Island Refugia and the Catalina Dynamic Ocean Chemistry Program

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ABSTRACT

Islands offer the possibility of being refugia from ocean acidification. Oceanic conditions may produce different mean pH values for islands relative to nearby mainland, while natural variations in pH may influence how marine fauna tolerate increasingly acidifying waters. The Catalina Dynamic Ocean Chemistry (CDOC) program is designed to investigate natural variations at Santa Catalina Island, California, USA. Measurements of various ocean chemical parameters, including pH, were made at 18.3-m depth from a mooring near Two Harbors. There were 5 deployments, each being approximately 3 weeks in duration. The average pH value amongst the deployments was 8.18, significantly larger than measurements reported from the mainland coast in the Southern California Bight. We find that during regimes of strong stratification and internal waves (i.e., summer conditions), pH is modulated significantly at internal wave frequencies and is highly correlated with temperature. Strong episodic upwelling events occurring in less stratified conditions (i.e., winter conditions) are also attended by more acidic water. We find the largest modulation in pH for either summer or winter conditions to be greater than 0.1 pH unit.

Figure 1. Location and protocols. Measurements of pH were made at two locations on Santa Catalina Island. Fixed-depth measurements (30-minute sampling for 2-week duration at 18.3 m) were made from a mooring at Two Harbors with thermographs placed along the mooring at 6.1, 12.2 and 24.4 m. Water column measurements (20-s sampling, 5-minute duration, 6-m increments, from 6-30 m) were made from boats, usually near Avalon.

