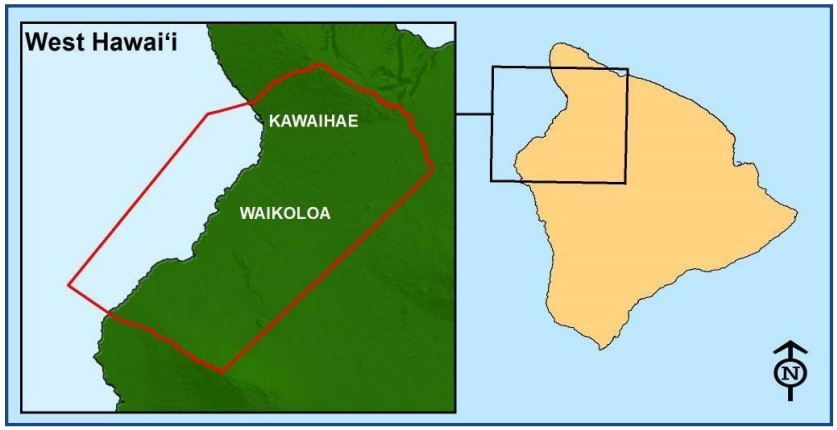
The Resilient Lands and Waters Initiative: *West Hawai'i*

Climate Impacts



The West Hawai'i Resilient Lands and Waters site is located on the north western side of Hawai'i Island. Climate change (CC) is currently affecting this area and these impacts will increase in the future. Climate change stresses for Hawai'i include increasing air and sea temperatures, changing ocean chemistry, rising sea levels, changes in precipitation, and increased risks from hurricanes[1]. Hawai'i's ecosystems are responding to these changes in complex ways.

Air and sea temperature

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%[2]. Hawai'i is growing warmer[3], with high temperatures in the ocean leading to two consecutive years of coral bleaching in 2014 and 2015[4]. 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[5]. Changing ocean chemistry (ocean acidification) will slow coral growth and may weaken reef structure[5].

Sea level

The rate of global mean seal level rise is approximately 3.4 mm/yr [6], and is predicted to accelerate[7]. Models project sea levels in Hawai'i to be a foot higher than current levels, and climbing, by 2050[8].

Rainfall and storms

In Hawai'i, measurements show that the dry season has grown longer and drier[9]. 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[1]. 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[10]. Eighteen named storms were recorded in the Central Pacific in 2015, over three times the annual average[2]. Rainfall and wind speeds associated with hurricanes are increasing; meanwhile, storm tracks are shifting northward, putting Hawai'i at greater risk[10].

Community responses

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.

Current Efforts & Potential Modifications

Table 1 provides a detailed account of climate related impacts in West Hawai'i and which organizations are currently addressing these issues. Table 2 lays out issues caused or enhanced by climate change along with suggested modifications to create more resilient landscapes.

Table 1 Potential climate change impacts across the West Hawai'i landscape and the groups currently incorporating these impacts in their efforts.

Area	Freshwater: Terrestrial water systems	Terrestrial	Coastal & low lying areas	Ocean systems	Agriculture
Climate change impacts	• Inc./dec. streamflow • Inc./dec. flooding • Inc. erosion, sedimentation • Drying of streambeds • Reduced groundwater supply • Decline in natives, inc. invasives	• More, larger wildfires • Longer periods of drought • Habitat, biodiversity loss • Hotter temperatures • Altered seasonal variation • Inc. of disease and pests • Inc. erosion • Damaged cultural sites	• Flooding and erosion • Saltwater intrusion • Extreme water levels (SLR), high run up (storms) • Vulnerable fish ponds • Degraded infrastructure	• Coral bleaching, disease outbreaks • Inc. number/intensity of storms • Fish population shifts • Reef erosion from acidification • Altered salinity • Decrease in trade winds	• Dec. crop productivity • Maladapted crop varieties • Irrigation shortages • Flooding of ag. lands • Saltwater intrusion • Faster weed growth
Organizations implementing current actions	➢ Kohala Watershed Partnership Restoration (Pelekane Bay Watershed) ➢ UH Sea Grant Waiulaula Restoration ➢ Hui Malama Loko I'a fishpond restoration ➢ UH Hilo erosion modeling	➢ Hawai'i Wildfire Organization ➢ Kohala Watershed Partnership Restoration (Pelekane Bay Watershed) ➢ UH Sea Grant ➢ USDA NRCS ➢ Kailapa Community fencing and native vegetation project	➢ Coral Reef Alliance cesspool ➢ South Kohala Coastal Partnership ➢ Hui Malama Loko I'a fishpond restoration ➢ Conservation International ➢ TNC ➢ USFS ➢ US FWS ➢ UH Hilo ➢ NOAA Habitat Blueprint/West Hawai'i Habitat Focus Area ➢ NOAA Sentinel Site ➢ NOAA NESDIS	➢ Hawai'i Humpback Whale National Marine Sanctuary ➢ NOAA Sentinel site ➢ NOAA Habitat Blueprint/West Hawaii Focus Area ➢ South Kohala Coastal Partnership ➢ Hui Malama Loko I'a fishpond restoration ➢ TNC and Jeff Maynard coral resilience study ➢ DLNR/DAR coral reef fish monitoring	

