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Water Quality Monitoring in the North Coast and Cascades Network

2011–2021 Data Summary

White River, Mount Rainier National Park.
NPS

Water quality monitoring in the North Coast and Cascades Network: 2011–2021 data summary

Science Report NPS/SR—2025/268

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Abstract

This report presents water quality and stream channel morphology data from twenty-six monitoring stations in national parks in Oregon and Washington States. The dataset includes one station at Ebey's Landing National Historical Reserve, three stations at Lewis and Clark National Historical Park, eight stations at Mount Rainier National Park, seven stations at North Cascades National Park, and seven stations at Olympic National Park. The report compares eleven years of data (2011–2021) collected by the National Park Service's North Coast and Cascades Inventory and Monitoring Network to state water quality standards and criteria, where available.

At twenty-five of the twenty-six stations network staff collected continuous air and stream water temperature data. In addition, at all stations staff collected annual measurements of core water quality parameters and channel morphology characteristics. Finally, staff conducted annual assessments of benthic macroinvertebrates at all stations. These macroinvertebrate data will be summarized in a separate report.

Terms, Acronyms, and Abbreviations

List of terms

Bankfull Width: Perpendicular measurements of the channel that contains bankfull (or every other year flooding) discharge.

Clean Water Act: A 1972 statute that established structure for regulating pollutant discharges into and quality standards for surface waters of the US.

Index period: The index period is the period of time that water quality samples should be collected to minimize seasonal and diel variation.

Intermittent waters: Streams that flow only during part of the year, such as in the spring and early summer after snowmelt, or ponds and wetlands that seasonally dry out.

Perennial stream: A stream that flows continuously throughout the year.

Reference condition: Represents the least human disturbed condition available in the NCCN for a given habitat. Reference condition waters are only found in watersheds free of the impacts resulting from lasting ground disturbance or land clearing, including maintained trails, and are used as benchmarks to compare the condition of other waters in the NCCN.

Sample Reach: A discrete segment of stream delineated as 40 times the mean wetted width; determined during reach delineation in the first year of survey and remains consistent from year to year.

Sensitivity: The capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest.

Seven-day Average of the Maximum Daily Temperature (A7DMT): The moving seven-day average of the daily maximum temperature.

Species of concern: A term used to describe a species about which NPS staff are concerned because the species is vulnerable to population or habitat loss within the park but does not appear on federal or state Endangered Species Act listings.

Status: Some statistic of a parameter over all monitoring sites within a single or well-bounded window of time.

Thalweg Depth: The line of lowest elevation within a watercourse.

Trend: A non-cyclic, directional change in a response measurement that can be with or without pattern.

Water Year: The period from October 1 to September 30 of the following year, to encompass a full cycle of precipitation.

Wetted Width: Perpendicular measurements of the stream channel covered in water.

Acronyms and Abbreviations

m: Meter

°C: Degrees Celsius

µS/cm: Microsiemens per centimeter

mg/L: Milligrams per liter

DO: Dissolved oxygen

NCCN: North Coast and Cascades Network

NPS: National Park Service

NTU: Nephelometric turbidity unit

PD: Percent difference

RPD: Relative percent difference

SOP: Standard operating procedure

USGS: United States Geological Survey

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Thank you also to the Makah Tribe and the Makah Tribe's Ocean Policy Work Group for providing access to Makah Lands on Umbrella Creek for the purposes of this project. In addition, thank you to Stephanie Martin (Makah Habitat Division Manager/Ecologist) for facilitating communication with the Ocean Policy Work Group and for participating with her staff in data collection on the Ozette River and Umbrella Creek.

1. Introduction

1.1 Background for Water Quality Monitoring in the North Coast and Cascades Network

Public lands are essential sources of fresh water. Across the United States, millions of people rely on water originating from watersheds managed as public lands. In the Pacific Northwest the headwaters of many of these watersheds are managed by the National Park Service (NPS). A defining characteristic of the national parks in the North Coast and Cascades Network (NCCN) is the high abundance of rivers and streams that support public uses, including recreational, commercial, and tribal fisheries, swimming and boating, and sources of water for human consumption. Parks in the NCCN also support habitat for several species of federally listed fish and numerous other species of fish, amphibians, and aquatic insects listed as threatened or endangered by the states of Oregon and Washington.

Due to their position in the landscape, waters in NCCN parks integrate the physical, chemical, and biological characteristics of the watersheds they drain. This puts them at an increased risk to a variety of environmental stressors and elevates the need to track the condition of these resources. To meet this need, NCCN staff developed a Water Quality Monitoring Protocol (Rawhouser et al. 2012), which focuses on monitoring the wadeable streams in the NCCN at highest risk of water quality degradation. The protocol documents the decision-making processes that prioritized individual water bodies for monitoring, selection of sample sites, and selection of the parameters to monitor along with their associated methods.

The NPS established its Inventory and Monitoring Division (IMD) in 2000 to document the status and long-term trends in the composition, structure, and function of park ecosystems and to determine how well current management practices are sustaining those ecosystems (Fancy et al. 2009). The IMD is organized nationally around 32 networks encompassing approximately 280 NPS units. The NCCN is composed of seven units: Ebey's Landing National Historical Reserve, Fort Vancouver National Historic Site, Lewis and Clark National Historical Park, Mount Rainier National Park, North Cascades National Park Service Complex (hereafter referred to as North Cascades National Park), Olympic National Park, and San Juan Island National Historical Park (Figure 1). The NCCN conducts water quality monitoring at five units; staff do not monitor water quality at Fort Vancouver National Historic Site or San Juan Island National Historical Park.

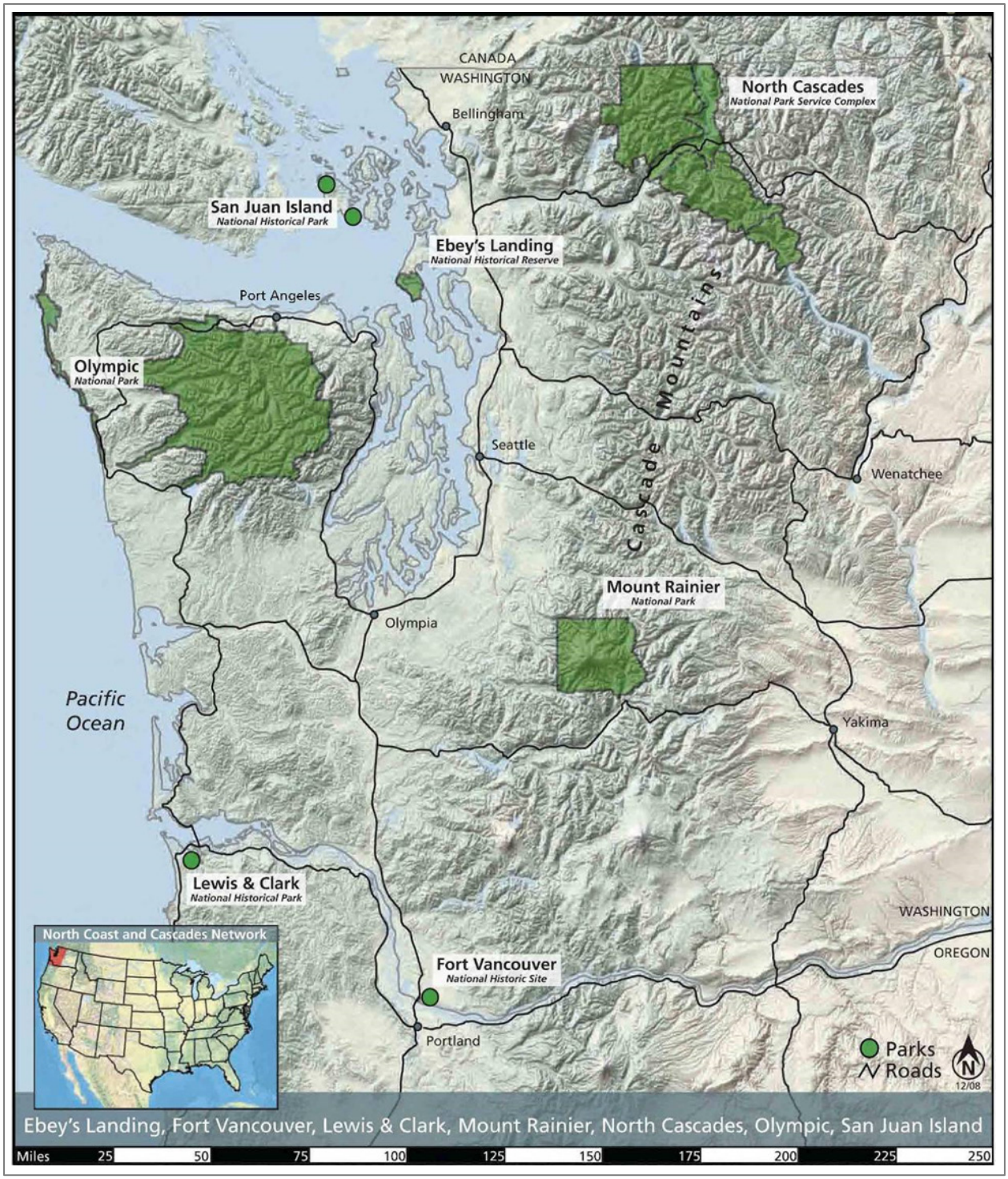

Figure 1. Parks of the North Coast and Cascades Network.
NPS

1.2 Program Monitoring Goals, Monitoring Questions, and Objectives

The NCCN Water Quality Monitoring Protocol by Rawhouser et al. (2012) established the primary goals of the monitoring program:

1. Determine the status and trends in the ecological conditions for a selection of wadeable rivers and streams distributed throughout the NCCN that are at a high risk of impairment.
2. Provide timely and high-quality data to park managers.
3. Identify and detect new and emerging threats to water quality.
4. Improve the understanding of the basic chemical, physical and biological processes that affect environmental quality of these surface waters and determine if they are within their natural and biological ranges.

The primary monitoring questions addressed by this protocol are:

1. What are the existing chemical and biological ranges in water quality within selected wadeable streams and rivers in the NCCN?
2. What are the long-term trends in the ecological condition for selected wadeable rivers and streams in watersheds that are at the highest risk of impairment?
3. Is the water quality in NCCN water bodies, as indicated by the selected wadeable rivers and streams, in compliance with the state designated beneficial uses?
4. What are the point and non-point pollution sources within the watersheds affecting the water quality of NCCN water bodies?

The protocol also established measurable objectives to be addressed by the monitoring program:

1. Determine the status and trends in key ecological conditions (water temperature, dissolved oxygen, specific conductance, pH, turbidity, benthic invertebrates, and the presence of invasive species) for selected wadeable rivers and streams found within the boundaries of the NCCN that are listed as impaired under Section 303(d) of the Clean Water Act.
2. Determine the status and trends in key ecological conditions (water temperature, dissolved oxygen, specific conductance, pH, turbidity, benthic invertebrates, and the presence of invasive species) for selected wadeable rivers and streams found within the boundaries of the NCCN that are at a high risk of impairment.

These selected waters are believed to be some of the most imperiled water bodies in the NCCN. Prior to this monitoring program, many had little or no water quality information that could be used to ascertain their ecological condition. Monitoring goals to evaluate the condition of park water quality in comparison with established standards include:

1. Compare water temperature data against state standards for chronic exceedance on a weekly, monthly, seasonal, and annual basis.
2. Compare indices of biological integrity against state standards for chronic exceedance on an annual basis.
3. Compare measurements of dissolved oxygen, pH and turbidity against state standards for chronic exceedance on an annual basis.

The primary purpose of this ten-year summary report is to provide managers with summaries of data collected thus far under this protocol (Goal 2). In addition, this report will aid NCCN staff in answering additional questions such as:

1. Are the program's data useful to park managers?
2. Are these data able to support the management of these sites given that they had been specifically chosen for monitoring due to their increased level of impairment or concern?
3. Are there any changes to the protocol that would better support our management goals for these sites?

To accomplish this, this report presents a status and summary of six water quality parameters, and a few select physical and biological parameters, for 26 water quality monitoring stations visited annually between 2011 and 2021 across NCCN parks. This report also evaluates the extent that these streams meet Washington State water quality criteria for continuous water temperature, dissolved oxygen, and pH. Through this evaluation, this report will address several more goals, questions, and objectives (Goals 1 and 4, Questions 1 and 3, measurable objectives 1 and 2, and comparison objectives 1 and 3).

Analysis of trends and benthic macroinvertebrate data are beyond the scope of this report. However, data summarized here may be utilized, along with additional information that may exist beyond this eleven-year dataset, to conduct analyses on macroinvertebrate data in a subsequent effort.

2. Methods

2.1 Monitoring Program Design

NPS staff collected the data presented in this report over an eleven-year period, between 2011 and 2021, from twenty-six rivers and streams within NCCN parks. NPS staff had identified these streams as being at the highest risk of impairment within the parks, based on their knowledge of park waters. Within each of these water bodies, the NPS established a permanent sample reach to serve as a benchmarked location for future monitoring. Staff visited each reach once a year on an annual basis during a specified index period. To control for seasonal and diurnal variability, field staff collected data within a two-week sample window of the initial sample event and between 10:00 am and 2:00 pm on the day of data collection.

2.2 Data Collection

At each site, NPS staff measured a suite of parameters intended to characterize the chemical, physical, and biological attributes of the sample reach (Table 1). Staff followed standard operating procedures (SOPs) documented in the NCCN Water Quality Monitoring Protocol (Rawhouser et al. 2012).

Table 1. Chemical, physical, and biological parameters collected on an annual basis as part of the NCCN water quality monitoring program. Full descriptions of the methods used are detailed in the NCCN Water Quality Monitoring Protocol and its Standard Operating Procedures (Rawhouser et al. 2012).

Attribute	Parameter	Field Method
Water Chemistry and Quality	Instantaneous temperature, dissolved oxygen, specific conductance, and pH	Seven separate measurements collected at the downstream end of the sample reach in a well-mixed location using a Hach HQD multi-parameter digital meter (NCCN SOP 7).
	Turbidity	Seven replicate samples per parameter collected at the downstream end of the reach in a well-mixed location and measured on site using a Hach 2100Q portable turbidity meter (NCCN SOP 7).
	Continuous temperature	Measurements collected with HOBO Pro v2 temperature loggers set to record every 60 minutes on a year-round basis. Loggers installed in the wetted channel in a well-mixed location of the sample reach and an air temperature logger installed one to three meters from the wetted channel adjacent to the water temperature logger (NCCN SOP 9).
Channel Morphology	Wetted width	Measured at ten equally spaced locations, from a random start, along the length of the sample reach using a laser range finder (NCCN SOP 6).
	Bankfull width	Measured at three equally spaced locations along the length of the sample reach using a laser range finder. Measurement locations selected based on the presence of definitive bankfull indicators (NCCN SOP 6).

Table 1 (continued). Chemical, physical, and biological parameters collected on an annual basis as part of the NCCN water quality monitoring program. Full descriptions of the methods used are detailed in the NCCN Water Quality Monitoring Protocol and its Standard Operating Procedures (Rawhouser et al. 2012).

Attribute	Parameter	Field Method
Channel Morphology (continued)	Thalweg depth	Measured at ten equally spaced locations along the length of the sample reach using a stadia rod. Measurements concurrent with wetted width measurements (NCCN SOP 6).
Biological	Invasive plants	Field observations made within 10 m of the bankfull channel edge (NCCN SOP 10).
	Invasive animals	Field observations made in and along the wetted edge of the stream channel (NCCN SOP 10).

In addition, the NCCN water quality monitoring program collects benthic invertebrates from its monitoring stations during each annual visit. NCCN staff and partners will summarize these data in a separate report.

2.3 Quality Assurance and Control Procedures

Program staff estimated precision, accuracy, bias, sensitivity, and completeness measures (Tables 2 and 3) for applicable data according to the quality assurance objectives described in the program Data Quality Assurance and Control Plan (SOPs 7, 9, and 15 of the NCCN Water Quality Monitoring Protocol).

Table 2. Descriptions of data quality indicators for each of the measured parameters used to support the data quality objectives established for the NCCN Water Quality Monitoring Program.

Data Quality Objective	Parameter	Description of Data Quality Indicator
Precision	Instantaneous temperature, dissolved oxygen, specific conductance, pH, and turbidity	Measured as Relative Percent Difference (RPD) using the first and last measurements for all the water temperature and chemistry parameters collected during a sample event.
	Continuous temperature	Measured as RPD using consecutive measurements recorded by the water temperature data logger during instrument calibration.
	Wetted width, bankfull width, thalweg depth	Measured as the RPD using two measurements made by different people in the same location of the stream during the same sample event.
Accuracy and Bias	Instantaneous temperature, dissolved oxygen, specific conductance, pH, turbidity	Measured as the Percent Difference (PD) between a measured value and an expected result using a calibration standard.
	Continuous temperature	Measured as the Absolute Value Difference, during instrument calibration, by comparison of a series of two values, one of which is an expected value and the other is the measured result.

Table 2 (continued). Descriptions of data quality indicators for each of the measured parameters used to support the data quality objectives established for the NCCN Water Quality Monitoring Program.

Data Quality Objective	Parameter	Description of Data Quality Indicator
Accuracy and Bias (continued)	Wetted width, bankfull width, thalweg depth	For width measurements (laser range finder), measured as the PD between two values, one of which is a known length. Accuracy and bias are not determined for thalweg measurements.
Sensitivity	Instantaneous temperature, dissolved oxygen, specific conductance, pH, turbidity	Measured as Alternate Measurement Sensitivity using seven consecutive measurements collected from a stream during the same sample event, once at the beginning of the field season, and once at the end of the field season.
	Continuous temperature	Measured as Alternate Measurement Sensitivity using seven consecutive measurements collected during instrument calibration, before deployment into the field and after being returned from the field.
	Wetted width, bankfull width, thalweg depth	Not applicable.
Completeness	All parameters	This report documents completeness for the entire 11-year dataset.
Representativeness	All parameters	Program staff note changes in data collection methods in annual reports when they occur.
Comparability	All parameters	This report documents completeness for the entire 11-year dataset; program staff detail data gaps in annual reports.

Table 3. Measurement quality objectives acceptance/rejection criteria for each of the measured values. TBD=criteria to be determined with additional years of data collection. Sensitivity as Alternate Measurement Sensitivity. NA=not applicable.

Parameter	Precision (RPD)	Accuracy and Bias (PD)	Sensitivity
Temperature	≤10	≤0.2	TBD
Dissolved Oxygen	≤10	± 10 (0 to 8 mg/L), ± 20 (>8 mg/L)	TBD
Specific Conductance	≤10	± 10	TBD
pH	≤10	± 10	TBD
Turbidity	≤10	± 10	TBD
Continuous Temperature	≤10	≤0.2 (Water), ≤0.4 (Air)	TBD
Wetted Width	≤10	± 10	NA
Bankfull Width	≤10	± 10	NA
Thalweg Depth	≤10	NA	NA

NPS staff assessed accuracy and bias of instantaneous measurements against National Institute of Standards and Technology traceable standards and thermometers before and after each sample event, and again at the beginning and end of the field season. Staff assessed the precision and accuracy of continuous water temperature measurements only before and after each deployment of the data loggers, against a traceable thermometer.

Measuring continuous water temperature accurately requires additional quality assurance and control procedures that were not part of the original Data Quality Assurance and Control Plan of the NCCN Water Quality Monitoring Protocol. These procedures include congruently graphing the air and water temperature data to identify and flag anomalies in the water temperature data that were not representative of well mixed water. For example, program staff used this process to identify periods of time when water temperature loggers were exposed to air, suspended in shallow poorly mixed water, or were buried in sediment. Staff evaluated these data in more detail by reviewing the deployment and retrieval pictures of the site, comparing water temperature data to flow data, when available, comparing against data from previous years and nearby temperature stations, and assessing the correlation of air and water temperature data for the dates of concern (Sowder and Steel 2012, Toohey et al. 2014). Staff flagged and removed data that did not meet the data quality objectives before conducting any summaries or analysis.

2.4 Comparison of Observations with Water Quality Criteria

For this report we calculated the seven-day moving average of daily maximum temperature and compared these calculations to the water quality criterion for the designated beneficial use of the stream (Table 4) (DOE 2016, Rawhouser et al. 2012). In addition, we presented associated air temperature measured with the same data loggers to illuminate the relationships of air temperature and stream water temperature for NCCN waters.

We summarized instantaneous data for temperature, dissolved oxygen, specific conductance, and turbidity and reported mean values for each index period. These data can indicate if a stream does not meet the federal Clean Water Act standards (DOE 2016) established for Washington and Oregon (Table 4). However, due to their instantaneous nature (one time grab vs. multiple measurements over an extended period) they should not be interpreted to indicate that a given stream is fully compliant with water quality standards outside of the index period. Since the index period for these streams occurs during base flow periods when dissolved oxygen is typically at the lowest levels annually, measurements of dissolved oxygen are likely providing adequate information to alert managers about potential issues related to this parameter. We did not compare the network monitoring data with criteria for turbidity, as background levels of turbidity for monitored stations and streams have not been established.

Table 4. Washington State water quality criteria for core parameters under federal Clean Water Act standards. The Skipanon River and Colewort Creek criteria are set according to Table 21 in the Oregon Department of Environmental Quality water quality criteria (DEQ 2017).

Park	Station	Aquatic Life Use Designation	Temperature [A]	Dissolved Oxygen [A]	pH	Turbidity [A]
Ebey's Landing National Historical Reserve	Ebey's Watercourse	Salmonid spawning, rearing and migration; and core summer salmonid habitat	16.0°C	8.0 mg/L	6.5–8.5	Not to exceed 5 NTU over background
Lewis and Clark National Historical Park	Skipanon River [B]	Salmon and trout rearing and migration (year-round)	18.0°C	8.0 mg/L [C]	6.5–8.5	Not to exceed 10% over background
	Skipanon River [B]	Salmon and steelhead spawning use (October 15th to May 15th)	13.0°C	11.0 mg/L [C]	6.5–8.5	Not to exceed 10% over background
	Megler Creek	Salmonid spawning, rearing and migration; and core summer salmonid habitat	16.0°C	8.0 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Colewort Creek [B, D]	Salmon and trout rearing and migration	18.0°C	8.0 mg/L [C]	6.5–8.5	Not to exceed 10% over background
Mount Rainier National Park	Nisqually River at Park Boundary	Core summer salmonid habitat (June 15 to September 15)	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 10% over background
	Nisqually River at Longmire	Char spawning and rearing	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 10% over background
	Nisqually River at Glacier Bridge	Char spawning and rearing	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 10% over background

[A] The temperature criterion is for the seven-day average of the daily maximum temperature. The dissolved oxygen criterion is for one-day lowest minimum. The turbidity criterion is set according to background levels; it shall not exceed 5 NTU over background when the background is 50 NTU or less, however when the background is more than 50 NTU it shall not exceed a 10% increase.

[B] Skipanon River and Colewort Creek are classified as cold water, as described in, Table 21 of the Oregon Department of Environmental Quality water quality criteria (DEQ 2017).

[C] Absolute minimum criteria (DEQ 2017) are applied here because only one day of sampling for dissolved oxygen is conducted under the NCCN Water Quality Monitoring Protocol.

[D] Recent restoration efforts in Colewort Creek have resulted in adult salmon returning to the creek. Reevaluation of this location in future years will likely result in salmon/steelhead spawning use designation.

[E] NPS proposed Designated Use (Rawhouser et al. 2012).

Table 4 (continued). Washington State water quality criteria for core parameters under federal Clean Water Act standards. The Skipanon River and Colewort Creek criteria are set according to Table 21 in the Oregon Department of Environmental Quality water quality criteria (DEQ 2017).

Park	Station	Aquatic Life Use Designation	Temperature [A]	Dissolved Oxygen [A]	pH	Turbidity [A]
Mount Rainier National Park (continued)	Paradise River	Char spawning and rearing	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Ohanapecosh River	Core summer salmonid habitat	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	White River at Park Boundary	Char spawning and rearing, core summer salmonid habitat [E], salmonid spawning, rearing, and migration [E]	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 10% over background
	White River at Littorals	Char spawning and rearing, core summer salmonid habitat [E], Salmonid spawning, rearing, and migration [E]	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 10% over background
	Fryingpan Creek	Char spawning and rearing, core summer salmonid habitat [E], salmonid spawning, rearing, and migration [E]	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 10% over background
North Cascades National Park	Stehekin River	Core summer salmonid habitat (June 15 to September 15)	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Bridge Creek	Core summer salmonid habitat (June 15 to September 15)	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background

[A] The temperature criterion is for the seven-day average of the daily maximum temperature. The dissolved oxygen criterion is for one-day lowest minimum. The turbidity criterion is set according to background levels; it shall not exceed 5 NTU over background when the background is 50 NTU or less, however when the background is more than 50 NTU it shall not exceed a 10% increase.

[B] Skipanon River and Colewort Creek are classified as cold water, as described in, Table 21 of the Oregon Department of Environmental Quality water quality criteria (DEQ 2017).

[C] Absolute minimum criteria (DEQ 2017) are applied here because only one day of sampling for dissolved oxygen is conducted under the NCCN Water Quality Monitoring Protocol.

[D] Recent restoration efforts in Colewort Creek have resulted in adult salmon returning to the creek. Reevaluation of this location in future years will likely result in salmon/steelhead spawning use designation.

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Table 4 (continued). Washington State water quality criteria for core parameters under federal Clean Water Act standards. The Skipanon River and Colewort Creek criteria are set according to Table 21 in the Oregon Department of Environmental Quality water quality criteria (DEQ 2017).

Park	Station	Aquatic Life Use Designation	Temperature [A]	Dissolved Oxygen [A]	pH	Turbidity [A]
North Cascades National Park (continued)	Company Creek	Core summer salmonid habitat (June 15 to September 15)	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Goodell Creek	Char spawning and rearing	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Newhalem Creek	Char spawning and rearing	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	North Fork Cascade River	Char spawning and rearing	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Ruby Creek	Char spawning and rearing	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
Olympic National Park	Barnes Creek	Salmonid spawning, rearing and migration; core summer habitat	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Umbrella Creek	Salmonid spawning, rearing and migration (year-round)	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Umbrella Creek	Core summer habitat; spawning/incubation (February 15 to July 1) [E]	13.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background

[A] The temperature criterion is for the seven-day average of the daily maximum temperature. The dissolved oxygen criterion is for one-day lowest minimum. The turbidity criterion is set according to background levels; it shall not exceed 5 NTU over background when the background is 50 NTU or less, however when the background is more than 50 NTU it shall not exceed a 10% increase.

[B] Skipanon River and Colewort Creek are classified as cold water, as described in, Table 21 of the Oregon Department of Environmental Quality water quality criteria (DEQ 2017).

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Table 4 (continued). Washington State water quality criteria for core parameters under federal Clean Water Act standards. The Skipanon River and Colewort Creek criteria are set according to Table 21 in the Oregon Department of Environmental Quality water quality criteria (DEQ 2017).

Park	Station	Aquatic Life Use Designation	Temperature [A]	Dissolved Oxygen [A]	pH	Turbidity [A]
Olympic National Park (continued)	Ozette River	Salmonid spawning, rearing and migration; core summer habitat	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Kalaloch Creek	Salmonid spawning, rearing and migration; core summer habitat	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Matheny Creek	Char spawning and rearing; core summer habitat	12.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	South Fork Calawah River	Salmonid spawning, rearing and migration (year-round)	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	South Fork Calawah River	Core summer habitat; spawning/incubation (February 15 to July 1) [E]	13.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Sol Duc River	Salmonid spawning, rearing and migration (year-round)	16.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background
	Sol Duc River	Core summer habitat; spawning and incubation (February 15 to July 1) [E]	13.0°C	9.5 mg/L	6.5–8.5	Not to exceed 5 NTU over background

[A] The temperature criterion is for the seven-day average of the daily maximum temperature. The dissolved oxygen criterion is for one-day lowest minimum. The turbidity criterion is set according to background levels; it shall not exceed 5 NTU over background when the background is 50 NTU or less, however when the background is more than 50 NTU it shall not exceed a 10% increase.

[B] Skipanon River and Colewort Creek are classified as cold water, as described in, Table 21 of the Oregon Department of Environmental Quality water quality criteria (DEQ 2017).

[C] Absolute minimum criteria (DEQ 2017) are applied here because only one day of sampling for dissolved oxygen is conducted under the NCCN Water Quality Monitoring Protocol.

[D] Recent restoration efforts in Colewort Creek have resulted in adult salmon returning to the creek. Reevaluation of this location in future years will likely result in salmon/steelhead spawning use designation.

[E] NPS proposed Designated Use (Rawhouser et al. 2012).

3. Results - Study Areas and Data Summaries

3.1 Ebey's Landing National Historical Reserve

Designated by Congress in 1978, Ebey's Landing National Historical Reserve was the first historical reserve in the National Park System. Congress created the unit "to preserve and protect a rural community which provides an unbroken historic record from 19th century exploration and settlement in Puget Sound to the present time." The 7,100-hectare reserve is located in the Olympic Rain Shadow subdivision of the Puget Lowland Ecoregion in northwestern Washington State (Omernik 2010). This unit is a mixture of state, private, and federal lands, with the majority in private ownership. The site receives 50 cm of precipitation annually (Baccus and Huff 2013).

3.1.1 Ebey's Watercourse Station

Ebey's Watercourse is the only stream included in the NCCN Water Quality Monitoring Program at this park unit. The primary sources of water for Ebey's Watercourse are surface runoff of rain and groundwater inflow. Remnant wetlands found in the watershed likely help to recharge groundwater inflow (Larrabee 2011). Program staff established a 150-m long index reach within a first order (Strahler 1952), confined channel section of Ebey's Watercourse. The reach is incised into the surrounding terrace and flows are intermittent.

Ebey's Watercourse, which holds an important place within the ecological landscape of the park and the surrounding area, is included in this water quality monitoring program due to several specific concerns. Whidbey Island, including the watershed surrounding Ebey's Watercourse, is a sole source aquifer, requiring Washington State's highest level of regulatory protection. The greatest threats to water quality in Ebey's Watercourse are hydrologic modifications associated with a network of buried drainage tiles, as well as the channelization of the stream to drain agricultural lands (Larrabee 2011). These conditions are compounded by urban and rural development, current agricultural practices, gravel mining, and high densities of roads and trails. Road density in the watershed is 2.37 km/km^2, placing it in the 90th percentile for road density within NCCN watersheds. The trail density is 0.34 km/km^2, falling within the 75th percentile for trail density in NCCN watersheds (Rawhouser et al. 2012).

The NCCN Water Quality Monitoring Protocol originally called for field staff to make observations at the Ebey's Watercourse Station during summer months, consistent with the monitoring schedule for other stations in the program. However, in summer 2012 program staff found the monitoring reach dry and thus established a mid-May index period for the station. Field staff returned to the site in May 2013 to install continuous water and air temperature loggers, making water year 2014 the first full year of data collection for the continuous temperature parameters. The program implemented the full monitoring protocol for the station from 2013 through 2021.

In addition to its typical intermittent flow during summer months, Ebey's Watercourse often experiences flash flood events during winter months. Signs of these include numerous bank failures and changes to the channel, as well as vegetation deposited by flooding well above the bankfull zone in most years.

Gaps in these data are largely due to intermittent flow. However, some gaps of missing data are results of channel instability. In 2021, for example, NPS staff were unable to recover the water temperature logger after a bank failure.

3.1.1.1 Continuous Water Temperature Data

Figures 2–4 present maximum, minimum, and seven-day average water temperatures for Ebey's Watercourse Station. The seven-day average of the daily maximum water temperature exceeded the state water quality criterion on 28 days between 2013 and 2021 (Table 5).

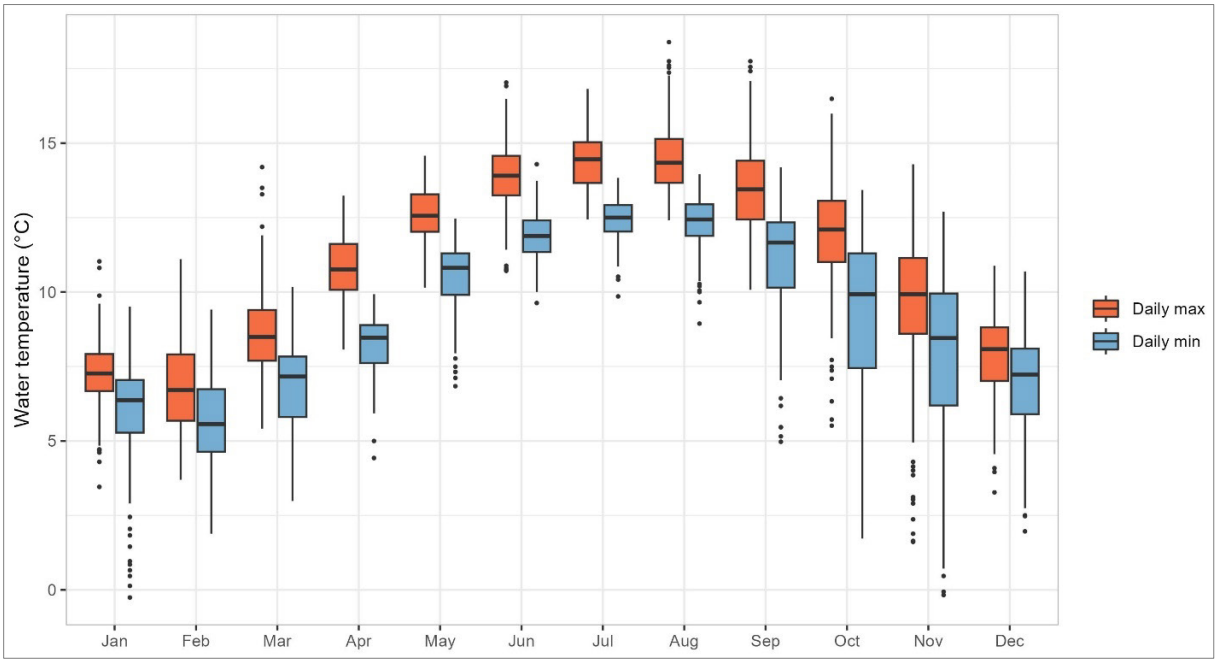

Figure 2. Maximum and minimum daily mean temperatures at the Ebey's Watercourse Station, 2013 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

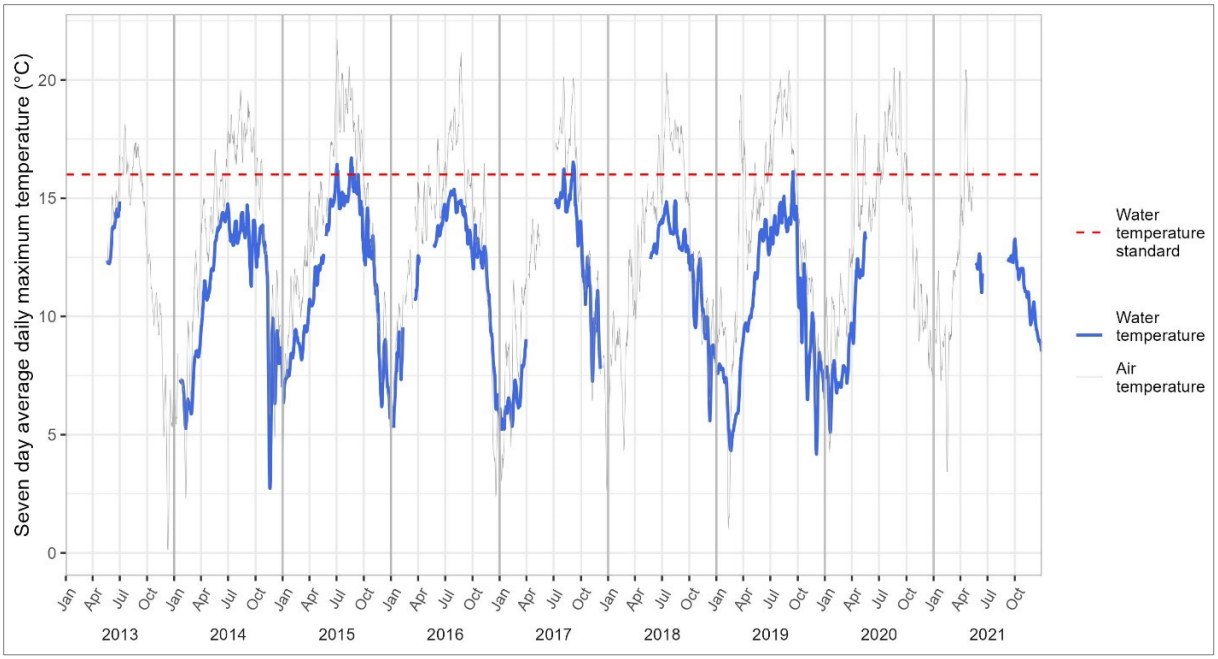

Figure 3. Seven-day average of the maximum daily water temperatures at the Ebey's Watercourse Station, 2013 to 2021. The red dashed line at 16°C indicates the year-round state criterion for aquatic life use designation of salmon spawning, rearing, and migration. Any seven-day average maximum daily water temperature above 16°C constitutes an exceedance.

NPS

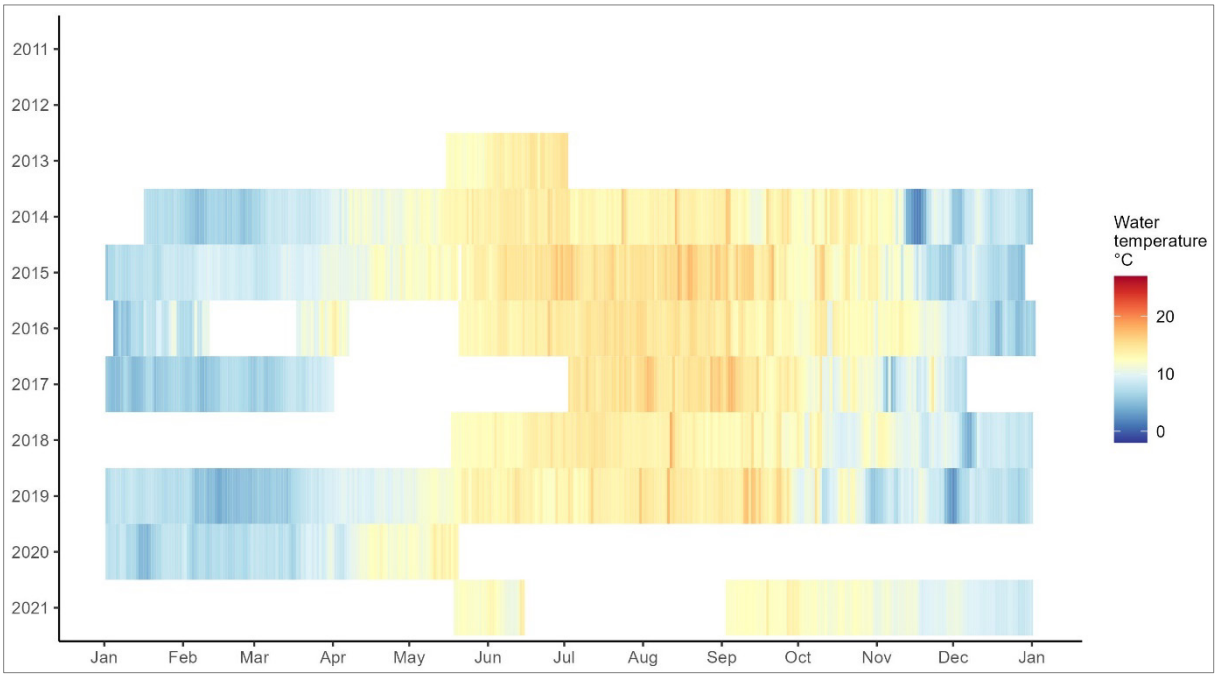

Figure 4. Maximum daily water temperatures at the Ebey's Watercourse Station, 2013 to 2021.

NPS

Table 5. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the year-round criterion of 16°C as well as the percentage of the days of the year with no data for that metric at the Ebey's Watercourse Station, 2013 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2013	none	88%
2014	none	6%
2015	15	3%
2016	none	27%
2017	12	34%
2018	none	39%
2019	1	full dataset
2020	none	62%
2021	none	62%

3.1.1.2 Instantaneous Water Temperature and Chemistry Data

Table 6 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for Ebey's Watercourse. This site's pH exceeded the Washington State criterion during the 2019 sampling event (Table 6).

Table 6. Water temperature and chemistry values at the Ebey's Watercourse Station, 2013 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
05/05/13	11.80	10.02	8.13	1,692.29	16.76
05/21/14	13.10	10.02	8.38	1,380.57	2.95
05/20/15	13.01	9.75	8.32	1,944.57	2.14
05/18/16	12.23	9.96	8.17	1,728.00	7.47
05/16/17	10.80	10.57	7.63	1,672.14 [B]	14.16
05/16/18	11.70	10.67	8.25	1,675.57	12.50
05/20/19	11.40	10.67	8.59 [A]	1,821.00	2.99
05/19/20	12.54	10.29	8.34	1,232.00	3.96
05/17/21	10.51	10.24	8.29	1,464.71	2.35
Minimum	**10.51**	**9.75**	**7.63**	**1,232.00**	**2.14**
Maximum	**13.10**	**10.67**	**8.59**	**1,944.57**	**16.76**

[A] pH value higher than Washington State criterion of 6.5–8.5 (Table 4) (also in red font).

[B] This reading is from 5/23/17, as the conductivity probe on 5/16 failed quality control checks.

3.1.1.3 Channel Morphology Metrics

Table 7 presents channel morphology measurements for Ebey's Watercourse Station, including data on bankfull width, wetted width, and thalweg depth.

Table 7. Channel morphology measurements from the Ebey's Watercourse Station, 2013 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
05/05/13	1.73	0.81	0.06
05/21/14	2.12	0.85	0.06
05/20/15	2.00	0.48	0.03
05/18/16	1.63	0.49	0.05
05/16/17	1.40	0.80	0.10
05/16/18	1.30	0.80	0.07
05/20/19	1.56	0.62	0.05
05/19/20	1.33	0.78	0.06
05/17/21	3.85	0.63	0.08
Minimum	**1.30**	**0.48**	**0.03**
Maximum	**3.85**	**0.85**	**0.10**

3.2 Lewis and Clark National Historical Park

Congress established 50-hectare Fort Clatsop National Memorial in 1958 and later expanded the site, in 2004, to over 1,200 hectares. The unit, renamed Lewis and Clark National Historical Park at the time of expansion, now incorporates seven separate units spread across 77 kilometers of the Pacific Coast within the Coast Ecoregion (Omernik 2010). The wide range of habitats found within the national historical park include estuarine mudflats and tidal marshes, shrub and forested swamps, and upland coniferous rainforests dominated by Sitka spruce (*Picea sitchensis*). The NCCN tracks water quality parameters at three locations within the park: on the Skipanon River, Megler Creek, and Colewort Creek.

3.2.1 Skipanon River Station

The Skipanon River, located in Oregon State, is a tidally influenced, rain and groundwater fed system. The river eventually flows into Young's Bay on the Columbia River. The monitoring reach is a 150-m long, second order, and single channel stream, highly constrained by incision within a coastal floodplain (Strahler 1952). Variation in stage (i.e., river height) is common at this site due to tidal influence, although the surface water here is entirely fresh.

NCCN staff selected the Skipanon River for inclusion in the water quality monitoring program due to its previously compromised status, human influence within the watershed, and concern for biological resources. The Oregon Department of Environmental Quality (DEQ 2017) flagged the Skipanon River for concerns regarding alkalinity and chloride and has listed this reach as a 303(d) waterbody for dissolved oxygen impairment under the federal Clean Water Act. Elevated road densities,

commercial forest management activities, agriculture, as well as rural and urban development within the watershed are the primary local human activities with the potential to impact water quality in the Skipanon River.

NCCN water quality monitoring staff initially installed air and water temperature loggers at the Skipanon River Station in 2011, as part of a pilot of the monitoring protocol. Unfortunately, staff did not install the water temperature logger deep enough for the range of water levels at the station reach, and the program lost significant amounts of data from water year 2011 and 2012. Staff reinstalled the logger at a greater depth in 2012 and subsequently collected a full suite of data each year from 2012 to 2021. The annual site visits typically occurred in the final week of July or the first week of August.

3.2.1.1 Continuous Water Temperature Data

Figures 5–7 present maximum, minimum, and seven-day average water temperatures for the Skipanon River Station in Lewis and Clark National Historical Park. The seven-day average of the daily maximum water temperature exceeded the year-round criterion of 18°C on 893 days between 2012 and 2021, while the seasonal criterion of 13°C was exceeded on 156 days between 2012 and 2020 (Table 8).

