Summary data from the Heatwaves and Coral-Recovery Database (HeatCRD) covering global coral reef sites from 1977-2020

Website: https://www.bco-dmo.org/dataset/933334
Data Type: Other Field Results, Synthesis
Version: 1
Version Date: 2024-08-15

Project
» Thermal stress and differential recovery of coral reefs (Coral Recovery)

Contributors	Affiliation	Role
van Woesik, Robert	Florida Institute of Technology (FIT)	Principal Investigator
Kratochwill, Chelsey	Florida Institute of Technology (FIT)	Data Manager
Mickle, Audrey	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
This dataset is a summary table of the Heatwaves and Coral-Recovery Database (HeatCRD) introduced in van Woesik and Kratochwill (2024). The HeatCRD is the most comprehensive reference on coral recovery following marine heatwaves and other disturbances, encompassing 29,205 data records spanning 44 years from 12,266 sites, 83 countries, and 160 data sources. These data provide essential information to coral-reef scientists and managers to best guide coral-reef conservation efforts at both local and regional scales. The dataset includes metadata for coral reef sampling events, such as site descriptions, geographical coordinates, depth, distance to shore, exposure, turbidity, coral cover percentages, MPA descriptions, temperature measurements, windspeed, and thermal stress indicators over 23 years. See van Woesik and Kratochwill (2024) https://doi.org/10.1038/s41597-024-03221-3 for more information.

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Coverage

Location: Global coral reefs
Spatial Extent: **N**:34.803 **E**:179.9644722 **S**:-30.2625 **W**:-179.97433333333
Temporal Extent: 1977-03-15 - 2020-08-15

Methods & Sampling

Data were collected from 160 data sources including data from established monitoring programs and new data extracted from the literature. To date, we have coral data for 12,266 sites, from 83 countries, from 1977 to 2020. Coral-cover data were extracted from the primary literature using WebPlotDigitizer version 4.6 (Marin, 2017). Sampling points that fell on land or were > 1 km from any coral reef were removed. If sites were not named or given explicit coordinates, the coordinates were estimated and a comment was added to the data table. The coordinates were entered into Google Earth and the location names, distance to land in meters, and exposure were determined and recorded for each site. Exposure to waves was based on a site's potential exposure to predominant winds, swell, and fetch (i.e., the extent of open ocean). Mean turbidity (Kd490) was added for each site (Sully and Woesik, (2020)). The Marine Ecoregions of the World (MEOW) shapefiles (Spalding et al., 2007) and IUCN's (International Union for Conservation of Nature) World Database on Protected Areas (2022) were used to determine in which marine realm and protected area each site was located. Veron et al. (2015)'s ecoregions shapefiles were used to determine the ecoregion of each site. Data on the types of reef habitats were extracted from the Allen Coral Atlas (Lyons et al., 2022). The Coral Reef Temperature Anomaly Database (CoRTAD version 6; Saha et al., 2018), which is a collection of sea surface temperature variables, was used to extract temperature metrics for each sampling event (Sully et al., 2019). CoRTAD values were only extracted for a sampling event if sampled data had a clearly defined month and year — where sampling events were missing a date, the 15th day of the month was used. For any data given as a range (i.e., depth or date), the midpoint was taken and a comment was added to the HeatCRD.

See van Woesik and Kratochwill (2024) https://doi.org/10.1038/s41597-024-03221-3 for more information.

Data Processing Description

WebPlotDigitizer (Marin, 2017; version 4.6) was used to extract coral-cover data from primary literature. Data figures from each publication were uploaded as image files, axes were calibrated based on the chart type, and points added to extract the coral cover values at each location. Those values were then added to the database.

QGIS (QGIS, 2024; version 3.26.3) was used to extract habitat, MPA, ecoregion, and realm. Habitat shapefiles were downloaded from Allen Coral Atlas (Lyons at al. 2022), Ecoregion shapefiles from Veron et al. (2015), Realm shapefiles from Marine Ecoregions of the World (MEOW) (Spalding et al., 2007). A csv with the coordinates of each site was uploaded to QGIS along with the aforementioned shapefiles. I ensured the coordinate reference systems were accurate then used the NNJoin (havatv, 2019; version 3.1.3) plugin to extract the shapefile values that correspond to each site coordinate. The NNJoin plugin gives a distance value for any points that fell outside of a polygon. These values were then added to the database.

