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**Klamath Basin Water Temperature Summary, Water Year 2020 and 2021**

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*Abstract.*— The U.S. Fish and Wildlife Service began extensively monitoring water temperature in the Klamath Basin in 2001 due to growing interest and concern over the effects of elevated water temperatures, particularly in relationship to Pacific salmonids. This report summarizes the results of water temperature monitoring for a set of locations within the Klamath River watershed that are accessible to anadromous fish for water years (WYs) 2020 and 2021. Temperature criteria for the Trinity River have been adopted by the Trinity River Restoration Program (TRRP) and are based upon the Trinity River Flow Evaluation Study and the Trinity River Mainstem Fishery Restoration: Final Environmental Impact Statement/Environmental Impact Report. We evaluated water temperatures on the Klamath River using the U.S. Environmental Protection Agency's Pacific Northwest salmonid life history stage temperature criteria. Water temperature criteria for all focal sites evaluated were exceeded on the Trinity and Klamath rivers during WY 2020 and 2021. All five focal sites on the Klamath River set new water temperature records by surpassing the historical seven-day average daily maximum temperature in WY 2020 (range 2 to 16 days exceeded) and WY 2021 (range 12 to 41 days exceeded). On the Trinity River, the daily average water temperatures surpassed the maximum historical daily average water temperatures at three of the four focal sites in WY 2020 (range 30 to 41 days exceeded) and all four focal sites in WY 2021 (range 1 to 55 days exceeded). The 2020 and 2021 WYs were designated as 'Critically Dry' by the TRRP. Although supplemental flow criteria of ≥23 ℃ for migrating adult salmonids was exceeded, no emergency flows were released from either Iron Gate or Lewiston dams in WY 2020, however there was an emergency release in August from Lewiston Dam in WY 2021 in an attempt to reduce mainstem Trinity River water temperature and mitigate disease outbreak in adult salmonids. Some methods were corrected for historical water temperature data in the 2019 WY water temperature report. Calculations for days-criteria-were-exceeded may be different in reports prior to 2019.

## 1. Introduction

The Klamath River Basin historically supported large runs of Chinook Salmon *Oncorhynchus tshawytscha*, Coho Salmon *O. kisutch*, and steelhead *O. mykiss* that contributed to economically and culturally important subsistence, sport, and commercial fisheries (Leidy and Leidy 1984; KRBFTF 1991; NAS 2004; USDOI et al. 2013). Dramatic declines in native fish populations over the past century have been attributed to various anthropogenic factors, including construction and operation of a series of hydropower dams on the mainstem Klamath and Trinity rivers (Poole and Berman 2001; Caissie 2006; Moyle et al. 2008, 2011; Hester and Doyle 2011). Some of these anthropogenic influences have exacerbated naturally warm water temperatures in parts of the basin, resulting in negative impacts to salmonid populations (KRBFTF 1991; McCullough 1999; NAS 2004; Bartholow 2005; NCRWQCB 2010).

The thermal regime of a river characterizes the central tendency and variability in temperature seasonally and over time, and has numerous cascading influences on the physiological, ecological, and life-history traits of salmonids and other aquatic organisms (Hallock et al. 1970; McCullough 1999; Harmon et al. 2001; USEPA 2003; Carter 2006; Olden and Naiman 2010). Water temperature influences the population performance of fishes, the impact of which is particularly well studied on the spawning and early life history stages of salmonids (Brett 1971; Bjornn and Reiser 1991; Baker et al. 1995; Marine and Cech 2004; Richter and Kolmes 2005). As poikilotherms, salmonid metabolic rates are directly impacted by the temperature of their environment. These metabolic changes have been linked to behavioral shifts such as a reduction in feeding (Brett 1971) and seeking thermal refugia (Sullivan et al. 2000; Goniea et al. 2006). Salmonid embryos and larvae are particularly susceptible to elevated temperatures, which can impact their ability to initiate exogenous feeding (Heming 1981). Temperature can also influence prevalence of disease in salmonid populations, inhibit individual survivability, and amplify group transmission of disease (Harmon et al. 2001; Guillen 2003; Turek at al. 2004; Ray et al. 2014). While water management often focuses on maintaining cooler water temperatures for salmonids, warm water also plays an important role in fish life history (Armstrong et al. 2021).

The Klamath River's largest tributary, the Trinity River, is the focus of a large-scale habitat restoration and salmonid recovery effort coordinated by the Trinity River Restoration Program (TRRP). The goal of this effort is to restore and maintain the anadromous fishery resources of the Trinity River (USFWS and HVT 1999; USDOI 2000; USFWS et al. 2000). One component of the restoration effort is the management of river discharge out of Trinity and Lewiston dams to improve thermal regimes for all life stages of anadromous salmonids that use the mainstem Trinity River. Temperature criteria were developed for holding and spawning adult and rearing juvenile anadromous salmonids in the Trinity River Flow Evaluation Study (TRFES; USFWS and HVT 1999) and were adopted by the Trinity River Mainstem Fishery Restoration: Final Environmental Impact Statement/Environmental Impact Report, Record of Decision (USDOI 2000; USFWS et al. 2000). The annual flow release schedule for the Trinity River is based on the recommendations of the December 2000 Trinity River Mainstem Fishery Restoration Record of Decision (ROD) and incorporates the water year (WY) type and restoration needs (USDOI 2000). A WY is defined as the 12-month period between October 1 and September 30 of the next calendar year (Paulson et al. 1985).

A set of numeric water temperature criteria comparable to the Trinity River's does not exist for the Klamath River. Instead, the Environmental Protection Agency's (EPA) criteria for Pacific Northwest water temperatures were adopted (USEPA 2003; Carter 2006) in this study. The EPA prepared these criteria as a set of guidelines for the development of water quality standards by Pacific Northwest states and Native American tribes. Using these criteria is not an assertion of any regulatory compliance, or lack thereof, but represent science-based, peer-reviewed criteria as a measure of the magnitude to which water temperatures may be impairing Pacific salmonid populations in the Klamath River.

Supplemental water releases from Iron Gate and Lewiston dams have been used in previous years as a water management tool to reduce the risk of disease in August and September. The temperature objective (Lagomarsino and Hetrick 2013) for the supplemental releases is to reduce the daily mean temperature below 23 ℃, the migration threshold for adult Chinook Salmon in the lower Klamath River (Strange 2010). These criteria were developed in response to the 2002 fish die-off in the lower Klamath River, where an estimated minimum of 34,000 adult salmonids died prior to spawning. This die-off was attributed to the increased disease outbreaks of *Ichthyophthirius multifiliis* and *Flavobacterium columnare* in adult salmonids returning to spawn. This was likely due to low river discharge, high water temperatures, and a large run size (Guillen 2003; Belchik et al. 2004; Turek et al. 2004). Efforts to abate the fish die-off in 2002, occurred too late for the water release to mitigate the effects of high-water temperature and disease. Emergency flow releases are now used as preventative measures to minimize the risk of infection during adult migration in August and September.

The Arcata Fish and Wildlife Office of the U.S. Fish and Wildlife Service (USFWS) began monitoring water temperature in the lower Klamath Basin in 2001 due to the significant effects of water temperature on anadromous salmonids and concern that elevated water temperature in the Klamath Basin could be impacting these populations. The primary objective of this report is to summarize the monitored thermal regime from 2020 through 2021 and compare with established criteria to inform future water management decisions in the Klamath Basin. Further details of these criteria and the management responses can be found in TRRP (TRRP 2012) and related memos (Lagomarsino and Hetrick 2013; Hetrick and Polos 2015). The secondary objective of this report is to help identify areas where water temperature falls outside the optimal range for salmonid life history requirements. Water temperature data included in this report are also used in the development, validation, and refinement of a predictive water temperature model (RBM10) for the basin (Perry et al. 2011; Jones et al. 2016). This water temperature model is also a key input for the Stream Salmonid Simulator (S3) fish population dynamics model (Perry et al. 2018) which in turn is relied upon to inform resource management decisions in the Klamath River Basin (Polos 2016; Som and Hetrick 2017).

## 2. Methods

### 2.1. Study Area

In this report we present data on focal sites generally related to key areas of life-history needs of anadromous fish in the lower Klamath Basin, namely the Trinity and Klamath rivers and their tributaries. Monitoring locations on the Trinity River extend from below

Lewiston Dam (TRBL) to the confluence with the Klamath River (TRWE). In 2019, two non-focal sites were added on the Trinity River above Lewiston on the East Fork near the mouth (EFTL) and above Trinity Lake (TRTL). Klamath River monitoring locations extend from Iron Gate Dam (KRIG) to near the estuary (KRTG; Figure 1; Table 1).

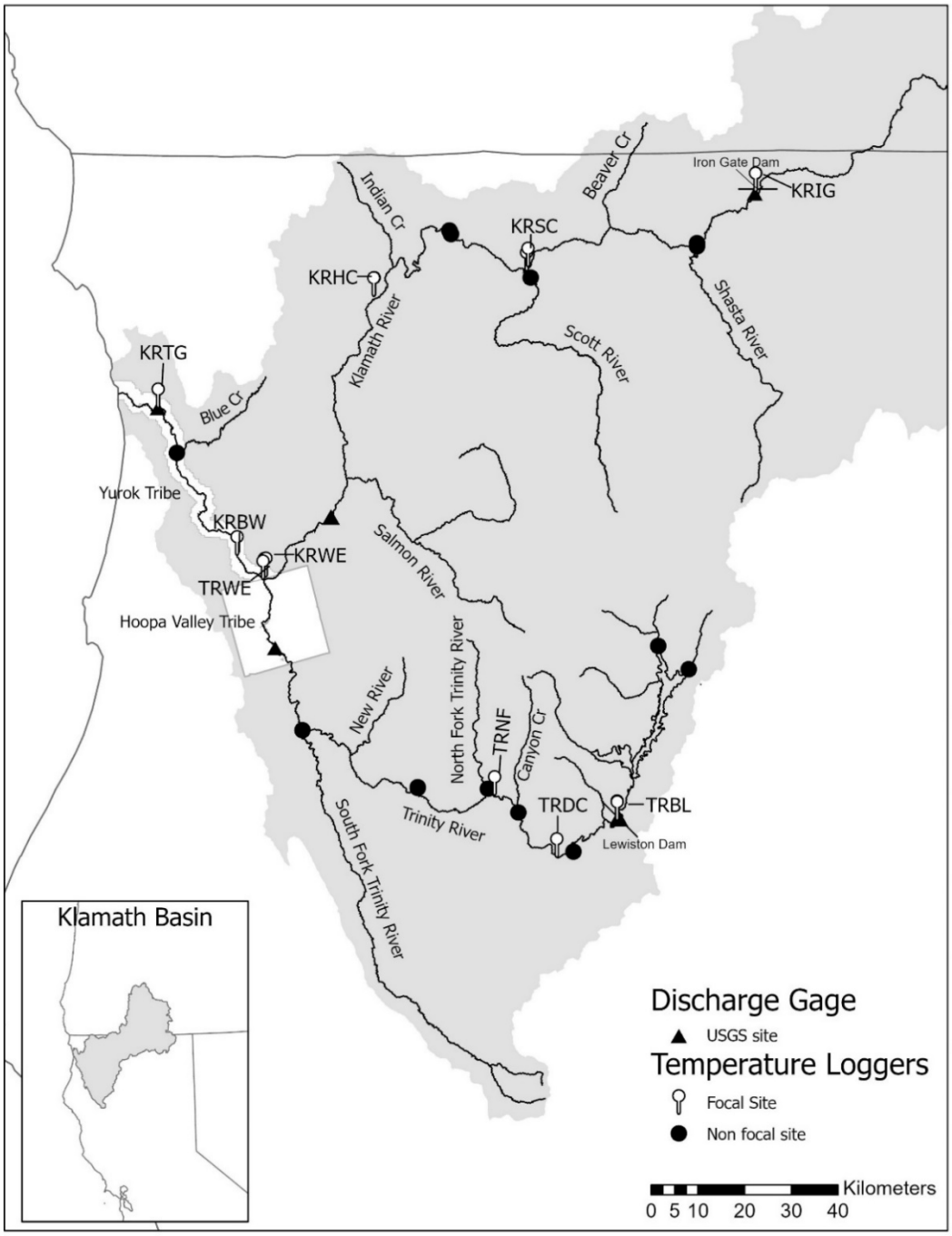


Figure 1. Locations in the lower Klamath River basin where river discharge was recorded at U.S. Geological Survey (USGS) gaging sites and where water temperature was recorded at U.S. Fish and Wildlife Service monitoring sites in Water Years 2020 and 2021. Anadromy is limited to below Iron Gate Dam on the Klamath River and below Lewiston Dam on the Trinity River.

Table 1. Water temperature monitoring locations in the Klamath River Basin operated by the U.S. Fish and Wildlife Service in WYs 2020 and 2021. Locations are ordered from upstream to downstream by river kilometer (Rkm) along the Klamath and Trinity rivers, with tributaries ordered by their entrance to the respective river. Focal monitoring sites are highlighted in gray. Years operated before 2019 do not include infilled data.

| River/Creek | Location | Location Code | Rkm | Latitude | Longitude | Years Operated |
|---|---|---|---|---|---|---|
| Klamath River | Below Iron Gate Dam | KRIG | 309.7 | 41.931049 | -122.4414 | 2001-2021 |
| Klamath River | Above Shasta River | KRSH | 288.5 | 41.83124 | -122.59338 | 2002-2021 |
| Shasta River | Near mouth | SHKR | 0.8 | 41.824759 | -122.59392 | 2001-2003, 2005-2021 |
| Klamath River | Above Scott River | KRSC | 233.2 | 41.779236 | -123.03325 | 2002-2021 |
| Scott River | Johnson Bar | SCKR | 2.5 | 41.765479 | -123.02266 | 2004, 2006-2021 |
| Klamath River | Seiad Valley | KRSV | 209.3 | 41.854087 | -123.23147 | 2001-2021 |
| Klamath River | Below Happy Camp | KRHC | 164.2 | 41.729647 | -123.42558 | 2002-2021 |
| Klamath River | Above TR Confluence (Weitchpec) | KRWE | 70.2 | 41.185991 | -123.70228 | 2002-2021 |
| Klamath River | At TR Confluence (Below Weitchpec) | KRBW | 61.7 | 41.227666 | -123.77259 | 2004, 2007-2021 |
| Klamath River | Above Blue Creek | KRBC | 26.2 | 41.423077 | -123.92933 | 2003-2021 |
| Klamath River | Upstream of Estuary (Blakes Riffle) | KRTG | 12.7 | 41.511184 | -123.97844 | 2004-2021 |
| E.F. Trinity River | Near mouth | EFTL | 4.1 | 41.008173 | -122.62036 | 2019-2021 |
| Trinity River | Above Trinity Lake | TRTL | 226.6 | 41.053538 | -122.69754 | 2019-2021 |
| Trinity River | Below Lewiston Dam | TRBL[b] | 180.6 | 40.717945 | -122.80313 | 2017-2021 |
| Trinity River | Below Lewiston Dam | TRRC | 173 | 40.720869 | -122.82912 | 2002-2003, 2005-2017 |
| Indian Creek | Near mouth | ICTR | 0.2 | 40.656452 | -122.91388 | 2002-2021 |
| Trinity River | Douglas City | TRDC | 151.3 | 40.646797 | -122.9562 | 2019-2021 |
| Trinity River | Douglas City | DGC [a] | 148.5 | 40.645278 | -122.95667 | 2002-2019 |
| Canyon Creek | Near mouth | CNTR | 0.3 | 40.731906 | -123.05382 | 2001-2021 |
| Trinity River | Above North Fork | TRNF | 1.2 | 40.777677 | -123.13138 | 2019-2021 |
| Trinity River | Above North Fork | NFH [a] | 119.7 | 40.766532 | -123.11448 | 2005-2019 |
| N.F. Trinity River | Near mouth | NFTR | 0.1 | 40.770324 | -123.12748 | 2001-2021 |
| Trinity River | Above Big French Creek | TRBF | 96.8 | 40.779208 | -123.3085 | 2001-2021 |
| Big French Creek | Near mouth | BFTR1 | 0.1 | 40.780475 | -123.30889 | 2001-2018, 2020-2021 |
| Trinity River | Above South Fork | TRSF | 50.8 | 40.88981 | -123.60204 | 2001-2003, 2005-2021 |
| S.F. Trinity River | Near mouth | SFTR | 0.1 | 40.889434 | -123.60221 | 2001-2021 |
| Trinity River | Above Klamath | TRWE | 0.8 | 41.181077 | -123.70581 | 2002-2021 |

[a] Locations monitored by the Bureau of Reclamation prior to 2019 when USFWS established monitoring sites at those locations. These data were obtained from the California Data Exchange Center website (https://cdec.water.ca.gov/index.html).

[b] Site 'Below Lewiston Dam' was relocated upstream in 2017 and the coordinates for TRBL have replaced TRRC as the location for this site.

## 2.2. Data Sources and Protocols

The USFWS recorded water temperature at 24 sites in the Klamath River Basin in 2020 and 2021 (Figure 1; Table 1). As of 2019, water temperature data previously reported by USGS at the Trinity River Douglas City site (DGC) and the Trinity River above North Fork site (NFH) are now collected at the USFWS sites TRDC and TRNF, respectively. Of the 24 locations, 13 were on the Trinity River and its tributaries and 11 were on the Klamath River and its tributaries. These locations were selected to be representative of different reaches in their respective rivers and were not determined to be inadvertently influenced by local conditions such as by springs, tributaries, or other sources of anomalous thermal variation.

All USFWS monitoring locations were fitted with digital data loggers (HOBO Water Temp Pro v2, Onset Computer Corporation) and standardized protocols (Dunham et al. 2005) utilized to monitor water temperature. Loggers were set to record at 30-minute intervals and were swapped out twice per year, once in late spring or early summer and once in late fall or early winter. Prior to and after deployment, each logger was tested to verify operation within the manufacturer's accuracy specification of ± 0.2℃. Data from USFWS monitoring locations are stored in a Water Information Systems by Kisters (WISKI) relational database and are available upon request.

### *2.2.1. Focal Sites*

Focal site selection was based on points representing the longitudinal thermal gradients of the mainstem Klamath or Trinity rivers. These points usually correspond to a landmark (e.g., a dam or large tributary) or are associated with temperature criteria locations. Four focal sites on the Trinity River and five focal sites on the Klamath River were selected for this analysis.

On the Trinity River, the most upstream focal site is just below Lewiston Dam (TRBL), the upper limit to anadromy. The remaining focal sites are located at Douglas City (TRDC), above the North Fork (TRNF), and above the Klamath River (TRWE) and were chosen based on downstream extent of water temperature criteria locations set by the TRRP.

On the Klamath River the most upstream focal site is below Iron Gate Dam (KRIG), which marks the current upper limit to anadromy. The other four focal sites are above the Scott River (KRSC), below Happy Camp (KRHC), at Weitchepec above the confluence with the Trinity River (KRWE), and at Blakes Riffle upstream of the estuary leading to the Pacific Ocean (KRTG). The KRSC site was chosen because it encompasses the first tributary that can substantially influence water temperature in the Klamath River downstream of Iron Gate Dam. The KRHC site was selected because previous monitoring identified this reach as the location where peak summer water temperature occurs in the mainstem Klamath River downstream of Iron Gate Dam (Magneson 2015). KRWE was chosen because it is upstream of the confluence with the Trinity River. Finally, KRTG was chosen near the mouth of the river.

### *2.2.2. Infilling Data Gaps*

Water temperature time series at some focal sites contained gaps due to the loss of loggers by high flow events, theft, exposure of loggers to air temperatures during low-flow periods, or corruption of logger data after deployment. When available, data from other loggers at the same or nearby locations were used to infill time series gaps. Sources of supplemental data include additional USFWS monitoring locations and data collected by the Karuk Tribe's Department of Natural Resources, U.S. Forest Service (USFS), USGS, and the Yurok Tribe's Environmental Program (YTEP). If directly comparable data were not available to infill missing data, but data were available from a relatively nearby monitoring location (maximum distance between locations = 69 rkm), a regression relationship within a season was developed between water temperatures at the two locations to estimate water temperatures on missing days at the focal location. Generalized least squares (GLS) regression with a first-order autoregressive correlation structure was used to account for the temporal error structure due to the strong thermal inertia of water. The GLS regressions were implemented using the *nlme* R package (Pinheiro et al. 2017). Historical data prior to 2019 was not infilled. A summary of data gaps is shown graphically in Appendix E.

### *2.2.3. Historical Data Gaps*

It should be noted that upon review of the temperature criteria in the literature, it was discovered that the criteria were applied incorrectly in previous water temperature reports. In all reports after 2018, including this report, the methods were corrected and all figures and calculations using historical data were redone and presented herein. Missing historical data were not infilled for data prior to 2019. As a result, some of this report's figures and calculations may be different from prior reports that purported to be presenting the same information.

## 2.3. Trinity River Evaluation Criteria

Trinity River WY is further described by type: 'Normal', 'Wet', 'Extremely Wet', 'Dry', and 'Critically Dry' (USDOI 2000). During 'Normal', 'Wet', and 'Extremely Wet' WYs, discharge from Trinity and Lewiston dams is managed, in part, to provide optimal thermal conditions throughout the primary juvenile salmonid outmigration period. During 'Dry' or 'Critically Dry' WYs, discharge from Trinity and Lewiston dams is managed to facilitate outmigration and provide thermal conditions conducive to juvenile survival.

Adult salmonid temperature criteria are the same regardless of WY and are applied from July to December (Table 2). Juvenile salmonid rearing and migrating temperature criteria differ depending on the WY type for the Trinity River and begin in early April and end July 9. In this report, April 1 was used as the beginning of the juvenile salmonid temperature objectives (USFWS and HVT 1999; USFWS et al. 2000). This date also coincides with the WY type determination which generally occurs April 1st.

Table 2. Water temperature criteria for the Trinity River as defined by the Trinity River Flow Evaluation Study and the Trinity River Mainstem Fishery Restoration: Final Environmental Impact Statement/Environmental Impact Report (USFWS and HVT 1999; USFWS et al. 2000).

| WY Type | Locations | Time Period | Days criteria is in effect | Temperature criteria (daily mean °C) | Life stage applicable to criteria |
|---|---|---|---|---|---|
| All types | Douglas City | July 1 - Sept. 14 | 77 | < 15.6 | Adult salmonid holding and spawning |
| All types | Douglas City | Sept. 15 - Sept. 30 | 16 | < 13.3 | Adult salmonid holding and spawning |
| All types | North Fork | Oct. 1 - Dec. 31 | 92 | < 13.3 | Adult salmonid holding and spawning |
| Normal, Wet, Extremely Wet | Weitchpec (above KR) | April 1 - May 22 | 52 | < 13.0 | Juvenile salmonid rearing and migrating |
| Normal, Wet, Extremely Wet | Weitchpec (above KR) | May 23 - June 4 | 13 | < 15.0 | Juvenile salmonid rearing and migrating |
| Normal, Wet, Extremely Wet | Weitchpec (above KR) | June 5 - July 9 | 35 | < 17.0 | Juvenile salmonid rearing and migrating |
| Dry and Critically Dry | Weitchpec (above KR) | April 1 - May 22 | 52 | < 15.0 | Juvenile salmonid rearing and migrating |
| Dry and Critically Dry | Weitchpec (above KR) | May 23 - June 4 | 13 | < 17.0 | Juvenile salmonid rearing and migrating |
| Dry and Critically Dry | Weitchpec (above KR) | June 5 - July 9 | 35 | < 20.0 | Juvenile salmonid rearing and migrating |

## 2.4. Klamath River Evaluation Criteria

The primary metric recommended by the EPA for evaluating water temperature is the seven-day average daily maximum temperature (7DADM), calculated as the average of daily maximum temperatures across a seven-day period, beginning three days before and ending three days after any given date. The EPA guidelines also recommend different criteria for each of the life history stages of Pacific salmonids (Table 3; USEPA 2003; Carter 2006). Spawning, egg incubation, and emergence criteria (13°C 7DADM) were applied to the period of October 1 through April 30, the time frame when most reproductive activities occur in the Klamath Basin (Leidy and Leidy 1984; Shaw et al. 1997). Criteria were applied to the Klamath River for juvenile rearing and migration (16°C 7DADM) starting April 1, and June 1 for adult migration (20°C 7DADM) (Table 3). The period for both criteria extends through September 30, due to overlapping run timing and life history strategies (Leidy and Leidy 1984; Shaw et al. 1997).

Table 3. Environmental Protection Agency criteria for Pacific Northwest water temperature to protect Pacific salmonids (US EPA 2003). These criteria were interpreted using the EPA recommended metric of seven-day average daily maximum temperature and were used in the evaluation of Klamath River during periods of water temperature concern.

| Temp. criteria (°C) | Time Period | Days | Life history focus |
|---|---|---|---|
| < 13.0 | Oct. 1 - April 30 | 212 | Spawning, egg incubation, and emergence |
| < 16.0 | April 1 - Sept. 30 | 183 | Rearing and redistribution of juvenile salmonids |
| < 20.0 | June 1 - Sept. 30 | 122 | Migrating adult salmonids |

## 2.5. Supplemental Water Releases Evaluation Criteria

To evaluate supplemental water release criteria, daily mean water temperatures were compared from five focal sites (TRBL, TRWE, KRIG, KRWE, KRTG), which are located just downstream of USGS streamflow gaging stations recording discharge. Daily mean water temperature from an additional non-focal site located on the Klamath River below the confluence with the Trinity River (KRBW) was also evaluated using the supplemental water release evaluation criteria. Temperature below the Trinity River confluence (KRBW) represents the most upstream site on the Klamath River after the confluence of the Trinity and Klamath rivers, while temperature near the mouth of the Klamath River (KRTG) represents the most downstream site. TRBL is located just below Lewiston Dam and KRIG just Below Iron Gate Dam. TRWE and KRWE are located upstream of the confluence on the Trinity and Klamath rivers, respectively. Daily mean discharge values were gathered from five USGS gaging stations to assess supplemental water release criteria exceedances on the lower Klamath River. USGS stations were located on the Klamath River at Iron Gate Dam (gage 11516530), Orleans (gage 11523000), and the town of Klamath (gage 11530500). On the Trinity River discharge data was used from stations at Lewiston Dam (gage 11525500) and Hoopa (gage 11530000).

Supplemental releases are a result of either water management decisions or for culturally important Tribal ceremonies. Due to the variation in timing of supplemental releases from Lewiston Dam, the period of evaluation shifts between years. For WYs 2020 and 2021 the evaluation period starts in April and extends through September, which encompasses all supplemental flow release events.

## 2.6. Analyses

Data for February 29 was removed for all leap years to make the number-of-days criteria consistent among years. For each day of the year at each focal site, the historical average, minimum, and maximum of daily mean water temperature on the Trinity River and 7DADM on the Klamath River were calculated across all years of available data (historical data was not infilled prior to 2019). These values provided the context (mean and range of observed values) for which to compare 2020 and 2021 water temperature. The number of days that exceeded the associated water temperature criteria were calculated for each focal monitoring location in each year. The highest and lowest of these annual values for each site are referred to as the historical range of criteria exceedance. If the observed data at a site prior to 2019 (not infilled) was incomplete during the period over which the criteria was applied, the calculations were reported, but not included in the historical ranges for that water year.

Finally, for each focal location's criteria, the historical average, minimum, and maximum number of days exceeding the associated water temperature criteria across all years were calculated. All analyses were performed using R software for statistical computing (R Core Team 2023).

## 3. Results

### 3.1. Trinity River

On the Trinity River, gaps in water temperature data were filled using data collected by USGS at the Trinity River Douglas City (TRDC) site for 81 days in WY 2020 (5/01/2020 to 7/28/2020) and 10 days in WY 2021 (10/11/2020 to 10/20/2020).

Water years 2020 and 2021 were designated as 'Critically Dry' on the Trinity River. In WY 2020, daily average water temperature surpassed the maximum of historic daily averages for 0 days at TRBL, 34 days at TRDC, 41 days at TRNF, and 30 days at TRWE (Figure 2a). During this period there were temperature criteria exceedances at two of three focal sites with established criteria. Daily criteria were exceeded for a total of 37 days at TRDC, 0 days at TRNF, and 38 days at TRWE (Table 4a; Figure 2a). The number of days criteria were exceeded in 2020 was more than the historical mean number of days exceeded at TRDC for the 15.6 ℃ criteria (6.4 days, Appendix A), but not the 13.3 ℃ criteria (1.3 days, Appendix A). The historical average was also exceeded at TRWE for the 17 ℃ (5.3 days, Appendix A) and 20 ℃ (17.4 days, Appendix A) temperature criteria periods, but not the 15 ℃ (8.5 days, Appendix A) temperature criteria period. No criteria were exceeded at TRNF in 2020. The upper historical range of 26 days exceedance for the 15.6 ℃ criteria at TRDC was surpassed with 37 days exceedance in 2020 (Appendix A).

In WY 2021, daily average water temperature surpassed the maximum of historic daily averages for 1 day at TRBL, 55 days at TRDC, 47 days at TRNF, and 45 days at TRWE (Figure 2b). During this period there were temperature criteria exceedances at all three focal sites with established criteria. Daily criteria were exceeded for a total of 23 days at TRDC, 3 days at TRNF, and 52 days at TRWE (Table 4b; Figure 2b). In 2021, the daily average water temperature at TRDC exceeded the 15.6 ℃ criteria for a duration of 23 days, surpassing the average of 8.2 days observed in previous years (Appendix A). The 13.3 ℃ criteria for TRDC was not exceeded in 2021, the historical average of exceedance days at this site is 1.3 (Appendix A).

