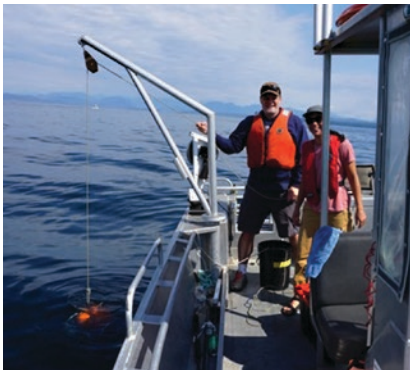
PACIFIC SALMON FOUNDATION



STRAIT OF GEORGIA HERRING:
RESTORING THE SALMON FOOD WEB

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Pacific herring are one of the most significant links in the Salish Sea food web. As the dominant forage fish in the Strait of Georgia, this relatively small unassuming fish performs the critical role of transferring energy from small plankton to larger predators — from Pacific salmon to whales, birds, and seals. For salmon, herring availability is intrinsic to their growth and survival throughout their seagoing lives. We as humans also depend on Pacific herring. BC has had a commercial herring fishery for over 100 years and herring has been a foundational food source for First Nations who relied on the abundant fish and prized roe since time immemorial.

With funding from BCSRIF, the PSF's Marine Science Program is working on addressing key questions and knowledge gaps with a new Salmon-Herring Interaction project. In this newsletter, we provide some background on the significance of Pacific herring to the Strait of Georgia food web and introduce the activities that make up the project.

Photo by Ryan Miller.
Cover photos by Eiko Jones (top), Planet Lab (left), Nicole Christiansen (centre) and Jess Qualley (right)

Milt from herring spawning can turn the water a spectacular colour.

Photo by Jess Qualley

HERRING BACKGROUNDER

Pacific herring are a coastal species with a range that includes the continental shelf, inlets, and estuaries from Baja California to the Bering Sea and over to Japan. They are considered a 'forage fish' meaning they feed low on the food chain (e.g. plankton) and then are prey for all sorts of predators including fish, seabirds, and marine mammals. This transfer of energy is of tremendous importance to coastal ecosystems and changes in herring abundance and distribution through time have broad implications.

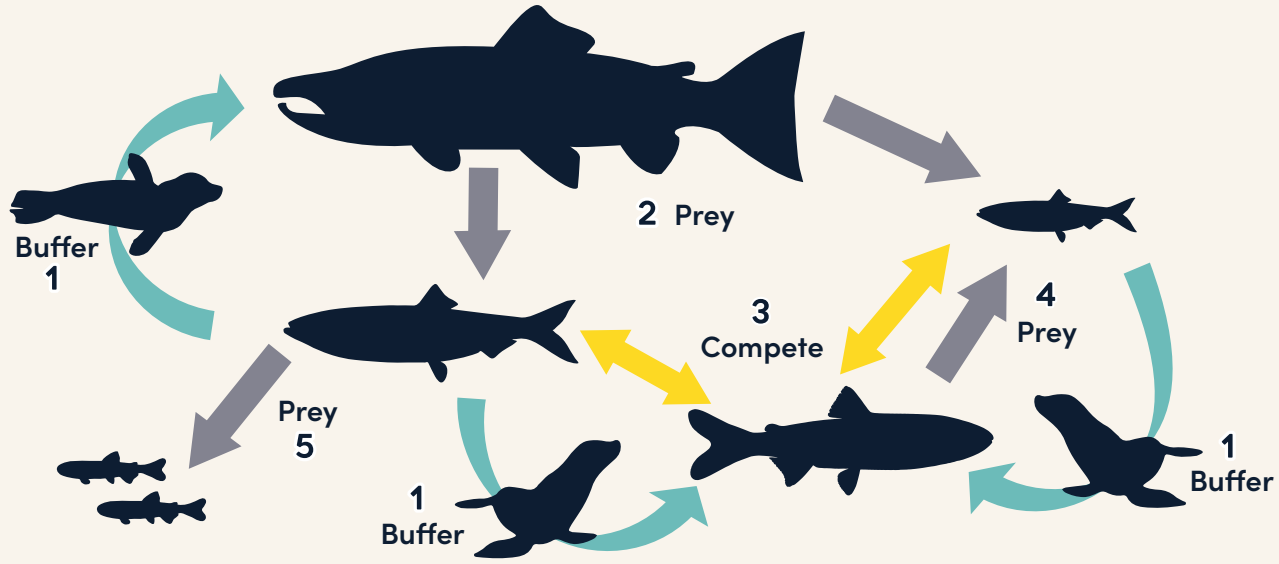
Herring spawning occurs in intertidal and subtidal habitats where females deposit small, sticky eggs on eelgrass, kelp, and other substrates then males release milt to fertilize them. This is one of the most dramatic shows on the coast, the water is coloured with beautiful turquoise plumes that can be seen from space. The annual spawning represents a massive pulse of food and energy to the marine food web. It attracts all kinds of life, including birds, seals, sea lions, and transient orcas. Interestingly, spawn timing is genetically controlled. In the Strait of Georgia, most spawn in March but some genetically distinct stocks in and around Puget Sound spawn anywhere between January to May. Most herring spawn for the first time at three years of age and, unlike salmon, they can spawn year after year with some living up to 10 years or more.