R (R Core Team, 2023; version 4.3.0) was used to extract CoRTAD and turbidity. R code (Sully, 2019a) was used to extract the turbidity data for each site as a raster. R code (Sully, 2019b) was used to extract the CoRTAD environmental data for each sampling event.

BCO-DMO Processing Description

-Extract "Sources_tbl" table from published Access database (van Woesik & Kratochwill, 2024) into "sources_without_errors.xlsx".
-Load "Heatwaves and Coral Recovery Database.xlsx" (as primary dataset), "Sources DOIs.csv", and "sources_without_errors.xlsx" into the BCO-DMO system.
-Join "Sources DOIs.csv" and "sources_without_errors.xlsx" on citation field.
-Find and replace special characters and non-standard spaces in all files.
-Find and replace garbled chars in all files.
-Add combined date field to primary dataset in yyyy-mm-dd format for rows with exact date.
-Round numbers to the 100th place in primary dataset.
-Publish final files as "933334_v1_heatwave_coral_recovery_data.csv" and "933334_supplement_heatwave_coral_recovery_data_sources".

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Data Files

File
933334_v1_heatwave_coral_recovery_data.csv (Comma Separated Values (.csv), 16.44 MB) MD5:d7fc2da1a834f2d8c8349d8093e30902 Primary data file for dataset ID 933334, version 1

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Supplemental Files

File
933334_supplement_heatwave_coral_recovery_data_sources.csv (Comma Separated Values (.csv), 26.72 KB) MD5:87e80194a395b66abc30bbb7c1db74a7 Supplemental publication source data for dataset ID 933334, version 1 Source_ID, Unique id in Sources_tbl table in the published Access database, unitless DOI, DOI associated with a publication, unitless Citation, Inline citation format used as a reference identifier in primary dataset, unitless Publication_Title, Title of publication, unitless Journal_Name, Title of publication journal, unitless Publication_Year, Year of publication, unitless

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Related Publications

Lyons, M, Larsen, K, & Skone, M. (2022). *CoralMapping/AllenCoralAtlas: DOI for paper at ~ v1.3* (Version v1.3) [Computer software]. Zenodo. doi:10.5281/zenodo.3833242
Software

Marin, F., Rohatgi, A., & Charlot, S. (2017). *WebPlotDigitizer, a polyvalent and free software to extract spectra from old astronomical publications: application to ultraviolet spectropolarimetry* (Version 4.6). arXiv. doi:10.48550/ARXIV.1708.02025
Software

QGIS, Q. G. (2024). Development Team.(2014). Quantum GIS Geographic Information System. Open Source Geospatial Foundation Project.
Software

R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/
Software

Spalding, M. D., Fox, H. E., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., Halpern, B. S., Jorge, M. A., Lombana, A., Lourie, S. A., Martin, K. D., McManus, E., Molnar, J., Recchia, C. A., & Robertson, J. (2007). Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. BioScience, 57(7), 573–583. doi:10.1641/B570707
Methods

Sully, S. (2019). Coral-bleaching-a-global-analysis-of-the-past-two-decades (Commit 0c605b3) [Software]. Github. https://github.com/InstituteForGlobalEcology/Coral-bleaching-a-global-analysis-of-the-past-two-decades/tree/0c605b3290810a6c1de7616c9a25153e1aaca3dc
Software

Sully, S. (2019). Turbid-reefs-moderate-coral-bleaching-under-climate-related-temperature-stress (commit 1d2c300d17ef13d68b22f21c4ea5b2d4f7f77f20 on Nov 30th, 2020). [Software]. Github. https://github.com/InstituteForGlobalEcology/Turbid-reefs-moderate-coral-bleaching-under-climate-related-temperature-stress/tree/1d2c300d17ef13d68b22f21c4ea5b2d4f7f77f20
Software

Sully, S., & Woesik, R. (2020). Turbid reefs moderate coral bleaching under climate-related temperature stress. Global Change Biology, 26(3), 1367–1373. Portico. doi:10.1111/gcb.14948
Methods

Sully, S., Burkepile, D. E., Donovan, M. K., Hodgson, G., & van Woesik, R. (2019). A global analysis of coral bleaching over the past two decades. Nature Communications, 10(1). doi:10.1038/s41467-019-09238-2
Methods

