Difference in Coral Reef Lagoon Chemistry Between Instances of Isolation

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1 Graphical Abstract

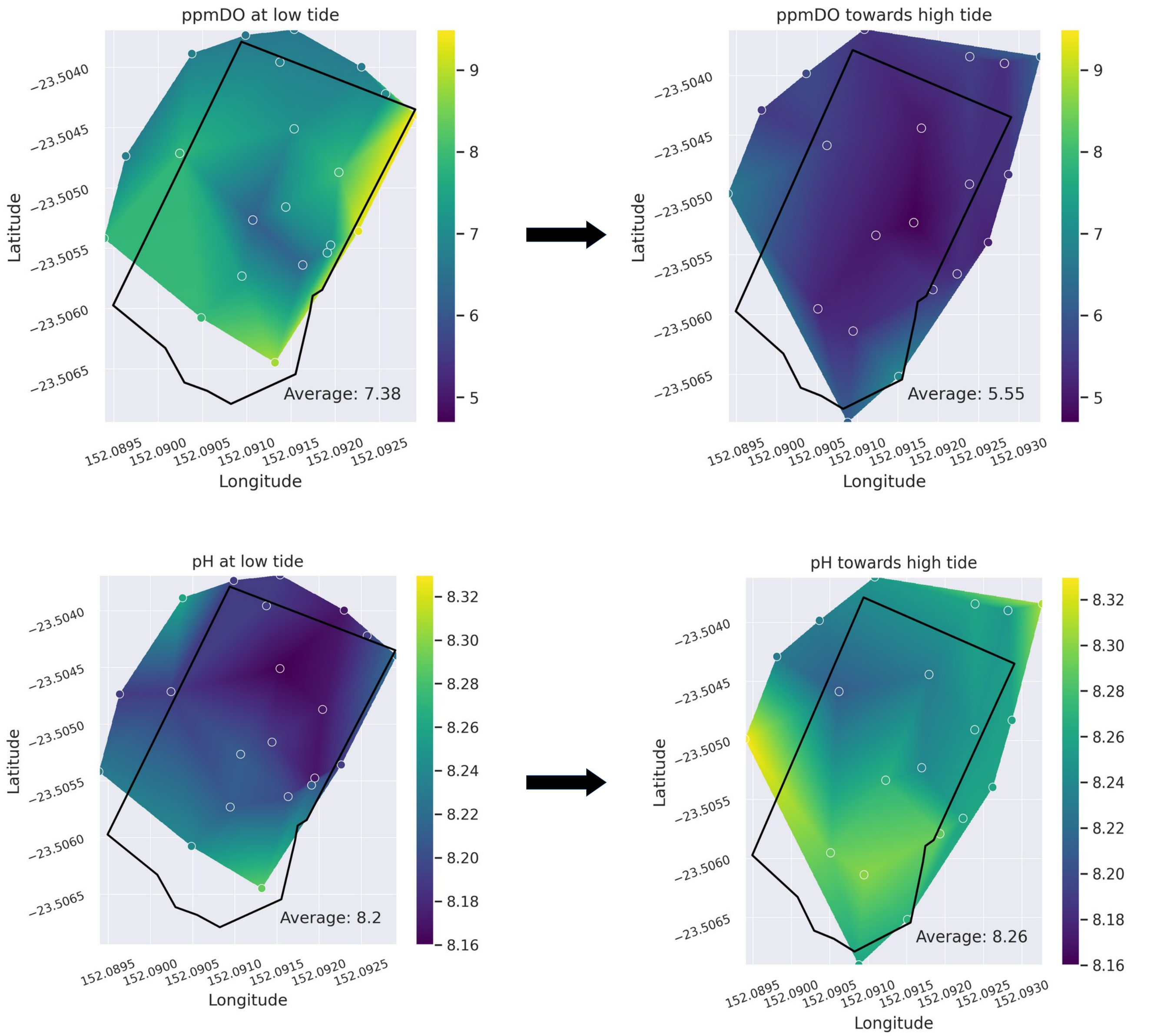

Figure 1: Comparison of levels of dissolved oxygen (DO) and pH at low tide and towards high tide. The coloured circles are representative of the values at measurement sites, while the background represents the linear interpolation between data points to visualize distribution across the study area. We found that ppmDO decreased as the tide came in, while pH increased.

2 Aim

In this study we wanted to investigate variation in the chemistry of the main lagoon at One Tree Island caused by mixing as the isolated lagoon experienced inflow from the ocean between low and high tide. An indicative understanding of this mixing can be derived by comparing a spatial distribution of chemical properties in the lagoon at low tide and half way towards high tide. As no distributions were extant, in this report we create these distributions for comparison and conduct a visual comparison.

