APPENDIX A: CASE STUDIES OF RESTORATION EFFECTIVENESS FOR PUERTO RICO

Community-Based Restoration of Elkhorn Coral (*Acropora palmata*) in Vega Baja, Puerto Rico (2008–2023):

In response to the severe fragmentation of *Acropora palmat*a stands caused by a major winter swell in March 2008, an emergency community-based low-tech restoration effort was initiated in Vega Baja, Puerto Rico by local non-governmental organizations VIDAS and Sociedad Ambiente Marino (SAM), with the support of the Center for Applied Tropical Ecology and Conservation (CATEC) of the University of Puerto Rico. 628 *A. palmata* clippings generated from broken fragments at risk (~10–25 cm maximum length) were outplanted to a natural open backreef substrate by direct wedging into reef crevices and cracks in roughly 10 plots of ~200–250 m^2 each, forming colony clusters of approximately 50–75 fragments per plot (Figure 1). As a result, out-planted *A. palmata* mean colony surface area increased from 265.3 cm^2 in 2008 to 1734.6 cm^2 in 2012 (5.5-fold increase), 9726.4 cm2 in 2016 (35.7-fold increase), 26,444.2 cm^2 in 2020 (98.7-fold increase), and 47,123.4 cm2 (176.6-fold increase) in 2023. This represents roughly ~3142 cm^2 of annual colony surface expansion. This restoration effort proved to be highly successful, leading to coral survival and growth and to sustained recovery of fish assemblages, particularly herbivore guilds (Hernández-Delgado et al., 2024). The authors recommendations and lessons learned for improving future impacts of restoration efforts of shallow high-energy coral reef habitats on fish communities include integrating fish assemblage recovery into coral restoration strategies, establishing natural coral nursery plots for future coral sourcing, and incorporating the concept of nursery seascapes for a holistic and ecosystem-based approach to restoration (Hernández-Delgado et al., 2024).

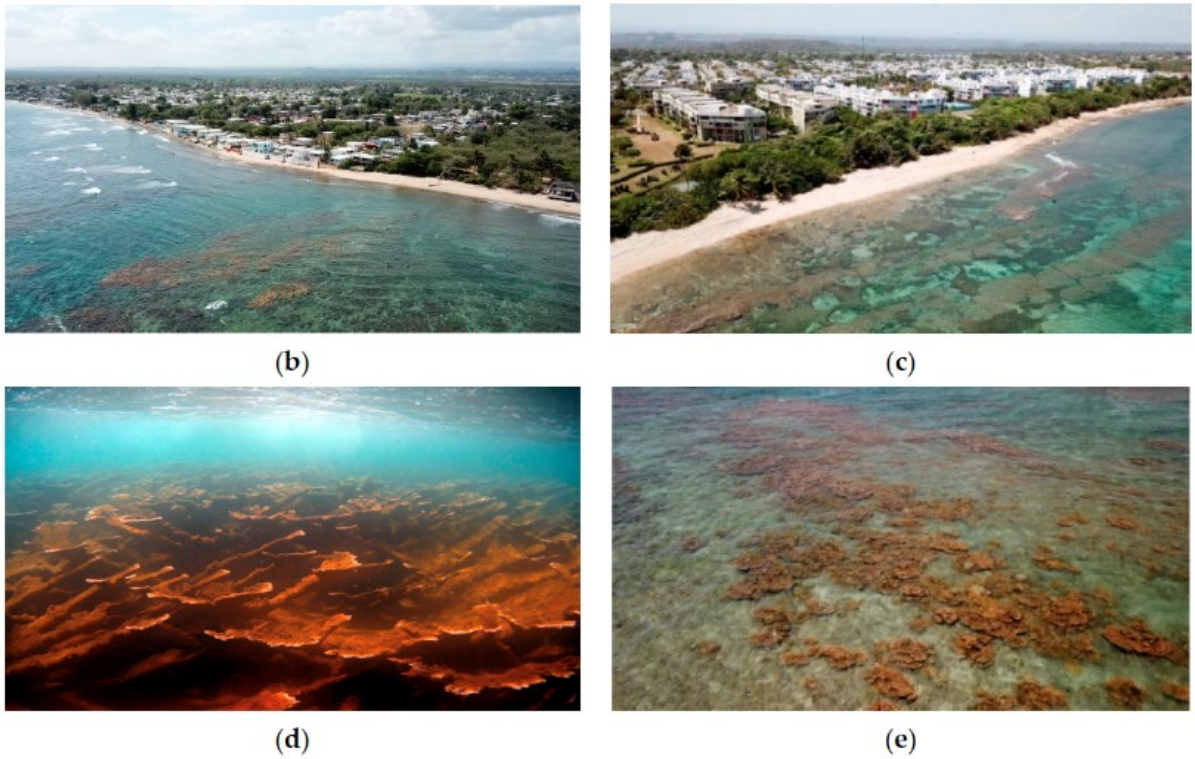


Figure 1. (b) the aerial view showing restored shallow reefs; (c) Vega Baja fringing reefs and paleo-shorelines are vital geological features that contribute to wave energy and runup attenuation, protecting the shoreline and adjacent infrastructure; (d) a typical remnant *A. palmata* stand at Vega Baja; (e) a detailed view of restored plots (Hernández-Delgado et al., 2024).

Restocking of the keystone herbivore sea urchin species *Diadema antillarum*, to reduce algal overgrowth:

The dominant benthic substrate on many coral reefs in Puerto Rico consists of fleshy macroalgae and turf algae, especially turf with sediment, which are detractors for the settlement of post-larval corals and growth and survivorship of juvenile corals. *Ramicrusta*, an encrusting red alga from the Peyssonneliaceae family (Rhodophyta), was observed at 70% of the monitoring sites (42 sites) in the 2017-18 DNER's Puerto Rico Coral Reef Monitoring Program (PRCRMP) surveys (Williams, 2018). Started during the summer of 2017, the objective of this project by the Institute for Socio-Ecological Research was to increase herbivory rates on coral reefs to decrease the algal abundance, specifically *Ramicrusta* spp, fleshy macroalgae, and turf with sediment. By effectively controlling these nuisance algae, *D. antillarum* creates a more favorable environment for coral recruitment

and growth. It is expected that effective coral recruitment rates will increase as an indirect consequence of *D. antillarum* herbivory effect.

In the first trials in 2018 and 2019, 480 lab-reared *D. antillarum* were transferred to two reefs in Fajardo, and 276 were transferred to Enrique's back reef in La Parguera. By the end of the studies in 2018 and 2019, the abundance of fleshy macroalgae decreased by a mean of 77% (up to 100%), while *Ramicrusta* and thick turf algal/sediment mats decreased by 53% (up to 71%) and 56% (up to 100%), respectively. The presence of clean substrate, crustose coralline algae, and filamentous turf algae increased by one to two orders of magnitude (Williams, 2022).

Similar results were reported for the *D. antillarum* restocking in 2020-2021 at Cayo Largo north (CLN) and Palomino (PN) in Fajardo. On November 12, 2021, 500 lab-reared *Diadema antillarum* were released onto CLN and PN reefs where the sea urchins were previously absent (Williams, 2022). Before restocking, both sites were characterized by high coverage of the encrusting alga *Ramicrusta*, with a mean cover of 73.1% at CLN and 73.7% at PN. In 2021, follow-up assessments were conducted at both CLN and PN, and CLN demonstrated exceptionally high retention of *D. antillarum*. Through restocking, *D. antillarum* densities increased from one order of magnitude at PN to two orders of magnitude at CLN. Significant changes in benthic composition were observed at both sites over time, mainly due to reductions in *Ramicrusta* cover. After two weeks, *D. antillarum* almost completely removed *Dictyota* at CLN, reducing the cover by 93% and after one month, *Ramicrusta* was reduced by 90% at the end of the monitoring period. By two months at CLN, clean substrate increased by two orders of magnitude. The high density of *D. antillarum* at CLN led to a benthic substrate dominated by clean pavement and crustose coralline algae, indicative of effective grazing pressure by the sea urchins (Figure 2).

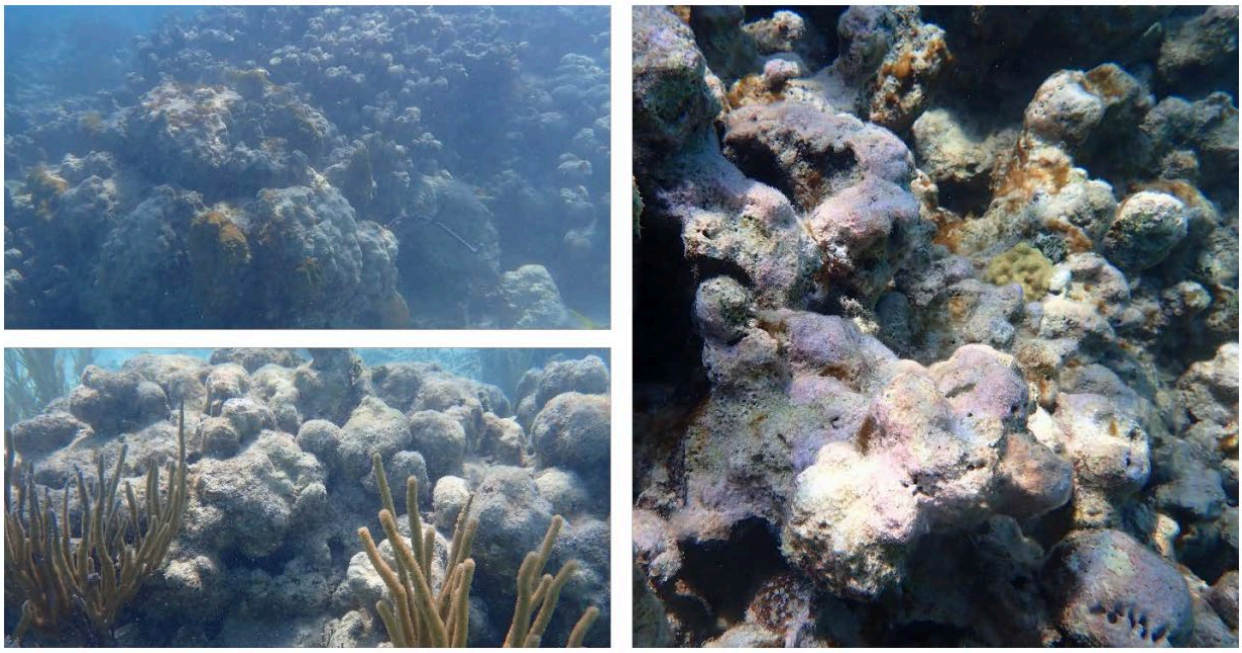


Figure 2. Photographs taken in 2024 at Cayo Largo Norte in Fajardo, a site where *Diadema antillarum* were released in 2021, in which a benthic substrate dominated by clean pavement and crustose coralline algae can be seen. (Williams, 2024)

The results also indicate that *D. antillarum* retention and subsequent ecological impacts vary significantly between sites, influenced by factors such as reef structure, wave exposure, and predator presence. The high retention at CLN (2021) suggests it is an optimal site for future restocking and coral outplanting efforts due to the effective reduction of nuisance algae and maintenance of cleaner substrates. To enhance restocking success at other locations, the authors recommend considering site-specific conditions, conducting night-time surveys for more accurate urchin counts, and ensuring suitable shelter and protection from predators to support *D. antillarum* populations (Williams, 2024). In conclusion, the Cayo Largo 2021 site exemplifies a successful model for *D. antillarum* restocking and demonstrates the potential benefits of such efforts in restoring coral reef health.

Coral Propagation in Puerto Rico by NOAA, Sea Ventures, HJR Reefscaping and the Institute for Socio-Ecological Research:

As coral populations continue to decline, proactive intervention is becoming increasingly warranted as coral restoration and the consequent addition of structural complexity can restore reef ecosystems. Each year in Puerto Rico, coral outplants are transplanted from nurseries to reefs impacted by vessel groundings,

storms, or by other physical impacts, to aid in the restoration of the damaged reefs. Corals are also transplanted to reefs where populations were once prevalent but have declined in the past few decades because of disease outbreaks, storms, and/or bleaching events, to assist in the recovery of the coral populations. Coral propagation can also increase genetic diversity at sites where there is low genetic diversity to increase chances of sexual reproductive success. Over the past two decades, nursery operations in Puerto Rico have expanded exponentially from just two nurseries in Culebra to twenty-seven in-situ and land-based nurseries.

Both *A. cervicornis* and *A. palmata* have suffered dramatic declines throughout the entire Caribbean over the last few decades with adult populations typically having low densities and genetic diversity, resulting in a reduction in genetic connectivity for this genus. The NOAA Restoration Center has thus focused on Acroporid propagation and outplanting in Puerto Rico to support ESA coral population recovery, fishery habitat enhancement and coastal protection objectives. During 2022, NOAA, Sea Ventures, HJR Reefscaping, and the Institute for Socio-Ecological Research, planted over 18,000 corals to 50 outplanting sites on 13 different reefs around Puerto Rico. These corals were sourced through a combination of outplanting from coral nurseries, harvesting cuttings from previous *Acropora palmata* outplants, and reattaching at risk fragments from storms. Species outplanted from the in situ nurseries included *Acropora cervicornis* and *A. palmata*. Other species outplanted from the ex-situ nurseries included *Colpophyllia natans, Diploria labyrinthiformis, Montastrea cavernosa, Orbicella faveolata, O. annularis, O. franksi and Pseudodiploria strigosa*. In 2023, nurseries focused on 5 species (*Acropora cervicornis, Dendrogyra cylindrus, Meandrina meandrites, Xetospongia muta, and Porites porites*) all of which have suffered recent mass mortalities due to the 2023 mass bleaching event, SCTLD and/or other legacy conditions. There have also been relocation efforts to respond to imminent bleaching emergencies on the reefs by increasing the geographical distribution of *A. palmata* fragments from different putative genotypes to contribute to safeguarding some genotypes from local extinctions and maintaining as much genetic diversity as possible between the sites (NOAA et al., 2024).

In southern Puerto Rico, a great expansion of restoration efforts since 2016 occurred after Hurricane Matthew damaged *A. palmata* thickets on Gilligan's reef in Guánica and approximately 1,800 at-risk storm fragments were originally transplanted to Cayo Coral (Figures 3 and 4). By the end of 2022, the number of transplanted corals using cuttings from previous outplants and at-risk corals increased to over 13,000 colonies and the restoration footprint increased from 2,500 m2 in 2016 to over 13,000 m2 in 2022 (NOAA et al., 2022).

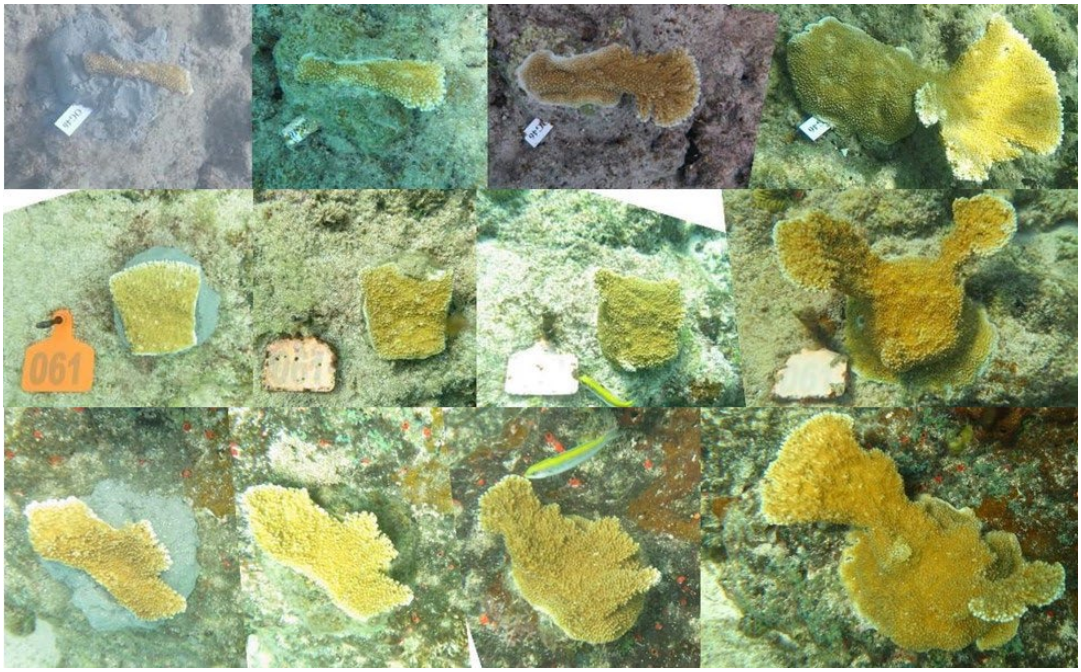


Figure 3. Time series of *Acropora palmata* cuttings at (from left to right) 0 months, 1 month, 4 months, and 12 months at Cayo Coral, Guanica.

