

Hakai

Oceanography Report

March–September 2018

Recent Key Findings:

- *Marine heatwave remains at depth from the open ocean to Rivers Inlet*
 - *Evidence that historical heatwaves may have contributed to collapse of the Rivers Inlet fishery*
- *Deep water in Bute Inlet is warmest since 1950s*
- *A marine front has been discovered in Johnstone Strait that likely separates ecosystems*
- *Diatom communities have greatly shifted over three years of monitoring off Quadra Island*
- *Stable zooplankton communities off Quadra Island show resilience despite shifts in phytoplankton bloom*
- *First realistic estimates of jellyfish (*Aurelia aurita*) biomass garners media attention for both the quantity and the drone methods employed*

Scientific Context and Goals

Ongoing monitoring by the Hakai Institute is changing our understanding of Central Coast ocean dynamics. This region of the coast has been historically understudied by federal and academic researchers, and Hakai research is yielding significant new insights into the dynamics of both this specific complicated system and coastal processes on the grand scale. Our intensive efforts have enabled us to leverage sporadic historical data to elucidate how this system has changed through time, and recent work has teased out linkages between the coastal and open ocean environments. This fundamental work is fascinating in its own right and also provides a backdrop for numerous Hakai research initiatives.

From the Discovery Islands through the Central Coast, we are learning much about the marine environment of the BC coastal margin. Hakai scientists are leveraging sporadic data collected since the 1950s and pairing it with Hakai's frequent (weekly–monthly) observations to illuminate long-term change in this system. With a specific focus on Johnstone Strait and Bute and Rivers Inlets, this work has significant implications for determining the local impacts of climate change.

With ecological observatories based on Quadra and Calvert Islands, Hakai is able to frequently visit oceanographic study sites in the Discovery Islands and around the Central Coast. The geographic advantages afforded by this proximity mean that data collection is possible more frequently and with less expense compared to research programs based from southern BC locations. We maximize this proximity through our frequent sampling of regions that historically may have only been visited one to three times a year.

Frequent observation of the oceanographic conditions are helping Hakai scientists to determine the patterns of circulation along this stretch of coast and how it varies both intra- and interannually. Monitoring from the continental shelf into the coastal fjords is helping us determine the strength of connections between the open ocean and estuarine waters. We're finding strong connections between offshore and nearshore environments through our collaborations with national (DFO moorings, Line CS, and Line P) and international (Argo Program) partners. These data are invaluable in describing the spectrum across the riverine coastal domain.

Active monitoring of coastal conditions is leveraged into model development through the development of an

FVCOM model that is examining the currents of coastal Queen Charlotte Sound from Vancouver Island to north of Calvert Island. Hakai data are also being used in validation of other models being developed by Susan Allen at the University of British Columbia and other academic partners.

The products of this work will help us understand how the physical properties of the marine environment influence the ecosystem. Hakai data have already shown that pico and nano-plankton, which are typically understudied, play an outsized role in food webs of the Central Coast and Strait of Georgia. This work will be further advanced through the coming application of genomic and biochemical techniques that will elucidate the influence of these organisms on higher trophic levels.

Data from the Hakai oceanography program is foundational to other research initiatives. Logical collaborators in this research, such as those working with ocean acidification and ocean food webs, draw heavily from the oceanography data pool. In addition those working in nearshore monitoring and juvenile salmon rely heavily on our data as do any other researchers investigating the coastal ocean.

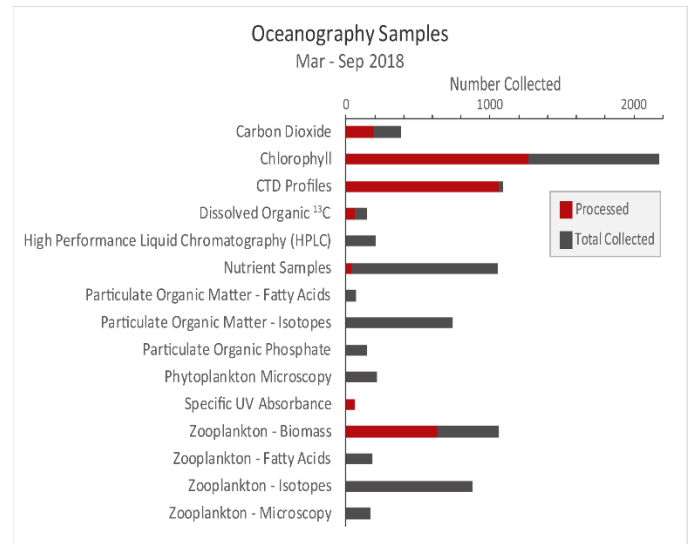


Figure 1: Quantitative summary of recent oceanography sampling.

