

State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2025

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Abstract

Boldt, J.L., Joyce, E., Tucker, S., Gauthier, S., and Jackson, J. (Eds.). 2026. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2025. Can. Tech. Rep. Fish. Aquat. Sci. 3797: viii + 347 p. <https://doi.org/10.60825/839g-q046>

Fisheries and Oceans Canada is responsible for the management and protection of marine resources along the Pacific coast of Canada. There is strong seasonality in coastal upwelling and downwelling, considerable freshwater influence, and variability from coupling with events and conditions in the tropical and North Pacific Ocean. The region supports ecologically and economically important resident and migratory populations of invertebrates, groundfish, pelagic fishes, marine mammals and seabirds.

Since 1999 an annual State of the Pacific Ocean meeting has been convened by DFO to bring together the marine science community in the Pacific Region and present the results of the most recent year's monitoring in the context of previous observations and expected future conditions. The workshop to review ecosystem conditions in 2025 was a hybrid meeting, convened both in-person in Nanaimo, B.C. and virtually, March 4-5, 2026. This technical report includes submissions based on presentations given at the meeting and poster summaries.

Climate change is a dominant pressure acting on North Pacific marine ecosystems, causing, for example, increasing temperatures, deoxygenation, and acidification, and changes to circulation and vertical mixing. These pressures impact ecosystem nutrient concentrations and primary and secondary productivity, which then affect higher trophic levels through the food chain.

Résumé

Boldt, J.L., Joyce, E., Tucker, S., Gauthier, S., and Jackson, J. (Eds.). 2026. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2025. Can. Tech. Rep. Fish. Aquat. Sci. 3797: viii + 347 p. <https://doi.org/10.60825/839g-q046>

Pêches et Océans Canada est chargé de la gestion et de la protection des ressources maritimes sur la côte Pacifique du Canada. Sur le plan océanique, il y a une forte saisonnalité dans les remontées d'eaux profondes côtières et les plongées d'eaux, une forte influence des eaux douces, et une variabilité provenant des phénomènes et des conditions dans l'océan Pacifique tropical et l'océan Pacifique Nord. La région soutient des populations résidentes et migratrices écologiquement et économiquement importantes d'invertébrés, de poissons de fond, de poissons pélagiques, de mammifères marins et d'oiseaux de mer.

Depuis 1999, une réunion annuelle sur l'État de l'océan Pacifique est organisée par le MPO afin de réunir la communauté scientifique dans la région du Pacifique et de présenter les résultats de la dernière année de surveillance dans le contexte d'observations précédentes, ainsi que les conditions futures attendues. L'atelier organisé du 4 au 5 mars, 2026 pour examiner les conditions de l'écosystème en 2025 était un événement hybride avec une rencontre en personne à Nanaimo, C.-B. incluant une option virtuelle. Le présent rapport technique comprend des soumissions basées sur les présentations données durant l'atelier et des résumés d'affiches.

Les changements climatiques constituent une pression dominante qui agit sur les écosystèmes marins du Pacifique Nord et sont la cause, entre autres, de l'augmentation des températures, de la désoxygénation et de l'acidification, et des changements dans le régime de circulation et le mélange vertical. Ces pressions ont des effets sur les concentrations d'éléments nutritifs et la productivité primaire et secondaire des écosystèmes, ce qui a une incidence sur les niveaux trophiques supérieurs par l'intermédiaire de la chaîne alimentaire

Highlights, Introduction, and Overview

1. HIGHLIGHTS

1. Globally, 2025 was the 3rd hottest year on record and the 5th warmest in B.C., with near normal precipitation but with below normal snowpack. There was record-high rainfall and severe flooding in the Fraser valley in December.
2. Despite strong La Niña conditions throughout the year, offshore Northeast Pacific waters continued to have reduced salinity levels and high temperatures, underscoring a long-term trend of increasing sea surface temperatures in coastal waters over the last century.
3. In some regions, near-bottom oxygen concentrations during the summer were again at or near the lowest values in the records.
4. In coastal waters, annual biomass was above average for all principal groups of zooplankton ('southern', boreal, and subarctic copepods).
5. The biomass of Pacific Herring, an important small pelagic forage fish, varies among areas; for example, it increased off West Coast Vancouver Island, is high and near unfished biomass in the Strait of Georgia, but is in a low biomass and low productivity state in Haida Gwaii.
6. About 80% of the assessed Pacific salmon Conservation Units (CU) are in the Red (poor) or Amber (fair) Wild Salmon Policy status zones.
7. The biomass of shelf rockfish, several slope rockfish, and many flatfish species has increased. In contrast, there were ongoing decreases in the biomass of Arrowtooth Flounder, Pacific Spiny Dogfish, Fraser River Eulachon, and Pacific Hake (outside coast stock).
8. The Sea Otter population has been increasing and expanding spatially.
9. The European Green Crab (an Aquatic Invasive Species) continues to spread in the Salish Sea and one species of invasive tunicates was detected in metro Vancouver for the first time.

2. INTRODUCTION

Fisheries and Oceans Canada (DFO), Pacific Region, facilitates and assembles an annual overview of the physical, chemical and biological conditions in the ocean off Canada's west coast (Figure 2-1). This compilation helps to develop a picture of how the ocean is changing and provides advanced identification of important changes which may potentially impact human uses, activities, and benefits from the ocean. This is done in a two or three day meeting, usually held in February or March of the year following the year being considered. The first meeting was held in 2000 to assess conditions in 1999; reports from these reviews are available online (see [Technical reports – State of the Pacific Ocean](#)).

Reviews and reports from 2007 to 2013 were conducted under the direction of the Fisheries and Oceans Canadian Science Advice Secretariat (CSAS). In 2014, these State of the Pacific Ocean reviews were moved to a separate process and are now presented as Fisheries and Oceans Canada Technical Reports. The report from 2025 (for conditions in 2024) is available online ([State of the Physical, Biological and Selected Fishery Resources of Pacific Canadian Marine Ecosystems in 2024](#)).

The 27th annual DFO State of the Pacific Ocean (SOPO) meeting, to review conditions in the NE Pacific and B.C. coastal waters in 2025, was a hybrid meeting, convened both in-person in Nanaimo, B.C. and virtually, March 4-5, 2026. Due to the hybrid platform, this year's meeting reached a broad audience from the Pacific Coast marine science community. These annual meetings represent a unique opportunity for scientists from different disciplines to highlight the results of atmospheric, oceanographic, and marine species observations in 2025 and to update a wide range of data time series.



Figure 2-1. Map of regions described in this report.

This year's meeting was attended by 398 researchers from 110 organizations (Figure 2-2). Organizations included the federal and B.C. governments, First Nations and Indigenous organizations, academia, national and international partners, and the private sector. For example, attendees included scientists from Fisheries and Oceans Canada, Parks Canada, Environment and Climate Change Canada, Department of National Defense, and First Nation and Indigenous organizations, such as the Council of the Haida Nation, Cowichan Tribes, Malahat Nation, Tsawout First Nation, Musqueam Indian Band, Heiltsuk Integrated Resource Management Department, Seabird Island Band, and Witset First Nation, among others. Other attendees included the Province of B.C., Hakai Institute, University of British Columbia, University of Victoria, Ocean Networks Canada, North Pacific Marine Science Organization, and the Pacific Salmon Foundation.

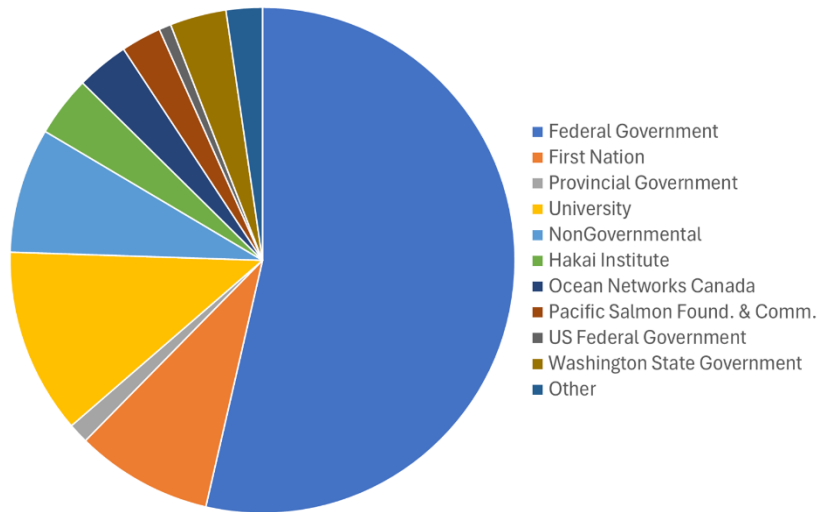


Figure 2-2. 2026 SOPO meeting participants' affiliations.

Elder Sandra Good from the Snuneymuxw First Nation provided opening remarks to start the meeting. Regional Director of Science, Andrew Thomson, also provided opening remarks, including his appreciation for the SOPO meeting and report. He noted that it is only through these types of collaborative processes that we can bring together different types of knowledge to gain a better understanding of how ecosystems are changing and to identify actions for DFO and address future needs in Science.



Sandra Good from the Snuneymuxw First Nation and DFO's Regional Director of Science, Andy Thomson, provided opening remarks.

The SOPO report provides a summary of scientific results from many DFO field operations (Figure 2-3) outlined in DFO's [Fieldnotes](#) as well as Canadian Hydrographic Service (CHS) surveys (Shultis, Section 50; Riedel, Section 51). SOPO reports inform DFO's National Initiatives, including 1) the State of the Ocean Reporting to develop [Canada's Oceans Now reports](#), and 2) the [Ecosystem Approaches to Fisheries Management](#) to integrate environmental variables into single species stock assessments and fisheries management decisions. SOPO reports are also used for Regional DFO initiatives, such as [State of the Salmon](#) reporting.

At the meeting, 42 talks, 1 poster-spotlight talk, and 22 posters were presented, and included an opening special session on Highlights from the Marine Conservation Targets Initiative in B.C. waters. Topics ranged from annual precipitation to large-scale atmospheric and physical oceanographic conditions, to species composition of the phytoplankton and zooplankton communities, to fish and marine mammal stock status, to ocean noise, and many things in between, providing a comprehensive overview of conditions in the Pacific Region in 2025. Meeting invitations were circulated to individuals (First Nations, federal and provincial government, academia, and non-government organizations) that had participated or attended previous SOPO meetings. For the last several years, the organizing team has taken a proactive approach and invited all First Nations and Indigenous organizations in B.C. to participate in the meeting. This year there were 34 participants from 23 First Nations and Indigenous organizations. An invitation to all First Nations and Indigenous organizations was also extended to present or co-present at this and future meetings. There were 2 co-presentations: 1) collaborators from DFO, Gwaii Haanas Parks Canada, the Council of the Haida Nation, and the Hakai Institute gave a joint presentation on "2025 Ocean Conditions in and Potential Monitoring Metrics for Gwaii Haanas & Haida Gwaii" and 2) researchers from the Tsawout First Nation

gave a presentation entitled “Á,LE.ENE.: Tsawout’s Dungeness Crab Stewardship for Future Generations”.

The meeting and report enable scientists to interpret field-based findings and summarize information that can ultimately be used to inform fisheries management decisions, examine the implications of climate change, and complement DFO’s [National state of the ocean reporting](#). Many of the SOPO time series are available in an open-source R package, [pacea](#), which will help facilitate an ecosystem approach to fisheries management (Edwards, Section 48).



2026 SOPO meeting and poster session participants.

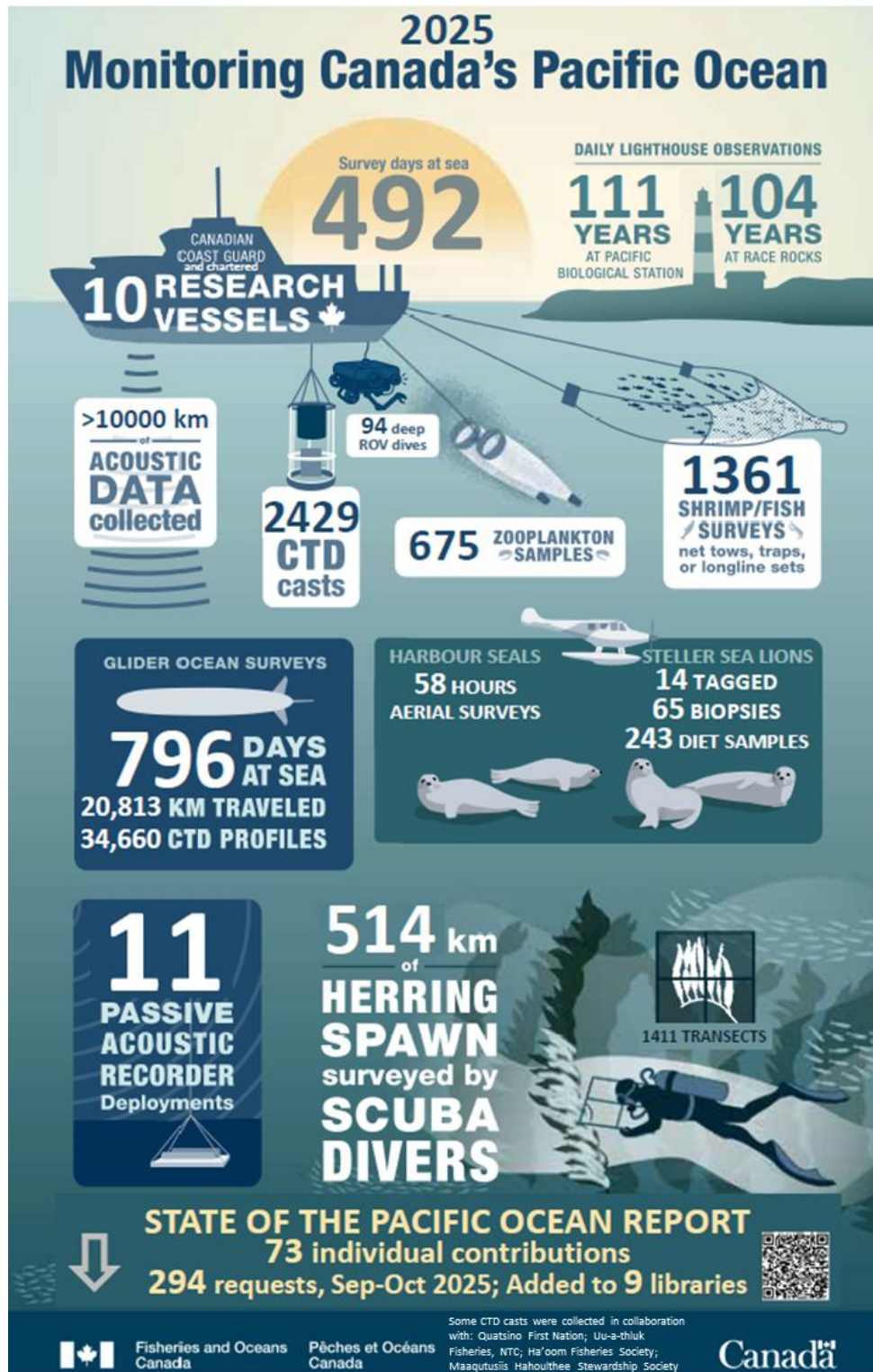


Figure 2-3. In 2025, hundreds of days at sea surveying Canada's west coast contributed to the collection of data used for monitoring Pacific ecosystems. From daily lighthouse observations to aerial and dive surveys, over time, these annual monitoring efforts add to our understanding of the status and trends in the marine environment. Some CTD casts were collected in collaboration with: Quatsino First Nation; Uu-a-thluk Fisheries, NTC; Ha'oom Fisheries Society; Maaqutusiis Hahoulthee Stewardship Society.

The agenda for the meeting is presented in Appendix 1, and the meeting participants are listed in Appendix 2. The meeting was co-chaired by Strahan Tucker (Pacific Biological Station), Jennifer Jackson (Institute of Ocean Sciences), Jennifer Boldt (Pacific Biological Station), Stéphane Gauthier (Institute of Ocean Sciences), and organized by Elizabeth Joyce. In addition to helping with meeting organization, all technical aspects of the virtual meeting were run by Stephen Page (Institute of Ocean Sciences), with support from Lucius Perreault (Institute of Ocean Sciences) and Lindsay Mazzei (Institute of Ocean Sciences). Convening this large-scale hybrid meeting involved planning and organization above and beyond the requirements for past SOPO meetings and was once again made possible with the skills and hard work of Elizabeth, Stephen, Lucius, and Lindsay.



2026 SOPO meeting organizers (left to right), Elizabeth Joyce, Stéphane Gauthier, Jennifer Jackson, Stephen Page, Jennifer Boldt, Lindsay Mazzei, Strahan Tucker, Lucius Perreault.

This technical report presents the highlights and summaries of the presentations and discussions at the workshop. These summary reports are not peer reviewed, and present the status of data, results, and interpretations as of the date of the SOPO meeting. For use of, or reference to individual contributions, please contact individual authors and, where appropriate, please cite individual contributions, as in this example:

Robb, C., Norgard, T., Dangerfield, N., Detering, J., Obradovich, S., Page, S., Snow, B., and Vermeulen, D. 2026. Highlights from the Marine Conservation Targets (MCT) initiative: Overview of MCT surveys. p. 31-35. In: Boldt, J.L., Joyce, E., Tucker, S., Gauthier, S., and Jackson, J. (Eds.). 2026. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2025. Can. Tech. Rep. Fish. Aquat. Sci., 3797: viii + 347 p.

3. OVERVIEW AND SUMMARY

2025 STATE OF PHYSICAL ECOSYSTEMS

Basin-scale and outer coast

Globally, 2025 was the 3rd hottest year on record since 1880 (Ross and Robert, Section 8). Annual air temperatures were the 5th warmest on record in B.C. (1940-present) and are increasing by 0.26 °C (Curry and Dah, Section 6). B.C.'s snowpack was below-normal throughout B.C. and well below-normal in coastal watersheds (Curry and Dah, Section 6). Compared to previous years, drought conditions in 2025 were less severe overall; however, basins in northeast and southeast B.C. continued to experience abnormally dry conditions (Curry and Dah, Section 6).

Northeast Pacific sea surface temperatures (SSTs) in 2025 were warm; SST was approximately 1°C above the 1991-2020 period (Ross and Robert, Section 8). Throughout 2025, the Pacific Decadal Oscillation (PDO) was strongly negative and there were La Niña conditions; however, this did not result in cool ocean temperatures as would be expected because this occurred on a background of steadily rising temperatures due to climate change (Figure 3-1; Ross and Robert, Section 8). Climate forcing affects ocean temperatures, currents, upwelling, stratification, sea level, and other physical and biological variables (Hourston and Thomson, Sections 10 and 11; Han and Chen, Section 14; Allen and Latornell, Section 39; Suchy and Allen, Section 40; Boldt et al., Section 49; Riedel, Section 51; Jones and Hannah, Section 53). SSTs varied seasonally and spatially. In the open northeast Pacific, overall annual SSTs were slightly warmer than the 1991-2020 period; however, there was a marine heatwave (MHW) in summer months (vessel sampled data; Ross and Roberts, Section 8; Lee et al., Section 15). Within B.C.'s Exclusive Economic Zone (EEZ), SSTs were warmer than normal in most areas throughout the year, and the summer MHW encroached on the EEZ (satellite data; Hilborn et al., Section 16; model simulations; Han and Chen, Section 14). Modeled bottom temperatures were above normal over the shelf, but were below normal over the slope (model simulations; Han and Chen, Section 14). Nearshore coastal water SSTs were generally above the 1991-2020 average particularly around northwestern Vancouver Island and the central and north coast (shore-station data; Jackson, Section 9). Overlying multi-year oscillations in the annual SST, there is a long-term trend with ocean temperatures rising at a rate of 0.9 °C per 100 years (Figure 3-1; Jackson, Section 9). Surface waters (above 100 m depth) in the NE Pacific continued to be anomalously fresh in 2025, extending from Ocean Station Papa (OSP) to the B.C. coast; this continues a freshening trend observed for the last eight years (Ross and Robert, Section 8). Winter stratification was stronger in 2024/2025 (and 2023/2024), suggesting less mixing of nutrients to the surface than in the previous 5 years (Ross and Robert, Section 8).

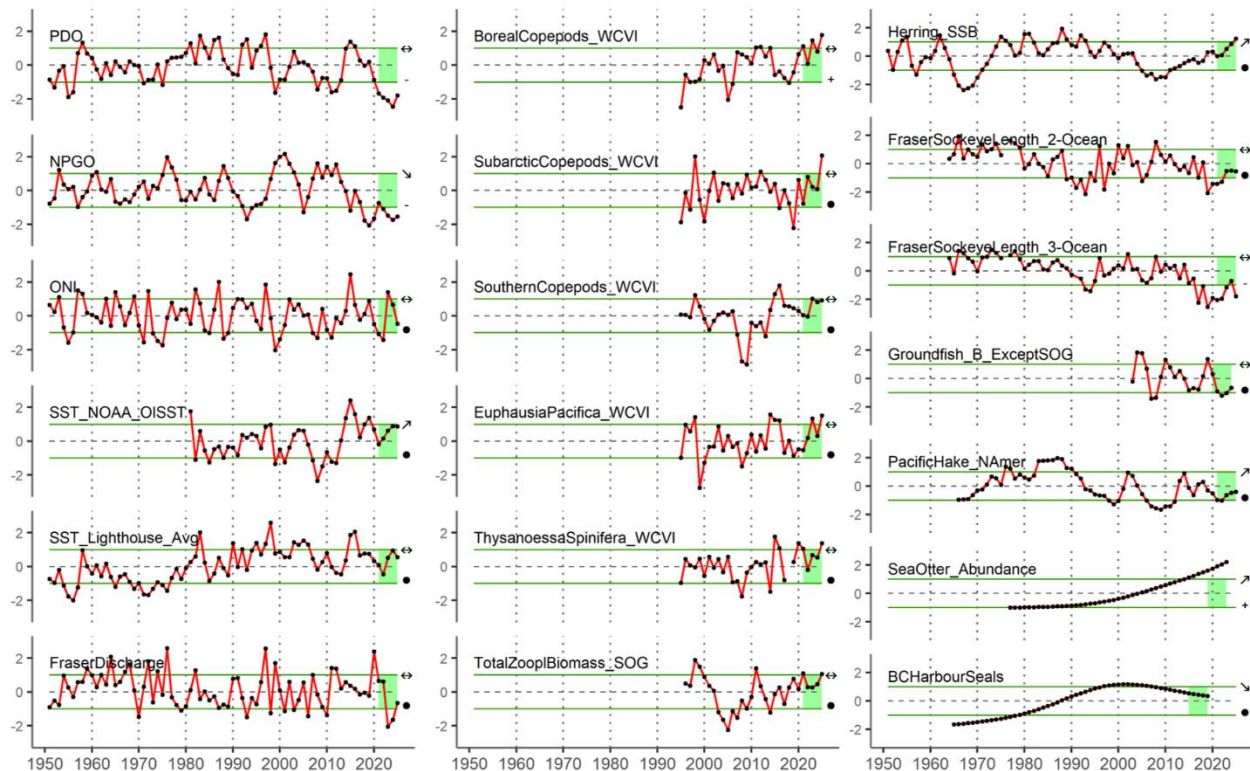


Figure 3-1. Selected indicators of the physical environment (left column), lower and upper biological trophic levels (middle and right column) of B.C.'s marine ecosystems (1950-2025). Time series (red line and black dots) have been standardized (over the length of each time series) to have a mean of 0 (dashed horizontal line) and a standard deviation of 1 (horizontal green lines). The last five years of the time series are highlighted in green. The symbols to the top-right of each graph indicate the trend in the last five years of the time series (values in the last five years show no (↔), increasing (^), or decreasing (\) linear trend). The symbols to the bottom-right of each graph indicate the status (mean value in the last five years is within (•), above (+), or below (-) one standard deviation). Broad-scale indicators PDO, NPGO, ONI (Ross and Robert, Section 8); NOAA's ERDAPP SST (<https://coastwatch.pfeg.noaa.gov/erddap/files/>); Sea Surface temperatures from B.C.'s shore stations (SST_LighthouseAvg; Jackson, Section 9); Fraser River discharge (FraserDischarge; Giesbrecht and Moore, Section 7); west coast Vancouver Island (WCVI) copepods and euphausiids biomass anomalies (Sastri and Galbraith, Section 19); total Strait of Georgia zooplankton biomass (SOG_TotalZooplanktonBiomass (Young et al., Section 42); Coastwide Pacific Herring Spawning Biomass (Herring_SSB; Cleary et al., Section 22); Fraser River ocean age-2 and -3 Sockeye Salmon length (Latham et al., Section 45); groundfish biomass (GroundfishB; summed survey biomass of all groundfish except those in the SOG; Anderson et al., Section 27); outside stock of Pacific Hake biomass (PacificHake_NAmer; Gauthier and Stanley, Section 28); B.C. Sea Otter abundance (Nichol et al., Section 31); B.C. Harbour Seal abundance (updated from Tucker and Majewski 2020 with Tucker et al. 2025). Most time series were acquired from authors; some were acquired from the R package pacea (Edwards and Tai, Section 48; Edwards et al. 2024).

Subsurface oxygen concentrations are declining in B.C. waters at most locations where there are data (Hannah, Section 13; Bluteau et al., Section 12; Lee et al., Section 15); this includes oxygen near-bottom, at mid-depths, and at 50 m depth. It is likely that reduced oxygen input at the surface of the Northwest Pacific (ventilation) is affecting subsurface oxygen in the Northeast Pacific including B.C. (Mecking and Drushka 2024; Hannah, Section 13). One potential cause of the decline is freshening of the subarctic Pacific due to input from melting Alaska glaciers (Zemp et al. 2019; Hannah, Section 13). Some nearshore waters, such as Fitz Hugh Sound, may offer refugia from hypoxic conditions due to tidal mixing over shallow entrances (Evans, Section 17).

The timing and magnitude of upwelling of deep, nutrient-rich water off the west coast of Vancouver Island (WCVI) is an indicator of marine coastal productivity across trophic levels, from plankton to fish to sea birds. Variability in the upwelling index corresponds with variations in the strength and/or longitudinal position of the Aleutian low-pressure system in the Gulf of Alaska. The 2025 transition timing and magnitude of spring upwelling were near average relative to the 1991-2020 mean, resulting in an expectation of average upwelling-based coastal productivity (Figure 3-1; Hourston and Thomson, Section 10; Wang et al., Section 52). The winter of 2025-2026 was characterized by near-average downwelling-favourable winds, indicating that winter storm activity was near normal (Hourston and Thomson, Section 10). Persistent upwelling, particularly along the southern Vancouver Island continental slope, brings California undercurrent source waters onto the shelf, supplying nutrients and saline water to surface waters and extending deep, oxygen-poor waters over the shelf eastward toward the coast. Surface water chlorophyll-a concentration was higher than normal in 2025, with early, strong blooms on the west coast of Vancouver Island and central coast, as well as higher than normal productivity in late summer on the west coast of Haida Gwaii (Hilborn et al., Section 16; Lee et al., Section 15).

Salish Sea

In spring 2025, the Salish Sea was generally warmer than the 1999-2025 average. In summer, conditions were warmer than normal in the Strait of Georgia but cooler than normal in the Juan de Fuca Strait, and the whole region was saltier than normal. In fall, conditions were warmer than normal, saltier than normal, and had lower than normal dissolved oxygen concentrations (Jackson, Section 38; Esenkulova et al., Section 41). In 2025, the annual Fraser River discharge was below average for May to December, with December seeing unusually high discharge (Figure 3-1; Giesbrecht and Moore, Section 7). Increasing CO₂ in the atmosphere has increased the acidification of the ocean. A reduction in the storm season intensity in the northern Salish Sea resulted in an increase in the extent of the water column exhibiting corrosive conditions for Ω_{cal} (Evans, Section 17).

2025 STATE OF BIOLOGICAL ECOSYSTEMS

Lower trophic levels and forage base

Outer, central, and north coast phytoplankton and zooplankton

In 2025, satellite chlorophyll-a was higher than normal (since 1998) for most outer, central, and north areas of B.C. (Hilborn et al., Section 16). Along the Continuous Plankton Recorder transect (shelf and offshore) the phyto- and zooplankton communities were near average abundance and composition (since 2002); the numbers of copepods typically associated with warm waters were low, and the mean copepod length was average (Ostle and Batten, Section 20). In 2025, DFO-sampled-WCVI zooplankton biomass anomalies were positive for both cool and warm water indicator groups (Figure 3-1; Sastri and Galbraith, Section 19). Biomass of endemic copepods and euphausiids were greater than average for both the Northern Vancouver Island (NVI) and Southern Vancouver Island (SVI) shelf/slope regions (Sastri and Galbraith, Section 19). Total biomass of gelatinous zooplankton was near-average for the SVI and NVI offshore (Sastri and Galbraith, Section 19).

Salish Sea microbes, phytoplankton, and zooplankton

Annual variation in spring bloom timing and community composition may affect the food web through a temporal match or mismatch between prey and predators. In the SOG in 2025, models indicate the spring bloom timing was early compared to the long-term average (since 1968; Allen and Latornell, Section 39); observations confirm this for central SOG but also indicate a late bloom in north SOG (Del Bel Belluz, Section 18). Additional observations during 2023-2025, indicate bloom timing was similar during these three years (Kafrissen et al., Section 56). In-situ chlorophyll fluorescence observations indicated that there was a relatively weak “double” spring bloom in March and May (Esenkulova et al., Section 41). Microbes (Bacteria, Archaea, and Protists) are important to higher trophic levels of marine food webs. In 2025, warmer, saltier, nutrient-rich intermediate waters selected against SAR11 bacteria, Nitrosopumilaceae and Methylophilaceae prokaryotic clades, but favoured nitrite-oxidizing and hydrocarbon- and polysaccharide-degrading bacteria (Kellogg et al., Section 54).

In 2025, the SOG total zooplankton biomass (averaged over the year) was above average and higher than the time series mean since 1996 (Figure 3-1; Young et al., Section 42). Medium and large-sized copepods, euphausiids, and amphipods (important juvenile salmon prey) dominated biomass (Young et al., Section 42); whereas, smaller copepods dominated abundance (Young et al., Section 42; Coskuner et al., Section 59).

Invertebrates

The Tsawout First Nation has established an adult Dungeness Crab (*Metacarcinus magister*; Á,ĆEX) Monitoring Program in the QEN,T Indigenous Protected and Conserved Area. STÁUTW’s fisheries-independent surveys of adult crab will fill current data gaps, with promise of better understanding the effects of two commercial closure areas within the IPCA on Dungeness Crab size and population dynamics.

Forage Fish

Forage fish form a critical link in marine ecosystems, transferring energy from lower trophic levels (phytoplankton and zooplankton) to upper trophic levels (e.g., groundfish, seabirds, and marine mammals). Forage fish species include Pacific Herring, Eulachon, and Northern Anchovy, among others. Coastwide Pacific Herring spawning biomass increased during 2010-2025, dominated by the SOG and WCVI stocks; however, in some assessed areas, such as Haida Gwaii, there have been prolonged periods of low spawning biomass (Figure 3-1; Cleary et al., Section 22). In 2025, adult Pacific Herring summer biomass in continental shelf waters off the WCVI (mixed stocks) was the 4th highest in the 2006-2025 time series; scientific survey catch per unit effort values (CPUEs) are typically high off the southwest coast of Vancouver Island (Boldt et al., Section 23). In the SOG in 2025, the relative biomass of age-0 Pacific Herring was below the time series mean (Boldt et al., Section 43). Age-0 herring were smaller than average, but their condition was above average.

In 2025, the index of Fraser River Eulachon spawning stock biomass was estimated to be amongst the lowest in the time series, since 1995 (~8 tonnes; Flostrand et al., Section 44) at a level comparable to 2022-2024. In addition, the mean Eulachon CPUE from a WCVI multispecies bottom trawl survey declined (Flostrand et al., Section 44).

In 2024, Northern Anchovy were present in ~60% of the SOG age-0 Pacific Herring survey sets; and the estimated biomass was the 2nd highest since 1992 (Boldt et al., Section 43). Other indicators of forage fish distribution and availability include analyses of predatory species' diets; for example, Pacific Herring are an important component of Chinook Salmon diets in the SOG and WCVI (Tabert et al., Section 46). Fatty acid analysis can also be used to understand food web connections (McLaskey and Hunt, Section 62). Interestingly, some forage fish species, such as Northern Anchovy, can contain thiaminase, an enzyme that degrades thiamine, which can lead to deficiency in Pacific salmon (McLaskey et al., Section 61).

Upper trophic levels

Groundfish

Changes to the physical environment and forage communities can impact higher trophic levels, such as groundfish, salmon, seabirds, and marine mammals. There was a continued increase in the biomass of shelf rockfish, several slope rockfish, and many flatfish species in the most recent 5-10 years (Anderson et al., Section 27) with Lingcod, Yellowtail Rockfish, and Dover Sole estimated to be above their Limit Reference Point and above their Upper Stock Reference in 2025. In contrast, Arrowtooth Flounder and Pacific Spiny Dogfish biomass declined in recent years (Figure 3-1). Dogfish stocks experienced the steepest declines with a particularly precipitous decrease in outside Vancouver Island waters (Anderson et al., Section 27). The 2025 inside Pacific Hake population (Strait of Georgia) continued to increase since 2010 (Gauthier and Stanley, Section 28). For the migrating Pacific Hake stock off the west coasts of Canada and the U.S., 2025 was the lowest estimated biomass of the survey time-series, with an estimated 0.65 million tons. Under 1% of the total estimated survey biomass was encountered in Canadian waters, the lowest of the survey time series.

Pacific Salmon

Many stocks of Pacific salmon have exhibited declines in abundance, coinciding with human activity and climate-related changes in freshwater and marine ecosystems. Wild Salmon Policy (WSP) statuses are available for 70 of the 381 Pacific salmon Conservation Units (CUs; MacDonald et al., Section 25). Efforts are ongoing to expand coverage to the remaining CUs. Of the assessed CUs, ~80% are in the Red or Amber WSP status zone, indicating poor or fair biological status. This includes many Fraser Sockeye, Fraser Chinook and Yukon Chinook CUs, Fraser Chum, and two West Coast Vancouver Island Chinook CUs. CUs in good (Green) status include Fraser Pink, some Interior Fraser Coho and Barkley Sockeye CUs, South Thompson and Shuswap Chinook, and one WCVI Chinook CU.

In the marine environment, juvenile Coho Salmon in the SOG had higher than average abundance in both summer and fall, with all other juvenile Pacific salmon in the SOG or the southern B.C. continental shelf having average or below average abundance indices. (King et al., Section 24). Juvenile Pacific salmon condition in summer and fall was average or above average with the exception of fall-caught juvenile Pink Salmon in the Salish Sea, which was below average (King et al., Section 24). Lengths of both returning Fraser Sockeye Salmon and Pink Salmon in 2025 were smaller than long term averages but larger than the record small sizes observed in recent years (Latham et al., Section 45). In 2025, the return of Fraser Pink Salmon was the earliest on record, and a higher proportion of the return followed the southern migration route around Vancouver Island than in any other year on record (i.e., since 1959).

Ecosystem modeling suggests future marine habitat compression in Vancouver Island inlets for salmon under a scenario of climate change (Geng et al., Section 26)

Seabirds

The growth rate of Cassin's Auklets is linked to the abundance of their primary prey, *Neocalanus cristatus* copepods, which are more abundant during relatively cold years (Hipfner, Section 29). Diets fed to nestling Cassin's Auklets on Triangle Island in the second half of June 2025 included normal amounts of *Neocalanus cristatus* in contrast to their complete absence in 2024 (Hipfner, Section 29). The fish-based diets fed to nestling Rhinoceros Auklets are also affected by prey availability, with nestling auklets growing more quickly in years in which their diets include more Pacific Sand Lance. In 2025, diets fed to nestling Rhinoceros Auklets on Pine Island in southern Queen Charlotte Sound included less-than-normal amounts of Pacific Sand Lance, their most important prey, relative to a 2006-2024 baseline (Hipfner, Section 29). In contrast, diets on Lucy Island in Chatham Sound included normal amounts of Pacific Sand Lance. In the Salish Sea, mean annual densities of Rhinoceros Auklet in 2022-2025 were half the peak observed in 2019; conversely, in 2024-2025, mean annual densities of Ancient Murrelet were high for the third year in a row, relative to the 2015-2025 time series (Bertram et al., Section 30).

Marine Mammals

As of 2023, the B.C. Sea Otter population is estimated at 12,058 (95%CI 11,048-13,717) individuals (Nichol et al., Section 31). The population, established from a small number of animals translocated from Alaska (1969-1972), continues to recover into historically occupied habitat along the B.C. coast, changing the structure of nearshore communities (rocky reef, kelp forest, soft sediment, and eelgrass). Systematic cetacean surveys have provided the first effort-corrected, season-specific, and spatially-resolved density estimates for Humpback Whales, Harbour Porpoises, and Dall's Porpoises in the southern Salish Sea and on Swiftsure Bank (2020-2024; McMillan et al., Section 47) and the north coast of B.C. (2023-2025; Mossman et al., Section 32). All three species were present year-round, but showed strong seasonal variability in abundance, density, and distribution patterns with distinct species patterns.

Habitat

The Marine Conservation Targets (MCT) initiative was launched in 2016, subsequently renewed in 2021, helping Canada fulfil international commitments to protect 30% of marine and coastal areas by 2030. Through monitoring and collaborations with partners and stakeholders, DFO's MCT-related objectives are to 1) assist in establishing new MPAs and Marine Refuges, and 2) ensure current sites are effective and providing ecological benefits. MCT survey efforts have been highly collaborative, involving multiple divisions within DFO's Science branch, as well as partnerships with First Nations and research groups. Over 90 surveys, with over 1000 survey days, have been completed with support from the MCT Initiative since 2016.

One example of MCT-research includes conducting and supporting surveys to fill key knowledge gaps about water properties and oceanographic exchange processes in the proposed Kitkatla Inlet Marine Protected Area (Bluteau et al., Section 5c).

Another example of MCT-supported work includes research surveys of deep sea Ecologically or Biologically Significant Areas (EBSAs). Deep sea cold seeps (an EBSA) can provide key ecosystem services, including a role in deep-sea primary production (chemosynthesis), essential fish habitat for commercial species, nursery grounds for Deep-Sea Octopuses, and stable hard substrates that support diverse communities of deep-sea species including corals and sponges (Gartner et al., Section 5b). Research surveys have resulted in updated numbers of visually confirmed cold seep fields from 6 (in 2018) to 23 (in 2025). In addition, cold seep flares mapped from ship based echosounders have increased from 250 (in 2018) to over 1600 (in 2025; (Gartner et al., Section 5b)).

Pressures

Climate change continues to be a dominant pressure acting on NE Pacific marine ecosystems with a multitude of physical oceanographic impacts ranging from warming, to stratification and upwelling, to hypoxia, just to name a few. These changes are having profound impacts on species distribution, reproduction, condition, and survival. Moreover, rising CO₂ in the atmosphere has increased the acidification of the ocean leading to a cascade of negative impacts on marine organisms, which will continue to intensify with the rise of anthropogenic carbon levels in the atmosphere (Evans, Section 17).

Harmful algal blooms produce toxins, such as domoic acid, that can cause finfish, shellfish, and marine mammal mortalities, as well as impacts to human health, and economic losses (Esenkulova et al., Section 41; Esenkulova, Section 55). The SOG in 2025 was marked by sustained phytoplankton activity, beginning with very high early-spring occurrence of *Chaetoceros convolutus/concavicornis* (which can be mechanically harmful to fish gills), followed by strong summer blooms of *Rhizosolenia setigera* and *Pseudo-nitzschia* spp., substantial *Dictyocha* spp. blooms, moderate levels of *Heterosigma akashiwo*, and notably increased summer occurrence of *Noctiluca scintillans* (Esenkulova et al., Section 41). *Pseudo-nitzschia* can produce domoic acid that is responsible for amnesic shellfish poisoning (Ross and Mueller 2024). In 2025, domoic acid (DA) peaked later and at higher concentrations than usual at long-term monitoring sites in Malaspina Strait and Cowichan Bay (Ross et al., Section 34). In Malaspina Strait, paralytic shellfish poisoning (PSP) toxins peaked at concentrations far higher than average, more like those typically reached on the west coast of Vancouver Island (Ross et al., Section 34). Overall DA and PSP toxins appear to be increasing in the Strait of Georgia.

Marine Aquatic Invasive Species (AIS) are increasing in both range and abundance in B.C. European Green Crab continue to spread in B.C., with a large number of new detections in 2025 occurring on the North Coast, especially around Prince Rupert (Howard et al., Section 35). This high-impact invader negatively affects eelgrass, an important fish habitat. *Styela clava* (Clubbed Tunicate) was detected in Metro Vancouver for the first time in 2025, following three years of increasing detections in Nanaimo and Ladysmith (Howard et al., Section 35). Preventing the spread of AIS requires management and monitoring of anthropogenic pathways and vectors, as early detection of AIS can inform management and policy.

Other anthropogenic pressures include oil spills, vessel traffic, and underwater noise. Commercial vessel sound inputs on Swiftsure Bank and western Juan de Fuca Strait locations increased in the fall in 2025, consistent with increased demand on oceanic shipping routes prior to Christmas (Burnham and Vagle, Section 36). The soundscape in the Strait of Georgia has

been shown to be shaped by ferry schedules (Burnham and Vagle, Section 36). Regional water movements, oceanographic conditions, and climate-induced variation impacts the speed of sound in water (Taves et al., Section 37). As oceans warm and marine heatwaves become more common, sound speeds in the Salish Sea are expected to increase, with the potential to create conditions where anthropogenic noise emissions travel further, leading to elevated ambient sound levels, and therefore, potentially creating greater disturbance to marine life (Taves et al., Section 37). Other sources of noise include on-land and underwater detonation activities conducted by the Department of National Defence and Canadian Armed Forces (DND/CAF) on properties located at the southern tip of Vancouver Island. Detonation noise measurements inform acoustic modelling of conservative detonation scenarios (Quijano, Section 66).

Monitoring

Advanced technologies and new monitoring programs can improve our ability to detect changes in B.C.'s marine ecosystems and guide MPA selection. [Ocean Networks Canada \(ONC\)](#), an initiative of the University of Victoria, is a Major Research Facility of Canada, and an Implementing Partner for the United Nations Decade of Ocean Science for Sustainable Development (2021–2030). ONC operates deep-sea and coastal observatories on Canada's Pacific coast, such as a cabled infrastructure and coastal radar (Wang et al., Section 52). Examples of advanced technologies and recent or proposed monitoring programs (*not already mentioned in the above summary*) include: 1) a proposed West Coast B.C. Distributed Biological Observatory (WCDBO), from Victoria through the inside passage to Prince Rupert, providing a tool to observe land-ocean systems and identify and interpret Earth system change at multiple scales (Bauer, Section 33); 2) an annual monitoring program conducted at the Pacific Biological Station and the Institute of Ocean Sciences (Nelson et al., Section 65); 3) a monitoring survey of seasonal, inter-annual, and long-term variability of euphausiid and other zooplankton production dynamics in Barkley Sound (Young et al., Section 57); 4) combined advanced technologies to capture images of zooplankton using an optical instrument followed by semi-automatic image classification and measurements using machine learning (Smith et al., Section 58); 5) comparison of different technologies to measure energy density of forage fish (Dennis-Bohm and Boldt, Section 60); 6) use of eDNA to monitor juvenile Pink and Chum Salmon outmigration and habitat use through Burrard Inlet (Melchers et al., Section 63); 7) Laser Ablation Inductively Coupled Plasma Mass Spectrometry to identify the life history strategies of WCVI Ocean-type Chinook Salmon (LaForge et al., Section 64). Finally, there is a new Sustainable Blue Economy (LSBE) Certificate Program offering courses that focus on science communication, research, data analytics, ethical science, and collaboration skills (Efford et al., Section 67).

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4. ACKNOWLEDGEMENTS

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**Individual reports on conditions in the Northeast Pacific and British
Columbia's outer coast**

5A. HIGHLIGHTS FROM THE MARINE CONSERVATION TARGETS (MCT) INITIATIVE: OVERVIEW OF MCT SURVEYS

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5A.1. Highlights

- Over 90 surveys, with over 1000 survey days, have been completed with support from the MCT Initiative since 2016.
- MCT survey efforts have been highly collaborative, involving multiple divisions within DFO's Science branch, as well as partnerships with First Nations and research groups.
- Surveys have utilized protocols developed for an array of survey tools to sample within ecosystems ranging from rocky and soft shorelines and coastal fjords, to offshore seamounts, hydrothermal vents, and cold seeps.
- Data from MCT-funded efforts have been combined with data collected from long-term DFO research surveys to provide foundational information for MPAs and Marine Refuges.

5A.2. Marine Conservation Targets (MCT) Initiative

The Marine Conservation Targets (MCT) initiative was launched in 2016, and subsequently renewed in 2021, to help Canada fulfil international commitments to protect 30% of marine and coastal areas by 2030, in accordance with the Kunming-Montreal Global Biodiversity Framework (CBD 2022; DFO 2025). Within Fisheries and Oceans Canada (DFO), the protection tools available to support the achievement of the 30% target include *Oceans Act* Marine Protected Areas (MPAs) as well as *Fisheries Act* Marine Refuges, which qualify as other effective area-based conservation measures (OECMs) that provide long-term biodiversity conservation benefits (DFO 2025).

5A.3. MCT Science in the Pacific Region

In the Pacific Region, DFO's Science branch (specifically the Aquatic Diagnostics, Genomics, and Technology (ADGT), Ecosystem Science (ESD), and Ocean Sciences (OSD) divisions) was allocated resources under the MCT initiative to assist in establishing new MPAs and Marine Refuges, and to ensure current sites are effective and providing ecological benefits through monitoring and collaborations with partners and stakeholders.

To meet those objectives, work has focused on providing scientific support to the development of the Great Bear Sea MPA Network in the Northern Shelf Bioregion (Beaty et al. 2024), co-authoring biophysical and ecological overview reports for proposed MPAs to document the current state of ecological knowledge (e.g., Bannar-Martin et al. 2025), developing sampling protocols, collaborating on the development of monitoring frameworks and strategies at a site

and network level (Du Preez et al. 2024; MPA Network B.C. Northern Shelf Initiative 2024), collecting baseline data and starting to perform repeat monitoring within MPAs across the Pacific Region, and producing coastwide spatial datasets on the distribution of species, habitats, and oceanographic processes, including projected changes associated with climate change.

5A.4. MCT Research Surveys

Extensive internal and external collaborations allowed the comprehensive collection of biodiversity and oceanographic data to support the MCT initiative. These collaborations ensured ensuing reports and research papers incorporated the breadth of DFO Science's knowledge. For example, the Non-Destructive Survey Tools team in ADGT has collaborated with ESD and OSD staff and partner groups to pilot remotely operated vehicles (ROVs) to collect baseline information in coastal and offshore MPAs. In 2025, the YellowEye ROV, acquired using capital funding available through the MCT initiative, was used to visually confirm deep-sea cold seeps, recognized as ecologically and biologically significant areas (DFO 2018), and begin to implement monitoring guidance for rockfish conservation areas (RCAs). MCT funding has also been used to fund surveys targeted within proposed MPAs, such as the coastal biodiversity surveys designed to collect baseline data for areas identified for protection in the Northern Shelf Bioregion (NSB; e.g., Proudfoot et al. 2025), and to supplement the funding of long-term data collection efforts, such as oceanographic data collected through the B.C. Moorings Program and the Glider Program. Data from MCT funded efforts have been combined with data collected from long-term core program funded fisheries and oceanographic surveys that provide foundational information in MPAs and Marine Refuges.

Since 2016, over 90 surveys, with over 1000 survey days, have been completed across the Pacific Region with support from the MCT initiative (Figure 5A-1). Sampling has been conducted from Canadian Coast Guard research vessels, led from shore or using small research boats, and collected using autonomous tools such as gliders or moorings utilized by OSD, with survey effort increasing in the second phase of the MCT initiative (Figure 5A-2). A variety of sampling methods (Figure 5A-3) have been used to collect data within ecosystems ranging from rocky and soft shorelines and coastal fjords to offshore seamounts, hydrothermal vents, and cold seeps.

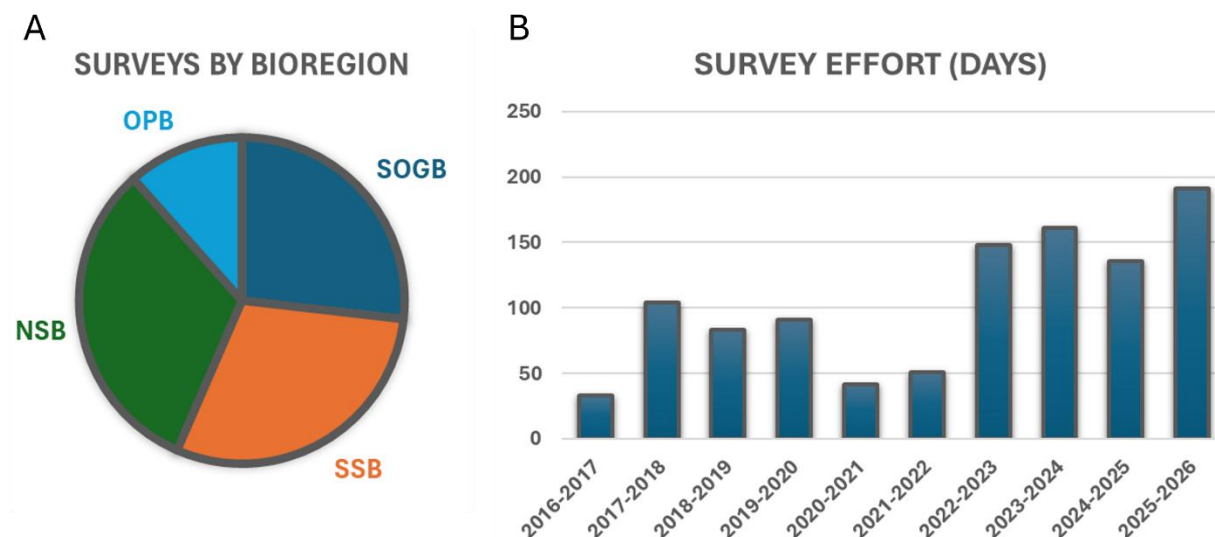


Figure 5A-1. Effort associated with surveys supported by the MCT Initiative in the Pacific Region since 2016. A) Count of surveys conducted within each marine bioregion (NSB: Northern Shelf Bioregion; OPB: Offshore Pacific Bioregion; SOGB: Strait of Georgia Bioregion; SSB: Southern Shelf Bioregion). While fewer surveys were conducted within the OPB, offshore surveys were often longer in duration than the small boat or shore-based surveys conducted with the SOGB and SSB. B) Annual count of survey days for research surveys supported by the MCT initiative.

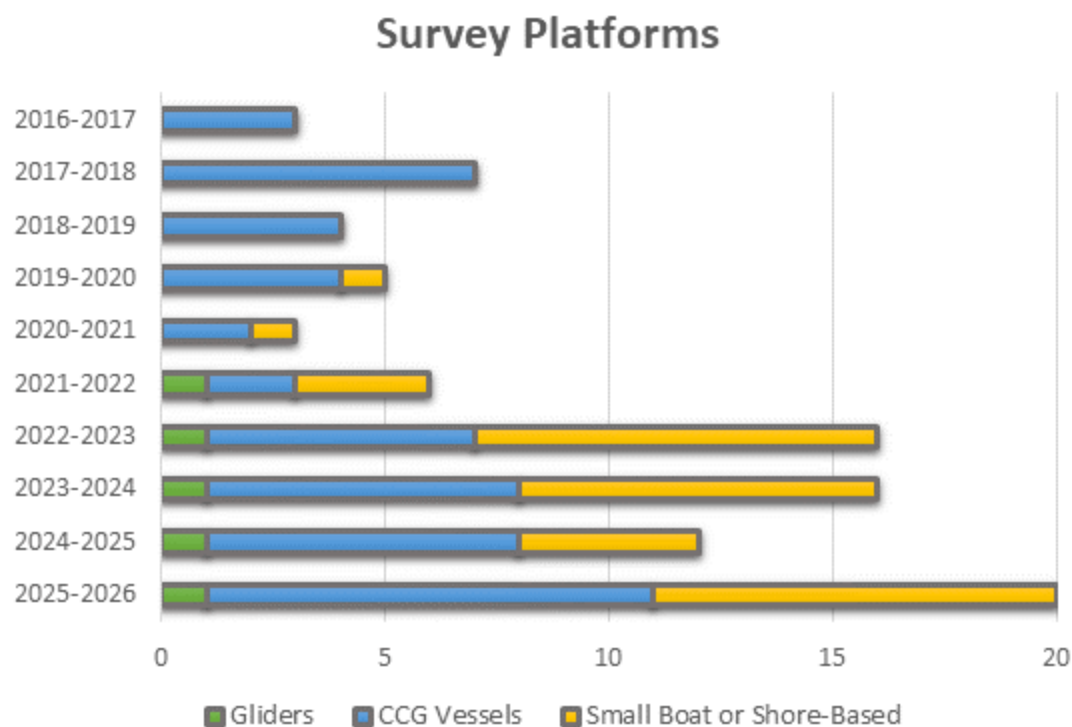


Figure 5A-2. Survey platforms used for MCT surveys from 2016-2026. In a few instances, third-party vessels were contracted for surveys using remoted operated vessels (ROVs) but have been grouped with the Canadian Coast Guard (CCG) Vessels.

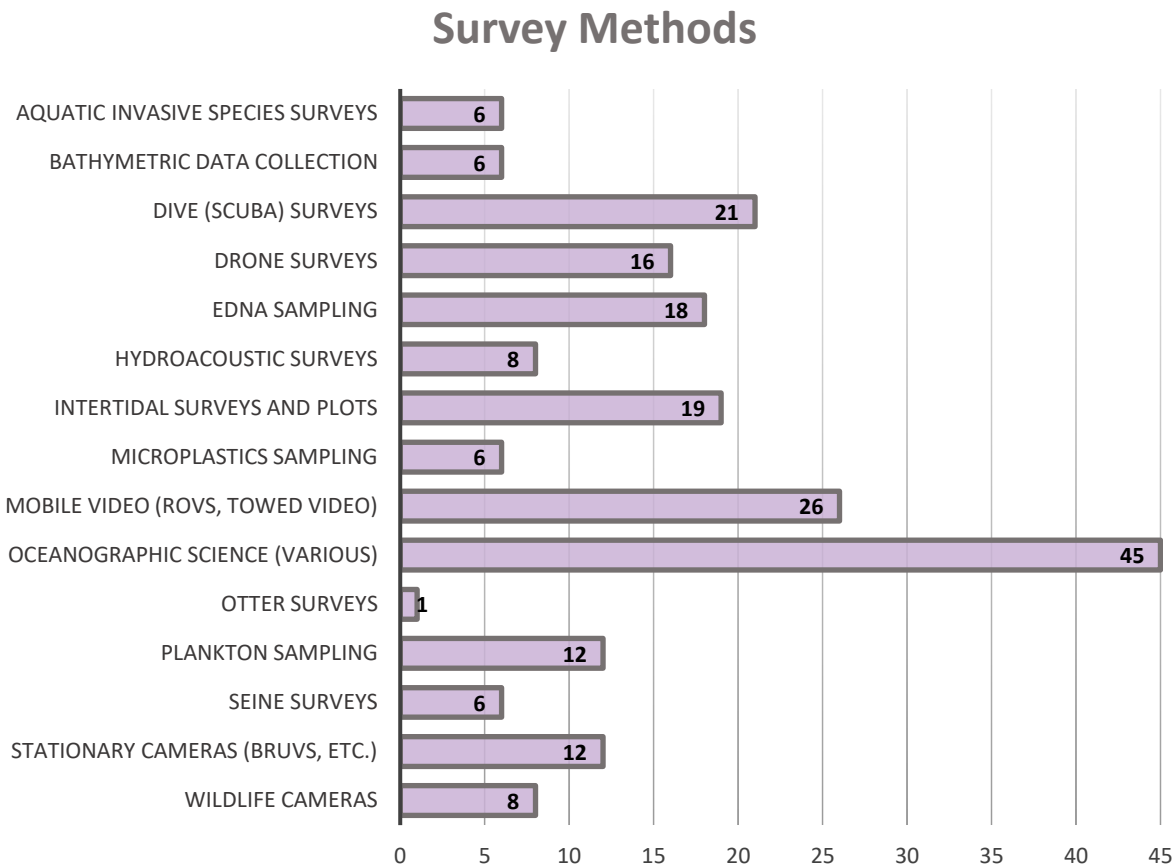


Figure 5A-3. Count of surveys conducted with support from the MCT initiative since 2016 that have used each type of survey method. Protocols have been developed and tested to support the collection of baseline data and inform ecological monitoring guidance. Some surveys may utilize multiple methods. For example, ten sampling methods were employed during the 2022 coastal biodiversity survey (Proudfoot et al. 2025).

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5B. NORTHEAST PACIFIC DEEP-SEA EXPLORATION PROJECT AND UPDATED KNOWLEDGE ON COLD SEEPS

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5B.1. Highlights

- Research conducted since 2018 has updated the number of visually confirmed cold seep fields from 6 (2018) to 23 (2025).
- Cold seep flares mapped from ship based echosounders have increased from 250 (2018) to over 1600 (2025).
- Cold seep habitats all share the common characteristic of venting fluid and hosting chemosynthetic communities, however, each seep habitat can be quite diverse and includes habitats such as mud volcanoes, carbonate ridges, and massive mounds with gas hydrate.
- We have documented commercial species utilizing the habitats and the impacts of bottom-contact fishing.

5B.2. Extended Abstract

Cold seep ecosystems in Pacific Canada have historically been overlooked, but a significant shift occurred in 2018 when the Federal Government recognized them as Ecologically or Biologically Significant Areas (DFO 2018). Cold seeps occur where hydrocarbon-rich water escapes from beneath the sea floor, often near boundaries of tectonic plates (DFO 2018). Microbes metabolize these chemical compounds and form the base of chemosynthetic communities, increasing abundance and biodiversity of life (biological hotspots), and creating carbonate structure (habitat forming that supports secondary communities). Research expeditions undertaken by the NorthEast Pacific Deep-sea Exploration Project (NEPDEP) have focused on collaborating with partners at Natural Resources Canada and GEOMAR to update our knowledge of these ecosystems in Pacific Canada.

Ship-based gas flare mapping has revealed far more extensive cold seep activity along our coast than previously known (with over 1600 flares mapped to date). Some of the flares provide

insight into the significance of these cold seep sites to the carbon cycle with plumes reaching over a kilometre into the water column and/or reaching the ocean's surface.

NEPDEP expeditions have now visually confirmed an additional 17 cold seep vent fields (Figure 5B-1; bringing the total to 23 from the 6 documented in 2018) and have documented diverse seep ecosystems encompassing mud volcanoes, carbonate ridges, and massive mounds with gas hydrate. On-going data processing continues to reveal each site's comprehensive oceanographic, geological, and ecological characterization that generates valuable new knowledge regarding cold seep distributions, processes, and services.

NEPDEP, and collaborating partners, are working to identify key ecosystem services provided by these cold seeps, including their role in deep-sea primary production (chemosynthesis), essential fish habitat for commercial species, nursery grounds for Deep-Sea Octopuses, and stable hard substrates that support diverse communities of deep-sea species, including corals and sponges. Additionally, the extensive carbonate features and gas hydrates observed have implications for better understanding deep-sea carbon cycling in these cold seep habitats: i) the large authigenic carbonate features (e.g., rocks, crusts, chimneys) formed over thousands of years from the precipitation of carbonates from the microbial anaerobic oxidation of the bubbling methane, and ii) the large gas hydrates represent a massive reservoir of carbon built under pressure and cold temperatures. Both these processes are vulnerable to anthropogenic activities such as bottom contact fishing and warming waters due to climate change. The ROV imagery revealed widespread fishing impacts and derelict fishing gear in these areas, underscoring both the ecological vulnerability of cold seeps and their complex interactions with human activities on the seafloor.

Our updated knowledge offers crucial insights into these chemosynthetic-based ecosystems, supporting conservation and management. A meaningful example of NEPDEP collaborative research informing management occurred in September 2025. During a NEPDEP expedition, Haida and DFO scientists were using multibeam technology to map the seafloor and water column when they detected new flares along the west coast of Haida Gwaii. In real time, the team was able to evaluate and plan together a dive and the research objectives for the following day. The subsequent dive documented an impressive cold seep field that spans a feature that crosses the proposed boundary of a Marine Protected Area (Zone 504). This information is shared, through both organisations, to inform management and planning of these important areas.

NEPDEP is a United Nations Ocean Decade endorsed project that contributes to our global understanding of the deep sea through the Challenger 150 program. Project partners are the CHN, DFO, Nuu-chah-nulth Tribal Council, Ocean Networks Canada, Royal BC Museum, and the University of Victoria.

5B.3. References

DFO. 2018. Assessment of Canadian Pacific Cold Seeps against Criteria for Determining Ecologically and Biologically Significant Areas. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/002.

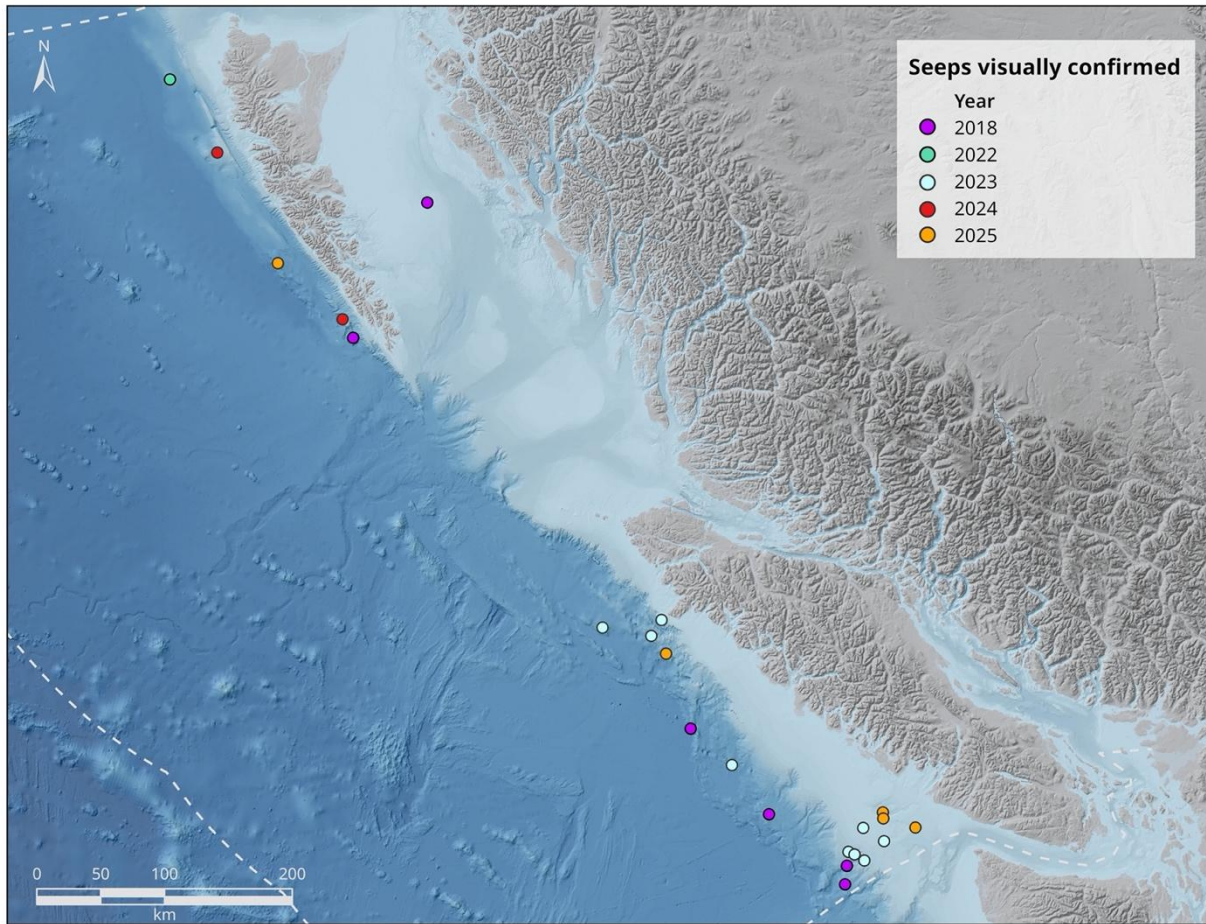


Figure 5B-1. Cold seep field sites confirmed with submersible technology over time by the NorthEast Pacific Deep-sea Exploration Project.

5C. KITKATLA OCEANOGRAPHIC HIGHLIGHTS FROM THE MARINE CONSERVATION TARGETS INITIATIVE

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5C.1. Highlights

- The biophysical overview for the proposed Kitkatla Inlet Marine Protected Area (MPA; Bannar-Martin et al. 2026) identified key knowledge gaps in water properties and exchange processes.
- Seasonal variability in dissolved oxygen partly reflects variability in source waters, as subsurface intrusions from Chatham Sound and Hecate Strait enter the Kitkatla region via Ogden Channel to the north and Beaver and Schooner Passages to the south.
- Strong mixing in Kitkatla Channel likely elevates dissolved oxygen within the proposed MPA, with surface nutrient availability also expected to be enhanced by mixing in the channel and in adjacent waterways such as Ogden Channel and Beaver Passage.

5C.2. Description of the time series

The biophysical and ecological overview of the proposed MPA within the Kitkatla region highlighted the limited oceanographic property measurements in the adjoining waterways and within Kitkatla Inlet and Channel (Bannar-Martin et al. 2026). Figure 5C-1 illustrates the bathymetry in the proposed MPA. The orange line denotes the 60 m depth contour at which

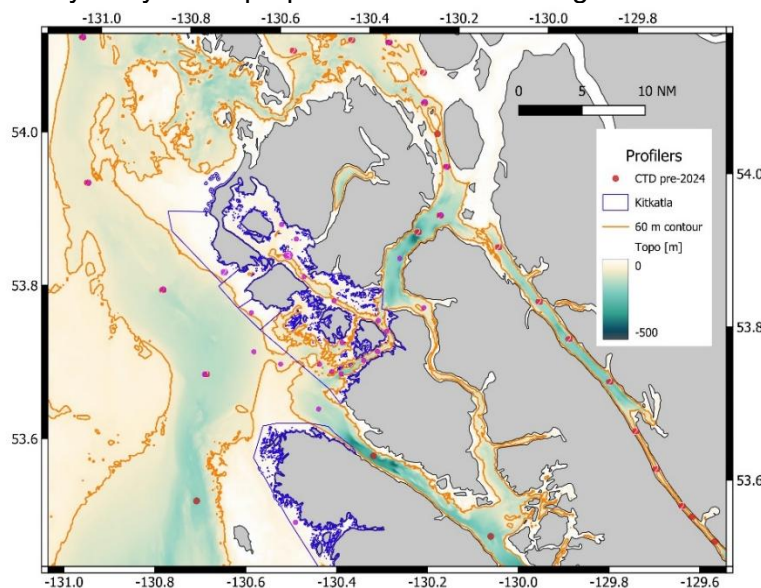


Figure 5C-1. Locations of CTD profiles collected in the Kitkatla region since 2020 in red, while the newest profiles since 2024 are in purple. Oxygen values at 100m for each survey since 2024 are in Figure 5C-2.

water can flow freely throughout all the zones. In particular, water connects with Chatham Sound, the Caamaño-Douglas area via Principe and Grenville Channel, and Hecate Strait.

Areas deeper than 60-m entering from the south into Kitkatla Channel includes Principe Channel, Beaver Passage, and Schooner Passage, and Browning Entrance which are linked with Hecate Strait.

Waterways that enter Kitkatla Channel at its northern entrance include Ogden Channel that connects with Grenville Channel and Chatham Sound via Marcus and Arthur Passages where the Skeena River flows to meet the ocean. Petrell Channel is a

secondary waterway linking the south waterway Principe Channel to Ogden Channel entering Kitkatla from the north.

In 2024, oceanographic observations in the Kitkatla region were expanded to include Kitkatla Channel and Inlet, Beaver and Schooner Passages, and Petrel Channel. The objectives were to compare water properties within Kitkatla Channel and Inlet with adjacent waterways and to identify water exchange pathways and directions. Measurements primarily consisted of conductivity–temperature–depth (CTD) profiles collected during the intertidal MCT survey (May 2024), annual mooring recovery surveys (summer 2024 and 2025), and an inlets monitoring survey (May 2025). These profiles provided temperature, salinity, fluorescence (chlorophyll-a proxy), and dissolved oxygen throughout the water column. Additional surveys planned for March and December 2026 will capture seasonal variability in freshwater inputs and their influence on estuarine circulation and subsurface intrusions, with observations spanning all adjoining waterways to assess water exchanges using water property analyses.

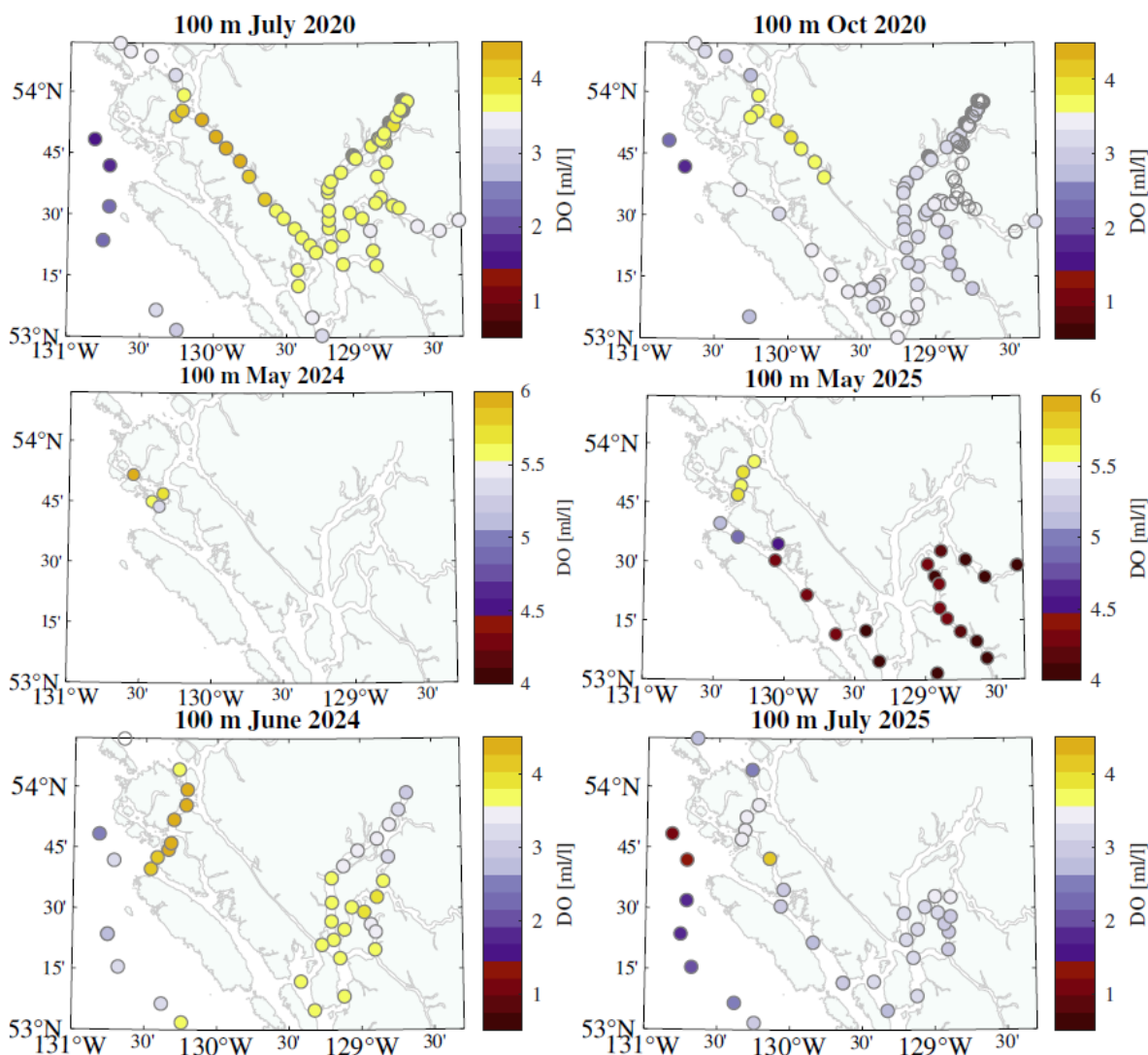


Figure 5C-2. Subsurface dissolved oxygen measured at 100 m across six different field surveys that were measured near or within the Kitkatla Inlet and Channel. Only the surveys in May 2024 and 2025 entered the proposed Kitkatla Inlet MPA (most stations are shallower than 100m). The two middle panels representing the May 2024 and May 2025 datasets are presented on a higher scale to better illustrate spatial variations in dissolved oxygen.

5C.3. Status and trends

We focused on dissolved oxygen at 100 m depth, below the intermediate layer that typically lies above ~60 m, using four datasets from 2024 and 2025 (Figure 5C-2). Mixing processes that increase deep oxygen are also associated with warmer temperatures and lower salinity (Bannar Martin et al. 2026).

At 100 m, dissolved oxygen was higher in waterways adjoining the northern entrance of Kitkatla, such as Grenville and Ogden Channels, than in water source regions such as Chatham Sound and the Caamaño–Douglas inlets and fjords. Dissolved oxygen was lower in Principe Channel than in Grenville Channel (Figure 5C-2), likely due to stronger currents and enhanced mixing in the narrower and shallower Grenville Channel, leading to warmer and fresher deep waters. South of the Kitkatla region, the lowest dissolved oxygen occurred in Hecate Strait west of Browning Entrance. Despite this, dissolved oxygen at 100 m in Principe Channel was typically higher at its western end (Figure 5C-2; May 2025), likely reflecting deep water exiting Principe Channel beneath the intermediate intrusion that entered above the 60 m isobath via Browning Entrance.

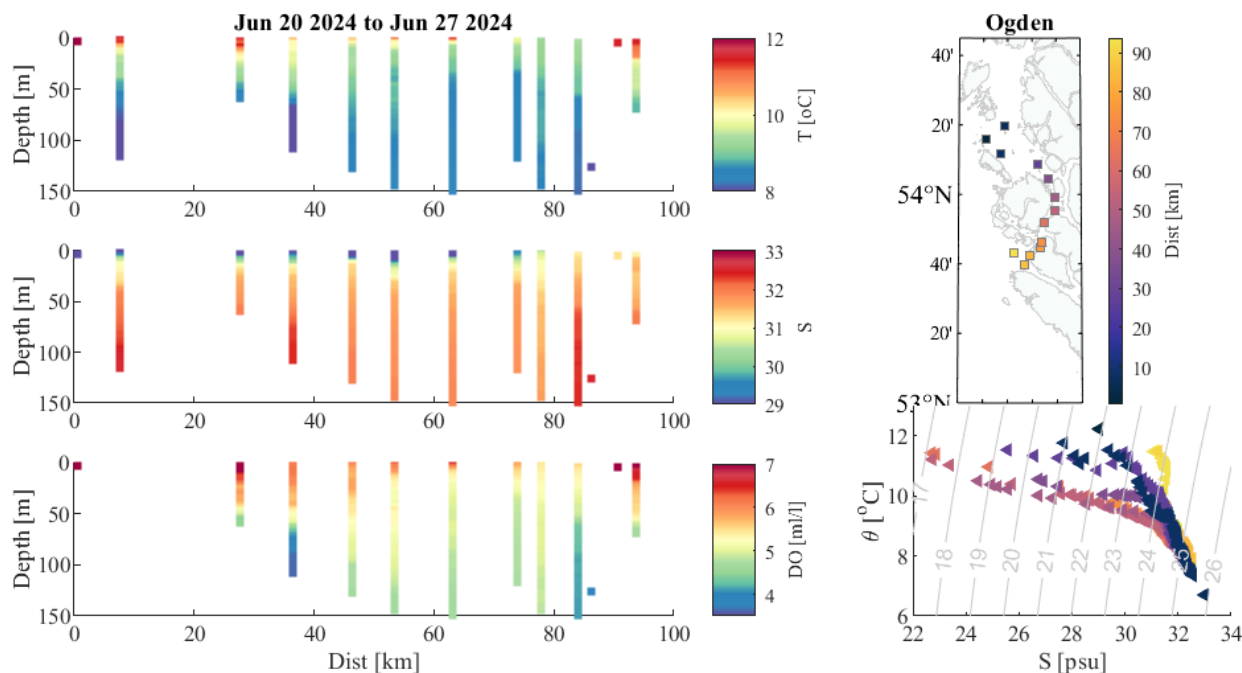


Figure 5C-3. Transects of temperature (T), salinity (S in psu), dissolved oxygen (DO) of CTD profiles collected from Chatham Sound into Marcus Passage, Arthur Passage, Ogden Channel, Beaver Passage and ending in Browning Entrance. The distance along the transect are shown in the top right map. All data were collected during the summer 2024 mooring cruise.

Seasonally, dissolved oxygen was highest in late winter due to strong winds in Hecate Strait and Chatham Sound, and lowest in late summer or early fall (Figure 5C-2), a pattern common along the B.C. coast (Bluteau et al., Section 12). Across the summer datasets from 2020, 2024, and 2025, dissolved oxygen at 100 m in the northern Ogden Channel appeared higher when oxygen concentrations were elevated in Chatham Sound, although these deep waters likely represent a mixture of Grenville Channel and Chatham Sound waters (Bannar-Martin et al. 2026). Mooring observations in Hecate Strait along Moresby Trough (SRC1) also indicated

lower dissolved oxygen in July 2025 compared to June 2024 (Bluteau et al., Section 12). The limited and inconsistent spatial coverage among summer surveys prevents assessment of conditions at the southern entrance to the Kitkatla region.

The summer 2024 dataset provided the first continuous transect of spatial observations from Chatham Sound, through Ogden Channel and Beaver Passage, and across Browning Entrance into Hecate Strait. This transect and associated property diagram (Figure 5C-3) shows this area undergoes strong mixing patterns. At the southern end of Beaver Passage (83 km) where it approaches Principe Channel, water properties resembled those of deep waters entering through Browning Entrance. Waters within Beaver Passage (60–83 km) were more oxygenated than those in Browning or Principe Channels, although intermediate waters (~50 m) in Ogden Channel exhibited higher dissolved oxygen than in Beaver Passage. Increases in dissolved oxygen began in Marcus and Arthur Passages, consistent with observations from the 2020 dataset.

5C.4. Factors influencing those trends

Kitkatla Inlet and Channel receive freshwater runoff from the Caamaño and Skeena watersheds, producing a layered estuarine circulation (Bannar-Martin et al. 2026). A shallow (< ~20 m), seaward-flowing surface layer overlies an intermediate layer that generally flows landward and occupies depths above ~60 m due to regional bathymetry (Figure 5C-1). Waters below 60 m are typically more quiescent; however, sills and constrictions (e.g., Beaver and Schooner Passages) and the exposed southern coastline promote vertical exchanges of oxygen and heat downwards, and nutrients up towards the surface through mixing processes.

The Kitkatla region lies along the outer edge of the rainfall-dominated Caamaño watershed, which peaks in fall and early winter, and is also strongly influenced by snowmelt-driven Skeena River discharge entering Ogden Channel via Arthur and Marcus Passages from May to July (Bannar-Martin et al. 2026). Despite its smaller size, the Caamaño watershed generates relatively large runoff, supplying fresher surface waters year-round to Kitkatla via Grenville and Principe Channels, particularly evident in northern Grenville Channel during winter when Skeena flows are low (Bannar Martin et al. 2026). Beneath these freshwater outflows, intermediate waters (>~60 m) intrude into the region, with Hecate Strait waters entering south of Kitkatla through Beaver Passage and a second intrusion entering from the north via Chatham Sound into Ogden Channel.

5C.5. Implications of those trends

Water properties within Kitkatla Inlet and Channel indicate that the region is relatively well oxygenated and nutrient rich compared to surrounding waterways. Conditions reflect contributions from Hecate Strait, Chatham Sound, and the nearby Caamaño-Douglas region, but are also maintained by mixing in adjoining channels, particularly Ogden Channel and Beaver Passage (Figure 5C-3). For example, surface waters at the Ogden-Grenville-Arthur junction exhibited elevated nutrient concentrations that were not depleted during summer, in contrast to surface waters in Hecate Strait (Bannar-Martin et al. 2026).

Enhanced mixing at this junction, and within Principe and Grenville Channels, produces warmer and more oxygenated deep waters near Kitkatla Channel than in Caamaño-Douglas, Hecate Strait, or Chatham Sound (Bannar-Martin et al. 2026). Strong mixing is also likely occurring at

the southern entrance of Kitkatla Channel, further elevating dissolved oxygen within the proposed MPA in Kitkatla Channel and Inlet.

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6. LAND TEMPERATURE AND HYDROLOGICAL CONDITIONS OVER B.C. IN 2025

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6.1. Highlights

- Annually, 2025 was the fifth warmest year since 1940 in B.C., while autumn was record warm. All regions experienced annual temperatures above the historical 80th percentile.
- Despite near-normal precipitation in most areas, snowpack remained below normal throughout the province, and well below normal in coastal watersheds.
- Compared to previous years, drought conditions eased somewhat in 2025; however, northeast and southeast B.C. basins continued to experience abnormally dry conditions.

6.2. Introduction

Air temperature and precipitation can provide valuable insight into seasonal conditions in B.C. that have important impacts on the northeast Pacific Ocean. This section describes the seasonal evolution of weather and snowpack conditions across B.C. in 2025 to help complement information from oceanographic data analyses. In this effort, we use monthly temperature and precipitation pseudo-observations from a global atmospheric reanalysis and both manual and automated monthly measurements of snow water equivalent from the B.C. River Forecast Center.

6.3. Description of the data

6.3.1. *Temperature and Precipitation*

Observations of temperature and precipitation made at B.C. weather stations have been compiled on an ongoing basis since 2010 under the Climate Related Monitoring Program (CRMP; [Data Portal | Pacific Climate Impacts Consortium](#)). The dataset consists of observations from the CRMP partners—the provincially run networks, BC Hydro, the Capital Regional District, Metro Vancouver, and Rio Tinto—along with data from Environment Canada’s observing network. However, due to gaps in spatial and temporal data coverage, especially in northern B.C., since 2023 we have performed the analysis using the fifth generation European Centre for Medium-range Weather Forecasting (ECMWF) Atmospheric Reanalysis Product (ERA5; Hersbach et al. 2020). This product, which ingests some of the data contained in the CRMP database as well as from other observations, comprises a gridded representation of the historical climate spanning 1940 to present at a horizontal resolution of approximately 30 km x 30 km over the globe.

Long-term records of mean monthly temperature and precipitation were used to calculate 30-year climate normals for each month in the recent historical climate (we used 1981-2010, but our results are independent of the chosen period due to the use of relative rankings; see below). Anomalies in monthly temperature and precipitation were then computed relative to these normals for the entire 1940 to 2025 time series covering B.C. The time series of gridded anomalies were then spatially divided among the B.C. River Forecast Centre’s 23 Snow Index Basin regions. Spatial averages were taken across each region to form a monthly time series of

regional anomalies, which were then aggregated into seasonal and annual values. Finally, the anomalies were ranked by magnitude to assess how each season in 2025 compares with those of all previous years, for each variable. We define the first percentile and number 1 ranking as the warmest/wettest over the 86-year period of 1940 to 2025 and the 100th percentile as the coldest/driest with a ranking of 86. We define broad anomaly categories ranging from record cold/record dry, much below-normal, below-normal, near normal, above-normal, much above-normal, record warm/record wet. These categories correspond to the percentile bins 100th, 100th to 90th, 90th to 66th, 66th to 33rd, 33rd to 10th, 10th to 1st, and 1st, respectively.

6.3.2. Snow

Monthly measurements of snowpack are made by the Ministry of Environment and Climate Change Strategy and BC Hydro through manual snow surveys and automated snow weather stations across the province. Snowpack monitoring is important because in most basins, early spring snowpack strongly influences the potential for riverine flooding during the late spring melt season, and the potential for hydrologic drought in summer and fall. In addition, the Ministry of Forests River Forecast Centre compiles monthly snowpack data (snow water equivalent) at available stations from early January through June. In each region, the ratio (percentage) of the monthly snowpack, averaged over stations, to the 1991-2020 mean value reflects how the current year's accumulated snow amount compares with historical normals.

6.4. Status and trends

6.4.1. Temperature and Precipitation

In 2025, the average annual temperature across B.C. was the fifth warmest since 1940 (Figure 6-1, left). All basins ranked in the top quintile of the entire record. Temperatures were the second-warmest ever in the Kootenays, Similkameen and Okanagan regions. Annual precipitation anomalies were near normal across the province (Figure 6-1, right).

Seasonal temperatures were above normal over all basins in B.C., and well above normal in spring and fall. Summer temperatures reached well above normal levels in southern coastal basins only. Otherwise, summer temperatures were less remarkable than in previous years. On average, autumn was warmest across the province, with record warm temperatures in the Northwest and throughout the Southeast.

Over the winter of 2024-2025, precipitation amounts were near normal in northern basins, but below normal elsewhere. In spring, conditions were wetter than normal over much of the province, much wetter in Haida Gwaii and the Northwest. By contrast, precipitation over the Northeast was below- to well-below normal. By summer, precipitation returned to near-normal over much of the province, but with below normal amounts recorded in the interior and south coast. Precipitation in these areas returned to near-normal levels in fall, and indeed over most of B.C. except the northeast and southeast. While some basins in these areas ranked in the lowest historical quartile of precipitation, amounts were larger than in recent years.

BC Temperature: **well above** normal

BC Precipitation: near **normal**

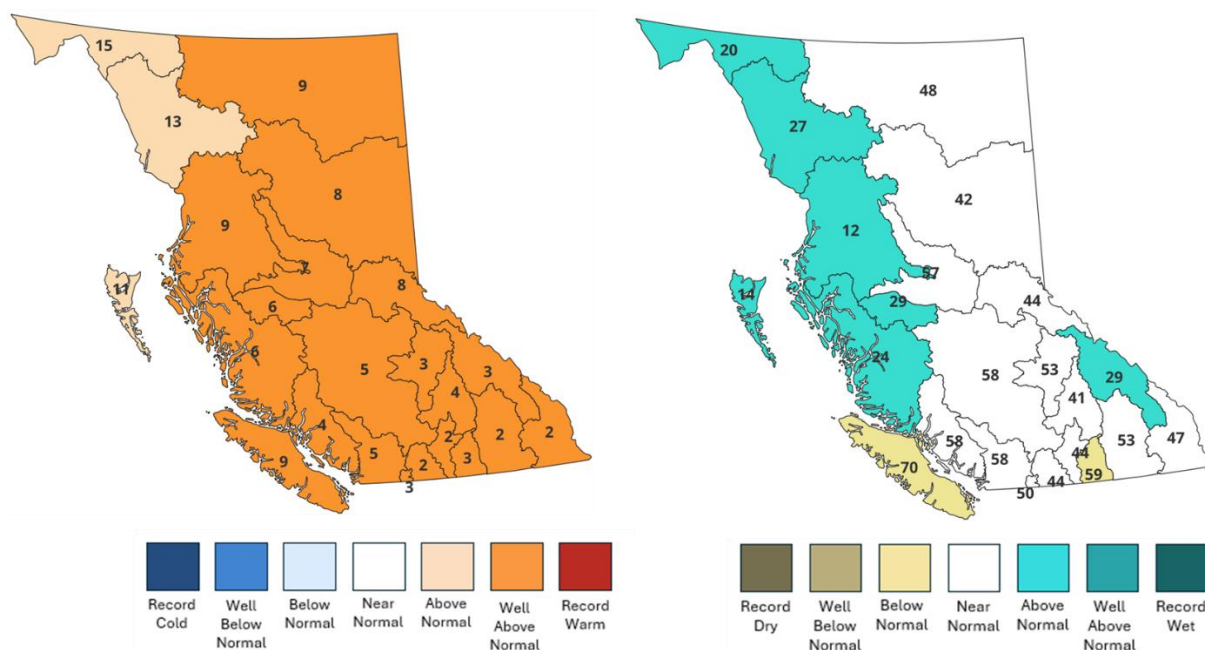


Figure 6-1. Annual anomalies for average daily mean temperature (left panel) and total precipitation (right panel) for 2025 in B.C. Colour scale is based on percentiles as provided in the text. Labels on the map refer to ranking by year (1940 – 2025) with 1 being the warmest/wettest year and 86 being the coldest/driest year. Results are based on the ERA5 Reanalysis product from ECMWF: <https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5>.

Using recent analyses of trends in seasonal and annual temperature and precipitation anomalies, we report province-wide trends for the time period spanning 1948 through 2023. Temperature trends are more easily detected due to the smaller spatial and interannual variability compared to precipitation data. The trends in mean monthly temperature are positive and statistically significant ($p < 0.05$) annually and in all seasons except autumn (Table 6-1). The trends in precipitation are positive and statistically significant in spring, autumn and annually. The computed trends for the 1948-2023 period presented here differ from those for 1940-2024 presented in last year's report, due to the different temporal range and datasets used.

Table 6-1. Linear trends in seasonal and annual daily mean temperature and total precipitation, spatially averaged over B.C. Only trends that are significant at the 5% significance level are shown. Temperature trends are calculated from the CanGridT monthly V3.1 dataset (recently updated from Vincent et al. 2020), while precipitation trends are computed from the CanGridP monthly V2 dataset (Wang et al. 2026). Note: last year's version of the table reported trends calculated from 1940-2024 for both variables from ERA5. The CanGrid analyses were not available until 2025, and are considered more reliable than ERA5 for Canada, although they presently extend only to 2023.

Trends over 1948-2023	ANN	MAM	JJA	SON	DJF
Mean Temperature ($^{\circ}\text{C decade}^{-1}$)	+0.26	+0.23	+0.21	+0.13	+0.44
Precipitation ($\% \text{ decade}^{-1}$)	+1.3	+3.3	–	+2.0	–

6.4.2. Snow

While snowpack briefly reached near-normal levels in eastern B.C. over the early winter of 2024-2025, abnormally low snowfall over subsequent months led to below-normal levels by spring, ranging from 45 to 85% of normal (Figure 5-2; River Forecast Center 2025). Due to rapid snowmelt during the unusually warm spring (see above), no basins retained more than 65% of their normal snowpack by June 1, except for the Stikine. Snowpacks in the coastal basins were all <50% of normal. This demonstrates that despite the near-normal annual precipitation, seasonal and regional deficits coupled with abnormally warm winter and spring temperatures strongly limited snowpack recovery over most of the province.

6.4.3. Hydrologic drought and streamflow

Compared to the severe hydrologic drought levels that affected B.C. from 2022-2024, conditions in 2025 eased somewhat in many regions due to wet conditions in fall 2024 and spring 2025. Drought was largely alleviated in coastal basins. An exception was the Northeast, where severe drought persisted into July. Due to the well above normal spring temperatures, freshets occurred earlier than usual with below normal peak flows due to lower snowpacks. From June through November, many Interior basins (e.g., Columbia and Okanagan) faced moderate to extreme drought. The proportion of B.C.'s agricultural land areas experiencing abnormally dry to extreme drought progressed from roughly 50% in early May to around 95% by November.

6.5. Factors behind trends and implications

Observed temperature anomalies in 2025 are consistent with ongoing warming in B.C., as indicated by the trend analysis (Table 6-1). According to the data shown in Table 6-1, annual mean temperatures in B.C. have risen by $0.26\text{ }^{\circ}\text{C decade}^{-1}$ on average over the last 76 years, exceeding the global mean temperature trend of $+0.16\text{ }^{\circ}\text{C decade}^{-1}$ (using 1950-2024 ERA5 data from KNMI Climate Explorer 2025).

Indices of tropical Pacific Ocean temperatures (e.g., the Oceanic Nino Index; Lindsey 2009) indicated a mostly neutral ENSO state during 2025, with the emergence of a weak La Niña pattern from October through December ($\text{ONI} < -0.5$). This is consistent with the near-normal precipitation patterns seen in B.C. over most of the year.

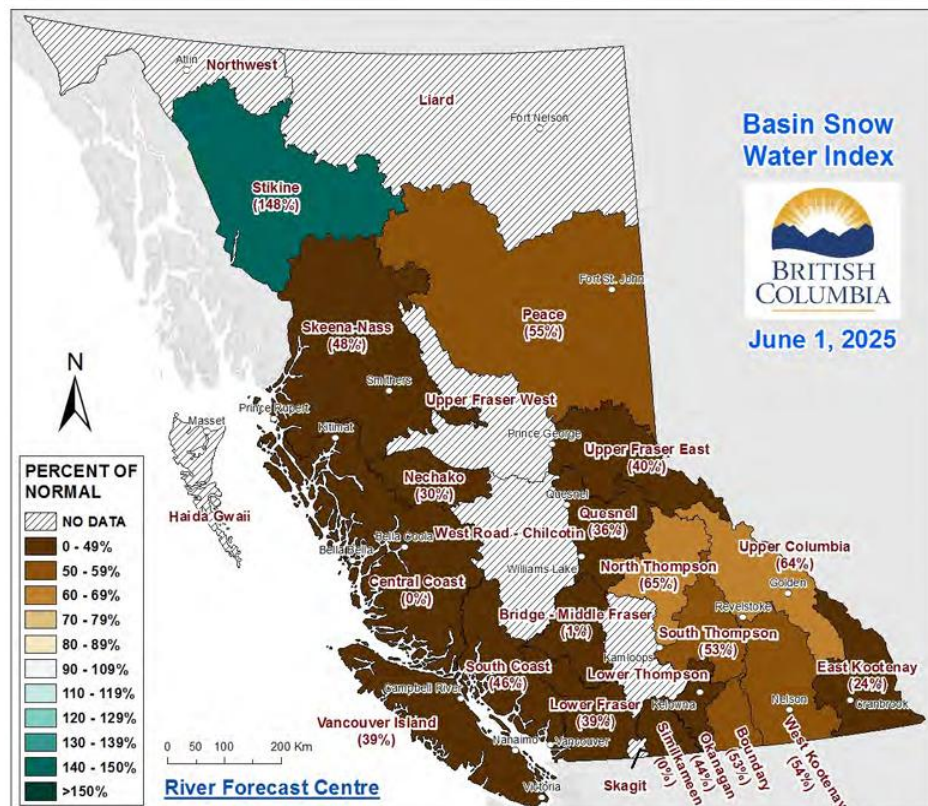
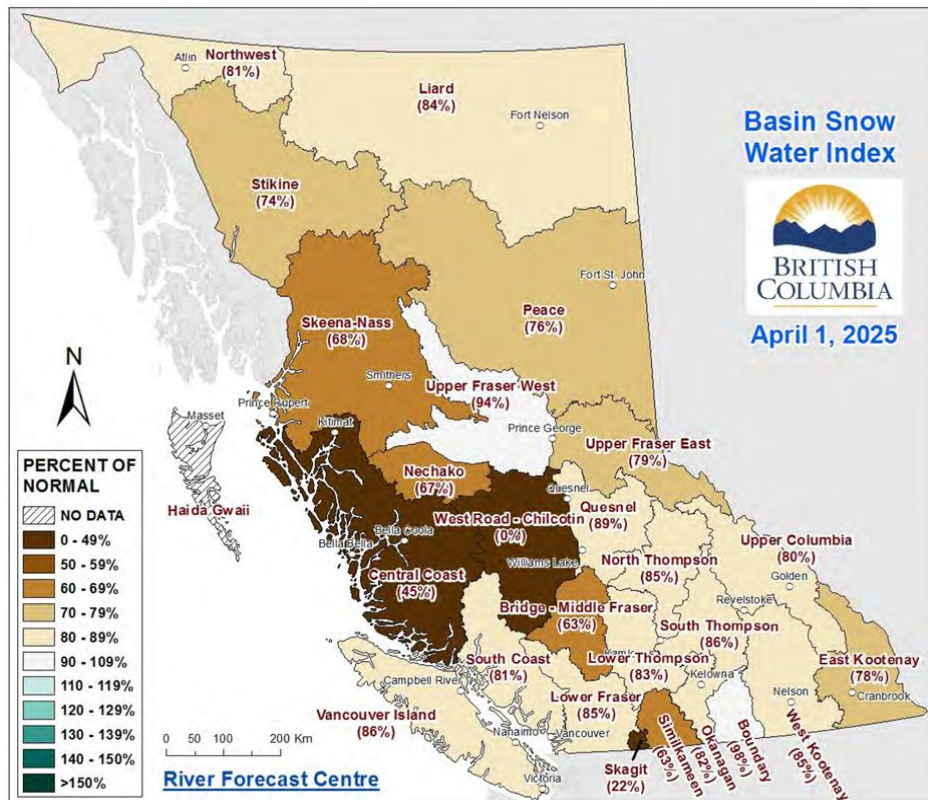


Figure 6-2. B.C. snowpack, expressed as a fraction of 1991-2020 amounts, for April (above) and June (below), 2025. Maps were produced by the B.C. Ministry of Forests River Forecast Centre (River Forecast Centre 2025).

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7. RIVER DISCHARGE TO THE COASTAL PACIFIC OCEAN OF B.C. IN 2025

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7.1. Highlights

- In 2025, very low January discharge was observed from diverse small coastal watersheds (e.g., Sarita, Oyster, Yakoun).
- Below average snowmelt freshet (May – June) was observed across large continental watersheds (Fraser, Skeena, Nass) and small coastal watersheds (e.g., Kitimat, Oyster, Stawamus).
- Above average fall/winter flows were observed across diverse watersheds.
- Estimated Fraser River discharge at the outlet was well above normal in December. The magnitude of this runoff anomaly would have been significantly underestimated by relying on discharge data from the commonly used Fraser River gauge at Hope.

7.2. Description of the time series

Freshwater discharge has important effects on the physical, chemical, and biological dynamics of the northeast Pacific coastal ocean (e.g., Carmack et al. 2015). Long-term river discharge data can help explain anomalies in long-term oceanographic datasets. While large continental watersheds like the Fraser are important point sources of freshwater runoff, thousands of small coastal watersheds (< ~10,000 km²) are thought to produce an important “line source” of freshwater to the larger coastal margin (e.g., Royer 1982). The main goal of this study was to report freshwater discharge anomalies from all of the large continental watersheds and a range of representative small coastal watersheds on the B.C. Pacific coast. A second goal was to determine if conclusions about Fraser River discharge anomalies are sensitive to assumptions about flow contributions from downstream of the commonly used gauge at Hope.

Our study area is the coast of B.C. and the associated drainage areas within B.C. Streamflow regimes in the region vary from pluvial (rain), to nival (snow), to glacial, to several hybrid regimes, depending on catchment characteristics (Eaton and Moore 2010; Giesbrecht et al. 2022). For each of five major watershed types, we selected three representative gauges (Figure 7-1) while considering the following criteria: gauges should be spatially distributed along the coast, representative of diverse watershed types and characteristics (e.g., elevation, glacier cover, mean annual precipitation, and precipitation as snow), located near the watershed outlet, have high quality data, and have at least a 30-year record. To select representative gauges, we referenced the geospatial (watersheds) data and historical average streamflow regimes from a previously published watershed classification analysis (Giesbrecht et al. 2022).

Discharge data were acquired for the period 1996 – 2025 from the Water Survey of Canada (WSC). Data from the most recent calendar year (2025) are typically in a provisional state in March when the State of the Pacific Ocean (SOPO) meeting takes place. We used R (R Core

Team 2024) and a recently updated version (v 1.0.0) of the tidyhydat package (Albers 2017) to acquire both approved historical data and provisional data from the WSC. Long-term summary statistics were computed using the FASSTR package (Goetz et al. 2023) for the period 1996 – 2025. For consistent interpretation, we define the 30-yr normal range by 25th to 75th percentiles.

The best available single gauge on the mainstem of the Fraser – the Fraser River at Hope gauge (08MF005; 217,000 km²) – is located 150 km upstream of the outlet and misses the discharge from 6.5% of the total Fraser River watershed (232,137 km²). We accounted for the area downstream of Hope (15,137 km²) by summing flows from the three main gauged tributaries (1,851 km²) and by predicting flows from the ungauged area (13,286 km²). Daily discharge in the ungauged area was predicted with area-scaling of discharge from a donor watershed with a broadly similar climate (Chilliwack River). We used historical data from the Port Mann gauge (1983 – 1992) – which captures 232,000 km² and 99.9% of the watershed area – to assess the accuracy of our estimated outlet discharge. Two of the Fraser-tributary gauges had data gaps, which we filled using linear regression with a gauge on the Coquihalla River (~3% of the Chilliwack timeseries with $R^2 = 0.83$ and ~2% of Chehalis timeseries with $R^2 = 0.68$).

7.3. Status and trends

Snow continental watersheds in B.C. (Fraser, Skeena, Nass) typically have a sustained period of snowmelt-driven runoff, with flows rising through April and May, peaking in June, and snowmelt-sustained flows that can extend into July and sometimes August (Figure 7-1). In 2025, spring freshet was below average (May – June) in all three watersheds and below normal from May through September in the Fraser River watershed. This is similar to the low-freshet anomaly in 2024 but less pronounced. Both the Fraser and Skeena rivers were above normal in December 2025.

Glacierized mountain watersheds are normally at low flow in the winter months and high flow in the summer (Figure 7-1). In 2025, May – July flows from the Wannock and Klinaklini rivers were near or below the low end of the normal range. Homathko river showed a different pattern with near normal flows in June followed by above normal flows from July through September. December discharge was well above normal in all three watersheds.

Snow mountain watersheds normally have a period of high flow in spring and early summer due to snowmelt and a period of high flow in fall and early winter due to rainfall events (Figure 7-1). In 2025, two of the three rivers had above normal flows in March. All three had spring flows at or below the lower end of the normal range and fall/winter (Oct – Dec) flows above the normal range.

Rain mountain watersheds normally have high discharge in the fall and winter followed by declining flows in spring and a low flow period in summer (Figure 7-1). In 2025, January flows were well below normal, March flows were near or above the upper end of the normal range, May – July flows were below normal, and some fall/winter months (Oct – Dec) were above normal.

Northern rain hill watersheds typically have runoff timing that is broadly similar to rain mountain watersheds, but with a longer low-flow period in summer (Figure 7-1). In 2025, flows were well

below normal in January and below normal in February, in the two rivers with data. Above normal flows were observed at Yakoun and San Josef in May, August, and December.

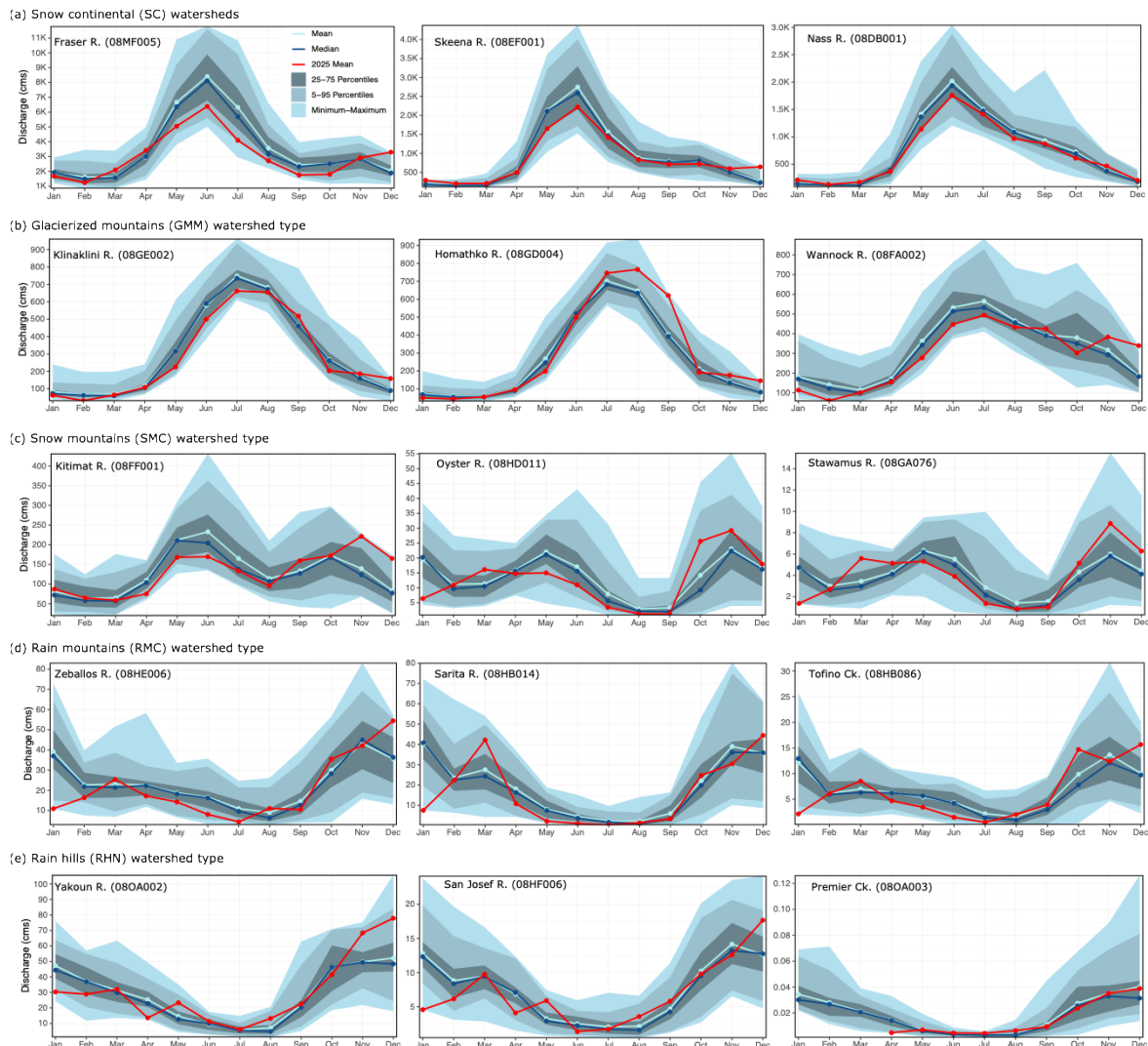


Figure 7-1. Mean monthly discharge in 2025 compared to historical summary statistics (1996 – 2025), for different watershed types in B.C. Rivers (names top left corner) and gauge station identification numbers (parentheses) are noted on each panel.

Estimated Fraser River outlet discharge was 1.4 times the observed discharge at Hope and Port Mann discharge was 1.5 times the observed discharge at Hope. Our findings suggest the gauge at Hope significantly underestimates the magnitude of Fraser River discharge to the coastal ocean, particularly during runoff events in the fall and winter (Figure 7-2). Unusually high flows in December 2025 were estimated for the outlet but were not observed at Hope. Similarly, March 2025 flows were estimated to be more unusually high at the outlet than at Hope. Despite these differences, both the Hope gauge and our outlet estimate suggest that Fraser River discharge was below normal from May through September in 2025.

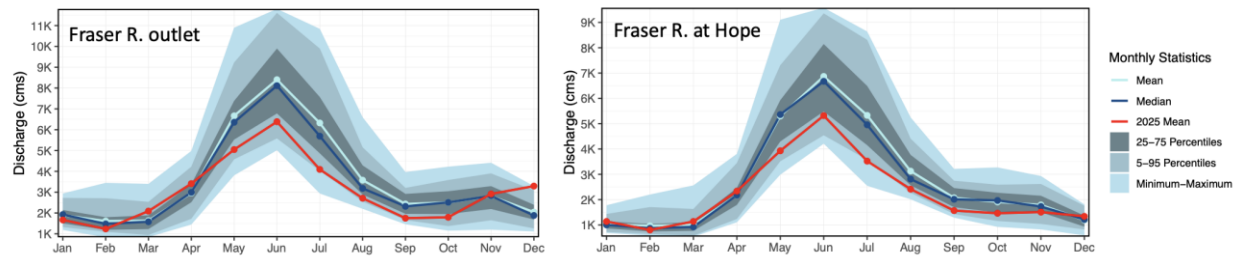


Figure 7-2. Comparison of estimated discharge at the Fraser River outlet (left) and observed discharge at the Hope gauge 150 km upstream on the Fraser River.

Limitations

Two main limitations should be considered. First, the provisional flow data used in this analysis are subject to change by the Water Survey of Canada during final data review. Second, the reported discharge from the Skeena River must underestimate the true discharge to the coast because the gauge we used (the best available single gauge on the Skeena River) is located well upstream of the outlet. Future work should estimate Skeena River discharge at the outlet given the significant area of coastal mountains downstream of the gauge.

7.4. Factors influencing trends

Unusually low discharge in January was associated with unusually low precipitation that month (BC River Forecast Centre 2025). A low winter snow pack contributed to below normal spring – summer discharge; a pattern that was more pronounced in 2024 (BC River Forecast Centre 2025). High rainfall including significant atmospheric river events (Ardizzone 2026) led to above normal flows in the fall – winter months.

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8. NORTHEAST PACIFIC CONTINUES TO BE FRESH, AND TEMPERATURES WERE HIGH DESPITE STRONG LA NIÑA CONDITIONS THROUGHOUT YEAR

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8.1. Highlights

- Temperatures in the NE Pacific (NEP) were warm in 2025.
 - This continues the recent phenomenon of the NEP being out of phase with the globe: 2023 and 2024 were warmest years on record globally and near normal in NEP, while 2025 was cooler globally and warmer in the NEP.
- Winter mixing in 2024 and 2025 was weak, like the Blob years.
- NEP surface waters continue to be fresher than normal (now for the past nearly 10 years).

8.2. Description of the time series

Sea surface temperatures (SSTs) were collated from the NOAA Physical Science Laboratory website ([NOAA Extended SST v4](#)). Pacific climate indices examined in this report include the Relative Oceanic Niño Index ([RONI](#)), North Pacific Index ([NPI](#)), Pacific Decadal Oscillation ([PDO](#)), Southern Oscillation Index ([SOI](#)), and North Pacific Gyre Oscillation ([NPGO](#)) (see Ross and Robert 2021, Section 7.3., for descriptions of all indices except the RONI).

The **Relative Oceanic Niño Index (RONI)** is a monthly index which is a 3-month running mean of the relative Niño-3.4 index plotted on the center month. The relative Niño-3.4 index is the difference between SST anomalies in the Niño 3.4 region (5° N-5° S, 120°-170° W) and the tropical mean (SST anomalies for the entire tropics, 20° S - 20° N). This comparison to the entire tropics is the key change from the previously used ONI index; it's been shown that this differencing better accounts for global warming (L'Heureux et al. 2024). As with the Niño-3.4 index, SST anomalies are calculated based on 30-year base periods that are updated every 5 years. The relative index is then rescaled to match the amplitude of the traditional index to provide continuity with historical thresholds. RONI is provided by the NOAA's National Weather Service National Centers for Environmental Prediction CPC: https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso/roni/.

Sub-surface profiles of temperature and salinity were obtained from the Line P time series and Argo float data. Line P is an oceanographic survey line that started in 1959; it extends from the mouth of the Juan de Fuca Strait to Ocean Station Papa (OSP) at 50°N and 145°W in the middle of the Gulf of Alaska (Freeland 2007). Typically, there are three cruises per year, in Feb/Mar, May/Jun and Aug/Sep. Each gives specific information: the Feb/Mar cruise tells us the depth of the winter mixed layer (MLD) or how deep the waters are well mixed with constant temperature and density, as well as how stratified the ocean is; both are key to understanding delivery of nutrients into surface waters to fuel primary productivity (the rate at which phytoplankton convert sunlight to usable energy which is then moved up the food chain by zooplankton). The May/Jun cruise allows us to see how much nutrients were consumed by

phytoplankton during spring and exactly how much nutrients are still available for summer primary production, and the Aug/Sep cruise tells us how much of those nutrients have been used and how good the primary and secondary production was for that summer (Peña and Varela 2007; Kwong et al. 2022).

Argo float data are also used to create a synthetic Line P section for each calendar month. Argo floats typically profile from 2000 decibars to the surface every 10 days, reporting temperature and salinity in near real-time (Wong et al. 2020). Since mid-2001, the Gulf of Alaska has supported an array of Argo floats and their observations were used to interpolate temperature and salinity profiles at each Line P station. Argo temperature and salinity data were accepted into the computation from a wide area of the Northeast Pacific (NEP), but the interpolation was carried out using a Gaussian covariance function with a 300 km e-folding scale (Freeland and Ross 2019). For each month, the mean profile is centered on the 15th and data are accepted into the interpolation with a time window of ± 15 days. Since the Argo record is still short of the 30-year standard for climatologies, these Argo-based synthetic Line P data are plotted as anomalies referenced to a seasonally-corrected mean of temperature or salinity based on a combination of Argo and Line P cruise data.

8.3. Status and trends

Based on NOAA's land and SST data dating back to 1880, 2025 was the third warmest year on record globally (NOAA State of the Climate 2025). This is consistent with the recent trend, wherein all ten of the warmest years globally are in the last decade. In ranked order, the ten warmest years are 2024, 2023, 2025, 2016, 2020, 2019, 2017, 2015, 2022 and 2021. Despite the less warm year globally, sea surface temperatures (SSTs) in the NEP were warmer in 2025 relative to 2024; in 2025 SSTs were $\sim 1^\circ\text{C}$ above the average for the 1991-2020 base period (www.ncdc.noaa.gov/sotc/service/global/map-blended-mntp/202501-202512.png).

In the NEP, the seasonally-averaged SSTs were slightly warmer than the 1991-2020 climatological values throughout 2025, but most notably during the summer marine heatwave (JAS; Figure 8-1). Coastal temperatures were normal throughout the first half of the year (Figure 8-1) and warmer than average in the second half. Also notable was the large negative SST anomalies near the equator (Figure 8-1); i.e., the La Niña conditions throughout 2025. La Niña typically increases SST in the NEP, so the warm temperatures throughout 2025 (Figures 8-1 and 8-2) are in spite of, not because of, the La Niña. From the Ocean Station Papa timeseries (OSP; 50N, 145W; Figure 8-2), we can see that the warmer than average temperatures extended throughout the upper water column (0-200 m) and that the largest extremes were below the seasonal mixed layer (e.g., short-lived anomalies exceeding 3 standard deviations at 80 m and 150 m).

