

# Revealed: Spratly Reefs Without Human Activity Have Less Chlorophyll-a Than Occupied Reefs

Analysis By Similarity  
August 11, 2021



## Executive Summary

This report is a follow up to our July 12, 2021 report “Sewage From Anchored Ships Is Damaging Spratly Reefs”. It addresses feedback we have received on that report:

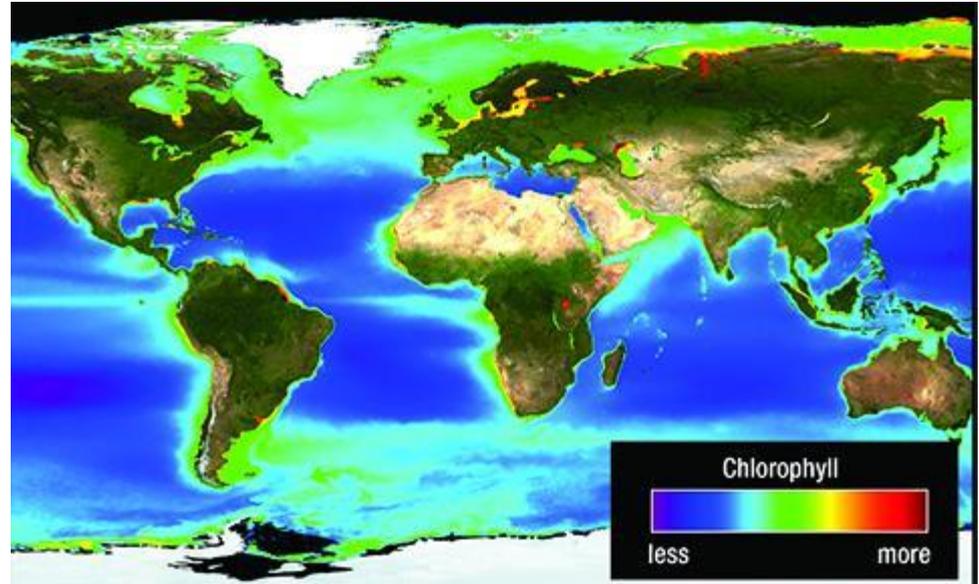
- On July 19<sup>th</sup>, we published a science overview on measuring Chlorophyll-a from space. It can be viewed [here](#). On August 5<sup>th</sup>, we published a calibration of our methods with ground truth water quality data from Diego Garcia island [here](#).
- This report illustrates how the Chlorophyll-a concentration value can be represented with either grayscale or false color visualizations. The grayscale images were published in our July 12 report. In this report we include the corresponding false color images to aid in visualization of the changes in Chlorophyll-a concentrations.
- We include a scale for measuring the impact of Chlorophyll-a concentration, based on the Great Barrier Reef water quality standards.
- We show the Chlorophyll-a concentrations, over the same 5 year period, for three reefs in the Spratly islands that have had significantly less human activity than the reefs in the Union Banks. These three reefs have shown a significant reduction in Chlorophyll-a concentrations, in contrast to the majority of Union Banks reefs.
- We provide more scientific sources that cite Chlorophyll-a concentration as an indicator of reef damaging eutrophication caused by excess nutrients.

**Conclusion: there is significant evidence that the Union Banks reefs are being damaged by “excess nutrients” and have more reef degrading macroalgae than similar reefs which are not occupied.**

## Visualizing Light Outside Of the Visual Spectrum

### HOW DO WE VISUALIZE LIGHT WE CAN'T SEE?

False color, or representative color, is used to help scientists visualize data from wavelengths beyond the visible spectrum. Scientific instruments onboard NASA spacecraft sense regions within the electromagnetic spectrum—spectral bands. The instruments direct the electromagnetic energy onto a detector, where individual photons yield electrons related to the amount of incoming energy. The energy is now in the form of "data," which can be transmitted to Earth and processed into images.<sup>1</sup>



To help scientists visualize a data set of just one range of values, such as temperature or rainfall, the values are often mapped to a color scale from minimum to maximum. A commonly used color scale has red at one end and blue at the other creating a “rainbow-like” scale.<sup>1</sup>

Source: National Aeronautics and Space Administration (NASA), Science Mission Directorate. (2010). Wave Behaviors. Retrieved July 18, 2021, from [NASA Science website](#)

## Two Ways To Visualize Chlorophyll-a Concentrations

### Grayscale

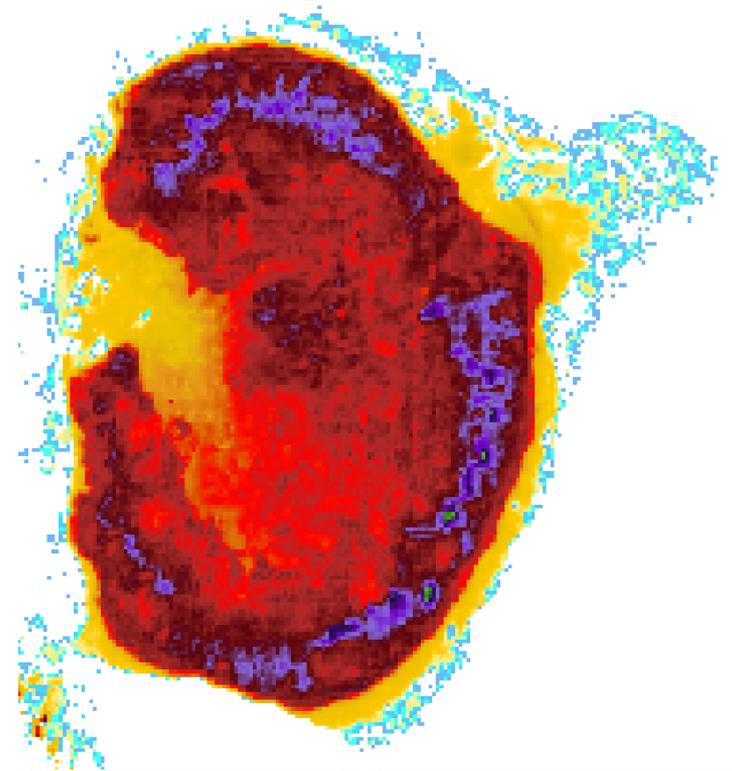
Same satellite data: Ross Reef, June 17, 2021. Same Chlorophyll-a values. Different ways to visualize the same data.

Subtle variations are generally more visible in the grayscale images because the scale is linear and so every measurement is represented as a shade of gray.

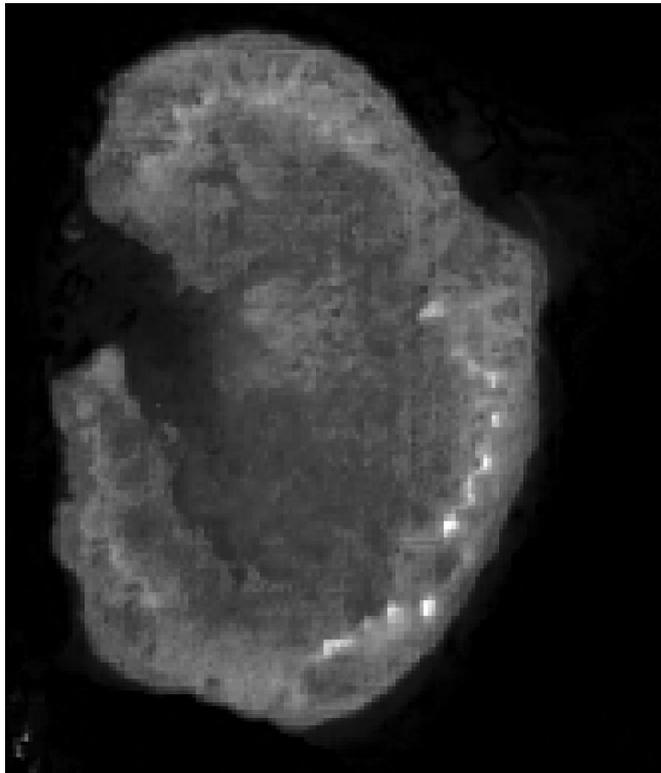
The false color scale is **not linear**, and minimizes the difference between large concentrations of Chlorophyll-a because it groups measurements into color bands, rather than representing them individually.

We are including both because the false color images can make it easier to visualize the changes.

### False Color



Maximum value represented here is 41.65, even though the top of the color band range is 45.



Maximum value represented is 41.65

# Chlorophyll-a Concentration False Color Key

“The analyses show that levels of Chlorophyll and water clarity are strong indicators of ecosystem health of the GBR and should be considered for use in any monitoring program of reef health.”<sup>3</sup>

From [Water Quality Guidelines For the GBR Summary](#) by [Dr Katharina Fabricius](#)

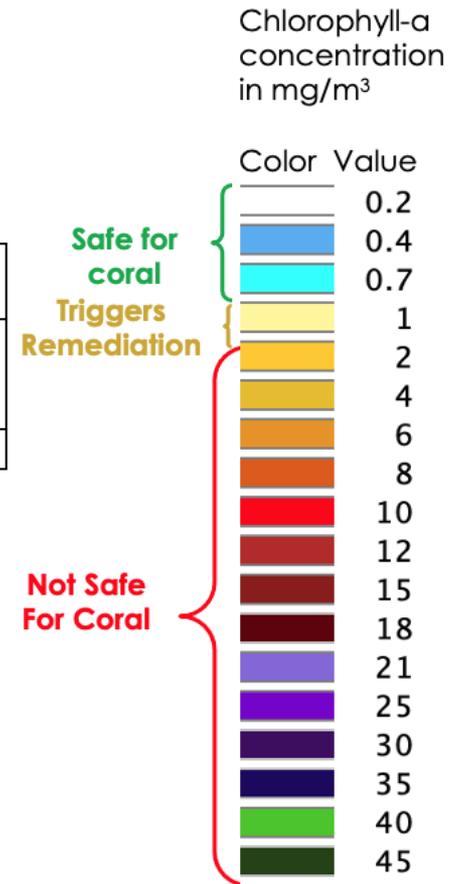
Table 2: Guideline trigger values for water clarity and chlorophyll a

Parameter\Water Body	Enclosed coastal (Wet Tropics/Central Coast)	Open coastal	Midshelf	Offshore
<b>Secchi (m) (minimum mean annual water clarity)<sup>1</sup></b>	1.0/1.5	10	10	17
<b>Chl a (µg/L)<sup>2</sup></b>	2.0	0.45	0.45	0.4

<sup>1</sup> At shallower depths Secchi will be visible on the seafloor. Guideline trigger values for water clarity need to be decreased by 20% for areas with greater than 5 m tidal ranges. Seasonal adjustments for Secchi depths are presently not possible due to the lack of data.

<sup>2</sup> Chlorophyll values are ~40% higher in summer and ~30% lower in winter than mean annual values.