The historical average of 4.4 days for the 13.3 ℃ criteria at TRNF was not exceeded (Appendix A). At TRWE the water temperature criteria were exceeded for all three periods. Criteria were exceeded for 17 days surpassing the 8.5 historical average, 10 days surpassing the 5.6 average, and 25 days surpassing the 17.6 average for the 15 ℃, 17 ℃, and 20℃ criteria respectively (Appendix A). The upper historical range of temperature criteria exceedances was not surpassed at any sites in 2021 (Appendix A).

Table 4a. Number of days that exceeded water temperature criteria in water year (WY) 2020 (deemed "Critically Dry") at focal sites on the Trinity River. Periods where no management criteria were identified for the site are indicated with NC for no criteria

| Criteria Location | Location Code | 4/1-5/22 15°C | 5/23-6/4 17°C | 6/5-7/9 20°C | 10/1-12/31 13.3°C | 7/1-9/14 15.6°C | 9/15-9/30 13.3°C |
|---|---|---|---|---|---|---|---|
| Douglas City | TRDC | NC | NC | NC | NC | 37 | 0 |
| North Fork | TRNF | NC | NC | NC | 0 | NC | NC |
| Weitchpec (above KR) | TRWE | 8 | 10 | 20 | NC | NC | NC |

Table 4b. Number of days that exceeded water temperature criteria in water year (WY) 2021 (deemed "Critically Dry") at focal sites on the Trinity River. Periods where no management criteria were identified for the site are indicated with NC for no criteria.

| Criteria Location | Location Code | 4/1-5/22 15°C | 5/23-6/4 17°C | 6/5-7/9 20°C | 10/1-12/31 13.3°C | 7/1-9/14 15.6°C | 9/15-9/30 13.3°C |
|---|---|---|---|---|---|---|---|
| Douglas City | TRDC | NC | NC | NC | NC | 23 | 0 |
| North Fork | TRNF | NC | NC | NC | 3 | NC | NC |
| Weitchpec (above KR) | TRWE | 17 | 10 | 25 | NC | NC | NC |

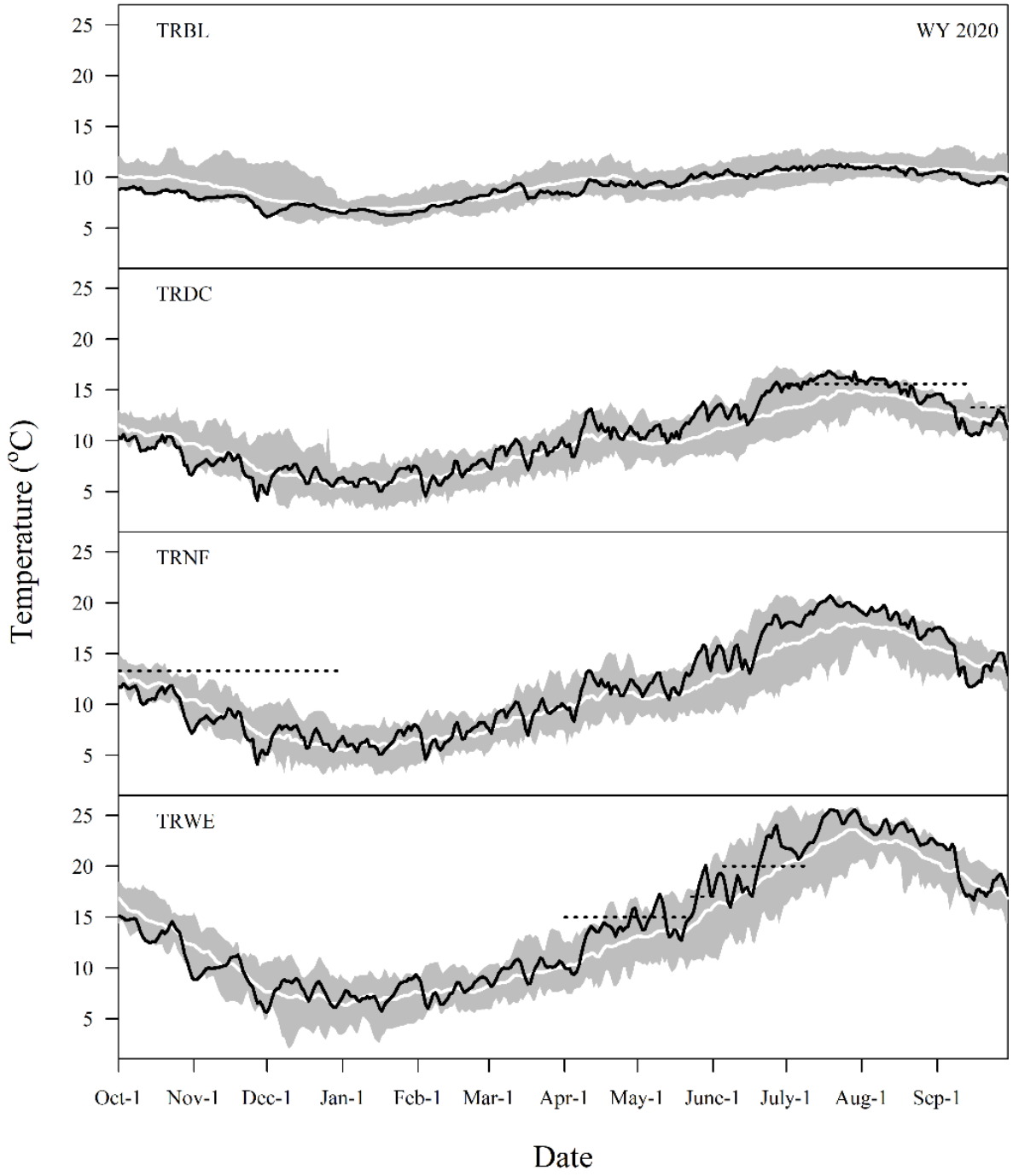


Figure 2a. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2019 – September 30, 2020, with historical summaries from water years (WYs) 2002 to 2019. Black line = daily mean water temperature in 2020; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature criteria.

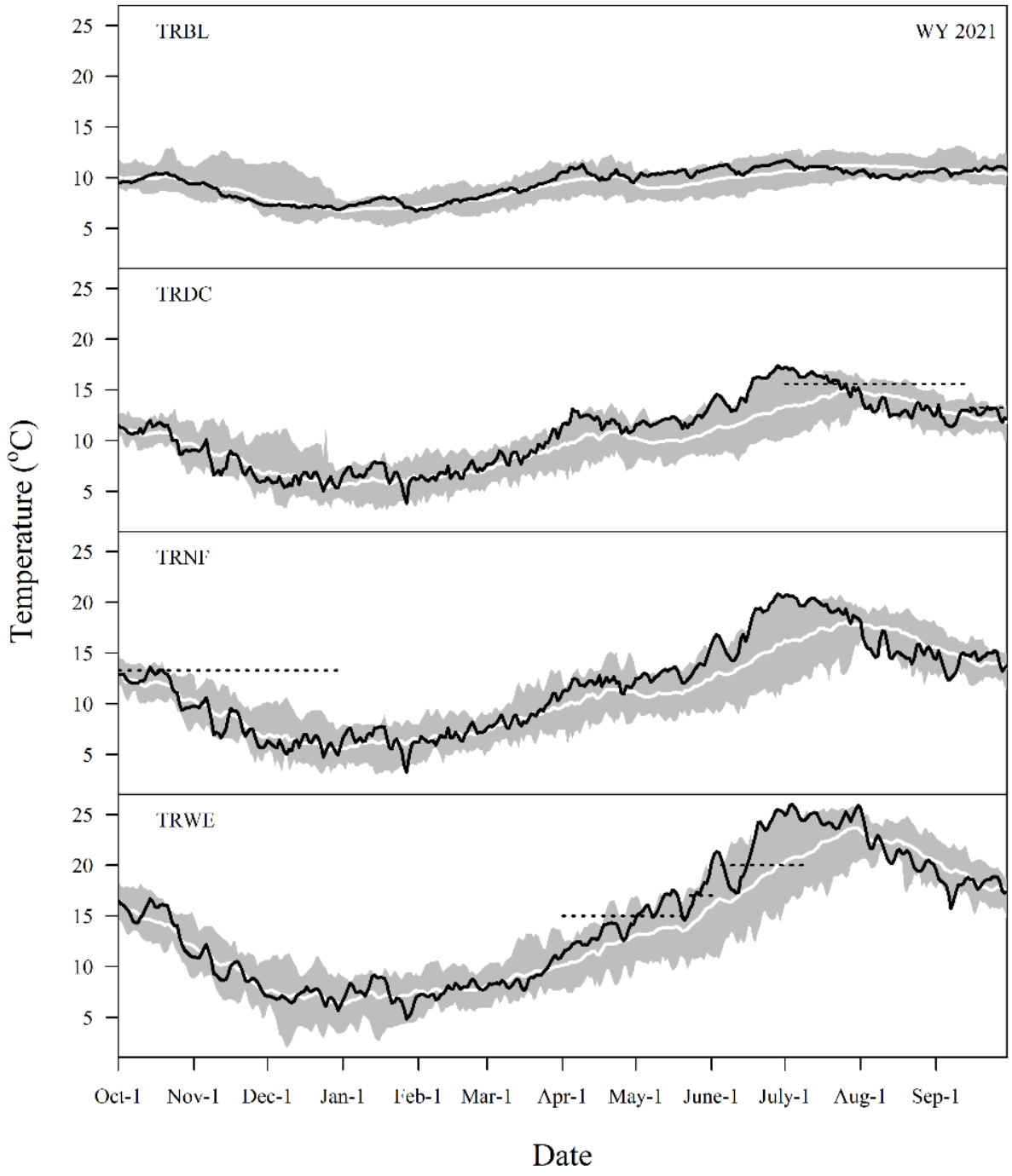


Figure 2b. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2020 – September 30, 2021, with historical summaries from water years (WYs) 2002 to 2020. Black line = daily mean water temperature in 2021; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature criteria.

Water temperature criteria for juvenile salmonids in WY 2020, evaluated April 1 through July 9, was exceeded in all three periods at the Trinity River at Weitchpec Site (TRWE; Table 4a). Daily mean water temperature exceeded 15 ℃ for 8 of 52 days, 17 ℃ for 10 of 13 days, and 20 ℃ for 20 of 35 days (Table 4a) at TRWE. The adult holding and spawning criterion was exceeded for one out of two periods at TRDC (Table 4a). Daily mean water temperature exceeded the 15.6 ℃ criteria during the period July 1 through September 14 for 37 of 77 days. The 13.3 ℃ criterion was not exceeded at TRNF during the 92-day period, October 1, 2019, through December 31, 2019 (Table 4a).

Juvenile salmonoid water temperature criteria in WY 2021, evaluated April 1 through July 9, was exceeded in two of three periods at TRWE (Table 4b). Daily mean water temperature exceeded 15 ℃ for 17 of 52 days, 17 ℃ for 10 of 13 days, and 20 ℃ for 25 of 35 days (Table 4b). The adult holding and spawning criterion was exceeded for one out of two periods at TRDC (Table 4b). Daily mean water temperature exceeded the 15.6 ℃ criteria during the period July 1 through September 14 for 23 of 77 days, and 13.3 ℃ for 0 of 16 days from September 15 through September 30. During the 13.3 ℃ criterion period, October 1, 2020, through December 31, 2020, daily mean water temperature exceeded 13.3 ℃ for 3 of 92 days at TRNF (Table 4b).

Water years 2020 and 2021 on the Trinity River were both forecasted and observed to be "Critically Dry" (TRRP 2020, TRRP 2021). The 23 ℃ criterion was not exceeded at TRBL, located just below Lewiston Dam (Figure 3a, Figure 3b) in either 2020 or 2021. This criterion was exceeded for extended periods on the Trinity River at TRWE in both 2020 and 2021. In 2020 there were three days at TRWE that exceeded the 23 ℃ criterion in late June. Daily mean water temperature dropped below the 23 ℃ threshold until July 14, 2021, and continued to exceed criteria until late August for 41 days (Figure 3a). Except for water released in early September to aid salmonids in the lower river, all other discharges were based on the standard TRRP hydrograph planning process for WY 2020 (TRRP 2020; Figure 3a). The highest instantaneous discharge was reported on April 24, 2020, with a peak discharge of approximately 3,900 cfs (TRRP 2020). Despite several occasions where the 23 ℃ criterion was exceeded at TRWE (Figure 3a), an emergency release of supplemental water was not triggered from Lewiston Dam in 2020.

In WY 2021, water was released from April 16$^{th}$ to May 1$^{st}$ for restoration on the Trinity River, September 2$^{nd}$ to September 10$^{th}$ for the culturally significant Hoopa Valley Tribe Boat Dance Ceremony, and an emergency release of 1,365 Acre Feet (AF) of water from Lewiston Reservoir intended to lower water temperature at Hoopa from August 8$^{th}$ to August 4$^{th}$ (TRRP 2021). Prior to the release in August, criteria were exceeded on the Trinity River at TRWE starting in late June and continuing through early-August for 45 days (Figure 3b). After the August release, the 23 ℃ criterion was not exceeded for the remainder of WY 2021. The highest instantaneous discharge for WY 2021 was reported on April 28, 2021, reaching approximately 4,070 cfs (TRRP 2021). The Hoopa Valley Tribe Boat Dance Ceremony flow release involved 16,110 AF of water starting September 2 (TRRP 2021). Flows peaked at 2,710 cfs on September 6, before returning to summer baseflow (450 cfs) on September 10 (TRRP 2021). After the September flow release water temperature declines sharply on the Trinity River upstream of the confluence with the Klamath River (TRWE) and on the Klamath River downstream of the confluence with the

Trinity River at the site above Blue Creek (KRBW), as well as a small decrease on the Klamath River upstream of the ocean (KRTG; Figure 3b).

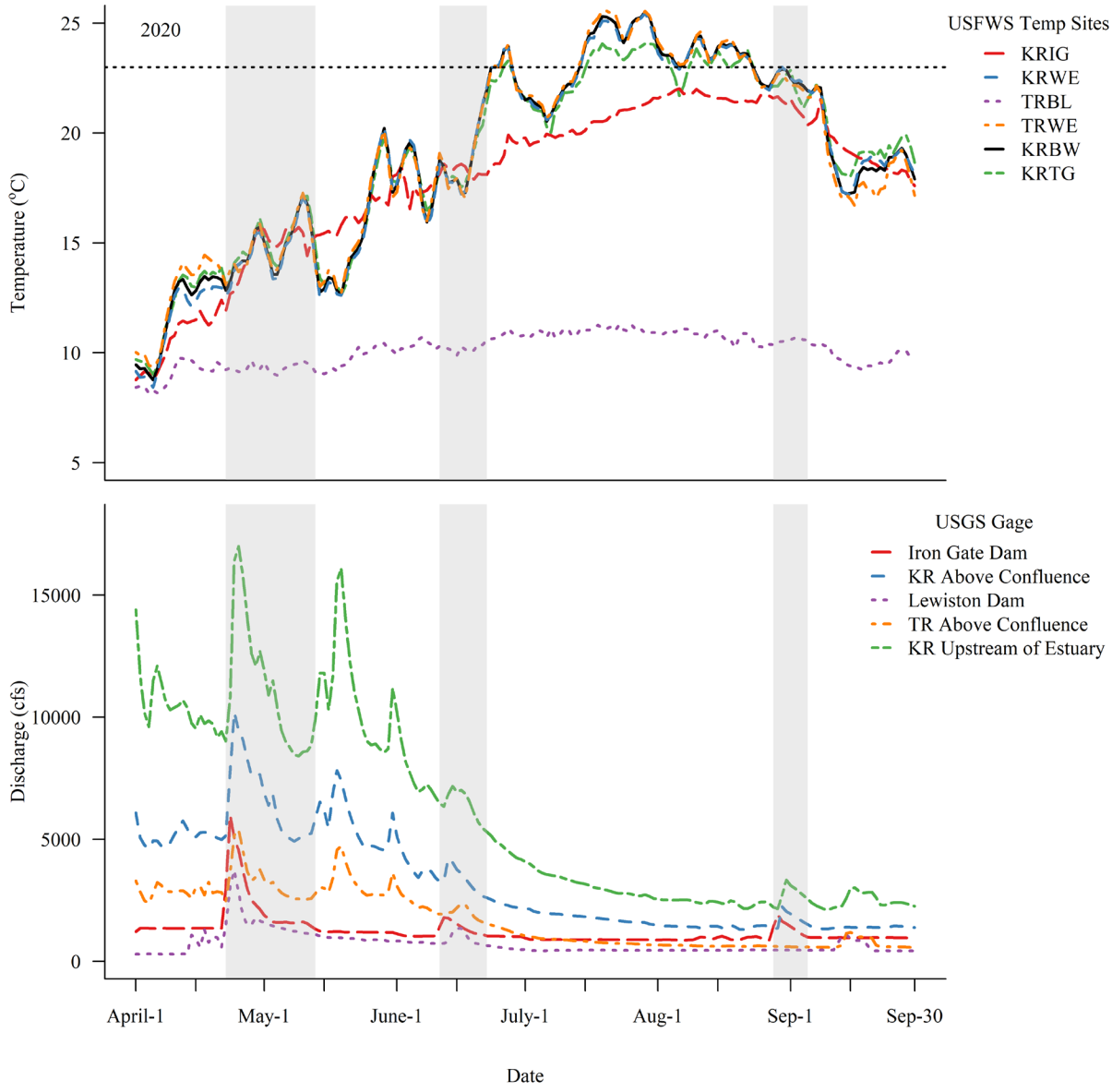


Figure 3a. River discharge (cfs) at five locations and daily mean water temperature (°C) at six locations in the Klamath River (KR) and Trinity River (TR) before, during, and after supplemental releases from Trinity Reservoir and Iron Gate Dam, April 1 – September 30, 2020. Gray shading indicates periods of supplemental flow release. Horizontal dotted black line on the top graph represents 23°C. U.S. Fish and Wildlife Service water temperature monitoring sites are just downstream of U.S. Geological Survey gages recording flows.

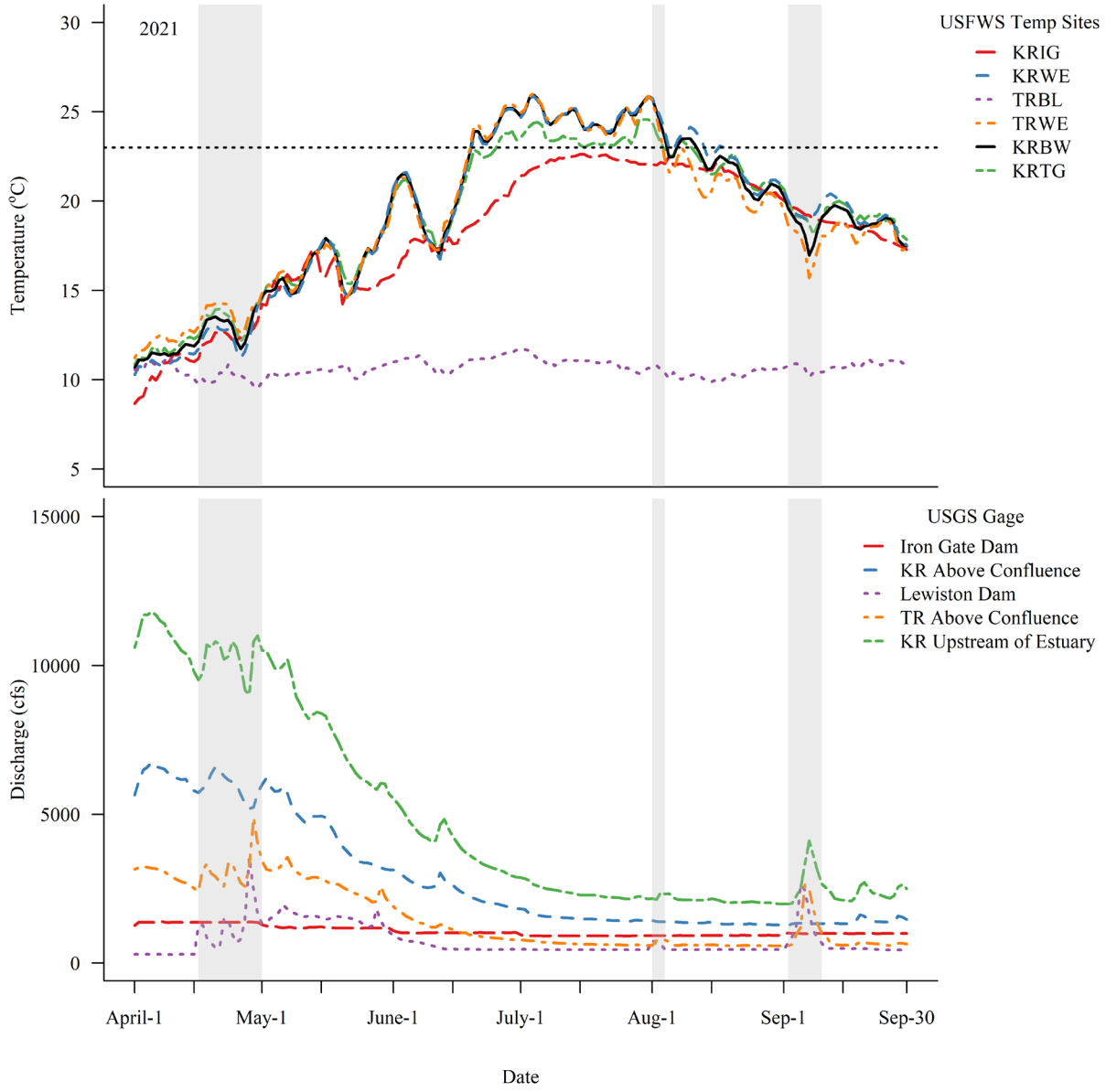


Figure 3b. River discharge (cfs) at five locations and daily mean water temperature (°C) at six locations in the Klamath River (KR) and Trinity River (TR) before, during, and after supplemental release from Trinity Reservoir and Iron Gate Dam, April 1 – September 30, 2021. Gray shading indicates periods of supplemental flow release. Horizontal dotted black line on the top graph represents 23°C criteria. U.S. Fish and Wildlife Service water temperature monitoring sites are just downstream of U.S. Geological Survey gages recording flows.

### 3.2. Klamath River

On the Klamath River, USFWS water temperature data gaps at Below Iron Gate Dam (KRIG) site for WY 2020 were filled from a nearby PacifiCorp monitoring site for 17 days (7/13/2020 to 07/29/2020).

For WY 2021, USFWS water temperature data gaps at the Klamath River USFWS site below Happy Camp (KRHC) site were filled from a nearby site monitored by the U.S. Forest Service for 2 days (7/26/2021 to 7/27/2021).

In WY 2020, the number of days exceeding the spawning, incubation, and emergence EPA 13.0 ℃ 7DADM criterion at focal Klamath River monitoring sites ranged from 30 days at KRHC, to 45 days at KRTG (Table 5a; Figure 4a; Appendix C). The number of days exceeding the juvenile rearing EPA 16.0 ℃ 7DADM criteria ranged from 129 days at KRWE, to 137 days at KRSC (Table 5a; Figure 4a; Appendix C). The number of days exceeding the adult migration EPA 20.0 ℃ 7DADM criteria ranged from 60 days at KRIG, to 83 days at KRSC and KRHC (Figure 4a; Table 5a; Appendix C).

In WY 2021, the number of days exceeding the spawning, incubation, and emergence EPA 13.0 ℃ 7DADM criterion at focal Klamath River monitoring sites ranged from 26 days at KRHC and KRWE, to 40 days at KRTG (Table 5b; Figure 4b; Appendix C). The number of days exceeding the juvenile rearing EPA 16.0 ℃ 7DADM criterion ranged from 130 days at KRIG, to 148 days at KRSC (Table 5b; Figure 4b; Appendix C). The number of days exceeding the adult migration EPA 20.0 ℃ 7DADM criteria ranged from 68 days at KRIG, to 89 days at KRHC (Table 5b; Figure 4b; Appendix C).

In WY 2020, the historical range of criteria exceedance was not exceeded at any site for any of the criteria (Appendix C), however the lowest number of days exceedance was matched at KRIG for the 20.0 ℃ 7DADM criterion (same as 2010 for 60 days). For the 20.0 ℃ 7DADM criterion, the number of days exceeded were above their respective historical averages at all sites except KRIG (Appendix C). The number of days exceeded were above their respective historical averages at all sites for both the 13.0 ℃ 7DADM and 16.0 ℃ 7DADM criteria (Appendix C). 7DADM water temperature surpassed the maximum 7DADM historical range for 8 days at KRIG, 2 days at KRSC, 3 days at KRHC, 12 days at KRWE, and 16 days at KRTG (Figure 4a).

No site exceeded the historical range of water temperature criteria for either the 13.0 ℃ 7DADM or 20.0 ℃ 7DADM criteria (Appendix C) in WY 2021. However, the historical range was exceeded for the 16.0 ℃ 7DADM criterion at KRTG (144 days) and matched at KRSC (same as 2018 for 148 days; Appendix C). The number of days exceeding the 20.0 ℃ 7DADM criterion were above their respective historical averages at KRHC, KRWE, and KRTG (Appendix C). The number of days exceeding the 16.0 ℃ 7DADM criterion were above their respective historical averages at KRSC, KRHC, KRWE, and KRTG (Appendix C). The number of days exceeding the 13.0 ℃ 7DADM criterion were above their respective historical averages at KRIG, KRSC, KRHC, and KRTG (Appendix C). 7DADM water temperatures surpassed the maximum 7DADM historical range for 12 days at KRIG and KRSC, 21 days at KRHC, 32 days at KRWE, and 41 days at KRTG (Figure 4b).

In WY 2020 the mean daily water temperature reached or exceeded the 23 ℃ criterion at all sites except KRIG below Iron Gate Dam (Figure 3a). This criterion was exceeded for 44

days immediately upstream of the Trinity River confluence with the Klamath at KRWE, 44 days just below the confluence of the Klamath and Trinity rivers at KRBW, and 35 days upstream of the estuary at KRTG (Figure 3a). Exceedances began in late June and continued through late August. Daily mean water temperature at KRBW briefly decreased at the end of June, before increasing July 16$^{th}$ (Figure 3a).

Throughout WY 2021, water temperature recorded at KRIG on the Klamath River below Iron Gate Dam never reached or exceeded the threshold of 23 ℃ (Figure 3b). This criterion was exceeded for 54 days immediately upstream of the Trinity River confluence with the Klamath at KRWE, 44 days just below the confluence of the Klamath and Trinity rivers at KRBW, and 43 days upstream of the estuary at KRTG (Figure 3b). Exceedances began in late June and continued through mid-August (Figure 3b).