Recent Progress

Over the last six months, oceanography had a very productive field season during which operations were streamlined, safety was improved, proposed work was funded, past samples were sent for processing, and others were written up for publication.

The fair weather field season was quite productive (Figure 1). Successful efforts to integrate the Calvert and Quadra oceanography programs were possible through finding efficiencies and limiting sampling to active investigations. The integrated program now

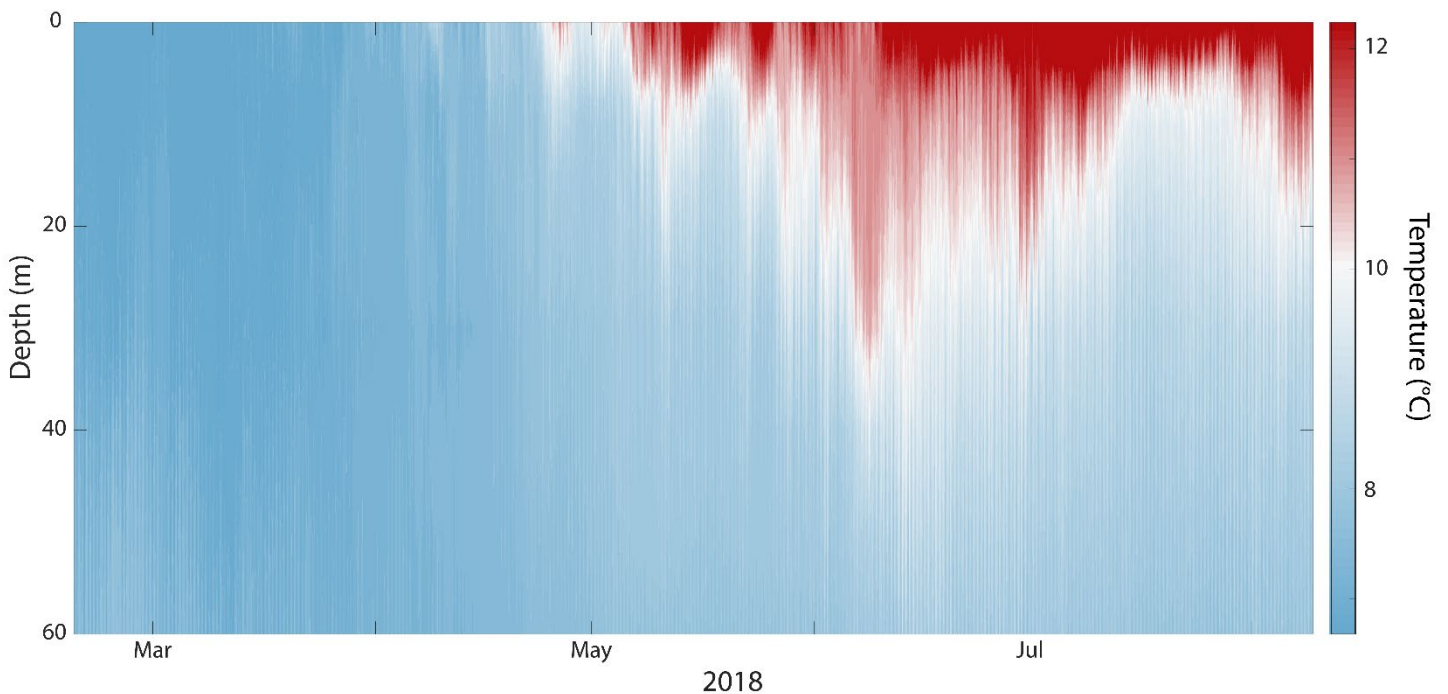


Figure 2: A temperature timeseries from Pruth Station in Kwakshua Channel from late February 2018–early September 2018. Data collected on a mooring with 12 TidbiT temperature sensors making measurements every 10 minutes.

