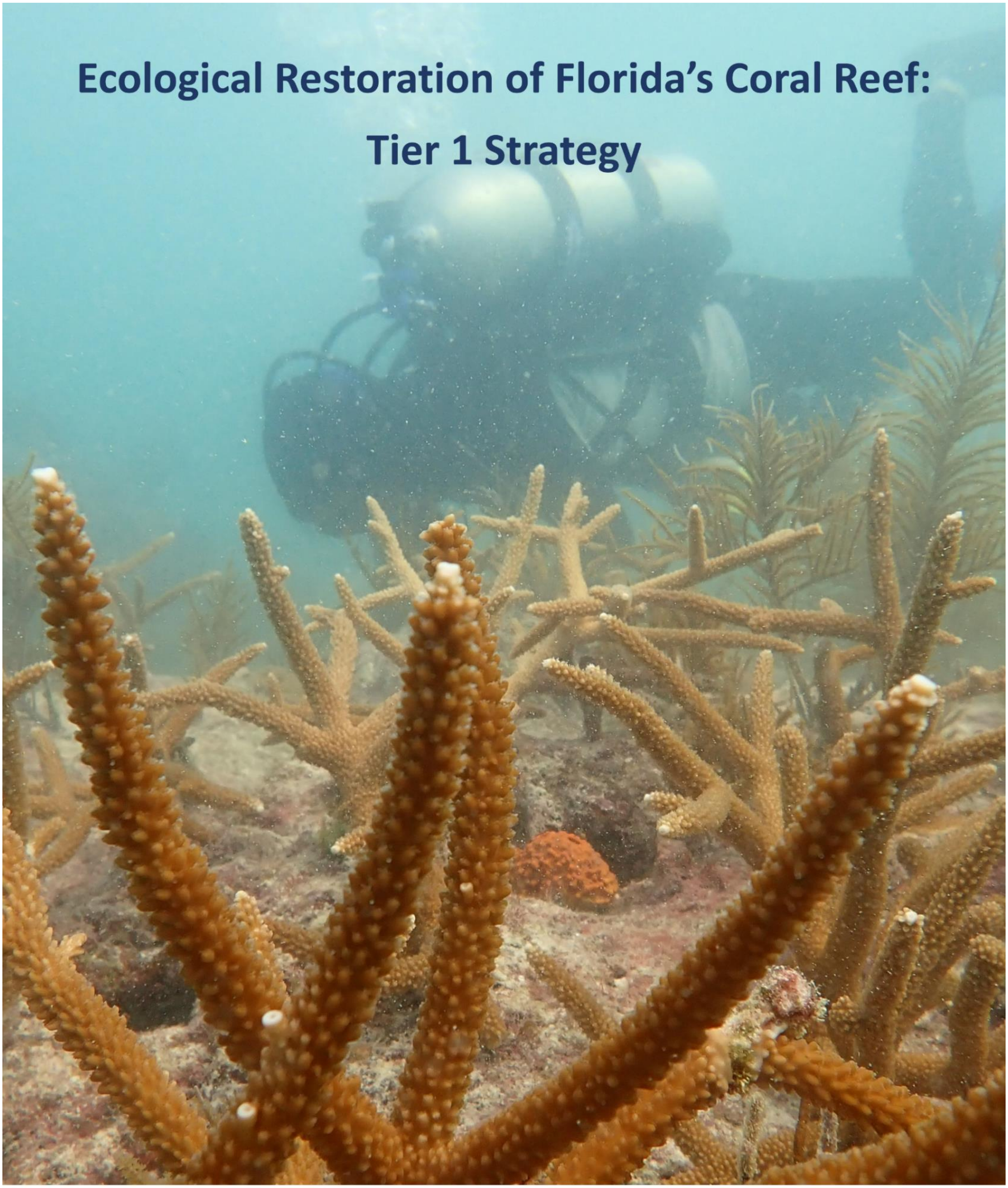
Ecological Restoration of Florida's Coral Reef:

Tier 1 Strategy



Florida's Coral Reef Resilience Program

FLORIDA'S CORAL REEF

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Executive Summary

As effort and funding for coral reef restoration scales to unprecedented levels, a need for systematic restoration planning was identified by Florida's resource managers. Due to the complexities of planning across various management jurisdictions, the reef managers identified three levels of planning. Tier 1, presented here, includes a vision and goals for restoration of Florida's Coral Reef, high-level guidance on restoration principles that should be applied at all sites, and the selection of focal areas across the reef tract where restoration is likely to contribute to large-scale recovery of the system.

This Strategy combines long-term coral monitoring data with state-of-the-art coral larval connectivity modeling to identify those focal areas where outplanted corals are likely to survive to maturity and that serve as sources for other reefs. By focusing large-scale restoration in these focal areas, we can reasonably assume that the area of impact of restoration will be larger than the immediate footprint of restoration. The purpose of this Strategy is to guide state investments in reef restoration and to serve as a starting point for more detailed jurisdictional restoration planning efforts.

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List of Acronyms and Abbreviations

ACER	*Acropora cervicornis*
Coral AP	Kristin Jacobs Coral Reef Ecosystem Conservation Area Aquatic Preserve
CRC	Coral Restoration Consortium
CREMP	Coral Reef Monitoring and Evaluation Program
DEP	Florida Department of Environmental Protection
DRM	Disturbance Response Monitoring
EPA	Environmental Protection Agency
FCR	Florida's Coral Reef
FWC	Florida Fish and Wildlife Conservation Commission
FWRI	Florida Fish and Wildlife Research Institute
MCAV	*Montastrea cavernosa*
NCRMP	National Coral Reef Monitoring Program
NPS	National Park Service
NOAA	National Oceanic and Atmospheric Administration
OFAV	*Orbicella faveolata*
PSTR	*Pseudodiploria strigosa*
RRN	Reef Resilience Network
SCTLD	Stony coral tissue loss disease

Background

Florida's Coral Reef (FCR) spans 350 miles from the St. Lucie Inlet south and west to the Dry Tortugas in the Gulf of Mexico. These reefs are a cornerstone of the economy and way of life for South Floridians. Reefs support fisheries, protect beaches and shorelines, and provide recreational opportunities for both tourists and residents. The total tourism value of FCR is estimated at $6 billion annually. On average, 41,000 people use the reefs for fishing, boating, diving or snorkeling every day, and 71,000 jobs annually are supported by reefs. FCR also provides $675 million in flood protection benefits to the state each year (Storlazzi et al., 2019). These values show what is at stake if action is not taken to both protect and actively restore FCR to sustain the ecosystem's function and services that it provides to people.

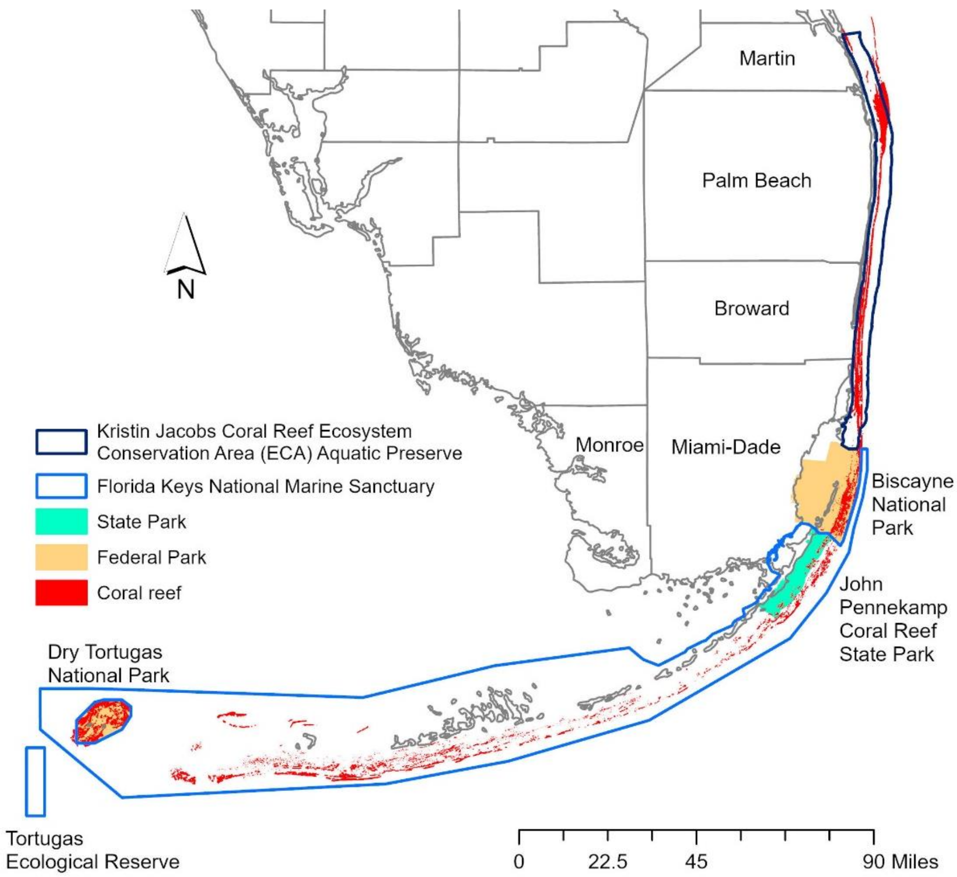


Figure 1. A map of Florida's Coral Reef with the reef area in red and management jurisdictions outlined.

Florida's Coral Reef is threatened by local, regional, and global stressors, ranging from anchor damage, to poor water quality, to the impacts of global climate change. Between 1996 and 2015, the Coral Reef Evaluation and Monitoring Program (CREMP) documented a 53.8% decline in stony coral cover (from 12.3 to 5.3%) due predominantly to thermal stress, disease and damage from hurricanes (FWC, unpublished data). This was accompanied by a shift from the large reef-building species to faster-growing, weedy species. Further declines have been documented since 2015, mostly due to stony coral tissue loss disease (SCTLD), which has proven lethal to more than half of the species of stony corals found in Florida. Table 1 shows the estimated number of corals lost in the Florida Keys for three of the four key species identified in this Strategy that are susceptible to SCTLD, and the number of corals that would be needed to replace 1%, 5%, and 10% of the corals lost to SCTLD with an annual outplant survival estimate of 65% included (FWC, unpublished data).

Table 1. Estimated losses of key species due to SCTLD in the Florida Keys, and numbers needed to replace those lost with 35% annual mortality estimate built in (FWC, unpublished data).

Species	Estimated Losses	1%	5%	10%
Montastrea cavernosa	8,818,179	119,045	595,227	1,190,454
Orbicella complex	1,895,413	25,588	127,940	255,881
Pseudodiploria strigosa	3,181,450	42,949	214,748	429,496

Similar declines in live tissue area and changes in species assemblages were documented in Southeast Florida between 2015 and 2018 due to SCTLD (Hayes et al., 2022).

Since 2004, Florida's coral scientists and restoration practitioners have been developing techniques for propagating and outplanting stony corals to encourage the natural recovery of the declining populations. This work started with the branching coral *Acropora cervicornis*, but has since grown to include a wide range of stony corals and associated species that are foundational to maintaining the structural integrity of FCR. Florida led the nation in developing coral propagation and restoration initiatives and continues to collaborate with international partners to increase success, scale up, and develop cutting-edge techniques.

In addition to the work already being conducted in nurseries across Florida, the State brought thousands of corals into captivity as a result of SCTLD. This included colonies that had not yet been exposed to the disease and potentially disease-resistant colonies that survived in SCTLD's wake. These colonies are now being treated as broodstock and are being fostered at zoos and aquaria across the country while additional facilities are built or expanded to meet the projected need for large-scale propagation and future restoration efforts. This effort offered the unique opportunity to understand reproductive strategies and evaluate methods for promoting successful spawning in corals. This is expected to lead to a sustainable source of juvenile corals ready for outplant each year, many more than could be produced by collecting gametes or larvae in the wild.

The aim of this Tier 1 Strategy is to guide the reestablishment of successful sexual reproduction in the wild by outplanting corals of genetically distinct individuals where they are likely to survive long enough to release gametes and contribute to the natural recovery of species' populations. Using larval connectivity modeling, a network of connected sites were identified that, once restored, will amplify the impact of each restoration effort. Coupled with other conservation efforts to reduce local and regional threats to the reef, the ultimate goal is to restore the health and resilience of Florida's Coral Reef ecosystem.

Due to the rapidly expanding interest and capacity around coral reef restoration efforts, the State of Florida developed this Tier 1 Strategy to help ensure that individual efforts are contributing to larger goals aimed at restoring the structure and function of Florida's Coral Reef.

