Percent cover of corals from photoquadrats on shallow reefs of St. John, USVI, 1992-2024

Website: https://www.bco-dmo.org/dataset/1010990
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Project
» RUI: Pattern and process in five decades of change on Caribbean reefs (St John Coral Reefs)

Contributors	Affiliation	Role
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Abstract
Percent cover of brain corals (Diploria and Pseudodiploria), pillar coral (Dendrogyra cylindrus) and Porites astreoides from photoquadrats on shallow reefs of St. John, US Virgin Islands, 1992-2024. This dataset supports the results of the publication "Encroaching rarity of Caribbean reef corals" (Edmunds et al., 2026) and is part of the study described below. Study description: Declining coral cover is causing coral colonies to occur farther apart and at lower 21 densities, thus challenging their persistence. Here we test for population declines of 22 Caribbean brain (Diploria labyrinthiformis, Pseudodiploria strigosa, and P. clivosa) and 23 pillar (Dendrogyra cylindrus) corals on the reefs of St. John, US Virgin Islands, and use 24 hectare-scale sampling with geolocation of corals to evaluate the implications of low 25 densities. Sampling over four decades using photoquadrats demonstrated declines in 26 population size, but surveys of 4.63 hectares of reef in 2024 revealed lower density 27 estimates, even though 1,323 colonies were found. Many colonies occurred closer 28 together than chance alone would predict, with mean nearest neighbor distances of 29 0.8–11.4 m for brain corals and ~74 m for pillar coral. Brain corals also formed clusters 30 in high-density hot spots. Nonetheless, ≤7% of brain corals were close enough together 31 to support 30% fertilization, and 33% of brain colonies were far enough apart that 32 fertilization was 0%. Populations of these species in St. John may be facing further 33 population declines through Allee effects, with the risk acute for Dendrogyra. These 34 results underscore the need to augment monitoring of coral reefs with spatially explicit 35 sampling of corals on a hectare scale. See the Related Datasets section for other datasets from this study.

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Coverage

Location: St. John, USVI
Spatial Extent: **N**:18.3176 **E**:-64.7211 **S**:18.3075 **W**:-64.7297
Temporal Extent: 1992 - 2023

Dataset Description

This dataset is one of several that support the results publication "Encroaching rarity of Caribbean reef corals" (Edmunds et al., 2026). See the Related Datasets section for the others.

Methods & Sampling

Methods preface:
This methodology describes all sampling and analyses for the study "Encroaching rarity of Caribbean reef corals" (Edmunds et al., 2026). The data are published as several related datasets at BCO-DMO (see the Related Datasets section), and this page contains the data from the percent cover data from the photoquadrat sampling. Methods for the other datasets are included here for context.

Overview

Surveys were conducted on the shallow (≤ 9-m depth) reefs of the US Virgin Islands that have been monitored since 1992. Six study sites are located between White Point and Cabritte Horn, where they were randomly selected in 1992. Because analyses of coral abundances (described below) revealed that some species have declined in density, additional surveys were implemented in 2024 to sample at a hectare scale. These surveys were completed on snorkel and were used to locate colonies of *Dendrogyra cylindrus*, *Diploria labyrinthiformis*, *Pseudodiploria strigosa*, and *P. clivosa,* and to geolocate their position with GPS.

Photoquadrat sampling

The sites between White Point and Cabritte Horn have been sampled annually since 1992, most frequently in July. At each site, ~ 18 photoquadrats (0.5 × 0.5 m) were placed at random locations along a permanently marked 20-m transect each year, with positions re-randomized annually and sampling continued in this format until 1999. In 2000, transects were extended to 40-m length, permanently marked at their new ends, and the sample size increased to ~ 40 photoquadrats site^{-1} (0.5 × 0.5 m). The positions of the 40 photoquadrats along the longer transects were again randomized every year. The increased transect length was motivate by additional funding and digital photography that allowed more photoquadrats to be recorded on each dive.