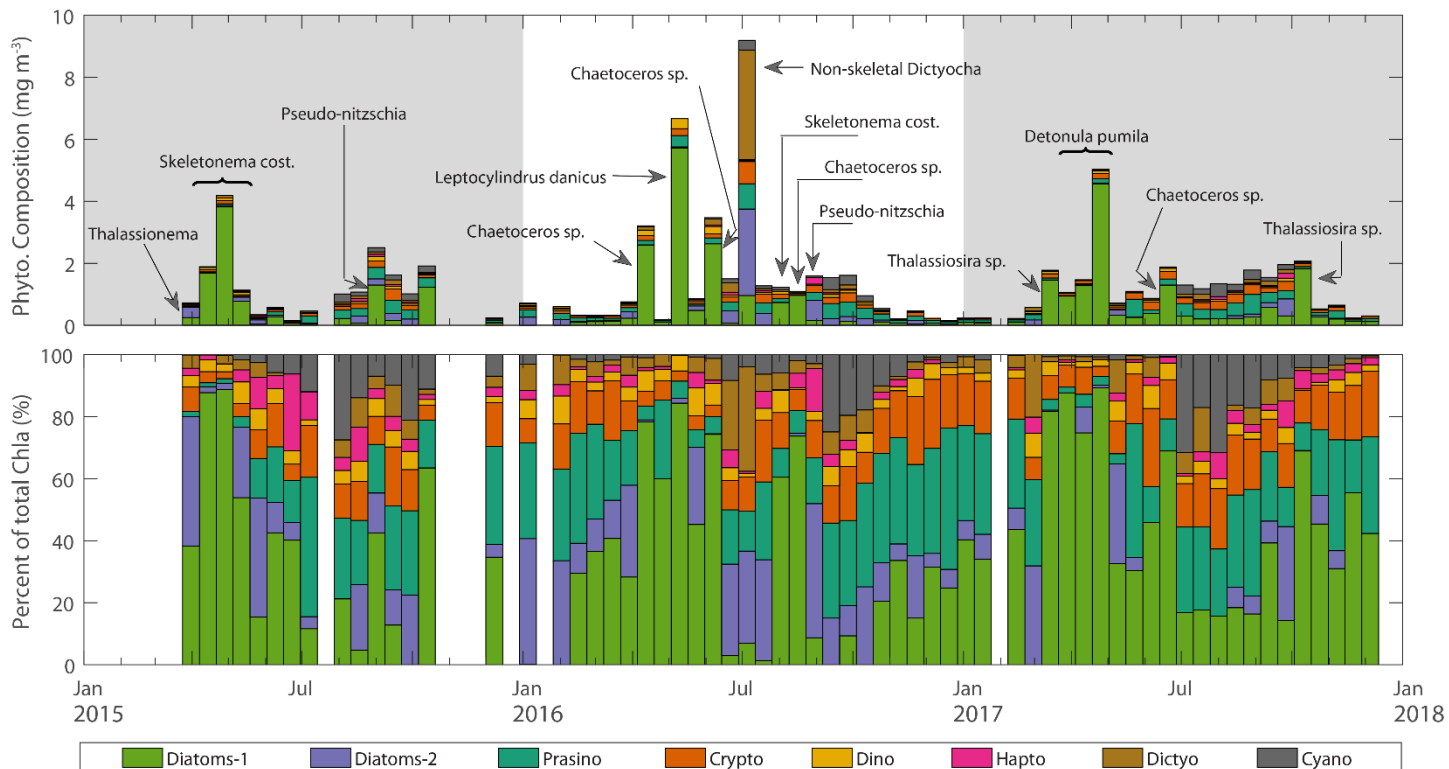


Figure 3: Recent CHEMTAX timeseries output for QU39 at 5 m depth. The top panel shows absolute Chlorophyll a concentrations for each phytoplankton group and the bottom panel shows the relative contribution to total biomass. The input phytoplankton groups are Diatoms-1 (green), Diatoms-2 (purple), Prasinophytes (turquoise), Cryptophytes (orange), Dinoflagellates (yellow), Haptophytes (pink), Dictyophytes (brown), and Cyanobacteria (grey).

