

Draft Action Plan for Coral Reef Restoration in the Main Hawaiian Islands

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Project Description

In early 2020, the Division of Aquatic Resources (DAR) selected a planning team of managers and scientists to follow the process in the Reef Resilience Network's *Manager's Guide to Coral Restoration Planning and Design*. The planning team developed this draft action plan with guidance and input from a coach and an advisor. The team also received input and feedback on each of the four steps in the planning process from an advisory committee of technical experts and resource managers, in addition to mentors and Reef Resilience Network staff.

This draft Coral Restoration Action Plan fits within the *State of Hawai'i 2020-2030 Hawai'i Coral Strategy*, in particular the Makai Restoration Pillar, which is to "increase the ecological function and integrity of coral reefs by: 1) developing DAR's role in coral reef ecosystem management for restoration projects statewide; and, 2) supporting effective restoration projects, especially those that are led by public and private partners" (State of Hawai'i, 2020). The planning team also coordinated development of a restoration permitting framework process, which is being led by the State.

To identify priority goals, the planning team considered the ecosystem services that coral reefs provide as well as the stressors they are facing. Coral reef ecosystems are important to the people of Hawai'i and provide substantial economic value through coastal fisheries and tourism. Other important services that coral reefs provide include cultural value, coastal protection, and recreational uses. Additionally, as active coral reef restoration is relatively new in the Pacific, the importance of developing and testing methods was identified as critically important. Stressors include climate change impacts (e.g., bleaching and ocean acidification), land-based sources of pollution, overfishing, and intensive human uses in some areas.

This led to the following priority goals:

1. Build capacity to develop, test, and apply restoration methods that enhance the resistance and recovery of coral reefs impacted by bleaching.
2. Develop and test restoration methods to enhance coastal protection.
3. Develop and test restoration methods to enhance fisheries habitat.

After further discussion, including input from the advisory committee, mentors, and coaches, the planning team decided that the highest priority was the need to restore corals lost during recent bleaching events, which have resulted in severe coral cover declines in some areas. In 2014-2015, Hawai'i experienced its first back-to-back mass-bleaching event. Significant coral cover (up to 40%) was lost in some areas of the state, in particular in West Hawai'i and Maui. Hawai'i experienced its second major bleaching event in 2019, and coral mortality caused by this event is still being determined. Importantly, these periodic marine heatwaves are projected to become more frequent and severe as climate change intensifies, with some models predicting annual bleaching by 2040. Additionally, the importance of building capacity and developing and testing methods was determined as crucial to effectively implementing and scaling-up restoration across Hawai'i.

Priority Restoration Goal

The priority goal selected for this restoration action plan is: **Build capacity to develop, test, and apply restoration methods that enhance the resistance and recovery of coral reefs impacted by bleaching.**

Rationale for selecting geographic focus areas

Fourteen candidate regions for restoration were identified based on known areas that had experienced severe impacts to coral communities during the recent bleaching events. The candidate restoration regions are depicted in Figure 1. These regions were analyzed using a climate vulnerability assessment (Appendix 1) as a proxy for coral survivorship. Three of the 14 proposed regions (all on the north coast of Kaua'i) were not considered, as the data underpinning the assessments were not available for these areas.

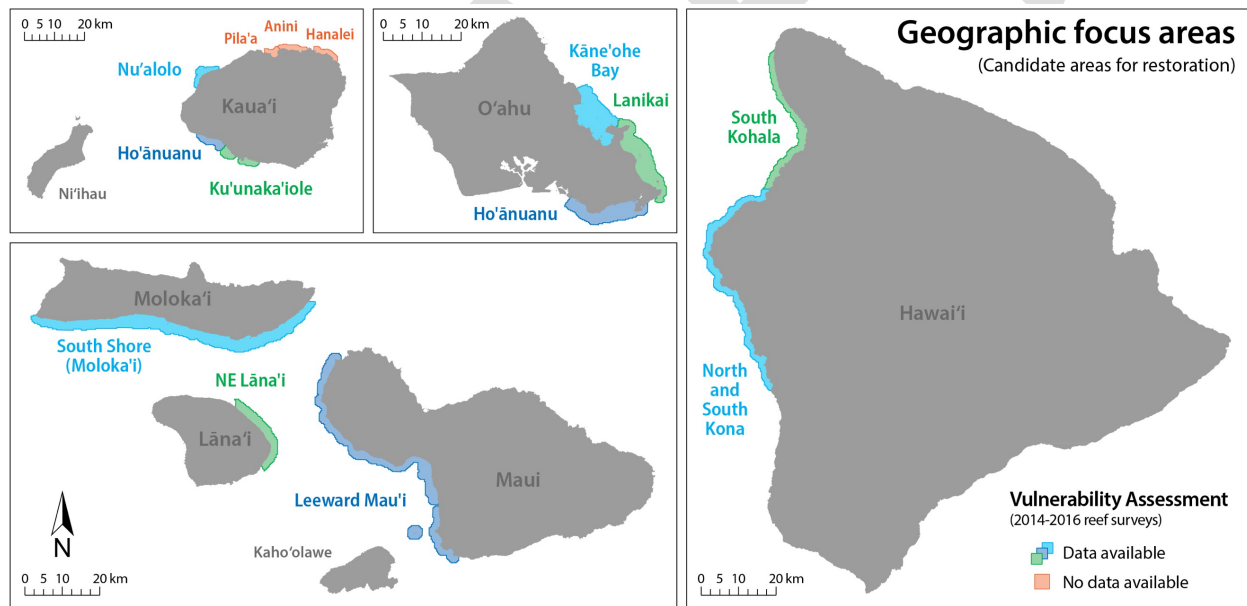


Figure 1. Candidate regions for consideration.

Climate vulnerability is the output of combining projected future exposure to disturbances with reef resilience and human impacts. The assessments identified areas within the regions that have the lowest vulnerability and hence highest relative restoration priority (in this analysis). The selection of geographic focus areas involved numerous planning team meetings and two meetings with the advisory committee, which included, (1) a discussion with Jeff Maynard (Symbioseas) to present the vulnerability modelling process and candidate geographic area ranking results, and (2) a presentation of the synthesis of top candidate geographic focus areas developed by

the planning team with feasibility and support integrated into the selection. The DAR 30x30 team and other DAR staff outside the planning team were also consulted for responses to specific area questions and ground-truthing throughout the completion of this step. Comments and feedback from these meetings and individual discussions were integrated into contextual notes for each candidate area and ultimately guided the selection of 11 candidate geographic focus areas from within the candidate regions.

O'ahu, two regions were selected with priority candidate restoration geographic focus areas: 1) the Kāne'ohe Bay region included He'eia NERRS (includes Moku o Lo'e/ Coconut Island), HIMB, and South Kāne'ohe Bay, and 2) South shore including Waialae/Kahala and the reef area adjacent to the Waikīkī.

Hawai'i Island, geographic focus areas were selected from two regions: 1) the South Kona region included priority areas in the Kealakekua Bay MLCD and the Keauhou/ Kahalu'u area, and 2) the South Kohala/North Kona region included areas at Ka'ūpūlehu/ Kiholo Bay and the Mauna Lani resort area including Honoka'ope Beach and Maka'iwa Bay.

