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U.S. VIRGIN ISLANDS

Coral Reef Restoration Plan

VI-CRAG
VIRGIN ISLANDS CORAL REEF ADVISORY GROUP

Coral Tree Cleaning
Credit: UVI, Nicholas C. Durgadeen

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Acronyms

APC	Area of Particular Concern
CMES	Center for Marine and Environmental Studies
CRF	Coral Restoration Foundation
CRC	Coral Restoration Consortium
CTD	Conductivity, Temperature, and Depth
CWOP	Coral World Ocean Park
CWORI	Coral World Ocean and Reef Initiative
DOI	Department of the Interior
DPNR	Department of Planning and Natural Resources
DPNR CZM	DPNR Division of Coastal Zone Management
DPNR DFW	DPNR Division of Fish and Wildlife
EEMP	East End Marine Park
ESRI	Environmental Systems Research Institute, Inc.
FEMA	Federal Emergency Management Agency
MPA	Marine Protected Area
MIR	Mission: Iconic Reefs
NCRMP	National Coral Reef Monitoring Program
NOAA	National Oceanic and Atmospheric Administration
NOAA CRCP	NOAA Coral Reef Conservation Program
NOAA NMFS	NOAA National Marine Fisheries Service
NOAA OCM	NOAA Office for Coastal Management
NOAA RC	NOAA Restoration Center
NPS	National Park Service
PVC	Polyvinyl Chloride
SCTLD	Stony Coral Tissue Loss Disease
TCRMP	Territorial Coral Reef Monitoring Program
TNC	The Nature Conservancy
USVI	United States Virgin Islands
UVI	University of the Virgin Islands
VI-RoCS	Virgin Islands Restoration of Coral Squad
VITEMA	Virgin Islands Territorial Emergency Management Authority







Photo Credit: Leslie Henderson

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Photo Credit: Leslie Henderson

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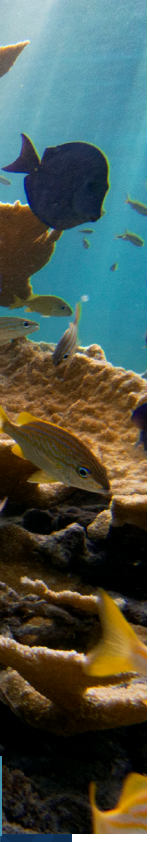
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Overview of Restoration Plan

BACKGROUND

Coral reefs are one of Earth's most biologically diverse ecosystems, teeming with life that depends on food and shelter provided by reefs. Additionally, coral reefs contribute food, jobs, and recreation to society, valued at approximately $172 billion per year globally (Moberg et al. 1999). Reef-associated tourism alone in the Caribbean is estimated at over $7.9 billion, driving a total of 7.4 million visitors to the region (Spalding et al. 2018). Despite their ecological and economic importance, coral reefs are one of the most vulnerable ecosystems in the world (Wilkinson 1999, Knowlton and Jackson 2008). Climate change, overfishing, land-based sources of pollution, disease outbreaks, and coastal development have led to the drastic loss of coral reefs globally (Rogers 1990, Hughes et al. 2003, Mumby et al. 2014).

Climate change, recognized as a global scale stressor, has manifested on reefs in periodic marine heat waves, driving mass coral bleaching and mortality events. The appearance of stony coral tissue loss disease (SCTLD) in Florida and the Caribbean, and the dramatic coral die-offs that continue today, further emphasizes the need for increasing the resilience of coral reefs to climate change through restoration. On a local scale, coral reefs are also affected by human activities. This includes changes in fish assemblages from fishing pressures, coral damage from tourism activities, and the introduction of land-based sources of pollution to watersheds, coastlines, and marine ecosystems. Shifts in fish assemblages, such as the loss of herbivorous fish and top predators, can alter the food web dynamics leading to an increase in competitive algae, resulting in challenging conditions for coral larvae to settle and grow. As reefs have continued to decline despite traditional conservation measures, resource managers are increasingly supporting the use of active restoration techniques to mitigate reef degradation, promoting recovery and resilience (Possingham et al. 2015, Boström-Einarsson et al. 2020, Shaver et al. 2020).

USVI Coral Reef Management Priorities: 2020–2025

RESTORATION OBJECTIVE

Identify areas where restoration efforts will be most successful and beneficial, incorporating an assessment of multiple stressors and cumulative impacts considering environmental, ecological, economic and social factors.

DRAFT ACTIVITY

Develop a prioritized restoration plan that identifies potential restoration sites to be used in mitigation of planned impacts and identify areas where previous restoration efforts were implemented.

Coral reef ecosystems are critically important to U.S. Virgin Islands (USVI) communities for subsistence fishing activities and provide substantial economic value through tourism. In the USVI, reef-based tourism alone contributes an estimated $492 million per year in direct and indirect spending (Spalding et al. 2018). Recreation and tourism values derived from coral reefs show an average expenditure value of $3 million per square kilometer (247 acres) of reef per year in the USVI. The total economic value of USVI coral reefs has been estimated at $187 million (Van Beukering et al. 2011). Coral reefs also provide coastal protection, and resilience to climate hazards, such as extreme weather events and related storm surge and flooding; it has been reported that healthy reefs can dissipate up to 97 percent of incoming wave energy (Ferrario et al. 2014). USVI coral reefs serve as natural breakwaters, providing up to $47 million in annual flood protection benefits to people, properties, and economic activity (Storlazzi et al. 2019).



Divers apply disease treatment to affected corals. Photo Credit: Nicholas C. Durgadeen

Because of their importance, scientists have been documenting coral reef community dynamics in the USVI for decades ((Ennis et al. 2020, Tsounis and Edmunds 2017). Benthic cover trends show declines in coral cover over 30 years with no signs of significant recovery (Rogers and Miller 2006). The decline of USVI reefs became devastating in 2005 when the most severe bleaching event eever documented in the USVI had enormous impacts on coral cover, leaving only 40% of some reef's coral cover alive (Miller et al. 2009). The extensive bleaching left corals vulnerable, leading to mass disease outbreaks throughout the territory (Rogers et al. 2009). As global and local stressors on reefs continue to increase in intensity, coral reefs will continue to experience more frequent mass mortality events well beyond their capacity to naturally recover or adapt (National Academies of Sciences, Engineering, and Medicine 2019a). Hurricane damage and the arrival of SCTLD have further exacerbated reef decline in the territory. The ***2020 Coral Reef Condition report*** for the USVI rated the reefs as fair, leaving much room for improvement even before the recent coral losses from hurricanes and SCTLD (NOAA CRCP 2020). As corals themselves are a critical component of healthy reef systems, supporting and guiding coral reef restoration efforts is a management priority for the USVI. The ***USVI Coral Reef Management Priorities: 2020-2025*** suggest developing a prioritized restoration plan that identifies: a) potential restoration sites to be used in mitigation of planned impacts, and b) areas where previous restoration efforts have been implemented (Rothenberger and Henderson 2019). The development of this USVI Coral Reef Restoration Plan (hereafter referred to simply as 'the Plan') fulfills this objective.

The USVI coral restoration planning team (i.e., the Virgin Islands Restoration of Coral Squad or "VI-RoCS") was established in late 2020 and has conducted monthly meetings since January 2021. VI-RoCS consists of representatives from the USVI Department of Planning and Natural Resources (DPNR), the University of the Virgin Islands (UVI), The Nature Conservancy (TNC), Coral World Ocean and Reef Initiative (CWORI), the National Park Service (NPS), the National Oceanic and Atmospheric Administration (NOAA), and Thriving Islands LLC. Other stakeholders were consulted throughout the process to incorporate additional areas of expertise. Through a series of remotely-facilitated meetings and an in-person workshop, VI-RoCS members collaborated to develop this Plan for restoration of priority coral reef sites in the USVI.

CURRENT CORAL REEF RESTORATION IN THE USVI

Coral restoration practitioners in the USVI have extensive experience with propagating, restoring, maintaining, and monitoring reefs throughout the territory. Some version of coral farming or restoration has been ongoing in the USVI since 2009, when TNC began its first coral nursery on St. Croix. Since that time, the infrastructure and variety of techniques designed to facilitate growing and outplanting corals onto reefs has advanced significantly. The Nature Conservancy, DPNR, CWORI and UVI currently operate nurseries to propagate coral for restoration efforts in the USVI. The Nature Conservancy



TNC coral nursery dome
Photo Credit: Jessica Ward

operates four in-water nurseries on St. Croix at Cane Bay, Channel Rock, Llew's Reef, and Buck Island Reef National Monument, as well as a land-based nursery at Estate Little Princess in Christiansted. The Department of Planning and Natural Resources currently maintains a small in-water nursery at Sweeper's Complex near Cramer's Park in the East End Marine Park (EEMP). The University of the Virgin Islands currently maintains in-water nurseries at Flat Cay, Great St. James Island, and Lovango Cay, as well as a land-based nursery at the UVI campus on St. Thomas. Coral World Ocean and Reef Initiative operates an in-water nursery in Coki Bay and land nurseries at Coral World Ocean Park. Plans are underway to install an in-water nursery in Butler Bay in St. Croix that will be operated by Thriving Islands LLC.

PURPOSE

The Plan directly addresses management actions identified in the USVI Coral Reef Management Priorities (Rothenberger and Henderson 2019), a document intended to guide coral reef management and conservation efforts in the USVI from 2020-2025. The vision from that planning process states "Over the next 5-7 years, manage coral reefs so that ecosystem function, support of the USVI economy & provision of ecosystem services are preserved, & resilience is increased. At a minimum, no further degradation from current coral reef ecosystem condition" (Rothenberger and Henderson 2019, page iii).

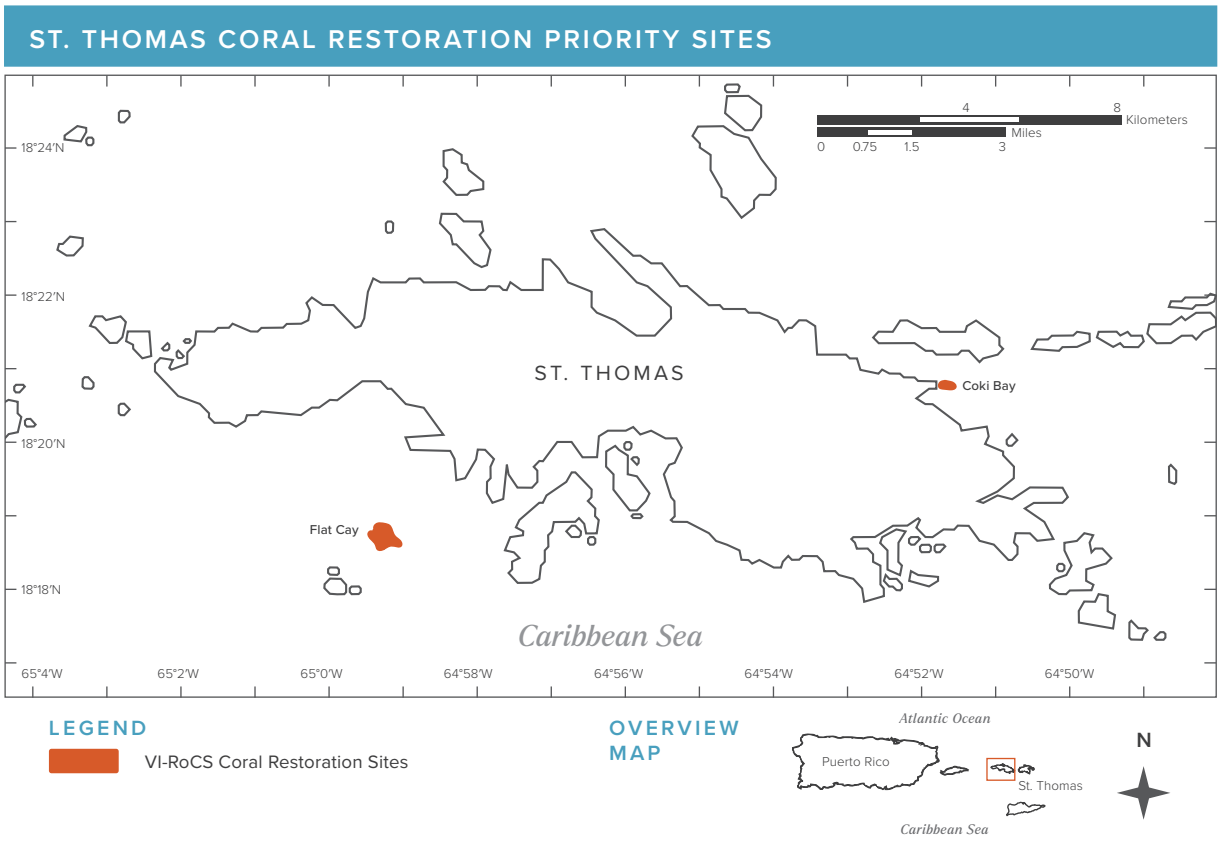
Coral restoration accelerates coral reef recovery while also providing opportunities for research and education (Lirman and Schopmeyer 2016). Federal agencies such as the Federal Emergency Management Agency (FEMA) have worked with partners in Puerto Rico to reattach over 10,000 coral fragments broken during hurricanes back to the reef, finding 90 percent survival rates in corals after three years (NOAA Fisheries 2023). NOAA's Coral Reef Conservation Program (CRCP) and partners in Florida developed a decades-long plan, Mission: Iconic Reefs (MIR), to restore reefs of the Florida Keys National Marine Sanctuary (NOAA 2020). The USVI Coral Reef Restoration Plan draws heavily upon the MIR approach as Florida reefs face similar bleaching and disease events to the USVI. Development of this Plan allows territorial managers and local experts a strong guiding voice in restoration efforts and the ability to highlight specific prioritized reefs. It also fosters improved communication and coordination across multiple inter-island partners and provides a benchmark of stated goals and targets in order to track coral restoration success.

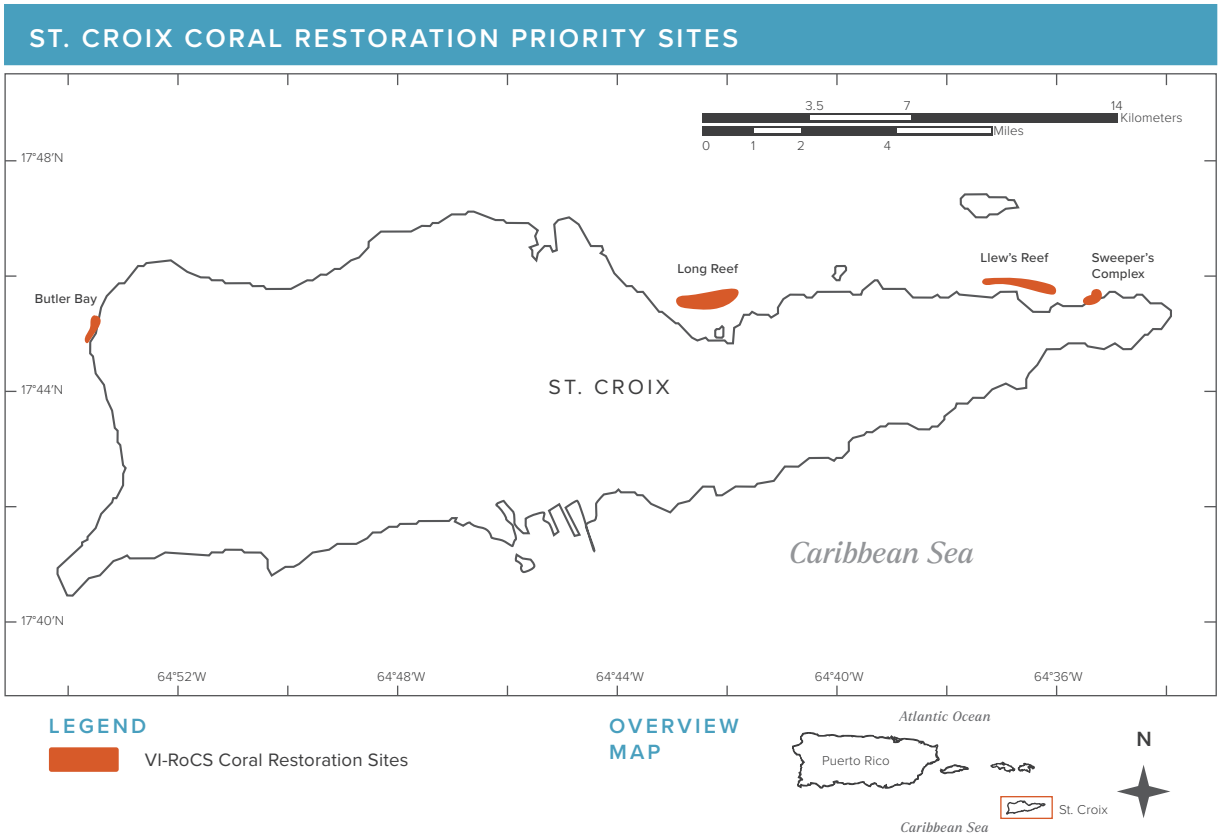
This Plan is focused only on USVI coral reefs occurring in marine waters managed by the USVI government. Other marine waters in the USVI are managed federally by NPS. The National Park Service conducted its own coral restoration planning process, with support from TNC, for coral reefs prioritized within NPS boundaries (Toline et al. 2020). This Plan utilized methods and calculations that mirror the NPS process. As such, these two plans are intended to be separate, but complementary.

SUMMARY OF PLANNED RESTORATION

This Plan provides a benchmark of stated goals and targets in order to track coral restoration progress at prioritized sites on St. Croix and St. Thomas. Through a coordinated and cooperative process, VI-RoCS chose six priority sites including two on St. Thomas and four on St. Croix. The map in *Figure 1* illustrates the location of each of the six sites. *Appendix B* provides additional information about the cooperative process used to select sites.

Figure 1. Map of Priority Restoration Sites



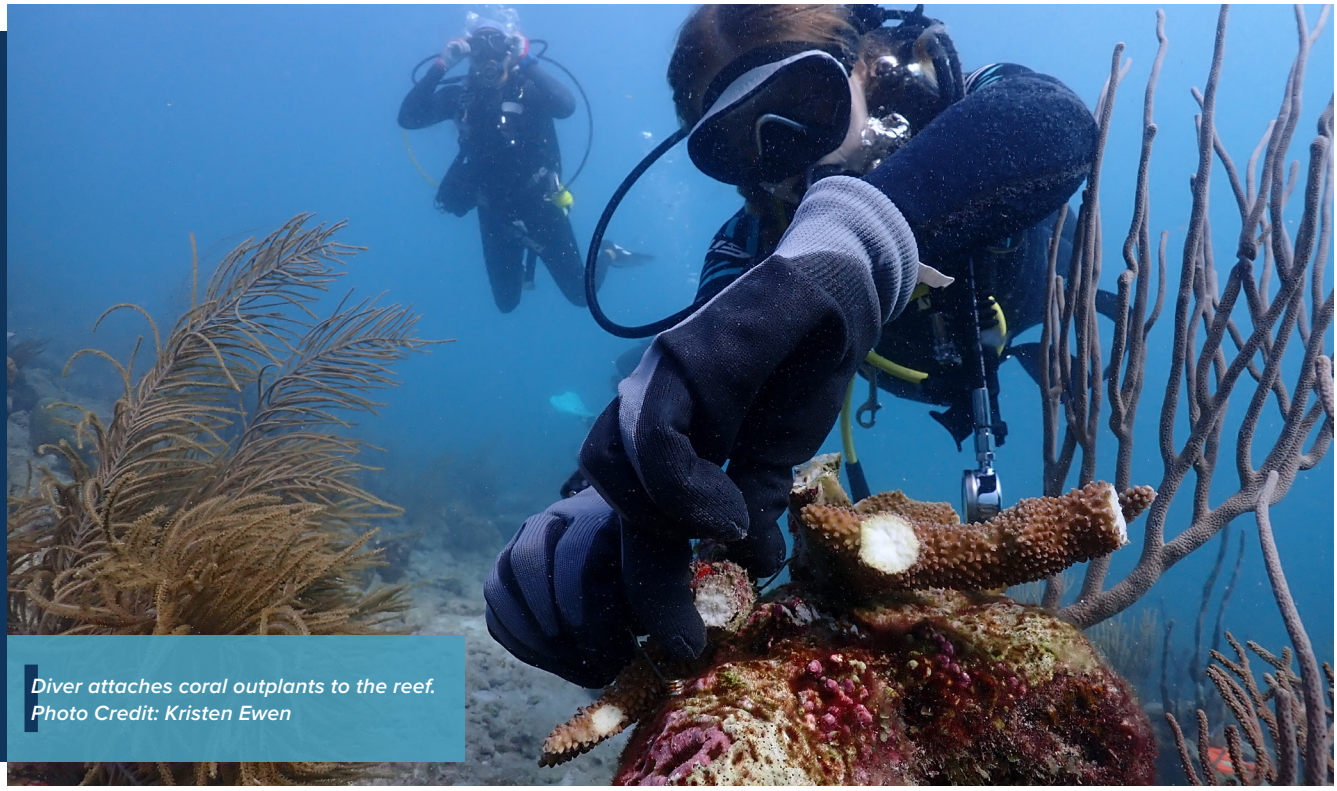


In developing this Plan, VI-RoCS established site restoration targets for each priority site over a 10-year timeframe. The focus of restoration intervention strategies in the USVI is outplanting corals; outplanting refers to the act of growing corals and planting them in the wild. *Table 1* provides a summary of intended outplanting actions by site.

