PURPOSE

Pursuant to the Revised Charter of Honolulu ("RCH") Section 6-107(h), the City & County of Honolulu Climate Change Commission ("Commission") is charged with gathering the latest science and information on climate change impacts to Hawai'i. It provides advice and recommendations to the mayor, City Council, and executive departments as they look to draft policy and engage in planning for future climate scenarios as well as reduce Honolulu's contribution to global greenhouse gas emissions.

The purpose of this document is to better understand the intersection between climate change and tourism - where tourism activities both contribute to global greenhouse gas (GHG) emissions and can be impacted by the effects of climate change. Tourism has many impacts … To the extent possible, this document provides indicators (i.e. data and data compilation) that can be used and tracked to better understand the intersectionality of climate change and tourism on O'ahu.

RECOMMENDATIONS

The Commission has conducted research on tourism... The Commission finds the following:

- Measure these indicators to have an informed understanding of which sectors of our economy from which to base future policy. Examples such as:
    - Water usage
    - GHG impacts: air travel, electricity, ground transportation
    - Environmental degradation
    - Food insecurity
    - Increased risks during natural disasters/Burden on emergency services/
- Increase coordination between tourist industry and climate
    - Existing infrastructure/mechanisms
        - destination management plan (DMAP) is meant to manage impact. Consider climate vulnerability as an impact
        - Beach Improvement District
    - Gaps
        - network in the visitor industry > hotels are part of international chains that have limited involvement in local/regional
        - provision of public goods is largely paid out of property revenues... mismatch between benefit and burden
- External examples/models to draw upon…

I. INTRODUCTION

Tourism is Hawai'i's largest industry, comprising about a quarter of Hawai'i's economy (Bond-Smith and Fuleky, 2022). Tourism arrivals statewide hit a record high of 10.4 million in 2019, prior to the COVID-10 pandemic, and recovered to 9.2 million in 2022 (UHERO, 2023). In 2019, visitors spent $19.8 billion ($2022) and, in 2022, $19.3 billion ($2022) (UHERO, 2023). Over half of visitors are destined for O'ahu (53 and 58% for 2019 and 2022, respectively), though with a smaller proportion of statewide spending (46 and 44% for 2019 and 2022, respectively). Though tourism is Hawai'i's largest industry and thus a substantial contributor to Hawai'i's economy and tax base, it has not been an engine of economic growth for quite some time. Per capita visitor expenditures have been in a declining trend since 1992 (Bond Smith and Fuleky, 2022). That tourism today has more environmental impacts through increasing visitor arrivals but with relatively fewer economic gains, perhaps helps to explain growing discontent by residents of the tourism industry and resident demand for more tourism management (HTA, 2023). The COVID-19 pandemic, with visitor arrivals dropping by 98% in the second quarter of 2020 (UHERO, 2023), was also a window into the role that tourism plays in Hawai'i - both economically and environmentally. This document identifies ways in which visitors and the tourism industry intersect with climate change - both its causes and its consequences - as well as identifies sources of data and models to further build understanding as well as track relationships between tourism and climate change over time.

The Commission has identified a number of ways that climate change intersects with the tourism sector. They are:

- Visitor and tourism industry contributions to global GHG emissions.
- Visitor and tourism industry consumption of natural resources that are also affected by climate change; specifically, water.
- Visitor impacts to environmental/ecological degradation, such as the overuse of trail systems, that might also be affected by climate change.
- Visitor impacts to local food systems, that might also be affected by climate change; however, there is limited research about the nexus of tourism, local food systems and climate change.
- Impacts of acute disaster events on visitors and the tourism industry, including response needs.

II. VISITORS AND CLIMATE CHANGE IN HAWAI'I

1. Visitors and GHGs

In 2019 Hawai'i contributed 22.01 million metric tonnes of carbon dioxide equivalent (MMTCO2e, based on global warming potential) into the global atmosphere (DOH, 2023).[1] This is an increase from 21.92 MMTCO2e in 2018. The highest estimated annual GHG emissions for Hawai'i is for 2007, which was 27.04 MMTCO2e. Energy, Industrial Processes and Product Use, Agriculture, Forestry and other Land Use, are the major categories of measured GHG emissions within the State's GHG inventory, which follows national and international inventory and reporting standards (See IPCC, 2019). The Energy sector is by far the largest contributor to Hawai'i's GHG emissions, comprising 88% of sources in 2019 (DOH, 2023). Energy sector emissions include stationary combustion (primarily electricity generation), transportation (ground, marine and domestic aviation), oil and natural gas systems, waste incineration and a small portion of non-energy uses. International aviation is also measured within the State's GHG

[1] If sinks are considered, this drops to 19.42 MMTCO23 (DOH, 2023).

inventory, though not reported in the total accounting per best practices within inventory accounting methods (DOH, 2023).

