

**THE TALE OF TWO TIDEPOOLS: EXAMINING CARBONATE CHEMISTRY
IN THE INTERTIDAL**

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Abstract

Tidepools are a prominent feature of the intertidal zone, housing a great diversity of both macroalgae and mobile animal components. Tidepool organisms are exposed to wide variations in temperature, salinity, and pH over the course of the low tide. As of yet, very few studies have quantified the changes in carbonate chemistry in tidepools. The objective of this study was to quantify the changes in carbonate chemistry in tidepools over the course of three consecutive low tides and to determine if biological additions would alter the degree of change in carbonate parameters occurring over the course of the low tide. The carbonate chemistry in the tidepools we surveyed underwent drastic changes over the course of the low tide. With increasing isolation time, the total alkalinity and dissolved inorganic carbon decreased, and the pH increased. However, no signal from the addition of *Ulva sp.* or *Mytilus trossulus* was detected in this study.

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Introduction

Tidepools contain dynamic assemblages of organisms. Organisms living in intertidal tidepools must endure wide variations in physical factors such as light, temperature, and pH. The biotic component of tidepools is likely determined by physiological responses to physical factors in the tidepool. The most important physical factor affecting the composition of tidepools is tidal height, however, other physical factors such as temperature, salinity, light, depth and pH also influence the biota found in tidepools (Klugh 1924).

The biological component of tidepools can alter the overall chemistry of the pool. At night, respiration by organisms releases carbon dioxide, thereby increasing total carbon content of the seawater medium (Trouchot and Duhamel 1980). During the daylight hours, photosynthesis overcomes respiration and consumes carbon dioxide (and releases oxygen), which reduces the amount of dissolved inorganic carbon. However, photosynthesis of algae is inhibited at high O_2 levels (Warburg effect), especially when little CO_2 is available which may occur in tidepools with a high abundance of algae (Truchot and Duhamel 1980).

Algae can use either HCO_3^- or dissolved CO_2 as the carbon substrate for photosynthesis and the preferred carbon species used for photosynthesis depends on the species of algae. Whether algae use HCO_3^- or dissolved CO_2 , the chemistry of the tidepool is altered. They are pulling carbon from the seawater medium, thereby, lowering the total dissolved inorganic carbon (DIC). Photosynthetic processes and calcification can also alter the total alkalinity in a tidepool. As organisms calcify, they remove CO_3^{2-} from the seawater medium resulting in a decrease in total alkalinity.

In this study we explored how the carbonate chemistry of two tidepools changed over the course of the low tide. We asked 1.) How do parameters of carbonate chemistry such as total alkalinity, total dissolved inorganic carbon, and pH change over the course of a low tide in two pools with naturally occurring biota and 2.) Do these carbonate parameters change with additions photosynthesizing and respiring organisms?

Methods

Study Site

Two rock tidal pools with similar tidal heights and relatively similar biota were selected in July of 2011 at Dead Man's Cove on San Juan Island, WA (N 48°30.837, W123°08.763, figure 1). Using a meter stick, volume was based on rough estimates of surface area and average depth. Tidal height was determined by using a stadia rod and a hand level and was the main factor used to select the pools in order to control for variation due to tidal height as much as possible. With respect to tidal height, pools in the *Fucus* zone were chosen; thus the pools would be exposed for a large portion of the low tide and potentially increase the chance of detecting extreme variation. Abundance of macroalgal flora was determined as percent cover by species and estimates of animal abundance were obtained by using the semi-quantitative scale: present/absent (none/1), few (< 10), abundant (< 50), and many (50+) (table 1).



Figure 1: Location of sampling sites in Dead Man's Cove, San Juan Island, WA (N 48°30.837, W123°08.763). An X marks an approximate location of the two tidepools, and

the location in the strait where samples were collected.

Quantifying Chemical composition over a tidal cycle

Samples (500 ml) for carbonate chemistry were obtained from each pool at four time points during the tidal cycle: immediately after isolation from sound waters (time zero), 2 hours, 4 hours and right as sound waters were beginning to enter into the pools. A sample of water from the Haro Strait (located > 100 m from the tide pools within the cove) was also taken at the beginning and end of the tidal cycle in order to characterize the extent of physical and chemical fluctuations tidal pool biota likely experience relative to the Strait. Samples were collected using a modified version (a rubber stopper with an air hole and tygon tubing running from the top of the stopper to the bottom of a Schott Duran borosilicate glass bottle) of the dissolved oxygen collecting device described in Daniel (1975) in order to minimize gas exchange and perturbation of the chemistry. Samples were poisoned with mercuric chloride at the time of collection and stored according to the protocols described by Dickson et al. (2007) until analyzed.

On day 1 and 3 tide pool measurements were taken every hour during tidal exposure: temperature, salinity, and dissolved oxygen. On day 2, measurements were limited to temperature only due to equipment constraints (salinity meter info, temperature probe info). Additionally, we placed temperature tidbits (OnSet) in the tide pools to record temperature while the tide pools were exposed.

Samples were analyzed in the lab for total alkalinity, dissolved inorganic carbon (DIC), and pH (Dickson et al. 2007). DIC was measured using a Licor infra-red analyzer and total alkalinity was measured with an Agilent automatic titrator (model 34970). pH was measured using an Ocean Optics spectrophotometer with 10 cm pathlength optical

cells following the methods of Dickson et al. (2007). As preliminary measurements of tidepool pH exhibited high pH values, we utilized two different dyes to measure pH. *m*-cresol purple can provide an accurate pH over the range of 7.4 to 8.2 (Dickson et al. 2007) whereas thymol blue as been reported to provide more accurate pH measurements for pH values > 8.0 (Zhang and Byrne 1996).

A $8 \times 10^{-1} \text{ mol dm}^{-3}$ solution of thymol blue was mixed in 10% ethanol, and 90% water under heat. To aid the dye in dissolution, 600 μ L of NaOH was added while heating the dye. The pH of each sample was determined on the spectrophotometer according to the procedure outlined by Zhang and Byrne (1996).

To check the accuracy of the measured pH values, we calculated pH at 25°C in CO2Calc using the constants for Lueker et al. (2000), Dickson (1990b), and Wanninkhof (1992). These calculated values were closest to the *m*-cresol purple values. However, as *m*-cresol purple is not reported to be accurate above a pH of 8.2, we used the CO2Calc pH values in our analysis after they were corrected for sample temperature and reported on the total H⁺ scale (mol kg⁻¹ SW). See Figure 2 for differences in calculated pH values and those determined by *m*-Cresol purple and thymol blue.

Values from these machines were checked for precision and accuracy with Certified Reference Materials (CRM, Batch 111, A_T = 2222.8 μ mol kg⁻¹ DIC = 2045.7 μ mol kg⁻¹, A. Dickson, Scripps Institute of Oceanography).

