In Cooperation with Coast Salish Nation

Coast Salish and U.S. Geological Survey Tribal Journey Water-Quality Project 2014

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By Sarah K. Grossman and Eric E. Grossman

Prepared in cooperation with the
Swinomish Indian Tribal Community
Coast Salish Nation & U.S. Geological Survey

COVER:
This photograph is of Squaxin Island canoe family preparing to leave shore from Esquimalt, British Columbia, Canada.
Photo by S. Grossman

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This series documents the scientific basis for the monitoring of surface-water conditions across the Salish Sea during the annual Tribal Journey. This document is not intended to be a definitive statement on Salish Sea conditions, but rather a progress report on ongoing investigations.

Conversion Factors

Multiply	By	To obtain
	Length	
kilometer (km)	0.6214	mile (mi)
meter (m)	3.281	foot (ft)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F= (1.8×°C) +32
Specific conductance is given in millisiemens per centimeter at 25 degrees Celsius (mS/cm at 25°C).

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By Sarah K. Grossman[1] and Eric E. Grossman[2]
1. Swinomish Indian Tribal Community: 11430 Moorage Way, La Conner, Washington 98257
2. U.S. Geological Survey, Pacific Coastal and Marine Science Center and Western Fisheries Research Center: 6505 NE 65th, Seattle, Washington 98115

Abstract
In June 2014, traditional Coast Salish canoes mapped surface water quality properties along the annual Tribal Journey – Journey to Bella Bella. Surface-water temperature, salinity, pH, dissolved oxygen and turbidity data were collected roughly every 20 m from Victoria, British Columbia to Comox, British Columbia on Vancouver Island. These data provide a unique and extensive spatial data set that help characterize shallow estuary and nearshore marine environmental conditions where canoes are able to access during mid-summer when the estuarine conditions undergo dynamic change in response to shifts in seasonal warming, runoff, coastal upwelling and productivity. The results fill information needs to monitor and detect variations, trends, and water quality impairments across shallow estuarine areas where data are sparse.

Introduction
For millennia, indigenous peoples of the Salish Sea maintained a rich culture around the sustainable use of diverse marine resources and intimate interactions with their environment. Today after 150 years more than 60 species of ecologically, culturally, and economically important fish, mammals, birds, and invertebrates are endangered or threatened (Fraser and others, 2006) due to unsustainable land practices, industry, and urbanization, and changes in the world's oceans and climate that are affecting water quality and habitat conditions. Efforts to examine and monitor changes and regulate impacts to the Salish Sea ecosystem have steadily increased in extent beginning in the late 1800s in both British Columbia and Washington (Keeling 2007).

Today, numerous federal, provincial, state, local, and tribal governments, as well as academic institutions conduct research in the Salish Sea across a wide variety of disciplines, with most notable monitoring efforts led by Washington State Department of Ecology (DOE), British Columbia Department of Fisheries and Oceans Canada (DFO), and the many coastal tribes and First Nations. Starting in the 1990's DOE and DFO began conducting routine monitoring of water properties at networks of stations across The Strait of Juan de Fuca, Strait of Georgia and Puget Sound. Repeat monitoring of stations at discrete points and along transects provide important information generally in open water ways and channels at monthly and yearly snapshots. Beginning in the 2000s, moorings provide continuous measurements at the surface and with the advent of profiling buoys through the water column at select locations (NANOOS, *http://www.nanoos.org/*). In 2007, the Puget Sound Partnership was created by the Washington State legislature to coordinate and monitor efforts related to recovery of the Puget Sound ecosystem. The Puget Sound Partnership developed a set of Puget Sound health indicators in order to track progress towards the recovery effort. As of 2012, the Puget Sound Partnership reported that only two indicators, Shellfish Beds and Estuaries were showing progress towards meeting 2020 recovery goals due to large habitat restoration projects. Despite this success, Marine Water Quality, Swimming Beaches, Chinook Salmon, Herring, Marine Sediment Quality, and Eelgrass indicators were all showing “no progress” towards 2020 recovery goals (Puget Sound Partnership 2013), highlighting that there is still a lot of work to be done.

In 2008, The Coast Salish Nation in partnership with the U.S. Geological Survey (USGS) began conducting a multiyear environmental study to complement these monitoring efforts by providing continuous spatial measurements across the entire Salish Sea in middle of summer and particularly along nearshore areas where data was sparse but where terrestrial runoff strongly influences coastal habitats and biological resources. The partnership provided a new strategy combining science and cultural practices to gather quantitative water quality data by traditional Coast Salish canoes. The foundation of the study is the annual Tribal Journey, during which canoe families traveling along multiple routes of their ancestral highways, celebrate and share their rich cultural heritage. Canoes traveling at the pace of tides and currents are an ideal platform for collecting surface-water quality measurements that are unaffected by motors, their turbulence, and associated contaminants. The routes traveled by Coast Salish each summer offer an unprecedented opportunity to gather data in shallow coastal areas difficult to reach by typical research vessels. Simultaneous mapping along multiple routes across the entire Salish Sea provide a unique data set to improve understanding of the spatial variability in water quality patterns and the biophysical processes that shape them. The purpose of the Tribal Journey Water Quality Project (TJWQP) is to utilize the partnership to provide Coast Salish with additional science and monitoring capacity needed to develop and address questions and uncertainties around landscape and local-scale water property patterns affecting the Salish Sea ecosystem and of concern to tribes and First Nations.

In addition to in-situ water samples from canoes, canoe pullers and scientists collect observational data along the Journey, providing context for the quantitative canoe-track data. Also, as resources permit, special projects are conducted from support vessels and moorings deployed in select nearshore areas. Efforts from support vessels include profiling water properties with instruments through the water column, collection and analyses of water samples for nutrients, plankton, and suspended sediment concentrations. Moorings gather time-series data on water properties and water levels to provide temporal context for the canoe track results. The blending of science with cultural ways and the discussions of the project as the Journey stops in each indigenous community throughout the Salish Sea provide an excellent means to learn of emerging concerns among communities and promote expanded understanding of ecosystem issues, conservation and stewardship. Local indigenous knowledge shared during these visits helps guide the Project’s focus and provides unprecedented opportunities to learn about the Salish Sea’s natural history in ways science alone cannot offer.

Through the partnership, USGS provides valuable synthesis and interpretation of scientific measurements, helping to quantify environmental patterns, identify areas of impairment and through time, detect changes and trends related to land use and climate change. These results are used to implement follow-up studies with Coast Salish and assist partners in developing improved understanding and predictions of ecosystem vulnerability.

The Salish Sea

The Salish Sea is a semi-enclosed coastal basin covering roughly 135,000 km^2 with a watershed outlined by the crests of the Olympic Mountains, Vancouver Island Ranges, and the Cascade Mountains (Fraser and others, 2006). The Salish Sea has a surface area of 16,925 km^2 with 7,470 km of coast line. Open-ocean water from the Pacific enters the Salish Sea from the north through a series of shallow narrow channels and from the west through the Strait of Juan de Fuca flowing both to the south into Puget Sound (United States) and to the north into the Strait of Georgia (Canada) through a complex system of sills and basins. At its deepest point, the depths reach 420 m (SeaDoc, 2008). The tidal regime of the Salish Sea is predominantly mixed semi-diurnal.

The Fraser and Skagit Rivers are the largest freshwater sources to the Salish Sea. The Fraser River accounts for 25 percent of the total freshwater input to Georgia Strait and the Skagit River contributes ~35 percent of the freshwater to Puget Sound. These two rivers support runs of all five species of Pacific salmon and are considered critical for their recovery throughout the entire Salish Sea ecosystem (Puget Sound Partnership, 2008). Over the last several decades, the Fraser River discharge pattern has undergone changes with a decrease in the peak summer flow and the spring freshet arriving earlier than historically (Morrison et al., 2002).

Water properties in the Salish Sea are influenced by multiple factors on regional and local scales. Tidal mixing, river flow, snowpack and glacier melt, (Fraser, temp recorded in 2008): stratification, air temperatures, local winds and waves, and regional upwelling conditions (Davenne and Masson 2001; Masson, 2006). Projections of climate change indicate that summer water properties are likely to be strongly affected by changes in the timing and rate of change of these processes. Of concern are rapidly retreating snowpack and glaciers that reduce the spring freshet volume and lead to lower summer river low flows and warmer fresh waters delivered to the Salish Sea. Shifts in the amount and timing of fresh-water pulses into the Salish Sea will cause shifts in other physical and biological processes. Stratification caused by freshwater helps drive surface-waters out of the Salish Sea towards the Pacific, drawing in Pacific water at depth. This stratification creates stability in the vertical circulation which creates an ideal situation for plankton communities to bloom but fails to draw up nutrient rich bottom waters to sustain the blooms. These blooms make up the base of the Salish Sea food web. Also of concern are increases in summer air temperature, increasing ocean acidification caused by acidic ocean waters and nutrient pollution, and changes in winds and the strength and timing of coastal upwelling that mix marine waters into the Salish Sea. The Tribal Journey Water Quality Project maps the patterns of summer water properties owing to these processes and relates the responses found to the drivers in an attempt to better understand mechanisms that mix waters and to better predict future conditions.

In identifying areas of water-quality impairment, the methods employed by this project collect sufficient quantitative data that may help define spatial gradients in water-quality and habitat conditions that affect biota. Although examples of gradients in temperature and salinity near shallow embayments and rivers clearly are influenced by freshwater inputs and warming of shallow waters, striking and abrupt gradients in water quality also occur in other areas of the Salish Sea, particularly across boundaries between water masses with different properties. One of the strengths of the data obtained by the TJWQP is their ability to reveal these abrupt changes in water properties that occur over very short distances. Traditional water-quality monitoring and water-property models frequently rely on repeated sampling at a single location which can only show changes with time.

