Fresh Water

Climate Change Adaptation Summary for Maui, Lānaʻi, and Kahoʻolawe

An Important Note About this Document: *This document represents an initial effort to identify adaptation actions for fresh water on Maui Nui*[1] *based on stakeholder input and existing information. Specifically, the information presented below comprises stakeholder input,*[2] *peer-review comments and revisions, and relevant examples from the literature or other similar efforts. The aim of this document is to expand understanding of possible adaptation actions for Maui Nui fresh water in response to climate change.*

Ecosystem Service Vulnerability

Fresh water ecosystem services on Maui Nui were evaluated as having high vulnerability to climate change due to high sensitivity to climate and non-climate stressors, high exposure to projected future climate changes, and moderate-high adaptive capacity. Climatic changes such as increasing drought frequency and severity, increasing precipitation variability, and warmer air temperatures are likely to reduce fresh water supply, and sea level rise may impair water quality. Shifting wind patterns may exacerbate changes in precipitation by altering orographic precipitation regimes, and changes in atmospheric circulation will likely increase trade wind inversion frequency, resulting in decreased rainfall. Other disturbance regimes such as wildfire and disease may reduce or alter native vegetation cover, impairing water capture and filtration. Non-climate stressors – including residential and commercial development, agriculture, energy development, water diversions, and groundwater development – alter water use and delivery, potentially exacerbating future climate-driven reductions in water availability; at a minimum, these stressors increase competition among water uses, which may become more problematic under drier climate conditions. Human land uses (e.g., roads, urban areas) and activities (e.g., recreation) can also impair water quality by introducing contaminants and alter water capture by increasing runoff and introducing invasive species. These invasive species – including invasive parasites/pathogens (e.g., ʻōʻhia rust [*Austropuccinia psidii*]), trees (e.g., strawberry guava [*Psidium cattleianum*], miconia [*Miconia calvescens*], and kiawe [*Prosopis pallida* and *P. juliflora*]), and ungulates (e.g., feral pigs, axis deer, goats, and cattle) – undermine watershed health and integrity, reducing water storage and degrading water quality. The diverse uses of fresh water increase management challenges, particularly in the face of drier climate conditions. However, workshop participants indicated that fresh water is highly valued, which may support ecosystem service stewardship. Additionally, native landscape protection and restoration may help sustain fresh water quality and supply under variable climate conditions, although changes in societal water management, politics, and economics will also influence management opportunities.

Adaptation Strategies and Actions

Table 1 presents a summary of possible adaptation strategies and actions for Maui Nui fresh water ecosystem services, and consists of stakeholder input during an adaptation workshop as well as additional options from

[1] 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 the PICCC were invited to participate in a one-day workshop with the Molokaʻi Climate Change Network in April 2017 to discuss adaptation options. Members of the network are continuing to meet to discuss potential next steps, including developing an implementation and funding plan.

[2] This information was gathered during a climate adaptation planning workshop in April 2017 (http://www.ecoadapt.org/workshops/mauiadaptationworkshop). 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.

the literature or other similar efforts. Stakeholders identified ways in which current management actions could be modified to reduce ecosystem service vulnerabilities as well as future management actions that are not currently implemented but could be considered for future implementation.

Resilient management requires implementing a range of adaptation options within these different categories in order to achieve short-, mid-, and long-term resilience. These adaptation strategies and actions can generally be grouped according to one of five categories:

1. **Resistance**. These strategies can help to prevent the effects of climate change from reaching or affecting a resource.
2. **Resilience**. These strategies can help a resource withstand the impacts of climate change by avoiding the effects of or recovering from changes.
3. **Response**. These strategies intentionally accommodate change and/or enable resources to adaptively respond to changing and new conditions.
4. **Knowledge**. These strategies are aimed at gathering more information about climatic changes, impacts, or the effectiveness of management actions in addressing climate change.
5. **Collaboration**. These strategies may help coordinate efforts and/or capacity across landscapes and agencies.

Table 1. Summary of possible adaptation options for Maui Nui fresh water ecosystem services. All strategies and actions were identified by Maui Nui workshop participants unless noted otherwise. Adaptation approaches are classified by implementation timeframes (*Near-term*: 0-5 years; *Mid-term*: 5-20 years; *Long-term*: >20 years).