Maui, all selected geographic focus areas were within the Leeward region: Olowalu, Ma'alaea, and Kealia (Sugar Beach). Geographic focus area options were also discussed for Kaua'i, Moloka'i and Lana'i, and were determined to have relatively lower priority due to low feasibility, infrastructure, and capacity, as well as unknown community support. These areas may be revisited in future planning discussions.

Hanauma Bay was then added by DAR for consideration. Data were then compiled about the geographic focus areas (Figure 3) and were the focus of discussions with the planning team and the advisory committee.

Five areas (Figure 2) were then selected as focus areas for restoration, based on a combination of: recent bleaching impacts, climate vulnerability (Appendix 1), restoration feasibility, existing management, local knowledge (e.g., site characteristic ground-truthing), water quality, ability to source corals nearby, collaboration opportunities, current community support and outreach needs (Table 1). Areas were also prioritized based on the goal of "building capacity to develop and test methods." The focus areas are: Waikīkī and Hanauma Bay on O'ahu, Olowalu on Maui, and Ka'ūpūlehu and Kealakekua Bay on Hawai'i. Specific restoration sites within these geographic focus areas will be selected as part of the implementation process, which will include site specific planning.

Please note the contents of the Draft Action Plan for Hawai'i Coral Restoration is still draft and subject to change

SITE NAME/DESCRIPTION	ISLAND	AVERAGE CORAL COVER IN 2015-2016 (%)	AVERAGE CORAL COVER IN 2019 (%)	WATER QUALITY (combined effluent in gal/km ² /day)	CUMULATIVE HUMAN IMPACTS (from Ocean Tipping Points)	VULNERABILITY AVERAGE	PROJECTED YEAR OF ANNUAL SEVERE BLEACHING (from climate models)	MANAGEMENT	COMMUNITY CAPACITY/POTENTIAL FOR PARTNERSHIPS	FEASIBILITY/PRACTICALITY	ACCESSIBILITY	EXISTING NURSERY INFRASTRUCTURE	NEARBY SOURCING POTENTIAL	WATERSHED CONDITION	OTHER RESTORATION EFFORTS IN AREA
North shore Kealakekua Bay	Hawaii	21.4	-	3519	0.12	0.27	2052	●	●	●	●	●	●	●	N
North of Keauhou Harbor, South of Kahalu'u Bay	Hawaii	33.0	21.4	862	0.26	0.29	2051	●	●	●	●	●	●	●	N
Ka'upulehu/Kiholo	Hawaii	30.9	21.9	281	0.15	0.46	2049	●	●	●	●	●	●	●	N
South Maka'iwa Bay, North Honoka'ope Bay (Mauna Lani Resort)	Hawaii	30.1	12.0	1957	0.16	0.54	2054	●	●	●	●	●	●	●	N
Kealia, Sugar Beach	Maui	52.3	-	705	0.12	0.19	2061	●	●	●	●	●	●	●	N
Maalaea Bay	Maui	-	-	10,295	0.16	0.17	2057	●	●	●	●	●	●	●	N
Olowalu	Maui	33.7	22.0	2236	0.09	0.39	2052	●	●	●	●	●	●	●	N
South Kaneohe Bay	Oahu	-	-	552	0.29	-	2041	●	●	●	●	●	●	●	Y
He'eia NERRS (includes Moku o Lo'e)	Oahu	-	-	2582	0.33	0.45	2041	●	●	●	●	●	●	●	Y
Waialae/Kahala	Oahu	3.4	-	10,170	0.16	0.38	2053	●	●	●	●	●	●	●	Y
Hanauma Bay	Oahu	-	-	418	0.16	-	2052	●	●	●	●	●	●	●	Y
Waikiki Aquarium	Oahu	0.6	1.0	4663	0.33	0.56	2057	●	●	●	●	●	●	●	Y

● HIGH OR GOOD ● MEDIUM OR FAIR ● LOW OR POOR ● UNKNOWN OR NOT ENOUGH INFORMATION

Table 1. Dashboard of information that was considered during planning discussions that narrowed the 11 candidate areas to the 5 geographic focus areas. Color-coded bins represent a qualitative assessment conducted by the planning team, scientific advisors, and other experts.

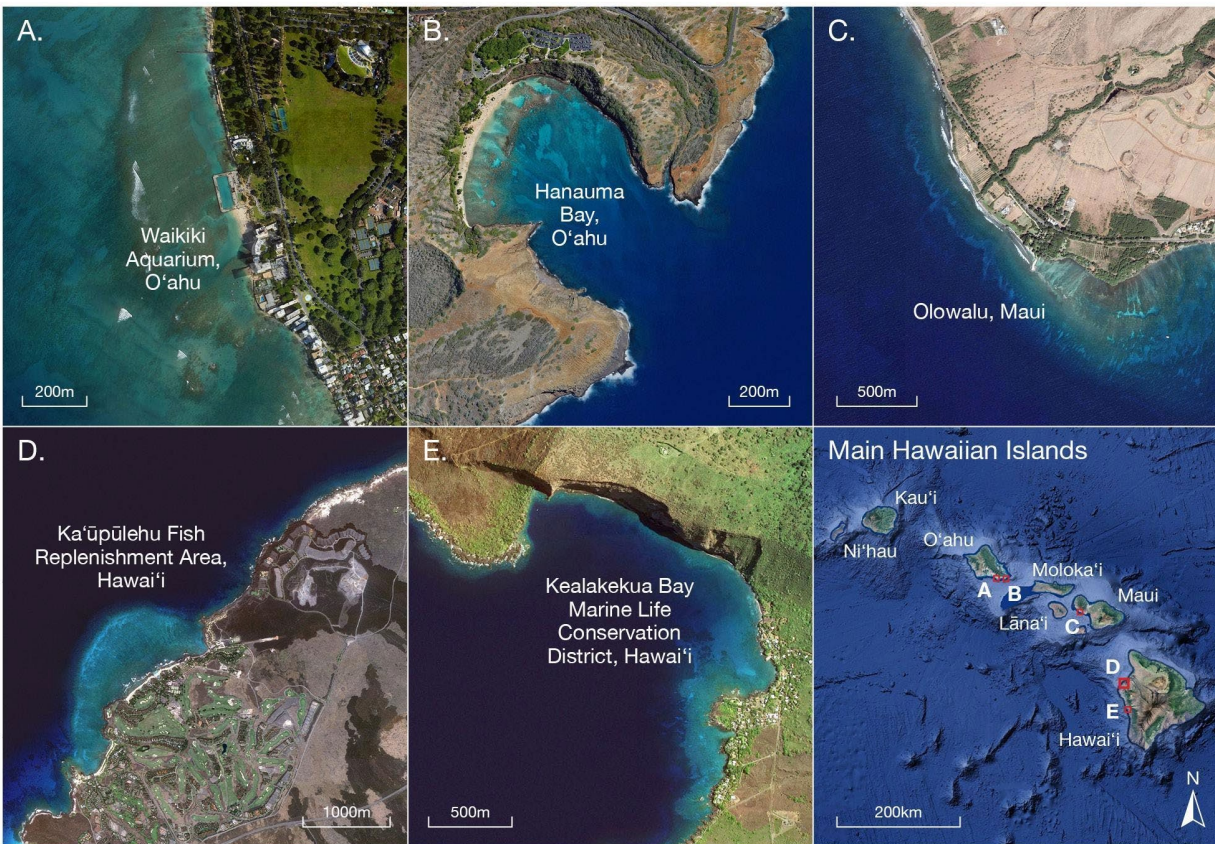


Figure 2. Map of the 5 priority geographic focus areas.