Depending on the water temperature, eggs will hatch after about two weeks. Initially, the tiny larvae are extremely vulnerable to environmental conditions and a lot of mortality occurs early on. Those that survive school in nearshore habitats such as kelp beds, seagrass meadows, and even under the docks at marinas. At this stage, they are really important food for salmon and other predators. Then at some point over the next two years, the cohort of herring will join the adult population. Although when and where they join adults is unknown, but we know that adult schools contain a mix of age classes.

For Strait of Georgia herring, adult herring generally migrate between summer feeding grounds off the West Coast of Vancouver Island on the continental shelf, and spring spawning grounds in inshore areas within the Strait of Georgia. Some adult herring stay in the Strait of Georgia through summer as 'resident herring', though this is not always the case. The historical record of resident herring is sparse. Resident herring were first documented in 1964 and were said to be abundant year-round in the Strait of Georgia until the 1990s, when the resident population seemed to disappear. In recent years, local anglers have reported large aggregations of herring in the Strait of Georgia in summer. Salmon diet data collected since 2017 through the PSF-funded Adult Salmon Diet Program at the Juanes Lab at UVic, indicates that adult herring make up the majority of Chinook and coho salmon diets in the Strait of Georgia in summer.

PACIFIC SALMON AND HERRING: A CRITICAL AND COMPLEX RELATIONSHIP

Throughout the herring and salmon life cycle the interactions between the two species shifts and changes, it is not simply that salmon eat herring.



1 ▸ **Herring buffer the impact of predation on salmon** – Herring and salmon are both important prey for seals and other marine predators. High abundance of herring can buffer the impact of predators on juvenile salmon and even adult salmon.

2 ▸ **Herring are important prey for adult Chinook and coho –** As the Adult Salmon Diet Study has shown, adult Strait of Georgia Chinook and coho salmon continue to rely on herring to form the majority of their diets.

3 ▸ **Juvenile salmon and juvenile herring are also competitors –** There are points when the juveniles of both species fill a similar ecological niche and compete for the same food and habitat resources.

4 ▸ **Juvenile Chinook and coho eat juvenile herring –** Studies from the Salish Sea Marine Survival Project showed that the consumption of juvenile herring supports accelerated growth of juvenile Chinook and coho, which is of vital importance given the link between early marine growth, marine survival, and population productivity.

5 ▸ **Herring may also consume juvenile salmon –** You don't commonly think of herring preying on salmon, but adult herring can prey vulnerable pink and chum fry that enter the marine environment shortly after hatching.