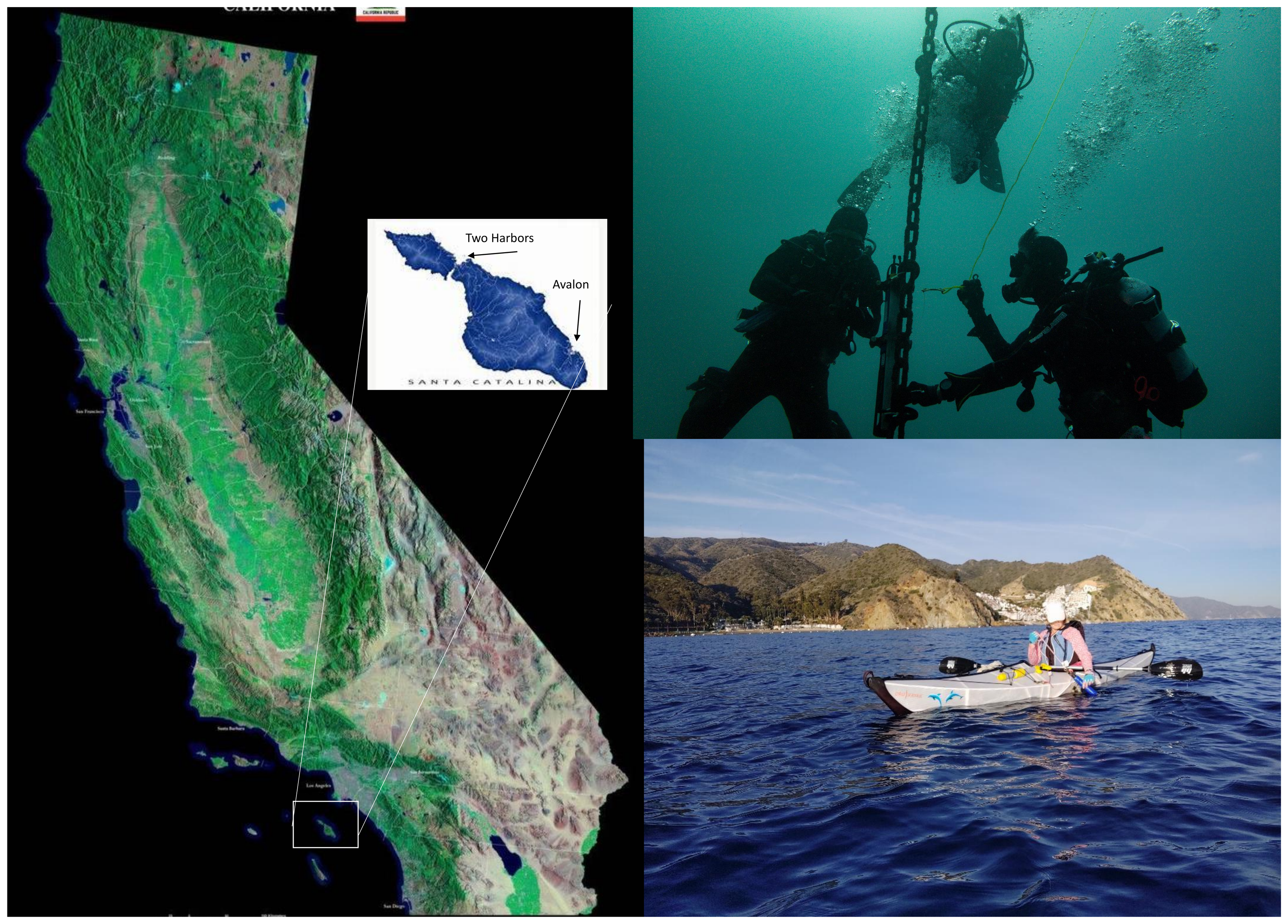


Figure 2. Example time series. Typical time series of pH, temperature and salinity for summer (stratified) and winter (well mixed) conditions. The major variations during the summer are internal waves as determined by the frequency and abiotic parameter variations. pH is well correlated with temperature and salinity.

