of Hawai‘i’s tourism product.

Decision-makers and planners need to know when the “tipping point” occurs, i.e., the time scale of climate change for policy planning is not yet clear and requires further investigation. On the other hand, this report raises issues regarding Hawai‘i’s natural resources and tourism sector that would be important even without climate change impacts. Planning options for sustainable development and resource conservation can therefore be explored in any case.

In order to estimate in detail the cost of climate change in Hawai‘i, or the economic value of the impacted resources, further climate science, economic and related impacts data collection, and analysis are needed. High-resolution maps that show the projected increase in sea level along Hawai‘i’s coasts are currently being developed by the National Oceanographic and Atmospheric Administration (NOAA) and the University of Hawai‘i. Quantification of the expected impact of sea-level rise and coastal flooding will result in better estimates of economic losses, and will facilitate prioritization of sea-level rise adaptation.

A detailed economic analysis and contingency plans for disruption of major transportation assets (e.g., roads, airports, harbors) around the state is necessary. The increase in the probability of extreme weather events related to climate change is connected to a potential increase in the cost of damages. Information about the maintenance costs for the major highways as well as of airport facilities and harbors around the state would help estimate the value of the assets at risk. Efforts to assess the impact of climate change to transportation assets is currently underway by the Oahu Metropolitan Planning Organization among others.

More detailed information is needed about tourist expenditures per activity. The available data only provide information about total expenditures for all recreational activities. However, in order to estimate the direct economic value of specific natural and constructed systems such as coral reefs, forests, beaches, and golf courses, the market value of each is needed. This could be achieved by surveying the businesses that offer land and sea tours or services in the most popular locations.

Whereas some general information on visitor expenditures exists, no such information exists for hotels, restaurants, and/or other tourism related businesses. Since climate change will increase the costs for energy and maintenance, investigating these costs for accommodations and retail operations is needed in order to obtain estimates for the impact of increasing energy prices and extreme weather events.

The field of climate change impact on public health in Hawai‘i and related costs (e.g., for medical emergencies and insurance) needs to be developed to allow better preparedness for crisis and climate-related issues. Medical facilities need to be able to use this information and plan for capital improvement and specialized staffing.



Overall, the adaptation measures suggested in this report require further development to gain specificity. This research suggested general strategies and best practices based on the issues found. However, a more detailed study of what can be done specifically for each impacted sector is needed.

An investigation into how Hawai‘i competitors, or similar tropical island destinations, are dealing with environmental and economic issues related to climate change is needed. More research is needed on both national (e.g., Florida) and international (e.g., Caribbean Islands and Indian Ocean destinations) in economy and legislation to be able to relate the case of Hawai‘i to other similar realities.

Climate change is a global issue and Hawai‘i, as tourist destination for visitors from other countries, will suffer direct and indirect repercussions. In order to gain perspective and complete the picture of climate change impacts on tourism in Hawai‘i, further investigation into how climate will affect the income in countries where tourists come from, e.g., in the four Major Market Areas (Eastern U.S., Western U.S., Canada, and Japan) that provide most of the tourists today is also needed.

A ranking of the vulnerabilities found in this research is also necessary. Surveys of various tourism stakeholders to assess their preparedness are needed. The companion outreach workshops planned as part of this project are expected to partly clarify stakeholders’ perception of climate change and identify most pressing needs and gaps.

It is also important to determine if resilient sectors of tourism exist as well as if climate change could produce positive effects to sectors of the economy related to tourism.

A static or dynamic economic model could be developed to further the economic analysis. The entire tourism system is very complex and composed of different elements. Assuming a change in one of the elements due to climate change, then the effects on the other elements can be investigated. This requires the parameterization to quantify the relationship between different elements.

### *Policy and management*

This study relates to an ongoing institutional effort towards climate change adaptation and its integration into management plans and business strategies. Climate change affects the whole community, not just tourists and tourism-related businesses. Therefore, a strategy to cope with the effects of climate change for entire state and resources is key.

