Final Cruise Report for U2022-041(PAC #2022-040)

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1 Survey long-term objectives

The Salish Sea biophysical survey started in 1999 to monitor the physical oceanography of the Salish Sea and better understand its regional circulation and seasonal variability. In 2015, the survey expanded to include nutrient monitoring, which helps inform DFO management about the ecosystem's overall health in a changing climate. DFO scientific publications addressing changes in the extent and timing of deep-water renewal, and phytoplankton blooms have used the program's data as a primary source of information. Other uses include tracking changes in water mass composition (e.g., dissolved oxygen) that depend on the interplay between freshwater inputs, winds, and biogeochemical processes and exchanges with offshore waters. This survey supports DFO's goal of managing a sustainable aquatic ecosystem by conducting fundamental ecosystem research in a waterway subject to considerable environmental stressors.

This is one of DFO's long-term monitoring programs and includes waters impacted by the Fraser River, Puget Sound, and offshore conditions at the entrance of Juan de Fuca Strait. This area is heavily transited because of shipping to and from significant ports near Vancouver and Seattle with freshwater inputs from urbanized catchments. Changes in ocean and coastal conditions have been the subject of heightened interest over the past decade, given possible regime shifts in the region's major physical processes responsible for water exchanges. Notably, the shifts in magnitude and timing of peak freshwater inputs relative to changes in offshore wind regimes alter the deep exchanges into the Salish Sea, which propagate through the ecosystem, given the vigorous mixing in some of the passes in Haro and Georgia Strait. These processes enable deeper, nutrient-rich waters to reach the surface and fuel plankton blooms in the well-lit surface layer, supporting local fisheries and including species that, under certain conditions, produce harmful toxins.

Below we summarize the observations collected during the June 2022 (U2022-041) biophysical survey. There were no major impediments to sampling other than reduced ship time, which prevented sampling stations in Rosario Strait. The summary is followed by post-processing analysis methods and key findings reported in DFO’s State of the Pacific Ocean annual report (Boldt et al. 2023).

2 Summary of data collection

The survey typically visits 80 stations in the Salish Sea and Georgia Strait (Figure 1) with a maximum of 23 stations visited in US waters (Table 1). There are 42 stations south of the 49^{th} parallel. During the June 2022 survey, 18 US stations were visited as those in Rosario Strait (# 51 to 54) were skipped due to lack of ship time. The ship track in Figure 2 also shows Station 50 in Boundary Bay was skipped. Most of the US stations involve collecting stand-alone conductivity-temperature-depth (CTD) profiles although water is collected at four stations to analyze in the laboratory (typically nutrients and chlorophyll-A).

