# Marine Conditions 2008–2019 Report Series: Beach Temperature and Salinity

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King County

Department of Natural Resources and Parks
Water and Land Resources Division
Science and Technical Support Section
King Street Center, KSC-NR-5600
201 South Jackson Street, Suite 5600
Seattle, WA 98104
206-477-4800 TTY Relay: 711
www.kingcounty.gov/EnvironmentalScience

Alternate Formats Available
206-477-4800 TTY Relay: 711

# Marine Conditions 2008–2019 Report Series: Beach Temperature and Salinity

## Submitted by:

**Wafa Tafesh**
King County Water and Land Resources Division
Department of Natural Resources and Parks

Cover photo: Quartermaster Harbor taken by Stephanie Jaeger

King County
Department of
Natural Resources and Parks
**Water and Land Resources Division**

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# 1.0 INTRODUCTION

For over 50 years, King County has conducted extensive water quality monitoring to assess conditions in the Central Puget Sound Basin (King County waters). The King County Marine Monitoring Program is managed by scientists in the Water and Land Resources Division within the Department of Natural Resources. The program includes two types of monitoring at offshore and beach locations:

- **Ambient monitoring:** baseline monitoring to assess background conditions, and
- **Outfall monitoring:** monitoring to assess conditions near King County's wastewater treatment plant (TP), combined sewer overflow (CSO), and CSO wet weather treatment station (TS) marine outfalls.

The goals of the Marine Monitoring Program are to characterize water quality and food web (phytoplankton and zooplankton) conditions in King County receiving waters, provide information for management decisions, and evaluate the status and trends of marine waters within King County. These data provide insight into both short and long-term variations and form a baseline from which water quality conditions can be assessed on multiple temporal and spatial scales. Please see *Marine Conditions Report Series 2008–2019: Marine Monitoring Program Overview* (King County, 2022) for a more detailed description of the background and purpose of the Marine Monitoring Program.

The monitoring data are used to:

- Assess potential water and sediment quality impacts following TP upset discharges by comparing against historical data
- Assist in special studies such as siting new TP outfalls (King County, 2001) and evaluating marine conditions in specific areas with suspected water quality issues (King County, 2014)
- Assess the influence of large-scale and regional climate patterns on riverine and freshwater inputs and water quality
- Evaluate water and sediment quality data against applicable Washington State Water and Sediment Quality Standards
- Evaluate how food web lower trophic levels respond to climate variations and water quality conditions spatially and temporally
- Data are used to support science-based management decisions
- Support regional efforts and collaborations such as the Puget Sound Ecosystem Monitoring Program (PSEMP) Marine Waters Workgroup marine conditions monthly update meetings, Puget Sound Marine Waters Annual Report (PSEMP Marine Waters Workgroup, 2019), Washington Department of Ecology's (Ecology) Nutrient Reduction Effort, and regional modeling efforts.

This report presents a summary of results for the beach temperature and salinity monitoring component of the program collected between 2008 and 2019, including long-term trend analysis. Changes in water temperature is an important factor in an estuary. As water temperature rises, biological and chemical activity generally increases and the capacity of water to hold dissolved oxygen decreases. Water temperatures is dependent on various factors including, season, amount of tidal mixing, wind, storms, amount of freshwater input, and stratification. Waters usually experience changes in salinity as freshwater input increases or decrease. Salinity also fluctuates with tides, precipitation, and water column mixing from winds.

Multiple parameters were monitored concurrently at each sampling location for both offshore and beach waters. A summary of the types of data collected at each station is provided in *Marine Conditions Report Series 2008–2019: Marine Monitoring Program Overview* (King County, 2022). Results for other Marine Monitoring Program components between 2008–2019 (except pH) are provided in separate reports. These data summary reports are provided in separate reports with hyperlinks (click on titles to access reports) below and include the following topics:

- Marine Monitoring Program overview
- Nutrients in offshore waters
- Nutrients in beach waters
- Dissolved oxygen in offshore waters
- Temperature, salinity, and density in offshore waters
- Water clarity in offshore waters
- Fecal indicator bacteria in beach and offshore waters
- Chlorophyll in offshore waters
- Phytoplankton
- Zooplankton
- Chemical and physical parameters and benthic infauna in beach (intertidal) and offshore (subtidal) sediments
- Chemical parameters in clam tissues.

# 2.0 METHODS

The following sections provide an overview of the sampling and analysis methods used to collect and analyze temperature and salinity data. A more detailed description of the station locations and methods can be found in the *Marine Conditions Report Series 2008-2019: Marine Monitoring Program Overview* (King County, 2022) and the Sampling and Analysis Plan (SAP) (King County, 2020; https://your.kingcounty.gov/dnrp/library/2020/kcr3135/kcr3135.pdf ).

## 2.1 Sampling Locations

Temperature and salinity data were collected monthly from 2008 – 2019 from 28 ambient and outfall locations; however, 8 ambient stations were discontinued in 2011 due to budget reductions (Figure 1 and Table 1). Sampling locations are located within the Puget Sound Central Basin, extending south to Dumas Bay and north to Edwards Point. Elliott Bay, a large urban embayment, which includes the City of Seattle waterfront, is located within the monitoring area. The eastern shoreline of Vashon Island and Quartermaster Harbor, an embayment between Vashon and Maury Islands, are also included in the sampling area.

Data sets for sites in the northern portion of the monitoring area represent some of King County's longest monitoring records, starting in the early 1980's. Sites in the central portion of the monitoring area and Elliott Bay were introduced in the late 1980s and southern stations were introduced in the early 1990s. Only one Duwamish River beach station was included in the monitoring program, Duwamish Park (LTTL02), where data were collected from 2007 to 2010. Water quality of the Duwamish River is better assessed at the 4 active offshore monitoring locations (HNFD01, LTKE03, LTUM03, and LTXQ01).

Ambient beach station locations are located along the shoreline away from either a nearshore or offshore wastewater treatment plant outfall to assess background conditions. However, stormwater outfalls are located about every 50 ft along the shoreline within the City of Seattle limits, therefore beach water quality may be affected by stormwater input. Locations for ambient sites were chosen based on continuation of a long-term dataset (e.g., multiple stations sampled since 1970), high-use public beach, or for spatial coverage to assess beach water quality away from direct wastewater discharges. Beach stations were most recently added to the ambient program in 2007 to increase spatial coverage within King County waters.

Outfall beach stations are located in the vicinity of either a nearshore or offshore treatment plant outfall. Although most treatment plant outfalls are located substantially offshore, sampling locations were placed along the nearshore in order to evaluate water quality at beach sites in the vicinity of effluent discharges. Station JSVW04 is located east of the Brightwater Treatment Plant outfall, which is over 1,600m (1 mile) offshore. Two stations, KSSN04 and KSSN05, are located on the north and south side of West Point, respectively. Station LSKR01 is located north of the location where the Alki CSO TP outfall exits the shoreline. Station MSJL01 is located on the beach directly west of the Vashon TP

outfall and KSHZ03 is located directly east of the Carkeek CSO TP outfall. A beach station is not located near the South TP outfall as the outfall is over 10,000 feet offshore. Station MTLD03 was initially sampled as an ambient location; however, it was subsequently determined that the Miller Creek Wastewater Treatment Plant outfall was offshore of this location.

