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Coral Bleaching

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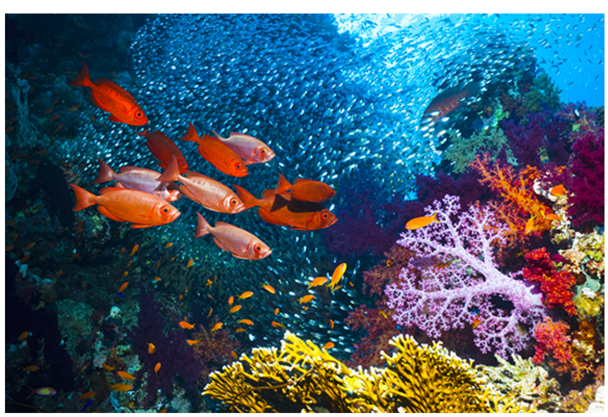
(A) Introduction:

Coral Reefs are one of the most important ecosystems on this planet. Corals not only provide other marine animals with food and shelter, but support local economies, and provide us with food. It's vital to track and maintain corals, to determine whether they are at risk of bleaching or not. This can be mitigated through Citizen Science projects. Such projects allow everyday locals to go out and collect data on their local community in order to create one massive database. However, many people discredit this work, seeing that's it's not done by "professionals."

Background:

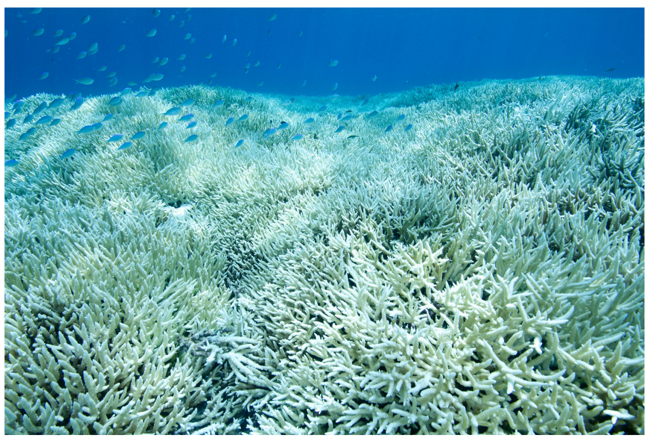
Corals are living animals, made up of single identical polyps, that reside in colonies of thousands, creating a reef. These reefs are symbiotic, meaning they interact with other organisms that live in close physical association. The organisms mutually benefit each other. Within each coral polyp lives a one-celled alga called zooxanthellae. The algae gives off oxygen and other nutrients that the coral polyp needs to live and in return the polyp gives the algae carbon dioxide and other substances the algae needs. That is why coral reefs grow so near the surface of the water where it is the sunniest—the algae need sunshine for photosynthesis, (Texas A&M University).

Figure 1: Coral Reef Image (Author: Unknown)



When corals are stressed by changes in conditions, such as temperature, light, or nutrients, they expel the symbiotic algae living in their tissues, which causes them to turn white, (NOAA.gov). The Great Barrier Reef is the longest and largest coral reef in the world, spanning at 1,400 miles. In 2015, 2 billion corals were recorded in the Great Barrier Reef. In 2016, a massive bleaching event occurred due to heat in the atmosphere warming up the water, which strangled and starved the coral. It was estimated that 1 in 3 corals died within those first 9 months of 2016. Shortly after, in 2017, a second bleaching event occurred, in which 1 in every 2 corals were killed, (Meyer). The heat came from the accumulation of heat trapping pollution in the atmosphere, which raised the world's average temperature, and thus also raised the ocean's temperature. The back-to-back bleaching events in addition to the additional heat made the oceans warmer and thus less hospitable to the tropical corals. In regard to a coral's ability to feed, the heat, caused the polyp to be unable to feed enough off of the algae and other nutrients.

Figure 2: Dead Coral Reef (savingthegreatbarrierreef.org)



On a large scale, the stakeholders in this includes everyone who lives on this planet- including the organisms in the oceans. On a smaller scale, the dying coral reefs will impact the sea life the most. In regards of how this will impact humans, the death will be a huge loss – as much as $375 billion annually- for the local economies along the globe they support. Reefs support local tourism and the commercial fishing industry. They also protect coastlines from flooding during extreme storms, (Worldland).

