Aesthetic Values

Ecosystem Service Climate Change Vulnerability Assessment Synthesis for Maui, Lāna'i, and Kaho'olawe

An Important Note About this Document: *This document represents an initial evaluation of vulnerability for aesthetic values on Maui Nui[1] based on expert input and existing information. Specifically, the information presented below comprises vulnerability factors selected and scored by habitat experts,[2] relevant references from the literature, and peer-review comments and revisions (see end of document for methods and defining terms). The aim of this document is to expand understanding of ecosystem service vulnerability to changing climate conditions, and to provide a foundation for developing appropriate adaptation responses.*

Ecosystem Service Description

Aesthetic ecosystem services include the value of visual scenery, emotional response, and appreciation of the natural environment experienced by humans (e.g., sand between toes, smell of a plant, joy of a sunset; Vuln. Assessment Workshop, pers. comm., 2016). The perception of visual aesthetic value increases with perceived naturalness, well-preserved manmade cultural elements, percentage of plant cover, presence of water or mountains, color contrasts (Arriaza et al. 2004), and landscape heterogeneity (de la Fuente de Val et al. 2006). Aesthetic values and wildness (or naturalness) are two of the most important predictors of place attachment (Brown & Raymond 2007). This chapter focuses primarily on aesthetic values as they pertain to natural/environmental resources; however, cultural context also plays a large role in determining aesthetic value, especially for local people, and these are mentioned here as well (Vuln. Assessment Reviewer, pers. comm., 2017).[3]

Ecosystem Service Vulnerability

Aesthetic value ecosystem services on Maui Nui were evaluated as having moderate vulnerability to climate change

Aesthetic Values	Rank	Confidence
Sensitivity	Moderate	Moderate
Future Exposure	Moderate-High	Moderate[1]
Adaptive Capacity	Moderate	High
Vulnerability	**Moderate**	**High**

[1] Moloka'i is considered separately from this assessment. The vulnerability assessment workshop approach was not applied to Moloka'i as the PICCC funded Ka Honua Momona between 2014–2016 to host a workshop series to identify climate-related risks and vulnerabilities, and brainstorm potential solutions and partnerships. EcoAdapt and PICCC were invited to participate in a one-day workshop with the Moloka'i Climate Change Network in April 2017 to discuss adaptation options.

[2] This information was gathered during a vulnerability assessment and scenario-planning workshop in August 2016 (http://ecoadapt.org/workshops/mauivulnerabilityworkshop). Further information and citations can be found in the *Hawaiian Islands Climate Vulnerability and Adaptation Synthesis* and other products available online at www.bit.ly/HawaiiClimate.

[3] The vulnerability of cultural knowledge and heritage ecosystem services was evaluated in a separate assessment.

due to moderate sensitivity to climate and non-climate stressors, moderate-high exposure to projected future climate changes, and moderate adaptive capacity.

This ecosystem service is sensitive to factors that impact or alter iconic or highly valued natural areas (e.g., beaches, waterfalls), including sea level rise, coastal erosion, and changes in the amount of precipitation. Disturbances, such as wildfire, tropical storms/hurricanes, and insect outbreaks, may cause noticeable damage to these natural areas, affecting people's enjoyment of natural and cultural features. Additionally, development and agriculture/aquaculture activities can also cause damage or exacerbate the impact of climate stressors.

Tourism is a large part of the economy of Maui Nui, which is known for its beautiful landscapes, so public support for aesthetic values is relatively high. However, this ecosystem service receives little support as a management priority.

Sensitivity and Exposure

Climatic Factors and Disturbance Regimes

Aesthetic ecosystem services may experience increasing stress under changing climate conditions, which may alter the aesthetic value of many natural and built environments on Maui Nui (Table 1; Vuln. Assessment Reviewer, pers. comm., 2017). The sensitivity of aesthetic values to climate change is closely tied to the magnitude of change occurring, with large changes impacting human appreciation of the landscape to a greater degree (Vuln. Assessment Workshop, pers. comm., 2016). Significant alterations in the natural landscape, such as the loss of native species, drought-related dieback, severe beach erosion, and burned areas are likely to affect aesthetic values for many user groups (e.g., tourists, recreational users). Outside of potential increases in precipitation, there are few climate changes that would benefit this ecosystem service (Vuln. Assessment Workshop, pers. comm., 2016).