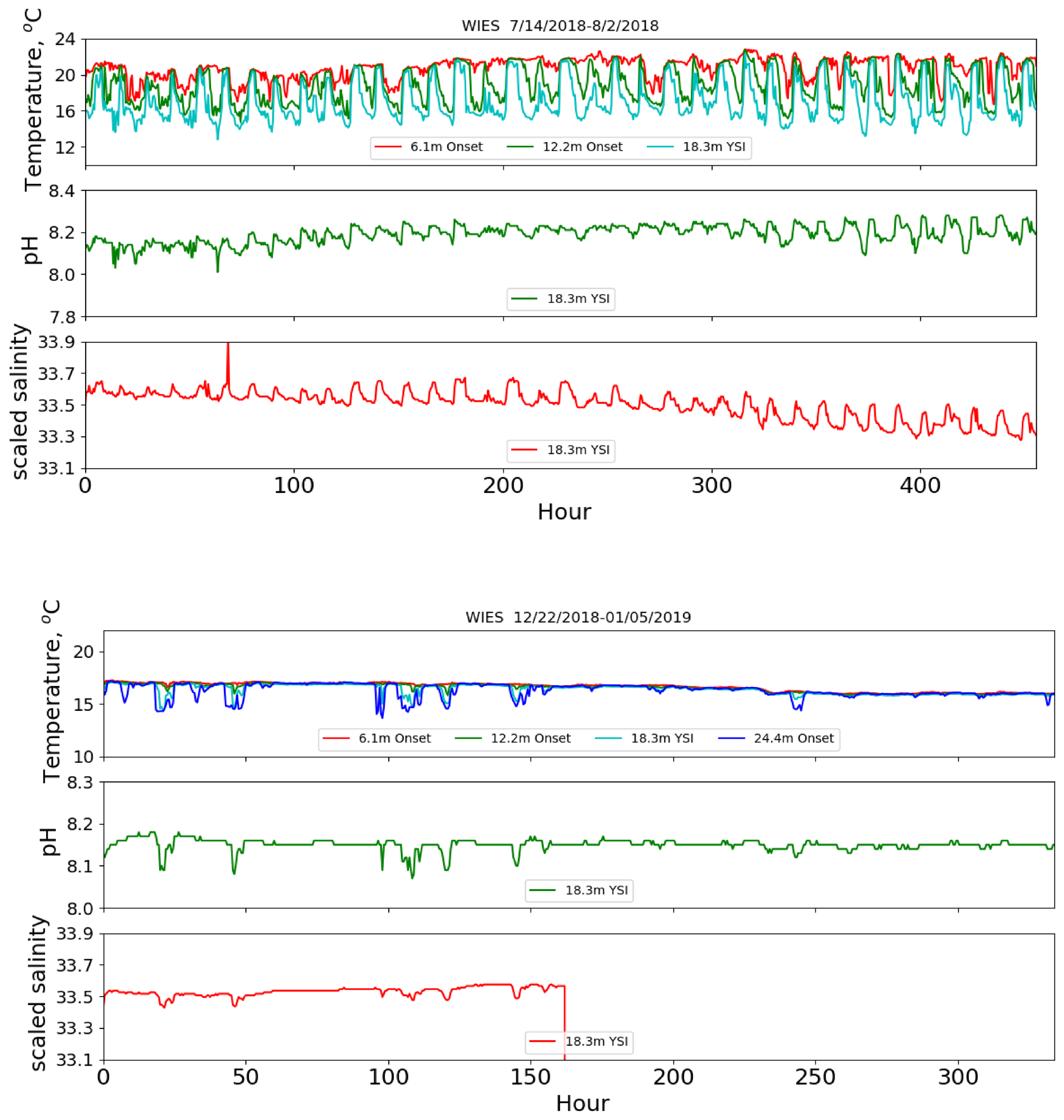


Figure 3. Temperature Dependence. The vertical advection produced by the internal waves carries water of different temperatures and other parameter values past the sonde. Chlorophyll, dissolved oxygen and pH are shown versus temperature for the 7/14/2018 data. Note that chlorophyll and DO maximize at 16° C, while pH maximizes at the highest temperatures observed.

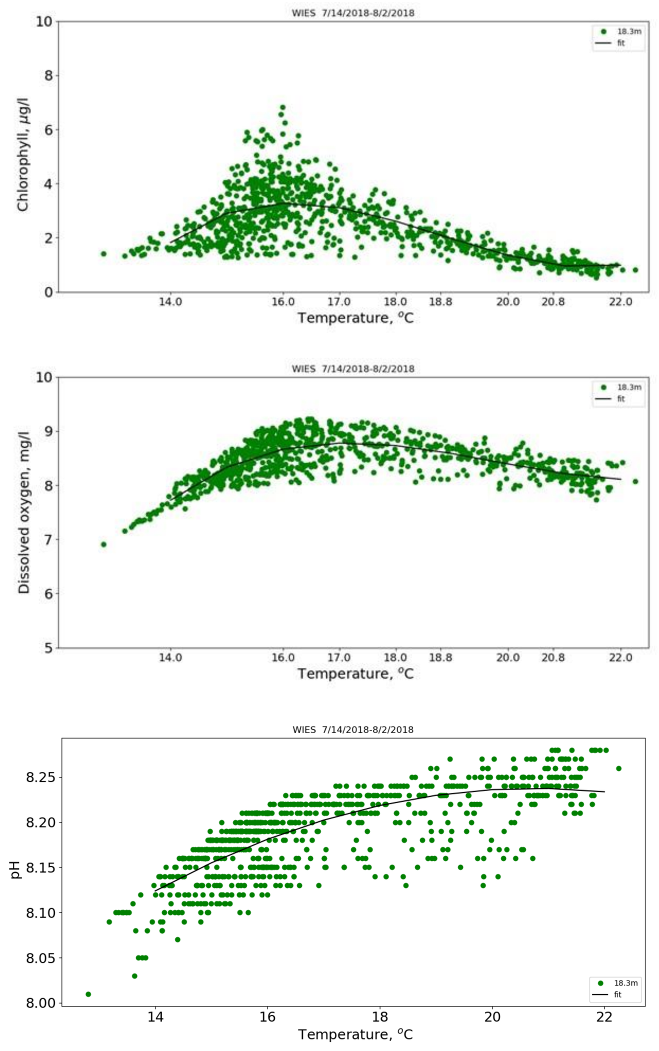


Figure 4. Depth Dependence. The temperature dependence can be converted into a nominal depth dependence. Chlorophyll and DO are found to maximize below the sonde. The depth dependence for pH is shown for the fixed-depth mooring. Below are also shown the temperature and pH the for depth-profiling data. The profiles are of two types, stratified and not stratified. Note how the stratified pH tend to larger values, while the stratified temperatures tend to smaller values.

