SEA STAR

Washington Sea Grant

University of Washington

Autumn 2013

A Thousand-Mile Crab Walk

Sea Grant researchers track the epic migration of the Bering Sea's snow crabs, finding better ways to manage this footloose delicacy.

Page 2

THE BERING SNOW CRAB'S THOUSAND-MILE WALKABOUT

Andre Punt and Cody Szuwalski develop dynamic new spatial models for managing this highly valued, highly mobile delicacy.

By Margaret C. Siple, Washington Sea Grant Science Writing Fellow

When fishery managers inventory the resources they oversee, they use models that assume that fish spread out evenly throughout their habitats, like gas in a jar. That may be true of highly mobile species such as tuna, but we know it's not for other species. You only have to see how fishing vessels cluster in "good fishing spots" to see that fish favor certain areas and fishers (not to mention scientists) often have a pretty good idea where those areas are. Failing to consider that uneven distribution can lead to overfishing — but accounting for spatial complexity and movement is much more difficult than assuming uniform distribution. Now Andre Punt, the director of the University of Washington's School of Aquatic and Fishery Sciences, and his doctoral student Cody Szuwalski are testing fisheries models that do just that, and which just might help prevent overfishing.

Punt sits on the Bering Sea/Aleutian Islands Crab Plan Team, which recommends management strategies to the governing North Pacific Fishery Management Council. Szuwalski's graduate research, which is supported by a Sea Grant and NOAA Marine Fisheries Service Marine Population Dynamics Fellowship, focuses on snow crab (*Chionoecetes opilio*), a crustacean of modest size, high value, and predictably uneven distribution.

That distribution makes Eastern Bering Sea snow crabs unusual among commercially fished species. The crabs form a single population, but the thousand-mile journeys they make over their lifetimes cause them to segregate dramatically according to size and maturity. Juvenile crabs move offshore onto the Bering shelf as they mature, starting in the northeast, and migrate southwest into deeper, cooler waters as they grow. Large males, which are fair game, tend to congregate in the middle of the shelf, so crabbing boats often do too.

"It'd be like if we were all born on the East Coast and walked west over our lives," Szulwalski explains, "All the middle-aged people would be in the Midwest and if you made it to old age, you'd be on the West Coast."

If fishing boats concentrate on just one part of the shelf, it may disproportionately affect one age group. That may explain why the East Bering snow crab population has failed to fully recover since 1991, when it was declared overfished. But even as a recovering stock, it is valuable. In 2011 the fishery yielded 54.5 million pounds of crab, worth $79 million.

Szuwalski and Punt recently published a paper showing that the snow crab population's success depends partly on the number of spawning females, but environmental pressures can be even more influential. After hatching, snow crab larvae drift freely in the water column. They need ocean currents that can sweep them to choice nursery grounds, and they need ample phytoplankton to eat while they drift.

Szuwalski and Punt found that crabs do best in warm years, when larvae have more food, mature faster, and spend less time drifting in predator-filled waters. But during a "cold regime" — several years of persistent cold — they do better in the coldest years. Szuwalski and Punt hypothesize that this apparent paradox occurs because those warm and extra-cold years both produce the same result at the seafloor: more of the food-rich cold water that provides prime settlement habitat for snow crab larvae. (In warm years, this is because warmer waters above cause more stratification, trapping a cold layer at the bottom.)

Currents are intimately related to ocean temperature. The currents in the East Bering Sea sweep larvae and fertilized eggs to their future settling grounds. Young, newly mature crabs spawn in larger volumes than do older individuals. These crabs, however, are still at the beginning of their walk of life, on the northeast end of the shelf. So when currents carry larvae from the northeast, recruitment is high, but when they shift to flow from other directions, such as where the older individuals concentrate, recruitment drops. These broad changes likely cause the East Bering Sea's dramatic multi-year shifts in snow crab recruitment.

Szuwalski and Punt argue that their analysis shows the importance of considering climate in snow crab assessments. But they also note that a more thorough

analysis would consider how space influences recruitment. When properly designed, spatial conservation plans such as marine protected areas can foster the recovery of stocks and the growth of fisheries. The snow crab fishery is one of several large commercial fisheries that might benefit from spatial management techniques but have yet to employ them; it operates under size and sex restrictions but has no limits on where boats can fish.