Summary of Geographic Focus Areas Prioritized for Restoration

Below is a brief description of the priority geographic focus areas prioritized for active restoration interventions. For each focus area (Figure 2), information is provided on relevance to restoration goal, potential to improve condition, climate vulnerability, human impacts, and any other notes.

1. Waikīkī

- Relevance to Restoration Goal:

This area has recently undergone thermal stress, with varying levels of coral cover loss documented in recent bleaching events.

- Potential to Improve Condition:

The Waikīkī Marine Life Conservation District prohibits take of marine life. The Waikīkī-Diamond Head Shoreline Fisheries Management Area closes fishing every other year. In addition, this area currently has several complementary efforts to control invasive macroalgae, and DAR has begun outplanting native urchins.

Extensive baseline data exist for this area, including historical studies (e.g., coral surveys; Edmondson 1946, benthic surveys for beach sand replenishment projects; Forsman et al. 2013, alien algal removal; Celia Smith & Cindy Hunter). These existing data can provide context for future restoration activities and can help gauge improved conditions.

The area has excellent available infrastructure and collaborative opportunities (Waikīkī, University of Hawai'i, Kewalo Marine Lab, DAR Coral Nursery, NOAA airport coral nursery, Sea Grant). This area is unique in the potential partnership with sectors of the hospitality industry; Waikīkī is internationally renowned with a thriving tourism industry and has the potential for public/private partnerships. There may be interest in supporting coral restoration through ecotours and other endeavors with local businesses (e.g. Atlantis Adventures, local dive operators, Waikīkī hotels).

- Climate vulnerability

Climate vulnerability of coral reefs near the Waikīkī MLCD is high relative to all sites assessed (using 2019 NOAA NCMRP survey data) in the Main Hawaiian Islands. Relative climate vulnerability is also high for this area when compared only to reef sites around Oahu.

- Human Impacts:

Coral restoration activities in this area may be challenged by human impacts, including high levels of visitation and usage, possible water quality issues, frequent boat strikes, and the presence of invasive macroalgae and possibly other invasive species.

- Other Notes:

This area is relatively easily accessible via Honolulu boat harbors.

Coral restoration activities in this area may also be beneficial to the secondary and tertiary goals of enhancing fisheries habitat and controlling coastal erosion. There are also unique public education opportunities because Waikīkī is world famous.

There is currently experimental restoration research occurring in this area offshore of the Halekulani Hotel (Mark Hixon, UH Mānoa, Coral Resilience Module Experiment).

This area has frequent summer swell events, the larger of which are known to dislodge larger colonies of branching coral. Nearby sourcing potential for corals of opportunity is high due to human impacts such as boat strikes and occasionally very high swell events.

There is a need to consider beach replenishment areas within sand channels when siting restoration activities.

2. Hanauma Bay

- **Relevance to Restoration Goal:**

This area has recently undergone thermal stress and resultant coral bleaching events, with minor levels of coral cover loss documented.

- **Potential to Improve Condition:**

Hanauma Bay is one of the most famous and popular snorkeling spots in the state. Hanauma Bay was the first MLCDD designated in the State of Hawai'i with high levels of enforcement and compliance. Baseline coral cover and fish abundance and biomass data exist for both fixed and randomized areas in this area (CRAMP data, UH Mānoa HIMB (Dr. Kuulei Rogers), and UH Mānoa Life Sciences (Dr. Mark Hixon)). These existing data provide context for future restoration activities and can help gauge improved conditions.

There is also a unique amount of action and collaboration between community groups in the area, including the University of Hawai'i Sea Grant Program's Hanauma Bay Education Program, Friends of Hanauma Bay, Mālama Maunaloa, the Hixon Lab at the University of Hawai'i at Mānoa, and the DLNR DAR Hawai'i Coral Restoration Nursery (HCRN).

- **Climate vulnerability**

Climate vulnerability of coral reefs within Hanauma Bay is medium-high relative to all sites assessed (using 2019 NOAA NCMRP survey data) in the Main Hawaiian Islands. However, climate vulnerability is medium-low and low for this area when compared only to reef sites around O'ahu. The presence of a robust herbivore assemblage may help support existing coral assemblages and future coral restoration activities by helping to mitigate surrounding algal growth.

- **Human Impacts:**

This area is heavily utilized for recreational purposes and for diving and snorkel tourism. An extensive outreach program is established at this area to help minimize visitor impacts and visitation is somewhat controlled. Relatively few people visit the outer bay.

- **Other Notes:**

Regular access to this area could be limited due to MLCDD rules.

Nearby sourcing potential for corals of opportunity at this area may be low, but may be available due to occasional diver or visitor damage and swell events.

There are currently other on-going coral restoration activities in the area, conducted by the DAR Coral Nursery and the University of Hawai'i at Mānoa (Dr. Mark Hixon).

3. Olowalu (Leeward Maui)

- **Relevance to Restoration Goal:**

This area has recently undergone thermal stress and resultant coral bleaching events, with varying levels of coral cover loss documented in each event. Large massive corals were impacted during recent bleaching events.

- **Potential to Improve Condition:**

The 939-acre Olowalu reef has been identified as one of the most essential reefs on the island of Maui and was declared a Mission Blue Hope Spot in 2017. Research has shown that this large reef is an important source of larvae for other reefs in Maui Nui.

This area is regulated by statewide rules established by DAR. In addition, this area currently has several complementary efforts to control erosion and sedimentation in the adjacent watershed area (the Olowalu ahupua'a). TNC will be initiating multi-stakeholder planning for sediment mitigation in the adjacent watersheds. DOFAW is proposing to do large-scale watershed restoration projects including building fencing and removing pigs that may impact sediment export to the reef.

Somewhat limited baseline coral cover and fish abundance and biomass data exist for survey sites in this area (CRAMP, DAR, NOAA CRED). Sedimentation data may also be available for specific subsites. These existing data can provide context for future restoration activities and can help gauge improved conditions. An NCRMP Class III monitoring super site will be established at Olowalu, including CO₂/ocean acidification buoy plus NCRMP fish, benthic, SfM, and climate monitoring, cetacean acoustic monitoring, and water quality measurements (nutrients, total suspended solids, etc.).

Potential collaboration and partnership opportunities exist with the Maui Ocean Center, the Maui Ocean Center Marine Institute (MOCMI), Maui Nui Marine Resource Council, Hawai'i Humpback Whale National Marine Sanctuary, UH Mānoa/Maui, PacIOOS, and community groups.

- **Climate vulnerability**

Relative climate vulnerability of coral reefs near Olowalu varies when compared to all sites assessed (using 2019 NOAA NCMRP survey data) in the Main Hawaiian Islands and when compared only to sites in Maui. There are medium-low, medium-high, and high vulnerability sites in the Olowalu area in both assessments. Coral diversity is high in this area. This area is known to be a natal reef for all of Maui Nui. Numerous large, massive poritid coral colonies were lost during recent bleaching events.