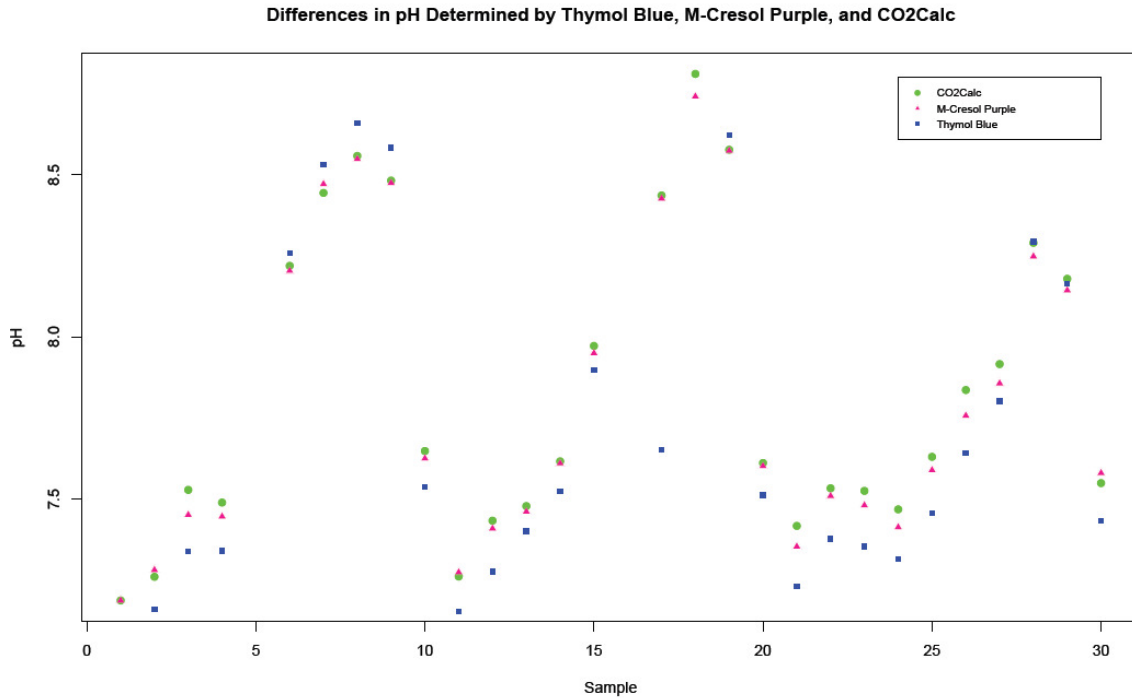


Figure 2: Differences in pH as determined spectrophotometrically by thmol blue and m-Cresol purple. Calculated pH values were calculated from CO2 calc using DIC and total alkalinity

Tidepool Manipulations

In order to better understand the relative contributions of photosynthesizing and respiring organisms, we added organisms to one of the tide pools on day 2 and day 3. Organisms were added to the smaller tidepool of the two in order to increase the likelihood of detecting a signal. This tidepool will be referred to as the ‘treatment’ pool and the unmanipulated pool will be referred to as the ‘reference’ pool. On day one, both tidepools were sampled without addition of any biota. On day two, 1.042 m² of *Ulva* sp. were added at time zero to the small tide pool and removed after the last sample. (See appendix for methods used to determine the surface area of *Ulva* sp.). Mussels used for day three were collected from the dock at Argyle Creek (48°31’09.92”N 123°00’47.68”W) six days prior to the start of the experiment. *M. trossulus* were brought

back to Friday Harbor labs where all encrusting biota were removed. Buoyant weight was determined 24 hours prior to addition of mussels by suspending mussels in seawater from a bottom-loading balance (Davies 1989). Mussels were maintained in a seawater table until addition to the pools. On day three, 278.1 g (buoyant weight) of *M. trossulus* were added throughout the small tide pool at time zero and then removed after the last sample.

Normalization of Data to the Reference Pool

The chemistry of the tidepool is expected to change on the different days due to confounding factors such as precipitation, light, and temperature. However, the difference between the reference and treatment pool is assumed not to change due to these confounding factors. Because of this assumption, we used the ratio of the difference between the reference pool and the treatment pool on the treatment day (day 1 and day 2) to the difference on the unmanipulated day (day 1) to detect any changes from the addition of biota.

$$\frac{\text{Treatment}_{\text{addition}} - \text{Reference}_{\text{addition}}}{\text{Treatment}_{\text{unmanipulated}} - \text{Reference}_{\text{unmanipulated}}}$$

If there was no difference between the addition day and the treatment day, the ratio will be one. If the treatment pool has a larger value in comparison to the reference pool, then the normalization value is positive. If the treatment pool has a smaller value in comparison to the reference pool, then the normalization value is negative.

Results

Physical characters of study site

Although the light irradiance at the study site may have been slightly different, the light irradiances from the weather station at Friday Harbor Laboratories were used to quantify available light at our study site (Figure 3). There were differences in light irradiance between the three sampling days, with day one and day two reaching approximately 900 W/m^2 . However, the light irradiance on day one was higher earlier in the sampling period as compared to day 2. On day 3, the light irradiance was lower overall, and only reached a maximum of approximately 450 W/m^2 .