Purpose

FCR is managed by various state and federal agencies including the Florida Department of Environmental Protection (DEP), Florida Fish and Wildlife Conservation Commission (FWC), National Park Service (NPS), and National Oceanic and Atmospheric Administration (NOAA). The agencies identified a need for large-scale coral reef ecosystem restoration, and some have developed plans that cover their specific jurisdictions. A first-of-its-kind strategic plan to help coordinate individual restoration efforts will be essential to drive effective large-scale restoration. There are many practitioners working on fine tuning site-specific and species-specific restoration, both as part of jurisdictional plans and at sites selected by practitioners. As restoration continues to scale up and larger investments and state initiatives are created to support coral reef ecosystem restoration, there is a need to build a decision framework that guides restoration efforts towards achieving a broader ecosystem approach based on research and the needs of those who rely on the reefs for their livelihood, safety, and recreation.

This Tier 1 Strategy will be used to guide state investments in restoration efforts. Restoring a network of connected sites will help to ensure that efforts at any given site are contributing to large-scale and long-term recovery of FCR.

We recognize that protection and restoration of connected habitats such as seagrass beds and mangroves is important to a healthy coral reef ecosystem, but the scope of this Strategy is focused on corals and the organisms on the reef that improve their likelihood of survival, such as herbivores.

Related documents and resources

The Strategy was not developed to supersede any existing restoration plans or efforts, but instead to supplement them and to provide guidance on developing future plans to better support the recovery of the coral reef ecosystem. Restoration guidance has been provided through various other documents and resources, and a brief overview of each related document is included below.

Resilience Action Plan for Florida's Coral Reef 2021-2026 – The purpose of the Resilience Action Plan, created by reef managers with facilitation support by The Nature Conservancy, is to serve as a call to action to address ongoing threats to FCR and to identify priority actions that the reef management community, policy makers, and reef users must take now and maintain for the foreseeable future to tackle the threats to reefs and rapidly increase existing restoration efforts. This document includes actions related to restoration activities and research, and the development of this Tier 1 Strategy was identified as one of the related priorities.

State of Florida Restoration Priorities for Florida's Coral Reef: 2021-2026 – This document summarizes priorities identified by the FWC and DEP related to coral restoration activities. The most immediate needs are highlighted in its Appendix.

Restoring Seven Iconic Reefs: A Mission to Recover the Coral Reefs of the Florida Keys – Mission: Iconic Reefs is a blueprint for ecosystem restoration at seven specific sites located within the Florida Keys National Marine Sanctuary. This plan, developed with input from the reef management and restoration communities, identifies places, actions and costs needed to scale restoration to ecologically meaningful levels at the seven selected sites.

A Manager's Guide to Coral Reef Restoration Planning and Design – The Manager's Guide, written by The Nature Conservancy's Reef Resilience Network with support from NOAA, the U.S. Environmental Protection Agency (EPA) and others, assesses the steps associated with planning for coral reef restoration at local or jurisdictional scales.

Coral Restoration Consortium – The Coral Restoration Consortium (CRC) is a high-level community of practice that comprises scientists, managers, coral restoration practitioners, and educators dedicated to enabling coral reef ecosystems to adapt and survive the 21st century and beyond. The CRC has compiled guidance documents on a range of topics from genetic considerations to monitoring protocols, hosts webinars and a symposium every two years, and provides an opportunity for practitioners and scientists to engage on issues related to restoration.

Reef Resilience Network – The Nature Conservancy's Reef Resilience Network (RRN) serves as a global leader in building the capacity of marine managers to effectively manage, protect, and restore coral reefs and reef fisheries around the world. The RRN hosts training opportunities, webinars and exchanges that enable reef managers to become familiar with the various aspects of planning and conducting reef restoration.

Tiered approach to restoration planning

This Strategy was developed and reviewed by a group of federal and state reef managers and restoration practitioners familiar with the reefs and restoration landscape in Florida. It serves to provide high-level guidance to ensure that more detailed restoration planning efforts are contributing to the overall recovery of the entire ecosystem. In order to categorize different levels of restoration planning and understand how they interact; three Tiers have been identified.

Tier 1 – High level guidance on ecological restoration goals, focal areas for restoration (up to 24 hectares or 60 acres in area), principles for successful restoration, and guidance for planning at Tiers 2 and 3. This document is focused on Tier 1.

Tier 2 – Place-based or managed area level plans that may prioritize both ecological and socioeconomic goals, rank or prioritize focal areas, and describe restoration activities that will be used to achieve the goals; an example of Tier 2 planning would be a restoration plan for the Kristin Jacobs Coral Reef Ecosystem Conservation Area Aquatic Preserve in southeast Florida.

Tier 3 – Specific plans that dictate what restoration and/or research activities will take place at specific sites (up to 12 hectares or 31 acres in area) to meet defined restoration goals. An example of Tier 3 planning is the plans for each of the seven reefs in the Florida Keys identified by Mission: Iconic Reefs.

Currently, most restoration site selection decisions are being made by practitioners working in the vicinity of their nurseries and/or land-based facilities. By providing this broader strategy framework and guidance, complementary efforts can contribute more effectively to the larger goals.

Florida's Coral Reef restoration: vision and goals

Tier 1 Vision

Restore Florida's Coral Reef to a thriving, diverse, resilient condition that sustains coral ecosystems and their valuable services for current and future generations.

Tier 1 Goals

1. **Enhance coral population and coral community resilience**
   Resilience, as defined by Florida's Coral Reef Resilience Program, is the ability of systems to absorb disturbances, to resist phase shifts, and to regenerate and reorganize in order to maintain key functions and processes in a time and space relevant to resource use and management activities. As populations and communities decline over time, resilience is often diminished. The purpose of this first goal is to focus on restoration activities that help restore resilience within species' populations and within communities of different species that coexist in the same areas of the reef. Such activities could include restoring a wide array of genotypes of the same species and/or a mix of a number of different species, restoring herbivore populations alongside coral populations, or working to restore a balance among benthic species.

2. **Enhance habitat quality in support of coral recruitment**
   Coral recruitment of reef-building broadcast spawning species has been relatively low on FCR over the last 25 years (Williams et al., 2008; Bartlett, 2014; Harper, 2017, Harper et al., 2023). Causes include declines in adult coral populations and increases in sedimentation and competitor populations which now blanket portions of the reef that were once open settlement space for coral larvae. This second goal of this strategy would improve reef habitat through activities such as species recovery, removal of competitors, and/or enhancement of settlement cues. This will support healthy, reproductive coral populations, encourage settlement and perhaps lead to discoveries about settlement cues to encourage successful recruitment and improve habitat.

3. **Increase coral survivorship**
   Few outplanted corals and natural colonies are thriving on FCR due to continued chronic and acute stressors. Scientists are working to understand the many causes of coral mortality, and in the meantime, actions such as proper site selection, predator removal, and regular site maintenance may help outplanted corals survive until they are reproductively active and have contributed to a new generation of corals.

These three ecological goals are best achieved through a strategic, reef-wide restoration effort, which is why they are included as Tier 1 goals. When accomplished together, these goals will increase restoration success and promote the recovery of Florida's Coral Reef.

During Tier 2 and 3 planning efforts, ecosystem service goals or other ecological goals may also be applied to help identify priority focal areas and sites, and determine which restoration interventions to undertake at each site. These goals do not necessarily need to be applied across the entire reef to achieve success. These goals could include:

- Restore specific species that have been lost at individual reef sites
- Conduct research aimed at answering specific restoration questions

- Improve fisheries habitat at high-value fishing sites and across the ecosystem
- Improve reef condition at high-value tourism sites
- Maintain and improve wave attenuation to protect shorelines

Restoration principles

Throughout the development of this Strategy, several general restoration principles were identified.

1. **Integrate restoration with other management approaches.** The threats that continue to cause declines on FCR have not been fully abated, and therefore, outplanting alone will not achieve the desired restoration success. Restoration should be conducted in conjunction with a suite of threat abatement and management approaches that help to support a healthy reef system. The Resilience Action Plan for Florida's Coral Reef provides a compilation of the actions that should be taken in conjunction with restoration activities to achieve a healthier reef system.

2. **Use adaptive management approaches**. It is well-recognized that both the reef system in Florida and the capacity and knowledge around coral reef restoration are rapidly changing. As new information becomes available, the Strategy, and how it is applied, will be updated to best achieve the stated vision and goals and incorporate adaptive management.

3. **Do no harm**. This is a common tenet in restoration ecology, ensuring that decisions about how to conduct restoration first consider whether a certain action is likely to have any unintended negative consequences. This is specifically important as it relates to genetic management of outplants or testing novel outplant techniques.

4. **Innovate cautiously**. There is a great deal of effort right now aimed at better understanding the science of restoration and how humans can intervene to help corals adapt to a changing climate and other stressors. However, there is inherent risk in introducing new techniques before they have been fully tested because of the potential for unintended consequences, so innovative techniques should be implemented only after extensive investigation and evaluation of the relative risks and potential rewards.

5. **Engage communities**. Coral reefs are critical to South Florida's economy and way of life. Local communities care about the reefs for a variety of reasons, so they can also be advocates for the protection and restoration of our reefs. Too often, communities are not fully engaged in decision-making that may affect them, so efforts should be made, particularly at Tier 3 when specific sites are being identified and projects developed, to

engage with stakeholder groups who hold local knowledge and could become advocates for individual sites or the restoration effort as a whole.

6. **Consider disease risk**. Related to adaptive management, the level of coral disease risk at individual sites should be continually evaluated, and changes made as necessary to avoid sites with higher disease incidence. If necessary, restoration should cease until a disease outbreak subsides or effective disease interventions are conducted. Current outplanting protocols developed by Florida reef managers require disease prevalence at an outplant site to be less than 5% for any outplanting to occur; the most up-to-date protocols and best management practices should always be followed.

7. **Define metrics and track success**. To implement adaptive management, one must have a clear definition of success, and monitor restoration sites in a way that tracks success and provides quick feedback that can be used to make necessary changes. An evaluation tool for understanding restoration success across projects and programs has been developed and provides restoration performance metrics for the assessment of restoration projects and the application of adaptive management strategies (Schopmeyer et al., 2024). For more information on monitoring success, see Goergen at al., 2020. [Coral reef restoration monitoring guide: Methods to evaluate restoration success from local to ecosystem scales. (crc.world)]

Identifying focal areas for restoration (abbreviated methods)

A detailed description of the methods used can be found in Appendix 1. This serves as a high-level summary of the methods and decisions that were made in developing them.

At the scale of Florida's Coral Reef, there are certain reef areas that have the ability to contribute more than others to the overall recovery of the ecosystem. In this Tier 1 Strategy, we refer to these areas as Tier 1 focal areas. Despite a wide range of potential selection criteria (see Appendix 2), an advisory group of reef managers decided to focus on three criteria for selecting Tier 1 focal areas: identification of exclusion areas where restoration is unlikely to succeed due to human uses and limits to current restoration techniques (e.g., depth), the coral demographics within a region, and the capacity to serve as a source of larvae to other reefs but also as a sink (i.e., site of recruitment) for larvae coming from other reefs. By supplementing corals at sites that are already supporting relatively higher populations, outplanting can contribute to successful sexual reproduction and the larvae produced can help reseed other reefs. Conversely, conducting restoration at larval sink sites might help recreate the conditions necessary for successful larval settlement.

While restoration will eventually be conducted with a large suite of coral species, this Tier 1 Strategy focuses on four key species: *Acropora cervicornis*, *Montastrea cavernosa*, *Orbicella faveolata*, and *Pseudodiploria strigosa*. These species were selected because they are relatively widespread across the reef, remain prevalent enough following recent large-scale disturbances to get a better understanding of where restoration could be successful, and restoration practitioners are already propagating and outplanting them at scale. As more coral species become available for large-scale efforts, coral demographics and larval connectivity can be revisited to identify additional Tier 1 restoration priorities and create focal area maps for these species. Many other coral species are found in more niche habitats, which will require a more detailed site selection process. However, connectivity between reefs should be considered, as much as possible, for all species and at all levels of planning.

