SEA STAR

Washington Sea Grant

University of Washington

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COPEPODS MAY COPE, BUT KRILL CRINGE WHEN THE WATER TURNS SOUR

By Margaret C. Siple, WSG Science Writing Fellow

To understand how changing ocean chemistry will affect marine food webs, UW's Julie Keister and Anna McLaskey put tiny crustaceans to the acid test.

One food-web ecologist likes to call crustacean zooplankton "yummy crunchy things." They certainly are for a wide range of marine animals, from herring and hake to salmon and baleen whales; these free-swimming, 20-micron to 20-millimeter-long cousins of shrimp and crabs are foundations of the marine food web. For Julie Keister, an assistant professor in the University of Washington's School of Oceanography, they are something more: keys to understanding how the emergent threat of ocean acidification will affect marine ecosystems.

With support from Washington Sea Grant, Keister and her team study the effects of acidified water on the hatching and survival of two important pelagic crustacean taxa, copepods and krill (a.k.a. euphausiids). In the open ocean, these little animals face a gauntlet of threats from the day their lives begin. The species Keister studies, *Euphausia pacifica* and the copepod *Calanus pacificus,* are free-spawning, so their eggs begin to sink as soon as they're released. If they sink below the photic zone, where sunlight penetrates, they can become lost in a food desert. After they hatch, both species are regularly devoured by juvenile and forage fish. Young salmon packing on the pounds seek out fat-rich crustacean zooplankton.

Changing ocean chemistry may make the seas even more dangerous. Basic life processes such as organisms' respiration of CO_2 have always affected pH on the local scale, especially in shallow and confined embayments. But "ocean acidification" (OA) refers to something bigger: a persistent drop in the sea's pH with a clear cause.

When we burn fossil fuels, we release CO_2 into the air. The ocean, the world's largest carbon reservoir, absorbs much of that atmospheric CO_2. As CO_2 dissolves in seawater, it forms carbonic acid and lowers the water's pH. Ocean pH has already dropped 0.1 points on a 14-point logarithmic scale, equating to a 30 percent rise in relative acidity. The ocean's pH is expected to drop another 0.2 to 0.4 points by 2100. And as acidity rises, the amount of available carbonate drops, making shelled marine animals use more energy to find calcium carbonate and build their shells.

Whether or not they build calcified shells, all organisms must regulate their internal pH. Plankton have small bodies, so their surface-to-volume ratio is huge, allowing rapid chemical exchange. This means that zooplankton are particularly sensitive to the chemistry of the water they float through.

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BOWLING FOR SAND DOLLARS, AND ALL THE OTHER CRITTERS IN THE SEA

Washington Sea Grant hosts the 2014 Orca Bowl and prepares to welcome the Super Bowl of high school ocean science to Seattle. An Orca Bowl veteran explains why these quiz games matter.

By Eric Scigliano

When she looks back at the path that brought her where she is today, Alexis Valauri-Orton recalls the time she dressed up as a pirate to answer questions about bioluminescent plankton and sea jelly life-cycles before an audience of hundreds.

As a high school junior, Valauri-Orton cofounded a team that nearly won a statewide marine-science competition called the Orca Bowl. Each March this event, sponsored by the UW College of the Environment and hosted by WSG, brings student teams from 20-plus high schools together with working scientists for some high-wire brain-teasing, face-to-face networking, and a few costumed hijinks. The Orca Bowl winner then goes on to face 25 other states' champions at the National Ocean Sciences Bowl (NOSB), which UW and WSG will host for the first time this year.

Six years later, Valauri-Orton is back, after finishing her undergraduate studies and a globe-trotting fellowship project on ocean acidification. She'll assist at this year's Orca Bowl and the national bowl, even as she works with WSG on an ocean acidification curriculum project. And she thanks Orca Bowl for helping her find her vocation.

Valauri-Orton attended Seattle's Garfield High School, an inner-city school renowned for its long-running marine biology program. Garfield once fielded an Orca Bowl team, but that effort fell by the wayside years before Valauri-Orton arrived. Marine biology was her favorite class, and when she learned that Garfield used to be an Orca Bowl contender, she and a marine-minded classmate (who now works at the Seattle Aquarium) decided to start a new team.

Later that year she and four other Garfield juniors took the bowl stage.

