# TROUT POPULATION MONITORING WITHIN NANTAHALA RIVER BYPASS REACH, MACON AND SWAIN COUNTIES, NC, IN RESPONSE TO RECREATIONAL FLOW RELEASES

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Amanda M. Bushon
Jacob M. Rash
Christopher J. Goudreau

North Carolina Wildlife Resources Commission
Division of Inland Fisheries
Raleigh

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*Abstract.*—Recreational flow releases were established within Nantahala River Bypass Reach through the Federal Energy Regulatory Commission relicensing of Duke Energy's Nantahala Project. In 2012–2013, the North Carolina Wildlife Resources Commission, in conjunction with other resource managers, attempted to monitor the influence of recreational flow events on wild trout populations within Nantahala River Bypass Reach and Nantahala Tailwater. Monitoring included temperature loggers, fish population sampling, and fish held in live cages during the flow events. Temperature effects of release events were most pronounced during late summer and fall releases. Densities and standing crop estimates of adult wild trout did not vary substantially among the sample dates; however, age-0 Rainbow Trout were not present during the last sample date at either site. Short-term effects of the releases were not apparent in fish held in live cages. Although recreational releases have the potential to affect wild trout populations, stocking trout in the bypass reach remains a viable management approach.

Nantahala River and its Bypass Reach, Swain and Macon counties, provide a diversity of recreational opportunities below Nantahala Dam. Currently, the North Carolina Wildlife Resources Commission (NCWRC) manages trout fisheries within these waters under its Public Mountain Trout Waters (PMTW) program. Two PMTW regulatory classifications are present on three stream segments: Hatchery Supported Trout Waters (Nantahala Dam to Whiteoak Creek); Delayed Harvest Trout Waters (Whiteoak Creek to Nantahala hydropower discharge canal); and Hatchery Supported Trout Waters (Nantahala hydropower discharge to Fontana Reservoir water level). These waters are stocked annually with a total of 25,500 Brook Trout *Salvelinus* *fontinalis*, Rainbow Trout *Oncorhynchus mykiss*, and Brown Trout *Salmo trutta.* These resources also contain self-reproducing populations of Rainbow Trout and Brown Trout, and wild Brook Trout from Nantahala River tributaries can be found occasionally.

Through Duke Energy's Federal Energy Regulatory Commission (FERC) relicensing of the Nantahala Project, Section 5.3 of the Nantahala Cooperative Stakeholder Team Settlement Agreement established recreational flows within the Nantahala Bypass Reach via spillway releases from Nantahala Dam (Appendix; Smutko and Addor 2004). The NCWRC and other resource managers were charged with monitoring the wild trout populations in response to these releases (Smutko and Addor 2004).

PMTW resources are popular destinations for anglers (Responsive Management 2007) and contribute substantially to local economies (Responsive Management 2009). Spillway releases from Nantahala Dam introduce Lake Nantahala surface water into Nantahala Bypass Reach, and as such, these releases have the potential to alter temperature regimes within receiving waters. Water temperature is a critical parameter for the survival and growth of fishes, and temperatures consistently below or above a species threshold can cause stress or mortality (Krause et al. 2005). This report provides information regarding thermal and biological monitoring of PMTW waters influenced by recreational flow releases into Nantahala Bypass Reach and Nantahala Tailwater.

## Methods

From 2012–2014, wild salmonid population and temperature monitoring efforts were conducted at sites within lotic waters of Nantahala River below Nantahala Dam (Figure 1). These survey efforts concentrated on temporal periods associated with scheduled recreational releases within Nantahala Bypass Reach (Table 1).

*Fish surveys.*—Depletion samples were conducted as described by the SDAFS Trout Committee (1992) at two sites within Nantahala Bypass Reach: above White Oak Creek (F1) and above Nantahala Powerhouse (F2; Figure 1). Samples were conducted on 24 September 2012 (prior to the first release event), 4 October 2012, and 3 October 2013. Block nets were used at each site to ensure that the sample population was closed during depletion sampling, and three upstream-electrofishing passes were made within the site via one backpack electrofisher and netter per every three meters of the average wetted stream width. All fish captured were transported to a workup station upstream of the sample site following each sampling pass. For each pass, all trout were weighed (g) and total length measured (mm, TL), and non-trout species were identified and enumerated, with a range in total length (mm) and an aggregate weight (g) obtained for each non-trout species. All fish from each pass were placed into live cages outside of the sample site and released throughout the sample site following completion of the final pass. Depletion data were analyzed with *MicroFish 3.0* (Van Deventer and Platts 1989) to develop estimates of density (number fish/ha) and standing crop (kg/ha) for age-0 (≤100 mm TL) and adult (>100 mm TL) salmonids.

In addition, live cages containing salmonids were used to evaluate potential thermal impacts during recreational releases at two sites within Nantahala Bypass Reach (above White Oak Creek and Wayah Road bridge; Figure 1) and one reference location (Piercy Creek; Figure 1). Two live cages (310 x 150 x 510 mm) with 5-mm mesh were anchored at each site and submerged in locations protected from increased flows (adjacent to banks and behind structure) prior to release events. Five trout were collected from Nantahala Bypass Reach or Piercy Creek via backpack electrofishing for each live cage (10 trout per site) on 28 September 2012, 1 July 2013, and 27 September 2013. All trout were weighed (g), measured (mm, TL), and placed into cages. Zippers on all cages were secured to prevent escapement. Live cages were monitored during release events to ensure they remained secure during high flows. Additionally, cages were checked for dead or lethargic fish on 29 and 30 September 2012, 1 October 2012, 2 July 2013, and 28 and 30 September 2013. All fish were released at sample locations.

*Temperature monitoring.*—From 1 August 2012–15 July 2014, Onset Computer Corporation HOBO Pro v2 temperature data loggers (Bourne, MA) were deployed above Dicks Creek (T1), above White Oak Creek (T2), above Nantahala Powerhouse (T3), within the upper Nantahala Tailwater (T4), and within the lower Nantahala Tailwater (T5) to obtain temperature recordings (ºC) (Figure 1). Temperature recordings were obtained hourly throughout the study duration; however, loggers were set to record at 5-min intervals during release events.

## Results and Discussion

Brook Trout, Brown Trout, and Rainbow Trout were captured during fish surveys on the Nantahala Bypass Reach during the 2012–2013 survey period. Rainbow Trout were the predominate salmonid captured, followed by Brown Trout and Brook Trout. Brown Trout and Rainbow Trout were captured at both sites during each of the three surveys. One Brook Trout was captured during the study period at site F2 during the 3 October 2013 sample. This fish was most likely of hatchery origin and therefore excluded from density and standing crop estimates. Eight non-trout species were collected during the surveys (Table 2).