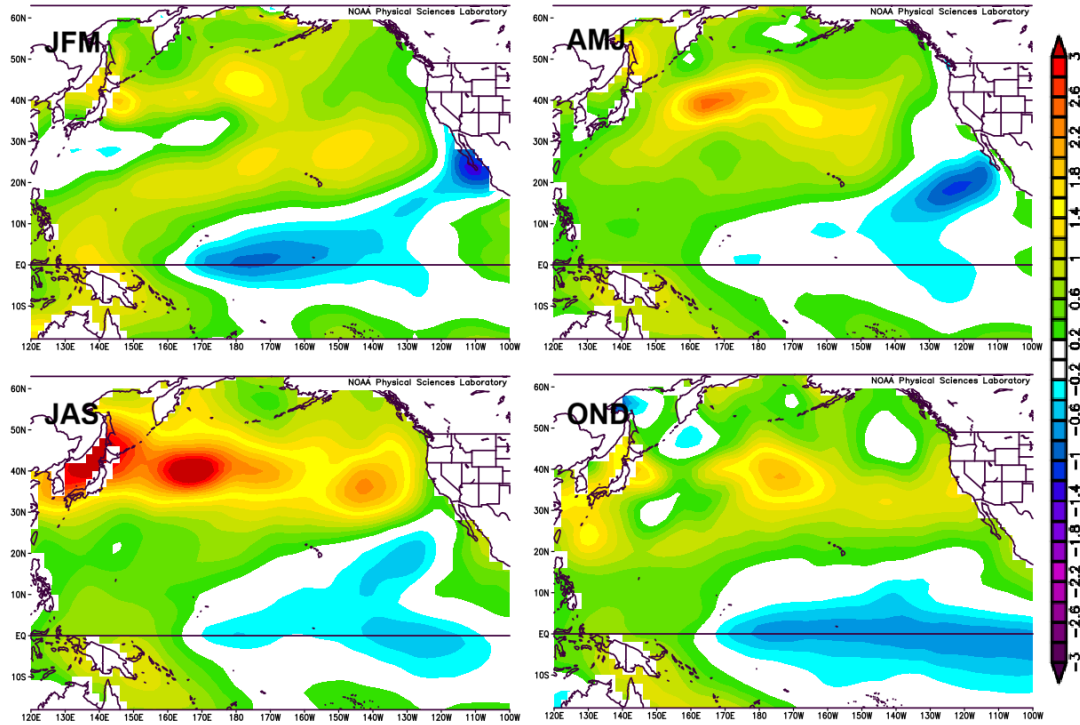


Figure 8-1. Seasonal maps of temperature anomalies in the Pacific Ocean for each quarter in 2025 (labelled by month groupings). The colour bar on the right, showing the temperature anomaly in °C, applies to all panels. Anomalies are relative to 1991-2020 base period. Source: NOAA Extended SST v4 <http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl>.

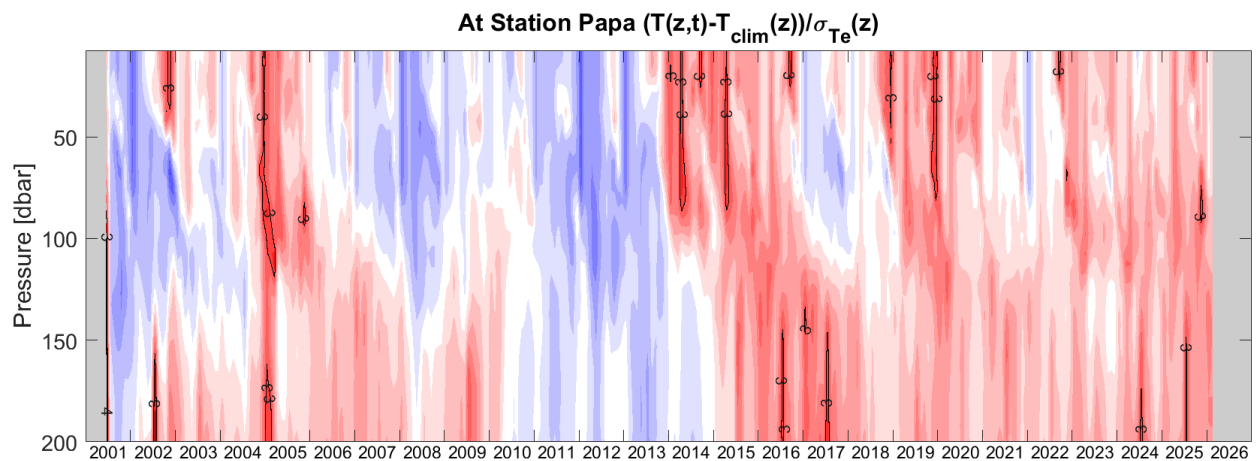


Figure 8-2. Plot of temperature anomalies, as observed by Argo floats near Ocean Station Papa. Anomalies are calculated relative to the 1991-2020 seasonally-corrected mean and standard deviation (from the Line P time series). Cool colours indicate cooler than average temperatures and warm colours indicate warmer than average temperatures. Dark colours indicate anomalies that are large compared with standard deviations from the climatology. The black lines highlight regions with anomalies that are 3 and 4 standard deviations above the mean.

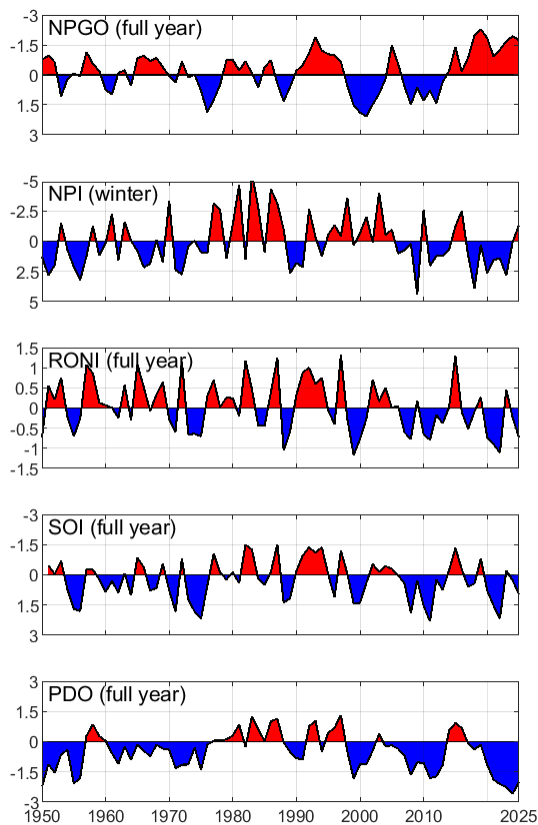


Figure 8-3. Time series of yearly-averaged Pacific climate indices (with the exception of the NPI which is averaged over NDJFM). Some series are reversed so that all series are red when coastal B.C. waters tend to be warm.

There were strongly negative Pacific Decadal Oscillation (PDO) conditions throughout 2025 (Figure 8-3), but this did not result in a cool year for the NEP because it occurred on a background of steadily rising temperatures due to climate change. The PDO is a measure of the strength of a SST pattern with positive values when the eastern North Pacific is warm relative to the western North Pacific. Like 2024, there were more extreme marine heatwaves in the western North Pacific in 2025, and we saw a strongly negative PDO state and warm temperatures in the NEP (Figure 8-1), particularly in summer, but also spring and fall. With climate change, we can (and did) have a strong negative PDO state and warm temperatures in the NEP.

Looking at the climate indices collectively (Figure 8-3), they do not show a clear pattern. The North Pacific Gyre Oscillation (NPGO) and North Pacific Index (NPI) pointed to a warm year in the NEP in 2025. Meanwhile, the Relative Oceanic Niño Index (RONI), PDO, and the

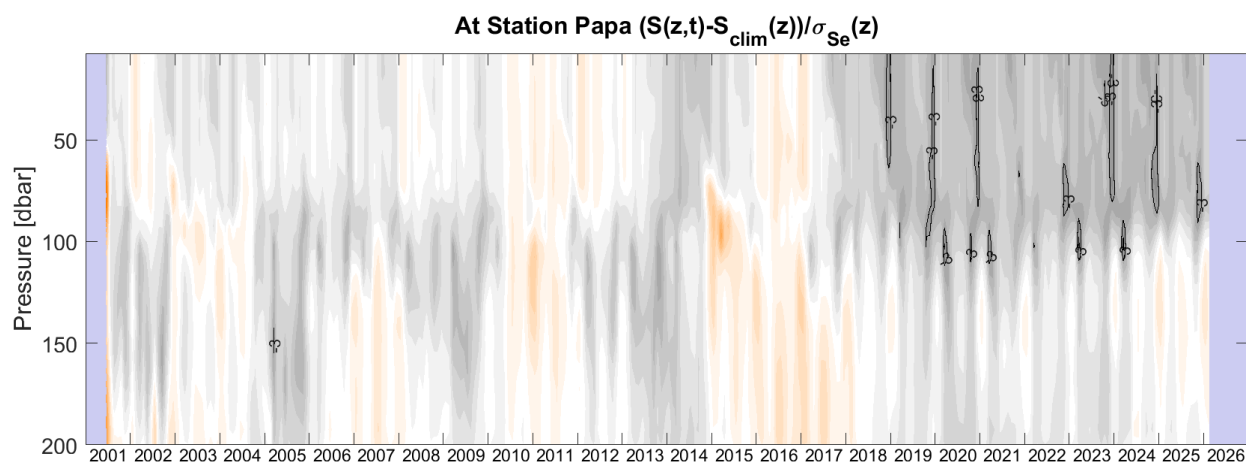


Figure 8-4. Plot of salinity anomalies as observed by Argo floats near Ocean Station Papa, with anomalies calculated relative to the 1991-2020 seasonally-corrected mean and standard deviation (from the Line P time series). The grey indicates fresher than average and orange indicates saltier than average. Dark colours indicate anomalies that are large compared with standard deviations from the climatology. The black lines highlight regions with anomalies that are 3 and 4 standard deviations below the mean.

Southern Oscillation Index (SOI) suggested the opposite. Strangely, while almost all the indices were similarly cooler tending or more weakly warmer tending in 2025 than in 2024, temperatures in the northeast Pacific were warmer in 2025.

At OSP in the Alaskan Gyre, the water continued to be slightly warm and quite fresh, consistent with the last 7-8 years. As mentioned earlier, temperatures in the upper 200 m were warmer than the 1991-2020 mean in 2025 (Figure 8-2). It is the salinity anomaly timeseries that is more striking, however, showing that 2025 continues the series of years with very large salinity anomalies above 100 m depth (relative to the 1991-2020 Line P climatology; Figure 8-4). We have observed anomalies 3 standard deviations above the typical variability each winter and less extreme negative anomalies throughout the year.

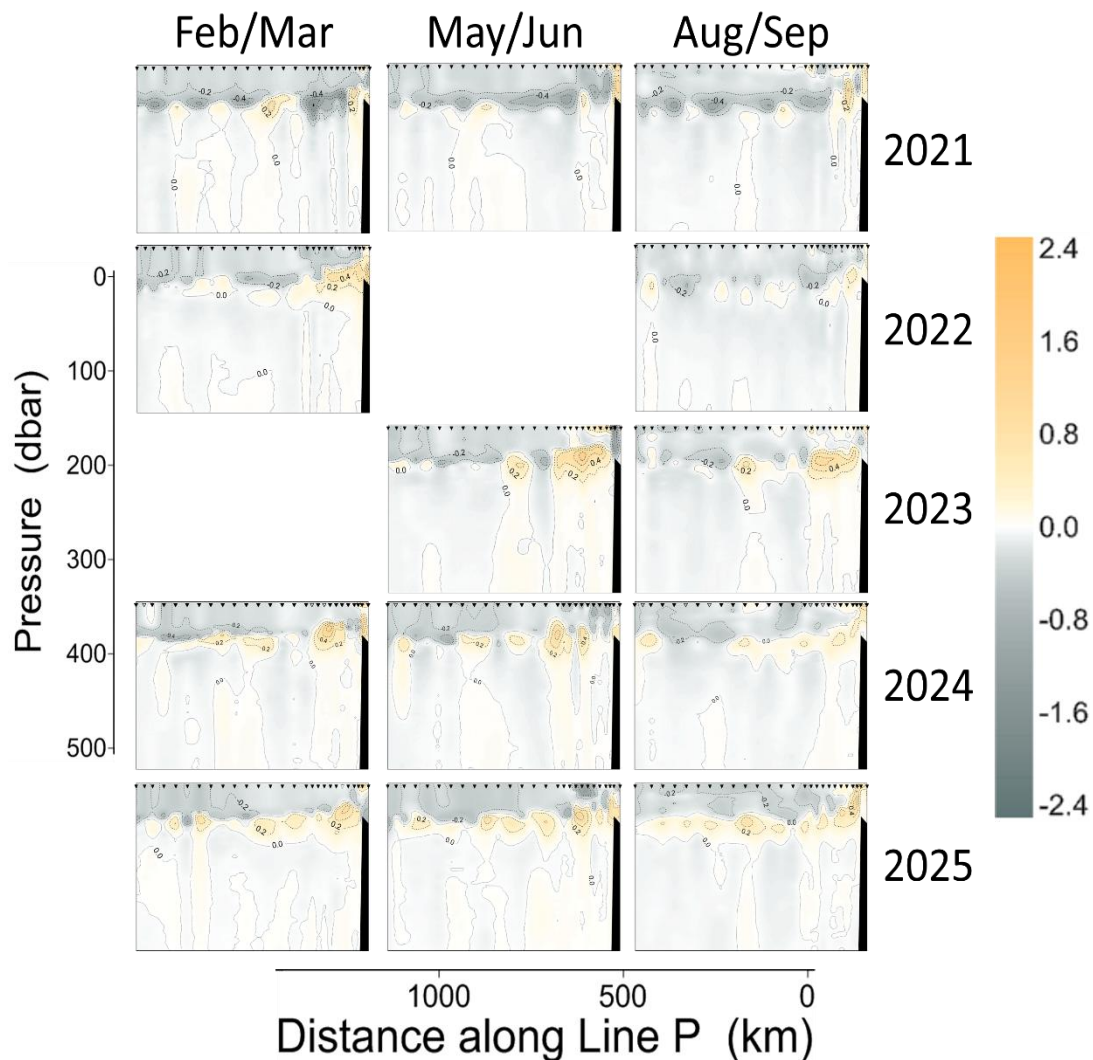


Figure 8-5. Salinity anomalies (psu) along Line P from 2021 to 2025 with respect to the 1991-2020 mean. NB: Aug 2024 and all 2025 data are preliminary (i.e., have not been quality controlled and adjusted).

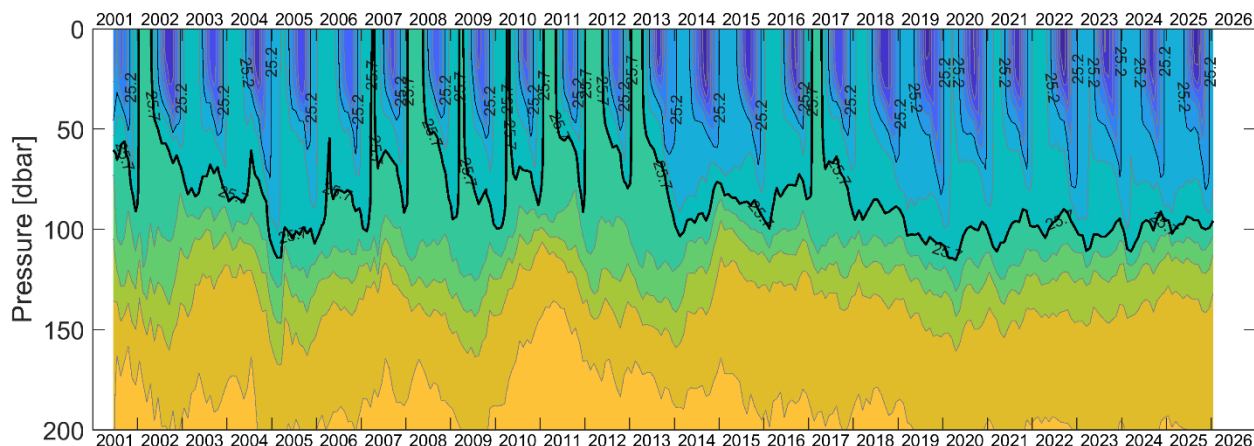


Figure 8-6. Coloured contour plot of density as observed by Argo floats near Ocean Station Papa (P26: 50° N, 145° W). The colours indicate potential density (yellow is denser and blue lighter). The black lines highlight the $\sigma_t=25.2$ kg/m³ (thin) and 25.7 kg/m³ (thick) isopycnals.

The section plots along Line P show that the salinity anomalies in the upper 100 meters stretch from OSP to the B.C. coast (Figure 8-5). The salinity anomalies have been similar in magnitude since 2021 and while usually consistent across Line P, there were some positive salinity anomalies near the coast in the late-summer cruise. The magnitude of these salinity anomalies is -0.2 psu, which has an equivalent effect on surface water density as a 0.7°C warming.

The winter stratification was stronger in 2024/25 and 2023/24 relative to recent years (Figure 8-6) suggesting less winter mixing than in the previous 5 years. For context, the 2024/25 winter stratification was similar to the 2018/19 winter and the 'Blob (2014-2016)' years. Thus, the mixing of nutrients to the surface was likely weaker in 2024/25 relative to normal, and quite similar to the extreme heatwave years.

8.4. Factors influencing trends

The warmer than normal temperatures observed in the northeast Pacific were in spite of both the PDO and ENSO being in a cool phase, which highlights how much more important the background of long-term climate warming has become. The salinity anomalies, i.e., the freshening of the surface waters in the northeast Pacific in the last 7-8 years, has been recently linked to weakening production of Okhotsk Sea Intermediate Water (Whitney 2025) and increased river discharge due to accelerated glacial melt (e.g., Hugonnet et al. 2021; Whitney 2025).

8.5. Implications of those trends

With the PDO in a cool phase and the temperatures slightly warm, it is likely that during the next positive PDO, the northeast Pacific will be extremely warm. And this is not just at the surface. At Ocean Station Papa, there haven't been any negative anomalies in the upper 200 m since early 2022 and there hasn't been a "cool year" since 2013 (Figure 8-2).

The ‘Blob’ and the 2019-20 marine heatwave reduced winter mixing (Freeland 2015; Ross and Robert 2021), which led to surface nutrients among the lowest on record in the summer of 2019 (Peña and Nemcek 2020). The history of the $\sigma_\theta=25.7$ kg/m³ isopycnal (highlighted with a thick black line in Figure 8-6) illustrates this nicely. It remained very deep throughout the 2014-2016 marine heatwave, deeper even than much of the 2003-2005 warm period, while in 2017-2018 mixing was similar to 2007-2013 and it shoaled during the winter. Mixing decreased again during 2019-20 and it has not shoaled again. We now need to look at the next lighter isopycnal (grey line between the two labelled black line in Figure 8-6) to see the variability in winter mixing in recent years. The 2025 and 2024 winter mixing was as weak as during the marine heatwave years. This weaker mixing suggests that nutrient supply from deep waters were reduced and that there would have been fewer nutrients to fuel spring phytoplankton blooms.

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9. SEA SURFACE TEMPERATURE AND SALINITY OBSERVED ALONG THE B.C. COAST IN 2025

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9.1. Highlights

- Sea surface temperatures (SST) were generally above the 1991-2020 average throughout the B.C. coast, particularly on the north and central coast.
- SST showed a continued long-term warming trend of 0.9°C per 100 years, with waters warmer than average since 2012.
- Sea surface salinity (SSS) was near the 1991-2020 average in the Strait of Georgia, Juan de Fuca Strait, and west coast of Vancouver Island, and saltier than average on the north and central B.C. coast.
- Overall, SSS has been freshening at a rate of about 0.1 salinity units per 100 years though there were regional differences.

9.2. Description of the time series

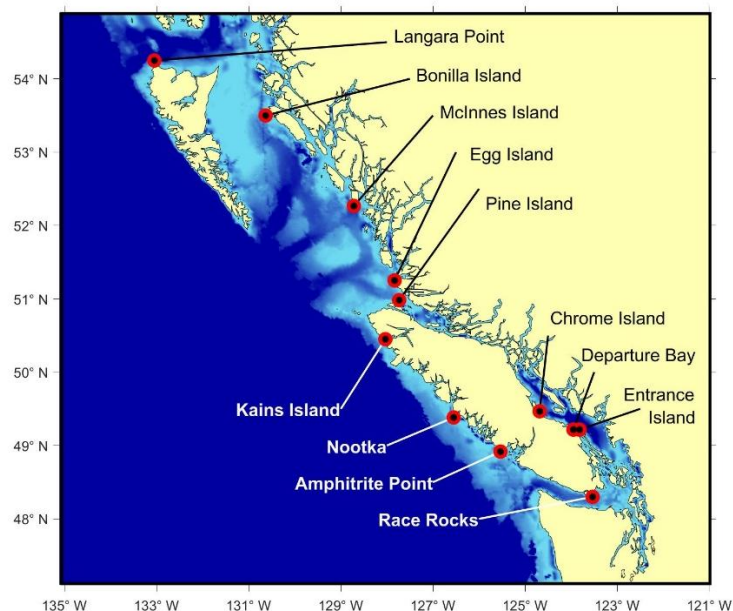


Figure 9-1. Red dots with black centers show the locations of 12 shore stations.

Table 9-1. Details of station data coverage for all time and for 2025.

Station	Years of data	% good all time	% good 2025
Departure Bay	111	87	99
Race Rocks	104	97	91
Nootka	91	58	0*
Amphitrite Point	91	96	95
Kains Island	90	95	68*
Langara Island	89	91	98
Entrance Island	89	95	36*
Pine Island	88	93	0*
McInnes Island	71	92	47
Bonilla Island	65	98	100
Chrome Island	64	93	0*
Egg Island	55	89	65
AVERAGE	84	90	58

As part of the B.C. Shore Station Oceanographic Program, SST and SSS are measured daily at 12 shore stations, at the first daylight high tide. Most stations are at lighthouses (Figure 9-1) with observations made by lighthouse keepers using a handheld electronic instrument (YSI Pro 30).

Records have been collected at two-thirds of the stations for over 80 years and for at least 50 years at the remaining stations, making this dataset particularly valuable for the study of long-term trends, as well as climate variability and changes. These datasets are amongst the longest series of this kind worldwide. Data coverage is over 90% on average but varies from year to year and site to site. There was, however, below average data collected during 2025, mostly due to poor coverage at six of the 12 stations. The conditions for sampling were often too treacherous at one lighthouse (McInnes), the stairs at one station were closed so the sampling location could not be accessed (Nootka), and there were staffing issues at three lighthouses (Pine, Chrome, Entrance). For the others, most of the missing data was due to poor weather conditions and/or poor data quality. Overall, the average coverage for 2025 was 58% with 3 stations above the 95% mark (Table 9-1).

9.3. Status and Trends

The observations show that the annual average daily SST at all stations was warmer in 2025 than in 2022 and 2023 but colder than in 2024, with a coast-wide average SST of 10.6°C. Overall, annual SSTs observed at the Strait of Georgia and southwest coast of Vancouver Island in 2025 were close to the mean calculated over the 1991-2020 period (Figure 9-2) while the annual SSTs observed at northwestern Vancouver Island and the central and north coast were warmer than average. Regionally in 2025, the Strait of Georgia stations (11.9°C) exhibited warmer SSTs than the West Coast stations (11.2°C) and the North Coast stations (10.1°C).

With respect to SSS (Figure 9-2), the 2025 coast-wide annual average was 30.2 based on the stations with sufficient data coverage (a 65% minimum coverage per year and per station was used). This is slightly higher than the annual mean of 29.4 calculated over 1991-2020. An important part of this difference can be attributed to the absence of data from five stations which did not pass the coverage criteria and which are all located in areas of relatively high SSS (Chrome, Entrance, Pine, McInnis, and Nootka). These annual means are therefore skewed towards higher SSS values. Egg and Langara stations stand out from the 1991-2020 observed range in 2025, with both being saltier than the annual maximum observed. Regionally, waters in the Strait of Georgia (Departure), Juan de Fuca Strait (Race Rocks), and west coast of Vancouver Island (Amphitrite and Kains) were average.

Assuming a linear change over the entire data record (1935-present) the time series of temperature at all of the shore stations (combined) indicate a warming trend in the order of 0.9°C over 100 years (Figure 9-3). Similarly, a coast-wide freshening in the order of 0.1 salinity units per 100 years was found based on combining all of the shore station (Figure 9-3). These estimates vary from site to site and are very sensitive to the period used for the analysis. More work will be done in the coming year to understand how and whether the trends differ across B.C.

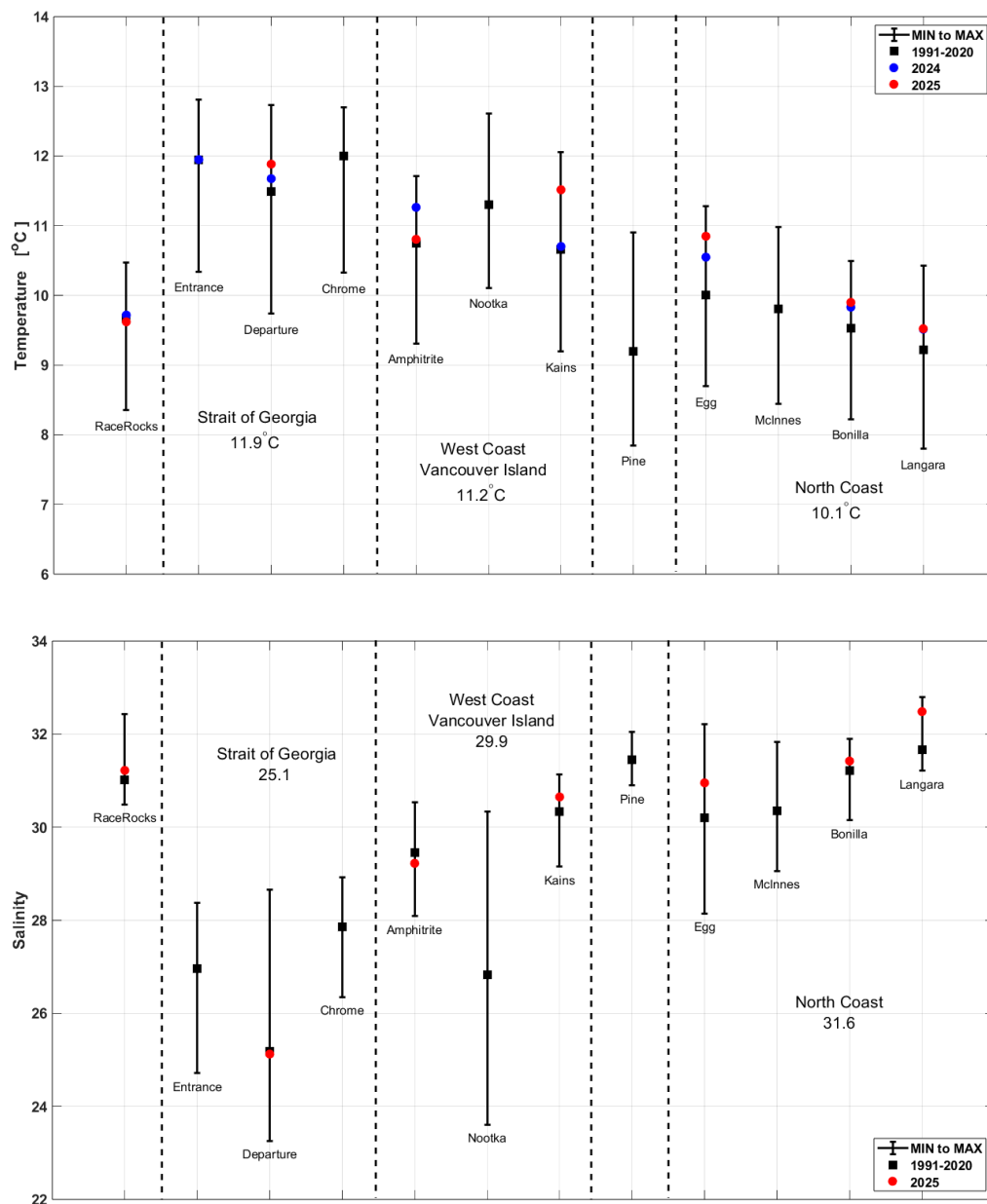


Figure 9-2. Annual average SST (upper) and SSS (lower) in 2025 from daily observations at shore stations along the west coast of Canada. The area is divided in three geographically distinct regions (Strait of Georgia, West Coast, and North Coast). Two stations lie at the periphery of these regions: Race Rocks and Pine, which may be subject to distinct oceanographic regimes. The black squares represent the climatological mean computed over the 1991-2020 period (30 years). Blue (2024) and red (2025) dots represent annual average at each station for those years when data were collected at least 66% of the time.

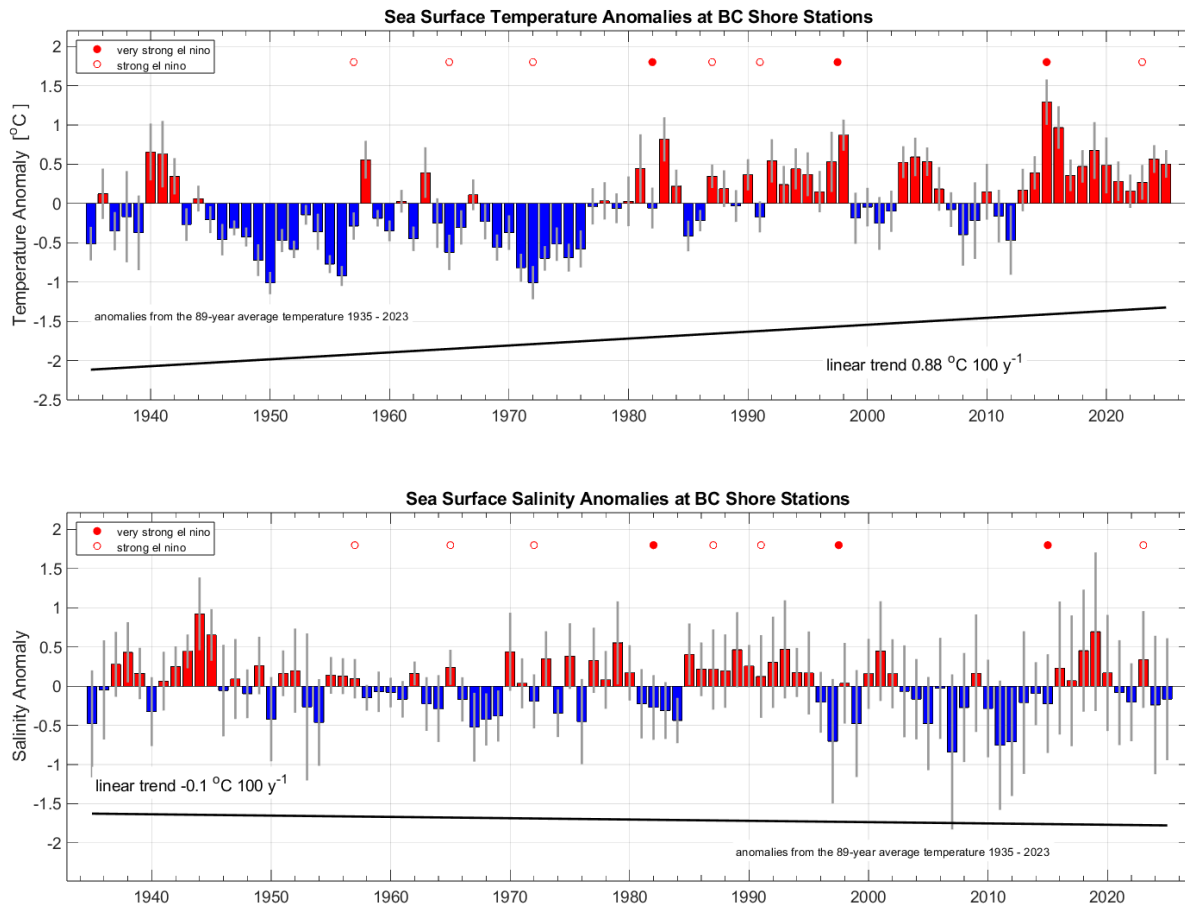


Figure 9-3. Trend in annual SST (upper) and SSS (lower) based on the observations of all lighthouses (black line). The bars represent the anomalies averaged over all stations (a coast wide indicator), (red – above average, blue – below average), the vertical grey lines show the variability (standard deviations) in the lighthouse data for each year (1935-2025). Important El Niño years are shown as red circles and dots (strong phase).

9.4. Factors influencing trends

Ocean temperature is an important environmental indicator because it influences physical processes such as circulation and mixing, chemical processes such as deoxygenation, and the condition and behaviour of species that live in the ocean. SST is an effective indicator of long-term change because direct observations have been made for many decades and on a nearly global and regular way in recent decades with satellite sensors, autonomous monitoring platforms, and other technical developments. The amount of data included in SST analyses continues to expand.

Although SSTs were notably warmer during the marine heatwave of 2014-16, conditions in 2025 continue the period of warmer than normal water (where normal is defined as the average on the long-term SST record starting in 1935). This warm water period has lasted for thirteen years, the longest span of above normal SSTs in the time series. While the record shows multi-year and multi-decadal oscillations in the annual SST, there remains a long-term trend towards rising ocean SSTs.

The long-term salinity records show a trend to fresher conditions at most stations along the B.C. Coast. However, in comparison with temperature, salinity trends have greater uncertainty due to higher spatial and temporal variability. Below average runoff from the Fraser River (Giesbrecht and Moore, Section 7) likely caused high salinity in the Strait of Georgia.

9.5. Implications of those trends

There is growing interest in determining the predictability of the physical processes of the north Pacific Ocean, including associated biological responses, on time scales of months to years. The models that are being used for this are similar to those used for climate change studies. The process of developing, evaluating, and improving forecast systems can provide important insights into the key processes controlling physical, chemical, and biological ocean properties. It remains an open question whether the extent to which the ecosystem will respond to a slow warming will resemble those that were associated with the recent marine heatwaves.

10. WIND-DRIVEN UPWELLING/DOWNWELLING ALONG THE NORTHWEST COAST OF NORTH AMERICA: TIMING AND MAGNITUDE

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10.1. Highlights

- The 2025 Spring Transition timing was average relative to the 1991-2020 mean, which is associated with average upwelling-based coastal productivity.
- The length of the 2025 summer upwelling season, from the Spring to the Fall Transition, was near average, favouring near-average, wind-generated upwelling-based coastal productivity.
- Between 45° and 60° N, the magnitude of upwelling-favourable winds in 2025 was a bit below but near the 1991-2020 average during the warm season, favouring near-average upwelling-based coastal productivity.
- The winter of 2024-2025 was characterized by near-average downwelling-favourable regional winds, indicating that winter storm activity was near normal overall.

10.2. Description of the time series

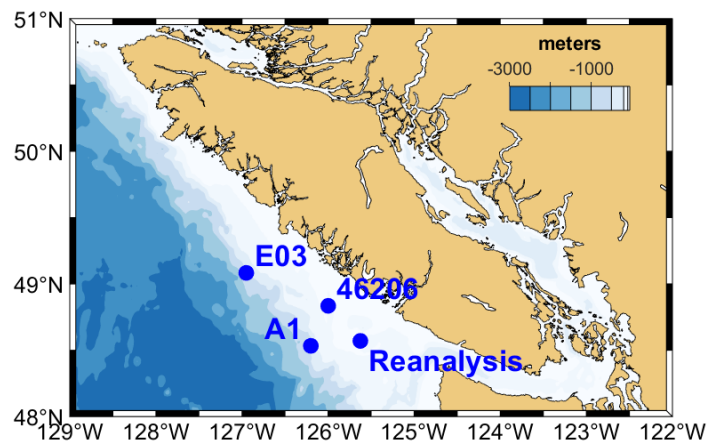


Figure 10-1. Locations of moorings A1 and E03 used for wind velocity, meteorological buoy 46206 used for wind stress, and Reanalysis 1 used for wind stress.

Spring and fall transition timing: The shift in spring from predominantly downwelling-favourable poleward winds in winter to predominantly upwelling-favourable equatorward winds in summer is referred to as the Spring Transition. The reverse process in fall is called the Fall Transition. The alongshore winds drive a seasonal cycle in the alongshore surface currents over the continental slope, from poleward in winter to equatorward in summer. The Spring and Fall Transitions for the Pacific Coast are derived using alongshore wind stress time series from NCEP/NCAR Reanalysis-1 (Kistler et al.

2001), alongshore wind velocity from the Environment and Climate Change Canada meteorological buoy 46206, and the alongshore current velocity at 35 and 100 m depth at moorings A1 and E03 (Figures 10-1 and 10-2; Folkes et al. 2017; Thomson et al. 2013).

Upwelling Index: Because they drive offshore surface Ekman transport and compensating onshore transport at depth, the strength (duration and intensity) of upwelling-favourable (northwesterly) winds are considered indicators of coastal productivity, e.g., Xu et al. (2019). To gauge low-frequency variability in coastal productivity, we have summed the upwelling-favourable-only wind stress by month along the west coast of North America from 45° to 60° N

latitude (Figure 10-3) using the NCEP/NCAR Reanalysis-1 analyses (Kistler et al. 2001) and subtracted the 1991-2020 mean to derive the Upwelling Index.

Downwelling Index: Analogous to the Upwelling Index, the Downwelling Index is derived in the same way but by only considering the poleward (downwelling-favourable) wind stress (Figure 10-4). Because the poleward wind stress is typically stronger in winter as a result of storms tracking eastward across the North Pacific, the Downwelling Index can reflect the strength of storms hitting the B.C. coast, a shift of storm tracks closer to or further away from the coast, a longer or shorter storm season, or some combination of all three. The index also reflects the strength/weakness of wintertime vertical mixing of the surface water column near the coast.

10.3. Status and trends

10.3.1. Spring and Fall Transition timing

In 2025, the timing of the Spring Transition was close to the 1991-2020 mean (Figures 10-2 and 10-5). The 2025 Spring Transition date was taken as the transition to predominantly equatorward flow in currents at 35 m depth at station E03, and that was close to the timing at 100 m as well as from the wind stress from both Reanalysis and meteorological buoy 46206. They were all within a few days of each other. Surface chlorophyll increased significantly at the time of Spring Transition, indicating increased productivity upon the onset of upwelling. There were also significant spikes in chlorophyll following upwelling or upwelling-like (relaxed downwelling) events in January and June. Late Spring Transitions are associated with below average productivity in plankton, fish, and birds, as was particularly the case in 2005 (DFO 2006). For the 2025 Fall Transition we have chosen to ignore the effect of a late September storm on the winds, so the Fall Transition date to primarily poleward winds is Oct.18. That makes the 2025 Fall Transition near average, although the lack of subsurface current data gives this assessment less confidence.

Over the period 2014-2020, the Fall Transition was trending later, such that the upwelling season was getting longer – and the downwelling (storm) season was getting shorter (Figures 10-2(b) and (c)). However, the late Spring Transitions in 2022 and 2023 resulted in a dramatic reset of the length of upwelling and downwelling seasons making them shorter and longer than average, respectively. The upwelling season was near average length in 2025, favouring near-average productivity that year. The average Spring and Fall Transition dates shown in Figure 10-2(b) are about a week earlier than in Thomson et al. (2014), but it's unclear if this is a significant difference or trend.

10.3.2. Upwelling Magnitude: The Upwelling Index

The Upwelling Index time series indicates that upwelling-favourable wind stress magnitude was slightly below but near average over the 45° to 60° N latitude range over the 2025 warm season (Figures 10-3 and 10-5). Like the previous six of seven years, there were strong upwelling-favourable winds in winter, which in 2025 occurred in January. No trends in upwelling-favourable winds since 2013 are evident in Figure 10-3.

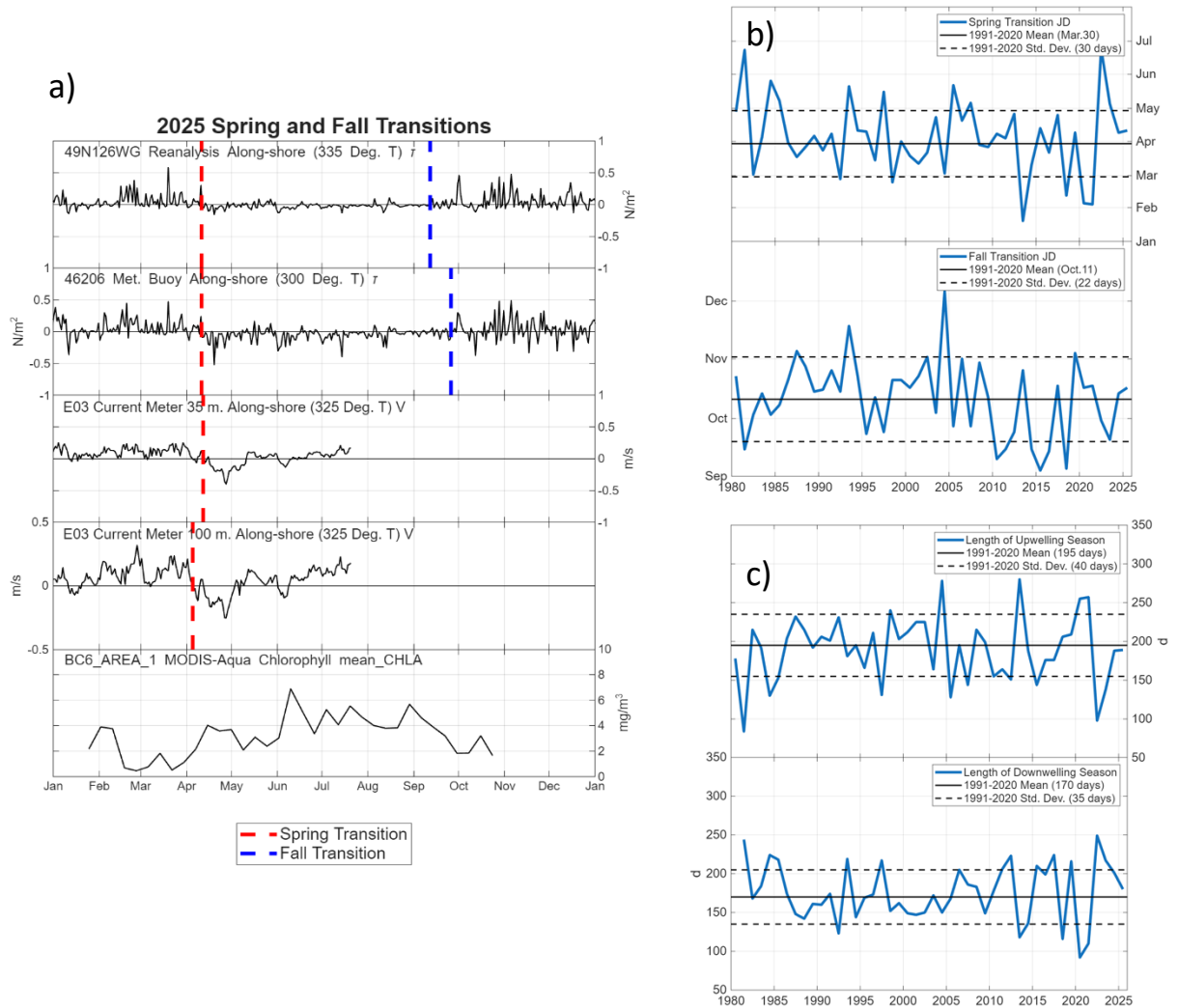


Figure 10-2. (a) Time series depicting the Spring and Fall Transitions off the west coast of Vancouver Island in 2025. Wind stress at Reanalysis-1 grid point 49°N 126°W and meteorological buoy 46206; alongshore current velocity at 35 and 100 m depth at mooring E03 (Folkes et al. 2017; Thomson et al. 2013) and MODIS-Aqua chlorophyll-a (A. Hilborn, pers. comm.). Positive flow is poleward (downwelling-favourable) and negative flow is equatorward (upwelling-favourable). Vertical dashed lines show derived transition times using a cumulative sum approach (e.g., Foreman et al. 2011); (b) The annual Spring and Fall Transitions derived from a time series in panel a; and (c) The length of the upwelling and downwelling seasons derived from the time series in panel b. The length of the downwelling season for a given year is the difference between the spring transition of that year and the fall transition of the previous year.

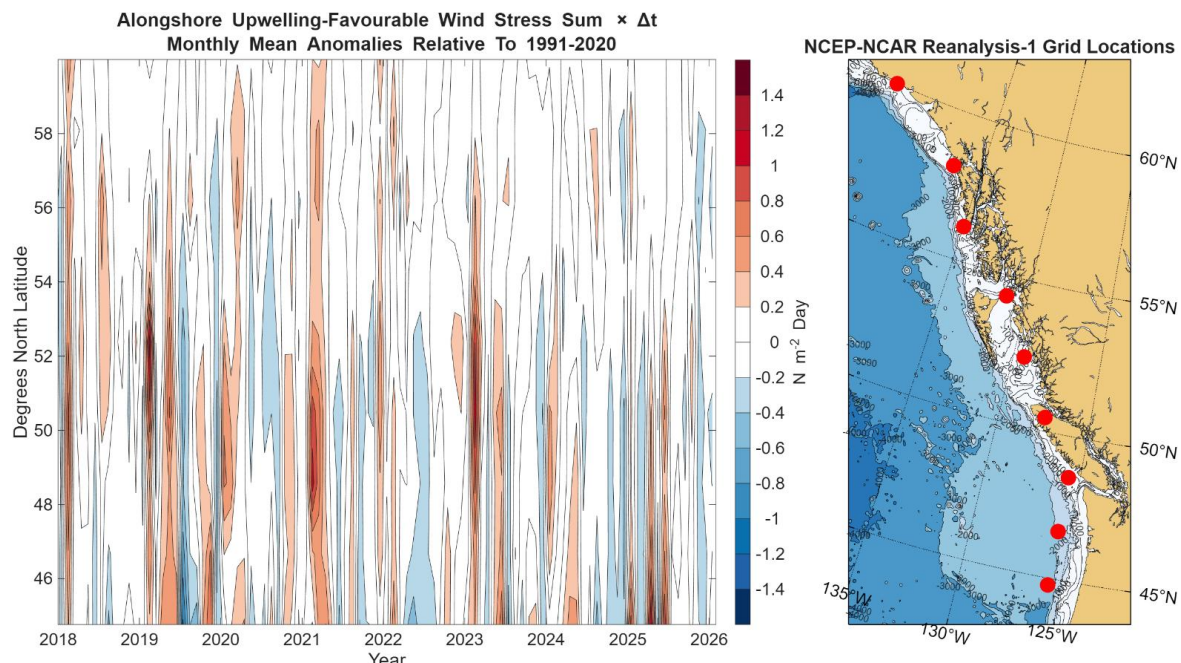


Figure 10-3. Recent (2018 to 2025) monthly mean anomalies (relative to 1991-2020) of monthly sums of alongshore upwelling-favourable (equatorward) wind stress (in newtons per square metre summed over days) from the NCEP/NCAR Reanalysis-1 coastal surface wind stress grid locations, 45-60° N.

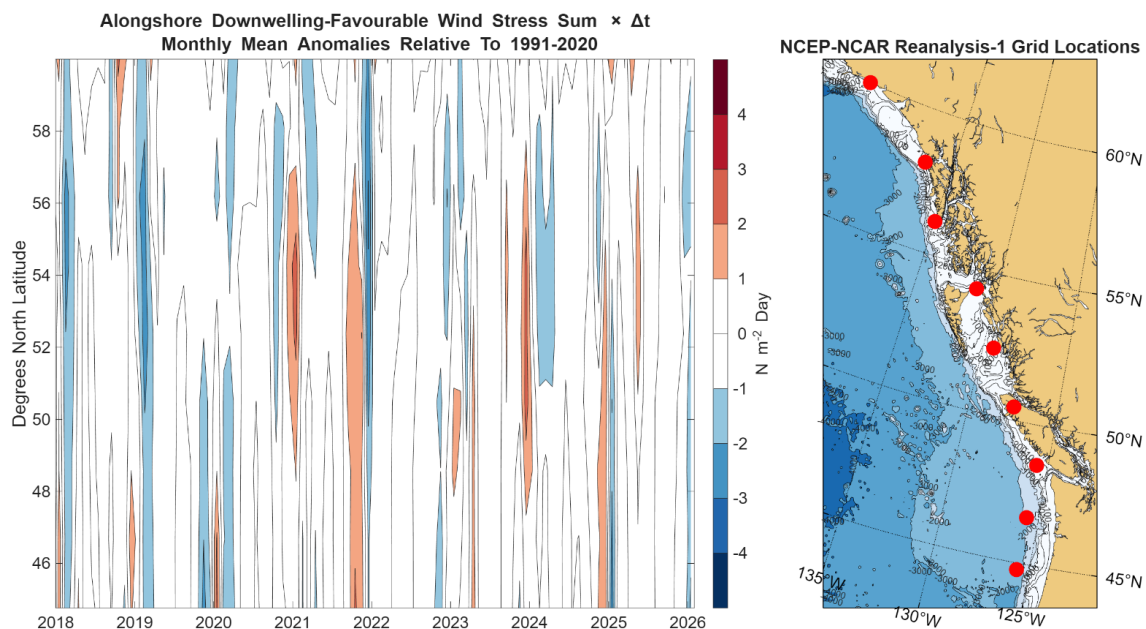


Figure 10-4. Recent (2018 to 2025) monthly mean anomalies (relative to 1991-2020) of monthly sums of alongshore downwelling-favourable (poleward) wind stress (in newtons per square metre summed over days) from the NCEP/NCAR Reanalysis-1 coastal surface wind stress grid locations, 45-60° N.

10.3.3. Downwelling Magnitude: The Downwelling Index

The Downwelling Index was lower than average over five to seven of the eight previous winters, depending on the coastal location (Figure 10-4). This indicates reduced wintertime surface mixing and shallower mixed layer depth near the coast that was usually associated with higher surface temperatures the following summer, such as the marine heatwave conditions observed in 2014 and 2019. Over the winter of 2024-2025, the index was near average, but was below average in late 2025, indicating the year ended with weaker than average winter downwelling conditions and related storm activity.

10.4. Factors influencing trends

The Spring Transition timing has been near average the last two years but does not exhibit much of a trend over the last 25 years. The reason the Fall Transition may be occurring later over most of the last 15 years is unknown. While the Upwelling and Downwelling indices were above average over the ten-year period 2000-2010 (indicating a period of consistently both stronger summertime and wintertime winds), the wintertime Downwelling Index had been lower than average over the period 2012-2020 and 2022 and 2023 north of 50° N, excluding 2015-2016. This indicates weaker winter storms, or a shorter winter storm season, or winter storms that are tracking further to the northwest, away from the B.C. Coast, or some combination of these three factors. Observations over the previous three winters, however, indicate these factors appear to be returning to average conditions.

10.5. Implications of those trends

The onset of seasonal upwelling that accompanies the Spring Transition varies from year to year (Thomson et al. 2014). This interannual variability may have implications related to the degree of winter ocean surface mixing, the vertical extent of the surface mixed layer, and the level of upper ocean stratification and productivity. In years such as 2005 and 2010, when the Spring Transition was relatively late, marine coastal productivity across trophic levels, ranging from plankton to fish to birds, was generally average to below-average, and was particularly poor in 2005 (DFO 2006). In years when the Spring Transition timing was average to early, such as 1999 and 2014, productivity was generally average to above-average (cf. Chandler et al. (2015) reports on outer B.C.). Like 2024, the 2025 Spring Transition timing was near the long-term average, favouring average upwelling-based coastal productivity.

Between 45° and 60° N, the magnitudes of warm season upwelling-favourable winds in 2025 were near average, favouring near average upwelling-based coastal productivity.

The significantly weaker-than-average Downwelling Index in the winter of 2013-2014 was an accurate indicator of the weaker than average winter winds associated with the marine heatwave that year (Bond et al. 2015), and is likely also the case for most of the winters since 2018-2019, as well as future marine heatwave events. In addition, the weaker winter storm activity associated with a weaker Downwelling Index implies weaker surface mixing, a shallower mixed layer depth, stronger stratification, and possibly lower productivity. However, the higher than average Downwelling Index over winter 2023-2024 and near-average values in 2024-2025 indicate a return to near-average winter downwelling, storm activity and surface mixing.

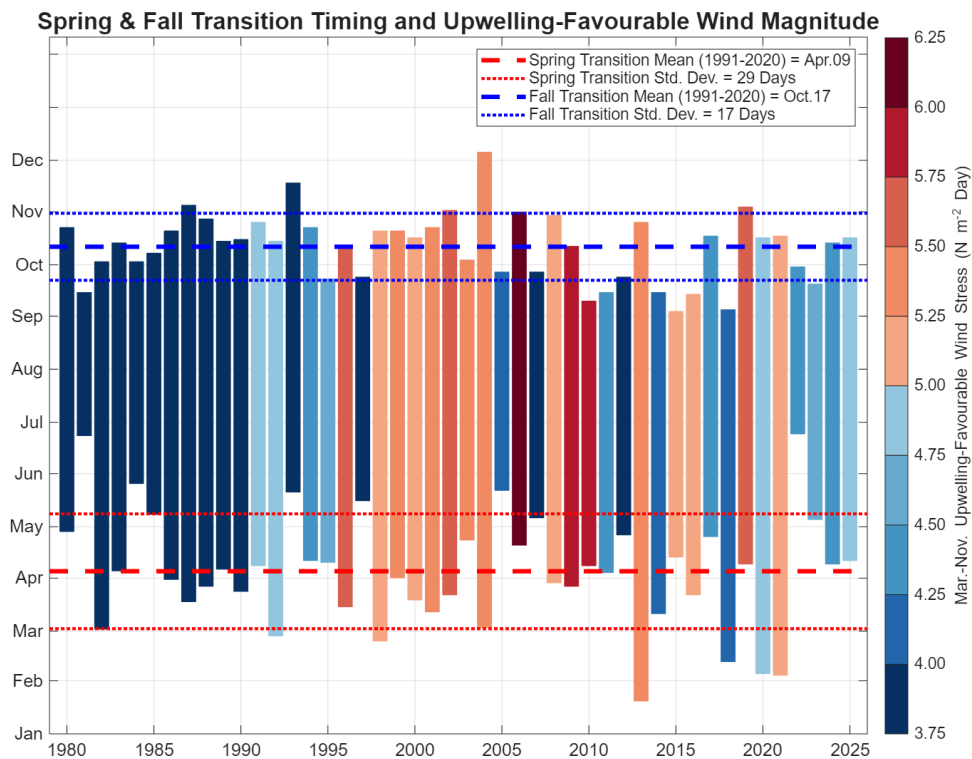


Figure 10-5. Annual Spring and Fall Transition Timing and March-November upwelling-favourable wind stress magnitude for the period 1980-2025 for the region near the stations depicted in Figure 10-1. Note that the dashed lines representing the standard deviations for the Spring and Fall transitions span a band of values in the spring and fall, respectively (see the left-hand time axis).

10.6. Acknowledgements

Mooring ocean velocity and temperature data provided by the Institute of Ocean Sciences Data Archive, Ocean Sciences Division, Department of Fisheries and Oceans Canada.

<http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/index-eng.html> and <https://www.waterproperties.ca/data/>.

NCEP-NCAR Reanalysis 1 wind stress data provided by the NOAA Physical Sciences Laboratory, Boulder, Colorado, USA, from their website <https://psl.noaa.gov>.

Environment and Climate Change Canada meteorological buoy wind stress data provided by CIOOS Pacific at https://data.cioospacific.ca/erddap/tabledap/ECCC_MSC_BUOYS.html.

MODIS-Aqua chlorophyll-a data provided by Andrea Hilborn, Institute of Ocean Sciences, Ocean Sciences Division, Department of Fisheries and Oceans Canada.

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11. VANCOUVER ISLAND WEST COAST SHELF BREAK CURRENT, WATER TEMPERATURE, WIND STRESS, AND SEA LEVEL

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11.1. Highlights

- There was a strong upwelling-like (downwelling relaxation) event in January, 2025, concurrent with weaker than average poleward currents, stronger than average equatorward wind stress, and below average sea surface temperatures and sea level.
- In both April and June 2025, there were stronger than average upwelling events associated with stronger than average equatorward currents and wind stress, and below average sea surface temperatures and sea level.
- In December, 2025, sea surface temperatures and sea level were above average, and the equatorward wind stress was stronger than average.

11.2. Description of the time series

Subsurface temperatures and current velocities at the shelf break have been observed at mooring E03 (water depth ~400 m; Figure 11-1) since 1990, but with an extensive data gap between 2006-2020. Nearby alongshore wind velocity from the Environment and Climate

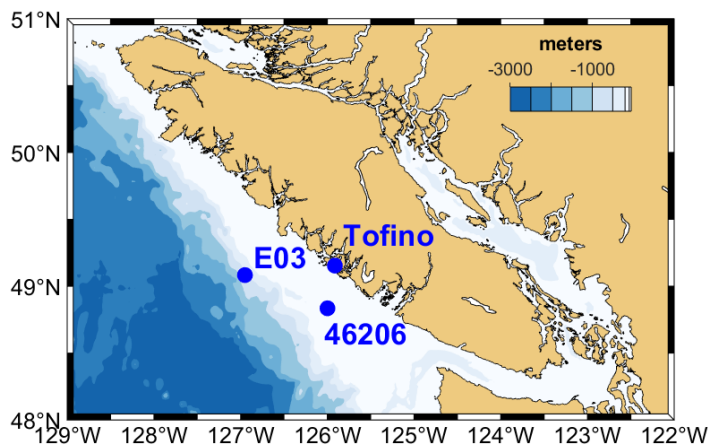


Figure 11-1. Locations of mooring E03 for temperature and velocity, meteorological buoy 46206 for surface water temperature and wind stress, and Tofino for water level.

Change Canada meteorological buoy 46206 has provided sea surface temperature at 80 cm depth and wind velocity time series at 5 m elevation (corrected to the standard height of 10 m) since 1988. Water level has been observed at Tofino by the Canadian Hydrographic Service since 1963. We have combined these series to obtain the vertical structure of water level, temperature, and flow within the water column off Vancouver Island.

11.3. Status and trends

Water temperatures at the surface were significantly below average in early 2025 reflecting a strong upwelling-like event

in January and the continuation of a La Niña event (NOAA 2026). They were also strongly below average from May through July, and finished the year above average (Figure 11-2, left). Subsurface temperatures were only available from mooring E03 at 400 m depth and they were also strongly below average through to the middle of the year. Data recorded at depth after July 2025 will not be available until the mooring is recovered in summer 2026.

In 2025, alongshore winds and currents were much weaker poleward than average in January and more strongly equatorward (upwelling-favourable) than average in April and June (Figure

11-2, right) due to a stronger than average North Pacific high pressure system over the northeast Pacific at those times. This also led to lower-than-average sea level and below average temperatures at the surface and at depth. The April and June events were both followed by increases in surface chlorophyll (Hourston and Thomson, Section 10). The strong upwelling-like event in January was atypical and was a reversal of typical winter circulation patterns. However, it did echo similar winter upwelling events early in the previous six of seven years. Mixed conditions at the end of 2025, reflected that the Aleutian Low had moved well onshore. The higher than normal sea levels in mid-December may have been due to stronger than normal poleward currents associated with the poleward passage of Coastal Trapped Waves (CTWs) during a period of weak winds. Observed current data to verify the latter will be available next summer.

Historically, temperature anomalies are negative during a La Niña as was the case over 1998-2000, 2007-2008, 2010-2011, and 2020-2022 (Figure 11-3, left). For water level and alongshore flow during La Niña years, negative anomalies tend to occur, but the anomaly pattern has been less consistent (Figure 11-3, right). That said, below average temperatures and water levels as well as weaker than average poleward flow were also observed over the first half of 2025, with the continuation of the La Niña event that began in 2024.

There do not appear to be long-term trends in surface and subsurface temperatures and currents on the shelf or shelf break on the west coast of Vancouver Island over 1990-2025, but the recent large gap in subsurface data make that assessment for subsurface conditions uncertain at best. Mean water levels at Tofino also do not appear to exhibit a long-term trend over 1990-2025 (Figure 11-3; and see Riedel, Section 51).

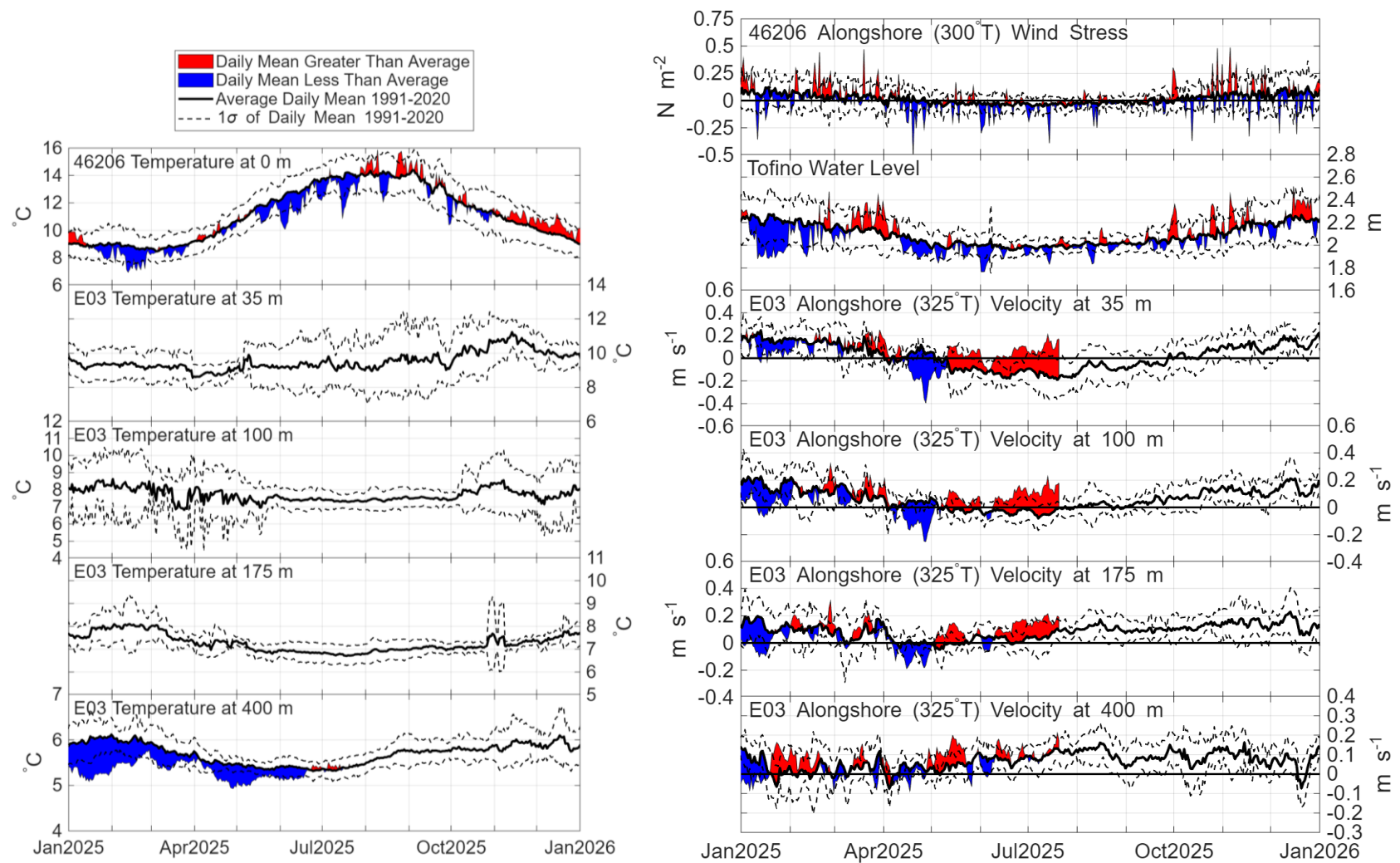


Figure 11-2. Daily mean values of temperature (left panels) and alongshore wind stress, sea level, and alongshore ocean current (right panels) at the surface, 35 m, 100 m, 175 m, and 400 m depth from, respectively, Environment and Climate Change Canada meteorological buoy 46206, DFO mooring E03, and Canadian Hydrographic Service (CHS) Tofino station. Angle in brackets ($^{\circ}\text{T}$) is the principal direction of the wind or current vector in degrees true compass bearing.

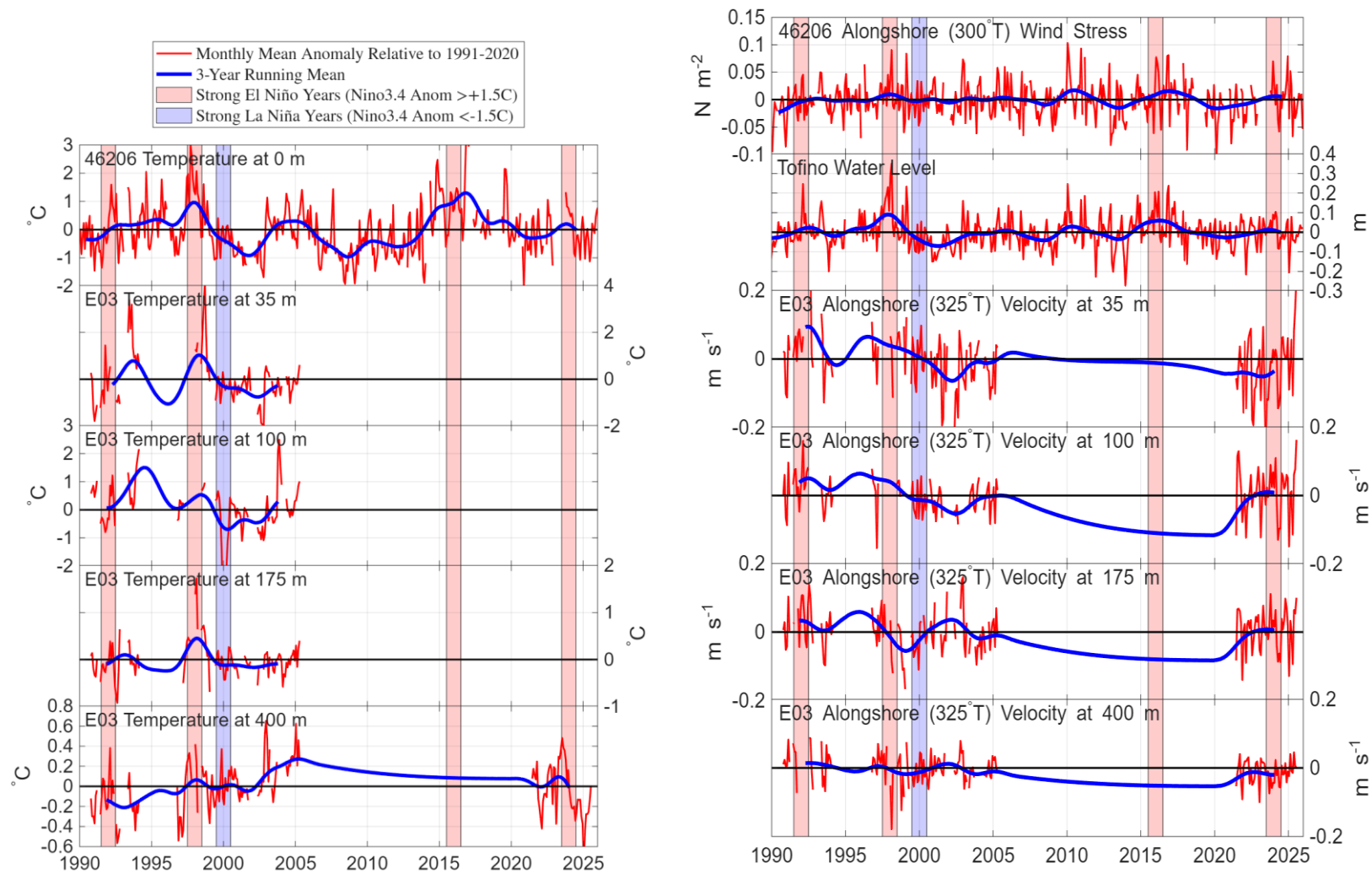


Figure 11-3. Monthly anomalies of temperature (left panels) and alongshore wind stress, water level, and alongshore ocean current (right panels) at the surface, 35 m, 100 m, 175 m, and 400 m depth from, respectively, Environment and Climate Change Canada meteorological buoy 46206, DFO mooring E03, and Canadian Hydrographic Service (CHS) Tofino station. Angle in brackets ($^{\circ}\text{T}$) is the principal direction of the wind or current vector in degrees true compass bearing. Strong El Niño or La Niña years are those with at least three consecutive months of OISST.v2.1 SST anomalies $\geq +1.5^{\circ}\text{C}$ or $\leq -1.5^{\circ}\text{C}$ over the Niño 3.4 region (5°N - 5°S , 120° - 170°W).

11.4. Factors influencing trends

Although no long-term trends are evident, the strong El Niño of 2015-16 and recent years with increased occurrences of marine heatwaves are reflected in higher-than-average ocean temperatures at the surface and at depth (Hourston and Thomson 2022). Weaker than average poleward flow in winter is also associated with marine heatwaves. This in turn reflects weaker storm activity and/or storm activity shifting westward and/or a stronger winter North Pacific high. Strong El Niños, like that of 2015-2016, are associated with enhanced poleward flow in winter, which was evident over the 2015-2016 winter (Hourston and Thomson 2022), and was the case over the 2023-2024 winter due to the El Niño event.

11.5. Implications of those trends

Recent El Niño and marine heatwave events have been associated with significant departures from average ocean surface and subsurface temperatures and currents. However, conditions returned to average a year or two after these events. The most recent observations indicate that conditions are above average, but that no long-term trend is occurring (but see Ross and Robert, Section 8; Jackson, Section 9). If these types of events increase in frequency in the future, they could result in long-term trends.

11.6. Acknowledgements

Mooring ocean velocity and temperature data provided by the Institute of Ocean Sciences Data Archive, Ocean Sciences Division, Department of Fisheries and Oceans Canada.

<http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/index-eng.html> and <https://www.waterproperties.ca/data/>.

Water level data provided by Canadian Hydrographic Service from their website at <https://tides.gc.ca/en/tides-and-water-levels-data-archive> and D. Riedel at the Institute of Ocean Sciences <https://www.pac.dfo-mpo.gc.ca/science/facilities-installations/index-eng.html#ios>.

Niño 3.4 Region OISST V2 anomaly data provided by the NOAA Climate Prediction Center College Park, Maryland, USA, from their website <https://origin.cpc.ncep.noaa.gov/data/indices/>.

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12. SUBSURFACE OCEAN CONDITIONS ALONG THE B.C. COAST FROM MOORED OBSERVATIONS

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12.1. Highlights

- The cooling of annual temperature minimums at 40 m along the B.C. shelf associated with the recovery from the Blob event and the 2015-16 El Niño had ceased in early 2023. These waters had begun to warm but have since resumed cooling according to the latest 2024-2025 observations.
- Strong wintertime upwelling events continue to occur, albeit with less pronounced effects on dissolved oxygen near the bottom of Scott2 mooring (north of Cape Scott). The sequence of strong downwelling, upwelling, and then downwelling led to anomalously high oxygen concentrations and low salinity at depths of at least 150 m but not 200 m.
- Winter upwelling in mid-February 2025 at Scott 2 resulted in the same magnitude drop in oxygen at 150 m seen two-weeks earlier near the bottom of E01 (95 m), where oxygen dropped from 5.7 down to 2.3 ml/l in late January 2025. Oxygen measurements at ~150 m along the B.C. coast were also highly correlated, showing a progressive decline northwards into Moresby Trough.

12.2. Description of the time series

The B.C. Shelf Mooring Program has maintained 8-12 instrumented moorings on the B.C. shelf

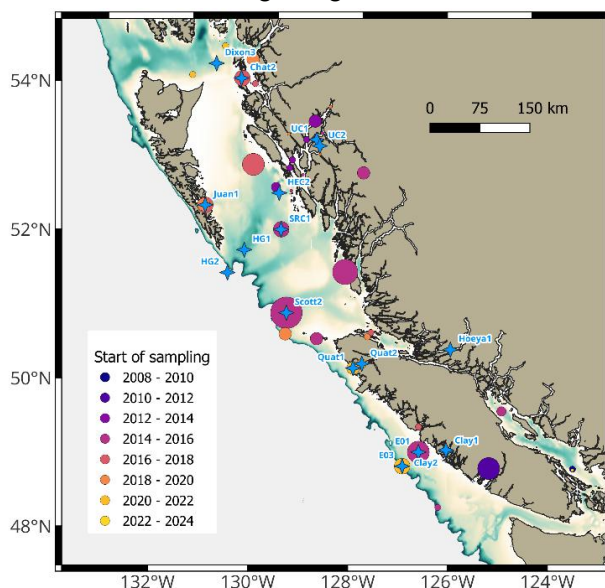


Figure 12-1. Mooring locations. Magenta crosses indicate those in the water from July 2024 to July 2025. The circles are sized according to the total duration of available oxygen data, with the color denoting the start of data collection.

since 2016 (Figure 12-1). Measurements at all locations include temperature, salinity, and dissolved oxygen at multiple depths, and water velocity through the water column. Moorings are recovered and redeployed on an annual basis during the summer months. Currently, there are 7 moorings in planned or existing Marine Protected Areas (MPA) in the northern shelf bioregion. This sampling could be the backbone of a monitoring program for the region's MPA Network.

The goal is to maintain an array of moorings from southern Vancouver Island to Dixon Entrance, subject to operational constraints. A keystone mooring, Scott2, has been kept in 300 m of water north of the Scott Islands since 2016. Other moorings of note are E01 (Estevan Point), SRN1 and SRC1 (Sponge Reef North and Central), Juan1 (Juan Perez Sound), Dixon 3 and Chat2 (Chatham Sound). New moorings HG1 and HG2 were deployed in

2025 to monitor water entering Hecate Strait through Moresby Trough. The program inherited the long time series (30+ years) at E01, on the inner Vancouver Island shelf, and A1 at the edge of the Vancouver Island shelf (48.5351°N, 126.1937°W). E01 continues to be maintained. A1 was abandoned in 2021 after the mooring was hit and cut by mid-water trawls thrice in four years. E03 is the replacement for A1. The mooring records at E01 (Estevan Point) on the inner Vancouver Island shelf go back to 1990 with oxygen sensors being regularly deployed since 2020 at this site. Hence, the oxygen records at Scott2 are longer having been fitted with oxygen sensors since its inception in 2016 (Figure 12-1).

12.3. Status and trends

Temperature trends

A declining trend in the annual minimum temperature at 40 m has been evident broadly across the shelf since 2017 (Figure 12-2). As predicted in the 2024 report (Hannah et al. 2024), water temperatures at 40 m increased across the B.C. shelf in response to 2023/24 El Niño. In the last year, the minimum temperatures have remained stable or dropped at some sites (Figure 12-2).

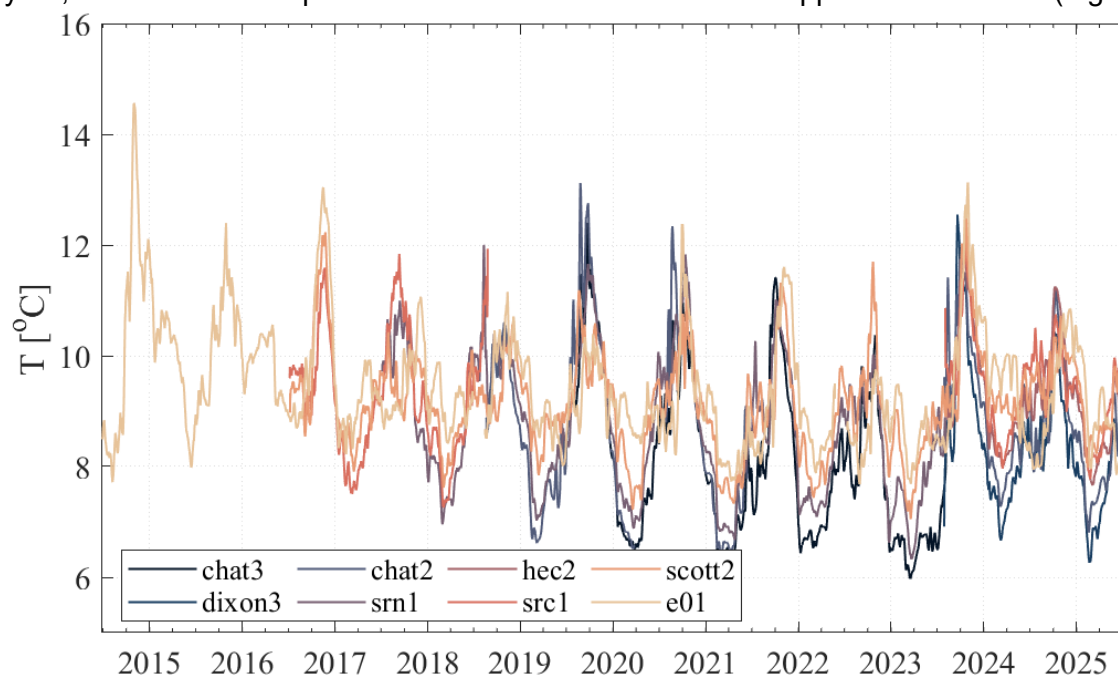


Figure 12-2. Subsurface water temperatures measured from moored instruments at approximately 40 m along B.C. coast. A 7-day running mean was applied to the measurements, which are typically collected at 10 to 30 min intervals. Line colors represent the moorings' latitude from south (yellow) to north (dark blue). The notable feature is the decline in annual minimum temperatures (winter) from 2017 to 2023 followed by a warming to post-Blob 2016 temperatures.

At E01, subsurface temperatures were below historical averages except in early winter from December 2024 to mid-January 2025 and in April 2025 (Figure 12-3). Seasonal averages were lower than those from the previous year near the bottom (Figure 12-3) and throughout the water column (not shown). At Scott2 mooring, subsurface temperatures were also lower compared to the previous year, especially compared to Fall 2023 and Winter 2024 (Figure 12-3). Warmer than historical average temperatures were measured in late 2024, followed by unusually cold

temperatures in February 2025. Summer near-bottom water temperatures were slightly warmer in spring 2025 than the year before (Figure 12-3).

Oxygen trends

The oxygen time series at Scott2 and E01 have a substantial seasonal cycle with a typical peak-to-trough range of 1 ml/l and 4 ml/l near the bottom, respectively (Figure 12-3). The higher range at E01 is partly due to the shallow depth of its deepest sensor (95 m) compared to Scott2 (280 m). In winter, the mixed-layer depth can deepen to below 100 m along the B.C. coast, resulting in higher dissolved oxygen. The lowest concentrations are typically in summer when concentrations regularly drop below the hypoxia limit of 1.4 ml/l at both sites (Figure 12-3).

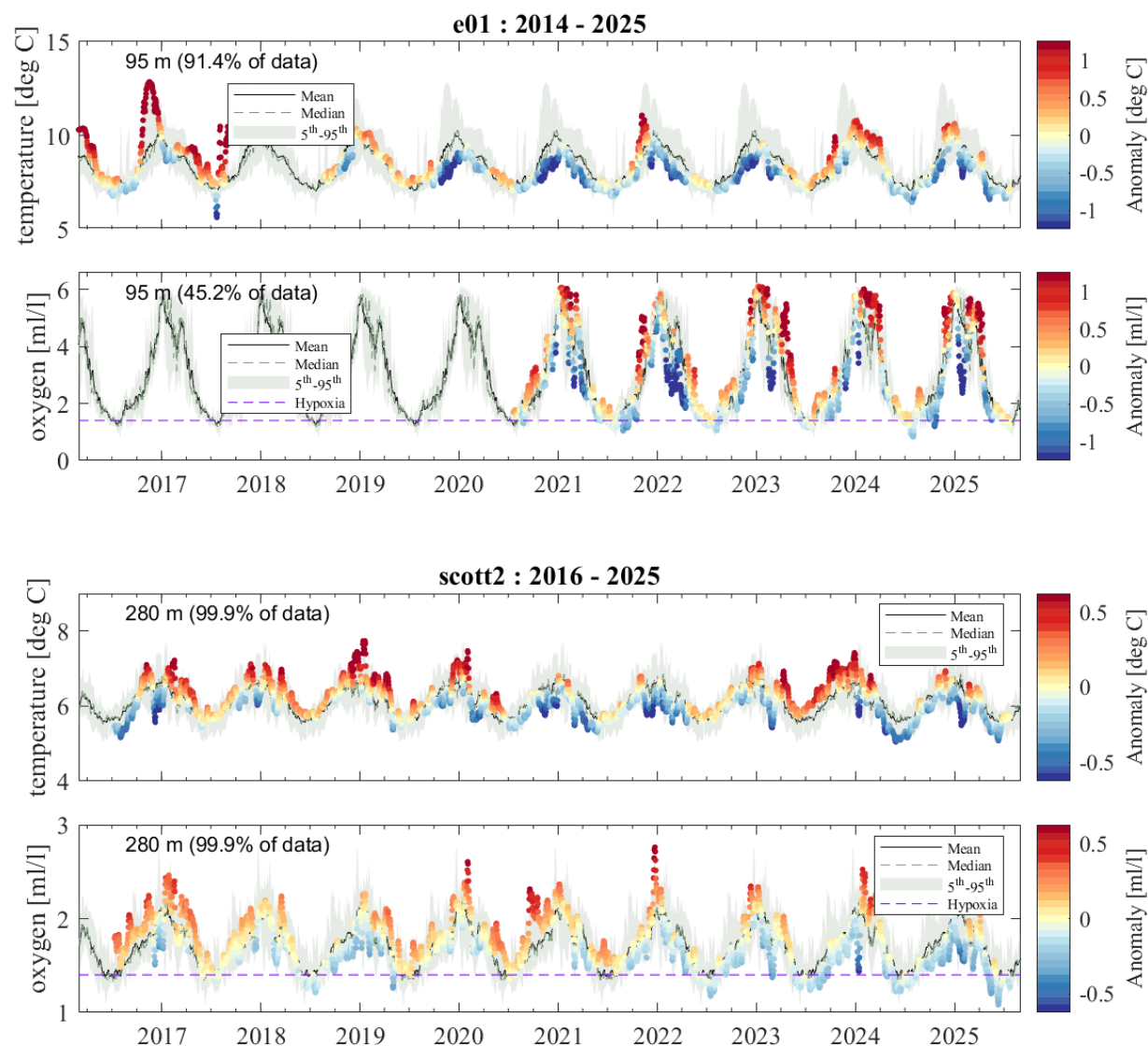


Figure 12-3. Near-bottom daily subsurface temperature and dissolved oxygen measured at E01 mooring (top two panels) and Scott2 mooring (bottom two panels) plotted against the statistics obtained at the same measurement depth from 2016 to 2025 for Scott2 and 2014 to 2025 for E01. The measurements are color coded based on anomalies calculated using the historical average. The color and y-axis scale for the Scott2 measurements at 280 m is half of those near the bottom of E01 at 95 m.

At Scott2, sustained hypoxia has now occurred for four years near the bottom during the spring and summer of 2022 to 2025. Oxygen levels at depths deeper than 150 m were below historical averages for most of the year (not shown). The lowest near-bottom dissolved oxygen of the entire timeseries were recorded in June 2025 as the annual minimum oxygen levels continue to decrease overtime (Figure 12-3). The 2025 winter seasonal average for deep oxygen (at 280 m) also reached the lowest of the entire record (not shown), although the 2025 winter minimum was less severe than the hypoxic event recorded in February 2023 at Scott2 (Figure 12-3). This feature was associated with high salinity, cooler and low oxygen water upwelled on the shelf (Hourston and Thomson, Section 10), which is particularly noticeable in records between 100 m and 200 m (not shown). Overall, January 2025 displayed continued evidence of winter upwelling. This event lasted longer than those in 2023 and 2024 although the oxygen concentrations did not drop below the hypoxic threshold of 1.4 ml/l (Figure 12-3). Hypoxic levels were reached though in late spring and summer for a total of 84 days in 2024 compared to 110 days in 2023 and 0 days in 2021.

At E01, winter upwelling was also evident in late January 2025, more so and earlier than waters below 150 m at Scott2 given the near-bottom oxygen dropped from 5.8 down to 2.4 ml/l at E01 (Figure 12-3 and 12-4). Near-bottom oxygen levels at E01 were on average slightly lower in the summer 2024 than the previous summer. The lowest values of the entire record (0.8 m/l) were measured in August 2024 after the most recent recovery. Although oxygen levels are trending downwards, the number of days when concentrations drop below the hypoxic value of 1.4 ml/l have dropped since the first year of oxygen measurement (mid 2020). Near-bottom oxygen concentrations were below 1.4 ml/l for 30 days in 2024 compared to 50 days in 2021.

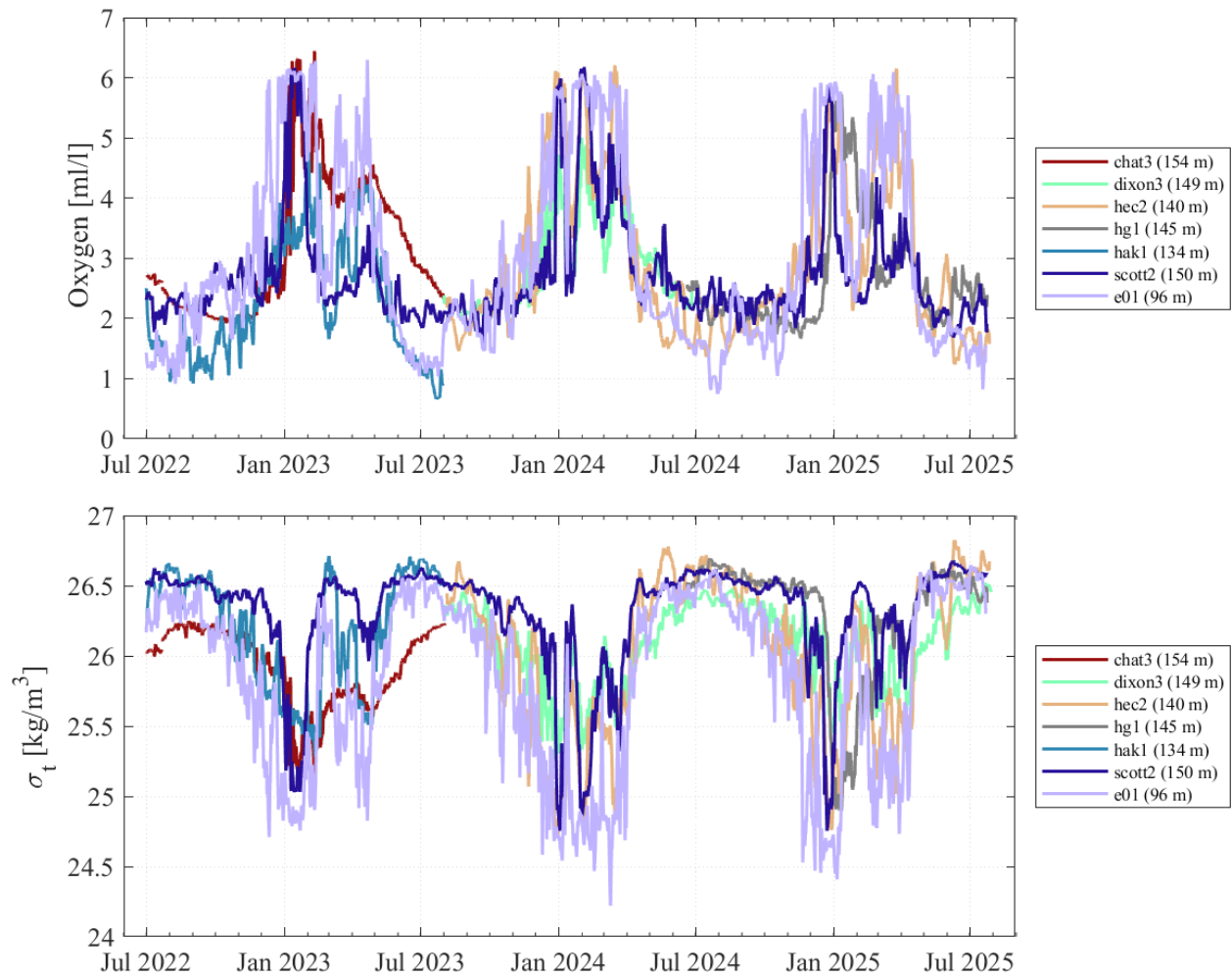


Figure 12-4. Density (bottom panel) and dissolved oxygen (top panel) measured at different sites along the coast at a depth close to the bottom-most sensor at E01.

Dissolved oxygen concentrations and densities at about 130 m depth are presented for select moorings in Figure 12-4. This figure illustrates the spatial coherence from the west coast of Vancouver Island (E01) and various moorings along the coast deployed between 2022-2025. The most correlated ($R=0.86$) timeseries was Hec2 (140 m) during the 2023-2025 deployment period despite being located east of Moresby Trough (Figure 12-1). Even the observations at Dixon 3 were fairly well correlated with E01 ($R=0.78$) considering the lower correlation between E01 and the much closer mooring at Scott2 ($R=0.72$). A strong correlation ($R=0.8$) also existed between Hak1 and E01 during the 2022-2023 deployment period but not between Scott2 and Hak1 ($R=0.53$), despite them being situated in Queen Charlotte Sound (Figure 12-1). A reduction of dissolved oxygen was noticeable during the 2025 winter upwelling event, with the reduction happening later than January at sites further north along the coast (Figure 12-4). From this cursory analysis, subsurface waters around 100 to 150 m depth are the least spatially coherent in the region north of Vancouver Island (southern arm) in Queen Charlotte Sound.

12.4. Factors influencing trends

The B.C. shelf-wide increase in water temperatures at 40 m caused by El Niño as was predicted in 2024 (Hannah et al. 2024), which reversed the trend of declining annual minimum

temperatures at 40 m post-Blob. This trend reversal at Scott2 decreased with depth, especially near the bottom at 280 m, which may be attributable to the stronger than average upwelling in spring and summer (Hourston and Thomson, Section 10). This stronger upwelling may partly explain the below-average oxygen below 150 m (Figure 12-3 and 12-4). However, it's unlikely that upwelling is the only cause for the four summers of low oxygen conditions below 150 m at Scott2 and more broadly in southern Queen Charlotte Sound (Hannah, Section 13).

The winter upwelling event of 2025, resulted in a cooling of the winter minimum temperature near the bottom of Scott2 (Figure 12-3). From the latest recovered data, minimum water temperatures dropped to values below those observed before the 2024 El Niño, largely because of the decreased minimums observed during winter. The winter low oxygenated waters at Scott2 were associated with potential densities greater than $\sim 1026.8 \text{ kg/m}^3$. In comparison, in summer, these low concentrations are found in slightly lighter water, 1026.75 kg/m^3 . This lower oxygen is likely the result of increased oxygen consumption during the spring and summer blooms (e.g., Franco et al. 2023).

For the last 9 years, Hourston and Thomson (2025) have reported wintertime upwelling offshore of Vancouver Island. Although wintertime upwelling events can be identified elsewhere in the timeseries, the winter events of 2023 and 2024 have been the most intense in terms of reducing near-bottom oxygen since starting measurements in 2016. These events were preceded by unusually low water density further up in the water column, presumably from wind induced winter mixing. Winter upwelling events have become a regular feature on the B.C. shelf. The winter upwelling event that reduced subsurface oxygen levels along the coast starting at E01 in late January 2025, was also observed across the coast, although later.

12.5. Implications of those trends

The deep water north of Vancouver Island appears to contain less oxygen than water with comparable density offshore of Vancouver Island, although there are strong seasonal variations in oxygen content at depths shallower than about 200 m. The reduced oxygen content north of Vancouver Island is most noticeable during summer. It is also counter-intuitive when considering that the proportion of water attributed to the lower-oxygen California Undercurrent weakens when moving northwards (Thomson and Krassovski 2010).

Future analysis will focus on establishing which processes dictate the changes in oxygen minima across the B.C. coast. The moored observations clearly show that strong wintertime upwelling events are a common occurrence. Thus, winter is not a time of continuous high oxygen; sustained low oxygen events are now to be expected in the winter. The regional patterns of high and low oxygen in the summer are complicated and are not well understood. Recent papers by Maier et al. (2025) and Stevens et al. (2025) have taken steps towards linking oxygen trends on the shelf with those over the slope and beyond. We hope that others will continue to build on the pioneering work of Crawford and Peña (2016) and provide an understanding of the spatial patterns and temporal trends of dissolved oxygen on the B.C. shelf.

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13. SUBSURFACE OXYGEN IN B.C. WATERS

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13.1. Highlights

- During the spring and summer of 2025, at most locations, near-bottom oxygen concentrations were again at or near the lowest values in the records.
- The average rate of decline of subsurface oxygen for 10 locations around the B.C. shelf is about $5 \mu\text{mol kg}^{-1} \text{ decade}^{-1}$ ($0.1 \text{ ml l}^{-1} \text{ decade}^{-1}$), which is consistent with declining trends reported for Ocean Station Papa since the 1950s.
- The declining oxygen trends are not just a near bottom feature. The declines observed at 50 m are as large, or larger, than the mid depth and near bottom ones.
- It is likely that reduced oxygen input at the surface of the Northwest Pacific (ventilation) is affecting subsurface oxygen in the Northeast Pacific including B.C.

13.2. Description of the time series

Time series of oxygen concentrations include:

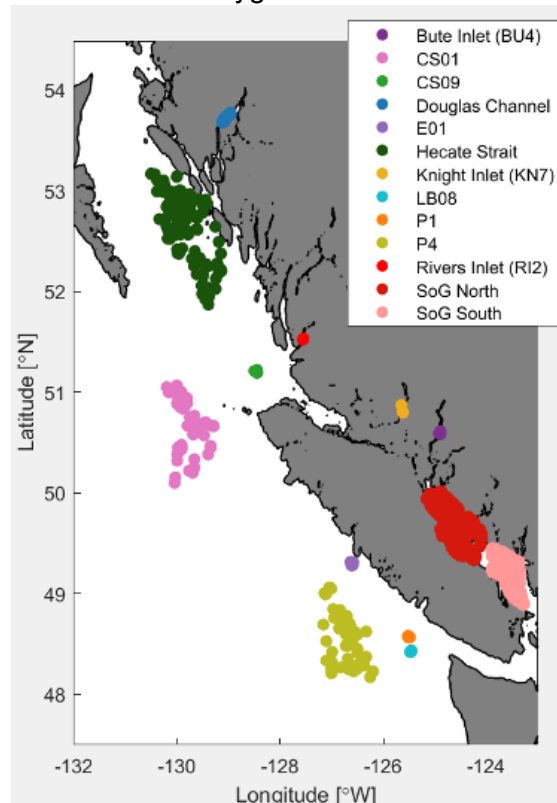


Figure 13-1. Map showing the locations where time series of subsurface oxygen have been compiled from bottle data and CTD oxygen sensor data. An update on near-bottom oxygen conditions for 2025 is provided at P1 and CS09.

1. Time series of near bottom concentrations for Stations P1 and CS09 (Figure 13-1) were updated for 2025 (Figure 13-2).

2. At 12 locations around B.C. oxygen time series have been compiled up to the end of 2024 (Figure 13-1). The dataset combines data from both Winkler titrations and oxygen sensors on the CTD-Rosette. The time series were updated for Strait of Georgia South (SoG-S) at 150 m (Figure 13-3).

Many of the new stations are not single locations but a broader area (Figure 13-1). For the shallower shelf stations the time series were created for 50 m and the near-bottom, for deeper shelf stations (and inlets) the time series were created for 50 m, 150 m, and 300 m (or near bottom). For the 2 slope stations (P4 and CS01) the oxygen time series were created for 5 isopycnals (constant density surfaces): 26.3, 26.5, 26.7, 27.1, and 27.3 g kg^{-1} . Time series for temperature and salinity were also created.

We did not update the oxygen time series at P4 and P26 (Ocean Station Papa) this year.

Temperature, salinity, and oxygen time series for most B.C. inlets can be found at <https://ios-osd-dpg.github.io/bc-inlets/>. The webpages include plots of sampling statistics. The data can be found at waterproperties.ca.

13.3. Status and Trends

At both P1 and CS09, the near-bottom oxygen concentrations defined a new lower bound, or tracked the previous lower bound, during the spring and summer of 2025 (Figure 13-2). The same pattern was observed at LB08 (near P1). At E01, in 100 m of water off Estevan Point on the Vancouver Island shelf, the oxygen was low but did not define a new lower bound. At CS09, hypoxia (oxygen concentration less than 1.4 ml l^{-1} or $60 \mu\text{mol kg}^{-1}$) was not observed prior to 2021, however, since 2021 near bottom hypoxia in the summertime has become routine and 2025 was no exception.

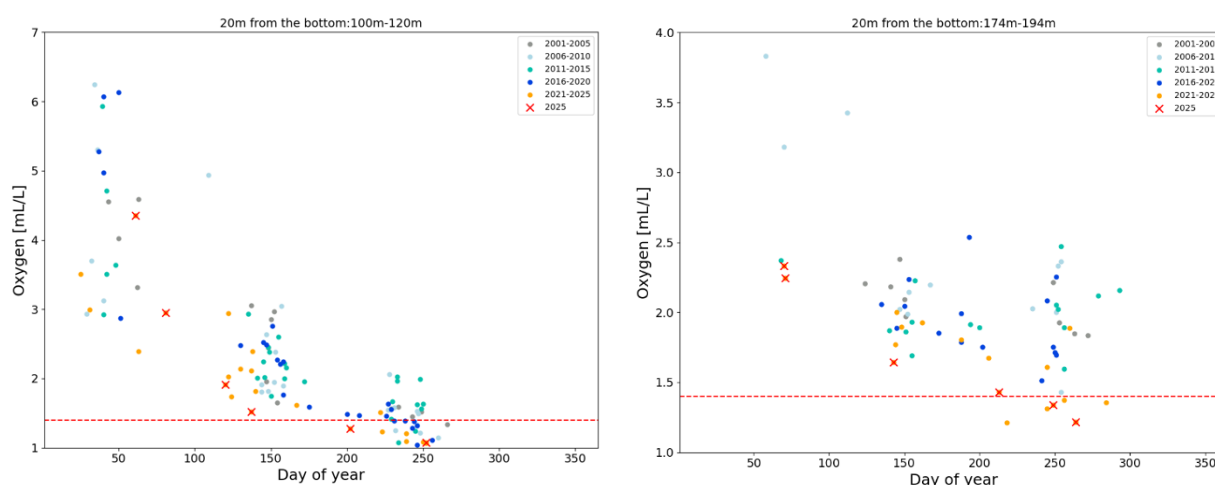


Figure-13-2. Near bottom oxygen at station P1 (100-120 m) on the southern Vancouver Island shelf (left panel) and at station CS09 (174-194 m) in southern Queen Charlotte Sound (right panel). The data from 2025 is shown as red X. At P1 the observed oxygen concentrations start tracking along the lower limit of the observations (since 2001) at about Day 125. At CS09, the tracking of the lower limit starts about Day 61.

The southern Strait of Georgia (SoG-S) has the longest data record and the most data of all the stations. The oxygen at all three depths (50 m, 150 m, 300 m) has been declining since the 1970s and at 50 m it may have been declining since the 1950s. At 150 m, the rates of decline since 1980 are -0.45 , -0.56 , $-0.79 \mu\text{mol kg}^{-1} \text{ yr}^{-1}$ at 50 m, 150 m, and 300 m, respectively, and all are statistically significant and different from zero at 95% confidence (Figure 13-3). These declines are comparable to those reported by Johannessen et al. (2014) for the period 1970-2009.

The near-bottom data at E01 on the inner Vancouver Island shelf (about 100 m) shows an interesting feature. The shipboard data points fit nicely into the U-shaped valley defined by the moored observations and the oxygen concentrations are highly variable in the fall and winter (Figure 13-4). This latter feature is largely due to the winds switching back and forth between upwelling (equatorward) and downwelling (poleward). Similar wintertime variability is observed at 200 m in Hecate Strait (HS). Thus, at these two locations, it is fair to say that whether you observe high or low near-bottom oxygen in the winter depends on which way the wind is blowing.

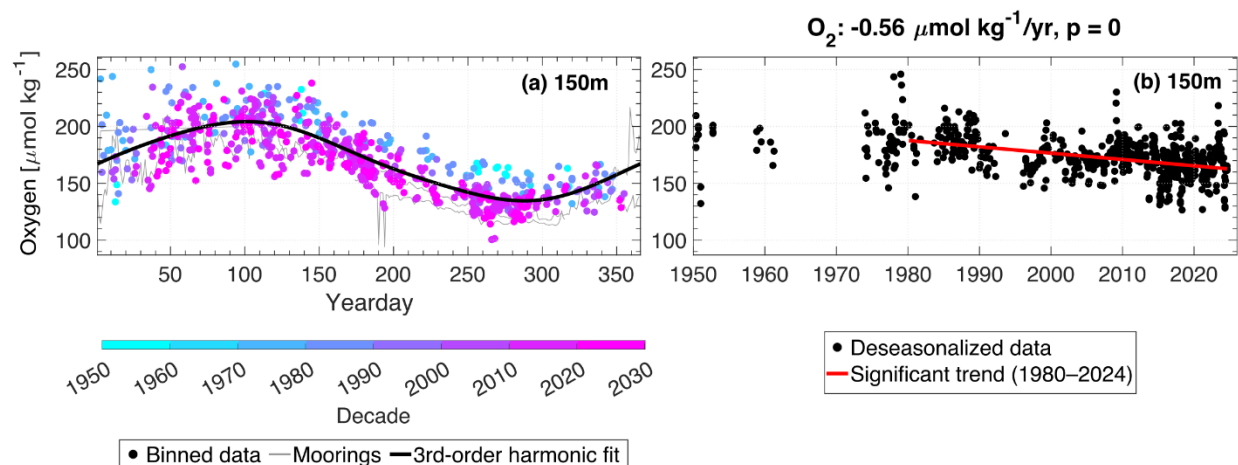


Figure 13-3. Subsurface oxygen time series for the Southern Strait of Georgia (SoG-S) at 150 m. The left panel shows the data plotted relative to the day of the year. The right panel shows the time series anomalies relative to the annual cycle (the black line in the left panel) with the record mean added back in. In the left panel the data points are coloured by decade, with light blue for the 1950s and pink for the 2020s. SOG-S is the longest time series, with data going back to the 1950s.

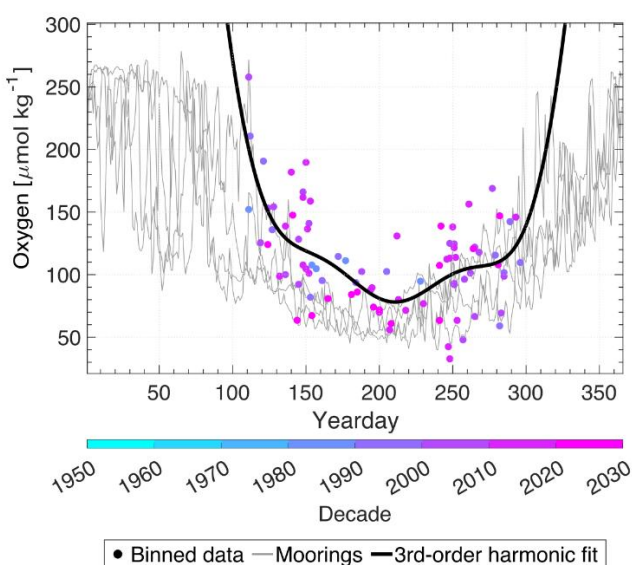


Figure 13-4. Near-bottom oxygen concentrations for the E01 mooring off the west coast of Vancouver Island at 100 m depth. The data is plotted relative to the day of the year. The data points are coloured by decade, with light blue for the 1950s and pink for the 2020s. The grey lines are data from moored sensors at 90m from July 2020 to June 2024. They illustrate the large variability in the winter months.

On the shelf the typical decline in the oxygen concentrations is about $-0.5 \mu\text{mol kg}^{-1} \text{ yr}^{-1}$ (respecting all the confidence intervals; Figure 13-5). The trends on the shallower isopycnals at the slope stations (P4 and CS01) are comparable to the typical shelf values whereas the trends on the deeper isopycnals are smaller. In some cases, the lack of a statistically significant trend may be due to high variability and not enough data points. In other cases, there simply does not seem to be a trend. For example, at E01 (50 m) in eastern Hecate Strait (HS; 50 m and 150 m) the oxygen trends are statistically different from zero, however, the near bottom trends (100 m

at E01 and 200 m at HS) are not different from zero (Figure 13-5) and there is no suggestion of a trend in the observations.

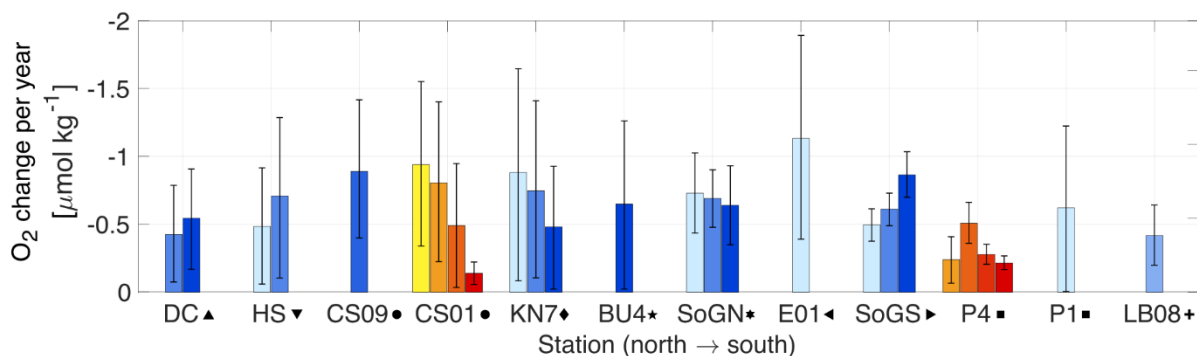


Figure 13-5. Oxygen trends at 10 shelf locations (blue tones) and 2 upper slope station (yellow and orange tones). The light blue bars are at 50 m, the darker blue is 150 m (or bottom), and the darkest blue is 300 m or the bottom. The 95% confidence limits are shown.

There are numerous papers documenting the declining subsurface oxygen concentrations across the subarctic Pacific Ocean (Ono et al. 2001; Deutsch et al. 2005; Whitney et al. 2007; Crawford and Peña 2016; Ito et al. 2017 and 2019; Sasano et al. 2018; Cummins and Ross 2020; Stramma et al. 2020). At Ocean Station P (OSP), there was a 20% decline in oxygen between 0-1550 m from 1960 to 2018 (Cummins and Ross 2020). On isopycnals (density surfaces) between 26.2 to 27.0 kg m⁻³ (roughly 100-300 m depth) the oxygen concentrations declined by 4 to 6 μmol kg⁻¹ per decade (0.09 to 0.13 ml l⁻¹ per decade) over the period 1960 to 2019 (Cummins and Ross 2020).

13.4. Factors influencing trends

At OSP the declining oxygen concentrations are attributed to declines in winter ventilation in the western North Pacific (e.g., Ono et al 2001; Whitney et 2007; Ito et al. 2019). This decline is basically due to warmer winters over continental Asia which leads to reduced ice formation in the Okhotsk Sea and a reduction in the exposed isopycnal area to the east of the Kamchatka Peninsula (outcrop area). Estimates of transit time from the oxygen ventilation areas to Ocean Station Papa (OSP; P26) range from 6-10 years depending, in part, on the isopycnal of interest (Mecking and Drushka, 2024; Franco et al. 2023; Ueno and Yasua 2003, Whitney et al. 2007). Stevens et al (2025) estimated a transit time of 8 years from the ventilation area east of Kamchatka to Queen Charlotte Sound on the 26.5 isopycnal. This suggests a pathway to Queen Charlotte Sound that does not go through OSP.

On the shelf, the declining oxygen trends since the 1970s have been attributed to declining oxygen over the upper continental slope (Crawford and Peña 2013; Johannessen et al 2014; Jackson et al. 2021). A causal link between the oxygen time series at OSP and P4 (on the upper slope) has not yet been established. The California Undercurrent which brings low oxygen water from the south along the upper continental slope limits direct communication between OSP and the B.C. coast. Maier et al (2025) show that the mid-depth subsurface water properties over the upper continental slope off Vancouver Island shelf are a highly variable mix of warm salty water from the south and cold fresh water from the subpolar gyre.

The result that the typical rate of oxygen decline on the B.C. shelf is about the same size as the decline observed at Ocean Station Papa supports the idea that the declines on the B.C. shelf are caused, in part, by the declines on the open North Pacific.

13.5. Implications of these trends

Given the linkage with declining ventilation in the Northwest Pacific, we should expect oxygen concentrations in the subsurface waters of coastal B.C. to continue to decline. The decadal variability in the North Pacific Ocean means that the declines may stop or reverse for a decade or so.

Declining background oxygen levels means that extreme low oxygen events (hypoxia; oxygen concentration less than 1.4 ml l^{-1} or $60 \mu\text{mol kg}^{-1}$) are becoming more common in B.C. shelf waters, even in places where they previously did not occur. For example, a sustained hypoxia event has occurred for 4 consecutive summers in southern Queen Charlotte Sound (Hannah 2025), an area where hypoxia was not observed prior to 2011 (Crawford and Peña 2013).

One might expect that the declining subsurface oxygen trends would have an impact on the groundfish populations. However, Pacific Canadian groundfish stock status and surveys show generally improving stock status since 2010 (Anderson et al., Section 27). In addition, the oxygen breakpoints for 22 groundfish species computed by Thompson et al. (2023) indicate that the current subsurface oxygen levels are not affecting the distribution of those species. Thus, it seems that declining oxygen concentrations are not an immediate crisis for B.C. groundfish.

There are two possible resolutions to this conundrum. The first is spatial variability. Consider the 3 stations on the southern Vancouver Island shelf, LB08, P1, and E01. All three are in 100 – 120 m of water. At LB08, a location where summertime hypoxia has been observed for a long time, there is a statistically significant decline in the near-bottom oxygen at 95% confidence. Nearby at P1 the decline is almost but not quite significant at 95%. At E01, further north near Estevan Point, there is no suggestion of a declining trend. So, we need to be cautious about assuming we know what is going on where we have not looked.

The second is temporal variability. The NE Pacific is subject to strong decadal scale variability and the Pacific Decadal Oscillation has been shown to affect oxygen concentrations along the west coast of North America. Visual inspection of some of the time series suggest that there has been no decline since about 2010. A more sophisticated analysis than simple linear trends would be required to address this.

Acknowledgments

Our thanks to Lu Guan (OSD/DFO) for Figure 13-2.

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14. WATER CURRENTS AND TEMPERATURE OFF THE B.C. COAST

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14.1. Highlights

- Satellite altimetry measurements showed that in 2025 the shelf-edge surface current was more equatorward at the West Vancouver Island transect. The shelf-edge surface current was weaker than normal at the Queen Charlotte Sound transect.
- A validated ocean circulation model showed that in 2025 the Vancouver Island Coastal Current was weaker than normal, the upper shelf-edge current was more equatorward than normal, and the California Undercurrent was weaker than normal.
- In 2025, the modeled sea surface and bottom temperatures off the B.C. coast were above normal, except the bottom temperature over the slope.

14.2. Description of the time series

14.2.1. Altimetric shelf-edge surface currents

Geostrophic surface currents were calculated at two transects (Figure 14-1) by using 10-day interval along-track satellite altimetry sea surface height data from October 1992 to December 2025, following the method in Han and Chen (2022). One transect was located off the West Coast of Vancouver Island (WCVI) and the other was located at the mouth of Queen Charlotte Sound (QCS). The geostrophic surface currents were in the direction normal to the transect (positive poleward) and approximately represented the longshore flow. The calculated geostrophic surface currents were further averaged both seasonally and over-transect. The mean currents averaged over 1993-2020 (the reference period) were removed to produce altimetric current anomalies.

Next, near-surface (averaged within the top 30 m) currents normal to the transects were derived based on the model output from a 1/36° Northeast Pacific Ocean Model (NEPOM, Han 2025). The model currents averaged over 1993-2020 were added to altimetric current anomalies to produce the total seasonal mean currents. The model sea level, temperature, salinity, and current were evaluated against observations at two long-term monitoring sites off West Vancouver Island, demonstrating good skills at those locations (Han 2025).

Further, the seasonal current climatology was calculated by averaging the total seasonal mean currents over 1993-2020 for each season. The seasonal current anomalies were produced by subtracting the seasonal climatology from the total seasonal mean currents. Finally, the standardized current index was calculated by dividing the seasonal current anomalies by their standard deviation over 1993-2020.

14.2.2. SWOT sea surface currents

Sea surface height anomaly data from the Surface Water and Ocean Topography (SWOT) wide-swath satellite altimetry were mapped using optimal interpolation over the shelf and slope off the B.C. coast for the period from August 2023 to November 2025. Geostrophic current

anomalies were derived from the mapped sea surface height anomaly fields and evaluated against current meter data. For the first time ever, SWOT made it possible to provide observational seasonal circulation patterns with a horizontal resolution of a few kilometres over the B.C. shelf and slope.

14.2.3. Model volume transport of major currents

A transect off West Vancouver Island (T2E and T2W; Figure 14-1) was selected to calculate the volume transport associated with the Vancouver Island Coastal Current (VICC, T2E), the Upper-layer Shelf-edge Current (USC, T2W_Up), and the California Undercurrent (CU, T2W_Low) from the NEPOM output over 1993-2025. The model transport values were averaged seasonally. Further, the seasonal transport climatology was calculated by averaging the total seasonal transports over 1993-2020 for each season. The seasonal transport anomalies were produced by subtracting the seasonal climatology from the total seasonal transports. Finally, the standardized transport index was calculated by dividing the seasonal transport anomalies by their standard deviation over 1993-2020.

