

# ***The President's Resilient Lands and Waters Initiative: Hawai'i***

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*This report was collaboratively produced by the Pacific Islands Climate Change Cooperative (PICCC), The National Oceanic and Atmospheric Administration (NOAA), and the Environmental Protection Agency (EPA).*



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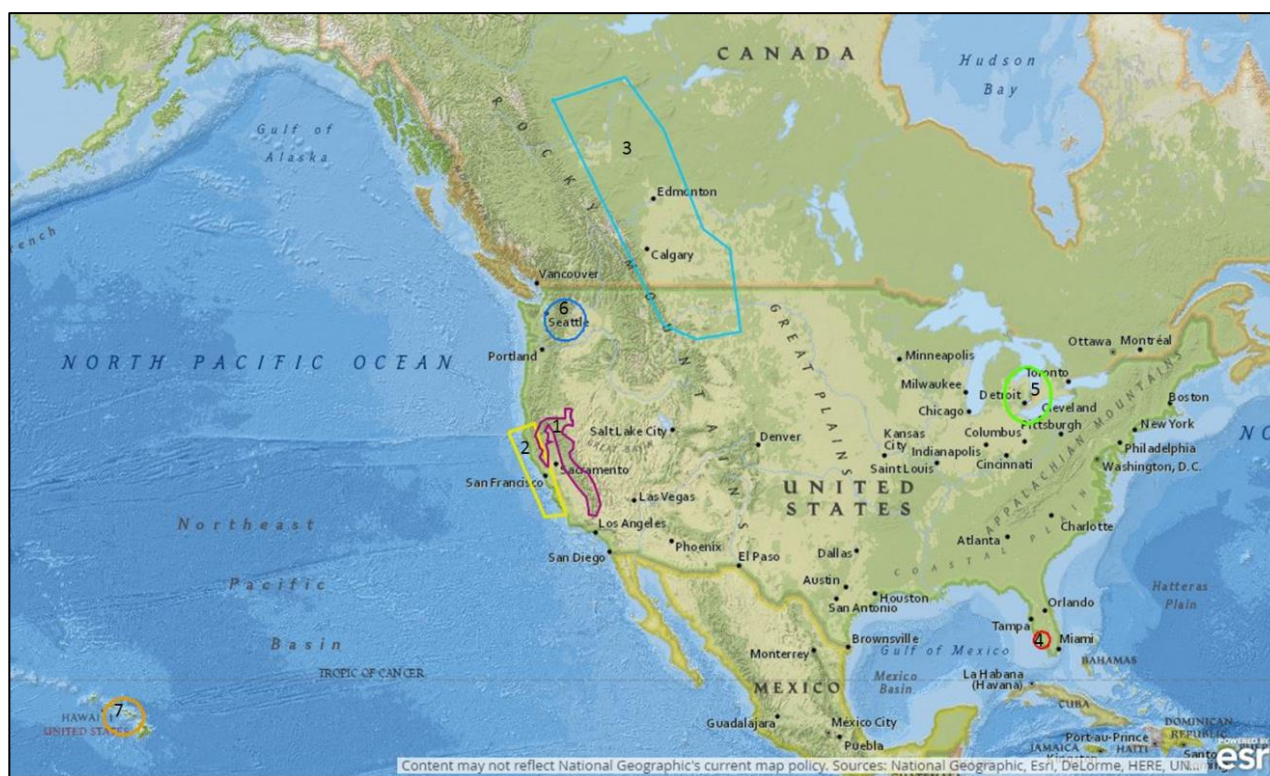
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## ***Resilient Lands and Waters Initiative Background***

In the fall of 2014, the Obama Administration released the *President's Priority Agenda for Enhancing the Climate Resilience of America's Natural Resources*. This plan sought to identify landscape conservation priorities throughout the United States in order to strengthen environmental resilience. Continuing the goals of this agenda, President Obama announced the *Resilient Lands and Waters Initiative* (RLW) on April 21, 2015, which highlighted seven exemplary places from across the nation where successful partnerships including Federal agencies, states, tribes and other partners are working to improve the resilience of landscapes and seascapes in the face of climate change (Figure 1).



**Figure 1** The seven landscapes identified as part of the Resilient Lands and Waters Initiative include the 1) California Headwaters Partnership; 2) California's North-Central Coast and the Russian River Watershed; 3) Crown of the Continent; 4) Southwest Florida; 5) the Great Lakes; 6) Washington; 7) and Hawai'i (West Hawai'i, West Maui, He'eia Watershed).

The RLW Initiative was drafted by the Climate and Natural Resources Working Group and support by a DOI-NOAA Steering Committee with assistance from the Management Team of the National Fish, Wildlife, and Plants Climate Adaptation Strategy (NFWPCAS) Joint Implementation Working Group. In addition to the honor of being included in this initiative, the partnerships working within these seven landscapers across the country were tasked with identifying and evaluating approaches to improve the natural defenses against extreme weather, protect biodiversity, and conserve natural resources in the face of a changing climate.

The objectives of the RLW Initiative were to demonstrate across the chosen sites the benefits of landscape-scale approaches to conservation and management that contribute to climate resilience by building upon the existing collaborative inter-agency partnerships. These robust partnerships are instrumental in their areas, working to protect and restore ecosystems by reducing threats such as invasive species, land-based pollution, and wildfire. As a result of this Presidential Initiative outlining a comprehensive commitment by the Federal government to support the resilience of natural resources in the United States, these partnerships availed themselves of existing science, planning, and management expertise within the Department of Interior (DOI), National Oceanic and Atmospheric Administration (NOAA), and the Environmental Protection Agency (EPA) to support forward-looking conservation strategies which help address future stressors, such as changes in rainfall, drought, and sea-level rise.

The RLW Initiative projects and efforts progressed for just under one and half years, and included monthly national phone calls as well as a discussion panel consisting of four of the seven RLW landscapes at the International Union for Conservation of Nature World Conservation Congress meeting, which was held in Honolulu, Hawai'i in September 2016. Although the RLW Initiative concluded in the fall of 2016, the efforts of the landscape partnerships to demonstrate and enhance resilience will continue through dynamic mapping tools, websites and summaries that highlight the impressive progress of these seven sites. Products from the RLW Initiative will enable organizations and partnerships throughout the country to create pre-planning and management schemes which will preserve and bolster resilience for years to come.

### ***Focusing on Resilient Lands and Waters: Hawai'i***

Although the majority of the landscapes chosen nationwide to partake in the RLW Initiative are contiguous areas on the mainland United States; Hawai'i is the only focus area composed of islands. Considering the diverse and expansive nature of Hawai'i as an island state, three sites across the state were chosen for the RLW Initiative: He'eia (O'ahu), West Maui and West Hawai'i (Figure 2). These three landscape priority areas in Hawai'i have ongoing and active management schemes in place with participation from federal, state, and local government agencies as well as community and non-profit organizations. All three locations in Hawai'i are designated as priority locations by the State of Hawai'i or NOAA, and therefore were natural choices to contribute to the RLW Initiative.

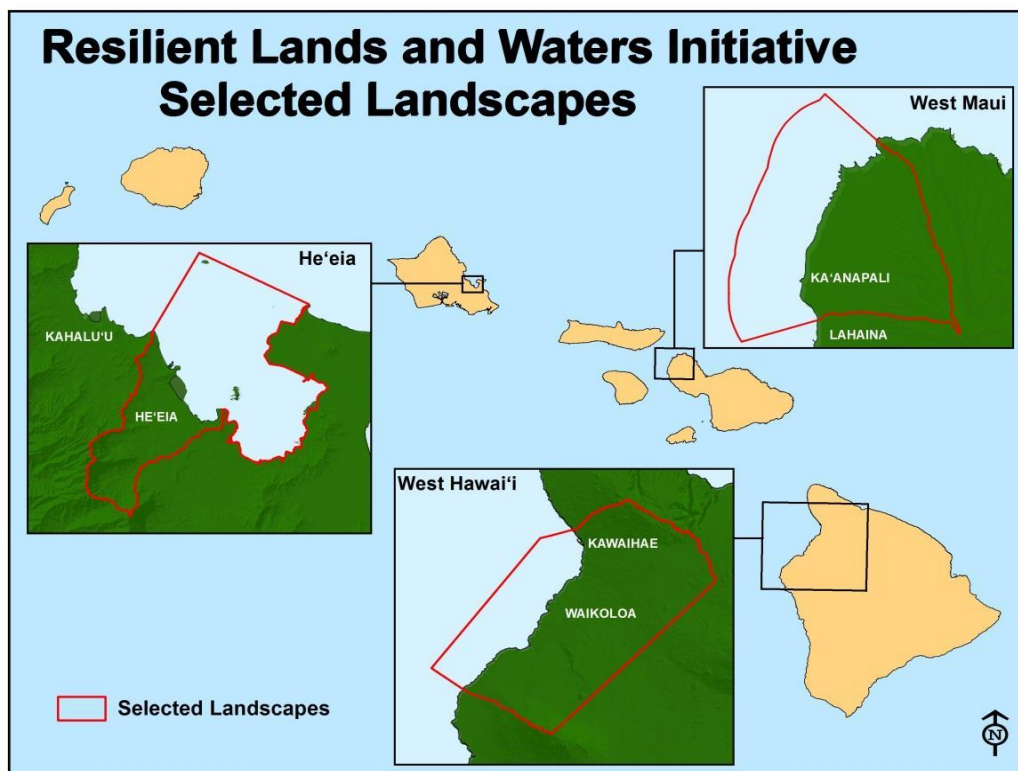
**He'eia** (O'ahu) is a NOAA Sentinel Site and the State is currently nominating it for inclusion in NOAA's National Estuarine Research Reserve System. This site is located on the windward side of the island of O'ahu north of the city of Kaneohe. The RLW boundary runs from the Ko'olau Mountains to the coast and includes Kane'ohe Bay. Several local non-profits are leading conservation efforts in He'eia, which include stream and wetland restoration, invasive species eradication, and fishpond restoration. Organizations working in He'eia are implementing activities such as improving local food security, refining understanding of fishpond production systems, constructing school gardens, removing invasive species, and restoring natural habitats.

