PUGET SOUND INSTITUTE

UNIVERSITY of WASHINGTON | TACOMA

Salish Sea Currents

timely, local stories about ecosystem recovery

2014

Special Report

for

PUGET SOUND POLICYMAKERS

salmon
toxics
shellfish
floodplains
eelgrass
stormwater
marine birds
shoreline armoring

ABOUT THE PUGET SOUND INSTITUTE

The Puget Sound Institute is a cooperative agreement between the University of Washington, the U.S. Environmental Protection Agency, and the Puget Sound Partnership, seeking to catalyze rigorous, transparent analysis, synthesis, discussion and dissemination of science in support of the restoration and protection of the Puget Sound ecosystem.

SPONSORS

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2014 Salish Sea Ecosystem Conference

Cover:

School of juvenile salmonids. USFWS/Togiak National Wildlife Refuge (CC BY-NC-ND 2.0)

Map of the Salish Sea & Surrounding Basin, Stefan Freelan, WWU, 2009

LETTER FROM THE DIRECTOR

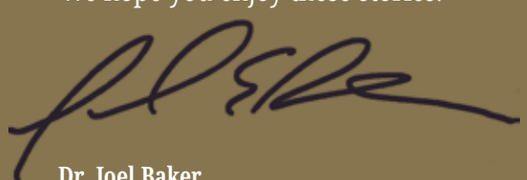
Every day, Puget Sound policymakers are faced with tough choices. They must balance the needs of an ever-increasing number of people and a growing economy with a fragile and extraordinary ecosystem. Puget Sound, and by its larger reach the Salish Sea, is a region of international significance that supports thousands of species and billions of dollars in natural resources. It is also home to world-leading environmental scientific research that fuels innovative approaches to restoring and protecting this complex coastal sea. At the University of Washington Puget Sound Institute (PSI), our goal is to provide Puget Sound policymakers with relevant and timely analysis and interpretation of the best and latest findings from the science community, allowing often-difficult choices to stand on solid, vetted science.

The *Salish Sea Currents* series provides the latest decision-critical science about the Puget Sound. In these pages, we bring you ten stories that every policymaker should read. In 2014, PSI, with support from the EPA and in collaboration with the Puget Sound Partnership, assembled talented science writers to document key sessions at the Salish Sea Ecosystem Conference in Seattle. These writers worked closely with an editorial board of leading scientists to provide the most accurate and current information, and to place it into the context of other work going on in the region.

Ranging from flooding to toxics and from young salmon to seabirds, these articles highlight many significant new findings, including:

- In Seattle and elsewhere, decaying seawalls and piers must be replaced, providing significant opportunities to improve conditions for fish while protecting valuable property (p. 14).
- The everyday activities of individual citizens are now the leading source of toxic chemicals flowing into Puget Sound and scientists feel strongly that by making more informed choices people can curb the problem (p. 12).
- Up to $14 billion dollars per year over 30 years is needed to fully address stormwater pollution in the region (p. 20).
- There is not a “silver bullet” approach to salmon restoration. The habitat needs for one group of juvenile salmon might not be the same as for another, and scientists emphasize the importance of restoration strategies tuned to the specific life history of the population (p. 10).
- Young coho and Chinook salmon and steelhead are growing slower in Puget Sound than in nearby waters, which may partially explain their recent declines in Puget Sound (p. 8).

We hope you enjoy these stories.



Dr. Joel Baker

Director, Puget Sound Institute

Salish Sea Currents

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INTRODUCTION

More than 4,600 miles of coastline wind from southern Puget Sound to northern British Columbia along what is known as the Salish Sea. It is a land of connections and contradictions. Snowmelt from three national parks feeds more than a thousand creeks and rivers that in turn flow to the rich floodplains and estuaries of places like the Skagit and the Nisqually Delta. It is one of the most diverse and spectacular ecosystems in the world, a fact made even more incredible because it is also home to 8 million people.

In this sense, the Salish Sea is as much about salmon and orcas as it is about traffic jams and development. Humans have called the Salish Sea home for thousands of years, but over the past century, our presence has taken its toll. Increasingly, we turn to science to help us understand our effect on the ecosystem. Researchers across two nations and dozens of tribes now measure and study the region's health, and hundreds of millions of dollars are spent every year on its protection.

The *Salish Sea Currents* series grows out of an urgent need to tell this story. It starts at the Salish Sea Ecosystem Conference, a biennial gathering of more than a thousand researchers and managers from the United States and Canada. Every two years, the conference provides the premier showcase for the science driving Salish Sea recovery, and a rare opportunity.

At the 2014 conference in Seattle, more than 450 talks featured nearly as many topics, and we have distilled some of the most critical in these pages. In this report, the series kicks off with a story on the region's declining seabird population. Close to a third of the birds in the Salish Sea are classified as species of concern, and some scientists believe this may hold clues to the overall health of the ecosystem. Later, we report on why so many of Puget Sound's salmon are dying young, and look at efforts to restore eelgrass, an unassuming plant that many consider to be crucial to the area's biodiversity. All told, you will find ten stories featuring the latest policy-relevant science, and we look forward to bringing you many more in the coming year.

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Pair of marbled murrelets, Guemes Channel. Photo: Andrew A. Reding / (CC BY-NC-ND 2.0)

Western grebe, Public Pier, Blaine, WA. Photo: Andrew Reding

Why did all the grebes leave? Where did they go? And what does their disappearance say about the health of the Salish Sea? Seasonal declines among some regional bird species could hold important clues to the overall health of the ecosystem.

KEY TAKEAWAYS

- *Many bird species that winter in the Salish Sea are experiencing severe declines.*
- *Close to a third of all bird species in the Salish Sea are classified as "species of concern."*
- *Birds are considered to be good indicators of the health of the ecosystem.*
- *Some seabird declines may be related to declines in forage fish.*
- *The ecosystem is in flux and some species like bald eagles, rhinoceros auklets and some whales actually appear to be on the rise, potentially competing with declining species for food.*

Declines in marine birds trouble scientists

In the late summer and early fall, western grebes will flock to the marine waters of the West Coast, where they gather by the thousands to dine on a smorgasbord of small fishes. And for years, masses of wintering grebes were a fixture of the Salish Sea. The waters from the Strait of Georgia in Canada south to Puget Sound in the United States hosted roughly 70% of the species' entire population. Now, though, surveys estimate that only 4% of the population continues to winter here—a decline of 95%. Why did all the grebes leave? Where did they go? And what does their disappearance say about the health of the ecosystem? A group of scientists shared their research at the 2014 Salish Sea Ecosystem Conference.

The Salish Sea is vital habitat for 172 species of birds, and with the exception of salmon, there may be no other type of species that occupies a wider variety of environments. Birds—seabirds in particular—provide a critical link between the land and the saltwater, making them of special interest to Puget Sound recovery efforts.

TIMING IS EVERYTHING

Outwardly, then, some of the signs are troubling. Of those 172 species, close to a third are classified as species of concern in the U.S. and Canada. Managers would like to reverse that trend, but knowing where to start can be tricky. The Salish Sea's bird species vary dramatically depending on the season, something that makes studying them a challenge. Ironically, that very challenge might also hold a clue to their declines.

In the Salish Sea, when it comes to birds, timing is everything.

In the summer, for example, the region is dominated by species such as common murres, Cassin's and rhinoceros auklets, many of which breed in colonies along the outer coast. Most surveys of these summer birds show little in the way of consistent trends. Some, like the Cassin's auklet, are increasing in number; some, like the common murre, are fairly stable; and some, like the endangered marbled murrelet, continue to decline.

Winter patterns are more consistent and clear. A number of birds that rely on the Salish Sea in winter show a plain trend: down. Scoters are declining. Loons are declining. And, of course, western grebes are almost entirely gone from the region. Why is that?

NEW RESEARCH

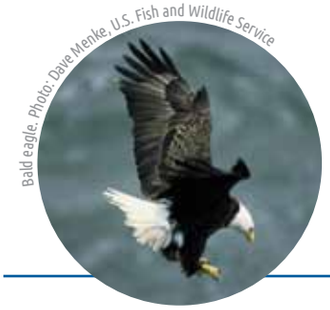
Biologists have suggested a number of reasons, ranging from top-down effects like the recovery of the predatory bald eagle, to bottom-up effects having to do with food availability. Research presented at the 2014 Salish Sea Ecosystem Conference focused on the role of forage fish, a favorite prey item of many seabirds. Oily and calorie-rich, these fish, such as sandlance, surf smelt and Pacific herring are known for their importance to the food web. Normally an abundant source of sustenance for a wide variety of predators, they have declined significantly over the decades.

"Half of all herring stocks in Puget Sound are designated as either depressed or low abundance," says Dr. Nacho Vilchis, a former postdoctoral researcher with the SeaDoc Society, "and the same is true for British Columbia."

A study by Vilchis and others shows that wintering bird species in decline are more likely to be specialist feeders of these fish. Computer models from the study show that birds with more diverse diets, like mergansers, or flexible diets, like gulls, are less likely to decrease. This is significant because species that use the Salish Sea only in winter would be expected to be more willing to leave it when conditions become less favorable. Specialists with stronger ties—those that breed here, for example— might try to tough it out. A change in wintering grounds is a likely explanation for most of the disappearances, argues Vilchis.

[CONTINUED]

> *"Seabirds are good biological indicators. Their diet reflects fish populations. They're good indicators of contaminants. And we monitor them just because we care about birds."*
>
> *Scott Pearson, WA Dept of Fish and Wildlife*



Bald eagle. Photo: Dave Menke, U.S. Fish and Wildlife Service

That appears to be the case with the western grebe. While the overall wintering population has declined by more than half since 1975, the decline means different things to different places: where the Salish Sea wintering population has dropped off almost completely—by 95%— the smaller wintering populations in southern California have increased by an astounding 300%. The grebes have simply shifted their wintering grounds.

GENERALISTS STAY, SPECIALISTS LEAVE

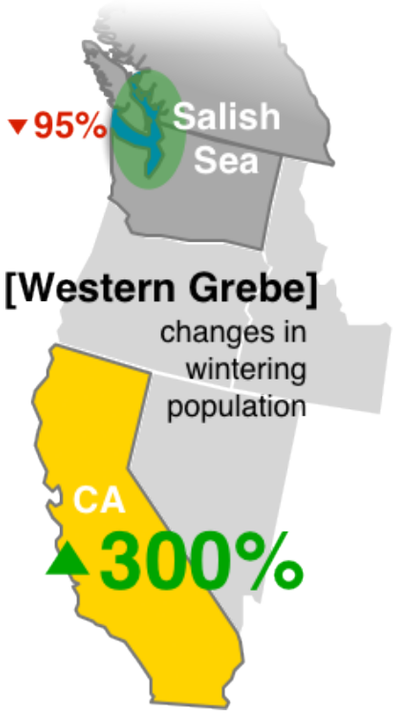
Peter Arcese, a biology professor at the University of British Columbia who was a co-author on the western grebe paper, says that the grebe's rigid diet explains their new preference for California waters. While Pacific herring in the Salish Sea have declined, Pacific sardine in California have recovered; since 1985, the stock has increased from an estimated few thousand metric tons to 1.42 million in 2007. Disinclined to forage for other prey, western grebes, sensibly, have followed the food they like. "Generalists change their diet," Arcese says. "Specialists leave."

But if the story of the western grebe shows the challenges that specialists face, even those Salish Sea species that are generalists, such as the glaucous-winged gull, are not immune to the shifting fortunes of their environment.