14.2.4. Sea surface temperature and bottom temperature

The coastal and shelf waters off West Vancouver Island and off the northern B.C. coasts were divided into eight areas (Figure 14-1). The model sea surface temperature (SST) and bottom temperature (BT) from 1993 to 2025 were averaged both seasonally and over-area. Further, the seasonal temperature climatology was calculated by averaging the total seasonal currents over 1993-2020 for each season. The seasonal temperature anomalies were produced by subtracting the seasonal climatology from the total seasonal temperature. Finally, the standardized temperature index for SST and BT was calculated by dividing the seasonal current anomalies by their standard deviation over 1993-2020.

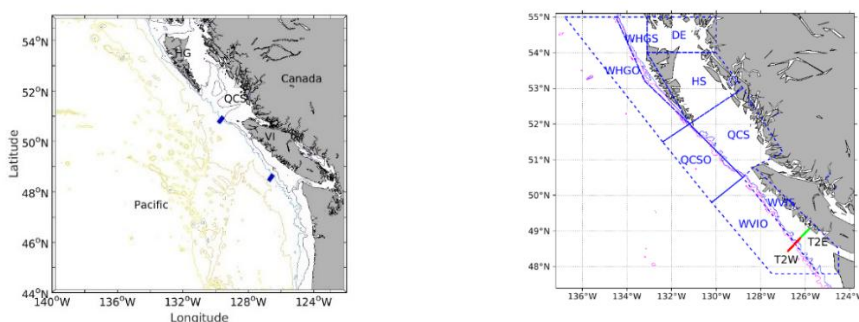


Figure 14-1. The study area showing the location of two altimetry transects (blue) and bathymetry (200- (black), 1000- (blue), 2000- (green) and 3000-m (yellow) isobaths (left panel). HG: Haida Gwaii. QCS: Queen Charlotte Sound. VI: Vancouver Island. Right panel. The location of a transect off West Vancouver Island for the model transport (T2E and T2W) and the eight areas for the model sea surface temperature and bottom temperature (right panel).

14.3. Status and trends

At the WCVI transect the climatological seasonal surface current was poleward in winter/fall and equatorward in spring/summer, with the long-term mean surface current close to zero (Han

2024). There was little apparent long-term trend in the altimetric surface current over 1992-2025 (Figure 14-2, left panel). In 2025, the equatorward surface current anomaly was below normal in spring in winter, spring and fall. At the QCS transect, the climatological seasonal surface current was poleward in winter and fall, but weakly equatorward in summer (Han 2024). In 2025, the surface current anomaly was below normal in winter and spring and above normal in fall (Figure 14-2, right panel).

Over the shelf and slope off the B.C. coast, SWOT results show that overall, the winter poleward currents were weaker in 2025 than 2024 (Figure 14-3 (a) and (c)). The summer equatorward currents were similar in strength for the two years (Figure 14-3 (b) and (d)).

There was little apparent trend in the model transport over 1993-2025 (Figure 14-4). In 2025, the model results show that the VICC transport anomaly was below normal in winter and fall and to a lesser degree above normal in spring and fall. The USC transport anomaly was below normal in winter, spring and fall, consistent with satellite results. The CU transport anomaly was below normal in winter, summer and fall.

The SST shows rising trends over both the shelf and slope over 1993-2025, while the BT shows a rising trend over the shelf only (Figures 14-5 and 14-6). In 2025, the SST was above normal over the slope in winter, summer and fall and over the shelf in winter and fall. The BT was above normal in winter and fall over the shelf, but below normal over the slope.

14.4. Factors influencing trends

El Niño and La Niña could affect ocean temperature and currents off the B.C. coast (Hourston and Thompson 2020). They could also be influenced by other large-scale climate factors such as the Pacific Decadal Oscillation, possibly via its impacts on large-scale and regional wind patterns. In 2025 there was a transition from neutral to La Niña conditions. The Pacific Decadal Oscillation remained in a cool phase.

The SST variations over the continental shelf and slope off the B.C. coast appeared to be related to El Niño and La Niña. The BT appeared to be related to El Niño and La Niña over the shelf and to the Pacific Decadal Oscillation over the continental slope.

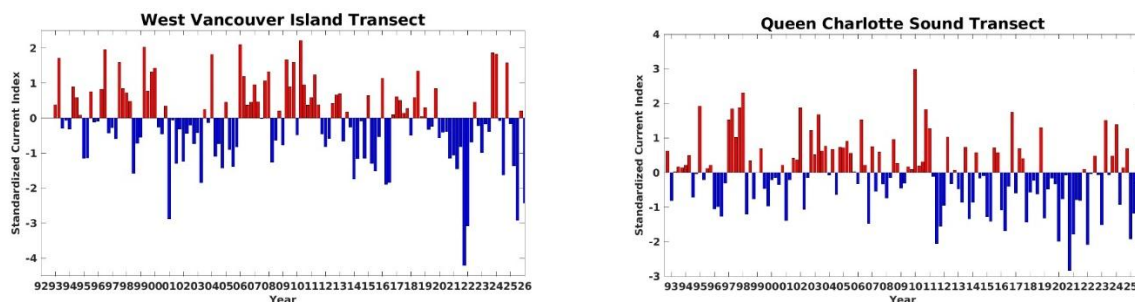


Figure 14-2. The standardized current index based on satellite altimetry measurements at the WCVI (left) and QCS (right) transects, calculated by dividing the seasonal current anomaly by its standard deviation over 1993-2020.

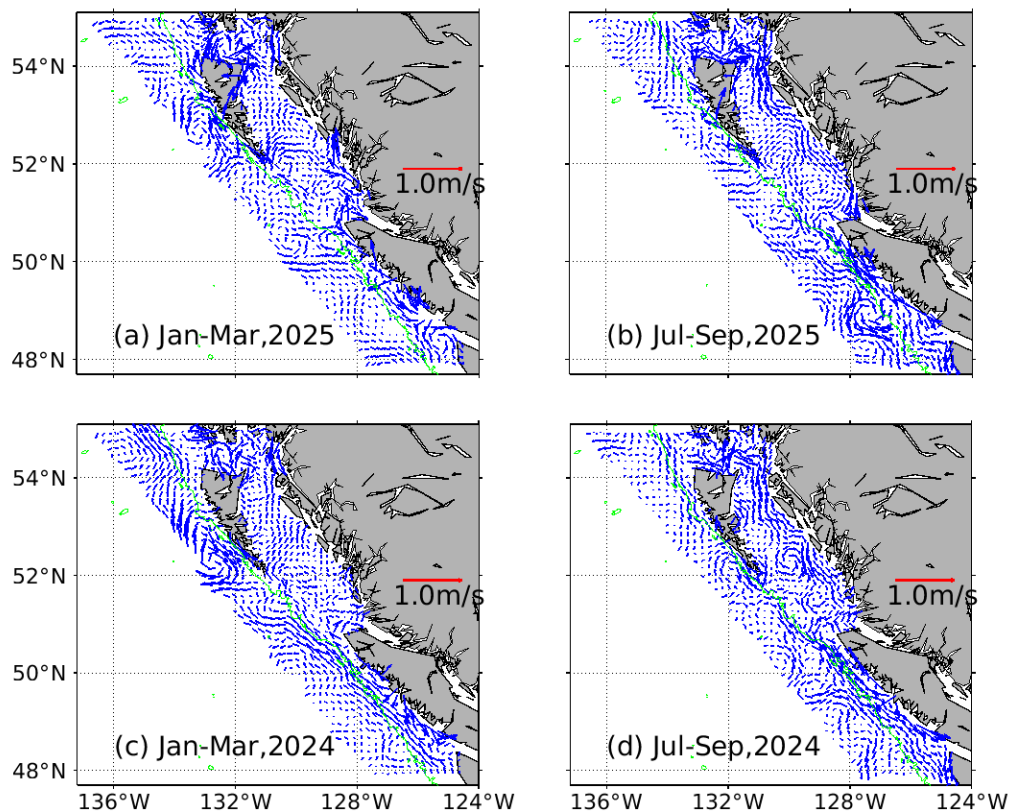


Figure 14-3. The winter and summer surface current anomalies over the shelf and slope off the B.C. coast in 2024 and 2025, derived from sea surface height anomalies observed by the SWOT satellite.

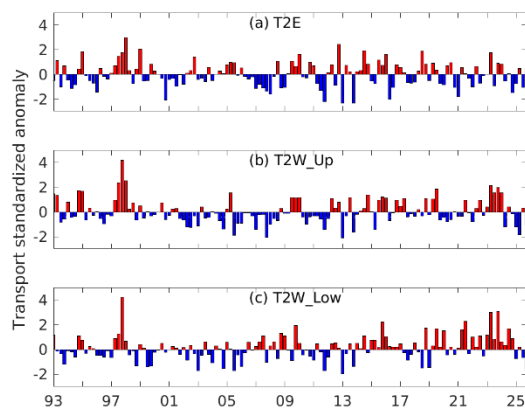


Figure 14-4. The mode-based seasonal transport anomaly index for the (a) Vancouver Island Coastal Current, (b) Upper Shelf-edge Current, and (c) California Undercurrent, calculated by dividing the seasonal transport anomalies by their standard deviation over 1993-2020.

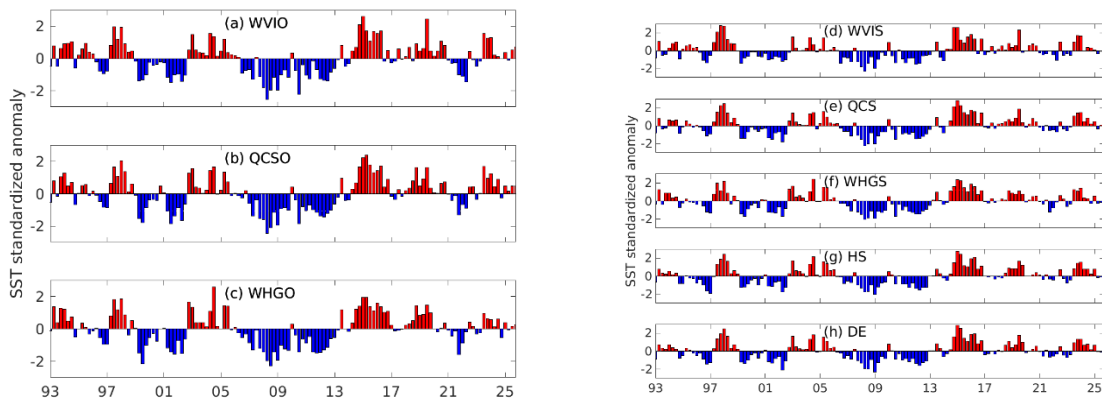


Figure 14-5. The model-based seasonal sea surface temperature anomaly index for regions over the slope (left panels) and shelf (right panels), calculated by dividing the seasonal transport anomalies by their standard deviation over 1993-2020.

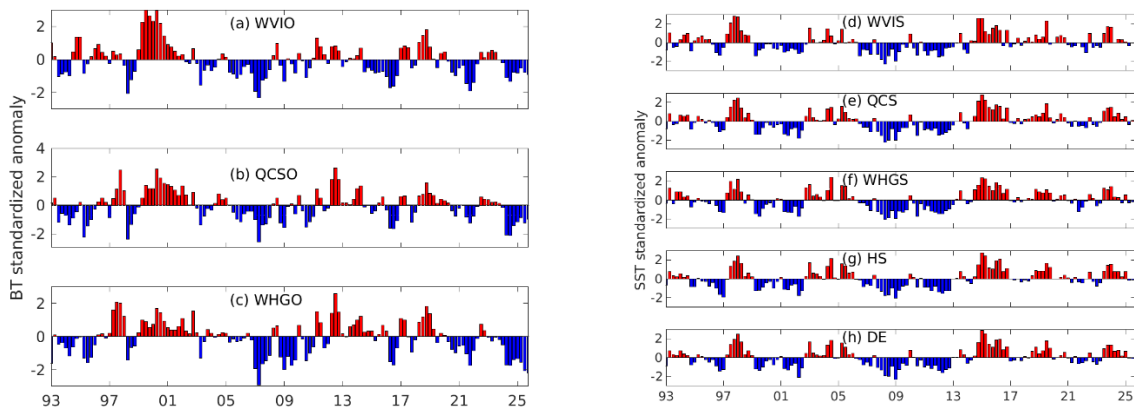


Figure 14-6. The model-based seasonal bottom temperature anomaly index, for regions over the slope (left panels) and shelf (right panels), calculated by dividing the seasonal transport anomalies by their standard deviation over 1993-2020.

14.5. Implications of those trends

Ocean currents can affect water properties such as temperature, salinity, nutrients, and dissolved oxygen (Thomson and Krassovski 2010). Both ocean currents and temperature can impact transport and distribution of fish eggs and larvae and fish migration routes (e.g., Dufresne et al. 2025). Folkes et al. (2018) showed that surface currents can be a useful predictor for the return timing and northern diversion rate of Fraser Sockeye Salmon.

14.6. References

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15. 2025 OCEAN CONDITIONS AND POTENTIAL MONITORING METRICS FOR GWAII HAANAS AND HAIDA GWAI

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15.1. Highlights

- On average from satellite data, 2025 sea surface temperature was higher than the historical baseline (1991-2020) but lower than 2024; however, Gwaii Haanas West (GHW) and Gwaii Haanas South (GHS) had a higher number of days over the marine heat wave (MHW) threshold in 2025 compared to 2024, and Gwaii Haanas East (GHE) and Gandaawuu.ngaay Xyangs (GX) had a slightly lower number of MHW days.
- Large differences in surface phytoplankton biomass were observed between the three Gwaii Haanas areas. In 2025, GHE had higher phytoplankton biomass at the surface (and at depth as observed in sampling station data), and a strong, early spring phytoplankton bloom and strong, but short-lived, late summer bloom. GHW had higher than normal phytoplankton in late summer and fall.
- Occasional inflows of dense deep water from Hecate Strait brought in low oxygen and reduced deep water oxygen. Deep water inflow lowered oxygen levels in Gandaawuu.ngaay Xyangs a month earlier in 2025 than in 2024. Spring and summer 2025 deep water oxygen levels were below average for the time series. Deep water in winter 2025 was warmer than average but not as warm as in 2024.
- No ship time was available for the collaborative Council of the Haida Nation-Gwaii Haanas-Fisheries and Oceans Canada (CHN-GH-DFO) Haida Gwaii **Chaan sk'ada gud ahl hlGanggulaa | Tang.gwan gan gud ad hlGang.gulxa** Working Together Ocean Science Expedition in 2025.

15.2. Description of the time series

Monitoring metrics are being developed for ocean conditions in Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site (hereafter Gwaii Haanas (GH); 51.25°N to 53.5°N and 128.5°W to 132°W), a land-sea protected area cooperatively managed by the Council of the Haida Nation (CHN) and Canadian federal

government represented by Parks Canada and Fisheries and Oceans Canada (DFO). These ocean condition indicator metrics are part of the Gwaii Haanas Marine Ecological Sustainability Monitoring program that aims to understand and routinely update ocean condition status and trends, and are being collaboratively developed by the GH-CHN-DFO Gwaii Haanas Ocean Condition Working Group that has been meeting since 2019. Preliminary metrics shown here are based on satellite sea surface temperature (SST) and sea surface chlorophyll-a (chl-a) for all of Gwaii Haanas (1981-present), and mooring- and CTD-measured temperature and oxygen from Gandaawuu.ngaay Xyangs (GX) *Juan Perez Sound* (JPS; JUAN mooring; 2017-present): annual and seasonal (or other timeframe) SST and chl-a and anomalies; days per year over or under ecological thresholds such as SST over 15°C, deep water dissolved oxygen (DO) below 1.4 mL/L and 3.5 mL/L; and days per year experiencing marine heat wave conditions. Other potential metrics that have been discussed by the working group include cumulative SST over ecologically significant time frames, growing and/or cooling degree days over specified temperatures related to ecological processes, and zooplankton and phytoplankton composition, biodiversity, and key species abundances.

To monitor conditions throughout the Gwaii Haanas marine area, satellite-measured metrics are important for broad area coverage and for covering time periods when field sampling does not occur. Gwaii Haanas marine waters are divided into three subregions: Gwaii Haanas West (GHW), Gwaii Haanas South (GHS) and Gwaii Haanas East (GHE) for reporting of satellite-derived ocean condition metrics, as well as for Gwaii Haanas overall (GH) (Figure 15-1). Satellite-derived SST and chl-a, a proxy for phytoplankton biomass in the surface layer of the ocean, are metrics reported here (see Hilborn et al., Section 16 for analytical details). These satellite-based ocean condition metrics are also reported for the Haida Gwaii continental shelf subregion (HGSh).

Within GHE, Gandaawuu.ngaay Xyangs *Juan Perez Sound* is an important location of high biodiversity to monitor because the oxygen dynamics in GX are fundamentally different from most B.C. mainland inlets and fjords. Here, due to winter storm mixing, the near-bottom oxygen maximum is in the winter, while spring and summer inflows of water from Hecate Strait can lower deep water oxygen concentrations (Jackson et al. 2025). Fisheries and Oceans Canada (DFO) scientists at the Institute of Ocean Sciences (IOS) in collaboration with Gwaii Haanas Parks Canada have maintained a single subsurface oceanographic mooring in GX from 2017-present. From 2017-2019, the mooring was located at station *Juan1* in 365 m of water and from 2019-2025, the mooring was located at station *Juan2* in 220 m of water (Figure 15-2). The moorings have been typically equipped with 3 or 4 Seabird CTD sensors which measure temperature, salinity, and pressure at different depths. Most years, the two deepest CTD instruments also collected dissolved oxygen (DO) data.

CTD and oxygen profiles were also collected annually at 7 stations in GX on the annual mooring cruise. Water bottle samples at various depths and locations, as well as zooplankton Bongo net tows, were collected at some stations, and also on other DFO cruises and collaborative CHN-GH-DFO Chaan sk'ada gud ahl hlGanggulaa · Tang.gwan gan gud ad hlGang.gulxa Working Together Ocean Science Expeditions on the RV David Thompson in 2019, CCGS Sir John Franklin in 2022, and CCGS John P. Tully in 2023 and 2024. Data reports from the collaborative expeditions remain to be drafted. Prior to this monitoring starting in 2017, very little data existed for oceanographic conditions in Gandaawuu.ngaay Xyangs, therefore many more

years of data will be required to understand or detect any long-term trends in the subsurface waters.

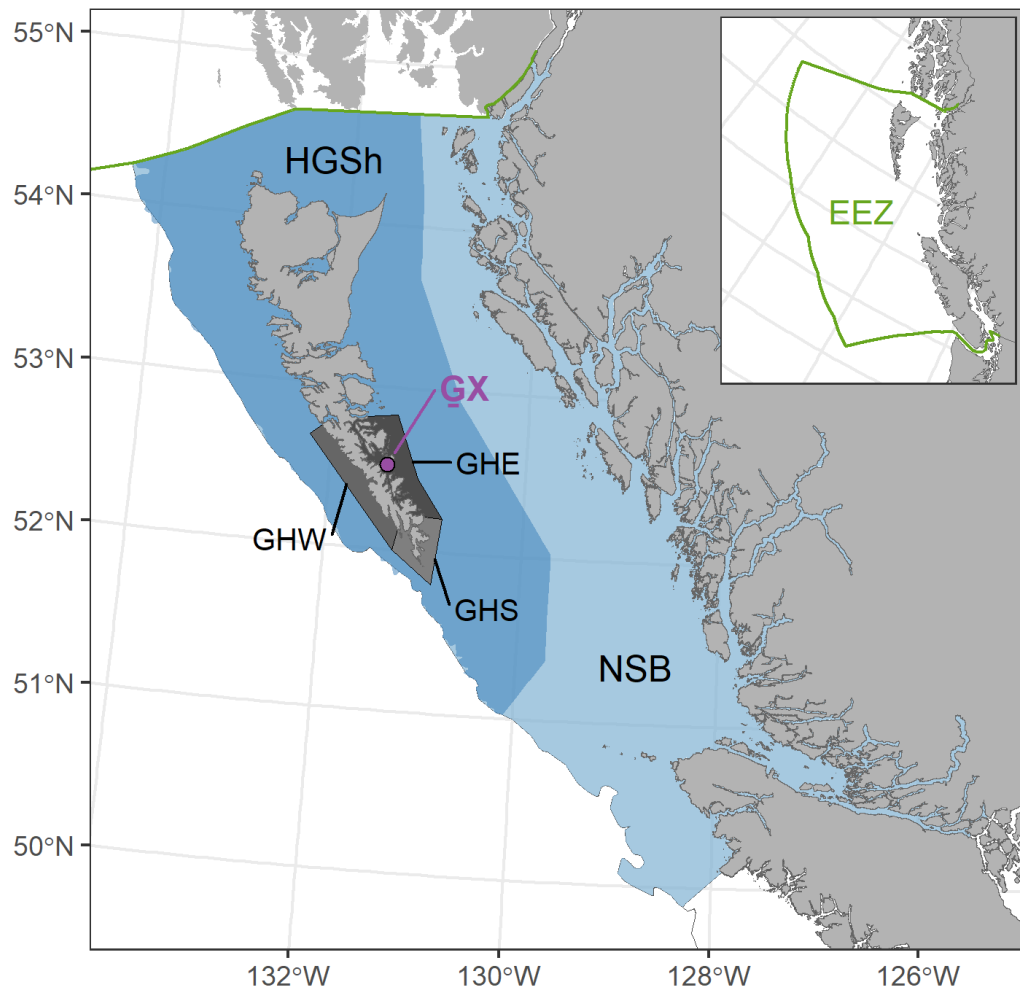


Figure 15-1. Location map showing the boundaries of reporting for satellite-derived metrics. From broader to finer scale, the areas are: Exclusive Economic Zone (EEZ; inset map), Northern Shelf Bioregion (NSB), Haida Gwaii Shelf (HGSb), Gwaii Haanas (GH; three Gwaii Haanas subregions together), Gwaii Haanas West (GHW), Gwaii Haanas South (GHS), and Gwaii Haanas East (GHE), and mean JUAN mooring location in Gandaawuu.ngaay Xyangs (GX).

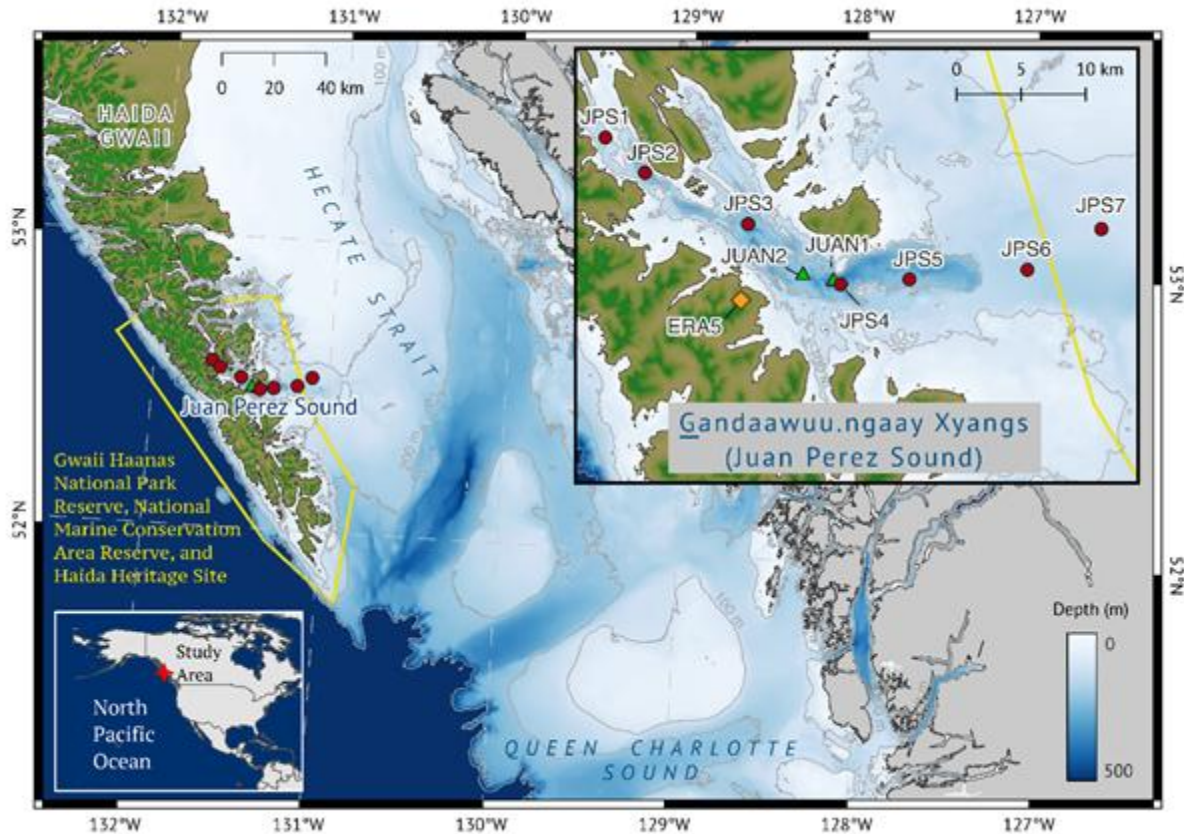


Figure 15-2. Location map showing the GH boundary (yellow line) and regularly sampled stations in *Gandaawuu.ngaay Xyangs* (red points). The mooring (green triangles on inset map) was located at either Juan1 (2017-2019 and 2023-present) or Juan2 (mid 2019-2023). Map credit: Alex Hare, Hakai Institute.

15.3. Status and Trends

Consistent with previous years, satellite-derived phytoplankton biomass in surface waters (chl-a) emphasized consistently higher productivity in GHE than in GHW and GHS, while SST between these subregions remained very similar (Figure 15-3). In summer 2025, anomalously high chl-a was observed from late July to the end of September extending along the whole west coast of Haida Gwaii. The concentration of phytoplankton in surface waters for GHW was over double the usual amount for this period, reaching 2.5 mg m^{-3} (see Hilborn et al. 2026, Section 16). This anomalous pattern was not observed to the same extent in the surface waters along the east coast of Gwaii Haanas and Haida Gwaii, though there was a strong, slightly early spring bloom south of Daajing Giids during April and May. Chl-a reached its usual higher concentrations during summer, with a late summer bloom occurring slightly early, at the end of July. GHS, which typically has similar chl-a to GHW, had slightly elevated chl-a throughout the year compared to normal, particularly during late summer during the same period as GHW. In GHE, the spring phytoplankton peak was earlier and higher compared to the long-term average, reaching 3 mg m^{-3} . In general, over the chl-a time series, years with warmer SST had less chl-a and years with cooler SST had more chl-a (Figure 15-3).

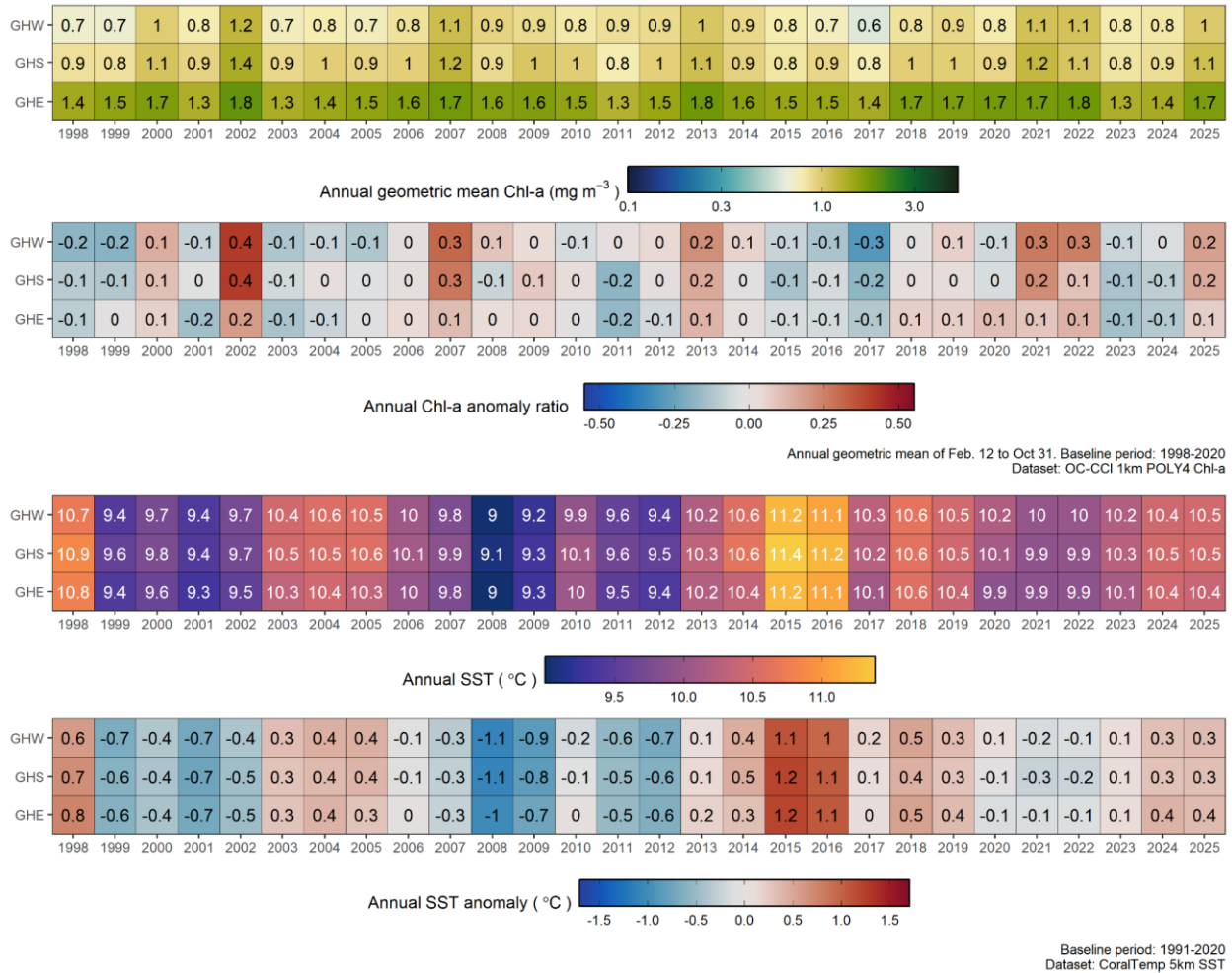


Figure 15-3. Satellite-derived average annual sea surface chl-a (top), annual sea surface chl-a anomalies (second), and annual sea surface temperature (third) and sea surface temperature anomalies (bottom) for GHW, GHS, and GHE from 1998-2025. The baseline for the chl-a anomalies spanned from 1998-2020, and the baseline for SST anomalies was 1991-2020.

Satellite-derived SSTs were warmer than normal for much of the winter, late summer, and fall of 2025. Near-normal or slightly cooler than normal SSTs were present from late May until the end of August throughout Gwaii Haanas, as well as its broader adjacent areas (Figure 15-1). Overall, 2025 was similar to and slightly cooler than 2024, being 0.3-0.4°C warmer than the 1991-2020 long-term average (Figure 15-4). 2025 had the highest anomalies during the summer, while 2024 had higher anomalies during both winter and summer (Figure 15-4). Fewer days in 2025 than 2024 exceeded 15°C, a threshold getting closer to an 18°C threshold used to approximate *hikāam · hikyama* bull kelp (*Nereocystis leutkeana*) physiological stress. To date, no days have averaged over 18°C in SST to generate a time series for days over the higher threshold. The number of days where SSTs were in marine heatwave (MHW) status between the regions was similar between 2025 and 2024, although the GHW and GHS had slightly more MHW days in 2025, while GHE had fewer (Figure 15-5). Long-term warming is evident in the satellite SST record, where cool anomalies were much less frequent. Warming during the summer into fall was especially evident, with very few cooler summers observed since 2013,

which are emphasized in the metrics plots of days per year over 15°C, and marine heat waves days per year (Figure 15-5).

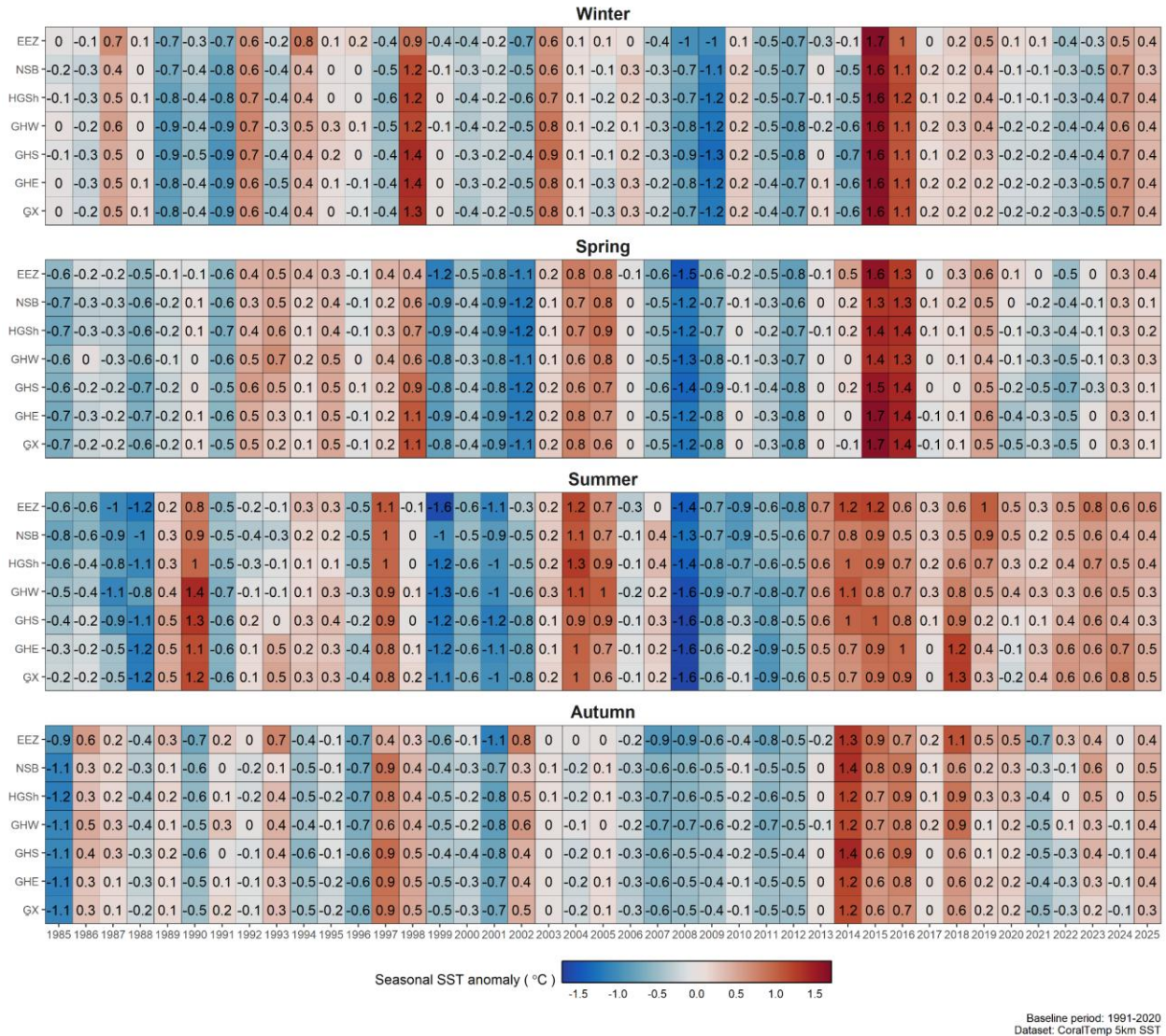


Figure 15-4. Satellite-derived ocean condition metrics for sea surface temperature by season from 1985 to 2025 for each of the geographic regions in and around Gwaii Haanas scaled from the EEZ to the ocean condition mooring buoy in Gandaawuu.ngaay Xyangs (GX). See Figure 15-1 for map of area boundaries. Seasons are 3-month periods over each year starting in winter from January-March. Baseline years for SST anomalies span from 1991-2020.

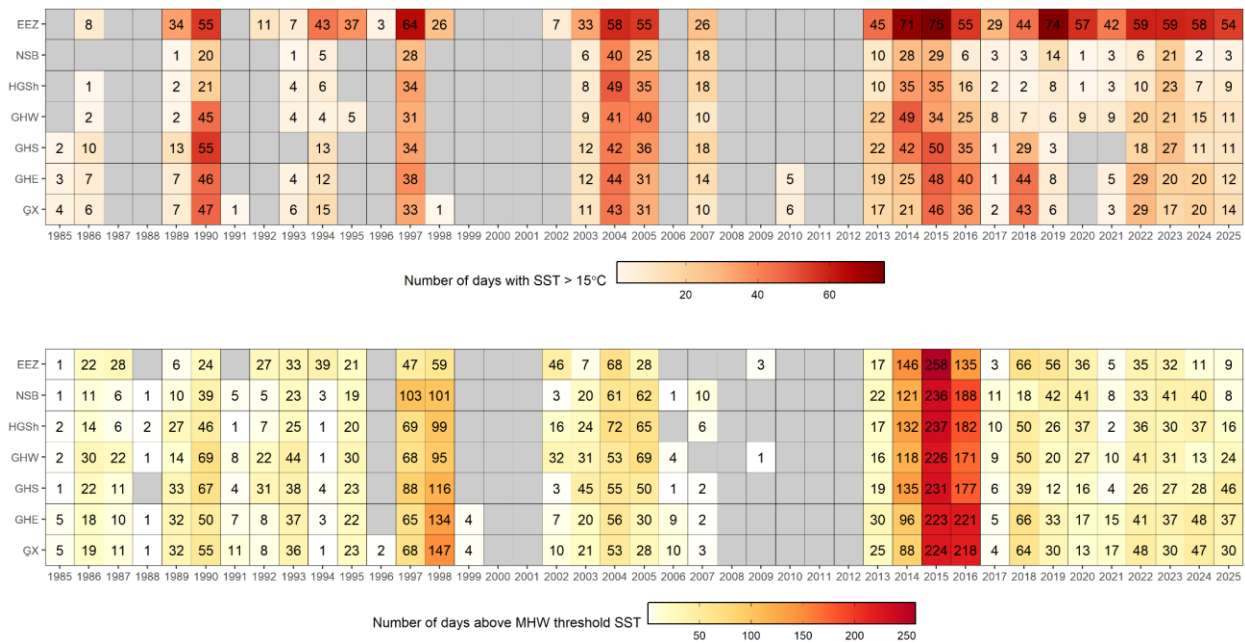


Figure 15-5. Two additional examples of satellite-derived metrics plots: (1) Number of days per year with area mean SST > 15°C (bull kelp physiological stress; 18°C would typically be used, but the mean area SST does not yet reach this value), compared to broader adjacent areas up to the NSB and EEZ (top), and (2) Number of days per year with area means exceeding the threshold for marine heatwave SSTs (SST exceeding the 90th percentile of the long-term baseline average from 1991-2020; bottom).

The Gwaii Haanas mooring (JUAN, combining stations Juan 1 or Juan 2 depending on the deployment year) data time series since 2017 showed that the water column in Gandaawuu.ngaay Xyangs became approximately well-mixed with nearly constant temperature, salinity and density in the winter months and deep water oxygen values greater than 5 mL/L (Figure 15-6). Deep water oxygen and temperatures were above average during winter except during a brief period in February 2025 when a winter upwelling event was observed along many moorings off the B.C. coast (see Bluteau et al., Section 12). The deep water oxygen then declined over the rest of the year due to biological consumption and inflows of low oxygen water from Hecate Strait (Jackson et al. 2025). Water intruded from Hecate Strait in early May 2025, a month earlier than 2024, resulting in decreased temperature and oxygen, and increased salinity (Figure 15-6). Spring and summer 2025 deep water oxygen levels were below average for the time series.

Mooring data showed summer surface waters of 2018, 2023 and 2024 and winter 2023 were higher than the baseline (Figure 15-6), consistent with satellite-based SST anomalies (Figure 15-4). Deep waters were warmer in winter when the relatively warm surface water was mixed downwards, while they were cooler in summer as increased solar radiation, reduced winds and freshwater inputs increased stratification in the water column. The warmest deep water year in the time series occurred from fall 2023 to late spring 2024, with generally warmer deep waters from 2018-2020 as well (Figure 15-6).

Over the mooring time series, GX had no days of deep water oxygen below 1.4 mL/L, the threshold at which waters are considered hypoxic, and approximately 200 days per year under 3.5 mL/L, the threshold at which many marine species start to experience physiological stress

(Figure 15-7). Gandaawuu.ngaay Xyangs, north Hecate Strait, and the northern fjords seem to have highest deep water oxygen levels, with the most days of lower oxygen observed at the Scott Islands buoy at the north end of Vancouver Island.

A transect of CTD sampling stations across Hecate Strait in summer 2025 showed that the east side of Hecate Strait had cooler, saltier (and thus denser) and lower oxygen deep water than on the west side in GX. Water mass properties indicate that Hecate Strait waters in summer are similar from GX east across most of the strait until the most easterly sample in Caamaño Sound.

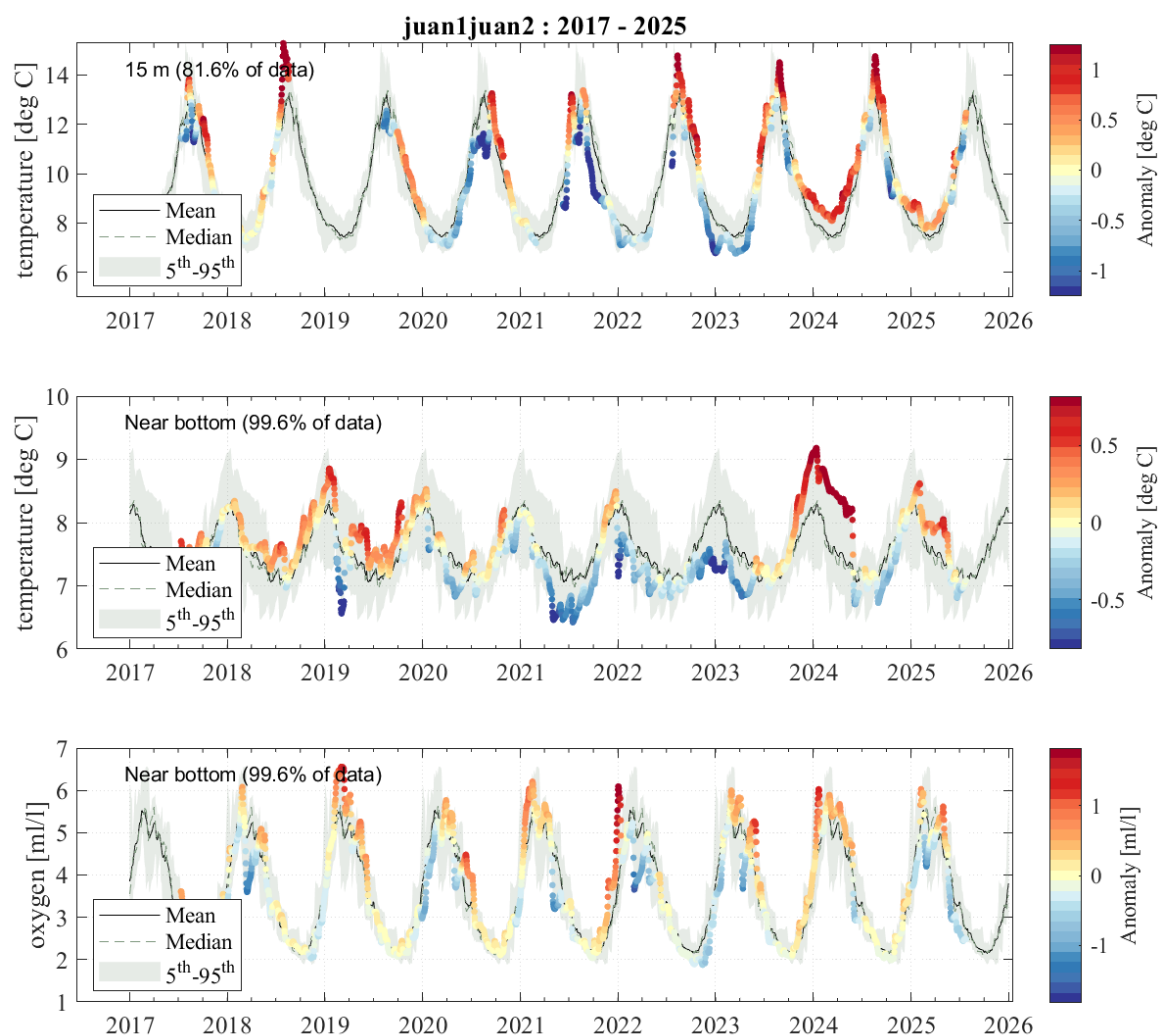


Figure 15-6. Daily subsurface temperature and dissolved oxygen measured near the bottom (bottom two panels) and near-surface temperature (top panel) at JUAN mooring. The observations are plotted against the statistics obtained at the same measurement depth from 2017 to 2025. The measurements are colour coded based on anomalies calculated using a baseline average over the entire time series. Note that the colour scale for the near-surface temperatures are twice those measured near the bottom.

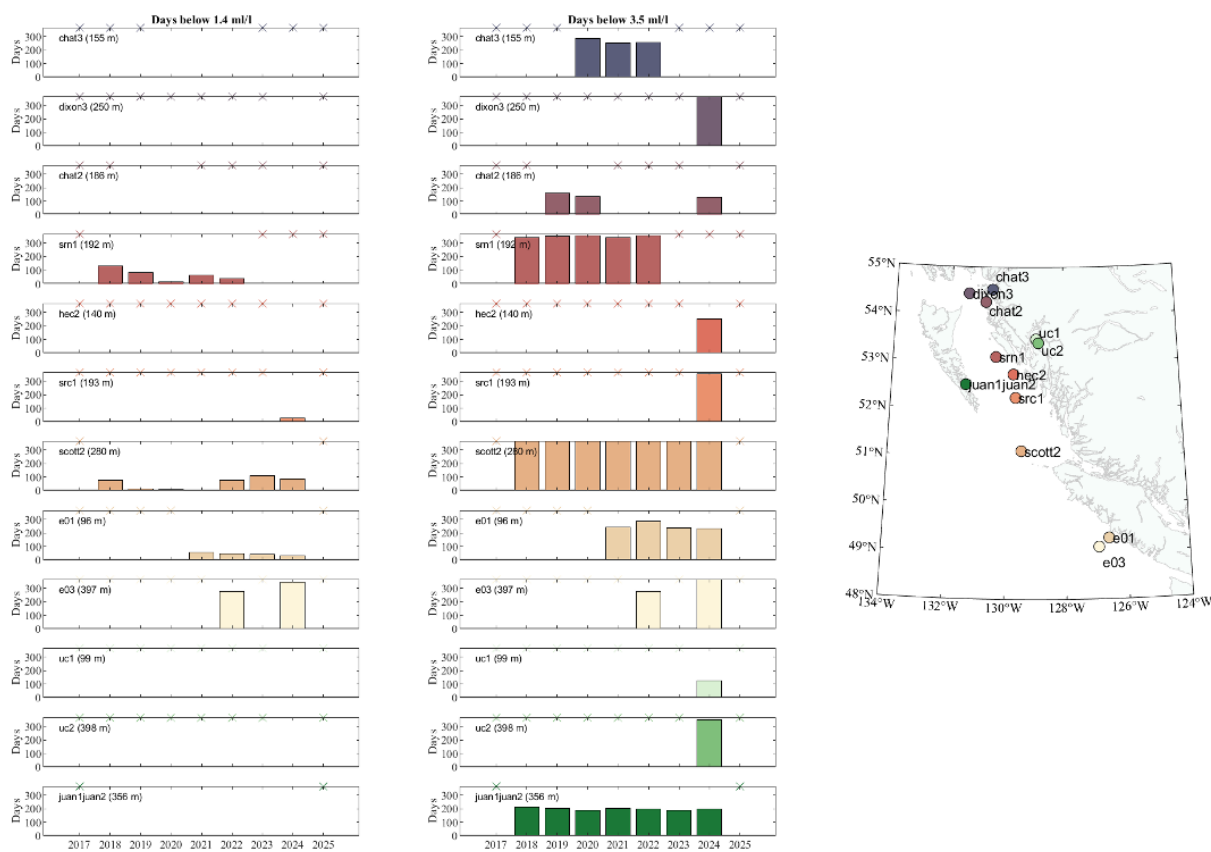


Figure 15-7. Number of days per year below two deep water oxygen thresholds - 1.4 mL/L indicating anoxic conditions (left) and 3.5 mL/L indicating significant physiological stress for many marine species (right) - for oceanographic mooring buoys across the B.C. coast from 2017-2025, putting Gwaii Haanas conditions in context with other parts of the B.C. coast.

15.4. Factors influencing trends

While El Niño Southern Oscillation (ENSO) neutral conditions were present in 2025, developing into a weak La Niña toward the end of the year, SSTs were overall warmer than average, though similar to the climatology during spring. Increasing evidence is showing that the cooling effect of La Niña may be counterbalanced by climate warming.

Jackson et al. (2025) showed that the winter storms are responsible for mixing the water column and providing the mechanism generating high dissolved oxygen (DO) concentrations in deep water. They also showed that while the two winters with the lowest wind energy (2017-2018 and 2019-2020) had the lowest DO, the winter with the highest DO (2018-2019) did not necessarily have the strongest winds, thus other factors like timing of winds relative to the overall stability of the water column and intrusion of low oxygen bottom water from Hecate Strait, also play a role in deep water oxygen levels.

Further analyses of satellite-based, mooring and CTD data may provide insights into factors that are influencing observed ocean conditions and trends, for example, correlations between SST and chl-a levels and between ocean temperatures at various depths at different times of year.

15.5. Implications of these trends

The dissolved oxygen dynamics are different in Gandaawuu.ngaay Xyangs than most other B.C. mainland inlets and fjords with shallower and less exposed entrances. In GX, fall and winter storms continued to mix and de-stratify the entire water column (Figure 15-6), which results in high oxygen being distributed to the near-bottom. This winter mixing provides some protection against the overall declining subsurface oxygen being observed on the B.C. continental shelf (Hannah and Maier, Section 13) and may mean that GX is an important nearshore marine refugia as ocean conditions change. However, since pulses of shelf water cascade into GX and lower deep water oxygen concentrations, declining oxygen levels on the B.C. continental shelf are likely to continue to impact deep oxygen in GX in the spring, summer and fall.

The prolonged, higher than normal productivity in the surface waters along Haida Gwaii's west coast continued in 2025. Strong warm anomalies were present in late August and September, with over 80% of the Northeast Pacific in marine heatwave status during this time, particularly in offshore waters. Additional work is needed to examine whether there is a link between phytoplankton growth and ocean temperatures and/or other driving processes in this area.

Continuing warmer-than-average SST in all Gwaii Haanas subregions and in the EEZ more broadly is expected to affect the condition and trends of ecological indicators in Gwaii Haanas. For example, warmer waters are generally expected to cause increased physiological stress on some kelp species and eelgrass, and facilitate increased growth and range expansion of invasive species that thrive in warmer waters such as chain tunicates, European Green Crab, Sargassum Seaweed, and Pacific Oyster.

15.6. CHN-GH-DFO Collaborative Science Expeditions

The collaborative **Chaan sk'ada gud ahl hlGanggulaa | Tang.gwan gan gud ad hlGang.gulxa** *Working Together Ocean Science Expeditions* on board CCGS research vessels did not take place in 2025 due to limited ship time with ship refit. The CHN-GH-DFO team is aiming to continue the Haida Gwaii expeditions in 2027. Previous expeditions took place onboard the RV David Thompson in June/July 2019, CCGS Sir John Franklin in September 2022, and CCGS John P. Tully in September 2023 and 2024. Cruise reports are available for each expedition, and data reports remain to be completed.

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16. SATELLITE OBSERVATIONS OF SURFACE CHLOROPHYLL-A, TEMPERATURE AND MARINE HEATWAVES IN 2025

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16.1. Highlights

- Sea-surface temperatures (SSTs) were warmer than normal throughout the EEZ in 2025, similar to 2024. While in 2024, cool anomalies were prevalent in spring and fall, in 2025 they were mainly observed in late winter and spring.
- There was significant heat in the North-East Pacific (NEP) surface ocean in late July through September. For a couple weeks, >80% of the NEP had marine heatwave-level SSTs.
- Overall, chlorophyll-a concentration in B.C.'s surface waters was higher than normal. There were early, strong blooms on the west coast of Vancouver Island, and along B.C.'s central coast. The west coast of Haida Gwaii experienced higher productivity than usual through late summer.
- Widespread coccolithophore blooms were present in coastal waters and inlets throughout the summer, with extensive, long-lasting blooms visible in Kyuquot Sound and Barkley Sound.

16.2. Description of the time series

Numerous sources of moderate-resolution satellite data were used to monitor SST and chlorophyll-a concentration (Chl-a), a proxy for phytoplankton biomass, in B.C. coastal waters. Chl-a was acquired by downloading remote-sensing reflectance (Rrs) data from the European Space Agency (ESA) Ocean Colour Climate Change Initiative (OC-CCI; <https://www.oceancolour.org/>) at 1 km pixel resolution. An updated version of the POLY4 Chl-a algorithm as described in Clay et al. (2019) was applied to retrieve Chl-a with higher accuracy for B.C. coastal waters (see: <https://github.com/bio-rsg/oceancolour> for code and coefficients). SST time series for regions of interest along the B.C. coast were extracted from the NOAA CoralTemp SST product (<https://coralreefwatch.noaa.gov/index.php>) for 1985 to present at 5 km pixel resolution. Marine Heatwave (MHW) information for the NEP was also calculated using the Optimum Interpolation SST (OISST) dataset, which spans 1981 to present at 25 km spatial resolution (<https://doi.org/10.25921/RE9P-PT57>; see Hilborn et al. 2025 for details).

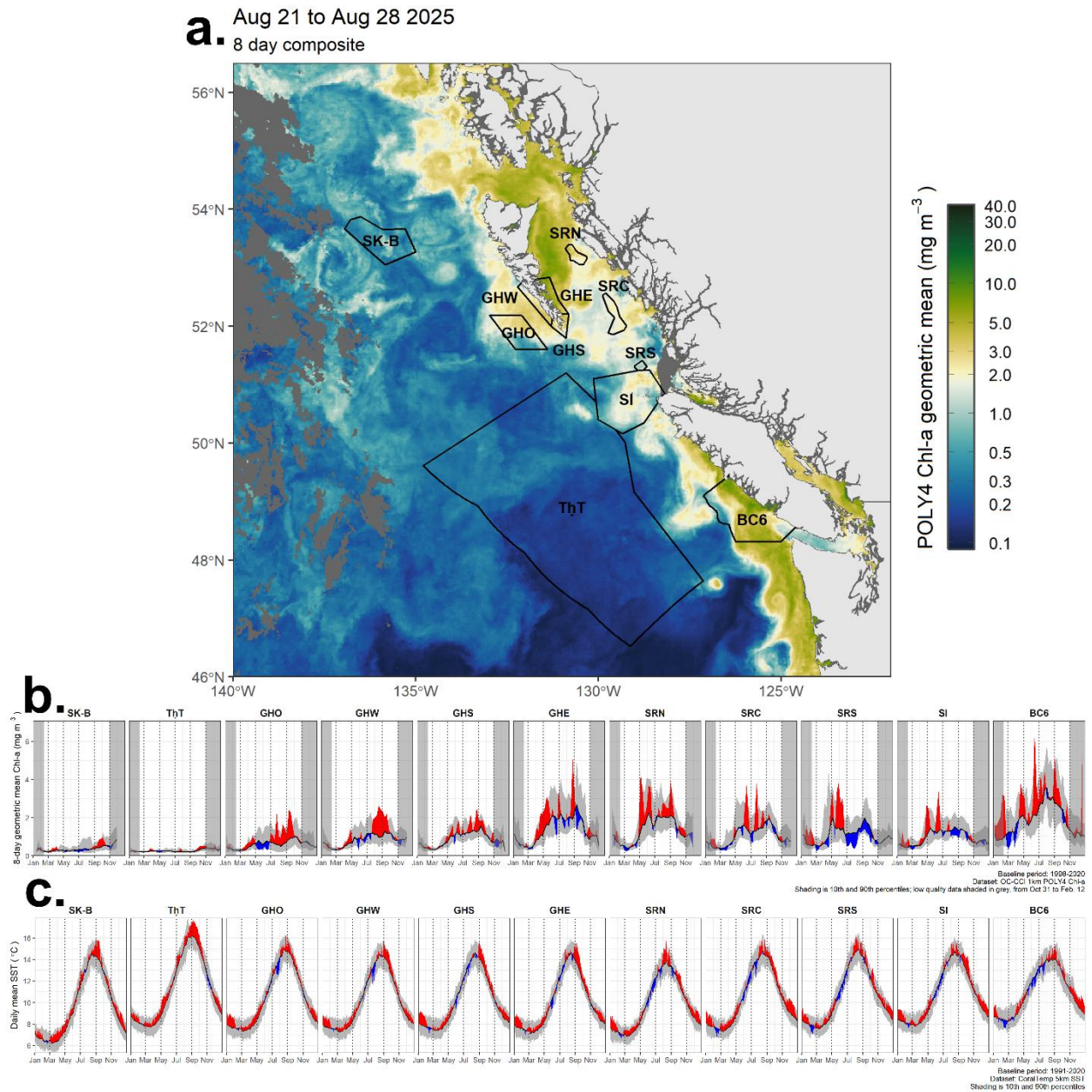


Figure 16-1. a. Subregions indicated in black polygons on 8-day composite images of modified OC-CCI Chl-a from late August. **b.** 2025 Chl-a shown as deviation (red and blue area) from long-term average (black line) for the regions on the map. **c.** 2025 SST (red and blue) shown on long-term average values.

Temporal statistics were extracted for the B.C. Exclusive Economic Zone (B.C. EEZ) and subregions of interest (Figure 16-1). These include Oceans Act marine protected areas (MPAs): Hecate Strait/Queen Charlotte Sound Glass Sponge Reefs (north, central and southern sections: SRN, SRC and SRS), SGaan Kinghlas-Bowie Seamount (SK-B), and Tanggwan – hačhiqak – Tsigis (ThT). Other areas included Scott Islands marine National Wildlife Area (SI), the Gwaii Haanas Offshore area (GHO), as well as Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve and Haida Heritage Site (Jackson et al. 2024) divided into three subregions (GHE, GHW, GHS). Lastly, the BC6 region (Hourston, Section 10)

is located on the west coast of Vancouver Island. For all areas, time series, climatologies, and anomalies were extracted. For SST, the mean and standard deviation (SD) were calculated, using the 1991-2020 climate period for the baseline. For Chl-a, as it has a log-normal distribution in the ocean, the geometric mean and geometric SD were used during calculations, and the shorter period 1998-2020 was used for the baseline. MHWs were defined as events during which SSTs exceeded the 90th percentile of the 30-year climatology (or 1.29 SDs; Hobday et al. 2016).

16.3. Status and trends

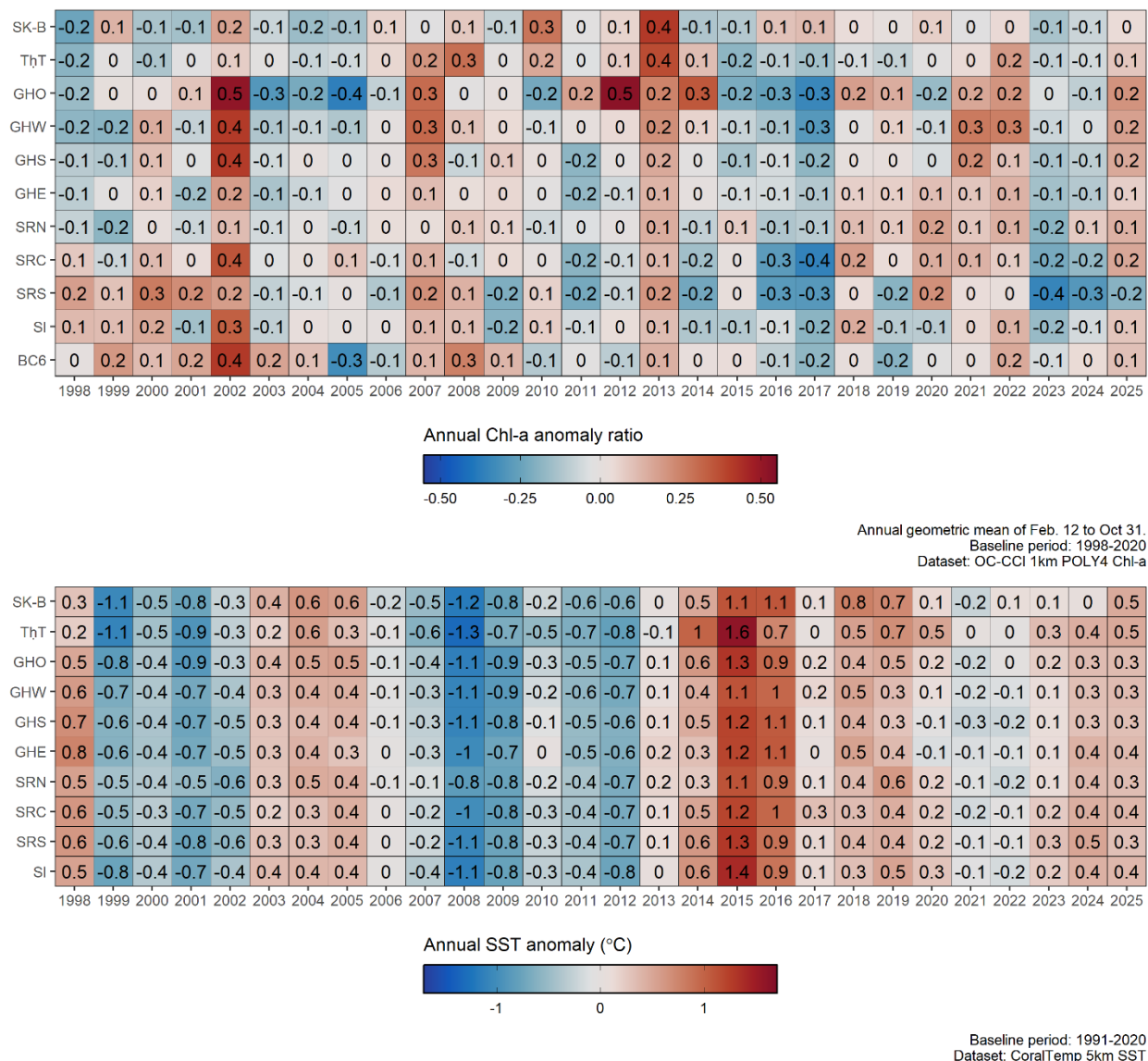


Figure 16-2. Annual anomalies for Chl-a (top) and SST (bottom), for the subregions (abbreviations on the left). 1985-1997 were excluded in this visualization for the SST. For Chl-a, the anomaly ratio was used, where the difference (2025 Chl-a with long-term mean subtracted) is divided by the long-term value.

In 2025, when aggregating Chl-a and SST into annual anomaly values, both were higher than normal throughout all regions for SST, and most for Chl-a (Figure 16-2). The annual mean SST anomalies were very similar between 2024 and 2025, with all regions except SRS equivalent to or warmer than 2024. SRS was also the only region where the Chl-a anomaly ratio was lower than the long-term average.

Chl-a in regions offshore of the continental shelf remained low year-round (i.e., SK-B and ThT), compared to coastal and continental shelf waters. A phytoplankton bloom in July, which persisted until mid-September, along the western coast of Gwaii Haanas was evident in the 2025 regional Chl-a, with GHO and GHW seeing much higher phytoplankton biomass compared to their long-term averages (Figure 16-1 b). In GHE, on the other hand, an early, strong phytoplankton bloom was observed in late April, with an earlier than usual summer peak in late August. In Hecate Strait, the Sponge Reefs MPA sub-regions had differing phenologies, with SRN higher than normal during the spring and summer, SRC higher than normal for June and July, and a strong spring bloom observed in SRS though much lower biomass following for the rest of the year. SI, a large region, had larger than normal Chl-a peaks occurring at the beginning of May, and mid-June. BC6, a region added this year, showed the highest overall phytoplankton biomass, though a differing phenology throughout the year, with a peak occurring in mid-July. 2025 saw very dynamic Chl-a, with a very early bloom occurring during February, and numerous other Chl-a peaks over the spring and summer.

SST, on the other hand, was similar between regions. Most regions had warmer than usual SST throughout the year, with a short cool period occurring in February to early March, and again in June and July. For GHO and GHW, June was near normal, with stronger cool anomalies in July, precluding its late summer phytoplankton bloom. BC6 saw longer-lived cool periods, related to the strong upwelling observed (Hourston, Section 10). MHW conditions were less prevalent in 2025 than 2024, though in late July a large MHW encroached on the EEZ, and covered over 80% of the NEP by early September (see: [https://github.com/IOS-OSD-DPG/Pacific SST Monitoring](https://github.com/IOS-OSD-DPG/Pacific_SST_Monitoring)). This corresponded to the largest NEP mean SST anomaly observed since 1981. By the end of 2025, all sub-regions were warmer than normal, with MHWs present in BC6 during December.

16.4. Factors influencing trends

Numerous early increases in phytoplankton biomass were observed in the satellite Chl-a, with strong phytoplankton growth during the summer. Generally, blooms were observed to be early or on-time in the spring, and further exploration of the very early bloom observed in February off the west coast of Vancouver Island is warranted. Phytoplankton taxonomy would be a useful measure for understanding this event. Strong upwelling, delivering nutrients and visible as cooler temperatures in the SST evident during spring and early summer, may have contributed to the strong phytoplankton growth in mid and late summer (Hourston and Thomson, Section 10).

While 2025 was an ENSO-neutral and La Niña year, SSTs were generally warmer than normal. 2025 was the fifth warmest year since 1981 for the larger NEP, and seventh-warmest for the EEZ. Offshore areas had larger SST warm anomalies, showing the linkage to the warmth present in the surface waters of the open ocean. Warming in the open-ocean waters of the north Pacific are shown to be linked to climate warming (Barkhordarian et al. 2022).

16.5. Implications of those trends

Anomalously warm SSTs can have negative ecosystem impacts. MHWs can contribute to Harmful Algae Bloom events or suppress nutrient transfer necessary for phytoplankton growth (Bond et al. 2015; Crozier 2015). SSTs in B.C. waters have been increasing in the long-term (Cummins and Masson 2014), and the frequency, duration and intensity of MHWs are increasing globally due to anthropogenic climate change (Laufkötter et al. 2020).

Early phytoplankton blooms may have negative impacts on the ecosystem by reducing food available to higher trophic levels or altering timing of food availability (e.g., match/mismatch), with early blooms potentially more detrimental compared to late blooms (Suchy et al. 2022).

Given ENSO neutral conditions, and emergence of a weak La Niña, we expected that 2025 may be cooler than 2024. As shown in other SOPO contributions, 2025 showed less agreement between large scale climate indices, which suggest conditions should have been cooler than normal, and the physical conditions in the NEP, which were warmer than normal in the surface ocean and at depth (Ross and Robert, Section 8), with anomalously warm terrestrial conditions as well (e.g., Curry and Dah, Section 6). Predictions for 2026 include ENSO neutral conditions, potentially transitioning to El Niño in the second half of the year, suggesting that 2026 will likely be warmer than 2025. If El Niño is present over the winter of 2026-2027, especially a strong El Niño, we worry that this may have negative ecosystem impacts, as observed in other years with warmer than usual winters (e.g., 2014 and 2015).

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17. BIOGEOCHEMICAL OBSERVATIONS AT SELECT NEARSHORE LOCATIONS ON THE B.C. MARGIN DURING 2025

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17.1. Highlights

- O₂ levels in Fitz Hugh Sound below 1.8 ml l⁻¹ were observed in August, 3 months after the arrival of seawater with density $\geq 1026 \text{ kg m}^{-3}$. O₂ below 1.6 ml l⁻¹ was observed during this period but not to the degree seen in 2023. There remained no observations of hypoxia (O₂ < 1.4 ml l⁻¹) within the Hakai Institute data holdings for this region.
- The extent of the water column in Fitz Hugh Sound and in the northern Strait of Georgia exhibiting undersaturated conditions for calcite increased in 2025 compared to recent years. A weak storm season between September 2024 and April 2025 contributed to the increase in corrosivity in the Strait of Georgia.
- Winter outflow winds within Bute Inlet during February drove the establishment of an intermediate cold layer. This layer was well oxygenated during the spring, however oxygen levels declined through the summer while the layer maintained cold temperatures.

17.2. Description of the time series

Biogeochemical time series are presented from three regions (Figure 17-1): Fitz Hugh Sound on the central B.C. coast, the northern Strait of Georgia, and Bute Inlet. Oceanographic data from Fitz Hugh Sound were collected through the water column at station KC10 (51.650°N, 127.951°W) on seven occasions during 2025. Oceanic data were also obtained from the KC buoy. ERA5 data were used to describe wind conditions for this location. Atmospheric and oceanic data collected in the northern Strait of Georgia were obtained from the Environment and Climate Change Canada (ECCC) Sentry Shoal weather buoy (46131) and from station QU39 (50.031°N, 125.099°W), respectively. Data from station QU39 were collected through the water column every 2 weeks. Oceanographic data presented from Bute Inlet were collected at station BU4 (50.587°N, 124.903°W) in the central fjord. Observations were also obtained from a new M_{Ap}CO₂ buoy, Bute Inlet Ocean Observing Station (BIOOS; 50.598°N, 124.900°W). Within each of these regions, oxygen (O₂) measurements were obtained using calibrated optodes on conductivity-temperature-depth (CTD) profilers, and calcite and aragonite saturation states (Ω_{cal} and Ω_{arag} , respectively) were computed from inorganic carbon measurements made on seawater samples collected using Niskin bottles following Evans et al. (2025). Hakai Institute CTD and real-time buoy data can be viewed here: <https://hakai-ctd-map.server.hakai.app/>. Hakai Institute ocean data products can be accessed here: <https://catalogue.hakai.org/>.

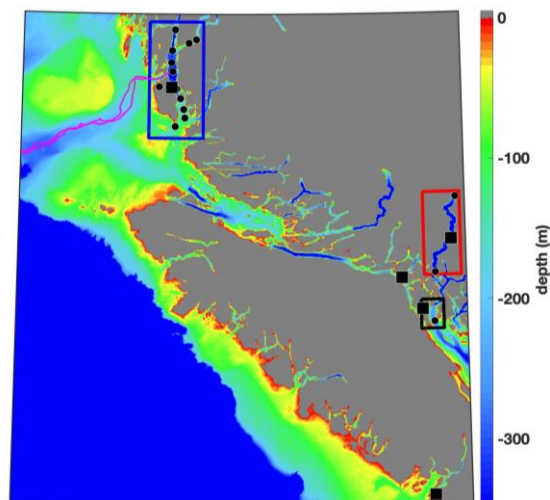


Figure 17-1. The distribution of ocean observing activities conducted by the Hakai Institute in 2025. The blue box delineates work conducted on the central B.C. coast, the black box highlights work in the northern Strait of Georgia, and the red box marks work in Bute Inlet. Black squares are ocean carbon time series locations, circles are CTD stations, and the magenta trace represents the CPROOF Queen Charlotte Sound glider line.

17.3. Biogeochemical time series

17.3.1. Central Coast / Fitz Hugh Sound

Our work has shown previously that the spring bloom precedes observations of dense upwelled water ($\rho_0 > 1026 \text{ kg m}^{-3}$) inundating Fitz Hugh Sound, and that low oxygen content ($\text{O}_2 < 1.8 \text{ ml/l}$) appears on the order of months after dense water is present (Evans 2025). This sequence of events was evident in 2025, with the spring bloom initiating in late March, dense water appearing in May, and oxygen content at depth declining to $< 1.8 \text{ ml/l}$ in August. The time separation between the arrival of dense upwelled water and the emergence of low oxygen conditions suggests local organic matter input is important for deriving this signal, as opposed to low- O_2 upwelled water flowing directly into Fitz Hugh Sound from the continental shelf. Figure 17-2 shows that this pattern of seasonally low O_2 at depth lagging the arrival of dense upwelled water occurs each year in the 12-year time series. This pattern is particularly evident during years when O_2 levels were exceptionally low ($< 1.6 \text{ ml/l}$), such as in 2015, 2018, 2023 and 2025. Despite observations of very low O_2 during these years, and more frequent occurrences of hypoxia on the Queen Charlotte Sound shelf during recent years (Stevens et al. 2025), hypoxic conditions ($\text{O}_2 < 1.4 \text{ ml/l}$) have yet to be observed within Fitz Hugh Sound.

Both Ω_{arag} and Ω_{cal} follow a similar seasonal pattern with O_2 (Figure 17-2). When O_2 levels are highest below 100 m between winter and spring, the saturation horizon for Ω_{arag} (depth where $\Omega_{\text{arag}} = 1$) extends below 100 m and undersaturated Ω_{cal} conditions are not evident. As O_2 declines at depth beginning in late spring, the Ω_{arag} saturation horizon simultaneously shoals to $< 50 \text{ m}$ over the summer months until the arrival of autumn storms, with undersaturated Ω_{cal} levels often observed below the Ω_{arag} saturation horizon during late summer and autumn (Figure 17-2). Seawater with $\Omega_{\text{cal}} < 1$ was seen over a greater duration and extent of the water column during 2025 compared to recent years. These conditions were evident between late summer and early autumn and from 150 to 250 m, with calcite saturation states below 100 m at that time

generally near saturation. Note there are instances in this time series when corrosive conditions for Ω_{cal} do not co-occur with observations of low O_2 (e.g., 2019).

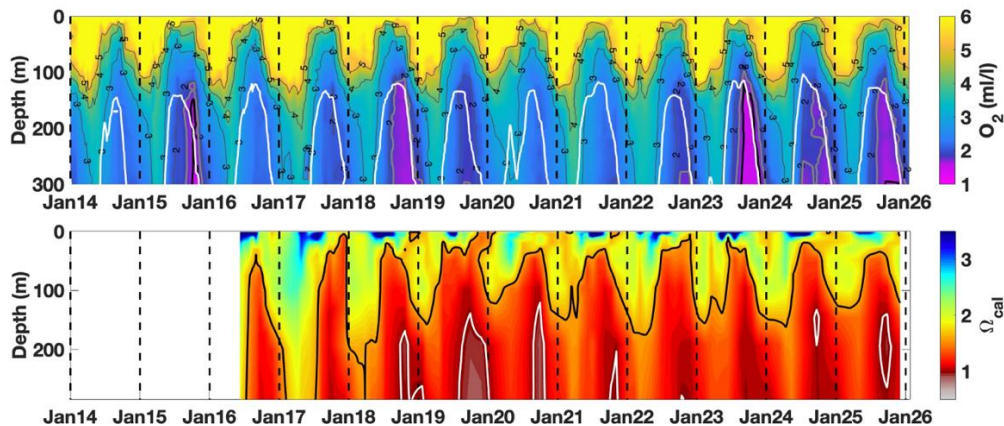


Figure 17-2. Observations from Fitz Hugh Sound. The top panel is oxygen (ml l^{-1}) over the upper 300 m at oceanographic station KC10 in Fitz Hugh Sound from 2014 to 2026. Highlighted oxygen contours are 1.8 ml l^{-1} (gray) and 1.6 ml l^{-1} (black). White contours represent the 1026 kg m^{-3} isopycnal and indicates the arrival of dense upwelled water. The bottom panel shows calcite saturation state (Ω_{cal}) with the white contours representing the calcite saturation horizon ($\Omega_{\text{cal}} = 1$). Also shown is the aragonite saturation horizon ($\Omega_{\text{arag}} = 1$) as a black contour.

17.3.2. Northern Strait of Georgia

The northern Strait of Georgia did not exhibit the low O_2 levels seen in Fitz Hugh Sound, but because of being generally weakly-buffered (Evans et al. 2019), it is prone to exhibiting extended periods of corrosive Ω_{cal} conditions. The emergence of these corrosive Ω_{cal} levels has been shown to be amplified by storm season intensity (Evans et al. 2025). Between 2020 and 2023, the storm seasons had been intensifying such that the extent of corrosive conditions for Ω_{cal} had been declining. This pattern reversed beginning in 2024, with the reduction in storm season intensity coinciding with an increase in the extent of the water column exhibiting corrosive conditions for Ω_{cal} (Figure 17-3). The annual mean percent of the water column with $\Omega_{\text{cal}} < 1$ increased from 13% in 2024 to 41% in 2025.

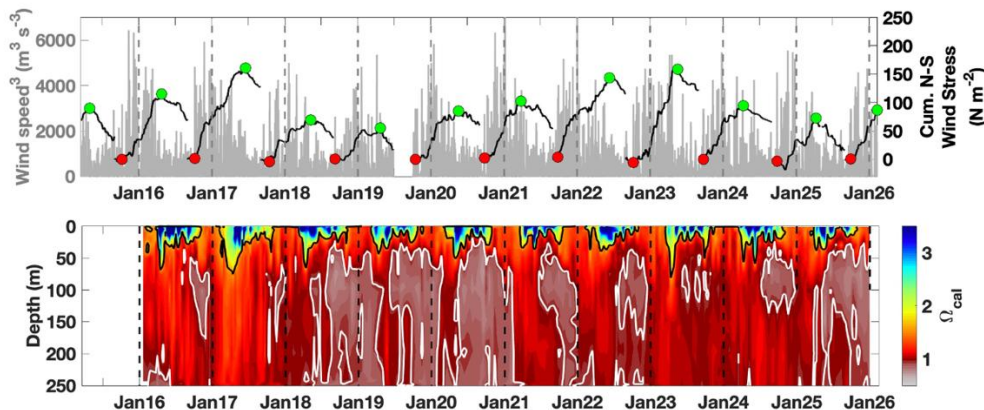


Figure 17-3. Observations from the northern Strait of Georgia. Top panel is the wind speed cubed ($\text{m}^3 \text{s}^{-3}$) and cumulative north-south wind stress (N m^{-2}) computed using measurements from the ECCC Sentry Shoal weather buoy (46131) from March 18, 2015 to March 2, 2026. Red dots in the top panel mark the first day in September that experienced gale force winds, and the green dots mark the inflection in the cumulative wind stress curve as wind direction shifts during spring to blow predominantly from the north. The red and green dots denote the start and end of the winter storm season, respectively, and the height of the cumulative wind stress curve is a measure of storm season intensity. The bottom panel shows Ω_{cal} over the upper 250 m of the water column at oceanographic station QU39 from January 20, 2016 to December 31, 2025. The white contours are the calcite saturation horizon, and the black contours are the aragonite saturation horizon.

17.3.3. Bute Inlet

Winter outflow winds have been shown to cool and reoxygenate intermediate water within Bute Inlet (Jackson et al. 2023), and this mechanism may serve as a reprieve from the general pattern of oxygen loss within B.C.'s inlets (Jackson et al. 2021b). During 2025, ocean observing efforts within Bute Inlet were enhanced by deploying a M_{Ap}CO₂ buoy and augmenting oceanographic surveys to include detailed biological and chemical sampling. Wintertime observations revealed intense surface cooling at the time the buoy was deployed in February (Figure 17-4). The 1023 kg m^{-3} isopycnal, representing the upper bound of intermediate water, was at the surface at this time, and cold, oxygenated conditions extended to the 1023.5 kg m^{-3} density surface near 100 m. By April, temperatures started to warm in the surface layer, and undersaturated pCO₂ with respect to the atmosphere persisted from spring through summer. During this period, cold temperatures persisted between the 1023 and 1023.5 kg m^{-3} isopycnals; however, oxygen content appeared to decline. High chlorophyll biomass was observed during spring and episodically in summer, and these conditions may have provided organic matter substrate to fuel oxygen consumption and subsequent decline within intermediate water. Cool conditions persisted within this layer, as did pCO₂ undersaturation at the surface and the signals of high phytoplankton biomass, until the storm season began in October (Figure 17-3).

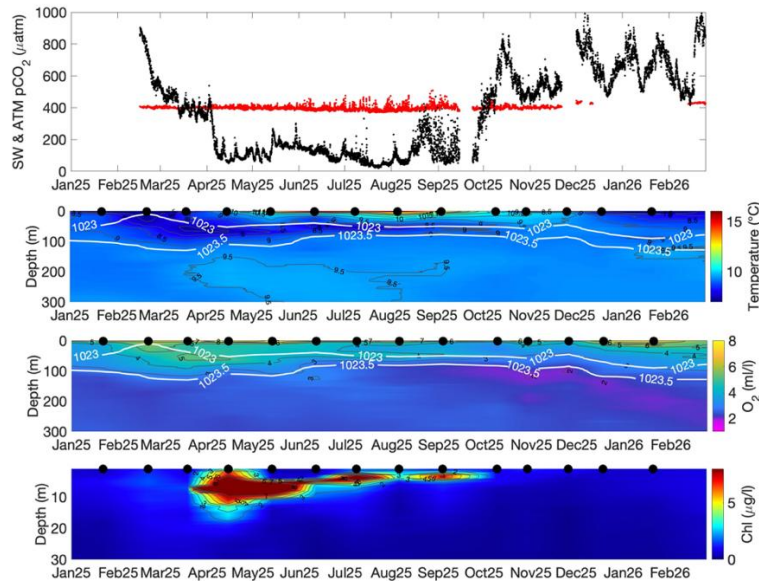


Figure 17-4. Observations from station BU4 in Bute Inlet. Top panel is seawater (black) and atmospheric (red) $p\text{CO}_2$ (μatm) from the Bute Inlet Ocean Observing Station (BIOOS) buoy. Second panel is temperature ($^{\circ}\text{C}$) with the white traces as the 1023 and 1023.5 kg m^{-3} density surfaces. Third panel is oxygen content (ml/l) with the white traces as the 1023 and 1023.5 kg m^{-3} density surfaces. Fourth panel is chlorophyll content ($\mu\text{g/l}$) over the upper 30 m.

17.4. Factors influencing trends

Data from each of these locations illustrate the responsive nature of biogeochemical patterns to physical and biological forcings in dynamic coastal B.C. waters. Within Fitz Hugh Sound, mixing along the shallow entrances to the region, supplies oxygen to depth during the spring and provides some protection from the inundation of hypoxic conditions originating from the continental shelf during the summer. However, the respiration of locally-produced organic matter may offset the gains from mixing and be a significant contributor to the late summer emergence of low- O_2 and corrosive conditions for calcite. This balance between source water character and local contributions to the observed biogeochemical patterns is an active area of research.

Storm season intensity is strong predictor of calcite corrosivity in the northern Strait of Georgia (Evans et al. 2025). Strong storm seasons lead to greater modification of the inorganic carbon content within the surface layer by enhanced dilution via discharge from the surrounding watersheds and by intensified gas exchange via the persistently elevated wind speeds. The modified surface layer is transported to and vertically mixed in Haro Strait (Pawlowicz et al. 2007), and this then impacts the character of intermediate water that is circulated northward in the Strait of Georgia (Stevens et al. 2021) leading to more saturated conditions for calcite over the months following the storm season. These modifications do not occur during weak storm seasons. Additionally, weak storm seasons exhibit higher particulate organic carbon loads (Evans et al. 2025), which can fuel remineralization and enhance calcite corrosivity.

B.C. fjords are now being recognized as regions subject to high rates of change (Jackson et al. 2021b) that can manifest biogeochemical extremes (Hare et al. 2020; Jackson et al. 2021a). Identifying time periods and locations that act as refugia from adverse conditions is critical, and the effect of winter outflow winds has been suggested to be a driver of refuge conditions for low

oxygen (Jackson et al. 2023). However, data from Bute Inlet collected during 2025 suggest the internal metabolism of the fjord has potential to offset these conditions. Continued work within this inlet aims to examine this relationship, providing a reference point for understanding physical-biogeochemical interactions within B.C. fjords more broadly.

17.5. Implications of those trends

Oxygen declines, including episodes of hypoxia, are being reported more frequently in shelf and fjord environments within B.C. waters, and simultaneously, there is growing evidence for refugia within these regions. Nearshore waters, like Fitz Hugh Sound, may exhibit some protection from shelf hypoxia by virtue of enhanced tidal mixing over the shallow entrances connecting these areas to the open continental shelf. The inlets and fjords of B.C. may also experience some reprieve from adverse conditions due to the influence of winter outflow winds. Intense storm seasons may offer some reprieve from corrosive conditions in semi-enclosed areas like is seen in the northern Strait of Georgia. Physical mechanisms establish refuge conditions in each of these cases; albeit, there is a high potential for biological intervention – periods of locally-derived high organic matter input that enhances oxygen consumption and CO₂ production at depth. This balance between physics and biology that shapes biogeochemistry is constantly shifting because of changes to climate and continued anthropogenic CO₂ uptake. An important question is: how long will these mechanisms be able to provide refuge for marine life? Only by maintaining our ocean observing capacities will we be able to address this question, understand the impacts of refuge contraction, and build appropriate adaptation and mitigation measures.

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18. 2025 TRENDS IN PHYTOPLANKTON BIOMASS AND COMMUNITY COMPOSITION FROM THE TIME-SERIES STATIONS IN THE NORTHERN SALISH SEA AND CENTRAL COAST, B.C.

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18.1. Highlights

- The second latest spring bloom (since 2015) was observed in the northern Salish Sea following strong spring wind conditions. The Central Coast spring bloom occurred earlier than the time-series median, during an abatement of winds.
- The northern Salish Sea showed strong spring season biomass (3rd highest) and moderate annual biomass (5th highest) due to a lack of an autumn bloom.
- The Central Coast showed characteristically high spring biomass with multiple diatom blooms and a late October bloom during freshwater driven re-stratification following a storm.

18.2. Description of the time series

Phytoplankton pigment time-series were analyzed from QU39 (northern Salish Sea) and KC10 (Central Coast), both maintained by the Hakai Institute (Figure 18-1). Sampling frequencies in 2025 differed from historical: QU39 bi-weekly (versus weekly) and KC10 seven times (versus monthly prior to 2024). Phytoplankton functional group contributions (TChla, mg m⁻³) were estimated from HPLC pigment samples collected at 5 m following Del Bel Belluz et al. (2021; 2024). To account for reduced 2025 sampling at QU39, prior years' weekly TChla were downscaled to bi-weekly means for seasonal comparisons.

At both stations, the spring bloom was defined as the first annual occurrence of TChla > 5 mg m⁻³ (or, at KC10, 2 m buoy chlorophyll fluorescence). The QU39 11-year time-series was divided into three seasonal components: the productive season (bloom initiation to the annual cumulative TChla anomaly peak); the spring bloom season (bloom initiation to stratification onset with diatom contribution < 40%); and summer (spring bloom season end to September 21). Seasonally integrated TChla (cumulative sum per period) was used to compare biomass across years.

At KC10, vertical biomass trends were characterized from CTD fluorescence profiles calibrated against discrete chlorophyll concentrations, and temporal variability from nightly median values of the 2 m buoy fluorometer (Chl_{BUOY}).

Physical drivers were examined using Hakai CTD-derived salinity, temperature, and stratification ($\Delta\rho_{30-2m}$). At QU39, Sentry Shoal buoy wind data (Environment Canada) were used to calculate north-south cumulative wind stress following Evans et al. (2025) and wind speed cubed. A windy-to-calm metric was derived by identifying transitions from high (5-day

mean $> 400 \text{ m}^3 \text{ s}^{-3}$) to calm (following day $< 100 \text{ m}^3 \text{ s}^{-3}$) conditions. Central Coast wind data were from the Hakai "Lookout" station on western Calvert Island.



Figure 18-1. Study area map showing the location of the Central Coast (KC10) and northern Salish Sea (QU39) sampling locations.

18.3. Status and Trends

In the northern Salish Sea, the 2025 spring bloom initiated on April 9th, the second latest of the time-series (median = March 20th), following windy spring conditions (Figure 18-2). The prior 28-day cumulative N-S wind stress, a strong predictor of bloom timing ($r^2 = 0.70$, $p = 0.001$), was the second highest on record. A secondary bloom developed in late June, just prior to seasonal stratification onset (July 2nd, the time-series latest), forming the annual maximum concentration. Together, the two blooms produced the 3rd highest spring-season integrated TChla on record (Figure 18-3). This metric is largely driven by windy-to-calm transitions ($r^2 = 0.93$, $p < 0.001$) but could not be calculated for 2025 due to wind data gaps. Low summer biomass and the absence of an autumn bloom resulted in the 5th highest annual productive-season integrated TChla.

Unlike the northern Salish Sea, the Central Coast (KC10) bloomed early, on March 25th, prior to the median initiation date (April 8th) and following the cessation of strong winds (Figure 18-4). As in prior years, multiple subsequent blooms occurred into June following wind events. Summer chlorophyll was moderate, with no strong subsurface chlorophyll maximum in the CTD profiles. An autumn bloom peaked on September 7th, and surface chlorophyll resurged on October 5th, coincident with a sharp salinity drop following a storm.

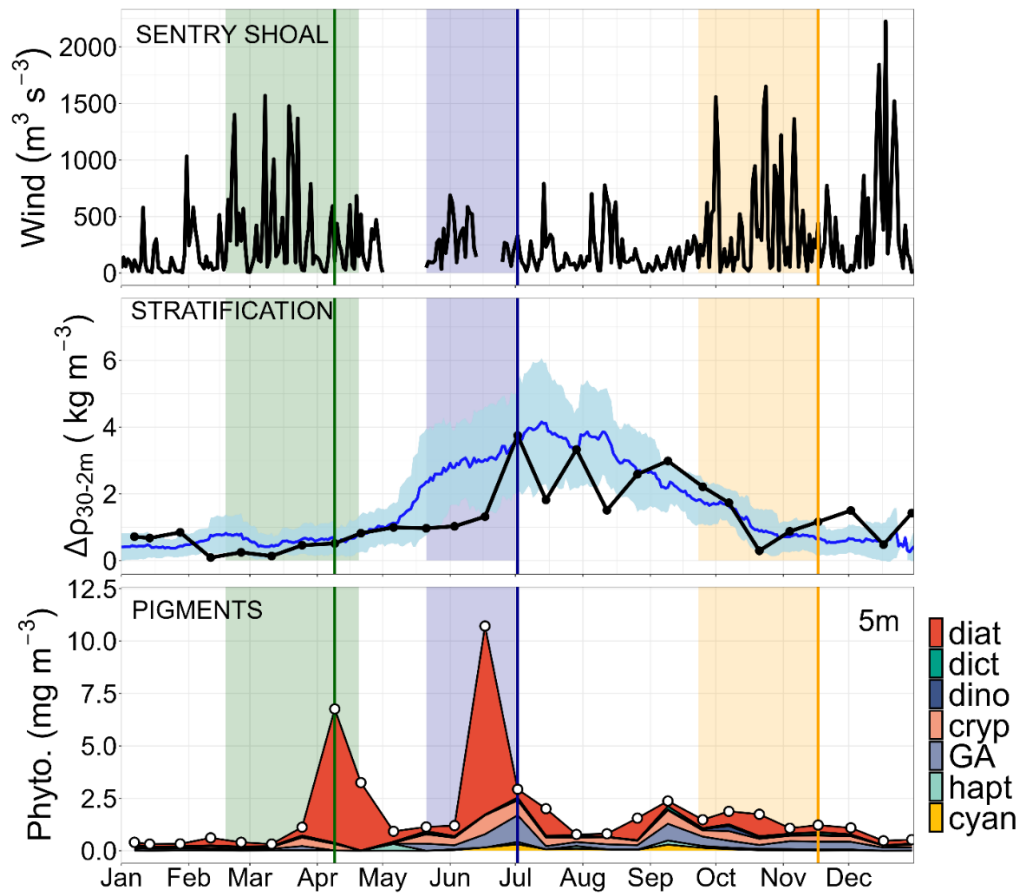


Figure 18-2. Station QU39 (Northern Salish Sea) 2025 time-series of: a) daily wind speed cubed ($\text{m}^3 \text{s}^{-3}$) from the Environment Canada Sentry Shoal buoy; b) CTD-derived stratification ($\Delta\rho_{30-2m}$, black line) with time-series 21-day rolling mean climatology and ± 1 SD shading and; c) 5 m depth CHEMTAX phytoplankton functional group contributions (TChla, mg m^{-3}). Vertical lines indicate 2025 timing of spring bloom initiation (green), spring bloom season end (blue), and productive season end (orange); shaded areas show the time-series range of each.

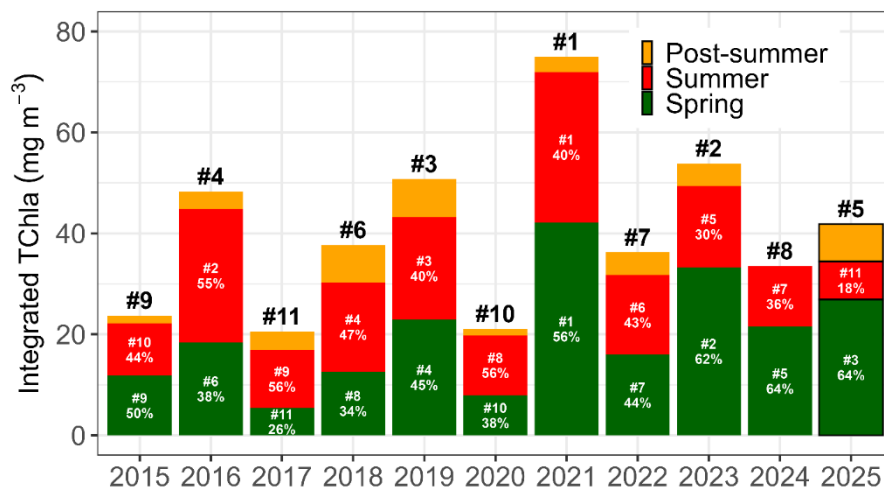


Figure 18-3. Station QU39 (northern Salish Sea) 2015–2025 annual productive season integrated TChla (mg m^{-3}), with seasonal contributions shown as stacked bars: spring bloom season (green), summer season (red), and post-September 21st remainder (orange). Numbers indicate time-series rank and seasonal percent contribution.

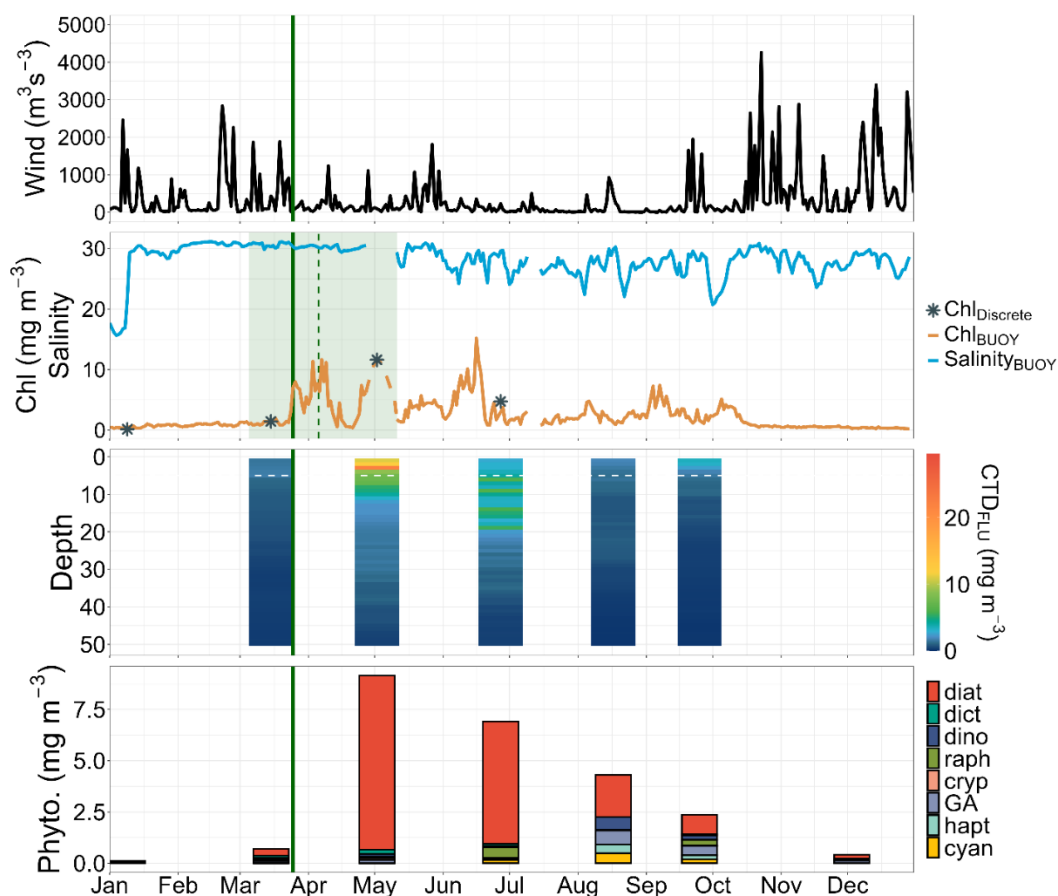


Figure 18-4. Station KC10 (Central Coast) 2025 time-series of: a) wind speed cubed ($\text{m}^3 \text{s}^{-3}$) from the Hakai "Lookout" weather station; b) buoy 2 m depth nightly median chlorophyll fluorescence (Chl_{BUOY} , mg m^{-3} , orange), daily median salinity ($\text{Salinity}_{\text{BUOY}}$, blue), and 1 m depth discrete chlorophyll ($\text{Chl}_{\text{Discrete}}$, mg m^{-3} , grey stars); c) NPQ-corrected CTD chlorophyll fluorescence profiles (0–50 m depth); d) 5 m depth CHEMTAX phytoplankton functional group contributions (TChla, mg m^{-3}). The solid green vertical line marks the 2025 spring bloom initiation date; the dashed vertical line in b) marks the time-series median initiation date. The shaded green region in b) indicates the historical range of spring bloom initiation dates.

18.4. Factors influencing those trends

In the northern Salish Sea, the time-series correlation between spring bloom timing and the prior 28-day cumulative N–S wind stress indicates that both wind direction and sustained intensity govern bloom timing: reduced wind speeds limit mixing and lift light limitation, making them a primary driver of bloom onset (Collins et al. 2009; Allen and Wolfe 2013). The late 2025 bloom contrasts with the earlier blooms reported elsewhere in this report (Allen and Latornell, Section 39; Esenkulova et al., Section 41), potentially reflecting the tendency for later blooms in the northern Salish Sea during years combining low freshwater input and windy conditions (Suchy et al. 2019).

At station QU39, spring-season integrated TChla largely reflects season length and the frequency of windy-to-calm transitions. In 2025, the late spring bloom was offset by the time-series' latest stratification onset, extending the season enough for a strong mid-June diatom bloom. The correlation between spring biomass and windy-to-calm transitions supports the need

for post-bloom wind events to replenish surface nutrients (Collins et al. 2009) and subsequent calm periods for biomass accumulation.

As usual, stratification onset coincided with succession to flagellate-dominated conditions, underscoring the role of stratification and nutrient depletion in limiting diatoms (Del Bel Belluz et al. 2021). Yet the drivers of interannual variability in summer diatom blooms, despite frequent nutrient renewal and drawdown, and of transient autumn blooms remain unclear.

On the Central Coast, 2025 spring bloom dynamics were broadly consistent with wind-driven forcing. The absence of a strong summer subsurface chlorophyll maximum and low summer biomass contrast with prior years, though limited CTD sampling constrains interpretation. As in 2024, an October chlorophyll resurgence coincided with storm-driven salinity reductions, highlighting the role of freshwater in providing stratification for late-season blooms. These appear to be a recurring feature, likely under-sampled by discrete and satellite observations (Johannessen et al. 2019).

18.5. Implications of those trends

Spring bloom timing and magnitude are key ecological metrics linked to the quality and survival of higher trophic level species (Borstad et al. 2011; Tommasi et al. 2013; Suchy et al. 2022). Regionally, anomalous bloom timing has been associated with smaller, less energy-rich zooplankton communities, smaller herring year-classes, and reduced seabird breeding success (Borstad et al. 2011; Schweigert et al. 2013; Tommasi et al. 2013; Suchy et al. 2022). In 2025, bloom timing in both the northern Salish Sea and Central Coast fell within the typical range relative to longer satellite time-series. Coupled with high spring biomass at both stations, these conditions were likely favourable for food webs.

Of growing importance are intermediate and deep-water corrosivity and oxygen depletion in both the northern Salish Sea and Central Coast (Evans et al. 2025). At both locations, high spring biomass may exacerbate these conditions through enhanced vertical organic matter export. On the Central Coast, continued summer diatom biomass and strong subsurface chlorophyll maxima may both support more efficient food webs (Tréguer et al. 2018; Lerner et al. 2022) and increase corrosivity and oxygen depletion.

The Hakai time-series demonstrate strong links between spring phytoplankton biomass and wind forcing at both locations, with ongoing work developing predictive metrics and linkages to food-web and biogeochemical processes. As ocean conditions change under a warming climate (Bidlack et al. 2021), these time-series provide the temporal resolution and biological context needed to detect and interpret emerging shifts in phytoplankton communities.

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19. WCVI ZOOPLANKTON BIOMASS TIME SERIES UPDATE: 2025

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19.1. Highlights

- The West Coast of Vancouver Island (WCVI) zooplankton biomass anomalies were positive for both cool and warm water indicator groups, during a year characterized by anomalously cool spring conditions during upwelling and anomalously warm winter and fall conditions.
- Biomass of endemic copepods and euphausiids was greater than average for both the Northern Vancouver Island (NVI) and Southern Vancouver Island (SVI) shelf/slope regions.
- The annual biomass of 'southern' copepods and chaetognaths has been greater than the long-term average since 2023.
- Total biomass of gelatinous zooplankton was near-average for the SVI and NVI offshore; while total crustacean zooplankton biomass was also near-average for NVI but above-average for SVI.

19.2. Description of the time series

Zooplankton biomass anomaly time-series are calculated for Southern Vancouver Island (SVI; 1979-present), Northern Vancouver Island (NVI; 1990-present), Line P (1996-present), and Hecate Strait (1990-present), with lower density and/or taxonomic resolution early in NVI and Hecate Strait time-series. Additional locations are included when available. See Mackas (1992) and Mackas et al. (2001) for methodology of zooplankton monitoring surveys along the West Coast. This report is focused on the SVI and NVI shelf and offshore time series (2000-2025).

A zooplankton climatology was calculated for each region, following the ICES protocol (O'Brien et al. 2013) for $\log_{10}$ transformed biomass anomaly calculations. The climatological period for Vancouver Island regions is 1991-2020. The amplitude of the seasonal cycle is large so biomass anomalies are first calculated on a seasonal basis and then averaged within year for each region (Figure 19-1).

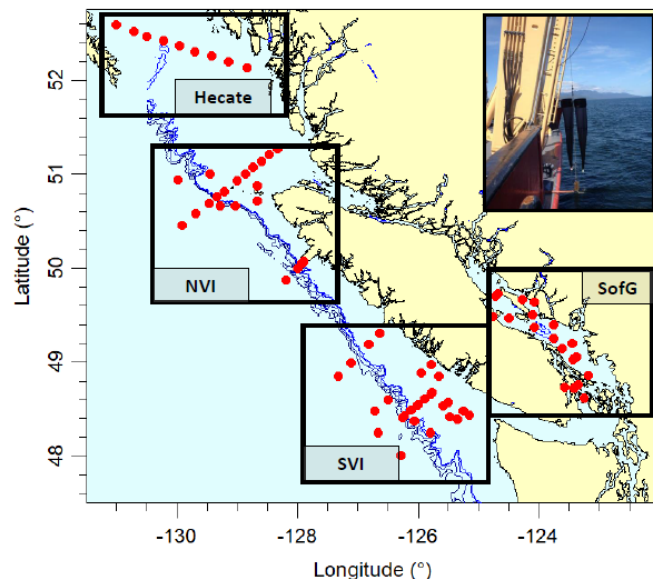


Figure 19-1. WCVI zooplankton time series sampling locations (red symbols) in B.C. marine waters. Data are averaged for samples within each statistical region. Additional sampling within each region is included in seasonal/annual reporting.

The west coast of Vancouver Island (WCVI) lies in the transitional zone between the equatorward flowing California Current and the poleward flowing Alaska Current. Zooplankton composition and biomass in this area are subject to variation in the position of the transitional zone and strong seasonality in timing and intensity of upwelling and downwelling. Sea surface temperature (SST) anomalies for SVI, Amphitrite Point, and NVI, Kains Island lighthouse (Jackson, Section 9), were calculated for seasons generally corresponding to coastal upwelling and downwelling. Time series of zooplankton groupings (see Table 19-1 for compositions) with shared geographic affinity and ecological roles provide meaningful indicators of biological response to climate variability (Mackas et al. 2006). The biomass anomaly time series for these zooplankton are expressed as indicator groups: ‘southern’, ‘subarctic’, ‘boreal shelf’, etc., described below and limited to SVI and NVI shelf/slope (Table 19-2 and Figure 19-1) for this report. Cool years tend to favour production of endemic ‘northern’ taxa (e.g., boreal and subarctic calanoid copepods); whereas, warm years are typically associated with an elevated abundance of ‘southern’ taxa. All data presented here should be treated as preliminary since sample identification and enumeration is ongoing; the magnitude of anomalies will change as analysis is completed but the sign (i.e., positive/negative) does not usually change.

Table 19-1. Zooplankton groups described in the time series in Figure 19-2, 19-3 and 19-5.

Zooplankton group	Species	Comments
Southern copepods	<i>Acartia danae</i> , <i>A. arbruta</i> , <i>Clausocalanus</i> spp., <i>Calocalanus</i> spp., <i>Ctenocalanus vanus</i> , <i>Eucalanus californicus</i> , <i>Mesocalanus tenuicornis</i> , <i>Paracalanus</i> spp.	Centered about 1000 kilometers south of our study areas (either in the California Current and/or further offshore in the North Pacific Central Gyre)
Boreal shelf copepods	<i>Calanus marshallae</i> , <i>Pseudocalanus</i> spp., <i>Acartia longiremis</i>	Southern Oregon to the Bering Sea
Subarctic oceanic copepods	<i>Neocalanus plumchrus</i> , <i>N. cristatus</i> , <i>N. flemingeri</i> , <i>Eucalanus bungii</i>	Inhabit deeper areas of the subarctic Pacific and Bering Sea from North America to Asia
Euphausiids	<i>Euphausia pacifica</i> , <i>Thysanoessa spinifera</i>	Centered off west coast of N. America; euphausiid biomass corrected for day/night tows.
Southern chaetognaths	<i>Mesosagitta minima</i> , <i>Serratosagitta bierii</i> , <i>Parasagitta euneritica</i>	Centered off California/Mexico
Northern chaetognaths	<i>Parasagitta elegans</i> , <i>Eukrohnia hamata</i>	Boreal Pacific into the Arctic

19.3. Status and trends

In 2025, ‘southern’ copepod species were more abundant in the SVI shelf/slope relative to the NVI shelf/slope region, but annual biomass anomalies were positive in both. Annual biomass anomalies for this grouping had been positive but declining to the climatological mean since the extreme marine heatwave in 2015 for all areas (Figure 19-2b). This pattern reversed in 2023 and continued through 2024 with large positive biomass anomalies for both NVI and SVI associated with a strong El Niño event (Figure 19-2a). Large positive ‘southern’ copepod

biomass anomalies persisted into 2025, a year characterized by neutral and/or La Niña conditions (Curry and Dah, Section 6; Ross and Robert, Section 8).

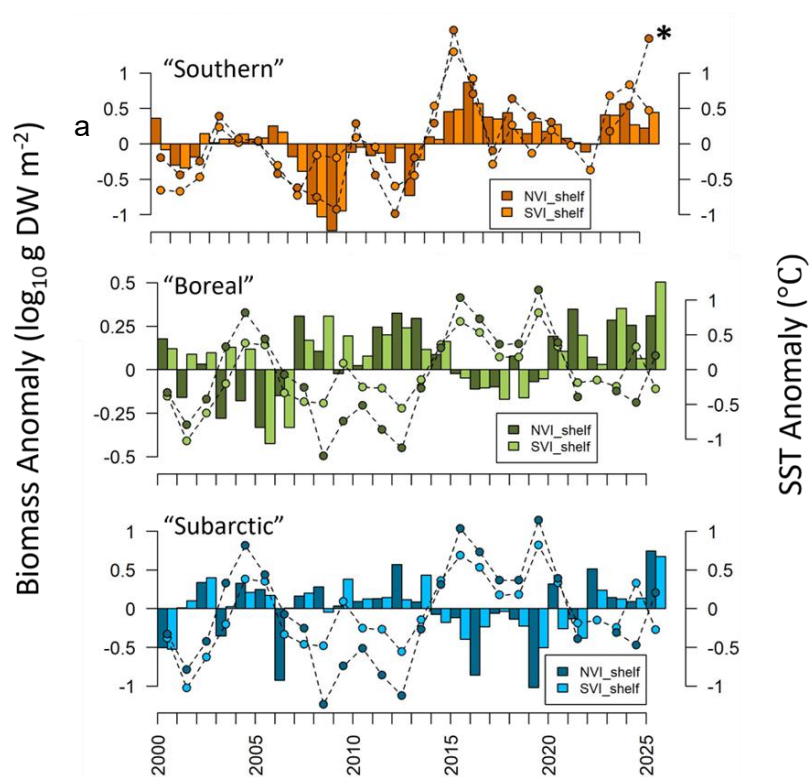


Figure 19-2. Annual biomass anomalies of copepod indicator groups for the WCVI regions illustrated in Figure 19-1. Panel (a) annual 'southern' copepod biomass anomaly ($\log_{10}$ g DW m^{-2}), orange bars, and mean SST anomalies for annual downwelling period, dashed lines; b) annual 'boreal' copepod biomass anomaly ($\log_{10}$ g DW m^{-2}), green bars, and mean SST anomalies for annual upwelling period, dashed lines; and c) annual 'subarctic' copepod biomass anomaly ($\log_{10}$ g DW m^{-2}), blue bars, and mean SST anomalies for annual upwelling period. NVI and SVI regions represented by darker and lighter shaded bars, lines, and symbols, respectively. *Note, Kaines Island mean SST anomalies for 2025 downwelling period (a) are likely biased high due to the absence of November and December 2025 measurements.

The large subarctic copepods, *Neocalanus* spp., and *Eucalanus bungii* dominate crustacean zooplankton biomass in the offshore and slope along the west coast of Vancouver Island; whereas, euphausiids dominate annual crustacean production on the shelf. In 2025, the biomass of euphausiids in the SVI and NVI shelf/slope region was greater than the climatological mean and due to positive biomass anomalies for both *Euphausia pacifica* and *Thysanoessa spinifera* (Figure 19-3).

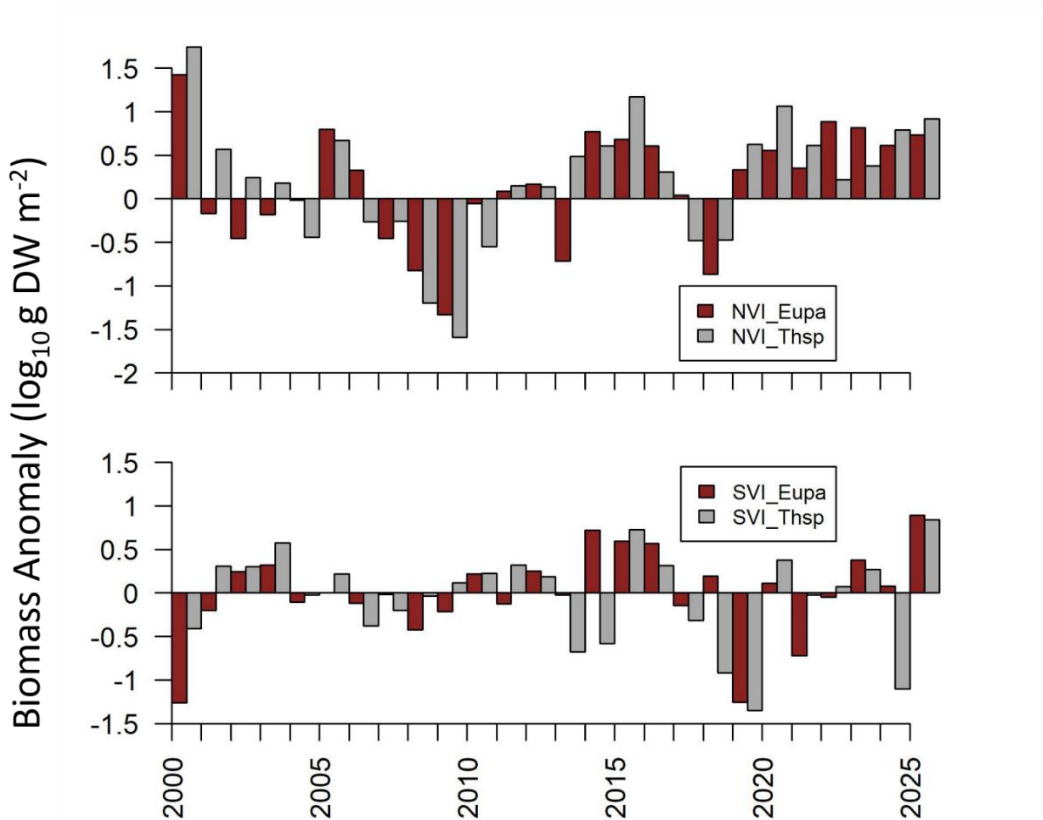


Figure 19-3. Biomass anomaly time series for dominant WCVI shelf Euphausiid species: *Euphausia pacifica* (Eupa), red and *Thysanoessa spinifera* (Thsp), grey. a) Northern Vancouver Island (NVI), and b) Southern Vancouver Island (SVI) shelf.