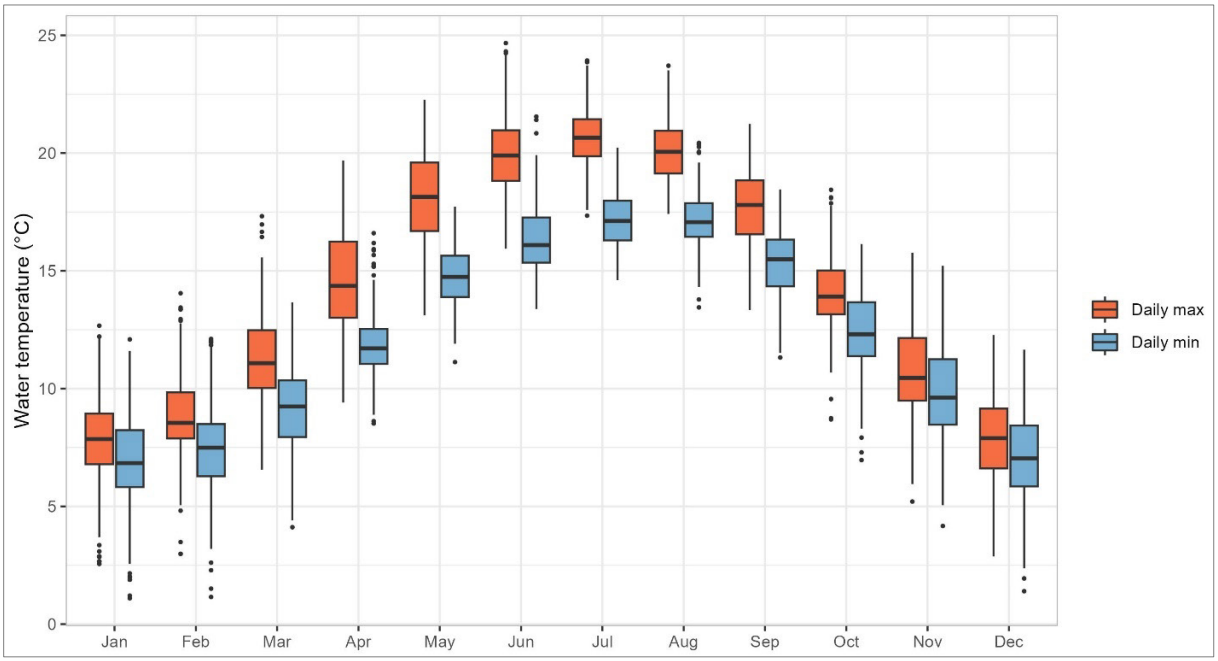

Figure 5. Maximum and minimum daily mean temperatures at the Skipanon River Station, 2011 to 2020. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

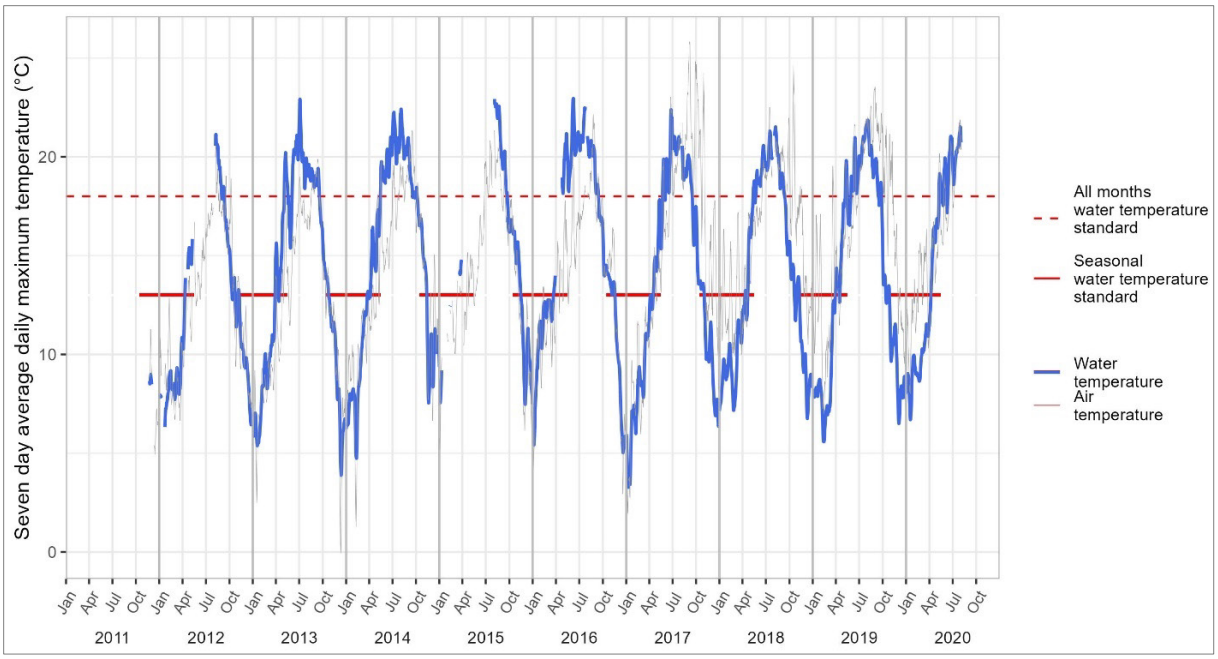

Figure 6. Seven-day average of the maximum daily water temperatures at the Skipanon River Station, 2011 to 2020. The red dashed line at 18°C indicates the year-round state criterion for aquatic life use designation of salmon and trout rearing and migration. The solid red line at 13°C indicates the seasonal state criterion for salmon and steelhead spawning. Any seven-day average maximum daily water temperature in any month above 18°C or above 13°C between October 15 and May 15 constitutes an exceedance.

NPS

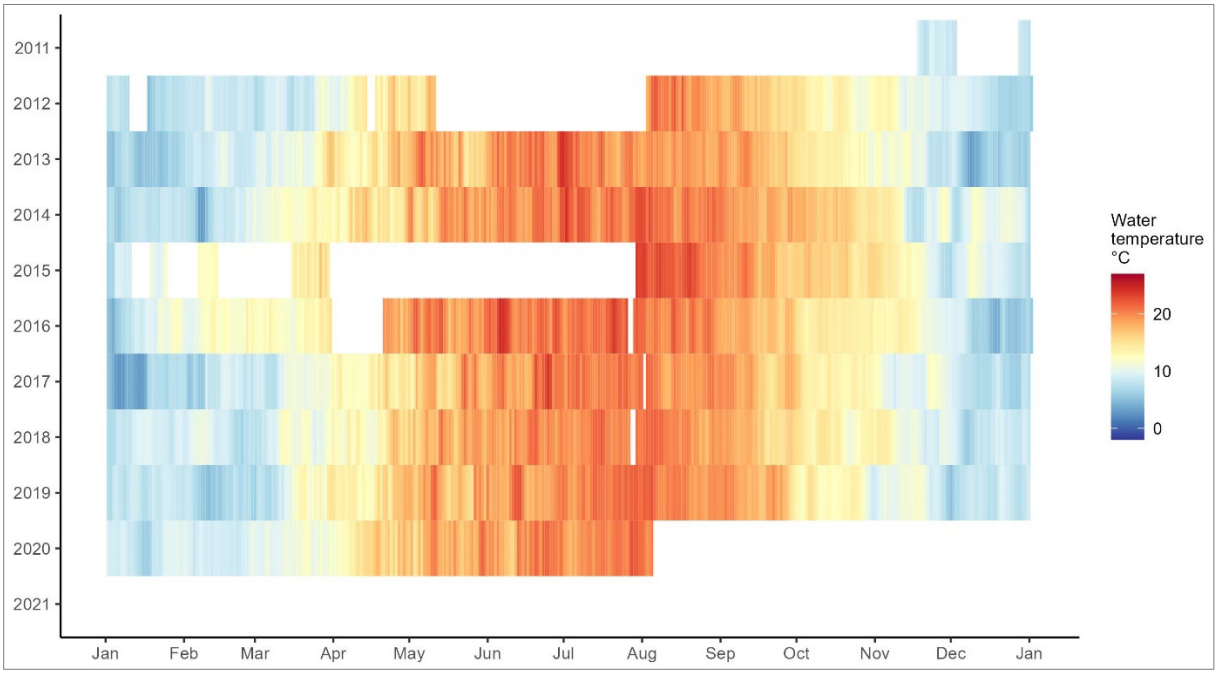

Figure 7. Maximum daily water temperatures at the Skipanon River Station, 2011 to 2020.

NPS

Table 8. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the year-round criterion of 18°C and the seasonal criterion of 13°C as well as the percentage of the days of the year with no data for that metric at the Skipanon River Station, 2011 to 2020.

Year	Number of Days with Observed Exceedances		Proportion of the Year with No Data
	Year-Round Criterion	Seasonal Criterion	
2011	none	none	97%
2012	31	12	31%
2013	122	9	full dataset
2014	138	28	full dataset
2015	51	32	53%
2016	134	34	9%
2017	108	18	2%
2018	112	17	2%
2019	122	6	full dataset
2020	75	none	41%

3.2.1.2 Instantaneous Water Temperature and Chemistry Data

Table 9 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Skipanon River Station. This site's dissolved oxygen was lower than the Oregon State criterion of 8.0 mg/L during each sampling event from 2012–2021 (Table 9).

Table 9. Water temperature and chemistry values at the Skipanon River Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
07/31/12	16.57	5.01 [A]	6.97	184.27	8.02
07/29/13	17.80	5.85 [A]	6.89	210.37	11.44
07/29/14	19.34	5.39 [A]	6.63	174.23	8.55
07/28/15	18.33	5.85 [A]	7.01	210.84	9.92
07/26/16	19.91	6.09 [A]	6.96	186.59	11.14
08/01/17	17.14	5.01 [A]	6.77	205.10	14.06
07/20/18	19.54	5.84 [A]	7.03	202.10	16.67
08/06/19	18.00	5.91 [A]	6.86	333.29	17.59
08/04/20	18.00	6.26 [A]	6.81	241.00	21.26
08/04/21	18.10	6.63 [A]	6.92	218.83	21.17

[A] DO value lower than the Oregon State criterion of 8.0 (Table 4) (also in red font).

Table 9 (continued). Water temperature and chemistry values at the Skipanon River Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
Minimum	**16.57**	**5.01**	**6.63**	**174.23**	**8.02**
Maximum	**19.91**	**6.63**	**7.03**	**333.29**	**21.26**

[A] DO value lower than the Oregon State criterion of 8.0 (Table 4) (also in red font).

3.2.1.3 Channel Morphology Metrics

Table 10 presents channel morphology measurements for the Skipanon River Station, including data on bankfull width, wetted width, and thalweg depth.

Table 10. Channel morphology measurements from the Skipanon River Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
07/31/12	6.53	5.12	0.63
07/29/13	7.23	4.67	0.63
07/29/14	7.07	4.54	0.54
07/28/15	5.73	5.38	0.71
07/26/16	6.23	4.50	0.78
08/01/17	6.47	5.56	1.25
07/20/18	5.42	4.79	0.92
08/06/19	7.73	5.10	0.92
08/04/20	7.43	5.71	0.85
08/04/21	8.97	5.78	1.89
Minimum	**5.42**	**4.50**	**0.54**
Maximum	**8.97**	**5.78**	**1.89**

3.2.2 Megler Creek Station

Megler Creek is a small perennial stream that drains into the Columbia River. Located in the Washington State portion of the park, it is fed primarily by rain runoff and groundwater inflow. The Megler Creek Station consists of a 150-m long reach, approximately 100 m upstream from the confluence with the Columbia River at 42 m above sea level. The sample reach is located in a second order segment of Megler Creek and exists as a single channel. The reach is minimally constrained within its floodplain by debris aprons.

NCCN staff chose Megler Creek for inclusion in this program to monitor the potential effects of commercial forest management on Critical Habitat for federally endangered Chinook salmon (*Oncorhynchus tshawytscha*). There was also a general lack of information regarding the creek's biological resources (Welch and Rawhouser 2017). Roughly 20% of the Megler Creek watershed is

managed by the NPS, while the remaining land is privately owned and managed for commercial forestry. Logging activities and associated access roads within the Megler Creek watershed have the greatest potential to impact water quality.

Based on regional distribution data and habitat requirements, this section of stream should support up to twelve species of fish. However, prior to 2016 the mouth of Megler Creek was routed through a perched 122 cm culvert. NPS staff found that this culvert was likely to restrict salmonid passage (Clatterbuck email comm. 2014). Above the culvert, but below the sample reach, NPS staff have observed four species of salmonids with densities much lower than below the culvert, suggesting that the culvert comprises a substantial barrier to fish passage. A recent NPS restoration project replaced the undersized culvert with a concrete box culvert, which improved access for fish (ESA Vigil-Agrimis 2015)

NCCN staff initially collected water quality data and installed air and water temperature loggers at the Megler Creek Station in 2011, as part of a pilot monitoring program. Since installation this site has been moderately stable, though high flow events have occasionally buried the water temperature logger. NCCN staff conducted the full water quality monitoring protocol at this station each year from 2012 to 2021. Staff typically visited the sites in the final week of July or the first week of August.

3.2.2.1 Continuous Water Temperature Data

Figures 8–10 present maximum, minimum, and seven-day average water temperatures for the Megler Creek Station in Lewis and Clark National Historical Park. The monitoring program did not find any exceedances of the seven-day average daily maximum water temperature criterion of 16°C between 2011 and 2021 (Table 11).

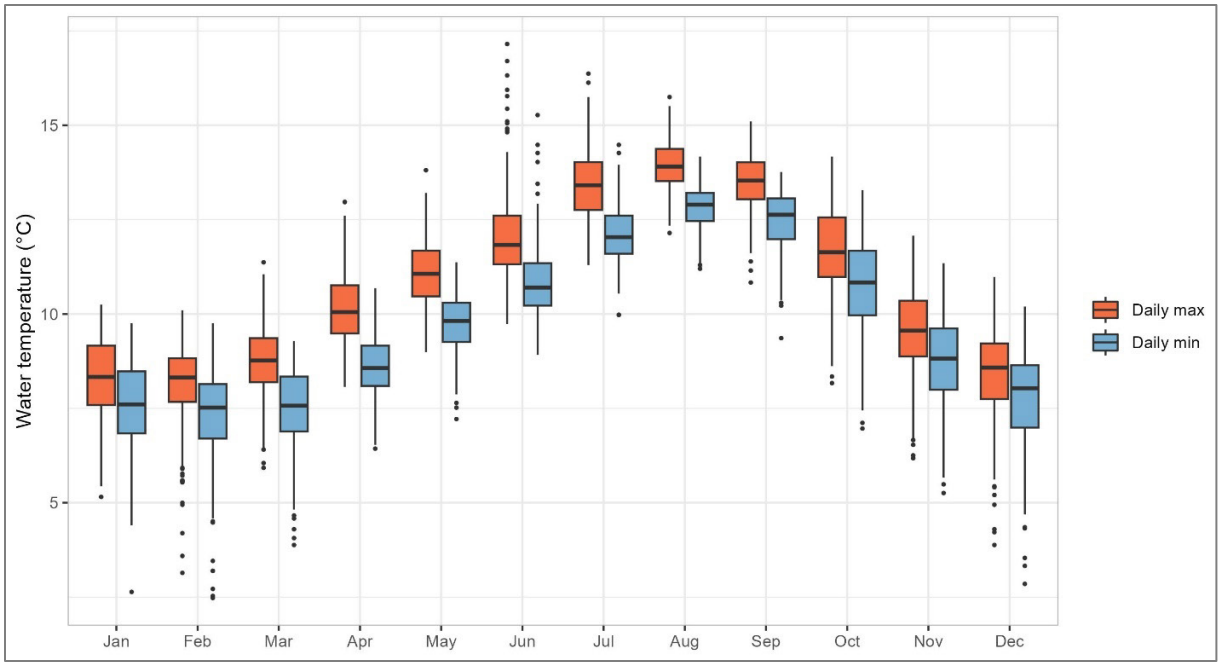

Figure 8. Maximum and minimum daily mean temperatures at the Megler Creek Station, 2011 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

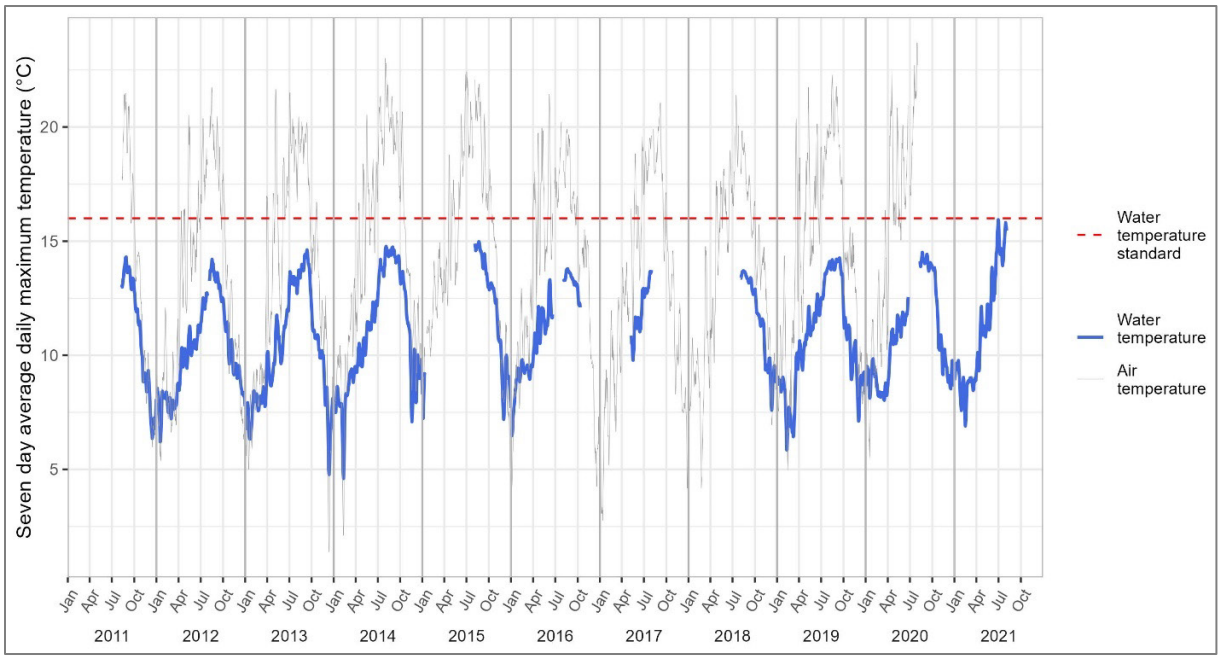

Figure 9. Seven-day average of the maximum daily water temperatures at the Megler Creek Station, 2011 to 2021. The red dashed line at 16°C indicates the year-round state criterion for aquatic life use designation of salmon spawning, rearing, and migration. Any seven-day average maximum daily water temperature above 16°C constitutes an exceedance.

NPS

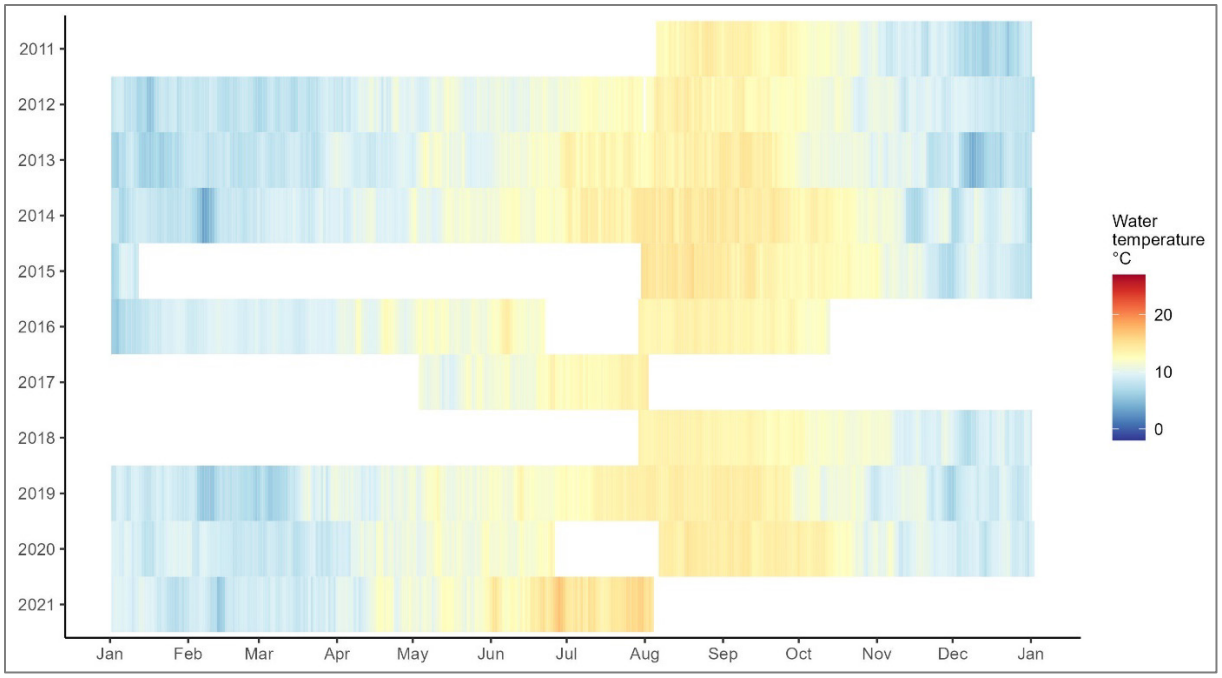

Figure 10. Maximum daily water temperatures at the Megler Creek Station, 2011 to 2021.
NPS

Table 11. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 16°C as well as the percentage of the days of the year with no data for that metric at the Megler Creek Station, 2011 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2011	none	61%
2012	none	2%
2013	none	full dataset
2014	none	full dataset
2015	none	56%
2016	none	34%
2017	none	77%
2018	none	59%
2019	none	full dataset
2020	none	13%
2021	none	41%

3.2.2.2 Instantaneous Water Temperature and Chemistry Data

Table 12 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Megler Creek Station.

Table 12. Water temperature and chemistry values at Megler Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (ºC)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
07/30/12	12.77	9.82	7.14	88.69	1.63
07/30/13	12.21	10.68	7.14	105.39	1.55
07/30/14	13.34	10.25	7.31	105.93	1.18
07/29/15	13.21	10.02	7.60	106.09	0.57
07/27/16	14.01	8.51	7.19	102.47	1.45
08/02/17	13.70	9.43	7.09	103.34	0.80
07/28/18	13.21	10.38	7.59	105.79	0.53
08/06/19	13.80	10.03	7.32	107.80	0.72
08/03/20	13.49	10.32	7.29	101.27	0.62
08/03/21	13.80	9.05	6.83	100.60	0.97
Minimum	**12.21**	**8.51**	**6.83**	**88.69**	**0.53**
Maximum	**14.01**	**10.68**	**7.60**	**107.80**	**1.63**

3.2.2.3 Channel Morphology Metrics

Table 13 presents channel morphology measurements for the Megler Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 13. Channel morphology measurements from the Megler Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
07/30/12	5.03	2.17	0.11
07/30/13	5.17	2.33	0.06
07/30/14	4.11	1.91	0.10
07/29/15	4.40	1.40	0.09
07/27/16	6.40	1.61	0.16
08/02/17	3.13	2.11	0.12
07/28/18	3.84	1.46	0.10
08/06/19	4.93	1.79	0.14
08/03/20	7.23	1.93	0.13
08/03/21	7.03	2.07	0.20
Minimum	**3.13**	**1.40**	**0.06**
Maximum	**7.23**	**2.33**	**0.20**

3.2.3 Colewort Creek Station

Located in the Oregon portion of Lewis and Clark National Historical Park, Colewort Creek is a small, perennial stream that drains into the Lewis and Clark River. Colewort Creek is primarily fed by surface runoff of rain and groundwater inflow. The sample reach starts approximately 700 m upstream from the creek's confluence with the Lewis and Clark River and is 10 m above sea level. Occupying a single channel located in an unconstrained, broad valley, the 150 m long index reach occurs within a second order segment of Colewort Creek (Strahler 1952).

NPS staff monitor water quality at Colewort Creek in order to track potential impacts to biological resources caused by high road density and active commercial forestry within the surrounding watershed. The road density in the watershed is 1.61 km/km^2 (75th percentile of NCCN watersheds), while trail density is 0.22 km/km^2 (60th percentile of NCCN watersheds) (Rawhouser et al. 2012). These relatively high densities of roads and trails may degrade habitat quality for numerous aquatic organisms. NPS staff have documented the presence of three species of fish, including one federally threatened species, in the Colewort Creek sample reach. Based on regional distribution data and habitat requirements, however, it is possible that this creek may support up to nineteen fish species and nine amphibian species (Wydoski and Whitney 2003, Samora et al. 2015, Galvan et al. 2005, Welch and Rawhouser 2017).

During the initial visit to the Colewort Creek sampling reach in 2012, NPS staff completed the full version of the monitoring protocol, along with the installation of air and water temperature loggers. Since installation, this site has been highly stable with minimal data gaps. Network staff conducted the full protocol each year from 2012 to 2021, with annual site visits typically occurring in the final week of July or the first week of August.

3.2.3.1 Continuous Water Temperature Data

Figures 11–13 present maximum, minimum, and seven-day average water temperatures for the Colewort Creek Station in Lewis and Clark National Historical Park. The monitoring program did not find any exceedances of the seven-day average daily maximum water temperature criterion of 16°C between 2017 and 2021 (Table 14).

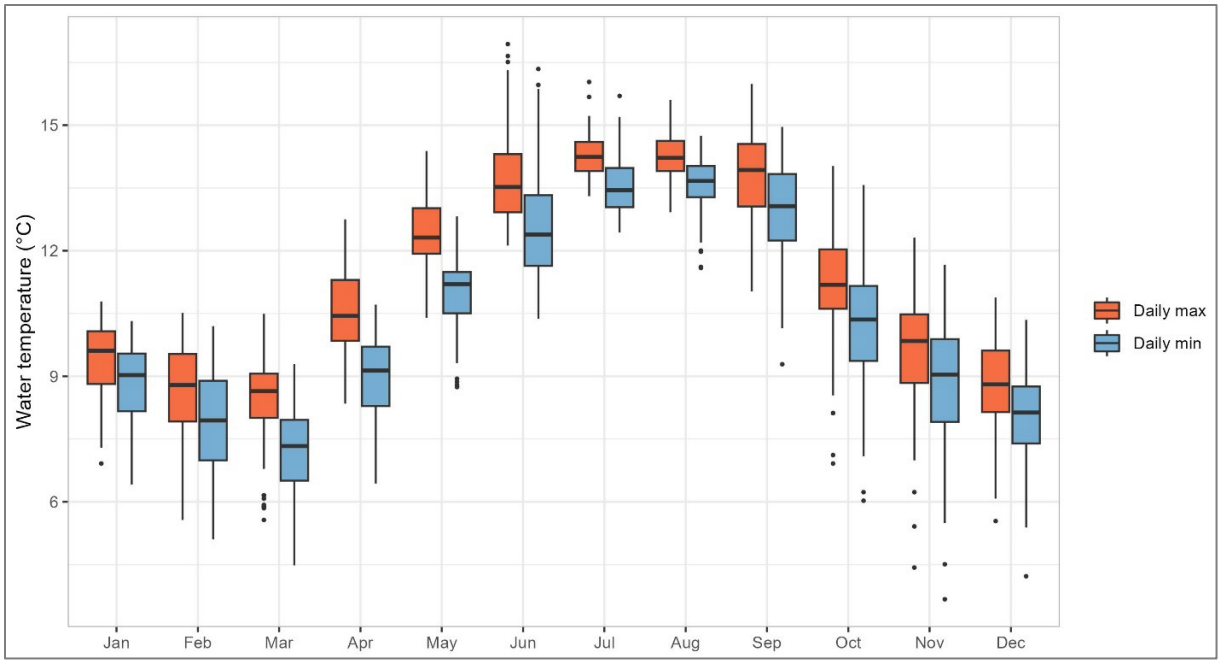

Figure 11. Maximum and minimum daily mean temperatures at the Colewort Creek Station, 2017 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

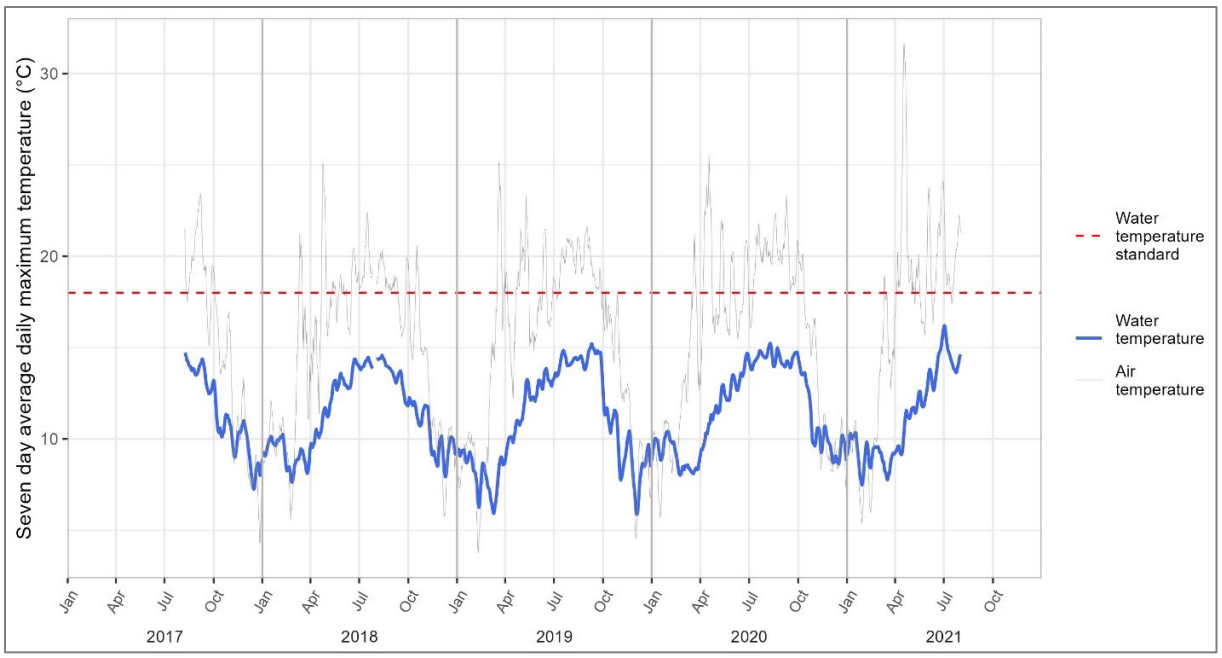

Figure 12. Seven-day average of the maximum daily water temperatures at the Colewort Creek Station, 2017 to 2021. The red dashed line at 18°C indicates the year-round state criterion for aquatic life use designation of salmon and trout rearing and migration. Any seven-day average maximum daily water temperature above 18°C constitutes an exceedance.

NPS

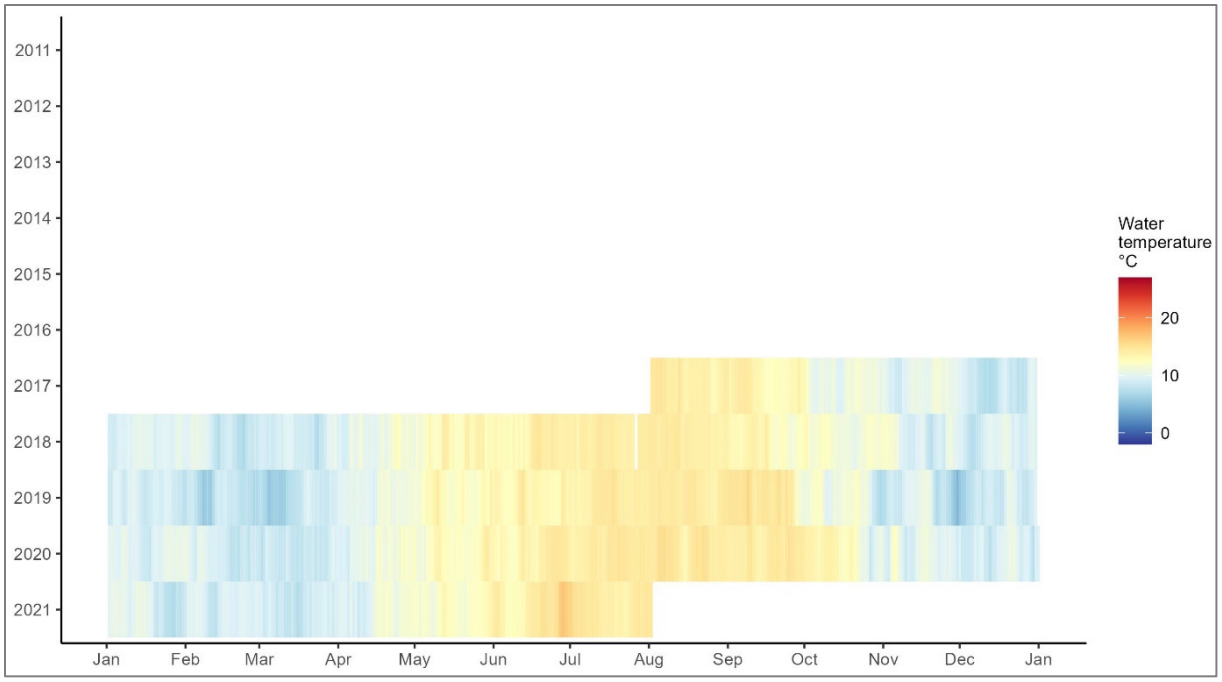

Figure 13. Maximum daily water temperatures at the Colewort Creek Station, 2017 to 2021. *NPS*

Table 14. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 16°C as well as the percentage of the days of the year with no data for that metric at the Colewort Creek Station, 2017 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2017	none	60%
2018	none	2%
2019	none	full dataset
2020	none	full dataset
2021	none	41%

3.2.3.2 Instantaneous Water Temperature and Chemistry Data

Table 15 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Colewort Creek Station. This site's dissolved oxygen was lower than the Oregon State criterion of 8.0 mg/L during sampling events in 2016, 2019, and 2021 (Table 15).

Table 15. Water temperature and chemistry values at Colewort Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
07/31/12	12.74	9.20	7.37	87.87	0.66
07/29/13	13.07	9.47	6.84	101.69	0.72
07/29/14	15.37	8.70	7.41	100.56	0.99
07/28/15	14.74	8.47	6.84	99.17	1.08
07/27/16	15.09	6.61 [A]	6.87	98.36	2.33
08/01/17	14.41	9.11	6.73	99.13	6.52
07/27/18	15.49	8.64	7.00	100.40	1.60
08/05/19	15.26	7.70 [A]	6.81	101.47	1.73
08/04/20	14.79	8.44	6.74	97.34	3.17
08/03/21	15.61	6.26 [A]	6.66	99.06	1.96
Minimum	**12.74**	**6.26**	**6.66**	**87.87**	**0.66**
Maximum	**15.61**	**9.47**	**7.41**	**101.69**	**6.52**

[A] DO value lower than Oregon State criterion of 8.0 (Table 4) (also in red font).

3.2.3.3 Channel Morphology Metrics

Table 16 presents channel morphology measurements for the Colewort Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 16. Channel morphology measurements from the Colewort Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
07/31/12	2.25	1.55	0.10
07/29/13	2.67	1.38	0.13
07/29/14	3.54	1.60	0.15
07/28/15	3.17	1.75	0.26
07/27/16	3.37	2.01	0.18
08/01/17	3.13	2.14	0.19
07/27/18	2.59	1.49	0.14
08/05/19	4.10	1.45	0.11
08/04/20	9.47	1.96	0.18
08/03/21	7.57	1.31	0.12
Minimum	**2.25**	**1.31**	**0.10**
Maximum	**9.47**	**2.14**	**0.26**

3.3 Mount Rainier National Park

Congress established Mount Rainier National Park in 1899 to protect lands around Mount Rainier, a stratovolcano that stands at 4,392 m above sea level in Washington State. The peak is the tallest in Washington State and contains the highest concentration of glaciers in the contiguous United States. The nine major watersheds in the park are largely fed by Mount Rainier's numerous glaciers. Habitats in Mount Rainier National Park include alpine, subalpine meadows, montane forests, dynamic glacial river valleys, and abundant wetlands, streams, and lakes. The park is 953.5 square kilometers, 97% of which are federally designated wilderness.

NPS staff monitor water quality at eight stations within the park under the NCCN Water Quality Monitoring Protocol (Rawhouser et al. 2012). Four of these are on the Nisqually River; three stations are on the main stem and one station is on a tributary. The lowest elevation station of these is located near the park boundary. The Nisqually River at Longmire Station is 26 km upstream of the park boundary, while the Nisqually River at Glacier Bridge Station is further upstream near the headwaters of the Nisqually River at the Nisqually Glacier.

NCCN staff also monitor water quality at two stations on the main stem of the White River. The lowest elevation station of these is on the White River at the NPS boundary, while another station is 10 km upstream in an area referred to by NPS staff as the "littorals." NPS staff also monitor water quality on Fryingpan Creek, a tributary of the White River, and on the Ohanapecosh River.

3.3.1 Nisqually River at Park Boundary Station

The station exists within a 500 m long fourth order (Strahler 1952) reach that is typified by a braided channel in an unconstrained, broad floodplain. Surface runoff from snowpack and glacial melt, as well as seven mountain lakes, primarily feed the Nisqually River. Torrent evidence strongly suggests that both scouring and deposition occur in this reach. Beason et al. (2014) determined average aggradation for the river at this station to range from -0.17 m/year in 2005 to 0.36 m/year in 2012.

According to park managers, water quality in the Nisqually River is potentially impacted by numerous sources that include roads, trails, NPS infrastructure (campgrounds, offices, concessions), water withdrawal, channel dredging, discharge of treated wastewater, and high levels of recreational use. Biological resources within the Nisqually watershed that could be impacted by these external forces include fish, amphibians, and a rare insect of interest. Specifically, three species of fish and five species of amphibians have been documented along the river at this station (Samora et al. 2013b, Galvan et al. 2005, Samora and Anderson 2010, Samora et al. 2013a). Cope's giant salamander (*Dicamptodon copei*) is potentially present as observers have noted the species nearby (Leonard et al. 1993, WNHP WDFW BLM 2005, Samora et al. 2013a). The Nisqually watershed also supports the Fender's soliperlan stonefly (*Soliperla fenderi*), a federal species of concern found in only two locations in Washington State (Kondratieff and Lechleitner 2002, WNHP WDFW 2014).

NPS staff collected discrete water temperature and chemistry data at this station between 1999 and 2011, before implementation of the NCCN Water Quality Monitoring Protocol. We present these

legacy data in Appendix B, but do not place them side by side with the NCCN data presented in this section due to differences in quality control standards between the datasets.

3.3.1.1 Continuous Water Temperature Data

Figures 14–16 present maximum, minimum, and seven-day average water temperatures for the Nisqually River at Park Boundary Station in Mount Rainier National Park. The seven-day average of the daily maximum water temperature exceeded the seasonal state water quality criterion in summer (June 15 to September 15) on 7 days in 2016 (Table 17). There are not enough data from 2012 to represent a seven-day moving average for that year (Figure 15).

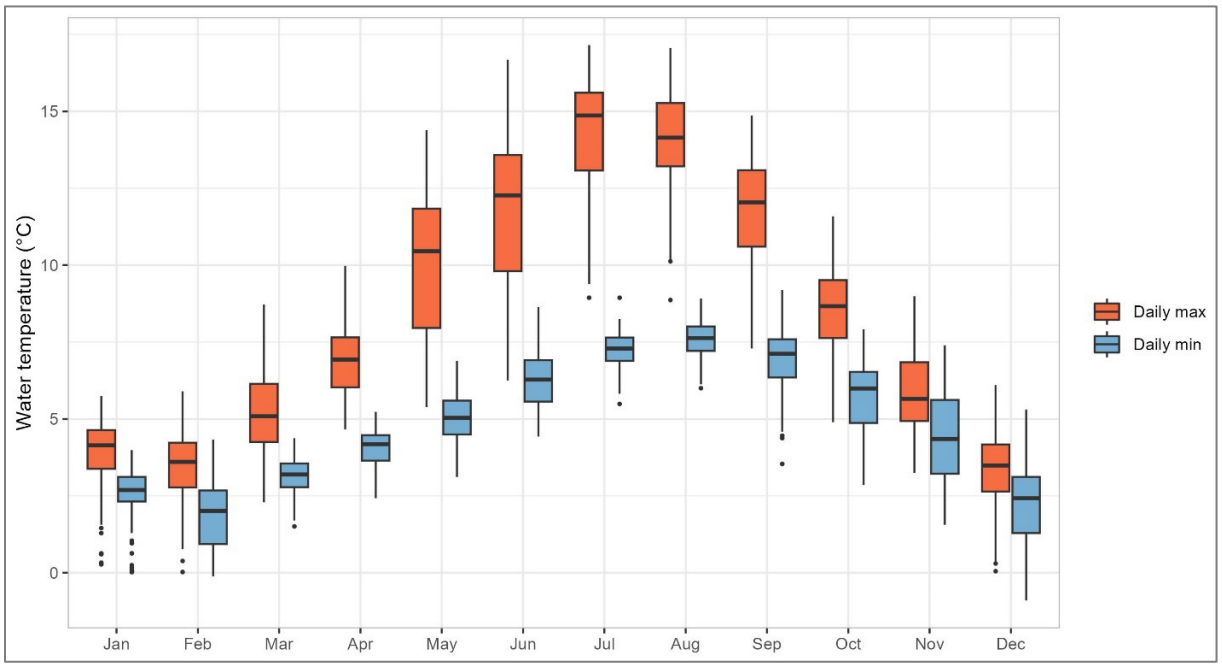

Figure 14. Maximum and minimum daily mean temperatures at the Nisqually River at Park Boundary Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.
NPS

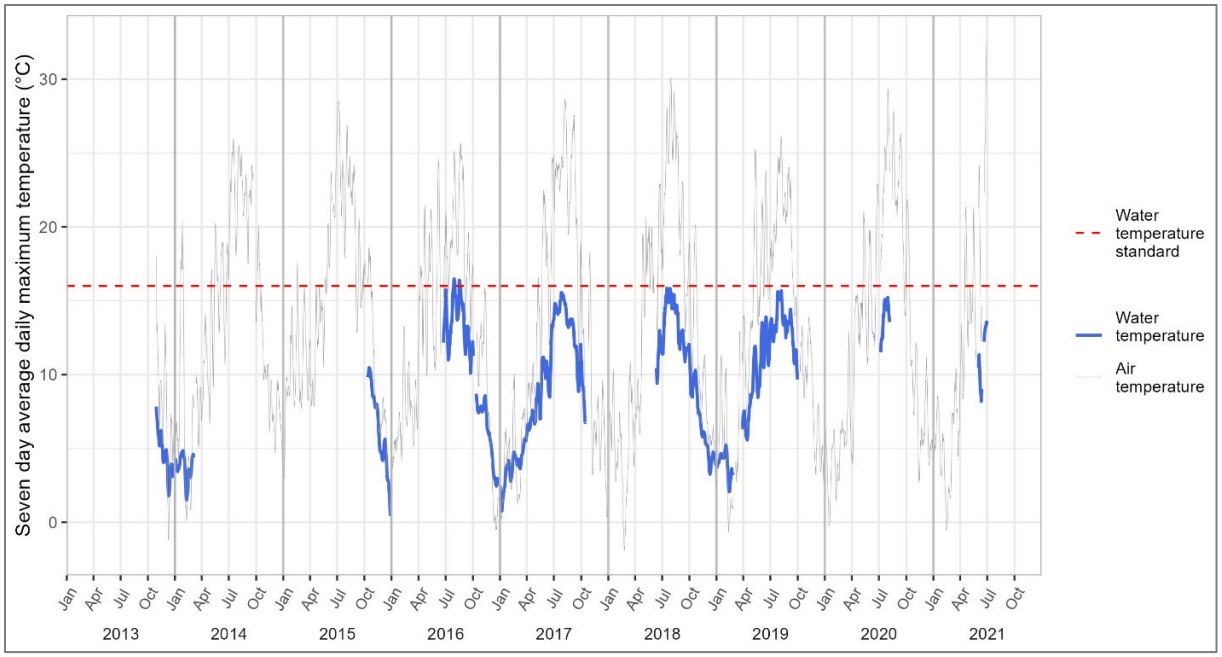

Figure 15. Seven-day average of the maximum daily water temperatures at the Nisqually River at Park Boundary Station, 2013 to 2021. The red dashed line at 16°C indicates the state criteria for aquatic life use designation of core summer (June 15 to September 15) salmonid habitat. Any summer water temperature above 16°C constitutes an exceedance of that criterion.

NPS

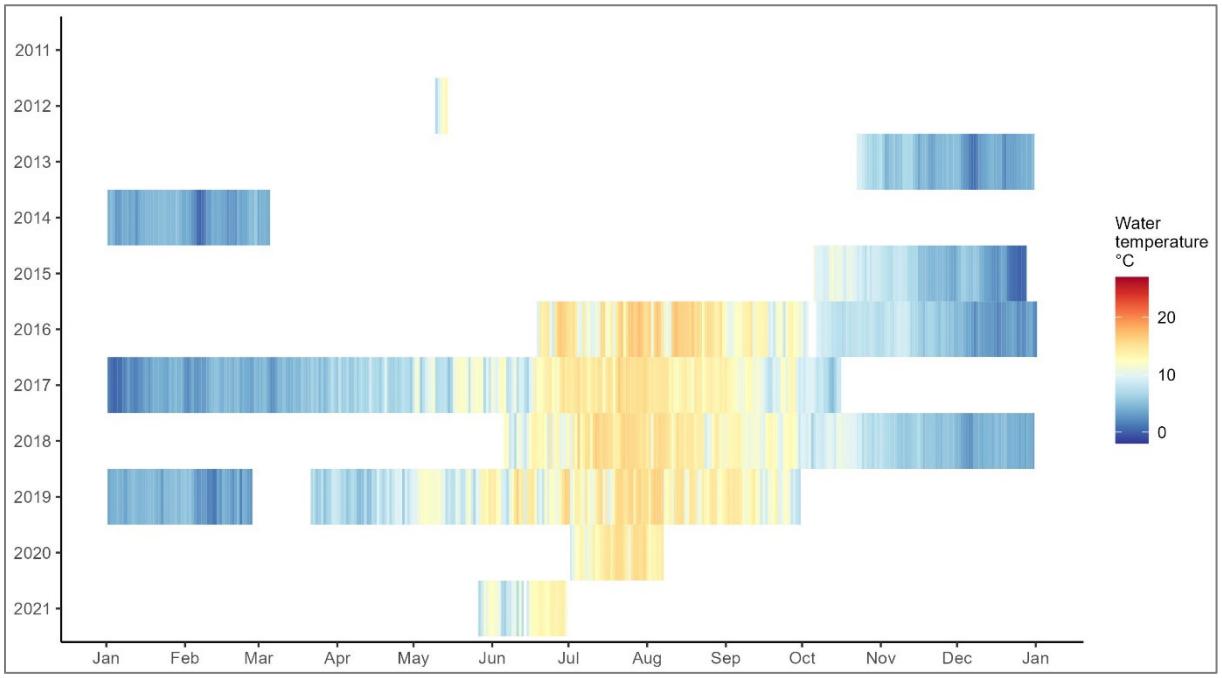

Figure 16. Maximum daily water temperatures at the Nisqually River at Park Boundary Station, 2012 to 2021.

NPS

Table 17. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the seasonal criterion of 16°C in summer (June 15 to September 15) as well as the percentage of the days of the year with no data for that metric at the Nisqually River at Park Boundary Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	100% [A]
2013	none	82%
2014	none	82%
2015	none	79%
2016	7	50%
2017	none	21%
2018	none	44%
2019	none	33%
2020	none	92%
2021	none	94%

[A] While there are continuous water temperature data from 2012, there are not enough observations to calculate a seven-day moving average.

3.3.1.2 Instantaneous Water Temperature and Chemistry Data

Table 18 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Nisqually River at Park Boundary Station. This site's pH was lower than the Washington State criterion during the 2017 sampling event (Table 18).

Table 18. Water temperature and chemistry values from the Nisqually River at Park Boundary Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
10/01/12	11.23	10.40	7.13	64.14	357.71
10/22/13	9.13	10.61	6.53	70.59	20.90
10/07/14	9.94	10.22	6.76	47.01	165.14
10/05/15	10.69	10.21	6.93	67.33	52.70
10/04/16	8.11	11.95	7.57	82.59	19.66
09/21/17	6.36	11.66	6.42 [A]	92.40	26.01
09/24/18	10.50	10.68	7.72	75.00	34.77
10/01/19	5.30	11.61	7.54	73.30	17.04
10/08/20	9.21	10.79	7.10	56.46	49.84
10/04/21	9.51	10.90	7.35	68.39	31.57

[A] pH value lower than Washington State criterion of 6.5–8.5 (also in red font).

Table 18 (continued). Water temperature and chemistry values from the Nisqually River at Park Boundary Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
Minimum	**5.30**	**10.21**	**6.42**	**47.01**	**17.04**
Maximum	**11.23**	**11.95**	**7.72**	**92.40**	**357.71**

[A] pH value lower than Washington State criterion of 6.5–8.5 (also in red font).

3.3.1.3 Channel Morphology Metrics

Table 19 presents channel morphology measurements for the Nisqually River at Park Boundary Station, including data on bankfull width, wetted width, and thalweg depth.

