Salish Sea Marine Survival Project

2016 Canadian Progress Report

Bringing People Together...Deploying New Technology
Executive Summary

In 2009 the Pacific Salmon Foundation’s volunteer board of directors funded a proposal to address the precipitous declines in Coho and Chinook in the Strait of Georgia. This nascent effort expanded into what is now the Salish Sea Marine Survival Project; a five-year (2014-2018), trans-boundary effort encompassing the entire Salish Sea. The Project draws from a broad network of expertise and resources to make a project of this scope possible.

In 2016, the Salish Sea Marine Survival Project managed 40 projects conducted by more than 30 partners with a total expenditure of $3.2 million. Field studies will continue during 2017, while 2018 will be dedicated to assimilation of results, analysis and dissemination of key findings.

Key Findings 2016

- An outbreak of Heart and Skeletal Muscle Inflammation (or HSMI) was found in fish from one Atlantic salmon fish farm. This was the first time HSMI was diagnosed in British Columbia.

- Results from juvenile salmon predation studies included:
  - initial estimates that Harbour seals in the Strait of Georgia are consuming up to 40 per cent of juvenile Chinook and 47 per cent of juvenile Coho;
  - in Cowichan Bay and the Big Qualicum River estuary, Harbour seals are:
    - showing different feeding strategies in the estuary compared to further afield; and;
    - consuming different kinds of salmon during the year, with more juvenile Chum eaten in the fall and more juvenile Chinook and Coho in the spring.
  - Tracking of “tagged” Cowichan hatchery Chinook showed that their survival in-river may be significantly impacted by predators such as other fish, mergansers, otters, and even raccoons.

- The survival of Cowichan hatchery fry increased when they were released at locations further downstream from the hatchery, which could inform future hatchery release strategies.

- Our Citizen Science oceanography project allowed nine vessels to be out on the Salish Sea for 22 days, with all of the Strait of Georgia sampled each day. They undertook 1,369 sampling events, which resulted in more than 8,000 samples for analysis.
Community-Based Small Science Vessels (Citizen Science Program)

A major asset of the project will be the capacity to collect data across the Salish Sea simultaneously with the conversion of several small fishing boats to mini science vessels. The retrofitted vessels will take a variety of oceanographic measurements and samples and will access shallow water in estuaries and bays that would normally not be reachable by traditional, larger research vessels. These mini science vessels exemplify the "citizen science" that will be incorporated into the Salish Sea project.

**What do salmon eat (bottom-up)?**
The project will study biological production of what salmon eat, starting from the smallest marine plants and continuing to the small pelagic fishes like sand lance, herring and eulachon larvae.

**How do you sample everything at once?**
Studies will assess the spring plankton bloom through to a salmon’s food items and other juvenile fishes that are important as competitors in the Salish Sea ecosystem.

New technology and a carefully designed plan will allow the project to simultaneously address all levels of the biological oceanography of the Salish Sea. Existing weather buoys, remote sensing satellites, outfitted community science vessels and BC Ferries will all be leveraged to provide the most comprehensive biological study of the Salish Sea in history.
Estuaries
Estuaries are where young salmon adjust to saltwater environments as they leave freshwater. The project will support study and restoration of these critical transition habitats in the Salish Sea with an emphasis on planting kelp and eelgrass that provide young salmon protection from predators and sheltered feeding areas.

Hatcheries
A collaborative study with Fisheries and Oceans Canada will seek to understand how competition for food with hatchery Coho salmon impacts marine survival of wild Coho salmon. Simultaneously, the study will test strategies that are geared to improve survival of hatchery Coho salmon, ultimately to provide for sustainable local fisheries.

BC Ferries Ocean Sampling
BC Ferries, Ocean Networks Canada, and University of Victoria have teamed up to collect data on shallow ocean conditions for three of the southern BC Ferries routes. This continuously recorded data provides complementary data for the Citizen Science Program.