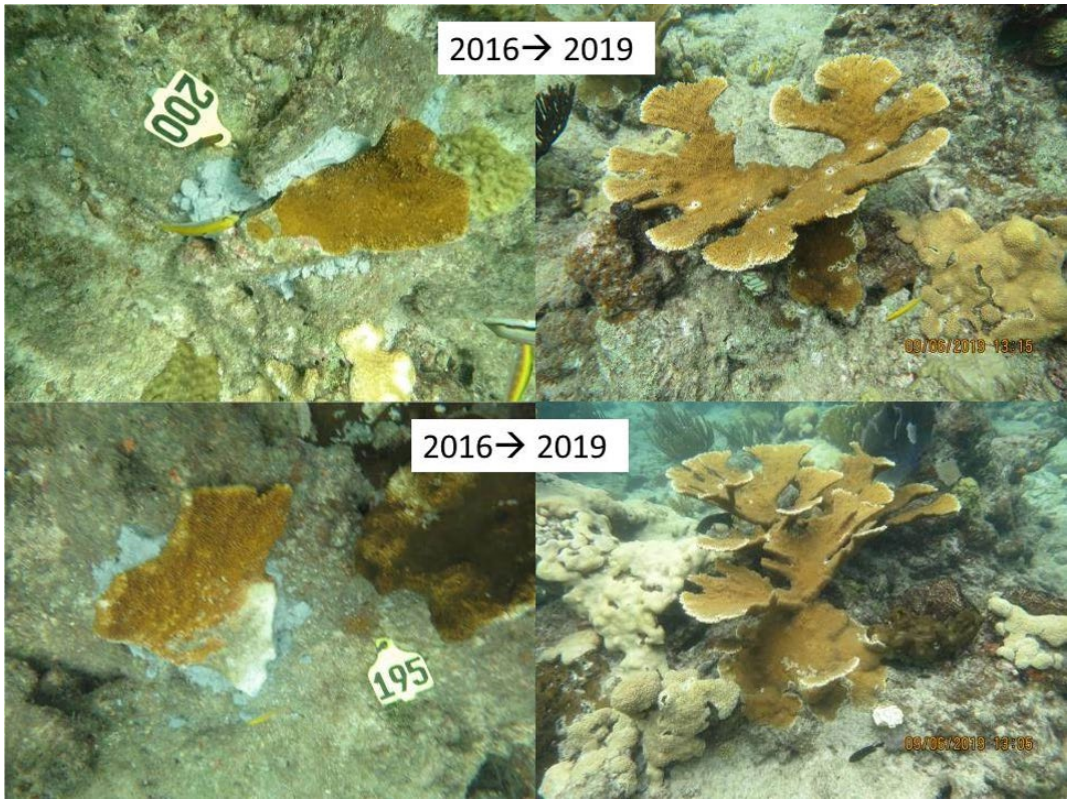


Figure 4. 3-year growth of *Acropora palmata* cuttings that were transplanted at Cayo Coral Guanica in 2016.

This coral propagation technique and approach was then replicated off the east coast of Puerto Rico. Beginning in 2017, comprehensive restoration on the shallow reefs (3-10m) around Palomino Island and Cayo Largo using multiple species of propagated corals took place (Figure 5). Around 5,000 elkhorn coral colonies (*A. palmata*) were outplanted in the northern coast of Palomino Island in Fall 2022, covering an area of roughly 5,000 m^2 (Canals 2024). In 2023, approximately 7,645 corals were outplanted to 5 different reef sites in the Puerto Rico Habitat Focus Area, off the northeast coast. In addition, 260 sea urchins (*D. antillarum* and *T. ventricosus*) were outplanted at Palomino. Maintenance was also conducted at outplanting sites to increase survival and growth of the outplants.

There were around 831 corals in the nurseries during 2023, and the in-situ nurseries were located at 2 different sites: Cayo Lobos and Sand Slide. Restoration efforts at Sand Slide since 2017 have reattached over 5,000 corals and cover an approximate restoration area of 6,972 meters squared (NOAA Restoration Center et al., 2023). Monitoring revealed that overall, there was high survivorship at the mound level. The reefs around Palomino Island in the NE Puerto Rico Habitat Focus Area demonstrate comprehensive restoration of coral habitats that PR-DNER, NOAA and stakeholders deemed valuable for fisheries, ESA recovery, tourism and coastal protection. Obtaining detailed field observations of wave transformation and evolution over these restored reefs will serve as preparation for conducting the first rigorous observations of wave dissipation over a restored elkhorn coral reef, ultimately improving our understanding of wave dissipation by restored reefs.

Figure 5. Photo of one year old *Orbicella faveolata* microfragments and one year old *Diadema antillarum* transplants at Sand Slide off Palomino Island.

Restoration efforts at Los Corchos, Culebra began with transplanting ~1,300 *A. palmata* storm fragments in 2018 and continuing to the present with the expansion of outplanting at that reef with cuttings (NOAA et al., 2023). A significant increase in the number of colonies in one of the photomosaic plots at that site was observed over time, with 70 colonies in 2019, 92 in 2021, 119 in 2022, and 147 in 2023. This increase in colony counts resulted in an increase in total *A. palmata* area from a minimum of $3m^2$ in 2019 to a maximum of $11m^2$ in 2022 (267 % increase) (Figure 6). A comparison of the coral cover percentage between control (non-harvest) areas with areas where cuttings were harvested did not reveal a difference. It did reveal that the donor colony population healed, suggesting that harvesting cuttings is a viable technique for restoration. Both areas increased from 0% *A. palmata* cover to 13% cover in about 4 to 5 years (one plot in Guanica increased from 0 to 18% coral cover) which was accomplished by planting one *A. palmata* per square meter. For the most part, the average percent cover for *A. palmata* after 3 years is about 3.2% at most sites. Monitoring results showed that the survival for the outplanted corals averaged 59% to 100% in 2021 (NOAA et al., 2021). Survival over 3 years was between 60-90% and the average size ranged from 16-30 cm in diameter (NOAA et al., 2022).

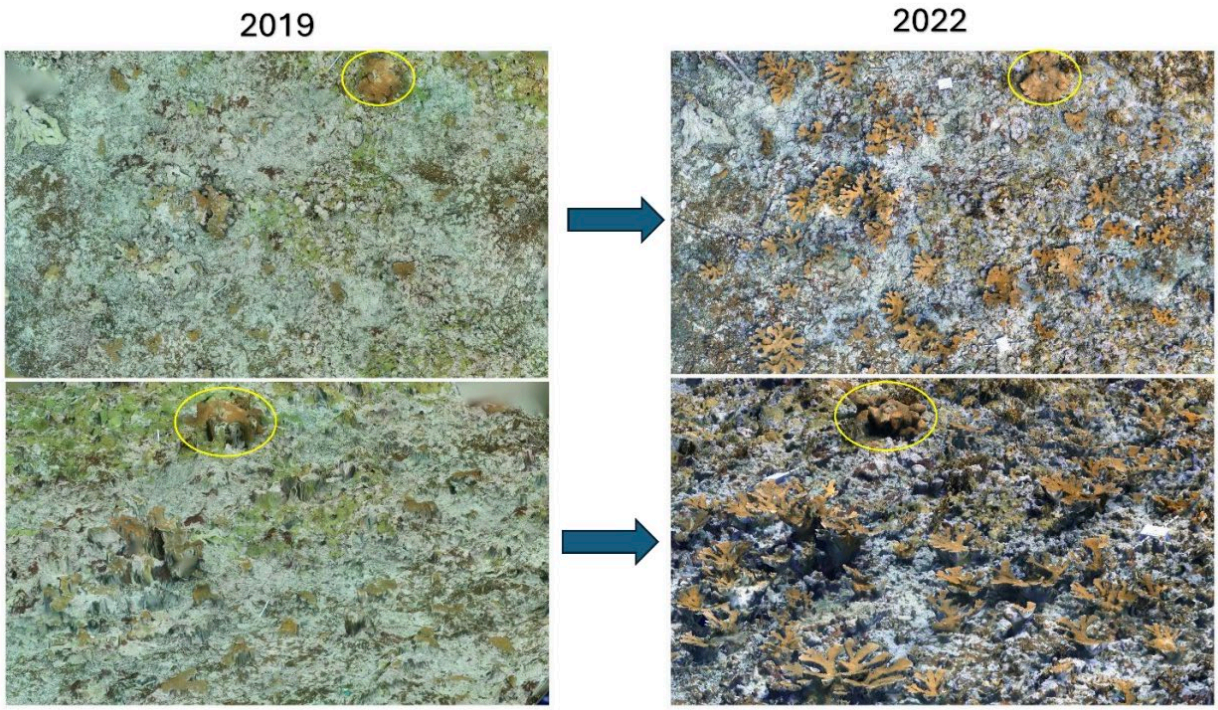


Figure 6. Close up view of Los Corchos Mosaic # 1 [3D model] where an increase of *A. palmata* live tissue area of 267% between 2019 and 2022 was estimated. Yellow circles identify a wild colony that was present in the plot for visual reference. (Funding Agency: NOAA RC, Fieldwork contractor: Sea Ventures MRU).

Regarding Acroporids, it has been imperative to expand propagation efforts where Acroporids survived the 2023 mass bleaching event (i.e. Fajardo). Thus, maintenance and monitoring site visits were conducted in December 2023 and March of 2024 in several Acropora survey sites in Fajardo. These included: Sand Slide, Wave Attenuation, and Cayo Largo. Most wild and outplant *A. palmata* colonies observed on all sites were apparently healthy with normal coloration and no recent mortality. The observations suggest *A. palmata* populations at the Palominos and Cayo Largo reef systems were not severely impacted by the 2023 thermal anomaly and bleaching event.

Genetic samples collected from nurseries and cutting sites in Puerto Rico has identified 218 different *Acropora spp.* genotypes, suggesting there is good genetic diversity at most of those sites (NOAA et al., 2022). Preliminary data analysis on fish communities collected separately at the Culebra and the Guayanilla sites suggest that fish density and diversity are significantly higher at the outplant sites,

particularly for juvenile fishes. Herbivore guilds have also shown a significant increase within restored sites in comparison to areas with no outplants.

The authors note that other sites will vary depending on multiple factors (growth rates, survival, outplanting densities, etc.). A suggested technique to include in the restoration toolbox for *Acroporids* moving forward is allowing cuttings to be collected from wild colonies and directly transplanted to some restoration sites, as it is less expensive and faster than just growing corals in nurseries. While this is a viable technique for scaling up, the authors note that it should be conducted alongside having nurseries, and that there are likely some sensitive areas where it is not desirable to collect from.

Works Cited

Canals Silander, Miguel F. 2024. "Final Report: High-resolution Observations of Wave Energy Dissipation over a Reef Restoration Project at Palominos Island" Submitted to Sea Ventures Inc. / NOAA Coral Restoration. UPRM Center for Applied Ocean Science and Engineering / CARICOOS

Hernández-Delgado, Edwin A., and Ricardo Laureano. 2024. "Bringing Back Reef Fish: Sustainable Impacts of Community-Based Restoration of Elkhorn Coral (Acropora palmata) in Vega Baja, Puerto Rico (2008–2023)" Sustainability 16, no. 14: 5985. https://doi.org/10.3390/su16145985

NOAA, SeaVentures, and HJR Reefscaping. 2019. Coral Propagation in Puerto Rico Report. NOAA National Marine Fisheries Service, Office of Habitat Conservation. Silver Spring, MD. 15pp

NOAA, SeaVentures, HJR Reefscaping and Institute for Socio-Ecological Research. 2021. Coral Propagation in Puerto Rico Report. NOAA National Marine Fisheries Service, Office of Habitat Conservation. Silver Spring, MD. 15pp

NOAA, SeaVentures, HJR Reefscaping and Institute for Socio-Ecological Research. 2022. Coral Propagation in Puerto Rico Report. NOAA National Marine Fisheries Service, Office of Habitat Conservation. Silver Spring, MD. 15pp

NOAA and SeaVentures. 2024. 2023 Coral Propagation in Puerto Rico Report. NOAA National Marine Fisheries Service, Office of Habitat Conservation. Silver Spring, MD. 46pp

NOAA, SeaVentures. 2023. Los Corchos *Acropora palmata* outplanting Photomosaics Data Summary Report. 24 pp.

NOAA Restoration Center, SeaVentures and Institute for Socio-Ecological Research. 2023. Palomino Comprehensive Coral Restoration Report Year 2 Report 2023. 11 pp.

NOAA, SeaVentures, and Institute and the Coral Restoration Foundation. 2024. Sea Ventures Marine Response Unit Fieldwork Report Submitted to Coral Restoration Foundation (CRF)

Project: Services Agreement for NOAA GRANT #NA23NMF4630065 Task: Acropora palmata cuttings outplanting and relocation from outplanting areas between Fajardo and Culebra in Puerto Rico. 11pp

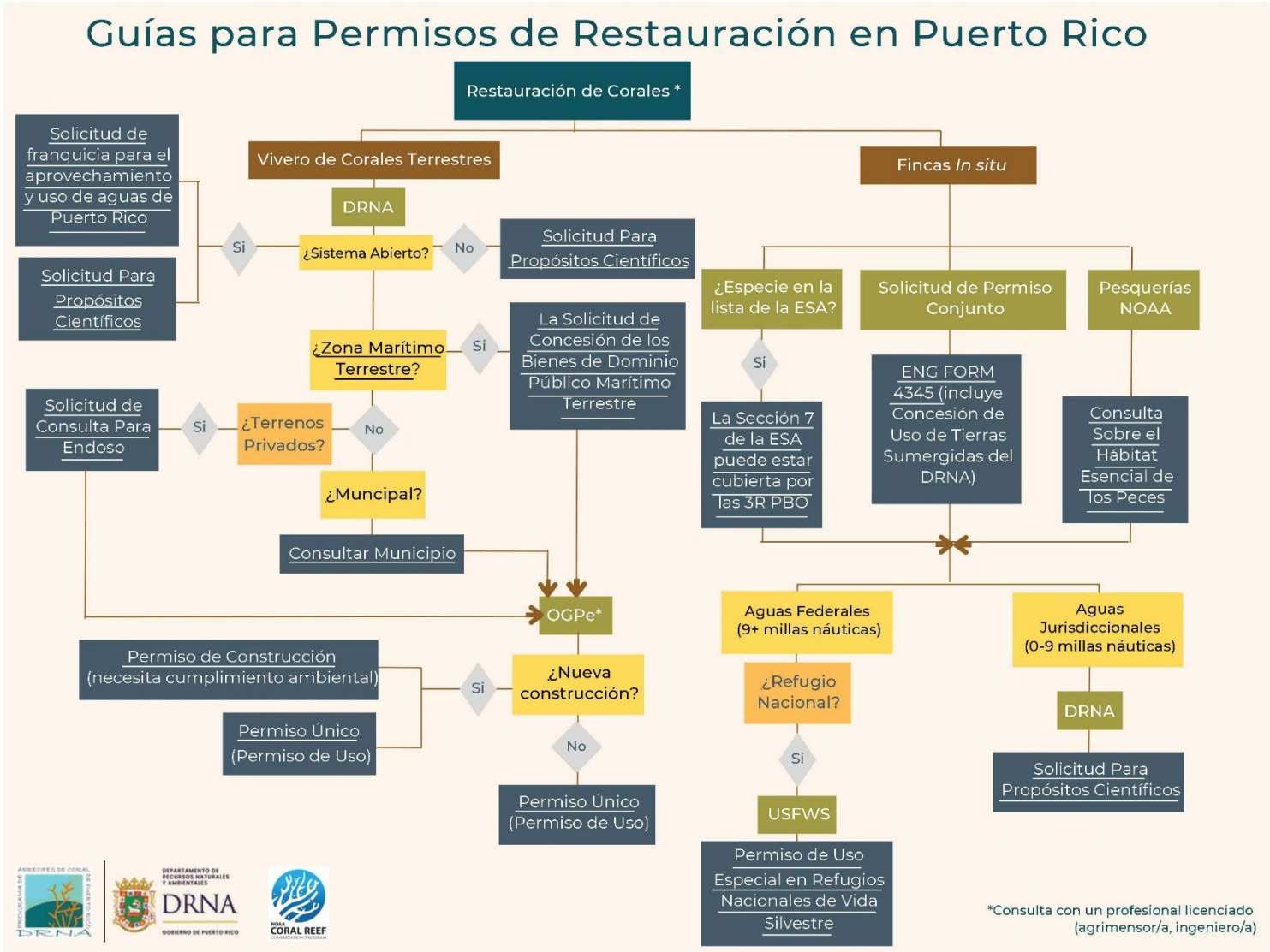
Williams, Stacey. (2018). The control of algal abundance on coral reefs through the reintroduction of *Diadema antillarum*. Department of Natural and Environmental Resources (DNER). Puerto Rico. 46pp

Williams, Stacey. (2022). The reduction of harmful algae on Caribbean coral reefs through the reintroduction of a keystone herbivore, the long spined sea urchin, *Diadema antillarum*. Restoration Ecology. 30. 10.1111/rec.13475.