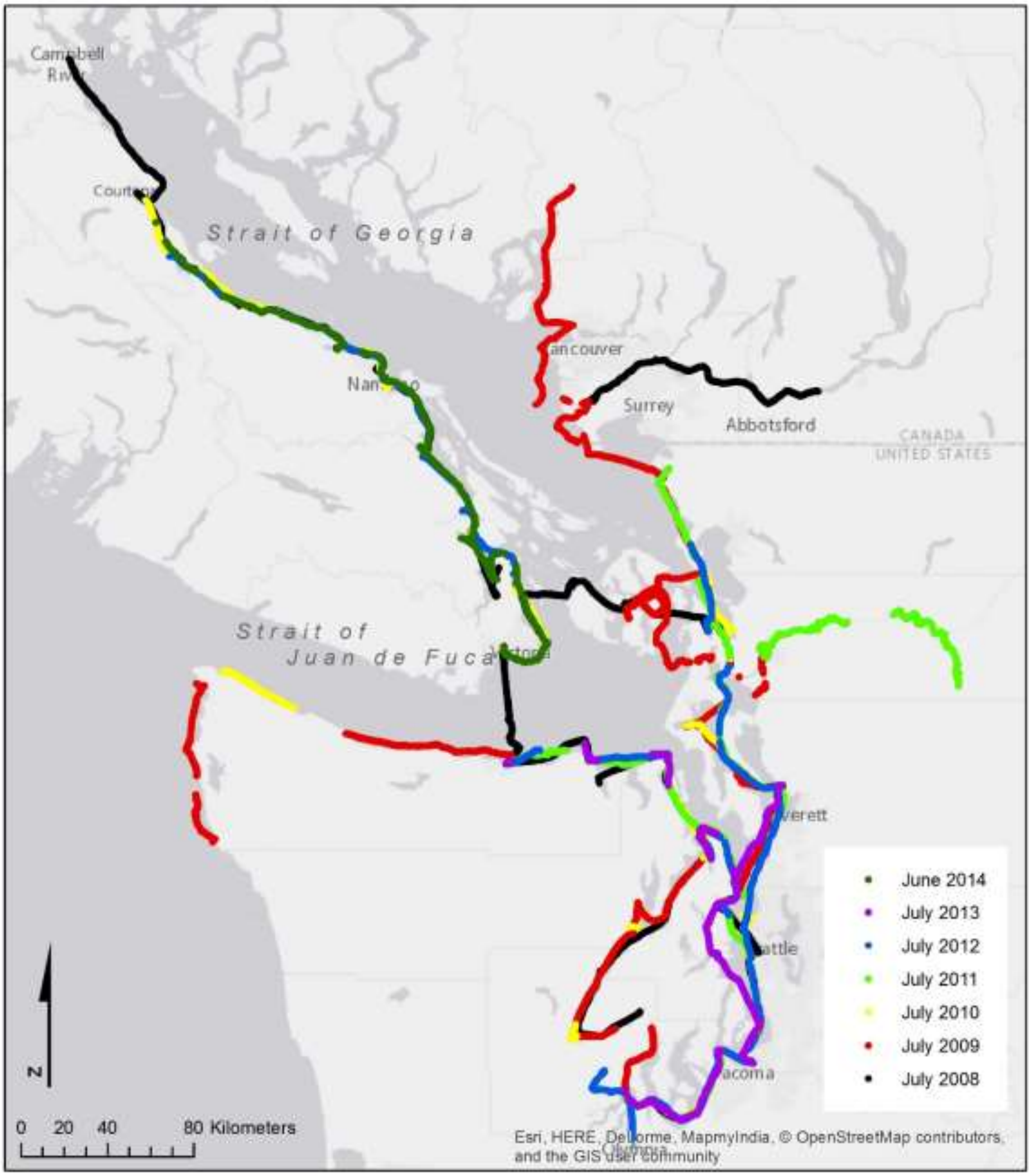

Figure 1. The Salish Sea with 2008 (black), 2009 (red), 2010 (yellow), 2011 (green), 2012 (grey), 2013 (purple), and 2014 (blue) monitoring routes and reporting regions. The final landing for the 2014 Tribal Journey water quality monitoring was at Comox, British Columbia Canada (white star).

Purpose and Scope

This report summarizes the TJWQP data collected during the Tribal Journey to Bella Bella, British Columbia and is the latest in a series of reports that present the data collected beginning in 2008 (Akin et.al. 2009, Akin and Grossman, 2010, Grossman and Grossman, 2012, 2013, and 2014). Collection of TJWQP data required the development of monitoring methods which are outlined in Akin et. al.2009. For analysis and reporting purposes the TJWQP track data are grouped into basins as defined by Shipman, 2008 for Puget Sound and the Strait of Juan de Fuca and the British Columbia Watershed Atlas Group for the Georgia Strait (British Columbia 2007). The data presented in this report were gathered during USGS Field Activity 2014-636-FA. A subset of the data collected during all six years of the TJWQP monitoring can be viewed using GoogleMaps at *http://www.usgs.gov/coastsalish*.

Methods

This section summarizes the protocols and development of the methods used during the TJWQP. Coordination with canoe families, determination of routes, equipment, data acquisition and quality, water-quality assessment, and water-quality criteria are discussed. Methods employed during the 2014 Tribal Journey follow protocols outlined in the EPA-approved Quality Assurance Project Plan for the Tribal Journey Water Quality Project (PA-00J32201-0), submitted by the Swinomish Indian Tribal Community, April 2011. Below is a summary of the methods used for route planning, data collection, and data analysis. These methods are consistent with methods employed during previous monitoring years, see Akin et al 2009, Akin and Grossman 2010, Grossman and Grossman 2011 for a more detailed description.

Geographic Scope and Routes

The planning process for the Tribal Journey takes place within the individual Canoe Families and at Canoe Skippers planning meetings hosted monthly by various Tribes and First Nations around the region. The TJWQP does not attempt to influence the planning process because the TJWQP is an added component to, not a driver of, the Tribal Journey. After the Tribal Journey routes have been established, TJWQP monitoring tracks are chosen according to two main criteria: (1) routes extending the greatest extent of Salish Sea, and (2) willingness of the Canoe Families to participate in the Project.

In 2014 one route was monitored (fig 1). Squaxin Island canoe family, pulling from Victoria, British Columbia to Bella Bella participated in the 2014 monitoring. The 2014 survey began June 24, 2014 in Esquimalt First Nation territory and was completed July 30, 2014, in Comox, British Columbia at the K'omoks First Nation hosted landing.

Equipment and Data Quality

Water-quality measurements were made by towing water-quality sondes behind traditional Coast Salish canoes. The canoes move relatively slowly and steadily through the water at a pace between 3 to 9 km/hr (2 to 6 mi/hr). The multi-parameter sondes were programmed to collect data at 10-second intervals which at these rates resulted in an average measurement spacing of ~20 m ((75 ft), relatively dense-spaced data. Water-quality data were collected within the top half meter of the water column. Water-quality data were collected using YSI Environmental model 6920 V2 sondes (figure 2). The YSI 6920 V2 sondes recorded temperature [degrees Celsius (°C)], salinity [practical salinity units (psu)], pH (pH units), dissolved oxygen concentration [milligrams per liter (mg/L)], dissolved oxygen percent saturation (% sat), and turbidity [Formazin Nephelometric Units(FNU)]. The YSI 6920 V2 optical ports were equipped with optical ROX dissolved oxygen and Turbidity 6136 sensors. Specifications for all sensors are provided in Appendix I. Daily data collection generally began after the launching ceremony and ended just prior to the canoes coming ashore for the evening. Data collection procedures and YSI instrument setup methods are outlined in Akin and Grossman, 2010.

YSI sondes were calibrated and audited daily to ensure data accuracy and to correct for any instrument drift. Calibration and audit procedures were performed by the water-quality technicians according to manufacturer recommendations. Quality-control procedures for acceptance or rejection of data are described in the USGS National Field Manual for the Collection of Water-Quality Data (Wilde, 2005) and were reviewed by USGS water-quality specialists (Akin and others, 2009 and Akin and Grossman, 2010). Data are accepted or rejected based on the determined acceptable precision drift range (table 1).

Table 1. Instrument accuracy and audit criteria for conductivity, dissolved oxygen, pH, and turbidity.

Parameter	Units	Method Accuracy	Precision
Conductivity	mS/cm	± 0.5% of reading	± 0.3ms/cm
Dissolved Oxygen	mg/L	± 0.2 mg/L	± 0.5 mg/L
pH	pH units	± 0.2 units	± 0.2 units
Turbidity	FNU	2 % of range	5 % of range

Data Acquisition and Classification

Raw YSI data files were downloaded each day and processed according to the following steps: (1) raw track data files were merged with the 10-second interval corresponding GPS file containing latitude, longitude, and speed; (2) calibration and audit logs were examined for each of the instruments for each of the days to determine which parameters met data-quality objectives (table 1); (3) errors in the merged data files were flagged with a numerical codes (table 3); and (4) flagged data errors were corrected, where possible, before files proceeded for subsequent analyses.

Following initial quality-control processing, data collected in U.S. waters were grouped and attributed into seven basins following the Puget Sound Nearshore Ecosystem Restoration Project classification (Shipman, 2008) using ArcGIS 10.1 software (table2). Data collected in British Columbia were grouped into six basins following the British Columbia Watershed Atlas (British Columbia, 2007). Data were also mapped in Google Maps and disseminated near real-time online at the Project Web site *(*http://www.usgs.gov/coastsalish*)*. Maxima, minima, mean and standard deviation for each parameter were analyzed, except for pH, where the median was determined for each of the basins and freshwater bodies.

Table 2. Basin codes created by the Puget Sound Nearshore Ecosystem Restoration group and the British Columbia Watershed Atlas group.

Code	Basin Name	Code	Basin Name
COMX	Comox	WB	Whidbey
PARK	Parksville	NC	North Central Puget Sound
COWN	Cowichan	SC	South Central Puget Sound
SQUM	Squamish	HC	Hood Canal
LFRA	Lower Fraser	SP	South Puget Sound
VICT	Victoria	PC	Pacific Coast
SJ	San Juan	Fraser	Fraser River
JF	Juan de Fuca	Skagit	Skagit River

We compared the results with an established set of regulatory standards to evaluate the variation in the water quality across the study area. Washington State has developed water-quality standards through the Washington Administrative Code to protect the marine and fresh surface waters of the State, with specific levels of protection designated by quality of aquatic life uses for marine surface waters. Marine waters are classified as being of extraordinary quality, excellent quality, good quality, and fair quality as outlined in Washington Administrative Code Title 173-201A, 2006 (Appendix II). The marine surface-water results by basin from the TJWQP were compared to WAC-173-201A-210 standards, and results for temperature, dissolved oxygen, and pH are reported in this document.

Environmental Conditions

To characterize water property results relative to environmental conditions, we synthesize existing atmospheric data for the months surrounding the Tribal Journey which exert influence on resulting surface water measurements. Atmospheric data including air temperature, wind speed and direction, atmospheric pressure and precipitation were obtained from National Weather Service (National Oceanic and Atmospheric Administration 2015) and Environment Canada (Environment Canada 2015) weather stations. Tide and marine water temperature data were collected from National Oceanic and Atmospheric Administration (NOAA) tide gauges. River flow and water properties including temperature, turbidity and dissolved oxygen (where available) were obtained from USGS and Environment Canada stream gauges. Coastal upwelling indices were obtained from the University of Washington Columbia Basin Research DART (Data Access in Real Time) website that disseminates the original data courtesy of NMFS Pacific Fisheries Environmental Laboratory. A list of stations used for the compilation of Salish Sea environmental conditions can be found in Appendix IV. Data were compiled for one station located closest to the marine water within each basin. These data were used to determine if water properties across the Salish Sea reflected variability in atmospheric and stream runoff conditions that affect estuarine and nearshore water properties and mixing. Observations of daily weather conditions were also recorded during the Journey noting presence of clouds, sun, winds and precipitation to further interpret water property results.

Results

The results presented in this report summarize the water-quality patterns of the Salish Sea in 2014 and provide comparisons to the 2008 to 2014 results (Akin and others, 2009; Akin and Grossman, 2010, Grossman and Grossman 2012, 2013, and 2014) at the landscape scale and basin scale. Site-specific patterns in a subset of the seven years of data are available online at *http://www.usgs.gov/coastsalish/* or complete data files by request.

A total of 13,667 data points were collected during the 2014 Tribal Journey, capturing surface-water temperature, salinity, pH, dissolved oxygen concentration and percent saturation, and turbidity. The Squaxin Island canoe pulling during the TJWQP covered roughly 250 km of the Salish Sea during the period from June 24 to June 30, 2014.

The results of the monitoring conducted by the canoe families are summarized by basin within northern most region of the Salish Sea, wholly within Canadian waters, with corresponding summary maps for surface-water temperature, salinity, pH, dissolved oxygen, and turbidity.