Photoquadrats were recorded using a camera mounted on a frame that held it perpendicular to the reef and fitted with two strobes (Nikonos SB105). Prior to 2001, photoquadrats were captured on Kodachrome 64 slide film with a Nikonos V camera, and from 2001 onwards, digital cameras were used, with resolution increased from 3.3 megapixels in 2001 to 45.7 megapixels in the most recent sampling. For the study species, increasing the transect length did not meaningfully alter the estimates of coral cover or colony density because of the scarcity of these corals. Sampling longer transects in 2000 increased the number of colonies of each species that were encountered at all six sites from 1 to 2 for *Dendrogyra* (an increase from 0.02% to 0.13% cover), from 3 to 7 for *D. labyrinthiformis* (0.10% to 0.17% cover), and from 3 to 7 for *D. strigosa* (0.03% to 0.07%) (pooled among sites, n = 214 quadrats). All images are in the public domain at: https://coralreefs.csun.edu/data/coral-image-viewer/

The slide film was digitized (4000 dpi) and analyzed for percentage cover of space holders using CPCe or CoralNET software. Cover was estimated by overlaying the images with 200 randomly positioned dots that were manually annotated to resolve three functional groups of space holders as well as coral genera. Functional groups were defined as coral, macroalgae, and “CTB”. CTB is the summed cover of crustose coralline algae, algal turf, and bare space that could not be distinguished in photoquadrats. Coral cover is reported for *Diploria* and *Dendrogyra*, with *Porites* used as a benchmark for a common coral. In 2012, the taxonomy of *Diploria* was revised to distinguish *Diploria* and *Pseudodiploria*, but these genera were not resolved in the early analyses of the photoquadrats. The historic data on cover and abundance therefore are therefore reported for “*Diploria*”, in which *Diploria* and *Pseudodiploria* are pooled, but the more recent data applies the contemporary taxonomy.

To obtain higher resolution in coral abundances, photoquadrats were also analyzed for the abundance and size of coral colonies to the lowest taxonomic level possible. The high-resolution images of small photoquadrats allowed colonies to ~ 5-mm diameter to be detected and provided a linear resolution of about ± 1 mm when ImageJ software was use to measure colony sizes. With the low density of corals and their small sizes, most colonies counted for density were within the photoquadrats. Colonies that were partially within the photoquadrats were recorded if more than half of their colony area was estimated to fall within the photoquadrat.

A separate estimate of colony abundance was obtained from sampling initiated in 1994 to quantify small corals (i.e., ≤ 4-cm diameter) at six permanently marked sites at 5–9 m depth between White Point and Cabritte Horn. The sites were selected haphazardly to provide replicate areas of the shallow habitat where small corals were common in 1994. Five sites were surveyed in 1994 and 1996–1998, 2 sites in 1995, and six sites in all other years. Small corals were counted in 40 quadrats (0.5 × 0.5 m) randomly placed along a 40-m transect at each

site, and surveys were completed mostly in July and August. The densities of *Diploria* (*Diploria* + *Pseudodiploria*) and *Porites* spp. are reported using quadrats as replicates (pooled among sites) to contrast the dynamics of one target genus of uncommon corals (*Diploria* spp.) and a benchmark genus for a common coral (*Porites* spp.), respectively.

For the sites sampled using photoquadrats, coral cover and the colony abundance were averaged by site, with trends described within years using sites as replicates. A five-year centered rolling mean was used to smooth among-year variance caused by enumerating uncommon corals in randomly placed photoquadrats; these data (mean ± SE) are plotted by year without a rolling mean. Changes in colony sizes were estimated by averaging sizes across five-year blocks using results pooled among the six sites. Five-year intervals were used because only small numbers of corals of each taxon were detected in any one year. Because the same transects were surveyed every year with randomly-located quadrats, some colonies probably were measured multiple times in different years.

