Carbonate production and erosion rates across shallow-water coral reef habitats (2–5 m depth) on Pohnpei and Kosrae, Federated States of Micronesia

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Project
» Adjustment of western Pacific Ocean coral reefs to sea-level rise and ocean warming (Coral Reef Adjustment)

Contributors	Affiliation	Role
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Abstract
Carbonate production and erosion rates across shallow-water coral reef habitats (2–5 m depth) on Pohnpei and Kosrae, Federated States of Micronesia. This dataset includes output of the model run. The results of two different iterations are provided as supplemental Excel files. The input data files and R scripts are included in the supplemental .zip file and from the BCO-DMO Github repository (https://github.com/BCODMO/Carbonate-production-Pohnpei-and-Kosrae/tree/1.0)

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Coverage

Spatial Extent: **N**:7.01269 **E**:163.03798 **S**:5.26278 **W**:158.08464

Dataset Description

R scripts and related data are available in a .zip file: Carbonate-production-Pohnpei-and-Kosrae-1.0.zip
These files are also available in the following GitHub repository: Carbonate-production-Pohnpei-and-Kosrae (release 1.0)

Acquisition Description

Details of field methods and data analysis are published in van Woesik & Cacciapaglia (2019).

Twenty-four study sites were randomly selected in each of Pohnpei (6.2°N, 158.2°E) and Kosrae (5.3°N, 162.9°E), Federated States of Micronesia (FSM), using a randomly stratified sampling approach with the

package *sp* in R. In Pohnpei, reefs were stratified as inner reefs, patch reefs, and outer reefs. In Kosrae, we only stratified the reefs as either inner reefs or outer reefs (because of the lack of patch reefs). Sample size of each strata was determined by calculating the geographic area of each reef type, using the *area* function from the R package *raster*, and allocating the number of sites in accordance with the area estimates. Reef surveys focused on the 2–5 meters depth contour to estimate shallow-water carbonate production.

Six, 10 m transects, using a modified line-intercept technique that followed the reef substrate, were used to measure the benthic composition for every centimeter, at each site of the 48 sites. A few meters gap was allocated between the ends of the transects to ensure no overlap of substrate between transects. Corals were recorded to species level, except massive Porites and encrusting Montipora, which were recorded in the field as growth forms. All other organisms along each transect were identified to the highest possible taxonomic resolution. Rugosity was recorded using the planar length of a second transect that spanned across the reef horizontally. Echinoids were recorded within 30 cm on either side of the 10 m tape. The urchins were recorded as Echinometra, Diadema, and 'Other', and the diameter of each echinoid test was measured to the nearest 0.5 cm. The abundance of Acanthaster solaris (crown-of-thorns sea star) were recorded within 5 m along each of the six 10 m transects. Herbivorous parrotfishes were videoed and identified to species and their estimated length was recorded to the nearest cm along six transects, each of which was 30 m long by 4 m wide. Care was taken to record the fish-transect videos ahead of the other transects to avoid any disturbance to the fishes.

Gross production was estimated as the total rate of carbonate production, excluding erosion rates. Erosion includes parrotfish and urchin erosional forces combined (which does not include sea urchin (*Acanthaster solaris)* erosion). Net production was estimated from gross carbonate production minus the erosional estimates and sedimentation inputs. Refer to van Woesik & Cacciapaglia (2019) for more information.

Processing Description

BCO-DMO Processing:
Originally submitted GitHub repository https://github.com/rvanwoesik/Carbonate-production-Pohnpei-and-Kosrae forked to https://github.com/BCODMO/Carbonate-production-Pohnpei-and-Kosrae and tagged with release 1.0, which corresponds with this dataset submission. The original repository may have continued updates.