*Length-frequency distributions.*—Size structures of Brown Trout and Rainbow Trout during the 24 September 2012 sampling event consisted of individuals with lengths ranging from 103 to 483 mm TL (mean=198 mm TL; SD=107.9) and 71 to 355 mm TL (mean=140 mm TL; SD=54.0), respectively (Figure 2). On 4 October 2012, size structures for Brown Trout and Rainbow Trout were comprised of individuals with lengths ranging from 91 to 379 mm TL (mean=180; SD=83.1) and 74 to 383 mm TL (mean=151; SD=64.8), respectively (Figure 2). Brown Trout lengths ranged from 116–349 mm TL (mean=182; SD=69.6) and Rainbow Trout lengths ranged from 101–279 mm TL (mean=171; SD=45.6) during the final collection event on 3 October 2013 (Figure 2).

Length-frequency distributions revealed that the overall proportion of age-0 (≤100 mm TL) Rainbow Trout declined throughout the survey period: 32% (September 2012), 19% (4 October 2012), and 0% (3 October 2013). The proportion of age-0 Brown Trout was also low during the study period (range=0–17%). These values for both species are lower than 10 other Rainbow Trout populations in North Carolina (range=35–88%; mean=52%) reported by Borawa et al. (2001).

*Trout density and standing crop.*—Age-0 trout density and standing crop estimates were variable over all sampling events and sites (Figure 3). Age-0 Rainbow Trout densities declined at both sites during the study period (Table 3). At Site F1 densities were 176 trout/ha (95% CI: 185, 168) prior to the first release and declined to 10 trout/ha on 3 October 2013. Age-0 Rainbow Trout densities at site F2 declined from 109 trout/ha (95% CI: 122, 96) on 24 September 2012 to 0 trout/ha on 3 October 2013. Age-0 Rainbow Trout standing crop estimates followed a similar pattern; except at site F1, where standing crop increased from 1.1 kg/ha (95% CI: 1.3, 1.0) to 1.2 kg/ha (95% CI: 1.2, 0.1) and then decreased to 0 on 3 October 2013 (Table 4). Age-0 Brown Trout were only captured on 4 October 2012 at site F1. The variability in age-0 densities and standing crop could be attributed to natural environmental variation (Borawa et al. 2001). Western North Carolina experienced elevated rainfall in 2013. This heightened precipitation increased discharge within Nantahala River and its Bypass Reach, especially during summer months. High flows associated with natural and release events during spring and summer had the potential to influence observed age-0 Rainbow Trout values. Rainbow Trout spawn during late winter to late spring and fry usually emerge at the swim up stage 45–75 d later, depending on temperature (Raleigh et al. 1984). During this stage young fish have limited swimming capabilities and are susceptible to downstream displacement (Irvine 1986; Heggenes and Traaen 1988; Nuhfer et al. 1994; Jenson and Johnson 1999). Additionally, spring and summer release events may coincide with the swim-up stage of Rainbow Trout and present the potential of downstream displacement, but determining the influence of releases on trout recruitment during years of elevated participation is difficult.

Adult trout densities and standing crop estimates were less variable than age-0 trout during the study period (Figure 4). Total adult trout densities (species combined) ranged from 170 trout/ha (95% CI; 196, 144) to 570 trout/ha (95% CI: 608, 532) (Table 3). Total adult trout standing crop ranged from 12.3 kg/ha (95% CI: 15, 8) to 32.0 kg/ha (95% CI: 36, 28) (Table 4). Adult Rainbow Trout densities decreased at site F1 during the study period, while standing crop was highest (20.3 kg/ha; 95% CI: 24, 17) during the last sample on 3 October 2013. Adult Rainbow Trout densities and standing crop estimates at site F2 were highest on the final sample date (Table 3). Adult Brown Trout densities followed the same pattern at both sites (Table 3). As with age-0 trout, high annual variability in density and standing crop estimates is common for adult trout (Borawa et al. 2001). Based on data observed within this study, sources of such variability are difficult to identify and ultimately, differentiate from natural processes.

*Live cages.*—A total of 71 Rainbow Trout, 17 Brown Trout, and two Brook Trout (most likely hatchery origin) were collected and used for live cages in Nantahala Bypass and Piercy Creek. Trout ranged in length from 61 to 299 mm TL (mean=168 mm TL; SD=53.5). Of the 60 trout placed in live cages in Nantahala Bypass Reach, 52 survived and three were either found dead or missing. An additional five fish were not recovered when a live cage was stolen on 29 September 2013. Twenty-three of the 30 fish placed in live cages in Piercy Creek survived, while seven were either dead or missing.

The cause of death of the three observed deceased fish within Nantahala Bypass Reach is unknown. Release events introduced elevated flows, temperatures, and sedimentation into Nantahala Bypass Reach. Each of these alterations can work independently to increase stress levels in fish, but it is also possible that some combination of these worked to impact fish health. Deceased individuals within Piercy Creek exhibited scars consistent with negative interactions with other fishes that likely resulted in their death.

*Temperature monitoring.*—Temperatures were recorded at three sites in the Nantahala Bypass Reach and two sites in Nantahala Tailwater from August 2012 July–July 2014. Temperature effects of release events were most pronounced during fall and summer releases at temperature logger sites in Nantahala Bypass Reach (T1–T3). Average and maximum daily temperatures at sites T1, T2, and T3 increased during fall and summer release events (Figure 5).

Fall releases resulted in a slight rise in temperature at sites within Nantahala Bypass Reach. The maximum daily temperatures at Site T1 during fall 2012 release events were over 21.0°C and stayed there for approximately five h each release day (Table 5; Figure 6). This temperature is above the preferred temperature range of Rainbow Trout (12–19°C) and Brown Trout (12.4–17.6°C); however, it is below the upper incipient lethal temperature (UILT) for Brown Trout and

Rainbow Trout, which range from 24–26°C (Ferguson 1958; MacCrimmon and Marshall 1968; Coutant 1977; Raleigh et al. 1984; Eaton et al. 1995; Weherly et al. 2007). The remainder of the sites stayed below 21.0°C during the two releases (Table 5). Overall, the mean daily maximum water temperature at sites T1, T2 and T3 during the fall 2012 release event peaked at approximately 4–5°C higher on release days than on seven non-release days surrounding the event (Figure 7). The daily temperature range for sites in Nantahala Bypass Reach was approximately 5°C during the release days, well below the maximum temperature range of 8.8°C that Weherly et al. (2007) reported Brook Trout and Brown Trout can withstand for up to three days (Figure 6). Temperature differences at sites T4 and T5 in the tailwater were not as pronounced and stayed below 18°C during both days (Table 5).