In the early 20th Century, glaucous-winged gulls declined due to intense egging, when people would collect wild bird eggs en masse to eat. After the practice was banned in the 1920s, they started to recover. However, in the past 30 years, their numbers have begun to drop again. The roots of the decline seem to stem from waning reproduction: between 1962 and 2009, gulls laid fewer eggs each year, and those eggs tended to be smaller. (The smaller the egg from which a chick hatches, the less likely that chick is to fledge, generally.)

Why has egg production tailed off? Arcese and researcher Louise Blight believe that, as with the western grebe, the culprit is food, or its absence. Stable isotope analysis by Arcese and Blight of gull head and wing feathers from museum specimens dating back to the 1860s shows that gulls are feeding at lower levels in the food web now than they were in centuries past. Like the grebes, gulls used to forage for Pacific herring. Unlike the grebes, when the herring disappeared, the gulls stayed. As generalists, they were able to shift their diet, but appear to be paying a price for that.

■ *The Salish Sea is vital habitat for 172 species of birds, and with the exception of salmon, there may be no other type of species that occupies a wider variety of environments. Birds—seabirds in particular—provide a critical link between the land and the saltwater, making them of special interest to Puget Sound recovery efforts.*



Cassin's Auklet. Photo: Steve Hillebrand, U.S. Fish and Wildlife Service

[172 SPECIES OF BIRDS]

32% SPECIES OF CONCERN IN THE SALISH SEA

TURNING A CORNER?

Not all the news is dire. Despite the downturns, Arcese suspects that the Salish Sea "might be turning a corner," after years of low overall biological productivity. Rhinoceros auklets are returning, as are humpback whales and minkes, the former having disappeared due to whaling in the early 1900s. These whales, in turn, might be competing with birds for forage fish. And gulls, for their part, might not be declining just because of food; bald eagles, whose recovery has occurred concurrently with the gull decline, might be suppressing the numbers of those birds that thrived in their absence.

Could the Salish Sea ecosystem simply be returning to some earlier norm, with hungry whales and marauding eagles, and seabirds in between? Or do the range shifts of grebes and the declines of gulls herald a new normal? For Arcese, these are not necessarily the most helpful questions. Even if people speak in terms of balance or equilibrium, the ecological communities that may or may not be rebalancing themselves do so in an environment vastly different from what it once was. More important is to understand the health of the ecosystem in its present state, regardless of how it came to be the way it is. That means watching the seabirds, he says, something scientists will be doing intensely in coming years as they continue to measure the health of the Salish Sea.

BY: ERIC WAGNER | Editor: Jeff Rice | Topic Editor: Joe Gaydos | Published: July 22, 2014

■ Visit the online version of "Declines in Marine Birds Trouble Scientists" to learn more: www.eopugetsound.org/magazine/marine-birds

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Maury - Vashon Island Low Tide Celebration
Photo: Kyle Murphy/DNR (CC BY-NC-ND 2.0)

Inside the Eelgrass beds. Photo: Eric Heupel (CC BY-NC 2.0)

Scientists say eelgrass, an unassuming flowering plant found just off shore in Puget Sound, is vital to the health of the ecosystem. They also say the plant is declining. New and increasingly urgent efforts to restore it brought a group of researchers to the 2014 Salish Sea Ecosystem Conference.

KEY TAKEAWAYS

- *Many species including salmon, Pacific herring, Dungeness crabs and even killer whales rely on eelgrass for survival.*
- *Eelgrass is declining in parts of Puget Sound.*
- *Declines may be linked to a wide variety of factors including nitrogen pollution that diminishes available light that plants need for growth.*
- *Scientists propose planting more eelgrass in suitable areas to meet recovery targets set by the state.*
- *State and federal agencies recently launched the Puget Sound Eelgrass Recovery Strategy to evaluate progress toward recovery goals.*

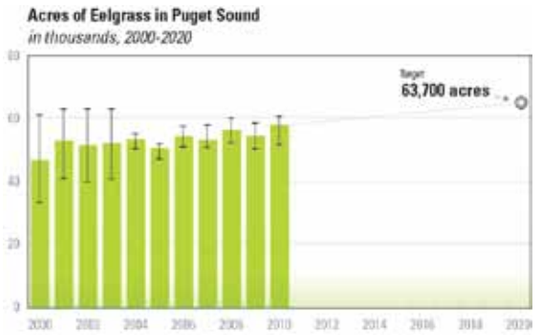
Shedding new light on eelgrass recovery

It harbors as much life as an old growth or tropical forest, and it hides in the waters just off shore. Without it, scientists say, there would be precious few salmon or herring, and little prey for orcas. It means hundreds of millions—perhaps billions—to the local economy, and chances are, most Puget Sound residents have never heard of it. It is eelgrass, and there may be no plant more central to Puget Sound's environmental wellbeing.

"Eelgrass is critical to what we know and love about Puget Sound," says Ron Thom, a biologist working on eelgrass restoration at the Pacific Northwest National Laboratory.

Like most scientists who study the plant, Thom is something of an eelgrass evangelist. He ticks off just a few of the plant's benefits: Eelgrass protects young salmon and shellfish such as Dungeness crabs. It stymies coastline erosion with its root and shoot system, and is central to the food web. Its narrow, olive-colored leaves house millions of tiny organisms that will in turn feed larger invertebrates, and eventually, the fish we catch and the birds and whales we watch.

In short, healthy eelgrass (*Zostera marina*) indicates a healthier Puget Sound, which is why Thom and a group of scientists were out on the water last summer planting some unusual garden plots. Studies show that eelgrass is in decline in significant areas of Puget Sound, and scientists are looking for ways to bring it back to its historical levels. In a very literal way, they hope to plant the seeds of Puget Sound recovery.



Source: Aquatic Resource Division, Nearshore Habitat Program, Washington State Department of Natural Resources. Modified from the 2012/2013 Action Agenda for Puget Sound.

WHY NOT JUST PLANT MORE?

One of the goals set by the state's Puget Sound Action Agenda is to add 20 percent more eelgrass to the region by 2020. But three years into the effort, there's been little or no progress, and growing perplexity. Studies show that some eelgrass beds are increasing while others are in decline. Several sessions at the 2014 Salish Sea Ecosystem Conference featured new research and possible new directions for recovery efforts

If eelgrass is declining, why not just plant more of it? That's one of the ideas under consideration by state and federal agencies. Last summer, divers planted nine experimental plots at five sites in Puget Sound, including sites of unexplained eelgrass loss.

As part of the process, Thom, along with his colleagues at the Washington State Department of Natural Resources and the Environmental Protection Agency, unveiled a computer model that identifies areas in Puget Sound where eelgrass could potentially thrive. The model compiles instrument readings from across the Sound, including light availability, salinity, temperature, and depth. When the right measurements align, the model suggests a planting site.

> *"Eelgrass is critical to what we know and love about Puget Sound,"*
>
> *Ron Thom,*
> *Biologist working on eelgrass restoration at the Pacific Northwest National Laboratory.*

Light in particular is key, says Thom. It turns out that getting enough of that precious resource can be a challenge. Eelgrass evolved as a shade-adapted plant, able to thrive in the region's relatively low light. But other, human-caused factors appear to be changing conditions beyond the plant's tolerance.

THE POLLUTION FACTOR

One of those factors is increased nitrogen. While eelgrass needs nitrogen to survive, too much of it sends phytoplankton, the plant's algal neighbors into a frenzied growth that blocks sunlight. Without the light, eelgrass can't harvest energy through photosynthesis. Fred Short of Washington's Department of Natural Resources, has been studying this phenomenon, and says it is localized in certain areas of Puget Sound with higher pollution.

[CONTINUED]

Eelgrass in Dumas Bay, Central Puget Sound 2013. Photo courtesy of DNR.

A BILLION-DOLLAR PLANT?

Successful eelgrass recovery efforts would mean a boon for the ecosystem, but also for the Puget Sound economy.

Achieving the state goal of a 20 percent increase in eelgrass by the year 2020 would increase the number of fish available for commercial and recreational fishing in the Sound, according to a 2012 study published in the journal Ecosystems by researchers at the Northwest Fisheries Science Center. In all, the study looked at 37 different cases where eelgrass provided ecosystem services "of either provisioning or cultural value," from benefits to salmon and commercial geoduck harvests to recreational fishing of rockfish and lingcod.

Take into account eelgrass as an overall anchor for the nearshore ecosystem, and the dollar return is significant. Salmon alone infuse hundreds of millions of dollars per year into the local economy, as do Pacific herring and shellfish, such as Dungeness crabs. Iconic, tourist-friendly wildlife like seabirds and killer whales also depend on eelgrass for their survival, directly or indirectly.

"Killer whales don't eat eelgrass, but they do eat salmon, and salmon grow up in the eelgrass," says biologist Fred Short.

"It's an issue in parts of Puget Sound, not all of Puget Sound," he says, but where it occurs the evidence is fairly obvious. "Stick your camera under the water and take a picture and it's just green [with phytoplankton]," says Short.

Short first noticed the problem of decreasing light for eelgrass on the East Coast and has been testing whether the same situation exists in Puget Sound. As on the East Coast, eelgrass is "not growing as deep as it used to grow," he says, "which is a good indicator of decreasing water clarity." Potential causes include stormwater runoff, failing septic tanks and sewage treatment discharge. Runoff from dairy and meat production also boost nitrogen.

The planting model seems to support that idea. It predicts less success for eelgrass near places like southern Puget Sound, where higher nitrogen levels occur. Most of the experimental plantings followed the model's predictions, while a few struggled for unknown reasons. Last summer's work was a first step in what researchers expect to be an ongoing process.

ADAPTING TO UNKNOWNS

If nitrogen pollution is a significant barrier to eelgrass recovery, then scientists are not without hope. Water quality can get better, they say.

"We can enhance the [eelgrass] productivity of the Sound and prevent it from degrading further," says Short, who points to solutions like improving sewage treatment plants and filtering stormwater and agricultural runoff.

Even so, scientists acknowledge that many other threats to eelgrass remain, from heavy metals to shoreline development, damage from boat propellers and dredging and even emerging concerns like eelgrass wasting disease. They also point to the specter of climate change. Paradoxically, ocean acidification, the result of increased carbon dioxide absorption from the atmosphere into Puget Sound waters, could actually benefit eelgrass because it would increase carbon dioxide used by the plant; but as the oceans warm and sea levels rise, climate change also threatens fragile habitat.

Scientists say the key for them will be to adapt as conditions change and as new information becomes available.

Selecting plants from donor cultures. Divers get ready to plant. Donor stock. Photo: Ron Thom, John Vavrinec
Eelgrass bed. Photo: Susannah Anderson (CC BY-NC-ND 2.0)

NEXT STEPS

One strategy is to take a so-called portfolio approach. Some argue that responding to every single threat to eelgrass, while desirable in theory, might not be practical and could take huge amounts of resources. A May 2014 article in the journal Coastal Management reviewed comments from 19 scientists who study eelgrass in the region, and suggests narrowing efforts to several areas with the most potential for eelgrass restoration.

The article points to overwater structures, nitrogen pollution and shoreline armoring as key focus points, and scientists are looking at how this might apply to local management actions.

Just weeks before the Salish Sea Ecosystem Conference, representatives from multiple agencies including the Department of Natural Resources, Puget Sound Partnership, Department of Ecology, the University of Washington's Puget Sound Institute, NOAA, the Samish Tribe, the Washington Association of Counties and other groups, met to launch the Puget Sound Eelgrass Recovery Strategy.