Table 5a. Number of days exceeding the Environmental Protection Agency's seven-day average daily maximum (7DADM) temperature criterion for Pacific Northwest water temperature to protect Pacific salmonids, at Klamath River focal monitoring sites in 2020.

| Location code | 13.0°C 7DADM | 16.0°C 7DADM | 20.0°C 7DADM |
|---|---|---|---|
| KRIG | 32 | 132 | 60 |
| KRSC | 34 | 137 | 83 |
| KRHC | 30 | 134 | 83 |
| KRWE | 32 | 129 | 82 |
| KRTG | 45 | 131 | 82 |

Table 5b. Number of days exceeding the Environmental Protection Agency's seven-day average daily maximum (7DADM) temperature criterion for Pacific Northwest water temperature to protect Pacific salmonids, at Klamath River focal monitoring sites in 2021.

| Location code | 13.0°C 7DADM | 16.0°C 7DADM | 20.0°C 7DADM |
|---|---|---|---|
| KRIG | 36 | 130 | 68 |
| KRSC | 35 | 148 | 80 |
| KRHC | 26 | 138 | 89 |
| KRWE | 26 | 137 | 88 |
| KRTG | 40 | 144 | 83 |

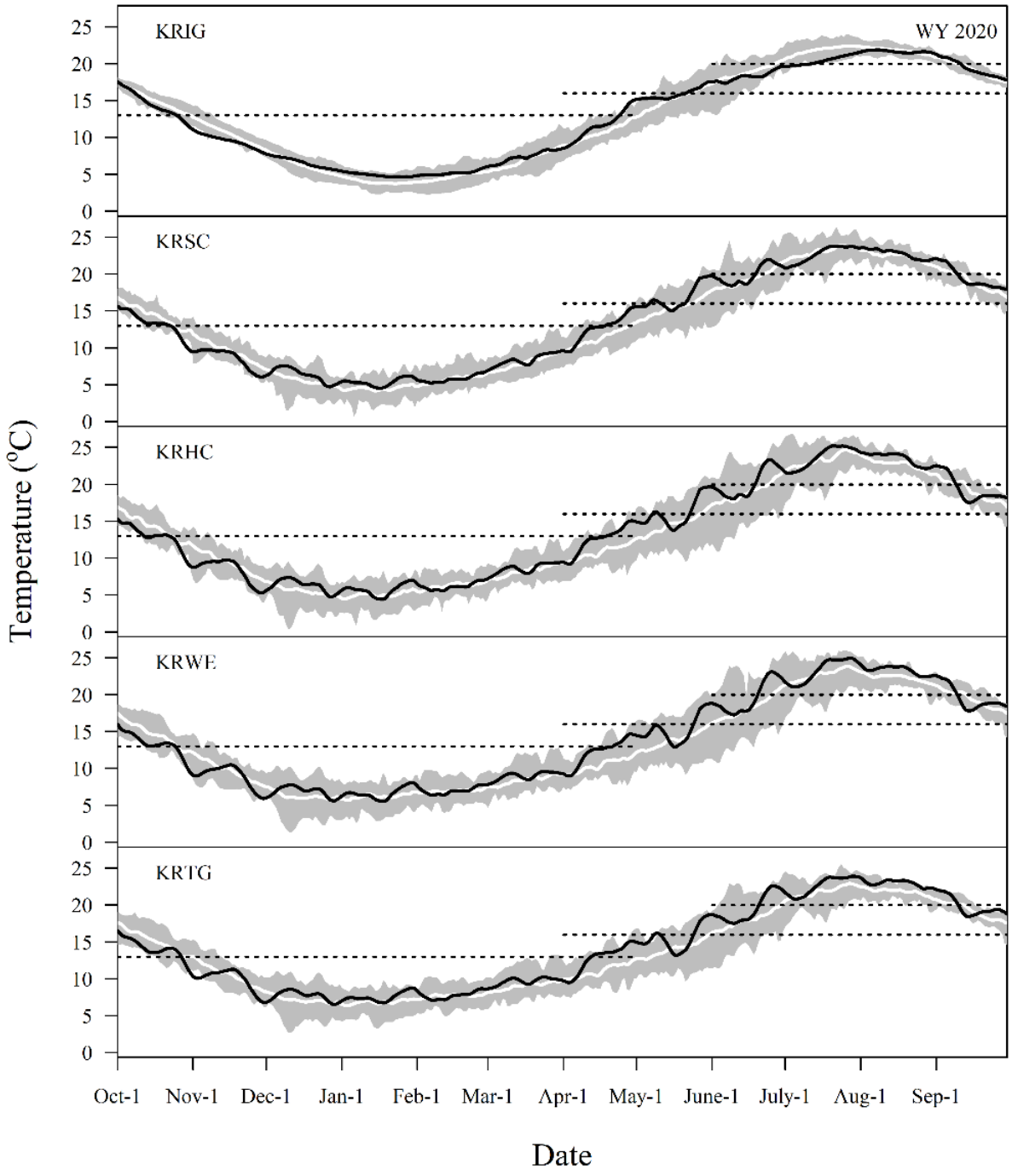


Figure 4a. Seven-day average daily maximum temperature (7DADM) at focal Klamath River monitoring sites, October 1, 2019 – September 30, 2020, with historical summaries from water years (WYs) 2001 to 2019. Black line = 7DADM water temperatures in 2020; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = EPA Pacific Northwest water temperature criteria.

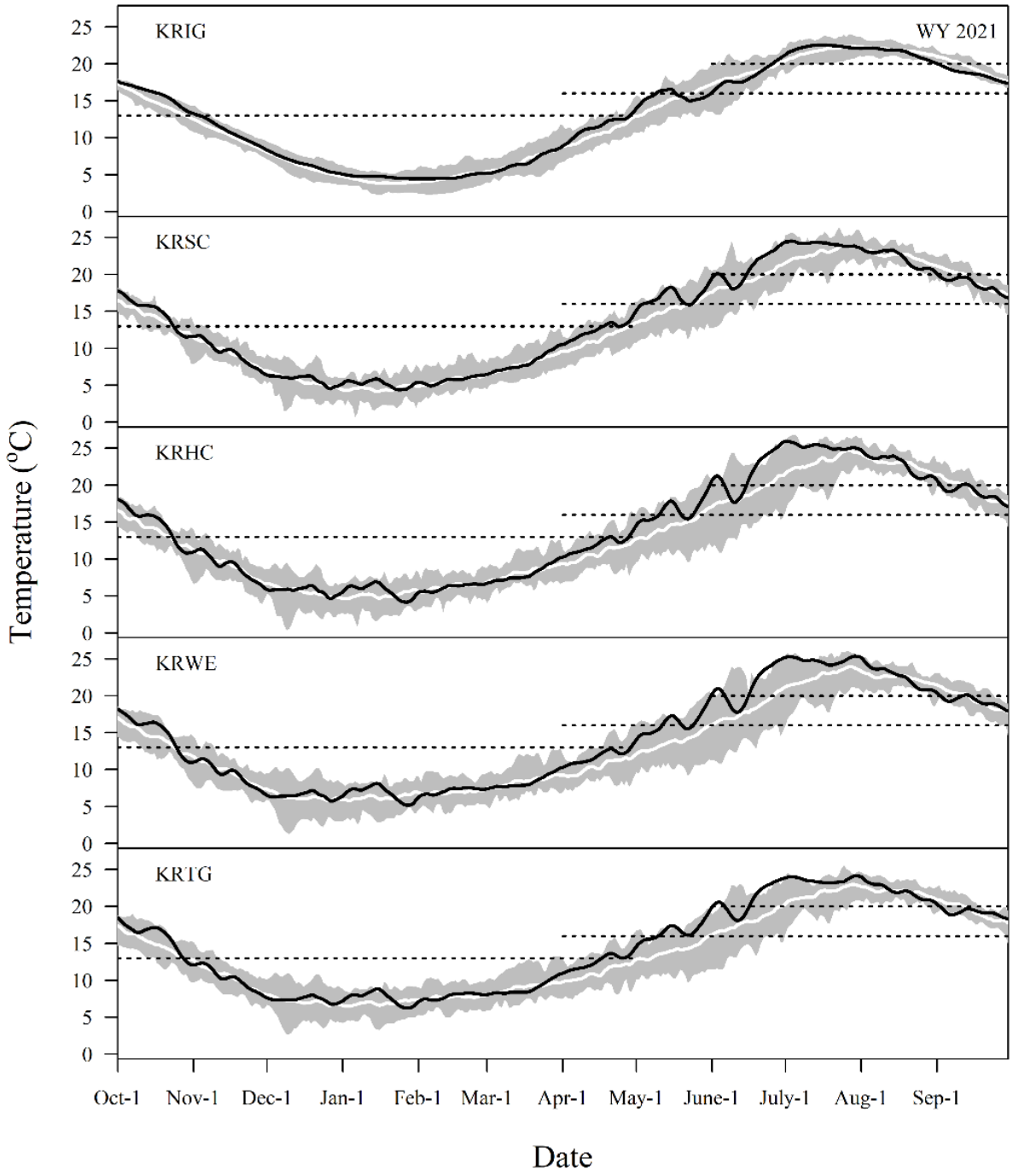


Figure 4b. Seven-day average daily maximum temperature (7DADM) at focal Klamath River monitoring sites, October 1, 2020 – September 30, 2021, with historical summaries from water years (WYs) 2001 to 2020. Black line = 7DADM water temperatures in 2021; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = EPA Pacific Northwest water temperature criteria.

In 2020, daily mean discharge observed at USGS gage 11516530, directly below Iron Gate Dam, increased noticeably due to a rain event in late January and early February. Discharge dropped back down until the Bureau of Reclamation implemented a flushing flow, from April 22nd to May 13th, peaking at just over 6,000 cfs on April 23rd. An augmentation flow was implemented from June 11th to June 22nd, reaching close to 2,000 cfs. Discharge increased again when water was released for the Yurok Tribe Boat Dance Ceremony from August 28th through September 5th.

Discharge remained low in WY 2021, with no water management actions taken to release water from Iron Gate Dam. The highest daily mean discharge observed at USGS gage 11516530, directly below Iron Gate Dam, occurred in April and did not exceed 1,500 cfs for the remainder of the WY.

## 4. Discussion

The TRRP and Trinity Management Council (TMC) based their annual water release schedule recommendation on the California Department of Water Resources' forecasted WY type as "Critically Dry" in 2020 and 2021 (TRRP 2020; TRRP 2021). The monthly volume of discharge out of Lewiston Dam was two to four times lower in April through July in 2020 and 2021, relative to 2019. In August and September, discharge was low but similar to releases in 2019 (CDEC 2023a).

In 2020, the Trinity River (Table 2) surpassed the water temperature criteria more frequently than in 2019. This was observed during one of the two periods at TRDC and one of three periods at TRWE. The water temperature criteria were surpassed the same number of days for both years during one period at TRWE (Appendix A). In 2021, the Trinity River experienced a higher number of days surpassing the water temperature criteria (Table 2) compared to 2019. This was observed for one of the two periods at TRDC, and for all three periods at TRWE (Appendix A). The 2019 WY was designated as "Wet" resulting in lower water temperatures used for stricter criteria at TRWE. Even with more strict criteria being applied in 2019, criteria at TRWE were exceeded more times in 2020 and 2021 than in 2019. The total number of days criteria were exceeded at TRDC in 2020 (37 days) and 2021 (23 days) was greater than the total number of days at TRDC (4 days) in 2019. The number of exceedances at TRNF and TRWE in WY 2020 and 2021 were similar to WY 2019, except for WY 2020 had lower numbers of exceedance during the first period at TRWE than in 2019 or 2021.

The monthly volume of Iron Gate Dam discharge peaked in April for both the 2020 WY (120,200 acre-feet [AF]) and 2021 WY (81,562 AF; CDEC 2023b). Discharge for the remainder of the year were similar in 2020 and 2021, but much lower than in WY 2019. Discharge in 2021 was similar to 2020, but about 10,000 AF lower in May and June (CDEC 2023b). Discharge during the months of July through September were comparable to previous years on the Klamath River.

Although the 23 ℃ supplemental flow criterion was exceeded at multiple sites in the Klamath Basin, there were no emergency releases from Iron Gate or Lewison dams in 2020. All major flow events taking place during adult migration were for the Yurok Tribe Boat Dance Ceremony or natural events. In 2021 there was an emergency release in August out of Lewiston Dam. The 23 ℃ supplemental flow criterion was exceeded around the same

time, mid-June in 2020 and 2021, but in WY 2020 temperatures decreased until mid-July, while daily mean water temperature in WY 2021 continued to exceed the criterion. While there were no flow events or rain that would have contributed to the decrease in water temperature in July 2020 (PRISM 2023), there was a decrease in air temperature. This could be a result solar radiation being filtered by smoke from surrounding fires.

Water released from Iron Gate Dam to the lower Klamath River, for the Yurok Tribe Boat Dance Ceremony on September 11, 2020, caused a sharp, but brief decrease in water temperature at KRIG, KRSC, KRHC, KRWE, KRTG, and KRBW (Figure 3a). In 2021 the Hoopa Valley Boat Dance Ceremony occurred on the Trinity River (Figure 3b).

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## 6. Literature Cited

Armstrong, J.B., A.H. Fullerton, C.E. Jordan, J.L. Ebersole, J.R. Bellmore, I. Arismendi, B.E. Penaluna, and G.H. Reeves. 2021.The importance of warm habitat to the growth regime of cold-water fishes. Nature Climate Change 11:354–361.

Baker, P.F., T.P. Speed, and F.K. Ligon. 1995. Estimating the influence of temperature on the survival of Chinook salmon smolts (*Oncorhynchus tshwaytscha*) migrating through the Sacramento – San Joaquin River Delta of California. Canadian Journal of Fisheries and Aquatic Sciences 52:855–863.

Bartholow, J.M. 2005. Recent water temperature trends in the lower Klamath River, California. North American Journal of Fisheries Management 25:152–162.

Belchik, M., D. Hillemeir, and R.M. Pierce. 2004. The Klamath River fish kill of 2002; analysis of contributing factors. Yurok Tribal Fisheries Program.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Publication. 19:83-138.

Brett, J.R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon (*Oncorhynchus nerka*). American Zoologist 11:99–113.

Caissie, D. 2006. The thermal regime of rivers: A review. Freshwater Biology 51:1389–1406.

Carter, K. 2006. The effects of temperature on steelhead trout, Coho salmon, and Chinook salmon biology and function by life stage: Implications for Klamath basin TMDLs. California Regional Water Quality Control Board, North Coast Region.

(CDEC) California Department of Water Resources. 2023a. Accessed August 28, 2023. https://cdec.water.ca.gov/dynamicapp/QueryWY?Stations=TNL&SensorNums=66&End=2022-05-04&span=20+years.

(CDEC) California Department of Water Resources. 2023b. Accessed August 28, 2023. https://cdec.water.ca.gov/dynamicapp/QueryWY?Stations=KLI&SensorNums=66&End=2022-05-04&span=20+years.

Dunham, J., G. Chandler, B. Rieman, and D. Martin. 2005. Measuring stream temperature with digital data loggers: A user's guide. U.S.D.A. Forest Service, Rocky Mountain Research Station. General Technical Report RMRS-GTR-150WWW.

Goniea, T.M., M.L. Keefer, T.C. Bjornn, C.A. Perry, D.H. Bennett, and L.C. Stuehrenberg. 2006. Behavioral thermoregulation and slowed migration by adult fall Chinook salmon in response to high Columbia River water temperatures. Transactions of the American Fisheries Society 135:408–419.

Guillen, G. 2003. Klamath River fish die-off, September 2002: causative factors of mortality. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Report Number AFWO-F-02-03.

Hallock, R.J., Elwell, R.F., and D.H. Fry. 1970. Migrations of adult king salmon Oncorhynchus tshawytscha in the San Joaquin Delta as demonstrated by the use of sonic tags. State of California, Department of Fish and Game.

Harmon, R., J.S. Foott, K. Nichols, J. Faukner, and B. McCasland. 2001. Physiological responses of juvenile Chinook Salmon held in the lower Klamath River and thermal refugia (June-August 2000). U.S. Fish and Wildlife Service, California-Nevada Fish Health Center.

Heming, T.A. 1981. Effects of temperature on utilization of yolk by Chinook Salmon (*Oncorhynchus tshawytscha*) eggs and alevins. Canadian Journal of Fisheries and Aquatic Science 39:184–190.

Hester, E.T., and M.W. Doyle. 2011. Human impacts to river temperature and their effects on biological processes: a quantitative synthesis. Journal of the American Water Resources Association 47(3):571–587.

Hetrick, N., and J. Polos. 2015. Response to request for technical assistance regarding 2015 fall flow release. USFWS Memorandum to Federico Barajas, U.S. Bureau of Reclamation Northern California Area Manager.

Jones, E.C., R.W. Perry, J.C. Risley, N.A. Som, and N.J. Hetrick. 2016. Construction, calibration, and validation of the RBM10 water temperature model for the Trinity River, northern California. U.S. Geological Survey Open-File Report 2016-1056.

(KRBFTF) Klamath River basin Fisheries Task Force. 1991. Long range plan for the Klamath River basin conservation area fishery restoration program.US Fish and Wildlife Service, Klamath River Fishery Resource Office.

Lagomarsino, I., and N.J. Hetrick. 2013. 2013 fall flow release recommendation. Joint USFWS/NOAA Memorandum to Brian Person, U.S. Bureau of Reclamation Northern California Area Manager.

Leidy, R.A., and G.R. Leidy. 1984. Life stage periodicities of anadromous salmonids in the Klamath River basin, northwestern California. U.S. Fish and Wildlife Service, Department of Ecological Services, Sacramento, California.

Magneson, M.D. 2015. Klamath River flow and water temperature, water year 2012. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2015-42, Arcata, California.

Marine, K.R., and J.J. Cech Jr. 2004. Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook Salmon. North American Journal of Fisheries Management 24:198–210.

McCullough, D.A. 1999. A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to Chinook salmon. Prepared for the U.S. Environmental Protection Agency Region 10, Seattle, Washington. EPA 910-R-99-010.

Moyle, P.B., J.A. Israel, and S.E. Purdy. 2008. Salmon, steelhead, and trout in California: status of emblematic fauna. UC Davis Center for Watershed Sciences.

Moyle, P.B., J.V.E. Katz, and R.M. Quiñones. 2011. Rapid decline of California's native inland fishes: a status assessment. Biological Conservation 144:2414–2423.

[NAS] National Academy of Sciences. 2004. Endangered and threatened fishes in the Klamath River basin: Causes of decline and strategies for recovery. Committee on Endangered and Threatened Fishes in the Klamath River basin. National Academy Press.

(NCRWQCB) North Coast Regional Water Quality Control Board. 2010. Final staff report for the Klamath River total maximum daily loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California. Santa Rosa, California.

Olden, J.D., and R.J. Naiman. 2010. Incorporating thermal regimes into environmental flows assessments: modifying dam operations to restore freshwater ecosystem integrity. Freshwater Biology 55:86–107.

Paulson, R.W., E.B. Chase, J.S. Williams, and D.W. Moody. 1985. National Water Summary 1990-91: Hydrologic events and stream water quality. U.S. Geological Survey Water – Supply Paper 2400:578–585.

Perry, R.W., J.C. Risley, S.J. Brewer, E.C. Jones, and D.W. Rondorf. 2011. Simulating daily water temperatures of the Klamath River under dam removal and climate change scenarios. U.S. Geological Survey Open-File Report 2011-1243.

Perry, R.W., J.M. Plumb, E.C. Jones, N.A. Som, N.J. Hetrick, and T.B. Hardy. 2018. Model structure of the stream salmonid simulator (S3)— A dynamic model for simulating

growth, movement, and survival of juvenile salmonids. U.S. Geological Survey Open-File Report 2018-1056.

Pinheiro J., D. Bates, S. DebRoy, D. Sarka, and R Core Team. 2017. nlme: Linear and nonlinear mixed effects models. R package version 3.1-131.

Polos, J. 2016. Adult salmon water temperature targets. Trinity River Restoration Program Performance Measure. Trinity River Restoration Program.

Poole, G.C., and C.H. Berman. 2001. An ecological perspective on in-stream temperature: Natural heat dynamics and mechanisms of human-caused thermal degradation. Environmental Management 27:787–802.

PRISM Climate Group, Oregon State University. 2023. Accessed September 15, 2023. https://prism.oregonstate.edu/explorer/

R Core Team. 2023 RStudio: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Ray, R.A., R.W. Perry, N.A. Som, and J.L. Bartholomew. 2014. Using cure models for analyzing the influence of pathogens on salmon survival. Transactions of the American Fisheries Society 143:387–398.

Richter, A., and S.A. Kolmes. 2005. Maximum temperature limits for Chinook, Coho, and chum salmon, and steelhead trout in the Pacific Northwest. Reviews in Fisheries Science 13:23–49.

Shaw, T.A., C. Jackson, D. Nehler, and M. Marshall. 1997. Klamath River (Iron Gate Dam to Seiad Creek) life stage periodicities for Chinook, Coho, and steelhead. U.S. Fish and Wildlife Service, Costal California Fish and Wildlife Office, Arcata, California.

Som, N.A., and N.J. Hetrick. 2017. Response to request for technical assistance – Predictive model for estimating 80% outmigration threshold of natural juvenile Chinook salmon past the Kinsman trap site, Klamath River. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Technical Memorandum.

Strange, J.S. 2010. Upper thermal limits to migration in adult Chinook salmon: Evidence from the Klamath River Basin, transactions of the American Fisheries Society, 139:4, 1091–1108, DOI: 10.1577/T09-171.1.

Sullivan, K., D.J. Martin, R.D. Cardwell, J.E. Toll, and S. Duke. 2000. An analysis of effects of temperature on salmonids of the Pacific Northwest with implications for selecting temperature criteria. Sustainable Ecosystems Institute, Portland Oregon.

(TRRP) Trinity River Restoration Program. 2012. 2012 fall flow release recommendation. Memorandum to Brian Person, U.S. Bureau of Reclamation Northern California Area Manager.

(TRRP) Trinity River Restoration Program. 2020. Trinity River Restoration Program 2020 Annual Report. Trinity River Restoration Program, Weaverville, California.

(TRRP) Trinity River Restoration Program. 2021. Trinity River Restoration Program 2021 Annual Report. Trinity River Restoration Program, Weaverville, California.

Turek, S., M. Rode, B. Cox, G. Heise, W. Sinnen, C. Reese, S. Borok, M. Hampton, and C. Chun. 2004. September 2002 Klamath River fish-kill: Final analysis of contributing factors and impacts. California Department of Fish and Game.

(USDOI) U.S. Department of the Interior. 2000. Record of decision Trinity River mainstem fishery restoration, final environmental impact statement/environmental impact report.

(USDOI et al.) U.S. Department of the Interior, U.S. Department of Commerce, and National Marine Fisheries Service. 2013. Klamath dam removal overview report for the Secretary of the Interior an assessment of science and technical information, Version 1.1, March 2013.

(USEPA) U.S. Environmental Protection Agency. 2003. EPA Region 10 guidance for Pacific Northwest state and tribal temperature water quality standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, Washington.

(USFWS and HVT) U.S. Fish and Wildlife Service and Hoopa Valley Tribe. 1999. Trinity River flow evaluation, final report.

(USFWS et al.) U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, Hoopa Valley Tribe, and Trinity County. 2000. Trinity River mainstem fishery restoration, final environmental impact statement/report.

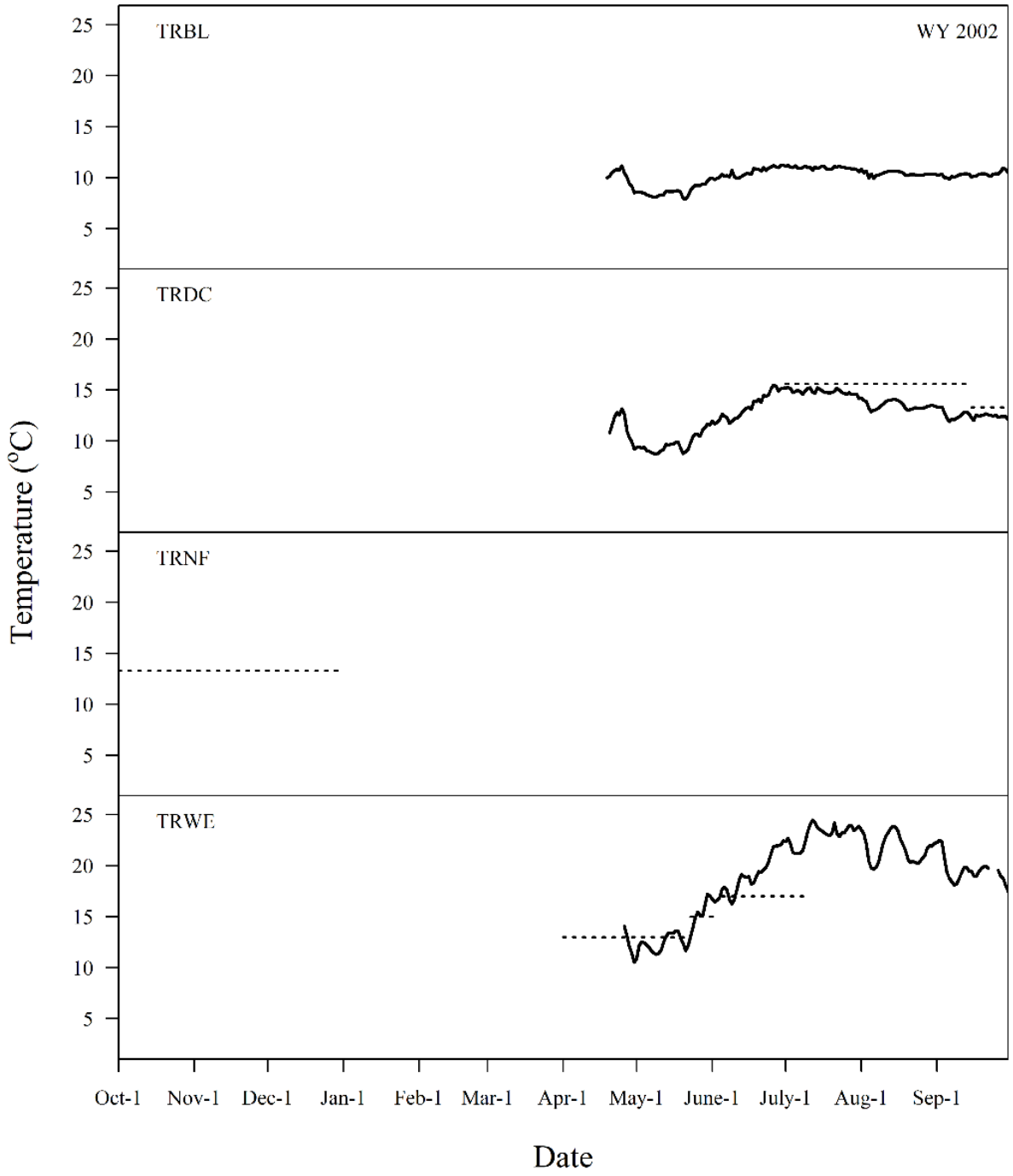
## 7. Appendices

Appendix A. Number of days water temperature criteria were exceeded at four focal locations on the Trinity River, 2002-2021. Historical *Average A,* number of days criteria were exceeded 2002-2019 for comparison to water year (WY) 2020 and historical *Average B,* 2002-2020 for comparison to WY 2021 were also calculated and shown in the table. The historical range of criteria exceedance is indicated with the upper end of the range highlighted in bold. The historical minimum number of days water temperature criteria were exceeded is not highlighted, since it frequently occurred as zero at all sites. Years where data was not collected for a site are indicated by ND for no data.

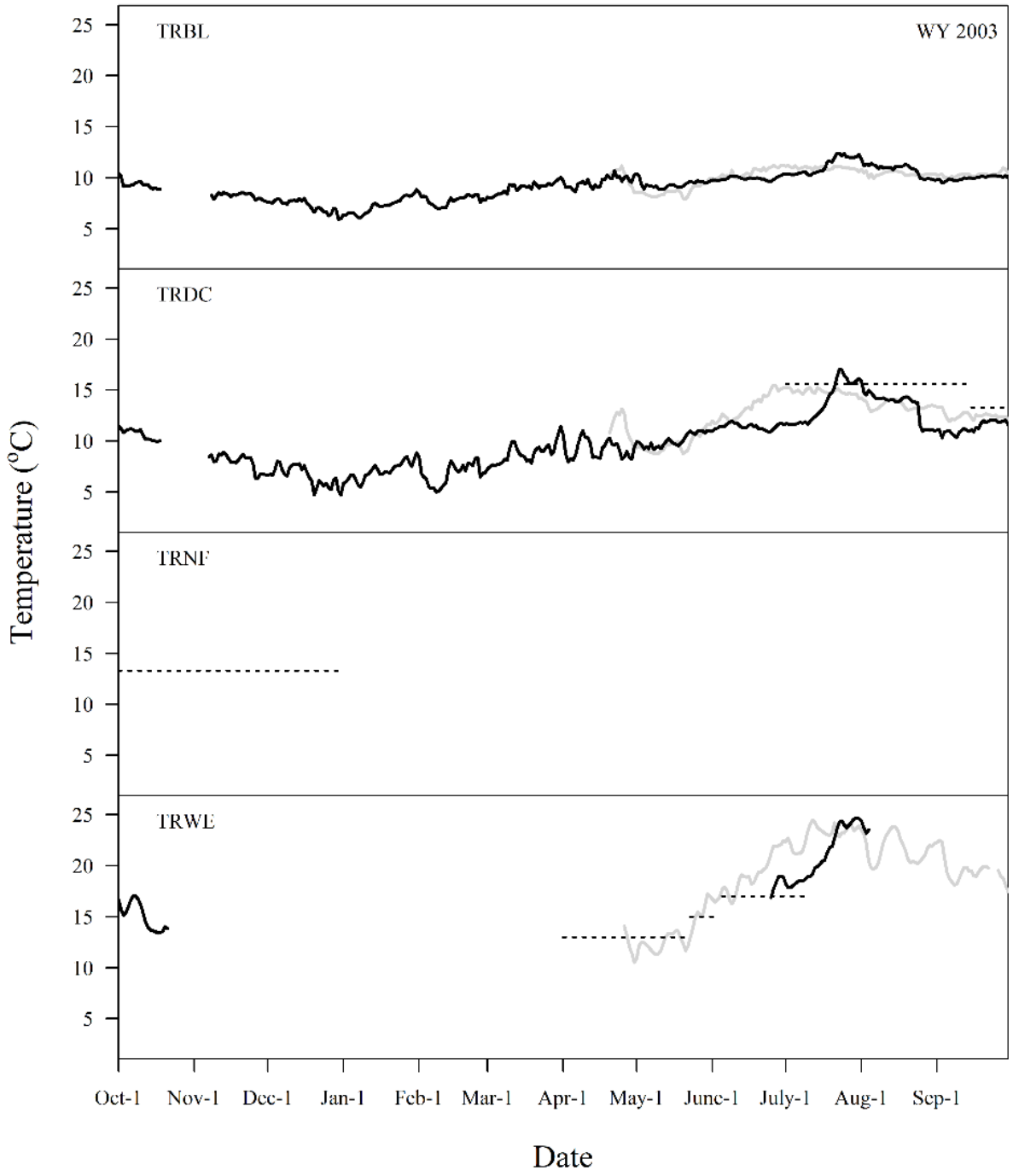
| WY | TRDC 15.6°C | TRDC 13.3°C | TRNF 13.3°C | TRWE 15 °C | TRWE 17 °C | TRWE 20 °C | WY Type |
|---|---|---|---|---|---|---|---|
| 2002 | 0 | 0 | ND | 8[a] | 10 | 32 | Normal |
| 2003 | 11 | 0 | ND | 0[a] | 0[a] | 14[a] | Wet |
| 2004 | 0 | 0 | ND | 18[a] | 1 | 24 | Wet |
| 2005 | 1[a] | 0 | ND | 0[a] | 0[a] | 13 | Wet |
| 2006 | 7 | 0 | 1 | 3 | 0 | 4 | Ex. Wet |
| 2007 | 4 | 0 | 0 | 0 | 6 | 13 | Dry |
| 2008 | 0 | 0 | 0 | 0 | 0 | 0 | Dry |
| 2009 | **26** | **7** | 5 | 0[a] | 0[a] | 15 | Dry |
| 2010 | 5 | 1 | 1[a] | 0 | 0 | 10 | Wet |
| 2011 | 0 | 0 | 7 | 0 | 0 | 7 | Wet |
| 2012 | 0 | 0 | 1 | 8 | 3 | 14 | Normal |
| 2013 | 0 | 0 | 2 | 5 | 3 | 18 | Dry |
| 2014 | 10 | **7** | 0[a] | 14 | 11 | 27 | Crit. Dry |
| 2015 | 15[a] | **7** | 15 | 20 | 11 | **34** | Dry |
| 2016 | 14 | 0 | **18** | **24** | 6 | 22 | Wet |
| 2017 | 0 | 0 | 3 | 6 | **15** | 21 | Ex. Wet |
| 2018 | 23 | 0 | 0 | 15 | 7 | 22 | Crit. Dry |
| 2019 | 2 | 2 | 5 | 16 | 6 | 20 | Wet |
| 2020 | **37** | 0 | 0 | 8 | 10 | 20 | Crit. Dry |
| 2021 | 23 | 0 | 3 | 17 | 10 | 25 | Crit. Dry |
| *Average A* | 6.4 | 1.3 | 4.8 | 8.5 | 5.3 | 17.4 | |
| *Average B* | 8.2 | 1.3 | 4.4 | 8.5 | 5.6 | 17.6 | |

[a] Incomplete data set for period of criteria.