Similar to 2012, daily maximum temperatures during fall 2013 releases peaked over 21.0°C at site T1 and stayed at or above that temperature for two to four hours (Table 5; Figure 6). Temperatures at the remaining sites stayed below 21.0°C. Mean daily maximum temperatures in the Nantahala Bypass Reach during fall 2013 release days at sites T1, T2 and T3 were approximately 3.3–3.8°C higher than non-release days surrounding the event (Figure 7). The average temperature range for sites in Nantahala Bypass Reach was approximately 6°C (Figure 8). Temperatures in the Nantahala Tailwater were not substantially affected during the fall 2013 release events. Sites T4 and T5 had an average daily maximum temperature of 16.5 (SE=0.1) and 17.4°C (SE=0.1), respectively. Mean daily maximum temperatures during the seven days surrounding the release events were 16.1 (T4; SE=0.8) and 17.0°C (T5; SE=0.5); therefore, average maximum temperatures were only raised by 0.4°C on release days at both sites in the tailwater.

Spring 2013 release events did not appear to have a negative effect on water temperatures in Nantahala Bypass Reach or Nantahala Tailwater. Maximum temperatures never reached 15°C, and in many instances, the maximum temperatures during the release events were lower than on non-release days (Table 5; Figure 7; Figure 8). The mean daily maximum temperatures were elevated during the spring 2014 releases; however, the difference between release and non-release days was within 2°C (Figure 7). Maximum daily water temperatures ranged from 16.8–17.7°C at Sites T1, T2, and T3 during the releases, and 12.9–13.4°C at sites T4–T5 (Table 5; Figure 8).

Summer release events produced high maximum water temperatures in Nantahala Bypass Reach. Maximum water temperatures were over 21.0°C at all sites in Nantahala Bypass Reach during the four summer 2013 release days, and site T4 in the tailwater reached 21.5°C during the final summer release on 1 September 2013 (Table 5). During the three release days in June and July 2013 maximum temperatures in Nantahala Bypass Reach ranged from 21.1–24.6°C (Table 5; Figure 9). While the maximum temperatures in Nantahala Bypass Reach were over 21.0°C during the June and July 2013 releases, the mean daily maximum temperature at sites T1, T2 and T3 were 1.8–2.7°C warmer than the seven days surrounding each release (Figure 7). In contrast to Nantahala Bypass Reach, temperatures at sites T4 and T5 in Nantahala Tailwater stayed below 16.5°C during the first three summer releases in 2013, and mean daily maximum temperatures during release events were lower than the seven days surrounding the releases (Figure 7).

The warmest temperatures of the summer 2013 releases were recorded during the final release on 1 September 2013. On this date, the maximum temperature was 24.9°C at site T1 and site T4 reached 21.5°C (Table 5). Temperatures at T1 stayed above 24.0°C for over five hours (Figure 9). Maximum temperatures at sites T2 and T3 were 23.9°C and 22.8°C, respectively, and stayed above 21.0°C for 10.5 h at T2 and 8.4 h at T3 (Figure 9). Water temperatures in Nantahala

Bypass Reach and Nantahala Tailwater were elevated during this time of year; the mean daily maximum temperatures during the 1 September 2013 release was 2.9–3.9°C higher than non-release days at Sites T1–T4. Temperatures in Nantahala Bypass Reach were above preferred temperatures of Brown Trout and Rainbow Trout during all the summer 2013 release days. Furthermore, temperatures were close to or within the UILT range for Brown Trout and Rainbow Trout at site T1 on 1 July 2013 (24.6°C) and sites T1 and T2 on 1 September 2013 (24.9°C and 23.9°C, respectively) (Table 5). However, these temperatures were brief, and Weherly et al. (2007) reported that Brown Trout can withstand maximum temperatures of up to 27.6°C for one day, with Rainbow Trout most likely having similar tolerances. Also, temperatures downstream of those sites were below the lethal range and could have provided thermal refuge during recreational flows.

Similar results were observed during the first two summer 2014 releases. Maximum temperatures peaked over 22.0°C at sites T1, T2 and T3 during the 21 June 2014 release (Table 5). Temperatures at these sites stayed over 21.0°C for six to 11.5 h (Figure 9). During the 2 July 2014 release, temperatures reached 25.9°C at site T1 and stayed at that temperature for 55 min. Maximum temperatures reached over 22.3°C in the tailwater at site T4 and stayed there for one h. Temperatures stayed at or above 21.0°C at sites T1, T2, T3 and T4 for 7.5 h to 16.3 h due to the release on 2 July 2014 (Figure 9). Similar to summer 2013 releases, temperatures in Nantahala tailrace and bypass reach during non-release days were also relatively warm. Average maximum temperatures at sites T1, T2, T3 and T4 during release days were 2.6–3.6°C warmer than non-release days surrounding the release events (Figure 7).

## Summary

Wild trout densities and standing crop estimates generated for Nantahala Bypass Reach during the study were variable; however, age-0 Rainbow Trout were not present during the last sample date at either site. These observations may be attributed to natural variation or the spring and summer release events displacing fry downstream. Results from live cage trials did not reflect high incidences of acute mortality during release events.

Temperature monitoring revealed elevated temperatures in Nantahala Bypass Reach during fall and summer releases; highest temperatures occurred during summer months. Warmest temperatures were found above the Dicks Creek confluence, which is currently designated as Hatchery Supported Trout Waters but not considered wild trout habitat. Temperatures farther downstream in Nantahala Tailwater were considerably lower, but did exceed 22°C during summer 2014 releases. Concurrent releases from Nantahala Powerhouse lessened temperature effects from the spillway releases in Nantahala Tailwater, which is important to the sustainability of the wild trout fishery within the tailwater.