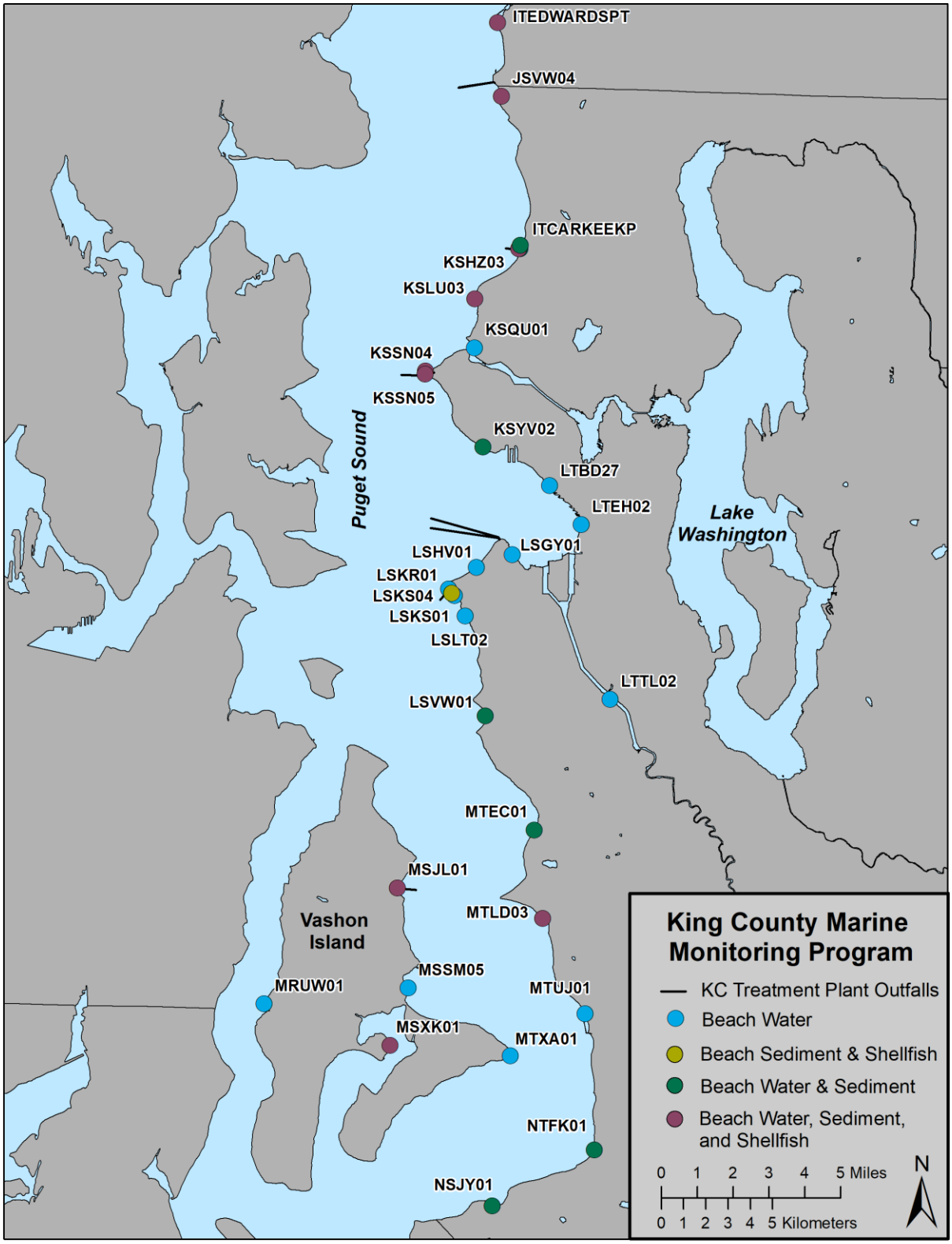


**Figure 1. Map of King County marine monitoring locations, including beach temperature and salinity stations (blue, pink, and green dots).**

### 2.1.1 Beach Monitoring Stations

Each beach station (Table 1) is categorized as north, middle, south, or Duwamish River for the purpose of this report and supporting figures. Stations are additionally categorized by the following:

- **Central Basin**: all stations except Duwamish River sites
- **Mainstem**: all stations except Elliott Bay, Duwamish River and Quartermaster Harbor sites.

Period of record varies between stations (Table 1) since monitoring was initiated at different times and some stations were discontinued in 2010 Stations were chosen to represent ambient conditions and conditions directly influenced by wastewater and wet weather treatment outfalls.

**Table 1. Beach water monitoring station regions and sampling period listed north to south.**

| Locator Name | Location | Region | Sampling Period |
|---|---|---|---|
| ITEDWARDSPT | Edwards Point | North – Central Basin | 2000 – 2010 |
| JSVW04 | Point Wells, southern end | North – Central Basin | 1984 – present |
| ITCARKEEKP | Carkeek Park, outside influence of Piper's Creek outflow | North – Central Basin | 2000 – present |
| *KSHZ03 | Carkeek Wet Weather TS – near Piper's Creek outflow | North – Central Basin | 1984 – present |
| KSLU03 | Golden Gardens Park | North – Central Basin | 1984 – present |
| KSQU01 | Lake Washington Ship Canal in Shilshole Bay outflow | North – Central Basin | 1984 – 2010 |
| *KSSN04 | West Point TP – north side of Discovery Park | North – Central Basin | 1984 – present |
| *KSSN05 | West Point TP – south side of Discovery Park | North – Central Basin | 1984 – present |
| *KSYV02 | Magnolia CSO – Smith Cove | Middle – Central Basin | 1985 – present |
| LTBD27 | Seattle Art Museum sculpture park pocket beach | Middle – Elliott Bay | 2007 – present |
| LTEH02 | Elliott Bay at Pier 48 | Middle – Elliott Bay | 1984 – 2010 |
| LSGY01 | Seacrest Park in western Elliott Bay | Middle – Elliott Bay | 1997 – present |
| LSHV01 | Alki Beach | Middle– Central Basin | 1985 – present |
| *LSKR01 | Alki Wet Weather TS – north side of Alki | Middle – Central Basin | 1985 – present |
| *LSKS01 | Alki Wet Weather TS – south side of Alki | Middle– Central Basin | 1984 – present |
| LSLT02 | Me-Kwa-Mooks Park in West Seattle | Middle – Central Basin | 2007 – 2010 |

| Locator Name | Location | Region | Sampling Period |
|---|---|---|---|
| LTTL02 | Duwamish River Park in Duwamish River | Duwamish River | 2007 – 2010 |
| LSVW01 | Fauntleroy Cove | Middle – Central Basin | 1984 – present |
| MTEC01 | Seahurst Park | South – Central Basin | 1989 – 2010 |
| *MSJL01 | Vashon TP – near Gorsuch Creek on Vashon Island | South – Central Basin | 2002 – present |
| *MTLD03 | Miller Creek TP – Normandy Park | South – Central Basin | 1998 – present |
| MSSM05 | Tramp Harbor on Vashon Island | South – Central Basin | 1990 – present |
| MRUW01 | Lisabuela Park on Vashon Island | South – Central Basin | 2007 – 2010 |
| MTUJ01 | Des Moines Creek Park, north of public pier | South – Central Basin | 2007 – present |
| MSXK01 | Burton Acres Park | South – Central Basin – Quartermaster Harbor | 2007 – present |
| MTXA01 | Point Robinson Park on Vashon Island | South – Central Basin | 2007 – 2010 |
| NTFK01 | Redondo Beach | South – Central Basin | 2007 – present |
| NSJY01 | Dumas Bay Park | South – Central Basin | 2007 – present |

*Denotes outfall monitoring stations

## 2.2 Sampling Methods

Sample collection at beach sites occur within a 25m transect parallel to the water's edge at each station's prescribed position. Samples are collected monthly at a single depth just below the water surface. Actual sample depth may vary depending upon wave conditions. The sample collector will wade into the water to a depth of approximately one meter to collect the sample. Bottle samples for salinity measurement are collected by inverting the sample bottle just above the water surface, then sinking the bottle down to approximately three to six inches below the surface. No specific tidal height or tidal stage are targeted to collect samples from a variety of conditions. Water temperature is measured and recorded in the field using a YSI EXO handheld multiprobe. Temperatures are measured at approximately the same depth as the bottle samples.

## 2.3 Laboratory Procedures

Salinity analysis is determined according to SM 2520 B (APHA 2017) and KCEL SOP #3016 (KCEL, 2018). The MDL and RDL for this analysis are 2 and 3 PSU (Practical Salinity Unit), respectively. Salinity is determined by measuring the conductance of an electrical current through the sample kept at constant temperature of 25˚C (set at 2˚C above mean ambient room temperature) and comparing the measurement to the conductivity of a certified and calibrated Standard Seawater. The relative measurement can be displayed as a conductivity ratio or practical salinity. The control and measurement conversion is performed by a

microprocessor in the instrument to calculate salinity corrected for the bath temperature to give the equivalent salinity relative to Standard Seawater at 15˚C.

All salinity analyses were performed using appropriate QC procedures. QC measures include calibration QC for instrument standardization, check standards and laboratory duplicates.

The YSI EXO multiprobes are used for the measurement of in-situ temperature at beach sampling sites. Data can be collected electronically and downloaded to LIMS or stored in the Data Logger and retrieved later for manual data entry to LIMS. Data are reviewed to ensure compliance to QC limits and that downloading was accurately performed. Records are kept on calibration and system maintenance.

Temperature probe calibration is factory-set and requires no daily calibration. Temperature probe calibration is confirmed at least annually with a side-by side comparison of the probe response at two separate temperatures to a NIST-traceable thermometer. The probes and NIST-traceable thermometer are placed in a container of water that was allowed to equilibrate for 24 hours at room temperature. Once the probe response has stabilized (no longer than 10 minutes), the probe and thermometer readings are recorded in the calibration logbook. The probes and NIST-traceable thermometer are then placed in a beaker of reverse osmosis water that has been stored overnight in the walk-in cooler at 4˚C. Once the probe response has stabilized (but no longer than 10 minutes), the probe and thermometer readings are recorded in the calibration logbook. For both temperature points, the probe response must be within ± 0.2˚C of the measured response of the NIST-traceable thermometer. If not, the meter should be returned to the manufacturer for recalibration.

## 2.4 Data Analysis

Data for three historic sampling sites where monitoring was discontinued prior to 2008 due to budget constraints are not included in this report (Fey Bainbridge Park [KRJY01], 2001; Lincoln Park [LSTU01], 2004; Seattle Waterfront – Grain Terminal [LTAB01], 2005). Also excluded are salinity data collected prior to 1998 due to a change in methods.

Data validation was conducted on all sample results included in this report prior to data analysis. Laboratory QC checks for salinity were reviewed, including data qualifiers. Data that were assigned an “E” (estimated value) qualifier were assessed for usability. Data that were deemed suspect or unusable were removed prior to data analysis.

To compare seasonal patterns data were grouped as the following:

- Winter – January, February, and March
- Spring – April, May, and June
- Summer – July, August, and September
- Fall – October, November, and December.

Temperature and salinity data (2007-2019) were averaged by month and site to assess long term trends. Temperature data collected in 2007 (monitoring start year of the last added long-term monitoring stations added to the program) were added to the data set used for long-term trend analysis. Seasonal Mann-Kendall analyses were then performed using the censeaken function in the R package NADA2 package for each station (Julian and Helsel, 2022). Temperature data collected in 2007 were added to the data set used for long-term trends analysis.

# 3.0 RESULTS

## 3.1 Seasonal and Spatial Patterns

### 3.1.1 Temperature

Beach water temperature results (2008-2019) were used to evaluate seasonal and spatial patterns. Temperatures were warmer in summer and more variable, around 10 °C difference from the max and min among all stations during spring months (Figure 2). In contrast, winter temperatures were cooler and less variable, with about a 5 °C difference from the max and min among stations. Surface waters are warmed by solar radiation and cooled by local air temperatures and freshwater inputs, including precipitation events and riverine flow. Site specific conditions influence water temperatures.