Table 2 (above) shows trigger values for water clarity and Chlorophyll-a. When these values are exceeded, further reef management action is initiated to address the issue. This table was obtained from the most current water quality guidelines of the Great Barrier Reef: [Water Quality Guidelines for the Great Barrier Reef Marine Park](#). Great Barrier Reef Marine Park Authority, Townsville. REVISED EDITION 2010 <sup>2</sup>

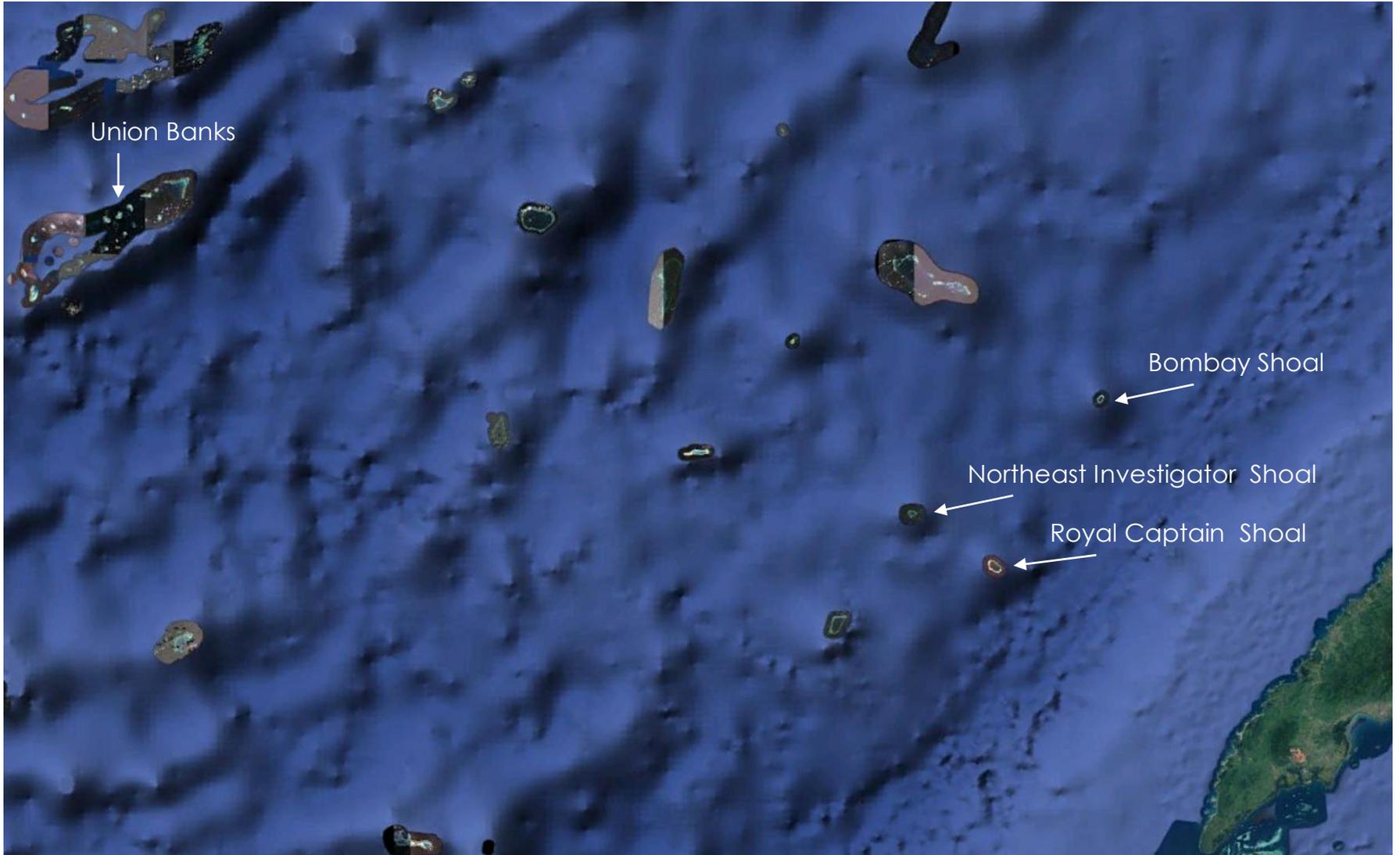


# Chlorophyll-a Values For Spratly Reefs Without Human Activity

The same methodology was used to generate these images as with the Union Banks images previously published, and a similar 5 year time period was used.

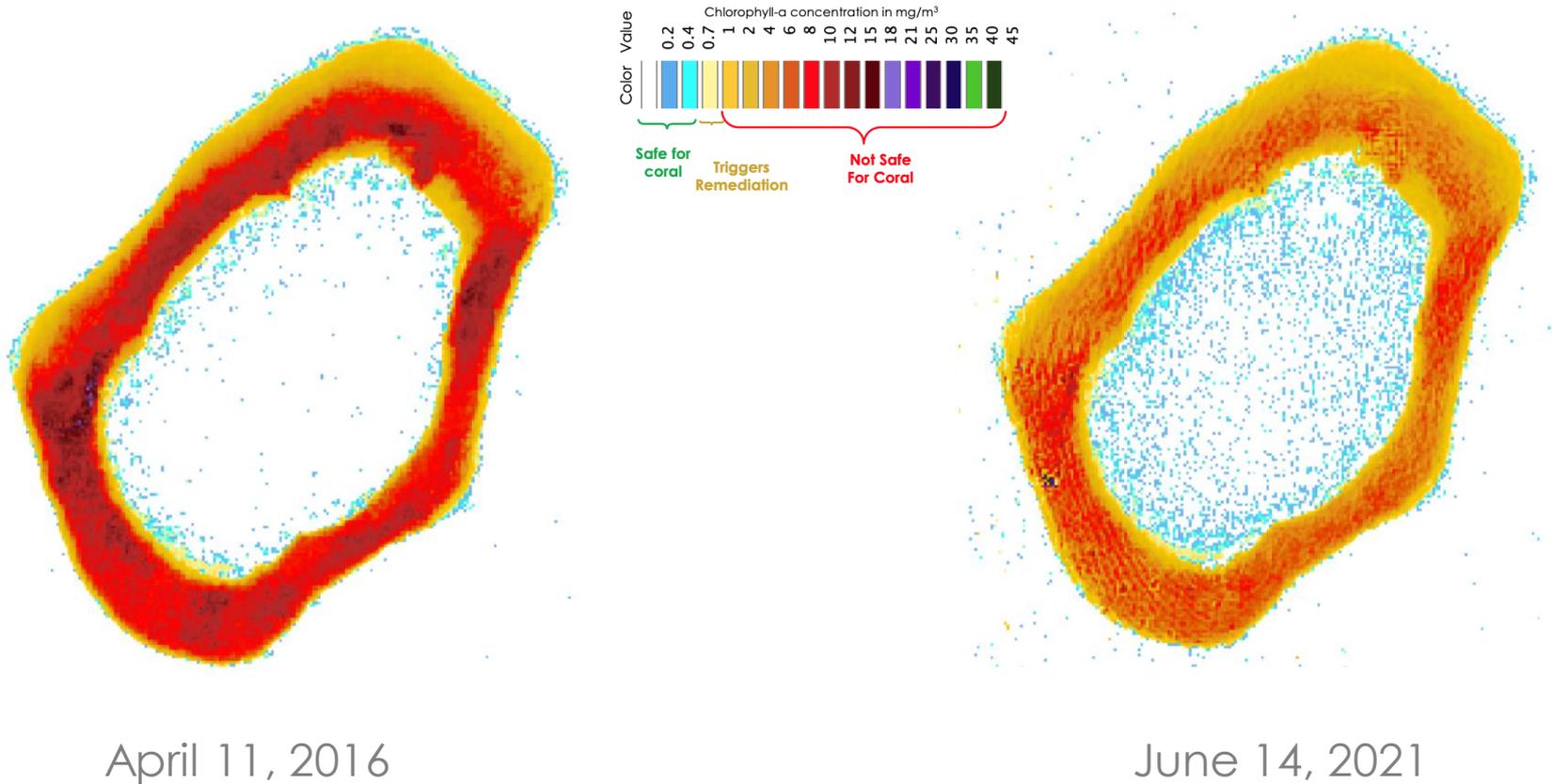
The image dates vary slightly from the Union Banks ones only because cloud-free images are necessary and were not available for the exact same dates.

## Orientation: Spratly Reefs East Of Union Banks



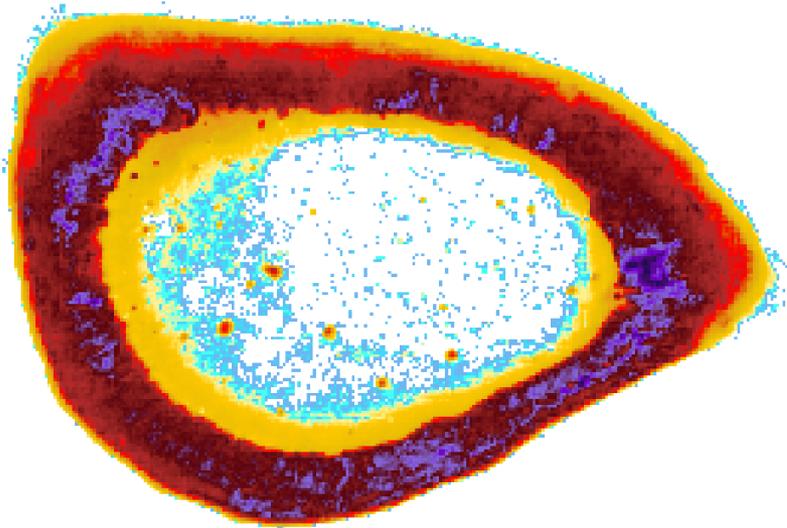
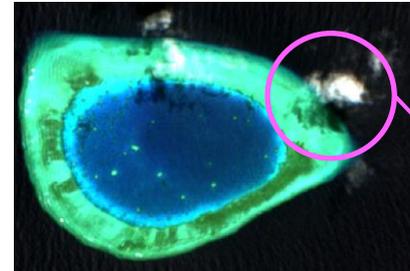
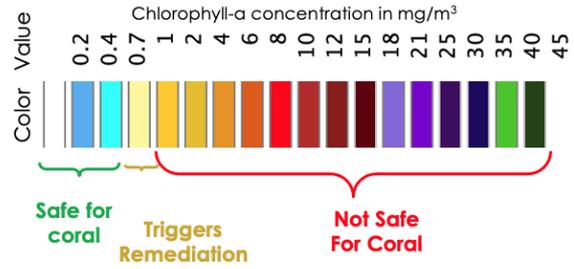
# Bombay Shoal: Chlorophyll-a Concentration

There is significantly **less** Chlorophyll-a on the rim of the reef in 2021 than in 2016, and safe levels of Chlorophyll-a in the lagoon in 2021.

