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Natural Resource Stewardship and Science

Southeast Alaska Network Freshwater Water Quality Monitoring Program

2015 Annual Report

Natural Resource Report NPS/SEAN/NRR—2016/1131

ON THE COVER
Jennifer Hamblen poses next to the Salmon River water quality sonde
Photograph courtesy of Craig Murdoch/National Park Service

Southeast Alaska Network Freshwater Water Quality Monitoring Program

2015 Annual Report

Natural Resource Report NPS/SEAN/NRR—2016/1131

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Executive Summary

Freshwater water quality is an indicator of aquatic and terrestrial ecosystem health and one of twelve priority Vital Signs in the National Park Service's Southeast Alaska Network (SEAN), which includes Glacier Bay National Park and Preserve, Klondike Gold Rush National Historical Park, and Sitka National Historical Park. Data collected under this program inform several management-relevant topics:

- Assessing whether state and federal water quality standards are met
- Measuring the *natural* quality of wilderness lands in Glacier Bay
- Describing effects of a changing climate on the physical and chemical properties of park waters (For example, how do changes in glacial watershed coverage, wetland water filling patterns, or forest cover affect long-term water quality patterns?)

This sixth annual report is intended to be a concise data summary and regular product for park staff, managers, superintendents, and other interested parties. All annual reports and data products are publicly available at the SEAN website:

http://science.nature.nps.gov/im/units/sean/FQ_Main.aspx

In 2015, hourly water temperature, specific conductance, dissolved oxygen, and pH data were collected in the Salmon River (Glacier Bay) from April 23 through December 2, and in the Indian River (Sitka) from April 27 through November 19. The same parameters plus turbidity were collected in the Taiya River (Klondike Gold Rush) from April 6 through November 19. No observations signaled obvious point source pollution or a change to the fundamental water quality of the three rivers.

Water temperatures collected in 2015 from April through July were generally warmer than previous monitoring years 2010 through 2014, but not of concern. Daily mean temperature for the Salmon River ranged from 2.6 to 12.2°C, while the Indian River ranged from 5.1 to 11.2°C. Both rivers peaked in temperature on August 18. Daily mean temperature for the glacially influenced Taiya River ranged from 0.7 to 7.3°C and peaked on June 14 and August 18. Taiya River hourly turbidity measurements ranged from 0 to greater than 1,000 NTU and were synchronized with high flow events.

Patterns in the medians and distributions of specific conductance, dissolved oxygen, and pH were generally similar to previously observed ranges for all three rivers. The critically low dissolved oxygen conditions of the Indian River observed during summer 2013 were not observed in 2015. On September 10, the Taiya River sonde recorded a pH spike of 8.8 (increase of 1.4 units) that persisted for several hours before dropping to more typical levels. Supporting data and environmental conditions during this period were reviewed closely, and it is believed that the data are accurate, but the specific cause of the spike is unknown at this time.

Acknowledgments

This work could not be accomplished without the annual support of SEAN Program Manager Mike Bower and many park staff. G. Arnold, C. Behnke, B. Carter, J. Hamblen C. Murdoch, J. Sparks, and C. Thole efficiently conducted field work and transmitted data for processing. D. D'Amore, J. Fellman, E. Hood, and S. Nagorski provided valuable discussion regarding potential mechanisms causing the pH spike in the Taiya River during September 2015. The SEAN Vital Signs program is supported by funding from the NPS National Inventory and Monitoring Program and the NPS Water Resources Division.

List of Acronyms and Abbreviations

°C	Degrees Celsius
cfs	Cubic feet per second
DO	Dissolved oxygen
GLBA	Glacier Bay National Park and Preserve
KLGO	Klondike Gold Rush National Historical Park
m^3/s	Cubic meters per second
mg/L	Milligrams per liter
mS/cm	Millisiemens per centimeter
NPS	National Park Service
NTU	Nephelometric Turbidity Units
SEAN	Southeast Alaska Inventory & Monitoring Network
SITK	Sitka National Historical Park
SOP	Standard Operating Procedure
USGS	United States Geological Survey

Introduction

Water quality is an indicator of aquatic and terrestrial ecosystem health in Southeast Alaska, a rainforest landscape dominated by a wet and mild maritime climate. The Southeast Alaska Network (SEAN; Figure 1) of the National Park Service (NPS) has prioritized Freshwater Water Quality as one of 12 Vital Signs for long-term ecological monitoring based on its vulnerability to alteration by human stressors and sensitivity for detecting fundamental environmental changes (Moynahan et al. 2008). Trends in water quality can signify chronic or developing watershed issues within national parks.

The SEAN water quality monitoring program has the following objectives:

- Track the status and trends of each core water quality parameter (specific conductance, dissolved oxygen, pH, and water temperature; plus turbidity in the Taiya River) for at least one river in each SEAN park unit
- Describe the timing and magnitude of seasonal and annual variation for each core water quality parameter
- Evaluate whether state and/or federal water quality standards are met or exceeded

The SEAN water quality monitoring protocol (Sergeant et al. 2013) includes an extended description of each water quality parameter in Section 1.6. Briefly, specific conductance measures the ability of water to conduct an electrical current at a standardized temperature of 25°C. In Southeast Alaska, higher values generally represent groundwater influence and lower values represent rain and snow runoff. Dissolved oxygen (DO) is a measure of the amount of microscopic oxygen bubbles in water and is essential for aquatic organism respiration. DO is mainly regulated by temperature, but fluctuations in DO can be caused by other factors such as organic matter accumulation, biological decomposition, and water aeration. The pH of water is a unit-less measure of hydrogen ion concentration reflecting relative acidity or alkalinity; it affects aquatic organism respiration, salt exchange, and many biogeochemical processes. Turbidity is a measure of water clarity; increases in Taiya River turbidity typically signal glacial runoff.

This report summarizes results from the 2015 sampling season and compares it with data collected since 2010. During 2016, SEAN staff will draft a synthesis report presenting more in-depth trend analyses and broadened discussion of programmatic successes and necessary modifications. Guidance for annual report formatting and analysis is described in Standard Operating Procedure (SOP) 10 of the water quality monitoring protocol (Sergeant et al. 2013).

Study areas

The sampling goal of this monitoring program is to track water quality status and trends in at least one river in each of the three SEAN parks. In 2010, sonde locations were finalized for the Salmon (GLBA) and Indian (SITK) Rivers. The Taiya River (KLGO) was added in 2011. Sampling sites were chosen based on individual park interests and dependable long-term site access. Until the SEAN freshwater water quality monitoring program began, no long-term continuous data were available for these three rivers (Eckert et al. 2006a; Eckert et al. 2006b; Hood et al. 2006).

Salmon River (GLBA)

GLBA, the largest park unit in the SEAN, has more than 310 streams (Soiseth and Milner 1995) flowing for over 3,380 km through a diverse landscape. Upstream of the water quality monitoring station, the Salmon River is 32.7 km long within a 9,600 ha watershed that collects most of its water from Excursion Ridge to the east (Figure 1A; Table 1). The water quality monitoring site is located on the river left bank at approximately river km 9.0 (Figure 1A; Table 1) several meters upstream of the NPS boundary. The lowermost portion of the river (river km 0.0 to 9.0) is outside of NPS boundaries and within the town of Gustavus. The Salmon River has gravel riverbed habitat and supports populations of gamefish species such as pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*O. keta*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), cutthroat trout (*O. clarkii*), and Dolly Varden (*Salvelinus malma*; Eckert et al. 2006a). Staghorn (*Leptocottus armatus*) and coastrange sculpin (*Cottus aleuticus*) have been observed in the river (C. Soiseth, personal communication). Recently, USGS began monitoring stage, discharge, and water temperature data for the Salmon River approximately 1 km downstream from the park boundary. Data are available from May 15, 2014 onward, and can be downloaded at:
http://nwis.waterdata.usgs.gov/ak/nwis/uv/?site_no=15057596&agency_cd=USGS

Taiya River (KLGO)

The Taiya River is located west of Skagway and one of two major drainages flowing through KLGO. Upstream of the water quality monitoring station, the Taiya River is approximately 25.7 km long and drains approximately 45,500 ha (Figure 1B; Table 1). The water quality monitoring site is located on the river left bank slightly downstream of the Taiya River Bridge (Figure 1B; Table 1) and adjacent to the United States Geological Survey (USGS) streamflow gaging site. From 1970 to 2015, the annual mean discharge from the Taiya River has ranged from a minimum of 24.9 m^3/s (880 cfs) in 1973 to 43.6 m^3/s (1,540 cfs) in 2013. Peak flows typically occur in August and September (USGS website for Taiya River gage 15056210:
http://waterdata.usgs.gov/nwis/nwisman/?site_no=15056210&agency_cd=USGS)

Skagway is notably drier than other Southeast Alaska communities, averaging 69 cm of precipitation per year, in comparison to 142 cm in Gustavus and 217 cm in Sitka (Western Regional Climate Center Data: http://www.wrcc.dri.edu/summary/Climsmak.html). The glacial influence on the Taiya watershed is unique among streams currently monitored in the SEAN. As of 2001, approximately 36% of the watershed was covered by glaciers (Sergeant and Nagorski 2014). Glacial outburst events have led to large floods and created a highly dynamic physical environment (Hood et al. 2006). The Taiya watershed supports chum, pink, and coho salmon populations, as well as Dolly Varden.

