Intertidal Storytellers: Barnacles join the discourse

For all the landlubbers' talk of how climate change will affect our human lives, what happens when you peel back the intertidal and look at an organism, smaller than a thimble, who is unable to join the discourse, and hold a lens to its response? You would learn that changing conditions could limit the animal's very survival: what and how it eats, its ability to "breathe", and ultimately whether it grows enough to do its part in the ecosystem.

Iconic to the rocky shore, barnacles are important prey for birds, fish, and other invertebrates, and they play a key role in transferring energy from the water to the ocean floor. They do all this while maintaining a simple design and a limited repertoire of behaviors, which made them an ideal candidate to study for Mike Nishizaki, a former PhD student in Dr. Emily Carrington's Lab at the University of Washington's Friday Harbor Marine Station.

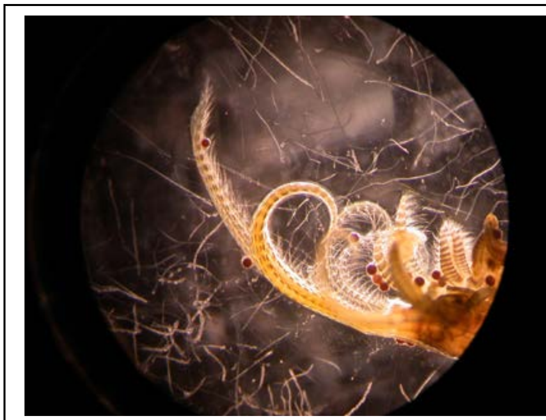
Mike Nishizaki scoping out barnacle habitat on Sucia Island, WA.

"If you can't find a barnacle you're not much of a marine biologist," says Nishizaki, who reaffirmed his position time and again while gathering the barnacle *Balanus glandula* for his study. But how do marine biologists distill a complex global issue into a multi-week experiment? Nishizaki's idea was three-fold. First, better understand the barnacle's feeding and respiratory behaviors in a lab. Next use the data to construct a model for optimal growth conditions. Lastly, cap it off with a wild idea, industrial water heaters, and a trip to a nearby lagoon.

Feeding, Breathing, and Behavior

Peeking closely at a submerged barnacle, you might see what looks like a long eyelash poke out, unfurl, sweep side to side, and slink back into its volcano-like home. This "eyelash" is actually the barnacle's legs, and they're called cirri. Rather than blinking, they're beating in a rhythm, waving in the water like little nets, trying to be in the right place at the right time to catch a meal. In the past, many scientists have relied on counting how often these cirri beat and assuming that beat rate correlated to meal size.

Nishizaki's study showed feeding success, however, depends on more than just beat rate. Under close analysis of hours of videotape, he and his colleagues tracked variation in cirral beating styles; some beat their cirri in a full motion, while others just tested the waters. These differing behaviors, influenced by water speed and temperature, affected the barnacles' success at capturing food. Nishizaki verified their success by dissecting the barnacles and counting the shrimp brine cysts inside their gut.



Barnacle cirri, seen under a dissecting scope, with cysts all around. Not a bad catch for an immobile fisherman.

"They're very efficient at catching food in slow moving water. When it moves too quickly, the particles slip through their cirri," said Nishizaki.

In addition to feeding, barnacle legs are also used for breathing. As an animal with no lungs, barnacles "breathe" by passing oxygen across their bodies, including their cirri. When the surrounding water is too slow or stagnant and not delivering enough oxygen, Nishizaki observed them beat their cirri faster, perhaps to stir and bring fresh oxygenated water closer. They also beat faster when faced with higher temperatures, which may increase ventilation. The variations in beating behavior take energy; energy that's no longer available to help the barnacle grow.

Using what he learned, Nishizaki built a model that incorporated not only feeding efficiency and respiration rates, but also cirral beating behavior, which showed a more robust and accurate picture of what can happen under multiple environmental conditions.

Modeling in the Field

To test his model in a controlled situation, he faced a major design challenge: how to heat continuously flowing natural seawater.

