First Edition

Citizen Scientist

SALISH SEA

Monitoring Guide

Compiled by

Clear Creek Task Force
Silverdale, Washington

Generous funding provided by

First Federal
COMMUNITY FOUNDATION
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WHAT'S INSIDE?

- SECTION 1: NATURAL HISTORY
- SECTION 2: HABITAT DEGRADATION
- SECTION 3: WATER QUALITY & HEALTHY HABITAT
- SECTION 4: HABITAT RESTORATION
- SECTION 5: PLANNING YOUR CITIZEN SCIENCE PROJECT

Introduction

This guidebook includes the sections about the natural history of the Salish Sea, changes caused by European settlement, as well as current water quality and habitat restoration work to improve the ecosystem, and activities for teachers and students, volunteer stewards and citizen scientists to support habitat restoration, through in-class and outdoor environmental education, field monitoring projects, and service learning activities.

This guidebook also includes tips to help citizen scientists learn how to determine the quality of the water in local salmon streams, including chemical, physical and biological measures. This curriculum was developed in partnership with school districts, colleges, universities, government agencies, and stewardship groups. The topics help train students and citizen scientists to achieve greater scientific literacy, appreciation and ownership of their natural environment.

Field trip discussions can focus on comparing and contrasting data from marine and fresh water monitoring sites, and comparing to applicable water quality standards. Through inquiry and discussion, everyone will learn what constitutes healthy salmon habitat, discuss human impact on the habitat and the important role they play in monitoring and restoring the habitat.

TABLE OF CONTENTS

- SECTION 1: NATURAL HISTORY
- SECTION 2: HABITAT DEGRADATION
- SECTION 3: WATER QUALITY & HEALTHY HABITAT
- SECTION 4: HABITAT RESTORATION
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ACKNOWLEDGEMENTS

- The **First Federal Community Foundation** for their generous grant to develop this guidebook for teachers, students, volunteer stewards, and citizen scientists.
- **Mary Earl**, Clear Creek Task Force, Silverdale, WA, for transforming the Clear Creek Trail into a living classroom, making volunteers feel welcome and important, grant writing, and forging strong community partnerships.
- **Chris Butler-Minor**, Community Engagement Specialist, National Marine Sanctuary Foundation, Port Angeles, WA, for designing and implementing a 5-year volunteer citizen science monitoring program at Clear Creek.
- Olympic College, Bremerton, WA: **Amy Lawrence** for grant writing, lesson planning, piloting field trips with students, coordinating student volunteers, and sharing OC's LabQuest2 and field data collection probes.
- SEA Discovery Center: **Denise Kilkenny-Tittle,** Associate Director of Education and Outreach for grant writing, curriculum development, donating materials, and volunteering for student field trips.
- Kitsap Public Health, Bremerton, WA: **Kristina Bonsell** for volunteering and comparing the YSI with Vernier's LabQuest 2 field data collection probes.
- **Josh Hopp**, sustainability leader and environmental chemist by trade, for quietly and competently volunteering as citizen scientist, field trip leader, teacher, lesson planner, and co-author of this first edition guidebook.
- Central Kitsap School District, Silverdale, WA: **Doug Dowell** for Vernier LabQuest2 training, and **Bridgette Burke** and **Chelsea Walsh** for piloting citizen science field trips at Clear Creek with students.
- Bremerton School District and Great Peninsula Conservancy, Bremerton, WA: **Dawn Parker-Hensley** and **Jennifer Hadegaard,** and **Claire Voris** for piloting citizen science field trips at Chico Creek with students.
- Kitsap County Public Works, Stormwater Division, Port Orchard, WA: **Pat Kirschbaum**, Education & Outreach Coordinator for volunteering as a stormwater expert, stream steward and naturalist for student field trips.
- The **Russell Family Foundation** for their generous grant for new monitoring equipment and to design, develop and pilot new citizen science curriculum for students.
- The **KETA Legacy Foundation** for their generous grant to expand access for Bremerton School District students to pilot citizen science field trips.

SECTION 1

NATURAL HISTORY

Fishing for salmon, Suquamish Tribe.

Introduction & Background of the Salish Sea

In 1988, recognizing the need for a geographic term to encompass the ecosystem that spans across the international border of the United States and Canada, marine biologist Bert Webber proposed the Salish Sea name.

The designation Salish Sea is a collective term that identifies the transborder commonality of water, air, wildlife, and history. The name recognizes people of the Coast Salish tribes and First Nations who were the sea's first stewards. These people have lived in what is present-day western Washington and southwestern British Columbia for more than 10,000 years.

The people of the Salish Sea had a culture heavily influenced by the sea, traveling extensively throughout the region to fish, collect shellfish, hunt, and gather plants. They revered salmon for their nutritional value and their importance to the habitat they lived in.

The people traveled extensively to fish, following the seasonal migration routes of different species. Their hand-hewn cedar canoes and hard baskets were watertight – ideal for fishing, carrying water, and cooking. They heated stones over fires and dropped them into water-filled baskets to heat soups made with smoked salmon and potato-like tubers of the Wapato, also known as the broadleaf arrowhead plant (*Sagittaria latifolia*).

The term "Coast Salish" refers to a language family, including two dozen distinct languages and many dialects, and is used to indicate the cultural group of indigenous peoples who speak or spoke these languages.

The connection between people, land and water is at the center of their cultural beliefs and practices. The earth is the ultimate source of nourishment and knowledge, providing food, shelter, clothing and medicine.

First Foods ceremonies celebrate their respect for the earth. These ceremonies honor traditional foods such as water, clams, duck, elk, salmon, sprouts and berries. At the end of the First Salmon ceremony, an important type of First Foods ceremony, the bones of the salmon are returned to the water. This shows the salmon was well–treated and it will be welcomed the following year.

Adapted from Salishan Languages Map in Barbara Brotherton (ed). *S'abadeb: The Gifts, Pacific Coast Salish Art and Artists*. Seattle: Seattle Art Museum and University of Washington Press: 2008: p.xix.

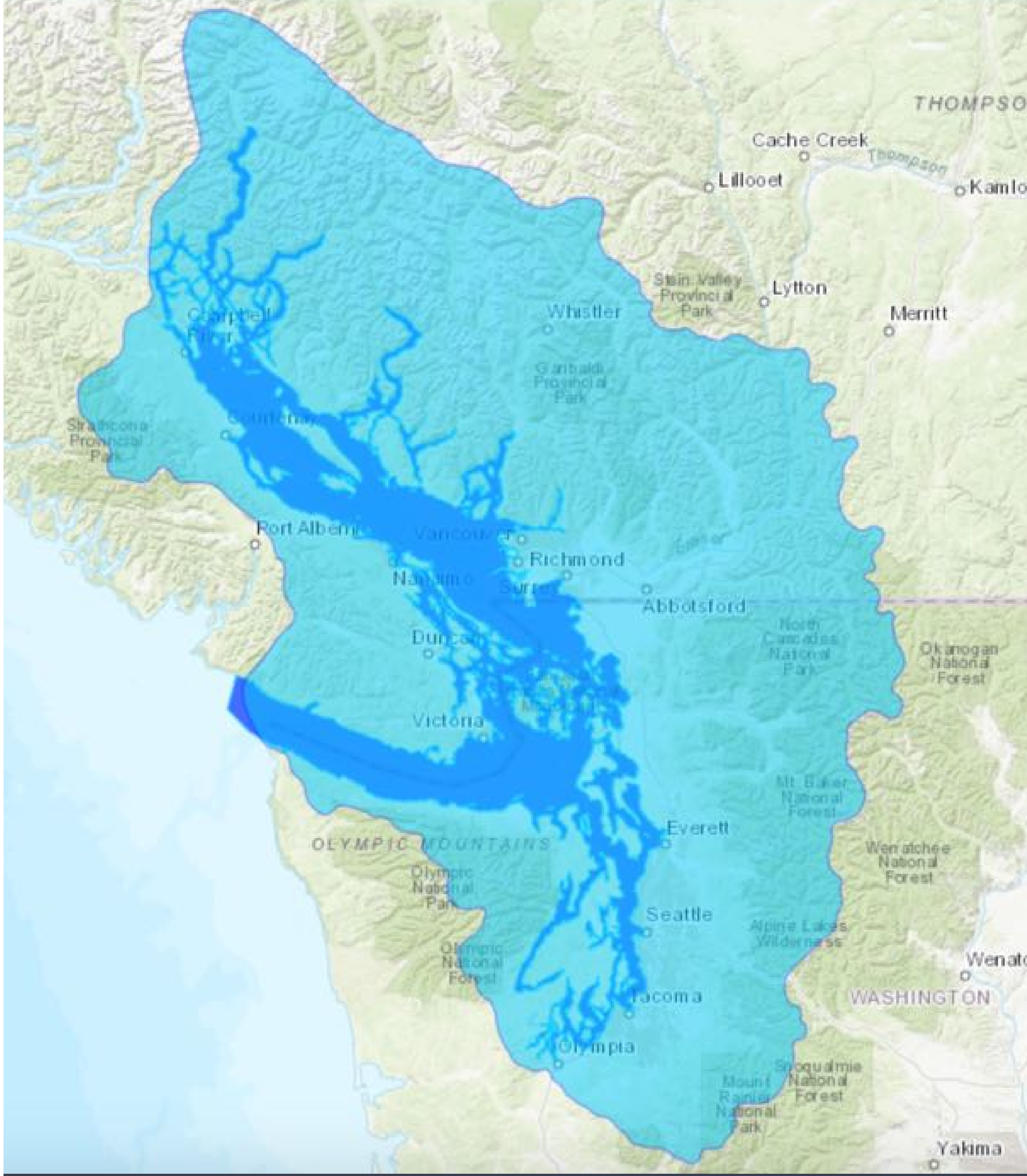
Geography of the Salish Sea

The Salish Sea is an area of biologically diverse marine waters and aquatic species. It spans from Olympia, Washington in the south to the Campbell River, British Columbia in the north, and west to Neah Bay and includes the large cities of Seattle and Vancouver.

The region includes portions of Vancouver Island and Lower Mainland British Columbia in Canada to parts of western Washington in the United States. The international sea includes the Strait of Georgia, Puget Sound and the Strait of Juan de Fuca. Bellingham and Western Washington University, the home of the Salish Sea Institute, are situated at the heart of the region.

The Salish Sea covers 16,925 km (6,533 mi) of sea surface and 7,470 km (4,639 mi) of shoreline, and a maximum depth of 650 m (2,132 ft). With about 419 islands that provide a total land area of 3,660 km (1,413 mi), and many lowland peninsulas, the Salish Sea is home to approximately 8 million people.

The region is also home to snow-capped volcanoes and mountain ranges, coniferous forests, fresh water watersheds, and marine water ecosystems. More than 70% of the total fresh water inflow for the Salish Sea comes from British Columbia's Fraser River watershed.



Salish Sea basin and water boundaries. The Salish Sea water boundary (dark blue) includes the Strait of Georgia, Desolation Sound, The Strait of Juan de Fuca, and Puget Sound. The larger watershed basin (light blue) is the area that drains into Salish Sea waters. Map: Environmental Response Management Application. Web application. Northwest. National Oceanic and Atmospheric Administration, 2014.

Species in the Salish Sea

Twice a day, the ebb and flood of tides has shaped the rhythm of life for plants and animals of the Salish Sea.