On a legislative level, in July 2012 Hawai‘i’s Governor Neil Abercrombie signed Senate Bill 2745 into law as Act 286, making Hawai‘i one of a few states in the nation to adopt a statewide climate adaptation policy. The bill integrates climate change adaptation priority guidelines into the current statewide overarching planning system. The guidelines were developed through collaboration between county, state, and federal agencies, as well as businesses, community, and Native Hawaiian organizations. The State of Hawai‘i Office of Planning, through the Coastal Zone Management (CZM) program is coordinating with state and county agencies on integrating the climate adaptation policy into current rules and regulations, with the support of the University of Hawai‘i Sea Grant College Program.

Hawai‘i’s natural capital (marine resources, watersheds, other terrestrial resources, and coastal areas) provides environmental amenities and well-being to Hawai‘i’s residents, and simultaneously serves as the vital capital base for the production of visitor industry services. Attention must be paid to the management of these resources as a whole, complex ecosystem. Protection of the whole ecosystem is a public good that the tourism sector as well as any other private sector will have to provide.

### *Guideline implementation*

Beside efforts in research and planning, the implementation of the suggested adaptation strategies and guidelines is crucial. Climate change and its impact on tourism must be addressed by the means we possess now. Some impacts can be addressed by the private sector (e.g., hotel associations), others by the public (e.g., administration). An opportunity exists for collaboration between the two, which might lead to new institutional arrangements, on different levels, time, and intensity. Action is needed on all administrative levels (federal, state, city and county) and by all stakeholders (tourism sector managers, individuals, communities).

### **Role of the Hawai‘i Tourism Authority**

Since its establishment in 1998, the Hawai‘i Tourism Authority (HTA) has served as the lead state agency for tourism. The HTA’s responsibilities<sup>3</sup> include:

- (1) Setting tourism policy and direction with the goal of contributing to the ongoing, sustainable growth of Hawai‘i’s economy.
- (2) Developing and implementing the state’s tourism marketing plan and efforts.
- (3) Managing programs and activities to sustain a healthy visitor industry.
- (4) Developing and implementing the Hawai‘i Tourism Strategic Plan.
- (5) Coordinating tourism-related research, planning, promotional and outreach activities with the public and private sectors.

Given its central role in Hawai‘i’s policy and economic sectors, the HTA has the power to innovate tourism in Hawai‘i and at the same time contribute to the conservation of its natural resources. Therefore, the HTA can actively support conducting and coordinating research on climate change impacts and adaptation policy. This would not only allow for the protection of Hawai‘i’s precious natural resources, but also support sustainable choices with the opportunity for rejuvenating Hawai‘i as a tourist destination and increase its market value. This climate research effort has been supported by the HTA and reinforces the HTA’s commitment to the five areas of responsibility listed above.

In a broader perspective, the HTA can continue to cooperate with other state and public entities in all sectors of economy and society to address climate change. Adaptation needs to be comprehensive and, since tourism involves various economic sectors, HTA can serve as sponsor and mediator between stakeholders to leverage different interests towards a common goal.



<sup>3</sup> <http://www.hawaii tourism authority.org/about-hta/>

# A Pacific perspective

## Hawai‘i as a case study for the Pacific region

Coasts and small islands are particularly vulnerable to direct and indirect impacts of climate change, given that much of the critical infrastructure such as accommodation and businesses, power plants, wastewater treatment, and transportation assets are at low elevations and located within close proximity to the shoreline. The impacts of climate change in Hawai‘i - including those analyzed in previous sections - are common to the various states and territories in the Pacific Islands region.

The Secretariat of the Pacific Regional Environment Programme (SPREP) recognizes that climate change is one of the greatest challenges to sustaining current development, and ensuring future development is sustainable. It also recognizes that failure to adapt to climate change now could lead to rapidly increasing social and economic costs in the near future. The Pacific Islands region includes many islands that are extremely vulnerable to the various effects of climate change. Small atolls and low-lying islands will be among the first to suffer the impacts of climate change, and entire populations may be forced to adapt or even relocate from their home islands. The impacts of climate change will be particularly strong because of the small island states' low adaptive capacity, high sensitivity to external shocks, and high vulnerability to climate-enhanced natural disasters.