**West Maui** is a State and US Coral Reef Task Force-designated priority area with a watershed restoration initiative led by a large, multi-stakeholder group including numerous federal agencies such as NOAA, FWS, NRCS, and USGS in partnership with the State, as well as community and local non-profit organizations. The West Maui RLW boundary includes the west portion of the West Maui Mountains and spans the landscape from the peaks of the mountains to the coral reefs lining the coast. Partnerships throughout West Maui are active in their involvement with natural resources. Fencing to restrict ungulates, fire planning and pre-suppression, surveying coral reef bleaching, and reducing sediment runoff and nutrient pollutants are just a few of the many campaigns being implemented.

**West Hawai'i** is located on the Big Island of Hawai'i. The State of Hawai'i and the US Coral Reef Task Force have designated South Kohala within West Hawai'i as a priority area, which is a NOAA-designated Sentinel Site location and Habitat Blueprint Focus Area. Priorities in the West Hawai'i site include reef resilience, erosion and wildfire control, and coastal, estuarine and dry forest restoration. Organizations and partnerships are currently working in West Hawai'i toward more effective

management regulations for coral reef fishes, restoring traditional Hawaiian fish ponds and estuarine habitat, controlling erosion and developing best land management practices, conducting community education on aging cesspools and alternative waste water treatment, studying nutrient and sediment impacts on the coral reef ecosystem and assessing the resilience of corals.

While each location has its own set of organizations and partnerships dedicated to managing, protecting and conserving natural resources, they all incorporate robust community engagement and multi-sectoral partnerships when addressing a range of resilience options. Many of the tasks involved in the RLW Initiative utilized existing methods and services while using new science and tools to understand climate vulnerability and develop management options. One of the main priorities during the RLW Initiative project was to focus on the needs of the scientists, organizations and volunteers working in the three areas throughout Hawai'i. It was identified that imperative work is already being conducted, and often times the more limiting factors are funding and able bodies. Therefore, the intention of the RLW work was not to dole out more tasks to be performed, but to clearly identify who is doing what, and where, in terms of actions promoting resilience of landscapes and communities living within these landscapes.



The Resilient **Figure 2** Three sites across the Hawaiian Islands compose the Hawaii Resilient Lands and Waters Initiative: Heeia, West Maui, and West Hawaii. Page 6

## Climate Change in Hawai'i

Globally, 15 of the 16 warmest years on record have occurred since 2000, with 2015 topping the chart as the warmest year on record by 20%<sup>1</sup>. It is widely accepted that Hawai'i is growing warmer<sup>2</sup>, with high temperatures in the ocean leading to two consecutive years of coral bleaching in 2014 and 2015<sup>3</sup>. Looking to the future, high summer temperatures are projected to create severe bleaching conditions every year by about 2040, which is likely to substantially change the character of coastal ecosystems<sup>5</sup>. Changing ocean chemistry (ocean acidification) will inevitably slow coral growth and may weaken reef structure<sup>4</sup>, while the rate of global mean sea level rise (SLR) is approximately 3.4 mm/yr<sup>5</sup>, and is predicted to accelerate<sup>6</sup>. In fact, models project sea levels in Hawai'i to be a foot higher than current levels, and climbing, by 2050<sup>7</sup>.

Impacts of climate change in Hawai'i can be seen on the ocean and across the land, affecting plants, animals as well as humans. A main concern for humans is water supply, especially since measurements show that the dry season has grown longer and drier<sup>8</sup>. Considerable disagreement currently exists between climate models in terms of future rainfall, but any shift in rainfall patterns would result in stream flows varying from present day values. Potential issues arising from altered rainfall patterns include flooding, decreased fresh water availability, drought and consequent irrigation shortages, decline of native aquatic species and increased populations of invasive aquatic species<sup>9</sup>. Changes in rainfall will interact with increasing temperatures in ways that could stress crops and lead to changes in upland forests. Storm frequency and intensity have also been changing throughout the Pacific region<sup>10</sup>. Eighteen named storms were recorded in the Central Pacific in 2015, over three times the annual average<sup>2</sup>. Rainfall and wind speeds associated with hurricanes are increasing; meanwhile, storm tracks are shifting northward, putting Hawai'i at greater risk<sup>11</sup>.

Due to human-caused warming of the global system, the climate in Hawai'i will transform in the coming decades to a new and changing state, different from the recent past. Those working to conserve and enhance our environment should consider the range of possible impacts of climate change, examine their current efforts, and consider or devise reasonable modifications to current efforts that will achieve greater resilience to climate change. Understanding this, the RLW Initiative team set out to



comprehensively review the current climate change science in each of the three locations in Hawai'i, identifying focus areas and strategies for addressing climate impacts.

## **Resilient Lands and Waters Part I: Understanding the Partnerships**

Through the Resilient Lands and Waters Initiative in Hawai'i, we aimed to demonstrate the benefits of landscape-scale approaches to conservation and management that contribute to climate resilience by building upon existing collaborative inter-agency partnerships. These robust partnerships were already implementing actions to protect and restore ecosystems by reducing threats such as invasive species, land-based pollution, and wildfire, while many organizations have been adding climate change plans into their operations as well. The goal under this Initiative was to further develop a Federal partners' toolbox from the PICCC, NOAA, and EPA, aiming to coalesce collective products and services to augment the on-the-ground efforts already occurring.

In order to grasp the extent of work being done throughout the three RLW sites, it was necessary to identify all organizations and partnerships actively working at these sites. Along with this, mapping and describing the actual activities and scope of the work being done was critical. The objective of the first portion of the RLW project was to develop maps of resilience activities being conducted by partnerships in the three RLW sites, which decrease negative impacts from climate change on ecosystem services. The first step necessary in identifying the needs for enhancing the resilience of Hawai'i's landscapes was visually organizing past and current efforts. More than 130 individuals from organizations working throughout Hawai'i's RLW sites were contacted in an effort to identify past and ongoing resilience activities that aim to ensure the continuation of healthy ecosystem services. Approximately 50 respondents from over 40 organizations participated by submitting responses to a detailed poll including questions regarding their respective organizations. These questions specified their goals, plans, actions, partnerships, and publications, and more specifically the involvement of climate change in their operations. It was found through the polls that a considerable number of organizations have formed partnerships and are collaborating throughout the three sites (Table 1, Table 2, and Table 3).

*Over 100 organizations/individuals were asked to participate in an initial RLW poll.*

*When asked 'Do you think climate change is relevant to your activities or planning?' Of the 43 respondents, 41 answered yes, while 2 offered no response.*



**Table 1** Organizations working in collaboration in He'eia (O'ahu).

Partnership name	Partners/individual entities
Lower He'eia Stream Restoration Project	U.S. Fish and Wildlife Service; Western Pacific Fishery Management Council; National Oceanic and Atmospheric Administration; Kako'o 'Oiwi, Ko'olaupoko Hawaiian Civic Club; Community members and volunteers; Hawai'i Community Foundation; Hawai'i Fish Habitat Partnership; The Nature Conservancy; Hawai'i Community Development Authority; Hawai'i Office of Hawaiian Affairs; Harold K.L. Castle Foundation
He'eia Stream Restoration Project- Phases I-III	Kamehameha Schools; Hui Ku Maoli Ola; Hawai'i Pacific University; Papahana Kūāloa; community members and volunteers; U.S. Environmental Protection Agency; State of Hawai'i Department of Health; Hawai'i Tourism Association; Hawai'i Community Foundation
Ahupua'a Restoration Council of He'eia	Watershed Partners and Projects, Ko'olau Mountain Range
Wetland Restoration	<u>Kāko'o 'Ōiwi</u> ; Koloaupoko Hawaiian Civic Club; HCDA, Castle Foundation; HI Community Foundation; Koolau Foundation; OHA; NOAA; USACE; USFWS; USGS; USDA; TNC; STAHR; Kāhala Neighborhood board; Kaneohe Neighborhood board; BWS; DPP; Carpenter's Union; Kaneohe Business Group; Townscape Inc. Environmental and Community Planning; Paepae o He'eia; Fresh From the Farm LLC; Queen Liliuokalani Children's Center; UH Hawai'i Institute of Marine Biology (UH-HIMB); UH Kamakūokalani Center for Hawaiian Studies; UH Hilo College of Agriculture, Forestry, and Natural Resource Management; Castle-Kahuku Complex Schools; City Councilmember Ikaika Anderson; City Councilmember Donovan Dela Cruz; State Representatives Ken Ito, Pono Chong, Jessica Wooley; State Senators Clayton Hee, Jill Tokuda; U.S. Representative Mazie Hirono; U.S. Senators Daniel Akaka and Daniel Inouye
Fishpond Restoration	Paepae o He'eia, Kamehameha Schools, Community volunteers and members, University of Hawai'i Institute of Marine Biology, University of Hawai'i, USGS, NOAA, Hawaiian Civic Club, Oceanic Institute
Super Sucker Reef Restoration	He'eia State Park, Kama'aina Kids, TNC, HIMB, NOAA, Paepae o He'eia, Kako'o Oiwi

**Table 2** Organizations working in collaboration in West Maui.

Partnership name	Partners/individual entities
West Maui Ridge to Reef Initiative (WMR2R)	USACE; DLNR-Commission on Water Resource Management (CWRM); Division of Aquatic Resources (DAR); Division of Forestry and Wildlife (DOFAW); NOAA; NRCS; West Maui Soil & Water Conservation District; DOH-CWB; EPA; USGS; WMMWP, TNC, PICCC, FWS, State of HI; CZM

West Maui Mountains Watershed Partnership (WMMWP)	County of Maui; Department of Water Supply; State of Hawai'i; Department of Land and Natural Resources; Ka'anapali Land Management Corp.; Kahoma Land Company L.L.C.; Kamehameha Schools Makila Land Company L.L.C., Maui Land & Pineapple Company, Inc.; The Nature Conservancy of Hawai'i; Wailuku Water Company, L.L.C.; Associate Partners: Tri-Isle Resource Conservation & Development Council; U.S. Fish and Wildlife Service; Research Corporation of the University of Hawai'i; Pacific Cooperative Studies Unit at UH Manoa
The Corals and Climate Adaptation Planning (CCAP)	A collaborative effort of the U.S. Coral Reef Task Force Climate Change Working Group and is co-lead by EPA and NOAA. The goal of the project is to advance the ability to select and implement real-world, effective adaptations to climate change. In West Maui, the CCAP Adaptation Design Tool (tool) was tested to identify possible climate-smart management options and watershed experts provided feedback to improve the tool. The tool will be refined and eventually developed into a module for The Nature Conservancy's Reef Resilience Toolkit. A webinar for He'eia and West Hawai'i partnership stakeholders will be scheduled in Fall 2016.