Table 19. Channel morphology measurements from the Nisqually River at Park Boundary Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
10/01/12	No Data	40.42	0.68
10/22/13	100.00	25.08	0.58
10/07/14	129.40	31.20	0.76
10/05/15	130.67	22.46	0.67
10/04/16	127.47	30.11	0.59
09/24/18	209.47	15.38	0.65
10/01/19	99.43	16.16	0.58
10/08/20	247.83	32.35	0.68
10/04/21	178.20	13.55	0.55
Minimum	**99.43**	**13.55**	**0.55**
Maximum	**247.83**	**40.42**	**0.76**

3.3.2 Nisqually River at Longmire Station

The Nisqually River at Longmire Station sits on a 500 m long reach, with its lower elevation at 837 m above sea level. The sample reach is in the bottom of a classic U-shaped glacial valley. The narrow floodplain is constrained by debris aprons and is primarily fed by surface runoff from snowpack, glacial melt, and two mountain lakes. The reach is considered third order in the Strahler Classification System (Strahler 1952) and occupies a braided channel, constrained by incision due to dredging. Torrent evidence strongly suggests that both scouring and deposition occur in this sample reach. Average annual aggradation rates from 1997 to 2012 range from ~0 m/year to 0.14 m/year (Beason et al. 2014).

This reach supports an assemblage of fish, amphibians, and insects similar to the Nisqually River at Park Boundary sample reach. NPS biologists have documented three species of fish and six

amphibian species here (Samora et al. 2013b, Tyler et al. 2003, Galvan et al. 2005, Samora and Anderson 2010, Samora et al. 2013a). These biological resources, in combination with the high density of human activity within the watershed, guided the decision to monitor this location. The NPS compound at Longmire—consisting of parking areas, maintenance facilities, residential housing, administrative offices, and a campground—is directly adjacent to the sample reach, further elevating concerns for water quality impairment.

3.3.2.1 Continuous Water Temperature

Figures 17–19 present maximum, minimum, and seven-day average water temperatures for the Nisqually River at Longmire Station in Mount Rainier National Park. The seven-day average of the daily maximum water temperature was not observed to exceed the Washington State water temperature criterion on any days in 2011–2019 (Table 20).

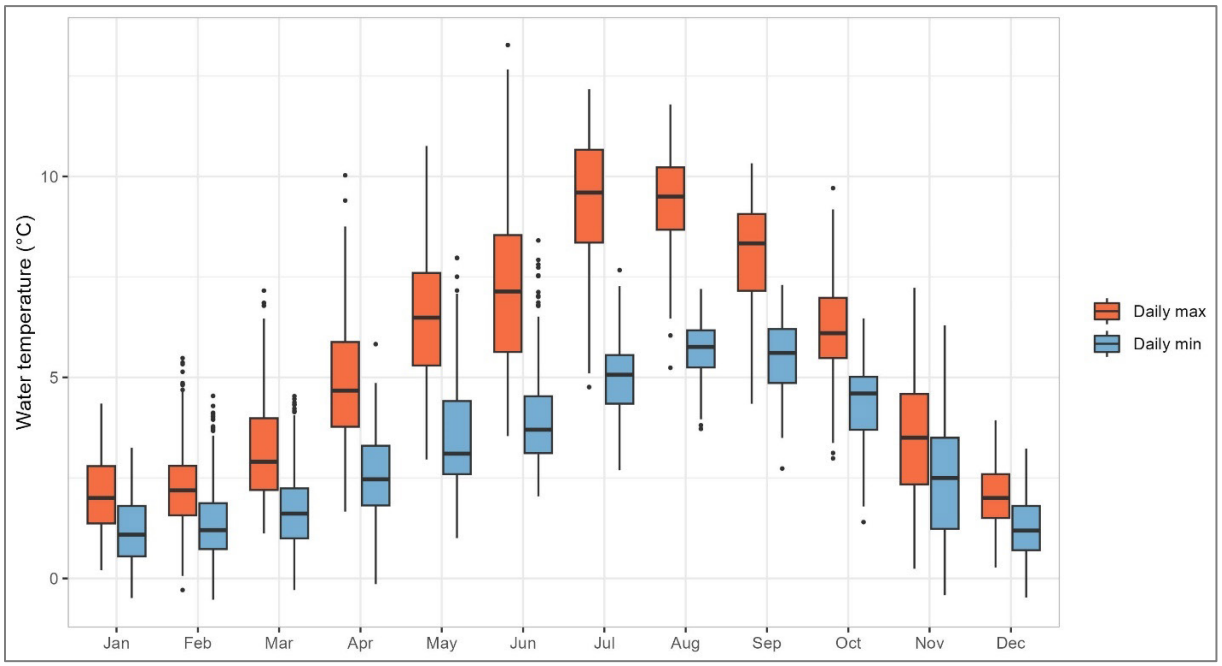

Figure 17. Maximum and minimum daily mean temperatures at the Nisqually River at Longmire Station, 2011 to 2019. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

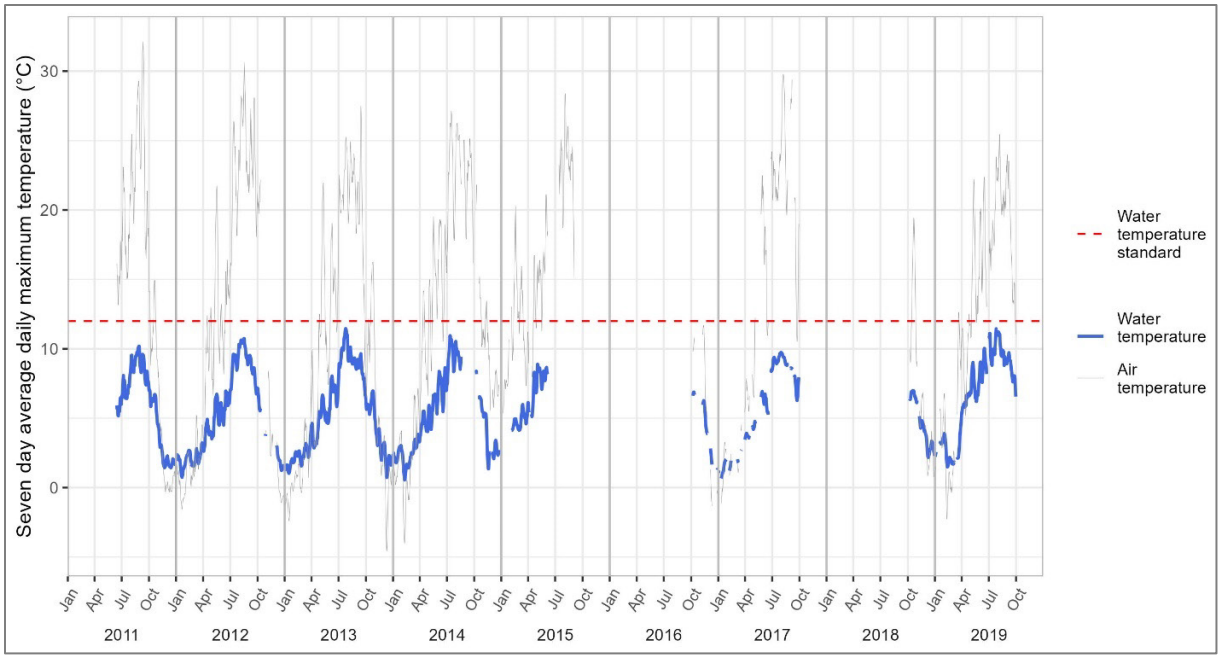

Figure 18. Seven-day average of the maximum daily water temperatures at the Nisqually River at Longmire Station, 2011 to 2019. The red dashed line at 12°C indicates the year-round state criterion for aquatic life use designation of char spawning and rearing. Any seven-day average maximum daily water temperature above 12°C constitutes an exceedance.

NPS

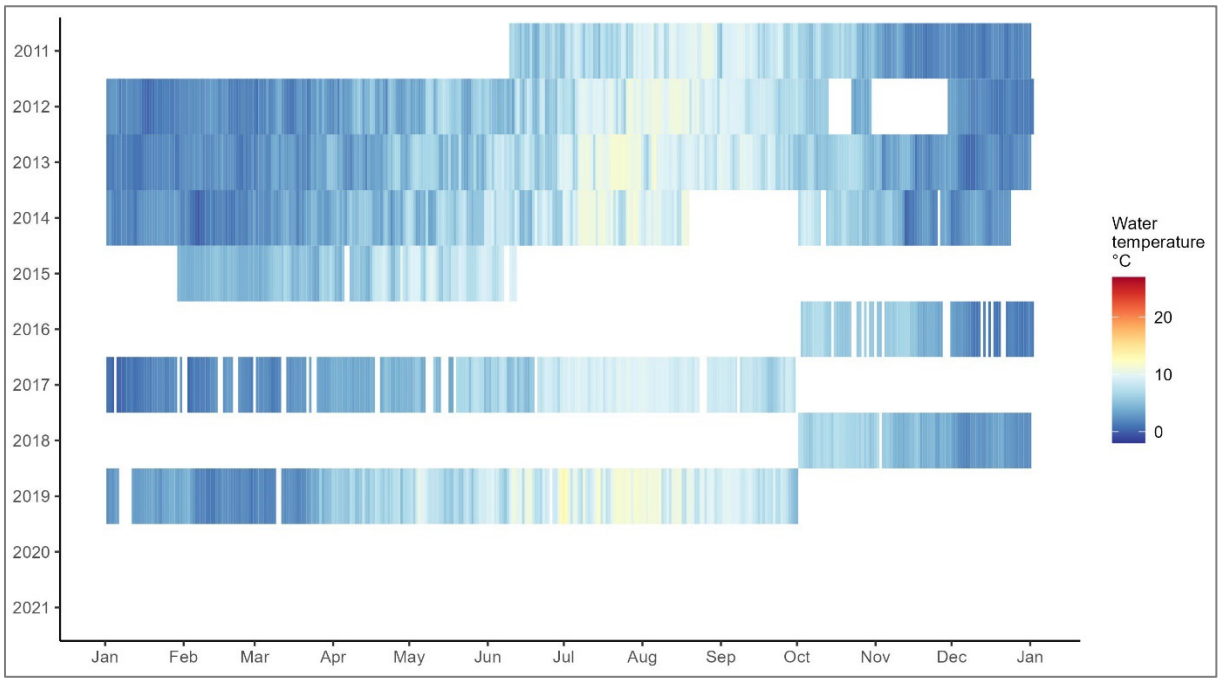

Figure 19. Maximum daily water temperatures at the Nisqually River at Longmire Station, 2011 to 2019.

NPS

Table 20. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 12°C as well as the percentage of the days of the year with no data for that metric at the Nisqually River at Longmire Station, 2011 to 2019.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2011	none	45%
2012	none	14%
2013	none	full dataset
2014	none	20%
2015	none	68%
2016	none	91%
2017	none	54%
2018	none	78%
2019	none	32%

3.3.2.2 Instantaneous Water Temperature and Chemistry Data

Table 21 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Nisqually River at Longmire Station.

Table 21. Water temperature and chemistry values from the Nisqually River at Longmire Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
10/02/12	7.60	11.21	7.24	29.67	186.29
10/22/13	7.76	10.79	7.24	43.20	32.91
10/07/14	8.70	10.24	6.55	33.34	224.14
10/06/15	6.43	11.23	6.72	44.91	62.44
10/04/16	6.10	12.23	7.40	54.90	17.29
10/02/17	6.70	11.65	7.28	58.06	20.06
09/24/18	6.10	11.63	7.52	53.77	38.84
10/01/19	3.70	11.79	7.42	52.47	11.79
10/05/20	8.33	10.65	7.03	35.00	141.43
10/04/21	3.23	12.52	7.24	52.57	9.78
Minimum	**3.23**	**10.24**	**6.55**	**29.67**	**9.78**
Maximum	**8.70**	**12.52**	**7.52**	**58.06**	**224.14**

3.3.2.3 Channel Morphology Metrics

Table 22 presents channel morphology measurements for Nisqually River at Longmire Station, including data on bankfull width, wetted width, and thalweg depth.

Table 22. Channel morphology measurements from the Nisqually River at Longmire Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
10/02/12	78.33	19.92	0.52
10/22/13	64.83	17.36	0.63
10/07/14	91.10	20.00	0.59
10/06/15	78.40	12.50	0.47
10/04/16	68.70	12.32	0.54
10/02/17	23.77	11.21	0.52
09/24/18	77.03	10.27	0.48
10/01/19	61.87	11.85	0.54
10/05/20	82.03	16.23	0.58
10/04/21	52.77	13.00	0.56
Minimum	**23.77**	**10.27**	**0.47**
Maximum	**91.10**	**20.00**	**0.63**

3.3.3 Nisqually River at Glacier Bridge Station

The Nisqually River at Glacier Bridge sample reach is 400 m long and starts at 1,158 m above sea level. This reach is a second order (Strahler 1952) braided channel, located in a narrow valley constrained by debris aprons. Torrent evidence strongly suggests that both scouring and deposition occur in this sample reach.

For this reach, NPS staff sought to monitor the heightened risks posed to biological resources by infrastructure and human use at this site. This station is impacted by the Highway 706 crossing at Glacier Bridge, riverbank protection structures, water withdrawal from a tributary to supply the Paradise Visitor Complex, discharge of treated waste from the Paradise sewage treatment plant into the Nisqually River, storm water runoff from roads and bridges, and road maintenance that includes frequent deposition of fallen rock in the Nisqually River.

This sample reach supports an assemblage of fish and amphibians similar to the downstream locations on the Nisqually River. Documented taxa include two species of fish (Samora et al. 2013b) and two species of amphibians (Galvan et al. 2005, Samora et al. 2013a).

3.3.3.1 Continuous Water Temperature Data

Figures 20–22 present maximum, minimum, and seven-day average water temperatures for the Nisqually River at Glacier Bridge Station in Mount Rainier National Park. Observations did not find

the seven-day average of the daily maximum water temperature to exceed the state water temperature criterion on any days between 2013 and 2019, though there are large gaps in the available data (Table 23).

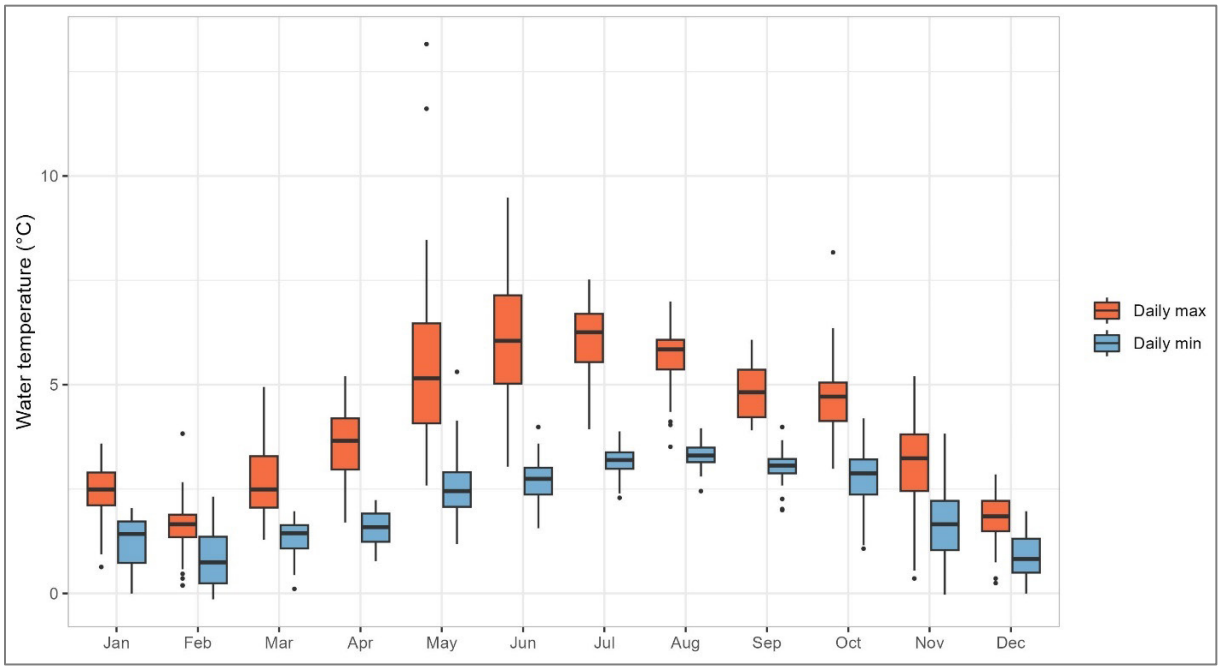

Figure 20. Maximum and minimum daily mean temperatures at the Nisqually River at Glacier Bridge Station, 2013 to 2019. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.
NPS

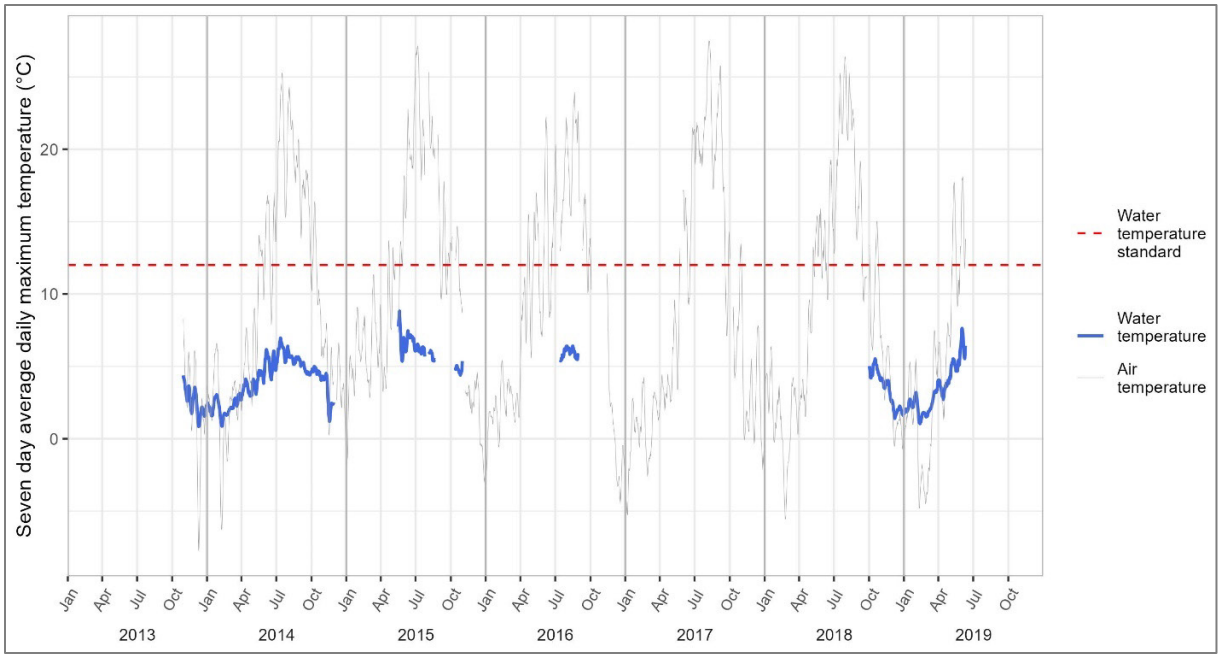

Figure 21. Seven-day average of the maximum daily water temperatures at the Nisqually River at Glacier Bridge Station, 2013 to 2019. The red dashed line at 12°C indicates the year-round state criterion for aquatic life use designation of char spawning and rearing. Any seven-day average maximum daily water temperature above 12°C constitutes an exceedance.

NPS

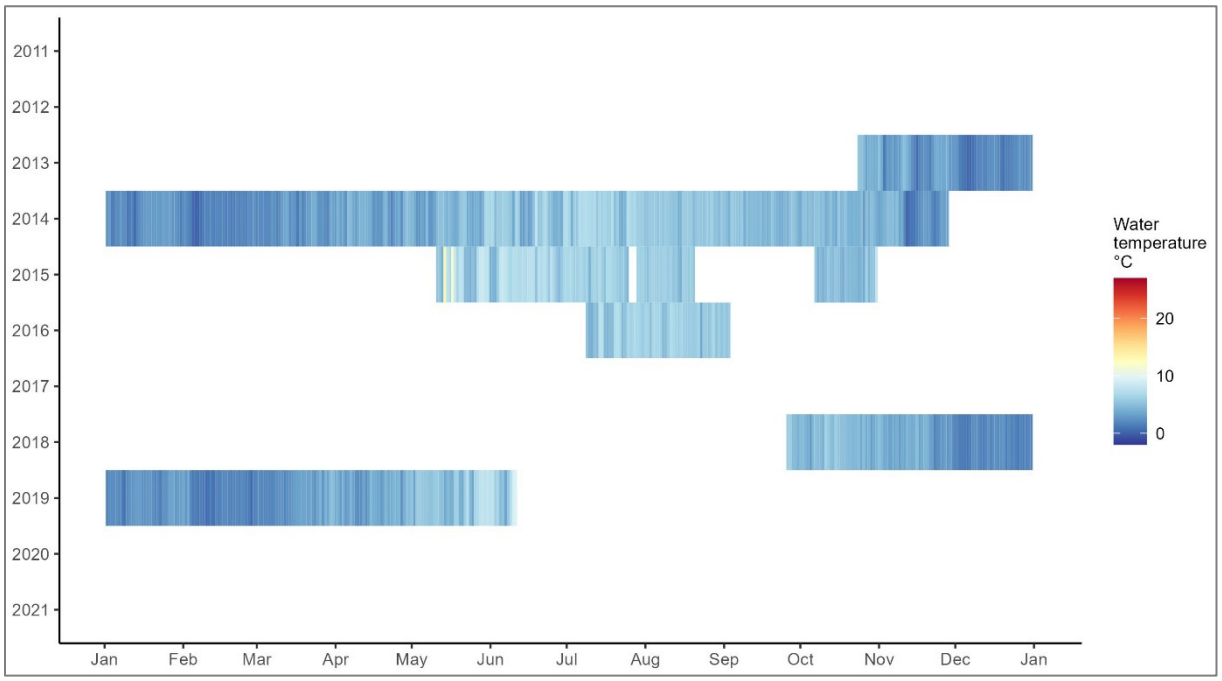

Figure 22. Maximum daily water temperatures at the Nisqually River at Glacier Bridge Station, 2013 to 2019.

NPS

Table 23. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 12°C as well as the percentage of the days of the year with no data for that metric at the Nisqually River at Glacier Bridge Station, 2013 to 2019.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2013	none	83%
2014	none	9%
2015	none	71%
2016	none	86%
2017	none	100%
2018	none	75%
2019	none	56%

3.3.3.2 Instantaneous Water Temperature and Chemistry Data

Table 24 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Nisqually River at Glacier Bridge Station.

Table 24. Water temperature and chemistry values from the Nisqually River at Glacier Bridge Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (ºC)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
10/02/12	3.91	12.00	7.37	21.48	211.29
10/23/13	3.14	11.71	7.21	43.94	62.20
10/08/14	3.73	11.34	6.74	33.41	106.46
10/06/15	4.70	11.36	6.97	37.43	79.16
10/04/16	3.80	12.34	7.45	52.80	31.26
10/03/17	3.04	12.88	7.49	63.10	39.29
09/25/18	4.90	11.61	7.39	43.66	200.86
09/30/19	3.90	11.29	7.48	52.37	22.93
10/08/20	5.46	11.09	6.86	27.53	75.49
10/05/21	4.60	11.66	7.03	41.77	37.81
Minimum	**3.04**	**11.09**	**6.74**	**21.48**	**22.93**
Maximum	**5.46**	**12.88**	**7.49**	**63.10**	**211.29**

3.3.3.3 Channel Morphology Metrics

Table 25 presents channel morphology measurements for the Nisqually River at Glacier Bridge Station, including data on bankfull width, wetted width, and thalweg depth.

Table 25. Channel morphology measurements from the Nisqually River at Glacier Bridge Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
10/02/12	105.33	11.05	0.95
10/23/13	30.40	9.42	0.76
10/08/14	179.77	13.01	0.54
10/06/15	32.83	10.50	0.47
10/04/16	47.00	7.64	0.46
10/03/17	113.60	8.31	0.42
09/25/18	155.67	10.12	0.66
09/30/19	39.57	6.84	0.48
10/08/20	123.13	8.20	0.66
10/05/21	148.37	8.26	0.55
Minimum	**30.40**	**6.84**	**0.42**
Maximum	**179.77**	**13.01**	**0.95**

3.3.4 Paradise River Station

Paradise River is primarily fed by surface runoff from snowpack and glacial melt. The Paradise River sample reach is 150 m long and starts at 1,354 m above sea level.. In a narrow valley constrained by bedrock, boulder walls, and debris aprons, the reach exists within a single channel of a second order stream (Strahler 1952).

Potential impacts to water quality at the Paradise River location include a nearby dense network of paved roads, paved trails, and large paved areas for parking. The network of roads within the Paradise River watershed ends at Paradise, which is one of the most popular visitor destinations in Mount Rainier National Park. The visitor complex at Paradise is composed of the Jackson Visitor Center, the Paradise Inn, the Guide House, the Paradise Ranger Station, and a water supply dam on Edith Creek (upstream in the watershed from the Paradise Creek site). This supply dam requires occasional sediment excavation to maintain. Furthermore, the adjacent Narada Falls area has storage sheds used for road maintenance equipment and materials.

These human activities could imperil the five amphibian species documented from the Paradise River sample reach (Samora et al. 2013a). While a 57-m high waterfall that lies just below the start of the Paradise River sample reach blocks all fish passage, four species of fish have been documented below the falls (Samora et al. 2013b).

3.3.4.1 Continuous Water Temperature Data

Figures 23–25 present maximum, minimum, and seven-day average water temperatures for the Paradise River Station in Mount Rainier National Park. The monitoring program did not find any

exceedances of the seven-day average daily maximum state water temperature criterion of 12°C between 2012 and 2021 (Table 26).

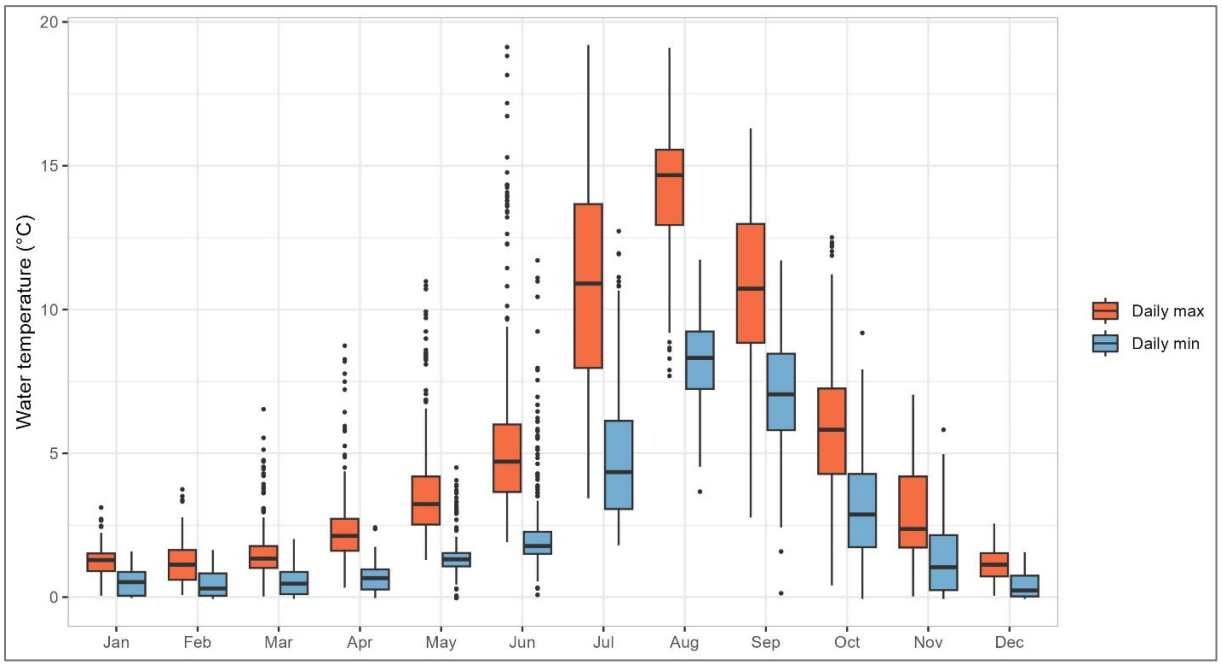

Figure 23. Maximum and minimum daily mean temperatures at the Paradise River Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

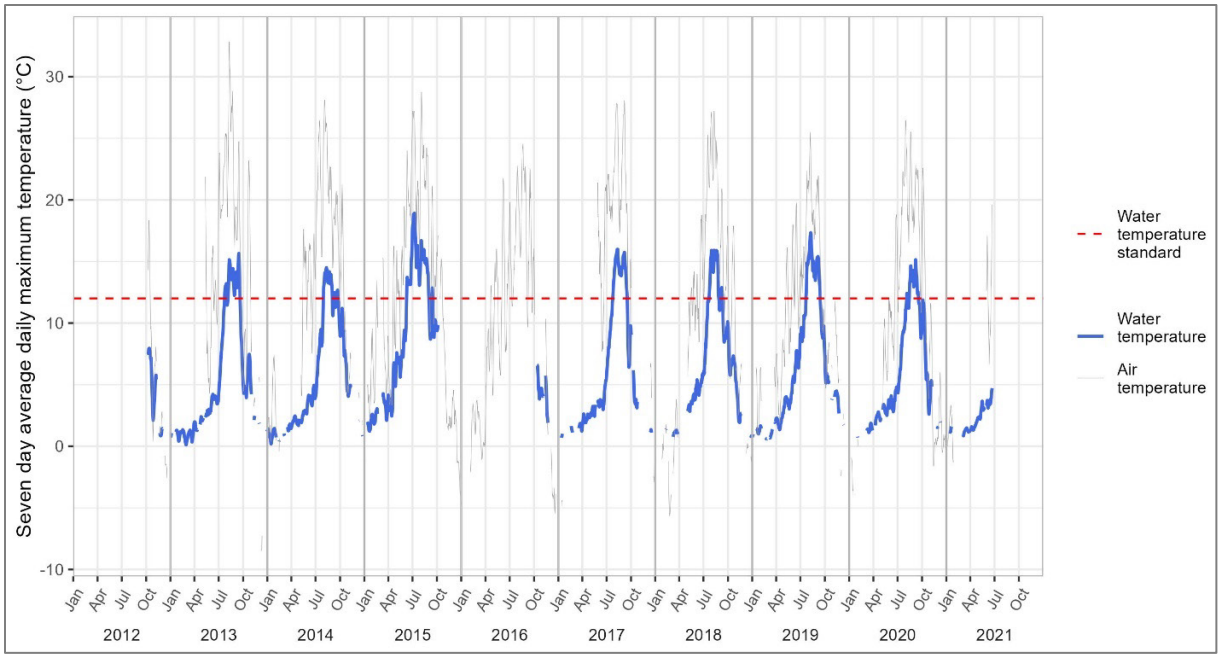

Figure 24. Seven-day average of the maximum daily water temperatures at the Paradise River Station, 2012 to 2021. The red dashed line at 12°C indicates the year-round state criterion for aquatic life use designation of char spawning and rearing. Any seven-day average maximum daily water temperature above 12°C constitutes an exceedance.

NPS

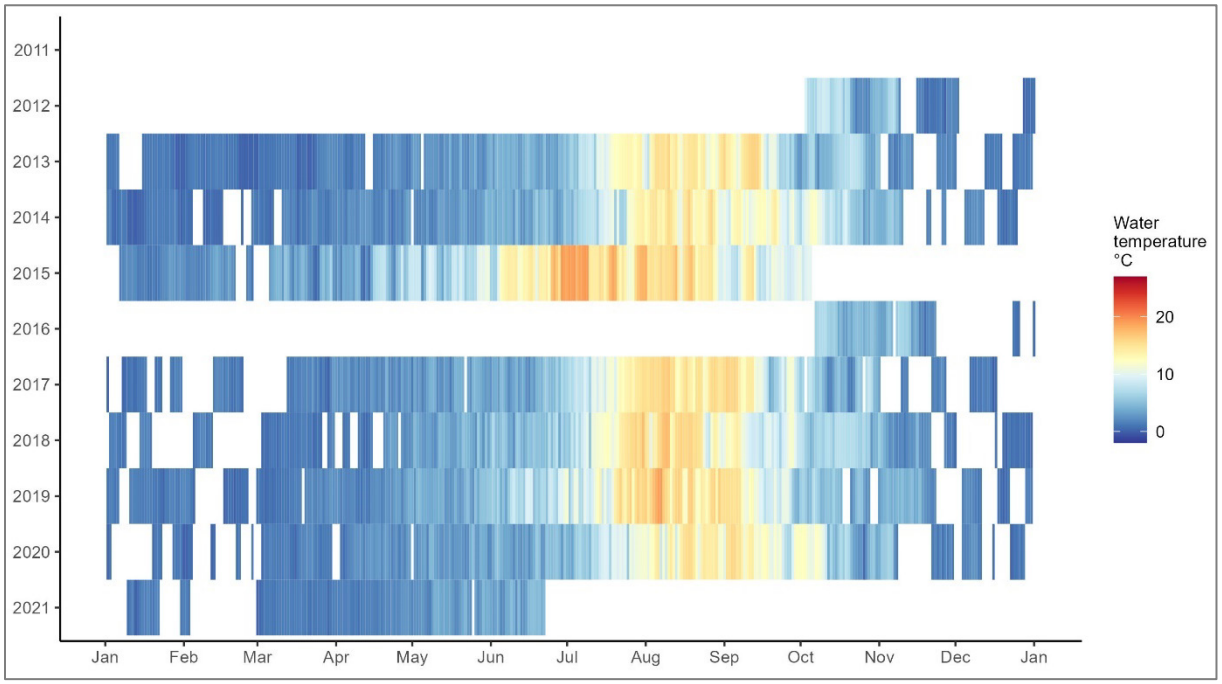

Figure 25. Maximum daily water temperatures at the Paradise River Station, 2012 to 2021.

NPS

Table 26. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the state criterion of 12°C as well as the percentage of the days of the year with no data for that metric at the Paradise River Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	88%
2013	55	23%
2014	40	25%
2015	87	32%
2016	none	91%
2017	54	39%
2018	44	37%
2019	54	27%
2020	38	36%
2021	none	69%

3.3.4.2 Instantaneous Water Temperature and Chemistry Data

Table 27 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Paradise River Station.

Table 27. Water temperature and chemistry values from the Paradise River Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
10/02/12	7.96	10.52	7.68	158.80	0.59
10/23/13	3.66	11.24	7.15	91.81	0.59
09/24/14	8.50	9.86	6.90	94.54	0.53
10/06/15	8.80	10.21	7.94	245.00	0.18
10/04/16	4.90	11.65	7.62	120.17	0.68
10/03/17	4.61	11.90	7.85	178.40	0.39
09/25/18	6.80	10.86	8.10	188.37	1.56
10/02/19	3.10	11.34	7.89	153.20	0.17
10/07/20	9.27	9.91	7.94	173.44	0.28
10/05/21	6.00	10.79	7.78	152.81	0.34
Minimum	**3.10**	**9.86**	**6.90**	**91.81**	**0.17**
Maximum	**9.27**	**11.90**	**8.10**	**245.00**	**1.56**

3.3.4.3 Channel Morphology Metrics

Table 28 presents channel morphology measurements for the Paradise Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 28. Channel morphology measurements from the Paradise River Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
10/02/12	8.37	5.47	0.48
10/23/13	8.80	6.14	0.48
09/24/14	7.97	6.46	0.59
10/06/15	9.03	5.34	0.31
10/04/16	7.60	6.08	0.59
10/03/17	7.70	5.07	0.52
09/25/18	9.30	5.01	0.43
10/02/19	9.97	6.38	0.40
10/07/20	9.77	3.67	0.36
10/05/21	10.37	6.10	0.51
Minimum	**7.60**	**3.67**	**0.31**
Maximum	**10.37**	**6.46**	**0.59**

3.3.5 Ohanapecosh River Station

The Ohanapecosh River Station is 500 m long and starts at 583 m above sea level. Snowpack, glacial melt, groundwater, and approximately 15 mountain lakes are the primary water sources for the reach. The station is on a fifth order (Strahler 1952) reach of the Ohanapecosh River located in a canyon, constrained by bedrock and boulders.

NCCN water quality monitoring in the Ohanapecosh River watershed tracks potential impacts from NPS infrastructure, roads, trails, and visitor use. Specific examples include the Ohanapecosh Visitor Center and campground, ranger and maintenance stations, paved access roads, paved areas for parking, and waste treatment facilities. The NPS also withdraws water from Laughingwater Creek and an unnamed creek in the Ohanapecosh River watershed to supply various facilities. These activities could have adverse effects on several aquatic species: two species of fish that have been documented in the reach (Samora et al. 2013b), another five fish species that may be present but have not been documented (Wydoski and Whitney 2003), six different species of amphibians documented in the Ohanapecosh River sample reach, and an additional five that have been documented in the watershed (Galvan et al. 2005, Samora et al. 2013a).

3.3.5.1 Continuous Water Temperature Data

Figures 26–28 present maximum, minimum, and seven-day average water temperatures for the Ohanapecosh River Station in Mount Rainier National Park. The monitoring program did not find

any exceedances of the seven-day average daily maximum water temperature criterion of 16°C between 2012 and 2021 (Table 29).

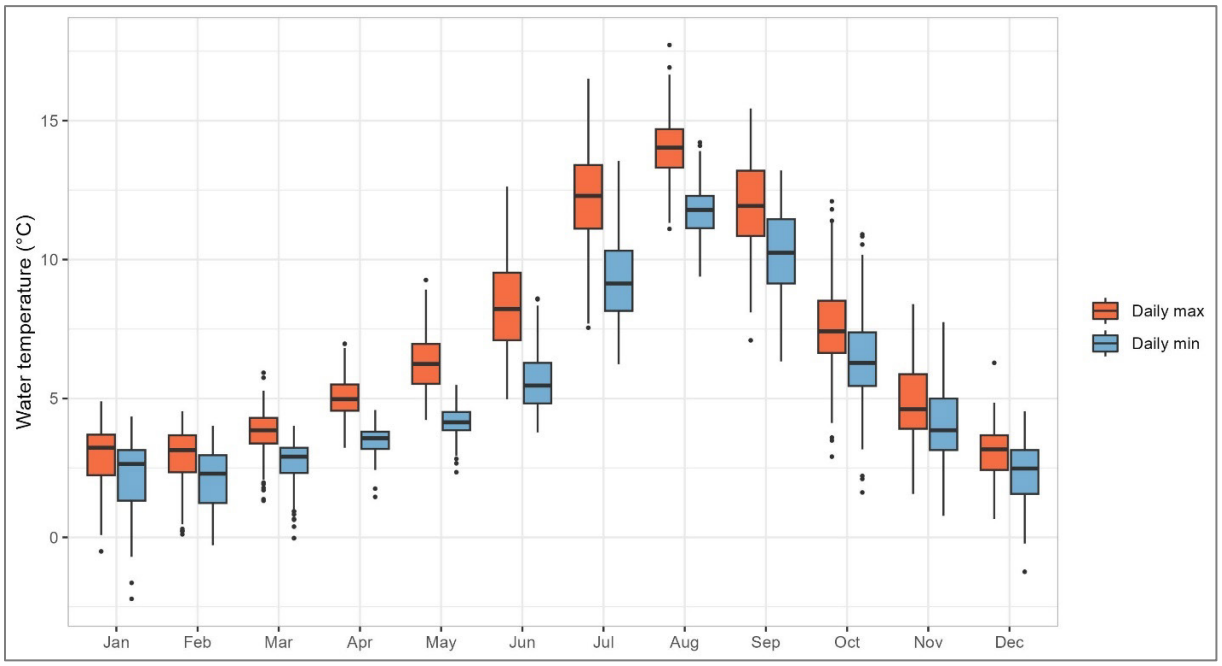

Figure 26. Maximum and minimum daily mean temperatures at the Ohanapecosh River Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

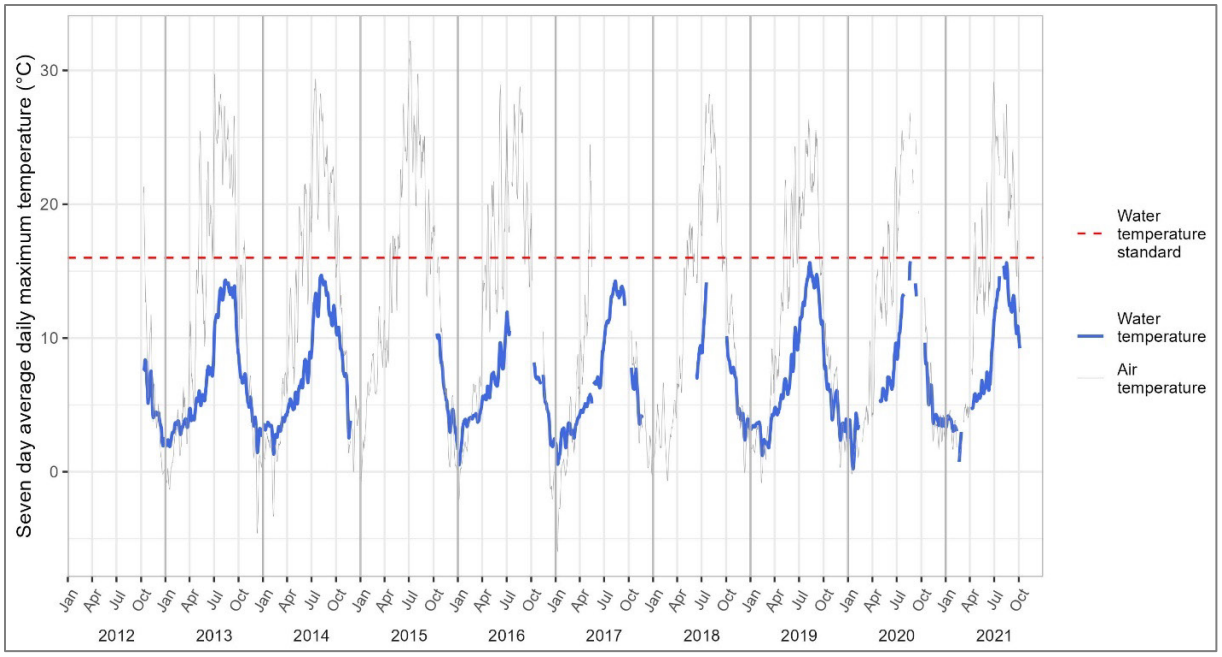

Figure 27. Seven-day average of the maximum daily water temperatures at the Ohanapecosh River Station, 2012 to 2021. The red dashed line at 16°C indicates the state criterion for aquatic life use designation of core summer (June 15 to September 15) salmonid habitat. Any summer water temperature above 16°C constitutes an exceedance.

NPS

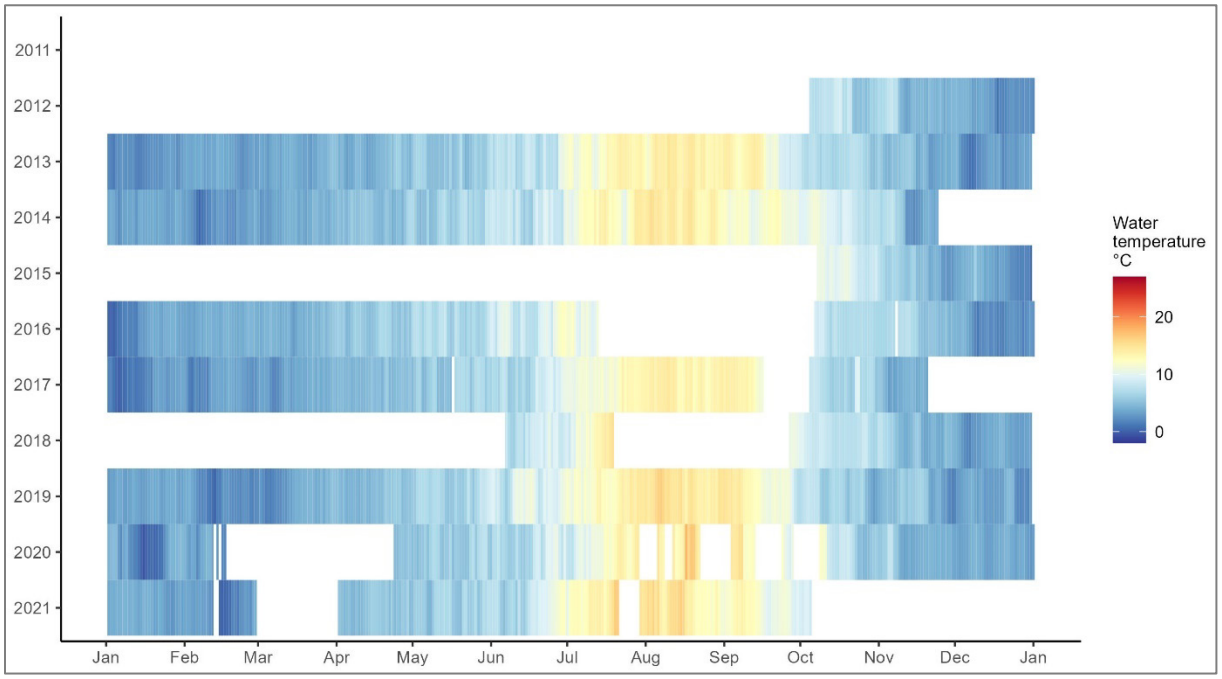

Figure 28. Maximum daily water temperatures at the Ohanapecosh River Station, 2012 to 2021.

NPS

Table 29. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the seasonal criterion of 16°C in summer (June 15 to September 15) as well as the percentage of the days of the year with no data for that metric at the Ohanapecosh River Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	78%
2013	none	full dataset
2014	none	10%
2015	none	78%
2016	none	27%
2017	none	20%
2018	none	65%
2019	none	full dataset
2020	none	40%
2021	none	40%

3.3.5.2 Instantaneous Water Temperature and Chemistry Data

Table 30 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Ohanapecosh River Station.

Table 30. Water temperature and chemistry values at the Ohanapecosh River Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
10/03/12	7.21	11.77	7.61	57.37	0.69
10/23/13	6.90	11.36	7.02	49.47	0.43
09/23/14	11.51	10.12	6.96	55.83	1.76
10/07/15	9.80	10.79	7.70	75.86	0.40
10/05/16	8.47	12.30	7.52	59.50	0.35
10/04/17	6.60	12.16	7.51	66.10	0.41
09/26/18	7.80	11.51	7.46	64.60	0.32
10/02/19	5.40	11.78	7.37	56.80	0.23
10/07/20	9.60	10.77	7.15	58.10	0.69
10/05/21	8.40	11.33	7.21	56.17	0.82
Minimum	**5.40**	**10.12**	**6.96**	**49.47**	**0.23**
Maximum	**11.51**	**12.30**	**7.70**	**75.86**	**1.76**

3.3.5.3 Channel Morphology Metrics

Table 31 presents channel morphology measurements for the Ohanapecosh River Station, including data on bankfull width, wetted width, and thalweg depth.