Szuwalski wants to test the capacity of the current crabbing rules to ensure the fishery's survival under different spatial scenarios. Since much remains to be discovered about the secret life of snow crabs, Szuwalski must allow for multiple hypotheses about their biology, testing the fishery rules' capacity to cope with a wide range of potential circumstances.

To test the robustness of the current management policies, Szuwalski is constructing several operating models — mathematically generated crab populations, each embodying a different hypothesis about how snow crabs grow and reproduce. In one model, for example, many adults return to spawn on the middle shelf. In another, only large mature males get to breed. Simulated fishing boats then harvest these modeled populations according to today's rules.

After 50 simulated years, Szuwalski examines the outcomes: Did the rules that the Alaskan fishery follows today allow an optimal crab harvest? If the management objective was to allow the population to recover from overfished levels, did that occur under some or all of the population scenarios?

This approach, under which the effects of harvest rules are tested on several hypothetical populations, is called a management strategy evaluation, or MSE. The concept may sound simple, but Szuwalski says implementing the MSE is the most challenging part of the project. It means modeling both the hypothetical populations and fishing strategies. In a single-species fishery, an MSE usually involves only a single population. The version that Szuwalski is creating adds the dimension of space, so he has to model population dynamics and movement. This process will take at least a year and involve a level of programming that would leave most graduate students shaking in their boots.

The outcomes should be useful in future decisions, such as how much catch to allow given what we don't know about snow crabs. The MSE analysis will also identify elements of crab biology in which space is really important. This will not only lead to more effective catch rules. It will protect the fishery from the gaps in our knowledge.

THE UNITED NATIONS OF SEA GRANT

Budding marine scientists come from around the world to work on Sea Grant-supported research. In America they find more funding, a freer atmosphere, fisheries managers who listen — and messier labs.

by Jocelyn Robinson, WSG Science Writing Fellow

Students come from around the world to work on research projects at the University of Washington — many of them funded by Washington Sea Grant. In addition to the usual challenges of working and studying overseas — making sure visas are in order, overcoming language barriers, being away from family and friends — these international students must also adjust to an American research culture that can be very different from those of their home countries.

Marine Brieuc and Kotaro Ono, wife and husband from France, came to UW to earn their doctoral degrees in fishery sciences. Ono uses statistical and modeling tools to evaluate and improve various methods of managing groundfish fisheries. By assessing stocks and the size of populations, managers can more accurately develop quotas for fishermen. Brieuc is a fish geneticist working on a Sea Grant-funded study of the adaptive evolution of salmonids, specifically Columbia River Chinook (see "Code of Many Colors," p. 4). The first step in tracing this evolution was to characterize the Chinook genome by creating a linkage map to determine the relative positions of loci on its 34 chromosomes; the map Brieuc is working on now has more than 7,000 markers. By comparing salmon populations, researchers can identify different regions of the genome under selection, a first step toward tracing local adaptation.

Denmark's Nis Jacobsen missed the faculty attention he had there, but found closer ties between labmates here. Photo: William Nielsen

After working in France, Ono and Brieuc find the approach to research here both novel and bracing. Fisheries management and research are more closely linked in the United States, says Ono, and managers tend to listen more to scientists. Overall, says Brieuc, research is more highly valued in America than in other places: "There is more money dedicated to research, and people are more creative because they have the means to be so."

Felipe Hurtado-Ferro, a fishery sciences PhD student from Bogotá

United Nations of Sea Grant • continued on page 6

A CODE OF MANY COLORS: THE SA

by Margaret C. Siple, WSG Science Writing Fellow

Geneticists Kerry Naish and Jim Seeb map the Chinook genome, revealing key turning points in salmon evolution and pointing the way toward smarter hatchery practices.