Table 2 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
Invasive species	-Outreach & education: invasive species management info. to be included in all public awareness programs in relation to CC -Reduce existing invasive species threats to increase the capacity of native species & ecosystems to adapt to CC (e.g. fencing if not doing it already) -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. -Increased monitoring-scope, range, occurrence -Conduct risk assessment of any potential plant introductions (good practice) -Anticipate (using climate models/VA) and prevent range expansion of invasive plants - Advertise benefit of planting natives over ornamental species	◆ Vorsino et al. 2014[11] ◆ Somers and Asner 2012[12] ◆ Hawai'i and Pacific Islands National Climate Assessment[13]	◆ McNeely et al. 2001[14] ◆ Kriticos et al. 2010[15] ◆ Burgiel and Hall 2014[16]
Habitat shift/loss	-Consider assisted colonization/experimental relocation using species distribution models -Protection or conservation of remnant ecosystems through covenants or nature reserves -Captive breeding -Species reintroductions -Control invasives in future habitat -Control invasives and manage development in future habitat -Model habitat movement	◆ Corlett and Westcott 2013[17] ◆ Fortini et al. 2013[18] ◆ Price et al. 2007[19]	◆ 2009 California Climate Adaptation Strategy (CAS) [20]
Drought, stream flow, water availability	-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) -Community-based stream groups that take care of the streams -Prepare for overdraft subsidence, decreased water quality/pollution -Increased outreach to educate and prepare the public -Stand-Alone Drought Plans, actions taken by individuals, industry, government, before drought occurs to reduce or mitigate impacts and conflicts arising from drought	◆ Timm et al. 2014[21] ◆ Zhang et al. 2012[22] ◆ Kundewicz et al. 2013[23]	◆ Colorado Drought Mitigation and Response Plan (2013)[24]
Wildfire	-Remote (plane, satellite) operational monitoring of forests -Plant drought tolerant plants/trees -Monitor climate effects on forest health and the effectiveness of management actions -Prohibit campfires in parks, beaches, camping grounds -Provide training on how to prevent and fight forest fires	◆ Trauernicht et al. 2015[25] ◆ Ellsworth et al. 2014[26]	◆ CAL FIRE Adaptation to Climate Change[27] ◆ Williams et al. 2009[28]

Table 2 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
Sea level rise	-Plan for shoreline change/estuary retreat (needs modeling) and infrastructure flooding/inundation -Plan for less reef protection of shoreline over time (as coral reefs "sink") -Urge sewer infrastructure to replace cesspools/septic systems (onsite wastewater systems) vulnerable to rising water table -Plan for lack of drainage of ponds near SL (i.e. aquaculture ponds, fishponds, maybe raise bottom and sides) -Plan for decreased storm water drainage -Create living shorelines with wetlands that absorb floods, slow erosion, and provide habitat -Promote increased coastal setbacks-a prescribed distance to a coastal feature such as the line of permanent vegetation	◆ Anderson et al. 2015[29] ◆ Fletcher et al. 2012[30] ◆ Fletcher et al. 2002[31] ◆ Fletcher et al. 2010[32] ◆ Reynolds et al. 2012[33]	◆ Sea Level Rise Hawaii[34] ◆ Surging Seas: Sea level rise analysis by Climate Central[35] ◆ Sea Level Rise Adaptation Strategy for San Diego Bay January 2012[36] ◆ 2009 California Climate Adaptation Strategy[20]
Coral health	-Expand marine protected areas around reefs -Proactively tailor activities addressing land-based pollution (e.g. sediment and nutrient delivery to nearshore waters) to consider climate change predictions/uncertainties -Integrate CC predictions and uncertainties into Hawai'i's comprehensive planning laws and procedures -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 -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 -Identify and protect transition/alternative habitats that will provide for range shifts in distribution and abundance of species and habitats affected by CC -Determine and map areas of high and low resilience to CC in order to identify refugia and prioritize management efforts -Partner with stakeholder groups, such as the tourism industry, to understand CC implications, reduce climate footprint, and prepare adaptation plans -Reduce land-based sources of pollution through erosion control and re-vegetation; identify erosion hotspots	◆ Kittinger et al. 2011[37] ◆ Munday et al. 2009[38] ◆ Keller et al. 2009[39] ◆ van Hooidonk et al. 2015[5]	◆ Bentivoglio 2003[40] ◆ Climate Change Action Plan for the Florida Reef System 2010-2015[41] ◆ Great Barrier Reef Climate Change Action Plan 2012-2017[42] ◆ EPA's Pacific Southwest Strategic Plan for Coral Reefs[43]
Fisheries & Agriculture	-Reduce land-based sources of pollution and destructive fishing practices -Reduce destructive fishing practices, increase best fishing practices -Change fishing rules to protect reef-critical species -Implement temporary MPAs ('try wait' program) for other areas -Change timing or locations of fishing as species arrive earlier/later, or shift to new areas -Water supply and irrigation systems: retrofit and modify existing systems (Ag.) - Contemplate forest restoration of former agricultural lands where current/future conditions preclude productive agriculture -Use/create different crop variety/species (Ag.) based on climatic factors and inundation	◆ Howell et al. 2012[44] ◆ McIlgorm et al. 2010[45] ◆ Bell et al. 2011[46]	◆ Shelton 2014[47] ◆ Sriskanthan and Funge-Smith 2011[48]