"The Salish Sea and surrounding lowlands provide habitat for thousands of species of plants and animals, but exactly how many species is yet to be determined.

"Scientists have identified 253 fish species observed in marine or brackish waters of the Salish Sea ecosystem. The marine macroinvertebrate fauna of this region is very poorly known; no list of species exists and the only published estimate—about 3000 species—is undoubtedly conservative." (Gaydos and Brown, 2009; Gaydos personal observation)

"In contrast, the birds and mammals that depend on the Salish Sea ecosystem are well known: 172 bird and 37 mammal species are highly dependent on Salish Sea intertidal and/or marine habitat as well as on marine derived food." (Gaydos and Pearson, 2011)

SeaDoc Society has a list of the biggest, best, and oldest species of the Salish Sea, which can be accessed using this link:
www.seadocsociety.org/salish-sea-biggest-oldest

From top left: Two bald eagles by Kirkpatrick Photography; J53 "Kiki" by Dave Ellifrit, Center for Whale Research; and a Chinook salmon spawning at Clear Creek by Pat Kirschbaum.

SECTION 2

HABITAT DEGRADATION

Circa 1900, 21-foot diameter old growth tree, courtesy ofKitsap Historical Society.

Settlement

The purpose of this section is to help readers understand changes to the Salish Sea ecosystem as a result of European settlement. In 1791 through 1795, Britain's Captain George Vancouver, with his ships "Discovery" and "Chatam", explored and charted the Salish Sea. The maps produced by this expedition opened the region to settlement, initiating events which led to vast changes in the region's natural environment.

Many settlers following the Oregon Trail wandered north to settle in the Salish Sea area. Because the dense old growth forests made overland travel difficult, many of the first Europeans arrived by boat and settled along the shores of the region. With its extensive shoreline and limited access by land, small private boats transported freight and passengers to other points around the Salish Sea. These early settlers began to clear the land for logging and agriculture.

Gold rushes – like the Fraser Gold Rush of 1858 and the Klondike Gold Rush of 1897-1898 – were important historical milestones that brought more European settlers to western British Columbia and Washington. Railroads were built to connect Vancouver, BC and Seattle, Washington to the rest of North America by land, while seaports were built in these cities to connect growing industries and traders with the rest of the world by water.

Coastal & Inland Impacts

Logging was the first major industry in the region. Immigrants from Scandinavia, England, Ireland, and other countries worked for the many lumber mills along the bays and estuaries of the Salish Sea.

In estuaries, log dumps were filled and the timber was easily floated to sawmills dotting the Salish Shores. The finished lumber was loaded onto ships and sold up and down the West Coast.

As the shorelines were cleared, logging operations progressed further into the interior. Homesteaders either clear-cut their land or sold logging rights to these timber companies. The deforested creek and river banks began to erode, producing silt that was detrimental to health of the water.

The loss of trees and plants exposed the rivers and creeks to unfiltered sunlight for the first time. Sunlight warmed the water, the temperature rose, and dissolved oxygen levels fell, unsettling the biological balance of invertebrates and salmonids.

The sun-exposed areas of coastal lands were then put to domestic use. Farming and livestock further altered the natural landscape.

A resident Great Blue Heron searches for fish near a former logging pond by Mary Earl.

Through a land berm, two 72-inch culverts constrain the tidal flow from stream to inlet and back again.

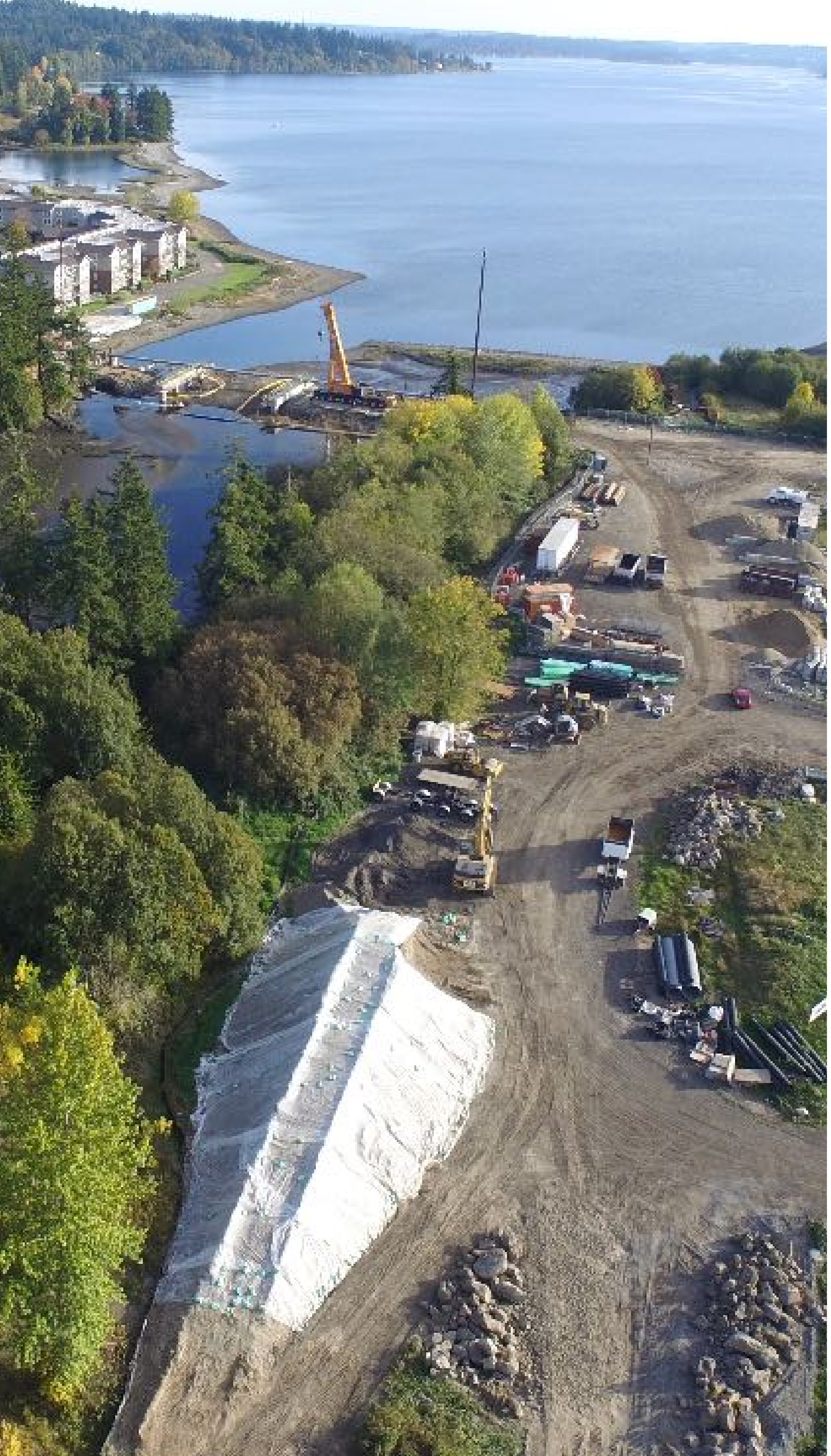
Changing the Natural Balance

Wave energy in the Salish Sea creates an ever changing ecosystem which balances temperature, transports sediment and organisms, and circulates nutrients and oxygen. Each day, high tides move seawater into the estuary where it meets fresh water and creates a brackish zone. Then low tides reverse these currents.

Because fresh water flowing into the estuary is less dense, it often floats on top of the heavier seawater. The amount of mixing depends on wind, tides, estuary shape, volume, and flow of water. These factors often change seasonally. For example, a heavy spring rain, unseasonably warm temperatures or a sustained shift in winds, can drastically affect the salinity, flow and temperature of the water in an estuary. (Sumich, 1996)

Daily tidal action is an integral part of the evolving Salish Sea ecosystem, which causes natural changes to much of the shoreline. When impervious structures are built — such as dams, dikes, bridges, bulk-heads, and culverts — a new problem develops. Nearshore construction changes the natural balance and shape of the beach, causing erosion and more coastal impacts.

For example, the Elwha River Dam, completed in 1914 to provide hydroelectric power to the region, greatly decreased the quality of habitat for spawning salmon. Docks and shoreline armoring further destroyed nearshore forage fish habitat and salmon migration routes. These barriers limit a salmon's access to food and upstream spawning and rearing habitats. For better and worse, with each generation of human settlement, the natural balance of the Salish Sea ecosystem has evolved with every incoming tide.



Aerial view of a construction site beside a fresh water stream and estuary.

Development & Infrastructure

The Salish Sea was perfect for naval installations and many facilities were built throughout the region during World War II. Military activity brought a flood of new residents and many remained after the war ended. Housing, roads, utilities and regulations were hastily expanded. Economic activity shifted away from farming to businesses that serve the larger population.

Many wetlands were drained or filled to accommodate buildings. More buildings and roads replaced forests and created more impervious surfaces. In a forest, rainfall waters the plants and trees, filters into the soil, and gets absorbed by roots. Rainfall also fills lakes, rivers and streams. But with fewer trees and plants, replaced by pavement and rooftops, the unfiltered rainfall runs across pavement and rooftops directly into water bodies. Unfiltered runoff increased, carrying sediment and other pollutants to the Salish Sea.

Streams and rivers were further constrained into irrigation ditches. Without the vegetation to absorb the rain, the runoff ran unfiltered into the wetlands, rivers and creeks, affecting the quality of the water. It also caused more frequent, intense, and prolonged high velocity flows. Excessive flows incised streams and rivers. And washed away gravel and woody debris essential for salmon spawning habitat.

Later, large portions of estuaries were filled in to accommodate automobile travel. Rivers and streams were further constrained by land berms and culverts or dams. Stormwater outfalls discharged heavy metals, petroleum products and road sediment into the once-pristine salmon habitat. More and more road construction contributed to increased runoff.

Urbanization & Climate Change

Today, over 8 million people live, work, and play in the Salish Sea watershed. However, because of the growing population, the area's rich natural resources have suffered, causing poor water quality and diminished vegetation. Now climate plays a greater role in interrupting the natural balance of the Salish Sea ecosystem. These interruptions have consequences.

Human activity has increased global greenhouse gas emissions, resulting in warmer temperatures for the region's climate. This means heavier winter rainstorms and less snowpack in the mountains. Lower summer stream flows cause water scarcity, drought and wildfires that negatively affect farmers, hydropower, drinking water, salmon, and recreation. Warmer ocean temperatures led to shifts in the marine ecosystem like sea-level rise, ocean acidification, challenges for salmon, and large harmful algal blooms.

Each year, salmon return to spawn and bring nutrients from the ocean into the reaches of their natal fresh water streams and rivers. These nutrients nourish stream bugs, riparian plants and wildlife when the salmon spawn and die. Urban population centers and rural groundwater wells are pumping groundwater from shallow aquifers at a greater rate than it is replenished by infiltrating rainwater, further causing decreased flow in salmon streams.

The Salish Sea ecosystem continues to experience habitat loss and detrimental impacts from human development and climate warming with significant loss of marine fish and wildlife populations. These changes can impact quality of life for humans, salmon and other aquatic life. From bears to orcas to trees, many species depend on salmon and the nutrients they provide in the Salish Sea watersheds.