Temperature data collected during summer and fall releases showed that maximum water temperatures can be near or above the preferred temperature range of trout, but these temperatures were brief and below the upper lethal temperature tolerance reported for Rainbow Trout and Brown Trout. However, temperatures recorded during summer and fall 2013 were most likely not representative of typical conditions expected during release events. Water temperatures were most likely cooler than normal given uncharacteristically high precipitation and cooler ambient air temperatures for the period. Warmer and dryer conditions were present in 2014, but monitoring only lasted through the first two summer releases. Therefore, further monitoring is needed to assess the thermal impacts of summer and fall spillway releases on Nantahala Bypass Reach and Nantahala Tailwater.

Although this study focused upon wild trout resources, it is important to note that popular stocked-trout fisheries remain in the study area. It does not appear that spillway releases during the study impacted these resources or NCWRC's ability to manage them. Flows did alter angler use patterns for these fisheries via unsafe or undesirable angling conditions, but improvements to informational signage along Nantahala Bypass Reach during the study increased angler awareness of spillway-release events. It is important that these and other efforts to educate the angling public about release events continue. Additionally, spillway releases should remain in periods outside of NCWRC stocking events to avoid heightened angler usage and minimize the loss of stocked trout via downstream displacement (NCWRC unpublished data).

## Management Recommendations

1) Continue monitoring temperatures and flow within Nantahala Bypass Reach and Nantahala Tailwater during spillway releases through 2016. Monitoring should focus on summer and fall releases due to the elevated potential for thermal impacts.

2) Monitor Nantahala Lake surface temperatures at spillway gates through 2016 to determine the potential of spillway releases to impact Nantahala Bypass Reach or Nantahala Tailwater.

3) Continue concurrent releases from Nantahala Powerhouse to alleviate impacts to the Nantahala Tailwater fishery.

4) Continue to inform the angling public in advance and on the day of spillway-release events.

5) Continue to integrate NCWRC trout stocking events into spillway-release scheduling.

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TABLE 1.—Releases during 2012 to 2014 study period.

| Release Event | Target release dates | Release dates | | | Target flow ($ft^3/s$) | Release duration (hr) | Target times | High flow duration | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2012 | 2013 | 2014 | | | | At White Oak | At Powerhouse |
| Spring | 15–30 Apr | ----- | 27-Apr | 26-Apr | 250 | 6 | 1000–1600 | 1000–1800 | 1130–1930 |
| | | ----- | 28-Apr | 27-Apr | 350 | 6 | 1000–1600 | 1000–1800 | 1115–1930 |
| Summer | 15 Jun–31 Aug | ----- | 22-Jun<br>1-Jul<br>17-Jul<br>1 Sep* | 21-Jun<br>2-Jul<br>19-Jul<br>16-Aug | 250 | 3 | 1600–1900 | 1600–2100 | 1730–2230 |
| Fall | 15–30 Sep | 29-Sep | 28-Sep | 27-Sep | 300 | 7 | 1000–1700 | 1000–1900 | 1130–2030 |
| | | 30-Sep | 29-Sep | 28-Sep | 425<br>250 | 5<br>2 | 1000–1500<br>1500–1700 | 1000–1930 | 1115–2100 |

*Date moved outside of time frame with FERC approval

TABLE 2.—List of non-trout species collected during Nantahala River Bypass Reach electrofishing samples, 2012–2013.

| Common Name | Scientific Name |
|---|---|
| Blacknose Dace | *Rhinichthys atratulus* |
| Central Stoneroller | *Campostoma anomalum* |
| Creek Chub | *Semotilus atromaculatus* |
| Longnose Dace | *Rhinichthys cataractae* |
| Mirror Shiner | *Notropis spectrunculus* |
| Mottled Sculpin | *Cottus bairdi* |
| Northern Hog Sucker | *Hypentelium nigricans* |
| Smoky Dace | *Clinostomus sp.* |

TABLE 3.—Age-0 (≤100 mm TL) and adult (>100 mm TL) trout density (number/ha) estimates and associated 95 percent confidence intervals by species for Nantahala River Bypass Reach during sampling period, 2012–2013.

| | | Brook Trout | | Brown Trout | | Rainbow Trout | | All trout | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Site | Age-0 | Adult | Age-0 | Adult | Age-0 | Adult | Age-0 | Adult |
| 24 Sept 2012 | F1 | 0 | 0 | 0 | 166 (186, 146) | 176 (185, 168) | 404 (437, 371) | 176 (185, 168) | 570 (608, 532) |
| | F2 | 0 | 0 | 0 | 30 (56, 4) | 109 (122, 96) | 208 (235, 182) | 109 (122, 96) | 238 (274, 202) |
| 4 Oct 2012 | F1 | 0 | 0 | 34 (69, -1) | 136 (166, 106) | 113 (124, 103) | 374 (399, 349) | 147 (168, 127) | 510 (549, 472) |
| | F2 | 0 | 0 | 0 | 20 (28, 12) | 10 | 150 (175, 125) | 10 | 170 (196, 144) |
| 3 Oct 2013 | F1 | 0 | 0 | 0 | 101 (122, 80) | 0 | 343 (374, 311) | 0 | 443 (481, 405) |
| | F2 | 0 | 10* | 0 | 40 (59, 20) | 0 | 366 (476, 257) | 0 | 406 (517, 295)* |

*Hatchery Brook Trout was removed from overall estimates

TABLE 4.—Age-0 (≤100 mm TL) and adult (>100 mm TL) trout standing crop (kg/ha) estimates and associated 95 percent confidence intervals by species for Nantahala River Bypass Reach during sampling period, 2012–2013.

| | | Brook Trout | | Brown Trout | | Rainbow Trout | | All trout | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Site | Age-0 | Adult | Age-0 | Adult | Age-0 | Adult | Age-0 | Adult |
| 24 Sept 2012 | F1 | 0.0 | 0.0 | 0.0 | 15.4 (19, 12) | 1.1 (1.3, 1.0) | 16.6 (20, 14) | 1.1 (1.3, 1) | 32.0 (36, 28) |
| | F2 | 0.0 | 0.0 | 0.0 | 0.8 | 0.9 (1.1, 0.7) | 11.5 (15, 8) | 0.9 (1.1, 0.7) | 12.3 (15, 8) |
| 4 Oct 2012 | F1 | 0.0 | 0.0 | 0.4 (0.9, -0.2) | 8.2 (13, 3) | 1.2 (2.3, 0.1) | 14.4 (17, 11) | 1.6 (2.6, 0.5) | 22.6 (28, 17) |
| | F2 | 0.0 | 0.0 | 0.0 | 4.1 (7, 1) | 0.1 | 19.2 (24, 15) | 0.1 | 23.3 (28, 19) |
| 3 Oct 2013 | F1 | 0.0 | 0.0 | 0.0 | 7.3 (8, 7) | 0.0 | 20.3 (24, 17) | 0.0 | 27.6 (31, 24) |
| | F2 | 0.0 | 0.4* | 0.0 | 4.8 (9, 0) | 0.0 | 19.4 (25, 14) | 0.0 | 24.2 (30, 18)* |

