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Vignette 01: The Salish Sea Estuary System

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01 | THE SALISH SEA ESTUARY SYSTEM

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The entirety of the Salish Sea is an estuarine ecosystem. Nested within the larger Salish Sea watershed, this estuarine ecosystem is the source of the rich biological structures and functions that make the Salish Sea of particular interest. It is the place where the freshwater from land drainages mixes with the waters of the Pacific Ocean and results in water with a measurable, although sometimes small amount of freshwater. One of the Salish Sea's unique characteristics is that in most places the water is quite salty. The Pacific Ocean off the Washington coast is around 34 PSU (practical salinity units, how salinity in water is measured), while most places in the Salish Sea have a surface salinity only a bit less—around 29 PSU. To most people's taste, this water would seem as salty as the ocean, but it is still a genuine estuary, where seawater is diluted with freshwater.

The Salish Sea is among the preeminent estuaries of North America, such as San Francisco Bay, the Florida Everglades, Chesapeake Bay, the St. Lawrence River, and Bristol Bay to name a few. All of these estuaries share the characteristic of high biological productivity. Estuaries are four times more productive than terrestrial grasslands, are twenty times more productive than the open ocean, and rival the most productive terrestrial crop, sugar cane, in terms of biological productivity. Like forests, grasslands, and intensively cultivated agriculture lands, estuaries produce high amount of organic material.

The food webs—pelagic, demersal, and nearshore—are diverse and rich. In the water of the estuary there is an abundant and complex array of species. The foundation of the pelagic zone is the photosynthesis of microscopic organisms—the phytoplankton. They create the food source that sustains the animal life, including the species we value as food, like the forage fish, and the larger species of fish, like salmon and rockfish. As well, many bird and mammal species depend on this complex food web. Near the shorelines the estuary supports rich beds of seagrasses and kelps, species with high value as habitat for many animal species.

We have known for some time (the 1970s and 1980s work of Curtis Ebbesmeyer and others) that there is a two-way circulation of waters in the Salish Sea. Surface waters move towards the ocean, and deeper waters move from the ocean into the Salish Sea. The movement is subtle and cannot be easily detected looking at the surface of the water on timescales in which we might make casual observations.

What causes the estuarine circulation? As the water from a river flows over the surface of the estuary, it moves seaward, pushed by the incoming river flow. As the freshwater moves across the surface of the estuary, the friction between the river flow and estuary below causes the deeper water to be pulled towards the surface, a process called entrainment. In a flat bottom estuary like Chesapeake Bay, entrainment continually pulls saltier water from below, and the salinity of surface water increases. In the absence of any other disturbance like wind, entrainment continues until the water is well-mixed and uniform.

The Salish Sea is different. Because of the irregular bathymetry, there are locations with active tidal currents where the water is agitated from surface to bottom. In these "washing machine" areas, water is vigorously mixed from surface to bottom, and surface water salinity increases. This is the mechanism that results in the surface water of the Salish Sea being so salty. Once through the tidal currents, the estuarine circulation is restored, with saltier water on the bottom and fresher water at the surface, and the journey to the mouth of the estuary continues.

So how much water is involved with the estuarine flow? The annual discharge of Salish Sea rivers allows us to calculate the total annual estuarine flow. The amounts are immense. Estuarine scientists have determined the entrainment of deeper water by the pushed surface water is between 10 and 20 times the river flow. This mixing of the rivers' freshwater and the deep Pacific Ocean water creates an immense movement of surface water towards the ocean mostly via the Strait of Juan de Fuca. A conservative estimate indicates that the amount of the outward estuarine flow from the Salish Sea through the Strait of Juan de Fuca is equal to a value that is eight times the annual flow of the Columbia River.

This freshwater flow drives estuarine circulation throughout the Salish Sea. We know that the replacement time of the total water of Puget Sound (the residence time) is around 3-6 months. That is, the volume of Puget Sound is replaced about tthree times a year by estuarine circulation. The outgoing estuarine flow is replaced by higher salinity, nitrogen-rich ocean water entering the Salish Sea at depth. This inflow works its way into all parts of the Salish Sea, providing the relatively high values of biological nitrogen that fuel the productive ecosystem.

While most of the biological nitrogen originates from the ocean waters, high concentrations of biological nitrogen remain in the outflow as well, stimulating primary productivity of ocean surface waters off Vancouver Island and the northwest coast of Washington.

The nature of this circulation, the rich biological systems dependent of the flow, and the resilience of the freshwater sources that drive estuarine flow are central to the Salish Sea Ecosystem.

The Salish Sea from space
Photo: NASA 2021