The Seattle Times Search

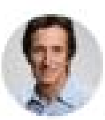
Federal officials see more wildfire smoke and other negative effects on the horizon for the Northwest as a result of climate change. The 2015 drought, with soaring temperatures and water problems, could be a vision of our future, according to a new report.

By Evan Bush
Seattle Times staff reporter

Climate change's effects – among them, increasing wildfires, disease outbreak and drought – are taking a toll on the Northwest, and what's to come will threaten and transform our way of life from the salmon streams to ski slopes, according to a new federal climate assessment released Friday.

The Seattle Times Search

Migrating salmon on the Columbia River face tough odds for survival as the lack of snowmelt water and searing summer heat have sent water temperatures soaring.



By Hal Bernton
Seattle Times staff reporter

HOME VALLEY, Skamania County — In a quiet, green pool off the Lower Columbia River, upstream from the Bonneville Dam, dozens of sickly sockeye salmon spend their final days.

They shouldn't be here. Instead, the fish should have forged deep into the drainages of North Central Washington, the Okanagan region of British Columbia or Redfish Lake in central Idaho.

But their journey has been short-circuited by a startling surge in water temperatures that has turned the Columbia into a kill zone where salmon immune systems are weakened and fish die of infections.

Duwe'iq Stormwater Treatment Wetland in Silverdale by Mary Earl.

Stormwater

Stormwater can overwhelm streams and rivers, causing more intense and prolonged high water and bank erosion, carrying excess sediment downstream. High velocity flows also carry away salmon eggs and alevin, and disturb spawning gravel and woody debris — essential salmon habitat features.

One acre area of impervious surface (such as roads and rooftops) produces 27,150 gallons of runoff for every one inch of rain. In Seattle, with about 37 inches of rain per year, that equals one million gallons of runoff, per acre, per year. In urban settings, stormwater rushes across impervious surfaces, transporting runoff in "fast lanes" during periods of heavy rain and snowmelt. These hard surfaces channel water into storm drains that go to the nearest collection point or body of water. This excess untreated water can overwhelm streams and rivers, causing them to overflow and possibly result in flooding.

Because urbanization has traded forest floors for paved parking lots, rainwater can no longer follow its natural pattern. Stormwater management has become a challenging and expensive issue for taxpayers. Techniques used by local governments include monitoring flow conditions in streams and rivers, controlling and treating stormwater with retention ponds, green roofs, rain gardens, soak away pits, bioswales, filter strips, and permeable pavement.

Retention ponds were once a standard; now, low impact and green stormwater systems are used. These systems mimic natural process, by slowing the release rate of stored water into the ground, using plants to filter and microbes to treat stormwater in ways that improve water quality, then infiltrate the treated water to recharge local groundwater aquifers.

Marine biologist Paul Dorn and citizen scientists with a coho salmon during a near short beach seine by Mary Earl.

Plight of the Pacific Salmon

Salmon are a key indicator of the health of the Salish Sea. Cutthroat, coho, sockeye, steelhead and some Chinook stay in fresh water up to a year and are more vulnerable to habitat degradation than chum, pink and some Chinook that migrate to salt water within weeks. Some species are listed as threatened under the Federal Endangered Species Act. And wild salmon have disappeared from many Salish Sea runs.

Salmon harvest management is extremely complicated, factoring in international agreements and allocations between user groups. A 1974 court case *U.S. v. Washington,* decided by U.S. District Court Judge George Boldt, re-affirmed the tribe's rights to harvest salmon and steelhead and established them as co-managers of Washington fisheries. The Washington Department of Fish and Wildlife (WDFW) has worked with tribal co-managers and NOAA Fisheries to develop an integrated harvest-management system that supports sustainable fisheries while protecting weak salmon populations. Salmon harvest management continues to evolve, with limits for sport, commercial, and tribal harvest rates so adequate numbers of wild and hatchery fish can return to rivers and hatcheries.

Hatchery salmon can carry and spread disease, and with habitat degradation, they compete with wild fish for habitat and food. Young hatchery salmon feed on pellets, are protected from predators until release, and have less genetic diversity, with spawning controlled by staff. With the decrease in biodiversity, habitat degradation and diminishing salmon runs, the food chain in the Salish Sea is declining for orcas, salmon and native plants.

NATIONAL GEOGRAPHIC

An orca known as J35 in the Pacific Northwest, carrying her dead calf. Experts say the killer whale was mourning the loss of her offspring.

PHOTOGRAPH COURTESY CENTER FOR WHALE RESEARCH (PERMIT #21238)

ANIMALS

Orca Mother Drops Calf, After Unprecedented 17 Days of Mourning

A Pacific Northwest orca likely bonded closely with her calf before it died, which could help explain her record-breaking emotional sojourn.

2 MINUTE READ

BY LORI CUTHBERT AND DOUGLAS MAIN

PUBLISHED AUGUST 13, 2018

AN ORCA NAMED J35 has finally dropped her dead calf, which she'd been pushing with her head for at least 17 days and 1,000 miles off the Pacific Northwest coast, in an unprecedented show of mourning that drew international attention.

The sad spectacle was a prime example, and confirmation, of the complex emotional lives of these sophisticated cetaceans, experts say.

Other orcas, and similar animals like dolphins, have been seen apparently mourning their dead, but this is by far the longest recorded example of such behavior.

Plight of the Southern Resident Orcas

The plight of Southern Resident orcas (*Orcinus orca*) in the Salish Sea has attracted global attention. These salmon eating orcas serve as another indicator of the health of our waters. They are starving due to low salmon populations. Southern Resident orcas and their prey are exposed to an ever-increasing mixture of pollutants in the Salish Sea. Many of the pollutants are poorly metabolized, persist in the environment and bioaccumulate and biomagnify in the food web. These toxins can reduce salmon survival, including Chinook salmon, the preferred food of these orcas.

In 2018, three Southern Resident orcas were tragically lost – Crewser (L92), three-year-old Scarlet (J50 to malnutrition) and the newborn calf of Tahlequah (J35). The most heart-wrenching was that of Tahlequah's calf. The world watched as she swam 1,000 miles with her dead calf, supported by her J-pod family, finally letting the body go after a 17-day vigil. In 2019, three more Southern Residents were presumed dead, according to the Center for Whale Research. But two more calves were born – bringing the number of Southern Residents to just 73.

Bigg's orcas – also know as "transients" – are the mammal-eating cousin to the Southern Residents. There are reportedly around 400 Bigg's orcas currently in the waters of the Salish Sea, according to the Georgia Strait Alliance. Bigg's orcas have been thriving in recent years, with more than 70 documented new births. Southern Residents are now spending more time on the western coast of Vancouver Island, where salmon are more abundant, while Bigg's orcas have been able to find plenty of food in the Salish Sea, especially pinnipeds like seals and sea lions.

SECTION 3

WATER QUALITY & HEALTHY HABITAT

Salish Sea Star by Mary Earl

Integrated Ecosystem

The Salish Sea is an integrated ecosystem of salt water and fresh water from the following sources:

- High peaks of dormant volcanoes and mountain ranges, home to glacial ice and snow.
- Upland coniferous forests where meltwater and rainwater meet the root systems of red cedar, Douglas fir, western hemlock, ferns, and salal, with various soil layers, and species of algae, fungi, nitrogen-fixing lichen and bacteria – a source of nutrients for downstream fresh water and marine water habitats.
- Fresh water streams, rivers, lakes, and wetlands with nutrient-rich organic materials, and subsurface groundwater aquifers are sources of cool, clean, calm water for salmon spawning. Watersheds, based on geography of their surrounding land areas, channel fresh water toward the inlets and bays of the Salish Sea. Water flows in and out of each watershed.
- Marine water from the Pacific Ocean, which enters inland Salish Sea areas like straits, canals, bays, inlets, and estuaries of the region, creates features like sand bars, mudflats, salt marshes, and habitats like eelgrass beds, undersea kelp forests, seafloor sediment, rocky reefs, and intertidal tide pools.

Mountains & Ridges

Tectonic forces and water in all its forms – mist, rain, snow, ice and glacial melt water – have sculpted the landscape of the Salish Sea. Upward tectonic forces have been working for millennia to create the Insular Mountains of Vancouver Island, and the Coast, Olympic, and Cascade Mountain Ranges that frame the perimeter peaks of the Salish Sea.

Peaks like Mt. Waddigton, Mt. Garibaldi, Mt. Meager, and Mt. Olympus, and active volcanoes like Glacier Peak, Mt. Rainier and Mt. Baker are some of the snowiest places on Earth. They are icons of the Salish Sea landscape. Glacial snowmelt and rain from these peaks drain to large rivers, which provides cool fresh water flow to their watersheds, where salmon congregate in their natal waters.

The shearing force of glaciers helped form the islands and fjords of the Salish Sea – including Vancouver Island, the Gulf Islands, the archipelago of the San Juan Islands, the Strait of Juan de Fuca, Puget Sound, and the Strait of Georgia. Where snow is rare in the lowlands, ridges covered with trees receive rain water, which runs down to nearby collection points like wetlands, creeks and beaver ponds.

Snow-covered peaks provide cool meltwater for the rivers in summertime by Josh Hopp.

Forests – Plants Play a Big Part

Important to the Salish Sea is maintaining the hydrological cycle. Plants are key to this cycle, influencing the amount of rain retained by the soil and what is returned to the atmosphere. Plants generate shade, which reduces topsoil evaporation, prevents erosion, and cools the water temperature. Decaying large woody debris provides shelter from predators. Beavers build dams, which provide cool ponds for juvenile salmon during hot weather.

Some important upland forests include:

- Pacific Rim National Preserve
- Garibaldi & Strathcona Provincial Parks
- Mt. Baker-Snoqualmie National Forest
- Okanogan-Wenatchee National Forest
- Olympic National Forest

The amount of vegetation in the watershed plays a big role in water quality. When vegetative cover is reduced to less than 65% of the total watershed area, water quality and stream flows are negatively affected. Recent studies have shown that water quality can be affected if as little as 7% of the total watershed area is covered by impervious surfaces (e.g. paved areas, roofs).

A stand of Douglas fir trees at the Mt. Baker-Snoqualmie National Forest in Washington by Josh Hopp.

Fresh Water

Fresh water resources are vital to the sustainability of wildlife biodiversity, food production, and healthy habitat. Rainfall and snowmelt are the primary sources of fresh water in the Salish Sea. Precipitation naturally soaks into the soil, and fills collection points like ponds, lakes, wetlands, riparian areas, creeks, streams, rivers, and lakes.

Fresh water flows down from mountains and forests via a network of streams and rivers, like the Fraser, Campbell, Skagit, and Duwamish, to the intertidal habitats like marshes, wetlands and bays. Some water infiltrates much deeper into underground reservoirs called aquifers. As the water seeps into the soil, contaminants are filtered before the water reaches the nearest collection point.

During the hot months, some streams receive cool water from melting higher elevation snow pack, which combines with groundwater to keep an adequate base flow. Low flow naturally occurs during summer months when there is less rain. This is especially important for the preservation of fresh water pools where some salmon (coho and cutthroat) spend the summer months.

The blueish green river carries meltwater and sediment from the mountains to the Salish Sea by Mary Earl.

Watersheds

The fresh water areas of the Salish Sea are divided into watersheds. Watersheds come in all shapes and sizes and cross provincial, state and international boundary lines. Watersheds are land areas that channel precipitation and snowmelt into wetlands, riparian areas, creeks, streams, rivers, and lakes, and eventually to outflow points such as the inlets and bays of the Salish Sea. The size of a watershed is based on the geography of the surrounding area.

