Analysis of Dissolved Oxygen Dynamics on the Siletz River, Oregon

Water Quality Program
Draft: March 20, 2019

Water Quality Program
700 NE Multnomah St.
Suite 600
Portland, OR 97232
Phone: 503-229-5777

Contact: Ryan Shojinaga

www.oregon.gov/DEQ

DEQ is a leader in restoring, maintaining and enhancing the quality of Oregon's air, land and water.

State of Oregon
Department of Environmental Quality

This report prepared by:

Oregon Department of Environmental Quality
700 NE Multnomah Street, Suite 600
Portland, OR 97232
1-800-452-4011
www.oregon.gov/deq

Contact:
Ryan Shojinaga
503-229-5777
shojinaga.ryan@deq.state.or.us

DEQ can provide documents in an alternate format or in a language other than English upon request. Call DEQ at 800-452-4011 or email deqinfo@deq.state.or.us.

Table of Contents

1. Abstract

The Siletz River is located in the Siletz-Yaquina subbasin (USGS HUC8 17100204) of the Oregon Mid-Coast Basin. The segment from Siletz River Mile (RM) 21.6 to 65.3 is included on Oregon's 2012 Section 303(d) Category 5 list as water quality limited for dissolved oxygen (DO). The listing applies during the designated salmonid spawning season defined in rule as September 1 to June 15 to protect the beneficial use of salmonid spawning. The applicable numeric criteria are 11 milligrams per liter (mg/L) and 95 percent oxygen saturation in water. Assessment of historical data in the coastal streams indicate that DO criteria are often not met during the early portion of the spawning period when (a) flows may still be low and (b) water temperature has not significantly decreased.

For the remainder of the year (June 16 to August 31) the designated beneficial use for salmonids in the Siletz River is for cold-water aquatic habitat (native trout and salmonid rearing and migration) with applicable criteria of 8 mg/L and 90 percent saturation. Previous assessment of historical data from 1998 to 2003 did not show violations of the cold-water period.

Oregon's dissolved oxygen standard contains temporal and spatial aspects to its applicability and averaging periods. Please refer to OAR 340-Div 41 for detailed information and associated maps for the Mid-Coast Basin. In this document, we use consistent language throughout to discuss the DO standards and how these are applied.

To evaluate the Section 303(d) Category 5 status and to investigate potential causes for violations of the water quality standard, if observed, the Oregon Department of Environmental Quality (DEQ) conducted water quality monitoring from July to September of 2017. DEQ also collected water quality data in July, outside of the designated spawning period, based on data collected from other Mid-Coast rivers and consultation with local stakeholders. Continuous data loggers were deployed at three sites over a 43 km reach to monitor several water quality parameters, including DO and temperature. Surface water samples were collected twice daily for four days during each period and analyzed for supporting chemistry (e.g., nutrients and other water column constituents. Field measurements of temperature, specific conductivity, pH, and dissolved oxygen were taken using hand-held water quality probes. DEQ also collected flow data and channel dimensions during the sampling period on the Siletz River and selected tributaries.

To support the assessment effort and development of a dissolved oxygen TMDL, the Lincoln County Soil and Water Conservation District (LSWCD) collaborated with DEQ to collect time-series DO and temperature data using loggers at an expanded set of sites on the Siletz River. The LSWCD monitoring periods targeted a minimum 30 days during summer (1 to 2 months at 12 sites) and minimum 7 days during the September monitoring period.

From both the DEQ and LSWCD data, 30-day mean minimum DO concentrations and saturations consistently met the cold-water criteria of 8 mg/L and 90 percent saturation during the designated cold-water period; however, violations of DO criteria (seven-day minimum mean of 6.5 mg/L and absolute minimum of 6.0 mg/L) were observed at one of the LSWCD sites.

DO concentrations did not consistently achieve the spawning concentration criterion of 11.0 mg/L during September, however, the minimum DO saturations during the spawning period consistently remained above the 95 percent threshold. It is DEQ's position that additional analysis is required to assess the influence of water temperatures on DO concentrations and saturations during the spawning period.

In addition to assessment of DO relative to the standards, DEQ analyzed the DO data using several approaches to better understand the nature of DO dynamics and water quality in the Siletz River. This analysis includes assessment of nutrient inputs and stream metabolism.

DEQ uses established processes and methods to assess water quality status and factors affecting Oregon's waters and we are currently following that process in the Siletz River watershed with respect to DO. The

regulatory aspect of that process is called total maximum daily loads or TMDLs. The TMDLs represent a pollution “budget” and allocate pollutant loads to both point sources and nonpoint sources of pollution. Oregon’s TMDLs regulations are found in OAR-340-Division 42. Successive steps involve identifying sources and activities contributing significant pollution and then developing strategies to reduce those loads. The analysis in the report represents preliminary steps to characterizing the nature of and degree to which DO violations in the Siletz River occur.

2. Introduction

The Siletz River is a coastal watershed that drains into the Pacific Ocean on Oregon's Mid-Coast Basin. The contributing watershed is within the Siletz-Yaquina subbasin hydrologic unit (HUC 17100204). The contributing area for the Siletz River is comprised of four watersheds: The Lower Siletz River (HUC10 1710020407), Middle Siletz (1710020405), Upper Siletz (1710020404), and Rock Creek (1710020406).

The Siletz River is included on Oregon's 2012 Clean Water Act Section 303(d) Category 5 list as water quality limited for dissolved oxygen (DO). The "listing" applies during the designated salmonid spawning season, defined in Oregon's regulations as September 1 to June 15 (OAR-340-Div 41). Refer to Table 1 for a complete list of the 2012 303(d) Category 5 listings.

From July through October of 2017, the Oregon Department of Environmental Quality (Oregon DEQ) collected extensive surface water monitoring data in the Siletz River in collaboration with local, state and Tribal partners. The monitoring was conducted to (a) assess the overall DO conditions in the freshwater segment of the Siletz River (above tidal influence), (b) identify the timing, extent and severity of any DO impairments and (c) collect the data needed to support analysis for development of total maximum daily loads or TMDLs where warranted.

Oregon DEQ is in the process of conducting an in-depth evaluation of that data and this Report presents the preliminary results of the analysis and identifies next steps in the evaluation process. We are working closely with Oregon DEQ's Water Quality Assessment section to ensure that the data can be used to inform the Section 303d process and decisions regarding assessment "status".

According to the Oregon Department of Fish and Wildlife, the Siletz River and its tributaries provide critical habitat to multiple native salmonids and lamprey at several life stages[1]. Adult Chinook salmon are present in the watershed in fall and spring, and adult Steelhead in summer, fall and winter. Other designated beneficial uses include public and private drinking water supply, aquatic life habitat, fishing, recreation, agricultural uses and aesthetics. Refer to the designated beneficial use tables in OAR-340-Div 41[2]:

The Siletz River is listed on the ODEQ 2012 Clean Water Act Section 303(d) Category 5 list as water quality limited for DO specifically for affecting the beneficial use of fish and aquatic habitat[3]. The Siletz River segment from river miles (RM) 21.6 to 65.3 is listed for not meeting the salmonid spawning designated DO criteria of 11 mg/L or 95 percent saturation[4] (Figure 1) from September 1 to June 15. The Siletz River was placed on Oregon's 303(d) list by U.S. EPA based on a limited number of grab samples and we therefore used a more in-depth monitoring approach to evaluate whether applicable criteria are being met.

The Siletz River and many of the tributaries are also designated as cold-water aquatic life outside of the spawning season. The basic DO standard for supporting cold-water aquatic species is 8 mg/L or 90% saturation. The violations of the DO criteria observed on the Siletz River in the past impact the state-designated beneficial uses of salmonid spawning and cold-water aquatic life.

To address the 2012 Section 303(d) Category 5 listing, DEQ is in the process of developing a TMDL for DO to assist in the management of the Siletz River for the designated beneficial uses. Ultimately, the TMDL will quantify contributing factors affecting DO in the Siletz River and determine appropriate pollutant load and wasteload allocations of those factors. As part of that process, DEQ conducted water quality monitoring on the Siletz River and issued a call for voluntary data from the local stakeholders.

---

[1] https://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=refid
[2] https://www.oregon.gov/deq/Rulemaking%20Docs/Table220A.pdf
[3] https://www.oregon.gov/deq/wq/Pages/2012-Integrated-Report.aspx
[4] https://sos.oregon.gov/archives/pages/oregon_administrative_rules.aspx

During the summer of 2017, DEQ collected data representing (1) cold-water aquatic life (June 16 – Aug 31) and (2) salmonid spawning use (Sept 1 – June 15). The Lincoln County Soil and Water Conservation District (LSWCD) contributed time and resources to collect and submit to DEQ voluntary monitoring data in addition to the data collected by DEQ. The LSWCD data consists of nearly 3 months of continuous DO and temperature data collected at 12 sites along the 303(d) listed segment, including the characterization of upstream and downstream boundary conditions.

This report presents a thorough examination of the data collected in the summer and fall of 2017 to ascertain the level of DO impairment, if any, with respect to the applicable criteria. DEQ will use the data and analysis from this study as a first step in developing the TMDL.

3. Study Area

This section presents a summary of the Siletz River watershed and predominant landscape and human factors that impact water quality in the River and its tributaries. These factors generally include physical characteristics, hydrology, climate, hydrodynamics, geology, soils, land cover and vegetation. Information on anthropogenic factors, such as land use and water use, are also presented herein.

3.1 Physical Characteristics

The Siletz River watershed is 955 square kilometers (km^2) located in primarily in Lincoln County, Oregon, with smaller portions of the eastern watershed in Polk County. The area of the watershed upstream of the listed segment is 684 km^2 (Figure 1). The reference point established within this report is from where the Siletz Bay estuary ends, approximately 4 km from the Pacific at Highway 101 in Kernville. This reference point is at RM 0 for the Siletz River. The beginning of the 303(d) listed segment begins at RM 21.6 relative to the beginning of the Siletz River.

Watershed elevations range from near mean sea level (MSL) to 1080 m above MSL.

3.2 Estuary and River Transitions

In addition to the Siletz Bay and River transition, there are two other natural transitions related to estuary/ river interfaces that form significant boundaries: limits of salt intrusion and the heads of tide.

The upstream-most extents of salt intrusion is where the boundary between estuary and the freshwater reach occurs. The Draft Methodology for Oregon's 2018 Water Quality Report and List of Water Quality Limited Waters (Oregon DEQ 2018a) uses the Coastal and Marine Ecological Classification Standard (CMECS; FGDC 2012) to define the limits of the estuaries along the Oregon Coast. The CMECS boundary for the Siletz River occurs at approximately RM 19.7.

The head of tide is farthest point upstream in a river that is controlled, in some part, by tidal fluctuations (Davis and Dalrymple 2011). This boundary occurs at the downstream locations of the 303(d) listing, RM 21.6 (Oregon Coastal Atlas 2018). These boundaries define where specific dissolved oxygen criteria apply and during which period of the year. See Section 4.5.1 for more detail.

3.3 Climate and Hydrology

The Siletz River catchment is within the warm, dry summer (Csb) and cool summer (Csc) Mediterranean Köppen-Geiger classification system depending on elevation (Kottek et al. 2006). Based on conditions from the previous three decades (1980 – 2010), mean annual precipitation within the watershed ranges from 1740 mm in the lowlands (south and west) to 4070 mm in the mountainous terrain (north and east) (Di Luzio et al. 2007). Mean annual temperatures vary within the Siletz River watershed. The mean annual minimum temperatures range from 40°C in the northeast corner to 45°C in the northwest corner. The mean annual maximum temperatures range from 55°C in the northeast corner to 62°C in the southeast corner of the watershed (Di Luzio et al. 2007).

Flow data within the watershed are currently recorded at two sites: (1) the USGS flow gage 14305530 at Siletz, Oregon (US Geologic Survey 2018) and (2) the OWRD flow gage 14304350 on Sunshine Creek (Oregon Water Resources Department 2018). The USGS gage corresponds to DEQ sampling station 38918 (Figure 1). Figure 2 provides a sample of flows recorded at the USGS gage from July to November 2017, with concurrent monitoring campaigns.

3.4 Geophysical Settings

Siletz River Volcanics Formation (basalt) dominates the northern portion of the watershed, forming much of the mountains and higher elevations, while the Tyee Formation (marine sandstone and carbonaceous siltstone) dominates the southern portion of the watershed (Walker and Duncan, 1989).

Soils in the watershed vary significantly in terms of soil types, with the Tolovana-Reedsport complex, Preacher-Bohannon-Slickrock complex, and Formader-Klistan-Hemcross complex comprising 28 percent of the total soils within the watershed (US Department of Agriculture 2016). Overall, there are 67 different soils classifications. The predominant hydrologic soils consist of group B soils (62 percent) and C soils (27 percent). These soils are generally classified as well-drained.

3.5 Land Cover

Land cover varies significantly within the watershed, particularly with respect to elevation and distance upstream. Forests and regenerating forest areas predominate in upland areas while rural residential, paved roads, and agricultural land are more prevalent in lowland areas, particularly along the middle and lower reaches of the Siletz River. Table 2 presents the total area and percent of total area for the watershed of the 303(d) listed segment (MLRC 2017).

Hay/pasture and cultivated cropland area made up only a small fraction of land cover in the watershed (1.3 percent combined), however, more than 93 percent of the area comprised by these classes are clustered within 1 kilometer of the mainstem of the river. Remaining land cover classes that make up small fractions of watershed cover included open water, barren land, woody wetland, and emergent herbaceous wetlands.

3.6 Non-point Source Pollution Sectors

Non-point source pollution (NPS) generally originates from diffuse inputs of pollutants from land surfaces to surface or ground waters. U.S. EPA identifies eight primary NPS "Sectors"[5]. Within those sectors, potential NPS pollution sources include:

- Agricultural runoff, e.g., nutrients and organic matter from livestock manure or biosolids application of sewage;
- Urban storm water runoff;
- Runoff from rural residential lands;
- Discharge from failing or poorly functioning septic systems;
- Human-induced erosion of sediments from roads;
- Hillslopes and stream banks;
- Degradation of riparian vegetation that increases light input to waterbodies; and
- Runoff during and after silvicultural operations.

In contrast to point sources, which can be more readily characterized and regulated to limit discharge of specific pollutants, reducing NPS pollution often requires multiple actions on different parts of the landscape to limit input, movement, and delivery of pollutants to waterbodies.

The Siletz River contains one identified point source input that requires a NPDES permit – the Siletz WWTP. DEQ's source evaluation and linkage analysis for TMDLs development will focus on the influences of watershed processes and NPS sectors on DO concentrations and saturation in the reach upstream of the WWTP. Based on information from regional databases and local stakeholders, NPS

[5] Basic Information about Nonpoint Source (NPS) Pollution, https://www.epa.gov/nps/what-nonpoint-source

pollution sources that potentially influence DO in the Siletz River include agricultural practices, runoff from rural residential lands, poorly functioning or failing septic systems, runoff during and after silvicultural operations, including fertilization, and modification and degradation of riparian zones and stream channels (See Figure 3). Specific details on NPS sectors and management practices will be provided in a subsequent technical document describing loading capacity and load allocations for the watershed.

3.7 Regulated Point Sources and Waste Management

One NPDES permitted point source, the Siletz Sewage Treatment Plant (STP), discharges to the Siletz River at RM 38.1. The STP is classified as Minor Domestic using a sequencing batch reactor and has an average dry weather design flow (ADWF) of 0.157 million gallons per day (MGD; Oregon DEQ 2018b). The Siletz STP has permit limits for carbonaceous oxygen demand (CBOD), total suspended solids (TSS), pH, *Escherichia coli* (*E. coli*), and removal efficiency for CBOD and TSS (Oregon DEQ 2018b).

Biosolids application occurs within the Siletz River watershed, primarily on pasture and cultivated crop areas. Class B biosolids are tracked from creation (at STPs) to destination (land application), however Class A biosolids may be applied without reporting location, rates and times. Currently this issue is being investigated in more depth and will be the subject of subsequent analysis, hence, biosolids application is not evaluated in detail in this Report.

The Logsden Transfer Station and Brush Disposal Site[6] is a former solid waste management facility near Moonshine Park. The station was decommissioned in January 2016. We will evaluate how best to assess the potential for this facility to impact dissolved oxygen during the TMDLs source assessment.

3.8 Water Rights

Withdrawal of water from surface water sources has the potential to impact water quality and aquatic life in several ways, including changes to habitat through flow regime modifications, changes to native wildlife populations, and changes to morphology (Kingsford 2000), and changes to water temperature.

In the contributing area of the Siletz watershed encompassing the 303(d) listed segment, there are 668 water rights for surface water diversion or storage. There are no water rights for groundwater appropriation. There may, however, be unreported domestic or agricultural wells. Included in the diversions and storages, the Cities of Siletz, Newport, and Toledo, as well as the Georgia-Pacific facility in Toledo, withdraw water within the vicinity of the City of Siletz for a total permitted diversion rate of 14.4 cfs. There are 11 water rights for livestock and 56 diversions for irrigation.

The Oregon Water Resources Department has multiple in-stream water rights in the Siletz and its tributaries for aquatic and salmonid habitat. Water rights and diversions will be a component of the analysis and TMDL development moving forward.

[6] Facility ID: 82616; SWIFT Facility ID: 104078; Permit #: 194

4. Methods

This section describes the methods used to collect and analyze data on the middle reach of the Siletz River. The water quality monitoring and analysis were conducted with the intention of determining if and to what level the 303(d) listed segment is water quality impaired for dissolved oxygen. The data were also collected with the intention to support TMDL development.

4.1 Data Inquiries

Inquiries about the data from the Siletz River 2017 monitoring can be addressed by directing the inquiry to one of the following sources of information:

- Oregon DEQ collected data in 2017 in the Siletz watershed (continuous DO, temperature, pH and conductivity, field data & grab chemistry) as part of assessment of water quality status (compared to standards). The data is available in the Ambient Water Quality Monitoring System (AWQMS)[7] for a subset of sites (see below) on the attached list. Please contact David Waltz or Steve Hanson with a specific request for the DEQ-generated data.
- The 2017 LSWCD data and supporting field parameters were submitted to DEQ via the Volunteer Monitoring program data submission process in summer 2018. That data is publically available in AWQMS as part of the 2018 WQ Assessment process.
- Oregon DEQ (TMDLs/Nonpoint Source program) will be using the collection of data described in this section to evaluate against applicable standards (numeric criteria) and to support development of water quality model(s). DEQ has used the collected data to generate this report summarizing and interpreting the monitoring results concerning whether or not water quality criteria were met at sites or segments, Section 303(d) recommendations, and next steps in the TMDLs development process.

4.2 DEQ Monitoring

The primary objective of the 2017 DEQ monitoring project on the Siletz River was to obtain diel dissolved oxygen dynamics and variation during critical periods and at key locations within the listed segment of the Siletz River. The DO data were paired with a suite of chemistry data needed to assess potential processes and factors affecting DO. Collection of the data generally corresponded with the critical periods during both the cold-water and spawning periods. Those periods are shown in Figure 2 and Table 3.

DEQ deployed YSI multiparameter sondes[8] to collect continuous data at three sites between Moonshine Park and Jack Morgan Boat Ramp (see Figure 1). These sites are as presented in Table 3.

The sondes collected DO concentration in milligrams per liter (mg/L) as well as supporting chemistry data including temperature, pH, specific conductivity, turbidity and depth. DO as a percent of saturation was calculated using the DO concentration, temperature, atmospheric pressure at each site.