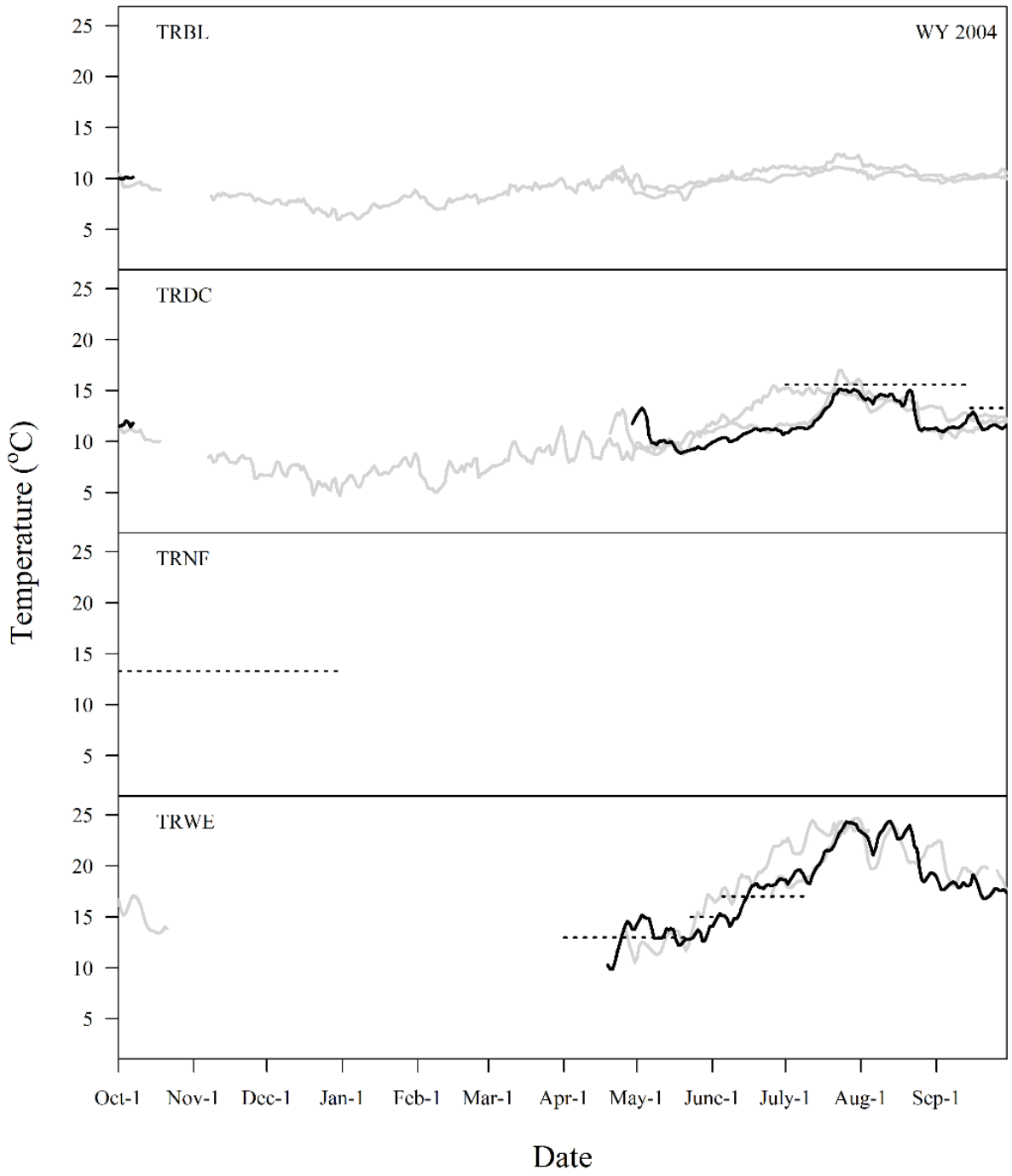
Appendix B. Daily mean water temperature at focal Trinity River monitoring locations during water years 2002-2019, with historical conditions. Includes only observed water temperature.



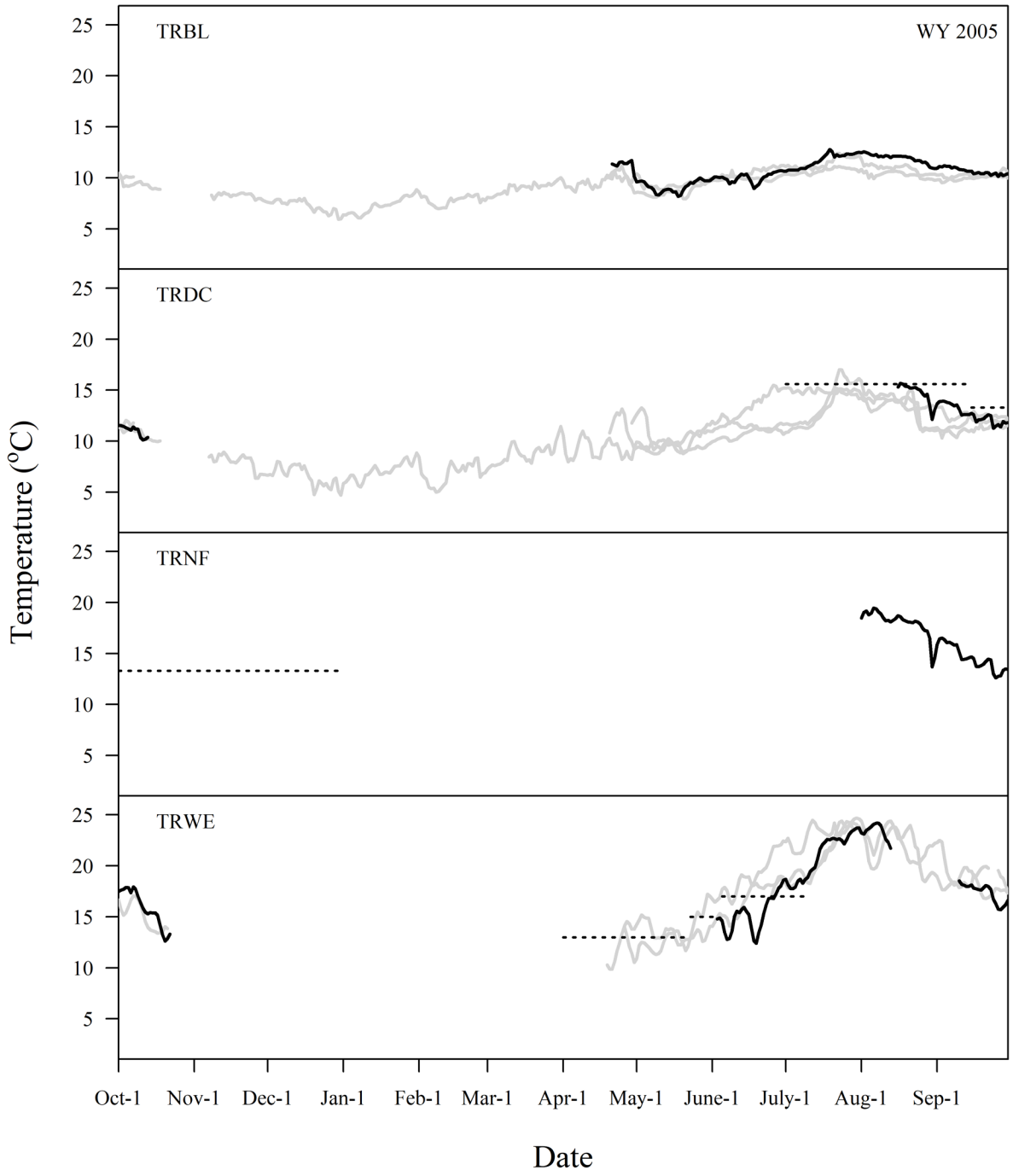

Appendix B1. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2001–September 30, 2002. Black line = daily mean water temperature in water year (WY) 2002; gray line = historical daily mean water temperature; black dotted line = water temperature objectives. Sections that are blank indicates no data exists at that site for the period.



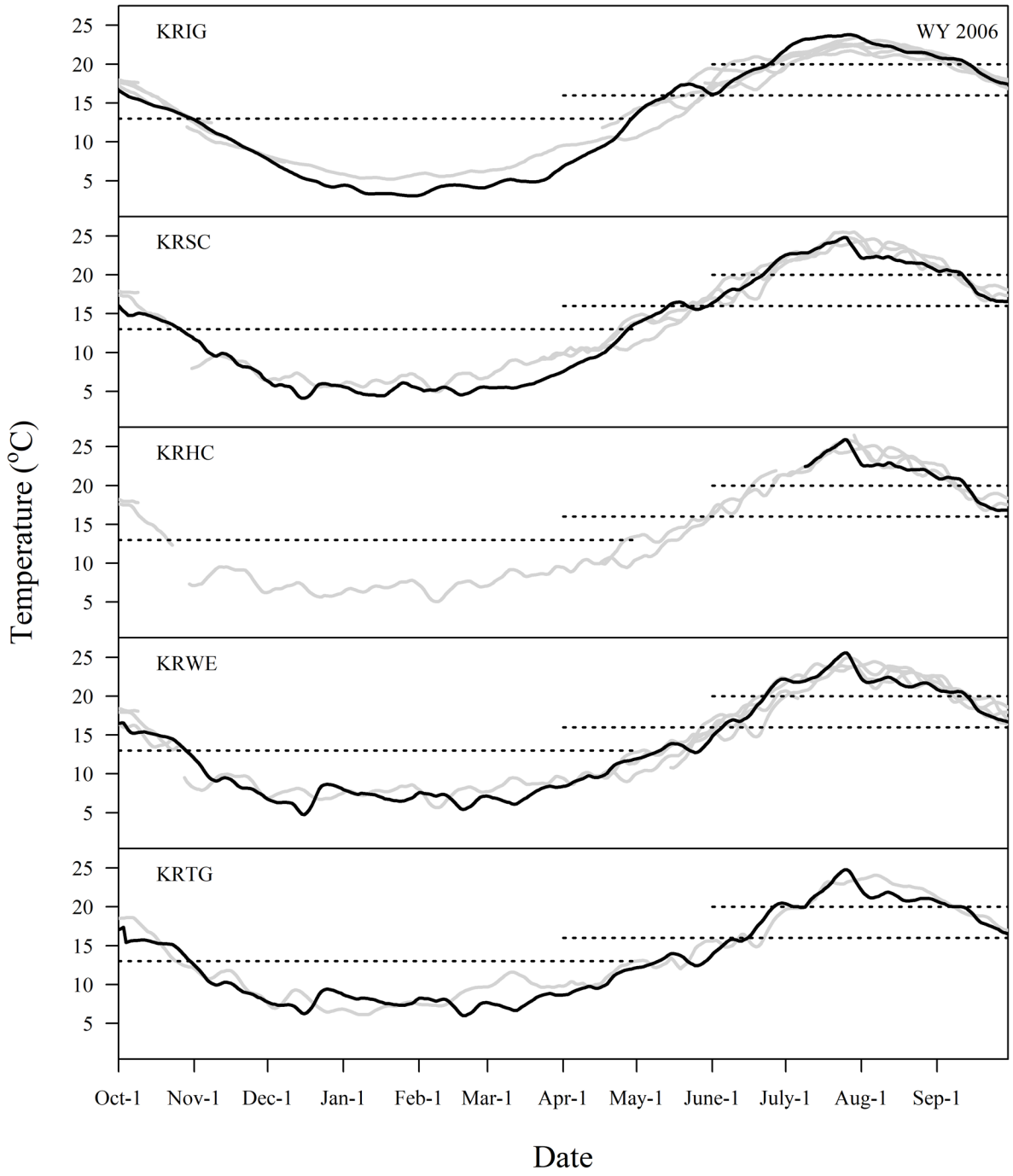

Appendix B2. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2002 – September 30, 2003, with historical summaries from water year (WY) 2002. Black line = daily mean water temperature in WY 2003; gray line = historical daily mean water temperature; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.



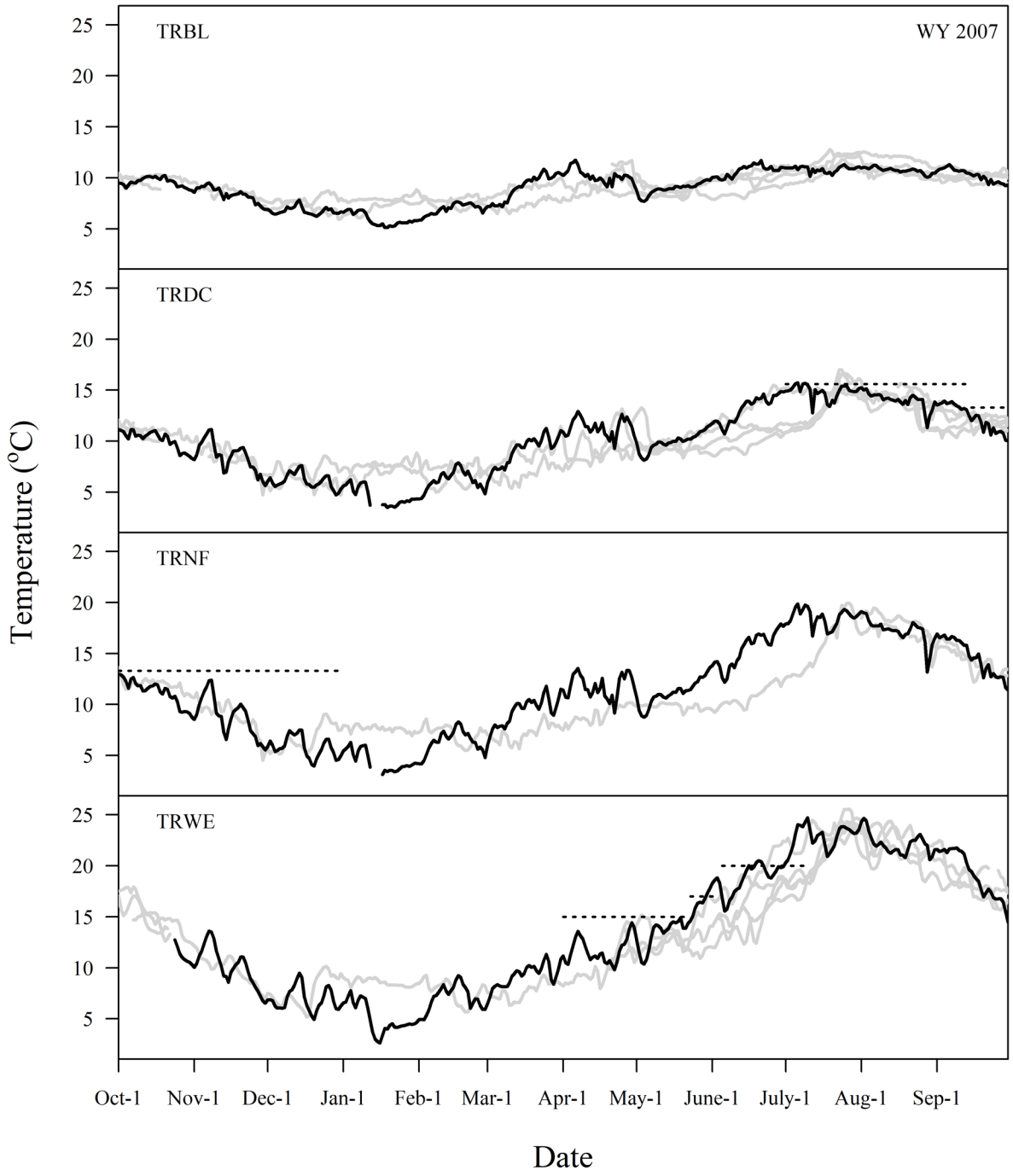

Appendix B3. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2003 – September 30, 2004, with historical summaries from water years (WYs) 2002 to 2003. Black line = daily mean water temperature in WY 2004; gray line = historical daily mean water temperature; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.



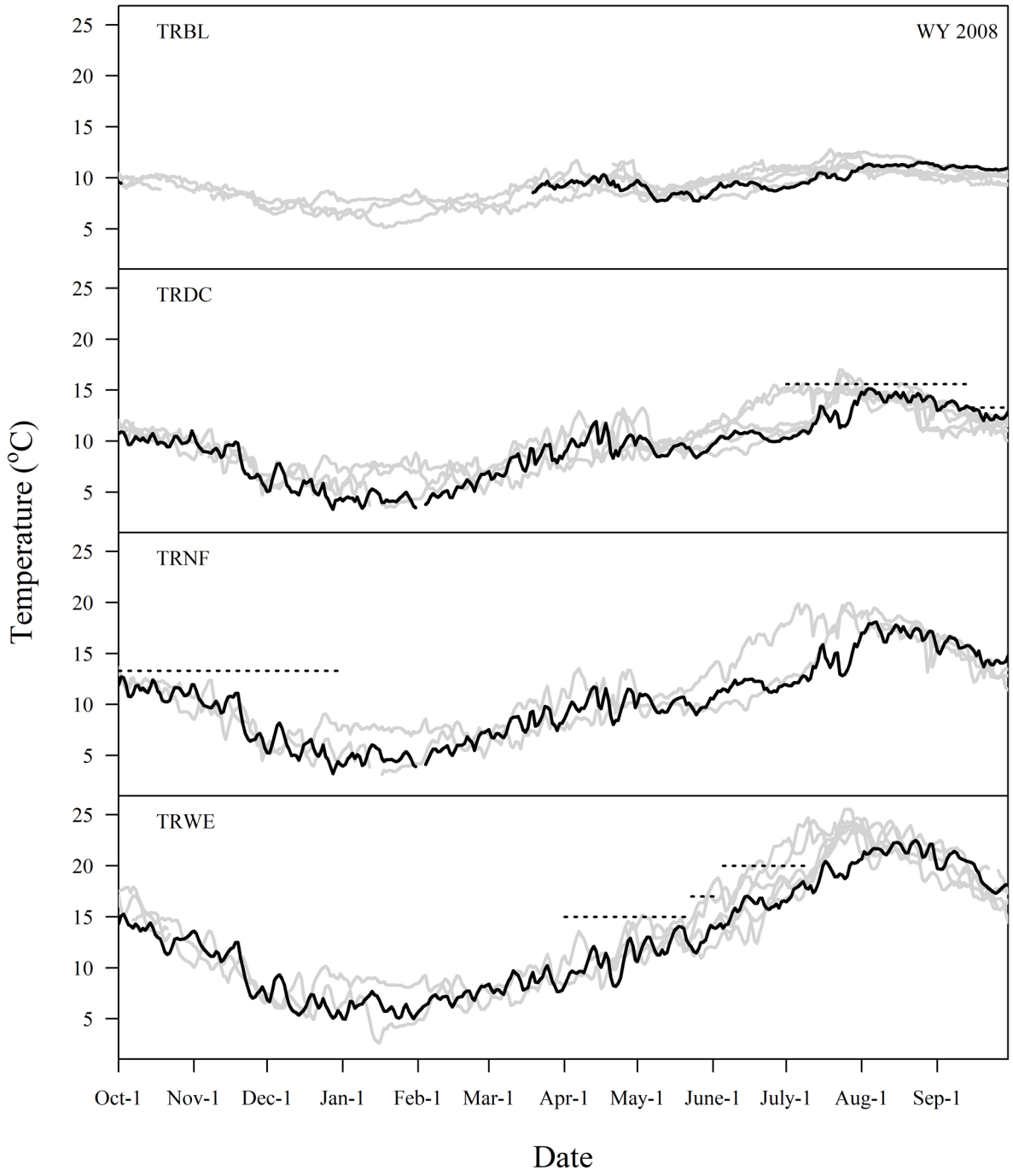

Appendix B4. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2004 – September 30, 2005, with historical summaries from water years (WYs) 2002 to 2004. Black line = daily mean water temperature in WY 2005; gray line = historical daily mean water temperature; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.



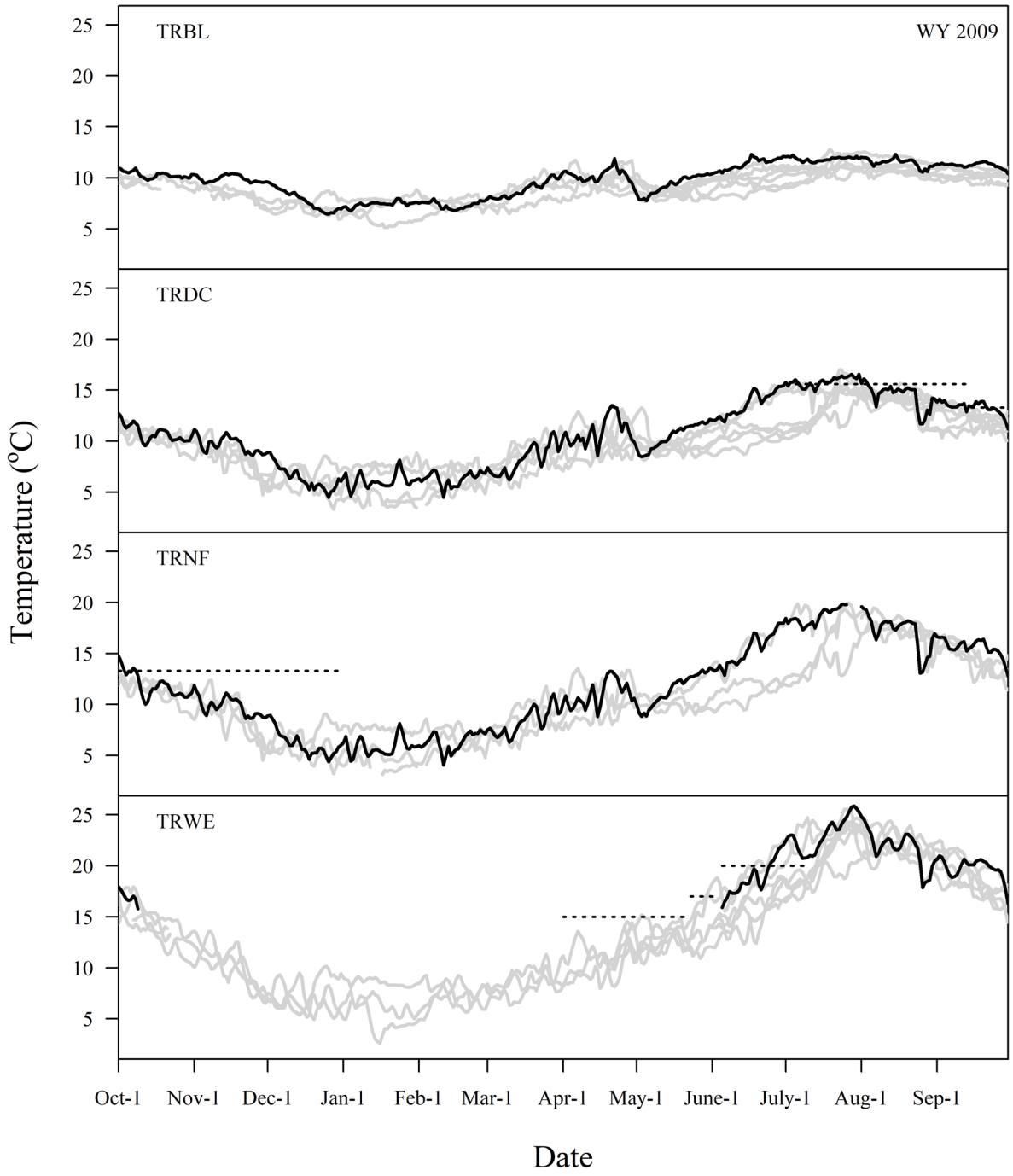

Appendix B5. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2005 – September 30, 2006, with historical summaries from water years (WYs) 2002 to 2005. Black line = daily mean water temperature in WY 2006; gray line = historical daily mean water temperature; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.



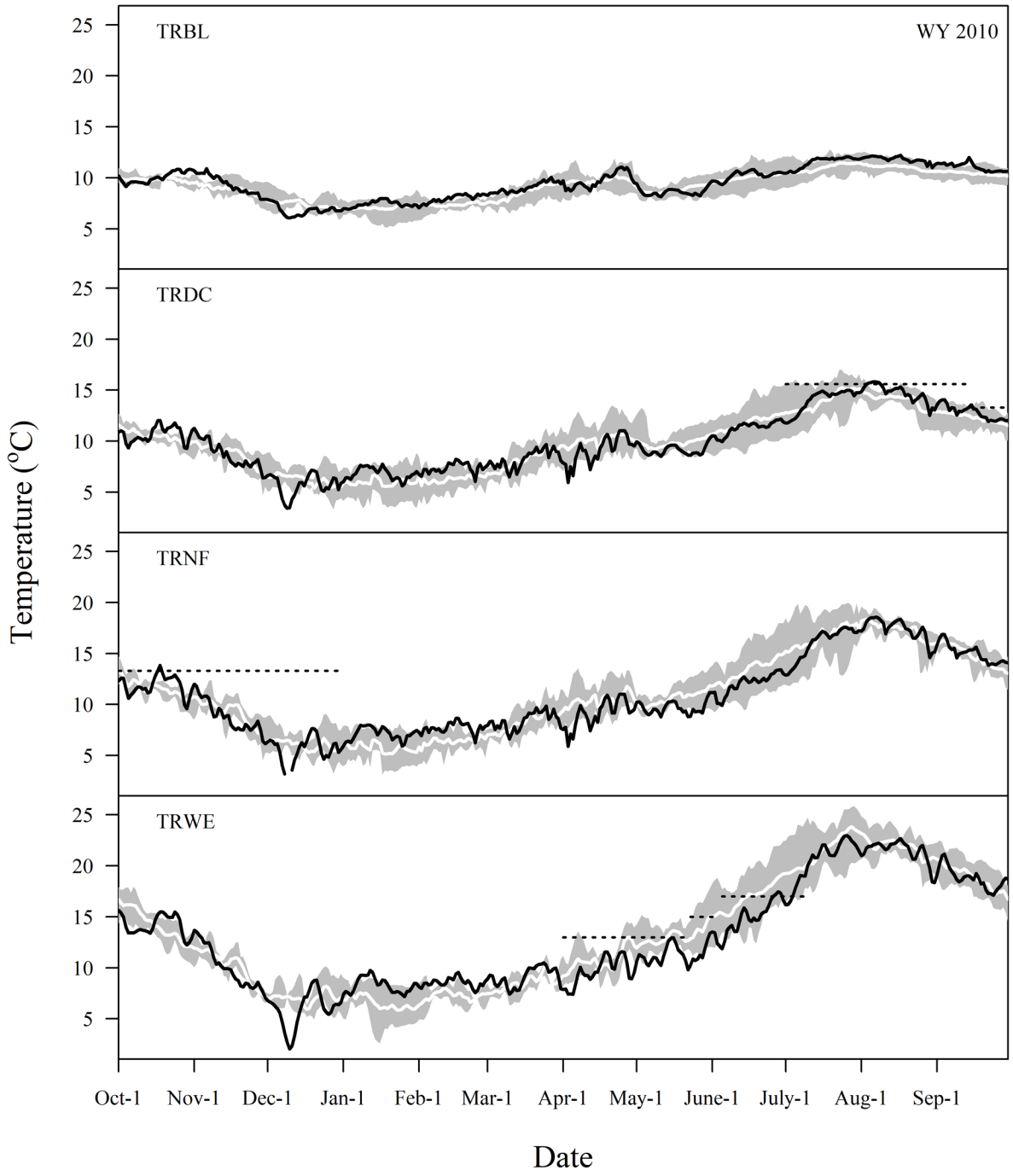

Appendix B6. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2006 – September 30, 2007, with historical summaries from water years (WYs) 2002 to 2006. Black line = daily mean water temperature in WY 2007; gray line = historical daily mean water temperature; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.