Williams, Stacey. (2024). Re-stocking of the keystone herbivore species, *Diadema antillarum*, to reduce algal overgrowth (Phase III). Department of Natural and Environmental Resources (DNER). Puerto Rico. 37pp

APPENDIX B: PERMITTING GUIDANCE

Coral Restoration Permitting Guidelines


Guías para Permisos de Restauración en Puerto Rico
Restauración de Corales *
Vivero de Corales Terrestres
Fincas In situ
DRNA
Solicitud de franquicia para el aprovechamiento y uso de aguas de Puerto Rico
Solicitud Para Propósitos Científicos
Si
¿Sistema Abierto?
No
Solicitud Para Propósitos Científicos
¿Zona Marítimo Terrestre?
Si
La Solicitud de Concesión de los Bienes de Dominio Público Marítimo Terrestre
Solicitud de Consulta Para Endoso
Si
¿Terrenos Privados?
No
¿Muncipal?
Consultar Municipio
OGPe*
Permiso de Construcción (necesita cumplimiento ambiental)
Permiso Único (Permiso de Uso)
Si
¿Nueva construcción?
No
Permiso Único (Permiso de Uso)
¿Especie en la lista de la ESA?
Si
La Sección 7 de la ESA puede estar cubierta por las 3R PBO
Solicitud de Permiso Conjunto
ENG FORM 4345 (incluye Concesión de Uso de Tierras Sumergidas del DRNA)
Pesquerías NOAA
Consulta Sobre el Hábitat Esencial de los Peces
Aguas Federales (9+ millas náuticas)
¿Refugio Nacional?
Si
USFWS
Permiso de Uso Especial en Refugios Nacionales de Vida Silvestre
Aguas Jurisdiccionales (0-9 millas náuticas)
DRNA
Solicitud Para Propósitos Científicos
*Consulta con un profesional licenciado (agrimensor/a, ingeniero/a)

APPENDIX C: PUERTO RICO CORAL REEF MONITORING PROGRAM DATA

Table 1: Percent Coral Cover and Change for Reef Stations with Baseline Survey Before 2015 (Garcia-Sais et al. 2022)

Reef Station	Baseline Survey	Mean % Coral Cover Baseline	Mean % Coral Cover 2018 / 2019	Mean % Coral Cover 2021	% Change Baseline	% Change 2018/2019 to 2021	Driver
Boya Esperanza 10m	2001	36.03	9.58	2.65	-92.65	-72.34	2005 & 2019 Bleaching
Puerto Botes 20m	2000	48.01	11.62	11.89	-75.23	2.32	2005 Bleaching
Playa Mujeres 20m**	2000	36.41	11.68	11.07	-69.60	-5.22	2005 Bleaching
Puerto Botes 15m	2004	19.23	9.98	8.28	-56.94	-17.03	2005 Bleaching
Caya Coral 10m	1999	24.5	13.75	11.26	-54.04	-18.11	2005 Bleaching
Las Carmelitas 10m**	2000	25.42	9.28	12.38	-51.30	33.41	2005 Bleaching
West Reef 10m	1999	24.4	15.22	12.03	-50.70	-20.96	2005 Bleaching
Derrumbadero 20m	2001	41.67	20.06	20.7	-50.32	3.19	2005 Bleaching
Puerto Canoas 30m	2004	48.42	29.6	24.55	-49.30	-17.06	2005 Bleaching
Canjilones 20m	2001	24.54	13.32	13.68	-44.25	2.70	2005 Bleaching
Tourmaline 10m	2004	49.1	41.66	35.53	-27.64	-14.71	2005 Bleaching
Tres Palmas 10m	2004	20.92	19.89	16.71	-20.12	-15.99	Unknown
Tourmaline 20m	2004	31.79	27.59	25.58	-19.53	-7.29	2005 Bleaching
Resuellos 10m	2000	18.25	18.82	16.58	-9.15	-11.90	2019 Bleaching
Tres Palams 20m	2004	23.15	21.96	23.53	1.64	7.15	n/a

Tourmaline 30m	2004	13.54	21.48	17.23	27.25	-19.79	2019 Bleaching

*Notes: **2010 and 2020 data; stations with a percent change from baseline with a statistical significance (p>0,05; Fact ANOVA) in red.*

Table 2: Percent Coral Cover and Change for Reef Stations with Baseline Survey 2015 or Later

Reef Station	Baseline Survey	Mean % Coral Cover Baseline	Mean % Coral Cover 2018 / 2019	Mean % Coral Cover 2021	% Change Baseline	% Change 2018/2019 to 2021	Driver
Dominos 5m	2018	58.34	58.34	3.98	-93.18	-93.18	TS Isaias (2020)
Canal Luis Pena 5m	2016	16.98	8.26	7.28	-57.13	-11.86	H. Maria (2017)
Las Cabezas 5m	2018	13.3	13.3	6.28	-52.78	-52.78	2019 Bleaching
Cibuco 5m	2011	47.3	39.32	26.6	-43.76	-32.35	2019 Bleaching
Carlos Rosario 10m	2016	19.83	16.85	11.55	-41.75	-31.45	2019 Bleaching
Dakity 20m	2016	15.1	13.76	9.01	-40.33	-34.52	2019 Bleaching
Palominito 10m	2016	32.75	27.33	19.94	-39.11	-27.04	2019 Bleaching
El Seco 30m	2011	43.2	33.75	26.49	-38.68	-21.51	2019 Bleaching
Palomino 20m	2016	30.72	27.13	19.43	-36.75	-28.38	2019 Bleaching
Cayo Aurora 5m	2015	42.48	38.46	27.28	-35.78	-29.07	H. Maria (2017)
Tres Palmas 5m	2015	37.42	34.4	26.4	-29.45	-23.26	H. Maria (2017)
Beril de Guanica 20	2015	18.23	17.87	12.92	-29.13	-27.70	2019 Bleaching
Cayo Caribes 10m	2016	16.88	16.97	12.01	-28.85	-29.23	2019 Bleaching
Cayo Diablo 5m	2016	20.89	13.77	15.1	-27.72	9.66	H. Maria (2017)
El Negro Reef 5m	2016	28.2	27.3	22.03	-21.88	-19.30	2019 Bleaching
Cayo Ratones 5m	2016	19.92	18.79	15.9	-20.18	-15.38	2019 Bleaching

Maria Langa 5m	2016	5.04	4.01	4.05	-19.64	1.00	H. Mathew (2016)
El Negro Reef 5m	2016	20.7	21.82	16.76	-19.03	-23.19	2019 Bleaching
Gallardo 5m	2016	54.64	40.87	47.58	-12.92	16.42	H. Maria (2017)
Cayo Rodriguez 5m	2016	21.4	20.2	19.19	-10.33	-5.00	H. Maria (2017)
Manchas Exteriores 20m	2016	20.4	17.8	19.48	-4.51	9.44	H. Maria (2017)
Guanajibo 20m	2016	36.6	34.3	34.97	-4.45	1.95	H. Maria (2017)
Manchas Exteriores 10m	2016	26.5	25.2	25.36	-4.30	0.63	
Boya Vieja 20	2015	19.6	24.24	20.49	4.54	-15.47	2019 Bleaching
Maria Langa 20m	2016	15.12	13.85	15.85	4.83	14.44	n/a
Media Luna 10m	2017	31.46	30.94	33.92	7.82	9.63	n/a
Media Luna 5m	2015	11.67	12.16	12.73	9.08	4.69	n/a
Maria Langa 10m	2016	17.67	20.95	21.11	19.47	0.76	n/a

Notes: Stations with a percent change from baseline with a statistical significance (p>0,05; Fact ANOVA) in red.

APPENDIX D: SITE SELECTION MATRIX

Methodology for priority site selection

Prior to the in-person workshops with the Core Team and technical advisors, a site selection matrix and Webmap was created to collect, compile, and visualize data. The site selection matrix automatically included all sites from long-term PRCRMP data. Additional sites and corresponding data were solicited from the technical advisors identified by the Core Team. The Core Team decided to include only PRCRMP sites not NCRMP sites as PRCRMP sites are monitored every two years and thus can show change over time, while NCRMP sites are randomly sampled.

Data included in the matrix focused on the following seven (7) categories: 1) potential to improve condition; 2) resilience; 3) climate refugia; 4) human impacts; 5) management actions; 6) logistics and 7) community support. Basic data such as reef type, depth, location and region, and quantitative data from models or surveys were also filled in prior to the workshops.

To make data comparable, Z-scores were calculated to quantitative data to provide the mean of the raw data and two (2) standard deviations above and below the mean. The Z-scores were then binned and made unidirectional from 0-5 so that higher scores indicated better reef health. For example, if higher raw data indicated better coral reef health, such as coral cover, a higher coral cover was assigned a higher score (3, 4 or 5 depending on data). If lower data indicated better coral reef health, such as macroalgae, a lower macroalgae score was assigned a higher score. For qualitative data, a value was assigned based on available information. For example, for the category of "watershed management plan in place", if a watershed management plan was in place, the site received a 4, if a watershed management plan was not in place, the site received a 0.

Two in-person workshops (San Juan and Cabo Rojo) were conducted to solicit additional data and expert knowledge about specific areas. These workshops focused on soliciting information qualitatively for sections of the site selection matrix in which data was unavailable (primarily human impacts, logistics and any other background data). During these workshops the technical advisory team also had the opportunity to discuss the weighting of metrics, and site prioritization.

Post workshop, the Core Team met several times to discuss site prioritization and comments received from the technical advisory team. Due to comments received and in alignment with the areas of attention identified in the goal setting process, the Core Team decided to give double weight to areas with: 1) no take MPAs; 2)

good water quality based on water quality monitoring data; 3) climate refugia; 4) strong community support, and; 5) current or future restoration actions.

Table 1: Site Characteristics and Potential to Improve Condition at Puerto Rico Coral Reef Monitoring Program (PRCRMP) Reef Sites

Site	Site Code	Latitude	Longitude	Overall Score (Divided by factors available)	Reef Type	Depth (Meters)	Location	Region	Potential to Improve Condition: % Change in Coral Cover (Unidirectional)	Potential to Improve Condition: Overall Score (Divided by factors available)
Beril		17.89755	-66.95998	3.23	Spur & Groove	intermediate (15-21m)	La Parguera	South	2	2
Boya Vieja (2015)	BOYA20	17.88827	-66.9978	3.63	Spur & Groove	intermediate (15-21m)	La Parguera	South	3	3
Cabezas de San Juan	CABE05	18.38544	-65.62972	2.25	Pavement	very shallow (0-8m)	Fajardo	East	1	1
Canal Luis Pena	LPEN05	18.30493	-65.32772	3.70	Aggregate reef	very shallow (0-8m)	Isla Culebra	Culebra	2	2
Canjilones (Vieques)	CANJ15	18.08964	-65.59008	2.63	Spur & Groove	intermediate (15-21m)	Isla Vieques	Vieques	2	2
Carlos Rosario	CROS10	18.32779	-65.332	3.73	Aggregate reef	shallow (8-14m)	Isla Culebra	Culebra	3	3
Cayo Aurora	AURO05	17.93657	-66.87385	3.56	Pavement	very shallow (0-8m)	Guanica	South	3	3
Cayo Caribes (2016)	CARI10	17.91544	-66.21401	2.72	aggregate reef	shallow (8-14m)	Salinas	South	2	2
Cayo Coral	CORA10	17.93626	-66.88836	3.50	Aggregate reef	very shallow (0-8m)	Guanica	South	1	1
Cayo Diablo (2016)	DIAB05	18.36033	-65.53089	3.41	Aggregate reef	very shallow (0-8m)	Fajardo	East	2	2
Cayo Ratones	RATO05	17.93457	-66.3025	2.73	Patch reef	very shallow (0-8m)	Salinas	South	2	2
Cayo Rodriguez	RODR05	18.1893	-67.1919	3.15	Patch reef	very shallow (0-8m)	Mayagüez	West	3	3
Cibuco (2013)	CIBU05	18.48955	-66.3736	2.97	Patch reef	shallow (8-14m)	Vega Baja	North	2	2
Dakiti	DAKI20	18.27587	-65.2773	3.26	aggregate reef	intermediate (15-21m)	Isla Culebra	Culebra	3	3
Derrumbadero	DERR20	17.90404	-66.60856	2.39	Spur & Groove	intermediate (15-21m)	Ponce	South	2	2
Dominos	DOMI05	18.46222	-66.0517	3.09	Patch reef	very shallow (0-8m)	San Juan	North	1	1
El Negro 10m	NEGR10	18.14653	-67.24803	3.26	Aggregate reef	shallow (8-14m)	Cabo Rojo	West	4	4
El Negro 5m	NEGR05	18.14658	-67.24758	3.50	Aggregate reef	very shallow (0-8m)	Cabo Rojo	West	3	3
Esperanza	ESPE10	18.08057	-65.48794	2.88	Patch reef	shallow (8-14m)	Isla Vieques	Vieques	1	1
Gallardo (2019)	GALL05	18.0017	-67.3299	3.00	Patch reef	very shallow (0-8m)	Cabo Rojo	West	5	5
Guanajibo	GUAN20	18.17202	-67.25297	3.16	Aggregate reef	intermediate (15-21m)	Mayagüez	West	3	3
Manchas Exteriores 10m	MEXT10	18.23353	-67.20057	2.74	Aggregate reef	shallow (8-14m)	Mayagüez	West	4	4
Manchas Exteriores 20m	MEXT20	18.2335	-67.20092	2.74	Aggregate reef	intermediate (15-21m)	Mayagüez	West	4	4
Maria Langa 10m (2016)	MLAN10	17.96093	-66.75284	2.64	aggregate reef	shallow (8-14m)	Guayanilla	South	2	2
Maria Langa 20m (2016)	MLAN20	17.95955	-66.74697	2.69	Spur & Groove	intermediate (15-21m)	Guayanilla	South	4	4
Maria Langa 5m	MLAN05	17.9649	-66.7563	3.00	Aggregate reef	very shallow (0-8m)	Guayanilla	South	4	4
Media Luna 10m (Parguera)	MLUN10	17.93472	-67.0485	3.84	aggregate reef	shallow (8-14m)	La Parguera	South	4	4
Media Luna 5m (Parguera)	MLUN05	17.93937	-67.05067	3.53	Patch reef	very shallow (0-8m)	La Parguera	South	4	4
Palominitos (2016)	PALT10	18.33537	-65.56555	3.53	Spur & Groove	shallow (8-14m)	Fajardo	East	2	2
Palominos (2016)	PALN20	18.35466	-65.56711	3.50	aggregate reef	intermediate (15-21m)	Fajardo	East	2	2
Puerto Botes 15m	**BOTE15**	**18.382**	**-67.48833**	**2.21**	**Patch reef**	**intermediate (15-21m)**	**Isla Desecheo**	**Desecheo**	**1**	**1**

Site	Site Code	Latitude	Longitude	Overall Score (Divided by factors available)	Reef Type	Depth (Meters)	Location	Region	Potential to Improve Condition: % Change in Coral Cover (Unidirectional)	Potential to Improve Condition: Overall Score (Divided by factors available)
Puerto Botes 20m	BOTE20	18.38158	-67.4886	2.25	Patch reef	intermediate (15-21m)	Isla Desecheo	Desecheo	1	1
Resuellos	RESU10	17.99116	-67.23322	3.52	Aggregate reef	shallow (8-14m)	Cabo Rojo	West	4	4
Tourmaline 10m	TOUR10	18.16304	-67.27367	3.39	Spur & Groove	shallow (8-14m)	Cabo Rojo	West	2	2
Tourmaline 20m	TOUR20	18.16517	-67.27524	2.93	Spur & Groove	intermediate (15-21m)	Cabo Rojo	West	1	1
Tres Palmas 10m	TRES10	18.34732	-67.26997	3.67	Aggregate reef	shallow (8-14m)	Rincon	West	2	2
Tres Palmas 20m	TRES20	18.34652	-67.27118	3.45	Aggregate reef	intermediate (15-21m)	Rincon	West	1	1
Tres Palmas 5m	TRES05	18.35072	-67.26688	3.88	Pavement	very shallow (0-8m)	Rincon	West	3	3
West Reef	CDMU10	17.89507	-66.52824	2.61	Aggregate reef	very shallow (0-8m)	Ponce	South	2	2

Notes: Blue shading = sites included in priority areas, Pink shading = sites included in second priority areas, Purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2. Source: Puerto Rico Coral Reef Monitoring Program (PRCRMP) 2022.