O'ahu is the state's largest county based on population and therefore also has the largest measured annual GHG emissions. O'ahu contributed 14.45 MMTCO2e to the global atmosphere in 2019, which is 66% of the state's total GHG sources. 13.62 MMTCO2e were from the Energy sector, 94% of O'ahu's total GHG emissions.

Coffman et al. (2022) accounts for visitor contributions to Hawai'i's GHG emissions, both upstream and downstream sources (this can also be thought of as direct and indirect GHG emissions). The study uses the State GHG inventory for 2016 as well as the State's Input-Output Table (DBEDT, 2016) within a general equilibrium model (i.e. with price effects) to estimate visitor contributions to a policy scenario of a state-level carbon tax. This analysis measures all contributions of visitor demand in Hawai'i, including direct demand of GHG-intensive sectors through activities like driving a rental car to indirect demand through activities like electricity within hotel accommodations. The study finds that visitors would pay between 27-36% of total carbon tax revenues between the years 2025 and 2045 (increasing over time). This finding means that visitors contribute the same proportional amount in GHG emissions within the Hawai'i economy. Because the simulated tax rate is assumed to go into effect in 2025, and visitors are found within Fuleky, Zhou and Bonham (2014) to have inelastic demand for a Hawai'i vacation, the proportion of visitor contributions to GHG emissions would be smaller in 2020, but only slightly. Approximately a quarter of GHG emissions can be attributed to the visitor industry statewide.

A limitation of this analysis, however, is that as a tax scenario it accounts only for GHG emissions that are fueled within the borders and jurisdiction of the state. Outside of the scope, therefore, are domestic aviation flights originating elsewhere and flying to Hawai'i, military activities, and international aviation and marine fuels (in both directions). It is inventory accounting practices to attribute only the originating leg of the trip to the location, so as to not double count GHGs between localities. Should a more holistic "GHG footprint" analysis be desired, rather than an inventory, visitor demand of domestic aviation can simply be multiplied by two. International visitors, including those on international cruise liners, would consume additional transportation fuels. International bunker fuels are reported within the State's GHG inventory (DOH, 2023). Because visitors do not consume military services while on a vacation, this is moot.

1.1 Aviation emissions

To get a more comprehensive picture of the visitor contribution and "GHG footprint" from the aviation industry, the Commission provides the following calculations. Within the State's 2019 GHG inventory, a total of 4.95 MMTCO2e are attributed to domestic aviation and 1.64 to international bunker fuels (the vast majority of which will be aviation, and for this illustration, assumed to be in its entirety). Adding these together and multiplying by two, to account for the roundtrip, results in 13.18 MMTCO2e. As a next step, a factor of 0.84 is applied, to account for the ratio of passengers to cargo (see Technical Appendix CAP, 2022). Next, a factor of 0.86 is applied, to account for the pre-pandemic ratio of visitors to residents (see Technical Appendix CAP, 2022). With this, there is a total of 9.52 MMTCO2e attributed to the visitor travel footprint in the year 2019. Aviation has additional short-lived climate forcers, for example from NOx contributions. There are still few definitive studies in this area and therefore *low confidence* within IPCC estimates of additional forcing from processes like contrails (IPCC, 2021). The IPCC AR6 states that: "Overall, cirrus and contrail cirrus warming, as well as NOx-induced ozone increase, induce strong but short-lived warming contributions … (medium confidence) ... while CO2 both gives a warming effect in the near term and dominates the long-term warming impact (high confidence) (6.6.2.3 Transportation).

1.2 Rental vehicle emissions

Emissions from rental cars may provide a significant contribution to GHGs emissions though there is no current indicator used in Hawai'i. A potential proxy for rental car emissions is the consumption of petroleum manufacturing from the State's Input-Output table. In 2017, visitors demanded $20 million of the approximately $3,700 million in petroleum manufacturing, which is likely to come mostly from the use of rental cars. This cannot be simply converted into emissions from rental vehicles but it does give a sense of the magnitude that visitors contribute to emissions compared to the total emissions from petroleum manufacturing statewide. Additionally, Saito (2013) measured rental vehicle energy consumption on Hawai'i Island to establish a baseline energy consumption across different sectors in the tourism industry. Saito found that of the total energy produced on Hawai'i Island, about 20% was consumed by the sectors in the tourism industry. Of this 20%, rental cars consumed about 20% totalling 23,000 tonnes of oil or equivalent annually. It should be noted that the sample size of rental cars was very small in this study and not used in correlation analyses like the other sectors. This study used methods outlined in Becken et al. (2003), which estimated the energy use of visitor transportation compared across different modes. These authors conducted a survey of visitors on the West Coast of Aotearoa New Zealand's South Island. To calculate the average energy use, the authors considered the energy intensity of each travel mode, the average load, and the average distance traveled. Like the State I-O table, these surveys do not directly measure emissions but can be used as proxy measurements. However, this data is not currently collected in Hawai'i but could be collected through surveys as in Saito (2013) and Becken et al. (2003). It could also be collected directly from the rental car companies for greater accuracy. [Can add details of the proposed rental car emission study here]