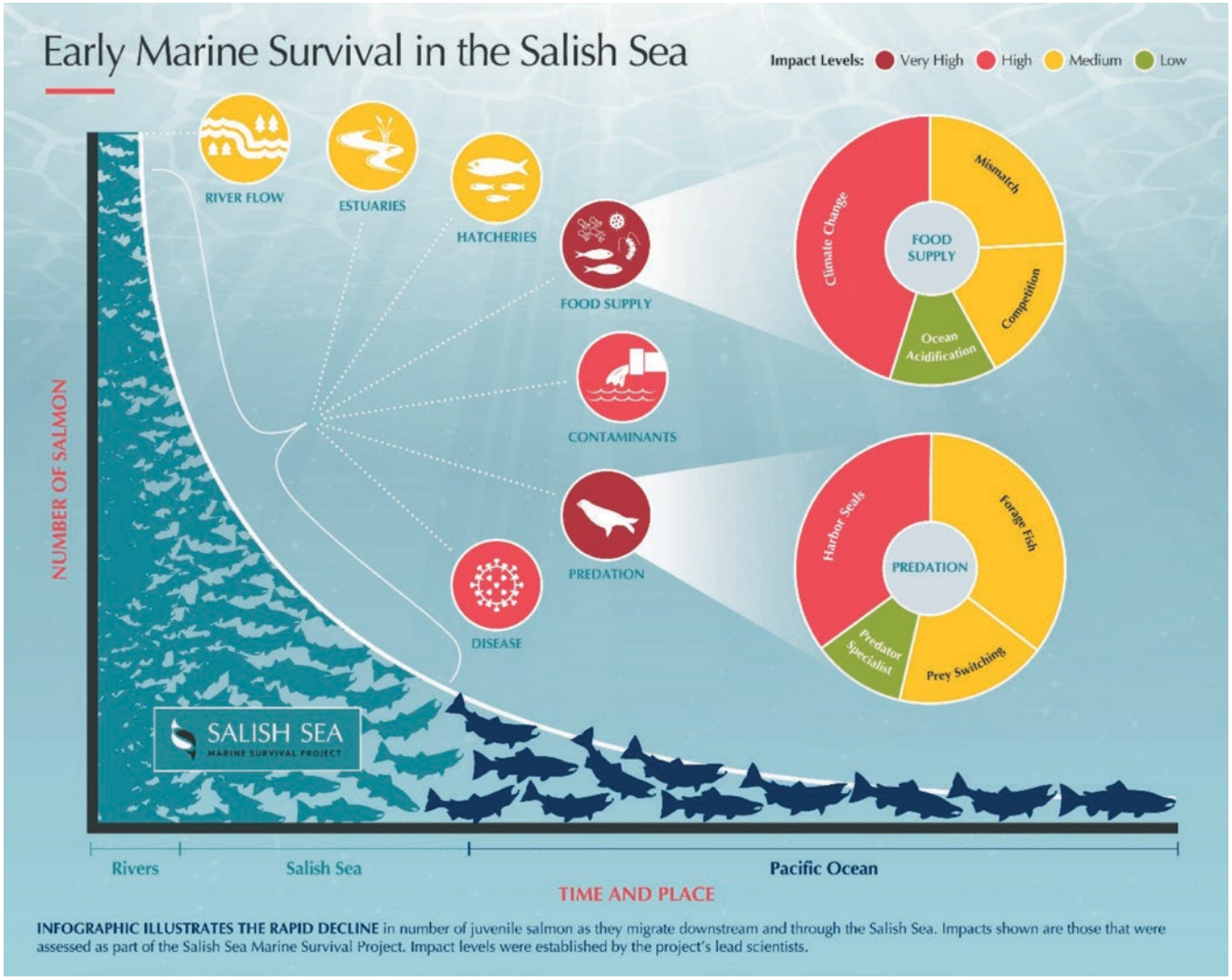
FROM FINDINGS TO WORKSHOP TO PROJECT

With the results of the Salish Sea Marine Survival Project pointing to 'Food Supply' and 'Predation' as the most impactful pressures on early marine survival of salmon (figure below), and herring being inherently linked to both, improving our understanding of Pacific herring in the Strait of Georgia was a clear next step.

In anticipation of upcoming funding opportunities, the PSF's Marine Science team with partners from UVic, UBC, and Cowichan Tribes convened a workshop in October of 2021 to bring together researchers, First Nations, and community groups to hear concerns and discuss herring research priorities. Among the topics brought up, the looming uncertainty due to climate change, shifts in spawning location and timing, and what this means for salmon and the food web were key themes. Additionally, many First Nations' representatives brought up a sense of loss for Coastal Nations, both for herring as a fading food resource and for the loss of the knowledge and traditions associated with it.

The findings of the workshop went on to form the basis of a successful BCSRIF proposal. We are now starting a new herring research program that will be funded through 2026. The overall project is focused on salmon-herring interactions and is built around four activities described below. All activities are being developed and implemented in cooperation with partnering Strait of Georgia First Nations with the concurrent aim of building capacity within those Nations.

Predator and prey shown together. Herring, such as this one which is nearly half the length of the salmon that consumed it, are a vital food source for Pacific salmon.



INFOGRAPHIC ILLUSTRATES THE RAPID DECLINE in number of juvenile salmon as they migrate downstream and through the Salish Sea. Impacts shown are those that were assessed as part of the Salish Sea Marine Survival Project. Impact levels were established by the project's lead scientists.

