# Methods of monitoring coral bleaching
Version 1

The method of monitoring coral bleaching from satellite imagery, described below, was replaced by a new method in April 2023. The new method is described on the **Science and Methods page of the Allen Coral Atlas website**.

The monitoring of possible coral bleaching relies upon the initial indication of bleaching threat by marine heatwaves. The National Oceanic and Atmospheric Administration Coral Reef Watch (NOAA-CRW) records daily sea surface temperature (SST) anomalies. These data are used to indicate a level of warning for coral reef bleaching for 214 coral regions around the globe. When a region enters a level of "Bleaching Warning" or higher in the NOAA system, the Allen Coral Atlas initiates processing of Sentinel-2 satellite data for that region on a bi-weekly basis. Conversely, when a region goes from "Warning" or higher to "No Stress" in the NOAA system, the Allen Coral Atlas system stops processing that region.
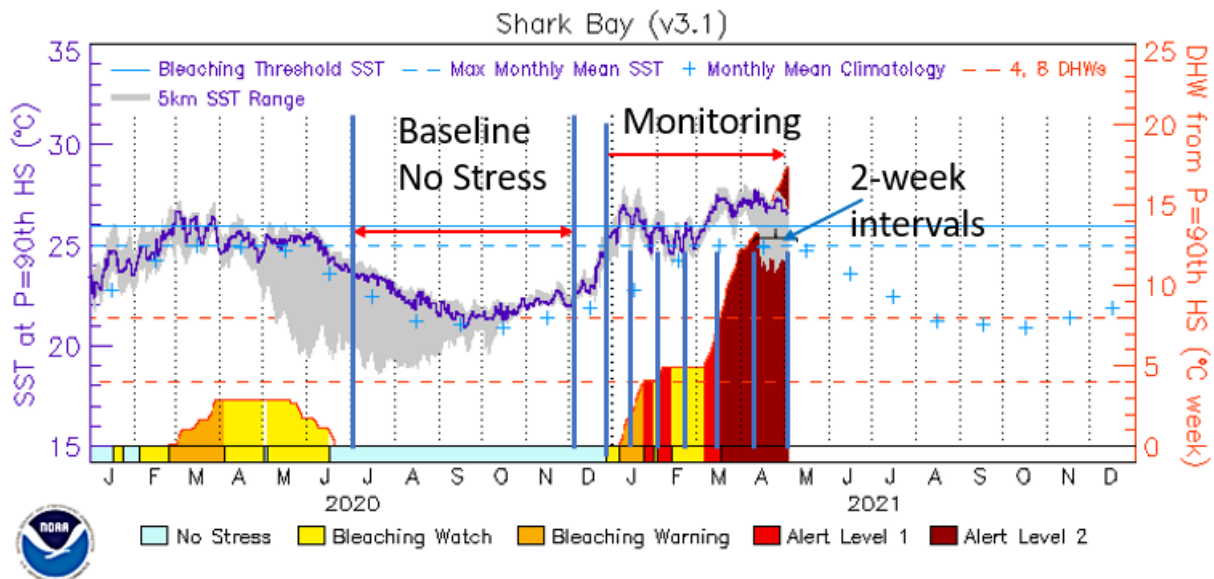
Example of Shark Bay Sea Surface Temperature data.

Methods

To monitor a region that is under a NOAA bleaching alert, we first establish a mean baseline reflectance during a period when the region is not under thermal stress. This is typically during a period of cool water temperatures.   The Sentinel-2 satellite data are masked in Google Earth Engine (GEE) using the QA60 and Scene Classification Map (SCL) bands of Sentinel-2 data to remove pixels with cloud, shadow, and other disturbances.   This collection of image pixels is then processed by using the Mean Reducer in GEE for the baseline period in order to get a clean surface reflectance

image. In addition to the mean surface reflectance, we also calculate the standard deviation of reflectance to indicate the level of natural, non-thermally stressed variation that a pixel may experience prior to the thermal event.

The mean surface reflectance image generated from Sentinel-2 data is then converted to bottom (seafloor) reflectance as described in Li et al. (2020). With this method, we use the depth of the water as an input along with the properties of the water column. The depth data are also derived from the Sentinel-2 imagery as described by Li et al (2021).