(B) Data:

The data collected by coralreef.org was and is created by locals who record the color and state of the coral when they dive. It is a Citizen Science project based at the University of Queensland, in Brisbane, Australia. The site is a place to engage non-scientists around the globe to understand and support effective reef management by using engaging tools to provide people with accessible information and hands-on-experience collecting scientific data about the health of corals using the Coral Health Chart. The data collected standardizes the changes in coral colors and provides a simple way for people to quantify coral health and contribute to the global database. The Coral Health Chart is used by dive centers, scientists, school groups and tourists, (Coral Watch).

Figure 3: Coral Watch logo (courtesy of CoralWatch.org)

The question this research attempts to answer is: does the data provided by Coral Watch (a Citizen Science program) coincide with other scientific literature? In other words, how reliable is citizen science data? how predictable is the data that's being researched?

The Coral Watch data comes via a Citizen Science project. Citizen Science allows citizens to partake in a wide range of scientific discovery. Using their technology, such as smartphones, the internet and accessible research technologies to contribute to a broader understanding of a variety of topics. Science relies on observation, and with more people examining the natural phenomena, recording it and sharing the information, we are able to better understand the world, (ecology.com (guest)). It's vital to determine whether the data being collected is predictable and to observe patterns. By looking into the patterns, it's possible to study if another bleaching event is likely to occur- and when.

The second dataset used came from NOAA.gov, through their coral reef watch. Satellite imagery data is taken twice-weekly to provide current reef environmental conditions to quickly identify areas at risk for coral bleaching. The continuous satellite monitoring of the sea surface temperature at global scales among their other tools provides resource managers, scientific researchers, and other coral reef ecosystem stakeholders with tools to understand and better manage the complex interactions leading to coral bleaching. These tools can be used to trigger bleaching response plans and support appropriate management decisions and communication with the public.

Figure 4: NOAA Coral Reef Watch logo (courtesy of NOAA.gov)

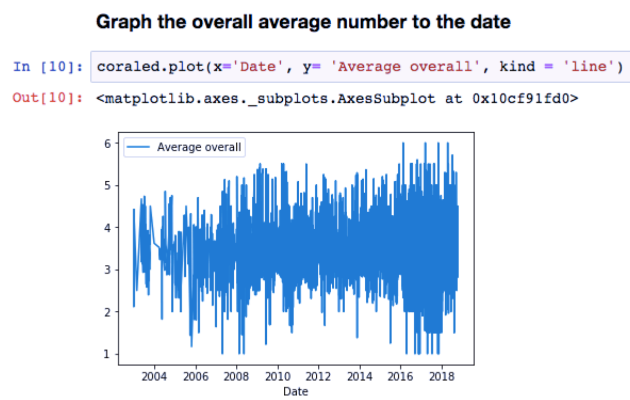
(C) Methods

The original plan of action was to begin pulling smaller CSVs off of Coral Watch's website, and combine them into one large dataframe using Jupyter notebooks. After further email correspondence, I was able to use a large CSV of all of the current data. This dataset contained 15 years' worth of data, spanning from January 2003 up to October 2018. 28 columns were present with the 228,688 rows of data.

After loading the data into Python, I began to toy with it to see what data was there as well as any interesting overall trends I could find. I first narrowed down the 28 columns to 11 of what I believed to be most useful columns: *Date, Water Temperature, Branching, Coral Type, Average lightest, Average darkest, Average overall, Lightest Letter, Lightest Number, Darkest Letter,* *Darkest Number*. I then dropped any data with empty columns, as a way to shorten the amount of rows. With these, I began visualizing the overall impacts of the average's, letters, and numbers.

I first looked at the overall average number trend to see if there was a significant spike or increase anywhere. I noticed there was a slight increase in the overall average, showing slightly higher numbers, meaning more bleached coral as time went on, as well as more data, as more and more people began entering their findings. After toying with this massive amount of data through time and the other specified columns, I continued to find the same slight increase between all of the different columns.

Figure 5: Trend of the Overall Average (Bleaching Number)



At this point in cleaning, I was determining ways to determine the accuracy of the data and attempted to clean up the '*Participating As', 'Reef'* and *'Country'* columns. I started by looking at the different locations and doing a crosstab of the amount of data within each location. Something that came up was deciding between was the validity of each user (the '*Participating As*' column). I noticed that a lot of the data comes from schools and volunteers- which is exciting! The data is great, but I had to decide whether or not it was necessary to validate or cross-check their work versus others such as scientists or biologists. I eventually decided against it due to the lack of details. "Schools" was quite broad for me to determine if that meant an elementary, middle or high school versus a college or university. Volunteers can also be biologists, scientists or even have local knowledge on the subject. Another way I began to look into the data was looking for the "most bleached" data, using their light-dark color scale (coded numerically) and comparing that to the date it was recorded (along with the background research).