- **Human Impacts:**

The adjacent watershed has experienced ongoing development and pressures from feral ungulates and wild hogs that have potentially exacerbated erosion in the area and sedimentation on the reef. A 2021 USGS report found that sediment plumes in West Maui's nearshore waters were caused by streambank erosion of historic fill terraces,

deposited as a legacy of agriculture¹. However, several complementary efforts to control erosion and sedimentation are currently underway and being proposed².

- Other Notes:

Coral restoration activities at this area may also be beneficial to the other restoration goals of enhancing fisheries habitat and controlling coastal erosion.

The area is easily accessed by shoreline or boat.

The potential for sourcing corals of opportunity nearby is currently unknown.

4. Ka'ūpūlehu (North Kona, Hawai'i Island)

- Relevance to Restoration Goal:

Ka'ūpūlehu also experienced severe coral mortality and loss in cover during the 2015 bleaching event². A subsequent bleaching event occurred in 2019 with less severe bleaching reported³. Both localized coral recovery and structural loss due to bioerosion have been reported in this area.

- Potential to Improve Condition:

Beginning in 2016, this area has been protected as a “no take” rest area as a result of the Try Wait Initiative. Planning is currently underway to guide a sustainable reopening in 2026. These protective regulations and current existing community and stakeholder partnerships will likely enhance restoration activities. Currently, there's a strong existing network of partners and tentative community support for restoration in this area.

Baseline coral cover and fish abundance and biomass data exist for both fixed and randomized sites in this area (TNC, DAR, NOAA CRED, community monitoring). These existing data provide context for future restoration activities and can help gauge improved conditions.

- Climate vulnerability

Climate vulnerability of coral reefs near Ka'ūpūlehu is low and medium-low relative to all sites assessed (using 2019 NOAA NCMRP survey data) in the Main Hawaiian Islands.

¹ Stock, J.D., and Cerovski-Darriau, Corina (2021) Sediment budget for watersheds of West Maui, Hawaii: U.S. Geological Survey Scientific Investigations Report 2020–5133, 61 p., 1 plate, scale 1:25,000, <https://doi.org/10.3133/sir20205133>

² Kramer KL, Cotton SP, Lamson MR, Walsh WJ (2016) Bleaching and catastrophic mortality of reef-building corals along west Hawai'i island: findings and future directions. Proceedings of the 13th International Coral Reef Symposium, Honolulu: 219-230

³ Winston M, Couch C, Huntington B, Vargas-Ángel B, Suka R, Oliver T, Halperin A, Gray A, McCoy K, Asbury M, Barkley H, Gove J, Smith N, Kramer L, Rose J, Conklin E, Sukhraj N, Morioka J. (2020) Preliminary results of patterns of 2019 thermal stress and coral bleaching across the Hawaiian Archipelago. NOAA Admin Rep. H-20-04, 13 p. doi:10.25923/8pqg-tq06

When compared only to sites around Hawai'i Island, coral reefs near Ka'ūpūlehu all have low relative climate vulnerability.

Current “no-take” protective restrictions have resulted in replenished target fish assemblages, including herbivores. The presence of a robust herbivore assemblage may help support existing coral assemblages and future coral restoration activities by helping to mitigate surrounding algal growth.

- Human Impacts:

Human impacts are currently mitigated by regulations including ‘no-take’ restrictions for a portion of the bay. Light to moderate tourism occurs at some shoreline areas of this site.

- Other Notes:

Nearby coral sourcing potential is relatively low for this area. Corals of opportunity may be generated by bioerosional processes and seasonal swell events.

Coral restoration activities at this area may also be beneficial to the tertiary goal of enhancing fisheries habitat.

This area is only fairly accessible, with no immediately adjacent harbor for boating access. The area is approximately 15 miles from Honokōhau Harbor or the Puakō boat launch. Shoreline access may be coordinated with the adjacent resort and associated facilities (Four Seasons).

5. Kealakekua Bay MLCD (South Kona, Hawai'i Island)

- Relevance to Restoration Goal:

Kealakekua Bay experienced severe coral mortality and cover loss during the 2015 bleaching event. A subsequent bleaching event occurred in 2019 with less severe mortality reported. Continual bioerosional processes have affected the remaining dead coral structure (live rock), resulting in a reduction in complexity of the reef framework in many areas. This area still hosts surviving populations of relatively uncommon coral species, including *Pavona duerdeni* and *Porites monticulosa*, and has shown signs of gradual recovery for certain common species, including *Porites lobata*.

- Potential to Improve Condition:

Kealakekua Bay is one of the oldest Marine Life Conservation Districts (MLCD) on Hawai'i Island and complementary management regulations are already in place, including ‘no-take’ restrictions for a portion of the bay. Currently, there is an existing draft Management Plan for Kealakekua Bay State Park, which surrounds and includes the MLCD. This document is scheduled for revision with additional community input and

finalization in 2022-2023. Additional management components will likely be incorporated into the plan, including usage rules and possible visitor facilities.

In addition, baseline coral cover and fish abundance and biomass data exist for both fixed and randomized sites in this area (DAR, NOAA CRED). These existing data provide context for future restoration activities and can help gauge improved conditions.

- **Climate vulnerability**

Climate vulnerability of coral reefs near Kealakekua is medium-high relative to all sites assessed (using 2019 NOAA NCMRP survey data) in the Main Hawaiian Islands. Also, when compared only to sites around Hawai'i Island, coral reefs near Ka'ūpūlehu are assessed as having medium-high relative climate vulnerability.

Because of its 'no-take' status within a portion of the MLCD, the area hosts a robust assemblage of both fish and invertebrate herbivores. Signs of intensive grazing are apparent in this geographical focus area, and large macroalgal blooms have not been documented since the severe loss in coral cover in 2015.

- **Human Impacts:**

Human impacts are currently mitigated by regulations including 'no-take' restrictions for a portion of the bay and other regulations associated with MLCD designation. This area is heavily utilized by numerous dive, snorkel and recreational tourism companies. Many of these charters include educational programs on the significance of natural and cultural resources at the site.

- **Other Notes:**

This area has strong potential for community collaboration and partnerships, despite some ongoing controversy regarding site management. Several dive tourism companies that frequent this area have expressed interest in coral restoration activities.

Nearby coral sourcing potential is relatively low for this area. Corals of opportunity may be generated by bioerosional processes, diver/visitor damage and swell events. Bleached and non-bleached colonies were tagged at Kealakekua during the 2019 bleaching event to start a "living library" with known coral histories to support future coral resilience research.

Coral restoration activities at this area may also be beneficial to the tertiary goal of enhancing fisheries habitat, as well as public education.