Table 31. Channel morphology measurements from the Ohanapecosh River Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
10/03/12	23.37	14.80	0.89
10/23/13	32.90	17.86	0.86
09/23/14	30.50	16.46	0.96
10/07/15	24.40	17.45	0.72
10/05/16	28.85	17.24	0.88
10/04/17	41.07	16.80	0.64
09/26/18	32.33	16.59	0.77
10/02/19	62.33	17.93	0.66
10/07/20	33.17	16.23	0.92
10/05/21	26.00	16.04	0.70
Minimum	**23.37**	**14.80**	**0.64**
Maximum	**62.33**	**17.93**	**0.96**

3.3.6 White River at the Park Boundary Station

The White River at the Park Boundary sample reach is 500 m long and starts at 863 m above sea level, fed primarily by runoff from snowpack, glacial melt, and at least 13 mountain lakes. The station is on a fourth order reach (Strahler 1952) of the White River that occupies an unconstrained braided channel in a broad valley. Torrent evidence suggests that both scouring and deposition occur in this sample reach.

The impacts of roads, trails, NPS infrastructure, and recreational use are the principal threats to water quality and aquatic life, including several species of federally listed salmon and native char, at this site. A network of roads within the watershed leads to the Sunrise recreation site, which includes the Sunrise Visitor Center, the Sunrise Day Lodge, paved access roads, and large parking areas. To support the numerous facilities within the watershed, the NPS withdraws water from Klickitat Creek and two other unnamed tributaries. Additional hazards are associated with the Washington Department of Transportation waste transfer station, adjacent to the main stem of the White River. Runoff from this location, which may come in contact with stored road and facility maintenance materials, could enter the White River, possibly threatening water quality. Lastly, there are multiple areas along the watershed's road network that require flood protection structures. Rip rap revetments, rock barbs, levees, and road stream crossings require frequent maintenance and stream disturbance, and many are not designed for aquatic biological connectivity. Such infrastructure could impact the eight species of fish documented here—including federally listed Chinook salmon (*Oncorhynchus*

tshawytscha) and bull trout (*Salvelinus confluentus*)—as well as the seven different species of amphibians documented in the sample reach (Galvan et al. 2005, Samora et al. 2013a).

3.3.6.1 Continuous Water Temperature Data

Figures 29–31 present maximum, minimum, and seven-day average water temperatures for the White River at Park Boundary Station in Mount Rainier National Park. The seven-day average of the daily maximum water temperature exceeded the criterion of 12°C on 338 days between 2012 and 2021 (Table 32).

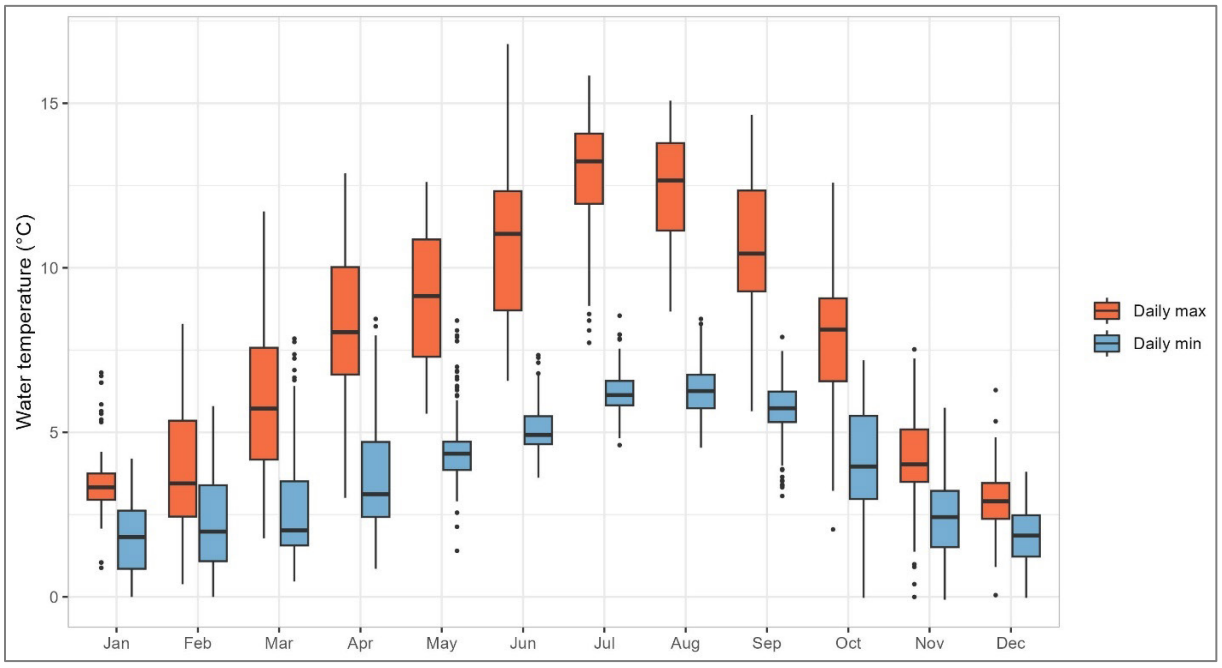

Figure 29. Maximum and minimum daily mean temperatures at the White River at Park Boundary Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

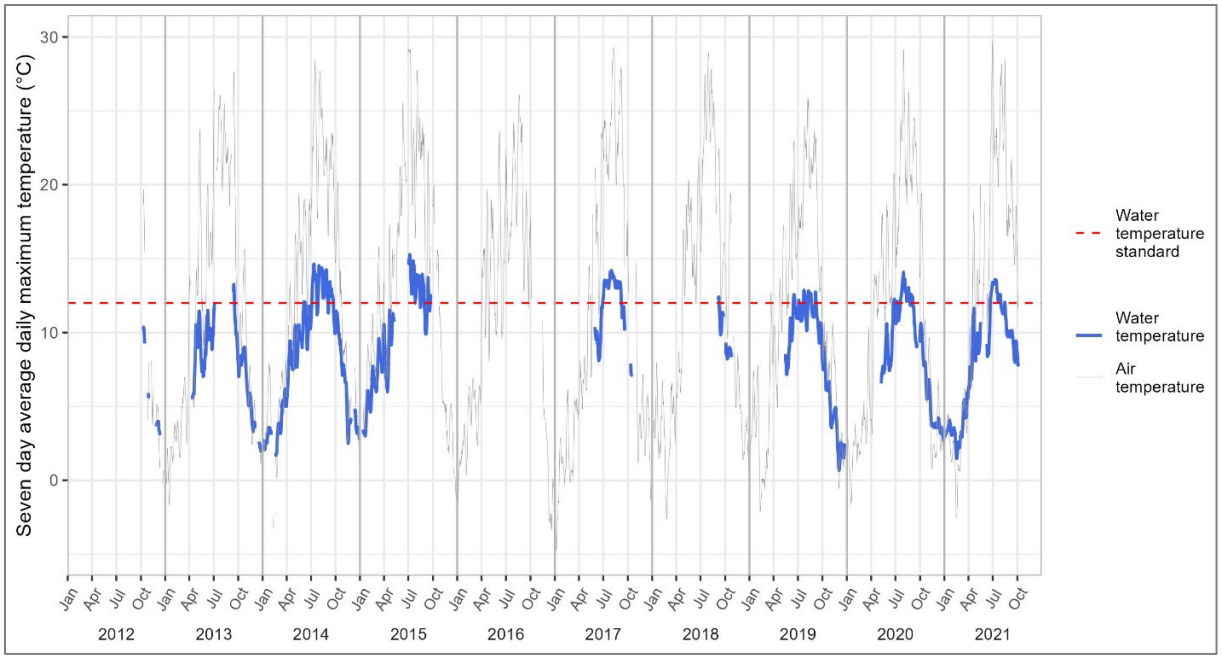

Figure 30. Seven-day average of the maximum daily water temperatures at the White River at Park Boundary Station, 2012 to 2021. The red dashed line at 12°C indicates the year-round state criterion for aquatic life use designation of char spawning and rearing. Any seven-day average maximum daily water temperature above 12°C constitutes an exceedance.

NPS

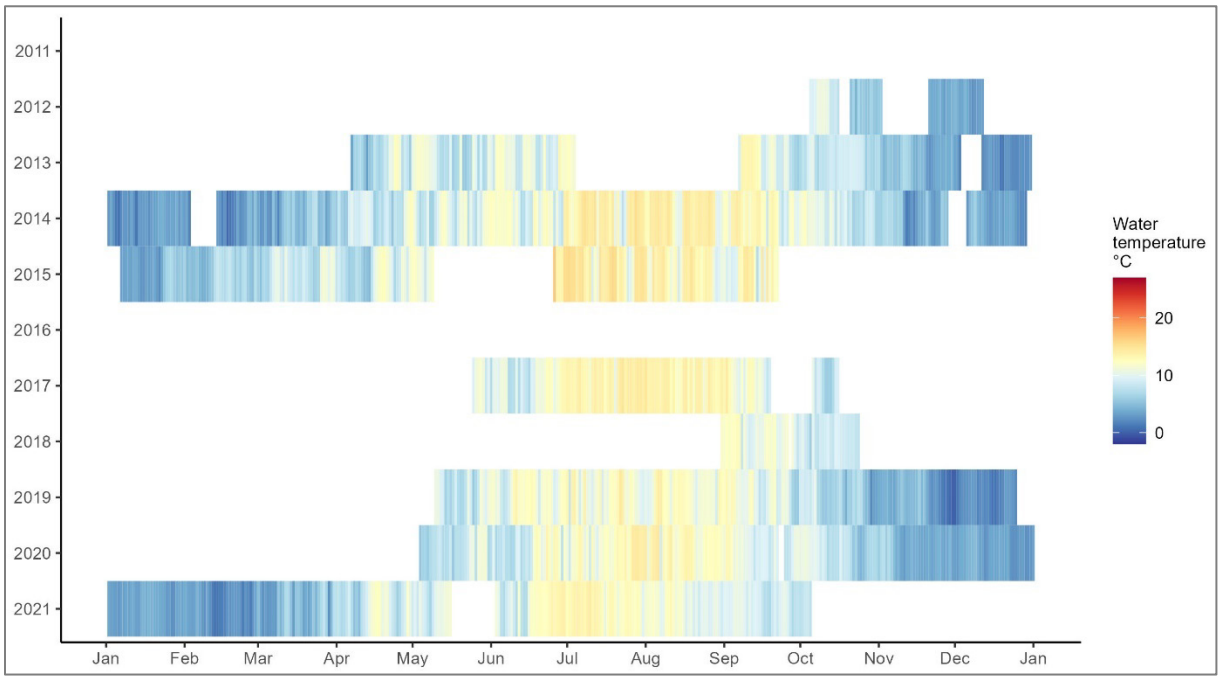

Figure 31. Maximum daily water temperatures at the White River at Park Boundary Station, 2012 to 2021.

NPS

Table 32. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 12°C as well as the percentage of the days of the year with no data for that metric at the White River at Park Boundary Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	92%
2013	5	51%
2014	76	8%
2015	64	45%
2016	none	100%
2017	70	68%
2018	2	88%
2019	31	39%
2020	49	38%
2021	41	30%

3.3.6.2 Instantaneous Water Temperature and Chemistry Data

Table 33 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the White River at Park Boundary Station.

Table 33. Water temperature and chemistry values from the White River at Park Boundary Station, 2012 to 2021.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
10/04/12	2.83	12.77	7.39	47.21	65.14
10/24/13	4.80	11.52	7.11	58.00	10.02
09/23/14	7.29	10.81	6.73	37.70	215.14
10/08/15	7.60	11.11	6.85	52.00	258.14
10/06/16	7.73	12.00	7.39	58.87	36.86
10/05/17	4.27	12.65	7.33	61.03	28.00
09/27/18	6.70	11.37	7.42	48.90	133.71
10/01/19	2.60	12.18	7.43	54.76	34.57
10/06/20	6.10	11.30	7.03	44.99	80.41
10/06/21	5.69	11.70	7.28	59.30	30.13
Minimum	**2.60**	**10.81**	**6.73**	**37.70**	**10.02**
Maximum	**7.73**	**12.77**	**7.43**	**61.03**	**258.14**

3.3.6.3 Channel Morphology Metrics

Table 34 presents channel morphology measurements for the White River at Park Boundary Station, including data on bankfull width, wetted width, and thalweg depth.

Table 34. Channel morphology measurements from the White River at Park Boundary Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
10/04/12	90.00	13.59	0.60
10/24/13	116.33	17.97	0.48
09/23/14	65.37	36.61	0.59
10/08/15	88.90	25.28	0.45
10/06/16	103.37	23.50	3.94
10/05/17	123.00	21.26	0.46
09/27/18	95.37	24.41	0.52
10/01/19	104.00	17.18	0.45
10/06/20	98.73	22.18	0.54
10/06/21	107.97	11.56	0.44
Minimum	**65.37**	**11.56**	**0.44**
Maximum	**123.00**	**36.61**	**3.94**

3.3.7 White River at Littorals Station

Higher in elevation than the other station on the White River, this sample reach is primarily fed by the runoff from melting snowpack, glaciers, and approximately five mountain lakes. The 400 m sample reach starts at 1,160 m above sea level on a fourth order segment of the White River (Strahler 1952), occupying an unconstrained, braided channel.

NPS staff documented five species of fish in the White River at Littorals sample reach (Samora et al. 2013b), including federally threatened bull trout (*Salvelinus confluentus*). Based on regional distribution data and habitat requirements, another five fish species may be present but have not been documented (Wydoski and Whitney 2003). NPS staff documented five species of amphibians in the White River at Littorals sample reach, and an additional two in the watershed (Galvan et al. 2005, Samora et al. 2013a). Water quality for these species is potentially impacted by the network of roads associated with the Sunrise Visitor Area. Additionally, this station is located immediately downstream from the Washington Department of Transportation waste transfer facilities.

Continuous water and air temperature data have not been included in this summary for the White River at Littorals site. While water temperature monitoring equipment was initially installed at this location, maintaining a water temperature logger that successfully collected continuous data proved challenging; due to the volatile conditions of the glacial meltwater-driven White River, water temperature loggers were frequently buried or dewatered for extended periods of time, leading to

large gaps in the dataset. Temperature monitoring equipment was removed from this site in 2015, at which point discrete sampling was also discontinued.

3.3.7.1 Instantaneous Water Temperature and Chemistry Data

Table 35 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the White River at Littorals Station in Mount Rainier National Park.

Table 35. Water temperature and chemistry values from the White River at Park Littorals Station, 2012 to 2015.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
10/03/12	5.73	11.43	7.38	39.19	113.13
10/24/13	3.41	11.64	7.26	56.00	27.53
10/08/14	6.10	10.64	6.59	38.59	112.86
10/07/15	6.81	11.17	6.68	46.73	No Data
Minimum	**3.41**	**10.64**	**6.59**	**38.59**	**27.53**
Maximum	**6.81**	**11.64**	**7.38**	**56.00**	**113.13**

3.3.7.2 Channel Morphology Metrics

Table 36 presents channel morphology measurements for the White River at Littorals Station, including data on bankfull width, wetted width, and thalweg depth.

Table 36. Channel morphology measurements from the White River at Littorals Station, 2012 to 2015.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
10/03/12	45.67	11.75	0.56
10/24/13	48.33	10.68	0.44
10/08/14	93.33	18.29	0.52
10/07/15	63.30	17.05	0.44
Minimum	**45.67**	**10.68**	**0.44**
Maximum	**93.33**	**18.29**	**0.56**

3.3.8 Fryingpan Creek Station

Park and network staff did not select Fryingpan Creek initially for water quality monitoring under this program, but they redirected efforts to this location in 2015 after the NPS discontinued White River at Littorals Station (see above). The continuous water and air temperature loggers were both installed in October of 2014, making water year 2015 the first full year of data collection for the continuous temperature parameters. Staff commenced implementing the full monitoring protocol at this station in 2016. Visits typically occurred in the first few weeks of October. Not unlike other sites

located in glacially fed rivers, this station proved challenging for continuous data collection, resulting in large data gaps.

3.3.8.1 Continuous Water Temperature Data

Figures 32–34 present maximum, minimum, and seven-day average water temperatures for the Fryingpan Creek Station in Mount Rainier National Park. The seven-day average of the daily maximum water temperature exceeded the criterion on at least 90 days between 2015 and 2021 (Table 37).

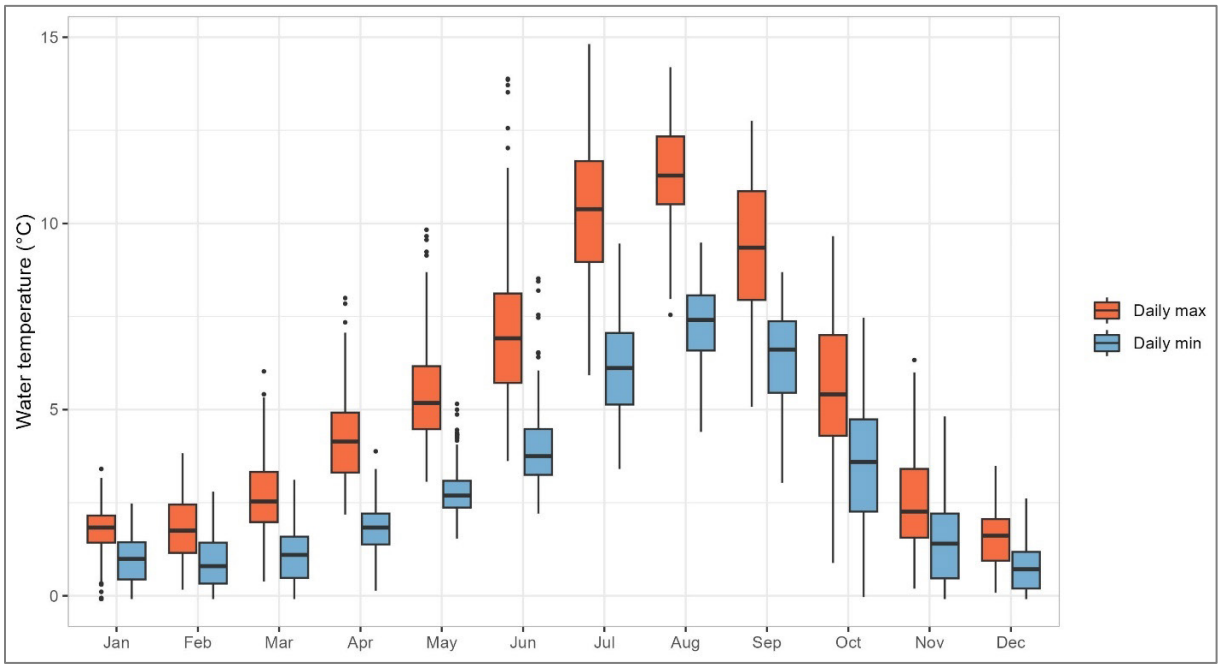

Figure 32. Maximum and minimum daily mean temperatures at Fryingpan Creek Station, 2014 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

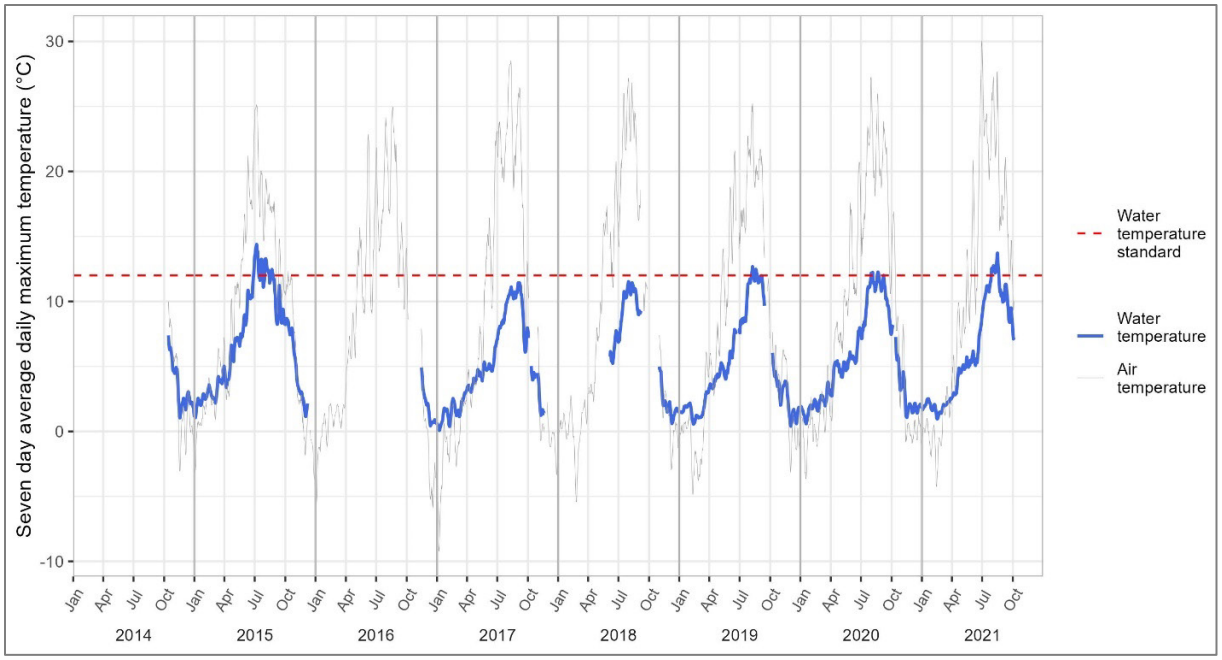

Figure 33. Seven-day average of the maximum daily water temperatures at the Fryingpan Creek Station, 2014 to 2021. The red dashed line at 12°C indicates the year-round state criterion for aquatic life use designation of char spawning and rearing. Any seven-day average maximum daily water temperature above 12°C constitutes an exceedance.

NPS

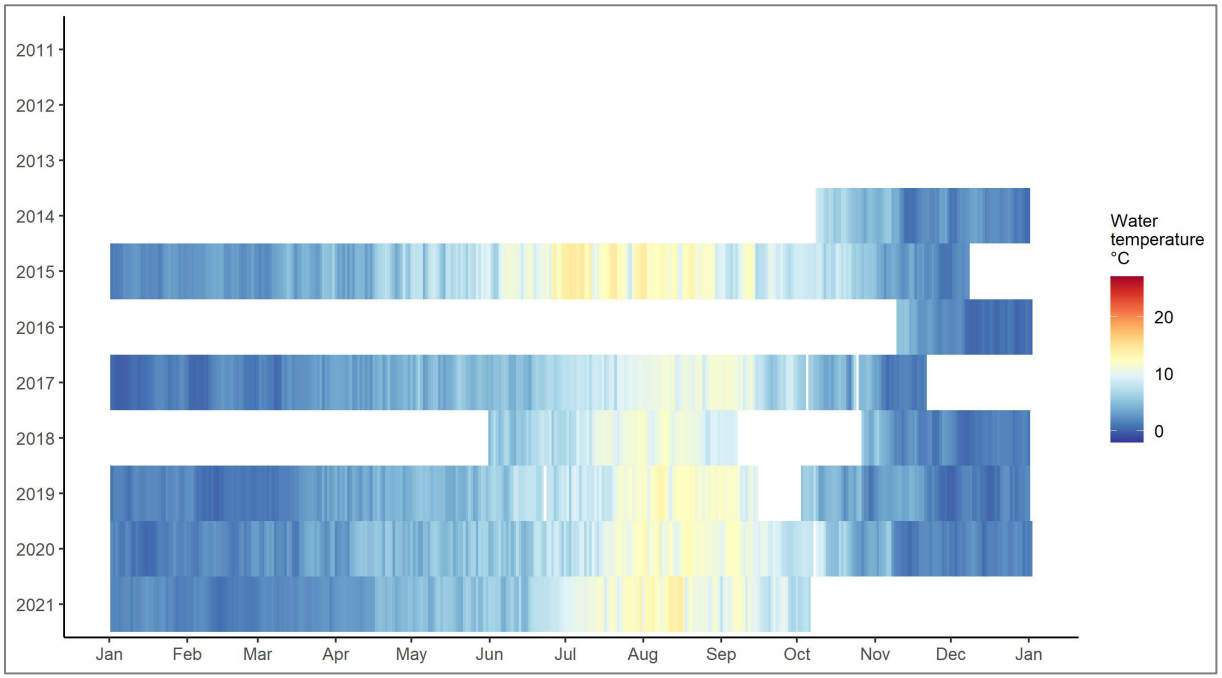

Figure 34. Maximum daily water temperatures at the Fryingpan Creek Station, 2014 to 2021.

NPS

Table 37. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 12°C as well as the percentage of the days of the year with no data for that metric at the Fryingpan Creek Station, 2014 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2014	none	78%
2015	22	7%
2016	none	87%
2017	none	15%
2018	none	58%
2019	5	8%
2020	1	2%
2021	11	24%

3.3.8.2 Instantaneous Water Temperature and Chemistry Data

Table 38 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Fryingpan Creek Station.

Table 38. Water temperature and chemistry values at the Fryingpan Creek Station, 2016 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
10/06/16	5.50	12.10	7.27	30.20	1.33
10/04/17	5.90	11.64	7.04	28.53	0.81
09/26/18	7.70	10.80	7.34	28.10	0.45
10/01/19	4.34	11.26	7.33	28.00	2.12
10/06/20	8.80	10.25	7.02	26.01	2.13
10/06/21	5.74	11.01	7.43	28.50	1.60
Minimum	**4.34**	**10.25**	**7.02**	**26.01**	**0.45**
Maximum	**8.80**	**12.10**	**7.43**	**30.20**	**2.13**

3.3.8.3 Channel Morphology Metrics

Table 39 presents channel morphology measurements for the Fryingpan Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 39. Channel morphology measurements from the Fryingpan Creek Station, 2016 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
10/06/16	44.30	9.44	0.39
10/04/17	33.37	10.34	0.38
09/26/18	48.60	10.81	0.39
10/01/19	42.33	11.10	0.35
10/06/20	44.40	11.25	0.49
10/06/21	40.90	8.25	0.34
Minimum	33.37	8.25	0.34
Maximum	48.60	11.25	0.49

3.4 North Cascades National Park

North Cascades National Park Service Complex is comprised of North Cascades National Park and the Ross Lake and Lake Chelan National Recreation Areas. The Complex drains into the Columbia River, Puget Sound, and the Fraser River in Canada, and most of the land base (93%) is federally designated wilderness. Many non-NPS managed watersheds drain into the park, impacting its aquatic resources. The Park and Recreation Areas all lie in the North Cascades Ecoregion (Omernik 2010), a landscape composed of high, rugged mountains, the greatest concentration of active alpine glaciers in the conterminous United States, and a variety of climatic zones. A dry, continental climate occurs in the east, and mild, maritime, rainforest conditions are found in the west. The Complex is underlain by sedimentary and metamorphic rock, in contrast to the adjoining southern Cascades which are composed of volcanics. Elevations range from 100 to 2,810 m. The minimum and maximum annual precipitations of 43 and 394 cm/year, respectively, are both found in the southeastern portion of the complex (PRISM 2006).

3.4.1 Stehekin River Station

The Stehekin River sample reach is 500 m long and starts at an elevation of 366 m above sea level. Several mountain lakes, groundwater inflow, runoff from snowmelt and 103 glaciers feed the Stehekin River (NPS 2012). The sample reach, on a fifth order stream in the Strahler Classification System (Strahler 1952), sits 2 km upstream of the confluence with Lake Chelan in the bottom of a classic U-shaped glacial valley. It occupies an anastomosing channel that is constrained by incision into alluvial terraces.

Water quality in the Stehekin River is potentially impacted by numerous sources including trails, roads, residential development, pastoral agriculture, NPS infrastructure, recreational use, a hydropower project located on Company Creek, and five documented abandoned mines in the watershed. Among those, the greatest threats to water quality in the lower reaches of the watershed are from residential development, NPS infrastructure, and road maintenance.

Infrastructure and human use could impact the six species of fish documented in the Stehekin River sample reach (Zyskowski 2007, Anthony and Glesne 2013), as well as an additional ten species of

fish that may also be present (Wydoski and Whitney 2003). No amphibian species have been documented in the Stehekin River sample reach, though surveys have documented six species in the watershed (Bury and Adams 2000, WNHP WDFW BLM 2005).

The Stehekin River water quality sampling reach was visited annually from 2011 to 2021 during mid to late September. The NPS installed continuous water and air temperature loggers in September of 2011, resulting in water year 2012 being the first full water year of data collection for the continuous temperature parameters. Since 2011, the Stehekin River sample reach has been reasonably stable, allowing for almost full protocol execution.

3.4.1.1 Continuous Water Temperature Data

Figures 35–37 present maximum, minimum, and seven-day average water temperatures for the Stehekin River Station in North Cascades National Park. The monitoring program did not find any exceedances of the seven-day average daily maximum water temperature criterion of 16°C between 2011 and 2021 (Table 40).

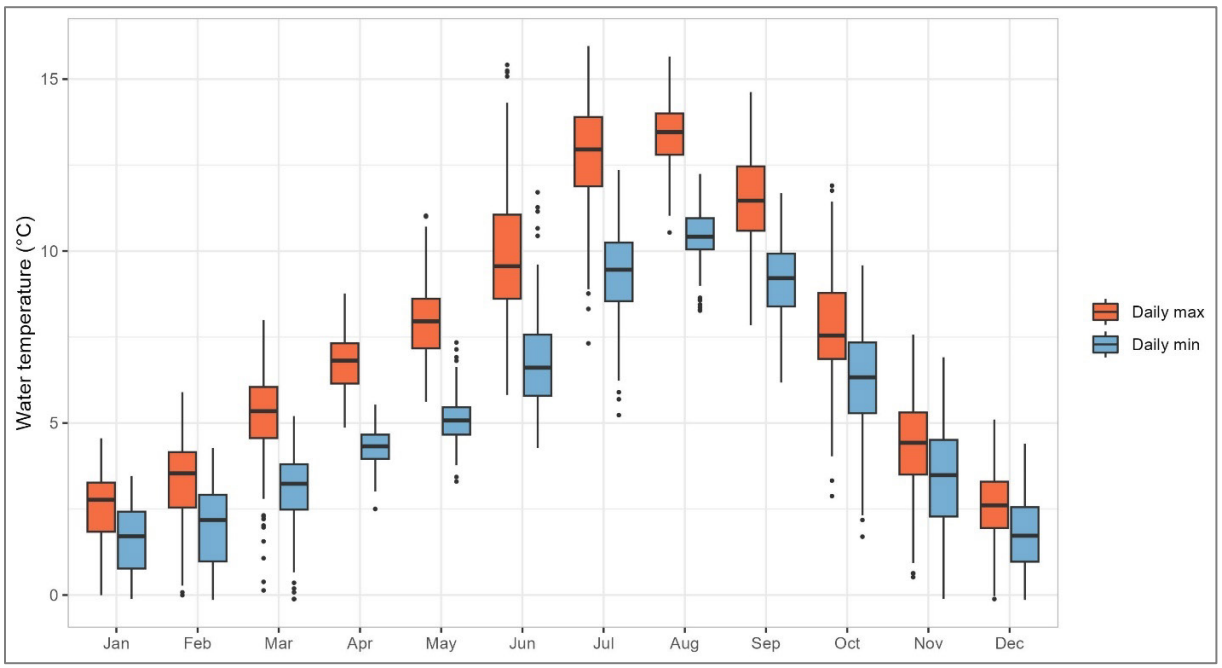

Figure 35. Maximum and minimum daily mean temperatures at the Stehekin River Station, 2011 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

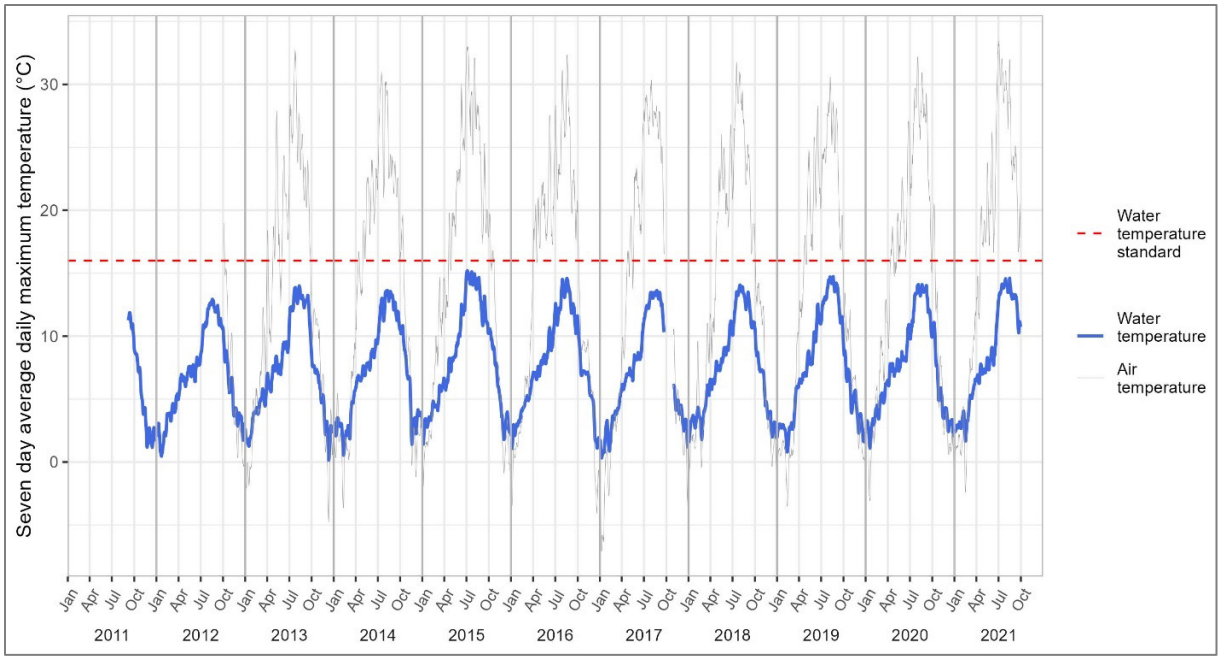

Figure 36. Seven-day average of the maximum daily water temperatures at the Stehekin River Station, 2011 to 2021. The red dashed line at 16°C indicates the state criteria for aquatic life use designation of core summer (June 15 to September 15) salmonid habitat. Any summer water temperature above 16°C constitutes an exceedance.

NPS

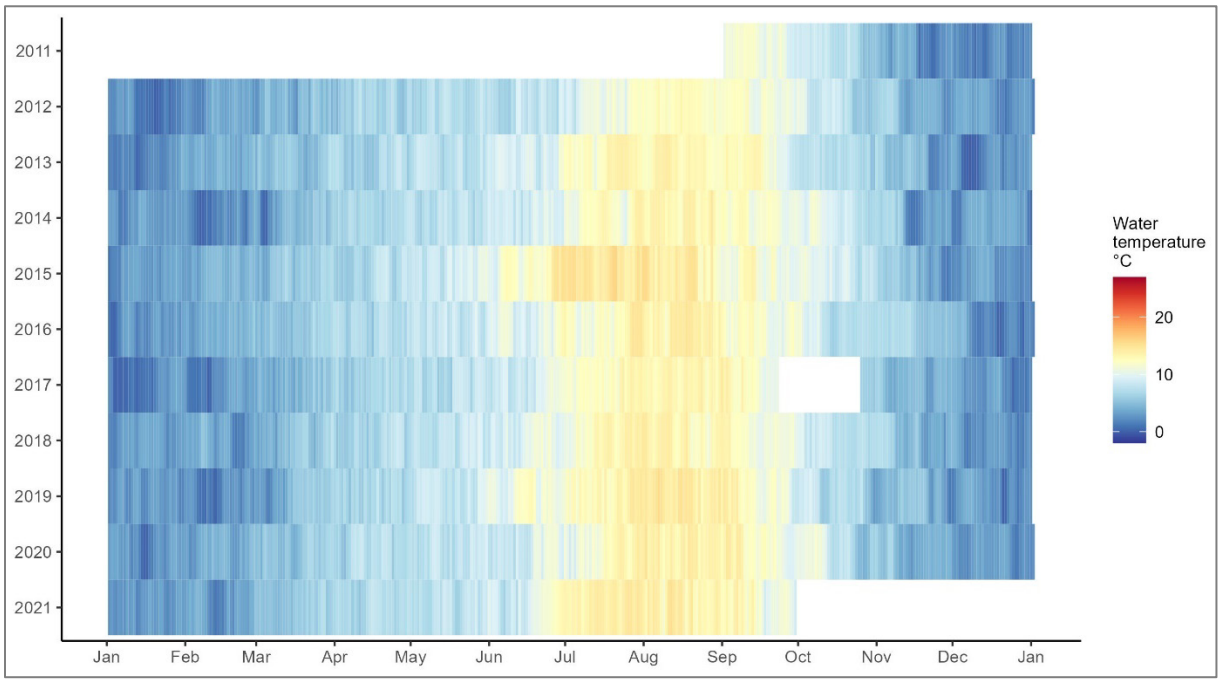

Figure 37. Maximum daily water temperatures at the Stehekin River Station, 2011 to 2021.

NPS

Table 40. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the seasonal criterion of 16°C in summer (June 15 to September 15) as well as the percentage of the days of the year with no data for that metric at the Stehekin River Station, 2011 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2011	none	68%
2012	none	full dataset
2013	none	full dataset
2014	none	full dataset
2015	none	full dataset
2016	none	full dataset
2017	none	10%
2018	none	full dataset
2019	none	full dataset
2020	none	full dataset
2021	none	25%

3.4.1.2 Instantaneous Water Temperature and Chemistry Data

Table 41 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Stehekin River Station.

Table 41. Water temperature and chemistry values at the Stehekin River Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (ºC)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
09/27/12	8.61	11.71	7.23	42.50	1.18
09/25/13	8.40	11.45	6.93	42.00	1.30
09/19/14	10.10	10.72	6.56	42.80	2.59
09/29/15	10.03	11.32	7.05	49.17	1.13
09/22/16	8.79	11.37	7.22	47.06	1.27
09/23/17	10.40	10.89	7.53	52.30	0.67
10/03/18	6.87	11.42	7.12	42.40	3.74
09/24/19	9.40	11.32	7.28	44.51	1.90
09/30/20	9.30	11.52	7.27	42.33	1.30
09/29/21	8.10	11.40	7.38	44.10	1.73
Minimum	**6.87**	**10.72**	**6.56**	**42.00**	**0.67**
Maximum	**10.40**	**11.71**	**7.53**	**52.30**	**3.74**

3.4.1.3 Channel Morphology Metrics

Table 42 presents channel morphology measurements for the Stehekin River Station, including data on bankfull width, wetted width, and thalweg depth.

Table 42. Channel morphology measurements from the Stehekin River Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
09/27/12	71.33	36.50	1.47
09/25/13	69.60	37.29	1.23
09/19/14	75.97	54.65	1.27
09/29/15	39.50	37.56	1.03
09/22/16	69.53	33.11	0.97
09/23/17	44.07	38.15	1.32
10/03/18	64.33	38.51	1.38
09/24/19	100.37	37.90	1.12
09/30/20	59.47	43.55	1.19
09/29/21	96.03	42.76	1.09
Minimum	**39.50**	**33.11**	**0.97**
Maximum	**100.37**	**54.65**	**1.47**

3.4.2 Bridge Creek Station

The sample reach in Bridge Creek is 400 m long and starts at an elevation of 1,216 m above sea level. This reach occupies a single V-shaped channel, constrained by bedrock and large boulders. The site is located on a third order (Strahler 1952) segment of Bridge Creek typical of mountain channels in the North Cascades. The Rapid Habitat Assessment conducted for the Bridge Creek sample reach indicated optimal habitat conditions. Three mountain lakes, groundwater inflow, and surface runoff of snowpack melt primarily feed Bridge Creek.

Bridge Creek's proximity to State Route 20, high trail densities and abundant infrastructure in the watershed, and high numbers of recreational users can cause water quality issues. Human activity within the watershed consists of 9.6 km of roads, 26.2 km of trails, and a few USFS facilities. The road and trail densities are 0.26 km/km^2 and 0.72 km/km^2 and are above the 50th and 90th percentiles for NCCN watersheds, respectively (Rawhouser et al. 2012). This is one of the most heavily used recreation areas in the North Cascades, with over 320,000 vehicles traveling through the watershed on State Route 20 in 2013. Only one fish and one amphibian species have been documented in the vicinity of the Bridge Creek sample reach (Zyskowski 2007, Rawhouser et al. 2009). However, based on regional distribution data and habitat requirements, this area potentially contains an additional fish species and four additional amphibian species, all of which could potentially be impacted by high rates of human activity in the watershed (Leonard et al. 1993, Wydoski and Whitney 2003, Galvan et al. 2005, WNHP WDFD BLM 2005).

3.4.2.1 Continuous Water Temperature Data

Figures 38–40 present maximum, minimum, and seven-day average water temperatures for the Bridge Creek Station in North Cascades National Park. The monitoring program did not find any exceedances of the seven-day average daily maximum water temperature criterion of 16°C between 2012 and 2021; however, several gaps in the dataset exist (Table 43).

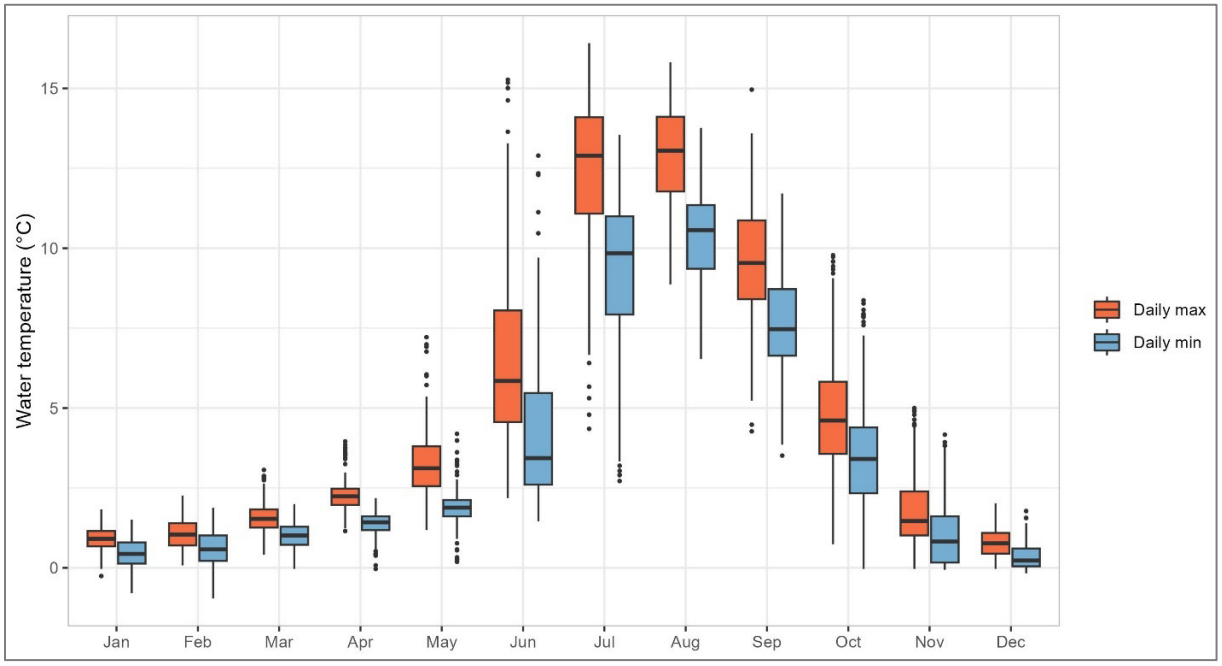

Figure 38. Maximum and minimum daily mean temperatures at the Bridge Creek Station, 2011 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

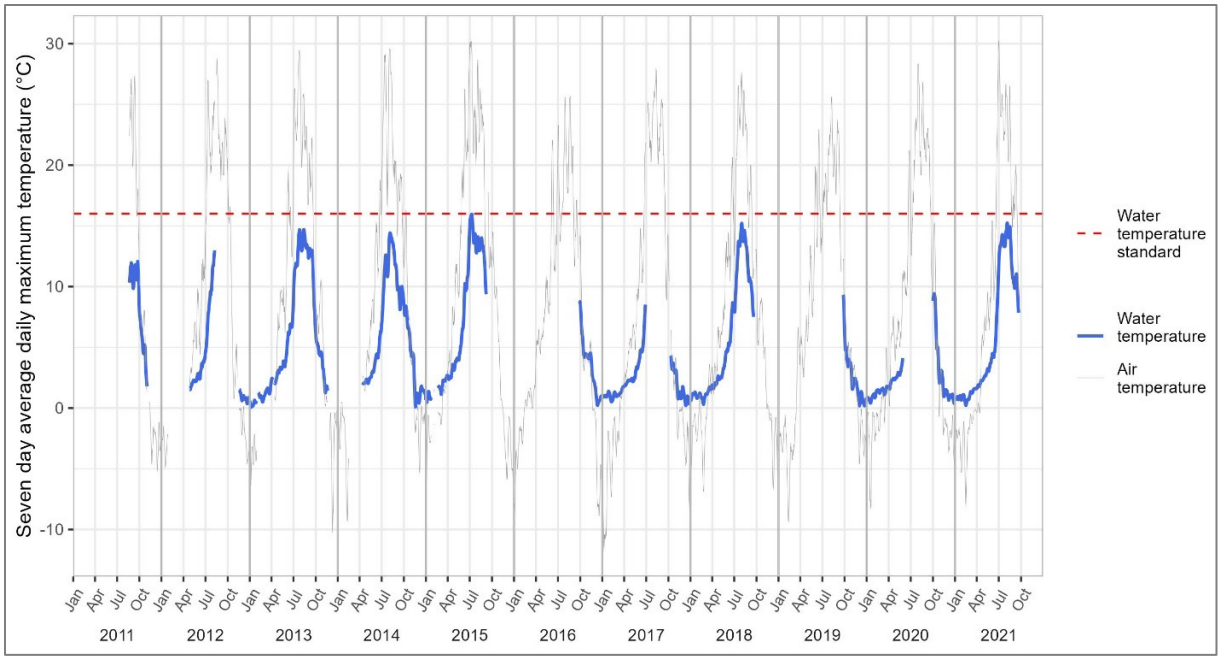

Figure 39. Seven-day average of the maximum daily water temperatures at the Bridge Creek Station, 2011 to 2021. The red dashed line at 16°C indicates the state criteria for aquatic life use designation of core summer (June 15 to September 15) salmonid habitat. Any summer water temperature above 16°C constitutes an exceedance.