The group will examine why eelgrass recovery has faltered, and will keep an eye on experiments like those by Thom and others searching for new breakthroughs.

"Every time you do a restoration project, it's an experiment," says Thom. "We need to be clear about linking the action to the response in a systematic way and learning from it. If we're seeing an improvement, we can better predict what we need to do in the future to make it work for [eelgrass] to come back."

BY: KATIE HARRINGTON | Editor: Jeff Rice | Topic Editor: Charles Simenstad | Published: August 8, 2014

- Visit the online version of "Shedding New Light on Eelgrass Recovery" to learn more:
  www.eopugetsound.org/magazine/eelgrass

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School of juvenile salmonids
Photo: USFWS/Togiak National Wildlife Refuge (CC BY-NC-ND 2.0)

Chinook Salmon (Juvenile) Photo: Roger Tabor/USFWS. (CC BY 2.0)

Scientists say Puget Sound's salmon are dying young and point to low growth rates in the marine environment as a possible cause. In Part 1 of this two-part series, scientists consider threats facing young salmon in the open waters of Puget Sound.

KEY TAKEAWAYS

- *Marine survival of young coho, Chinook and steelhead has declined significantly in Puget Sound over the past 20 to 30 years.*
- *Low growth rates among young salmon in the marine environment are a strong suspect in declining marine survival.*
- *Scientists say poor diet may be the cause of smaller salmon, but little is known about salmon feeding behavior in deep Puget Sound waters.*
- *Increasing numbers of predators such as harbor seals may also have an impact.*
- *Marine survival of young salmon is a growing area of research in the Salish Sea.*

What is killing young salmon in Puget Sound?

For every Chinook, coho, or steelhead that leaves a local stream or hatchery, fewer and fewer adults are returning to spawn. Survival rates in Puget Sound for these salmon have decreased over the past 20 to 30 years, according to research presented at the 2014 Salish Sea Ecosystem Conference in Seattle. Scientists believe this high marine mortality is a major impediment to salmon recovery, but the cause remains a mystery. Several possible explanations are prompting a hot debate: should managers focus on the salmon's food or its predators?

BIGGER IS BETTER

When young salmon enter Puget Sound from their natal streams, they have already begun a race to grow, eating at every opportunity and packing on the ounces. In their early life, one thing is clear: bigger is better. Bigger salmon are in better condition to survive their first winter in the Puget Sound estuary, and these otherwise bite-size morsels are less vulnerable if they can outgrow the jaws of their predators. In fact, one study shows that if a Puget Sound Chinook doubles in size in these early stages, it is four times more likely to survive to adulthood.

Caspian Tern with Chinook Salmon Smolt. Photo: David Craig (CC BY-SA 2.0)

In many cases, however, this crucial growth is not happening. Some species of young Puget Sound salmon are consistently smaller than their counterparts in other regions, making low growth rates a strong suspect in population declines.

THE ZOOPLANKTON X FACTOR

Could poor diet be the cause? That is one of the theories proposed by scientists, but supporting evidence has been hard to come by. While much is known about what salmon eat in the freshwater, little is known about the diets of young salmon in the open waters of Puget Sound.

Crab larva (Brachyura). Photo: Josef Reischig (CC BY-SA 3.0)

"Much research has focused on [freshwater environments], and what affects salmon survival there," says Iris Kemp, research biologist with Long Live the Kings, a nonprofit organization working to restore wild salmon and steelhead in the Pacific Northwest. "But the nearshore and offshore marine system is still largely a black box."

Salmon hatch and grow to an adolescent stage (called a smolt) in freshwater, then make their way to saltwater. Once there, many smolts spend their first weeks or months near the shoreline. After reaching a certain size, they move deeper into Puget Sound and begin eating small, free-swimming marine organisms, called zooplankton.

Zooplankton generally include small invertebrates such as crustaceans and insects that drift in the water column. Scientists say that the tiny creatures are notoriously hard to study, and little is known about their ecology in Puget Sound. They are always on the move (plankton in Latin means "drifting" or "wandering"), and are often "strong swimmers which are able to avoid nets," says zooplankton expert and UW professor Julie Keister. Narrowing down the distribution of the types of zooplankton that salmon like to eat is particularly difficult, she says.

[CONTINUED]

Harbor seal chasing and eating salmon. Photo: Andrew Reding (CC BY-NC-ND 2.0)

DANGER FROM ABOVE?

Knowing what preys on salmon may be easier to gauge. Large fish (including adult Chinook salmon and steelhead, Pacific cod, walleye Pollock, spiny dogfish, sculpins and others), seabirds, and marine mammals all eat young salmon. Although many seabirds are in decline in Puget Sound, marine mammals (especially harbor seals, the region's most common pinniped) are increasing in abundance. Previously hunted through a state-funded bounty program aimed at reducing competition for salmon and other fish, seals and sea lions are capable of eating an enormous amount of fish. Megan Moore of the National Marine Fisheries Service believes that this may partly account for low survival of young steelhead. Concurrent declines in forage fish abundance, especially Pacific herring, could also be pushing bird and mammal predators to switch to immature salmon to round out their meals, say scientists. Understanding the balance of threats from 'above' (predation) and from 'below' (food supply) is considered critical to salmon protection.

Coho smolt. Photo: Paul Kaiser/USFWS (CC BY 2.0)

COMPETITION FOR THE ZOOPLANKTON BUFFET

Given the widely perceived importance of zooplankton for salmon growth, could competition for food be another factor explaining low juvenile growth and survival? Zooplankton are also important in the diets of forage fish – small, silvery, schooling fish such as Pacific herring, surf smelt, and Pacific sand lance – that live in Puget Sound. Given that herring often outnumber juvenile salmon in Puget Sound, scientists wonder if there is a link.

Herring school near Rosario, WA. Photo: © Patty Michaud.

Although in recent years herring have been declining in some places in Puget Sound, they are increasing in others. Schools of herring may act as zooplankton vacuum cleaners, clearing the water of food important for salmon survival. But scientists acknowledge that not enough is known about forage fish to define their interactions with salmon. For example, the current status and trends of surf smelt and sand lance in Puget Sound are wholly unknown. Some Puget Sound herring populations are in decline, but the causes remain a mystery. Further complicating the issue, forage fish are critical prey for adult Chinook salmon, so maintaining healthy populations of forage fish is important for healthy salmon. Understanding the complex food-web entanglements between salmon and forage fish is doubly important because both Pacific herring and Chinook salmon are targeted for recovery by the Puget Sound Partnership. Scientists argue that understanding more about these complex interactions between species in the Puget Sound food web is critically important not only for salmon recovery, but also for maintaining the overall function of the Puget Sound ecosystem.

NEXT STEPS

To better understand the salmon food supply, Keister and her colleagues at the University of Washington have designed a comprehensive plan to survey Puget Sound zooplankton. The hope is that the resulting data can be used in mathematical models of the Puget Sound ecosystem, to predict how salmon may respond to shifts in their food supply.

On the predator side, University of British Columbia researcher Austen Thomas and colleagues are developing a new method for counting the number of salmon a seal eats by implanting Passive Integrated Transponders (PIT) tags into juvenile salmon and mounting detectors on seals' heads. UW masters student Madilyn Gamble plans to use fish scales to determine where and when salmon face the toughest challenges to their growth and survival.

Results from this recent burst of research should help to answer several basic questions: Is there enough food available at the right place and time for salmon to achieve the growth they need? Is the only solution to cull predators as the state once did before federal protections of seals and sea lions? Can managers simultaneously recover salmon and protect forage fish, which compete for food but are critical prey themselves for birds and mammals? Answers could still be five years away or more, experts say, but one thing is becoming clear: solving the juvenile survival mystery is now a priority.

> "Over 150 scientists and technicians from federal, state, tribal, academic, and nonprofit institutions are in the field today, and in laboratories assessing the condition of juvenile Chinook, coho and steelhead and their marine environment."
>
> *Long Live the Kings*

One large effort is already under way. A transboundary collaboration launched by Long Live the Kings and dubbed the Salish Sea Marine Survival Project enlists dozens of U.S. and Canadian scientists to investigate marine survival of juvenile salmon and steelhead in the Salish Sea. The project began in late 2013 and is the largest of many research efforts focusing on U.S. and Canadian waters. According to Long Live the Kings, "Over 150 scientists and technicians from federal, state, tribal, academic, and nonprofit institutions are in the field today, and in laboratories assessing the condition of juvenile Chinook, coho and steelhead and their marine environment."

BY: MEGSIE SIPLE | Editor: Jeff Rice | Topic Editor: Tessa Francis | Published: August 28, 2014

- Visit the online version of "What is killing young salmon in Puget Sound?" to learn more: www.eopugetsound.org/magazine/young-salmon

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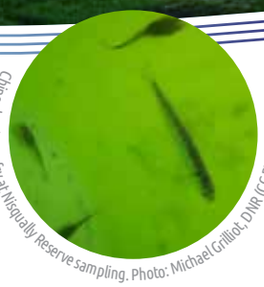
Tidal Marsh Panorama Low Tide; Nisqually National Wildlife Refuge. Photo: David Patte/U.S. Fish and Wildlife Service (CC BY 2.0)



Chinook salmon fry at Nisqually Reserve sampling. Photo: Michael Grilliot, DNR (CC BY 2.0)

The growth and survival of young salmon in streams, river deltas and floodplains are seen as crucial pieces of the salmon recovery puzzle. In part two of this two-part series, researchers at the Salish Sea Ecosystem Conference in Seattle say the complexities of the salmon life cycle require new coordination among scientists.

KEY TAKEAWAYS

- *Freshwater habitats—and transition zones to saltwater such as deltas and tidal marshes—provide key habitat for growth of baby salmon.*
- *This habitat is threatened by human development.*
- *There is no single approach to salmon restoration. The habitat needs for one group of juvenile salmon might not be the same for another.*
- *Scientists emphasize the importance of restoration strategies based on the specific life history of the population.*
- *Collaboration and coordination can help scientists tackle larger efforts such as the Nisqually Delta restoration.*

McAllister Creek at Low Tide, west side of Nisqually Delta. Credit: Russ McMillan (CC BY-NC-ND 2.0)

> *"Restoration efforts usually fail or end in unquantified performance because the proper goal was not identified at the start."*
>
> *Jamie Thompson, R2 Resource Consultants*

No salmon left behind: The importance of early growth and freshwater restoration

After a long day pulling nets out on the Nisqually Delta, biologist Aaron David clambers ashore, waders askew. What he's lugging up onto the bank—two 5-gallon buckets full of water and alive with palm-length juvenile Chinook salmon—might hold the answers to one of the region's most pressing environmental questions: Are efforts to recover Salish Sea salmon working?

David, a scientist with University of Washington's Wetland Ecosystem Team, is one of a small army of restoration ecologists who are monitoring 862 acres of the Nisqually Delta that are coming back to life, transformed from farmland back to tidal marsh by the breach of several agricultural dikes in 2006 and 2009. David plans to take the diminutive salmon back to the lab, remove their stomachs, and sort through the contents to find out what the fish have been eating.

By examining their diets, David hopes to tell if the Nisqually restoration is giving the young Chinook more opportunity to eat and grow before heading out into Puget Sound. One of the major goals of restoration projects like this one is to reopen habitat for salmon during their early life stage (known as rearing), based on the belief that one of the keys to survival is their rapid early growth before they migrate into the open saltwater.