Photo by Jake Dingwall

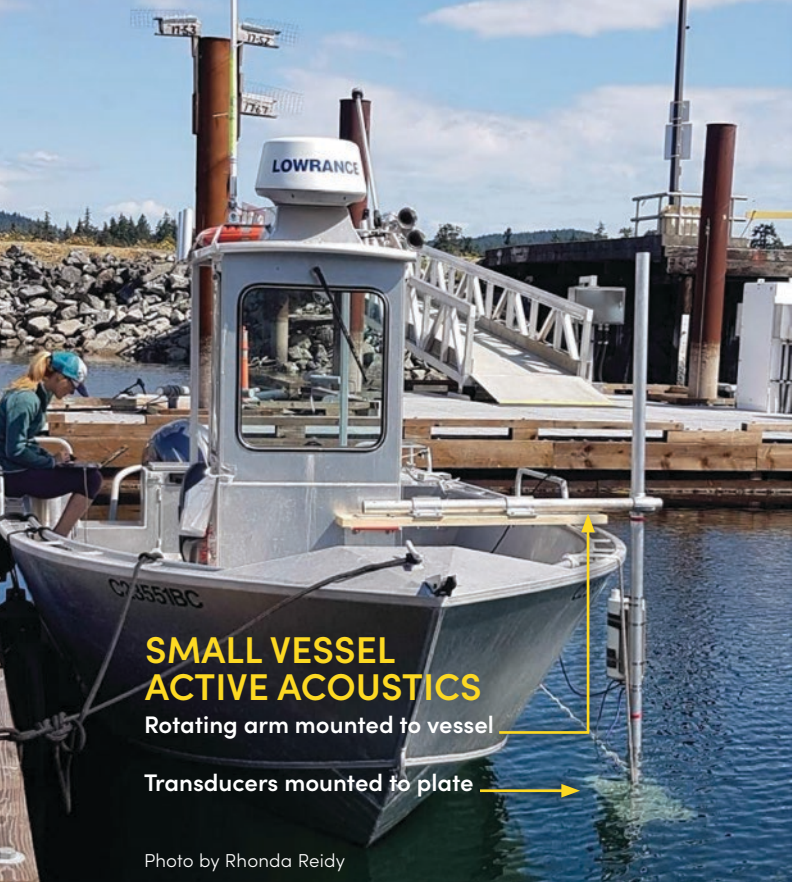
ACTIVITY 1 ▸ AVAILABILITY OF AGE-0 HERRING TO SALMON

Herring in their first year of life (age-0) are critically important prey for Chinook and coho salmon in their first year at sea. Comparing recent and historical salmon diet information suggests that age-0 herring may be less available to juvenile salmon than they were during periods of higher salmon survival and abundance (prior to the 1990s). This reduced availability could be a consequence of lower age-0 herring abundance, later appearance of age-0 herring in the spring, increased herring size relative to juvenile salmon (making them too large to eat), or some combination of these three factors operating at different regional scales in the Strait of Georgia.

The focus of the first activity will be on factors controlling the availability of age-0 herring to salmon. A key question will be to understand whether loss of spatial and temporal diversity in spawning is impacting the availability of juvenile herring to juvenile salmon.

Part of this activity will be a desktop exercise, revisiting historical data from DFO's herring spawn and juvenile herring surveys to determine whether the presence of local spawns may influence when, at what abundance, and at what size, juvenile herring become available to juvenile salmon.

This activity will also include a field sampling program in collaboration with Strait of Georgia First Nations to investigate the availability of juvenile herring to juvenile salmon in periods and regions not covered by existing sampling programs. This work will involve microtrolling, a flexible, low-cost method of systematically and non-lethally sampling juvenile salmon with hook and line as well as beach seining and hand-hauled purse seining to assess when, where and at what size herring first appear in their diets.



Stereo camera, built by Chris Rooper (DFO), that will capture images at depth to confirm fish presence, size, and species.

PSF's Jess Qualley jigging to gather herring otolith samples

ACTIVITY 2 ▸ UNDERSTANDING NON-MIGRATORY HERRING

At the end of the twentieth century, First Nations, community stewards, and fishers reported the disappearance of adult herring that were formerly abundant in the Strait of Georgia during the summer. Traditional ecological knowledge suggests that herring had previously been available to Coastal First Nations year-round. In the last 10 years, anecdotal accounts suggest at least a partial return of these fish, with large, primarily deep-water schools of adult 'resident/non-migratory' herring consistently observed through summer in the Northern Strait of Georgia.