Aesthetic ecosystem services will likely decline under changing climate conditions due to shoreline loss resulting from sea level rise and beach erosion, loss of forest areas due to water stress, wildfire, insect/disease outbreaks, and invasive species, and the potential loss of many iconic and highly valued endemic species, such as the kiwikiu (Maui parrotbill; *Pseudonestor xanthophrys*), the Haleakalā silversword (*Argyroxiphium sandwicense macrocephalum*), and others. Potential refugia may include intact natural habitats preserved through careful management, in which climate-driven changes may be staved off in small areas (Vuln. Assessment Workshop, pers. comm., 2016).

Table 1. Current and projected future trends in climatic factors and disturbance regimes, as well as their potential impacts on aesthetic values. This ecosystem service is sensitive to the climatic factors and disturbance regimes listed below, and will likely be exposed to projected future changes in them.[4]

Climatic factors and disturbance regimes	Moderate impact (high confidence)	
Sea level rise & coastal erosion	***Historical and current trends*** • At Kahului station, sea levels rose an average of 2.1 mm/year (0.08 in) from 1947–2016 (equivalent to a change of 0.21 m [0.69 ft] in 100 years; NOAA/National Ocean Service 2017) • Maui beaches eroded by an average of 0.17 m/year (0.56 ft) across all beaches, with 85% of beaches eroding and 14% to 18% of beaches accreting since the early 1900s; in that time, 11% of total beach length (6.8 km [4.23 miles]) was completely lost to erosion and is now seawalls (Romine & Fletcher 2012) • No historical/current trends are available for Lānaʻi and Kahoʻolawe ***Projected future trends*** There is high certainty that sea levels will continue to rise at increasing rates, but the magnitude and timing of change is less certain. Possible future scenarios include: • By 2100, global sea level will likely rise between 0.3 to 2.5 m (0.98 to 8.2 ft); relative sea level may be higher in the Hawaiian Islands compared to global levels, ranging from 0.4 to 3.3 m (1.3 to 10.8 ft; Sweet et al. 2017); no regional sea level rise projections are available	***Potential impacts on ecosystem service*** • Rising sea levels and coastal flooding may impact many aspects of the landscape that are tied to aesthetic value; for instance, they may: ○ Accelerate beach erosion; Maui beaches are the most erosive in Hawaiʻi (Fletcher et al. 2012) ○ Deposit large amounts of debris and sediment in estuaries and nearshore habitats (Richmond et al. 2001; Jokiel 2006) • Coastal flooding and erosion are likely to threaten vulnerable cultural/heritage sites tied to aesthetic value, inundating archeological remains and eroding sand deposits from structures, burials, still-buried artifacts, and features related to the historical collection and processing of fish and other marine resources (Kane et al. 2012; Johnson et al. 2015)

[4] Additional factors that were not selected and scored by workshop participants may also impact aesthetic ecosystem services; these include temperature, which would likely exacerbate the impacts of drier conditions on native ecosystems, and disease and pathogens (e.g., malaria, dengue, rapid ʻōhiʻa death) that degrade the aesthetic value of forests and native bird populations (Vuln. Assessment Reviewers, pers. comm., 2017).

