



## Groundwater, Seep, and Spring Habitats

### *Climate Change Vulnerability Assessment Synthesis for Maui, Lānaʻi, and Kahoʻolawe*

**An Important Note About this Document:** This document represents an initial evaluation of vulnerability for groundwater, seep, and spring habitats on Maui Nui<sup>1</sup> based on expert input and existing information. Specifically, the information presented below comprises vulnerability factors selected and scored by habitat experts,<sup>2</sup> 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 habitat vulnerability to changing climate conditions, and to provide a foundation for developing appropriate adaptation responses.

## Habitat Description

Groundwater systems include freshwater lenses floating over saltwater on flank lavas and high-level or perched water impounded by low-permeability features such as volcanic dikes (Oki et al. 2010; Rotzoll et al. 2010; Keener et al. 2012). Groundwater flows toward the coast, discharging to streams, springs, and submerged marine seeps (Keener et al. 2012). Terrestrial perennial seeps and springs can be found along banks of severely incised streams and coastal rock faces (Gingerich 1999; Pacific Coast Joint Venture Hawaiʻi 2006). On Maui, springs also emerge from perched aquifers on Keʻanae Point (Pacific Coast Joint Venture Hawaiʻi 2006).

## Habitat Vulnerability

Maui Nui groundwater, seep, and spring habitats were evaluated as having moderate vulnerability to climate change due to moderate-high sensitivity to climate and non-climate stressors, moderate-high exposure to projected future climate changes, and moderate adaptive capacity.

Groundwater, Seep, and Spring Habitats	Rank	Confidence
Sensitivity	Moderate-High	High
Future Exposure	Moderate-High	Low
Adaptive Capacity	Moderate	High
<b>Vulnerability</b>	<b>Moderate</b>	<b>High</b>

<sup>1</sup> Molokaʻi is considered separately from this assessment. The vulnerability assessment workshop approach was not applied to Molokaʻi 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 Molokaʻi Climate Change Network in April 2017 to discuss adaptation options.

<sup>2</sup> This information was gathered during a vulnerability assessment and scenario planning workshop in August 2016 (<http://ecoadapt.org/workshops/maui/vulnerabilityworkshop>). 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](http://www.bit.ly/HawaiiClimate).

Groundwater, seeps, and springs are sensitive to climate-driven changes and non-climate stressors that affect groundwater recharge, storage, and water quality. Tropical storms promote recharge while shifts in precipitation amount and timing and drought potentially reduce recharge, increasing vulnerability to saltwater intrusion. Groundwater recharge and storage are also negatively impacted by urban water withdrawals and water diversions. Comparatively, agricultural irrigation promotes groundwater recharge, but irrigation contributions have been declining over the past several decades, and the future of large-scale agriculture is uncertain with the recent cessation of sugarcane production.

The extent and integrity of groundwater, seep, and spring habitats are threatened by increasing withdrawal rates; the location of a given system, along with current and past management, will affect its ability to resist and recover from impacts. Workshop participants indicated that Maui's groundwater, seeps, and springs are moderately valued by the public. However, these habitats compete for water with a variety of off-stream water uses, and these conflicts may increase in a drier climate.

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## Sensitivity and Exposure

### Climatic Factors and Disturbance Regimes

A variety of climatic factors affect groundwater recharge patterns and water quality (Table 1). Precipitation (including storm-derived precipitation) exerts the largest control on groundwater recharge, followed by drought and air temperature. Sea level rise and saltwater intrusion affect groundwater quality.

**Table 1.** Current and projected future trends in climatic factors and disturbance regimes, as well as their potential impacts on groundwater, seep, and spring habitats. These habitats are sensitive to the climatic factors and disturbance regimes listed below, and will likely be exposed to projected future changes in them. Factors presented are those ranked as having a moderate or higher impact on these habitats; additional factors that may influence these habitats to a lesser degree include soil moisture.