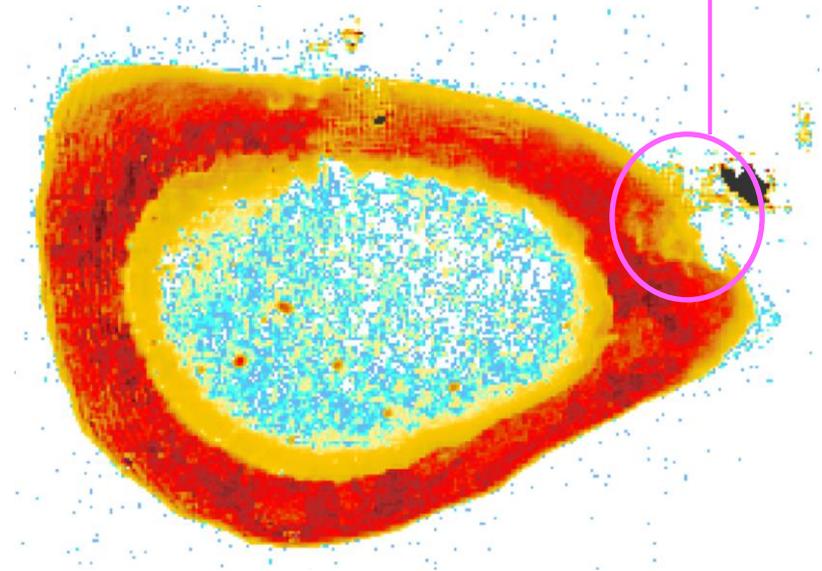


# Northeast Investigator Shoal: Chlorophyll-a Concentration

There is significantly **less** Chlorophyll-a on the reef in 2021 than in 2016.



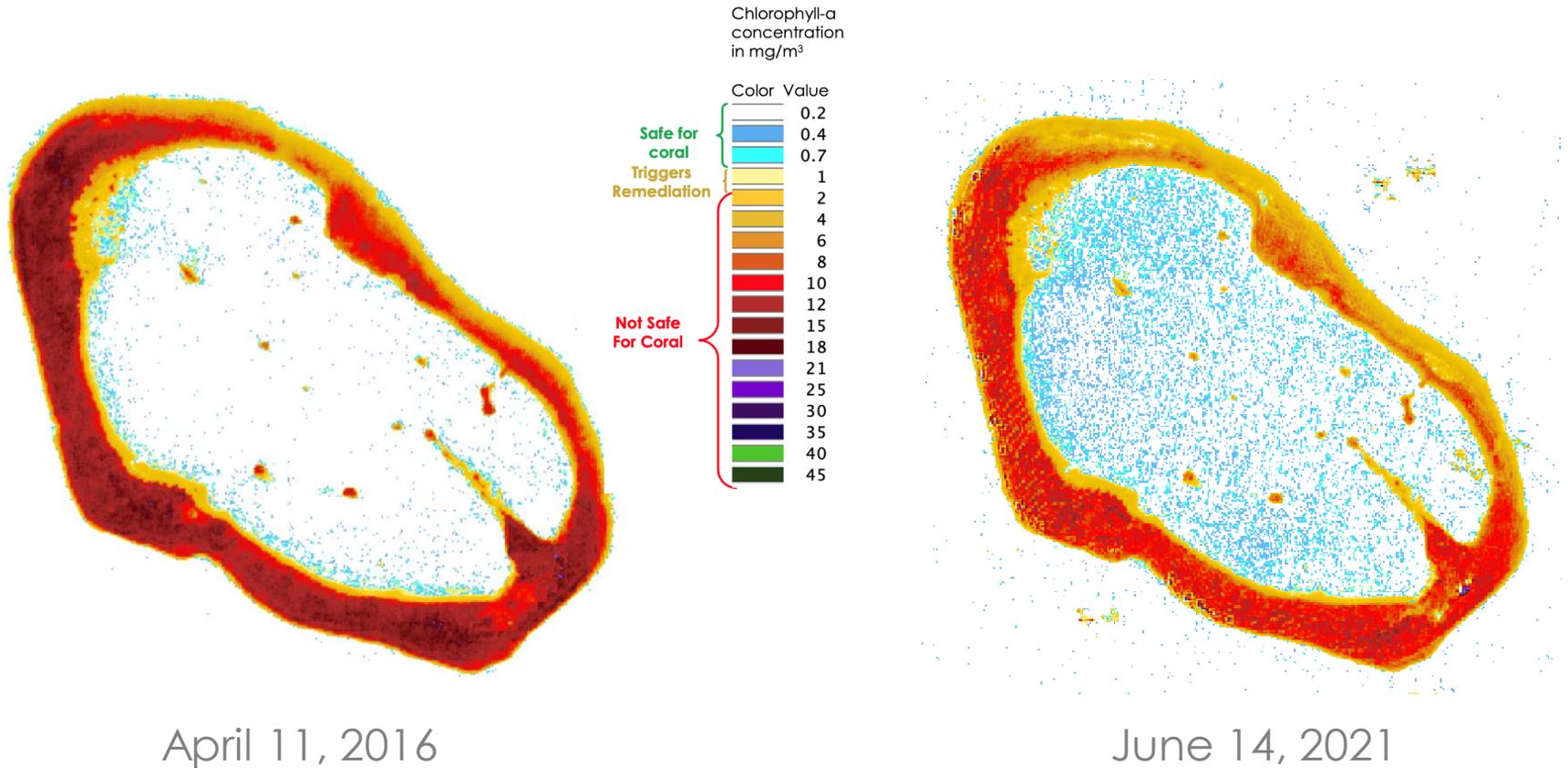
April 11, 2016



June 14, 2021

# Royal Captain Shoal: Chlorophyll-a Concentration

There is significantly **less** Chlorophyll-a on the reef in 2021 than in 2016..



# Conclusion: Chlorophyll-a Values For Spratly Reefs Without Human Activity Decreased From 2016 to 2021

Chlorophyll-a values decreased in the last 5 years for each of these reefs. The lower Chlorophyll-a levels indicate the coral is less likely to be damaged by macroalgae overgrowth.

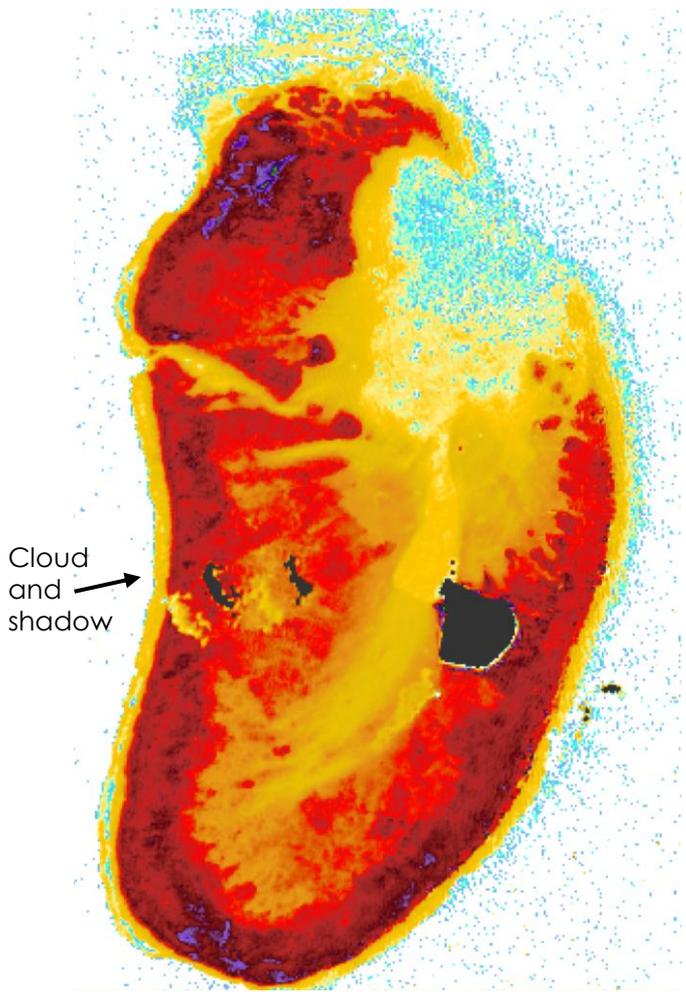
# False Color Versions Of The Union Banks Chlorophyll-a Concentration Images Previously Published

The false color representations of the previously published grayscale images are provided here for comparison to the uninhabited reefs above.

This is just a different visualization method of the same images and Chlorophyll-a concentrations previously published as grayscale images. The original grayscale images, as well as the new ones for the uninhabited reefs, are in the appendix.

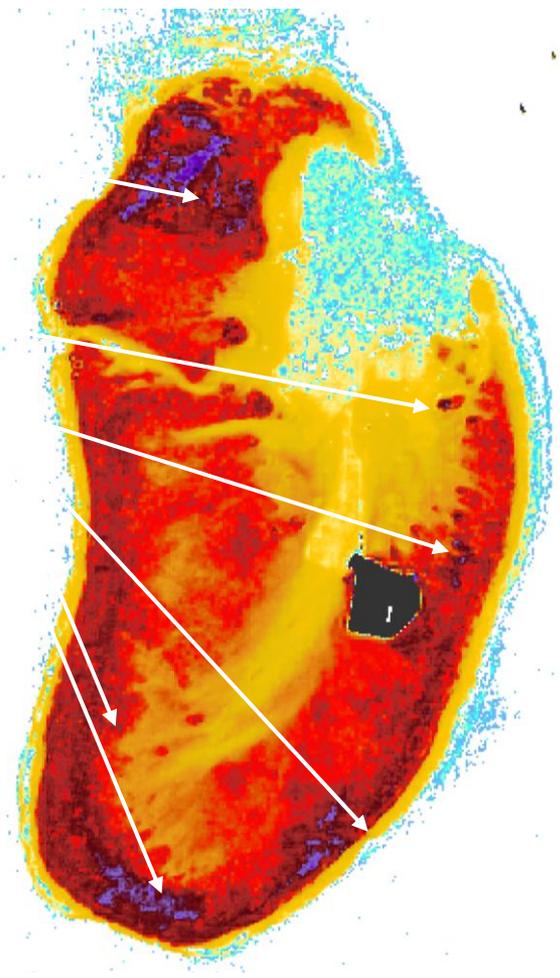
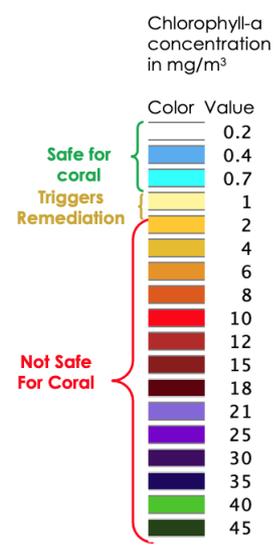


# Johnson South Reef: Chlorophyll-a Concentration



May 14, 2016

By 2021, the edges of the reef have **higher Chlorophyll-a concentrations** (seen as more purple in these images), highlighted by the white arrows.



