

# Salish Sea Currents

timely, local stories about ecosystem recovery

Photo copyright: Pete Schroeder

*From orcas to starfish to humans, disease affects every living creature in the ecosystem. Scientists are increasingly alarmed by its potential to devastate already compromised populations of species in Puget Sound.*

## Going viral: Concerns rise over potential impacts of disease on the ecosystem

As the sleek black-and-white orcas glided like torpedoes beneath the waves, researchers in a 42-foot boat did their best to stay alongside, watching and waiting for a whale to surface. Suddenly, it happened.

“Whoosh” went the eruptive sound of an exhaled breath. A cloud of mist hung in the air.

Without hesitation, veterinarian Pete Schroeder reached out toward the misty cloud with a long pole, capturing moist droplets from the whale’s breath as they landed on a set of Petri dishes. This sampling technique, used on 16 whales, was designed to find out what microorganisms might be threatening the Southern Resident orcas of Puget Sound.

What Schroeder and his fellow researchers discovered in their NOAA-funded study has raised concerns for the future health of this endangered orca population and has strengthened calls for an ongoing health assessment of each individual whale. It is one of several studies bringing Puget Sound scientists together for a wider look at the potential impacts of disease on the ecosystem as a whole.

### DISEASE AS AN ECOLOGICAL FORCE

The risk of a deadly disease is ever-present among wild populations, domesticated animals and even humans. It is a powerful ecological force, scientists say, often underestimated and under-researched.

Some would argue that disease can shape the ecosystem as much or more than predator-prey relationships, which are often spelled out in a who-eats-whom diagram of a food web. You will never see bacteria, viruses, protozoa or fungi cluttering up these simple charts — but these microorganisms are there, lurking in the background.

“The crazy thing about disease is that it isn’t really on people’s radar,” says Joe Gaydos, a veterinarian with SeaDoc Society, a nonprofit research group. [Gaydos is also a topic editor for the Encyclopedia of Puget Sound.] “It is a smoldering factor in our environment, but one that can break out at any time.”

Given the right circumstances, a single species of microorganism can kill or weaken any animal, even those at the top of the food web. Apex predators — such as killer whales — are often said to have no natural enemies (except for possibly humans), but that idea discounts the role of disease.

It is all too easy to forget about disease organisms in Puget Sound, even when fish and other marine animals are dying. Without dead bodies lying around or obvious declines in population, an outbreak often goes unnoticed.

Such was the case before divers began noticing that sea stars appeared to be melting in place as they died. The deadly “sea-star wasting disease” became widespread along the West Coast in a matter of months, killing millions of individuals and affecting 20 different species of sea stars.

Effects of this massive die-off are still being measured, but sea stars have long been considered a “keystone species,” meaning their loss can significantly alter the entire ecosystem.

Meanwhile, other diseases found in Puget Sound may be reducing the populations of herring and other forage fish, thus limiting the food supply for larger fish such as salmon and steelhead, which have their own diseases to battle. Disease effects could be playing a role in the recovery of threatened chinook salmon populations and the orcas that eat them.

More research is needed to measure the incidence of disease in organisms, as well as the effects and the factors that can trigger outbreaks, Gaydos says. Some people believe that increased pollution in Puget Sound, along with higher water temperatures caused by global warming, could increase the risk of infection for a variety of species, including humans.

### RISKS FOR KILLER WHALES

Studies on the breath samples from Southern Resident orcas have revealed a total of more than 50 pathogenic bacteria in the orcas’ respiratory systems, according to Schroeder, a veterinarian who has studied marine mammals for five decades. Among the potentially dangerous pathogens discovered were Salmonella, Vibrio, Pseudomonas, Staphylococcus and Streptococcus.

How the bacteria may be affecting the health of the individual whales remains unclear, Schroeder says. Some individuals may have developed immunity to some pathogens. But any of these bacteria can cause illness under the right conditions, such as when an animal has a weakened immune system.