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Resistance *Near-term approach*	Improve water conservation efforts	• Develop a water budget to account for all water sources, connectivity, uses/withdrawals, and disposal/discharge • Increase agricultural water conservation (i.e. promote soil moisture management, capture rain water) • Increase public and private water system conservation (i.e. alter rate structure, use low-flow fixtures, detect and fix leaks)
	Manage invasive species	• Practice strategic watershed fence placement from mauka to makai to best enhance water quality[3] • Prevent introduction of new diseases and pathogens by increasing biosecurity controls (e.g., quarantines, intraisland policies, optional vs. mandatory restrictions)[4]
	Maintain/improve water quantity and quality	• Alter well drill depths and practice optimal well placement to minimize vulnerability to saltwater intrusion[3] • Investigate and reduce non-point source pollution[5]
	Reduce non-climate stressors	• Increase public education to minimize disturbance and/or degradation of vulnerable habitats or species[6]

[3] Developed by Oʻahu adaptation workshop participants in April 2017.
[4] Developed by Kauaʻi adaptation workshop participants in June 2017.
[5] Developed by Hawaiʻi adaptation workshop participants in June 2017.
[6] EcoAdapt. 2017. Climate Adaptation Strategies and Actions. Bainbridge Island, WA.

Adaptation Approach	Adaptation Strategy	Specific Adaptation Actions
Resilience *Near- to mid-term approach*	Protect forests to increase recharge and water retention	• Support healthy native forests through land acquisition and plant restoration
	Mandate acquisition of new technologies to maintain and enhance water quality	• Extract sodium to increase fresh water supplies • Install diversion gates
	Increase ecosystem resilience, connectivity, and integrity	• Restore hydrologic function (i.e. reduce/remove diversions, convert ditches to pipes)
	Build fire-resilient native communities	• Stabilize soils following wildfires to prevent post-burn erosion[5]
Response *Long-term approach*	Increase ecosystem resilience, connectivity, and integrity	• Acquire land for mauka migration in anticipation of sea level rise, increasing temperatures, and precipitation changes
	Maintain/improve water quantity and quality	• Integrate climate projections into Water Commission planning efforts[3]
Knowledge *Near- to long-term approach*	Monitor pollutants to protect water quality	• Monitor and regulate salinity and other indicators of water quality in wells and groundwater • Monitor point- and non-point source pollutants associated with agriculture and development (e.g., fertilizers, insecticides, agricultural byproducts)
Collaboration *Near- to long-term approach*	Increase collaborative efforts to conserve streams and watersheds	• Expand watershed conservation to lower elevations by enhancing watershed partnerships and seeking legislative changes at the state and local levels

Table 2 identifies key Maui Nui fresh water ecosystem service vulnerabilities that may be reduced and/or addressed by various adaptation actions. Linking vulnerabilities to adaptation options can help managers decide which actions to implement and aid prioritization based on multiple factors (e.g., habitat type, observed or projected changes, ecosystem service). However, when selecting adaptation actions for implementation, it is also important to consider secondary effects on other resources, both positive and negative. For example, fencing may benefit native forest ecosystems by limiting ungulate access and activity, but may increase ungulate stress on other habitats. For more information about Maui Nui adaptation strategies and actions developed by workshop participants, many of which are relevant to resilient management of fresh water ecosystem services, including where and how to implement adaptation actions, implementation timeframe, collaboration and capacity required, and secondary effects on other resources (both positive and negative), please see the report *Hawaiian Islands Climate Vulnerability and Adaptation Synthesis*.

Table 2. Key vulnerabilities of Maui Nui fresh water ecosystem services linked to specific adaptation actions and management activities (linkages are based on expert opinion); implementation of adaptation actions (central column) may help to directly reduce and/or address the impacts of identified climate and non-climate stressors and disturbance regimes (right columns). Actions highlighted in **red** represent adaptation strategies that enhance resistance, those highlighted in **orange** promote resilience, and those highlighted in **green** facilitate response. Adaptation actions aimed at increasing knowledge and collaboration are not included in this table as they address vulnerability indirectly. Adaptation actions listed in this table include those identified by stakeholders, in the scientific literature, and in other similar efforts.