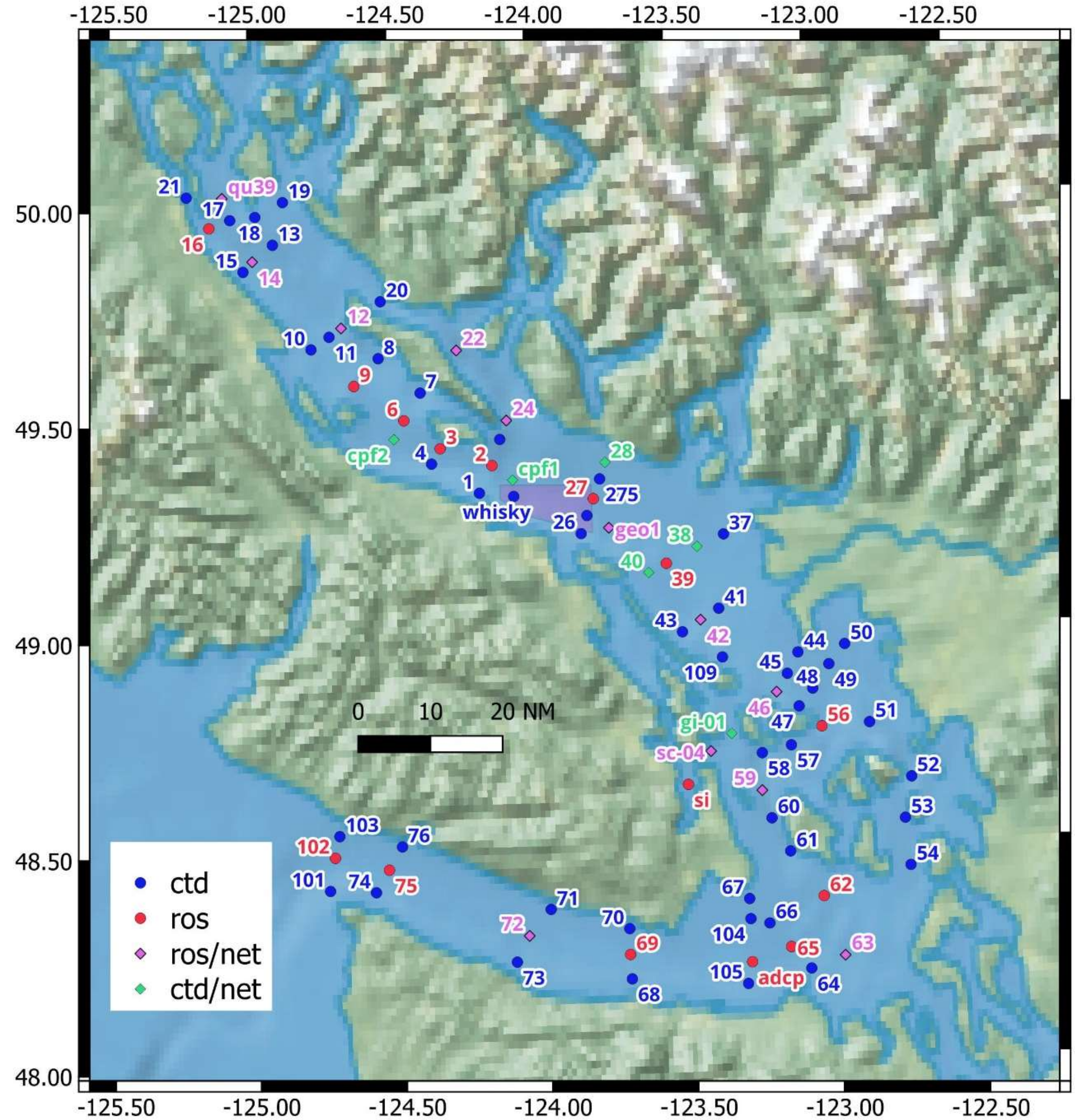

Figure 1. Map of stations typically visited in any given year during DFO's Salish Sea Biophysical Survey.

Table 1. List of stations in US waters. Stations 50 to 54 were not visited.

Station name	Latitude	Longitude	dataType	Geographic Region
44	48.94667	-123.1	ctd	Boundary Bay
48	48.86167	-123.053	ctd	Boundary Bay
49	48.91667	-122.993	ctd	Boundary Bay

50	48.96167	-122.935	ctd	Boundary Bay
59	48.63	-123.243	ros/net	Haro Strait
60	48.565	-123.213	ctd	Haro Strait
61	48.48667	-123.153	ctd	Haro Strait
62	48.38	-123.043	ros	Haro Strait
63	48.24086	-122.978	ros/net	Juan de Fuca
64	48.21333	-123.097	ctd	Juan de Fuca
65	48.265	-123.163	ros	Juan de Fuca
68	48.20333	-123.717	ctd	Juan de Fuca
72	48.31	-124.067	ros/net	Juan de Fuca
73	48.25	-124.112	ctd	Juan de Fuca
74	48.41833	-124.593	ctd	Juan de Fuca
101	48.42333	-124.752	ctd	Juan de Fuca
102	48.5	-124.733	ros	Juan de Fuca
105	48.18333	-123.317	ctd	Juan de Fuca
adcp	48.23333	-123.3	ros	Juan de Fuca
51	48.77833	-122.86	ctd	Rosario Strait
52	48.64833	-122.722	ctd	Rosario Strait
53	48.55333	-122.75	ctd	Rosario Strait
54	48.44333	-122.738	ctd	Rosario Strait

