Depth-dependent irradiance from sunrise to sunset across the shallow to mesophotic depth gradient for three coral morphologies from a backward Monte Carlo ray-tracing model

Website: https://www.bco-dmo.org/dataset/841083
Data Type: model results
Version: 1
Version Date: 2021-02-18

Project
» Collaborative Research: Sponge Growth is Nitrogen Limited over the Shallow to Mesophotic Depth Gradient (MCESponge)

Contributors	Affiliation	Role
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Abstract
Mesophotic coral reefs, defined as deep reefs between 30 and 150 m, are found worldwide and are largely structured by changes in the underwater light field. Additionally, it is increasingly understood that reef-to-reef variability in topography, combined with quantitative and qualitative changes in the underwater light field with increasing depth, significantly influence the observed changes in coral distribution and abundance. Here we take a modeling approach to examine the effects of the inherent optical properties of the water column on the irradiance that corals are exposed to along a shallow to mesophotic depth gradient. In particular, the roles of reef topography including horizontal, sloping and vertical substrates are quantified as well as the differences between mounding, plating and branching colony morphologies. Downwelling irradiance and reef topography interact such that for a water mass of similar optical properties the irradiance reaching the benthos varies significantly with topography (i.e., substrate angle). Corals with different morphologies also interact with these benthic irradiances; model results show that isolated hemispherical colonies consistently “see” greater irradiances across depths, and throughout the day, compared to plating and branching morphologies. The differences in the photoautotrophic potential of different coral morphologies, based on the changes in irradiance modelled here, are not, however, consistent with depth-dependent distributions of these coral morphotypes. Other factors (e.g., heterotrophy) arguably contribute, but irradiance driven patterns are a strong proximate cause for the observed differences in mesophotic communities on sloping versus vertical reef substrates.

Table of Contents

Acquisition Description

The results publication for these data has been submitted (Lesser et al., submitted). See further methodology details there once published. Data were analyzed using published inherent optical properties

(IOP)s and irradiances for coral reefs.

Inherent optical properties (IOPs)

PARcos, PARhs, and PARbr simulate the plating, mounding and branching morphologies of scleractinian corals, respectively, at specific depths. Specifically, planar irradiance, PARcos is the light intercepted per unit area for a plating coral where the plates are orientated parallel with the reef surface. Hemispherical scalar irradiance, PARhs, is the light incident on an isolated mounding coral, per unit area of the reef surface it occupies. PARbr is the average light incident per unit area of the coral surface for branching corals, this can be understood as the average light incident on a polyp in a branching coral. Finally, PARo is the spherical quantum scalar irradiance, equivalent to a '4p' sensor just in front of the reef substrate.

There is no specific location associated with these data. The focus of the project was the Caribbean Basin and the attenuation of light with depth and the role of light in structuring shallow and mesophotic coral reef communities.

Processing Description

Software: HydroLight

BCO-DMO data manager processing notes:
* Original data file submitted to BCO-DMO "Lesser et al Ed Model Outputs.xlsx" Sheet1 contained many subtables named by site and slope|wall and depth. Transformed the data so it could be imported into bco-dmo with the following steps:

* Transposed all data so data in columns of the same type instead of rows.
* Expanded site name and slope so it was filled in for every row.
* Split site name (wall or slope) and depth into separate columns
* joined all subtables into one data table.
* exported data as csv before importing into the BCO-DMO data system.

[table of contents | back to top]

Related Publications

Lesser, M.P., Mobely, C.D., Hedley, J.D., Slattery, M. submitted. Mesophotic corals experience irradiance constrained by reef topography and colony morphology. Functional Ecology.
Results

Numerical Optics, Ltd. (2021) Hydrolight. Version 6 [software]. Available from https://www.numopt.com/hydrolight.html [accessed 2021-02-18]
Software

[table of contents | back to top]

Parameters

Parameter	Description	Units
reef_type	Reef type (back reef, fore reef, or fringing) for the inherent optical properties (IOPs)	unitless
position	Reef topography (wall, slope, or top)	unitless
z	Depth (z)	meters
thetaSun	Solar zenith angle of the sun ranging from -80 (Sunrise) to 0 (Noon) to 80 (Sunset).	units
PARd_in_air	Downwelling photosynthetically active radiation (PARd) in air	micromol quanta/(m^2 sec)
PARo	Spherical quantum scalar irradiance, equivalent to a '4p' sensor just in front of the reef substrate. Photosynthetically Active Radiation (PAR).	micromol quanta/(m^2 sec)
PARhs	Hemispherical scalar irradiance. The light incident on an isolated mounding coral, per unit area of the reef surface it occupies. Photosynthetically Active Radiation (PAR).	micromol quanta/(m^2 sec)
PARcos	Planar irradiance. The light intercepted per unit area for a plating coral where the plates are orientated parallel with the reef surface. Photosynthetically Active Radiation (PAR).	micromol quanta/(m^2 sec)
PARbr	Average light incident per unit area of the coral surface for branching corals. This can be understood as the average light incident on a polyp in a branching coral. Photosynthetically Active Radiation (PAR).	micromol quanta/(m^2 sec)