At first the Garfield pirates struggled with the unfamiliar buzzers they had to press to answer questions. By the end, however, they found their mojo, came in ninth out of 16 teams competing, and won the bowl's sportsmanship award.

"We were surprised at how much we knew," Valauri-Orton recalls.

By the next year she and her teammates had taken physics, which left them better prepared to answer tough questions about waves and currents. They very nearly won that Orca Bowl and a ticket to the national finals, but were edged out by the ExCEL Academic League from Vancouver, Washington.

Garfield's pirates received a runner-up prize, however: They got to join a research cruise with the Northwest Association of Networked Ocean Observing Systems.

"We had an incredible time," recalls Valauri-Orton – at the bowl as well as on the cruise. "It was so exciting to be at UW, around all these scientists and researchers, and to envision ourselves as marine biologists one day."

That experience helped form her decision to dedicate herself to marine science and education. But she also wanted to attend a smaller liberal arts college. She landed at North Carolina's Davidson College, which though inland offered an excellent biology program and generous scholarship. Valauri-Orton in turn enriched Davidson's offerings: When her senior class on climate change included nothing on ocean acidification, she petitioned successfully to give a presentation.

Upon graduating, Valauri-Orton received a Watson Fellowship, a yearlong stipend for select graduates from liberal arts colleges to pursue original research overseas. She traveled to fishing villages around the world, examining their dependence on resources threatened by ocean acidification. That's led to her current work developing an online collection of ocean acidification curricula and teaching tools with WSG acidification specialist Meg Chadsey and Suquamish tribal biologist Paul Williams. The need is urgent, Valauri-Orton explains: "Nobody my age knows much about OA."

Another generation of Garfield pirates made a strong start at this year's Orca Bowl in March. But then one pirate jumped the buzzer to answer the question: "How many plates do chitons commonly have?"

"Eight," she replied – the most common number, but the wrong answer. "Seven or eight" was the multiple-choice answer she didn't wait to hear. Orca Bowl rules, like life in the sea, are unforgiving. One of two teams fielded by Everett's Ocean Research College Academy (that's right, ORCA) won the bowl and a shot at the national title.

The pressure will be even higher at the National Ocean Sciences Bowl, which unfolds at UW's Fishery Sciences Building on May 3 and 4. This year's theme is ocean acidification – befitting the venue, since leading OA researchers from UW and NOAA will attend.

Such competitions are widely hailed as a way to stimulate student interest not just in ocean science but also in STEM studies and careers generally. They give students a chance to meet peers, potential teachers, and mentors from around the state and country. They let science buffs shine, just as athletes do on fields and courts.

And they let volunteers from marine fields and the wider community boost both the effort and their own ocean literacy – and to have fun, especially if they volunteer here in Washington. At Orca Bowl, uniquely among the 25 regional competitions, many of the 100 or so volunteers wear marine-themed costumes. Those attending last year could have seen WSG's director, Penelope Dalton, decked out as a coral polyp.

Dalton didn't go coral this year, though it would have suited the OA theme. But Alexis Valauri-Orton did dust off her pirate togs.

Left: Garfield's pirates count chiton plates in a showdown with Redmond High. Above: Friday Harbor B Team in competition and the 2014 Orca Bowl champions from ORCA at the awards ceremony at the Seattle Aquarium.

To volunteer at next year's Orca Bowl, or to become a sponsor, contact *orcabowl@uw.edu*. Or, if you know of a high school that's interested in starting a team, please contact us! You'll find more information about Orca Bowl at *wsg.washington.edu/orcabowl*.

Photos: NOAA

By Jakob Jarecki, WSG Science Writing Fellow

Nearly three years have passed since the Tōhoku earthquake and resulting tsunami struck northeast Japan with devastating force. When the destructive surge returned to the sea, it left nearly 16,000 people dead and another 6,000 injured, and carried away an estimated 5 million tons of debris. Perhaps 70 percent of that load sank to the seafloor off the Japanese coast. The remaining 30 percent was swept out into the ocean.

Initially, many media sources predicted that large deposits of tsunami debris would wash up on the west coast of North America. But by compiling reports from citizen beachcombers, WSG's Port Angeles-based marine hazard specialist, Ian Miller, pieced together a very different story.

"It appears that tsunami debris, ranging from small lumber and Styrofoam to large fishing vessels and docks, has landed in smaller, intermittent bursts along the coast all the way from Alaska to California," says Miller.