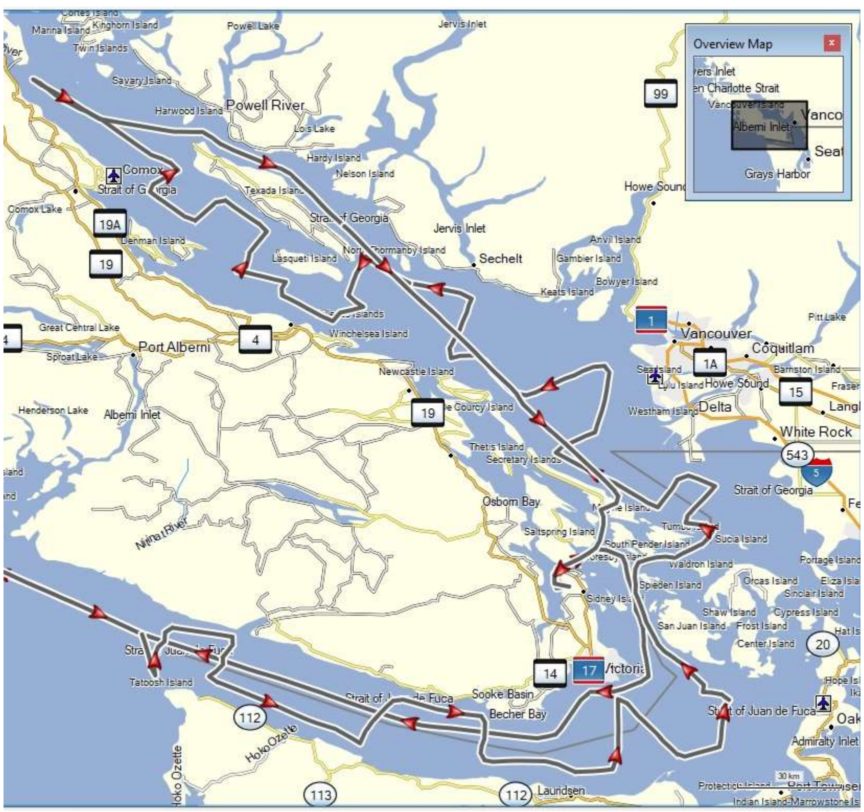

Figure 2. Ship track during the U2022-041 survey from June 23 to June 29, 2022.

2.1 CTD processing and laboratory analysis

The raw CTD is processed in-house at Fisheries and Oceans Canada with quality-control checks against salinity, dissolved oxygen, and chlorophyll-A measured from water samples at certain stations. Nutrient concentrations (nitrite+nitrate, phosphate, and silicate) and extracted chlorophyll-A were analyzed in the laboratory while the dissolved oxygen samples were processed immediately onboard the vessel. These laboratory methods are described in the header of each uploaded NetCDF file, which is reproduced below.

Chlorophyll samples were filtered onto 25mm GF/F filters after collection, and immediately frozen and stored in a -80C freezer until analysis. All samples were returned to the Institute of Ocean Sciences and analyzed 9 weeks after the cruise on a Turner Trilogy 7200-000 fluorometer, using methods described in Holm-Hansen et al. (1965). Fluorescence readings taken before and after sample acidification were used to calculate chlorophyll and phaeopigment concentrations. Flags and comments apply to chlorophyll values only. No flags or comments are assigned for Phaeo-Pigment values.

Oxygen samples were analyzed at sea using an automated Winkler titration System (Metrohm Dosimat model 876 and a UV light source and detector with a 365nm filter controlled by LV02_876 software designed and constructed by Scripps Institution of Oceanography) with modifications based on Carpenter (1965) and adhering to WOCE protocols (Culberson 1991). Salinity samples were collected in 200 mL type II glass bottles with disposable nylon inserts and screw caps supplied by Ocean Scientific International Limited. They were analyzed in a temperature-controlled lab on a Guildline 8400B Salinometer standardized with IAPSO standard seawater 30 - 34 days after collection.

Nutrient samples were collected in plastic tubes and quickly frozen in aluminum blocks stored in a -20C freezer. For samples 400m and deeper a second set of samples are collected and stored cool for silicate analysis. All samples were returned to the Institute of Ocean Sciences and they were analyzed using an Astoria-Pacific Analyzer following methods described in IOS Nutrient Methods Barwell-Clarke and Whitney (1996).