Veron, J., Stafford-Smith, M., DeVantier, L., & Turak, E. (2015). Overview of distribution patterns of

zooxanthellate Scleractinia. Frontiers in Marine Science, 1. doi:10.3389/fmars.2014.00081
Methods

havatv (2019). Plugin for QGIS NNJoin 3.1.3. https://plugins.qgis.org/plugins/NNJoin/version/3.1.3/
Software

van Woesik, R., & Kratochwill, C. (2024). A global database on coral recovery following marine heatwaves. Scientific Data, 11(1). doi:10.1038/s41597-024-03221-3
Results

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Related Datasets

Different Version

van Woesik, R., & Kratochwill, C. (2024). A global database on coral recovery following marine heatwaves. Figshare. https://doi.org/10.6084/M9.FIGSHARE.C.6956478.V1
https://doi.org/10.6084/m9.figshare.c.6956478.v1

HasPart

Saha, K., Zhao, X., Zhang, H.-M., Casey, K. S., Zhang, D., Zhang, Y., Baker-Yeboah, S., Relph, J. M., Krishnan, A., & Ryan, T. (2018). *The Coral Reef Temperature Anomaly Database (CoRTAD) Version 6 - Global, 4 km Sea Surface Temperature and Related Thermal Stress Metrics for 1982 to 2019* [Data set]. NOAA National Centers for Environmental Information. doi:10.25921/ffw7-cs39

UNEP-WCMC and IUCN. *Protected Planet: The World Database on Protected Areas (WDPA).* Cambridge, UK: UNEP-WCMC and IUCN. Available at: https://www.protectedplanet.net (2022).

References

NASA Ocean Biology Processing Group. (2022). *Aqua MODIS Level 3 Mapped Downwelling Diffuse Attenuation Coefficient Data, Version R2022.0* [Data set]. NASA Ocean Biology Distributed Active Archive Center. https://doi.org/10.5067/AQUA/MODIS/L3M/KD/2022

Saha, K., Zhao, X., Zhang, H.-M., Casey, K. S., Zhang, D., Zhang, Y., Baker-Yeboah, S., Relph, J. M., Krishnan, A., & Ryan, T. (2018). *The Coral Reef Temperature Anomaly Database (CoRTAD) Version 6 - Global, 4 km Sea Surface Temperature and Related Thermal Stress Metrics for 1982 to 2019* [Data set]. NOAA National Centers for Environmental Information. doi:10.25921/ffw7-cs39

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Parameters

Parameter	Description	Units
Site_ID	Unique identifier for each site.	unitless
Sample_ID	Unique identifier for each sampling event.	unitless
Latitude_Degrees	Latitude coordinates in decimal degrees.	decimal degree
Longitude_Degrees	Longitude coordinates in decimal degrees.	decimal degree

Ocean_Name	Ocean where sampling took place.	unitless
Realm_Name	Marine realm where sampling took place.	unitless
Ecoregion_Name	Ecoregion where sampling took place.	unitless
Ecoregion_distance	Distance in degrees of the site from the nearest ecoregion polygon.	degrees
Country_Name	The country where sampling took place.	unitless
State_Island_Province_Name	The state, province, or island where sampling took place.	unitless
Location_Name	Site or reef where sampling took place.	unitless
Site_Name	Accepted name of the site or the name given by the team that sampled the reef.	unitless
Habitat_Type	Habitat type where sampling took place.	unitless
Habitat_Distance	Distance in degrees the site coordinate fell from the nearest habitat polygon.	degrees
Date_Day	Day of month of the sampling event.	unitless
Date_Month	Month of the sampling event.	unitless
Date_Year	Year of the sampling event.	unitless
Date	Date of sampling event, YYYY-mm-dd	unitless
Depth	Depth (m) of the sampling site.	meters (m)
Distance_to_shore	Distance (m) of the sampling site from the nearest land.	meters (m)
Exposure	Site was considered exposed if it had > 20 km of fetch, if there were strong seasonal winds, or if the site faced the prevailing winds. Otherwise, the site was considered sheltered.	unitless