Table 2: Site Characteristics and Potential to Improve Condition at Reef Sites Submitted by Stakeholders and Technical Advisors

Site	Site Submitted By	Latitude	Longitude	Overall Score (Divided by factors available)	Reef Type	Depth (Meters)	Location	Region
Atrevesado	ISER	17.93549	-67.08429	4.08	Patch Reef/Back Reef	very shallow (6-7m)	La Parguera	South
San Cristobal	ISER	17.94070	-67.077186	4.08	Forereef Slope	very shallow (5m)	La Parguera	South
Cayo Largo	ISER	18.31469	-65.57926	3.50	Backreef	very shallow (2m)	Fajardo	East
Arrecife El Banderote	SAM	18.31492	-65.317963	3.41	Aggregate reef/colonized pavement	very shallow (3-6m)	Culebra	Culebra
Punta Soldado Reef	SAM	18.28061	-65.286847	3.65	Aggregate reef / aggregated patch reef / colonized pavement	very shallow (2-5m)	Culebra	Culebra
Melones Reef*	SAM	18.30434	-65.3115908	3.48	Aggregate reef / colonized pavement	very shallow (3-6m)	Culebra	Culebra
Arrecife Mosquito	Crystal Clear Vieques	18.16209	-65.5000482	3.23	Atoll	very shallow (2-5m)	Vieques	Vieques
SW Comandante	Crystal Clear Vieques	18.15412	-65.4733	3.07	Patch reef	very shallow (7-9m)	Vieques	Vieques
Ensenada Honda	Crystal Clear Vieques	18.11603	-65.3571376	3.00	Patch reef	very shallow (1-6m)	Vieques	Vieques
Cueva del Indio	Dr. Matt Lucas	18.49175	-66.642583	3.55	Finging & Hard Bottom	shallow (1-15 m)	Arecibo	North
Penon de Mera	Dr. Matt Lucas	18.48845	-66.677602	3.59		shallow (1-10m)	Arecibo	North
Moncho Rock / Diaz	Dr. Matt Lucas	18.47315	-66.478752	3.86		shallow (1-10m)	Manati	North
San Juan Barrier Reef	Sail4Reefs (Antares Ramos-Álvarez)	18.45944	-66.028888	3.26	Barrier Reef	intermediate (2-20m)	San Juan	North
Playuelas	Cabo Rojo Workshop	18.47192	-67.16928	3.94	Aggregate Patch Reef	very shallow (0-5m)	Aguadilla	West
Crash Boat	Cabo Rojo Workshop	18.45772	-67.1646	3.38	Pier and pier debris, artificial structures	Shallow (3-10m)	Aguadilla	West
El Eco	Cabo Rojo Workshop	18.49133	-66.41105	3.76	Fringing Reef	Very shallow (0-6m)	Vega Baja	North
Shacks	Cabo Rojo Workshop	18.51567	-67.10217	3.91	Fringing Reef	Very shallow (0-6m)	Isabella	North
Isla Verde	Cabo Rojo Workshop	18.44908	-66.0141	2.73	Fringing Reef	Very shallow (0-6m)	San Juan	North

Notes: Blue shading = sites included in priority areas, Pink shading = sites included in second priority areas, Purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2. *Data from National Coral Reef Monitoring Program (NCRMP) site 6344 used for Melones Reef. **Data from NCRMP site 6367 used for Arrecife el Banderote.

Table 3: Resilience Factors and Scores at Puerto Rico Coral Reef Monitoring Program (PRCRMP) Reef Sites

Site	Site Code	Coral Diversity Simpson Index (Unidirectional) (PNCRMP 2022)	Hard Coral % Cover (Unidirectional) (PNCRMP 2022)	Herbivorous fish Biomass (Unidirectional) (PNCRMP 2022)	Macroalgae percent cover (Unidirectional) (PNCRMP 2022)	Fraction of scleractinian colonies without disease (Unidirectional) (PNCRMP 2022)	Herbivore Diversity (Unidirectional) (PNCRMP 2022)	% Cover of CCA (Unidirectional) (PNCRMP 2022)	Percent Cover Orbicella (Unidirectional) (PNCRMP 2022)	Percent Cover Acroporid (Unidirectional) (PNCRMP 2022)	Distance to mangrove nursery habitat (m) (Unidirectional) (TNC 2015)	Distance to seagrass nursery habitat (m) (Unidirectional) (Schill et al. 2021)	Overall Score (Divided by factors available)
Beril		3	2	2	2	2	3	4	2	2	2	2	2.36
Boya Vieja (2015)	BOYA20	3	2	5	2	2	2	5	3	2	2	2	2.73
Cabezas de San Juan	CABE05	2	1	1	1	3	3	2	1	2	3	3	2.00
Canal Luis Pena	LPEN05	3	2	5	1	3	2	2	2	2	3	3	2.55
Canjilones (Vieques)	CANJ15	3	2	2	1	3	3	2	3	2	3	3	2.45
Carlos Rosario	CROS10	3	2	2	1	3	3	2	3	2	3	3	2.45
Cayo Aurora	AURO05	0	4	1	3	3	3	2	1	5	3	3	2.55
Cayo Caribes (2016)	CARI10	3	2	5	3	2	1	3	2	2	3	3	2.64
Cayo Coral	CORA10	3	2	3	3	2	3	2	2	2	3	3	2.55
Cayo Diablo (2016)	DIAB05	3	2	3	1	3	2	3	3	2	2	3	2.45
Cayo Ratones	RATO05	1	2	3	2	0	2	3	2	2	3	3	2.09
Cayo Rodriguez	RODR05	3	3	2	3	1	3	2	3	2	3	3	2.55
Cibuco (2013)	CIBU05	3	3	1	2	3	1	2	3	2	3	3	2.36
Dakiti	DAKI20	3	2	4	0	3	3	3	2	2	3	3	2.55
Derrumbadero	DERR20	3	2	3	1	3	3	4	3	2	2	2	2.55
Dominos	DOMI05	3	3	1	2	3	4	2	3	2	3	3	2.64
El Negro 10m	NEGR10	3	3	3	3	2	2	2	3	2	2	3	2.55
El Negro 5m	NEGR05	3	3	3	3	2	2	2	3	2	2	3	2.55
Esperanza	ESPE10	3	1	2	1	3	3	2	2	2	3	3	2.27
Gallardo (2019)	GALL05	0	5	4	2	3	2	2	1	5	1	1	2.36
Guanajibo	GUAN20	2	4	3	3	1	3	3	5	2	2	3	2.82
Manchas Exteriores 10m	MEXT10	3	4	3	3	2	2	2	4	2	3	3	2.82

Site	Site Code	Coral Diversity Simpson Index (Unidirectional) (PNCRMP 2022)	Hard Coral % Cover (Unidirectional) (PNCRMP 2022)	Herbivorous fish Biomass (Unidirectional) (PNCRMP 2022)	Macroalgae percent cover (Unidirectional) (PNCRMP 2022)	Fraction of scleractinian colonies without disease (Unidirectional) (PNCRMP 2022)	Herbivore Diversity (Unidirectional) (PNCRMP 2022)	% Cover of CCA (Unidirectional) (PNCRMP 2022)	Percent Cover Orbicella (Unidirectional) (PNCRMP 2022)	Percent Cover Acroporid (Unidirectional) (PNCRMP 2022)	Distance to mangrove nursery habitat (m) (Unidirectional) (TNC 2015)	Distance to seagrass nursery habitat (m) (Unidirectional) (Schill et al. 2021)	Overall Score (Divided by factors available)
Manchas Exteriores 20m	MEXT20	3	3	2	4	2	2	2	3	2	3	3	2.64
Maria Langa 10m (2016)	MLAN10	3	2	1	3	0	3	2	3	2	3	3	2.27
Maria Langa 20m (2016)	MLAN20	3	2	3	3	2	3	2	2	2	3	3	2.55
Maria Langa 5m	MLAN05	2	1	2	4	2	4	5	1	2	3	3	2.64
Media Luna 10m (Parguera)	MLUN10	3	3	2	4	2	2	4	3	2	3	3	2.82
Media Luna 5m (Parguera)	MLUN05	2	2	3	3	1	1	3	4	2	3	3	2.45
Palominitos (2016)	PALT10	3	3	2	2	3	3	2	4	2	2	3	2.64
Palominos (2016)	PALN20	3	3	3	3	3	3	2	2	2	2	3	2.64
Puerto Botes 15m	BOTE15	3	2	2	2	3	4	3	2	2	0	0	2.09
Puerto Botes 20m	BOTE20	3	2	2	1	2	3	3	2	2	0	0	1.82
Resuellos	RESU10	3	3	3	4	3	2	2	3	2	2	3	2.73
Tourmaline 10m	TOUR10	3	4	4	2	3	3	2	2	2	1	3	2.64
Tourmaline 20m	TOUR20	3	2	4	2	2	2	2	3	2	1	2	2.27
Tres Palmas 10m	TRES10	3	2	1	3	3	3	3	1	2	3	3	2.45
Tres Palmas 20m	TRES20	3	2	2	2	3	3	2	2	2	2	3	2.36
Tres Palmas 5m	TRES05	0	4	2	3	3	3	2	1	5	3	3	2.64
West Reef	CDMU10		2	3	4	1	2	2	2	2	2	3	2.30

Notes: Blue shading = sites included in priority areas, pink shading = sites included in second priority areas, purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2.

Table 4: Resilience Factors and Scores at Reef Sites Submitted by Stakeholders and Technical Advisors

Site	**Site Submitted by**	**Coral Diversity Simpson Index** (Unidirectional)	**Hard Coral % Cover** (Unidirectional)	**Herbivorous fish Biomass** (Unidirectional)	**Macroalgae percent cover** (Unidirectional)	**Fraction of scleractinian colonies without disease** (Unidirectional)	**Herbivore Diversity** (Unidirectional)	**% Cover of CCA** (Unidirectional)	**Percent Cover Orbicella** (Unidirectional)	**Percent Cover Acroporid** (Unidirectional)	**Distance to mangrove nursery habitat (m)** (Unidirectional) (TNC 2015)	**Distance to seagrass nursery habitat (m)** (Unidirectional) (Schill et al. 2021)	**Overall Score** (Divided by factors available)
Atrevesado *	ISER	-	1	-	4	3	-	2	-	-	3	3	2.67
San Cristobal*	ISER	-	1	-	4	3	-	2	-	-	3	3	2.67
Cayo Largo	ISER	-	1	-	4	3	-	2	-	-	2	3	2.50
Arrecife El Banderote* **	SAM	2	5	1	3	1	0	-	1	2	3	3	2.10
Punta Soldado Reef	SAM	-	-	-	-	-	-	-	-	-	3	3	3.00
Melones Reef**	SAM	0	4	2	2	3	1	-	3	2	3	3	2.30
Arrecife Mosquito	Crystal Clear Vieques	-	-	-	-	3	-	-	-	-	3	3	3.00
SW Comandante	Crystal Clear Vieques	-	-	-	-	3	-	-	-	-	2	3	2.67
Ensenada Honda	Crystal Clear Vieques	-	-	-	-	-	-	-	-	-	3	3	3.00
Cueva del Indio	Dr. Matt Lucas	-	-	-	-	-	-	-	-	-	3	3	3.00
Penon de Mera	Dr. Matt Lucas	-	-	-	-	-	-	-	-	-	3	3	3.00
Moncho Rock / Diaz	Dr. Matt Lucas	-	-	-	-	-	-	-	-	-	3	3	3.00
San Juan Barrier Reef	Sail4Reefs (Antares Ramos-Álvarez)	-	-	-	-	-	-	-	-	-	3	3	3.00
Playuelas	Cabo Rojo Workshop	-	-	-	-	-	-	-	-	-	2	2	2.00
Crash Boat	Cabo Rojo Workshop	-	-	-	-	-	-	-	-	-	2	3	2.50

Site	Site Submitted by	Coral Diversity Simpson Index (Unidirectional)	Hard Coral % Cover (Unidirectional)	Herbivorous fish Biomass (Unidirectional)	Macroalgae percent cover (Unidirectional)	Fraction of scleractinian colonies without disease (Unidirectional)	Herbivore Diversity (Unidirectional)	% Cover of CCA (Unidirectional)	Percent Cover Orbicella (Unidirectional)	Percent Cover Acroporid (Unidirectional)	Distance to mangrove nursery habitat (m) (Unidirectional) (TNC 2015)	Distance to seagrass nursery habitat (m) (Unidirectional) (Schill et al. 2021)	Overall Score (Divided by factors available)
El Eco	Cabo Rojo Workshop	-	-	-	-	-	-	-	-	-	3	3	3.00
Shacks	Cabo Rojo Workshop	-	-	-	-	-	-	-	-	-	2	3	2.50
Isla Verde	Cabo Rojo Workshop	-	-	-	-	-	-	-	-	-	3	3	3.00

Notes: Blue shading = sites included in priority areas, pink shading = sites included in second priority areas, purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2. *Data source: Townsend et al, Unpublished data (2024) **Data source: National Coral Reef Monitoring Program (NCRMP) site 6344 used for Melones Reef. ***Data source: NCRMP site 6367 used for Arrecife el Banderote.

Table 5: Climate Refugia Factors and Scores at Puerto Rico Coral Reef Monitoring Program (PRCRMP) Reef Sites

Site	**Historical DHW** (Sum of DHW > 4°C 1985-2019) (Unidirectional) (Dixon et al. 2021)	**Projected DHW** (Sum of DHW > 8°C 2020-2100) (Unidirectional) (Dixon et al. 2021)	**Projected Annual Bleaching** (Unidirectional) (UNEP 2020)	**Larval Connectivity In** (Unidirectional) (Schill et al. 2017)	**Larval Connectivity Out** (Unidirectional) (Schill et al. 2020)	**Exposure to Intense Storm Activity** (Unidirectional) (Knapp et al. 2017)	**Overall Score** (Divided by factors available)
Beril	2	1	2	4	2	3	2.33
Boya Vieja (2015)	2	1	2	4	2	4	2.50
Cabezas de San Juan			2				2.00
Canal Luis Pena	1	3	2	2	2	1	1.83
Canjilones (Vieques)			1				1.00
Carlos Rosario	2	3	2	2	2	1	2.00
Cayo Aurora	2	1	2	4	2	3	2.33
Cayo Caribes (2016)	3	3	3	2	2	3	2.67
Cayo Coral	2	1	2	4	2	3	2.33
Cayo Diablo (2016)	1	4	2	2	2	1	2.00
Cayo Ratones	3	3	2	2	2	3	2.50
Cayo Rodriguez	4	2	4	4	2	3	3.17
Cibuco (2013)	4	3	3	1	2	2	2.50
Dakiti	1	3	2	2	2	1	1.83
Derrumbadero			2				2.00
Dominos	3	4	4	1	2	1	2.50
El Negro 10m	3	2	4	4	2	3	3.00
El Negro 5m	3	2	4	4	2	3	3.00
Esperanza	0	3	1	2	2	1	1.50
Gallardo (2019)	2	1	2	4	2	4	2.50
Guanajibo	3	2	2	4	2	3	2.67
Manchas Exteriores 10m			4				4.00
Manchas Exteriores 20m			4				4.00
Maria Langa 10m (2016)	2	1	2	4	2	3	2.33
Maria Langa 20m (2016)	2	1	2	4	2	3	2.33
Maria Langa 5m	2	1	2	4	2	3	2.33
Media Luna 10m (Parguera)	3	2	2	4	2	3	2.67
Media Luna 5m (Parguera)	3	2	2	4	2	3	2.67
Palominitos (2016)	3	4	2	2	2	1	2.33
Palominos (2016)	3	4	2	2	2	1	2.33
Puerto Botes 15m			2				2.00
Puerto Botes 20m			2				2.00

Site	**Historical DHW** (Sum of DHW > 4°C 1985-2019) (Unidirectional) (Dixon et al. 2021)	**Projected DHW** (Sum of DHW > 8°C 2020-2100) (Unidirectional) (Dixon et al. 2021)	**Projected Annual Bleaching** (Unidirectional) (UNEP 2020)	**Larval Connectivity In** (Unidirectional) (Schill et al. 2017)	**Larval Connectivity Out** (Unidirectional) (Schill et al. 2020)	**Exposure to Intense Storm Activity** (Unidirectional) (Knapp et al. 2017)	**Overall Score** (Divided by factors available)
Resuellos	2	2	2	4	2	4	2.67
Tourmaline 10m	3	2	2	4	2	3	2.67
Tourmaline 20m			2				2.00
Tres Palmas 10m	3	1	2	1	5	3	2.50
Tres Palmas 20m	3	1	2	1	5	3	2.50
Tres Palmas 5m	3	1	2	1	5	3	2.50
West Reef			2			5	3.50

Notes: Blue shading = sites included in priority areas, pink shading = sites included in second priority areas, purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2. Climate refugia was given 2 times weight for the overall scores.