Management Activity	Adaptation Actions	Climate Stressors			Disturbance Regimes				Non-Climate Stressors								
		Sea level rise; ↑ Saltwater intrusion	Δ Precipitation (amount/timing); ↑ Drought	↑ Air temperature	Δ Wind & circulation	↑ Wildfire	Increasingly variable riverine flooding	↑ Disease	Residential & commercial development	Agriculture & aquaculture	Pollution & poisons	Energy production	Roads, highways & trails	Groundwater development	Water diversions	Recreation	Invasive species
Water Resources Management Activities	Develop a water budget to account for all water sources, connectivity, uses/withdrawals, and disposal/discharge								✔	✔		✔		✔	✔		
	Increase agricultural water conservation (i.e. promote soil moisture management, capture rain water)		✔							✔		✔			✔		
	Increase public and private water system conservation (i.e. alter rate structure, use low-flow fixtures, detect and fix leaks)		✔						✔			✔		✔	✔		
	Practice strategic watershed fence placement from mauka to makai to best enhance water quality																✔
	Prevent introduction of new diseases and pathogens by increasing biosecurity controls (e.g., quarantines, intraisland policies, optional vs. mandatory restrictions)							✔									✔
	Alter well drill depths and practice optimal well placement to minimize vulnerability to saltwater intrusion	✔												✔			
	Investigate and reduce non-point source pollution								✔	✔	✔		✔				
	Increase public education to minimize disturbance and/or degradation of vulnerable habitats or species					✔										✔	✔
	Support healthy native forests through land acquisition and plant restoration		✔				✔										✔
	Extract sodium to increase fresh water supplies	✔															
	Install diversion gates	✔															
	Restore hydrologic function (i.e. reduce/remove diversions, convert ditches to pipes)								✔	✔					✔		
	Stabilize soils following wildfires to prevent post-burn erosion					✔											
	Integrate climate projections into Water Commission planning efforts		✔						✔	✔				✔	✔		
	Acquire land for mauka migration in anticipation of sea level rise, increasing temperatures, and precipitation changes	✔	✔	✔	✔			✔									

In addition to directly reducing vulnerabilities (Table 2), some adaptation actions may indirectly address vulnerabilities. For example, increasing water conservation in agricultural, private, and public water systems may reduce vulnerability to drought and precipitation changes by maintaining overall higher water availability.

Two other important considerations when selecting adaptation actions for implementation include feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability; Figure 1). An adaptation action with high feasibility has no obvious barriers and a high likelihood of implementation, whereas an action with low feasibility has obvious and/or significant barriers to implementation that may be difficult to overcome. An adaptation action with high effectiveness is very likely to reduce associated vulnerabilities (listed in Table 2) and may benefit additional management goals or resources, whereas an action with low effectiveness is unlikely to reduce vulnerability and may have negative impacts on other resources.

Feasibility of Implementing the Action

- *High*: There are no obvious barriers and it has a high likelihood of being implemented
- *Moderate*: It may be possible to implement the action, although there may be challenges or barriers
- *Low*: There are obvious and/or significant barriers to implementation that may be difficult to overcome

Action Effectiveness at Reducing Vulnerabilities

- *High*: Action is very likely to reduce vulnerability and may benefit additional goals or habitats
- *Moderate*: Action has moderate potential to reduce vulnerability, with some limits to effectiveness
- *Low*: Action is unlikely to reduce vulnerability

Figure 1. Description of action feasibility and effectiveness rankings.

Figure 2 plots adaptation actions listed in Table 1 according to feasibility and effectiveness (rankings described in Figure 1 effectiveness), better target management efforts toward specific challenges (e.g., actions with low or moderate feasibility but high effectiveness), and/or evaluate whether to proceed with implementation (e.g., actions with high feasibility but low effectiveness). For the latter two purposes, managers may consider the following questions:

- **Low or Moderate Feasibility/High Effectiveness Actions**: What steps can be taken to increase the likelihood of this action being implemented in the future?
  - *Example*: Would improving public outreach and education or enhancing public/private collaboration facilitate increased management access and activity on private lands (e.g., to remove invasive species)?
- **High Feasibility/Low or Moderate Effectiveness Actions**: Does this action still make sense given projected climate changes and impacts?
  - *Example*: If conditions are projected to become drier, should groundwater pumping still continue to support lowland wetland hydrology?