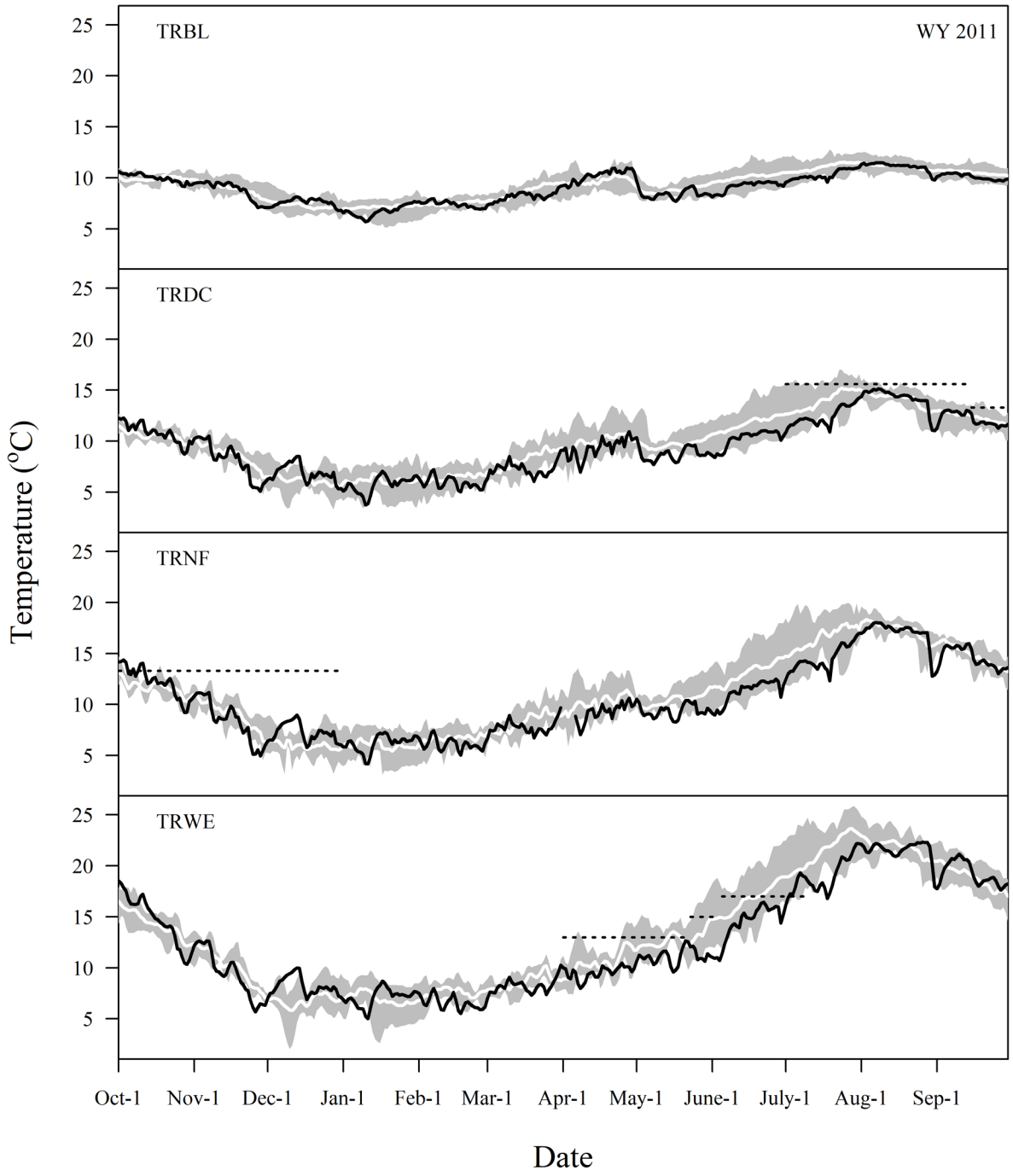

Appendix B7. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2007 – September 30, 2008, with historical summaries from water years (WYs) 2002 to 2007. Black line = daily mean water temperature in WY 2008; gray line = historical daily mean water temperature; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.



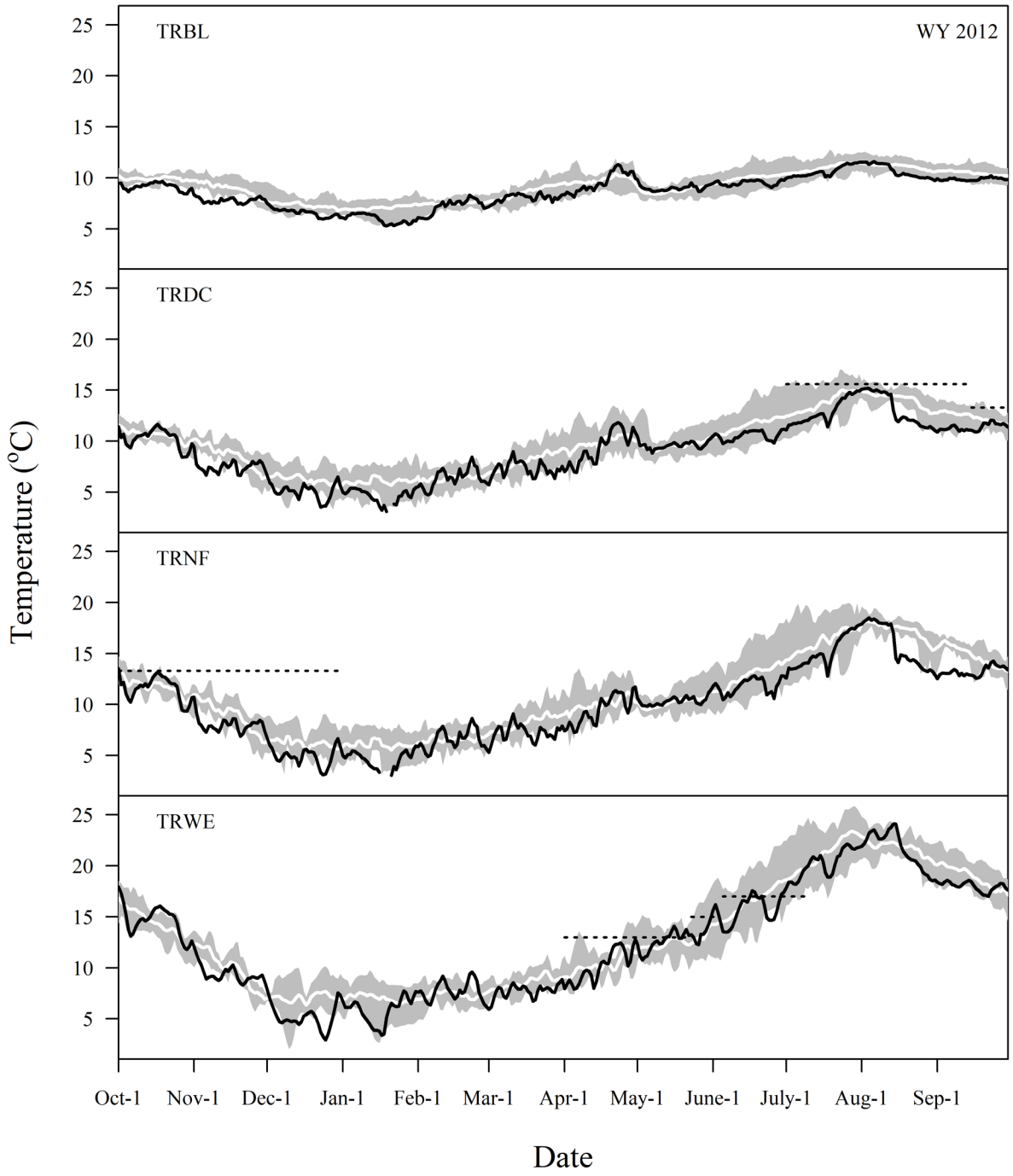

Appendix B8. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2008 – September 30, 2009, with historical summaries from water years (WYs) 2002 to 2008. Black line = daily mean water temperature in WY 2009; gray line = historical daily mean water temperature; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.



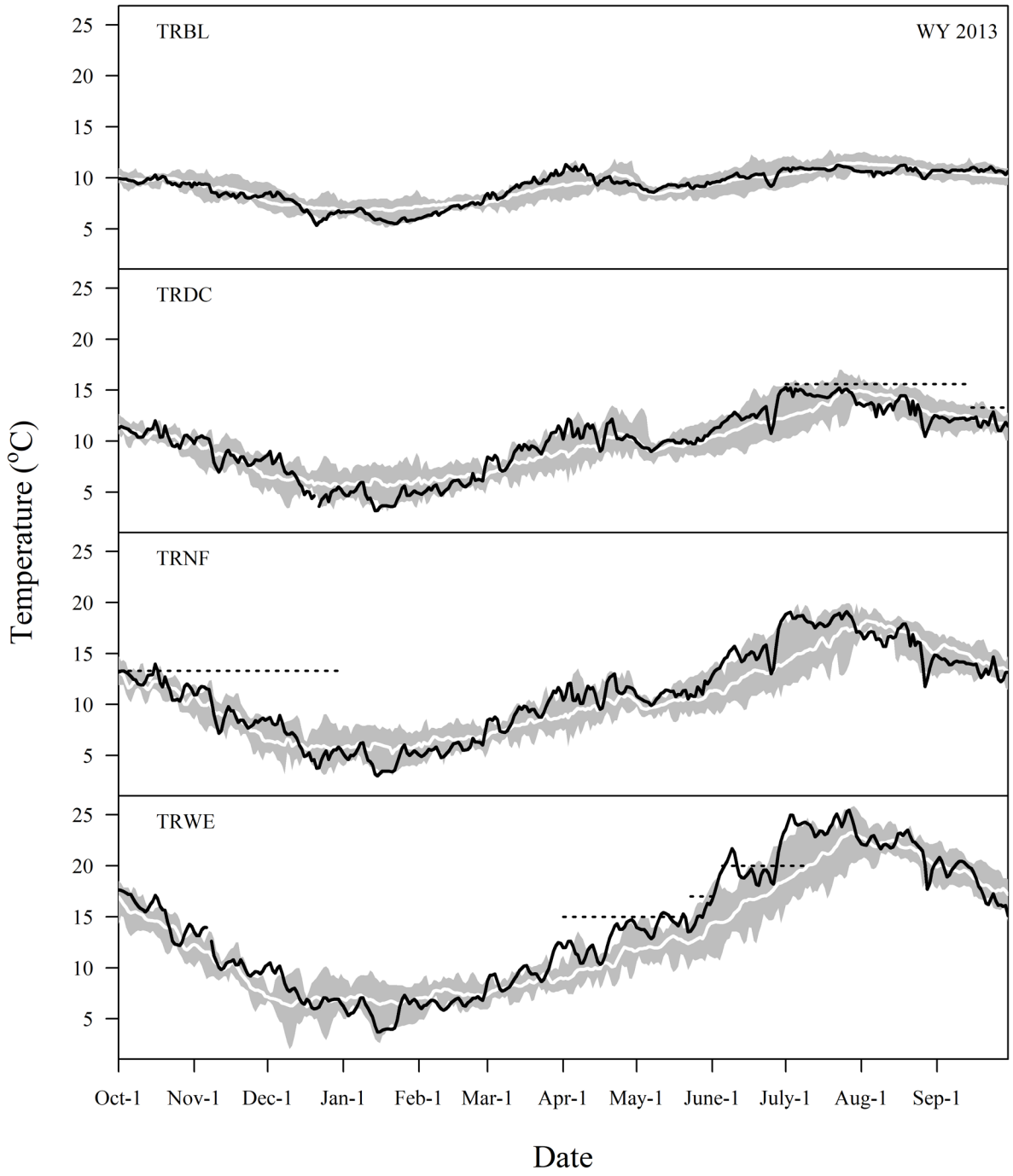

Appendix B9. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2009 – September 30, 2010, with historical summaries from water years (WYs) 2002 to 2009. Black line = daily mean water temperature in WY 2010; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature objectives.



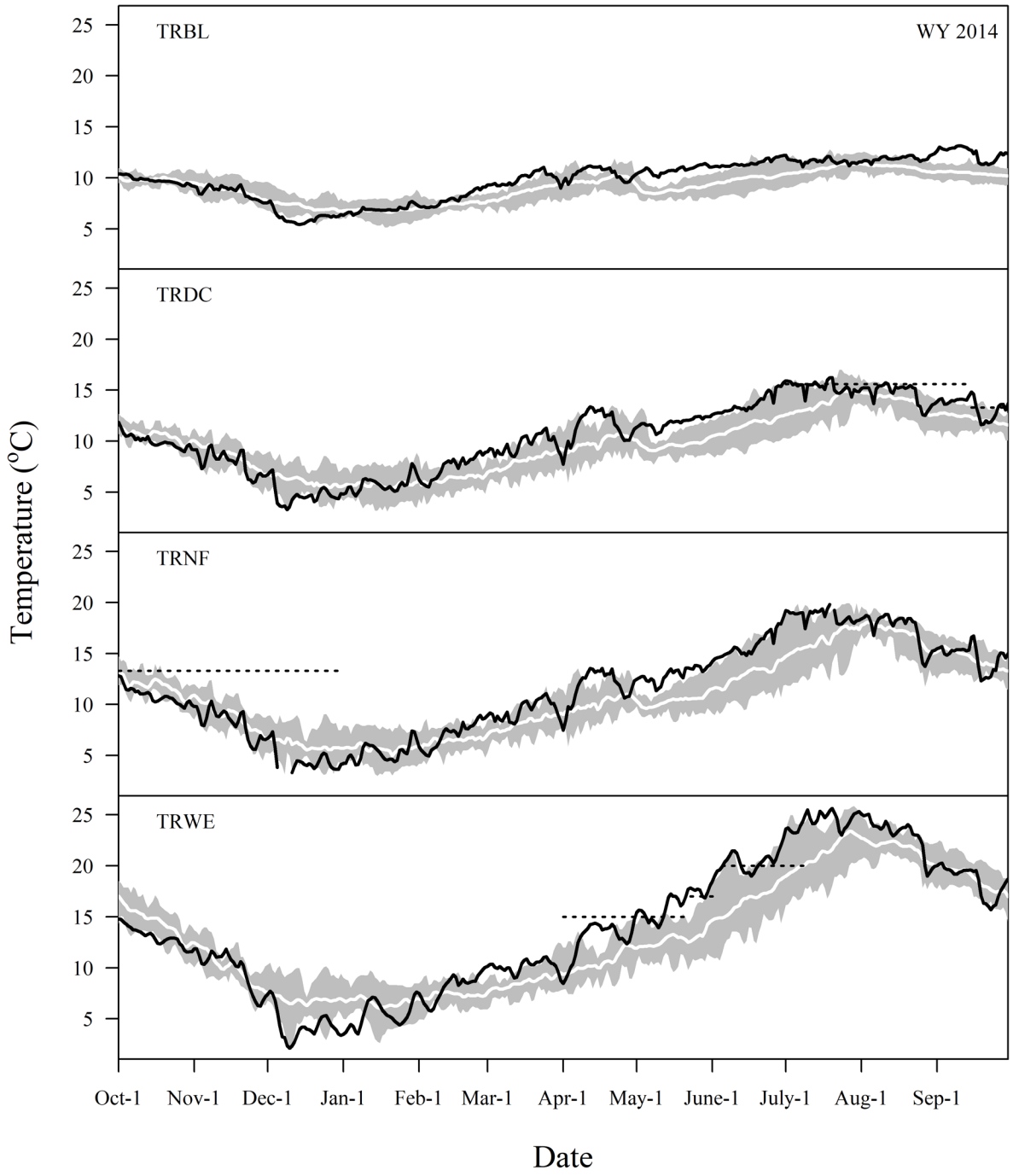

Appendix B10. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2010 – September 30, 2011, with historical summaries from water years (WYs) 2002 to 2010. Black line = daily mean water temperature in WY 2011; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature objectives.



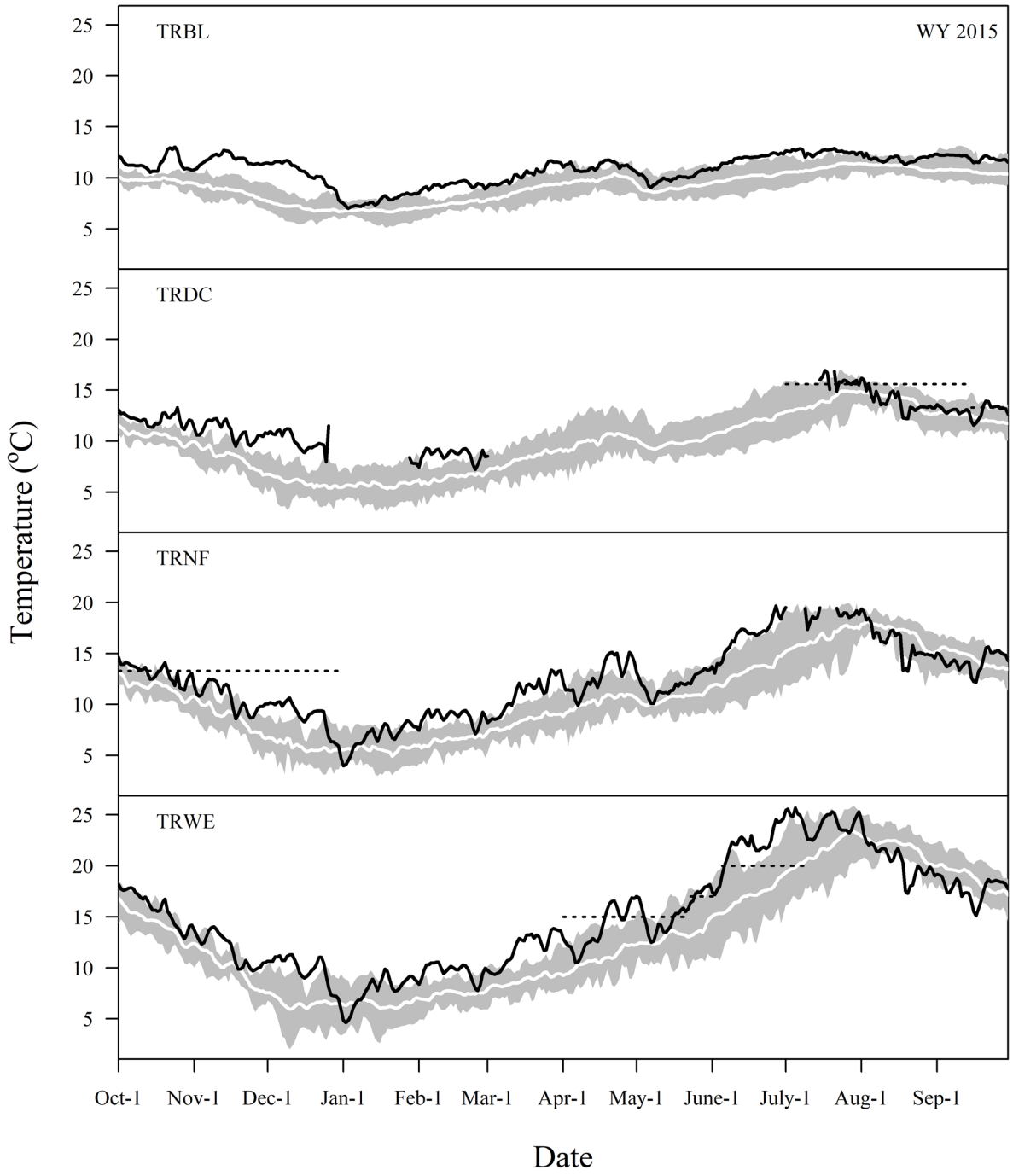

Appendix B11. Daily mean water temperature at focal Trinity River monitoring locations, October 11, 2011 – September 30, 2012, with historical summaries from water years (WYs) 2002 to 2011. Black line = daily mean water temperature in WY 2012; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.



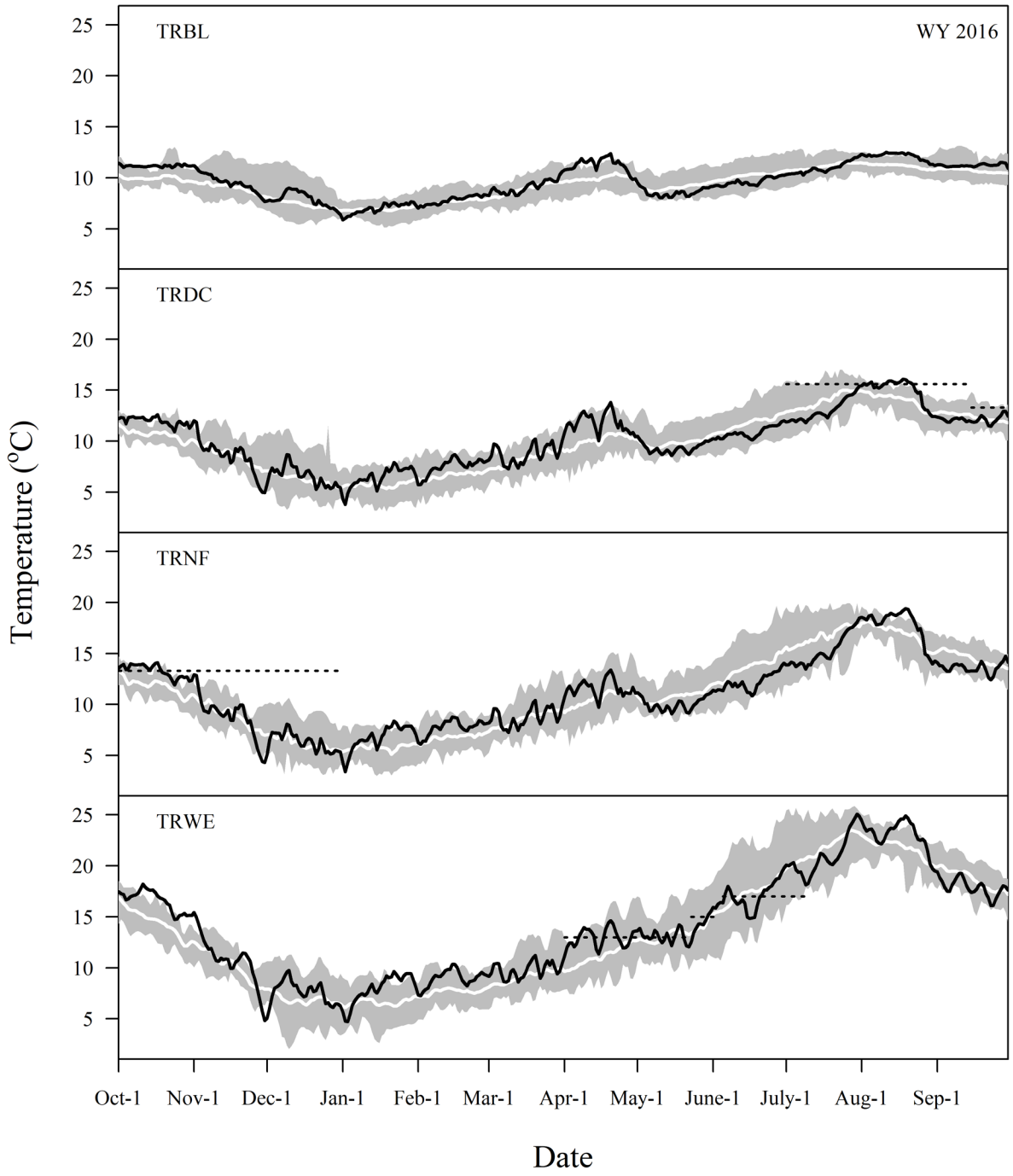

Appendix B12. Daily mean water temperature at focal Trinity River monitoring locations, October 12, 2012 – September 30, 2013, with historical summaries from water years (WYs) 2002 to 2012. Black line = daily mean water temperature in WY 2013; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.



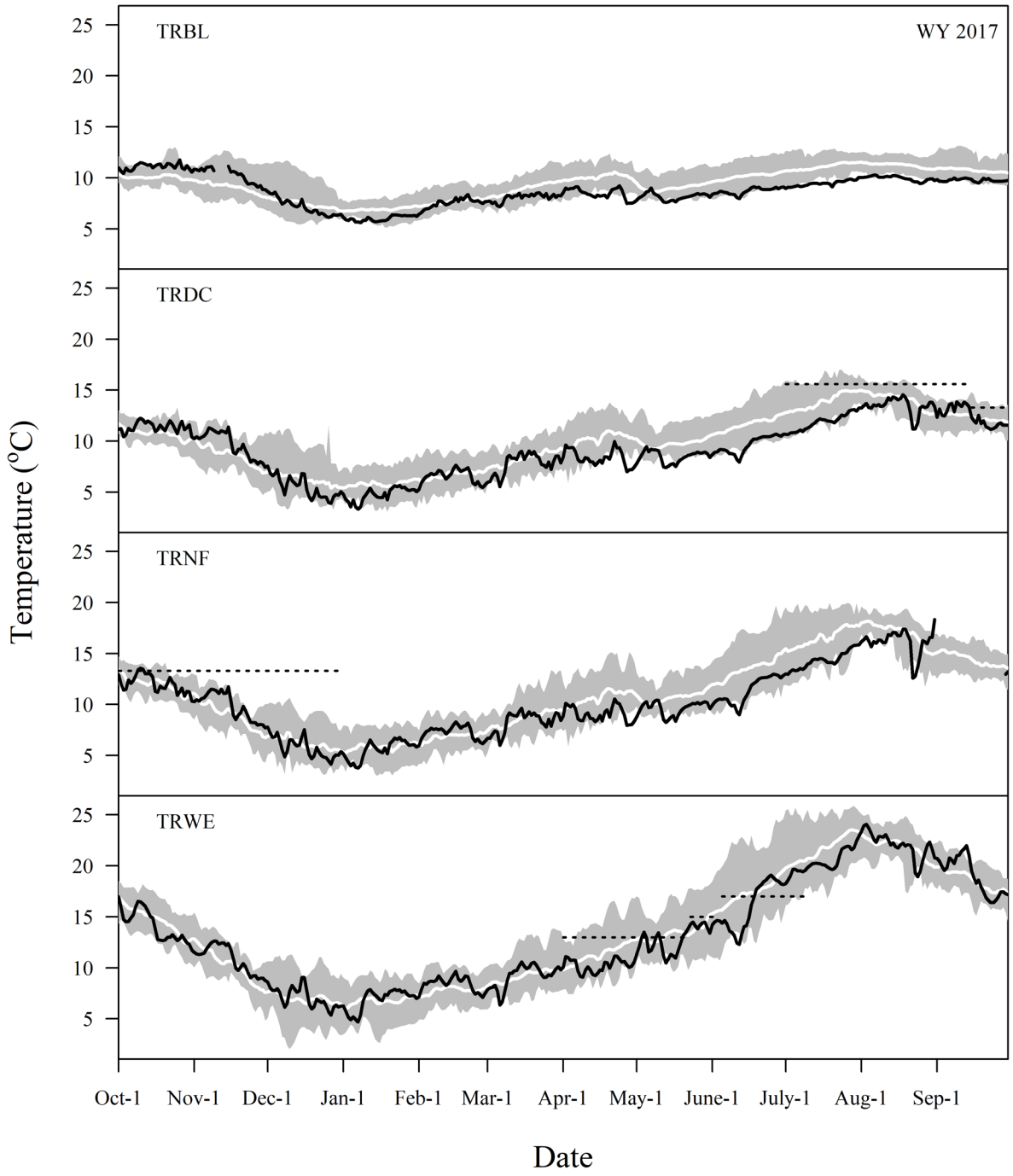

Appendix B13. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2013 – September 30, 2014, with historical summaries from water years (WYs) 2002 to 2013. Black line = daily mean water temperature in WY 2014; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature objectives.