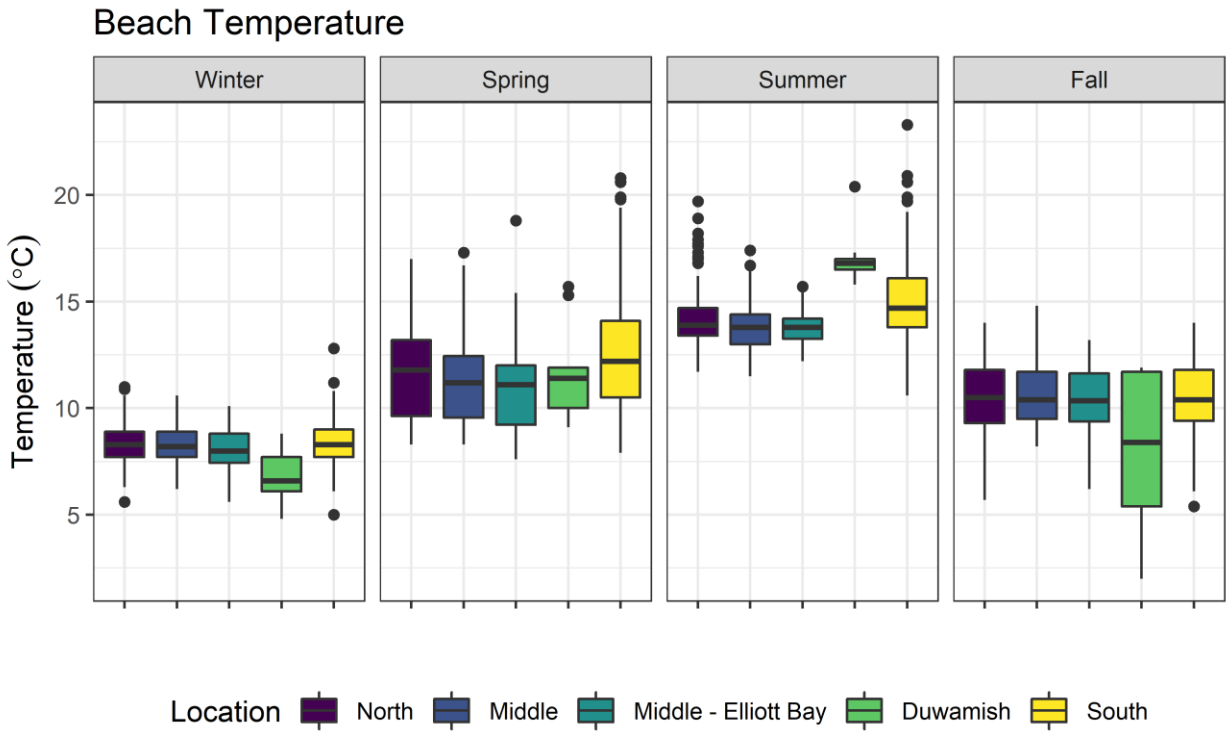


**Figure 2. Boxplots of beach temperature (2008-2019) by location. Heavy black line represents median; outliers are shown as black dots.**

During the winter months, the coldest mean temperatures were observed at the station with the greatest volume of freshwater input, Duwamish Park (LTTL02), just south of ƛaɬtałucid Park and Shoreline Habitat in the Duwamish River subestuary. The highest mean summer temperatures were also measured at this station. Note that data for this site were only collected for 4 years (2007 - 2010).

Minimum temperatures at the northern (Point Wells, JSVW04) and southernmost beach stations (Dumas Bay, NSJY01) were similar during winter months. Dumas Bay experienced higher maximum temperatures than Point Wells during the summer (Figure 3). The largest difference in maximum summer temperatures was seen in August of 2018 when Dumas Bay was seven degrees warmer than Point Wells. Temperatures in southern bay stations (Dumas Bay and Poverty Bay) are warmer due the depth of surrounding waters and warmer waters and residence times in the South Sound. In contrast, northern stations are deeper, and summer upwelling transports deep cooler water to the surface (King County, 2022). Upwelling and the absence of major river inflow adjacent to the southern stations results in less stratified waters compared to more northern stations (Moore et al., 2008).

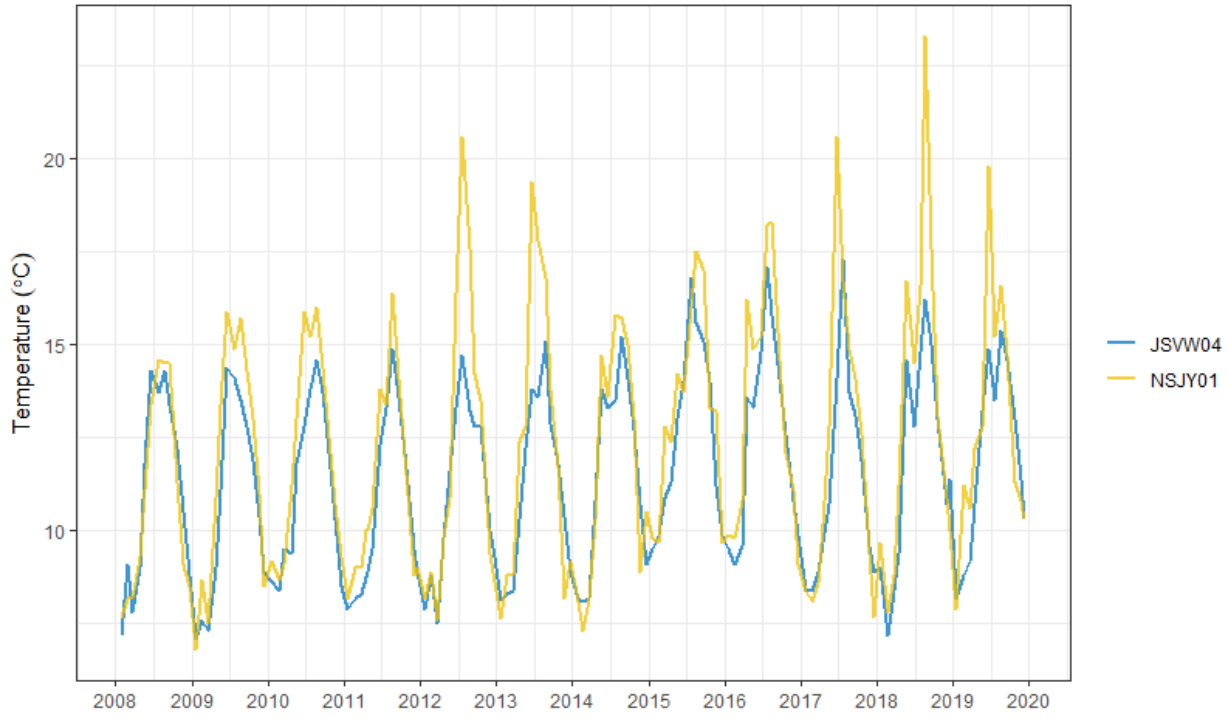


**Figure 3. Time series temperature (˚C) data (2008-2019) at most northern (Point Wells - JSVW04) and southern beach station (Dumas Bay - NSJY01).**

### 3.1.2 Salinity

Salinity results (2008-2019) were used to assess seasonal and spatial patterns in beach water salinity. Salinity was variable across all stations and months. Mean annual salinity concentrations ranged from 25–30 Practical Salinity Scale (PSS) at all stations during all seasons except at Duwamish Park (LTTL02), the only site with a major freshwater input (Figure 4).

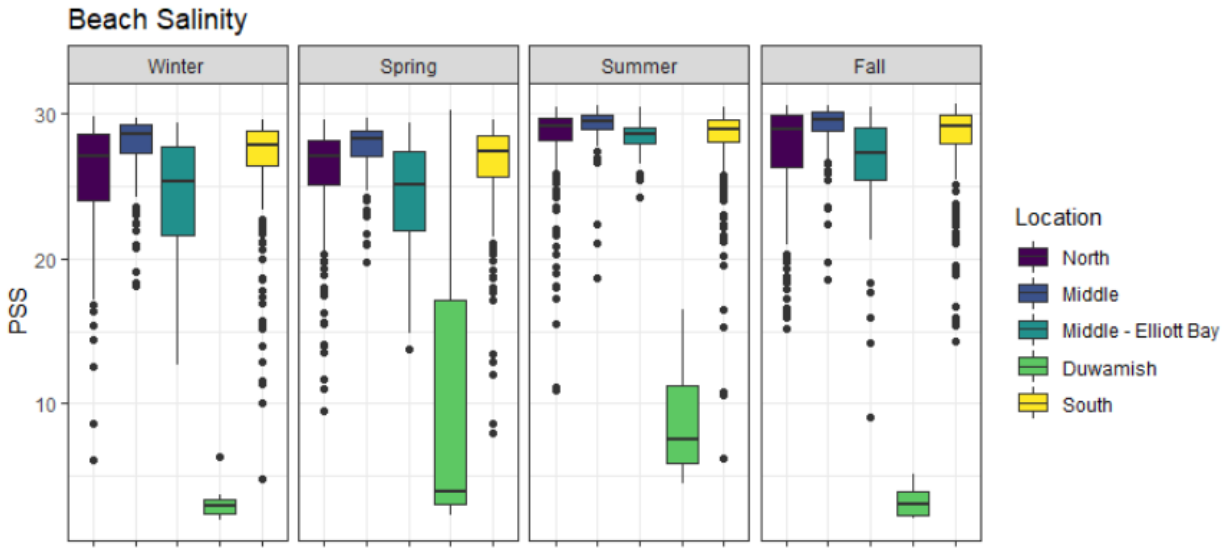


**Figure 4. Boxplots of beach salinity (PSS) (2008-2019) by general location and season. Heavy black line represents median; outliers shown as black dots.**

Salinity at the northern most station (Point Wells - JSVW04) is generally higher and less variable than salinity at the southernmost Dumas Bay station (NSJY01) (Figure 5). Point Wells has less freshwater influence so changes in salinity are typically due to upwelling events. Dumas Bay, a shallow embayment in the Central Basin, experiences salinity fluctuations due the influence of freshwater inputs from Joes Creek and the Puyallup River (see Section 3.2 in King County, 2022).