Alternatively, there may be some actions that do not reduce vulnerability directly but could provide important information, tools, or support to address vulnerability down the line. For example, actions aimed at increasing knowledge through monitoring or modeling could provide key information for future restoration activities (e.g., creating detailed species genetic profiles to select genetically and ecologically suitable plant species for future conditions). Managers may want to weigh the costs and benefits of implementing actions with the timeframe required to reduce vulnerability directly. Additionally, actions focused on coordination and collaboration may not directly address vulnerabilities, but these remain important steps toward better planning and management.

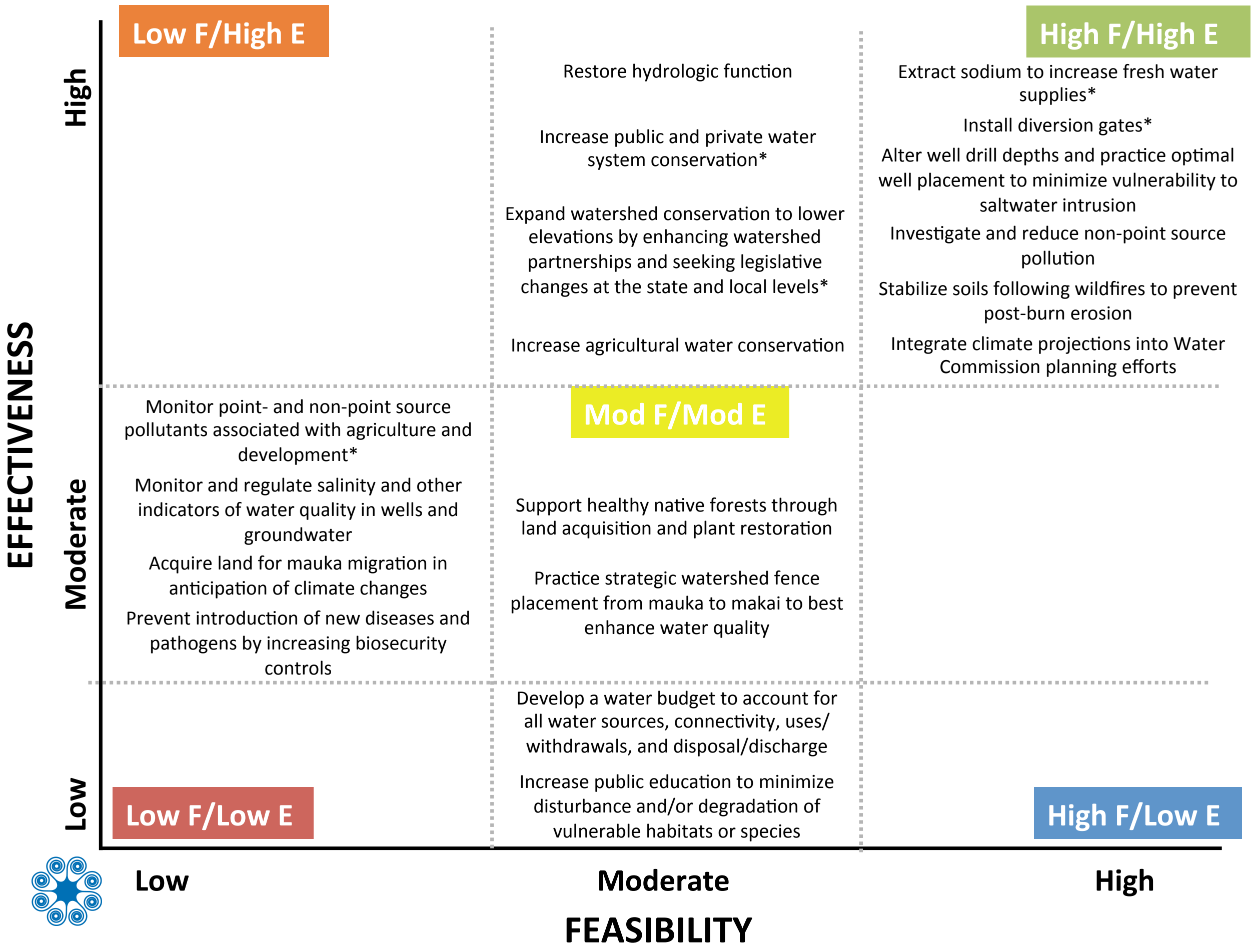

Figure 2. Maui Nui fresh water ecosystem service adaptation actions plotted according to implementation feasibility (action capable of being implemented) and effectiveness (action reduces vulnerability). Those actions having high feasibility and effectiveness appear in the upper right corner and those actions having low feasibility and effectiveness appear in the bottom left corner. An asterisk (*) denotes adaptation actions evaluated for feasibility and effectiveness by workshop participants. All other adaptation action evaluations are based on expert opinion.