**Table 3** Organizations working in collaboration in West Hawai'i.

Partnership name	Partners/individual entities
Kohala Watershed Partnership	Parker Ranch; Ponoholo Ranch; Queen Emma Land Co.; Kohala Preserve Conservation Trust; Hawai'i State DLNR; Laupahoehoe Nui LLC; Kahua Ranch; HI State Dept. of Hawaiian Home Lands; Kamehameha Schools; The Nature Conservancy; Hawai'i County Dept. of Water Supply
NOAA- West Hawai'i Habitat Blueprint Focus Area and Sentinel Site	National Park Service; State of Hawai'i Department of Land and Natural Resources; The Nature Conservancy; Kohala Center; University of Hawai'i Sea Grant; Community Associations in Ka'upulehu, Kiholo, Puako; Kohala Watershed Partnership; Hawai'i Coral Reef Initiative; U.S. Geological Survey; University of California Berkeley; Pacific Islands Ocean Observing System; West Hawai'i Fisheries Council; Hawai'i County Mayor's Office; Harold K.L. Castle Foundation Conservation International/Hawai'i Fish Trust
South Kohala Coastal Partnership	The Nature Conservancy; University of Hawai'i Sea Grant; United States Department of Agriculture; Natural Resource Conservation Service; Mauna Kea Soil and Water Conservation District; National Oceanographic and Atmospheric Administration (NOAA) Coral Reef Conservation Program; Hawaiian Island Humpback Whale National Marine Sanctuary; National Park Service; Ala Kahakai National Historic Trail Association; Hawai'i Department of Land and Natural Resources; Hawai'i Division of Aquatic Resources.

### *Poll Responses*

The majority of organizations polled responded that they conduct monitoring, research, and community education, while about half said that they are involved in restoring agriculture or

aquaculture systems; controlling processes such as wildfire, erosion, and pollution; controlling invasive species; and restoring native species or habitat.

Using the survey responses, along with data available online and personal communication with organization leads, maps were created using the DataBasin platform, outlining RLW boundaries, the organizations functioning within these boundaries, and the activities being carried out related to climate change resilience. Numerous efforts and activities that are not geo-referenced were hand drawn onto

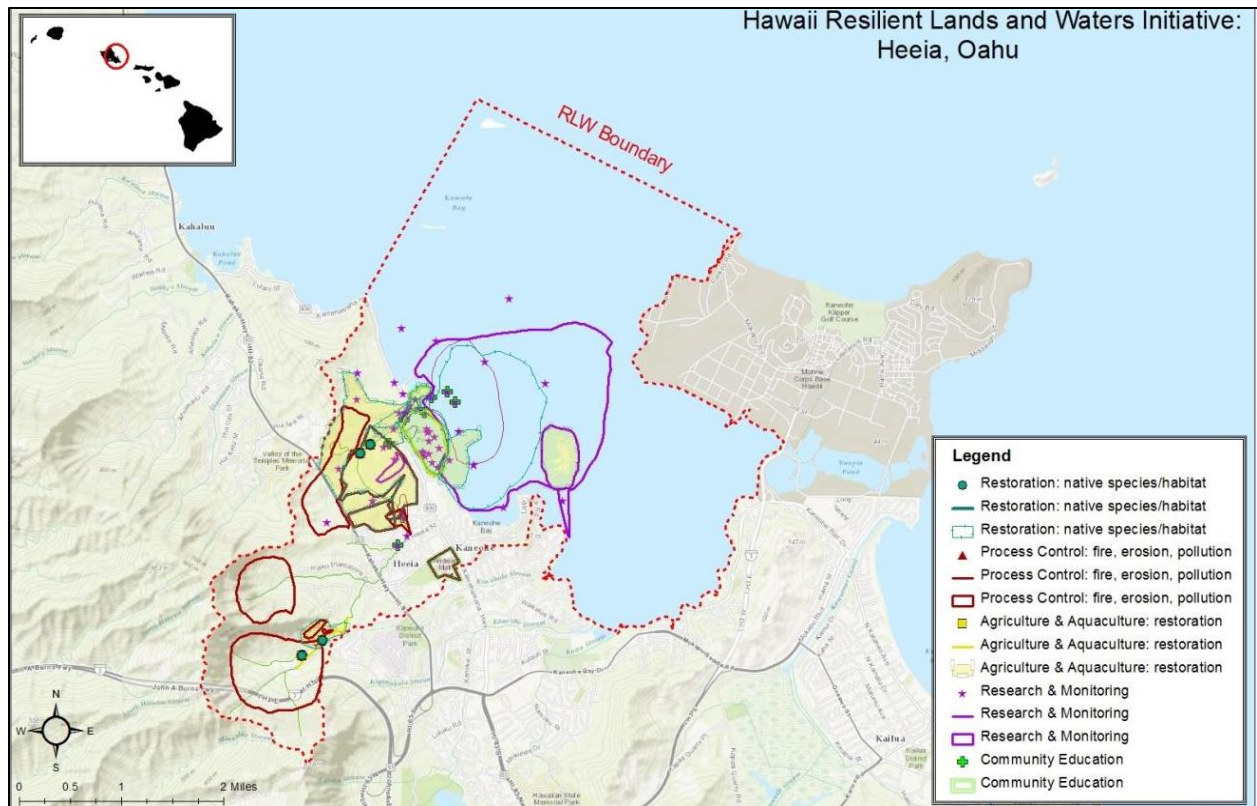
*When asked 'What would you need to be able to enhance or achieve resilience in your area?'*

*Research received the most votes. Monitoring data and information (e.g. climate projections) tied as the second most popular responses. 67% of the individuals listed more bodies and funding, while 51% of those polled said they would need examples from other*

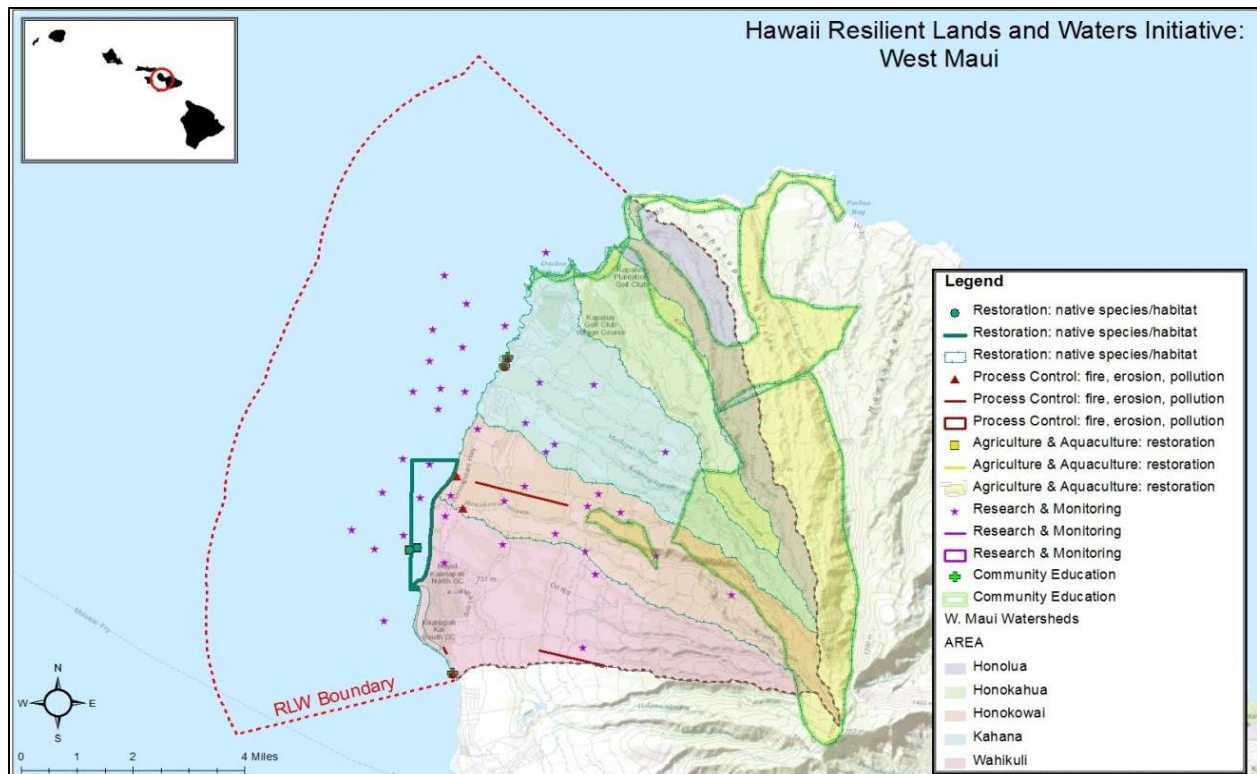
the maps (Figure 3, Figure 4, Figure 5). Ten key partnerships were identified throughout this exercise, composed of federal, state and non-profit organizations, who conduct work throughout the RLW sites. Their efforts are diverse and wide-ranging in topic and implementation, but collectively aim to recognize and maintain the priceless benefits of services provided by ecosystems such as coral reefs, coastal wetlands, fishponds, and native forests. The partnership research and resilience activity maps were created for each of the three RLW sites and portray the identified resilience activities, which are delineated into six categories: 1) Restoration of native species/habitat; 2) Controlling processes such as fire, erosion, and pollution; 3) Restoring

agriculture/aquaculture systems; 4) Conducting research/monitoring; and 5) Organizing/carrying out community education.