2. *Visitors and Water*

Climate change is impacting the availability of water across the state through declines in supply and increases in demands. Historic rainfall data shows that average annual precipitation has declined over the last century. While there is no consensus about expected future rainfall patterns, as different projection methods have led to different outcomes, the decline over the last century has already diminished the supply of water (Climate Change Brief, 2023). In addition to less supply, greater demands on water due to climate change will also impact its availability in the future. Climate change has caused prolonged and more intense droughts across the islands (Climate Change Brief, 2023). Droughts require more reliance on groundwater as the source for water consumption, while also limiting the ability for aquifers to recharge. In turn, this limits the ability to draw on groundwater sources in the future. Climate change has also caused more days of extreme heat (Climate Change Brief, 2023), which can create a greater water stress. With both the likelihood of less water availability and increasing demands for water caused by climate change, the tourism industry is likely to be impacted as a significant consumer of water.

1.2 Recreational water use

The entire state consumed 275,500 million gallons of freshwater in a year period from 2018 to 2019, where O'ahu consumed a total of 47,500 million gallons of water (17%) (Hawai'i Data Book Table 5.25). The Hawai'i Data Book (Table 5.28) reports that 6 of the top 10 consumers of water on O'ahu in 2017 were golf courses, which provides an activity consumed by both residents and visitors. Isolating the consumption of water by visitors is a difficult research task that, unlike GHGs, has not been recently done. Similar to GHGs, an accepted method for unpacking resident and visitor consumption of water (direct and indirect) could be based on the State's Input-Output data and a complementary general equilibrium model. Input-Output data (also called I-O table) show the flow of sector demand through an economy, including intermediate industries and final consumers. A previous analysis was published by the Department of Business, Economic Development and Tourism in 2006, using the 1997 Input-Output data (DBEDT, 2006). This study found that a $1 million ($1997) increase in visitor spending related to a 1.12 million gallon increase in demand for non-agricultural water.

1.3 Water use in accommodations

Both residents' and visitors' expenditures are given in Hawai'i's 2017 I-O table. We provide an illustration of how visitor water consumption can be characterized with available data for O'ahu and the state. Using the 2017 State I-O tables, visitors are, as a first pass, estimated to have consumed 19% of the total value of water consumed in the state during 2017. This is largely due to the high use of utilities by the accommodation industry ($48.7 million, 9.8% of total utility demand) and the high demand visitors have for accommodation (62% of total demand for the industry) while visiting. Visitors make up the highest portion of spending on accommodation in the City and County of Honolulu relative to the demand for the industry, then Hawai'i County, Kaua'i County, and Maui County respectively. Only the demand for utilities on O'ahu is greater than 10% (about 13%). The rest of each counties' demand for utilities through accommodation is less than 6%. These estimates do not, however, constitute a precise measure and should be further evaluated because the I-O table lumps the value of water utilities with gas and sewer utilities. At the county level, utilities can also include electricity. This estimate assumes that they are in equal shares - and a more precise estimate would decompose the value of individual utilities. In addition, a modeling approach (like computable general equilibrium) could tease out further indirect water demand, e.g. water demand by residents that exists due the resident income generated by visitor spending. In general, the I-O table shows that visitors have a high demand for industries such as accommodation, eating and drinking, and retail. Some of the visitors' most demanded industries also have significant utility use (accommodation), which includes water utilities. Therefore, visitor demand for water can be estimated by assessing the visitor demand for industries with utility use.

1.4 Wastewater

Wastewater, like freshwater, is difficult to separate between residential and tourism generated. The Hawai'i Data Book only tracks the treatment and reuse of wastewater but this does not break down the generation between residents and visitors. Since 2013, approximately 134 million gallons of wastewater have been treated every day and as of 2022, about 19% of treated wastewater is reused. A 2005 study from the Department of Business, Economic Development, and Tourism (DBEDT) found that of the 40 billion gallons of water consumed by industries in 1997, approximately 22 billion gallons ended up as wastewater (DBEDT, 2005). This data is not consistently gathered. The number of wastewater treatment plants is also tracked though the volume of wastewater treated at each plant is not tracked. Even if the volume is measured at each plant, then it would still be difficult to attribute it to visitors or residents. In addition to the volume of wastewater, wastewater impacts might also be considered. Downs et al. (2022) studied the runoff from beach showers and found that popular tourist beaches on O'ahu, Maui, and Hawai'i island had higher traces of pollutants from sunscreens due to beach showers. There are several considerations wastewater in the tourism industry though it will be difficult to attribute wastewater to visitors or residents.

In sum, visitors and the visitor industry creates additional demand for freshwater, both from direct consumption but also in indirect activities. The visitor industry also creates additional demand because it, in part, supports the size of the resident population; for example, through supporting visitor-industry jobs. The magnitude of visitor demand for freshwater is substantial and thus should be considered in broader water management strategies in the face of climate change.