*Hatchery Brook Trout was removed from overall estimates

TABLE 5.—Average, maximum, and minimum temperatures (°C) at temperature logger sites within Nantahala River Bypass Reach and Nantahala River during release events, 2012–2014.

| | | | | Temperature (°C) | | | |
|---|---|---|---|---|---|---|---|
| Release | Site | Date | N | Average | SE | Maximum | Minimum |
| Fall 2012 | T1 | 29 Sept 2012 | 288 | 18.6 | 0.1 | 21.3 | 15.0 |
| | T2 | 29 Sept 2012 | 288 | 17.5 | 0.1 | 20.5 | 14.7 |
| | T3 | 29 Sept 2012 | 288 | 17.2 | 0.1 | 19.9 | 15.3 |
| | T4 | 29 Sept 2012 | 288 | 15.3 | 0.1 | 17.9 | 12.7 |
| | T5 | 29 Sept 2012 | 288 | 14.7 | 0.0 | 15.9 | 13.9 |
| | T1 | 30 Sept 2012 | 288 | 19.3 | 0.1 | 21.2 | 16.2 |
| | T2 | 30 Sept 2012 | 288 | 18.4 | 0.1 | 20.7 | 15.4 |
| | T3 | 30 Sept 2012 | 288 | 17.9 | 0.1 | 20.3 | 15.8 |
| | T4 | 30 Sept 2012 | 288 | 15.3 | 0.1 | 17.3 | 12.7 |
| | T5 | 30 Sept 2012 | 288 | 15.0 | 0.0 | 16.1 | 14.1 |
| Spring 2013 | T1 | 27 Apr 2013 | 288 | 14.6 | 0.0 | 14.9 | 14.2 |
| | T2 | 27 Apr 2013 | 288 | 13.9 | 0.0 | 14.5 | 13.3 |
| | T3 | 27 Apr 2013 | 288 | 13.6 | 0.0 | 14.2 | 12.8 |
| | T4 | 27 Apr 2013 | 24 | 10.0 | 0.0 | 10.3 | 9.8 |
| | T5 | 27 Apr 2013 | 24 | 10.7 | 0.0 | 10.9 | 10.4 |
| | T1 | 28 Apr 2013 | 288 | 13.6 | 0.0 | 14.2 | 12.0 |
| | T2 | 28 Apr 2013 | 288 | 12.9 | 0.0 | 13.5 | 11.2 |
| | T3 | 28 Apr 2013 | 288 | 12.3 | 0.0 | 13.0 | 11.1 |
| | T4 | 28 Apr 2013 | 24 | 9.9 | 0.1 | 10.3 | 9.4 |
| | T5 | 28 Apr 2013 | 24 | 10.4 | 0.1 | 10.9 | 10.1 |
| Summer 2013 | T1 | 22 June 2013 | 288 | 19.5 | 0.1 | 23.0 | 17.0 |
| | T2 | 22 June 2013 | 288 | 17.9 | 0.1 | 22.0 | 15.4 |
| | T3 | 22 June 2013 | 288 | 17.8 | 0.1 | 21.1 | 15.7 |
| | T4 | 22 June 2013 | 288 | 11.2 | 0.0 | 12.6 | 10.5 |
| | T5 | 22 June 2013 | 24 | 12.1 | 0.2 | 13.7 | 10.9 |
| | T1 | 1 July 2013 | 288 | 20.3 | 0.1 | 24.6 | 17.7 |
| | T2 | 1 July 2013 | 288 | 18.6 | 0.1 | 22.8 | 16.0 |
| | T3 | 1 July 2013 | 288 | 18.2 | 0.1 | 21.4 | 16.5 |
| | T4 | 1 July 2013 | 288 | 12.9 | 0.1 | 16.2 | 10.9 |
| | T5 | 1 July 2013 | 24 | 12.6 | 0.2 | 15.8 | 11.3 |
| | T1 | 17 July 2013 | 288 | 21.7 | 0.0 | 22.6 | 21.1 |
| | T2 | 17 July 2013 | 288 | 20.8 | 0.0 | 22.2 | 20.0 |
| | T3 | 17 July 2013 | 288 | 20.6 | 0.1 | 22.0 | 19.6 |
| | T4 | 17 July 2013 | 288 | 13.8 | 0.0 | 14.5 | 13.4 |
| | T5 | 17 July 2013 | 24 | 15.0 | 0.2 | 16.4 | 14.1 |
| | T1 | 1 Sept 2013 | 288 | 21.2 | 0.1 | 24.9 | 18.7 |
| | T2 | 1 Sept 2013 | 288 | 20.0 | 0.1 | 23.9 | 17.9 |
| | T3 | 1 Sept 2013 | 288 | 20.0 | 0.1 | 22.8 | 18.6 |
| | T4 | 1 Sept 2013 | 288 | 17.8 | 0.1 | 21.5 | 14.6 |
| | T5 | 1 Sept 2013 | 288 | 16.4 | 0.0 | 18.5 | 15.7 |

TABLE 5.—Continued.