Eulachon (*Thaleichthys pacificus*) have been reported to run up the Taiya River in the spring (Hood et al. 2006).

Indian River (SITK)

The lowest 1 km of the Indian River is the only significant freshwater habitat within SITK and can be characterized as a low gradient alluvial channel with gravel-cobble substrate that supports anadromous fish species, including coho, pink, chum, and Chinook salmon (*O. tshawytscha*), steelhead, Dolly Varden, and non-anadromous species such as resident rainbow trout (*O. mykiss*), three-spine stickleback (*Gasterosteus aculeatus*), and coastrange sculpin (Eckert et al. 2006b). Upstream of the water quality monitoring site, the Indian River is approximately 19.8 km long within a steep and well-drained 3,100 ha watershed (Figure 1C; Table 1). The monitoring site is located on the river right bank approximately 60 m upstream of park boundaries at river km 0.8 (Figure 1C; Table 1).

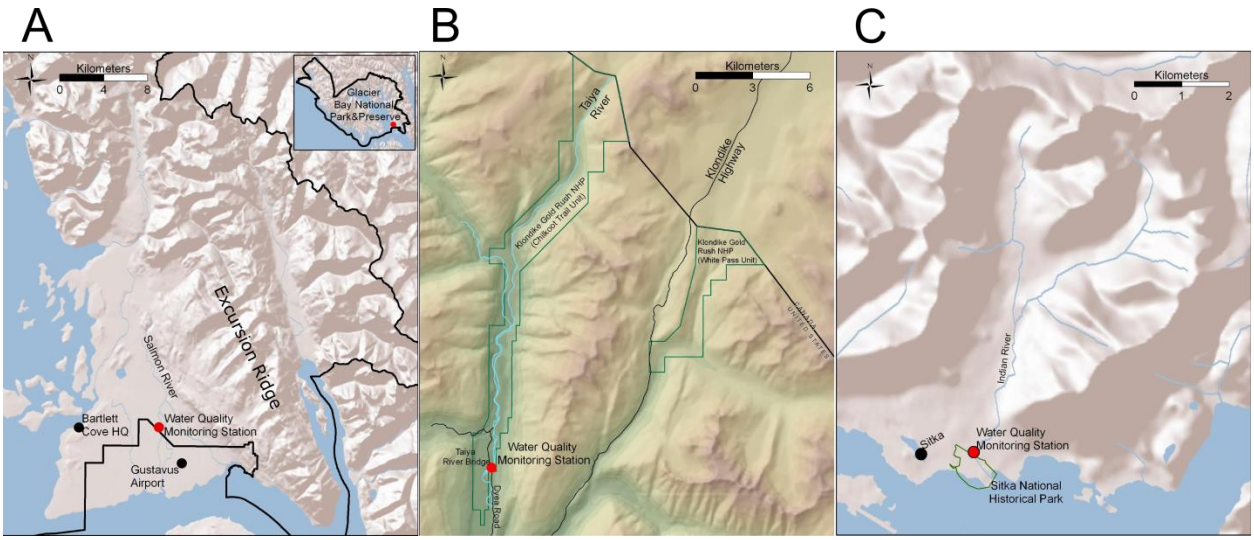

Figure 1. The three SEAN water quality monitoring station locations (solid red circles). (A) Salmon River in GLBA; black line denotes park boundary (B) Taiya River in KLGO; green lines denote park boundaries (note that the park units are not contiguous) (C) Indian River in SITK slightly upstream of park boundary; green line denotes park boundaries.

Table 1. The three SEAN water quality monitoring stations watershed characteristics. Watershed characteristics were measured for the areas upstream of each monitoring station (data adapted from Sergeant and Nagorski 2014).

River	Watershed (km^2)	Length (km)	Max. elevation (m)	Glacier (%)	Wetland (%)	Forest (%)	Sampling site (river km)
Salmon	96	32.7	1079	0	37	44	9
Taiya	455	25.7	1829	36	2	20	3.5
Indian	31	19.8	1158	1	18	55	0.8

Methods

Station instrumentation

The Salmon, Taiya, and Indian Rivers were sampled hourly for specific conductance (mS/cm), dissolved oxygen (mg/L), pH, and water temperature (°C). Additionally, turbidity (NTU) was measured in the Taiya River. For all sondes, DO saturation was derived from DO concentration and temperature and included with the final data set downloadable from the SEAN website (http://science.nature.nps.gov/im/units/sean/FQ_Main.aspx). Multi-parameter water quality sondes (Table 2) collected and logged data at single fixed sites in the Salmon River from April 23 through December 2, the Taiya River from April 6 through November 19, and the Indian River from April 27 through November 19 (Figure 1; Table 3). Each year, sampling is planned to occur from at least May 1 through October 31, and extends into November if ice conditions and staff resources allow.

Table 2. YSI, Inc. instruments used for 2015 water quality sampling.

Equipment description	Model number
Multi-parameter water quality logger	6920V2-2
Multi-parameter display system	650
Conductivity/temperature probe	6560
pH probe	6561
Optical oxygen sensor	6150
Optical turbidity sensor	6136

In all three rivers, a sonde was mounted inside a perforated 4-inch ABS pipe. In the Salmon River the pipe was attached to an angle-iron rod set in the streambed, while in the Taiya and Indian Rivers the pipe was bolted to a large boulder in the stream channel. A bolt mounted through the ABS pipe set the sonde height in the water column. After sondes were installed, Park Leads visited the sondes approximately once per month to check calibration for each sensor and clean components, as needed. These calibration checks were used to assess data quality and ensure that the water quality instruments were functioning properly.

Table 3. Summary of 2015 freshwater water quality sampling effort.

	Month									
River	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Core parameters collected?
Salmon										Y[1]
Taiya										Y[2]
Indian										Y

Full month

Partial month

[1] from June 21 to July 3, some missing core parameter measurements due to low water

[2] DO sensor failed on April 27 and replaced May 27

Data processing

This report follows guidance provided in the SEAN monitoring protocol FQ-2013.1 (Sergeant et al. 2013). The protocol narrative and SOPs 1 through 3 describe the data collection, monthly error/calibration checks, and data processing in detail (Sergeant et al. 2013). Park and SEAN staff generally conducted error/calibration checks monthly at each water quality station from May through early December (Table 4). The early October maintenance check for the Indian River sonde was not completed due to lack of available staff.

The SEAN has established data "ratings" and "grades" to describe overall data quality. Data ratings denote unusable measurements for reasons such as the sonde being out of water during an error/calibration check or an erroneous value due to instrument malfunction. Before analysis, data with a '2' or '3' rating were removed from the dataset. Data with '0' (no question regarding accuracy) or '1' (determined useable by the professional judgement of the Project Leader despite potential mistakes in precisely following protocols) ratings were used for analysis. SOP 13 of the water quality protocol (Sergeant et al. 2013) describes each data rating in detail. Comments contained in the water quality database are available on the SEAN website (http://science.nature.nps.gov/im/units/sean/FQ_Main.aspx) and contain explanations for each assigned rating other than zero.

Data grades refer to the point-in-time accuracy of each water quality sensor as ascertained from regular error/calibration checks and range from 'Poor' to 'Excellent'. The grades determined by these point checks were back-dated to the previous error/calibration check and applied to all data during that time period. Due to potential subjectivity, the SEAN does not correct (adjust) data values based on error/calibration checks (as described in Wagner et al. 2006), but sensor values from calibration checks are available by downloading field sheets from the SEAN website (http://science.nature.nps.gov/im/units/sean/FQ_Main.aspx),allowing data users to perform any particular corrections they deem appropriate.

The final datasets were analyzed and summarized according to the guidelines in SOP 10 (Sergeant et al. 2013).

Results

Data collection

Water quality measurements were generally high quality during 2015, but several minor issues were encountered with continuous data collection on the Taiya and Salmon Rivers. From May 31 through July 3, periods of low water on the Salmon River resulted in periodic sensor drying and erroneous measurements. On July 3, park staff moved the sonde approximately 3 m downstream to a slightly deeper pool with more water availability. On April 27, the Taiya River DO sensor failed and was replaced on May 27. Erroneous values resulting from these problems have been removed from the analyses below.

Turbidity quality grades for the Taiya River were rated 'Poor' for the entire monitoring season (Table 4). It should be noted that this is mostly an artifact of the two-point error checking method for the sensor, which uses 0 and 126 NTU standards for comparison (see SOP 2 in Sergeant et al. 2013). The Poor quality grade is mostly attributable to the 0 NTU portion of the error checking. Each month, the sensor generally was in very good coherence with the 126 NTU standard. The observed values were generally within reasonable sensor accuracy expectations, but turbidity values are best used for relative seasonal trends in water clarity and less appropriate as absolute individual measurements.

Table 4. Summary of 2015 freshwater water quality data grades. E = Excellent, G = Good, F = Fair, P = Poor. Definitions for each grade are found in SOP 2 (Sergeant et al. 2013) and are based on USGS recommendations (Wagner et al. 2006). Shaded areas represent periods when data grades are not available due to sensor malfunction. SC = specific conductance; DO = dissolved oxygen.