3. Visitors and Environment/Ecology

Many tourists come to Hawai'i to experience the natural environment. Like many residents, visitors enjoy the beaches, swim in the ocean, and hike up mountains. Due to the diversity of activities, comprehensively measuring the impact that visitors have to the natural environment is a monumental task; however, some research exists as it relates to degradation of beach, nearshore ecological systems, and hiking trails.

Beachgoers often contribute to the degradation of beach dunes due to the high volume of foot traffic (Eversole, 2009). However, attributing impacts to visitors separate from residents is often a difficult task. Similarly, trail erosion has also been studied as an impact of overuse. According to DLNR, trail erosion is a problem on O'ahu but, similar to beach erosion, it is currently difficult to separate the impacts of visitors from the impacts of residents. There is a proposal for the Hawai'i Tourism Authority to study which trails visitors frequent based on cell phone data, which would help assign environmental impacts to visitors or residents (Yerton, 2019).

The degradation of coral reefs in Hawai'i is also a potential impact as a result of tourism, though available studies do not necessarily tease out tourists and residents in their assessment of impacts of visitors to a coral reef system. Lin et al. (2023) shows the relationship between beachgoers and coral - where live corals attract more visitors to the reef (both residents and tourists) but also more visitors relate to lowering coral cover. Essentially, the abundance of coral attracts visitors but this also makes the reef more susceptible to degradation. Rodgers et al. (2023) quantified the impact of visitors to the reef (residents and tourists) to Hanauma Bay as "one reef disturbance for every two individuals," which can begin to isolate the impact from visitors to Hawai'i compared to the impact from residents. Lin et al. (2023) measured the impacts on corals, which include trampling and polluting of corals, through high resolution imagery. Measuring the impact visitors have on coral reefs is important because warming oceans due to climate change are already affecting the viability of coral (Climate Change Brief, 2023).

While the degradation of dunes, hiking trails, and coral reefs are stand alone problems, they also interact with climate change. The potential impacts visitors have on these systems may also be exacerbated by the impacts of climate change. For example, beach dunes provide a natural barrier to high wave flooding. Whereas healthy beach dunes help to mitigate erosion and provide a natural barrier to high wave flooding, an eroded beach dune could on the other hand exacerbate coastal erosion and subsequent impacts from sea level rise. Similarly, the erosion of hiking trails may be exacerbated by intense precipitation events and cause flash flooding as well as landslide events. Lastly, coral reefs are already being stressed through coral bleaching and ocean acidification. Otherwise stressed corals are less likely to survive the impacts of climate change (Climate Change Brief, 2023).

4. *Visitors and Food Systems*

In 2018, Hawai'i farmers produced 105 million pounds of food locally according to the Aloha+ Challenge dashboard. Food production (in pounds) has been trending downward since the 1980s, and there are statewide goals to increase (double) local food production (to double it, by 2030, according to the Aloha+ Challenge). Another goal of the State's 2050 Sustainability Plan is to increase the statewide consumption of locally grown foods by 20-30%. Though it is difficult to track what portion of locally grown foods go to the visitor industry versus residents, again the State's I-O table provides some insights.

The State's I-O tables indicate that less than 1% of residents expenditures and visitor expenditures are spent directly on crop production in Hawai'i. Demand for locally grown crops by both visitors and residents is mostly indirect as

most of the outputs from crop production (73%) go into food processing. A majority of outputs from food processing (67%) are demanded by the eating and drinking industry which is highly demanded by both visitors (29%) and residents (42%). Visitors can affect the outcome of 2050 Sustainability goals by choosing to consume locally grown or raised foods either through direct purchase or through their choice of restaurants. Typically, locally grown foods are more expensive than imported foods, which can make it difficult for the average consumer (resident and visitor) to purchase the locally produced food item. However, a recent study found that visitors are more willing to pay higher prices for food if it is locally grown or raised (Linnes, 2022). This indicates that visitors may play an important, though indirect, role in supporting local food systems by creating demand for locally grown food.

Climate change may have an impact on Hawai'i's food systems by affecting crop production. First, changing weather patterns and rising sea levels may affect the viability of certain crops growing in the islands. Already, farmers are experimenting with the salt tolerance of different kalo varieties. Furthermore, changing precipitation patterns can lead to less favorable growing environments for many crops (Climate Change Brief, 2023). Under the RCP 8.5 scenario, which is the most extreme climate change scenario, Hawai'i could lose up to 35% of its current land viable for agriculture as determined by the area of land in agriculture production in pre-contact Hawai'i (Kurashima, Fortini, & Ticktin, 2019). Though not all of the currently viable land is in agricultural production, or even zoned for agriculture, this study indicates that climate change, especially changing rainfall patterns, will affect agricultural practices across the islands. Examples of climate change affecting crop production have already occurred in other places. For example, shifting temperatures in Florida have made its citrus industry more susceptible to citrus greening, a disease that is seriously harmful to citrus plants, because the climate is more and more suitable to the pest that causes the disease (Taylor et al., 2019). Climate change is likely to impact food production since there are many aspects of the food system that are climate dependent.