Use your home, school, or business address to find and explore your local watershed using the following interactive watershed websites:

Canadian Geographic Watershed Map

www.canadiangeographic.com/watersheds/map/

Washington Water Resources Inventory Areas

ecology.wa.gov/Water-Shorelines/Water-supply/Water-availability/Watershed-look-up

Fresh water conservation measures can help to maintain drinking water levels and groundwater needed for stream flows and salmon survival.

Salish Sea basin, water and watershed boundaries. The pink lines are used to delineate provincial or state watersheds, the areas that drain to the Salish Sea.
Map: Environmental Response Management Application. National Oceanic and Atmospheric Administration, 2014.


Sunset over the Salish Sea by Josh Hopp.

Marine Water

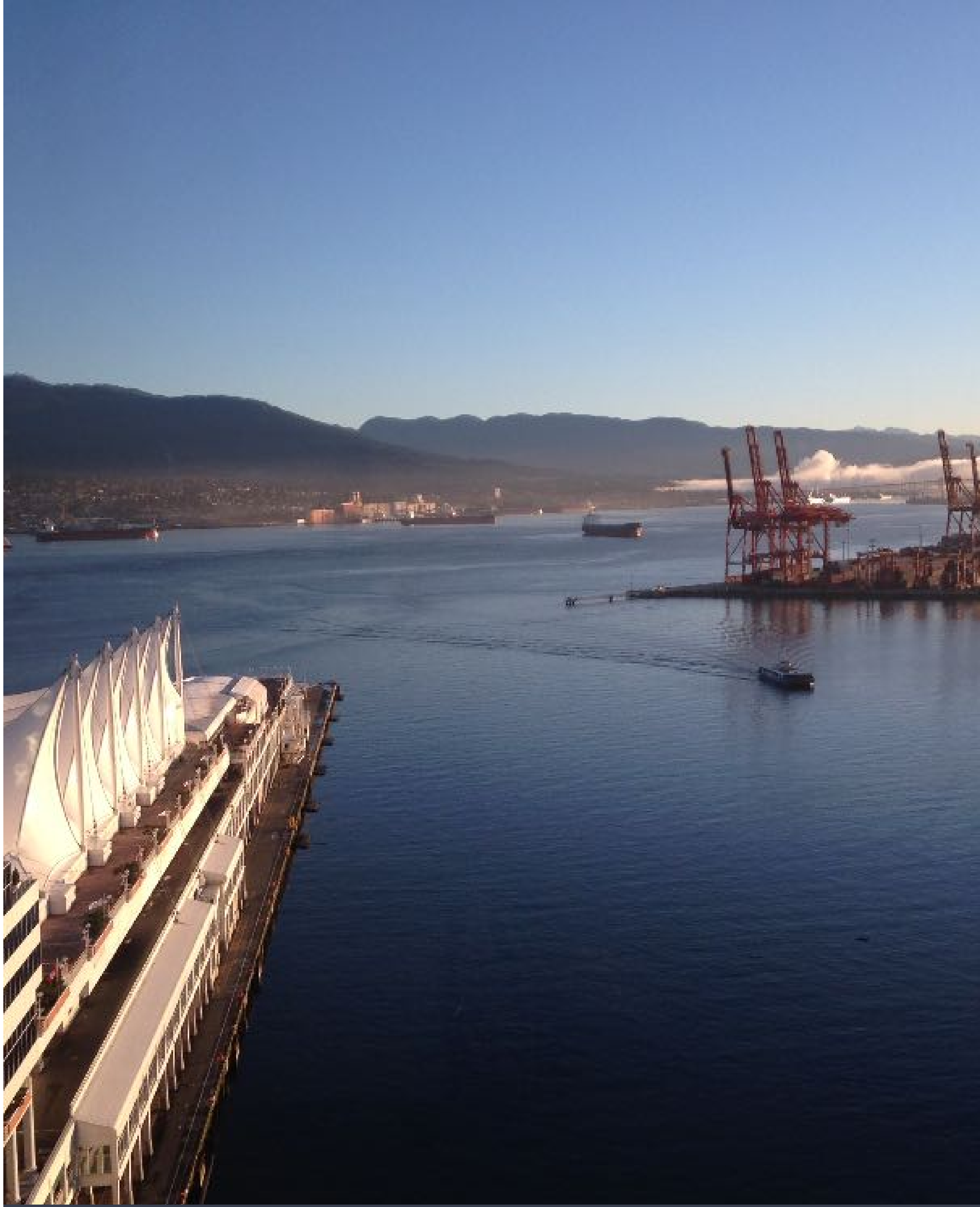
Each marine habitat is adapted to the ever-changing physical, chemical, and biological challenges of that environment including:

- Estuaries – among the most productive places for plant and animal communities to thrive, protected areas of brackish water where fresh water flowing from the land combines with seawater from the ocean.
- Bays and Mudflats – wind-sheltered areas formed at the mouth of a major river with soft sediment-rich habitat ideal for filter-feeding shellfish and other invertebrates, as well as foraging migratory birds.
- Intertidal Zone – the narrow band of shoreline between high and low tides.
- Tidepools – nearshore shallow pools that retain water, creating habitats for plants and animals that thrive for many hours at time in and out of water.
- Salt Marshes – formed at the mouth of river and stream deltas, where vegetation provides stability, a critical habitat for young salmon, as well as birds, fish, and mammals.
- Eelgrass beds – *Zostera marina L.* is a common plant in soft sediment, shallow waters along the Salish Sea shoreline, important for healthy ecological functions, and habitat for many species like herring, crab, shrimp, shellfish, waterfowl, and salmonids.
- Kelp – including bull kelp and northern giant kelp attach to rocks and float in the Salish Sea currents, providing food and shelter for invertebrates, fish, and marine mammals.

Clean Water Acts

The Federal Water Pollution Control Act of 1948 was the first major law in the United States to address water pollution. Growing public awareness and concern led to sweeping amendments and the Clean Water Act in 1972. Those amendments gave the U.S. Environmental Protection Agency authority to implement pollution control programs, set surface water quality standards for all contaminants, prohibited polluted discharges into navigable waters, and funded the construction of sewage treatment plants.

The Canada Water Act of 1970 provides the framework for cooperation with the provinces and territories in the conservation, development and use of Canada's water resources. It was incorporated into the Canadian Environmental Protection Act in 1988 and later into of the Canadian Environmental Protection Act, 1999. Environment and Climate Change Canada administers the International River Improvements Act, which provides for licensing of activities that may alter the flow of rivers flowing into the United States; International Boundary Waters Treaty Act 1985; Canadian Environmental Protection Act 1999; and the Department of the Environment Act.



Burrard Inlet between Vancouver, Canada's downtown peninsula and the Brockton Peninsula of Stanley Park.

SECTION 4

HABITAT RESTORATION

Citizen scientist collecting flow data by Mary Earl.

Restoration Efforts

Restoring healthy salmon habitat in the Salish Sea is the focus of many people and partnerships – governments, scientists, environmental organizations, stewardship groups, citizen scientists, and individuals. Each plays an important part in restoration efforts limited only by their abilities and financial resources.

Restoration efforts include the expensive and well-planned removal of man-made features that block or hinder the natural flow of water and salmon runs. Examples of these obstructions include shoreline armoring, dams, reservoirs, locks, culverts, land berms and dikes.

In 2012, removal of the Elwha and Glines Canyon Dams by the U.S. National Park Service took decades to plan and execute and cost $60 million. Threatened Chinook salmon, whose overall population has declined by 60 percent since 1984, have almost doubled in the Elwha River since the dam removal. A major bridge replacement project over Hood Canal's Duckabush River, which flows out of the Olympic Mountains, is estimated to cost roughly $90 million, to improve the migration and survival of salmon and trout.

On a smaller scale, stewardship groups spend their volunteer days removing ivy and yellow flag iris from riparian areas and replanting with native trees and shrubs. The cost? A hot lunch, salvaged trees and many "thank yous". The work to preserve and restore watersheds, remnant forests, riparian areas, and wetlands to fully functioning systems is the mission of many of these groups. They are improving water quality in rivers and creeks, recreating and enhancing healthy habitat for salmon and many other species of the Salish Sea ecosystem.


The Point No Point Lighthouse stands watchful over Admiralty Inlet by Josh Hopp.

Governments

The U.S. and Canadian federal governments share a unique responsibility to address the transboundary environmental challenges of our shared Salish Sea ecosystem. In 2000, the U.S. Environmental Protection Agency and Environment and Climate Change Canada signed a Joint Statement of Cooperation that commits to work collaboratively, and to develop and periodically update action plans to achieve common goals. The 2017–2020 Action Plan focuses on:

- Promoting information exchange and coordination, including the Health of the Salish Sea Ecosystem Report and the Salish Sea Ecosystem Conference.
- Supporting coordination and information sharing at the tribal/First Nation, state/provincial, and federal levels.
- Supporting information sharing activities relating to major federal initiatives and environmental assessments.

Both countries are long-range planning to ensure salmon survival. These plans improve fresh water flow, habitat and stormwater management. Public-private entities have formed partnerships to collect the latest research and make recommendations regarding infrastructure projects that remove salmon barriers – projects like culvert removals, stream restoration, and erosion control measures.

Puget Sound Partnership is Washington's state agency to protect and restore Puget Sound. Hundreds of agency partners align to ensure smart investments and support priorities like improving policymaking, streamlining regulatory systems, and accelerating ecosystem recovery. www.psp.wa.gov/

Environmental Organizations

Around the Salish Sea, there are many organizations focusing on professional research and environmental science, including:

Washington State and British Columbia sponsor a three-day **Salish Sea Ecosystem Conference**, the largest of its kind in the region, where scientists, tribal, First Nations and government agency representatives, community and business leaders, educators, and students present the latest research on the Salish Sea ecosystem. salishseaconference.org/

The **David Suzuki Foundation** uses evidence-based research, education and policy analysis to conserve and protect the natural environment, and support a sustainable Canada. davidsuzuki.org/projects/

The **Center for Whale Research** is dedicated to the study and conservation of the Southern Resident orca population in the Pacific Northwest. www.whaleresearch.com/

The **Salish Sea Marine Survival Project** uses resources from the U.S. and Canada to study the physical, chemical and biological factors impacting salmon survival in the Salish Sea. marinesurvivalproject.com/resources/

The **United States Geological Survey** provides science about the health of our ecosystems and environment; and the impacts of climate and land-use change. www.usgs.gov/states/washington

SeaDoc Society conducts and sponsors marine research to uncover the environmental factors threatening to unravel the web of life in the Salish Sea and surrounding watersheds. www.seadocsociety.org/

Environmental Organizations (continued)

Salish Sea Wiki is a collection of cross-linked web pages and documents and shared resources that helps people and organizations work together to rebuild ecosystems. salishsearestoration.org/wiki/

Beavers Northwest focuses on how beavers can be used as restoration tools to increase the health of local streams. Through their dam building activities, beavers create healthy habitats for mammals, fish, amphibians, and birds. Beaver ponds also slow down erosive flood waters, improve water quality, and recharge groundwater. www.beaversnw.org/home.html

Hood Canal Salmon Enhancement Group is one of 12 Regional Fisheries Enhancement in Washington, focusing on research and habitat restoration on the Hood Canal. Their Salmon Center has educational programs for students, teachers, and life-long learners. pnwsalmoncenter.org/

British Columbia Conservation Foundation fosters partnerships, works independently, and undertakes fish and wildlife habitat inventories, research, restoration, stewardship, and environmental education. bccf.com/

Encyclopedia of Puget Sound is an innovative website of collaborators and partners, used to gather rigorous environmental research, and disseminates science-based information to support habitat restoration and government policymaking. www.eopugetsound.org/

Puget Sound Institute brings together scientists, engineers and policymakers working on the restoration and protection of Puget Sound and provides expert advice based on the best-available science. www.pugetsoundinstitute.org/

Environmental Stewardship

Environmental stewardship is the responsible use and protection of the natural environment. This includes conservation, biodiversity and sustainable practices that protect air, water, and natural habitats for future generations to enjoy. Some organizations also use advocacy to raise awareness of stewardship opportunities for productive and sustained relationships between humans and their natural environment.