Salmon Tracking
Strategically placed lines of receivers across the seafloor will allow researchers to trace the migration path of individually tagged fish. Acoustic tags transmit unique signals that are received and recorded by the receivers. If a tagged fish passes a receiver within approximately 300 metres, the receiver records that event.
Salmon Health
A collaborative study with Genome BC and Fisheries and Oceans Canada will analyze the health and fitness of hatchery and wild salmon as they enter the ocean. Analysis will include assessment of pathogens present in wild, hatchery and commercial aquaculture fish utilizing state-of-the-art genomic research tools.

Weather Data
The environment around the Salish Sea is tremendously dynamic. The project will use existing instrumentation at locations like airports to assess weather variation from one year to the next and to better understand patterns in salmon survival. Wind patterns will be of particular interest given evidence that suggests they drive spring plankton blooms that begin the production of food for young salmon in the Salish Sea.

What eat salmon (top-down)?
Understanding the other animals that eat, compete with, or kill juvenile salmon, as well as the influence of diseases and parasites, will be major parts of the project. This will include study of marine mammals, fish-eating birds, predator fish, hatchery and aquaculture interactions with wild fish, contaminants, and changes to local marine habitats.

Infographic: Salish Sea Marine Survival Project
Background

In 2009 the Pacific Salmon Foundation’s volunteer board of directors funded a proposal to address the precipitous declines in Coho and Chinook in the Strait of Georgia. This nascent effort built the foundation for what is now the Salish Sea Marine Survival Project.

Recent catches in the Strait had been less than one-tenth of past levels, resulting in a ban on retention of wild Coho salmon and historically low catches of Chinook. Other losses had also been observed by communities surrounding the Strait such as loss of kelp beds, herring spawning sites and forage fish “bait balls”. Although these losses were well acknowledged, understanding causes of the declines remained a mystery.

So we set out to design an ecosystem-based restoration plan that built on the community relationships forged through our historical work in freshwater. Fast forward several years, and our Strait of Georgia project has grown into a five-year, trans-boundary effort encompassing the entire Salish Sea, facilitated by the Foundation’s ability to catalyze multiple stakeholders toward common goals. The Project draws from a broad network of expertise and resources including government, First Nations, community groups, industry, academia and NGO’s. The breadth of this multi-disciplinary group is what makes a project of this scope possible. But it also ensures all of the key stakeholders will be engaged in 2018, when our research findings become plans for long-term monitoring, evaluation and restoration that will stretch years into the future.
Bringing Back a Salmon Ecosystem

The Strait of Georgia supports approximately 3,000 species of marine life, including all seven species of Pacific salmon. Unfortunately, twenty years ago, this body of water saw a vast decline in Coho and Chinook salmon. Because salmon are an “indicator species”, understanding what’s causing salmon declines in the Strait will also improve our understanding of challenges facing other species like killer whales. The Pacific Salmon Foundation has successfully managed and maintained thousands of freshwater salmon projects. Now it’s embarking on a major saltwater program with Long Live the Kings to aid in the restoration of wild Coho, Steelhead, Chinook and the entire Salish Sea ecosystem.

If you would like to be a part of this initiative, please text “SALMON” to 45678, which will provide a $10 tax-receiptable donation to help bring these salmon home.

www.psf.ca
Thank you to our Donors!

More than 100 individuals, businesses and foundations have donated to the Pacific Salmon Foundation’s Salish Sea Marine Survival Project to date.

PARTNERS

The Pacific Salmon Foundation needs to keep raising $450,000 annually from donations in order to keep the Project going at full speed. Your donation will support research and restoration projects that help restore Coho and Chinook salmon in the Salish Sea. Contact Pacific Salmon Foundation staff to make a difference.

Become a Supporter...
Restore Coho and Chinook Salmon in the Salish Sea

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Progress on Meeting Project Objectives

Objective 1: Re-build production of wild Pacific salmon and Steelhead through a program that is ecosystem-based, considers hatchery effectiveness, and engages communities.

The Pacific Salmon Foundation and its 30 partners successfully completed the second year of intensive research. Activities within the Salish Sea Marine Survival Project include studies of hatchery effectiveness, support for estuary restoration of habitats through community groups, and extensive sampling of juvenile Chinook and Coho salmon. An important development in 2016 has been the initiation of an ecosystem-based mathematical model to represent our local marine ecosystems. Building models will be an essential step in testing our knowledge and integrating all elements of the Project in the Salish Sea. In 2017, the Foundation will begin community meetings to discuss outcomes to date and explore future community engagements.