Southern Resident killer whales contain higher concentrations of polychlorinated biphenyls and other immune-suppressant chemicals than almost any marine mammal population in the world. Their immune systems may also be affected by stress, as they cope with a historically low number of chinook salmon — their primary source of food — and all sorts of noisy boats that share their habitat.

Of the bacteria identified in the breath of orcas, more than half were resistant to one or more common antibiotics, according to the research findings, likely to be submitted next month to a scientific journal. Resistant forms of bacteria are likely to come from human, rather than natural, sources.

“Living in that water for an air-breathing animal creates a certain amount of risk,” Schroeder says. “Any pathogenic bacteria present a risk. The more you find, the more risk there is.”

Some antibiotic-resistant bacteria also could pose a risk to humans, since these bacteria could work their way into the seafood that people eat.

Looking into the water, the researchers found 26 different groups of bacteria in the sea surface microlayer, a thin, oily biofilm that floats on the surface. Some bacteria found in the microlayer were the same as those found in the whales, and some were different. Since the whales swim through this microlayer each time they surface to breathe, they continually run the risk of being exposed to a variety of pathogens — including those released in sewage effluent and urban stormwater.

### THREATS TO THE POPULATION

In 2004, a group of researchers, including Joe Gaydos, identified pathogens capable of infecting, spreading and potentially killing orcas within the three pods that frequent Puget Sound. Expanding on previous studies, their report found 15 infectious agents among captive and free-ranging killer whales, as well as another 28 pathogens in closely related whales and dolphins.

Marine Brucella, cetacean poxvirus, cetacean morbilliviruses and herpes viruses were ranked as the most dangerous pathogens that could potentially reduce the Southern Resident population.

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One group, the morbilliviruses, are known to cause measles in humans, canine distemper in dogs, phosine distemper in seals and rinderpest in cattle, buffalo, antelope, deer and giraffes — although the latter virus was declared eradicated in 2011 after an extensive, worldwide effort.

One related and particularly dangerous virus, cetacean morbillivirus, is associated with the deaths of more than 1,500 bottlenose dolphins in two years along the East Coast. Several hundred additional deaths were actually reported, but these 1,500 were specifically tied to the morbillivirus during an “unusual mortality event” declared by the federal government between July 2013 and March 2015.

The effect of this outbreak on the total population of bottlenose dolphins has not yet been reported by federal biologists, but a similar outbreak in 1987 and '88 appears to have killed about half the “inshore” population of dolphins in areas being studied. Symptoms can include skin lesions, pneumonia and brain damage.

Gaydos says it is not known for certain that killer whales are susceptible to the same virus that killed all those bottlenose dolphins on the East Coast. Still, closely related species, including short-finned pilot whales and common dolphins, have been infected with the virus and could potentially transmit it to the Southern Residents of Puget Sound.

Infection is likely to spread when one animal inhales the breath of an infected individual, such as occurs when traveling with synchronous surfacing or when sharing food. The virus may also be transmitted from mother to offspring in the womb, where it can lead to abortion, or when a young calf takes milk from its mother.

If morbilliviruses prove to be highly virulent to orcas and the Puget Sound pods become infected, the resulting outbreak “could have catastrophic consequences and could threaten the long-term viability of this population,” states the report by Gaydos and his colleagues.

Infection often leads to bronchial pneumonia, according to a report on cetacean morbillivirus by 32 researchers published last year in the journal “Viruses.” Animals that survive the initial disease may succumb later to other infections, probably because of damage to their immune systems.

Despite the prevalence of cetacean morbillivirus on the East Coast and in Europe, only scattered outbreaks have been reported in the Pacific Ocean — including a small number of common dolphins that washed up dead in California between 1995 and 1997.

Gaydos and his colleagues have proposed an ongoing health assessment for the individual orcas, including information derived from breath and fecal samples. Understanding the health of each whale could help experts formulate a possible response if the whales suddenly become sick.