More information for this area is available at: <https://dlnr.Hawai'i.gov/dar/regulated-areas/kealakekua-bay-mlcd/>)

Ongoing Management

All selected geographic focus areas are regulated by general statewide rules including gear restrictions, regulated species rules, and lay net rules. More information about DAR statewide rules is available at: <https://dlnr.Hawai'i.gov/dar/fishing/fishing-regulations/regulated-areas/>

The Waikīkī Geographic Focus Area is situated within the Waikīkī Marine Life Conservation District. The adjacent Waikīkī-Diamond Head Shoreline Fisheries Management Area is closed to fishing in the area every other year. In addition, this area currently has several complementary efforts to control invasive macroalgae, including DAR's project to outplant urchins and enhance herbivory in the area. More information about the Waikīkī Marine Life Conservation District can be found at: <https://dlnr.Hawai'i.gov/dar/marine-managed-areas/hawaii-marine-life-conservation-districts/oahu-waikiki/>

The Hanauma Bay Geographic Focus Area falls within the Hanauma Bay Marine Life Conservation District. This MLCD was the first to be designated in the State of Hawai'i. Regulations prohibit the take of any marine life or geological feature. Visitation to the bay is managed with a reservation system and associated fees. More information about the Hanauma Bay Marine Life Conservation District can be found at: <https://dlnr.Hawai'i.gov/dar/marine-managed-areas/hawaii-marine-life-conservation-districts/oahu-hanauma-bay/> and <http://www.honolulu.gov/parks-hbay/home.html>

The Olowalu Geographic Focus Area does not have its own specific spatial management rules and is regulated by the general DAR statewide rules described above. On-going projects are occurring and planned in the adjacent ahupua'a (watershed) to help control erosion and sedimentation at this site. In addition, the entire island of Maui is within a Lay Net Prohibited Area. More information about the Maui Lay Net Prohibited Area can be found at: <https://dlnr.Hawai'i.gov/dar/fishing/fishing-regulations/gear-restrictions/>

The Ka'ūpūlehu Geographic Focus area falls within the Ka'ūpūlehu Marine Reserve, and is currently protected as a temporary "no take" rest area as a result of the Try Wait Initiative, which went into effect in July 2016. Planning is currently underway to help guide a sustainable reopening in 2026. Detailed information about regulations at Ka'ūpūlehu can be found at: <https://dlnr.Hawai'i.gov/dar/fishing/fishing-regulations/regulated-areas/regulated-fishing-areas-on-hawaii/#west-hawaii-regional-fishery-management-area>

Kealakekua Bay is one of the oldest Marine Life Conservation Districts (MLCD) on Hawai'i Island and rules include 'no-take' restrictions for a portion of the bay. Currently, there is an existing draft Management Plan for Kealakekua Bay State Park, which surrounds and includes the MLCD. This document is scheduled for revision with additional community input and finalization in 2022-2023. In addition, a collaborative

planning process with relevant stakeholders began in late 2021 to develop a Conservation Action Plan (CAP) for this area.

Detailed information about regulations within Kealakekua Bay MLCD can be found at: <https://dlnr.hawaii.gov/dar/marine-managed-areas/hawaii-marine-life-conservation-districts/hawaii-kealakekua-bay/>

Additionally, several statewide management initiatives are currently being developed by DLNR/DAR. Please see Appendix 3 for more details.

Restoration Interventions

To identify restoration options, the team used the *National Academy's Review of Coral Interventions* and other available resources, including DAR's permitting framework process.

Six restoration intervention options were identified for potential implementation at the priority geographic focus areas (*Waikīkī, Hanauma Bay, Olowalu, Ka'upulehu, Kealakekua Bay*). The team did not assign specific interventions to each area, because more detailed planning processes will be carried out at each geographic focus area prior to pilot project implementation with local stakeholders. The six interventions considered by the planning team were:

1. Opportunistic fragment, colony, and/or substrate stabilization (within site)
2. Direct transplantation of corals of opportunity to resilient sites (from adjacent sites)
3. Coral gardening with corals of opportunity (*in situ* and *ex situ*)
4. Coral gardening through selective collection and propagation (4A Selecting resilient corals for gardening, 4B Stress testing to inform selection)
5. Gamete and larval seeding and larval tenting
6. Substrate addition (artificial reefs, bio-rock, live rock/CCA)

In addition to the six active restoration interventions being considered, complementary actions were identified to be conducted as part of the site preparation and site maintenance. These could include coral predator management, herbivore introduction and enhancement, and/or macroalgae removal.

The team developed a multi-criteria evaluation framework to rank and prioritize the restoration intervention options while accounting for the priority restoration goal. The evaluation framework consisted of seven criteria and associated weightings: effectiveness potential, social/community involvement, feasibility, capacity development, learning opportunity, risk, and external benefits. The evaluation framework was distributed to the advisory committee and additional technical experts to complete.

15 experts completed the evaluation spreadsheets and additional input was gathered during meetings. Average weights were used to determine the highest ranked interventions.

Coral gardening was the highest ranked intervention, both with corals of opportunity and selective collection (Options 3 and 4). These options are defined in more detail below.

Additional interventions that ranked high when considering individual areas were direct transplantation for all areas and opportunistic stabilization for Olowalu, Hanauma Bay, and Waikīkī.

Comments were summarized from evaluators and also taken into consideration and coral gardening with selective collection received the most positive comments for an intervention to achieve the defined restoration goal.

Coral gardening with corals of opportunity (*in situ* and *ex situ*)

Corals of opportunity within the restoration site or in close proximity to the restoration site will be collected for propagation and a grow-out period. The dominant reef building coral species for each site would be targeted by using modeling data (PACIOOS website) and/or in-water survey data (DAR, NOAA CRED, TNC). Coral gardening would involve either *in situ* or *ex situ* asexual propagation techniques (fragmenting, microfragmenting and microskinning) or whole colony outplanting.

In situ nurseries would be established in protected sites or embayments or by using structures able to withstand wave action. *Ex situ* nurseries require infrastructure, but some institutions on O'ahu and Maui already have available expertise and capacity including: 1) the DAR Coral Nursery, 2) Maui Ocean Center, 3) Hawai'i Institute of Marine Biology, 4) NOAA. Developing the infrastructure and capacity for an *ex situ* nursery on Hawai'i Island has been identified as a high priority.

Coral gardening through selective collection and propagation

- 4A Selecting resilient corals for gardening
- 4B Stress testing to inform selection

This intervention entails selective collection of resilient corals or thermal stress testing of corals of opportunity. Take of corals for propagation will target resilient corals to enhance survival of outplants during future bleaching events. These corals will be propagated through fragmenting, microfragging and microskinning techniques either through *ex-situ* or *in-situ* options (see above).

Live coral take should be limited to:

4A: Known corals that have been identified, tagged, and the phenotype monitored through one or more bleaching events. Researchers have already been tracking individual coral colonies in certain locations (Coral Resilience Lab in Kāne'ohē Bay, Kealakekua Bay, and Hixon lab in Waikīkī and Hanauma Bay).

4B: Small samples from live corals or corals of opportunity taken for thermal stress testing in the laboratory to determine level of resilience to bleaching (Coral Resilience

Lab currently conducting R & D on this technique on O'ahu). This information could be used to preferentially take fragments for asexual propagation from more resilient corals.

Objectives and Performance Metrics

The specific objectives and performance metrics that will be used to assess project progress are detailed here. A summary is provided in Appendix 2 with more detailed timelines. A team of scientists and technical experts is working to develop standardized monitoring metrics for restoration projects statewide.