Objective 2: Promote sustainable fisheries and increase their value to local B.C. communities.

Media coverage in 2016 of parts of the Project – particularly related to the Citizen Scientist Program and the Strategic Salmon Health Initiative – have already started to raise public awareness and appreciation of wild Pacific salmon in communities across B.C. Since inception, the Foundation has seen a growing roster of charitable fishing derbies raising funds in support of the Project. These derbies have provided opportunities to educate people at the local level about the importance of sustainable fisheries and how we can support them. More work will continue as new findings from the Project come to light. In 2018 we will begin synthesizing recommendations for rebuilding Pacific salmon and Steelhead, and associated fisheries, once all of the data has been analyzed.

Objective 3: Provide a foundation for long-term monitoring of the Salish Sea and salmon health.

The Strait of Georgia Data Centre, funded by Sitka Foundation in partnership with The University of British Columbia, was one of the first initiatives of the Project, providing a vital repository of knowledge to inform cohesive continued monitoring and restoration of the Strait. The Citizen Scientist Program has allowed us to collect an unprecedented amount of data at a fraction of the cost of traditional research vessels. The Program has also provided a framework for ongoing monitoring of the Strait’s ever-changing environmental conditions and its impacts on salmon, particularly through innovative applications of remote sensing [satellites] and collaborations with BC Ferries and others.
CEO Letter
By Dr. Brian Riddell

Our Busiest Year Yet
In 2016, the Pacific Salmon Foundation managed 40 projects conducted by more than 30 partners with a total expenditure of $3.2 million. Field studies will continue during 2017, while 2018 will be dedicated to assimilation of results, analysis and dissemination of key findings.

Heart and Skeletal Muscle Inflammation Found in One Fish Farm
2016 began with the announcement of a disease (Heart and Skeletal Muscle Inflammation) not previously identified in British Columbia. The discovery resulted from sampling on one (Atlantic salmon) aquaculture farm that was included in our Strategic Salmon Health Initiative (SSHI), which is being conducted with Science Branch, Department of Fisheries and Oceans (DFO) and supported by Genome BC and the Foundation.

The concern now shifts to whether there are risks of this disease being transmitted to wild Pacific salmon. To date, research conducted by fish health scientists in DFO Science Branch, indicates that the suspected infectious agent for HSMI can be transferred to Pacific salmon but they have not reported the development of HSMI in these studies.

Salmon Migration Tracked for the First Time through the Discovery Islands Region
While we know that millions of juvenile salmon migrate through the Strait of Georgia and Johnstone Strait, we don’t know their migration rates, or paths, or their natural survival through these regions.

How do we study this? ... by using acoustic tags that ‘ping’ as they pass strings of receivers on the sea floor. These tiny tags (less than half a gram in weight) transmit unique signals that identify individual fish, allowing researchers to determine migration rates, paths and survival rates.

In 2016, we observed that half of the tagged Fraser River Sockeye smolts which migrated through Discovery Channel showed very high survival. In contrast, the other half which used the narrow channels between the various islands had about one half the survival. Though fish using these narrow channels would have greater exposure to salmon farms, it would be very brief and transmission of pathogens could not account for the mortalities we measured with these acoustic tags. Any associated mortality associated with disease would occur weeks after exposure.

Image (Right): Kintama research is tracking salmon migration using acoustic receivers.
Continuing to be “Everywhere at Once” with our Citizen Scientists

Our ‘Citizen Science’ oceanographers have proved their value again. In 2016, we supported nine vessels sampling on 22 days resulting in 1,369 sampling events for oceanographic data ... and providing more than 8,000 samples for analysis.

This intensity of sampling is approximately three times the efforts undertaken by larger government ships; but more important is that our program allows sampling of the entire Strait of Georgia on a single day.