Table 6: Climate Refugia Factors and Scores at Reef Sites Submitted by Stakeholders and Technical Advisors

Site	**Historical DHW** (Sum of DHW > 4°C 1985-2019) (Unidirectional) (Dixon et al. 2021)	**Projected DHW** (Sum of DHW > 8°C 2020-2100) (Unidirectional) (Dixon et al. 2021)	**Projected Annual Bleaching** (Unidirectional) (UNEP 2020)	**Larval Connectivity In** (Unidirectional) (Schill et al. 2017)	**Larval Connectivity Out** (Unidirectional) (Schill et al. 2020)	**Exposure to Intense Storm Activity** (Unidirectional) (Knapp et al. 2017)	**Overall Score** (Divided by factors available)
Atrevesado	3	2	2	4	2	4	2.83
San Cristobal	3	2	2	4	2	4	2.83
Cayo Largo	3	5	2	2	2	1	2.50
Arrecife El Banderote	1	3	2	2	2	1	1.83
Punta Soldado Reef	1	3	2	2	2	1	1.83
Melones Reef	1	3	2	2	2	1	1.83
Arrecife Mosquito	1	4	1	2	2	1	1.83
SW Comandante			1				1.00
Ensenada Honda			1				1.00
Cueva del Indio	4	2	3	1	2	2	2.33
Penon de Mera	4	2	3	1	2	2	2.33
Moncho Rock / Diaz	4	3	3	1	2	2	2.50
San Juan Barrier Reef	3	4	4	1	2	1	2.50
Playuelas	3	2	5	1	5	3	3.17
Crash Boat			5				5.00
El Eco	4	3	3	1	2	2	2.50
Shacks	3	2	3	1	3	3	2.50
Isla Verde			4				4.00

Notes: Blue shading = sites included in priority areas, pink shading = sites included in second priority areas, purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2. Climate refugia was given 2 times weight for the overall scores.

Table 7: Human Impacts Scores and Factors at Puerto Rico Coral Reef Monitoring Program (PRCRMP) Reef Sites

Site	**Productivity - Chl-a (ug/L)** (Unidirectional) (Courtney et al, Unpublished data 2024)	**Pollution (NOx)** (Unidirectional) (Courtney et al, Unpublished data 2024)	**Sedimentation** (Unidirectional) (National Centers for Coastal Ocean Science 2024)	**Marine Based Pollution** (TAC/SAG)	**Watershed based pollution** (Unidirectional) (TAC/SAG)	**Fishing Pressure** (Anecdotal) (TAC/SAG)	**Fishing Pressure** (Unidirectional) (DNER)	**Enforcement** (TAC/SAG)	**Marine Debris** (TAC/SAG)	**Coastal Development** (TAC/SAG)	**Tourism** (Unidirectional) (TAC/SAG)	**Shipping** (Unidirectional) (TAC/SAG)	**Ship Groundings** (Unidirectional) (DNER & TNC 2024)	**Overall Score** (Divided by factors available)
Beril	-	-	5	-	-	Recreational and Commercial	1	-	-	-	2	4	2	3.50
Boya Vieja (2015)	2	3	5	-	-	Recreational and Commercial	-	-	-	-	2	4	3	3.80
Cabezas de San Juan	2	3	-	-	2	Recreational	3	-	Low	-	1	0	0	1.57
Canal Luis Pena	3	3	5	-	4	No Take	5	Low	-	None	High	2	3	4.17
Canjilones (Vieques)	2	3	5	-	-	-	-	-	-	Off of navy area - not restricted but Fish and Wildlife Area not available to development	3	2	3	3.60
Carlos Rosario	2	3	5	-	4	No Take	5	Low	-	None	High	2	3	4.00
Cayo Aurora	3	2	5	-	-	-	-	-	-	-	3	4	3	4.00
Cayo Caribes (2016)	2	2		-	-	-	2	-	-	-	3	4	2	2.50
Cayo Coral	3	2	5	-	-	-	-	-	-	-	3	4	3	4.00
Cayo Diablo (2016)	3	3	5	-	4	Recreational	2	-	Low	-	1	0	0	2.57
Cayo Ratones	2	3	5	-	1	-	-	-	-	-	3	4	2	3.33
Cayo Rodriguez	1	3	3	-	2	-	1	-	-	-	-	4	3	2.83
Cibuco (2013)	2	3	3	-	1	Commercial	-	-	High	High	Low	4	3	3.20
Dakiti	3	3	-	-	4	Recreational	-	-	-	None	High	2	1	2.60
Derrumbadero	4	3	-	-	1	-	3	-	-	-	3	0	3	2.43
Dominos	4	2	5	-	1	Commercial	-	-	Fiber Cables, low debris	High	1	0	2	2.50

Site	**Productivity - Chl-a (ug/L)** (Unidirectional) (Courtney et al, Unpublished data 2024)	**Pollution (NOx)** (Unidirectional) (Courtney et al, Unpublished data 2024)	**Sedimentation** (Unidirectional) (National Centers for Coastal Ocean Science 2024)	**Marine Based Pollution** (TAC/SAG)	**Watershed based pollution** (Unidirectional) (TAC/SAG)	**Fishing Pressure** (Anecdotal) (TAC/SAG)	**Fishing Pressure** (Unidirectional) (DNER)	**Enforcement** (TAC/SAG)	**Marine Debris** (TAC/SAG)	**Coastal Development** (TAC/SAG)	**Tourism** (Unidirectional) (TAC/SAG)	**Shipping** (Unidirectional) (TAC/SAG)	**Ship Groundings** (Unidirectional) (DNER & TNC 2024)	**Overall Score** (Divided by factors available)
El Negro 10m	4	3	-	-	-	-	1	-	-	-	-	4	3	3.00
El Negro 5m	2	2	5	-	-	-	1	-	-	-	-	4	3	3.40
Esperanza	3	3	5	-	-	Recreational	1	-	Has some fishing debris	Already developed	3	2	3	3.33
Gallardo (2019)	2	2	5	-	-	-	1	-	-	-	-	4	3	3.40
Guanajibo	2	3	5	-	-	-	1	-	-	-	-	4	3	3.60
Manchas Exteriores 10m	2	2	5	-	2	-	-	-	-	-	-	0	3	2.80
Manchas Exteriores 20m	3	2	5	-	2	-	-	-	-	-	-	0	3	3.00
Maria Langa 10m (2016)	0	3	5	-	1	-	-	-	-	-	3	0	3	2.50
Maria Langa 20m (2016)	2	3	-	-	1	-	-	-	-	-	3	0	3	2.00
Maria Langa 5m	1	2	4	-	1	-	-	-	-	-	3	0	3	2.33
Media Luna 10m (Parguera)	2	3	5	-	-	Recreational and Commercial	-	-	-	-	2	4	2	3.60
Media Luna 5m (Parguera)	2	2	5	-	-	Recreational and Commercial	-	-	-	-	2	4	2	3.40
Palominitos (2016)	3	3	5	-	3	Recreational	2	-	Low	-	1	0	0	2.43
Palominos (2016)	3	2	5	-	3	Recreational	2	-	Low	-	1	0	0	2.29
Puerto Botes 15m	2	3	-	-	-	-	-	-	-	-	-	4	3	3.00
Puerto Botes 20m	4	3	-	-	-	-	-	-	-	-	-	4	3	3.50

Site	**Productivity - Chl-a (ug/L)** (Unidirectional) (Courtney et al, Unpublished data 2024)	**Pollution (NOx)** (Unidirectional) (Courtney et al, Unpublished data 2024)	**Sedimentation** (Unidirectional) (National Centers for Coastal Ocean Science 2024)	**Marine Based Pollution** (TAC/SAG)	**Watershed based pollution** (Unidirectional) (TAC/SAG)	**Fishing Pressure** (Anecdotal) (TAC/SAG)	**Fishing Pressure** (Unidirectional) (DNER)	**Enforcement** (TAC/SAG)	**Marine Debris** (TAC/SAG)	**Coastal Development** (TAC/SAG)	**Tourism** (Unidirectional) (TAC/SAG)	**Shipping** (Unidirectional) (TAC/SAG)	**Ship Groundings** (Unidirectional) (DNER & TNC 2024)	**Overall Score** (Divided by factors available)
Resuellos	3	3	5	-	-	-	-	-	-	Bad sedimentation - deforestation occurring and increasing	-	4	3	4.50
Tourmaline 10m	2	3	5	-	-	Seasonal No Take	4	-	-	-	3	4	3	4.00
Tourmaline 20m	3	3	5	-	-	Seasonal No Take	4	-	-	-	3	4	3	4.17
Tres Palmas 10m	2	3	4	-	-	No Take	5	-	There is debris based on swell, including tires	Under High and increasing Pressure	2	4	3	3.83
Tres Palmas 20m	4	3	4	-	-	No Take	5	-	There is debris based on swell, including tires	Under High and increasing Pressure	2	4	3	4.17
Tres Palmas 5m	3	3	5	-	-	No Take	5	-	There is debris based on swell, including tires	Under High and increasing Pressure	1	4	3	4.00
West Reef	2	1	5	-	1	-	-	-	-	-	2	0	3	2.33

Notes: Blue shading = sites included in priority areas, pink shading = sites included in second priority areas, purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2. Double weight was given to water quality factors with quantitative data (productivity, pollution [NOx], and sedimentation). Categories with notes only were not included in overall score due to lack of information but were considered as additional factors in site selection.

Table 8: Human Impacts Scores and Factors at Reef Sites Submitted by Stakeholders and Technical Advisors

Site	**Productivity - Chl-a (ug/L)** (Unidirectional) (Courtney et al, Unpublished data 2024)	**Pollution (NOx)** (Unidirectional) (Courtney et al, Unpublished data 2024)	**Sedimentation** (Unidirectional) (National Centers for Coastal Ocean Science 2024)	**Marine Based Pollution** (TAC/SAG)	**Watershed based pollution** (Unidirectional) (TAC/SAG)	**Fishing Pressure** (Anecdotal) (TAC/SAG)	**Fishing Pressure** (Unidirectional) (DNER)	**Enforcement** (TAC/SAG)	**Marine Debris** (TAC/SAG)	**Coastal Development** (TAC/SAG)	**Tourism** (Unidirectional) (TAC/SAG)	**Shipping** (Unidirectional) (TAC/SAG)	**Ship Groundings** (Unidirectional) (DNER & TNC 2024)	**Overall Score** (Divided by factors available)
Atrevesado			4			Recreational and Commercial			When grounding release marine debris		2	4	2	4.00
San Cristobal			4			Recreational and Commercial			When grounding release marine debris		2	4	2	4.00
Cayo Largo			5		3	Recreational	2		Low		1	0	0	2.20
Arrecife El Banderote			5		2	No Take	5	Low		Low - but suffered high mortality	High	2	3	4.25
Punta Soldado Reef			5		4	Recreational				Low	High	2	1	4.00
Melones Reef			5		2	No Take	5	Low		Low to Medium - but high impact	High	2	3	4.25
Arrecife Mosquito			5			Commercial	3		Has some fishing debris	None - far	3	2	2	3.75
SW Comandante			5						None or low	None - far	FALSE	2	3	5.00
Ensenada Honda			5			Recreational and Commercial	3			None - mangrove bay and restricted area	3	2	3	4.00
Cueva del Indio			4		4	Recreational	2			High	2	4	3	3.80
Penon de Mera			4		4	Recreational	2			High	2	4	3	3.80
Moncho Rock / Diaz			5		4					High	2	4	3	4.50

Site	**Productivity - Chl-a (ug/L)** (Unidirectional) (Courtney et al, Unpublished data 2024)	**Pollution (NOx)** (Unidirectional) (Courtney et al, Unpublished data 2024)	**Sedimentation** (Unidirectional) (National Centers for Coastal Ocean Science 2024)	**Marine Based Pollution** (TAC/SAG)	**Watershed based pollution** (Unidirectional) (TAC/SAG)	**Fishing Pressure** (Anecdotal) (TAC/SAG)	**Fishing Pressure** (Unidirectional) (DNER)	**Enforcement** (TAC/SAG)	**Marine Debris** (TAC/SAG)	**Coastal Development** (TAC/SAG)	**Tourism** (Unidirectional) (TAC/SAG)	**Shipping** (Unidirectional) (TAC/SAG)	**Ship Groundings** (Unidirectional) (DNER & TNC 2024)	**Overall Score** (Divided by factors available)
San Juan Barrier Reef			5		1	Commercial			Fiber Cables, low debris generally	High	1	0	3	2.50
Playuelas			5									4	3	6.00
Crash Boat			5									4	3	6.00
El Eco			5		1	Commercial			Spark plugs	High	1	4	3	3.50
Shacks			5		4	Recreational	3			High	1	4	3	4.00
Isla Verde					1	Commercial			Fiber Cables west of Isla Verde, low debris		1	0	3	1.25

Notes: Blue shading = sites included in priority areas, pink shading = sites included in second priority areas, purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2. Double weight was given to water quality factors with quantitative data (productivity, pollution [NOx], and sedimentation). Categories with notes only were not included in overall score due to lack of information but were considered as additional factors in site selection.

Table 9: Management Actions Scores and Factors at Puerto Rico Coral Reef Monitoring Program (PRCRMP) Reef Sites

Site	**Protection Status/Site is in MPA** (Unidirectional) (DNER / Protectores de Cuencas)	**Watershed Management Plan in Place for site** (Unidirectional) (DNER)	**Identified as a priority area in "Puerto Rico's Coral Reef Management Priorities" Doc** (Unidirectional) (Puerto Rico's Coral Reef Management Priorities)	**Other management Plans in place for site? (**TAC/SAG)	**Current restoration site** (Unidirectional) (TAC/SAG)	**Future Restoration Site** (Unidirectional) (TAC/SAG)	**Overall Score** (Divided by factors available)
Beril	3	4	3	Special planning zone for land-based reserves at all La Parguera Sites	0	0	2.00
Boya Vieja (2015)	3	4	3		0	0	2.00
Cabezas de San Juan	2	0	4		0	0	1.20
Canal Luis Pena	6	4	4	Law 66	4	0	3.60
Canjilones (Vieques)	0	0	3		0	2	1.00
Carlos Rosario	6	4	4	Law 66	4	0	3.60
Cayo Aurora	3	4	4		4	0	3.00
Cayo Caribes (2016)	0	0	2		0	0	0.40
Cayo Coral	3	4	4		4	0	3.00
Cayo Diablo (2016)	4	4	4		4	0	3.20
Cayo Ratones	0	0	2		0	0	0.40
Cayo Rodriguez	0	4	3		0	0	1.40
Cibuco (2013)	2	0	2	Pending designation for reserve	0	0	0.80
Dakiti	0	4	4	Law 66	4	0	2.40
Derrumbadero	0	0	3		0	0	0.60
Dominos	0	0	2	FEMA plan, San Juan Estuary program	0	2	0.80
El Negro 10m	0	4	3		0	0	1.40
El Negro 5m	0	4	3		4	0	2.20
Esperanza	0	0	3		0	2	1.00
Gallardo (2019)	0	0	4		0	0	0.80
Guanajibo	0	0	3		0	0	0.60
Manchas Exteriores 10m	1	0	3		0	0	0.80
Manchas Exteriores 20m	1	0	3		0	0	0.80
Maria Langa 10m (2016)	0	0	3		0	0	0.60
Maria Langa 20m (2016)	0	0	3		0	0	0.60
Maria Langa 5m	0	0	3		4	0	1.40
Media Luna 10m (Parguera)	3	4	3		2	0	2.40

Site	**Protection Status/Site is in MPA** (Unidirectional) (DNER / Protectores de Cuencas)	**Watershed Management Plan in Place for site** (Unidirectional) **(**DNER)	**Identified as a priority area in "Puerto Rico's Coral Reef Management Priorities" Doc** (Unidirectional) (Puerto Rico's Coral Reef Management Priorities)	**Other management Plans in place for site? (**TAC/SAG)	**Current restoration site** (Unidirectional) (TAC/SAG)	**Future Restoration Site** (Unidirectional) (TAC/SAG)	**Overall Score** (Divided by factors available)
Media Luna 5m (Parguera)	3	4	3		0	0	2.00
Palominitos (2016)	4	4	4		4	0	3.20
Palominos (2016)	4	4	4		4	0	3.20
Puerto Botes 15m	4	0	3		0	0	1.40
Puerto Botes 20m	4	0	3		0	0	1.40
Resuellos	0	4	4		0	0	1.60
Tourmaline 10m	3	4	3	Prohibitions on anchoring - Federally	0	0	2.00
Tourmaline 20m	3	4	3	Prohibitions on anchoring - Federally	0	0	2.00
Tres Palmas 10m	6	0	3		4	0	2.60
Tres Palmas 20m	5	0	3		0	0	1.60
Tres Palmas 5m	6	0	3		4	0	2.60
West Reef	4	0	3		0	0	1.40

Notes: Blue shading = sites included in priority areas, pink shading = sites included in second priority areas, purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2, Red Shading = overall score 0-1. Double weight was given to sites with no-take zones in MPA's.