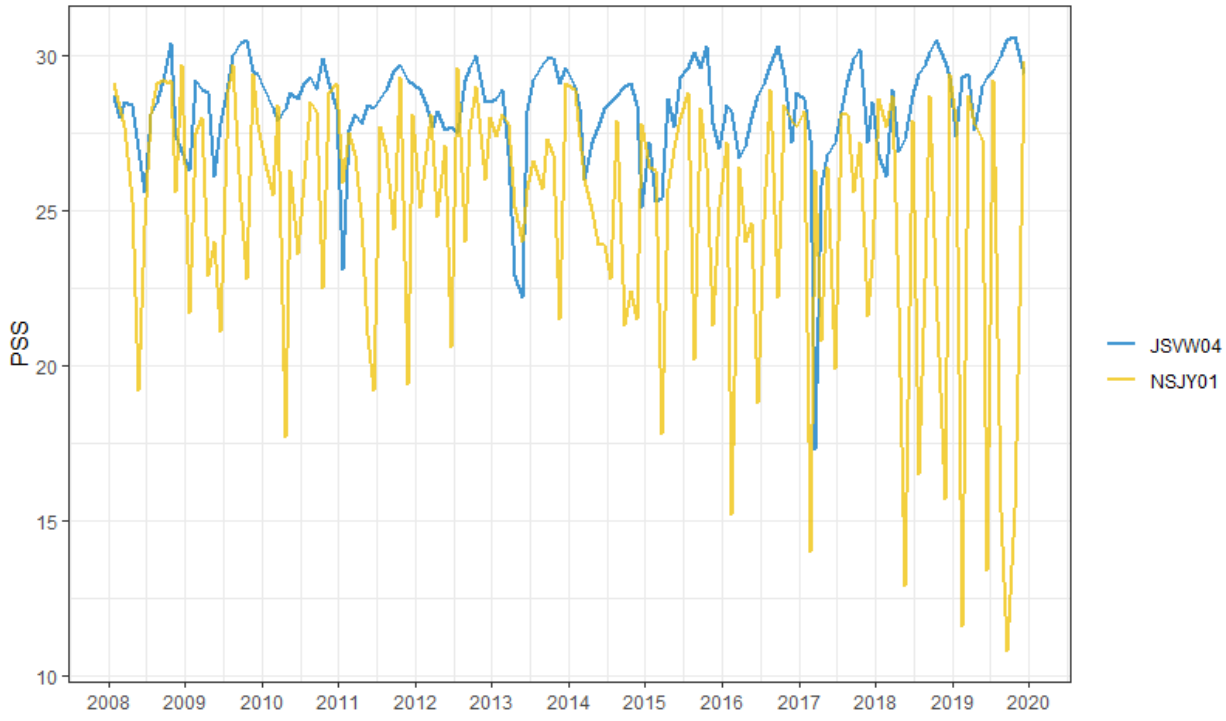


**Figure 5. Time series salinity data (PSS) (2008-2019) at most northern (Point Wells - JSVW04) and southern (Dumas Bay - NSJ01) beach stations.**

# 3.2 Interannual Variability

## 3.2.1 Temperature

Temperatures in marine beach waters (2008-2019) are generally consistent between years and station (Figure 6). Maximum temperatures ranged from 13.8 ˚C at Point Roberts Park (MTXA01) to 23.3 ˚C at Dumas Bay (NSJY01). Minimum temperatures during this period ranged from 2 ˚C at Duwamish Park (LTTL02) in December to 7.4 ˚C at Fauntleroy Cove Beach (LSVW01) in January (Table 2). Most minimum (monthly) temperatures were observed earlier in the reporting period, between 2008 and 2011 (Figure 7), typically during La Niña events (2008-2009, and 2010-2014). Conversely, most maximum (monthly) temperatures were measured later in the reporting period (2015 and 2016) during the marine heat wave (Figure 8). This reflects warming temperatures through the reporting period (see 3.3.1).

Maximum temperatures were measured at nine stations during marine heat wave years (2015 or 2016) (Table 2). Most maximum temperatures were observed in 2009 and 2016, when up to seven sites experienced its highest measured temperature during the reporting period. Most maximum (monthly) temperatures by site were measured in 2010 and between 2015 - 2019 (Table 2).

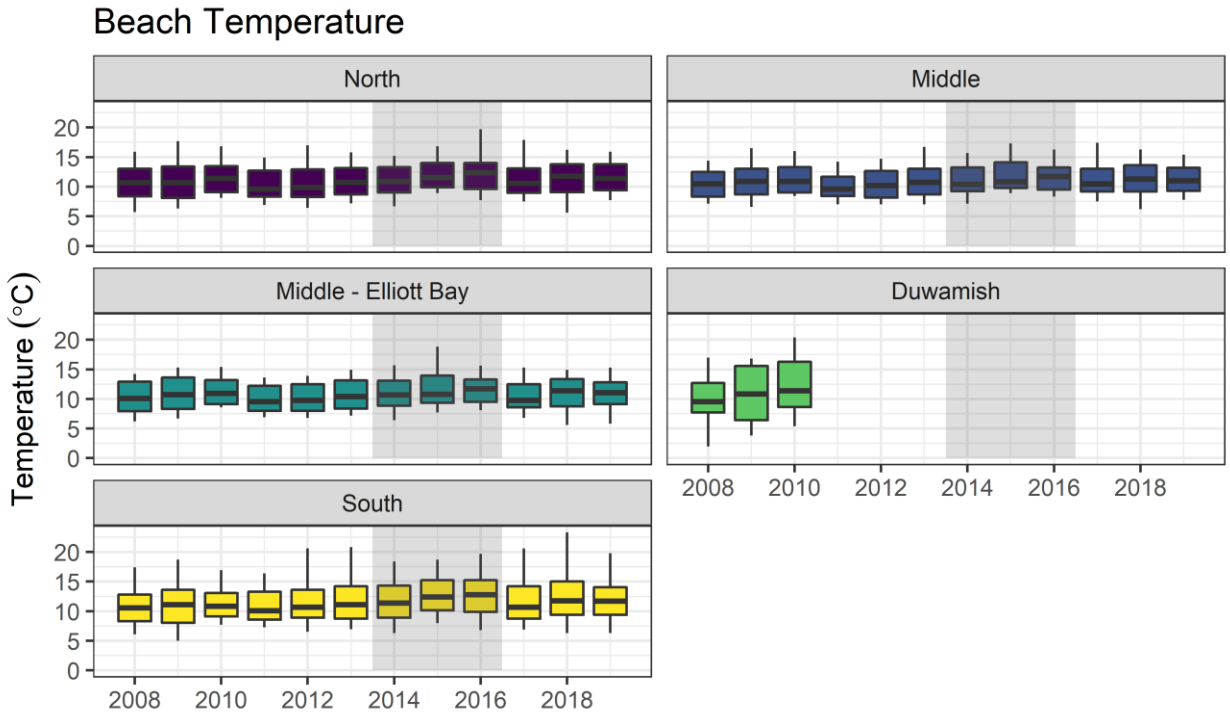


**Figure 6. Boxplots of temperature (˚C) (2008-2019) in beach waters by general location. Median represented by heavy horizontal black line; outliers shown as black dots. Gray shading represents marine heat wave period.**

**Table 2. Maximum and minimum temperatures (2008-2019) in beach waters by location; marine heat wave years (2014-2016) highlighted in gray.**

| Locator | Region | Max. temperature (°C) | Year of max. temperature occurrence | Min. temperature (°C) | Year of min. temperature occurrence |
|---|---|---|---|---|---|
| ITEDWARDSPT | North | 15.1 | 2008 | 6.6 | 2009 |
| JSVW04 | North | 17.3 | 2017 | 7.1 | 2009 |
| ITCARKEEKP | North | 18.9 | 2016 | 6.3 | 2009 |
| *KSHZ03 | North | 19.7 | 2016 | 6.5 | 2009 |
| KSLU03 | North | 16.1 | 2016 | 6.8 | 2014 |
| KSQU01 | North | 17.7 | 2009 | 7.1 | 2008 |
| *KSSN04 | North | 15.6 | 2009 | 7 | 2011 |
| *KSSN05 | North | 17.9 | 2017 | 5.6 | 2018 |
| *KSYV02 | Middle | 17.3 | 2015 | 6.2 | 2018 |
| LTBD27 | Middle | 18.8 | 2015 | 5.6 | 2018 |
| LTEH02 | Middle | 15.4 | 2010 | 6.7 | 2009 |
| LSGY01 | Middle | 15.6 | 2016 | 6.2 | 2008 |
| LSHV01 | Middle | 17.4 | 2017 | 6.6 | 2009 |
| *LSKR01 | Middle | 16.7 | 2013 | 6.9 | 2018 |
| *LSKS01 | Middle | 17.4 | 2017 | 7.1 | 2008 |
| LSLT02 | Middle | 14.1 | 2009 | 7.2 | 2008 |
| LTTL02 | Duwamish River | 20.4 | 2010 | 2 | 2008 |
| LSVW01 | Middle | 16.5 | 2009 | 7.4 | 2008 |
| MTEC01 | South | 15.7 | 2009 | 7.3 | 2009 |
| *MSJL01 | South | 18.7 | 2015 | 7.2 | 2009 |
| *MTLD03 | South | 19.9 | 2013 | 6.3 | 2014 |
| MSSM05 | South | 16.7 | 2018 | 7 | 2009 |
| MRUW01 | South | 14.5 | 2009 | 7.3 | 2009 |
| MTUJ01 | South | 20.9 | 2018 | 6.9 | 2008 |
| MSXK01 | South – Quartermaster Harbor | 19.7 | 2016 | 5 | 2009 |
| MTXA01 | South | 13.8 | 2009 | 6.8 | 2009 |
| NTFK01 | South | 17.4 | 2016 | 6.5 | 2009 |
| NSJY01 | South | 23.3 | 2018 | 6.8 | 2009 |

*Denotes outfall monitoring stations.