FINDING AND FIXING BOTTLENECKS

Puget Sound Chinook salmon were placed on the Endangered Species List in 1999; Puget Sound steelhead followed in 2007. The region's coho populations, once considered robust, are currently undergoing a precipitous decline. Since the ESA listings, little tangible progress has been made on increasing threatened salmon numbers, and recovering Puget Sound's salmon has presented a puzzle as large and complex as the watershed itself. Over their life cycles, salmon are subject to stresses from headwaters to estuary to ocean, creating unique challenges for restoration efforts. Faced with limited time and money, ecologists and managers around the Salish Sea have started to ask: Are there survival bottlenecks that, if identified and fixed, could turn the tide of salmon recovery in Puget Sound? Traditionally, restoration efforts have focused on spawning habitat, but scientists argue that may no longer be enough. New research presented at the 2014 Salish Sea Ecosystem Conference suggests that, though by no means a silver bullet, conserving and increasing high-quality freshwater rearing habitat could be one of the most effective ways to support salmon recovery in the Salish Sea.

READY, SET, GROW

Researchers say survival of a young salmon on its journey from an egg in the gravel to a silvery smolt ready to enter Puget Sound pivots on the crucial matter of growth. The faster a baby salmon can grow in these early stages, the bigger and healthier it will be; the lower the chance it will be lunch for another fish or bird; the better it can outcompete its siblings for food; and the better its overall chances at making it out into Puget Sound.

Studies show that floodplains and salt marshes like the Nisqually Delta provide vital habitat for this growth, but the equation gets complicated quickly. Habitat that's important for one group of juvenile salmon might not be important for another. Within just one river system, different salmon species, or even groups within a species, vary in the timing and location of when and where they spawn, grow and migrate to the Sound.

[CONTINUED]

Hylebos Creek habitat restoration site. Photo: Port of Tacoma (CC BY-NC-ND 2.0)

FACING HABITAT LOSS

Like many wetland areas in the United States, Puget Sound's freshwater and tidal marshes are threatened by human development. The U. S. Geological Survey (USGS) estimates that river or stream valley bottoms cover about 5% of the Puget Sound basin, but are the site of 30% of highly developed urban areas and 70% of cultivated land.

Floodplains and deltas are not the only environments under pressure: Most of the streams best suited for coho salmon rearing, for example, are located in developed lowlands, where they are prone to "urban stream syndrome." Its symptoms: Lower water quality, loss of streamside vegetation and altered food-webs, simplified stream channels, changed stream flows, and warmer temperatures, all of which have consequences for salmon.

Findings presented at the Salish Sea Ecosystem Conference further illustrate the problem: Puget Sound streams converted from forest to urban land uses between 1984 and 2001 experienced a 75% decline in coho salmon abundance, relative to streams in watersheds that remained forested, according to Robert Bilby of Weyerhaeuser and others. Their studies showed that urbanized land cover at the impacted sites increased by 14%. Projections by University of Washington professor Marina Alberti and researcher Dan Miller show that 60% of high-quality coho streams in central Puget Sound watersheds will be developed by 2050.

NO SALMON LEFT BEHIND: THE IMPORTANCE OF EARLY GROWTH AND FRESHWATER RESTORATION [CONTINUED]

RESTORATION: ONE SIZE DOES NOT FIT ALL

In light of this complexity, how can scientists respond in a coordinated fashion? Several researchers speaking at the conference pointed to a need for more on-the-ground information.

Washington Department of Fish and Wildlife scientist Joe Anderson says that a detailed knowledge of life history—the when and where of spawning, growing, and migrating—within individual Puget Sound salmon populations will be central to planning successful recovery strategies. Anderson recently uncovered previously unknown levels of diversity in several populations of Puget Sound Chinook: What biologists previously thought were just one or two types of Chinook turned out to be more, all with unique habitat needs. Those with a stream-type life history showed signs of being food-limited, while those that migrate to the ocean soon after hatching did not.

Anderson believes this is a critical finding that identifies a potential bottleneck within a specific life-history type. He concludes that for some populations, rearing habitat for juveniles, and not spawning habitat for adults, is the dominant limiting factor. These results beg the question: Should agencies keep spending money to restore adult spawning habitat? Not if adult spawning habitat isn't what's creating the bottleneck in a particular river, says Anderson, because increasing numbers of juveniles competing for a limited amount of resources actually may harm their overall growth and survival.

Similar results have been found for other species. In a study of ESA-listed Skagit River steelhead, Jamie Thompson of R2 Resource Consultants was intrigued to find that each Skagit tributary studied had a unique combination of factors—temperature, food availability, and physical habitat—affecting salmon growth in different ways.

Young steelhead at Ballard Locks. Photo: Ingrid Taylar (CC BY 2.0)

Nisqually Reserve Fish Sampling March 2012. Photo: Michael Grilliot, DNR (CC BY-NC-ND 2.0)

THE NEED FOR COORDINATION

Stories like these have led many scientists to call for a more complete and wide-ranging accounting of habitat needs. "We need a comprehensive map of Puget Sound's potential to support salmon so we can prioritize restoration actions," says Robert Bilby, a scientist at Weyerhaeuser. Such a map is currently under development through the Puget Sound Partnership in cooperation with Long Live the Kings and other groups, and in 2013 NOAA established a coordinated monitoring framework for Puget Sound Chinook.

The University of Washington's Aaron David believes that managers should also coordinate their efforts and "go big." Given the wide variety of habitat types and pressure points facing salmon at multiple turns, managers run the risk of having their work diluted or fragmented. He argues that small-scale restoration projects might not be as effective without widespread coordination among salmon researchers.

That's one of the philosophies behind the Nisqually restoration project. It is the largest project of its kind ever to be attempted in the Pacific Northwest, and is led by multiple collaborators including the Nisqually Tribe, the U.S. Geological Survey, Ducks Unlimited and the Washington Department of Fish and Wildlife. Over a period of just a few years, the areas under restoration are approaching the function and quality of a nearby, never-diked reference marsh. Young Chinook are using the restored marshes, and seem to be eating and growing almost as well as Chinook in more pristine areas. Less than a decade after the Nisqually dikes were breached, the tidal wetlands there have regained a lot of their biological function—though they still have a ways to go.

Overall, scientists are discovering that life-history diversity translates into different potential reasons for population decline: Some salmon populations lack sufficient or high-quality food during early growth stages, others have specific water temperature or flow requirements. These same scientists emphasize the importance of devising restoration strategies based on the specific life history needs of the population in question to ensure a better return on our restoration investments. Says Thompson: "Restoration efforts usually fail or end in unquantified performance because the proper goal was not identified at the start." In the Nisqually Delta, restoring critical salt marsh habitat might be working for the Chinook salmon that rear there. Recovering salmon populations across the Salish Sea, however, will likely require solutions as diverse as the fish themselves, researchers say. And a focus on young salmon's earliest experiences could be the key.

BY: EMILY DAVIS | Editor: Jeff Rice | Topic Editor: Tessa Francis | Published: September 9, 2014

- Visit the online version of "No salmon left behind" to learn more: www.eopugetsound.org/magazine/young-salmon-2

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Salsa Dancing on Alki Beach. Photo: Razvan Orendovici (CC BY 2.0)

Double-crested Cormorants Nesting. Photo: Donna Dewhurst, U.S. Fish and Wildlife Service

New research presented at the 2014 Salish Sea Ecosystem Conference shows that some of the greatest dangers to Puget Sound marine life come from our common, everyday activities. These pervasive sources of pollution are so woven into our lives that they are almost invisible to us, but it's becoming impossible to ignore their effects.

KEY TAKEAWAYS

- *The everyday activities of individual citizens are now the leading source of toxic chemicals flowing into Puget Sound.*
- *Many sources of contaminants have changed, although pernicious chemicals persist in the environment and continue to contaminate the food chain.*
- *The more you look, the more you find. Studies are turning up evidence of exotic chemicals in almost every environment, including remote coastal islands.*
- *Runoff from roads, parking lots, and roofs is one of the largest sources of contaminants flowing into Puget Sound.*
- *Because much of Salish Sea's chemical contaminants stem from human activities, scientists feel strongly that by making more informed choices people can curb the problem.*

> *"We have an incredibly active and engaged population here.... Changing people's behavior is the key."*
>
> *John Elliott, Environment Canada*

Stormwater flowing into catch basin carries contaminants to our waterways. Photo: Ben McLeod (CC BY-NC-SA 2.0)

Citizens now the leading cause of toxics in Puget Sound

On tiny Mandarte Island in British Columbia, a group of biologists gathers for a pre-dawn raid on a population of double-crested cormorants. They will flush the birds from their nests just long enough to collect a sampling of eggs that they will take back to the lab for testing. But in this case, they are not studying the birds as much as they are documenting human behavior.

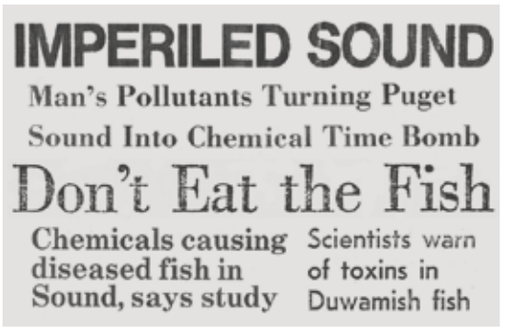
The scientists are tracking the chemical signatures of modern civilization. The eggs will turn out to be carrying a slew of compounds, from flame-retardants, to commercial stain repellents like Scotchgard, and even the dwindling residue of DDT, a long-banned pesticide. Researchers are finding similar patterns across the Salish Sea, with birds like great blue herons and rhinoceros auklets.

"We are seeing this in many species," says John Elliott of Environment Canada, who presented the egg studies at the 2014 Salish Sea Ecosystem Conference. Elliott has traveled throughout British Columbia, visiting remote islands by Zodiac or helicopter, climbing trees or grubbing for eggs in seabird burrows. The story is always the same. "It's actually hard to keep track" of the growing list of chemicals showing up in research sites around the region, he says.

The Salish Sea has become an alphabet soup of contaminants. The more you look, the saying goes, the more you find.

A CHANGING VIEW

Here in Puget Sound, water pollution first came to the prominent attention of the public in the 1970s and 1980s, when scientists noticed tumors developing in bottom-dwelling fish near the Duwamish River. Those tumors were caused by PCBs and other chemicals, and people were shocked to find that what they once idealized as a pristine environment—a place with sweeping views and abundant wildlife—was a de facto dumping ground. Headlines rang out calling Puget Sound a "Chemical Time Bomb" and warned residents, "don't eat the fish." Now, long after places like the Duwamish and the Foss waterways have become Superfund sites, the understanding of the toxic threat to Puget Sound continues to evolve. Those early industrial pollutants still remain, affecting orcas and people alike, but the number of threats has expanded.



IMPERILED SOUND

Man's Pollutants Turning Puget Sound Into Chemical Time Bomb

Don't Eat the Fish

Chemicals causing diseased fish in Sound, says study

Scientists warn of toxins in Duwamish fish

Collage of newspaper headlines

Scientists at the 2014 Salish Sea Ecosystem Conference met to discuss this trend, and while the names of the chemicals varied from talk to talk, there was one common denominator: us. The cross-border Salish Sea region includes more than 7 million people and is growing fast. By 2025 that number is expected to rise to more than 9 million. Researchers say each one of us is a source of pollution.

PICK YOUR POISON

In some cases, the vector from human to environment is clear. A recent study shows how flame retardants from couch cushions and TVs actually pass through wastewater treatment plants and into local waterways (and eventually the eggs of seabirds).