Table 10: Management Actions Scores and Factors at Reef Sites Submitted by Stakeholders and Technical Advisors

Site	**Protection Status/Site is in MPA** (Unidirectional) (DNER / Protectores de Cuencas)	**Watershed Management Plan in Place for site** (Unidirectional) (DNER)	**Identified as a priority area in "Puerto Rico's Coral Reef Management Priorities" Doc** (Unidirectional) (Puerto Rico's Coral Reef Management Priorities)	**Other management Plans in place for site?** (TAC/SAG)	**Current restoration site** (Unidirectional) (TAC/SAG)	**Future Restoration Site** (Unidirectional) (TAC/SAG)	**Overall Score** (Divided by factors available)
Atrevesado	3	4	3		4	0	2.80
San Cristobal	3	4	3		4	0	2.80
Cayo Largo	0	4	3		4	0	2.20
Arrecife El Banderote	6	4	4	Law 66	4	0	3.60
Punta Soldado Reef	0	4	4	Law 66	4	0	2.40
Melones Reef	6	4	4	Law 66	4	0	3.60
Arrecife Mosquito	0	0	3		0	2	1.00
SW Comandante	0	0	3		0	2	1.00
Ensenada Honda	0	0	3		0	2	1.00
Cueva del Indio	1	0	1		0	2	0.80
Penon de Mera	0	0	1		4	0	1.00
Moncho Rock / Diaz	0	0	2	Pending designation for reserve	4	0	1.20
San Juan Barrier Reef	1.5	0	1	FEMA plan, San Juan Estuary program	0	2	0.90
Playuelas	0	0	1		0	0	0.20
Crash Boat	0	0	1		0	0	0.20
El Eco	0	0	2	Pending designation for reserve	4	0	1.20
Shacks	0	0	2		4	0	1.20
Isla Verde	3	0	2	FEMA plan, San Juan Estuary program	0	2	1.40

Notes: Blue shading = sites included in priority areas, pink shading = sites included in second priority areas, purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2, Red Shading = overall score 0-1. Double weight was given to sites with no-take zones in MPA's.

Table 11: Logistics and Community Support Scores and Factors, Plus Additional Notes on Sites at Puerto Rico Coral Reef Monitoring Program (PRCRMP) Reef Sites

Site	**Proximity to in-situ or ex-situ nurseries (m)** (Unidirectional) (DNER)	**Accessibility** (Unidirectional) (TAC/SAG)	**Other logistic considerations** (TAC/SAG)	**Overall Score for Logistics** (Divided by factors available)	**Site has strong community support?** (Unidirectional) (TAC/SAG)	**Overall Score for Community Support** (Divided by factors available)	**Other Notes**
Beril	4	2		3.00	4	4.00	- La Parguera sites in general are good candidates, lots of support, CIROM, DMS
Boya Vieja (2015)	4	2		3.00	4	4.00	
Cabezas de San Juan	3	2		2.50	4	4.00	- In general, in Fajardo 60-80% of substrate ramicrusta - Historically had huge orbicella - Goes shallow to deep in the general area - Very little boat damage
Canal Luis Pena	2	2	Need to get to Culebra and materials to Culebra, there are unexploded ordinances	2.00	4	4.00	
Canjilones (Vieques)	3	2	There are unexploded ordinances, need to get there by ferry	2.50	0	0.00	
Carlos Rosario	2	2	Need to get to Culebra and materials to Culebra, there are unexploded ordinances	2.00	4	4.00	- Carlos Rosario to Punta Solado could all be included as one area - Carlos Rosario has better structure than Banderote for restoration
Cayo Aurora	4	2		3.00	0	0.00	- Historically great populations of acroporids - Cabo Rojo group generally thinks this reef should not be prioritied for restoration as there are only shallow areas with no depth gradient
Cayo Caribes (2016)	1	2		1.50	0	0.00	
Cayo Coral	4	2		3.00	0	0.00	- Past restoration at Cayo Coral - Historically great populations of acroporids - grew thicket very fast
Cayo Diablo (2016)	4	2	Moorings Available	3.00	4	4.00	
Cayo Ratones	1	2		1.50	0	0.00	
Cayo Rodriguez	2	2		2.00	0	0.00	

Cibuco (2013)	0	2	Really high wave energy, hard to work	1.00	4	4.00	- East of river mouth, less pollution, tons of SCTLD, still healthy orbicellas - Cibuco reef has a huge patch of acropora
Dakiti	2	2	Need to get to Culebra and materials to Culebra, there are unexploded ordinances	2.00	4	4.00	- Lots of groundings
Derrumbadero	3	2		2.50	0	0.00	
Dominos	1	2	Strong currents, high energy, seasonal, could be accessed by shore	1.50	4	4.00	
El Negro 10m	2	2		2.00	0	0.00	- Considered by some to be more resilient due to the currents and riverine inputs - Riverine pollution is high - But benefit from deeper water and currents - Always looks clean - River outflow moves north primarily - Treat different depth gradients as same area
El Negro 5m	2	2		2.00	0	0.00	- Considered by some to be more resilient due to the currents and riverine inputs - Riverine pollution is high - But benefit from deeper water and currents - Always looks clean - River outflow moves north primarily - Treat different depth gradients as same area
Esperanza	3	2	Need to get there by ferry	2.50	4	4.00	- Close to restaurant areas, might experience some of the land based source - SAM is planning to add more in-situ nurseries very close, Cayo real - The decline in coral cover may have been related to hurricane damage - Esperanza just to look really good – could be a good candidate for restoration
Gallardo (2019)	2	2		2.00	0	0.00	- Still has healthy palmata
Guanajibo	2	2		2.00	0	0.00	- Riverine pollution is high - But benefits from deeper water and currents - Always looks clean - River outflow moves north primarily - Guanajibo looked great historically but was hit very hard by stony coral tissue loss disease
Manchas Exteriores 10m	2	2		2.00	0	0.00	
Manchas Exteriores 20m	2	2		2.00	0	0.00	
Maria Langa 10m (2016)	4	2		3.00	0	0.00	- Historically a good site, depth gradient, historical industry support, and interest in continuing support - Stacey notes that shallow sections have been hit hard and it hasn't been healthy for awhile - Cervicornis areas were wiped out - Deeper reef area dominated by soft corals
Maria Langa 20m (2016)	4	2		3.00	0	0.00	
Maria Langa 5m	4	2		3.00	0	0.00	
Media Luna 10m (Parguera)	4	2		3.00	4	4.00	
Media Luna 5m (Parguera)	4	2		3.00	4	4.00	

Palominitos (2016)	4	2	Moorings available	3.00	4	4.00	
Palominos (2016)	4	2	Moorings available, CariCoos virtual buoy	3.00	4	4.00	- Restoration seems to be working - Hotels could be a resource in future for these reef areas
Puerto Botes 15m	1			1.00	0	0.00	
Puerto Botes 20m	1			1.00	0	0.00	
Resuellos	3	2		2.50	0	0.00	
Tourmaline 10m	2	2		2.00	0	0.00	- Treat all depths as same
Tourmaline 20m	2	2		2.00	0	0.00	
Tres Palmas 10m	2	2	Would not want to put an in-situ nursery	2.00	4	4.00	- In general, Tres Palmas sites can be thought of as same area
Tres Palmas 20m	2	2	Would not want to put an in-situ nursery	2.00	4	4.00	
Tres Palmas 5m	2	4	Would not want to put an in-situ nursery	3.00	4	4.00	- Still has healthy Palmata - The swell doesn't impact the adhesion of ouplanted corals much - Tres Palmas shows much better projected temperature according to the Mejias-River and Courtney 2024 Paper - Think of the 5-meter site as representative of the inner reef
West Reef	3	2		2.50	0	0.00	

Notes: Blue shading = sites included in priority areas, pink shading = sites included in second priority areas, purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2, Red Shading = overall score 0-1.

Table 12: Logistics and Community Support Scores and Factors, Plus Additional Notes on Sites at Reef Sites Submitted by Stakeholders and Technical Advisors

Site	**Proximity to in-situ or ex-situ nurseries (m)** (Unidirectional) (DNER)	**Accessibility** (Unidirectional) (TAC/SAG)	**Other logistic considerations** (TAC/SAG)	**Overall Score for Logistics** (Divided by factors available)	**Site has strong community support?** (Unidirectional) (TAC/SAG)	**Overall Score for Community Support** (Divided by factors available)	**Other Notes**
Atrevesado	3	2	-	2.50	4	4.00	- GPS error in La Parguera that causes lots of groundings
San Cristobal	4	2	-	3.00	4	4.00	- Historically great populations of acroporids (all types)
Cayo Largo	4	2	Very easy access	3.00	4	4.00	-
Arrecife El Banderote	2	2	Need to get to Culebra and materials to Culebra, there are unexploded ordinances	2.00	4	4.00	- Seagrass restoration in these sites as well
Punta Soldado Reef	2	2	Need to get to Culebra and materials to Culebra, there are unexploded ordinances	2.00	4	4.00	- Seagrass restoration in these sites as well
Melones Reef	2	2	Need to get to Culebra and materials to Culebra, there are unexploded ordinances	2.00	4	4.00	- Seagrass restoration in these sites as well
Arrecife Mosquito	3	2	Need to get there by ferry	2.50	4	4.00	- Far offshore - but waste treatment plant is on the north side
SW Comandante	3	2	Need to get there by ferry	2.50	4	4.00	- Fish populations look great, especially hogfish - Huge colonies of OFAV plus fish populations make it a special site, also lots of juveniles, less impacts from bleaching than other sites Sarah has seen - Far offshore - but waste treatment plant is on the north side
Ensenada Honda	2	2	Need to get there by ferry	2.00	4	4.00	- Pollution impacts are likely low
Cueva del Indio	3	4	Strong currents, high energy, seasonal	3.50	4	4.00	- May be a coral nursery here - Receive many immigrant boats / groundings - Dominated by Acropora - Flat reef
Penon de Mera	1	4	Strong currents, high energy, seasonal	2.50	4	4.00	- Receive many immigrant boats / groundings
Moncho Rock / Diaz	0	4	Strong currents, high energy, seasonal	2.00	4	4.00	- Receive many immigrant boats / groundings

San Juan Barrier Reef	1	2	Strong currents, high energy, seasonal, could be accessed by shore	1.50	4	4.00	- Inconsistent reports of LBSPs - Western part of site funding was approved for FEMA, Eastern side NFWF funding
Playuelas	3	-	-	3.00	4	4.00	-
Crash Boat	3	-	-	3.00	4	4.00	-
El Eco	2	4	Strong currents, high energy, seasonal	3.00	4	4.00	- Groundwater cooled reefs, slower bleaching, high palmata, trying to make it an MPA, starts shallow goes deeper (maybe 30 feet) - Reefs receive lots of impacts from jet skis
Shacks	4	4	Strong currents, high energy, seasonal	4.00	4	4.00	- Receive many immigrant boats / groundings
Isla Verde	1	4	Strong currents, high energy, seasonal, could be accessed by shore	2.50	4	4.00	- Reni/Stacey don't think this is a good candidate for restoration - very flat pavement

Notes: Blue shading = sites included in priority areas, pink shading = sites included in second priority areas, purple shading = overall scores > 4, Green shading = overall scores 3-4, Yellow shading = overall score 2-3, Orange shading = overall score 1-2, Red Shading = overall score 0-1.

APPENDIX E: DATA GAPS IDENTIFIED

Throughout the process of goal setting and site selection the Core Team and Technical Advisors identified a number of data gaps for Puerto Rico. The list below is not all inclusive but does track data gaps discussed during the process of creating the Restoration Action Plan.

- Coral larval connectivity for Puerto Rico
- Genetic information of corals in nurseries
- Genetic information for resilient corals
- Restoration effectiveness assessments
- Coastal and reef water quality
- Marine debris
- Watershed based pollution
- Enforcement of water quality regulations and MPA management
- Coastal development
- Tourism impacts

APPENDIX F: INTERVENTIONS RECOMMENDED BY TECHNICAL ADVISORS AND THE NATIONAL ACADEMY OF SCIENCE, ENGINEERING, AND MEDICINE

Table 1: Interventions Recommended by Technical Advisors for Archipelago and Priority Areas

Priority Area / Archipelago	Coral Reef Restoration Interventions	Management Interventions	Research	Education and Outreach
Archipelago	– **Interventions to increase resilience to climate change** – Transplanting of cross island species – Assisted fertilization (in ocean fertilization) – Coral outplanting – Transplanting corals of opportunity – Develop programs for sexual reproduction of corals – Improve Larval Connectivity – Disease Management – Fish Community Interventions (aquaculture, FAD's, other interventions to attract fish to restoration sites)	– **Water quality management, particularly in the North Coast and Vieques** – Identify jurisdictions that are involved in water quality management and regulations for particular areas (roadmap/protocol for enforcement) – Develop and implement Stormwater Water Quality Monitoring Program – Frequent water quality monitoring for reef areas – Notification around acute water quality	– **Effectiveness assessments to understand which interventions are most effective at achieving improved ecological function and health** – **Genetic and environmental studies to understand why certain populations of corals have survived in the face of bleaching and disease** – Demographic performance analysis and genetics	– **Education and outreach to prevent recreational impact on reefs, specifically signs marking restoration sites and mooring installation and maintenance** – Design and long-term implementation of educational/ capacity building programs to address root causes of impaired water quality – EPA, NOAA, municipality and AAA coordination for services,

Priority Area / Archipelago	Coral Reef Restoration Interventions	Management Interventions	Research	Education and Outreach
Archipelago	– Herbivore Propagation and Release	events (pumping etc.) for a future goal of coordinating, preventing and mitigating risk to reefs – Enforcement of existing local land use regulations, to address illegal and unsustainable construction/ development – Integrate agencies beyond DNER and NOAA to support coral reef management and restoration – Comprehensive literature review of Caribbean restoration effectiveness assessments	– Assessment of Storm Risk for Selecting Areas of Coral Restoration – Reassessment of ocean dumping sites impacts on coral reef areas	equipment lending and water quality programs for community water quality monitoring

Priority Area / Archipelago	Coral Reef Restoration Interventions	Management Interventions	Research	Education and Outreach
Archipelago		– ESA Status Review of Declined or Declining Coral Species – Expansion of citizen science monitoring programs – Reassess the PRCRMP monitoring method / transects to focus on colonies rather than transects or combination of both – Emergency Response Planning – Create Emergency Plan For Bleaching		
La Parguera Area Reefs	– Selective breeding and propagation of disease and bleaching resistant coral species	– Marker buoy's for groundings at San Cristobal	– Research on resilience, specifically a study to understand	– Outreach and education programs for local community and visitors. Seek