The data collected during 2015-16 has now been collated and will allow very detailed mapping of oceanographic patterns not previously possible. It probably sounds ‘geekie’, but this level of data is key for producing very fine-scale comparisons of time and space to understand the differences in salmon production that obviously occurs between years.

New Models to Understand the Past and Predict the Future

Finally, in 2016, we took a major step in the analyses of all the results being generated by the Project. To explain what occurred in the past or predict the future, we must integrate our understanding of the marine ecosystem into a mathematical framework (i.e. a model) and then test our understanding with the three years of detailed information collected. Not an easy task.

But UBC’s new Institute for the Oceans and Fisheries has stepped up to lead this task and will develop a team of local experts to participate. On the U.S. side of the Project, a similar process is underway and will develop a separate but parallel model.

This is a critical step, because independent models with common objectives are really the only means to test the accuracy or “reality” of a model that represents our understanding of nature. It’s an exciting process. If we don’t get good agreement immediately, we then find key sensitivities in the models and adjust as we learn.

Harbour Seals Eating Lots of Salmon?

The study of Harbour seal predation on juvenile salmon also continues to develop. Working with UBC’s Marine Mammal Unit since 2012, our first estimates of Harbour seal predation on juvenile Chinook and Coho in the Strait of Georgia were up to 40 per cent and 47 per cent respectively. But these estimates seemed very high to our Science Team so we initiated a new 2016 program to broaden diet studies throughout the Strait.

Now a recent report from Puget Sound states a very similar impact from seal predation. As these estimates were independently determined, they add strength to their validity. The American study also equated this mortality on juvenile salmon to the total weight of Chinook salmon consumed by the Southern Resident Orcas in one year. This is an increasingly complex web we are weaving!

Two More Years to Go

After eight years of designing the Project and working to fund its various initiatives, it is hard to believe that we only have two years remaining. With about 150 participants in Canada and the United States, and hundreds of individual initiatives, the Project has been a wonderful example of the power of collaboration and networking in science.
Strategic Salmon Health Initiative Identifies HSMI in Fish Farm Salmon

One of the Salish Sea Marine Survival Project’s major studies is the Strategic Salmon Health Initiative (SSHI), whose goal is to clarify the presence and/or absence of microbes in Pacific salmon. The study is a partnership between Genome BC, the Department of Fisheries and Oceans (led by Dr. Kristi Miller-Saunders), and the Pacific Salmon Foundation. Researchers are using the Fluidigm BioMark™ HD System, an innovative research platform that can assess up to four dozen salmon microbes at once, a scale never before achieved for any species.

SSHI had a significant breakthrough in 2016, as something was discovered in the tissues of some aquaculture salmon that were being sampled. It was an outbreak of Heart and Skeletal Muscle Inflammation (or HSMI) in Atlantic salmon from one farm. HSMI is a disease that affects fish (but with no risk to human health). Prior to this study, HSMI had not been diagnosed in B.C. but, to-date it has not been found in our wild Pacific salmon.

The lesions discovered in fish sampled by Dr. Miller-Saunders’ lab are the same as those previously identified by the same histopathologist in farm audit samples collected 2011-2013. It appears that this disease has been present in BC aquaculture facilities for a few years. SSHI will continue to work with its partners and the aquaculture industry to learn more about this disease and its potential impact on salmon in British Columbia.

The Role of Harbour Seals in the Decline of Salmon Populations

So how big a factor have Harbour seals played in the decline of salmon populations in the Salish Sea? Research by the Marine Mammal Research Unit at University of British Columbia (under Dr. Andrew Trites) in Cowichan Bay and the Big Qualicum River estuary has begun to shed some light on this question.

One interesting finding from data collected during 2015 was that the seals appeared to show different foraging strategies depending on where they were living and feeding. Alternative strategies included, estuary-focused seals, a “mixed” strategy, (seals that fed in both the estuary and further afield) and a “non-estuary” feeding strategy.
Finally, the types of salmon eaten vary depending on the season. Harbour seals primarily consume adult salmon of lesser conservation concern [such as Chum] in the fall. But the opposite was the case in spring, when seals preferred juvenile salmon of greater conservation concern such as Chinook and Coho. The data also suggests that Harbour seals prefer Chinook salmon over the much more abundant Chum salmon.