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Related Publications

Van Woesik, R., & Cacciapaglia, C. W. (2019). Carbonate production of Micronesian reefs suppressed by thermal anomalies and Acanthaster as sea-level rises. PLOS ONE, 14(11), e0224887. doi:10.1371/journal.pone.0224887
Results

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Parameters

Parameter	Description	Units
State	State (Kosrae | Pohnpei) of site	unitless
locat	Reef habitats stratified as either 'outer', 'inner', or 'patch' reef	unitless
NP	Net carbonate production including all erosion, sedimentation, and production of carbonate at each site	kilograms calcium carbonate per year (kg CaCO3 yr-1)
GP	Gross carbonate production, excluding all sedimentation and erosional forces, at each site	kilograms calcium carbonate per year (kg CaCO3 yr-1)
BFj	Biological erosion caused by parrotfishes at each site	kilograms calcium carbonate per year (kg CaCO3 yr-1)
BUj	Biological erosion caused by sea urchins at each site	kilograms calcium carbonate per year (kg CaCO3 yr-1)
lon	Longitude of site	Decimal degrees
lat	Latitude of site	Decimal degrees

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Project Information

Adjustment of western Pacific Ocean coral reefs to sea-level rise and ocean warming (Coral Reef Adjustment)

Coverage: Western Pacific: Palau, Yap, Pohnpei, Kosrae, Republic of the Marshall Islands, Kiribati

NSF Award Abstract: Increases in ocean temperatures and sea-level rise are threatening coral reef ecosystems worldwide. Indeed, some island nations are no more than 1 m above modern sea level. Yet, building sea walls on tropical coasts, to keep out the ocean, as they do in the Netherlands, is a substantial economic burden on small-island nations. Healthy coral reefs, however, have the capacity to lay down sufficient calcium carbonate to grow vertically and keep up with sea-level rise, as they did in the geological past. By contrast, damaged coral reefs do not have the capacity to keep up with sea-level rise, making the coastal communities vulnerable, and inflicting a large economic burden on the coastal societies to build sea walls. In addition, and very recently, coral reefs are being subjected to high water temperatures that are causing considerable damage to corals. This study will ask some critical questions: Are coral reefs in the western Pacific Ocean keeping up with sea-level rise? Where are reefs keeping up with sea-level rise, and what is preventing reefs in some localities from keeping up? This study will also examine whether geographical differences in ocean temperatures influence the capacity of reefs to keep up with sea-level rise. Where coral reefs cannot keep up with sea-level rise, these natural storm barriers will disappear, resulting in the loss of habitable land for millions of people worldwide. The broader impacts of the study will focus on training a post-doctoral researcher, and developing and running one-week training workshops in the proposed study locations in Palau, Yap, Chuuk, Pohnpei, Kosrae, Majuro, and Kiribati. The investigators will work with local stakeholders on the various islands, focusing on connecting science to management practices to reduce local stressors to coral reefs. Coral reefs are one of the world's most diverse and valuable marine ecosystems. Since the mid-Holocene, some 5000 years ago, coral reefs in the Pacific Ocean have been vertically constrained by sea level. Contemporary sea-level rise is releasing these constraints, providing accommodation space for vertical reef expansion. Yet recently corals have been repeatedly subjected to thermal-stress events, and we know little about whether modern coral reefs can "keep up" with projected future sea-level rise as the ocean temperatures continue to increase. This study will examine whether and where coral reefs are keeping up with sea-level rise across a temperature gradient in the Pacific Ocean, from Palau in the west to Kiribati in the east. The spatial differences in the capacity to keep up with sea level will be explored, and it is hypothesized that differential rates of coral growth and capacity to keep up with sea-level rise will be a function of regional temperatures, local water-

flow rates, and land-use. One of the major tasks of this study is to determine the contribution of the various components of each reef to potential carbonate production, across the geographical temperature gradient. The investigators will quantify the rates of carbonate production, by corals and calcareous algae, and the rates of carbonate destruction, by reef eroders, by measuring the space occupied by each benthic component at each study site. The team will then sum that information to interpret the overall capacity of the reef to produce carbonate. At each study site mobile benthic eroders will be estimated, as counts and size measurements of echinoids and herbivorous fishes. The investigators will measure the densities of the different coral species, from different habitats, and develop models that relate the coral morphologies with the potential rate of carbonate deposition. This study will assess the contribution of sea surface temperature, flow rates, and land-use practice to the capacity of reefs to keep up with sea-level rise. Two different approaches will be used to predict the relationship between carbonate production and sea-level rise. The first model will assume that the capacity of vertical reef accretion is directly related to the extension of Porites microatolls at the various island locations. The second model will take a hierarchical Bayesian approach to examine reef growth, which depends on the presence and density of calcifying organisms, and on physical, chemical, and biological erosional processes.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1657633

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