Turbidity	Mean 490kd with a buffer of 10 km.	reciprocal meters (m-1)
Citation	Original source of the data.	unitless
Site_Comments	Comments on any issues with the site or additional information.	unitless
Sample_Comments	Comments on any issue or additional information about the sampling event.	unitless
Percent_Hard_Coral_Cover	Percentage live coral cover.	percent
Percent_Macroalgal_Cover	Percentage of macroalgal cover.	percent
Cover_Comments	Comments on any issue or additional information about the cover.	unitless
MPA_Name	Name of the protected area.	unitless
Designation	Designation of the protected area.	unitless
Designation_Type	Category of the protected area.	unitless
IUCN_Category	IUCN management category.	unitless
Marine	Describes if a protected area is totally or partially within the marine habitat. 0 (predominantly or entirely terrestrial), 1 (Coastal: marine and terrestrial), and 2 (predominantly or entirely marine). The value '1' is only used for polygons.	unitless
Reported_Marine_Area	Area of protected area in marine habitat in km2.	km2
No_Take	Whether the taking of resources is prohibited.	unitless
No_Take_Area	Area of no take in km2.	km2
Status	Status of the protected area.	unitless
Status_Year	Year the status of the protected area was effective.	year

Governance_Type	Organization/government in charge of the protected area.	unitless
Ownership_Type	Organization/government that legally 'owns' a protected area.	unitless
Management_Authority	Group that manages the protected area.	unitless
MPA_Distance	Distance of site to nearest MPA polygon in degrees.	degrees
ClimSST	CoRTAD. [Climatological Sea-Surface Temperature (SST)] based on weekly SSTs for the study time frame, created using a harmonics approach in degrees Celsius.	degrees Celsius
Temperature_Kelvin	CoRTAD. SST in Kelvin.	Kelvin
Temperature_Mean	CoRTAD. Mean SST in degrees Celsius.	degrees Celsius
Temperature_Minimum	CoRTAD. Minimum SST in degrees Celsius.	degrees Celsius
Temperature_Maximum	CoRTAD. Maximum SST in degrees Celsius.	degrees Celsius
Temperature_Kelvin_Standard_Deviation	CoRTAD. The standard deviation of SST in Kelvin.	Kelvin
Windspeed	CoRTAD. Weekly-averaged 10 m wind speed time series from 1982–2012. Units are in meters per hour.	meters per hour
SSTA	CoRTAD. (Sea-Surface Temperature Anomaly) weekly SST minus weekly climatological SST in degrees Celsius.	degrees Celsius
SSTA_Standard_Deviation	CoRTAD. The Standard Deviation of weekly SSTA in degrees Celsius over the entire period.	degrees Celsius
SSTA_Mean	CoRTAD. The mean SSTA in degrees Celsius over the entire period.	degrees Celsius
SSTA_Minimum	CoRTAD. The minimum SSTA is in degrees Celsius over the entire period.	degrees Celsius
SSTA_Maximum	CoRTAD. The maximum SSTA is in degrees Celsius over the entire period.	degrees Celsius

SSTA_Frequency	CoRTAD. (Sea Surface Temperature Anomaly Frequency) Number of times over the previous 52 weeks that SSTA > = 1 degree Celsius.	SSTA per time period
SSTA_Frequency_Standard_Deviation	CoRTAD. The standard deviation of SSTA Frequency in degrees Celsius over the entire period of 23 years.	SSTA per time period
SSTA_FrequencyMax	CoRTAD. The maximum SSTA Frequency is in degrees Celsius over the entire period.	SSTA per time period
SSTA_FrequencyMean	CoRTAD. The mean SSTA Frequency is in degrees Celsius over the entire period of 23 years.	SSTA per time period
SSTA_DHW	CoRTAD. (Sea Surface Temperature Degree Heating Weeks) the sum of the previous 12 weeks when SSTA > = 1 degree Celsius.	weeks
SSTA_DHW_Standard_Deviation	CoRTAD. The standard deviation SSTA DHW in degrees Celsius over the entire period.	weeks
SSTA_DHWMax	CoRTAD. The maximum SSTA DHW in degrees Celsius over the entire period of 23 years.	weeks
SSTA_DHWMean	CoRTAD. The mean SSTA DHW in degrees Celsius over the entire period of 23 years.	weeks
TSA	CoRTAD. (Thermal Stress Anomaly) weekly SST minus the maximum of weekly climatological SSTs in degrees Celsius.	degrees Celsius
TSA_Standard_Deviation	CoRTAD. The standard deviation of TSA in degrees Celsius over the entire period of 23 years.	degrees Celsius
TSA_Minimum	CoRTAD. The minimum TSA is in degrees Celsius over the entire period of 23 years.	degrees Celsius
TSA_Maximum	CoRTAD. The maximum TSA in degrees Celsius over the entire period of 23 years.	degrees Celsius
TSA_Mean	CoRTAD. The mean TSA in degrees Celsius over the entire period of 23 years.	degrees Celsius
TSA_Frequency	CoRTAD. The number of times over the previous 52 weeks that TSA > = 1 degree Celsius.	TSA per time period