Climatic factors and disturbance regimes		Moderate-high impact (moderate confidence)
Precipitation (amount & timing)	<b>Historical and current trends</b> <ul style="list-style-type: none"><li>• 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 &amp; Giambelluca 2017)</li><li>• 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 &amp; Giambelluca 2017)</li><li>• 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 &amp; Giambelluca 2017)</li><li>• 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)</li></ul>	<b>Potential impacts on habitat</b> <ul style="list-style-type: none"><li>• Precipitation is the primary source of groundwater infiltration and recharge (Oki et al. 2010); high precipitation periods can temporarily increase the thickness of the freshwater lens (Keener et al. 2012)</li><li>• 20<sup>th</sup> century precipitation declines contributed to reduced baseflows in Hawaiian streams, which is a likely indicator of reduced groundwater recharge and storage (Rotzoll et al. 2010; Bassiouni &amp; Oki 2013); however, recharge rates are also affected by other anthropogenic factors (Gingerich &amp; Engott 2012; Bassiouni &amp; Oki 2013)</li><li>• Some springs have been observed to go dry during dry conditions (Gingerich</li></ul>

	<p><b>Projected future trends</b></p> <p>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:</p> <ul style="list-style-type: none"> <li>• Little to no change in average precipitation by 2100 (Keener et al. 2012)</li> <li>• 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)</li> <li>• 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)</li> </ul>	<p>1999)</p> <ul style="list-style-type: none"> <li>• Groundwater systems are less responsive to El Niño/La Niña conditions than stream systems (Bassiouni &amp; Oki 2013)</li> </ul>
<i>Tropical storms/ hurricanes</i>	<p><b>Historical and current trends</b></p> <ul style="list-style-type: none"> <li>• Tropical storm frequency was particularly high from 1982–1995, but then decreased slightly from 1995–2000 (Chu 2002)</li> <li>• Overall, tropical storm frequency increased slightly since 1966–1981 (Chu 2002)</li> </ul> <p><b>Projected future trends</b></p> <p>Tropical storm 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:</p> <ul style="list-style-type: none"> <li>• Increased frequency and strength of tropical storm activity around the Hawaiian Islands due to a northwest shift in storm track and increased strength because of large-scale changes in environmental conditions (Murakami et al. 2013)</li> </ul>	<p><b>Potential impacts on habitat</b></p> <ul style="list-style-type: none"> <li>• Intense rainfall events contribute to aquifer recharge (Rotzoll et al. 2010)</li> </ul>
<i>Drought</i>	<p><b>Historical and current trends</b></p> <ul style="list-style-type: none"> <li>• Drought length increased in 1980–2011 compared to 1950–1979 (Chu et al. 2010)</li> <li>• Drought conditions are usually less prevalent during La Niña years, and more prevalent during El Niño years (Chu et al. 2010)</li> </ul>	<p><b>Potential impacts on habitat</b></p> <ul style="list-style-type: none"> <li>• Drought reduces groundwater recharge (Engott &amp; Vana 2007), which can temporarily shrink the freshwater lens (Keener et al. 2012) and/or increase</li> </ul>

	<p><b>Projected future trends</b></p> <p>Drought projections are highly uncertain because they are primarily dependent on precipitation projections, which are variable and have high uncertainty. Possible future scenarios include:</p> <ul style="list-style-type: none"> <li>• Maui drought risk is likely to increase by 2100 for low- and mid-elevation leeward slopes, decrease on mid-elevation windward Haleakalā slopes and the summit Mauna Kahālāwai, and remain static elsewhere (Keener et al. 2012)</li> <li>• Drought risk is likely to increase by 2100 for Lānaʻi and Kahoʻolawe, except for the summit of Lānaʻi, which may not experience a change in drought risk (Keener et al. 2012)</li> </ul>	<p>groundwater salinity (Gingerich &amp; Engott 2012)</p> <ul style="list-style-type: none"> <li>• Future droughts (similar in severity to the 1998–2002 drought) could reduce groundwater recharge by 27%; recharge could decline by 46% if drought occurs after agricultural production stops in central and west Maui (Engott &amp; Vana 2007)</li> </ul>
<i>Air temperature</i>	<p><b>Historical and current trends</b></p> <ul style="list-style-type: none"> <li>• From 1975–2006, the rate of air temperature increases has accelerated to 0.2°C (0.36°F) per decade, compared to overall increases of 0.04°C (0.07°F) per decade for all records from 1919–1975; the strongest warming is found at high elevations and in winter minimum temperatures (Giambelluca et al. 2008)</li> <li>• The annual number of freezing days on Haleakalā has declined since 1958 (Hamilton 2013)</li> </ul> <p><b>Projected future trends</b></p> <p>Projections that air temperature will increase are highly certain, although the magnitude of change is less certain. Possible future scenarios include:</p> <ul style="list-style-type: none"> <li>• Air temperature increases by 2.0°C (3.6°F) to 3.5°C (6.3°F) across the Hawaiian Islands by 2100, with more significant increases at higher elevations (Zhang et al. 2016)</li> <li>• More frequent and more intense extreme heat days (Keener et al. 2012)</li> </ul>	<p><b>Potential impacts on habitat</b></p> <ul style="list-style-type: none"> <li>• Higher air temperatures increase evaporation, which can reduce groundwater recharge (Keener et al. 2012), particularly when paired with decreases in precipitation</li> </ul>
<i>Sea level rise &amp; saltwater intrusion</i>	<p><b>Historical and current trends</b></p> <ul style="list-style-type: none"> <li>• 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); no historical/current trends are</li> </ul>	<p><b>Potential impacts on habitat</b></p> <ul style="list-style-type: none"> <li>• Saltwater intrusion increases groundwater salinity (Keener et al. 2012), affecting freshwater supply</li> </ul>