[CONTINUED]

EMERGING CONTAMINANTS

One wild card for researchers is a new classification of pollutants knows as emerging contaminants. These represent potentially thousands of compounds that come from industrial sources, as well as many of the pharmaceutical and personal care products that people use every day.

Emerging contaminants generally occur at low concentrations in the environment and usually don't directly kill organisms, but they may have a variety of biological effects. Many are potential endocrine disrupters, meaning they can affect hormones linked to reproduction and development.

Scientists have begun to document a variety of these chemicals in Puget Sound. For example, antibiotics, antihistamines, and triclocarban, an ingredient in antibacterial soap, have been found in sediments in Seattle's Elliott Bay and elsewhere.

Exactly where emerging contaminants are found, however, and what they do remains poorly understood. For one thing, researchers say it would be overwhelmingly expensive to measure and monitor them all because there are just too many, and chemists are constantly inventing new ones.

For this reason, many researchers are working to identify how exposure to the complex mixture of contaminants in water and sediments affects gene expression in aquatic species. This would provide a rapid, reliable way to measure the effect of toxics, even if scientists don't know which specific chemicals are present in any one place, and capture how mixtures of contaminants may cause harm.

Preliminary data presented at the conference by University of Washington graduate student Louisa Harding shows that young coho salmon exposed in the lab to the antidepressant fluoxetine have altered transcript levels of reproductive hormones, and that swimming in water laced with estrogen from birth control pills alters the expression of 670 genes in these fish. Other researchers are working on similar studies involving mussels, oysters, sculpin, and other species.

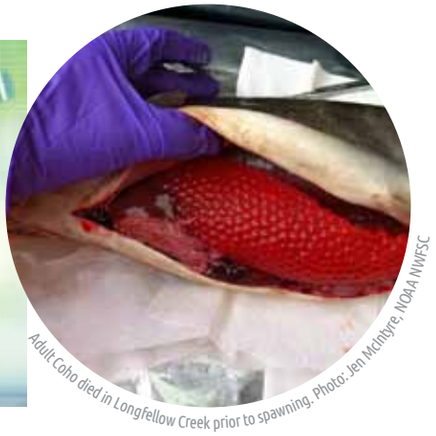
Behind these studies is the conviction that just because emerging contaminants are complex to monitor and their effects can be subtle doesn't mean that we can ignore them. After all, says Evan Gallagher, professor of environmental toxicology at the University of Washington School of Public Health, "All chemicals at one time or another were considered emerging contaminants."

In other cases, it is more mysterious. One of the region's major sources of pollution is stormwater that flows directly from our neighborhoods and roads. Stormwater washes about 2 million pounds of toxic chemicals into Puget Sound every year, but it is not always clear what those chemicals are. Potentially thousands of different compounds flow down the drain with every rainstorm. That has created more than a few mysteries for scientists, who have been documenting the effects of runoff on wildlife.

THREATS TO SALMON

One of the most dramatic examples presented at the 2014 conference, involved studies of so-called pre-spawn mortality among salmon. For the past decade, scientists have been investigating mysterious die-offs of coho salmon returning to spawn in the fall. These fish seem healthy when they enter Puget Sound streams, but within hours they become listless, disoriented, and off balance. Most fish that develop these symptoms die before they are able to spawn. So many coho are perishing in this way that scientists say many affected runs could be extinct within decades.

Antibacterial hand gel. Triclocarban molecule added. Credit: trontnort (CC BY-NC 2.0)


Adult Coho died in Longfellow Creek prior to spawning. Photo: Jen McIntyre, NOAA NWFSC

This condition is worse after a heavy rain, and laboratory experiments by scientists at NOAA's Northwest Fisheries Science Center in Seattle have been unequivocal. Fish placed in baths of stormwater developed characteristic pre-spawn mortality symptoms or died within four hours. Those that spent time in well water remained healthy. In the wild, fish would rarely be exposed to such concentrated runoff, but scientists say the experiment demonstrates that runoff contains a deadly mixture.

Despite difficulties in pinpointing the cause of pre-spawn mortality, scientists have made progress in understanding how to prevent the syndrome by filtering runoff through a specially designed mixture of soil, sand, and organic matter – a technology known as bioretention. "The results are really dramatic," NOAA's Nat Scholz said at the conference. Coho spawners exposed to filtered stormwater do not develop any pre-spawn mortality symptoms. "We're seeing 100 percent reversal" of previous results, Scholtz said.

Similarly, filtering runoff through bioretention columns also prevents most of stormwater's ill effects on small aquatic invertebrates, young coho salmon, and developing fish eggs.

THE SILVER LINING

Completely solving Puget Sound's stormwater problem may be far off, but scientists say there is at least one silver lining. Despite the Salish Sea's rising population, the fact that humans are at the root of the pollution problem means that humans can also do something about it.

In this sense, John Elliott finds hope in the eggs on Mandarte Island. His group's study shows that slowly but surely DDT and related chemicals are decreasing in seabird eggs. Similarly, a class of flame retardant chemicals called PBDEs increased and then decreased in seabird eggs collected between 1990 and 2010. The change occurred in concert with restrictions on the use of these chemicals. Such results sound a hopeful note that policy can make a difference, even for persistent contaminants.

"What we are learning is that the monitoring works," Elliott says. If we know the contaminants are showing up, we can stop using them or releasing them into the environment. "We have an incredibly active and engaged population here," he says. "Changing people's behavior is the key."

BY: SARAH DEWEERDT | Editor: Jeff Rice | Topic Editor: Andy James | Published: October 7, 2014

- Visit the online version of "Citizens now the leading cause of toxics" to learn more: www.eopugetsound.org/magazine/toxics

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Seattle's central waterfront at sunset.Photo: Michael Matti (CC BY-NC 2.0)

Juvenile salmon at the Seattle Aquarium. Photo: Sid (CC BY-SA 2.0)

The decaying seawall along Seattle's waterfront is providing scientists with an opportunity to improve long-lost habitat for migrating salmon. It could also show the way for habitat enhancements to crumbling infrastructure worldwide. One University of Washington researcher describes the project.

KEY TAKEAWAYS

- *Young salmon avoid shaded areas like piers and docks, potentially delaying their migrations.*
- *The quality and availability of food for salmon may be compromised near seawalls.*
- *Artificial habitats created at the downtown Seattle seawall supported the growth of small invertebrates that salmon like to eat.*
- *In cases where piers are necessary, research shows that salmon will respond favorably to light-penetrating surfaces like glass that are built into overwater structures.*
- *Deteriorating shoreline infrastructure must be replaced, providing significant opportunities to improve conditions for fish while protecting valuable property.*

Brighter future for salmon at downtown seawall

Peering over the railings at Seattle's downtown waterfront, tourists can often see thousands of young salmon schooling next to shore. These recently hatched Chinook, chum, and pink salmon have just swum into Elliott Bay from the Duwamish River. Millions like them will pass through Puget Sound during the spring and summer as they migrate to habitats in the Salish Sea or to more distant areas throughout the northeast Pacific Ocean.

For these particular salmon, however, the natural, sloping beaches that their ancestors once followed have given way to murky passages through a series of docks and piers.

The salmon move back and forth next to the seawall, staying within a few meters of land. Their movements show a pattern: the fish are not swimming underneath the pier, but are milling about searching for a pathway. Their eyes adjust slowly to darkness, reducing their ability to school, find food, or see predators. They would rather avoid these shaded areas than continue to travel along the seawall.

A THREAT TO YOUNG SALMON

Overwater structures like piers and seawalls can pose serious challenges to migrating salmon, and Seattle's downtown waterfront was one of the case studies discussed by scientists at the 2014 Salish Sea Ecosystem Conference in Seattle.

The salmon in Elliott Bay will eventually make it past the seawall, but their lag at the waterfront may threaten their survival to adulthood. Salmon migrations are complex and have evolved to coincide with blooms of prey at locations sometimes hundreds of miles away. Even a subtle delay can make salmon dangerously late to the table, causing them to miss out on crucial calories needed for growth and survival.

Meanwhile, the food along the seawall itself is different than in pristine areas. The salmon schooling here are searching for prey that their ancestors were able to find in the shallow sediments of Elliott Bay's beaches, but after more than a hundred years of shoreline alterations, scientists suspect that much of that food source has disappeared. Other traditional sources of prey such as insects from shoreline vegetation are also harder to find.

Example of the gribble, a wood boring isopod. Photo: Auguste Le Roux (CC BY 3.0)

AN UNEXPECTED OPPORTUNITY

While scientists have long suggested that the downtown Seattle waterfront provides impaired habitat for juvenile salmon, major changes to the shoreline were seen as impractical because of the building costs and potential impacts to businesses and tourists. The situation was mostly static until 2001, when a massive 6.8 earthquake forced the issue, causing significant damage to Seattle's infrastructure, including the downtown seawall.

Originally built with old-growth timber, the seawall had already exceeded its engineered lifetime, and on top of damage from the earthquake, small marine crustaceans known as "gribbles" had made the seawall look—and function—like a leaky sponge. Studies showed that another quake could cause the seawall to fail outright. The city and voters recognized that the structure needed to be rebuilt, providing a rare opportunity to design a waterfront with enhanced habitat for salmon.

[CONTINUED]

1895 photo of the eastern shoreline of Elliott Bay. Photo: Seattle Municipal Archives

A LONG HISTORY OF SHORELINE ARMORING

People have used the waterfronts of Puget Sound for millennia and the effect of development is now so widespread that in many cases descriptions of natural conditions are limited to century-old photographs and accounts given by local tribal elders.

In Seattle, shoreline development began to change in the 1850s when European settlement occurred. Industries like timber and mining facilitated the rise of Seattle as a transportation hub and in 1934, the Elliott Bay seawall was completed to facilitate waterfront use and to armor the shoreline from erosion. The seawall replaced Elliott Bay's beach and mudflat shorelines with wood and dirt and eventually cement, and covered most of the intertidal zone.

The conversion of natural shorelines to armored waterfronts in Elliott Bay, although an extreme example, is representative of shoreline development across similar urban areas in the Puget Sound region. On average, twenty-seven percent of Puget Sound's shoreline is armored and one mile of new shoreline armoring is installed every year.