TSA_Frequency_Standard_Deviation	CoRTAD. The standard deviation of the frequency of TSA in degrees Celsius over the entire period of 23 years.	TSA per time period
TSA_FrequencyMax	CoRTAD. The maximum TSA frequency in degrees Celsius over the entire period of 23 years.	TSA per time period
TSA_FrequencyMean	CoRTAD. The mean TSA frequency in degrees Celsius over the entire period of 23 years.	TSA per time period
TSA_DHW	CoRTAD. (Thermal Stress Anomaly Degree Heating Weeks) the sum of the previous 12 weeks when TSA > = 1 degree Celsius.	weeks
TSA_DHW_Standard_Deviation	CoRTAD. The standard deviation of TSA DHW in degrees Celsius over the entire period of 23 years.	weeks
TSA_DHWMax	CoRTAD. The maximum TSA DHW in degrees Celsius over the entire period of 23 years.	weeks
TSA_DHWMean	CoRTAD. The mean TSA DHW in degrees Celsius over the entire period of 23 years.	weeks

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Project Information

Thermal stress and differential recovery of coral reefs (Coral Recovery)

Coverage: Global

NSF Award Abstract:

Coral reefs are the world’s most diverse marine ecosystem that provide invaluable goods and services for millions of people worldwide. Yet, coral reefs are experiencing thermal-stress events worldwide and their communities are changing. While coarse-grained climate models predict that few coral reefs will survive the 3ºC sea-surface temperature rise in the coming century, field studies show localized pockets of coral survival and recovery, even under high temperature conditions. Quantifying recovery from thermal-stress events is central to making accurate predictions of coral reef trajectories into the near future. This study examines the differential rates of coral recovery following thermal-stress events, globally, and determines the extent to which regional and local conditions influence recovery. This research is taking advantage of the recent progress in spatio-temporal analyses. One of the most transformative aspects of this work is determining where coral recovery rates differ from expectations, and how those differences relate to regional and local conditions. The research is of relevance to all persons that live and work near coral reefs. What happens to reef corals has cascading consequences on other reef-associated organisms and influences whether coral reefs can keep up with sea-level rise. This project is increasing scientific capacity by training a post-doctoral scholar and a PhD student in big-data analysis and making these analysis techniques broadly available. High quality and free online tutorials are supporting standards-driven instruction for high school math, science, and computer teachers in R, a programming language and software environment used for statistical computing and graphics. The project is producing large-scale data and computational resources, which are benefitting diverse users such as students, scientists, resource managers and the broader public.

The current rapid rate of climate change threatens coral reefs. Quantifying recovery from thermal-stress events is central to making accurate predictions of coral-reef trajectories into the near future. Coral populations in different geographic regions and under different local conditions vary in their capacity to tolerate or recover from thermal stress. However, how and why coral responses differ remains poorly understood. There is a clear need for accurate predictions of coral trajectories following thermal-stress events and for determining which interacting factors most influence coral recovery. This study is characterizing the relationships between the rates of coral recovery, frequency and intensity of thermal-stress events, geographic location, habitat, and local conditions that slow or enhance coral recovery. Four approaches are being used to analyze coral recovery: (i) a binary approach, (ii) a meta-analysis approach, (iii) an inverse-problem approach, and (iv) a state-space approach. Spatial and temporal differences in rates of coral recovery are being quantified by capitalizing on the latest developments in spatio-temporal analyses within a Bayesian framework. Observed outcomes of coral recovery are being compared with predicted outcomes to identify areas where recoveries are either higher or lower than expected, and to assess context-dependencies of coral recovery in relation to local and regional conditions. The most transformative aspect of the study is the identification of localities with greater than expected recovery rates, which could guide future conservation decisions by enabling managers to target coral reefs with specific characteristics for protection from human disturbances by designating them as potential refuges as the oceans continue to warm.

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.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2048319

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