My stakeholder suggested researching a few specific coral bleaching events, finding the dates for those (which would help specify the data and thus quicken the pace in Python) and narrow my focus on a more direct target. I chose to focus on data from December of 2015 to December 2017, and only look at 4 columns, *Date, Water Temperature, Average Overall and Coral Type*. With this timeframe, I hoped to analyze whether or not the data showed mass bleaching or not on a smaller scale. Reducing and cleaning the dataset, took longer than expected, as I found a lot of data that was left blank or was gibberish. For the most part, the geolocations seemed on par, and the easier "demographic" based columns were clean, as were the specified columns.

Figure 6: Cleaning the data

```
In [28]: df_nc = narrowed2016corals.dropna(how='any')
         print("There are {0:,} rows of data after dropping, down from the {1:,} originally.".format(len(coraled),len(narrowedcc
         df_nc.head()

There are 214,939 rows of data after dropping, down from the 228,688 originally.

Out[28]:
```

	Date	Water Temperature	Branching	Coral Type	Average lightest	Average darkest	Average overall	Lightest Letter	Lightest Number	Darkest Letter	Darkest Number
24110.0	2017-12-31	29.0	3.0	Boulder	2.33	4.71	3.52	D	2.0	D	5.0
24111.0	2017-12-31	29.0	3.0	Boulder	2.33	4.71	3.52	E	2.0	E	5.0
24112.0	2017-12-31	29.0	3.0	Boulder	2.33	4.71	3.52	B	2.0	B	5.0
24113.0	2017-12-31	29.0	3.0	Soft	2.33	4.71	3.52	C	3.0	C	5.0
24114.0	2017-12-31	29.0	3.0	Boulder	2.33	4.71	3.52	D	3.0	D	5.0

The NOAA data I received came in images (jpeg) and .txt forms, which proved to be more difficult to use. The images came in handy, as it still provided information on the sea surface temperature that was easy to understand. Because of this, I began using panda data frames to analyze the data, to look at the trend between time and water temperature.

Figure 7: A sample coral bleaching watch diagram (courtesy of NOAA.gov)

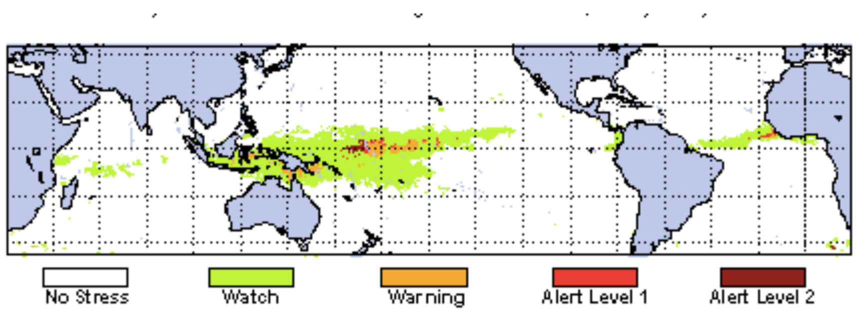
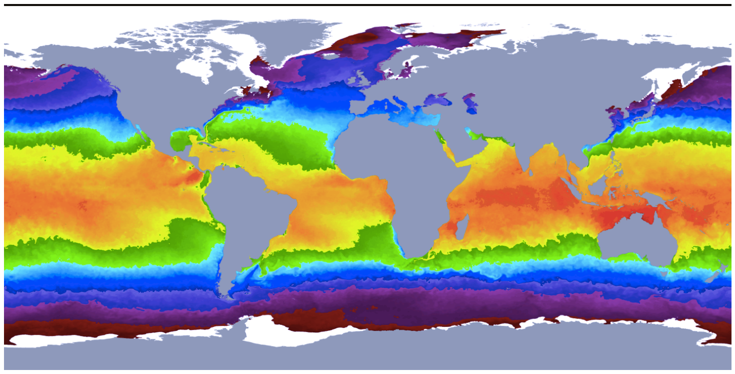


Figure 8: A sample of a NOAA image from March 1, 2016, one of the peak times of the bleaching



With these images, I decided to use a pandas method to search for dates with the highest water temperature. Corals usually reside in water temperatures of around 20-32°C or 68-90°F. There were 345 instances in which the sea temperature was greater than the average 32°C. The highest sea temperature seemed like an outlier, and possibly typed in wrong. A high of 668°C, or 1,234.4°C, was far too high. After further examination, it was found it was an empty placeholder. The next highest recorded sea temperature of 85°C, or 185°F, was recorded 20 times, mostly in September to November of 2016. Surprisingly, there were 1,180 times in February of 2016 and December of 2017 where the sea temperatures became too cold, hitting below 20°C. This could also be a cause of coral bleaching, as the temperature is not the only factor- but the duration (longer than 4 weeks) can cause bleaching, as well.