Raising the first slab on the Railroad Avenue seawall, May 15, 1934. Photo: Seattle Municipal Archives

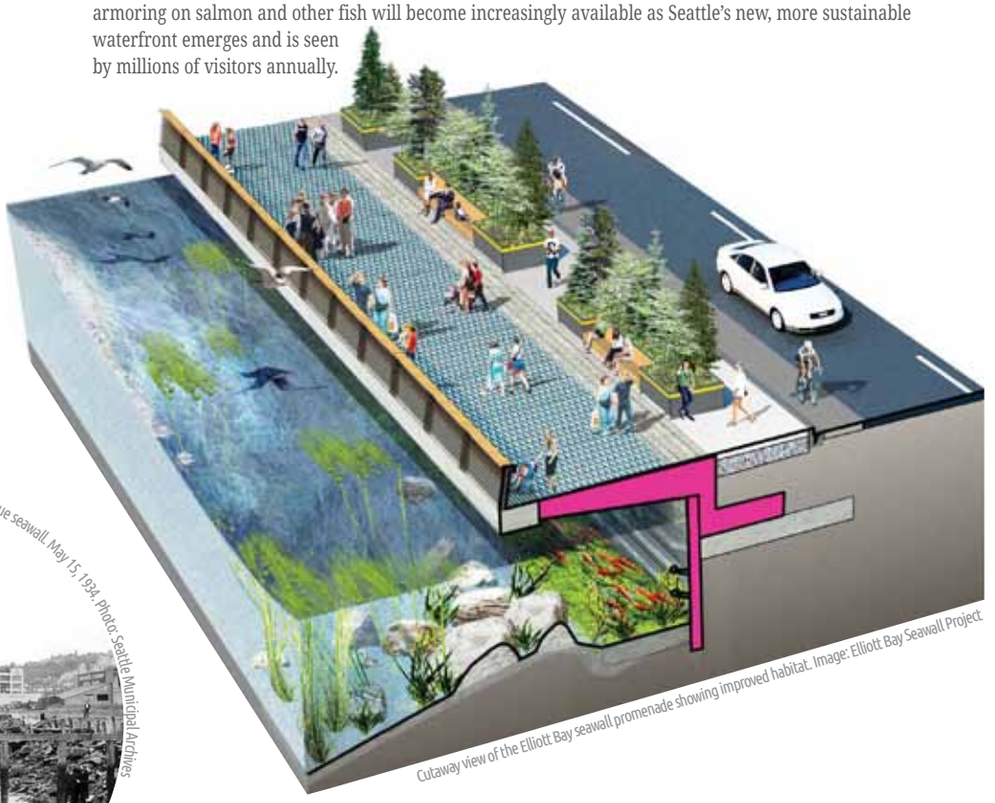
BRIGHTER FUTURE FOR SALMON AT DOWNTOWN SEAWALL [CONTINUED]

With the seawall reconstruction planned several years in advance, a team of researchers at the University of Washington as well as representatives from the City of Seattle, King Conservation District and the federal Sea Grant program began testing experimental enhancements [the author of this article was a member of the University of Washington team as a graduate student researcher].

PROMISING RESULTS

The pilot studies focused in large part on food and light availability. An artificial habitat bench in front of the existing seawall supported the growth of small invertebrates that salmon like to eat, as did textured panels that protruded from the flat seawall. Glass blocks set into a pier next to the Seattle Aquarium allowed more sunlight to reach beneath the water, opening up potential pathways for salmon. With these and other promising results, the City of Seattle decided to go forward with widespread enhancements to the downtown waterfront habitat as its seawall is reconstructed.

Scientists hope that these enhancements will provide effective tools for improving degraded shallow habitats around the world. It was argued at the Salish Sea Ecosystem Conference that no seawalls last forever, and crumbling shoreline infrastructure provides an opportunity to create more sustainable waterfronts everywhere. That's the message to the general public as well. Educational opportunities about the effects of shoreline armoring on salmon and other fish will become increasingly available as Seattle's new, more sustainable waterfront emerges and is seen by millions of visitors annually.



Cutaway view of the Elliott Bay seawall promenade showing improved habitat. Image: Elliott Bay Seawall Project

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LEADING PUGET SOUND RECOVERY

2014 Salish Sea Ecosystem Conference

BY: STUART MUNSCH | Editor: Jeff Rice | Topic Editor: Charles Simenstad | Published: October 29, 2014

- Visit the online version of "Brighter future for salmon at downtown seawall" to learn more: www.eopugetsound.org/magazine/seawall

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Aerial photo of Hansen Creek restoration site in Skagit County, WA. October 15, 2010. Photo: Kari Neumeyer/NWIFC

Pink salmon spawning in Hansen Creek. October 22, 2009. Photo: Kari Neumeyer/NWIFC

Scientists are rethinking floodplain management in Puget Sound. Can we have our farms and salmon too?

KEY TAKEAWAYS

- *Floodplains include some the richest and most fertile agricultural lands in Puget Sound while providing critical habitat for salmon and other wildlife.*
- *While levees and dikes can protect flood-prone areas, they exert a price on the natural environment and are expensive to maintain.*
- *Scientists are looking for alternative ways to prevent flooding that also restore salmon habitat.*
- *Hansen Creek and other restoration projects were successful in reducing flood risk without the use of costly levees and dredging.*
- *Floodplains by Design is managed by The Nature Conservancy, the Puget Sound Partnership and the Washington State Department of Ecology to provide support for projects that promote multi-benefit floodplain restoration.*

Nature inspires new approach to flood control

Every year, winter rains bring the threat of millions of dollars in property damage, or even the loss of life, from floods. Rivers have historically been channeled and tamed to protect towns and farms in low-lying floodplains, but research shows that this approach may actually be making flooding worse, while at the same time threatening Puget Sound's salmon. At Hansen Creek in the Skagit Valley, scientists say nature is the best engineer.

Hansen Creek is a tributary of the Skagit River that wends roughly seven miles from Lyman Hill in the foothills of the Cascades down to the river. As is the case with many wetland habitats in the Skagit Valley and throughout Puget Sound, the creek has undergone significant transformations. In the 1940s, it was dredged and diked, primarily to protect local farms from the ebb and flow of floods that have been a part of the valley for millennia.saying goes, the more you find.

This held the water back, but cut off from its historic floodplain and then shunted through a series of ditches and culverts, Hansen Creek and the farmers paid a price. The creek had lost its natural, braided character. Salmon that had used it to migrate to and from the sea found themselves restricted to its warm main channel where there was less food and more risk from predators.

It wasn't much better for farmers. Nutrient-rich sediment flowing down the river was no longer allowed to spread out over the plain. It built up in the creek, raising water levels and increasing the risk of flooding. Farmers were left with the prospect of more and more expensive dredging with diminishing returns.

> *"It's like Mother Nature was saying, 'Lemme out! Lemme out!'"*
>
> *Lauren Rich, Upper Skagit Tribe*

Lauren Rich and Congressman Rick Larsen tour the Hansen Creek site. Sept 2010. Photo: Kari Neumeyer/NWIFC

That started to change in 2007, when the Upper Skagit Indian Tribe led a multi-agency collaboration to restore the upper floodplain portion of the creek on a patch of county-owned land within the Northern State Recreation Area. In stark contrast to levees and dredge buckets, the project planted more than 100,000 native shrubs and trees and installed log structures throughout the site. They enlisted the help of natural engineers like beavers that built dams and lodges, creating new habitat for salmon. Side channels, too, were restored. At the time, it was the largest freshwater floodplain restoration in the United States.

Photo: Kari Neumeyer/NWIFC

2009 construction crews use heavy equipment to create habitat in Hansen Creek

A CASE STUDY

Last May, Lauren Rich, manager of the environmental planning and community development program for the Upper Skagit Tribe, moderated a session on the lessons of Hansen Creek at the Salish Sea Ecosystem Conference. It was a case study of what has come to be known as multi-benefit floodplain management [see sidebar]. The premise: If designed right, projects that help salmon can also help farmers, and vice versa.

The results have been promising. For salmon, studies show that the restored habitat at Hansen Creek is functionally similar

[CONTINUED]

FLOODPLAINS BY DESIGN

Scientists recognize the importance of floodplains to both humans and the ecosystem. The USGS estimates that valley bottom areas cover about 5% of the Puget Sound basin, but are the site of 30% of highly developed urban areas and 70% of cultivated land. Healthy floodplains are also a key ingredient for salmon health. Studies show that they promote faster salmon growth, and increased productivity, among other benefits.

Now a multi-partner effort funded by the EPA's National Estuary Program is seeking a win/win for both salmon and humans. Floodplains by Design is managed by The Nature Conservancy, the Puget Sound Partnership and the Washington State Department of Ecology to provide support for projects that promote multibenefit floodplain restoration.

Established in 2013, the program is distributing $33 million dollars to floodplain restoration programs throughout the region, while leveraging already existing local, state and federal funding.

> *"Each year, an estimated load of 6.5 million tons of sediment is transported by rivers to Puget Sound and its adjacent waters—enough to cover a football field to the height of six Space Needles."*
>
> *USGS Fact Sheet 2011-3083*

to more pristine reference areas: The fish density is the same, the prey base is the same and fish are getting the same quality and amount of food. The new side channels add habitat, and the water temperature has dropped as well, something crucial for salmon. "From the basic goal of creating real estate for the fish to use, the project certainly did that," says Jeff Cordell, a biologist from the University of Washington who led the monitoring. "All of that new plain opened up, and the fish are clearly using it."

MORE CAPACITY

But the benefits extended well beyond salmon. "We ended up with greater flood storage capacity," Rich says. The land and the creek could now hold more water without breaching. "This meant less frequent flooding, and shorter flood events [attributable to the creek]," she says, "and that makes the farmers happier."

This last element is key, says Rich. Some farmers worried that the restoration wouldn't do enough to stop flooding that occurred due to the buildup of sediment in the creek. Flooding had become such a problem that landowners formed a flooding sub-district in 1982.

But the restoration work reactivated Hansen Creek's alluvial fan—a geologic feature that removes silt and gravel from the water and spreads it across the landscape, helping to absorb what floods there are. It was so successful that the landowners disbanded the flooding district in 2010. "The county hasn't had to spend any money on flood mitigation since the project went in," says Jeff McGowan, a salmon habitat specialist with Skagit County Public Works. "It was a template for a lot of potential projects on the creek."

October 24, 2009 view of completed restoration at Hansen Creek. Photo: Kari Neumeyer/NWIFC

NATURE'S FLOODGATES

Now, four years after the work has finished, Hansen Creek has the manicured scrubbiness of a habitat that has been reset. There are willows and cottonwoods and short pines, blue herons and snipes. "It's a fascinating system, and it responded really quickly," Cordell says. "There are some areas where you can walk along the creek bed and you can't tell that it was a blank field just three years ago."

If there is one thing the project has shown, Rich says, it is the vitality of the site, long held in check. Just after the restoration started, the creek broke free, cutting itself a new, unplanned channel. "We had two weeks from implementation, and then pop! The creek just did what it wanted," she says. "It's like Mother Nature was saying, 'Lemme out! Lemme out!'"

BY: ERIC WAGNER | Editor: Jeff Rice | Published: November 19, 2014

- Visit the online version of "Nature inspires new approach to flood control" to learn more: www.eopugetsound.org/magazine/floodplains

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Salish Sea Currents

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Shellfish foraging at Centre for Shellfish Research, Vancouver Island University Deep Bay Marine Field Station. Photo: VIUDeepBay (CC BY-ND 2.0)

Olympia oysters. Photo: VIUDeepBay (CC BY 2.0)

The shellfish industry is a cornerstone of the Puget Sound economy, but the region's famed mollusks provide more than just money and jobs. They offer what are called ecosystem services—a wide variety of benefits that humans derive from an ecosystem.

KEY TAKEAWAYS

- *The state of Washington is the nation's largest commercial producer of oysters, clams and mussels.*
- *In addition to their importance to the economy, bivalves can help to clean water and enrich habitat—benefits known as ecosystem services.*
- *In 2005, the United Nations Millennium Ecosystem Assessment designated four types of ecosystem services: provisioning (i.e., products an ecosystem provides); regulating (i.e., benefits that come from regulating ecosystem processes); supporting (i.e., services that support all other ecosystem services); and cultural (i.e., non-material benefits that people derive from functional ecosystems).*
- *Shellfish account for all four of these types of ecosystem services.*
- *Historically, not all harvesting of shellfish has been beneficial. The native Olympia oyster was nearly wiped out in the 19th and early 20th centuries due to overharvesting and pollution, but is making a comeback due to restoration efforts.*

Gifts from the sea: shellfish as an ecosystem service

In 1864, Samuel Clemens, better known to posterity as Mark Twain, spent several happy months in San Francisco. The young writer, as Andrew Beahrs recounts in his book, Twain's Feast, was a dedicated foodie, and he was drawn to one item in particular. Twain would later write that, each night, he felt compelled "to move upon the supper works and destroy oysters gotten up in all kinds of seductive styles."