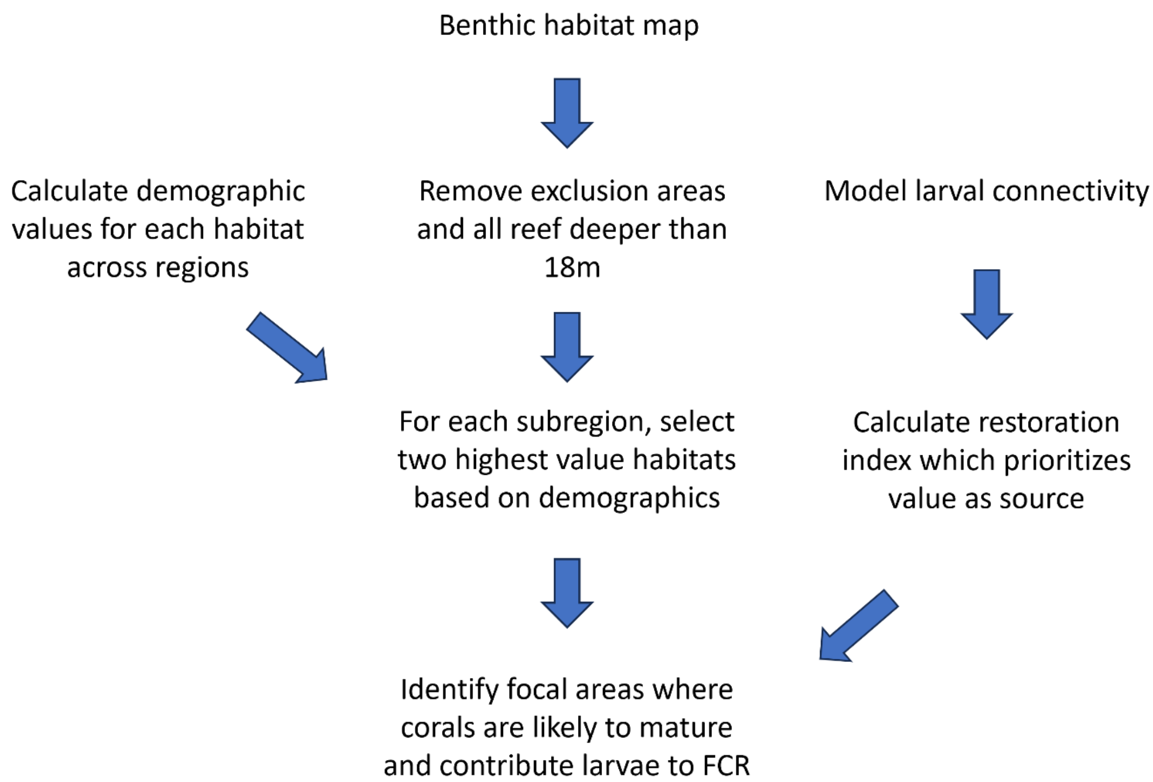


Figure 2. Flow chart of steps taken to define focal areas. The Benthic habitat map used was the Unified Reef Map - Level 2 - Coral Reef and Hardbottom (FWRI, 2016).

First, a set of exclusion areas was defined by reef managers that helped to eliminate areas of FCR that are at risk of human impact and that are not feasible for outplanting using current restoration methods. The full list of exclusion areas can be found in Appendix 1, but in general these areas occurred in the Southeast Florida region and included potential impact areas from dredging, beach renourishment, other coastal construction, and large vessel anchoring. Although specific to only one region, exclusion areas were included within the Tier 1 analysis to provide as much viable habitat as possible for restoration while minimizing the effect of human impacts. Additionally, all habitat deeper than 18 m (~60 feet) was excluded because current methods of coral reef restoration make operations at scale much less efficient and more costly in deeper water.

Since larger coral colonies (>10 cm) are likely reproductively active and the presence of juveniles at a site indicates that the site may support adult corals and recruitment, coral demographic data, including persistence over time and current size structure of the selected species, was then used to prioritize habitats. This resulted in identification of habitats with higher abundance of corals representing a relatively broad size class distribution. These habitat values were calculated across each region (Southeast Florida, the Florida Keys, and Dry Tortugas), and the two habitats in each region with the highest demographic score were considered for further analysis.

Figure 3. Regions and subregions as defined by the Disturbance Response Monitoring and National Coral Reef Monitoring Programs.

The demographic results were then layered with connectivity modeling that used larval competency models (an understanding of how quickly coral larvae become competent following fertilization, how long coral larvae are viable, and how they move within the water column) from the four key coral species combined with high-resolution bio-physical dispersal modeling (how ocean currents move larvae from place to place) to predict the likelihood of a given reef habitat area's ability to serve as larval "sources" and "sinks". An area's value as a source increases with the number of connections out to other areas and the number of larvae predicted to be dispersing from the source. Similarly, its value as a sink increases with the number of connections in from other areas and the number of larvae being delivered to it.

By combining high value coral demographics and predicted larval connectivity of targeted coral species, the Strategy prioritizes focal areas that are likely to support corals through reproductive maturity and for the resulting larvae to settle elsewhere on FCR. Decisions about prioritizing focal areas were made by subregion to ensure a spread of Tier 1 focal areas across FCR, and within each subregion approximately 30% of the highest ranked habitat and approximately 20% of the second-highest ranked habitat was selected where they overlapped the highest connectivity scores in that subregion (exceptions to this existed and they are described in Appendix 1).

The set of maps below shows the Tier 1 focal areas that were selected for each subregion along Florida's Coral Reef. As not all habitat is suitable for acroporid restoration, two sets of maps have been included here for subregions where *A. cervicornis* is abundant enough to have been surveyed. One set of maps (A) shows the prioritized focal areas for *A. cervicornis* separately from the boulder corals, while the other set of maps (B) shows the prioritized focal areas for all four species together. In cases where restoration is focused just on *A. cervicornis*, or on a mix of boulder coral species, the first set of maps should be used. In cases where a wide range of species will be used, including both branching and boulder forming species, the second set of maps (B) should be used unless there are green polygons in first map. The green areas represent overlap between the optimal habitats for *A. cervicornis* and the boulder coral species, so these areas should be prioritized in the Keys where they exist.

In A, blue polygons represent the focal areas selected for multi-species boulder coral restoration, red polygons represent focal areas for *A. cervicornis* restoration, and green polygons represent focal areas where there is overlap between the boulder corals and *A. cervicornis*. In B, purple polygons represent the focal areas selected for multi-species restoration including both branching and boulder forming species. The Marquesas subregion was not included in this analysis because the data for this area is limited and currently there is not enough capacity to focus large-scale restoration in the subregion. The location results are available upon request as a spreadsheet or GIS layer file.

Tier 1 focal areas for Martin subregion

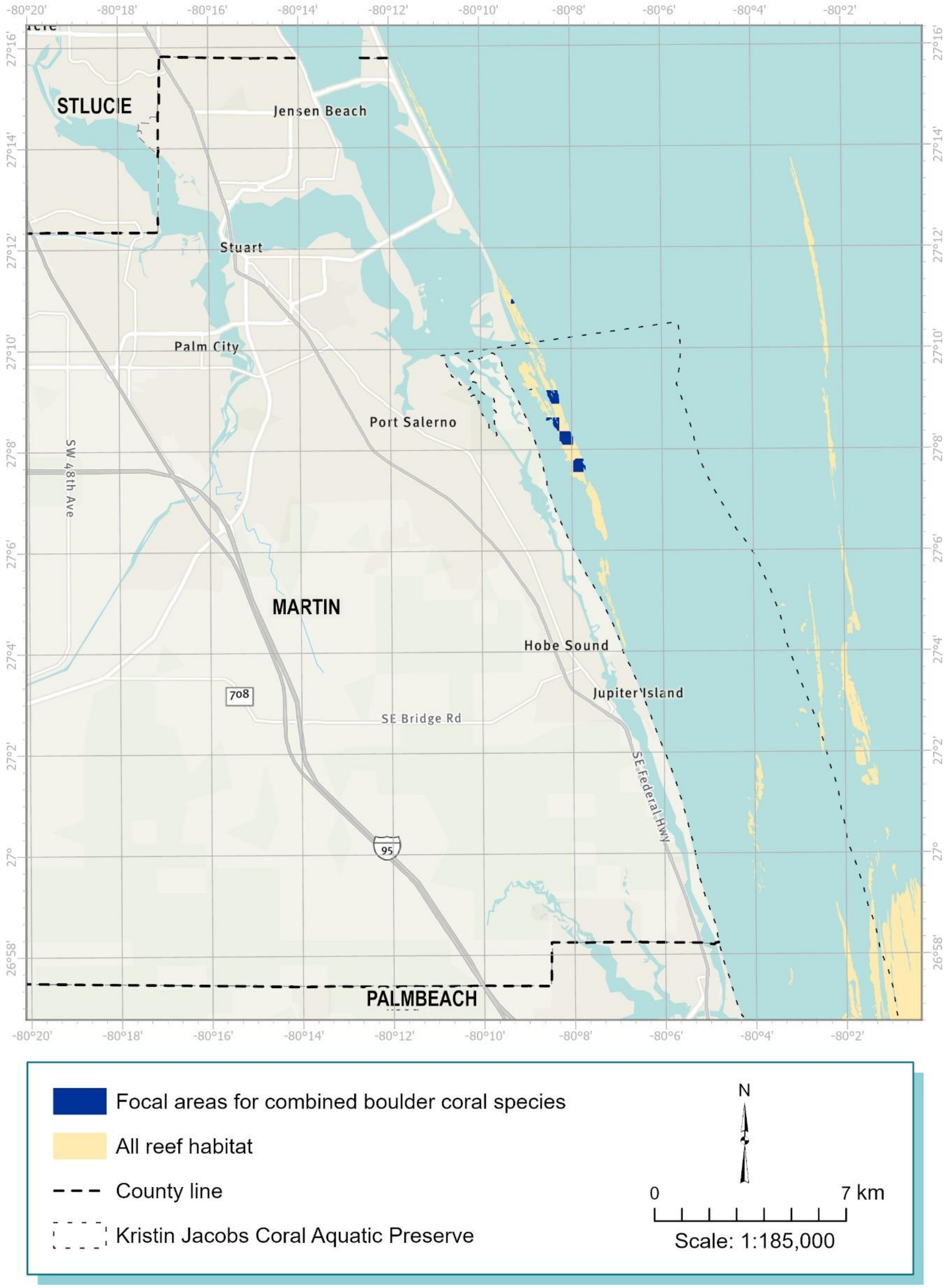


Figure 4. Focal areas for boulder coral restoration identified in blue*. A. cervicornis *was not observed in this subregion, so there is only one set of results.

Tier 1 focal areas for North Palm Beach subregion

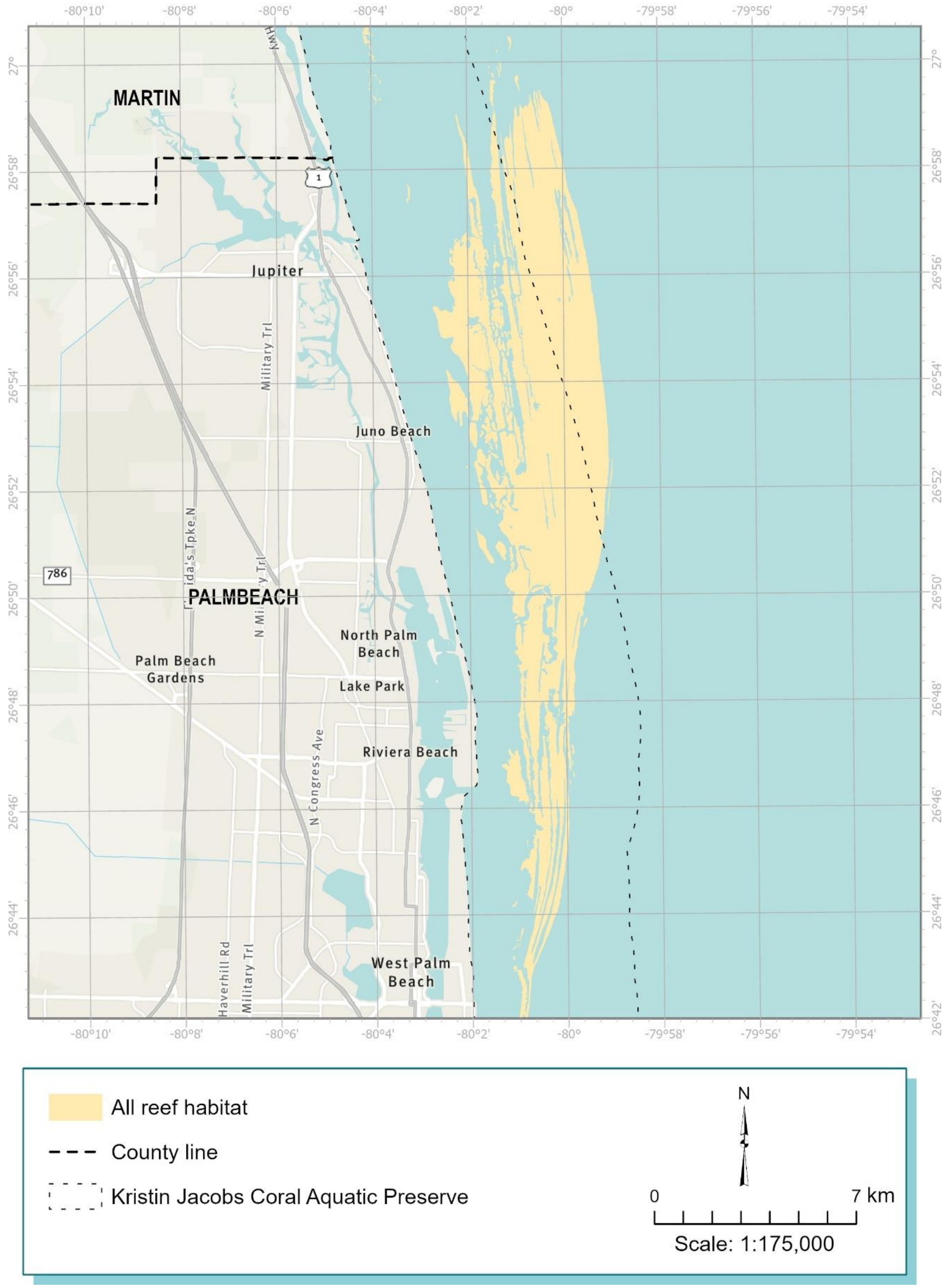


Figure 5. No focal areas were identified in North Palm Beach because the habitat is all deeper than 18m (~60 feet) and was excluded from consideration.