While this Plan calculates restoration requirements (i.e., the number and types of corals to be outplanted) for each of the priority sites by coral reef habitat zone, additional site-specific planning for achieving ecological indicators should be conducted as funding is secured. Similarly, more monitoring protocols and metrics will be established for the sites in the future.

Table 1. Summary of Proposed Restoration Interventions Over 10 Years

Island	Site	Restorable Area (m^2)	Number of coral outplants needed	Cost
St. Thomas 	Flat Cay	42,352	56,578	$17,796,634
	Coki	5,662	8,879	$3,211,710
St. Croix 	Llew's Reef	28,860	15,238	$6,251,457
	Long Reef	212,706	188,230	$58,075,851
	Butler Bay	38,741	9,243	$3,053,805
	Sweeper's Complex	5,021	6,212	$2,278,296
Total		**333,341**	**284,380**	**$89,971,623**

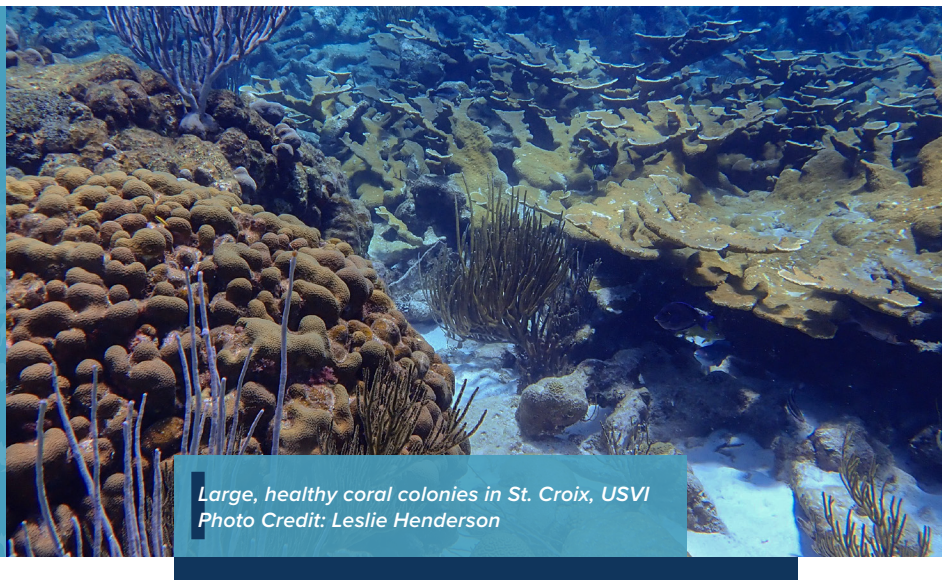


Diver attaches coral outplants to the reef. Photo Credit: Kristen Ewen

Goal Selection

Overarching USVI Coral Restoration Goal

To combat coral reef degradation caused by environmental change and human impacts, we will reestablish and/or maintain the ecological function at several (5-10) priority coral reef restoration sites across the territory within the next 10 years.



Large, healthy coral colonies in St. Croix, USVI
Photo Credit: Leslie Henderson

To develop a coral restoration goal, VI-RoCS met both as a whole group and as island-specific groups for more detailed discussions on restoration activities in St. Croix and St. Thomas. The group ultimately decided to move forward with one overarching goal in order to provide continuity across the territory. *Appendix A* includes more information on island-specific goals that were developed and led to the territorial goal selection.

This goal addresses the need to intervene and replace corals that have been lost because natural recovery is either not taking place at all or not taking place on a timescale relevant for local communities in the USVI. The planning group, VI-RoCS, defines ecological function as: *the natural processes, products, or services that living and non-living environments provide or perform within or between species, ecosystems and landscapes/seascapes.* In recognition of the critical role that stony corals play in construction and maintenance of USVI coral reefs, and the vital economic and cultural value that coral reefs provide, this restoration plan focuses on increasing abundance and diversity of these reef-building coral species. Increases in reef-building coral species are assumed to help shift previously coral-dominated habitats back to their healthy and self-sustainable coral-dominated states. The chosen goal reaffirms the territory's commitment to effective management of its coral reefs so that reefs will continue to provide vital ecosystem services to our community for future generations. To meet the goal of this restoration plan, VI-RoCS developed a set of indicators that can be used to evaluate ecological function. These indicators are discussed below in the *Implementation* section and focus on achieving coral population enhancement targets and at least two additional reef health criteria.

While socioeconomic and outreach goals were identified as valuable due to the important role of stakeholder and community engagement in restoration projects, the team determined that this restoration planning process, and the existing coral restoration funding and infrastructure, was best suited to address an ecological goal. However, restoring reefs for ecological function will also have benefits that spill over into socioeconomic and outreach values and services. Additional information on coral restoration outreach and education can be found in the *Stakeholder Engagement and Outreach* section of the Plan.



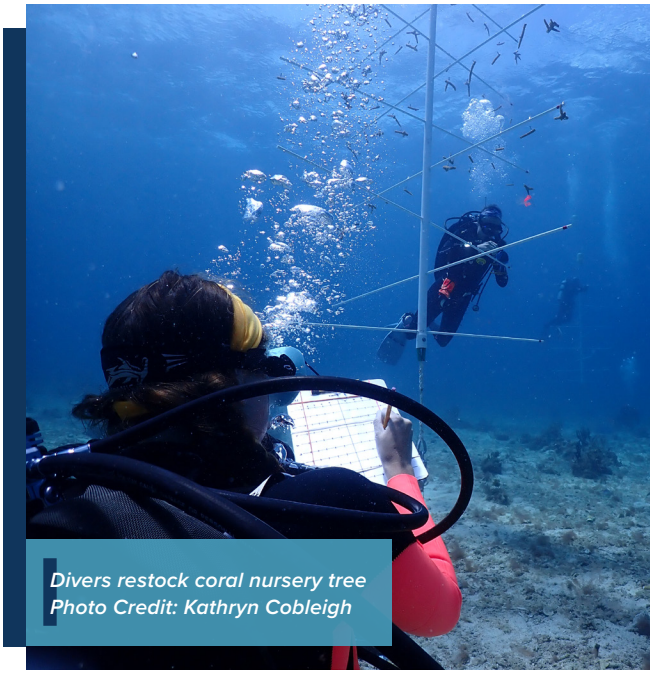
St. Croix East End Marine Park, north shore
Photo Credit: Leslie Henderson

Site Selection

General regions for potential restoration sites were initially identified based on expert local knowledge. Within each region, specific sites were identified, spatially delineated, and discussed at length. A total of 33 sites on St. Thomas and 15 sites on St. Croix were considered. The rationale for including each of the initial sites is detailed in *Appendix B*. Factors considered in identifying sites included (but were not limited to): management/monitoring in effect, ecosystem services provided by the reef, availability of information regarding the site, connectivity, accessibility, suitability for outplanting, and the potential for long-term success of outplanting. The process that VI-RoCS undertook to determine the six final priority sites is described in *Appendix B*, along with a detailed description of the rationale for selection of each priority site.

To finalize the selection of priority sites, the group took into account additional considerations, including the ranking by team members, feasibility (e.g., accessibility of the site for outplanting and potential negative human impacts at the site), whether a site had any established or planned funding source, and distribution of site locations across the region.

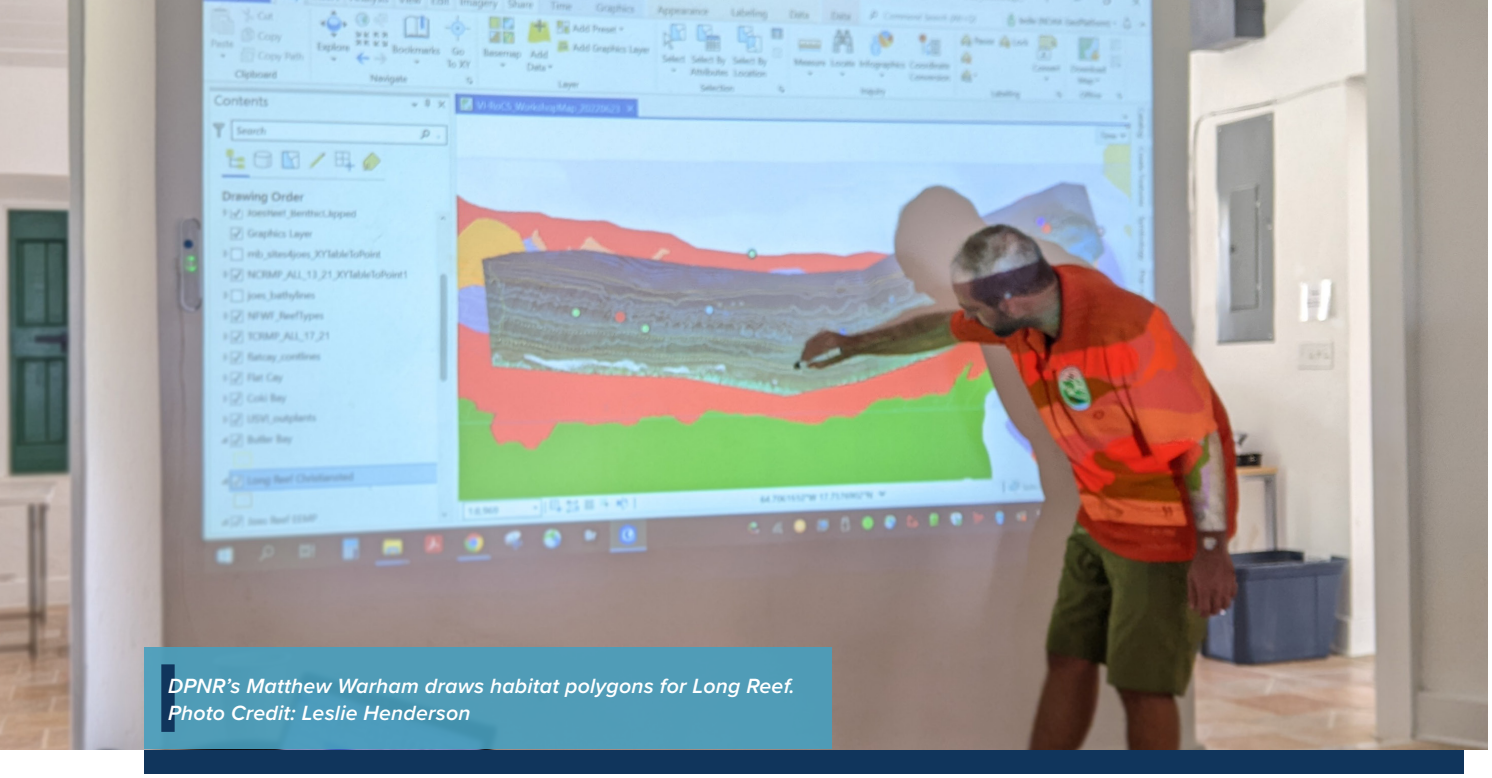
Ultimately, VI-RoCS identified six priority sites, described below in *Table 2*. These six sites are just the starting point for territorial coral restoration planning efforts, and other sites will be considered and added as resources and time permit.



Divers restock coral nursery tree
Photo Credit: Kathryn Cobleigh

Table 2. Priority Sites

Island	Site	Description
ST. THOMAS	**Flat Cay** 	Flat Cay is located off the southwest coast of St. Thomas, downstream from Crown Bay/Gregorie Channel and the water treatment plant at Red Point. UVI has an in-water coral nursery in this location and it is close to UVI's Center for Marine and Environmental Science.
	Coki 	The Coki restoration site is located along the northern coast of the Coki Point peninsula and extends from Coki beach to the eastern edge of Coral World Ocean Park. A substantial portion of the restoration site resides within Coral World Ocean Park's submerged land lease and is accessible by land or via the Park's underwater observatory tower.
ST. CROIX	**Llew's Reef** 	Llew's Reef is a shallow barrier reef located on the northeast side of St. Croix within the EEMP and south of Buck Island Reef National Monument. This reef system extends eastward almost to the eastern tip of the island and restoration efforts can be continued eastward as efforts progress.
	Long Reef 	Long Reef is a shallow barrier reef located on the northside of St. Croix. This reef system runs parallel to Christiansted Harbor and provides coastal protection from storm events and wave inundation. The eastern end of the reef marks the edge of the channel entering Christiansted Harbor which is frequented by recreational and commercial vessel traffic.
	Butler Bay 	Butler Bay is located in the northwest region of St Croix. Within this site there are four coral reef habitat types: pavement, scattered coral and rock, aggregate shallow reef, and reef crest (this reef crest runs adjacent to the shoreline). Restoration is planned for a 300 m stretch of aggregate shallow reef known as Butler Ledge as well as reef crest that exists on both sides of the Bay.
	Sweeper's Complex 	Sweeper's Complex is located within the recreational zone of the EEMP. This series of three small patch reefs rises from shallow seagrass which characterizes this area of the lagoon in northeast St. Croix. The patches rise to a depth of approximately 0.6 m (2 ft) at the shallowest. For consistency, the three patch reefs included in this site are called Patch Reefs (PR) 2, 3 and 6, based on the naming conventions used during the era of work by the Fairleigh Dickinson-West Indies Lab (in the early 1980s).



DPNR's Matthew Warham draws habitat polygons for Long Reef. Photo Credit: Leslie Henderson

Mapping Process

Following the selection of the priority sites, VI-RoCS held a three-day in-person workshop (Benthic Habitat for Priority Sites Workshop, in July 2022) to bring together practitioners, researchers, and resource managers. Together, participants used their local knowledge, prior experience, satellite imagery, local data, and several benthic habitat maps including the Allen Coral Atlas (2022), NCCOS Biogeographic Assessments (2001), and the Caribbean Science Atlas: Coral Reef Restoration Tool (TNC 2022) to produce finer-scale habitat maps for each priority site. Within a given priority site, polygons for restoration were delineated based on the benthic habitat type, historical coral composition, and any ongoing restoration efforts. Participants defined habitat classifications based on elements such as benthic topography, substrate, depth, and orientation to the surrounding reef (see *Table 3*). Once a polygon was delineated and given a habitat classification, the group estimated (based on local ecological knowledge) the amount of hard bottom habitat present, as well as the potential restorable area within it. This was completed for each polygon at each priority site. Restorable area was defined as *"the proportion of reef habitat that is devoid of desirable species and therefore suitable for restoration, or that can be prepared for restoration."*

Post-workshop, polygon boundaries were refined by a Geographic Information System (GIS) analyst using Environmental Systems Research Institute, Inc. (ESRI)'s ArcGIS Pro software using a combination of the following products: Hexagon Aerial Imagery (2020), Google Earth Imagery, the Continually Updated Shoreline Product (CUSP) (National Geodetic Survey 2023), NCCOS's Biogeographic Assessments for St. Croix, St. Thomas, and St. John (2001), and bathymetric contours derived from the Continuously Updated Digital Elevation Model (CUDEM) Mosaic (Elevation Values) (NCEI 2023). The coral reef habitat zones within each restoration site were identified by specific coral barrier characteristics, the shoreline, and depth using the data products mentioned above. Polygons were drawn around these identified coral reef habitat zones using the WGS 1984 Geographic Coordinate System. Maps of each restoration site illustrating the identified coral reef habitat zones are included in the *Implementation* section below.

Table 3. USVI Coral Reef Habitat Zone Classifications

Coral Reef Habitat Zone Classification	Description
Reef Crest	Shallow (> 2m [7 ft]) zone of reef laying between back and fore reef zones. Breaking waves can occur with high wave action, but the area is generally workable.
Shallow Reef Crest	Very shallow (< 2m [7 ft]) zone of reef laying between back and fore reef zones. Breaking waves almost always occur. Work in this area is hazardous.
Forereef Terrace	Seaward facing slope feature with shallow angle.
Backreef	This zone lies between the seaward edge of a lagoon floor and the landward edge of the reef crest.
Aggregate Reef - shallow	Hard-bottom continuous or consolidated reef substrate with corals. This zone is usually *Orbicella spp.* dominated (< 30m [98 ft]) and does not conform to the traditional spur and groove formations.
Aggregate Reef - deep*	Hard-bottom continuous or consolidated reef substrate with corals (> 30m [98 ft]).
Spur and Groove	Made up of ridges of reef formed by coral spurs separated by channels, which may have sediment or rubble.
Patch Reef	Isolated to semi-isolated coral outcrop arising from a sandy-bottomed area. Less than ¼ acre in extent.
Dense *A. Palmata* Framework	Branching reef-building zone of *Acropora palmata* (Elkhorn coral) (e.g., haystacks at Buck Island Reef). Can exist on reef crest zones.
Scattered Coral and Rock	Made up of corals and rock that are scattered and not aggregated enough to be considered a patch reef.
Unconsolidated Reef/Rubble Zone*	Barren zone of scattered coral fragments (some loose) and sand.
Artificial	Non-biogenic, introduced artificial reef structure. Manmade or placed, non-naturally occurring structure.
Bedrock	Made up of igneous, sedimentary (non-carbonate), or metamorphic rock and can take boulder form or huge slabs. Difficult to nail into.
Pavement/Rhodolith	Made up of flat, low-relief, solid carbonate rock or a rhodolith field.
Sand	Composed of sand substrate.
Seagrass	Composed of seagrass flowering plants.

Notes: Asterisk indicates a classification was not applicable for the priority sites in this Plan,but may be used in additional future site planning.

Restoration Intervention Strategies

There is a growing interest globally in using active restoration interventions to mitigate reef degradation and to promote recovery and resilience (Possingham et al. 2015, Boström-Einarsson et al. 2020). Restoration interventions can take many forms, as detailed in the 2020 NOAA Action Plan on Coral Interventions and supporting research reports (Vardi et al. 2020; National Academies of Sciences, Engineering and Medicine 2019b). In the USVI, the main intervention strategy is outplanting coral, utilizing both in-situ (in-water) and ex-situ (land-based) techniques for growing corals. Treating coral disease is another ongoing restoration intervention, which is used in the USVI. Other intervention strategies being applied in the USVI are less intrusive, including site preparation and maintenance and maintaining genetic diversity. In addition to discussing the restoration intervention strategies currently in practice in the USVI, this section also explains the strategy used to determine the restoration requirements (i.e., the number and types of corals to be outplanted) for the priority sites.