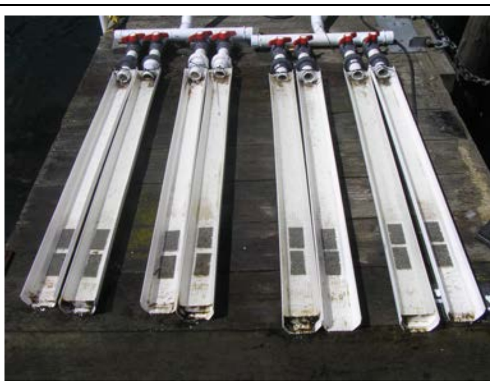
A big university like UW exposes students to people doing all types of research. "You see a method from a different field and say, 'Well I wonder if I can make that work in my field.' A lot of my gadgeteering kind of percolates from this. If you're just watching other marine ecologists, you're basically following somebody too closely. They're already doing that paper. To build the gadget that they're building isn't super useful. To break out of the box, you're often looking for inspiration in other places."

Inspired by UW's culture of makers and doers, Nishizaki turned to the local hardware store to solve his design challenge. There, he found materials for a homemade raceway, or flow-through system. He constructed the system on a dock, using a series of industrial grade water heaters. The rig pulled natural water from the harbor, passing it through two reservoirs before reaching the raceways where he grew the barnacles and differentiated temperatures and flow rates to see how they responded.

How did they get here?

In their larval stage, barnacles swim around, find a substrate that suits their fancy, and in a most loyal maneuver glue their head down, never to relocate again. Upside down with legs left waving in the water, these larval masons then build with interlocking plates to create their home, a volcano-like shield that's ubiquitous to intertidal zones the world over. "We don't really know why they glue their heads to the substrate. They need to find a spot, and they need to stay stable, since they're in a wave swept environment. It could just be that their head is the only place where glue is produced. Maybe they need those legs to be out in the water column. Nobody knows the answer."

As predicted in the model, the barnacles "breathed" and ate easiest at moderate flows. Having plenty of food and oxygen *and* having it delivered at a reasonable enough pace to react efficiently, let the barnacles optimize their available energy. And like humans, when barnacles are well fed and stress free, they have more energy to grow.



Creating a miniature Riviera in the Puget Sound, seawater flowed from two heating reservoirs into eight raceways before spilling back into the harbor.

Nishizaki then moved into the field to test the model's predictions under natural conditions. For five weeks, Argyle Creek, which joins a saltwater lagoon to the ocean, became home to his barnacles. The creek provides a rare opportunity to use a naturally existing flow-through chamber, complete with temperature variation, tidal fluctuations, and flow reversal. The experiment once again conformed to his model.

A Glimpse into the Future

It turns out studying something that is so ubiquitous and simple is really useful. Barnacles don't exist in a vacuum. Everything is intricately linked, from water quality to predator-prey relationships. Predictive modeling gives a glimpse at what will happen under temperatures that don't yet exist, a valuable insight in a changing world. Changes in water velocity, but probably more importantly in temperature, could throw barnacles off their optimal growing conditions pretty easily. "As far as how will they adapt in the future, that's a little more difficult. You'd have to follow an experiment for a generation or two, exposing barnacles to high temperatures and then rerunning the experiment to see if the graph starts to look different. Does it shift upwards? Are they stuck? Are barnacles unable to adapt? This is an interesting follow up."

As for their role in the intertidal, quite a few species will be rooting in their favor.

- **Katie Harrington (2014)**

About Mike: From Washington to the Great Lakes.

Mike Nishizaki is currently in the Great Lakes Region, where he's looking at the effects of temperature and flow on physical transport processes in lakes, a direct influence of his work in the Carrington Lab at Friday Harbor. Looking at barnacle physiology, specifically respiration and oxygen concentrations, inspired Mike to want to see the process in more detail. He's currently looking at the transfer of oxygen and other nutrients to and from the bed of lakes and the effects of water flow and temperature on that exchange, only this in much greater detail, collecting very fine scale measurements using an eddy correlation system. He has changed ecosystems and scales, but eventually, he says, he'll return to the intertidal community.

Interested in the physiological ecology of marine organisms and want to learn more about current research happening in the Carrington Lab? Check out the Lab's website: http://faculty.washington.edu/ecarring/.