		Date ranges							
River	**Parameter**	**4/23-5/29**	**5/29-6/30**	**6/30-7/30**	**7/30-8/28**	**8/28-9/30**	**9/30-11/1**	**11/1-12/2**	
Salmon	SC (mS/cm)	E	G	F	F	P	G	G	
	DO (mg/L)	E	E	G	E	E	E	E	
	pH	E	E	E	E	E	E	E	
	Temperature (°C)	E	G	E	E	E	G	G	
		4/6-5/5	**5/5-5/27**	**5/27-7/1**	**7/1-8/5**	**8/5-9/16**	**9/16-10/2**	**10/2-11/6**	**11/6-11/19**
Taiya	SC (µS/cm)	E	E	E	E	E	E	G	G
	DO (mg/L)	G	G	E	E	E	E	E	F
	pH	E	E	E	E	E	E	E	E
	Temperature (°C)	G	E	G	G	G	G	G	E
	Turbidity (NTU)	P	P	P	P	P	P	P	P
		4/27-6/12	**6/12-7/9**	**7/9-8/11**	**8/11-9/9**	**9/9-11/19**			
Indian	SC (µS/cm)	G	E	G	E	G			
	DO (mg/L)	G	E	E	E	E			
	pH	E	E	E	E	E			
	Temperature (°C)	G	E	E	E	G			

Comprehensive time series data

Hourly time series data for all water quality parameters in all three rivers are graphed in Appendix A. Daily average streamflow time series data from all three rivers compared to daily average water quality data are in Appendix B. Indian River streamflow is reported as relative stage height because a current discharge-stage relationship (rating curve) has not been finalized by the SEAN and local

program partners. The gage control pool is prone to frequent scour, which continually shifts the rating curve. In the Taiya and Indian rivers, streamflow data were collected in the same location as water quality data. The Salmon River streamflow gage is approximately 1 river km downstream of the water quality monitoring site. Recently, USGS began publishing stage, discharge, and water temperature data for the Salmon River. Data are available back to May 15, 2014, and can be downloaded at: http://nwis.waterdata.usgs.gov/ak/nwis/uv/?site_no=15057596&agency_cd=USGS

Salmon River

Temperature

In comparison to average daily mean values from 2010-2014, 2015 water temperatures were much warmer from May through August (Figure 2), but this result should be interpreted with caution because of the short time series available. During the period of monitoring, the daily mean water temperature in the Salmon River ranged from 2.6 to 12.2°C (Table 5) and peaked on August 18 (2010-2014 average peak temperature date = August 11, standard deviation = 13 days). Median daily mean water temperature during the monitoring period was 8.0°C. Monthly mean daily average temperatures ranged from 4.4 to 10.7°C (Table 5). Variation in daily mean temperatures was similar across all months but most variable in May (Table 5).

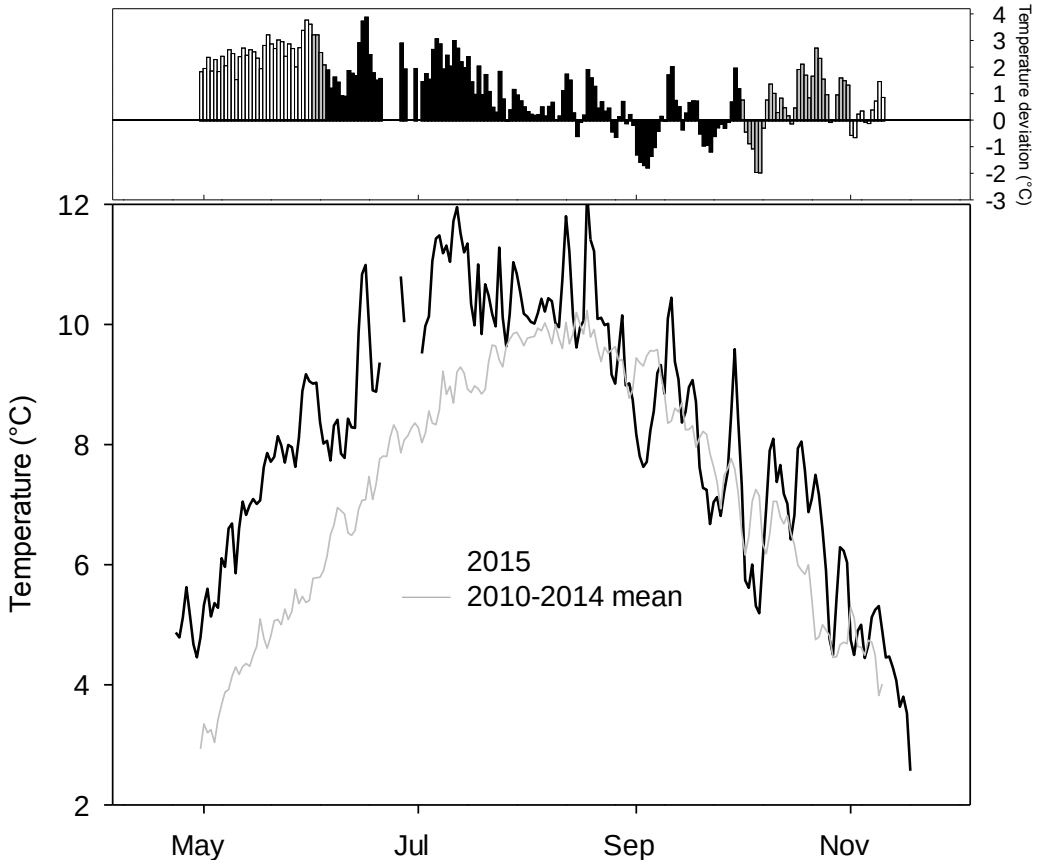

Figure 2. Daily mean water temperature for the Salmon River in 2015 and 2010-2014 mean (lower panel) and temperature deviations from 2010-2014 mean (upper thin panel). In the upper panel, deviations were compared against average daily temperatures calculated using 3 years of historical data (white bars), 4 years (gray bars), or 5 years (black bars). Due to the short time series, interpret deviations cautiously.

Table 5. Monthly mean and standard deviation, minimum daily mean, and maximum daily mean water temperature for the Salmon, Taiya, and Indian Rivers in 2015. Only months with at least 75% of total monthly hours measured were included. See the Methods section for sonde installation dates for each river.

	Salmon			Taiya			Indian		
Month	**Mean daily average (SD)**	**Min**	**Max**	**Mean daily average (SD)**	**Min**	**Max**	**Mean daily average (SD)**	**Min**	**Max**
April				4.2 (0.7)	2.7	5.4			
May	7.1 (1.1)	5.1	9.2	5.5 (0.2)	5.1	6.0	7.2 (1.2)	5.1	9.1
June	9.0 (1.0)	7.7	11.0	6.0 (0.6)	5.0	7.3	8.8 (0.5)	7.8	9.8
July	10.7 (0.7)	9.5	12.0	6.2 (0.4)	5.6	7.0	9.4 (0.5)	8.4	10.4
August	10.2 (0.8)	8.7	12.2	6.0 (0.4)	5.4	7.3	9.3 (0.6)	8.6	11.2
September	8.3 (1.0)	6.7	10.4	5.7 (0.4)	4.7	6.7	8.4 (0.6)	7.6	10.1
October	6.6 (1.0)	4.5	8.1	4.4 (0.6)	3.2	5.1	7.8 (0.5)	6.8	8.8
November	4.4 (0.7)	2.6	5.3	2.0 (1.0)	0.1	3.5	6.1 (0.6)	5.1	6.9

Specific conductance, DO, and pH

Individual specific conductance measurements ranged from 0.04 to 0.40 mS/cm with a median of 0.21 mS/cm (Figure 3). DO ranged from 7.8 to 14.0 mg/L with a median of 10.4 mg/L (Figure 3). DO reached the minimum observed value on August 11. Values for pH ranged from 7.3 to 8.2 with a median of 7.9 (Figure 3).