To understand the possible factors affecting DO dynamics, grab samples were collected twice daily (morning and afternoon) on three consecutive days during each critical period. DEQ collected water samples at nine sites (See Figure 1). The objective was to characterize diel and seasonal variation in primary water quality parameters that have the potential to influence DO concentrations (Pelletier et al. 2006) either directly or through biogeochemical processes. Grab sample data included: ammonia (NH_3-

[7] Ambient Water Quality Monitoring System: https://www.oregon.gov/deq/wq/Pages/WQdata.aspx
[8] Yellow Springs Instruments (YSI) Inc., Yellow Springs, OH; Data points collected every 15 minutes

N), nitrate/nitrite (NO_3-N)[9], total Kjeldahl nitrogen (TKN), total phosphorus (TP), orthophosphate (PO4), 5-day Carbonaceous Biological Oxygen Demand (CBOD), total suspended solids (TSS), and total organic carbon (TOC). It should be noted DEQ did not collect data on algal biomass, survey for extents of benthic algal communities in the river, or sample for surrogates of algal photosynthesis, such as chlorophyll-*a*.

4.3 Volunteer Monitoring

In support of the Siletz River water quality assessment and pending TMDL development, the Lincoln County Soil and Water Conservation District (LSWCD) implemented a monitoring program to collect continuous DO and temperature data for a longer period of time and at more sites than what DEQ collected. The District's efforts were funded by a combination of an Oregon Nonpoint Source Implementation (319) grant and ODA funds with the intent to inform the District's activities in its current Agricultural Focus Area[10]. The periods with valid data are shown in in Figure 2 and Table 3.

The LSWCD monitoring program was primarily focused on collection of continuous DO and temperature data as well as field parameters (i.e., pH and specific conductance) and nutrient samples in September that will be available for the development of the TMDL. The LSWCD monitoring program involved deployment of 13 Onset U26 DO data loggers[11], including two sites on Rock Creek. Figure 1 presents the locations of the U26 sites.

[9] Nitrite typically oxidizes quickly in the environment to nitrate, and nitrate is the predominant component of this parameter. The combined analyte of nitrate and nitrite will be referred to as just nitrate for the remainder of this document.
[10] https://www.oregon.gov/ODA/programs/NaturalResources/AgWQ/Pages/AgWQPlans.aspx
[11] HOBO® Dissolved Oxygen Logger (U26-001); Data points collected every 15 minutes

4.4 Quality Assurance

All data collection, sampling procedures, and chemical analyses, including the LSWCD data, were conducted in accordance with DEQ's laboratory quality assurance procedures, including: TMDL QAPP, the Sampling and Analysis Plan[12], and LAB Data Validation and Qualification Manual (Oregon DEQ 2017). Only data with quality assurance "A" and "B" grades were included for this data analysis.

4.5 Data Analysis

4.5.1 DO Criteria

The main method of analyzing the DO data to assess whether the Siletz River is water quality impaired and if so, the periods, is to compare the relevant data to the applicable water quality criteria. The water quality criteria are established based on the beneficial uses of the water body. For the Siletz River and with regard to DO, the fish and aquatic life beneficial uses are salmonid spawning from September 1 to June 15, and core cold water habitat from June 16 to August 31. The full set of criteria associated with dissolved oxygen are in Oregon Administrative Rules (OAR) 340-041-0016, and summarized as follows:

1. For water bodies identified as active spawning areas the following criteria apply:
    a. The dissolved oxygen may not be less than 11.0 mg/l as seven-day mean minimum[13]. However, if the minimum intergravel dissolved oxygen, measured as a spatial median, is 8.0 mg/l or greater, then the DO criterion is 9.0 mg/l;
    b. Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 11.0 mg/l or 9.0 mg/l criteria, dissolved oxygen levels must not be less than 95 percent of saturation;
    c. The spatial median intergravel dissolved oxygen concentration must not fall below 8.0 mg/l.
2. For water bodies identified by the Department as providing cold-water aquatic life, the dissolved oxygen may not be less than 8.0 mg/l as an absolute minimum. Where conditions of barometric pressure, altitude, and temperature preclude attainment of the 8.0 mg/l, dissolved oxygen may not be less than 90 percent of saturation. At the discretion of the Department, when the Department determines that adequate information exists, the dissolved oxygen may not fall below 8.0 mg/l as a 30-day mean minimum[14], 6.5 mg/l as a seven-day minimum mean[15], and may not fall below 6.0 mg/l as an absolute minimum;

The metrics of evaluating compliance with the criteria are to assess weekly or monthly averages of daily statistical values (e.g., mean or minimum) based on the available data.

Because dissolved oxygen concentration and saturation are directly related to local temperature and barometric pressure, we assessed the available temperature data against the applicable criteria to determine whether DO saturation criterion were met for all values of DO concentration. The applicable temperature criteria are given OAR 340-041-0028, paraphrased as follows:

[12] DEQ17-LAB-0035-SAP
[13] The seven-day mean minimum for dissolved oxygen means the minimum of the seven consecutive-day average of the calculated daily mean dissolved oxygen concentration.
[14] The 30-day mean minimum for dissolved oxygen means the minimum of the 30 consecutive-day floating average of the calculated daily mean dissolved oxygen concentration.
[15] The seven-day minimum mean for dissolved oxygen means the minimum of the seven consecutive-day floating average of the daily minimum concentration.

- The seven-day-average maximum[16] temperature of a stream identified as having salmon and steelhead spawning use may not exceed 13°C; and
- The seven-day-average maximum temperature of a stream identified as having core cold water habitat use may not exceed 16°C.

4.5.2 Data Analysis

We first present the data descriptively to understand the dynamics of DO. To this end, the following graphical analysis of the multiple DEQ and LSWCD datasets are presented:

- Time series of the DEQ sonde data at the three sites. The DEQ time series are plots of the sonde data collected as a function of time. These plots show the diurnal variation of each parameter, and provide some understanding of the seasonal variation of each parameter.
- DEQ Grab sample data multiple sites for both cold-water and spawning. We attempted to collect two samples at the grab sample sites in order to show the potential diurnal fluctuation of each parameter. The data also demonstrate seasonal variations as shown in the comparison of the two monitoring periods.
- Time series of the LSWCD U26 data at the 12 sites. The data collected for DO and temperature are long enough with these data sets to facilitate the statistical analysis required in Section 4.5.1 for each period.
- Box plots of the LSWCD as a function of the longitudinal distance from the start of the river. Given the spatial and temporal extents of the LSWCD data, we have plotted the DO and temperature data as a function of river mile.

Following the presentation of the abovementioned data, we calculate the descriptive statistics on each time series based on the applicable portion of the criteria outlined in Section 4.5.1. That is we calculate the following statistics for the cold-water and spawning periods:

- DO during cold-water period
    - 30-day mean minimum DO concentration
    - Seven-day mean minimum
    - Seven-day minimum mean
    - 30-day mean minimum DO saturation
- DO during salmonid spawning
    - 7-day mean minimum concentration
    - 7-day mean minimum saturation
- Temperature for both cold-water and spawning
- For the DO saturation calculations, the assumed maximum percent saturation is 100 percent. That is, DO concentration and saturation measurements used in the daily mean calculations that were in excess of 100%, were valued at the saturation (100%) concentration as per OAR 340-041-0002(15). This approach is consistent with DEQ's 2018 Draft WQ Assessment Methodology[17].

[16] The seven-day average maximum temperature means a calculation of the average of the daily maximum temperatures from seven consecutive days made on a rolling basis.
[17] https://www.oregon.gov/deq/wq/Pages/2018-Integrated-Report.aspx

4.5.3 Stream Metabolism Estimates

We provide estimates of stream metabolism of dissolved oxygen at each site. Metabolism characterizes how energy and matter (e.g., carbon, nitrogen, and phosphorus) enter, cycle, and exit an ecosystem. Energy predominantly enters ecosystems through photosynthesis, in which carbon dioxide gas and water react in the presence of light and chlorophyll to form organic compounds in autotrophic organisms (e.g., plants, algae and some bacteria). Through photosynthesis, oxygen gas (O2) is released as a byproduct. Autotrophic systems are ecosystems dominated by organisms capable of fixing and creating their own food from light and inorganic compounds.

Energy cycles and exits ecosystems through the process of respiration, in which heterotrophic organisms (e.g., animals and fungi) release energy stored in organic compounds for cellular work by consuming O2 and producing carbon dioxide gas and water. Heterotrophic organisms also require sufficient quantities of nutrients to form compounds for executing cellular work. Heterotrophic systems are ecosystems that require external sources of energy.

Hence, stream metabolism estimates consist of rates of production and consumption of DO through processes such as photosynthesis and microbial digestion of organic matter. The two fundamental components of metabolism are gross primary production (GPP) and ecosystem respiration (ER). In autotrophic systems GPP is greater than ER, and in heterotrophic systems, ER is greater than GPP.

GPP and ER cannot be easily measured without the specialized equipment. An alternative approach that allows open system estimates from readily available data can be achieved through modeling oxygen concentrations in the water column and determining oxygen production and consumption through supersaturation or deficit. We used the streamMetabolizer package (Appling et al. 2018) within the statistical program R[18] to estimate daily metabolism rates for each site and for each season. We present the results in the next section in the following ways:

- Box plots of daily GPP and ER rates for each period (i.e., cold-water and spawning). It should be noted, ER is typically expressed on its own as a negative value because it represents consumption or loss of oxygen from the system
- Two-dimensional density plots of GPP and ER. These figures demonstrate the paired values of mean GPP and ER for each day. That is, on any given day, when the mean GPP is a certain value, it is plotted against the mean value of ER.
- Box plots of the ratios of daily GPP and ER. Similar to the density plots above, the ratio of GPP and ER is expressed as GPP divided by the absolute value of ER. A ratio of 1 indicates oxygen is being consumed at the same rate it is being produced. A ratio of less than 1 indicates consumption is greater than production (heterotrophic), and a ratio greater than 1 indicates production is greater than consumption (autotrophic).

The reaeration rate is another critical factor affecting the concentration of DO in the water because it is a reflection of the physical rate of oxygen exchange across the free water surface. While not specifically a component of stream metabolism, it is often included in the discussion of stream metabolism because it describes how fast DO can equilibrate (achieve 100% saturation) in the water column from oxygen supersaturation or deficit. We report the reaeration as K600, the gas transfer velocity corrected to a Schmidt number of 600, a standardized method for this parameter. We present box plots of the daily reaeration rates for each season for each site within this section.

It should be noted the metabolism analysis, including reaeration, was conducted using the one-station method, which assumes the upstream reach for which the station is representative is long and relatively homogeneous (Chapra and Di Torro 1991).

---

[18] https://www.r-project.org/

5. Results

This section presents the results of the 2017 Siletz River water quality monitoring. For reference to data collection and analysis methods refer to Section 4.

5.1 DEQ Continuous Data

Figure 4 shows the time series plots of the continuous DO data collected by DEQ. In examination of the data, the general details of the data show:

- For DO, the typical range of concentrations during the cold-water period was 8.4 to 10.6 mg/L and the range during the spawning period was 8.5 to 11.0 mg/L. Moonshine demonstrated the smallest range of diurnal variation, and Jack Morgan Park (36367) the greatest. The daily maxima typically occurred from 1 P.M. to 6 P.M., with Moonshine Park (37396) peaking earliest and Jack Morgan Park (36367) latest. Daily minimum concentrations typically occurred between 10 P.M. to 6 A.M., again Moonshine Park (37396) dipping the earliest. The data for Jack Morgan Park (36367) and the USGS Gage (38918) mimicked each other closely in diurnal variation, range and time of maxima and minima. This is likely due to similarities in landscape and channel slope.
- For DO saturation, the typical diurnal range during the cold-water period was from 91 to 120 percent saturated, and during the spawning period from 90 to 122 percent saturation. Otherwise, DO saturation data demonstrated similar time-series behavior to that of the DO concentrations.
- For temperature, the typical diurnal range during the cold-water period was from 15.0 to 23.0°C, and during the spawning period 15.0 to 21.0°C. Moonshine Park (37396) showed the greatest diurnal swing, with a mean daily range of 4.3°C per day during the cold-water period. The USGS Gage (38918) showed the greatest diurnal swing during the spawning period with a mean of 2.4°C per day. Jack Morgan Park (36367) demonstrated the hottest water temperatures on average, and Moonshine Park (37396) demonstrating the coolest water temperatures. This could possibly be linked to a combination of factors including effective shading, geomorphology and channel slope.
- Specific conductance and turbidity did not demonstrate any particular diel fluctuation, which is typical with of parameters less affected by variations in atmospheric or water temperature.

The graphs include the water quality criteria for applicable periods, however because the standards generally require comparison with calculated values (e.g., 30-day mean minimum), and because those statistics have not been calculated for these data, we have not commented on the data relative to the criteria in this section.

5.2 DEQ Grab Sample Data

This section discusses the DEQ grab sample analysis of water chemistry from selected sites during the cold-water and spawning monitoring periods. For display purposes the eight constituents were divided into two sets and presented in two figures. Figure 5 shows cold-water and spawning period data for total Kjeldahl nitrogen (TKN), ammonia (NH_3-N), nitrate/nitrite (NO_3-N), and 5-day Carbonaceous Biological Oxygen Demand (CBOD). Figure 6 shows cold-water and spawning period data for orthophosphate (PO_4), total phosphorus (TP), total organic carbon (TOC) and total suspended solids (TSS). Data samples not detected at the detection limits for a given parameter were assumed to be equal to half of the method detection limit (MDL). The non-detected samples are represented in the figures as hollow shapes, and detected values as solid shapes.

In general, the data demonstrate the following patterns and water quality characteristics:

- Nitrate, represented as combined nitrate and nitrite, is an important nutrient for biological production. Nitrate was detected during all sampling events at all sites during both periods. Rock Creek (demonstrated the highest concentrations during both the cold-water period (0.46 mg/L at 38928) and the spawning period (0.26 mg/L). Moonshine Park (37396) showed the lowest mean cold-water nitrate concentration at 0.12 mg/L and the highest mean spawning nitrate concentration at 0.08 mg/L. The mean spawning nitrate concentration (0.06 mg/L) for all sites (aggregated) was less than half of the mean cold-water nitrate concentration (0.17 mg/L). Nitrate concentrations in the morning were slightly higher (0.119 mg/L) than those collected in the afternoon (0.11 mg/L).
- Orthophosphate was detected in 14 of the 45 samples (31 percent) collected with a typical method detection limit (MDL) of 0.005 mg/L. Each of the samples collected in Rock Creek (one in cold-water and one in spawning) were detected at concentrations greater than the MDL. The highest concentrations of orthophosphate was 0.009 mg/L, measured during at spawning period in Rock Creek (38930) and the first bridge (29287). Thirteen of the 14 detected samples were observed during the spawning period, with Rock Creek (38929) the only sample detected above the MDL during the cold-water period. Six of the 14 detected samples were collected at the first bridge (29287).
- Ammonia was detected in three of the 56 samples collected at concentrations greater than the MDL (0.01 mg/L). The three samples detected at concentrations greater than the MDL were collected during the spawning period, one in Rock Creek (38930) and two at Ojalla Boat Ramp (38300).
- Total Organic Carbon was detected in more than 50 percent of the samples (24 of 46 total), and of those 24, 21 were collected in the spawning period. During the spawning period, Moonshine Park demonstrated the lowest TOC in the water column with no samples detected at concentrations above the MDL. The mean concentrations for the remainder of the sites during the spawning period was 1.30 mg/L. The highest TOC concentration was observed at Jack Morgan Park (36367) at 1.57 mg/L.

5.3 LSWCD Continuous Data

This section presents the continuous DO and temperature data collected by the LSWCD. This data set will for the primary basis of the statistical analysis and evaluation of DO relative to the standards, as well as establishing the foundation of the modeling and TMDL development.

5.3.1 Time Series

Figure 7 through Figure 9 present the LSWCD continuous DO concentration, DO percent saturation and temperature respectively for both the cold-water and spawning periods. It should be noted that data were not collected for both periods at all sites due to resource limits and equipment issues. Five sites are characterized by two full periods of data: Ojalla Boat Ramp (38300), USGS gage (38919), downstream of Rock Creek (38928), Logsden (11246), and Moonshine Park (37396). The following sections discuss the key points relating to the data and parameters.

5.3.1.1 Cold-water Habitat Period

During the cold-water monitoring period, two sites demonstrate periods of significant primary production during the month of August: Ojalla Boat Ramp (38300) and downstream of Rock Creek (38928). The Siletz River at the first bridge site (29287) demonstrated low DO concentrations and is the only site for which DO was recorded to be less than the absolute minimum component of the cold-water criterion of 6 mg/L. On 08/05/2017 the DO concentration was observed to be 5.6 mg/L, and on 08/08/2017 it was observed to be 6.0 mg/L.

The maximum diel DO concentrations ranged from around 10.0 to 13.0 mg/L with a peak of 13.2 mg/L observed downstream of Rock Creek (38928). Minimum DO concentrations ranged from 7.0 to 8.0 mg/L. The site at Moonshine (37396) showed some limited production between 08/05/2017 and 08/22/2017. All of the sites for which cold-water period data were collected demonstrated DO concentration minima around 08/05/2017. Typically, diel maxima DO concentrations were observed in the afternoon between 2 and 6 P.M. while minima were observed in the mornings from 5 to 11 A.M.

DO saturation patterns generally paralleled DO concentrations patterns in terms of location, variation, productivity, and deficits. The absolute maximum DO saturation was observed at the site downstream of Rock Creek (38928) at 147 percent on 08/24/2017, and from 08/02/2017 to 08/28/2017, daily DO saturation maxima were greater than 120 percent and often greater than 130 percent. Minimum DO saturation was observed at the first bridge (29287) at 65 percent on 08/04/2017.

Water temperatures during the cold-water period peaked at all sites on 08/03/2017, with the maximum observed temperature at 26.2°C at the Ojalla Boat Ramp (38300). The minimum water temperature observed was 14.6°C at Moonshine Park (37396) on 07/21/2017.

Maximum water temperatures and minimum DO concentrations correspond approximately to the period in the cold-water period of maximum air temperatures.

5.3.1.2 Salmonid Spawning Period

The overall trends of DO and temperature in the spawning season were inversely related: as water temperatures decreased, DO concentrations and saturations increased. The maximum DO concentration of 12.2 mg/L observed at Moonshine Park (37396) on 10/15/2017, and the minimum DO concentration of 8.0 mg/L was observed at Jack Morgan Park (36367) on 09/13/2017. The maximum DO saturation of 123 percent observed on 09/16/2017, and the minimum DO saturation of 86 percent observed on 09/13/2017 both at Jack Morgan Park (36367). The maximum temperature of 21.4°C observed at Jack Morgan Park (36367) on 09/10/2017, and the minimum temperature of 6.8°C was observed at the confluence (38912) on 10/15/2017.

Two precipitation events occurred during the spawning period that were the likely cause of changes in DO and temperature. Between 09/17/2017 and 09/21/2017, the Newport Municipal Airport meteorological station (NCDC 2018) recorded 2.0 inches of rainfall. During that time, the flow at the USGS gage station (38919) increased from a low of 68.5 cubic feet per second (cfs) on 09/17/2017 to a peak of 794 cfs at 6:45 P.M. on 09/20/2017. Whereas water temperatures were generally decreasing prior to that time, the drop in average daily water temperature was more pronounced, and the diurnal variation decreased following the events from 9/17/2017 to 9/20/2017. Corresponding DO concentrations increased at a slightly higher rate than before and the diurnal variation decreased. An increase in air temperatures immediately after that (09/25/2017 – 09/28/2017) resulted in increased water temperatures and lower DO concentrations (NCDC 2018).