The **Salmon Recovery Conference** is an event focused on improving salmon recovery in Washington. The conference brings together people involved with salmon recovery for information sharing and networking about the 4 H's of salmon recovery: habitat, hydropower, hatcheries, and harvest. rco.wa.gov/salmon-recovery/salmon-recovery-conference/

West Sound Conservation Council is a coalition of conservation groups in Puget Sound dedicated to bringing the voice of environmental responsibility to the public debate. westsoundconservationcouncil.org/

Puget Sound Starts Here is an advocacy campaign that raises awareness of how our everyday actions impact waterways the Puget Sound region and what we can do to prevent pollution. Partners include federal, state and local governments, tribes, nonprofit organizations and businesses. www.pugetsoundstartshere.org

Salmon Safe is a certification program, leading the movement to improve farming and development practices to protect water quality, maintain watershed health and restore natural habitat. salmonsafe.org/about/

Environmental Stewardship (continued)

Mid Sound Fisheries Enhancement Group works to restore degraded salmon habitat with projects that ensure a future for wild salmon through community stewardship for streams and beaches. www.midsoundfisheries.org/

Adopt-A-Stream Foundation was created to identify and address degraded streams and wetland ecosystems. Their Northwest Stream Center, in Everett, Washington, is a place to teach, learn, and discover, for young and old, individuals, organizations, schools, and governments, working together to protect streams and wetlands. www.streamkeeper.org/

Audubon Society - Whidbey is a chapter of the National Audubon Society, dedicated to the protection of wildlife species and their habitats on Whidbey Island. They host environmental and wildlife education meetings and birding trips. whidbeyaudubon.org/

Nature Conservancy of Washington works to preserve the plants, animals and natural communities that represent the diversity of life by protecting the lands and waters they need to survive. www.nature.org/en-us/about-us/where-we-work/united-states/washington/

Orca Network is dedicated to raising awareness about the whales of the Salish Sea, and the importance of providing them healthy and safe habitats. Individuals can use their website to report or view whale sightings. www.orcanetwork.org/Main/

Environmental Stewardship (continued)

Fraser Basin Council is a non-profit organization that works to advance sustainability in the Fraser Basin and across British Columbia. Their focus is on healthy water and watersheds, action on climate change and air quality. www.fraserbasin.bc.ca/

Seattle Aquarium provides various citizen science and educational events for children and adults. www.seattleaquarium.org/

Port Townsend Marine Science Center is an educational and scientific organization promoting citizen science, coastal education and conservation. ptmsc.org/

Shared Strategy for Puget Sound is a collaborative initiative by Puget Sound communities to protect and restore salmon runs. www.sharedsalmonstrategy.org/index.htm

Skagit County Resource Conservation Directory is a guide to the many diverse organizations operating within Skagit County, Washington, dedicated to the conservation of the county's natural resources, including education resources, estuaries, farmlands, farmer's markets, forests, fresh water, mountains, open space, rivers, salt water, shorelines, tidelands, tribal governments, and wetlands. www.skagitlandtrust.org/

The Whale Museum is located in Friday Harbor, Washington, and focuses on promoting stewardship of whales and the Salish Sea ecosystem through education and research. whalemuseum.org/

Environmental Networks in Canada

The following is a directory of environmental groups, organizations, networks and associations in Canada.

- Canadian Environmental Network (RCEN) – www.rcen.ca
- Canadian Network for Environmental Education and Communication (EECOM) – www.eecom.org
- Stewardship Canada – www.stewardshipcanada.ca

In addition to the networks and associations listed above, here are more influential environmental organizations in Canada:

- Environmental Defence Canada – environmentaldefence.ca/
- Evergreen Foundation – www.evergreen.ca/
- Greenpeace Canada – www.greenpeace.org/canada/en/
- Nature Conservancy Canada – www.natureconservancy.ca/en/
- Sierra Club of BC – sierraclub.bc.ca/
- World Wildlife Fund Canada – www.wwf.ca/

Canadian geese migrate across North America by Mary Earl.

Citizen Science

Citizen science is research conducted, in whole or in part, by amateur or nonprofessional scientists. They can accelerate scientific research, perform hands-on learning, and share and contribute to data monitoring and collection programs. In the field, students to retirees learn about environmental science and collect data by following practical scientific protocols.

This environmental data collection could include water chemistry testing, benthic invertebrates and native plant diversity inventory, bird counts, and other conservation and restoration projects. Citizen science projects engage the community directly with learning about science and nature, forging connections to their ecosystems and watersheds.

Programs like Salmon in the Schools (King County, Washington) and Salmon in the Classroom (Kitsap County, Washington) bring teachers and students from classrooms to local streams, increasing awareness about healthy salmon habitat and boosting salmonid populations in streams.

Other citizen science programs focus on stream health, wildlife diversity, or water quality.

Olympic College students conducting water quality monitoring at Clear Creek estuary in Silverdale, Washington.


Citizen scientist collects elevation data for an estuary monitoring project by Josh Hopp

Citizen Science (continued)

You can volunteer for citizen science projects hosted by environmental groups, government agency programs, academic researchers at universities and colleges, or crowdsourcing sites. Depending on your interest and availability, there are opportunities at all levels including local, county, regional, state, provincial, national, and international projects. You are bound to find one that suits your interest! The following community based programs have opportunities for would-be citizen scientists of the Salish Sea:

Citizen Science Journal: Theory and Practice is an open-access, peer-reviewed journal published by Ubiquity Press on behalf of the Citizen Science Association. The journal focuses on advancing the global field of citizen science by providing a venue for citizen science researchers and practitioners to share best practices that facilitate public participation in scientific endeavors. theoryandpractice.citizenscienceassociation.org/about/

Friday Harbor Laboratory, part of the University of Washington, has a list of opportunities in the San Juan Islands, Salish Sea and the surrounding area. fhl.uw.edu/community/citizen-science/

Friends of Skagit Beaches, Washington hosts lectures and supports beach education, restoration, research and stewardship. www.skagitbeaches.org

The **Green Seattle Partnership** is a collaborative effort between the City of Seattle, Forterra, and an amazing community of partners working together to create a sustainable network of healthy forested parkland. Parks give so much, but they need our help too. www.greenseattle.org/about-us/

Volunteers collect and record stream flow data by Mary Earl.

Citizen Science (continued)

NatureWatch monitoring programs are suitable for all levels and interests, designed for you to learn about your environment and develop your scientific observation and data collection skills, so you can actively contribute to scientific understanding of Canada's environment. www.naturewatch.ca/

Strait of Georgia Citizen Science Data Centre is a collaborative program between the Pacific Salmon Foundation and the Institute for the Oceans and Fisheries, University of British Columbia, to build a secure data archive for marine ecosystem information on the Strait of Georgia. sogdatacentre.ca/people/citizen-science/

Washington State University (WSU) Extension programs help community members receive at least 80 hours of university-caliber training and then select from a wide diversity of volunteer opportunities to deepen their learning while conserving local natural resources. pubs.cahnrs.wsu.edu/programs/

- Beach Watchers are volunteers trained to research, educate and steward the nearshore Salish Sea ecosystem.
- Sustainable Community Stewards are trained to share research-based environmental sustainability information with others to encourage practices that protect the environment and conserve natural resources.
- Stream Stewards engage people of all ages and backgrounds in watershed stewardship, by learning about stream ecology, salmon, forests, water quality, and habitat restoration in the classroom and in the field.


A volunteer citizen scientist uses stadia rods to collect elevation data by Josh Hopp

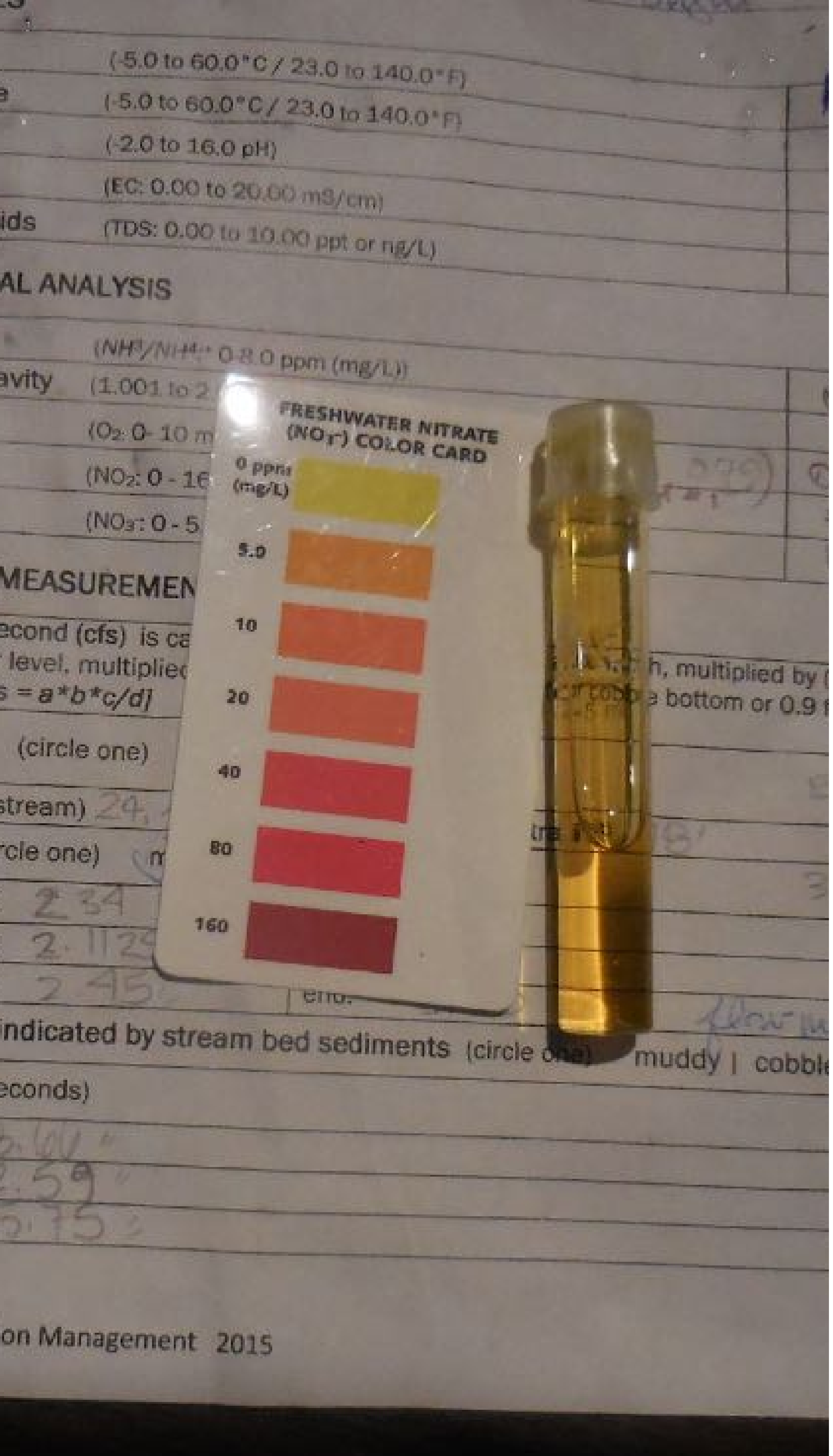
What Can You Do?