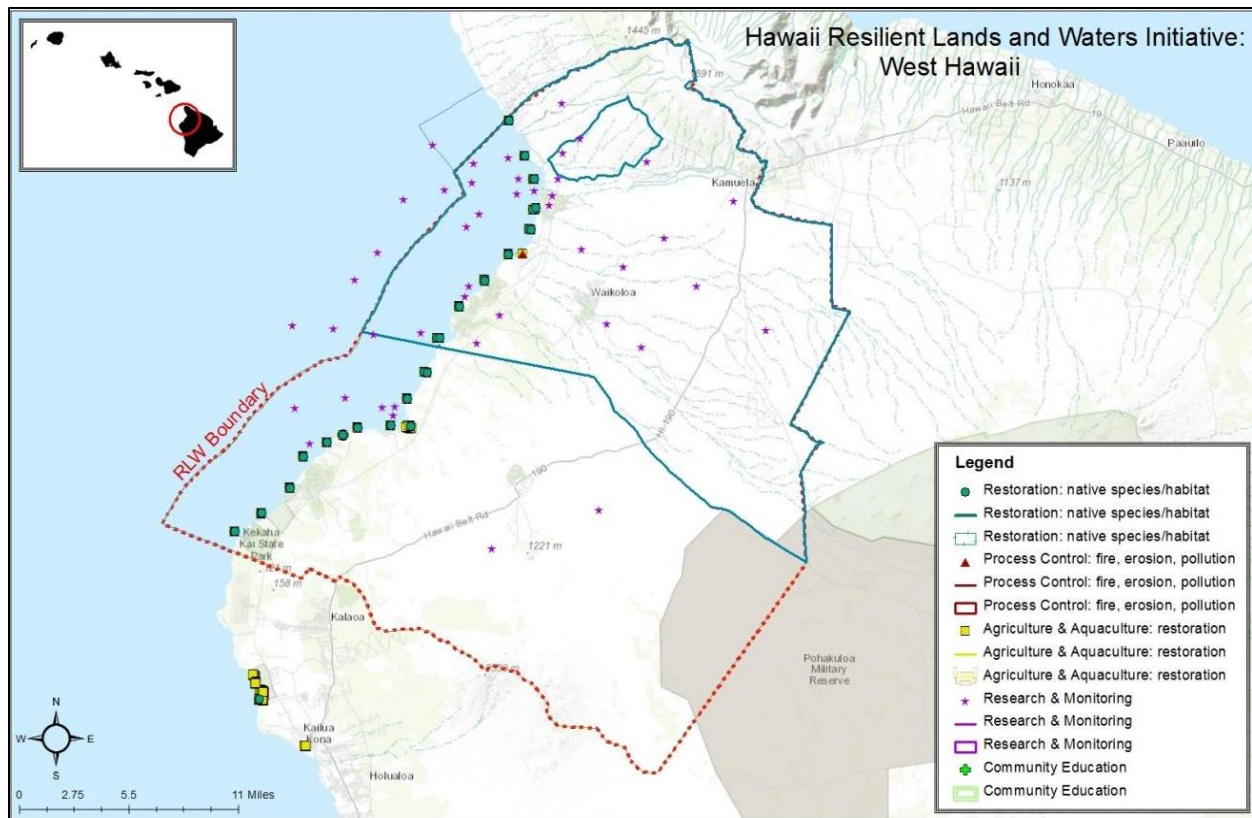
Visually displaying all efforts concerning natural resource and climate change impact management throughout the RLW sites in Hawai'i will allow organizations and individuals to identify gaps in knowledge and action. Through actions such as research and monitoring of an ecosystem or species, collaboration between organizations with common goals, measuring efficiency of an ecosystem service, or education of human inhabitants to enhance understanding and awareness of their surroundings, this mapping tool is and will continue to be an invaluable asset when it comes to maintaining climate change resilience in Hawai'i.



**Figure 3** He'eia is located on the island of Oahu just north of Kaneohe. The RLW Initiative site spans from the mountains to the ocean with numerous organizations working in areas such as natural resource management, sustainable food productions, and fish pond restoration.



**Figure 4** The northwestern most portion of the island of Maui was chosen as an RLW Initiative site due to the progressive and involved environmental management there. This site has five designated watersheds which support agriculture, aquaculture and numerous tourist destinations.



**Figure 5** The RLW Initiative boundary on the island of Hawai'i includes an expansive section of the North West portion of the island. Some of the cities within the RLW boundary include Kawaihae, Waikoloa, and Waimea.

## **Resilient Lands and Waters Part II: Examining the Science and Current Efforts**

The amount of collaborative work being done across the three RLW sites in Hawai'i is vast and impressive. Many organizations are often limited by funds and individuals at their disposal to aid efforts, and are often stumped in their goals due to lacking scientific certainty and communication. Scientific papers are continually published, often making it difficult to discern the most current and reliable state of knowledge on a specific topic. Providing a comprehensive list of studies and published works pertaining to the three RLW sites was one of the top priorities of this project. Therefore, the second set of processes in the Hawai'i RLW project involved conducting reviews of current climate change science for each of the three RLW sites in Hawai'i. This information was then utilized to outline potential modifications to conservation work already being done, in order to foster greater resiliency across the land and ocean environments. First, a list of specific climate change impacts was developed for each site, based on survey responses from organizations working in the three sites along with scientific reports pertaining to the Hawaiian Islands, accompanied by a list of organizations currently considering these impacts in their efforts. Next, a list of potential modifications to current actions was drafted by researching similar environments around the world with like problems and looking into what organizations working within these areas are doing to remedy these issues. This list was accompanied by current scientific findings pertaining to each climate change impact. Lastly, examples of actions and strategic plans being implemented across the globe to address climate change impacts were compiled to illustrate the feasibility of implementing modifications as well as the lessons learned through trial and error of adaptation and mitigation efforts.

An extensive literature review was conducted detailing current research and findings pertaining to the impacts of climate change in and around islands, with specific focus on the Hawaiian Islands (See Appendix for list of publications). Leading scientists and collaborators in Hawai'i were also consulted in an effort to seek the most recent scientific findings. This review led to the categorization of the main environmental areas impacted by climate change in the three RLW sites. These delineations include: freshwater aquatic systems; terrestrial systems; coastal and low lying areas; ocean systems; and agriculture. Following the categorization of impacted areas, the literature review was again utilized to identify specific impacts resulting from climate change for each area in the landscape. With this information, strategic plans for partnerships and organizations working in each of the three RLW sites



were reviewed to note which were currently addressing any of the listed climate change impacts in the delineated areas.

Additionally, specific climate change issues and potential ways to remedy these efforts to enhance resilience were researched and compiled. The climate change issues included in this portion of the project were: invasive species; habitat shift/loss; drought/water availability; wildfire; sea level rise; coral health; and fisheries and agriculture. Current scientific findings on each of these issues were compiled to truly understand the magnitude of effects and thereby provide the most relevant remedial actions.

Through this activity, we identified five focus areas across the land and ocean systems in Hawai'i where impacts of climate change are being seen. Tables 4, 5 and 6 show potential climate change impacts across the landscape and the groups currently incorporating these impacts in their efforts each focus area. Organizations and partnerships working in each of the three RLW areas who are currently addressing any of the listed climate change impacts were highlighted. Through research and personal communication, a comprehensive list of efforts was created; however, it is possible not all organizations and their actions are listed. Climate change impacts that are not highlighted in the tables below provide areas for actions and prioritization for communities and partnerships for future plans. Again, it is possible that some of the impacts not highlighted are being addressed, but were not submitted in the RLW organization surveys.

Along with identifying key impacts of climate change across freshwater, terrestrial, coastal/low lying areas, and the agricultural sector, it was imperative to provide ways in which these impacts can be addressed with adaptation or mitigation efforts (Table 7). Many of the suggested modifications to current efforts that would enhance resilience are slight changes or additions to efforts already in progress, while others would take larger scale planning and funding. Seven key issues are outlined in this table along with an extensive list of potential modifications to current actions that organizations are taking, which would better address resilience. Up-to-date scientific findings are also included in this table to demonstrate the current knowledge regarding each issue. Finally, relevant and insightful examples of how other organizations and governments around the world are transforming their actions to better address climate change are included.

**Table 4.** Potential climate change impacts across the He'eia landscape. Highlighted impacts are those currently being addressed by listed organizations.