The ratio of crustacean zooplankton (greater lipid and protein content), to the soft-bodied zooplankton (higher water content, less protein or lipids) is an indicator of food availability/quality for forage fish, seabirds, and marine mammals. This ratio is referred to as the CSIndex or “Crunchies (crustacean): Squishies (gelatinous)” Index (see Galbraith and Young 2019 for a more detailed explanation). In 2025, the CSIndex saw near long-term average biomass for both groups in the NVI shelf/slope region and near-average for soft-bodied animals and above average crustacean zooplankton biomass in the SVI shelf/slope region.

Larvaceans, siphonophores, and ctenophore biomass anomalies were positive mainly on the WCVI shelf but the annual biomass of salps and doliolids were below their climatological mean on the SVI shelf (Figure 19-4). In the NVI shelf region, the biomass of salps and doliolids was above average with a large year-over-year increase relative to 2024 and possibly associated with anomalously warm conditions during late summer/early fall in the NVI shelf region (see SST anomalies, Figure 19-2a).

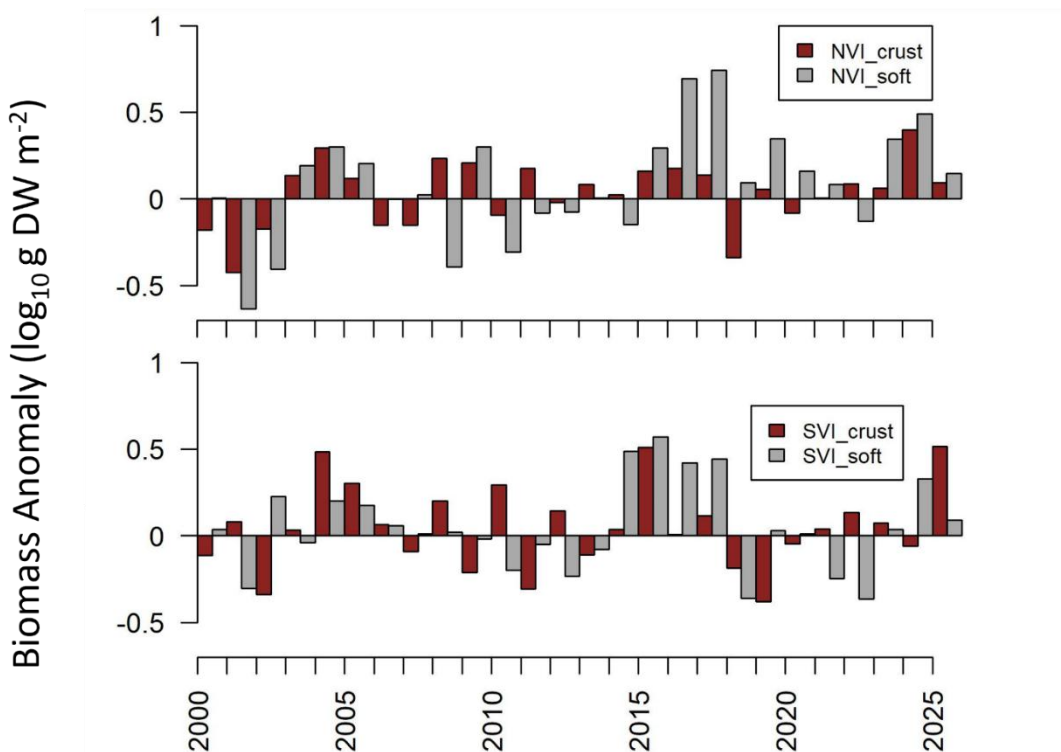


Figure 19-4. Biomass anomaly time series for selected crustaceans (dark red bars: Crunchies) and soft-bodied (grey bars: Squishies) zooplankton. a) Northern Vancouver Island (NVI), and b) Southern Vancouver Island (SVI) offshore.

Biomass anomaly time series of 'northern' and 'southern' chaetognath species groups (Table 19-1) are similar in pattern to the 'northern' versus 'southern' copepod groupings (Figure 19-5). The southern chaetognaths are especially sensitive and essentially absent from WCVI samples during typical La Niña events. The biomass of southern chaetognaths (and southern copepods) declined steadily from ~2015 (extreme marine heatwave) to 2022. The 2023-2024 El Niño event was accompanied by a large and positive biomass anomaly for 'southern' chaetognaths in both NVI and SVI shelf and offshore regions. Biomass anomalies for this group were still positive but reduced in 2025 relative to 2024.

19.4. Factors causing trends

Southern copepod and chaetognath biomass anomalies tend to vary in a positive manner with SST anomalies during downwelling (Figure 19-2a), reflecting degree of transport from the south and offshore in winter and fall, respectively. Whereas, the copepod groups endemic to the WCVI ('boreal shelf' and 'subarctic', copepods and northern chaetognaths) tend to vary in a negative relationship with SST anomalies during the upwelling season, when most of their surface production occurs. SST anomalies in 2023, 2024, and 2025 were positive during downwelling (associated with greater transport of 'southern' copepods), and negative during upwelling (supporting production of 'endemic' copepods). The positive annual biomass anomalies of *both* southern and endemic zooplankton during the 2023-2025 period is not common to the WCVI zooplankton time series, and points to a shift starting with the 2023-2024

El Niño (favouring transport from the south; Fisher et al. 2015; Fisher et al. 2020), characterized by both warmer downwelling and cooler than average upwelling conditions in the WCVI region.

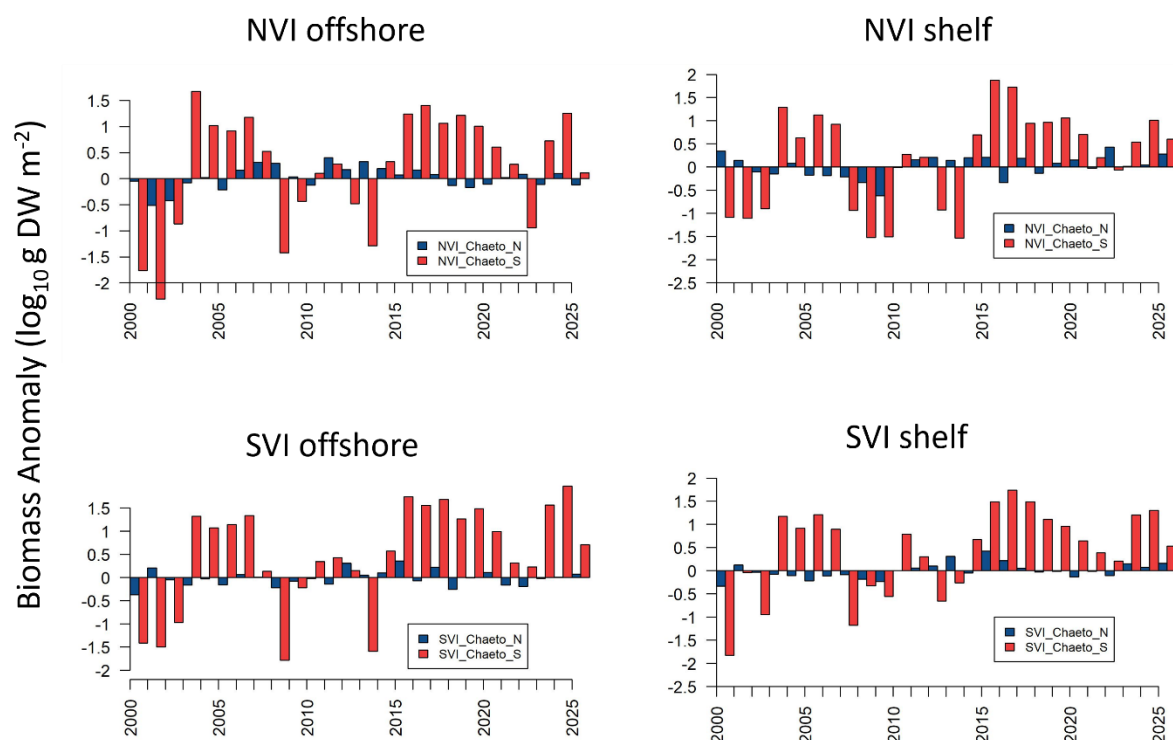


Figure 19-5. Northern chaetognaths (*Chaeto_N*; blue) and Southern chaetognaths (*Chaeto_S*; red), biomass anomalies time-series for. Northern Vancouver Island (NVI) offshore and shelf, upper panels, and Southern Vancouver Island (SVI) offshore and shelf, lower panels.

19.5. Implications of observed trends

Overall, the 2025 biomass of southern copepods, southern chaetognaths, and soft-bodied zooplankton increased in all regions. The relatively strong production of euphausiids coupled with the spring/early summer increase of subarctic and boreal copepods (with high lipid content) may have provided good feeding conditions for larval fish, juvenile fish (especially out-migrating Pacific salmon smolts), and planktivorous seabirds.

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20. LOWER TROPHIC LEVELS IN THE NORTHEAST PACIFIC

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20.1. Highlights

- Spring 2025 plankton indicators were largely within the long-term envelope, including diatom abundance (mostly within ± 1 SD) and low warm-water copepod abundance on the shelf, suggesting a partial return toward pre-heatwave community structure.
- A notable offshore zooplankton peak occurred in April–May 2025, with April dominated by *Para-Pseudocalanus* spp. and May showing one of the highest Thecosomata (pteropod) counts on record for the offshore B.C. Continuous Plankton Recorder (CPR) series.

20.2. Description of the time series

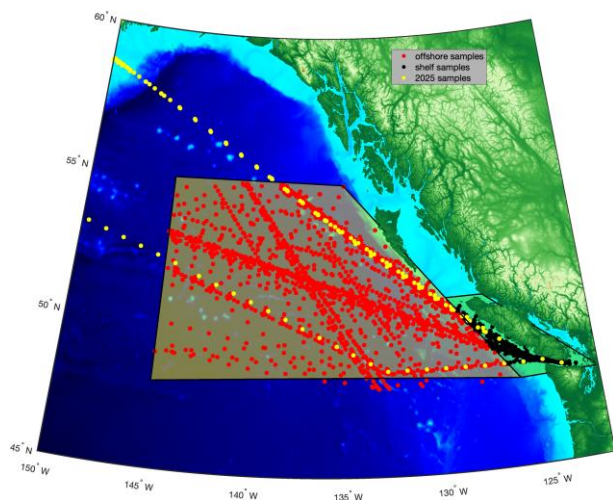


Figure 20-1. Map showing the location of historic CPR samples (2002-2025) red = offshore, black = shelf. Yellow circles are the location of the 2025 samples, note some 2025 samples are not yet analysed so are not shown.

The CPR is an instrument towed behind commercial ships, and, in the NE Pacific, samples approximately monthly, 6-9 times per year, between March and October, continuing a time series that began in 2000 (Figure 20-1). Each CPR sample contained the near-surface (about 7 m depth) plankton from an 18.5 km length of transect, filtered using 270 μ m mesh, and afterwards analyzed microscopically to give taxonomically resolved abundance data. 2025 CPR data presented within this report are provisional and only include the months March-June, as the rest of the samples are still being analyzed. All 2025 tows were completed as scheduled (Figure 20-1, see yellow circles).

Sea Surface Temperature (SST) data from 2000 to 2025 were obtained from the International Comprehensive Ocean-

Atmosphere Data Set (ICOADS, 1° enhanced data,

www.esrl.noaa.gov/psd/data/gridded/data.coads.1deg.html) for each region to characterize the physical environment.

Please note as of writing this report the ICOADS Sea Surface Temperature dataset (<https://downloads.psl.noaa.gov/Datasets/icoads/1degree/global/std/>) has not been updated beyond July 2025 so this is not a complete year of sea surface temperatures and we have therefore not included Community Temperature Indices in this report.

Phytoplankton: The CPR effectively retains larger phytoplankton cells, especially chain forming diatoms and hard-shelled dinoflagellates, and several time series were generated which reflect abundance and community composition changes in the offshore and shelf regions, showing broad community composition and mean monthly diatom abundances. Zooplankton: Mesozooplankton, especially crustacea, were well-sampled by the CPR and several zooplankton time series were generated; total zooplankton abundance, taxon specific lengths and abundances were used to calculate the mean copepod length, monthly mean abundances.

20.3. Status and Trends

20.3.1. Phytoplankton

The phytoplankton community composition had higher numbers of round diatoms than heatwave years, reflecting numbers that were closer to years prior to the heatwave in 2014 (Figure 20-2).

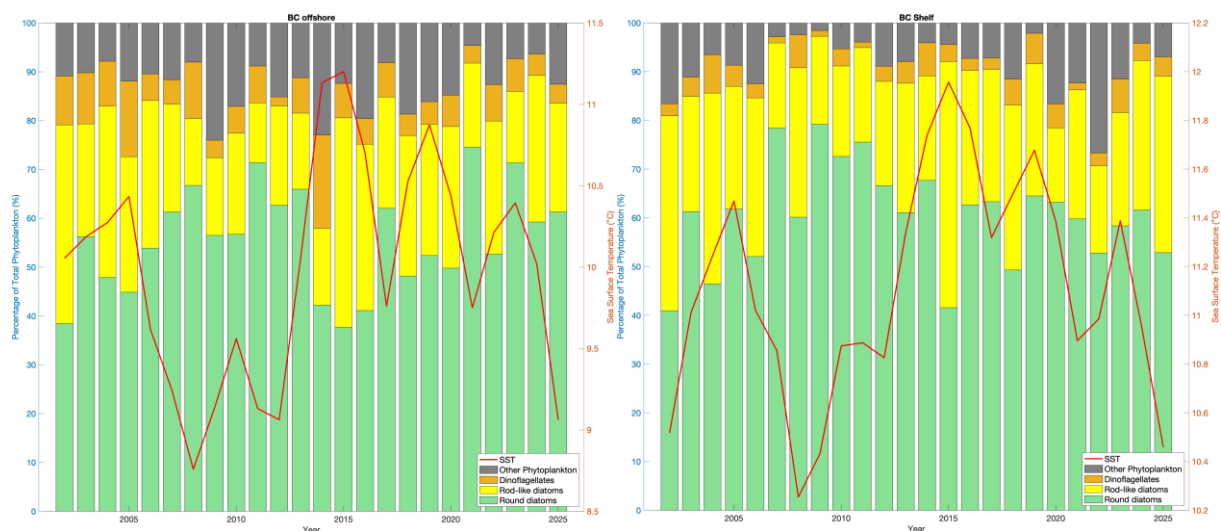


Figure 20-2. Contribution of each group to the mean annual phytoplankton community offshore (left) and on the shelf (right). SST is shown in red (right-hand axis, °C). Note: 2025 CPR data are provisional and only for spring months to date. **Please note as of writing this report the ICOADS Sea Surface Temperature dataset (<https://downloads.psl.noaa.gov/Datasets/icoads/1degree/global/std/>) has not been updated beyond July 2025 so this is not a complete year of sea surface temperatures.**

Monthly diatom abundances in 2025 for both regions were mostly within 1 standard deviation of the long-term (2002-2024) mean (Figure 20-3), however April 2025 in the offshore region picked up a high abundance of *Chaetoceros* spp.

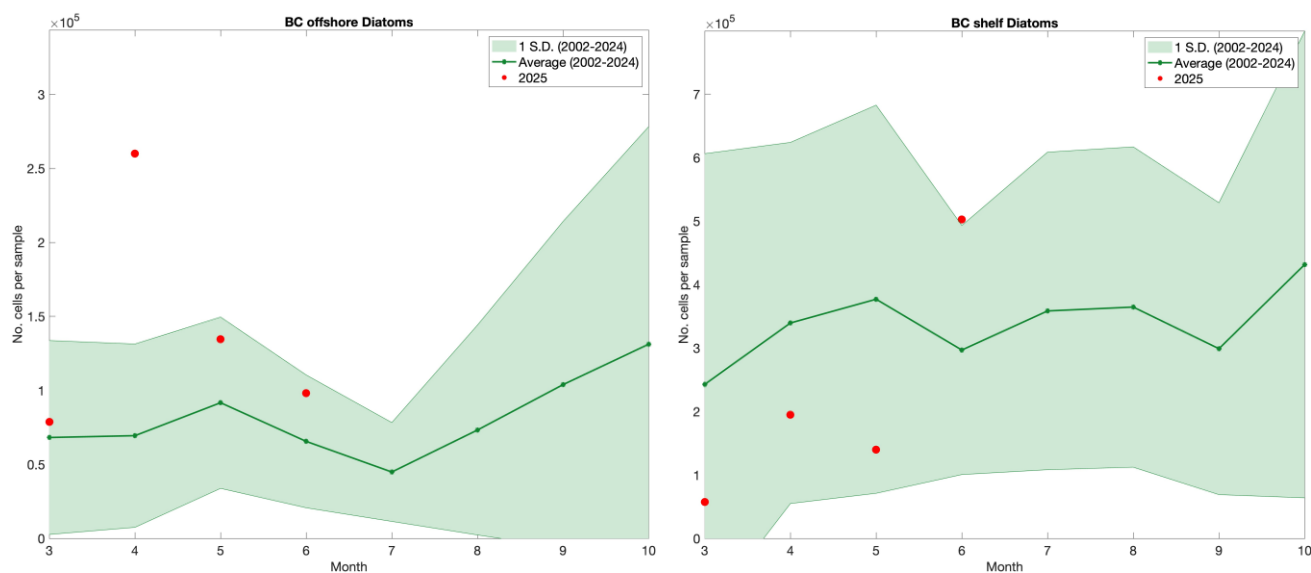


Figure 20-3. Seasonal mean monthly diatom abundance for offshore B.C. (left) and shelf B.C. (right), from 2004-2024 with shaded area representing 1 standard deviation of the mean and red circles showing the 2025 monthly means. Note: 2025 data are preliminary.

20.3.2. Zooplankton:

The numbers of copepods typically associated with warm waters were low in the shelf region, and the mean copepod length remained at average for both regions in 2025 (Figure 20-4). Numbers of salps and doliolids (gelatinous plankton) in both regions were low, and the high numbers of jellies recorded in the offshore region in 2024 have not been recorded in 2025 (Figure 20-4).

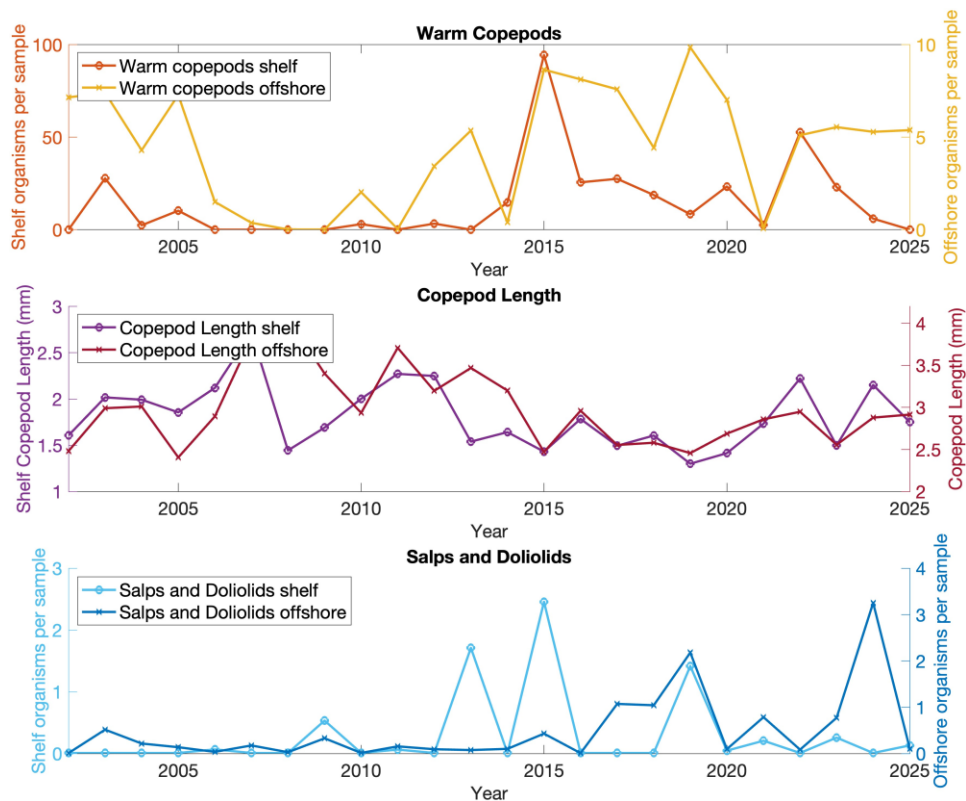


Figure 20-4. The mean annual abundance of warm water copepods (top), mean copepod length (middle), and salp and doliolid abundance (bottom) for both the shelf (left axis) and offshore (right axis) regions of B.C. Note: The CPR only captures small or fragments of salps and doliolids. Note: 2025 data are provisional and only for spring months to date.

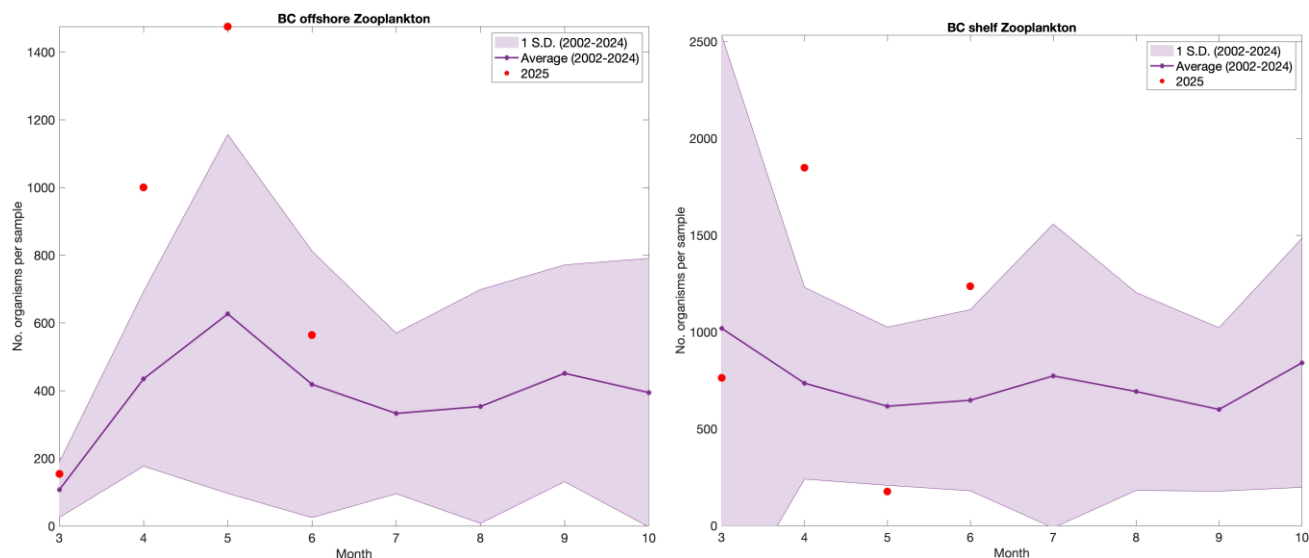


Figure 20-5. Seasonal mean monthly zooplankton abundance for offshore B.C. (left) and shelf B.C. (right), from 2004-2024 with shaded area representing 1 standard deviation of the mean and red circles showing the 2025 monthly means. Note: 2025 data are preliminary.

In the offshore region there were high numbers of zooplankton captured in April and May, 2025 (Figure 20-5). The April CPR samples were dominated by *Para-Pseudocalanus* spp. and the

May CPR samples were dominated by Thecosomata (Sea butterflies), which was the second largest record of Thecosomata in the CPR dataset in this region over the 23-year sampling period.

20.4. Factors Influencing the trends

Plankton variability in the NE Pacific reflects the combined influence of (i) basin-scale climate forcing that drives marine heatwaves (MHWs) and persistent “warm blob” conditions, and (ii) regional processes that regulate upper-ocean stratification, mixing, and nutrient supply. The NE Pacific has experienced several major MHW episodes in the past decade; these events are linked to anomalous atmospheric circulation and weakened wind-driven mixing/heat loss, and can persist across seasons or years (Bond et al. 2015; Di Lorenzo and Mantua 2016; Amaya et al. 2020; Chen et al. 2021). Reduced mixing and enhanced stratification typically lower nutrient replenishment to the euphotic zone and can restructure phytoplankton abundance and morphology, patterns now demonstrated explicitly using CPR data for NE Pacific heatwave summers (Kléparsi et al. 2025). Zooplankton responses often follow via changes in prey fields and advection/transport of water masses; warm-water copepod incursions and community shifts in CPR time-series are known to be sensitive to these physical drivers (Batten and Walne 2011), and ecosystem-wide “winners and losers” during the 2013–2015 anomaly underline how quickly the pelagic community can reorganise under extreme warming (Cavole et al. 2016).

20.5. Implication of these trends

Changes in plankton community composition and size structure affect food-web efficiency and the availability of prey for fish and higher predators, so shifts associated with warm anomalies can propagate rapidly through the ecosystem (Cavole et al. 2016). Given robust evidence that marine heatwaves are increasing in frequency, duration, and severity under ongoing warming, continued volatility, and the associated ecological and socio-economic risks, should be treated as an expected feature of the system rather than an exception (Oliver et al. 2018; Frölicher et al. 2018; Smale et al. 2019). The marked offshore Thecosomata signal is also potentially significant: pteropods are important prey and contributors to shallow carbonate export (Mackas & Galbraith 2012; Buitenhuis et al. 2019), but are additionally viewed as sensitive indicators of cumulative stressors including warming and ocean acidification (Bednaršek et al. 2016). Where strong pteropod variability is observed, both food-web support and biogeochemical cycling are relevant, strengthening the case for sustained monitoring and interpretation alongside physical context (e.g., stratification and water-mass anomalies; Scannell et al. 2020).

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21. UPDATE: Á,LEÑENEÇ: TSAWOUT'S DUNGENESS CRAB (Á,ĆEX) STEWARDSHIP FOR FUTURE GENERATIONS

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21.1. Highlights

- In response to community concerns and limited fisheries-independent data on Dungeness Crab populations across B.C., STÁUTW First Nation is developing a social-ecological tool for evaluating Dungeness Crab health that will draw from life stage-specific surveys and interviews with STÁUTW knowledge holders.
- Initial visualizations of DFO commercial data indicates intensive crab harvest within the QEN,T Indigenous Protected and Conserved Area (IPCA; area of study focus), whilst DFO fisheries-independent data is revealed to be lacking and inconsistent in survey methods used across years (1989-2024).
- STÁUTW's fisheries-independent surveys of adult crab will fill current data gaps, with promise of better understanding the effects of two commercial closure areas within the IPCA on Dungeness Crab size and population dynamics.

21.2. Description of the time series

In June of 2023, STÁUTW First Nation established the QEN,T Indigenous Protected and Conserved Area (IPCA; spanning 150 km² or 3% of Tsawout's 4500-km² traditional territory; Figure 21-1; Indigenous Circle of Experts 2018) to address historical and ongoing exclusion of the Nation from sustainable management of its traditional waters. The STÁUTW Marine & Stewardship Division is leading initiatives to enact STÁUTW's primary role in protecting and conserving ecosystems within the QEN,T IPCA. Based on longstanding community concerns, a focus of the Division's efforts is to develop culturally-grounded, social-ecological tools for evaluating the health of Dungeness Crab (*Metacarcinus magister*; Á,ĆEX). Efforts toward this goal have included attaining access to DFO's commercial fisheries and fisheries-independent data for the area, facilitating STÁUTW's own life-stage-specific surveys of Á,ĆEX, and interviewing STÁUTW knowledge holders/harvesters.

To date, STÁUTW has collected 3 seasons of larval Á,ĆEX data (using light traps; 2023 start), 3 seasons of incidental juvenile Á,ĆEX data (through European Green Crab monitoring; 2023 start), and 2 years of adult Á,ĆEX data (using Dunham et al. (2011) standardized methods; 2024 start). Accessing DFO's Dungeness Crab data for the area (PFMAs 19-5 and 19-6) revealed a long-term biological survey dataset including data points from 1989 to 2024, as well as commercial crab landing data spanning 1990-2023.

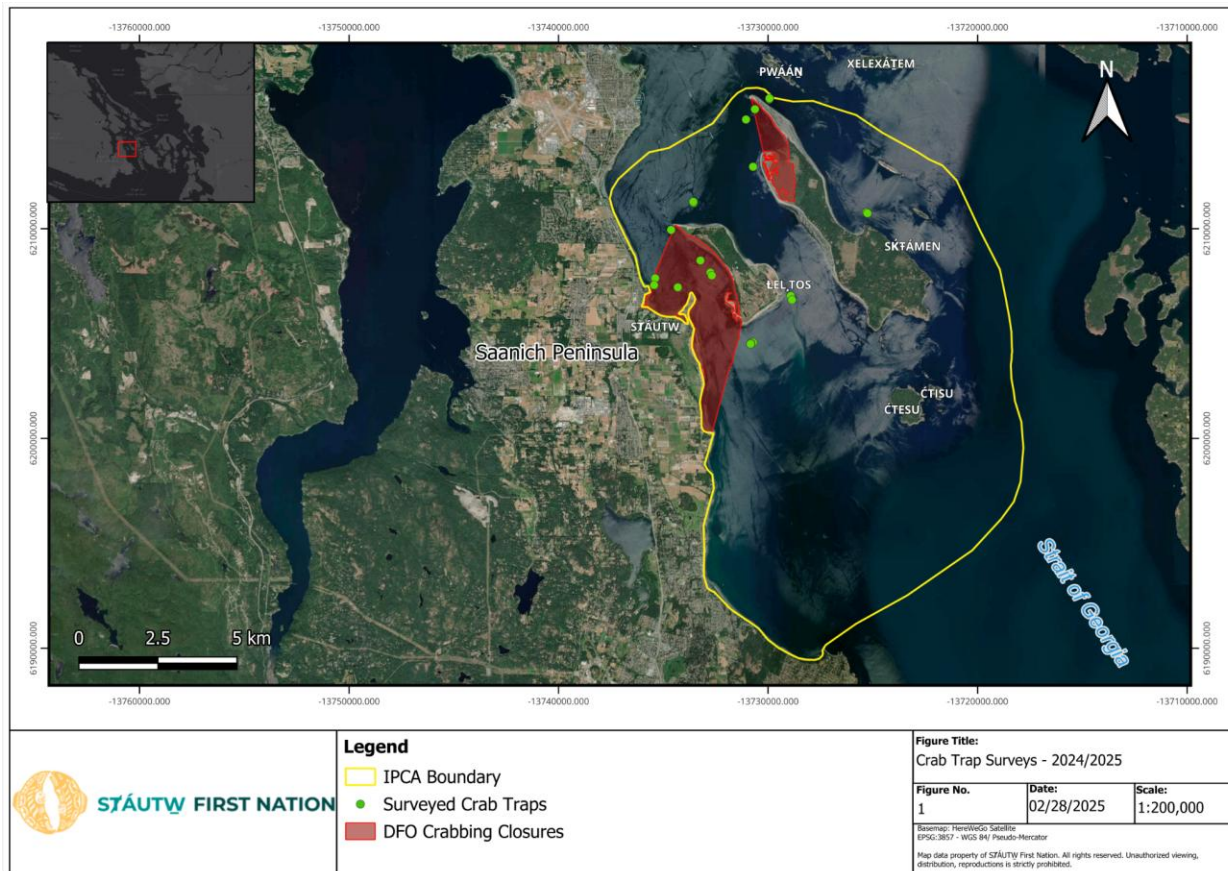


Figure 21-1. Area of study with survey locations represented within the QEN,T Indigenous Protected and Conserved Area (IPCA) and current spatial closures for commercial fisheries within the QEN,T IPCA (DFO 2024). The QEN,T IPCA is located within PFMA 19-5 and 19-6.

21.3. Status and trends

Initial visualizations of DFO's Dungeness Crab data and STAUTW's adult ÁĆEX data have been completed. Plotting Dungeness Crab weight landed (lb) data from the commercial fishery revealed that across all years where location information is available (2000-2024), crab originating from inside the QEN,T IPCA made up the majority of total crab landed within PFMA 19-5 and 19-6 (Figure 21-2), despite the IPCA covering only approximately half of the total area of these PFMA. Interestingly, initial visualizations of CPUE inside versus outside the IPCA tentatively indicate that harvesters may actually be able to catch more crab outside the IPCA (per unit of effort).

Plotting biological survey data provided by DFO revealed that, although these data appear to be an inherently valuable long-term dataset (i.e., spanning 1989-2024), the sampling methods and effort across years is highly variable, making it difficult to make strong inferences. Dungeness Crab injury and shell hardness information is also not collected through these surveys. With this, the near completion of a full STAUTW's adult crab survey dataset is especially notable (i.e., 15 study sites will be fully sampled 4 times across fall/winter/spring/summer seasons by end of 2026). Consistent methodology and detailed data collection make this dataset a valuable contribution to better understanding ÁĆEX health. This dataset is anticipated to also shed light on the efficacy of 2 commercial crab closures located within the QEN,T IPCA.

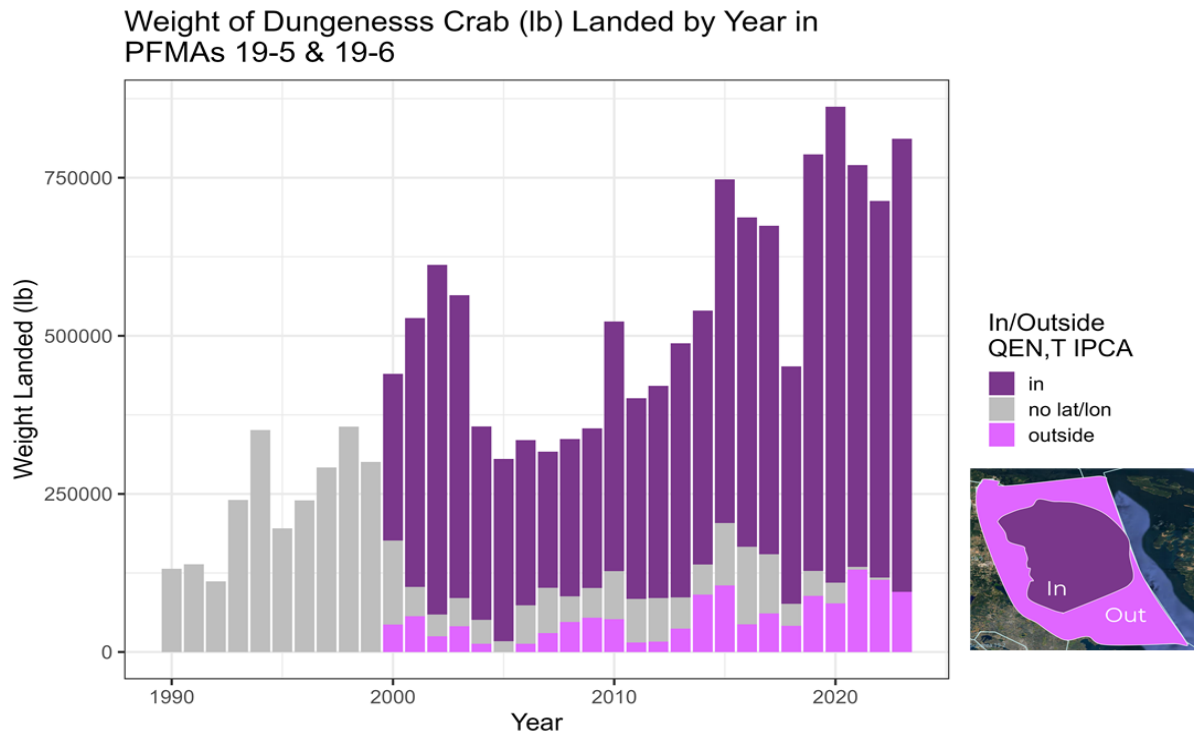


Figure 21-2. Weight landed (lb) of Dungeness Crab by the commercial crab fishery between 1990-2023 within PFMA 19-5 and 19-6 (white bordered area within inset). Origins of crabs landed within these PFMA 19-5 and 19-6 could be traced back to either inside the QEN,T IPCA (purple) or outside the QEN,T IPCA (pink). Some data lacked location specificity (grey).

21.4. Factors influencing trends and implications of those trends

One early, potential explanation for seemingly contrasting trends observed within DFO's commercial crab landing data (i.e., high effort put into harvesting within the IPCA despite lower CPUE) could be that unaccounted for factors are influencing harvester decision making regarding where to set traps. Further investigation into whether factors like proximity to ports, tides, and/or shielding from weather conditions affect commercial harvester preference on where they deploy traps may be merited. High commercial reliance on crab originating from within the QEN,T IPCA has implications for SṠÁUTW's constitutionally-affirmed food, social, and ceremonial priority access, Douglas Treaty rights to 'fish as formerly', and Nation-to-Nation discussions moving forward.

DFO's survey data have not been standardized and effort has been unevenly sustained within PFMA 19-5 and 19-6. The SṠÁUTW survey will address these issues. The ongoing efforts led by SṠÁUTW emphasizes how Indigenous-led data collection and stewardship always has been (and is increasingly becoming) essential to healthy coastal ecosystems.

We anticipate that SṠÁUTW's spatially-specific Dungeness Crab surveys and Á,ĆEX stewardship plans for the QEN,T IPCA will complement DFO's regionally-focused biological survey program. Together, these distinct yet complementary approaches to managing and monitoring Dungeness Crab may strengthen our collective ability to assess Dungeness Crab

population health, fisheries impacts, and shifts caused by climate change. Overarchingly, this research underscores the urgent need for respectful, ethical knowledge exchange and adaptive management strategies. By continuing to present updates on these efforts, our hope is to iteratively embrace opportunities for collaborative insights and feedback as results and trends in these data begin to arise in future years.

21.5. References

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22. PACIFIC HERRING IN B.C., 2025

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22.1. Highlights

- In recent years, following a declining trend from approximately 1980 to 2010, weight-at-age for all B.C. stocks of Pacific Herring have remained unchanged.
- Total B.C. coastwide spawning biomass summed across the 5 major stocks increased during 2010-2025; however, this varies among assessed stocks. In 2025, the majority of the total herring biomass in B.C. occurred in the Strait of Georgia (SOG) and West Coast of Vancouver Island (WCVI); WCVI biomass has increased since 2020.

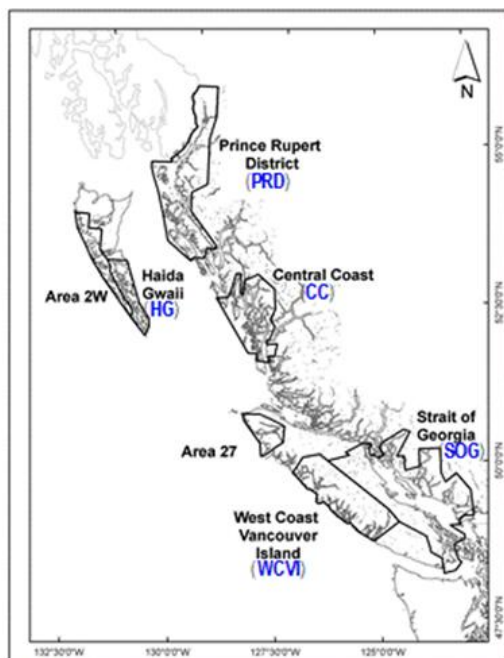


Figure 22-1. Location of the five major (Strait of Georgia, West Coast of Vancouver Island, Prince Rupert District, Haida Gwaii, and Central Coast) as well as two minor (Area 2W, and Area 27) Pacific Herring stocks in B.C.

22.2. Summary

In B.C., Pacific Herring are managed as five major stocks (SOG; WCVI; Prince Rupert District, PRD; Haida Gwaii, HG; and Central Coast, CC), and two minor stocks (Area 2W and Area 27) (DFO 2026a, b, c; Figure 22-1). For each stock, Pacific Herring population trends are based on stock-specific model estimates of biomass. Statistical catch-at-age models are fit to time series data: commercial and test fishery biological samples (age, length, weight, sex, etc.), Pacific Herring spawn survey data (spawn index), and commercial harvest data (DFO 2026a, b, c).

22.3. Status and trends

In all five major Pacific Herring stocks there was a declining trend in weight-at-age from the 1980s through to 2010, with a leveling off in recent years (Figure 22-2). Since 2000, the HG stock continues to exist in a low biomass, low productivity state (Figure 22-3), fluctuating above and below the limit reference point (LRP) and does not show signs of a rebuilding trend (DFO 2026c). The estimated stock biomass for

PRD is above the LRP and increased in 2019, and 2021 to 2024 (DFO 2026b). The CC survey biomass is above the LRP; with an increasing trend from 2015-2020 and declining to a lower biomass level from 2021-2025 (DFO 2026c). The SOG spawning biomass is above the LRP and has fluctuated above and below the long-term average unfished spawning biomass, B_0 , for the last 10-years, since increasing from 2010 (DFO 2026a; Figure 22-3). WCVI stock biomass increased since 2020 and is above the LRP and the long-term average unfished spawning biomass (DFO 2026c; Figure 22-3).

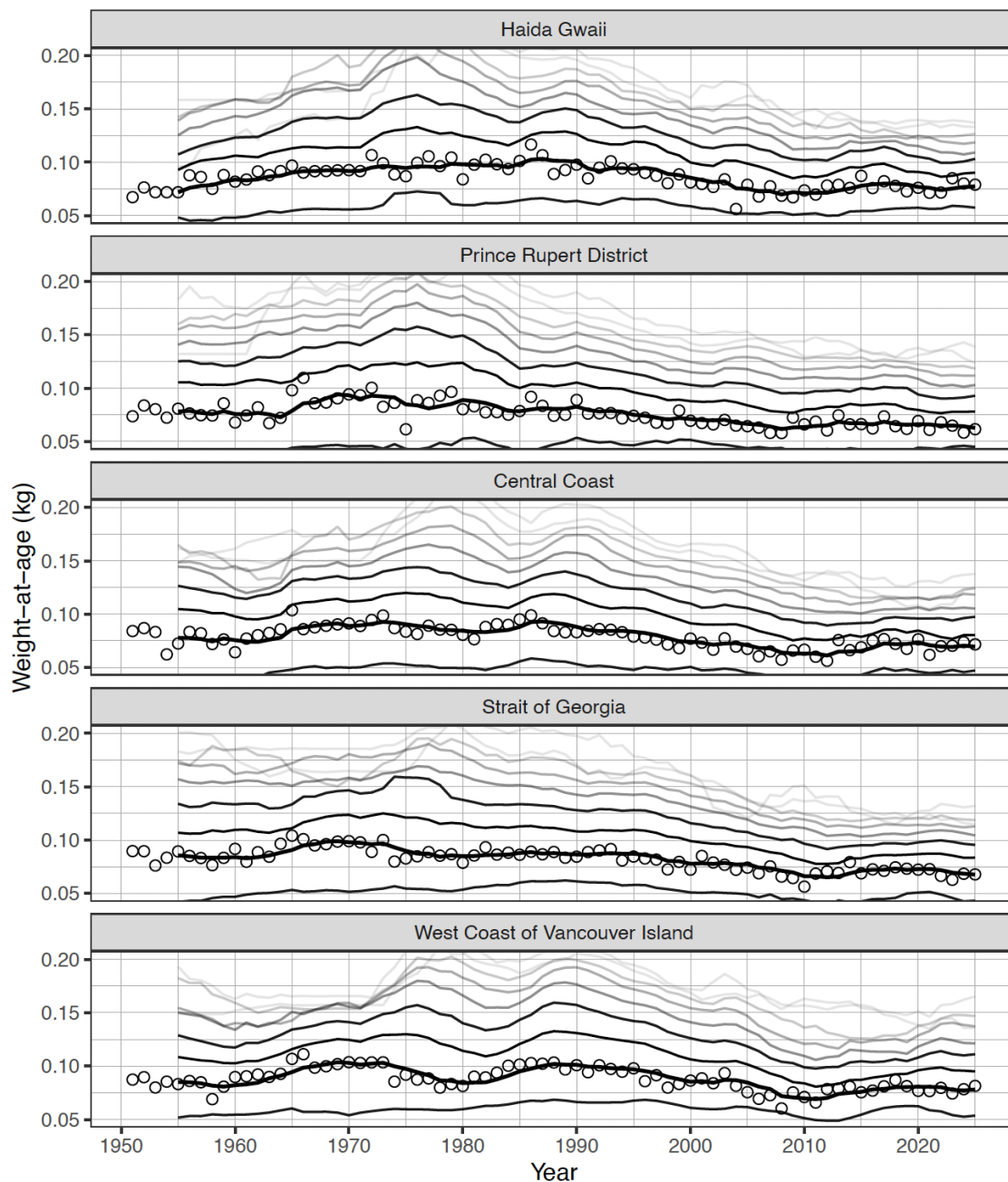


Figure 22-2. Observed weight-at-age 3 (circles) and five-year running mean weight-at-age 3 (dark line) for major Pacific Herring stocks, 1951 to 2025. Thinner black lines represent five-year running mean weight-at-age 2 (lowest) and ages 4-10+ (incrementing higher from age 3). Figure from DFO (2025b).

22.4. Factors influencing trends in herring biomass

Common trends in Pacific Herring weight-at-age observed for all B.C. stocks suggests that large-scale factors may be influencing Pacific Herring growth. Changes in environment, food

supply and quality, predator abundance, and competition are factors that could affect trends in Pacific Herring biomass and weight-at-age (Schweigert et al. 2010; Hay et al. 2012).

Pacific Herring are zooplanktivorous, consuming primarily euphausiids (krill) and some copepods (Wailes 1936). Changes in ocean conditions, such as temperature or currents, could affect the amount and types of prey available. For example, a northerly current direction results in the presence of California Current waters off the WCVI and may bring southern zooplankton species that have a lower energetic value, creating poorer feeding conditions for Pacific Herring (Schweigert et al. 2010; Mackas et al. 2004).

There are a wide variety of Pacific Herring predators, including Pacific Hake, Lingcod, Spiny Dogfish, Pacific Cod, Sablefish, Arrowtooth Flounder, Pacific Halibut, Steller Sea Lions, Northern Fur Seals, Harbour Seals, California Sea Lions, and Humpback Whales (Schweigert et al. 2010). Pacific Herring - predator interactions have been studied off of the WCVI, where the abundance of most marine mammal predators has increased (Tucker et al. 2025; DFO 2025; Wright et al. 2021). Spatio-temporal model results suggest that the strongest drivers of summer distribution and biomass of Pacific Herring off the WCVI include: 1) zooplankton prey availability, 2) predator avoidance, particularly Pacific Hake, and 3) competition with Pacific Sardines (Godefroid et al. 2019).

22.5. Implications of trends

Trends in Pacific Herring biomass have implications for both fisheries and predators. Pacific Herring are an important component of commercial fisheries in B.C. Harvest options (total allowable catch, TAC) considered by Fisheries Management reflect application of simulation tested management procedures (MP) to one-year forecasts of biomass over a 15-year future projection using an operating model framework. All TAC options reflect MPs that meet the conservation objective of avoiding the LRP with a minimum 75% probability over the specified 15-year projection period.

Trends in Pacific Herring biomass have implications for their predators, such as fish, marine mammals and seabirds. The relative importance of Pacific Herring in each predator's diet varies; however, Pacific Herring may represent up to 88% of Lingcod diet (Pearsall and Fargo 2007), 40% of Pacific Cod and Pacific Halibut diets (Ware and McFarlane 1986), and 23% to 45% of pinniped diets (Womble and Sigler 2006; Trites et al. 2007; Olesiuk 2008; Trzcinski et al. 2024). Depending on the level of diet specialization and ability to switch to alternate prey, Pacific Herring abundance and condition may affect predators' growth and abundance. Predator consumption rates of WCVI Herring show strong mechanistic links to modelled natural mortality rates for WCVI Herring, whereby Humpback Whales currently have the highest herring consumption rates (Doherty et al. 2024).

Time series of diets of animals for each stock area would further improve our ability to examine temporal trends in predator-prey interactions and implications of those trends.

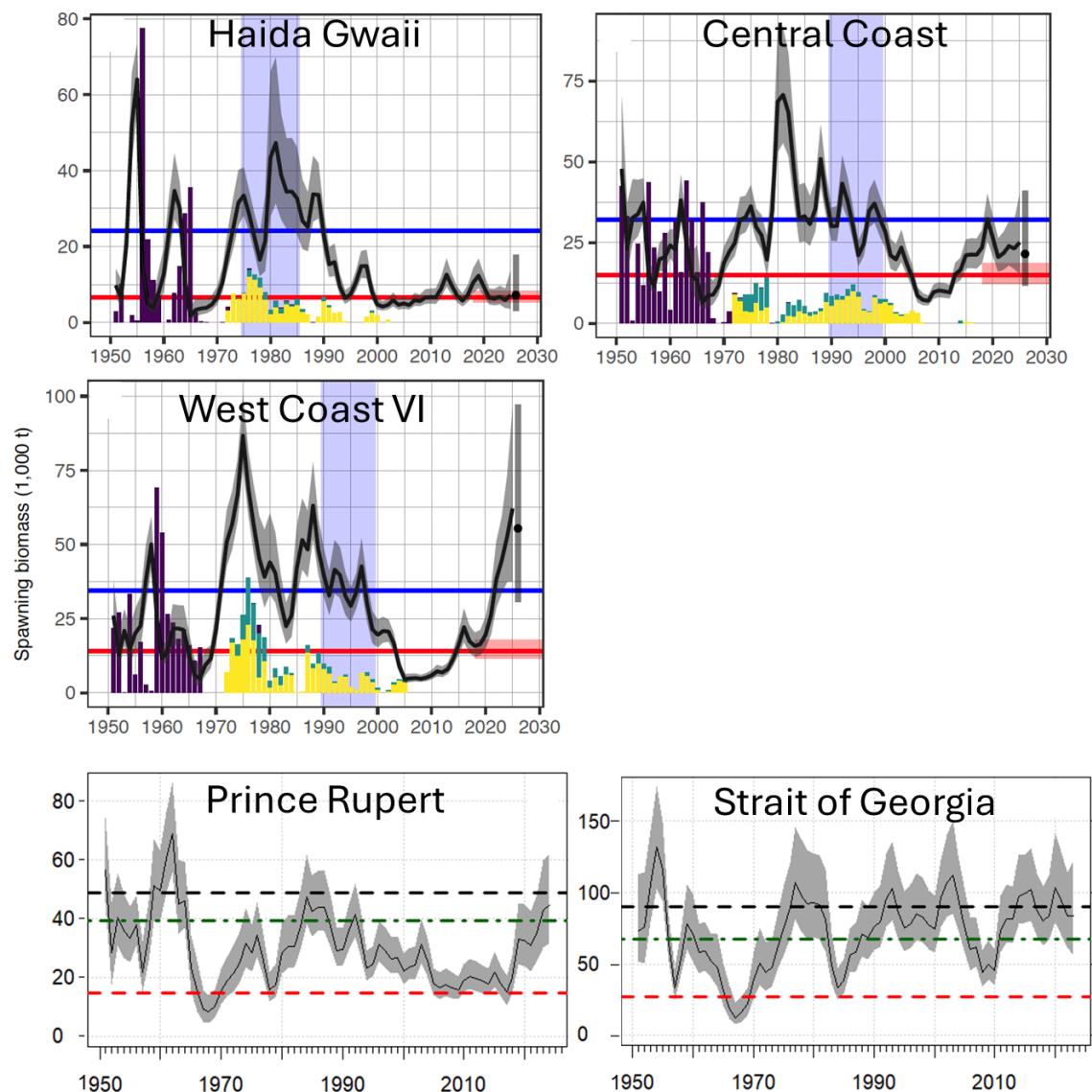


Figure 22-3. Pacific Herring spawning biomass, 1951- 2025 for HG, CC and WCVI stocks: Black lines with surrounding grey envelopes represent medians and 5-95 % credible intervals. The projected spawning biomass given zero catch is shown at the far right (solid circle and vertical lines). Time series of vertical bars denote commercial catch (excluding commercial spawn-on-kelp; colours indicate different gear types). Red line= limit reference point ($0.3B_0$), where B_0 = average unfished spawning biomass. Blue-shading denotes productive years used to calculate the upper stock reference (USR, blue line). Pacific Herring spawning biomass for SOG (1951-2023) and PRD (1951-2024) are presented using the operating model status for each of these stocks (black line, with 95% credible interval (grey shading)); red line= limit reference point ($0.3B_0$); green line= USR for the productive period; black dashed line= B_0 . Note that operating model status is to be updated every 3-5 years. Figure adapted from DFO 2026a, b for SOG and PRD, and from DFO2026c for HG, CC and WCVI.

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23. PACIFIC HERRING SUMMER DISTRIBUTION AND ABUNDANCE OFF THE VANCOUVER ISLAND CONTINENTAL SHELF

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23.1. Highlights

- In July 2025 off the west coast of Vancouver Island, Pacific Herring biomass was the 4th highest in the time series, 2006-2025, decreased from the peak in 2022.

23.2. Description of the time series

Since 2017, the Integrated Pelagic Ecosystem Science (IPES) survey has been conducted to study the structure and function of the pelagic ecosystem on the Vancouver Island continental shelf (< 200 m bottom depth), during the summer (see King et al. 2019; Boldt et al. 2020; Boldt et al. 2024). The goal of the survey is to understand factors affecting the distribution, abundance, and food web linkages of pelagic fish species, such as Pacific Herring (*Clupea pallasii*). Survey objectives are to: 1) examine species distribution, composition, and abundance; 2) collect morphometric data, diet data, and biological samples; and 3) examine the prey environment by sampling zooplankton (vertical bongo net hauls) and conducting oceanographic monitoring (temperature, salinity, fluorescence). This is a random stratified trawl survey that has 8 strata, defined by depth and biological communities. Each survey year, a subset of blocks is randomly selected (allocated by strata sizes) and a midwater trawl net is used to sample fish (2017: CanTrawl 250; 2018-present: LFS 7742; see Anderson et al. 2019) at randomly assigned depths (0 or 15 m). Catch per unit effort (CPUE) is estimated as species' catch weights divided by swept volume (product of net mouth opening height, width, and distance towed). Two products of this survey are Pacific Herring biomass and distribution, which are the focus of this summary. To extend the time series, Pacific Herring biomass was estimated using a spatio-temporal model (Anderson et al. 2022) that combined IPES data with historic night-pelagics survey data (2006-2014; see Flostrand et al. 2014), while accounting for important variables, such as daytime or nighttime trawl sets and gear depth. In 2025, the survey was scheduled from July 1-30, 2025; unfortunately, the last 2 weeks were cancelled due to CCG staffing issues.

23.3. Status and trends

Pacific Herring dominated the catches and represented 41% of the total survey catch weight. Pacific Herring are typically broadly distributed on the Vancouver Island continental shelf in the upper ~45 m of the water column during night time hours. Areas of highest CPUE are typically located off the southwest coast of Vancouver Island; however, not many stations were completed in that area (Figure 23-1). In 2025, Pacific Herring biomass, estimated using nighttime trawl tows and a spatio-temporal model, was the 4th highest in the time series at 94,254 t (Figures 23-1 and 23-2).

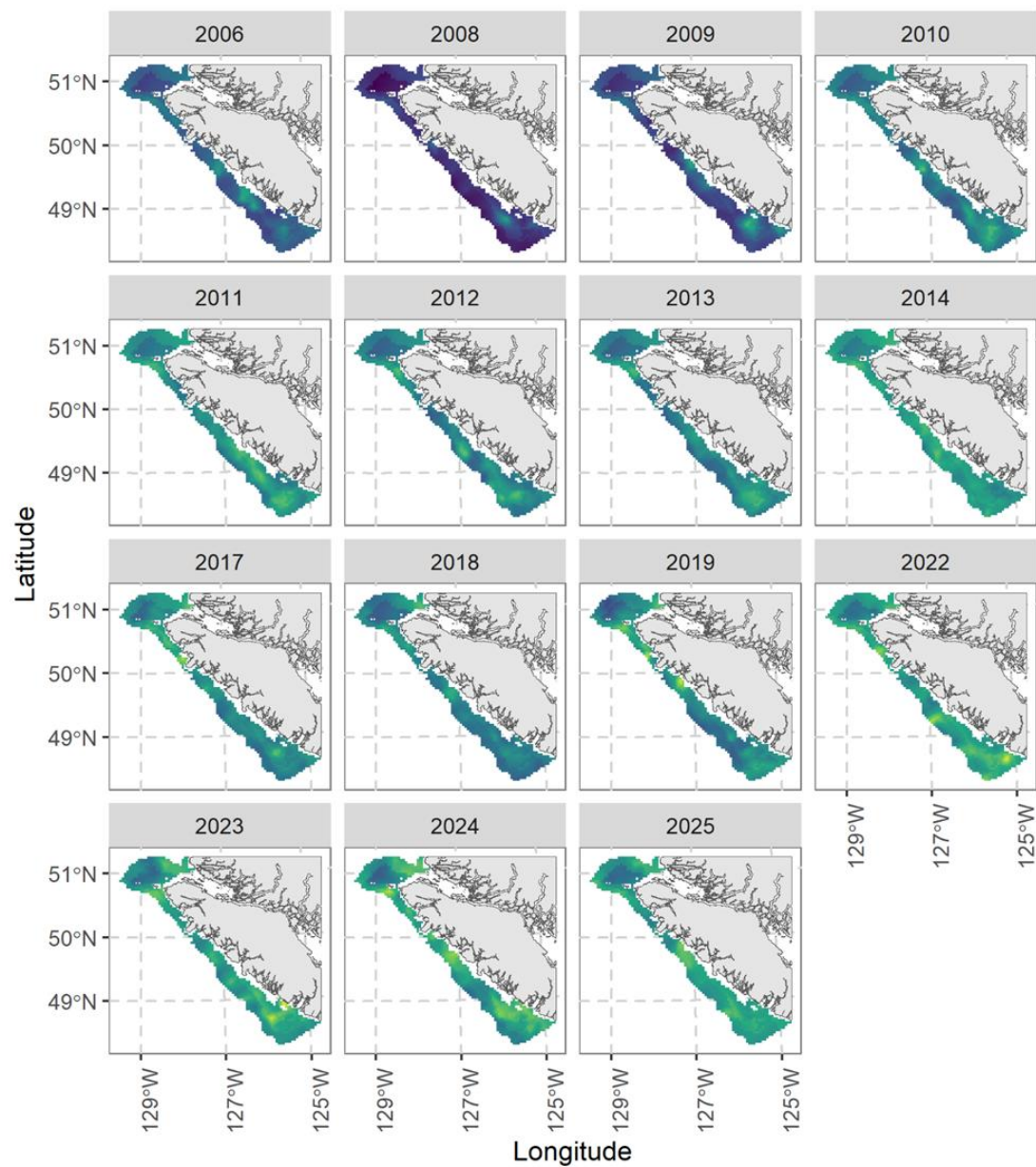


Figure 23-1. Pacific Herring biomass, as estimated with a spatio-temporal model, in the night pelagics (2006-2014) and Integrated Pelagic Ecosystem Science surveys (2017-2025) (nighttime data only).

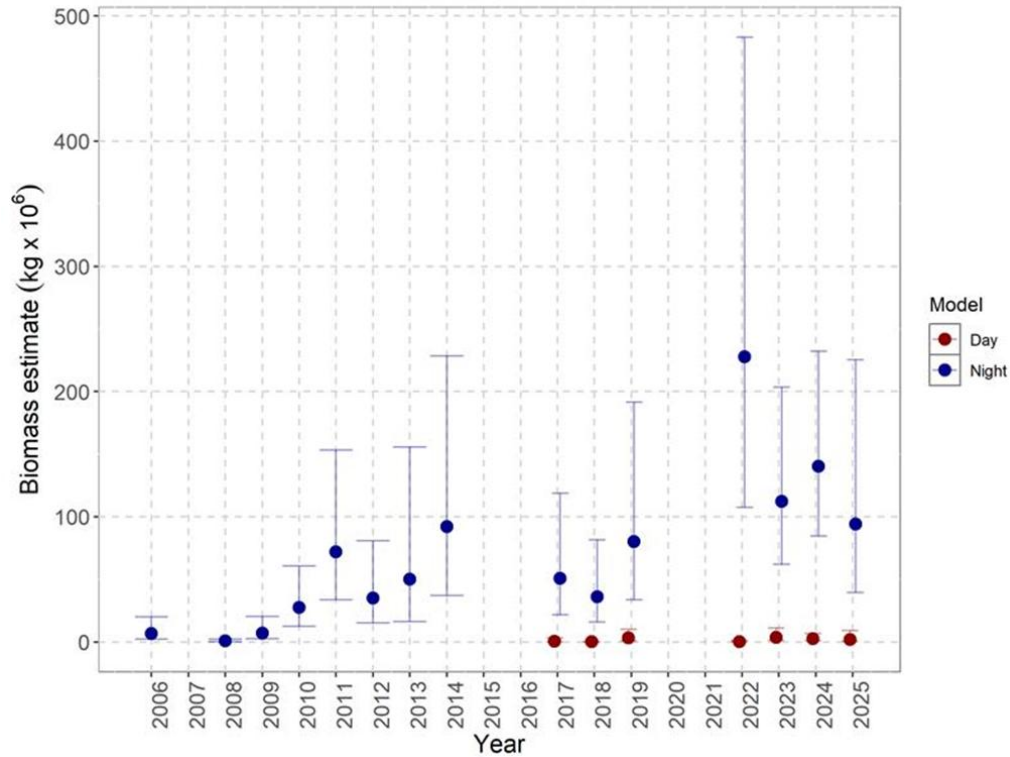


Figure 23-2. Pacific Herring biomass, as estimated with a spatio-temporal model, in the night pelagics (2006-2014) and Integrated Pelagic Ecosystem Science surveys (2017-2025). Modeled biomass estimates are shown for daytime trawl tows (red) and nighttime trawl tows (blue).

23.4. Factors influencing trends

Environmental variables, such as temperature, are known to affect Pacific Herring recruitment and survival (Tester 1948; Ware 1991). Bottom-up control of production can also influence fish abundance (Ware and Thompson 2005; Perry and Schweigert 2008; Schweigert et al. 2013; Boldt et al. 2019a). Pacific Herring are zooplanktivorous, consuming primarily euphausiids and some copepods (Wailes 1936). Changes in ocean conditions, such as temperature or currents, could affect the amount, types, and quality of prey available. For example, a northerly current direction could bring warm-water, low-lipid copepods to the west coast of Vancouver Island, creating poorer feeding conditions for herring (Mackas et al. 2004; Schweigert et al. 2010).

There are a wide variety of herring predators on the west coast of Vancouver Island, including Pacific Hake, Lingcod, Pacific Spiny Dogfish, Pacific Cod, Sablefish, Arrowtooth Flounder, Pacific Halibut, Steller Sea Lions, Northern Fur Seals, Harbour Seals, California Sea Lions, and Humpback Whales (Schweigert et al. 2010). At the margins of Pacific Hake and Pacific Herring aggregations, consumption of Pacific Herring by Pacific Hake may be high (Ware & McFarlane 1986, 1995) and in areas where Pacific Hake densities are high, Pacific Herring may have to trade off predation risk against finding prey (e.g., euphausiids; Godefroid et al. 2019).

23.5. Implications of those trends

One of the many types of data collected on this survey is a time series of Pacific Herring abundance and distribution during their summer foraging period. Stock assessments for Pacific

Herring are driven by spring egg dive surveys to estimate spawning stock biomass; however, stock assessments indicate temporal changes in natural mortality – the causes of which are unknown. This survey examines Pacific Herring abundance and distribution in the summer, providing an improved understanding of factors affecting their mortality. Spatial data from this survey supports the hypothesis that Pacific Hake predation is an important factor to include in estimating Pacific Herring mortality (Boldt et al. 2019b; Godefroid et al. 2019). Pacific Herring aggregations along the west coast of Vancouver Island are also informative when determining variability in seabird and marine mammal distributions. Mismatch between Pacific Herring aggregations and seabird or marine mammal foraging areas could translate into decreased growth or survival of those predators. This time series provides an indicator of ecosystem productivity and the availability of Pacific Herring to their predators.

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24. 2025 JUVENILE SALMON SURVEYS IN THE COASTAL WATERS OF SOUTHERN B.C.

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24.1. Highlights

- 305 midwater trawl fishing events were conducted through southern B.C. waters in the summer and fall of 2025, including through the Salish Sea and on the continental shelf of the north and west coasts of Vancouver Island.
- Geostatistical models show juvenile Coho Salmon in the Strait of Georgia had higher than average abundance in both summer and fall, with all other Pacific salmon in the Strait of Georgia (SOG) or the southern B.C. continental shelf having average or below average abundance indices.
- After 2 years of improved Sockeye Salmon relative abundance in summer and fall, 2025 showed a return to a lowered abundance index in both areas. The indices for the continental shelf were still considered average, however the SOG abundance was lower than the long term average.
- Juvenile Pacific salmon condition in summer and fall was either average or above average in both the Salish Sea and the continental shelf survey zones, with the exception of fall-caught juvenile Pink Salmon in the Salish Sea, which was below average.

24.2. Description of the Time Series

24.2.1. Strait of Georgia (SOG) Juvenile Salmon Survey

This survey was conducted in summer (June) and Fall (September) through the Strait of Georgia (SOG) and associated waters, including the Discovery Islands, Desolation Sound, and Johnstone Strait. It builds on a juvenile salmon trawl time series that was started in 1998 (Neville et al. 2023). Tow locations were fished during the day using an LFS 7742 midwater trawl net at surface, 15 m, or 30 m headrope depth. In 2025, 74 tows were completed in the summer, and 74 tows during the fall survey.

24.2.2. Summer Integrated Pelagic Ecosystem Survey

The Integrated Pelagic Ecosystem Survey was started in 2017 as a stratified random design with 4×4 km blocks divided into eight strata (King et al. 2019). A random set of 70 blocks are selected annually, proportional to the stratum area, with each tow location fished during both day and night using an LFS 7742 midwater trawl net at either the surface or 15 m headrope depth. This survey provides data continuity with juvenile Pacific salmon surveys conducted on the continental shelf of the northern and western coast of Vancouver Island since 1998 (Anderson et al. 2019).

In 2025, the second half of the survey was cancelled due to a Coast Guard crew shortage. The reduced survey was able to complete 70 tows on the continental Shelf.

24.2.3. Fall Juvenile Salmon Survey

Fall surveys for juvenile Pacific salmon have been conducted intermittently on the continental shelf and inlets of Vancouver Island since 1998. Tows are conducted at standard stations along the coast and within inlets using similar trawl gear and depths to summer surveys. 77 tows were completed in fall 2025 on the continental shelf from Queen Charlotte Sound to the mouth of Juan de Fuca (Figure 24-1).

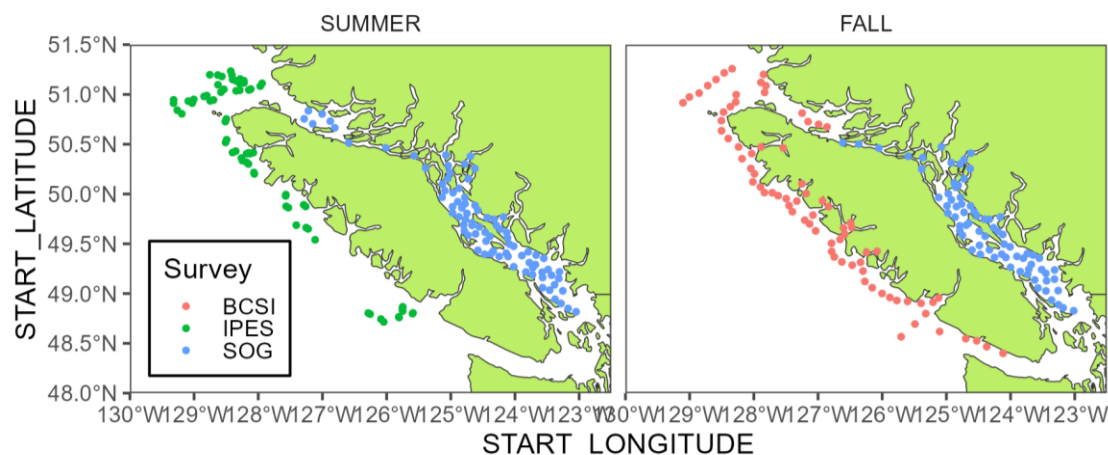


Figure 24-1. Locations of midwater trawls conducted in the summer and fall of 2025 during pelagic ecosystem surveys conducted in southern B.C. coastal waters. Point color indicated the survey series, with blue representing the Strait of Georgia survey, green points indicating locations of the Integrated Pelagic Ecosystem survey tows, and orange as the locations of the Fall Juvenile Salmon survey.

24.3. Status and Trends

24.3.1. Relative Abundance

Changes in survey design, timing, and sampling conditions affect catch-per-unit-effort indices. Regional, seasonal and species-specific abundance indices (log), as developed in Freshwater et al. (2024) and Thompson and Neville (2024), are therefore estimated using geostatistical models that account for survey effort, headrope depth, diurnal sampling, and design changes. The Strait of Georgia abundance estimates currently include catches located within the Strait of Georgia, and do not include other associated waters in the Salish Sea that were also fished.

In the Strait of Georgia, Coho Salmon indices were above average in both summer and fall. Summer Chum Salmon abundance was average, however the remaining species in the SOG were below average in summer and fall (Figure 24-2).

On the continental shelf in summer, Sockeye Salmon and Pink Salmon were below the long term averages. In the fall, Sockeye Salmon and Chinook Salmon indices were below average. Other seasonal species estimates fell within the long term averages (Figure 24-3).

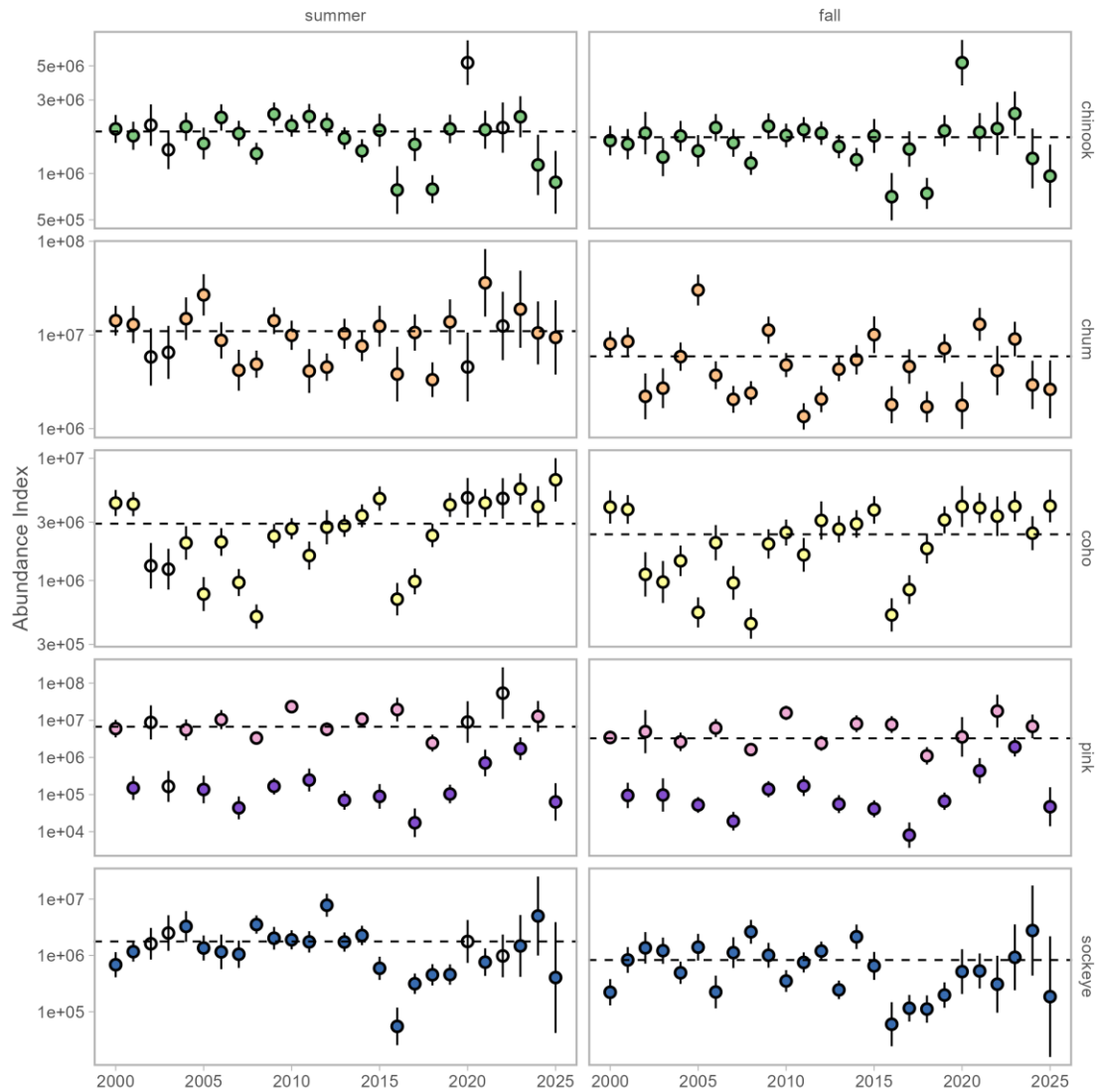


Figure 24-2. Annual Abundance Index (log) estimated from geostatistical models for juvenile Chinook, Chum, Coho, Pink and Sockeye Salmon caught in summer and fall in the Strait of Georgia. Dashed lines indicate the long-term averages. Open circles denote years without survey data in that season; index values for missing years estimated from both annual autocorrelation and the other season if available. See Thompson et al. (2024) for estimation methods.

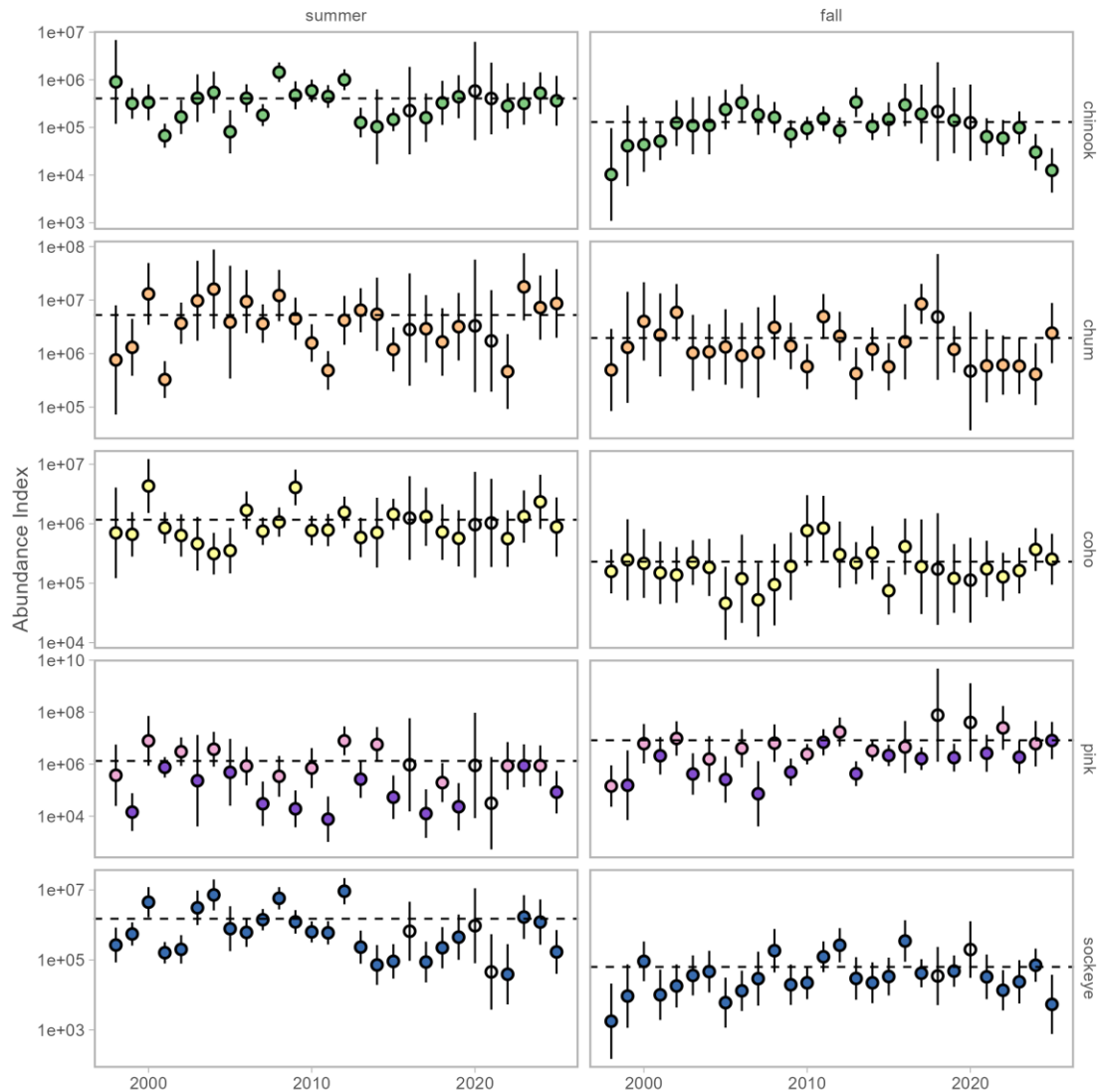


Figure 24-3. Annual Abundance Index (log) estimated from geostatistical models for juvenile Chinook, Chum, Coho, Pink and Sockeye Salmon caught in summer on the continental shelf of Vancouver Island and in fall on the continental shelf and inlets of Vancouver Island. Dashed lines indicate the long-term averages. Open circles denote years without a survey in that season; index values for missing years estimated from both annual autocorrelation and the other season if available. Estimations for Fall 2023 and Summer 2025 are based on reduced survey area. See Freshwater et al. (2024) for estimation methods.

24.3.2. Condition

Most Pacific Salmon caught in the Salish Sea in 2025 had median weight residuals that were within an average range compared to the long term averages of the time series. Exceptions were summer Chinook Salmon and fall Sockeye Salmon, which had a higher than average condition, and fall-caught Pink Salmon, which showed weight residuals that were below the long term averages (Figure 24-4).

Median weight residuals for summer-caught Coho Salmon and fall-caught Chinook Salmon were above average, indicating that these juveniles were fatter than normal (Figure 24-5).

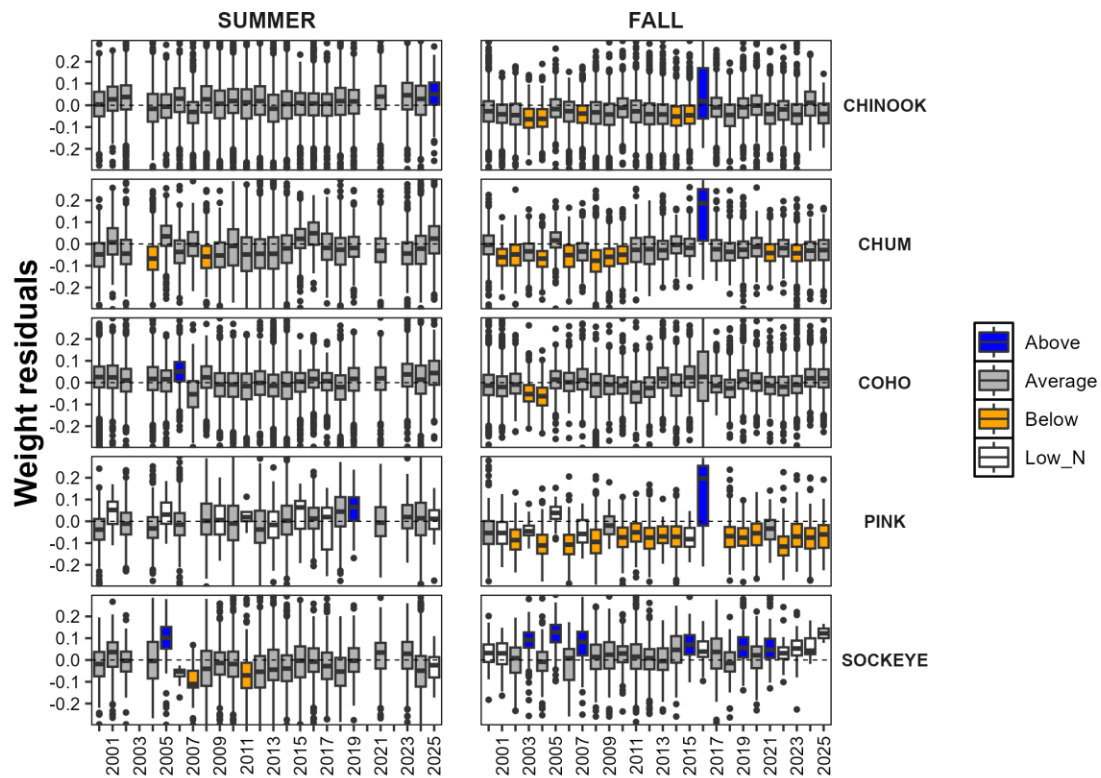


Figure 24-4. Box plots of weight residuals calculated from species-specific length-weight regressions (all years and seasons combined) for juvenile Chinook, Chum, Coho, Pink and Sockeye Salmon caught in summer and fall in the Salish Sea of B.C.

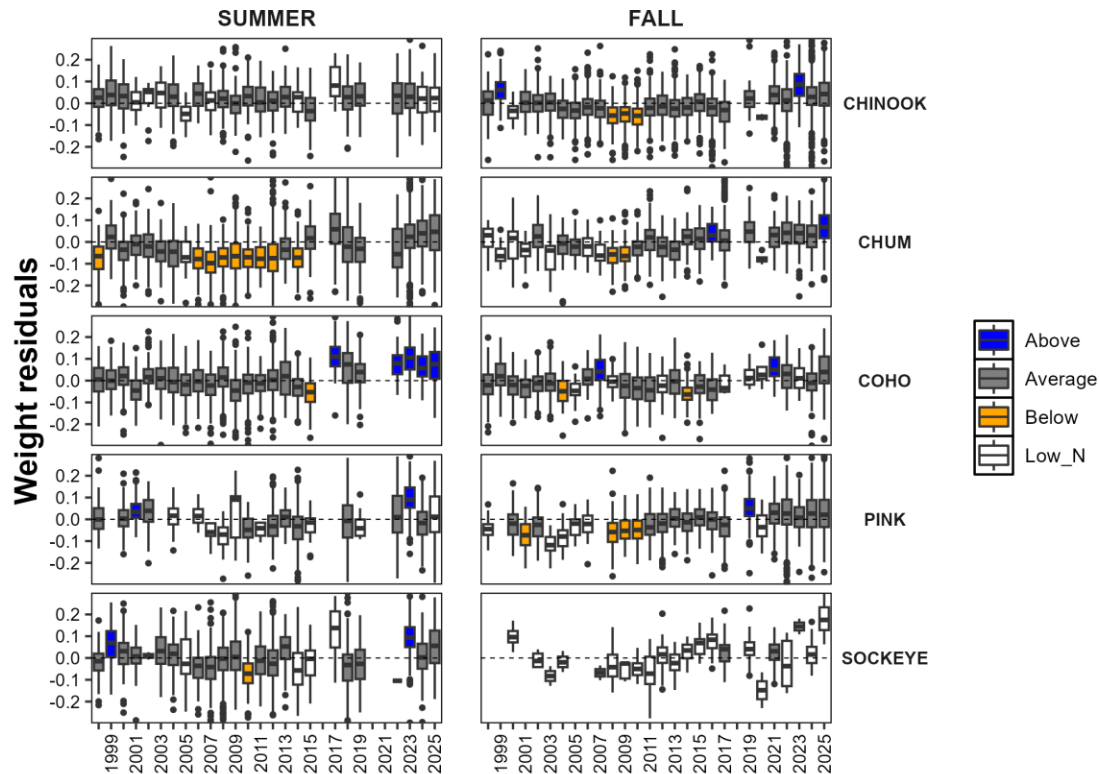


Figure 24-5. Box plots of weight residuals calculated from species-specific length-weight regressions (all years and seasons combined) for juvenile Chinook, Chum, Coho, Pink and Sockeye Salmon caught in summer on the continental shelf of Vancouver Island in fall on the continental shelf and inlets of Vancouver Island.

24.3.3. Diets

The stomach contents of juvenile Pacific Salmon were analyzed at sea to identify their prey composition. Diets in 2025 were consistent with previous observations. Juvenile Chinook Salmon and Coho Salmon are the most piscivorous, especially for specimens caught on the West Coast continental shelf with fish prey that was identifiable was predominately Pacific Herring. Juvenile Pink Salmon and Sockeye Salmon diets are dominated by zooplankton, primarily Euphausiids and Amphipods, while juvenile Chum Salmon are most likely to have unidentifiable remains (often from quickly digested gelatinous prey) in addition to zooplankton (Figure 24-6).

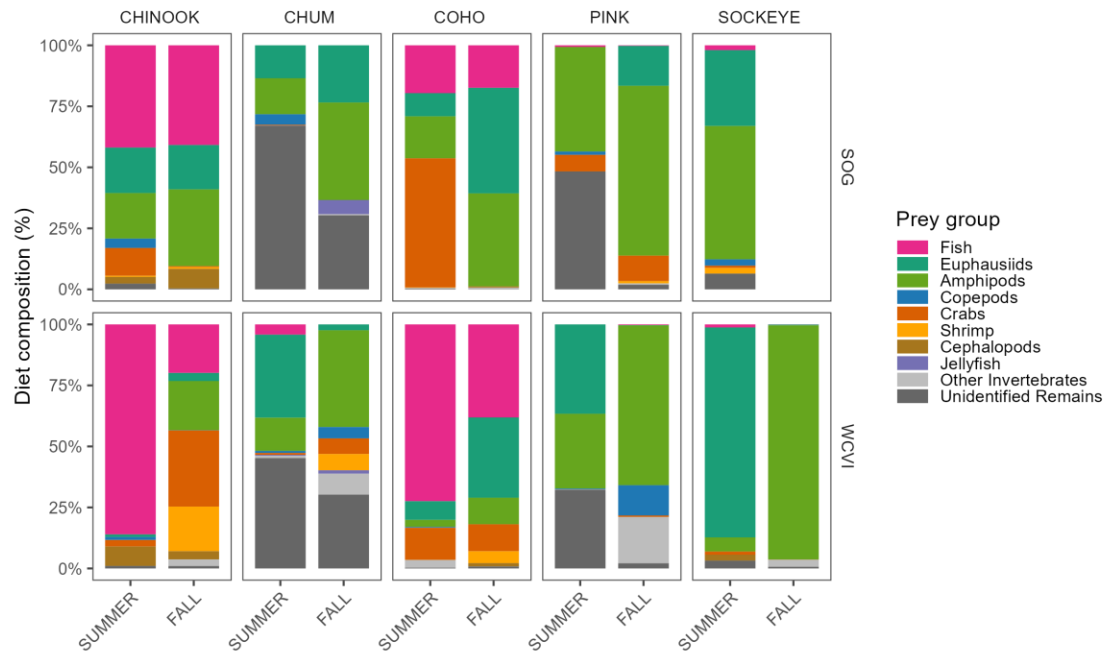


Figure 24-6. Major prey groups consumed by juvenile Pacific salmon caught in the summer and fall of 2025 in southern B.C. coastal waters.

24.4. Factors Influencing Trends

The relative abundance of juvenile Pacific Salmon in coastal regions reflects cumulative impacts, including, but not limited to, spawner-egg-fry productivity in freshwater, in river mortality for out-migrating smolts and ocean conditions coupled with trophic impacts (prey quality and availability, predation) in the first few months in the ocean. Prey quality and availability can also influence condition. For example, Coho Salmon and Chinook Salmon feed primarily on fish, notably on Pacific Herring, which has increased in biomass off the WCVI since 2006-2009 (Boldt et al., Section 23).

24.5. Implications of Those Trends

The abundance indices and condition plots apply to the specific populations in the area at the time of surveys. The juvenile Pacific salmon encountered in these surveys will return to spawn at varying times, but generally these abundance indices and condition apply to Coho Salmon and Pink Salmon returning in 2026, stream-type Chinook Salmon and Sockeye Salmon returning in 2027, and ocean-type Chinook Salmon and Chum Salmon returning in 2028. Genetic stock identification from previous surveys provides a general indication of regional origins of the salmon encountered. Salish Sea survey catches are primarily Fraser origin stocks for all Pacific salmon species, with additional East Coast Vancouver Island (ECVI), southern B.C., and Puget Sound stocks.

On the west and north coast of Vancouver Island, stock composition is more varied. The average abundance and condition of Chinook Salmon in summer applies mainly to stream-type Columbia River stocks returning in 2026, while the fall abundance (below average) and condition (higher than average) represents primarily WCVI stocks. The Abundance Index and

conditions for Chum Salmon apply predominately to WCVI stocks (summer and fall) and ECVI stocks (fall) returning in 2027. The above average condition of juvenile Coho Salmon, returning in 2026, applies to west coast stocks (Vancouver Island, Washington State, Columbia River) and Puget Sound stocks in summer and WCVI and ECVI in the fall. After showing an improved abundance index for the past 2 years, Sockeye Salmon has a below average abundance index for both summer and fall in 2025. Sockeye Salmon in summer most likely apply to WCVI and Fraser River stocks migrating past northern Vancouver Island, that will return in 2027. 2025 is not a dominate run year for juvenile Pink Salmon, so the abundance index is average when compared to other odd years. There are insufficient genetic stock identification results from previous surveys to indicate the dominant region of origin for Pink Salmon encountered.

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25. STATE OF CANADIAN PACIFIC SALMON

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25.1. Highlights

- Wild Salmon Policy (WSP) statuses are available for 70 of the 381 Pacific salmon Conservation Units (CUs). Efforts are on-going to expand coverage to the remaining 311 CUs.
- Of the assessed CUs, ~80% are in the Red or Amber WSP status zone, indicating *poor* or *fair* biological status. This includes many Fraser Sockeye, Fraser Chinook and Yukon Chinook CUs, Fraser Chum, and two West Coast Vancouver Island Chinook CUs.
- CUs in *good* (Green) status include Fraser Pink, some Interior Fraser Coho and Barkley Sockeye CUs, South Thompson and Shuswap Chinook, and one WCVI Chinook CU.
- Many Canadian populations of Pacific salmon have exhibited declines in abundance, coinciding with human activity and climate-related changes in freshwater and marine ecosystems.

25.2. Description of the Canadian Pacific salmon time series

Catch data are available up to 2024 for the five Pacific salmon species managed by DFO (Sockeye, Chinook, Coho, Pink and Chum; NPAFC: <https://npafc.org/statistics/>).

Wild Salmon Policy (WSP) rapid statuses describe the current extinction risk of Pacific salmon Conservation Units (CUs), where Red reflects an imminent threat of extinction, Amber describes an intermediate risk, and Green indicates a low probability of extinction. Conservation Units (CUs) represent fundamental units of biodiversity for Canadian Pacific salmon (Holtby and Ciruna 2007). Statuses are available for 70 Pacific salmon CUs, within DFO's Pacific Salmon Status Scanner (The Scanner), an interactive data visualization tool for salmon experts (Pestal et al. 2023; DFO 2024; Grant et al. 2026). These include statuses for Fraser Chinook, Okanagan Chinook, West Coast Vancouver Island (WCVI) Chinook, Yukon Chinook, Fraser Sockeye, Okanagan Sockeye, Barkley Sockeye, Fraser Coho, Fraser Chum, and Fraser Pink. Statuses are available up to 2023 for most CUs and up to 2024 for Barkley Sockeye and Yukon Chinook. There is a lag between completing field assessments to estimate spawner abundances and completing status evaluations with local experts, and this lag varies between CU groups.

The WSP rapid status approach uses standardized metrics of extinction risk within a decision tree framework to generate WSP rapid statuses (Holt 2009; Holt et al. 2009; Pestal et al. 2023; Grant et al. 2026). Briefly, escapement data were obtained from DFO staff and were processed to produce a quality-controlled composite escapement time series for each CU. Processing

steps included data quality filtering, site selection, and infilling, where appropriate (Pestal et al. 2023; Grant et al. 2026). Applicable metrics were calculated for each CU, and the rapid status decision tree was applied to generate WSP rapid statuses (Pestal et al. 2023). Each step of this process was reviewed with CU experts to ensure that data and metrics were applied appropriately and any relevant local knowledge was considered. The review step included experts from Indigenous communities, DFO science, academia, and environmental NGOs (see list of contributors at the end of this report).

25.3. Canadian Pacific salmon statuses and trends

25.3.1. Trends in salmon catch

Total catch of the five DFO-managed Pacific salmon species has declined in recent decades (Figure 25-1). This is due to declines in harvested salmon populations, and constraints placed on mixed-stock fisheries to protect co-migrating salmon populations in poor status. Catches since 2019 have been extremely low, averaging 3.0 million.

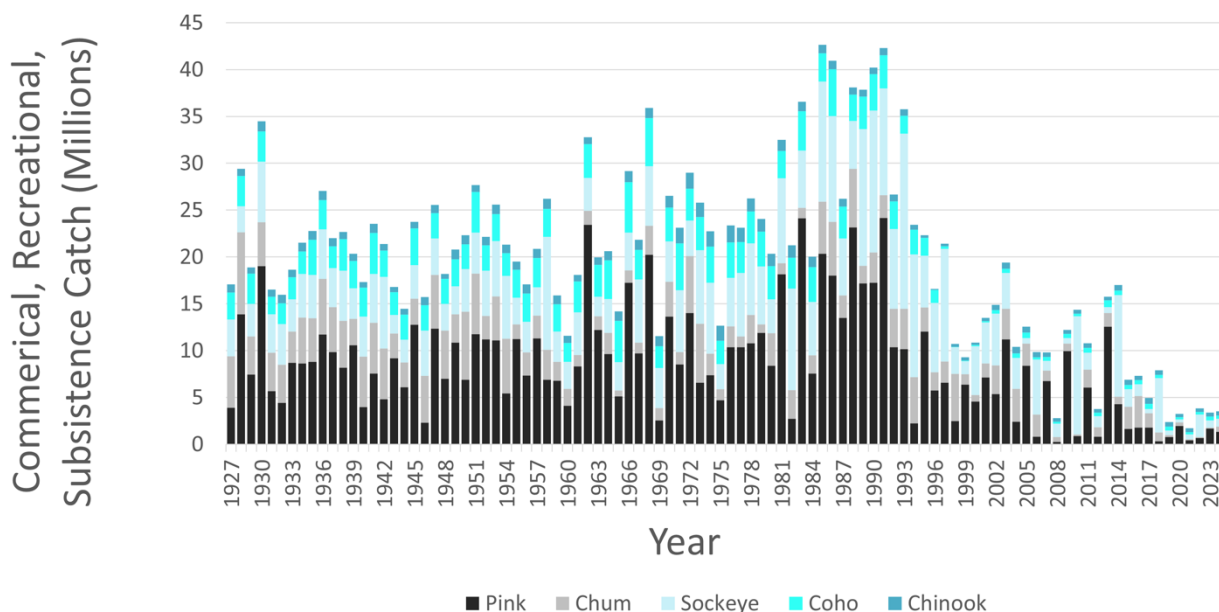


Figure 25-2. Commercial, recreational and Indigenous subsistence catch of Canadian Pink, Chum, Sockeye, Coho and Chinook Salmon. Average catch from 1925-1993 was 24.2 million, and from 1994-2014 was 13 million. Catch since 2019 has averaged 3 million, with the lowest catch on record occurring in 2021 (2 million). Data source: North Pacific Anadromous Fish Commission (NPAFC 2025). NPAFC Pacific salmonid catch statistics (updated December 2025). Accessed February, 2026. Available: <https://www.npafc.org>.

25.3.2. Canadian Pacific salmon statuses and trends in status

In the most recent decade (2013-2023), the proportion of Red status CUs in the data set increased from 30% to 39% (Figure 25-2). This increase was primarily due to improved data availability, meaning that Red status CUs could be assessed in 2023 but were data deficient in 2013. Notably, the proportion of Green status CUs declined from 20% to 13%, while Amber CUs

increased from 31% to 39%. The number of data deficient CUs has declined to below 20% since 2013.

In the Fraser River watershed, almost half of the 17 Fraser Chinook CUs were in Red (poor) status in 2023 (8 Red status CUs), many of which have been Red status for the past decade. Only two Fraser Chinook CUs were in Green (good) status in 2023, while 6 CUs were Amber (fair) status and one CU was data deficient (Figure 25-3). Fraser Sockeye statuses in 2023 were split between Red (10 of 24 CUs) and Amber (12 of 24 CUs) status, while two CUs were data deficient. Notably no Fraser Sockeye CUs were Green status. Fraser Sockeye CUs have declined in status since 2013, with one third of CUs declining by at least one status zone. Two Fraser Sockeye CUs in the Harrison watershed declined from Green to Red status since 2013. Interior Fraser Coho were in fair (2 Amber CUs) or good (3 Green CUs) status in 2023. These CUs have been stable or have improved in status since 2013. Lower Fraser Coho (2 CUs) cannot be assessed due to data deficiencies. Fraser Pink were in good status in 2023 and have been stable over the past decade. Fraser Chum can only be assessed from 2019 onwards and have declined from Amber status to Red status in 2023.

Okanagan Chinook were consistently in poor status from 2013 to 2023, while Okanagan Sockeye declined from Green status in 2015 to consistently Amber status from 2016 up to 2023 (Figure 25-3).

On Vancouver Island, WCVI Chinook ranged from Red to Green status in 2023 with one CU in each of the three status zones (Figure 25-3). These statuses have been mostly stable since 2013. Barkley Sockeye were also stable over the past decade and were in fair (1 CU) or good (2 CUs) status in 2024.

Yukon Chinook were predominantly in poor status in 2024 (Figure 25-3). Almost 60% of Yukon Chinook were in the Red status zone, while the remaining non-data deficient CUs were Amber (4 CUs). More than half of the CUs were in the same status zone as a decade ago, while two CUs declined in status. The remaining Yukon Chinook CUs could only be assessed for status in very recent years.

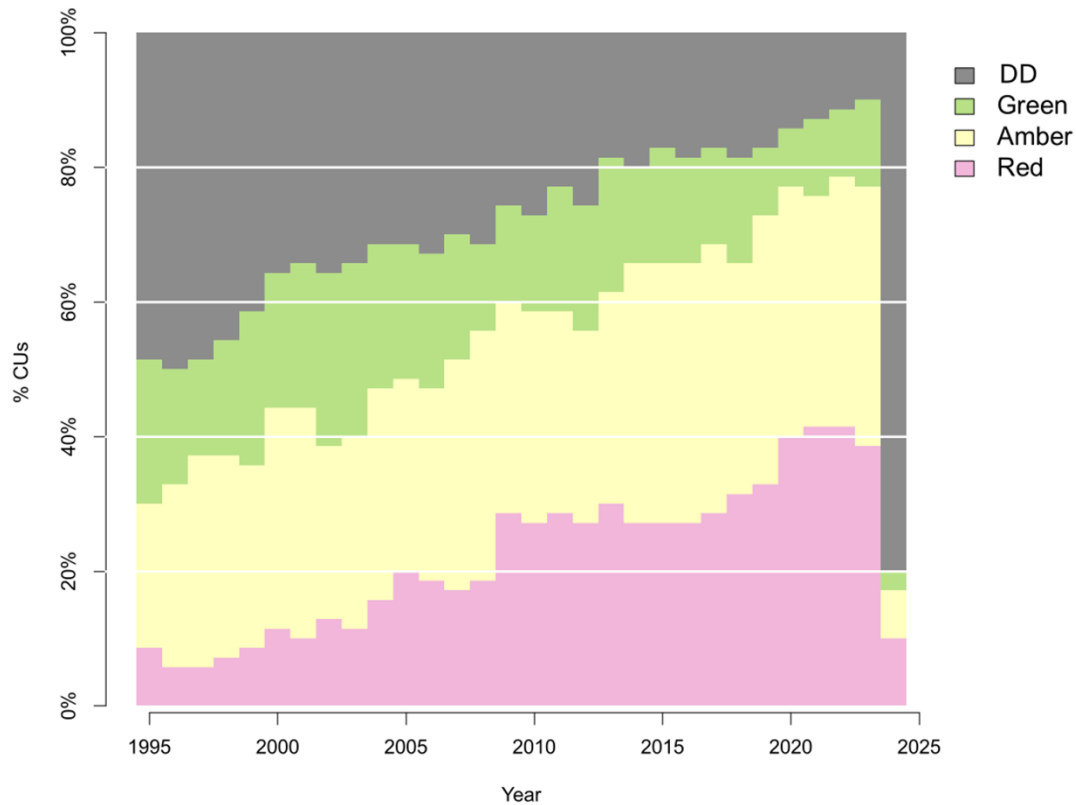


Figure 25-2. The percentage of assessed CUs assigned to each WSP status category. The 70 assessed CUs include Fraser Sockeye, Fraser Chinook, Fraser Coho, Fraser Chum, Fraser Pink, Okanagan Sockeye, Okanagan Chinook, WCVI Chinook, Barkley Sockeye, and Yukon Chinook. Note that WSP statuses are only available for Yukon Chinook and Barkley Sockeye in 2024; all other CUs are currently data deficient due to time lags between completing field work and producing approved statuses. DD indicates data deficient.



Figure 25-3. The most recent WSP rapid statuses for Barkley Sockeye (2024), Okanagan Sockeye (2023), Fraser Sockeye (2023), Fraser Pink (2023), Fraser Coho (2023), Fraser Chum (2023), Yukon Chinook (2024), West Coast Vancouver Island Chinook (2023), Okanagan Chinook (2023), and Fraser Chinook (2023). Numbers and bar size indicate the number of CUs in each status zone in the assessment year: Red, Amber, Green, and Data Deficient (grey).

25.4. Factors Influencing Pacific Salmon Trends

Climate and landscape changes are impacting Pacific salmon throughout their life-cycle by altering their habitats and food availability (Grant et al. 2019). Pacific salmon are exposed to multiple stressors, which can include direct mortality from fisheries and predation, as well as increased competition for prey associated with high abundances of hatchery-origin salmon in the North Pacific Ocean. Other stressors can include pathogens, contaminants, and landscape changes due to human activities like forestry, development, and agriculture. Climate change acts as an overarching driver that impacts both fresh water and marine ecosystems, and can amplify these other threats.

In freshwater systems, the combined effects of climate change and natural or human-caused landscape change can lead to changes in hydrology, sediment loads, and frequencies of landslides. In the Northeast Pacific Ocean, warming temperatures and marine heatwaves are affecting ocean food webs. Shifts in zooplankton species composition towards less nutritious species were observed in waters along the west and north coast of Vancouver Island, and broadly in the NE Pacific during and after recent marine heatwaves (Galbraith and Young 2020; Grant et al. 2020).

25.5. Implications of those trends

Recent trends in salmon statuses yield a growing, but incomplete, view of Pacific salmon vulnerability to climate change. Continued monitoring and expansion of WSP statuses to include additional CUs will improve our understanding of vulnerability and how it is affected by variation

in salmon life histories, habitats, and other characteristics (Crozier et al. 2019; McClure et al. 2023). This is needed to support forward-looking, proactive adaptation to both current and future changes across salmon populations and habitats (Moore and Schindler 2022; MacDonald and Grant 2023).

WSP rapid statuses provide decision makers with critical information on the current extinction risk of Pacific salmon CUs to inform fisheries management, salmon enhancement, and habitat restoration activities. In combination with ecological, social, and economic information, WSP status trends and climate vulnerability information will help decision-makers prepare for, and adapt to, coming changes through ensuring that decisions are aligned with future salmon production and biodiversity (Nelitz et al. 2007; Hunter and Wade 2015; Hunter et al. 2015; Crozier et al. 2019, 2021; Grant et al. 2019; MacDonald and Grant 2023). Continued expansion of the Pacific Salmon Status Scanner will support this work.

25.6. Contributors

WSP statuses assessments are not possible without the work and knowledge of many contributors including DFO staff and experts from Indigenous communities, academia, consulting companies, and environmental NGOs. The following list of people contributed to the WSP status results presented here:

DFO staff: Michael Arbeider, Sara Martin, Colin Bailey, Amber Messmer, Isabella Borea, Simon-Luc Noel, Nicholas Brown, Wilf Luedke, Charmaine Carr-Harris, Diana McHugh, Brendan Connors, Christie Morrison, Brooke Davis, Athena Ogden, Scott Decker, Helen Olynyk, Kaitlyn Dionne, Adam O'Dell, Morgan Dunne, Chuck Parken, Sean Everitt, Tommy Pontbriand, Dylan Glaser, Lynda Ritchie, Marissa Glavis, Howard Stiff, John Gray, Joe Tadey, Matthew Townsend, Julie Hewlett, Nicole Trouton, Carrie Holt, Pieter Van Will, Hannah Hunter, Dawn Machin.

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National Government), Stephanie Peacock (PSF), Samantha Pham (Okanagan Nation Alliance), Ian Riemenschneider (EDI), Andy Rosenberger (Raincoast Conservation Foundation), Gillian Rourke (TTC), Ben Schonewille (EDI), Hannah Turner (CTFN), William Twardek (Ecofish), Amelia Vos (Huu-ay-aht First Nations), and Michelle Walsh (Secwépemc Nation).

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26. ASSESSING CLIMATE CHANGE AND POTENTIAL IMPACTS TO PACIFIC SALMON IN CLAYOQUOT SOUND

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26.1. Highlights

- Simulated future ocean temperatures increased by ~ 1.15 °C in the Clayoquot Sound area from 2024 to a 2055 scenario based on a high-emissions pathway (RCP 8.5).
- Simulated future precipitation decreased in summer and increased in fall, leading to changes in river runoff and an increase in surface salinity in summer and a decrease in fall.
- The 17 °C temperature stress threshold for salmon is increasingly exceeded in the future scenario in the surface layers of all inlets in Clayoquot Sound and in the whole water column in Tofino Inlet.

26.2. Introduction to modelling study

We employed the Finite Volume Community Ocean Model (FVCOM; Chen et al. 2003) configured for the west coast of Vancouver Island (Foreman et al. 2024) to investigate ocean conditions in five inlets in Clayoquot Sound (Sydney, Shelter, Herbert, Bedwell, and Tofino Inlets; Figure 26-1), with a focus on temperature and salinity under present-day (March to December 2024) and a future climate scenario. The model used an unstructured triangular grid, allowing spatial resolution to vary across the domain. Horizontal resolution was relatively coarse on the continental shelf, with element lengths of up to ~ 6 km, and increased substantially within coastal inlets, reaching resolutions of up to 20 m. Vertically, the model employed 20 terrain-following (sigma) layers, with higher resolution in the top and bottom of the water column. This flexible horizontal and vertical resolution enabled the model to adequately resolve the complex bathymetry and coastline of a fjord system like Clayoquot Sound. Model performance was evaluated against observational data collected in 2024 within Clayoquot Sound and on the adjacent continental shelf. The model reproduced observed conditions with reasonable accuracy, providing confidence in its suitability for future scenario simulations.

The future scenario used a delta approach, in which monthly climate-change anomalies were added to the model's 2024 forcing (e.g., initial conditions, atmospheric forcing, open boundary conditions). This approach conserved the variability of the 2024 simulation overlapped to a new climate mean. The anomalies were computed from regional climate simulations representing a historical period (1986-2005) and a future (2046-2065) scenario under the RCP 8.5 emissions pathway (Holdsworth et al. 2021).

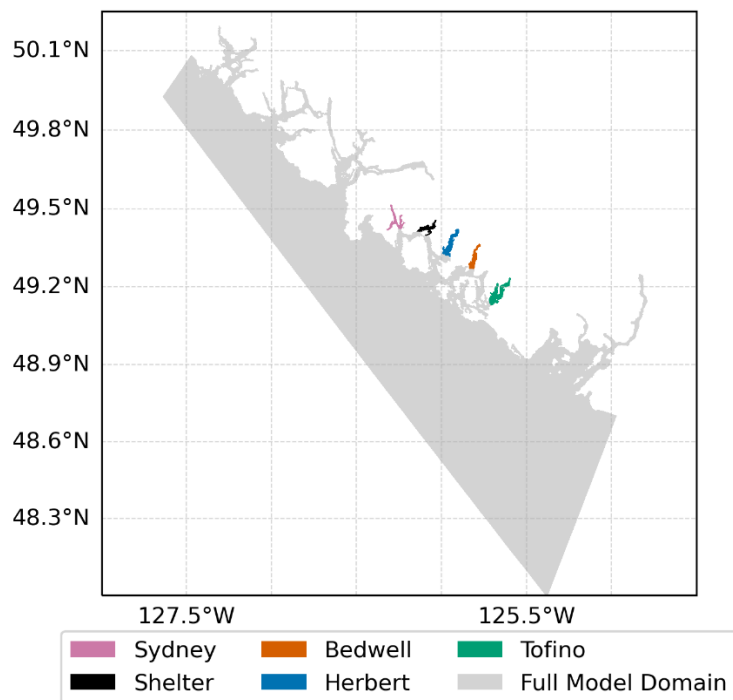


Figure 26-1. West coast of Vancouver Island Finite Volume Community Ocean Model (FVCOM) domain, highlighting the inlets of interest within Clayoquot Sound.

26.3. Status and trends

Ocean temperatures increased by approximately 1.15 °C between the present-day simulation and the future scenario due to the increased temperature in initial and boundary conditions (Figure 26-2). This warming signal was spatially and temporally consistent throughout the model domain. Variability in sea surface temperature was closely linked to precipitation patterns and associated changes in river runoff.

Projected salinity changes were comparatively small and are primarily confined to the surface layer, where they are strongly influenced by freshwater input from rivers. In the future scenario, river runoff decreased during summer, resulting in increased surface salinity. Surface warming was also most pronounced during this season. Reduced summer runoff limited the input of relatively cool freshwater to the inlets, decreasing the cooling effect normally exerted by river discharge and thereby enhanced surface ocean warming.

In contrast, precipitation and river runoff increased during autumn. The enhanced freshwater input led to reduced surface salinity during this period. Although sea surface temperatures remain higher in the future scenario compared to present-day conditions, the magnitude of warming in autumn was smaller than in other seasons due to the moderating influence of increased river discharge.

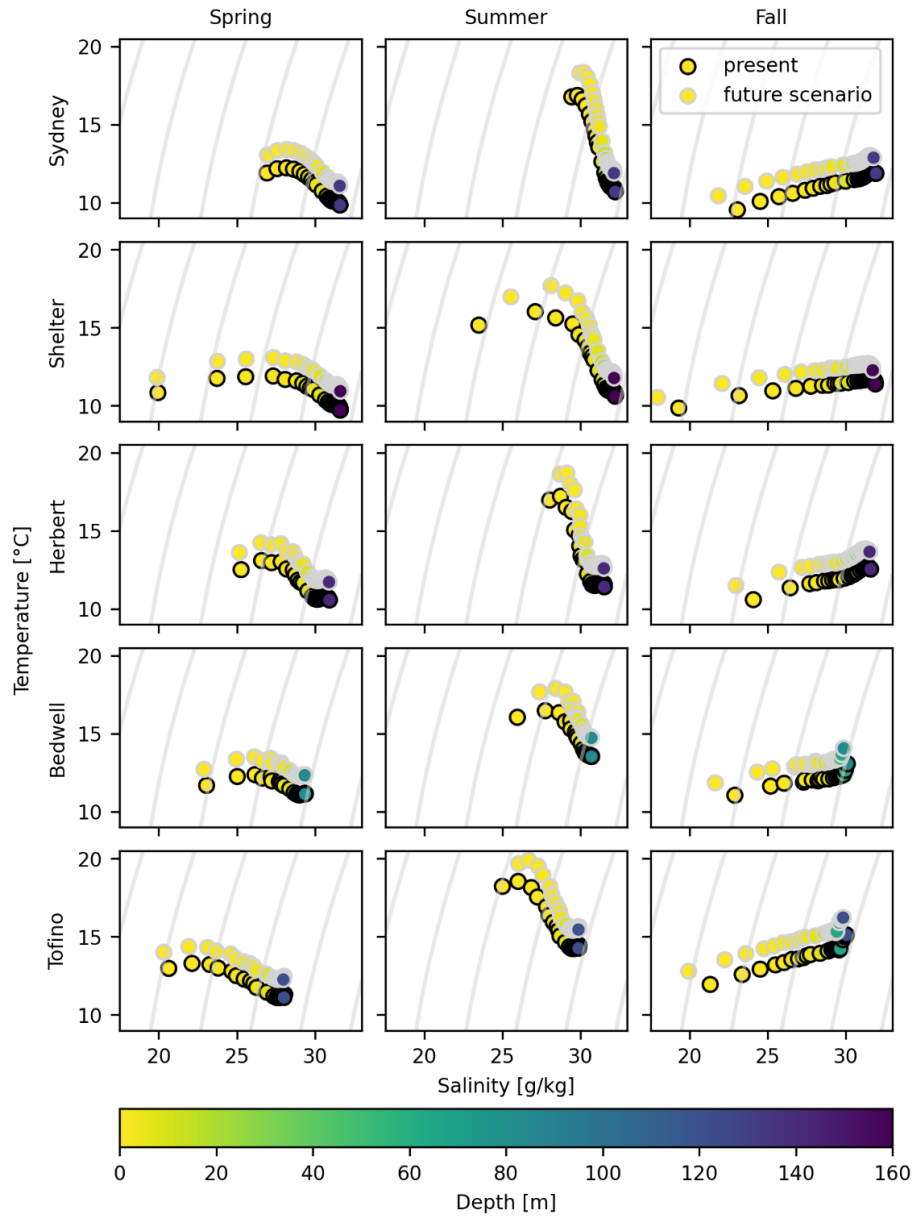


Figure 26-2. Temperature-Salinity diagrams for average conditions in each inlet and the three simulated seasons for present day conditions (black marker edges) and future scenario (light grey marker edges). Seasons displayed are spring (April-June), summer (July-September), and fall (October-December).

26.4. Implications of trends

Salmon are highly sensitive to elevated water temperatures, which can impair swimming performance, increase physiological stress, heighten susceptibility to additional stressors such as contaminants, and ultimately lead to increased mortality (Grant et al. 2019). To assess present and future thermal stress conditions, a temperature threshold of 17 °C was applied.