Mist from the breath of killer whales is collected at the end of a long pole then tested for dozens of different types of bacteria. Researchers discovered that the whales were carrying a variety of antibiotic-resistant bacteria as well as normal strains. Photo: Pete Schroeder

## DEALING WITH DISEASE

Flying under the radar, infectious diseases may be spreading through populations of marine animals in Puget Sound, crossing from one species to another and even increasing risks to human residents of the region.

One group of researchers would like to incorporate the search for disease organisms in Puget Sound into existing programs that monitor populations, measure toxic contamination and examine changes in the ecosystem. Some sampling, such as collecting the breath of killer whales, causes little or no harm to the animals. Other sampling involves taking various tissues from dead animals.

“If someone is doing lethal sampling, we hope that they could also collect material for pathogen analysis,” says Linda Rhodes, a research microbiologist with NOAA’s Northwest Fisheries Science Center.

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Rhodes and Gaydos of SeaDoc Society are leading a new work group on disease that will include a broad spectrum of scientists focused on Puget Sound. The goal would be to better understand how disease could affect the efforts to restore Puget Sound to a healthy condition.

The new work group, scheduled to meet for the first time at the end of this month is likely to fit into the Puget Sound Partnership’s overall Ecosystem Monitoring Program (PSEMP), Rhodes says. The new work group on disease could become a close partner with an existing monitoring group on toxic chemicals.

As the science of ecosystem restoration advances, researchers are coming to understand the interplay of various ecological forces, such as predation, toxic chemicals and disease, said Scott Redman, science program director for the Puget Sound Partnership, which is coordinating the restoration of Puget Sound.

“For years, the marine mammal people have been talking about compromised immune systems and the effects of disease on populations,” Redman says. Now, climate change is creating significant shifts in water conditions, which may be shifting the game for pathogens.

In a way, Redman said, the sudden appearance of sea star wasting disease became a wake-up call for what could happen to other Puget Sound populations. The idea of integrating disease factors into the overall effort to restore Puget Sound makes a lot of sense, he added.

Gaydos and Rhodes presented their case for increased attention to disease during a recent meeting of the Puget Sound Leadership Council, the governing body for the partnership.

Ken Dzinbal, monitoring program manager for the partnership, said the idea of widespread monitoring for pathogens is a good one, but the effort needs to be strategic to manage the costs of laboratory analysis. He looks forward to recommendations from the disease work group.

The partnership developed a “gap analysis,” which listed new scientific projects needed to get a better understanding about what is going right and wrong in the Puget Sound ecosystem. The Legislature used the report last year to fund new research projects. When the gap analysis is updated, Dzinbal said, focused studies on disease might well be included.

Human health is closely tied to ecological health, especially for people who consume seafood from Puget Sound or work or play outdoors. The Washington Department of Health has been forced to increase its surveillance for disease-causing organisms and to temporarily close commercial shellfish beds more often because of a growing number of dangerous pathogens.

The loss of biodiversity may also raise the risk of people contracting a dangerous disease, according to a report by a dozen researchers in the journal *Nature*.

“In recent years, a consistent picture has emerged,” the report says.

“Biodiversity loss tends to increase pathogen transmission and disease incidence. This pattern occurs across ecological systems that vary in type of pathogen, host, ecosystem and transmission mode.”

For example, West Nile virus, which is spread by mosquitoes, finds a suitable host in birds, although some bird species are more susceptible to the virus than others. At least three studies show correlations between low bird diversity and increased human incidence of disease.

The primary reason, according to the report, is that when the number of bird species is low, species that amplify the virus tend to dominate. On the other hand, a high diversity of species allows for more birds that reduce or block the spread of disease. Similar results have been reported for other pathogens that cross from wildlife to humans.

According to Gaydos, a better understanding of disease in the overall ecosystem will lead to better restoration projects for the entire Puget Sound region and could even help to maintain a healthy human population.