5.3.2 Longitudinal Profiles of Distributed Data

Figure 10 through Figure 15 show box plots of the data for each monitoring period at each site as a function of distance along the Siletz River:

- Figure 10 and Figure 11 are box plots of DO concentration for each site during the cold-water and spawning period respectively.
- Figure 12 and Figure 13 are box plots of DO saturation for each site during the cold-water and spawning period respectively.
- Figure 14 and Figure 15 are box plots of temperature for each site during the cold-water and spawning period respectively.

Rock Creek data have been separated into a discrete stream reach with the location of its confluence with the Siletz River shown on the Siletz reach.

Analysis of the data presented in this format yields the following observations:

- Median DO concentrations generally decrease from the Upper Gorge (38912) to the first bridge (29287), and increase from the first bridge to downstream of Cedar Creek (38944). One exception to this is downstream of Rock Creek (38928) where median DO concentrations are less than the adjacent upstream and downstream sites. During the cold-water periods, the variation in DO concentrations is greatest at the site downstream of Rock Creek (38928) and the Ojalla Boat Ramp (38300). Median concentrations for all of the sites, including Rock Creek, are greater than the cold-water 30-day mean minimum concentration of 8.0 mg/L. Variation in the DO concentration data is generally greater during the cold-water period than it is the spawning period.
- Median temperatures generally increase from upstream to downstream during both monitoring periods. The exceptions to this are during the cold-water period downstream of Cedar Creek (38944) and downstream of Rock Creek (38928). Variation in the temperature data is generally greater during the spawning period than it is the cold-water period.
- The DO saturation data do not have an apparent trend in direction upstream or downstream. During the cold-water period the 25th percentile of data at all sites is greater than the minimum (90 percent). During the spawning period, only for the Ojalla Boat Ramp (38300) and Upper Gorge (38912) are 25th percentile of data less than spawning criterion (95 percent). During both periods, the median DO saturation was not less than the spawning criterion (95 percent) at any of the sites.

5.3.3 Statistical Comparisons to Water Quality Criteria

This section presents the statistical analysis of the LSWCD continuous data as required to the DO criteria. The results of the analysis were applied to the applicable criteria, forming the basis of determining impairment.

As per OAR 340-041-0016 the DO criteria for both periods involve hierarchical sequences where sufficient data exist to support the analysis described in Section 4.5. Comparison of continuous temperature data with OAR 340-041-0028 is also presented. The following figures plot the statistical time series calculations relative to the DO criteria:

- Cold-water Period
  - Figure 16 – Comparison of the 30-day floating averages of the calculated daily mean DO concentration to the minimum of 8.0 mg/L.
  - Figure 17 – Comparison of the 7-day floating average of the daily minimum DO concentration to the minimum of 6.5 mg/L.
  - Figure 18 – Comparison of the instantaneous DO values to the minimum of 6.0 mg/L.
  - Figure 19 – Comparison of the 30 consecutive-day floating averages of the calculated daily mean DO saturations to the minimum of 90 percent.

- Salmonid Spawning Period
    - o Figure 20 – Comparison of the 7-day floating averages of the calculated daily mean DO concentration to the minimum of 11 mg/L.
    - o Figure 21 – Comparison of the 7-day floating averages of the calculated daily mean DO saturations to the minimum of 95 percent.
- Figure 22 – Comparison of the 7-day floating averages of the daily maximum temperatures to either the cold-water criterion of 16°C or the spawning criterion of 13°C.

Figure 16 and Figure 19 show that the DO concentrations and saturations meet the long-term daily average criteria for all sites throughout the monitoring period. Figure 17 and Figure 18 show that DO concentrations are less than the applicable portion of the cold-water DO criteria at one site, the first bridge (29287).

Figure 20 shows 7-day mean minimum DO at all of the sites is less than the 11.0 mg/L criterion for most, if not all of the monitoring period. Figure 21 demonstrates, however, that 7-day DO saturations, even for data capped at 100 percent saturation values, comply with the minimum of 95 percent saturation for all sites during the entire period of monitoring. The attainment of 7-day mean minimum DO concentrations of 11.0 mg/L is not possible due to stream temperatures above the applicable temperature criteria (Figure 22), and therefore the DO saturation standard (95 percent) supersedes the DO concentration standard. Hence, during the spawning period, the Siletz River is in compliance with the applicable DO criteria.

It should be noted some data at some stations were insufficient in length to calculate the targeted statistical value.

5.4 Stream Metabolism of Dissolved Oxygen

Analysis of the stream metabolism consists of visual representation of the metabolism results from the streamMetaboliser package in R. Most of the visual presentation is in the form of box plots showing the results for each site longitudinally distributed, downstream to upstream going from left to right. The two sites in Rock Creek are presented at the far right of the figures. Figure 23 and Figure 24 show boxplots of GPP and ER during the cold-water and spawning periods respectively.

- During the cold-water period the USGS Gage (38918) and downstream of Rock Creek (38928) data demonstrated the highest GPP and ER with median absolute values of each greater than 2.0 g O_2 m^{-2} d^{-1}. The lowest median absolute daily GPP and ER were observed at the Ojalla Boat Ramp (38300) at 0.71 g O_2 m^{-2} d^{-1}. At the remainder of the sites the median absolute daily GPP and ER rates were all between 1 and 2 g O_2 m^{-2} d^{-1}.

- During the spawning period, median absolute daily GPP and ER at Jack Morgan Park (36367), Toledo Intake (37848), USGS Gage (38918) and Moonshine (37396) were all greater than 2 g O_2 m^{-2} d^{-1}. Again the lowest rates were observed at Ojalla (38300). ER at Confluence was higher than what was observed at any other site for all monitoring dates, with an absolute median daily ER of 4.2 g O_2 m^{-2} d^{-1}.

Figure 25 and Figure 26 show density plots of GPP and ER for the cold-water and spawning periods respectively. Figure 28 shows box plots of the GPP/ER ration for both periods. The items of note for these figures include:

- The absolute GPP/ER ratio is approximately 1 (dimensionless) for both periods at most of the sites for both periods. The gray line diagonally bisecting the plotting area in Figure 25 and Figure 26 represents a GPP/ER ratio of 1, and the plots for most of the sites during both seasons indicate

GPP and ER reflect each other responsively. That is, as GPP increases so does ER, and vice versa.

- The highest ratio observed was at Logsden (11246) with a median ratio of 1.23 indicating higher production than respiration. The lowest ratio was observed at the confluence (38912) with a median ratio of 0.35.

Figure 28 shows reaeration rates at each site during each period. The following points are observed from examining the data:

- The spatial trend of reaeration is increasing air exchange moving upstream. The lower sites (Logsden and below) have median daily K_{600} less than 6.0 d^{-1} both seasons; Moonshine (37396) and the confluence (38912) medians daily rates are greater than 6.0 d^{-1}. The highest median daily K_{600} is at Moonshine in summer at 12.6 d^{-1}, and the lowest median daily K_{600} is at first bridge (29287) during the cold-water period at 0.5 d^{-1}.

6. Discussion

The analysis in Section 5.3.3 demonstrates that during the cold-water period, the 30-day mean minimum DO concentrations were above the 8 mg/L minimum threshold, and the 30-day mean minimum DO saturation values were greater than the 90 percent threshold for the entire cold-water period at all of the sites. For the 7-day minimum mean and absolute minimum, DO concentrations at the first bridge (29287) were less than their respective thresholds (6.5 and 6 mg/L, respectively). From 08/06 to 08/11, the 7-day minimum mean is less than 6.5 mg/L because of the daily minimum observations of 5.61 mg/L observed on 08/04 and 5.99 mg/L observed on 08/08.

For the spawning period, whereas the Siletz River did not meet the DO concentration minimum of 11 mg/L for all of the sites during most of the spawning period, the percent DO saturation minimum of 95 percent is consistently met at all of the sites.

While the data show that the Siletz River is mostly meeting the water quality standard for DO, during the monitoring period in 2017, they do not provide a complete understanding of DO dynamics during other periods, such as critical low flows. Additionally, the 7-day average daily maximum temperature exceed the criteria at all sites during the entire cold-water period and for a significant portion of the time that data were collected during the spawning period, excluding Strome Park (38941). Hence, the full extent of impacts of water temperatures on DO dynamics in the Siletz are unknown at this point.

Additional considerations to this discussion include the following points:

- Significant nutrient inputs from Rock Creek may influence primary production in the river and subsequently DO concentrations and supersaturated conditions during the cold-water period. One possible factor, at least concerning sources of nitrogen and carbon, includes the composition of land cover and percent contribution of flow just downstream of the Siletz River and Rock Creek confluence. The Rock Creek watershed is 24 percent of the total Siletz River watershed at the confluence with Rock Creek, however the Rock Creek watershed is 30 percent deciduous and mixed forest. Deciduous and mixed forest in the Mid-Coast are made up of, in significant portion, Red alder (*Alnus rubra*) which fixes atmospheric nitrogen in the soil thereby increasing nitrogen within the system (Sigleo and Frick 2004). This is a possible source of the elevated nitrate concentrations in Rock Creek, and potentially a reason for the observed increased production in the Siletz River downstream of Rock Creek (38928) but not at Logsden (11246).
- Data at the Ojalla Boat Ramp (38300) and Moonshine (37396), to a lesser degree, demonstrate primary production characteristics similar to downstream of the Rock Creek confluence. At the First Bridge site (29287), the data show a deficit in DO during the cold-water period. It is unclear at this point what the causes of these phenomena are. Discharge from the Siletz STP could be causing the dip in DO at the first bridge (29287), however, the data show that the Siletz STP does not appear to be affecting GPP or ER at Ojalla Boat Ramp.
- Overall, the concentrations of nutrients and sediment are low in July and are representative of baseflow conditions. Elevated concentrations during September relative to July are likely due to minor rainfall events from 09/07/2017 to 09/09/2017. Even though the flows were receding during the sampling events during the spawning period, runoff can transport residual sediment and associated nutrients with it.
- The metabolism results indicate the steam is predominantly autotrophic (Allen 1995) in the lower reaches and increasingly heterotrophic moving from downstream to upstream sites. These results may be due to increased light availability, as the river becomes larger and wider downstream and greater stocks of organic matter for consumption by heterotrophs at upstream sites (Naiman and Sedell 1980). Reaeration increases in the upstream reaches, indicating increased channel slope

and morphology resulting in increased oxygen exchange moving from downstream to upstream reaches. Overall, rates of GPP and ER suggest that the Siletz River during the monitoring period had relative average rates of productivity compared to other similarly sized rivers in temperate biomes of North America (Minshall et al. 1983).

7. Conclusions and recommendations

Our examination of DO and other water quality data suggest a complex, multi-factored system of dynamics affecting DO concentrations in the Siletz River. The two questions in the Discussion section regarding (1) temperatures and DO concentration/saturations, and (2) production and deficit at particular locations, would benefit significantly from numerical modeling to assess the contribution of various factors for their influence on system dynamics. The quantity and quality of the data collected during 2017 are sufficient for developing mechanistic watershed and water quality models to evaluate flow, temperature, nutrients and other factors' impact on DO levels in the Siletz River. We recommend that TMDL development efforts for DO use a calibrated watershed (HSPF) model coupled with a calibrated water quality model (QUAL2Kw) for both the cold-water and spawning periods.

Another factor that may be affecting water quality (and flow) in the middle Siletz watershed is shallow ground water input to surface water. Groundwater-surface water interactions via seeps and channelized flow that emanate from the banks of the Siletz River at lower and baseflow conditions are observed along this segment. One working hypothesis is that shallow ground water may be a source of nutrients, primarily nitrate, affecting nutrient availability and algal production in the mainstem river. DEQ is evaluating how and whether a shallow ground water monitoring project, coupled with ground water modeling, could be used to address uncertainties associated with this hypothesis and potentially assist in nonpoint source assessment and developing nutrient load estimates.

8. References

Allen, D.J. 1995. Stream Ecology: Structure and function of running waters. Chapman and Hall. ISBN 0-412-29430-3

Appling, A.P., Hall, Jr, R.O., Yackulic, C.B. and Arroita, M 2017. Overcoming Equifinality: Leveraging Long Time Series for Stream Metabolism Estimation. Journal of Geophysical Research: Biogeosciences. 10.1002/2017JG004140.

Chopra, S.C and Di Torro, D.M. 1991. Delta method for estimating primary production, respiration and reaeration in streams. Journal of Environmental Engineering, 117: 640-655.

Davis, Jr., R.A. and Dalrymple, R.W. 2011. Principles of Tidal Sedimentology. Springer Science & Business Media. p. 82. ISBN 978-94-007-0123-6. 20 October 2011.

Di Luzio M., G.L. Johnson, C. Daly, J. Eischeid, J.G. Arnold 2007. Constructing Retrospective Gridded Daily Precipitation and Temperature Datasets for the Conterminous United States. Journal of Applied Meteorology and Climatology.

FGDC 2012. Coastal and Marine Ecological Classification Standard. Federal Geographic Data Committee, Marine and Coastal Spatial Data Subcommittee. FGDC-STD-018-2012. June 2012.

Kingsford, R.T 2000. Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia. Austral Ecology (2000) 25, 109-127.

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006: World Map of the Köppen-Geiger climate classification updated. Meteorol. Z., 15, 259-263. DOI: 10.1127/0941-2948/2006/0130.

MLRC 2017. National land cover database - 2011. Map, Reston, VA: US Geological Survey, Multi-Resolution Land Characteristics Consortium. https://www.mlrc.gov.

Minshall, WG, RC Petersen, KW Cummins, TL Bott, JR Sedell, CE Cushing, and RL Vannote. 1983. Interbiome comparison of stream ecosystem dynamics. Ecological Monographs 53: 2-25.

Naiman, J.N. and Sedell, J.R. 1980. Relationships between metabolic parameters and stream order in Oregon. Can. J. Fish. Aquat. Sci. 37: 834-847

NCDC 2018. Surface Data Hourly Global. Newport Municipal Airport Station 726950 24285. National Climate Data Center. Accessed July 2018. www.ncdc.noaa.gov.

Oregon Coastal Atlas 2018. Estuary Data Viewer. Accessed August 2018. https://www.coastalatlas.net/estuarymaps/

Oregon DEQ 2017. LAB Data Validation and Qualification Manual. DEQ09-LAB-0006-QAG, v3.0. 03/31/17.

Oregon DEQ 2018. Draft Methodology for Oregon's 2018 Water Quality Report and List of Water Quality Limited Waters. May 2018.

Oregon DEQ 2018. NPDES Permit Renewal Evaluation Report and Fact Sheet. Permit Number: 101680. May 14, 2018.

Oregon Water Resources Department. 2018. Oregon Water Resources Department Near Real Time Hydrographics Data. Accessed August 2018. http://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/.

Pelletier, G J, S C Chapra, and H Tao. 2006. QUAL2Kw - A framework for modeling water quality in streams and rivers using a genetic algorithm for calibration. Environmental Modeling and Software 21: 419-425.

Sigleo, A. and Frick, W 2004. Seasonal Variations in River Flow and Nutrient Concentrations in a Northwestern USA Watershed. First Interagency Conference on Research in the Watersheds, V753, pp370-376. U.S. Department of Agriculture, Agricultural Research Service.

US Department of Agriculture 2016. Soil Survey Geographic (SSURGO) database for Lincoln and Polk Counties. Fort Worth, Texas U.S. Department of Agriculture, Natural Resources Conservation Service.

US Department of Agriculture 2016. Soil Survey Geographic (SSURGO) database for Lincoln County. Fort Worth, Texas U.S. Department of Agriculture, Natural Resources Conservation Service.

US Geologic Survey 2018. USGS Current Water Data for the Nation. Accessed August 2018. https://waterdata.usgs.gov/nwis/rt

Walker, G.W. and Duncan R.A. 1989. Geologic Map of the Salem 1° by 2° Quadrangle, Western Oregon. US Geologic Survey. Miscellaneous Investigations Series Map I-1893.