NPS

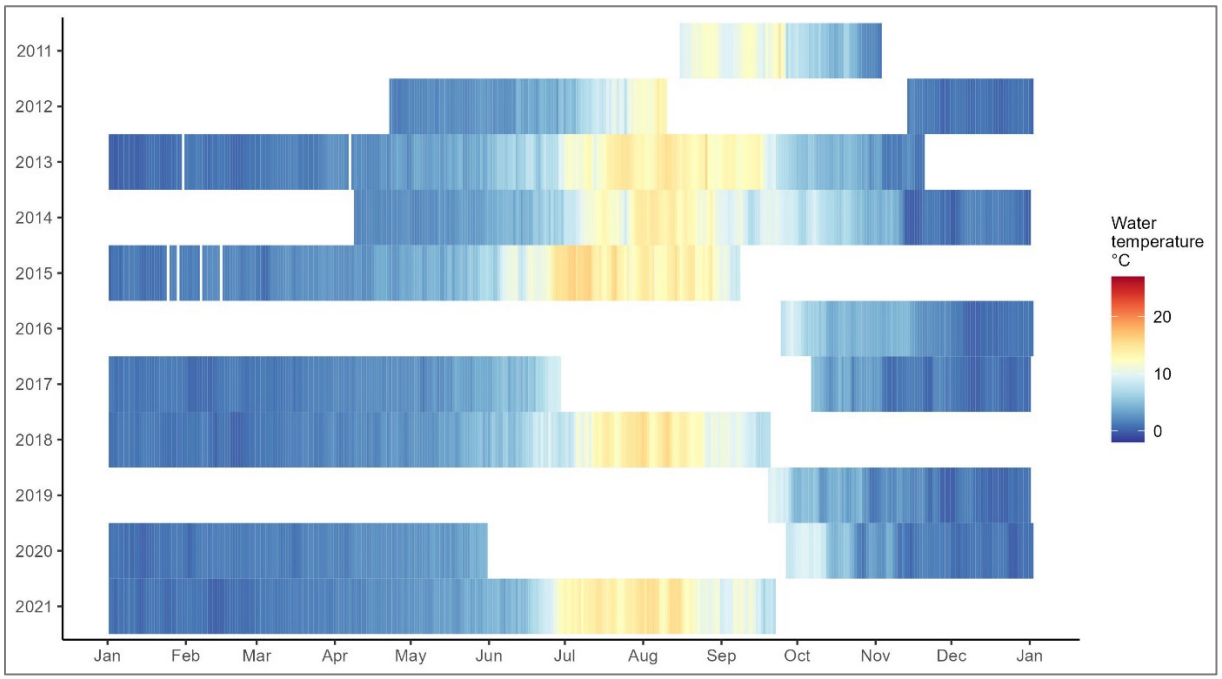

Figure 40. Maximum daily water temperatures at Bridge Creek Station, 2011 to 2021.

NPS

Table 43. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the seasonal criterion of 16°C in summer (June 15 to September 15) as well as the percentage of the days of the year with no data for that metric at the Bridge Creek Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	80%
2012	none	60%
2013	none	15%
2014	none	28%
2015	none	38%
2016	none	75%
2017	none	29%
2018	none	28%
2019	none	73%
2020	none	34%
2021	none	28%

3.4.2.2 Instantaneous Water Temperature and Chemistry Data

Table 44 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Bridge Creek Station.

Table 44. Water temperature and chemistry values at the Bridge Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
09/17/12	9.67	10.07	7.58	47.21	0.25
09/13/13	11.20	9.77	6.97	39.43	0.61
08/27/14	10.80	9.76	7.09	40.27	0.52
09/08/15	8.91	10.02	7.07	50.16	0.21
09/22/16	7.20	10.92	7.90	45.96	0.20
10/05/17	3.56	12.21	7.70	56.93	0.48
09/20/18	6.42	10.09	6.96	53.00	0.17
09/18/19	8.20	10.37	7.48	48.01	0.45
09/01/20	9.24	10.24	7.35	49.91	0.26
09/21/21	6.70	11.00	7.60	51.77	0.23
Minimum	**3.56**	**9.76**	**6.96**	**39.43**	**0.17**
Maximum	**11.20**	**12.21**	**7.90**	**56.93**	**0.61**

3.4.2.3 Channel Morphology Metrics

Table 45 presents channel morphology measurements for the Bridge Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 45. Channel morphology measurements from the Bridge Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
09/17/12	10.23	5.78	0.56
09/13/13	7.10	5.61	0.67
08/27/14	8.60	8.25	0.62
09/08/15	9.77	7.30	0.34
09/22/16	9.85	6.28	0.44
10/05/17	13.83	6.04	0.31
09/20/18	10.17	5.82	0.36
09/18/19	9.00	6.94	0.44
09/01/20	12.13	5.77	0.41
09/21/21	14.47	5.42	0.48
Minimum	**7.10**	**5.42**	**0.31**
Maximum	**14.47**	**8.25**	**0.67**

3.4.3 Company Creek Station

The Company Creek sample reach is 400 m long and starts at an elevation of 387 m above sea level. The sample reach begins 1.5 km upstream from the confluence with the Stehekin River and is within a third order (Strahler 1952) segment of Company Creek. It occupies an anastomosing channel that is constrained by human alteration and incision into an alluvial fan. Torrent evidence suggests that high flows have caused scouring and deposition of substrate above the bankfull level. Groundwater inflow and surface runoff of snowpack and glacial melt primarily feed Company Creek, which drains directly into the Stehekin River approximately 10 km upstream from Lake Chelan.

In addition to the visitor use and infrastructure impacts that occur in other reaches in the park, a hydropower project operated by the Chelan Public Utility District on Company Creek presents an additional need for monitoring in this reach. This facility, consisting of a hydroelectric plant and three diesel generators, is the only source of electricity for the residents and NPS facilities in the Stehekin Valley. Installed in 1976, the hydroelectric plant has a gravity fed penstock that diverts flow from Company Creek 1,200 m upstream of the powerhouse. The diversion entrance is a grate spanning one third of the creek that funnels water into a two-foot diameter penstock. During high flows, the penstock can carry up to 0.48 m^3/s, and during low flows, it carries a reduced flow of 0.28 m^3/s (Kirchhoffer and Malte 2003). This operation has the potential to impact habitat quality for the four documented and three potentially present fish species at this site (Zyskowski 2007, Wydoski and Whitney 2003). Previous NPS inventories of Company Creek did not document the presence of any amphibians within the sample reach (Rawhouser et al. 2009), nor have any been documented in the

watershed, but based on regional distribution and habitat requirements, five species potentially occur in the area (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFD BLM 2005).

Though park and network staff determined that the Company Creek sample reach was in an optimal condition at this program's onset, subsequently they have documented several impacts to the stream system. Specifically, human modifications have confined and channelized the stream, which has resulted in reduced habitat diversity, increased erosion, and reduced bank stability. Currently, the stream banks and riparian zone appear to be adequately protected by vegetation, but this could rapidly change during torrential flows.

3.4.3.1 Continuous Water Temperature Data

Figures 41–43 present maximum, minimum, and seven-day average water temperatures for the Company Creek Station in North Cascades National Park. The monitoring program did not find any exceedances of the seven-day average daily maximum water temperature criterion of 16°C between 2012 and 2021 (Table 46).

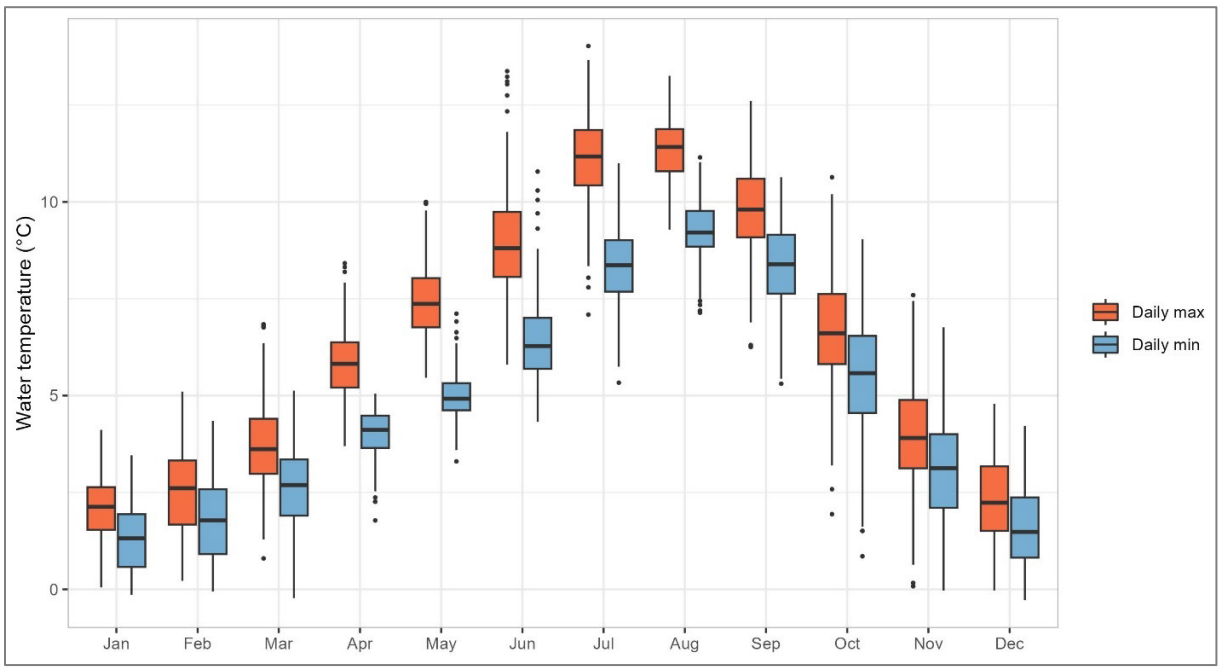

Figure 41. Maximum and minimum daily mean temperatures at the Company Creek Station, 2011 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

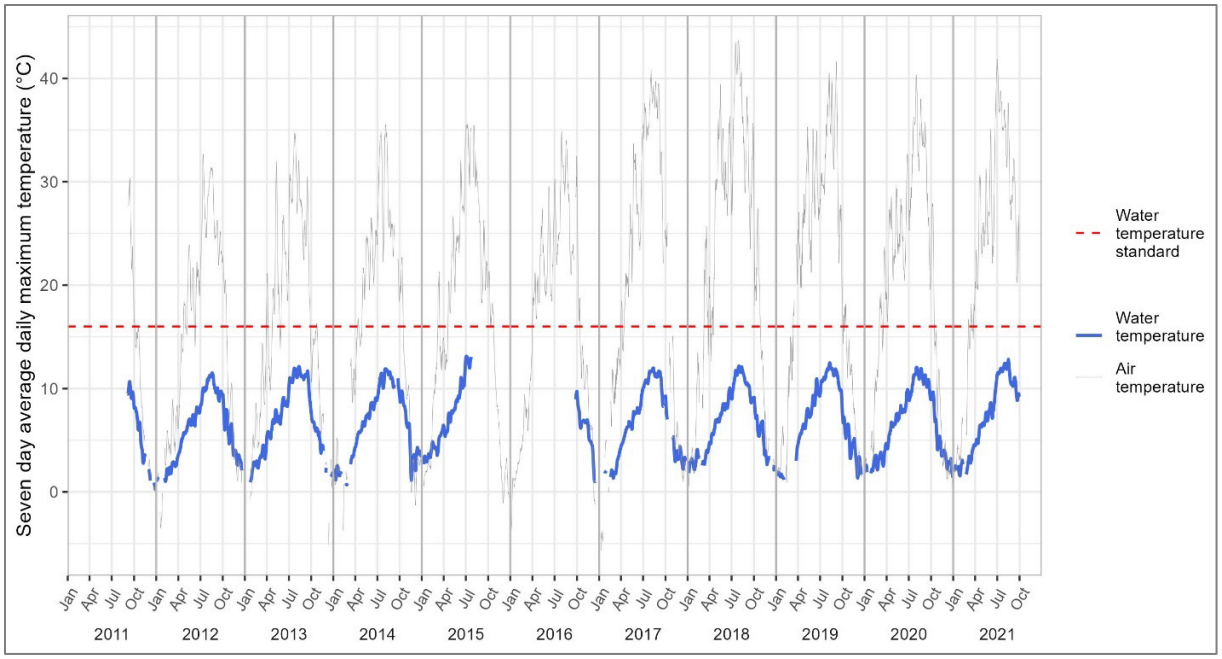

Figure 42. Seven-day average of the maximum daily water temperatures at the Company Creek Station, 2011 to 2021. The red dashed line at 16°C indicates the state criteria for aquatic life use designation of core summer (June 15 to September 15) salmonid habitat. Any summer water temperature above 16°C constitutes an exceedance.

NPS

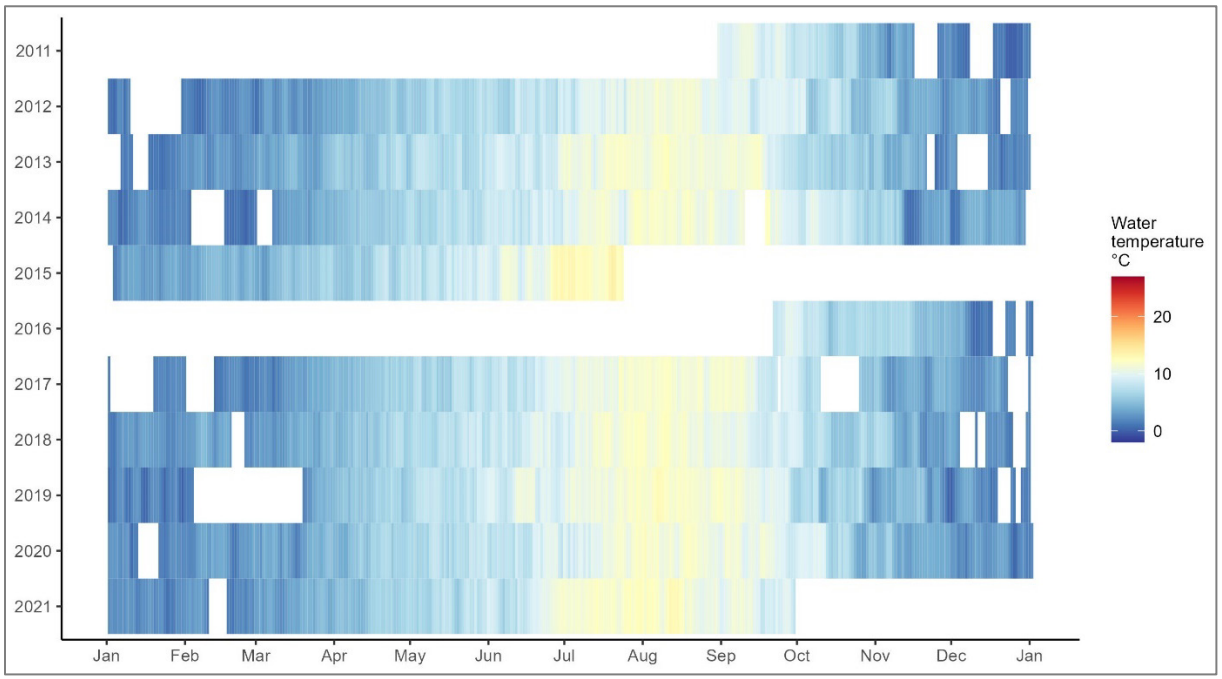

Figure 43. Maximum daily water temperatures at the Company Creek Station, 2011 to 2021.

NPS

Table 46. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the seasonal criterion of 16°C in summer (June 15 to September 15) as well as the percentage of the days of the year with no data for that metric at the Company Creek Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	76%
2012	none	10%
2013	none	13%
2014	none	13%
2015	none	46%
2016	none	78%
2017	none	21%
2018	none	11%
2019	none	18%
2020	none	4%
2021	none	29%

3.4.3.2 Instantaneous Water Temperature and Chemistry Data

Table 47 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Company Creek Station.

Table 47. Water temperature and chemistry values at the Company Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (ºC)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
09/26/12	8.30	11.55	7.26	54.51	0.32
09/24/13	6.94	11.74	6.89	53.79	0.44
09/19/14	9.10	10.90	7.02	53.96	0.46
09/29/15	6.43	11.66	7.21	61.16	0.36
09/20/16	6.90	12.74	7.65	56.80	0.39
09/23/17	8.46	11.51	7.26	61.86	0.26
10/01/18	5.70	12.00	7.40	55.40	0.40
09/24/19	10.20	10.98	7.18	57.50	0.27
09/28/20	7.50	11.59	7.27	55.10	0.36
09/29/21	7.30	11.65	7.52	58.80	0.32
Minimum	**5.70**	**10.90**	**6.89**	**53.79**	**0.26**
Maximum	**10.20**	**12.74**	**7.65**	**61.86**	**0.46**

3.4.3.3 Channel Morphology Metrics

Table 48 presents channel morphology measurements for Company Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 48. Channel morphology measurements from the Company Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
09/26/12	12.97	7.49	0.60
09/24/13	12.00	8.12	0.56
09/19/14	10.53	7.58	0.54
09/29/15	9.63	5.62	0.50
09/20/16	10.40	7.37	0.55
09/23/17	12.95	8.24	0.47
10/01/18	12.50	7.09	0.48
09/24/19	13.60	7.64	0.43
09/28/20	13.30	7.08	0.62
09/29/21	10.10	7.34	0.44
Minimum	**9.63**	**5.62**	**0.43**
Maximum	**13.60**	**8.24**	**0.62**

3.4.4 Goodell Creek Station

Goodell Creek is a tributary to the Skagit River, which drains to the Puget Sound. Several mountain lakes, groundwater inflow, and surface runoff of snowpack and glacial melt feed the creek. The 500-m long sample reach, immediately upstream of the State Route 20 Bridge that spans the creek, begins at an elevation of 149 m above sea level. Flowing through an alluvial fan, this sample reach is on a fourth order (Strahler 1952) segment of Goodell Creek, which is within an anastomosing and braided channel constrained by bank armoring.

Water quality in Goodell Creek is potentially impacted by roads, campgrounds, and recreational use, but the primary stressors are related to an active gravel pit, several in-stream channel modifications that have greatly altered the natural flow of Goodell Creek, and an existing levee constructed in the 1980s. Parts of this levee have been identified as a historic industrial dump site containing metals, glass, and asphalt materials, associated with Washington Department of Transportation and Seattle City Light operations. The exact contents of this portion of the levee are unknown; however, it has been reported that this site is probably contaminated with arsenic and lead from sand blasting waste (NPS 2011). Monitoring is key to understanding potential impacts to nine different species of fish documented in the sample reach (Zyskowski 2007, WDFW 2014). Though amphibian surveys have been conducted in Goodell Creek, the sample reach itself has not been surveyed (Rawhouser et al. 2009). Two species of amphibians have, however, been documented in the watershed (Leonard et al. 1993, WNHP WDFW BLM 2005, Rawhouser et al. 2009).

3.4.4.1 Continuous Water Temperature Data

Figures 44–46 present maximum, minimum, and seven-day average water temperatures for the Goodell Creek Station in North Cascades National Park. The seven-day average of the daily maximum water temperature exceeded the criterion of 12°C on 541 days between 2012 and 2021 (Table 49).

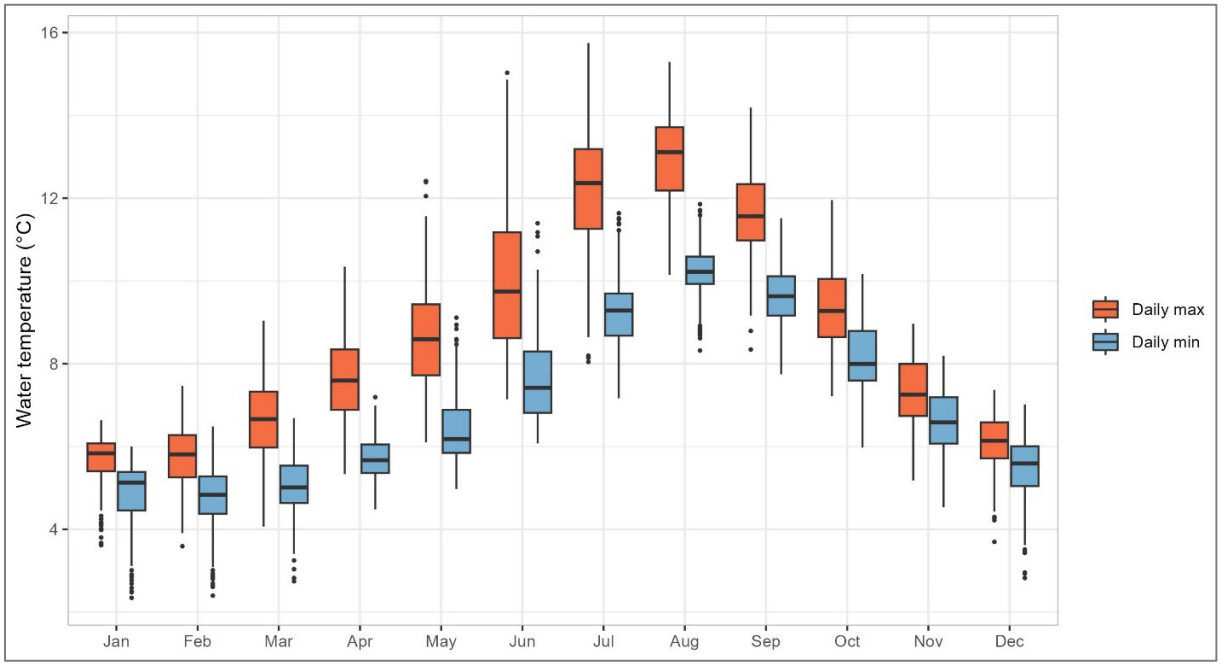

Figure 44. Maximum and minimum daily mean temperatures at the Goodell Creek Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

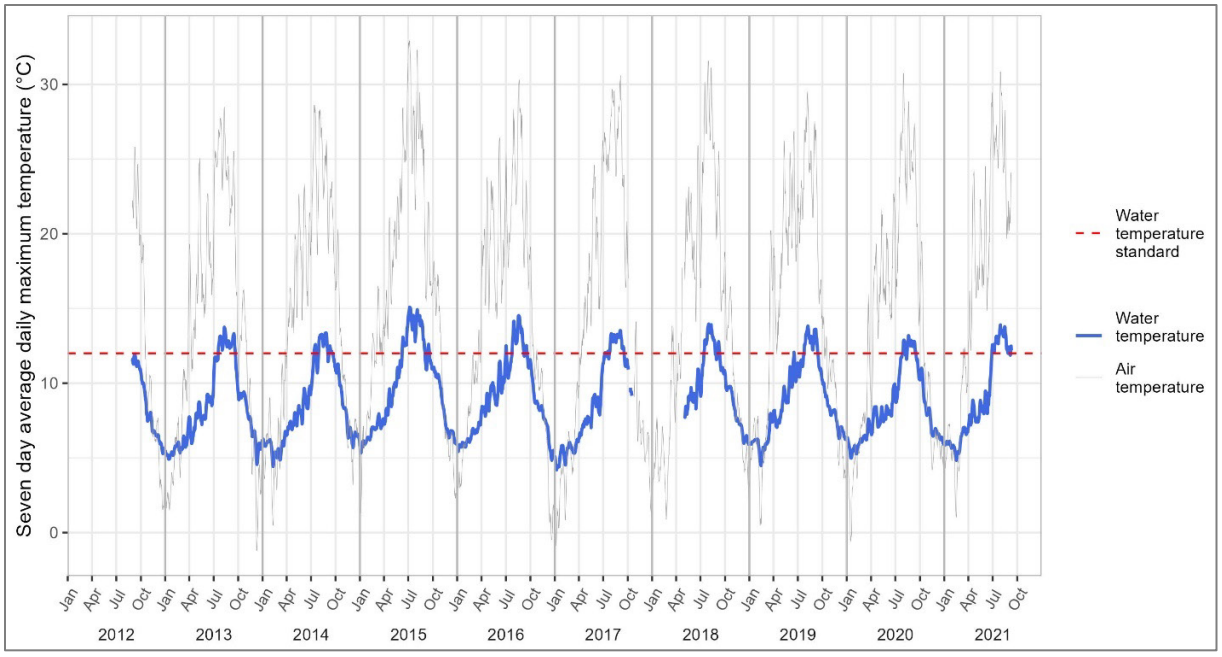

Figure 45. Seven-day average of the maximum daily water temperatures at the Goodell Creek Station, 2012 to 2021. The red dashed line at 12°C indicates the year-round state criterion for aquatic life use designation of char spawning and rearing. Any seven-day average maximum daily water temperature above 12°C constitutes an exceedance.

NPS

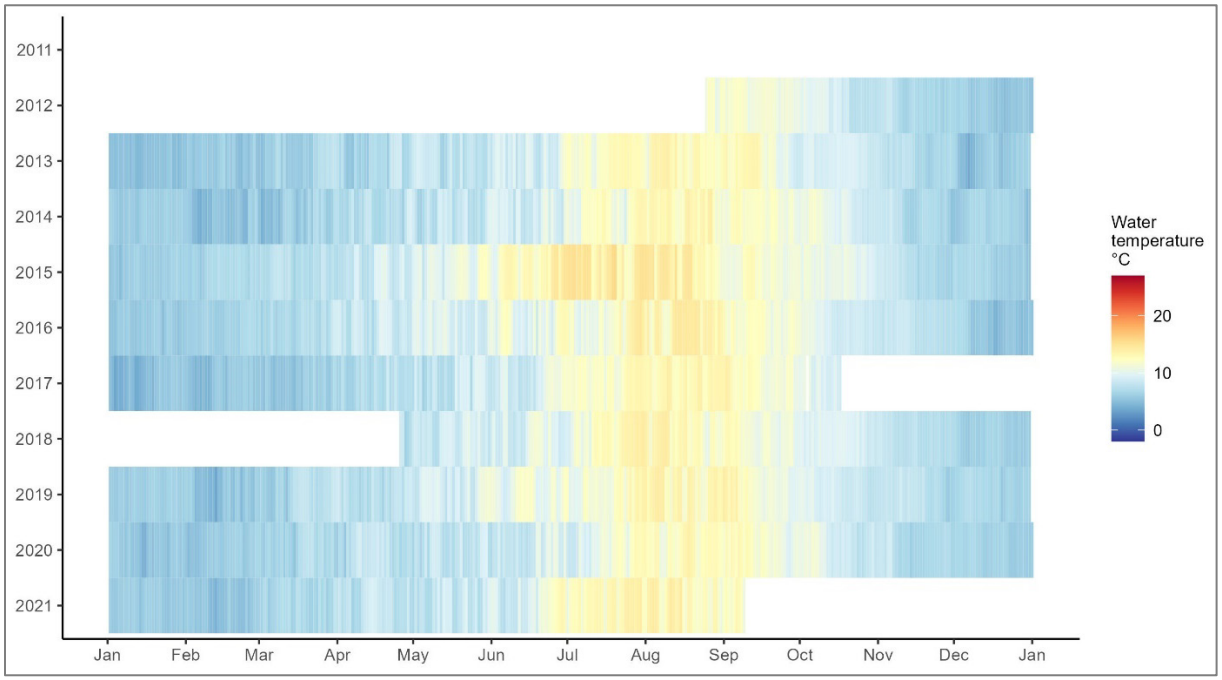

Figure 46. Maximum daily water temperatures at the Goodell Creek Station, 2012 to 2021.

NPS

Table 49. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 12°C as well as the percentage of the days of the year with no data for that metric at the Goodell Creek Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	66%
2013	64	full dataset
2014	54	full dataset
2015	91	full dataset
2016	55	full dataset
2017	60	22%
2018	51	33%
2019	52	full dataset
2020	43	full dataset
2021	71	31%

3.4.4.2 Instantaneous Water Temperature and Chemistry Data

Table 50 presents temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Goodell Creek Station.

Table 50. Water temperature and chemistry values at the Goodell Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
08/28/12	10.70	10.93	7.25	16.02	0.41
08/26/13	10.70	10.90	7.18	17.77	0.29
09/03/14	11.30	10.95	6.79	17.42	0.31
10/01/15	9.20	11.37	6.73	21.29	0.24
08/30/16	11.70	11.94	7.45	21.02	0.22
10/04/17	9.43	11.34	6.97	21.18	1.25
09/06/18	10.40	11.50	7.15	20.84	0.22
08/26/19	11.30	10.83	6.78	20.21	0.17
08/26/20	11.70	11.40	6.66	17.76	0.24
08/25/21	10.10	10.99	6.92	18.53	0.23
Minimum	**9.20**	**10.83**	**6.66**	**16.02**	**0.17**
Maximum	**11.70**	**11.94**	**7.45**	**21.29**	**1.25**

3.4.4.3 Channel Morphology Metrics

Table 51 presents channel morphology measurements for Goodell Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 51. Channel morphology measurements from the Goodell Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
08/28/12	50.87	33.66	0.94
08/26/13	69.73	33.72	0.79
09/03/14	45.57	38.70	0.75
10/01/15	50.73	23.37	0.70
08/30/16	17.75	16.02	0.71
10/04/17	52.60	25.49	0.56
09/06/18	40.65	26.26	0.73
08/26/19	72.40	31.31	0.77
08/26/20	71.13	30.32	1.08
08/25/21	39.33	26.09	0.67
Minimum	**17.75**	**16.02**	**0.56**
Maximum	**72.40**	**38.70**	**1.08**

3.4.5 Newhalem Creek Station

Newhalem Creek is a tributary of the Skagit River and is fed by several mountain lakes, groundwater inflow, and the runoff of snowpack and glacier melt. The Newhalem Creek sample reach is 500 m long and starts at an elevation of 149 m above sea level. Beginning at the confluence with the Skagit River, the reach is in a fourth order (Strahler 1952) segment of Newhalem Creek occupying a single channel, constrained by incision into an alluvial fan.

Principal concerns for water quality in Newhalem Creek are the Newhalem Creek Hydroelectric Project as well as impacts related to an abandoned road network. From 1965 to 1967, 2.55 km^2 were clear-cut and 13.5 km of road were constructed in the watershed by the USFS (NPS 2011). Following North Cascades National Park's establishment in 1968, the forest has regenerated into mixed stands. Unused, the road system was left in place with many of the culverts and much of the road prism still intact, possibly negatively affecting water quality. Since 2004, under Section 303(d) of the federal Clean Water Act, Washington State has listed Newhalem Creek as having impaired habitat due to insufficient in-stream flow (WDOE 2012). The US Geological Survey (USGS) installed a real-time gaging station as a result of this listing (USGS 2014). Insufficient in-stream flow and poor water quality could impact the seven fish species documented in the sample reach (Zyskowski 2007, WDFW 2014), three species of amphibians that have been documented in the watershed (Bury and Adams 2000, Galvan et al. 2005, Rawhouser et al. 2009), as well as additional species of fish and amphibians that could be present based on regional distributions and habitat requirements.

3.4.5.1 Continuous Water Temperature Data

Figures 47–49 present maximum, minimum, and seven-day average water temperatures for the Newhalem Creek Station in North Cascades National Park. The seven-day average of the daily maximum water temperature exceeded the criterion of 12°C on at least 357 days between 2012 and 2021 (Table 52).

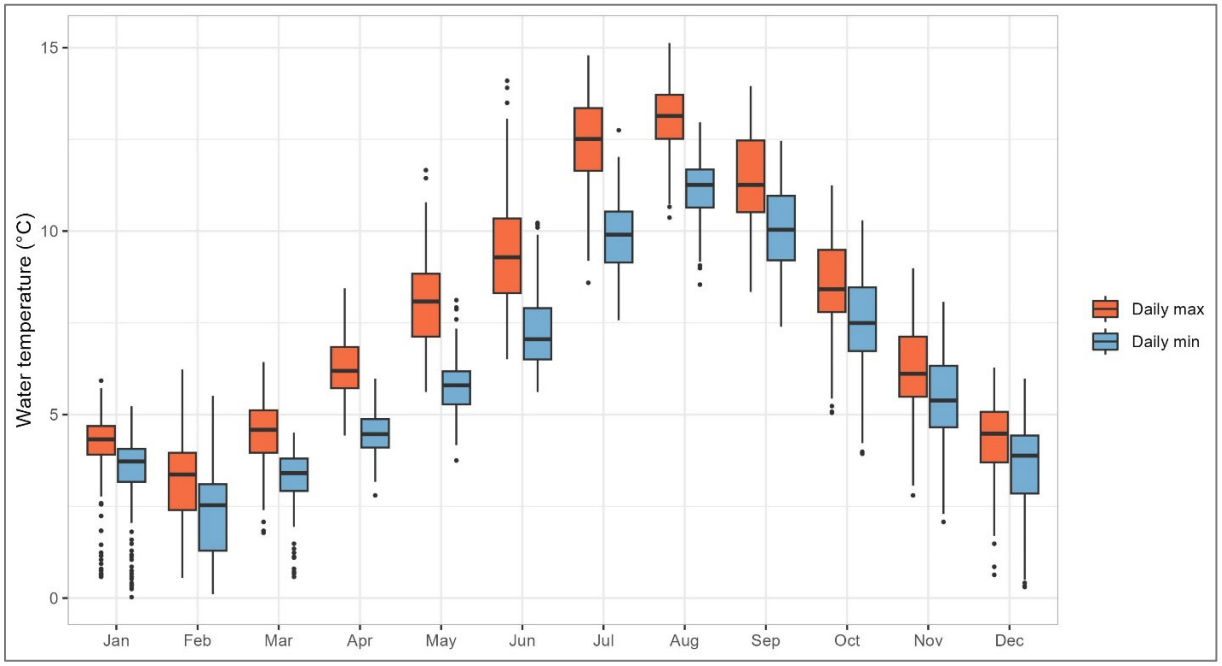

Figure 47. Maximum and minimum daily mean temperatures at the Newhalem Creek Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

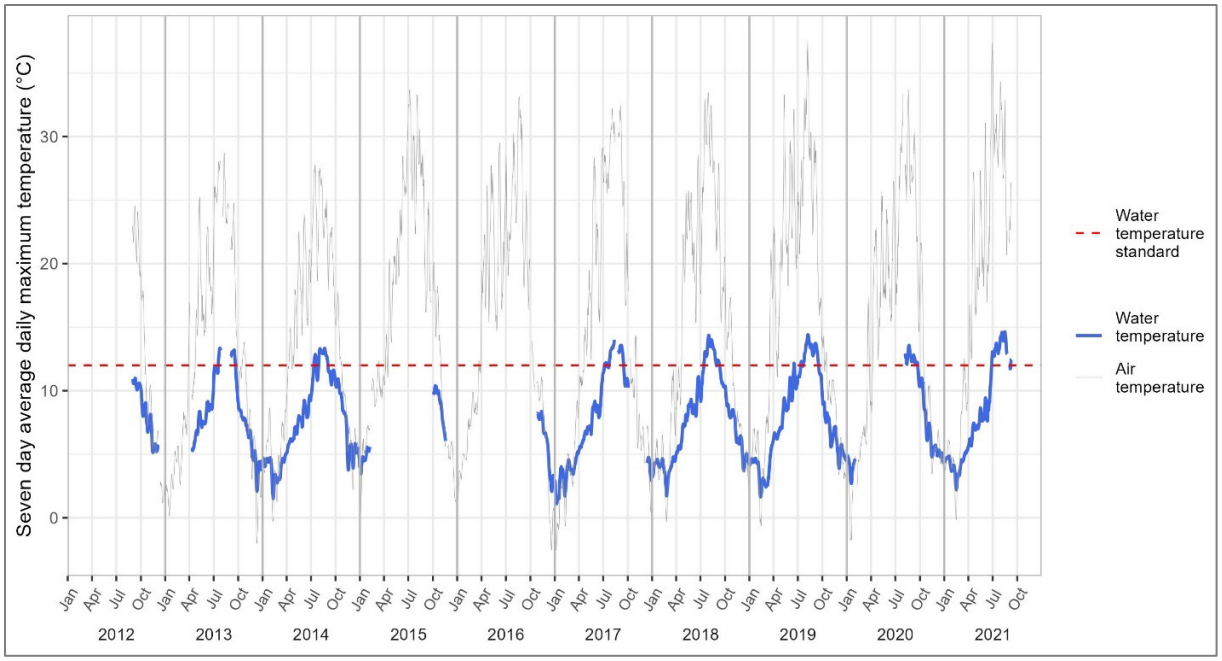

Figure 48. Seven-day average of the maximum daily water temperatures at the Newhalem Creek Station, 2012 to 2021. The red dashed line at 12°C indicates the year-round state criterion for aquatic life use designation of char spawning and rearing. Any seven-day average maximum daily water temperature above 12°C constitutes an exceedance.

NPS

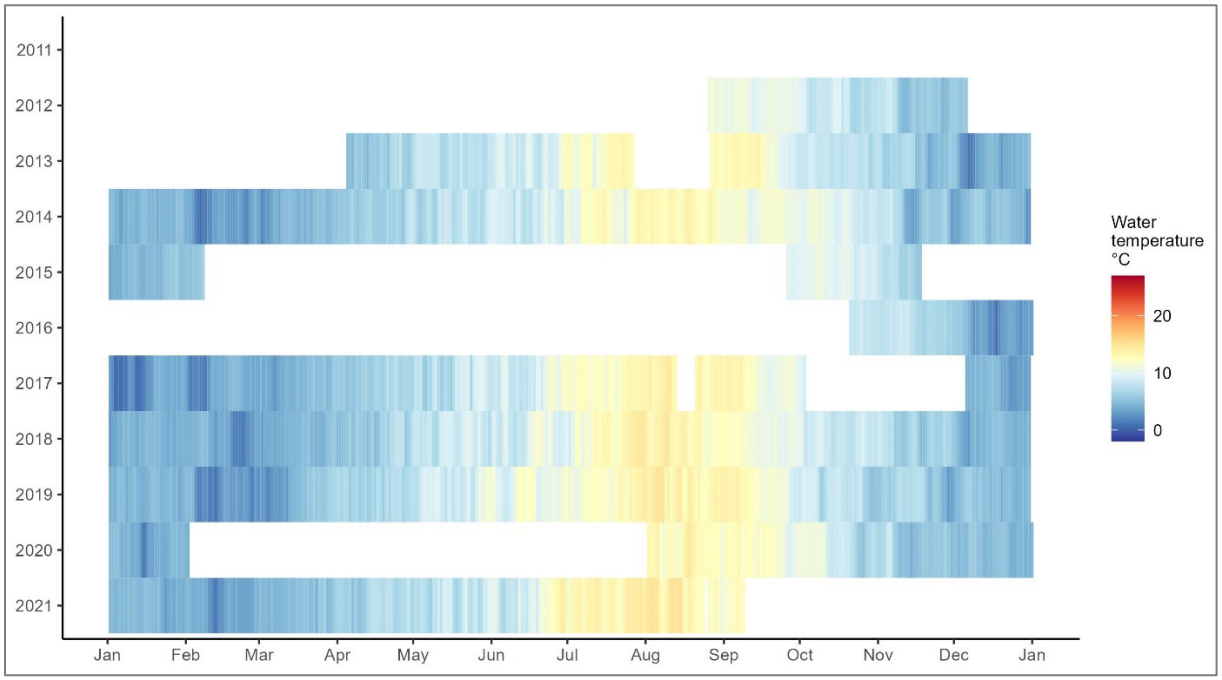

Figure 49. Maximum daily water temperatures at the Newhalem Creek Station, 2012 to 2021.

NPS

Table 52. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 12°C as well as the percentage of the days of the year with no data for that metric at the Newhalem Creek Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	74%
2013	28	37%
2014	44	full dataset
2015	none	76%
2016	none	82%
2017	54	22%
2018	58	full dataset
2019	65	full dataset
2020	47	51%
2021	61	33%

3.4.5.2 Instantaneous Water Temperature and Chemistry Data

Table 53 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Newhalem Creek Station. All measurements fell within Washington State aquatic life criteria during the study period.

Table 53. Water temperature and chemistry values at the Newhalem Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
08/28/12	9.91	11.00	7.26	20.37	0.45
08/26/13	12.20	10.53	7.19	22.16	0.24
09/03/14	12.04	10.87	6.84	22.33	0.25
09/25/15	10.30	10.77	6.52	25.80	0.35
09/30/16	11.63	11.99	7.47	25.83	0.22
10/04/17	7.60	11.96	7.15	27.27	0.16
08/29/18	11.93	10.76	7.55	24.36	0.46
08/26/19	11.10	10.90	6.78	25.90	0.21
08/26/20	10.80	11.64	6.95	22.29	0.23
08/25/21	11.80	11.00	7.35	25.30	0.25
Minimum	**7.60**	**10.53**	**6.52**	**20.37**	**0.16**
Maximum	**12.20**	**11.99**	**7.55**	**27.27**	**0.46**

3.4.5.3 Channel Morphology Metrics

Table 54 presents channel morphology measurements for the Newhalem Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 54. Channel morphology measurements from the Newhalem Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
08/28/12	22.63	14.35	0.79
08/26/13	24.97	15.42	0.64
09/03/14	19.77	15.85	0.73
09/25/15	23.93	17.40	0.72
09/30/16	21.00	16.55	0.64
10/04/17	25.90	13.87	0.50
08/29/18	24.37	16.87	0.60
08/26/19	24.43	14.31	0.71
08/26/20	21.53	16.12	0.76
08/25/21	19.93	16.03	0.49
Minimum	**19.77**	**13.87**	**0.49**
Maximum	**25.90**	**17.40**	**0.79**

3.4.6 North Fork Cascade River Station

The North Fork Cascade River sample reach is 500 m long and starts at 588 m above sea level. Fed by several mountain lakes, groundwater inflow, snowpack, and glacial melt, the sample reach is on a fourth order (Strahler 1952) segment of the North Fork Cascade River. The reach sits in a U-shaped glacial valley and occupies a braided channel, minimally constrained by debris cones and aprons. Torrent evidence suggests the sample reach experiences periodic high flows that cause increased rates of erosion and scour.

The NPS monitors water quality in the North Fork Cascade River to better understand potential impacts from roads, trails, mine drainage from 43 abandoned mines in the watershed, and recreational use. The Cascade River Road parallels the river in the riparian zone for much of its length, and the high volume of vehicle traffic—almost 11,000 vehicles entered the area to access popular trails in 2010 (NPS 2014)—is of notable concern. One species of fish has been documented within the North Fork Cascade River sample reach (Zyskowski 2007), with two additional species possibly present (Wydoski and Whitney 2003). Park staff have not documented any amphibians present in the sample reach or watershed; however, there have not been any systematic surveys conducted within this area. Based on regional distributions and habitat requirements, there may be up to six species of amphibians present (Leonard et al. 1993, Bury and Adams 2000, Galvan et al. 2005, WNHP WDFW BLM 2005).

3.4.6.1 Continuous Water Temperature Data

Figures 50–52 present maximum, minimum, and seven-day average water temperatures for the North Fork Cascade River Station in North Cascades National Park. The seven-day average of the daily maximum water temperature exceeded the criterion of 12°C on at least 90 days between 2012 and 2021 (Table 55).

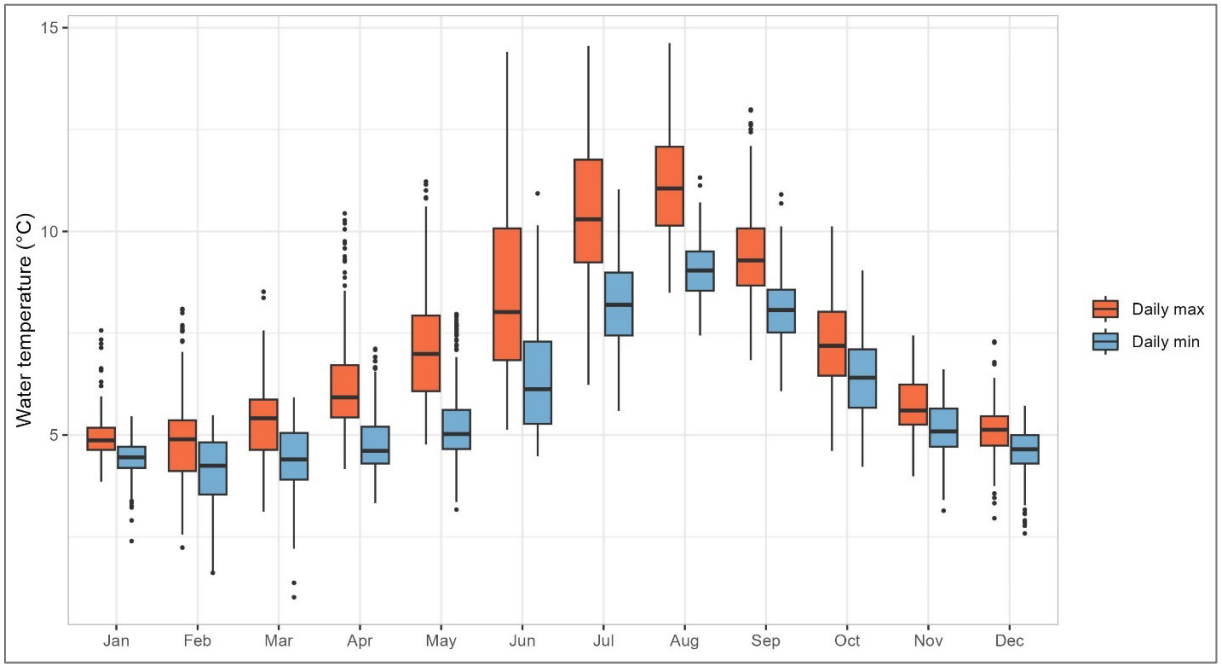

Figure 50. Maximum and minimum daily mean temperatures at the North Fork Cascade River Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

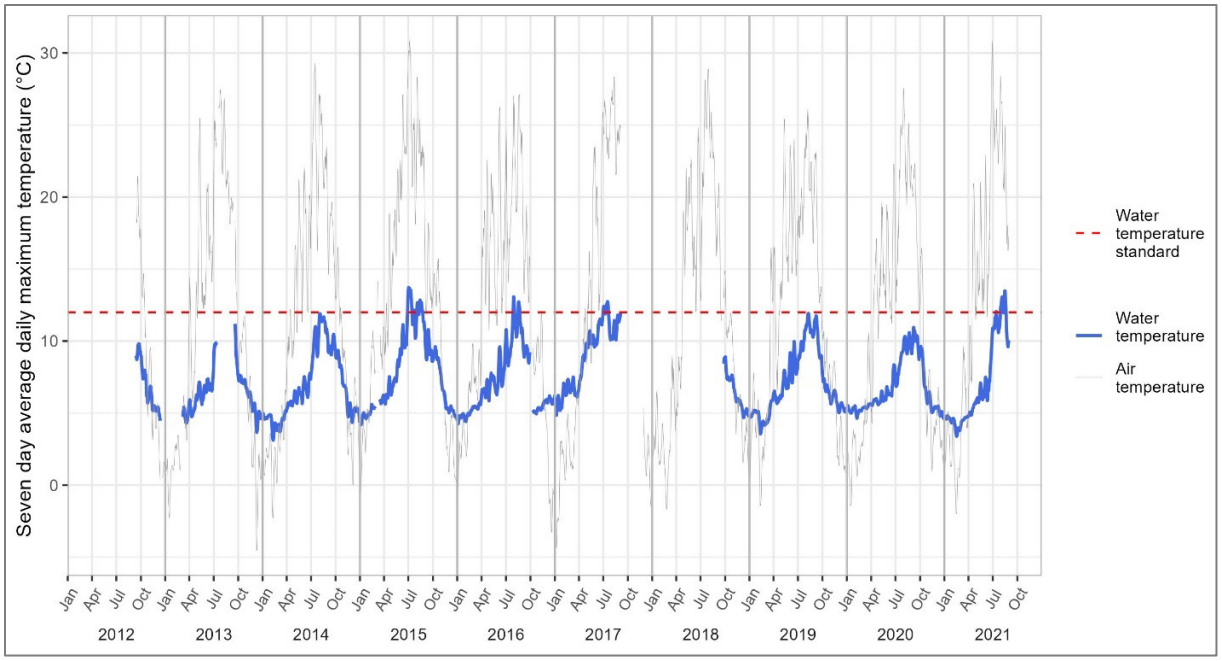

Figure 51. Seven-day average of the maximum daily water temperatures at the North Fork Cascade River Station, 2012 to 2021. The red dashed line at 12°C indicates the year-round state criterion for aquatic life use designation of char spawning and rearing. Any seven-day average maximum daily water temperature above 12°C constitutes an exceedance.