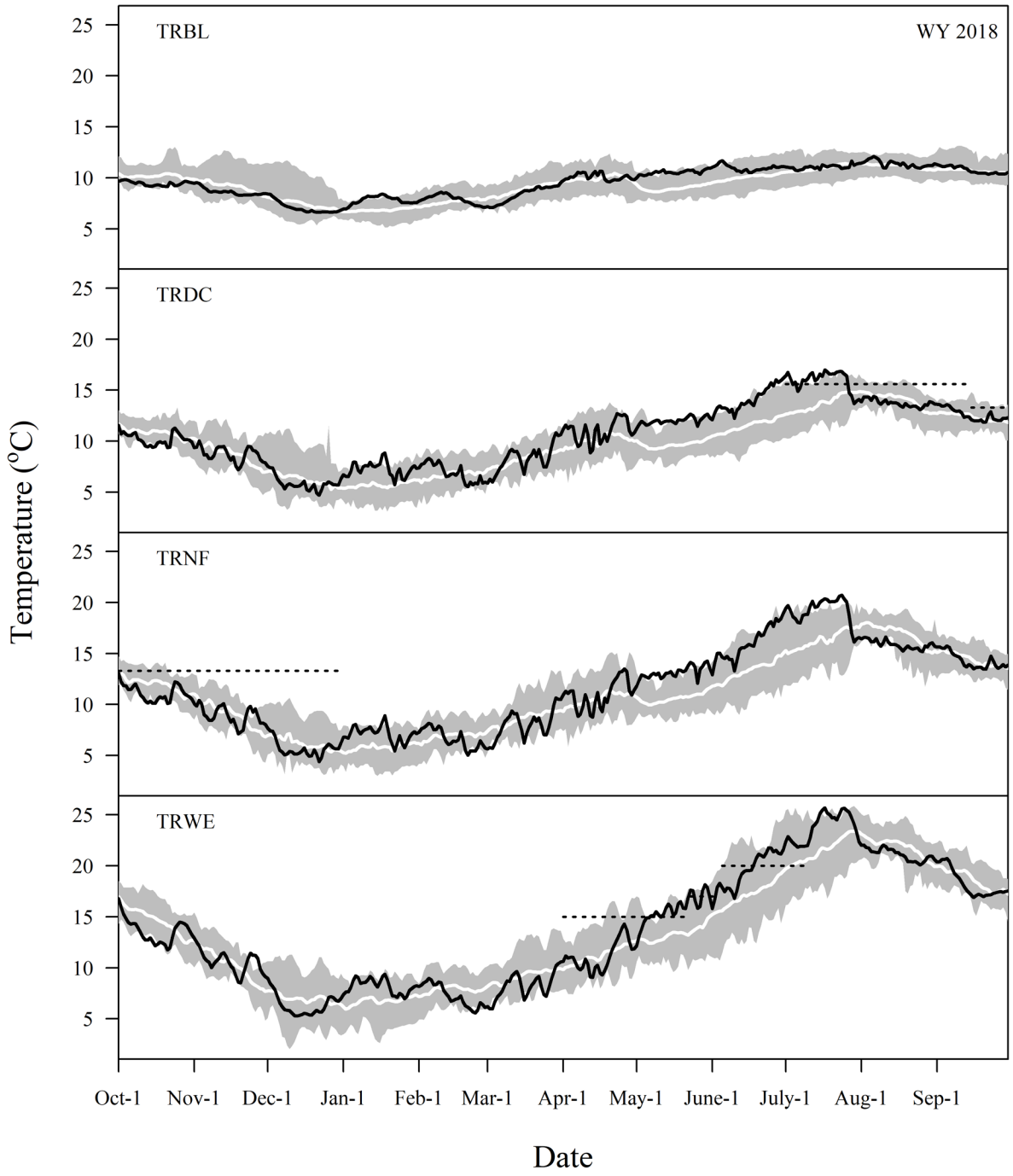

Appendix B14. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2014 – September 30, 2015, with historical summaries from water years (WYs) 2002 to 2014. Black line = daily mean water temperature in WY 2015; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.



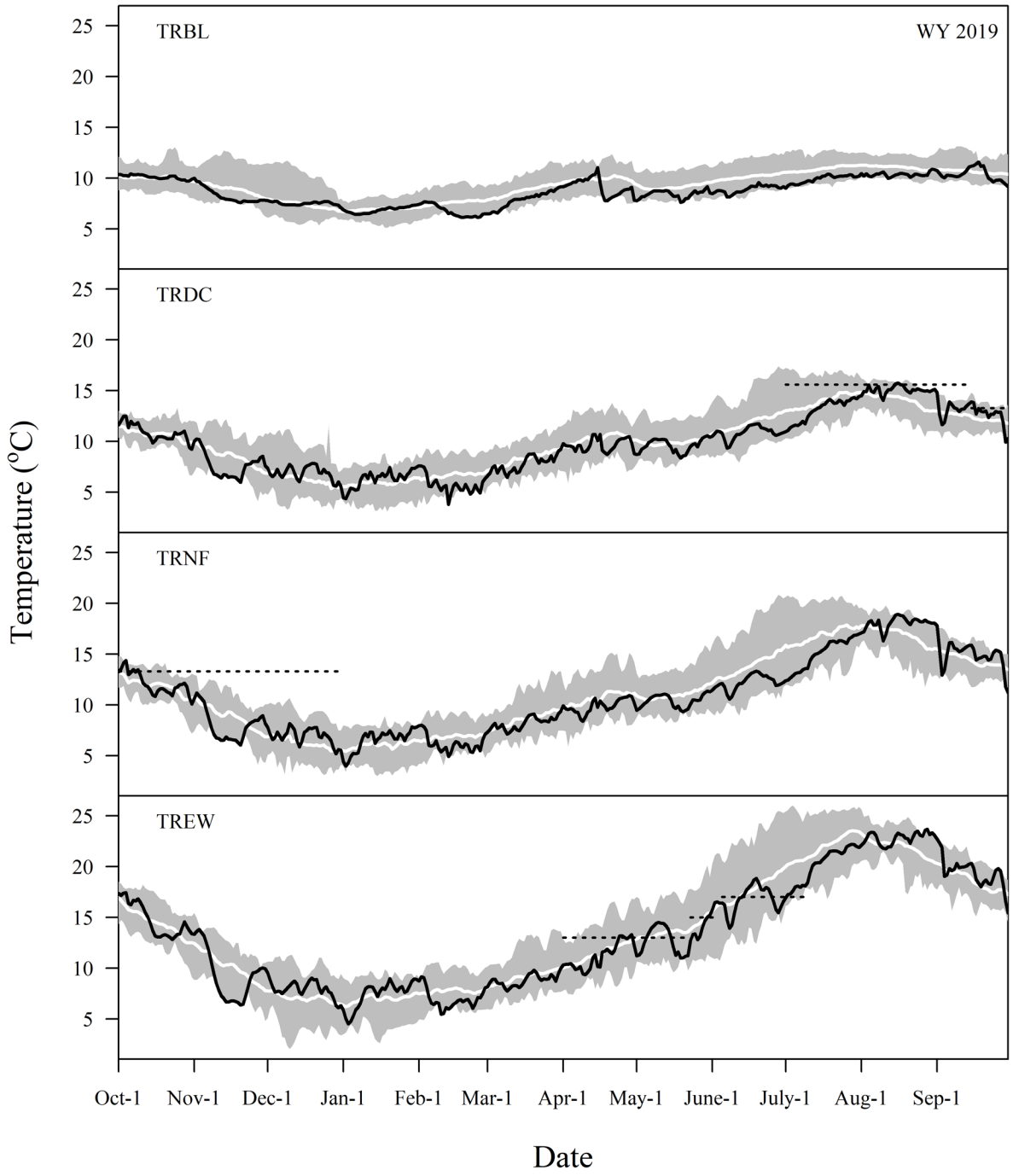

Appendix B15. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2015 – September 30, 2016, with historical summaries from water years (WYs) 2002 to 2015. Black line = daily mean water temperature in WY 2016; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature objectives.




Appendix B16. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2016 – September 30, 2017, with historical summaries from water years (WYs) 2002 to 2016. Black line = daily mean water temperature in WY 2017; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature objectives. Sections that are blank indicate no data exists at that site for the period.




Appendix B17. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2017 – September 30, 2018, with historical summaries from water years (WYs) 2002 to 2017. Black line = daily mean water temperature in WY 2018; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature objectives.

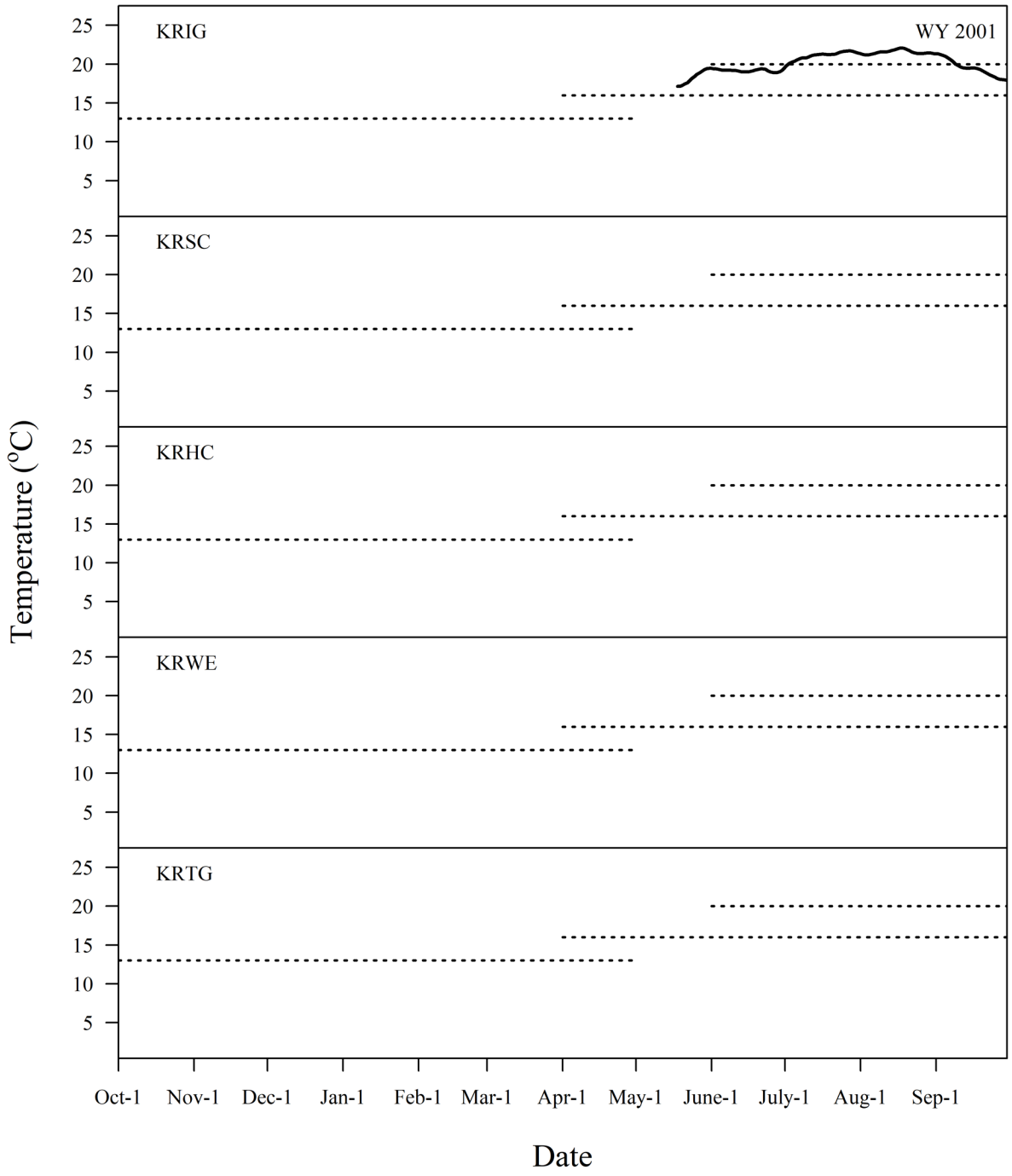



Appendix B18. Daily mean water temperature at focal Trinity River monitoring locations, October 1, 2018 – September 30, 2019, with historical summaries from water years (WYs) 2002 to 2018. Black line = daily mean water temperature in 2019; white line = average historical daily mean for each day of the year; gray polygon = range of historical daily mean water temperature for each day of the year; black dotted line = water temperature criteria.

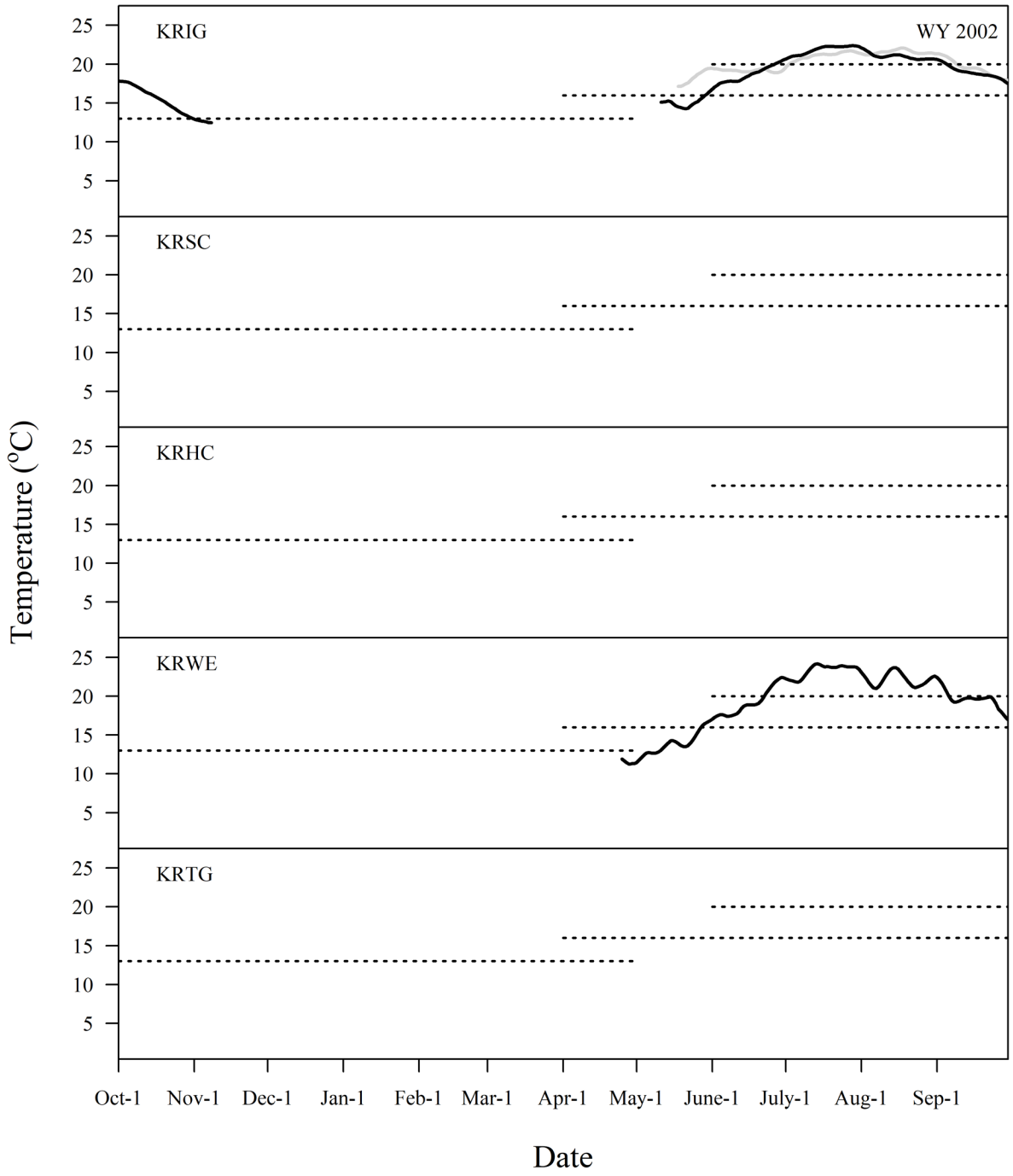
Appendix C. Number of days exceeding seven-day average daily maximum (7DADM) EPA criteria for Pacific Northwest water temperature to protect Pacific salmonids at five Klamath River focal locations, 2001-2021. Historical Average A, number of days criteria were exceeded 2002-2019 for comparison to water year (WY) 2020 and historical Average B, 2002-2020 for comparison to WY 2021 were also calculated and shown in the table. Bold numbers indicate the minimum and maximum number of days water temperature criteria are exceeded historically, excluding years where data gaps exist. The historical range of days criteria exceedance is indicated with the minimum and maximum number of days exceeding numeric water temperature criteria highlighted in bold. Years where data was not collected for a site are indicated by ND for no data. Numbers that were calculated with partial data missing during the period of the criteria have are noted with a superscript a.

| | *20°C 7DADM criterion* | | | | | *16°C 7DADM criterion* | | | | | *13°C 7DADM criterion* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WY** | **KRIG** | **KRSC** | **KRHC** | **KRWE** | **KRTG** | **KRIG** | **KRSC** | **KRHC** | **KRWE** | **KRTG** | **KRIG** | **KRSC** | **KRHC** | **KRWE** | **KRTG** |
| 2001 | 68 | ND | ND | ND | ND | 136[a] | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| 2002 | 70 | ND | ND | 75 | ND | 124[a] | ND | ND | 126[a] | ND | 31[a] | ND | ND | 0[a] | ND |
| 2003 | **98** | 82 | 70[a] | **46** | ND | 126 | 128 | 116[a] | **93** | ND | 25[a] | 0[a] | 0[a] | 24[a] | ND |
| 2004 | 79 | 86 | 67[a] | 86 | ND | 132[a] | 131[a] | 103 | 121 | ND | 15[a] | 16[a] | 13[a] | 9[a] | ND |
| 2005 | 69 | 74 | 74[a] | 69 | 62 | 125[a] | **82** | 129[a] | 104[a] | 104 | 28[a] | 26[a] | 21[a] | 25[a] | 24 |
| 2006 | 81 | 82 | 66[a] | 83 | 74 | 140 | 130 | 84[a] | 117 | 107[a] | 32 | 29 | ND | 28 | 30 |
| 2007 | 85 | 92 | **96** | ND | 81 | 138 | 138 | 131 | ND | 129[a] | 28 | 27 | 26 | 22[a] | 27 |
| 2008 | 73 | 78 | 15[a] | 78 | 63 | 120 | 113 | 30[a] | 111 | 112 | **20** | **17** | 17 | 0[a] | 18 |
| 2009 | 72 | 81 | 92 | 85 | 71[a] | 133 | 137 | 135 | 131 | 103[a] | 26 | 26 | 9[a] | 22 | 32 |
| 2010 | **60** | **65** | 61 | 55 | 56 | 112 | 110 | 101 | 99 | 100 | 25 | 24 | 25 | 27 | 18[a] |
| 2011 | 78 | 70 | **57** | 55 | **54** | **109** | 110 | **99** | **93** | 100 | 32 | 23 | 22 | 22 | 24[a] |
| 2012 | 0[a] | 72 | 75 | 72 | 55 | 0[a] | 128 | 119 | 114 | 111 | 35 | 24 | 24 | 25 | 28 |
| 2013 | 79 | 90 | 94 | 93 | 89 | 140 | 138 | 132 | 130 | 126 | 19[a] | 39 | 28 | 28 | 44 |
| 2014 | 73 | 90 | 92 | 103 | 81 | **141** | 142 | 141 | 139 | 139 | 28 | 26[a] | 27 | 18 | 41 |
| 2015 | 85 | **92** | 78[a] | **104** | **90** | 131 | 146 | 130[a] | **150** | 138 | **43** | **44** | **42** | **45** | **57** |
| 2016 | 65[a] | 77 | 78 | 3[a] | 70 | 103[a] | 133 | 128 | 27[a] | 126 | 39[a] | **44** | 34 | 35[a] | 42 |
| 2017 | 87 | 87 | 85 | 82 | 78[a] | 129 | 128 | 108 | 107 | **99** | 28 | 21 | 15 | **16** | **17** |
| 2018 | 79 | 90 | 88 | 84 | 77[a] | **141** | **148** | **142** | 138 | 110 | 24 | 21 | **14** | 18 | 29 |
| 2019 | 92 | 87 | 83 | 80 | 69 | 136 | 131 | 124 | 123 | 123 | 37 | 34 | 20 | 33 | 36 |
| 2020 | **60** | 83 | 83 | 82 | 82 | 132 | 137 | 134 | 129 | 131 | 32 | 34 | 30 | 32 | 45 |
| 2021 | 68 | 80 | 89 | 88 | 83 | 130 | **148** | 138 | 137 | **144** | 36 | 35 | 26 | 26 | 40 |
| *Average A* | *78.1* | *82.1* | *81.9* | *78.1* | *70.3* | *130.5* | *127.6* | *121.9* | *119.0* | *115.7* | *29.8* | *28.7* | *24.5* | *25.6* | *32.7* |
| *Average B* | *77.1* | *82.1* | *82.0* | *78.4* | *71.2* | *130.6* | *128.2* | *122.8* | *119.7* | *116.8* | *30.0* | *29.1* | *24.9* | *26.2* | *33.6* |

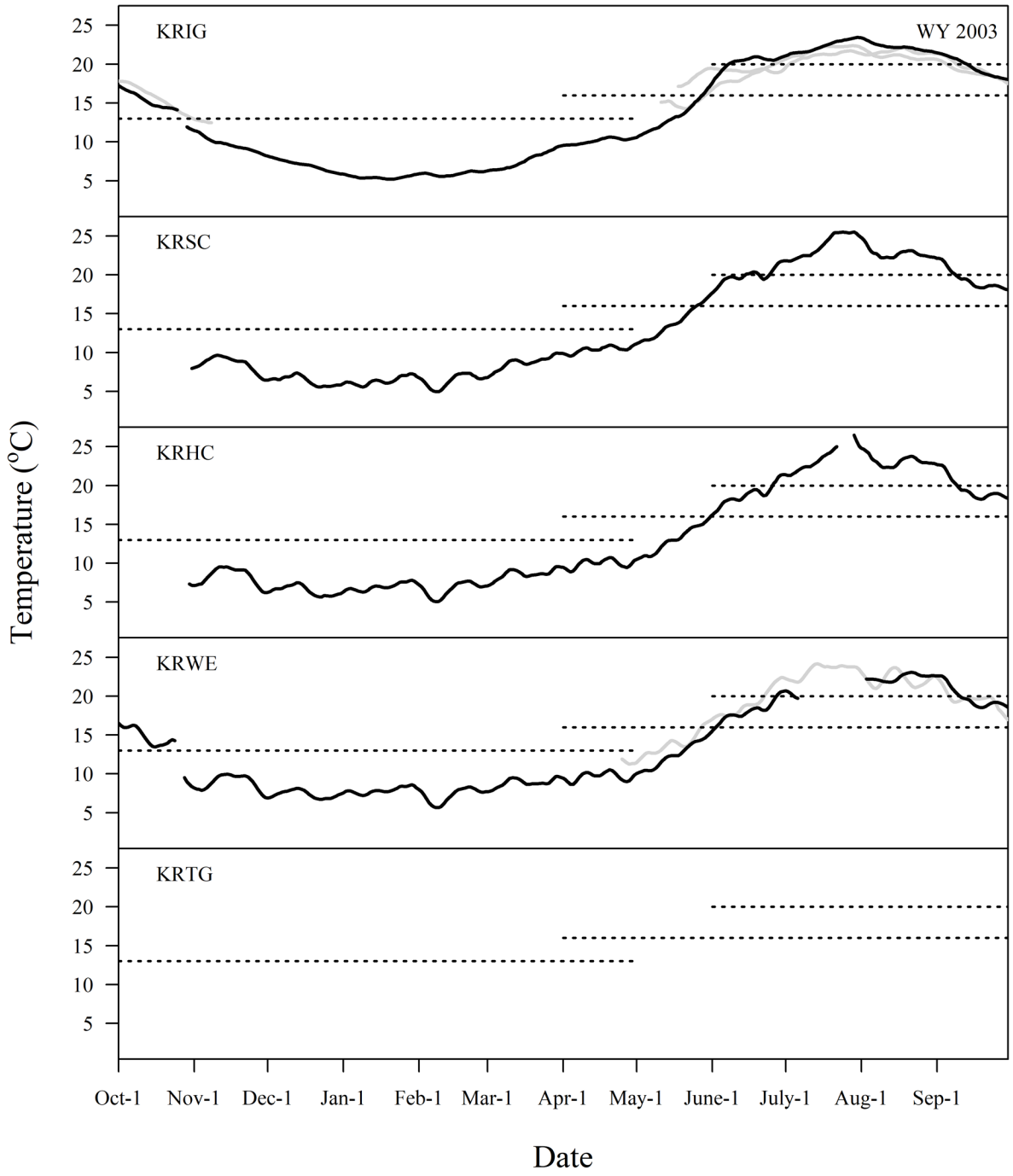
Appendix D. Seven-day average daily maximum water temperature at focal Klamath River monitoring locations, 2001-2019 water years, with historical conditions. Includes only observed water temperature.



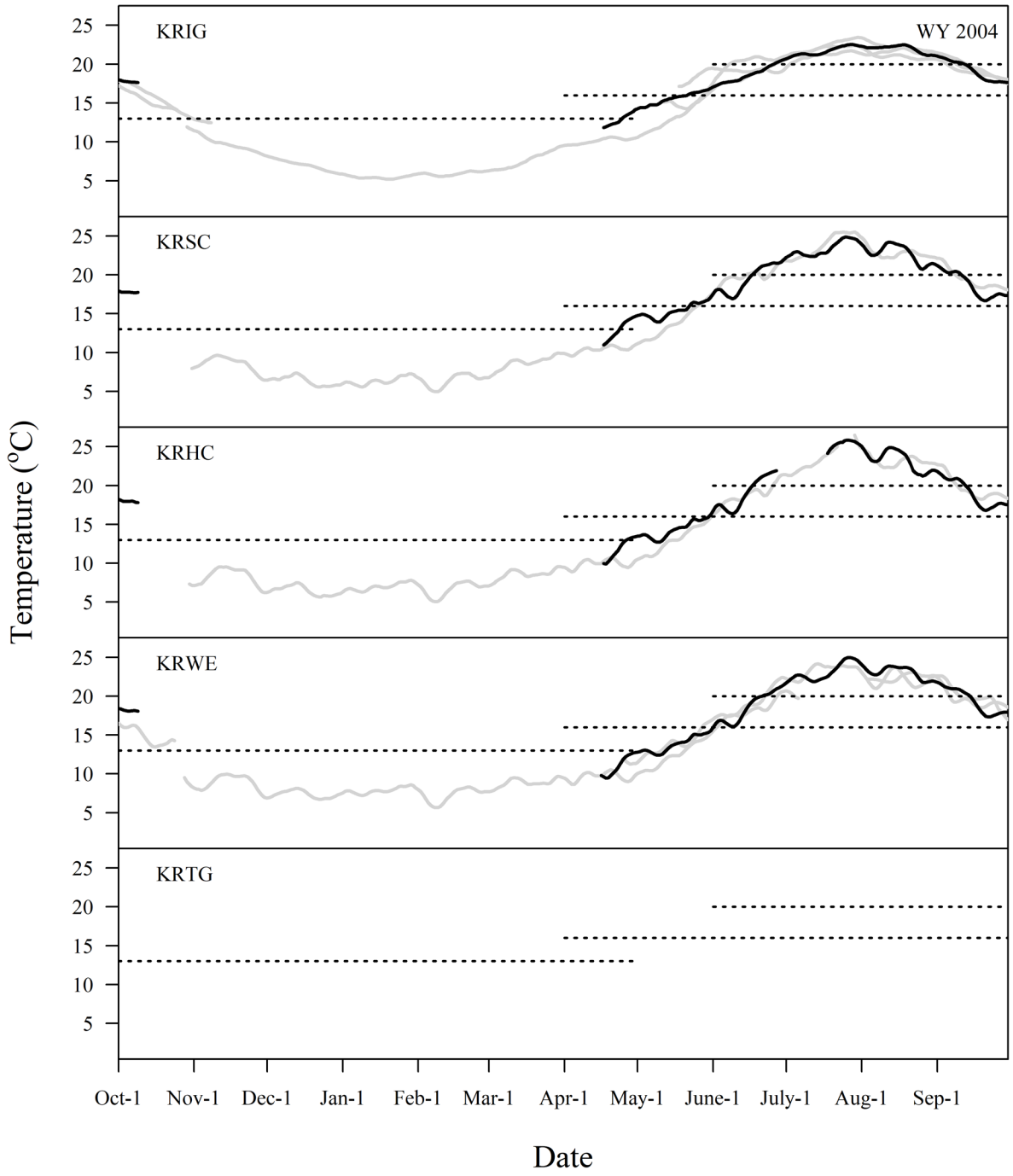

Appendix D1. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2000 – September 30, 2001. Black line = 7DADM water temperature in water year (WY) 2001; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