9. Figures

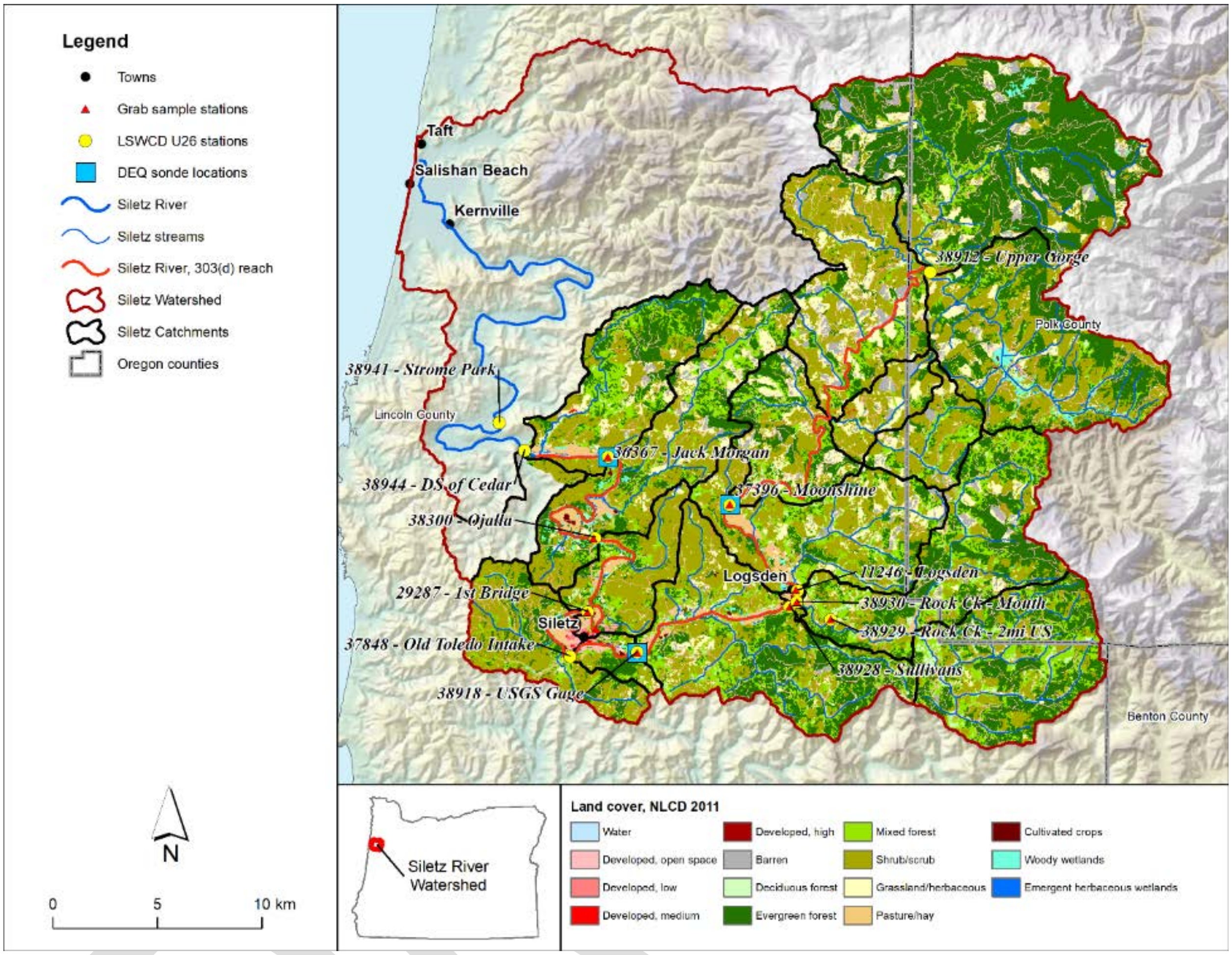

Figure 1. The Siletz River watershed, land cover and field monitoring sites

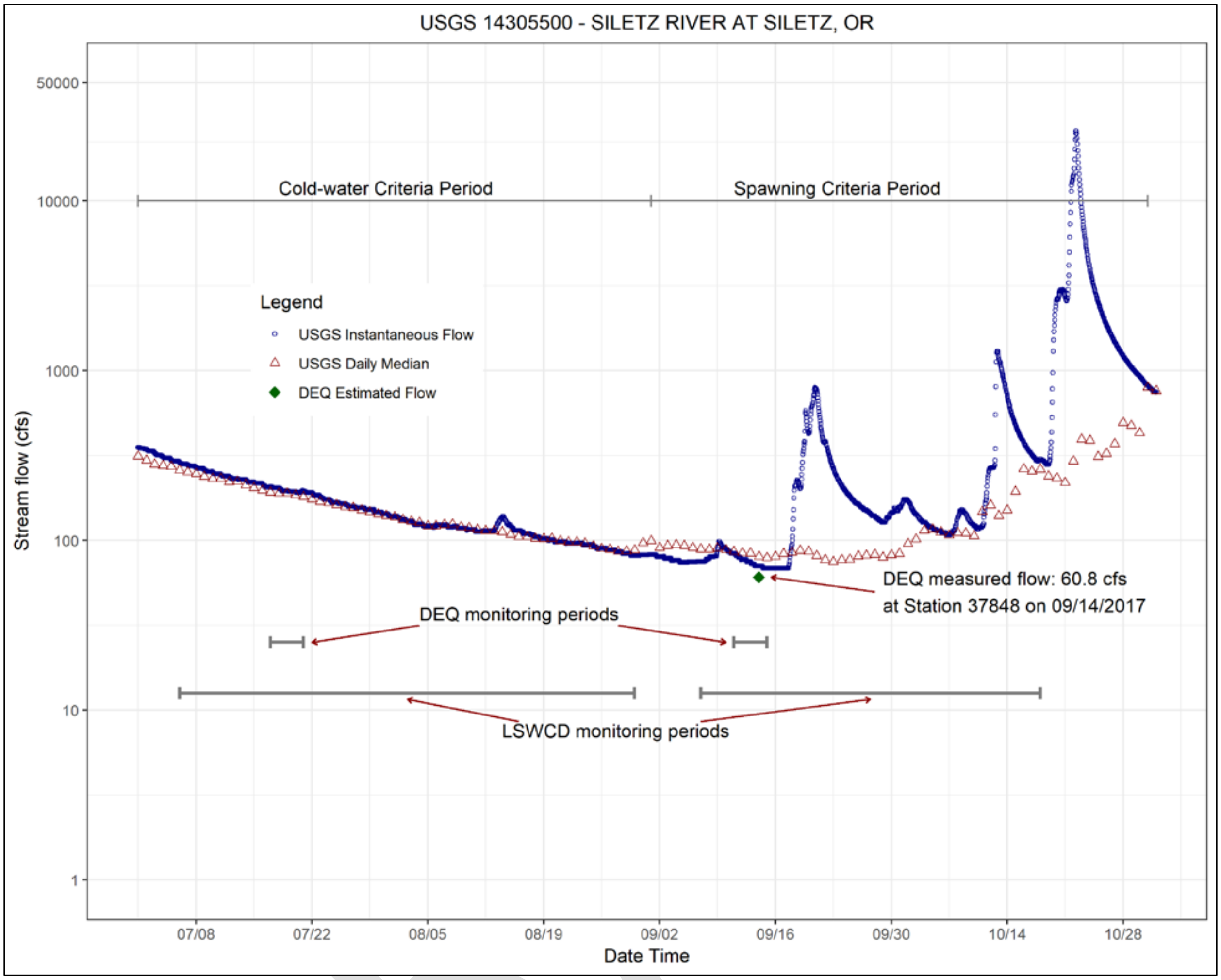

Figure 2. Siletz River flow data at USGS gage 14305530, including monitoring periods and DEQ measured flow on 09/14/2017

To be completed

Figure 3. Siletz River watershed zoning map

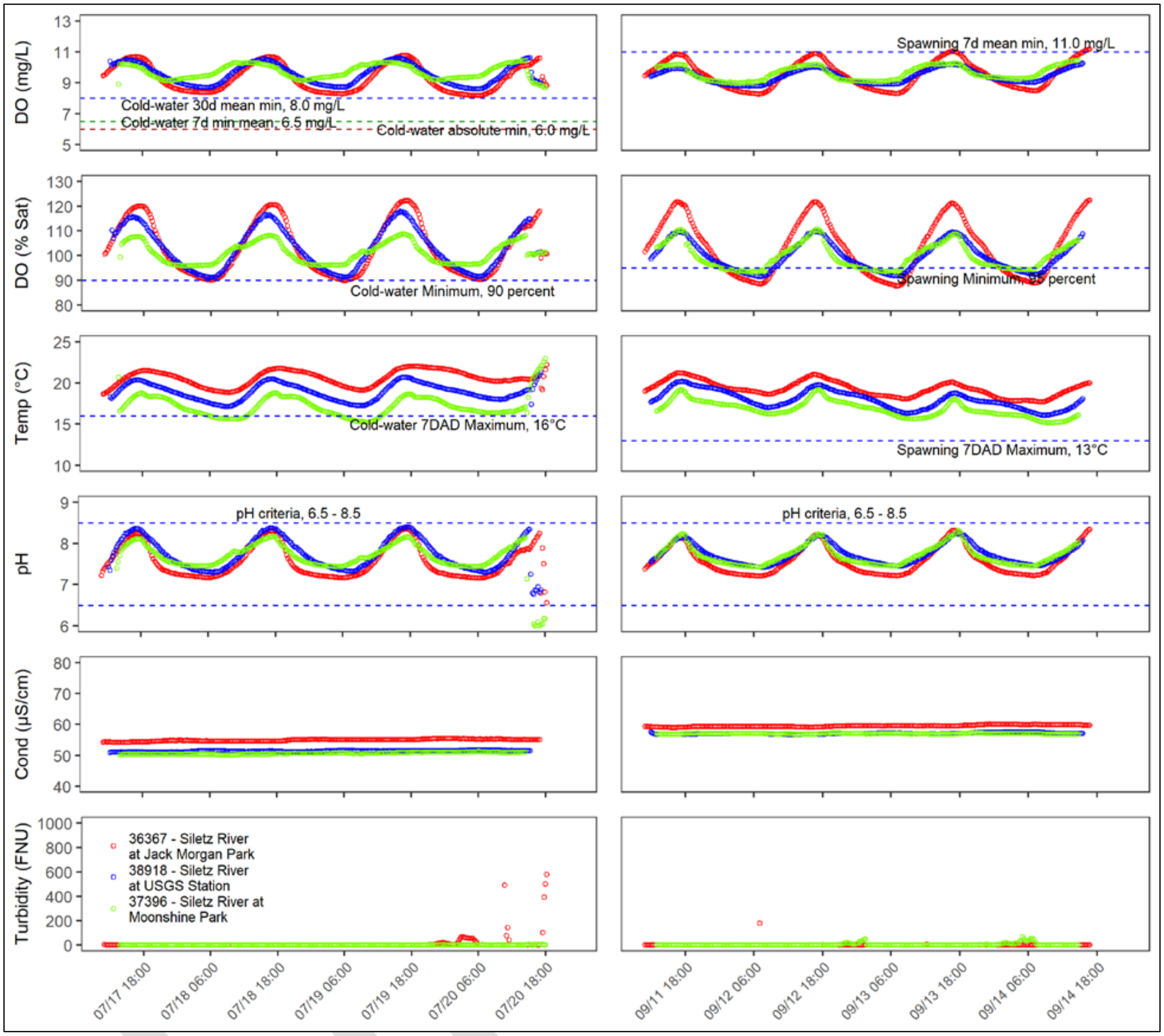

Figure 4. Continuous DEQ sonde data; cold-water (left) and spawning (right)

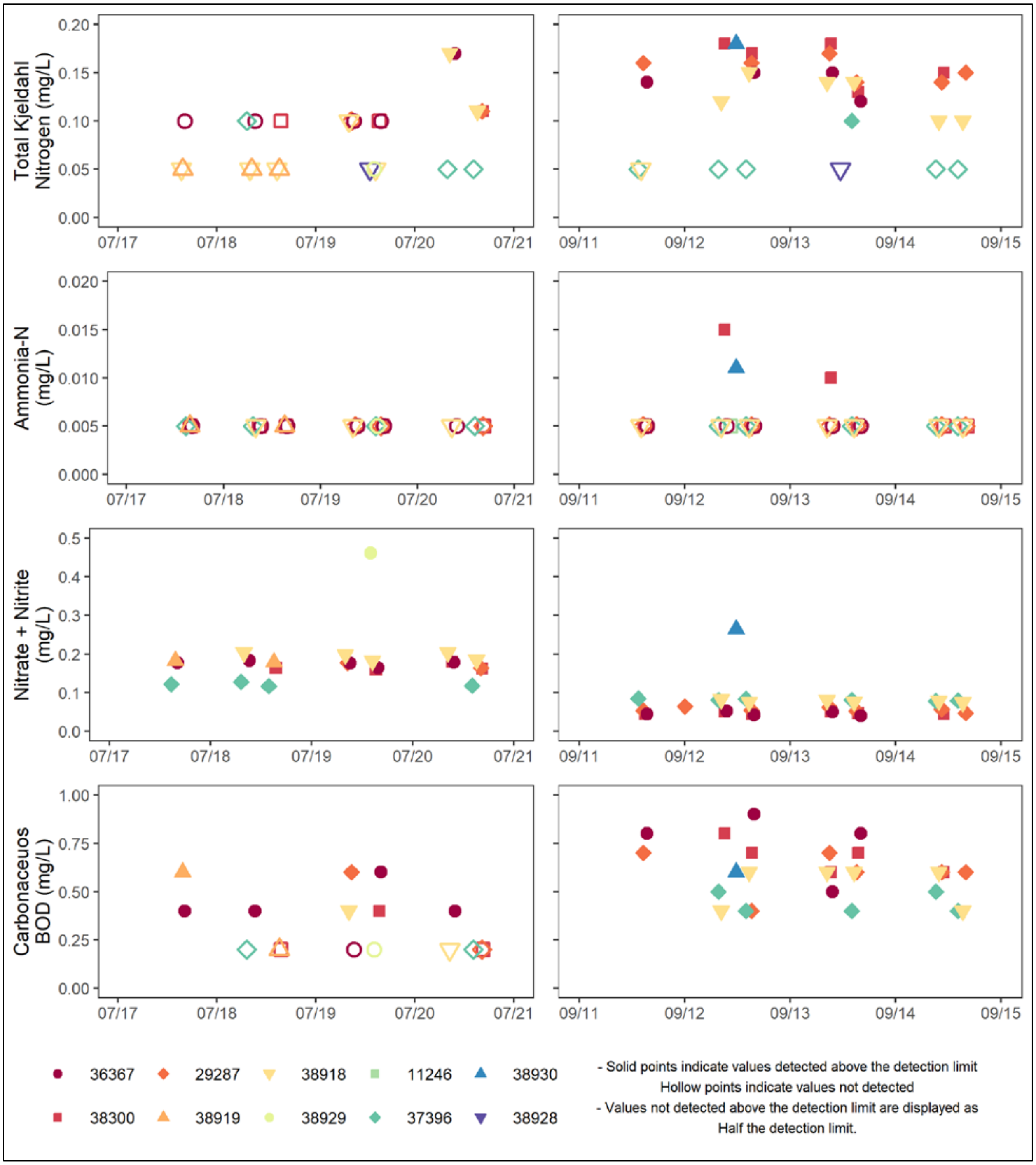

Figure 5. Water quality DEQ grab samples, constituent set 1: TKN, NH3, NO3/NO2, and CBOD; cold-water (left) and spawning (right)

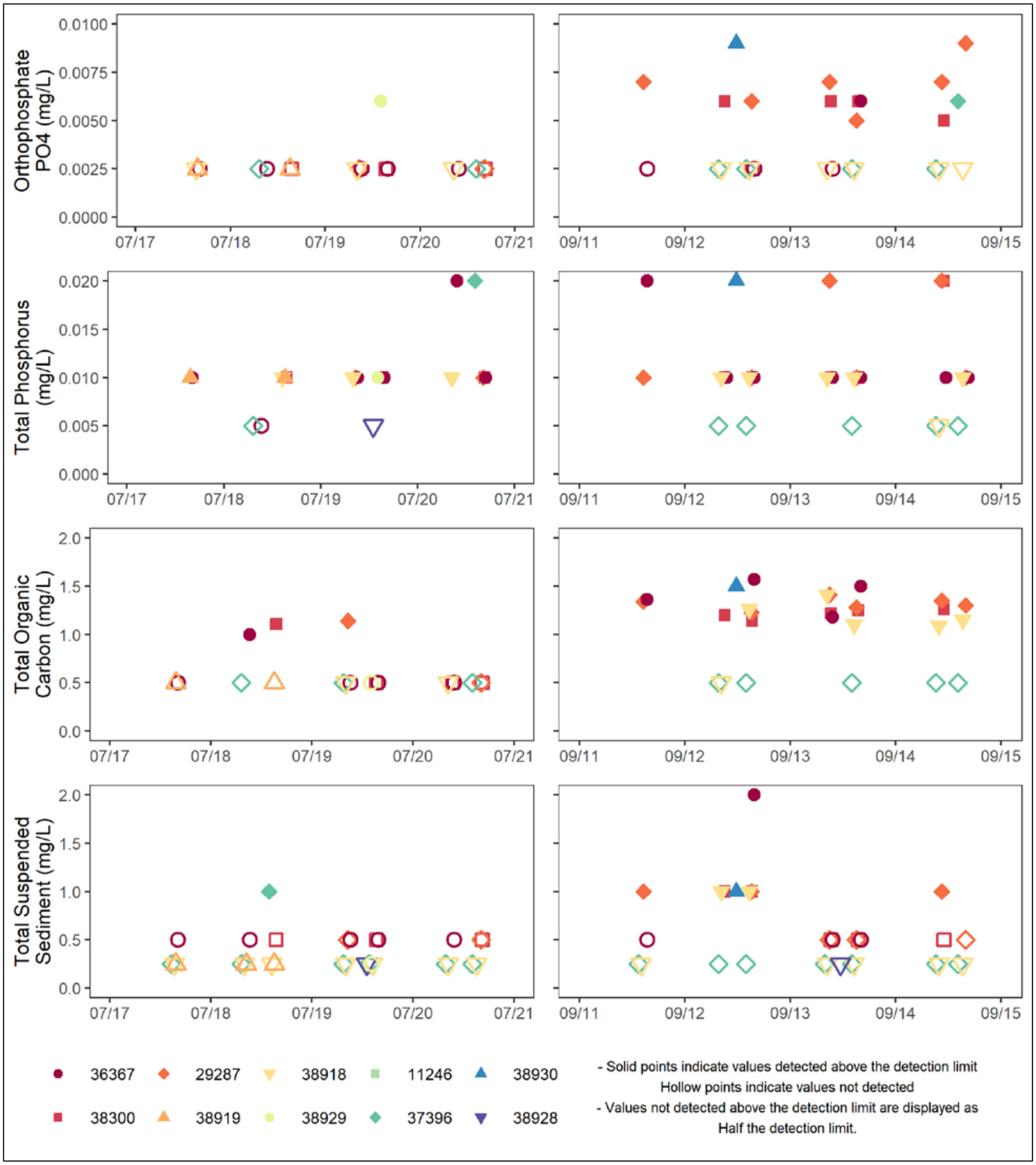

Figure 6. Water quality DEQ grab samples, constituent set 2: SPR, TP, TOC, and TSS; cold-water (left) and spawning (right)