Objective 1.1: Within 3 years, two new pilot restoration sites from the five geographic focus areas are established where restoration interventions are developed, tested, and evaluated with engagement by community and partners.

Performance Metrics:

- Number of site assessments conducted/baseline data collected at geographic focus areas
- Number of restoration permits obtained
- Number of restoration sites/nurseries established
- Number of methods/interventions being tested
- Monitoring protocols developed
- Research gaps/needs documented
- Design parameters developed to determine efficacy (e.g., BACI), including standardized methods across sites
- Survival rate of outplanted corals
- Community network knowledge exchange/sharing
- Economics of restoration (scalability)

Activities:

- Identify and engage community stakeholders and partners to incorporate place-based knowledge in site-specific planning
- Develop site specific restoration plan(s) including experimental design, target restoration outcomes, methods, and interventions for restoration and control sites
- Determine in-situ and/or ex-situ nursery capacity options for each pilot site
- Secure permits for restoration sites with technical/scientific advisor(s) identified
- Synthesize existing data, conduct baseline monitoring, and site assessment
- Establish 2 sites piloting active restoration interventions
- Develop monitoring protocols and implement monitoring to evaluate efficacy of interventions
- Analyze data, write reports, synthesize project accomplishments, and share lessons learned
- Scope out development of nursery infrastructure on neighbor islands

Objective 1.2: Within 6 years, ex-situ and/or in-situ nursery infrastructure is established on at least three islands and effective restoration interventions are implemented at five restoration sites, including active engagement with community groups and partners.

Performance Metrics:

- Number of restoration sites established
- Number of methods/interventions tested and applied
- Number of *ex-situ* nurseries established
- Number of corals outplanted and percent of resilient corals outplanted
- Survival rate of outplanted corals
- Number of community stakeholders and partners identified and engaged in restoration planning and implementation
- Collaborative network of restoration practitioners is established

Activities:

- Use lessons learned from pilot sites to inform implementation and replication of effective restoration techniques at multiple sites
- Establish in-situ and/or ex-situ nursery infrastructure on at least three islands that is actively supporting restoration activities
- Provide technical training in restoration and monitoring techniques to community groups and partners and seek active participation when appropriate
- Implement restoration activities at multiple sites, ensuring site-based planning and permitting is completed at each site
- Continue conducting monitoring to evaluate efficacy of restoration interventions
- Facilitate a collaborative network of restoration practitioners and science advisors and provide regular specialized trainings to build network capacity
- Prepare for future climate impacts at restoration sites by analyzing data during and after bleaching event(s) to determine efficacy of interventions and evaluate potential mitigation efforts to ensure future restoration efforts are climate smart
- Analyze data, write reports, synthesize project accomplishments, and share lessons learned

Objective 1.3: Within 10 years, successful restoration techniques are being implemented at a scale that increases the resilience of coral reefs in Hawai'i.

Performance Metrics:

- Number of methods/interventions applied
- Number of restoration sites/nurseries implemented and maintained
- Number of *ex-situ* nurseries established
- Number of corals outplanted and percent of resilient corals outplanted
- Size of corals outplanted
- Survival rate of outplanted corals
- Number of restoration practitioners using active interventions to restore Hawaiian coral species
- Compare survivorship between restoration interventions.
- Compare survivorship through periods of bleaching conditions
- Community capacity is scaled up across the state
 - Site workshops/ trainings/community involvement at local restoration site

- Expand to broader public/inter community sharing

Activities:

- Conduct evaluation of restoration efforts across multiple sites; synthesize data to prioritize effective and climate-resilient restoration interventions at scale
- Continue to implement restoration activities at multiple sites, ensuring site-based planning and permitting is completed at each site
- Maintain and expand in-situ and/or ex-situ nursery infrastructure that is actively supporting restoration activities
- Expand the implementation of restoration interventions that enhance the resilience of coral reefs across Hawai'i, ensuring appropriate permitting is secured
- Conduct monitoring to evaluate efficacy of interventions at scale
- Maintain and expand collaborative network of restoration practitioners, scientific advisors, and community stakeholders
- Ensure coral restoration projects are integrated into place-based management plans across the state
- Conduct a meta-analysis to determine ecosystem impacts, cost effectiveness of restoration efforts

Stakeholder Engagement and Outreach

Once the draft action plan is complete, the next step will be to reach out to partners and stakeholders to share and gather input on the plan before it is finalized. These engagement efforts will be focused on outreach about the planning process, draft action plan, and selection of geographic focal areas. There will be a more detailed planning process in the future at each geographic focus area prior to implementation where restoration sites and interventions will be selected with involved discussions with local stakeholders and community members.

The planning team identified the following key steps:

1. Outreach to critical stakeholders, community members, and decision makers in the five priority geographic focal areas. These will be small, targeted conversations to gather input and feedback and obtain their support. This will be an opportunity to understand community priorities, other activities/projects underway in the area, and other stakeholders to engage in the detailed planning process.
2. Outreach to a broader audience of the coral restoration community. This will be in webinar format targeted at stakeholders engaged in coral reef and watershed restoration, research, and management. This may consist of multiple presentations to communities here in Hawai'i, the broader Pacific, and nationwide.
3. Stakeholder engagement during site-specific planning process. This will entail working directly with local stakeholder and community members prior to implementation. Topics will include restoration site selection, restoration interventions, restoration targets, species, etc.

Appendix 1. Summary of *Climate Vulnerability Assessment for the Main Hawaiian Islands.*

A climate vulnerability assessment was completed to evaluate potential coral restoration areas for likelihood of coral survivorship and probability of restoration project success. This assessment integrated data on: 1) projected future exposure to bleaching conditions under a business-as-usual emissions scenario; 2) reef resilience (using available data for coral and macroalgal cover, reef builder ratio, herbivore biomass, and temperature variability); and 3) human impacts (using a cumulative impacts index; Lecky 2019). Relative vulnerability was assessed for ~600 sites that were surveyed in 2019. Vulnerability for each site was assessed as relative to sites only at that island (intra-island), as well as sites at all islands (inter-island). The assessment rated sites as low, medium-low, medium-high, and high vulnerability. Corals likely have a greater chance to survive at sites with lower relative vulnerability, so vulnerability was an important consideration when evaluating the focus areas. The results of the all-islands and inter-island vulnerability assessment are shown below as Figures A1 and A2.