	• Historical rates of beach erosion on Maui are likely to double with sea level rise by mid-century; 87% of beaches are likely to be eroding by 2050 (Anderson et al. 2015) • No projected future trends are available for Lānaʻi and Kahoʻolawe	
Precipitation (amount and timing)	***Historical and current trends*** • Since 1920, precipitation has decreased across the Hawaiian Islands, with the strongest drying trends occurring over the last 30 years (Frazier et al. 2016; Frazier & Giambelluca 2017) • From 1920 to 2012, dry season (May–Oct.) precipitation declined 1% to 5% per decade for most areas on Maui and Lānaʻi, particularly in leeward areas; Kahoʻolawe experienced more modest drying of up to 1.2% per decade (Frazier & Giambelluca 2017) • From 1920–2012, Maui experienced the most significant wet season (Nov.–April) precipitation declines of any island in the state, decreasing 27.6 mm per decade, which ranged from 2% to 5% per decade in East Maui (Frazier & Giambelluca 2017) • The frequency of trade wind inversion (TWI) occurrence increased an average of 20% since 1990, resulting in a 31% reduction in wet season rainfall and a 16% reduction in dry season rainfall at nine high-elevation sites on Maui (over 1,900 m [6,234 ft]; Longman et al. 2015) ***Projected future trends*** Precipitation projections are highly uncertain because they vary in projected direction and magnitude, and will be affected by shifts in the El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO), as well as the amount of future greenhouse gas emissions. Possible future scenarios include:	***Potential impacts on ecosystem service*** • Reduced precipitation may degrade the health and integrity of native ecosystems and species (Cristini et al. 2013); for instance, water stress is contributing to the rapid decline of Haleakalā silversword, an iconic species endemic to alpine habitats in Maui (Krushelnycky et al. 2012, 2016) • Drier conditions may reduce or eliminate streamflow in some areas (Bassiouni & Oki 2013), and may impact the streams and waterfalls in Maui with high aesthetic value (King 2013) • Increased rainfall may benefit aesthetic value by increasing rainbows, waterfalls, and green landscapes in localized areas (Vuln. Assessment Workshop, pers. comm., 2016); however, increased runoff and associated erosion would likely have negative effects on the aesthetic value of coastal areas and roadways (Vuln. Assessment Reviewer, pers. comm., 2017)

	• Little to no change in average precipitation by 2100 (Keener et al. 2012) • Significant decreases in precipitation across all seasons by 2100, particularly in leeward areas (30% to 80% decrease in wet-season leeward precipitation and -20% to +20% change in wet-season windward precipitation; 10% to 90% decrease in dry-season precipitation) (Elison Timm et al. 2015) • By 2100, increased rainfall on windward slopes of Maui (up to 30% in the dry season), and decreased rainfall on Lānaʻi and leeward slopes of Maui in both seasons (Zhang et al. 2016)	
Tropical storms/ hurricanes	***Historical and current trends*** • Tropical cyclone frequency was particularly high from 1982–1995, but then decreased slightly from 1995–2000 (Chu 2002) • Overall, tropical cyclone frequency increased slightly since 1966–1981 (Chu 2002) ***Projected future trends*** Tropical cyclone projections are highly uncertain because they are influenced by large-scale patterns within the ocean and atmosphere (Murakami et al. 2013). Possible future scenarios include: • Increased frequency of tropical cyclone activity around the Hawaiian Islands due to a northwest shift in cyclone track and increased strength due to large-scale changes in environmental conditions (Murakami et al. 2013)	***Potential impacts on ecosystem service*** • Hurricanes can cause extremely heavy surf, high winds, and torrential rainfall, causing extensive damage to coastal areas, forests, and other landscapes with aesthetic value (Gerrish 1980; Richmond et al. 2001; Jokiel 2006; Coffman & Noy 2009) • Heavy rainfall and storm surge can cause flooding and erosion around coastal heritage sites (Kane et al. 2012; Johnson et al. 2015) • Strong winds can damage native forest vegetation, resetting succession in damaged areas and potentially allowing the colonization and growth of invasive species in forests with high aesthetic value (Loope & Giambelluca 1998)
Wildfire	***Historical and current trends*** • From 1904–2011, the overall trend has been towards increases in area burned across all of the Hawaiian Islands, but with high interannual variability (Trauernicht et al.	***Potential impacts on ecosystem service*** • Active wildfires and burned areas undermine landscape aesthetic quality (Trauernicht et al. 2015) • Proximity to post-burn areas can potentially lower