June 17, 2021

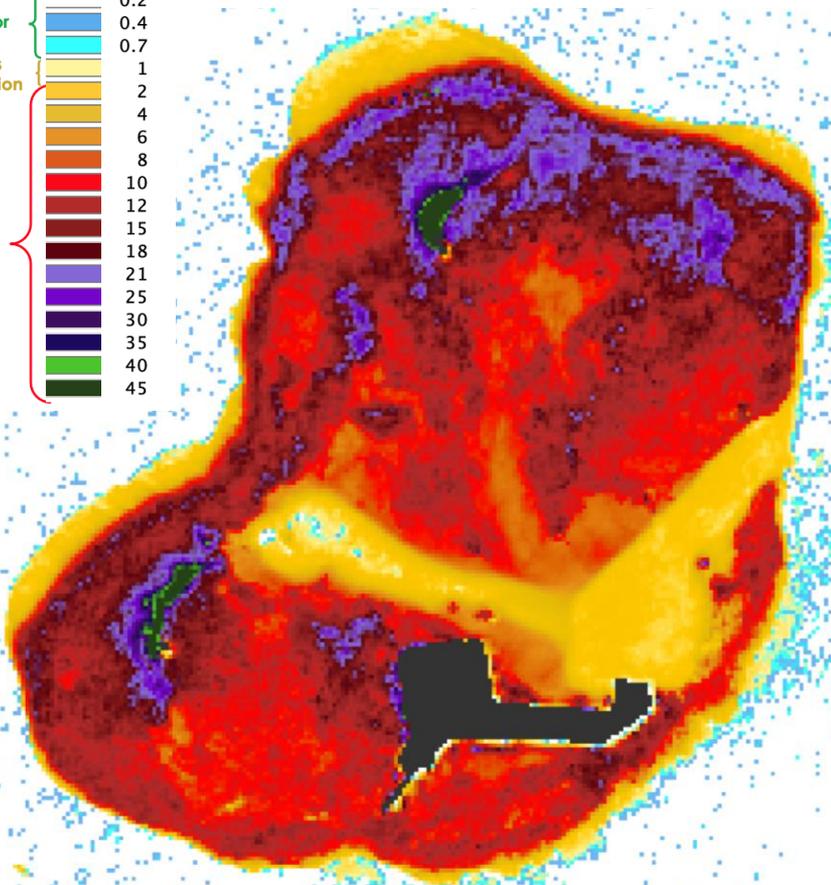
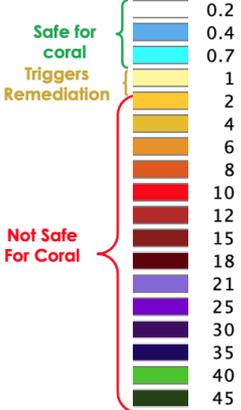
The reef outpost is automatically masked in black.



# Hughes Reef: Chlorophyll-a Concentration

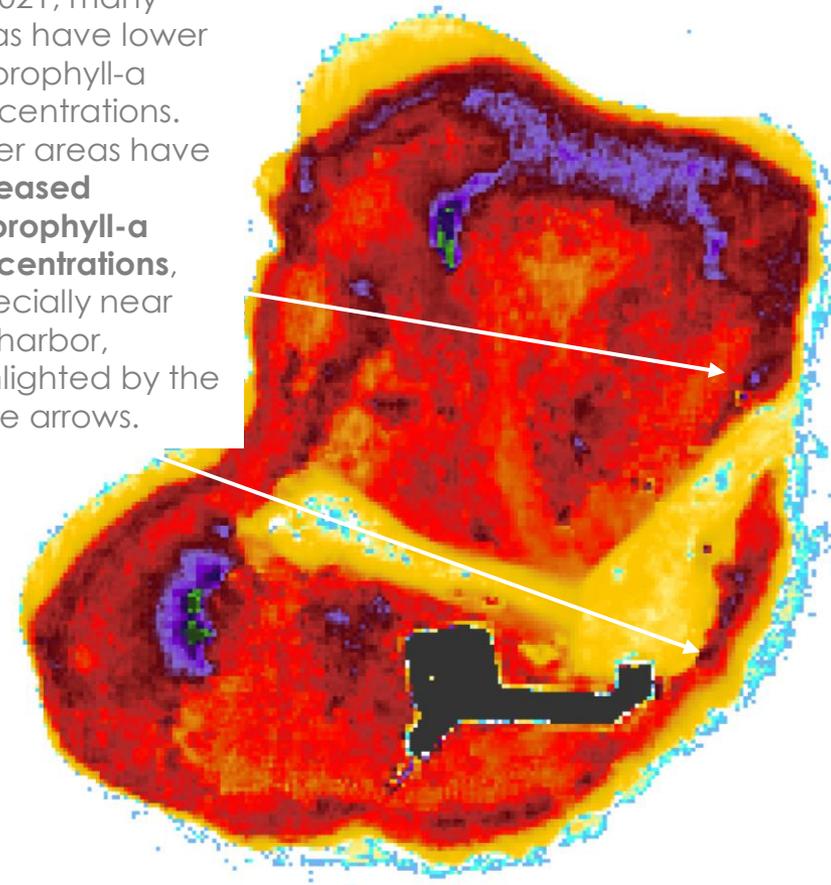
Chlorophyll-a concentration in mg/m<sup>3</sup>

Color Value



May 14, 2016

By 2021, many areas have lower Chlorophyll-a concentrations. Other areas have **increased Chlorophyll-a concentrations**, especially near the harbor, highlighted by the white arrows.

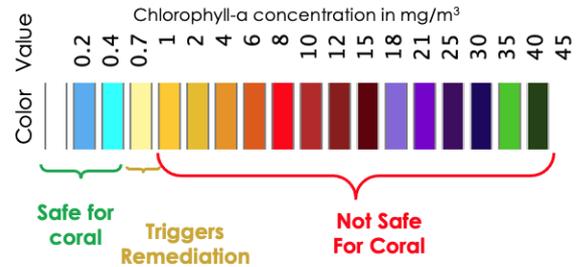


June 17, 2021

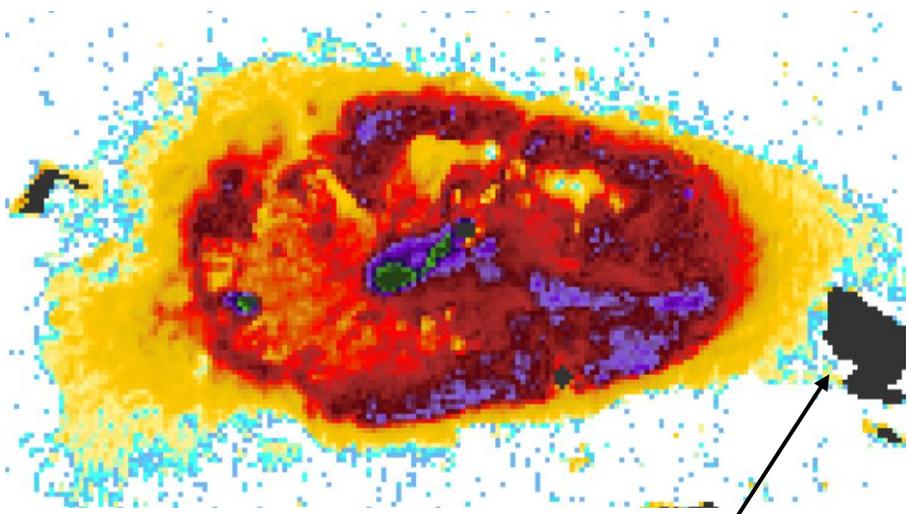
The reef outpost is automatically masked in black.



# Lansdowne Reef: Chlorophyll-a Concentration

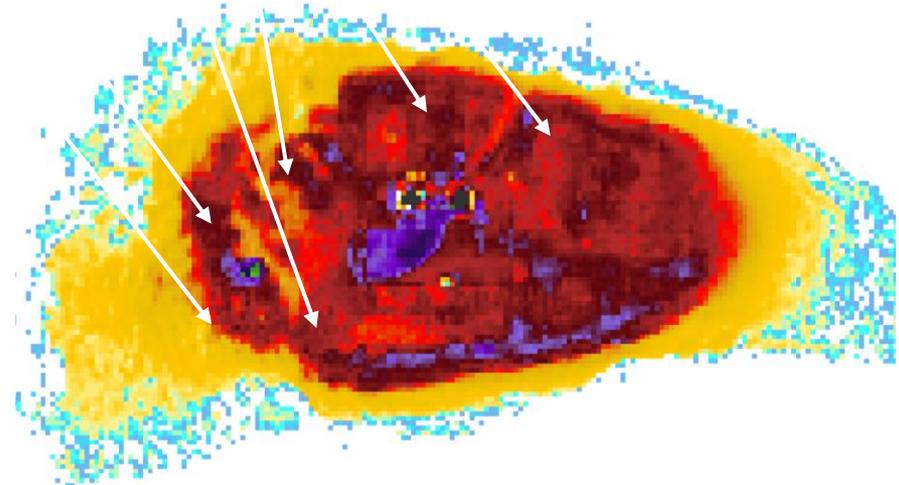


A second outpost was built in 2017. By 2021, this reef has become significantly higher in Chlorophyll-a. The white arrows on the 2021 view of Lansdowne reef highlight the many areas where the **Chlorophyll-a concentration has increased**.



May 14, 2016

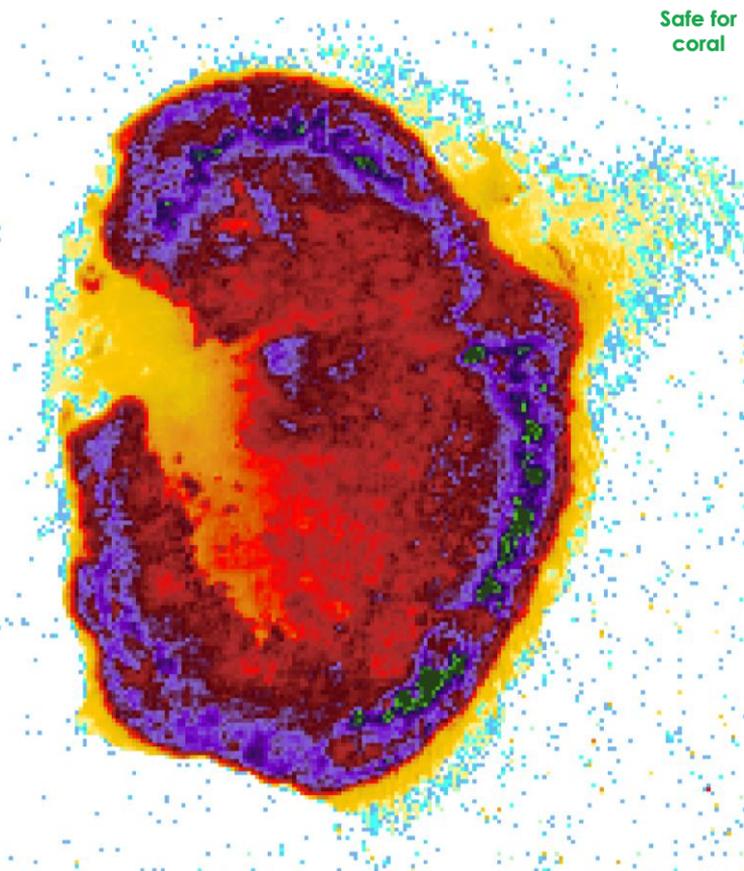
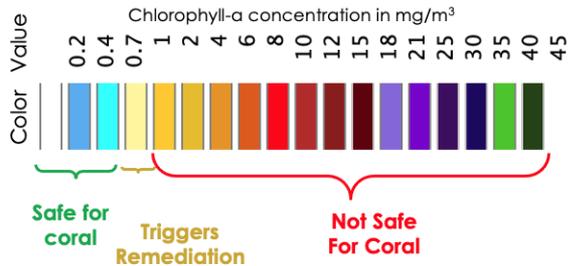
These are clouds masked in black.