While more work needs to be done, the evidence is indicating that Harbour seal predation does contribute to the trends in salmon survival.

“Tags” Shed Light on Juvenile Salmon Survival

Salmon biologists believe that juvenile salmon die at a very high rate for the first few months at sea [something known as the ‘critical mortality period’]. But they haven’t been able to actually test that hypothesis – until now.

Passive Integrated Transponder technology – or PIT tags – are starting to change that. These super-small tags were inserted in small Chinook salmon (during their first summer at sea) during the past two years. These fish are beginning to return to the Cowichan River and are detected as they swim over a mat [actually a detection antennae array] installed across the lower Cowichan River.

In 2016 we used PIT tags to study in-river survival of wild and hatchery produced Chinook salmon. Unfortunately, the study revealed poor survival from the upper end of the river to a location 40 kilometers downstream at the antenna array. Paired releases of wild and hatchery fish from multiple locations along the river indicated a proportional reduction in survival with migration distance (the farther upstream fish were released the greater the mortality.)

The study also shed some light on what is actually happening to these fish. There is strong evidence that many of the fish are being eaten by various predators, as some tags were detected moving back upstream. Since salmon don’t typically do that when alive, it would seem that the tags are being detected inside the stomachs of predators. Raccoons, otters and mergansers were identified as the likely culprits, with some actually captured on film engaging in feeding behavior.

These results have reinforced the need to separate mortalities in-river versus mortalities in marine waters. Another complication. Surprisingly, there was very limited evidence of predation by trout.

Image (Above): The BC Conservation Society installed a Biomark array in the Cowichan River
## At a Glance: Projects for 2016