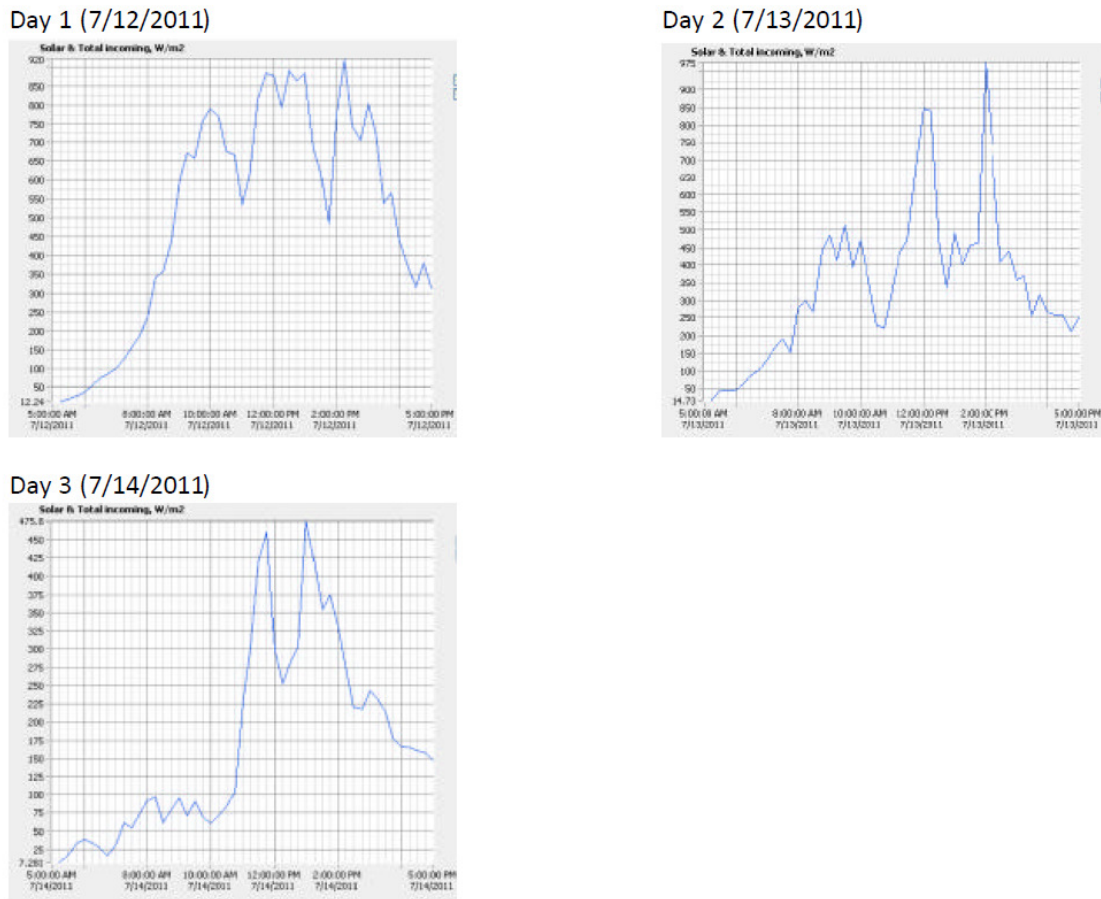


Figure 3: Available irradiance (W/m^2) at Friday Harbor Laboratories on sampling days

There was an increasing tidal exchange over the course of the three sampling days (figure 4). The greatest tidal exchange occurred on the third sampling day, and so, on this

day the study pools were isolated for a greater period of time. The reference pool had a volume of 0.41 m^3 while the treatment pool's volume was 0.10 m^3 .

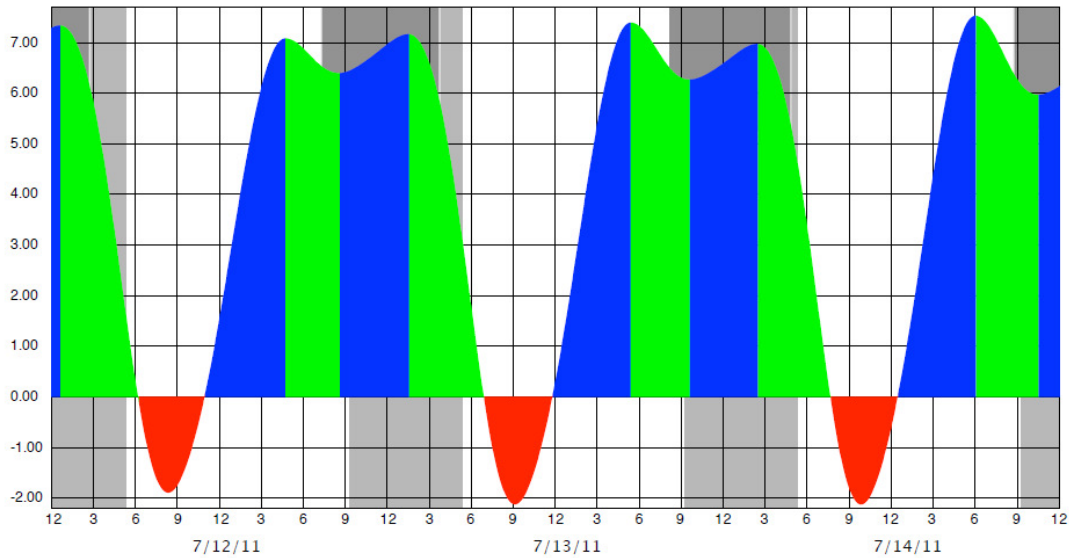


Figure 4: Tidal cycle during sampling days

Temperature in both tidepools increased throughout the low tide (figure 5). On day 1, temperatures in the tidepools increased the most, due to higher light irradiance on this day. The reference tidepool heated up more than the treatment tidepool during the low tide.

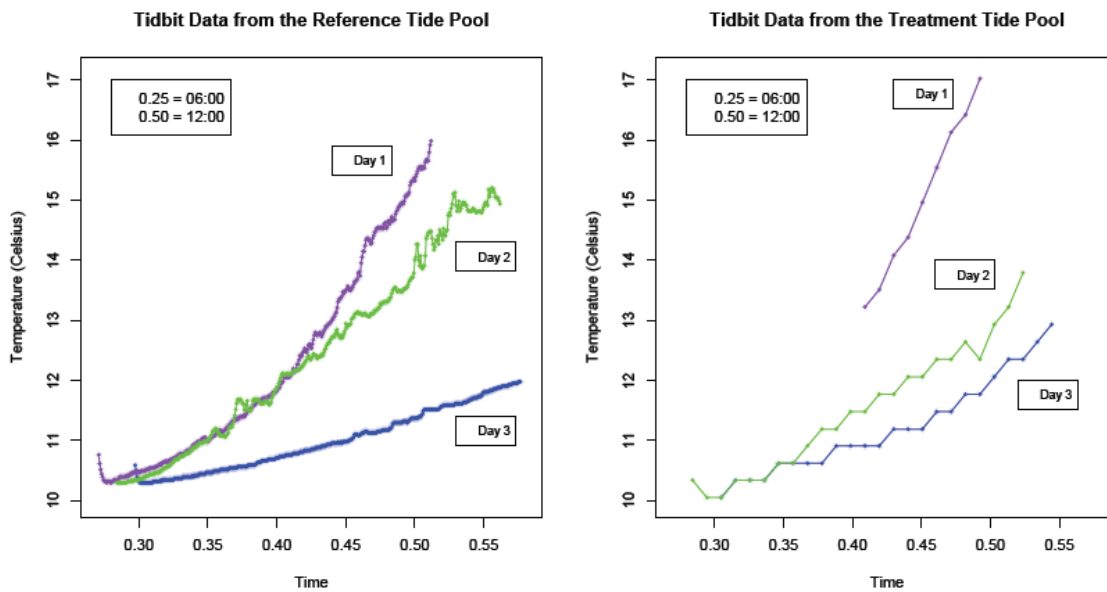


Figure 5: Temperature data from the two tidepools over the sampling period on the three sampling days. 0.25 is 6:00 am and 0.50 is 12pm. Day 1 is the unmanipulated day, Day 2 is the *Ulva sp.* addition day, Day 3 is the *Mytilus* addition day. Additions were only made to the Treatment Pool.