There is no “Planet B”. The United Nations suggests that climate change is not just the defining issue of our time, but we are also at a defining moment in history. Weather patterns are changing and threatening food production, and sea levels are rising and could cause catastrophic flooding across the globe. Countries must make immediate actions to avoid a future with irreversible damage to major ecosystems and planetary climate.

What can we do to pitch in and help save our Salish Sea ecosystem? There are plenty of things you can do every day to help reduce greenhouse gases and your carbon footprint to make a less harmful impact on the environment. These actions are adapted from the U.S. Environmental Protection Agency, HowStuffWorks.com and the *Salmon Field Guide, Kitsap* Edition.

Conserve Water

Conserving water is important in terms of sustaining healthy water quality, improving infiltration and providing the best salmon habitat. An average home devotes 30% of its daily water consumption to outdoor uses. Instead install rain gardens, green roofs, and permeable paving to conserve water and to allow rain to soak into the ground and be naturally filtered. Use rain barrels and cisterns to water gardens. Don’t let the water run while brushing teeth, washing your car or doing dishes. Collect the water and water your landscape instead. Leaky faucets could drip as much as 90 gallons (340 liters) of water down the drain every day. Consider water efficiency next time you buy a washing machine, dishwasher, refrigerator, tap or shower head, or toilet.



The colorimetric water quality monitoring test for nitrates in fresh water.

What Can You Do? (continued)

Be Car-conscious

Stay off the road two days a week or more. You'll reduce greenhouse gas emissions by an average of 1,590 pounds (721 kilograms) per year. Maintain your car on a regular basis, including fixing leaks. You can improve your gas mileage by 0.6 percent to 3 percent by keeping your tires inflated to the proper pressure. Wash your car at a car wash where the water is filtered or on the grass, never on pavement where the gray water could infiltrate a water body.

Walk, Bike, Take Public Transit or Car Pool

Walking and biking are obvious ways to reduce greenhouse gases. So are carpooling, taking a bus, ferry or train. One car off the road makes a difference.

Reduce, Reuse, Recycle, Repurpose

In 2015, Americans generated 262.4 million tons (238 metric tons) of trash. Only 23.4 million tons (21.2 metric tons) of that was composted. Some was recycled and some was combusted for energy, but almost half of it — 137.7 million tons (124.9 metric tons) — ended up in the landfill.

You can help reduce pollution by putting cans, plastic bottles, paper and cardboard in recycling. Case in point: If an office building of 7,000 workers recycled all of its office paper waste for a year, it would be the equivalent of taking almost 400 cars off the road.

Buy secondhand equipment and clothes from the secondhand store, garage sales, swap meets, Craigslist and OfferUp.

As seen on this timeline, plastic water bottles may never decompose by Mary Earl.

What Can You Do? (continued)

Give Up Plastic

The statistics are shocking: People around the world buy 1 million plastic drinking bottles every minute, and use up to 5 trillion single-use plastic bags every year. Hardly any of it – about 9 percent – gets recycled. A staggering 8 million tons (7.25 metric tons) ends up in the ocean every year.

Break the cycle. Stop buying bottled water. Switch to filtered tap water. You'll save a ton of cash and help reduce a ton of plastic waste in the process. A single plastic bag can take 1,000 years to break down in the environment. Say no to plastic shopping bags and use cloth bags instead. Take single use bags to the grocery to recycle.

Don't use plastic straws. Drink from a reusable cup instead of a plastic one. Don't buy and avoid using plastic "disposable" plates, spoons, forks, knives, or cups. Or wash and reuse again and again. Disposable just means landfill or worse - Salish Sea. Buy products that are made of recycled materials. Every little bit helps.

Switch to LED

Compact fluorescent light bulbs (CFLs) are great, but they're hard to dispose of because they contain mercury.

Light-emitting diode, or LED bulbs emit light in a very narrow band wavelength so they're energy-efficient. They cost more than CFLs, but equivalent LED bulbs can last around 25,000 hours.

What Can You Do? (continued)

Live Energy Efficient

Make your home more energy efficient and save money. Your home's windows are responsible for 25 to 30 percent of residential heat gain and heat loss. If they're old and inefficient, consider replacing them.

The amount of insulation your home needs depends on the climate, type of HVAC system, and where you're adding the insulation. Insulation is measured in terms of its thermal resistance or R-value – consider replacing with a higher R-value, for more effective insulation.

Little things you can do right away include replacing your air filter regularly so your HVAC system doesn't have to work overtime. Keep your window shades and drapes closed when it's extremely hot and cold outside. Install a programmable thermostat so your system isn't running and wasting energy when you're not home.

Compost

Composting helps reduce the amount of waste you produce and what eventually winds up in your local landfill. Plus, compost recycles yard waste and makes a great natural fertilizer.

Kick nets and sieves are often used to conduct benthic invertebrate sampling to monitor watershed health.

What Can You Do? (continued)

Eat Sustainable Foods

Today, large-scale food production accounts for as much as 25 percent of the greenhouse emissions. Highly processed foods usually contain some form of sugar, plenty of salt and other chemicals to keep the foods free flowing or “fresh.” These highly processed foods usually come in ready-to-eat non-recyclable plastic containers or wrap. Grow your own fruits and vegetables. Plant a vegetable garden.

Plant Trees for the Environment

In 2018, the United Nations' Intergovernmental Panel on Climate Change Report suggests an additional 2.5 billion acres (1 billion hectares) of forest in the world could limit global warming to 2.7 degrees Fahrenheit (1.5 degrees Celsius) by 2050.

Planting a young tree can absorb CO_2 at a rate of 13 pounds (5 kilograms) per tree. Every year. And that's just a baby tree. Once that tree reaches about 10-years old, it's at its most productive stage of carbon storage. Then it can absorb 48 pounds (21 kilograms) of CO_2 per year. Trees also remove all other kinds of junk from the air, including sulfur dioxide, nitrogen oxides and small particles. So go ahead, plant trees.

Volunteers from local scout troops planting native trees at their neighborhood stream.

SECTION 5

PLANNING YOUR CITIZEN SCIENCE PROJECT

Caddis fly larvae by Mary Earl.

Where to Begin

With decades of urban development, dwindling natural habitat and climate change, every citizen science project that preserves, improves and protects natural habitat, or monitors the diverse populations of birds, bugs, vegetation and threatened salmon and orcas benefits the restoration of the Salish Sea.

The rise of citizen scientists, conservation and stewardship groups gave rise to environmental education programs offered by those groups, state, local, and tribal governmental agencies, and local colleges and universities. Citizen science projects engage volunteers of all ages and skill levels and encourage the next generation of environmental stewards. When people learn about their environment through citizen science projects, they develop attitudes and beliefs that improve their relationship with nature.

As with any project, big or small, planning is essential. Identify who will fund, administer and perform the project. Clarify the objectives, duration and expected results. Then recruit project partners with equipment and materials. Fortunately, you have learned that governments, environmental organizations and stewardship groups have aligned to focus on restoring natural habitats around the Salish Sea ecosystem.

With the help and guidance from the following resources, may you find your way to restore a part of your community and watershed.

Volunteer citizen scientists measuring, collecting and recording estuary water quality data and habitat observations.

Citizen Science Toolkits

Many agencies have created scientific protocols for diverse fields of environmental monitoring with step-by-step instructions to implement citizen science data collection, conservation, and restoration projects.

Monitoring protocols and guidelines can be hard to find and understand for volunteers. The guidelines set forth in the U.S. Environmental Protection Agency's (EPA) *Volunteer Estuary Monitoring: A Methods Manual, Second Edition* and the *Puget Sound Ecosystem Monitoring Program Nearshore Protocols* are two resources to help you begin scoping and executing your citizen science project.

EPA's manual covers general project planning, training volunteers, quality assurance project planning, sampling considerations, data management, aquatic vegetation, and more.

www.epa.gov/nep/volunteer-estuary-monitoring-methods-manual

The *Puget Sound Ecosystem Monitoring Program Nearshore Protocols* was compiled as a standardized approach for volunteer citizen science groups. The Shoreline Monitoring Toolbox uses methods that are simple and affordable for monitoring restoration sites. The toolbox is coordinated with the Puget Sound Ecosystem Monitoring Program's Nearshore Work Group and provides resources for technical expertise as well. You'll find helpful 1—page protocols to follow, plus printable log sheets for riparian vegetation, birds, beach profiling, benthic invertebrates and more.

www.eopugetsound.org/articles/puget-sound-shoreline-monitoring-toolbox

More Toolkits

After passing the **American Innovation and Competitiveness Act** in 2017, the U.S. government has made efforts to institutionalize citizen science including the **Federal Crowdsourcing and Citizen Science Toolkit** meant to provide resources and step-by-step guidance applicable to all agencies. www.citizenscience.gov/toolkit/#

The U.S. Forest Service's **Citizen Science Toolkit** was developed for training Forest Service employees but is shared with the public because its content is useful to a broader audience. You'll find a helpful planning guide, webinars and resources for your project. www.fs.fed.us/working-with-us/citizen-science/citizen-science-toolkit

Cornell Lab of Ornithology Citizen Science Toolkit was developed to help scientists and volunteers design a project, refine protocols, analyze data, measure effects, and disseminate results. www.birds.cornell.edu/citscitoolkit/toolkit

Green Seattle Partnership has online resources for volunteer forest stewards contributing to restoration work in parks across the city. www.greenseattle.org/information-for/forest-steward-resources/

Students discuss monitoring results and what constitutes a healthy salmon stream by Mary Earl.

Volunteers at low tide use sieves to measure and record the sediment composition and macroinvertebrate abundance by Josh Hopp.

Citizen Science Toolkits

David Suzuki Foundation joined the U.S.-based SciStarter program, which connects scientists and community leaders to more than 1,100 citizen science projects and to anyone wishing to contribute to scientific research. davidsuzuki.org/take-action/volunteer/citizen-science/

Adopt-A-Stream Foundation has developed education materials to teach people how to become stewards of their watersheds. www.streamkeeper.org/environmental-education-materials/

Washington State Department of Ecology addresses the challenging and complex environmental issues with a tool box for environmental education for Puget Sound, wetlands, shoreline and coastal management, water quality and water supply. ecology.wa.gov/Water-Shorelines

Pacific Northwest Aquatic Monitoring Partnership maintains a searchable current list of monitoring programs, many of which are associated with one or more organizations. They also maintain established protocols that can be used as is or tailored for your project. www.monitoringresources.org/

Puget Sound Starts Here has stormwater education resources for formal and informal educators. www.pugetsoundstartshere.org/Resources.aspx

Don't forget: if you see something, say something! As your citizen science monitoring continues, educate volunteers about expected and observed trends, and report any notable findings to a local health department or environmental protection agency for further investigation or remediation.