June 17, 2021

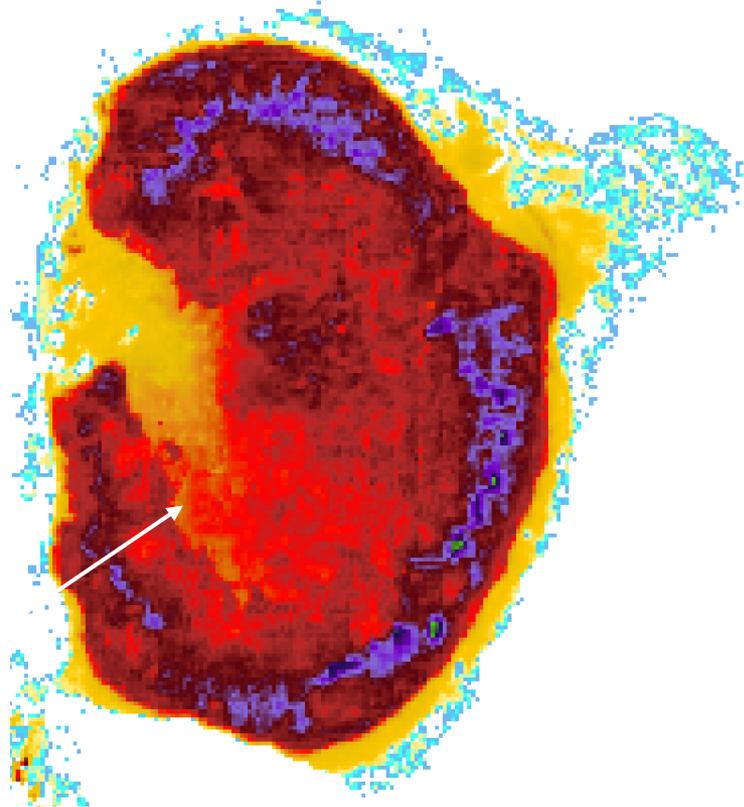
# Ross Reef: Chlorophyll-a Concentration

Not occupied but located near significant human activity



May 14, 2016

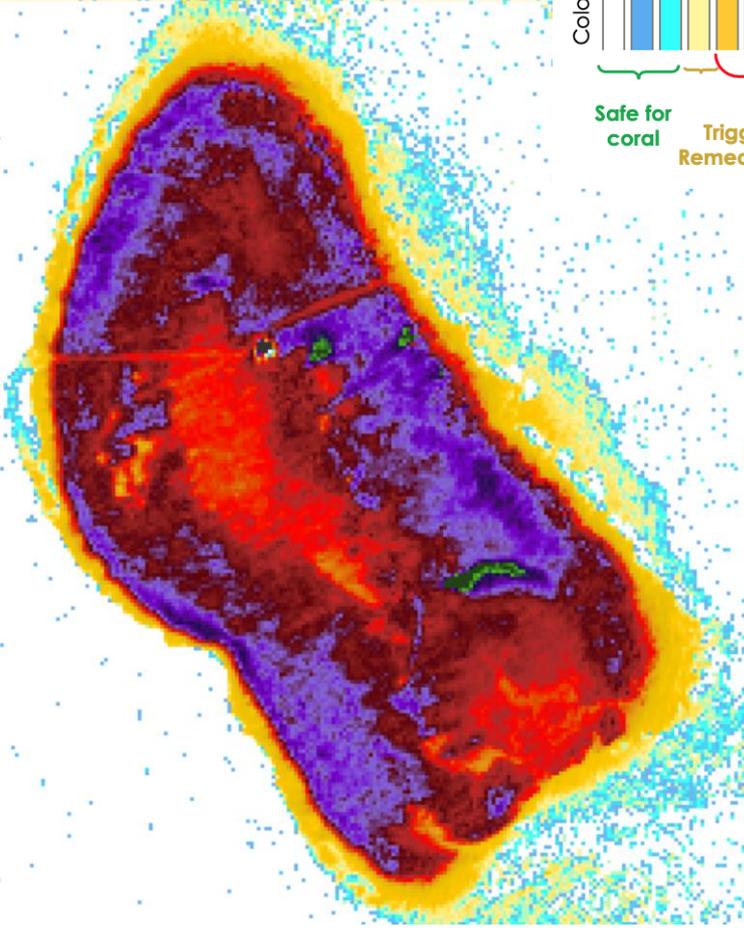
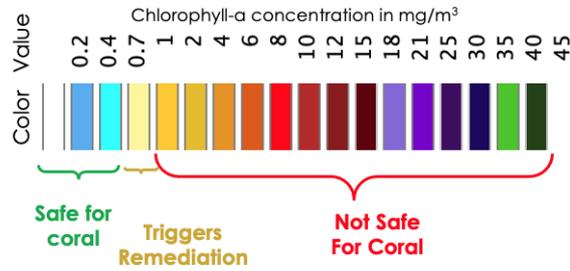
By 2021, the reef has reduced its maximum Chlorophyll-a (less green and purple). However, there is more bright red where there used to be orange, indicating **increased Chlorophyll-a**, highlighted by the white arrow.



June 17, 2021



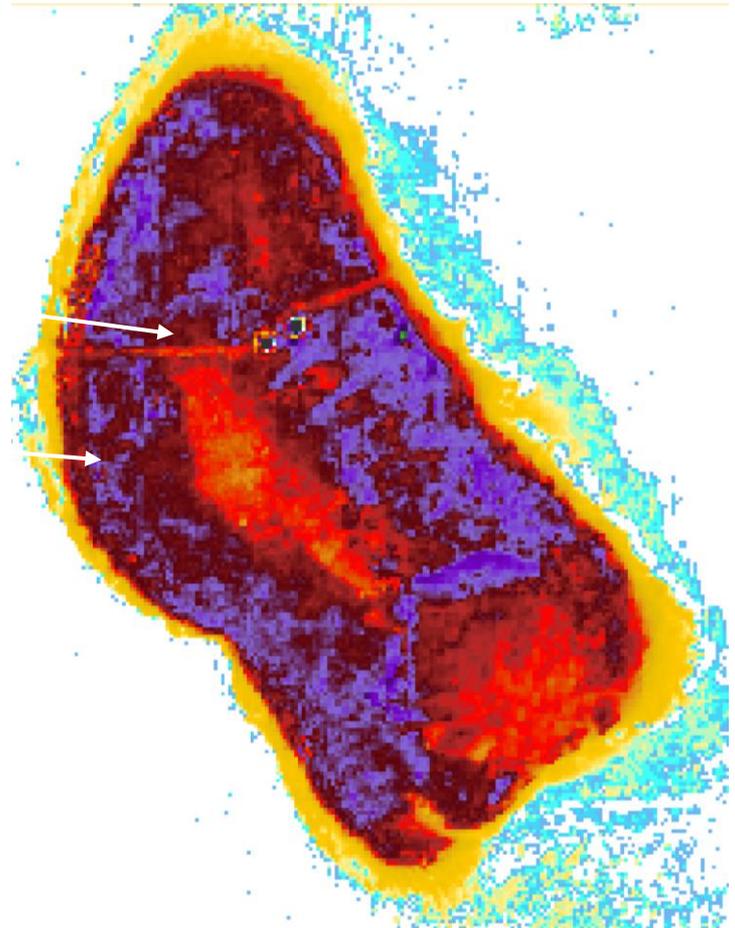
# Collins Reef: Chlorophyll-a Concentration



May 14, 2016

A second outpost was built in 2017.

By 2021, the reef has reduced its maximum Chlorophyll-a concentration. However, the interior red area has become darker red, and the yellow area on the West side has disappeared, indicating **increased Chlorophyll-a** in these areas, highlighted by the white arrows.



June 17, 2021

## Evidence of Large-Scale Chronic Eutrophication in the Great Barrier Reef: Quantification of Chlorophyll a Thresholds for Sustaining Coral Reef Communities<sup>6</sup>

“Long-term monitoring data show that hard coral cover on the Great Barrier Reef (GBR) has reduced by >70 % over the past century. Although authorities and many marine scientists were in denial for many years, it is now widely accepted that this reduction is largely attributable to the chronic state of eutrophication that exists throughout most of the GBR”<sup>4</sup>

“We also discuss the concept of threshold values for water quality parameters that best define the degree of eutrophication. We note that in the initial stages of eutrophication chlorophyll a (Chl a) is considered the best indicator of the degree of eutrophication of the water column; the reason being that the soluble inorganic nutrients are taken up rapidly by the algae and hence their concentrations will generally be quite low (Laws and Redalje 1979). A significant advantage in being able to use Chl a as the indicator of the degree of eutrophication is that it is relatively cheap and easy to measure and can be detected remotely, even by satellite.”<sup>4</sup>

*Eutrophication: excessive richness of nutrients in a lake or other body of water, frequently due to runoff from the land, which causes a dense growth of plant life and death of animal life from lack of oxygen.*

[Definitions from Oxford Languages<sup>5</sup>](#)

Evidence of Large-Scale Chronic Eutrophication in the Great Barrier Reef: Quantification of Chlorophyll a Thresholds for Sustaining Coral Reef Communities

Authors: Peter R. F. Bell, Ibrahim Elmetri, and Brian E. Lapointe  
Ambio, 2014 Apr; 43(3): 361–376. Published online 2013 Oct 11.