The treatment and reference tidepool had different mobile animal compositions (Table 1). The treatment tidepool was dominated by hermit crabs and limpets while the treatment tidepool was dominated by sculpins and *Nucella*.

Table 1: Mobile animal abundance in each tide pool (Few = <10, Many = 10-50, Abundant = >50).

Tidepool	Present	Few	Many	Abundant
Reference		chiton spp., <i>Semibalanus cariosus</i> , amphipod spp., <i>Calliostoma spp.</i> , <i>Littorina sitkana</i> , <i>Nucella spp.</i>		Medium and large <i>Pagarus spp.</i> , <i>Lottia spp.</i> (at least 2 different kinds)
Treatment	nemertean worm, <i>Katharina tunicata</i>	<i>Hemigrapsus nudus</i>	<i>Littorina sitkana</i> , small <i>Pagarus spp.</i> , <i>Spirorbidae spp.</i> , limpet	<i>Oligocottus maculosus</i> , <i>Nucella</i>

The algal composition of the two tidepools was similar, i.e. they were both dominated by articulated coralline species. However, the reference tidepool had a larger percentage cover of these articulated coralline species and of *Odonthalia floccosa* than did the treatment tidepool. Overall, the reference tidepool had a greater biomass and percentage cover of algal species than did the treatment tidepool.

Table 2: Algal composition of the two tidepools. Percent cover determined by visual estimation.

Tidepool	Species	Percent Cover
Treatment	Crustose coralline	40%
	<i>Corallina vancouveriensis</i> and <i>Bossiella plumosa</i> .	35%
	<i>Ulva sp.</i>	15%
	<i>Polysiphonia sp.</i>	<1%
	<i>Porphyra sp.</i>	<1%
	<i>Fucus distichus i.</i>	<1%
	<i>Saccharina sessilis</i>	<1%
	<i>Hallosaccion glandiforme</i>	<1%
	<i>Microcladia coulteri</i>	<1%
	<i>Odonthalia floccosa</i>	<1%
Reference	Crustose coralline	10%
	<i>Corallina vancouveriensis</i> and <i>Bossiella plumosa</i>	55%
	<i>Fucus distichus. (loose)</i>	5%
	<i>Odonthalia floccosa</i>	30%
	<i>Prionitis lanceolata</i>	<5%
	<i>Leathesia marina</i>	<5%
	<i>Soranthera ulvoidea</i>	<1%

Chemical Characterization of Tidepools

Total alkalinity decreased over the course of the low tide in both the reference tidepool and in the treatment tidepool (figure 6). The total alkalinity in Haro Strait also decreased over the course of the sampling period, however, this decrease was less pronounced than the decrease observed in the tidepools (figure 6). In the reference pool, the amount that total alkalinity decreased was variable between the three sampling days. In the treatment pool, total alkalinity decreased the most on the day in which no manipulations were performed and the least on the day in which mussels were added. There was not a obvious signal detected in the treatment pool due to additions of either *Ulva sp.* or mussels.

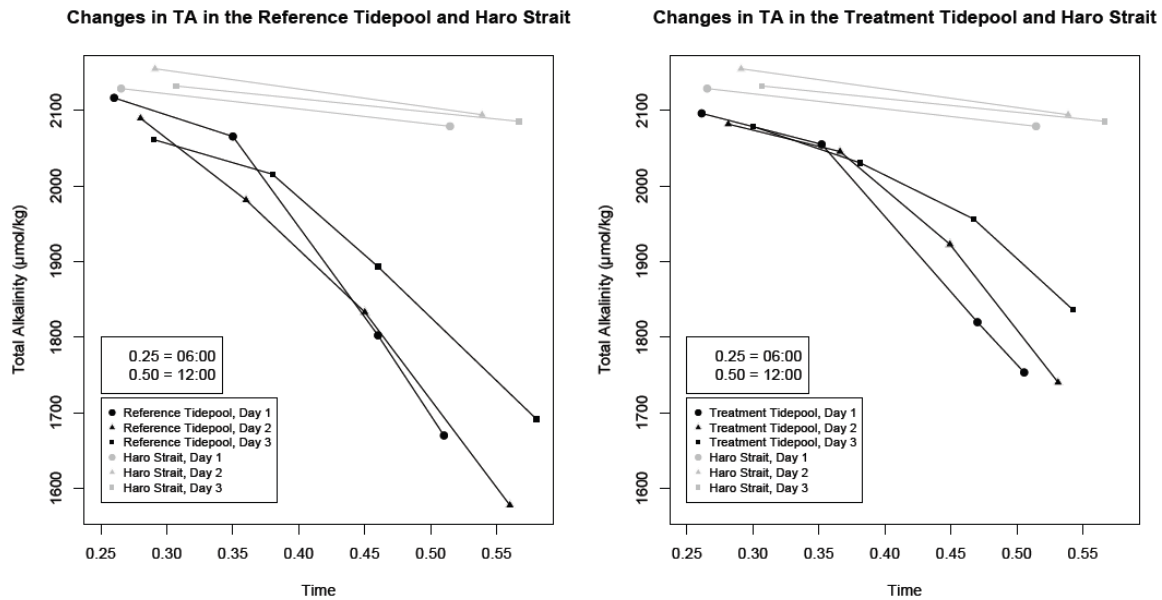


Figure 6: Observed changes in total alkalinity over the three sampling days in the reference tidepool and the treatment tidepool with baseline Haro Strait values.

There was a large amount in variability in the normalization data for total alkalinity. Day 2 exhibited higher variability between timepoints than did day 3, however, it is not clear that the biological inputs were necessarily the cause.