The second activity aims to develop the ability to track changes in the abundance of resident/non-migratory herring in the Strait of Georgia, and in turn, understand factors that may be driving these changes and implications for salmon and the rest of the ecosystem.

The first part of this activity develops innovative means to survey herring abundance and biomass using scientific echosounders validated with drop cameras and jigging. The goal of the acoustic surveys will be to derive minimum biomass estimates for Strait of Georgia resident/non-migratory herring. The team will also build the capacity of partner nations to carry on the techniques and become actively engaged in marine fisheries research and assessment.

A second part of this activity builds on Project Manager, Jess Qualley's Masters work to distinguish migrants and residents in the Strait of Georgia population using otolith microchemistry (carbon and oxygen stable isotopes). Otoliths are small 'ear bones' that grow like rings in a tree throughout a fish's life. The rings record element signals from the surrounding environment which can be used to differentiate fish with different migration histories. Migratory herring that move between offshore regions off West Coast Vancouver Island and inshore areas of the Strait of Georgia have different otolith element composition than residents that spend most of their lives in the Strait of Georgia. An otolith tool to tell migrants and resident apart, can identify factors that may control the abundance of resident herring over time, such as growth rates at different stages. Another application is to use otolith micro-chemistry to assess the proportion of resident herring in fisheries catches to help fisheries managers protect resident herring that are key prey for salmon in the Strait of Georgia in summer.

UVic masters student Loïc Dallaire will investigate satellite imagery for evidence of herring spawning beyond the scope of DFO's overflight surveys.

UVic masters student Jake Dingwall will investigate habitat factors that may affect herring spawning.

ACTIVITY 3 ▸ HERRING SPAWN HABITAT ASSESSMENT

Spawn duration and distribution have decreased since the 1980s in the Strait of Georgia, with peak spawning now occurring around early March. Spatial spawn distribution has also shifted to be concentrated in the northwestern regions of the Strait of Georgia, whilst southern spawn sites have been abandoned for reasons unknown.

The third activity focuses on spawn habitat, to understand why spawn distribution has changed and what characterizes good or healthy spawning habitat. There are two projects within this activity and they are being carried out by two UVic Master's students.

From Maycira Costa's lab, Loïc Dallaire is using satellite imagery to detect spawning events that may be missed by the existing DFO overflight surveys. The techniques can be applied to a historical satellite imagery database dating back to the 1980s which may provide higher resolution of spatial declines in spawning or detect small and ephemeral spawns that have been overlooked. This will address the concerns of First Nations that existing programs built around documenting spawn in core fishing areas may miss spawns within their territories.

In Amanda Bates' lab, Jake Dingwall is investigating potential drivers of spawning habitat loss. Various anthropogenic and environmental factors will be compared at sites where spawns have disappeared or are intermittent to sites that continue to have persistent spawns to look at what makes healthy spawn habitat. By understanding this, we can better conserve those habitats, and potentially rehabilitate abandoned habitats that were once productive.

Satellite imagery of spawning herring around Hornby Island and near Courtenay and Comox.

ACTIVITY 4 ▸ TRADITIONAL ECOLOGICAL KNOWLEDGE

The herring research priorities workshop underscored the need to document the historical importance and abundance of herring from oral histories to put contemporary abundance into perspective to understand long-term changes.

The final activity will work with Strait of Georgia First Nations to host events and workshops within their communities to come together and share traditional ecological knowledge about how once abundant herring influenced the traditions, distribution, and settlement of First Nations surrounding the Strait of Georgia. Historically, abundant herring supported a healthy food web and provided marine resources to those communities. The goal of this activity is to celebrate herring and share those traditions during community events to produce educational, audiovisual products that can be distributed within and for the community. Building upon the materials that will be created, a second component is to bring together youth and elders to educate youth about the cultural importance of herring to First Nations culture.

The benefits of this final activity will be a shared understanding of the historical status and utilization of herring in the Strait of Georgia, to inform understanding of current science. The work will also provide tools for Strait of Georgia First Nations to communicate the cultural impacts of the loss of access to herring to fishery managers. Importantly the work will also engage and educate youth to develop the next generation of marine stewards.

School of herring

Juvenile Chinook salmon

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