Tier 1 focal areas for South Palm Beach subregion

Figure 6. Focal areas for boulder coral restoration identified in blue. **A. cervicornis** ***was not observed in this subregion, so there is only one set of results.***

Tier 1 focal areas for Deerfield subregion

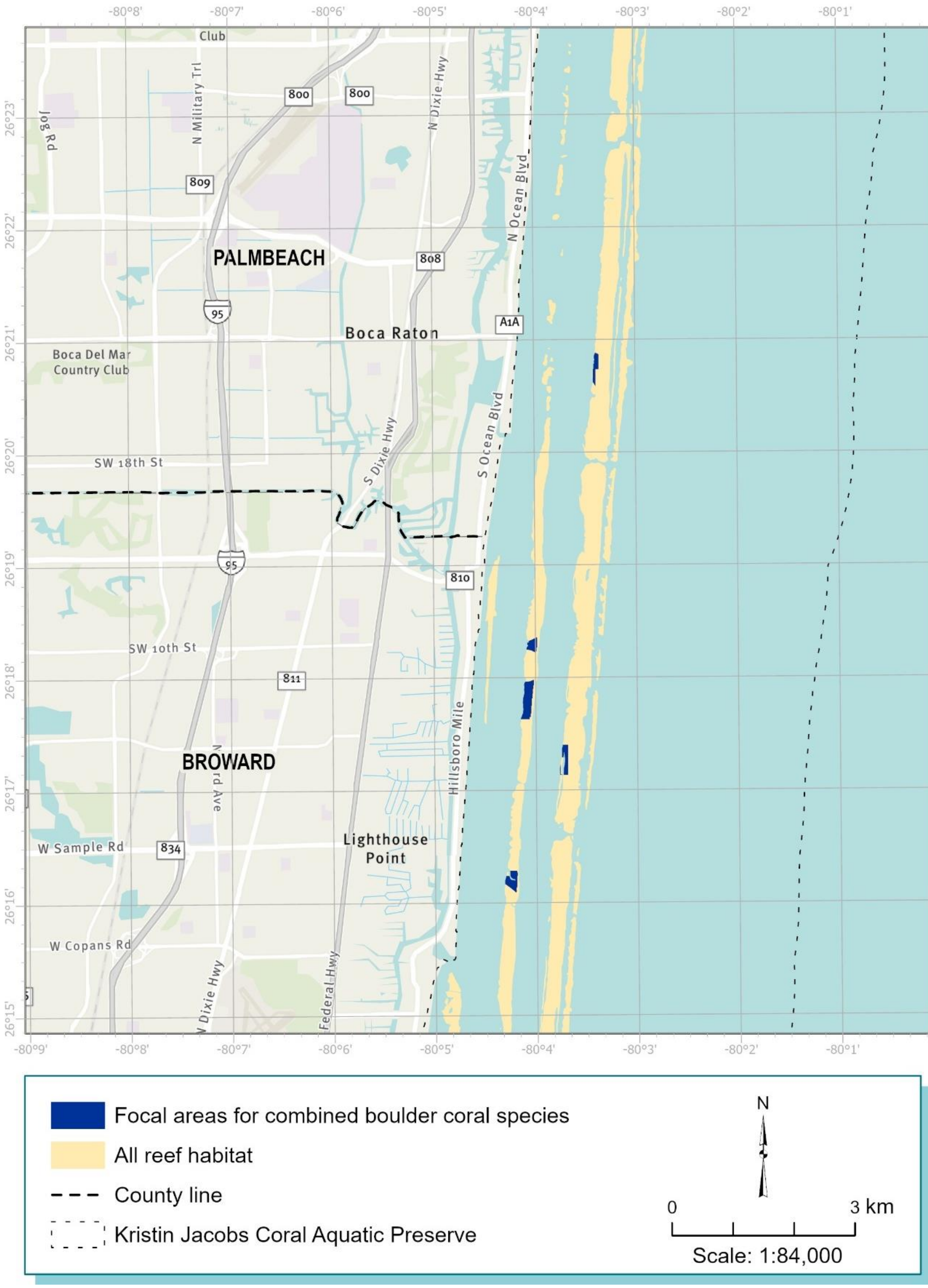


Figure 7. Focal areas for boulder coral restoration identified in blue. **A. cervicornis** ***was not observed in this subregion in the data sets used, so there is only one set of results.***

Tier 1 focal areas for Broward-Miami subregion

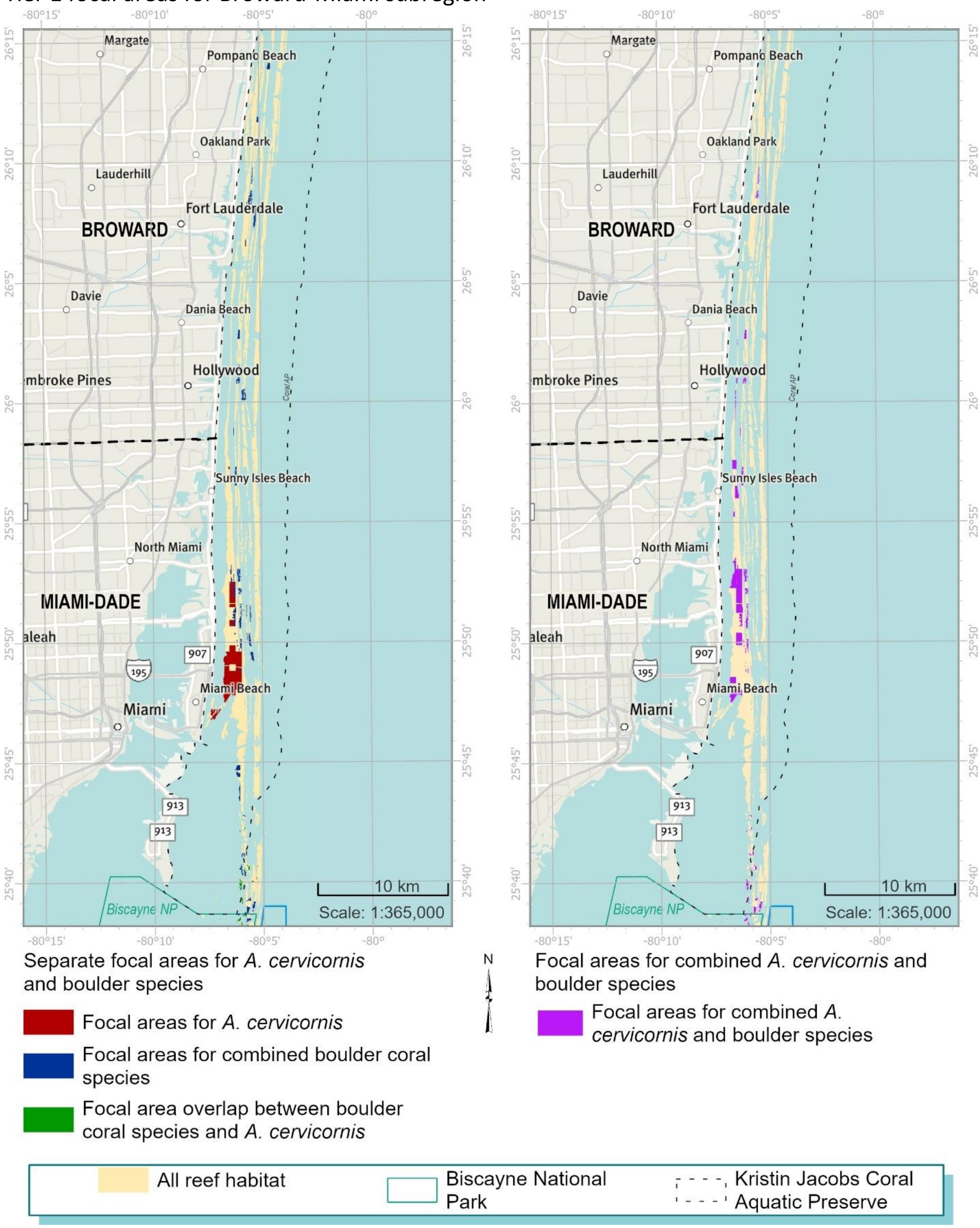


Figure 8. A) Focal areas for boulder coral restoration identified in blue, for **A. cervicornis** ***in red, and for all four species in green. B) Focal areas for multi-species restoration identified in purple. Multi-species restoration in this region is most likely to be successful in the green areas where the habitat selection was maximized for the two sets of species independently.***

Tier 1 focal areas for Biscayne subregion

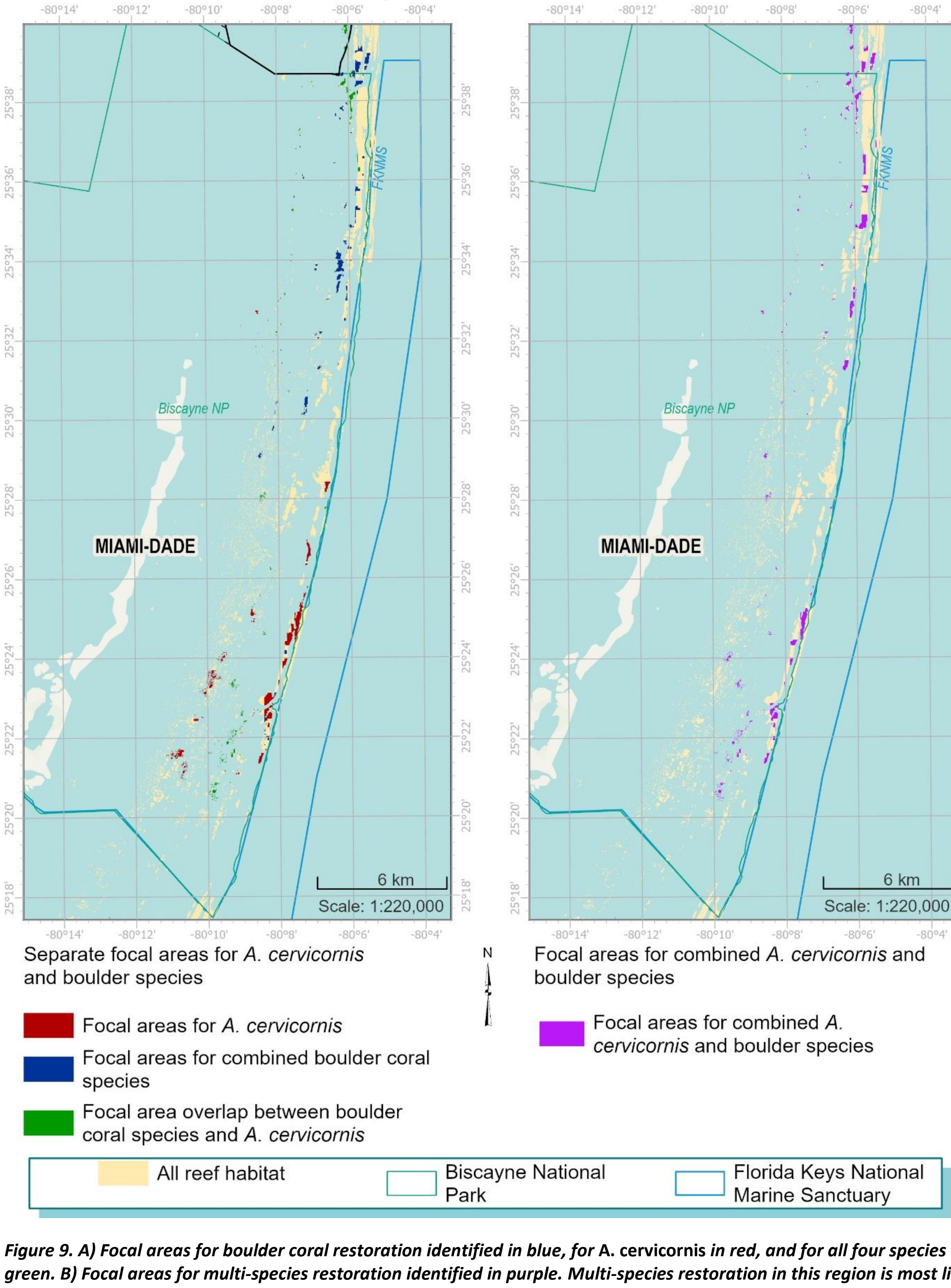


Figure 9. A) Focal areas for boulder coral restoration identified in blue, for* A. cervicornis *in red, and for all four species in green. B) Focal areas for multi-species restoration identified in purple. Multi-species restoration in this region is most likely to be successful in the green areas where the habitat selection was maximized for the two sets of species independently.