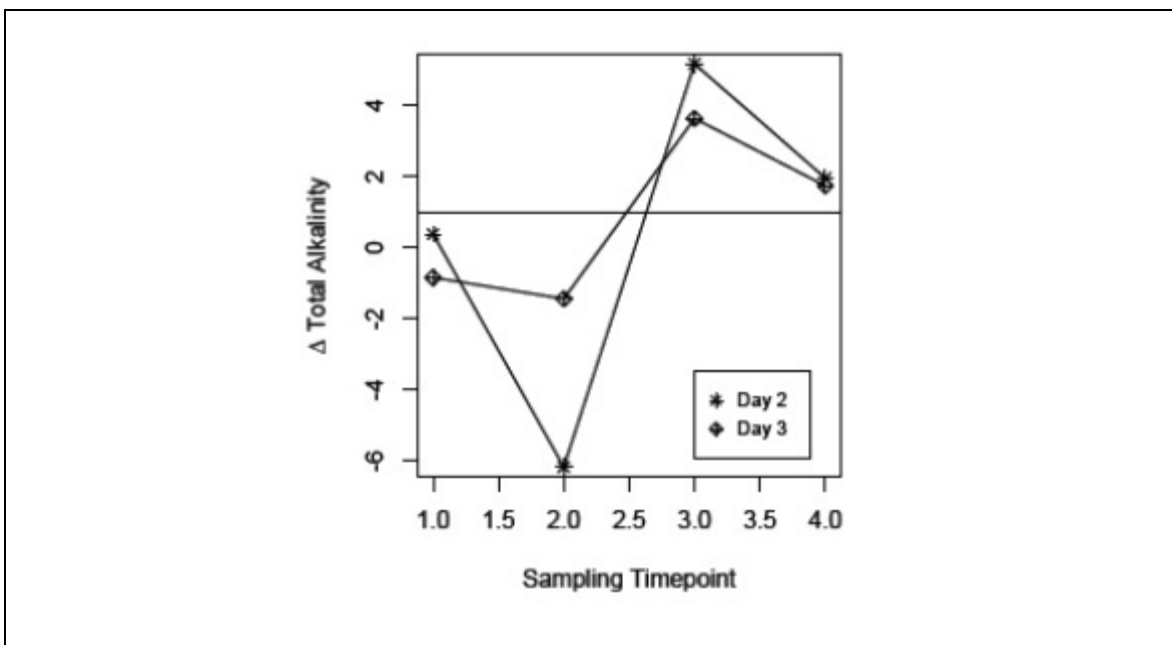


Figure 7: Normalization of the observed difference between the reference pool and the treatment pool for changes between treatment days and the unmanipulated day in total alkalinity.

DIC decreased over the course of the low tide in both the reference pool and in the treatment pool (figure 8). DIC decreased the least on day 3, most likely because light availability was less on this day than on either day 1 or 2. In general, DIC values began at approximately $2200 \mu\text{mol kg}^{-1}$, but decreased to approximately $1200 \mu\text{mol kg}^{-1}$ by the end of the sampling period. In Haro Strait, DIC decreased only slightly over the course of the low tide, but remained relatively constant. DIC values for the Haro Strait were in the range of $2050\text{-}2150 \mu\text{mol kg}^{-1}$.

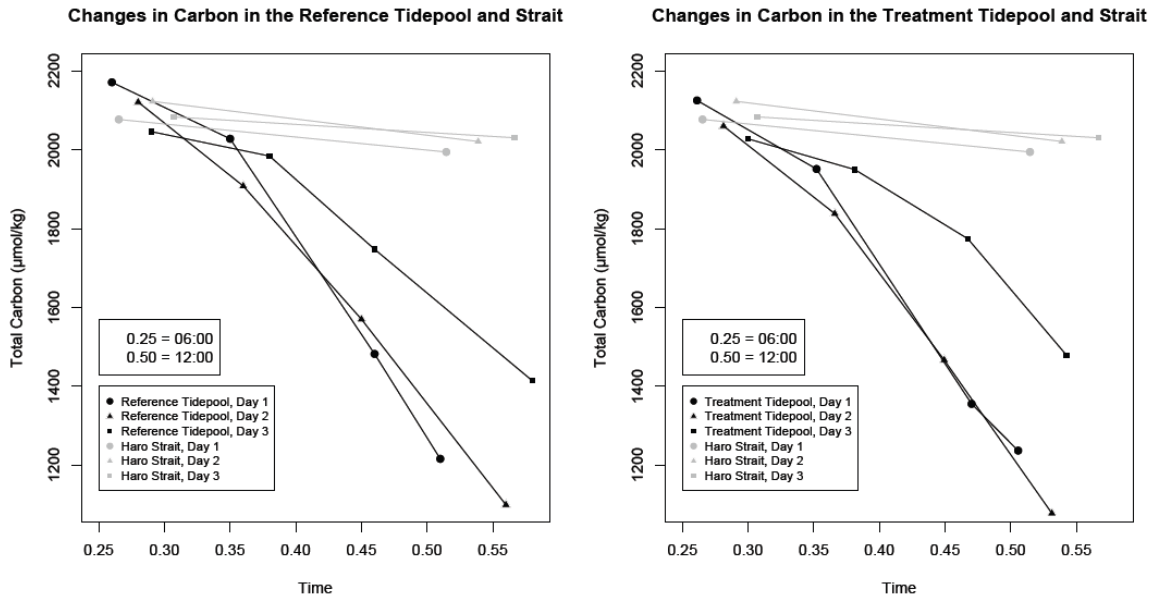


Figure 8: Observed changes in total carbon over the three sampling days in the reference tidepool and the treatment tidepool with baseline Haro Strait values. Day 1 is the unmanipulated day, day 2 is the *Ulva sp.* treatment day, day 3 is the mussel addition day. Additions were only made to the treatment pool.

When data was normalized to the difference seen between the reference tidepool and the treatment tidepool on Day 1 (no manipulations performed), predicted effects were seen only in the last time point (figure 9). In the first three sampling points, the difference seen between the reference pool and the treatment pool were similar to the difference seen between these two pools on day 1 (the first three sampling points are close to 1). However, in the fourth sampling point of day 2, there was a marked deviation from the difference seen between the pools on day 1 (figure 9). The difference between the reference pool and the treatment pool on this day was negative as compared to the difference on day 1. Likewise, on day 3 (mussel addition day), differences were similar to those observed on day 1 (unmanipulation day) for the first three time points (values are close to one). In the fourth sampling point, however, the difference between the two pools had a more positive trend than the difference seen on day 1.