Monitoring at Clear Creek

The Clear Creek Task Force citizen science program began five years ago when a construction project at Clear Creek was announced. The estuary was bisected by a land berm with two perched culverts. Salmon had been returning to spawn but they had to wait for high tide in order to swim upstream through the culverts.

The work to remove the land berm and replace it with a 240-foot span promised to achieve substantial improvements to fish passage, as well as estuarine ecological processes, and nearshore habitat functions for salmonids, forage fish, aquatic and marine biota.

Chris Butler-Minor, then a graduate student working on her Master's in Environmental Management, partnered with the Clear Creek Task Force to launch what would become a multi-year citizen science data collection program to accurately reflect the stream's conditions before, during, and after restoration work.

The objectives were to design a water quality monitoring program that would provide monthly measurements of water chemistry, vegetation, benthic invertebrate diversity, and elevations to monitor the changes to the stream bed that had accumulated decades of sediment upstream of the land berm.

Chris Butler-Minor teaches a young citizen scientist how to do a colorimetric field test by Mary Earl.

7th grade citizen scientists are excited to be learning outdoors!

Monitoring at Clear Creek (continued)

Five monitoring sites were chosen along the creek and the project duration was established for five years to fulfill the following three objectives:

1. To collect water quality monitoring measurements before, during and after the restoration of the Bucklin Hill estuary bridge project,
2. To provide high quality, comparable data to assess the health of Dyes Inlet's marine water quality.
3. To engage the community in the overall understanding of Dyes Inlet and the Clear Creek watershed functions.

Since the program began in 2014, citizen scientists have collected over 300 data points, on water chemistry, stream bed elevations, vegetation, and benthic macroinvertebrates. This data has improved understanding about the results of the restoration work and the health of this salmon stream.

In the fifth year, the monitoring program expanded with financial contributions from the Russell Family Foundation. The Dyes Inlet Estuary Water Quality Monitoring Project was designed to meet Next Generation Science Standards for local middle school students. Local educators developed the curriculum and their students visited Clear Creek and Chico Creek to collect habitat observations and learn hands-on water quality monitoring protocols.

This pilot program turned local estuaries into field classrooms, and introduced students to monitoring tools, data recording and sharing results. Students now understand the connection between salinity, dissolved oxygen and temperature in an urban salmon habitat. Find examples on the next pages…

GLOSSARY OF TERMS

Gleaned from the *Volunteer Estuary Monitoring: A Methods Manual, Glossary*

Accuracy – A measure of confidence in a measurement; as the difference between the measurement of a parameter and its "true" or expected value becomes smaller, the measurement becomes more accurate.

Acid – Any substance capable of giving up a proton; a substance that ionizes in solution to give the positive ion of the solvent; a solution with a pH measurement less than 7.

Acidity – A measure of the number of free hydrogen ions ($H+$) in a solution that can chemically react with other substances.

Algae – Organisms containing chlorophyll and other pigments that permit photosynthesis. Algae lack true roots, stems, or leaves. Algae bloom is from excessive nutrients such as nitrogen and phosphorus.

Alkalinity – The capacity of water to neutralize acids, a property imparted by the water's content of carbonate, bicarbonate, hydroxide, and on occasion borate, silicate, and phosphate. It is expressed in milligrams per liter of equivalent calcium carbonate (mg/L $CaCO3$).

Benthic – Pertaining to the bottom (bed) of a waterbody.

Biodiversity – A measure of variety at the genetic, species, and ecosystem level.

Brackish – Having a salinity between that of fresh and marine water.

Chemical forms – For example, nitrogen comes in many different chemical forms, including nitrite ($NO2$) and nitrate ($NO3$).

Conductivity – A measure of the ability of water to pass an electrical current, recorded as micro siemen per centimeter [µS/cm]. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). As the concentration of salts in the water increases, electrical conductivity rises; the greater the salinity, the higher the conductivity. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity.

Dissolved oxygen (DO) – The concentration of DO is an important environmental parameter contributing to water quality. Oxygen molecules that are dissolved in water and available for living organisms to use for respiration. Usually expressed in milligrams per liter or percent of saturation.

GLOSSARY OF TERMS

Ecosystem – A community of species interacting with each other and with the physical environment.

Effluent – A discharge into a body of water from a defined or point source, generally consisting of a mixture of waste and water from municipal facilities.

Emergent Plants – Plants rooted under water, but with their tops extending above the water.

Environment – All the factors that act upon an organism or community of organisms, including climate, soil, water, chemicals, radiation, and other living things.

Erosion – The process where wind, water, ice, and other mechanical and chemical forces wear away rocks and soil, breaking up and moving particles from one place to another.

Estuary – Transition zones between fresh water and the salt water of an ocean, which has free connection with the open sea and within which seawater is measurably diluted with fresh water derived from land drainage.

Food web – A complex system of energy and food transfer between organisms in an ecosystem. Refers to the way that organic matter is transferred from the primary producers (plants) to primary consumers (herbivores), and on up to higher feeding (trophic) levels.

Fresh water – Water that is not salty. Freshwater enters estuaries from rivers, streams and through precipitation.

Groundwater – Water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations; called an aquifer when it can yield a usable quantity of water.

Habitat – The place where a population or community (e.g., microorganisms, plants, animals) lives and its surroundings, both living and nonliving.

Habitat disruption – Destruction or alteration of a habitat by cutting across or establishing barriers to migration routes or destroying breeding areas or food sources. Loss of habitat is the primary cause of loss of biodiversity.

Impervious surface – Artificial structures such as pavements (roads, sidewalks, driveways and parking lots, and considerable paved areas) that are covered by water-resistant materials.

Invasive Species – Species that migrate or are carried by animals and humans into ecosystems outside their normal range of occurrence. These “alien invaders” are known by many names, including alien, non-native, introduced, nuisance, non-indigenous, and exotic species. Some of these organisms can wreak havoc on any ecosystem–including estuaries–once they become established.

GLOSSARY OF TERMS

Invertebrates – Animals that lack a spinal column or backbone. Includes mollusks (e.g., clams and oysters), crustaceans (e.g., crabs, shrimp), insects, starfish, jellyfish, sponges, and many types of worms that live in the benthos.

Ions – An atom or molecule with a net electric charge due to the loss or gain of one or more electrons.

Larva, larvae – An immature form of an organism that will undergo metamorphosis to become a juvenile and then an adult.

Macroinvertebrates – Organisms that are large (macro) enough to be seen with the naked eye and lack a backbone (invertebrate).

Marsh or salt marsh – A protected intertidal wetland where fresh water and salt water meet, with plants that tolerate salt water such as salt hay, Lyngby's sedge, and pickleweed.

Milligrams per liter (mg/L) – A weight per volume designation used in water and wastewater analysis. Equivalent to parts per million (1 ppm = 1 mg/L).

Neutral – On the pH scale, neither acid nor alkaline. Pure water is neutral, and has a pH of 7.

Nitrates – One form of nitrogen that plants can use for growth.

Nitrogen – An essential nutrient for plant and animal development; too much can cause accelerated plant growth, algae blooms, and increase the amount of material available for decomposition (which lowers dissolved oxygen).

Parts per million (ppm) – The unit commonly used to represent small concentrations. Larger concentrations are given in percentages.

Runoff – Water from rain, melted snow, agricultural or landscape irrigation that flows over the land rather than being absorbed.

Salinity – A measure of the amount of salts dissolved in water. Generally reported as "parts per thousand" (i.e., grams of salt per 1,000 grams of water) and abbreviated as ppt. Estuaries vary in salinity from 0 to 34 ppt.

Seagrass – In marine environments, rooted vascular plants that generally grow up to the water surface but not above it.

Sediment – Mud, sand, silt, clay, shell debris, and other particles that settle on the bottom of waterways.

Sedimentation – The settling of suspended matter carried by water, wastewater, or other liquids, by gravity.

GLOSSARY OF TERMS

Shellfish – Any aquatic animal with a shell, as the clam, oyster, mussel, and scallop. The organism feeds by filtering water through its gills and removing food materials.

Species – A single, distinct kind of organism, having certain distinguishing characteristics, forming a natural population that transmit specific characteristics from parent to offspring.

Stormwater – Rain and snow melt that runs off rooftops, paved streets, highways, and parking lots. As it runs off, it picks up pollution like oil, fertilizers, pesticides, soil, trash, and animal manure. Stormwater is often not treated, even when it goes into a street drain.

Stream flow – The volumetric discharge expressed in volume per unit time (typically cubic feet per second (ft3/s) or cubic meters per second (m3/s)) that takes place in a stream or channel and varies in time and space. Excess streamflow can create damaging floods, although excess streamflow is also a natural occurrence and healthy for the ecosystem.

Temperature – A measure of the hotness or coldness of anything, usually determined by a thermometer. Temperature is determining factor for biological and chemical processes.

Tide – The alternating rise and fall of the ocean and estuary surface, caused by the gravitational pull of the sun and the moon upon the earth. Normally, two high tides and two low tides in a given 24 hours.

Transpiration – The process of water movement through a plant and its evaporation from aerial parts, such as leaves, stems and flowers. Water is necessary for plants, but only a small amount is taken up by the roots and used for growth and metabolism, while 97–99.5% is lost by transpiration.

Water quality parameters – Any of the measurable qualities or contents of water. Includes temperature, salinity, nutrients, dissolved oxygen, and others.

Watershed – Area of land whose runoff of water, sediments, and dissolved materials (e.g., nutrients, contaminants) drain into a river, lake, estuary, or ocean.

Wetlands – Lands that are often transitional areas between terrestrial and aquatic systems, with enough surface or groundwater to support a complex chain of life, including microorganisms, vegetation, reptiles, fish, and amphibians. Wetlands usually border larger bodies of water such as rivers, lakes, bays, estuaries and the open sea, and may serve as breeding grounds for many species. Examples include swamps, marshes, and bogs.

Example Field Trip: Water Quality at Your Creek, City, State/Province

Objectives:

- Record observations about the stream and wetland habitat at multiple estuary locations.
- Collect and record water quality and stream flow measurements.
- Understand how water quality and other indicators influence the health of the estuary.
- Compare and communicate results.

Equipment (each team needs the following):

- Water shoes, boots or waders
- Water chemistry kits or probes (temperature, pH, conductivity, dissolved oxygen)
- Carrying case for equipment
- Blank **Field Data Collection Sheet**
- Two clipboards with pen/pencil
- Measuring tape reel 50-100 feet, for stream width and transect measurements)
- Measuring rod/stick (for stream depths)
- Net and three floating objects (like ¼-full 4oz. plastic lemon juice squeeze bottles)
- Camera/video recorder
- Stopwatch
- Bags and gloves for trash collection

Monitoring Sites:

In-Stream Measurement Methods:

Attached is a Field Data Collection Sheet for students to use Vernier's LabQuest2 and various probes for collecting the water quality monitoring data set. Electronic field data collection with Vernier's probes will hopefully result in more reproducible measurements than field investigations with older equipment such as thermometers, test strips, or colorimetric and titration methods.