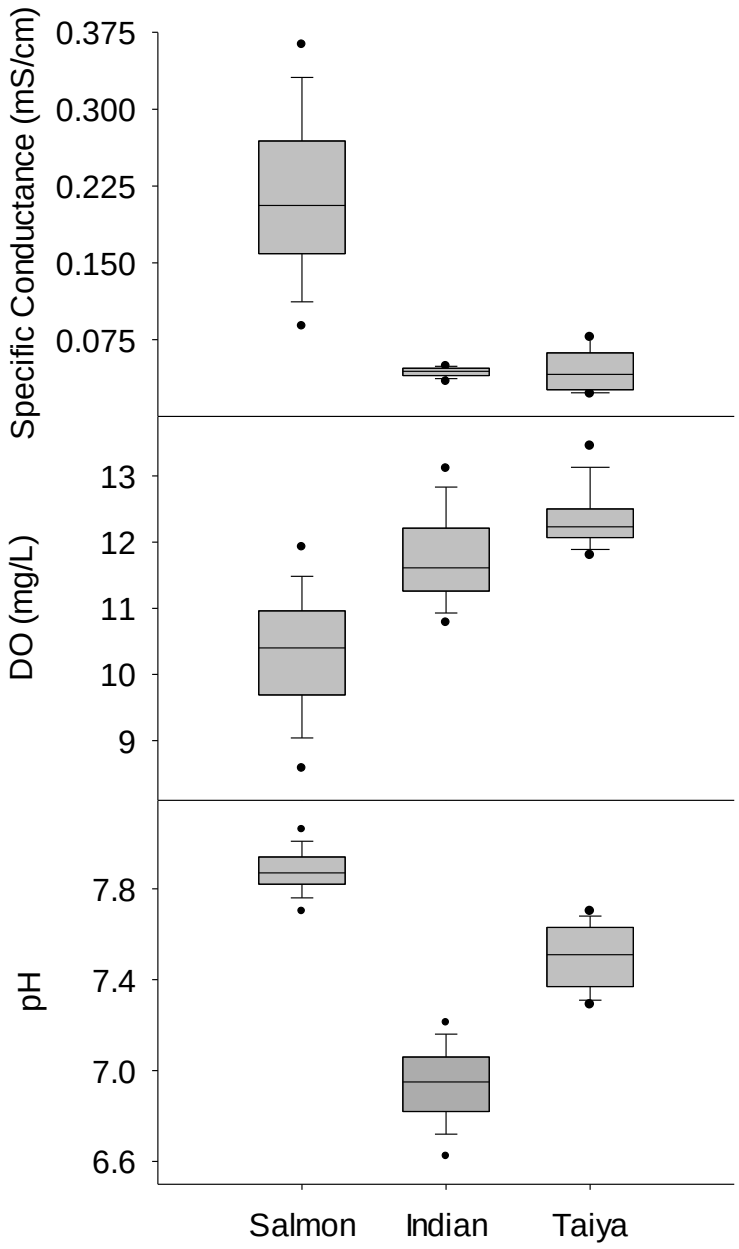

Figure 3. Box plots summarizing all valid measurements for pH, dissolved oxygen (DO), and specific conductance for the Salmon, Taiya, and Indian Rivers in 2015. The horizontal line within each box indicates median values, horizontal lines bounding the upper and lower portion of the boxes represent 25th and 75th percentiles, lower and upper whiskers represent 10th and 90th percentiles, and single points represent 5th and 95th percentiles.

Taiya River

Temperature

In comparison to average daily mean values from 2011-2014, 2015 water temperature was slightly warmer than average from April through late July and during late October (Figure 4). This result should be interpreted with caution because of the short time series available. During the period of

monitoring, the daily mean water temperature in the Taiya River ranged from 0.1 to 7.3°C (Table 5) and peaked on June 14 and August 18. Historical comparisons of peak temperature days are subjective because the Taiya River's glacially influenced thermal regime often peaks on multiple days within a given monitoring season. Median daily mean water temperature during the monitoring period was 5.6°C. Monthly mean daily average temperatures ranged from 2.0 to 6.2°C (Table 5).

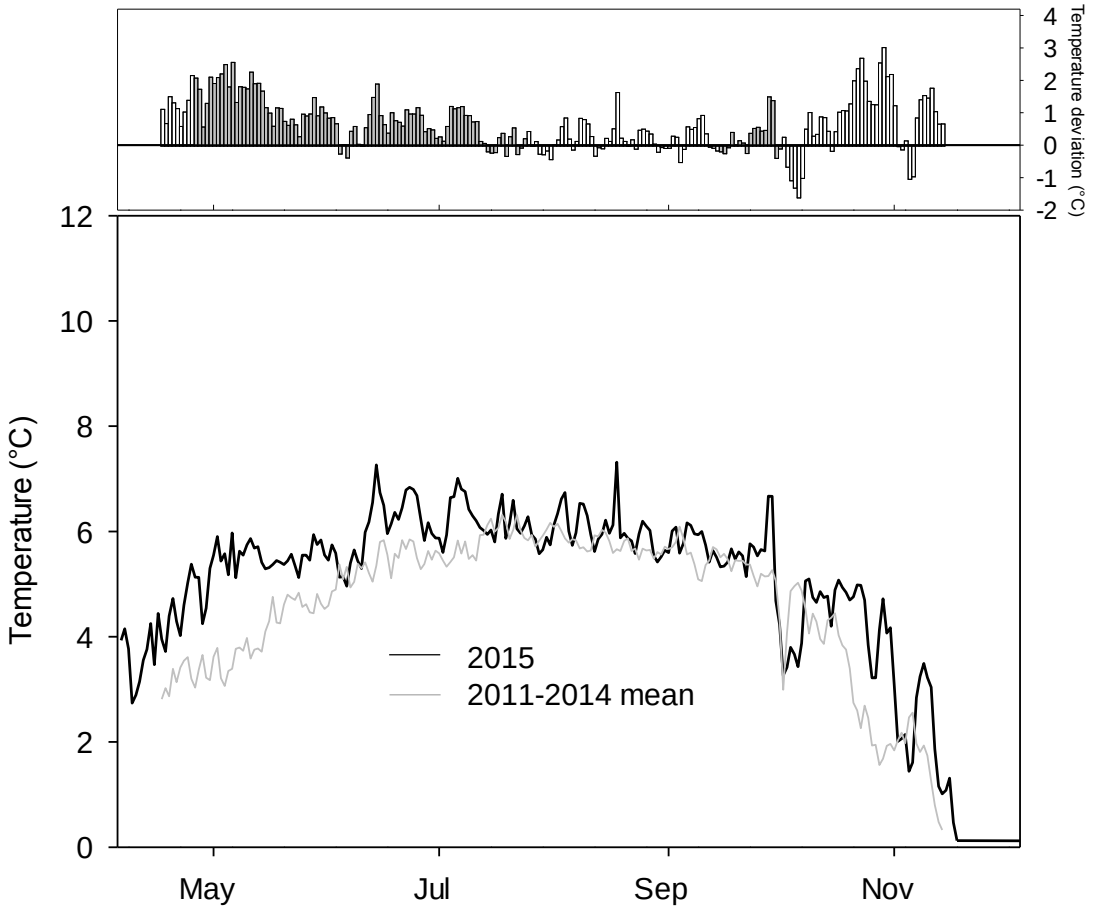

Figure 4. Daily mean water temperature for the Taiya River in 2015 and 2011-2014 mean (lower panel) and temperature deviations from 2011-2014 mean (upper thin panel). In the upper panel, deviations were compared against average daily temperatures calculated using 3 years of historical data (white bars) or 4 years (gray bars). Due to the short time series, interpret deviations cautiously.

Turbidity

In 2015, Taiya River hourly turbidity measurements ranged from 0 to greater than 1,000 NTU (the turbidity sensor maximum) during the sampling season, with the largest two peak events occurring in mid- to late September (Figure 5). The daily mean turbidity maximum was 837 NTU. Turbidity spikes began in mid-May and continued through late October. Turbidity events were consistently timed with high flow events most likely caused by increased input of glacial melt water (Appendix B; Figure 11).

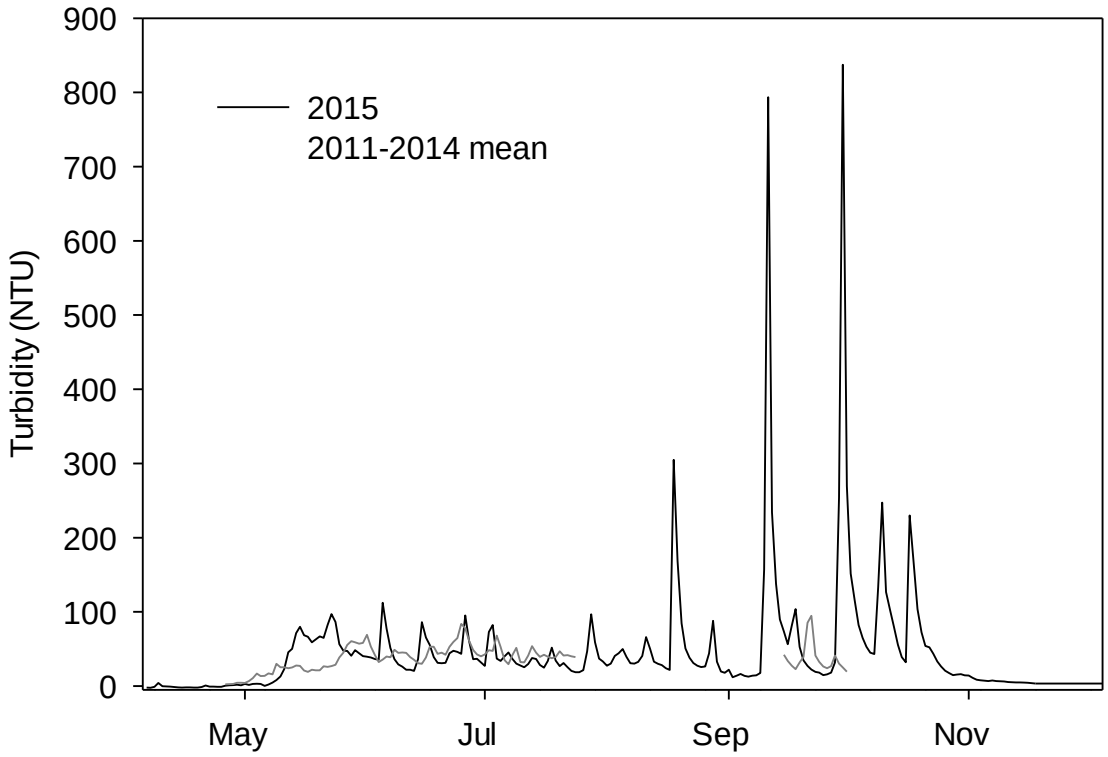

Figure 5. Daily mean turbidity for the Taiya River in 2015 and averaged across commonly measured dates in 2011-2014.