	2015) • The majority of wildfires on Maui occur during summer (June–Aug.), when conditions are warm and dry, accounting for 57% of the annual area burned (Chu et al. 2002) • No wildfire data is available for Lānaʻi and Kahoʻolawe ***Projected future trends*** • No regional wildfire projections are available, but increased wildfire is likely if drier conditions and more drought occur (Trauernicht et al. 2015)	property values (Stetler et al. 2010) and reduce user enjoyment of recreation areas (Brown et al. 2008) • Wildfire increases flooding and erosion by removing vegetation; this also contributes to downstream flooding and sedimentation in coastal and nearshore habitats (Trauernicht et al. 2015), degrading aesthetic value in those areas • Rapid response to wildfires (e.g., bulldozing fire lines on leeward Haleakalā) can cause severe damage to historic/cultural sites and other resources that have high aesthetic value (Vuln. Assessment Reviewer, pers. comm., 2017)

Insects	***Historical and current trends***
	• No information is available about trends in insect outbreaks
	
	Projected future trends
	• 0.4 million forested acres across the Hawaiian Islands are at risk of experiencing a 25% decrease in standing live basal area by 2027 due to the combined threat of insects and disease (not taking climatic changes into account; Krist et al. 2014)
	    ○ 61,000 acres across the Hawaiian Islands are at risk due to myoporum thrips (*Klambothrips myopori*); on Maui, the greatest threat is in low-elevation forests on the leeward side (Krist et al. 2014)
	    ○ 12,000 acres across the Hawaiian Islands are at risk due to Erythrina gall wasp (*Quadrastichus erythrinae*); on Maui, the greatest threat is in low-elevation forests on the leeward side (Krist et al. 2014)
		Potential impacts on ecosystem service
		• Insect outbreaks have the potential to impact large areas of forest, targeting keystone species that contribute to aesthetic quality such as koa (*Acacia koa*; Haines et al. 2009) and wiliwili (*Erythrina sandwicensis*) trees (Rubinoff et al. 2010)
		• Little fire ants (*Wasmannia auropunctata*) impact native species, reducing invertebrate diversity (e.g., through predation, displacement, and competition for resources) and attacking vertebrates, which can result in injury or death (Loope & Giambelluca 1998; Nishida & Evenhuis 2000; Wetterer & Porter 2003); little fire ants also have an extremely painful sting and may reduce human enjoyment of parks and other recreation areas (Lee et al. 2015)
		• Warmer temperatures may alter insect development, reproduction, survival, and distribution (Régnière et al. 2012), exacerbating the above effects

Non-Climate Stressors

Sensitivity of the ecosystem service to climate change impacts may be highly influenced by the existence and extent of, and current exposure to, non-climate stressors (Table 2). Development and agriculture/aquaculture activities can contribute to the loss of native habitats and/or can degrade popular sites valued for their aesthetic qualities.

Table 2. Key non-climate stressors that affect the overall sensitivity of aesthetic values to climate change.[5]

Non-climate stressors	Low-moderate overall impact (low confidence)
Residential & commercial development	***Potential impacts on ecosystem service*** • Trash and debris associated with developed areas degrade the aesthetic value of beaches (Tudor & Williams 2003) • Increased development reduces forest area and fragments natural habitats (Vuln. Assessment Workshop, pers. comm., 2016) • Sedimentation associated with development contributes to plumes in coastal/nearshore environments, reducing the aesthetic value of these environments (Vuln. Assessment Reviewer, pers. comm., 2017) • More extensive area within the wildland-urban interface may increase the risk of wildfire and/or the amount of damage that would occur during a fire (Vulnerability Assessment Reviewer, pers. comm., 2017) • Ongoing development and associated increases in the cost of living have contributed to a large homeless population, who are disproportionately of native Hawaiian ancestry; the presence of homeless individuals and families forced to camp in public areas is considered an aesthetic problem by many business owners, residents, and tourists, and campers may leave behind trash and belongings after they leave (Nagourney 2011; C. Peraro Consulting, LLC 2016)
Agriculture & aquaculture	***Potential impacts on ecosystem service*** • Agriculture has contributed to the loss and alteration of Hawai'i's coastal (Bantilan-Smith et al. 2009), stream (Oki et al. 2010), and forest habitats (Pau et al. 2009), accelerating the decline of iconic native plants and wildlife (e.g., colorful Hawaiian honeycreepers; Conry & Cannarella 2010) and the displacement/decimation of cultural sites and resources (Vuln. Assessment Reviewer, pers. comm., 2017) • Aquaculture has contributed to invasive fish (Brasher 2003) and invasive marine algae introductions in Hawai'i, which can degrade aesthetic value (Hunter 2007; Havird et al. 2013)

[5] Additional factors that were not selected and scored by workshop participants may also impact aesthetic ecosystem services; these include invasive species (i.e. plants, insects, and pathogens may have aesthetic impacts on large areas of forest), roads/highways, water diversions, and wind farms, which may affect aesthetic views and recreational access (Vuln. Assessment Reviewers, pers. comm., 2017).