NPS

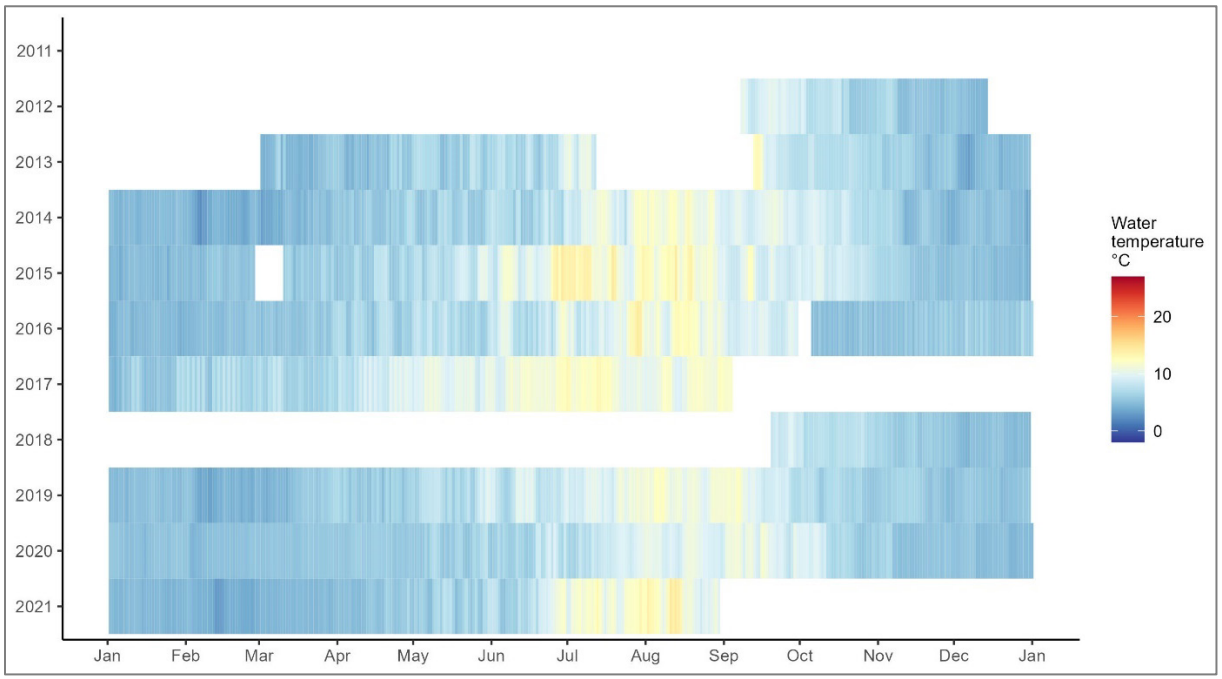

Figure 52. Maximum daily water temperatures at the North Fork Cascade River Station, 2012 to 2021.

NPS

Table 55. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 12°C as well as the percentage of the days of the year with no data for that metric at the North Fork Cascade River Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	75%
2013	none	37%
2014	none	full dataset
2015	38	5%
2016	12	3%
2017	18	32%
2018	none	73%
2019	none	full dataset
2020	none	full dataset
2021	22	34%

3.4.6.2 Instantaneous Water Temperature and Chemistry Data

Table 56 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the North Fork Cascade River Station. This site's pH was lower than the Washington State criterion of 6.5–8.5 during sampling events in 2013 and 2018 (Table 56).

Table 56. Water temperature and chemistry values at the North Fork Cascade River Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
09/07/12	8.00	10.74	7.08	26.70	0.39
09/12/13	10.30	10.42	6.31 [A]	20.85	0.97
08/25/14	9.37	10.61	6.57	27.64	0.34
09/08/15	8.80	9.65	7.29	24.00	3.45
09/30/16	8.40	11.39	7.32	33.61	0.29
09/05/17	11.60	9.86	6.79	24.30	1.43
09/01/18	7.15	10.21	6.35 [A]	36.00	0.18
10/02/19	7.10	10.86	6.87	35.90	0.91
08/31/20	8.30	11.04	6.79	28.10	0.40
08/30/21	9.24	10.43	7.07	54.31	0.56
Minimum	**7.10**	**9.65**	**6.31**	**20.85**	**0.18**
Maximum	**11.60**	**11.39**	**7.32**	**54.31**	**3.45**

[A] pH value lower than Washington State criterion of 6.5–8.5 (also in red font).

3.4.6.3 Channel Morphology Metrics

Table 57 presents channel morphology measurements for North Fork Cascade River Station, including data on bankfull width, wetted width, and thalweg depth.

Table 57. Channel morphology measurements from the North Fork Cascade River Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
09/07/12	38.50	14.71	0.74
09/12/13	24.50	15.01	0.62
08/25/14	26.97	14.45	0.72
09/30/16	22.30	16.67	0.49
09/05/17	No Data	15.15	0.48
09/01/18	22.73	13.09	0.49
10/02/19	34.83	13.04	0.44
08/31/20	49.20	12.78	0.83
08/30/21	31.00	10.18	0.62
Minimum	**22.30**	**10.18**	**0.44**
Maximum	**49.20**	**16.67**	**0.83**

3.4.7 Ruby Creek Station

The Ruby Creek sample reach starts 512 m above sea level and is 500 m long. The Ruby Creek station is on a fourth order (Strahler 1952) segment of the creek located at the bottom of a V-shaped valley in a river canyon, highly constrained by boulder, bedrock, and steep valley walls. Groundwater inflow and surface runoff from rain and snowmelt feed Ruby Creek, which flows into the Skagit River at Ross Lake Reservoir.

Less than 2% of the Ruby Creek watershed is managed by the NPS. Much of the watershed is managed by the Mount Baker and Wenatchee National Forests, and the Washington State Department of Transportation manages the State Route 20 corridor. There are numerous risks to aquatic habitat associated with this reach. First, impacts stem from trails and road maintenance. This is a heavily used area, containing popular trailheads and a large network of trails accessed by State Route 20. State Route 20 runs parallel to the creek and in the riparian zone for much of its length. The highway supports a high volume of vehicle traffic seven months of the year and routinely experiences flooding and landslide damage that requires extensive rebuilding. Furthermore, active mining and mine drainage present potential impacts. The watershed has a total of 153 active and historic mines, which is more than any other watershed monitored within the network. Additionally, illegal agricultural activities are problematic for water quality. In 2008, the NPS discovered an illegal marijuana growing operation within the watershed. To facilitate the growth of these crops, roughly 0.02 km^2 of land had been cleared, creeks had been impounded, and fertilizers, pesticides, and herbicides had been applied to the landscape.

Organisms potentially affected by these activities include rainbow trout (*Oncorhynchus mykiss*) and federally threatened bull trout (*Salvelinus confluentus*) (USFW 2004), as well as an additional three species that may be present (Wydoski and Whitney 2003). Although surveys have found no amphibians in the sample reach, two species have been documented within the watershed, including the Columbia spotted frog (*Rana luteiventris*), a Washington State candidate species (Rawhouser et al. 2009, WDFW 2015). An additional five species are potentially present (Leonard et al. 1993, WNHP WDFW BLM 2005).

3.4.7.1 Continuous Water Temperature Data

Figures 53–55 present maximum, minimum, and seven-day average water temperatures for the Ruby Creek Station in North Cascades National Park. The seven-day average of the daily maximum water temperature exceeded the criterion of 12°C on at least 409 days between 2012 and 2021 (Table 58).

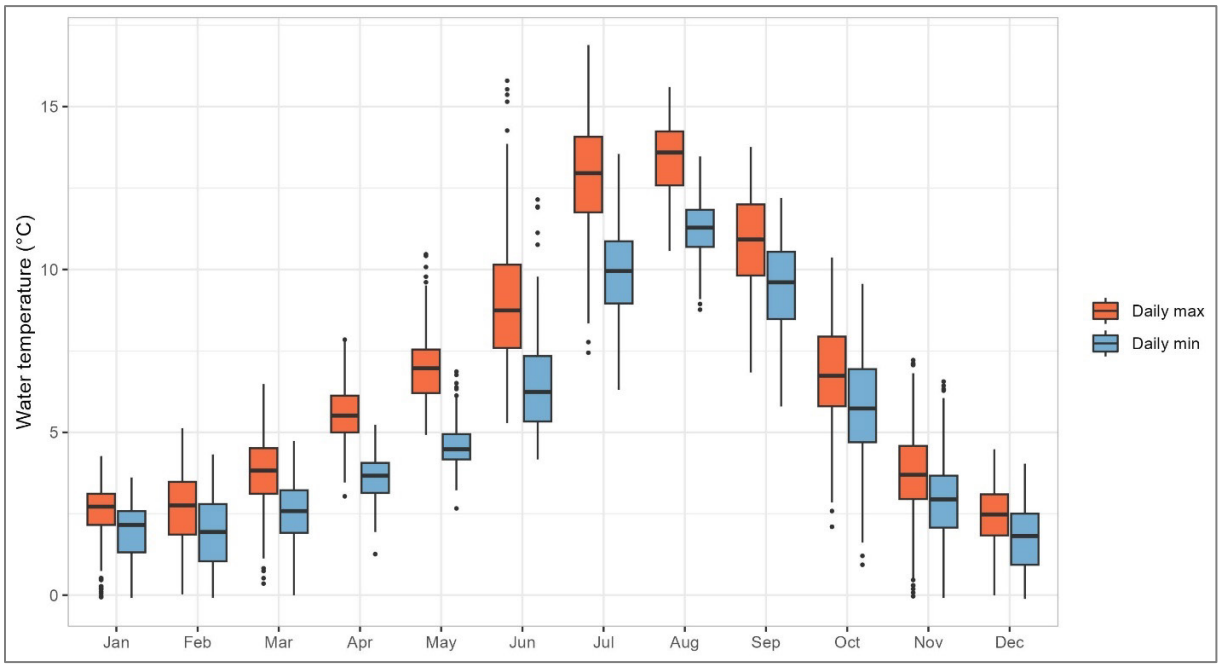

Figure 53. Maximum and minimum daily mean temperatures at the Ruby Creek Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

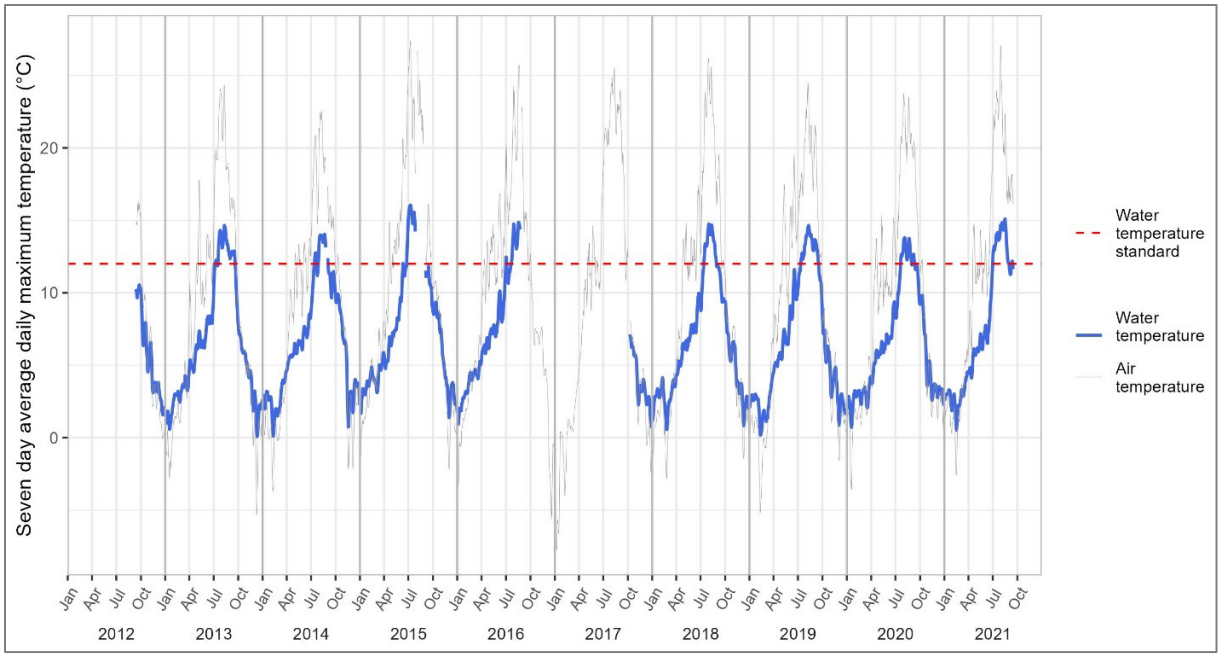

Figure 54. Seven-day average of the maximum daily water temperatures at the Ruby Creek Station, 2012 to 2021. The red dashed line at 12°C indicates the year-round state criterion for aquatic life use designation of char spawning and rearing. Any seven-day average maximum daily water temperature above 12°C constitutes an exceedance.

NPS

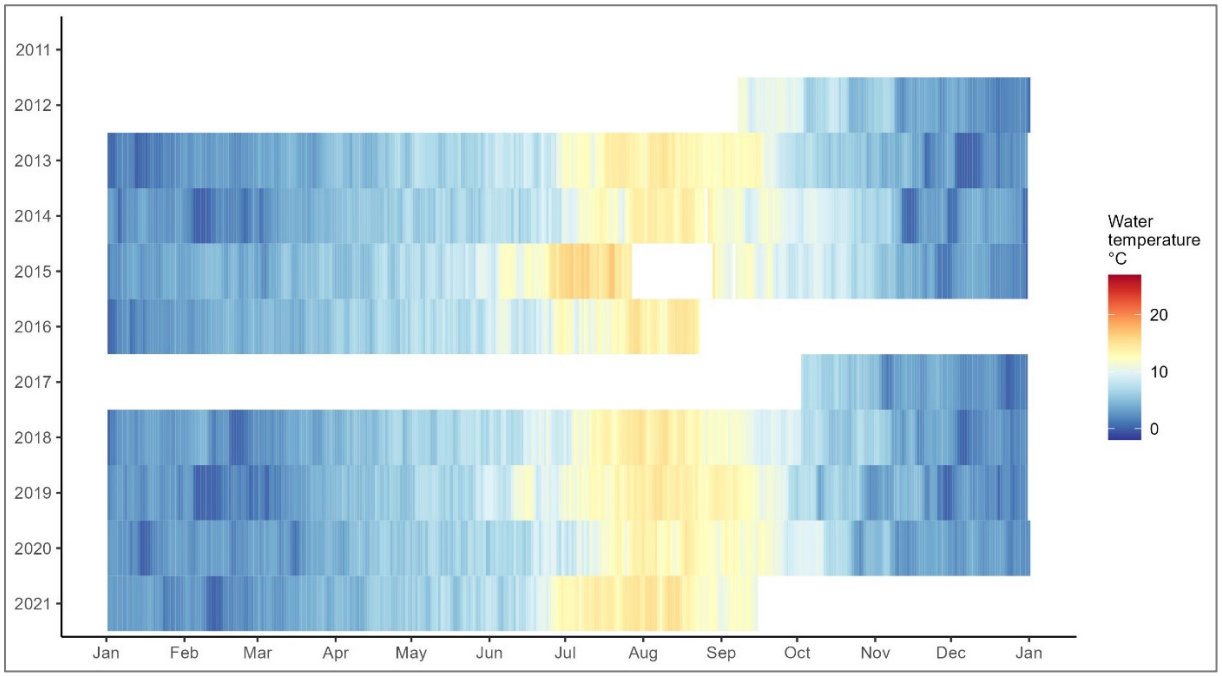

Figure 55. Maximum daily water temperatures at the Ruby Creek Station, 2012 to 2021.

NPS

Table 58. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 12°C as well as the percentage of the days of the year with no data for that metric at the Ruby Creek Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	70%
2013	71	full dataset
2014	38	2%
2015	34	12%
2016	36	36%
2017	none	77%
2018	47	full dataset
2019	67	full dataset
2020	51	full dataset
2021	65	29%

3.4.7.2 Instantaneous Water Temperature and Chemistry Data

Table 59 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Ruby Creek Station.

Table 59. Water temperature and chemistry values at the Ruby Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
09/07/12	10.21	10.03	8.41	104.93	0.47
09/18/13	10.20	11.00	7.51	84.47	4.68
08/26/14	12.30	10.26	7.33	93.30	0.43
09/06/15	9.20	10.66	7.16	98.29	0.27
08/30/16	10.60	11.49	7.94	101.10	0.29
10/02/17	6.50	11.90	7.90	117.80	0.71
09/05/18	9.80	11.28	8.16	108.41	0.20
09/16/19	10.51	10.50	8.04	99.00	0.32
08/31/20	10.87	10.52	7.96	101.54	0.33
09/15/21	10.50	10.64	8.02	112.70	0.12
Minimum	**6.50**	**10.03**	**7.16**	**84.47**	**0.12**
Maximum	**12.30**	**11.90**	**8.41**	**117.80**	**4.68**

3.4.7.3 Channel Morphology Metrics

Table 60 presents channel morphology measurements for the Ruby Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 60. Channel morphology measurements from the Ruby Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
09/07/12	32.43	18.33	1.01
09/18/13	27.27	18.61	0.68
08/26/14	24.27	19.74	0.93
09/06/15	27.27	18.61	0.68
08/30/16	25.63	19.76	0.82
10/02/17	31.83	17.44	0.50
09/05/18	30.40	19.03	0.85
09/16/19	28.37	18.43	0.79
08/31/20	31.40	20.35	0.79
09/15/21	28.23	18.33	0.67
Minimum	**24.27**	**17.44**	**0.50**
Maximum	**32.43**	**20.35**	**1.01**

3.5 Olympic National Park

Congress established Olympic National Park on Washington State's Olympic Peninsula in 1938. The park is 3,734 square kilometers, 95% of which are federally designated wilderness. Olympic National Park supports a large diversity of habitat types, including glaciated alpine regions, coastal zones, upland forests, and temperate rainforests.

NPS staff track water quality parameters at seven stations in Olympic National Park under the NCCN Water Quality Monitoring Protocol (Rawhouser et al. 2012). Three of the stations are coastal, while the remaining four are inland. All the streams associated with these stations drain into the Pacific Ocean except for Barnes Creek, which flows into the Strait of Juan de Fuca.

Water quality monitoring stations in the park represent several ecoregions (Omernik 2010) including Coastal Lowlands, Coastal Uplands, Low Olympics, High Olympics, and Volcanics Ecoregions. The Coastal Lowland Ecoregion is characterized by a marine influenced climate, beach habitat with low gradient, meandering, tannic streams, and forests dominated by Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla)*, and Douglas-fir (*Pseudotsuga menziesii*). Riparian areas within this ecoregion support red alder (*Alnus rubra)*, big leaf maple *(Acer macrophyllum)*, and western red cedar *(Thuja plicata)*. The Coastal Upland Ecoregion is similar to the Coastal Lowland Ecoregion but supports medium to high gradient tannic streams. The Low Olympics Ecoregion supports streams with steep gradients and watersheds with high levels of precipitation, yielding rainforest conditions and extremely high biomass. Dominant vegetation in this habitat includes

several varieties of epiphytes, western hemlock, western red cedar, Douglas-fir, and Pacific silver fir *(Abies amabilis)* at higher elevations. Located at even higher elevations, the High Olympics Ecoregion transitions from a Pacific silver fir and mountain hemlock *(Tsuga mertensiana)* dominated forest to alpine meadows with lakes and wetlands present, as well as areas of bare rock at the highest elevations. The Volcanics Ecoregion has similar precipitation levels and plant communities as the Olympics Ecoregion but is differentiated by a basaltic rock foundation (Omernik 2010).

3.5.1 Barnes Creek Station

The 400 m sample reach in Barnes Creek starts approximately 100 m upstream from its confluence with Lake Crescent, at an elevation of 180 m above sea level. Barnes Creek, a third order stream (Strahler 1952), is fed primarily by three mountain lakes, snowpack, groundwater inflow, and surface runoff. The reach runs through a broad alluvial fan and occupies a single channel, which is constrained by incision and human activities.

The isolation of the Lake Crescent basin has created a unique fish community within the lake and its tributaries. Included in the numerous species of fish and amphibians present is an endemic population of rainbow trout (*Oncorhynchus mykiss*), locally referred to as Beardslee trout (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005, Brenkman et al. 2014). Kokanee (*Oncorhynchus nerka*) and pygmy whitefish (*Prosopium coulteri*) also occur in the lake. Park staff have also documented the presence of two distinct populations of coastal cutthroat trout (*Oncorhynchus clarkii clarkii*), locally referred to as the Crescenti cutthroat trout, in the basin. The two populations are identified as either spring spawning or fall spawning. The Barnes Creek sample reach provides critical spawning habitat to the spring spawning Crescenti cutthroat trout (Brenkman et al 2014).

The impacts of infrastructure, roads, heavily used trails, and recreational use on this watershed's unique fish community are the most crucial monitoring concerns in this reach. In total, the Barnes Creek watershed contains 20.2 km of trails and has a trail density of 0.5 km/km^2, placing it above the 90th percentile for NCCN watersheds (Rawhouser et al. 2012). Nine abandoned mines are also present within the Barnes Creek watershed. Furthermore, in operation from May to January, the Lake Crescent Lodge includes over fifteen buildings and a network of paved access roads and parking lots. Some of these developments are within 10 m of the wetted channel. Three bridges (State Highway 101, a service road, and a trail) cross Barnes Creek within 1 km of its confluence with Lake Crescent. These structures confine Barnes Creek into a single channel, leading to channel incision and isolating the creek from its historic alluvial floodplain. This fundamentally changes the hydrologic structure and function of the creek and alters the process of gravel build up at the mouth of the creek.

3.5.1.1 Continuous Water Temperature Data

Figures 56–58 present maximum, minimum, and seven-day average water temperatures for the Barnes Creek Station in Olympic National Park. The monitoring program did not find any exceedances of the seven-day average daily maximum water temperature criterion of 16°C between 2012 and 2021; however, years 2014 to 2016 are missing from the dataset (Table 61).

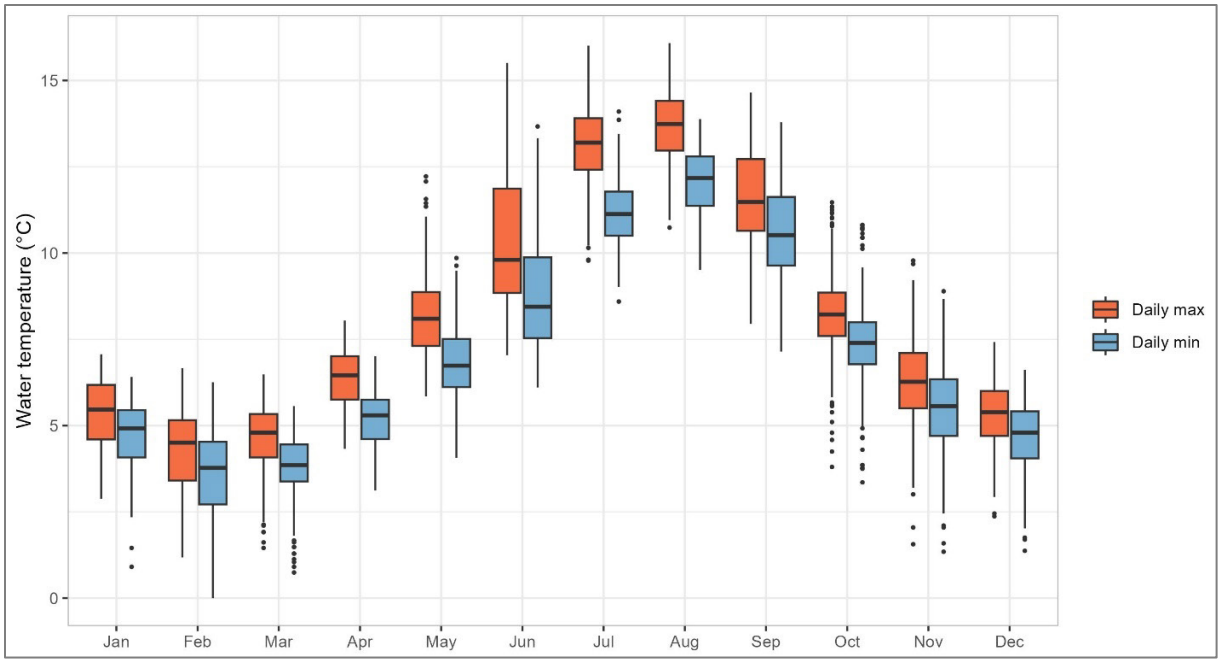

Figure 56. Maximum and minimum daily mean temperatures the Barnes Creek Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

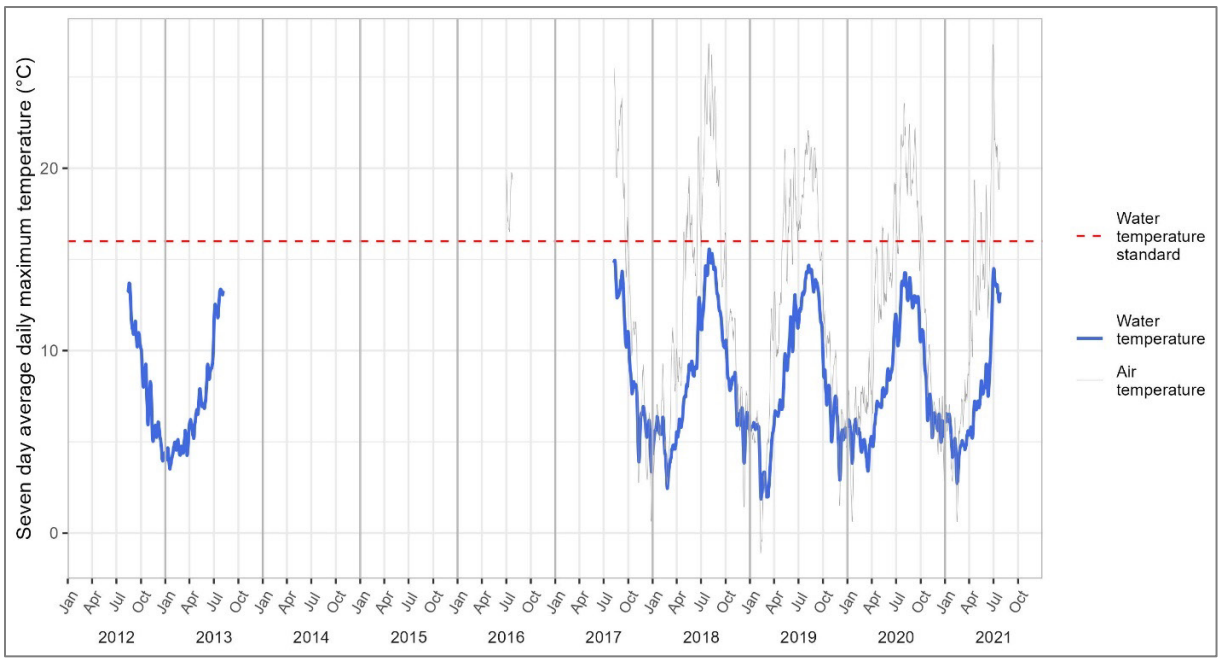

Figure 57. Seven-day average of the maximum daily water temperatures at the Barnes Creek Station, 2012 to 2021. The red dashed line at 16°C indicates the year-round state criterion for aquatic life use designation of salmon spawning, rearing, and migration. Any seven-day average maximum daily water temperature above 16°C constitutes an exceedance.

NPS

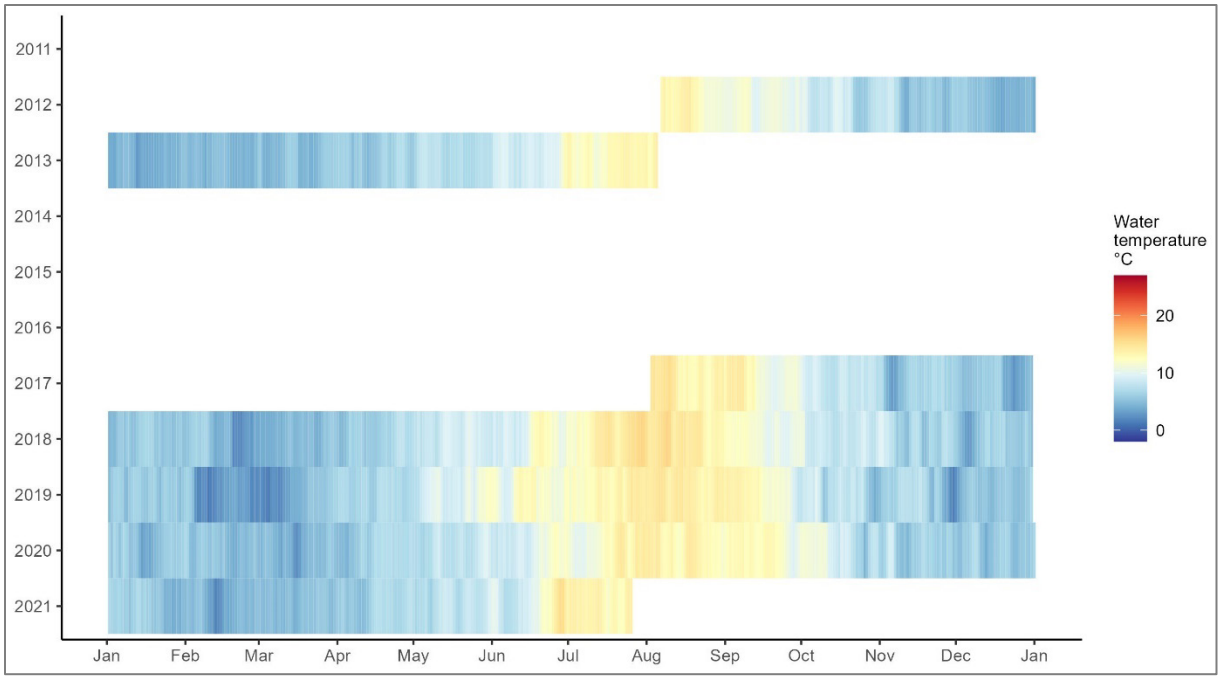

Figure 58. Maximum daily water temperatures at the Barnes Creek Station, 2012 to 2021.
NPS

Table 61. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 16°C as well as the percentage of the days of the year with no data for that metric at the Barnes Creek Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	61%
2013	none	41%
2014	none	100%
2015	none	100%
2016	none	100%
2017	none	60%
2018	none	full dataset
2019	none	full dataset
2020	none	full dataset
2021	none	43%

3.5.1.2 Instantaneous Water Temperature and Chemistry Data

Table 62 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Barnes Creek Station. This site's pH was higher than the Washington State criterion of 6.5–8.5 during the sampling event in 2016 (Table 62).

Table 62. Water temperature and chemistry values at the Barnes Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
08/06/12	13.17	9.77	6.82	108.30	0.48
08/05/13	14.10	10.13	7.50	126.41	0.30
08/04/14	15.39	9.85	8.03	137.06	0.35
08/02/15	15.31	9.63	8.25	143.31	0.20
07/25/16	14.61	11.32	9.37 [A]	135.89	0.60
08/02/17	13.69	10.35	7.61	128.69	0.51
08/03/18	13.20	10.87	8.28	138.03	0.22
07/29/19	14.39	10.17	7.93	135.17	0.17
07/27/20	13.20	10.15	7.81	131.20	0.24
07/26/21	13.10	10.43	7.94	126.90	0.29
Minimum	**13.10**	**9.63**	**6.82**	**108.30**	**0.17**
Maximum	**15.39**	**11.32**	**9.37**	**143.31**	**0.60**

[A] pH value higher than Washington State criterion of 6.5–8.5 (also in red font).

3.5.1.3 Channel Morphology Metrics

Table 63 presents channel morphology measurements for the Barnes Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 63. Channel morphology measurements from the Barnes Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
08/06/12	15.17	9.45	0.41
08/05/13	23.80	8.72	0.43
08/04/14	12.07	9.49	0.46
08/02/15	17.27	9.49	0.18
07/25/16	17.63	6.62	0.42
08/02/17	13.13	7.63	0.40
08/03/18	12.20	7.33	0.22
07/29/19	13.10	6.51	0.29
07/27/20	12.70	8.40	0.40
07/26/21	13.37	9.79	0.27
Minimum	**12.07**	**6.51**	**0.18**
Maximum	**23.80**	**9.79**	**0.46**

3.5.2 Umbrella Creek Station

Groundwater inflow and surface runoff primarily feed Umbrella Creek, which is a tributary to Lake Ozette. Umbrella Creek, a third order stream (Strahler 1952), migrates in a braided channel across its floodplain. The 240 m sample reach in Umbrella Creek starts approximately 1 km upstream from its confluence with Lake Ozette at an elevation of 20 m above sea level. The upstream extent ends just below the bridge on the Hoko Ozette Road. Torrent evidence suggests that this section of Umbrella Creek is in a depositional zone.

The impacts of logging and road construction on Umbrella Creek, which has at least seven species of fish, several likely species of amphibians, and serves as a significant contributor to available sockeye salmon (*Oncorhynchus nerka*) spawning habitat, make this a critical monitoring location (Leonard et al. 1993, Wydoski and Whitney 2003, Galvan et al. 2005, WNHP WDFW BLM 2005). Lake Ozette is the home of the only run of sockeye, a prized salmon, within the Makah Territory. The Makah Tribe (the Tribe) has worked to enhance and understand the sockeye population at Lake Ozette (currently listed as Threatened under the US Endangered Species Act) to return to traditional uses. The Tribe is particularly interested in habitat conditions in Lake Ozette, Umbrella Creek, and other tributaries which may inhibit the full recovery of this important treaty resource.

When park and network staff established this monitoring station, the surrounding land belonged to the Cascade Land Conservancy, and it was anticipated that the land would eventually be acquired by the NPS. However, following discussions between the NPS and the Makah Tribe, the Tribe acquired the land in 2015. The NPS continues to monitor water quality in this location with the permission of and in partnership with the Makah Tribe.

The greater Umbrella Creek watershed is almost entirely privately held and managed as commercial forest, with a small area managed by the state of Washington. Human activity within the watershed consists primarily of roads, logging, and recreational activities associated with Lake Ozette. Specifically, the Umbrella Creek watershed contains 120.2 km of roads and a road density of 4.11 km/km^2, which is the 3rd highest for all NCCN units (Rawhouser et al. 2012). The Washington Department of Ecology lists Umbrella Creek as impaired under Section 303(d) of the federal Clean Water Act for water temperature exceedances and dissolved oxygen levels (WDOE 2012). These conditions are likely the result of road construction and a legacy effect from past logging practices.

3.5.2.1 Continuous Water Temperature Data

Figures 59–61 present maximum, minimum, and seven-day average water temperatures for the Umbrella Creek Station in Olympic National Park. The seven-day average of the daily maximum water temperature exceeded the year-round state water quality criterion on at least 231 days in 2013–2021, while the seasonal criterion was exceeded on at least 208 days in 2013–2021 (Table 64).

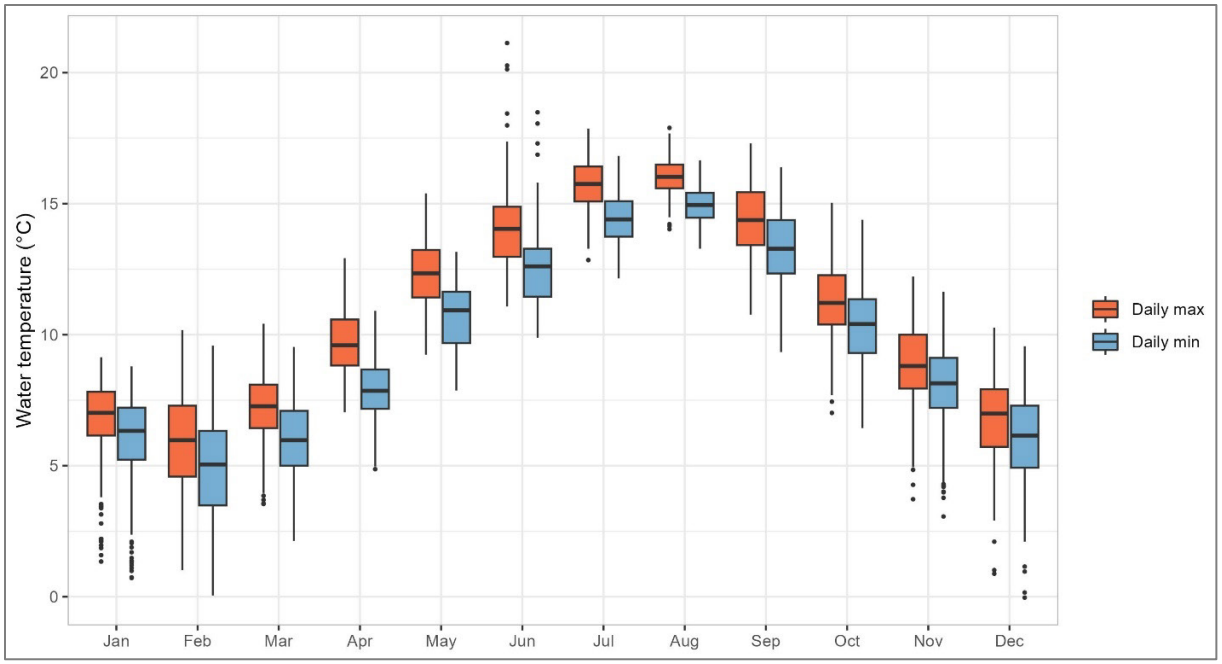

Figure 59. Maximum and minimum daily mean temperatures at the Umbrella Creek Station, 2013 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

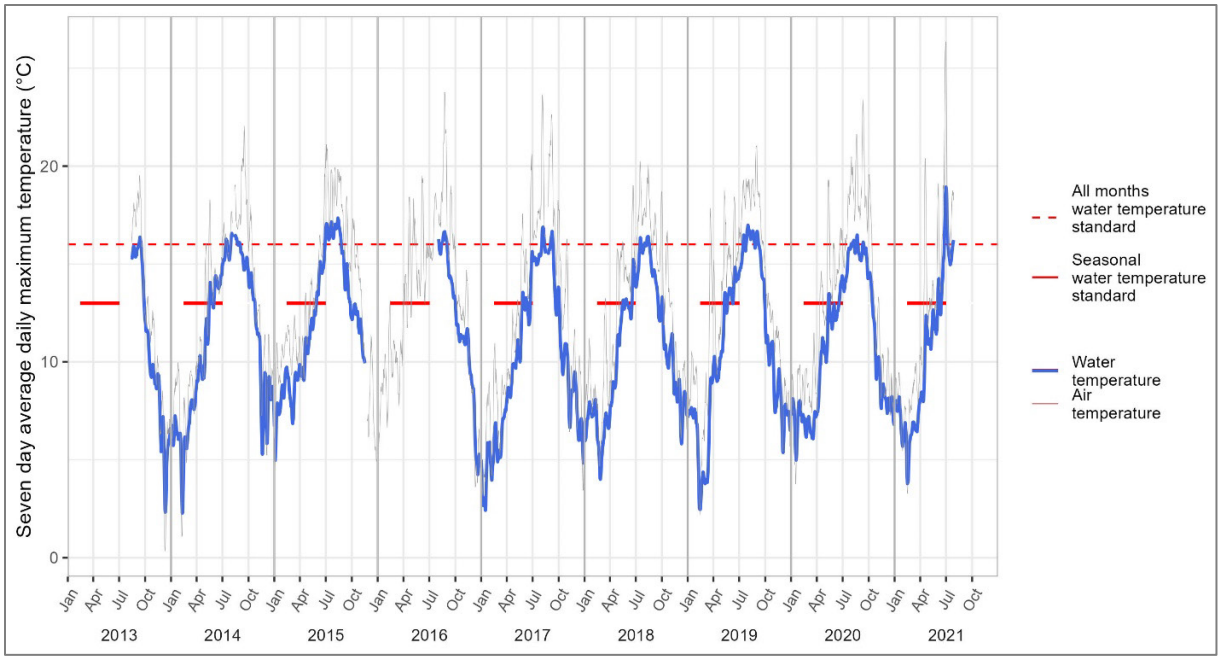

Figure 60. Seven-day average of the maximum daily water temperatures at the Umbrella Creek Station, 2013 to 2021. The red dashed line at 16°C indicates the year-round state criterion for aquatic life use designation of salmon rearing and migration. The thicker red long-dashed line at 13°C indicates the seasonal state criterion for salmon and steelhead spawning and incubation. Any seven-day average maximum daily water temperature above 16°C in any month or above 13°C between February 15 and July 1 constitutes an exceedance.

NPS

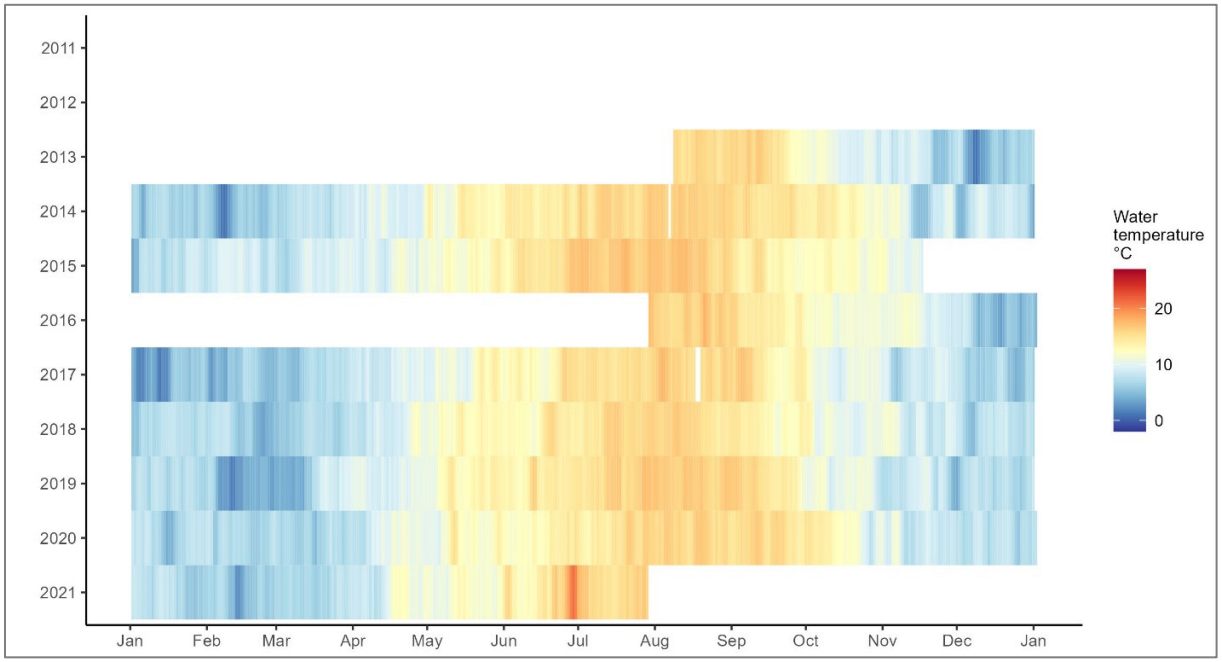

Figure 61 Maximum daily water temperatures at the Umbrella Creek Station, 2013 to 2021.

NPS

Table 64. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the year-round criterion of 16°C and the seasonal criterion of 13°C as well as the percentage of the days of the year with no data for that metric at the Umbrella Creek Station, 2013 to 2021.

Year	Number of Days with Observed Exceedances		Proportion of the Year with No Data
	Year-Round Criterion	Seasonal Criterion	
2013	8	none	62%
2014	28	42	2%
2015	57	34	12%
2016	21	none	59%
2017	18	19	2%
2018	19	26	full dataset
2019	47	45	full dataset
2020	16	18	full dataset
2021	17	24	43%

3.5.2.2 Instantaneous Water Temperature and Chemistry Data

Table 65 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Umbrella Creek Station. This site's dissolved oxygen was lower than the Washington State criterion of 9.5 mg/L during numerous sampling events between 2012 and 2021 (Table 65).

Table 65. Water temperature and chemistry values at the Umbrella Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
08/08/12	15.70	8.96 [A]	6.96	105.16	0.56
08/07/13	14.50	9.43 [A]	6.99	89.39	0.63
08/06/14	15.56	8.57 [A]	7.35	98.43	0.84
08/05/15	16.00	8.31 [A]	7.21	109.43	0.70
07/27/16	15.76	10.20	7.52	96.56	0.82
08/03/17	16.00	8.56 [A]	7.08	97.53	0.78
08/02/18	15.40	8.82 [A]	7.28	106.00	0.80
07/31/19	16.50	8.72 [A]	6.89	109.07	0.76
07/29/20	14.96	8.92 [A]	7.17	102.73	0.76
07/28/21	15.20	7.92 [A]	7.16	109.60	0.96

[A] DO value lower than the Washington State criterion of 9.5 (Table 4) (also in red font).

Table 65 (continued). Water temperature and chemistry values at the Umbrella Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (ºC)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
Minimum	**14.50**	**7.92**	**6.89**	**89.39**	**0.56**
Maximum	**16.50**	**10.20**	**7.52**	**109.60**	**0.96**

[A] DO value lower than the Washington State criterion of 9.5 (Table 4) (also in red font).

3.5.2.3 Channel Morphology Metrics

Table 66 presents channel morphology measurements for the Umbrella Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 66. Umbrella Creek sample reach Channel Morphology measurements from 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
08/08/12	16.10	7.54	0.39
08/07/13	17.47	4.81	0.36
08/06/14	15.53	7.73	0.58
08/05/15	17.63	6.48	0.49
07/27/16	12.97	6.56	0.49
08/03/17	17.77	5.58	0.37
08/02/18	18.23	7.02	0.55
07/31/19	15.70	9.72	0.59
07/29/20	17.93	6.81	0.34
07/28/21	17.00	5.58	0.35
Minimum	**12.97**	**4.81**	**0.34**
Maximum	**18.23**	**9.72**	**0.59**

3.5.3 Ozette River Station

The Ozette River is the outlet for Lake Ozette, primarily a rain and groundwater system, and flows directly into the Pacific Ocean. The sample reach begins at an elevation of 20 m above sea level, at the confluence with Lake Ozette, and is 500 m in length. This reach is on a third order segment (Strahler 1952) of the Ozette River that occupies a single channel and is constrained by incision into an alluvial terrace.

Monitoring of this reach helps assess threats to at least eleven species of fish and four species of amphibians posed by roads, trails, forestry, NPS infrastructure, and visitor use, as well as legacy effects from past human activities. NPS staff have observed numerous non-native aquatic species at or near this monitoring station, including largemouth bass (*Micropterus nigricans),* yellow perch

(Perca flavescens), brown bullhead catfish *(Ameiurus nebulosus),* yellow bullhead catfish *(Ameiurus natalis),* and American shad *(Alosa sapidissima)* (Pat Crain, pers. comm, 2024).