Northwest Salish Sea Basins

The Northwest Salish Sea region includes Victoria (VICT), Cowichan (COWN), Parksville (PARK), and Comox (COMX) basins along the western shoreline of the Strait of Georgia. VICT Basin is a mixing zone where water-quality parameters are influenced significantly by water from the Strait of Juan de Fuca and by waters circulating through the Georgia Strait (San Juan and Canadian Basins) and Puget Sound. VICT (table 3) was monitored June 24 and 25, 2014, COWN (table 4) was monitored June 25, 26, and 27, 2014, PARK (table 5) was monitored June 27, 28, 29, and 30, 2014, and COMX (table 6) was monitored June 30, 2014. It is important to note that during the 2014 Journey to Bella Bella canoes traveling through the Salish Sea nearly a month earlier than all other monitoring years.

Also, during the 2014 Journey, canoes were traveling northward along the eastern shore of Vancouver Island. In previous monitoring years, canoes following these same routes traveled south, making it important to be careful in direct comparisons of daily track results, that can be affected by diurnal patterns of environmental forcings (e.g. daylight warming, tide/current regimes). While geographically the monitoring occurred along tracks similar to previous years, the results presented in this report, in a way, stand alone as representing early summer conditions. Northwest Salish Sea results for temperature, salinity, pH, dissolved oxygen, and turbidity (where applicable) are shown in figures 2 to 7.

Victoria Basin

VICT Basin surface-water temperatures ranged from 9.5 to 19.4°C, with an average of 12.5 ± 2.5 °C (n=2,981) over the two days (table 4). Of the 2,981 surface-water measurements five (exceeded 19 °C, 328 (11%) measurements were between 16 and 19 °C, and 657 (22%) measurements were between 13 and 16 °C. The minimum salinity measured in VICT Basin was 22.5 and the maximum 30.8 psu, with an average of 29.2 ± 0.8 psu (n=2,981). Surface-water pH ranged from 7.3 to 8.4 pH units, with a median reading of 7.9 pH units (n=2,981). Dissolved oxygen concentrations ranged from a minimum of 6.5 to a maximum of 13.9 mg/L, with an average of 8.9 ± 2.0 mg/L (n=2,980). Dissolved oxygen concentration fell below 7.0 mg/L for 423 (14%) of the 2,980 samples. Dissolved oxygen saturation ranged from 69.4 to 166 percent, with an average of 102 ± 28 percent (n=2,980). Turbidity results ranged from 0.0 to 183.9 FNU, with an average of 8.3 ± 18.1 FNU (n=2,872).

Cowichan Basin

The Cowichan Basin surface-water temperatures ranged from 12.0 to 21.1 °C, with an average of 15.9 ± 2.2 °C (n=4,208) (table 3). Of the 4,208 surface-water measurements zero exceeded 22 °C and 478 (11%) were between 19 and 22 °C, 1,356 (32%) measurements were between 16 and 19 °C, 2,027 (48%) measurements were between 13 and 16 °C, and 347 (8%) were below 13°C. The salinity ranged from 22.6 to 29.4 psu, with an average of 26.4 ± 1.4 psu (n=4,208) in the surface waters. The median pH reading was 8.3 pH units (n=4,208), and ranged from a minimum of 7.3 to a maximum of 8.4 pH units. Dissolved oxygen concentrations ranged from 7.7 to 12.3 mg/L, with an average of 10.3 ± 1.1 mg/L (n=4,208). Dissolved oxygen saturation ranged from 86.1 to 152percent and averaged 123 ± 16 percent (n=4,208). Turbidity ranged from 0.1 to 175 FNU, and averaged 1.9 ± 4.1 FNU (n=4,201).

Parksville Basin

The Parksville Basin surface-water temperatures ranged from a minimum of 12.0°C to a maximum of 18.7 °C, and averaged 15.4 ± 1.4 °C (n=5,409) (table 3). Of the 5,409 surface-water measurements zero exceeded 19 °C, 1,904 (35%) were between 16 and 19 °C, and 3,449 (64%) measurements were between 13 and 16 °C. Surface-water salinity ranged from 1.3 at the outlet of Englishman River to 28.4 psu, and averaged 26.2 ± 1.5 psu (n=5,409). The pH of the surface-water ranged from 7.4 to 8.5 pH units, and the median pH reading was 8.2 pH unit (n=5,409). The minimum surface-water dissolved oxygen concentration was 6.9 and the maximum 12.8 mg/L, and averaged 9.3 ± 1.0 mg/L (n=5,409). Of the 5,409 dissolved oxygen measurements nine (<1%) were below 7.0 mg/L. Dissolved oxygen saturation ranged from 76.8 to 151 percent, with an average of 109 ± 14 percent (n=5,409). Turbidity ranged from a minimum of 0.0 to a maximum of 90.8 FNU, with an average of 5.1 ± 11.7 FNU (n=5,379).

Comox Basin

Due to GPS errors that occurred during the final day of monitoring the last 448 samples of the day do not have coordinates associated with them and are not included on maps of results. However, the canoes were traveling well within the bounds of Comox Basin so the data are included in the basin summary statistics presented below. The Comox Basin surface-water temperatures ranged from a minimum of 12.4 °C to a maximum of 20.2 °C, and averaged 18.1 ± 1.0 °C (n=1,069) (table 3). Of the 1,069 surface-water measurements zero exceeded 22 °C, 86 (8 %) were between 19 and 22 °C, and 929 (87%) measurements were between 16 and 19 °C. Surface-water salinity ranged from 21.7 to 28.5 psu, and averaged 25.0 ± 1.1 psu (n=1,041). The pH of the surface-water ranged from 8.0 to 8.3 pH units, and the median pH reading was 8.3 pH unit (n=1,069). The minimum surface-water dissolved oxygen concentration was 7.8 and the maximum 13.2 mg/L, and averaged 10.1 ± 0.6 mg/L (n=1,069). Dissolved oxygen saturation ranged from 88 to 142 percent, with an average of 123 ± 7 percent (n=1,069). Turbidity ranged from a minimum of 0.0 to a maximum of 36 FNU, with an average of 1.0 ± 1.9 FNU (n=1,066).

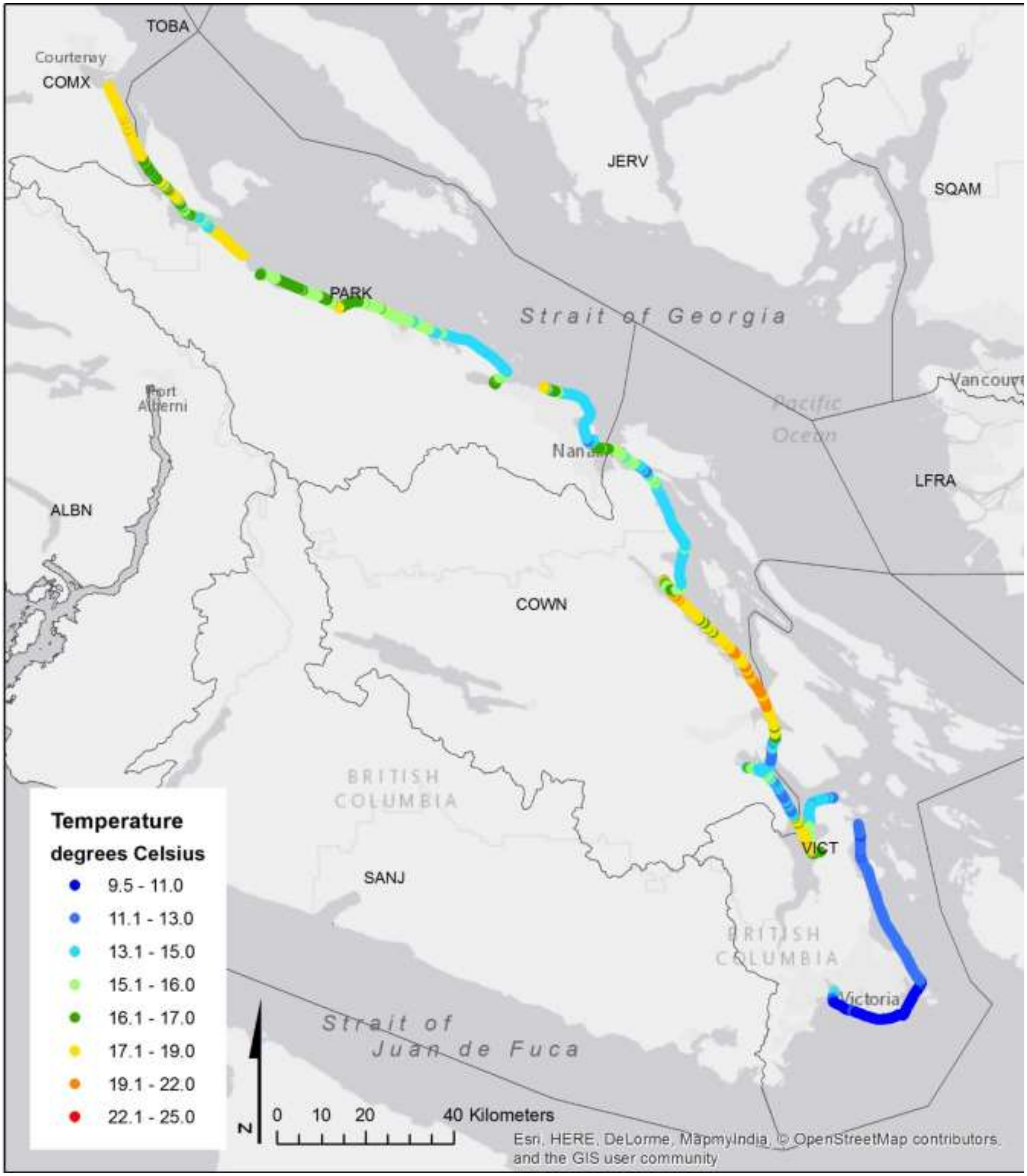

Figure 2. Surface-water temperature recorded in degrees Celsius in the Northwest Salish Sea from June 24 to June 30, 2014.