Adaptive Capacity

Maui is known for its beautiful landscapes, and aesthetic values are viewed as important to both residents and the island's large tourism industry (Table 3). However, this ecosystem service is difficult to quantify and receives little societal support, especially in terms of funding.

Table 3. Adaptive capacity factors that influence the ability of aesthetic ecosystem services to adapt to projected future climate changes. Factors that receive a ranking of "High" enhance adaptive capacity for this ecosystem service (+), while factors that receive a ranking of "Low" undermine adaptive capacity (-).

Adaptive capacity factors	Moderate adaptive capacity (high confidence)
Intrinsic value & management potential	+ Moderate-high public value: Maui is well known for its beautiful beaches, forests, and alpine landscapes (Vuln. Assessment Workshop, pers. comm., 2016), and aesthetic values are important to both residents and tourists (Vuln. Assessment Reviewer, pers. comm., 2017) + Moderate human willingness to change behavior: The economic value of tourism (Leong et al. 2014) may increase willingness to consider the impacts of climate change on aesthetic values (Vuln. Assessment Workshop, pers. comm., 2016); the renaissance of Hawaiian culture may also encourage greater awareness of impacts to this ecosystem service (Vuln. Assessment Reviewer, pers. comm., 2017) +/- It may be possible to preserve intact natural habitats if careful management can increase resistance to climate-driven changes within specific small areas; however, there are many unknowns (Vuln. Assessment Workshop, pers. comm., 2016) - Low societal support for management: Support for aesthetic ecosystem services receives <1% of the state budget and changes with the political climate (Vuln. Assessment Workshop, pers. comm., 2016) - It is difficult to estimate the value of ecosystem services like aesthetic values, frequently resulting in omission from analyses (Bremer et al. 2015); one study found that the Koʻolau watershed on Oʻahu provided aesthetic benefits valued at $1.04–$3.07 billion (Kaiser et al. 1999; no similar studies have been carried out for Maui Nui).

Recommended Citation

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Hawaiian Islands Climate Synthesis Project:
Vulnerability Assessment Methods and Application

Defining Terms

Exposure: A measure of how much of a change in climate or climate-driven factors a resource is likely to experience (Glick et al. 2011).

Sensitivity: A measure of whether and how a resource is likely to be affected by a given change in climate or factors driven by climate (Glick et al. 2011).

Adaptive Capacity: The ability of a resource to accommodate or cope with climate change impacts with minimal disruption (Glick et al. 2011).

Vulnerability: A function of the sensitivity of a particular resource to climate changes, its exposure to those changes, and its capacity to adapt to those changes (IPCC 2007).

Vulnerability Assessment Model

The vulnerability assessment model applied in this process was developed by EcoAdapt[6] (Hutto et al. 2015, EcoAdapt 2014a, EcoAdapt 2014b, Kershner 2014), and includes evaluations of relative vulnerability by local stakeholders who have detailed knowledge about and/or expertise in the ecology, management, and threats to focal habitats and ecosystem services. Stakeholders evaluated vulnerability of each resource by discussing and answering a series of questions for sensitivity and adaptive capacity. Habitat exposure was evaluated by EcoAdapt using future climate projections from the scientific literature; ecosystem service exposure was evaluated by workshop participants using the climate impacts table provided by EcoAdapt. Each vulnerability component (i.e. sensitivity, adaptive capacity, and exposure) was divided into specific elements. For example, habitats included three elements for assessing sensitivity and five elements for adaptive capacity. Elements for each vulnerability component are described in more detail below.