In addition to impacts to production, climate change can also impact the infrastructure of the food system. Hawai'i imports nearly 90% of its food (Loke & Leung, 2013), which highlights the importance of shipping and transportation infrastructure within the food system. Honolulu Harbor and the airport are two important entry points for food in the state, as well as all other import/export goods (including visitors), and they are both vulnerable to sea level rise impacts. Proactive planning to ensure the future viability of critical infrastructure is therefore of utmost importance.

5. Visitors and Emergency Services

Emergency services related and unrelated to climate change are required by visitors and residents alike; services include police, fire, rescue and health. Climate related emergency services include, for example, search and rescue in the event of flash flooding or hurricanes, and health services for impacts related to extreme heat. Both visitors and residents require emergency services but there may need to be special considerations for visitors, especially when facing a climate related disaster.

5.1 Evacuation

Many visitors that come to O'ahu stay in Waikīkī, which is exposed to several climate hazards that make it a vulnerable location. As a coastal area, Waikīkī is vulnerable to hurricanes, tsunamis, storm surge flooding, and flooding associated with sea level rise. As a result of its exposure to acute hazards, emergency evacuation is a vital component of disaster response in services in Waikīkī. For some hazards like tsunamis and flooding, which will likely occur more frequently and intensely as a result of climate change, vertical evacuation is an acceptable option.

Though many buildings in Waikīkī are tall enough to evacuate vertically, there is still a large population that needs to evacuate the area (horizontal evacuation). According to scenario modeling for tsunami evacuations in Waikīkī, Kim (2022) found that increasing the network capacity for evacuees and increasing the available evacuation times are two important factors for reducing fatalities associated with tsunamis. Improving these factors would also help reduce the burden on emergency services during a disaster event as it would maximize safety.

The fires in Lahaina have shown the importance of evacuation planning for climate related impacts. Due to efforts by officials in the tourism industry, many West Maui visitors were able to evacuate in the hours and days following the outbreak of the fire. Although this was not an evacuation from immediate danger, it helped recovery efforts by freeing up hotel rooms for displaced residents (Downey, 2023). For emergencies with greater notice, such as a hurricane, the counties have established evacuation shelters and offer transportation to these shelters. During Hurricane Lane for example, the City and County of Honolulu offered free bus rides to evacuation shelters (Freidheim, 2018). This is available for residents and visitors alike but may be particularly useful for visitors who do not have cars or social connections for places they can shelter. The City has also aided evacuation efforts by conducting a study on coastal evacuation. The outcomes of this study were improved signage indicating tsunami evacuation areas, evacuation routes, and safe sites (DEM, 2019). However, Kim, Pant, and Yamashita (2015) studied evacuation in urban Honolulu by creating models that accounted for shelter accessibility and travel times to shelter and found that there is an inadequate amount of shelter options.

5.2 Shelters

Hurricanes present different challenges for emergency services. Hurricanes are expected to increase in frequency and potentially intensity as a result of climate change (Marra & Kruk, 2017; Murakami et al., 2013). Instead of evacuating the hazard area, hurricane response is typically to shelter in place. However, there are challenges to sheltering in place across the O‘ahu due to the aged infrastructure. Sheltering in place is only ever advisable if the house you are sheltering in is built to withstand hurricane force winds (on O‘ahu, this practice was only required for residences built after 1995). This leaves a lot of residents vulnerable to hurricanes, as well as visitors. According to the State’s “Hurricane Evacuation Shelter Planning and Operations Guidelines” many of the larger hotels will have shelter-in-place plans in the event of an emergency. However, visitors staying in smaller to medium sized hotels or in older vacation rentals, will need to find an emergency shelter. This will likely place a greater burden on emergency services since visitors are less likely than residents to be able to stay with another resident or friends, thus requiring the need for an emergency shelter.

Emergency shelters present another set of challenges for emergency services. First, most of the emergency shelters are not built to withstand winds greater than a tropical storm. Therefore, these shelters will likely not be highly effective in the face of a hurricane stronger than a tropical storm (HI-EMA, 2017). Additionally, it is assumed that many people that choose to shelter in emergency shelters will not have the necessary supplies to wait out the storm (HI-EMA, 2017). This is especially true for visitors as they are much less likely to have stockpiled food supplies in preparation for a hurricane. In 2018, a “rain bomb” in Hanalei, Hawai‘i dumped about 50 inches of rain in a 24 hour period and caused severe flooding. Of the people that chose to shelter at the emergency shelter, most were tourists. Due to a lack of supply preparation for a disaster event and the inaccessibility of the shelter from the flooding, they temporarily ran out of food and water (Torrential Rains Leave Dozens Stranded in Hawaii Shelter, 2018). This example illustrates the potential increased burden on emergency services from tourism.

