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Monitoring Changes in Community Structure Due to Coastal Acidification and Warming in the Rocky Intertidal with Citizen Scientists

John A. Cigliano, Ph.D.
Environmental Conservation Program, Department of Biological Sciences, Cedar Crest College, Allentown, PA
Schoodic Institute, Winter Harbor, ME

The Problem

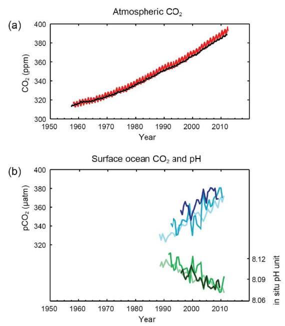


Figure 1. Relationship between atmospheric CO_2 concentration, ocean CO_2 concentration, and pH. From IPCC (2013) Summary for Policymakers.

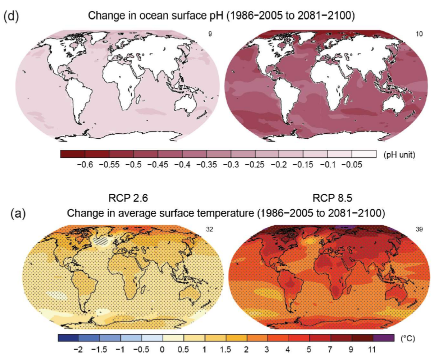


Figure 2. Maps of projected late 21st century change in ocean surface pH and annual mean surface temperature. From IPCC (2013) Summary for Policymakers.

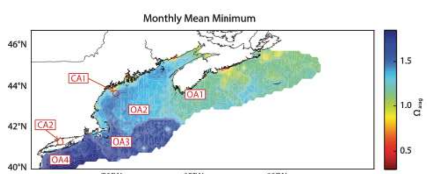


Figure 3. Mapped distribution of minimum average sea surface aragonite saturation state...for the Northeast Coastal Acidification Network (NECAN) study region based upon a coupling of the surface pCO2,sw to total alkalinity ... **NOTE: dark blue = corrosive (aragonite<1).** Gledhill et al. (2015) *Oceanography* 28(2):182–197

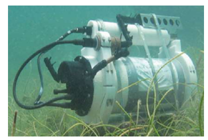
Acknowledgments

This project is funded by the Earthwatch Institute through the IGNITE Program. I would like to thank all the amazing Earthwatch citizen scientists who have worked on the project. I would also like to thank all the amazing people at Acadia National Park and the Schoodic Institute, especially Hannah Webber and Abe Miller-Rushing for their support.

The Program

Research Goal: To understand the combined effects of coastal acidification and warming on temperate organisms and communities to inform management and conservation.

Research Objective: Using field surveys, (1) develop a time-series of intertidal community structure / ecological states and (2) monitor for shifts in zonation and (3) determine whether changes correlate with changes in pH, temperature, salinity, and alkalinity.



Methods:

- 13 study sites; sites were chosen that were (i) extensive enough for multiple permanent quadrats and transects and (ii) contained barnacles and other calcifying organisms.
- Species composition / transition at each site is determined by sampling 4 permanent, gridded, 0.6m x 0.6m quadrats per site; 25 points per quadrat. Data analysis will follow the methodology of Wootton et al. (2008), who used Markov chain models to correlate environmental change to *in situ* dynamics of a marine intertidal community (NW Pacific coast of USA) to predict longterm impacts of ocean acidification on community structure.
- Three permanent transects at ten sites were established to monitor changes in zonation patterns over time. Transects were set up from the upper intertidal zone to the lower intertidal zone. Data analysis will follow methodology used by the Northeast Temperate Network
- Five 10cm X 10cm plots were established at four sites to monitor larval settlement and recruitment of barnacles (*Semialanus balanoides*). Density will be determined from photographs. Plots are scraped in November and data from May will indicate larval settlement. Changes in density between May and July will indicate recruitment. Pre-scrape density in November will indicate survival to reproduction. Comparisons will be made from year to year to determine if settlement, recruitment, and survival to reproduction changes over time.
- pH, salinity, temperature, and dissolved 0₂ are monitored continuously using a SeapHOx Ocean CT(D)-pH-DO Sensor (Sea-Bird electronics); deployed off the Schoodic peninsula in 2016.