Washington's first encounter with large tsunami debris came on June 15, 2012, when a 20-foot fiberglass boat washed up at Cape Disappointment State Park in Ilwaco on the Long Beach Peninsula. That summer a plastic fishing tote and a soccer ball labeled "Ōtsuchi Soccer Club" – an eerie token of the devastated coastal town of Ōtsuchi – washed up farther north in Olympic National Park. On December 18, 2012, a 65-foot-long dock from the Japanese port of Misawa landed on the beach near LaPush; it was cut up and removed in March 2013. Next up, a cement cylinder landed at Leadbetter Point in Long Beach, Pacific County, on February 23, 2013. A month later a 20-foot fishing vessel landed in Long Beach on March 22, 2013. The vessel contained five striped beakfish, the first vertebrates to come ashore in tsunami debris – and an invasive species. Four were euthanized, and the fifth went on display at Oregon's Seaside Aquarium.

So far, says Miller, "damage from the debris has been limited to the ingestion of Styrofoam shards by marine animals." Many coastal residents feared that radioactive flotsam would wash up onshore, but "so far no elevated radiation levels have been detected on debris or in coastal waters."

The observed deposition pattern reflects the complex relationship between large-scale ocean currents and local weather conditions. The debris initially was swept into the mighty Kuroshio and Oyashio currents, which meet to form the eastbound North Pacific Current off Japan's east coast. As the debris approached North America, it was borne either north and west by the Alaska Current or south by the California Current. Next, storm patterns nudged patches of the circulating debris toward land; others continued circulating along the vast gyre that circles the infamous North Pacific Garbage Patch.

Forget the dire forecasts of massive wash-ups and a sea star-killing "radiation wave." Washington Sea Grant's Ian Miller tracks the curious tsunami relics that are actually reaching our shores.

AFTER THE TSU

Two other celebrated incidents have given oceanographers insight into how today's tsunami debris may behave in the Pacific. In the 1990s Seattle-based oceanographer Curtis E. Ebbesmeyer tracked the contents of two spilled shipping containers in the North Pacific, one containing Nike shoes and the other plastic bath toys. This flotsam circulated for an average of 2.9 years; some traveled as long as five years and as far as 7,000 miles.

From Ebbesmeyer's findings and other circulation data, we can assume that the Pacific Ocean still contains plenty of tsunami debris. But that debris has broken up and dispersed, making it undetectable by satellite. It is safe to assume we will see more make landfall in the next few years, just as the Nikes and bath toys continued washing up.

But we won't likely see the "radiation wave" that dire news stories and blog posts have described as creeping across the Pacific and even, according to some unfettered speculation, causing mysterious sea star die-offs along the West Coast. The time elapsed between the tsunami and the failure of the Fukushima Daiichi power plants, plus the sheer size of the sea, ensure against this.

"The power plants did not deteriorate and start leaking radiation until well after the tsunami surge had returned to the sea," says Miller. And any radioisotopes that did escape were dispersed widely in the immense volume of the Pacific Ocean.

TUGBOATS AND CRAB FISHERMEN CAN GET ALONG

WSG's Steve Harbell helps two industries find a better way to share the waters.

More info: *http://wsg.washington.edu/lanes*

For 41 years the West Coast's crab-fishing and tug-and-barge industries have been working out their differences at the negotiating table. The challenge: how to minimize the costly entanglement of crab gear by tugs and barges, while leaving the crabbers room to fish and assuring safe, efficient tow lanes. Now the process, which has already made the seaways safer for both industries, is nearing full fruition. Steve Harbell, WSG's Montesano-based marine field agent, is brokering a final agreement between Oregon's fishermen and tug companies, and hopes to see its terms extended down the California coast.

"Tug and barge encounters with crab gear are almost always fatal to the gear," says Dale Beasley, president of the Columbia River Crab Fisherman's Association and the Coalition of Coastal Fisheries. They're also dangerous to the tugs and barges that get fouled.

Harbell, together with California Sea Grant, originally assisted Oregon Sea Grant in the effort. But in 1997 he took the lead in what's now called the Commercial Crabber Towboat Lane Agreement Project, mediating between the two industries all the way from San Francisco to Washington's Cape Flattery. He hopes to have the final Oregon agreement in place this December, when the 2014-15 crabbing season starts.