Tier 1 focal areas for Upper Keys subregion

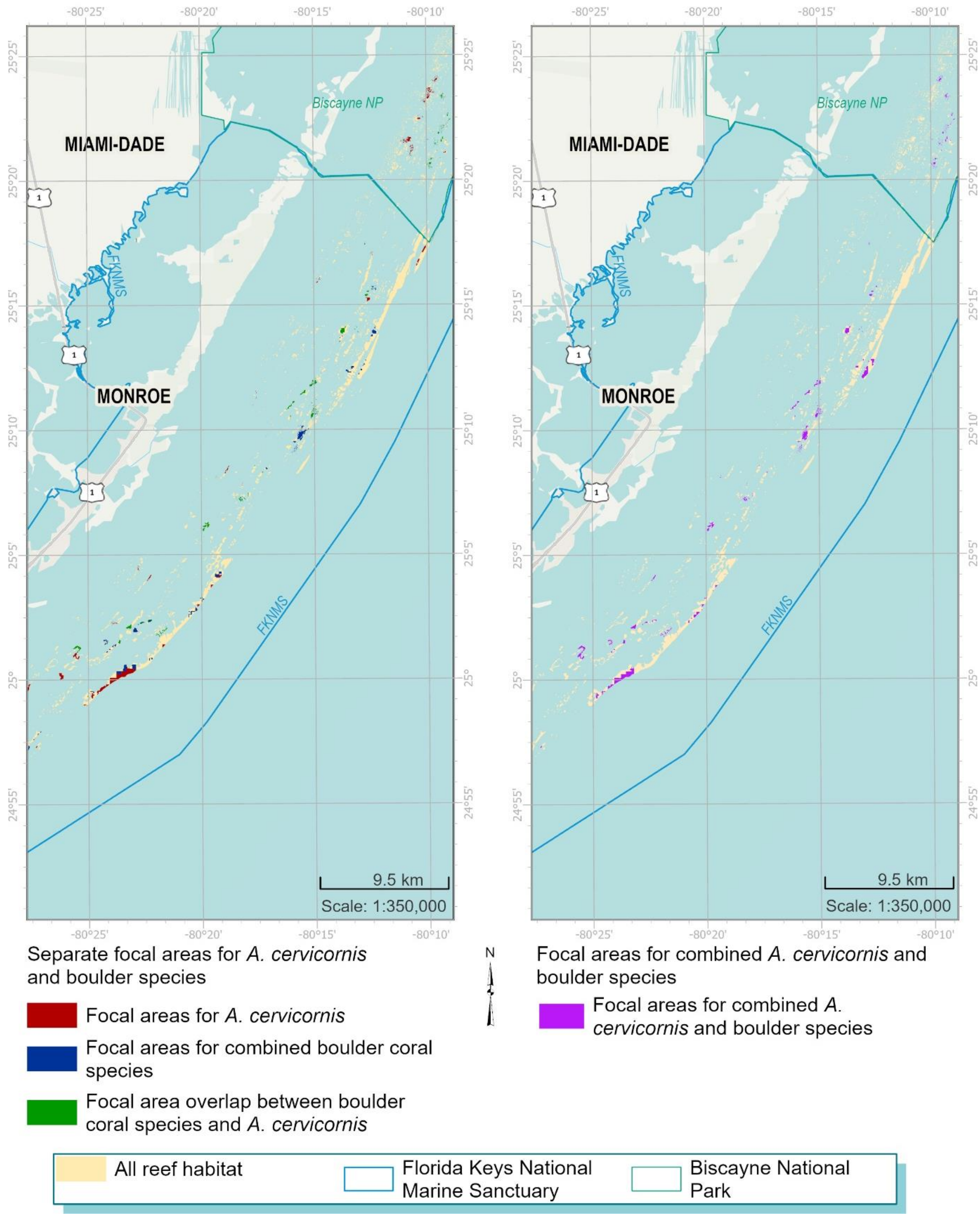


Figure 10. A) Focal areas for boulder coral restoration identified in blue, for A. cervicornis ***in red, and for all four species in green. B) Focal areas for multi-species restoration identified in purple. Multi-species restoration in this region is most likely to be successful in the green areas where the habitat selection was maximized for the two sets of species independently.***

Tier 1 focal areas for Mid-Upper Keys Transition subregion

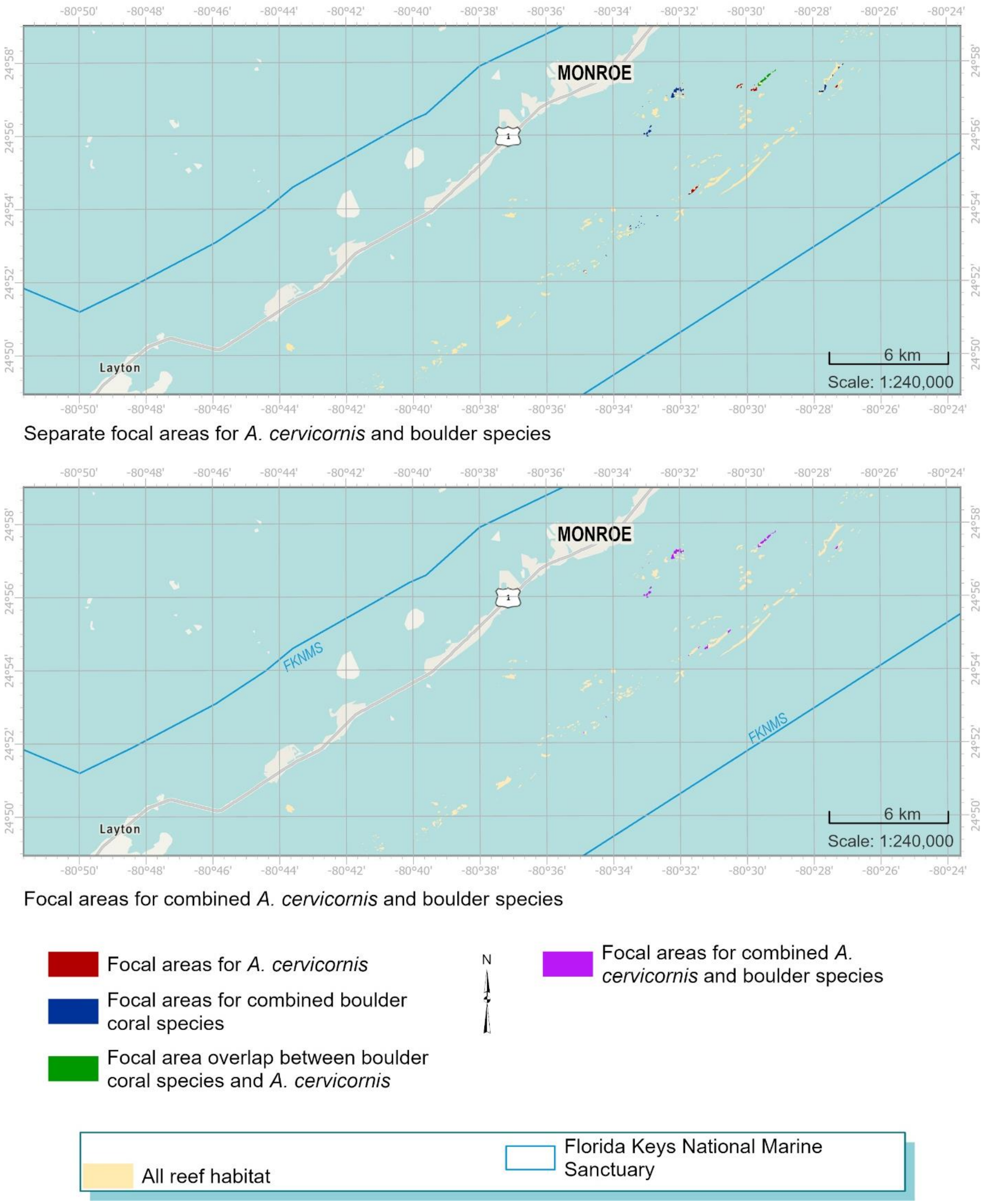


Figure 11. A) Focal areas for boulder coral restoration identified in blue, for* A. cervicornis *in red, and for all four species in green. B) Focal areas for multi-species restoration identified in purple. Multi-species restoration in this region is most likely to be successful in the green areas where the habitat selection was maximized for the two sets of species independently.

Tier 1 focal areas for Middle Keys subregion

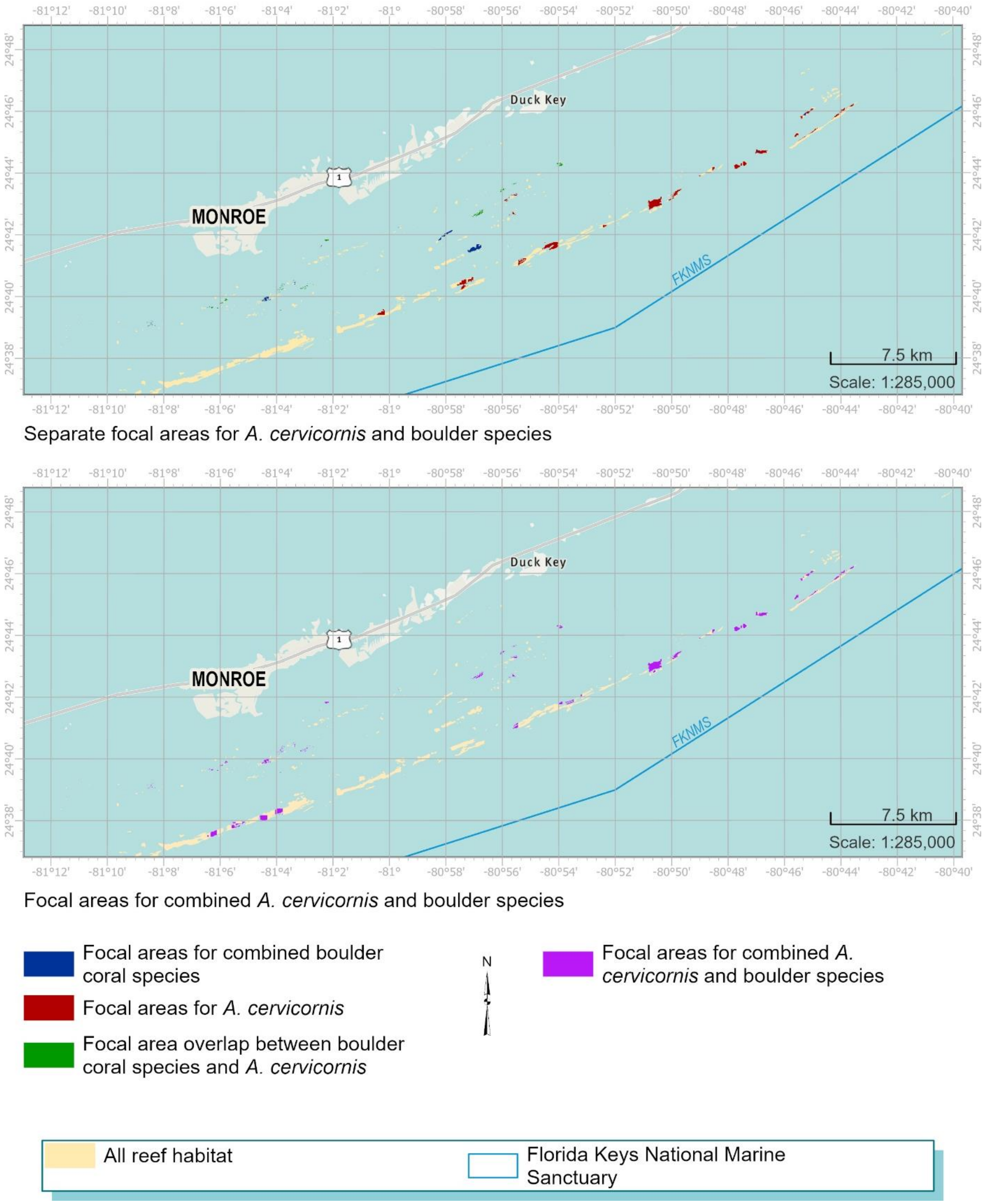


Figure 12. A) Focal areas for boulder coral restoration identified in blue, for **A. cervicornis** ***in red, and for all four species in green. B) Focal areas for multi-species restoration identified in purple. Multi-species restoration in this region is most likely to be successful in the green areas where the habitat selection was maximized for the two sets of species independently.***