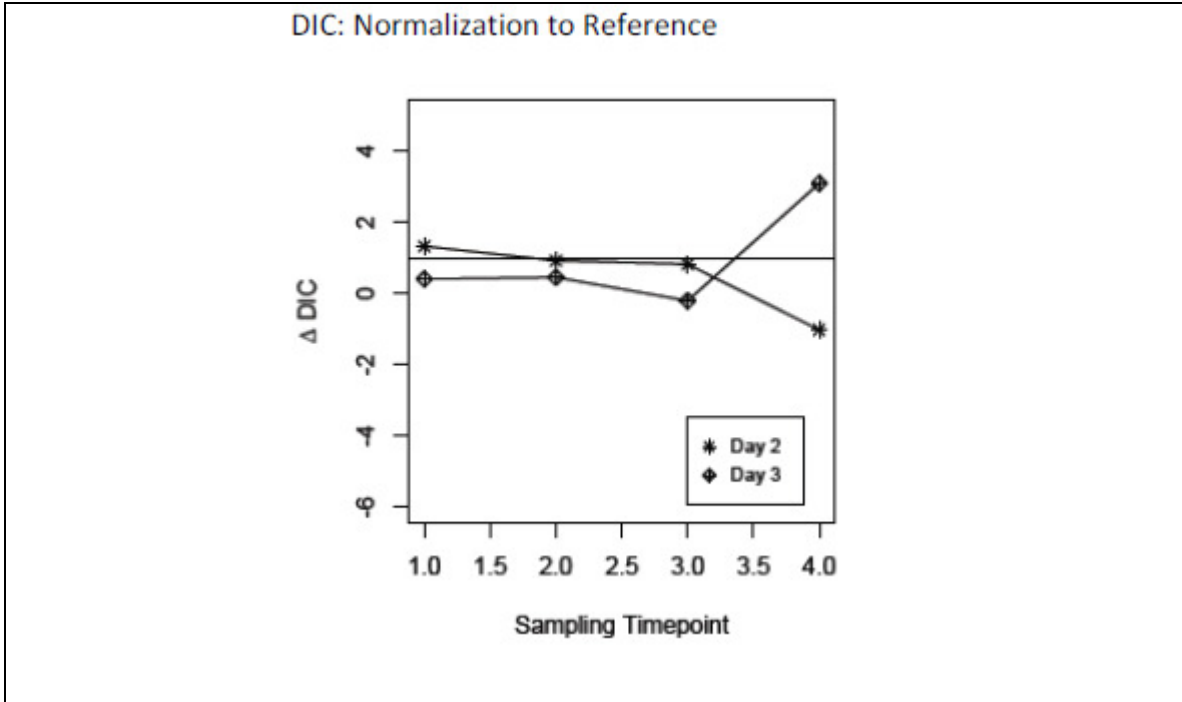


Figure 9: Normalization of the observed difference between the reference pool and the treatment pool for changes between treatment days and the unmanipulated day in DIC.

pH in both the reference pool and the treatment pool increased over the sampling period on all three sampling days (figure 10). In the reference pool, pH increased the most in day 1 (from 7.361-8.602) and day 2 (7.439-8.692). pH in the reference pool increased the least in day 3 (7.605-8.340). Since no additions were made to the reference pool, this difference is most likely due to the differences in light availability on the three days.

In the treatment pool, pH increased the most on day 2 (7.636-8.942). This suggests that there was an effect of photosynthesis. If the algae are consuming CO_2 , the medium of the water will be more basic. Likewise, the pH increased the least on day 3 (7.736-8.469) because the mussels are releasing CO_2 , thereby making the medium more acidic. However, since differences were also seen in the reference pool, it is difficult to

attribute the differences in the treatment pool to biology alone. It is likely that the effect of biology was seen because of confounding factors on the different sampling days.

pH values of the Haro Strait remained relatively constant for the duration of the sampling period. pH values in the strait ranged from 7.68-7.831.

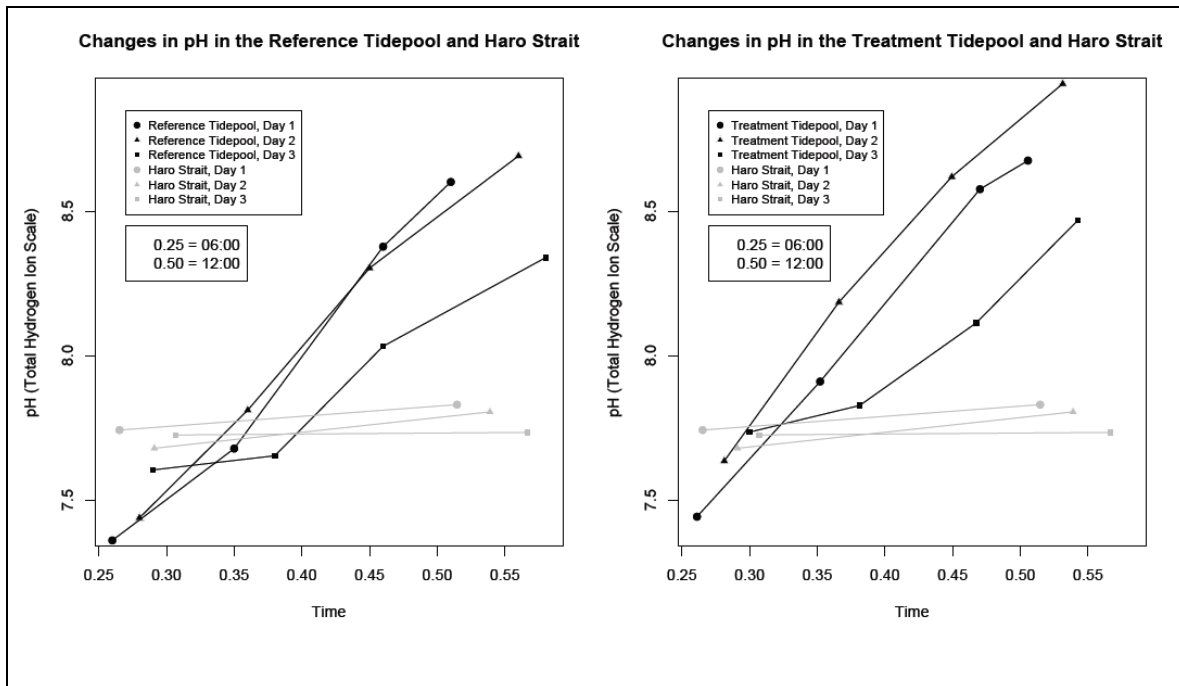


Figure 10: Observed changes in pH over the three sampling days in the reference tidepool and the treatment tidepool with baseline Haro Strait values. Day 1 is the unmanipulated day, day 2 is the *Ulva* sp. treatment day, day 3 is the mussel addition day. Additions were only made to the treatment pool.

On day 2 (*Ulva* sp. addition), the normalized data show that there was a positive difference between the two pools as compared to the difference on day 1 (unmanipulated day). pH on this day increased more between the two pools than on the unmanipulated day. The same general trend was seen on the mussel addition day, however, timepoints two and three show that there was a negative difference as compared to day 1. However, for both addition days, the last timepoint shows that there was a greater increase in pH as compared to the difference on the unmanipulated day.