RESTORATION METHODS AND TECHNIQUES

In-situ (In-water) Restoration

In-situ restoration is defined as restoration activities that take place in natural marine environments.

- **Sexual Propagation** - Facilitated sexual propagation of corals is performed by collecting gametes from wild parent colonies. One way this is accomplished is by placing a gamete collection net over selected donor corals on the reef during spawning times, which can be predicted for individual species using the lunar cycle and timing of sunset. Once gametes are collected they are brought to shore, and gametes from multiple parent colonies are combined to promote fertilization. Resulting planulae can be settled onto conditioned recruitment substrates in a land-based facility or an in-water nursery, or they can be released directly onto a reef to settle on natural substrate.
- **Asexual Propagation** - Asexual propagation in the USVI consists either of collecting fragments of opportunity resulting from storm, anchor, or other disturbance damage, transporting the fragments to a nursery to allow for a grow-out phase, or collection from wild colonies and then outplanting them onto selected reef areas. This process is typically most successful with branching corals. A new in-situ asexual propagation technique referred to as “direct outplanting” has begun testing in the USVI. This method consists of taking a small section of a living in-place coral colony, fragmenting the piece into smaller pieces and, within the same day, outplanting them either within the same site or at other locations. This process forgoes a nursery stage and has been tested with significant success for *Acropora palmata* (Elkhorn coral).

Ex-situ (Land-based) Restoration

Ex-situ restoration is defined as restoration activities that take place in controlled land-based water tank systems.

- **Sexual Propagation** - Captive spawning is performed by collecting donor colonies and maintaining them in land-based seawater systems at least one to two weeks prior to their expected spawning date. Around the night of expected spawning, colonies are typically isolated in containers and monitored for the release of gametes. Upon release, gametes are collected by gently skimming them from the surface into a small container. At this point, gametes can be separated for selective breeding or mixed together for batch fertilization. Planulae are then induced to settle on conditioned substrates and may be inoculated with specific Symbiodiniaceae or allowed to acquire them passively from unfiltered seawater. These substrates can then be outplanted onto the reef along with any coral recruits that have settled on them.
- **Asexual Propagation** - Asexual coral propagation is accomplished through fragmentation and micro-fragmentation. Fragmentation is carried out



Collecting coral gametes for sexual propogation. Photo Credit: Leslie Henderson



Diver applies antibiotics to diseased coral. Photo Credit: Joe Snyder

using tile saws and or clippers to cut donor coral colonies into smaller pieces, roughly between 3-10 centimeters (cm) in diameter. This creates more surface area for the original donor colony to grow and also initiates a wound-healing response which results in faster growth. Micro-fragmentation follows similar methods but requires specialized band saws to cut fragments into "micro-fragments," measuring less than 1.5 cm. Coral fragments are glued to a base (i.e., cement plug or array) and labeled to track progeny. The freshly cut fragments are cared for in land-based nurseries until they are large enough for outplanting or further asexual coral propagation. Fragments from the same donor colony are then outplanted in arrays of multiple fragments close together so that they will eventually fuse back together.

Site Preparation and Maintenance

In some cases, it is critical to perform site preparation before outplanting, or maintenance periodically post-outplanting, on the reef. This might include but is not limited to: removal of algae or other nuisance benthic organisms that compete for space with corals, removal of snails or other predators that eat corals, stabilization of corals after high wave energy or other disturbance events, and maintenance of any monitoring plot or location markers.

One method of site maintenance that has yet to be explored in the USVI is herbivore restoration alongside coral restoration. By growing and outplanting herbivorous snails, urchins, crabs, or fish, corals are subject to less competition with algae for space on the reef. While herbivore restoration targets are not included in the Plan, scientists and practitioners are performing active research on methods and the hope is to implement small-scale efforts in the USVI and evaluate their impact and feasibility in the future.

Disease Intervention

In addition to actively restoring coral reefs through direct outplanting efforts, the territory is currently implementing actions from the Coral Disease Outbreak Response Plan as part of the USVI coral reef management strategy (see ***vicoraldisease.org***). One action under this Coral Disease Outbreak Response Plan to combat stony coral tissue loss disease (SCTLD), is to deploy teams of specially trained divers, known as strike teams, to regularly visit reef sites found to have high coral disease prevalence, high abundances of endangered species, or high abundances of particularly susceptible species. Strike teams search out affected corals and apply an antibiotic treatment paste directly on coral lesions. Of the six USVI priority sites for restoration, four sites (Coki, Butler Bay, Long Reef, and Llew's Reef) are visited regularly for antibiotic treatment. Sweeper's Complex has been treated

in the past, but is not part of routine strike team intervention. Flat Cay does not have a history of coral disease treatment efforts, but has been closely monitored throughout the disease outbreak to obtain data on reef impacts from SCTLD.

When colonies of highly susceptible and endangered species become affected beyond the point of antibiotic treatment, strike team coordinators are notified to determine if rescue is necessary. During coral rescue operations, strike teams remove lesion-free pieces of the specified coral colony and transport them to a land-based nursery for isolated treatment and monitoring. Bringing corals fated for mortality into captivity prevents further loss of genetic diversity should the parent colony die in the wild. These rescued colonies can be saved and used in future restoration efforts once SCTLD is no longer a threat to their survival.

Genetic Diversity

An important intervention strategy being employed in the USVI throughout all coral nursery and outplanting operations is to consider genetic diversity when performing coral outplanting. Maximizing genetic diversity of coral outplants is critical as it promotes ecological resilience to threats such as disease and climate change, and reduces impacts from inbreeding/outbreeding depression and general loss of fitness (Alfiq-Rosli et al. 2018; Baums 2008). According to Shearer et al. (2009), at least 10 genotypes randomly selected from the local population should be used in outplanting to retain at least 50 percent of the genetic diversity, while keeping 20-to-25 genets in a nursery is recommended to capture 95 percent of allelic diversity (Baums et al. 2019). Achieving high levels of genetic diversity is more easily accomplished with sexual restoration techniques as crosses create new genotypes. However, it is still important to maintain a variety of parent colonies from which these crosses are made (Baums et al. 2019 recommends 5 to 10 genets for batch cultures). Selecting parents for desirable traits such as disease or thermal bleaching resistance or resilience may increase the fitness of resulting cohorts of outplants, but caution should always be applied and overall genetic diversity maintained.

Coral reefs in the USVI have faced a number of significant events, including multiple damaging storms, thermal anomalies leading to mass bleaching, and most recently, SCTLD. It is presumed that the remaining corals on USVI reefs are *de facto* resistant and/or resilient genetic strains, and that propagating these genotypes will bolster local ecological resilience. Within the remaining coral population of the USVI, there is a range of tolerance to common stressors (e.g., water temperature, quality, or frequency of disturbance) driven by the varying conditions in the location where a coral has persisted. Incorporating genotypes sourced from these varying existing conditions should increase robustness of restoration stock and result in outplants most suited to thrive in current and future water conditions.

CALCULATION OF RESTORATION REQUIREMENTS

To set targets for the increase in coral cover needed to allow the territory to meet its overall restoration goal, VI-RoCS went through a rigorous coordinated process. This section describes the process employed to calculate the restoration requirements (i.e., the number of corals or clusters) that would need to be outplanted over the 10-year timeframe of the Plan to achieve the designated percent restored coral cover.

Restoration requirements are calculated based on a desired coral cover percentage increase for the restorable area of each site. At each site's starting point, or year 0, the restorable area's coral cover percentage is 0 because restorable area by definition does not include any portions of the hardbottom that already have coral growing on it. As such, the target percentages (aka "restored coral cover") reflect the planned increase in the coral cover of the restorable area only and are not interchangeable with overall coral cover of a site.

Percent Restored Coral Cover

During the in-person workshop, VI-RoCS estimated the existing coral cover of six different species groups within each habitat zone for each site. Then, the group agreed on 10-year targets for restored coral cover of those same species groups, for each

habitat zone for each site. These estimates and targets were based on literature, expert knowledge, existing conditions, and restoration techniques employed by each coral practitioner group. The species groups selected for restoration include: Elkhorn coral (*Acropora palmata*), Staghorn coral (*Acropora cervicornis*), Star corals (e.g., *Orbicella spp., Montastraea cavernosa*), Brain corals (e.g., *Pseudodiploria spp., Colpophyllia natans, Diploria labyrinthiformis*), Pillar coral (*Dendrogyra cylindrus*), and other small stony corals (e.g., *Porites spp.*). *Appendix C* provides detailed tables illustrating the percent restored coral cover targets by species group and coral reef habitat zone for each site.

Number of Coral Outplants Needed

The number of coral outplants needed may refer to one or several coral fragments depending on the outplanting technique. If multiple fragments are outplanted as a single unit with the intention of ultimately fusing into a single colony, it is counted as one outplant, commonly referred to as a cluster or an array. Alternatively, if a single coral fragment is outplanted by itself, it is also counted as one outplant. Throughout this Plan, a coral outplant can be either type (single or clustered) depending on the circumstance. To calculate the number of coral outplants needed to meet the USVI restoration targets, the model developed for Mission Iconic Reefs in the Florida Keys (NOAA 2020) was applied. This spreadsheet model included assumptions about outplant size, survival rates, and growth rates for each species group (see NOAA 2020 for details). Using this model, the number of coral outplants by species group that would be necessary to achieve a particular site's percent restored coral cover targets was calculated. Table 4 presents the results in terms of the number of coral outplants by species group, for each site. *Appendix C* provides a further breakdown of the number of coral outplants by coral reef habitat classification for each site.

Table 4. Number of Coral Outplants Needed to Reach 10-Year Targets



Island	Site	Elkhorn Coral	Staghorn Coral	Star Coral	Brain Coral	Pillar Coral	Small Stony Coral	Total
St. Thomas 	Flat Cay	2,535	2,256	27,040	6,359	133	18,256	**56,578**
	Coki	725	76	3,120	3,537	0	0	**8,879**
St. Croix 	Llew's Reef	6,018	2,720	2,779	2,779	0	941	**15,237**
	Long Reef	5,039	0	57,164	16,259	0	109,768	**188,230**
	Butler Bay	6,154	0	528	826	0	1,734	**9,243**
	Sweeper's Complex	1,314	17	870	2,655	0	1,355	**6,212**
Total		**21,786**	**5,068**	**91,502**	**32,416**	**133**	**133,475**	**284,380**

Implementation

To assess the success of coral restoration in the context of our stated goal, VI-RoCS developed a set of ecological function indicators to be evaluated at the site level over time throughout the 10-year period. Ecological function will be evaluated by monitoring and tracking coral cover as well as at least two additional indicators, as outlined in *Table 5*. The targets specified in *Table 5* were discussed and agreed upon by VI-RoCS through a series of monthly meetings. These targets are intended to be a guide for coral restoration efforts in the 10-year timeframe; however, VI-RoCS recognizes that the overall goal of a minimum 10 percent total coral cover target may not be possible at all six chosen priority sites for a variety of reasons.

Table 5. Ecological Indicators

Indicator/Parameter	Target
FOR ALL SITES	
Overall coral cover of reef zones at restoration site	Within 5 percent of a predetermined site-specific historical baseline, or at least to a minimum of 10 percent total coral cover for reef habitat zones at a site.
IN ADDITION TO TWO OF THE FOLLOWING	
Coral species diversity/richness at restoration site	Maintain at least 50 percent of a predetermined historic baseline of species diversity and/or richness based on specific reef habitat and which spans the various key morphotypes for that habitat (e.g., framework builders, cementers).
Outplanted coral genotypic diversity	Outplants have a minimum of five genets for hermaphroditic species and at least 10 genets for gonochoric species for each site to increase chances of successful sexual reproduction and resilience against disease and bleaching events (Baums et al. 2019). *(Note, as efforts scale up this target may be revisited.)*
Outplanted coral survivorship	For *fragments:* 80 percent survivorship for at least one-year post-outplanting. For *settled recruits:* Three to five percent survivorship for at least one-year post-outplanting.
Outplanted coral reproductive maturity/capacity	Outplanted corals reach a presumptive sexually mature size within 3-5 years for fast-growing species and 10-15 years for slow-growing species.
Coral recruitment at restoration site	Increased (relative to control TCRMP sites and/or baseline data at restoration sites) recruitment of outplanted species at restoration sites. *(Note, since data are limited on natural recruitment, this metric is comparative.)*

Further, the 10 percent coral cover target specified in *Table 5* is intended to be averaged across reef zones at the site scale. Therefore, the values in *Table 5* are not directly comparable to the restored coral cover targets in *Appendix C*, which includes the targeted percent coral cover increase by reef habitat zone, for the restorable area only. For considering the impact of restored coral cover on site-scale overall coral cover, an area-weighted average was calculated (see *Appendix D*).

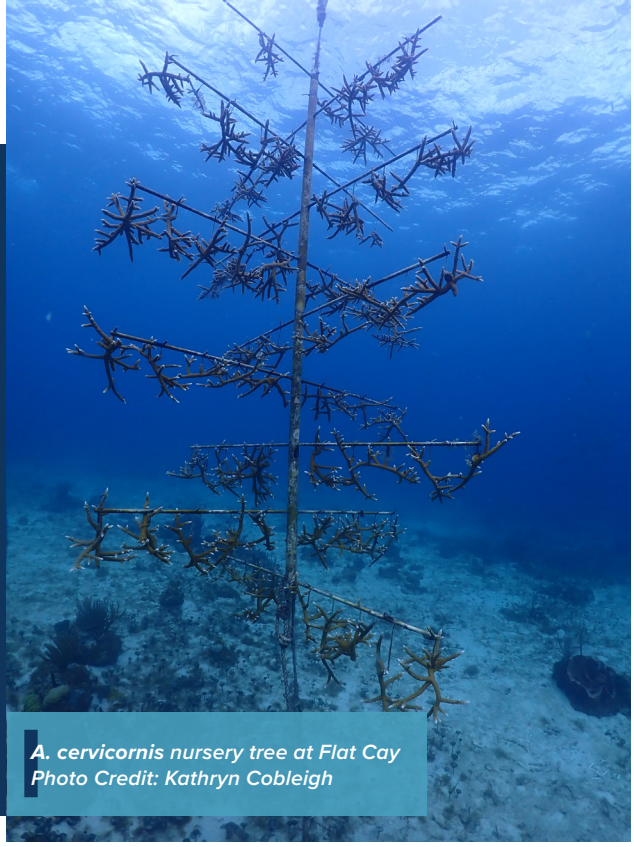
Future efforts will focus on developing a more in-depth monitoring plan to accompany this document. Monitoring at the restoration sites will be based on guidance developed by the Coral Restoration Consortium (CRC), but adapted for local feasibility and capacity (Goergen et al. 2020). Currently planned or ongoing maintenance and monitoring efforts are described below for each of the priority sites. In general, practitioners are moving towards the use of Structure-from-motion (SfM) photogrammetry to create photomosaic models and enhance monitoring at several of the sites.

Along with this Plan and the future monitoring protocols, VI-RoCS is also developing an online Environmental Systems Research Institute, Inc. (ESRI) mapping tool that will help with coordinating implementation and tracking of coral restoration in the USVI. This tool will host relevant local coral reef data and be accessible to all VI-RoCS members. For all priority sites, the tool will display coral reef habitat zones, targets, and other relevant metrics for ease of access and transparency. The tool will be updated annually by VI-RoCS with all available new coral outplant data. This will serve as a method of tracking progress towards specified outplant targets in each zone. As more rigorous coral reef restoration monitoring protocols are developed, and standardized monitoring data at priority sites becomes available, these data also could be displayed visually and tracked within the mapping tool.

As described in the previous section, the number of coral outplants needed was calculated by species group and coral reef habitat zone for each priority site. Each of the chosen priority sites is in a different stage with respect to restoration planning and implementation. The following sections detail the current status and ongoing management activities at each site and discuss the scheduled restoration activities as guided by this Plan. This section is not intended to provide specific management plans for each site; more detailed site-specific planning may be conducted at a later date as funding becomes available.



Diver surveys coral health in the USVI. Photo Credit: Leslie Henderson



A. cervicornis nursery tree at Flat Cay
Photo Credit: Kathryn Cobleigh

FLAT CAY

ST. THOMAS

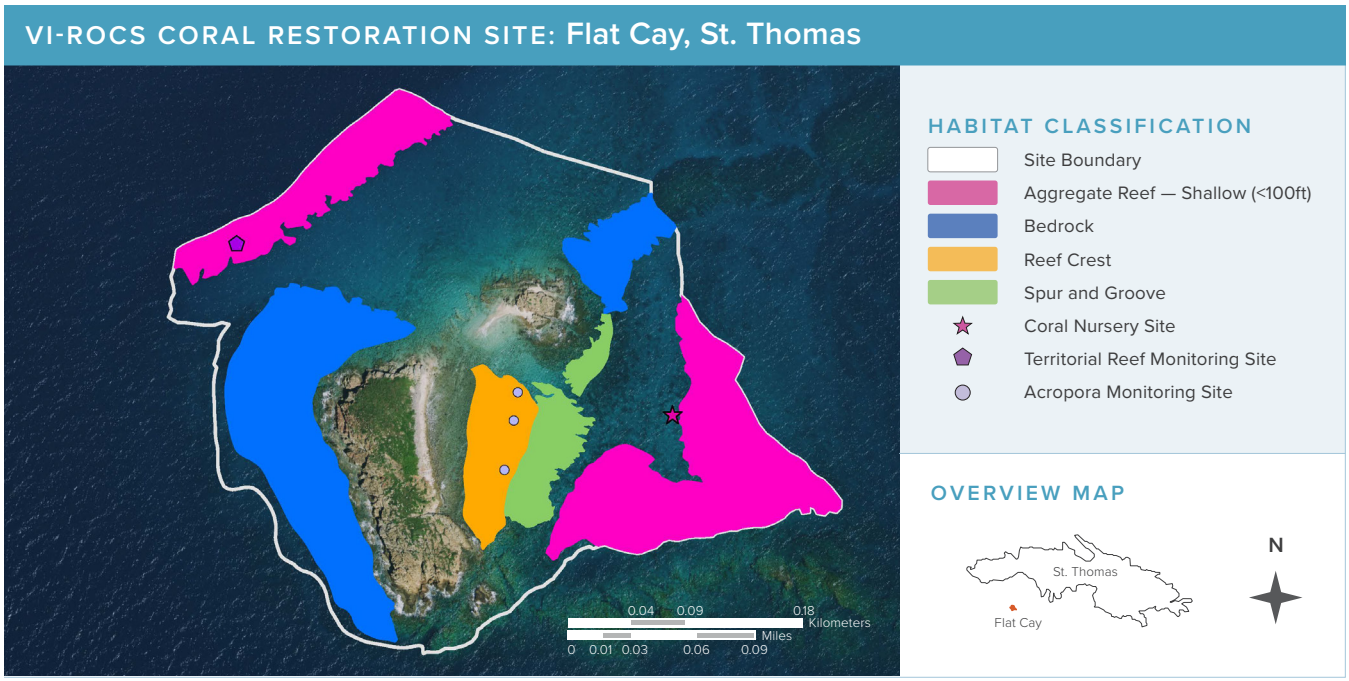
Current Status and Ongoing Management Activities

The Flat Cay restoration site consists of the reef areas surrounding the islands of Flat Cay and Little Flat Cay located 1.8 miles (2.8km) southwest from UVI's Center for Marine and Environmental Studies (UVI CMES). *Figure 2* provides a map of the site, illustrating the types of reef habitat present at the site. Aggregate coral reef dominated by boulder star coral and dense branching coral stands were historically abundant in the waters surrounding the two cays. In the past two decades, Flat Cay has experienced severe coral loss and mortality resulting from multiple environmental disturbances. The Caribbean-wide mass bleaching event of 2005 caused a significant drop in coral cover on the Flat Cay aggregate coral reef areas, but these reefs had shown recovery to pre-bleaching levels by 2010. In the fall of 2017, *A. palmata* and *A. cervicornis* populations were severely impacted by hurricanes Irma and Maria. Recovery of these populations has been hampered by the dominance of the invasive algae *Ramicrusta spp.* (identification provisional) which quickly overgrows and destabilizes *Acropora spp.* Flat Cay is also down current from a major sewage outfall, an industrial port and cruise ship docking areas where it is believed that stony coral tissue loss disease (SCTLD) was first introduced to the USVI in late 2018/early 2019 through ballast water transport. There are several popular day-use moorings located on the west side of Flat Cay that provide SCUBA divers access to the deeper aggregate reef, and one mooring located to the east providing access to the dense branching coral areas.