Tier 1 focal areas for Lower Keys subregion

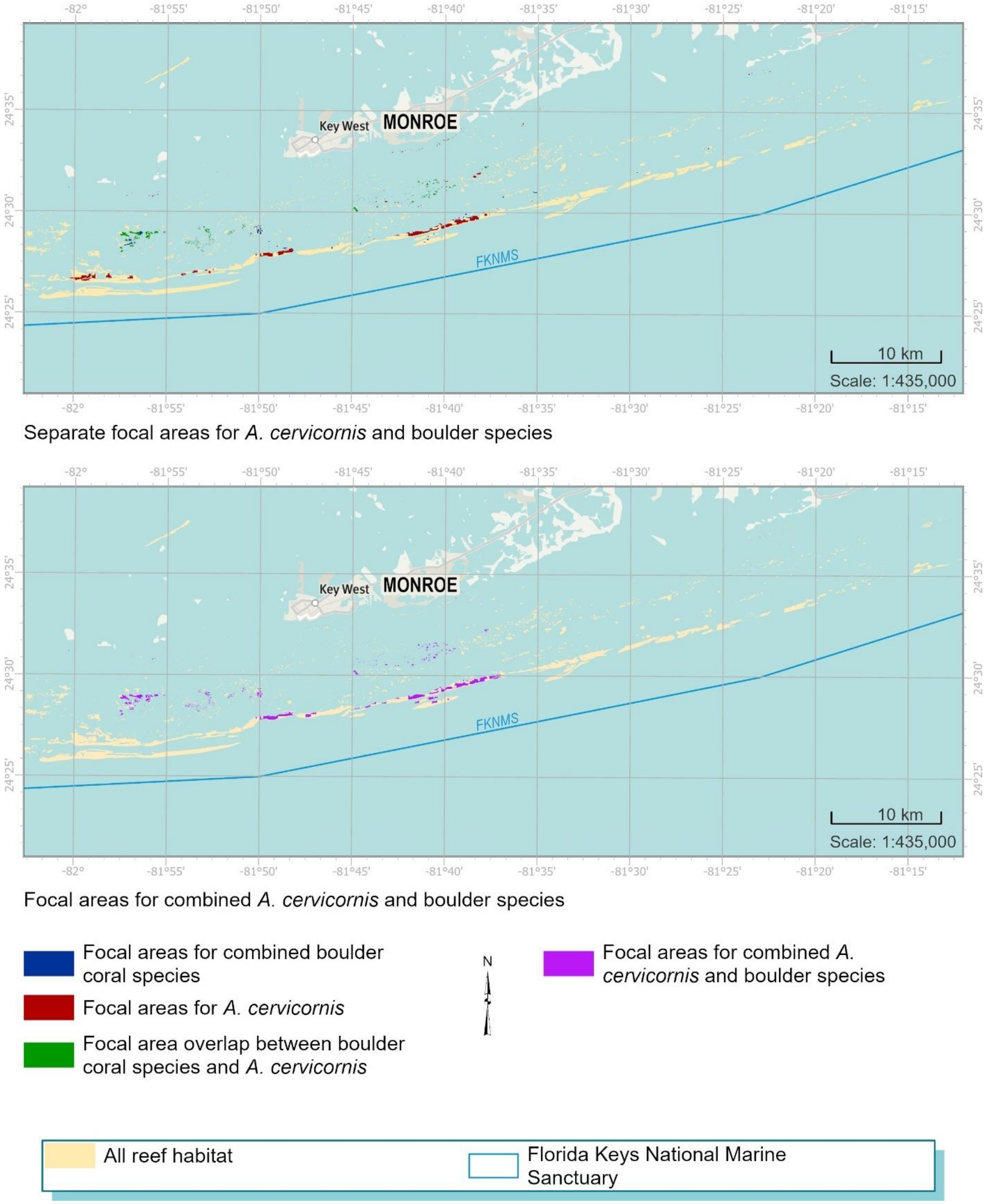
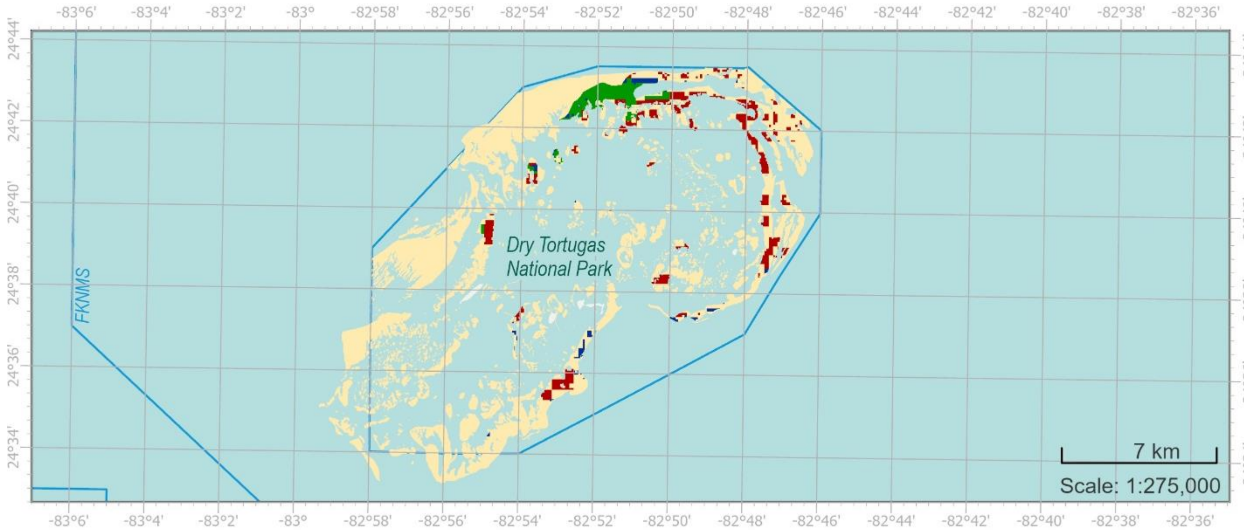
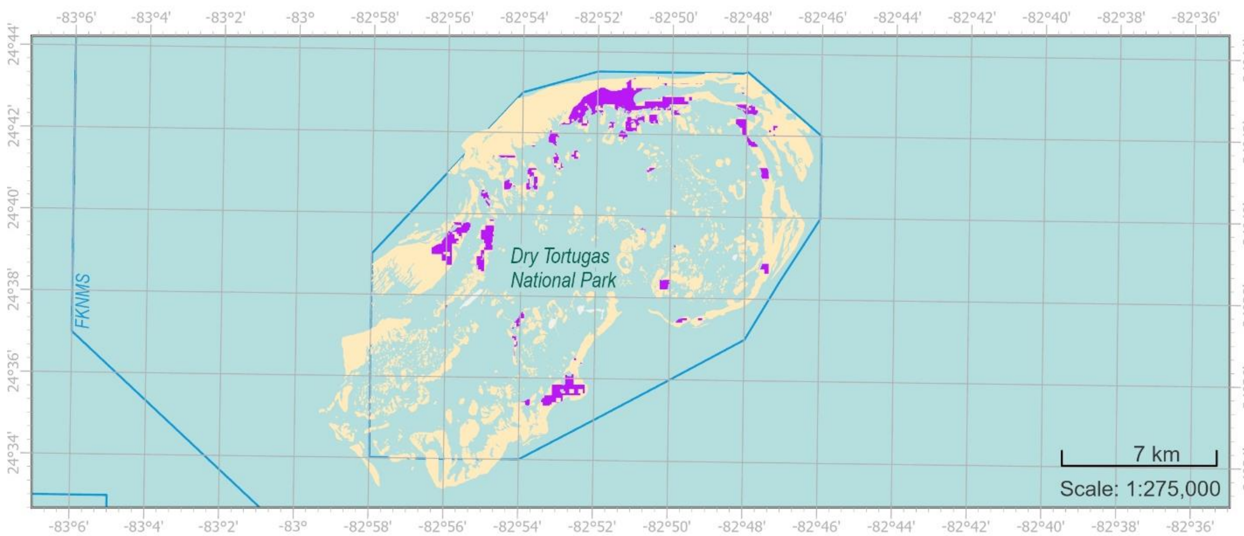


Figure 13. A) Focal areas for boulder coral restoration identified in blue, for* A. cervicornis *in red, and for all four species in green. B) Focal areas for multi-species restoration identified in purple. Multi-species restoration in this region is most likely to be successful in the green areas where the habitat selection was maximized for the two sets of species independently.

Tier 1 focal areas for Dry Tortugas subregion



Separate focal areas for *A. cervicornis* and boulder species



Focal areas for combined *A. cervicornis* and boulder species

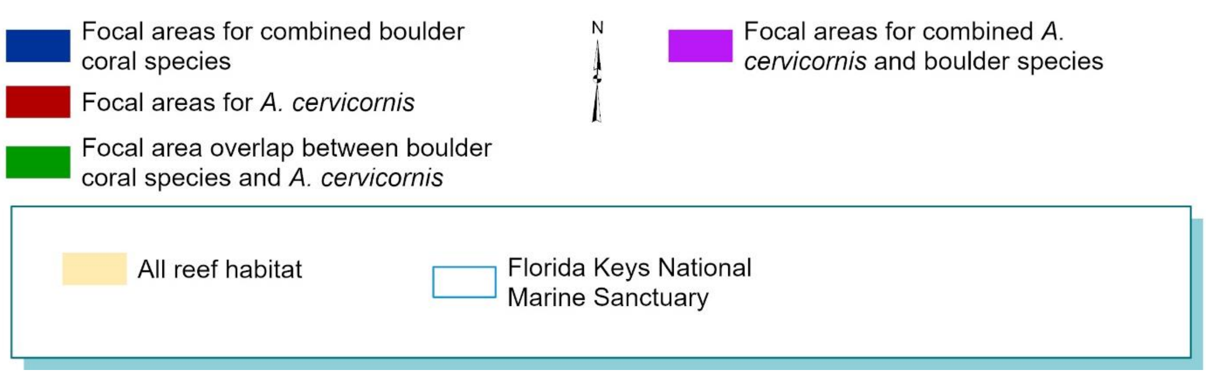


Figure 14. A) Focal areas for boulder coral restoration identified in blue, for **A. cervicornis** ***in red, and for all four species in green. B) Focal areas for multi-species restoration identified in purple. Multi-species restoration in this region is most likely to be successful in the green areas where the habitat selection was maximized for the two sets of species independently.***

Next steps

This Tier 1 Strategy lays the groundwork for more detailed restoration planning at the place-based or managed area and site levels by providing overarching guidance and identifying focal areas that are more likely to contribute to large-scale ecological recovery of Florida's Coral Reef. A robust set of site selection criteria were developed and considered during this process and the list is included in Appendix 2 for reference for future Tier 2 and 3 planning efforts. In Tier 2, managers and practitioners may determine how best to implement this Strategy within their jurisdiction and consider whether there are other ecological, ecosystem service, or research goals that are particularly important within their jurisdiction. The focal areas identified in Tier 1 could be further narrowed based on jurisdictional goals, conditions, and/or logistics that do not necessarily apply to all of Florida's Coral Reef. Similarly, Tier 2 plans might identify a suite of interventions that will be used to conduct large-scale restoration and/or a set of standard metrics that will be used to evaluate success and trigger adaptive management within the jurisdiction. Because Tier 1 (and in some cases Tier 2) focal areas are being selected using a desktop analysis and large-scale interpolated data, ground-truthing should be conducted either at the end of Tier 2 planning or the beginning of Tier 3 planning to ensure that any potential site within the prioritized focal area is indeed suitable for restoration.

In Tier 3 planning, focal areas will be downscaled to individual sites (up to 12 hectares or 31 acres in area) using expert opinion and ground-truthing surveys. Managers and practitioners can then develop site-level plans that include detailed information on objectives, restoration methods, species, and monitoring, considering differences between each site. At this level, A Manager's Guide to Coral Reef Restoration Planning and Design and/or the planning document for Mission: Iconic Reefs can provide guidance on building a specific action plan to guide and monitor restoration.

Appendix 1: Methods for identifying focal areas

Coral demographics

The data used for the coral demographics analysis were collected under two long-term benthic monitoring programs, Disturbance Response Monitoring (DRM) and the National Coral Reef Monitoring Program (NCRMP).

For the purposes of this analysis, data were used to calculate a persistence index (i.e., presence/absence over time) and a size class distribution index for each of the four key species in each of the habitats along the reef. Habitats rather than strata were used based on advice provided by NOAA NCRMP scientists. The indices were then combined to prioritize habitats within each region (e.g., Dry Tortugas, Florida Keys, Southeast Florida) as defined by the Disturbance Response Monitoring and National Coral Reef Monitoring Programs (Figure 3). Due to the statistical methods used to collect the monitoring data, use of finer-scale geographic designation results, for example by subregion, would not have been statistically valid. The results of this analysis were used to indicate which coral habitats in each region are most likely to support outplanted coral colonies to sexual maturity.