| Release | Site | Date | N | Temperature (°C) Average | SE | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| Fall 2013 | T1 | 28 Sept 2013 | 288 | 18.7 | 0.1 | 21.3 | 14.8 |
| | T2 | 28 Sept 2013 | 288 | 17.3 | 0.1 | 20.4 | 13.5 |
| | T3 | 28 Sept 2013 | 288 | 16.7 | 0.1 | 19.7 | 14.0 |
| | T4 | 28 Sept 2013 | 288 | 15.3 | 0.0 | 16.4 | 14.5 |
| | T5 | 28 Sept 2013 | 288 | 15.7 | 0.0 | 17.3 | 14.7 |
| | T1 | 29 Sept 2013 | 288 | 19.3 | 0.1 | 21.1 | 16.1 |
| | T2 | 29 Sept 2013 | 288 | 18.1 | 0.1 | 20.4 | 14.6 |
| | T3 | 29 Sept 2013 | 288 | 17.6 | 0.1 | 19.9 | 15.0 |
| | T4 | 29 Sept 2013 | 288 | 15.6 | 0.0 | 16.6 | 14.7 |
| | T5 | 29 Sept 2013 | 288 | 16.0 | 0.0 | 17.4 | 15.1 |
| Spring 2014 | T1 | 26 Apr 2014 | 288 | 14.6 | 0.1 | 17.1 | 11.3 |
| | T2 | 26 Apr 2014 | 288 | 14.0 | 0.1 | 16.9 | 10.6 |
| | T3 | 26 Apr 2014 | 288 | 13.9 | 0.1 | 16.8 | 10.9 |
| | T4 | 26 Apr 2014 | 288 | 10.2 | 0.1 | 13.1 | 7.9 |
| | T5 | 26 Apr 2014 | 288 | 10.6 | 0.1 | 13.4 | 8.8 |
| | T1 | 27 Apr 2014 | 288 | 15.5 | 0.1 | 17.7 | 12.1 |
| | T2 | 27 Apr 2014 | 288 | 15.0 | 0.1 | 17.6 | 11.4 |
| | T3 | 27 Apr 2014 | 288 | 14.9 | 0.1 | 17.5 | 11.7 |
| | T4 | 27 Apr 2014 | 288 | 10.5 | 0.1 | 12.9 | 8.1 |
| | T5 | 27 Apr 2014 | 288 | 10.3 | 0.1 | 13.3 | 8.4 |
| Summer 2014 | T1 | 21 June 2014 | 288 | 21.3 | 0.1 | 24.3 | 19.1 |
| | T2 | 21 June 2014 | 288 | 20.0 | 0.1 | 23.1 | 17.7 |
| | T3 | 21 June 2014 | 288 | 20.0 | 0.1 | 22.3 | 18.2 |
| | T4 | 21 June 2014 | 288 | 16.1 | 0.3 | 20.8 | 9.3 |
| | T5 | 21 June 2014 | 288 | 13.1 | 0.1 | 18.3 | 10.7 |
| | T1 | 2 July 2014 | 288 | 22.4 | 0.1 | 25.9 | 19.7 |
| | T2 | 2 July 2014 | 288 | 21.0 | 0.1 | 24.7 | 18.2 |
| | T3 | 2 July 2014 | 288 | 20.9 | 0.1 | 23.9 | 18.2 |
| | T4 | 2 July 2014 | 288 | 16.7 | 0.3 | 22.3 | 9.8 |
| | T5 | 2 July 2014 | 288 | 14.0 | 0.1 | 18.8 | 11.9 |

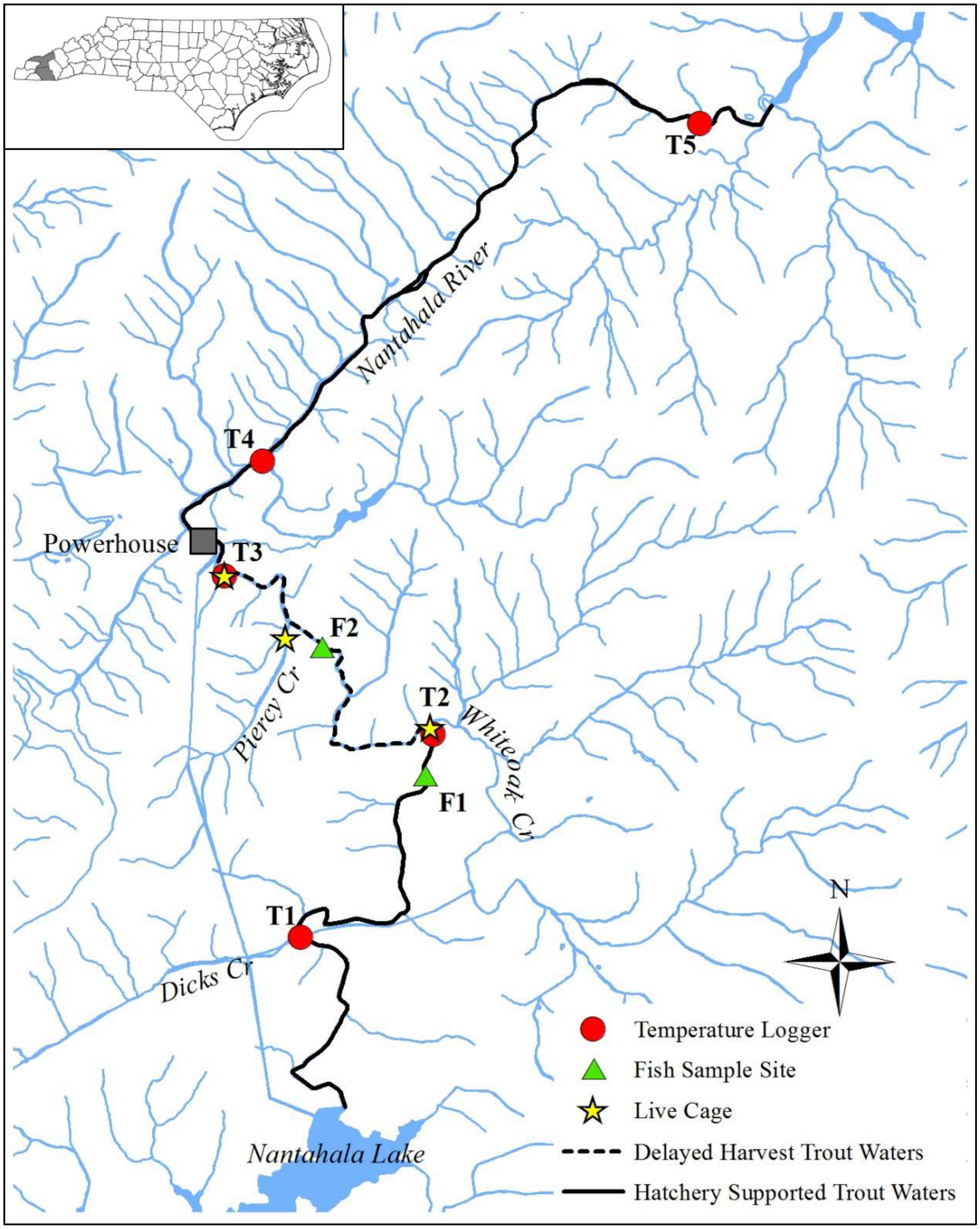


FIGURE 1.—Temperature logger (circle), electrofishing (triangle), and live cage (star) locations within Nantahala River Bypass Reach and Nantahala River, Swain and Macon County, North Carolina.