Flat Cay is an important research site for UVI due to its geographic proximity to campus and diverse reef structures. UVI's largest in-water coral nursery is located on the eastern side of Flat Cay. This nursery consists of polyvinyl chloride (PVC) coral trees with spaces for up to 20 trees, and rears fragments of *A. cervicornis* colonies that are used for outplanting at multiple locations across St. Thomas by UVI's restoration program known as Reef Response. Despite hosting a nursery, significant outplanting has yet to be conducted at Flat Cay itself.

A long-term monitoring site located on the west side of Flat Cay is part of the Territorial Coral Reef Monitoring Program (TCRMP). Within this long-term monitoring site, six fixed 10 m transects are surveyed annually for benthic cover, coral demographics and health. The TCRMP program also performs annual fish surveys at the site, collecting data on fish diversity, abundance, and size structure. Additionally, TCRMP collects environmental data such as temperature using in-situ loggers and conductivity, temperature and depth (CTD) casts, as well as data on sediment accumulation and current profiles through sampling and use of other instruments. Annual monitoring at the Flat Cay TCRMP location has occurred since 2005. For more information about the TCRMP program please visit ***usvitcrmp.org***. UVI has more recently established *A. palmata* monitoring plots in the shallows on the eastern side. These plots were established in 2021 and record recruitment, growth and mortality of the natural *A. palmata* populations. The monitoring also includes following tagged colonies through time using photographs and *in situ* measurements twice a year. Results from the *Acropora* monitoring program will be available on the Reef Response website (***reefresponse.org***) in the near future.

Figure 2. Flat Cay Site Map



Planned Restoration Activities

At Flat Cay, the UVI in-water coral nursery will be updated and expanded to scale-up coral production for restoration. This involves reinforcing PVC coral tree anchoring attachments to prevent tree loss through storms, as well as new tree designs that will allow UVI to grow more corals per tree. Staghorn corals (*A. cervicornis*) grown in the nursery are occasionally outplanted on the east side of Flat Cay.

Starting in 2024, using funding from the Coral Reef Conservation Program through the National Marine Sanctuary Foundation, UVI will be outplanting coral larvae that are selectively bred and engineered for thermal-tolerance and disease resistance. Species that will be targeted for outplanting include Elkhorn coral (*A. palmata*) and Mountainous star coral (*Orbicella faveolata*).

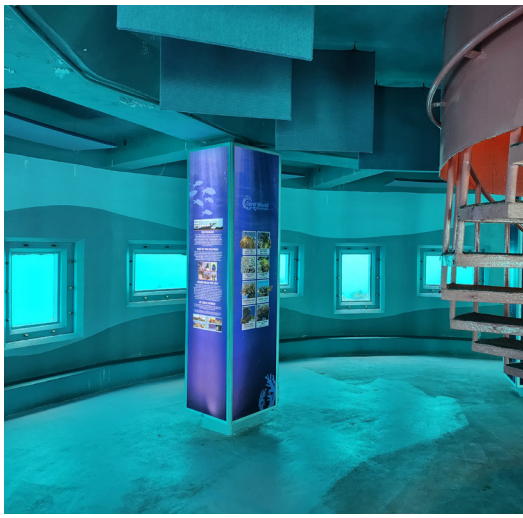
The restoration requirements over the ten-year life of the Plan are shown in *Table 6* for Flat Cay.

Table 6. Flat Cay 10-Year Restoration Targets

Flat Cay Site Totals	
Total Mapped Area (m^2)	**56,374**
Restorable Area of Reef (m^2)	**42,352**
Number of Coral Outplants Needed	
Coral Restoration Components	**Total**
Elkhorn Coral	2,535
Staghorn Coral	2,256
Star Coral	27,040
Brain Coral	6,359
Pillar Coral	133
Other Small Stony Coral	18,256
Totals	**56,578**



Coral World Ocean Park
Photo Credit: Logan Williams



COKI

ST. THOMAS

Current Status and Ongoing Management Activities

The Coki restoration site is located north of Estate Coki Point, St. Thomas, USVI and encompasses 5,662 square meters of restorable reef habitat that fall within recreational and protected zones managed by the territorial government and Coral World Ocean Park, respectively. Coki is an active coral disease intervention and monitoring site that has suffered substantial losses in coral cover, abundance and diversity since the invasion of SCTLD in early 2020.

Coki Beach is a public beach that is managed by the Department of Planning and Natural Resources (DPNR). The beach is easily accessible by road and is a popular destination for tourists and resident Virgin Islanders. Recreational activities, including snorkeling, SCUBA diving, line-fishing, and small personal watercraft usage, are permitted within the bay waters.

Coral World Ocean Park (hereafter referred to as CWOP) is a marine facility, including a public aquarium, which provides opportunities for visitors to connect to marine life and has served as an important marine education resource for the territory since its establishment in 1978. The facility's underwater observatory tower descends to a depth of approximately 15 feet and is surrounded by roughly 9,367 square meters of privately-managed and protected, submerged lands that CWOP leases from DPNR. As the lessee, CWOP is granted the right to prevent the entry of all persons and extraction of all marine resources within its waters. Only CWOP and Coral World Ocean and Reef Initiative (CWORI) staff, Sea Trek® and SNUBA® customers, and visiting scientists/restoration practitioners, are granted entry to these waters via the underwater observatory dive platform.

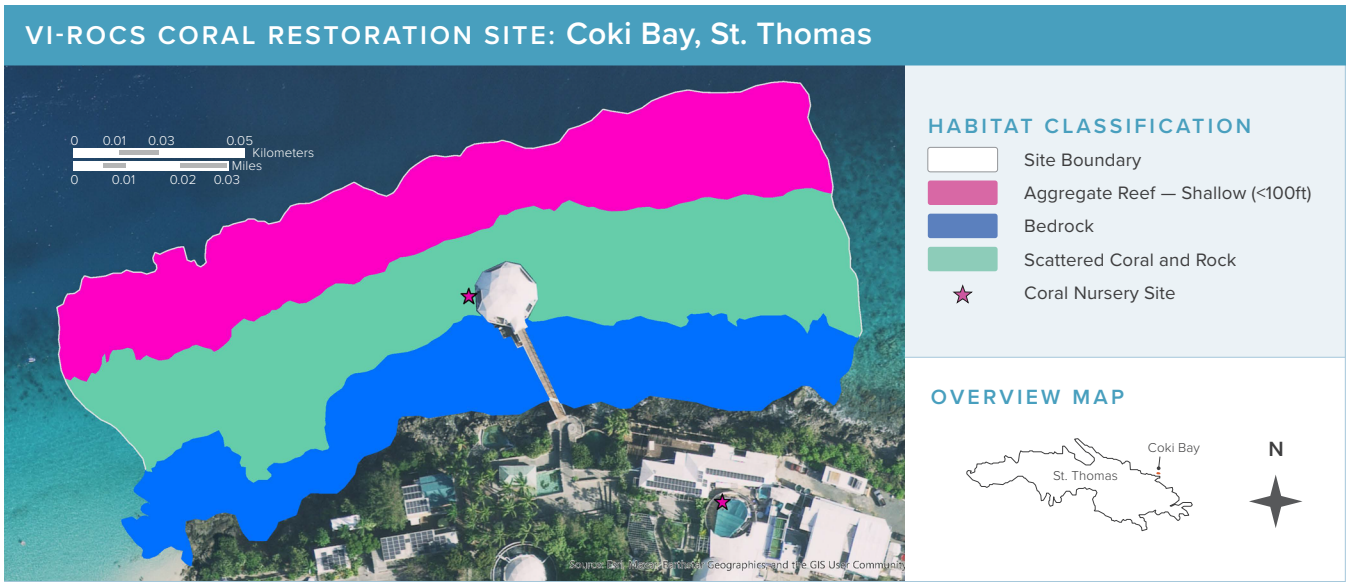
Visitors to CWOP are granted access to the underwater observatory tower and can participate in Sea Trek® and SNUBA® operations. These amenities and offerings provide opportunities for coral restoration and conservation efforts to be displayed to, and interpreted for, the public. The Coral World Ocean and Reef Initiative is a non-profit dedicated to conserving marine habitats; CWORI staff lead the restoration efforts at the Coki site.

In collaboration with UVI, both SCTLD resistant and susceptible coral species have been outplanted to substrates within bedrock, scattered coral and rock, aggregate reef zones, and artificial structures surrounding the underwater observatory tower. Between 2021 and 2022, approximately 302 corals were outplanted at this site. *Figure 3* provides a map of the site, illustrating the types of reef habitat present at the site.



Coki Acropora prolifera outplant
Photo Credit: Logan Williams

Figure 3. Coki Site Map



Planned Restoration Activities

CWORI restoration practitioners will continue to execute and manage restoration activities within the Coki restoration site, and the targets specified in this Plan will guide outplanting efforts. Initial restoration efforts will focus on expanding and diversifying CWORI's existing in-water and land-based nurseries, the rearing and outplanting of fast-growing, disease-resistant *A. palmata* and *A. cervicornis*, and the collection, rehabilitation, and asexual propagation of SCTLD susceptible species. Outplanting work will occur in phases with fast-growing, shallow reef-building *Acropora* corals selected for initial outplanting efforts (years 1 and 2), followed by the outplanting of slower-growing and SCTLD susceptible brain and star corals.

In 2024, UVI will be outplanting selectively bred and engineered coral larvae (as with Flat Cay) as part of a CRCP project funded through the National Marine Sanctuary Foundation. *A. palmata* and *O. faveolata* are target species for outplanting.

The targeted restoration components over the ten-year life of the Plan are shown in *Table 7* for the Coki restoration site.

Table 7. Coki 10-Year Restoration Targets

Coki Site Totals	
Total Mapped Area (m^2)	16,479
Restorable Area of Reef (m^2)	5,662
Number of Coral Outplants Needed	
Coral Restoration Components	**Total**
Elkhorn Coral	725
Staghorn Coral	76
Star Coral	3,120
Brain Coral	3,537
Pillar Coral	0
Other Small Stony Coral	1,420
Totals	**8,879**

LLEW'S REEF

ST. CROIX

Current Status and Ongoing Management Activities

Llew's Reef falls within a protected area of the St. Croix East End Marine Park (EEMP). The EEMP was created in 2003 and is managed by DPNR. The most recent management plan for the EEMP was developed in a collaborative effort with local fishermen and dive operators, professionals at universities, and local and federal agencies (*Brown et al. 2016*). The Park is zoned for multiple uses to accommodate a variety of users while protecting vulnerable and valuable habitats. For more information about the East End Marine Park go to ***eastendmarineparkfriends.org/***.

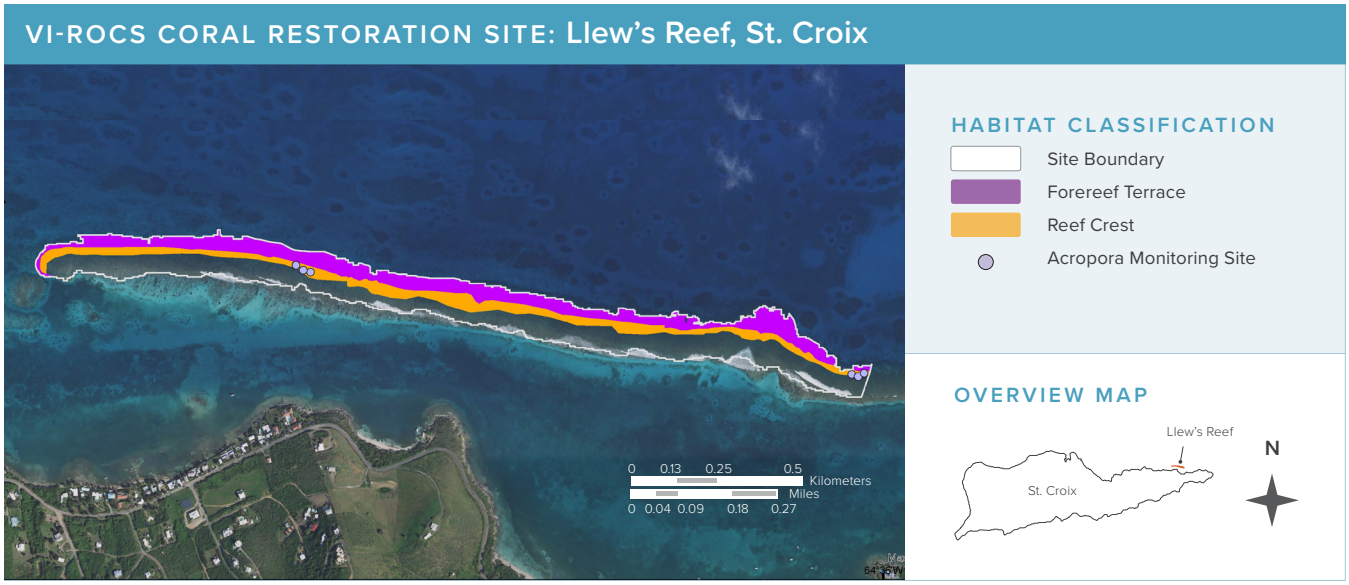
Llew's Reef falls partly within a No Take Zone of the Park and partly within a Recreational Zone. The No Take Zone is designed to protect large contiguous habitats (e.g., the barrier reef). As such, all fishing, extraction, and use of personal watercraft (ex: jetski) is prohibited; however snorkeling, diving, and boating are permitted in the No Take Zone. The Recreational Zone allows snorkeling, diving, boating, personal watercraft use and shoreline recreational hook and line fishing. Catch and release guide-fishing and cast net bait fishing are allowed only with a valid Marine Park Permit. In addition, gill nets used for bait fishing are allowed but cannot exceed eight (8) feet in depth and a span of six hundred (600) feet. All other traditional fishing methods are prohibited in the Recreational Zone (DPNR 2007).



Elkhorn coral outplant cluster fuses together. Photo credit: Jessica Ward

Both TNC and UVI currently have ongoing restoration and monitoring programs at Llew's Reef. TNC is conducting a large-scale restoration project encompassing roughly 50 acres of reef habitat along Llew's Reef, while UVI has several Elkhorn coral (*A. palmata*) monitoring plots. ***Figure 4*** provides a map of the site, illustrating the types of reef habitat present at the site.

Figure 4. Llew's Reef Site Map



Planned Restoration Activities

The targeted restoration components over the ten-year life of the Plan are shown in *Table 8* for the Llew's Reef restoration site. Large-scale outplanting will be carried out at Llew's Reef by TNC as guided by calculated targets. To maintain and enhance ecological and geological features that provide coastal resilience, coral species groups selected represent a diversity of life history traits and morphotypes, including fast-growing framework-builders (e.g., Elkhorn and Staghorn corals - *A. palmata* and *A. cervicornis*), as well as additional slower growing reef-building groups (e.g., Star corals - *Orbicella* and *Montastraea spp.*) and Brain corals (*Diploria and Pseudodiploria spp.*) appropriate to the reef type and habitat conditions. Each species group has differing growth rates and outplanting timelines, also contingent on their life history, morphology, and restoration technique.

The first phase of outplanting is focused on fast-growing (and SCTLD-resistant) Elkhorn and Staghorn (*A. palmata* and *A. cervicornis*) corals propagated in TNC's in-water nurseries, while the second phase includes outplanting of slower growing massive species grown-out in both land-based and in-water nurseries. TNC has current plans to outplant 6,740 corals at this site by the end of 2025 with available funding. This includes the following: 2,720 Elkhorn corals in the reef crest zone by 2024, 1,520 Staghorn corals in the forereef zone by 2025, and 2,500 Brain, Star and other corals in the forereef zone in 2024-2025.

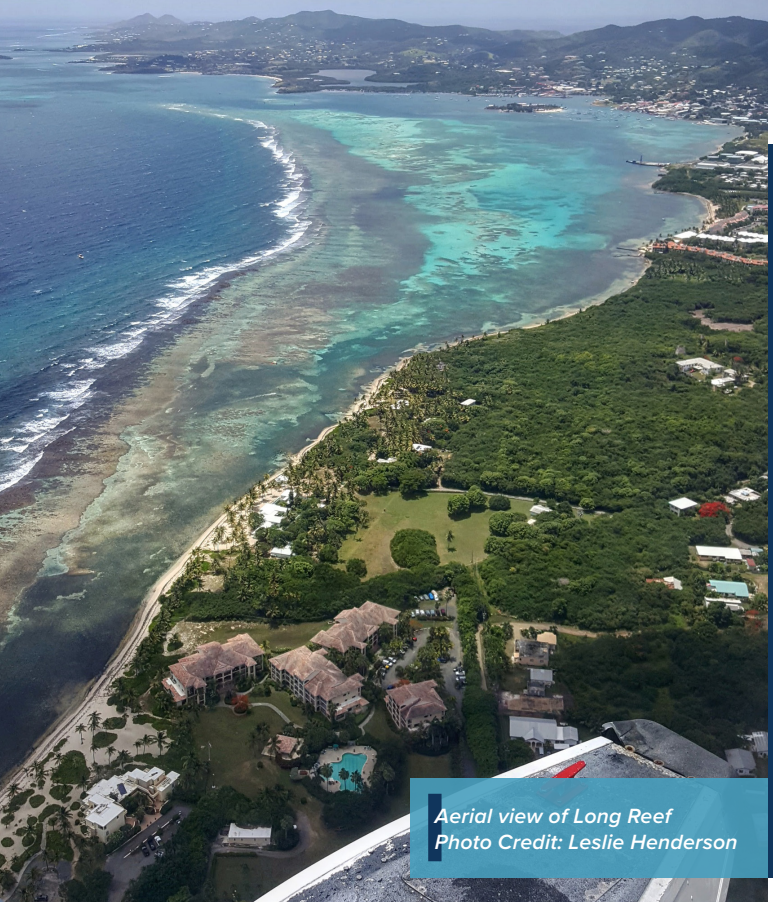
Phase 1 of the plan was initiated in November 2022, with approximately 560 clustered outplants of Elkhorn coral outplanted on the reef crest at Llew's Reef. Additional detailed site-specific planning will be conducted at a later date.

Baseline ecological surveys were conducted by TNC at Llew's Reef in September of 2022; surveys will be conducted biannually to collect data on coral health and abundance and fish diversity and abundance to assess impacts to the overall reef community from restoration efforts. In addition to these surveys, permanent monitoring plots will be established and photogrammetry surveys (i.e., Structure-from-Motion or SfM) will be used to assess survivorship, health, and growth of a subset of tagged outplants as well as to track the expansion of the ecological footprint. Photogrammetry surveys will also be used to create digital surface model products used to monitor changes in the restoration site (e.g., coral growth and loss, changes in structural complexity). By generating digital surface models from stereo photos, small changes in coral growth and loss will be monitored at the millimeter scale based on changes in the three-dimensional structure (e.g., rugosity).

In addition to asexual propagation and outplanting, the TNC program at Llew's Reef also includes facilitated sexual reproduction, involving the collection of coral gametes and propagation of genetically diverse larvae. These are then settled on substrates, allowed to grow out in nurseries past the high-mortality stage, and then outplanted on the reef with the aim of increasing genetic diversity and resilience at the restoration site.