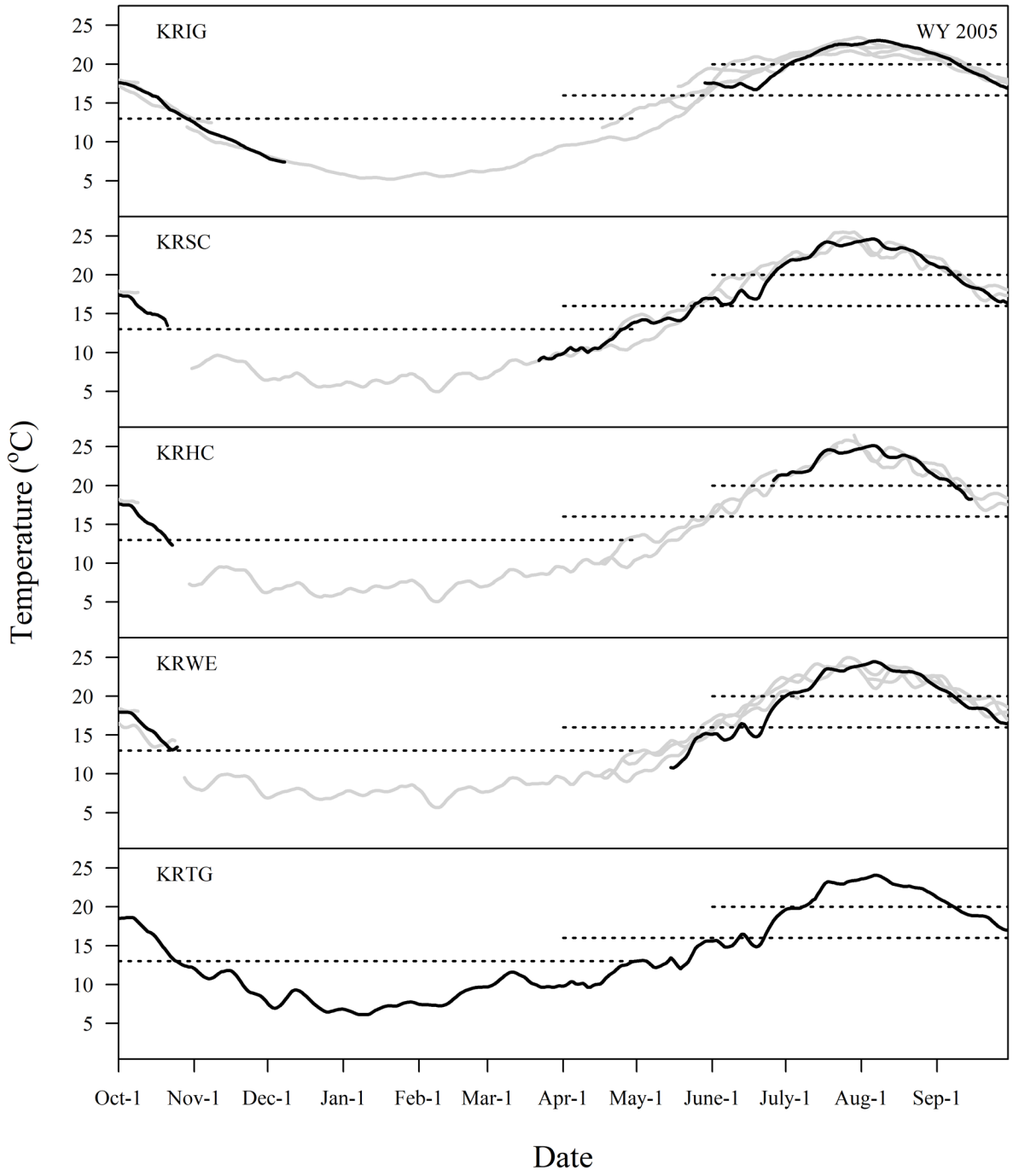

Appendix D2. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2001 – September 30, 2002, with historical summaries from water year (WY) 2001. Black line = 7DADM water temperature in WY 2002; gray line = historical 7DADM water temperature; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



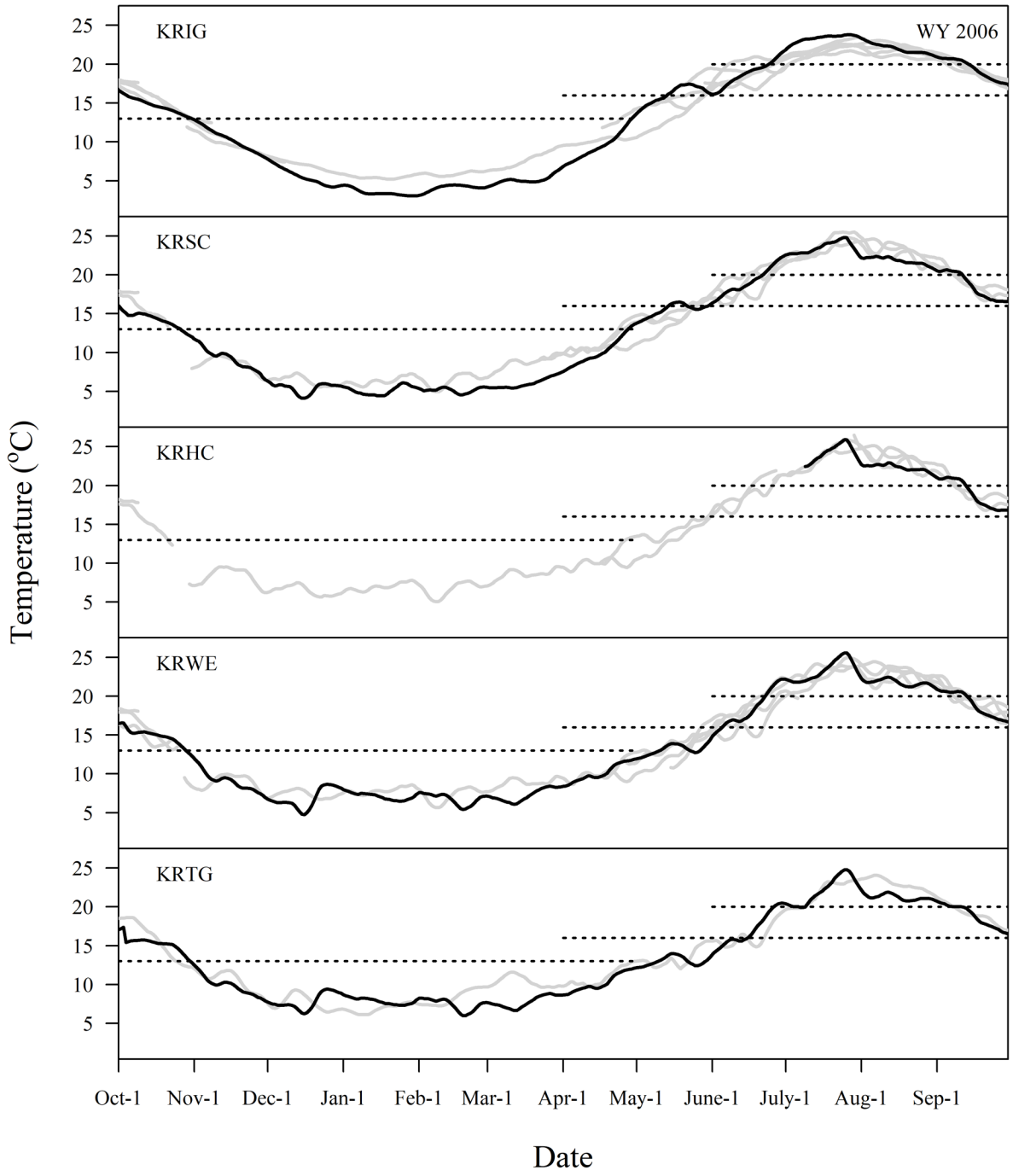

Appendix D3. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2002 – September 30, 2003, with historical summaries from water years (WYs) 2001 to 2002. Black line = 7DADM water temperature in WY 2003; gray line = historical 7DADM water temperature; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



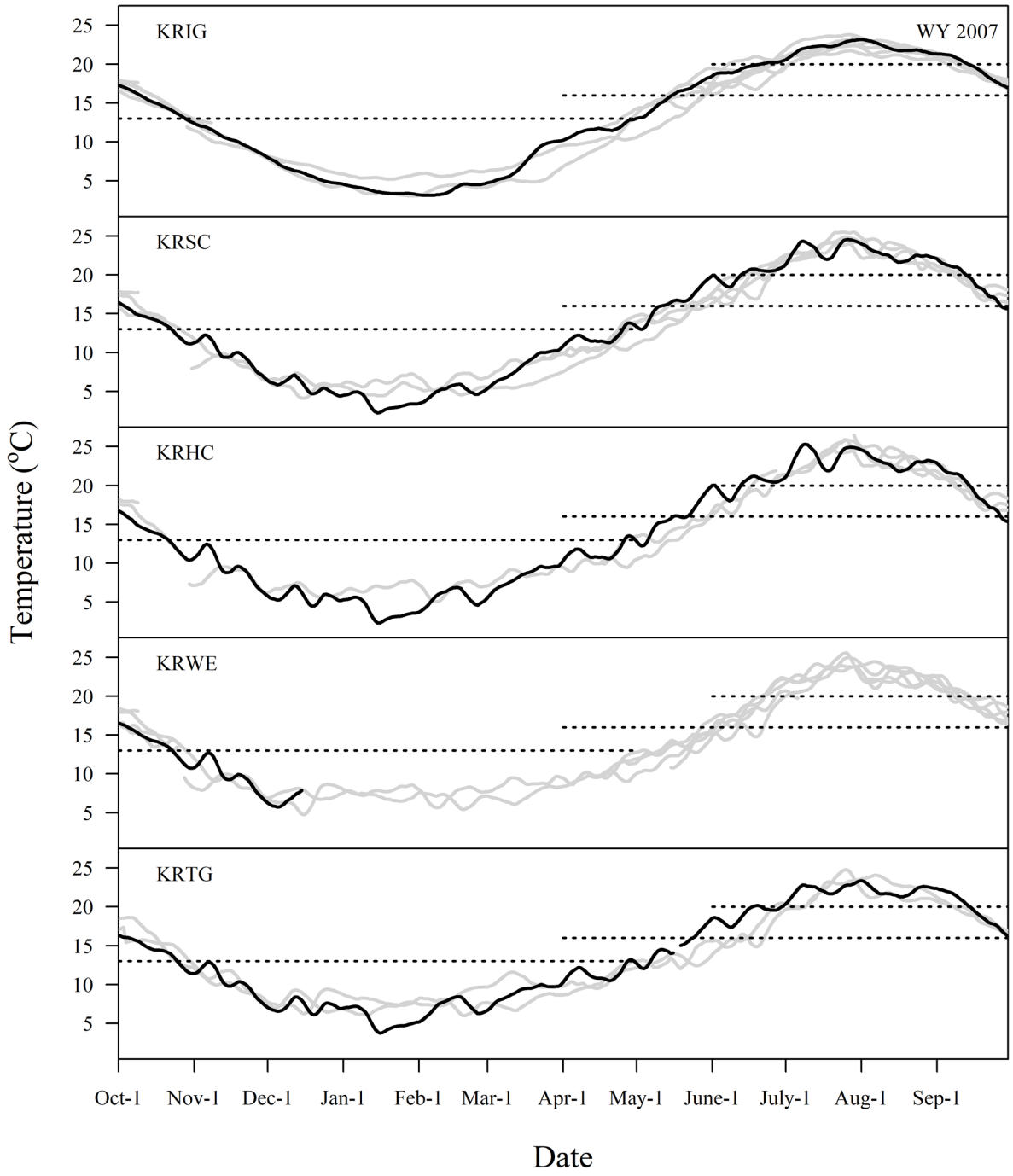

Appendix D4. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2003 – September 30, 2004, with historical with historical summaries from water years (WYs) 2001 to 2003. Black line = 7DADM water temperature in WY 2004; gray line = historical 7DADM water temperature; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



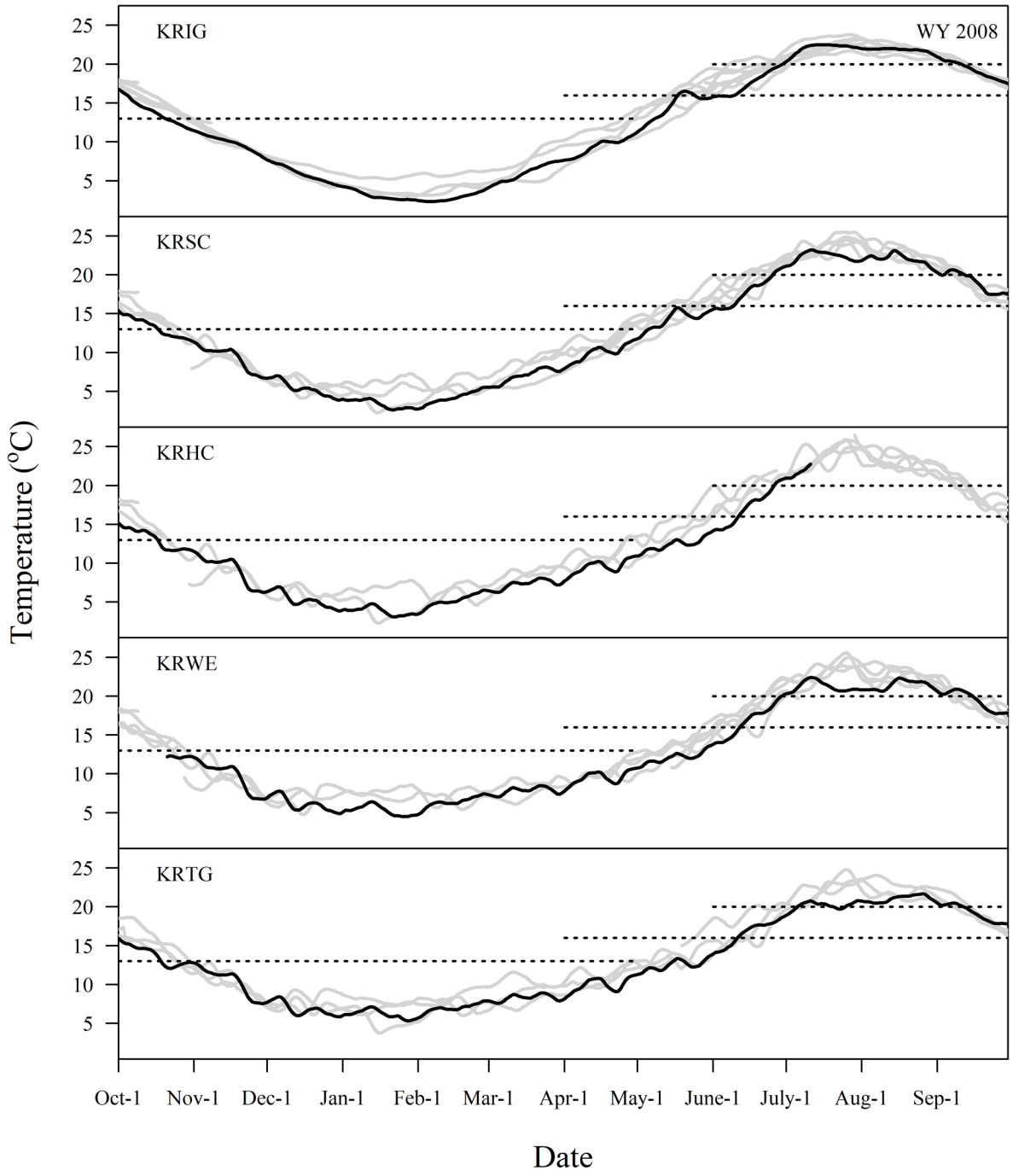

Appendix D5. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2004 – September 30, 2005, with historical summaries from water years (WYs) 2001 to 2004. Black line = 7DADM water temperature in WY 2005; gray line = historical 7DADM water temperature; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period ind exists for the site.



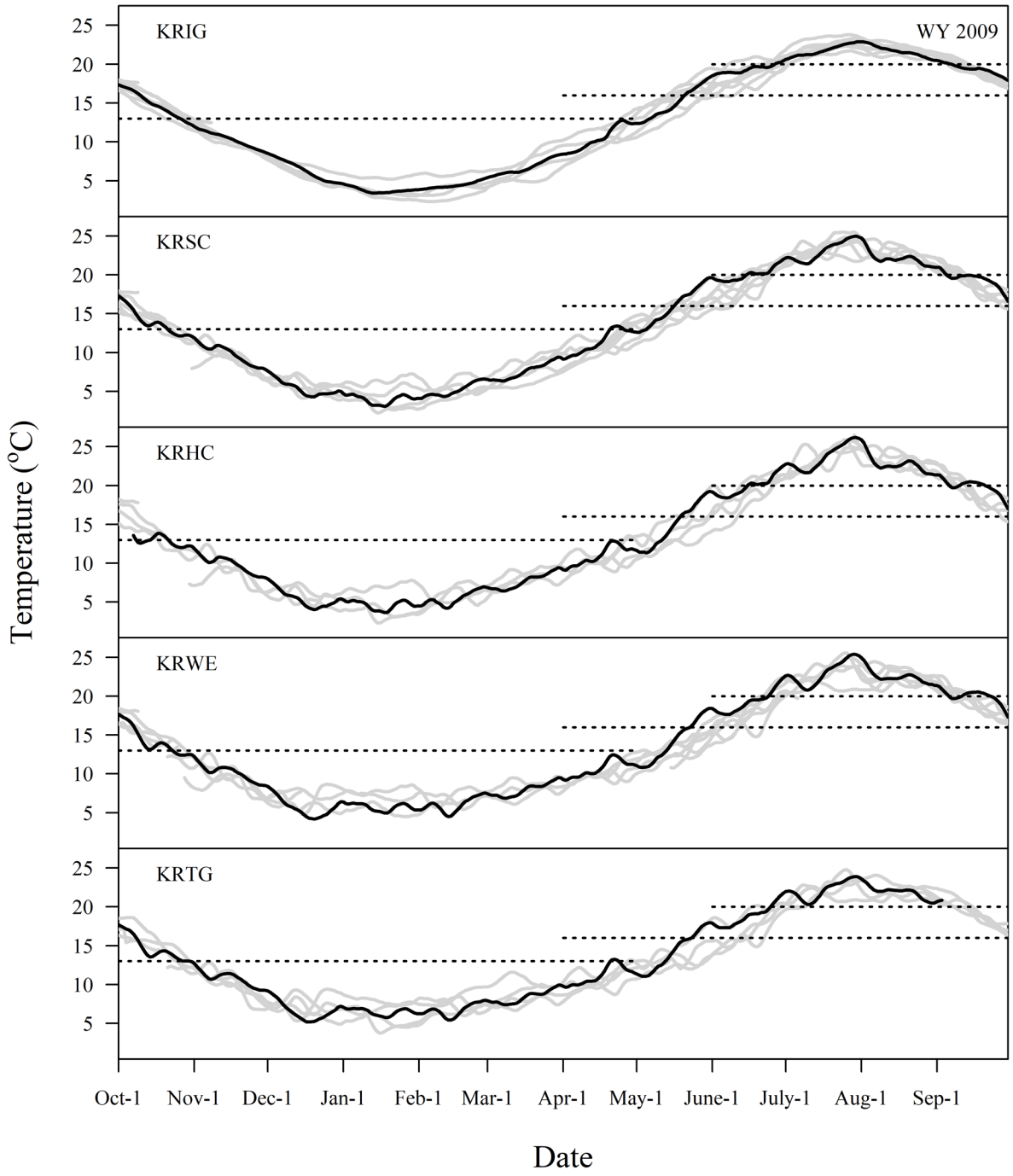

Appendix D6. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2005 – September 30, 2006, with historical summaries from water years (WYs) 2001 to 2005. Black line = 7DADM water temperature in WY 2006; gray line = historical 7DADM water temperature; dotted black line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



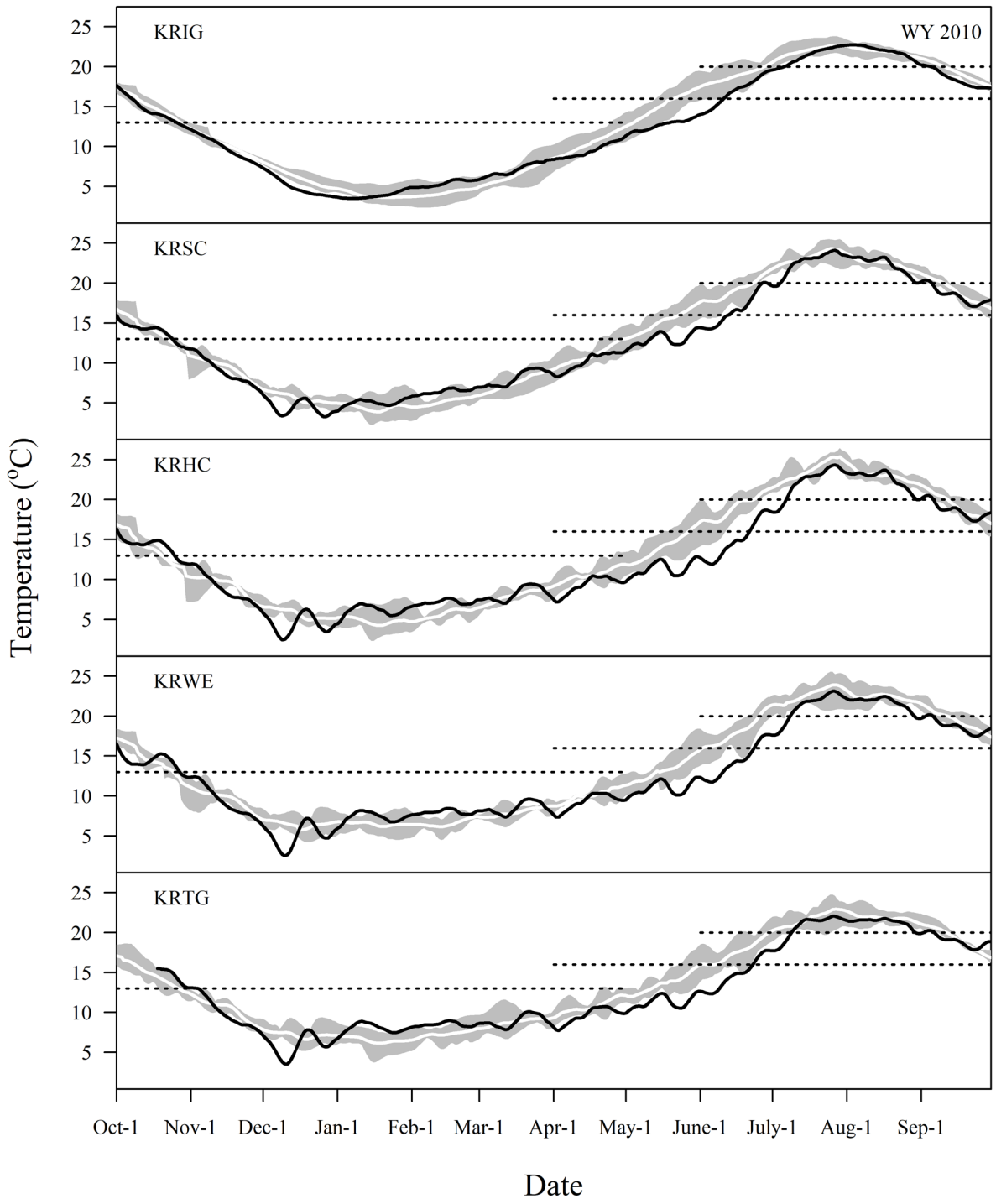

Appendix D7. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2006 – September 30, 2007, with historical summaries from water years (WYs) 2001 to 2006. Black line = 7DADM water temperature in WY 2007 gray lines= historical 7DADM water temperature; dotted lines = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



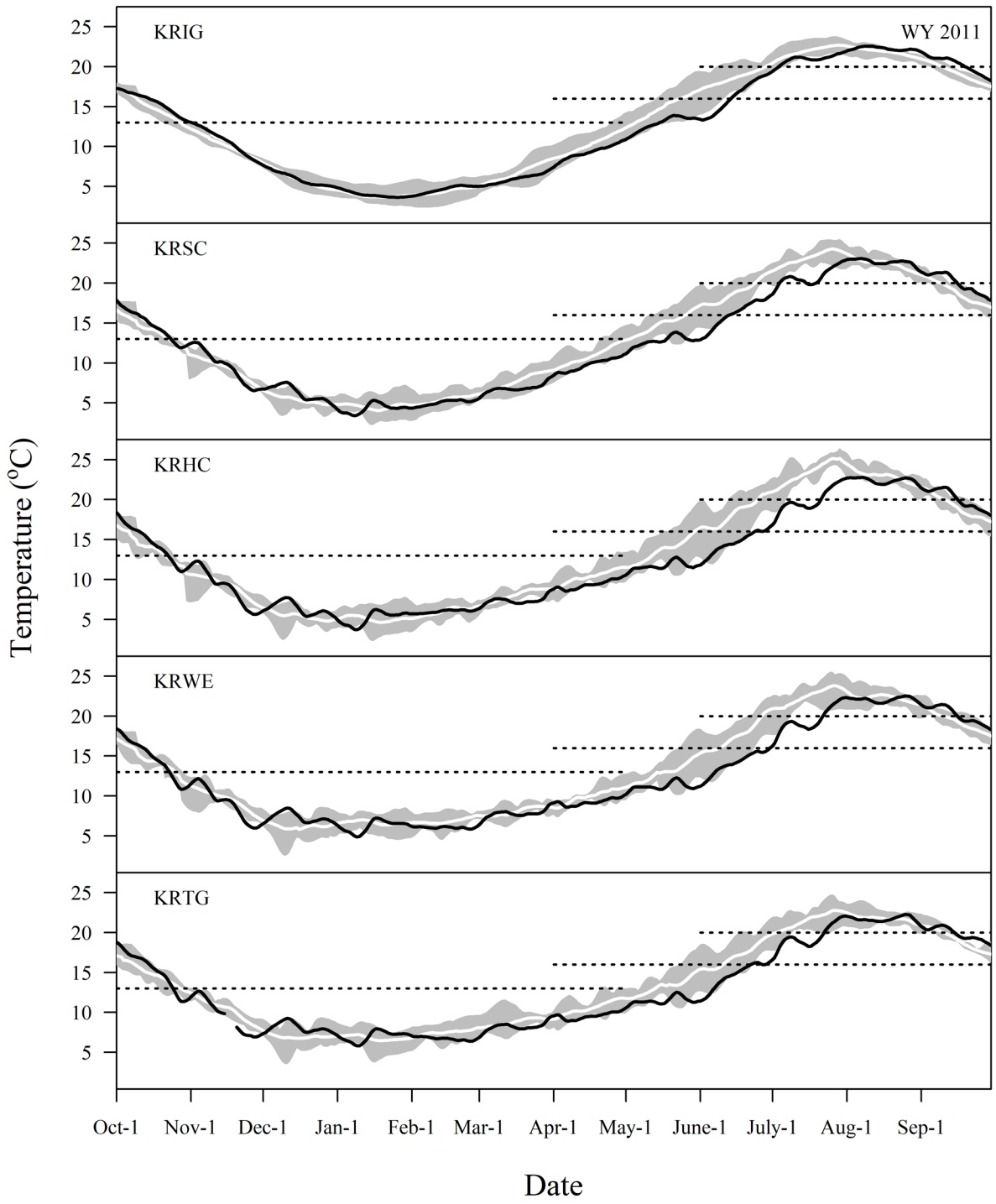

Appendix D8. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2007 – September 30, 2008, with historical summaries from water years (WYs) 2001 to 2007. Black line = 7DADM water temperature in WY 2008; gray line = historical 7DADM water temperature; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



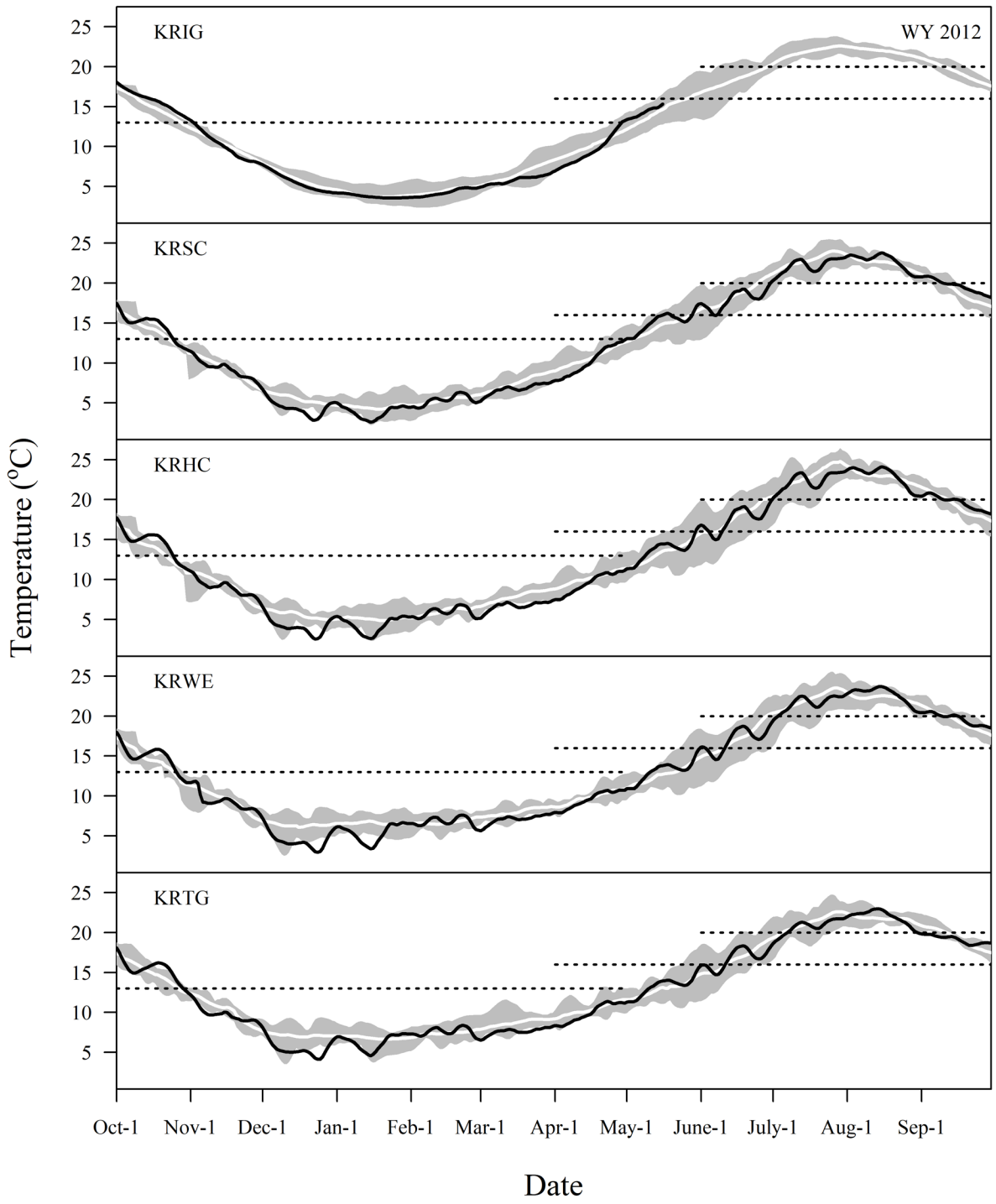

Appendix D9. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2008 – September 30, 2009, with historical summaries from water years (WYs) 2001 to 2008. Black line = 7DADM water temperature in WY 2009; gray line = historical 7DADM water temperature; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