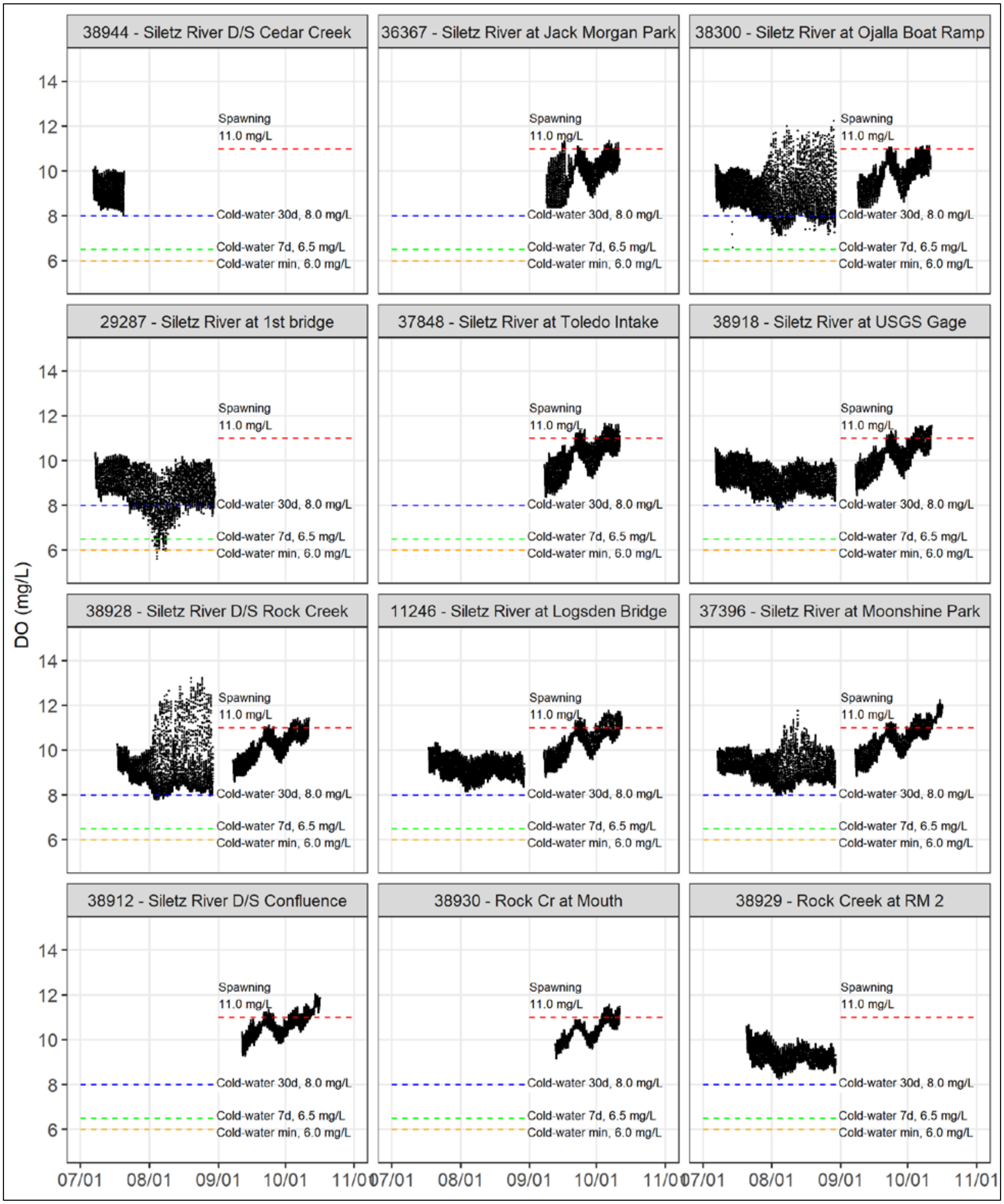

Figure 7. Continuous LSWCD U26 DO concentration data, cold-water and spawning

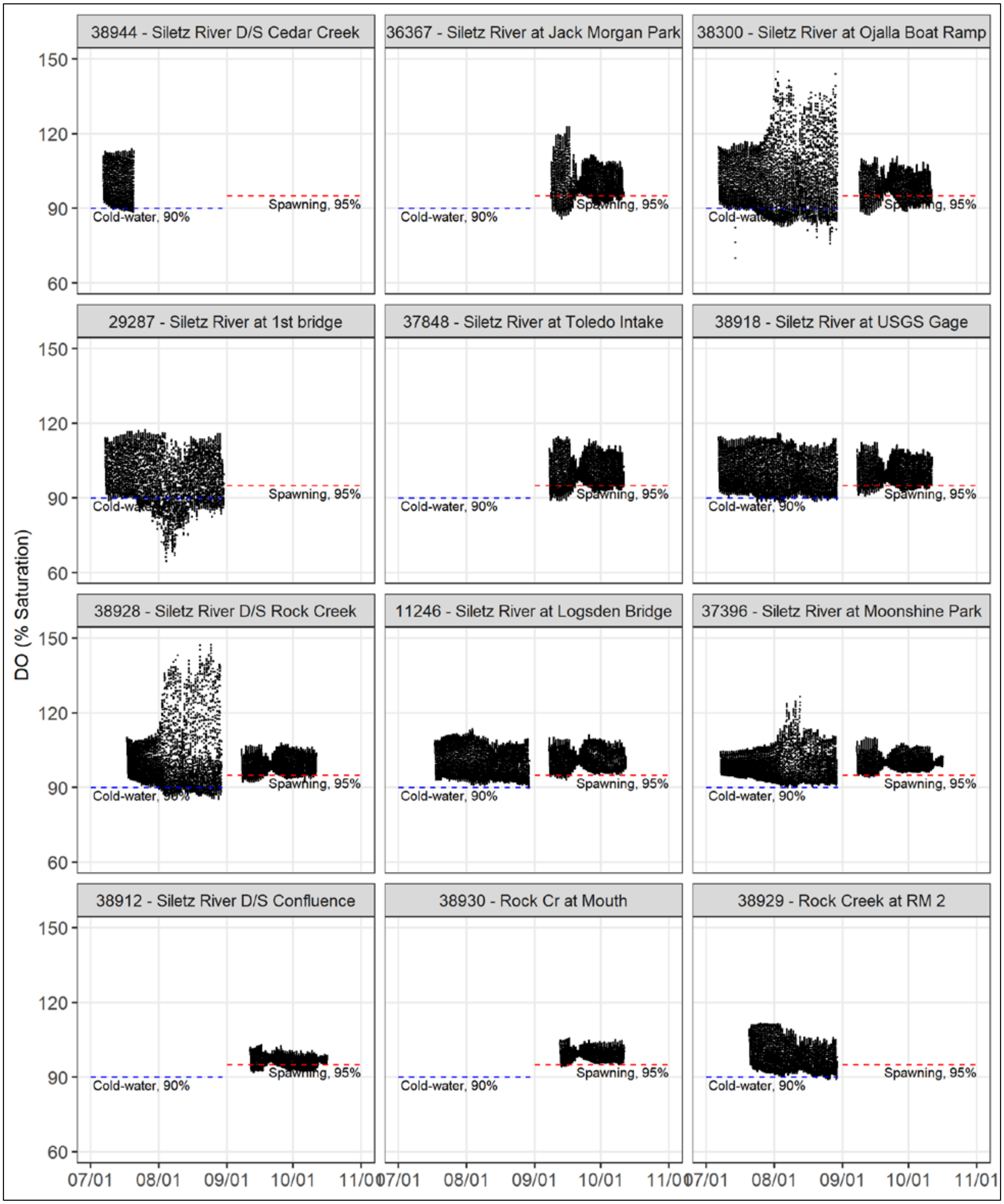

Figure 8. Continuous LSWCD U26 DO saturation data, cold-water and spawning

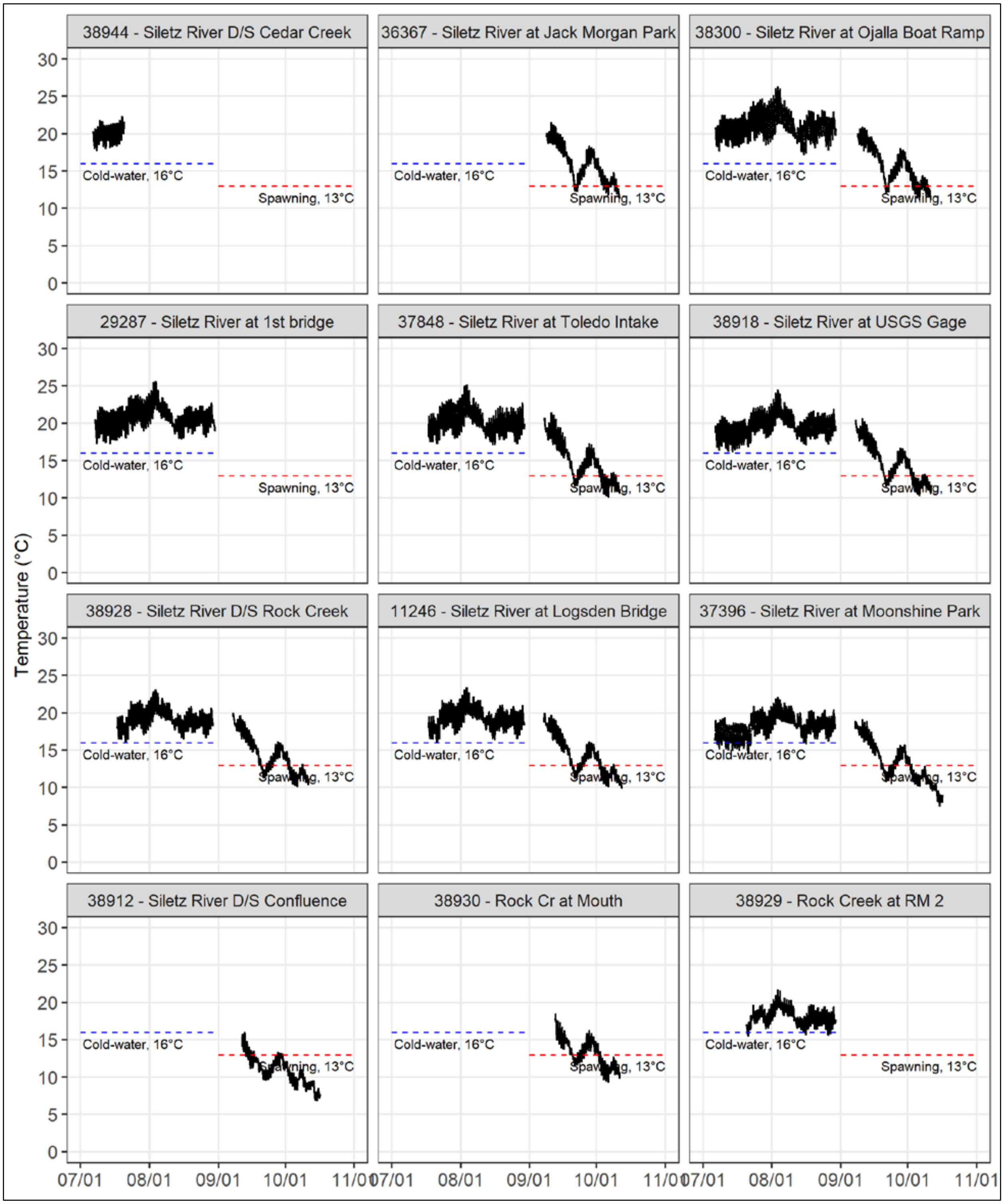

Figure 9. Continuous LSWCD U26 temperature data, cold-water and spawning

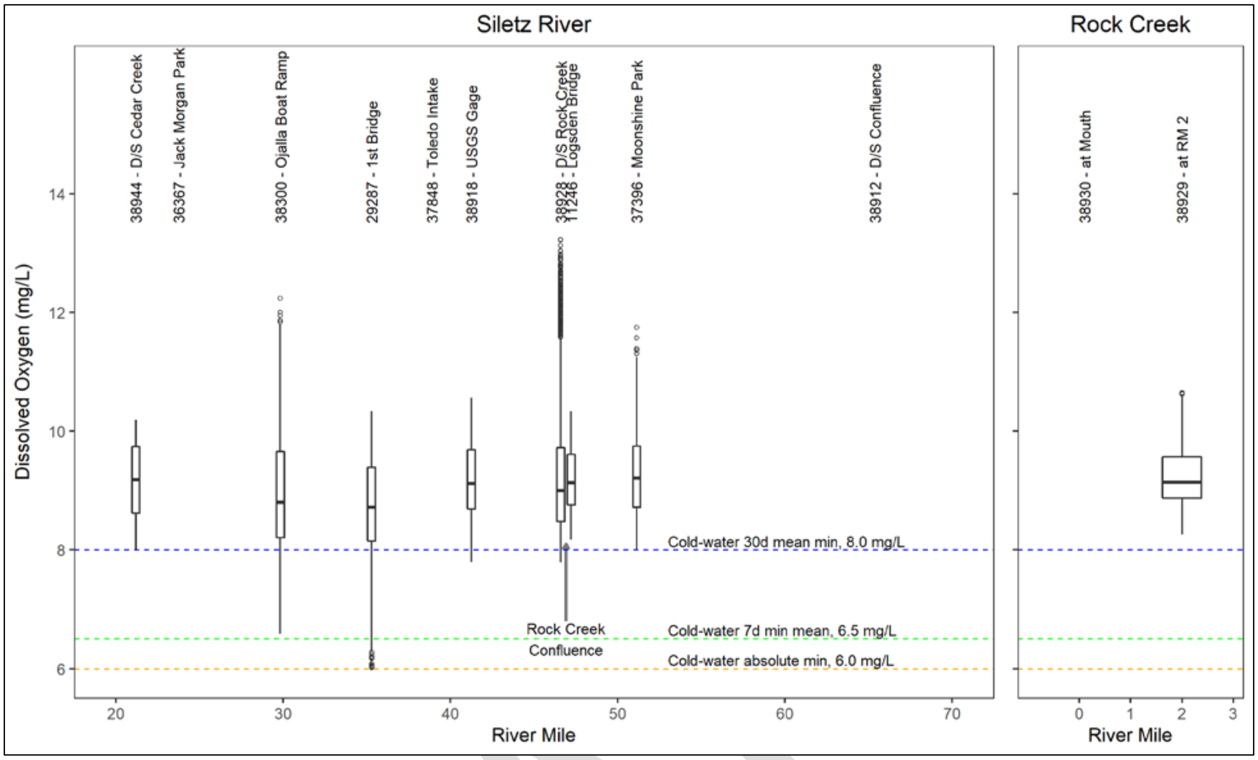

Figure 10. Boxplots of SWCD U26 DO concentration, cold-water

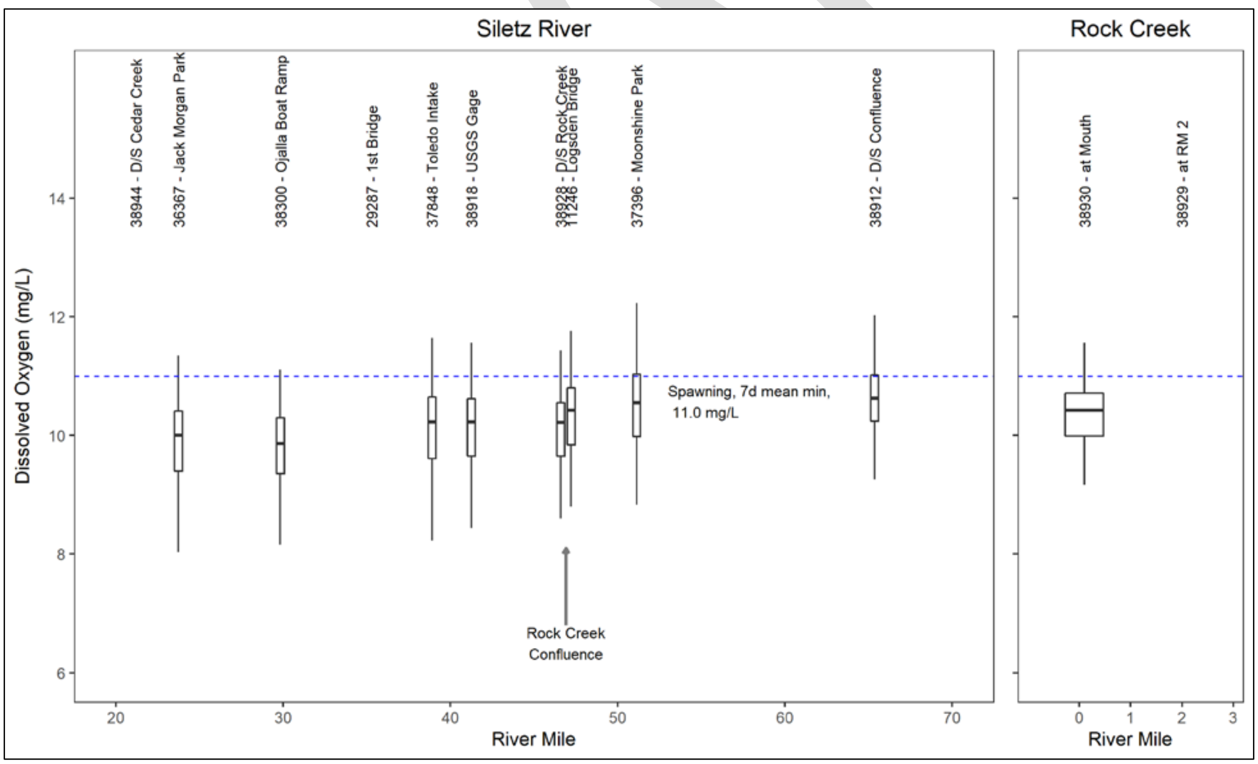

Figure 11. Boxplots of SWCD U26 DO concentration, spawning

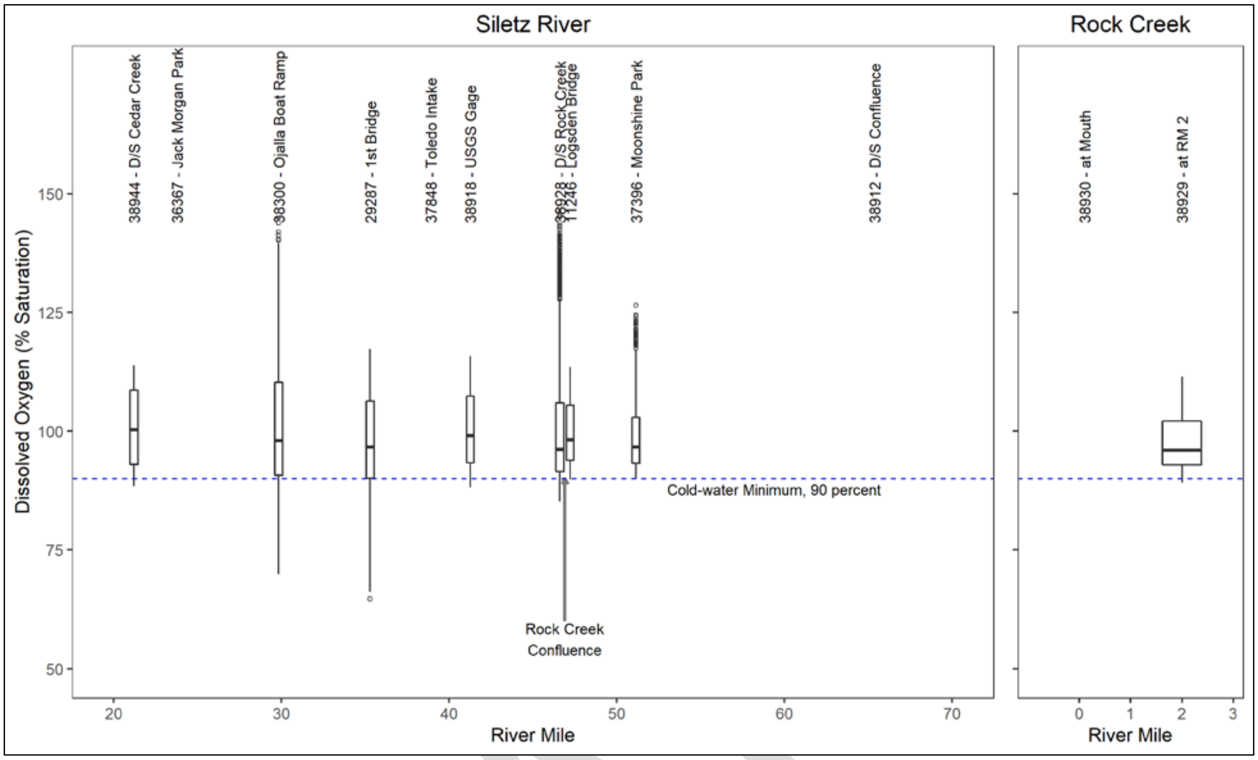

Figure 12. Boxplots of SWCD U26 DO saturation, cold-water

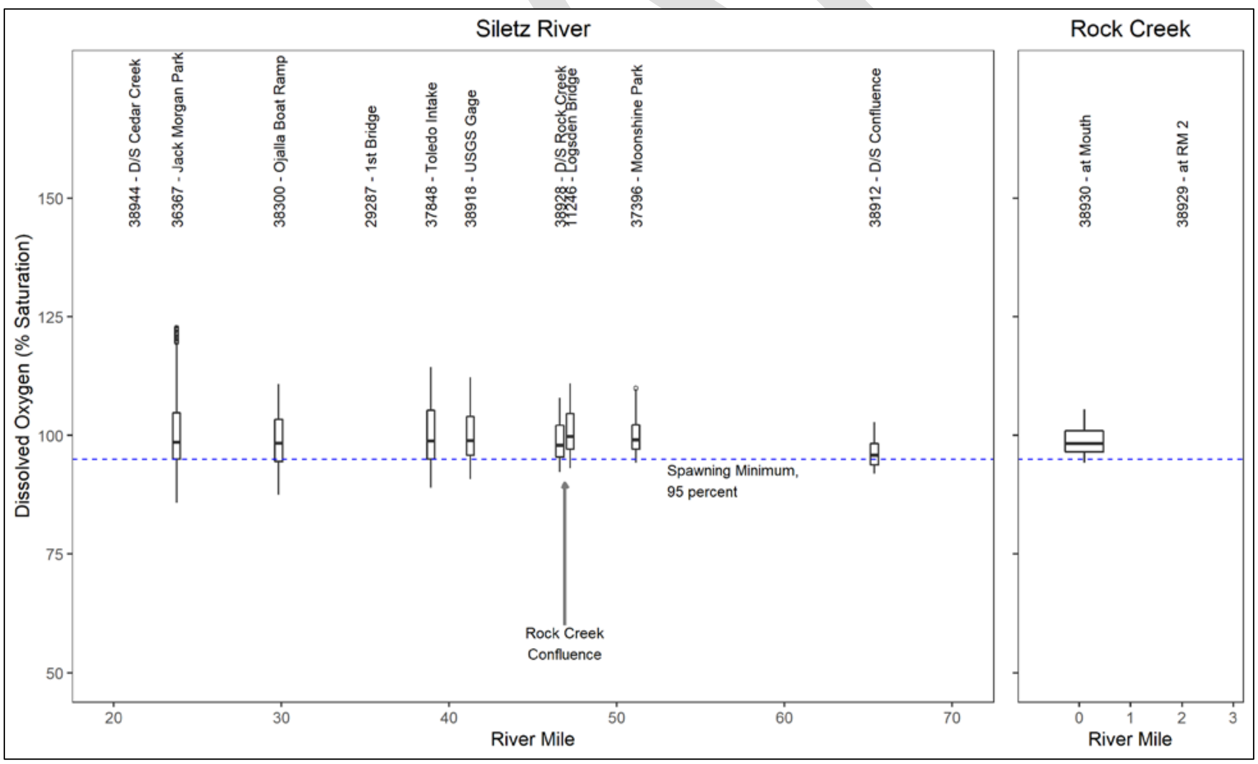

Figure 13. Boxplots of SWCD U26 DO saturation, spawning

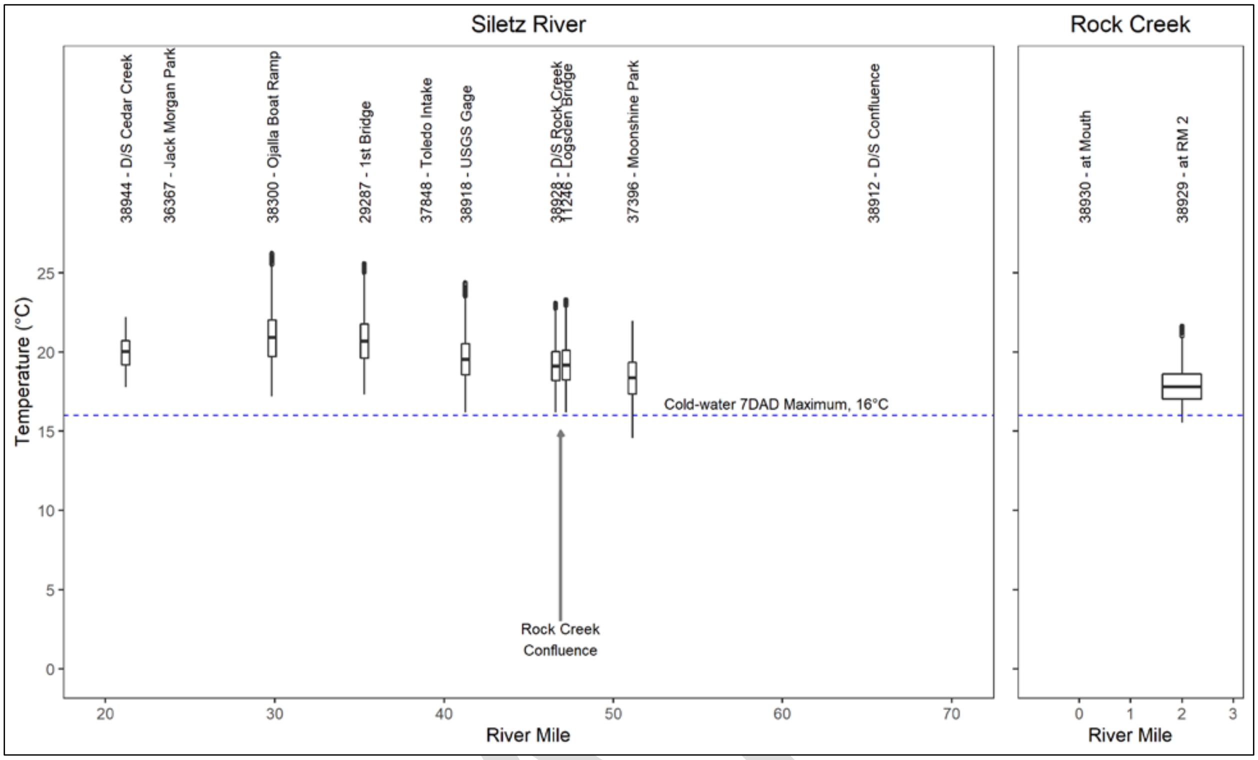

Figure 14. Boxplots of SWCD U26 temperature, cold-water

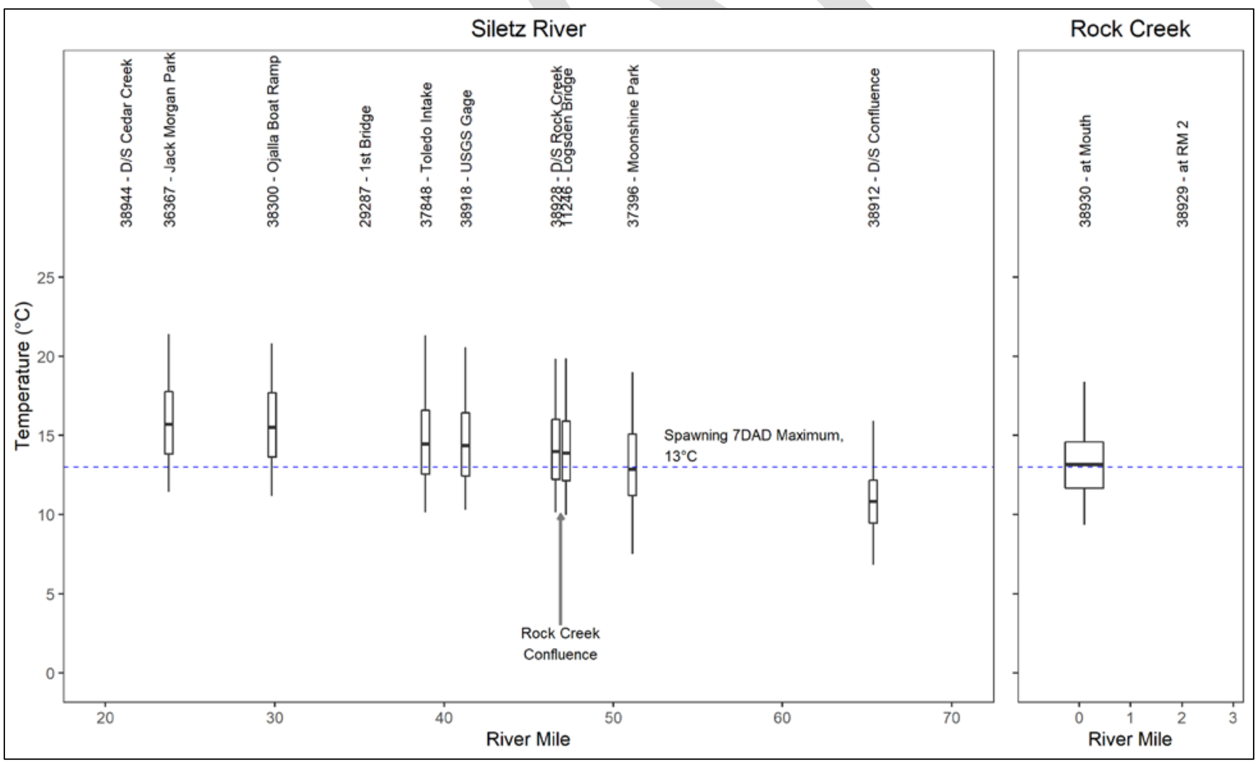

Figure 15. Boxplots of SWCD U26 temperature, spawning

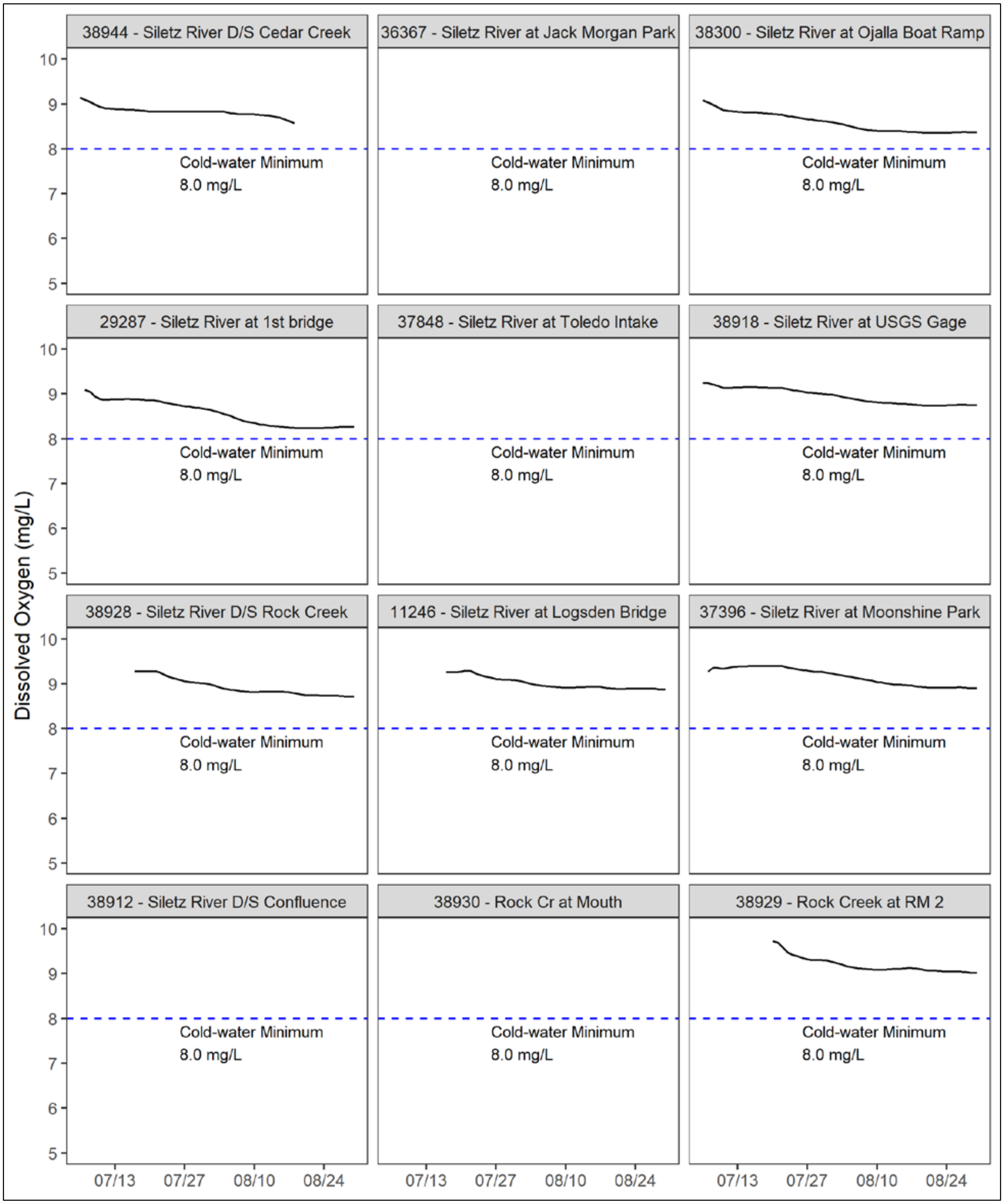

Figure 16. 30-day mean minimum DO concentration, cold-water

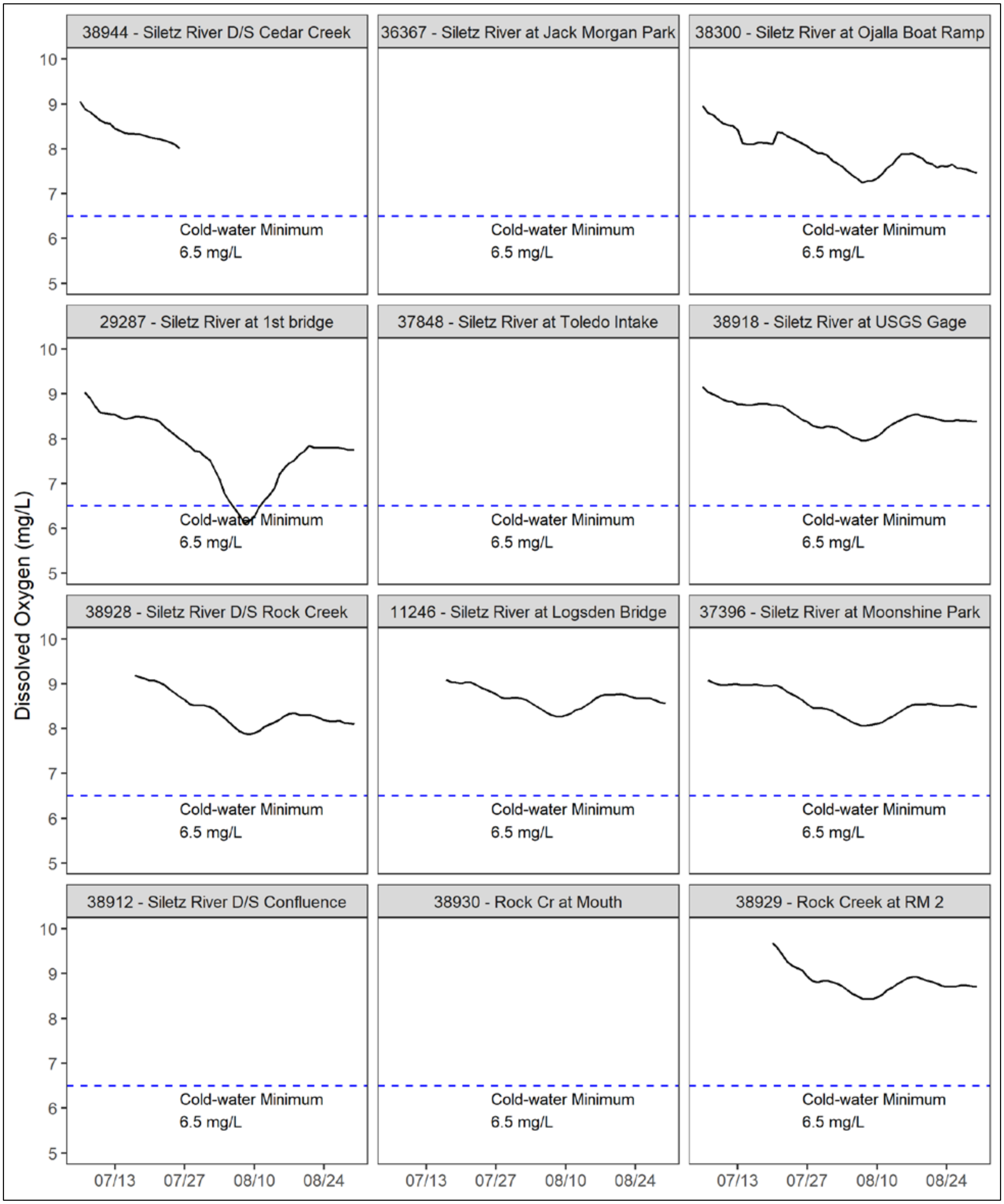

Figure 17. 7-day minimum mean DO concentration, cold-water

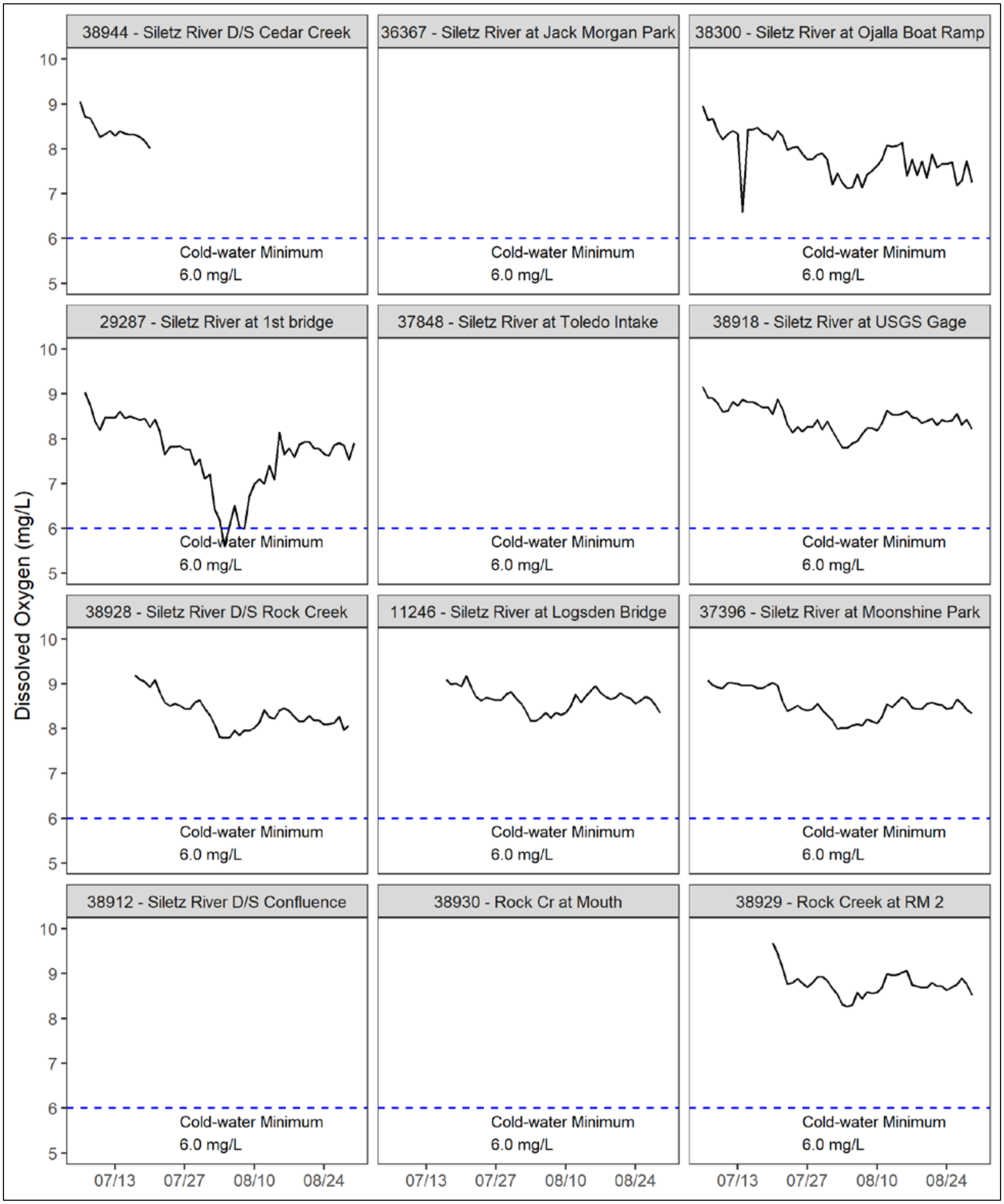

Figure 18. Absolute minimum DO concentration, cold-water

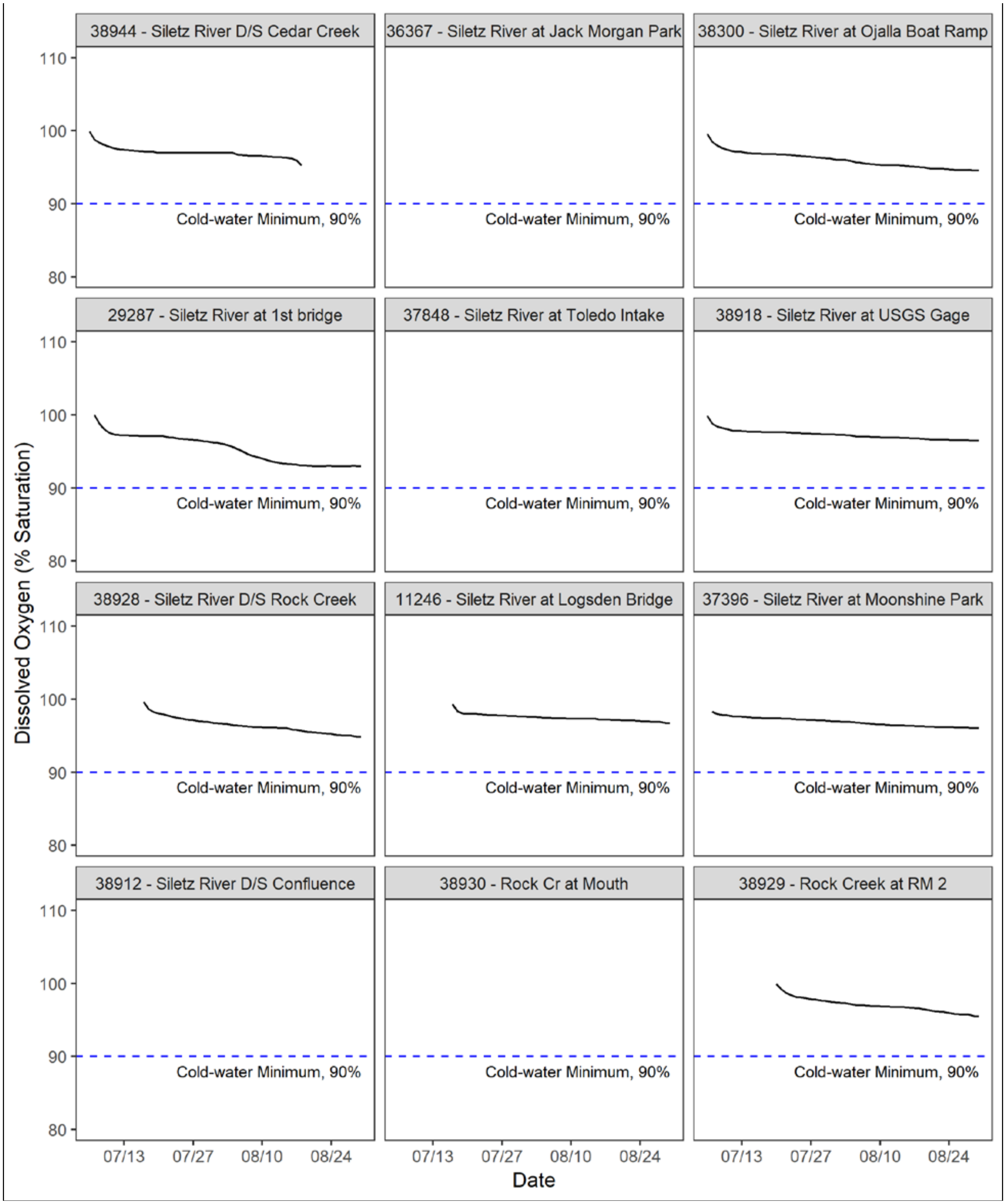

Figure 19. 30-day mean minimum DO saturation, cold-water