Imagine your genome is a palette of paints, and you are a painting. Having a duplicated genome is like having twice as many tubes of paint at hand: If both genes express the same trait, you can double up and lay down a thicker coat of that color, or have a backup in case one tube runs out. Having two genes for the same trait can also give one of the genes the freedom to perform another function, so that your painting becomes richer and more complex. Salmonids (the fish family that includes salmon, char, grayling and trout) are rendered with twice as many genetic paints as smelt (family *Osmeridae*), with which they share a relatively recent common ancestor. The range of genetic colors present in salmon has led to an extraordinary array of life histories, morphologies, and behaviors.

This diversity can be measured and at least partly explained by deciphering the salmon genome. UW geneticists Kerry Naish and Jim Seeb, professors in the School of Aquatic and Fishery Sciences (SAFS), are mapping the genomes of several wild and hatchery Chinook populations. These maps will help scientists answer questions about how salmon have evolved, what genes are important in natural selection, and how hatchery practices affect their genetic diversity.

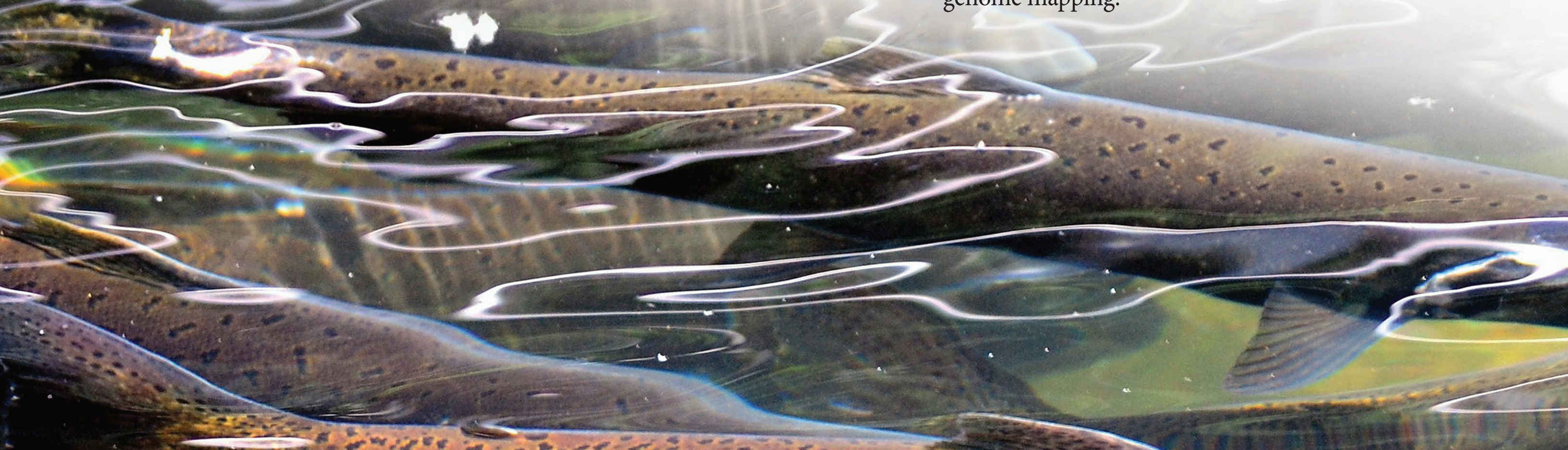
Naish has two Washington Sea Grant-funded projects underway, both of which are crucial early steps in revealing the genetic basis for the salmon's remarkable evolutionary capacity. The first is a collaboration with Jim Seeb, a research professor at SAFS who studies salmon genetics. With the help of a $4 million grant from the Gordon and Betty Moore Foundation, Seeb's group acquired state-of-the art genotyping technology, which he and Naish are now using to map the Chinook genome. Their goal is to place map "coordinates" across the Chinook genome. These coordinates are molecular markers that will be used to survey the genome for evolutionary clues and recent genetic changes in the population. Naish's second project uses these mapped markers to study the processes behind the divergence of Columbia River Chinook into diverse populations with a broad array of traits.

Mapping the genome is not the same as fully sequencing it. Instead of sequencing the entire Chinook genome, Naish and her team are constructing maps made up of about 80,000 short regions for each individual, each of which is about 100 base pairs long (in a genome with 3 billion base pairs). These will serve as a basis for future genetic explorations.