In the present-day simulation, temperatures exceeding this threshold occurred in all inlets, primarily during summer and largely confined to the upper 5 m of the water column (Figure 26-3, light green lines). Under the future scenario, the amount of surface waters above 17 °C was

increased (Figure 26-3, dark green lines). In addition, portions of the subsurface layer (5–30 m depth, dark blue lines) exceeded the threshold in Sydney and Bedwell Inlets. In Tofino Inlet, exceedance became particularly pronounced in the future scenario, with substantial portions of the surface, sub-surface and deep (30–100 m depth, black lines) water layers surpassing 17 °C from mid-September to mid-October.

These model results suggested that thermal refuge within the water column may be greatly reduced or absent during this period, particularly in the Tofino Inlet area, potentially exposing salmon to sustained thermal stress.

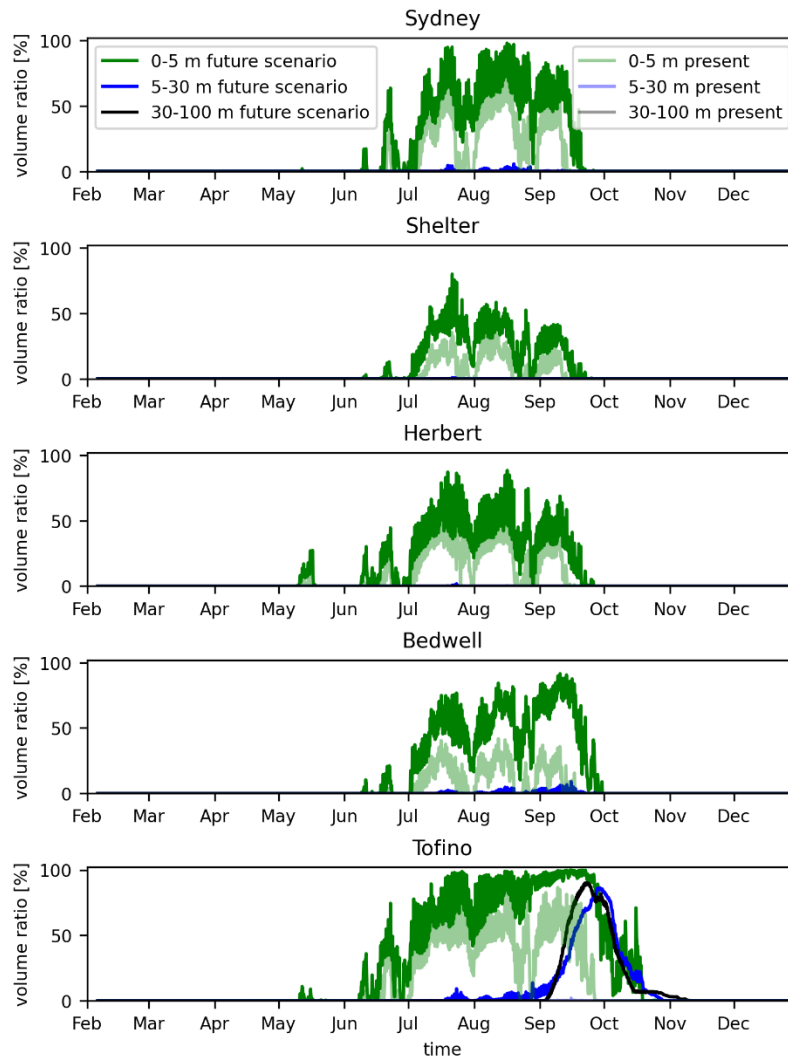


Figure 26-3. Percentage of the water column above the temperature threshold for average inlets at depth bins. Surface, 0–5 m, in green, sub-surface, 5–30 m, in blue, and deep, 30–100 m, in black/grey. Dark shades of each color represent the future scenario simulation, light colors the present day simulation.

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27. TRENDS IN PACIFIC CANADIAN GROUND FISH STOCK STATUS AND SURVEYS

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27.1. Highlights

- Average groundfish stock status declined from 1950 to around 2000, and following management changes, has remained relatively stable since then.
- In 2025, Lingcod, Yellowtail Rockfish, and Dover Sole were estimated to be above their Limit Reference Point (LRP) and above their Upper Stock Reference (USR) with very high probability (>99%). Yelloweye Rockfish was estimated to be above its LRP with very high probability and above its USR with ~97% probability.
- Over the last two decades, survey indices increased for ~68% of stocks, remained neutral (<1% change per year) for ~11%, and declined for ~21% of stocks.
- All assessed shelf rockfish (Bocaccio, Canary, Redstripe, Silvergray, Widow, Yellowtail) and several slope rockfish increased in surveyed biomass over the last ~10 years; surveyed biomass also increased for several flatfish (Petrable, English, Rex, and Dover Sole) but declined for Arrowtooth Flounder over the last 5–10 years with some signs of increase in 2025.
- Survey indices for Pacific Spiny Dogfish stocks had the steepest declines across all stocks—particularly for the outside stock—despite low fishing pressure compared to historical levels

27.2. Description of the time series

DFO conducts a suite of randomized surveys using bottom trawl, longline hook, and longline trap gear that, in aggregate, cover Canada's Pacific Coast (Anderson et al. 2019). Synoptic trawl surveys in Queen Charlotte Sound (Areas 5A and 5B) and Hecate Strait (Areas 5C and 5D) are conducted in odd-numbered years, while the West Coast of Vancouver Island (WCVI; Areas 3C and 3D) and the West Coast of Haida Gwaii (WCHG; Area 5E) surveys are conducted in even-numbered years. In addition, four biennial Hard Bottom Longline (HBLL) surveys are conducted: two in "inside" waters (east of Vancouver Island; Area 4B) and two in "outside" waters (everywhere else). Lastly, a coast-wide longline trap survey targeting Sablefish is conducted every year and DFO collects biological information from the International Pacific Halibut Commission (IPHC) Setline Survey. In 2025, the HBLL outside north, HBLL inside north, synoptic QCS, synoptic HS, and Sablefish surveys were run.

Stock assessments for major fish stocks in B.C. combine fishery-dependent data (such as commercial catches) with fishery-independent data (data from scientific surveys) to estimate quantities such as spawning stock biomass, growth, and maturity, and to derive measures of fishing intensity and stock status. Stock status is typically assessed with respect to two reference points: (1) the Limit Reference Point (LRP), a "status below which serious harm is occurring to the stock"; and (2) the Upper Stock Reference Point (USR), which represents the "threshold below which removals must be progressively reduced in order to avoid reaching the

LRP” (DFO 2009). While stock assessments represent the gold-standard of estimated trends in population status, assessments are time and labour intensive and therefore frequently lag high quality datasets such as indices of abundance from scientific surveys, which often closely reflect population trends from assessments. Geostatistical spatiotemporal models allow spatially adjacent areas surveyed in various years to be combined into single annual indices that can help track changes in surveyed abundance between assessments.

Here, we explored population trends for groundfish stocks using two methods: (1) we updated a hierarchical Bayesian state-space time-series model (Anderson et al. 2021) to explore trends until the year 2025, and (2) we developed model-based indices from relevant surveys for all assessed stocks, as well as stocks with outstanding requests for Science Advice.

We gathered Bayesian posterior distributions of estimated biomass from assessments for 30 stocks, including four updated assessments (coastwide Dover Sole, coastwide Yellowtail Rockfish, outside Yelloweye Rockfish, outside Lingcod). From these distributions, we modelled overall (i.e., all stocks combined) mean log stock status as a latent random walk with individual stocks assumed to have an auto-regressive observation model with their ‘true’ status drawn from their stock-assessed posterior distribution (see Anderson et al. 2021).

For these 30 stocks, as well as stocks with outstanding requests for Science Advice, and stocks with assessments that lacked the necessary posterior distributions for inclusion in the above model (40 total stocks), we combined regional surveys that used the same gear and protocols. We then fit spatiotemporal models to survey abundance or biomass density with the R package sdmTMB to derive standardized biomass and abundance indices (Anderson et al. 2025) and scaled the indices to the existing stock assessment population trends based on overlapping years. Data and code to reproduce our analysis are available at <https://github.com/pbs-assess/gftrends>.

27.3. Status and trends

Across all stocks, there was a decline in average stock status until approximately 2000 (Figure 27-1). The late 1990s and early 2000s marked the beginning of a relatively stable average status. We estimated the overall mean B/LRP (biomass divided by the LRP) in 2025 to be 4.1 (95% CI: 3.4–4.8). The overall mean B/USR and B/B_{MSY} (biomass divided by biomass at maximum sustainable yield) in 2025 were 2.0 (95% CI: 1.7–2.4) and 1.9 (95% CI: 1.6–2.3), respectively (Figure 27-1, 27-2). Despite the overall pattern in the average biological status, there was considerable variation within and across individual stocks, especially when recent survey trends are considered (Figure 27-3).

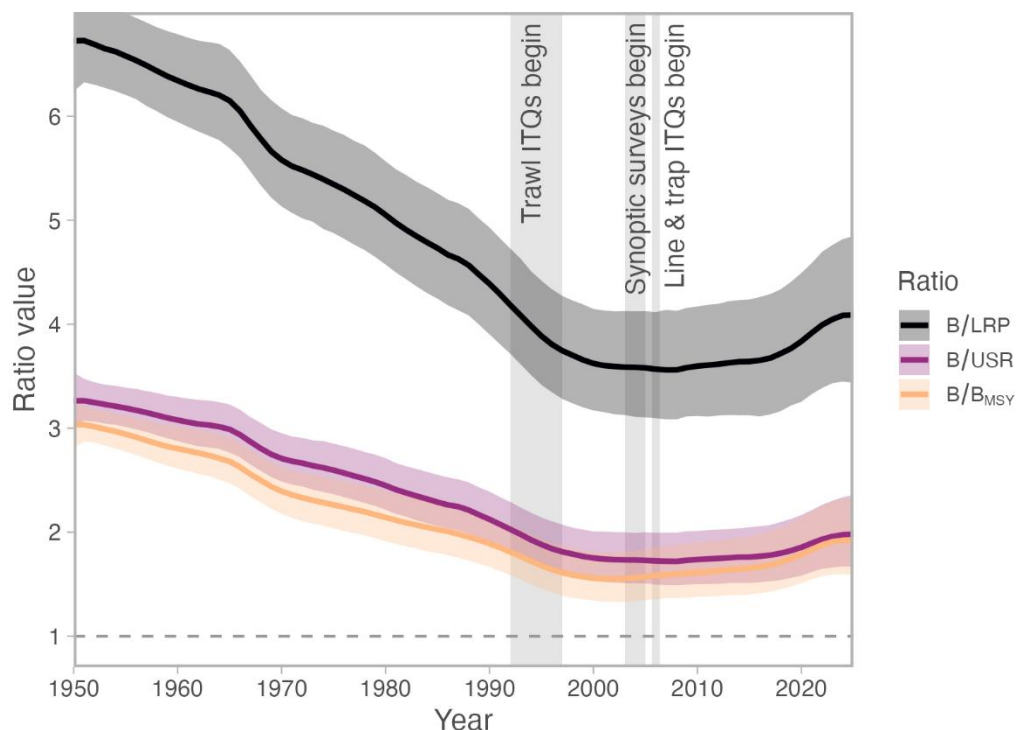


Figure 27-1. Overall mean biomass status across all stocks for B/LRP , B/USR , and B/B_{MSY} (see text for definitions) from the hierarchical time-series model. Dark lines represent the posterior median and shaded ribbons represent 95% quantile credible intervals. ITQ = individual transferable quota.

Estimated biomass was above the LRP and USR for most stocks as of the most recent assessment (Figure 27-2). Of the stocks with full posterior distributions available, inside (4B) Lingcod, inside Quillback Rockfish, Pacific Cod 3CD, and outside Pacific Spiny Dogfish were the only stocks with 5% or greater posterior density below their LRP (Figure 27-2). Coastwide Bocaccio had 5% posterior density below its LRP in 2020 (DFO 2020a) but effectively 0% by 2021 after a large recruitment cohort in 2016 (DFO 2022a). Meanwhile, 8/30 of the stocks in Figure 27-2 had $\geq 25\%$ probability of being below their USR.

When we used survey indices to explore more recent changes across species, additional patterns emerged. Survey indices for most assessed shelf rockfish (Bocaccio, Canary, Redstripe, Silvergray, Widow), and some slope rockfish (e.g., Yellowmouth and Shortspine Thornyhead) increased in the past ~ 10 years (Figure 27-3). The survey indices also allowed us to explore surveyed population trends of species that have not yet received full assessments, such as many flatfish and Chondrichthyans. Most of the included flatfish (soles: Petrale, English, Rex, Dover) appeared to increase in survey biomass over the last ~ 10 years. However, the trawl survey index and stock assessment indicate that Arrowtooth Flounder have declined over the same time span with some increase in the survey index in 2025 (Figure 27-3). Big Skate and Longnose Skate have increased in inside waters while Big Skate in outside waters has declined in recent years (Figure 27-3). Pacific Spiny Dogfish stocks experienced the steepest declines of all stocks (Figure 27-3), with a particularly steep decline in outside Vancouver Island waters.

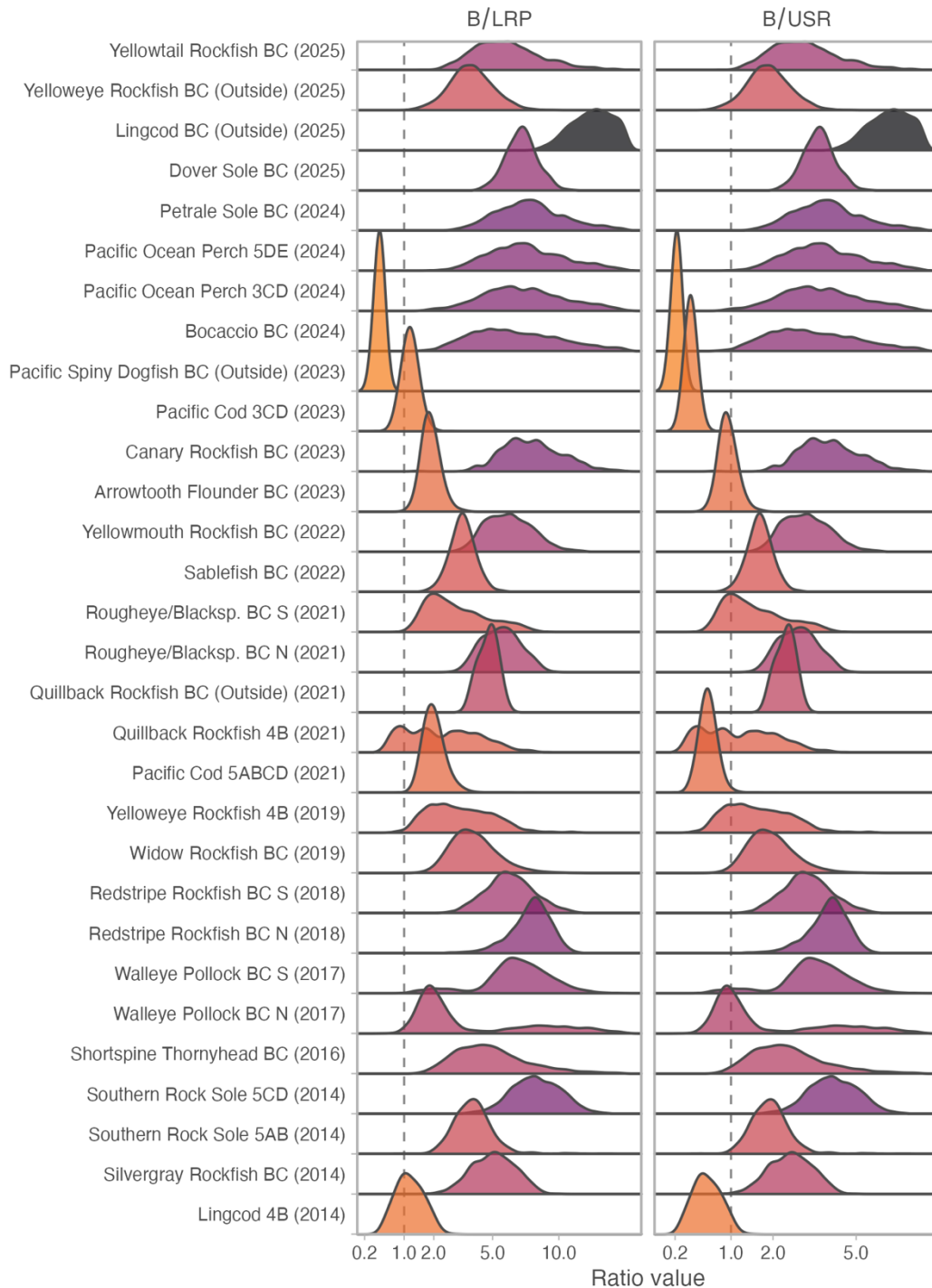


Figure 27-2. Posterior distribution of the two measures of stock status for 30 assessed stocks (Edwards et al. 2011, 2013; Edwards et al. 2014; DFO 2015, 2019, 2020b, 2020c, 2020d, 2022b; Holt et al. 2016a, 2016b; Starr et al. 2016; Starr and Haigh 2017, 2021a; DFO 2021; Starr and Haigh 2021b; Starr and Haigh 2023; DFO 2023a; DFO 2023b; DFO 2023c; DFO 2024a, 2024b; DFO 2025a, 2025b, 2025c; DFO 2026; Huynh et al. 2024; Mazur et al. 2025; Anderson et al. 2026; Doherty et al. 2026; Fisch et al. 2026). Stocks are arranged in order of assessment with the most recent assessments at the top; years in the first column indicate the year the status represents. Colours represent the mean B/LRP value such that black is highest and orange is lowest. Vertical dashed lines are at values of 1.0 in all columns. The x-axis has been square root transformed to compress high ratio values for visualization.

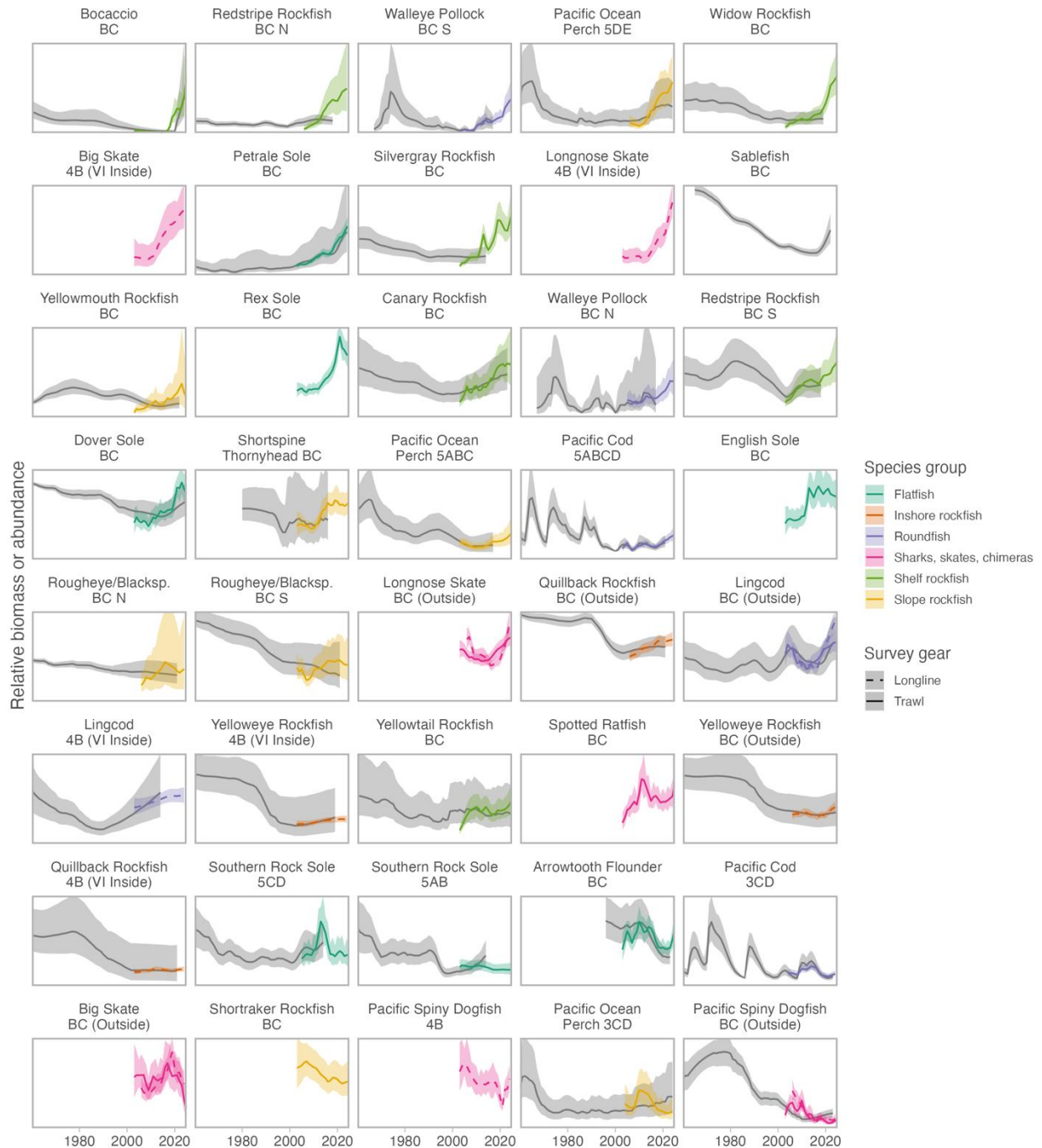


Figure 27-3. Trends for 40 B.C. groundfish stocks with assessments in the last ~20 years or outstanding requests for Science Advice. Dark grey lines and ribbons represent output from stock assessments: trajectories of median B/LRP and 95% quantile credible intervals (see citations in Figure 27-2 caption). Coloured lines and ribbons represent model-based indices for the most relevant survey(s) for each stock. Survey trends are scaled to existing assessments based on the geometric mean in overlapping years to account for survey catchability. Sablefish are indexed through a trap survey, which is not modelled here; however, the assessed biomass extends to 2023.

27.4. Factors influencing trends

The long-term overall groundfish trend is likely to have been primarily influenced by fishery removals and management interventions. The transition from declining average B/LRP and

B/USR to a relatively stable trajectory coincided with the implementation of individual transferable quotas (ITQs) for the trawl fleet, the introduction of 100% at-sea observer coverage over the period 1992–1997 (Turris 2000), and the initiation of the current synoptic trawl surveys in 2003. Furthermore, ITQs and electronic at-sea monitoring were introduced into the longline and trap fisheries in 2006 (Stanley et al. 2015). More recently, however, monitoring requirements for groundfish trawl vessels have changed. Since April 2020, no at-sea observers have been deployed on groundfish trawl vessels. Instead, groundfish trawl vessels require an Electronic Monitoring (EM) system to meet the 100% at-sea monitoring requirement (Fisheries and Oceans Canada 2025).

Other patterns may be driven by species interactions and/or climatic effects. For example, Pacific Spiny Dogfish are not currently targeted commercially and used to be caught in higher numbers—the reason for their survey declines is not clear and is currently a subject of research (Davidson et al. 2025). Possibilities include legacy effects of fishing, increases in predation, and climate-driven redistribution (Davidson et al. 2025; Anderson et al. 2026). For several species, there is evidence that temperature velocity—the pace a fish would have to move to maintain consistent temperature—may be related to a fine-scale redistribution of population density in Canadian Pacific waters (English et al. 2022). Recent oceanographic conditions are hypothesized to have negatively affected spawning habitat and resulted in years of low recruitment in some groundfish (e.g., Pacific Cod in nearby Alaskan waters, Laurel and Rogers 2020). On the other hand, after decades of consistently low recruitment, recent increases in several shelf rockfish species due to high recruitment around 2016—most notably Bocaccio—may in part be driven by transient availability of oxygen-rich water at depth during gestation (Schroeder et al. 2019; DFO 2022a).

27.5. Implications of those trends

The Sustainable Fisheries Framework and the Fish Stocks provisions of the Fisheries Act require that “major stocks” be maintained above their LRP with high probability ($\geq 75\%$ if subject to the Fish Stocks provisions). Two stocks had $>25\%$ probability of being below their LRP as of their last assessment and none are currently a major stock under the Fish Stocks provisions. Eight of 30 assessed stocks had $>25\%$ probability of being in the cautious zone where removals should be progressively reduced to avoid reaching the LRP. Rebuilding plans for stocks in the critical zone and precautionary management for those in the cautious zone are intended to support stock recovery. These efforts may be more effective when combined with favourable environmental conditions.

27.6. Acknowledgements

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28. PACIFIC HAKE INSIDE AND OUT: TRENDS IN THE SALISH SEA POPULATION OF PACIFIC HAKE (*MERLUCCIIUS PRODUCTUS*) AND UPDATE ON THE COASTAL MIGRATING STOCK

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28.1. Highlights

- The inside Pacific Hake population continues to increase since 2010, with survey estimated biomass for age-2+ of 38,363 metric tons for 2025 in the Strait of Georgia core strata.
- For the migrating Pacific Hake stock, 2025 was the lowest estimated biomass of the survey time-series, with an estimated 0.65 million tons. Under 1% of the total estimated survey biomass was encountered in Canadian waters, the lowest of the survey time series.

28.2. Description of the time series

In B.C. there are two distinct populations of Pacific Hake (*Merluccius productus*): 1. local stocks (also referred as “inside hake”) are found in the Strait of Georgia (SOG) as well as the inlets and sounds along the coast and 2. a migrating stock (also referred to as “outer-coast hake”) ranging from southern California to northern B.C. (25-55° N). The populations of Pacific Hake found in the Salish Sea and inside waters are genetically distinct from the migrating stock (Iwamoto et al. 2004; King et al. 2012; Longo et al. 2024).

The SOG is an important spawning, nursery and rearing ground for many fish taxa, among which Pacific Hake and Walleye Pollock (*Theragra chalcogramma*) are the two most abundant demersal species. Usually, hake adults migrate into the central-southern SOG in preparation for spawning in early winter, and then aggregate in the deep basins (> 200m) to spawn around late February to May (McFarlane and Beamish 1985). Acoustic-trawl surveys have been conducted sporadically since the 1970s and annual surveys began again in February-March of 2023 and 2024. Over the past thirty years, the operating acoustic system has transitioned from BioSonics to dual-frequency EK500 in 1995, and then to multi-frequency EK60 in 2009 and EK80 since 2020. The survey design includes a series of parallel transects within the core area (with ~5 nmi spacing, >50 m depth), and zig-zags transects in the narrower straits, inlets, and sounds. Based on catch data and camera video, acoustic backscatter recorded along survey transects were classified and partitioned into species aggregations, integrated to acoustic density estimates, and eventually converted to biomass estimates over survey area using established species-specific target strength (TS) to length models (Traynor 1996).

The outer coast migratory stock is thought to spawn mainly off the southern to central California coast during January to March (Saunders and McFarlane 1997). Adults migrate north in the spring and, by summer, can be detected in large aggregations from northern California to the northern end of B.C., with distributions sometimes exceeding these boundaries. Size and age generally increase with increasing latitude during the migratory season. The Pacific Hake fishery is one of the largest fisheries on the west coast of the U.S. and Canada. The joint U.S.

and Canadian integrated acoustic-trawl survey is the primary fishery-independent source of data used to assess the distribution, abundance and biology of the Pacific Hake population (see Edwards et al. 2026). The survey was completed on a triennial basis during 1995-2003, when the decision to switch to a biennial basis was made; there was an additional survey in 2012.

The acoustic survey typically starts in southern California in mid-June and progresses northward in a continuous and uninterrupted sequence, ending in northern Canada in early September. The survey design consist of E-W transects from the 50 m to the 1500 m isobaths, or beyond if echosign indicates fish extend over this limit. The transects are 10-30 nmi apart. Acoustic marks are targeted periodically (whenever acoustic backscatter significantly changes) with a midwater trawl to assess species composition and collect biological samples. Backscatter values assigned to Pacific Hake are interpolated between transects using kriging to obtain an overall estimate of abundance for the entire coast.

28.3. Status and trends

The hake biomass estimates in the SOG were at a similar level (> 65,000mt) between 1981 and 1988, while the biomass dropped from ~ 60,000 mt in 1996 by half (~30,000 mt) in 1998 (Figure 28-1). The anomalously high biomass estimate in 1993 was probably an overestimate due to inclusion of plankton backscattering (Keiser et al. 1999). Early biomass estimates of this time-series likely included some juvenile Pacific Hake (age-1), while those are accounted for separately since 2010 (similar to the acoustic survey estimates for the migrating stock). In the 2010s, hake biomass for age-2+ was at historical low level of approximately 7,178 mt in 2011, but rose up to over ~20,000 mt in 2014 and 2016, and to almost 30,000 mt in 2023. The estimated biomass of age-2+ in 2025 was at 38,363 mt (Figure 28-1).

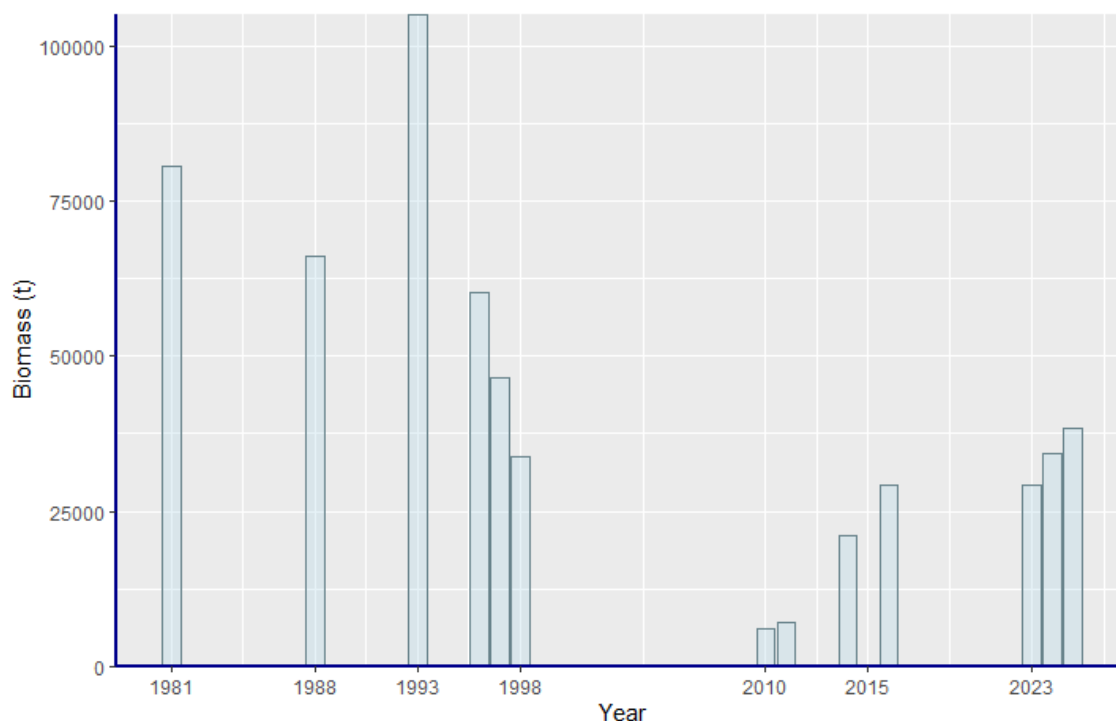


Figure 28-1. Biomass time-series for Strait of Georgia Pacific Hake age-2+.

Distinct north-south separation in spatial distribution of Pacific Hake and Walleye Pollock is observed in the SOG. More specifically, the biomass of Pacific Hake displayed largely consistent spatial distributions over the central-northern SOG, with higher biomass near the north tip of Texada Island for adults (Figure 28-2) while Walleye Pollock distribution was mainly constricted in central-southern SOG with the highest biomass south of the Fraser River (Figure 28-2). For juveniles (age-1 hake), aggregations were numerous and found throughout the north of the Strait, whereas in previous years were confined to some of the inlets (Figure 28-2).

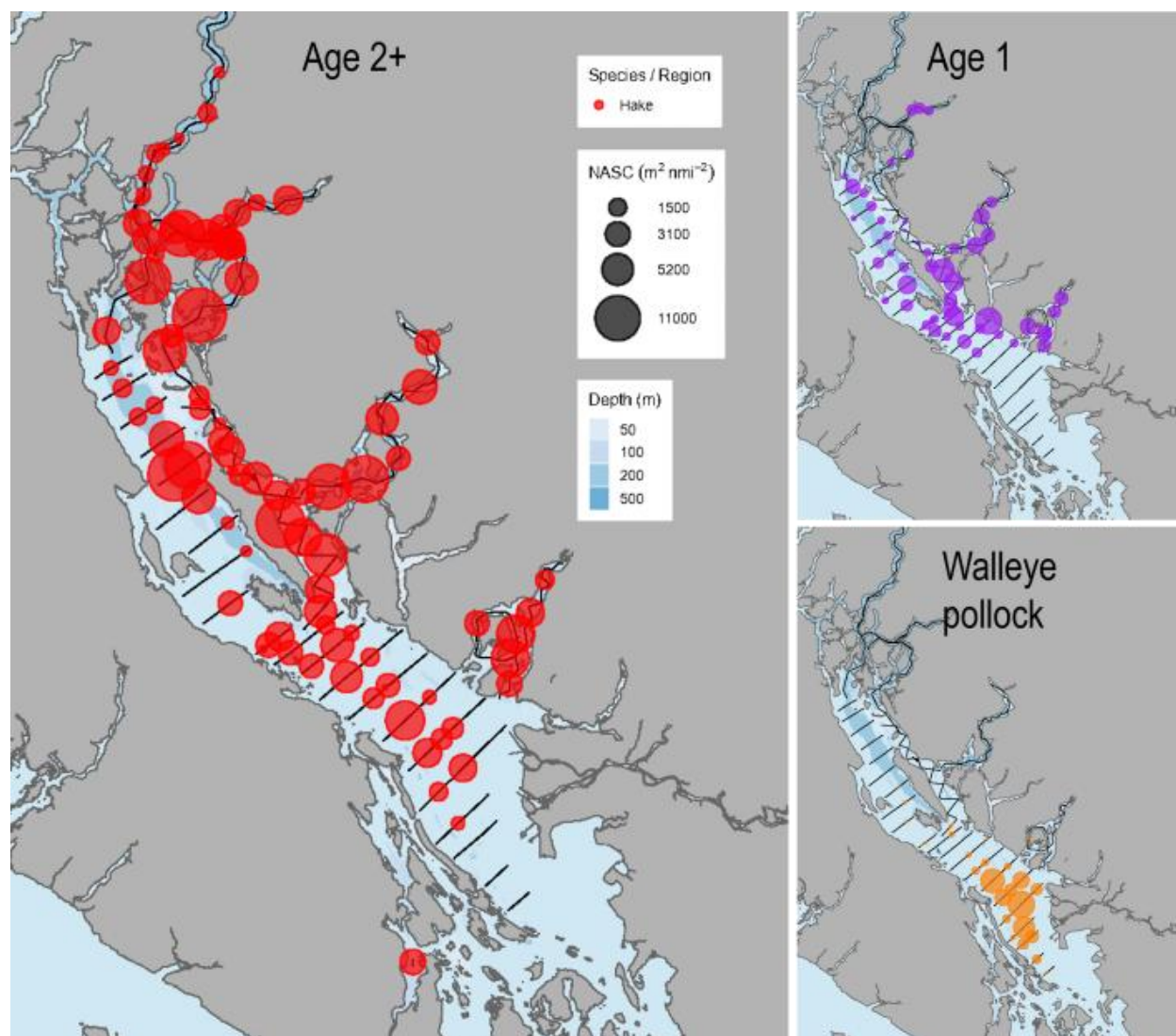


Figure 28-2. Distribution of acoustic density, expressed as Nautical Area Scattering Coefficients ($m^2 \text{ Nmi}^{-2}$) of age-2+ Pacific Hake (left panel), age-1 Pacific Hake (upper right panel) and Walleye Pollock (lower right panel) within the Strait of Georgia. Note that NASC values are proportional to the circle size and that scales differ for age-1 (maximum of $3000 m^2 \text{ nmi}^{-2}$).

For the migrating stock of Pacific Hake, distribution has been variable over the history of the joint US-Canada survey, with the widest distribution seen in 1998 with aggregations found throughout the Canadian coast and into Alaskan waters. In 2025, the distribution in Canadian waters was confined to the southern end of west coast of Vancouver Island, with less than 1%

of the estimated biomass of adult Pacific Hake (age-2+). This was the lowest proportion (and biomass) of the time series marking lows for three consecutive surveys (2021, 2023, and 2025).

28.4. Factors influencing trends

For the SOG stock, the drop in biomass in 1998 and the low estimates in 2011 were associated with warm ocean conditions. This time-series, however, contains many gaps and was only recently re-instated, and continued observations will be necessary to study the local stock dynamics and to explore their links to local oceanographic conditions.

For the migrating stock, it has been observed that during warm ocean conditions (such as the 1998 El Niño event) a larger proportion of the stock migrates into Canadian waters, apparently due to intensified northward transport (Agostini et al. 2006). This was also observed in 2015 (with the so-called warm “Blob”), although the distribution did not extend much beyond the northern tip of Vancouver Island. The proportion of Pacific Hake that migrated into Canadian waters in 2017 was over 27% and the largest observed since 2005, while in 2019 the proportion in Canadian waters was only 11%. In 2021 this proportion was less than 5%, in 2023 it was less than 3%, and in 2025 it was less than 1%, the lowest of the time series. Commercial catches in Canada for 2025 were low (3,913 t. merely 3.7% of the quota), which is, at least in part, due to the lack of larger and older fish in the population (since larger and older fish tend to migrate further north). The increasing trend of hypoxic events along the shelf break in B.C. and along the Washington and northern Oregon state may also affect the movement of fish during their northward migration.

28.5. Implications of those trends

The local population of Pacific Hake within the SOG increased; continued assessment of this stock will be necessary to investigate the potential effects of warming ocean conditions and other environmental factors. The lack of outer coast Pacific Hake migrating into Canadian waters continues to be a concern and a challenge for the Canadian fishing industry. Recent trends in distribution suggest that temperature alone may not be a good predictor of Pacific Hake northward migration extent, but that other mechanisms (such as the source and onset of warming conditions) have differential effects on poleward currents, distribution and availability of prey, or other factors influencing the distribution of these fish.

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29. SEABIRD OBSERVATIONS ON THE B.C. COAST IN 2025

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29.1. Highlights

- Relative to a 1994-2024 baseline, diets fed to nestling Cassin's Auklets on Triangle Island in the second half of June in 2025 included normal amounts of the copepod *Neocalanus cristatus*, their most important prey.
- Diets fed to nestling Rhinoceros Auklets in 2025 on Pine Island in southern Queen Charlotte Sound included less-than-normal amount of Pacific Sand Lance, their most important prey, relative to a 2006-2024 baseline. In contrast, diets on Lucy Island in Chatham Sound included normal amounts of Pacific Sand Lance.

29.2. Description of the time series

Annually since 1996, Environment and Climate Change Canada and Fisheries and Oceans Canada have monitored the diets fed to Cassin's Auklet (*Ptychoramphus aleuticus*) nestlings on Triangle Island as indicator of zooplankton prey availability and seabird productivity (Hipfner et al. 2020). Analyses in recent years include only data collected in late June in all years.

In addition, scientists have been annually quantifying predation by Rhinoceros Auklets (*Cerorhinca monocerata*) on fish, including salmon smolts, since 2006 as an indicator of seabird productivity and salmon mortality (Tucker et al. 2016). Nestling diets in 2025 were quantified at Pine, Lucy, and Triangle islands.

29.3. Status and Trends

Diets fed to Cassin's Auklet nestlings

In 2025, diets fed to nestling Cassin's Auklets in late June included normal amounts of the subarctic copepod *Neocalanus cristatus* relative to a 1996-2024 baseline (Figure 29-1). This indicates that the birds were experiencing favourable feeding conditions.

Diets fed to Rhinoceros Auklet nestlings

Diets fed to nestling Rhinoceros Auklets in 2025 on Pine Island in southern Queen Charlotte Sound included less-than-normal amount of Pacific Sand Lance (*Ammodytes hexapterus*), their most important prey, relative to a 2006-2024 baseline. This indicates that the birds were experiencing suboptimal feeding conditions at that site. In contrast, diets on Lucy Island in Chatham Sound included normal amounts of Pacific Sand Lance and Pacific Herring (*Clupea pallasii*) in 2025 (Figure 29-2). In general, there is increased year-to-year variation in the composition of diets at Lucy Island than at Pine Island.

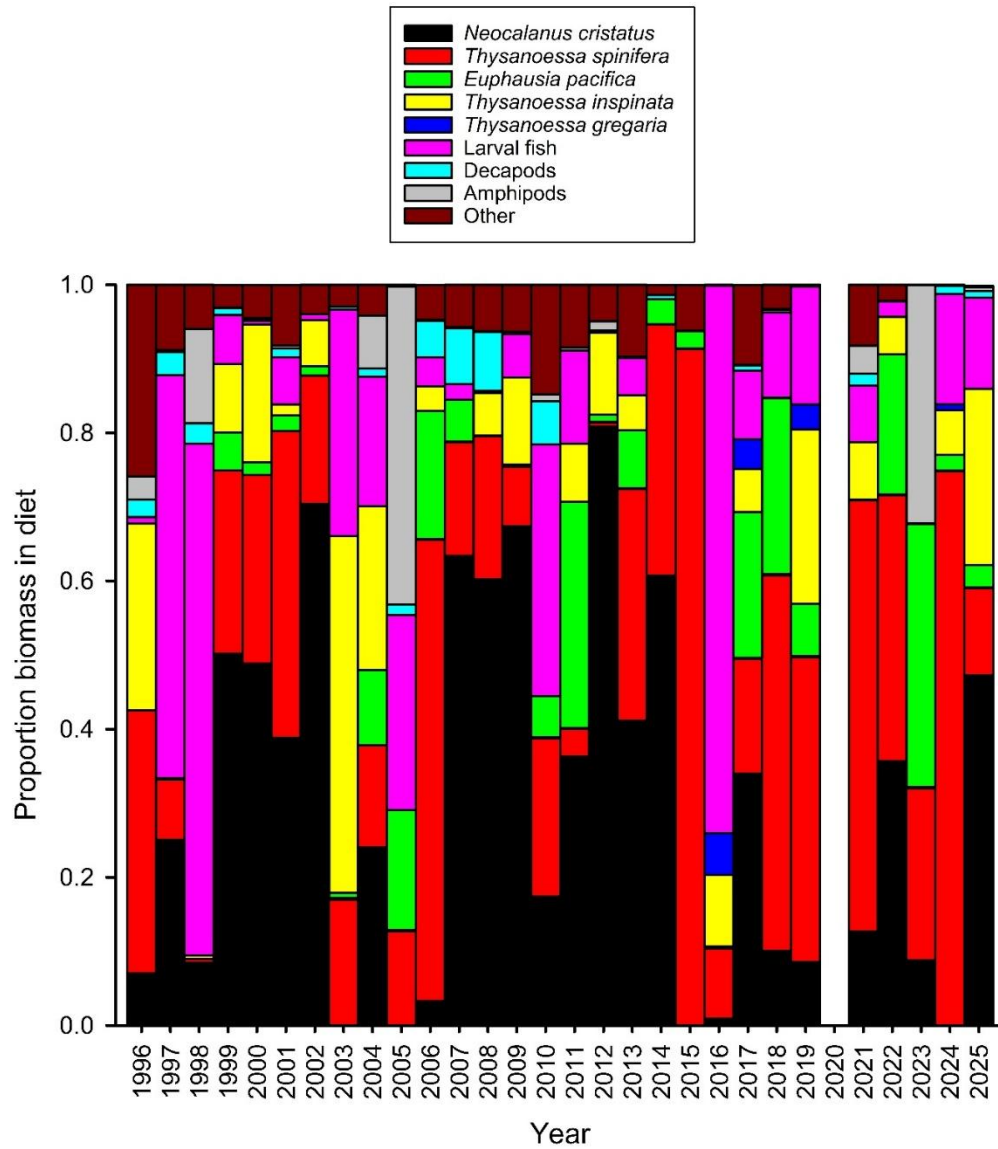


Figure 29-1. Composition of the diets fed to nestling Cassin's Auklets in the second half of June, 1996 to 2025.

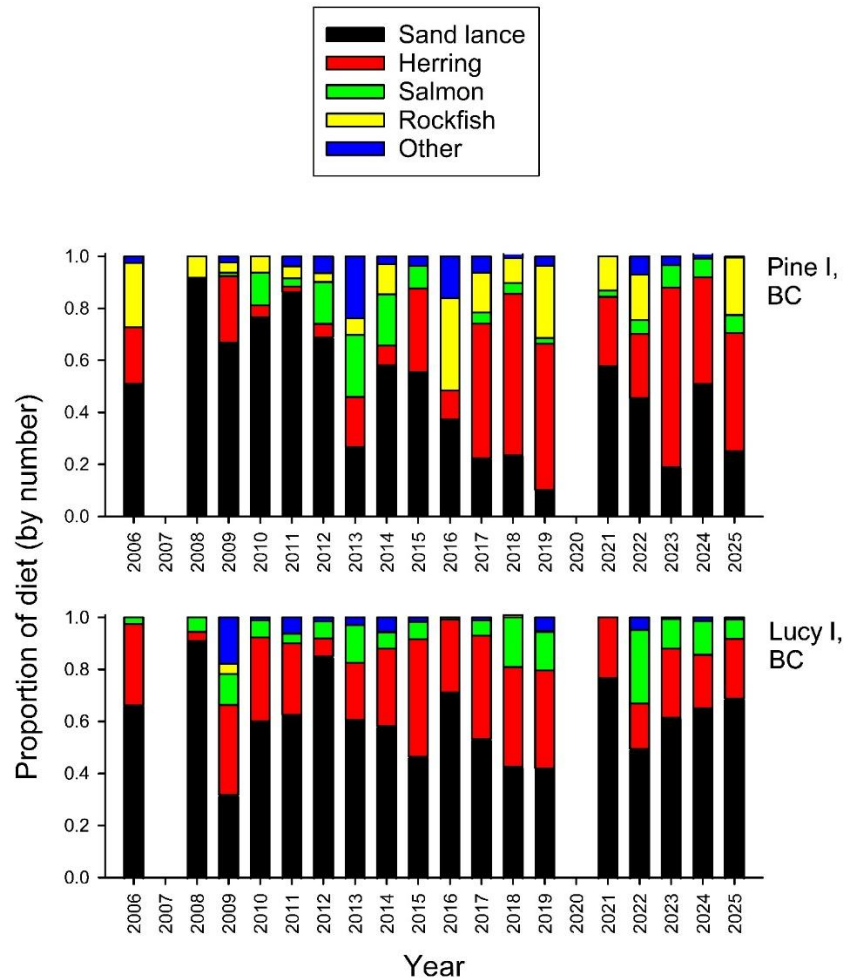


Figure 29-3. Species composition (by number) of the diets delivered to nestling Rhinoceros Auklets on 2 colonies in B.C. in 2006-2025.

29.4. Factors influencing trends

The zooplankton-based diets fed to nestling Cassin's Auklets on Triangle Island, the world's largest breeding colony, are affected very strongly by oceanographic conditions, which have a profound influence on seasonal patterns of prey availability. In general, nestling auklets grow more quickly on Triangle Island in cold-water years when the subarctic copepod *N. cristatus* is abundant in offshore waters and persists in their diets through the bulk of the provisioning period from mid-May to late June (Hipfner et al. 2020).

The fish-based diets fed to nestling Rhinoceros Auklets on colonies in B.C. are also affected by oceanographic conditions (Thayer et al. 2008). In general, nestling auklets grow more quickly in years in which their diets include more Pacific Sand Lance, a small forage fish (Borstad et al. 2011).

29.5. Implications of those trends

Lower proportions of the subarctic copepod *N. cristatus* in diets of Cassin's Auklet nestlings may result in lower growth rates. Low growth rates of nestlings will translate to low survival and lower population growth.

On their northerly seaward migration, the vast majority of Pink Salmon (*Oncorhynchus gorbuscha*), Chum Salmon (*O. keta*) and Sockeye Salmon (*O. nerka*) smolts from stocks in southern and central B.C. funnel past aggregations of hundreds of thousands of Rhinoceros Auklets breeding on colonies scattered along the Province's central and north coasts. The auklets are wing-propelled, pursuit-diving seabirds that forage mainly in the top 5-10 m of the water column and within ~90 km of their breeding colonies. The smolts' migration occurs in June and July, coinciding with the period when the auklets are delivering whole and intact fish, including salmon smolts, to their nestlings (Hipfner et al. 2025). These predators could potentially have an impact on salmon survival, although the birds tend to take small, poor condition smolts (Miller et al. 2013; Tucker et al. 2016).

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30. INTERANNUAL VARIATION IN MARINE BIRD COUNTS WITHIN THE HARO STRAIT REGION OF THE SALISH SEA: 2015-2025

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30.1. Highlights

- Mean annual summer densities of Rhinoceros Auklet in 2022-2025 were half the peak observed in 2019.
- Mean annual winter densities of Ancient Murrelet were high in 2025 (relative to 2015-2025), for the third year in a row.
- In fall 2018 Common Murre numbers peaked and in winter 2018 Marbled Murrelet numbers peaked, relative to the time series (2016-2025, 2015-2025, respectively).

30.2. Description of time series

The areas around Sidney and Victoria, B.C. have long been recognized as key marine bird habitats with Migratory Bird Sanctuaries, Important Birds Areas, Parks, and Ecological Reserve designations. On February 22, 2019, the National Energy Board (now the Canada Energy Regulator) submitted its Reconsideration Report to approve the Trans Mountain Expansion (TMX) project, to twin the pipeline to carry Bitumen from Edmonton, Alberta, to Burnaby, B.C. Tanker vessel traffic was expected to rise by 7 fold. To mitigate shipping related impacts on birds, Environment and Climate Change Canada adopted Recommendation 3 to “Implement a marine bird monitoring and protection program to improve the understanding of the impacts to marine birds from ships in the Salish Sea”.

In 2015, in anticipation of the pipeline developments, we initiated a marine bird at-sea monitoring program with cruises between Sidney to Victoria, B.C. We chartered a vessel (FV Misty Lady) and conducted 200 m strip transect surveys with a trained bird observer on the starboard side of the vessel. The route had an ‘inside’ track heading south and an ‘outside’ track on the return leg for a total of 85 km, which took about 7 hours to complete (Figure 30-1). We recorded all bird species, plus time and location at 10 minute intervals. From 2015-2025 we conducted semi-monthly or monthly, year-round surveys, to form the basis of our time series.

Here we report inter-annual patterns in density for four alcid species, which are seasonal visitors or found year-round, in our study area. Rhinoceros Auklet (*Cerorhinca monocerata*) breed nearby on Protection Island, WA, and are predictable visitors during summer breeding, feeding on forage fish. Ancient Murrelet (*Synthliboramphus antiquus*, *Special Concern*) predictably visit the Salish Sea in winter during the non-breeding season, and consume primarily euphausiids, but also juvenile Pacific Herring (*Clupea pallasii*, Gaston et al. 1993). Post-breeding Common

Murre (*Uria aalge*) visit our study region in fall, likely from Oregon and Washington (Bertram et al. 2023). Adult males feed fish to their single fledgling on the water, as shown in the photo inserts. *Threatened* Marbled Murrelet (*Brachyramphus marmoratus*) are found year-round in our study region, with some of the highest numbers observed in winter.

For each year, we averaged densities of Rhinoceros Auklets from May, June, July, and August to produce annual summer estimates. For Ancient Murrelet and Marbled Murrelet we averaged densities from November, December, January, and February to produce annual winter estimates. For Common Murre we averaged densities in September and October for fall estimates. Restrictions on field work due to Covid 19 resulted in few monthly surveys in 2020 and 2021.

30.3. Status and Trends

For the Rhinoceros Auklet, the largest densities were observed in 2019 with over 100 birds/km² (Figure 30-3). The last three years, including 2024, have had similar low densities of around 25 birds/km². For the Ancient Murrelet, the highest densities (38 birds/km²) were observed in 2023, with 2024 and 2025 close behind (30 birds/km²; Figure 30-3). Marbled Murrelets typically do not form large groups like the other auks, but also peaked in 2018 (2.5 birds/ km²). Common Murre densities peaked in 2018 (85 birds/km²).

30.4. Factors Influencing Trends

Seabird population status is measured on breeding colonies, and we expect that the interannual variation in bird densities shown here reflects local interannual variation in prey availability. The Haro Strait region contains Pacific Sand Lance (*Ammodytes personatus*) subtidal habitat and is considered to be a climate refugium during the summer (Robinson et al. 2024). The predictable presence of Rhinoceros Auklets during summer is likely linked to the availability of Pacific Sand Lance, and accounts for the consistent predominance of Pacific Sand Lance in the nestling diets of the large auklet population on nearby Protection Island (Wagner et al. 2024). For Common Murre in fall, and Marbled Murrelet in winter, 2018 was the dominant year, but the reason is unknown. Year-round density patterns of Marbled Murrelet indicate that they were not moving to moult and that they over winter in Puget Sound (Pearson et al. 2022). Our results show an increase of birds in our study area in the fall and winter (Figure 30-2), some of which could be from Washington. In winter, Ancient Murrelet numbers have been relatively high for the last three winters. Canada has a major stewardship responsibility for the species because 50% of the global population breed exclusively in Haida Gwaii. After breeding in B.C., the birds move to the Bering Strait to moult, then 2/3 go to the Sea of Japan/East Sea and 1/3 go to northern/central California Current Ecosystem and Salish Sea, which comprise the birds observed in our study area (Gaston et al. 2017). Ongoing gillnet bycatch mortality in winter in the Sea of Japan/East Sea is a major conservation concern for Ancient Murrelet, coupled with recent rat predation on a large colony in Gwaii Haanas, Ramsay Island.

In 2024 and 2025, in collaboration with DFO, and University of Victoria, we conducted monthly acoustic sampling of prey fields at marine bird hot spots in along our route (Sidney Channel and Discovery Island) to quantify seasonal patterns in forage fish and zooplankton prey. Replicated acoustic datasets of prey could help to explain the observed seasonal, and interannual variation in marine bird densities in Haro Strait.

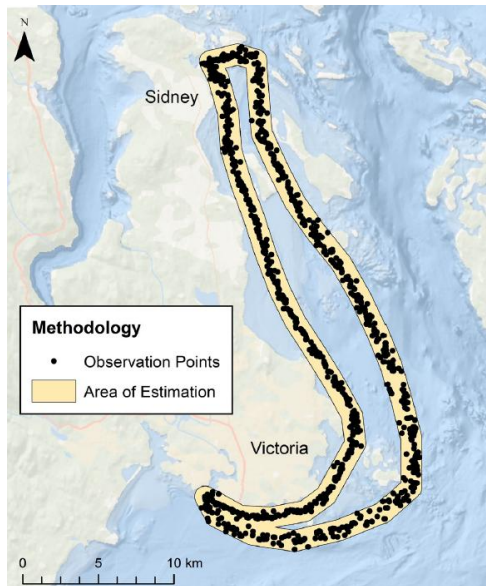


Figure 30-1. Marine survey route between Sidney and Victoria B.C., showing the general area of estimation of bird numbers and density (from Bertram et al. 2023).

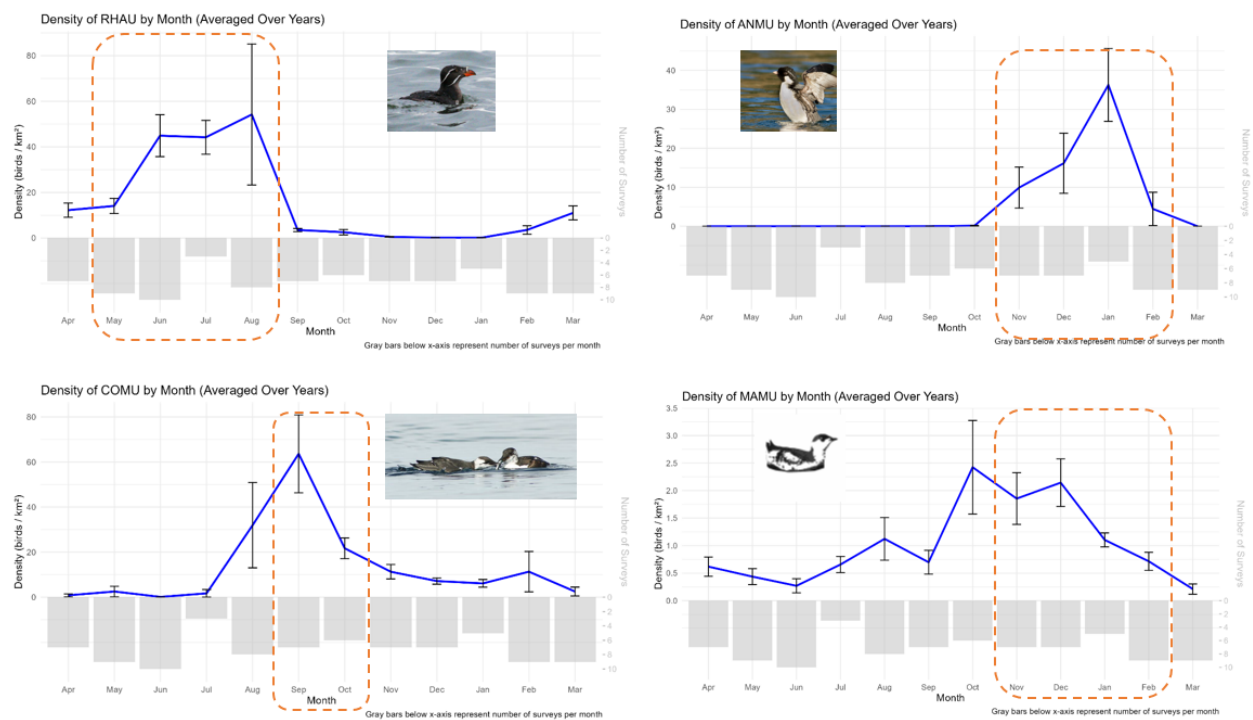


Figure 30-2. Seasonal densities (birds/km²) of Rhinoceros Auklet (RHAU), Ancient Murrelet (ANMU), Common Murre (COMU), and Marbled Murrelet (MAMU) using averaged monthly values from 2015-2025. The red boxes show the periods selected to represent summer for RHAU, fall for COMU, and winter for ANMU and MAMU.

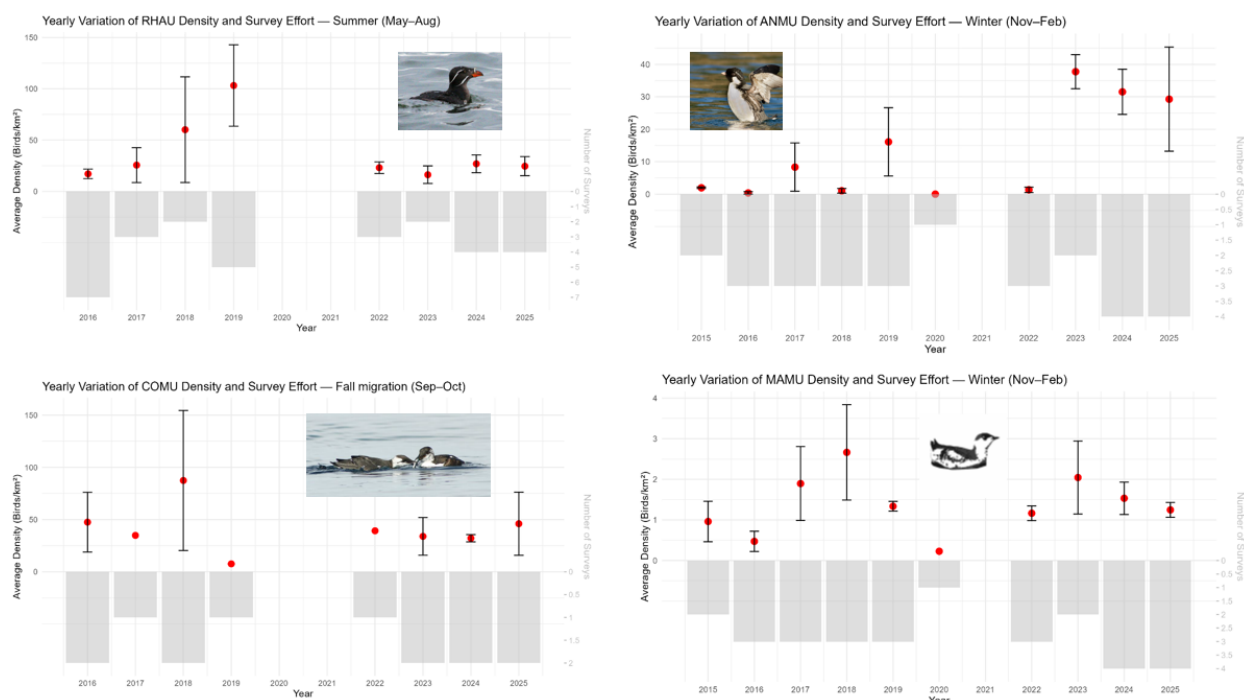


Figure 30-3. Inter-annual variation in average density (birds/km²) in summer for Rhinoceros Auklet (RHAU), Common Murre (COMU) in fall, and Ancient Murrelet (ANMU) and Marbled Murrelet (MAMU) in winter. The numbers of monthly surveys used to derive the annual estimates are shown in the grey bars below.

30.5. Acknowledgements

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31. TRENDS IN GROWTH AND ABUNDANCE OF B.C.'S SEA OTTER POPULATION

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31.1. Highlights

- As of 2023, the B.C. Sea Otter population is estimated at 12,058 (95%CI 11,048-13,717) individuals.
- The population, established from a small number of animals (of the same subspecies) translocated from Alaska (1969-1972), continues to recover into historically occupied habitat along the B.C. coast.
- Where Sea Otters have become established, the structure of nearshore communities (rocky reef, kelp forest, soft sediment, and eelgrass) has changed.

31.2. Description of the timeseries

Prior to the maritime fur trade that began in the late 18th Century in B.C., Sea Otters were distributed in nearshore coastal habitats along the Pacific Rim. Sea Otters ranged from Baja California, Mexico, north along the coast of continental North America, along the Aleutian Islands and Bering Islands and across to northern Japan. Intensive trade of European goods for Sea Otter pelts from Indigenous peoples resulted in rapid depletion of the Sea Otter population. In B.C., the intense trade was over by the 1850s, about 75 years after it began. Sea Otters, reduced to a mere fraction of their pre-fur trade population size, were likely ecologically extinct before the 1850s. By 1911, it is estimated that across its entire historic range in the north Pacific, the Sea Otter had been reduced to less than 1% of its pre-fur trade population size. In B.C., the last occurrence of a single Sea Otter dates from 1929, after which the species was considered extirpated from Canada. A small number of Sea Otters (89) were translocated to B.C. from parts of Alaska in three translocation events in 1969, 1970 and 1972. Today's Sea Otters are descended from those translocated animals.

Following their reintroduction, the first Sea Otter population survey in B.C. occurred in 1977. Since 1988 a standardized boat-based survey method has been used to obtain population counts, and this method has continued to present. As of 2022, 26 survey segments comprise the occupied range of the species in B.C.

31.3. Status and Trends

As of 2023, the Sea Otter population is estimated at 12,058 (95%CI 11,048-13,717) (DFO 2026). Average annual growth from 2018-2023 was estimated at 4.6% per year. Growth rates, however, vary amongst the sub-regions (groupings of adjacent survey segments) that comprise the occupied range (Figure 31-1). In general, the longest occupied areas have the lowest growth rates and more recently occupied areas have higher growth rates.

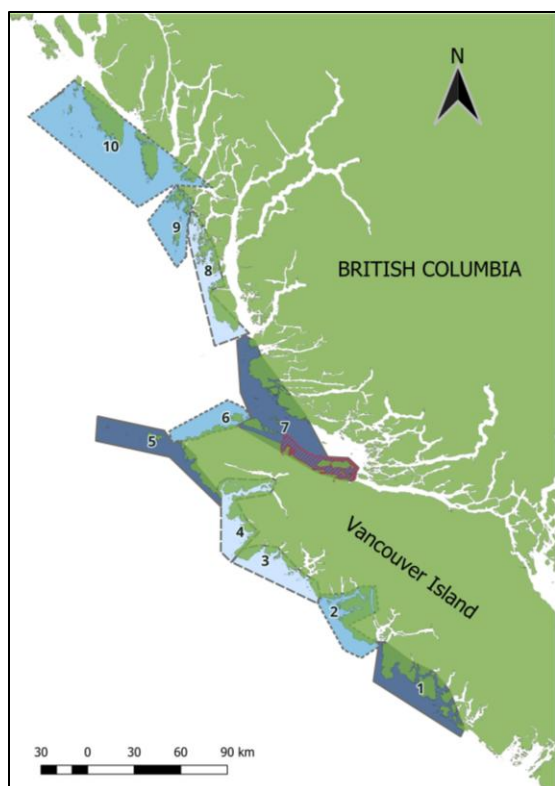


Figure 31-1. Ten sub-regions encompassing the surveyed, occupied range of Sea Otters in B.C. by 2024. Range expansion in 2022 indicated by red hatched polygon. Sub-region formatting denotes average annual growth rates (2018-2023): low (< 3.5% per year; pale blue, long dash outline), medium (3.5 to < 7.0% per year, blue, short dash outline), and high ($\geq 7.0\%$ per year, dark blue, solid line). (DFO 2026). Sea Otter reintroductions in 1969, 1970 and 1972 were all made into sub-region 3.

31.4. Factors influencing trends

Following reintroduction, B.C.'s Sea Otter population grew rapidly as they recovered into habitats that had been unoccupied for a century, because in these places invertebrate populations had increased dramatically in the absence of their natural predator, the Sea Otter. Over time, Sea Otter population growth slowed in long occupied areas, as a result of density-dependent processes that operate largely through mortality of juveniles as a result of prey availability. Sea Otters are non-migratory and occupy small lifetime home ranges. Over time as Sea Otter abundance increases in an area, otters spend more time foraging and exhibit individual dietary specializations – important strategies that reduce competition with other Sea Otters and allow more individuals to meet their daily caloric needs. Still, juvenile mortality is higher where Sea Otters have been long-established because of prey limitations. Meanwhile population growth, as a result of initial immigration and high juvenile survival rates in adjacent unoccupied habitats, is higher where prey availability is not yet limiting. These physiological and behavioural constraints explain the pattern of growth observed in Sea Otter recovery throughout their range.

31.5. Implications of those trends

Despite their relatively small size for a marine mammal, Sea Otters exert profound effects on nearshore ecosystems, as a result of their foraging behaviour. Sea Otters consume the

equivalent of about 25% of their body weight daily in invertebrate prey, to fuel their high metabolic rate that is needed to survive in the cold waters of the north Pacific.

The ecosystem effects of Sea Otter predation on urchins has been well described. By preying on dense population of urchins that arise in the absence of Sea Otters, rocky reef communities transition from urchin barrens to complex kelp forest communities. This occurs as kelps are released from the intense herbivory by urchins when urchin numbers are reduced (Estes and Palmisano 1974).

In B.C. along the west coast of Vancouver Island where Sea Otters are present, kelp beds are significantly bigger, and fish abundance and food web complexity is higher in these kelp forests, than in areas where Sea Otters are absent (Markel and Shurin 2015). Kelp beds represent a complex mosaic and are comprised of canopy forming and understory algal species many of which are long lived perennials. Though the growth of kelp forests in the presence of Sea Otters is well established, it is also evident along Vancouver Island, that kelp beds vary in species composition as a result of differences in kelp recruitment patterns, species succession, the age of plants in the kelp forest; these effects are driven by the timing of Sea Otter colonization and foraging (Waston and Estes 2011).

Foraging Sea Otters also contribute to the structure of soft sediment habitats. Clams are a key part of the diet of Sea Otters, and otter predation changes the abundance and species composition of clams (Kvitek and Oliver 1992). Where Sea Otters excavate clams from sediment supporting eelgrass meadows, their disturbance of the eelgrass rhizomes provides conditions that favour eelgrass reproduction by flowering and seed production over vegetative reproduction, which increases genetic diversity of eelgrass meadows (Foster et al. 2021).

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32. CENORTH PROJECT: SEASONAL ABUNDANCE, DENSITY AND DISTRIBUTION OF CETACEANS FROM SYSTEMATIC SURVEYS IN B.C.'S NORTH COAST

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32.1. Highlights

- Systematic surveys conducted from 2023–2025 have provided season-specific and geographically-resolved abundance and density estimates for Humpback Whales, Harbour Porpoises, and Dall's Porpoises in the north coast of B.C.
- All three species were present in the area year-round; abundance and density estimates for all three species varied seasonally and between geographic strata. Humpback Whales were most abundant in the fall while Harbour and Dall's Porpoise were most abundant in the spring-summer.

32.2. Description of the time series

Year-round, systematic survey coverage is required to address longstanding data gaps and assess seasonal trends in cetacean abundance and distribution off the coast of northern B.C. These data gaps impede cetacean abundance and density estimation and resulting assessments of anthropogenic threats and mitigation. A series of vessel-based line-transect surveys were conducted from 2023 to 2025 to address these data gaps in areas of high or increasing marine traffic surrounding the Port of Prince Rupert.

The CeNorth study area (Figure 32-1) was stratified geographically into four regions: North Hecate Strait (offshore), South Hecate Strait (offshore), Chatham Sound and Principe Channel (inshore), and major Inlets (Grenville Channel, Ogden and Petrel Channels and Port of Prince Rupert). Nine surveys were completed over the three years, with each survey occurring in a separate month in order to maximize temporal coverage across seasons. For further details on methods, refer to Mossman et al. (*in prep.*). Distance sampling protocols were used to collect sighting and environmental condition data and produce effort-corrected abundance and density estimates (Buckland et al. 2001). Due to differing survey design and lack of sufficient sightings, data collected within the Inlets strata were used to inform detection function models but were excluded from abundance estimation. Surveys were conducted in all months of the year with the exception of January, March and August. The Spring-Summer season included April to July, while Fall was defined as September to December. No abundance or density estimates could be generated for South Hecate Strait during Fall due to lack of survey coverage caused by inclement weather conditions.

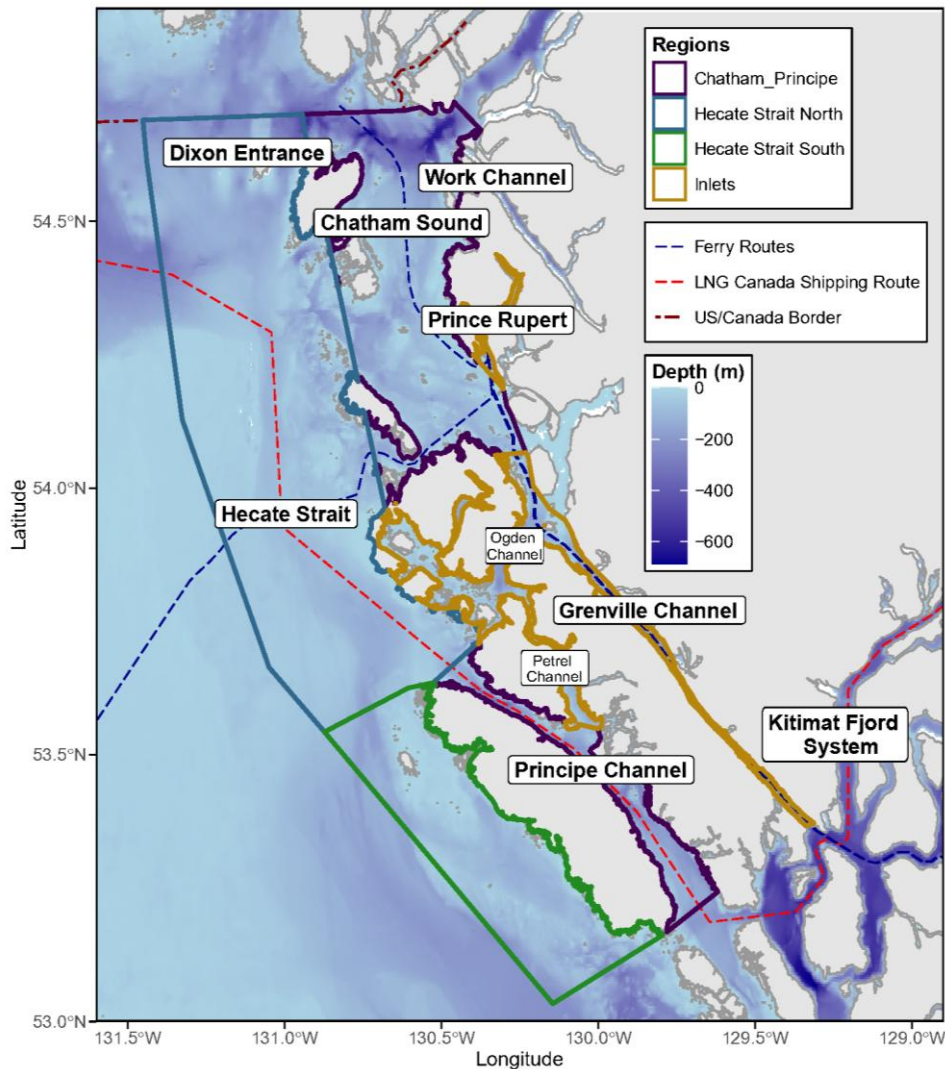


Figure 32-1. Stratification of the survey area, showing the offshore strata including North Hecate Strait (blue) and South Hecate Strait (green), the inshore strata including Chatham Sound and Principe Channel (purple) and the Inlets strata (yellow). The LNG Canada shipping route is indicated in the red dashed line, B.C. ferry routes in the blue dashed line and the US / Canada border by the burgundy dashed line.

32.3. Status and trends

A total of nine vessel-based line transect surveys were conducted from 2023 to 2025. A total 8964 km of visual effort was completed, resulting in 823 sightings of a total of 1869 individuals of eight cetacean species. Sufficient sighting data were collected to estimate season-specific abundance and density estimates for Humpback Whales, Harbour Porpoises, and Dall's Porpoises within three geographic strata excluding South Hecate Strait in Fall (Figure 32-2). Abundance estimates varied by season and geographic strata area (Table 32-1).

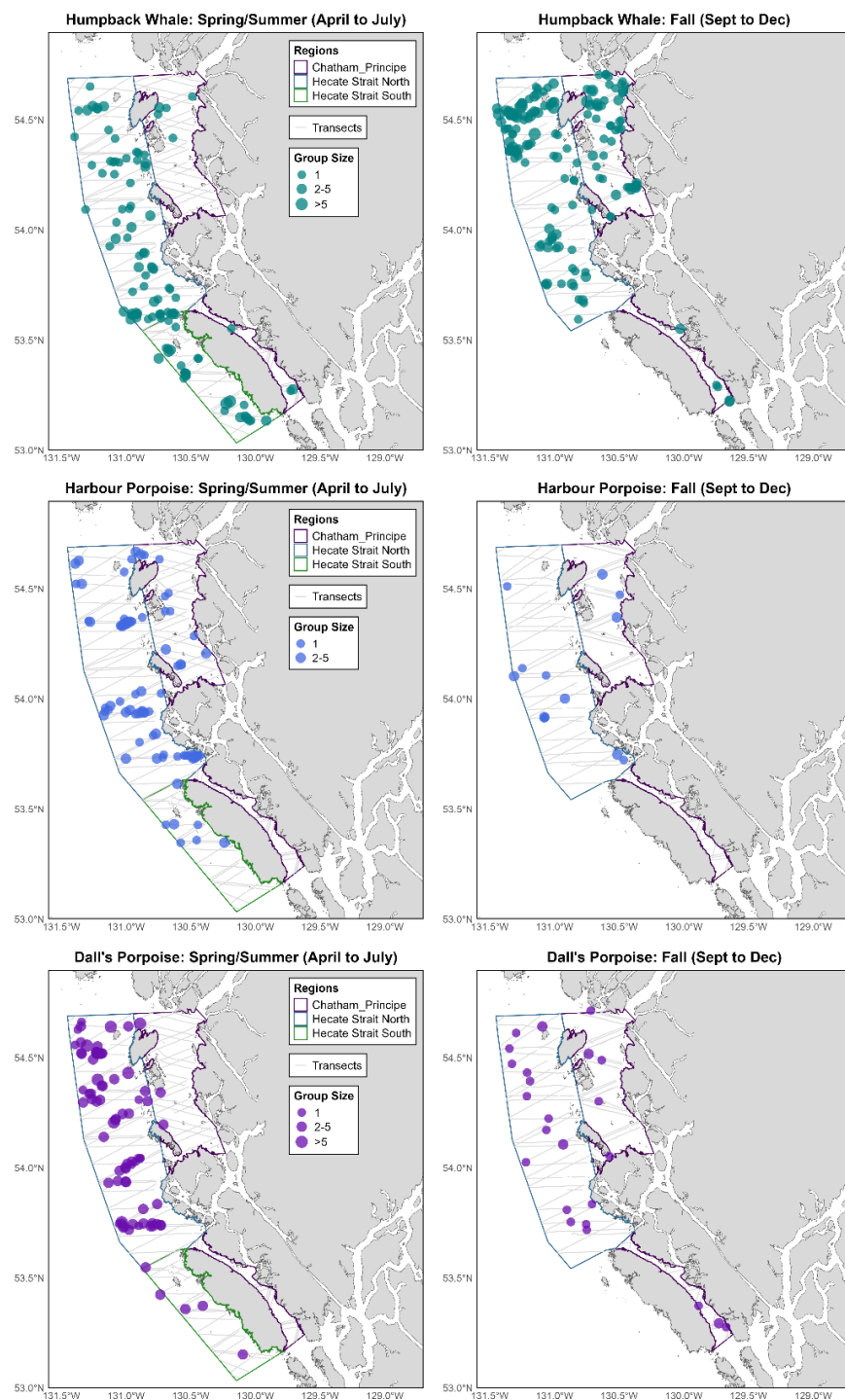


Figure 32-2. Upper panels show Humpback Whale on-effort sightings (teal) and realized survey effort by season and geographic strata; Spring-Summer is shown on the left and Fall on right. Middle panels show Harbour Porpoise on-effort sightings (blue) and lower panels show Dall's Porpoise (purple) on-effort sightings; monthly survey data are pooled by season and geographic stratum. Seasons are defined as Spring-Summer from April to July and Fall from September to December. Relative point size indicates group size for each sighting.

Humpback Whales were the most frequently sighted species (419 sightings of 712 individuals) in CeNorth surveys. Humpback Whales were sighted during all months surveyed. Humpback Whales were evenly dispersed in both offshore Hecate strata during Spring-Summer. In Fall, Humpback Whales were primarily concentrated in Chatham Sound and the northern waters of the North Hecate stratum (Figure 32-2). CeNorth estimates of Humpback Whales were higher in Fall in the North Hecate Strait and Chatham Sound and Principe Channel strata (Figure 32-3; Table 32-1).

Table 32-1. Estimated species abundance by season and geographic stratum with the lower and upper bounds of a log-normal 95% confidence interval and coefficient of variation (CV). Seasons are defined as Spring-Summer from April to July and Fall from September to December.

Species	Geographic Stratum	Spring-Summer	Fall
Humpback Whale	Chatham and Principe	15.01 (95% CI: 6.18–36.43; CV=0.47)	147.74 (95% CI: 81.24–268.65; CV=0.31)
	North Hecate Strait	152.62 (95% CI: 90.87–256.31; CV=0.26)	336.09 (95% CI: 196.87–573.75; CV=0.27)
	South Hecate Strait	62.37 (95% CI: 27.9–139.39; CV=0.41)	-
	Study Area	229.99 (95% CI: 150.35–351.82; CV=0.22)	483.82 (95% CI: 316.01–740.74; CV=0.22)
Harbour Porpoise	Chatham and Principe	155.44 (95% CI: 64.63–373.87; CV=0.46)	39.96 (95% CI: 12.8–124.75; CV=0.62)
	North Hecate Strait	531.38 (95% CI: 258.21–1,093.54; CV=0.37)	113.94 (95% CI: 44.55–291.38; CV=0.50)
	South Hecate Strait	61.65 (95% CI: 18.26–208.22; CV=0.65)	-
	Study Area	748.47 (95% CI: 409.22–1,368.97; CV=0.31)	153.90 (95% CI: 69.64–340.10; CV=0.42)
Dall's Porpoise	Chatham and Principe	50.58 (95% CI: 12.44–205.67; CV=0.71)	141.86 (95% CI: 65.6–306.78; CV=0.40)
	North Hecate Strait	770.87 (95% CI: 416.86–1,425.51; CV=0.32)	331.86 (95% CI: 180.82–609.05; CV=0.31)
	South Hecate Strait	52.69 (95% CI: 22.62–122.72; CV=0.43)	-
	Study Area	874.14 (95% CI: 500.88–1,525.56; CV=0.28)	473.72 (95% CI: 289.9–774.11; CV=0.25)

In the current study, Harbour Porpoise were the second most frequently sighted species (195 sightings of 309 individuals) and were detected in all surveys. Harbour Porpoise were evenly dispersed throughout the study area in both seasons with frequent sightings in mid-Hecate Strait in Spring-Summer and at the entrance to Prince Rupert Harbour across the majority of months sampled (Figure 32-2). CeNorth estimates of Harbour Porpoise were higher in Spring-Summer in the North Hecate Strait and Chatham Sound and Principe Channel strata (Figure 32-3; Table 32-1).

Dall's Porpoise were the third most frequently sighted species (151 sightings of 531 individuals) and were sighted in all surveys. Dall's Porpoise were more frequently sighted in the offshore strata in all seasons and were concentrated in North Hecate in Spring-Summer (Figure 32-2). In the North Hecate Strait stratum, Dall's Porpoise estimates were higher in Spring-Summer versus Fall (Figure 32-3; Table 32-1); however, these differences must be interpreted cautiously for this stratum due to a lack of precision in estimates likely from limited sample size (Figure 32-3; Table 32-1).

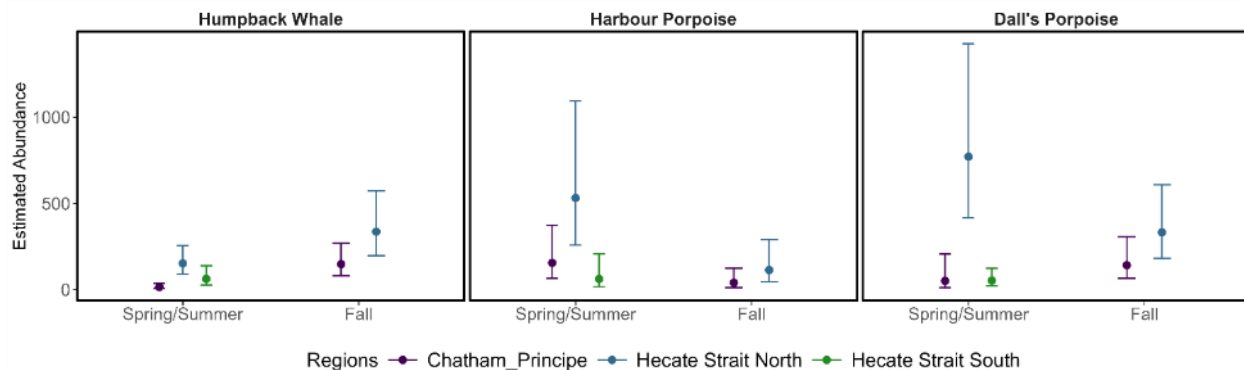


Figure 32-3. Estimated species abundance by season and geographic stratum with the lower and upper bounds of a log-normal 95% confidence interval. Seasons are defined as Spring-Summer from April to July and Fall from September to December.

32.4. Factors influencing trends

Humpback Whale abundance and density varies seasonally due to this species undertaking annual, long-distance migrations between Southern breeding grounds and Northern feeding grounds; the majority of Humpback Whales which occur in southeast Alaska and northern B.C. migrate to breeding grounds in Hawaii (McMillan et al. 2023; Cheeseman et al. 2024). Seasonal abundance and density estimates of Humpback Whales within the CeNorth study area are consistent with trends seen in other areas of coastal B.C. For example, season-specific Humpback Whale estimates in the Salish Sea increase from a low in Winter (January to March) to a high in Fall (October to December; McMillan et al. 2025). The increased abundance density of Humpback Whales in the study area in Fall may lead to a corresponding seasonal increase in whale-vessel co-occurrences and resulting vessel strikes.

Since the end of commercial whaling in 1967, the North Pacific Humpback Whale population rebounded to a peak abundance in 2012, followed by a 20% decline between 2013 and 2021 which has been linked to intense marine heatwaves due to climate change (Cheeseman et al. 2024). The CeNorth season-specific density estimates for Humpback Whales were higher in all strata than the density estimates determined in past studies (with the exception of Spring-Summer in the Chatham Sound and Principe Channel stratum) which could indicate that Humpback Whales in this area did not experience, or have already recovered from, similar declines following the Northeast Pacific marine heatwave (Best et al. 2015; Cheeseman et al. 2024; Doniol-Valcroze et al. 2024)

Seasonal abundance and density of Harbour and Dall's Porpoise, and factors influencing their distribution, are poorly understood in B.C. waters (Hall, 2004; Nichol et al. 2013; Dracott et al. 2022). Similar to other studies in Chatham Sound and southeast Alaska, both species appear to have higher seasonal abundance and density estimates during Spring-Summer and lower in Fall, excluding Dall's Porpoise estimates in the inshore stratum. In other coastal areas of B.C. where these species co-occur, resource and habitat-partitioning have been noted with Dall's Porpoise exploiting deeper water habitats and nocturnal feeding in contrast to Harbour Porpoise which tended to exploit shallow water habitat (Nichol et al. 2013). Opposing trends in seasonal abundance and distribution of both species have been seen in the Salish Sea (McMillan et al.

2025). This suggests that seasonal abundance and density of these species may be area-specific and influenced by a combination of local scale environmental variables and sympatric species interactions.

32.5. Implications of those trends

Season-specific abundance and density estimates for all three species across geographic strata can be used to inform anthropogenic threat assessment and mitigation. The CeNorth study area encompassed the Port of Prince Rupert which is the second largest port in B.C. and the third largest seaport in Canada (Powell et al. 2024). The study area also overlaps significantly with the LNG Canada shipping route which is predicted to increase large vessel (length >180 m) traffic by a magnitude of four times the levels present in 2019 and whale-vessel co-occurrences 30-fold by 2030 in the nearby Kitimat Fjord System (Keen et al. 2023). The CeNorth estimates will be key to the assessment of anthropogenic threats to cetaceans in this area, especially those linked directly to marine traffic including vessel strikes and acoustic disturbance (Powell et al. 2024). Density surface modeling can be used to produce spatially-explicit abundance estimates and density layers for these three species to inform anthropogenic risk assessment and guide management and mitigation decisions (Wright et al. 2021).

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33. CONTINUING TO EXPLORE THE POTENTIAL FOR A WEST COAST B.C. DISTRIBUTED BIOLOGICAL OBSERVATORY (WCDBO)

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33.1. Highlights

- The WCDBO provides a tool to observe our land-ocean systems and identify and interpret Earth system change at multiple scales, which is critical for creating the knowledge needed to maintain the resilience of the Earth system as a whole.
- We propose to continue establishing the WCDBO from Victoria, through the Inside Passage, to Prince Rupert.
- We are currently continuing to explore this concept through broad and inclusive engagement (e.g., First Nations, researchers, NGOs, government).
- We are interested in and seeking community broad feedback and participation interest to help shape the success of this program.
- Once established, the proposed WCDBO can serve as a 'branching off' framework for existing and emerging site-specific programs.

33.2. Background

[The background for the WCDBO is described in our 2025 SOPO summary.](#) Briefly, the West Coast B.C. Distributed Biological Observatory (WCDBO) is proposed as a complement to the existing panarctic Distributed Biological Observatory (DBO) program, which conducts standardized long-term marine and biological sampling (Moore and Grebmeier 2018). The argument for the WCDBO is based on three unifying concepts. The first is the critical role of Pacific water as a hydrological feature, where its influence extends through the Bering Strait to dominate heat, material fluxes, and nutrient distributions across the Arctic and into the North Atlantic (Tully and Barber 1960; Coachman and Barnes 1961; Coachman et al. 1975; Stigebrandt 1984; Aagaard and Carmack 1989). The second focuses on the critical interdependency between terrestrial and marine systems along the B.C. coast. For example, rivers, watersheds, and nearshore processes strongly influence the chemistry, circulation, and productivity of the coastal ocean, and thus an integrated observatory would be useful to track these coupled changes and their impact on ecosystems and communities (Dosser et al. 2021; Hunt et al. 2024; Evans et al. 2025). Finally, the third is the framework of Planetary Boundaries, which supports the WCDBO domain as a regional-scale model of the Earth system, providing a framework for integrating data, knowledge, policy, and governance (Rockström et al. 2009; Richardson et al. 2023).

33.3. The opportunity

The CeNorth Program, funded through DFO Science's Coastal Environmental Baseline and Cetacean Monitoring and Research programs (CEBP and CeMoRe), consisted of a series of nine line transect surveys conducted aboard the Arctic Research Foundation vessel, R/V *Tiriarnaq* between June 2023 and December 2025. DFO and Arctic Research Foundation offered the opportunity to use the transits, to and from Prince Rupert (PR) to conduct sampling work along the route. Beginning in 2024, Ocean Networks Canada (ONC) committed in-kind

funds to support and coordinate transit cruises and to help explore the WCDBO program more broadly.

As part of these efforts, a multidisciplinary Working Group emerged and continues to advance the concept of implementing the WCDBO. The WCDBO pilot phase was officially launched in 2024, inspired by the Arctic DBO framework (Grebmeier et al. 2019). Its aim is to create a coast-wide, inclusive observing system capable of tracking biological and biogeochemical change while strengthening Indigenous leadership in marine stewardship and fostering knowledge co-production and sharing across academia, industry and governance organizations. In this first phase (Aug 2024–Nov 2025), the WCDBO collaborative program conducted five successful pilot cruises aboard the Arctic Research Foundation (ARF) operated R/V *Tiriarnaq*, engaged with over 12 of the First Nations on the B.C. coast, and demonstrated the feasibility and community interest for co-developed data collection across more than a dozen ocean stations between Victoria and Prince Rupert, B.C., Canada (Figure 33-1).

33.4. Pilot cruises

As part of the pilot project, five cruises were completed, each consisting of a transit between Victoria and Prince Rupert, sampling multiple stations along the way. Notably, during the December transit (2024), poor weather resulted in the vessel having to return to Prince Rupert, only making it as far south as Shearwater. During all cruises, science sampling time was limited to a total of 12-hours of operations across the entire transit.

The data collected on these initial cruises focussed on water properties including temperature, salinity, oxygen, chlorophyll fluorescence, and nutrients. At each sampling site, we performed Conductivity-Temperature-Depth (CTD + dissolved oxygen + additional optical sensors) casts and collected water samples using a small rosette (sampled for nutrients and chlorophyll) (Figure 33-2). DFO provided support for the water sampling and analyses (Figures 33-2 and 33-3). The CTD data are freely available through Ocean Networks Canada's data management system, Oceans 3.0. Results of physical sample analysis will be available by email on request.

A summary of sample stations visited during the cruises are presented in Table 33-1. These initial station locations were co-developed between DFO, ONC, and in consultation with a variety of coastal communities through multiple virtual information sharing sessions. For possible future expeditions, we are aiming to continue to add stations in regions of high scientific interest, where historical data exists, and/or to complement existing monitoring and stewardship initiatives to broaden our collective understanding of the coastline. Some of these additional stations are outside ONC's existing partnership network, and thus we are currently seeking input and feedback from the First Nations whose territories these stations fall within, as well as community feedback on potential new or adjusted stations from all parties. We did not undertake sampling in regions with limited engagement or without approval.

Beyond data collection, each pilot cruise was purposefully designed as a mobile platform for engagement, knowledge exchange, and co-development with coastal and Indigenous communities. Community engagement was a core component of these cruises, focused on building meaningful relationships with local partners and leadership through standardized ocean observing. These efforts included but not limited to: in-person community visits, multiple virtual information sharing sessions, and the participation of an Indigenous Youth Science Ambassador on the May 2025 cruise, all designed to share the observatory's goals while listening to local

priorities for marine stewardship. Engagement activities ranged from hosting public open house boat tours to more formal information-sharing sessions within communities. These interactions provided space for dialogue on the concept of the WCDBO and allowed local knowledge holders to help share marine priorities for their respective territories. Ultimately, these efforts aim to continue to foster future knowledge co-production and support Indigenous leadership in monitoring biological and biogeochemical changes along the coast.

Collectively, these pilot efforts validated the WCDBO model as an effective bridge between community observation, scientific monitoring, and decision support. They confirmed the technical feasibility, social readiness, and ecological relevance of scaling the WCDBO along B.C.'s coast and into new regions.

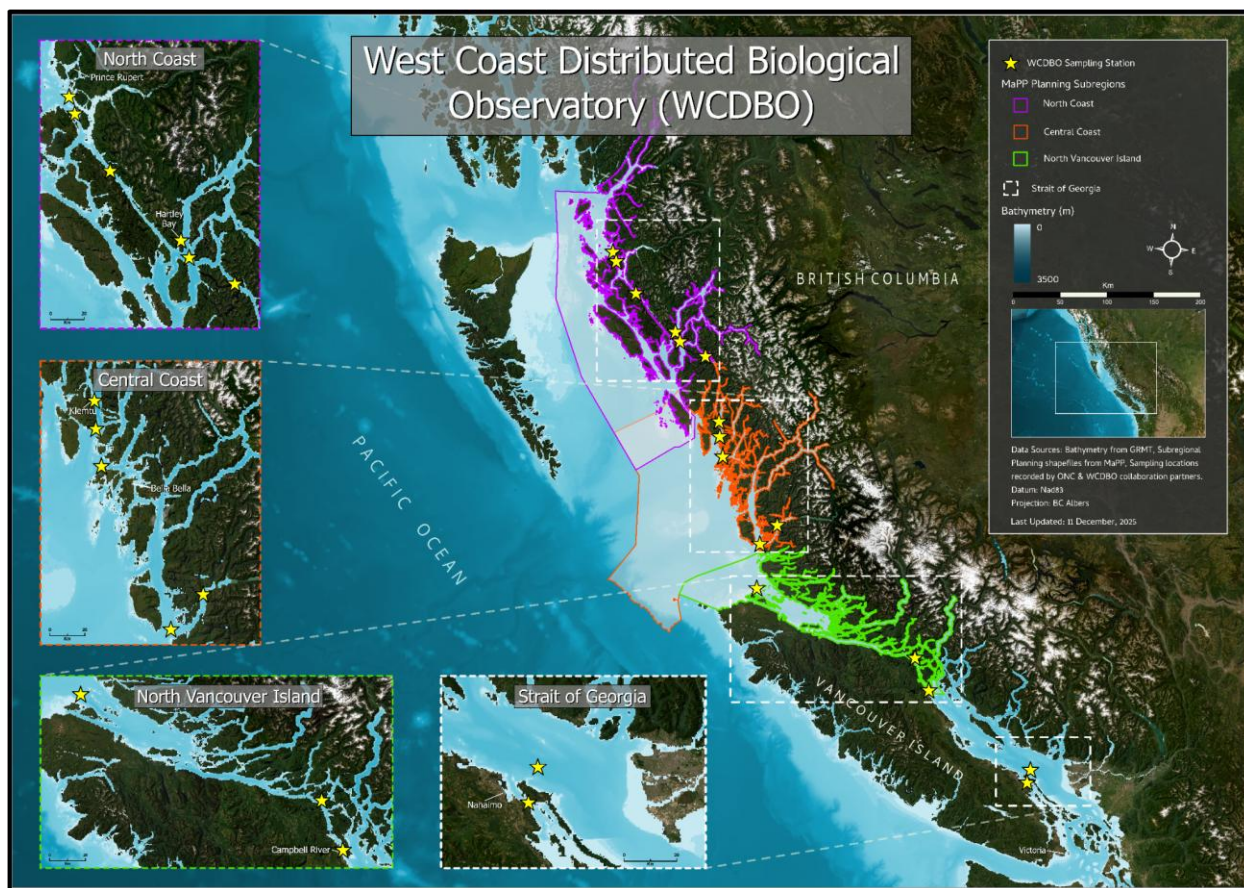


Figure 33-1. A map of the current WCDBO route and stations sampled between 2024-2025.

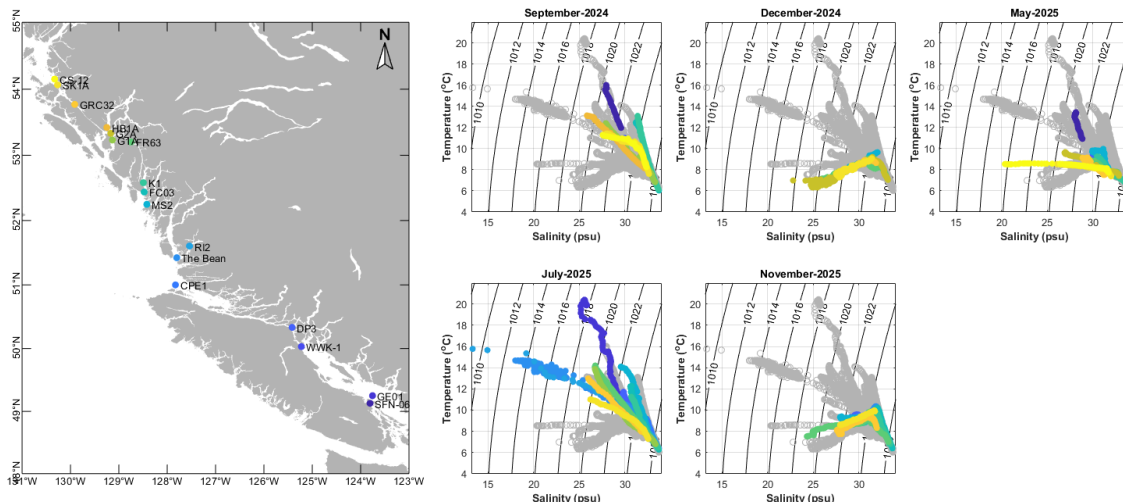


Figure 33-2. Water properties plots. The map shows all the locations sampled during the pilot cruises. Map insets display Temperature-Salinity plots using the CTD data, with the grey points representing data from all previous months. The colorbar represents latitude, with the warmer colors representing more northerly stations.

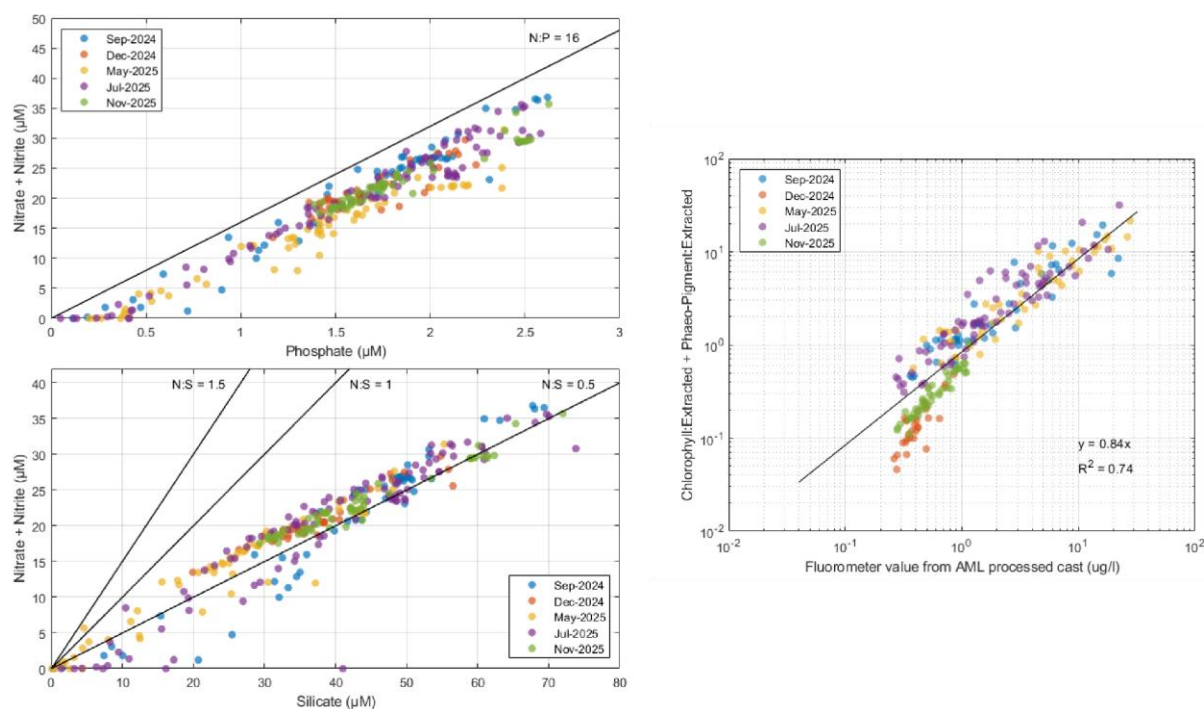


Figure 33-3. Nutrient and Chlorophyll data, measured with support from DFO Water Properties group. The plots on the left represent N, P, and Si nutrient data measured by DFO Water Properties. Canonical Redfield ratios are displayed as straight lines. The plot on the right represents the bottle sample Chlorophyll (y-axis) vs. AML-6 LGR CTD chlorophyll X2Change sensor, with linear regression displayed. Strong agreement between the bottle samples and CTD measurements imply a correction factor may be used to rely on the CTD data. During winter months (December, November), the relationship is weaker due to overall lower levels of in-situ productivity.

33.5. Looking forward

The WCDBO Working Group submitted (December 2025) a proposal to MEOPAR's Strategic Shiptime program in an effort to secure additional shiptime funding for the program. The Working Group proposal included multiple investigators and collaborators from diverse sectors including; researchers, NGOs, government, and First Nations. At the heart of this proposal are two-track operations; (1) Core Collaborative Cruises (2 per year (contrasting seasons), 6-berth spaces): annual ship-based campaigns similar to the pilot cruises on ARF's R/V *Tiriarnaq* dedicated to core time-series sampling, process based studies, and co-training with First Nations, students, and partner scientists. As with the Arctic DBO, these "core sites" form the scientific and logistical backbone of the network, providing reference points that integrate local variability into a coherent regional picture of ecosystem change. The cruises are also a platform for continued in-person community engagement and can serve as a mobile workshop and knowledge sharing space with communities along the route. (2) Funding for distributed community-led sampling (year-round): Community-led patrols and community vessels implement standardized protocols at WCDBO stations between cruises. The WCDBO model is intentionally inclusive and participatory, and the WCDBO will formalize Nation co-lead roles at regional nodes and co-develop protocols so community-based monitoring can run year-round observations between core cruises.

A core goal of the WCDBO is to build a more collaborative and inclusive ocean observing system that bridges academic, federal, Indigenous, industry, and community efforts along the B.C. coast.

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34. MARINE BIOTOXIN MONITORING IN B.C. COASTAL WATERS

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34.1. Highlights

- The unusual trends in algal biotoxin production seen during 2024 continued in 2025.
- In Malaspina Strait domoic acid (DA) peaked even later than usual (July) and at the highest concentrations (up to ~200 ng/L) recorded there since 2020.
- DA also peaked later (July) and at higher concentrations than usual in Cowichan Bay.
- In Malaspina Strait the peak concentration of paralytic shellfish poisoning (PSP) toxins was the second highest on record after 2024, when it reached unusually high levels.
- PSP toxins in Cowichan Bay are consistently higher than in Malaspina Strait.
- Overall DA and PSP toxins appear to be increasing in the Strait of Georgia.

34.2. Description of the time series

In 2015 an extraordinary phytoplankton bloom occurred along the continental shelf of western North America, including B.C. The bloom contained species of the pennate diatom *Pseudo-nitzschia* (Perry et al. 2023) that, under certain conditions, produce the neurotoxin domoic acid (DA). This algal biotoxin is responsible for amnesic shellfish poisoning (ASP) in humans and has been associated with illness and mortality in marine mammals (Lefebvre et al. 2018; Moriarty et al. 2021). In 2019, DFO funding was provided to study DA and other algal biotoxins including those responsible for paralytic (PSP) and diarrhetic shellfish poisoning (DSP) at nearshore aquaculture facilities in collaboration with B.C. salmon farmers. Since 2020 DFO has also been collaborating with the Pacific Salmon Foundation (PSF) Citizen Science Oceanography Program to monitor algal biotoxins, phytoplankton taxonomy, and environmental conditions in the Salish Sea. In 2022 our biotoxin monitoring program was extended to include samples collected by DFO during Salish Sea biophysical surveys and La Perouse surveys along the west coast of Vancouver Island (WCVI). In 2023 we began monitoring biotoxins in Barkley Sound in support of the Pacific Salmon Strategy Initiative (PSSI) Follow the Fish (FtF) project. This report provides a summary of results obtained between 2020 and 2025 by DFO's collaborative Marine Biotoxin Monitoring Program (Ross and Mueller 2024).

Surface seawater samples are collected monthly at long-term monitoring sites (Figure 34-1; yellow dots) by B.C. salmon farmers and PSF citizen scientists and in Barkley Sound (dashed

box), by DFO colleagues as well as two or three times a year from multiple locations during DFO surveys (red dots), along with taxonomic samples and environmental data. Samples for biotoxin analysis are obtained using a 1-L filter holder and vacuum pump to draw up to 1000 mL of seawater through a 0.45- μ m filter and collect the filtrate. The filter is then stored at -80 °C in a 5-mL cryovial and the filtered seawater at -20 °C in a 1-L plastic bottle. After thawing at room temperature, biotoxins are recovered from the filter using solvent extraction and from the filtrate using solid-phase extraction. Both extracts are then analyzed for DA and PSP toxins using hydrophilic interaction chromatography, and for DSP and other lipophilic toxins using reversed phase liquid chromatography, combined with tandem mass spectrometry. Filter and filtrate measurements are used to investigate the distribution of dissolved vs. particulate biotoxin, or combined to obtain the total concentrations of biotoxins in seawater (Ross et al. 2025).



Figure 34-1. Locations where surface seawater is collected for algal biotoxin analysis. Long-term monitoring sites in Malaspina Strait (IS-2), Cowichan Bay (CBE-2) and Clayoquot Sound (Farms A and B) are highlighted in yellow. Barkley Sound is shown by the dashed box and Southern Resident Killer Whale critical habitat by the dashed circle.

34.3. Status and trends

Time series of total concentration (Figures 34-2 and 34-3) for DA and PSP toxins detected at long-term monitoring sites in Malaspina Strait (IS-2) and Cowichan Bay (CBE-2) show consistent seasonal trends between mid- to late 2020 and December 2023, as represented by the historical average values (solid black line). Results for 2024 (blue dots) and 2025 (dotted red line) showed significant deviations from these trends. For example, DA normally peaks in April at IS-2 but peaked in June in 2024 and at the highest concentrations on record in May and July 2025 (Figure 34-2), reaching levels (100 to 200 ng/L) associated with DA uptake in shellfish (Perry et al. 2023). DA also peaked later and at higher concentrations than usual at CBE-2.

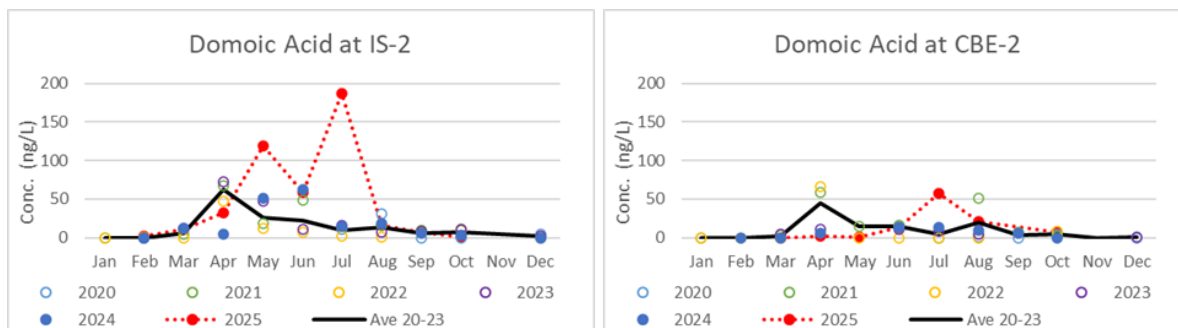


Figure 34-2. Time series for Domoic Acid at IS-2 in Malaspina Strait and CBE-2 in Cowichan Bay (Figure 34-1).

PSP toxins peaked in September/October at IS-2 in 2024 (Figure 34-3) at concentrations far higher than average (~1,200 ng/L), more like those typically reached on the west coast of Vancouver Island. In 2025, PSP toxins at IS-2 peaked in August at levels higher than in any other year except 2024. Total PSP toxin concentrations at CBE-2 in 2025 were closer to average but remained significantly higher than at IS-2. This was also true in August 2023 and 2024 when PSP toxins at CBE-2 spiked to unusually high levels (~2,000 ng/L).

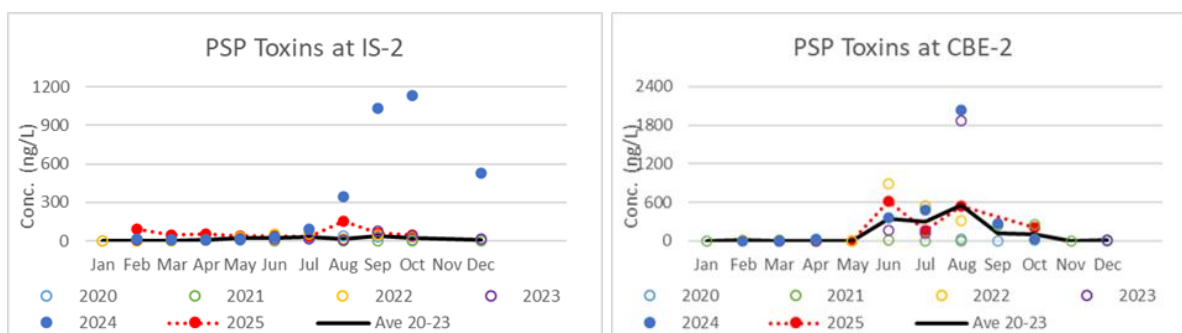


Figure 34-3. Time series for Total PSP Toxins at IS-2 in Malaspina Strait and CBE-2 in Cowichan Bay (Figure 34-1).

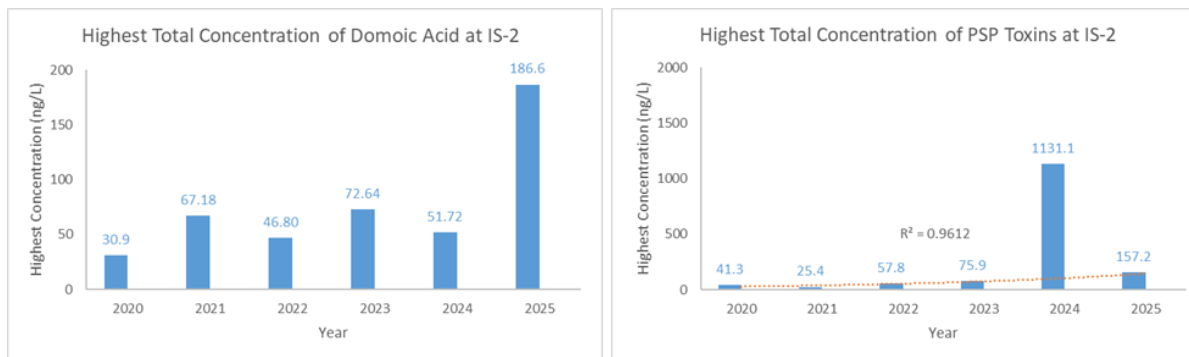


Figure 34-4. Interannual trends in maximum Domoic Acid and PSP Toxin concentrations at IS-2 in Malaspina Strait.

The highest total concentration of DA measured at IS-2 each year since 2020 averaged about 50 ng/L from 2020 to 2024 but reached nearly 200 ng/L in 2025 (Figure 34-4). The highest total concentration of PSP toxins measured each year spiked in 2024 but has otherwise also increased approximately four-fold from ~40 to 160 ng/L since 2020. Overall, the total concentrations of DA and PSP toxins at IS-2 in Malaspina Strait appear to be increasing.

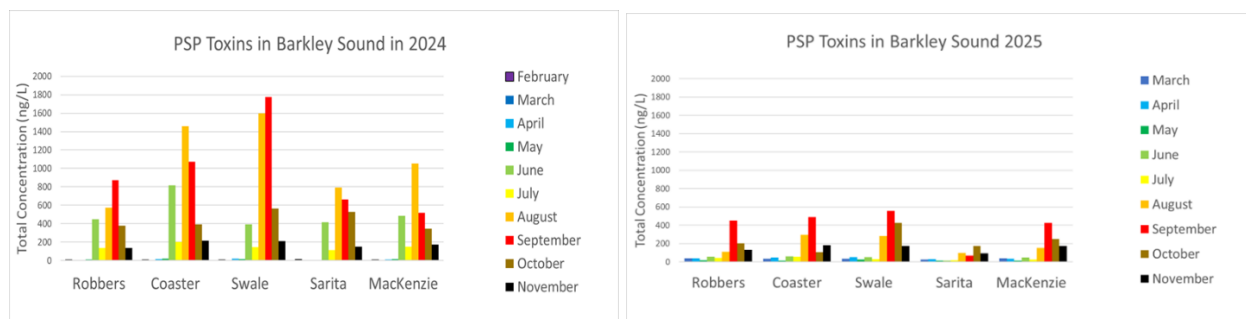


Figure 34-5. Total PSP Toxin concentrations at 5 stations in Barkley Sound (Figure 34-1) during 2024 and 2025.