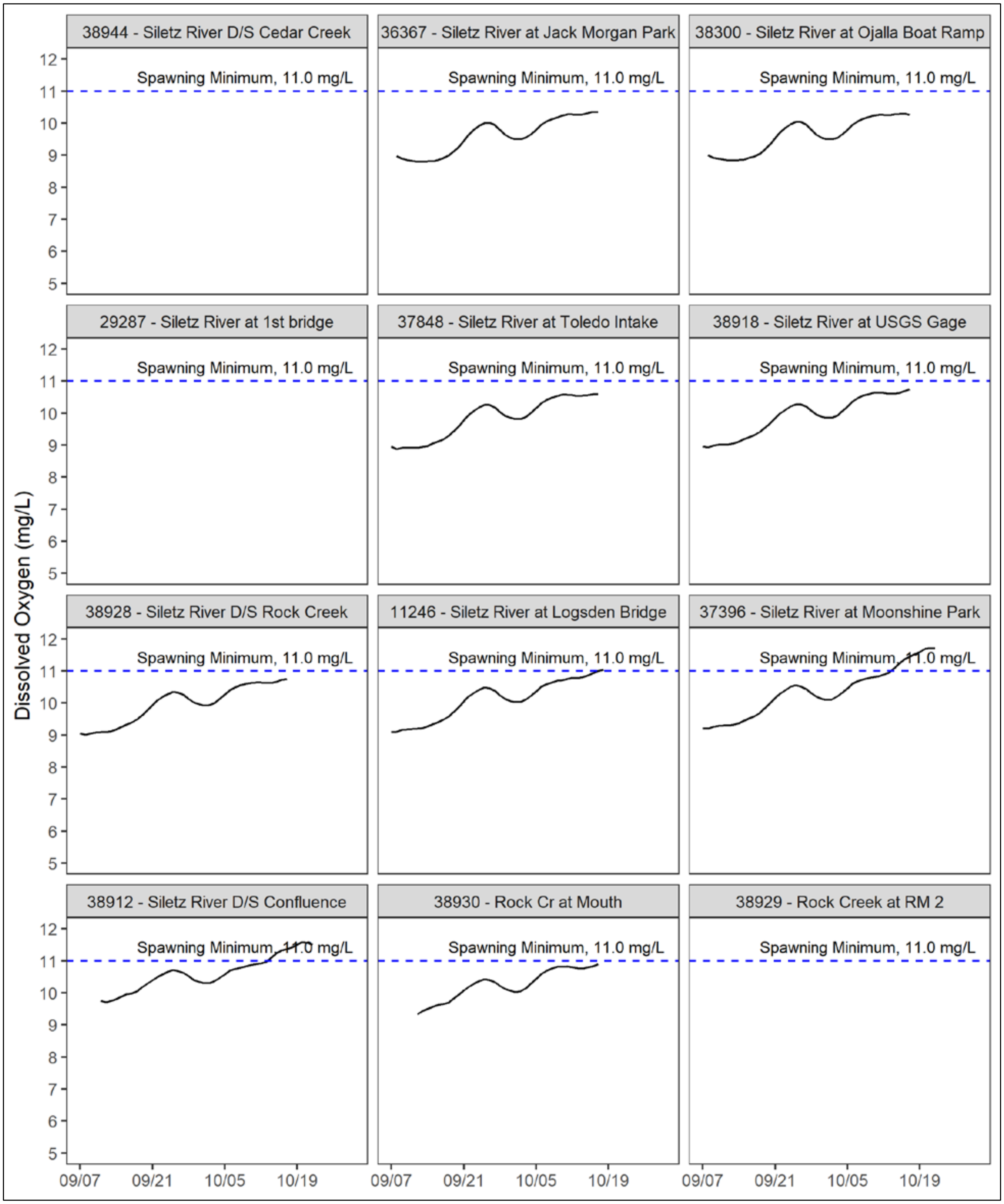

Figure 20. 7-day mean minimum DO concentration, spawning

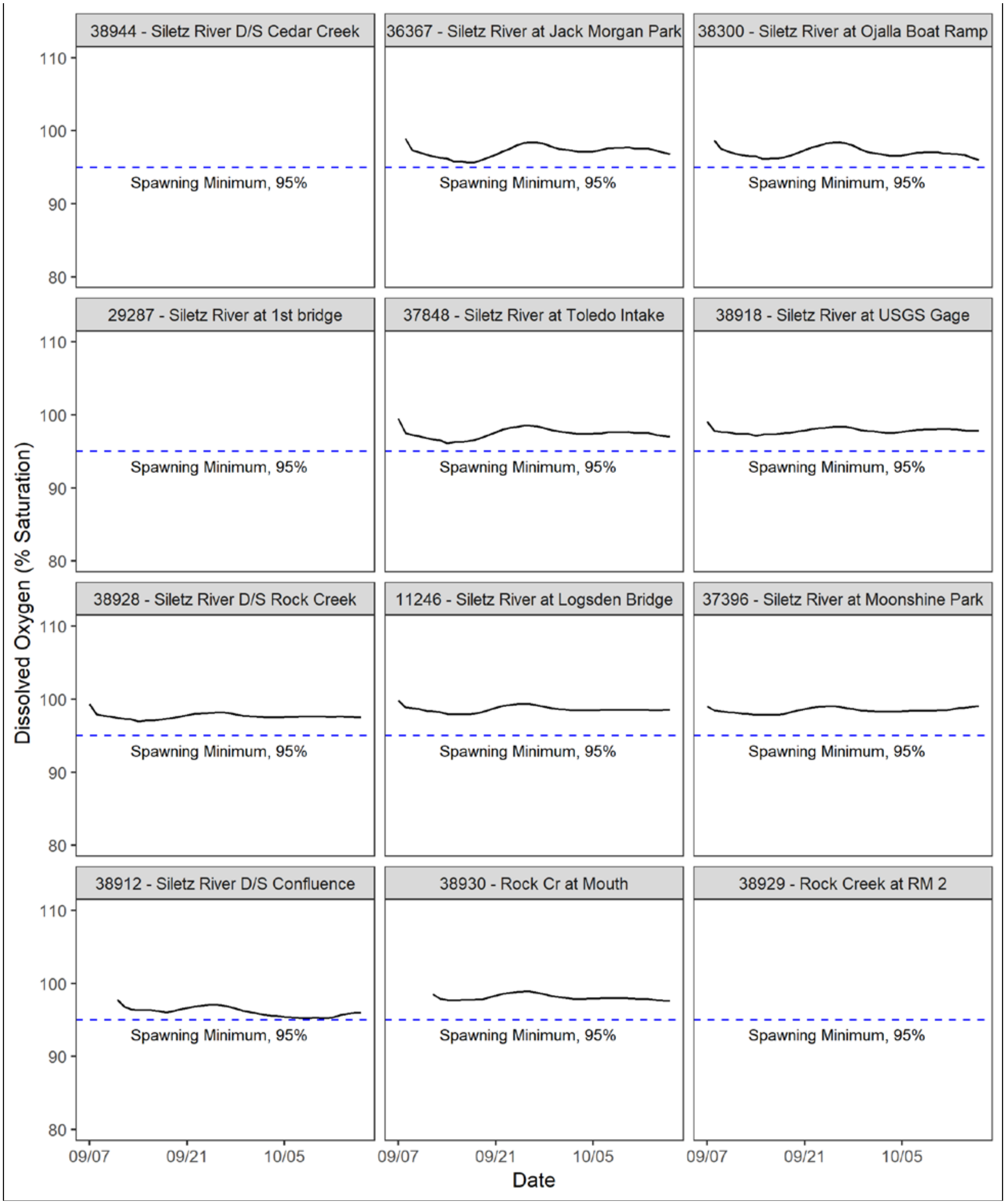

Figure 21. 7-day mean minimum DO saturation, spawning

Figure 22. 7-day average daily maximum temperatures, cold-water and spawning

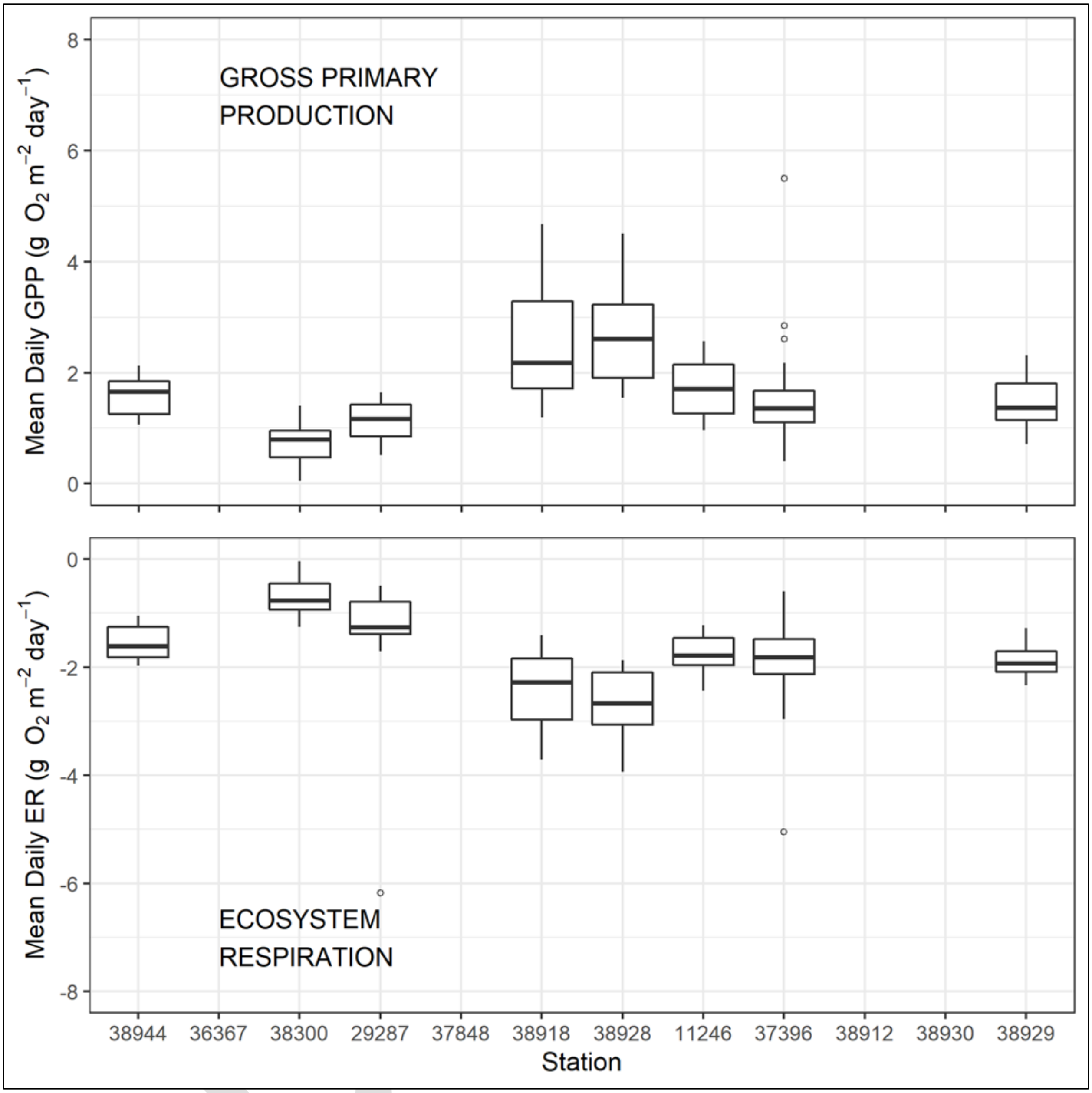

Figure 23. Boxplots of GPP and ER, cold-water

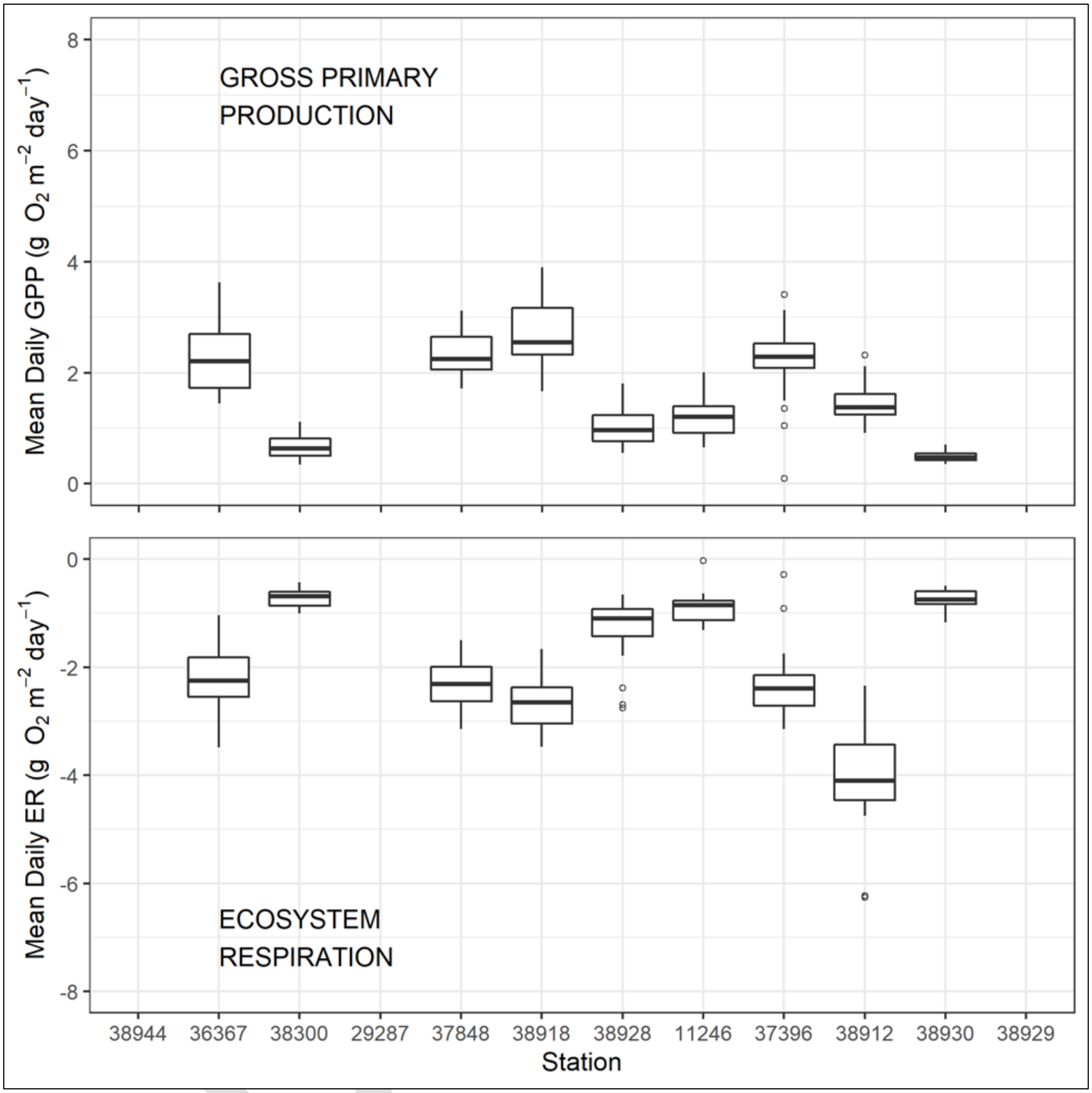

Figure 24. Boxplots of GPP and ER, spawning

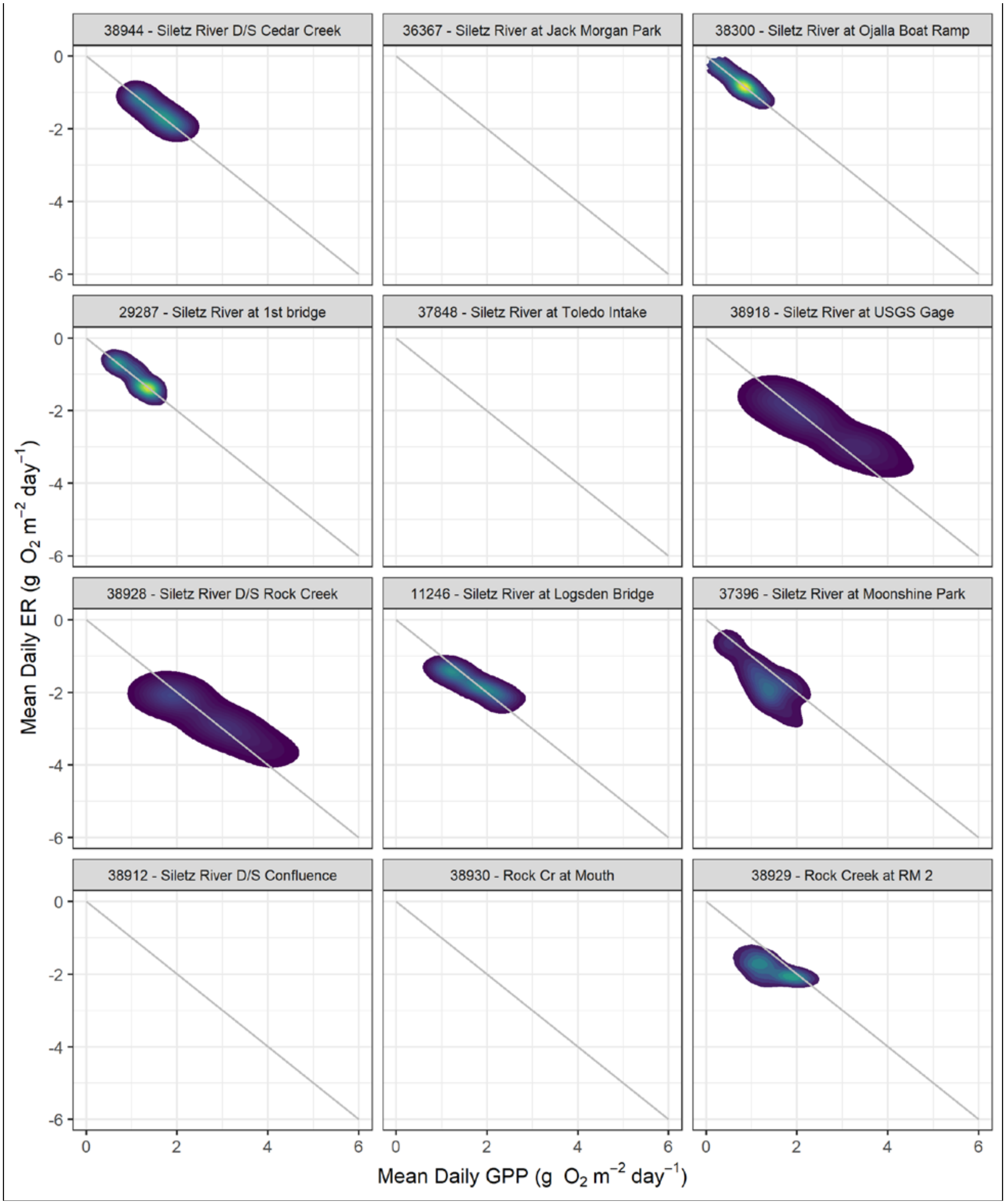

Figure 25. GPP and ER ratio density plots, cold-water

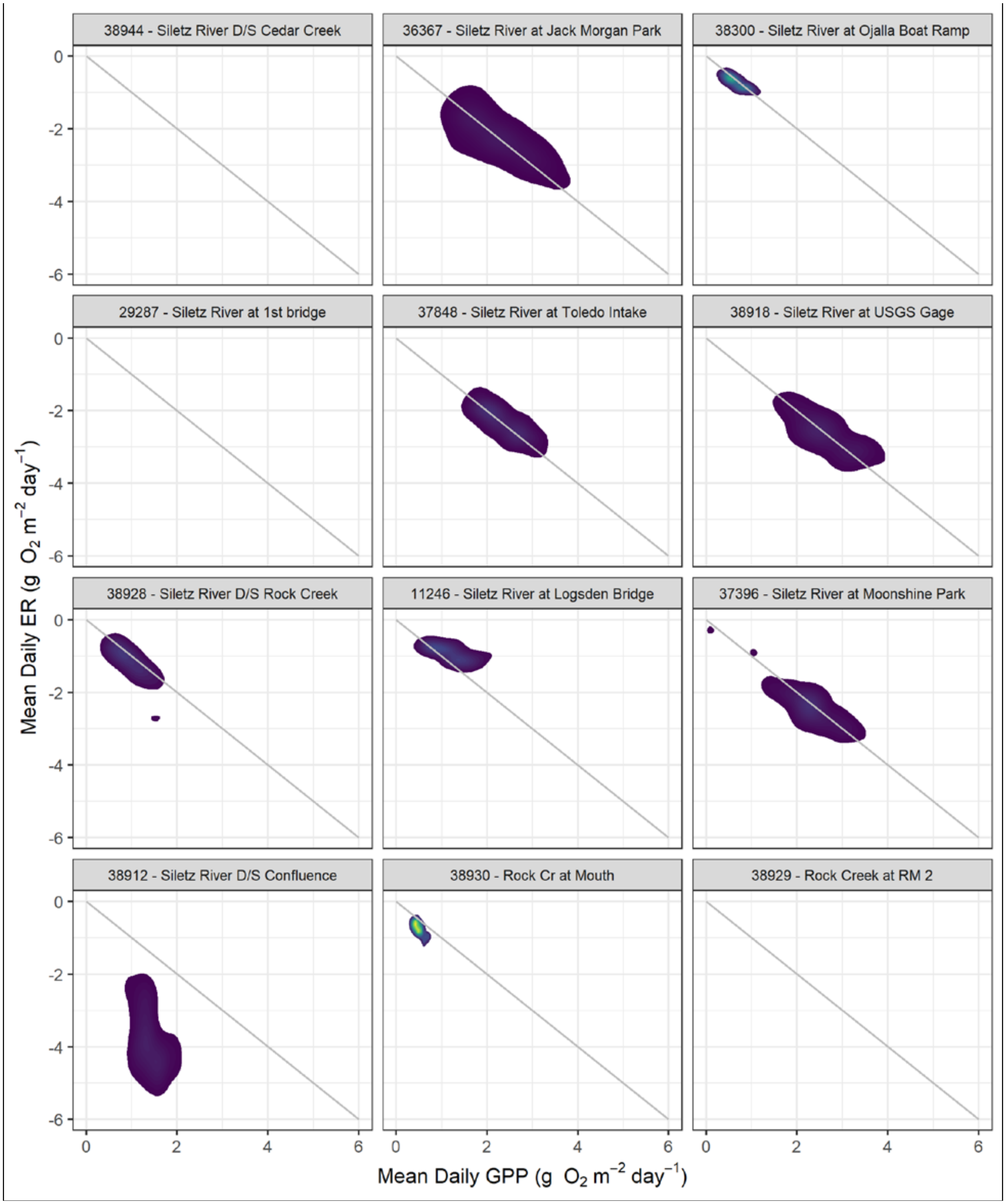

Figure 26. GPP and ER ratio density plots, spawning

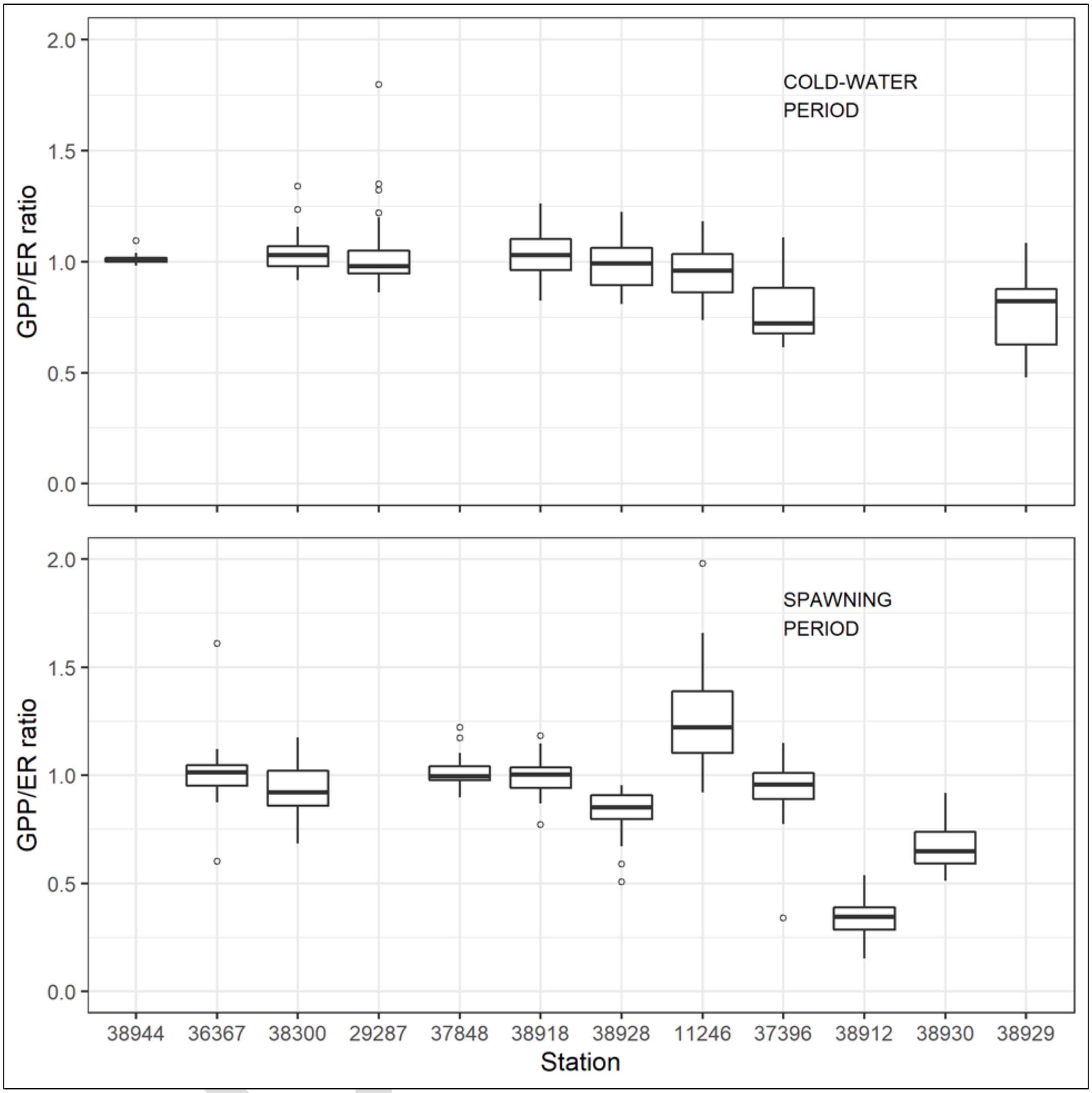

Figure 27. Boxplots of GPP/ER ratios, cold-water (top) and spawning (bottom)

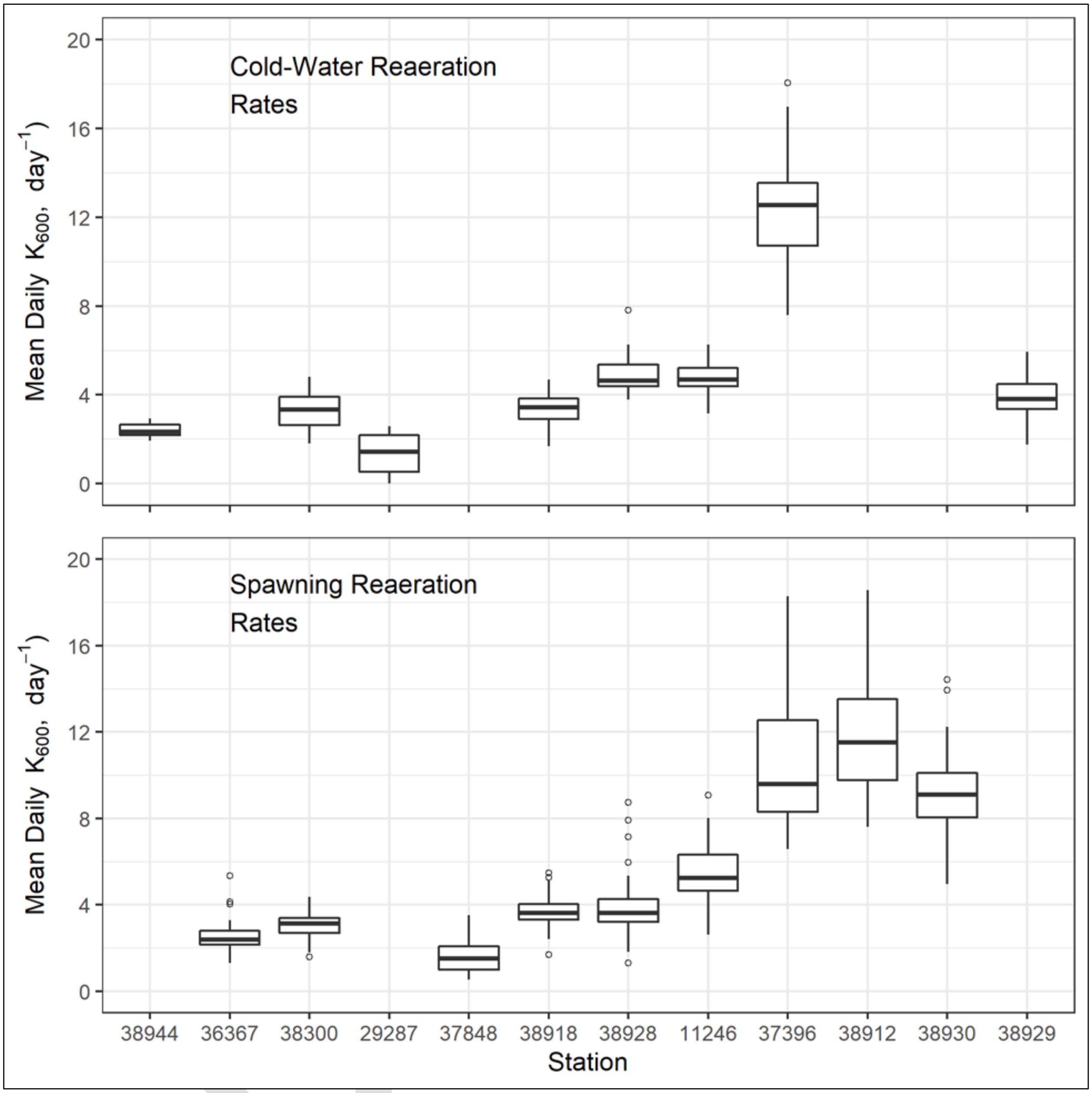

Figure 28. Box plots of reaeration rates, cold-water (top) and spawning (bottom)

10. Tables

Table 1. 2012 Siletz River 303(d) Category 5 Listed Segments

Water Body	River Miles	Segment Miles	Pollutant	Season	Criteria	Beneficial Uses
Siletz River	21.6 to 65.3	43.7	Dissolved Oxygen	September 1 - June 15	Spawning: Not less than 11.0 mg/L or 95% of saturation	Salmonid spawning
Siletz River	7 to 46.8	39.8	Temperature	Summer	Rearing: 17.8 C	Salmonid fish rearing; Anadromous fish passage