This accord will replace the current pair of two-mile-wide tow lanes along the Oregon coast — an inshore lane open summer and fall and an offshore lane open winter and spring – with a single mile-wide lane located in between the two and open year-round. It will maintain entrances to Coos Bay and Newport but close unused lanes into Garibaldi, Umpqua, and Siuslaw. Provisional lanes will be reserved, in case tug traffic resumes to those minor ports.

These changes promise not only to improve safety but also to lower fuel costs for tug operators as they save miles and avoid the stormier winter weather farther offshore. The fishermen will lose access to the new single lane all year long, but will gain more than 175 square miles of new crabbing area in the old lanes. Both will benefit from greater certainty as to who belongs where.

A similar accord is in the works down the coast, from Coos Bay, Oregon, to Eureka, California. In Washington, tug operators have already shown that, using modern navigation equipment, they can operate in a lane just one mile wide. Harbell estimates that, coast-wide, the accords in progress already save the two industries more than $1 million a year, including 5,000 crab pots that would otherwise be lost. Thanks to the ongoing regular meetings, he says, "we've already seen greater cooperation on a variety of issues outside the tow-lanes between the two industries, plus the international shipping industry."

Fisheries coalition president Beasley seconds the emotion. "The agreement is a collaborative effort free from government intervention," he says, "and a great example of industries sharing mutual respect for each others' needs and looking for solutions that are mutually beneficial. As new industries come to the ocean, they can learn a lot from this collaboration. We hope Sea Grant will be able to expand its role as a mediator of shared ocean space." — *Eric Scigliano*

Copepods • continued from page 1

If conditions are unfavorable for a long time, it becomes difficult for zooplankton to regulate their internal pH. This kind of internal regulation demands a large investment of energy and may leave them with less energy to spend on other things, such as finding food and laying healthy, viable eggs. So far, most studies have tested these species under extreme conditions that will not be experienced for centuries. Keister is one of the first zooplankton ecologists to study the effects of a changing ocean on copepods and krill at more ecologically relevant levels – those experienced now and those expected in 2100.

Keister and her graduate student Anna McLaskey conduct their experiments at NOAA's Northwest Fisheries Science Center. To get specimens, they must travel to Everett for krill and Shilshole Bay for copepods and trawl for egg-laden females, distinguishable by the intense purple that infuses their genitalia. They bring these back to the lab and keep them until their eggs hatch, usually overnight.

Keister and McLaskey carefully control the water's carbonate chemistry. A computerized seawater filtration system scrubs ambient CO_2 from the water and then restores it to a specific level, ensuring a precise pH. They then pump the water into the small jars where the zooplankton live.

The greatest challenge, McLaskey says, is achieving conditions "that make the chemists and the krill happy." Controlling acidity in the lab is extremely difficult, and ocean chemists have to keep close tabs on the water's temperature, oxygen concentration, and pH. This requires much time-consuming measurement and, at times, troubleshooting. During early experiments, the complex tank system that automatically balances all these factors contained a plastic that contaminated the tanks and killed the krill. So McLaskey developed a procedure that keeps the krill healthy while maintaining the correct water chemistry. This delicate chemical balancing act only ends after the krill finish their second molt, when she preserves and sorts them and evaluates their body condition.

Based on the few previous studies on these crustaceans' response to acidification, copepods seem to be more tolerant of acidified water than the delicate krill. Copepod species other than *C. pacificus* have remained robust at dissolved-CO_2 levels that would kill Atlantic krill (*E. superba*) eggs.

Keister and McLaskey expect to find similar differences between krill and copepods to those seen in the earlier research. Indeed, their initial results suggest that *C. pacificus* may withstand a wider range of dissolved CO_2 than *E. pacifica*. As in the previous studies, the copepods seem to show some ability to adapt to rising CO_2.

Hatching success varies widely among breeding copepod females, which are raised individually in NOAA's ocean acidification lab. Even at dissolved-CO_2 levels we don't expect to see for 100 years or more, some of them do lay eggs that hatch. If this pattern is consistent across the whole population, could it be a sign that copepods could adapt to dramatic changes in ocean chemistry?

"It's way too early to tell," McLaskey says. "Climate change is going to change the zooplankton community, but we don't know how yet."