Stakeholders assigned one of five rankings (High, Moderate-high, Moderate, Low-moderate, or Low) for sensitivity and adaptive capacity. Stakeholder-assigned rankings for each component were then converted into scores (High-5, Moderate-high-4, Moderate-3, Low-moderate-2, or Low-1) and the scores averaged (mean) to generate an overall score. For example, scores for each element of habitat sensitivity were averaged to generate an overall habitat sensitivity score. Scores for exposure were weighted less than scores for sensitivity and adaptive capacity; this was due to greater uncertainty about the magnitude and rate of future change. Sensitivity, adaptive capacity, and exposure scores were combined into an overall vulnerability score calculated as:

Vulnerability = [(Climate Exposure*0.5) x Sensitivity] - Adaptive Capacity

[6] Sensitivity and adaptive capacity elements were informed by Glick et al. 2011, Manomet Center for Conservation Sciences 2013, and Lawler 2010.

Elements for each component of vulnerability were also assigned one of three confidence rankings (High, Moderate, or Low). Confidence rankings were converted into scores (High-3, Moderate-2, or Low-1) and the scores averaged (mean) to generate an overall confidence score. These approximate confidence levels were based on the Manomet Center for Conservation Sciences (2013) 3-category scale, which collapsed the 5-category scale developed by Moss and Schneider (2000) for the IPCC Third Assessment Report. The vulnerability assessment model applied here assesses both the confidence associated with individual element rankings, and also uses these rankings to estimate the overall level of confidence for each component of vulnerability as well as overall vulnerability.

Rankings and scores presented should be considered measures of relative vulnerability and confidence (i.e. comparing the level of vulnerability between the focal resources evaluated in this project).

Vulnerability and confidence rankings and scores for a given element were supplemented with information from the scientific literature. The final vulnerability assessment summaries for a given resource include stakeholder-assigned rankings, confidence evaluations, and narratives summarizing expert opinions and information from the scientific literature.

Habitat & Ecosystem Service Elements

Sensitivity & Exposure (Applies to Habitats and Ecosystem Services)

1. Climate and Climate-Driven Factors: e.g., air temperature, precipitation, freshwater temperature, sea surface temperature, sea level rise, soil moisture, altered streamflows, etc.

2. Disturbance Regimes: e.g., wildfire, flooding, drought, insect and disease outbreaks, wind, etc.

3. Future Climate Exposure: e.g., consideration of projected future climate changes (e.g., temperature and precipitation) as well as climate-driven changes (e.g., altered fire regimes, altered flow regimes, shifts in vegetation types). Experts were provided with a summary of historical, current, and projected future climate changes for the main Hawaiian Islands.

4. Non-Climate Stressors: e.g., land-use conversion (e.g., residential or commercial development), agriculture and/or aquaculture, transportation corridors (e.g., roads, railroads, trails), water diversions, invasive and other problematic species, pollution and poisons, etc. For non-climate stressors, experts were asked to evaluated sensitivity, whether the habitat or ecosystem service is currently exposed to that stressor, and whether the pattern of exposure is widespread and/or consistent across the study area or is highly localized (e.g., exposure to aquaculture is highly localized but exposure to invasive grasses was often widespread).

Adaptive Capacity (Habitats)

1. Extent and Integrity: e.g., habitats that occur in multiple locations vs. single, small areas; high integrity vs. degraded habitats

2. Habitat Isolation: e.g., adjacent to other native habitat types vs. isolated habitats, barriers to dispersal (e.g., development, energy productions, roads, water diversions, etc.)

3. Resistance and Recovery: e.g., *resistance* refers to the stasis of a habitat in the face of change, *recovery* refers to the ability to "bounce back" more quickly from stressors once they do occur

4. Habitat Diversity: e.g., diversity of component native species and functional groups in the habitat

5. Management Potential: e.g., ability of resource managers to alter the adaptive capacity and resilience of a habitat to climatic and non-climate stressors (societal value of habitats, ability to alleviate impacts)

Adaptive Capacity (Ecosystem Services)

1. Intrinsic Value and Management Potential: e.g., ability of managers to alter the adaptive capacity and resilience of a service to climatic and non-climate stressors (societal value of ecosystem services, ability to alleviate impacts)

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