Many of the Diatom and Dinoflagellates species within these groups can be identified using the current microscopy method and are used to “ground-truth” the CHEMTAX results. Yet, Prasinophytes, Cryptophytes, and Haptophytes appear to be important components of the community during certain times of the year and these cannot be resolved without fine scale microscopy. Microbial research will likely provide valuable information on cyanobacteria compositions and concentrations.

requires 40 percent fewer days in the field compared to the prior schedule. Even with these cuts, over 1,000 Conductivity, Temperature, Depth (CTD) profiles were gathered in a field plan that was considerably more targeted than prior summers. Field testing also found that TidbiT temperature loggers prove to be a reliable and cost-effective sensor for the upper 100 m (Figure 1), but work is ongoing to identify a similar temperature-salinity sensor that would be worthy of going on a mooring. Finally, a permanent water level station with millimeter accuracy was mounted to the pier at Calvert and has been integrated into the [Canadian Hydrographic Service](#) and international sea level studies like the [Global Sea Level Observing System](#).

Unfortunately, field operations also lost two CTDs at sea. These were tough lessons to learn, but safety protocols have been instituted to reduce risk in future operations. Additionally, occupational health and safety plans were put into place in July which included eliminating the use of formalin. These procedures will

improve safety for equipment and staff both in the field and in the lab.

Also in the lab, all chlorophyll analyses are now being done on a cross calibrated fluorometer that is regularly being monitored for drift. Over 300 high-performance liquid chromatography (HPLC) samples from the QU39 timeseries have been sent off for analyses. These samples were primarily from the five-meter bottle samples collected between 2015 and 2017. The first data have been returned and CHEMical TAXonomy (CHEMTAX) parameters are being refined throughout the analyses while results were recently presented at the October PICES meeting in Tokyo, Japan (Figure 2).

Collective oceanography results were presented on 15 different occasions in the last six months at local, national, and international meetings including an invited presentation by Brian Hunt at the University of Concepción in Chile. Results were also written up in 10 publications that have been recently submitted or are