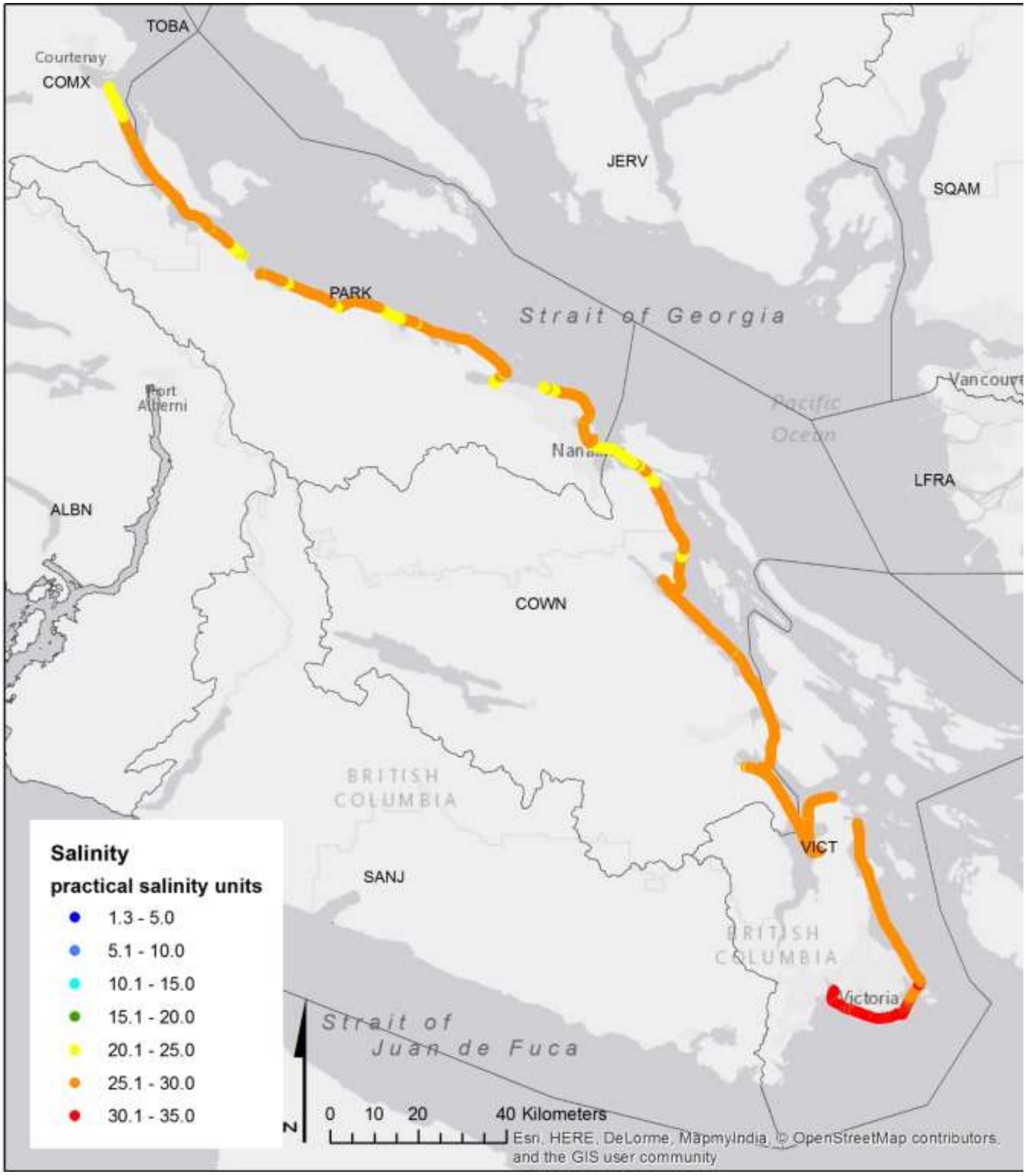

Figure 3. Surface-water salinity recorded in practical salinity units in the Northwest Salish Sea from June 24 to June 30, 2014.

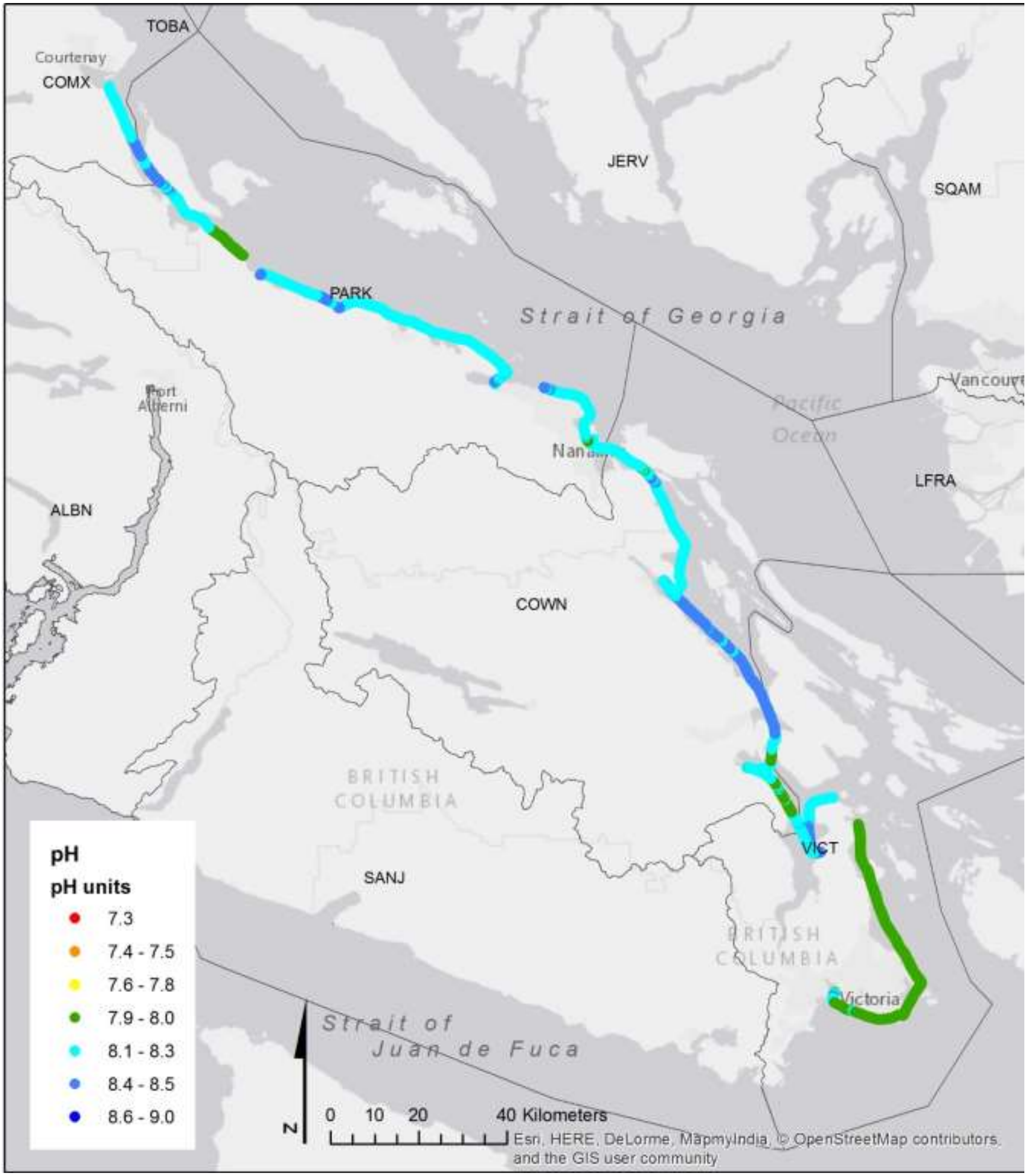

Figure 4. Surface-water pH recorded in pH units in the Northwest Salish Sea from June 24 to June 30, 2014.

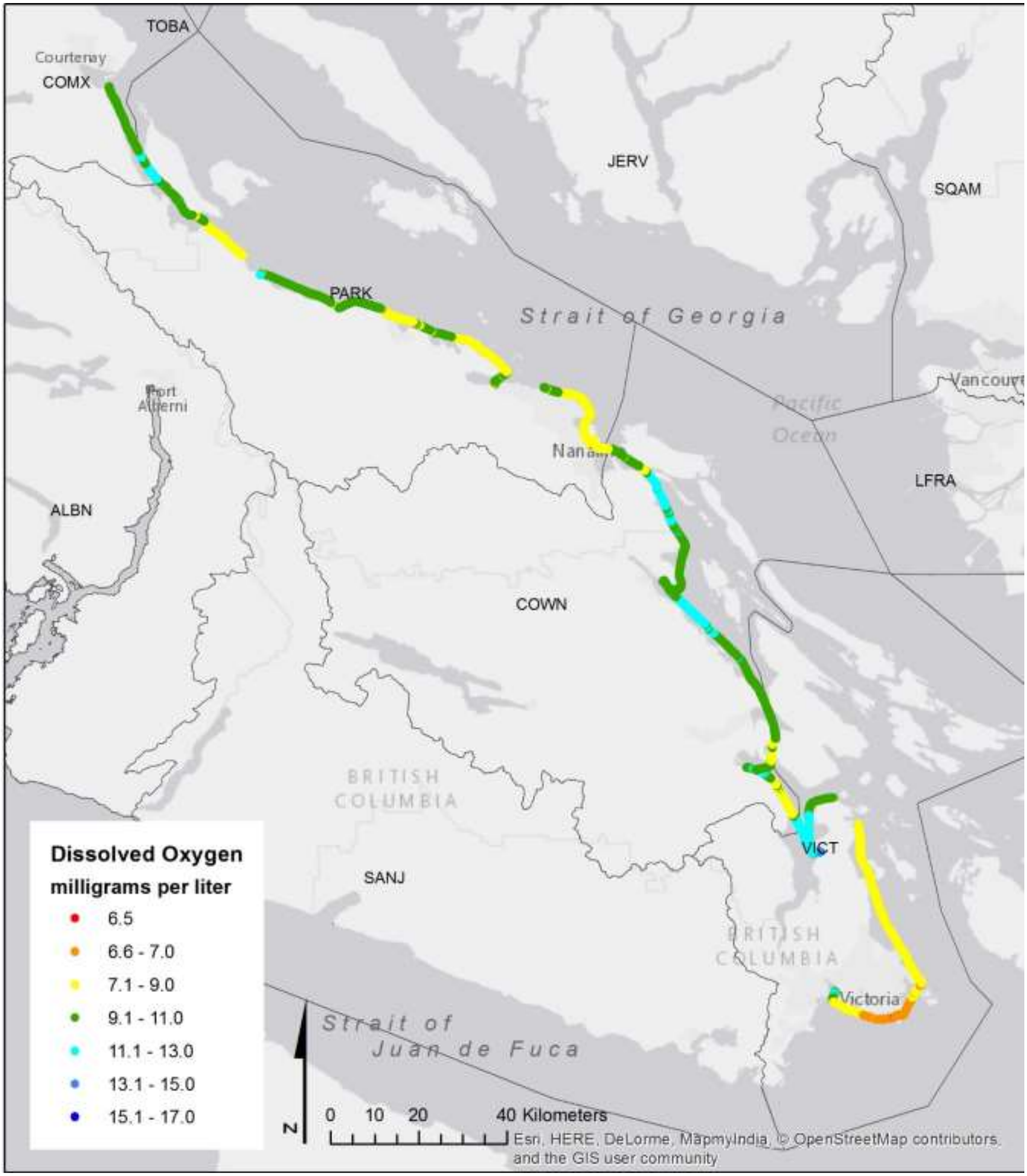

Figure 5. Surface-water dissolved oxygen recorded in milligrams per liter in the Northwest Salish Sea from June 24 to June 30, 2014.