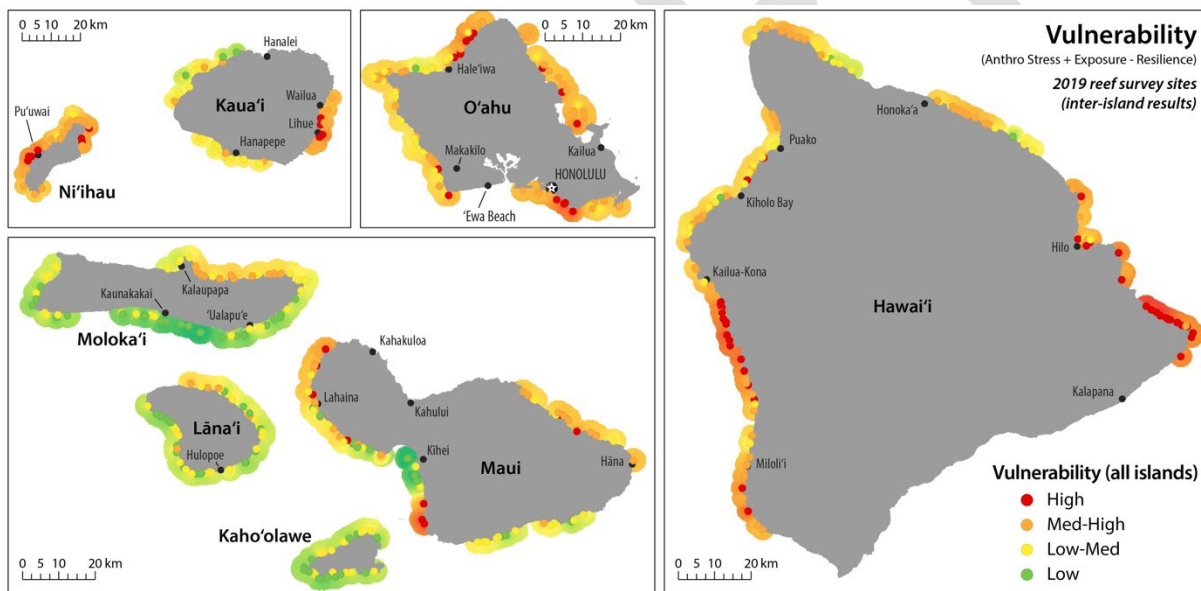
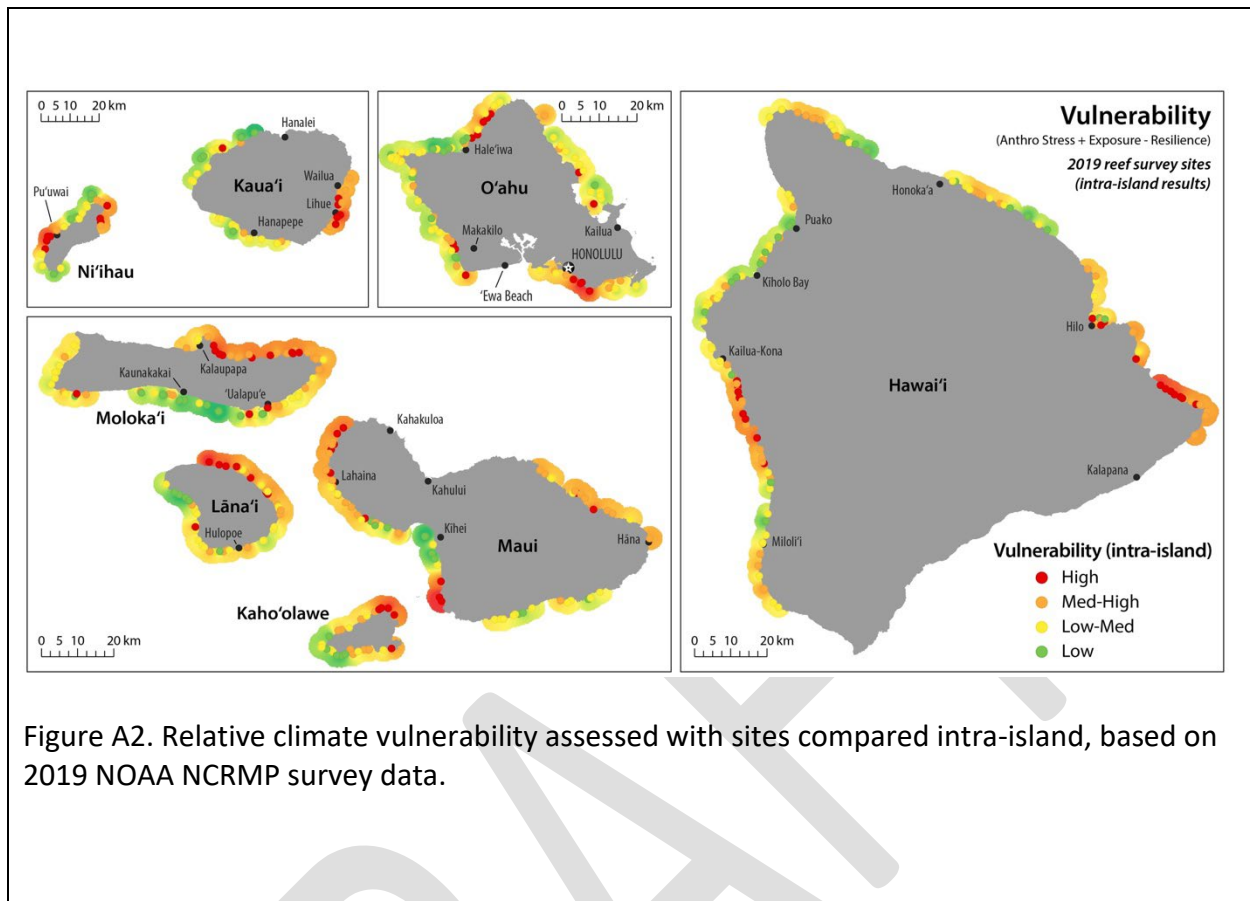


Figure A1. Relative climate vulnerability assessed as all sites relative to sites at all islands, based on 2019 NOAA NCRMP survey data.

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Appendix 2. Action Plan Summary Matrix

<p>Goal: Build capacity to develop, test, and apply restoration methods that enhance the resistance and recovery of coral reefs impacted by bleaching.</p>		
<p>SMART Objective 1.1: Within 3 years, two new pilot restoration sites from the five geographic focus areas are established where restoration interventions are developed, tested, and evaluated with engagement by community and partners.</p>		
<p>Performance metrics</p> <p>Short-term (1-3 years)</p> <ul style="list-style-type: none"> • Number of site assessments conducted/baseline data collected at priority sites • Number of restoration permits obtained • Number of restoration sites/nurseries established • Monitoring protocols developed • Research gaps/needs documented • Design parameters developed to determine efficacy (e.g. BACI) 		
Activities		Timeframe
A1.1	Identify and engage community stakeholders and partners to incorporate place-based knowledge in site-specific planning	Year 1
A1.2	Develop site specific restoration plan(s) including experimental design, methods, and interventions for restoration and control sites	Year 1
A1.3	Determine in-situ and/or ex-situ nursery capacity options for each site	Year 1
A1.4	Secure permits for restoration sites with technical/scientific advisor(s) identified	Year 1
A1.5	Synthesize existing data, conduct baseline monitoring, and site assessment	Year 1

A1.6	Establish 2 sites piloting active restoration interventions	Years 1-2
A1.7	Develop monitoring protocols and implement monitoring to evaluate efficacy of interventions	Years 1-3
A1.8	Analyze data, write reports, synthesize project accomplishments, and share lessons learned	Year 3
<p>SMART Objective 1.2: Within 6 years, ex-situ and/or in-situ nursery infrastructure is established on at least three islands and effective restoration interventions are implemented at five restoration sites, including active engagement with community groups and partners.</p>		
<p>Performance metrics:</p> <p>Mid-term (4-6 years)</p> <ul style="list-style-type: none"> • Number of restoration sites/nurseries established • Number of methods/interventions tested and applied • Number of ex-situ nurseries established • Number of corals outplanted and percent of resistant corals outplanted • Survival rate of outplanted corals • Number of community stakeholders and partners identified and engaged in restoration planning and implementation • Collaborative network of restoration practitioners is established 		
Activities		Timeframe
A2.1	Use lessons learned from pilot sites to inform implementation and replication of effective restoration techniques at multiple sites	Year 4
A2.2	Establish in-situ and/or ex-situ nursery infrastructure on at least three islands that is actively supporting restoration activities	Years 4-6
A2.3	Provide technical training in restoration and monitoring techniques to community groups and partners and seek active participation when appropriate	Years 4-6