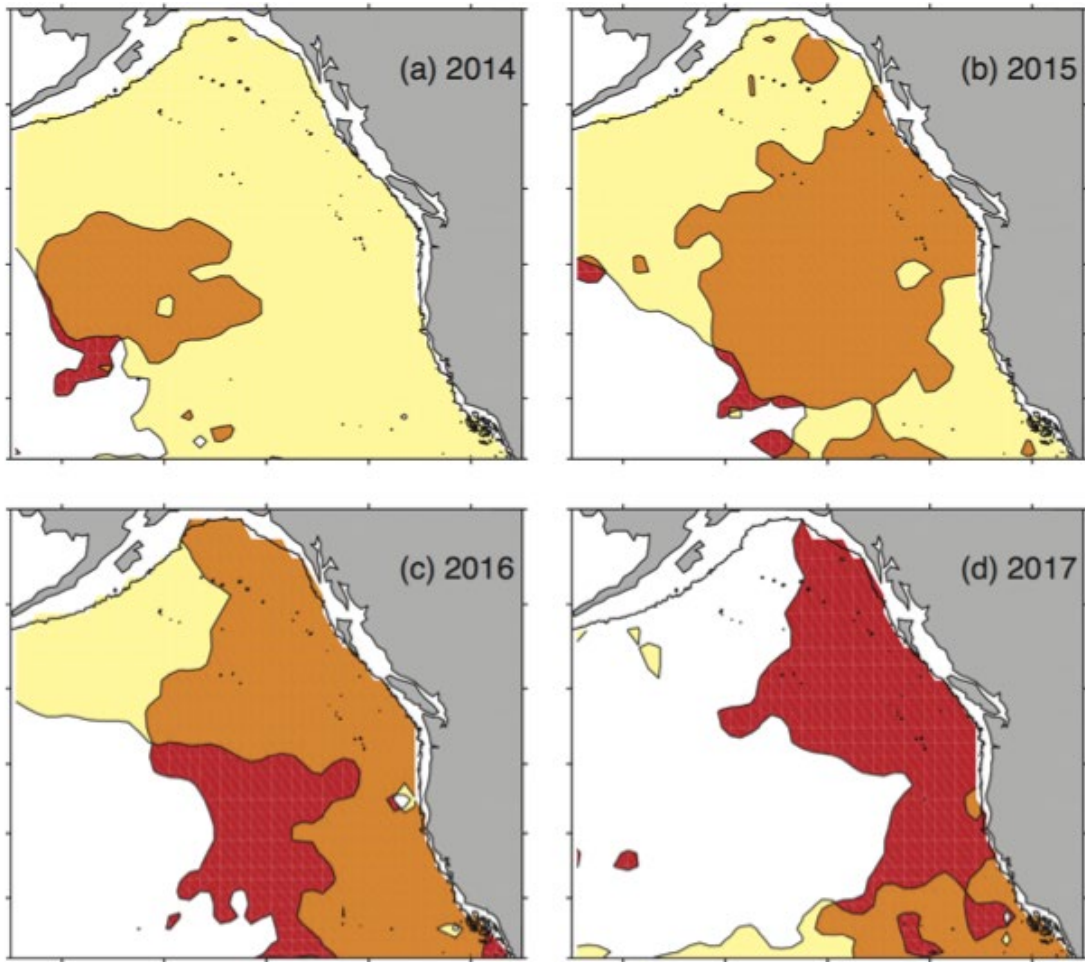


Figure 4: Regions where the average temperature was greater than the 2004–2017 monthly means by 0.25 °C at 140 m (shaded red), the surface (shaded yellow), and at both levels (shaded orange) for (a) 2014, (b) 2015, (c) 2016, and (d) 2017.

already published in peer-reviewed journals or as book chapters. Jen Jackson’s paper connecting Hakai’s Rivers Inlet monitoring to the persistent marine heatwave that remains at depth in the northeast Pacific was highlighted by editors from the American Geophysical Union (Figure 3). The collective works garnered attention in 14 external media articles in local and international media.

We are excited about the success of proposals that were funded in the past six months. Collaborations with Maycira Costa will help us understand the variability of biogeochemistry from BC and SE Alaska and with Laura Bianucci will improve DFO’s FVCOM model of the Discovery Islands and Broughton Archipelago. We are thankful for continued Tula Foundation support to purchase an acoustic Doppler current profiler (ADCP) that will be deployed next year, and we are looking forward to developing that vital oceanographic capability within Hakai. We are also actively planning

our three seven-day research cruises aboard the R/V *Achiever* to Bute, Toba, and Knight Inlets in 2019.

While we had hoped to deploy an oceanographic glider to characterize the continental shelf off Calvert Island this fall, was damaged during its shipment from the manufacturer. Hayley Dossler, who completed the training course in March 2018, is taking advantage of the instrument delay by planning a deployment to characterize the marine transition to upwelling conditions in the spring or early summer of 2019.

Looking Ahead

In addition to standard monitoring operations around Calvert and Quadra, over the next six months we will also be working on the reanalysis of historical chlorophyll samples (2015 to 2018), sending off hundreds of samples for HPLC and microscopy analyses, and further refining CHEMTAX protocols.

Outside of the lab, four manuscripts are currently being worked on for journal submission. H. Dosser is writing up the discovery of a front in Johnstone Strait that is likely strong enough to be an ecological boundary. J. Belluz is writing up a comparative description of differences between the phytoplankton communities and physiology at Calvert and Quadra. J. Jackson is currently working on detailing the oxygen minimum in Rivers Inlet. And finally, B. Hunt is writing about the distinct zooplankton communities that are present from the Strait of Georgia to Queen Charlotte Strait. Each of these authors plans to significantly advance these reports toward publication over the coming months.

Collaborations and Summary

The oceanographic monitoring at Hakai is really foundational for many other Hakai initiatives. Oceanographic stations around Calvert and Quadra have become valuable timeseries that are utilized by ocean acidification, nearshore monitoring, and ocean food webs working groups to name a few. Working with these programs, we collect specialized samples, as with ocean acidification's carbon dioxide samples that provide context for their monitoring efforts at fixed points and ship of opportunity. Additionally, we regularly provide other groups with data from the CTD profiles and environmental variables that provides vital context to the interpretation of their own data.