Siletz River	39.5 to 65.3	25.9	Turbidity	Undefined	Conditions deleterious to fish or other aquatic life; affect the potability of drinking water; the palatability of fish or shellfish are not allowed.	Drinking water; Water supply
South Fork Siletz River	0 to 11.4	11.4	Biological Criteria	Year Round	Biocriteria: Waters of the state must be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.	Aquatic life
South Fork Siletz River	0 to 11.4	11.4	Temperature	Year Round (Non-spawning)	Core cold water habitat: 16.0 degrees Celsius 7-day-average maximum	Core cold water habitat

Table 2. Siletz River land cover data, 2011

Land Cover	Area (km^2)	Percent Area
Shrub/scrub	217.4	31.8%
Evergreen forest	214.8	31.4%
Mixed forest	109.9	16.1%
Grassland	54.2	7.9%
Developed (incl. roads)	41.3	6.0%
Barren	14.8	2.2%
Deciduous forest	13.1	1.9%
Wetlands	8.8	1.3%
Pasture/Hay	8.4	1.2%
Cultivated land	0.6	0.1%
Open water	0.4	0.1%
Total	684	

Table 3. Siletz River monitoring activities in 2017

Station ID	LSWCD Deploy Dates[a]	DEQ Deploy Dates[a]	Water Body	River Mile	Description	Notes
38941	CW: NA SP: 9/19-1/5		Siletz River	16.3	Strome Park	Outside of the listed segment; included for context, but not included in analysis
38944	CW: 7/6-7/20 SP: NA		Siletz River	21.1	Downstream of Cedar Creek	Characteristic of the downstream boundary for the modeling
36367	CW: NA SP: 9/8-10/11	CW: 7/17-7/20 SP: 9/11-9/14	Siletz River	23.7	Jack Morgan Park	This site characterizes the lower section of the listed segment
