**FREQUENCY AND INTENSITY OF EXPOSURE TO CARBONATE CORROSIVE WATERS IN A NEAR-SHORE UPWELLING ENVIRONMENT**

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**ABSTRACT**

A primary consequence of increasing atmospheric CO₂ is the lowering of ocean pH and the associated stress on calcium carbonate bearing organisms. Coastal regions are vulnerable to low-pH conditions due to seasonal upwelling, which periodically introduces CO₂-enriched deep water to the surface. Time-series of pH, chlorophyll, temperature, and salinity from a near-shore sensor at Trinidad Head, California (41°N 124°W) were analyzed to ascertain the frequency and intensity of exposure to carbonate corrosive waters from 2006-2011. Most years during this period experienced sporadic, moderate upwelling events with 11-35 days of exposure to corrosive water. More frequent, intense upwelling in 2010 resulted in 61-84 days of exposure. The exposure intensity, as indicated by cumulative under-saturation, was 3-4 times that of the other years. Exposure intensity would have been stronger during spring and early summer was it not for enhanced phytoplankton productivity in response to upwelled nutrients. During late summer exposure was limited by stratification which inhibited CO₂-enriched deep water from reaching surface. This analysis could be used to inform laboratory based experiments designed to test low-pH exposure on calcite bearing organisms.

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**METHODS**

- **PH Filter**
  - Sensor recorded pH, temperature, salinity, oxygen and fluorescence at 15 minute intervals
  - Flow pH (gray) filtered using moving median-mean with a 12 scan window centered at each data point (black)
  - Aragonite saturation (Ωarag) was derived from sensor pH using two methods

- **Salinity Derived DIC**
  - Sensor pH used to infer Dic from a pH-Ωarag regression based on bottle alkalinity and DIC samples collected along Humboldt Line
  - Sensor pH and an inferred DIC from a Salinity-DIC regression based on bottle salinity and DIC samples collected along the Humboldt Line

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**RESULTS**

**2007: ARAGONITE SATURATION AND DENSITY**

- The two methods for determining Ωarag are in general agreement during corrosive events
- Aragonite under-saturation varies in frequency and duration from year to year (blue highlights)
- Periods of under-saturation coincide with peaks in upwelling as indicated by peaks in surface density (yellow line)
- Variable degrees of under-saturation between years, despite similar peak densities at surface 2007: stronger than normal upwelling between April-May [McClatchie et al., 2008] with 4 corrosive events
- 2010: warm, fresh surface water early summer, late-onset, anomalously strong upwelling [Bjorkstedt et al., 2010] with 10 frequent and sustained corrosive events

- **2010: ARAGONITE SATURATION AND DENSITY**

  - Table shows number of days/year of exposure to Dic<sub>Ωarag-1</sub> (red blue) and pH<sub>4.75</sub> (black)
  - 2010 experienced twice as many days of exposure to corrosive water compared to average

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**DISCUSSION**

- Under-saturation is primarily controlled by the frequency and intensity of upwelling
- Relationship of timing and intensity of upwelling to primary productivity could buffer potential under-saturation via biological carbon pump
- A cumulative under-saturation index (CUI) was devised to combine frequency and intensity of under-saturation

- **2010 CUI was 2.5x average for this time-period**
- May have resulted from interaction of climate patterns (ENSO, PDO) that: 1) delayed spring 2010 upwelling which accumulated DIC below mixed-layer and 2) intensified summer upwelling which brought this DIC enriched/under-saturated water to surface
- Predicting future exposure to under-saturated waters will require in-depth knowledge of the inter-annual variability which is likely influenced by climate patterns

- **Comparison of chlorophyll (green) and filtered pH (black)**, during 1 week suggests exposure to corrosive conditions is mitigated by biological productivity
- Upwelled nutrients result in enhanced photosynthesis which decreases DIC and elevated pH above corrosive threshold
- Predicting future exposure to under-saturated waters will require in-depth knowledge of the timing and extent of biological buffering