Coral cover and colony densities were tested for linear relationships with time using Model I regression, with the statistical assumptions of the tests evaluated through graphical analyses of residuals. Kruskal Wallis tests were used to compare densities of small corals over time, as they did not meet parametric assumptions. Statistical procedures were completed using Systat 13 Software (Grafiti LLC, Palo Alto, CA).

Hectare-scale sampling

In 2024, sampling was implemented to enumerate corals in large areas at sites around St. John. Sampling focused on *Dendrogyra cylindrus*, *Diploria labyrinthiformis*, *Pseudodiploria strigosa*, and *P. clivosa* and was accomplished by surveying shallow reefs (≤ 8 m depth) adjacent to the shore. Surveys were conducted with paired snorkelers operating in a “lawnmower pattern” to survey the reef in non-overlapping bands perpendicular to the shore. One snorkeler located colonies, with colonies to a few centimeters in diameter detected. When found, the second snorkeler positioned a GPS (Garmin 78s) above each colony on the surface to record a waypoint (to 8 decimal places). A single waypoint was used when multiple colonies were co-located within ~ 1 m of one another. Empirical testing of the resolution of the Garmin 78s GPS in St. John revealed a mean (± SE, n = 15) resolution of 1.2 ± 0.3 m in determining the location of fixed reference points.

The waypoints for each coral colony, grouped by species, were imported into ArcGIS Pro to calculate colony densities, nearest neighbors, and to test for spatial clustering using two approaches. First, a sampling polygon was prepared from the outer waypoints at each site, and its area was calculated using the Measure Area tool. This area served as the denominator for calculating colony density (colonies hectare^{-1}). Second, dynamic density estimates were calculated using the Density function (in the GeoAnalytics desktop) with 3 m square bins within 9 m square neighborhoods to generate maximum and minimum (non-zero) densities by species and site. The binning function in ArcGIS aggregates features (colony occurrences) into discrete areas, and the neighborhood function determines densities by summing features within the neighborhood around each bin and reporting the density by bin averaged over the neighborhood. Three-meter bins were close to the accuracy of the GPS unit, and the 9-m neighborhood minimized downward bias of estimates caused by inclusion of non-reef habitat. Densities were not calculated for neighborhoods in which corals were absent.

Tests for clustering of colonies were completed two ways. First, the Average Nearest Neighbor (NN) tool (Spatial Statistics Tools) with Euclidian Distance was used to compare actual mean NN distance (meters) to the NN distance assuming a uniform distribution across the sampled area, with clustering tested using z-scores. The Generate Near Table tool (in Analysis Tools) was used to obtain the distance (in meters) from each coral to its nearest neighboring conspecific within each study area. Second, the Optimized Hot Spot tool (in the Geoprocessing desktop) was used to test for clustering using the Getis-Ord Gi* statistic with cell dimensions derived empirically from the data. The absence of a justification for an a priori selection of cell dimensions provided the rationale for this approach. Within each site, the analysis was constrained to a sampling polygon bounding the data using the Minimum Bounding Geometry (in the Geoprocessing desktop) module with convex hull geometry followed by editing of the polygon (using Reshape in Editor tool gallery) to exclude null areas (e.g., land or seagrass). The results are visualized as a raster map layer, revealing significant hot spots (clusters) and cold spots (dispersed colonies) based on confidence intervals, and summarized as the numbers of cells in which significant clustering was detected ($P < 0.05$).

Data Processing Description

The following software was used for all project data in this study:
Image J software

Systat 13 statistical software
ArcGIS pro

BCO-DMO Curation Notes

Curation Actions Performed on Data
* Diplora -> Diploria (part of the column name in data table)
* freetext in "Site Locations.docx" for site information reformatted into a data table (added as supplemental file site_locations.csv)
* Location for East Tektite in the site list changed to -64.7229 (submitter provided this correction).

Curation Actions Performed on Metadata
* Standard metadata entry and formatting of provided metadata.
* Metadata modified to describe each dataset individually (4 related datasets were described in one submission so individual titles, abstracts etc were needed). The data manager added prefaces to abstract with dataset-specific information, made descriptive titles, added a preface to methods, and shared the changes with the data submitter for their review and revision as needed.