Long term disaster recovery may be impacted by climate change since Hawai'i's main points of entry (the port of Honolulu and the airport) are exposed to climate hazards. For example, if the port or airport are substantially damaged, it will be much more difficult to import disaster relief and emergency service workers or to evacuate visitors or residents (HI-EMA, 2021). In addition to entry points, impacts to critical infrastructure will affect the ability to quickly and effectively recover. In the worst case flood scenario from hurricane storm surge and tsunami that accounts for sea level rise, 69% of arterial roads will be flooded, as well as 44% of highways, 38% of freeways, and 40% of local streets (Kim, 2014). The impacts to transportation infrastructure will make evacuation and recovery difficult in the event of a disaster, for residents and visitors alike.

In sum, climate change is expected to increase the frequency and impacts of acute hazards. Visitors may create a greater burden on emergency services in hazard response because of their lack of resources on the island. For example, visitors may be less likely to have access to a vehicle and require support for evacuation, as well as seek emergency shelter. Specific plans for visitor-oriented disaster planning, such as is done for Waikīkī, may become increasingly relevant.

5.3 Displacement

"Climate-related displacement" or "climate-induced displacement" are terms used to describe people who are forced to permanently relocate as a result of a climate disaster. As this brief is concerned with the intersection of the tourism industry and climate change, it will consider how the tourism industry can support people displaced by climate change. After the Lahaina fires, many hotels have housed displaced residents though this is not a permanent nor a common solution, in part due to the high costs of accommodations on Maui. Hotels on the mainland US were used as temporary accommodation in the aftermath of Hurricane Maria for displaced residents with medical needs (Avilés Mendoza et al., 2021). One consideration for using hotels as housing would be the ability to retain social networks though we found no studies to support this. However, coastal communities in Alaska, Louisiana, and other Pacific Islands are facing displacement as a result of sea level rise and have struggled to relocate coastal areas while retaining their culture and identities (Maldanado et al., 2013). It is important to consider the tradeoffs of housing and social networks in discussions on the viability of the tourism industry housing people displaced by climate change.

Tourism and Sea Level Rise

Global mean sea level rise (SLR) is expected to rise 3.2 feet by 2100 and 3.8 feet in the Intermediate scenario for Hawai'i according to Sweet et al. (2022). A rise in sea levels will also cause the erosion of coastlines and more frequent and extreme flooding events. A 2017 report found that 13 miles of O'ahu's beaches have already been lost to coastal erosion (DLNR, 2017). Tavares et al. (2020) modeled erosion from different sea level rise scenarios and found that over 90% of the sandy beaches on the north and west facing shores of O'ahu could be chronically eroding by mid century at an approximate rate of 0.2-0.3 meters per year with the continuation of shoreline hardening practices. In addition, rising sea levels might affect the visitor industry through physical impacts to tourism infrastructure and a reduction in tourism.

Sea level rise poses a high risk to hotels given their proximity to coastal areas. In Waikīkī, a popular destination for visitors to stay, several hotels are located within the 3.2 feet SLR-XA scenario (Hawai'i State GIS Program). Those not within the exposure area will continue to see impacts such as high wave flooding. Waikīkī has previously taken action to address impacts of coastal erosion through a beach nourishment project completed in 2021. A similar project proposed to renourish the beach in Ka'anapali, Maui was rejected by DLNR in 2023. These cases, and the

interest that hotels have in beach nourishment, indicate the threat the sea level rise poses to the tourism industry. In addition to hotels, highways and roads are other significant infrastructure threatened by SLR that could impact the tourism industry. Over 38 miles of roads, including 11 miles of coastal roads, would be chronically flooded under the 3.2 feet SLR scenario. Chronically flooded roads may make tourism less desirable and accessible. The next paragraph will detail how SLR will not just affect the physical infrastructure of tourism but potentially the

Many visitors come to Hawai'i for the beaches and marine activities (Lin et al., 2023), so understanding the impacts of SLR on beaches and marine environments is important for the tourism industry in Hawai'i. A study conducted at Kailua Beach Park found the beachgoers are feeling more crowded since the survey was first conducted in 2007 and the percent of beachgoers dissatisfied with their experience at the beach increased from 5% to 21% (Needham et al., 2008; Szuster & Peng, 2021). With the loss of beaches, it is reasonable to assume less people will be interested in visiting Hawai'i. In addition to beach loss, SLR may cause other impacts that could lower tourism flows like the pollution of nearshore environments. O'ahu has over 1,000 cesspools in SLR-XA under the 3.2 scenario that may be flooded by rising sea levels and can leach the waste and pollutants into the nearshore area. Examples of sewage effluent entering Kāne'ohe Bay and the ocean off of Kihei and Lahaina caused algae blooms that are known to crowd out native species (Whittier & Al-Kadi, 2015). Kim et al. (2015) modeled the impacts of SLR on urban Honolulu and found that 80% of the economy is impacted under a worst case flooding hazard in a 3.2 foot SLR scenario. With 3-5 feet of SLR, $2.6 million of the tourism industry is exposed and nearly 41,000 jobs are exposed. The tourism industry will have difficulties supporting visitors with the exposure of the industry under a 3.2 feet SLR scenario.