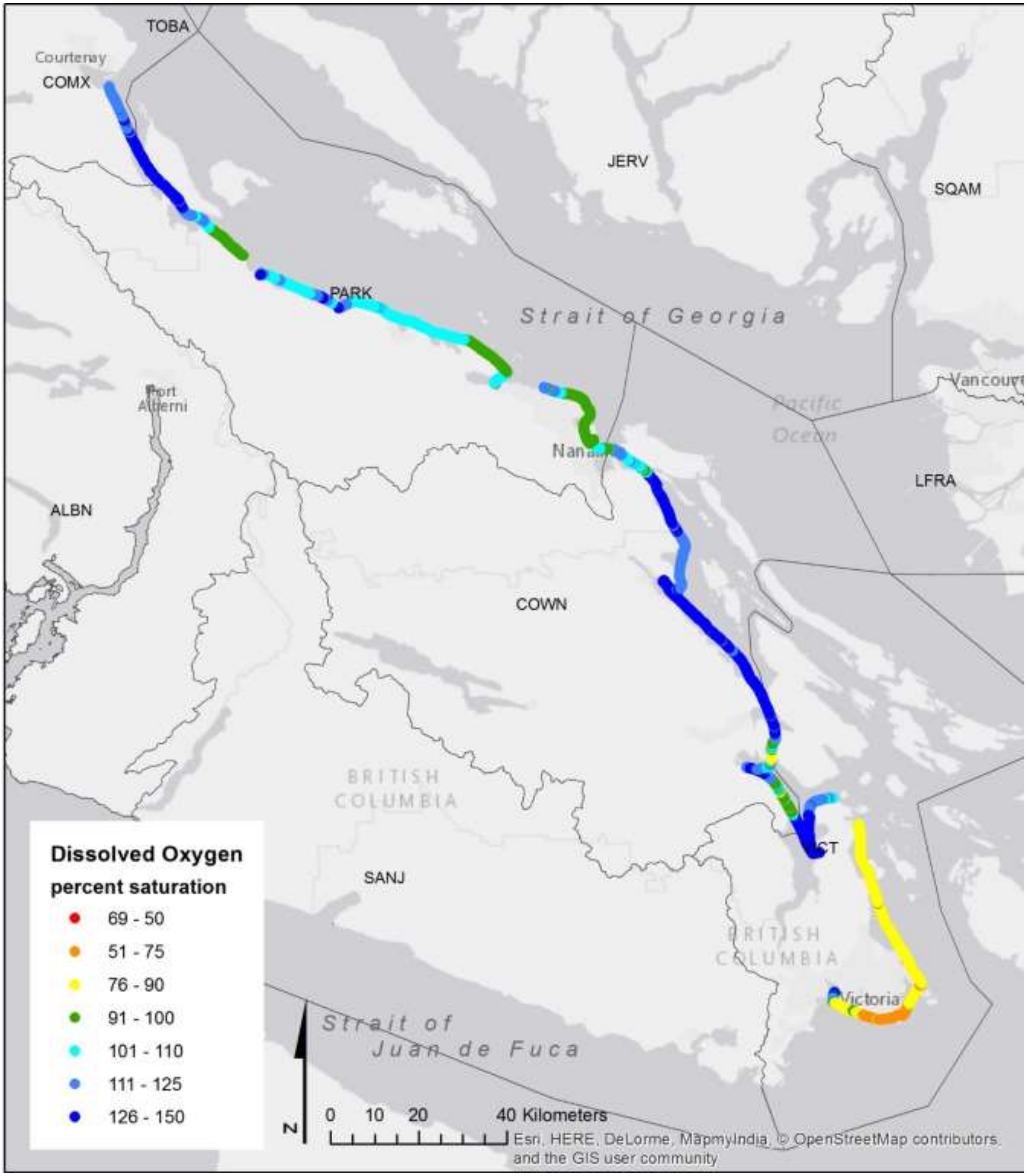

Figure 6. Surface-water dissolved oxygen recorded as percent saturation in the Northwest Salish Sea from June 24 to June 30, 2014.

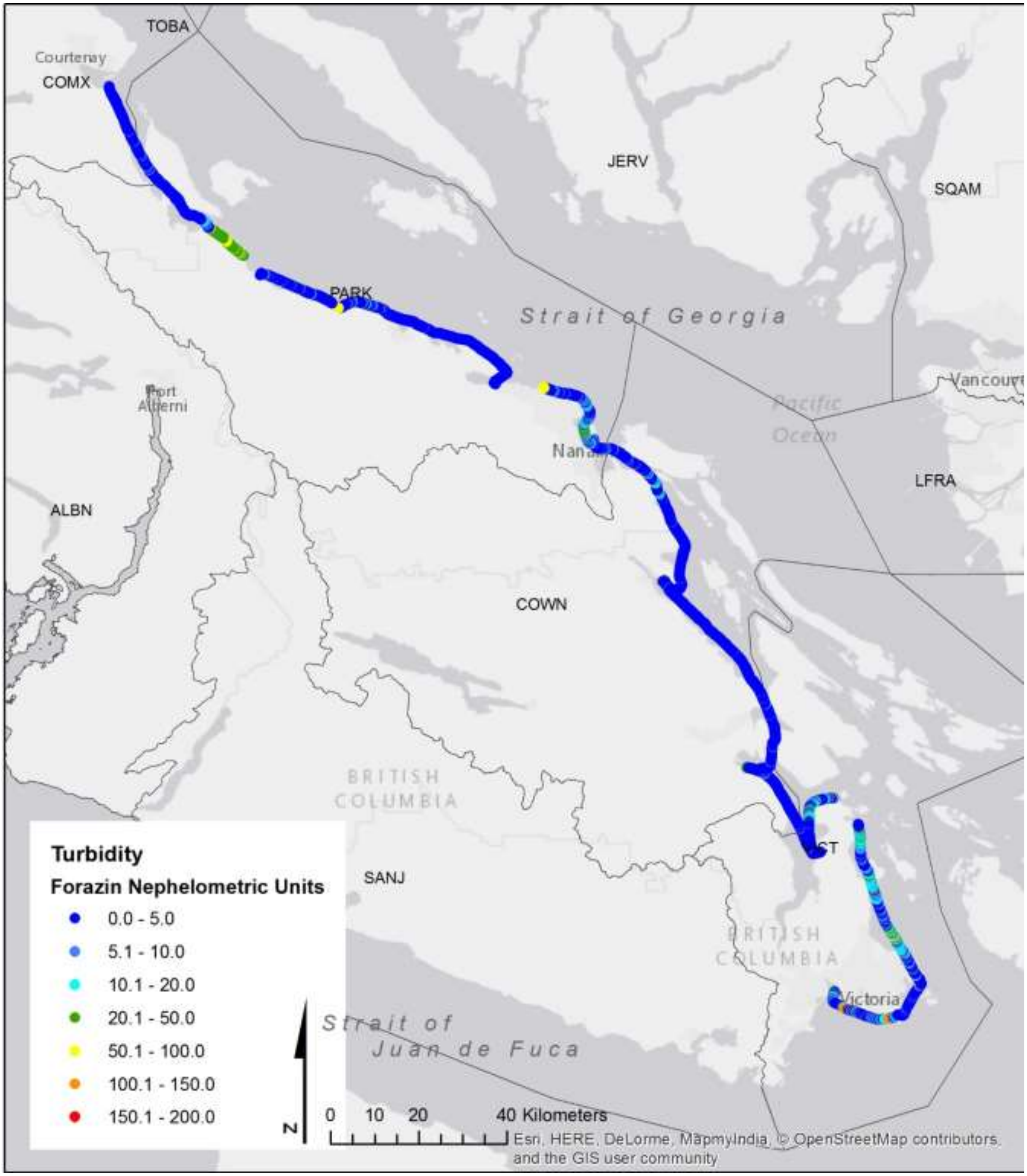

Figure 7. Surface-water turbidity recorded in Formazin Nephelometric Units in the Northwest Salish Sea from June 24 to June 30, 2014.

Table 3. Water-quality statistics for Victoria, 2014.

[Average, median, maximum, minimum, standard deviation (StdDev), and number of observations (n) for temperature in degrees Celsius, salinity in practical salinity units, pH in pH units, dissolved oxygen in milligrams per liter and percent saturation, and turbidity in Formazin Nephelometric Units.]

Victoria			
Date	6/24/2014	6/25/2014	All Days
Temperature in degrees Celsius			
Average	12.0	17.9	12.5
Maximum	16.9	19.4	19.4
Minimum	9.5	16.1	9.5
StdDev	1.9	0.7	2.5
n	2,722	259	2,981
Salinity in practical salinity units			
Average	29	29	29
Maximum	31	29	31
Minimum	23	29	23
StdDev	0.9	0.0	0.8
n	2722	259	2,981
pH in pH units			
Median	7.9	8.3	7.9
Maximum	8.4	8.3	8.4
Minimum	7.3	8.1	7.3
n	2,722	259	2,981
Dissolved Oxygen in milligrams per liter			
Average	8.7	11.4	8.9
Maximum	13.9	11.6	13.9
Minimum	6.5	8.6	6.5
StdDev	2.0	0.3	2.0
n	2,722	259	2,981
Dissolved Oxygen in percent saturation			
Average	98	143	102
Maximum	166	146	166
Minimum	69	104	69
StdDev	26	4	28
n	2,722	259	2,981
Turbidity in Formazin Nephelometric Units			
Average	9.0	1.2	8.3
Maximum	184	12	184
Minimum	0.0	0.2	0.0
StdDev	18.8	1.6	18.1
n	2,722	259	2,981

Table 4. Water-quality statistics for Cowichan Basin, 2014.

[Average, median, maximum, minimum, standard deviation (StdDev), and number of observations (n) for temperature in degrees Celsius, salinity in practical salinity units, pH in pH units, dissolved oxygen in milligrams per liter and percent saturation, and turbidity in Formazin Nephelometric Units.]

Cowichan				
Date	6/25/2014	6/26/2014	6/27/2014	All Days
Temperature in degrees Celsius				
Average	14.0	17.3	14.9	15.9
Maximum	18.6	21.1	17.7	21.1
Minimum	12.0	12.2	12.0	12.0
StdDev	1.5	2.1	0.8	2.2
n	687	2,071	1,450	4,208
Salinity in practical salinity units				
Average	28.7	26.4	25.2	26.4
Maximum	29.4	28.9	27.5	29.4
Minimum	26.7	22.6	22.6	22.6
StdDev	0.7	0.9	0.6	1.4
n	687	2,071	1,450	4,208
pH in pH units				
Median	8.0	8.4	8.2	8.3
Maximum	8.3	8.4	8.4	8.4
Minimum	7.9	7.4	7.3	7.3
n	687	2,071	1,450	4,208
Dissolved Oxygen in milligrams per liter				
Average	9.5	10.6	10.3	10.3
Maximum	12.0	12.3	12.1	12.3
Minimum	7.7	7.7	8.0	7.7
StdDev	1.3	1.0	0.9	1.1
n	687	2,071	1,450	4,208
Dissolved Oxygen in percent saturation				
Average	110.5	129.4	118.5	122.6
Maximum	146.0	151.8	140.4	151.8
Minimum	87.1	86.1	90.7	86.1
StdDev	17.6	14.7	10.5	15.7
n	687	2,071	1,450	4,208
Turbidity in Formazin Nephelometric Units				
Average	2.2	1.5	2.3	1.9
Maximum	175	40	26	175
Minimum	0.3	0.1	0.2	0.1
StdDev	8.8	1.8	2.6	4.1
n	687	2,071	1,450	4,208

Table 5. Water-quality statistics for Parksville Basin, 2014.

[Average, median, maximum, minimum, standard deviation (StdDev), and number of observations (n) for temperature in degrees Celsius, salinity in practical salinity units, pH in pH units, dissolved oxygen in milligrams per liter and percent saturation, and turbidity in Formazin Nephelometric Units.]