Name corrections in metadata:
* Pseudodiplora strigosa -> Pseudodiploria strigosa (in abstract)
* D. strigosa -> P. strigosa (in methods, question sent to submitter to confirm this was the intended species).
* Diplora -> Diploria (in column description updated to match changed column name)

Geospatial bounds for dataset taken from supplemental file Site Locations.docx (added here as data table site_locations.csv. The location for East Tektite longitude was changed to -64.7229 (submitter's correction).

Known Issues [Potentially Impacting Reuse]

Suggestions:
* add unique identifiers to tables (for example, coral colony_id could be used to disambiguate individual colonies in "coral_geolocation_in_2024.csv").
* add site metadata like lat lon directly to the data table.

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Related Publications

Edmunds PJ Didden C, Frank, K, Mahoney, L (n.d.) Encroaching rarity of Caribbean reef corals (in prep) *Results*

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Related Datasets

IsRelatedTo

Edmunds, P. J. (2026) **Colony size of corals from photoquadrats on shallow reefs of St. John, USVI, 1992-2023.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-10-28 http://lod.bco-dmo.org/id/dataset/1011011 [view at BCO-DMO]
Relationship Description: Data from the same study published in the results paper "Encroaching rarity of Caribbean reef corals" Edmunds et al. (2026).

Edmunds, P. J. (2026) **Density of corals from photoquadrats on shallow reefs of St. John, USVI, 1992-2023.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-10-28 http://lod.bco-dmo.org/id/dataset/1011003 [view at BCO-DMO]
Relationship Description: Data from the same study published in the results paper "Encroaching rarity of Caribbean reef corals" Edmunds et al. (2026).

Edmunds, P. J. (2026) **Density of small corals from quadrats on shallow reefs of St. John, USVI,**

1994-2024. Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-10-28 http://lod.bco-dmo.org/id/dataset/1010997 [view at BCO-DMO]
Relationship Description: Data from the same study published in the results paper "Encroaching rarity of Caribbean reef corals" Edmunds et al. (2026).

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Parameters

Parameters for this dataset have not yet been identified

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Instruments

Dataset-specific Instrument Name	Garmin 88s GPS
Generic Instrument Name	Global Positioning System Receiver
Generic Instrument Description	The Global Positioning System (GPS) is a U.S. space-based radionavigation system that provides reliable positioning, navigation, and timing services to civilian users on a continuous worldwide basis. The U.S. Air Force develops, maintains, and operates the space and control segments of the NAVSTAR GPS transmitter system. Ships use a variety of receivers (e.g. Trimble and Ashtech) to interpret the GPS signal and determine accurate latitude and longitude.

Dataset-specific Instrument Name	Nikonos V and Nikon D850
Generic Instrument Name	Underwater Camera
Dataset-specific Description	Nikonos V camera and twin SB105 strobes Nikon D850 DLSR and twin SB105 strobes
Generic Instrument Description	All types of photographic equipment that may be deployed underwater including stills, video, film and digital systems.

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Project Information

RUI: Pattern and process in five decades of change on Caribbean reefs (St John Coral Reefs)

Website: http://coralreefs.csun.edu/

Coverage: United States Virgin Islands, St. John: 18.318, -64.7253

This project has been supported by continuing grants:
OCE-2019992 "RUI: Pattern and process in four decades of change on Caribbean reefs" (2020-2026)
OCE-2546549 "RUI Pattern and process in five decades of change on Caribbean reefs" (2026-2029)

NSF award OCE-2546549 project summary:

Overview

This proposal focuses on American coral reefs in the United States Virgin Islands, most of which are trending towards persistent low coral colony abundances. This is a conspicuous aspect of the coral reef crisis, and while much is known of the disturbances causing corals to die, little is known about the ecological implications of low coral abundance. This project leverages four decades of research in St. John by using multiple sites to test five hypotheses addressing mechanisms preventing depleted coral populations from increasing in size, and they are developed in a hierarchical framework to advance basic ecology, and enhance understanding of coral reefs and the ecological processes structuring marine communities in the Anthropocene. The project is mensurative because it is conducted in an MPA, but its scope is broadened through: (a) analyses of algal symbionts (Symbiodiniaceae) with co PI, Cunning (Shedd Aquarium), (b) by extending the coral reef time-series from 40 to 43 yrs, and (c) applying wavelet analyses to the time-series. Three years of funding will support 1 mo/y of fieldwork, 11 mo/y of analysis, QA/QC, graduate training, a one year postdoc, outreach, and manuscript preparation. This RUI proposal is targeting the OCE call NSF PD 23-1650.

Intellectual merit

The intellectual merits lie in the *hypotheses* focused on the mechanisms leading to persistent low abundance coral communities. This project is designed around a conceptual model that preserves the integrity of a 43 yr time series and tests 5 integrated hypotheses addressing four science needs: (1) advancing basic ecology, (2) leveraging of existing data to realize emergent properties, (3) serving data to end users, and (4) outreach benefitting American stake holders. Over three years, fieldwork and analyses will address: H_1 Coral reef community structure is converging to a stable low coral abundance state; $\mathbf{H_2}$. The impact of disturbances is mediated by the spatial structuring of community dynamics, and the expression of portfolio effects**;** $\mathbf{H_3}$ Intensification of the coral recruitment 'bottleneck' and its gradual transition to settlement failure; $\mathbf{H_4}$ Declining populations sizes of echinoids limit the formation of grazing halos in which corals settle; $\mathbf{H_5}$ Persistence of low abundance coral communities is favored by changes in the symbiodiniacaea complement.

Broader impacts

This project will advance discoverability of time-series data in the public domain, student mentoring and experiential fieldwork, research on the causes of changes affecting marine communities, and in-person outreach at schools in California an Illinois, the University of the Virgin Islands, and the Friends of the VI National Park. Open access to high resolution data quantifying coral reefs over five decades is a critical community need to which this project will respond by placing in > 14,000 photoquadrats in the public domain (1987-present). Up to five graduate (MS) students will be mentored in marine science through fieldwork and lab analysis, and one REU students will be supported in a graduate mentoring framework. At middle schools, an "aquarium library" program will place marine animals in classrooms for 2–3 weeks in collaboration with the non-profit organization, 'Underwater Zoo'. At high schools, 'marine biology clubs' will address project themes, provide research opportunities, and entrain teachers in field trips. In the field, teachers will conduct research leading to publications and will lead outreach activities with children in the junior ranger program administered by the Friends of the VI National Park. The efficacy of outreach tasks will be assessed through pre/post surveys and questionnaires administered using Google forms by teachers at partner schools. The results of assessment will be used to tune project deliverable to better meet the needs of the outreach audience.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

Related Projects:

- Affiliated with MCR-LTER - https://www.bco-dmo.org/project/2222
- Serves as a new project that builds on NSF DEB-1350146 - RUI-LTREB Renewal: Three decades of coral reef community dynamics in St. John, USVI: 2014-2019 - https://www.bco-dmo.org/project/734983
- Overlaps with OCE 17-56678 (which focuses on soft corals with H. Lasker) - Collaborative Research: Pattern and process in the abundance and recruitment of Caribbean octocorals - https://www.bco-dmo.org/project/752508
- LTREB Long-term coral reef community dynamics in St. John, USVI: 1987-2019 - https://www.bco-dmo.org/project/2272
- RUI: Pattern and process in four decades of change on Caribbean reefs - https://www.bco-dmo.org/project/835192
- RAPID: Hurricane Irma: Effects of repeated severe storms on shallow Caribbean reefs and their changing ecological resilience - https://www.bco-dmo.org/project/722163

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2019992
NSF Division of Ocean Sciences (NSF OCE)	OCE-2546549

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