Acknowledgements

The Commission thanks Isabella Roberson and the University of Hawai'i Mānoa Institute for Sustainability and Resilience for their research assistance, X and Y for their helpful comments and feedback, and members of the public for their feedback during Commission meetings. Isabella Roberson is a Healy Climate Fellow with the Institute for Sustainability and Resilience.

References

Aloha+ Challenge

Avilés Mendoza, G. J., Finne, K. P., Torre Leon, F., Burke, L. M., Cabrera-Marquez, J., Mercado Casillas, A. M., Malave, G., Brown, C., Kelman, J., & Kopp, J. B. (2021). Observations from the emergency management of dialysis patients evacuated from the US Virgin Islands to Puerto Rico following hurricane Irma. *BMC Health Services Research*, *21*(1), 1239. https://doi.org/10.1186/s12913-021-07194-6

Bond-Smith, S., & Fuleky, P. (2022). The effects of the pandemic on the economy of Hawaii. Current Issues in Tourism, 1–7. https://doi.org/10.1080/13683500.2022.2151875

Climate Action Plan (CAP) 2020-2025: Technical Appendix. (2022). City & County of Honolulu. https://health.hawaii.gov/cab/files/2023/05/2005-2018-2019-Inventory_Final-Report.pdf

Climate Change Brief 2023 (2023). City and County of Honolulu Climate Change Commission. https://static1.squarespace.com/static/5e3885654a153a6ef84e6c9c/t/64374370c0631e3ac922692a/1681343347345/Climate+Change+Brief+2023.pdf

Coffman, M., Bernstein, P., Schjervheim, M., La Croix, S., & Hayashida, S. (2022). Economic and GHG impacts of a US state-level carbon tax: The case of Hawai'i. *Climate Policy*, 22(7), 935-949. https://doi.org/10.1080/14693062.2022.2061405

Department of Business, Economic Development, and Tourism (DBEDT). (2016). *The Hawaii State Input-Output Study: 2012 Benchmark Report*. State of Hawai'i.

Department of Business, Economic Development, and Tourism (DBEDT). (2005). *Planning for Sustainable Tourism*. State of Hawai'i. https://files.hawaii.gov/dbedt/visitor/sustainable-tourism-project/drafts/Modeling-Report.pdf

Department of Emergency Management (DEM). (2019). *O'ahu Coastal Communities Evacuation Planning Project: Phase 2 Final Report*. City and County of Honolulu. https://oahumpo.org/?wpfb_dl=2079

Department of Health (DOH). (2023). *Hawai'i Greenhouse Gas Emissions Report for 2005, 2018, and 2019*. State of Hawai'i. https://health.hawaii.gov/cab/files/2023/05/2005-2018-2019-Inventory_Final-Report.pdf

Eversole, D. (2009). *Pupukea-Paumalu (Sunset Beach Park) Beach Maintenance Guidelines* (TT-09-01). University of Hawaii SeaGrant College Program, SOEST.

Fuleky, P., Zhao, Q., and Bonham, C. (2014). Estimating demand elasticities in non-stationary panels: The case of Hawai'i tourism. Annals of Tourism Research, 44, 131-142. https://doi.org/10.1016/j.annals.2013.09.006

Hawai'i Data Book. (2019). Department of Business, Economic Development & Tourism (DEBDT). https://dbedt.hawaii.gov/economic/databook/2019-individual/_05/

Hawai'i Department of Business, Economic Development and Tourism (DBEDT). (2006). Planning for Sustainable Tourism. Part I: Summary Report. https://files.hawaii.gov/dbedt/visitor/sustainable-tourism-project/drafts/STPsummary.pdf

Hawai'i Emergency Management Agency (HI-EMA). (2017). *Hurricane Evacuation Shelter Planning and Operations Guidelines*. State of Hawai'i. https://dod.hawaii.gov/hiema/files/2018/02/State-Guidelines-for-Hurricane-Evacuation-Shelters.FINAL_.December-2017.pdf

Hawai'i Emergency Management Agency (HI-EMA). (2021). *State of Hawai'i Emergency Operations Plan*. State of Hawai'i. https://dod.hawaii.gov/hiema/files/2021/11/HI-EOP-SESF-1-Annex-Nov2021-part-1-signed-1.pdf