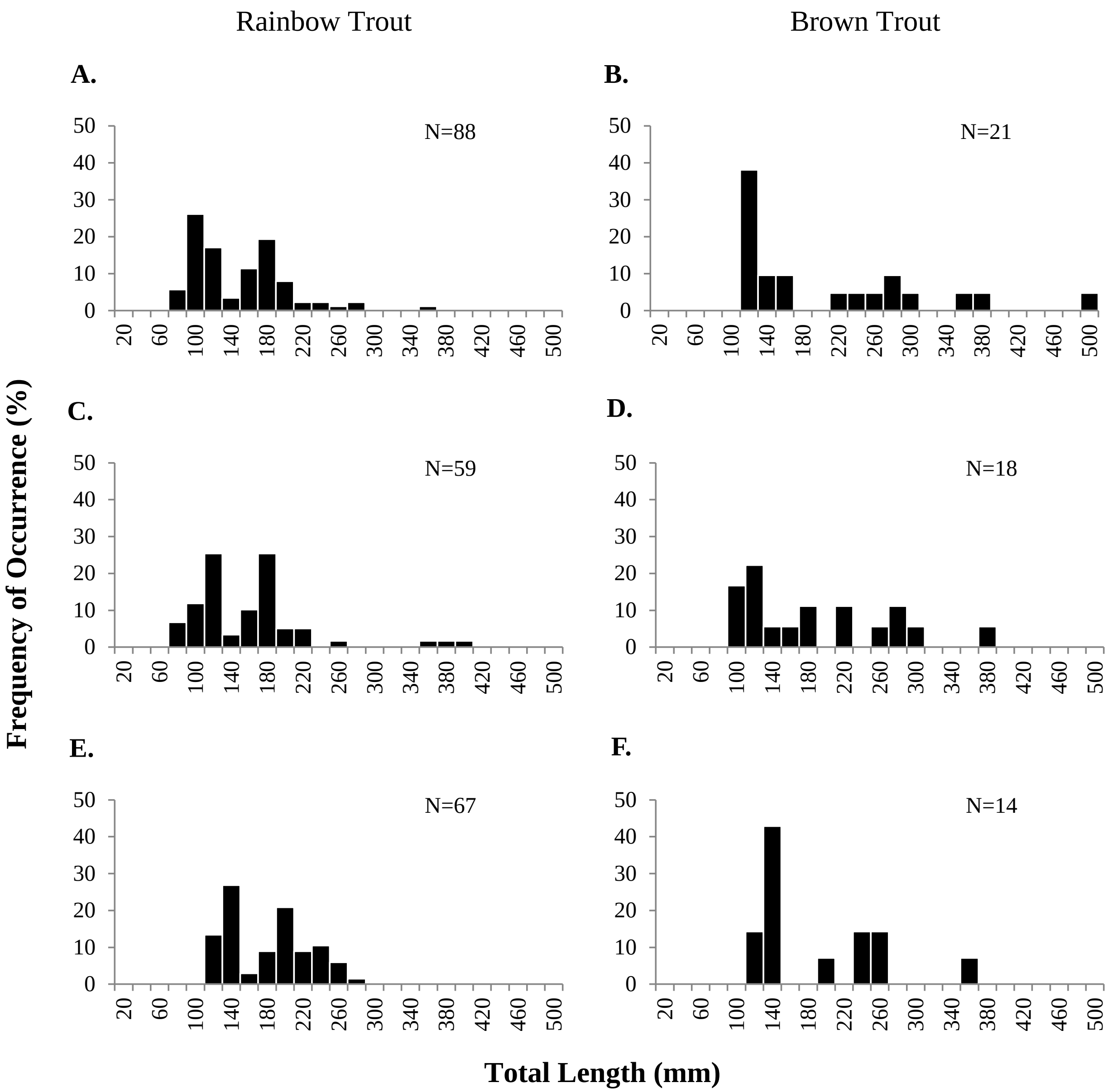


FIGURE 2.—Composite Brown Trout and Rainbow Trout length-frequency histograms (sites combined) from Nantahala Bypass Reach electrofishing samples on 24 September 2012 (A. and B.), 4 October 2012 (C. and D.) and 3 October 2013 (E. and F.).