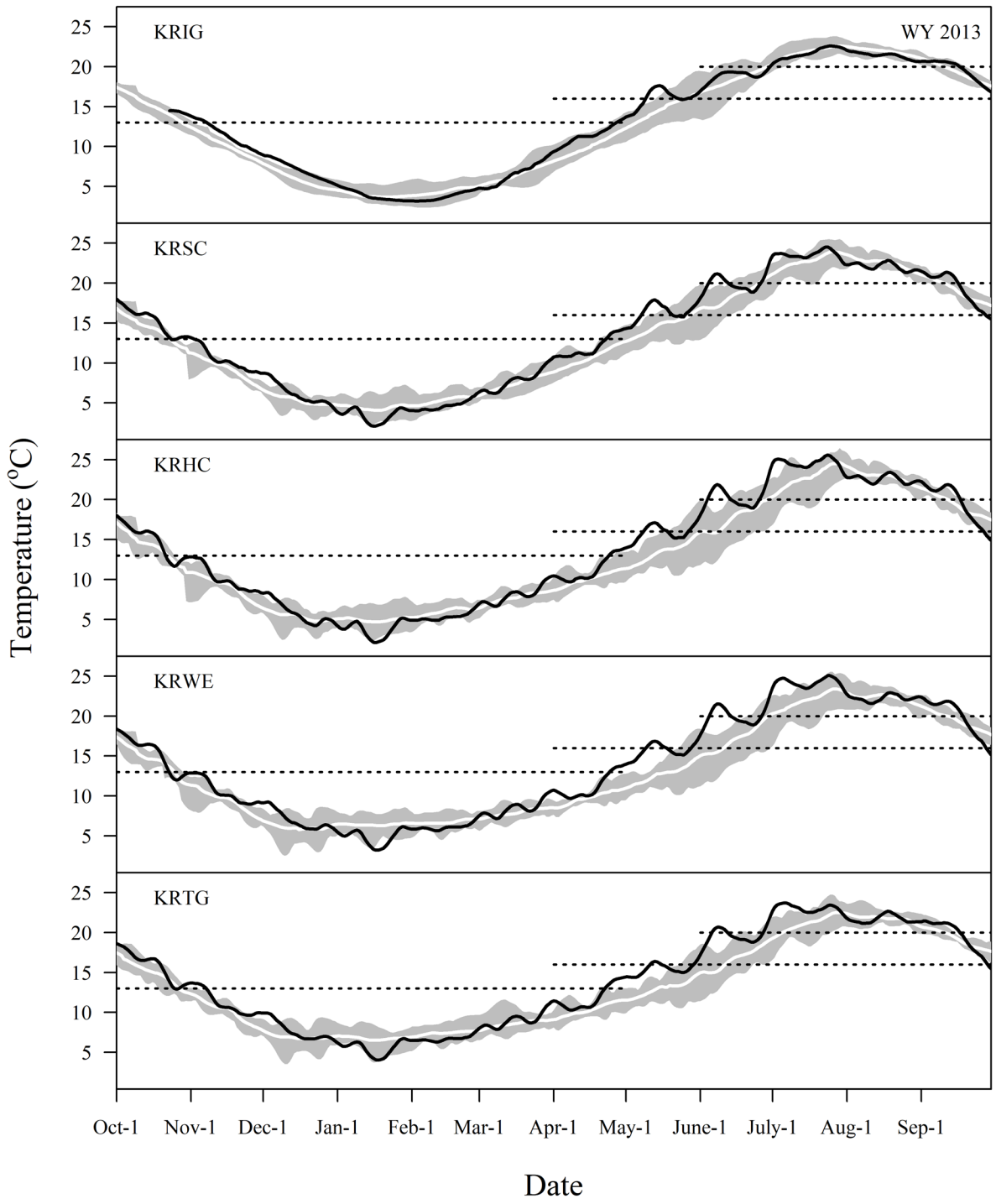

Appendix D10. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2009 – September 30, 2010, with historical summaries from water years (WYs) 2001 to 2009. Black line = 7DADM water temperature in WY 2010; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria.



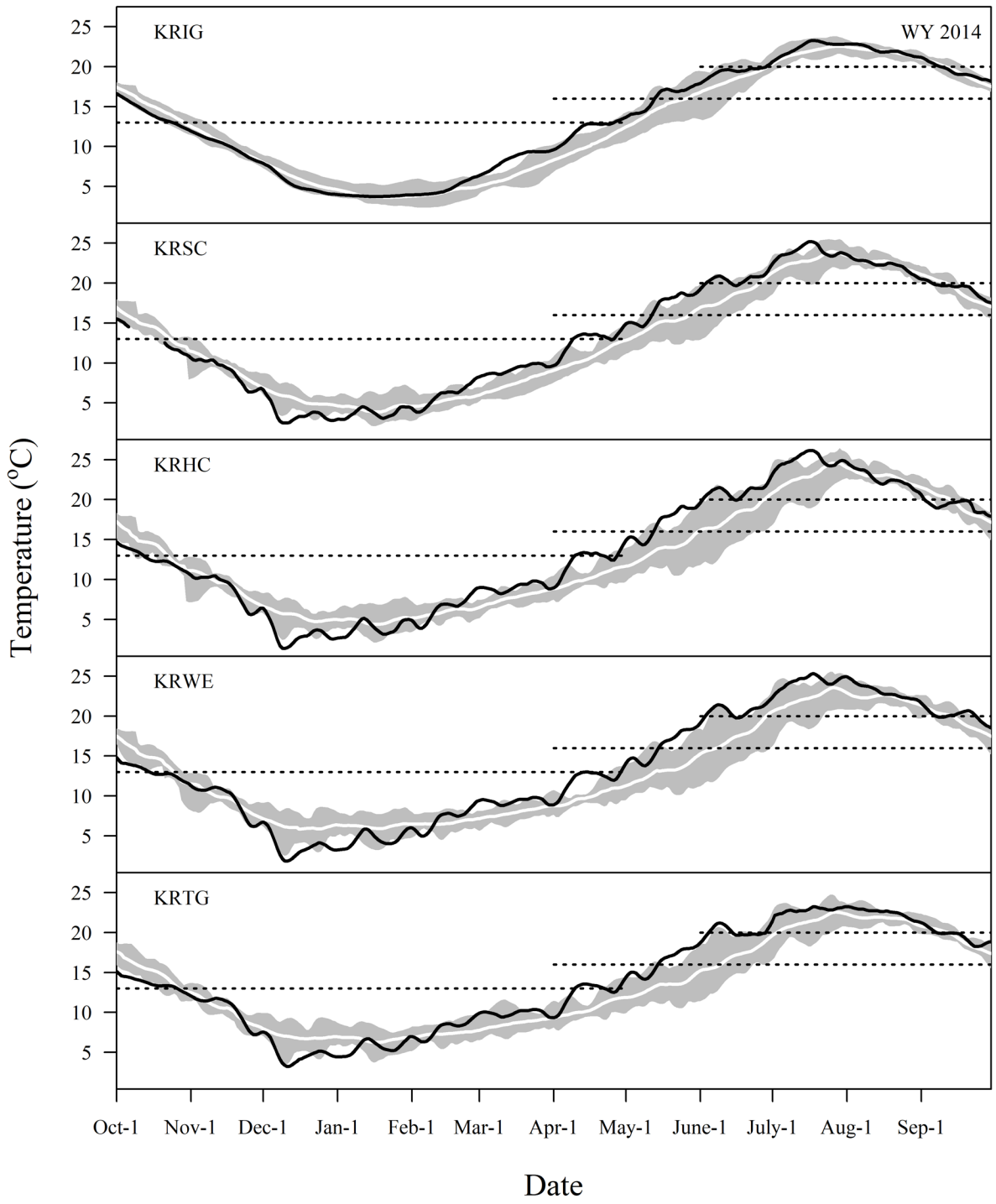

Appendix D11. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2010 – September 30, 2011, with historical summaries from water years (WYs) 2001 to 2010. Black line = 7DADM water temperature in WY 2011; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria.



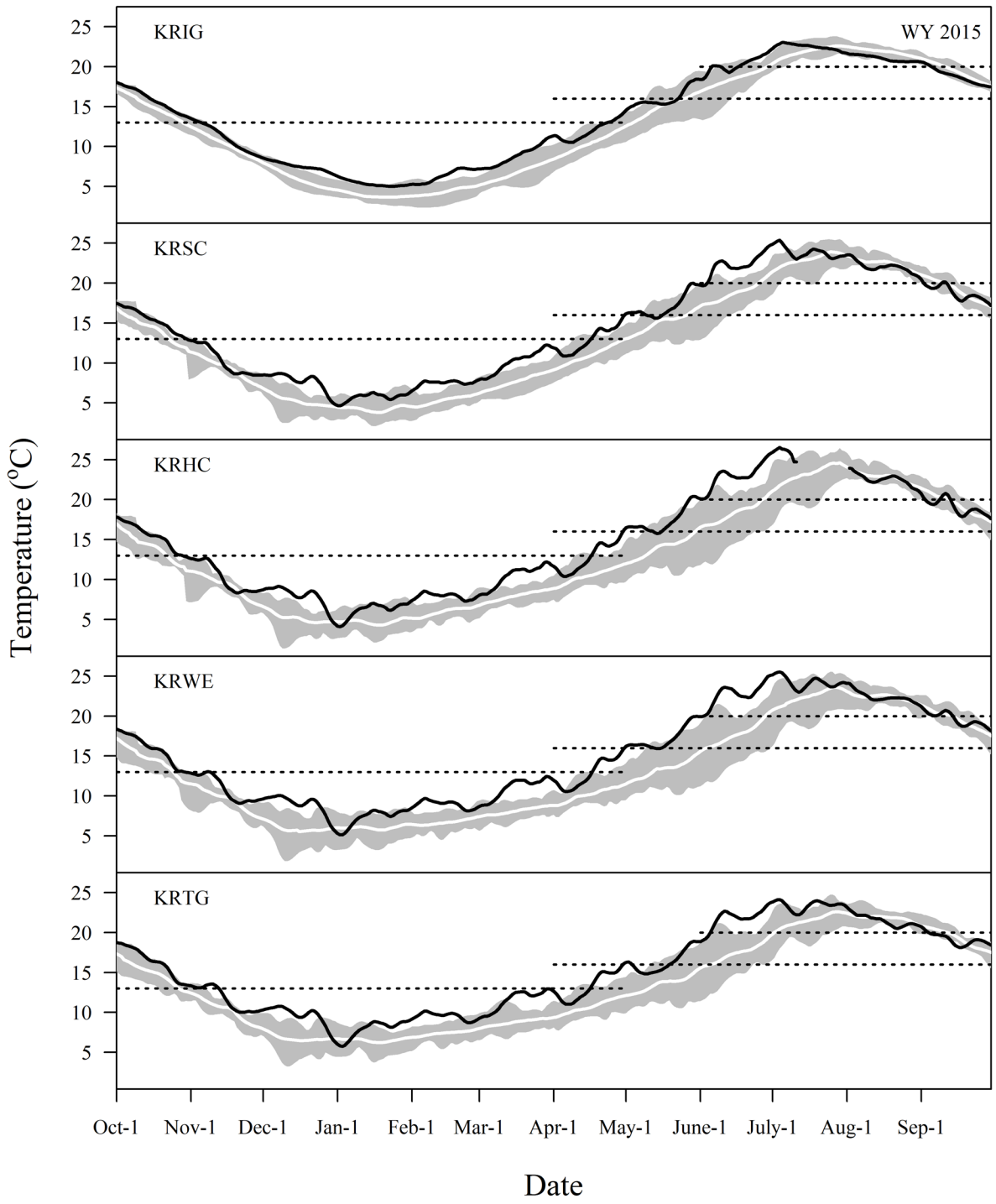

Appendix D12. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2011 – September 30, 2012, with historical summaries from water years (WYs) 2001 to 2011. Black line = 7DADM water temperature in WY 2012; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



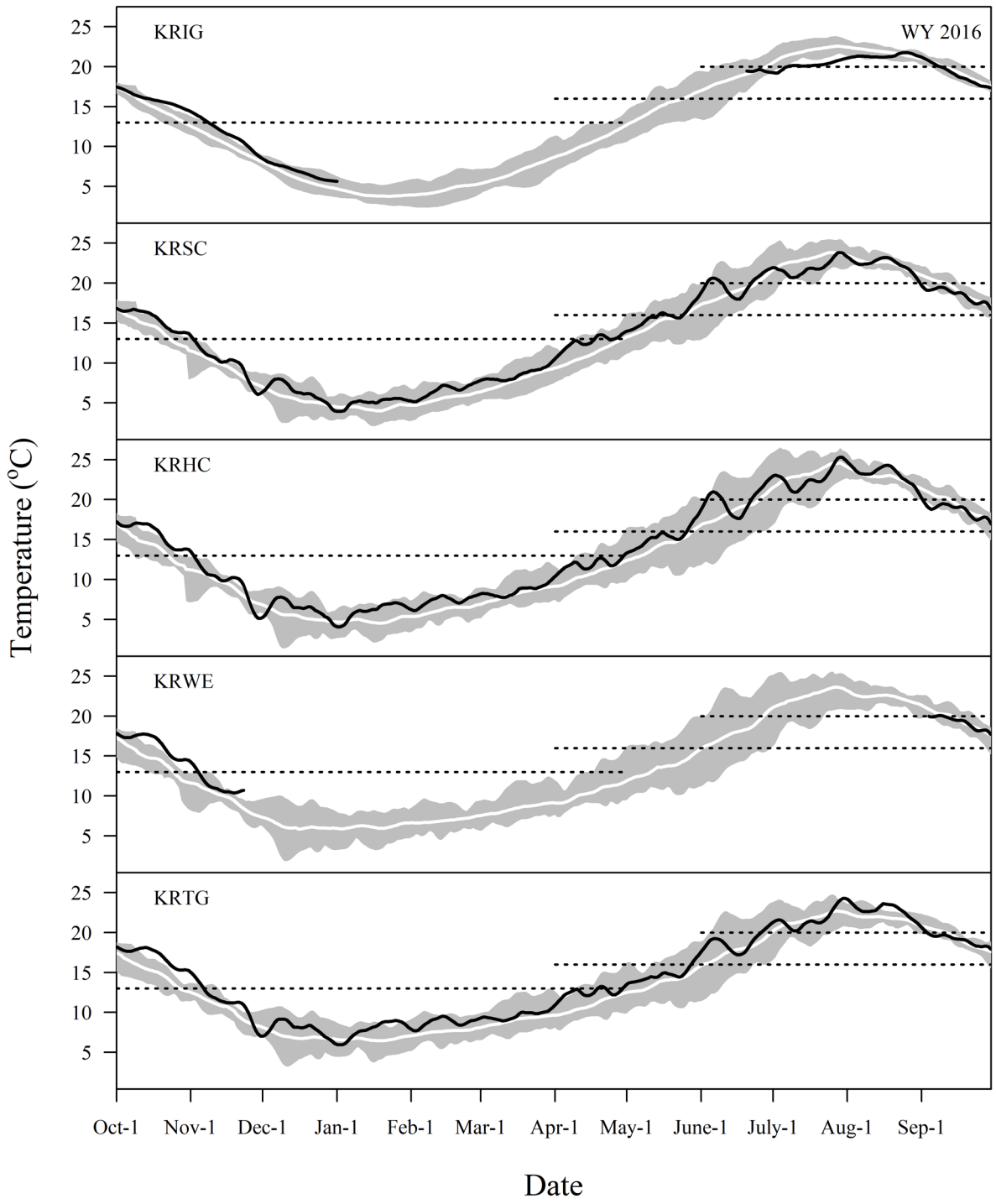

Appendix D13. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2012 – September 30, 2013, with historical summaries from water years (WYs) 2001 to 2012. Black line = 7DADM water temperature in WY 2013; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



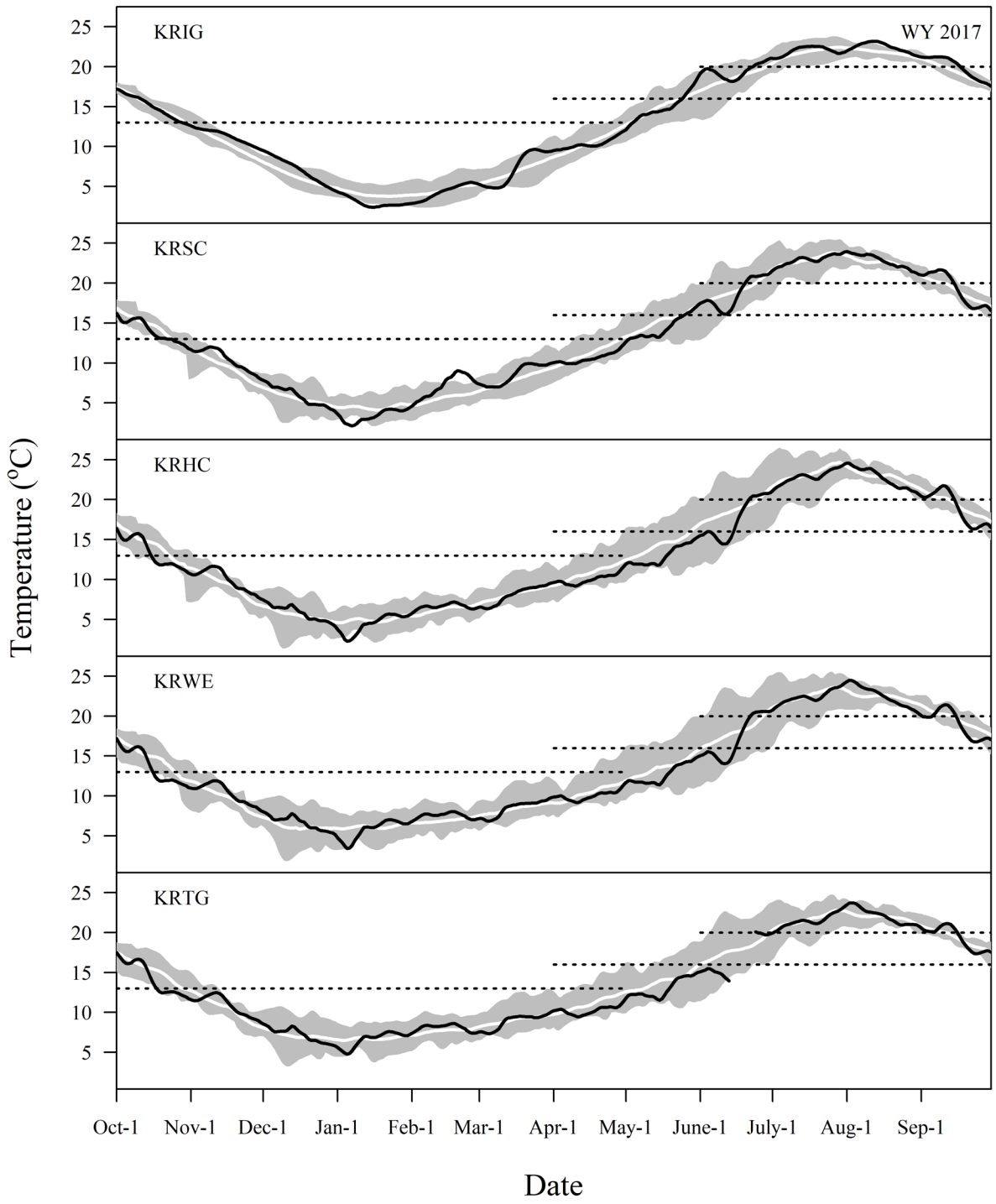

Appendix D14. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2013 – September 30, 2014, with historical summaries from water years (WYs) 2001 to 2013. Black line = 7DADM water temperature in WY 2014; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



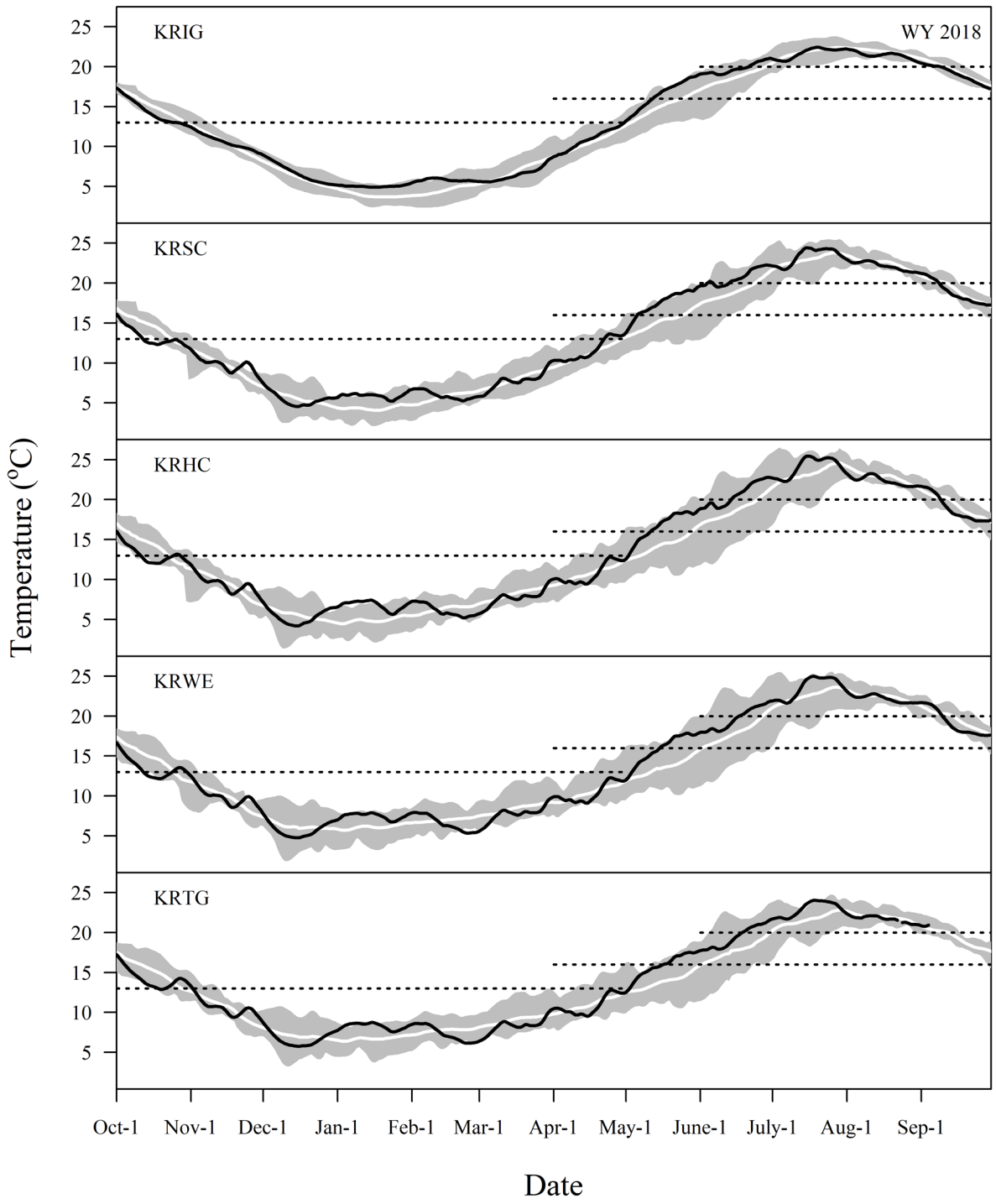

Appendix D15. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2014 – September 30, 2015, with historical summaries from water years (WYs) 2001 to 2014. Black line = 7DADM water temperature in WY 2015; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.



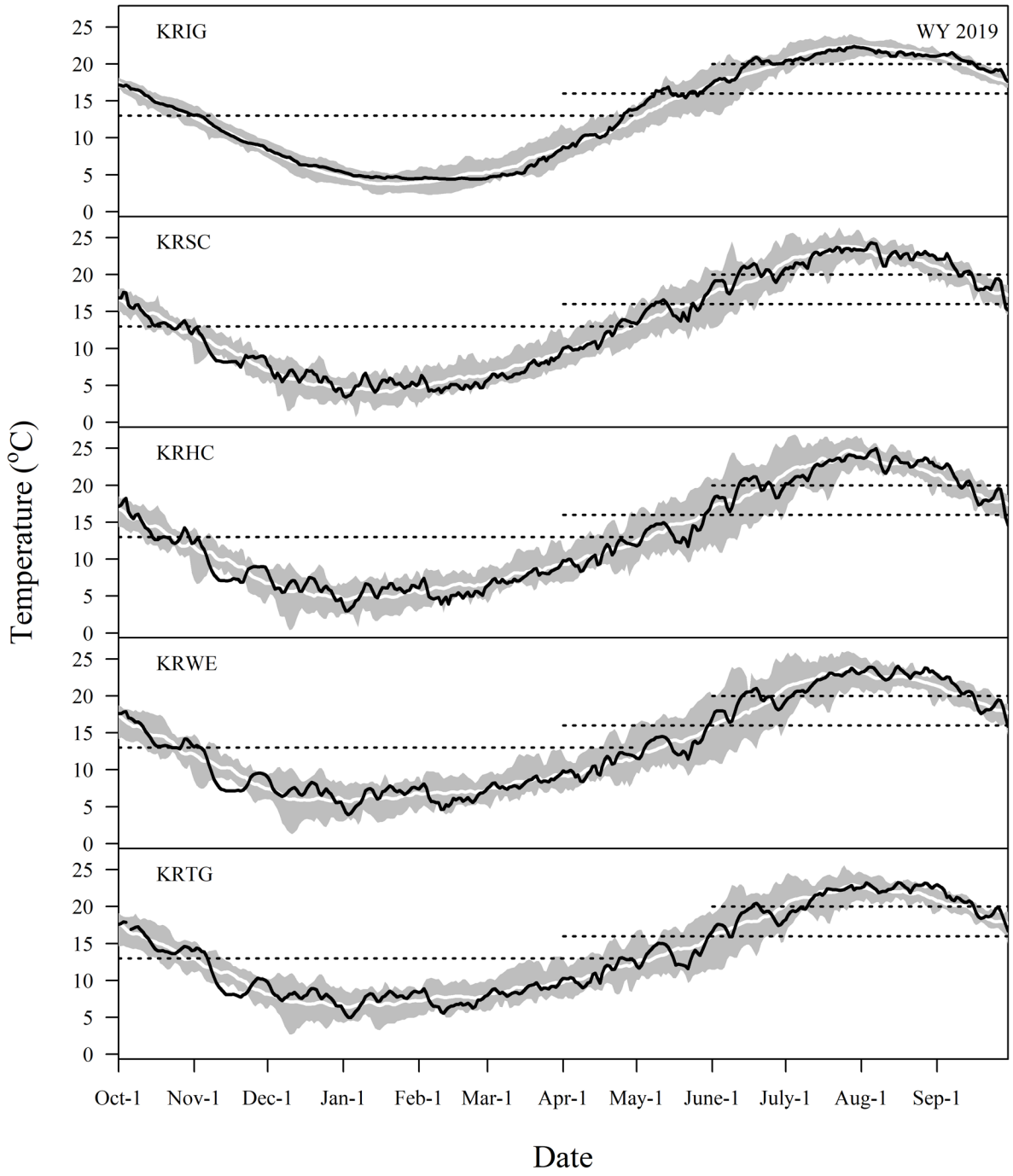

Appendix D16. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, April 15 – October 31, 2016, with historical summaries from water years (WYs) 2001 to 2015. Black line = 7DADM water temperature in WY 2016; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.




Appendix D17. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2016 – September 30, 2017, with historical summaries from water years (WYs) 2001 to 2016. Black line = 7DADM water temperature in WY 2017; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.




Appendix D18. Seven-day average daily maximum (7DADM) water temperature at focal Klamath River monitoring locations, October 1, 2017 – September 30, 2018, with historical summaries from water years (WYs) 2001 to 2017. Black line = 7DADM water temperature in WY 2018; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = Environmental Protection Agency Pacific Northwest water temperature criteria. Sections that are blank indicate that during that period no data exists for the site.




Appendix D19. Seven-day average daily maximum temperature (7DADM) at focal Klamath River monitoring locations, October 1, 2018 – September 30, 2019, with historical summaries from water years (WYs) 2001 to 2018. Black line = 7DADM water temperature in WY 2019; white line = average historical 7DADM for each day of the year; gray polygon = 7DADM historical range for each day of the year; black dotted line = EPA Pacific Northwest water temperature criteria.

Appendix E. Plot for missing historical data on the Klamath and Trinity rivers 2000-2021. Gaps indicate periods of missing water temperature data that was not infilled. Data from 2000-2018 was not infilled.