Lastly, it is important to consider long-term consequences of implementing adaptation actions. One way to evaluate this is to consider how easy it would be to reverse a management action once it has been implemented in case of unintended consequences. When considering action reversibility, managers should consider cost, personnel time, overall time required to reverse an action, and other relevant factors. For example, it would likely be easy to reverse an action focused on altered outplanting timing; outplanting timing could simply be changed to a more favorable time. Alternatively, it would likely be hard to reverse the successful introduction of a new biocontrol agent, requiring significant personnel time and funding. Generally, actions involving infrastructure installation, policy or legislative change, or new species introductions may be moderately difficult or hard to reverse.

Table 3 lists adaptation actions identified in Table 1 according to ease of reversibility, as well as feasibility and effectiveness. This table can help managers evaluate whether to proceed with implementation (e.g., easily reversible actions) and/or identify actions that may need more research, small-scale testing, careful planning and implementation, and/or heightened adaptive management (e.g., moderately difficult or hard to reverse actions).

Table 3. Maui Nui fresh water ecosystem service adaptation actions listed according to ease of reversibility, as well as feasibility and effectiveness. Actions that have high feasibility/effectiveness and are easy to reverse appear at the top of the list, and actions that have low feasibility/effectiveness and are hard to reverse appear at the bottom of the list. All adaptation action evaluations are based on workshop participant and expert opinion.

Adaptation Action	Feasibility	Effectiveness	Reversibility
Investigate and reduce non-point source pollution	High	High	Easy
Integrate climate projections into Water Commission planning efforts	High	High	Easy
Install diversion gates	High	High	Moderate
Extract sodium to increase fresh water supplies	High	High	Moderate
Stabilize soils following wildfires to prevent post-burn erosion	High	High	Moderate
Alter well drill depths and practice optimal well placement to minimize vulnerability to saltwater intrusion	High	High	Hard
Increase agricultural water conservation (i.e. promote soil moisture management, capture rain water)	Moderate	High	Moderate
Increase public and private water system conservation (i.e. alter rate structure, use low-flow fixtures, detect and fix leaks)	Moderate	High	Moderate
Expand watershed conservation to lower elevations by enhancing watershed partnerships and seeking legislative changes at the state and local levels	Moderate	High	Easy
Restore hydrologic function (i.e. reduce/remove diversions, convert ditches to pipes)	Moderate	High	Moderate
Support healthy native forests through land acquisition and plant restoration	Moderate	Moderate	Moderate
Practice strategic watershed fence placement from mauka to makai to best enhance water quality	Moderate	Moderate	Moderate
Develop a water budget to account for all water sources, connectivity, uses/withdrawals, and disposal/discharge	Moderate	Low	Easy
Increase public education to minimize disturbance and/or degradation of vulnerable habitats or species	Moderate	Low	Moderate
Monitor point- and non-point source pollutants associated with agriculture and development (e.g., fertilizers, insecticides, agricultural byproducts)	Low	Moderate	Easy
Prevent introduction of new diseases and pathogens by increasing biosecurity controls (e.g., quarantines, intraisland policies, optional vs. mandatory restrictions)	Low	Moderate	Easy
Monitor and regulate salinity and other indicators of water quality in wells and groundwater	Low	Moderate	Moderate
Acquire land for mauka migration in anticipation of sea level rise, increasing temperatures, and precipitation changes	Low	Moderate	Hard

This document presents a range of adaptation options available for Maui Nui fresh water ecosystem services. When applying adaptation principles in existing management frameworks, general best practices include:

- ✓ Utilizing a range of adaptation categories to promote short-, mid-, and long-term resilience.

- ✓ Thinking critically about which climate vulnerabilities an action can directly address versus those it may address indirectly.
- ✓ Identifying where opportunities overlap (e.g., actions that address multiple vulnerabilities or benefit multiple resources), and being cognizant of actions that could create detriments to other resources.
- ✓ Prioritizing actions for implementation based on 1) how effective an action will be in reducing identified vulnerabilities; 2) how feasible implementing the action will be, and; 3) how easy it would be to reverse an action in case of unintended consequences.

Recommended Citation

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