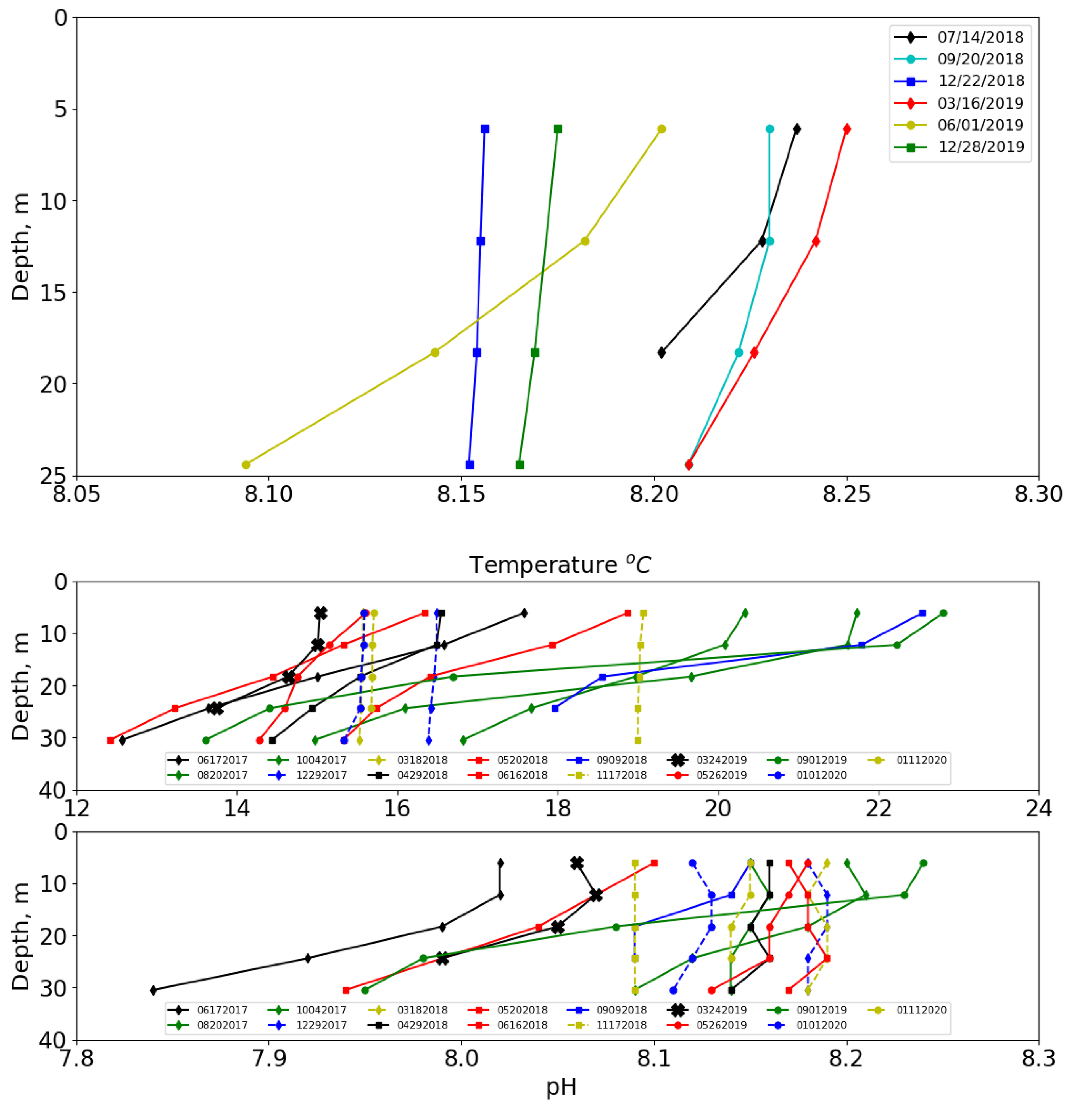


Figure 5. Surface and gradient relationships. The relationship alluded to is explored by plotting the 6-m pH and temperature values versus the its gradient. The temperature data show the expected relationship as determined from our temperature models. The pH does not.