## Methods, Sources, and References

### Sources:

Imagery: All imagery was provided by Sentinel 2 of the European Space Agency, [freely available at the ESA's open access hub](#)

### Methods:

Algorithm: The Chlorophyll-a Concentrations were determined using the [C2RCC algorithm](#) which is supplied with the European Space Agency's Sentinel Toolbox, SNAP, which is also freely available. Chlorophyll-a concentrations are in  $\text{mg}/\text{m}^3$ . Resources: [Study that validates C2RCC for Sentinel 2](#). Video [tutorial](#) on how to use C2RCC for Sentinel 2. PDF [tutorial](#) on how to use C2RCC for Sentinel 2.

### References:

1. National Aeronautics and Space Administration (NASA), Science Mission Directorate. (2010). Wave Behaviors. Retrieved *July 18, 2021*, from [NASA Science website](#)
2. [Water Quality Guidelines for the Great Barrier Reef Marine Park](#). Great Barrier Reef Marine Park Authority, Townsville. [REVISED EDITION 2010](#) produced by the Great Barrier Reef Marine Park Authority. Water quality guidelines for the Great Barrier Reef Marine Park 2010 [electronic resource]. Rev. ed. ISBN 978 1 921682 29 2
3. [Water Quality Guidelines For the GBR Summary](#) by [Dr Katharina Fabricius](#)
4. [Evidence of Large-Scale Chronic Eutrophication in the Great Barrier Reef: Quantification of Chlorophyll a Thresholds for Sustaining Coral Reef Communities](#) by [Peter R. F. Bell](#), [Ibrahim Elmetri](#), and [Brian E.](#)
5. Definition of Eutrophication from [Definitions from Oxford Languages](#)

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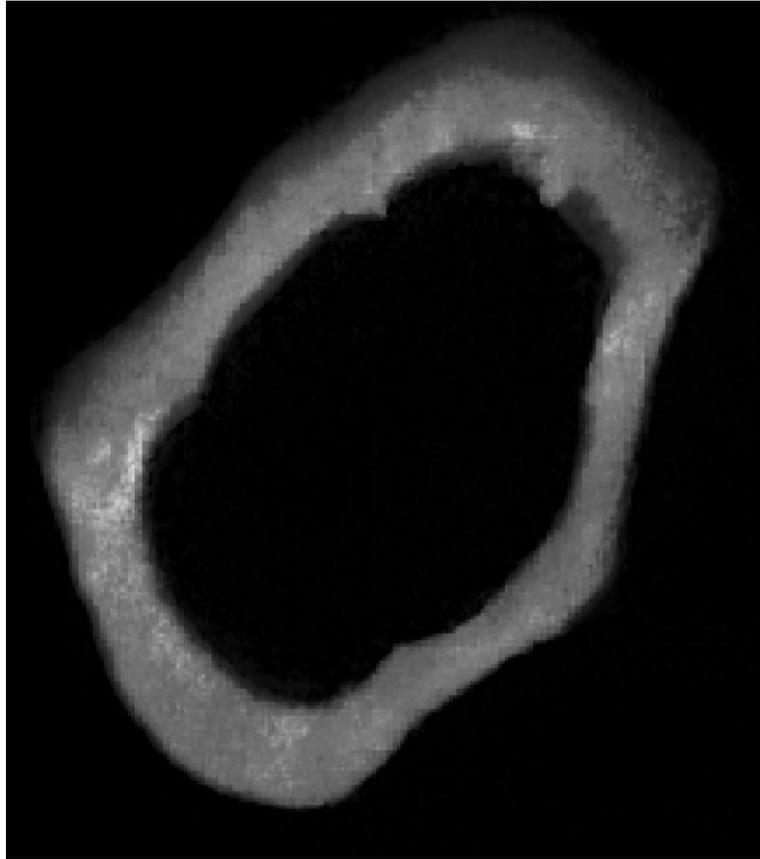
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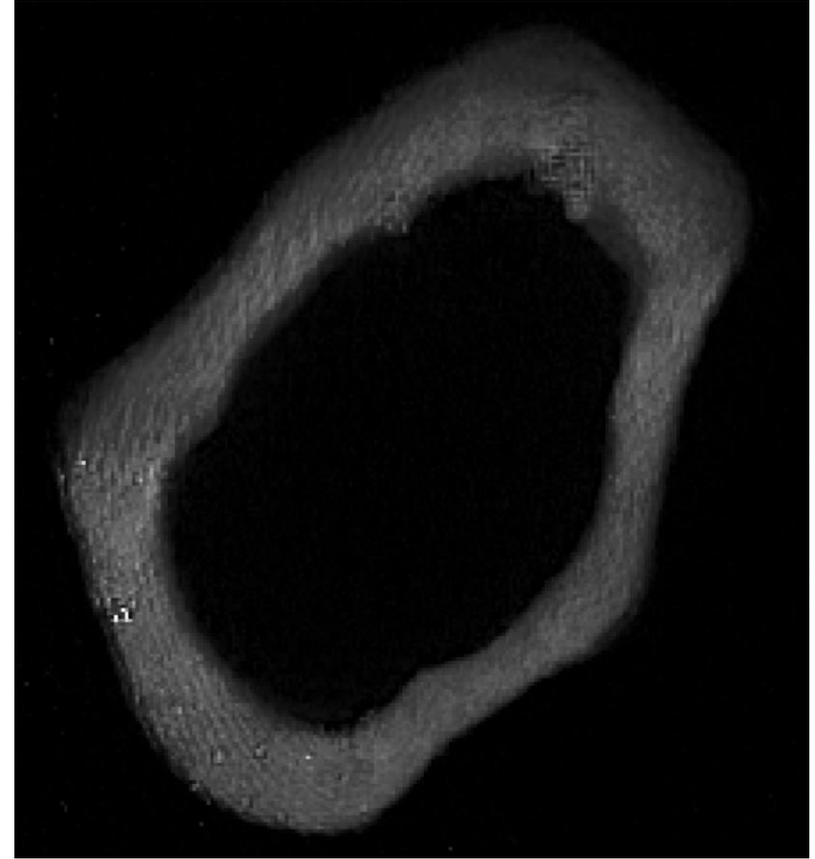
# Appendix – Grayscale Images

Includes the grayscale images for the newly examined reefs, and the previously published grayscale images for the Union Banks reefs.

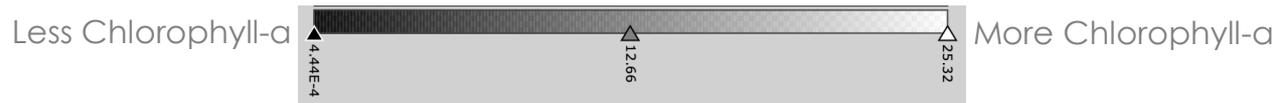
# Bombay Shoal: Chlorophyll-a Concentration