Priority Area / Archipelago	Coral Reef Restoration Interventions	Management Interventions	Research	Education and Outreach
La Parguera Area Reefs	– Thermal stress acclimatization research and work at ex-situ nurseries		resilience in surviving corals at Gallardo – Research on resilience, specifically marking corals that have shown resilience to climate change for sexual reproduction	collaboration of local community and external users.
Guayanilla Outer Reefs	– Invasive species management for soft corals – Substrate addition to enhance reef structure – Focus on *Acropora cervicornis* for outplanting activities - Enhance herbivory	– Create and implement a Watershed Management Plan		– Increase collaborations with surrounding industry to fund restoration activities
Arrecifes de la Cordillera including Cayo Largo		– Marker buoy's for groundings and shipping activity		– Create collaborations with hotels for funding of

Priority Area / Archipelago	Coral Reef Restoration Interventions	Management Interventions	Research	Education and Outreach
Arrecifes de la Cordillera including Cayo Largo		– Create management plan for charter companies		restoration activities – Education and outreach to prevent unsustainable recreational activities. With a specific action to focus on the reduction of marine debris
San Juan Barrier Reef	– Seagrass and mangrove restoration	– Marker buoys for groundings and shipping activity – Source control of land-based sources of pollution (LBSP), specifically identify and control specific outfalls that pose risk to restoration areas	– Storm modeling to select sites for restoration planning	– Create collaborations with tourism industry for funding of restoration activities

Priority Area / Archipelago	Coral Reef Restoration Interventions	Management Interventions	Research	Education and Outreach
San Juan Barrier Reef		– Create and implement a watershed management plan		
Vega Baja Area Reefs		– Marker buoys for groundings and jet skis – Source control of LBSP – Support creation and implementation of watershed management plan already in progress – Create management plan for recently designated MPA Reserva Natural de los Jardines Submarinos de Vaga Baja y Manatí	– Research on resilience, specifically research to understand if surviving *Acropora* is due to cooler water or genetic resilience	

Priority Area / Archipelago	Coral Reef Restoration Interventions	Management Interventions	Research	Education and Outreach
Vega Baja Area Reefs		– Planning for emergency response, specifically the creation of quick response plan for acute winter storms		
Tres Palmas	– Transplant corals of opportunity – Managed relocation of *Acropora palmata* from other locations in Puerto Rico – Develop program for sexual reproduction of *Acropora palmata*	– Source control of pollution from development activities – Enforcement of No Take zones	– Research on resilience for surviving *Acropora palmata*	
Canal Luis Peña Area Reefs Including Dakiti and Punta Soldado	– Physical substrate stabilization – Transplant cross island species (i.e. managed relocation)	– Source control of pollution from development activities – Facilitate implementation of Canal Luis Peña Natural Reserve		– Increase environmental education and awareness to achieve behavior change of 1) private Sector; 2) municipal

Priority Area / Archipelago	Coral Reef Restoration Interventions	Management Interventions	Research	Education and Outreach
Canal Luis Peña Area Reefs Including Dakiti and Punta Soldado		MPA Management Plan to achieve enforcement of no take zones, mark MPA area physically, and include the MPA area in nautical maps – Develop local infrastructure for debris removal		government; 3) state/federal agencies – Education and outreach to prevent unsustainable recreational activities and behaviors
Bioluminescent Bay of Vieques area reefs including Esperanza	– Build upon existing seagrass, mangrove and coral restoration – Reef stabilization – Transplanting corals of opportunity, specifically after storm events	– Source control for specific outfalls near El Blok – Create a no take zones	– Assessment of greywater impacts to coral reefs	– Education and outreach to prevent recreational unsustainable activities, specifically installing and maintaining moorings and signage for restoration sites

Note: Bold text indicates what interventions were most highly emphasized in workshops.

Table 2: National Academy of Science, Engineering, and Medicine Recommendations

Intervention Category	Specific Intervention
Genetic and Reproductive	Managed Selection
Genetic and Reproductive	Managed Breeding: Supportive Breeding
Genetic and Reproductive	Managed Breeding: Outcrossing Between Populations
Genetic and Reproductive	Managed Breeding: Hybridization Between Species
Genetic and Reproductive	Gamete and Larval Capture and Seeding
Genetic and Reproductive	Coral Cryopreservation
Genetic and Reproductive	Genetic Manipulation: Coral
Genetic and Reproductive	Genetic Manipulation: Symbionts
Physiological	Pre-exposure
Physiological	Algal Symbiont Manipulation
Physiological	Microbiome Manipulation
Physiological	Antibiotics
Physiological	Phage Therapy
Physiological	Antioxidants
Physiological	Nutritional Supplementation
Coral Population and Community	Managed Relocation: Assisted Gene Flow
Coral Population and Community	Managed Relocation: Assisted Migration
Coral Population and Community	Managed Relocation: Introduction to New Areas
Environmental	Shading: Atmospheric
Environmental	Shading: Marine
Environmental	Mixing of Cool Water
Environmental	Abiotic Ocean Acidification Interventions
Environmental	Seagrass Meadows and Macroalgal Beds

Notes: For details on what the intervention is, its current feasibility, potential scale, limitations and risks please see NASEM REPORT

APPENDIX G: WORKSHOP SUMMARIES

Restoration Action Plan Step 1 Workshop Summary: Goal Setting and Geographic Area

Location: TNC Cupey Office Date: 3/19/2024

Threats and Capacity

Threats

In order to select goals that address the most significant threats that Puerto Rico is experiencing, the Core Team went through an exercise to identify threats and select threats. They then ranked threats individually from most significant/harmful to coral reef ecosystems to least significant/harmful to Coral Reef ecosystems. In general, there was much agreement among the core team regarding the ranking of threats, and no strong disagreement. Some threats ended up taking equal place in the rankings. The threats are listed below:

1) Climate Change
2) Poor Water Quality
2) Disease
3) Herbivory loss
3) Coastal development
4) Invasive species
4) Overfishing
5) Debris
5) Predators to corals (snails, fireworms, damselfish, others)
5) Vessel groundings
6) Recreational diving
6) Lack of public education/understanding about corals/coral reef ecosystems

In addition to these broad threats, some specific threats, either in terms of a specific location, or a specific temporal event, were identified. Two are noted below, but others may be identified throughout the planning process.

- Specific outfalls
- Storm events

Capacity

The Core Team next identified the current capacity in Puerto Rico both in regard to existing infrastructure and program, and in regard to human capacity. The Core Team also identified areas where they would like to increase capacity for Coral Reef Restoration. Areas of capacity are listed below:

- Infrastructure/programmatic capacity
  a. In-situ nurseries
  b. Ex-situ nurseries (2 current nurseries, 1 in development)
  c. Monitoring programs (CRMP/PRCRMP, coral reef watch, citizen science, others)
  d. Production of corals (asexual, limited sexual production)
  e. Production of herbivores
  f. Rescue of corals (triage)
  g. Disease intervention

- Human capacity
  a. Government agencies (DNER, NOAA, USFW etc.)
  a. Practitioners (Universities, NGO's, Private practitioners)
  b. Citizen science
  c. Dive shops
  d. Volunteers

- Future capacity to build
  a. More sexual reproduction
  b. Genotyping
  c. More land-based/ex-situ nurseries
  d. More outplanting
  e. More resilient corals
  f. Scaling-up restoration
  g. Funding
  h. Research around top threats (more applied data for management needs)
  i. Regional collaborations/co-management/local partnerships

Goal Setting

After the identification of threats and capacity, the Core Team went through a series of exercises to identify the goal of the Puerto Rico Restoration Action Plan (Restoration Action Plan) Through these exercises the Core Team was able to select the main goal of the Restoration Action Plan. However, some research is still

needed to set specific targets/metrics in the goal. In addition, although the team did not set specific SMART objectives to accomplish the goal, during this process, there were a number of areas that were identified as areas for which SMART objectives should be developed. The setting of SMART objectives will take place in Step 4.

In the first goal setting activity the Core Team identified and ranked general goals/areas to address. Again, there was general agreement regarding the ranking of general goals/areas to address, and no strong disagreement. The ranking of the goals/areas to address is below:

1) Reef resilience/Climate Change
2) Ecosystem function and health
3) Population declines
4) Water Quality

Throughout the discussion, it was noted that the goal should focus on improving ecosystem function and health in the face of climate change, and that the SMART objectives that will be developed in step 4 will focus on water quality, reef resilience and population declines.

The goal the Core Team decided upon is:

> **"To increase ecosystem function and health through improving the Biological Condition Gradient by 1 level at 4-6 priority areas in 10 years by addressing population and diversity declines through restoration efforts to increase resilience to climate change, and through water quality management".**

Other areas that were discussed to add to future SMART Objectives include:

- Coastal protection and coral reefs as natural infrastructure (tied to funding opportunities/management plans)
- Respond to acute disturbances
- Reduce land based sources of pollution, specifically through sediment control/green infrastructure
- Scale-up restoration
- Mitigate population declines and loss of genotypes of x,y,z coral species optimizing propagation and survivorship of outplants
- Early warning systems for water quality variability and rescue efforts
- Increase restoration of herbivore key species

- Increase local physical and human capacity to address coral production for scaling up restoration
- Foster Regional collaboration, co-management and coral reef stewardship for disease intervention and scaling up restoration
- Promote local coral reef stewardship
- Mitigate illegal coastal development for ensuring resilient coral outplants successful restoration efforts

Geographic Focus Areas: Functionality and Benefit

The first part of the discussion regarding geographic focus areas centered on reviewing a GIS map created by Denis Perez with numerous management areas, threats, biogeophysical parameters etc. In this exercise the Core Team used printed maps and circled areas that centered on the three following questions:

- What areas currently or in the recent past have performed functions that are relevant to the goal? (Green)
- What areas are currently experiencing the problems that the goal seeks to address? (Red)
- Within these areas, where could reef restoration provide social and ecological benefits? (Blue)

The goal of this exercise was to narrow in on areas around Puerto Rico that would be the most beneficial for Coral Reef restoration. Photos of the maps with Geographic Areas identified are saved in the Box file management system here.

Geographic Focus Areas: Management and Biophysical Context

The second part of the exercise was to identify the Management and Biophysical Context within the areas identified in part one (functionality and benefit). However, during the initial discussion the Core Team decided they would prefer not to narrow down areas due to concerns about missing funding opportunities if a site was not in a geographic area and missing potential sites that could be good candidates for restoration. Instead, the Core Team decided upon an approach that included the whole of Puerto Rico, divided into the geographical sections listed below. As a next step, the Core Team will analyze the reef depth gradients in these areas and decide if they would like to narrow down areas based on the practicalities of working in the ocean.

- South

- West
- North
- East
- Culebra/Vieques

The Core Team then identified important management and biophysical context in these areas as a first step towards creating criteria for site selection. The management and biophysical context for each area is saved in the Step 1 Workbook.

During this process, the Core Team also began to identify parameters that could be used for site selection, which are listed below, and noted that the **focus of the Technical and Stakeholder Advisor Group should be on resilient sites/spots**, while the **implementation plan should be climate Smart**.

Possible site selection parameters for ecological function and health

- Depth gradients
- Accessibility
- Weather
- Climate refugia (Vega Baja?)
- Existing efforts
- Existing management plans
- Long-term investments and adaptability

Data Gaps

As part of the exercise to identify geographic focus areas, the Core Team also began to identify potential data gaps. This included data to provide to assist with mapping and spatial planning exercises, and data we do not have. These two categories are listed below.

- Data available to be provided to the Plan's team
  - Corridors/larval connectivity
  - Can ask Reni García and Carlos Prada
  - Denise has large scale
  - General studies/guidance on creating larval connectivity for corals
  - Nurseries
  - Restoration Sites
  - Watershed management geospatial data
  - Sea urchin density for some reefs
  - Reports/data on water quality

- Water temperatures – Coral Reef Watch
- Coral Predation
- Sponges data – thesis
- Disease data – DNER, Edwin, Weil
- AGGRA Surveys (recent bleaching and Diadema)
- Reefs used for restoration (mooring for dives)
- Fish surveys (CRMP)
- Resilience assessments (JJ and others)
- CariCoos data on currents etc.
- CariCoos data on ocean acidification
- Tourism overuse (tourism valuation?)
- Watershed Management Plans
- Geospatial data on land-based sources of pollution
- Sea Level Rise
- Nurseries no longer in use

- Data we don't have
  - Mesophotic reefs
  - Coral larval connectivity in PR
  - Genetic information for all nurseries (recommendations on the number of species, gene bank information)
  - Reefs used by fishers

Restoration Action Plan Step 2 Workshop Summary: Site Selection

Location: Cabo Rojo Date: 6/14/2024
Location: San Juan: Date: 6/27/2024

Introduction

- Stakeholders and Technical Advisors met on June 14th, 2024 in Cabo Rojo and on June 17th in San Juan to discuss site selection. Additional comments were received by Reni García and Stacey Williams. The primary topics of discussion were:
    - Providing information to fill data gaps in the site selection metrics (primarily human impacts, logistics, and other)
    - Discussion of weighting of different metrics
    - Discussion of site prioritization

Participants

- Cabo Rojo Workshop:
    - Core Team:
        - Michael Nemeth: NOAA
        - Roxana Aslan: Puerto Rico Department of Natural and Environmental Resources Fellow
    - Facilitator:
        - Lark Starkey
    - Technical and Stakeholder Advisors:
        - Denise Perez: The Nature Conservancy
        - Tania Metz: The Nature Conservancy
        - Evan Tuohy: Isla Mar
        - Miguel Figuerola Hernández: Puerto Rico Department of Natural and Environmental Resources and Sea Ventures
        - Catalina Morales Ruiz: Sea Ventures
        - René Esteves: Puerto Rico Sea Grant
        - Travis Courtney: University of Puerto Rico Mayagüez, Department of Marine Sciences
        - Sandra Schleier: Puerto Rico Departamento de Recursos Naturales y Ambientale Vessel Groundings
        - Ricardo López Ortiz: Puerto Rico Department of Natural and Environmental Resources

        - Daniel Matos Caraballo: Puerto Rico Department of Natural and Environmental Resources
        - Luis A. Rivera: Puerto Rico Department of Natural and Environmental Resources Port sampler

- San Juan Workshop
    - Core team:
        - Micheal Nemeth: NOAA
        - Aurora Justiniano: NOAA
        - María Vega Rodríguez: Puerto Rico Department of Natural and Environmental Resources
        - Roxana Aslan: Puerto Rico Department of Natural and Environmental Resources Fellow
    - Facilitator:
        - Lark Starkey
    - Technical and Stakeholder Advisors
        - In-person:
            - Roger Guzman: Sociedad Ambiente Marino (SAM)
            - Edwin E. Hernández: Sociedad Ambiente Marino (SAM)
            - Denise Perez: The Nature Conservancy
            - Tania Metz: The Nature Conservancy
            - Antares Ramos: Sail for Reefs
            - Sandra Schleier: Puerto Rico Department of Natural and Environmental Resources Vessel Groundings
            - Sarah Elise P. Field: Crystal Clear
            - Juan David Mucia Eslava: Coalición Restauración Ecosistemas Santurcions (CRES PR)
        - Online:
            - Helena Antoun: National Marine Fisheries Service, Protected Resources Division
            - Héctor Ruiz: HJR Reefscaping
            - Graciela García-Moliner: Caribbean Fishery Management Council
            - Mark Martin
            - Alfredo Montañez: Canal Luis Penal Natural Reserve Community Advisory Board
            - Yvette Núñez Sepúlveda: Coalición Restauración Ecosistemas Santurcions (CRES PR)

Site Prioritization Process

After an initial orientation presentation, the facilitator (Lark Starkey), with support from Denise Perez, used the Site Selection Matrix and Webmap to guide the discussion regarding filling in data gaps by region, in alignment to the geographical area. Starting with the regions that the group was most familiar with to least familiar with (i.e. West -> South -> East -> North -> Culebra/Vieques for the Cabo Rojo Workshop and Culebra -> Vieques -> East -> North -> South -> West for the San Juan workshop. In Cabo Rojo the group spent the majority of the time discussing the west, south and east regions. In San Juan the group spent the majority of the time discussing Culebra, Vieques, East and North Regions.

After filling in data gaps and refining some of the information in the site selection matrix, the overall site scores in the site selection matrix was recalculated and the group discussed if they did or did not agree with the prioritization according to the matrix.