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# Sidebar | Disease in herring threatens broader food web

*Pacific herring have long been considered an essential part of the Puget Sound food web. Now, studies are beginning to reveal how diseases in herring could be reverberating through the ecosystem, affecting creatures large and small. We continue our coverage of the ecological impacts of disease in Puget Sound with this look at the region's most well-known forage fish.*

Tiny herring eggs and larvae are eaten by a multitude of invertebrates, such as crabs and amphipods. They are also important to fish, such as juvenile salmon and smelt, as well as numerous marine and diving birds.

As herring grow into juveniles and adults, they enter into the larger food web, including numerous marine mammals, from harbor seals to orcas; vast numbers of birds, from tufted puffins to great blue herons; and a wide variety of fish, from Chinook salmon to halibut.

Paul Hershberger, research fisheries biologist with the U.S. Geological Survey, has been studying diseases of herring at his lab on Marrowstone Island near Port Townsend. It is the only lab in the world where herring are reared from eggs to keep them free of pathogens. This approach allows for a wide range of experimentation into how herring are able to fight off infections or else succumb to the effects of disease.

Like most vertebrates (animals with skeletons), herring benefit from an adaptive immune system, which has the ability to identify pathogens as foreign invaders, develop a biological response and then launch a counter-attack. If successful, the immune system will retain an “immunological memory” that can quickly respond to the next invasion by the same or a similar pathogen.

In fish and other cold-blooded animals, temperature can make the difference between victory and defeat over disease organisms, Hershberger said.

“A couple of degrees can make a real difference in whether a fish is susceptible to disease,” he noted, “but we also see the immune response ramp up at higher temperatures. Subtle changes in temperature can really impact basic biological processes.”

The specific response depends on the specific disease organism, he stressed. “We think of it as an arms race, the replication of the disease agent versus the response of the immune system.”

Herring in Puget Sound are threatened primarily by three pathogens: Ichthyophonus hoferi, a single-celled fungi-like organism that attacks organs and muscles; viral hemorrhagic septicemia virus or VHSV, which causes hemorrhaging of organs, skin and muscle; and erythrocytic necrosis virus, or ENV, which affects the red blood cells.

In adult herring, the prevalence of Ichthyophonus ranges between 20 and 55 percent throughout most of Puget Sound. Unlike many fish diseases, studies suggest that the infection rate increases with age, ranging from 12 percent in juveniles to 58 percent among the oldest adults. And the older animals seem to carry a greater number of the parasites.

In the laboratory, 80 percent of the herring without immunological protection die within two months of exposure.

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Recent studies demonstrate that infected fish are not able to swim as well, making them targets for predators including salmon and sculpins. In other words, predators may eat the diseased herring before the herring even have a chance to complete their battle against the disease.

These factors could help explain the disappearance of older and larger herring in Puget Sound, where the average age of adults has declined from more than 5 years old in the 1980s to about 3 years old today.



Pathogen-free herring are reared from eggs to allow a wide range of experiments on infectious organisms at the Marrowstone Marine Field Station. The laboratory, operated by the U.S. Geological Survey, is located on Marrowstone Island near Port Townsend. Photo: Christopher Dunagan, Puget Sound Institute

The loss of older herring from Puget Sound not only reduces the total biomass of fish available to feed into the food web, it can have an effect on the overall population, Hershberger said. Older females tend to lay a greater number of eggs, which are generally larger and more capable of survival.

Most worrisome is the Cherry Point herring stock, once the largest of the 18 Puget Sound stocks. The biomass of Cherry Point herring has declined from about 15,000 tons in 1973 to less than 800 tons today. The other Puget Sound stocks have avoided that level of decline. Instead, their total biomass has fluctuated widely between about 10,000 and 16,000 tons.

Newly hatched herring larvae from Cherry Point, located near Bellingham, have shown low birth weight, increased skeletal abnormalities and shorter survival times. Ongoing studies are trying to determine whether the majority of Cherry Point herring are simply dying before they reach sexual maturity. If so, the critical reproductive processes would be left to immature herring, which are likely to produce offspring with developmental problems.