The oysters that Twain so enthusiastically destroyed were Olympia oysters. Although a few were still harvested from San Francisco Bay at the time, the majority of Olys, as the small, sweet bivalves were called, had come from estuaries in Washington state.

The name Olympia oyster (Ostrea conchaphila) derives from the prominent 19th century oyster industry along Puget Sound's Olympic Peninsula, and the region remains one of the nation's leading exporters of shellfish. The popularity of shellfish of all types has only increased since Twain's day. In Washington, according to a 2013 report commissioned by the Pacific Shellfish Institute, shellfish aquaculture—which includes oysters, geoducks, smaller species of clams, and mussels—generated $184 million in revenue in 2010, while accounting for nearly 3,000 jobs.

But shellfish don't just support the region with money and jobs. They also provides other ecosystem services—benefits that humans derive from the environment. Such services might come from the animals in the system, as when native bees pollinate human food crops; or the vegetation, as when wetlands serve as a means of flood control.

ECOSYSTEM SERVICES DEFINED

In 2005, the United Nations Millennium Ecosystem Assessment designated four types of ecosystem services: provisioning (i.e., products an ecosystem provides); regulating (i.e., benefits that come from regulating ecosystem processes); supporting (i.e., services that support all other ecosystem services); and cultural (i.e., non-material benefits that people derive from functional ecosystems).

Foraging for shellfish on Vancouver Island. Photo: VIUDeepBay

Shellfish provide each type of service, says environmental consultant and biologist Marlene Meaders, who spoke at the 2014 Salish Sea Ecosystem Conference in Seattle. Of these, provisioning may be the most obvious. (The ecosystem, as Twain discovered, is delicious.) "I love oysters," Meaders adds. "I'm a big supporter of the locavore movement." Culturally as well, shellfish are important heritage markers, and have sustained local tribes and farmers for hundreds and even thousands of years.

[CONTINUED]

Clam gardens are characterized by a level terrace behind a rock wall in the lower intertidal zone. Photo: Amy S. Groesbeck

ANCIENT CLAM GARDENS

The Salish Sea has a long history of shellfish aquaculture. At the Salish Sea Ecosystem Conference, Amy Groesbeck, a marine ecologist and member of The Clam Garden Research Network, spoke of First Nations' clam gardens in British Columbia that are thousands of years old.

During the late Holocene, First Peoples constructed rock-walled terraces to elevate stretches of the intertidal of clam beaches. The walled beaches had slopes significantly less than nearby, non-walled beaches, increasing the area with conditions conducive to clam growth. In response, the density of butter and littleneck clams was more than double that of non-walled beach. "It shows one of the many ways people have been managing and altering marine environments for millennia," Groesbeck says.

Olympia oysters. Photo: VIUDeepBay (CC BY 2.0)

GIFTS FROM THE SEA: SHELLFISH AS AN ECOSYSTEM SERVICE [CONTINUED]

IMPROVED HABITAT AND CLEANER WATER

Shellfish also provide important regulating services. Shellfish reefs can protect shorelines from storm surges or waves. They can help stabilize land. By adding structure to what might otherwise be bare mudflat, they increase an area's habitat complexity, potentially making it more inviting to juvenile fish in search of refuge from predators, or as a haven for other intertidal invertebrates.

"In some parts of the country like Chesapeake Bay, governments pay millions of dollars to try to bring back lost shellfish beds" because of the benefits to the ecosystem, says Bill Dewey of Taylor Shellfish Farms, the nation's largest grower of oysters and other bivalves. "Here in Puget Sound, aquaculture provides that for free."

Bivalves like clams and oysters are prodigious filter-feeders; some species might filter as much as 55 gallons of seawater in a day. This can lead to another regulating service provided by shellfish: cleaner water. "The presence of shellfish culture can improve water quality by removing anthropogenic sources of nutrients," says Meaders.

Scientists are starting to explore the role of shellfish as bioremediators. At the conference, Aimee Christy of the Pacific Shellfish Institute described a project in Budd Inlet, in southern Puget Sound. The state of Washington had listed the waterway in 2007 as one of special concern. Pollution from urban development has led to excess nutrients in the inlet, which can promote algae growth, potentially choking the water of much-needed oxygen.

In Christy's study, she and her colleagues attached 300 nylon straps to the undersides of several docks, which then attracted tens of thousands of native mussels. The aim was to estimate just how much nitrogen a growing mass of mussels might remove from a small area. "It's nutrient bioextraction," Christy says. By the end of the experiment, she and her team had removed about 4,200 pounds of mussels altogether. Lab tests show that mussels are about 1 percent nitrogen, so the experiment resulted in the removal of 42 pounds of nitrogen from the water. The mussels were then hacked to pieces in a wood chipper and used as compost.

Photo: Pacific Shellfish Institute

Shellfish are nature's water filters. One mussel can filter upwards of 10 gallons of water each day.

The list of potential regulating benefits continues to grow, from bioirrigation, bioturbation, sediment and shoreline stabilization, essential fish habitat, shellfish habitats, significant filtering capacity, eutrophication control, and enhanced benthic-pelagic coupling, among others.

THE RETURN OF A NATIVE

That shellfish and shellfish aquaculture operations provide ecosystem services in one form or another is undisputed. More contentious are the potential drawbacks of this human use. Scientists are debating the impacts of aquaculture on native eelgrass, for example. Some point to localized declines from activities like oyster dredging while others argue that declines are minimal across landscape scales.

There are also concerns that much of the oyster aquaculture in Puget Sound and the Salish Sea relies on introduced species. Consider Twain's favored food, the Olympia oyster. The Olympia oyster's prestige would nearly prove to be its undoing. From the mid-1800s until the early 20th Century, native Olys were overharvested and practically wiped out. To this day, they persist in low numbers at only a few sites in Washington, on state oyster reserves in Willapa Bay and Puget Sound. In the early 20th century, shellfish aquaculture in the region shifted toward Japanese oysters, but Olympia oysters (the only oyster native to the West coast) are now on the road to recovery and can be found at oyster bars throughout Seattle.

Endangered oysters are not unique to Puget Sound. A recent study by The Nature Conservancy reports that native oyster reefs have declined by 85% globally, making them one of the world's most threatened marine habitats. That may be further magnified by threats like Ocean Acidification, scientists say. In Puget Sound, only 4% of the region's historic Olympic oyster population currently remains, but you can read about recovery efforts at the Puget Sound Restoration Fund.

BY: ERIC WAGNER | Editor: Jeff Rice | Published: December 11, 2014

- Visit the online version of "Gifts from the sea: shellfish as an ecosystem service" to learn more: www.eopugetsound.org/magazine/shellfish

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Soggy Crosswalk. Photo: sea turtle (CC BY-NC-ND 2.0)

A newly installed rain garden. Photo: JBLM PAO

Pollution from stormwater has been called one of the greatest threats to Puget Sound. How much will it cost to hold back the rain? A new EPA-funded study says the price could reach billions per year, a figure that dwarfs current state and federal allocations.

KEY TAKEAWAYS

- *Runoff—or stormwater—from roads, parking lots, and roofs is one of the largest sources of contaminants flowing into Puget Sound.*
- *An EPA-funded report projects costs of up to $14 billion dollars per year over 30 years to fully address stormwater pollution in the region.*
- *A longer time frame for fixing the problem may be more practical. Costs fall to $650 million dollars per year if work is done over a 100-year period.*
- *Stormwater pollution is made worse by urban development that prevents rain and snow from being absorbed by plants and soil.*
- *Among the innovations grabbing the attention of scientists and engineers is low impact development, which use a place's natural hydrology to control stormwater runoff.*

Stormwater fixes could cost billions

The figure is staggering: Close to half a trillion dollars over the next 30 years. That's what it could cost to completely address Puget Sound's growing stormwater problem, according to an EPA-funded study presented last spring at the Salish Sea Ecosystem Conference.

The study, prepared by researchers at the King County Department of Natural Resources and Parks, projects the capital and maintenance costs of the stormwater treatment facilities that would be needed to fully comply with the Clean Water Act. A 30-year time frame could mean capital outlays of as much as $14 billion dollars per year. Jim Simmonds, the report's lead author, acknowledges that, given the huge expense, a 30-year fix appears unlikely. But the report also looks at potential stormwater retrofits over the next 100 years. Costs over that time frame would average about $650 million dollars yearly. "That is far more realistic," he says, and would help undo a century-old problem.

The figures far exceed last year's state allocation of $100 million dollars, but Simmonds says the study is not meant to suggest that the legislature suddenly come up with an additional $14 billion dollars annually to deal with stormwater. Instead, he says, it tells a story of where we are and where we still have to go. Runoff—or stormwater—from roads, parking lots, and roofs is one of the largest sources of contaminants flowing into Puget Sound. "One of the questions that has come up repeatedly is 'how much will it take to fix this problem?'" he says. "This report puts that in context."

HOW WE GOT HERE

Sandwiched between the Olympic and Cascade mountain ranges, Puget Sound's urban areas receive up to 40 inches of rain each year. Historically, most of this water soaked into the ground or was taken up by plants. In forested areas in the Pacific Northwest, evergreen trees transport about 40% of rainfall back to the atmosphere through their needles. The remaining water filters through other plants and the soil. The ecosystem is driven by this water cycle, but over the past 100 years, human development has drastically altered this natural pattern.

Urban areas were originally designed to move stormwater quickly and efficiently downstream through a series of drains, pipes, and sewers. Flood prevention was the main reason for getting stormwater out of the city fast, but over the years municipalities have come to realize that speedy water removal is actually detrimental to the health of Puget Sound.

Without the filtering effect of plants and soil, surface runoff increases and stream flows become "flashier"—surges in runoff are more frequent and more intense. This means greater flooding, and more polluted water flowing into Puget Sound.

Raindrops on a cafe window. Photo: Jim Culp (CC BY-NC-ND 2.0)

> *"It took us 100 years to create the problem, and it's going to take a long time to fix it."*
>
> *Jim Simmonds, Environmental Programs Managing Supervisor, King County Natural Resources and Parks*

[CONTINUED]

Kids explore a newly installed rain garden. Photo: JBLM PAO

THE BIG IMPACT OF LOW IMPACT DEVELOPMENT

Among the innovations grabbing the attention of scientists and engineers are low impact development approaches to stormwater treatment, which use a place's natural hydrology to control stormwater runoff.

At the 2014 Salish Sea Ecosystem Conference, Mindy Fohn, a stormwater manager with Kitsap County, described one low impact development approach where managers are planting trees in notoriously impervious surfaces like parking lots to trap stormwater. In the past, these trees might have been planted on raised islands. Now planners are putting them in lower areas that draw the water between parking spots. These interventions are small, local, and often quite beautiful.

So far, bioretention from low impact development has shown promising results. A natural filtration system of soils and plants was recently demonstrated by NOAA to effectively eliminate some of the deadly effects of stormwater on coho salmon.

Another area of interest involves citizens themselves, in a more grass roots approach, installing rain gardens on their own properties. Rain gardens are simply landscaped areas that collect, absorb and filter stormwater runoff from rooftops, decks and other hard surfaces. The idea is to prevent stormwater from washing off individual properties which, if done in sufficient numbers, will have a large positive effect on watershed and basins. The Washington State University and Stewardship Partners are working together towards the goal of '12,000 Rain Gardens' by the year 2016.