The IPCC climate projections for the Pacific Islands region include warming of the air temperature and sea-level rise, although models indicate that these changes will not be geographically uniform (Christensen et al., 2007). Annual rainfall is likely to increase in the equatorial Pacific, while most models project decreases east of French Polynesia in the winter. Ocean-atmosphere interactions play a major role in determining the climate of the Pacific Islands, as they are generally located far from big landmasses which could influence climate. Climate change threatens many sectors of the economy upon which the global society depends. As specified by the IPCC, these include freshwater resources, food and agriculture, fisheries, transportation, industry, energy production, utilities, and infrastructure, and human settlement (Solomon, 2007).

Many coastal economies, particularly tropical islands, rely on tourism as the primary source of Gross National Product (GNP) and employment. For many Pacific Islands tourism is the major development option (Harrison, 2004). Climate change will have profound effects on coastal regions in the Pacific Islands and their natural resources, therefore, tourism will also be pressured and in need of particular adaptation strategies. As pointed out earlier, coastal tourism activities have been found to be greenhouse gas (GHG) intensive (Konan and Chan, 2010). Thus, efforts to modernize tourism infrastructure and move to more sustainable practices that include conservation and efficiency can play an important role in relation to climate change mitigation.

The type of tourism found in the Pacific Islands region depends on numerous factors. Among them, Harrison (2004) indicates the attractions offered, distance, ease and cost of access, their economic buoyancy, and general perceptions of health, safety, and development. Climate and the resultant weather itself is a principal resource for tourism. Adequate environmental conditions are key for most tourism activities, ranging from conventional beach tourism to special interest segments, such as eco-adventure, and sport tourism (UNWTO and UNEP, 2008). What attracts tourists in the Pacific Islands is mainly the natural environment (e.g., ocean and marine life, and beaches), ideal for those seeking sun, sea, and sand (Harrison, 2004).

Tourism in the Pacific can have many different characteristics, from Hawai‘i's mass tourism with 1.2 million residents and more than 7 million visitors a year<sup>4</sup> to Tuvalu's few arrivals with 10,000 residents and about 1000

<sup>4</sup> Data from the Hawaii Tourism Authority: <http://www.Hawaiitourismauthority.org/research-reports/research/visitor-highlights/>

tourists annually, mainly on business or to visit relatives and friends<sup>5</sup>. Mass tourism is primarily associated with the Hawaiian Islands in the North Pacific, while in the South and Central Pacific, mass tourism has not yet developed, although concentrated facilities exist in Fiji and French Polynesia which together account for some 50% of the region's arrivals (Harrison, 2004).

Arrivals data are not available continuously for every Pacific Island. Furthermore, tourism fluxes vary considerably between the various islands. Therefore, visualizing and comparing the trends in tourism growth is difficult<sup>6</sup>. Nevertheless, a calculation of the percentage change for the last couple of decades for each state reveals an increase in the fluxes of visitors for all Pacific Islands, with the exception of American Samoa (not shown). This measure of tourism growth indicates that, while not uniform, tourism has developed and expanded everywhere in the Pacific.

In order for the Pacific Island economies to adapt to climate change, the first step is to identify the vulnerabilities and hazards. This requires identifying vulnerabilities of the local and regional tourism sectors. Once these are determined, the tourism sector needs to transform climate adaptation into opportunities for sustainable growth.

The analytical approach used for Hawai'i has been also applied to the entire Pacific Island region to understand the effects of climate change and to identify strategies for adaptation (Cristini et al., submitted). The analysis shows similar results as for Hawai'i.

Given the importance of tourism in the economic development of the Pacific Islands region, more research should be carried out to assess the implication of climate change for the visitor industry and to identify the opportunities for sustainable, economic, and social development.



<sup>5</sup> Data from the Tuvalu Central Statistics Division: [http://www.spc.int/prism/country/tv/stats/Tourism\\_migration/tour\\_purpose.htm](http://www.spc.int/prism/country/tv/stats/Tourism_migration/tour_purpose.htm)

<sup>6</sup> Data compilations and charts of tourist arrivals for Hawai'i, New Zealand, Guam, New Caledonia, Fiji, Northern Mariana Isles, French Polynesia, Cook Islands, Papua New Guinea, Palau, Marshall Islands, Kiribati, Federated States of Micronesia, Vanuatu, Samoa, American Samoa, Tonga, Tuvalu, Solomon Islands and Niue can be provided together with the information sources by the authors.

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Published by the University of Hawai'i Sea Grant College Program