Table 8. Llew's Reef 10-Year Restoration Targets

Llew's Reef Site Totals	
Total Mapped Area (m^2)	**225,163**
Restorable Area of Reef (m^2)	**28,860**
Number of Coral Outplants Needed	
Coral Restoration Components	**Total**
Elkhorn Coral	6,018
Staghorn Coral	2,720
Star Coral	2,779
Brain Coral	2,779
Pillar Coral	0
Other Small Stony Coral	941
Totals	**15,237**



Aerial view of Long Reef
Photo Credit: Leslie Henderson

LONG REEF

ST. CROIX

Current Status and Ongoing Management Activities

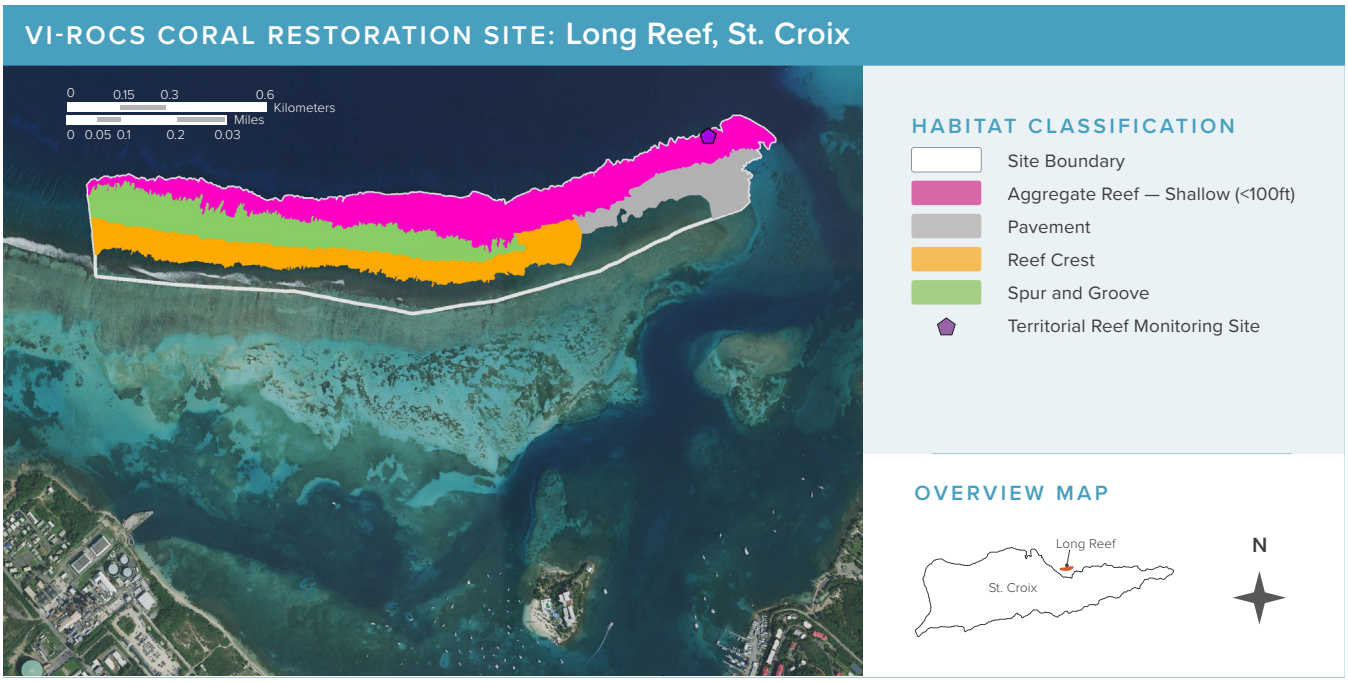
Long Reef does not fall within any current territorial management area, but is an important recreational and commercial area, surrounding one of St. Croix's largest towns, Christiansted. Due to its geographic location, Long Reef, in part, creates the safe harbor upon which Christiansted was built and depends today. Critical infrastructure such as the Richmond Power Plant, seaplane and ferry ports, and an entire waterfront of commercially important restaurants, hotels, shops, and businesses are protected by this reef.

Because Long Reef is adjacent to high urban and industrial development, much of the surrounding waters are classified as Class C bodies of water under the DPNR Amended Water Quality Standards and in alignment with the EPA and the Clean Water Act of 1972. Class C waters are those waters which are located in industrial harbors and ports and have less stringent water quality standards for certain parameters than Class B or Class A waters. DPNR's Division of Environmental Protection has long-term water quality monitoring stations established in and around Christiansted Harbor and conducts regular assessments of human health parameters such as *Escherichia coli (E. coli*). According to the most recent impaired waters report, the Long Reef monitoring station was found to be impaired for pH and the Christiansted Harbor monitoring stations were found to be impaired for pH, turbidity, and E.coli as of 2022 (DPNR 2022).

Despite existing in less-than-ideal water conditions, Long Reef is host to a wide variety of healthy reef-building corals. Their tolerance of Class C water conditions can be viewed as an advantage and makes genotypes on this reef especially valuable when considering planning for future climate and water scenarios. In addition to this ecological value, this site boasts high coastal protection value. The total annual value of all economic activity on St. Croix protected by coral reefs exceeds $21 million (value in 2010 U.S. dollars), with Christiansted Harbor and the surrounding area likely making up a significant portion of that total (Storlazzi et al. 2019). Because the Christiansted area supports a significant amount of economic activity in St. Croix, restoration efforts are needed to protect the surrounding area from coastal flooding and large storm events. The Nature Conservancy, the United States Geological Survey, and the University of California Santa Cruz are completing a modeling project in summer of 2023 that will project the effects of various restoration efforts on coastal flooding and the annual expected benefits to the local economy and community. This information can guide further discussions on the need for investment and the type of restoration that can benefit this reef and the surrounding area.

Long Reef has one long-term TCRMP site at the eastern end of the reef, at a heavily dived site named Eagle Ray. According to recent territorial monitoring data, coral cover gradually rose from about six and a half percent in 2003 to over seven percent in 2009, and about eight percent in 2019. However, the arrival of stony coral tissue loss disease (SCTLD) reduced coral cover to below four percent from 2019-2021. Eagle Ray has been consistently treated approximately once a month for SCTLD since 2020. *Figure 5* provides a map of the site, illustrating the types of reef habitat present at the site.

Figure 5. Long Reef Site Map



Planned Restoration Activities

To date, only one known, historical outplanting event has occurred in this area. The Nature Conservancy outplanted 400 fragments of *A. cervicornis* in 2014, in the spur and groove habitat zone, and the current condition of these outplants is unknown.

The Coral Restoration Foundation (CRF) was recently funded by the NOAA Fisheries Office for Habitat Conservation, through funds made available in the Bipartisan Infrastructure Law, to begin restoration activities at this site in collaboration with DPNR and other VI RoCS members, using this Plan as a guide. Coral Restoration Foundation's expertise and experience working on large scale restoration projects in Florida will build capacity in the territory and significantly contribute to the restoration of this site and potentially elsewhere in the USVI.

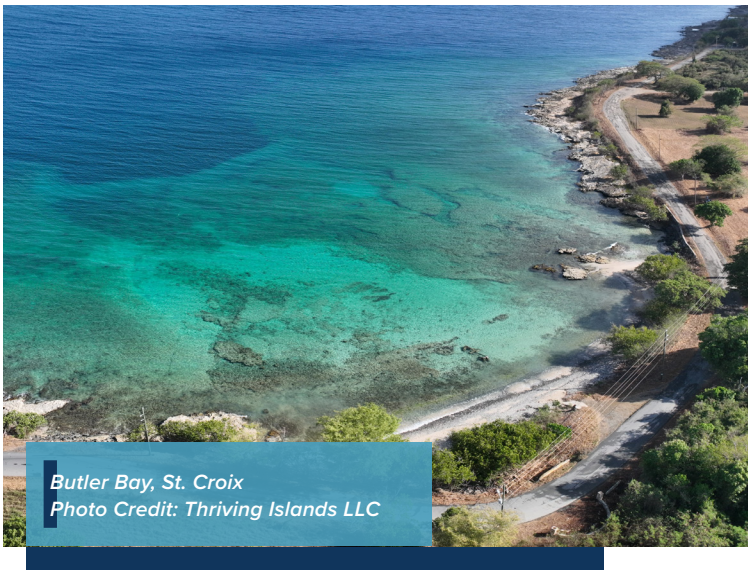
The targeted restoration components over the ten-year life of the Plan are shown in *Table 9* for the Long Reef restoration site.

Table 9. Long Reef 10-Year Restoration Targets

Long Reef Site Totals	
Total Mapped Area (m^2)	**385,933**
Restorable Area of Reef (m^2)	**212,706**
Number of Coral Outplants Needed	
Coral Restoration Components	**Total**
Elkhorn Coral	5,039
Staghorn Coral	0
Star Coral	57,164
Brain Coral	16,259
Pillar Coral	0
Other Small Stony Coral	109,768
Totals	**188,230**



A. palmata monitoring in Butler Bay
Photo Credit: Thriving Islands LLC



Butler Bay, St. Croix
Photo Credit: Thriving Islands LLC

BUTLER BAY

ST. CROIX

Current Status and Ongoing Management Activities

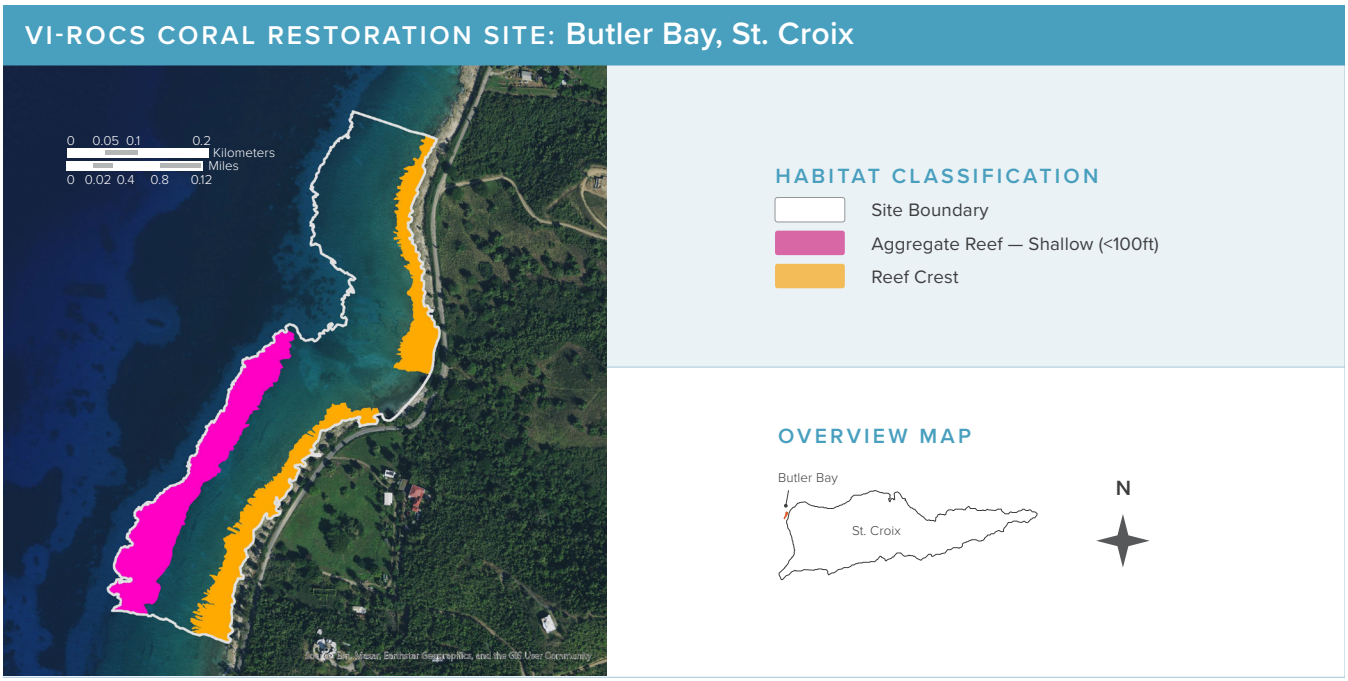
The coastal area of Butler Bay is a popular recreational site and has a history of research activity and a more recent interest in restoration activities. The area is frequented by divers from shore and by boat. Sailing charters and private yachts come from near and far to explore a variety of artificial reefs permitted in the 1970s.

The Butler Bay Artificial Reef Site was designated in 1974. It consists of a group of man-made structures 300-400 m offshore from Butler Bay in water depths of 15-40 m. Material placed within the Artificial Reef site between 1975 and 1984 includes: an old Hydrolab habitat from White Horse Reef off of Judith's Fancy, four large marine vessels including a tanker at approximately 33 m depth, a freighter at 21 m, a barge at 15 m, and a tugboat at 13 m. While these artificial reef structures are not within the planned restoration area, they are important attractions for the bay.

Between the artificial reef structures and the beach are the planned coral restoration areas: the shallow aggregate reef system (~10m) and the nearshore *A. palmata* reef crest zones to the north and south side of the bay (***Figure 6***). Butler Bay and the surrounding waters were identified as an area of 'high resilience' by Maynard et al. in a study funded by the NOAA Coral Reef Conservation Program in 2014 (Maynard et al. 2014). Between 2011 and 2013, Butler Bay was included as part of the UVI Elkhorn coral (*A. palmata*) monitoring program, but was not resampled between 2014 and 2022 due to lack of resources. Long term monitoring plots of *A. palmata* and continued monitoring has been re-established in 2023 by Thriving Islands LLC with support from UVI.

Butler Bay has been a coral disease treatment site since 2020. The aggregate shallow reef within the restoration site is currently treated once per month for active disease presence. ***Figure 6*** provides a map of the site, illustrating the types of reef habitat present.

Figure 6. Butler Bay Site Map



Planned Restoration Activities

Restoration activities at Butler Bay are focused on two main geographies: nearshore restoration areas (currently classified as "reef crest" due to its shallow water and high abundance of *A. palmata*) and the aggregate shallow reef at 10 m. There are three main target restoration activities planned:

1. Propagation and monitoring of Elkhorn coral (*A. palmata*) in an in-water nursery. Plans are underway to install an in-water nursery in Butler Bay that will be operated by Thriving Islands LLC.
2. Using corals of opportunity to replant the aggregate shallow reef with any loose *Montastraea cavernosa*, *Orbicella spp.*, *Pseudodiploria strigosa*, and *Psuedodiploria clivosa*.
3. Facilitated sexual propagation of brain corals (ex. *Diploria labrynthiformis*).

More detailed site-specific planning is currently underway for Butler Bay. As such, zones and targets will likely be adjusted as additional data is gathered and ground truthing efforts provide more information about in-water conditions. The targeted restoration components over the ten year life of the Plan are shown in *Table 10* for the Butler Bay restoration site.

Table 10. Butler Bay 10-Year Restoration Targets

Butler Bay Site Totals	
Total Mapped Area (m^2)	**44,776**
Restorable Area of Reef (m^2)	**38,741**
Number of Coral Outplants Needed	
Coral Restoration Components	**Total**
Elkhorn Coral	6,154
Staghorn Coral	0
Star Coral	528
Brain Coral	826
Pillar Coral	0
Other Small Stony Coral	1,734
Totals	**9,243**

SWEEPER'S COMPLEX

ST. CROIX

Current Status and Ongoing Management Activities

This site is located within the Recreational Zone of the St. Croix EEMP, managed by DPNR (Brown et al. 2016). This zone allows snorkeling, diving, boating, and personal watercraft use; hook-and-line fishing from the shore is also allowed. This zone also has provisions for permit-only cast net bait fishing and catch-and-release guide fishing. In addition, Cotton Garden Bay is a designated mooring and anchoring area, indicating that personal moorings could be installed here with a permit from DPNR's Division of Environmental Enforcement. However, due to its remote, untended location, no boat owners in the recent past have requested or installed moorings in this bay.

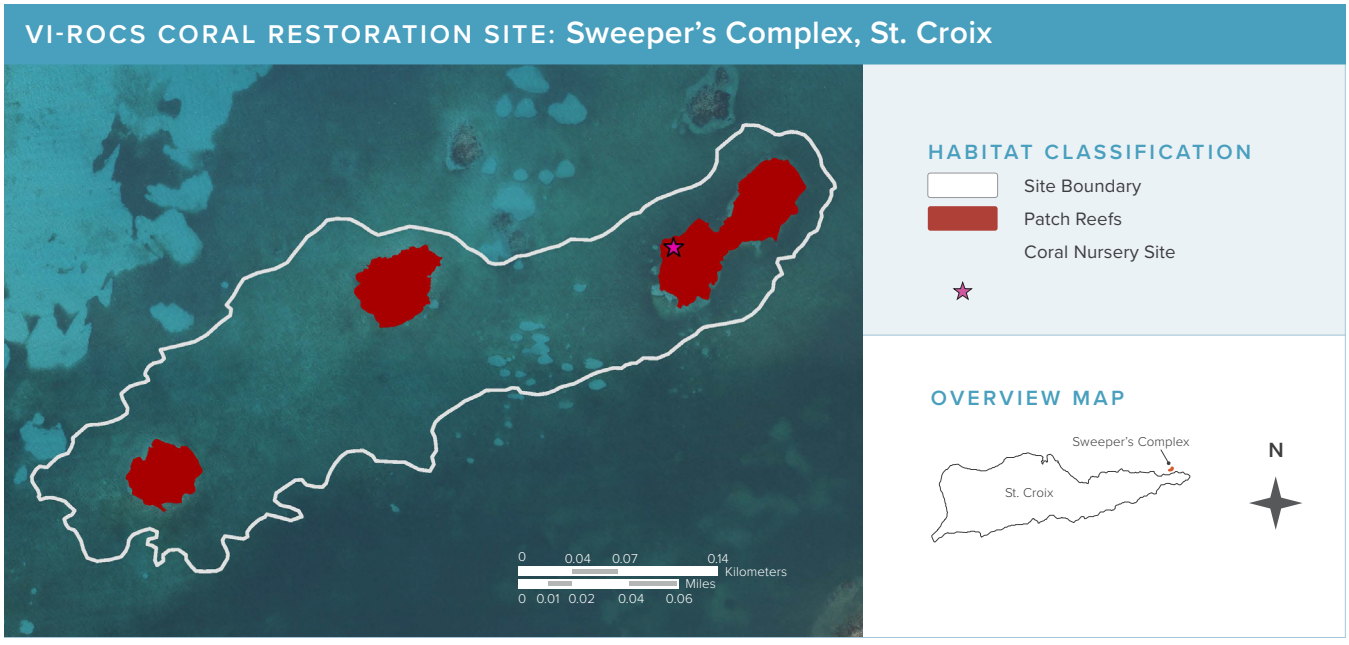
DPNR CZM East End Marine Park staff are responsible for maintaining an in-water demonstration nursery at the Sweeper's Knoll Patch Reef 6 (PR-6) site which was initially installed in March 2019. When deemed large or successful enough to sustain outplanting, fragments have been moved to suitable sites on the south end of the patch reef. A permanent, rectangular plot (10 m x 6 m) was established in 2019, and a photomosaic was produced by TNC in 2020.

Monitoring of outplants was done to Coral Restoration Consortium (CRC) standards and methods in 2021, but has not been repeated (Goergen et al. 2020). Stony coral tissue loss disease arrived on Sweeper's Knoll in mid-2021 and received limited antibiotic treatment on large colonies, with mixed success.

Two summer student research projects, executed by UVI undergraduates, have have used these reefs as field research sites. In 2021, students monitored outplants and followed SCTLD progression on PR-6. They found that out of 66 corals, comprised of 8 species, that were outplanted to the reef since 2019, 97% had survived. In 2022, a student monitored the progression of the sea urchin *Diadema antillarum* die-off on all three patch reefs. During the course of the surveys, both population density and individual urchin health decreased at each of the three patch reefs (Boissiere 2022).