Specific conductance, DO, and pH

In the Taiya River in 2015, individual specific conductance measurements ranged from 0.02 to 0.08 mS/cm with a median of 0.04 mS/cm (Figure 3). DO ranged from 11.5 to 14.3 mg/L with a median of 12.2 mg/L (Figure 3). From April 27 through May 27, the DO sensor was inoperable. Values for pH ranged from 7.2 to 8.8 with a median of 7.5 (Figure 3). On September 10, pH spiked to 8.8 during a high flow and turbidity event. Sensor performance was excellent during this time period (Table 4) and no entrained sediments were found in the sonde housing. We believe the data are accurate, but the specific cause of the pH spike is unknown at this time, and data should be interpreted with caution.

Indian River

Temperature

In comparison to average daily mean values from 2010-2014, 2015 water temperature was consistently warmer than average through mid-July (Figure 6), but this result should be interpreted with caution because of the short time series available. During the period of monitoring, the daily mean water temperature in the Indian River ranged from 5.1 to 11.2°C (Table 5) and peaked on August 18 (2010-2014 average peak temperature date = August 20, standard deviation = 8 days). Median daily mean water temperature during the monitoring period was 8.5°C. Monthly mean daily average temperatures ranged from 6.1 to 9.4°C (Table 5).

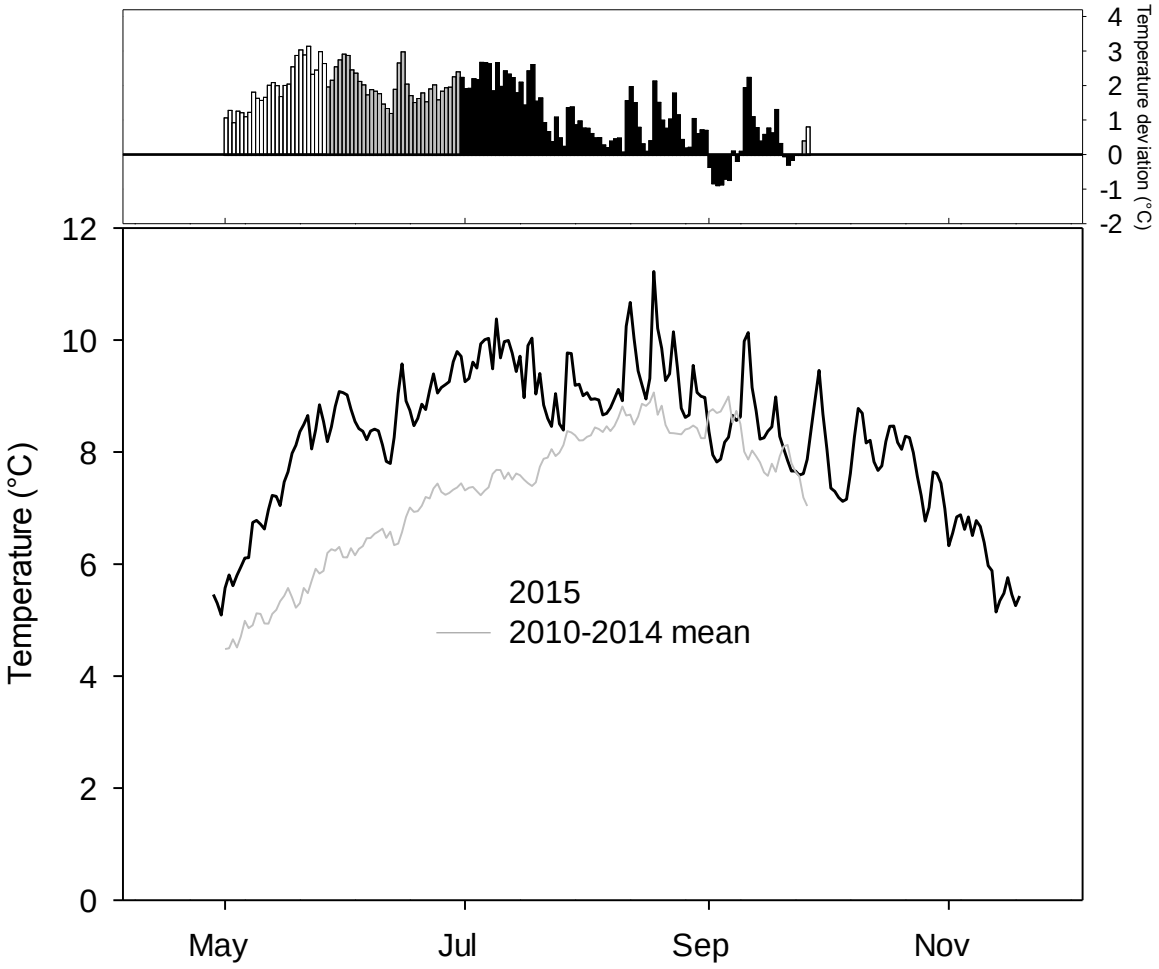

Figure 6. Daily mean water temperature for the Indian River in 2015 and 2010-2014 mean (lower panel) and temperature deviations from 2010-2014 mean (upper thin panel). In the upper panel, deviations were compared against average daily temperatures calculated using 3 years of historical data (white bars), 4 years (gray bars), or 5 years (black bars). Due to the short time series, interpret deviations cautiously.

Specific conductance, DO, and pH

In the Indian River, hourly specific conductance measurements ranged from 0.02 to 0.05 mS/cm with a median of 0.04 mS/cm. The critically low DO values observed during August 2013 (Sergeant and Johnson 2014) were not repeated during the summer of 2015. DO ranged from 9.6 to 13.6 mg/L with a median of 11.6 mg/L (Figure 3). The minimum DO value was reached on August 10. Values for pH ranged from 5.7 to 7.4 with a median of 7.0 (Figure 3).

Compliance with water quality standards

No observations from 2015 indicated exceedances of Alaska Department of Environmental Conservation water quality standards (Table 7; ADEC 2012) and water quality values in the three rivers never approached regulatory thresholds. The Taiya River sonde recorded two hourly pH measurements over 8.5 on September 10 (Table 6), but these were likely caused by natural occurrences within the watershed.

Table 6. Period of record and summary statistics for all freshwater water quality data collected and reported by the SEAN from 2010 through 2015.

				Summary statistics				
River	**Parameter**	**Period of Record**	**# obs.[1]**	**Median**	**Mean**	**Standard deviation**	**Min**	**Max**
Salmon	Conductivity (mS/cm)	Jun 4, 2010 to Dec 2, 2015	25,422	0.19	0.20	0.07	0.00	0.44
	Dissolved Oxygen (mg/L)		25,666	10.4	10.4	1.0	7.8	15.5
	Dissolved Oxygen (% Sat)		25,666	86.9	86.8	6.6	69.0	110.0
	pH		24,788	7.8	7.8	0.1	7.1	8.2
	Temperature (°C)		26,306	7.9	7.5	2.3	0.7	13.0
Taiya	Conductivity (mS/cm)	Apr 25, 2011 to Nov 19, 2015	23,617	0.04	0.04	0.02	0.00	0.09
	Dissolved Oxygen (mg/L)		18,641	12.4	12.5	0.6	10.7	14.9
	Dissolved Oxygen (% Sat)		18,641	97.5	97.4	3.1	79.8	110.5
	pH		23,392	7.4	7.4	0.2	6.5	8.8
	Temperature (°C)		23,617	5.1	4.9	1.6	0.0	9.6
	Turbidity (NTU)		23,472	26.2	36.3	58.1	-2.6[2]	1205.9
Indian	Conductivity (mS/cm)	May 26, 2010 to Nov 19, 2015	21,904	0.04	0.04	0.01	0.01	0.08
	Dissolved Oxygen (mg/L)		20,795	11.8	11.6	1.5	1.7	14.0
	Dissolved Oxygen (% Sat)		20,795	99.1	96.2	11.3	15.5	108.8
	pH		20,966	7.1	7.1	0.3	5.7	8.2
	Temperature (°C)		22,533	7.7	7.5	1.5	2.2	12.6

1 Data graded '2' or '3' were not counted as observations; Please see SOP 13 of the Freshwater Water Quality protocol (Sergeant et al. 2013) for descriptions of these water quality ratings.

2 Slightly negative turbidity values reflect inherent sensor imprecision

Table 7. Current Alaska Department of Environmental Conservation (ADEC) water quality standards, last amended April 8, 2012 (ADEC 2012). Superscript numbers denote the intended category of water use for which water quality criteria are relevant.