Genome mapping is a judicious approach to genetic exploration. The Human Genome Project, which inventoried the entire *Homo sapiens* genome, took about 10 years and $2.7 billion to complete. The genomes of 36 Chinook salmon can be mapped in two weeks at a cost of about $2,000. This is possible partly because mapping picks out and sequences shorter segments rather than all the DNA in a genome.

The map is made by making a cross between two individuals. The simplest cross is a haploid one, in which the offspring have just one set of chromosomes. To create haploid fertilized eggs, Dr. Naish's team shoots UV rays at salmon sperm, rendering the sperm's DNA ineffective. This way, only the mother's genes are transmitted to the offspring, and the resulting egg develops as a haploid individual with only one set of chromosomes.

Seeb and Naish needed to quickly and inexpensively map the genome using DNA from the haploid crosses. They recruited Michael Miller (now a professor at UC Davis), who developed a technique that shears DNA into short pieces and sequences them en masse. This technique, called restriction-site-associated-DNA or RAD tag sequencing, enables much faster, cheaper genome mapping.



ALMON GENOME REVEALED

The genome is shredded using restriction enzymes, which cut only when they find a certain base-pair sequence. Piece are shorn again, and the smaller pieces containing enzyme-cuts are sequenced. How frequently DNA sequences show up together indicates how close they are on the chromosome, which is then mapped accordingly. The importance of particular genes for selection can be determined when sequences from whole populations are overlaid on the linkage maps.

There are many applications for a genome-wide analysis of Chinook salmon. Genome analysis can identify the genes associated with important adaptive traits, such as knowing just the right time of year to enter freshwater. It can determine how salmon might respond genetically to external influences such as hatcheries and climate change. And it can identify fish caught in the open ocean as wild or hatchery-bred, so we can understand which wild populations contribute the most to resilience and diversity.

For these reasons, it's particularly important to measure genetic changes in salmon. But because Chinook embody such a plenitude of genetic possibilities, it's also very difficult. Whole-genome sequencing provides a wealth of data that was formerly inaccessible: With single-gene sequencing, salmon geneticists could examine about 15 loci in the salmon genome. Using whole-genome sequencing, Naish and her team are examining 4,000 loci for evolutionary signals, links to diseases, and genetic evidence of human impacts. After the sequences come back from their whirlwind trip through the lab, she says with a chuckle, "you spend the next 20 months analyzing them."

Naish's graduate student Marine Brieuc compares chromosomes among Chinook populations, looking for differences that are larger than what one might expect from random mutation or genetic drift in an isolated population. If the same gene in two Chinook groups varies more than one would expect under genetic drift, that gene becomes important in distinguishing the two populations. These are the genes to watch for selection, says Brieuc — the ones that likely code for characteristics that have influenced salmon evolution.

This work has important management implications. The Cle Elum Supplementation and Research Facility hatchery is currently exploring different ways to produce hatchery salmon that have a minimal impact on the wild population. Most hatcheries maintain segregated populations that do not interact with wild salmon on the spawning grounds. For four years, Naish has tracked genetic changes in "segregated" stocks (hatchery fish that spawn only with each other) and in hatchery stocks into which wild fish are periodically introduced. Segregated populations experience more drift and are therefore genetically different from both integrated stocks and other segregated stocks.

This means that by physically isolating salmon in hatcheries, humans are affecting their genetics. Though we don't know how this genetic isolation will translate into behavior, life history, or evolutionary fitness, genomic information could change how hatcheries operate: Mixing hatchery and wild populations might become more common, and genomics could illuminate whether hatchery populations are reducing the diversity of wild populations.

Naish, her team, and their collaborators at NOAA, the Cle Elum hatchery, and the Washington Department of Fish and Wildlife have found early evidence that certain practices, such as mixing a few wild individuals in with the hatchery fish each year, can keep hatchery populations much more genetically similar to their wild counterparts. This mixing increases the chances that a share of each hatchery cohort will survive, and might prevent the development of completely isolated, human-dependent hatchery populations.