Even in a single sampling season, overall hatching success can vary greatly. Keister and McLaskey will have to perform several more experiments before they know how OA will affect crustacean zooplanktons' success.

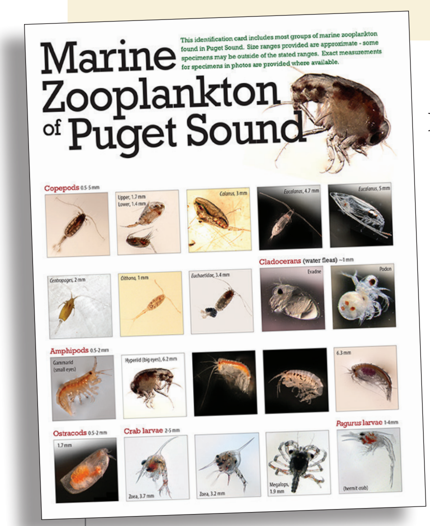
Keister's work is part of a recent push to understand some of the effects of increased CO_2 on zooplankton. These effects may manifest themselves not as acute forms of stress (changes in mortality rates, morphology, or embryonic development, for example) but as subtle differences in the animals' energetic capacities that still may have negative long-term implications.

Keister and McLaskey work in a region where OA will have especially strong impacts: the northeastern Pacific, a highly productive upwelling zone where cold, low-pH deep water rises to the surface. In this rich environment, *C. pacificus* and *E. pacifica* are ecologically essential: *C. pacificus* is the region's dominant large-bodied copepod, and *E. pacifica* is the most abundant krill species off the coasts of Washington and Vancouver Island. Keister's research stands to teach us what we can expect from vital marine food webs as the ocean's chemistry marches ever farther from its recent historical state.

HOW TO TELL KRILL FROM COPEPOD...

... not to mention ostacod from pteropod, polychaete from chaetognath, and crab larva from barnacle molt.

Last August, Washington Sea Grant published a beautifully illustrated letter-size identification card showing various life stages of these and other Puget Sound zooplankton species. The project grew out of a series of workshops that WSG and several partners convened to help boat-based education programs perform more meaningful data collection. During the second workshop, Julie Keister showed participants how to sample phytoplankton and zooplankton. They used a phytoplankton ID card developed by UW's School of Oceanography, and lamented the lack of a corresponding zooplankton card. In response, WSG worked with Keister and student Audrey Djunaedi to design one. Djunaedi took the photos (which illustrate this article). The resulting laminated cards have gone out to boat-based education programs all around Puget Sound; digital copies are available at *http://wsg.washington.edu/zooplankton-card*



FIELD NOTES

WSG coastal resources specialist **Jamie Mooney** and student assistant Emily Halvorsen have completed another long-awaited report, on the results of an in-depth survey of more than 100 coastal planners, managers, and officials in Washington on their experience with and strategies for adapting to climate change. It finds that an overwhelming majority have encountered multiple obstacles to adaptation efforts, especially a lack of consensus and shared sense of urgency, and insufficient staff and other resources – few of which they've managed to overcome. The Washington survey is one in a national series initiated by the National Sea Grant Office. *http://wsg.washington.edu/coastalsurvey*

WSG ocean acidification specialist **Meg Chadsey** and Caroline Gibson, the Northwest Straits Initiative's marine program manager, are presenting a session on "Novel Actions to Address Ocean Acidification in the Salish Sea" on May 1 at the 2014 Salish Sea Ecosystem Conference, at the Washington State Convention & Trade Center. See the complete schedule at *http://www.wwu.edu/salish-seaconference/schedule.shtml.*

In 2007, spurred by community concerns, the Washington Legislature asked WSG to conduct a comprehensive peer-reviewed study of the possible environmental effects of the state's fast-growing geoduck aquaculture. In December, WSG presented its final report, including a review of 420 papers on geoduck biology and shellfish aquaculture, to the legislature and public. The findings gauged the effects of geoduck culture and harvest on water quality, sediment chemistry, wild geoduck populations and other macrofauna, and eelgrass, a vital intertidal habitat. But they did not point to severe problems. "The range of effects varies from modestly negative to modestly positive," said UW biologist **Glenn VanBlaricom**, one of the report's principal investigators. "We found no evidence that geoduck aquaculture is causing fundamental shifts in ecosystem-scale structure or function in Puget Sound." However, VanBlaricom and the other researchers noted a number of aspects of geoduck culture that call for longer-term research or monitoring, from site-specific factors in its effects to genetic inputs into the wild population. Read the report and related materials at *http://wsg.washington.edu/research/geoduck*