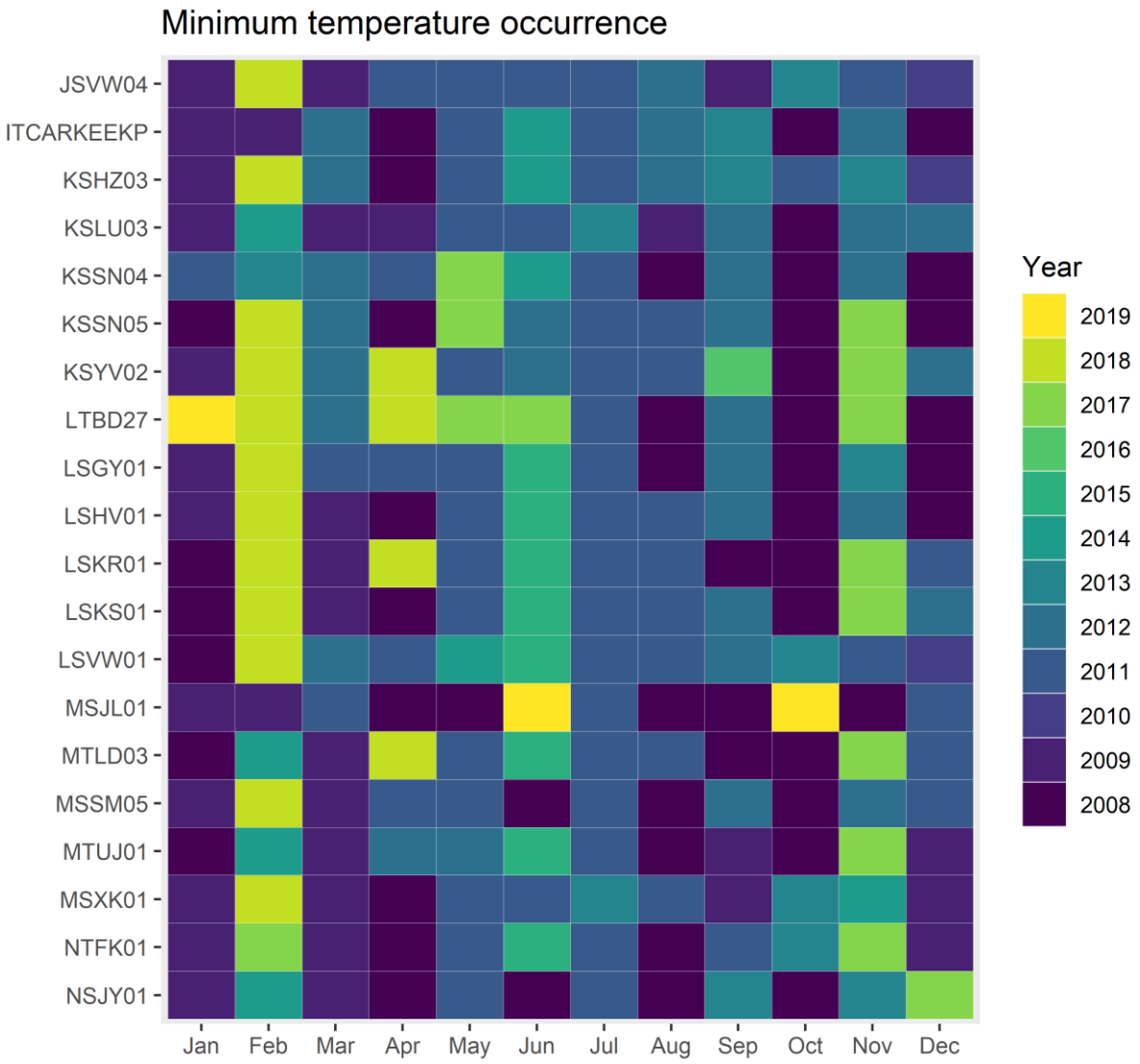


**Figure 7. Year of minimum temperature occurrence by month and site; listed north to south.**

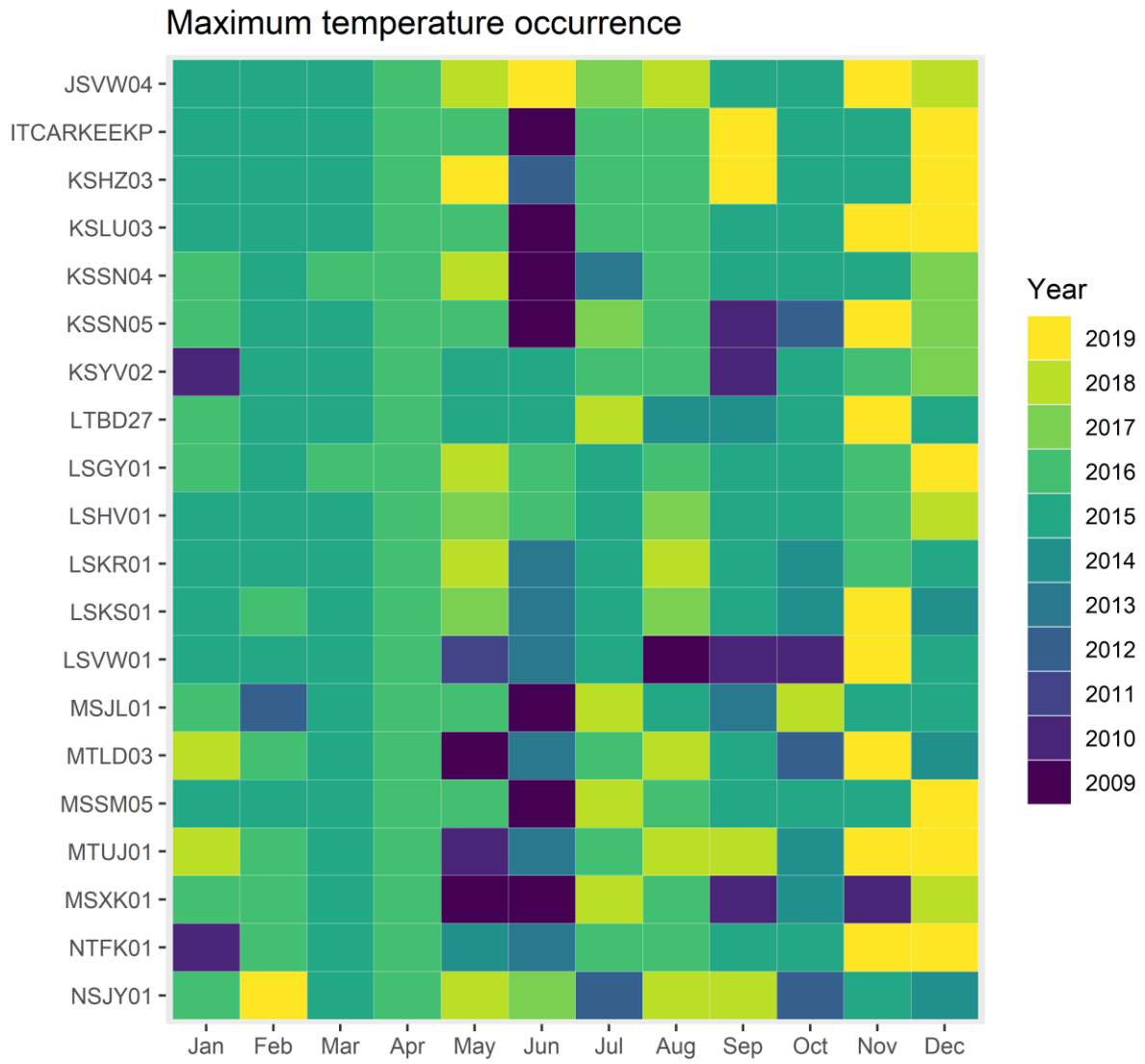


**Figure 8. Year of maximum temperature occurrence by month and site listed north to south.**

## 3.2.2 Salinity

Salinity concentrations in beach waters (2008-2019) were generally consistent between years (Figure 9). Maximum salinity concentrations ranged from 29.8 PSS at Dumas Bay (NSJY01) to 30.7 PSS at Point Roberts Park (MTXA01). Most maximum salinity levels were measured in 2009 and 2019 when up to eleven sites experienced its highest measured salinity levels during the reporting period (Table 3). Maximum monthly average temperatures at each station over the reporting period were most frequently observed during 2019 and 2015 (marine heat wave year) (Figure 10).

