# Data Dictionary for coral reef restoration surveys

The table below describes the attributes (data columns) for datasets describing reef site information, benthic composition, bioeroder abundance, carbonate budgets, and topographic complexity of coral reefs in the Lower Florida Keys. Reef surveys were conducted in areas of each reef with and without corals outplanted by Mote Marine Laboratory’s coral restoration program (<https://mote.org/research/program/coral-reef-restoration/>).

## Coral\_reef\_restoration\_surveys

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| Attribute \_Label | Attribute\_Definition |
| Site | The names of the reef sites where surveys were conducted. |
| Subsite | Unique identifier for the different areas of each reef surveyed. Most subsite names are based on the subsite identifiers assigned to different areas where corals were outplanted by Mote Marine Laboratory researchers and have the following format: Site abbreviation\_Mote subsite identifier. |
| Latitude | The latitude of the subsite, in decimal degrees. Coordinates were collected in the World Geodetic System of 1984 (WGS 84) coordinate system. |
| Longitude | The longitude of the subsite, in decimal degrees. Coordinates were collected in the World Geodetic System of 1984 (WGS 84) coordinate system. |
| Date\_outplanted | The date that corals were outplanted at each subsite by Mote Marine Laboratory researchers. |
| Year\_outplanted | The year that corals were outplanted at each subsite by Mote Marine Laboratory researchers. |
| Number\_of\_outplants | The number of corals that were outplanted at each subsite by Mote Marine Laboratory researchers. |
| Survey\_year | The year (either 2022 or 2023) that the reef surveys were conducted at each site. |
| Survey\_date | The date, Month/Day/Year, that the reef surveys were conducted at each site. |
| Transect\_ID | A unique identifier for each transect surveyed at each subsite including photographic transects used for structure-from-motion models and bioeroder surveys. Note that the photographic, sponge, and urchin surveys were conducted along the same 10-meter long transects, however, the parrotfish surveys were conducted along separate, longer (25-meter) transects. |
| Image\_name | A unique identifier for each of 10, 1-square-meter benthic images analyzed to quantify the percent composition of the benthos along each transect. The images were extracted from 10x1 meter orthomosaics of the reefs generated from the photographic surveys using structure-from-motion. The image name identifiers typically have the following format: Survey year\_Site abbreviation\_Subsite name\_Transect ID.jpg. |
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| Water\_depth\_ft | The water depth in feet (ft) where each transect survey was conducted as recorded from the underwater computers of researchers in the field. Note that there are small variations in the exact depths recorded by different researchers for each transect based on where along the transect the depth was recorded and differences in calibration/precision of the computers. |
| Restored? | Indicator of whether a transect was conducted in an area of the reef where corals were outplanted (“Y”=yes) or not (“N”=no). |
| Survey\_area\_m2 | The area of the reef surveyed for a given transect in square meters (m2). For bioeroder surveys, this is based on the size of the belt transect (parrotfish=25x4 meters, sponges=10x1 meters, urchins=10x2). For the topographic complexity dataset, this is the measured area of the structure-from-motion derived digital surface model of the transect. |
| Taxon | The taxon recorded in a reef survey. For the benthic surveys, the taxon list is based on the built in coral and other benthos labels provided by the online program CoralNet (<https://coralnet.ucsd.edu/>). No Data was used when a point fell on a missing portion of the transect in the orthomosaic (i.e., a hole or gap in the model). For the bioeroding parrotfish surveys, occurrences of the following taxa were recorded: *Sparisoma viride*, *Sp. aurofrenatum*, *Sp. rubripinne*, *Sp. chrysopterum*, *Scarus vetula*, *Sc. taeniopterus*, *Sc. iseri*, *Sc. guacamaia*, *Sc. coeruleus*, and *Sc. coelestinus*. For the bioeroding sponge surveys: *Cliona aprica, C. caribbaea, C. tenuis, C. varians, C. deletrix,* and *Siphonodictyon coralliphagum*. For the bioeroding urchin surveys: *Diadema antillarum, Echinometra lucunter, Ec. viridis,* and *Eucidaris tribuloides*. For the bioeroder surveys, NAs indicate that none of a given functional group of bioeroders was observed along a given transect and “Other” indicates a potential bioeroder in a given functional group that is not included in the list above. |
| Phase | The life phase of bioeroding parrotfish (IP=initial phase, TP=terminal phase, and JU=juvenile). NAs indicate that none of a given functional group of bioeroders was observed along a given transect. |
| Size | The size of bioeroding parrotfish or urchins observed in the surveys. Parrotfish were recoded within 10-centimeter size bins for fork length (0\_9, 10\_19, 20\_29, 30\_39, 40\_49, and 50\_59). NAs indicate that none of a given functional group of bioeroders was observed along a given transect. Urchins were recorded within 20-milimeter size bins of test diameter (0-20 mm, 21-40 mm, 41-60 mm, 61-80 mm, AND 81-100 mm), recorded in the dataset as the median value of the bin (10, 30, 50, 70, or 90). |
| Percent\_cover | The percent cover of corals and other benthos based on point count analysis of benthic images extracted from reef transects in the online program CoralNet (<https://coralnet.ucsd.edu/>). |
