The best of both worlds: A clever intertidal snail feeds on land and cools off in the sea
by Hilary Hayford

One of the most dynamic places on earth is the intertidal zone—the habitat between the lowest low tide and the highest high tide. Organisms that live in intertidal zones are both marine and terrestrial, surviving despite physical stresses of both the ocean and the land. This is particularly interesting when you think about all the ways climate change can affect the intertidal: increased air temperature, increased wind, increased extremes of rain storms and drought, increased water temperature, lowered ocean pH, lower dissolved oxygen in seawater, changes in salinity, and sea level rise. Because these plants and animals are already toughing out the extremes, I suspect they have cool tricks for mediating climate change.

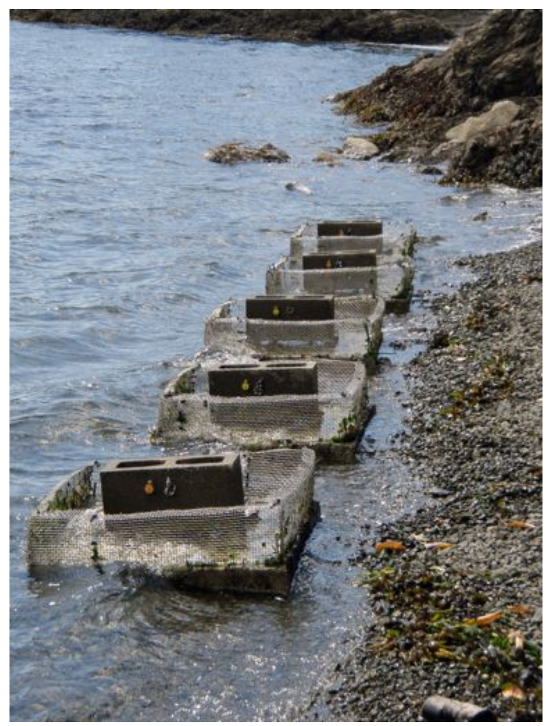
Tidal cycles determine whether intertidal areas are marine or terrestrial at any given point in time. Tidal cycles repeat every two weeks. They are driven by the position of the moon in relationship to the Earth and the Sun. When all three celestial bodies are in a line the gravity of the Moon and Sun adds up to a larger force and create the impressive "spring" tides with extreme high and low water levels. You can easily see when these line-ups are happening: both the full and the new moon are indicators. When these celestial bodies are not aligned, we experience "neap" tides with moderate high and low water levels. These differences are predictable; tidal cycles are so well known that predictions can be made decades in advance. In the Salish Sea there are two high tides and two low tides each day. Every six hours the ocean elevation and currents are different—sometimes drastically different.

The genus *Nucella*, of the Muricid whelk family, is found in the intertidal around the world. *Nucella ostrina* is common to rocky shores from Central California through Alaska. *N. ostrina* adults are typically 20-30 mm in length. It eats mostly barnacles and mussels, with populations preferring prey species that are abundant nearby. *N. ostrina* is a very slow feeder. After carefully selecting a victim of manageable size, it cracks into its prey by using its rasping radula to lick through the shell or through the ligaments holding the barnacle trap doors shut. Once through the shell, it injects digestive enzymes and slurps up the body tissue. The whole process can sometimes happen in as little as an hour, but typically takes 5-10 hours—too long to simply feed only when the tide is high. Most snails then move on to a nearby morsel, and continue on a feeding binge. They are extremely likely to be exposed to low tide conditions during some part of this rampage.

Mobile animals in the intertidal, such as *Nucella*, face a dilemma: more food is available higher on shore in weather-exposed locations, but these areas get lethally hot and dry more often than lower shore regions. Meanwhile, areas lower on shore or in cracks and crevices can provide shelter from the sun and wind, but will be the first depleted of any available food items. On some days of the tidal cycle you can easily spot *N. ostrina* on the surfaces of high intertidal rocks. On other days, only careful observers targeting choice cracks will be able to spot the snails. These observations led me to think about *N. ostrina* making behavioral decisions that might decrease its chances of getting cooked on a hot day.

I set out to test whether snails make predictable choices about when and where to feed and whether these choices helped them to avoid risky temperatures. I wanted to get as close to a natural setting as possible without losing all ability to control some factors. To do this I selected a gravel beach at the Friday Harbor Labs Preserve—a marine research station of the University of Washington located on San Juan Island for more than 100 years. I poured five concrete slabs (area ~1 square yard) on this beach to serve as whelk islands. On each island I placed a cinder block, slightly raised above the island, making a cool crack for snails to take refuge. I collected mussel shells with living barnacles attached to them and used these shells as bait to tempt the snails up the sides of the cinder block. They ˜were then to choose between taking refuge in the crack or feeding high up on the block. I went out during the low tide every day for two months to see which choice they made.