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# Sidebar | Are diseases playing a role in salmon decline?

*Chinook, coho and steelhead populations in Puget Sound have declined dramatically over the past 30 years. In some cases, counts of fish returning to the rivers are just a tenth what they were in the 1980s. While many possible causes of this decline are under consideration, some researchers are focusing on the combined effects of predators and disease. This article continues our coverage of the ecological impacts of disease in Puget Sound.*

Studying disease among migrating salmon is no easy task, said Michael Schmidt of Long Live the Kings, explaining why so few studies outside of hatcheries have focused on salmon diseases.

In hatcheries, people notice when fish are dying. They can send the dead fish to a pathology lab and identify the disease agent. Consequently, hatchery managers keep a list of diseases to watch out for and protect against.

These same infectious agents can affect wild fish, but it is much harder to track the spread of disease in open waters. As far as anyone can tell, the fish there just seem to disappear, although researchers have been able to show that 80 percent of juvenile steelhead in Puget Sound die before they reach the ocean. In Hood Canal, this disappearing act seems to take place around the Hood Canal bridge, which suggests that predators may be picking them off there.

Long Live the Kings is one of many participants in a \$20-million, five-year study examining the fate of salmon and steelhead in marine waters on both sides of the U.S.-Canada border. On the U.S. side, one intriguing study is looking at the effects of the parasite *Nanophyetus salmincola*, which seems to be infecting steelhead from streams in southern Puget Sound at a much higher rate than those from streams up north.

“Looking under a microscope, there is no kidney left in some of these fish.”

Paul Hershberger, Station Leader  
and Research Fishery Biologist at the  
Marrowstone Marine Field Station

*Nanophyetus* is a parasitic flatworm with a complex life cycle that involves three hosts, a snail and a warm-blooded animal, as well as the fish. “Salmon poisoning,” a potentially deadly disease in dogs, can occur when a dog eats raw fish infected with the *Nanophyetus* parasite. The parasite itself is relatively harmless to dogs, but it can carry a parasite of its own, *Neorickettsia helminthoecae*, which kills 90 percent of dogs that become infected — unless they are treated quickly. Salmon poisoning affects only the biological family Canidae, including dogs, wolves, foxes and related animals.

In a stream, the *Nanophyetus* parasite gets into freshwater snails via the feces of mammals and birds that have eaten the infected salmon. The parasite then leaves the snail, goes back into the water and burrows under the skin of a fish.

In the Nisqually River between Tacoma and Olympia, researchers have found that virtually all of the juvenile steelhead leaving the river are heavily infected with the parasite.

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“The parasite loads we see in these fish is really high,” said Paul Hershberger, whose Marrowstone Island lab is involved in the research. “Looking under a microscope, there is no kidney left in some of these fish. It looks really alarming, but whether it is killing the fish we don’t know.”

Compared to Nisqually, the percentage of steelhead infected is somewhat lower for other South Puget Sound streams, while in northern Puget Sound relatively few of the steelhead are infected. The cause of the variation may be related to the abundance of snails, but the reasons for more snails in South Puget Sound is unknown. Some say it could be related to temperature, streamflow or type of sediment.



Steelhead (*Oncorhynchus mykiss*). Photo: Eric Engbretson, U.S. Fish and Wildlife Service

Laboratory studies suggest that fish burdened with the parasites may be unable to swim as fast or as long as healthy fish. If that’s the case for steelhead in Puget Sound, they could be easy targets for predators, such as harbor seals. An upcoming experiment will test that idea by releasing an equal number of diseased and healthy steelhead migrants into South Puget Sound. Acoustic tags implanted in the fish will send out signals to determine how far the fish make it and possibly reveal their ultimate fate.

If *Nanophyetus* turns out to be a significant problem for steelhead and possibly other salmonid species, experts could look for ways to disrupt the life cycle of this parasite and reduce at least one obstacle to the long-term recovery of fish in Puget Sound.

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