For each thermal event, we depend on the use of two images at a bi-weekly time step. The first image is the baseline image created during the NOAA "no stress" period, described earlier. The second image is created by collecting the mean surface reflectance image for a 2-week period after the monitoring starts (Figure 2). We apply the same masking and bottom reflectance algorithms to the Sentinel-2 data for each 2-week period of monitoring. Each bi-weekly mean bottom reflectance is then compared to the bottom reflectance baseline image to identify when a pixel is one standard deviation above the baseline mean. By counting the number of times (i.e., number of 2-week intervals) a pixel is above this threshold, we infer that a brightening of that pixel has occurred (Figure 3).
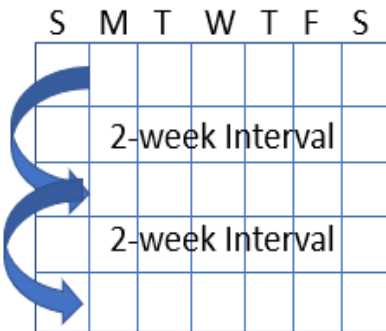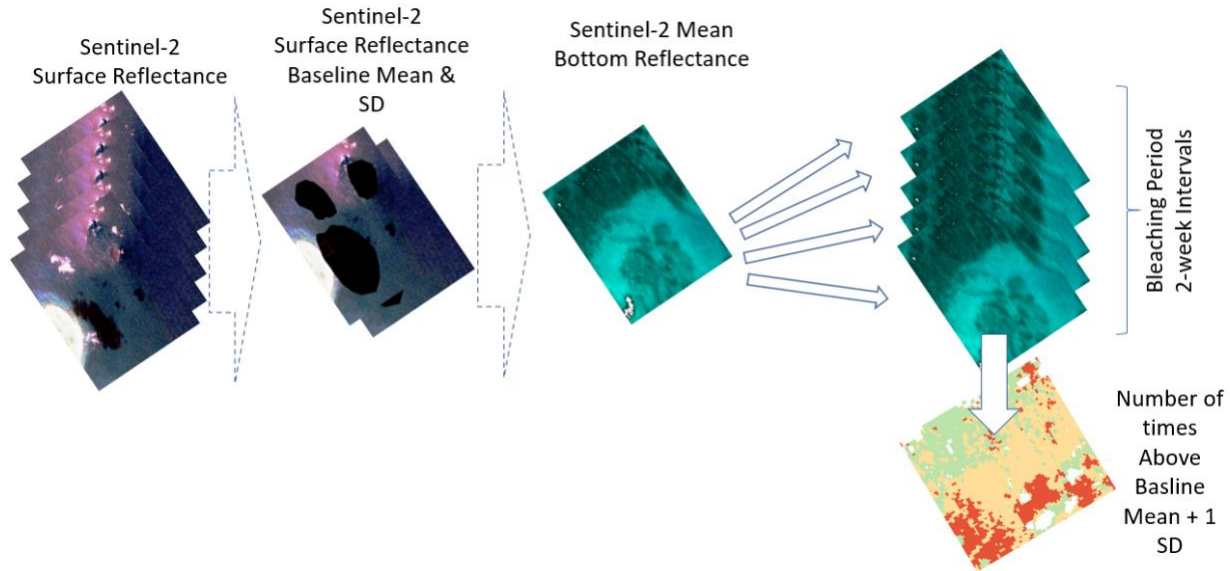

Figure 2.

Figure 3. Flowchart of processing and compilation of bi-weekly data for identifying areas of possible brightening.

The resulting pixel count is masked so that only the pixels in the "coral/algae" benthic class from the Allen Coral Atlas are included. Some areas that are monitored may not yet have a benthic mapping product available to indicate a coral/algae class. In those cases, we use a coral reef extent layer to only monitor pixels that are likely to be over reef areas. However, when an Allen Coral Atlas benthic map product is eventually available for the region, products for that region will be changed to utilize the new benthic map.

The pixel counts are converted to classes of low, moderate, and severe. The pixel counts indicate the number of 2-week intervals that a pixel is brighter than one standard deviation above the mean bottom reflectance from the baseline period. The threshold is set to be fairly conservative and can be adjusted as we receive feedback from observers in the field. Because of the potential for some pixels to be brighter as a result of anomalies that are not caught in the masking steps, we set the interpretation of the values such that a value of two (i.e. 2 two-week periods) will be the lowest value of possible bleaching (Low level of bleaching). As the more two-week periods pass, if the same area continually registers above the threshold, the PV will increase. A value of four is indicative of a Medium level of bleaching and 6 or higher is the most Severe level.

References

1. NOAA Coral Reef Watch. 2021, updated daily. NOAA Coral Reef Watch Version 3.1 Daily 5km Satellite Regional Virtual Station Time Series Data. College Park, Maryland, USA: NOAA Coral Reef Watch. Data set accessed 2021-04-13 at https://coralreefwatch.noaa.gov/product/vs/data.php.
2. Li, J.; Fabina, N.S.; Knapp, D.E.; Asner, G.P. The Sensitivity of Multi-Spectral Satellite Sensors to Benthic Habitat Change. Remote Sens. 2020, 12, 532.
3. Li, J.; Knapp, D.E.; Lyons, M.; Roelfsema, C.; Phinn, S. Schill, S.; Asner, G.P. Automated Global Shallow Water Bathymetry Mapping Using Google Earth Engine. Remote Sens. 2021, 13, 1469.