Area	Freshwater: Terrestrial water systems	Terrestrial	Coastal & low lying areas	Ocean systems	Agriculture
Climate change impacts	<ul style="list-style-type: none"> <li>● Inc./dec. streamflow</li> <li>● Inc./dec. flooding risk</li> <li>● Inc. erosion, sedimentation</li> <li>● Drying of streambeds</li> <li>● Reduced groundwater supply</li> <li>● Decline in natives, inc. invasives</li> </ul>	<ul style="list-style-type: none"> <li>● Longer periods of drought</li> <li>● Habitat, biodiversity loss</li> <li>● Hotter temperatures</li> <li>● Altered seasonal variation</li> <li>● Inc. of disease and pests</li> <li>● Inc. erosion</li> <li>● Damaged cultural sites</li> </ul>	<ul style="list-style-type: none"> <li>● Flooding and erosion</li> <li>● Saltwater intrusion</li> <li>● Extreme water levels (SLR), high run up (storms)</li> <li>● Inc. natural disasters (intensity, frequency, impact from winds and rain)</li> <li>● Vulnerable fish ponds</li> <li>● Degraded infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>● Coral bleaching, disease outbreaks</li> <li>● Inc. number/intensity of storms</li> <li>● Fish population shifts</li> <li>● Reef erosion from acidification</li> <li>● Changing circulation patterns</li> <li>● Altered salinity</li> <li>● Decrease in trade winds</li> </ul>	<ul style="list-style-type: none"> <li>● Dec. crop productivity</li> <li>● Maladapted crop varieties</li> <li>● Irrigation issues</li> <li>● Flooding of ag. lands</li> <li>● Saltwater intrusion</li> <li>● Faster weed growth</li> </ul>
Organizations implementing current actions	<ul style="list-style-type: none"> <li>➢ He'eia Stream Restoration Project</li> <li>➢ Kako'o 'Oiwi wetland restoration</li> <li>➢ Lower He'eia Stream Restoration Project</li> <li>➢ Papahana Kuaola native forestry and stream restoration</li> <li>➢ Water to Watch: Lower He'eia Stream</li> <li>➢ DOFAW</li> </ul>	<ul style="list-style-type: none"> <li>➢ Hawai'i Wildfire Organization</li> <li>➢ He'eia State Park-Kama'aina Kids</li> <li>➢ He'eia Stream Restoration Project</li> <li>➢ Kako'o 'Oiwi wetland restoration</li> <li>➢ Lower He'eia Stream Restoration Project</li> <li>➢ Papahana Kuaola native forestry</li> <li>➢ Water to Watch: Lower He'eia Stream</li> </ul>	<ul style="list-style-type: none"> <li>➢ He'eia State Park-Kama'aina Kids</li> <li>➢ He'eia Stream Restoration Project</li> <li>➢ Kako'o 'Oiwi wetland restoration</li> <li>➢ Lower He'eia Stream Restoration Project</li> <li>➢ Papahana Kuaola</li> <li>➢ Water to Watch: Lower He'eia Stream</li> <li>➢ Paepae o He'eia</li> </ul>	<ul style="list-style-type: none"> <li>➢ Hawaiian Islands Sentinel Site Program</li> <li>➢ Paepae o He'eia fishpond restoration</li> <li>➢ Super Sucker Reef Restoration</li> <li>➢ HIMB</li> <li>➢ He'eia Coastal Ocean Observing System</li> <li>➢ CO2 Monitoring buoys</li> </ul>	<ul style="list-style-type: none"> <li>➢ Kako'o 'Oiwi kalo lo'i</li> <li>➢ Lower He'eia Stream Restoration Project</li> <li>➢ Papahana Kuaola kalo lo'i and agriforestry</li> </ul>

**Table 5.** Potential climate change impacts across the West Maui landscape. Highlighted impacts are those currently being addressed by listed organizations.

Area	Freshwater: Terrestrial water systems	Terrestrial	Coastal & low lying areas	Ocean systems	Agriculture
<b>Climate change impacts</b>	<ul style="list-style-type: none"> <li>● Inc./dec. streamflow</li> <li>● Inc./dec. flooding risk</li> <li>● <b>Incr. erosion, sedimentation</b></li> <li>● Drying of streambeds</li> <li>● Reduced groundwater supply</li> <li>● Decline in natives, inc. invasives</li> </ul>	<ul style="list-style-type: none"> <li>● More, larger wildfires</li> <li>● Longer periods of drought</li> <li>● Habitat, biodiversity loss</li> <li>● Hotter temperatures</li> <li>● <b>Altered seasonal variation</b></li> <li>● <b>Inc. of disease and pests</b></li> <li>● <b>Inc. erosion</b></li> <li>● Damaged cultural sites</li> </ul>	<ul style="list-style-type: none"> <li>● Flooding and erosion</li> <li>● Saltwater intrusion</li> <li>● Extreme water levels (SLR), high run up (storms)</li> <li>● Inc. natural disasters (intensity, frequency, impact from winds and rain)</li> <li>● Degraded infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>● <b>Coral bleaching, disease outbreaks</b></li> <li>● Inc. number/intensity of storms</li> <li>● Fish population shifts</li> <li>● Reef erosion from acidification</li> <li>● Altered salinity</li> <li>● Decrease in trade winds</li> </ul>	<ul style="list-style-type: none"> <li>● Dec. crop productivity</li> <li>● Maladapted crop varieties</li> <li>● Irrigation shortages</li> <li>● Flooding of ag. lands</li> <li>● <b>Faster weed growth</b></li> </ul>
<b>Organizations implementing current actions</b>	<ul style="list-style-type: none"> <li>➤ West Maui Ridge2Reef</li> <li>➤ West Maui Mountains Watershed Partnership</li> <li>➤ DAR</li> <li>➤ NOAA</li> <li>➤ USGS</li> </ul>	<ul style="list-style-type: none"> <li>➤ Hawai'i Wildfire Organization</li> <li>➤ Maui Land and Pineapple Co. Pu'u Kukui Watershed Preserve &amp; Makai Conservation Lands</li> <li>➤ West Maui Ridge2Reef</li> <li>➤ West Maui Mountains Watershed Partnership</li> <li>➤ DLNR Forestry and Wildlife</li> </ul>	<ul style="list-style-type: none"> <li>➤ Napili Bay and Beach Foundation</li> <li>➤ West Maui Ridge2Reef</li> <li>➤ USGS Coastal and Marine Science Center-Santa Cruz</li> </ul>	<ul style="list-style-type: none"> <li>➤ Hawai'i Humpback Whale National Marine Sanctuary</li> <li>➤ West Maui Ridge2Reef</li> <li>➤ Napili Bay and Beach Foundation</li> <li>➤ DAR</li> <li>➤ NOAA</li> <li>➤ USGS</li> <li>➤ Maui Nui Marine Resource Council</li> <li>➤ Project SEA Link</li> <li>➤ Coral Reef Alliance</li> <li>➤ Maui Coral Reef Recovery Team</li> </ul>	<ul style="list-style-type: none"> <li>➤ Maui Land and Pineapple Co. Pu'u Kukui Watershed Preserve &amp; Makai Conservation Lands</li> </ul>

**Table 6.** Potential climate change impacts across the West Hawai'i landscape. Highlighted impacts are those currently being addressed by listed organizations.

Area	Freshwater: Terrestrial water systems	Terrestrial	Coastal & low lying areas	Ocean systems	Agriculture
Climate change impacts	<ul style="list-style-type: none"> <li>● Inc./dec. streamflow</li> <li>● Inc./dec. flooding</li> <li>● Inc. erosion, sedimentation</li> <li>● Drying of streambeds</li> <li>● Reduced groundwater supply</li> <li>● Decline in natives, inc. invasives</li> </ul>	<ul style="list-style-type: none"> <li>● More, larger wildfires</li> <li>● Longer periods of drought</li> <li>● Habitat, biodiversity loss</li> <li>● Hotter temperatures</li> <li>● Altered seasonal variation</li> <li>● Inc. of disease and pests</li> <li>● Inc. erosion</li> <li>● Damaged cultural sites</li> </ul>	<ul style="list-style-type: none"> <li>● Flooding and erosion</li> <li>● Saltwater intrusion</li> <li>● Extreme water levels (SLR), high run up (storms)</li> <li>● Vulnerable fish ponds</li> <li>● Degraded infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>● Coral bleaching, disease outbreaks</li> <li>● Inc. number/intensity of storms</li> <li>● Fish population shifts</li> <li>● Reef erosion from acidification</li> <li>● Altered salinity</li> <li>● Decrease in trade winds</li> </ul>	<ul style="list-style-type: none"> <li>● Dec. crop productivity</li> <li>● Maladapted crop varieties</li> <li>● Irrigation shortages</li> <li>● Flooding of ag. lands</li> <li>● Saltwater intrusion</li> <li>● Faster weed growth</li> </ul>
Organizations implementing current actions	<ul style="list-style-type: none"> <li>➢ Kohala Watershed Partnership Restoration (Pelekane Bay Watershed)</li> <li>➢ UH Sea Grant Waiulaula Restoration</li> <li>➢ Hui Malama Loko I'a fishpond restoration</li> <li>➢ UH Hilo erosion modeling</li> </ul>	<ul style="list-style-type: none"> <li>➢ Hawai'i Wildfire Organization</li> <li>➢ Kohala Watershed Partnership Restoration (Pelekane Bay Watershed)</li> <li>➢ UH Sea Grant</li> <li>➢ USDA NRCS</li> <li>➢ Kailapa Community fencing and native vegetation project</li> </ul>	<ul style="list-style-type: none"> <li>➢ Coral Reef Alliance cesspool</li> <li>➢ South Kohala Coastal Partnership</li> <li>➢ Hui Malama Loko I'a fishpond restoration</li> <li>➢ Conservation International</li> <li>➢ TNC</li> <li>➢ USFS</li> <li>➢ US FWS</li> <li>➢ UH Hilo</li> <li>➢ NOAA Habitat Blueprint/West Hawai'i Habitat Focus Area</li> <li>➢ NOAA Sentinel Site</li> <li>➢ NOAA NESDIS</li> </ul>	<ul style="list-style-type: none"> <li>➢ Hawai'i Humpback Whale National Marine Sanctuary</li> <li>➢ NOAA Sentinel site</li> <li>➢ NOAA Habitat Blueprint/West Hawai'i Focus Area</li> <li>➢ South Kohala Coastal Partnership</li> <li>➢ Hui Malama Loko I'a fishpond restoration</li> <li>➢ TNC and Jeff Maynard coral resilience study</li> <li>➢ DLNR/DAR coral reef fish monitoring</li> </ul>	