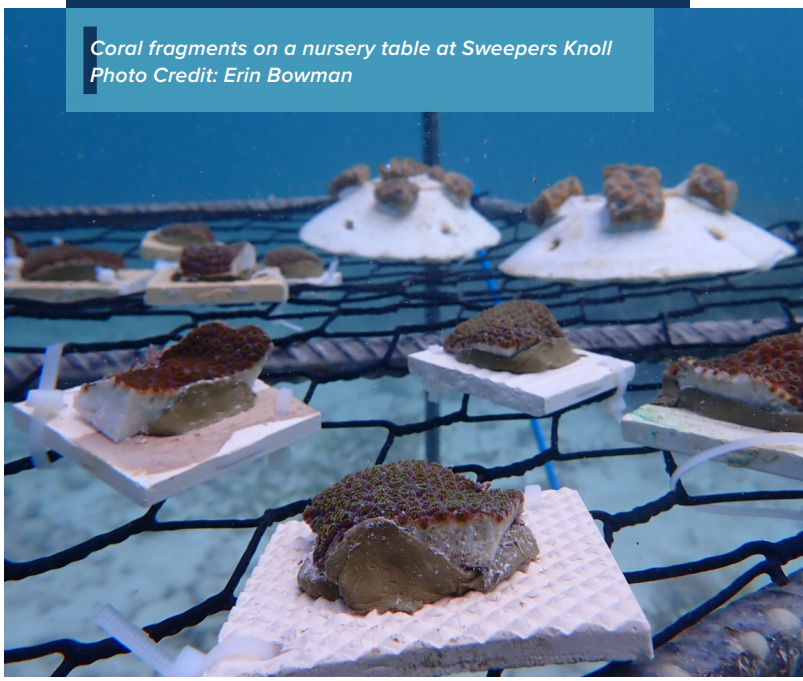
Patch Reef 2 (furthest west) and Patch Reef 3 (center) have not had any restoration interventions to date, but are similar in nature to PR-6 (furthest east) and will be sites for future restoration. *Figure 7* provides a map of the site, illustrating the location of the three patch reefs.

Figure 7. Sweeper's Complex Site Map





Aerial of Patch Reef 6, part of Sweeper's Complex
Photo Credit: MJS Visions



Coral fragments on a nursery table at Sweepers Knoll
Photo Credit: Erin Bowman

Planned Restoration Activities

As the nursery at this site is principally established for demonstration purposes, it explicitly has limited production. Capacity at the site has ranged from 51 corals on 2 tables to a maximum of 79 corals on 3 tables. Population of the tables has occurred through both (1) collection of fragments of opportunity and (2) fragmentation/microfragmentation of targeted donor colonies (with support from TNC).

In collaboration with NPS, the DPNR EEMP team relocated 26 large coral colonies from Christiansted Harbor to PR-6 in July of 2022. These colonies were removed during bulkhead replacement works in front of Fort Christianvaern and placed into a coral "cache" in the harbor in 2021, which was sporadically treated for SCTLD. EEMP staff worked with NPS to prioritize and relocate the large colonies to PR-6 and these colonies are now monitored during regular visits to the site.

Outplanting does not happen on a strict schedule but depends on the successful growth of table-husbanded fragments. Historically, this has involved one outplant event per year. Site preparation is characterized by removal of macroalgae and filamentous algae by hand and with abrasive tools. The EEMP intends to repeat the CRC monitoring method on a schedule of approximately every two years.

The targeted restoration components over the ten-year life of the Plan are shown in *Table 11* for the Sweeper's Complex restoration site.

Table 11. Sweeper's Complex 10-Year Restoration Targets

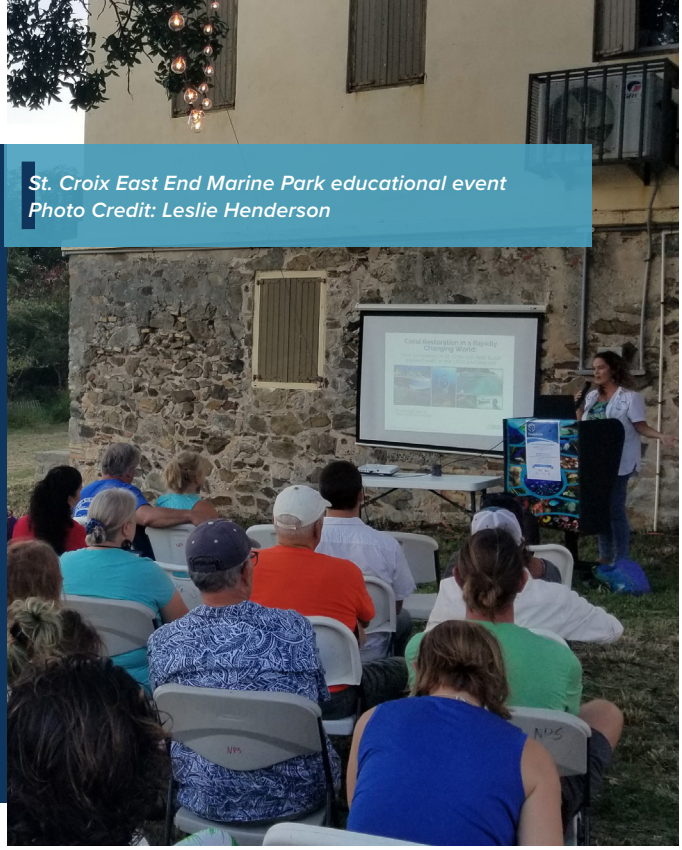
Sweeper's Complex Site Totals	
Total Mapped Area (m^2)	**5,751**
Restorable Area of Reef (m^2)	**5,021**
Number of Coral Outplants Needed	
Coral Restoration Components	**Total**
Elkhorn Coral	1,314
Staghorn Coral	17
Star Coral	870
Brain Coral	2,655
Pillar Coral	0
Other Small Stony Coral	1,355
Totals	**6,212**

Stakeholder Engagement and Outreach

This Plan will be used to guide activities by local coral restoration practitioners and managers. The Plan will be publicly available on the ***DPNR website***. The Plan will foster improved communication and coordination across inter-island partners by providing a benchmark of stated goals and targets to track coral restoration success. VI-RoCS will continue to meet periodically to facilitate information sharing as the Plan is implemented, and to foster collaboration and communication among coral reef restoration practitioners and stakeholders throughout the USVI. Future efforts by VI-RoCS will include developing an online ESRI tool that will help with coordinating implementation of coral restoration in the USVI. This ESRI tool will also have a public-facing version that will be viewable by anyone with interest.

Ongoing and planned outreach and education efforts related to coral restoration at the priority sites includes:

- **Coral World Ocean Park at Coki Point**
  As the only public aquarium on St. Thomas, CWOP is an important marine educational resource for the territory providing interpretation of coral restoration efforts. The park's underwater observatory tower and SNUBA® and SEATREK® operations provide opportunities for the public to view coral restoration and conservation efforts. The Coral World website (***coralworldvi.com/***) provides an array of educational materials related to corals and coral restoration.
- **Coral World Ocean and Reef Initiative (CWORI) Educational Opportunities**
  CWORI (***cwori.org/education-internships-jobs/***) currently provides internship opportunities in coral restoration. Interns gain practical experience in coral restoration techniques and coral nursery management, and help with citizen science events. CWORI also offers educational programs in association with educators in local schools.
- **The Nature Conservancy efforts on St. Croix**
  Various efforts to inform and engage the public are undertaken by TNC on St. Croix. These efforts include discussion of TNC's ongoing coral restoration projects in the USVI.
  - Provide weekly tours of the Coral Innovation Hub (currently Tuesdays at 2pm, RSVP to ***Lisa.terry@tnc.org*** or ***Macallan.durkin@tnc.org***). Many of the corals grown at the Hub are eventually outplanted at Llew's reef.
  - Offer lab-based and field-based programming for student field trips and summer camps. Lab-based programming includes a tour of the lab plus an activity, while field-based programming includes a presentation on coral restoration and a snorkel activity.
  - Host UVI summer undergraduate interns, Master of Marine and Environmental Science students, and workforce fellows in collaboration with the UVI SEAS Islands Alliance program.
  - Provide volunteer opportunities and community presentations to schools, community groups and neighborhood associations on request.
- **University of the Virgin Island's Reef Response Program (*reefresponse.org*)**
  This coral restoration program based out of UVI was founded in 2017 when the Flat Cay nursery was transitioned from TNC to UVI. The organization started as a citizen science program in which personnel worked alongside local dive shops to train recreational divers in in-water nursery techniques. Reef Response has since evolved into a more formal entity at the university, facilitating coral restoration efforts through best scientific practices and expanding citizen scientist opportunities. Currently, Flat Cay is the largest in-water, coral-production nursery operated by Reef Response. This and the Reef Response land-based nursery serve as training sites for land-based and in-water coral husbandry techniques and basic coral health assessments for undergraduate interns, graduate interns, citizen scientists, visiting researchers and school groups. Corals reared at



St. Croix East End Marine Park educational event
Photo Credit: Leslie Henderson



Coral World Ocean Park at Coki Point
Photo Credit: Logan Williams



VI Reef Response divers
Photo Credit: Dan Mele

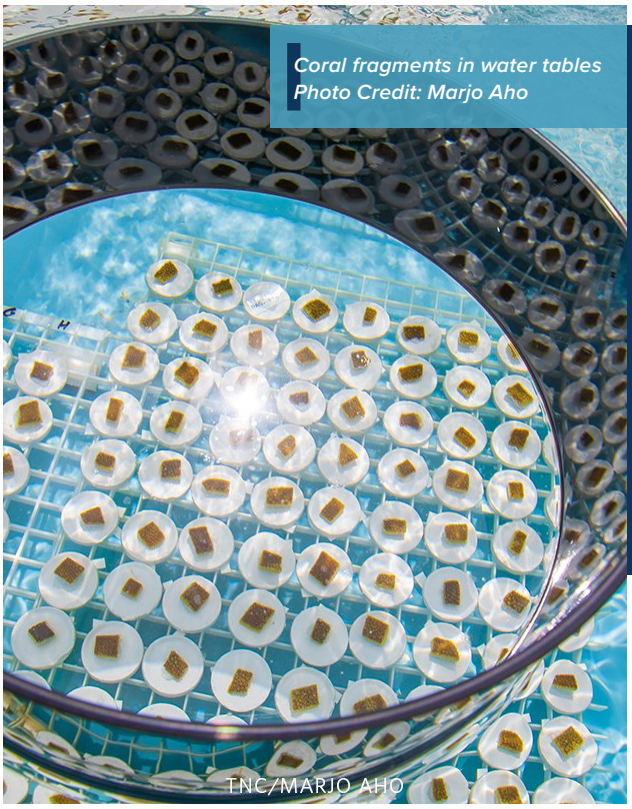
the nursery will be used to meet the Flat Cay site restoration goals and will be outplanted by the Reef Response team, interns, and interested participants as part of future restoration workshops.
Reef Response also operates and maintains two additional in-water coral nurseries, including a rebar table nursery easily accessible by tourists off the south coast of Lovango Cay. In a partnership with the Lovango Resort and Beach Club, signage was created by Reef Response and installed at the Resort, and a ***booklet*** documenting the restoration process was created and is being distributed to local stakeholders, schools, and other interested parties. Reef Response regularly contributes to UVI, DPNR, and Virgin Islands Marine Advisory Service (VIMAS) outreach events, including Afternoon on the Green, Science Saturday, Reef Fest, and Youth and Junior Ocean Explorers. Reef Response maintains a website (***reefresponse.org***) and a social media presence where operations are documented.

- **East End Marine Park snorkel tour**
  EEMP staff offer a quarterly nursery snorkel to Sweeper's Knoll for strong swimmers ages 14 and up to visit the site and observe both nursery and outplanted corals. The Park also occasionally involves students in research projects at the site and volunteers in some of the outplanting activities. The EEMP has a visitor center which showcases a wide variety of environmental education exhibits including many about coral reefs.

- **DPNR Division of Coastal Zone Management Coral Reef Initiative**
  The USVI is slated to host the U.S. Coral Reef Task Force in the Fall of 2023 on St. Thomas. Preliminary plans include a variety of field-based activities to educate federal partners and jurisdictional managers on priority needs and areas in the USVI. Potential snorkel trips to priority restoration sites are being considered as well as informative, in-water sessions to identify and treat SCTLD. The ***Coral Reef Initiative*** is also planning on hosting a USVI Coral Reef Week event in 2024 which will highlight all coral management and conservation work done by the partners listed in this Plan, among others. This event may include land-based and in-water nursery tours, fragging demonstrations, and coral disease identification and treatment at priority sites. This event will hopefully become a standing annual event for the territory and will serve as a wonderful platform for coral restoration outreach and education.

Cost Estimate

This section presents a high-level budget to provide an understanding of the funding necessary to execute this effort and give a sense of the scale of the Plan. It is anticipated that a mix of existing and new private and public sector funds will be utilized to implement the actions described in this Plan. Costs were estimated based on practitioners' real-world experience with restoration projects in the USVI. Given the established nursery infrastructure in the USVI, cost per coral (including all costs associated with growing and outplanting the corals) is well understood for these sites. Similarly, given ongoing restoration efforts in the USVI, the costs associated with monitoring and maintenance are well documented. Based on the restoration requirements in the Plan, estimated average cost per coral outplanted, costs for monitoring/maintenance, and anticipated contingency costs, the estimated cost for each site was calculated. *Table 12* presents total costs estimated for each site over the ten-year life of the Plan. *Appendix E* provides additional detail on how cost estimates were developed for the activities presented in the Plan.



Coral fragments in water tables
Photo Credit: Marjo Aho

Table 12. Estimated Total Cost for USVI Coral Reef Restoration Plan over 10 Years

Island	Site	Restorable Area (m^2)	Number of coral outplants	Cost
St. Thomas 	Flat Cay	42,352	56,578	$17,796,634
	Coki	5,662	8,879	$3,211,710
St. Croix 	Llew's Reef	28,860	15,237	$6,251,457
	Long Reef	212,706	188,230	$58,075,851
	Butler Bay	38,741	9,243	$3,053,805
	Sweeper's Complex	5,021	6,212	$2,278,296
Total		**333,341**	**284,380**	**$89,971,623**



Divers prepare to conduct coral and fish monitoring surveys
Photo Credit: Leslie Henderson

Conclusion

A team of coral restoration experts (VI-RoCS) collaborated to produce this Plan, fulfilling the objective identified in the ***USVI Coral Reef Management Priorities: 2020-2025*** of developing a prioritized restoration plan (Rothenberger and Henderson 2019). The Plan focuses on USVI coral reefs occurring in marine waters managed by the USVI government, establishing site restoration targets to restore six prioritized sites on St. Croix and St. Thomas over a 10 year timeframe. While this Plan developed restoration requirements (i.e., the number and types of corals to be outplanted) for each of the priority sites by coral reef habitat zone, additional site-specific planning to meet specific ecological indicators will be conducted as funding is obtained for each of the sites. Similarly, monitoring protocols will be established for the sites in the future.

VI-RoCS is also developing an online ESRI mapping tool that will host relevant local coral reef data and be accessible to all VI-RoCS members. For the priority sites, the tool will display habitat zones, targets, and other relevant metrics for ease of access and transparency. The tool will be updated annually by VI-RoCS with new coral outplant data. This tool will provide a means of tracking progress towards specified outplant targets in each habitat zone. As more rigorous coral reef restoration data monitoring protocols are developed, and standardized monitoring data at priority sites becomes available, these data could also be displayed visually and tracked annually within the ESRI mapping tool.

VI-RoCS anticipates continuing to meet periodically to evaluate progress under the Plan and to determine next steps prior to the end of the 10-year timeframe covered by the Plan. Meeting outplanting targets is an important step in the restoration of the priority sites; however, to ensure long-term success, VI-RoCS understands the need for and is committed to long-term site stewardship, monitoring, and adaptive management.

Appendix A: ISLAND SPECIFIC GOALS

As part of the goal development process, island-specific goals were initially developed by the planning teams for each island. Below is a summary of the general goals developed for each island and the key problems each is intended to address.

ST. THOMAS GENERAL GOALS

1. **Stewardship:** *Increase coral reef stewardship and awareness via new opportunities for local community engagement with current coral restoration programs for individuals at every career stage high-school level and above.*

   Key problems addressed:

   - Low community awareness of coral restoration including the need for it and activities
   - Lack of diversification in investment access by not including tourism sector via stewardship
   - Low levels of public-private partnerships to garner more support for restoration activities
   - Need to increase community buy-in, currently only narrow, need more overall and cohesive understanding of the need for restoration and addressing threats to coral reefs
   - Inaccessibility of coral restoration sites for community and education
   - Lack of awareness of economic role of coral reefs to island communities
   - Lack of appreciation of the importance of the natural resource for resilience, storm surge protection, promoting food security, aesthetics, etc. e.g., overall ecosystem services
   - Need for increased personal connection to coral reefs for individuals who do not work in tourism sector

2. **Resilience:** *Increased success (survivorship, persistence, and productivity of restored species in the face of multiple stressors) of coral outplants/restoration, with consideration of connectivity.*

   Key problems addressed:

   - Lack of resilience in previously outplanted populations
   - Restoring reefs without considering resilience could lower the reach per unit effort
   - Need for increased resilience to act as contingency plan to address multiple stressors, including learning from past lessons (such as Hurricane Irma impacts), as well as putting in place means to address future stressors

3. **Diversity:** *Test and promote inclusion of genotypic/species/taxa diversity in coral reef restoration.*

   Key problems addressed:

   - Loss of habitat structure due to synergistic stressors, need for more diversity to allow the restoration of structure important for fisheries and increased shoreline protection.
   - Lack of diversity in prior outplants
   - Need for improved reef structure restoration
   - Need to promote adaptability of these species through genetic diversity
   - Lack of restoration that provides self-sustaining populations, and recruitment

ST. CROIX GENERAL GOALS

1. **Resilience:** *Coral cover on permanent monitoring transects reaches and does not decrease below 10 percent at restoration site(s).*

   Key problems addressed:

   - Losses from stony coral tissue loss disease
   - Need to increase percent cover from low-susceptible species first while maintaining genetics of highly-susceptible species and including resilient genotypes (if available) in outplanting

2. **Stewardship:** Promote local coral reef stewardship

   Key problems addressed:

   - Wider USVI community and decision makers do not make coral reef health and persistence a priority in their daily habits and decisions

3. Representation: To encourage and enable representation of Virgin Islanders in coral restoration

   Key problems addressed:

   - Knowledge of, experience with and interest in the marine environment
   - Lack of local student awareness of opportunities associated with coral restoration

REFINED ISLAND-SPECIFIC GOALS

The island teams further refined these general goals to provide specific, measurable, achievable, relevant, and time bound priority goals. These are described in the following table.

Table A-1. Island-Specific Priority Goals

Island	Refined Priority Goals
St. Thomas 	1. Within 5 years, provide access to successful coral restoration demonstration sites through both virtual/remote and in-person platforms. 2. Within 5 years, provide at least 2 opportunities for community buy-in to these locations.Within 10 years, demonstrate persistence (survivorship and productivity of restored species) of outplanted coral populations across multiple sites in the face of environmental change and human impacts. 3. Within 5 years, establish 3-5 sites that measure the impact of diverse outplanting such as incorporating multi-genotypic, multi-species, and multi-taxa considerations in restoration.
St. Croix 	1. In recognition of the challenges presented by SCTLD and the expected declines in coral cover at impacted reefs, over the next 10 years coral cover on permanent monitoring transects reaches and does not decrease below 10 percent at restoration site(s). 2. Using periodic exit surveys of EEMP Visitor Center visitors, increase awareness of and understanding of coral restoration benefits to 40 percent by 2025. 3. To encourage and enable representation of Virgin Islanders in coral restoration through volunteer opportunities, internships, and careers by providing four field trips per year for the next five years to public elementary or high school classes to either the EEMP Visitor Center and the Sweeper's Complex demonstration site and/or the TNC Coral Innovation Hub.