Parksville					
Date	6/27/2014	6/28/2014	6/29/2014	6/30/2014	All Days
Temperature in degrees Celsius					
Average	16.2	14.3	15.2	16.2	15.4
Maximum	16.7	17.4	17.7	18.7	18.7
Minimum	14.5	12.6	12.0	13.8	12.0
StdDev	0.5	1.0	1.1	1.4	1.4
n	143	986	2468	1812	5,409
Salinity in practical salinity units					
Average	22.7	26.1	25.9	26.9	26.2
Maximum	25.4	27.9	28.4	28.0	28.4
Minimum	20.8	20.0	21.2	1.3	1.3
StdDev	0.9	1.6	1.1	1.4	1.5
n	143	986	2468	1812	5,409
pH in pH units					
Median	8.2	8.2	8.3	8.2	8.2
Maximum	8.2	8.4	8.5	8.4	8.5
Minimum	8.0	7.7	7.4	7.9	7.4
n	143	986	2,468	1,812	5,409
Dissolved Oxygen in milligrams per liter					
Average	8.7	8.5	9.0	10.0	9.3
Maximum	9.0	10.2	12.6	12.8	12.8
Minimum	8.0	7.6	6.9	7.5	6.9
StdDev	0.3	0.3	0.6	1.3	1.0
n	143	986	2,468	1,812	5,409
Dissolved Oxygen in percent saturation					
Average	101.4	97.8	105.5	120.3	108.9
Maximum	104.7	121.2	150.5	149.0	150.5
Minimum	94.0	90.6	76.8	93.4	76.8
StdDev	3.0	5.0	7.9	15.7	13.8
n	143	986	2,468	1,812	5,409
Turbidity in Formazin Nephelometric Units					
Average	2.6	6.9	1.6	9.2	5.1
Maximum	41	81	50	91	91
Minimum	0.5	0.0	0.1	0.0	0.0
StdDev	4.0	9.0	2.5	17.8	11.7
n	143	986	2,468	1,812	5,409

Table 6. Water-quality statistics for Comox Basin, 2014.

[Average, median, maximum, minimum, standard deviation (StdDev), and number of observations (n) for temperature in degrees Celsius, salinity in practical salinity units, pH in pH units, dissolved oxygen in milligrams per liter and percent saturation, and turbidity in Formazin Nephelometric Units.]

Comox	
Date	6/30/2014
Temperature in degrees Celsius	
Average	18.1
Maximum	20.2
Minimum	12.4
StdDev	1.0
n	1,069
Salinity in practical salinity units	
Average	25.0
Maximum	28.5
Minimum	21.7
StdDev	1.1
n	1,041
pH in pH units	
Median	8.3
Maximum	8.3
Minimum	8
n	1,069
Dissolved Oxygen in milligrams per liter	
Average	10.1
Maximum	13.2
Minimum	7.8
StdDev	0.6
n	1,069
Dissolved Oxygen in percent saturation	
Average	123.2
Maximum	141.5
Minimum	88.0
StdDev	7.3
n	1,069
Turbidity in Formazin Nephelometric Units	
Average	1.0
Maximum	36
Minimum	0.0
StdDev	1.9
n	1,069

Environmental Conditions of 2014

Air temperatures across the Salish Sea in June 2014 were generally lower than temperatures of July in previous years, which was to be expected due to the early travel dates (fig. 9). The skies were generally foggy in the morning and clear to partly cloudy in the afternoon during the two week monitoring period with breezy wind conditions on the water and a few days of moderate rain (Shell Beach). Of the basins examined, air temperatures were coolest and had the least amount of monthly variability (average 14.0 to 15.5 °C) in the central Salish Sea basins (San Juan, North Central Puget Sound, and Whidbey) and Juan de Fuca basin and warmest with higher monthly variability (average 18.3 to 18.9 °C) in the northern and southern Salish Sea basins (Comox, Parksville, and Cowichan).

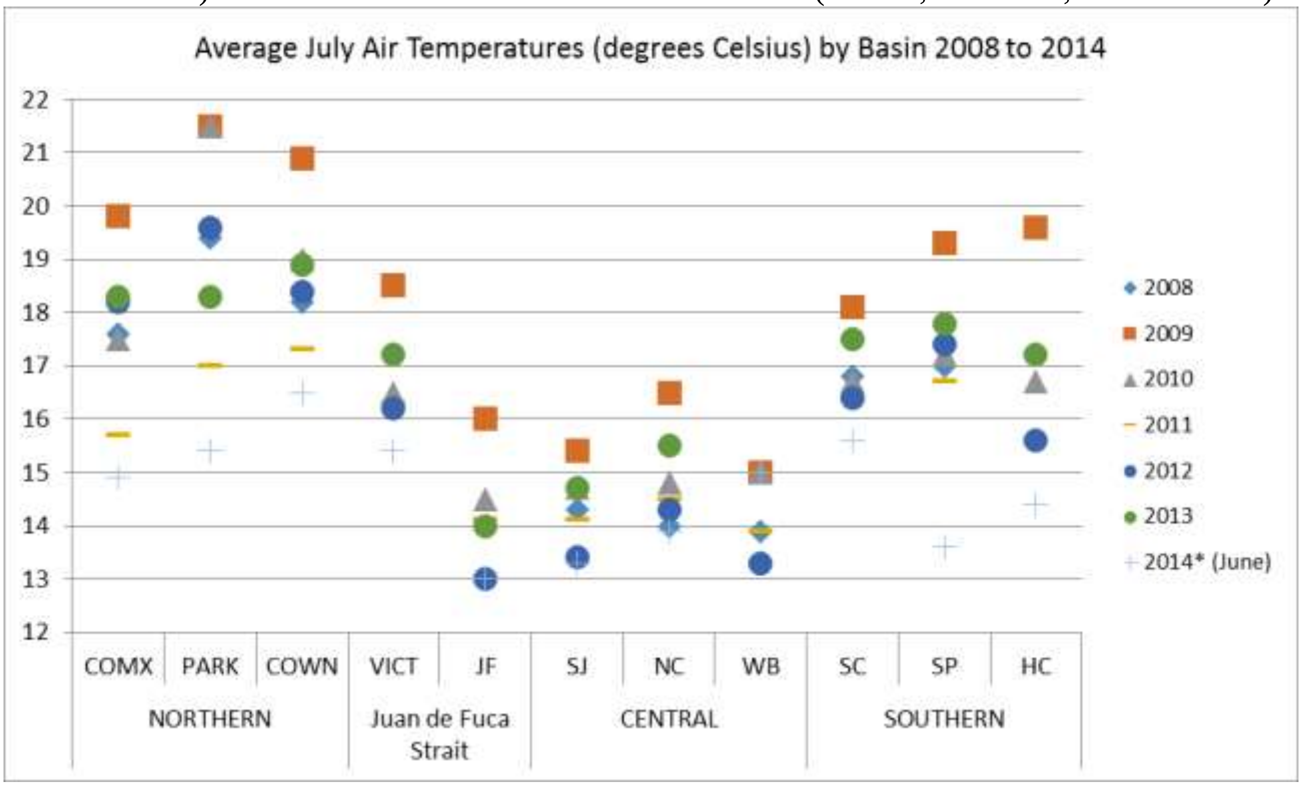

Figure 8. Average July air temperatures in degrees Celsius by basin for monitoring years 2008 to 2013 compared against June 2014.

The Department of Fisheries and Oceans Canada monitor river discharge at numerous sites throughout the Salish Sea. Data summaries were queried for the large rivers in the Salish Sea to provide context for interpreting the surface-water property patterns measured. The Fraser River runoff is briefly discussed here as it is the largest contributor of freshwater into the Salish Sea. The Fraser River peak discharge generally occurs in late June/early July each year. In summer 2014, measurements were at the 25-year max return interval during the peak freshet in early June falling to 30-year average discharge by mid-June (DFO 2014). Peak Fraser River water temperatures occurred in late July/early August (after the Tribal Journey) and remained above 19 ºC (above the mean temperature standard deviation for the time period) for much of the month of August (DFO 2014).

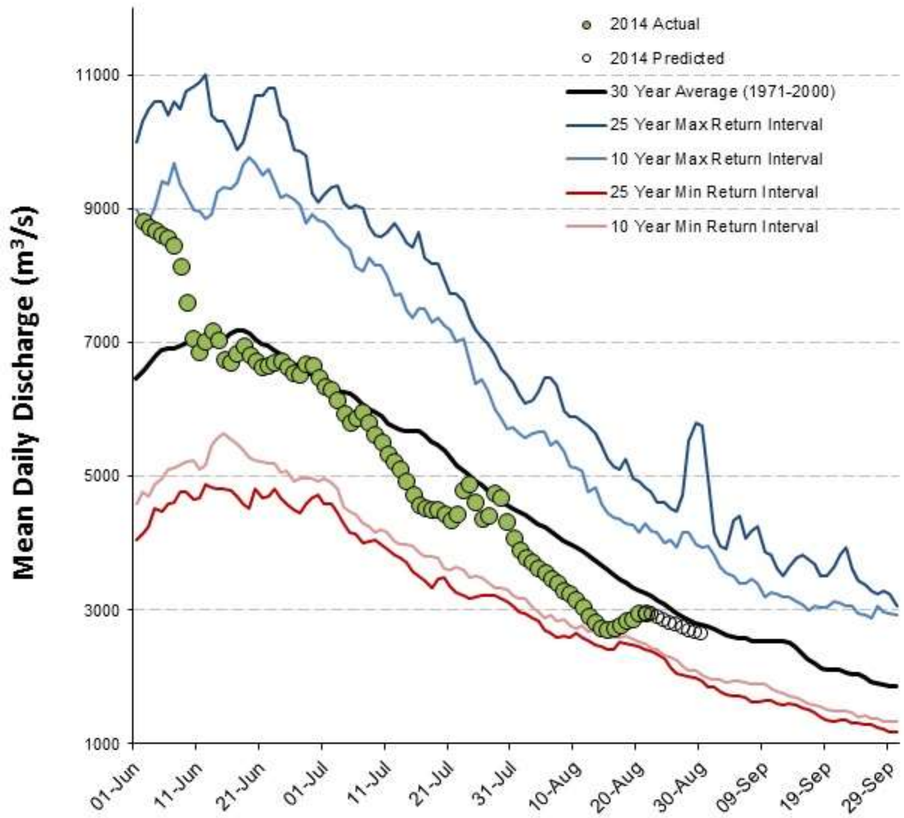

Figure 9. Fraser River mean daily discharge [http://www.pac.dfo-mpo.gc.ca/science/habitat/frw-rfo/reports-rapports/2014/2014-08-28/2014-08-28-eng.html].

Coastal upwelling in June 2014 near the entrance to the Strait of Juan de Fuca (48N, 125W) was very close to the historical mean, but a little lower than the mean between April and May preceding the Journey (figure 10). Coastal Upwelling in June 2014 was also slightly lower than all prior Canoe Journey surveys made in July of previous years, except 2011.