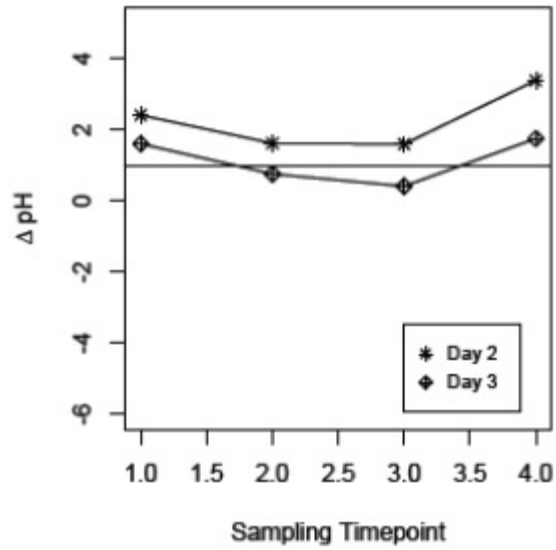


Figure 11: Normalization to the observed difference between the reference pool and the treatment pool for changes in pH.

On day 2, there was a positive difference in aragonite saturation as compared to the difference observed on day 1 (figure 12). On day 3, however, aragonite saturation difference between the two pools was less than the difference seen on day 1. Calcite saturation states followed the same trends as aragonite saturation states, and so, are not shown.

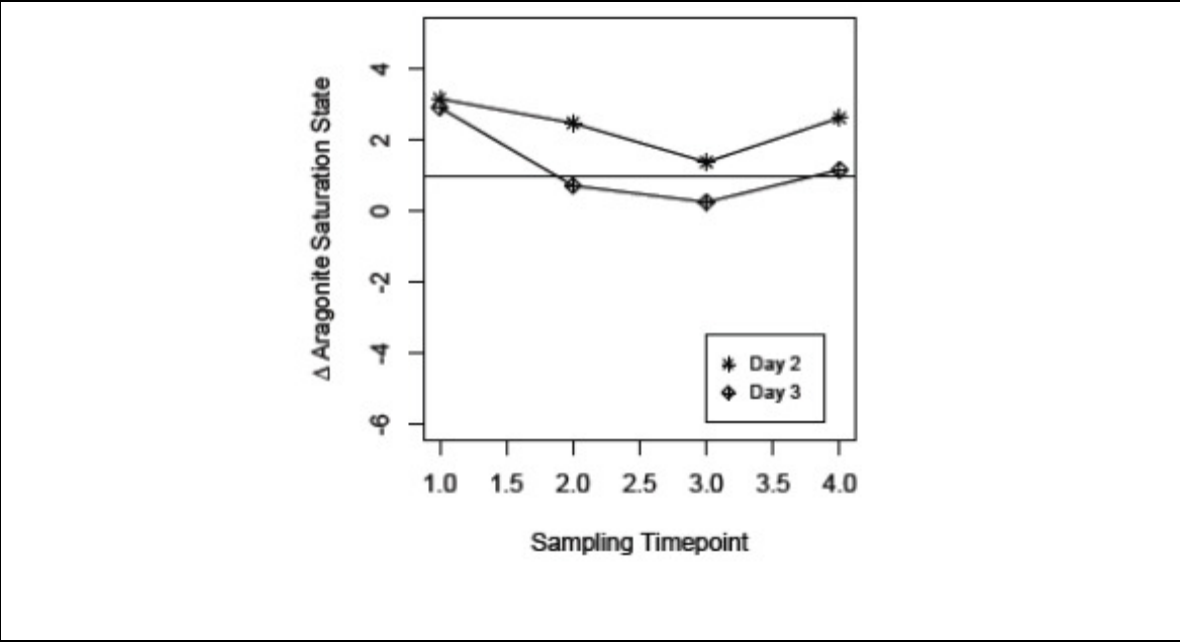


Figure 12: Normalization of the observed difference between the reference pool and the treatment pool for changes between treatment days and the unmanipulated day in aragonite saturation.

Discussion

Differences between reference and treatment tidepool

There were differences observed in the temperature changes between the reference and treatment tidepool. On the first day, the temperature in the treatment tidepool increased much more than in the reference tidepool. This trend is likely due to the fact that the treatment tidepool had a smaller volume than did the treatment tidepool. However, the opposite trend was seen on days 2 and 3, where the reference tidepool heated up more than did the treatment tidepool. This may be due to other characteristics of the tide pool other than volume. For example, the reference tidepool may have been less shaded on days 2 and 3 due to the sun's aspect. The differences in temperature between two day may also be attributed to differential placement of the tidbit temperature logger in the tidepool on the three sampling days. Since the tidbit was removed between the sampling days, it is possible that the differences seen could have resulted from placing the tidbit in slightly different places within the tidepool on the different sampling days.

Although the tidal heights of the two pools were similar, they had different biotic abundances of both macroalgae and mobile animals. The reference pool had a higher abundance of macroalgae, especially articulated coralline species than did the treatment pool. The reference pool also had a higher amount of mobile invertebrates than did the treatment pool. The higher abundances of macroalgae likely accounts for some of the differences seen between the two pools in carbonate chemistry since photosynthesis has a marked impact on carbonate chemistry.

Changes in carbonate chemistry

The carbonate chemistry in the tidepools we surveyed underwent drastic changes over the course of the low tide. With increasing isolation time, the total alkalinity and dissolved inorganic carbon decreased, and the pH increased. There were expected differences in tidepool chemistry over the course of the low tide, however, the magnitude of the differences found in this study were unexpected and somewhat surprising.

The change in DIC can be attributed to photosynthetic processes. The removal of both dissolved CO_2 and of HCO_3^- results in a decrease in DIC. The decrease in total alkalinity throughout the course of the tide is likely due to calcification processes occurring in these tidepools. Both tidepools were dominated by the articulated coralline species, *Corallina vancouveriensis*, and the decrease in total alkalinity may be attributed to the precipitation of calcium carbonate of this species. Calcification has been shown to lower total CO_2 content in seawater such that for each mole of CaCO_2 precipitated results in a 0.5 mole reduction for each equivalent of TA (Smith and Key 1975).

With increases in temperature and light, photosynthetic rates increase. Tidepools at low tide are progressively heating up and are likely exposed to saturation light irradiances, resulting in direct increases in photosynthesis. These increases can be linked to the changes in carbonate chemistry seen in these tidepools.

Since consumption and evolution of CO_2 by either animals or algae should not change the total alkalinity, the changes in alkalinity that we found were unexpected. It is possible that nutrients play a role in the variations in alkalinity. For example, if the algae are uptaking phosphorous, the total alkalinity should increase. This may explain the

increase in alkalinity seen between timepoints 2 and 3. The release of ammonia byproducts by mussels is also expected to increase alkalinity which may account for the increase in alkalinity seen between timepoints 2 and 3 on the day we added mussels to our treatment tidepool.