	<p>available for Lānaʻi and Kahoʻolawe</p> <ul style="list-style-type: none"> <li>• Saltwater intrusion has increased in north Maui, due primarily to groundwater withdrawals (Gingerich &amp; Engott 2012): <ul style="list-style-type: none"> <li>○ The freshwater lens became thinner between 1985 and 1999, as indicated by data from the Waiehu Deep Monitor Well</li> <li>○ There was no change in the width of the freshwater lens in west Maui, as indicated by data from the Māhinahina Deep Monitor Well</li> </ul> </li> </ul> <p><b><i>Projected future trends</i></b></p> <p>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:</p> <ul style="list-style-type: none"> <li>• 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</li> <li>• There are no projections available for saltwater intrusion, but it is likely to increase due to sea level rise, drought, and groundwater withdrawals (Rotzoll et al. 2010; Ferguson &amp; Gleeson 2012)</li> </ul>	<p>(Keener et al. 2012) and organism dispersal (Marrack 2014)</p>
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## Non-Climate Stressors

Sensitivity of the habitat to climate change impacts may be highly influenced by the existence and extent of, and current exposure to, non-climate stressors (Table 2). Non-climate stressors such as urban development and water diversions typically reduce groundwater recharge, enhancing vulnerability to and associated impacts of climate-induced recharge reductions. Additionally, groundwater withdrawal increases vulnerability to saltwater intrusion, particularly when combined with sea level rise.

**Table 2.** Key non-climate stressors that affect the overall sensitivity of groundwater, seep, and spring habitats to climate change.<sup>3</sup> All factors were ranked as having a moderate or higher impact on these habitats.

Non-climate stressors		High impact (high confidence)
<i>Residential &amp; commercial development</i>	<b>Potential impacts on habitat</b> <ul style="list-style-type: none"> <li>Increasing human populations and associated development can increase groundwater withdrawals, reducing water stored in the aquifer (Rotzoll et al. 2010) and increasing vulnerability to saltwater intrusion (Keener et al. 2012; Ferguson &amp; Gleeson 2012); groundwater withdrawal rates are highest in developed areas (Rotzoll et al. 2010)</li> <li>Annual groundwater withdrawal from the ʻĪao aquifer almost doubled from 1970-2005 due to human population growth (Engott &amp; Vana 2007)</li> <li><i>Pattern of exposure:</i> Highly localized</li> </ul>	
<i>Water diversions</i>	<b>Potential impacts on habitat</b> <ul style="list-style-type: none"> <li>Stream diversions significantly reduce groundwater recharge occurring in lower Nā Wai ʻEhā stream reaches during low flow periods (Oki et al. 2010)</li> <li><i>Pattern of exposure:</i> Highly localized</li> </ul>	
<i>Pollution &amp; poisons</i>	<b>Potential impacts on habitat</b> <ul style="list-style-type: none"> <li>Groundwater quality can be compromised by nutrient loading from agricultural and urban runoff, as well as from reclaimed water injection wells (Smith et al. 2005; Dailer et al. 2010)</li> <li><i>Pattern of exposure:</i> Consistent across habitat</li> </ul>	
<i>Agriculture &amp; aquaculture</i>	<b>Potential impacts on habitat</b> <ul style="list-style-type: none"> <li>Reduced forest cover historically caused springs to dry up (Wilcox 1997)</li> <li>Declining agricultural irrigation on Maui has significantly reduced groundwater recharge, particularly during dry years (Engott &amp; Vana 2007; Gingerich &amp; Engott 2012)</li> <li>The cessation of sugarcane production in late 2016 will likely cause groundwater recharge to be much lower than recent historical levels due to a reduction in acres irrigated, shifts in crop type, and different water management practices (Vuln.</li> </ul>	

<sup>3</sup> Additional factors that were not selected and scored by workshop participants may also impact groundwater, seep, and spring habitats; for example, invasive vegetation (e.g., kiawe [*Prosopis pallida*]) may be able to extract groundwater in shallow groundwater areas (Vuln. Assessment Reviewers, pers. comm., 2017).