I observed that *N. ostrina* only fed for two or three days out of every two weeks. Those feeding days were cool—during neap tides when the longest, lowest tides were early in the morning or at night. No snails fed during most of the spring tides. Even though not all spring tide days were hot, they were reliably risky. The snails seemed to be able to predict when the risk of high temperatures was greatest and consistently avoid those days of the tidal cycle. By the end of the experiment, I knew which days the snails would come out to feed because these patterns had become so regular. Snails also showed an additional strategy for avoiding getting sun-cooked:



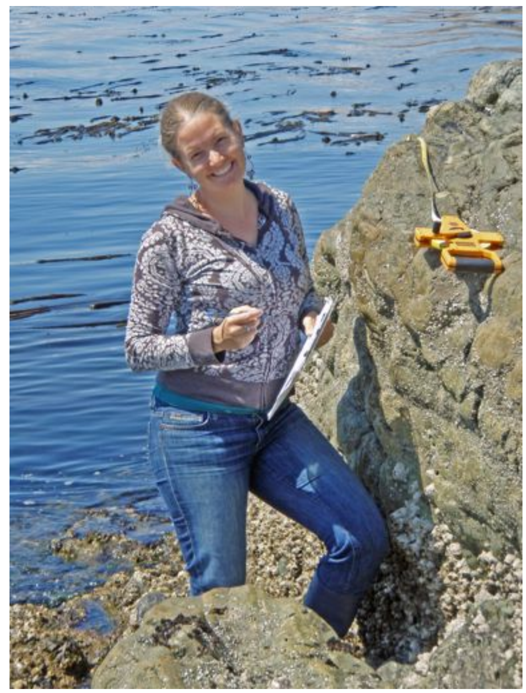
Experimental islands in the intertidal at the University of Washington's Friday Harbor Labs. Snails on each island must choose between feeding in weather-exposed areas or taking refuge and forgoing feeding. Their choice changes with the tidal cycle.

Nucella ostrina wearing a radio tag backpack. The radio tag can be detected as a unique ID number, even when the snail is under water.

choosing to feed on the side of the rock with the most shade. Because on some days the low tide occurs in the morning and some days the low tide occurs in the afternoon, the side of the block which is shaded changes throughout the tidal cycle. If the low tide is in the morning, only the east side will be hit by the sun before it is submerged by the incoming tide. The same is true for west sides of blocks when low tides occur after noon. We don't know which environmental cues these snails are using, but we know that they responding by changing where they are feeding.

I suspected that the conditions in my experiment were close enough to "real life" that the snails would have the same behavior they had while roaming freely, but I couldn't know this for sure from the tests I had done. I wanted to know when free-range snails moved to open, weather-exposed places on shore. Luckily for me, technology had just miniaturized radio tags that work in seawater. Radio tags (one of the most common forms also known as PIT tags) have been used for many years in wildlife tracking. One aquatic example is the tracking of salmon migrating between rivers and the ocean. I was able to epoxy these tags—about the size of long-grain rice—right onto the back of *Nucella* shells. Scanning intertidal areas for radio tags was six times more efficient than hunting around for visual tags such as numbers glued on shells. Relating the tags to shore elevation, I learned that snails were found higher on shore during the predicted low-risk tides than the rest of time.

Nucella ostrina moves from its cool ocean refuge to the barnacle buffet that exists in exposed, high-shore areas. It does this at the least risky time of the tidal cycle and chooses the coolest surfaces, minimizing its risk of experiencing lethal conditions. This tells us that it has some mechanism for timing the tidal cycles, determining when the least risky times for feeding will occur. Furthermore, it is able to detect or anticipate the cooler of two different rock surfaces. We don't currently know how it is sensing its environment, but we now know how it's responding to it. This specialized behavior means that it would be unlikely for a few degree increase in global temperature to be lethal to this species. Even though current temperatures often exceed lethal temperatures for *N. ostrina*, this snail isn't hanging out in air when and where it would experience them. However, temperature changes could greatly affect the timing and location of snail feeding and therefore the distribution of their prey.



The author, graduate student Hilary Hayford, recording tidal elevation of radio-tagged snails.