PSP toxins tend to peak in late summer/early fall and to reach higher total concentrations on the west coast of Vancouver Island than in the Salish Sea (Figure 34-5). In contrast to the trends observed for IS-2 in Malaspina Strait (Figure 34-4) concentrations of total DA (not shown) and PSP toxins in Barkley Sound fell for the third consecutive year in 2025. However, PSP toxin levels in 2024 were sufficiently high to result in detection of saxitoxin (the most harmful PSP toxin) in the livers of juvenile Chinook Salmon caught at Nanat Islet (near Robbers) in August and September.

34.4. Factors influencing trends

Analysis of seasonal biotoxin and environmental data collected during Salish Sea biophysical surveys suggest that biotoxin concentrations in the Strait of Georgia tend to be higher when surface salinity is lower, temperature higher, and/or harmful algae more abundant (Ross et al. 2025). Furthermore, the unusually high levels of DA seen in Malaspina Strait during 2025 are consistent with the high mean seasonal abundance of *Pseudo-nitzschia* (Esenkulova et al. *in prep.*) while two DA peaks (Figure 34-2) reflect the 2025 double spring bloom and associated drawdown of nutrients which, we believe, can induce biotoxin production in harmful algae (Ross et al. *in prep.*). Similarly, PSP toxins and the *Alexandrium* cells that produce them tend to be more abundant in Cowichan Bay than in Malaspina Strait (Figures 34-3) while results from Salish Sea biophysical and Barkley Sound krill surveys show that PSP toxins tend to peak during fall when algae that produce them are more abundant (Figures 34-5). Summer concentrations of DA and PSP toxins also tend to be elevated near the Victoria Sill which lies south of Victoria at a depth of about 100 m within critical habitat for Southern Resident Killer Whales (SRKW; Figure 34-1, dashed circle: see also Ross et al. 2025).

34.5. Implications of those trends

Detection of domoic acid within critical habitat for SRKW suggests that they may be at risk of exposure to DA, which has caused illness and mortality in other marine mammals (Lefebvre et al. 2018; Moriarty et al. 2021). PSP toxins are known to harm fish (Lebevre et al. 2005; Starr et al. 2017) and exposure of juvenile WCVI Chinook Salmon to these toxins in Barkley Sound may have implications for their long-term health and survival. Detection of DA and PSP toxins in juvenile Chinook gill and liver tissues (DFO 2025) also shows that results from our monitoring program can be used to assess the risk posed by algal biotoxins to wild (and farmed) fish as well as to shellfish and endangered marine mammals. They can also be used to inform decisions about the timing of hatchery releases in order to minimize biotoxin exposure, and to identify other biotoxins present in B.C. coastal waters that should be assessed for their toxicity towards wild and farmed species. Finally, long-term time-series data from PSF Citizen Science

sites (Figure 34-4) suggest that DA and PSP toxins in B.C. coastal waters are starting to trend upwards and/or show erratic behaviour, implying linkages with climate change and associated conditions that may have consequences for the future health of local marine ecosystems.

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35. UPDATE ON AQUATIC INVASIVE SPECIES IN PACIFIC REGION

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35.1. Highlights

- *Styela clava* (Clubbed Tunicate) was detected in Metro Vancouver for the first time in 2025, following three years of increasing detections in Nanaimo and Ladysmith.
- European Green Crab (EGC) continues to spread in B.C., with a large number of new detections occurring on the North Coast, especially around Prince Rupert.
- AIS Science has developed a risk assessment process to identify high risk AIS in both freshwater and marine ecosystems. Results can inform early detection/monitoring efforts and identify potential ecosystem changes.

35.2. Monitoring Efforts for AIS in the Pacific Region

Regular monitoring of biofouling aquatic invasive species (AIS) in ports and marinas in B.C. has been conducted by the AIS Science Program for over a decade, using weighted PVC plates (14x14 cm) deployed from floating docks (Clarke Murray et al. 2011; Iacarella et al. 2019). Typically, ten plates are deployed per site. Common biofouling species of concern include tunicates, encrusting bryozoans, and barnacles. In 2025, presence data for AIS at a total of 15 sites, including each of four core sites in both Prince Rupert and Metro Vancouver, was compiled for this report (Figure 35-1a). AIS Science also conducts long-term monitoring of established EGC populations on the west coast of Vancouver Island. New detections and delineation trapping for EGC is conducted by a large network of external partners (e.g., First Nations, NGOs, port authorities, etc.), all coordinated by the DFO National Core Program (NCP) (Figure 35-1b).

35.3. Status and Trends in Biofouling AIS

Overall, there was a general decreasing trend in the frequency of occurrence for AIS on the North Coast, with the exception of *Diplosoma listerianum* which was more common in 2025 than in any previous year (Figure 35-2a). The same pattern was observed for this species in the Salish Sea, with observations in Victoria, Ladysmith, and Campbell River (Figure 35-2b). In Metro Vancouver there were no significant changes in the frequency of occurrence of most AIS. However, 2025 was the first year that *Styela clava* was detected in the area, specifically Coal Harbour. Although the species is common on the east coast of Vancouver Island, there are no records of it from Metro Vancouver in the major global biodiversity databases (i.e., GBIF, OBIS). Although it is unclear if this indicates a recent range expansion or a delayed detection of a species already present; *S. clava* has been increasing on the east coast of Vancouver Island since 2023 (Figure 35-2b). In 2025 the species was especially common in Nanaimo and Ladysmith, occurring on 92% and 80% of plates, respectively.

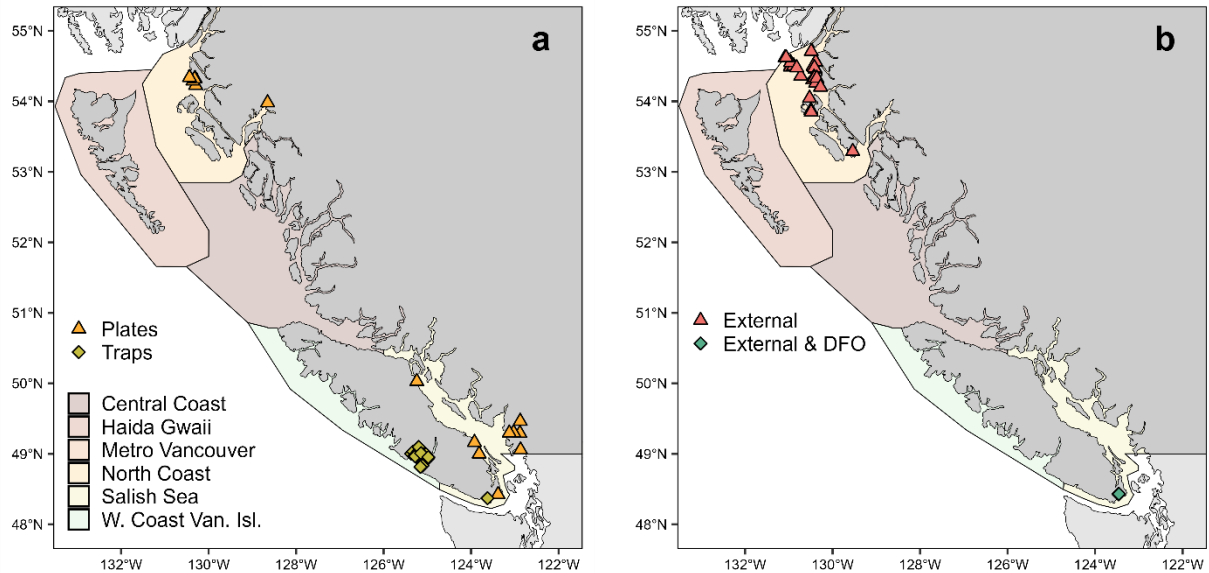


Figure 35-1. a) Settlement plate locations and long-term survey trapping locations for European Green Crab, deployed by DFO AIS Science in 2025; b) New detections of EGC for 2025, made by external partners with or without additional field assistance from DFO Science or National Core Program (NCP).

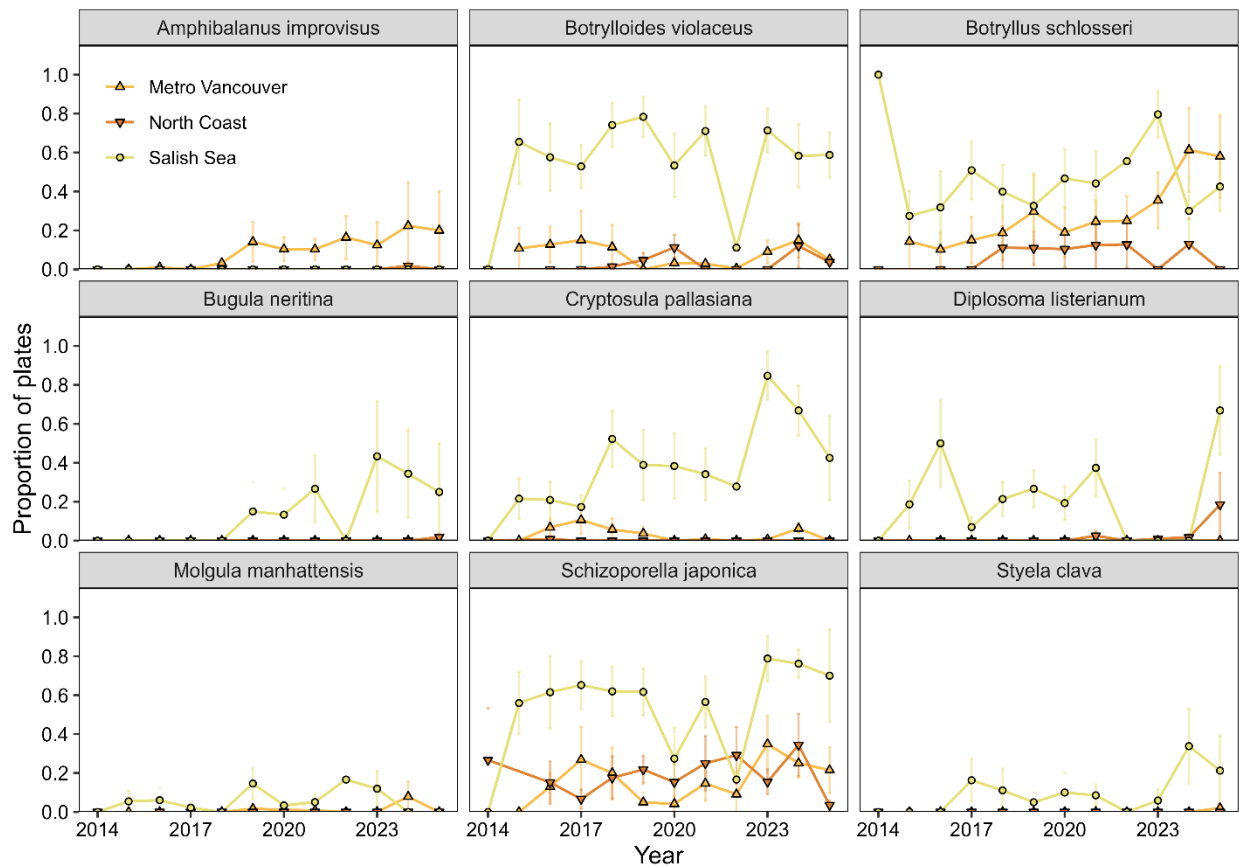


Figure 35-2. Change in frequency of occurrence of some AIS found on settlement plates in three areas in B.C. with DFO AIS Science data for 2025: North Coast (6 sites), Metro Vancouver (5 sites), and Salish Sea (4 sites). Presented as the proportion of plates at each site on which each species was found, averaged within areas. Only data from summer deployments (May–Sep/Oct) are shown.

35.4. Status and Trends in European Green Crab

European Green Crab continue to spread along most of B.C.'s coast, with most new detections made by external partners in conjunction with DFO Science or NCP made in the North Coast (Figure 35-1b). Larval EGC were initially reported in Prince Rupert in 2019 and adult EGC subsequently detected in the Skeena River estuary in 2023 (Howard and Therriault 2024). Although overall CPUEs remain low on the North Coast (average = 0.48 EGC/trap $\pm$ 0.08 SE) and in the Salish Sea (average = 0.17 EGC/trap $\pm$ 0.02 SE) compared to other areas of B.C. (Figure 35-3), both appear to be trending upward. This is likely partially driven by increasing population size, but CPUE is an imperfect measure of abundance and is influenced by other factors, such as improving site selection and trap placement over time, and the type of trapping program being conducted (e.g., early detection, response and management).

Conversely, there has been a significant decrease in CPUE in Sooke Basin. This trend follows two years of intense eradication trapping conducted by the Coastal Restoration Society throughout the Basin between 2021 and 2023. The Sooke Basin EGC population is known to be physically isolated from the rest of the Pacific EGC meta-population based on molecular analyses (C. Tepolt, pers. comm.), so the continued decline in catch suggests recruitment within the Basin itself has been extremely poor. If so, it may be that the eradication of EGC in Sooke Basin is possible with a sustained trapping effort.

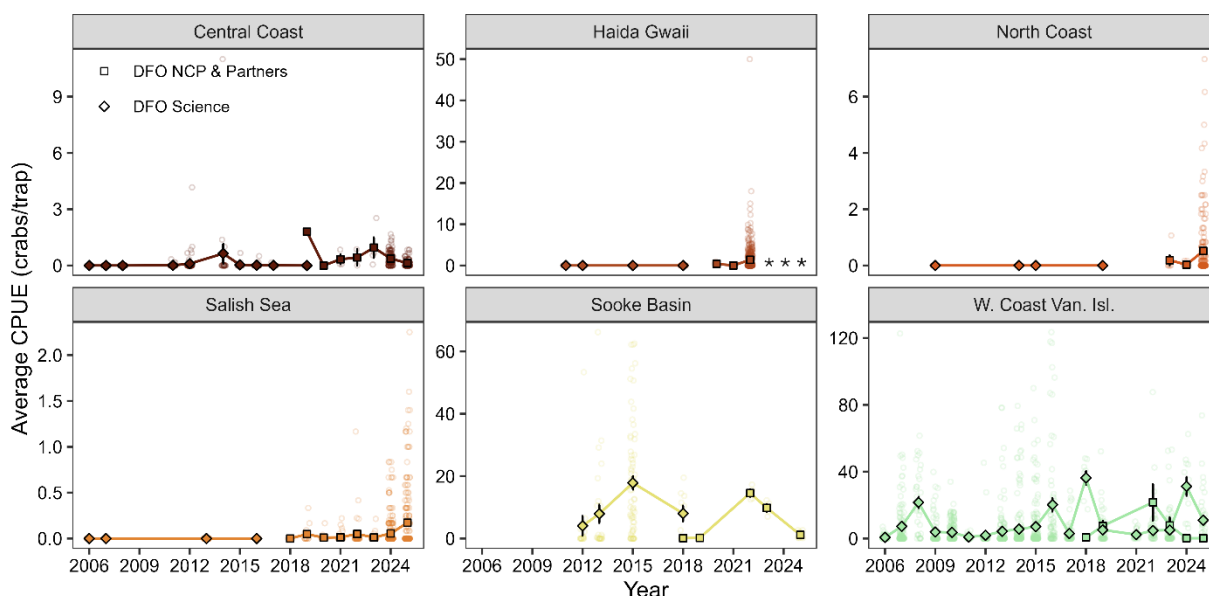


Figure 35-4. Annual CPUE of European Green Crabs (mean $\pm$ SE of all trapping events within an area) from the DFO Science trapping program (May-September only, diamond points) and DFO NCP and their external partners (square points) for major areas in B.C. Note the large differences in scale. Empty points represent individual trapping events. An asterisk indicates an area and year for which there are trapping data that was unavailable at the time of publication.

35.5. Risk Assessment to Improve Detection of New and Underreported Freshwater AIS

AIS Science is currently prioritizing potential AIS using the purpose-built Non-Indigenous Species Screening Tool (NISST) (Wilcox et al. 2025). Based on an initial horizon scan of >3200 freshwater and >300 marine species, those with important risk factors are now being assessed

using this tool. Of the 515 freshwater species already assessed, 49% are fish, 35% are plants, and 16% are invertebrates. Freshwater AIS are capable of significant impacts to salmon populations and other species at risk in B.C. (e.g., Sanderson et al. 2009). There is an identified need for tools like NISST to improve the capacity for managers to identify, monitor for, and report on high risk AIS.

35.6. Implications and Drivers of AIS Range Expansions in the Pacific Region

AIS are continuing to spread in B.C., facilitated by anthropogenic vectors and climate change. While this is most dramatically demonstrated by the rapid expansion of EGC throughout Haida Gwaii and the North Coast in less than five years, biofouling AIS are also increasing their ranges, as reported in this series. It is rarely possible to identify the specific vectors, natural or anthropogenic, that result in these expansions. However, focusing management on key vectors, such as the movement of vessels, structures, and aquaculture gear and stock, means there is a better chance of reducing spread of both established AIS and newly introduced or undetected ones whose impacts are not yet known.

The expanding ranges of marine AIS is only a partial picture of the total risk of invasive species to aquatic ecosystems in B.C. The impacts of invasive species to critical freshwater habitats for salmon and species at risk is substantial. However, the ability to monitor for and report on new and spreading freshwater AIS is limited, partly due to a mismatch between capacity and the scope of the problem. The large number of known and potential invaders makes it challenging to design effective monitoring plans. Hopefully, prioritization tools such as NISST will help focus detection efforts and help fill in the spatial and temporal gaps in the distribution of AIS in the Pacific region.

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Individual reports on inside waters (including the Strait of Georgia)

36. SOUNDSCAPE PATTERNS IN THE SALISH SEA (2018-2025)

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36.1. Highlights

- The timeseries of acoustic data collection was maintained, adding the eighth year of data for some locations.
- Spatiotemporal patterns in dominant anthropogenic and abiotic noise sources seen for 2025 was consistent with previous years.
- There was increased prevalence of wind and rain noise due to storm and atmospheric river events compared to previous years.

36.2. Description of the time series

Passive acoustic recorders were first deployed in early 2018 at six core locations. In subsequent years, additional recorders have been deployed in the Gulf Islands and the Strait of Georgia (Table 36-1). Autonomous Multichannel Acoustic recorders (AMAR, G4, JASCO Applied Sciences) with GeoSpectrum Technologies M36-100 hydrophones were deployed to collect continuous soundscape recordings. The hydrophones are positioned approximately 2 m from the ocean floor. Data from oceanographic sensors positioned on the moorings were used to calculate sound speeds and characterise water conditions (see Taves et al., Section 37 for more details) and, together with vessel tracking records and meteorological observations, were utilized in the analysis to determine dominant sound sources over time at each location.

Table 36-1. Deployment location, date, and water depth of each of the Salish Sea moorings currently deployed and contributing to the timeseries.

Moorings location	Latitude	Longitude	Depth (m)	First Deployment
Swiftsure	48.5154	-124.9360	75	April 2018
Port Renfrew	48.5045	-124.5169	170	Feb 2018
Jordan River	48.3967	-124.1345	120	Feb 2018
Sooke	48.2901	-123.6552	165	Feb 2018
Haro Strait	48.4959	-123.1931	235	Feb 2018
Boundary Pass	48.7326	-123.1521	180	Feb 2018
Swanson Channel	48.7390	-123.2557	75	Aug 2019
Strait of Georgia south east	48.8900	-123.1700	132	Jul 2023
Strait of Georgia south	48.9810	-123.4051	240	Aug 2020
Strait of Georgia north	49.1928	-123.3465	190	Aug 2020

Soundscape conditions were described by considering the sound level which was exceeded 99% of the time of the recordings (Q1), which represented minimum/background levels, with sound levels almost always greater than the one stated for Q1. Also considered was the sound level exceeded 50% of the time (Q50), for median/most typical sound levels; and the sound level exceeded only 5% of the time (Q95), representing the noisiest periods, which was exceeded rarely. Frequency ranges considered included those representing broadband noise (10 Hz to 100 kHz), typical flow noise (10-100 Hz), commercial vessel frequencies (100-1000 Hz, 57-71 Hz, 113-141 Hz), wind (7500-8500 Hz) and rain noise (19500-20500 Hz). The

soundscape and sound levels in each frequency range of interest is dependent on the dominant noise sources at any given mooring location through time. The sound levels from 2025 were compared to the data from previous years for these frequencies and using these percentiles.

36.3. Status and trends

The spatiotemporal patterns in the broadband frequency (10 Hz -100 kHz) were consistent with previous years (Figure 36-1). Commercial vessel inputs were prevalent for Swiftsure Bank and western Juan de Fuca Strait locations (Figure 36-1B), with increases in the fall. This is associated with increased demand on oceanic shipping routes in the lead up to Christmas. Broadband recordings did not show an obvious decline in sound pressure levels (SPL) in the summer months that might be expected from management measures, including a lateral displacement of tugs through Juan de Fuca (best captured at Jordan River, Figure 36-1C) and vessel slowdown requests on Swiftsure Bank and through Haro Strait (Figure 36-1A, E). The lower frequency ranges used to examine commercial vessel inputs showed an increase in background levels (Q1) during these trial periods.

The soundscape in the Strait of Georgia has been shown to be shaped by ferry schedules. However, seasonal increases in transit number were not captured, with an overall decrease in summer SPL, particularly in the north. This is likely due to oceanographic properties and boundary layers preventing emissions being recorded at the ocean floor at this time. Increased noise levels during the summer months for moorings in Juan de Fuca Strait and the Gulf Islands (e.g., Figure 36-1B, C, D, G) are attributed to a greater presence of recreational vessels. These add to the higher-frequencies during daylight hours and over weekends. This increase in vessel presence is best captured acoustically, because this vessel type is under-represented in the vessel tracking data. Decreased wind-noise inputs were noted at Swiftsure Bank and Port Renfrew during the summer months (Figure 36-1A, B and Figure 36-2A). This contrasts with Sooke (Figure 36-2B), which had a localised increase in regional winds at this time. More prevalent than in previous years were the additions in frequencies representing wind and rain during the winter-spring months which may be tied to storms and atmospheric rivers. This was particularly noted at Haro Strait (Figure 36-2C).

36.4. Factors influencing trends

Each mooring location differs in its proximity to the commercial shipping lanes, ports/harbours and ferry routes, exposure to wind and offshore influences, and presence of recreational vessels. These factors, as well as bathymetry and sound transmission properties can shape the overall soundscape recordings (see Burnham et al. 2021; Taves et al., Section 37). Understanding the abiotic additions (wind/waves/rain) helps better determine the impact of anthropogenic inputs.

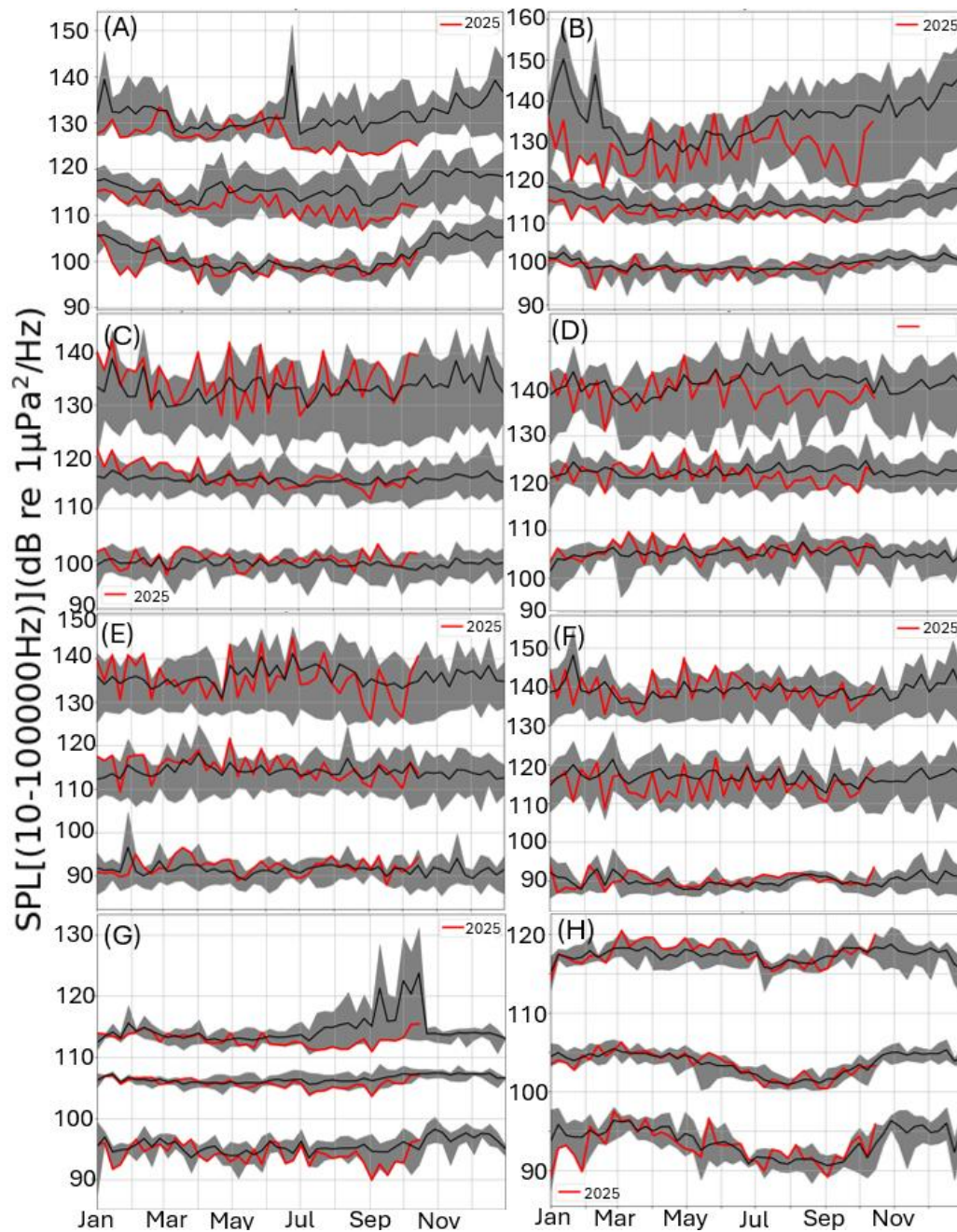


Figure 36-1. Broadband (10-100,000 Hz) weekly median sound pressure levels (SPL) for (A): Swiftsure Bank, (B): Port Renfrew, (C): Jordan River, (D): Sooke, (E): Haro Strait, (F): Boundary Pass, (G): Strait of Georgia South, (H) Strait of Georgia North. Grey shading: difference between minimum and maximum values (grey shading) for 2018 – 2024 (A-F) or 2020-2024 (G-H), with the black line representing the overall average for that period. Red lines = median values for 2025. Note changes in scale y-axis between locations.

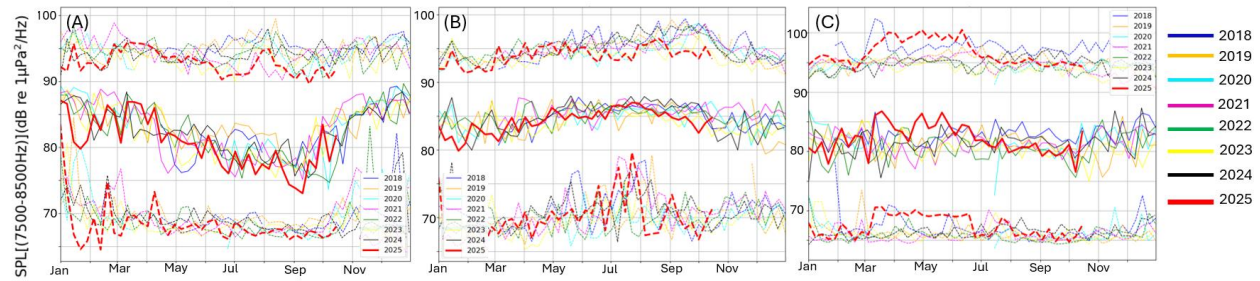


Figure 36-2. Weekly sound pressure levels (SPL) for the frequency range 7500-8500 Hz, representing wind at (A): Swiftsure Bank, (B): Sooke and (C): Haro Strait. **Red lines = values for 2025.** All for background (Q1) (lower), median (Q50)(middle), and noisiest (Q95) (upper lines) sound levels.

36.5. Implications of the observed trends

Spatiotemporal patterns are beginning to be understood for the soundscape in the Salish Sea from the acoustic time series. This sets a baseline from which anticipated vessel transit increases and climate influences can be compared, and estimates of acoustic disturbance to at-risk species made.

36.6. References

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37. SOUND SPEED MEASUREMENTS IN THE SALISH SEA

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37.1. Highlights

- Sound speed measures were calculated from oceanographic data collected at 10 locations in the Salish Sea.
- Seasonal variation was seen in all locations with sound speeds at the maximum in the winter and minimum during the summer.
- Spatial partitioning between sites was evident, with typically slower sound speeds in more western locations.
- Impacts from El Niño conditions from 2023 were evident into 2025 in the Strait of Georgia.

37.2. Description of the time series

Passive acoustic recorders have been deployed in the Salish Sea since early 2018 (see Burnham and Vagle, Section 36). Oceanographic sensors were added to these moorings to measure water properties that define sound speed profiles (Table 37-1). Positioned approximately 2 m from the sea floor, RBRconcerto CTDs were used to measure water conductivity, temperature, and pressure, from which salinity, density, and subsequently sound speeds were derived. Sound speed is important to understand sound propagation and therefore the soundscape characteristics. Measures were taken every thirty seconds throughout each deployment. Data were downloaded and instruments serviced every 3-4 months, and manufacturer calibrations undertaken annually.

Table 37-1. Deployment location, date, and water depth of each of the Salish Sea moorings where conductivity, temperature, and pressure measures were taken (CTD) for sound speeds

Moorings location	Latitude	Longitude	Depth (m)	RBRconcerto CTD data
Swiftsure Bank	48.5154	-124.9360	75	May 2020
Port Renfrew	48.5045	-124.5169	170	Jun 2020
Jordan River	48.3967	-124.1345	120	May 2020
Sooke	48.2901	-123.6552	165	Mar 2019
Haro Strait	48.4959	-123.1931	235	Mar 2019
Boundary Pass	48.7326	-123.1521	180	May 2020
Swanson Channel	48.7390	-123.2557	75	May 2020
Strait of Georgia south east	48.8900	-123.1700	132	Jul 2023
Strait of Georgia south	48.9810	-123.4051	240	Aug 2020
Strait of Georgia north	49.1928	-123.3465	190	Aug 2020

Once retrieved, the data were subject to quality assurance and quality control, data ‘despiking’ processes, and any erroneous data points removed through a standardised procedure. A time-series of near-bottom sound speed observations at each of the deployment locations through time was created. Sound speeds were calculated using salinity, temperature and pressure

measures using the GSW toolbox, TEOS-10 (McDougall et al. 2010). Reference to oceanographic measures, upwelling/downwelling data, and climatic and storm events was made to determine the driver of spatiotemporal patterns. Describing sound speed, and monitoring changes through time and space, aids in the understanding and interpretation of co-located passive acoustic data, helping to determine how sound will propagate in the area.

37.3. Status and trends

The data suggest an east-west division in sound speed properties of the mooring locations, divided by the location of the Victoria Sill. The measures taken from Sooke west to Swiftsure Bank were similar, as were measures from Haro Strait east to the Strait of Georgia (Table 37-1). Sound speeds calculated for Swiftsure Bank and Juan de Fuca Strait locations were typically slower than those to the east in Haro Strait, Boundary Pass and in the Strait of Georgia. Generally, sound speeds decreased during the spring to a minimum in the summer, and then increased during the fall, reaching a maximum in the winter months. The transitions and timing of minimum and maximum events were later for eastern sites compared to western (Figure 37-1).

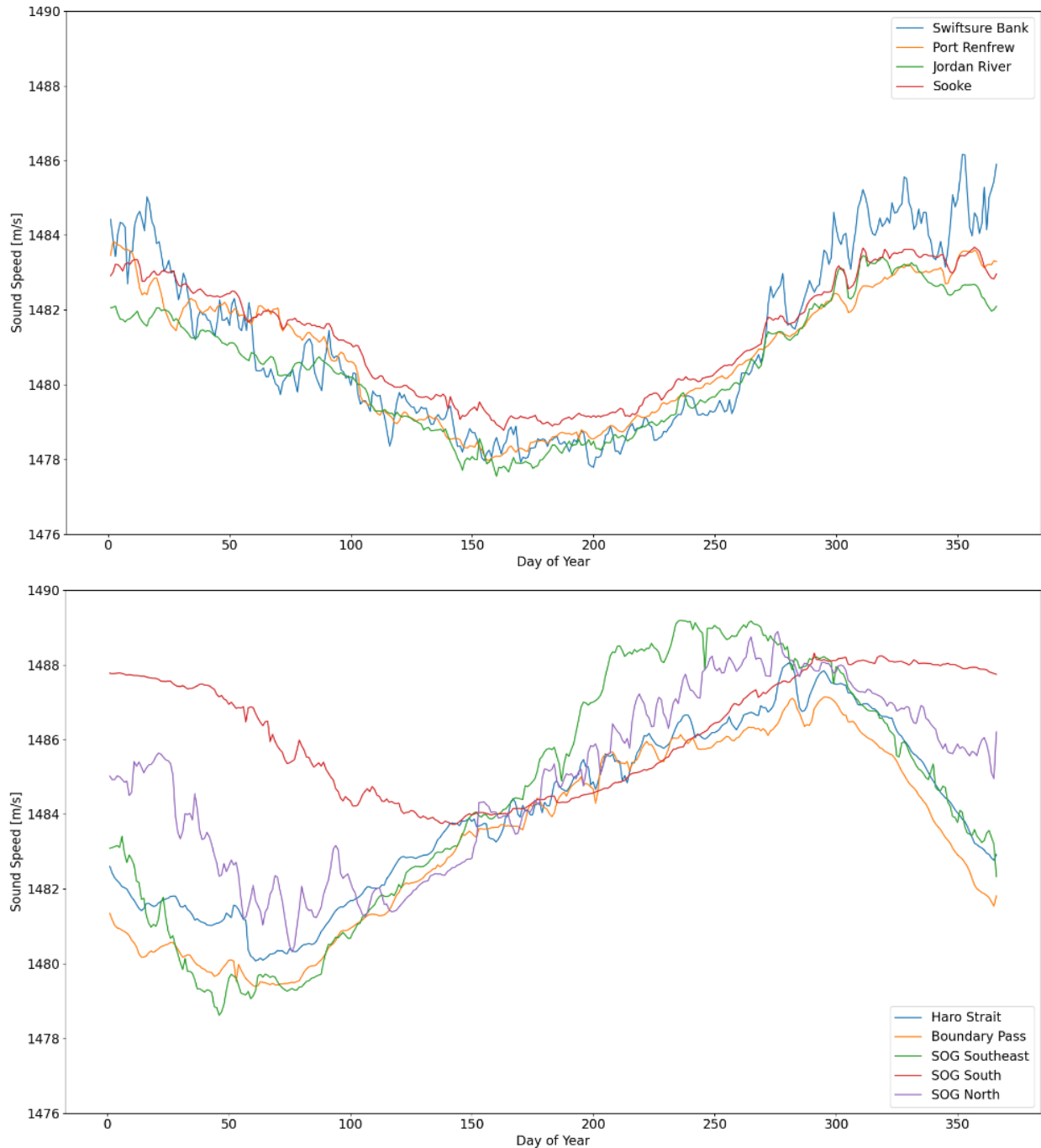


Figure 37-1. Near-bottom sound speeds through longitudinal space for the Swiftsure Bank and Juan de Fuca sites (top) and latitudinal space for Haro Strait to the Strait of Georgia (bottom). Data are daily averages.

Increased temperatures in near-bottom waters as a result of the 2023 El Niño Southern Oscillation (ENSO) reported by Hourston et al. (2024) and Amiri et al. (2024) were evident in the CTD measures and resulted in elevated sound speeds throughout the Salish Sea. Monthly and seasonal averages increased by up to 3 ms^{-1} compared to the same time in previous years. Locations in the western part of the study area, and particularly on Swiftsure Bank, which is open to more offshore influences and water mixing, returned to previous sound speeds by

spring 2024. However, the conditions of elevated sound speeds persisted through 2024, and into the fall of 2025 in the Strait of Georgia.

37.4. Factors influencing trends

As sound speeds are defined by water properties, they can be influenced by estuarine flow, upwelling/downwelling and mixing, tidal turbulence, and larger atmospheric events. The seasonal events in the Salish Sea are dominated by the summer estuarine flow regime, where near-bottom waters move eastward from the west coast, are tidally mixed over the Victoria sill, and eventually transported to the inner waters (Thomson et al. 2007). The spatial differences between locations arise from colder more saline waters from the western sites compared to the typically warmer and fresher waters in eastern locations. Strong downwelling winds in winter, mix warmer and fresher water from the surface to the near-bottom, and estuarine flow transports the near-bottom waters eastward. Broader-scale environmental influences such as elevated temperatures and stronger downwelling under ENSO conditions were seen to influence sound speeds. In the Strait of Georgia, freshet run-off will impact salinity, which could also alter acoustic transmission properties.

37.5. Implications of trends

Both regional water movements and oceanographic conditions, and broader climate-induced variation impacts the sound speed field. As oceans warm and marine heatwaves become more common, sound speeds in the Salish Sea are expected to increase, with the potential to create conditions where anthropogenic noise emissions travel further from the source and contribute to soundscapes over greater extents. This could lead to elevated ambient sound levels generally, and therefore, potentially to greater disturbance of marine life.

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38. SALISH SEA TEMPERATURE, SALINITY AND OXYGEN OBSERVATIONS IN 2025

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38.1. Highlights

- Salish Sea 2025 spring conditions were generally warmer than the 1999-2025 average.
- Summer 2025 conditions were warmer than normal in the Strait of Georgia but cooler than normal in the Juan de Fuca Strait; the whole region was saltier than normal.
- Fall 2025 conditions were warmer than normal, saltier than normal and had lower oxygen concentrations than normal.

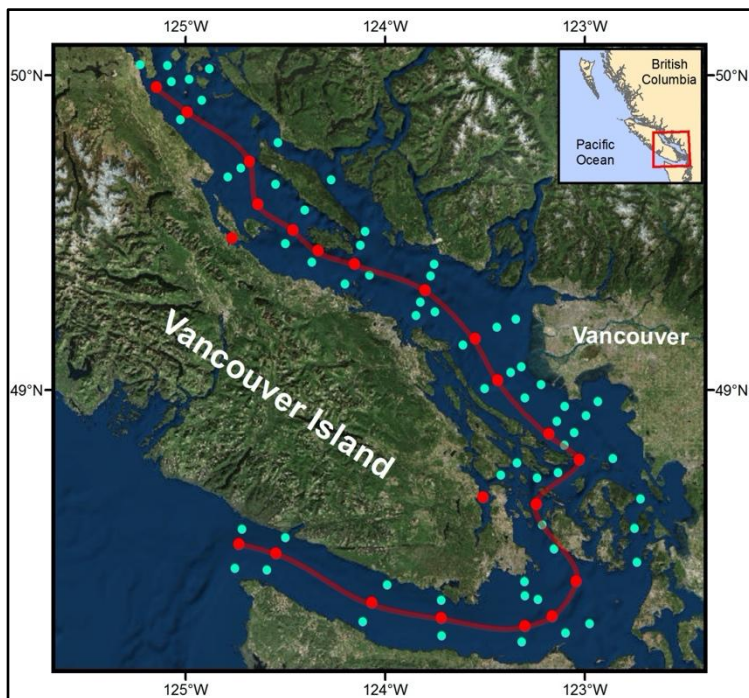


Figure 38-1. Dots show the locations of stations sampled during the Salish Sea Biophysical Surveys. The thalweg is shown as the red line joining the deepest stations along the centre line of the straits.

38.2. Description of the time series

Changes in the water properties of the Strait of Georgia and Juan de Fuca Strait have been monitored regularly since 1999 via a seasonal survey occurring 3-4 times per year. CTD (conductivity-temperature-depth) and oxygen sensor profiles and bottle samples using a rosette are collected at about 80 stations. (25 with bottles, see Figure 38-1). These profiles and samples can be used to study the physical, chemical and biological conditions of the area. The latest conditions and evolution of temperature, salinity and oxygen taken along the main thalweg are presented here.

In 2025, surveys were carried out April 10-15, June 11-17, and October 5-11.

38.3. Status and Trends

Observations of temperature, salinity and oxygen made in 2025 are compared to the 1999-2025 averages (26-year climatology) and shown as anomalies in Figures 38-2 to 38-4. During the April survey, temperature conditions were generally warmer than normal all along the thalweg, particularly in the central and northern Strait of Georgia (Figure 38-2). The salinity was fresher in Juan de Fuca Strait and slightly saltier in the Strait of Georgia. With respect to oxygen, spring conditions were variable, with some regions slightly higher and other regions slightly lower than normal.

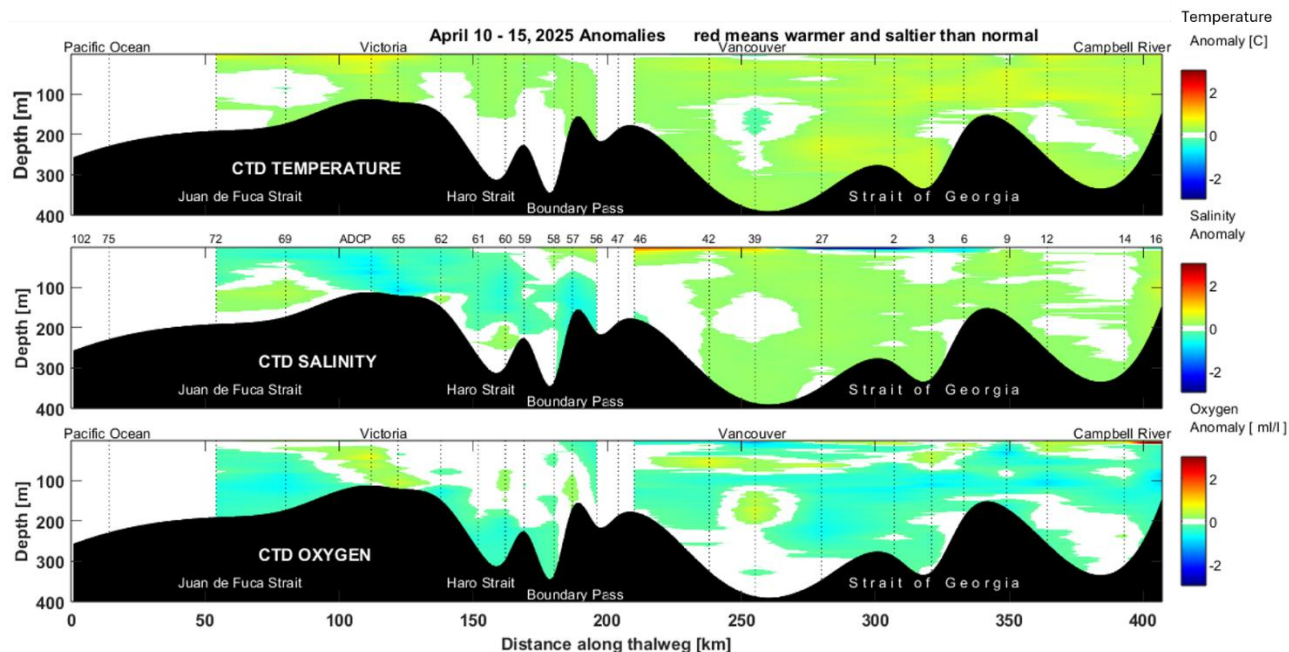


Figure 38-2. Temperature, salinity, and oxygen anomalies along the thalweg observed in the spring of 2025.

In summer, waters were warmer than the 1999-2025 average except in Juan de Fuca Strait and in north and central Strait of Georgia, where waters were colder (Figure 38-3). In addition, waters were saltier and had less oxygen than the average. It is likely that the increased salinity was linked to the low Fraser River runoff observed in 2025 (Giesbrecht et al., Section 7). The decreased oxygen could be linked to the relatively weak 2023-2024 storm season (Evans et al. 2025; Evans et al., Section 17).

The fall of 2025 had a similar pattern to the summer, with waters warmer than the 1999-2025 average everywhere except Juan de Fuca Strait and waters were saltier throughout the survey. With the exception of deep waters in the Strait of Georgia, oxygen concentrations were lower than normal throughout the study area. An eddy was observed centered at around 50 m depth at a station in the western Juan de Fuca Strait, which was characterized by warmer and more oxygenated waters.

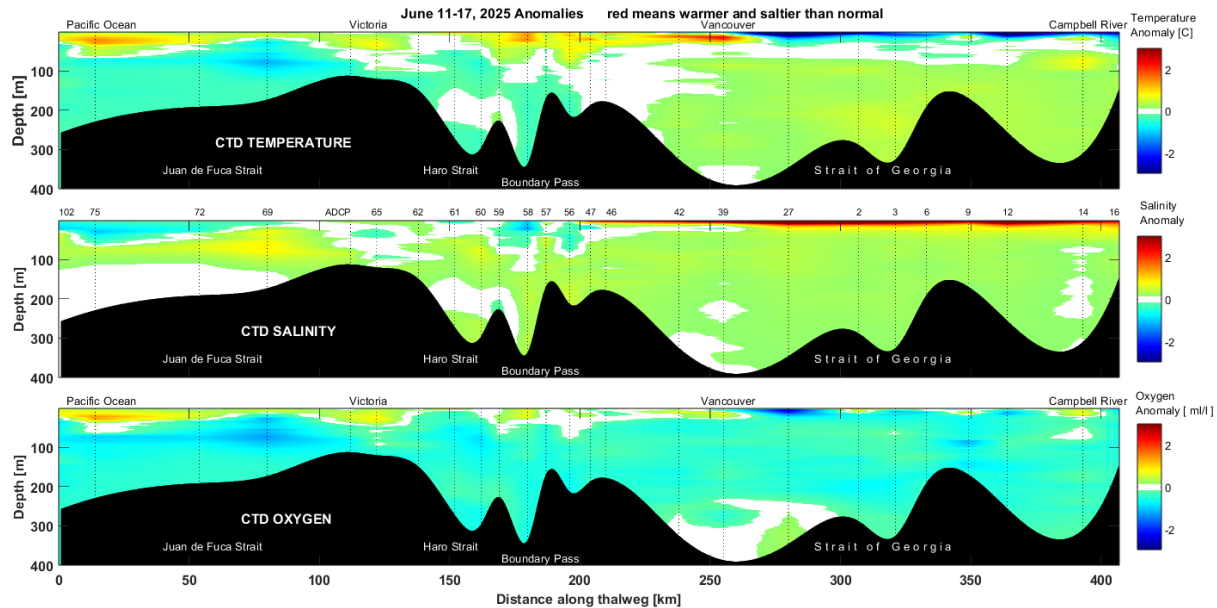


Figure 38-3. Temperature, salinity, and oxygen anomalies along the thalweg observed in the summer of 2025.

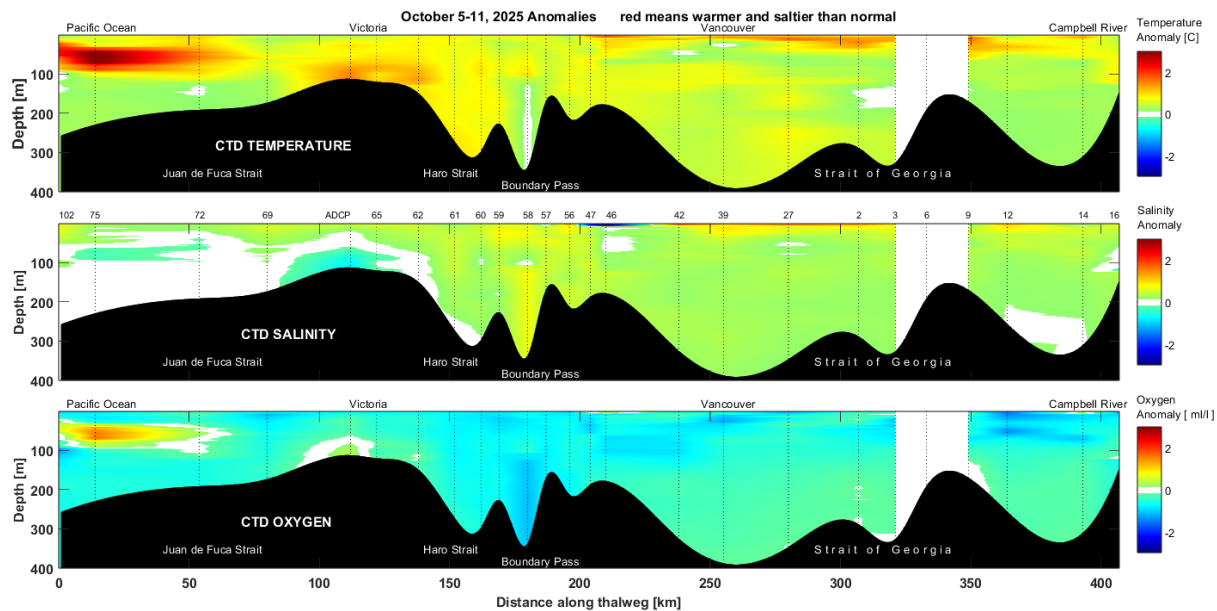


Figure 38-4. Temperature, salinity, and oxygen anomalies along the thalweg observed in the fall of 2025.

38.4. Factors influencing trends

Water properties in the Salish Sea are considerably influenced by ocean conditions at the western entrance of the Strait of Juan de Fuca, and the freshwater discharge of rivers, primarily the Fraser River. In addition to summer warming and winter cooling, seasonal changes occur as cold, salty, oxygen-poor ocean water is upwelled during the summer months, and Fraser River runoff peaks during the early summer. The global trends of ocean warming are reflected directly in the Salish Sea water temperature, and the trend of increased discharge of the Fraser River

as glacier melt increases. The intense tidal mixing that occurs in Haro Strait effectively controls the exchange of water masses between Juan de Fuca Strait and the Strait of Georgia (Masson 2002; Pawlowicz et al. 2007).

38.5. References

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39. SPRING PHYTOPLANKTON BLOOM TIMING IN THE STRAIT OF GEORGIA

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39.1. Highlights

- According to the model, the timing of the spring bloom in the Strait of Georgia in 2025 was early. The spring bloom timing was about a week earlier than in 2024.
- The timing of the 2026 spring bloom was typical according to the model.

39.2. Description of the time series

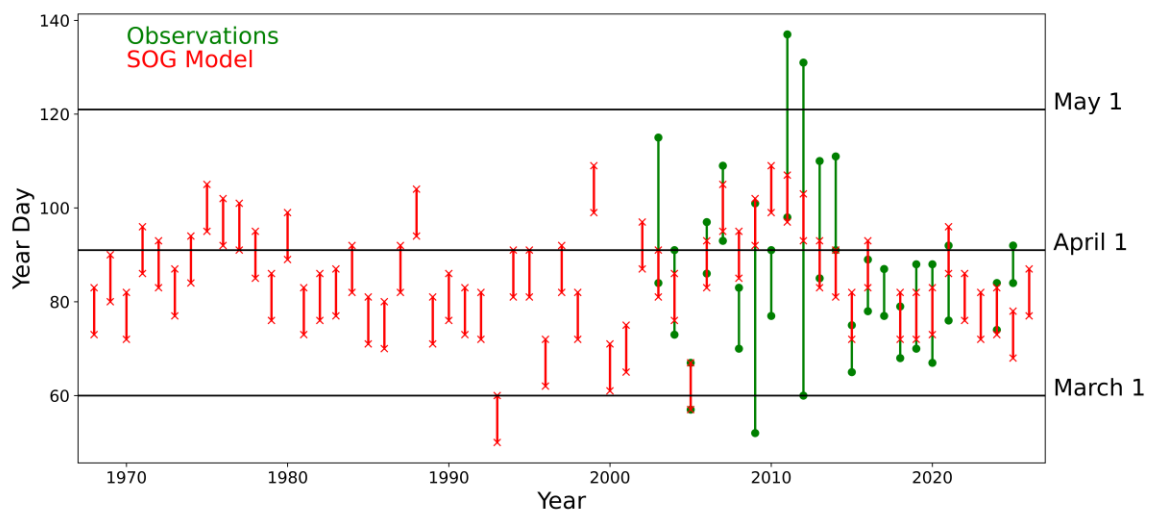


Figure 39-1. Time series of the timing of the peak of the spring phytoplankton bloom. Green- observations from various systems (see Sastri et al. 2019; 2024-5 from R. Pawlowicz personal communication). Red – SOG model.

Here we use a numerical model to show interannual variations in the phytoplankton in the Strait of Georgia (SOG). As described in previous reports, SOG is a vertical one-dimensional physical model coupled to a Nitrate-Diatom biological model (Collins et al. 2009). All lateral oceanographic processes not resolved by the model are parameterized. The model location, STRATOGEM station S3, is on the Tsawwassen to Duke Point ferry route in central SOG (Perry et al. 2021). The model is forced by winds measured at Sand Heads, clouds and temperature measured at YVR (Vancouver) airport, and river flow measurements from the Fraser River and the Englishman River. The Fraser River flow at Hope represents the snow melt dominated part of the Fraser River while the Englishman River represents all other rivers, and the rainfall dominated part of the Fraser River. We have produced a time series of spring bloom time back to 1967 (Allen and Wolfe 2013).

39.3. Status and trends

The 2025 spring bloom happened between March 8 – March 18, 2025, according to the SOG model; estimates from observations are later: March 25, 2025 – April 2, 2025 (Figure 39-1; R.

Pawlowicz, personal Communication). The 2026 spring bloom peaked between March 18 – March 28, 2026, according to the SOG model. For 2026, ferry data is not reliable before April 2.

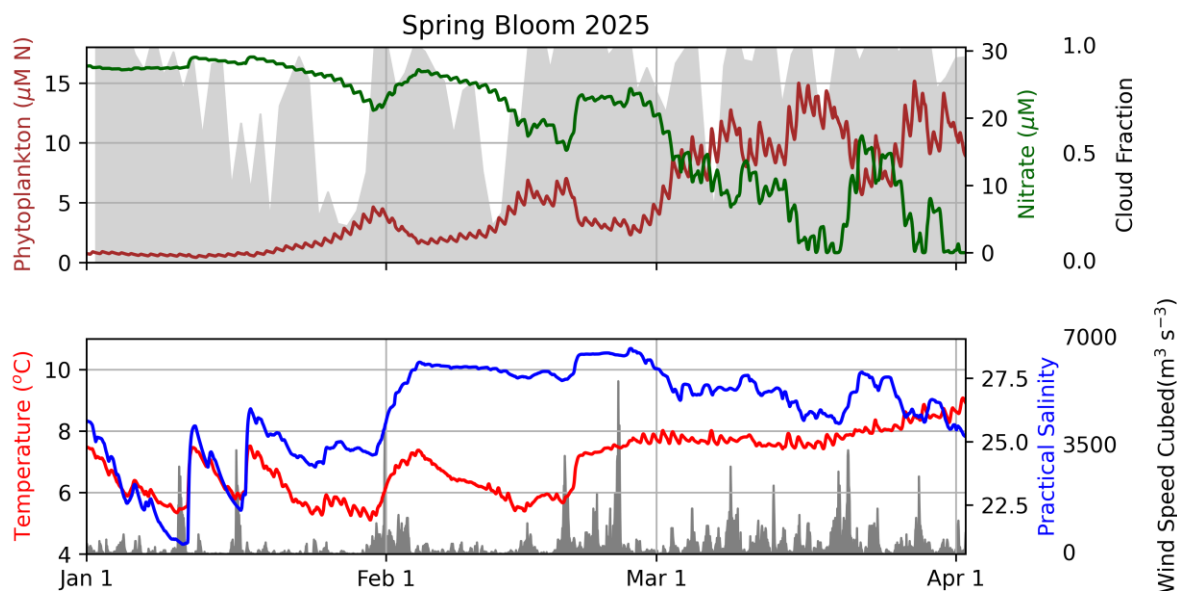


Figure 39-2. Hindcast of the 2025 spring bloom and related conditions in the Strait of Georgia. The lower panel shows temperature (in red) and salinity (in blue) averaged over the upper 3 m of the water column; in grey is the wind-speed cubed which is directly related to the strength of the mixing. The top panel shows phytoplankton biomass (in dark red) and nitrate (in green); in grey is the cloud fraction averaged over the day. The 2025 spring bloom was March 13 plus or minus 5 days.

According to the model, the 2022 to 2026 spring blooms all had similar timing. The mean/median of the SOG timeseries is March 26/27 with the first quartile on March 18 and the third quartile on April 1. All but two of the spring blooms since 2018 have been near first quartile timing. The one exception was 2021, which was late. Importantly, the years, 2022, 2023, 2024 and 2025 have had very similar timing but we did see a shift of over a week later between 2025 and 2026.

39.4. Factors influencing trends

In 2025, after two periods of good growth in late January and mid-February, storms in late February mixed the upper water column and phytoplankton decreased. Moderate winds with moderate clouds led to extended growth throughout March (Figure 39-2). Nitrate was first exhausted in mid-March but then re-introduced by mixing and was exhausted again in late March. According to the SOG model, the bloom peaked on March 13.

SalishSeaCast, a 3-dimensional model of the Salish Sea (Suchy et al, Section 40), allows us to have a spatial view of the 2025 spring bloom (Figure 39-3). The depth-integrated diatoms were high in the central Strait of Georgia, Hood Canal and the northern main basin of Puget Sound. High diatoms coincided with low nitrate. In the northern Strait of Georgia, nutrients were not yet low, suggesting the bloom happened later there.

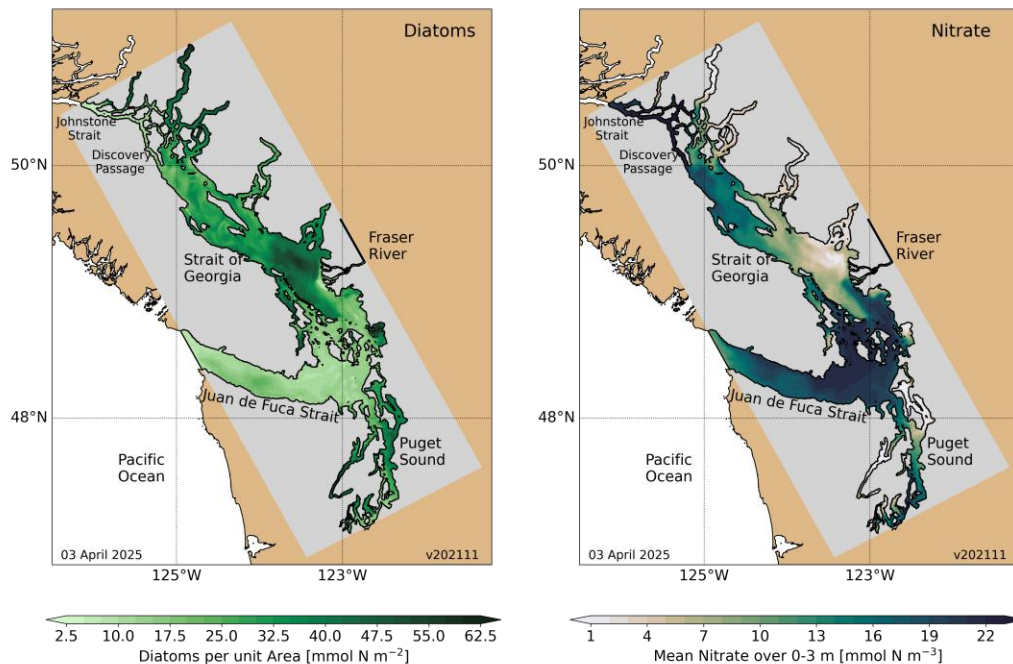


Figure 39-3. The 2025 Spring Bloom spatial distribution, on April 3, according to the SalishSeaCast Model. The left panel shows depth integrated diatom biomass; the right panel shows nitrate averaged over the upper 3 m of the water column; the grey box shows the model domain.

39.5. Implications of those trends

The timing of the spring phytoplankton bloom can impact age-0 herring abundance, with abundance being larger for blooms with typical timing (Boldt et al. 2018). Extreme shifts of timing have led to poor zooplankton growth (e.g., Sastri and Dower 2009) and late spring blooms are also associated with fewer large and medium copepods (Perry et al. 2021). With the 2025 spring bloom early (before the first quartile) but less than a week earlier than 2024, one would expect a good zooplankton year, particularly for large and medium copepods, but potentially lower age-0 herring abundance.

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40. INTERANNUAL SUMMER PRODUCTIVITY IN THE STRAIT OF GEORGIA

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40.1. Highlights

- Summer diatom biomass in the Strait of Georgia in 2025 was slightly higher than the long term mean.
- Zooplankton summer diet was more diatom based than the long term mean.
- Sea surface temperature was slightly warmer and winds were slightly below typical in 2025 compared to the long term mean, consistent with the near-typical productivity.

40.2. Description of the time series

Here we use a numerical model to estimate interannual variations in the phytoplankton and zooplankton in the Strait of Georgia (SoG). SalishSeaCast is a three-dimensional coupled bio-chemical-physical model of the Salish Sea (Figure 40-1). The physical model is based on the NEMO (Madec et al. 2015). Grid resolutions are approximately 500 m in the horizontal and 1–22 m in the vertical, with higher resolution near the surface (Soontiens et al. 2016). The model is forced by realistic winds and solar radiation from Environment and Climate Change Canada's HRDPS 2.5 km model (Milbrandt et al. 2016). River input is based on an empirical fit to local, gauged rivers. The biological model, SMELT, has 3 nutrient, 2 phytoplankton, 2 zooplankton, and 3 detritus groups (Olson et al. 2020; Suchy et al. 2023). The phytoplankton groups are: diatoms, representing both pennate and centric diatoms, and nanoflagellates, representing primarily haptophytes, cryptophytes, and prasinophytes. We present summer phytoplankton dynamics in the central SoG (Figure 40-1) based on version v202111 of the model, for which we now have a 19-year time series (2007-2025).

Previous studies have linked zooplankton biomass anomalies in the SoG to large scale climate indices such as the North Pacific Gyre Oscillation (NPGO; Mackas et al. 2013) and the Pacific Decadal Oscillation (PDO; Perry et al. 2021). Recently, we used SalishSeaCast to show that summer winds are the main mechanistic link between these correlations (Suchy et al. 2025). Summer diatom biomass is typically lower during warm years as weaker winds during warmer summers reduce nitrate flux,



Figure 40-1. Domain of the SalishSeaCast model showing central Strait of Georgia Box used for analysis.

which favours nanoflagellate growth. Warmer sea surface temperatures (SST) also favour the nanoflagellates.

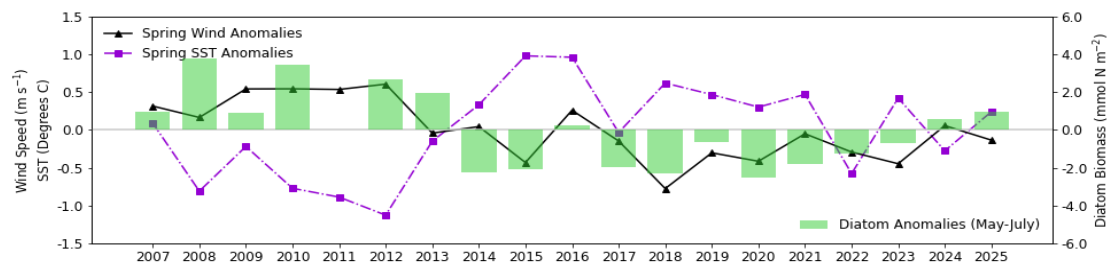


Figure 40-2. Spring (March to May) wind anomalies (black triangles), and spring sea surface temperature anomalies (purple boxes) versus May-July diatom biomass anomalies (green bars) in the central SoG. Note the positive correlation of diatom biomass with winds and the negative correlation with temperature.

40.3. Status and trends

Diatom biomass in the model Central SoG box (Figure 40-1) was integrated over the top 100 m and then averaged over May-July (critical period for juvenile salmon). Diatom biomass anomalies (Figure 40-2) were higher in years with cooler SST and stronger winds than those with warm SST and weaker winds. In 2025, winds, SST and diatom biomass were all close to the long term mean. While slightly weak spring winds and warm SST typically correlate with low biomass, diatom biomass was slightly above typical in May-July.

40.4. Factors influencing trends

Previous to 2024, negative phases of the NPGO were correlated with weak summer winds and warm SST in the Salish Sea (Suchy et al. 2025). Since 2017, the NPGO has been consistently in a negative phase. In 2025, diatom biomass was low in March and high in April and June, similar to NPGO positive (cold-phase) years (Figure 40-3). However, the NPGO was strongly negative in 2025.

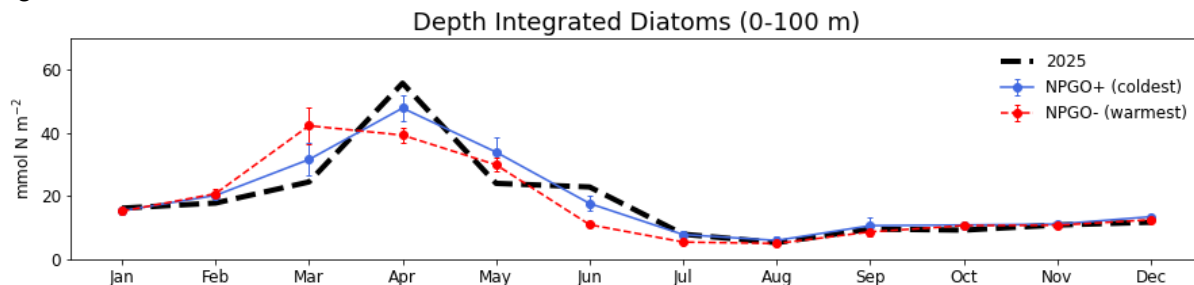


Figure 40-3. Depth-integrated diatom biomass in 2025 (black dashed line) compared to average positive NPGO years (blue) and average negative NPGO years (red) in the central SoG. Note the high biomass in June 2024 more typical of cold years.

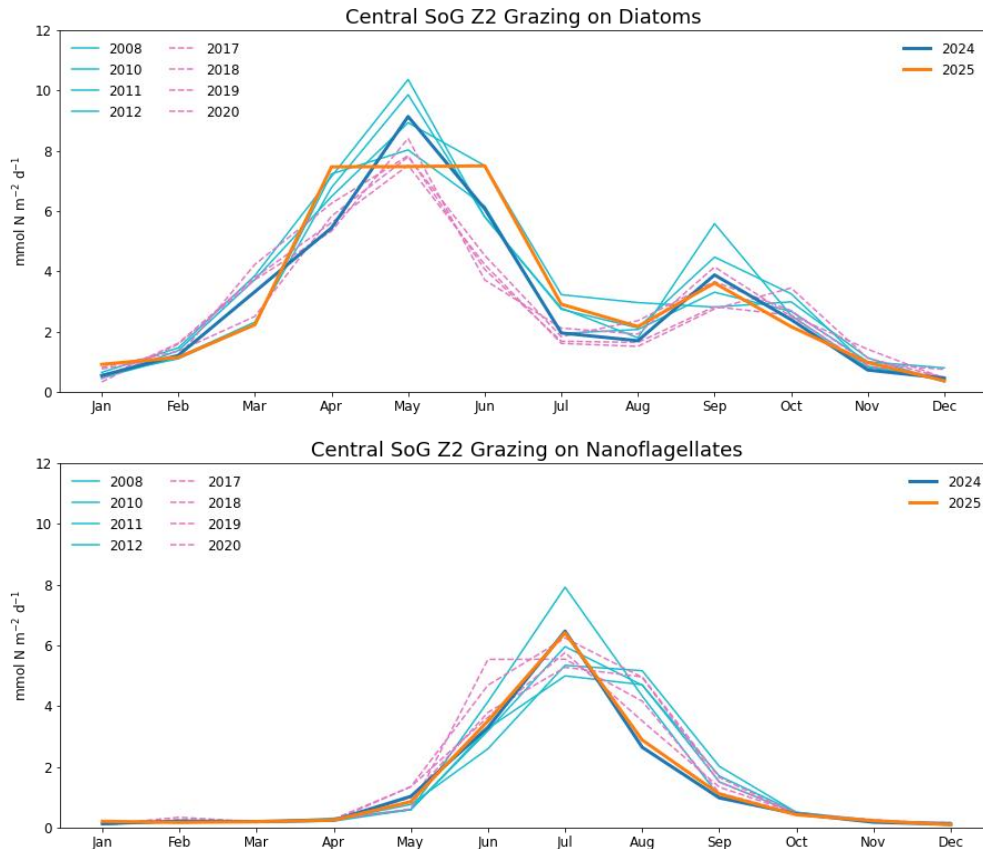


Figure 40-4. Depth-integrated monthly zooplankton grazing on diatoms (upper panel) and nanoflagellates (lower panel) for the four highest NPGO years in the time series (Cold Years, cyan) and the four lowest NPGO years in the time series (Warm Years, pink). Also plots 2024 (blue) and 2025 (orange).

40.5. Implications of those trends

Summer phytoplankton during warm, weak wind years, on average, have fewer diatoms and more nanoflagellates (Suchy et al. 2025). Thus, the food available to zooplankton may be significantly impacted by interannual variations in meteorological conditions. Summer diatom biomass in 2025 was slightly higher than average in the model. As a result, zooplankton in the model grazed on a higher proportion of diatoms in the summer of 2025, more similar to cold years than warm years (Figure 40-4).

40.6. References

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41. OCEANOGRAPHIC CONDITIONS AND HARMFUL ALGAL BLOOMS IN THE STRAIT OF GEORGIA 2025

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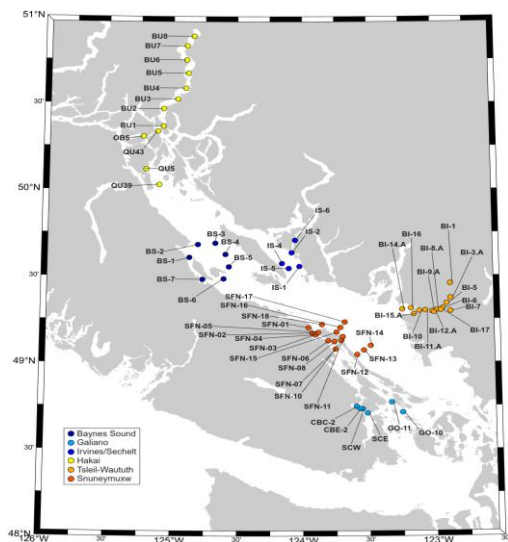
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41.1. Highlights

- The 2025 season was slightly warmer and saltier than the 11-year average, consistent with the lingering influence of weak 2024 El Niño conditions.
- Late-summer thermal (>17 °C in upper ~6 m) and oxygen (<6 ppm below ~25 m) thresholds relevant to salmon were again exceeded seasonally.
- The 2025 season was marked by sustained phytoplankton activity.
- Surface silica concentrations declined to levels not observed in several years, consistent with sustained diatom utilization during repeated bloom events.
- *Alexandrium* (PSP-causing taxa) occurrence and concentrations were very high, while *Dinophysis* (DSP-causing taxa) remained within its typical historical range.

41.2. Citizen Science Program



41.3. Description of the time series

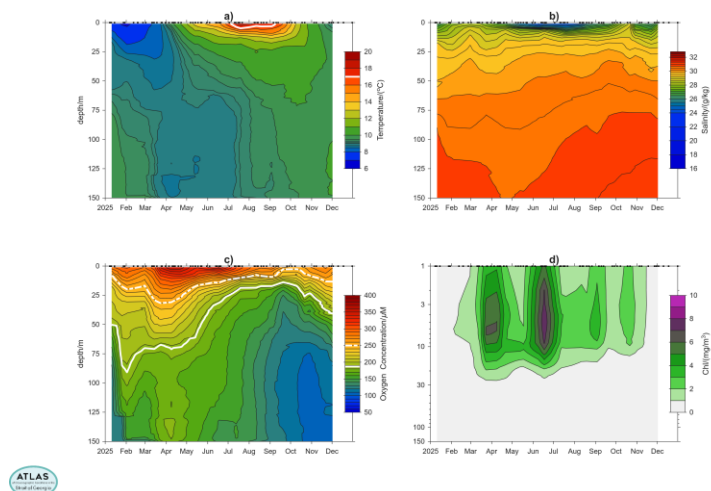


Figure 41-2. Annual cycle for water properties in the Strait of Georgia in 2025. White lines mark conservative physiological boundaries for salmonids (warmest temperature 17 °C, lowest O₂ 6ppm or 187 µM (solid) and 8 ppm or 250 µM (dashed) for instantaneous and 30-day mean limits in approved B.C. Water Quality guidelines for fish at all life stages).

In 2025, CitSci sampling occurred at 18 sites (Figure 41-1) in Baynes Sound, the Gulf Islands, and the Irvine Sechelt area, 2–3 times per month between February and October. Conductivity, temperature, depth, dissolved oxygen, chlorophyll, fluorescence (CTD/O₂/FI) profiles to 150 m depth were collected at all stations for a total of 242 profiles. These were combined with additional stations obtained by the Hakai Institute (92 profiles), the Tsleil-Waututh Nation (176 profiles), and the Snuneymuxw Nation (35 profiles) for averaging purposes. Raw data for all except Hakai profiles were archived and initially processed by ONC ([community fishers web app](#)). Nutrient samples

were collected at two depths (0 and 20 m) at 13 stations (273 samples in total), phytoplankton samples at the surface at all stations (256 samples). Surface seawater and filter samples were also collected at four stations for biotoxin analysis (46 samples) and environmental DNA (26 samples). Sample/measurement processing and analysis was done at the PSF, UBC, ONC, UoT, and DFO. Phytoplankton samples were analyzed on a Sedgewick-Rafter slide; specimens were identified to the lowest taxonomic level possible and enumerated (cells mL⁻¹) for dominant species or groups and species known or suspected to have negative effects on aquaculture in B.C. (Haigh et al. 2004).

41.4. Status and trends

In 2025, the Strait of Georgia had a typical seasonal cycle (Figure 41-2), but was slightly warmer and saltier than the 11-year average, perhaps reflecting the tail end of the weak 2024 El Niño conditions (Figure 41-3). However, the Nov. 2025 atmospheric river rainfall and flooding events can be seen in the reduced near-surface salinity at that time.

As in previous years, oxygen levels were greater than 6 ppm or 187 µM only in waters shallower than about 25 m depth in late summer, and greater than 8 ppm in waters shallower than about 10 m at the same time (Figure 41-2). We highlight a slightly more conservative upper limit of 6 ppm (or 187 µM) and 8 (or 250 µM) for instantaneous and 30-day mean thresholds for salmonids than published values (BCMECCS 1997a, 1997b). Similarly, temperatures greater than about 17 °C are thought to cause physiological stress in salmonids (US EPA 2003) and the upper 6 m of the water column were warmer than this in July and August.

A clear correlation can be seen in deep water temperature anomalies, obtained after subtracting a 2015-2025 seasonal average (and to a lesser degree in near-surface temperature anomalies) with an El Niño/Southern Oscillation (ENSO) index (Figure 41-3). This correlation between temperature anomalies and ENSO is now significantly better than the correlation with the Pacific Decadal Oscillation (PDO) index. Both shallow and deep salinity anomalies, however, are most strongly (and negatively) correlated with the North Pacific Gyre Oscillation (NPGO), and so remained high in 2023-2025. Dissolved oxygen anomalies, especially in deep water, and summer chlorophyll levels are also correlated with the NPGO.

One surprising aspect of 2025 was the recurring phytoplankton blooms over the summer, with additional peaks in June and September, especially around Baynes Sound and waters west of Texada Island (not shown here). Surface concentrations of silicic acid in summer dropped to levels not seen for many years, perhaps associated with diatoms in these blooms (Figure 41-4).

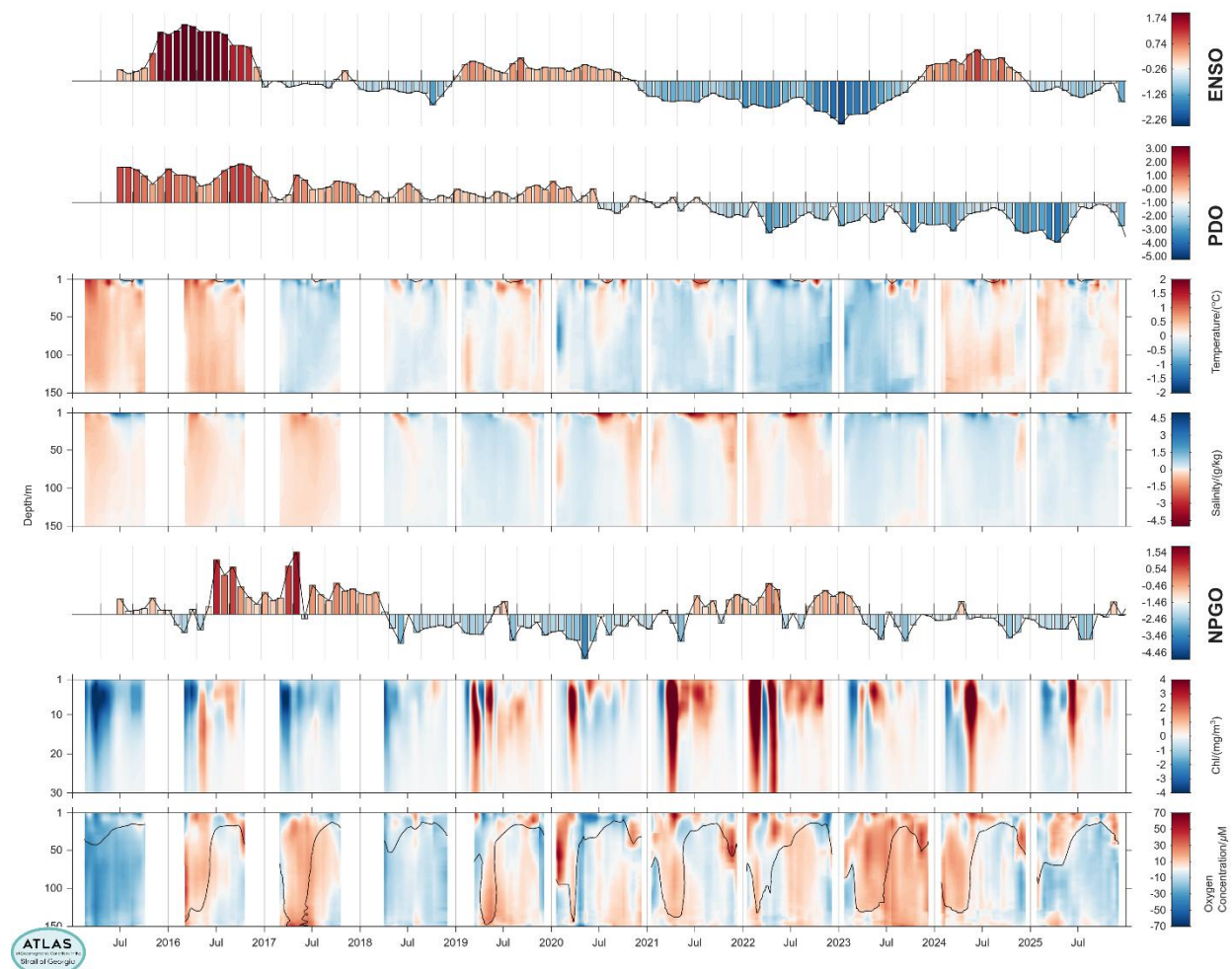


Figure 41-3. Strait-wide trends in water property anomalies from 2015-2025. Red values are higher than a 2015-2025 seasonal average, and blue values are lower (although this has been reversed for salinity). Interspersed are values of ENSO, PDO, and NPGO climate indices relevant to the NE Pacific.

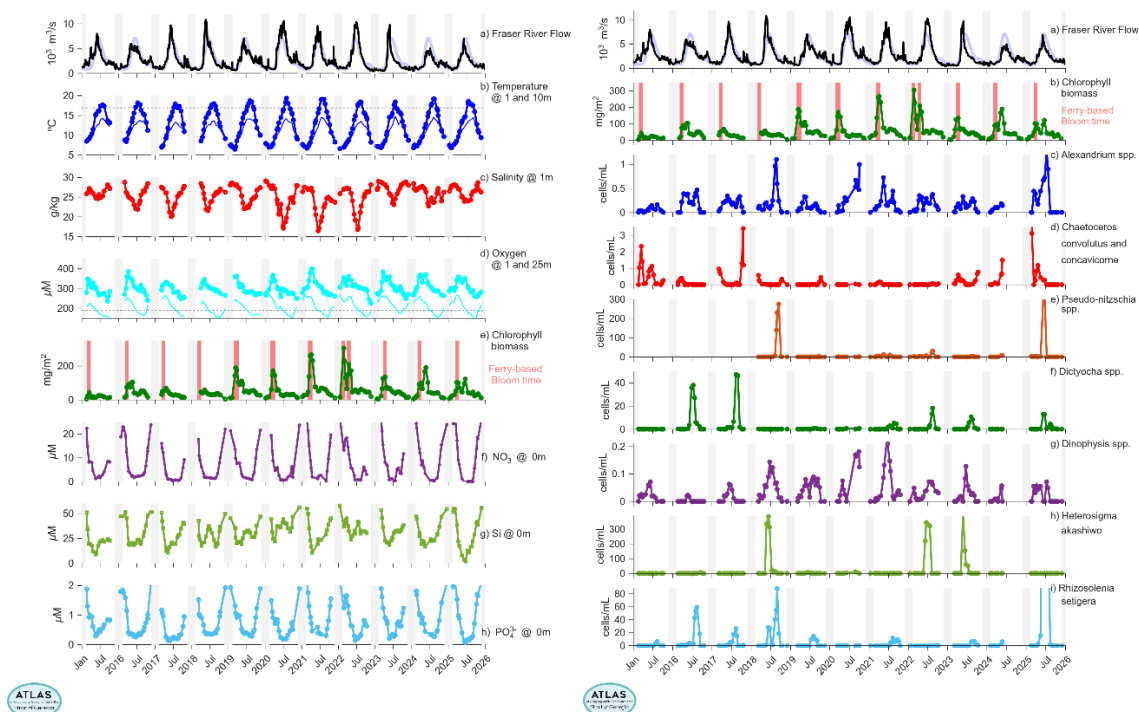


Figure 41-4. Strait-wide trends in average surface properties (left) and average harmful algae (right) over 2015-2025; note that Fraser River flow and Chlorophyll are duplicated in both sides to facilitate vertical comparisons; harmful algae (2015–2024) average based on ~55 sites and 2025 based on 18 sites. Shaded areas represent winter (Dec–Feb). Dotted lines in the temperature and oxygen panels indicate salmonid stress thresholds.

Irvine's Sechelt area: *Skeletonema costatum* concentrations were high at all stations sampled in February (5 of 18 sites in; up to ~600 cells mL⁻¹), lower in magnitude but similar in timing to the atypical February blooms observed in 2015 and 2022, when concentrations reached thousands of cells mL⁻¹. The following spring bloom primarily consisted of a mixture of chain-forming diatoms (*Thalassiosira*, *Chaetoceros*, *Skeletonema*), with surface concentrations reaching very high levels (>1,000 cells mL⁻¹) in March, April, and May in the Irvine Sechelt area and in a few coastal sites in Cowichan Bay and Baynes Sound.

Irvine Sechelt, the Gulf Islands, Cowichan Bay, and Baynes Sound areas: diatoms *Chaetoceros convolutus* / *conconcavicornis* (Figure 41-5), mechanically harmful to fish gills (Haigh et al. 2004), exhibited the highest February–March occurrence in the time series (present in ~9.5% of samples), along with the highest observed maximum concentration (20 cells mL⁻¹), placing it at the upper end of early-spring conditions recorded since 2015. Similar early-season occurrence was observed in 2015 (8.2%; max 13 cells mL⁻¹) and 2017 (8.5%; max 18 cells mL⁻¹).

Similar to many other years (Table 41-1), there were dense (>800 cell mL⁻¹) orange blooms of heterotrophic dinoflagellate *Noctiluca scintillans* in nearshore embayments within the Strait of Georgia (Figure 41-5). However, summer (June–August) occurrence of *Noctiluca scintillans* was unusually high as at least one cell was present in ~10% of the samples compared to usual 0-3% in 2015-2024 suggesting high productivity in the Strait and or trophic imbalance.



Figure 41-5. *Noctiluca* bloom in Brentwood Bay, April 25, 2025 (photo by Michelle Grant) and Kin beach, April 24, 2025 (photo by Oscar Hanke); *Noctiluca* cell under the microscope (photo by S. Esenkulova).

There were numerous summer blooms in 2025, including strong June blooms of diatoms *Rhizosolenia setigera* and *Pseudo-nitzschia* spp., along with moderate silicoflagellate *Dictyocha* spp. and raphidophyte *Heterosigma akashiwo* blooms (Table 41-1), placing 2025 among the higher years for seasonal mean abundance of this taxa. During the June DFO Juvenile Salmon Survey in Toba Inlet, another intense bloom ($\sim 30 \text{ mg Chl m}^{-3}$) was observed and appeared widespread throughout the area (Figure 41-2).

Species from *Alexandrium* and *Dinophysis* genera produce toxins that can cause shellfish poisoning (PSP and DSP) even at very low algae concentrations. Overall, *Alexandrium* spp. was more abundant than in any previous year of the monitoring period (2024 not included in comparison) while *Dinophysis* spp. remained within the typical range observed in past years (Table 41-1).

Table 41-1. March–September mean relative abundance (%) and annual maximum cell concentrations (cells mL^{-1}), indicated in brackets, of selected harmful taxa across Irvine Sechelt, Gulf Islands, Cowichan Bay, and Baynes Sound (2015–2025; 2024 excluded). Note: Years indicating *Noctiluca* blooms are based on CitSc samples as well as opportunistic samples, visual observations, and reported sightings.

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2025
Total number of samples	353	578	592	617	382	401	423	384	306	219
<i>Rhizosolenia setigera</i>	11.61 (250)	26.30 (500)	15.20 (1800)	17.34 (700)	9.69 (280)	0	13.24 (500)	0.52 (15)	5.56 (120)	24.66 (5000)
<i>Pseudo-nitzschia</i> spp.	n/a	n/a	n/a	8.10 (500)	2.88 (6)	4.99 (30)	25.53 (1800)	7.03 (80)	6.54 (350)	21.92 (5000)
<i>Noctiluca scintillans</i>	no	no	no	yes	yes	no	yes	yes	yes	yes
<i>Alexandrium</i> spp.	18.13 (16)	18.86 (15)	24.66 (10)	18.48 (12)	13.35 (10)	19.45 (18)	22.22 (12)	16.93 (5)	15.69 (8)	29.68 (20)
<i>Dinophysis</i> spp.	1.42 (1)	0.35 (1)	3.72 (5)	6.65 (4)	5.24 (4)	2.99 (2)	5.91 (3)	5.47 (3)	3.92 (3)	4.11 (2)
<i>Heterosigma akashiwo</i>	2.27 (6)	10.38 (150)	5.07 (20)	11.83 (5000)	8.90 (25000)	8.48 (7000)	0	7.81 (350)	9.48 (220)	3.20 (1300)
<i>Dictyocha</i> spp.	4.25 (5)	18.86 (700)	29.56 (400)	5.02 (10)	7.85 (8)	9.73 (50)	15.37 (150)	18.49 (130)	15.69 (800)	24.66 (230)

41.5. Factors influencing trends

Phytoplankton dynamics are directly governed by environmental factors. Harmful algae concentrations in SoG are linked to environmental parameters (e.g., temperature, salinity, nutrients, and stratification) and exhibit strong inter-annual and spatial differences (Esenkulova et al. 2021). Variations in oceanographic conditions and phytoplankton influence higher trophic levels (zooplankton and fish), however these links in SoG are not yet fully understood.

41.6. Implications of those trends

Salmonids are vulnerable to warm waters and hypoxia. The SoG was warm and approached the DO limits for salmonids in several areas at the end of summer 2025, although this is not

different than in most years; however, there are interannual changes in water conditions that are linked to the changing climate, and somewhat lower surface salinities in November due to the atmospheric rivers at that time. The 2025 summer season was characterized by a sequence of strong bloom events indicating a prolonged and productive growing season. Harmful algal blooms in the Strait of Georgia have previously been associated with economic losses to aquaculture, impacts on finfish health, and elevated shellfish toxin concentrations (Rensel et al. 2010; Haigh and Esenkulova 2014; Esenkulova et al. 2021, 2022). The co-occurrence of toxin-producing, mechanically harmful, and heterotrophic bloom-forming taxa in 2025 underscores the need to better resolve how environmental forcing, bloom succession, and toxin dynamics interact at seasonal scales. Strengthening knowledge of these linkages remains a critical gap and is necessary to better anticipate bloom impacts on aquaculture, fisheries, and ecosystem health.

41.7. References

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42. ZOOPLANKTON STATUS AND TRENDS IN THE CENTRAL AND NORTHERN STRAIT OF GEORGIA, 2025

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42.1. Highlights

- 2025 zooplankton biomass peaked in May with a secondary peak in September (although there was no survey in July).
- Small copepods dominated by numbers (abundance), but ‘fish food’ plankton (medium-large calanoids, euphausiids and amphipods) had a higher contribution by biomass. Medium and large calanoid copepod biomass trended down but euphausiid biomass trended up in 2025.
- 2025 zooplankton biomass was higher than average and was one of the top five mean total biomass anomalies in the 1996-2025 timeseries (preliminary).

42.2. Description of the time series

Zooplankton samples have been collected at approximately 20 standardized stations monthly from February to October since 2015, with historic (but sporadic sampling effort) data going back to 1996. In 2025, no sampling occurred in July.

We described current trends of abundance (m^{-3}) and biomass (mg m^{-3}) as monthly averages of all samples processed in 2025 in the deep (bottom depths greater than 50 m, and vertical net haul samples which covered over 70% of the water column), central and northern Strait of Georgia (SoG; averaged together, Figure 42-1). Sample processing is ongoing to fill in the other regions, and the results are preliminary.

For historical comparison, the seasonal variability in the zooplankton data was removed by calculating a regional, log-scale biomass anomaly for selected species for a given year. A multi-year (1996-2021) average seasonal cycle (“climatology”) was calculated as a baseline to compare seasonal conditions during any single year. Seasonal anomalies were then averaged within each year to give an annual anomaly (Mackas et al. 2013; Perry et al. 2021). The anomaly data by major zooplankton groups for 1996-2025 can be accessed in the ‘pacea’ R package (Edwards et al. 2023).

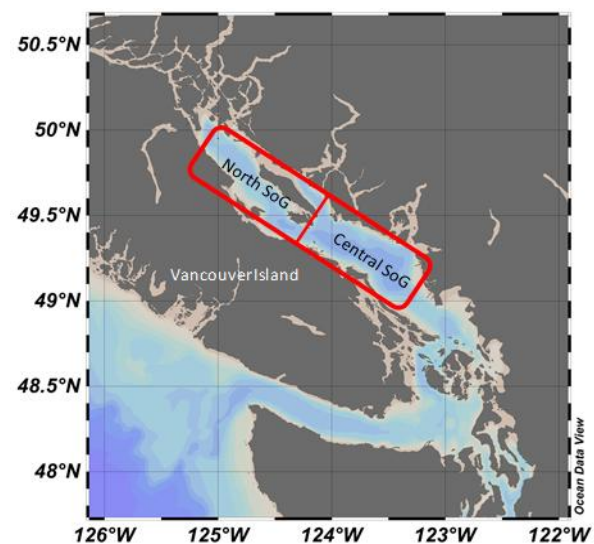


Figure 42-1. The central and northern Strait of Georgia (SoG) shown by the red boxes.

42.3. Status and trends

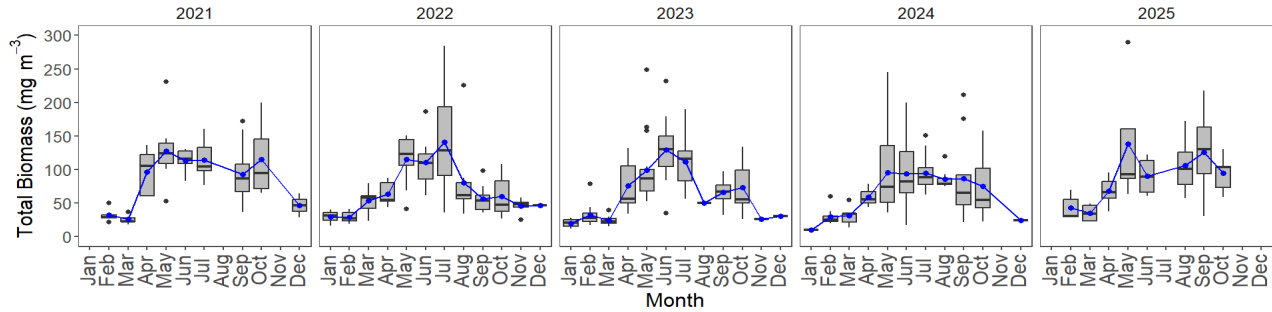


Figure 42-2. Average total biomass (mg m^{-3}) of zooplankton by month in the north and central (averaged together) Strait of Georgia for 2021-2025. Boxplots show median and spread of data, blue dot and line follows the mean biomass.

The total zooplankton biomass in 2025 ranged from $22.15 - 289.61 \text{ mg m}^{-3}$, with the lowest biomass occurring in March (mean 34.73 mg m^{-3} , sd 11.40 mg m^{-3}) and an initial peak in May (mean 138.49 mg m^{-3} , sd 91.90 mg m^{-3}) followed by a second peak in September (125.82 mg m^{-3} , sd 55.44 mg m^{-3} ; Figure 42-2). No sampling occurred in July 2025, which may have missed the typical summer biomass maximum.

Overall, the total biomass anomaly was above average in 2025 and was one of the top 5 years of the timeseries (Figure 42-3).

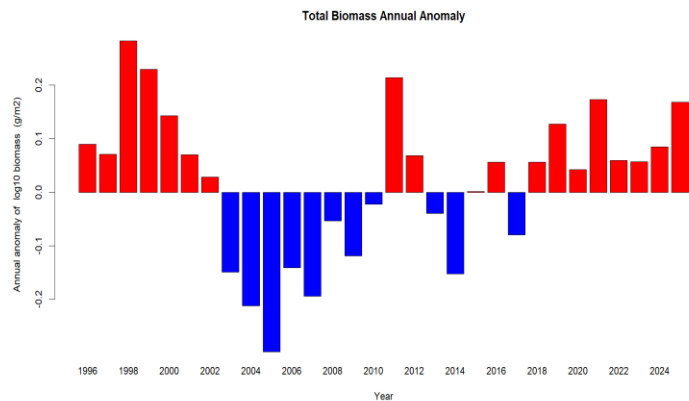


Figure 42-3. Annual biomass anomalies of total zooplankton biomass in the deep waters of the central and northern Strait of Georgia, 1996-2025.

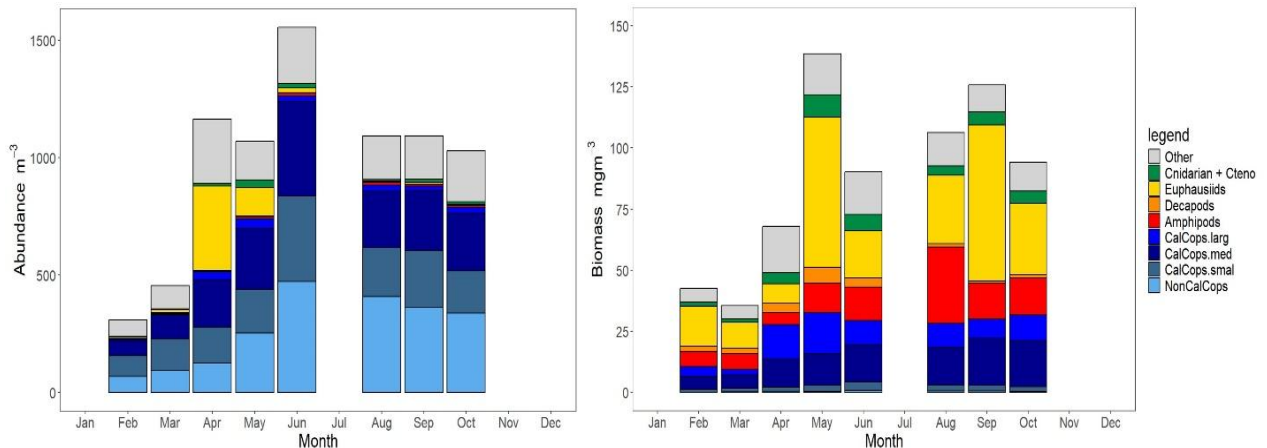


Figure 42-4. Taxonomic composition of zooplankton from northern and central Strait of Georgia in 2025, averaged by month. Left: abundance (m^{-3}); Right: biomass (mg m^{-3}). Legend: CalCops.larg – calanoid copepods, prosome length (PL) $> 3\text{mm}$; CalCops.med – calanoid copepods PL $1-3\text{mm}$; CalCops.smal – calanoid copepods PL $< 1\text{mm}$; NonCalCops – all other copepods; Amphipods – all amphipods (hyperiid and gammarid); Decapod – all decapods (shrimp, crab larvae); Euphausiid – all euphausiids (eggs, larvae and adults); Cnidarian + Cteno – all Cnidarian (medusa and siphonophores) and Ctenophores; Other – everything else: Molluscs, Polychaetes, Chaetognaths, Ichthyoplankton, Larvaceans, etc.

The peak timing of the abundance and biomass of the zooplankton in the SoG varied by species (Figure 42-4), and followed similar trends as previous years (e.g., Young et al. 2025). Copepods, particularly calanoid copepods, dominated the zooplankton by abundance (Figure 42-4, left).

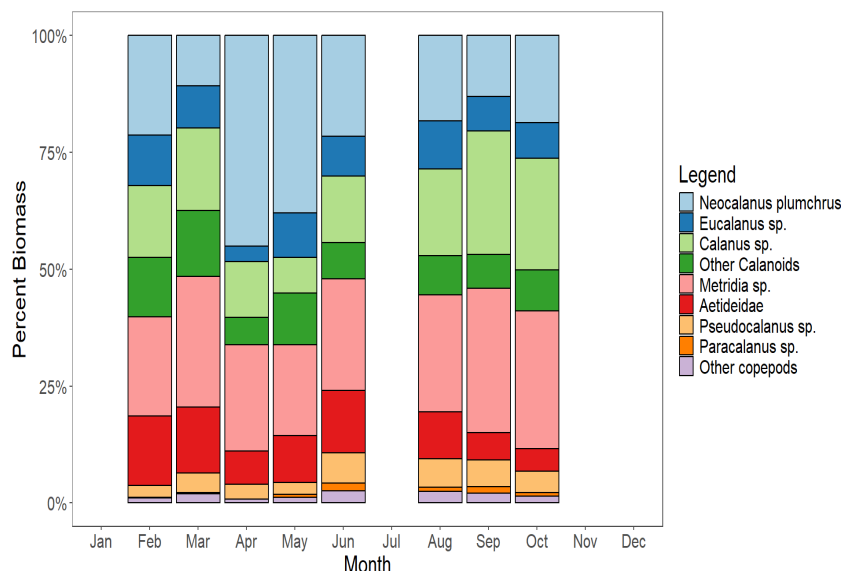


Figure 42-5. Monthly averaged percent biomass of copepods (summarized by major groups) for 2025.

Medium- and large-body calanoid copepods and the larger crustaceans (amphipods and euphausiids) dominated the biomass (Figure 42-4, right). The composition of copepods was similar to previous years with *Calanus* sp. (*C. pacificus* and *C. marshallae*) and *Metridia pacifica* making up the majority of the biomass except in spring (Apr-May) when *Neocalanus plumchrus* contributed almost 50% of the biomass (Figure 42-5).

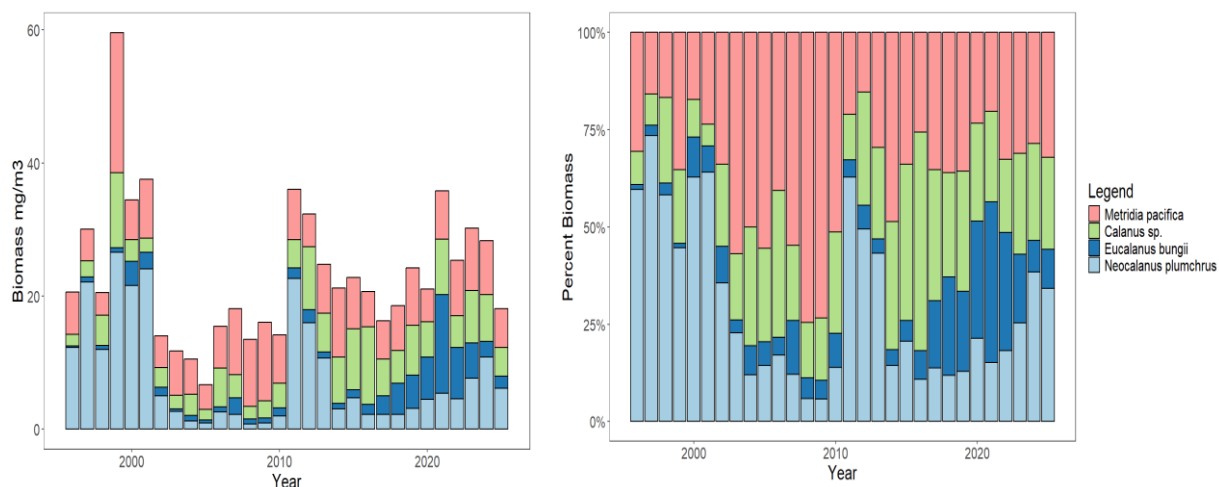


Figure 42-6. Yearly averaged biomass (left panel) and percent biomass (right) of the main medium-large calanoid copepods from 1996-2025.

The overall biomass of the medium-large calanoid group was lower in 2025 than it has been the last few years (Figure 42-6, left). The proportion of *N. plumchrus* and *Eucalanus bungii* of the large-sized copepods in 2025 was similar to 2024 (Figure 42-6, right).

42.4. Factors influencing trends

Trends in zooplankton composition and biomass have been linked to large scale climate indices (Li et al. 2013; Mackas et al. 2013; Perry et al. 2021), as well as local factors such as timing of the Fraser River freshet (Mackas et al. 2013), sea surface salinity and timing of the peak date of the spring phytoplankton bloom (Perry et al. 2021).

42.5. Implications of those trends

Medium and large sized crustaceans (calanoid copepods, euphausiids and amphipods) make up the majority of the total biomass of zooplankton in the SoG, and variations in these groups over time have been shown to be important variables in the modeled marine survival of some Chinook and Coho Salmon populations that enter the SoG as juveniles (Araujo et al. 2013; Perry et al. 2021). A consistent zooplankton monitoring program in the Salish Sea can assist with projections of future abundances of juvenile salmon.

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43. STRAIT OF GEORGIA JUVENILE HERRING SURVEY

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43.1. Highlights

- In 2025, the relative biomass of age-0 herring was below the time series mean.
- Age-0 herring were smaller than average, but their condition was above average.
- In 2025, Northern Anchovy relative biomass was the 2nd largest of the time series (with high variance).

43.2. Description of indices

The Strait of Georgia (SoG) juvenile (age-0) Pacific Herring survey is a monitoring program that samples the nearshore pelagic fish community, the zooplankton community, and physical water column properties. A goal of the survey is to estimate an index of the relative biomass (abundance) of age-0 Pacific Herring as a potential predictor of the abundance of age-3 Pacific Herring recruits estimated in the annual stock assessment model. This index may also represent trends in potential prey availability to Coho and Chinook Salmon and other predators.

Ten standard transects, each with three to five stations (total 48 standard stations), distributed around the perimeter of the SoG, have been sampled consistently during September-October since 1992 (except 1995 and 2020; Thompson et al. 2013; Thompson et al. 2003; Boldt et al. 2015; Figure 43-1). Additional transects were sampled in 2021 (1), 2022 (2), 2023 (1), and 2025 (1; Figure 43-1). Sampling was conducted after dusk when herring were near the surface with purse seine sets at predetermined stations. Species' catch weights were estimated and, in the laboratory, fish were sorted to species, weighed, and measured (nearest mm). The age-0 Pacific Herring index of catch weight per-unit-effort (CPUE and associated variance) was calculated using standard transects and Thompson's (1992) two-stage (transect, station) method and variance estimator (see Boldt et al. 2015). In addition, Pacific Herring condition was calculated as residuals from a double-log-transformed length-weight regression (Boldt et al. 2019). Since 2021, scientific echosounder data were collected at standard transects to supplement the survey. These data and stereo-optic camera collections will be analyzed and published.

43.3. Status and trends

In 2025, 9 of 10 standard and 2 additional southern transects were sampled. Weather prevented sampling of some stations. Age-0 Pacific Herring were caught in 38 of the 49 stations sampled. Estimates of mean catch weights (g), abundance, and CPUE (weight and abundance) of age-0 Pacific Herring varied interannually with no significant linear trend during 1992-2025 (Figure 43-2). The age-0 Pacific Herring indices tended to peak every two or three years, with the peaks occurring in even years during 2004-2012. During 2013-2022, the indices were intermediate-low compared to the peaks in the time series (Figure 43-1). In 2025, indices (using standard transects) decreased from the peak observed in 2023 and were below the time-series average

(for standard and all transects). High estimates of variability are associated with peak index values; the survey coefficient of variation (CV) was 0.49 (Figure 43-2).

Age-0 Pacific Herring length-weight residuals increased during 1997-2012, and were positive in 2005 and 2007-2025 (Figure 43-2). In 2025, Pacific Herring condition was above the time series average; however, in the last 5 years, the average length age-0 Pacific Herring has been below average (Figure 43-2). Energy density was the 2nd lowest, since measurements began in 2012 (Figure 43-2). In 2025, Northern Anchovy were caught in 29 of 49 stations sampled (Figure 43-3). The relative biomass index of anchovy was the 2nd highest in the time series, although the variance around biomass estimates was high.

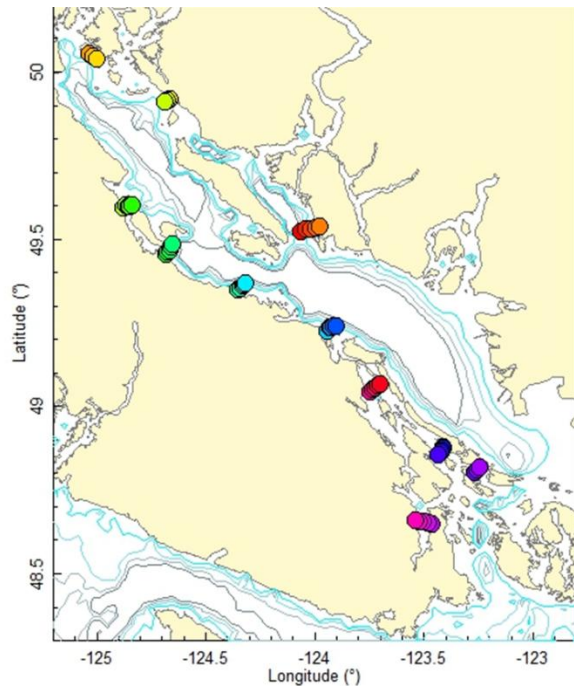


Figure 43-1. Stations sampled during the 2025 Strait of Georgia age-0 Pacific Herring survey (colours represent different transects).

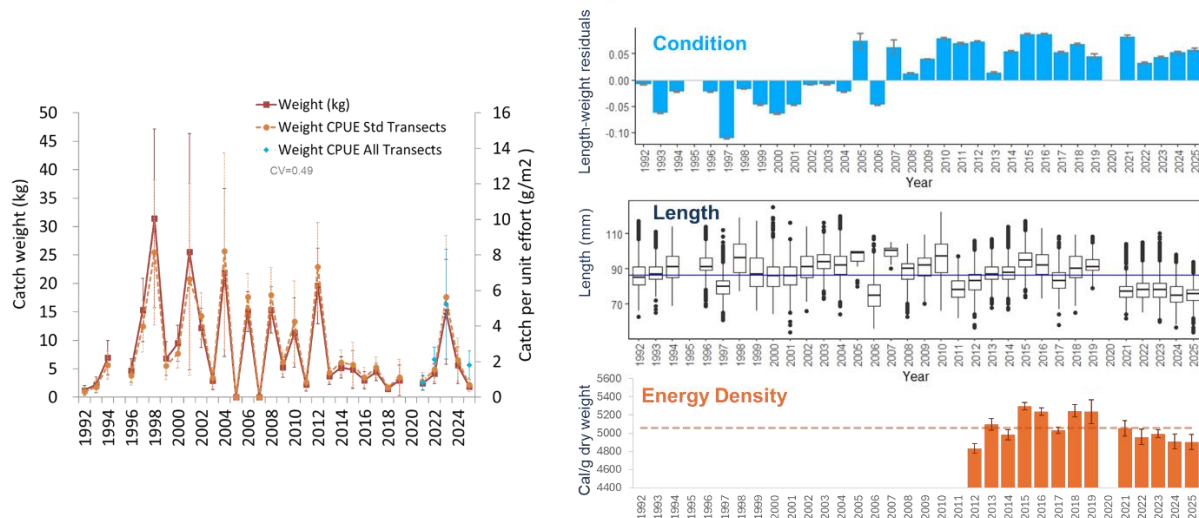


Figure 43-2. Mean catch weight (kg) and catch weight-per-unit-effort (weight CPUE; g/m^2 ; for standard stations (orange) and all stations (blue) sampled; left panel); mean condition (residuals from a double log-transformed length-weight regression; top right panel); mean standard length (mm) (middle right panel); and energy density (bottom, right panel) of age-0 Pacific Herring in the Strait of Georgia. Standard error bars are shown.

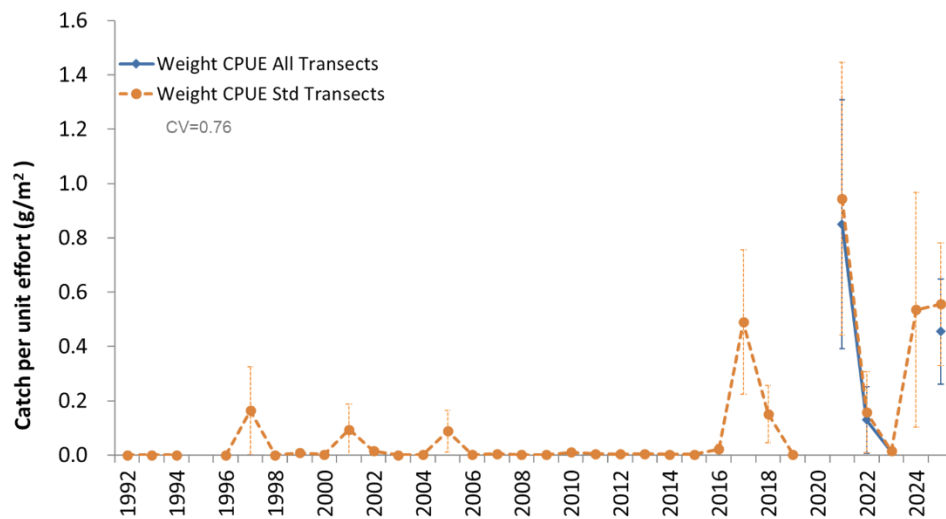


Figure 43-3. Mean catch weight-per-unit-effort (weight CPUE; g/m^2 ; for standard stations and all stations sampled; standard error bars are shown) of Northern Anchovy in the Strait of Georgia.

43.4. Factors causing trends

Bottom-up processes (prey-driven) are the main factors affecting the interannual variability in age-0 Pacific Herring abundance and condition (Boldt et al. 2018). Bottom-up factors include zooplankton prey availability, Pacific Herring spawn biomass, temperature, and the date when most Pacific Herring spawn relative to the spring bloom date. The timing or match-mismatch between spawning Pacific Herring and the subsequent availability of prey to juveniles appears

to be important in determining abundance of age-0 Pacific Herring in the fall (Schweigert et al. 2013; Boldt et al. 2018). No negative effects of the juvenile salmon competitors or predators were detected on age-0 Pacific Herring abundance (Boldt et al. 2018), implying that when conditions are good for age-0 Pacific Herring, they are also good for juvenile salmon species. Herring recruitment and survival has also been linked to water temperatures (Tester 1948; Ware 1991) and bottom-up control of production (Ware and Thompson 2005; Perry and Schweigert 2008; Schweigert et al. 2013).

43.5. Implications of trends

Age-0 Pacific Herring survey indices may provide a leading indicator of low recruitment years. In 2005 and 2007, there were low age-0 and subsequent low age-3 recruit abundances. Juvenile and adult Pacific Herring are prey for piscivorous fish, marine mammals, and seabirds and are important commercial species in B.C.'s coastal waters. Changes in Pacific Herring abundance may affect availability to commercial fisheries as well as the survival of predators, such as Coho and Chinook Salmon. Age-0 Pacific Herring in better condition may be more energy dense (Paul et al. 1998; Boldt and Rooper 2009). Fish that have a higher energy density have an improved chance at surviving reduced feeding opportunities during winter (Paul et al. 1998; Foy and Paul 1999) and they present a more energy-rich prey for predators. Understanding trends in the populations of small pelagic fish species and factors that affect their abundance and condition requires long-term monitoring of the nearshore pelagic ecosystem.

43.6. Acknowledgments

In memory of and with thanks to Doug Henderson for many years of hard work and good cheer as skipper and to Dr. Terrance J. Quinn II for his support with initial analyses. The 2025 Strait of Georgia juvenile herring survey was funded by Fisheries and Oceans Canada; some previous surveys were partially funded by the Herring Conservation and Research Society and the Pacific Salmon Foundation. Thank-you to skipper Barry Curic for helping with the survey in 2025.

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44. EULACHON STATUS AND TRENDS IN SOUTHERN B.C.

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44.1. Highlights

- In 2025, the Fraser River Eulachon egg and larval survey index of spawning stock biomass was amongst the lowest (~8 tonnes) of the timeseries at a level comparable to those in 2004 to 2011, 2016, 2017 and 2022 to 2024.
- In 2025, mean Eulachon catch per unit effort estimates from an annual spring west coast of Vancouver Island multispecies bottom trawl survey declined from moderate levels in 2021 to 2024, with a general lack of fish in the 11-13 cm standard length size range.