The Ozette River watershed consists primarily of privately held commercial forest, with smaller sections managed by the state of Washington. The Lake Ozette shoreline is owned and managed by the NPS. The Ozette District within the park is a popular destination, with 60,412 recreational visitors in 2012 (NPS 2014). The Washington Department of Ecology lists the Ozette River as impaired under Section 303(d) of the federal Clean Water Act for water temperature exceedances, and concerns about dissolved oxygen and pH levels (WDOE 2012). Lake Ozette is also listed for elevated levels of mercury (WDOE 2012). It is likely that habitat conditions within the lake have been significantly impacted by logging, development, and the historic practice of large woody debris removal beginning in the 1800s and continuing until 1985 (Kramer 1953, Haggerty et al. 2009). Absence of large wood in the channel, low pool frequency, and limited refuge cover are all consequences of the historic practice of wood removal.

The Rapid Habitat Assessment conducted for the Ozette River in 2012 indicated that the sample reach was in marginal condition due to low pool variability, low channel sinuosity, uniform habitat conditions, and poor vegetative protection. The removal of large woody debris has likely led to low habitat diversity within the reach. Furthermore, the prevalence of reed canary grass (*Phalaris arundinacea*), a non-native invasive species, also impacts habitat quality. Reed canary grass excludes native vegetation from growing, provides poor cover and shading within the riparian zone, and islands of reed canary grass within the channel may impact sediment transport.

3.5.3.1 Continuous Water Temperature Data

Figures 62–64 present maximum, minimum, and seven-day average water temperatures for the Ozette River Station in Olympic National Park. The seven-day average of the daily maximum water temperature exceeded the criterion of 16°C on at least 1,062 days in 2012–2021 (Table 67).

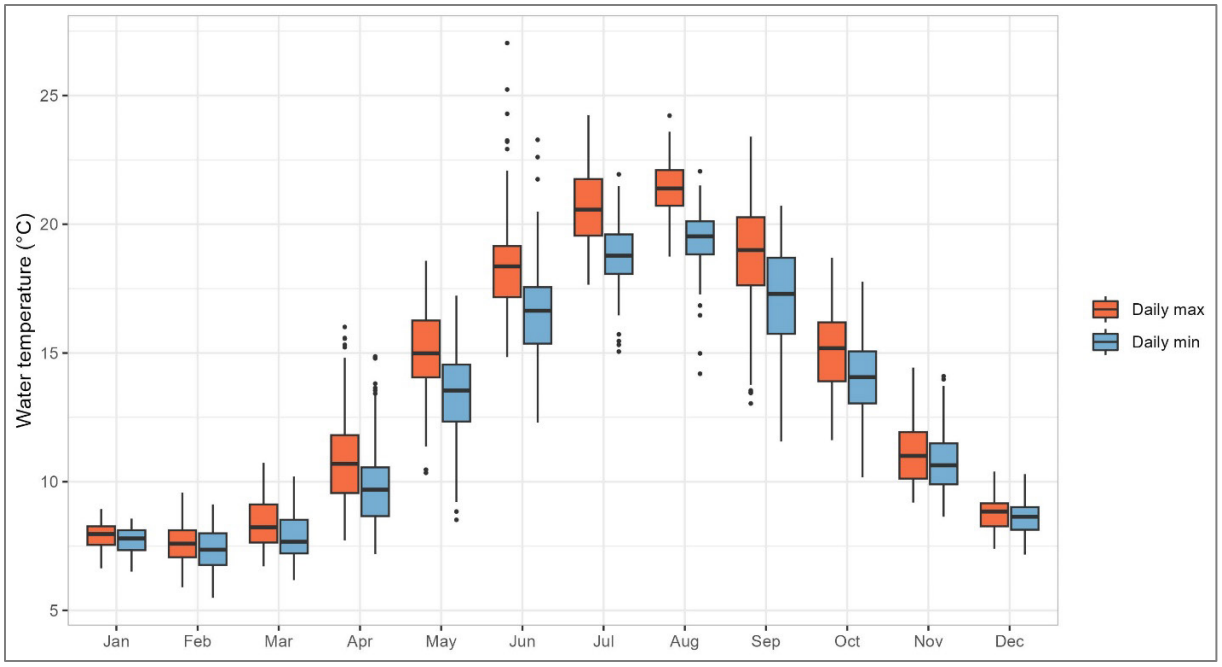

Figure 62. Maximum and minimum daily mean temperatures at the Ozette River Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

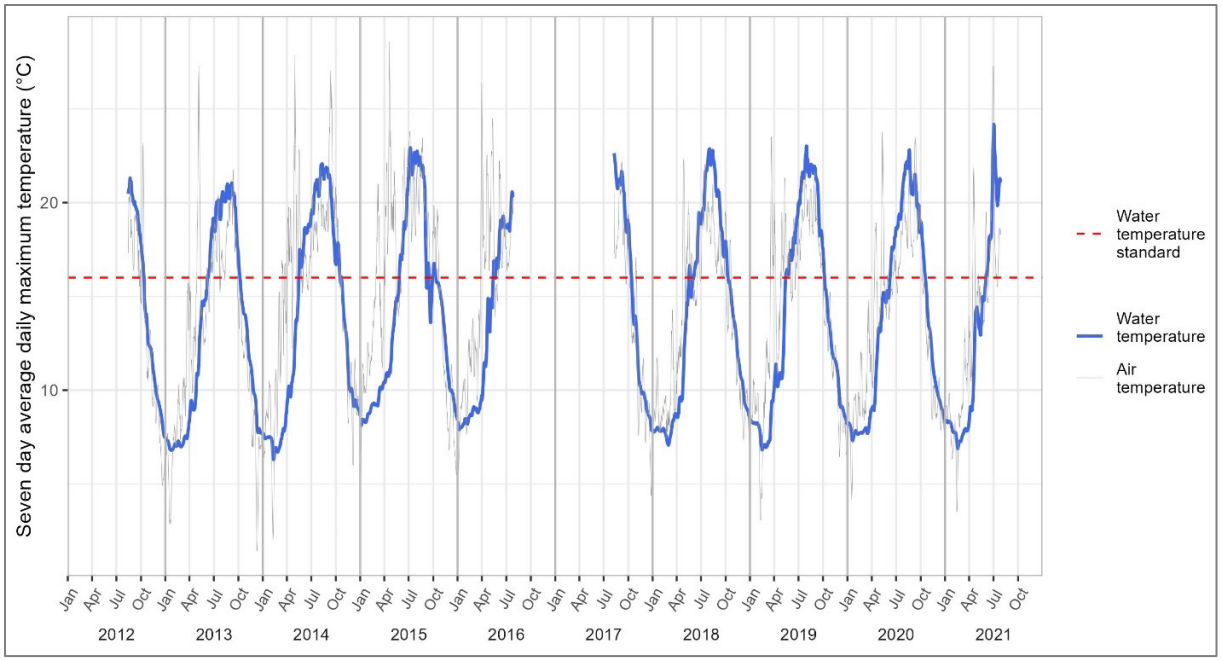

Figure 63. Seven-day average of the maximum daily water temperatures at the Ozette River Station, 2012 to 2021. The red dashed line at 16°C indicates the year-round state criterion for aquatic life use designation of salmon spawning, rearing, and migration. Any seven-day average maximum daily water temperature above 16°C constitutes an exceedance.

NPS

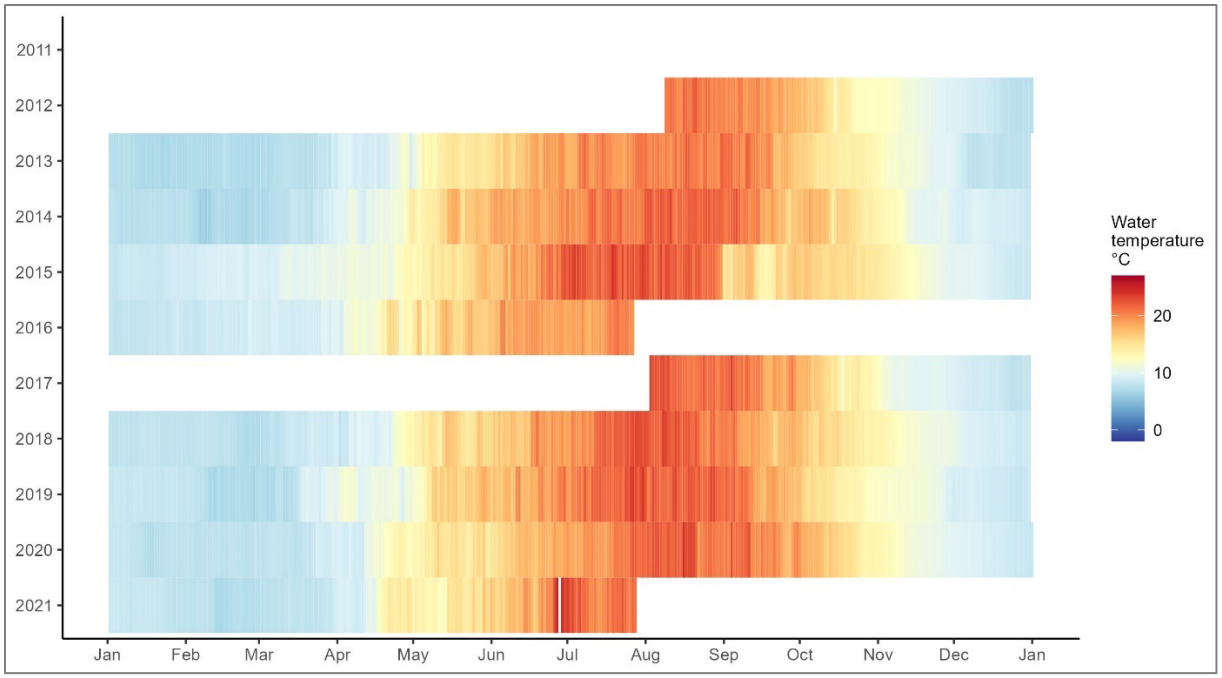

Figure 64. Maximum daily water temperatures at the Ozette River Station, 2012 to 2021.
NPS

Table 67. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 16°C as well as the percentage of the days of the year with no data for that metric at the Ozette River Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	60	62%
2013	121	full dataset
2014	156	full dataset
2015	120	full dataset
2016	73	43%
2017	66	60%
2018	134	full dataset
2019	145	full dataset
2020	132	full dataset
2021	55	43%

3.5.3.2 Instantaneous Water Temperature and Chemistry Data

Table 68 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Ozette River Station. This site's dissolved oxygen was lower than the Washington State criterion of 9.5 mg/L during each sampling event from 2012 through 2021, excluding 2016 (Table 68).

Table 68 Water temperature and chemistry values at the Ozette River Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (ºC)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
08/08/12	20.10	8.88 [A]	7.27	49.57	0.70
08/07/13	18.90	9.34 [A]	7.01	42.21	0.80
08/06/14	21.21	9.44 [A]	7.44	44.40	1.05
08/05/15	19.90	8.62 [A]	7.17	44.33	1.35
07/27/16	20.50	10.75	7.88	43.64	0.84
08/02/17	21.20	9.26 [A]	6.86	42.61	0.72
08/02/18	21.43	9.26 [A]	7.31	98.74	0.73
07/31/19	21.80	9.29 [A]	7.01	42.49	0.64
07/30/20	19.84	9.26 [A]	6.91	41.91	1.00
07/28/21	22.10	9.65 [A]	6.88	41.30	0.74
Minimum	**18.90**	**8.62**	**6.86**	**41.30**	**0.64**
Maximum	**22.10**	**10.75**	**7.88**	**98.74**	**1.35**

[A] DO value lower than the Washington State criterion of 9.5 (Table 4) (also in red font).

3.5.3.3 Channel Morphology Metrics

Table 69 presents channel morphology measurements for the Ozette River Station, including data on bankfull width, wetted width, and thalweg depth.

Table 69. Channel morphology measurements from the Ozette River Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
08/08/12	26.63	16.92	0.84
08/07/13	20.53	16.56	0.70
08/06/14	16.60	15.90	0.51
08/05/15	17.90	12.78	0.47
07/27/16	20.73	15.56	0.54
08/02/17	21.73	17.67	0.77
08/02/18	25.67	14.39	0.64
07/31/19	21.83	15.32	0.48
07/30/20	22.70	16.91	0.83
07/28/21	17.97	14.40	0.43
Minimum	**16.60**	**12.78**	**0.43**
Maximum	**26.63**	**17.67**	**0.84**

3.5.4 Kalaloch Creek Station

Kalaloch Creek drains directly into the Pacific Ocean and is fed primarily by groundwater inflow and precipitation generated surface runoff. The sample reach starts approximately 1 km upstream from the creek mouth at the Pacific Ocean and is at 6 m above sea level, which is beyond the influence of saltwater. The 400 m long sample reach is on a third order (Strahler 1952) segment of the Kalaloch Creek and where the stream is confined to a single channel, incised into a broad terrace.

The Kalaloch Creek watershed is primarily composed of state and privately held forestland, with a small portion managed by the NPS. Park staff have documented six species of fish in the reach, including federally threatened bull trout (*Salvelinus confluentus*), with several others potentially present (Wydoski and Whitney 2003). Due to the lack of public land, amphibian surveys have been limited, and only the northern red-legged frog (*Rana aurora*) has been documented in the sample reach, though seven others could be present (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005). The largest potential threat to these species comes from road development, forestry practices, and NPS infrastructure and recreational use. The watershed contains 117.2 km of roads and has a road density of 2.63 km/km^2, which is above the 90th percentile for NCCN watersheds (Rawhouser et al. 2012). Additional infrastructure includes seasonal housing, maintenance facilities, and a water treatment plant that withdrew water from the creek until the summer of 2014. The Washington Department of Ecology lists Kalaloch Creek as impaired under Section 303(d) of the federal Clean Water Act for water temperature exceedances (WDOE 2012).

3.5.4.1 Continuous Water Temperature Data

Figures 65–67 present maximum, minimum, and seven-day average water temperatures for the Kalaloch Creek Station in Olympic National Park. The seven-day average of the daily maximum water temperature exceeded the criterion of 16°C on 29 days between 2012 and 2021 (Table 70).

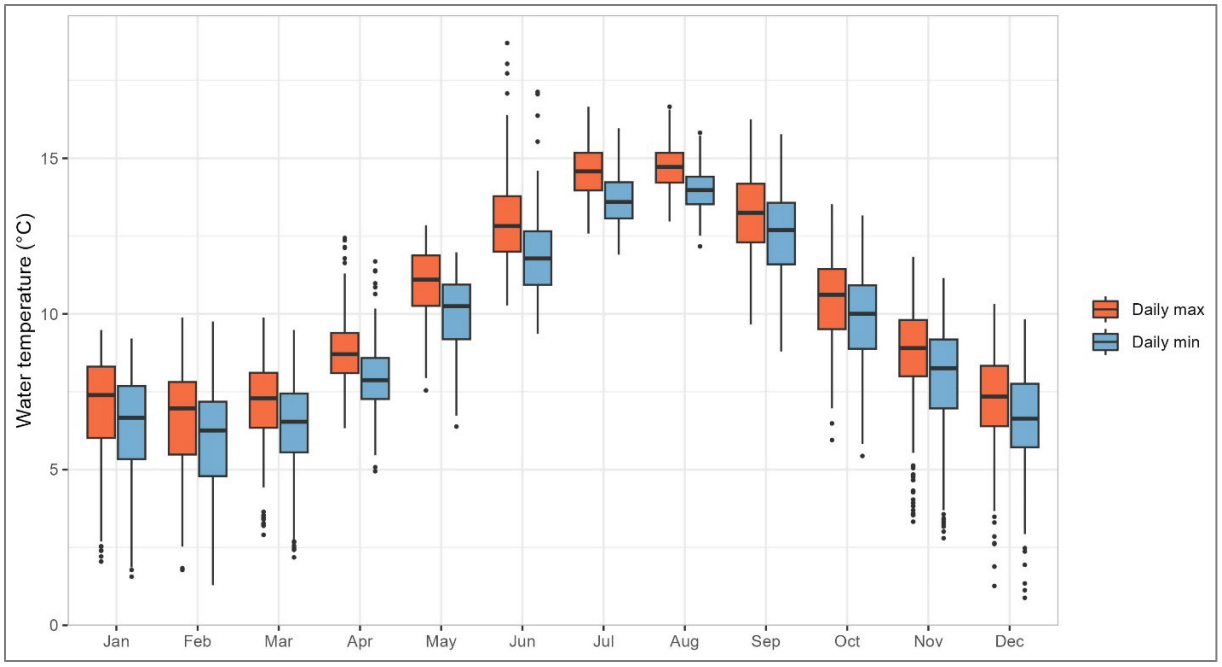

Figure 65. Maximum and minimum daily mean temperatures at the Kalaloch Creek Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

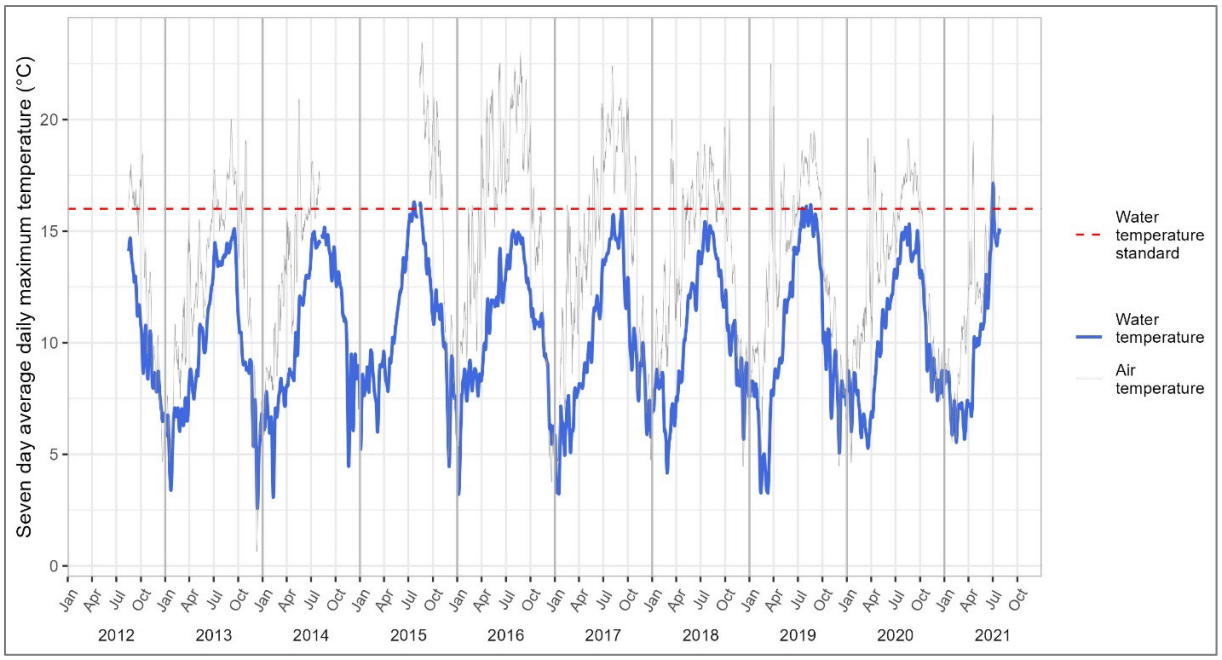

Figure 66. Seven-day average of the maximum daily water temperatures at the Kalaloch Creek Station, 2012 to 2021. The red dashed line at 16°C indicates the year-round state criterion for aquatic life use designation of salmon spawning, rearing, and migration. Any seven-day average maximum daily water temperature above 16°C constitutes an exceedance.

NPS

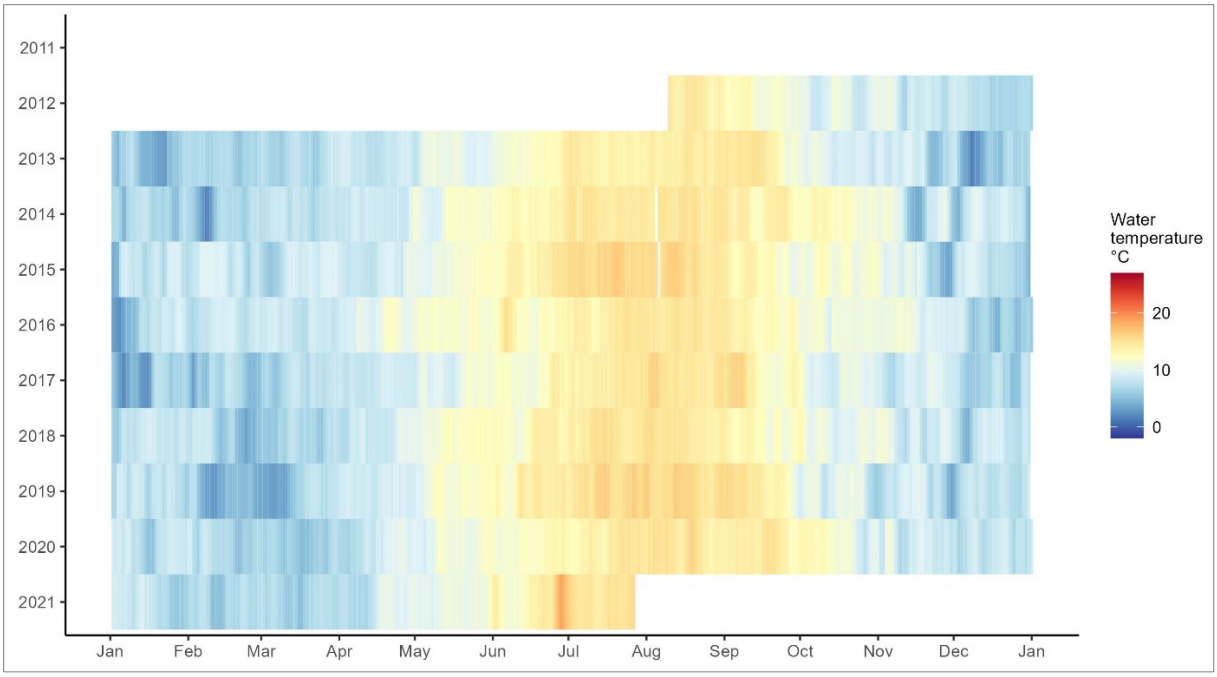

Figure 67. Maximum daily water temperatures at the Kalaloch Creek Station, 2012 to 2021.
NPS

Table 70. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the criterion of 16°C as well as the percentage of the days of the year with no data for that metric at the Kalaloch Creek Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	none	62%
2013	none	full dataset
2014	none	2%
2015	13	2%
2016	none	full dataset
2017	none	full dataset
2018	none	full dataset
2019	9	full dataset
2020	none	full dataset
2021	7	43%

3.5.4.2 Instantaneous Water Temperature and Chemistry Data

Table 71 presents water temperature and chemistry data including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Kalaloch Creek Station. This site's dissolved oxygen was lower than the Washington State criterion of 9.5 mg/L

during sampling events in 2012 and 2017, while pH at this location was higher than the state criterion of 6.5–8.5 during the sampling event in 2016 (Table 71).

Table 71. Water temperature and chemistry values at the Kalaloch Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
08/09/12	14.10	9.48 [A]	6.96	64.49	1.97
08/08/13	13.50	10.16	6.89	57.87	1.94
08/05/14	14.61	10.04	7.20	62.84	1.77
08/06/15	15.40	9.51	7.13	62.67	2.19
07/28/16	14.96	11.71	8.65 [B]	60.90	1.43
08/04/17	15.20	9.26 [A]	6.56	60.30	1.66
07/30/18	14.17	9.83	7.24	61.60	1.25
07/31/19	16.00	9.50	6.53	61.34	1.70
07/30/20	13.10	9.84	6.80	60.00	1.63
07/28/21	14.70	9.60	6.78	60.90	1.40
Minimum	**13.10**	**9.26**	**6.53**	**57.87**	**1.25**
Maximum	**16.00**	**11.71**	**8.65**	**64.49**	**2.19**

[A] DO value lower than the Washington State criterion of 9.5 (Table 4) (also in red font).

[B] pH value higher than Washington State criterion of 6.5–8.5 (Table 4) (also in red font).

3.5.4.3 Channel Morphology Metrics

Table 72 presents channel morphology measurements for the Kalaloch Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 72. Channel morphology measurements from the Kalaloch Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
08/09/12	18.30	12.18	0.74
08/08/13	23.43	12.23	0.81
08/05/14	15.17	11.44	0.63
08/06/15	19.03	10.88	0.52
08/04/17	17.30	11.23	0.71
07/30/18	20.77	12.37	0.93
07/31/19	20.53	11.75	0.91
07/30/20	20.03	14.26	0.96
07/28/21	20.57	12.45	0.67

Table 72 (continued). Channel morphology measurements from the Kalaloch Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
Minimum	**15.17**	**10.88**	**0.52**
Maximum	**23.43**	**14.26**	**0.96**

3.5.5 Matheny Creek Station

Groundwater inflow and surface runoff of rain feed Matheny Creek, a tributary to the Queets River. The Matheny Creek sample reach starts at 55 m above sea level, approximately 50 m upstream from the confluence with the Queets. The 500 m long sample reach is on a third order segment (Strahler 1952) of Matheny Creek that occupies an anastomosing channel, flowing largely unconstrained through a broad floodplain.

The Washington Department of Ecology lists Matheny Creek as impaired under Section 303(d) of the federal Clean Water Act for water temperature exceedances (WDOE 2012). Park staff consider legacy effects from historic forestry practices and road development, as well as current road and logging operations, as the primary stressors within the Matheny Creek watershed. Furthermore, the Rapid Habitat Assessment conducted for Matheny Creek in 2012 indicated optimal to sub-optimal habitat conditions within the sample reach. Stable and diverse habitat was created by a high diversity of velocity and depth regimes as well as a high frequency of riffle habitat. However, bank stability was compromised by lack of vegetative protection, and channel flow status was low, resulting in expansive areas of exposed gravel bars. These sub-optimal conditions and water temperature exceedances have the capacity to threaten aquatic organisms, including eight species of fish (Wydoski and Whitney 2003), four species of documented amphibians (Galvan et al. 2005), and up to six additional amphibians likely present (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005).

3.5.5.1 Continuous Water Temperature Data

Figures 68–70 present maximum, minimum, and seven-day average water temperatures for the Matheny Creek Station in Olympic National Park. The seven-day average of the daily maximum water temperature exceeded the state criterion of 12°C on at least 969 days between 2012 and 2021 (Table 73).

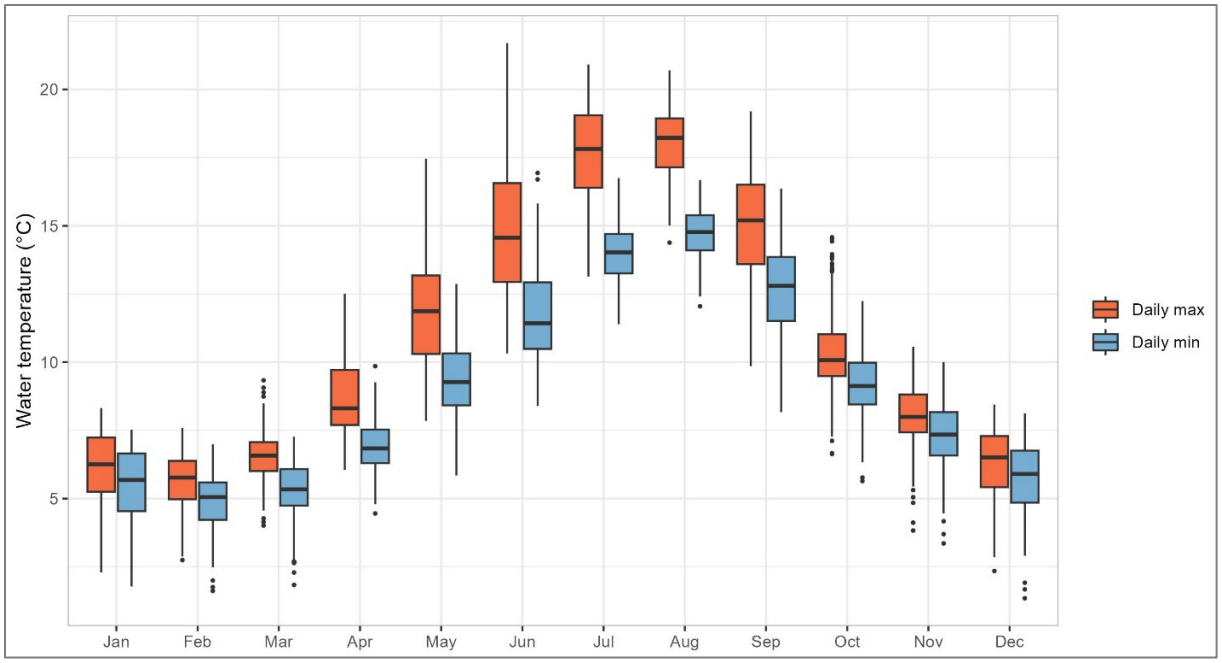

Figure 68. Maximum and minimum daily mean temperatures at the Matheny Creek Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

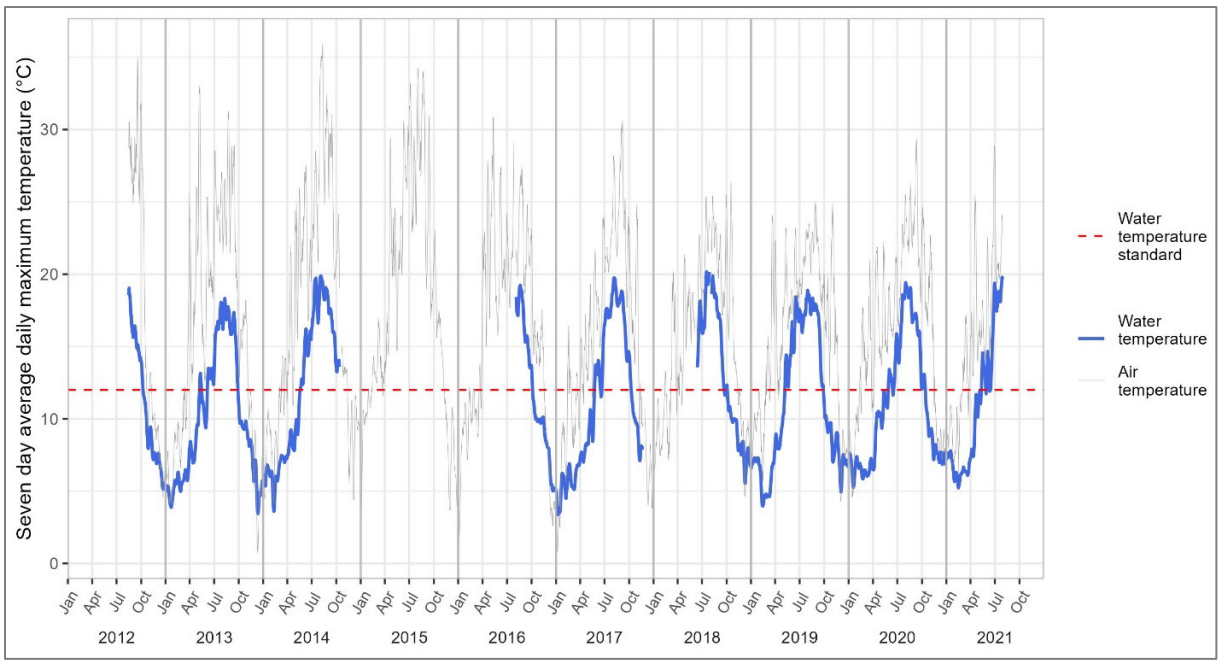

Figure 69. Seven-day average of the maximum daily water temperatures at the Matheny Creek Station, 2012 to 2021. The red dashed line at 12°C indicates the year-round state criterion for aquatic life use designation of char spawning and rearing. Any seven-day average maximum daily water temperature above 12°C constitutes an exceedance.

NPS

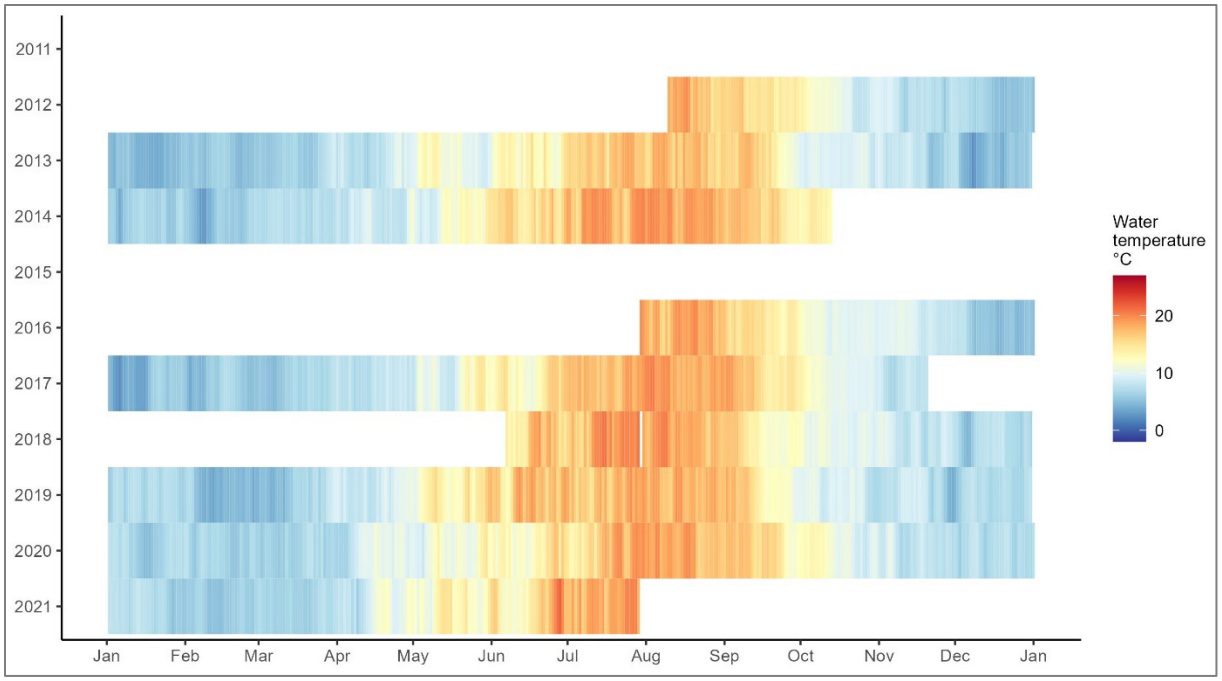

Figure 70. Maximum daily water temperatures at the Matheny Creek Station, 2012 to 2021. *NPS*

Table 73. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the state criterion of 12°C as well as the percentage of the days of the year with no data for that metric at the Matheny Creek Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances	Proportion of the Year with No Data
2012	54	62%
2013	122	full dataset
2014	147	22%
2015	none	100%
2016	62	59%
2017	132	11%
2018	99	47%
2019	144	full dataset
2020	135	full dataset
2021	74	42%

3.5.5.2 Instantaneous Water Temperature and Chemistry Data

Table 74 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Matheny Creek Station. This site's dissolved oxygen was lower than the Washington State criterion of 9.5 mg/L during the sampling event in 2012.

Table 74. Water temperature and chemistry values at the Matheny Creek Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
08/09/12	15.99	8.24 [A]	6.82	67.31	0.79
08/08/13	14.56	9.83	6.85	63.00	0.69
08/07/14	15.80	9.86	7.43	72.06	0.94
08/06/15	16.30	9.91	7.63	77.80	1.02
07/28/16	16.60	11.30	7.85	64.40	1.89
08/04/17	18.50	9.54	6.93	65.81	1.65
07/30/18	20.14	9.63	7.48	71.99	1.39
08/01/19	16.00	10.25	7.07	68.50	1.16
07/30/20	19.59	10.00	7.45	66.67	1.63
07/29/21	17.00	9.98	7.17	67.70	0.75
Minimum	**14.56**	**8.24**	**6.82**	**63.00**	**0.69**
Maximum	**20.14**	**11.30**	**7.85**	**77.80**	**1.89**

[A] DO value lower than the Washington State criterion of 9.5 (Table 4) (also in red font).

3.5.5.3 Channel Morphology Metrics

Table 75 presents channel morphology measurements for the Matheny Creek Station, including data on bankfull width, wetted width, and thalweg depth.

Table 75. Channel morphology measurements from the Matheny Creek Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
08/09/12	42.00	16.01	0.61
08/08/13	53.00	19.85	0.63
08/07/14	49.10	21.55	0.72
08/06/15	35.50	11.05	0.57
07/28/16	32.70	15.75	0.92
08/04/17	28.40	16.77	1.33
07/30/18	64.33	16.05	1.10
08/01/19	78.33	12.10	0.82
07/30/20	75.53	23.53	1.06
07/29/21	55.43	20.04	0.86
Minimum	**28.40**	**11.05**	**0.57**
Maximum	**78.33**	**23.53**	**1.33**

3.5.6 South Fork Calawah River Station

The South Fork Calawah River is a tributary to the Quillayute River, primarily fed by groundwater inflow and precipitation generated surface runoff. The sample reach starts at an elevation of 122 m above sea level and is 500 m long. Located in the bottom of a V-shaped valley, the reach is on a fourth order segment (Strahler 1952) of the South Fork Calawah River that is confined to a single channel constrained by bedrock and boulders. The sample reach also shows evidence of scour and erosion that likely reduces the extent of pool-riffle habitat.

Monitoring occurs for threats posed to water quality from commercial forestry, road development, and visitor use. The Washington Department of Ecology lists the South Fork Calawah River as impaired under Section 303(d) of the federal Clean Water Act for water temperature exceedances (WDOE 2012). Pool variability and sinuosity scored low, indicating a lack of diversity in available habitat. Additionally, low channel flow status led to a relatively narrow wetted width for the channel size, creating expansive gravel bars. Such conditions could impact documented riverine species, including seven species of fish in the sample reach, and several others that are potentially present (Wydoski and Whitney 2003). Only one species of amphibian has been documented in the South Fork Calawah River watershed (Galvan et al. 2005); however, regional distribution data and habitat requirements indicate that ten additional species are potentially present (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005).

3.5.6.1 Continuous Water Temperature Data

Figures 71–73 present maximum, minimum, and seven-day average water temperatures for the South Fork Calawah River Station in Olympic National Park. The seven-day average of the daily maximum water temperature exceeded the year-round criterion of 16°C on 637 days between 2012 and 2021 and the seasonal criterion of 13°C on 292 days between 2012 and 2021 (Table 76).

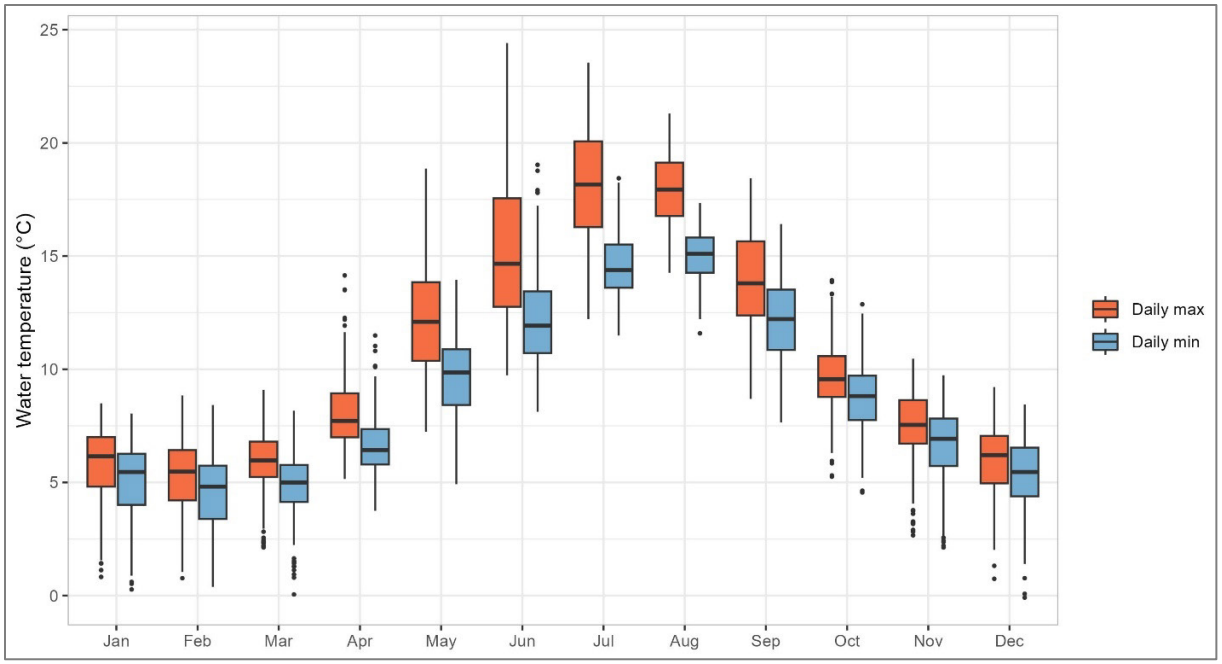

Figure 71. Maximum and minimum daily mean temperatures at the South Fork Calawah River Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

NPS

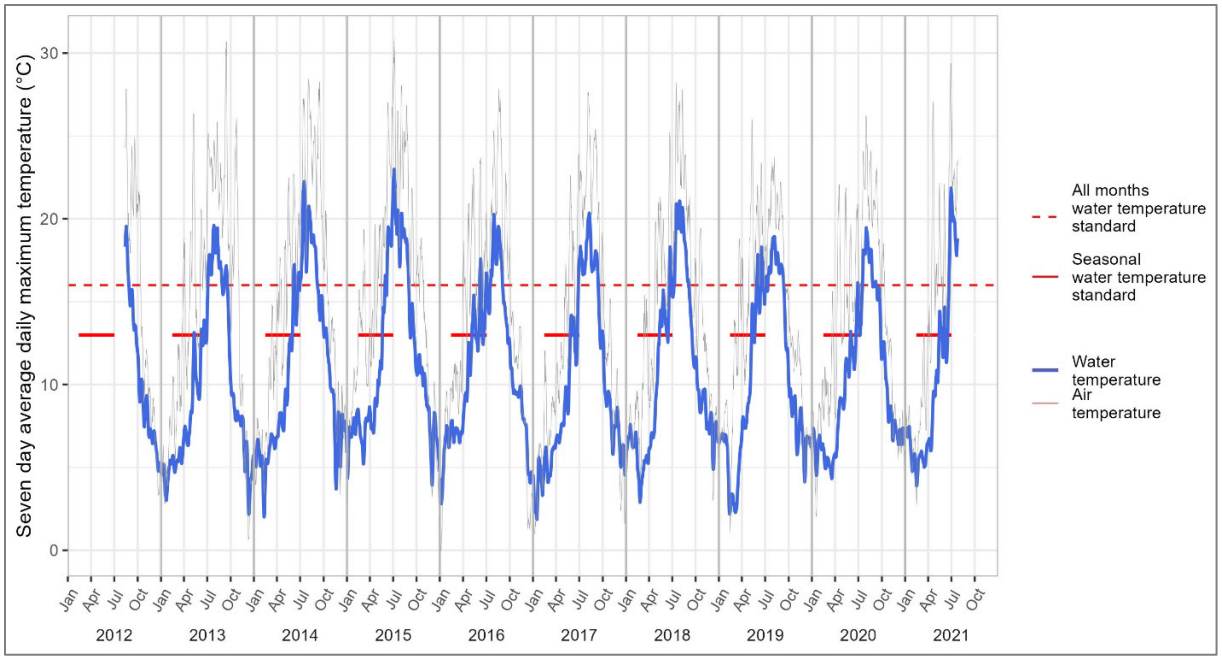

Figure 72. Seven-day average of the maximum daily water temperatures at the South Fork Calawah River Station, 2012 to 2021. The red dashed line at 16°C indicates the year-round state criterion for aquatic life use designation of salmon rearing and migration. The thicker red long-dashed line at 13°C indicates the seasonal state criterion for salmon and steelhead spawning and incubation. Any seven-day average maximum daily water temperature above 16°C in any month or above 13°C between February 15 and July 1 constitutes an exceedance.
NPS

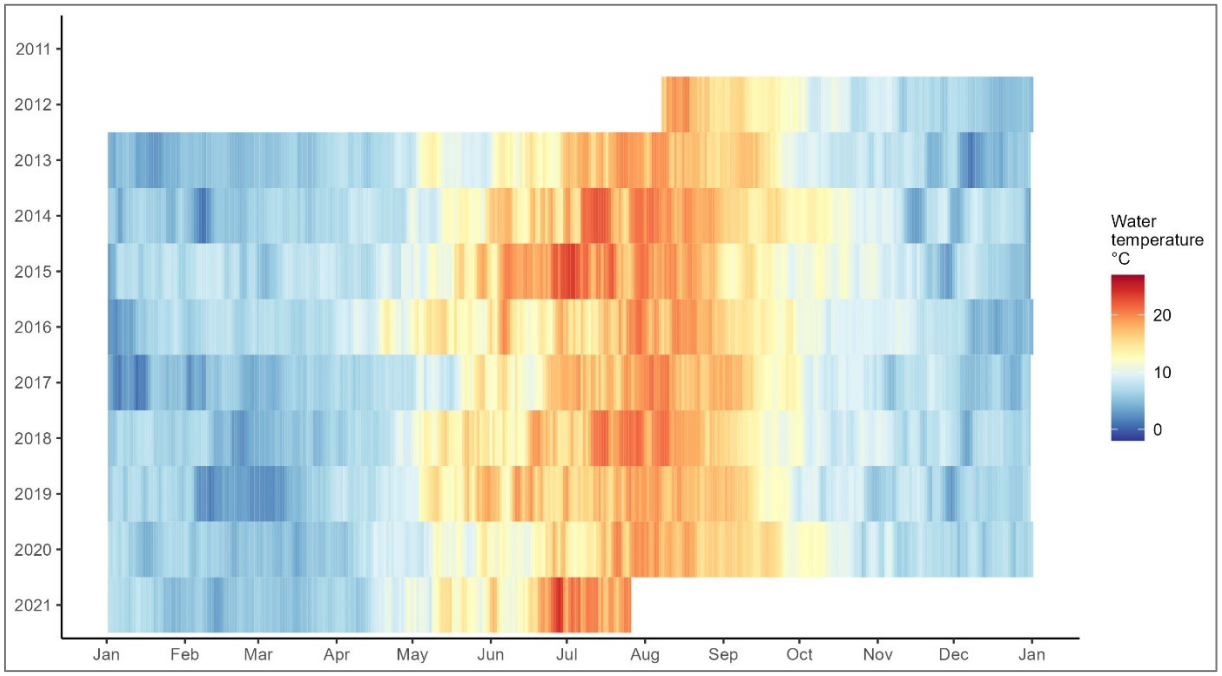

Figure 73. Maximum daily water temperatures at the South Fork Calawah River Station, 2012 to 2021.
NPS

Table 76. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the year-round criterion of 16°C and the seasonal criterion of 13°C as well as the percentage of the days of the year with no data for that metric at the South Fork Calawah River Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances		Proportion of the Year with No Data
	Year-Round Criterion	Seasonal Criterion	
2012	15	none	62%
2013	69	16	full dataset
2014	84	31	full dataset
2015	90	42	full dataset
2016	60	40	full dataset
2017	78	23	full dataset
2018	65	48	full dataset
2019	89	50	full dataset
2020	52	11	full dataset
2021	35	31	43%

3.5.6.2 Instantaneous Water Temperature and Chemistry Data

Table 77 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the South Fork Calawah River Station.