Parameter	Criteria
Specific conductance	None listed by ADEC
Dissolved oxygen (DO)[1]	DO must be greater than 7 mg/l in waters used by anadromous or resident fish. In no case may DO be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel used by anadromous or resident fish for spawning. For waters not used by anadromous or resident fish, DO must be greater than or equal to 5 mg/l. In no case may DO be greater than 17 mg/l. The concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection.
pH[1,2]	May not be less than 6.5 or greater than 8.5. May not vary more than 0.5 pH unit from natural conditions.
Temperature[1,2]	May not exceed 20°C at any time. The following maximum temperatures may not be exceeded, where applicable: Migration routes 15°C Spawning areas 13°C Rearing areas 15°C Egg & fry incubation 13°C For all other waters, the weekly average temperature may not exceed site-specific requirements needed to preserve normal species diversity or to prevent appearance of nuisance organisms.
Turbidity[3]	May not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 15 NTU. May not exceed 5 NTU above natural turbidity for all lake waters.

[1] Growth and propagation of fish, shellfish, other aquatic life, and wildlife
[2] Water supply/aquaculture
[3] Water recreation

Discussion

Observed trends

Across all three rivers monitored by the SEAN in 2015, no observed values or trends appeared to signal point source pollution or a fundamental change to existing water quality patterns. The critically low DO conditions of the Indian River observed during the summer of 2013 were not repeated in 2015.

The spike in Taiya River pH observed on September 10 has not been observed in previous monitoring seasons. Although we believe the data are accurate, the specific cause of the pH spike is unknown at this time. An exploratory analysis of the river's hydrograph and thermal regime during this period does not suggest a glacial outburst event. The pH measurements during this period drop smoothly from the peak, suggesting that sensor malfunction was not the cause. Sensor performance was validated and rated excellent before and after the event (Table 4). Bank erosion is a potential mechanism for the pH spike, but we do not have data to support this conclusion. These data are intriguing but should be interpreted with caution.

Program performance

In general, program operations were executed efficiently in 2015, but sensor malfunction and programming errors lead to several data gaps of up to one month (Table 3). Sensor malfunction is a common and usually unpreventable problem for water quality monitoring programs, but to reduce human mistakes such as programming errors, the SEAN continues to recommend pre-installation training at the start of each season for park staff with less than 3 seasons of water quality monitoring experience. Whenever possible, it is best to limit park water quality monitoring assistants to 1 or 2 staff throughout a single monitoring season to maintain better consistency in data collection and quality. SEAN staff will continue maintaining close communication with park staff to develop feasible staffing solutions each season.

The completion of the 2015 monitoring season marks 6 years of data collection for the Salmon and Indian Rivers, and 5 years for the Taiya River. After the completion of the 2015 annual report, SEAN staff will begin drafting a water quality synthesis report summarizing multi-year trends, program performance, and future program needs or modifications (see SOP 11 of Sergeant et al. 2013 for more reporting details). The synthesis report is expected to be completed in late 2016 or early 2017.

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Appendix A: Hourly time series by river for all water quality parameters

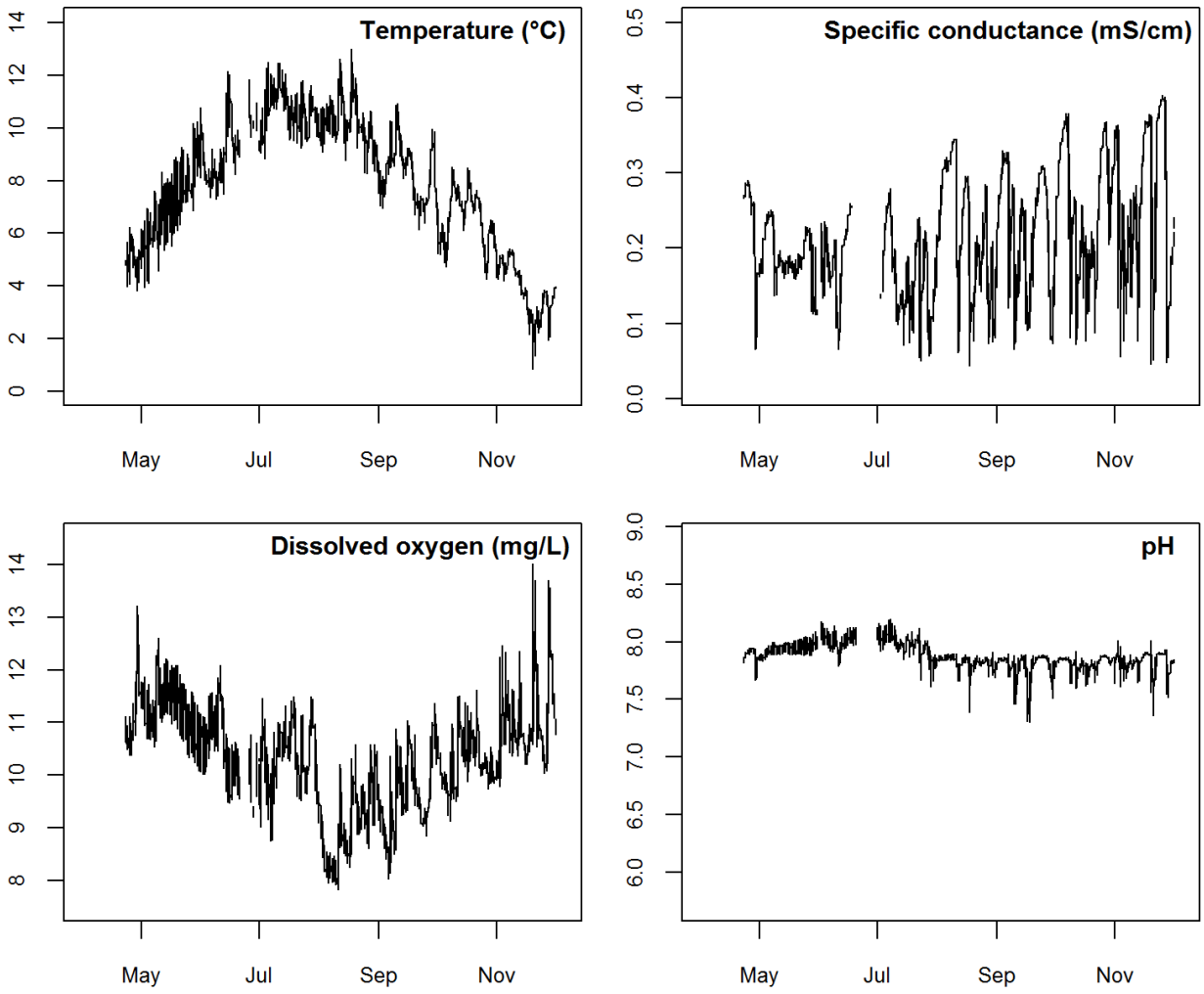

Figure 7. Hourly water quality data for the Salmon River in 2015.