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A2.4	Implement restoration activities at multiple sites, ensuring site-based planning and permitting is completed at each site	Years 4-6
A2.5	Continue conducting monitoring to evaluate efficacy of restoration interventions	Years 4-6
A2.6	Facilitate a collaborative network of restoration practitioners and science advisors and provide regular specialized trainings to build network capacity	Years 5-6
A2.7	Prepare for future climate impacts at restoration sites by analyzing data during and after bleaching event(s) to determine efficacy of interventions and evaluate potential mitigation efforts to ensure future restoration efforts are climate smart	Years 4-6
A2.8	Analyze data, write reports, synthesize project accomplishments, and share lessons learned	Year 6
<p>SMART Objective 1.3: Within 10 years, successful restoration techniques are being implemented at a scale that increases the resilience of coral reefs in Hawai'i.</p>		
<p>Performance metrics:</p> <p>Long-term (7-10 years)</p> <ul style="list-style-type: none"> • Number of methods/interventions tested and applied • Number of restoration sites/nurseries implemented • Number of ex-situ nurseries established • Number of corals outplanted and percent of resistant corals outplanted • Survival rate of outplanted corals • Number of restoration practitioners using active interventions to restore Hawaiian coral species • Community capacity is scaled up across the state • Site workshops/trainings/community involvement at local restoration sites • Expand to broader public/inter community sharing/larger community network knowledge exchange/sharing • Economics of restoration (Scalability) 		
Activities		Timeframe

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A3.1	Conduct evaluation of restoration efforts across multiple sites; synthesize data to prioritize effective and climate-resilient restoration interventions at scale	Year 7
A3.2	Continue to implement restoration activities at multiple sites, ensuring site-based planning and permitting is completed at each site	Years 7-10
A3.3	Maintain and expand in-situ and/or ex-situ nursery infrastructure that is actively supporting restoration activities	Years 7-10
A3.4	Expand the implementation of restoration interventions that enhance the resilience of coral reefs across Hawai'i, ensuring appropriate permitting is secured	Years 7-10
A3.5	Conduct monitoring to evaluate efficacy of interventions at scale	Years 7-10
A3.6	Maintain and expand collaborative network of restoration practitioners, scientific advisors, and community stakeholders	Years 7-10
A3.7	Integrate coral restoration as a key intervention in place-based management plans across the state	Years 9-10
A3.8	Conduct a meta-analysis to determine ecosystem impacts, cost effectiveness of restoration efforts	Year 10

Appendix 3. Relevant Statewide Management Initiatives

On Sept. 1, 2016, Governor David Ige announced the Sustainable Hawai'i Initiative, including a commitment to effectively manage Hawai'i's nearshore waters by 2030. Now known as, 'Holomua: Marine 30x30,' the goal is to effectively manage Hawai'i's nearshore waters, with at least 30% established as marine management areas. This initiative aims to focus on a broad range of marine management measures to sustain, conserve, and enhance marine resources so that communities can continue to benefit from abundant nearshore waters now and in the future. DLNR has since established new strategic directions to better nearshore resources by addressing local and global impacts. Currently, the Holomua team is working to develop management plans for existing managed areas.

More about the DLNR/DAR Holomua (30x30) program can be viewed at:

https://dlnr.Hawai'i.gov/dar/files/2020/12/HolomuaMarine30x30_Roadmap_web.pdf

DLNR/DAR is currently conducting public scoping and development of herbivore-specific statewide rules. These rules are intended to help enhance coral reef protection and post-bleaching recovery. The DLNR Division of Aquatic Resources (DAR) held a series of virtual scoping meetings in late 2020 to compile community input on options for management of key herbivores. Bag limits, size limits, gear regulations and/or seasonal protections are currently being evaluated.

More information about the scoping for statewide herbivore rules can be viewed at:

<https://dlnr.Hawai'i.gov/blog/2020/10/30/nr20-168/>

DLNR/ DAR is in the process of developing a framework for evaluating special activity permits (SAPs) for proposed coral restoration projects in the state. This initiative has involved compiling existing and new SAP documents into a statewide database and mapping coral collection data to help track on-going projects and inform future permitting decisions. In addition, a draft permit evaluation tool was developed to quantitatively assess proposed intervention methods for new restoration projects.

In 2020, the DLNR/DAR updated its Hawai'i Coral Reef Strategy, which now includes a pillar for Makai Restoration. The goal of this pillar is to increase the ecological function and integrity of coral reefs, with key objectives including: 1) developing DAR's role in coral reef ecosystem management for restoration projects statewide, and 2) supporting effective restoration projects, especially those that are led by public and private partners. The Hawai'i Coral Reef Strategy 2030 can be viewed at:

<https://dlnr.Hawai'i.gov/coralreefs/files/2020/08/Hawaii-Coral-Reef-Strategy-2030-Final.pdf>

During the 2021 legislative session DLNR/DAR submitted eight administrative bills, seven of which passed, including the creation of an ocean stewardship special fund, natural resource inspection authorization for DOCARE, updated laynet rules, and new adaptive management rules. Effective Oct. 1, 2021, the Board of Land and Natural Resource (BLNR) is able to temporarily adopt, amend, and repeal certain natural

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resource rules by formal action at a public meeting if BLNR finds it necessary to implement management measures in response to rapidly changing resource conditions.

The DLNR/DAR Aquatic Invasive Species team has several current projects, primarily on O'ahu to control invasive species and resulting damage to natural resources. AIS team projects include invasive algae reporting and control, marine debris inspection and removal, and ballast water/biofouling response. A key focus of the AIS team is to control of *Kappaphycus/ Eucheuma* (smothering seaweed) along with a variety of other species using physical clearing methods and herbivore reintroduction. More information about the AIS team is available at: <https://dlnr.Hawai'i.gov/ais/>

The DLNR/DAR the Ānuenue Coral Restoration Nursery located on Sand Island, O'ahu, aims to use professional-level coral husbandry techniques to grow small coral fragments, recombine them into large colonies, and then transplant them into the field in a fraction of the time it would take these corals to grow naturally. The Hawai'i nursery primarily uses corals for transplantation from harbors as they, 1) have lower ecological value compared to corals from natural areas, 2) may be more resilient to disturbances and environmental changes, and 3) do not impact natural reefs, and 4) support upkeep and maintenance of manmade structures. More information about the DAR Coral Nursery is available at: <https://dlnr.Hawai'i.gov/dar/habitat/coral-reefs/coral-restoration-nursery/>

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Appendix 4. Current Permitted Coral Restoration Projects in the Main Hawaiian Islands



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