Minimum salinity concentrations ranged from 2 PSS at Duwamish Park (LTTL02) to 27.3 PSS at Point Roberts Park (MTXA01) (Table 3). Minimum (monthly) salinity concentrations by site varied across years, with most occurrences in 2017 (Figure 11Year of minimum

salinity concentration (PSS) occurrence (2008-2019) by month and site; presented north to south.).

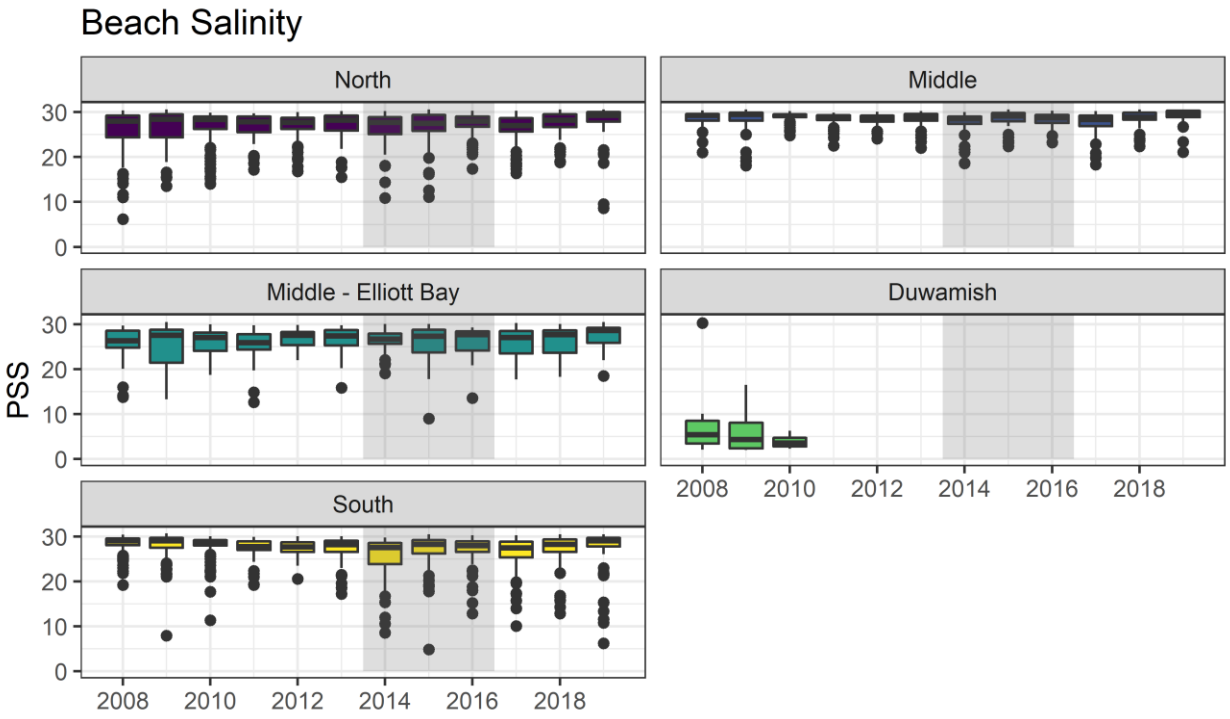


**Figure 9. Boxplot of beach salinity concentrations (PSS) (2008-2019) by general location and year. Black heavy line represents median; outliers shown as black dots.**

**Table 3. Maximum and minimum salinity (2008-2019) in beach waters by location. Marine heat wave years (2014-2016) highlighted in gray. *Denotes outfall monitoring stations.**

| Locator | Region | Max. salinity (PSS) | Year of max. salinity occurrence | Min salinity (PSS) | Year of min. salinity occurrence |
|---|---|---|---|---|---|
| ITEDWARDSPT | North | 30.6 | 2009 | 24.4 | 2009 |
| JSVW04 | North | 30.6 | 2019 | 17.3 | 2017 |
| ITCARKEEKP | North | 30.5 | 2018 | 17.9 | 2017 |
| *KSHZ03 | North | 30.3 | 2017 | 6.17 | 2008 |
| KSLU03 | North | 30.6 | 2018 | 14.4 | 2014 |
| KSQU01 | North | 30.4 | 2008 | 11.7 | 2008 |
| *KSSN04 | North | 30.6 | 2015 | 18.6 | 2011 |
| *KSSN05 | North | 30.6 | 2019 | 18.7 | 2017 |
| *KSYV02 | Middle | 30.1 | 2018 | 18.1 | 2009 |
| LTBD27 | Middle | 30.3 | 2019 | 12.7 | 2011 |
| LTEH02 | Middle | 29.9 | 2009 | 13.3 | 2009 |
| LSGY01 | Middle | 30.5 | 2019 | 9.02 | 2015 |
| LSHV01 | Middle | 30.6 | 2019 | 19.8 | 2009 |
| *LSKR01 | Middle | 30.6 | 2019 | 20.9 | 2017 |
| *LSKS01 | Middle | 30.6 | 2019 | 18.6 | 2014 |
| LSLT02 | Middle | 30.6 | 2009 | 27.3 | 2008 |
| LTTL02 | Duwamish River | 30.3 | 2008 | 2 | 2009 |
| LSVW01 | Middle | 30.5 | 2019 | 24.2 | 2017 |
| MTEC01 | South | 30.4 | 2009 | 21.5 | 2009 |
| *MSJL01 | South | 30.5 | 2009 | 22.3 | 2010 |
| *MTLD03 | South | 30.5 | 2019 | 17.2 | 2017 |
| MSSM05 | South | 30.6 | 2009 | 25.3 | 2017 |
| MRUW01 | South | 30.6 | 2009 | 24.8 | 2008 |
| MTUJ01 | South | 30.3 | 2008 | 4.86 | 2015 |
| MSXK01 | South – Quartermaster Harbor | 30.4 | 2018 | 17.4 | 2017 |
| MTXA01 | South | 30.7 | 2009 | 27.3 | 2009 |
| NTFK01 | South | 30.3 | 2019 | 10.6 | 2014 |
| NSJY01 | South | 29.8 | 2019 | 10.8 | 2019 |

*Denotes outfall monitoring stations.

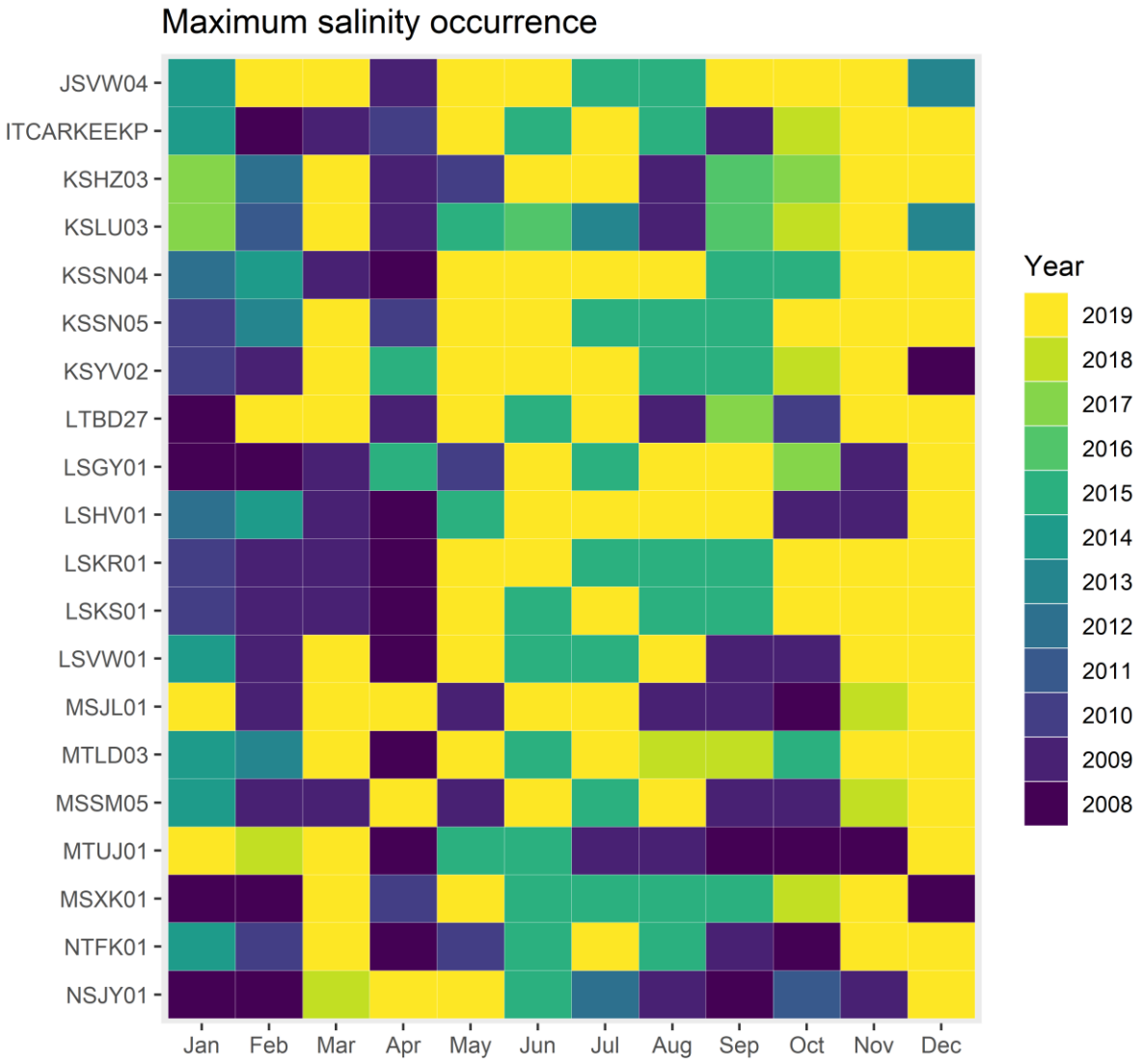


**Figure 10. Year of maximum salinity concentration (PSS) occurrence (2008-2019) by month and site; presented north to south.**