	<p>Assessment Reviewer, pers. comm., 2017); for example, previous modeling by Engott and Vana (2007) indicated that if/when agricultural production ends in central and west Maui, mean groundwater recharge could be reduced by 18%</p> <ul style="list-style-type: none"> <li>• <i>Pattern of exposure</i>: Highly localized</li> </ul>
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## Adaptive Capacity

The extent and integrity of groundwater systems, seeps, and springs on Maui have declined as a result of increasing groundwater withdrawal rates (Table 3). Groundwater system resistance to climate impacts is largely affected by location and past and current management. Workshop participants evaluated groundwater systems to be moderately valued by the public but have low-moderate societal support for management and conservation. Additionally, aquatic habitats compete for water with offstream human uses, and conflicts are likely to increase in a drier climate.

**Table 3.** Adaptive capacity factors that influence the ability of groundwater, seep, and spring habitats to adapt to projected future climate changes. Factors that receive a ranking of “High” enhance adaptive capacity for these habitats (+), while factors that receive a ranking of “Low” undermine adaptive capacity (-).

Adaptive capacity factors		Moderate adaptive capacity (high confidence)
<i>Extent &amp; integrity</i> High (high confidence)	-	Population growth and increasing groundwater withdrawals on Maui have reduced water availability and increased groundwater chloride concentrations (Engott & Vana 2007; Gingerich 2008; Gingerich & Engott 2012)
<i>Resistance &amp; recovery</i> Moderate (moderate confidence)	+/-	Groundwater resistance to climate and human impacts is dependent on location, past management (Vuln. Assessment Workshop, pers. comm., 2016), and current management (Ferguson & Gleeson 2012)
<i>Habitat diversity</i> Low-moderate (high confidence)	-	<p>Diversity is naturally low in Hawaiian aquatic systems due to isolation of the Hawaiian archipelago (Brasher 2003)</p> <p>In general, relatively little is known about aquatic systems (Vuln. Assessment Workshop, pers. comm., 2016)</p>
<i>Management potential</i> Moderate (moderate confidence)	+	<p>Moderate public value: Groundwater systems are valued for potable water as well as agricultural, commercial, traditional, recreational, and subsistence use (Vuln. Assessment Workshop, pers. comm., 2016)</p> <p>Management of groundwater systems is supported by the County Water Department, State Department of Health, the Division of Aquatic Resources, and the Commission on Water Resource Management, among other agencies (Vuln. Assessment Workshop, pers. comm., 2016)</p> <p>Moderate likelihood of alleviating climate change impacts: Some climate and human impacts can be alleviated by promoting positive change and funding conservation groups and research (Vuln. Assessment Workshop, pers. comm., 2016).</p>



	<ul style="list-style-type: none"> <li>○ For example, managing water consumption and removing water diversions historically used for agriculture can reduce vulnerability to saltwater intrusion (Gingerich 2008; Gingerich &amp; Engott 2012; Ferguson &amp; Gleeson 2012)</li> <li>+ Extreme events (e.g., tsunami, contaminant influx) would likely increase support for aquatic system management (Vuln. Assessment Workshop, pers. comm., 2016)</li> <li>+/- The cessation of sugarcane production has reduced groundwater recharge in central Maui and future groundwater withdrawal scenarios are under study to meet potable and other uses (Vuln. Assessment Reviewers, pers. comm., 2017)</li> <li>- Low-moderate societal support for groundwater management and conservation: There is currently a gap in the degree to which groundwater systems are valued and societal willingness to pay for aquatic habitat protection (Vuln. Assessment Workshop, pers. comm., 2016)</li> <li>- Aquatic systems face competing interests with development, agriculture, and other offstream water uses (e.g., community use; Vuln. Assessment Workshop, pers. comm., 2016); conflicts will likely increase if climate change reduces water supply (Bassiouni &amp; Oki 2013)</li> </ul>
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## 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<sup>4</sup> (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:

$$\text{Vulnerability} = [(\text{Climate Exposure} \times 0.5) \times \text{Sensitivity}] - \text{Adaptive Capacity}$$

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<sup>4</sup> 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 evaluate 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 is 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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