44.2. Description of indices

Indices for Eulachon (*Thaleichthys pacificus*) used to monitor population dynamics over time are based on:

- 1) Annual egg and larval surveys characterizing relative spawner abundance from sampling the Fraser River (1995 to 2025) as described in Hay et al. (2002) and McCarter and Hay (2003) with trends over 1995 to 2025 (reported herein), and from sampling the Columbia River (2000 to 2025) as described in the Joint Columbia River Management Staff (JCRMS 2025);
- 2) Eulachon catches and catch samples from the spring small-mesh multispecies bottom trawl surveys off the west coast of Vancouver Island (WCVI, 1973-2019, 2021-2025) with trends over 2000 to 2019 and 2021 to 2025 (reported herein), and from surveys in the Queen Charlotte Sound (1998-2012, 2016);
- 3) Catches of spawning Eulachon from commercial fishing in the Fraser River (1900-2004), and from the Columbia River (1888-2010 and 2014-2015);

44.3. Status and trends

Long-term declines of spawning Eulachon in many rivers have been observed throughout their distribution from California to Alaska in the past 2-4 decades. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed Eulachon in B.C. as three designatable unit (DUs) populations in 2011. The Fraser River and Central Pacific Coast DUs were assessed as endangered, and the Nass/Skeena DU was assessed as a species of special concern (COSEWIC 2011, 2013).

Eulachon is an important indigenous food, social and ceremonial (FSC) resource, and in-river FSC fisheries targeting Eulachon have occurred in years through 2025 (DFO 2026). Commercial fishing for Eulachon has been closed since 2004 but there was an active commercial fishery for Eulachon in the Fraser River for over 90 years until a closure in 1997, followed by temporary openings in 2002 and 2004 (DFO 2026).

In 2025, the index of Eulachon spawning stock biomass in the Fraser River from the 7-week core survey sampling period was estimated to be low (~8 tonnes), comparable to 2022 to 2024 and some of the other lowest estimates in the time series since 1995, such as in 2004 to 2011, 2016 and 2017 (Figure 44-1).

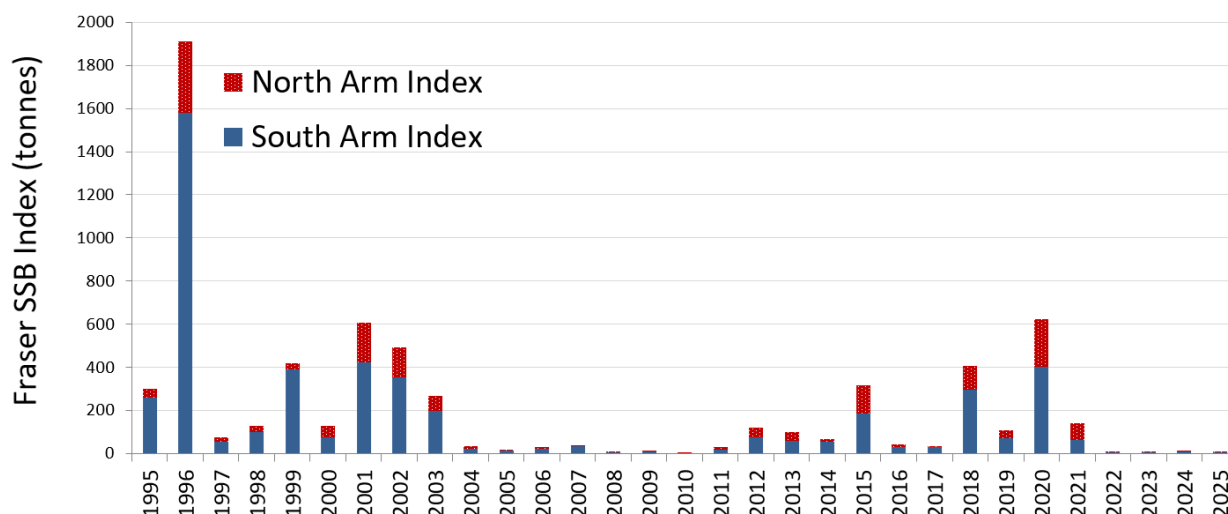


Figure 44-1. Estimated spawning stock biomass indices (SSB in tonnes) of Eulachon from the South and North Arms of the Fraser River, 1995-2025.

In 2025, mean Eulachon catch per unit effort (CPUE) observations from the spring WCVI multispecies trawl survey declined from 2021 to 2024 moderate levels (Figure 44-2). Standard length distributions were represented by statistically weighting fish length by the estimated total number of Eulachon caught in each fishing event and survey year and then standardizing by trawl duration (hours). In 2025, there was a general lack of fish in the 11-13 cm range and most fish caught were greater than 12.5 cm (Figures 44-2 and 44-3).

44.4. Factors causing those trends

There is considerable uncertainty associated with the ecology and stock dynamics of Eulachon. The reasons for the large interannual variation in Fraser Eulachon spawner index observations in recent years are not well understood. The low 2022- 2025 indices were not anticipated, especially given the moderately high marine WCVI CPUE trends in 2021-2024 and the relatively high Columbia River egg and larval survey indices in 2022-2024 (JCRMS 2025).

It is uncertain to what degree spawning stocks of different rivers and cohorts may mix in the marine environment and what may be the inter-annual drivers influencing metapopulation dynamics. There is also uncertainty with the age ranges and compositions comprising the Fraser Eulachon spawning stock each year, due to difficulties ageing Eulachon and limited collection and dissemination of biological sampling information of spawning Eulachon. Furthermore, although it is generally believed that most Eulachon die after spawning, there is some evidence to suggest that some individuals (especially females) may repeat spawn (Dealy and Hodes 2019).

For years of low Eulachon spawner levels, it was stated in Schweigert et al. (2012) that “no single threat could be identified as most probable for the observed decline in abundances among DUs [designatable units] or in limiting recovery. However, mortality associated with coastwide changes in climate, fishing (direct and bycatch) and marine predation were considered to be greater threats at the DU level, than changes in habitat or predation within spawning rivers.”

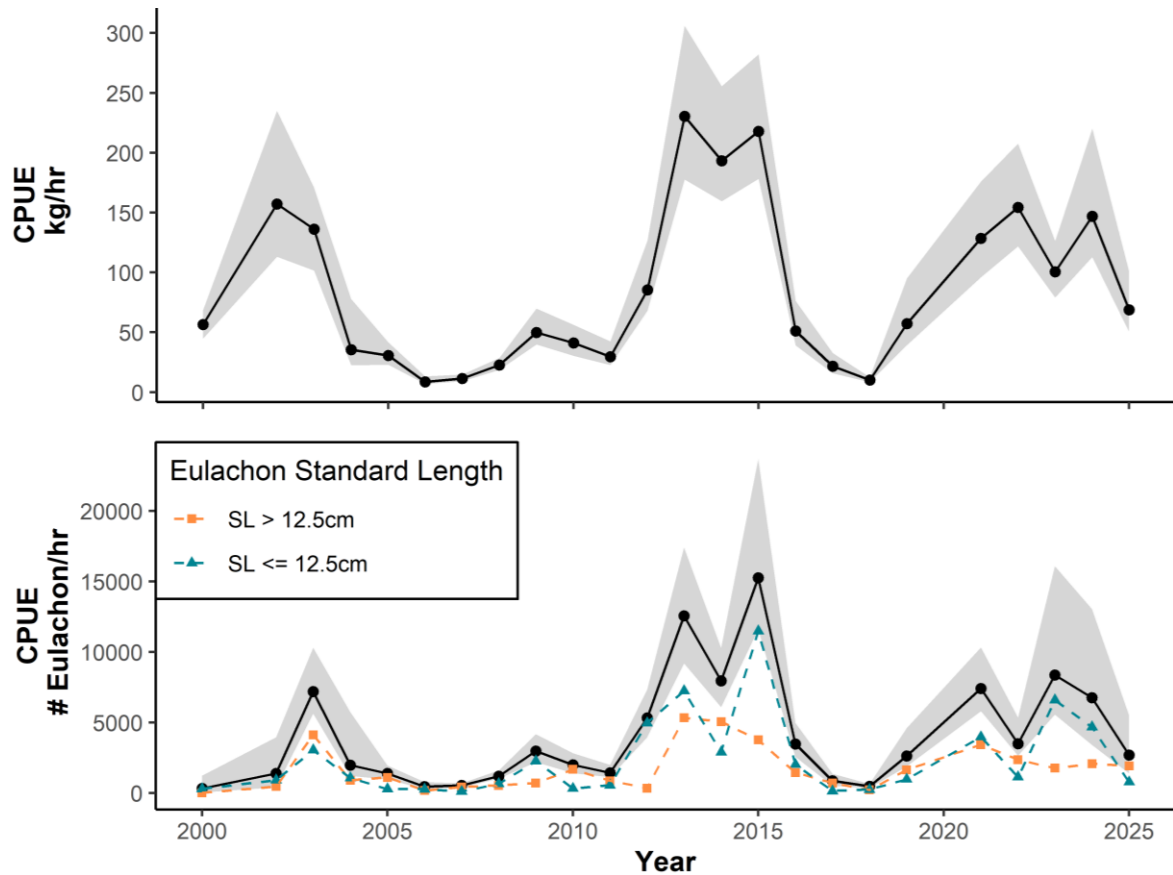


Figure 44-2. Eulachon mean CPUE from spring WCVI multispecies trawl surveys (2000- 2025, no survey in 2020) and 95% studentized bootstrap confidence intervals (gray envelopes), as catch weight per trawl tow duration (kg/hour, top panel) and number of fish per tow duration (bottom panel). Dashed lines represent mean catch number per unit effort of Eulachon greater than 12.5 cm standard length (orange) or less than or equal to 12.5 cm standard length (blue).

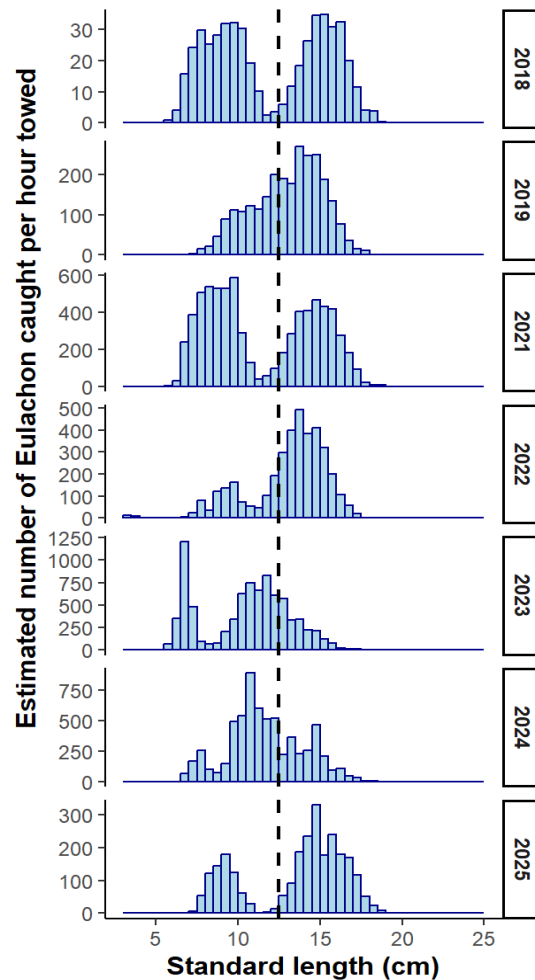


Figure 44-3. Eulachon standard length frequency histograms (in cm) from 2018-2025 WCVI survey samples, from statistically weighting data by the estimated total number of Eulachon caught in each fishing event and standardizing by the fishing duration. Dashed vertical lines are visual markers at 12.5 cm to assist comparisons between positions and shapes of length distributions.

44.5. Implications of those trends

Reduced biomass of Eulachon has negative implications for First Nations, commercial and recreational fishers. Eulachon are socially and culturally significant to many coastal First Nations people who have been harvesting them for millennia. There has been constant or growing interest by First Nation groups to fish and access Fraser River Eulachon but recent low spawner levels have made it difficult for them to achieve their goals (DFO 2026). Commercial and recreational fisheries targeting Eulachon have been closed for over a decade in response to conservation concerns (DFO 2026).

Low in-river Eulachon spawner trends and uncertainties associated with incidental capture rates and stock compositions of marine caught Eulachon by trawl fisheries targeting other species can have negative implications on those trawl fisheries by imposing fishing restrictions such as area and seasonal closures to reduce Eulachon fishing mortality.

Reduced Eulachon abundance likely has negative impacts on their predators. Important predators of Eulachon include: marine mammals (particularly seals and sea lions at or near estuaries), White Sturgeon, Spiny Dogfish, Chinook and Coho Salmon, Pacific Hake, Pacific Halibut, Walleye Pollock, Sablefish, rockfish, Arrowtooth Flounder, and others (Levesque and Therriault 2011). A better understanding of the predators and diets of Eulachon would improve our ability to examine temporal trends in predator-prey interactions and the implications of those trends.

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45. BODY SIZE AND MIGRATION BEHAVIOUR OF FRASER SOCKEYE AND PINK SALMON

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45.1. Highlights

- In 2025, the return of Fraser Pink Salmon was the earliest on record, and a higher proportion of the return followed the southern migration route around Vancouver Island than in any other year on record (i.e., since 1959).
- The length of migration delay of Fraser Sockeye Salmon in the Strait of Georgia in 2025 tied for longest in the time series (i.e., since 1986).
- Body sizes of Fraser Sockeye Salmon and Fraser Pink Salmon in 2025 were smaller than long term averages but larger than the record small sizes observed in recent years.

45.2. Description of the time series

Body size as well as the migration route and timing of mature Fraser River Sockeye and Pink Salmon likely reflect marine conditions and processes during their marine residence. Marine residence time is approximately 17 months for Fraser Pink Salmon, spending one winter at sea, 26-30 months for “2-ocean” Fraser Sockeye that spend two winters at sea, and 38-42 months for “3-ocean” Fraser Sockeye that spend three winters at sea. Data are collected by the Pacific Salmon Commission (PSC) during the homeward migrations of maturing Fraser Sockeye and Pink Salmon (Michielsens and Martens 2022), with fisheries and hydroacoustic methods providing reconstructed daily abundance estimates along northern and southern approach routes around Vancouver Island and in the lower Fraser River (Wong et al. *in press*). Samples from the fisheries provide sex and body size information, in addition to scales for age determination and fin tissue for genetic stock identification (GSI). For Sockeye Salmon, further stock-specific body size measurements are taken on the spawning grounds, together with otoliths for age determination. The resulting time series are briefly described below. More detailed documentation and interactive visualizations can be accessed via Shiny applications on the PSC website – for body size, age, and growth: <https://psc1.shinyapps.io/BioDataApp/>; for run size, timing, and diversion rate: https://psc1.shinyapps.io/PSC_Annual_Fraser/. Estimates are annual for Fraser Sockeye Salmon and biennial for Fraser Pink Salmon (returns of Pink Salmon to the Fraser River on even-numbered years are negligible).

We present the following time series: **diversion rate**, the proportion of the total return migrating via the northern route around Vancouver Island and through Johnstone Strait (1959-2025 and 1953-2025 for Fraser Pink and Sockeye Salmon, respectively); **marine timing**, the median arrival or “50% date” of salmon to Vancouver Island indexed to “Fisheries Management Area 20” in Juan de Fuca Strait (1959-2025 and 1982-2025 for Fraser Pink Salmon and four management units of Fraser Sockeye Salmon, respectively); **Late-run delay**, see below; and **body size anomaly**, the difference from long-term average body size of Fraser Pink Salmon (body weights in purse seine fisheries, 1927-2025) and Fraser Sockeye Salmon (stock- and age-specific lengths on spawning grounds, 1964-2025).

Of the above time series, estimates of Late-run delay are not yet available. Briefly, particular stocks of Fraser Sockeye Salmon have historically and remarkably returned to the Strait of Georgia and delayed their migration, holding off the mouth of the Fraser River for a period of three weeks or more. After this delay, they would enter the Fraser River and continue migrating to their spawning grounds. This characteristic behaviour was thought to have been stable and fixed (Killick 1955) until the mid-1990s, when large proportions of these stocks began entering the Fraser River after atypically short delays and dying without spawning (Hinch et al. 2012). This time series comprises the estimated difference in days between each year's median arrival in the Strait of Georgia and median entry into the Fraser River (1986-2025, for late-returning Sockeye Salmon stocks that historically displayed this behaviour).

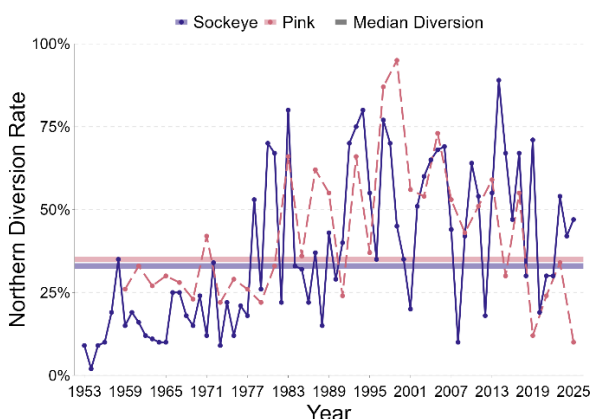


Figure 45-1. Northern diversion rate (percent of salmon returning by the northern route around Vancouver Island and through Johnstone Strait). Estimates are annual for Fraser Sockeye Salmon and biennial for Fraser Pink Salmon.

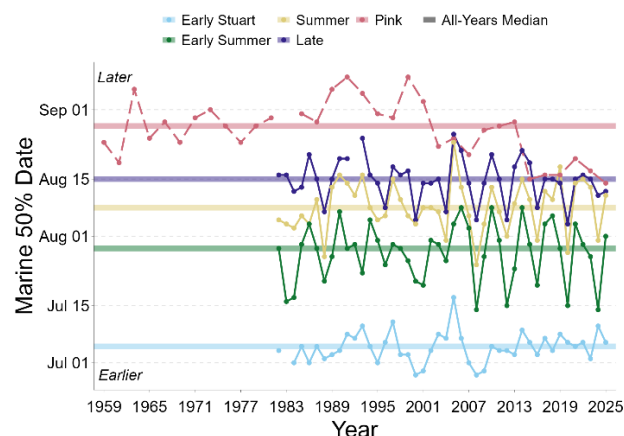


Figure 45-2. Median marine timing (50% date) of Fraser Sockeye and Fraser Pink Salmon. Estimates are annual for each of four Fraser Sockeye management units and biennial for Fraser Pink Salmon.

45.3. Status and trends

Diversion rates of both Sockeye Salmon and Pink Salmon returning to the Fraser River were typically below their long-term medians (33% and 35%) for approximately two decades prior to 1977 and 1983, respectively. A dramatic shift then occurred, characterized by an increase in variability and average diversion through the northern route around Vancouver Island. Recently, Fraser Sockeye Salmon diversion was low in three consecutive years (2018-2020), but not exceptional, and the estimate for 2025 was equal to the historical median since 1980 at 47% (Figure 45-1). By contrast, diversion of Fraser Pink Salmon has reverted to its pre-1983 pattern with the estimate in 2025 being the lowest on record at 10% (2019 was the second lowest at 12%; Figure 45-1).

Marine timing of Fraser River Sockeye Salmon exhibit a cyclic pattern, with early returns of Early Summer-, Summer-, and Late-run Sockeye Salmon occurring every four years on the 2024 cycle (see Figure 45-2). In 2025, the Late-run returned earlier than its historical median date, unlike other Fraser Sockeye Salmon groups, and its marine timing was earliest in the time series excluding the 2024 cycle (1984, 1988, ...2020, 2024). Marine timing of Fraser Pink Salmon was August 29 (the long-term median) or later from 1985-2001. Since 2001, Fraser Pink Salmon marine timing has been early. Six of the seven earliest return dates have occurred

since 2015, and the earliest marine timing in the 33-year time series was observed in 2025 (August 14, Figure 45-2).

Marine timing of Late-run Fraser Sockeye Salmon in 2025 was August 12 (Figure 45-2), but migration into the lower Fraser River was quite late (September 20 median date at Mission), and the estimated delay in the Strait of Georgia in 2025 was 27 days. This was the longest Late-run delay in the time series, tied with 1992. Delay behaviour since 2020 has been more consistent and pronounced than was observed in the middle portion of the time series, centered around the early 2000s, when this characteristic behaviour was often estimated to be absent (Figure 45-3).

Fraser River Sockeye Salmon and Pink Salmon declined in body size from the mid-1970s to mid-1990s, recovered to varying degrees in the 2000s, and exhibited extremely small sizes in some years in the late 2010s and early 2020s (Figure 45-4). Sockeye Salmon that returned in odd-numbered years exhibited more drastic declines than Sockeye Salmon that returned in even-numbered years. Pink Salmon (1-ocean) and both 2- and 3-ocean aged Sockeye Salmon declined in size markedly from the 1970s to 1990s and 3-ocean Sockeye Salmon declined more severely in recent years. In 2025, 3-ocean Fraser Sockeye Salmon were 4th smallest among odd-numbered years in the time series, whereas 2-ocean Fraser Sockeye Salmon and Pink Salmon were 15th smallest and 8th smallest, respectively (see Figure 45-4).

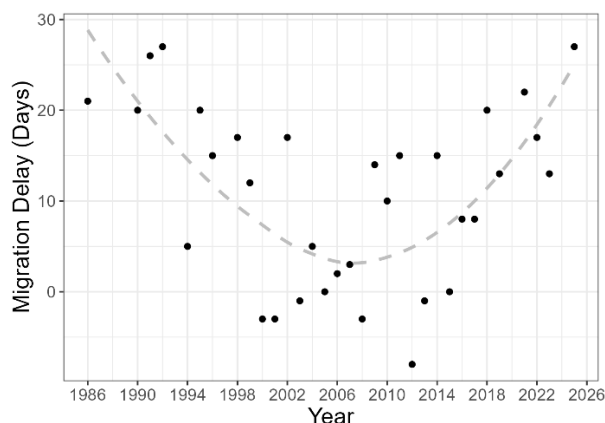


Figure 45-3. Annual estimates of delay of Late-run Fraser Sockeye Salmon in the Strait of Georgia, prior to Fraser River entry, based on daily reconstructed migrations in marine areas and in the lower Fraser River.

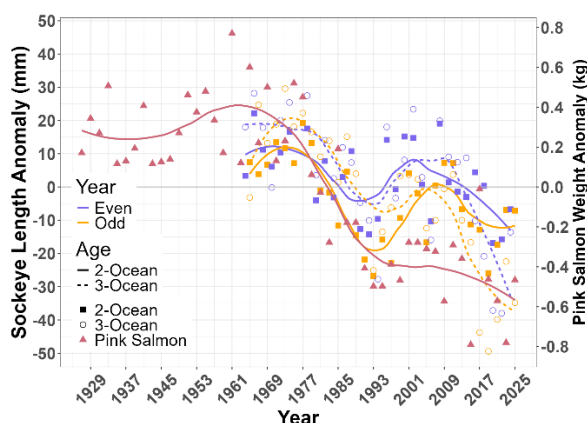


Figure 45-4. Annual body length anomalies of Fraser Sockeye and biennial weight anomalies of Fraser Pink Salmon. Sockeye estimates were differentiated by both age and year of return (odd- versus even-numbered years), and LOESS curves were fit separately to each time series.

45.4. Factors influencing trends

Factors driving migration behaviour and body size in these salmon are likely multifactorial and potentially interdependent, reflecting variable conditions encountered by Fraser Sockeye Salmon and Fraser Pink Salmon during their marine residence. Size at maturity reflects abundance and quality of food items, as well as both direct (i.e., metabolism) and indirect (e.g., abundance and quality of food items) effects of temperature (Cox and Hinch 1997; DFO 2020). Similarly, migration route and marine timing likely reflect variation in rearing locations of these populations within the northeastern Pacific Ocean, which may be directly influenced by temperatures (Blackbourn 1987; Folkes et al. 2018; Wong et al. *in press*) and indirectly influenced through effects of temperature on the distribution of food resources. In addition, body size may be related to migration route and arrival timing by the distribution of food in space and time or by the effect of body size on swimming speed, at least in Fraser Sockeye Salmon (Latham et al. 2024).

Fraser Sockeye Salmon and Fraser Pink Salmon demonstrated congruent changes in both diversion rate and body size from the 1970s to the 1990s (see Figures 45-1 and 45-3), suggesting some shared influences in marine conditions, although they are thought to rear mostly separately (e.g., Neville and Beamish 2022; McKinnell unpublished data). Competition from abundant Pink Salmon is implicated by the smaller Sockeye Salmon body sizes observed in odd-numbered compared to even-numbered years (Ruggerone et al. 2023); also, competition may affect the relative abundances of these species in space, again potentially mediated by temperature (e.g., temperature increases have favoured Pink Salmon; Connors et al. 2020).

Finally, whereas competitive effects may be expected to promote dispersion among populations and species with similar dietary preferences in the open ocean, schooling behaviour during their return has been offered as an explanation of trends in the migratory time series presented here. The “Stay-with-the-school” hypothesis posits contagious group behaviour that is conditional on the frequency of individuals with specific predispositions, particularly with respect to changing Late-run delay (English et al. 2005), but it may also help explain the advancement of marine timing of Fraser Pink Salmon, which do co-occur with some stocks of Fraser Sockeye Salmon as they approach coastal areas near the completion of their marine migration.

45.5. Implications of those trends

The body size of salmon affects their fecundity, their transport of nutrients to the Fraser River and natal spawning grounds, and their value in fisheries. The marine timing and route of their homeward migration affect coastal food webs and fisheries. For example, high northern diversion of Fraser Sockeye Salmon and Pink Salmon is associated with reduced exposure to fisheries in Washington State and increased exposure to fisheries potentially as far north as Alaska (PSC unpublished data). Patterns in migration route and marine timing also have an effect on the spatio-temporal overlap with stocks and species that differ in conservation concern and regulatory constraint (Wong et al. *in press*). For example, potential harvest of abundant Fraser River Pink Salmon has become more constrained, with earlier marine returns promoting increased mixing with Fraser River Sockeye Salmon, including several stocks of concern. Likewise, delay of late-run Sockeye Salmon affects species mixtures in the Strait of Georgia and in the Fraser River. Importantly, increased delay also improves the likelihood of successful spawning, as early river entry results in prolonged exposure to high temperatures and high rates

of en-route and pre-spawning mortality (Hinch et al. 2012). Shortened delay, first noticed approximately 30 years ago, has been extremely consequential, reducing spawning escapements and subsequent run sizes, increasing conservation concern, and motivating severe limitations on allowable harvest. A return to a consistent, lengthy delay may reduce conservation concerns and promote more fishing activity.

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46. ADULT CHINOOK SALMON DIETS AS INDICATORS OF SEASONAL AND ANNUAL FORAGING PATTERNS AND PREY DISTRIBUTIONS IN SOUTHERN B.C.

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46.1. Highlights

- Chinook Salmon stomach fullness was highest in the summer in the Strait of Georgia and on the west coast of Vancouver Island in 2025, similar to previous years.
- Pacific Herring were the dominant prey across most regions and seasons, and age 2+ herring were particularly important in the Strait of Georgia and west coast of Vancouver Island, continuing trends from previous years.

46.2. Description of time series

The Adult Salmon Diet Program (ASDP) collaborates with recreational salmon anglers to sample the diets of adult Chinook and Coho Salmon, providing insight into salmon foraging conditions and forage communities in coastal B.C. (Quindazzi et al. 2020; Greentree et al. 2026).

Digestive tracts of Chinook and Coho Salmon are collected from recreational anglers and fishing guides as well as collaborators including First Nations, creel surveyors, and NGOs. In the lab, prey items are identified and weighed, subsamples are measured, and otoliths are extracted and archived for future analysis.

To investigate spatial and temporal variation in diet composition and feeding intensity, we report 'partial fullness scores' (Magnussen 2011) for all prey categories across regions, seasons, and years. These scores are calculated as $(\text{prey category weight (g)})/(\text{cube of salmon length (cm)}) \times 1000$. Cube of salmon length is used as a proxy for weight when calculating fullness as lengths are more easily and accurately measured by anglers in the field than weights.

Our timeseries is split into two seasons. Winter is defined as October to March and summer as April to September; to prevent splitting the winter season between years, the months of October to December are shifted forward into the following calendar year. Starting in 2019, Chinook retention closures around the Salish Sea have limited sampling in some regions between April and July. To allow for comparison across years, samples collected in these regions and seasons before closures began and during spatially restricted mark selective fishery openings between April and July are removed for the partial fullness index. Six regions are used for this analysis: Gulf Islands/Haro Strait, Strait of Georgia (SoG), Howe Sound, Strait of Juan de Fuca, Barkley Sound, and West Coast Vancouver Island (WCVI) (Figure 46-1.). Salish Sea regions were assigned based on a diet cluster analysis (Greentree et al. 2026).

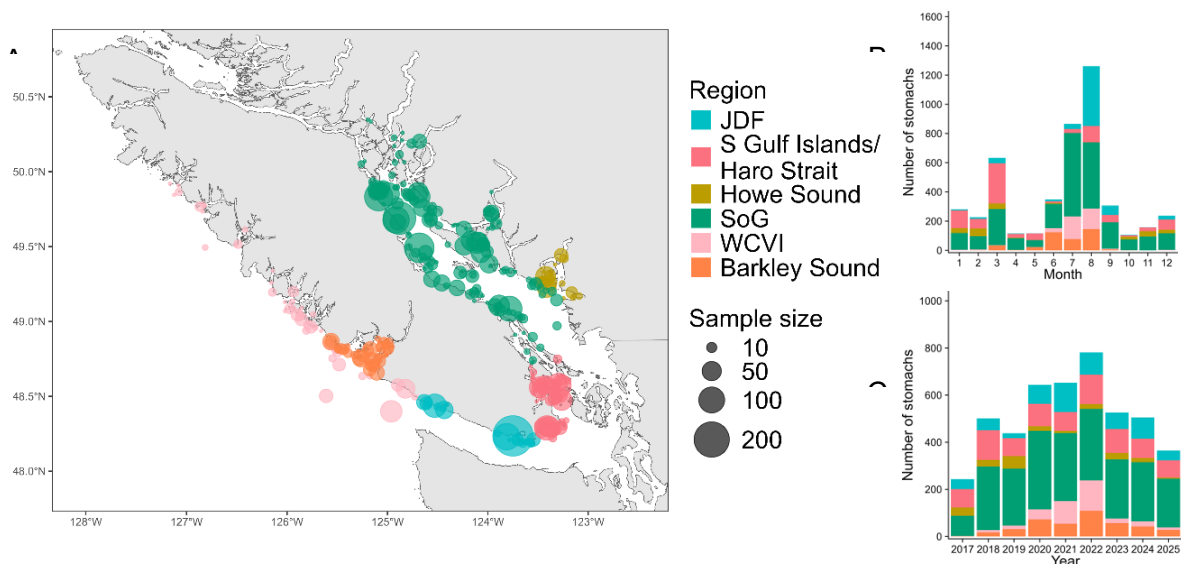


Figure 46-1. Sampling distribution of 4655 adult Chinook Salmon in space (A) and by month (B) and year (C). Colours indicate the five regions used to spatially aggregate samples. JDF = Juan de Fuca; SoG = Strait of Georgia; WCVI = West Coast Vancouver Island. This figure shows all samples processed by the program, not only those included in the time series reported here (see text). Salish Sea regions were assigned based on a diet cluster analysis (Greentree et al. 2026).

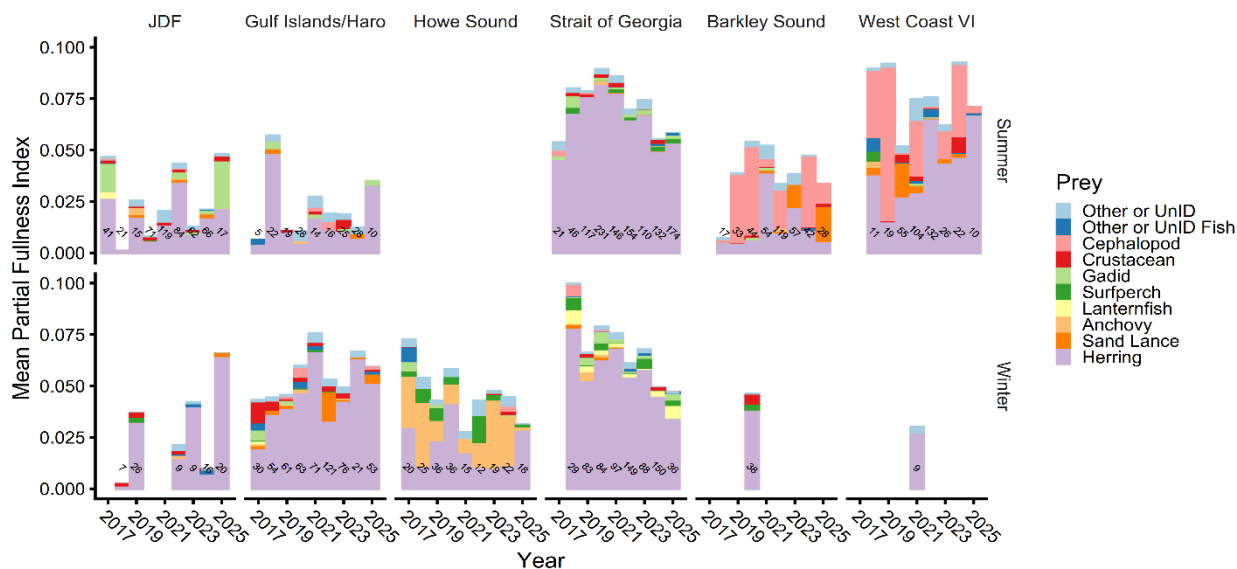


Figure 46-2. Mean Partial Fullness Index of adult Chinook Salmon diets in summer (April- September) and winter (October-March) for five regions (Figure 46-1) of coastal B.C. from 2017 to 2025. Note that data for some periods and regions were removed for all years to account for regional fisheries closures (see text for details). October-December were moved forward to the following calendar year to prevent splitting of a season. Only region/season combinations with more than 3 samples are shown. The sample size is overlaid for each year and region. JDF = Juan de Fuca; SoG = Strait of Georgia; WCVI = West Coast Vancouver Island.

46.3. Status and trends

Trends in Chinook Salmon stomach fullness and diet composition in 2025 were similar though with some variability compared to previous years (Figure 46-2). Chinook Salmon in the SoG had elevated fullness in summer and moderate fullness in the winter. Winter fullness in the SoG has generally declined across years since the timeseries began, and 2025 continued this trend as it was lower than all previous years in the timeseries. As in previous years, fullness in the SoG was heavily dominated by herring. Age-2+ herring (defined as $\geq 145\text{mm}$ standard length or estimated standard length from an otolith width to standard length regression) constituted the majority of the overall mass of herring consumed by Chinook Salmon in the SOG in all seasons (Figure 46-3.).

Pacific Herring were also an important prey item in the Strait of Juan de Fuca where fullness was higher in 2025 than in previous years in both summer and winter. Gadids appear to have been more important in summer in JDF than in previous years, however sample size was relatively small.

In the Gulf Islands and Haro Strait, winter fullness and diet composition were comparable to previous years with herring continuing to be the most important prey species in this region; summer fullness was relatively high in 2025 compared to other years. Prior to implementation of Chinook retention closures in 2019, Pacific Sand Lance were very important in diets from this region between April and July. Exclusion of these months from the data presented here likely leads to underestimation of the importance of Pacific Sand Lance in summer diets in the Gulf Islands/Haro Strait region.

In Howe Sound, winter fullness was moderate, with a lower proportion of Northern Anchovy observed in the diets compared to previous years. The occurrence of anchovy in this region has been observed consistently across years and has also been reported by anglers in the area (Duguid et al. 2019).

Fullness in Barkley Sound in the summer was moderate; squid, sand lance, and herring were important prey items in 2025. As in previous years, there was high fullness in WCVI in the summer and herring were particularly important in 2025; squid appear to be less important in 2025, however sample sizes were small.

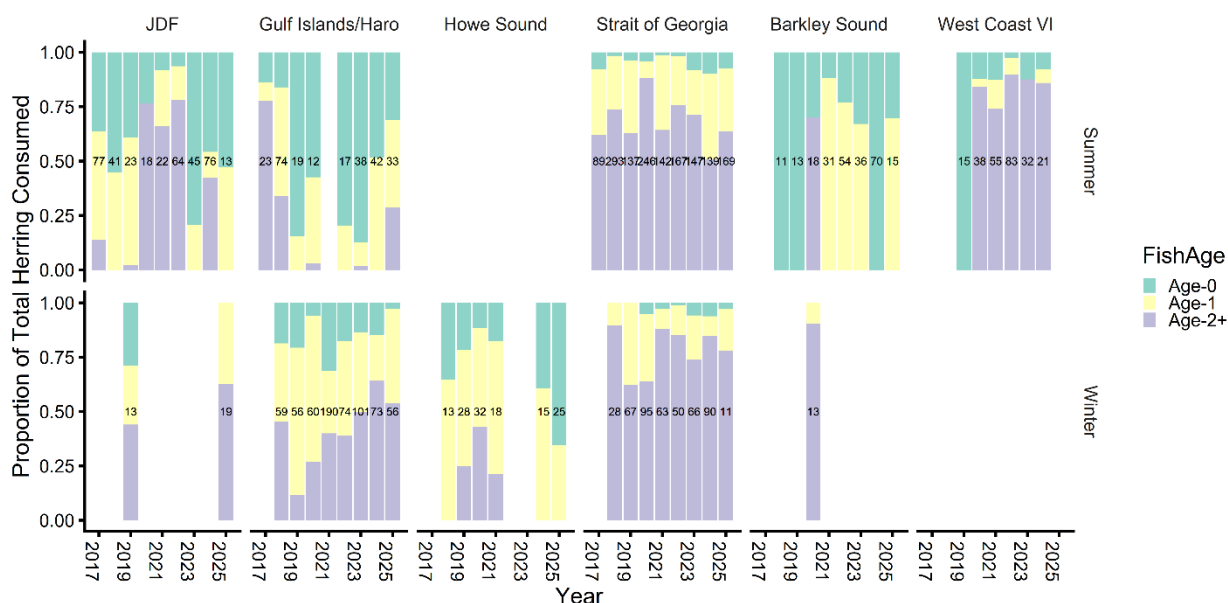


Figure 46-3. Age classes of herring consumed by adult Chinook Salmon proportionally by weight. Proportions are grouped by year, region, and season. Seasons are summer (Apr. 1 – Sep. 30.) and winter (Oct. 1 – Mar. 31). Note that Oct - Dec are not shifted into the following year for this figure as they are in other figures. Only region/season combinations with at least 10 samples are shown. JDF = Juan de Fuca; SoG = Strait of Georgia; WCVI = West Coast Vancouver Island.

46.4. Factors influencing trends

Trends in stomach fullness are likely driven by a combination of food availability (Brodeur 1990) and salmon feeding behaviour. In the S Gulf Islands/Haro Strait and JDF, low summer fullness may be the result of high levels of tidal mixing leading to low productivity and therefore low food availability (McKinnell et al. 2014). However, maturing salmon are known to cease feeding as they return to spawn and S Gulf Islands/Haro Strait and JDF as well as Barkley Sound may act as migratory corridors for maturing salmon that may not be actively feeding during the summer. High summer fullness off WCVI and in the SoG highlight the importance of these regions as summer foraging grounds for Chinook Salmon. The high proportion of herring in diets in both regions points to the importance of herring as a forage species. The high importance of age-2+ herring in diets in the SoG highlights that this region is an important spawning habitat for herring in the winter and may also act as a foraging ground for adult herring in the summer.

46.5. Implications of trends

From 2017-2025, our data on Chinook Salmon diets have suggested relatively consistent regional and seasonal patterns in fullness and diet composition. Shifting environmental conditions as a result of climate change may result in changes in the distribution and abundance of marine fish species globally (Perry et al. 2005). Through continuous monitoring of Chinook Salmon diets, we will be well positioned to detect major shifts in salmon feeding ecology and forage fish distribution and availability that may occur in the waters of B.C.

The importance of herring in Chinook Salmon diets highlights the essential role of herring as a forage species in the Salish Sea. Non-migratory age-2+ herring in the northern Strait of Georgia

are particularly important prey for adult Chinook Salmon and are likely playing an important ecological role as prey for other species.

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47. SEASONAL SPATIAL DENSITIES OF CETACEANS IN THE SOUTHERN SALISH SEA AND ON SWIFTSURE BANK

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47.1. Highlights

- Systematic cetacean surveys conducted from 2020 - 2024 have provided the first effort-corrected, season-specific, and spatially-resolved density estimates for Humpback Whales, Harbour Porpoises, and Dall's Porpoises in the southern Salish Sea and on Swiftsure Bank.
- All three species were present year-round, but showed strong seasonal variability in abundance, density, and distribution with distinct patterns for each species.
- Areas of highest density for Humpback Whales included Swiftsure Bank in all seasons and central and western Juan de Fuca Strait (JdF) in summer and fall. Highest seasonal Harbour Porpoise densities were predicted in parts of eastern JdF, Boundary Pass, and Haro Strait year-round, and the southern Strait of Georgia (SoG, south of Vancouver) in fall through spring. Dall's Porpoise density was highest in the southern SoG in fall and winter, and highest in the western portion of the study area in spring and summer.

47.2. Description of the time series

Systematic boat-based line-transect surveys in the southern Salish Sea and Swiftsure Bank were initiated in summer 2020 to address data gaps regarding the seasonal and spatially-explicit densities of whales and porpoises in this area. The study area encompassed the marine shipping route between Vancouver and Swiftsure Bank, including a 6 km buffer on either side of the shipping lanes, restricted to Canadian waters (Figure 47-1). Surveys were conducted during all seasons, using an equal-spaced zig-zag design with a distance of 18 km between transect line starting points. See McMillan et al. (2022, 2025) for further detail on survey design and methods. Briefly, sightings data were collected from 29 systematic cetacean surveys, conducted across all seasons from 2020 - 2024, comprising over 7,300 km of survey effort.

Density surface models (DSMs) were created for each of the three most frequently sighted species (Humpback Whales (*Megaptera novaeangliae*), Harbour Porpoises (*Phocoena phocoena*), and Dall's Porpoises (*Phocoenoides dalli*)) for each season (defined as winter: January - March, spring: April - June, summer: July - September, and fall: October - December). This two-stage approach using distance sampling data (Miller et al. 2013) first modelled how the detectability of each species was affected by distance from the transect line and by environmental conditions (Buckland et al. 2001; Marques et al. 2007). Survey data were then divided into segments of continuous effort, and the counts per segment were adjusted for detectability. The resulting density estimates were used as the response variable in generalized additive models to predict how density varies throughout the study area as a consequence of environmental covariates (e.g., slope, depth, sea surface temperature; Miller et al. 2013).

These surveys and spatial modelling yielded effort-corrected, season-specific density maps throughout the Canadian portions of the southern Salish Sea and Swiftsure Bank.

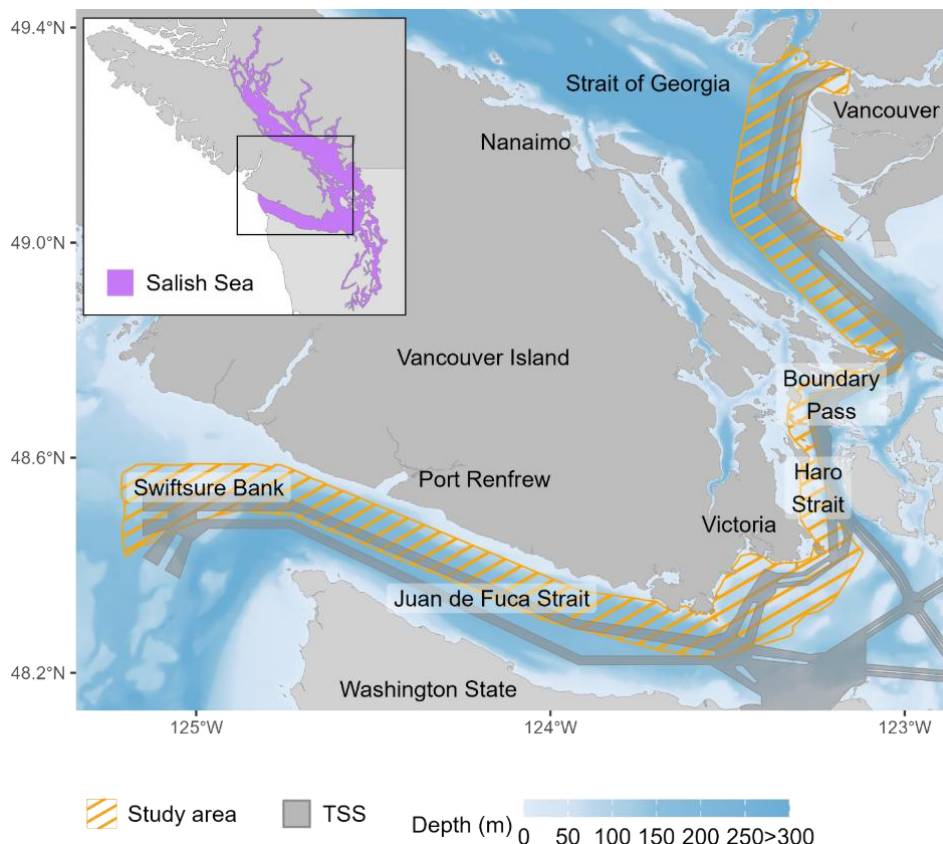


Figure 47-1. Study area for systematic cetacean line-transect surveys conducted between August 2020 and August 2024 (yellow diagonal lines) and locations of the inbound and outbound shipping lanes (traffic separation scheme (TSS), grey shaded area). The Salish Sea is indicated in purple in the inset.

47.3. Status and trends

Humpback Whales

Humpback Whales in Canadian Pacific waters were severely depleted by commercial whaling until 1967. As recently as 2004, no Humpback Whales were detected during summer marine mammal surveys conducted in this area (Williams and Thomas 2007). Humpback Whales are now present in the Salish Sea year-round, with estimated seasonal abundances increasing from a low in winter of 17 (95% CI: 9-34) to a high in fall of 416 (270-641) individuals (McMillan et al. 2025).

This time series provides additional insight into the year-round habitat use of Humpback Whales in the southern Salish Sea, noting that the western portion of the study area, including Swiftsure Bank, is important for Humpback Whales year-round (Figure 47-2). Highest densities are limited to the western portions of the study area in spring, extending into JdF in summer (up to 0.31 whales per km²), and are found in large numbers throughout the study area in fall with up to 0.91 whales per km² on Swiftsure Bank and central and western JdF. The waters of the southern

SoG, south of Vancouver, were predicted to have higher densities of Humpback Whales during fall compared to any other season.

Harbour Porpoise

Harbour Porpoises were present in relatively large numbers year-round in parts of the southern Salish Sea at least through the 1940s, followed by a period of very few sightings in the 1970s to 1990s (Elliser and Hall 2021). In U.S. portions of the Salish Sea, Harbour Porpoise density increased rapidly from 1994 – 2014 (Evenson et al. 2016) and the Canadian portion of the Salish Sea had an overall predicted density of 9.95 individuals per 25 km² in summer 2018 (Wright et al. 2021). In 2020 - 2024, we estimated that the season-specific densities of Harbour Porpoises in Canadian portions of the southern Salish Sea and Swiftsure Bank were highest in fall at 12.04 (8.29 – 17.48) porpoises per 25 km², and lowest in winter at 5.16 (3.11 – 8.56) individuals per 25 km² (McMillan et al. 2025).

Harbour Porpoises were the most frequently sighted cetacean species in all seasons. Areas of highest Harbour Porpoise density included Haro Strait, Boundary Pass, and eastern JdF year-round (Figure 47-3). Parts of the southern SoG were also predicted to have high densities of Harbour Porpoise in winter, spring, and fall. Swiftsure Bank and western JdF had lower densities of Harbour Porpoises year-round, though there is some uncertainty about how many sightings of this small and discreet species may have been missed during more challenging sea conditions.

Dall's Porpoise

Very little historical abundance and distribution data exist for Dall's Porpoise in the southern Salish Sea prior to the 1990s. Dall's Porpoise density decreased to near zero during 1994 – 2014 (Evenson et al. 2016). Since that time, surveys indicate that, although Dall's Porpoises are again present in the southern Salish Sea, their abundance in the area is lower than that of Harbour Porpoises. For 2020 - 2024, we estimated that Dall's Porpoise abundance in the study area is highest in winter at 348 (95% CI: 185-660) and lowest in summer at 64 (29-141) individuals (McMillan et al. 2025). The southern SoG had the highest densities of Dall's Porpoises in fall and winter, while the western portions of the study area, including western JdF and the area around Swiftsure Bank, had the highest densities of Dall's Porpoises in spring and summer (Figure 47-4).

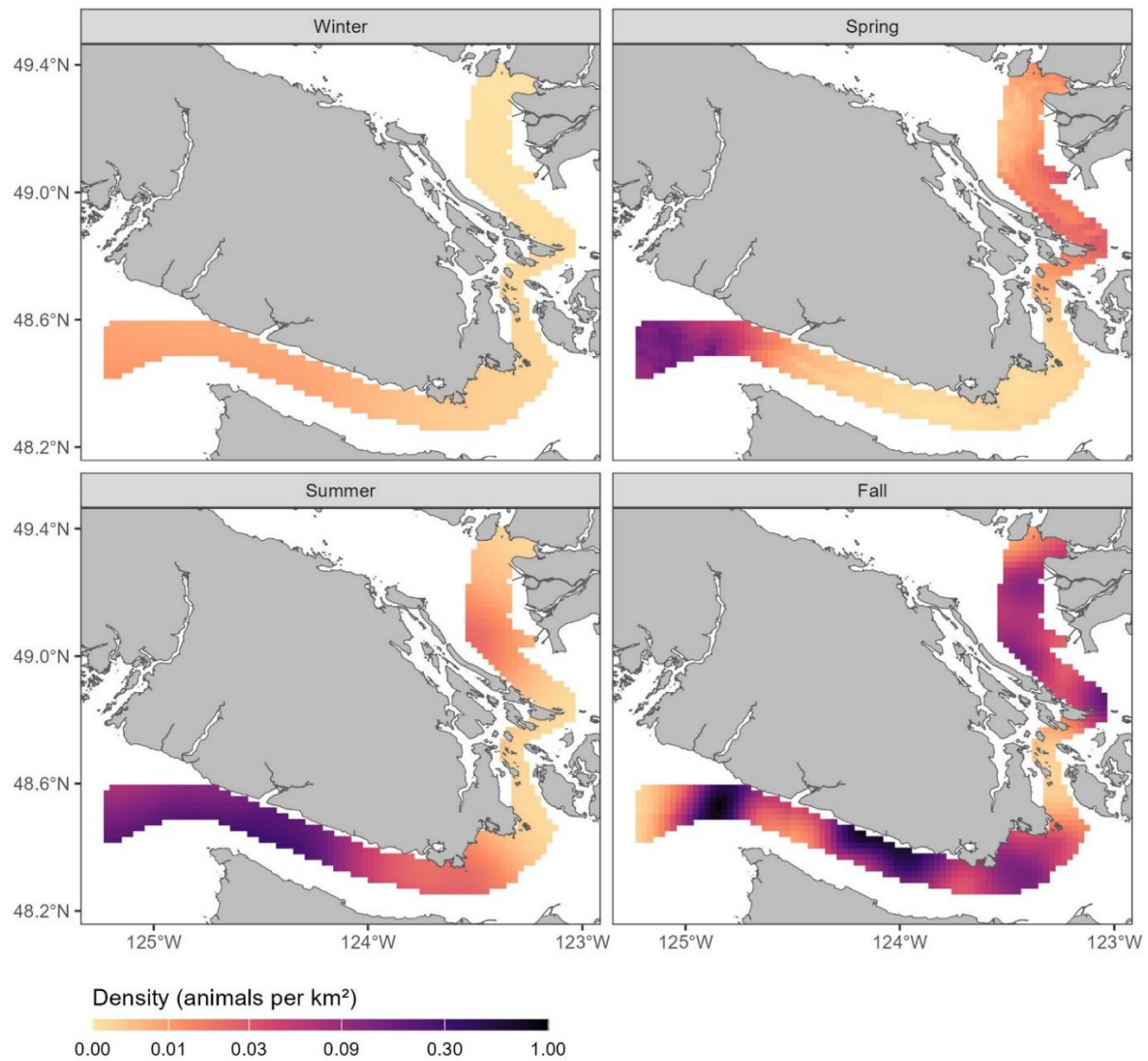


Figure 47-2: Seasonal density models of Humpback Whales (animals per km²) in Canadian portions of the southern Salish Sea and Swifsure Bank. Seasons were defined as Winter: January through March; Spring: April through June; Summer: July through September; and Fall: October through December.

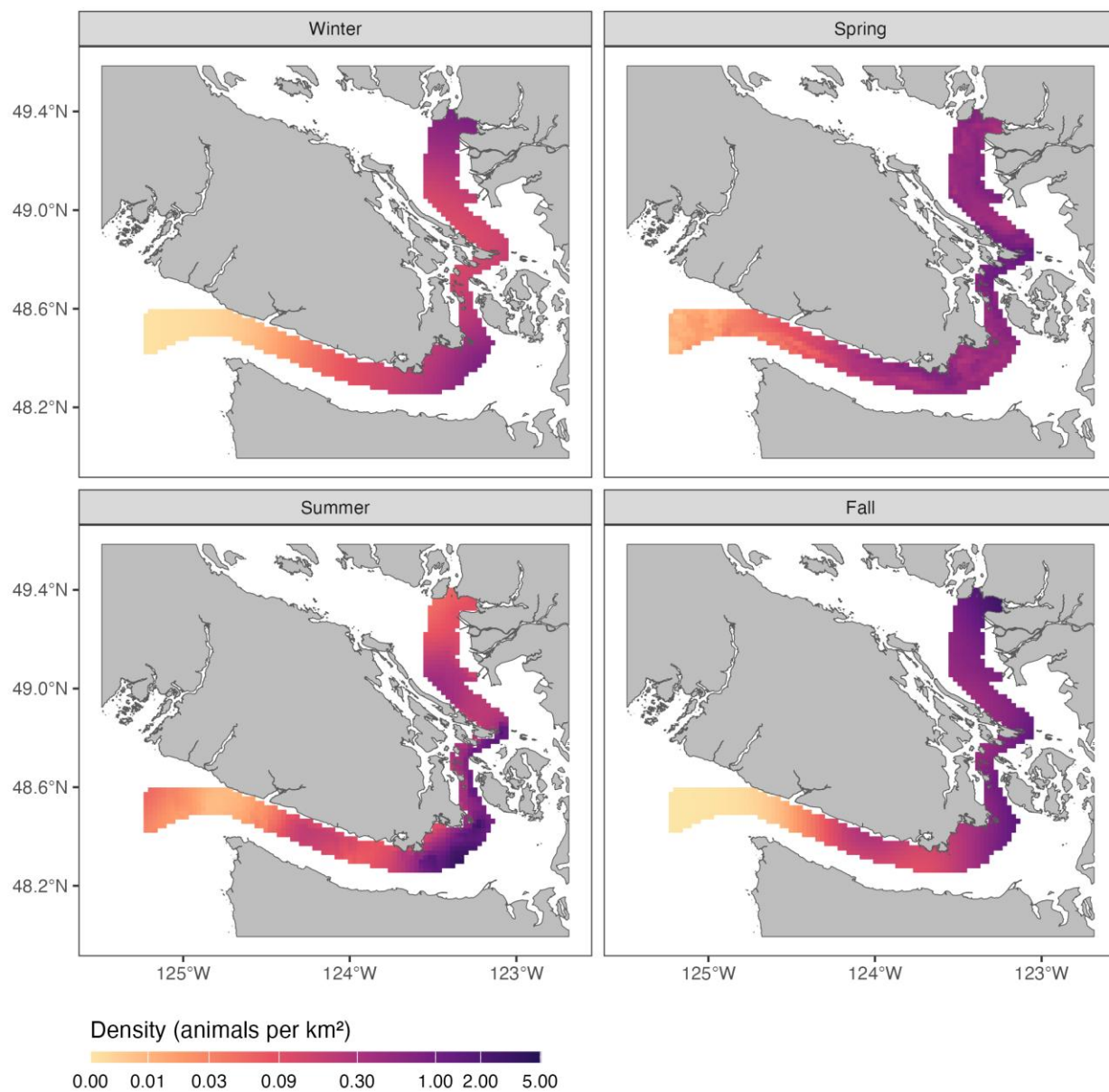


Figure 47-3: Seasonal density models of Harbour Porpoises (animals per km²) in Canadian portions of the southern Salish Sea and Swifsure Bank. Seasons were defined as Winter: January through March; Spring: April through June; Summer: July through September; and Fall: October through December.

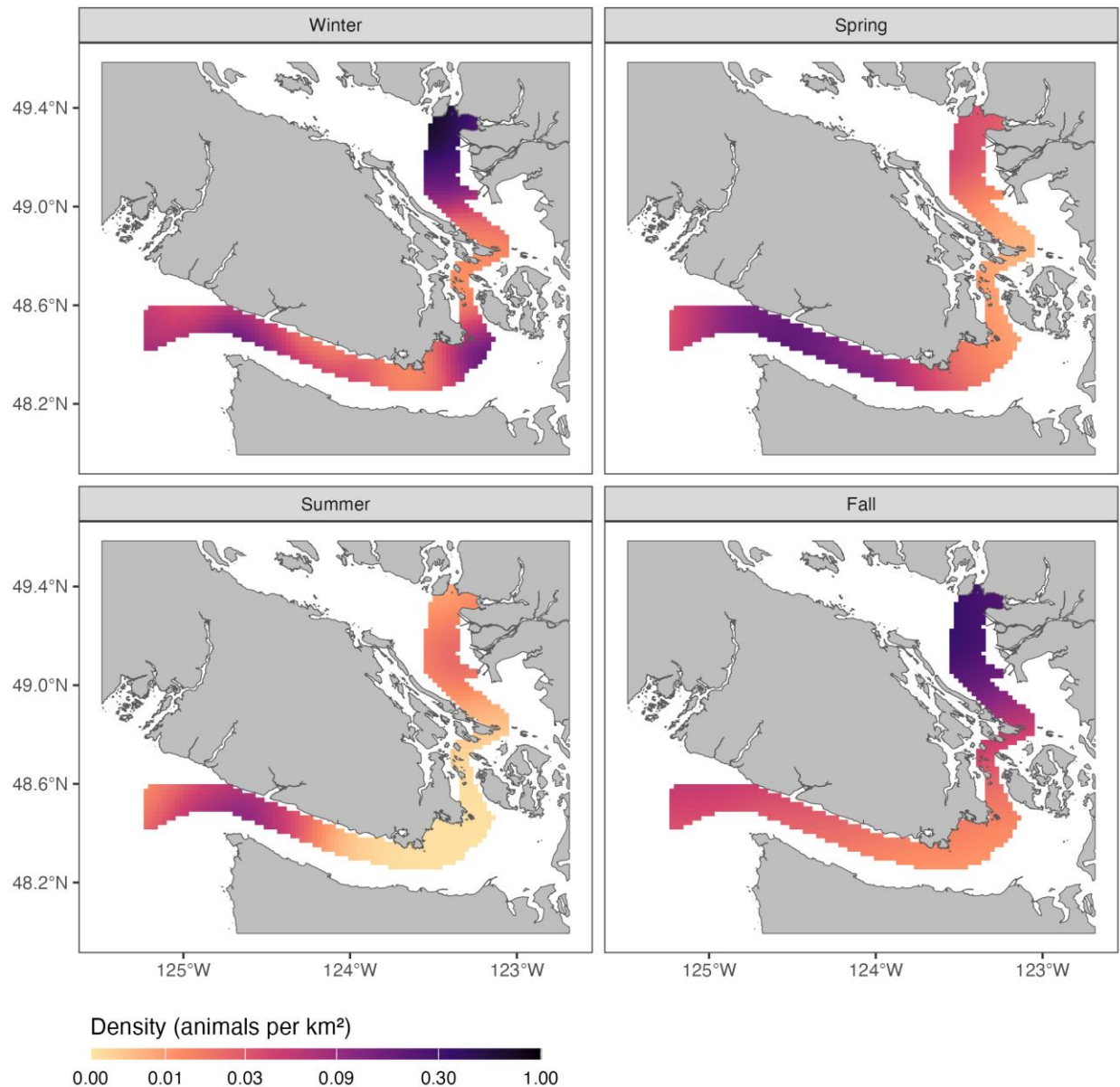


Figure 47-4: Seasonal density models of Dall's Porpoises (animals per km²) in Canadian portions of the southern Salish Sea and Swiftsure Bank. Seasons were defined as Winter: January through March; Spring: April through June; Summer: July through September; and Fall: October through December.

47.4. Factors influencing trends

Though North Pacific Humpback Whales have shown significant recovery throughout most of their range following cessation of commercial whaling, their return to the Salish Sea has been more recent than for many other parts of the B.C. coast. Though not well-understood, this delay may be due to strong maternally-driven site fidelity to specific areas which may limit Humpback Whales' rate of re-establishing historical habitat. Humpback Whale habitat use is often strongly linked to distribution of their prey species.

Factors influencing trends in porpoise abundance and distribution are largely unknown, though threats such as fisheries bycatch, pollution, and habitat degradation have likely contributed to previous declines (Elliser and Hall 2021). Hall (2011) identified Harbour and Dall's Porpoise hotspots in areas of high tidal currents within the southern Salish Sea and suggested that these areas serve as important foraging and breeding areas for these species. Interspecies dynamics may also contribute, as Harbour and Dall's Porpoises share many of the same prey species (Nichol et al., 2013) thus their respective density patterns may indicate some temporal habitat partitioning.

47.5. Implications of those trends

The return of Humpback Whales, Harbour Porpoises, and Dall's Porpoises to the southern Salish Sea provides evidence of this ecosystem's ability to support recovering populations of marine mammals. However, the waters of the southern Salish Sea are used for intensive human activities that can negatively impact each of these cetacean species. The Salish Sea is one of the busiest shipping corridors in North America, with over 3,000 large vessel arrivals at the Port of Vancouver alone in 2024, and shipping traffic is expected to increase due to additional development in the area. Humpback Whales are the cetacean species most frequently struck by vessels in Canadian Pacific waters (COSEWIC 2022), while Harbour Porpoises are considered particularly sensitive to acoustic disturbance (DFO 2009). The temporal changes in density and distribution for all three species underscore the need for management strategies to be aligned with seasonal patterns rather than relying on data from a single season or year. These seasonal density layers can inform ecosystem studies, recovery planning, and assessment of threats including vessel strikes, entanglement in fishing gear, and acoustic disturbance.

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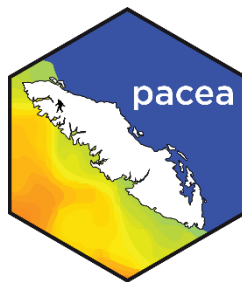
Individual reports from poster presentations

48. NEW INFORMATION ADDED TO PACEA SINCE LAST YEAR'S STATE OF THE PACIFIC OCEAN MEETING

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48.1. Highlights

- Pacea is an open-source R package that contains various types of ecosystem information and model output; pacea stands for PACific Ecosystem Approach.
- Since the 2025 State of the Pacific Ocean (SOPO) meeting, one new source of information has been added to pacea, and many others have been updated. These are summarised, along with recent and ongoing uses of pacea.



48.2. Extended abstract

New and updated information added to pacea (Edwards et al. 2024) since the 2025 SOPO meeting:

- Fraser River discharge measured at Hope, B.C., since 1912, of relevance for migrating salmon.
- The B.C. Continental Margin model (Peña et al. 2019) was originally only run up to 2019, but has now been extended by Angelica Peña (Fisheries and Oceans Canada) to 2025 and included in pacea.
- Ecosystem information continues to be updated annually or monthly as appropriate, including products regarding climate and oceanographic indices, sea surface temperature, zooplankton, Pacific Herring (*Clupea pallasii*), and Pacific Hake (*Merluccius productus*).

Pacea is becoming widely used. Example applications are:

- Understanding the influence of the environment on body condition for 35 fish demersal species (English et al. 2026).
- Species-specific ecosystem summaries or analyses for stocks of Pacific Hake (Edwards et al. 2026), Petrale Sole (*Eopsetta jordani*; Mazur et al. *under revision*), Dover Sole (*Microstomus pacificus*; Fisch et al. *under revision*), and Yelloweye Rockfish (*Sebastes ruberrimus*; Doherty et al. *under revision*).
- Ongoing uses include analyses of spatial densities of Humpback Whales (*Megaptera novaeangliae*), fluctuations of infectious hematopoietic necrosis virus in Sockeye Salmon

(*Oncorhynchus nerka*), and as a source of information for the [Salmon Prize prediction project](#).

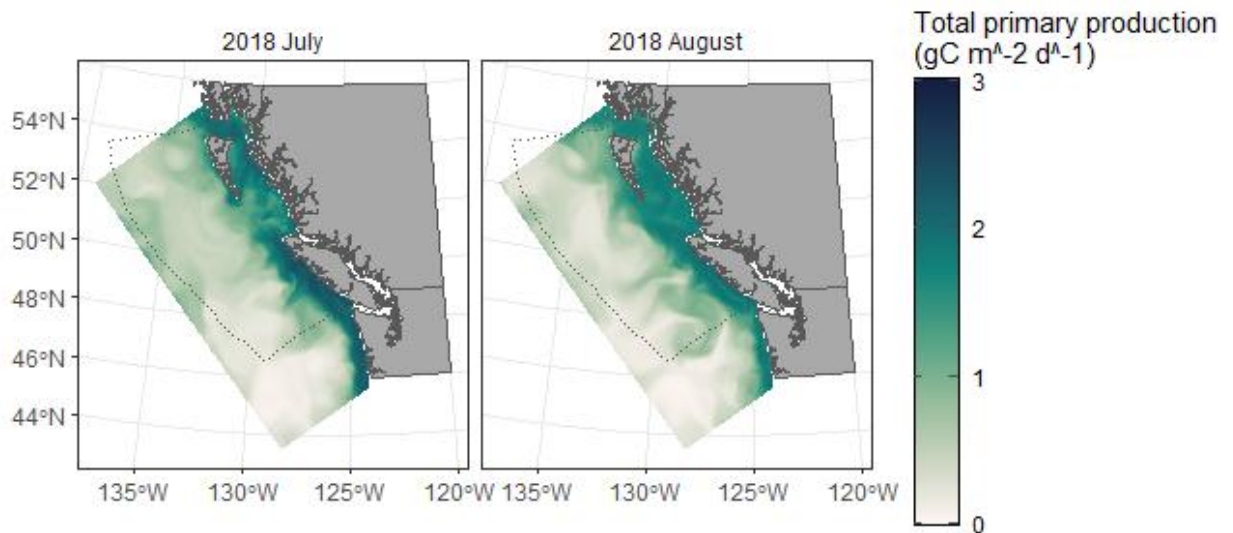


Figure 48-3: Example plot from the B.C. Continental Margin model output: mean daily depth-integrated primary production for each grid cell for July and August 2018. From pacea code: `plot(bccm_primaryproduction_full(), c("July", "August"), 2018)`.

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49. UNUSUAL EVENTS IN CANADA'S PACIFIC MARINE WATERS IN 2025

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49.1. Highlights

- Unusual events occur in Canada's Pacific marine waters every year but are often not reported or linked to the broader environmental context.
- Some unusual events in 2025 that were reported include: sightings of Loggerhead Turtles and a Great White Shark, a diesel spill near Zeballos, and more.

49.2. Description of the time series

Every year, unusual marine events occur in the Northeast Pacific: some are reported to DFO, many are not. These are often seen as “one-off” events, which are isolated from other events, in time and/or space, and collected by different observers. It is therefore difficult to make a complete story or a synthesis of such observations. However, if enough of these events are observed and reported, it may be possible to identify broader patterns and processes that collectively tell us how our marine ecosystems are changing and responding to diverse pressures. For example, the REDMAP (Range Extension Database and Mapping Project; <http://www.redmap.org.au>) program in Australia engages citizen scientists and the interested public to report their observations of unusual organisms and events to a structured network, which can subsequently be used in scientific (and other) publications (e.g., Pecl et al. 2014; Lenanton et al. 2017). This report presents a selection of unusual events in Canada's Pacific waters in 2025 that have been reported to or noted by the Pacific science community. Some of these events may be included in other sections of this document, whereas other observations may not be presented in detail or at all. In addition, participants were invited to provide their own observations of unusual events during the State of the Pacific Ocean meeting, which are included in this report.

49.3. Status and trends

Observations in 2025 that were documented and observations reported to DFO by participants at the 2026 State of the Pacific Ocean workshop are presented in Table 49-1. For example, in August 2025, a seven-arm octopus was found on a beach on Pender Island; these species are typically found in the Atlantic Ocean. Record high bycatch of Pacific Bluefin Tuna were caught in the Albacore Tuna commercial fishery. Other unusual occurrences are listed in Table 49-1.

Table 49-1. Observations of weird, wonderful and/or unusual marine events documented during 2025 or reported at the 2026 State of the Pacific Ocean meeting.

Event	Where	When	Reported by	(Brief) Details
Seven-arm Octopus on beach	Pender Island	Aug. 2025	CBC; Kathleen Durant spotted it	‘Septopus’; washed up on shore; typically found in the Atlantic Ocean
Spotted Ratfish on beach	Semiahmoo Bay in White Rock	May 2025	‘Suzanne’; through DFO communications	Several washed ashore (some dead, some alive)
Leatherback Sea Turtle swimming	Near Langara Island	July 14, 2025	Chek News; Victoria Bradshaw	Swimming in waters off Haida Gwaii coast
Farmed salmon die-off	North Clayoquot Sound	July- Sept, 2025	DFO	Die-off of farmed Atlantic Salmon at three Cermaq fish farm (16.5-37%) due to harmful algal blooms
Bryde’s Whale on beach	Port McNeill Bay	May 14, 2025	Chek News; Marine Education and Research Society and Bay Cetology	Dead on beach
Grey Whale on beach	Long beach, Tofino	May 7, 2025	Chek News	Dead on beach
Grey Whale on beach	Skidegate, Haida Gwaii	May 11, 2025	Chek News	Dead on beach
Pacific Blue Fin Tuna	Canadian EEZ and High Seas	2025	Sarah Hawkshaw, DFO	Significant increase to highest recorded bycatch of these in Canadian Albacore Tuna commercial fishery
Sea lions and dolphins affected	California	Feb. 2025	Seattle Times	Domoic acid poisoning from harmful algal blooms; at least 140 sea lions and 50 dolphins
Coccolithophore blooms	West coast Vancouver Island and Sounds, and Strait of Georgia	Spring-Summer	Andrea Hilborn, DFO	more than normal; some extensive and long-lived (Kyuquot Sound, Barkley Sound in particular)

49.4. Factors influencing trends

Potential factors influencing these events include a changing climate, natural population changes, and anthropogenic pressures. Disease is a potential factor causing mortality, but is difficult to assess. As the climate changes, extreme weather and long-term temperature increases will continue to be factors affecting marine biology.

49.5. References

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50. CHS 2025 HYDROGRAPHIC SURVEY UPDATE (PACIFIC REGION)

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50.1. Extended abstract

The 2025-26 survey program for the Canadian Hydrographic Service (CHS) was planned and established in collaboration with federal partners, Indigenous communities, Natural Resources Canada, Environment and Climate Change Canada, Dept. of National Defence, port authorities, Canadian Coast Guard and other stakeholders. The program supports efficient and safe navigation, marine infrastructure development, environmental monitoring, reconciliation commitments, and long-term coastal management across the coast of B.C.

On the central and north coast, priorities included Masset Inlet, Prince Rupert anchorages, the west coast of Haida Gwaii, Bentinck Arm and Portland Inlet. These surveys support new chart editions, chart updates, change detection monitoring, wildlife management and long-term anchorage impact assessments. Surveys were also prioritized for the proposed Ksi Lisims LNG facility at Whiskey Bay, with Brown Passage identified as the highest navigational risk corridor for LNG shipments.

On the south coast, survey areas included parts of north and south Vancouver Island, Phillips Arm, and the Saanich Peninsula in order to update nautical charts, develop “berthing-scale” Electronic Navigational Charts (ENCs), and identify obstructions. Infrastructure and monitoring surveys were completed at CFB Esquimalt’s B Jetty and Graving Dock, in Esquimalt-area anchorages for long-term environmental assessment, at Sisters Islets to support Canadian Coast Guard operations, and at Kingcome Inlet for disposal-at-sea monitoring.

Survey operations were carried out by three primary platforms: CCGS Vector, CCGS Otter Bay, and the CSL Czotter. CCGS Vector, a 39.7 m mid-shore science vessel, was deployed for 7.5 weeks and completed 430 hours of surveying with a 41% utilization rate, operating across the central coast, Haida Gwaii, Prince Rupert, and Kingcome Inlet, with additional opportunistic surveys near Victoria and the Gulf Islands. CCGS Otter Bay, a 13.4 m survey vessel, was deployed for 22 weeks and logged 583 survey hours with a 49% utilization rate, conducting operations in Masset Inlet, Prince Rupert, the Strait of Georgia and the Saanich Peninsula. The CSL Czotter, a 28-foot nearshore launch, completed 17 surveys totaling 142.5 hours and achieved a 58% utilization rate. The Czotter was loaded onboard the CCGS Sir Wilfred Grenfell to conduct lighthouse site surveys during the Grenfell’s spring refueling program; it also surveyed and laser scanned CFB Esquimalt’s B Jetty.

Community Hydrography initiatives, including a collaborative multibeam survey in Phillips Arm with the Kwiakah First Nation, further advanced Indigenous marine stewardship while improving official navigation charts. All bathymetric data were acquired and processed under ISO 9001:2015 and CHS Quality Management System standards using the CUBE workflow, meeting or exceeding Order 1a requirements. Overall, the 2025–26 survey season delivered high-quality hydrographic data supporting navigational safety, LNG risk mitigation, environmental stewardship, infrastructure development, and collaborative coastal governance throughout B.C.

51. SEA LEVEL IN B.C., 1910 TO 2025

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51.1. Highlights

- In 2025, the annual mean sea level anomaly at Victoria, Tofino, and Prince Rupert decreased for the third consecutive year.
- There was early evidence suggesting that a baseline shift occurred in 2013 lowering the subsequent Prince Rupert anomalies to 1.5 cm below the station's long-term trend.
- The sea level anomaly in 2025 at all three stations continued to lag the global rate of mean-sea-level increase.

51.2. Extended Abstract

The Canadian Hydrographic Service performs long-term monitoring of sea level at 40 locations along the B.C. coast at 1-minute intervals. The annual deviations from the long-term average (1981-2010) after correction for regional uplift are shown for these stations in Figure 51-1. A linear trend line was fitted to the full dataset for each location.

Table 51-1. Selected sea level measuring station information.

Station	Name	Latitude°	Longitude°	Instrumentation	Status
07120	Victoria Harbour	48.424 N	-123.371 E	Dry-counter weight	Permanent
08615	Tofino	49.154 N	-125.913 E	Dry-counter weight	Permanent
09354	Prince Rupert	54.317 N	-130.324 E	Dry-counter weight	Permanent

These ongoing time series allow us to review annual mean sea level with respect to long-term climate change. The trends also enable estimates of future water levels on the order of a decade.

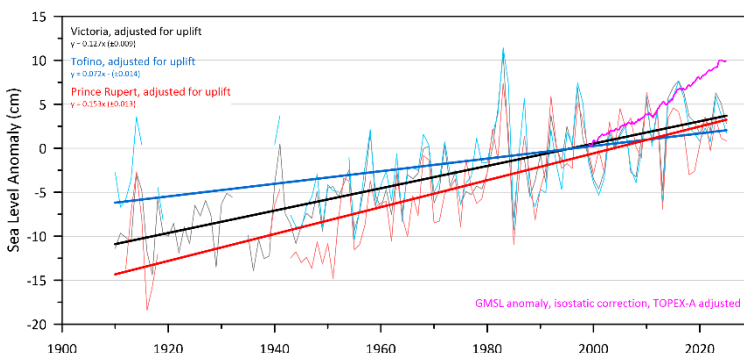


Figure 51-8. Long term trend in sea-level anomaly (relative to the averages from 1981-2010) at Victoria, Tofino, and Prince Rupert Tide Stations, corrected for regional uplift.

In 2025, the annual mean sea level anomaly at Victoria, Tofino, and Prince Rupert decreased for the third consecutive year. At Victoria and Tofino, the anomaly returned to the long-term trend line, while at Prince Rupert it was below the trend line for the sixth time in the past eight years.

Examining the difference between the Prince Rupert and Victoria

anomalies between 1940 and 2025 revealed the possibility that a baseline shift occurred in

2013 lowering the Prince Rupert anomalies to 1.5 cm below the long-term trend, while maintaining a comparable slope. The post-1999 rate of sea level rise in Victoria was comparable with the global ocean trend until the mid-2010s. However, from 2013 through 2025, the sea level anomaly at Victoria, Tofino and Prince Rupert has continued to lag the global mean sea level (GMSL) rate of increase.

51.3. References

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52. OCEAN OBSERVATORY CONTRIBUTIONS TO ASSESSING 2025 SOUTHERN B.C. COASTAL CONDITIONS

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52.1. Highlights

- The cumulative Bakun upwelling index in 2025 remained close to the long-term climatological mean through most of the spring and summer.
- Wind forcing in 2025 showed more sustained upwelling-favourable conditions compared to 2024.
- Fraser River discharge followed a typical seasonal cycle, with the spring freshet beginning in April and peaking in late May to early June.
- HF radar observations showed surface current speeds increasing from winter into late spring and early summer, with strongest currents during the Fraser River freshet.
- Fraser River discharge and Bakun upwelling index together explained ~78% of the variance in monthly HF radar surface current speeds, indicating strong coupling between wind forcing, freshwater input, and surface circulation.

52.2. Observations and Environmental Conditions

This analysis integrates several long-term observational time series to assess the oceanographic and atmospheric conditions influencing the Strait of Georgia during 2025. The datasets include the **NOAA Bakun Upwelling Index (48°N 125°W)** representing coastal wind forcing along the Washington–Vancouver Island margin, **Fraser River discharge** measured at Hope, B.C. by Environment and Climate Change Canada, **water-column observations** from Ocean Networks Canada cabled observatories (including SOG Central and Folger Deep), and **surface current measurements from the CODAR High-Frequency radar network** operating in the southern Strait of Georgia.

The coastal waters of B.C. are strongly influenced by seasonal wind-driven upwelling and downwelling along the outer coast of Vancouver Island. Southerly winds during winter generally produce downwelling-favourable conditions, while northerly winds during summer promote upwelling and offshore Ekman transport. In 2025, the cumulative Bakun upwelling index remained close to the long-term climatological mean through much of the spring and summer season, with seasonal transitions between downwelling and upwelling phases occurring near their typical climatological timing.

Fraser River discharge followed a typical seasonal pattern, increasing rapidly beginning in April and peaking in late May to early June at approximately **7000 m³ s⁻¹**, consistent with the historical climatological maximum associated with the Fraser River freshet. This freshwater input enhances surface stratification and buoyancy forcing within the Strait of Georgia.

Surface circulation observations from Ocean Networks Canada's HF radar network show a pronounced seasonal acceleration of surface currents from winter into late spring and early summer. Peak surface current speeds occurred during the Fraser River freshet period when freshwater discharge and buoyancy forcing were strongest. A multiple linear regression analysis

indicates that **Fraser River discharge and coastal wind forcing together explain approximately 78% of the variance in monthly HF radar surface current speeds**, highlighting the dominant role of these processes in modulating seasonal surface circulation.

Interior basin observations from the **Folger Deep observatory (95 m depth)** further illustrate the response of the water column to these surface forcing mechanisms. Seasonal cycles of temperature, salinity, density, and dissolved oxygen show enhanced stratification during late spring following the Fraser River freshet, consistent with increased freshwater input and buoyancy-driven surface layers.



Figure 52-1. Southern coast of B.C. showing Ocean Networks Canada ocean observing infrastructure in the Salish Sea. Red circles indicate regions referenced in this study, including the NOAA Bakun upwelling index location (48°N 125°W), Ocean Networks Canada cabled observatories in the Strait of Georgia, and HF radar CODAR stations measuring surface currents in the southern Strait of Georgia.

53. OCEAN CHARACTERISTICS SUPPORTING SEABIRDS IN THE SCOTT ISLANDS MARINE NATIONAL WILDLIFE AREA

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53.1. Highlights

- A sub-surface mooring has been continuously deployed in the Scott Islands marine National Wildlife Area (NWA) from 2016 through 2025.
- Dissolved Oxygen (DO) concentrations at 150m and 200m depths from August through November 2024, and January through February 2025, were at the bottom of the observed range from 2016-2025.
- Seasonal satellite SST anomalies within the NWA were correlated with SST anomalies measured at Kains Island lighthouse, 1995-2025. This suggests that SST measured at Kains Island can be used to calculate seasonal SST in the NWA for years prior to 1995.

53.2. Description of the time series

The Scott Islands are B.C. Provincial Protected Areas, protecting land breeding habitat for globally and nationally important seabird populations. The Scott Islands marine National Wildlife Area (NWA), which includes 11,546 km² of ocean, was established by the Government of Canada, under the *Canada Wildlife Act*, in 2018 to conserve the marine habitats providing forage species essential to the breeding seabirds (Figure 53-1). Together the land within the Provincial Protected Areas, with the marine habitats in the Federal NWA, collaboratively protect ecosystems important to maintain the breeding seabirds.

In 2015, the Canadian Wildlife Service of Environment and Climate Change Canada, and Ocean Sciences Division (OSD) of Department of Fisheries and Oceans Canada, developed a Collaborative Agreement (CA) to study ocean variables essential to understand the marine environment producing forage species for seabirds. The goals of the CA are described in Jones et al. (2021, 2022, 2023, 2024, 2025). The CA is being updated and is pending renewal in 2026.

The Scott2 subsurface oceanographic mooring in the marine NWA has been in place from 2016 through 2025. This mooring is part of the long-term OSD mooring program measuring sub-surface physical and biological parameters coast wide since 1975. The moorings measure: temperature, salinity, and oxygen at selected depths; ocean currents through the water column; samples of organisms that settle on the floatation; and some moorings have hydrophones. There has been mixed success measuring pCO₂ (Figure 53-2).

53.3. Status and trends

Dissolved oxygen (DO) concentrations in the ocean typically vary over time and location. DO has been measured at the Scott2 sub-surface mooring from 2016 through 2025. DO levels at 150 m and 200 m depths from August through November 2024 and January through February 2025, were at the low end of the range measured since 2016 (Figure 53-3). DO levels measured at 280m, were consistent with normal low levels near bottom.

Sea-surface temperatures (SST) within the NWA have been assessed using data from satellite platforms covering 1995 through 2025. SST at the Kains Island light-station, about 87 km from Triangle Island in the marine NWA, has been physically measured since 1935. Results indicate that seasonal SST anomalies at these 2 locations are reasonably consistent (Figure 53-4).

53.4. Factors influencing trends

Dissolved oxygen concentrations at depths have been decreasing on the shelf in recent years, including at the Scott2 sub-surface mooring (Hannah 2025). Current understanding suggests that DO has been declining in western Pacific Ocean, and that these waters are being transported to the eastern Pacific along Canada (Whitney et al. 2007; Crawford and Pena 2016; Stevens et al. 2025).

53.5. Implications of those trends

Oxygen is clearly necessary for fish and wildlife species. While declining DO has not been shown to reduce the demersal fish community, changes in ocean temperature and DO together have been associated with changes in many fish species, including Pacific Sand Lance (*Ammodytes hexapterus*) (Thompson et al. 2022). Pacific Sand Lance is an important forage species for piscivorous seabirds including Rhinoceros Auklet (*Cerorhinca monocerata*) (Borstad et al. 2011). It will be important to continue measuring DO to assess if it continues to decline, and if there are future negative implications on species important to conservation and human use.

Sea-surface temperatures fluctuate across time and locations. The close visual correlation of SST anomalies between the Scott Island NWA and the Kains Island light-station indicate that SST changes in these 2 areas are reasonably consistent from 1995 through 2025. This consistency indicates that Kains Island SST data can be used to assess the marine NWA SST's from 1935 to 1995. Variations in ocean temperature influence availability of zooplankton species important to planktivorous seabird populations (Hipfner et al. 2020). Hind-casting of SST may assist biologists to assess seabird populations pre-1995.

53.6. References

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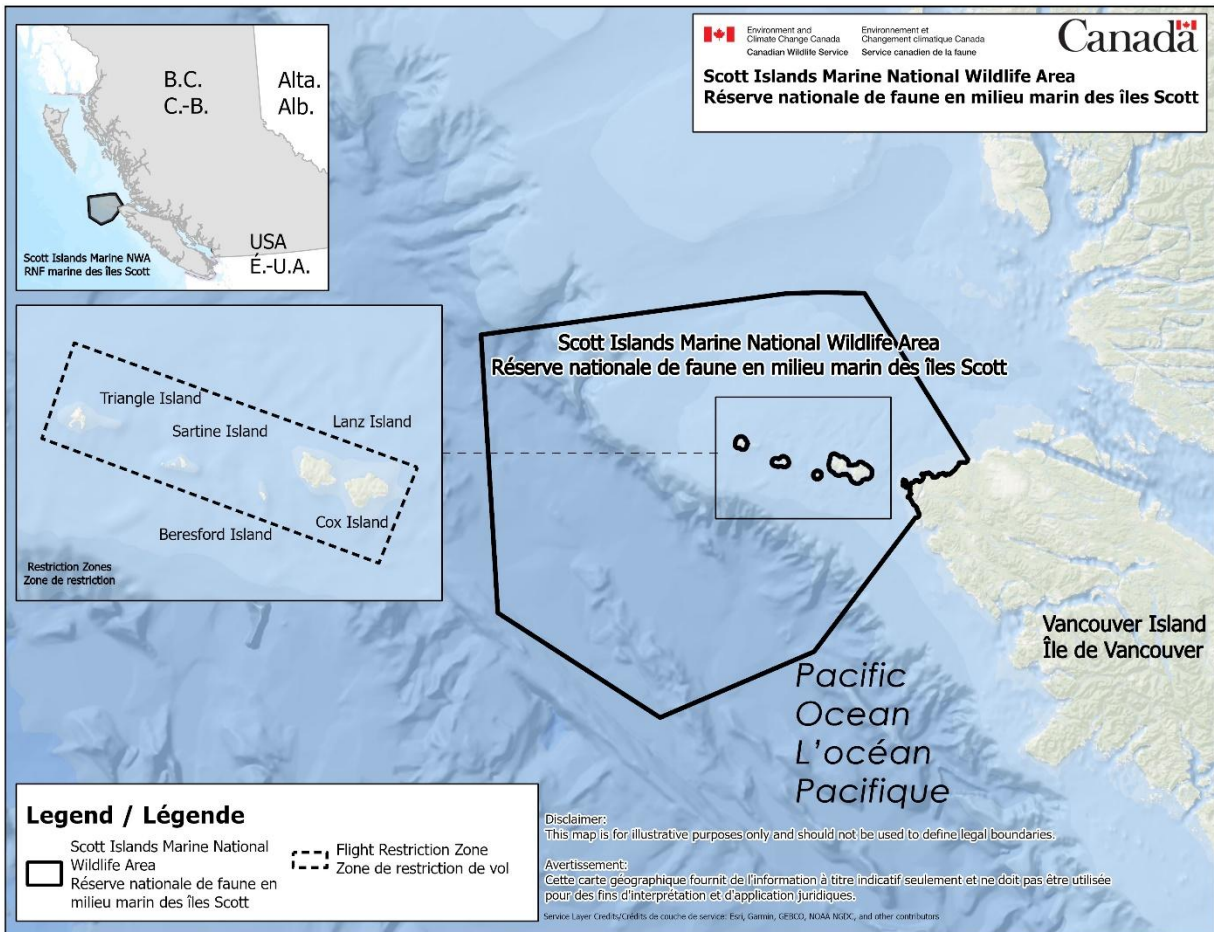


Figure 53-1. The Scott Islands marine National Wildlife Area, which includes 11,546 km² of ocean. Shows the Flight Restriction Zone protecting breeding seabirds from aircraft disturbance. Map provided by Environment and Climate Change Canada. The NWA is all marine, the islands are B.C. Provincial Protected Areas.

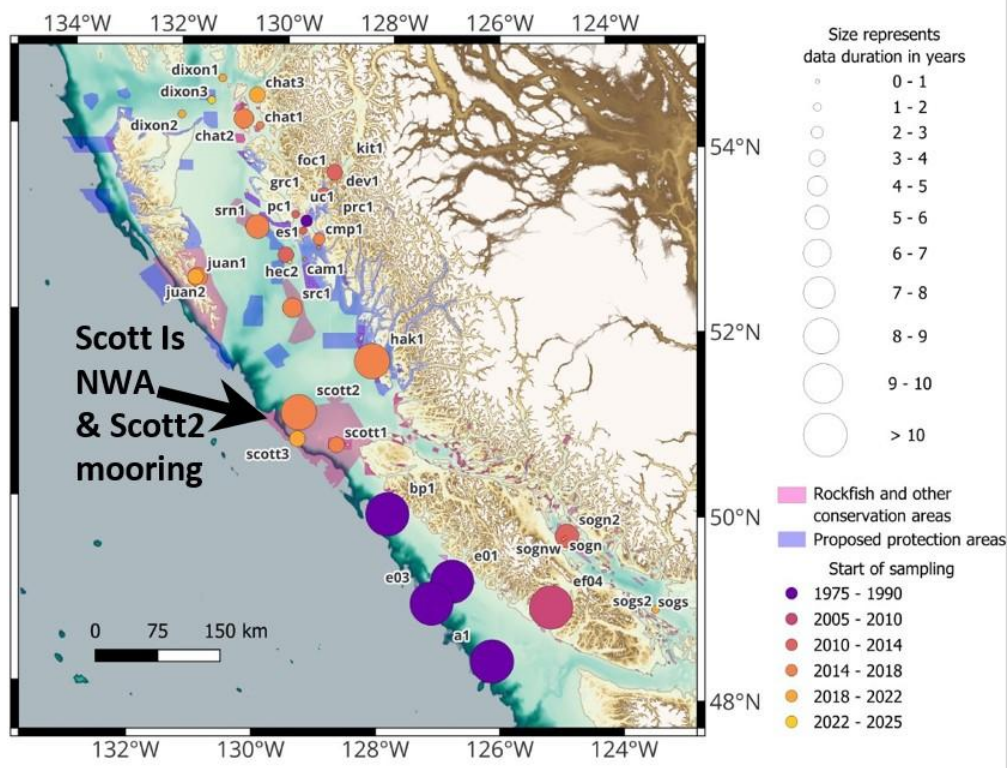


Figure 53-2. Sub-surface mooring in the Scott Islands NWA is part of the regional Ocean Sciences program. Size of circles represents duration in years of each mooring from 1975 – 2025. Figure by Cynthia Bluteau, DFO.

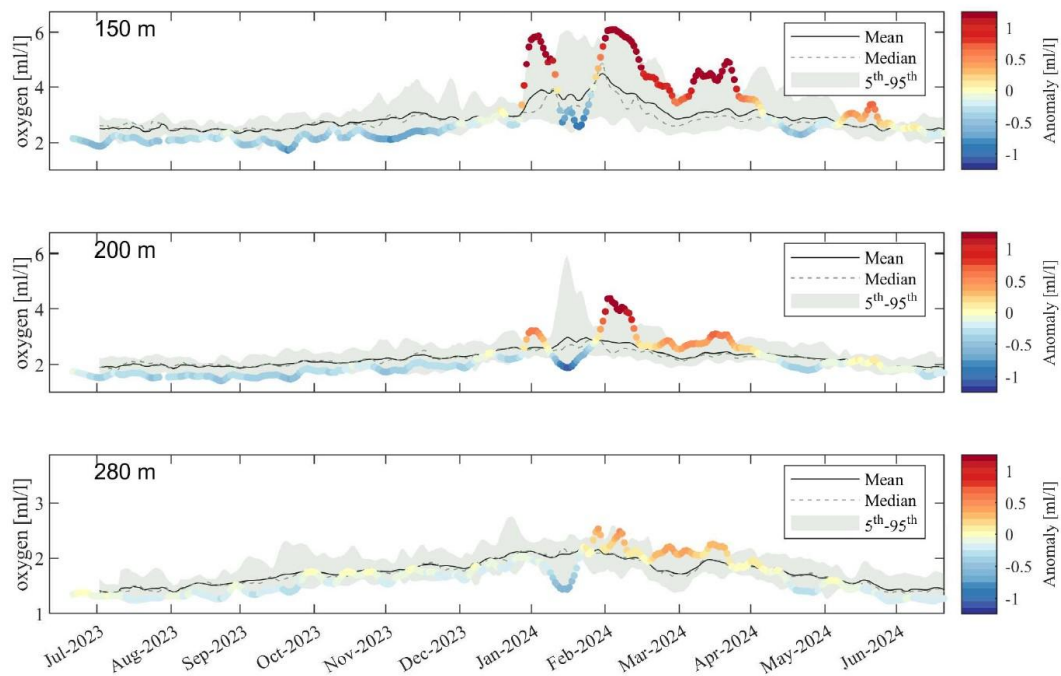


Figure 53-3. Dissolved Oxygen (DO) concentration at Scott2 sub-surface mooring. Grey: 5th – 95th percentile DO 2016-2023. Colours: DO anomaly. Figure by Cynthia Bluteau, DFO.

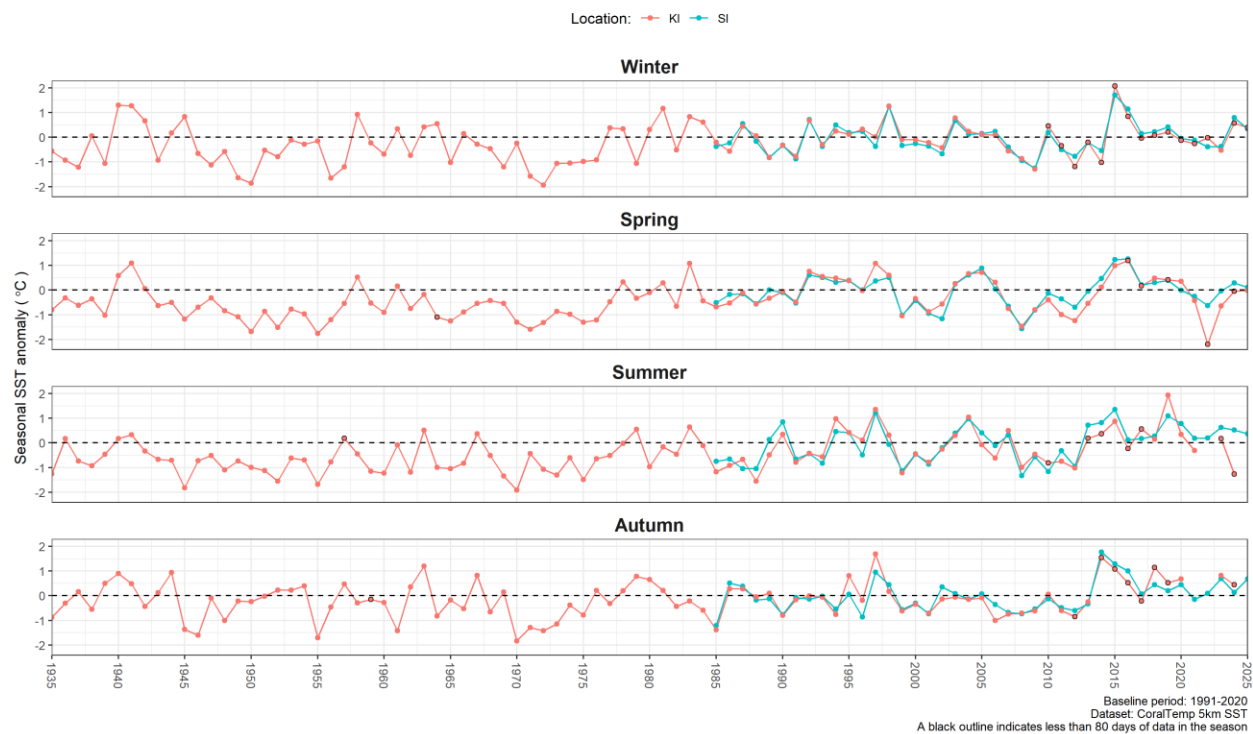


Figure 53-4. Sea-surface temperature anomalies in the Scott Islands NWA measured by satellite (blue line; 1995-2025), and the Kains Island light-station (red line, 1935-2025). Figure by Andrea Hilborn, DFO.

54. DRIVERS OF CHANGE IN SALISH SEA MICROBIAL COMMUNITIES

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54.1. Highlights

- Salinities in the northern Salish Sea remained anomalously high for the third year in a row, both in the surface mixed layer as well as in the intermediate and deep waters at Station QU39. Temperature and nutrients were also elevated, especially in the intermediate waters.
- Warmer, saltier, nutrient-rich intermediate waters selected against SAR11, Nitrosopumilaceae and Methylophilaceae prokaryotic clades, suggesting an impact on the cycling of C1-compounds and ammonia in intermediate waters in 2025. On the other hand, 2025 conditions favoured nitrite-oxidizing and hydrocarbon- and polysaccharide-degrading bacteria.

54.2. Extended Abstract

Microbes (Bacteria, Archaea, and Protists) play important roles in marine food webs. They are primary producers and food for higher trophic levels. They are carbon and nutrient cyclers, driving global biogeochemical cycles. The coastal margin of B.C. is experiencing multi-stressor events that have the potential to greatly impact ecosystem function. Developing a climatology is essential for uncovering the physical, chemical and biological drivers of marine microbial community change in this region and elucidating community responses to increasingly frequent ocean perturbations.

The Hakai Institute Ocean Observing Program has recently completed a decade-long weekly sampling campaign to establish planktonic biodiversity baselines in the Northern Salish Sea (Station QU39: 50.0307, -125.0992). As part of this effort, biomolecular samples from the surface waters to the depths of the Salish Sea were collected to genetically characterize marine microbes at an unprecedented temporal resolution. Prokaryotic community structure was interrogated through Illumina amplicon sequencing of the V4-V5 region of the 16S rRNA gene (McNichol et al. 2021) using a fusion primer approach (Comeau et al. 2017).

Broadly, we have defined the structure and seasonality of microbial communities from the surface waters to the depths at Station QU39. Richness minima occur at different times of year across the water column; typically, in April in the upper water column (0-30 m) but in June deeper in the water column (100-260 m). Community composition differs along this depth gradient (Figure 54-1A) as well as seasonally in the photic zone, in an annually repeatable way (Figure 54-1B). Interestingly, long-term change in community composition is more pronounced at the deeper depths sampled (100, 260 m) than in the surface waters (Figure 54-1B).

Waters in the surface mixed layer at QU39 remained anomalously salty for the 3rd year in a row (Figure 54-1C); nutrients and temperature were also above average. Actinomarinaceae and SAR11 clade I continue to be less abundant than earlier in the time series (Figure 54-1E). 2025

conditions favoured cyanobacteria (Figure 54-1E) as well as proteorhodopsin-containing cosmopolitan oligotrophs like Halieaceae and SAR86. Intermediate waters (100 m) at QU39 exhibited stronger water property anomalies (e.g., salinity, temperature, nutrients) compared to surface waters (Figure 54-1D). Warmer, saltier, nutrient-rich waters selected against SAR11, Nitrosopumilaceae and Methylophilaceae (Figure 54-1F), suggesting an impact on the cycling of C1-compounds and ammonia in intermediate waters. 2025 conditions favoured nitrite-oxidizing and hydrocarbon- and polysaccharide-degrading bacteria in intermediate waters. Looking back, the 2018-2021 corrosive conditions favored Thioglobaceae (Figure 54-1F) with a possible impact on sulfur cycling (Evans et al. 2025). Altogether, these findings highlight the connections between interannual changes in water properties and microbially-mediated biogeochemical cycling in the Salish Sea.

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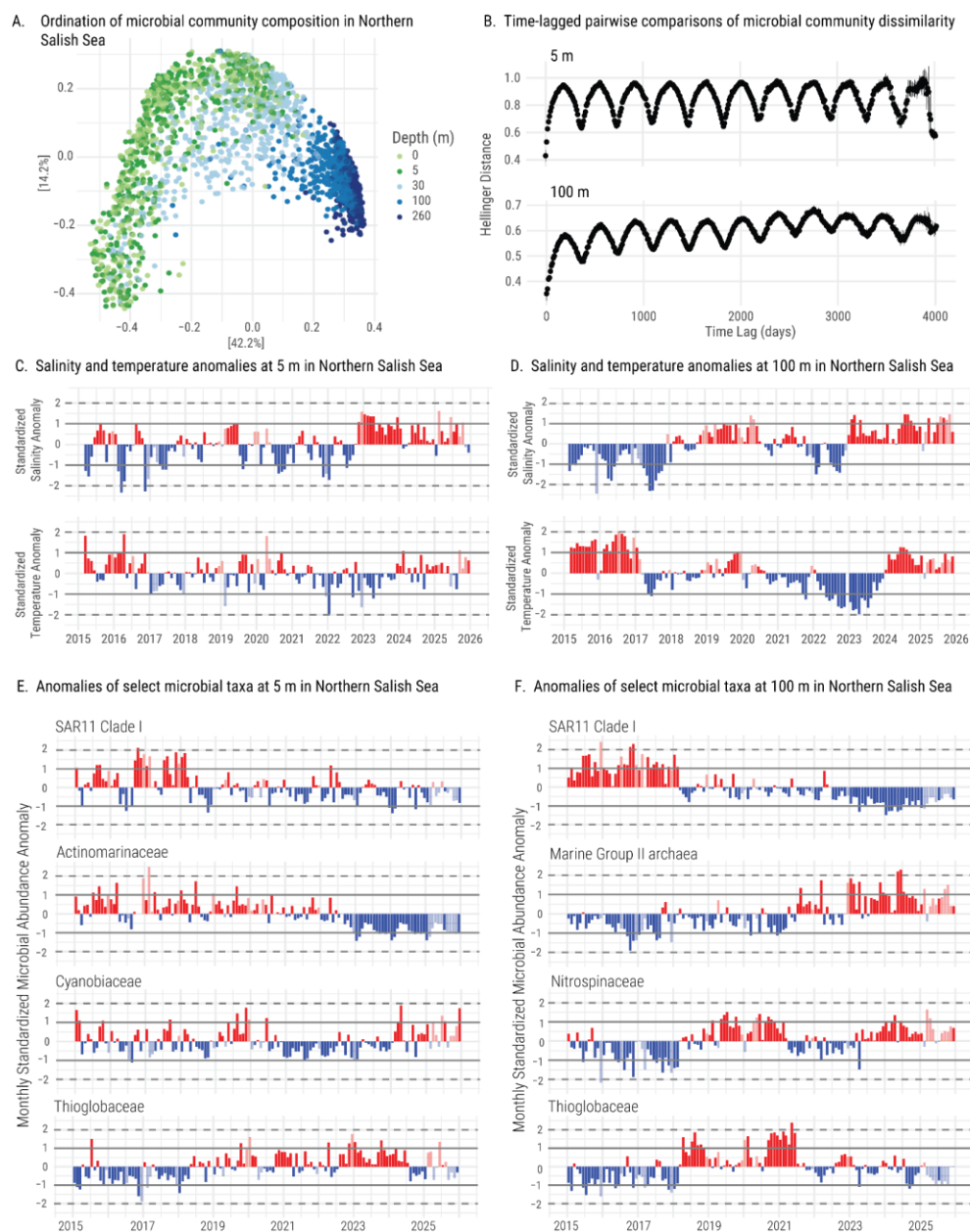


Figure 54-1. Structure and anomalies of microbial communities in the Northern Salish Sea water column (Station QU39). (A) Principal coordinates analysis of Bray-Curtis distance of microbial community composition, with points colored by sample depth. This reveals that microbial communities strongly differ with depth in the water column and that there is more change in shallower communities (green colors) across the dataset, as indicated by the bigger spread in points. This is driven by seasonal changes in microbial communities in the photic zone. (B) Time-lag analysis of microbial communities at 5 and 100 m; this compares community composition between samples collected over time (e.g., how similar is the community between samples collected 180 days apart or 365 days apart or 1460 days apart?). Samples that are more similar have a lower Hellinger distance. The cyclical nature of this plot shows that samples collected at the same time of year (intervals of 365 days apart) are most similar such that, for example, samples collected in the same week 6 years apart will be more similar to each other than those collected two months apart within the same year. (C) Standardized monthly salinity and temperature anomalies at 5 m. (D) Standardized monthly salinity and temperature anomalies at 100 m. (E) Standardized monthly anomalies for 4 prokaryotic families at 5 m. (F) Standardized monthly anomalies for 4 prokaryotic families at 100 m.

55. A DECADE OF UNUSUAL BLOOMS IN THE STRAIT OF GEORGIA

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55.1. Highlights

- An 11-year (2015–2025) citizen science oceanography monitoring program generated ~10,000 phytoplankton samples across the Strait of Georgia.
- Spring blooms typically occur in March–April and are dominated by chain-forming diatoms (*Thalassiosira*, *Chaetoceros*, *Skeletonema*); February blooms are uncommon but were observed in 2015, 2022, and 2024, dominated by *Skeletonema*.
- Multiple harmful or ecosystem-relevant taxa (*Chaetoceros*, *Pseudo-nitzschia*, *Alexandrium*, *Heterosigma akashiwo*, *Noctiluca scintillans*) showed interannual variability in occurrence and abundance. Rare bloom events (e.g., coccolithophores, *Gonyaulax*, *Heterocapsa*) were observed across the time series.

55.2. Extended abstract

From 2015 to 2025, the Pacific Salmon Foundation conducted an 11-year citizen science oceanography monitoring program in the Strait of Georgia in collaboration with multiple partners. Volunteer surveys collected data on physical conditions, nutrients, phytoplankton, and zooplankton, generating ~10,000 phytoplankton samples.

Spring blooms typically occurred in March–April and were dominated by chain-forming diatoms (*Thalassiosira*, *Chaetoceros*, *Skeletonema*). In some years (e.g., 2022), blooms developed in pulses. February blooms were rare but observed in 2015, 2022, and 2024 (*Skeletonema*).

Chaetoceros convolutus/concavicornis showed high early spring levels in 2015, 2017, and 2025, and low or absent levels in 2019, 2020, 2022, and 2024. *Pseudo-nitzschia* (monitored from 2018) showed strongest blooms in 2021 and 2025 and lower levels in 2019–2020. *Rhizosolenia setigera* formed dense blooms in 2016 and 2025 and was nearly absent in 2020 and 2022.

Noctiluca scintillans (Figure 55-1) was present in 2018–2019 and 2021–2025, and absent in 2015–2017 and 2020. *Alexandrium* showed high summer levels in 2017, 2021, 2024, and 2025, and low levels in 2019 and 2023. *Heterosigma akashiwo* showed high levels in 2018–2019 and very low levels in 2015, 2017, and 2021.

Additional events included a coccolithophore bloom (2016), *Gonyaulax* (2018), *Heterocapsa triquetra* (2021), mixed blooms (2021, 2025), and a co-occurring *Heterosigma* and *Noctiluca* event (2018).

This work was made possible through the vision, leadership, and dedication of those who built and sustained the program, along with the support of partners, contributors, funders, volunteers, and supporters. The 11-year record stands as a legacy dataset available to inform future research and ecosystem understanding.

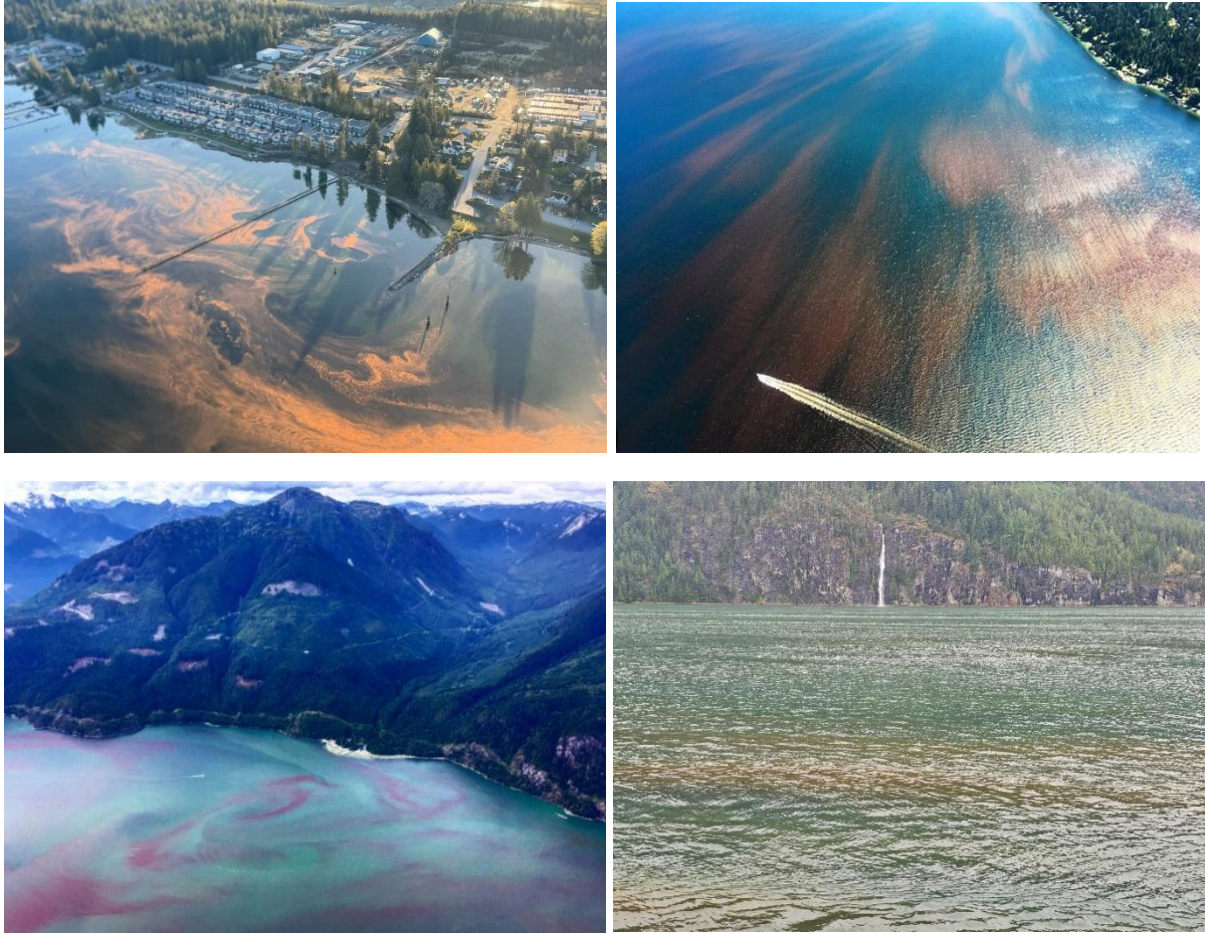


Figure 55-1. *Noctiluca scintillans* bloom (top left; Sechelt, 2024); *Gonyaulax* spp. (top right; Mill Bay, 2018); mixed bloom (bottom left; Howe Sound, 2021); mixed bloom (bottom right; Toba Inlet, 2025). Photos by M. Bahrey and S. Esenkulova

56. OBSERVATIONS OF PHYTOPLANKTON AND ZOOPLANKTON PRODUCTION, AND TRANSFER EFFICIENCY IN THE STRAIT OF GEORGIA, 2023-2025

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56.1. Highlights

- The timing of the spring bloom was average in all years (2023-2025) but the growing season was longer in 2025.
- Both zooplankton and phytoplankton production were spatially variable and showed strong seasonality.
- Gross phytoplankton production, crustacean zooplankton production, and transfer efficiency all increased over the period of sampling, 2023-2025.

56.2. Extended abstract

The study was conducted at three main stations (Figure 56-1) in the Strait of Georgia (SoG), at sites north of Texada Island (Stn 12; 49.7267°, -124.6800°), central SoG (Stn GEO1; 49.2500°, -123.7483°) and west of Vancouver (Stn 42; 49.0300°, -123.4367°). These three stations were the focus of paired, depth resolved phytoplankton and zooplankton production rate measurements (Figures 56-2; 56-3).

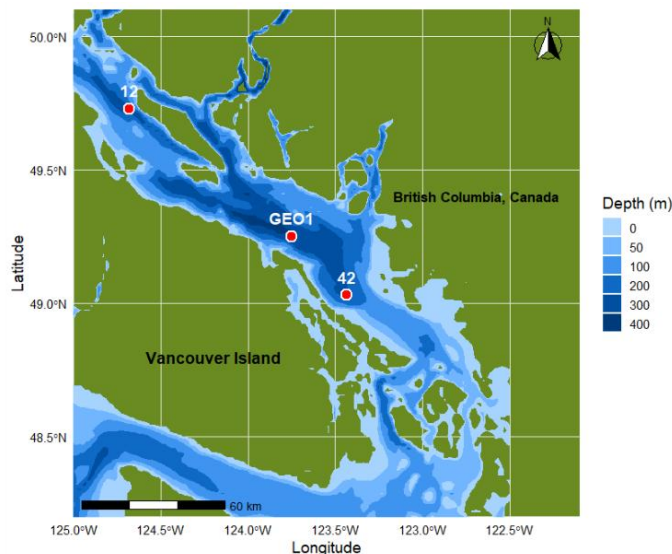


Figure 56-1. Productivity stations sampled in the Strait of Georgia, 2023-2025. Gross phytoplankton production was measured from 0-20 m, crustacean zooplankton production was measured from 5-50 m off the bottom.