**Table 7.** Common issues across the landscape and possible modifications to current efforts to enhance resilience.

Issue	Potential modifications to current actions	Current findings	Example plans/actions
<b>Invasive species</b>	<ul style="list-style-type: none"> <li>-Outreach &amp; education: invasive species management info. to be included in all public awareness programs in relation to CC</li> <li>-Reduce existing invasive species threats to increase the capacity of native species &amp; ecosystems to adapt to CC (e.g. fencing if not doing it already)</li> <li>-Re-examine plans that aim to restore past conditions or maintain current species assemblages/distributions. Describe and embrace new configurations and species, mixes that will thrive in new conditions.</li> <li>- Prioritize invasive species removal in coastal system to minimize re-introduction under sea level rise scenarios</li> <li>-Increased monitoring-scope, range, occurrence</li> <li>-Conduct risk assessment of any potential plant introductions (good practice)</li> <li>-Anticipate (using climate models/VA) and prevent range expansion of invasive plants</li> <li>- Advertise benefit of planting natives over ornamental species</li> </ul>	<ul style="list-style-type: none"> <li>• Vorsino et al. 2014<sup>11</sup></li> <li>• Somers and Asner 2012<sup>12</sup></li> <li>• Hawai'i and Pacific Islands National Climate Assessment<sup>13</sup></li> <li>• Marrack, 2016<sup>49</sup></li> </ul>	<ul style="list-style-type: none"> <li>• McNeely et al. 2001<sup>14</sup></li> <li>• Kriticos et al. 2010<sup>15</sup></li> <li>• Burgiel and Hall 2014<sup>16</sup></li> <li>• South Kohala Conservation Action Plan</li> </ul>
<b>Habitat shift/loss</b>	<ul style="list-style-type: none"> <li>-Consider assisted colonization/experimental relocation using species distribution models</li> <li>-Protection or conservation of remnant ecosystems through covenants or nature reserves</li> <li>-Captive breeding</li> <li>-Species reintroductions</li> <li>-Control invasives in future habitat</li> <li>-Control invasives and manage development in future habitat</li> <li>-Model habitat movement</li> <li>-Restoration of estuarine habitat and traditional Hawaiian fishponds as a sustainable food source, living shoreline, sediment catchment</li> </ul>	<ul style="list-style-type: none"> <li>• Corlett and Westcott 2013<sup>17</sup></li> <li>• Fortini et al. 2013<sup>18</sup></li> <li>• Price et al. 2007<sup>19</sup></li> </ul>	<ul style="list-style-type: none"> <li>• 2009 California Climate Adaptation Strategy (CAS)<sup>20</sup></li> </ul>
<b>Drought, stream flow, water availability</b>	<ul style="list-style-type: none"> <li>-Create drought exercises to properly train relevant stakeholders and to offer a forum for information exchange (e.g. suggestions for improving the drought-planning process)</li> <li>-Community-based stream groups that take care of the streams</li> <li>-Prepare for overdraft subsidence, decreased water quality/pollution</li> <li>-Increased outreach to educate and prepare the public</li> <li>-Stand-Alone Drought Plans, actions taken by individuals, industry, government, before drought occurs to reduce or mitigate impacts and conflicts arising from drought</li> </ul>	<ul style="list-style-type: none"> <li>• Timm et al. 2014<sup>21</sup></li> <li>• Zhang et al. 2012<sup>22</sup></li> <li>• Kundewicz et al. 2013<sup>23</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Colorado Drought Mitigation and Response Plan (2013)<sup>24</sup></li> </ul>
<b>Wildfire</b>	<ul style="list-style-type: none"> <li>-Remote (plane, satellite) operational monitoring of forests</li> <li>-Plant drought tolerant plants/trees</li> <li>-Monitor climate effects on forest health and the effectiveness of management actions</li> <li>-Prohibit campfires in parks, beaches, camping grounds</li> <li>-Provide training on how to prevent and fight forest fires</li> </ul>	<ul style="list-style-type: none"> <li>• Trauernicht et al. 2015<sup>25</sup></li> <li>• Ellsworth et al. 2014<sup>26</sup></li> </ul>	<ul style="list-style-type: none"> <li>• CAL FIRE Adaptation to Climate Change<sup>27</sup></li> <li>• Williams et al. 2009<sup>28</sup></li> </ul>

**Table 7 continued.** Common issues across the landscape and possible modifications to current efforts to enhance resilience.

Issue	Potential modifications to current actions	Current findings	Example plans/actions
<b>Sea level rise</b>	<ul style="list-style-type: none"> <li>-Plan for shoreline change/estuary retreat (needs modeling) and infrastructure flooding/inundation</li> <li>-Plan for less reef protection of shoreline over time (as coral reefs "sink")</li> <li>-Urge sewer infrastructure to replace cesspools/septic systems (onsite wastewater systems) vulnerable to rising water table</li> <li>-Plan for lack of drainage of ponds near SL (i.e. aquaculture ponds, fishponds, maybe raise bottom and sides)</li> <li>-Plan for decreased storm water drainage</li> <li>-Create living shorelines with wetlands that absorb floods, slow erosion, and provide habitat</li> <li>-Promote increased coastal setbacks-a prescribed distance to a coastal feature such as the line of permanent vegetation</li> </ul>	<ul style="list-style-type: none"> <li>• Anderson et al. 2015<sup>29</sup></li> <li>• Fletcher et al. 2012<sup>30</sup></li> <li>• Fletcher et al. 2002<sup>31</sup></li> <li>• Fletcher et al. 2010<sup>32</sup></li> <li>• Reynolds et al. 2012<sup>33</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Sea Level Rise Hawai'i<sup>34</sup></li> <li>• Surging Seas: Sea level rise analysis by Climate Central<sup>35</sup></li> <li>• Sea Level Rise Adaptation Strategy for San Diego Bay January 2012<sup>36</sup></li> <li>• 2009 California Climate Adaptation Strategy<sup>20</sup></li> </ul>
<b>Coral health</b>	<ul style="list-style-type: none"> <li>-Expand marine protected areas around reefs</li> <li>-Proactively tailor activities addressing land-based pollution (e.g. sediment and nutrient delivery to nearshore waters) to consider climate change predictions/uncertainties</li> <li>-Integrate CC predictions and uncertainties into Hawai'i's comprehensive planning laws and procedures</li> <li>-Decrease the likelihood of negative fishing, diving, and other reef use impacts to key habitats and important functional groups of plants and animals (e.g. herbivores) by increasing law enforcement presence and regulatory compliance</li> <li>-Promote minimum impact reef use activities (e.g. appropriate fishing gear, catch-and-release fishing) and voluntary avoidance of bleached, diseased or otherwise stressed coral reefs</li> <li>-Identify and protect transition/alternative habitats that will provide for range shifts in distribution and abundance of species and habitats affected by CC</li> <li>-Determine and map areas of high and low resilience to CC in order to identify refugia and prioritize management efforts</li> <li>-Partner with stakeholder groups, such as the tourism industry, to understand CC implications, reduce climate footprint, and prepare adaptation plans</li> <li>-Reduce land-based sources of pollution through erosion control and re-vegetation; identify erosion hotspots</li> </ul>	<ul style="list-style-type: none"> <li>• Kittinger et al. 2011<sup>37</sup></li> <li>• Munday et al. 2009<sup>38</sup></li> <li>• Keller et al. 2009<sup>39</sup></li> <li>• van Hooidonk et al. 2015<sup>5</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Bentivoglio 2003<sup>40</sup></li> <li>• Climate Change Action Plan for the Florida Reef System 2010-2015<sup>41</sup></li> <li>• Great Barrier Reef Climate Change Action Plan 2012-2017<sup>42</sup></li> <li>• EPA's Pacific Southwest Strategic Plan for Coral Reefs<sup>43</sup></li> </ul>
<b>Fisheries &amp; Agriculture</b>	<ul style="list-style-type: none"> <li>-Reduce land-based sources of pollution and destructive fishing practices</li> <li>-Reduce destructive fishing practices, increase best fishing practices</li> <li>-Change fishing rules to protect reef-critical species</li> <li>-Implement temporary MPAs ('try wait' program) for other areas</li> <li>-Change timing or locations of fishing as species arrive earlier/later, or shift to new areas</li> <li>-Water supply and irrigation systems: retrofit and modify existing systems (Ag.)</li> <li>-Contemplate forest restoration of former agricultural lands where current/future conditions preclude productive agriculture</li> <li>-Use/create different crop variety/species (Ag.) based on climatic factors and inundation</li> </ul>	<ul style="list-style-type: none"> <li>• Howell et al. 2012<sup>44</sup></li> <li>• McIlgorm et al. 2010<sup>45</sup></li> <li>• Bell et al. 2011<sup>46</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Shelton 2014<sup>47</sup></li> <li>• Sriskanthan and Funge-Smith 2011<sup>48</sup></li> </ul>

## Lessons Learned and Looking to the Future

The Resilient Lands and Water Initiative in Hawai'i illuminated current partnerships that are working to conserve the natural lands and waters and prepare them for impending climate change impacts. The Hawaiian Islands are immensely variable, not only between islands but even within each individual island. Microclimates and regions create very different issues with unique consequences and solutions. In light of this, landscape-scale solutions that may often work for a landscape in the contiguous United States may be less relevant at the small scales seen in Hawai'i or other island regions. Throughout the RLW project, many lessons were learned in terms of collaborating across organizations, disciplines and islands, which may be especially relevant to other islands or small-scale, isolated areas. These lessons include:

- Organizations may be doing resilience activities without knowing it. Individuals, organizations, and partnerships using our mapping products may discover similar projects to their own which are classified as resilience activities.
- Many organizations have not yet integrated climate change into their plans. By giving examples of resilience activities, we can help organizations identify which activities are feasible to include in their existing management plans.
- Even within a small geography like Hawai'i, organizations are often unaware of others doing similar activities across the landscape. Our mapping product clearly displays where partnerships are working and what they are doing in terms of resilience. Based on proximity and project type, organizations may be able to combine efforts to increase impact and potentially decrease costs.
- Many organizations are already performing actions across the landscapes that are addressing one or more impacts of climate change.
- Some of the climate change impacts are beyond control or scope of some organizations/partnerships.
- Many existing organizational/partnership plans are not up to date with scientific findings.