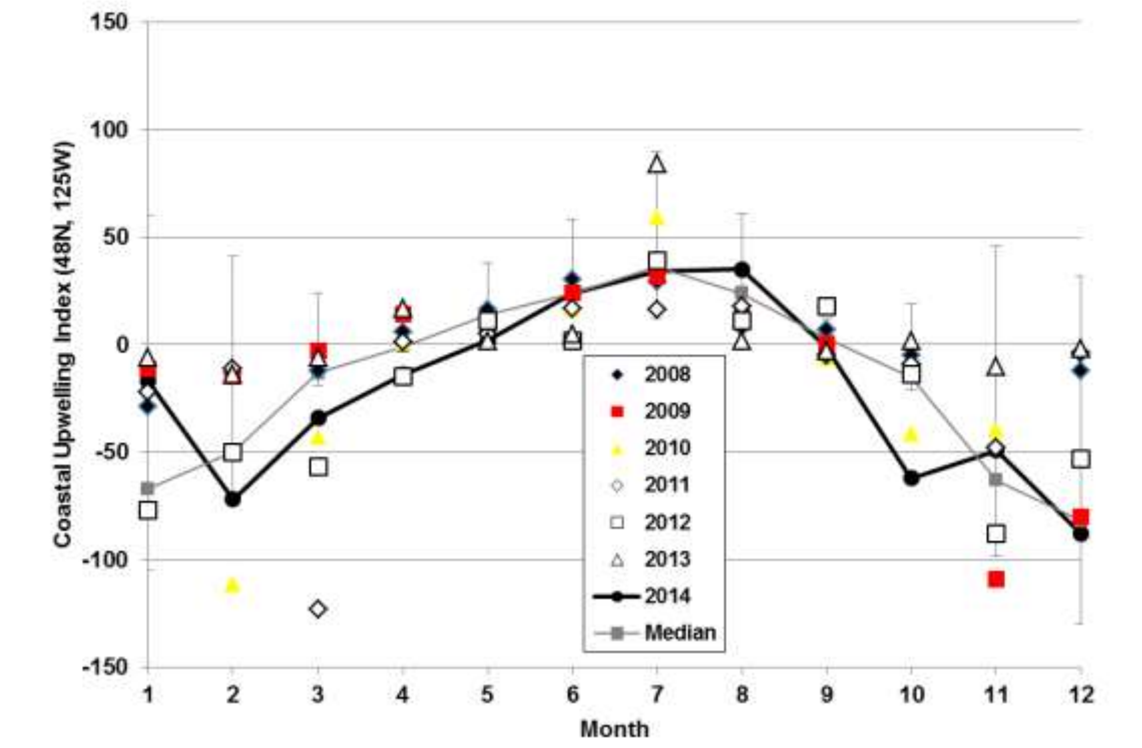

Figure 10. Coastal Upwelling Index for 2014 at La Push (48N, 125W) relative to prior study years and historical median (1967 to 2008) [*http://www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/NA/data_download.html*].

Discussion

The inland waters of the Salish Sea are a complex trans-boundary ecosystem governed by dynamic mixing of ocean and freshwater driven by coastal upwelling, high tidal range that invokes strong tidal mixing, and river runoff from steep watersheds with high precipitation. The TJWQP provides detailed information on water properties across a vast region of the Salish Sea at high temporal and spatial resolution. The measurements made during the Tribal Journey in middle to late summer are important for improving our understanding of ecosystem conditions during a time when the Salish Sea undergoes dynamic change in response to shifts in seasonal warming, runoff, coastal upwelling and productivity (Davenne and Masson, 2001). The information also fills important data gaps in shallow and nearshore areas where canoes travel and traditional research vessels cannot readily access. The information gathered provides a time-series with each successive year of sampling to detect patterns and trends related to climate and land-use change.

Of concern are how climate and land-use change will impact water quality that supports the Salish Sea ecosystem. Surface, middle and bottom water temperature have already been documented to have increased over the last century (Beamish, 2011) and projections of climate change indicate that summer water properties are likely to be strongly affected by changes in the magnitude, timing and rate of seasonal shifts in climate forcing on air temperature, precipitation, snow/glacier melt and runoff, as well as coastal upwelling (Tillmann and Siemann, 2011). Under projected climate change scenarios, retreating snowpack and glaciers are expected to reduce the spring freshet volume and lead to lower summer river low flows. As a consequence, warmer fresh waters are likely to be delivered to the Salish Sea during summer months. Increases in air temperature are projected to raise water temperatures, and changes in winds and the strength and timing of coastal upwelling are likely to affect the extent that deep marine waters with high acidity and low levels of dissolved oxygen mix into the Salish Sea.

Northern Salish Sea surface-waters monitored during the 2014 Tribal Journey show an average temperature of 15.1±2.5ºC (n=13,667). Surface-water temperatures by basin ranged from 9.5ºC in Victoria basin and steadily warmed traveling north to 21.1ºC in Cowichan basin. Surface-water temperatures exceeded 16ºC (*Good* classification) for 4% and exceeded 13 ºC (*Excellent* classification) for 33% of samples collected in June 2014. No surface-water temperature measurements exceeded 22 ºC. Comox basin had the highest overall temperature average and was the only basin to fall into the *Good* classification. Cowichan and Parksville basins received an *Excellent* classification for temperature and Victoria basin received an *Extraordinary* classifications for June 2014 (table 7).

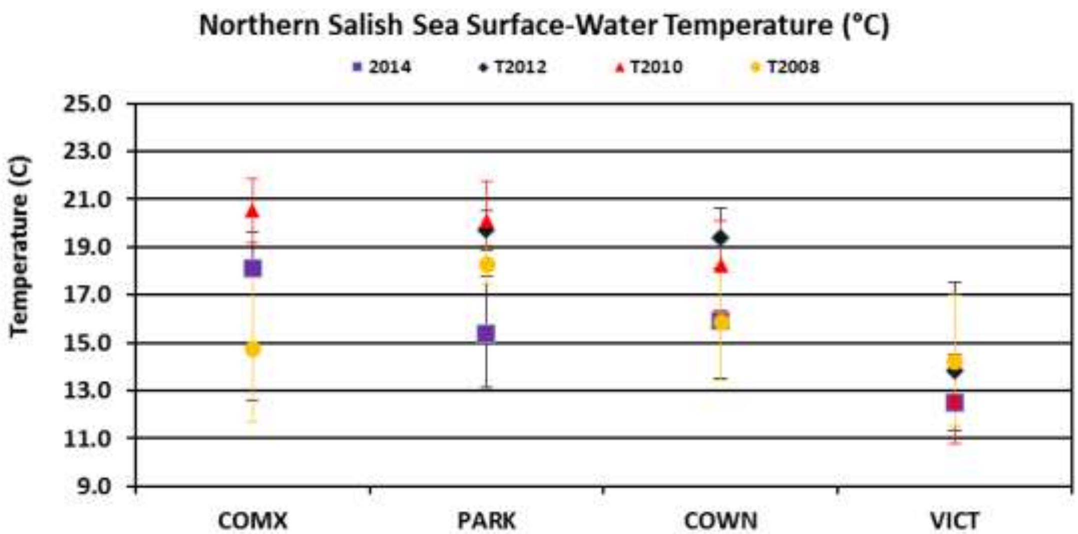

Figure 11. Surface-water temperature averages (in degrees Celsius) by basin in the Northern Salish Sea for monitoring years 2008 to 2014.

Table 7. Average temperature and dissolved oxygen classification in the Strait of Georgia, 2008 to 2014. Classifications are based on Washington State water quality criteria extraordinary, excellent, good, and fair quality aquatic life uses.

Victoria	2008	2009	2010	2011	2012	2013	2014
Temperature	Excellent	-	Extraordinary	-	Excellent	-	Extraordinary
Dissolved Oxygen	Extraordinary	-	Excellent	-	Extraordinary	-	Extraordinary
Cowichan	2008	2009	2010	2011	2012	2013	2014
Temperature	Excellent	-	Good	-	Good	-	Excellent
Dissolved Oxygen	Extraordinary	-	Excellent	-	Extraordinary	-	Extraordinary
Parksville	2008	2009	2010	2011	2012	2013	2014
Temperature	Good	-	Good	-	Good	-	Excellent
Dissolved Oxygen	Extraordinary	-	Excellent	-	Extraordinary	-	Extraordinary
Comox	2008	2009	2010	2011	2012	2013	2014
Temperature	Excellent	-	Good	-	-	-	Good
Dissolved Oxygen	Extraordinary	-	Excellent	-	-	-	Extraordinary

The 2014 surface water dissolved oxygen average for the Salish Sea was 9.6±1.4 mg/L (n=13,666). Mean values of dissolved oxygen in each basin were high in 2014 resulting in an *Extraordinary* classification for all Canadian basins monitored (table 7). Cowichan and Comox basins had the highest dissolved oxygen averages (10.3 and 10.1 mg/L respectively) and Victoria basin had the lowest at 8.9 mg/L. The surface water dissolved oxygen measurements fell below 7.0 mg/L (E*xcellent* classification) for 3% of the samples, a majority of which were in Victoria basin.

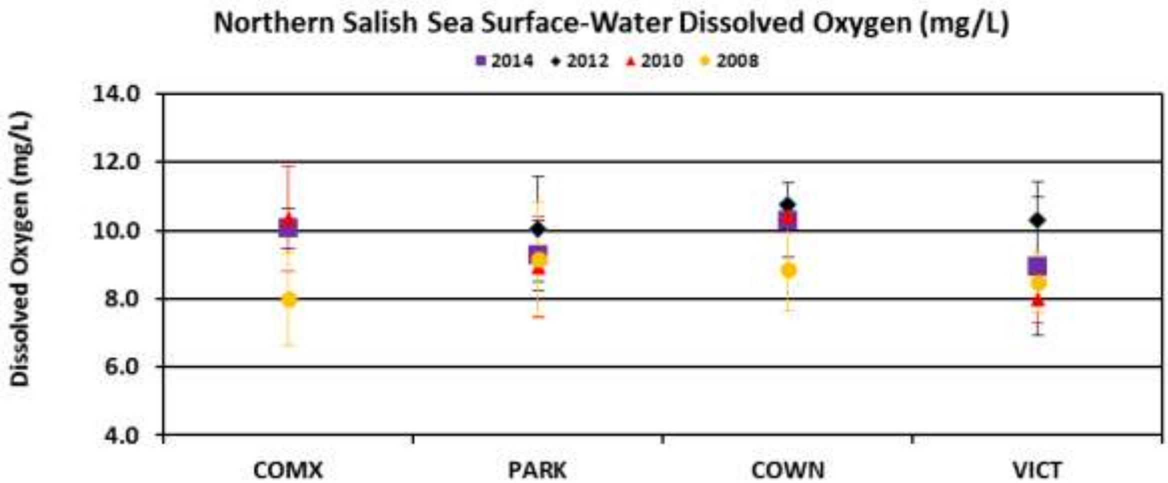

Figure 12. Surface-water dissolved oxygen averages (in milligrams per liter) by basin in the Northern Salish Sea for monitoring years 2008 to 2014.

The average surface water salinity in 2014 was 27 ±1.9 PSU (n=13,639). Mean basin salinity ranged from 25 ±1.1 PSU in Comox basin to 29 ±0.8 PSU in Victoria. Salinity results show that in June 2014 Canadian basins were not significantly more saline than other TJWQP monitoring years. Fraser River discharge in early June was higher than the 30-year average, but leveled off to near average flows by June 11, 2014. The freshwater discharge into the Strait of Georgia from the Fraser River generally depresses the basin salinity values (relative to Puget Sound basins).

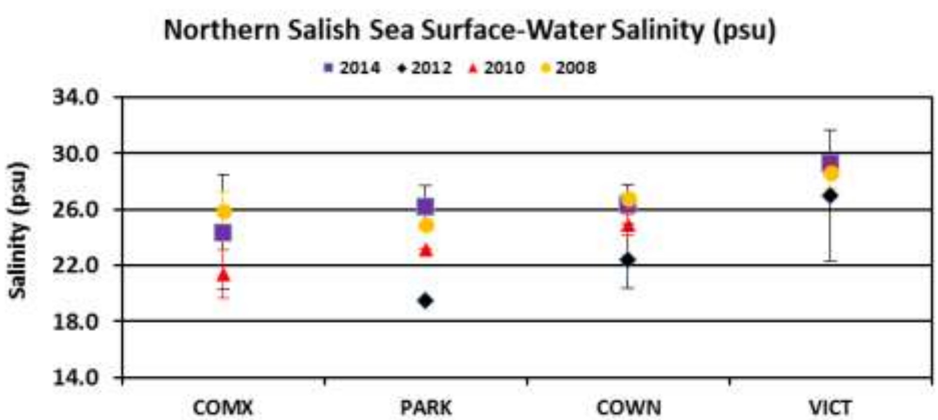

Figure 13. Surface-water salinity averages (in practical salinity units) for Northern Salish Sea basins monitored 2008 to 2014.