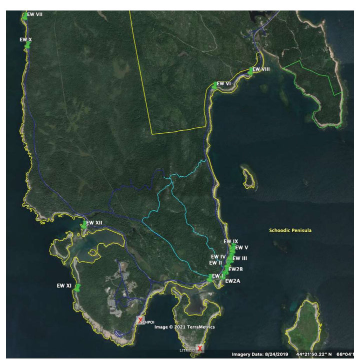


Figure 4. Study sites on Schoodic Peninsula. Screenshot of Google Earth Pro.

The Role of Citizen Scientists

Figure 5. Earthwatch citizen scientists scoring quadrats to monitor ecological transitions.

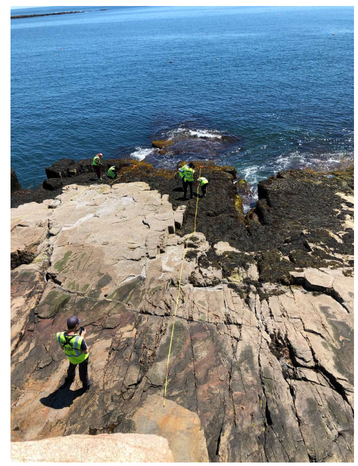


Figure 6. Earthwatch citizen scientists laying down a transect to monitor for changes in zonation patterns.

Figure 6. Barnacle settlement plots.

(Some of) The Results (So Far)

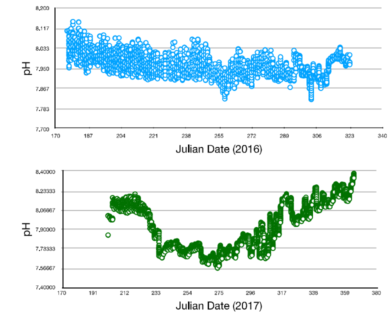


Figure 7. pH recorded by SeapHOx from 2016-2017.. For reference, 1 July 2016 is the 183rd day and 1 July 2017 is the 182nd day.

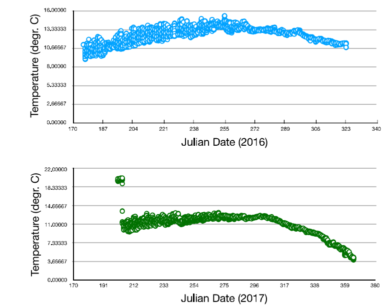


Figure 8. Temperature recorded by SeapHOx from 2016-2017. For reference, 1 July 2016 is the 183rd day and 1 July 2017 is the 182nd day.

Table 1. Ecological state categories sampled using fixed-point quadrats and corresponding codes used in data sheets. Codes correspond to codes used by the Northeast Temperate Network (NETN) of the United States Park Service.

BA	Barnacle, *Semibalanus balanoides*
RO	Bare rock / splash zone algae and cyanobacteria
SN	Snails: *Littorina littoria, L. obtusa, L. saxitalis, Nucella lapillus*
MU	Blue mussel, *Mytilus edulis*
AS	Knotted wrack, *Ascopyllum*
FU	Rockweed, *Fucus*
FE	*Fucus* epibiont, Pom pom
GA	Green seaweed, *Ulva*
FG	Filamentous green algae, *Spongomorpha, Cladophora, Enteromorpha*
CC	Crustose red algae
PA	Fleshy red algae, *Palmaria, Porphyra*
LM	Brown algae (Kelp), *Laminaria*
CM	Branching red algae, *Chondrus, Mastocarpus*

Table 2. Transition probabilities pooled across years from "Mordor," Probabilities in boldface are statistically-significant transitions. N is the total number of transitions in each group. Ecological state codes are from Table 1.

	To			
From	BA	RO	CM	FU
BA	0.370	**0.0476**	0.0000	**0.5794**
RO	**0.0619**	**0.8142**	**0.0177**	**0.1062**
CM	0.0000	1.00	0.0000	0.0000
FU	**0.2516**	**0.0440**	0.0000	**0.7044**
N	94	107	2	197