- There are numerous areas where efforts to address climate change impacts are overlapping, while ample areas exist where they aren't being addressed at all.

Although the national Resilient Lands and Waters Initiative project has now completed, efforts to enhance resilience will continue throughout the Hawaiian Islands. To aid in climate change education and action, an ESRI Storymap was created to carry the resilience efforts forward. This online portal will be available for organizations and partnerships to utilize and build upon. Pages within the storymap detail the current efforts across the islands to enhance resilience not only on the landscapes but throughout the community. By identifying current efforts outlined in conservation actions plans, partnership agreements, community outreach programs, etc., leaders within the respective communities whether scientific, governmental, or grass roots may learn how to improve upon their own entities efforts towards enhancing resilience. The information provided in the storymap also demonstrates examples of resilience activities in specific ecosystems and regions that may be mimicked and potentially implemented in like circumstances elsewhere. Please visit the RLW storymap for Hawai'i here:

<https://piccc.maps.arcgis.com/apps/MapSeries/index.html?appid=014a6b52b8d64780a0117a229746b8>

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## ***Appendix***

### ***Scientific Studies: He'eia***

\*Map number/letter corresponds to labels on Figure 3

Map Number/ Letter	Topic	Year	Authors	Category
L	Archaeological Literature Review and Field Inspection for the He'eia Fishpond Wall Repair Project	2012	Cruz	Cultural
J	Archaeological Monitoring Report for Vegetation Clearing at Leleahina Heiau	2011	Runyon	Cultural
K	Cultural Impact Assessment for the He'eia Wastewater Pump Station Improvements Project	2011	Genz	Cultural
AE	Cultural Impact Assessment for the He'eia Wastewater Pump Station Improvements Project, He'eia Ahupua'a, Ko'olaupoko District, O'ahu Island (TMK: [1] 4-6-023:041)	2011	Genz, Joseph H.	Cultural
AC	Archaeological Monitoring Plan for an Air Conditioning and Miscellaneous Upgrade Project (UHM 07-541-206) Hawai'i Institute of Marine Biology, Moku o Lo'e (Coconut Island), He'eia Ahupua'a, Ko'olaupoko District, O'ahu Island	2010	Hammatt, Hallett H.	Cultural
AD	Archaeological Monitoring Report for Vegetation Clearing at Leleahina Heiau, He'eia Ahupua'a, Ko'olaupoko District, Island of O'ahu, (TMK: [1] 4-6-010:042)	2010	Runyon, Rosanna	Cultural
Y	Archaeological Monitoring Plan for King Intermediate School at Kalimaloa, He'eia Ahupua'a, Ko'olaupoko District, O'ahu Island (TMK: [1] 4-6-004: 002)	2009	Altizer, Kendy	Cultural
Z	Archaeological Monitoring Report for the Windward Mall Food Court Renovation Project, He'eia Ahupua'a, Ko'olaupoko District, O'ahu Island (TMK: [1] 4-6-011: 001 por. & 041 por.)	2009	Altizer, Kendy	Cultural
AA	Cultural Impact Assessment for King Intermediate School at Kalimaloa, He'eia Ahupua'a, Ko'olaupoko District, O'ahu Island (TMK: [1] 4-6-004: 002 (por.))	2009	Fa'anunu, Angela	Cultural
AB	Archaeological Monitoring Plan for the Windward Mall Food Court Renovation Project, He'eia Ahupua'a, Ko'olaupoko District, O'ahu Island (TMK: [1] 4-6-011: 001 por. & 041 por.)	2009	Tulchin, Jon	Cultural
X	Archaeological Monitoring Report for Traffic Control Signal Work at the Intersection of Kamehameha Highway and Ha'iku Road, He'eia Ahupua'a, Ko'olaupoko District, O'ahu Island Tax Map Key (TMK: [1] 4-6-002, 011, 018, 021)	2008	Runyon, Rosanna	Cultural
F	Hoihoi kulana wahi pana	2008	Paris	Cultural
W	Archaeological Monitoring Plan for Traffic Control Signal Work at the Intersection of Kamehameha Highway and Ha'iku Road, He'eia Ahupua'a, Ko'olaupoko District, O'ahu Island Tax Map Key (TMK: [1] 4-6-002, 011, 018, 021)	2007	Runyon, Rosanna	Cultural
S	Archaeological Monitoring Plan for the Kamehameha Highway 16- 2006 Inch and 18-Inch Mains, He'eia, O'ahu Hawai'i (TMK: [1] 4-6-004: -008:, -016: and -033: various	2006	Hammatt, Hallett H.	Cultural
T	Phase III Cultural Resource Investigation for Two Kamehameha Schools' Parcels, He'eia Ahupua'a, Ko'olaupoko District, Island of O'ahu (TMK: [1] 4-6-14: 1, 6)	2006	McDermott, Matthew	Cultural



U	Phase I Cultural Resource Investigation for Two Kamehameha Schools' Parcels, He'eia Ahupua'a, Ko'olaupoko District, Island of O'ahu (TMK: [1] 4-6-14: 1, 6)	2006	Tulchin, Todd	Cultural
V	Phase II Cultural Resource Investigation for Two Kamehameha Schools' Parcels, He'eia Ahupua'a, Ko'olaupoko District, Island of O'ahu (TMK: [1] 4-6-14: 1, 6)	2006	Tulchin, Todd	Cultural
Q	Archaeological and Cultural Impact Evaluation for the Proposed Kamehameha Highway Waterline Project, He'eia, O'ahu (TMK: 1-4-6:04, 05, 06, 07, 08, 16, 20 por.)	2004	Freeman, Sallee	Cultural
R	Literature Review and Field Check for Intersection Improvements to Kahekili Highway, He'eia, Ahupua'a, O'ahu Island	2004	Tulchin, Jon	Cultural
O	Archaeological Inventory Survey of An Approximately 5-Acre Site for Proposed He'eia Kai 272 Reservoir, He'eia, Ko'olaupoko, O'ahu (TMK 4-6-14:5), Prepared for Board of Water Supply	1997	Hammatt, Hallett H.	Cultural
P	Archaeological Inventory Survey of the United States Coast Guard Omega Transmission Station, Ha'iku Valley, He'eia Ahupua'a, Ko'olaupoko, Island of O'ahu (TMK 4-6-15) DRAFT	1997	McDermott, Matthew	Cultural
C	Archaeological inventory survey of Heeia	1995	Stride and Hammatt	Cultural
D	Mokapu oral history	1995	Maly	Cultural
A	Inventory of human skeletal remains from Mokapu Peninsula	1994	Collins et al.	Cultural
N	Archaeological Reconnaissance Survey and Literature Search for the Proposed Improvements to a Portion of the He'eia Wastewater Collection System: He'eia, Ko'olaupoko, O'ahu	1990	Hammatt, Hallett H.	Cultural
M	Archaeological Reconnaissance and Literature Search He'eia Marsh, O'ahu; For Proposed Punawai Trunk Sewer	1989	Borthwick, Douglas F.	Cultural
B	Data recovery plan	1988	Williams	Cultural
E	Alii landing subdivision	1987	Kennedy	Cultural
H	He'eia fishpond: Aquaculture Support Facilities	1975	Hastert	Cultural
G	Some Legendary and Historical Aspects of Heeia Fishpond, Koolau, O'ahu	1973	Kelly, M.	Cultural
I	He'eia Fishpond Loko I'a O He'eia: An Interpretative Guide for the He'eia State Park Visitor	1973	Lehman L. (Bud) Henry	Cultural
21	Seasonal patterns of gonadal development, <i>Dendostrea sandvicensis</i>	2013	Garriques	Marine
33	Survey of benthic marine algae on the fringing reef adjacent to the planned Malulani Sports Complex, Heeia, Kaneohe Bay, Oahu	2013	Mcdermid	Marine
13	Growth comparison, Pacific oyster <i>Crassostrea gigas</i>	2012	Soares et al.	Marine
3	Nutrient inventories, phytoplankton during a storm	2011	Young	Marine
12	Improving sample collection of env. Data in fishpond	2011	McCoy	Marine
7	Characterization of physical env. In fishpond	2010	Benjamin	Marine
11	Alkaline phosphatase activity in fishpond	2010	Hull	Marine
32	Impact studies on the marine environment at Heeia Meadows	2010	AECOS Inc	Marine
20	Development of coral reef biocriteria for Hawaii	2009	Ku'ulei and Jokiel	Marine
18	Sediment composition, redox speciation, fishpond	2008	Ricardo	Marine
6	Extent and expansion of mangroves	2006	Chimner et al.	Marine
9	Ilgarol, Hawaiian coral reefs	2006	Knutson et al.	Marine