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<tr>
<th>Study Area and Partners</th>
<th>Description</th>
<th>What We Learned in 2016</th>
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<tr>
<td><strong>Physical and Chemical Oceanography</strong></td>
<td>Overall, it is apparent that there are extended periods of corrosive conditions during winter months. The severity has likely increased compared to pre-Industrial times. This may have impacts on overall coastal ocean productivity, with a potentially reduced ‘biological window’ during the spring/summer.</td>
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<td><strong>Citizen Science</strong></td>
<td>Volunteers use a “mosquito fleet” of their own fishing vessels to do oceanographic surveys in nine overlapping areas, making it possible to be “everywhere at once”.</td>
<td>Data gathered are being used to assess how the environmental conditions relate to prevalence of harmful algal blooms, types of phytoplankton and zooplankton, fish migrations, and fish mortality. Oceanographers at UBC are also using these data to address questions around water renewal, productivity changes and health of local inlets and harbours.</td>
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<td><strong>Zooplankton</strong></td>
<td>Zooplankton are small invertebrates that are the main consumers of phytoplankton and the main food source for larval and juvenile fish. These studies look at how zooplankton levels vary and how that impacts the growth and survival of juvenile salmon.</td>
<td>Statistically significant (although weak) relationships were found between marine survival of Strait of Georgia Coho populations and the abundance &amp; biomass of their preferred zooplankton prey.</td>
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| **Forage Fish** | The focus of these studies is on the small fishes that juvenile salmon feed on. Competitors and potential predators are also assessed with this technology. | Studies showed different distributions of the fish in the juvenile salmon food web:  
- Pacific hake in the central-north;  
- Walleye pollock in south-central;  
- Pacific herring more aggregated along the shore. |
<p>| <strong>Modelling</strong> | We will assess the numerous hypotheses for why juvenile Chinook, Coho and Steelhead have declined since the 1980s &amp; will develop a tool to bring ecosystem data into salmon return forecasting. | Several modelling efforts are being developed, including a Salish Sea ecosystem model at IOS, an overall synthesis model at UBC and a real-time, coupled bio-physical model of the Salish Sea at UBC. A trans-boundary ecosystem indicators project began in 2016. First steps have been focused on data collation and standardization. |</p>
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<td><strong>Juvenile Salmon</strong></td>
<td>These studies assess and identify the potential factors that impact the survival of juvenile salmon. Studies focus on their time in freshwater, and the early estuary/marine environment, and use a number of methodologies such as acoustic tags, PIT tags, and microtrolling.</td>
<td><strong>Cowichan</strong>&lt;br&gt;We confirmed low in-river survival of Cowichan hatchery Chinook, which may be due to raccoons, otters and mergansers. As well, we showed that survival increases when fry are released at locations downstream from the hatchery. Habitat variability may also be important for diet, growth and predator exposure. Finally, there were links between growth of Chinook and the amount of herring in their diet.</td>
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<td><strong>Partners</strong></td>
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<td>Key Mills Construction, Cowichan Tribes, J A Taylor &amp; Associates, BC Conservation Foundation, University of Victoria, DFO, Zotec Services, Raincoast</td>
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<td><strong>Fraser River</strong>&lt;br&gt;Chilko Chinook showed higher mortality in the clear headwater tributaries and higher survival in the more turbid (cloudy) lower Fraser. For Chilko Sockeye, 1 and 2 year old fish showed similar patterns, but the larger fish had slightly lower survival, which may be due to predation.</td>
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<td><strong>Study Area</strong></td>
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<td><strong>Nearshore Habitat</strong></td>
<td>These studies look at salmon habitat – specifically eelgrass beds and kelp forests, how they have changed over time, and the progress of the recent and continuing restoration efforts.</td>
<td><strong>Burrard Inlet</strong>&lt;br&gt;Burrard Inlet may be a mortality “hotspot” for migrating juvenile Seymour Steelhead smolts.</td>
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<td><strong>Research and Restoration</strong></td>
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<td>University of Victoria, Seachange, Simon Fraser University, Comox Valley Project Watershed Society, Nile Creek Enhancement Society</td>
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<td><strong>Discovery Islands and Johnstone Strait</strong>&lt;br&gt;The survival of Seymour Steelhead was dependent upon the migratory route. It was higher when they migrated north through Discovery Passage, and lower through Sutil Channel.</td>
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<td><strong>Study Area</strong></td>
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<td><strong>Predation</strong></td>
<td>Salmon have a number of predators and these studies are looking at what role predation – particularly from seals – plays on the survival of juvenile salmon.</td>
<td><strong>Harbour seals</strong>&lt;br&gt;Harbour seals appear to focus on juvenile Chinook and Coho, and even a low level of predation can be significant when the seal population is large. Our project provides evidence of a relationship between seal predation and the survival of Coho and Chinook salmon. Modeling studies have suggested that an average of 55 per cent of Coho smolts and 44 per cent of Chinook smolts were eaten by seals during their first year at sea each year between 1999 and 2007. However, low levels of predation by seals in the estuaries suggest that targeted seal removals would be unlikely to significantly improve salmon survival.</td>
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<td>University of British Columbia (UBC), DFO</td>
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<td><strong>Study Area</strong></td>
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<td><strong>Harmful Algae</strong></td>
<td>These studies examine potential harmful algae blooms and how they could impact juvenile salmon. What triggers harmful blooms is poorly known but they are increasingly observed in the Strait of Georgia.</td>
<td><strong>The spring phytoplankton bloom in 2016 started much later than the bloom the previous year. Its composition was also very different – a mix of species in 2016 compared to one dominant species in 2015. This may have implications for the food web, which translates into salmon productivity.</strong></td>
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<td>Microthalassia Consultants Inc. &amp; Pacific Salmon Foundation</td>
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<td><strong>Study</strong></td>
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<td><strong>Strategic Salmon Health Initiative</strong></td>
<td>This project is using genomic technology to study the microbes present in salmon in British Columbia that may be undermining the productivity of Pacific salmon.</td>
<td><strong>An outbreak of Heart and Skeletal Muscle Inflammation (or HSMI) was found in Atlantic salmon on one fish farm. HSMI is a disease that affects only fish. In places like Norway it can be a significant production challenge to an affected fish farm, where it can be associated with mortality. HSMI has not yet been diagnosed in wild Pacific salmon and has only been observed in farmed Atlantic salmon.</strong></td>
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*Image Credit (Above): Martin Fisch*