Size frequency distribution

Size frequency distribution was chosen as an indicator because a habitat that can support both adults and juveniles of a species is likely to be a good candidate site for outplanting. Additionally, with the goal of sexual reproduction, a site with a range of sizes, or ages, has larger, more fecund adults but also potentially younger, more temporally adapted genes to contribute to the gene pool. Size frequency distribution was calculated using data from the Florida Fish and Wildlife Commission's (FWC) Disturbance Response Monitoring (DRM) Program and NOAA's National Coral Reef Monitoring Program (NCRMP) for the years 2020-2022 using the following methods:

- Point survey data were obtained from NCRMP (https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:NCRMP-Benthic-Florida) and DRM (https://ocean.floridamarine.org/FRRP/Home/Reports). These data were exported into Excel and analyzed separately for each region (Dry Tortugas, Florida Keys and Southeast Florida). The three years of data (2020-2022) were summed for each of the key species in each region and habitat.
- The area surveyed was then calculated separately for the DRM and NCRMP data for each habitat in each region. DRM sites each consist of two 1m x 10m belt transects, while NCRMP sites consist of one such transect. For the DRM data, the number of survey sites was multiplied by $20m^2$; for the NCRMP data, the number of survey sites was multiplied by $10m^2$. Total area surveyed was calculated by adding the DRM total survey area to the NCRMP total survey area for each habitat in each region.

- The size frequency distribution of coral colonies per square meter (i.e., number of colonies present divided by survey area) was then calculated. Corals were binned into ecologically significant size classes: 0-10cm, 11-25cm, 26-50cm, 50-100cm and >100cm. These bins represent size classes from juvenile to adult based on the four species included in this analysis and were determined based on discussions with scientists at FWC's Florida Fish and Wildlife Research Institute (FWRI) including factors such as at what size colonies are likely to be sexually reproductive or able to evade predation. The number of colonies found in each bin was then divided by total area surveyed to obtain the colony density for each species in each habitat in each size class bin.
- The NCRMP and DRM colony densities were then summed to obtain the complete size class distribution for each habitat in each region and size class bin.
- The results for each species, size class bin, habitat and region were then examined and compared to develop a size frequency distribution rating that would reflect a spread of values across good, medium and poor ratings. The size frequency distribution ratings for each species are provided in Table A-1 below.
- Ratings were normalized to a score between zero and one to be on par with the persistence ratings. Scores closer to 1.0 represent a habitat with a more robust size frequency spread.

Table A1-1. Size frequency distribution rating scheme.

Pseudodiplora strigosa **scoring**

Score	**Criteria**	**Normalized score**
Good = 5	At least 3 size bins with 95 or more colonies/ha	1
Medium = 3	At least 2 size bins with 95 or more colonies/ha	0.6
Poor = 1	Less than 2 size bins with 95 or more colonies/ha	0.2

Orbicella faveolata **scoring**

Score	**Criteria**	**Normalized score**
Good = 5	At least 3 size bins with 50 or more colonies/ha	1
Medium = 3	At least 2 size bins with 30 or more colonies/ha	0.6
Poor = 1	Less than 2 size bins with 30 or less colonies/ha	0.2

Montastrea cavernosa **scoring**

Score	**Criteria**	**Normalized score**
Good = 5	At least 3 size bins with 100 or more colonies/ha	1
Medium = 3	At least 2 size bins with 50 or more colonies/ha	0.6
Poor = 1	Less than 2 size bins with 50 or more colonies/ha	0.2

Acropora cervicornis **scoring**

Score	**Criteria**	**Normalized score**
Good = 5	At least 3 size bins with 25 or more colonies/ha	1
Medium = 3	At least 2 size bins with 20 or more colonies/ha	0.6
Poor = 1	Less than 2 size bins with 20 or more colonies/ha	0.2

Table A1-2. Normalized size frequency scores by region and habitat for the 4 selected species addressed in the Tier 1 Strategy. Rating scores are described in Table A1-1 above. Blank cells represent 'not present'. Shading identifies different regions of FCR.

Region	Habitat	*A. cervicornis*	*M. cavernosa*	*O. faveolata*	*P.strigosa*
Dry Tortugas	Contiguous high relief	0.6	1	1	1
Dry Tortugas	Contiguous low relief	1	1	0.6	0.6
Dry Tortugas	Contiguous mid relief	0.2	1	0.6	0.6
Dry Tortugas	Isolated high relief	0.2	1	1	1
Dry Tortugas	Isolated low relief	0.2	0.2	0.2	1
Dry Tortugas	Isolated mid relief	0.2	1	0.6	1
Dry Tortugas	Spur and groove high relief	0.2	1	0.6	1
Dry Tortugas	Spur and groove low relief	0.2	0.2	0.6	0.6
Florida Keys	Contiguous high relief	0.2	0.6	0.1	0.2
Florida Keys	Contiguous low relief	0.2	0.6	0.2	0.2
Florida Keys	Contiguous mid relief		0.6	0.2	0.2
Florida Keys	Isolated high relief		1	1	0.6
Florida Keys	Isolated low relief		0.2		
Florida Keys	Isolated mid relief	0.2	1	1	0.6
Florida Keys	Reef high relief		0.2		
Florida Keys	Rubble low relief		0.2		0.2
Florida Keys	Spur and groove high relief	0.2	0.6	0.6	0.2
Florida Keys	Spur and groove low relief	0.2	0.2	0.2	0.2
Florida Keys	Spur and groove mid relief		0.6	0.2	0.2
Southeast FL	Aggregated Patch Reef Deep		1	0.2	
Southeast FL	Aggregated Patch Reef Shallow			0.2	
Southeast FL	Colonized Pavement Deep		1	0.2	0.2
Southeast FL	Colonized Pavement Shallow	0.6	0.6	0.2	0.6
Southeast FL	Deep Ridge Complex		0.2	0.2	
Southeast FL	Linear reef inner	1	0.6	0.2	0.6
Southeast FL	Linear reef middle		0.6	0.2	0.6
Southeast FL	Linear reef outer		1	0.2	0.2
Southeast FL	Patch reef		1	0.2	
Southeast FL	Ridge deep			0.2	
Southeast FL	Ridge shallow	1	0.2	0.2	0.6
Southeast FL	Spur and groove		1	0.2	

Persistence

Persistence was included as an indicator because size frequency distribution shows what to expect for coral demographics within a habitat now but may not capture long-term trends in survival in response to disturbances. Habitats where a species was observed more often may be better suited for that species than habitats where species were only observed a few times over the monitoring timeframe.

DRM data has been collected since 2005 and the number of sites surveyed each year has steadily increased; the managers chose to focus on 2014-2022 to capture the more robust data sets. Additionally, SCTLD was first observed in 2014, so data collected after that year more accurately represents current coral populations. Using DRM data from 2014 to 2022 and NCRMP data from 2014, 2016, 2018, 2020, 2021 and 2022, persistence for each species was calculated for each habitat in each region by dividing the number of years the species was observed by the number of years the habitat was sampled. Scores closer to 1.0 represent higher persistence over time. Some habitats were not sampled every year, so it is important to differentiate between lack of data and lack of corals.

Table A1-3. Persistence over the years 2014-2022 for the 4 selected species by habitat. Persistence was calculated by dividing the number of years a species was observed in a given habitat by the number of years that habitat was monitored.

Region	**Habitat**	***A. cervicornis***	***M. cavernosa***	***O. faveolata***	***P. strigosa***
Dry Tortugas	Contiguous high relief	0.67	1.00	1.00	0.78
Dry Tortugas	Contiguous low relief	0.89	1.00	1.00	1.00
Dry Tortugas	Contiguous mid relief	0.56	1.00	1.00	1.00
Dry Tortugas	Isolated high relief	0.56	1.00	0.89	1.00
Dry Tortugas	Isolated low relief	0.29	0.86	0.86	0.86
Dry Tortugas	Isolated mid relief	0.78	1.00	1.00	0.89
Dry Tortugas	Rubble low relief	0.00	0.50	0.50	0.00
Dry Tortugas	Spur and groove high relief	0.38	1.00	1.00	0.88
Dry Tortugas	Spur and groove low relief	0.44	1.00	0.89	0.78
Florida Keys	Contiguous high relief	0.50	0.50	1.00	0.50
Florida Keys	Contiguous low relief	0.00	1.00	1.00	1.00
Florida Keys	Contiguous mid relief	0.00	0.75	0.75	0.75
Florida Keys	Isolated high relief	0.00	1.00	1.00	0.75
Florida Keys	Isolated low relief	0.25	0.88	0.38	0.38
Florida Keys	Isolated mid relief	0.00	1.00	1.00	1.00
Florida Keys	Reef high relief	0.00	1.00	0.00	0.00
Florida Keys	Rubble low relief	0.20	0.80	0.20	0.20
Florida Keys	Spur and groove high relief	0.67	1.00	0.89	0.78
Florida Keys	Spur and groove low relief	0.78	1.00	1.00	1.00
Florida Keys	Spur and groove mid relief	0.00	1.00	1.00	1.00
Southeast FL	Aggregated patch reef deep	0.00	1.00	0.29	0.29
Southeast FL	Aggregated patch reef shallow	0.00	1.00	0.00	0.00
Southeast FL	Colonized pavement deep	0.00	0.88	0.25	0.00
Southeast FL	Colonized pavement shallow	0.78	0.89	0.44	0.67
Southeast FL	Deep ridge complex	0.00	0.80	0.00	0.00
Southeast FL	Linear reef inner	0.33	1.00	0.67	0.89
Southeast FL	Linear reef middle	0.00	0.89	0.78	0.89
Southeast FL	Linear reef outer	0.00	1.00	0.67	0.44
Southeast FL	Patch reef	0.00	0.83	0.00	0.17
Southeast FL	Ridge deep	0.00	0.40	0.20	0.00
Southeast FL	Ridge shallow	0.78	0.89	0.44	1.00
Southeast FL	Scattered Coral Rock and Sand	0.00	0.00	0.00	0.20
Southeast FL	Spur and groove	0.00	1.00	0.56	0.11

Combined demographic score

Reef managers participating in the Strategy development recommended combining the size frequency distribution and persistence scores into a combined demographic score. They also recommended giving more weight to persistence than to size frequency distribution. The specific recommendation was to weight the persistence score by 75% and the size frequency distribution score by 25%. Similarly, a recommendation was made to conduct this analysis in two ways: 1) by combining the boulder coral species and keeping *A. cervicornis* separate due to the more unique habitat requirements of *A. cervicornis*, and 2) by combining all four species to select focal areas where multi-species restoration including both branching and bouldering species would be more advantageous. The combined values for the three boulder coral species and for all four species was calculated by adding the values for those species. Demographic values closer to 1.0 for each species represent areas with higher persistence and a more robust size frequency distribution than others, thus representing areas where restoration should be focused.

Table A1-4. Demographic scores by region and habitat for the four selected species, and the combined score for the three boulder coral species. Abbreviations in the table are as follows: A. cervicornis (ACER), M. cavernosa (MCAV), O. faveolata (OFAV) and P. strigosa (PSTR).

Region	Habitat	ACER	MCAV	OFAV	PSTR	Boulder species combined	All species combined
Dry Tortugas	Contiguous high relief	0.75	0.90	0.90	0.73	2.53	3.28
Dry Tortugas	Contiguous low relief	0.92	1.00	0.80	0.90	2.7	3.62
Dry Tortugas	Contiguous mid relief	0.47	0.90	0.90	0.90	2.7	3.17
Dry Tortugas	Isolated high relief	0.47	0.90	0.72	0.90	2.52	2.99
Dry Tortugas	Isolated low relief	0.26	0.69	0.69	0.89	2.27	2.53
Dry Tortugas	Isolated mid relief	0.63	0.90	0.80	0.92	2.62	3.25
Dry Tortugas	Rubble low relief	0.00	0.38	0.38	0.00	0.76	0.76
Dry Tortugas	Spur and groove high relief	0.33	1.00	0.80	0.91	2.71	3.04
Dry Tortugas	Spur and groove low relief	0.38	0.90	0.72	0.73	2.35	2.73
Florida Keys	Contiguous high relief	0.43	0.43	1.00	0.38	1.81	2.24
Florida Keys	Contiguous low relief	0.05	0.90	0.80	0.80	2.5	2.55
Florida Keys	Contiguous mid relief	0.00	0.61	0.61	0.61	1.83	1.83
Florida Keys	Isolated high relief	0.00	0.80	0.80	0.61	2.21	2.21
Florida Keys	Isolated low relief	0.19	0.71	0.28	0.28	1.27	1.46
Florida Keys	Isolated mid relief	0.90	1.00	1.00	1.00	2.9	3.05
Florida Keys	Reef high relief	0.00	0.75	0.00	0.00	0.75	0.75
Florida Keys	Rubble low relief	0.15	0.60	0.15	0.20	0.95	1.1
Florida Keys	Spur and groove high relief	0.55	0.80	0.72	0.63	2.15	2.7
Florida Keys	Spur and groove low relief	0.63	0.80	0.80	0.80	2.4	3.03
Florida Keys	Spur and groove mid relief	0.00	0.80	0.75	0.75	2.3	2.3
Southeast FL	Aggregated patch reef deep	0.00	0.80	0.26	0.21	1.27	1.27
Southeast FL	Aggregated patch reef shallow	0.00	0.75	0.00	0.00	0.75	0.75
Southeast FL	Colonized pavement deep	0.00	0.71	0.24	0.05	1	1
Southeast FL	Colonized pavement shallow	0.83	0.82	0.38	0.55	1.75	2.58
Southeast FL	Deep ridge complex	0.00	0.65	0.00	0.00	0.65	0.65
Southeast FL	Linear reef inner	0.50	0.90	0.55	0.82	2.27	2.77
Southeast FL	Linear reef middle	0.00	0.82	0.63	0.72	2.17	2.17
Southeast FL	Linear reef outer	0.00	0.90	0.55	0.38	1.83	1.83
Southeast FL	Patch reef	0.00	0.68	0.00	0.13	0.81	0.81
Southeast FL	Ridge deep	0.00	0.35	0.15	0.00	0.5	0.5
Southeast FL	Ridge shallow	0.83	0.72	0.38	0.80	1.9	2.73
Southeast FL	Scattered coral rock and sand	0.00	0.00	0.00	0.15	0.15	0.15
Southeast FL	Spur and groove	0.00	0.80	0.47	0.08	1.35	1.35

While demographic values were calculated for each region, decisions within the Southeast Florida region were made specific to each subregion. This is because not all habitats extend across the entire region, so choosing the top habitat for the region would exclude focal areas from being chosen within certain subregions. Instead, the values for each region were assessed in each subregion and the top two values for each subregion were prioritized.