STORMWATER FIXES COULD COST BILLIONS [CONTINUED]

In Seattle, one acre of pavement can generate as much as a million gallons of stormwater each year. Water from downpours picks up all kinds of pollutants—from motor oil to dog waste—as it makes its way down the drains. Carcinogens, heavy metals, and harmful bacteria can all be counted in this mix. One study estimates that rainfall runoff events can transport up to 8 times the amount of copper and 6 times the amount of mercury compared to baseline conditions. That's bad news for wildlife and humans alike.

THE CLEAN WATER ACT

The Clean Water Act of 1972 was one of the first rigorous national laws dealing with water contamination, with the first concentration-based limits for pollution. The original goal was to eliminate the direct discharge of pollutants by 1985. Amendments to deal with stormwater weren't introduced until 1987, which required permits for all new development projects. In the 1980s and 1990s a slew of new legislation introduced more criteria for stormwater management. Currently all development and redevelopment projects require approved stormwater treatment, and that requires facilities and infrastructure.

So what about those billion dollar figures? Simmonds says the potentially high costs outlined in the King County report highlight the need for creative solutions. The report outlines a worst-case scenario that assumes all retrofit approaches will stay the same. New technologies and other innovations will almost certainly lower costs, he says, but the report does not focus on the how—just the how much. And whether the costs are in the hundreds of millions or the billions, Simmonds argues that we risk more if we ignore the problem. "Yes, this is a huge investment. But I don't think it has to be dismissed as too expensive,'" he says. "The [state and federal agencies] have all declared that stormwater is the biggest threat to Puget Sound. We have to decide how we're going to deal with that." The bottom line, he says: "It took us 100 years to create the problem, and it's going to take a long time to fix it."

Dump no waste. Drains to lake. Photo: Steve Mohundro (CC BY-NC-SA 2.0)

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PUGETSOUND PARTNERSHIP

2014 Salish Sea Ecosystem Conference

BY: VIRGINIA EMERY AND JEFF RICE | Editor: Kurt Marx | Published: December 17, 2014

- Visit the online version of "Stormwater fixes could cost billions" to learn more: www.eopugetsound.org/magazine/stormwater

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Passenger jets ready for takeoff at Sea-Tac Airport. Photo: © Port of Seattle

Natural beauty of Miller Creek. Photo: Michael @ NW Lens (CC BY-NC-ND 2.0)

How does one of the West's busiest airports deal with extreme stormwater, and what does that mean for water quality standards in the rest of the state?

KEY TAKEAWAYS

- *Sea-Tac Airport operates under one of the strictest stormwater permits in the state.*
- *Every inch of rain that falls at Sea-Tac generates about 6 million gallons of wasterwater, according to the airport.*
- *Despite many toxic chemicals used on-site, such as jet fuel and deicer, the airport reports that its most contaminated area is the expressway for visiting cars and trucks.*
- *Stormwater from other heavily traveled roads in Puget Sound may be just as contaminated.*
- *An evolving understanding of stormwater impacts may prompt new efforts to strengthen stormwater regulations throughout the state.*

Airport offers a glimpse at tightening stormwater regulations

When Sea-Tac Airport opened its controversial third runway in 2008, it also began a new chapter in Puget Sound stormwater regulations. Citizens and state regulators had raised concerns about how the runway might affect three nearby creeks flowing into Puget Sound, and the state Department of Ecology issued its most stringent industrial stormwater permit to date.

The airport posed a special challenge—a near "perfect storm" for stormwater—combining large amounts of impervious surfaces like runways with the heavy use of toxic chemicals ranging from jet fuel to deicer. Every inch of rain that falls at Sea-Tac generates "about 6 million gallons worth of wastewater that we have to deal with," says Elizabeth Leavitt, the airport's Director of Aviation Planning and Environmental Services. Leavitt spoke at the 2014 Salish Sea Ecosystem Conference as part of a special session on "Integrating economic growth with ecological protection and restoration of the Salish Sea."

At the session, Leavitt described how Sea-Tac is working to meet special controls on the toxicity of its stormwater, including strict limits on the amounts of heavy metals and other pollutants. But while the airport might be seen as an outlier with a unique set of challenges, it could also hold increasing relevance for the future of everyday stormwater management.

EXTREME STORMWATER

Based on its permit, the airport provides an example of what might be called extreme stormwater. Sea-Tac is "ahead of where other typical stormwater requirements are in the region," says Jerry Shervey, Industrial Unit Supervisor at the Department of Ecology. It requires special cleaning facilities and intense monitoring. The entire airport has been retrofitted to contain the pollutants that could otherwise wash into the surrounding environment. But, according to Leavitt, there is one surprise.

Even as 34 million passengers board several hundred thousand flights per year at Sea-Tac, the place with the nastiest pollution is a familar but unexpected culprit—the road into the airport. "Most people would think that the runways are the most contaminated place at the airport," Leavitt said at the conference. "It's actually not the runways, [but] the expressways that bring all the cars and trucks through."

Seattle-Tacoma International Airport. Photo: redlegsfan21 (CC BY-SA 2.0)

In that sense, industrial sites like the airport may not be the only places in Puget Sound with extreme stormwater. Hundreds of miles of highways in the region might be just as polluted.

Recent studies by NOAA bear this out. They point to stormwater runoff from highways as a likely suspect in the deaths of migrating salmon near stormwater outfalls. Known as "pre-spawn mortality," the problem is so severe that scientists worry that it could lead to the extinction of several runs of Coho salmon within decades. [Read more about toxics in Salish Sea Currents].

SEA: #15 in U.S.

More than 34 million passengers board several hundred thousand flights at Sea-Tac each year, making it among the nation's 15 busiest airports.

[CONTINUED]

Alaska Airlines 737 taking off from Sea-Tac Airport. Photo: © Port of Seattle by Don Wilson

Compared to the controlled environment at the airport, highways—and more broadly other municipal areas like towns and cities—are relatively open systems. Despite extensive stormwater treatment programs and regular monitoring, they all still face "potentially hundreds of outfalls and many thousands of potential inputs [of contaminants]," says Rachel McCrae, a municipal stormwater specialist at the Department of Ecology. From highway runoff to copper in moss killer, to PCBs in paint, and thousands of other contaminants, everyday stormwater is now viewed as one of the greatest threats to Puget Sound.

AN EVOLVING TREND

This growing awareness of the region's stormwater problem continues to prompt discussion of stricter controls. Although its efforts are still pending, the EPA has been working to update federal stormwater standards to include broader water quality limits. Other potential drivers include Washington's proposed new fish consumption rates. Stormwater is identified as a chief source of toxic contaminants in fish, and this month the governor's office and the Department of Ecology proposed new, stricter standards for surface water quality. These "drive pollution discharge limits for industries and other entities that discharge pollution," reads an announcement from the department.

The degree to which stormwater regulations might change in the near future is still an open question. But even if city streets aren't crowded with airplanes, tighter regulations may be taking off.

Read below about some of the ways that Sea-Tac Airport deals with its stormwater:

EFFLUENT LIMITS

Among the things setting the airport permit apart are so-called "effluent limits." There are currently about 1100 active industrial stormwater permits in Washington, but most of these are guided by what are known as benchmarks. If exceeded, benchmarks require a series of corrective actions but do not necessarily trigger fines.

Treatment facility. Photo: © Port of Seattle

That's not the case for the airport, which faces both fines and potential lawsuits if it exceeds the limits specified in its permit. This was tested early on during the runway's construction phase, when the airport was fined a total of $145,000 for a number of stormwater-related discharges into nearby creeks.

DEICING CHEMICALS

Treatment facilities deal with more toxic substances like glycol from deicing agents.

De-icing. Photo: © Port of Seattle

VEHICULAR TRAFFIC

Light rail and even proposed bicycle paths may also decrease toxics at the airport. "Most people would think that the runways are the most contaminated place at the airport. It's actually not the runways, [but] the expressways that bring all the cars and trucks through." —Elizabeth Leavitt

Sound Transit Light Rail. Photo: Michael B. (CC BY-NC-ND 2.0)

BIRD HAZARDS

The airport has its share of unique challenges. Stormwater treatment methods like catchment ponds have to balance environmental protection with federal safety regulations designed to avoid airplane bird strikes. Nets discourage birds from flocking to the area.

Catchment pond with netting. Photo: © Port of Seattle

STORMWATER OUTFALLS

The airport monitors 11 stormwater outfalls. "We're one of the first airports in the country or potentially in the world that actually now collects and has retrofitted the entire airport, so we have full control and treatment on all the water leaving SeaTac at this point." —Elizabeth Leavitt

Swale. Photo: © Port of Seattle

HEAVY METALS

Oyster shells are used to remove copper and zinc from stormwater.

Oyster shells. Photo: Lihagen (CC BY-SA 3.0)

SALMON-BEARING CREEKS

Map of salmon-bearing creeks . Data: WDFW. Map: NOAA

The airport's stormwater challenge is made greater by the presence of three salmon-bearing creeks that drain away from the airport, each eventually flowing into Puget Sound. These include the Miller-Walker creek system, Des Moines Creek and a small portion of Gilliam Creek (view the map to the right). "You can see while [Sea-Tac is] not the part of the port that sits right on the Puget Sound, we definitely have our impacts," says Elizabeth Leavitt.

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2014 Salish Sea Ecosystem Conference

BY: JEFF RICE | Editor: Kurt Marx | Published: January 23, 2015

- Visit the online version of "Airport offers a glimpse at tightening stormwater regulations" to learn more: www.eopugetsound.org/magazine/airport

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Encyclopedia of Puget Sound
eopugetsound.org

Puget Sound Institute
pugetsoundinstitute.org

2014 Salish Sea Ecosystem Conference proceedings
cedar.wwu.edu/ssec/2014ssec/

I don't believe in magic.
I believe in the sun and the stars,
the water, the tides, the floods,
the owls, the hawks flying,
the river running, the wind talking.
They're measurements.
They tell us how healthy things are.
How healthy we are.
Because we and they are the same.
That's what I believe in."

—Billy Frank, Jr.
1931–2014

Right, back cover: Map of the Salish Sea & Surrounding Basin, Stefan Freelan, WWU, 2009


The Salish Sea
& Surrounding Basin
The Salish Sea extends from the north end of the Strait of Georgia to the south end of the Puget Sound and west to the mouth of the Strait of Juan de Fuca
Mt. Waddington
Monmouth Mountain
Desolation Sound
Squamish River
Basin Boundary
N. Gulf Islands
Strait of Georgia
Vancouver Island
Fraser River
S. Gulf Islands
Mt. Baker
Skagit River
San Juan Islands
Cape Flattery
Strait of Juan de Fuca
Glacier Peak
Puget Sound
Pacific Ocean
Olympic Peninsula
Hood Canal
Nisqually River
Basin Boundary
Mt. Rainier
N
0 50 100 km.
0 50 mi.
Data Sources:
SRTM (CGIAR-CSI), NOAA, Wa. DFW, Wa. DNR, BC Digital Atlas, ESRI
http://staff.wwu.edu/stefan/SalishSea.htm
stefan freelan - 2009


Mt. Baker
Skagit River
Strait of Juan de Fuca
Pacific
Ocean
Olympic
Peninsula
Puget
Sound
Hood Canal
Basin Boundary
Mt. Rainier
N