[table of contents | back to top]

Project Information

Collaborative Research: Sponge Growth is Nitrogen Limited over the Shallow to Mesophotic Depth Gradient (MCESponge)

Coverage: Curacao, Cayman Islands

NSF Award Abstract:
Coral reefs are well known biodiversity hotspots of considerable interest to the public and scientific community. Reefs around the world are currently under threat from multiple factors such as pollution, coastal development, overfishing and climate change, where both the warming and acidification of tropical waters contributes to the loss of coral reefs and the many services they provide for us, such as protection from hurricane damage. Many studies are focused on corals, the conspicuously dominant group of organisms on many coral reefs, but other organisms are also important. One group, sponges, are essential for healthy reef function as they provide food and homes for many other reef organisms, they dramatically effect the nutrient cycles on reefs, and they synthesize important compounds of interest to the biomedical community. An emerging area of coral reef science is the study of deep reefs at depths greater than 30 meters. These coral reef systems, known as mesophotic coral reef ecosystems, were largely inaccessible until the transfer of technical diving approaches to the scientific community. In this project the investigators will study sponge populations from 3 meters to over 100 meters to examine their ability to utilize both dissolved and particulate food sources that may help explain increasing sponge biodiversity and growth rates with increasing depth. This project will provide training opportunities for undergraduate and graduate students as well as veterans and post-doctoral researchers, especially from underrepresented groups. Additionally, the investigators will develop unique outreach programs for public education.

Sponges are ubiquitous members of Caribbean coral reef communities, where they have multiple roles. There is evidence accumulating that sponge populations are increasing as coral cover declines due to anthropogenic and natural factors. Trophic interactions play crucial roles in controlling the distributions of species and community structure; however, the relative importance of top-down (predation) and bottom-up (nutrient resources) control of populations remains a hotly debated topic. Recently, it has been proposed that sponges consume large amounts of dissolved organic carbon (DOC) and release large numbers of choanocytes that fuel a "sponge loop" detrital pathway of significance to higher trophic levels. A largely overlooked, but clearly stated, requirement for the "sponge-loop" hypothesis to be broadly generalizable is that sponges must exhibit little, or no, net growth as the only way to balance the loss of carbon in the form of choanocytes (=detritus), with the intake of both particulate organic carbon (POC) and DOC; however, sponges do grow. Additionally, on both shallow and mesophotic coral reefs (MCEs: 3-150m depth), there is a strong vertical gradient in bacterioplankton resources on which sponges feed, and enhanced growth in the presence of spongivory argues for the importance of particulate organic carbon (POC). Missing so far in this discussion is the important role of dissolved and particulate organic nitrogen (DON/PON) that would be essential for sponge growth on coral reefs. This proposal has two goals: 1) quantify the DOC/POC and DON/PON resources available across the shallow to mesophotic depth gradient that has never been done before, and 2) quantify the depth dependence on these resources by a broad taxonomic representation of sponges that also includes multiple life-history strategies across shallow to mesophotic depths. To accomplish this second task the investigators will conduct studies on the growth of sponges from shallow to mesophotic depths to tease apart the independent and interactive roles of DOC/POC and DON/PON in sponge growth. They will also construct carbon, nitrogen and energetic budgets for sponges utilizing these resources. The project will provide the first comprehensive inventory of DOC/POC and DON/PON on several coral reefs. This will be complemented by studies of feeding and growth across the shallow to mesophotic depth gradient. With continuing changes in the community structure of both shallow and mesophotic reefs, understanding whether we can predict, using models of ecosystem function, which reefs will undergo transitions to sponge dominated communities and what factors contribute to these transitions, will be of use to local marine resource managers. These data will also inform the broader field of marine ecology, as well as provide new insights into mesophotic reef structure and function. Finally, sponge samples collected from mesophotic coral reefs often represent new species and they will be made available to scientists upon request.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1632348

[table of contents | back to top]