Comments Received

In addition to the data tracked on the matrix for individual sites/areas the following comments were received:

General comments:

- Puerto Rico Coral Reef Monitoring Program (PRCRMP) was designed to select for areas of high coral cover
- There are minimal differences in water chemistry by depth gradient of PRCRMP sites
- There is a need for long-term investment in restoration sites
- Accessibility is key- being able to manage/monitor sites with the frequency needed
- The NMFS critical habitat designation incorporates many factors needed for recovery of ecosystems
- There is a big potential gap in connectivity in the southeast, northeast, and northwest coasts
- Concerns about limits for funding in certain areas
- Throughout Puerto Rico there is spatial patchiness around coral survivorship

West:

- In the UNEP climate models, Aguadilla and Rincon show later and less bleaching than other areas
- The west and northwest regions are projected to have a longer timeline for annual severe bleaching, and in the past did not experience as severe bleaching as other regions
- Tourmaline in the west is also a very nice site – consider it for restoration

South:

- Any sites near shore to Ponce are more susceptible to pollution
- In La Parguera there is a plan for Playa Rosada in which Protectores de Cuencas develops a management plan for the area and the Montessori school implements the plan and takes over management
- In La Parguera, a few people are pushing to make San Cristobal a reserve / no take zone
- The effect on corals and marine life of inappropriate use of pesticides and acids in marinas and golf courses is a concern for many commercial fishermen, at least in Cabo Rojo. This would specifically affect the corals near the Joyuda and Puerto Real area. Likewise, the water treatment plants of Puerto Real. Without a doubt, this could be happening around PR.
- Sargassum is commonly seen on the Joyuda coast in western PR and in the Pitahaya sector, both in Cabo Rojo, probably eliminating larvae and juvenile fish that in turn are recruited and have functions in the reef.
- In the South Coast there is less knowledge about how to solve the threats corals are facing (bleaching, disease)

East:

- For the Fajardo area
    - Fuera is very helpful
    - Hotels could be a resource in future
    - Charters are helpful
    - Fajardo River has impacts
- Fajardo has some problems with abandoned vessels due to drug trafficking
- For the east coast generally, the 2005 bleaching event was worse than the 2023 bleaching event

North:

- For snapper larvae dispersal, in the north coast the larvae dispersal is against predominant wind direction (east to west)
- In San Juan there are concerns about water quality from pumping stations and the Puerto Rico Aqueduct and Sewer Authority (PRASA)

- North coast has the highest concentration of highly migratory species
- San Juan area reefs provide ecosystem services to protect critical infrastructure
- San Juan Barrier Reef has some special conditions that make it a good candidate for restoration
    - Depth, rugosity, exposure to open ocean
- San Juan Barrier Reef also has some impact from sedimentation and some of the shallow areas are more protected
- Observation that the north coast corals were more protected from bleaching
- North coast is considered a higher priority for Reni García

Culebra:

- Low enforcement of fishing regulations in no take zones all over Culebra (and throughout all marine protected areas)
- Low of military anchoring in Culebra
- Culebra has some problems with abandoned vessels due to drug trafficking
- There is pending funding for restoration on the west side of Culebra
- For the east coast generally, the 2005 bleaching event was worse than the 2023 bleaching event
- In Culebra there is ongoing restoration for Land Based Sources of Pollution
- Culebra is dominated by ramicrusta – herbivory could be a good intervention strategy

Vieques:

- Vieques has some problems with abandoned vessels due to drug trafficking
- There is a plan to do seagrass, mangrove, and coral restoration in the Marina Reserva Natural Bahía Bioluminiscente de Vieques
- For the east coast generally, the 2005 bleaching event was worse than the 2023 bleaching event
- Vieques is dominated by ramicrusta – herbivory could be a good intervention strategy

Recommendations

Cabo Rojo Workshop

- Add vessel grounding data to matrix/map (added to the Webmap/matrix)
- Think about sargassum influence regionally

- In the next update of the plan, consider the connection of the priority sites to mangroves and seagrasses; this could provide for multi-ecosystem restoration efforts
- Add UNEP data for climate projections (added to Webmap/matrix)
- There was general agreement in the group that climate refugia, resilience and community support/current restoration should be the biggest factors in decision making
- Consider sites for restoration that have a variety of depth gradients to support different populations of corals and to provide some refugia from high water temperatures
- Consider a different weighting system and slight reorganization for the matrix. Specifically:
    - Reorganize matrix to combine "site has community support" and "presence/proximity to other support facility" into 1 column
    - Rename "Other" category as "community support" and include current restoration, planned restoration and community support columns in this category
    - 2 x weight to climate refugia, resilience, and a community support category in order to encourage building upon existing efforts and prioritizing climate refugia and ecological resilience, and give less weight to columns that are more heavily anecdotal (human impacts and logistics categories)
        - Need to decide weight of management actions and potential to improve conditions categories under this proposed weighting
- Prioritize sites that close to other ecosystems such as mangroves and seagrasses in order to implement future multi-ecosystem restoration
- In addition to areas susceptible to vessel groundings, consider shipping channels.
- The plan needs flexibility because the best available data we are using, could be far from the current reality (data date)
- Consider more frequent updates or a shorter term for the plan, considering that the best available data may not be up to date.
- Include a plan for long term reef connectivity
- Consider a tiered system for site/area selection with first and second priority sites/areas identified
- There is a need to understand what specifically is impacting the reefs before going forward with restoration

Sam Juan workshop

- Add the NMFS designated critical habitats to the WebMap
- Revisit plan every 2 years
    - Coul incorporate a working group
- Plan for bleaching in intervention strategies
- Group Cibuco Moncho Rock and El Eco into Vega Baja Area Reefs
- Group Dominos and Isla Verde into San Juan Barrier Reef
- Gallardo survived some bleaching, Stacey recommends for prioritization
- Agree that La Parguera should be prioritized for restoration

Site Prioritization Recommendations by SAG/TAC

West:

1. Tres Palmas
2. El Negro / Surrounding areas
3. Tourmaline

South:

1. San Cristobal / La Parguera area reefs
2. Maria Langa (possibility – less consensus for this area)

East:

1. Palomino Area reefs (could expand to include the whole Reserva Natural Arrecifes de la Cordillera)

North:

1. San Juan Barrier Reef (In preference of ecosystem services provided to San Juan)
1. Vega Baja are reefs (Cibuco, Moncho Rock, El Eco) to protect natural reefs that have shown hotspots for resilience and patched of acropora

Culebra

1. Canal Luis Pena / the Canal Luis Pena reserve. Suggestion to extend area to Soldado reef
2. Dakiti and surrounding areas

Vieques

1. Esperanza and surrounding areas
2. SW Comandante and surrounding areas

Restoration Action Plan Step 3 Workshop Summary: Restoration Intervention Planning

Location: San Juan Date: 7/29/2024
Location: Cabo Rojo Date: 8/8/2024

Introduction

- Stakeholders and Technical Advisors met on July 29th in San Juan and August 8th in Cabo Rojo to discuss restoration intervention planning. The primary topics of discussion were:
    - Discussion of restoration intervention options
    - Discussion of appropriate restoration interventions for each priority area
    - Prioritization of restoration interventions island wide and for priority areas
    - Discussion of site prioritization

Participants

- San Juan Workshop:
    - Core Team:
        - Michael Nemeth: NOAA
        - Aurora Justiniano: NOAA
        - Nilda Jiménez Marrero: Puerto Rico Department of Natural and Environmental Resources
        - María Vega Rodríguez: Puerto Rico Department of Natural and Environmental Resources
        - Roxana Aslan: Puerto Rico Department of Natural and Environmental Resources Fellow
    - Facilitator:
        - Lark Starkey
    - Technical and Stakeholder Advisors:
        - In-Person
            - Denise Perez: The Nature Conservancy
            - Tania Metz: The Nature Conservancy
            - Ricardo Lugo: Arrecifes Pro Ciudad
            - Sarah Elise Field: Chrystal Clear
            - Helena Antoun NOAA

        - Edwin Hernández: SAM
        - Samuel Suleiman: SAM
        - Sandra Schleier: DNER
    - Online
        - Antares Ramos-Alvarez: Sail4Reefs
        - Juan David Mucia Eslava: Coalición Restauración Ecosistemas Santurcions (CRES PR)
        - Paco López-Mujica: Arrecifes Pro Ciudad
        - Alfredo Montañez: Canal Luis Penal Natural Reserve Community Advisory Board

- Cabo Rojo Workshop
    - Facilitator:
        - Lark Starkey
    - Technical and Stakeholder Advisors
        - Daniel Matos: DNER
        - Denise Perez: The Nature Conservancy
        - Tania Metz: The Nature Conservancy
        - Stacey Williams: ISER
        - Reni García

Restoration Intervention Planning Process

After an initial orientation presentation by the facilitator (Lark Starkey), and a short prestation on a case study of restoration effectiveness from Michael Nemeth (San Juan workshop only), the group used information gathered in previous steps and recorded in the Site Selection Matrix and the Webmap to guide the discussion surrounding intervention planning for restoration. This included adding additional intervention options to the intervention list, selecting interventions appropriate for each priority area which were recorded in the area specific intervention prioritization matrix, and assigning scores and a prioritization to island wide interventions in the island wide intervention prioritization matrix.

In both the San Juan and Cabo Rojo workshop, restoration intervention options were also identified for the area specific intervention prioritization matrix but were not scored. At the San Juan workshop intervention options were identified for the priority restoration areas in the North coast, East coast, Vieques and Culebra. In the Cabo Rojo area restoration intervention options were identified for the priority restoration areas on the South Coast and West Coast.

The Core Team will take the recommendations from both workshops and use them to create specific objectives for the next 5-10 years and prioritize specific interventions island wide and for priority areas as appropriate.

Comments Received

In addition to the comments tracked in the intervention list and the area specific and island wide intervention prioritization matrix, the following general comments were received.

- We think is necessary to work with coral reefs, seagrass and mangroves as one ecosystem to help with water quality (CRES PR)
- Community is often the best first responder after events (CRES PR)
- It is important to diversify efforts, add mangroves, seagrasses and artificial reefs for fish aggregations (CRES PR)
- For San Juan area, water quality is essential, so our suggestion is to focus on PRASA and other federal agencies. Meanwhile, restoration effort should take place at 14 " - 18 " or less with rugosity average, so sedimentation and light attenuation will mitigate. San Juan barrier reef is essential site surface for larvae connectivity form Culebra and Eastern island's coral population (CRES PR)
- There is current cross species relocation of corals between east and west
- Disease management should be a priority (María Vega Rodríguez)
- It is hard to get funding for restoration effectiveness as most funding does not allow research, only tier 1 monitoring
- Look into endosymbionts in surviving corals
- FADs have shows great success in recruiting fish to restoration areas in other areas
- Water quality enforcement is needed on the North Coast
- Work on genetics should be a priority – especially understanding what corals will be resilient to climate change in the future
- In regards to sites – there was a general recommendation to have smaller areas with longer term commitment to avoid fragmentation of restoration and higher ecological impact

Recommendations

Among both San Juan and Cabo Rojo workshops, the following interventions were most heavily discussed and most often mentioned:

- Effectiveness assessments to understand which interventions are most effective
- Genetic and environmental studies to understand why certain populations of corals have survived in the face of bleaching and disease
- Interventions to increase resilience to climate change
- Water quality management – particularly in the North Coast and Vieques
- Education and outreach to prevent recreational impact on reefs – specifically signs marking restoration sites and mooring installation and maintenance

DRAFT Intervention Options to Increase Ecosystem Function and Health

The full list of intervention options identified during both workshops is as follows. The intervention options in grey were suggested as interventions that apply to all priority areas, the intervention options in blue were suggested as interventions that apply to specific priority areas only, and the intervention options in green were suggested as interventions that apply to all priority areas but may be more relevant or useful for some areas over others. The Core Team will use this list, the area specific and island wide prioritization matrix, and other recommendations/discussion during the workshops to set objectives and prioritize interventions for the Restoration Action Plan.

Table 1: Archipelago Wide and Area Specific Interventions

Intervention Category	Specific Intervention	Area Specific	Island Wide
Coral Population	Coral propagation and outplanting		X
Coral Population	Develop programs sexual reproduction		X
Coral Population	Assisted fertilization		X
Coral Population	Transplanting of cross island species (i.e. managed relocation)		X
Coral Population	Transplanting corals of opportunity (storm fragments, etc.)	X	

Intervention Category	Specific Intervention	Area Specific	Island Wide
Reef Community	Fish community interventions (Artificial reef, reef FADs, acoustic enhancement to attract fish and coral larvae, fish aquaculture for important species)		X
Reef Community	Establish nursery areas for commercially important species		X
Reef Community	Improve larvae connectivity (research on hydrodynamics and larvae connectivity, corridors, focus on larval hotspots and impacts on surrounding areas)		X
Reef Community	Demographic performance analysis and genetics		X
Reef Community	Invasive species management	X	
Reef Community	Coral predator management	X	
Reef Community	Selective breeding and propagation	X	X
Reef Community	Disease management	X	X
Reef Substrate Management	Herbivore propagation and release		X
Reef Substrate Management	Substrate addition	X	
Reef Substrate Management	Substrate stabilization	X	
Reef Substrate Management	Macroalgae management (peyssonelid management including ramicrusta, fleshy macroalgae, other nuisance algae)	X	

Intervention Category	Specific Intervention	Area Specific	Island Wide
Environmental	Identify jurisdictions that are involved in water quality management and regulations for particular areas (roadmap/protocol for enforcement)		X
Environmental	Enforcement of existing local land use regulations, to address illegal and unsustainable construction/development		X
Environmental	Design and long-term implementation of educational/capacity building programs to address root causes of water quality. Target audiences: private sector. i.e. heavy machinery operators, tour guides, community landowners adjacent to MPAs, public agencies-municipal, state and fed agencies/decision makers		X
Environmental	EPA, NOAA, municipality and AAA coordination for services, equipment lending, and water quality programs for community monitoring		X
Environmental	Frequent water quality monitoring for reef areas. (There is a current project to develop monitoring program and set criteria for WQ standards for reefs)		X
Environmental	Develop a storm water sampling program		X
Environmental	Notification around acute water quality events (pumping etc.) for a future goal of coordinating, preventing and mitigating risk to reefs. (This could be included as part of a permitting condition)		X

Intervention Category	Specific Intervention	Area Specific	Island Wide
Environmental	Assessment of sediment transport extent and impacts from ocean dumping sites on restoration areas		X
Environmental	Source tracking of turbidity in La Parguera	X	
Environmental	Seagrass restoration or management	X	
Environmental	Mangrove restoration or management	X	
Environmental	Macroalgae bed management (for CO2 uptake)	X	
Environmental	Research on water quality impacts to coral reefs	X	
Environmental	Source control - specifically identify and control specific outfalls and pipes or pollution from development activities	X	
Environmental	Implementation/enforcement of water quality management plans	X	
Reef resilience to climate change	Apply cost benefit analysis of flood modeling for storms to planning for coral reef restoration / Assessment of storm risk for coral restoration planning		X
Reef resilience to climate change	Preserve diversity of coral species (seed bank) in ex-situ nurseries		X
Reef resilience to climate change	ESA status review of declining or declined coral species		X

Intervention Category	Specific Intervention	Area Specific	Island Wide
Reef resilience to climate change	Research on coral resilience in specific areas (genetic testing, symbionts, etc. on surviving corals) - Special study to analyze surviving corals of Gallardo - Special study to analyze acropora corals in Vega Baja - Mark surviving colonies for sexual reproduction or other reproduction	X	
Reef resilience to climate change	Thermal stress acclimatization in ex-situ nurseries	X	
Reef resilience to climate change	Implementation of MPA management plans	X	
Management/ Collaborations	Expansion of citizen science monitoring programs		X
Management/ Collaborations	Comprehensive literature review of Caribbean restoration effectiveness assessments		X
Management/ Collaborations	Reassess the PRCRMP monitoring method / transects to focus on colonies rather than transects or combination of both		X
Management/ Collaborations	Integrate other agencies to support coral reef management and restoration		X
Management/ Collaborations	Marker buoys for groundings	X	
Management/ Collaborations	Debris removal	X	

Intervention Category	Specific Intervention	Area Specific	Island Wide
Management/ Collaborations	Education/outreach to prevent recreational unsustainable activities/behaviors. Specifically, signs marking restoration sites and installation of moorings	X	
Management/ Collaborations	Management plans for charter companies in East coast	X	
Management/ Collaborations	Collaborations with industry/hotel to fund restoration activities	X	
Emergency response	Create emergency response plan for bleaching		X
Emergency response	Planning for emergency response that integrates existing management plans	X	X