22	Threats to native aquatic insect biodiversity in HI and Pacific	2005	Englund	Marine
15	Management of forest ecosystems, mangroves	2004	Enoki	Marine
10	Hawaiian fishponds	2000	Yang	Marine
5	Propagule predation in forest of nonindigenous mangroves	1999	Steel et al.	Marine
4	Mangroves as alien species	1998	Allen	Marine
17	Nitrogen-versus phosphorus-limited growth, coral macroalgae	1998	Larned	Marine
19	Ecological impact, fresh water reef kill in Kaneohe Bay	1993	Jokiel et al	Marine
31	Interspecific competition for cavities among intertidal	1993	Gassel	Marine
8	Distribution of Phymcomycetes in mangrove swamps	1983	Ulken	Marine
16	Introduction and spread of mangroves	1981	Wester	Marine
14	Fungi associated with roots of red mangrove	1973	Lee and Baker	Marine
2	Soil microfungi in mangrove swamp	1972	Lee and Baker	Marine
1	Mangrove swamp	1967	Walsh	Marine
23	Organic matter to tropical coastal sediments	2013	Briggs et al.	Terrestrial
34	Heeiea State Park : final environmental impact statement, Heeiea	2010	PBR HI	Terrestrial
25	Mitigating runoff, nearshore resource conservation	2005	Kaiser et al.	Terrestrial
24	Subsurface stratigraphy of southeastern Heeiea peninsula	1991	Schmeding	Terrestrial
39	He'eia Snapshot Water Quality Monitoring Day: March 12, 2011	2011	Hui o Ko'olaupoko (HOK)	Water
38	Snapshot Water Quality Monitoring Day 2010. O'ahu, Ko'olaupoko, He'eia State Park	2010	Hui o Ko'olaupoko (HOK)	Water
28	Fluvial fluxes of water, particulate matter, nutrients, impacts on coastal water	2009	Hoover and Mackenzie	Water
37	He'eia Stream Contaminants Study	1998	Easterbrook	Water
29	Aquatic sediments	1994	Sylvester et al	Water
30	Magnitude, frequency of flooding	1994	Wong	Water
36	Environmental assessment He'eia wastewater collection system	1993	Hammett	Water
27	Cleaning and maintenance of wetlands	1991	Miller et al.	Water
35	Archaeological Survey, Proposed Improvements, He'eia Wastewater Collection System	1991	Hammatt and Borthwick	Water
26	Heeiea wastewater collection system	1990	Hammatt and Borthwick	Water

## Scientific Studies: West Maui

\*Map number/letter corresponds to labels on Figure 4

Map Number/ Letter	Topic	Year	Authors	Category
1	Maui Nui circulation modeling	2013-2016	Storlazzi	Atmospheric
2	Rainfall, cloud-water interception, canopy throughfall	1995	Juvik and Nullet	Atmospheric
7	Benthic habitat mapping, coral reef ecosystem	2013-2016	Rooney	Marine
8	High-resolution benthic habitat mapping	2012-2015	Storlazzi	Marine
4	Sociological dimensions, coral reef protection area	2012-2014	Edwards	Marine
3	Surgeonfishes	2011-2015	Clements	Marine
5	Effects of fish and urchin herbivory on reef benthic	2010-2014	Kelly	Marine
9	Maui Nui reef geology and oceanography GIS	2105	Storlazzi	Marine
6	Biomarker expression in corals	2014	Richmond	Marine
13	Processes driving variability in flow, sheer, turbidity, coral reef	2008	Storlazzi et al.	Marine
11	Characterization green alga bloom	2005	Smit et al.	Marine
12	Reef coral populations	2004	Brown	Marine
16	Mapping shoreline change	2003	Fletcher et al.	Marine
15	Acoustic interaction of humpback whales, whale watching boats	2000	Au and Green	Marine
14	Behavior of humpback whales	1986	Herman	Marine
10	Abundance and behavior of humpback whales	1983	Darling et al.	Marine
41	Ecosystem services tool	2015-2016	Oleson	Terrestrial
23	Geochemical records, land-based pollution, climate change	2013-2016	Storlazzi	Terrestrial
22	Regional Sediment Management	2013-2014	Smith	Terrestrial
20	Sediment retention	2014	Babcock	Terrestrial
21	Dead zones porites compressa, anthro. Nutrient input	2012	Ross	Terrestrial
17	Phylogeography and ecology, endemic radiation, HI aquatic case-bearing	2008	Rubinoff	Terrestrial
25	Effects, Ag. Land-use changes and rainfall, ground-water recharge	2007	Engott and Vana	Terrestrial
29	Model shoreline change	2007	Vitousek and	Terrestrial
28	Mating system instability in Schiedea menziesii	2002	Rankin et al	Terrestrial
24	Terrestrial nutrient and sediment fluxes, coastal waters	1997	Soicher and	Terrestrial
26	Genetic structure, differentiation, Metrosideros polymorpha	1993	Aradhya and	Terrestrial
30	Lobelioideae chromosome numbers	1988	Lammers	Terrestrial
27	Ornithophily among HI Lobelioideae	1986	Lammers and	Terrestrial
18	Relationship between homosequential species of HI Drosophila	1974	Craddock	Terrestrial
19	Microevolution within three species, HI Drosophila	1969	Carson and Sato	Terrestrial
32	Wastewater effluent, coral physiology	2014-2016	Fox	Water
33	Landuse impacts of groundwater to coastal zones	2012-2016	Glenn	Water
34	Water quality sampling	2010-2014	Okubo	Water
35	Submarine groundwater discharge	2013	Swarzenski	Water
36	Efficacy of watershed management	2013	Vargas-Angel	Water
31	Watershed monitoring	2012	Brosius	Water
39	Groundwater availability	2012	Gingerish and	Water
40	Flood-frequency	2010	Oki et al.	Water
38	Inventory of rare and alien aquatic species in streams	2003	Englund et al.	Water
37	West Maui watershed owners manual	1997	State of HI	Water

## Scientific Studies: West Hawai'i

\*Map number/letter corresponds to labels on Figure 5

Map Number/ Letter	Topic	Year	Author	Category
4	Numerical simulations of sea-breeze circulation	2005	Zhang et al.	Atmospheric
3	Circulation and RF on leeward HI	2003	Yang and Chen	Atmospheric
36	Simulations of airflow over Hawaii island	2001	Cheng-Feng	Atmospheric
2	Airflow simulations and cloud distribution	2000	Chen and Feng	Atmospheric
1	Characteristics of local winds in NW HI	1981	Schroeder	Atmospheric
E	Cultural history of three traditional hawaiian sites	1993	Greene LW	Cultural
G	Mauna Lani Cove and Adjacent Golf Course Relocation Project	1991	Plan	Cultural
F	Archaeological inventory survey, Waikoloa Beach Resort	1990	Jenson	Cultural
C	Waimea-Kawaihae settlement system	1986	Clark	Cultural
D	Archaeological investigations of mudland Kawaihae road corridor	1983	Clark et al.	Cultural
I	Acreology at Puukohola National Historic Site	1978	Rosendahl and Carter	Cultural
B	Archaeological and historical surveys Waimea to Kawaihae	1974	Barrera and Kelly	Cultural
A	Archaeological survey of portions of Waikoloa	1972	Baevacqua	Cultural
H	Archaeological salvage of Hapuna-Anaeho omalu	1972	Rosendahl	Cultural
31	Movement of tiger sharks	2009	Meyer et al.	Marine
7	Survey of epiphytic dinoflagellates-coastal	2007	Parsons and Preskitt	Marine
29	Liquification of Kawaihae Harbor-Earthquake	2007	Brandes et al.	Marine
28	Wave climate and response, Kawaihae	2006	Thompson et al.	Marine
26	Melt water pulse drown-reef	2004	Webster et al.	Marine
25	Coral reef mitigation in Kawaihae	2001	Naughton and Jokiel	Marine
32	Ecology of green sea turtles at Kiholo Bay	2000	Rice et al.	Marine
24	Arc-eye Hawkfish	1996	DeMartini and Donaldson	Marine
23	Anchialine shrimp	1993	Bailey-Brock and Brock	Marine
21	Wave response in Kawaihai harbor	1990	Lillicrop et al.	Marine
20	Change in marine habitat Pelekane Bay	1988	Tissot	Marine
6	Physiography and marine fauna of Puu Kohala	1977	Cheney et al.	Marine
33	Preventing intro. and spread of nutrient driven invasive algal blooms	NA	Dailer	Marine
8	HI fruit fly pest management program	2008	Vargas et al.	Terrestrial
35	Dryland agriculture	2000	Ladefoged and Graves	Terrestrial
34	Concentrations of selected elements in soils-Kawaihae	1985	Barnard and Halbig	Terrestrial
5	Warbling Silverbill	1975	Berger	Terrestrial
19	Surface water metabolism	2014	Johnson and Wiegner	Water
9	Microbial communities in groundwater	2012	Walker	Water
37	Surface water metabolism potential leeward HI	2012	Johnson	Water
17	Point source groundwater discharge to ocean	2009	Peterson et al.	Water
16	Submarine groundwater discharge	2008	Street et al	Water
22	Growth rates and maturity of green sea turtles	1998	Abreu-Grobois et al.	Water
15	HI island aquifer identification	1993	Mink and Lau	Water
18	Arenicolous Halacaridae in Hawaiian waters	1988	Bartsch	Water
14	Water quality anchialine ponds-Kona	1987	Brock et al.	Water
13	Hydrological and ecological inventories of coastal waters	1977	Kay et al. 1977	Water
12	Groundwater conditions	1975	Bauer	Water
11	Coastal evidences of groundwater conditions, S. Kohala	1969	Cox et al.	Water