3 Introduction

3.1 Motivation

Coral reef ecosystems are being threatened by increased temperature and changes in ocean chemistry attributable to climate change (Lesser, 2007). Coral bleaching occurs when extreme temperatures lead to the breakdown of the symbiotic relationship between coral polyps and zooxanthellae (NOAA, 2021). The exact temperature at which coral bleaching occurs can be referred to as the “thermal tolerance” of the coral symbiosis. This thermal tolerance is influenced by the chemistry of water present in the system. De-oxygenation of ocean water can decrease thermal threshold of bleaching events by up to 1°C (Alderdice et al., 2022). Increased acidity in ocean water may inhibit photosynthesis by zooxanthellae and thus disrupt the symbiotic relationship, reducing the thermal threshold of bleaching (Anthony et al., 2008). Ocean acidification is of additional concern as it inhibits the growth of coral as the energy required to calcify is increased, sufficiently low pH may cause coral skeletons to dissolve (NOAA, 2020). Understanding the variation of these factors over shorter tidal timescales may inform reef sustainment efforts.

One Tree Island serves as a valuable case study for understanding the changes in coral reef chemistry that occur between low and high tide. The lagoon on the island is isolated from the ocean during low tide, and experiences inflow of ocean water towards high tide. The isolation of the lagoon during low tide allows for the measurement of changes in water chemistry due to photosynthesis and other processes that occur within the lagoon, while the inflow of ocean water during high tide provides a contrast for comparing to the local ocean chemistry. This information can provide insight into the short-term variations of ocean chemistry that occur on coral reef ecosystems.

3.2 Experimental Outline

We investigated the tidal and spatial variations of lagoon chemistry by taking samples of an area adjacent to lagoon inflow (the gutter) at One Tree Island near low tide and approximately halfway between low and high tide. Two datasets were created using measurements of pH and dissolved oxygen. Digital analysis was conducted to compare these datasets.

3.3 Expected Outcomes

It is expected that the recorded levels of dissolved oxygen should decrease towards high tide. As measurements for low tide were taken at 10 am, the lagoon should be saturated with oxygen as the large quantities of zooxanthellae will be performing photosynthesis to produce oxygen. Ocean water may contain lower quantities of dissolved oxygen on average (Hwb, 2023), thus as the ocean water flows in towards high tide the levels of dissolved oxygen should decrease.

We similarly expect that pH measurements should increase as the tide brings in ocean water. At low tide, the high level of photosynthesis should be removing CO_2 from the water. This reduction in CO_2 should drive a dissociation of HCO_2 back into H and CO_2. Acidity levels will decrease and pH will go up accordingly. Following this, we expect that ocean water should on average be less acidic due to lower photosynthesis activity and thus an inflow of ocean water should reduce acidity.

We expect ocean mixing to be strongest right next to the gutter, where inflow of ocean water is happening. The change in chemistry should be visibly stronger at the mouth of the gutter as this is where the inflow is happening and thus the highest concentration of ocean water should occur.

4 Method

4.1 Field Work

It was desirable to collect samples from the main lagoon at One Tree Island as it experiences an isolation from the ocean at low tide. As it was not feasible to collect a distribution of samples across the entirety of the lagoon with the resourcing available, a sample site was selected adjacent to the inlet of exchange between the lagoon and the ocean Figure 2.

Figure 2: Sample site (outlined in red) in relation to One Tree Island. The gutter (inflow and outflow to the ocean) is clearly visible to the right of the study area.

The researcher then procured a kayak, a GPS device, a HANNA HI 9829 Multiparameter probe, and an assistant to raise the alarm in the event of danger. The kayak was used to paddle to the location of each individual measurement. Each individual measurement was captured by marking a GPS coordinate, and taking a record of probe readings. The first set of measurements was taken at approximately 10 am, which was 45 minutes after low tide. The second set of measurements was taken at approximately 2pm, which was about halfway between tidal extremes. An imperfect coverage of the area was achieved by monitoring the current GPS track against the study site while kayaking; it is visible in Figure 3 that the sampled points adequately covered the selected study site. There were 21 successful measurements at 10am and 20 successful measurements at 2pm.