The Naish lab has only just begun its journey into the uncharted depths of Chinook salmon genomics. Once Naish and her team have identified the genes that have diverged among wild salmon populations on the Columbia River, they will sequence the same genes to uncover differences between hatchery and wild fish, and determine whether hatcheries are affecting the evolution of salmon in the Pacific Northwest. Their work will not only illuminate salmon evolution. It will show us how we can better safeguard their precious genetic legacy.

Dr. Kerry Naish (right) with Mike Miller, who adapted the RAD tag sequencing technique especially for the Chinook genome project. The bag of salmon eggs in Naish's hand will soon be fertilized with deactivated Chinook sperm to create haploid fertilized eggs. Photo: Jim Seeb

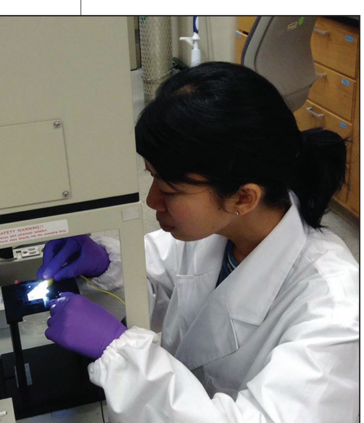
researching stock assessment and modeling at UW, appreciates the level of funding available in the United States. A shortage of money and other resources hampers research in Colombia, he explains: The scientists there are good but the quality of their papers depends on what resources are available to them. "You cannot get into massive projects if you don't have the funding."

To study here, Trinidad's Dara Farrell had to switch from microalgal biofuels to testing underwater noise propagation. But she found a taste of home on the Ave.

Dara Farrell, a PhD student from the Caribbean island of Trinidad, knows how critical funding can be, especially for international students seeking to do research in the United States. Farrell came to UW in 2008 to research the extraction of biofuels from microalgae. The project seemed the perfect way to apply both her degrees, in chemical and environmental engineering, as well as her work in the energy sector in Trinidad. But she wasn't able to get dedicated funding for it, so she's worked instead on a Sea Grant-funded project at UW's Applied Physics Laboratory, developing a new model for estimating underwater sound propagation from marine construction.

By improving the accuracy of these estimates, Farrell hopes to prevent both the harassment of marine mammals and unnecessary construction delays. The project's environmental significance was important to her. "At heart, I think of myself as an environmental engineer because that's what I've always wanted to do," she says. "Once something has environmental benefit, I'll be interested in that sort of research."

The opportunity to solve environmental problems is what drew second-year master's student Eri Amasawa to the material sciences program at UW. Amasawa, originally from Japan, came to Seattle for her bachelor's degree after attending a boarding school in Texas. She started in the environmental studies program but soon realized she wanted more hard science. "I like math and science and I was always good at it," she says. "I don't have to major in environmental studies to be an environmentalist."



Eri Amasawa appreciates the freedom American students have to undertake projects — but not the messy labs.

During an internship in Japan, Amasawa worked on life-cycle assessments, collecting data on carbon footprinting there. For her master's thesis, she is developing an energy-harvesting electrochromic window — a window that would function as a solar cell but also darken on sunny days to reduce cooling costs. Ideally, the energy it harvests would power that changeover.

Amasawa sees striking differences in the way research is conducted in Japan and the United States. The hierarchical culture of Japan extends into its scientific community, she says; roles are strictly defined by seniority and all involved know what their responsibilities are. The freedom American students have to initiate their own research is nice, Amasawa says, but the labs here get messy without that strict division of tasks; she prefers the structure in Japan because it keeps the labs clean and organized. She hopes to return there for her PhD.

Farrell, Brieuc and Ono have come to UW for extended periods, but some other student researchers spend only a few months here. Nis Jacobsen arrived from Copenhagen earlier this year and returned there in July. As part of earning his degree in Denmark, Jacobsen had to study abroad for a few months. He was already looking at coming to UW when he met fisheries professor Tim Essington at a conference in France and the two agreed to work together. Jacobsen notes that he has less one-on-one time with his UW adviser than he had with his adviser in Copenhagen, whom he'd talk to for at least two hours a week. But he does enjoy working more with his fellow labmates. "I feel like it's kind of cool that we have this lab environment where we have weekly meetings and help each other out," he said.