- Test 1: Temperature [A physical characteristic that can determine the rate of biochemical reactions in the aquatic environment.]
- Test 2: pH [pH is used to measure the acidity of the water. Most aquatic organisms have a limited range of pH in which they can thrive. The pH scale ranges from 0 to 14 pH units, with a pH of 7 being neutral. Most surface waters are between 6 and 8 pH units.]
- Test 3: Dissolved Oxygen [Dissolved oxygen in water is vital to aquatic life. It is a necessary for cellular respiration. Most aquatic organisms have an optimal range of dissolved oxygen. It is a key indicator for water quality.]
- Test 4: Salinity [Salinity is the amount of dissolved salts in water. Freshwater generally has a low salinity (<1ppt, parts per thousand) while seawater is generally 35ppt. Salinity concentrations in an aquatic environment affect the particular species that can live in it. Salinity affects control of internal salt levels, and too much salt can increase the pH level. All organisms are sensitive to changes in pH.]
- Test 5: Conductivity [Measure of the amount of electricity the water can conduct (transfer) due to the motion of electrically charged particles or unbound ions in it. It is recorded as micro siemen per centimeter [μS/cm]. Electrical current is transported by the ions in solution. Conductivity increases as the activity of dissolved ions increases. Electrical conductivity depends on temperature. Warmer water has higher conductivity.]

Stream flow/discharge is a measure of the volume of water that moves through a specific point in a stream during a given period of time. It is also responsible for shaping the stream bed and its surroundings. In addition to the water quality tests, students will record observations of the sediment at the deepest part of the stream, then use a measuring tape, measuring rod, stop watch (on their phone or LabQuest2 device), net, and floating fruit to collect measurements for stream flow/discharge calculations.

Habitat Observations:

Students will divide into teams and visit one of the monitoring sites at the estuary with a mentor or docent from a local stewardship or government organization. First, students should take photographs or video of the undisturbed monitoring site to share during their final assignment. In order to paint a more complete picture of estuary habitat, students will attempt to record notes about the creek banks such as obvious erosion or topographic changes, then identify and record species that inhabit the area around the monitoring sites. Record the types and counts of shellfish (oysters, crab, etc.), other in-stream marine life, and bird and duck species seen or heard in the area. Also, identify and record species of plants in bloom or experiencing growth spurts. Record other interesting observations during the field experience. Discuss observations with the mentor or docent, then record detailed notes on the Field Data Collection Sheet.

Field Data Collection Sheet: Water Quality Monitoring

Split into teams, record results for one of the estuary/stream monitoring sites in the table below.

Collection Date:	Stream:	Location Site #:
Data collector(s):		Latitude:
		Longitude:

IN-STREAM DATA COLLECTION	
Time begun:	Time ended:
Tide:	Clouds: Light, Partial, Full, None (circle one)
Wind direction: N, S, E, W, NE, NW, SE, SW (circle)	Wind speed estimation (1-5mph) :

LAB QUEST 2 & PROBES		
Salinity	[0 to 35 ppt]	
Conductivity (EC)	[0.00 to 2,000+ µS/cm]	
Dissolved Oxygen, Optical (DO_2):	[0 to 15 mg/L or ppm]	
pH	[0.0 to 14.0]	
Air temperature	[-5.0 to 60.0°C]	
Water temperature	[-5.0 to 60.0°C]	

Compare Water Quality Results

Gather teams and record results for each site on a large map. Compare sites and compare to Water Quality Standards (WQS) below. Note: Salinity drives the application of WQS for Surface Waters in WA, WAC 173-201A

Use Type	Freshwater Use Category	1-day Minimum DO*	Marine Use Category	1-day Minimum DO*
Aquatic Life Uses	Char spawning and rearing	≥9.5 mg/L	Extraordinary quality	≥7.0 mg/L
	Core summer salmonid habitat			
	Salmonid spawning, rearing, and migration	≥8.0 mg/L	Excellent quality	≥6.0 mg/L
	Salmonid rearing and migration only	≥6.5 mg/L	Good quality	≥5.0mg/L
	N/A	N/A	Fair quality	>4.0mg/L
	Non-anadromous interior redband trout	≥8.0 mg/L	*When a water body's D.O. is lower than the criteria above within 0.2 mg/L of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the D.O. of that water body to decrease more than 0.2 mg/L.	
	Indigenous warm water species	≥6.5 mg/L		

Use Type	Freshwater Use Category	pH Range	Marine Use Category	pH Range
Aquatic Life Uses	Char Spawning and Rearing*	6.5 to 8.5	Extraordinary quality*	7.0 to 8.5
	Core Summer Salmonid Habitat*		Excellent quality +	7.0 to 8.5
	Salmonid Spawning, Rearing, and Migration +	6.5 to 8.5	Good quality +	7.0 to 8.5
	Salmonid Rearing and Migration+		Fair quality +	6.5 to 9.0
	*human-caused variation within the above range of less than 0.2 units		+ human-caused variation within the above range of less than 0.2 units	

Use Type	Freshwater Use Category	7-day Maximum Temperature (7-DADMax)^	Marine Use Category	1-day Maximum Temperature (1-DMax) ^
Aquatic Life Uses	Char Spawning and Rearing*	12°C (53.6°F)	Extraordinary quality	13°C (55.4°F)
	Core Summer Salmonid Habitat*	16°C (60.8°F)	Excellent quality *	16°C (60.8°F)
	Salmonid Spawning, Rearing, and Migration*	17.5°C (63.5°F)	Good quality	19°C (66.2°F)
	Salmonid Rearing and Migration Only	17.5°C (63.5°F)	Fair quality	22°C (71.6°F)
	Non-anadromous interior redband trout	18°C (64.4°F)	*13°C (55.4°F) at the initiation of spawning for salmon and at fry emergence for salmon and trout.	
	Indigenous warm water species	20°C (68°F)	*Lethality to developing fish embryos can be expected to occur at a 1-DMax temperature greater than 17.5°C (63.5°F)	
	^Moderately acclimated (16-20°C, or 60.8-68°F) adult and juvenile salmonids will generally be protected from acute lethality by discrete human actions maintaining the 7-DADMax temperature at or below 22°C (71.6°F) and the 1-day maximum (1-DMax) temperature at or below 23°C			

Field Data Collection Sheet: Habitat Observations

Split into teams, record results for one of the estuary/stream monitoring sites in the table below or field notebook.

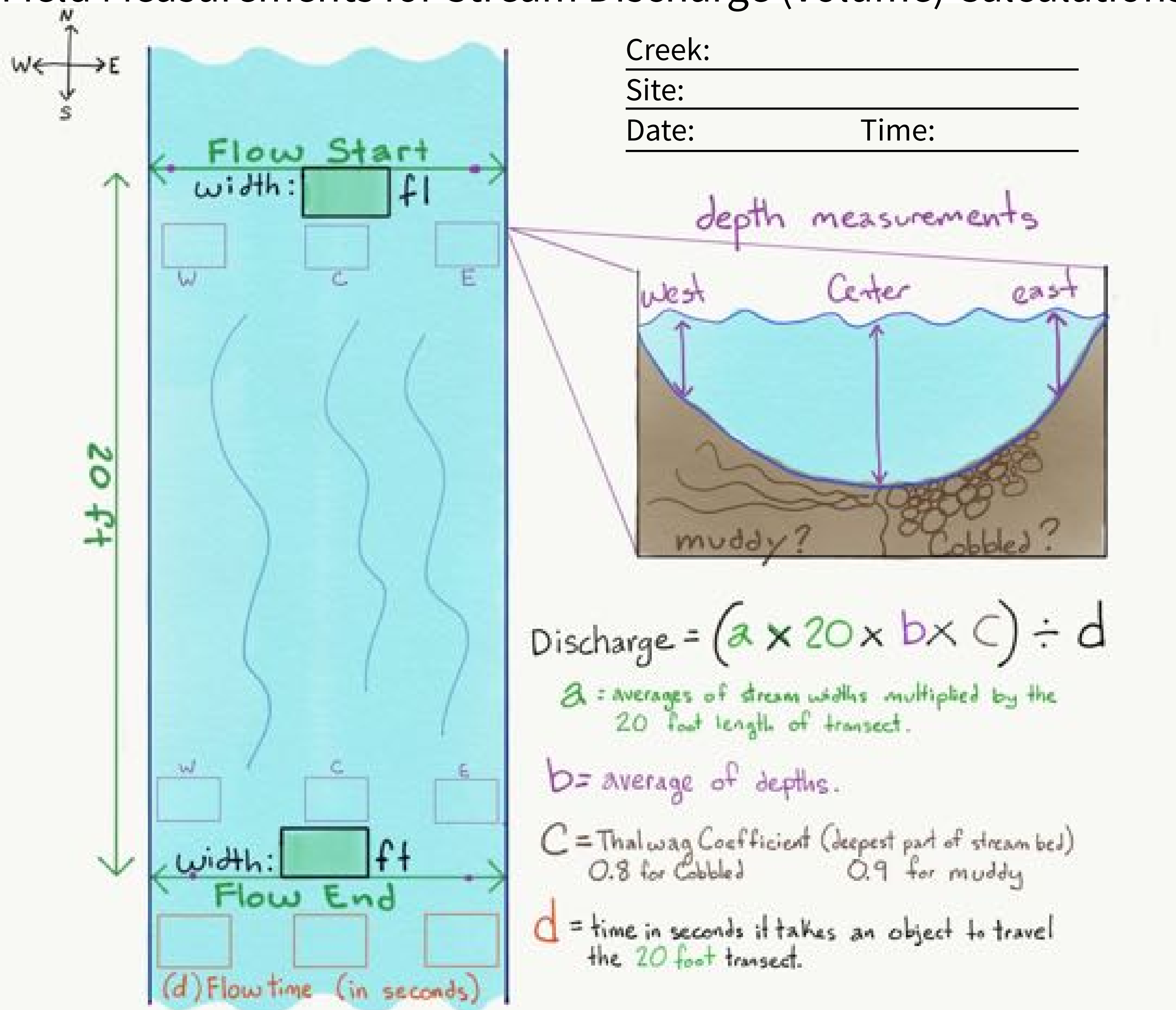
Collection Date:	Stream:	Location Site #:
Stream Observations (color, cloudiness, bank erosion, sedimentation, substrate, etc.)		
Photograph s or Video Taken? ☐		
Marine Life Observations (bugs, shellfish, fish, mammals, etc.)		
Photographs or Video Taken? ☐		
Animal Observations (birds, tracks in the mud, upland or in-stream mammals, etc.)		
Photographs or Video Taken? ☐		
Vegetation Observations (grass, trees, invasive species, etc.)		
Photographs or Video Taken? ☐		
Other Observations (smells, sounds, trash, pollution, decaying material, etc.)		
Photograph or Video Taken? ☐ Trash Collected & Discarded? ☐		

Field Measurements for Stream Discharge (volume) Calculations

Creek: ____________________

Site: ____________________

Date: ____________ Time: ____________



	Flow start	Flow end	Average
a) Stream Width			
b) Stream Depths	Flow start	Flow end	
West side			
Center			
East side			
Average			

c) Thalweg coefficient: based on the stream bed sediments at the deepest part of the stream.

(circle one) muddy or cobbled

d) Flow time in seconds	
West side	
Center	
East side	
Average	

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