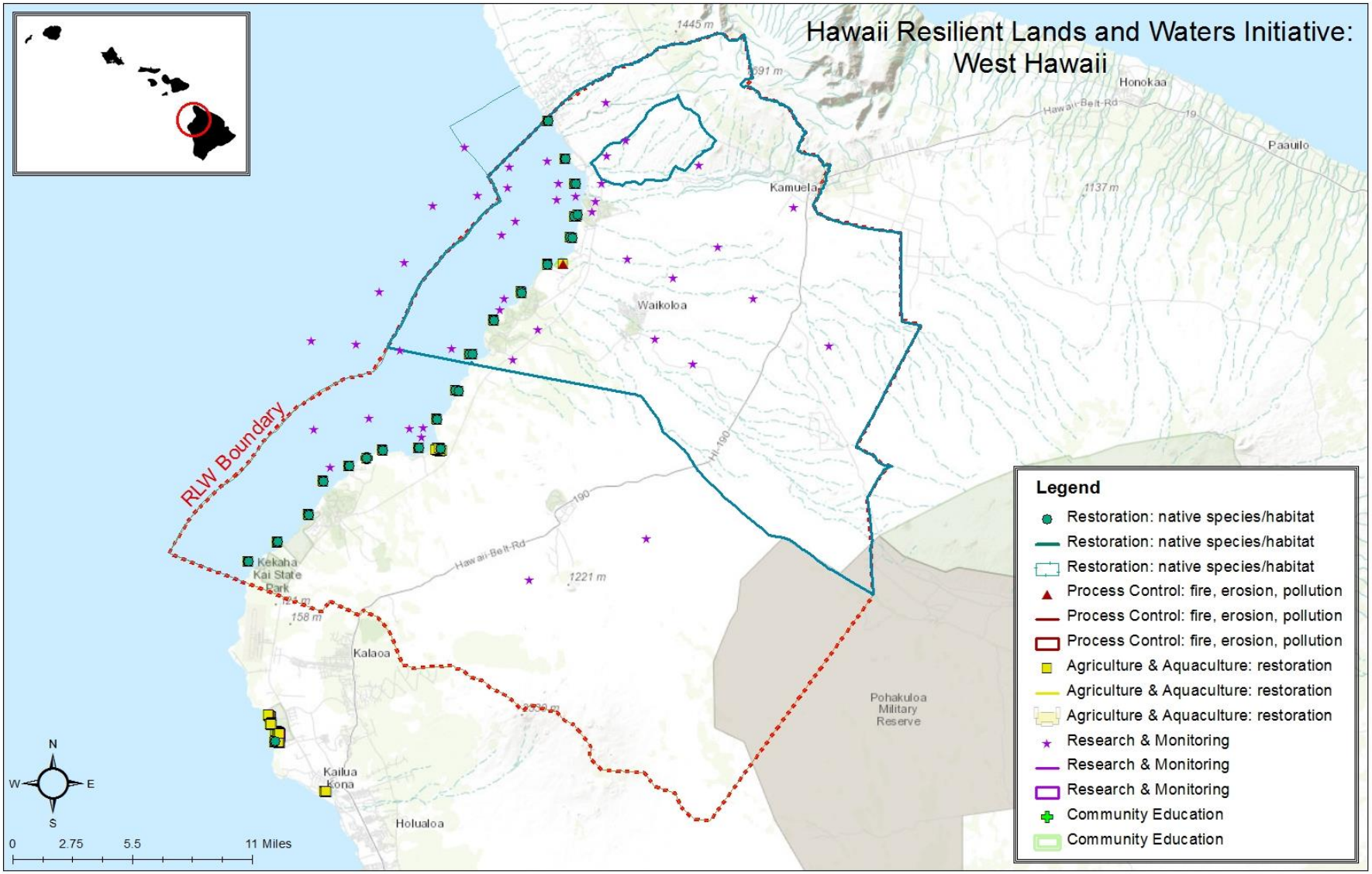


Figure 1 All identified resilience activities have been mapped, and are delineated into five categories: 1) Restoration of native species/habitat; 2) Controlling processes such as fire, erosion, and pollution; 3) Restoring agriculture/aquaculture systems; 4) Conducting research/monitoring; and 5) Organizing/carrying out community education.

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