‘Crossing Thresholds’ Demonstration

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You will need:

- **1 clear wide-rimmed glass**
- **1 warm can of root beer—**I use regular; I'm not sure if this demo works as well with diet. I prefer root beer to other types of soda because the dark liquid is easy to see, and root beer foams more than other drinks
- **3-4 *fresh* ice cubes—**It's important that these be straight out of the freezer and feel dry and ‘sticky’ to the touch. If they are wet and slippery, the demo won't work as well. Getting a good layer of foam on the root beer depends on the surface of the ice having microscopic roughness to nucleate the formation of CO2 bubbles.

Background:

The idea for this demo was provided by Dr. Richard Feely, an ocean acidification expert at NOAA's Pacific Marine Environmental Laboratory in Seattle, WA. Dr. Feely came up with this tipping glass analogy to help people understand why marine species that are accustomed to the dynamic coastal environment can nevertheless be harmed by the relatively small and gradual shift in seawater chemistry that is occurring because of ocean acidification.

It is true that coastal species, particularly those that inhabit the intertidal zone, experience swings in pH and carbonate chemistry that are much larger than those attributed to ocean acidification. Coastal seawater chemistry is influenced by variety of biological and oceanographic processes that operate on time scales ranging from hours (such as tides, photosynthesis, respiration and wind-driven mixing) to months (e.g. coastal upwelling), to years (e.g. the Pacific Decadal Oscillation; http://research.jisao.washington.edu/pdo/), and several of these processes can cause the level of dissolved CO_2 to spike.

Some have argued that because coastal species have evolved to cope with such large swings in pH and carbonate chemistry, they should be able to withstand the relatively small and gradual changes caused by ocean acidification. Unfortunately, this hypothesis is not supported by the evidence (see points 3 and 4 in this science summary published by the Washington Ocean Acidification Center: http://coenv.washington.edu/wp-content/uploads/2015/05/OA-in-the-Pacific-Northwest-v1.pdf; also summarized in points 11, 12 and 16 of this handout published by Washington Sea Grant: http://wsg.washington.edu/wordpress/wp-content/uploads/OA18PNWFacts14V5.pdf).

Dr. Feely explains that while coastal organisms can indeed tolerate short-term swings in seawater chemistry *as long as the conditions stay within their historical range*, the effect of ocean acidification layered on top of this natural variability is additive. In other words, ocean acidification makes the bad days worse, and more frequent (see scientific references below).

Set up:

Fill the cup ~2/3 full of root beer, pouring carefully down the side to avoid generating foam. Tip the glass gently back and forth, so that the root beer almost--but not quite--spills over the rim. Explain that the motion of the cup represents the dynamic nature of the coastal environment, and that level of the root beer in the glass represents the amount of dissolved CO_2 that is tolerated by coastal organisms. They can tolerate quite a bit of variability, as long as it stays within the historical range of conditions to which they have adapted over thousands of years (i.e. stays below the rim of the cup).

Have an assistant retrieve the fresh ice from the freezer (just a couple of cubes; not so many that their volume by itself would cause the root beer to overflow), and tell your audience that the ice represents humans' use of fossil fuels. While you continue to rock the glass back and forth, ask your assistant to drop the ice into the cup. The root beer should immediately foam up and spill over the rim of the glass. Tell your audience that the foam represents the excess CO_2 that humans have added to the ocean's surface layer via atmospheric emissions. That additional burden of CO_2 raises the overall level of CO_2 in the system to a point that many coastal organisms can't tolerate.

Scientific references:

1. Gruber, N., C. Hauri, Z. Lachkar, D. Loher, T. L. Frölicher, and G.-K. Plattner. 2012. *Rapid progression of ocean acidification in the California Current System*. Science, 337(6091): 220–223.
2. Hauri, C., N. Gruber, M. Vogt, S. C. Doney, R. A. Feely, Z. Lachkar, A. Leinweber, A. M. P. McDonnell, M. Munnich, and G.-K. Plattner. 2013. *Spatiotemporal variability and long-term trends of ocean acidification in the California Current System*. Biogeosciences, 10: 193-216.
3. Hauri, C., N. Gruber, A. M. P. McDonnell, and M. Vogt. 2013. *The intensity, duration, and severity of low aragonite saturation state events on the California continental shelf*. Geophysical Research Letters, 40: 3424-3428.