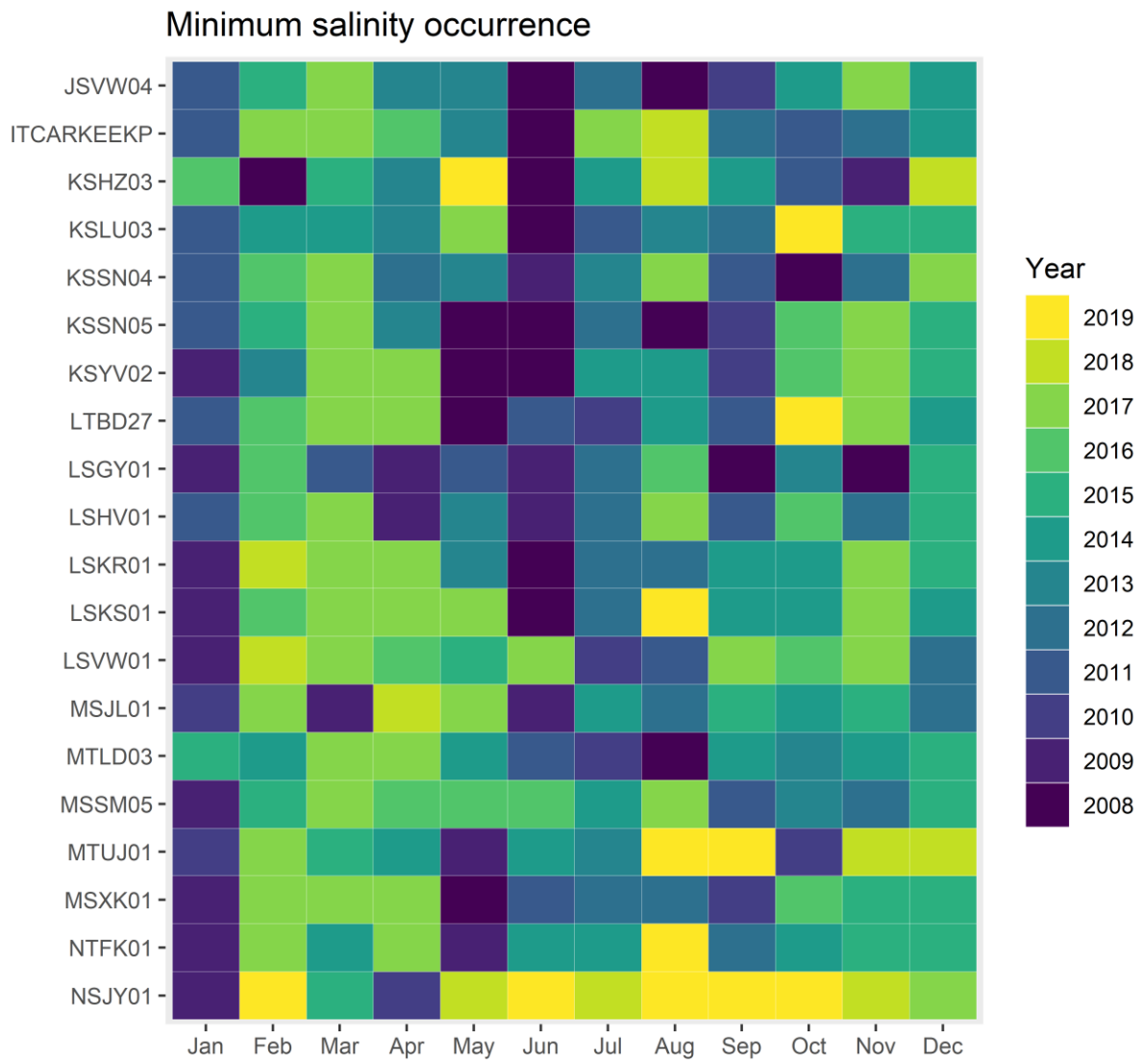


**Figure 11. Year of minimum salinity concentration (PSS) occurrence (2008-2019) by month and site; presented north to south.**

# 3.3 Long-Term Trends

## 3.3.1 Temperature

Results of the Central Basin trend analyses indicate an increase in temperature at beach stations, with an average trend slope of 0.23 °C/decade (Figure 12). When data were evaluated monthly, significant positive trends ($p < .05$) were seen for July - September and December and January, suggesting warmer summer and winter waters over time. Overall, most stations experienced increased warming with significant positive trends during one or more months at all stations except Magnolia CSO (KSYV02), Burton Acres Park, in Quartermaster Harbor (MSXK01), and Dumas Bay, the southernmost beach station (NSJY01). No significant temperature trends were seen for February and March.

The most significant positive trend (1.1 °C/decade; $p < .001$) was seen at Tramp Harbor (MSSM05) in December.

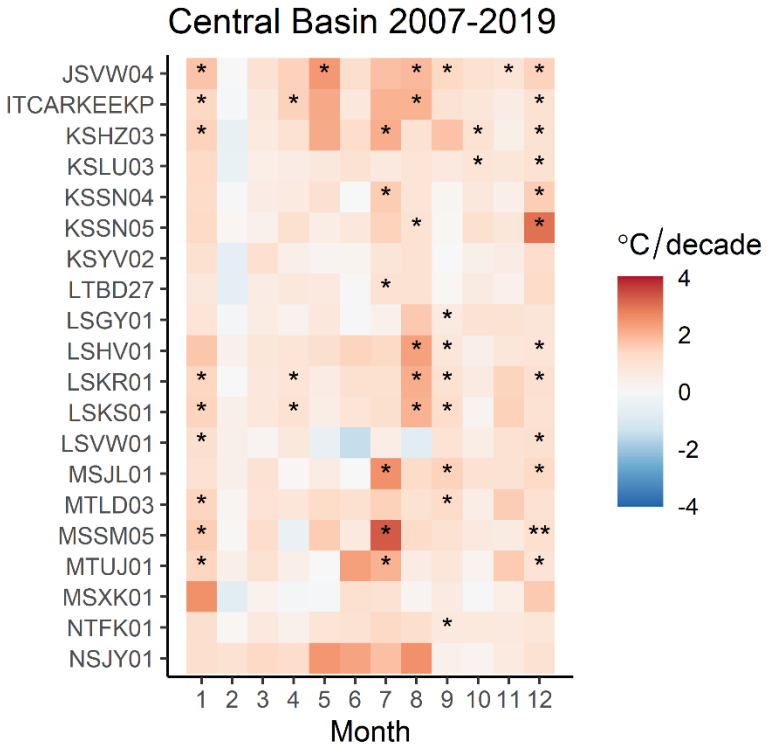


**Figure 12. Results of Seasonal Mann-Kendall trend analysis for temperature by station; all data (2007-2019) combined. Box color represents slope of trend. Symbols within boxes indicate significance at $p < .05$ (*) or $p < .001$ (**).**

Increasing the data range from 2007-2019 to 1998-2019 with fewer stations results in fewer significant trends and a shift from an average increase in temperature to an average decrease in temperatures with an average trend slope of -0.1 °C/decade (Figure 13). Trend results for the longer period of data indicated that Normandy Park (MTLD03) experienced a highly significant increasing trend ($p < .001$) in September (0.13 °C/decade) and significant trends ($p < .05$) in October (0.06 °C/decade) and November (0.14 °C/decade). Other significant trends were seen at Point Wells (JSVW04) in May (0.12 °C/decade) and October (0.07 °C/decade) and at Carkeek Park – Piper's Creek Outflow (KSHZ03) and Golden Gardens Park (KSLU03) in October (0.036 °C/decade and 0.042 °C/decade, respectively).

The only significant decreasing temperature trend (slope of -1.1 °C/decade). was seen at Fauntleroy Cove Beach (LSVW01) in August. It is likely that marine heat wave conditions in 2015-2016 and 2019 contributed to the higher slope for trends analyzed during the shorter period of 2007-2019.