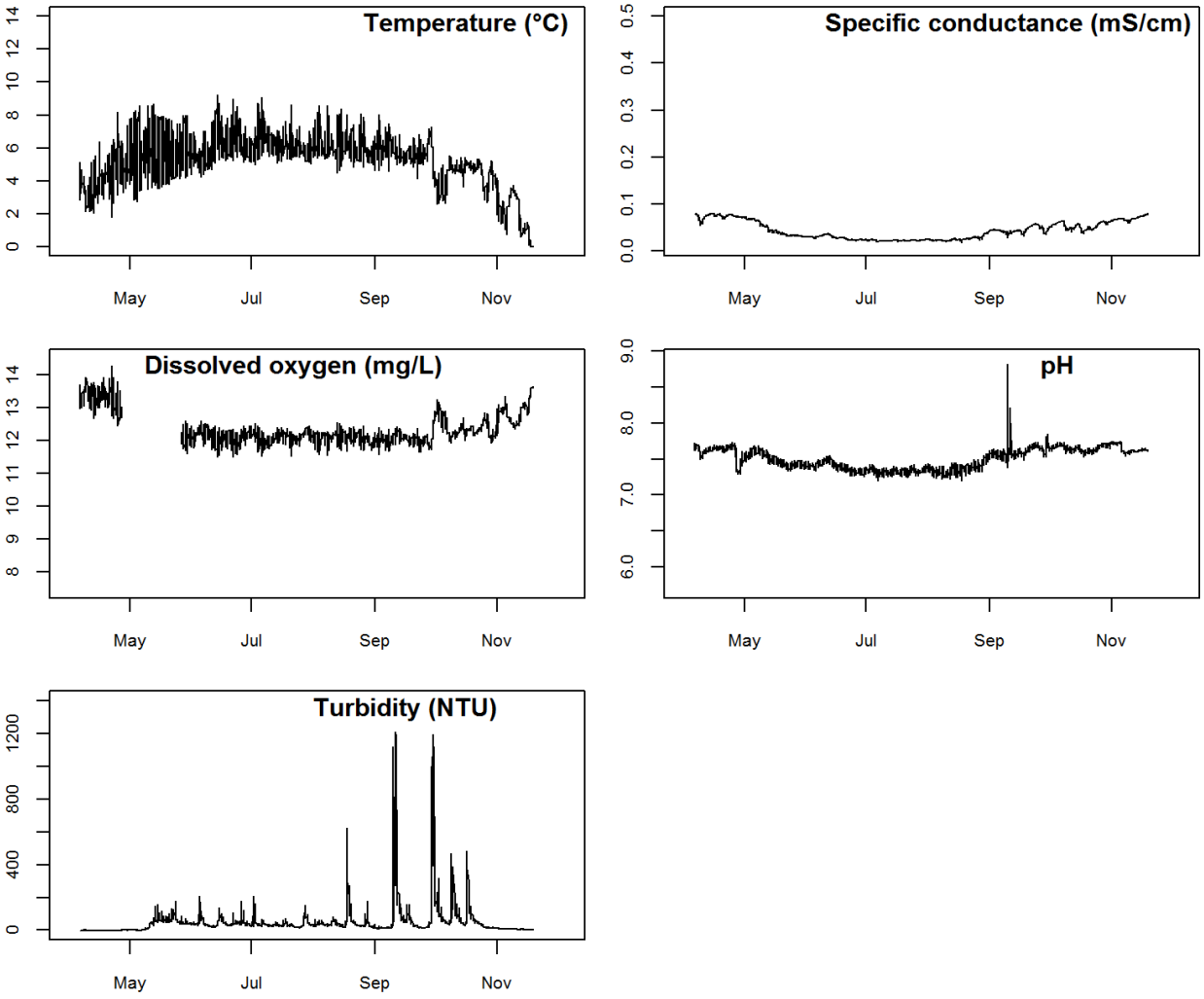

Figure 8. Hourly water quality data for the Taiya River in 2015.

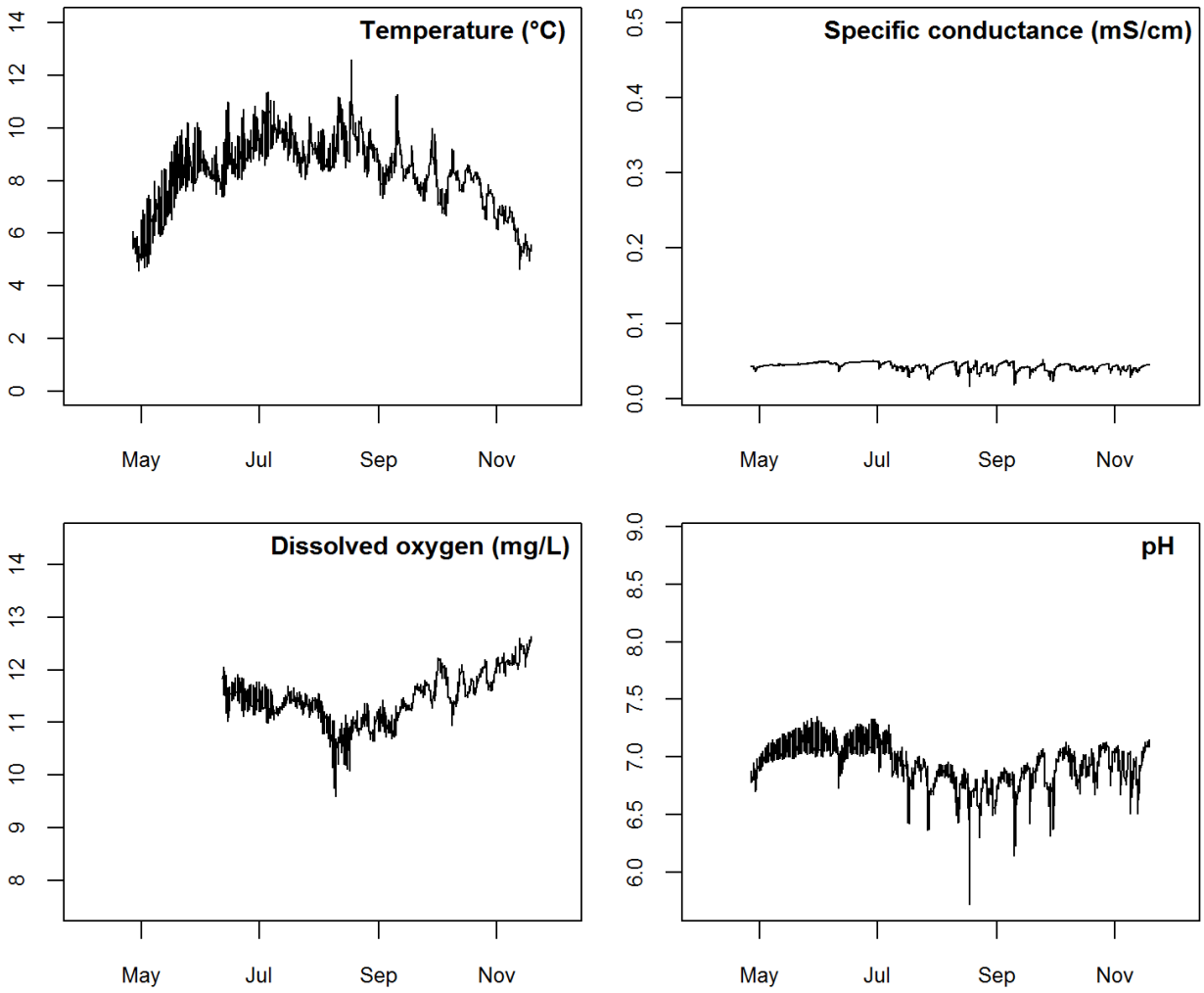

Figure 9. Hourly water quality data for the Indian River in 2015.

Appendix B: Streamflow time series versus all water quality parameters for all rivers

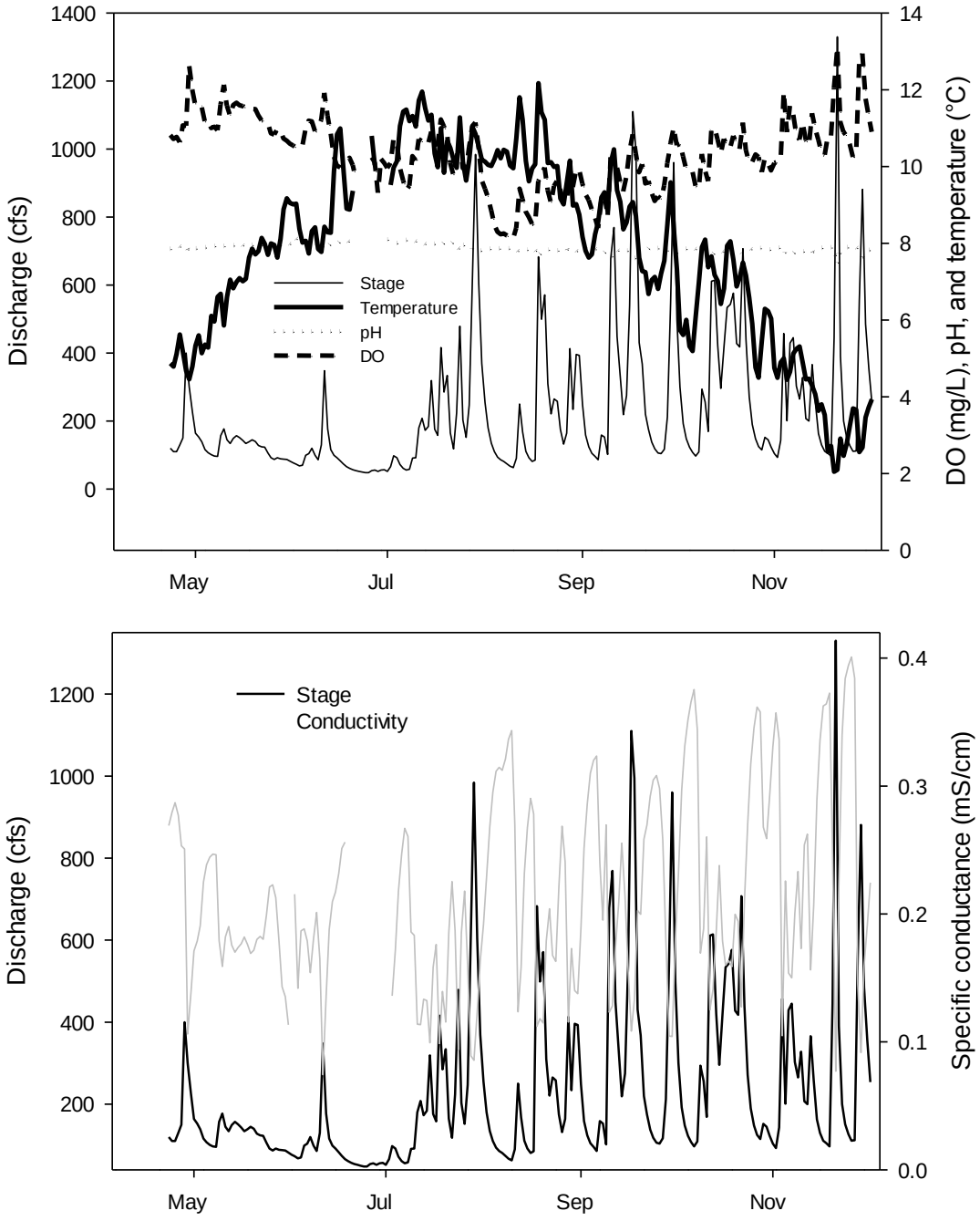

Figure 10. Daily average streamflow (log scale) versus daily averages for all water quality parameters in the Salmon River in 2015. Note the additional Y-axes on each panel. Streamflow data collected approximately 1 km downstream from water quality data and downloaded from the Salmon River USGS gage #1505596 (http://nwis.waterdata.usgs.gov/ak/nwis/uv/?site_no=15057596&agency_cd=USGS). Streamflow measurements from October 1 through December 2 were marked as 'provisional' by USGS at the time of publication.