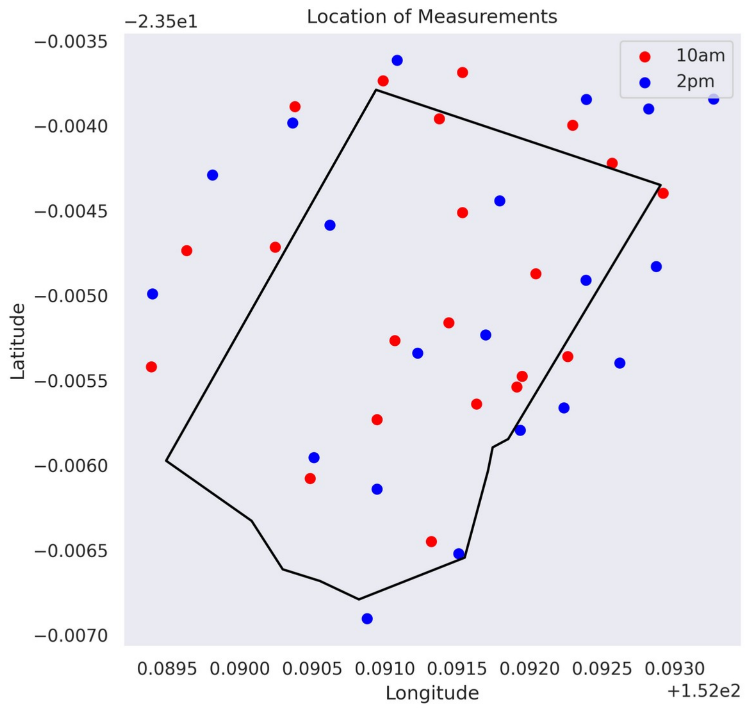

Figure 3: Comparison between study site (outlined in black) and location of recorded measurements.

4.2 Data Processing

Each probe measurement was manually transcribed into digital format and then joined with location data recorded using the GPS device, providing us with a dataset of all measurements taken. This data was then split into two distinct datasets, one for measurements taken at 10am and one for measurements taken at 2pm. For each measurement type, a linear interpolation was performed for the low tide and halfway tide datasets to visualise the properties of the water over the study area. These interpolations could then be compared to infer the impact of tidal change on the lagoon. An average of all points for each dataset was also calculated to provide a numerical comparison (Figure 1).

5 Results

From Figure 1 it is apparent that measurements of dissolved oxygen lowered and lagoon pH has increased as water from the ocean has flowed in. Observed levels of dissolved oxygen decreased by 1.8ppm and the observed pH increased by 0.06pH. This is partially in line with our original expectations, as we expected dissolved oxygen to decrease but did not expect pH to increase. It is also worth noting that there is no notable difference in magnitude of change directly at the mouth of the gutter, as expected.

6 Discussion

6.1 Impact of Tidal Exchange

Our results for this experiment were not in line with our expectations. We were unable to discern that ocean mixing was strongest right next to the gutter. It was expected that relative to the open ocean, oxygen levels in the isolated lagoon should increase due to high levels of photosynthesis. Requisitely it was assumed that high levels of photosynthesis would reduce levels of carbonic acid in the water, increasing the pH relative to the ocean. While dissolved oxygen increased, the lagoon actually became more acidic as the ocean water flowed in. We were unable to come up with an explanation for this. This indicates that there may be limitations in our methodology, making it difficult to derive a strong conclusion.

6.2 Limitations

A possible limitation in this experiment was high levels of rainfall at One Tree Island in the days before the experiment. This large influx of fresh water and run off from the coral cay into the lagoon system may have substantially lowered the pH of the lagoon prior to measuring the system at low tide (Fondriest Environmental, 2013b). This is in line with the decrease in dissolved oxygen towards high tide as salt water typically holds less dissolved oxygen than fresh water, mirroring the salty ocean water containing less dissolved oxygen than the possibly fresher lagoon water(Fondriest Environmental, 2013a). If the readings were taken in more favourable conditions, we may have observed a higher pH at low tide due to photosynthetic production.

Another constraint on the conclusions drawn from this experiment was the limited number of repeats possible. Additional samples would have illustrated longer term trends the chemistry of the lagoon system. Each collection was quite intensive as it required the researcher to row to 20 locations and take individual measurements at each site. The researcher had quite limited time on the island due to other commitments and lag time in deriving a project idea. Future research should consider alternative methods to increase the efficiency of taking measurements, potentially allowing for higher resolution and longer-term data.

The limited spatial extent of the study site possibly limited the ability to observe varying changes in chemistry over spatial variation. If the study site could be expanded to the whole lagoon it may be possible to observe stronger mixing at the inflow Future research could consider planting many automated probes throughout the lagoon to generate a larger dataset with better temporal resolution.

A possible erroneous technique to establish a consistent depth for each measurement may have impacted the quality of our data. Each measurement was taken approximately 1.5 metres below the water’s surface. Towards hight tide, this method may have only captured the top level where ocean water has flowed in, and may have failed to capture the properties of water where mixing has occurred deeper down. Future research may consider employing techniques to ensure measurements are taken at the level of mixing.

7 Conclusion

In conclusion, this study aimed to investigate the variation in the chemistry of the main lagoon at One Tree Island as the isolated lagoon experienced mixing from the ocean between low and high tide. We successfully constructed datasets of chemical properties distributed spatially through the lagoon in the lagoon at low tide and half way towards high tide. We found that dissolved oxygen levels decreased and pH levels increased as the tide brought in ocean water. These findings do not support our expected outcomes as we expected pH to decrease with oxygen levels. It is also not readily apparent that mixing is stronger at the mouth of the gutter. Future research should aim to address limitations in our experiment by taking more repeats over a longer period of time, taking measurements at the level of mixing, increasing the spatial extent of the study area, and considering factors such as rainfall and run off.

8 References

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