38300	CW: 7/6-8/29 SP: 9/8-10/11		Siletz River	29.8	Ojalla Boat Ramp	Two full periods of data were collected at this site
29287	CW: 7/7-8/30 SP: NA		Siletz River	35.3	First Bridge	North of the town of Siletz. U26 logger was lost during September deployment
37848	CW: NA SP: 9/7-10/11		Siletz River	38.9	Old Toledo Intake	Only the spawning season data are valid for use
38918	CW: 7/6-8/29 SP: 9/7-10/11	CW: 7/17-7/20 SP: 9/11-9/14	Siletz River	41.3	USGS Flow Gage	Upstream of the town of Siletz
38928	CW: 7/17-8/29 SP: 9/7-10/11		Siletz River	46.6	Downstream of Rock Creek	LSWCD collected two full periods of data
11246	CW: 7/17-8/29 SP: 9/7-10/12		Siletz River	47.2	Logsden Bridge	LSWCD collected two full periods of data
37396	CW: 7/6-8/29 SP: 9/7-10/16	CW: 7/17-7/20 SP: 9/11-9/14	Siletz River	51.1	Moonshine Park	Located at the boundary of areas of forest management
38912	CW: NA SP: 9/11-10/16		Siletz River	65.3	Downstream of North/South Fork Confluence	At the upstream boundary of the DO listed segment for DO
38930	CW: NA SP: 9/12-10/11		Rock Creek	0.0	At the mouth	Represents a large tributary inflow to the Siletz River, spawning data only
38929	CW: 7/20-8/29 SP: NA		Rock Creek	2.0	At RM 2	Represents a large tributary inflow to the Siletz River, cold-water data only

[a] All deployments occurred in 2017