Jacobsen works on ecosystem modeling, using size- and trait-based models that predict how fisheries and changes in them can affect non-target fish communities. For example, the model would try to predict how small fish would respond if all the big fish were taken from an ecosystem.

Like Jacobsen, Felipe Hurtado-Ferro, the fishery sciences student from Colombia, was drawn to UW by the opportunity to work with a particular professor, in his case Andre Punt, and by the strong quantitative fisheries culture here. "There's a huge community of people who aren't afraid of math," he explains. "A lot of the math used (in quantitative fisheries) was born here in Seattle or from people who are here in Seattle" — scientists like Essington, Trevor Branch, and Ray Hilborn.

Hurtado-Ferro is focusing on stock assessment and improved modeling for small pelagic fish such as sardines and anchovies. He looks at the spatial distribution of sardines across time. If a model assumes populations are homogenous, but fishing fleets are catching different-sized fish in different places, then that model produces errors. This leads to the second part of Hurtado-Ferro's research, how modeling can help assess fisheries regulations and management. He likes the work because he can see the impact of what he does and how it affects the lives of people whose livelihoods depend on the fisheries.

And he enjoys working and living in Seattle, even when gray clouds seem to set in forever; his hometown, Bogotá, has very similar weather. For other student researchers from overseas, the cosmopolitan nature of Seattle — especially evident on University Way — helps relieve the occasional bout of homesickness. Dara Farrell doesn't have to venture far for a taste of her Caribbean homeland. It's a short walk to Pam's Kitchen, a Trinidadian restaurant on the Ave, and some home-style curry roti.

FIELD NOTES

Meg Matthews arrived from Chicago in October to fill the new post of WSG assistant director for strategy and communications. In Chicago Meg served as manager of conservation communications at the John G. Shedd Aquarium, where she secured regional and national media placements, provided internal communications counsel, built social media channels from scratch, and managed the development of the aquarium's first long-term organizational sustainability plan. But she's no stranger to these saltier shores; she earned a BA in English at the University of Washington (followed by an MA in geographical research from England's Cambridge University) and worked as a communications specialist at the UW Botanic Gardens. Meg rides dressage, spends all the spare time she can with horses, and hopes to find a new thoroughbred to lease. She's also an avid runner, hiker, cyclist, and food grower, volunteers in cat rescue, and has been known to knit blankets for shelter kitties while watching TV.

Melissa Poe holds a joint appointment as environmental social scientist at WSG and NOAA's Northwest Fisheries Science Center. Her current projects include a collaborative study of shellfish harvesting as a cultural ecosystem service and community-based research on the sociocultural aspects of ocean acidification and coastal change along the Washington and Oregon coasts. Melissa brings wide experience to this work: She studied community forestry and wild mushroom commercialization in Oaxaca for her PhD in environmental anthropology from UW. As a post-doc fellow, she conducted a multiyear ethnographic study of urban foraging in Seattle and mapped human ecosystems values on the Olympic Peninsula. Melissa also worked on fire restoration, community forestry, and socioeconomic monitoring of the Northwest Forest Plan for the U.S. Forest Service. She's led sea kayaking and trekking expeditions in the Pacific Northwest, Mexico and Nepal. She tweets *@mpoetree*

In August, the Jamestown S'Klallam Tribe released its climate vulnerability assessment and adaptation plan, which Ian Miller, WSG's Port Angeles-based coastal hazards specialist, helped prepare — one of the first such assessments done for a native community in Washington state.

WSG marine advisory services leader Pete Granger and field agent Steve Harbell have offered a seafood retail course each autumn since 2010 as part of South Seattle Community College's meat cutting apprenticeship program. This year's intensive 12-hour class teaches new butchers about product origin, sensory evaluation, quality maintenance, safety and sanitation, marketing, and promotion. Each trainee receives a comprehensive manual — waterproof, of course.

WSG field staff will soon deliver their 100th cold-water survival class, a lifesaving milestone for the local fishing industry. Since WSG began safety training on the Columbia River, there have been no deaths in that formerly high-fatality fishery. Last year three Makah tribal fishermen survived a nighttime boat crash by sounding mayday, donning survival suits, and deploying their raft — procedures they'd learned in a WSG safety course just one month earlier.