Audubon does its Christmas bird count. WSG spends New Year's Eve monitoring imperiled sea stars. On December 31 WSG-funded researchers **Melissa and Ben Miner** (from UC-Santa Cruz and Western Washington University, respectively) shared their knowledge of sea star wasting disease, the mysterious syndrome that's ravaging the stars along the Pacific Coast, with WSG marine water specialist **Jeff Adams** and eight volunteers. The Miners showed the group how to monitor the ailing stars in two different habitats, Rockaway Beach on the east side of Bainbridge Island and Point White Pier on the west. Ben almost immediately found a sick star on Rockaway. Thus informed, Adams and his team searched further and found many stars, ranging in condition from healthy to what Adams calls "white mush," and measured all those on one large outcrop for ongoing monitoring. They also found "sea star bits and pieces everywhere" amidst the pilings at Point White Pier. "Volunteers familiar with the site said there were far fewer stars there than in early December. Many of those remaining showed signs of wasting disease." Adams's team will now train other individual naturalists and groups to monitor the stars in Central and South Puget Sound.

The Washington State Parks Department's Clean Vessel Program and Washington Sea Grant, which operates the Pumpout Washington program on behalf of State Parks, have been working overtime to help marinas and other boating facilities install sewage pump-out stations, and to get boaters to use them. Last year WSG boating program specialist **Aaron Barnett** and his volunteers distributed more than 4,000 hose-locking adapter kits to make pumping out cleaner and easier, and state-sponsored mobile pumpout stations took the service right to the boats. The Clean Vessel Program has meanwhile added pumpout stations in new locations and second units at marinas that only had one, and replaced older units with new ones that monitor volumes more accurately.

Are these efforts making Washington's waters cleaner? The numbers suggest they are. Last year Washington boaters pumped out more than 5.6 million gallons of onboard sewage — by one estimate, enough to fill downtown Seattle's Arctic Building. That's 1 million gallons more than last year, up from just 47 thousand gallons in 1996, before the state program started. All that even though boat sales and registrations have slumped. Congratulations to boaters still out on the water, who are keeping their wastes out of it. More info: *http://pumpoutwashington.org"*

2013-14 science writing fellow **Chelsea Kahn** is also reaching a new stage – a literal one. She'll speak on communicating about climate change at Seattle's Town Hall on May 19 at 6 pm, as one of 13 UW grad students sharing their science in the Engage Science Speakers Series. And congratulations to 2013 WSG science writing fellow **Margaret C. Siple**, who's been hired as an analyst by Seafood Watch, the Monterey Bay Aquarium-based project that produces those invaluable folding cards listing the most, less, and least sustainable and healthful seafood choices. Megsie will be evaluating herring, a tasty way to eat down the food chain and a foundation of the local marine food web, while she works on her PhD at UW Aquatic & Fishery Sciences. Her autumn *Sea Star* article on salmon genomics, "A Code of Many Colors," helped win her the job.

Correction: We got our crustaceans crossed when, copying an erroneous stock-service caption, we called our autumn cover critter a "snow crab." It's actually a Japanese spider crab.

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The ratfish prepare to attack

Illustration by Craig Coselini

FLOATABLE & QUOTABLE

Amazing single-celled bacteria-fishing wonder taco

"We discovered a completely new species [of single-celled haptophyte algae]. I've submitted the name *Chrysochromulina tobin* for it, after my son. I wanted to do something for him that would stay around a while after I go to the happy hunting ground.

"I showed him a picture and he said it was wimpy. I said, No you've got it all wrong, this is one tough little guy – it lives at pH 10. It hunts bacteria, using a long appendage called a haptonema that it uses like a fishing pole to retrieve them. We think it also farms the bacteria. It extrudes dissolved organic carbons, which bacteria feed on, and it needs vitamin B12, which bacteria produce. We think it selects the bacteria that grow around it.

"It's shaped like a taco, and 40 percent of its body weight is fat. If you want to retrieve oil [for biofuel], you just touch it and the oil falls out."

UW algal biologist and WSG researcher
Rose Ann Cattolico