Appendix B: DETAILED INFORMATION ON SITE SELECTION

This appendix provides a description of the process and rationale applied to identify the initial sites considered for restoration efforts, and final selection of priority sites. As mentioned above, site selection focused on St. Thomas and St. Croix; a separate coral restoration planning process has previously been completed by the National Park Service, which covers most of the key sites in St. John. From August 2021 through March 2022, each island subteam (St. Thomas and St. Croix) met several times to determine priority sites. Sites were initially identified based on team members' knowledge and experience in the region. Factors considered when identifying potential sites included (but were not limited to): management and monitoring in effect, ecosystem services provided by the reef, availability of information regarding the site, connectivity, suitability of site for outplanting, and the potential for long-term success of outplanting.

A description of the rationale for including each potential site in the process is included in Table B-1. During the next step (described further below) these potential sites were further evaluated to determine which should be chosen as priority sites.

Table B-1. Rationale for Consideration of Potential Sites

Region	Site Name	Rationale
ST. THOMAS 		
COKI BAY	Coki*	This site combines three areas: Coki World Tower, Coki Central, and Coki East Beach. The Coral Coki World Tower area is very accessible, protected with swim buoys, has high tourism value, has good visibility and consistent observation, and can be used for educational purposes. The Nature Conservancy previously outplanted 400 acres (destroyed by hurricane Hurricane Maria) at this site. The Coki Central area is frequently visited, providing high tourism value; it is also a SCTLD intervention site and an active monitoring site. There is good water flow/current here. Coki East Beach has easy access, Endangered Species Act listed Acroporids, and is used for educational purposes. It has recent outplants and is an intended outplanting location for a Virgin Islands Territorial Emergency Management Authority (VITEMA) funded hazard mitigation grant to UVI.
	Coki West	This is a potential future site; it is not being considered at this time because of resource considerations and because it has not been well explored.

Region	Site Name	Rationale
ST. THOMAS		
UNIVERSITY/ AIRPORT/ STT SW	**Fortuna**	Fortuna is a current UVI *Acropora* outplant site, which is shallow and accessible. The site has driving access and is a DOI grant site. Fortuna west reef is a SCTLD-focused restoration site.
	Perseverance Bay	This is a current UVI *Acropora* outplant site in an undeveloped watershed, which is boat accessible from UVI. It is the site of a multi-species outplant experiment (in early 2022).
	Black Point	Black Point is a historical outplanting site, long-term coral reef monitoring site, and accessible from UVI. This site has outplants that are returned corals from experiments, and will likely be a priority in the future.
	Brewer's Bay	This is a long-term coral reef monitoring site and an intended outplanting location for a VITEMA-funded hazard mitigation grant to UVI. It is accessible from UVI.
	Flat Cay*	Flat Cay is a long-term coral reef monitoring site and an intended outplanting location for a VITEMA-funded hazard mitigation grant to UVI and. This is a data-rich area from a long history of scientific studies conducted at the location by UVI. The site is easily accessible by boat from the UVI dock. Flat Cay has *Acropora* monitoring sites as well.
	Range Cay	Range Cay is accessible from shore. It has mangrove outplants on its shoreline and provides significant university outreach/education and monitoring potential; it is located next to the land-based coral nursery at UVI.
	Saba	Outplants at Saba did not do well during storms; thus investment in this location is unlikely.
	Porpoise Rocks	Outplants at Porpoise Rocks did not do well during storms; thus investment in this location is unlikely.

Region	Site Name	Rationale
ST. THOMAS 		
HULL BAY/ MAGENS BAY (including Peterborg/Hull Bay)	**Hull Bay Disease Intervention Site**	This is an SCTLD intervention site with disease response investment and ongoing monitoring. It is accessible from shore and an intended outplanting location for a VITEMA-funded hazard mitigation grant to UVI.
	Peterborg Point	This site is shoreline accessible and frequently visited by snorkelers and local fishermen. It is a SCTLD intervention site, an *Acropora* test outplanting site, and an Area of Particular Concern (APC). The local neighborhood association has requested a restoration partnership.
	Magens Bay	Magens Bay is an APC and a long-term coral reef monitoring site.
	Neltijeberg Bay	This was a TNC site in the past (50 colonies outplanted in 2020), but will likely not be considered in the future.
	Hendricks	Hendricks is a protected reserve and watershed. There is no planned outplanting here as it is hard to access.
BUCK ISLAND	**Buck Island (West)**	This is a VITEMA-funded restoration site.
	Buck Island (historic)	This is a historic outplant site for TNC and an intended outplanting location for a VITEMA-funded hazard mitigation grant to UVI. Staghorn coral did not do well here.

Region	Site Name	Rationale
ST. THOMAS 		
EAST END (includes St. Thomas East End Reserves, Sapphire, Dog Island, St. James)	**Nazareth**	Nazareth was a TNC outplant site in 2012, but was not successful.
	Sapphire	Sapphire was used as a source of fragments. Post-maria stabilization efforts were conducted by NOAA and SeaVentures but it is not currently a restoration site. The site has nearshore easy access via snorkel, has a marina, and is economically a good restoration location, close to Coral World.
	Great St. James North/ Belmar	This is a historic TNC site that was later assessed by the UVI Masters of Marine and Environmental Science Capstone research project. It is a mooring site, easily accessible, with good water quality, water flow/ currents, and an estuary connection. This is also a potential disease intervention site and an intended outplanting location for a VITEMA-funded hazard mitigation grant to UVI.
	Great St. James South	This is a historic TNC site where restoration will continue by UVI. There is a mooring, and a nursery, but not too much outplanting in this location.
	Stragglers	This is a historic TNC site that was later assessed by the UVI Masters of Marine and Environmental Science Capstone research project. It is a mooring site, easily accessible, with good water quality, water flow/currents, and an estuary connection. This is also a potential disease intervention site and an intended outplanting location for a VITEMA-funded hazard mitigation grant to UVI.
	Cocculus	Cocculus is located within the St. Thomas East End Reserves (STEER). It has high settlement and is a SCTLD intervention site and long-term coral reef monitoring site and an intended outplanting location for VITEMA-funded hazard mitigation grant to UVI.
	Little St. James	This is a VITEMA-funded restoration site.
	Less St. James	This is a historic 2017 coral outplanting site, but there are no future plans here.
	Secret Harbor	Secret Harbor is a potential VITEMA-funded restoration site.

Region	Site Name	Rationale
ST. THOMAS 		
NE OFFSHORE CAYES (Thatch, Grassy, Mingo Lovango, Congo)	**Lovango Restored Zone (North)**	This site has potential for partnership with Lovango Resort & Beach Club. It is offshore with good water flow and good access for community engagement.
	Lovango Research Zone (South)	This site has potential for partnership with Lovango Resort & Beach Club. It is offshore with water flow, has a high current and less access potential; oceanographic equipment has been ordered for monitoring (wave height, period, etc.).
	Thatch	Thatch is a UVI site for monitoring *Acropora*, but not for outplanting. This cay is privately owned and for sale.
	Mingo	This cay was donated as a land trust. Potential opportunity for underwater protection in future.
BOTANY POINT / SANDY BAY (West End)	**Botany Bay**	This is a long-term coral reef monitoring site where *Acropora* is being monitored. It is a planned outplanting location.
	West Cay	This monitoring site was turned over from TNC to UVI. There were some *Acropora* that were abandoned due to calcareous algal overgrowth and inaccessibility.
	Triangle Rocks	This is a VITEMA-funded restoration site.

Region	Site Name	Rationale
ST. CROIX		
WEST SIDE	Butler Bay*	Local partner (Thriving Islands LLC) that owns adjacent land is interested in investing in the reef. They actively participate in coral disease interventions. It is a SCTLD intervention site and shore access is available. The site is very warm in summer and has potential sedimentation issues.
	King's Corner	This is an active SCTLD intervention site with high connectivity, and a diverse coral population. King's corner is a shallow, popular dive site, with long-term coral reef monitoring in place. (Could combine King's Corner and King's Alley as one unit)
	King's Alley	This is an active SCTLD intervention site with high connectivity and a diverse coral population. King's Alley is a popular dive site, with more fish than King's Corner. (Could combine King's Corner and King's Alley as one unit)
	Sprat Hall	Sprat Hall is a long-term coral reef monitoring site with an established healthy reef.
NORTHEAST EEMP	Sweeper's Complex*	This is a demonstration nursery located at a public park (Cramer's Park) on the beach with easy access and downstream connectivity. This site connects to a continuous barrier reef, and is in a 'no traditional fishing' area within the St. Croix EEMP.
	Llew's Reef*	The Nature Conservancy has funding for Llew's Reef from the National Coastal Resilience Fund. It is an important barrier reef for resilient coastal communities that is upstream of other reefs (important connectivity consideration), connected to the Northern barrier reef, is in a 'no traditional fishing' area, is in close proximity to Buck Island, and has a higher abundance of parrotfish. This site is within the St. Croix EEMP, is a SCTLD intervention site, a long-term coral reef monitoring site, and there is a Yacht Club in the bay (outreach potential).
	Green Cay	The focus at this site would be on the east side only. There is a lot of fishing on the west side (although it is not legal right near the cay). There is high wave action on the north end, good tourism value (guided kayak tours), and healthy large coral in shallow areas. This area is owned by The U.S. Fish and Wildlife Service.

Region	Site Name	Rationale
ST. CROIX		
NORTHWEST	**Cane Bay**	Cane Bay has a significant history of outplanting. While there are sedimentation issues in certain areas, this could be and has been a nursery site. It is a high value tourism site and active dive site. There is spearfishing here but less commercial fishing. The Nature Conservancy may be moving away from outplanting here due to water quality and outplant survivorship issues. There is an established reef over a large depth gradient. The site is very accessible and is a diverse area in terms of species, but was hit hard by SCTLD. It is a SCTLD intervention site and long-term coral reef monitoring site.
	North Star	This site is similar to Cane Bay. There is less sedimentation (but still high), but it is harder to access. The coral was relatively healthy here prior to SCTLD. It is a popular dive site, less impacted by divers and snorkelers, and has highly diverse coral assemblages.
	Ham's Bluff	This site is very hard to get to, but it has the highest coral cover in St. Croix, great water quality and circulation, and high wave energy. This would be an interesting site to choose for a seeding project. There is limited access, and a lot of trap/recreational fishing occurs here.
	Davis Bay/ Carambola	This site has easy access, with a hotel with a dive shop nearby. It used to have high coral cover; however, algal cover is high within the past five years. It has potential watershed/land use pollution issues.
CHRISTIANSTED	**Round Reef**	Round Reef is a NPS transplant site. Boats hit the reef here often so it is not recommended as a restoration site, but it may be worth including data in the outplant/transplant database (for reference - not for inclusion in restoration site list).
	Long Reef*	The Long Reef site includes Eagle Ray, which is a long-term coral reef monitoring site, SCTLD intervention site, and recreational use site. It also includes the WAPA site. While water conditions are poor, this site is important for coastal resilience and storm protection. This is a candidate for long-term restoration for hardy corals. The Nature Conservancy has photos and diversity estimates for specific areas (WAPA, Turquoise Bay, Sugar Beach).
	Buccaneer	There was some TNC outplanting at this site in 2014. It is a nearshore snorkeling site where tourists frequent the beach; there is a hotel onshore.

Region	Site Name	Rationale
ST. CROIX		
	Pavilions	The Nature Conservancy previously outplanted at Pavilions in 2017. It is close to TNC's Estate Little Princess lab, and is on a high-value reef for shoreline protection.

** Site included as one of the chosen priority sites.*

Team members then ranked the sites, using a semi-quantitative framework outlined in *A Manager's Guide to Coral Reef Restoration Planning and Design* (Shaver et al. 2020)). This guide helps managers and practitioners make critical decisions about where and how restoration could be conducted. The framework considers three key factors:

- Relevance to restoration goal
- Factors related to short- and long- term coral survivorship (e.g., climate vulnerability)
  - Future exposure
  - Resilience/ecological processes
  - Human impacts
- Potential to improve site condition

Because not all members of the group were thoroughly familiar with each site, the ranking exercise provided input, but was not solely used to eliminate or choose specific sites.

Upon reviewing the results of the semi-quantitative ranking, VI-RoCS met in early 2022 to determine final priority sites. The group considered various factors in choosing the final priority sites, including the ranking, feasibility (e.g., suitability of the site for outplanting, human impacts at the site), whether a site had any established or planned funding source, and distribution of site locations across the region. Each member of the group selected their top three sites and those with the greatest number of responses were chosen as the final priority sites. These six sites are just the starting point for territorial coral restoration planning efforts, and other sites will be added as resources and time permit. *Table B-2* describes the rationale for each of the priority sites.

Table B-2. Summary of Rationale for Priority Sites

Island	Site Name	Summary of Rationale
ST. THOMAS 	**Flat Cay**	Flat Cay is a long-term monitoring site under TCRMP, demonstrating the greatest rate of recovery of all TCRMP sites after the 2005 bleaching event. The reef structure is largely intact and this is likely a high coral growth potential site. Proximity to the UVI coral nursery and UVI's Center for Marine and Environmental Science provides a significant logistical advantage. Some NOAA funding has already been secured for outplanting, and this site is an intended outplanting location for the VITEMA-funded hazard mitigation grant to UVI. This site is also the focal location for restoration using thermal- and disease- tolerant larvae funded by a National Marine Sanctuary Foundation grant. The reefs that surround Flat Cay are vibrant and diverse, with high rugosity at both the reef crest *Acropora*-dominated habitats and shallow aggregate reefs dominated by Orbicella species. It is offshore, which reduces impacts from local conditions including sedimentation, although there are concerns that its downstream position from Crown Bay/Gregorie Channel and the water treatment plant at Red Point contribute to pollution and introduction of pathogens. Declines in corals were preliminarily related to ocean warming, with later impacts from Ramicrusta, and SCTLD. There is a diverse fish community, though the area is not protected, resulting in some vulnerability from fishing activity.
	Coki	Coki is an active SCTLD intervention and monitoring site that is co-managed by Coral World Ocean and Reef Initiative Inc (CWORI) and UVI. Previous outplanting activities have been conducted here. Coki is an easily accessible and highly visible site with significant tourism value. A substantial portion of the restoration site resides within Coral World Ocean Park's submerged land lease and is accessible by land via the facility's underwater observatory tower. Coki previously hosted a diverse coral community that had relatively high abundances of SCTLD susceptible species including *Meandrina meandrites, Colpophyllia natans, Pseudodiploria strigosa, Diploria labyrinthiformis, Eusmilia fastigiata* and *Dendrogyra cylindrus*. Community composition post SCTLD is almost exclusively comprised of *Orbicella* and *Montastraea cavernosa* corals although several surviving colonies of *D. labyrinthiformis*, *P. strigosa* colonies, and a couple *C. natans* and *D. cylindrus*, are still present at the site. Previous outplanting activities have been conducted by CWORI in collaboration with UVI and include the transplantation of hundreds of coral fragments representing both SCTLD susceptible and resistant species to substrates within bedrock, scattered coral and rock, and aggregate reef zones. Planned restoration activities include the expansion of CWORI's in water nursery and the reintroduction of coral species most impacted by SCTLD.

Island	Site Name	Summary of Rationale
ST. CROIX 	**Llew's Reef**	Both The Nature Conservancy and the University of the Virgin Islands (UVI) currently have ongoing restoration and monitoring programs at Llew's Reef. The location of this site within the EEMP and south of Buck Island Reef National Monument provides a low threat of land-based pollution. Other factors contributing to the site's high potential for restoration success include prioritization for management interventions by DPNR and existing watershed management plans. This site ranked highest in an evaluation by TNC, which combined ecosystem services modeling with high-resolution remote-sensing data to identify sites where reefs provide high coastal protection value to human populations. Restoration interventions are most likely to result in increased coral cover and bolstered ecosystem services. This shallow barrier reef is key to mitigating impacts of flooding, sea-level rise, and storms, making it valuable for climate change resilience. Past and present coral outplanting efforts in the area have demonstrated high survival. Health and growth rates of source corals within an in-water nursery in the area are enhanced relative to other locations around the island. Large, healthy colonies of key coral species are still present along the barrier reef, indicative of reef-building potential and resilience of the genotypes that persist. Recent (2022) benthic surveys of this reef show the reef crest still supports healthy thickets of elkhorn coral (*A. palmata*), while the forereef slope supports existing and relic Porites porites structure as well as some remnant colonies of star coral species. Brain coral species have experienced a significant decline in this location following the spread of SCTLD. This site also provides the potential for future restoration efforts to be continued eastward as efforts progress.
	Long Reef	Due to its close proximity to the island's largest town (Christiansted), Long Reef experiences human induced stressors such as poor water quality and increased human usage from tour operators and boat traffic. Because water conditions are poor and survival potential is low, no restoration interventions have been conducted at this site to date. Long-term restoration focused on hardy corals would be beneficial for coastal resilience and storm protection. Photos and diversity estimates are available for specific locations within this site (WAPA, Turquoise Bay, and Sugar Beach). Eagle Ray, at the eastern end of the area, is a long term TCRMP site and has been continuously treated for SCTLD since 2019. Prior to SCTLD, this site was dominated by *Orbicella* reefs and historically represented a diverse and healthy reef. It also is a good area for connectivity and has been a source reef for restoration efforts underway at Llew's reef.

Island	Site Name	Summary of Rationale
ST. CROIX 	**Butler Bay**	Advantages of the Butler Bay site include a local partner who is actively participating in coral disease interventions, interested in partnering on reef restoration, and has received funding towards restoration of the site from DPNR. In addition, the site provides ease of access from shore. A challenge with this site is that it is very warm in summer and there is a potential sedimentation issue. Butler Bay is located in the northwest region of St Croix. Within this site there are four coral reef habitat types: pavement, scattered coral and rock, aggregate shallow reef (8-11 m [25-35 ft]), and reef crest (note, while classified as reef crest, this area is actually 1-6 m [3-15 ft] deep and is along the shoreline). Restoration is planned for a 300 m stretch of aggregate shallow reef known as Butler Ledge as well as reef crest that exists on both sides of the Bay The Butler Ledge coral community is characterized by target species in coral restoration: orbicellids, brain corals (Pseudodiploria strigosa, Diploria labyrinthiformis), Montastraea cavernosa, Porites astreoides, Siderastrea siderea), as well as soft corals and sponges. The nearshore reef crest has some of the largest Pseudodiploria strigosa colonies on the west end of St. Croix, as well as colonies of Psuedodiploria clivosa. These populations are critical as seeding sites for coral spawning. The main target species for restoration in the reef crest area is *A. palmata*, which is more dense on the north side of the bay and more sparse to the south of the bay. Both restoration areas are accessible from the shore. They have been treated for SCTLD since 2020.
	Sweeper's Complex	Sweeper's Complex is located within the Recreational Zone of the EEMP. This series of three small patch reefs rises from shallow seagrass (3-4 m [12-15 ft] depth), which characterizes this area of the lagoon in northeast St. Croix. The patches rise to a depth of approximately 2 feet at the shallowest. During the Fairleigh Dickinson era these reefs were known as Patch Reefs (PR) 2, 3 and 6 (Miller et al. 2003). The West Indies Laboratory of Fairleigh Dickinson University was active in St. Croix, conducting marine education and research from 1972 until Hurricane Hugo hit the island in 1989 (see https://alanafrew.wixsite.com/natural-disasters/west-indies-lab). Sweeper's Knoll (PR-6) is the largest of these reefs and has been the site of a shore accessible demonstration restoration site in the EEMP since 2019. These sites are discrete patches that support a diversity of coral species. They had good Diadema populations until the 2022 epidemic and still have good herbivore visitation. The sites are upcurrent of other lagoonal patch reefs within EEMP waters, making them both strategic and manageable sites Two summer research projects have used these sites as field research sites. PR-2 and PR-3 have not had any restoration interventions to date, but are similar in nature to PR-6 and will be sites for future restoration.