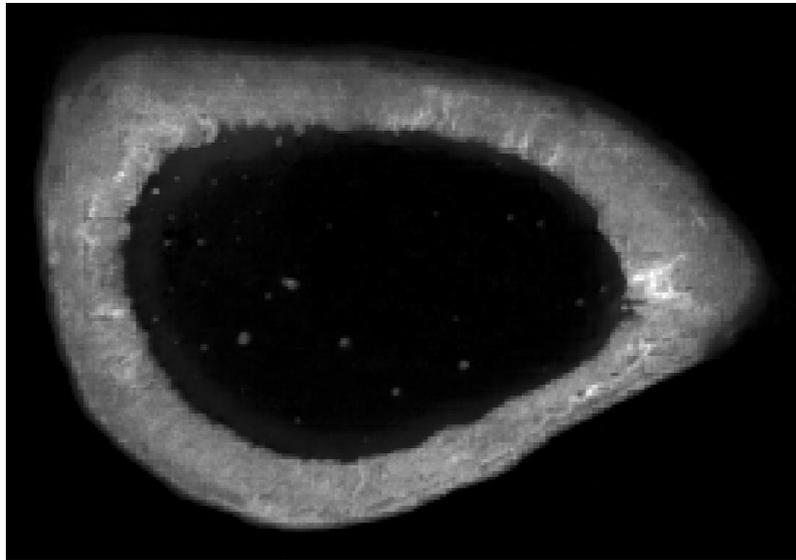
April 11, 2016



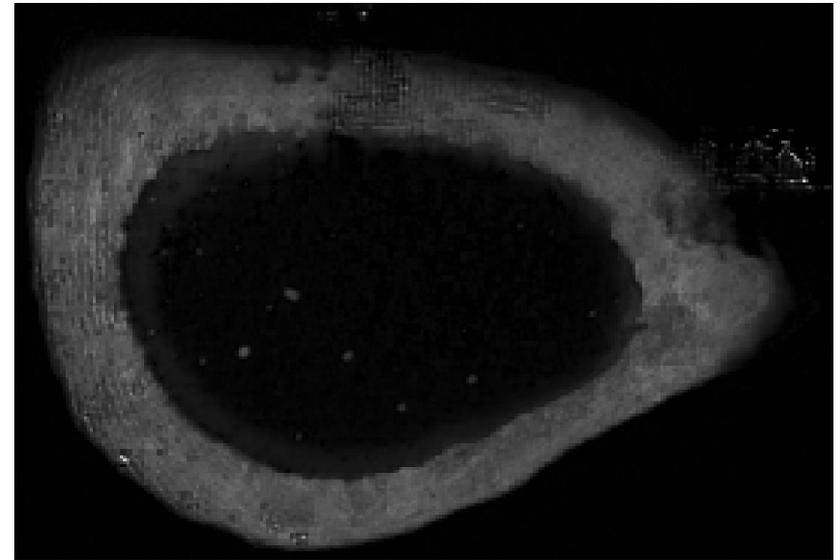
June 14, 2021



## Northeast Investigator Shoal: Chlorophyll-a Concentration

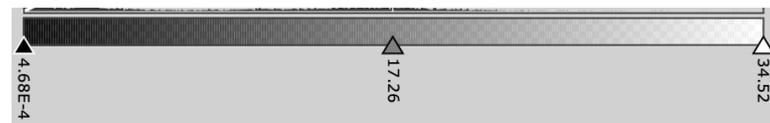


April 11, 2016



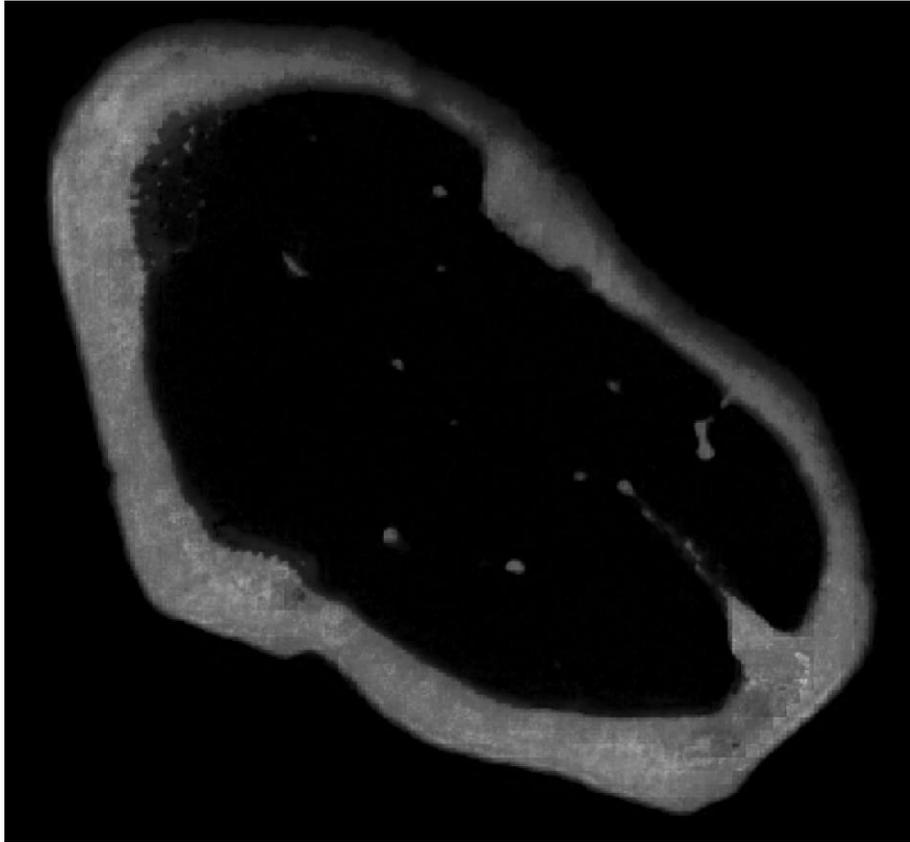
June 14, 2021

Less Chlorophyll-a

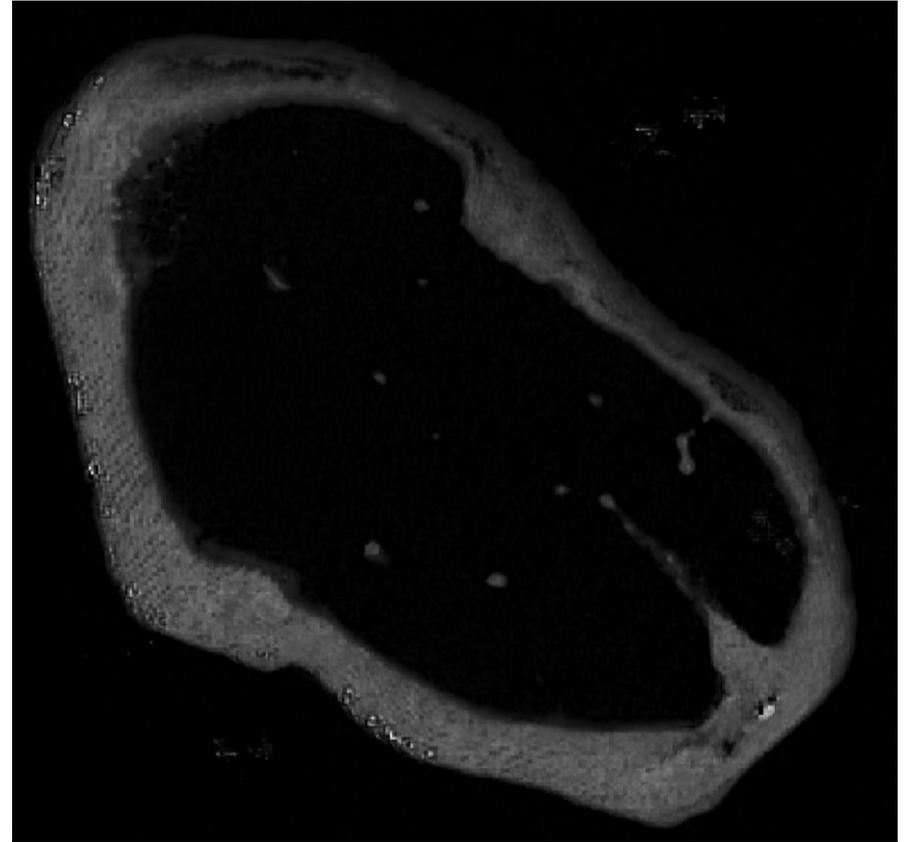


More Chlorophyll-a

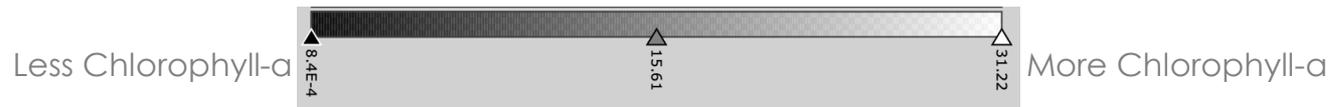
# Royal Captain Shoal: Chlorophyll-a Concentration



April 11, 2016



June 14, 2021



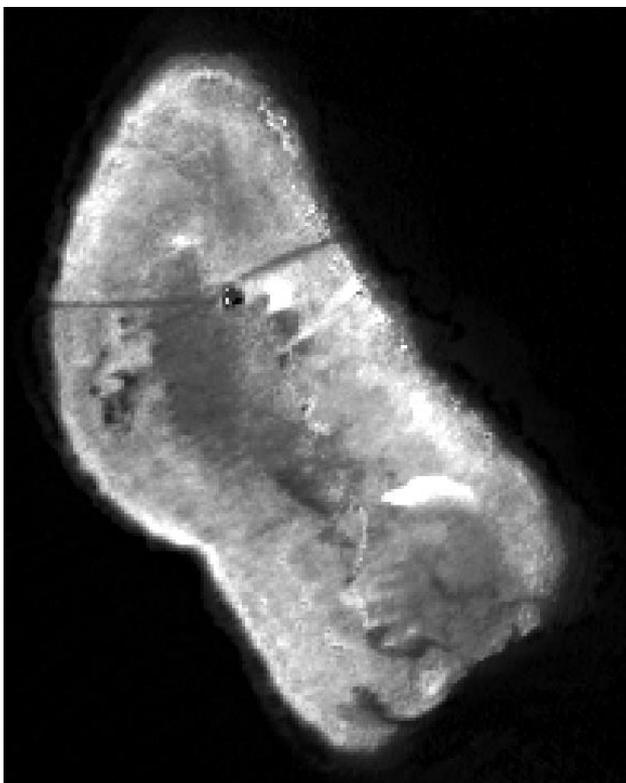
# Collins Reef: Chlorophyll-a Concentration

## Previously Published Grayscale Images



Notice:

- loss of dark areas (where there used to be lack of Chlorophyll-a)
- increasing overall light areas (indicating increased Chlorophyll-a)
- loss of differentiation as plants overtake distinctive reef features



May 14, 2016



June 17, 2021

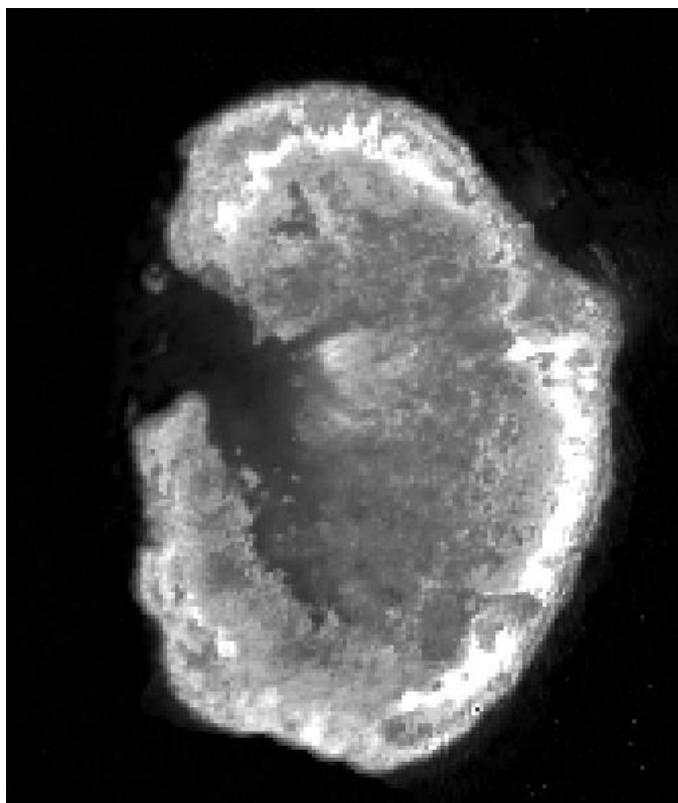
# Ross Reef: Chlorophyll-a Concentration



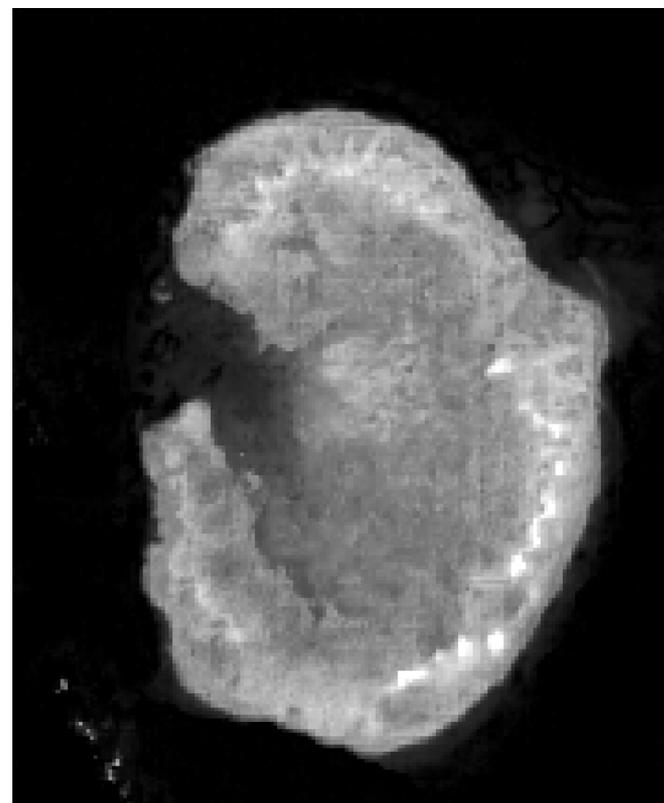
## Previously Published Grayscale Images

Notice:

- loss of dark areas (where there used to be lack of chlorophyll)
- increasing overall light areas (indicating increased chlorophyll)
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May 14, 2016