The median pH for the surface waters was 8.2 pH units (n=13,667). Median pH ranged from a low of 7.9 in Victoria basin to a high of 8.3 in both Cowichan and Comox basins. The pH measurements exceed 8.5 pH units in seven instances (maximum value 8.5 pH units), all of which occurred in Parksville basin. The basin pH medians decreased from north to south across the Strait of Georgia. This is consistent with the effect of coastal upwelling that was near its historic average and that drives deep, nutrient rich, oxygen poor, and acidic water intrusion into the Salish Sea.

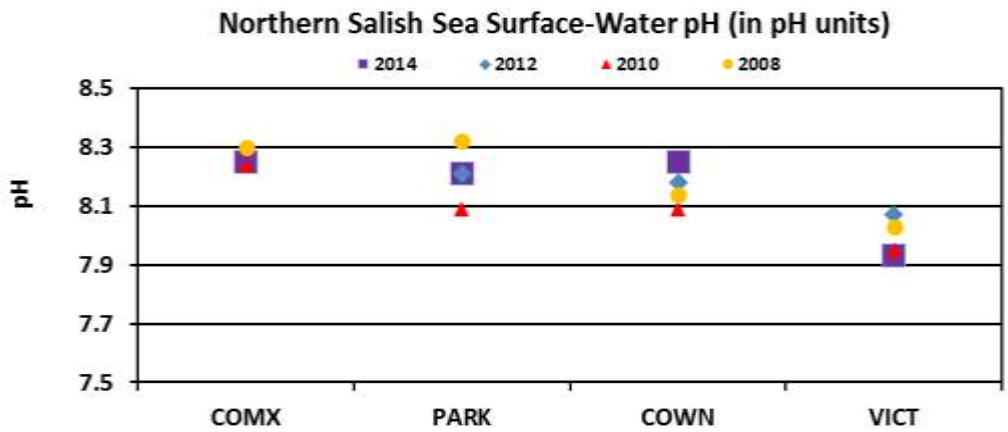

Figure 14. Surface-water median pH (in pH units) by basin in the Northern Salish Sea for monitoring years 2008 to 2014.

The average surface water turbidity was 4.5±11.7 FNU (n=13,518). Turbidity generally reflected river sources as observed across the Nanaimo River and Qualicum River plumes which ranged 20-50 FNU.

The fundamental quantitative and empirical information collected as part of the TJWQP help to characterize coastal ecosystems and establish baseline data for detecting change and finding solutions to minimize impacts. The TJWQP data collected across an extensive area of the Salish Sea and particularly shallow nearshore coastal environments help quantify landscape-scale and site-specific patterns in water quality and inform of complex estuarine gradients and the processes (drivers) that shape the Salish Sea ecosystem structure and its responses spatially and temporally. The spatial nature of the TJWQP results help to characterize areas of high variability that may be challenging to protect, restore or enhance if susceptible to additional climate and land use change relative to areas of low variability that may benefit from conservation measures to protect them as refuges for species sensitive to variability.

Along the Tribal Journey, stories were shared between the elders, youth, the Skippers, and the Pullers. For some people the Tribal Journey is a time of healing, for others it is a way to reconnect with long lost relatives, and for all it is a way to maintain tradition. With the introduction of the TJWQP, there is an added dialogue, the status of the environment. The TJWQP has created an excellent opportunity for a concerned group of people, many of whom do not have science backgrounds, to play a key role in a research effort and to reaffirm the Coast Salish People’s role as stewards of the environment.

With the success of the TJWQP, the Coast Salish People have made a significant contribution toward monitoring the waters of the Salish Sea. The outcome of the TJWQP will support the Coast Salish Nation’s effort to address increasing environmental impacts as well as documenting their annual Journeys through the Salish Sea. As the aboriginal inhabitants of the Salish Sea ecosystem, the Coast Salish People are responsible for the well-being and health of their ecosystem and communities and perhaps through the TJWQP will be increasingly compelled to share their understanding and vision for improving the health of the Salish Sea. The Coast Salish People have an important leading role in helping to manage their communities today and into the future. The TJWQP acknowledges this role and encourages all Coast Salish People to participate actively and learn more about the conditions affecting their traditional territories across the Salish Sea.

Degradation of water quality has caused economic hardship impacting fishing and shellfish activities of the Coast Salish People. Culturally and economically, these are the core resources that define Coast Salish communities. Environmental issues affecting these resources thus affect the families and relatives on both sides of the border because this project provides Coast Salish with a science tool and because the information derived from the project can be shared with the world. We now have a unique opportunity to address these shared environmental issues across political boundaries. We know that environmental issues cannot be addressed individually or resolved with only local policy and actions, but that ecosystems need to be addressed at a larger scale, especially in the Salish Sea where tidal currents mix waters across political boundaries on a daily basis. The TJWQP is building a scientific foundation to gather data and to provide information for improved and informed policy. Data and findings are disseminated through the Coast Salish Gathering, Federal agencies and are integrated into regional collaborative analyses of Salish Sea Ecosystem health (Grossman and Grossman, 2012, 2013). An open dialogue between the Coast Salish Gathering leadership and Federal representatives strengthen local efforts to provide a safe and healthy home for Coast Salish People for today and tomorrow. This is the common goal on a local and regional basis for the Coast Salish Nation and indigenous communities across the world who are experiencing hardships due to environmental degradation and considered to be the most vulnerable to climate change impacts (Hanna, 1997). The TJWQP shares lessons learned and guidance among similar efforts being implemented around the world in the Yukon and Kuskokwim Rivers Alaska, Siberia, Canada, South America, Africa, and Hawaii.

Acknowledgments

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Appendices

Appendix I: YSI 6920 V2-2 Sensor specifications including units, range, resolution, and accuracy. Units include milligrams per liter (mg/L), percent (%), Formazin Nephelometric Units (FNU)[1], millisemans per centimeter (mS/cm), parts per thousand (ppt), degrees Celsius (°C), pH standard units, millivolts (mV), and meters (m).

YSI Sensor	Units	Range	Resolution	Accuracy
ROX Optical Dissolved Oxygen	mg/L	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ± 0.1 mg/L or 1% of reading
	% Saturation	0 to 500%	0.10%	0 to 200 %: ± 1 % or 1% of air saturation
Dissolved Oxygen 6562 Rapid Pulse	mg/L	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ± 0.2 mg/L or 2% of reading
	% Saturation	0 to 500 %	0.10%	0 to 200 %: ± 2 % or 1% of air saturation
Turbidity 6136 Sensor	FNU	0 to 1,000 FNU	0.1 FNU	±2% of reading or 0.3 FNU, whichever is greater
Conductivity 6560 Sensor	mS/cm	0 to 100 mS/cm	0.001 to 0.1 mS/cm	±0.5% of reading + 0.001 mS/cm
Salinity	ppt	0 to 70 ppt	0.01 ppt	±1% of reading or 0.1 ppt, whichever is greater
Temperature 6560 Sensor	°C	-5 to +50°C	0.01°C	±0.15°C
pH 6561 Sensor	pH units	0 to 14 units	0.01 units	±0.2 units
ORP	mV	-999 to +999 mV	0.1 mV	±20 mV
Chlorophyll 6025	µg/L	~0 to 400 µg/L	~0.1	0.1 µg/L Chl
Depth - Shallow	m	0 to 9.1 m	0.001m	±0.02 m

1. The United States Geological Survey methods for reporting turbidity data collected with near-infrared turbidimeters following ISO 7027 protocols is reported as Formazin Nephelometric Units (FNU). More information can be found in the USGS National Field Manual (***http://water.usgs.gov/owq/FieldManual/Chapter6/6.8.pdf***)

Appendix II. Washington State aquatic-life criteria for (*A*) marine surface –waters temperatures, (*B*) dissolved oxygen, and (*C*) pH.

A

Aquatic Life Use	General Description
Extraordinary quality	Salmonid and other fish migration, rearing, and spawning; clam, oyster, and mussel rearing and spawning; crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing and spawning.
Excellent quality	Salmonid and other fish migration, rearing, and spawning; clam, oyster, and mussel rearing and spawning; crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing and spawning.
Good quality	Salmonid migration and rearing; other fish migration, rearing, and spawning; clam, oyster, and mussel rearing and spawning; crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing and spawning.
Fair quality	Salmonid and other fish migration.

B

Aquatic Life Temperature and Dissolved Oxygen Criteria in Marine Water WAC-173-201A-210 Table 210 (1)(*c*) and (*d*)		
Category	**Highest 1-Day Maximum, in degrees Celsius**	**Lowest 1-Day Minimum, in milligrams per liter**
Extraordinary quality	13 (55.4°F)	7
Excellent quality	16 (60.8°F)	6
Good quality	19 (66.2°F)	5
Fair quality	22 (71.6°F)	4

C

Aquatic Life pH Criteria in Marine Water WAC-173-201A-210 Table 210 (1)(*f*)	
Use Category	**pH Units**
Extraordinary quality	pH must be within the range of 7.0 to 8.5 with a human-caused variation within the above range of less than 0.2 units.
Excellent quality	pH must be within the range of 7.0 to 8.5 with a human-caused variation within the above range of less than 0.5 units.
Good quality	Same as above.
Fair quality	pH must be within the range of 6.5 to 9.0 with a human-caused variation within the above range of less than 0.5 units.

Appendix III. Asset list for the environmental conditions summary.

Parameter	Station Location	Station ID	Source
Air Temperature	Campbell River	EC-WE_1021261	Environment Canada
Air Temperature	Chemainus	EC-WE_1011500	Environment Canada
Air Temperature	Cherry Point	NOS_9449424	National Oceanic and Atmospheric Administration
Air Temperature	Comox	EC-WE_1021830	Environment Canada
Air Temperature	Friday Harbor	NOS_9449880	National Oceanic and Atmospheric Administration
Air Temperature	Howe Sound	EC-WE_10459NN	Environment Canada
Air Temperature	Nanaimo	EC-WE_1025370	Environment Canada
Air Temperature	Olympia	CLIOLM	National Weather Service
Air Temperature	Port Angeles	NOS_9444090	National Oceanic and Atmospheric Administration
Air Temperature	Port Townsend	NOS_9444900	National Oceanic and Atmospheric Administration
Air Temperature	Qualicum Beach	EC-WE_1026562	Environment Canada
Air Temperature	Quilcene	QCNW1	National Weather Service
Air Temperature	Seattle	NOS_9447130	National Oceanic and Atmospheric Administration
Air Temperature	Tacoma	NOS_9446484	National Oceanic and Atmospheric Administration
Air Temperature	Tsawwassen	EC-WE_1102425	Environment Canada
Air Temperature	Vancouver Harbour	EC-WE_1108446	Environment Canada
Air Temperature	Victoria Harbour	EC-WE_1018615	Environment Canada
River Discharge	Fraser River at Hope	08MF005	Department of Fisheries and Oceans Canada
River Discharge	Skagit River at Mt. Vernon	12200500	United States Geological Survey
Coastal Upwelling Index	La Push	48N125W	National Oceanic and Atmospheric Administration