Gross phytoplankton production (GPP) was measured using a Chelsea Technologies single turnover active fluorometer system (LabSTAF) (Oxborough 2022). Key measurements for these estimates were fluorescent light curves (FLC), constructed for each sample and used to derive electron transport rate and maximum gross carbon fixation (Figure 56-2; Boatman et al. 2019;

Oxborough 2022). Daily light integrals were measured during each sampling period and used to calculate daily carbon fixation rates from the instantaneous measurements. Total integrated GPP increased from 2023-2025 with observations from 2025 indicating a longer growing season, lasting into July. The timing of the spring bloom was average for all three years.

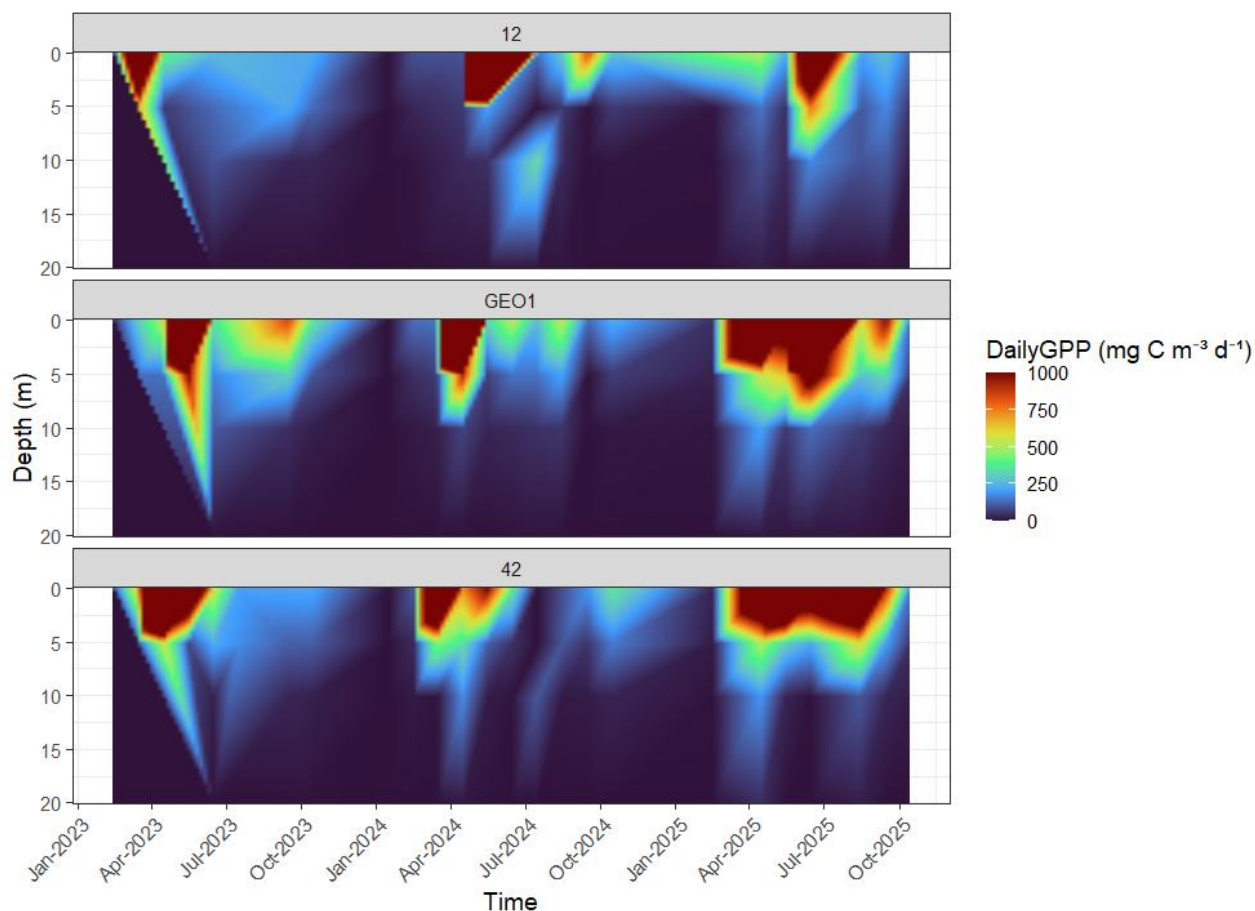


Figure 56-2. Daily gross phytoplankton production rates (GPP; $\text{mg C m}^{-3} \text{ day}^{-1}$) measured in the euphotic zone (0-20 m) at stations 12 (upper), GEO1 (middle) and 42 (lower) from 2023-2025.

Zooplankton abundance and biomass measurements have been a regular, if sporadic, part of sampling projects in the SoG extending back at least 30 years (Mackas et al. 2013; Perry et al. 2021; Young et al. 2024). Direct measurements of zooplankton production rates are much less common, but can provide crucial knowledge of the food web dynamics in the SoG. Starting in 2023, biweekly to monthly seawater incubation experiments were performed to measure *in situ* zooplankton biomass production rates (BPR) using the chitobiase enzyme decay method (Sastri and Dower 2006).

BPR was spatially heterogeneous and showed fairly strong seasonal patterns consistent with previous rate and biomass estimates (Figure 56-3; Sastri and Dower 2009; Perry et al. 2021). Although the highest BPR values were measured in the surface 50 m, our measurements showed that zooplankton production at depth (50-350 m) does contribute significantly to total BPR on annual timescales in the SoG (Figure 56--3). Total integrated yearly BPR, like GPP, increased from 2023-2025 (Figure 56-4).

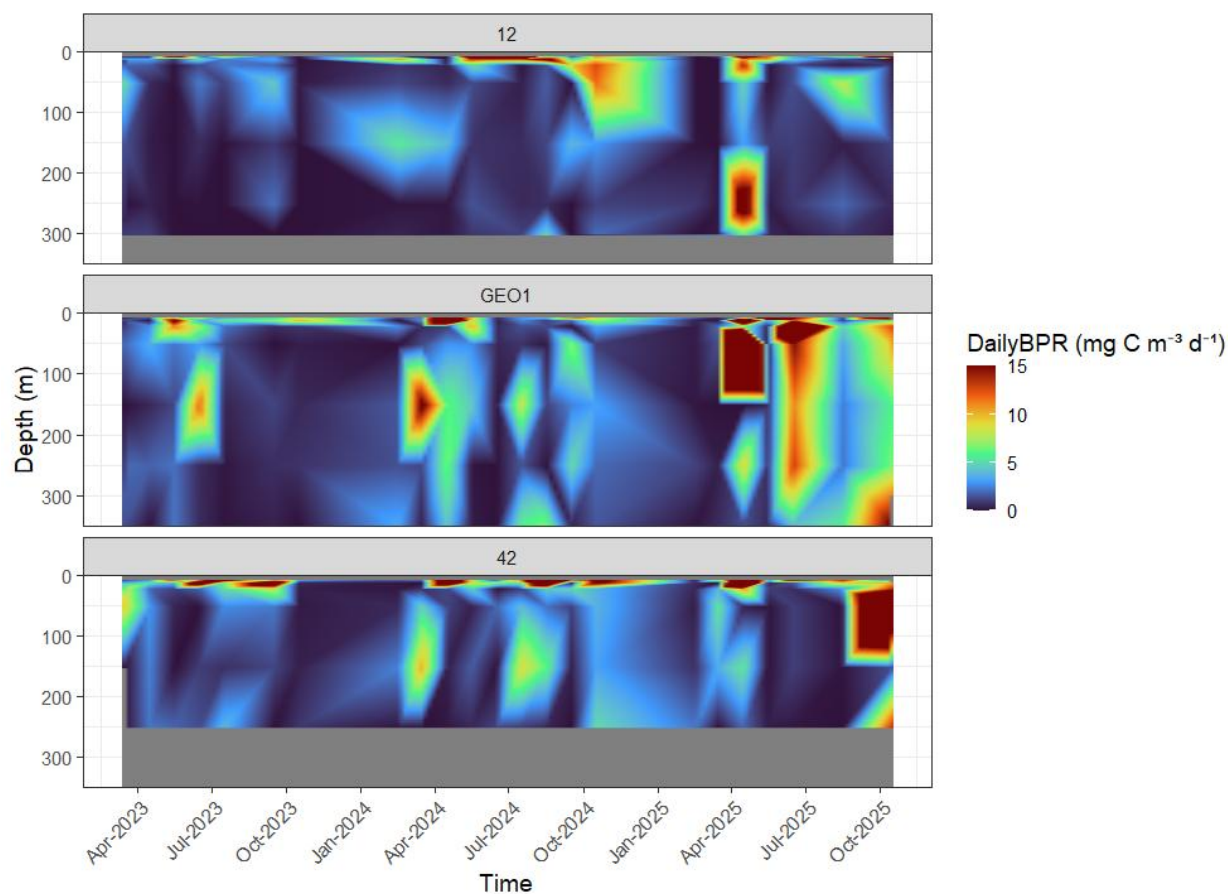


Figure 56-3. Chitobiase-based biomass production rates (BPR; $\text{mgC m}^{-3} \text{ day}^{-1}$) at stations 12 (top panel), GEO1 (center), and 42 (lower) in the Strait of Georgia, 2023-2025.

Transfer efficiencies (TTE) were calculated by dividing the integrated GPP by BPR. When GPP and BPR were integrated over the entire year and averaged for the entire SoG, TTE increased from 2023 (17.7%) to 2025 (23.5%; Figure 56-4). Seasonally integrated TTE was highest in winter and fall and lowest in the spring. Abundance/biomass observations suggest high winter TTE values are likely from capturing the start of the reproductive/growth cycle of overwintering euphausiids, amphipods and copepods at depth.

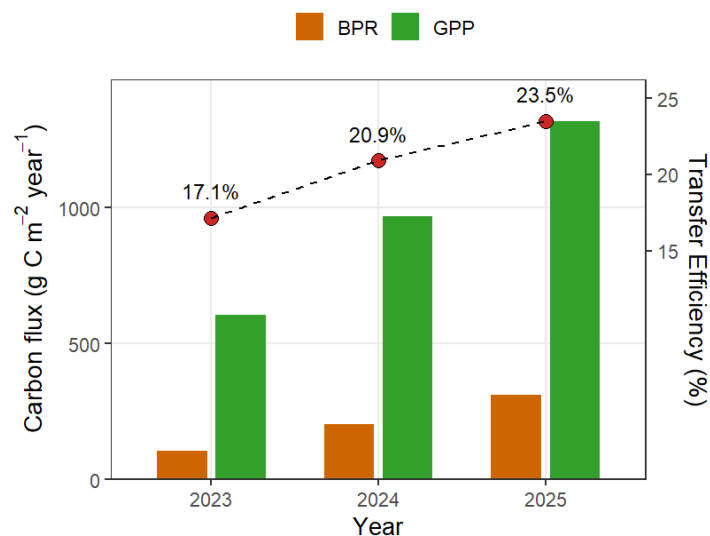


Figure 56-4. Average yearly gross phytoplankton production (GPP), crustacean zooplankton production (BPR) and Transfer efficiencies (TTE, %) averaged for all three stations in the Strait of Georgia.

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57. BARKLEY SOUND EUPHAUSIID AND PLANKTON MONITORING PROJECT

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57.1. Highlights

- Phytoplankton abundance was highest in May for all stations in 2023, and April or July in 2024, depending on station. Prymnesiophytes were more abundant in July-August 2023 than 2024 due to a coccolithophore bloom in Barkley Sound.
- Abundance and biomass of zooplankton increased through the spring and summer and varied by year and station. Small and medium calanoid copepods were most abundant at all stations, whereas biomass was mostly from medium calanoid copepods, amphipods, gelatinous zooplankton or larger crustaceans (euphausiids and decapod larvae), depending on station.

57.2. Extended abstract

The Plankton Ecology program at the Institute of Ocean Sciences, in collaboration with the Bamfield Marine Sciences Centre, is investigating the seasonal, inter-annual, and long-term variability of euphausiid production dynamics in Barkley Sound. This work advances our understanding of how climate-ocean driven changes in zooplankton composition and ecological processes at the base of the food web are relevant to juvenile salmon productivity (Tanasichuk 2002; Tanasichuk et al. 2014). Surveys in 2023-2024 were run once a month from February to November aboard the MV Alta. Samples were collected from five stations: Sarita, Swale, Coaster, Mackenzie and Robbers (Figure 57-1).

CTD casts were performed at Sarita and Swale until September 2023 and all stations thereafter. Water samples for nutrients, phytoplankton (for enumeration and ID), and chlorophyll were taken at the surface of all five stations. Water samples for nutrients and salinity were taken at the surface and deep (10 m off the bottom) for Sarita and Swale; and oblique Bongo net hauls were performed at Coaster, Swale, Robbers, and Mackenzie with 350 µm mesh nets.

Phytoplankton cells were identified to the lowest taxonomic level possible (following Nemcek et al. 2023) and summarized in broad algal classes as abundances in cells mL⁻¹. Phytoplankton abundance was highest in May for all stations in 2023, and April or July in 2024 depending on station (Figure 57-2). The most common types of phytoplankton were centric diatoms, prymnesiophytes and 'other' that included small flagellates. Dinoflagellates and prasinophytes were observed mostly in the summer months (Figure 57-2). Prymnesiophytes were more abundant in July-August 2023 than 2024 due to a coccolithophore bloom in Barkley Sound.

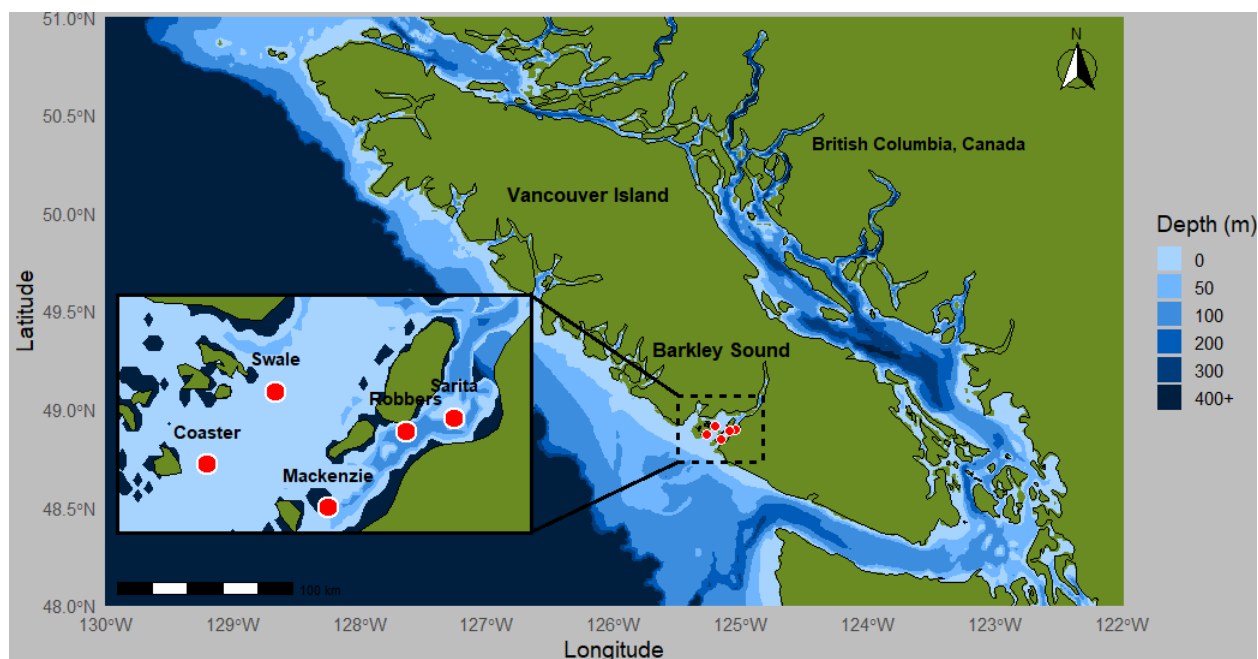


Figure 57-1. The five stations surveyed in Barkley Sound. Depth ranged from 200 m at the deepest (Sarita) to 60 m at the shallowest (Coaster).

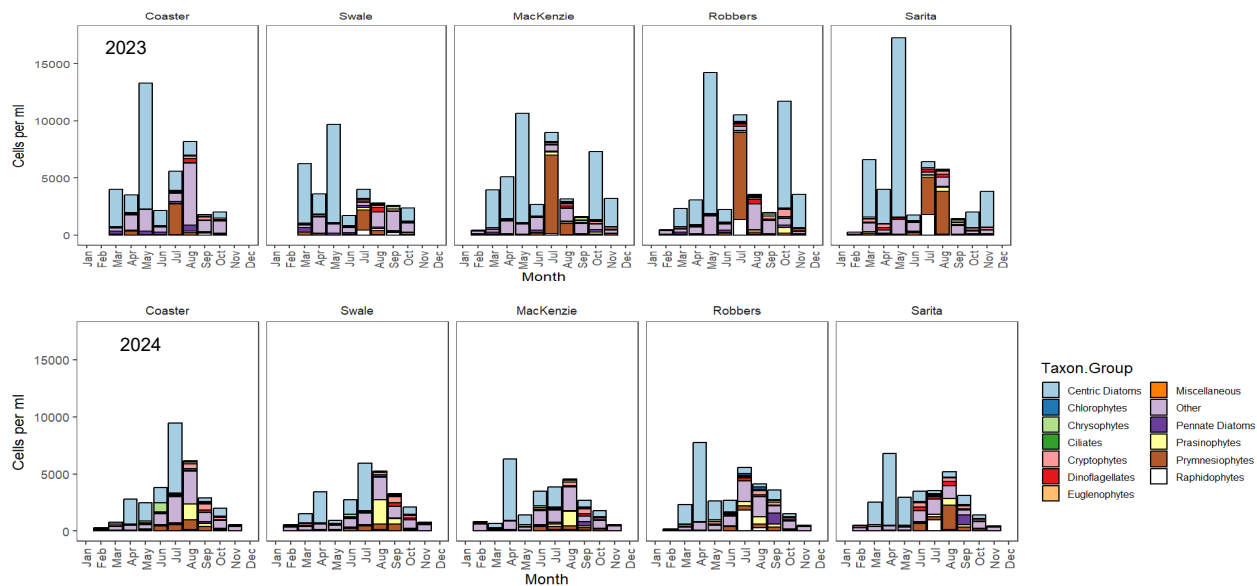


Figure 57-2. Phytoplankton composition by station and month from Lugol's preserved samples, aggregated by major phytoplankton taxonomic groups; 2023 (top panels) and 2024 (bottom panels).

Zooplankton samples were identified to species and life stage, and biomass was calculated from abundance following Lu et al. (2003) and Mackas (1992). Abundance and biomass of zooplankton increased through the spring and summer and varied by station (Figure 57-3). Small and medium calanoid copepods made a significant contribution to overall abundances at all stations (Figure 57-3, left). Biomass of amphipods was highest at Robbers throughout the year, and the biomass of gelatinous zooplankton (e.g., cnidarians and ctenophores) was higher

throughout the year at stations Coaster and Swale, with more gelatinous zooplankton in 2024 (Figure 57-3, right). Euphausiid community composition was similar to 2022 (Young et al. 2025).

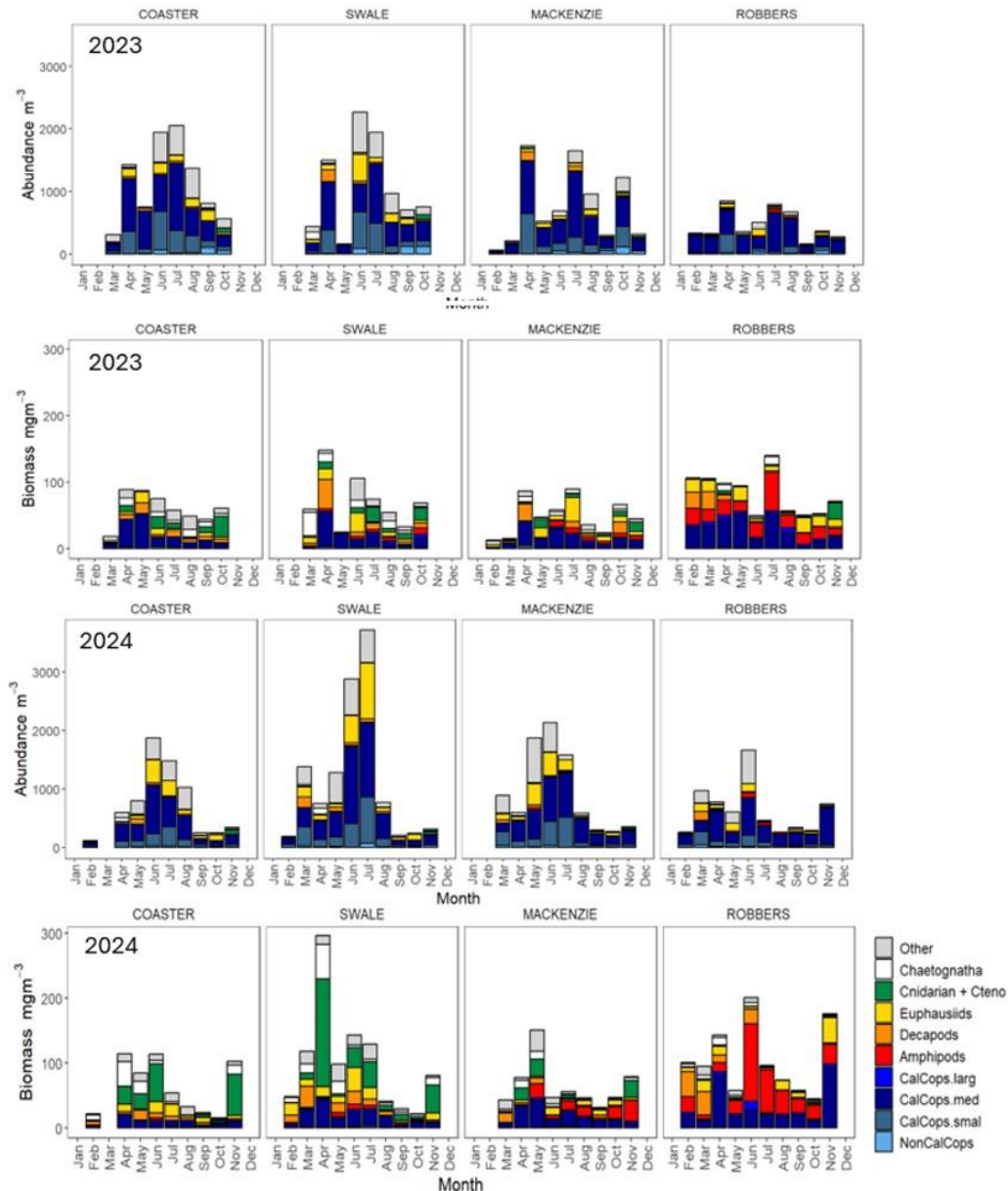


Figure 57-3. Zooplankton community composition by major groups of each station, averaged per month; 2023 (top two panels) and 2024 (bottom two panels). First and third row: average abundance (m^{-3}); Second and fourth row: average biomass ($mg\ m^{-3}$). Legend: NonCalCops – all other copepods; CalCops.small – calanoid copepods $PL < 1mm$; CalCops.med – calanoid copepods $PL\ 1-3mm$; CalCops.larg – calanoid copepods, prosome length ($PL > 3mm$); Amphipods – all amphipods (hyperiid and gammarid); Decapod – all decapods (shrimp, crab larvae); Euphausiid – all euphausiids (eggs, larvae and adults); Cnidarian + Cteno – all Cnidarian (medusa and siphonophores) and Ctenophores; Chaetognatha – all chaetognaths; Other – everything else: Molluscs, Polychaetes, Ichthyoplankton, Larvaceans, etc. See Perry et al. (2021) for full description of taxa and life stages included in each group.

Monthly monitoring continued for 2025 and data processing is ongoing. All CTD and bottle chemistry data can be downloaded from the Institute of Ocean Sciences Data Archive (<https://www.waterproperties.ca/data/>). Phytoplankton and zooplankton data are archived in the DFO-IOS Phytoplankton or Zooplankton Databases and available upon request.

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58. A COMPLEMENTARY IMAGE-BASED APPROACH FOR MONITORING ZOOPLANKTON ON LINE P AND LA PEROUSE PROGRAMS

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58.1. Highlights

- The Underwater Vision Profiler 6 (UVP6) is a new monitoring tool that improved the sampling resolution of zooplankton on major monitoring programs.
- Machine learning and image processing supported a semi-automated approach to classifying zooplankton and provided size based measurements for every individual.
- The UVP6 has a lower sampling volume capacity than the bongo net and as such sampled fewer Copepoda over standardized depths in a smaller size range.

58.2. Extended Abstract

UVP6 is an optical instrument designed for capturing in-situ images of zooplankton and large particles (Picheral et al. 2022). We deployed the UVP6 on three different oceanographic surveys from DFO's Line P and La Perouse monitoring programs (2025-004, 2025-008, 2025-015) to assess the effectiveness of the UVP6 as a new monitoring tool for zooplankton. The UVP6 was deployed on every rosette cast which provided full water column profiling for most casts and covered every oceanographic station sampled on each survey. Since plankton tows are neither conducted at every station nor sampled across the full water column of many stations, this extended both the spatial and depth coverage for zooplankton sampling on all surveys. Approximately 4 million images were collected from all three surveys and machine learning was used to semi-automatically classify the images into four main categories: copepoda, other zooplankton, detritus, and fecal pellets. A minimum of 30,000 validated images were used to build a classification library as a reference for the deep learning model to predict classifications of unvalidated images. To assess size variability within these predicted categories, image-derived metrics—such as equivalent spherical diameter and major axis—were utilized. The information from the improved sampling resolution helped us determine exactly how, in space and depth, the copepoda were distributed along the La Perouse and Line P transects. When compared to the bongo nets over standardized depths, the UVP6 sampled less total copepoda and from a smaller size range. This discrepancy can be explained by the lower sample volume capacity of the UVP6; the larger sampling volume of the bongo nets captures a greater total number of copepoda, which in turn increases the likelihood of capturing larger, less abundant individuals and effectively increases the size range sampled compared to that of the UVP6.

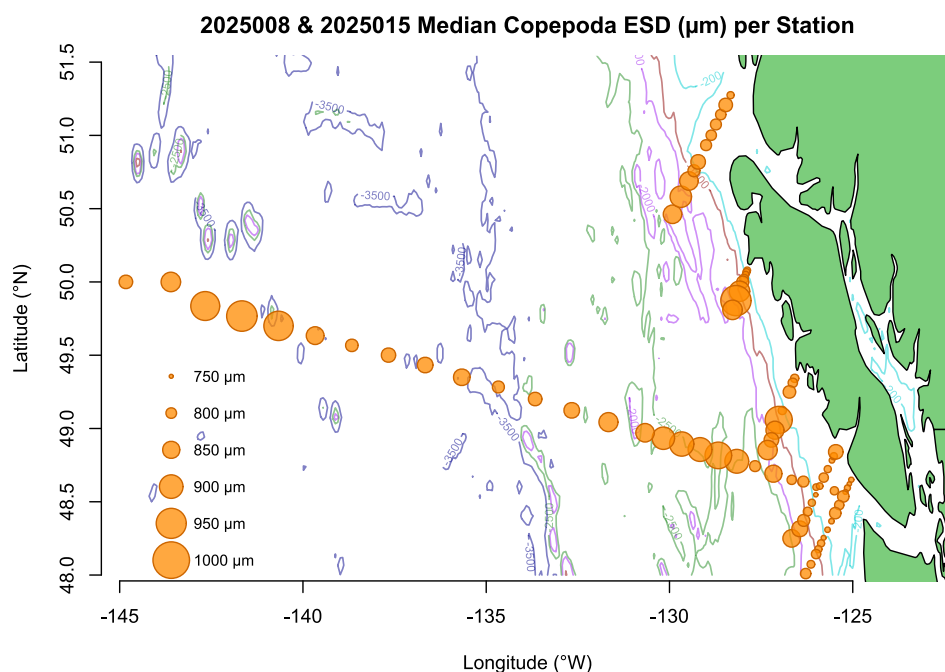


Figure 58-1. Scaled median ESD per station of Copepoda images from Line P (2025-008) and La Perouse (2025-015) surveys.

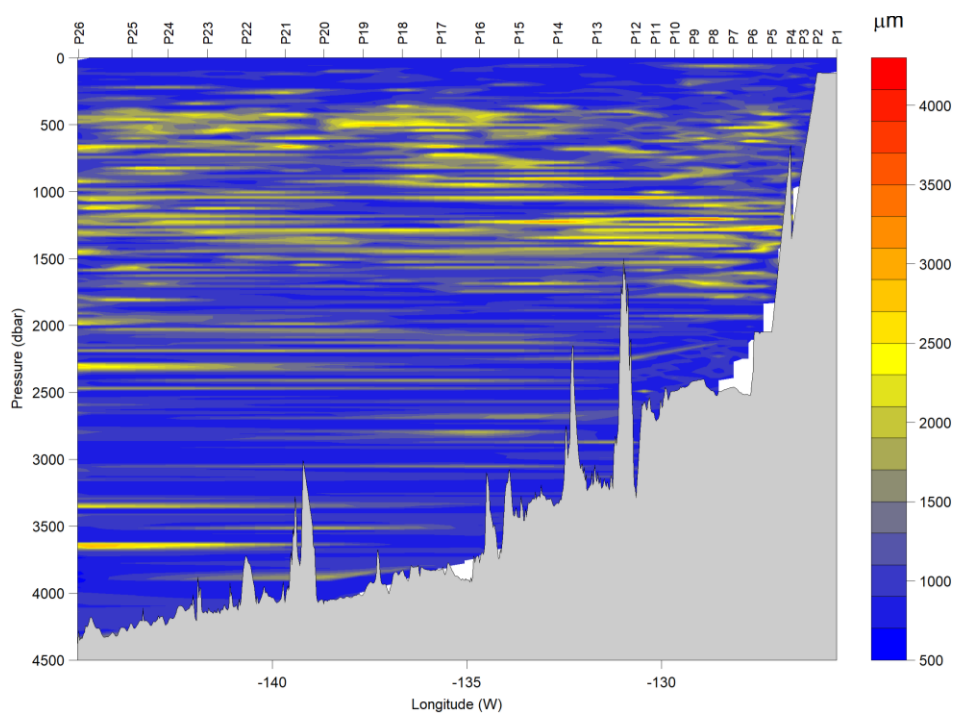


Figure 58-2. Section plot of Copepoda ESD from the Line P transect offshore Vancouver Island. Data was collected during the September Line P survey, 2025-008, using the UVP6. A total of 30,000 validated images of Copepoda were used for the deep learning model to predict unvalidated Copepoda images. The grey shading represents the bathymetry.

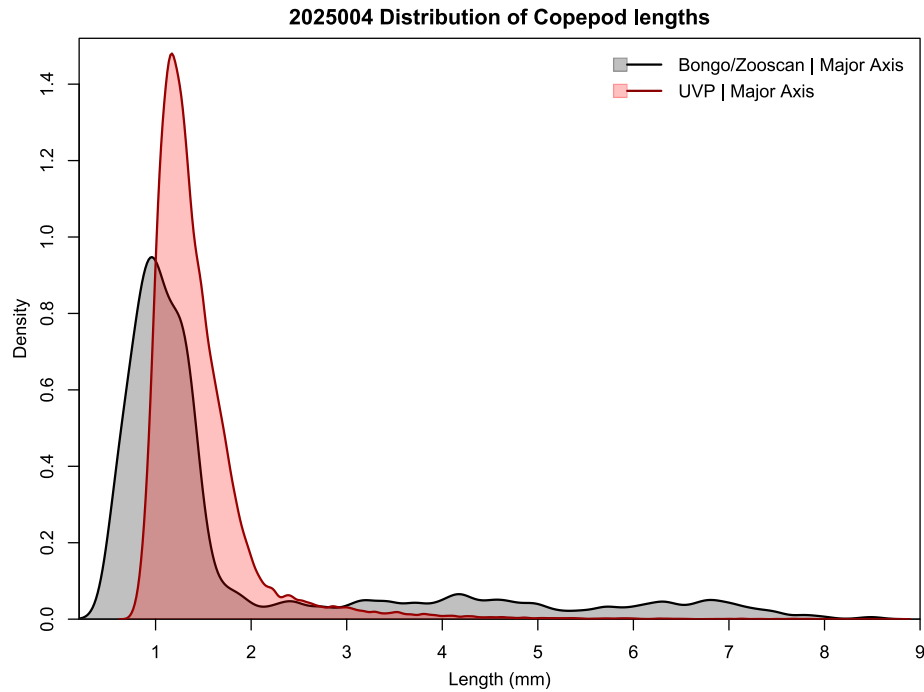


Figure 58-3. Density curves of the corrected total length of Copepoda from samples collected from the bongo and scanned by the zooscan (grey), and in-situ images collected by the UVP6 (red). The major axis depicts the length between the two most distant points of the best fitting ellipse of an image, which for Copepoda is comparable to total length.

58.3. References

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59. TEMPORAL DYNAMICS OF NEARSHORE ZOOPLANKTON COMMUNITIES IN THE STRAIT OF GEORGIA ASSESSED USING ZOOSCA

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59.1. Highlights

- Nearshore zooplankton dynamics in shallower environments are distinct and more seasonally variable than those in nearby deeper environments in Malaspina Strait.
- The relative abundance of zooplankton at the shallow site was more consistently dominated by small calanoid and cyclopoid copepods (smaller species with higher turnover), with less frequent shifts to other large-bodied taxa.
- The deeper sites show episodic spikes in biovolume mainly driven by large taxa (e.g., gelatinous zooplankton and larger crustaceans).
- There was distinct interannual variability and biovolume decreased since 2021.

59.2. Extended abstract

In recent decades, zooplankton communities in the Strait of Georgia (SoG) have shown pronounced inter-annual variability linked to large-scale climate oscillations (Li et al. 2013; Mackas et al. 2013; Suchy et al. 2022). Nevertheless, understanding of local drivers remains limited due to infrequent sampling characteristics of many monitoring programs. Additionally, zooplankton in nearshore habitats, which are vital for juvenile salmon and other forage fish, have been largely overlooked. To address this, zooplankton samples collected by Pacific Salmon Foundation's (PSF) Citizen Science Oceanography program from 2015 to 2025 are being leveraged in conjunction with ZooSCAN technology, a semi-automated image processing system, to assess the seasonal and interannual dynamics of the nearshore zooplankton assemblages in the SoG, and their relationship to oceanographic properties (Esenkulova et al. 2021). PSF's program engaged trained citizen scientists to collect zooplankton, temperature, salinity, depth, dissolved oxygen, turbidity, chlorophyll, nutrients, and harmful algae at three nearshore sites in Malaspina Strait, a key juvenile salmon migration pathway in the SoG (Furey et al. 2015; Healy et al. 2017). Samples were collected approximately one to two times a month from January 2015 to December 2025 (Figure 59-1). Zooplankton samples were processed using ZooSCAN which captures and processes high-resolution images of zooplankton samples, combined with image analysis using deep learning to rapidly identify major taxonomic groups. In addition, several metrics were calculated that are relevant to ecological studies and studies on fish diets, including organism size, organism biovolume, and community size spectra and biomass.

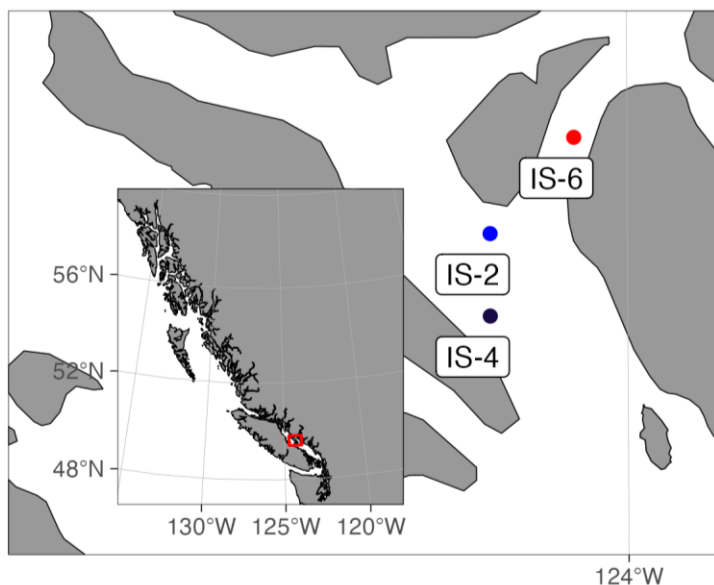


Figure 59-1: Map of sampling sites in Malaspina Strait. Sites are IS-2 (<30m depth), IS-4 (~420m depth), and IS-6 (~250m depth).

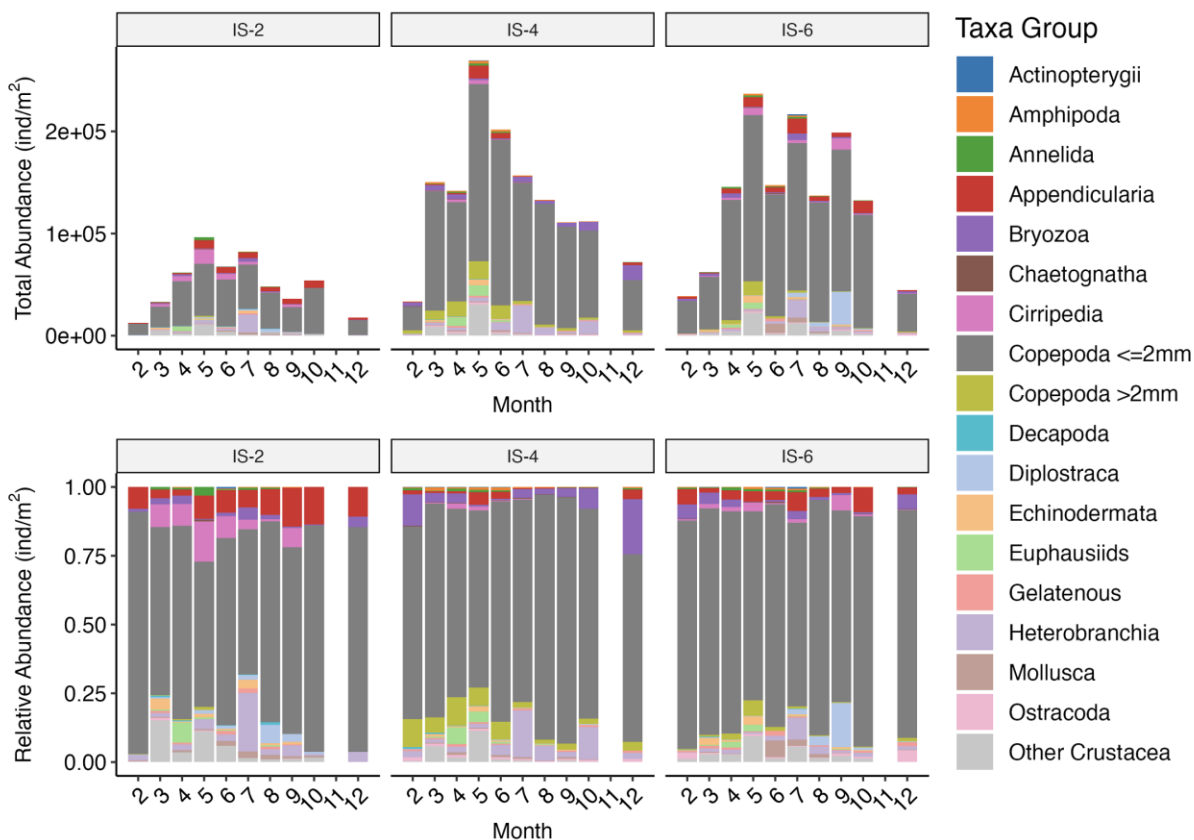


Figure 59-2: Monthly and spatial variation in zooplankton assemblage. Total (top) and proportional (bottom) zooplankton abundance by taxa group.

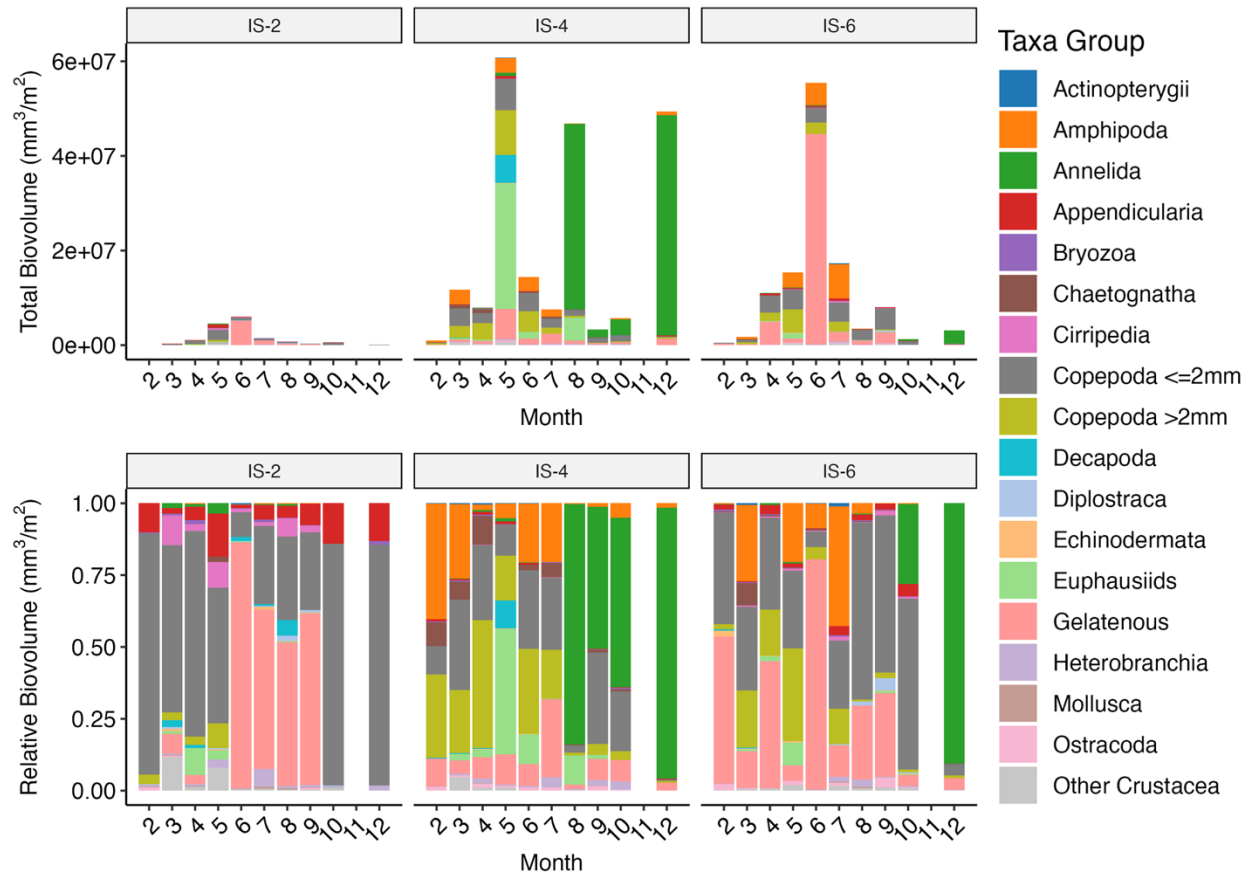


Figure 59-3. Monthly and spatial variation in zooplankton assemblage. Total (top) and proportional (bottom) zooplankton biovolume by taxa group.

Here we present preliminary results of the seasonal and interannual (2018-2024) dynamics of zooplankton assemblages from three nearshore sites in Malaspina Strait. In the 2024 seasonal analysis, across all sampling locations, peak abundance occurred in the summer (Figure 59-2), while peak biovolume was observed in the spring (Figure 59-3). Small calanoid copepods (≤ 2 mm) made up more than 50% of total abundance at all stations. The same major taxonomic groups were present across all stations, but their relative contributions and peak intensities varied. Depth played a critical role in structuring community composition. The relative abundance at the shallow site (IS-2) was more consistently dominated by small calanoid and cyclopoid copepods (smaller species with higher turnover), with less frequent shifts to other large-bodied taxa. The shallowest site also had larger contributions from meroplankton compared to the two deeper sites (IS-4 and IS-6). The deeper sites (IS-4 and IS-6) show episodic spikes in biovolume mainly driven by large taxa (e.g., gelatinous zooplankton and larger crustaceans). The interannual time series demonstrated distinct interannual variability (Figure 59-4). Since 2021, biovolume anomalies have decreased, reaching anomalously low levels in 2024. Nearshore zooplankton dynamics in shallower environments were distinct and more seasonally variable than those in nearby deeper environments. These variations may be driven by factors such as mixing, terrestrial influences, or predation pressure from forage fish. Future research will focus on the role of oceanographic variability and harmful algal blooms and its influence on zooplankton dynamics.

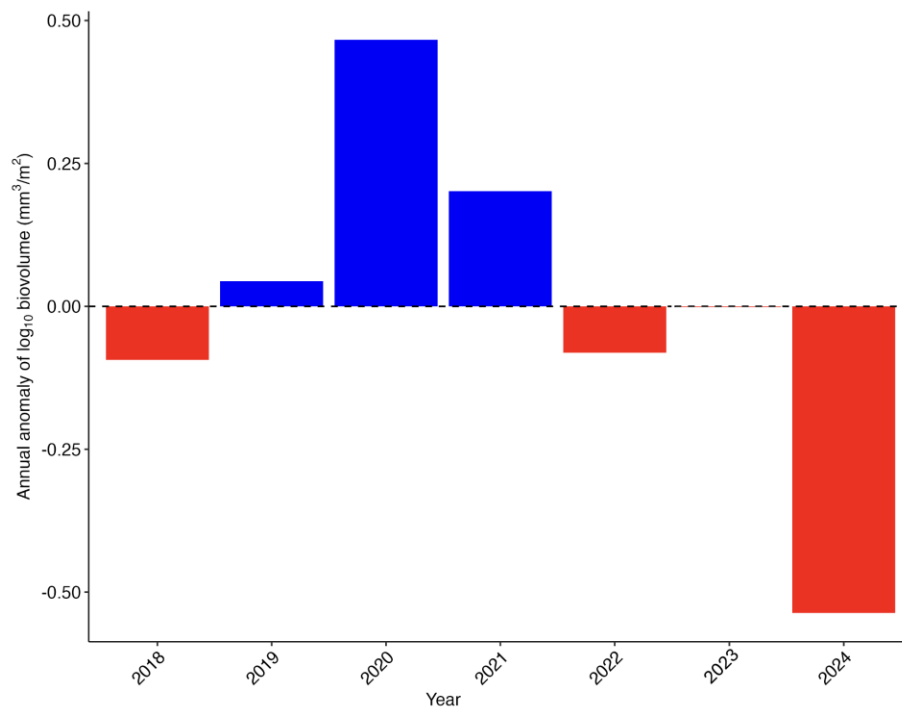


Figure 59-4. Interannual anomalies in $\log_{10}$ -transformed biovolume for years 2018-2022 and 2024. Anomalies are calculated by comparing annual to climatological biovolume means across the time series.

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60. COMPARE AND CONTRAST METHODS FOR OBTAINING ENERGY DENSITY VALUES FOR PACIFIC HERRING (*CLUPEA PALLASII*)

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60.1. Highlights

- Energy density (ED) was most strongly associated with organic tissue proportion, % ash-free dry weight (AFDW), indicating that biochemical composition was the primary determinant of caloric content as opposed to differences in body size.
- Morphometrics can be used as predictors of AFDW, which in turn can be used to as a predictor of energy density.

60.2. Extended abstract

Pacific Herring are a primary conduit of energy in the Northeast Pacific food webs, transforming plankton into dense, calorie-rich fuel for larger predators. Understanding variation in herring ED is essential for parameterizing bioenergetic models, evaluating the quality of prey in the marine ecosystem, and quantifying energy flow between trophic levels. We require cost and time-effective methods to study the variation in ED of herring over time and space. Sampling was conducted as part of the Integrated Pelagic Ecosystem Survey (IPES) in the summer of 2023 at 58 stations, where trawls were conducted both during the day and night. Morphometrics and Fatmeter readings were collected at sea and five herring were frozen for further analyses in the lab. Fish were dried and homogenized then measured for energy density using bomb calorimetry and AFDW using a muffle furnace for 5 hrs at 600°C. AFDW is an important metric because it quantifies the organic, energy containing portion of a sample's biomass, which provides a direct measure of the material available for trophic energy transfer. A Fatmeter is a portable instrument that provides a fast, non-destructive estimate of the lipid content of a fish by measuring how an electrical signal passes through the tissue. The underlying rationale for this study is that the higher the herring lipid content, the higher the Fatmeter reading, the higher the ED. Condition, length-weight residuals, measure the deviation of a fish's observed weight from its expected weight at a given length, this provides a size-independent measure of potential energetic condition of a sample.

The strongest predictor of energy density was % AFDW ($R^2 = 0.63$) while the Fatmeter explained ~18% of variation in energy density. Condition weakly predicted tissue composition ($R^2 = 0.10$), although energy density increased significantly with morphometrics indicating that larger individuals exhibit greater tissue energy content, and that size likely indirectly influences tissue composition ($R^2 = 0.42$; $R^2 = 0.35$). Morphometrics can be used as predictors of AFDW and therefore can be associated to energy density. Further data collection and Fatmeter readings will help improve the models and substantiate these relationships regarding energy density and condition of Pacific herring which will be helpful to investigate larger food web linkages.

Table 60-1. R^2 values from linear regression among various proxies used to predict energy density, * represents $p < 0.001$

Variables	Length	Wet Weight	% Dry Weight	Condition (l-w residuals)	Energy Density	% Ash-Free Dry Weight	Fatmeter
Length	---	---	---	---	---	---	---
Wet Weight	0.94*	---	---	---	---	---	---
% Dry Weight	0.33*	0.37*	---	---	---	---	---
Condition (l-w residuals)	0.01	0.09	0.10	---	---	---	---
Energy Density	0.35*	0.42*	0.64*	0.11	---	---	---
% Ash-Free Dry Weight	0.27*	0.30*	0.90*	0.07	0.63*	---	---
Fatmeter	0.04	0.04	0.46*	0.01	0.18*	0.45*	---

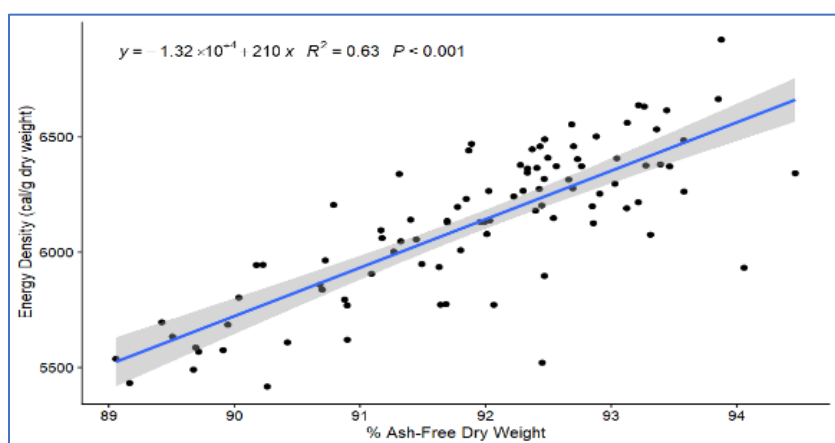


Figure 60-1. Relationship between % AFDW and energy density (cal/g dry weight)

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61. ESTABLISHING BASELINES, RISKS, AND MECHANISMS OF THIAMINE DEFICIENCY IN B.C. CHINOOK SALMON

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61.1. Highlights

- Thiamine (vitamin B1) deficiency is an emerging issue in the Pacific Ocean, affecting salmon from California to Alaska through elevated fry mortality and sublethal effects across their lifecycle.
- In the first large scale survey of thiamine deficiency in B.C., thiamine-deficient eggs were observed in all eight Chinook populations sampled in 2023-2024, with a greater proportion of females affected in 2024.
- Among Strait of Georgia prey species, Pacific Herring (*Clupea pallasii*) had the highest thiamine concentrations while myctophids (*Diaphus theta*) and Northern Anchovy (*Engraulis mordax*) had high levels of thiaminase—an enzyme that degrades thiamine.
- Chinook egg thiamine concentrations generally declined with increasing freshwater migration distance, but the effects of freshwater migration length and ocean distribution cannot be separated.
- Chinook egg thiamine concentrations were correlated with their fatty acids, showing that maternal diet composition affects egg thiamine status.

61.2. Extended abstract

Thiamine (vitamin B1) is required by all animals for basic cellular metabolism and must be acquired through their diet because thiamine is only produced by specific phytoplankton, bacteria, and fungi at the food web base. Thiamine deficiency causes a variety of cardiovascular and neurological problems and is ultimately lethal. It results from a disruption to the flow of thiamine up the food chain and is linked to shifts in prey communities. Although thiamine deficiency has long been known to occur in salmonids in the Laurentian Great Lakes and the Baltic Sea, it has only recently emerged in the Pacific Ocean, affecting salmon from Alaska (Larson and Howard 2019) to California (Mantua et al. 2025), motivating the first large scale survey of thiamine deficiency in B.C.

During 2023 and 2024 spawning seasons, we measured egg thiamine levels of eight different Chinook populations from the Fraser River and southern B.C. (Figure 61-1). These populations include most major life history types of Chinook Salmon, with differences in known run-timings (spring, summer, fall), marine distributions relative to the Fraser River (local/south, north, offshore) and freshwater migrations (coastal to upper Fraser). Egg thiamine levels were compared to thresholds for fry survival established in California to determine the occurrence of thiamine deficiency. We also investigated the causes of deficiency by measuring the thiamine nutrition of marine prey that salmon consume.

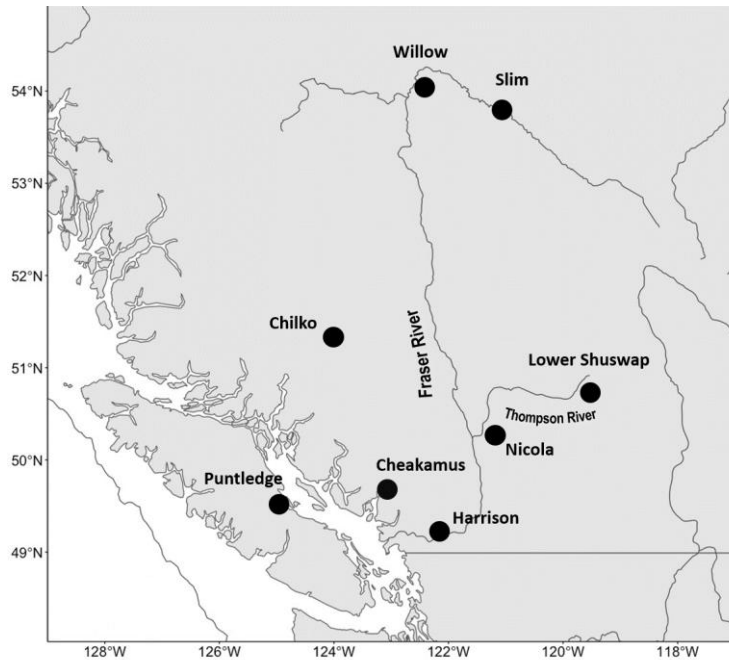


Figure 61-1. Locations of Chinook populations sampled for egg thiamine in 2023 and 2024.

There are three current hypotheses for how prey induce thiamine deficiency in predators: 1) low thiamine diets, 2) high thiaminase diets, and 3) high lipid diets—particularly a high ratio of omega-3 polyunsaturated fatty acids: thiamine. Thiaminase is an enzyme that can break down thiamine in the stomach, decreasing its availability and inducing thiamine deficiency in consumers. Thiamine accumulation is also influenced by dietary lipid content. Due to the central role of thiamine in energy metabolism, its requirements increase with dietary energy content. Therefore, metabolizing energy-dense lipids requires more thiamine than e.g., protein. In addition, omega-3 polyunsaturated fatty acids are highly susceptible to peroxidation, which can further increase thiamine use because it acts as an antioxidant.

Forage species in the Strait of Georgia displayed large differences in thiamine-relevant nutritional factors among taxa as well as high intra-specific variability. Pacific Herring (*Clupea pallasii*) had the highest mean thiamine concentrations. Thiaminase (thiamine degrading enzyme) was detected in Pacific Herring and Pacific Sand Lance (*Ammodytes hexapterus*), but the highest enzyme activities were found in the myctophid *Diaphus theta* and Northern Anchovy (*Engraulis mordax*), which also had the highest lipid content.

Across the eight Chinook populations sampled at spawning, we observed thiamine deficient eggs in all populations, and a greater incidence of thiamine deficiency in 2024 than in 2023. However, mean thiamine levels and the proportion of females affected varied among populations, suggesting different risks and drivers of thiamine deficiency. Thiamine concentrations generally declined with increasing freshwater migration distance; however, the effects of freshwater migration length and ocean distribution cannot be separated. Egg thiamine concentrations were also correlated with fatty acids, indicating that maternal diet composition affects thiamine status of her offspring.

The occurrence of thiamine deficiency is driven by interactions between salmon ocean distributions, shifting prey communities, and the drivers of prey thiamine / thiaminase levels, which require further research. Data from this project are currently viewable at https://jel1217.shinyapps.io/shiny_directory/ and will be publicly available following manuscript acceptance.

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62. FATTY ACID ANALYSIS FOR ECOLOGY: APPLICATIONS AND OPPORTUNITIES

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62.1. Highlights

- Fatty acid data are used to assess nutrition and health, track food web connections, and identify components of mixtures or communities.
- The Pelagic Ecosystems Lab at UBC routinely quantifies 48 different fatty acids in phytoplankton, zooplankton, fish, and shellfish.

62.2. Extended abstract

Fatty acid analysis has many applications in ecology and nutrition, but its use is often limited by access to facilities. The Pelagic Ecosystems Lab at the University of British Columbia now offers fatty acid analysis as a service, specializing in marine organisms.

Fatty acids are found in all organisms as components of energy storage, cell membranes, and bioactive molecules. The essential fatty acids are required for proper nutrition and must be obtained by consumers from their diet. They are needed for reproduction, immune response, and osmotic balance (reviewed by Parrish 2025). Therefore, fatty acids can constrain fish growth (Sargent et al. 1995), shape communities, and impact higher trophic levels. Fatty acids provide information on an organism's health and nutritional history, as well as their nutrition as prey for higher trophic levels.

Fatty acid data are used in food web research to identify prey sources and track diet shifts over time or across regions (McLaskey et al. 2024). Their diversity of forms and ubiquitous presence makes fatty acids versatile biomarkers in trophic studies. Specific fatty acids and ratios of fatty acids are used as biomarkers to identify key food web connections because diet is the primary source of fatty acids for most animals. At the food web base, different phytoplankton taxa, macrophytes, bacteria, and protists produce distinct fatty acid signatures. These are passed onto and retained by consumers, whose fatty acid composition reflects those of their prey. Fatty acid data offer more power to differentiate prey sources than stable isotopes and are a complementary method. Fatty acid data can also be used quantitatively when appropriate experimental data are available (Budge et al. 2006).

Anyone interested in fatty acid analysis services or with questions is welcome to contact the Pelagic Ecosystems Lab: <https://pelagicecosystems.oceans.ubc.ca/services/>.

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63. ASSESSMENT OF THE JUVENILE PINK AND CHUM SALMON OUTMIGRATION IN BURRARD INLET USING ENVIRONMENTAL DNA

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63.1. Highlights

- An eDNA survey was conducted between March and August of 2024 in partnership with the Tsleil-Waututh Nation (TWN) in Burrard Inlet, B.C. to study the outmigration, focusing on Indian River Pink and Chum Salmon.
- Chum and Pink Salmon were only detected in samples during the known juvenile outmigration period (March to June). Although eDNA cannot identify life stage, pairing ecosystem knowledge with proper sampling design shows that detections align with this targeted life stage.
- Juvenile Chum and Pink Salmon are negatively correlated with schooling species, and Chum Salmon are positively correlated with benthic species.

63.2. Extended abstract

For Pacific salmon, the first month of the juvenile marine outmigration period contributes disproportionately to lifetime mortality (Healy et al. 2017). The challenges of sampling the dynamic coastal environments juveniles inhabit result in persistent knowledge gaps (Beamish et al. 2003). There are inherent limitations and trade-offs with capture-based fish research (Godwin et al. 2026). Emerging molecular methods, particularly environmental DNA (eDNA), can provide a non-invasive and complementary approach to study this life stage in situations where capture-based methods fail. One coastal region that is understudied as a result of these limitations is səliłwət (in həŋqəmiŋəm), or Burrard Inlet, the body of water that Vancouver, B.C. surrounds. It is a highly developed and trafficked region, making conventional capture sampling impossible along much of the shoreline. This study, in partnership with the Tsleil-Waututh Nation, employed eDNA to monitor the juvenile Pink (*Oncorhynchus gorboscha*) and Chum Salmon (*Oncorhynchus keta*) outmigration through this urbanized inlet.

Sampling was conducted monthly from March until August of 2024. Two-liter water samples were collected in triplicate from shore, by bucket, or by paddleboard at 14 different nearshore sites throughout Burrard Inlet (Figure 63-1). Samples were filtered through a 0.22 micron Sterivex and extracted using a Qiagen DNEasy Blood and Tissue Kit plus a Zymo OneStep PCR Inhibitor Removal Kit. Samples were metabarcoded on a MiSeq using 12S MiFish (Miya et al. 2015) and COI-Salmon (Thomas et al. 2022) primers for fish community identification. Sequences were then processed using the BARQUE bioinformatics pipeline (Mathon et al. 2021). All subsequent analyses were conducted in R.



Figure 63-1. Map of *səlilwet* (Burrard Inlet) sampling sites. The 4 main basins of interest are identified, and all 14 sites used for analysis are displayed and coloured by corresponding habitat type.

Pink and Chum Salmon were only detected in eDNA samples during their known outmigration period, between March and June (Figure 63-2). Adult Pink Salmon did not return to spawn in the summer of 2024 given their odd-year cycle, and Chum Salmon do not return to their natal rivers in the inlet until October (Van Will et al. 2009). Given that neither Pink or Chum Salmon reside in the Salish Sea as adults until their return to spawn (Quinn and Losee 2022), the DNA detected in these samples likely originates from juveniles. The lack of DNA detected in July and August corroborates the observation that neither Pink or Chum Salmon reside in the Salish Sea as adults until their return to spawn (Quinn and Losee 2022).

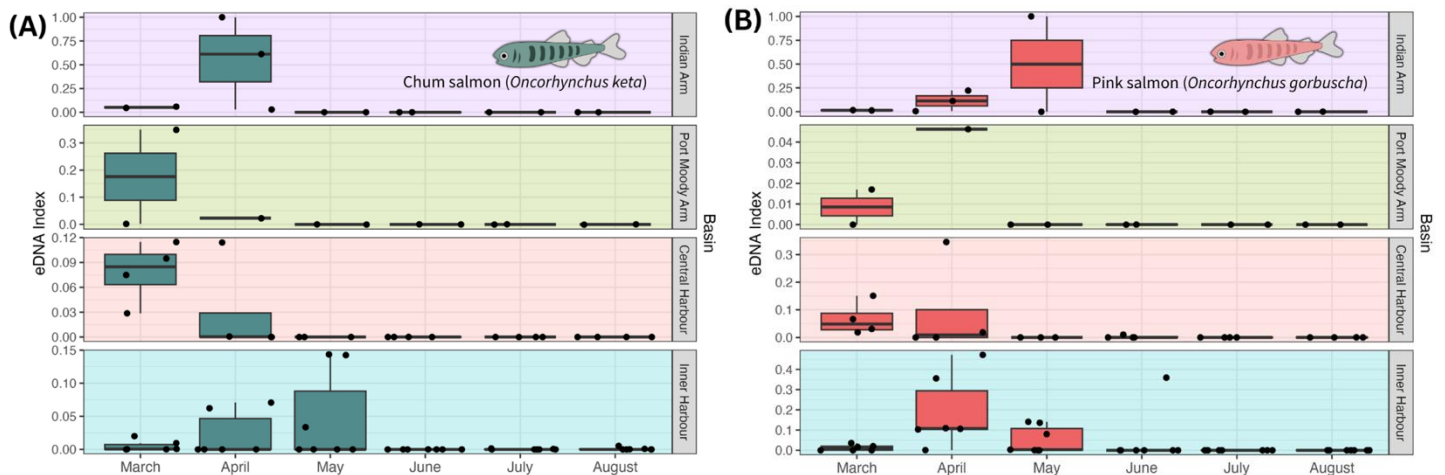


Figure 63-2. Tukey boxplots of eDNA index values for (A) Chum and (B) Pink Salmon ordered by month and separated by basin. Basins are ordered by distance from natal stream, with the shortest distance as the top plot (Indian Arm). Note the variable scales on the y axes.

Using a Spearman's rank correlation, both Pink and Chum Salmon were significantly negatively correlated with schooling species such as Shiner Perch and Northern Anchovy ($p < 0.05$), while Chum Salmon were significantly positively correlated with benthic species such as Righteye Flounders and sculpins ($p < 0.05$) (Figure 63-3).

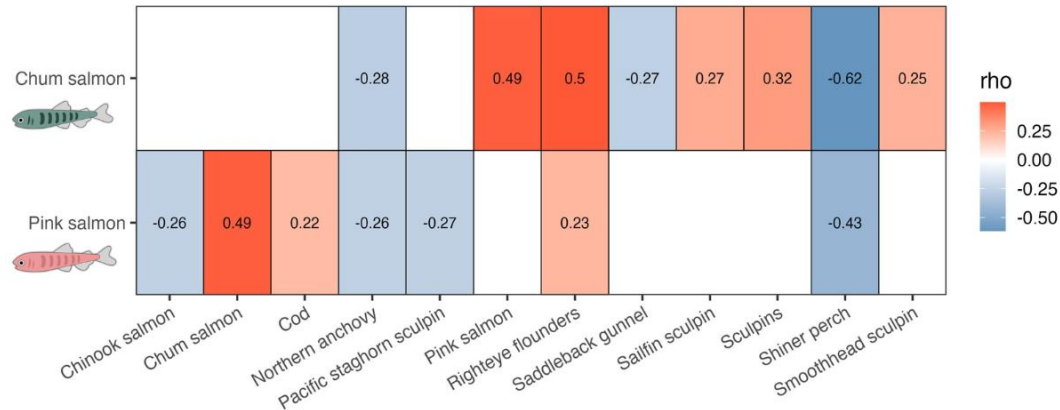


Figure 63-3. A heatmap displaying significant ($p < 0.05$) Spearman's rank correlation coefficients (ρ , values within cells) for Pink and Chum Salmon between all species detected using an ensemble eDNA index calculated by combining eDNA index values from 12S and COI-Sal primers. Dark red cells indicate a strong positive correlation between species, and dark blue indicate negative correlations. White cells indicate no significant correlation for that species combination.

These findings highlight the benefit of using eDNA to improve our understanding of the early marine outmigration phase for juvenile salmonids. This project has enabled the sampling of sites where seines and trawls cannot be deployed, providing new information on Chum Salmon and Pink Salmon migration routes, habitats, and species interactions in a highly disturbed nearshore environment.

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64. LIFE-HISTORY SPECIFIC SURVIVAL OF WEST COAST VANCOUVER ISLAND CHINOOK SALMON

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64.1. Highlights

- Chinook Salmon size at estuary entry and residency time were estimated, which enabled us to calculate life-history specific survival from 2015-2023 for the Sarita, Stamp/Somass/Robertson and Nitinat River systems.
- The life-history strategies of West Coast Vancouver Island (WCVI) Chinook Salmon vary by river system, and break-point models best reflect the differing growth rates observed in the fry and parr out-migrants.
- Early fast growth appears to be negatively correlated with size and age at return across every system.

64.2. Extended abstract

Characteristics that ultimately impact the age-specific survival and fecundity of organisms are known as life-history traits (Hutchings 2004). These characteristics can include size at maturity, age at senescence, and individual growth rates (Stearns 1992). Organisms that diverge in the expression of life-history traits during development are known as life-history types (Clemens and Schreck 2021). For example, two life-history types within Chinook Salmon (*Oncorhynchus tshawytscha*) include ocean type (smoltification before age 1) and stream type (smoltification after age 1) (Riddell et al. 2018). However, within these groups, there are more life-history types that may be displayed within a population, such as when juveniles leave the river (i.e., leave as fry or parr out-migrants).

Ocean type Chinook Salmon within Southern B.C. typically leave the river as either an emergent fry or as a parr (Fraser et al. 1982). Fry emigration occurs soon after the yolk sac is absorbed by individuals and occurs in late winter and early spring. Parr emigration typically occurs after several months of freshwater rearing. The production of fry is density independent, while the production of parr is density dependent (Zimmerman et al. 2015). The difference between the survival and fecundity of these two life-history types is not well known for many systems, but typically fry out-migrant survival is far lower than parr out-migrant survival (Apgar et al. 2021). As part of the Pacific Salmon Strategy Initiative, we investigated the relative survival and fecundity of these life-history types amongst ocean type Chinook Salmon on the West Coast of Vancouver Island.

We measured minor and trace elements within the otoliths of adult Chinook Salmon through Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) to identify whether natural origin individuals were fry or parr out-migrants, effectively allowing us to look back in time at the individuals successfully completing their life cycle. To back-calculate fork length, an

otolith radius to fork length regression was created for each system due to the differences inherent to each population.

While fry out-migrants are the most common life-history type within these systems, parr out-migrants always survived at a much higher rate (between 5-30 times higher). The difference in survival may arise during the first few months of fry emigration because we found that the proportion of fry to parr was not different between post-smolts collected from May to September for the Sarita River system (Figure 64-1), though both post-smolt and adult collections differed drastically from the run reconstruction made from the rotary screw trap analysis conducted by the environmental consultants at LGL Ltd.

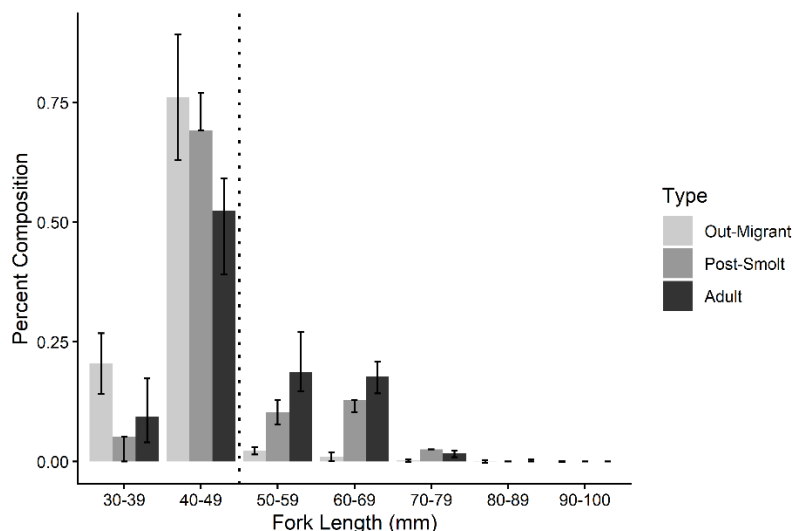


Figure 64-1. Percent composition of 10 mm fork length bins averaged across sampling years for natural origin Chinook Salmon leaving Sarita River as juvenile out-migrants, rearing in the nearshore marine environment in their first summer at sea as post-smolts, and returning to Sarita River as adults. Fork lengths were assigned based on Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry reconstructions of size at estuary entry for post-smolts and adults. Error bars represent pooled standard errors from rotary screw trap estimates for out-migrants, and the 95% confidence interval from the back-calculation error for post-smolts and adults. Dashed line indicates size at which fry out-migrants and parr out-migrants are separated from one another. Sample sizes: $n_{\text{out-migrant}} = 4,397$, $n_{\text{post-smolt}} = 39$, $n_{\text{adult}} = 219$.

Fry out-migrants survive at a lower rate than parr out-migrants, however, fry out-migrants were far more likely to return at an older age (0.38 years older on average). This was driven by fry out-migrants making up most of the European age 0.4 individuals, which is the oldest age class within WCVI systems. Older Chinook Salmon have higher fecundities and higher reproductive success generally (Haring et al. 2016; Ohlberger et al. 2020). Monitoring the relative contributions of fry and parr out-migrants to the natural origin portions of these populations will aid stock management efforts.

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65. RESEARCHING THE RESEARCH STATIONS: ANNUAL MONITORING AT PBS AND IOS

Jocelyn Nelson¹, Kayleigh Gillespie¹, Shannon Schmunk¹, Rob Skelly², Lucie Hannah², and Cathryn Murray²

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65.1. Highlights

- This annual monitoring project aims to create a time series of ecological and biophysical properties of areas surrounding the Pacific Biological Station (PBS) and the Institute of Ocean Sciences (IOS).
- By taking a collaborative approach, keeping protocols simple, and selecting areas that can be accessed without travel, the project aims to maintain annual monitoring long term.

65.2. Extended abstract

The Ecosystem Stressors Program at Fisheries and Oceans Canada (DFO), together with members from DFO's ROPES (Research in Ocean Properties and Ecosystem Stressors), MSEA (Marine Spatial Ecology and Analysis), AEMMS (Aquatic Ecosystem & Marine Mammals Section), Marine Invertebrates, Nearshore Ecosystems, and Integrated Marine Response Planning, initiated a monitoring program at each research station to track ecological and biophysical properties over time. By using established, standard protocols and selecting areas that we can access without travel, we aim to repeat the survey each year with the goal of creating a long-term dataset.

In 2025 we brought together a team of 24 people at IOS and 20 people at PBS. The intertidal survey documented 13 intertidal taxa at PBS and 22 at IOS, there were 29 fouling species on settlement plates at PBS and 23 at IOS (Figure 65-1). The drone survey was used to create orthomosaics of each site, and the teams quantified and collected marine debris over a 100 m transect survey covering the intertidal and backshore areas. Results from baited remote underwater videos and eDNA samples are still being processed. We are open to more survey methods if you have suggestions or requests; the only limitation is the availability of staff willing to commit to repeating the survey annually and within our goal of a single-day event.

If you are interested in participating in this collaborative field work, please contact us.



Figure 65-1. Photos of the 2025 intertidal survey at PBS (left), and IOS (middle and right)

66. UNDERWATER AND AIRBORNE NOISE FROM DETONATIONS AT WHIRL BAY AND BENTINCK ISLAND

Jorge E. Quijano, JASCO Applied Sciences, Victoria, B.C. jorge.quijano@jasco.com

66.1. Highlights

- Throughout the year, on-land and underwater detonation activities are conducted by DND/CAF on properties located at the southern tip of Vancouver Island (B.C.).
- JASCO conducted detonation noise measurements and used these data to inform acoustic modelling of conservative detonation scenarios.
- Measurements inform Mammal Avoidance Zones (MAZ) –in which detonations are halted if marine mammals are observed within the zone, to avoid adverse noise impacts.

66.2. Extended abstract

Throughout the year, the following detonation activities are conducted by Department of National Defence and the Canadian Armed Forces (DND/CAF) on properties located at the southern tip of Vancouver Island (B.C.): 1) On-land demolitions training at the Bentinck Island Surface Demolition Range; 2) Underwater demolitions training at the Whirl Bay Underwater Demolition Range; 3) On-land detonations for the destruction of surplus and outdated explosives at the Rocky Point Destruction Area. JASCO Applied Sciences (JASCO) was commissioned by PSPC on behalf of DND to analyze the potential for these activities to cause injury and behavioral disturbance in marine mammals, as well as injury or mortality in fish. Measurements were used to inform noise propagation modelling for the estimation of MAZ for each activity:

- Bentinck Island Surface Demolition Range: measurements of underwater and airborne noise from on-land detonations show that most underwater noise is due to ground-to-water coupling, and only a minor noise contribution is due to air-to-water coupling at close range (Quijano et al. 2025). Modelling shows that a MAZ distance of 163 m is sufficient to avoid adverse effects, including behavioural disturbance, to all marine mammals underwater. This MAZ corresponds to the largest allowable charge at the Range (2.5 kg C4).
- Whirl Bay Underwater Demolition Range: measurements of underwater noise from underwater detonations were collected at increasing distances from the Range (Figure 66-1). Measurements enabled us to quantify the noise propagation, as well as the effect of a bubble curtain and local bathymetry to reduce noise propagation. Modelling shows that a MAZ distance of 834 m is sufficient to avoid adverse effects, including behavioural disturbance, to all marine mammals. It corresponds to the noisiest modelled conditions: largest charge size (9.69 kg C4), the highest tide (2.5 m), and the charge placement that maximizes propagation toward the Juan de Fuca Strait.
- Rocky Point Destruction Area: modelling was conducted to quantify the effect of airborne and underwater noise on marine fauna. The model shows that fish are not affected under any of the modelled conditions. In addition, no injuries/ behavioural disturbance are expected for marine mammals underwater.

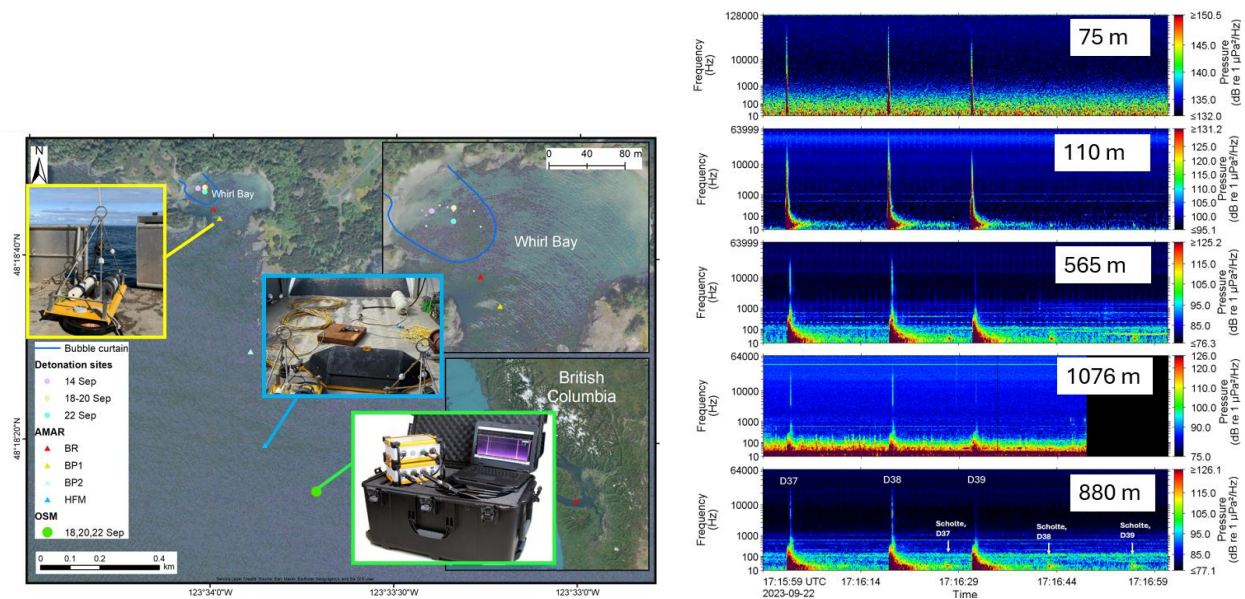


Figure 66-1. Experimental setup for the measurement of underwater detonation noise at Whirl Bay Underwater Demolition Range, using four bottom-mounted Autonomous Multichannel Acoustic Recorders (AMARs) and a hand-held Ocean Sound Meter (OSM) by JASCO Applied Sciences (left). Spectrograms produced by three detonations (D37, D38, D39), obtained at the indicated distances from the charges (right).

66.3. References

Quijano, J.E. and Koessler, M.W. 2025. Underwater noise from on-land blasting. JASA Express Lett. 5 (11): 113601-1:113601-7.

67. DEVELOPING MICRO-CREDENTIALS IN SUSTAINABILITY AND STEWARDSHIP FOR A SUSTAINABLE BLUE ECONOMIC FUTURE

Meaghan Efford, Rhea Storlund, and Brian Hunt, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, B.C. m.efford@oceans.ubc.ca, r.storlund@oceans.ubc.ca, b.hunt@oceans.ubc.ca

67.1. Highlights

- The Leadership in the Sustainable Blue Economy (LSBE) Certificate Program is a new, non-credit option for students and professionals to upskill in or transition into the sustainable blue economy
- Learners can pick three micro-certificate courses to complete to earn their LSBE Certificate
- The five micro-certificate courses focus science communication, research, data analytics, ethical science, and collaboration skills

67.2. Extended abstract

The Sustainable Blue Economy is a rapidly growing sector in Canada, and nowhere more so than along the Pacific coast. Canada's Pacific Ocean contributes critical marine shipping and transportation, fisheries, tourism, shipbuilding, aquaculture, and traditional livelihoods. All require skilled professionals to support sustainable development and stewardship. Developing and implementing training and education programs that are tailored to addressing this need is essential to make a sustainable blue economic future possible. The Leadership in the Sustainable Blue Economy (LSBE) Certificate Program is a new, non-credit option for students and professionals to upskill in or transition into the sustainable blue economy. Hosted by the Institute for the Oceans and Fisheries and made possible through partnerships with the Students on Ice (SOI) Foundation and the Ministry of Education, this Program is designed to support Canada's blue economy with newly skilled workers.

Through a longitudinal analysis and collaborative course development, this project seeks to provide essential up-skilling and re-skilling for students and professionals. The LSBE Certificate will require the completion of three of five micro-certificate courses. These micro-credentials will offer training in scientific research, transdisciplinary methods, ecosystem conservation and restoration, ethics, science communication, and key topics in the sustainable blue economy. To ensure that course offerings align with industry needs, we are seeking input from stakeholders across all blue economy sectors. Through a partnership with the Students on Ice Foundation and the Ministry of Education, these first five courses form the foundation of a training program that will equip learners with the skills needed to succeed in a rapidly evolving sector and contribute meaningfully to sustainable ocean development. We are seeking input on course development across sectors to ensure an effective and impactful training program.

Appendix 1 - Meeting Agenda

Oral presentations, SOPO DAY 1 - Wednesday March 4, 2026

#	Start time	End time	Name	Affiliation	Title
	9:00	9:10	Tucker, Gauthier, Boldt, Jackson	DFO	Introduction
	9:10	9:25	Elder Sandra Good	Snuneymuxw First Nation	Opening
	9:25	9:30	Andy Thomson	DFO	Welcome from DFO
1	9:30	10:00	Carrie Robb, Heidi Gartner, Marilyn Brière-Deschenes, Cynthia Bluteau	DFO/Council of the Haida Nation	Highlights from the Marine Conservation Targets Initiative - Overview of MCT Sampling - NorthEast Pacific Deep-sea Exploration Project (NEPDEP) and updated knowledge on cold seeps - Oceanographic Conditions in MCT
	10:00	10:30	Break		
2	10:30	10:45	Abigail Dah, Charles Curry	Pacific Climate Impacts Consortium, UVic	Land Temperature and Hydrological Conditions over B.C. in 2025
3	10:45	11:00	Ian Giesbrecht	Hakai Institute	River Discharge to the Pacific Ocean in B.C. 2025
4	11:00	11:15	Tetjana Ross	DFO	Review of temperature, salinity and density of the northeastern Pacific in 2025 using Argo, glider, satellite and Line P data
5	11:15	11:30	Jennifer Jackson	DFO	Sea surface temperature and salinity observed at shore stations along the B.C. coast in 2025
6	11:30	11:45	Roy Hourston	DFO	Wind-driven upwelling/downwelling along the northwest coast of North America: timing and magnitude. With an update of the La Perouse time series
7	11:45	12:00	Cynthia Bluteau	DFO	Subsurface ocean conditions along the B.C. coast from moored observations
	12:00	13:30	Lunch		
8	13:30	13:45	Charles Hannah	DFO	Oxygen and hypoxia in British Columbia waters
9	13:45	14:00	Guoqi Han	DFO	Ocean currents and temperature off the B.C. coast
10	14:00	14:15	Lynn Lee, Gwaii Haanas, Skil Jáada, CHN team, Stephen Page, DFO team, academic collaborators	DFO, Gwaii Haanas Parks Canada, Council of the Haida Nation, Hakai Institute	2025 Ocean conditions in and potential monitoring metrics for Gwaii Haanas & Haida Gwaii
11	14:15	14:30	Andrea Hilborn	DFO	Satellite observations of surface chlorophyll-a, temperature, and marine heatwaves in 2025
12	14:30	14:45	Wiley Evans	Hakai Institute	Ocean acidification dynamics in nearshore regions during 2025
13	14:45	15:00	Justin Del Bel Belluz	Hakai Institute	2025 trends in phytoplankton biomass and community composition from timeseries stations in the northern Salish Sea and central coast, British Columbia

#	Start time	End time	Name	Affiliation	Title
14	15:00	15:15	Akash Sastri, Moirra Galbraith	DFO	West Coast Vancouver Island zooplankton time series update for 2025
	15:15	15:35	Break		
15	15:35	15:50	Maycira Costa <i>CANCELLED</i>	DFO	Kelp persistence and resilience along the B.C. coast
16	15:50	16:05	Lais Chaves	Tsawout First Nation	Á, LENENEØ: Tsawout's Dungeness Crab stewardship for future generations
17	16:05	16:20	Jennifer Boldt	DFO	Pelagic fish: an update on status and trends
18	16:20	16:35	Amy Tabata	DFO	2025 juvenile salmon surveys in southern coastal waters of B.C.
19	16:35	16:40	Andrew Edwards	DFO	Updates since last year to pacea: an R package of Pacific ecosystem information to help facilitate an ecosystem approach to fisheries management (with a live demo during poster session)
	16:40	17:00	Tucker, Gauthier, Boldt, Jackson		Summary discussion
	17:00	19:00			POSTER SESSION

Oral presentations, SOPO DAY 2 - Thursday March 5, 2026

#	Start time	End time	Name	Affiliation	Title
	9:00	9:15	Tucker, Gauthier, Boldt, Jackson	DFO	Introduction
20	9:15	9:30	Clare Ostle	MBA	Lower Trophic Levels in the NE Pacific from CPR data
21	9:30	9:45	Bronwyn Macdonald, Sue Grant, Gottfried Pestal	DFO	State of Canadian Pacific Salmon
22	9:45	10:00	Marilena Geng	DFO	Simulating present and future ocean conditions in Clayoquot Sound and the potential impacts on Pacific Salmon
23	10:00	10:15	Sean Anderson	DFO	Trends in Pacific Canadian groundfish stock status and surveys
24	10:15	10:30	Stéphane Gauthier	DFO	Pacific Hake inside and out: trends in the Salish Sea population of Pacific Hake (<i>Merluccius productus</i>) and update on the coastal migrating stock
	10:30	10:45	Break		
25	10:45	11:00	Mark Hipfner	ECCC	Observations on seabirds along the B.C. coast
26	11:00	11:15	Douglas Bertram	ECCC	Inter-annual variation in marine bird counts within the Haro Strait region of the Salish Sea: 2015-2025
27	11:15	11:30	Linda Nichol	DFO	Trends in growth and abundance of B.C.'s Sea Otter population
28	11:30	11:45	Janet Mossman	DFO	CeNorth Surveys: Line transect surveys to estimate seasonal cetacean abundance, density and distribution off B.C.'s North Coast
29	11:45	12:00	Kohen Bauer	ONC	Exploring the potential for a West Coast B.C. Distributed Biological Observatory (DBO)
	12:00	13:30	Lunch		
30	13:30	13:45	Mackenzie Mueller	DFO	Marine biotoxin monitoring in B.C. coastal waters

#	Start time	End time	Name	Affiliation	Title
31	13:45	14:00	Brett Howard	DFO	Update on the distribution of aquatic invasive species in the Pacific Region
32	14:00	14:15	Rianna Burnham, Robyn Taves	DFO	Soundscape and sound speed monitoring of the Salish Sea 2018-2025
33	14:15	14:30	Jennifer Jackson	DFO	Salish Sea temperature, salinity and oxygen observations in 2025
34	14:30	14:45	Susan Allen	UBC	Timing and characteristics of the spring phytoplankton bloom and summer primary/secondary productivity in the Strait of Georgia and the summer productivity in the Strait of Georgia
35	14:45	15:00	Svetlana Esenkulova, Rich Pawlowicz	PSF	Oceanographic conditions and harmful algal blooms in the Strait of Georgia 2025
	15:00	15:15	Break		
36	15:15	15:30	Ian Perry, Kelly Young, Moira Galbraith	DFO	Zooplankton status and trends in the central and northern Strait of Georgia, 2025
37	15:30	15:45	Linnea Flostrand	DFO	Eulachon status and trends in southern British Columbia
38	15:45	16:00	Angela Phung, Steve Latham	PSC	Time Series of Fraser River Sockeye and Pink Salmon body size and migration behaviour
39	16:00	16:15	Nathanael Tabert	UVic	Adult salmon diets as indicators of prey species distribution and availability
40	16:15	16:30	Christie McMillan	DFO	Seasonal spatial densities of cetaceans in the southern Salish Sea and on Swiftsure Bank
	16:30	17:00	Tucker, Gauthier, Boldt, Jackson		Summary discussion

Poster presentations

SOPO DAY 1 - Wednesday March 4, 2026, 17:00-19:00

Poster #	Name	Affiliation	Title
1	Andrew Edwards	DFO	Updates since last year to pacea: an R package of Pacific ecosystem information to help facilitate an ecosystem approach to fisheries management (with a live demo during poster session)
2	Anna McLaskey	UBC	Fatty acid analysis for ecology: Applications and opportunities
3	Anna McLaskey, Jacob Lerner	UBC	Establishing baselines, risks, and mechanisms of thiamine deficiency in British Columbia Chinook Salmon
4	Tammy Shultis	CHS	2025 CHS Pacific Region Hydrographic Survey update
5	Jennifer Boldt	DFO	Unusual events
6	Greg Jones	DFO	Ocean characteristics supporting seabirds in the Scott Islands Marine National Wildlife Area
7	Kelly Young	DFO	PSSI Barkley Sound Euphausiid Monitoring Project
8	Jocelyn Nelson	DFO	Researching the research stations: annual monitoring at IOS and PBS
9	Meaghan Efford	UBC	Developing Micro-Credentials in Sustainability and Stewardship for a Sustainable Blue Economic Future

Poster #	Name	Affiliation	Title
10	Hilari Dennis-Bohm	DFO	Compare and contrast the methods for obtaining energy density values for pelagic fish species, Pacific Herring, at various life stages
11	Jorge Quijano	Jasco Applied Sciences	Underwater and airborne noise from detonations at Whirl Bay and Bentinck Island
12	Colleen Kellogg	Hakai	Drivers of change in Salish Sea microbial communities
13	Julian Smith	DFO	A Complementary Image-Based Approach for Monitoring Zooplankton on Line P and La Prouse Programs
14	Sile Kafritsen	DFO	Dynamics of Primary and Secondary Productivity in the Strait of Georgia: Insights from 2023-2024 Observations
15	Grace Melchers	UBC	Running the Gauntlet: Investigating urban salmonid migrations and interactions using eDNA
16	Deniz Coskuner	UBC	Temporal Dynamics of Nearshore Zooplankton Communities in the Strait of Georgia: Implications for Ecosystem Health
17	Cheri Herbert	Arctic Research Foundation	R/V Tiriarnaq, Serving the West Coast
18	Svetlana Esenkulova	PSF	A decade of unusual blooms in the Strait of Georgia
19	Nicole LaForge	DFO	Life-History Specific Survival of West Coast Vancouver Island Chinook Salmon
20	Jennifer Boldt	DFO	Department of Fisheries and Oceans monitoring in 2025
21	Dave Riedel	CHS	Sea Level in British Columbia, 1910 to 2025
22	Manman Wang	ONC	State of the Salish Sea in 2025 – Wind forcing, Fraser River Discharge, and Surface Deep Ocean Response

Acronyms

CHS Canadian Hydrographic Service
 CPR Continuous Plankton Recorder
 DFO Fisheries and Oceans Canada
 ECCC Environment and Climate Change Canada
 IOS Institute of Ocean Sciences
 MCT Marine Conservation Target
 MPA Marine Protected Area
 MBA Marine Biological Association
 NEP Northeast Pacific
 NOAA Fisheries National Oceanic and Atmospheric Administration - Fisheries, USA
 ONC Ocean Networks Canada
 PBS Pacific Biological Station
 PICES North Pacific Marine Science Organization
 PSC Pacific Salmon Commission
 PSF Pacific Salmon Foundation
 SOG Strait of Georgia
 SOPO State of the Pacific Ocean
 UBC University of British Columbia
 UVic University of Victoria
 VIU Vancouver Island University
 WCVI West coast Vancouver Island

Appendix 2 - Meeting Participants

Last Name	First Name	Organization
Abeyesirigunawardena	Dilumie	Ocean Networks Canada
Adams	Megan	Central Coast Indigenous Resource Alliance
Agbayani	Selina	Fisheries and Oceans Canada
Albers	Sam	Hakai Institute
Allen	Susan	University of British Columbia
Amidon	Hayden	University of Victoria
Anderson	Mike	Cermaq Seafood
Anderson	Sean	Fisheries and Oceans Canada
Arbeider	Michael	Fisheries and Oceans Canada
Avenant	Hannah	Canadian Wildlife Service
Bahadory	Taimaz	Canadian Integrated Ocean Observing System (CIOOS)
Bannerman-Maxwell	Lauren	University of Victoria
Barclay	Kristina	Tula Foundation/Hakai Institute
Barrette	Jessy	Canadian Integrated Ocean Observing System (CIOOS)
Barton	Leslie	Fisheries and Oceans Canada
Bass	Arthur	Fisheries and Oceans Canada
Bauer	Kohen	Ocean Networks Canada
Beaudin	Élise	Ocean Networks Canada
Bedard	Jeannette	Fisheries and Oceans Canada
Bell	Travis	Fisheries and Oceans Canada
Berden	Giuliana	University of Victoria
Bergshoeff	Jon	Hakai Institute
Bertram	Doug	Environment and Climate Change Canada
Blaine	Tristan	University of Victoria
Blanken	Hauke	Fisheries and Oceans Canada
Bluteau	Cynthia	Fisheries and Oceans Canada
Bohlender	Nicholas	Fisheries and Oceans Canada
Boldt	Jennifer	Fisheries and Oceans Canada
Bos	Julia	King County Government
Boulard	Marion	Ocean Networks Canada
Bowker	Ali	Fisheries and Oceans Canada
Boyko	Rayne	Council of the Haida Nation
Bradford	David	Fisheries and Oceans Canada
Branfireun	Marnie	Vancouver Island University
Bregulla	Hannah	Council of the Haida Nation
Briere-Deschenes	Marilyn	Council of the Haida Nation
Brkic	Dejan	Pacific Salmon Commission
Brooks	Becky	Fisheries and Oceans Canada
Brown	Ainsley	Council of the Haida Nation
Brown	Nicholas	Fisheries and Oceans Canada

Last Name	First Name	Organization
Brown	Nick	Fisheries and Oceans Canada
Bruce	Kevin	Fisheries and Oceans Canada
Buckiewicz	Natasha	University of British Columbia
Burke	Lily	Fisheries and Oceans Canada
Burnham	Rianna	Fisheries and Oceans Canada
Burton	Meghan	Fisheries and Oceans Canada
Cadavid Carrascosa	Maria Consolacion	Mowi Canada West Inc.
Cain	Kelsy	King County Government
Campbell	Jill	Fisheries and Oceans Canada
Castaneda	Rowshyra	Fisheries and Oceans Canada
Castle	Kristina	Fisheries and Oceans Canada
Chapman	Alan	WRIA 1 Planning Unit, Fishers Caucus Alternate
Charles	Katherine	Fisheries and Oceans Canada
Chaves	Lais	Tsawout First Nation
Chen	Anika	Hakai Institute
Chen	Crystal	University of British Columbia
Chen	Nancy	Fisheries and Oceans Canada
Chmelnitsky	Elly	Fisheries and Oceans Canada
Christiansen	Nicole	Pacific Salmon Foundation
Coskuner	Deniz	University of British Columbia
Crawford	Stu	Council of the Haida Nation
Cristi	Rodrigo	Mowi Canada West Inc.
Cristiani	John	Government of British Columbia
Cummins	Patrick	Fisheries and Oceans Canada
Curle	Lindsay	Council of the Haida Nation
Curran	Terry	Pacific Salmon Foundation
Curry	Charles	Pacific Climate Impacts Consortium (PCIC)
Dah	Abigail	Pacific Climate Impacts Consortium (PCIC)
Davidson	Lindsay	Fisheries and Oceans Canada
Davies	Shaun	Fisheries and Oceans Canada
de Groot	Valesca	Pacific Salmon Foundation
De Mendonca	Sarah	Fisheries and Oceans Canada
Deeg	Christoph	Fisheries and Oceans Canada
Del Bel Belluz	Justin	Hakai Institute
Denley	Danielle	B.C. Government
Dennis-Bohm	Hilari	Fisheries and Oceans Canada
Detering	Jackie	Fisheries and Oceans Canada
Donald	Tina	Simpcw
Doniol-Valcroze	Thomas	Fisheries and Oceans Canada
Dorsay	Cristionna	Fisheries and Oceans Canada
Dosser	Hayley	Environment and Climate Change Canada
Dougan	Kelsey	Fisheries and Oceans Canada
Driver	Jessica	Fisheries and Oceans Canada

Last Name	First Name	Organization
Duguid	Will	University of Victoria
Dumas	Zachary	Fisheries and Oceans Canada
Dunic	Jillian	Fisheries and Oceans Canada
Dyke	Karen	Fisheries and Oceans Canada
Eash-Loucks	Wendy	King County Government
Edwards	Andrew	Fisheries and Oceans Canada
Edwards	Courtney	CDEdwards Mapping
Efford	Meaghan	Fisheries and Oceans Canada
Eliason	Erika	Fisheries and Oceans Canada
Elvidge	Amy	Fisheries and Oceans Canada
Engel	Lilian	Pacific Northwest National Laboratory
England	Tasheena	Fisheries and Oceans Canada
English	Philina	Fisheries and Oceans Canada
Ens	Nicholas	University of Victoria
Erko	Lyubava	Quatsino First Nation
Evans	Wiley	Hakai Institute
Fan	Raina	Fisheries and Oceans Canada
Faris	Jonathan	Fisheries and Oceans Canada
Fei	Cong	New York University
Fernandez	Paige	Audubon California
Ferriss	Bridget	NOAA Alaska Fisheries Science Center
Filipovic	Karalea	Fisheries and Oceans Canada
Fisch	Nicholas	Fisheries and Oceans Canada
Fisher	Alex	Washington State Department of Ecology
Fitzpatrick	Lana	Fisheries and Oceans Canada
Fleming-Alho	Seth	Fisheries and Oceans Canada
Flostrand	Linnea	Fisheries and Oceans Canada
Folkes	Michael	Fisheries and Oceans Canada
Forster	Ian	Fisheries and Oceans Canada
Foster	Erin	Fisheries and Oceans Canada
Fournier	Marie	Fisheries and Oceans Canada
Fox	Caroline	Environment and Climate Change Canada
Francis	Fiona	Fisheries and Oceans Canada
Freeman	Alessandro	Musqueam Indian Band
Fung	Nicole	Fisheries and Oceans Canada
Galbraith	Moir	Fisheries and Oceans Canada
Gan	Julian	Fisheries and Oceans Canada
Gartner	Heidi	Fisheries and Oceans Canada
Gatien	Germaine	Fisheries and Oceans Canada
Gauthier	Stephane	Fisheries and Oceans Canada
Geng	Marilena	Fisheries and Oceans Canada
Gerick	Alyssa	Fisheries and Oceans Canada
Gilliland	Raquel	Washington government

Last Name	First Name	Organization
Glendale	Tiara	Vancouver Island University
Goodall	Aidan	Fisheries and Oceans Canada
Gooderham	Krista	Fisheries and Oceans Canada
Grant	Nicholas	University of British Columbia
Grant	Sue	Fisheries and Oceans Canada
Granum	Lorri	Fisheries and Oceans Canada
Green	Stephanie	University of Alberta
Guan	Lu	Fisheries and Oceans Canada
Gudmundson	Jo	Prince Rupert Port Authority
Guujaaw	Niisii	Council of the Haida Nation
Haggarty	Dana	Fisheries and Oceans Canada
Hall	Tanya	Heiltsuk Integrated Resource Management Department
Hallberg	Kirstyn	Cermaq Seafood
Hamilton	Ian	Lower Fraser Fisheries Alliance
Hamme	Roberta	University of Victoria
Han	Guoqi	Fisheries and Oceans Canada
Hankewich	Sandie	Fisheries and Oceans Canada
Hannah	Charles	Fisheries and Oceans Canada
Hannah	Lucie	Fisheries and Oceans Canada
Hardy	Schon	Fisheries and Oceans Canada
Hare	Alex	Hakai Institute
Hawkshaw	Sarah	Fisheries and Oceans Canada
Hay	Doug	Fisheries and Oceans Canada
Heimrich	Annika	University of Victoria
Herbert	Cheri	Arctic Research Foundation
Hessing-Lewis	Margot	Hakai Institute
Hilborn	Andrea	Fisheries and Oceans Canada
Hipfner	Mark	Environment and Climate Change Canada
Holdsworth	Amber	Fisheries and Oceans Canada
Holmes	John	Fisheries and Oceans Canada
Hourston	Emiko	Other
Hourston	Hana	Dalhousie University
Hourston	Roy	Fisheries and Oceans Canada
Huang	Ann-Marie	Fisheries and Oceans Canada
Huang	Jenny	Fisheries and Oceans Canada
Huard	Jacqueline	Comox Valley Project Watershed
Hundal	Navinder	Fisheries and Oceans Canada
Hung	Kristen	National Audobon Society
Hunt	Brian	University of British Columbia
Ikeda	Gregory	King County Government
Immonen	Chloe	Fisheries and Oceans Canada
Irvine	Jim	Other
Jáada	Skil	Council of the Haida Nation

Last Name	First Name	Organization
Jackson	Jennifer	Fisheries and Oceans Canada
Jeglum	Jeff	Cermaq Seafood
Jenkins	Maxwell	Fisheries and Oceans Canada
Johnson	Devan	Fisheries and Oceans Canada
Jones	Gregory	Fisheries and Oceans Canada
Jordison	Drew	Hakai Institute
Joyce	Elizabeth	Other
Jung	Nicole	University of British Columbia
Jung	Yeongha	Fisheries and Oceans Canada
Kaminski	Nicole	Seabird Island Band
Karpouzi	Vasiliki	Fisheries and Oceans Canada
Kattler	Kiara	University of Alberta
Keefe	Marisa	Fisheries and Oceans Canada
Keister	Julie	NOAA Alaska Fisheries Science Center
Kellogg	Colleen	Hakai Institute
Kemp	Iris	King County Government
Khmelevska	Kseniia	Tsleil-Waututh Nation
Kim	Seo Yeon	Fisheries and Oceans Canada
King	Jackie	Fisheries and Oceans Canada
Kitching	Tor	Fisheries and Oceans Canada
Koch	Lukas	Fisheries and Oceans Canada
Konik	Marta	University of British Columbia
Kot	Megan	Ocean Networks Canada
Kraft	Cameron	Fisheries and Oceans Canada
Kraus	Edith	Fisheries and Oceans Canada
Krembs	Christopher	Washington State Department of Ecology
Labbé	Daniel	Fisheries and Oceans Canada
Lachance	Roberto	Vancouver Island University
LaCoste	Cher	Fisheries and Oceans Canada
LaForge	Nicole	Fisheries and Oceans Canada
Laliberte	Bernette	Cowichan Tribes
Latham	Steve	Pacific Salmon Commission
Latornell	Doug	University of British Columbia
Lauch	Maximilian	Fisheries and Oceans Canada
Le Saout	Soizic	Heiltsuk Nation
Leaf	Brian	Fisheries and Oceans Canada
Leboeuf	Derek	A-Tlegay Fisheries Society
Lee	Hyungbeen	National institute of fisheries science, South Korea (Visiting scientist at IOS, DFO)
Lee	Lynn	Parks Canada Gwaii Haanas
Leeson	Jason	Tsleil-Waututh Nation
Lepori-Bui	Michelle	University of Washington
Li	Shaorong	Fisheries and Oceans Canada

Last Name	First Name	Organization
Liao	Xiangjun	Fisheries and Oceans Canada
Lin	Andy	Fisheries and Oceans Canada
Looby	Audrey	University of Victoria
Loro	Francesca	Fisheries and Oceans Canada
Lovindeer	Raisha	University of British Columbia
Luck	Jordan	Fisheries and Oceans Canada
Luft	Ryan	University of Victoria
MacDonald	Bronwyn	Fisheries and Oceans Canada
Macilroy	Kyla	Prince Rupert Port Authority
Mackenzie	Chris	Hakai Institute
Magera	Anna	Fisheries and Oceans Canada
Maher	Bridget	University of Victoria
Mahony	Amelia	Fisheries and Oceans Canada
Marroquin	Jerson	Fisheries and Oceans Canada
Marshall	Shannon	Other
Martin	Taylor	King County Government
Mastin	Portia	National Audobon Society
Mathias	Karin	Fisheries and Oceans Canada
Matwichuk	Kiana	Ka:yu:'k't'h' / Che:k'tles7et'h' First Nations
Mayers	Grant	Musqueam Indian Band
Mazur	Mackenzie	Fisheries and Oceans Canada
Mazzei	Lindsay	Fisheries and Oceans Canada
McClish	Shannon	University of British Columbia
McEwan	Nicole	Ocean Networks Canada
McHugh	Diana	Fisheries and Oceans Canada
McKay	Kerrith	Fisheries and Oceans Canada
McLaskey	Anna	University of British Columbia
McLeod	Annie	University of British Columbia
McMillan	Christie	Fisheries and Oceans Canada
Meier	Jessica	Fisheries and Oceans Canada
Melchers	Grace	University of British Columbia
Melica	Valentina	Fisheries and Oceans Canada
Mellon	Stefanie	Ocean Networks Canada
Melville	Olivia	Fisheries and Oceans Canada
Merrett	Rachael	Fisheries and Oceans Canada
Michalchuk	Trevor	Hakai Institute
Middleton	Katherine	Fisheries and Oceans Canada
Mike	Wetklo	Fisheries and Oceans Canada
Miller	Matt	University of Victoria
Mills	Meghan	Mowi Canada West Inc.
Moffatt	Jessica	Island Marine Aquatic Working Group
Morrow	Ben	B.C. Government
Mossman	janet	Fisheries and Oceans Canada

Last Name	First Name	Organization
Mueller	Mackenzie	Fisheries and Oceans Canada
Murchy	Kelsie	University of Victoria
Murray	Cathryn	Fisheries and Oceans Canada
Myles	Shannon	Hakai Institute
Nalini Morzaria-Luna	Hem	Other
Nantel	Martin	Fisheries and Oceans Canada
Nelson	Jocelyn	Fisheries and Oceans Canada
Nessman	Chantal	Fisheries and Oceans Canada
Nichol	Linda	Fisheries and Oceans Canada
Nielsen	Ashley	Fisheries and Oceans Canada
Nielsen	Erika	Fisheries and Oceans Canada
Nikal	Dallas	Witset first nation
Nordstrom	Chad	Fisheries and Oceans Canada
Norgard	Tammy	Fisheries and Oceans Canada
Nowosad	Damon	The QARS
Obradovich	Shannon	Fisheries and Oceans Canada
Ogden	Athena	Fisheries and Oceans Canada
O'Hara	Patrick	Environment and Climate Change Canada
Ohashi	Kyoko	Fisheries and Oceans Canada
Oldford	Greig	Fisheries and Oceans Canada
Olivas	Alicia	Hood Canal Coordinating Council
Olsen	Norm	Fisheries and Oceans Canada
Ostle	Clare	The Marine Biological Association
Ouellette	Eric	Other
Page	Stephen	Fisheries and Oceans Canada
Paleczny	Michelle	Fisheries and Oceans Canada
Pardo	Sebastian	Fisheries and Oceans Canada
Park	Ashley	Fisheries and Oceans Canada
Pascal	Gottfried	SOLV Consulting
Pawlowicz	Rich	University of British Columbia
Pearsall	Isobel	Fisheries and Oceans Canada
Pegg	James	Fisheries and Oceans Canada
Perez	Laura	Fisheries and Oceans Canada
Perreault	Lucius	Fisheries and Oceans Canada
Perry	Ian	Fisheries and Oceans Canada
Phung	Angela	Pacific Salmon Commission
Pierzchalski	Caitlin	Project Watershed
Pilkington	James	Fisheries and Oceans Canada
Pollock	Lydia	Hakai Institute
Pourfaraj	Vahab	Fisheries and Oceans Canada
Raftery	Erinn	Fisheries and Oceans Canada
Rannankari	Lynn	Ocean Networks Canada
Rayner	Marina	Huuayah First Nations Government

Last Name	First Name	Organization
Read	Silven	University of Victoria
Rechisky	Erin	Fisheries and Oceans Canada
Reid	Mike	Heiltsuk Integrated Resource Management Department
Reidy	Rhonda	University of Victoria
Rhoades	Olivia	Fisheries and Oceans Canada
Riddell	Dave	Ocean Networks Canada
Rimmer	Talen	Fisheries and Oceans Canada
Robb	Carrie	Fisheries and Oceans Canada
Roberts	Allison	Vancouver Island University
Rock	Christine	Environment and Climate Change Canada
Romaine	Steve	Fisheries and Oceans Canada
Room	Meeting	Ocean Networks Canada
Rooper	Chris	Fisheries and Oceans Canada
Rosenstock	Nate	Hakai Institute
Ross	Tetjana	Fisheries and Oceans Canada
Rubidge	Emily	Fisheries and Oceans Canada
Ruckdeschel	Gennavieve	Fisheries and Oceans Canada
Salinas Ruiz	Paulina	Pacific Salmon Foundation
San	Coral	Fisheries and Oceans Canada
Sastri	Akash	Fisheries and Oceans Canada
Sayers	Judith	Nuu-chah-nulth Tribal Council
Schubert	Aidan	Council of the Haida Nation
Schultz	Jessica	Uchucklesaht Tribe Government
Selleck	Jamey	Natural Resources Consultants
Seubert	Emily	University of Washington
Sezginer	Yayla	Canadian Integrated Ocean Observing System (CIOOS)
Sheriff	Andrew	Malahat Nation
Shimomura	Miki	Fisheries and Oceans Canada
Shultis	Tammy	Canadian Hydrographic Service
Siegle	Matthew	Fisheries and Oceans Canada
Skelcher	Cathy	Fisheries and Oceans Canada
Skubel	Rachel	Washington Department of Natural Resources
Slonimer	Alex	Ocean Networks Canada
Smith	Caitlin	Prince Rupert Port Authority
Smith	Julian	Fisheries and Oceans Canada
Sorensen	Melina	Department of National Defence
Sowerby	Erin	Fisheries and Oceans Canada
Spani	Michelle	Archipelago Marine Research
Speck	C.Matthew	Musqueam Indian Band
Spencer	Stephanie	Lyackson First Nation
Spilsbury	Dawn	Facet
St Germain	Candice	Council of the Haida Nation
Stanley	Chelsea	Fisheries and Oceans Canada

Last Name	First Name	Organization
Stark	Kimberle	King County Government
Stewart	Blair	Nisgaa Nation
Stocking	Jess	Washington Department of Fish and Wildlife
Storlund	Rhea	University of British Columbia
Suchy	Karyn	University of British Columbia
Sullivan	Florence	Coastal Observation and Seabird Survey Team (COASST)
Supernault	Janine	Fisheries and Oceans Canada
Sutherland	Tosh	Pacific Salmon Commission
Szaniszlo	Wendy	Fisheries and Oceans Canada
Tabata	Amy	Fisheries and Oceans Canada
Tabert	Andreas	Other
Tabert	Kirsten	Other
Tabert	Nathanael	University of Victoria
Tafesh	Wafa	King County Government
Tai	Travis	Fisheries and Oceans Canada
Talbot	Lauryn	Fisheries and Oceans Canada
Tall	Abdoul	University of British Columbia
Taves	Robyn	Fisheries and Oceans Canada
Taylor	Eric	Pacific Salmon Commission
Temple	Kathryn	Fisheries and Oceans Canada
Thebeau	Lauren	Fisheries and Oceans Canada
Therriault	Thomas	Fisheries and Oceans Canada
Thingsted	Anette	B.C. Government
Thompson	Mitch	Fisheries and Oceans Canada
Thupaki	Pramod	Fisheries and Oceans Canada
Tigano	Anna	Fisheries and Oceans Canada
Timmerman	Amanda	Virginia Institute of Marine Science
Tremblay-Boyer	Sara	Heiltsuk Integrated Resource Management Department
Troina	Genyffer	University of British Columbia
Tucker	Strahan	Fisheries and Oceans Canada
Umar	Aayla	Fisheries and Oceans Canada
Vagle	Svein	Fisheries and Oceans Canada
Vallery	Anna	Audubon Washington
Varco	Louisa	Fisheries and Oceans Canada
Vaughan	Chloe	Department of National Defence
Walker	Leah	Fisheries and Oceans Canada
Wan	Di	Fisheries and Oceans Canada
Wang	Autumn	Other
Wang	Manman	Ocean Networks Canada
Watson	Jordan	Ocean Networks Canada
Watson	Nicolette	Fisheries and Oceans Canada
Weekes	Carrie	Bamfield Marine Sciences Centre
Weir	Tyler	Government of British Columbia

Last Name	First Name	Organization
Wharram	Lynn	Fisheries and Oceans Canada
Wiebe	Milène	University of Alberta
Williamson	Martin	University of Victoria
Wilson	Christy	Fisheries and Oceans Canada
Winans	Amanda	University of Washington
Withers	Johanna	Fisheries and Oceans Canada
Wright	Cynthia	Fisheries and Oceans Canada
Wright	Madaline	Vancouver Island University
Wyeth	Malcolm	Fisheries and Oceans Canada
Young	Grace	Fisheries and Oceans Canada
Young	Kelly	Fisheries and Oceans Canada
Young	Sherry	University of Alberta
Zubkowski	Tyler	Fisheries and Oceans Canada