Manually annotated reef halos based on sattelite imagery from 6 study areas as training and test data for a deep learning model

Website: https://www.bco-dmo.org/dataset/932211
Data Type: model results
Version: 1
Version Date: 2024-12-18

Project
» CAREER: Decoding seascape-scale vegetation patterns on coral reefs to understand ecosystem health: Integrating research and education from organismal to planetary scales (Coral Reef Halos)

Contributors	Affiliation	Role
Madin, Elizabeth	University of Hawai'i at Mānoa (HIMB)	Principal Investigator, Contact
Franceschini, Simone	University of Hawai'i at Mānoa (HIMB)	Scientist
Soenen, Karen	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
Reef halos are rings of bare sand that surround coral reef patches. Halo formation is likely to be the indirectly result of interactions between relatively healthy predator and herbivore populations. To reduce the risk of predation, herbivores preferentially graze close to the safety of the reef, potentially affecting the presence and size of the halo. Reef halos are readily visible in remotely sensed imagery, and monitoring their presence and changes in size may therefore offer clues as to how predator and herbivore populations are faring. However, manually identifying and measuring halos is slow and limits the spatial and temporal scope of studies. There are currently no existing tools to automatically identify single reef halos and measure their size to speed up their identification and improve our ability to quantify their variability over space and time. Here we present a set of convolutional neural networks aimed at identifying and measuring reef halos from very high-resolution satellite imagery (i.e., ~0.6 m spatial resolution). We show that deep learning algorithms can successfully detect and measure reef halos with a high degree of accuracy (F1 = 0.824), thereby enabling faster, more accurate spatio-temporal monitoring of halo size. This tool will aid in the global study of reef halos, and potentially coral reef ecosystem monitoring, by facilitating our discovery of the ecological dynamics underlying reef halo presence and variability.

Table of Contents

Coverage

Spatial Extent: **N**:27.74960245 **E**:151.9375651 **S**:-23.47546301 **W**:-87.87905306

Methods & Sampling

Our study area included 20 areas of interest) from 6 countries.

SkySat satellite images were acquired through Planet Inc. Planet Explorer Catalogue. Obtained as a SkySat Collect product, each image was roughly 20km x 5.9km, with a spatial resolution ranging between 0.5m and 0.8m. Before download, all images were orthorectified, radiometrically calibrated, and atmospherically corrected to surface reflectance following Planet's standard procedures. All surface reflectance products are orthorectified using fine digital elevation maps (30-90m posting) and ground control points. Planet conducts atmospheric correction with the 6SV2.1 radiative transfer model which accounts for atmospheric absorption and scattering, with aerosol optical depth, water, vapor and ozone inputs from MODIS near-real-time data (MOD09CMA and MOD09CMG). All calculations were done in R. Satellite images cover a time interval from March 2019 to June 2021. The satellite images can not be shared due to file size issues and data-sharing policies, below are the Skysat unique identification numbers for each satellite image used in the project:

- 20201107_025354_ssc9_u0001
- 20190510_152255_ssc4_u0003
- 20190625_182659_ssc7_u0001
- 20190309_183114_ssc11_u0001
- 20190531_182931_ssc6_u0001
- 20200919_182915_ssc7_u0002
- 20190626_182402_ssc8_u0003
- 20201129_191646_ssc8_u0001
- 20201022_191415_ssc6_u0001
- 20201022_191415_ssc6_u0002
- 20200626_192104_ssc6_u0001
- 20200626_192104_ssc6_u0002
- 20200627_190037_ssc7_u0001
- 20200627_191435_ssc8_u0001
- 20190413_081243_ssc13d3_0004
- 20190413_081243_ssc13d3_0005
- 20190413_081243_ssc13d3_0006
- 20200202_110140_ssc7_u0001
- 20210627_034355_ssc19_u0001
- 20210127_154738_ssc12_u0001

All non-overlapping halos in the AOIs were labeled, resulting in 4,127 manually annotated halos. Halos were labeled using ArcGIS software (ver. 2.9.1), allowing the geo-referenced information for all objects to be retained. To avoid biases due to a single user's perception of halos size, five users were trained to the same labeling procedure – zooming into each halo at a 1:600 scale and tracing light contours with a mouse – and labeled the same AOIs. The dataset generated from the imagery annotation was divided into training and test sets (~70% and ~30%, respectively). The training set was used for model implementation and optimization, while the test set was used for comparing model-predicted vs. manually annotated halos. In addition, we selected independent areas (i.e., AOIs) where no halos were used for the training process) for the test set to estimate the model generalization properties better.

Simone Franceschini and Amelia C. Meier downloaded the satellite images used for this project. Halos data were labeled by Simone Franceschini, Amelia C. Meier, Aviv Suan, Kaci Stokes, and Elizabeth M.P. Madin. Simone Franceschini developed the model and estimated performance metrics.

Problem Description

The satellite images can not be shared due to file size issues and data-sharing policies.The images are from Planet (https://www.planet.com/) and are part of their SkySat product, which requires a purchase or subscription for access. The Skysat unique identification numbers for each satellite image can be used to purchase the same pictures.

The spatial information of each halo can be found in the shapefiles (supplemental files) only.