Connectivity modeling

Connectivity values were calculated by modeling the unstructured-mesh depth-integrated coastal ocean model SLIM to simulate currents over Florida's Coral Reef including the Florida Strait and part of the Gulf of Mexico. Building on prior work (Frys et al., 2020; King et al., 2023), the hydrodynamic model was run by Dr. Thomas Dobbelaere and Dr. Emmanuel Hanert for a period of 10 years (2012-2021) to encompass the variability in current patterns across time. This type of model can simulate the small-scale influences of reefs to a spatial resolution of approximately 100 m, giving a more accurate prediction of how currents flow in complex shallow water reef systems such as FCR. Sites that fall outside of what might be considered restorable reef (e.g., backcountry hardbottom in the Florida Keys) were removed.

The larval survival and competency dynamics models of key species identified by the Florida Department of Environmental Protection (DEP) were experimentally calibrated by Ryan Chabotte and Dr. Joana Figueiredo at Nova Southeastern University. The species that were funded by DEP in 2022 include *Colpophyllia natans*, *Orbicella faveolata*, *Acropora cervicornis*, and *Montastrea cavernosa*; additional species have been analyzed under other funding sources. The key species in this Tier 1 Strategy have larval survival and competency models; other species were not used as proxies.

To predict coral larval dispersal patterns and species-specific reef connectivity, a particle-tracking bio-physical dispersal model including larval dynamics, buoyancy/vertical swimming data, and high-resolution hydrodynamics was developed. Every polygon in the model receives four values: source, sink, isolation and self-recruitment.

To balance the desire to prioritize areas that serve as sources but also consider an area's value as a sink, the following index was calculated:

$$Ri = (Cout\_i)^{a} * (Cin\_i)^{(1-a)},$$

where Ri is the restoration index at reef i, Cout_i is the source index, Cin_i is the sink index and a is an exponent in the interval [0, 1].

In Martin County, where source values were very low, a different value was used to prioritize focal areas that represents the ability of a reef to replenish itself through self-recruitment.

Combining demographic and connectivity data sets

The reef habitats with the highest demographic scores were then narrowed by selecting areas with the most promising connectivity values.

Exclusion areas

The Unified Reef Map – Reef Habitat (Level 2) was edited by removing the exclusion areas identified in Table A1-5 and any area deeper than 18 meters (~60 feet). Many of the exclusion areas were due to human impact (ports, pipeline corridors, anchorages, etc.); deeper areas were excluded because current restoration methods are tailored to restoration at shallower depths, with most large-scale restoration occurring in 10m (~32 feet) or less. Excluding areas deeper than 18m (~60 feet) eliminated all reefs within the North Palm Beach subregion.

Table A1-5. Exclusion areas as identified by the reef managers.

Exclusion area name	Distance/buffer
Government Cut (Miami)	1000m buffer from entrance channel
Commercial anchorages (Miami)	Anchorage polygon
Commercial anchorages (Broward)	Started with anchorage polygon and extended west to include 2nd and 3rd reefs
Pipeline corridors	25m buffer
Coastal cable submarine lines	25m buffer
Sewage outfalls	200m buffer from outfall location
Inlets	1609km (1 mile) buffer from entrance
Port Everglades (Broward)	1609km (1 mile) buffer through 2nd and 3rd reef (to account for planned expansion)
Archeological sites	25m buffer
Permitted borrow areas (Palm Beach)	304.8m (1000 ft) buffer
Beach nourishment	300m from MHW along entire Southeast Florida region, unless more stringent requirements per County
Ship grounding site – Spar Orion	25m buffer
Navy Cable Landing Station anchor exclusion area (Broward)	No buffer
CREMP sites	250m buffer
Tire reef area (Broward)	100m buffer
Legare anchorage – (Biscayne NP)	No buffer
Deeper reef	Any reef area deeper than 18m (~60 feet)

Spatial analysis to combine demographic and connectivity data sets

FWC's Unified Reef Map does not include the NCRMP habitats as an attribute, so habitat codes were assigned to the reef by overlaying the NCRMP 50m sampling grid. The Identity tool in ArcGIS Pro (version 3.2) was used to assign an NCRMP habitat code to the edited reef layer. This modified reef layer formed the area that was then prioritized by the spatial result of the connectivity modeling.

Focal areas were selected from areas that met the following criteria:

- mapped in the Unified Reef Map
- included in the NCRMP sampling grid
- included in the spatial result of the connectivity modeling.

The spatial connectivity results were delivered in GIS layers as polygons that overlap reef, with each species in a separate GIS layer. Polygons are the same for all four species; the attribute values are different. The data set that was used for this Strategy is an average of the ten years that were modeled. Each connectivity polygon has a numeric value characterizing its capacity to send out coral larvae (i.e., serve as a source) and a numeric value characterizing its capacity to receive coral (i.e., to serve as a sink). In Tier 1 planning, the source value was prioritized but the sink value also contributed to the overall value. As described above, the following equation was used to calculate a restoration index value (Ri) to account for this:

Ri = Cout_i^0.8 * Cin_i^0.2

where Ri is the restoration index at reef i, Cout_i is the source index, Cin_i is the sink index and a is an exponent in the interval [0, 1].

To create the first set of maps (A), for the boulder coral species, the 3 values were then averaged to get a combined value; the restoration value for *A. cervicornis* was treated separately. To create the second set of maps (B), the values for all 4 key species were averaged to get a combined value.

The Identity tool in ArcGIS Pro was used to assign restoration values to the modified reef layer. The reef features were also merged by their connectivity index using the Dissolve tool. The area in hectares for each of these features was added as an attribute. Focal area selection was limited to the two habitats that had the highest combined demographic score in each subregion. High scores were chosen separately for *A. cervicornis* and the combined boulder corals.

For each top habitat in a subregion, the reef features were exported and sorted in descending order by the restoration value and the Accumulate function assigned the total accumulated area by adding its area to the sum of the previous features selected to the reef feature. This allows the reef features for the habitat to be filtered up to the desired area threshold.

The threshold rule adopted based on discussions with the reef managers was to select approximately 30% of the area of the habitat with the highest demographic score and 20% of the area of the habitat with the second highest score. Where two priority habitats had equal demographic scores, the percentage was split evenly for those habitats (for example, in the Dry Tortugas, two habitats tied for the second highest habitat value, and 10% of each of those two habitats was selected). Table A1-6 shows the area selected for each subregion in hectares; it is important to note that the hectares are only approximate percentages because reef area features cannot total to the exact percentage threshold.

Table A1-6. Number of hectares selected in each habitat in each subregion within Southeast Florida, for the combined boulder coral species, A. cervicornis, and all four species together. Blank cells represent no suitable hectares of reef strata within a region. North Palm Beach is not included because all habitat in that region is deeper than 18m (~60 feet).

Region	Habitat	Species	Martin	South Palm Beach	Deerfield	Broward-Miami
Southeast Florida	Linear reef inner	Combined boulder coral spp.				216
Southeast Florida	Linear reef middle	Combined boulder coral spp.			16	79
Southeast Florida	Linear reef outer	Combined boulder coral spp.		48	10	
Southeast Florida	Spur and groove	Combined boulder coral spp.		3		
Southeast Florida	Ridge shallow	Combined boulder coral spp.	70			
Southeast Florida	Ridge shallow	*Acropora cervicornis*				567
Southeast Florida	Linear reef inner	All species combined				184
Southeast Florida	Ridge shallow	All species combined				378
Southeast Florida	Linear reef middle	All species combined			17	
Southeast Florida	Linear reef outer	All species combined		49	7	
Southeast Florida	Spur and groove	All species combined		3		

Table A1-7. Number of hectares selected in each habitat in each subregion within the Florida Keys, both for the combined boulder coral species, A. cervicornis, and all four species together. Blank cells represent no suitable hectares of reef strata within a region.

Region	Habitat	Species	Biscayne	Upper Keys	Mid-Upper Keys Transition	Middle Keys	Lower Keys
Florida Keys	Isolated mid relief	Combined boulder coral spp.	154	165	25	39	237
Florida Keys	Contiguous low relief	Combined boulder coral spp.	127	87	10	20	50
Florida Keys	Spur and groove low relief	*Acropora cervicornis*	181	174	10	244	508
Florida Keys	Spur and groove high relief	*Acropora cervicornis*	11	45	1	7	51
Florida Keys	Isolated mid relief	All species combined	155	159	26	40	235
Florida Keys	Spur and groove low relief	All species combined	119	112	6	158	334

Table A1-8. Number of hectares selected in each habitat in each subregion within the Dry Tortugas, both for the combined boulder coral species, A. cervicornis, and all four species together. Blank cells represent no suitable hectares of reef strata within a region.

Region	Habitat	Species	Dry Tortugas NP
Dry Tortugas	Spur and groove high relief	Combined boulder coral spp.	49
Dry Tortugas	Contiguous low relief	Combined boulder coral spp.	307
Dry Tortugas	Contiguous mid relief	Combined boulder coral spp.	45
Dry Tortugas	Contiguous low relief	*Acropora cervicornis*	913
Dry Tortugas	Contiguous high relief	*Acropora cervicornis*	33
Dry Tortugas	Contiguous high relief	All species combined	33
Dry Tortugas	Contiguous low relief	All species combined	910

Exceptions

Throughout the process, a few exceptions were applied to the rules to allow a sufficient area of reef within each region to be selected in Tier 1. These exceptions and their justifications are outlined below.

Within the Southeast Florida region, the goal was to have at least a few focal areas selected within each County. However, due to the depth exclusion, no focal areas were selected in the North Palm Beach subregion. Additionally, there was not much habitat that was not excluded and ranked highly in South Palm Beach, so thresholds of 50% and 30% were applied to the top scoring habitats in that subregion to allow for more focal areas.

In the Martin County subregion, the only habitat in less than 18m (~60 feet) is Ridge Shallow. Based on expert opinion, it is our understanding that the Shallow Ridge habitat in Martin County is significantly different than that same habitat in the Broward-Miami subregion, but it ranked highly because it is considered the same habitat within the analysis. Similarly, the source connectivity values in this portion of the reef are very low. For these reasons, a connectivity value that represents self-replenishment was averaged for the three boulder coral species and used to identify focal areas.

Appendix 2: Site selection criteria evaluated

Sites identified as sources (coral larval connectivity)

Reef area

Low(er) bleaching incidence/high(er) bleaching recovery incidence

High(er) calcification rates

Low nutrient loads (proxy – distance from inlets/outfalls)

Low sediment loads (same and above + beaches)

Areas with less direct impacts to reef (to include potential for groundings) (protection, remoteness as possible proxies)

Low freshwater influences (distance from inlets and large canals as proxy)

Higher resilience scores (coral cover, macroalgae cover, bleaching resistance – proportion of community made of corals resistance to bleaching, coral diversity, coral disease, herbivore biomass, and temperature variability)

Areas identified as refugia (past and future acute temps, past and future chronic temps, hurricane vulnerability, connectivity in and out)

Areas identified as niches for certain species

Coral presence (current and/or recent past) (include successful recruitment and healthy adult colonies)

Intact communities (presence of herbivores and other key species; low levels of corallivores)

Areas with high rugosity or complex habitat

Ratio of old to young corals – are the conditions there likely to support 'younger' genotypes?

Low(er) disease incidence

Species presence (current and/or recent past)(includes successful recruitment and healthy adult colonies)

Open space on substrate

Past success of restoration efforts

Significant imbalance that can be influenced through site prep and introduction or removal of certain species