This work is also done in collaboration with over 25 collaborators external to Hakai, both around British Columbia, like numerous collaborators at Fisheries and Oceans Canada, and around the world, like Nico Weidberg from the University of Tromsø in Norway. Collaborations may be similar to where Hakai post-doctoral fellows, like Fernanda Giannini at the University of Victoria, use in kind support where Hakai collects and processes samples for their research. Or collaborations may be more hands-off as with Hakai contributions of data from Quadra Island sampling to the Salish Sea Marine Survival Project zooplankton database, a project supported by the Pacific Salmon Foundation. Hakai's oceanography program is proud of its current collaborations and is looking for additional opportunities to collaborate on future projects.

The past summer of 2018 has clearly been productive for advancing knowledge about marine dynamics on the

Central Coast. Each member of the team working toward the goal of describing the fundamentals of, and understanding changes to, this incredible oceanscape.

Publications (n = 10)

(Hakai researchers in bold)

Burd, B., **J. Jackson**, R. Thomson, and **K. Holmes**. (2018). Northern west coast of Canada, In: Sheppard, C. (Eds.), *World Seas An Environmental Evaluation: Volume I Europe, the Americas and West Africa*. (pp. 333-361). London, UK: Academic Press by Elsevier. PUBLISHED.

Evans, W., Jackson, J., and Hare, A. (2018). On the lack of northern Salish Sea summertime CO₂ outgassing in 2017. In Chandler, P.C., King, S.A., and Boldt, J. (Eds.) *State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2017*. Can. Tech. Rep. Fish. Aquat. Sci. 3266. PUBLISHED.

Hunt, B.P.V., Jackson, J.M., Belluz, J.D.B., and Barrette, J. (2018). Hakai oceanography program: British Columbia central coast time series (2012-2017). In Chandler, P.C., King, S.A., and Boldt, J. (Eds.) *State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2017*. Can. Tech. Rep. Fish. Aquat. Sci. 3266. PUBLISHED.

J.M. Jackson, G.C. Johnson, **H.V. Dosser**, and T. Ross. 2018. Warming from recent marine heat wave lingers in deep British Columbia fjord, *Geophysical Research Letters*, 45, doi:10.1029/2018GL078971. PUBLISHED.

J.M. Jackson, W.S. Goschen, N. Weidberg, M.J. Roberts, C.D. McQuaid, and F. Porri. 2018. Identification of very fast subsurface currents off headlands on South Africa's southeast coast. *African Journal of Marine Science*, SUBMITTED.

Jackson, J.M., Dosser, H., and Hunt, B. (2018). Rivers Inlet water properties in 2017 compared to a 1951 to 2017 time series. In Chandler, P.C., King, S.A., and Boldt, J. (Eds.) *State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2017*. Can. Tech. Rep. Fish. Aquat. Sci. 3266. PUBLISHED.

M. Smith, S. Stammerjohn, O. Persson, L. Rainville, G. Liu, W. Perrie, R. Roberston, **J. Jackson**, and J. Thomson. 2018. Episodic reversal of autumn ice advance caused by release of ocean heat in the Beaufort Sea. *J. Geophys. Res.*, 123(5), 3164-3185. doi:10.1002/2018JC013764 . PUBLISHED.

Mahara, N., E.A. Pakhomov, **J.M. Jackson**, and **B.P.V. Hunt**. 2018. Seasonal zooplankton development in a temperature semi-enclosed basin: two years with different spring bloom timing. *Journal of Plankton Research*, SUBMITTED.

N. Weidberg, W. Goschen, **J. Jackson**, P. Patrick, C. McQuaid, and F. Porri. 2018. Fine scale depth regulation of invertebrate larvae around coastal fronts, *Limnology and Oceanography*, SUBMITTED.

Schaub, J., **Hunt, B.P.V.**, Pakhomov, E.A., **Holmes, K.**, Lu, Y., **Quayle, L.**, 2018. Using unmanned aerial vehicles (UAVs) to measure jellyfish aggregations. *Marine Ecology Progress Series* 591, 29-36. PUBLISHED.