Figure 9: Determining counts of different water temperatures

```
In [114]: df6 = df_nc[(df_nc['Water Temperature'] == 85)]
          print(df6)

                Date  Water Temperature  Branching Coral Type  Average lightest  \
69873.0 2016-11-19                85.0       11.0     Boulder              2.35
69874.0 2016-11-19                85.0       11.0   Branching              2.35
69875.0 2016-11-19                85.0       11.0   Branching              2.35
69876.0 2016-11-19                85.0       11.0   Branching              2.35
69877.0 2016-11-19                85.0       11.0     Boulder              2.35
69878.0 2016-11-19                85.0       11.0   Branching              2.35
69879.0 2016-11-19                85.0       11.0     Boulder              2.35
69880.0 2016-11-19                85.0       11.0     Boulder              2.35
69881.0 2016-11-19                85.0       11.0   Branching              2.35
69882.0 2016-11-19                85.0       11.0   Branching              2.35
69883.0 2016-11-19                85.0       11.0     Boulder              2.35
69884.0 2016-11-19                85.0       11.0     Boulder              2.35
69885.0 2016-11-19                85.0       11.0   Branching              2.35
69886.0 2016-11-19                85.0       11.0     Boulder              2.35
69887.0 2016-11-19                85.0       11.0   Branching              2.35
69888.0 2016-11-19                85.0       11.0   Branching              2.35
69889.0 2016-11-19                85.0       11.0   Branching              2.35
69890.0 2016-11-19                85.0       11.0   Branching              2.35
69891.0 2016-11-19                85.0       11.0     Boulder              2.35
69892.0 2016-11-19                85.0       11.0     Boulder              2.35
75338.0 2016-09-24                85.0        1.0   Branching              3.50
75339.0 2016-09-24                85.0        1.0     Boulder              3.50
```

(D) Results

Through the analysis methods, the results showed that the Citizen Science data matched up with the images depicted from NOAA's Coral Reef Watch data, and there was a 'coral'-lation between what the two datasets portrayed. Both displayed high amounts of coral bleaching in 2016, and showed an increase in color lightness, average color and varying changes in water temperatures.

A few constraints this dataset held was the location of many of these points. My stakeholder and background research on Coral Watch mentioned that much of this work was done by volunteers and divers, who stayed closer to the shore, meaning that quite a few large bits of the coral sampled was in shallow water or in tourist attractions. Some of the other data, in other highly impacted areas of the oceans weren't recorded as frequently, creating bias. Some other bias that arose came from the realization that many resources for environmental monitoring- the equipment, expertise and money- aren't always evenly distributed around the world, meaning that people who are interested in this research or in coral reefs tend to cluster in areas with more resources, such as Australia.

(E) Next Steps

In the future, the data would be given to other organizations for further analysis or to add on additional data. The Paris Agreement on climate change aims to prevent the world's average temperature from rising by 2 degrees Celsius, 3.6 degrees Fahrenheit. Many countries signed on to the treaty, however the world is not on track to reach their goal, and the United States announced it would leave the treaty, (Meyer). It would be great to share the results with those who can help make a difference on a larger scale in regard to legal standings.

Among this, I would like to see this work go out to local citizens who may not understand what is happening, but also to citizens who are interested in this work. This research also depicts that their contributions, regardless how small do make an impact. Any data collected and entered into the database becomes real-time data *and* real-time analysis for people around the world. If Coral Watch or any other Citizen Science project is in need of a new marketing system, this research can help encourage and validate the idea that regular, or local people *can* participate by going out and collecting data while being as accurate as a scientific data. These projects have a ripple effect, and provide education and awareness, and are extremely important to the issues we are currently battling.

Additionally, it would be great to see this analysis used in inland ocean coalitions, including the CU-chapter of the Colorado Ocean Coalition. Because this topic has such a large number of stakeholders, on both a large and small scale, it's important that people are aware of what is happening to our oceans and reefs. The Great Barrier Reef is not the only reef in this world- others have been lucky and have managed to escape a massive bleaching event- but who is to say whether it will hit them in the next 50 years? It's shown that post-bleaching mortality has disproportionately transformed the assemblage structure and functional diversity of corals on reefs that experienced high levels of bleaching, (Hughes, Kerry and Baird). It's possible that we will lose all of our coral reefs- however, it's also possible that we can prevent this from occurring.

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