| Count | The number of bioeroding parrotfish and urchins in each size class and, for parrotfish, for each life phase observed along each reef transect. NAs indicate that none of a given functional group of bioeroders was observed along a given transect. |
| Sponge\_area | The surface area (in square meters) of bioeroding sponges observed along each reef transect. |
| Pmean | The average (mean) estimated gross carbonate production (P) in kilograms per meter square per year for areas of each reef site with and without coral outplants. Gross carbonate production for each transect was estimated by multiplying the percent cover of each reef calcifier along the transect by average area-normalized taxon-specific calcification rates provided in Courtney and others (2024). The transect-level estimates were averaged to generate the site-level average. NAs indicate that none of a given functional group of bioeroders was observed along a given transect. |
| Pmin | The minimum (min) estimated gross carbonate production (P) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the mean minus one standard error of transect-level estimates, which were calculated as described above. |
| Pmax | The maximum (max) estimated gross carbonate production (P) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the mean plus one standard error of transect-level estimates, which were calculated as described above. |
| SEmean | The average (mean) estimated bioerosion by sponges (SE) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Sponge bioerosion for each transect was estimated by multiplying the recorded surface area of each taxon by species-specific bioerosion rates, dividing that value by the total survey area, and summing those values across taxa following Perry and Lange (2019). The transect-level estimates were averaged to generate the site-level average. |
| SEmin | The minimum (min) estimated bioerosion by sponges (SE) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the mean minus one standard error of transect-level estimates, which were calculated as described above. |
| SEmax | The maximum (max) estimated bioerosion by sponges (SE) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the mean plus one standard error of transect-level estimates, which were calculated as described above. |
| UEmean | The average (mean) estimated bioerosion by urchins (UE) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Bioerosion rates of individual urchins were calculated using the taxon- and size-specific equations suggested by Perry and Lange (2019). Those values were summed for each transect and the transect-level estimates were averaged to generate the site-level average. |
| UEmin | The minimum (min) estimated bioerosion by urchins (UE) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the mean minus one standard error of transect-level estimates, which were calculated as described above. |
| UEmax | The maximum (max) estimated bioerosion by urchins (UE) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the mean plus one standard error of transect-level estimates, which were calculated as described above. |
| MEmean | The average (mean) estimated microbioerosion (ME) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Microbioerosion for each transect was estimated by multiplying percent cover of multiplying the percent cover of consolidated, non-calcifying reef substrate (from the point-count analysis) by generalized the western Atlantic mean microbioerosion rate of 0.24 kilograms per meter squared per year (Perry and Lange 2019). The transect-level estimates were averaged to generate the site-level average. |
| MEmin | The minimum (min) estimated microbioerosion (ME) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the mean minus one standard error of transect-level estimates, which were calculated as described above. |
| MEmax | The maximum (max) estimated microbioerosion (ME) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the mean plus one standard error of transect-level estimates, which were calculated as described above. |
| PEmean | The average (mean) estimated bioerosion by parrotfish (PE) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Parrotfish bioerosion for each transect was estimated by multiplying by multiplying the abundances of parrotfishes by the estimated species- and size-specific bioerosion rates provided in Perry and Lange (2019) and summing those values across taxa. The transect-level estimates were averaged to generate the site-level average. |
| PEmin | The minimum (min) estimated bioerosion by parrotfish (PE) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the mean minus one standard error of transect-level estimates, which were calculated as described above. |
| PEmax | The maximum (max) estimated bioerosion by parrotfish (PE) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the mean plus one standard error of transect-level estimates, which were calculated as described above. |
| MeanErosion | The estimated average (mean) total bioerosion in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the sum of SEmean, UEmean, MEmean, and PEmean. |
| MinErosion | The estimated minimum (min) total bioerosion in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the sum of SEmin, UEmin, MEmin, and PEmin. |
| MaxErosion | The estimated maximum (max) total bioerosion in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated as the sum of SEmax, UEmax, MEmax, and PEmax. |
| Gmean | The estimated average (mean) net carbonate production (G) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated by subtracting MeanErosion from Pmean. |
| Gmin | The estimated minimum (min) net carbonate production (G) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated by subtracting SEmin, UEmin, MEmin, and PEmin from Pmin. |