Conferences and Presentations (n = 15)

Del Bel Belluz, J.A., Jackson, J.M., Hunt, B.P.V. (2018). Fluorescence to Chlorophyll Ratios on the Central Coast of British Columbia, Canada. (Poster). State of the Pacific Ocean Meeting. March 7-8, 2018. Nanaimo, British Columbia.

Del Bel Belluz, J.A., Jackson, J.M., Hunt, B.P.V. (2018). Fluorescence, Beam Attenuation and Chlorophyll in Coastal British Columbia Waters. (Poster) ASLO Summer Meeting, June 11-15, 2015, Victoria, BC.

Dosser, H., Jackson, J., Waterman, S., Hunt, B., and Hannah, C., *New insights into the physics of upwelling and downwelling along the BC central coast, in ASLO Summer meeting, June 11-15, 2018, Victoria, BC.*

Dosser, H., Jackson, J.M., Hunt, B.P.V., Waterman, S., Hannah, C. Physical Ocean conditions in Johnstone Strait. State of the Pacific Ocean meeting, March 7-8, 2018, Nanaimo, BC.

Giannini, M.F., Costa M. **Hunt B.P.V.** Spatial-temporal dynamic of coastal marine biophysical provinces of British Columbia and SE Alaska - following the migration route of juvenile salmon. State of the Pacific Ocean meeting, March 7-8, 2018, Nanaimo, BC.

Giesbrecht, I., Korver, M., Haughton, E., Floyd, B., Jackson, J., Hunt, B., Lertzman, K., Weather driven dynamics of small pluvial watersheds on the central coast of British Columbia from 2013 to 2017, in State of the Pacific Ocean meeting, March 7-8, 2018, Nanaimo, BC.

Hunt, B.P.V. C3 Trans-Canada eDNA biodiversity mapping project. Canada C3 workshop, 12-14 April 2018, Dalhousie.

Hunt, B.P.V. Climate change at the unique land-sea interface of the BC coastal ocean. Coastal Connection Vancouver, 18 April 2018, Science World, Vancouver.

Hunt, B.P.V., Canada's three oceans and climate change. Knowing the "lay of the land" when developing solutions. Workshop: Ocean-based climate solutions - focus on Canada's 3-oceans. Liu Center, University of British Columbia.

Hunt, B.P.V., Ecosystem processes at the marine-terrestrial interface of the North Pacific Coastal Temperate Rainforest. Invited Presentation, University of Concepcion, Chile, 7 August 2018.

Hunt, B.P.V., Oliver, A., Tank, S. Giesbrecht, I. Terrestrial contributions to the marine food web in the Northeast Pacific Temperate Coastal Rainforest domain. 11th International Conference on the Applications of Stable Isotope Techniques to Ecological Studies 30 July – 3 August 2018, Universidad Andrés Bello, Viña del Mar, Chile.

Jackson, J.M., Dosser, H., and Hunt, B.P.V., RIVERS INLET WATER PROPERTIES IN 2017 COMPARED TO A 1951 TO 2017 TIME SERIES, in State of the Pacific Ocean meeting, March 7-8, 2018, Nanaimo, BC.

Jackson, J.M., Hunt, B.P.V., Belluz, J.D.B., and Barrette, J.B., Hakai Oceanography Program: British Columbia central coast time series, in State of the Pacific Ocean meeting, March 7-8, 2018, Nanaimo, BC.

Jackson, J.M., Whitney, F., **Belluz, J.D.B., and Hunt, B.P.V.,** Identification of a seasonal subsurface oxygen minimum in Rivers Inlet, British Columbia, American Society of Limnology and Oceanography summer meeting, June 11-15, 2018, Victoria, BC.

Suchy, K., Perry, I., Young, K., **Hunt, B.P.V.,** Esenkulova S., Costa M., Galbraith, M. Comparison of bottom-up processes in different subregions of the northern Salish Sea. Salish Sea Ecosystem Conference. 4-6 April 2018, Seattle, Washington, US.

External Media Coverage (n = 14)

Covering the use of drones to observe jellyfish blooms and the presence of the marine heatwave at depth in Rivers Inlet and the northeast Pacific.