Table 77. Water temperature and chemistry values at the South Fork Calawah River Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
08/07/12	16.39	9.55	7.40	88.93	0.44
08/06/13	16.36	10.11	7.34	78.30	0.26
08/05/14	19.37	10.32	8.26	86.36	0.27
08/04/15	19.70	9.73	8.36	91.29	0.25
07/26/16	17.20	11.54	7.60	77.16	0.29
08/03/17	18.99	9.78	7.88	79.66	0.29
07/31/18	18.51	10.17	8.41	85.27	0.26
07/30/19	17.57	10.14	7.84	78.29	0.26
07/28/20	17.60	9.79	7.65	79.21	0.30
07/27/21	19.00	9.72	7.52	82.20	0.37
Minimum	**16.36**	**9.55**	**7.34**	**77.16**	**0.25**
Maximum	**19.70**	**11.54**	**8.41**	**91.29**	**0.44**

3.5.6.3 Channel Morphology Metrics

Table 78 presents channel morphology measurements for the South Fork Calawah River Station, including data on bankfull width, wetted width, and thalweg depth.

Table 78. Channel morphology measurements from the South Fork Calawah River Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
08/07/12	26.17	21.63	0.85
08/06/13	33.17	19.38	0.77
08/05/14	29.87	22.28	0.82
08/04/15	29.17	17.08	0.59
07/26/16	30.10	19.83	0.81
08/03/17	29.90	18.79	0.71
07/31/18	25.80	16.31	0.70
07/30/19	25.00	18.50	1.03
07/28/20	30.93	16.88	0.84
07/27/21	24.43	17.92	0.64
Minimum	**24.43**	**16.31**	**0.59**
Maximum	**33.17**	**22.28**	**1.03**

3.5.7 Sol Duc River Station

The Sol Duc River sample reach starts at an elevation of 478 m above sea level. Groundwater inflow, over a dozen mountain lakes, and surface runoff from rainfall and snowpack melt primarily feed the Sol Duc River. The sample reach was extended to 680 m long, exceeding the maximum length defined in the protocol (Rawhouser et al. 2012), to start below a significant side channel and end above the Sol Duc Resort. This reach is on a fourth order segment (Strahler 1952) of the Sol Duc River where the river occupies an anastomosing channel and runs unconstrained within a broad terrace.

Park and network staff chose this reach on the Sol Duc River for monitoring to be co-located with the Washington Department of Ecology's listing of pH exceedances, under Section 303(d) of the federal Clean Water Act (WDOE 2012). The Department notes that it is uncertain whether the high pH readings are a result of human activity or geothermal activity (WDOE 2012). Dissolved oxygen and temperature are also of concern for this reach under Section 303(d) (WDOE 2012). These issues, at least in part, may be natural conditions arising from geothermal activity. Additional sources likely contributing to these violations include trails, roads, NPS infrastructure, the Sol Duc Hot Springs Resort, and recreational use.

The Rapid Habitat Assessment conducted for the Sol Duc River in 2012 indicated overall sub-optimal habitat conditions. Channelization due to bank armoring is contributing to low pool variety and reduced channel sinuosity, creating a lack of diversity in available habitat. The presence of the

Sol Duc Hot Springs Resort, adjacent to the stream channel in parts of the reach, contributes to low riparian zone scores. These issues, combined with the violations mentioned above, may impact the four species of fish documented in this sample reach (Wydoski and Whitney 2003), two documented amphibian species the Sol Duc River sample reach, and nine additional amphibian species documented in the watershed (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005).

3.5.7.1 Continuous Water Temperature Data

Figures 74–76 present maximum, minimum, and seven-day average water temperatures for the Sol Duc River Station in Olympic National Park. The seven-day average of the daily maximum water temperature did not exceed the year-round criterion of 16°C on any days between 2012 and 2021 but did exceed the seasonal criterion of 13°C on 46 days between 2012 and 2021 (Table 79).

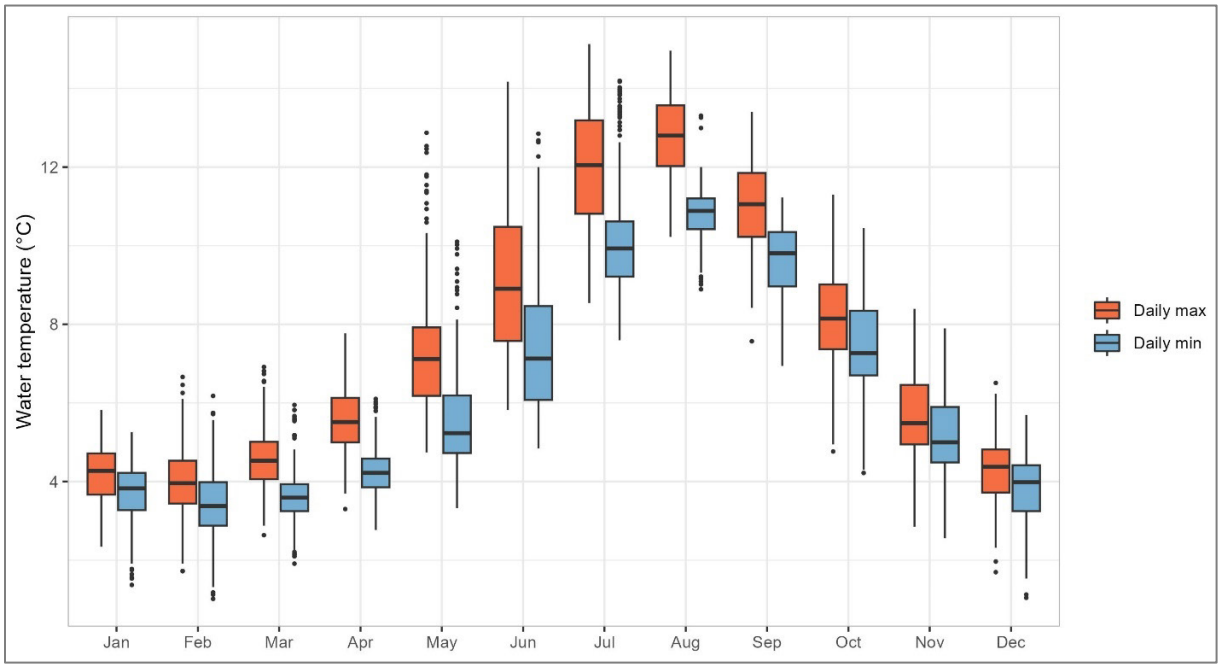

Figure 74. Maximum and minimum daily mean temperatures at the Sol Duc River Station, 2012 to 2021. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.
NPS

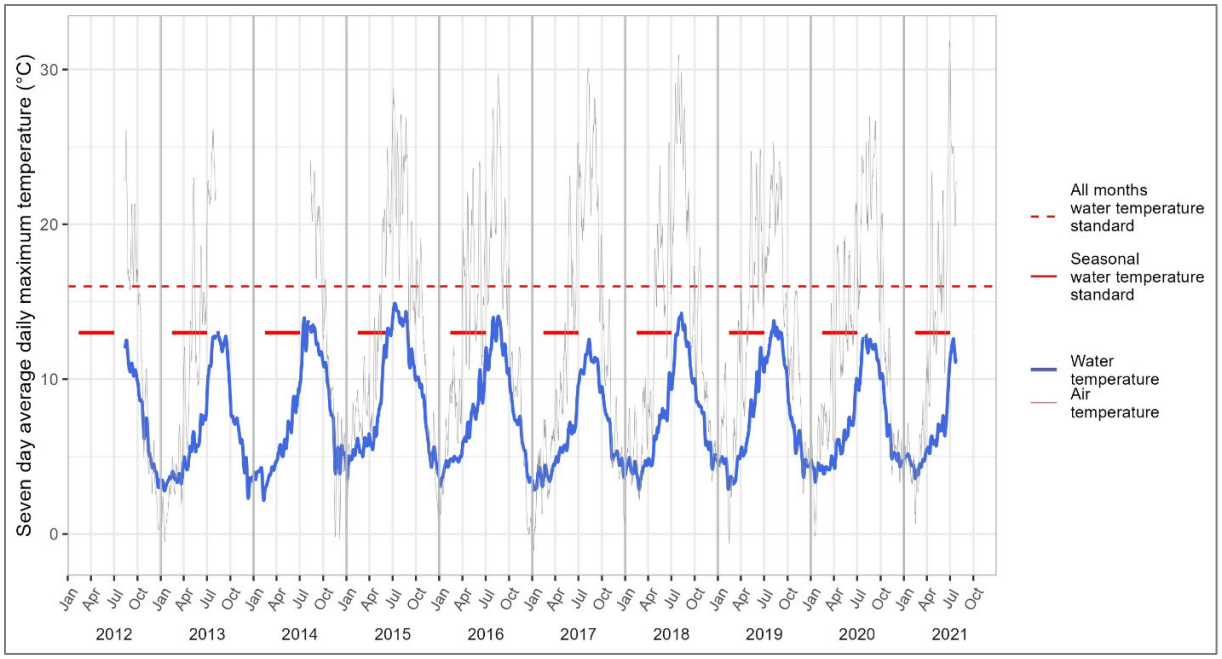

Figure 75. Seven-day average of the maximum daily water temperatures at the Sol Duc River Station, 2012 to 2021. The red dashed line at 16°C indicates the state criteria for aquatic life use designation of salmon rearing and migration. The thicker red long-dashed line at 13°C indicates the seasonal state criterion for salmon and steelhead spawning and incubation. Any seven-day average maximum daily water temperature above 16°C in any month or above 13°C between February 15 and July 1 constitutes an exceedance.

NPS

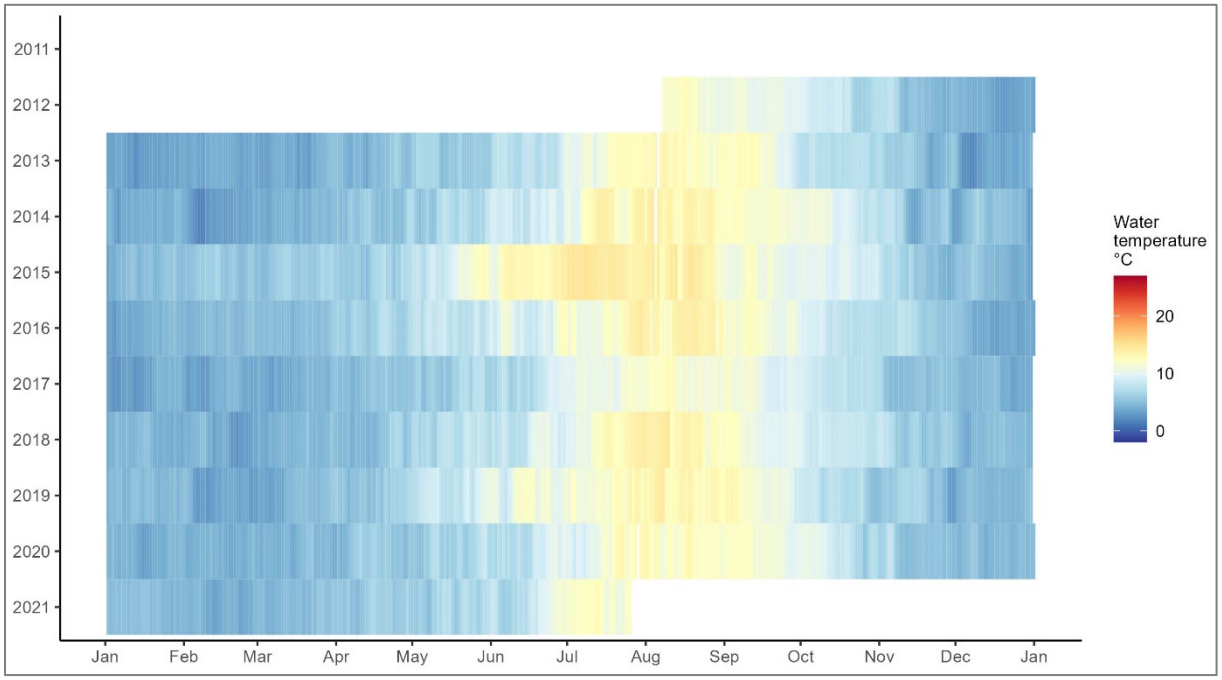

Figure 76. Maximum daily water temperatures at the Sol Duc River Station, 2012 to 2021.

NPS

Table 79. Number of days per calendar year that the seven-day average of the daily maximum water temperature exceeded the year-round criterion of 16°C and the seasonal criterion of 13°C as well as the percentage of the days of the year with no data for that metric at the Sol Duc River Station, 2012 to 2021.

Year	Number of Days with Observed Exceedances		Proportion of the Year with No Data
	Year-Round Criterion	Seasonal Criterion	
2012	none	none	62%
2013	none	none	2%
2014	none	none	2%
2015	none	15	full dataset
2016	none	none	full dataset
2017	none	none	full dataset
2018	none	none	full dataset
2019	none	none	full dataset
2020	none	none	2%
2021	none	31	43%

3.5.7.2 Instantaneous Water Temperature and Chemistry Data

Table 80 presents water temperature and chemistry data, including parameters for instantaneous water temperature, dissolved oxygen, pH, specific conductance, and turbidity for the Sol Duc River Station.

Table 80. Water temperature and chemistry values at the Sol Duc River Station, 2012 to 2021. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
08/07/12	11.04	9.86	7.82	90.90	0.18
08/06/13	10.90	10.06	7.08	91.27	0.38
08/05/14	12.00	9.80	7.52	99.29	0.33
08/03/15	11.90	9.34	7.54	111.46	0.25
07/26/16	12.17	10.68	7.85	99.24	0.23
08/02/17	12.10	10.20	7.42	91.90	0.26
08/01/18	13.31	9.95	7.75	99.07	0.20
07/30/19	11.64	9.90	7.26	101.19	0.18
07/28/20	11.63	9.43	7.32	93.40	0.24
07/27/21	11.00	10.09	7.23	91.19	0.21
Minimum	**10.90**	**9.34**	**7.08**	**90.90**	**0.18**
Maximum	**13.31**	**10.68**	**7.85**	**111.46**	**0.38**

3.5.7.3 Channel Morphology Metrics

Table 81 presents channel morphology measurements for the Sol Duc River Station, including data on bankfull width, wetted width, and thalweg depth.

Table 81. Channel morphology measurements from the Sol Duc River Station, 2012 to 2021.

Date	Bankfull Width (m)	Wetted Width (m)	Thalweg Depth (m)
08/07/12	25.00	21.80	0.91
08/06/13	26.83	20.54	0.60
08/05/14	25.60	22.87	0.63
08/03/15	21.33	15.03	0.55
07/26/16	47.03	15.26	0.52
08/02/17	49.63	17.38	0.58
08/01/18	25.47	17.59	0.51
07/30/19	52.37	14.65	0.54
07/28/20	28.00	17.29	0.66
07/27/21	25.77	16.89	0.54
Minimum	**21.33**	**14.65**	**0.51**
Maximum	**52.37**	**22.87**	**0.91**

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Appendix A. Graphical Representation of Instantaneous Water Quality Data

This appendix presents charts of instantaneous water quality monitoring data collected annually between 2012 and 2021 from twenty-five monitoring stations in national park units in the Pacific Northwest. Table 82 lists station and park names and the abbreviations for these used in the charts.

Table 82. List of Water Quality monitoring stations and their parks, along with abbreviations referenced in the charts below.

Park	Code	Full Station Name
Ebey's Landing National Historical Reserve (EBLA)	EbeysWC	Ebey's Landing Watercourse
Lewis and Clark National Historical Park (LEWI)	Skipanon	Skipanon River
	Megler	Megler Creek
	Colewort	Colewort Creek
Mount Rainier National Park (MORA)	NisqNIBO	Nisqually River at Park Boundary
	NisqNILO	Nisqually River at Longmire
	NisqNIGB	Nisqually River at Glacier Bridge
	Paradise	Paradise River
	OhanaOHCA	Ohanapecosh River
	WhiteBO	White River at Park Boundary
	WhiteLIT	White River at Littorals
	Fryingpan	Fryingpan Creek
North Cascades National Park (NOCA)	Stehekin	Stehekin River
	Bridge	Bridge Creek
	Company	Company Creek
	Goodell	Goodell Creek
	Newhalem	Newhalem Creek
	NFCascade	North Fork Cascade River
	Ruby	Ruby Creek
Olympic National Park (OLYM)	Barnes	Barnes Creek
	Umbrella	Umbrella Creek
	Ozette	Ozette Creek
	Kalaloch	Kalaloch Creek
	Matheny	Matheny Creek
	SFCalawah	South Fork Calawah River
	SolDuc	SolDuc Creek

Figure 77 presents instantaneous water temperature data collected during sampling events from 2012–2021 at long-term water quality monitoring sites in the North Coast and Cascades Network.

Represented national parks include Ebey's Landing National Historical Reserve, Lewis and Clark National Historical Park, Mount Rainier National Park, North Cascades National Park, and Olympic National Park. Temperatures collected range from <5°C to >20°C. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

Instantaneous dissolved oxygen data collected during sampling events from 2012–2021 at long-term water quality monitoring sites in the North Coast and Cascades Network are presented in Figure 78. Represented national parks include Ebey's Landing National Historical Reserve, Lewis and Clark National Historical Park, Mount Rainier National Park, North Cascades National Park, and Olympic National Park. Red dashed lines represent water quality criteria for dissolved oxygen. Data below these dashed lines were those that failed to meet state criteria for this water quality parameter. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers

Instantaneous pH data collected during sampling events from 2012–2021 at long-term water quality monitoring sites in the North Coast and Cascades Network are presented in Figure 79. Represented national parks include Ebey's Landing National Historical Reserve, Lewis and Clark National Historical Park, Mount Rainier National Park, North Cascades National Park, and Olympic National Park. Red dashed lines represent water quality criteria for pH levels. Data above or below these dashed lines were those that failed to meet state criteria for this water quality parameter. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

Instantaneous specific conductance data collected during sampling events from 2012–2021 at long-term water quality monitoring sites in the North Coast and Cascades Network are presented in Figure 80. Represented national parks include Ebey's Landing National Historical Reserve, Lewis and Clark National Historical Park, Mount Rainier National Park, North Cascades National Park, and Olympic National Park. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

Instantaneous turbidity data collected during sampling events from 2012–2021 at long-term water quality monitoring sites in the North Coast and Cascades Network are presented in Figure 81. Represented national parks include Ebey's Landing National Historical Reserve, Lewis and Clark National Historical Park, Mount Rainier National Park, North Cascades National Park, and Olympic National Park. Boxplots show the median, 25th percentile, and 75th percentile. Whiskers extend 1.5 times the interquartile range and black dots represent outliers.

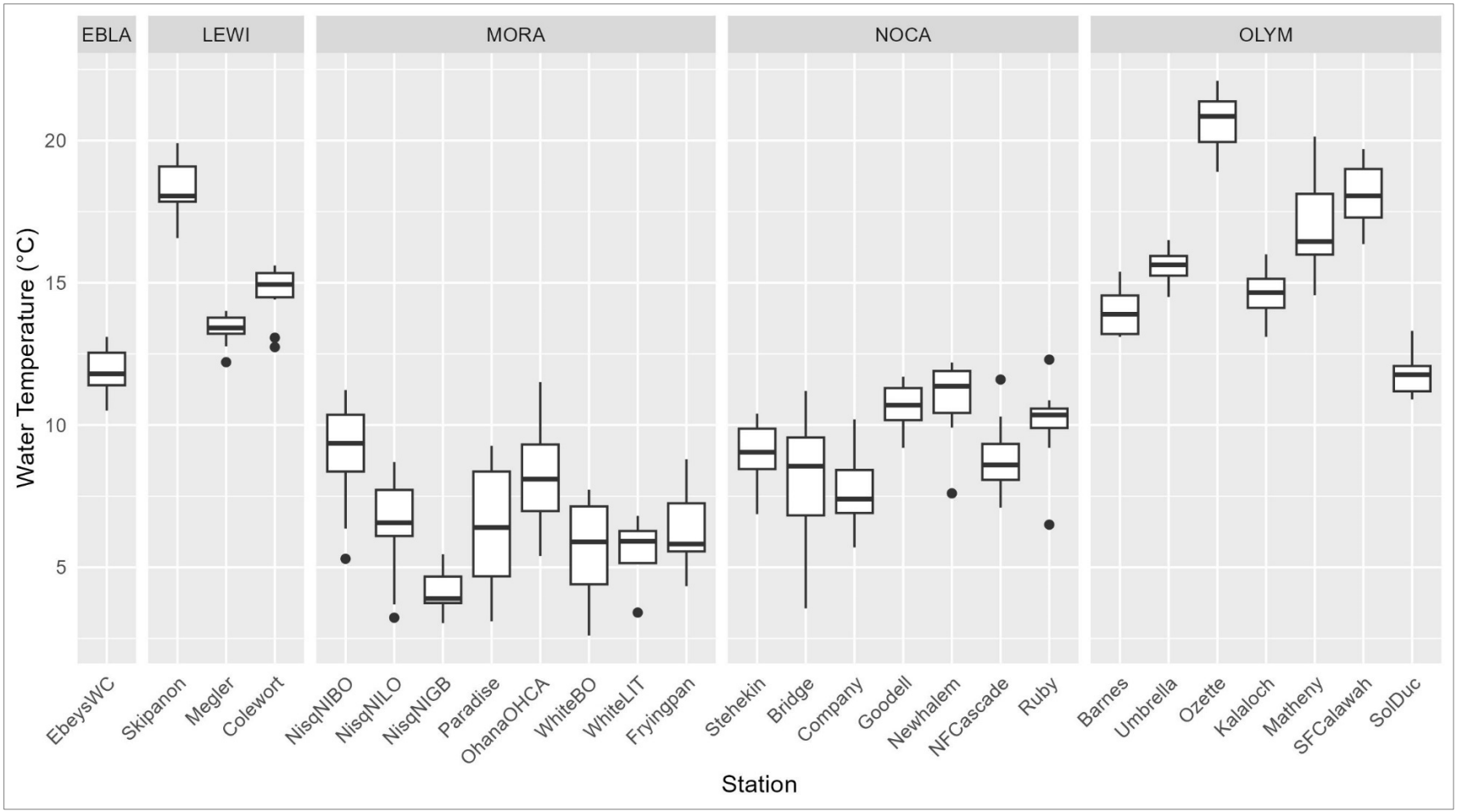

Figure 77. Instantaneous water temperature data measured once per year at twenty-five monitoring stations in national parks in the Pacific Northwest, 2012 to 2021.

NPS

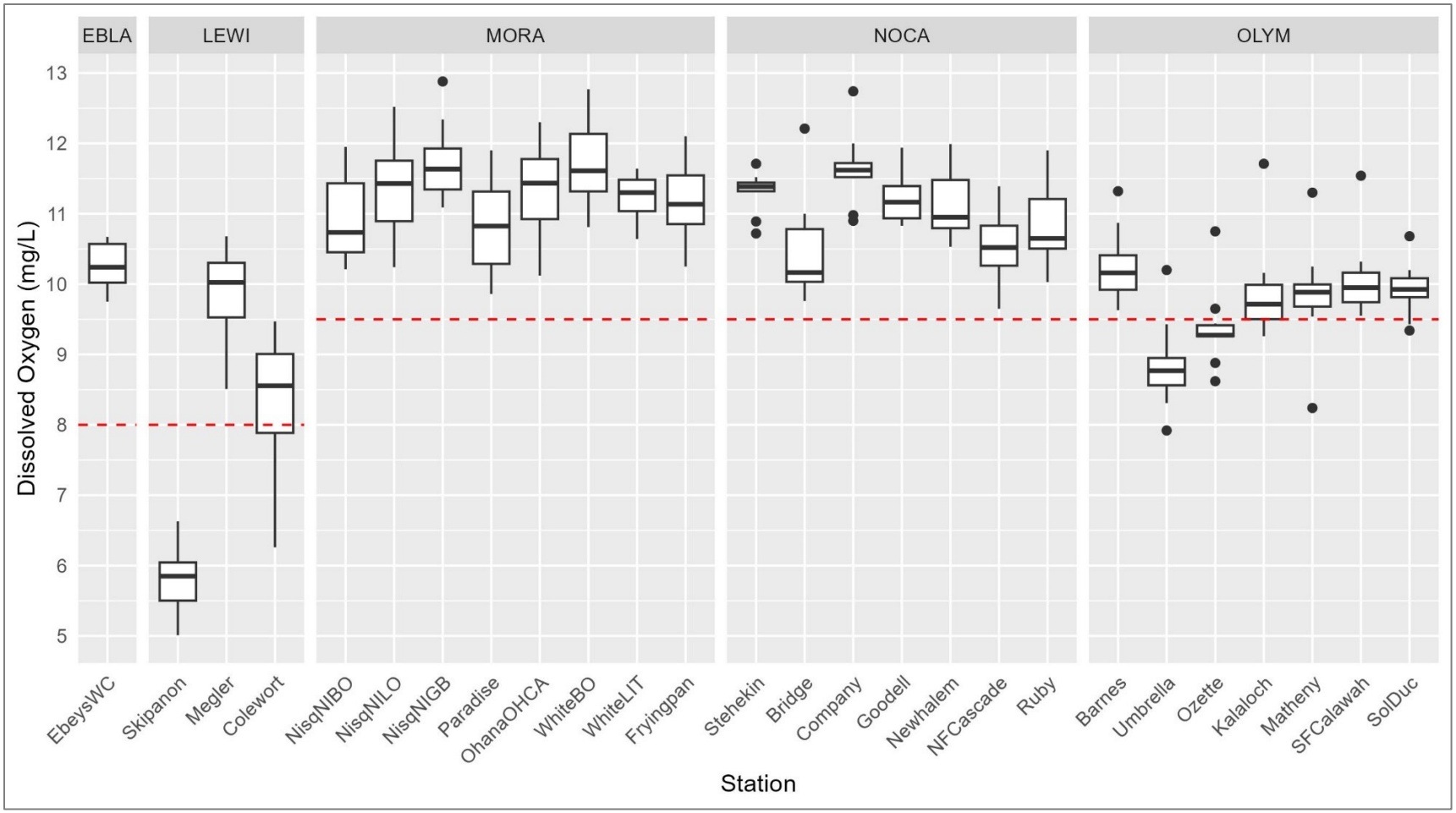

Figure 78. Instantaneous dissolved oxygen data measured once per year at twenty-five monitoring stations in national parks in the Pacific Northwest, 2012 to 2021. Red dashed lines represent Washington State water quality criteria for core parameters under the federal Clean Water Act (DOE 2016); Skipanon River and Colewort Creeks criteria are set according to Table 21 in the Oregon Department of Environmental Quality Water Quality Standards (DEQ 2017). Data below the red dashed lines represent dissolved oxygen observations that failed to meet these criteria. *NPS*

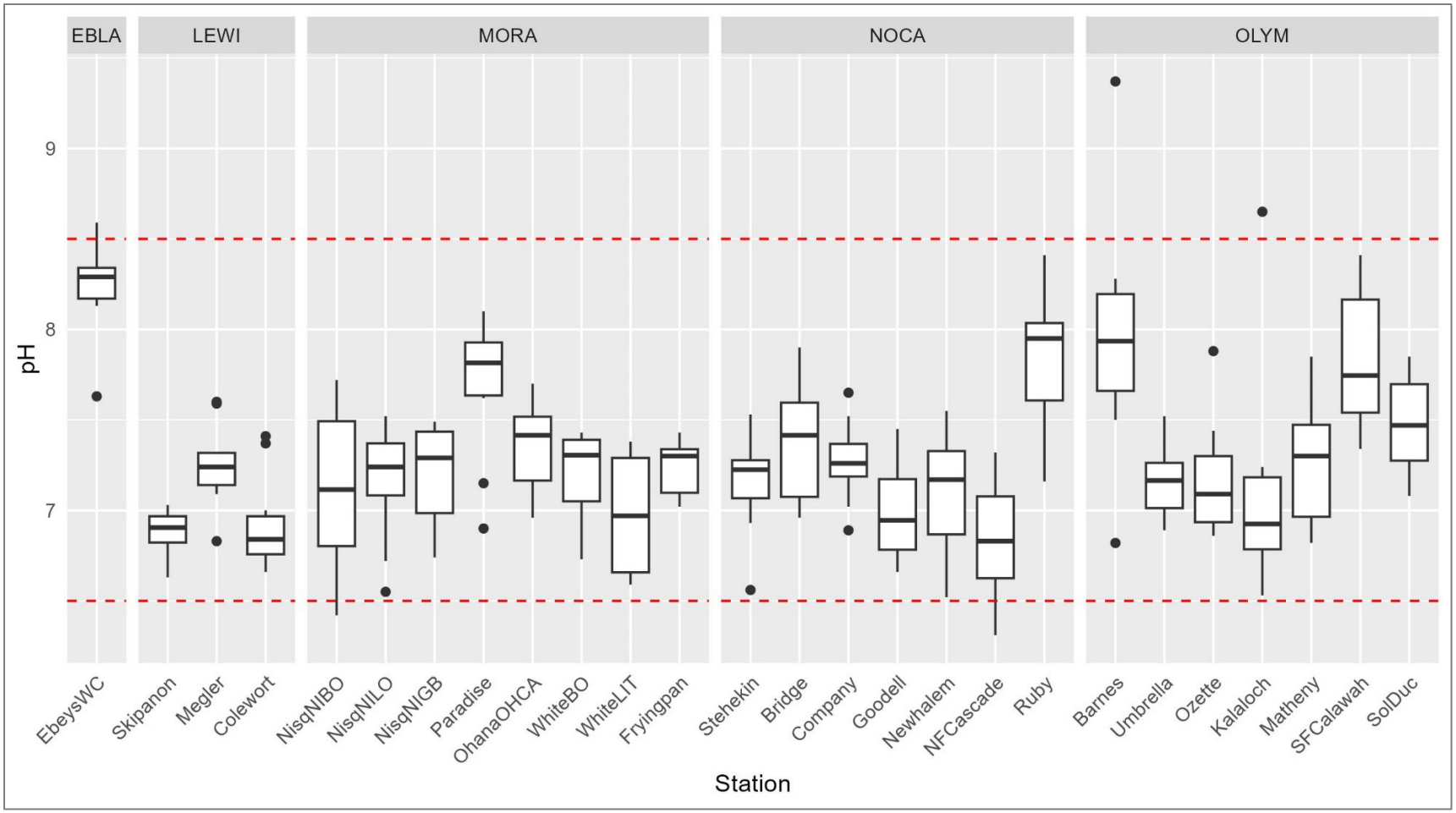

Figure 79. Instantaneous pH data measured once per year at twenty-five monitoring stations in national parks in the Pacific Northwest, 2012 to 2021. Red dashed lines represent Washington State water quality criteria for core parameters under the federal Clean Water Act (DOE 2016); Skipanon River and Colewort Creeks criteria are set according to Table 21 in the Oregon Department of Environmental Quality Water Quality Standards (DEQ 2017). Data above or below the red dashed lines represent pH observations that failed to meet these criteria.

NPS

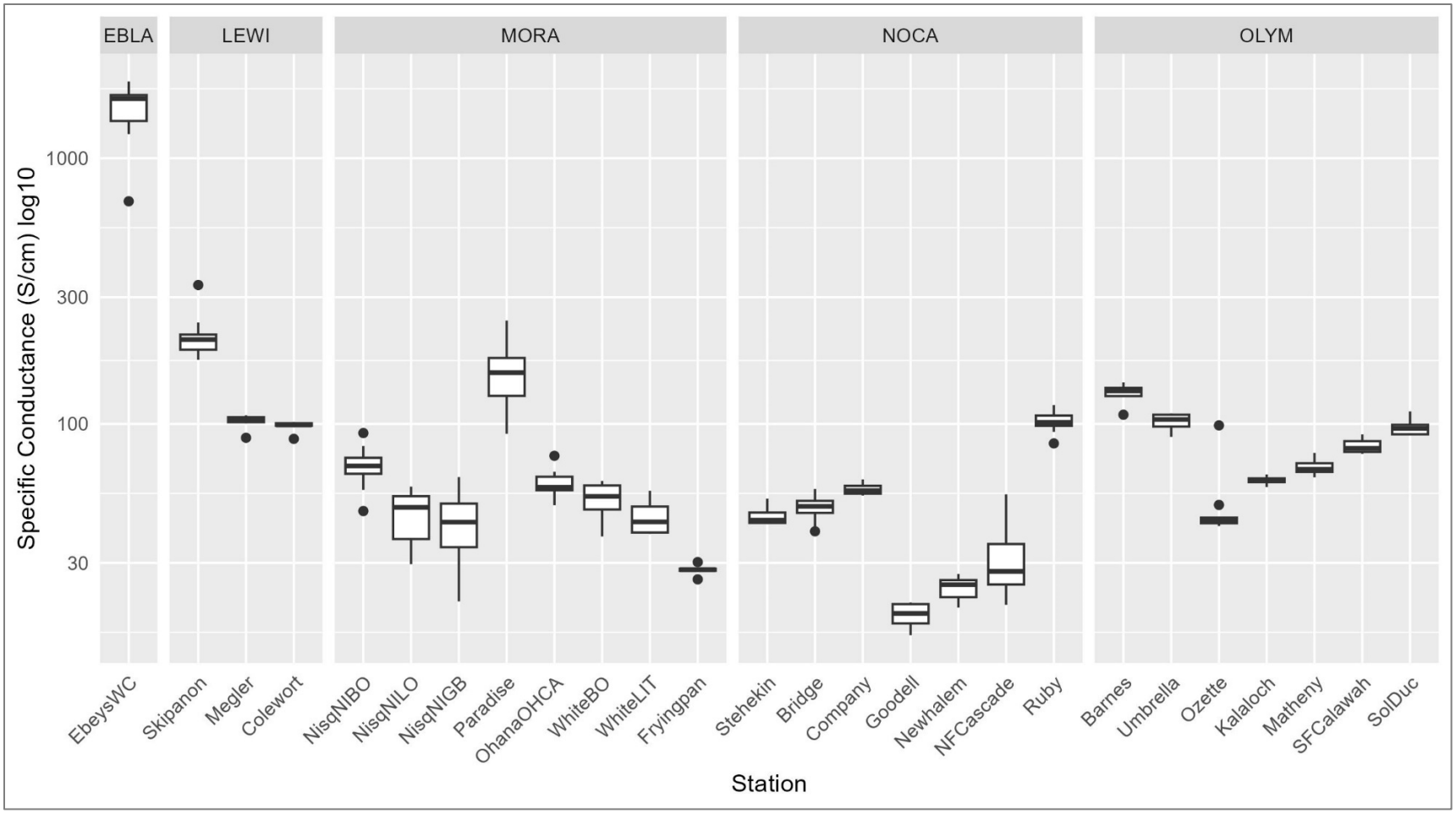

Figure 80. Instantaneous specific conductance data measured once per year at twenty-five monitoring stations in national parks in the Pacific Northwest, 2012 to 2021.

NPS

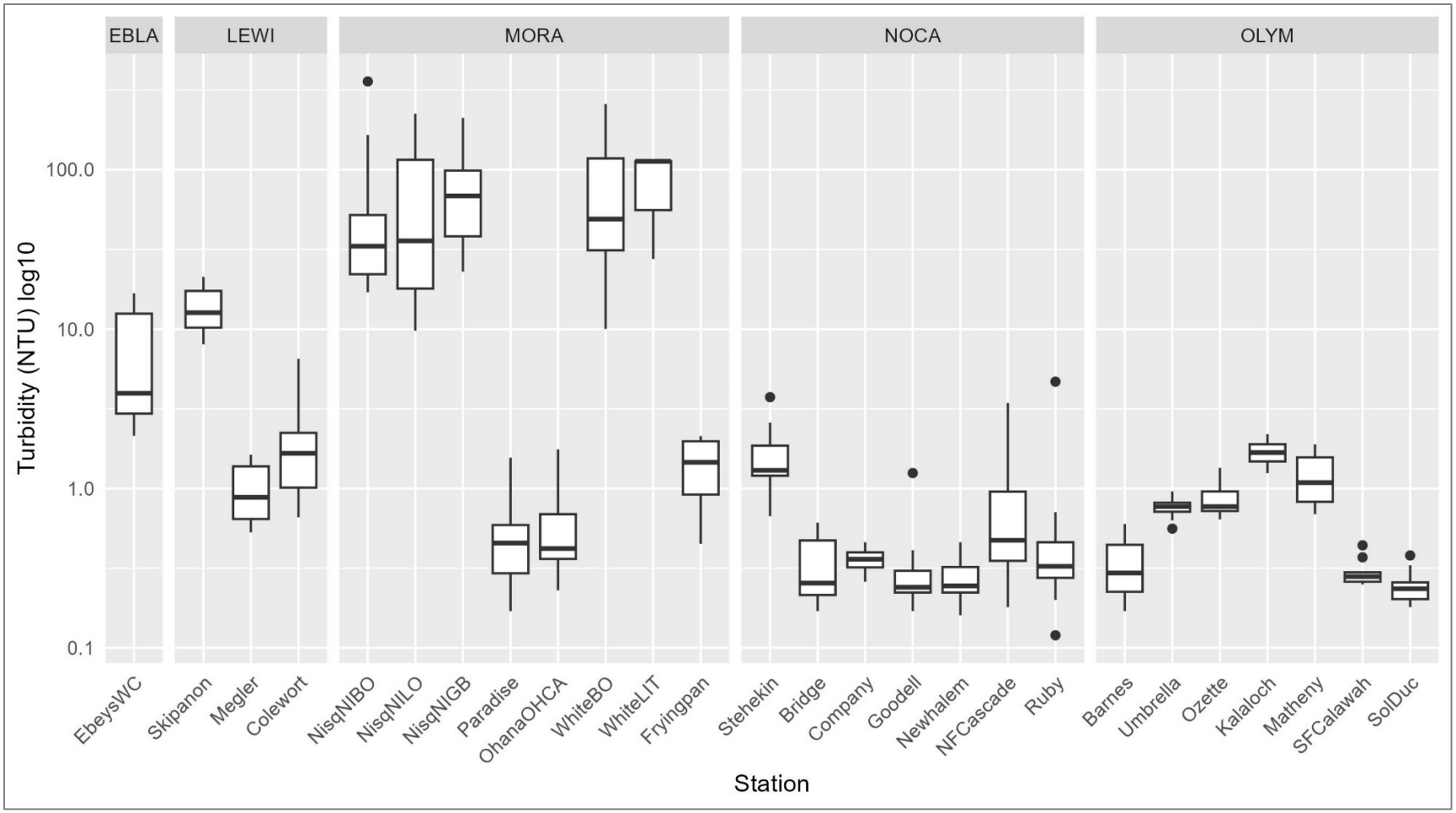

Figure 81. Turbidity data measured once per year at twenty-five monitoring stations in national parks in the Pacific Northwest, 2012 to 2021. *NPS*

Appendix B. Legacy Water Quality Data from Four Mount Rainier National Park Water Quality Monitoring Stations

Data presented in Table 83 represent legacy data collected between 1998 and 2021 at four monitoring stations within Mount Rainier National Park, before implementation of the NCCN Water Quality Monitoring Protocol (Rawhouser et al. 2012). Park staff collected these data at the same locations where NCCN staff later gathered the water quality monitoring data summarized in this report. We present these legacy data here, rather than with data collected under the network protocol, due to differences in quality control and equipment between the two datasets. We also present the legacy data with the number of significant digits originally reported by NPS observers who recorded the information, which differs from the precision reported for these parameters under the NCCN monitoring protocol. In some cases, park staff recorded more than one observation at a station for a single visit; for these we report the mean value between all observations.

Table 83. Water temperature and chemistry values at four water quality monitoring stations in Mount Rainier National Park, 1998 to 2011. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Station	Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
Nisqually River at Park Boundary	08/10/98	13.5	9.4	No Data	30	80
	07/07/99	6	10.6	7.17	35.1	17
	06/28/00	No Data	8.4	7.11	34.5	No Data
	07/13/00	8	9.1	7.09	40.2	92
	08/03/00	6	9.3	7.03	32.6	53
	09/27/00	5	9.5	7.12	41	113
	04/24/01	15	13	7.57	90.1	1.7
	07/09/01	9	7.4	7.06	38.9	110
	08/02/01	7.5	9.6	5.95	66	120
	09/26/01	9	9.5	7.24	49.8	75
	07/09/02	15	10.32	7.47	37.3	20
	08/12/02	9.5	10.51	7.32	38	47
	10/01/02	6	12.63	7.47	67	11
	07/08/03	9.5	11.5	6.87	40	32
	09/16/03	6	9.9	7.14	66	17
	06/16/04	14	10.37	7.03	35	5.6
	09/09/04	8	11.9	7.59	54	26
	06/06/05	7.5	11.11	7.48	56	4.9
	09/06/05	9	12.34	7.41	62	14
	02/14/07	3.9	12.7	6.86	72.3	2.5

Table 83 (continued). Water temperature and chemistry values at four water quality monitoring stations in Mount Rainier National Park, 1998 to 2011. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Station	Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
Nisqually River at Park Boundary (continued)	05/22/07	9.6	No Data	6.65	48.1	3.3
	08/07/07	9.06	11.58	6.55	34	65
	08/29/07	11.91	11.23	6.92	49	70
	10/29/07	7.19	14.32	7.33	73	14
	05/27/08	8	5.4	3.31	48.5	1.6
	08/19/08	11.29	10.35	5.55	37	45
	09/01/09	8.53	11.9	6.88	48	151
	08/10/10	10.1	11.46	6.59	44	123
	09/07/11	9.8	12.49	6.4	46.78	119.4
Nisqually River at Longmire	08/10/98	9	10.2	No Data	15	75
	07/06/99	8	9.8	6.89	20.9	8
	06/28/00	9.5	7.65	6.86	21	No Data
	07/13/00	9	10.2	7	23.9	57
	08/03/00	6	10.2	6.83	19.3	47
	09/27/00	4	10.3	6.8	32	93.4
	04/24/01	14	10.3	7.34	71.1	0.9
	07/09/01	14	8.5	7.1	27.5	150
	08/02/01	7	8.9	5.95	29	175
	09/26/01	9.5	10.2	7.55	340	25
	07/10/02	8	11.42	7.22	62.5	30
	08/12/02	10.5	10.54	7.33	119	115
	10/01/02	5	12.05	7.4	48	10
	07/08/03	8.01	11.4	6.57	25	27
	09/16/03	5.15	10.26	7.27	42	14
	06/17/04	6	12.19	7.01	21	3.8
	09/09/04	6	11.71	7.47	31	29
	06/06/05	7	10.07	7.46	38	7.3
	09/06/05	8	12.15	7.31	43	17
	02/14/07	3.1	13.1	6.87	56.33	0.9
	03/03/07	4	No Data	6.77	38	1
	03/15/07	4	No Data	6.77	38	1
	04/09/07	4	No Data	6.75	33.7	2
	06/12/07	8.8	No Data	6.71	27.8	9.6
	08/07/07	7.34	11.69	6.78	22	44

Table 83 (continued). Water temperature and chemistry values at four water quality monitoring stations in Mount Rainier National Park, 1998 to 2011. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Station	Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
Nisqually River at Longmire (continued)	08/27/07	8.65	11.17	7.17	40	43
	10/29/07	5.34	14.16	7.32	53	5.6
	05/27/08	4.5	5.35	3.18	23.9	1.9
	08/19/08	14.03	9.89	5.94	77	9
	09/01/09	9.2	11.02	6.95	No Data	38.4
	09/07/11	13.1	12.01	5.89	46.16	79.54
Nisqually River at Glacier Bridge	08/10/98	4.5	11.5	No Data	10.5	65
	07/06/99	6.5	10	6.91	21.1	20
	06/28/00	No Data	9.4	6.92	23.6	No Data
	07/13/00	5	8.8	6.93	24.8	80
	08/03/00	4	10.4	6.85	16	65
	09/27/00	3	9.1	6.79	26.9	297
	04/24/01	7	8.3	7.62	101.5	3.3
	07/09/01	6	7	7.08	19.8	170
	08/02/01	5	8.5	6.29	20.2	250
	09/26/01	5	11.2	7.09	25.7	50
	07/10/02	5	11.82	7.09	19.9	56.5
	08/12/02	6	12.95	6.91	11	325
	10/01/02	1	12.99	7.44	49	17
	07/08/03	3.93	11.6	6.43	23	47
	09/16/03	3.21	10.37	7.34	35	21
	06/16/04	No Data	11.55	6.63	27	12
	09/09/04	3	11.94	4.41	24	43
	06/06/05	3.5	10.92	7.22	44	24
	09/06/05	3.5	12.57	6.94	22	50
	08/07/07	3.64	11.45	6.73	17	83.5
	08/08/07	3.64	11.45	6.73	17	83.5
	09/13/07	3.68	12.3	7.05	24	No Data
	10/29/07	3.8	No Data	7.06	42.9	14
	06/16/08	2.33	15.36	7.43	52	6.3
	09/01/09	4.38	12.5	7.47	20	74.8
	08/10/10	5	10.55	6.68	20.9	29.4
	09/01/11	7.4	12.88	6.07	75.02	50.3
Ohanapecosh River	08/17/98	10	9.7	No Data	40	0.4

Table 83 (continued). Water temperature and chemistry values at four water quality monitoring stations in Mount Rainier National Park, 1998 to 2011. DO=Dissolved oxygen, SC=Specific conductance, Temp=Water temperature.

Station	Date	Temp (°C)	DO (mg/L)	pH	SC (µS/cm)	Turbidity (NTU)
Ohanapecosh River (continued)	07/06/99	6.1	9.7	7.12	25.9	0.95
	06/28/00	No Data	9.3	7.08	25.2	No Data
	07/05/00	8	11.3	5.98	10	0.37
	08/09/00	No Data	8.4	7.17	36.6	0.97
	09/26/00	5	9.2	7.27	53.6	0.36
	04/24/01	5	11.6	7.51	56	0.33
	07/10/01	10	8	7.13	51.2	0.75
	08/01/01	10	8.7	6.27	57.3	2.1
	10/02/01	12	9.9	7.32	71.1	0.58
	07/09/02	6	11.11	7.11	27.5	0.74
	08/13/02	10	10.85	7.35	43	0.95
	09/30/02	8	11.36	7.55	57	0.9
	07/07/03	8.17	10.9	6.57	32	0.7
	09/15/03	9	10.4	7.23	29	0.48
	06/16/04	5	12.46	6.31	34	1
	09/08/04	9	11.07	7.65	55	0.69
	06/08/05	6	11.33	7.52	42	0.64
	09/12/05	9.5	12.92	7.44	72	0.39
	06/07/07	4	No Data	6.88	24.3	0.57
	08/09/07	11.37	10.73	7.07	55	1
	08/29/07	10.16	11.7	6.84	55	2
	06/12/08	5.16	12.92	7.22	43	0.25
	09/04/08	8.14	10.8	6.49	61	0.5
	09/09/09	9.12	11.54	5.5	56	0.65
	08/23/10	11.7	9.89	6.77	53.2	0.24
	09/12/11	9.89	13.57	6.49	44.4	1.4

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