| Gmax | The estimated maximum (max) net carbonate production (G) in kilograms per meter square per year (kg m-2 y-1) for areas of each reef site with and without coral outplants. Calculated by subtracting SEmax, UEmax, MEmax, and PEmax from Pmax. |
| Amean | The estimated average (mean) reef-accretion potential (A) in millimeters per year (mm y-1) for areas of each reef site with and without coral outplants. Calculated by dividing Gmean by the product of the generalized estimate of calcium carbonate density of 2.9 grams per centimeter cubed and one minus the average reef framework porosity in the Florida Keys of ~0.675 (Toth and others, 2018). |
| Amin | The estimated minimum (min) reef-accretion potential (A) in millimeters per year (mm y-1) for areas of each reef site with and without coral outplants. Calculated by dividing Gmin by the product of the generalized estimate of calcium carbonate density of 2.9 grams per centimeter cubed and one minus the average reef framework porosity in the Florida Keys of ~0.675 (Toth and others, 2018). |
| Amax | The estimated maximum (max) reef-accretion potential (A) in millimeters per year (mm y-1) for areas of each reef site with and without coral outplants. Calculated by dividing Gmax by the product of the generalized estimate of calcium carbonate density of 2.9 grams per centimeter cubed and one minus the average reef framework porosity in the Florida Keys of ~0.675 (Toth and others, 2018). |
| Filter | The name of the point cloud classification filter applied to three-dimensional (3D) point cloud data used to build digital elevation models for terrain analysis: confidence, canopy, outplant, and outplantandcanopy. “Confidence” filter excludes low-confidence point noise (confidence <2 in the program Agisoft Metashape) from models. “Canopy” filter excludes low-confidence point noise and points identified as soft canopy (gorgonians and branching sponges) from models. “Outplant” filter excludes low-confidence point noise and points identified as *Acropora cervicornis* ­restoration outplants from models. “Outplantandcanopy” filter excludes low-confidence point noise, outplants, and canopy from models. |
| orig\_s\_area | The 3D surface area of the full transect area, in square meters. |
| full\_area\_rugosity | The ratio of the 3D surface area to the two-dimensional (2D) planar surface area (2D) of the transect. Calculated by dividing the 3D surface area by the planar 2D area. |
| max\_h | The maximum (max) elevation or height (h) within the transect, in meters. |
| min\_h | The minimum (min) elevation or height (h) within the transect, in meters. |
| elev\_range | The range of the elevation (elev) of the transect, in meters. Calculating as the difference between maximum elevation of the transect and minimum elevation. |
| elev\_mean | The mean elevation (elev) of the transect, in meters. Calculated by dividing the sum of all the elevation values divided by the number of elevation values. |
| elev\_sd | The standard deviation (sd) of elevation (elev) values from the mean, in meters. Calculated by taking the square root of the sum of squared differences from the mean divided by the total sample size. |
| stand\_mean\_elev | The mean reef elevation (elev) standardized (stand) to the minimum elevation of the transect, in meters. Calculated by taking the mean elevation minus the minimum elevation. |
| sapa\_mean | Surface Area to Planar Area (SAPA) is the mean of the arc-chord corrected (Du Preez 2015) surface area to planar area ratio for each 5 x 5 centimeter focal window. “sapa\_mean” is the estimated mean of the 5 x 5 centimeter cell values within the transect area. Values range from zero (smooth) to infinity (rough). |
| sapa\_sd | The standard deviation (sd) of surface area to planar area (sapa) values from the mean for the transect. Calculated by taking the square root of the variance in sapa values. |
| vrm\_mean | Vector Ruggedness Measure (VRM) is the dispersion of unit vectors normal to the terrain surface in meters calculated for each 5 x 5 centimeter focal cell. “vrm\_mean” is the estimated mean of the 5 x 5 centimeter cell values within the transect area. Values range from zero (smooth) to one (rough). |
| vrm\_sd | The standard deviation (sd) of vector ruggedness measure (vrm) values from the mean. Calculated by taking the square root of the variance in vrm values. |
| rie\_mean | Roughness Index of Elevation (RIE) is the local standard deviation of the residual topography surface in a 5 x 5 centimeter focal window. The residual topography surface is calculated as the digital elevation of the trensect values minus the focal mean of the digital elevations. This measure uses a raster of residual topography instead of a fitted plane. “rie\_mean” is the estimated mean of the RIE values calculate for the cells within the transect area. |
| rie\_sd | The standard deviation (sd) of roughness index elevation (rie) values from the mean. Calculated by taking the square root of the variance in rie values. |
| asd\_mean | Adjusted Standard Deviation (ASD) is the local standard deviation of the elevation values in a 5 x 5 centimeter window after removing the influence of slope by fitting a plane to the 5 x 5 centimeter window using ordinary least squares and extracting the residuals. “asd\_mean” is the estimated mean of the ASD values calculated for the cells within the transect area. Values range from zero (smooth) to infinity (rough). |
| asd\_sd | The standard deviation (sd) of adjusted standard deviation (asd) values from the mean. Calculated by taking the square root of the variance in asd values. |

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