[table of contents | back to top]

Data Files

File
932211_v1_modelinput.csv (Comma Separated Values (.csv), 354.41 KB) MD5:8f799ffd065796bcedc207eba7ef3624 Primary data file for dataset ID 932211, version 1

[table of contents | back to top]

Supplemental Files

File
Halos_Shapefiles.zip (ZIP Archive (ZIP), 16.73 MB) MD5:f824262a11bfd27d14f9c038e7836b94 Shapefiles of the manually annotated reefs. List of the coordinate reference system for each AOI: AOI,EPSG,CRS Name BHS01,32618,WGS84/UTM18N BHS02,32618,WGS84/UTM18N BHS03,32618,WGS84/UTM18N BHS04,54004,World Mercator BHS05,4326,WGS84 BHS06,32623,WGS84/UTM23N BLZ01,32618,WGS84/UTM18N BLZ02,32618,WGS84/UTM18N BLZ03,32620,WGS84/UTM20N BLZ04,54004,World Mercator BLZ05,32623,WGS84/UTM23N BLZ06,54004,World Mercator BLZ07,32618,WGS84/UTM18N EGY01,4326,WGS84 EGY02,3395,WGS84/World Mercator EGY03,4326,WGS84 SAU01,54004,World Mercator SAU02,32632,WGS84/UTM32N USA01,4326,WGS84 AUS01,32653,WGS84/UTM53N
Statistics Observed Halo's filename: 1-s2.0-S0034425723001359-mmc1.csv (Comma Separated Values (.csv), 264 bytes) MD5:466d64f2196f4bdc57ce026c46c710ce Depth statistics of the observed halo's per geographic area: mean depth (m), minimum depth (m) and maximum depth (m).

[table of contents | back to top]

Related Publications

Franceschini, S., Meier, A. C., Suan, A., Stokes, K., Roy, S., & Madin, E. M. P. (2023). A deep learning model for measuring coral reef halos globally from multispectral satellite imagery. Remote Sensing of Environment, 292, 113584. https://doi.org/10.1016/j.rse.2023.113584
Results

[table of contents | back to top]

Related Datasets

IsSourceOf

Madin, E., Franceschini, S. (2024) **Mask R-CNN and U-Net model and output of coral reef halo measurements based on global multispectral satellite imagery.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2024-12-18 doi:10.26008/1912/bco-dmo.943698.1 [view at BCO-DMO]
Relationship Description: Mask R-CNN and U-Net model using the manually annotated reef halos as input.

[table of contents | back to top]

Parameters

Parameter	Description	Units
AOI	Area of interest. Twenty areas in total. Country codes: AUS = Australia, BHS = Bahamas, BLZ = Belize, EGY = Egypt, SAU = Saudi Arabia, USA = United States of America (Florida)	unitless
Object_Id	ID of each specific object within each area of interest	unitless
SkySate_image_ID	Name of image used for manual annotation	unitless
Classname	Class of annotation: Halo	unitless
Mean_Latitude	Mean latitude of halo object (center)	decimal degrees
Mean_Longitude	Mean longitude of halo object (center)	decimal degrees
Subset	Indication if halo was used for as training or test data	unitless

[table of contents | back to top]

Project Information

CAREER: Decoding seascape-scale vegetation patterns on coral reefs to understand ecosystem health: Integrating research and education from organismal to planetary scales (Coral Reef Halos)

Website: http://oceansphere.org

Coverage: Hawai'i (field components) and global (synthetic components)

NSF Award Abstract:
Coral reefs worldwide are under increasing threat from a range of human-induced stressors. Climate change is understood to be a key global stressor threatening reefs, but the only proven levers for ecosystem managers to increase reef resilience is to mitigate local and regional stressors such as fishing pressure. A vexing question persists, however, which is how to measure the effects of fishing on ecosystems, particularly over the large spatial (e.g., >10s of meters) and temporal (multi-year) scales over which fishing occurs. One promising approach to doing so is using the large-scale vegetation patterns found on coral reefs globally, called "halos", to remotely observe when, where, and to what extent fishing pressure is affecting community structure and function. This program combines lab- and field-based experiments with cutting-edge satellite

imaging technology and computer science approaches to provide a leap forward in our understanding of how species-level interactions can scale up in space and time to shape coral reef seascapes around the world. By drawing on these approaches, the synergistic education program: 1) integrates science and art (i.e., murals and satellite imagery) to educate and inspire Hawai'i's students and general public about coral reef ecology; 2) builds technological capacity in Hawai'i's underrepresented minority high school to graduate students, and 3) empowers these students with science communication skills to communicate with diverse audiences. By leveraging this research program and the cutting-edge technologies it will involve, the investigator establishes a strong foundation for long-term teaching and mentoring activities focused on increasing capacity within STEM-underrepresented minorities with Hawaiian and other Pacific Islander backgrounds. Decoding what coral reef halos can tell us about the effects of fishing on reef ecosystem health provides valuable knowledge to reef ecosystem managers and conservation practitioners as reefs continue to rapidly change due to human stressors.

This project combines lab- and field-based experiments with cutting-edge satellite imaging technology and computer science approaches to address the goals of: 1) determining the mechanisms that create the "halos" that form around coral patch reefs, and 2) testing the predictions arising from these mechanisms in a global arena. This project uses a transdisciplinary approach – spanning ecology, oceanography, geospatial science, and computer science – to address these goals. This program has three scientific objectives: to determine 1) which species interaction mechanisms and environmental factors cause reef halos and what their relative importance is; 2) whether these mechanisms are globally consistent or vary geographically; and 3) whether halos can therefore be used as an indicator of aspects of coral reef ecosystem health. In the process, this research advances our understanding of how remote observation tools (satellite and drone imagery; camera traps) can be integrated with computer science (machine learning) and ecological approaches (mechanistic experiments) to generate emergent insights that would not otherwise be possible.

This project is jointly funded by the Biological Oceanography Program, the Established Program to Stimulate Competitive Research (EPSCoR), and Ocean Education Programs.

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.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1941737

[table of contents | back to top]