Coral reef and halo stats data from global satellite images

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Data Type: Other Field Results
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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
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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.

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Methods & Sampling

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. Satellite images cover a time interval from March 2019 to June 2021.

Our study area included 20 areas of interest) from 6 countries. Data for this project included four-band (blue, green, red, and near-infrared) SkySat satellite images 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. Labeled non-overlapping halos consisted of 4,127 manually annotated objects in a shapefile format.

Data Processing Description

Reef halos were manually labeled to build a training dataset. The training set was used for the deep learning model implementation and optimization, with the final aim of automatizing halos detection and measuring.

Halos were labeled using ArcGIS software (ver. 2.9.1), allowing the geo-referenced information for all objects to be retained. Both the Mask R-CNN and U-Net models were developed using Tensorflow (ver. 2.5.1), Keras (ver. 2.4.3), and PyTorch (ver. 1.8.2) libraries in Python (ver. 3.9) and ArcGIS (ver. 2.9.1.) The machine running the deep learning model had an Intel® Core™ i9-9900K CPU @3.60 GHz processor with 128 GB of installed RAM and a PNY NVIDIA Quadro A6000 GPU.

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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

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Parameters

Parameters for this dataset have not yet been identified

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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.

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Funding

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

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