Hawai'i Tourism Authority (HTA). (2023, February 8). *Resident sentiment toward tourism recovering after prolonged downturn*. Hawaii Tourism Authority. https://www.hawaiitourismauthority.org/news/news-releases/2023/resident-sentiment-toward-tourism-recovering-after-prolonged-downturn/

Kim, K., Pant, P., & Yamashita, E. (2015). Evacuation planning for plausible worst case inundation scenarios in Honolulu, Hawaii. *Journal of Emergency Management*, *13*(2), 93–108. https://doi.org/10.5055/jem.2015.0223

Lin, B., Zeng, Y., Asner, G. P., & Wilcove, D. S. (2023). Coral reefs and coastal tourism in Hawaii. Nature Sustainability, 6(3), 254–258. https://doi.org/10.1038/s41893-022-01021-4

Maldonado, J. K., Shearer, C., Bronen, R., Peterson, K., & Lazrus, H. (2013). The impact of climate change on tribal communities in the US: Displacement, relocation, and human rights. *Climatic Change*, *120*(3), 601–614. https://doi.org/10.1007/s10584-013-0746-z

Marra, J. J., & Kruk, M. C. (2017). *State of environmental conditions in Hawaii and the U.S. affiliated Pacific islands under a changing climate: 2017*. https://pirca.org/2017/11/30/state-of-environmental-conditions-in-hawaii-and-the-u-s-affiliated-pacific-islands-under-a-changing-climate-2017/

Murakami, H., Wang, B., Li, T., & Kitoh, A. (2013). Projected increase in tropical cyclones near Hawaii. Nature Climate Change, 3(8), 749–754. https://doi.org/10.1038/NCLIMATE1890

Needham, M. D., Tynon, J. F., Ceurvorst, R. L., Collins, R. L., Connor, W. M., & Culnane, M. J. W. (2008). Recreation carrying capacity and management at Kailua Beach Park on Oahu, Hawai'i. Final project report for Hawai'i Coral Reef Initiative – Research Program. Corvallis: Oregon State University, Department of Forest Ecosystems and Society. 74pp.

IPCC 2019, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize, S., Osako, A., Pyrozhenko, Y., Shermanau, P. and Federici, S. (eds). Published: IPCC, Switzerland.

IPCC, 2021: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 817–922, doi: 10.1017/9781009157896.008.

Rodgers, K. S., Graham, A. T., Murphy, S. K., Tripler, A. S., & Scidmore-Rossing, K. (2023). Assessing carrying capacity using demographics, visitor experience and field studies: the case of Hanauma Bay Nature Preserve. Tourism Recreation Research

Saito, O. (2013). Resource Use and Waste Generation by the Tourism Industry on the Big Island of Hawaii: Resource Use and Waste on Hawaii. *Journal of Industrial Ecology*, *17*, 578–589. https://doi.org/10.1111/jiec.12007

Szuster, B., Eversole, D., Spencer, D., & Lesar, L. (2019). *Recreational Use and Management at Kailua Beach Park*. https://seagrant.soest.hawaii.edu/wp-content/uploads/2020/12/FINAL-Kailua-Beach-Park-Report.pdf

Tavares, K.-D., Fletcher, C. H., & Anderson, T. R. (2020). Risk of shoreline hardening and associated beach loss peaks before mid-century: O'ahu, Hawai'i. *Scientific Reports*, *10*(1), 13633–13633. https://doi.org/10.1038/s41598-020-70577-y

Taylor, R. A., Ryan, S. J., Lippi, C. A., Hall, D. G., Narouei-Khandan, H. A., Rohr, J. R., Johnson, L. R., & Flory, L. (2019). Predicting the fundamental thermal niche of crop pests and diseases in a changing world: A case study on citrus greening. The Journal of Applied Ecology, 56(8), 2057–2068. https://doi.org/10.1111/1365-2664.13455

Torrential Rains Leave Dozens Stranded in Hawaii Shelter. (2018, April 16). CBS News. https://www.cbsnews.com/news/torrential-rains-leave-dozens-stranded-in-hawaii-shelter/

Total Real Visitor Expenditures. (2023). UHERO Data Portal. *https://data.uhero.hawaii.edu/#/series?id=154682&data_list_id=39&sa=true&geo=HI&freq=A&start=2012-01-01*

Total Visitor Arrivals. (2023). UHERO Data Portal. https://data.uhero.hawaii.edu/#/series?id=154682&data_list_id=39&sa=true&geo=HI&freq=A&start=2012-01-01

Yerton, S. (2019, July 17). *Hawaii Struggles to Maintain Its Worn-Out Hiking Trails*. Honolulu Civil Beat. https://www.civilbeat.org/2019/07/hawaii-struggles-to-maintain-its-worn-out-hiking-trails/

Whittier, R. B., & El-Kadi, A. I. (2009). *HUMAN AND ENVIRONMENTAL RISK RANKING OF ONSITE SEWAGE DISPOSAL SYSTEMS*. Department of Health.