Appendix C:
SITE-SPECIFIC RESTORATION REQUIREMENTS

This Appendix provides additional detail on the coral restoration targets broken out by zone (e.g., coral reef habitat classification, see *Table 3*). For each of the six priority sites included in this Plan, individual tables provide the total restorable area and number of coral outplants needed to meet the percent coral cover increase for each of the zones included in the site, broken down by coral species group.

FLAT CAY

The Flat Cay site encompasses four different zones: reef crest, aggregate reef - shallow, bedrock and spur and groove. For each zone, the following tables provide the restorable area, the total percent coral cover increase for restorable area and number of outplants needed by coral species.

Table C- 1. Flat Cay Site Restoration Requirements by Zone Over 10 Years

Flat Cay Zone	REEF CREST		
Restorable Area (m^2)	4,358		
Percent Coral Cover Increase for Restorable Area		Over 10 Years	
Total	3.55%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	3.00%	131	858
Staghorn Coral	0.00%	0	0
Star Coral	0.00%	0	0
Brain Coral	0.05%	2	115
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.50%	22	1,951

Flat Cay Zone	AGGREGATE REEF - SHALLOW		
Restorable Area (m^2)	19,236		
Percent Coral Cover Increase for Restorable Area		Over 10 Years	
Total	3.51%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	0.50%	96	631
Staghorn Coral	1.00%	192	1,244
Star Coral	1.00%	192	10,174
Brain Coral	0.50%	96	5,087
Pillar Coral	0.01%	2	73
Other Small Stony Coral	0.50%	96	8,610

Flat Cay Zone	BEDROCK		
Restorable Area (m^2)	3,124		
Percent Coral Cover Increase for Restorable Area		Over 10 Years	
Total	0.80%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	0.10%	3	20
Staghorn Coral	0.00%	0	0
Star Coral	0.20%	6	330
Brain Coral	0.20%	6	330
Pillar Coral	0.05%	2	59
Other Small Stony Coral	0.25%	8	699

Flat Cay Zone	SPUR AND GROOVE		
Restorable Area (m^2)	15,633		
Percent Coral Cover Increase for Restorable Area		Over 10 Years	
Total	4.60%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	1.00%	156	1,025
Staghorn Coral	1.00%	156	1,011
Star Coral	2.00%	313	16,536
Brain Coral	0.10%	16	827
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.50%	78	6,997

COKI

The Coki site encompasses three different zones: aggregate reef - shallow, scattered coral and rock, and bedrock. For each zone, the following tables provide the restorable area, the total percent coral cover increase for restorable area and number of outplants needed by coral species.

Table C- 2. Coki Site Restoration Requirements by Zone Over 10 Years

Coki Zone	AGGREGATE REEF - SHALLOW		
Restorable Area (m^2)	**2,506**		
Percent Coral Cover Increase for Restorable Area			
Total	**4.50%**	**Area of Restored Coral (m^2)**	**Outplants Needed (clusters/heads)**
Elkhorn Coral	0.00%	0	0
Staghorn Coral	0.00%	0	0
Star Coral	2.00%	50	2,651
Brain Coral	2.00%	50	2,651
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.50%	13	1,122

Coki Zone	SCATTERED CORAL AND ROCK		
Restorable Area (m^2)	**391**		
Percent Coral Cover Increase for Restorable Area			
Total	**4.75%**	**Area of Restored Coral (m^2)**	**Outplants Needed (clusters/heads)**
Elkhorn Coral	0.00%	0	0
Staghorn Coral	3.00%	12	76
Star Coral	0.50%	2	103
Brain Coral	0.75%	3	155
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.50%	2	175

Coki Zone	BEDROCK		
Restorable Area (m^2)	2,765		
Percent Coral Cover Increase for Restorable Area			
Total	**4.80%**	**Area of Restored Coral (m^2)**	**Outplants Needed (clusters/heads)**
Elkhorn Coral	4.00%	111	725
Staghorn Coral	0.00%	0	0
Star Coral	0.25%	7	366
Brain Coral	0.50%	14	731
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.05%	1	124

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LLEW'S REEF

The Llew's Reef site encompasses two different zones: forereef terrace and reef crest. For each zone, the following tables provide the restorable area, the total percent coral cover increase for restorable area and number of outplants needed by coral species.

Table C- 3. Llew's Reef Site Restoration Requirements by Zone Over 10 Years

Llew's Reef Zone	FOREREEF TERRACE		
Restorable Area (m^2)	**10,511**		
Percent Coral Cover Increase for Restorable Area			
Total	**5.10%**	**Area of Restored Coral (m^2)**	**Outplants Needed (clusters/heads)**
Elkhorn Coral	0.00%	0	0
Staghorn Coral	4.00%	420	2,720
Star Coral	0.50%	53	2,779
Brain Coral	0.50%	53	2,779
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.10%	11	941

Llew's Reef Zone	REEF CREST		
Restorable Area (m^2)	**18,349**		
Percent Coral Cover Increase for Restorable Area			
Total	**5.00%**	**Area of Restored Coral (m^2)**	**Outplants Needed (clusters/heads)**
Elkhorn Coral	5.00%	917	6,018
Staghorn Coral	0.00%	0	0
Star Coral	0.00%	0	0
Brain Coral	0.00%	0	0
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.00%	0	0

LONG REEF

The Long Reef site encompasses four different zones: spur and groove, aggregate reef - shallow, pavement, and reef crest. For each zone, the following tables provide the restorable area, the total percent coral cover increase for restorable area and number of outplants needed by coral species.

Table C- 4. Long Reef Site Restoration Requirements by Zone Over 10 Years

Long Reef Zone	SPUR AND GROOVE		
Restorable Area (m^2)	56,057		
Percent Coral Cover Increase for Restorable Area			
Total	1.50%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	0.00%	0	0
Staghorn Coral	0.00%	0	0
Star Coral	1.00%	561	29,647
Brain Coral	0.00%	0	0
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.50%	280	25,089

Long Reef Zone	AGGREGATE REEF SHALLOW		
Restorable Area (m^2)	85,143		
Percent Coral Cover Increase for Restorable Area			
Total	1.75%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	0.00%	0	0
Staghorn Coral	0.00%	0	0
Star Coral	0.50%	426	22,515
Brain Coral	0.25%	213	11,258
Pillar Coral	0.00%	0	0
Other Small Stony Coral	1.00%	851	76,214

Long Reef Zone	PAVEMENT		
Restorable Area (m^2)	37,829		
Percent Coral Cover Increase for Restorable Area			
Total	1.00%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	0.25%	95	620
Staghorn Coral	0.00%	0	0
Star Coral	0.25%	95	5,002
Brain Coral	0.25%	95	5,002
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.25%	95	8,465

Long Reef Zone	REEF CREST		
Restorable Area (m^2)	33,677		
Percent Coral Cover Increase for Restorable Area			
Total	2.00%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	2.00%	674	4,418
Staghorn Coral	0.00%	0	0
Star Coral	0.00%	0	0
Brain Coral	0.00%	0	0
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.00%	0	0

BUTLER BAY

The Butler Bay site encompasses two different zones: reef crest and aggregate reef - shallow. For each zone, the following tables provide the restorable area, the total percent coral cover increase for restorable area and number of outplants needed by coral species.

Table C- 5. Butler Bay Site Restoration Requirements by Zone Over 10 Years

Butler Bay Zone	REEF CREST		
Restorable Area (m^2)	18,764		
Percent Coral Cover Increase for Restorable Area			
Total	5.08%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	5.00%	938	6,154
Staghorn Coral	0.00%	0	0
Star Coral	0.00%	0	0
Brain Coral	0.03%	6	298
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.05%	9	840
Butler Bay Zone	**AGGREGATE REEF SHALLOW**		
Restorable Area (m^2)	19,976		
Percent Coral Cover Increase for Restorable Area			
Total	0.15%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	0.00%	0	0
Staghorn Coral	0.00%	0	0
Star Coral	0.05%	10	528
Brain Coral	0.05%	10	528
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.05%	10	894

SWEEPER'S COMPLEX

The Sweeper's Complex site is all patch reef, but encompasses three different patch reefs. For each zone, the following tables provide the restorable area, the total percent coral cover increase for restorable area and number of outplants needed by coral species.

Table C- 6. Sweeper's Complex Restoration Requirements by Zone Over 10 Years

PR-2 (i.e., Peep)

Sweeper's Complex Zone	PATCH REEF		
Restorable Area (m^2)	**1,035**		
Percent Coral Cover Increase for Restorable Area			
Total	**2.00%**	**Area of Restored Coral (m^2)**	**Outplants Needed (clusters/heads)**
Elkhorn Coral	0.50%	5	34
Staghorn Coral	0.00%	0	0
Star Coral	0.00%	0	0
Brain Coral	1.00%	10	548
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.50%	5	463

PR-3 (i.e., Blob)

Sweeper's Complex Zone	PATCH REEF		
Restorable Area (m^2)	**1,389**		
Percent Coral Cover Increase for Restorable Area			
Total	**2.00%**	**Area of Restored Coral (m^2)**	**Outplants Needed (clusters/heads)**
Elkhorn Coral	0.50%	7	46
Staghorn Coral	0.00%	0	0
Star Coral	0.25%	3	184
Brain Coral	1.00%	14	734
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.25%	3	311

PR-6 (i.e., Peanut)

Sweeper's Complex Zone	PATCH REEF		
Restorable Area (m^2)	2,597		
Percent Coral Cover Increase for Restorable Area			
Total	9.10%	Area of Restored Coral (m^2)	Outplants Needed (clusters/heads)
Elkhorn Coral	7.25%	188	1,235
Staghorn Coral	0.10%	3	17
Star Coral	0.50%	13	687
Brain Coral	1.00%	26	1,373
Pillar Coral	0.00%	0	0
Other Small Stony Coral	0.25%	6	581

Appendix D: EVALUATION OF SITE-SCALE CORAL COVER PERCENT TARGET

To understand the overall coral cover at the priority sites, weighted-average site-scale (e.g., for the overall site) coral cover target percentages were calculated (see *Table D - 1*). The percent coral cover targets of four of the six priority sites exceed the 10 percent target established for the overall site in *Table 5*. However, two sites (Flat Cay and Long Reef) have lower target cover percentages, for reasons that VI-RoCS found acceptable. Coral cover at Flat Cay has significantly decreased due to SCTLD since the 10 percent target was chosen; thus, it is reasonable that the target cover for this site (currently) is less than the goal minimum of 10 percent (~ 8.5 percent). Given the considerably larger size of Long Reef (compared to the other sites), and the current limited capacity and high demand for coral restoration work on St. Croix, a target less than 10 percent over the ten-year timeframe was considered appropriate at this site. An overall 5.5 percent coral cover target was established to ensure a reasonable target for outplanting across the entire site over 10 years. It is feasible that Long Reef could be divided into smaller pieces and outplanting efforts focused into a smaller portion of the site to achieve higher coral cover within that smaller area after 10 years. However, a site of this size will need either an unrealistic increase in local funding and capacity, or a plan with a longer time frame in order to reach 10 percent coral cover overall.

Table D – 1. Overall Site-Scale Coral Cover Percent Target

Reef Habitat Zone	Flat Cay	Coki	Llew's Reef	Long Reef	Butler Bay	Sweeper's Complex
Reef Crest	7.10%		12.00%	5.50%	22.05%	
Spur and Groove	12.00%			6.51%		
Forereef Terrace			10.50%			
Aggregate Reef - Shallow	8.31%	10.50%		4.76%	11.50%	
Patch Reef 2						7.25%
Patch Reef 3						6.75%
Patch Reef 6						14.85%
Weighted Average Percent Cover[1]	**8.54%**	**10.50%**	**11.45%**	**5.46%**	**16.61%**	**11.04%**

Notes: Weighted average calculated based on restoration area and target cover percentages for habitat zones considered "reef" (i.e. coral-dominated and coral-generated hard bottom habitat). Pavement, bedrock, and scattered coral and rock habitat zones were not included.

Appendix E: Support for Cost Estimate

This Plan presents a high-level budget estimate to provide an understanding of the funding necessary to execute this effort. It is anticipated that a mix of existing and new private and public sector funds will be utilized to implement the actions described in this Plan. For purposes of generating an approximate cost to implement the Plan, site level estimates are developed based on practitioners' real-world experience with restoration projects in the USVI and familiarity with the priority sites. Costs are estimated for each site over the ten-year life of the Plan. This section provides additional detail on how budget estimates were developed for the activities presented in this Plan.

Inputs into the cost calculations are summarized in Table E - 1. Four inputs were developed to estimate site level costs as follows:

- **Cost per Coral:** This represents the costs of recovering an individual coral unit from sourcing and grow-out, all the way to outplanting, including site preparation and cleaning, which is generally performed at the time of outplanting. Given the established nursery infrastructure in the USVI, cost per coral is fairly well understood for these sites. VI-RoCS chose to develop an average cost per coral restored, while understanding that costs vary depending on the species group and outplant site. For example, Elkhorn and Staghorn corals, which can grow quickly in in-water nurseries, can cost around $100, whereas slower growing species such as Star and Brain corals that require land-based nursery facilities can exceed $500 per coral (NOAA 2020). For the purposes of this budgeting exercise, the overall average cost per coral restored is $276.
- **Cost per day of monitoring/maintenance.** Given ongoing coral restoration efforts in the USVI, the costs associated with monitoring and maintenance are well documented. Based on the experience of local practitioners and site experts, monitoring and maintenance undertakings are often combined into one day of effort. For the purposes of this budgeting exercise, VI-RoCS chose to develop an average cost per monitoring/maintenance day, while understanding that costs vary depending on location and whether or not a vessel is required to reach the site. On average, the cost of monitoring and maintenance at USVI coral restoration sites is estimated to be $1,877 per day. This includes the cost of personnel (including fringe costs), tanks, vessels as needed, and supplies.
- **Number of monitoring/maintenance days.** The level of monitoring and maintenance required to support coral growth and health depends on the species and number of corals being outplanted. For purposes of this budgeting exercise, site experts determined the estimated average number of days per year that would be needed for monitoring and maintenance at each site over the ten-year period of the Plan. This ranged from 12 to 45 days per year depending on the site.
- **Contingency Cost.** To account for uncertainties and the need to respond to unanticipated or unplanned events, a contingency cost for adaptive management is included. Based on practitioners' experience and standard project budgeting assumptions, contingency costs are estimated at 10% of the subtotal of all other costs.

Cost calculations, and the resulting budget for each priority site are shown in *Table E - 2*.

Table E – 1. Cost Calculation Inputs

INPUTS	
Cost per Coral	$276
Monitoring/Maintenance Cost per Day	$1,877
Contingency Cost (% of subtotal)	10%

Table E – 2. Budget for Plan by Site

Region	Site	Total Area Restored	# of Coral Outplants Needed	Coral Propagation and Outplanting Cost	Monitoring/ Maintenance Days per Year	Monitoring/ Maintenance Cost (Days x Cost/day x 10 years)	Subtotal Cost by Site	10% Contingency	Total Cost by Site
St. Thomas	Flat Cay	42,352	56,578	$15,615,659	30	$563,100	**$16,178,758**	$1,617,876	**$17,796,634**
	Coki	5,662	8,879	$2,450,486	25	$469,250	**$2,919,736**	$291,974	**$3,211,710**
St. Croix	Llew's Reef	28,860	15,238	$4,205,647	45	$844,650	**$5,050,297**	$505,030	**$5,555,327**
	Long Reef	212,706	188,230	$51,951,578	45	$844,650	**$52,796,228**	$5,279,623	**$58,075,851**
	Butler Bay	38,741	9,243	$2,550,946	12	$225,240	**$2,776,186**	$277,619	**$3,053,805**
	Sweeper's Complex	5,021	6,212	$1,714,548	19	$356,630	**$2,071,178**	$207,118	**$2,278,296**
TOTALS		**333,341**	**284,380**	**$78,488,864**	**176**	**$3,303,520**	**$81,792,384**	**$8,179,238**	**$89,971,623**

Appendix F: References

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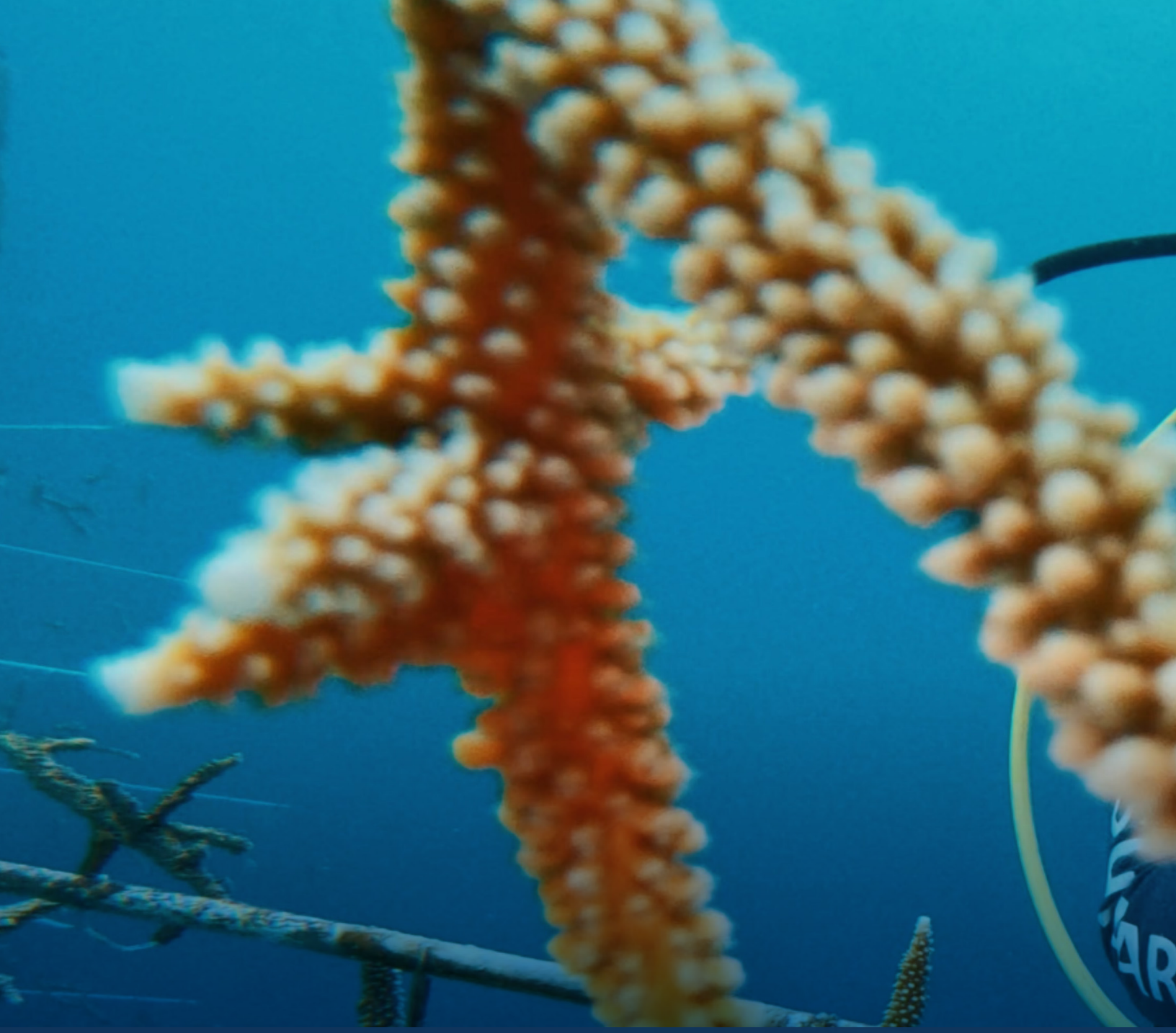
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