Biological Signal of *Ulva* and Mussel Additions

In this study, we were not able to demonstrate a strong influence of our biological additions. In part, this may be because we performed our sampling on different days and physical factors such as light and temperature influenced the chemistry of our pools more so than our additions. Additionally, since our pools were already composed of biological organisms, it was hard to detect an extra biological signal due to our additions. It is likely that we did not add enough biomass to our pools to detect an extra biological signal above the biological signal that was already present in our pools.

Photosynthesis by algae is inhibited at high O₂ levels due to the affinity of RUBISCO for O₂ over CO₂. If O₂ reacts with RUBISCO over CO₂, no photosynthesis occurs. On day 1, our pools were supersaturated with oxygen so much that it was out of the range of our dissolved oxygen probe. Therefore, it is possible that photosynthesis may have been inhibited by high O₂ levels in our tidepools, and may be a reason why we did not detect a biological signal from our *Ulva* addition.

One reason that the biological signal may not have been detected from our mussel addition is that it is possible that the mussels may have been slightly stressed, and only acclimated to our tidepool after several hours. In the normalization graph for DIC (figure 9), the last timepoint shows the expected response from the mussel addition. And so, it

may have taken the mussels several hours to acclimate to our pool and start to feed and release CO₂.

Implications for future Ocean Acidification Research

This study documented extreme variations in carbonate chemistry in tidepools over a short time period. It is important for researchers using intertidal organisms in their experiments to be aware of the wide fluctuations that these organisms are acclimated to and incorporate this variability into their experimental design. Additionally, it is imperative that researchers have knowledge to the fluctuations that their study organisms are exposed to in their natural environments. The same species growing or living subtidally may have a very different response than an organism living in the intertidal due to different acclimations by these organisms.

In conclusion, this was the first experiment in this area to quantify the changes in carbonate chemistry over the tidal cycle. That being said, it was only a very preliminary pilot study and future follow up research would be highly relevant.

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Appendices

***Ulva sp.* area determination methods**

Circular discs (n=11) of *Ulva sp.* were cut with a cork borer to obtain a standard area to dry weight ratio. These discs were dried in an oven (60°C, 24hrs) and dry weights were obtained with an analytical balance. The remainder of the *Ulva sp.* used in this experiment was also dried in an oven (60°C, 72hrs). The standard area to dry weight ratio of the discs was then applied to the total *Ulva sp.* added to the pool to obtain the total area of *Ulva sp.* added to the pool.

Summarization of carbonate parameters

Table 3: Summary table of carbonate parameters for measured and calculated values

SampleID	Day	Location	D.O. (% Saturation)	Temperature (°C)	Salinity (‰)	pH	TA ($\mu\text{mol/kg}$)	DIC ($\mu\text{mol/kg}$)	pCO2 (μatm)	HCO3 ($\mu\text{mol/kg}$)	Ω_{arg}
TP001	1	Reference	43.2%	10.25	30.1	7.187	2116.5	2171.5	3451.9	2042.5	0.392
TP002	1	Treatment	42.8%	10.10	30.8	7.260	2096.0	2125.4	2861.5	2008.2	0.470
TP003	1	Haro Strait	61.5%	10.17	30.4	7.528	2128.8	2077.2	1520.1	1969.0	0.913
TP004	1	Reference	95.7%	11.32	30.0	7.490	2065.4	2028.2	1620.4	1924.7	0.801
TP005	1	Treatment	125.9%	10.98	30.3	7.700	2055.0	1951.5	951.1	1835.4	1.292
TP006	1	Reference	224.4%	15.40	31.3	8.219	1802.4	1482.3	197.9	1268.0	3.202
TP007	1	Treatment	>200%	17.66	31.5	8.444	1819.8	1355.5	98.4	1055.6	4.641
TP008	1	Treatment	>200%	18.51	30.8	8.558	1753.3	1237.0	65.4	910.2	5.127

TP009	1	Reference	>200%	17.96	31.3	8.482	1669.9	1216.1	79.6	933.7	4.388
TP010	1	Haro Strait	84.8%	12.25	30.1	7.648	2078.9	1994.6	1099.2	1883.5	1.156
TP011	2	Reference	n/a	10.20	30.0	7.261	2089.5	2121.3	2853.9	2004.4	0.458
TP012	2	Treatment	n/a	10.15	30.1	7.433	2081.8	2060.5	1879.0	1955.7	0.704
TP013	2	Haro Strait	n/a	10.13	29.6	7.478	2155.0	2123.1	1746.0	2015.7	0.793
TP014	2	Reference	n/a	11.39	30.1	7.616	1981.4	1908.3	1134.8	1804.5	1.025
TP015	2	Treatment	n/a	11.24	30.2	7.972	2045.5	1838.1	463.8	1674.9	2.238
TP016	2	Reference	n/a	13.73	30.1	8.127	1833.1	1570.3	268.9	1386.0	2.689
TP017	2	Treatment	n/a	13.71	30.2	8.436	1922.8	1466.8	110.3	1161.3	4.664
TP018	2	Treatment	n/a	17.41	30.2	8.811	1740.2	1078.0	26.7	667.5	6.511
TP019	2	Reference	n/a	18.12	30.1	8.577	1577.7	1099.4	55.5	808.1	4.575
TP020	2	Haro Strait	n/a	11.27	30.1	7.611	2094.2	2021.2	1215.7	1912.0	1.066
TP021	3	Reference	63.4%	10.40	30.4	7.417	2061.3	2046.3	1926.3	1942.4	0.662

TP022	3	Treatment	77.6%	10.27	30.8	7.533	2078.7	2027.9	1458.0	1922.7	0.889
TP023	3	Haro Strait	77.4%	10.25	30.8	7.525	2132.2	2083.7	1525.1	1976.1	0.892
TP024	3	Reference	87.2%	11.00	30.8	7.468	2015.5	1984.4	1656.6	1883.4	0.743
TP025	3	Treatment	111.3%	11.10	31.0	7.630	2030.5	1950.0	1114.0	1841.9	1.094
TP026	3	Reference	140.8%	12.00	30.7	7.836	1893.2	1747.8	612.8	1622.7	1.592
TP027	3	Treatment	196.3%	12.20	30.9	7.916	1956.2	1774.2	510.9	1628.7	1.952
TP028	3	Treatment	>200%	13.80	30.8	8.290	1836.4	1479.1	164.4	1240.2	3.584
TP029	3	Reference	>200%	14.70	30.6	8.179	1691.8	1414.5	210.8	1230.1	2.729
TP030	3	Haro Strait	73.4%	11.30	30.8	7.549	2085.5	2030.7	1405.1	1924.9	0.926