More WSG-supported research is bearing publication fruit. Now in press: "Ecological Effects of the Harvest Phase of Geoduck Clam (Panopea Generosa Gould, 1850) Aquaculture on Infaunal Communities in Southern Puget Sound, Washington USA," by Glenn R. VanBlaricom, Jennifer L. Price, Julian D. Olden, and P. Sean McDonald, in the *Journal of Shellfish Research*, and Ed Melvin's and Troy Guy's "Best Practice Seabird Bycatch Mitigation for Pelagic Longline Fisheries Targeting Tuna and Related Species" in *Fisheries Research*. Ed's article "West Coast Long Liners Must Learn to Stream," on new streamer-line requirements in the West Coast sablefish fishery, is featured in the November issue of *Fishermen's News*.

In August, boating program specialist Aaron Barnett relocated the Pumpout Washington office from Seattle to Port Townsend's Northwest Maritime Center. "I moved here to have more presence," he explains. "It's such a maritime, boating-rich community — in Port Townsend, more than any other place I've seen, people know what Sea Grant is and what it does. People say 'I'm glad you're here.' That's also due to [continuing education coordinator] Sarah Fisken's work here over the years."

WSG staff and student volunteers made their last Pumpout Paddle of the summer at Port Townsend's Wooden Boat Festival in September. The Pumpout Paddlers have delivered 350 hands-free pumpout adapter kits, together with instructions, directly where they're needed: to anchored boats with sewage holding tanks. WSG has also distributed more than 3,000 of the adapters, which make it easier to contain sewage and protect local waters, at boat shows, marinas, and other landside venues. Boaters often seem more relaxed and receptive to the message when they're on the water.

Washington Sea Grant
University of Washington
Box 355060
3716 Brooklyn Avenue NE
Seattle, WA 98105-6716

Nonprofit
Organization
U.S. Postage
Paid
Seattle, WA
Permit No. 62

Editor, Eric Scigliano; Designer, Robyn Ricks; Web Editor, Marcus Duke. Meg Matthews, Communications Director. WSG-MR 13-02

206.543.6600
wsg@wecprotects.org
www.wsg.washingtonton.edu.

Tweeting @WASeaGrant
www.facebook.com/WaSeaGrant

FELLOWSHIPS OF THE FIN

Congratulations to these talented marine scholars, whom Washington Sea Grant has placed in these coveted fellowships:

2013-14 Marc Hershman Marine Policy Fellows

Rachel Aronson (UW School of Marine and Environmental Affairs), working at the Washington Dept. of Ecology

Haley Harguth (UW SMEA and Evans School of Public Affairs), at the Puget Sound Partnership

Hilary Frost Browning (UW SMEA), at Washington Dept. of Health

Katie Wrubel (WSU-Vancouver Environmental Science Program), at the Nature Conservancy

2014 Dean John A. Knauss Marine Policy Fellows

Bonnie DeJoseph (UW SMEA), at NOAA Office for Coastal Management

Marissa Jones (UW School of Aquatic and Fishery Sciences), at NOAA Office of Education

Megan Stachura (UW SAFS), at NOAA Office of Sustainable Fisheries, Domestic Fisheries Division

Angela Noakes (UW School of Law), at Office of Senator Edward Markey (D-MA)

2013 Sea Grant/NOAA Fisheries Fellowship in Population Dynamics

Cole Monnahan (UW SAFS)

Washington Sea Grant/NASA Space Grant Scholar

Michael Barsamian (UW freshman)

Left to right: Katie Wrubel, Hilary Frost Browning, Rachel Aronson, Haley Harguth, Bonnie DeJoseph, Angela Noakes, Megan Stachura, Marissa Jones.

THE WALRUS AND THE RESEARCHER

"O Oysters," said the researcher,
"Testing pH is such fun!
Shall we go seed the beds again?"
But answer came there none.
This was not odd, because the sea
Had melted every one.

With apologies to Lewis Carroll, Sir John Tenniel, and *Through the Looking Glass.*