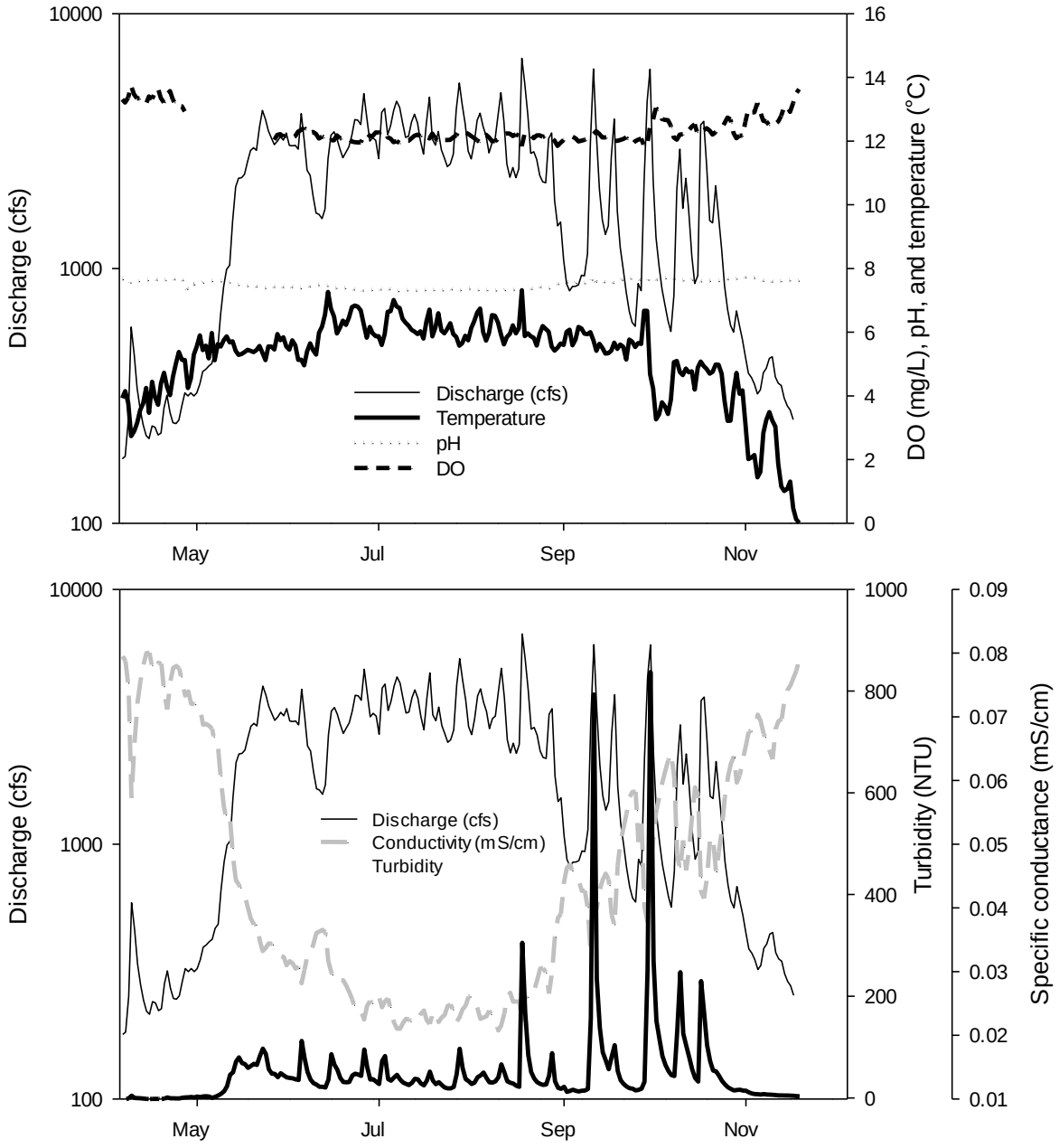

Figure 11. Daily average streamflow (log scale) versus daily averages for all water quality parameters in the Taiya River in 2015. Note the additional Y-axes on each panel. Streamflow data collected in the same location as water quality data and downloaded from the Taiya River USGS gage #1505621 (http://waterdata.usgs.gov/ak/nwis/uv/?site_no=15056210&PARAmeter_cd=00065,00060).

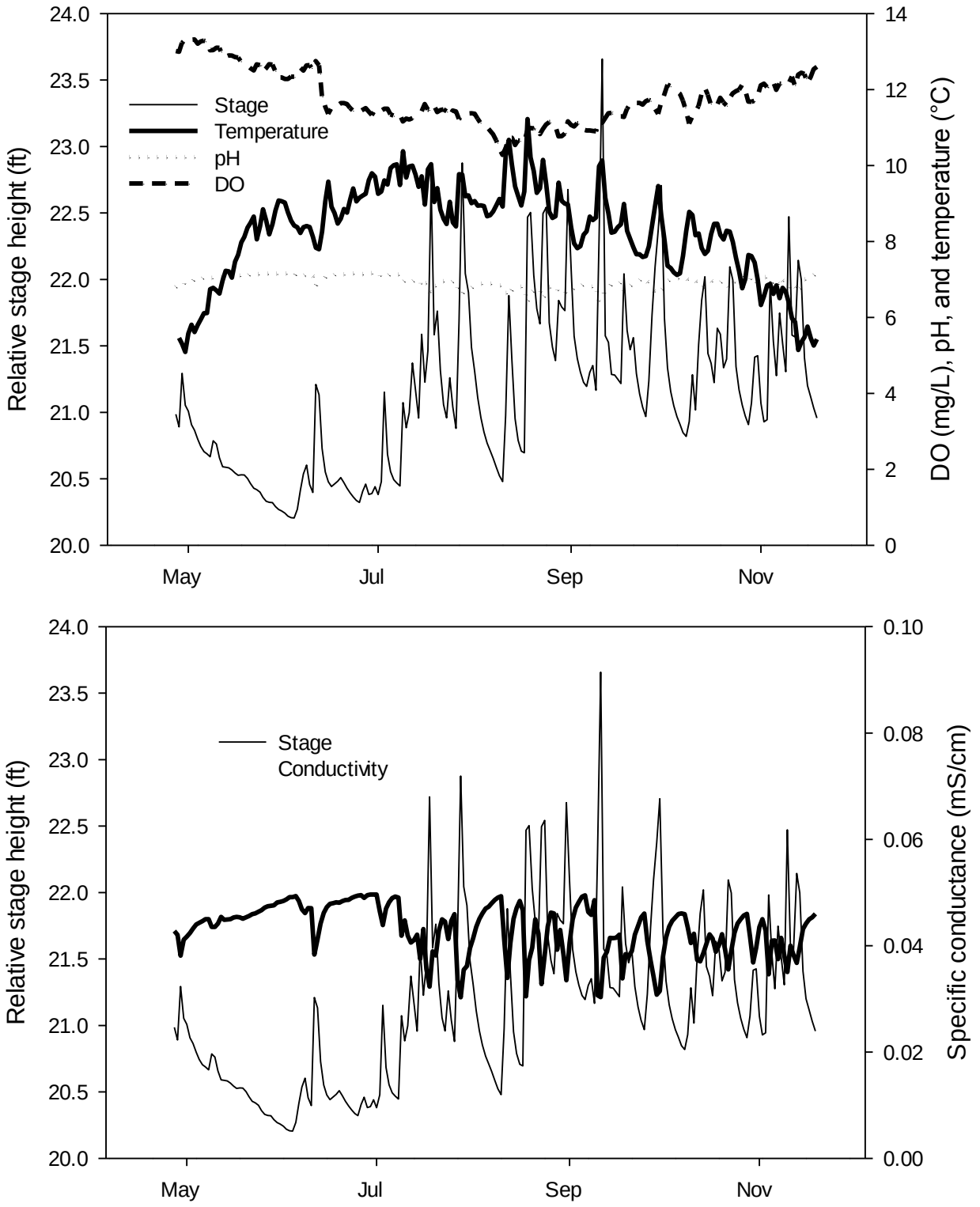

Figure 12. Daily average stage height versus daily averages for all water quality parameters in the Indian River in 2015. Note the additional Y-axes on each panel. Streamflow data collected in the same location as water quality data and housed with the SEAN. The SEAN is creating an Indian River streamflow protocol for long-term data collection and management. Real-time streamflow information can currently be viewed at: http://water.weather.gov/ahps2/hydrograph.php?wfo=pajk&gage=irva2&hydro_type=2

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