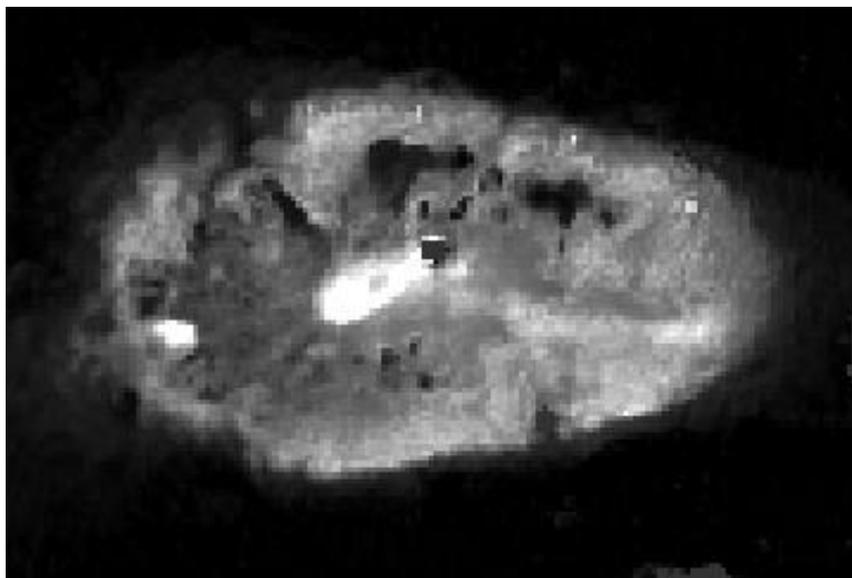
June 17, 2021

## Previously Published Grayscale Images

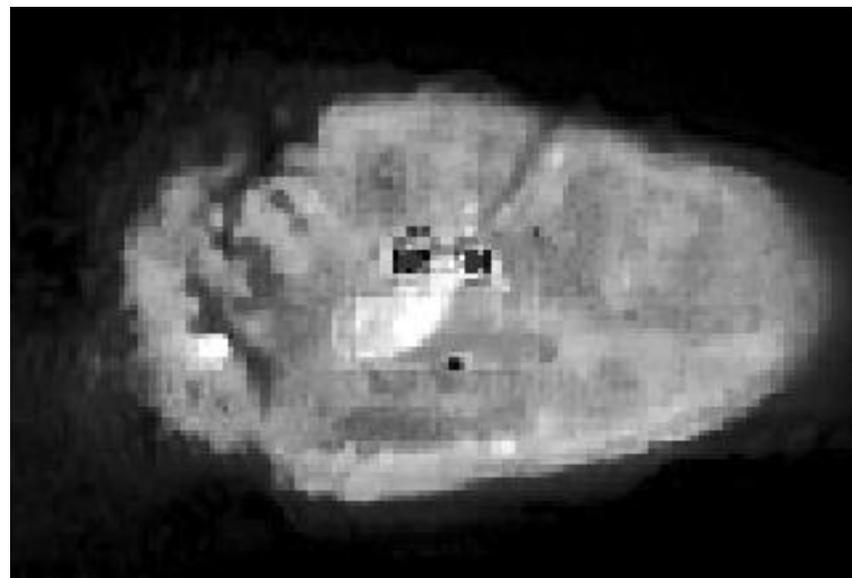


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June 17, 2021

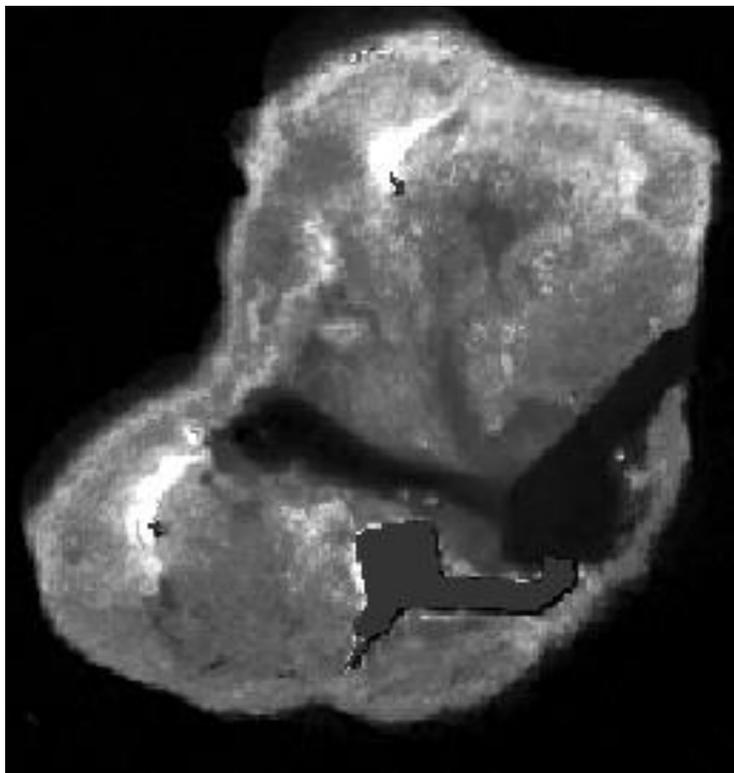
# Hughes Reef: Chlorophyll-a Concentration

## Previously Published Grayscale Images

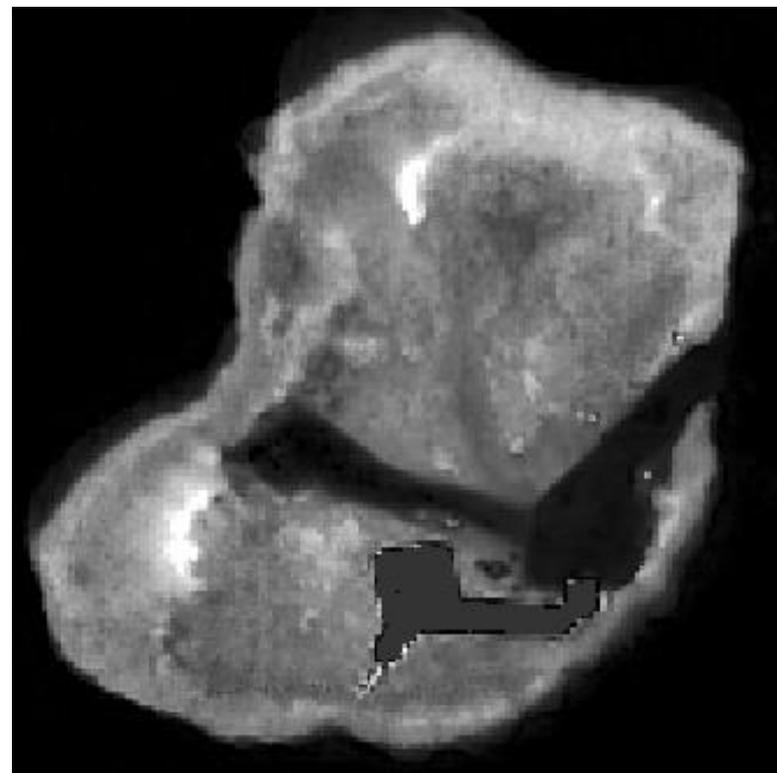


Notice:

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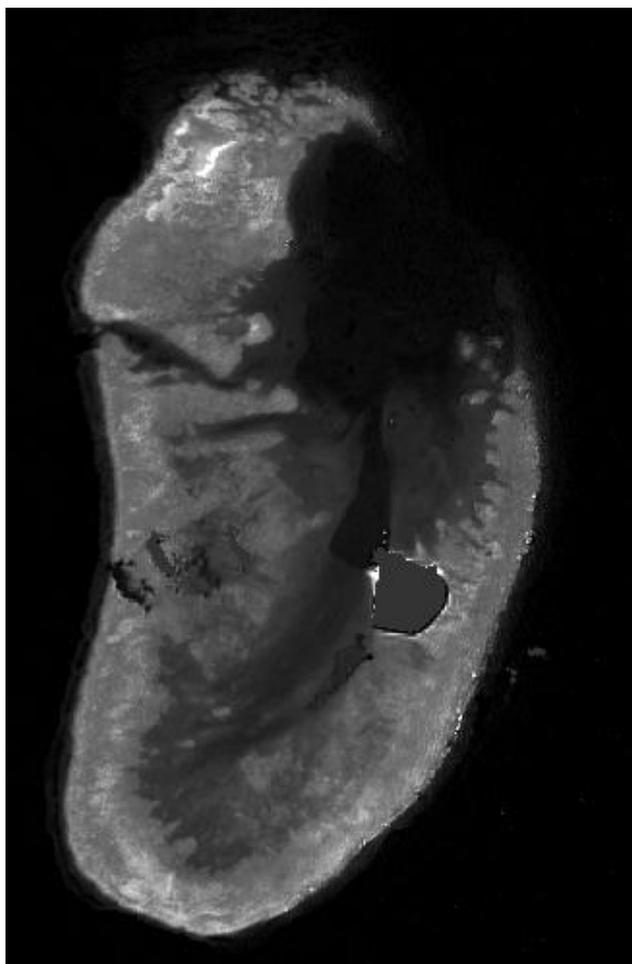


May 14, 2016

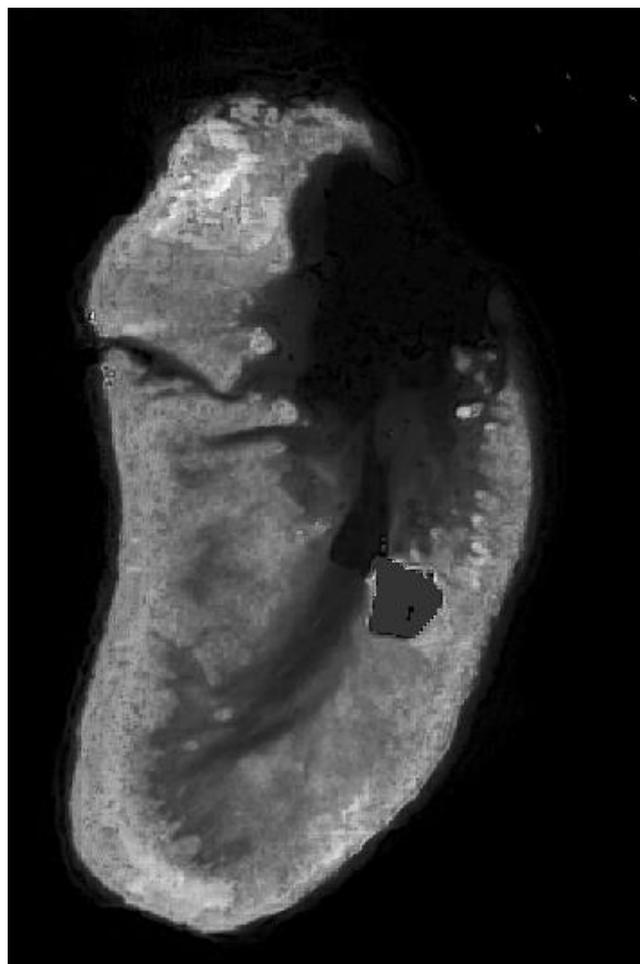


June 17, 2021

## Previously Published Grayscale Images



May 14, 2016



June 17, 2021

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