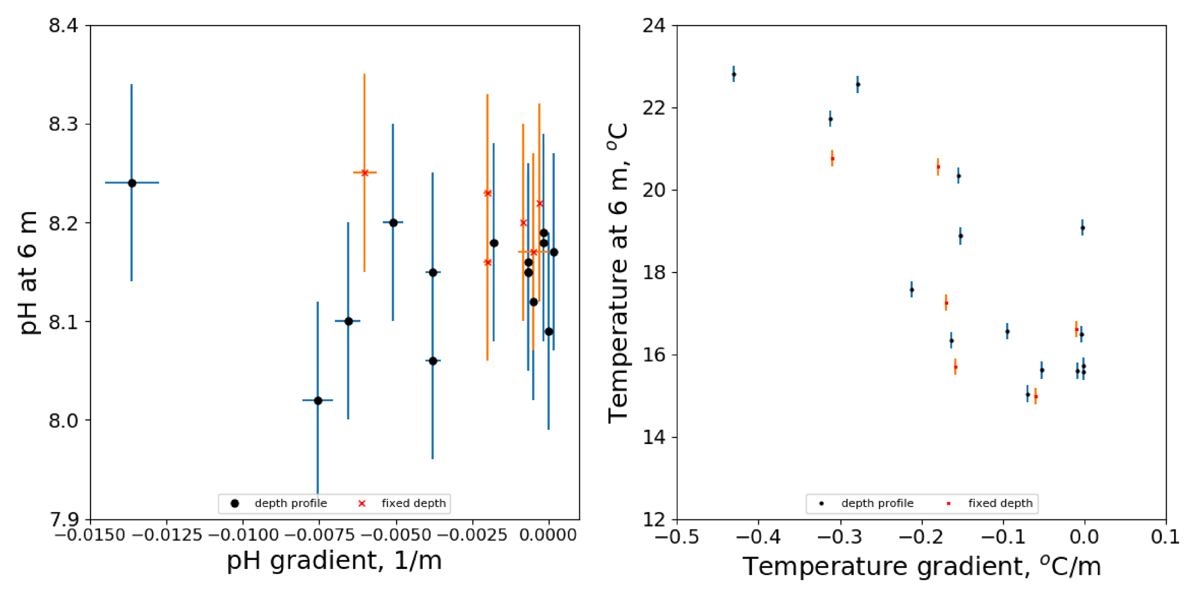
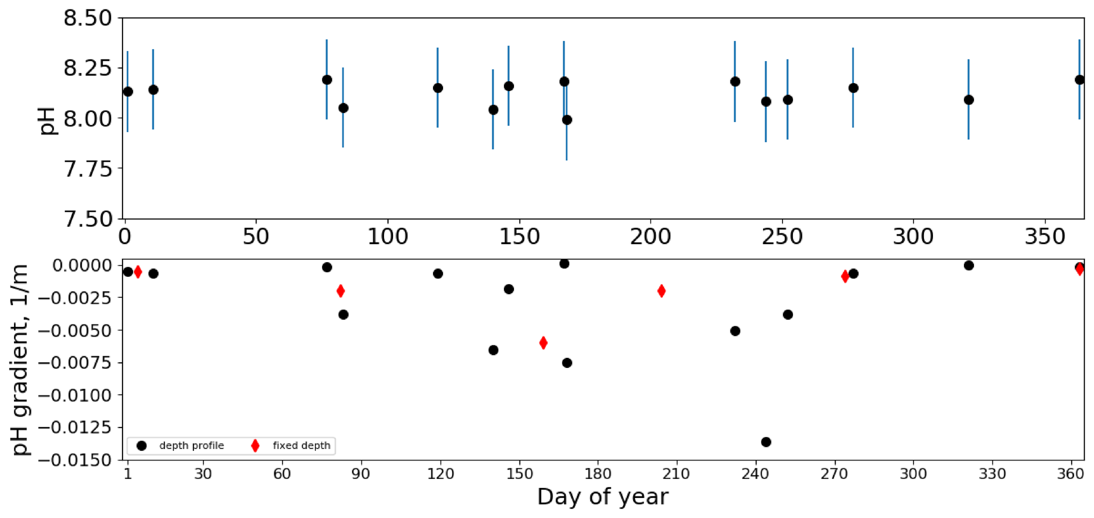


Figure 6. Seasonal Variation. The seasonal variation is investigated by plotting the 6-m pH from the depth profiling data as a function of Day-of-Year (top) and its gradient (below). Within the measurement uncertainty, the pH is constant. However, the gradient exhibits large variations during times of stratification, i.e., when internal waves are expected to increase variability of the measurements.



Tables 1 and 2. Average pH. The average pH values from the fixed-depth mooring (Table 1) and depth-profiling as a function of depth (Table 2). The results of the 2 procedures compare well at the same depth.

Table 1.

Date	Temperature 18.3m	pH
07/14/2018-08/02/2018	16.9	8.19
09/20/2018-10/12/2018	18.3	8.21
12/22/2018-01/05/2019	15.6	8.14
03/16/2019-03/30/2019	14.3	8.22
06/01/2019-06/15/2019	15.2	8.12
12/28/2019-01/12/2020	15.5	8.17
		8.175

Table 2.

Depth, m	Average pH
6.1	8.14
12.2	8.14
18.3	8.12
24.4	8.10
30.5	8.09

average

Summary and Discussion. Comparisons of the average pH measured from the two protocols with those of other independent researchers indicate that pH is higher at Santa Catalina Island than measurements in mainland kelp forest, off the mainland coast and from the Northern Channel Islands. We conjecture that the higher pH is the result of less upwelling at Catalina, as previous studies indicate. The seasonal gradient yet constant surface values suggest that the pH at depth is controlled by the vertical mixing of surface waters that are in equilibrium with the atmosphere.

As ocean acidification continues, locations such as Santa Catalina Island that exhibit higher pH may serve as refugia for marine fauna from deleterious effects of lower pH.

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