3 Key findings from annual reporting

3.1 Purpose of reporting

The Salish Sea Biophysical Survey has been one of the core monitoring programs of DFO in the Pacific Region since 1999 and the data is widely used by the government, universities, and other research organizations for long-term monitoring of the regional circulation and seasonal to interannual variability of the Salish Sea from the western entrance of Juan de Fuca Strait to the northern end of the Strait of Georgia. Previous and future research applications include:

- Long-term trends in temperature, salinity, oxygen, and nutrients and attribution of these trends to natural variability or climate change.
- Circulation and mixing of water masses, including those of open-ocean origin, and those originating from river inflow and Puget Sound, with a particular focus on deep water renewal and estuarine exchange flow in Georgia Strait and Juan de Fuca Strait.

- Monitoring ecosystem stressors such as marine heat waves, deoxygenation events, and ocean acidification.
- Quantifying seasonal and interannual variations in phytoplankton and zooplankton species composition and abundance and relating these changes to physical and biogeochemical variability in water properties. Monitoring biotoxins and domoic acid.

Within DFO, the results of these seasonal surveys are summarized and published in annual technical reports: "State of the Physical, Biological, and Selected Fishery Resources of Pacific Canadian Marine Ecosystems". These reports are accessible via the following link: https://www.dfo-mpo.gc.ca/oceans/publications/index-eng.html under 'State of the Pacific Ocean' - 'Technical Reports'. In addition, a preliminary analysis of the data from all surveys in a given year is presented annually at the 'State of the Pacific Ocean' meeting.

3.2 Key findings and papers for 2022

The survey data was presented in the annual meeting held in Victoria BC in March 2023. The proceedings with key findings are presented in the annual report (Boldt et al. 2023). The most relevant papers for the Salish Sea survey:

- Paper 37. Salish sea temperature, salinity and oxygen observations in 2022 by Donnet & Chandler.
- Paper 43. Zooplankton status and trends in the central and northern Strait of Georgia, 2022 by Young et al.
- Paper 47. Marine biotoxin monitoring in BC coastal waters by Ross et al.

Others rely on the observations for developing models, and their verification. The main highlights from these papers, specific to the summer survey:

- "2022 summer conditions were warmer, fresher and more oxygenated than usual near the surface but colder, saltier and less oxygenated than usual below. Thus, stronger summer stratification than average occurred in 2022" (Donnet & Chandler, paper 37).
- Over the span of 24 years (1999-2022), the marine system has been undergoing significant changes. The trends indicate a consistent increase in temperature and a decrease in oxygen at all depths. Additionally, salinity is showing a general shift towards fresher conditions at the surface and saltier conditions at depth (Donnet & Chandler, paper 37).
- "Small copepods dominated by numbers (abundance), but 'fish food' plankton (medium-large calanoids, euphausiids and amphipods) had a higher contribution by biomass" (Young et al, paper 43).
- "Algal biotoxins, including those responsible for amnesic, paralytic and diarrhetic shellfish poisoning, are present in B.C. coastal waters" (Ross et al, paper 47).

The basis of these findings are detailed in the paper, along with figures of the observations collected in the Salish Sea.

4 References

Barwell-Clarke, J. and Whitney, F. 1996. Institute of Ocean Sciences Nutrient Methods and Analysis. Canadian Technical Report of Hydrography and Ocean Sciences, No. 182, 43 pp.

Boldt, J.L., Joyce, E., Tucker, S., and Gauthier, S. (Eds.). 2023. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2022. Can. Tech. Rep. Fish. Aquat. Sci. 3542: viii + 312 p

Carpenter, J.H. 1965. The Chesapeake Bay Institute Technique for the Winkler Dissolved Oxygen Method. Limmnol. & Oceanogr., 10: 141-143.

Culberson, C.H. 1991. Dissolved oxygen. WOCE Hydrographic Programme Operations and Methods (July 1991). 15pp.

Holm-Hansen, O., Lorenzen, C.J., Holmes, R.W., and Strickland J.D.H. 1965. Fluorometric Determination of Chlorophyll. J.du Cons. Intl. Pour l'Epl. De la Mer. 30:3-15.