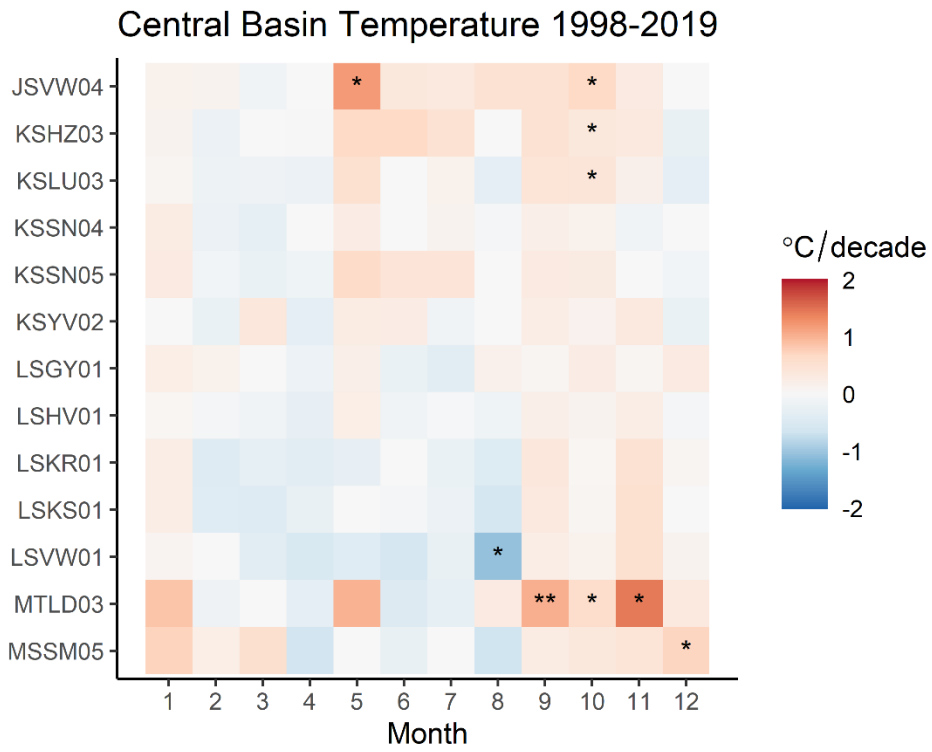


**Figure 13. Results of Seasonal Mann-Kendall trend analysis for temperature by station; all data (1998-2019) combined. Box color represents slope of trend. Symbols within boxes indicate significance $p < .05$ (*) or $p < .001$ (**).**

### 3.3.2 Salinity

Results of the Central Basin trend analyses (2007 - 2019), indicate a decrease in salinity at beach stations with an average trend slope of -0.6 PSS/decade (Figure 14). Trend results indicate beach waters are becoming less saline in winter and slightly more saline in summer. These trends corelate with regional precipitation levels; precipitation was generally highest during fall and winter and lowest during the summer (see Section 3.5 in King County, 2022).

A significant positive trend with a slope range of 1.3 – 4.1 PSS/decade was seen in June at four stations: Point Wells (JSVW04), Carkeek Park – Piper's Creek Outflow (KSHZ03), Golden Gardens Park (KSLU03), and SAM Sculpture Park (LTBD27). Two other significant positive trends were seen at West Point North Beach (KSSN04; 0.8 PSS/decade) and Normandy Park (MTLD03; 0.6 PSS/decade) in September and August, respectively.

The most significant decreasing trend was seen at Seacrest Park (LSGY01; -5.8 PSS/decade) in February.

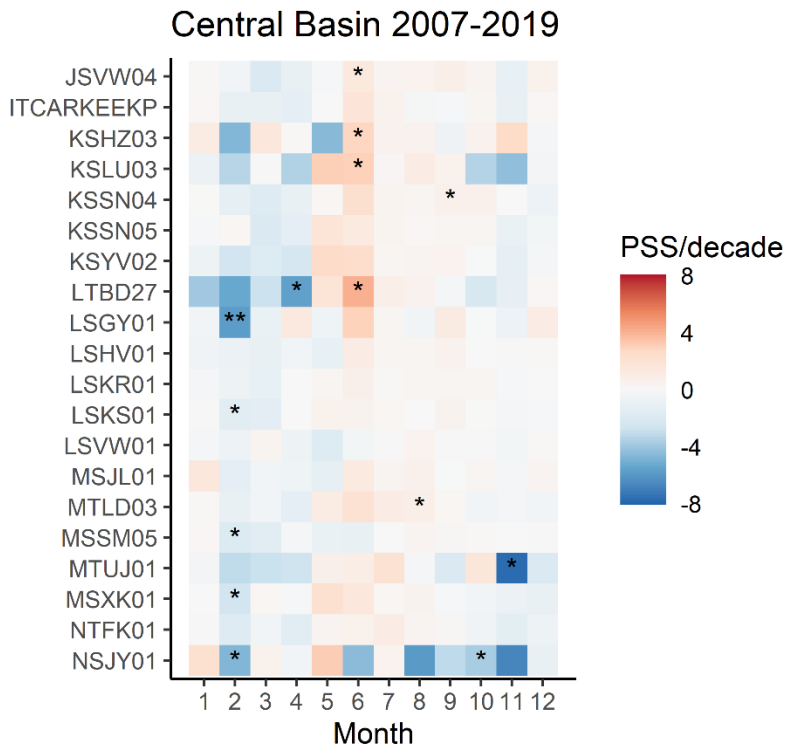


**Figure 14. Results of Seasonal Mann-Kendall trend analysis for salinity in beach waters by station; all data (2007-2019) combined. Box color represents slope of trend. Symbols within boxes indicate significance at $p < .05$ (*) or $p < .001$ (**).**

Increasing the data range from 2007-2019 to 1998-2019 with fewer stations resulted in detection of fewer significant trends and an average trend slope of -0.23 PSS/decade (Figure 15). Trends show we are experiencing fresher waters early in the year and slightly saline waters in summer. Three significant trends occurred in February at Seacrest Park (LSGY01; -3.3 PSS/decade), Constellation Park (LSKS01; 1.0 PSS/decade), and Tramp Harbor (MSSM05; 1.9 PSS/decade).

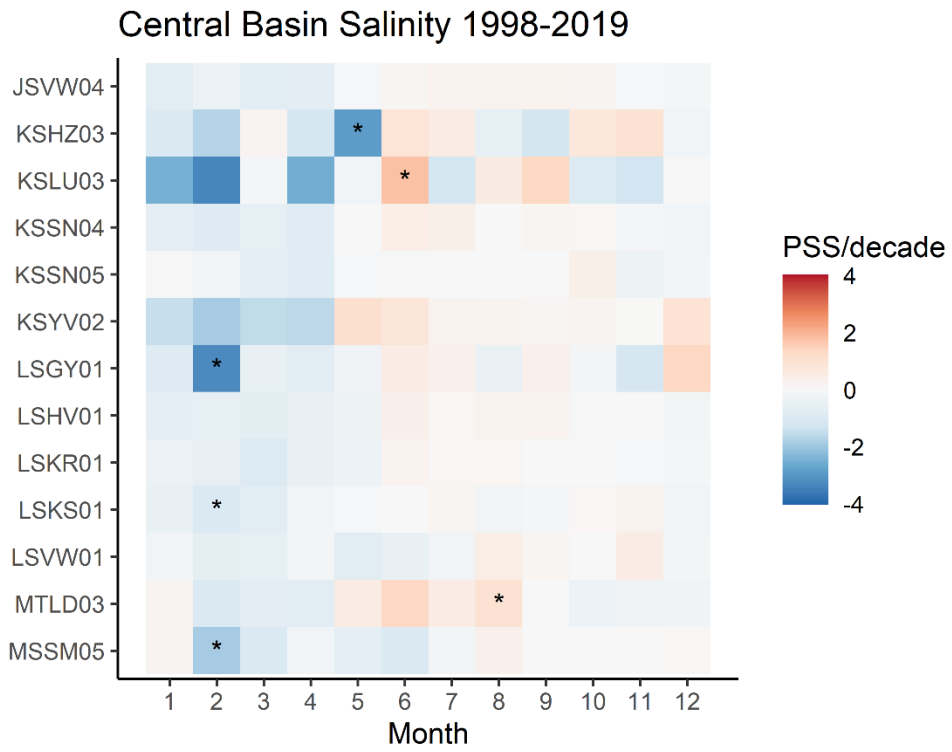


**Figure 15.** **Results of Seasonal Mann-Kendall trend analysis for salinity in beach waters by station; all data (1998-2019) combined. Box color represents slope of trend. Symbols within boxes indicate significance p < .05 (*) or p < .001 (**).**

# 4.0 SUMMARY

This section presented results for temperature and salinity monitored at beach stations between 2008 – 2019. Trend analysis results show increasing temperatures and decreasing salinity. Warmer beach temperatures were seen during marine heat wave conditions (end of 2014 -2016). Maximum salinity occurrences dominated in 2019 from May – December. Other highlights include:

- Results of the overall trend analyses (2008 – 2019) for beach waters in the Central Basin indicate increased temperatures at beach water stations, with an average trend slope of 0.23 °C/decade.
- Beach water temperatures were warmer in summer and more variable during spring months.
- During the winter months, the coldest mean temperatures were observed at the station with the greatest volume of freshwater input, Duwamish Park (LTTL02), just south of ƛaɬtałucid Park and Shoreline Habitat in the Duwamish River subestuary. This station also experienced the highest mean summer temperatures. Note that data were collected for only 4 years (2007 – 2010) at the Duwamish Park site.
- Most monthly minimum temperatures by site were seen earlier in the reporting period (2008 and 2011), and typically during La Niña events (2008-2009, and 2010-2014).
- Most monthly maximum temperatures by site were seen later in the reporting period (2015 and 2016) during marine heat wave conditions.
- Results of overall trend analyses for beach waters in the Central Basin (2007 – 2019), indicate decreased salinity with an average trend slope of -0.6 PSS/decade
- Mean annual salinity levels range from 25–30 PSS for all stations and seasons except at Duwamish Park (LTTL02), the only site with a major freshwater input to the Central Basin.
- Salinity at the most northern station (Point Wells, JSVW04) is generally much higher and less variable than salinity at the most southern station (Dumas Bay, NSJY01). Point Wells experiences less freshwater influence so changes in salinity are typically due to upwelling events. Salinity in Dumas Bay, a shallow embayment, fluctuates due to freshwater inputs from nearby Joes Creek and the Puyallup River.

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