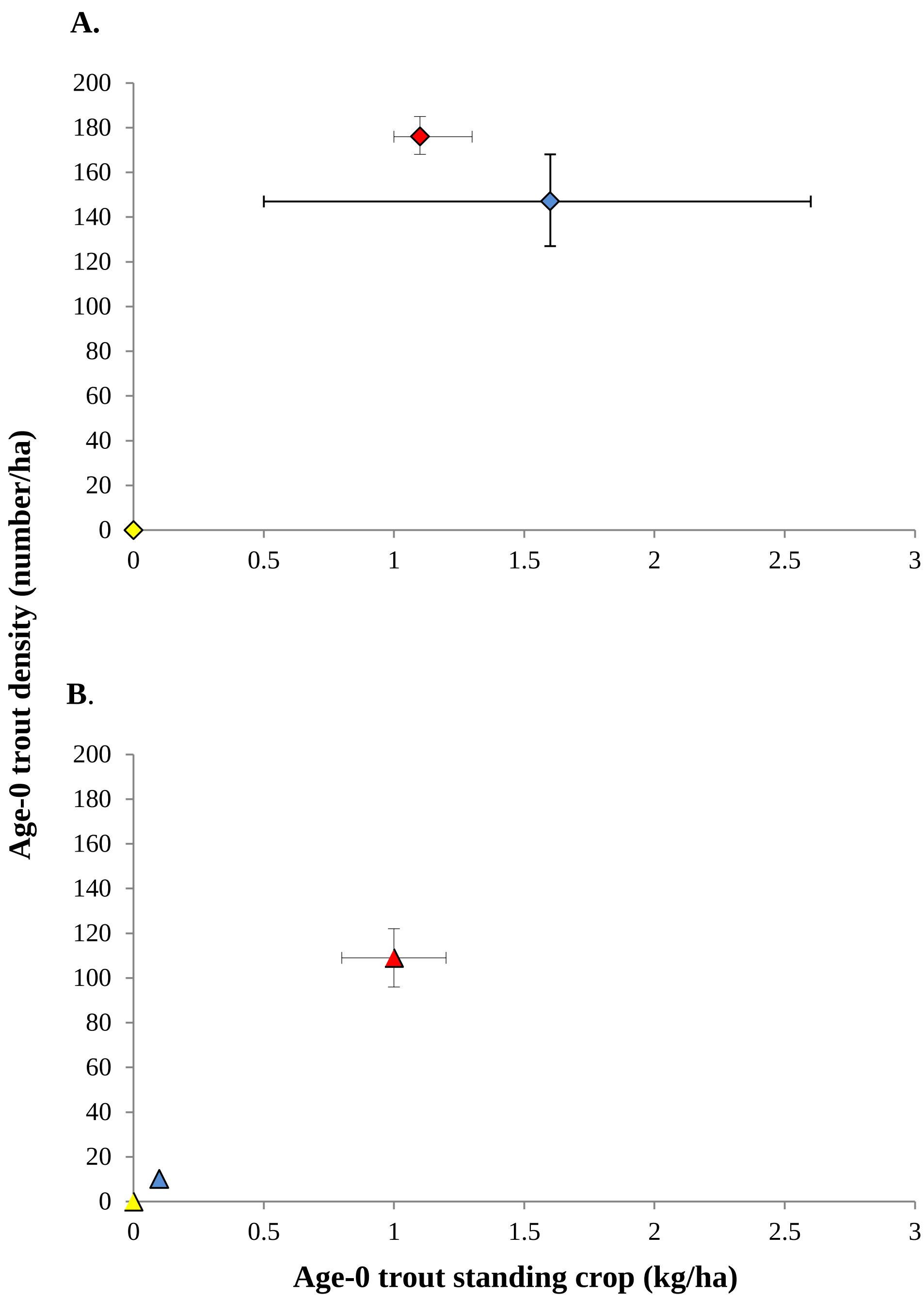


FIGURE 3.—Scatter-plots of age-0 (≤ 100 mm TL) trout (all species combined) density (number/ha) and standing crop (kg/ha) from Nantahala Bypass Reach during 2012–2013 at sites F1 (A.) and F2 (B.). Red fill represents data from 24 September 2012, blue fill represents 4 October 2012, and yellow fill represents 3 October 2013. Error bars indicate 95 percent confidence intervals.

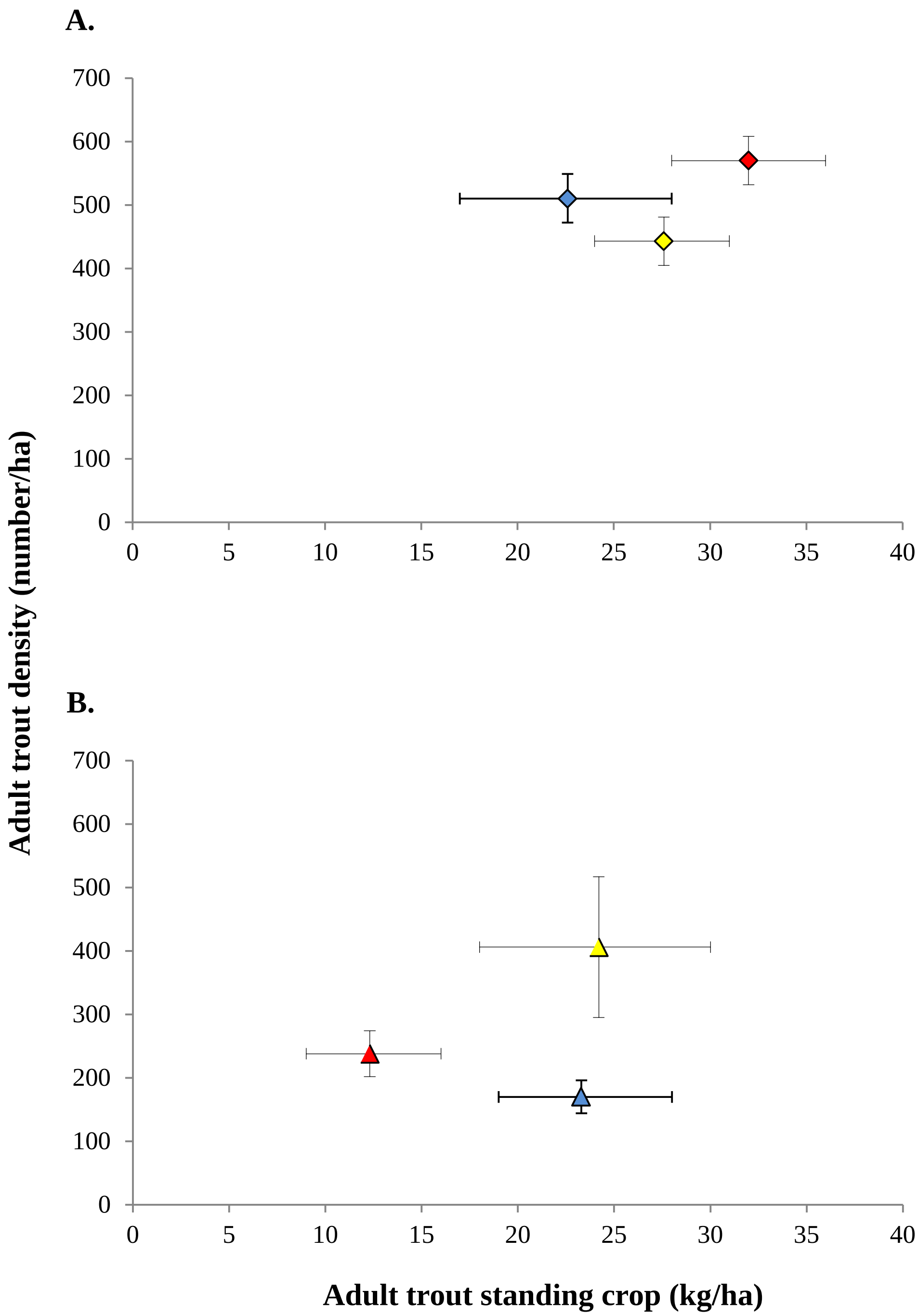


FIGURE 4.—Scatter-plot of adult trout (all species combined) density (number/ha) and standing crop (kg/ha) from Nantahala Bypass Reach during 2012–2013 at sites F1 (A.) and F2 (B.). Red fill represents data from 24 September 2012, blue fill represents 4 October 2012, and yellow fill represents 3 October 2013. Error bars indicate 95 percent confidence intervals. Hatchery Brook Trout from 3 September 2013 was removed from estimates.

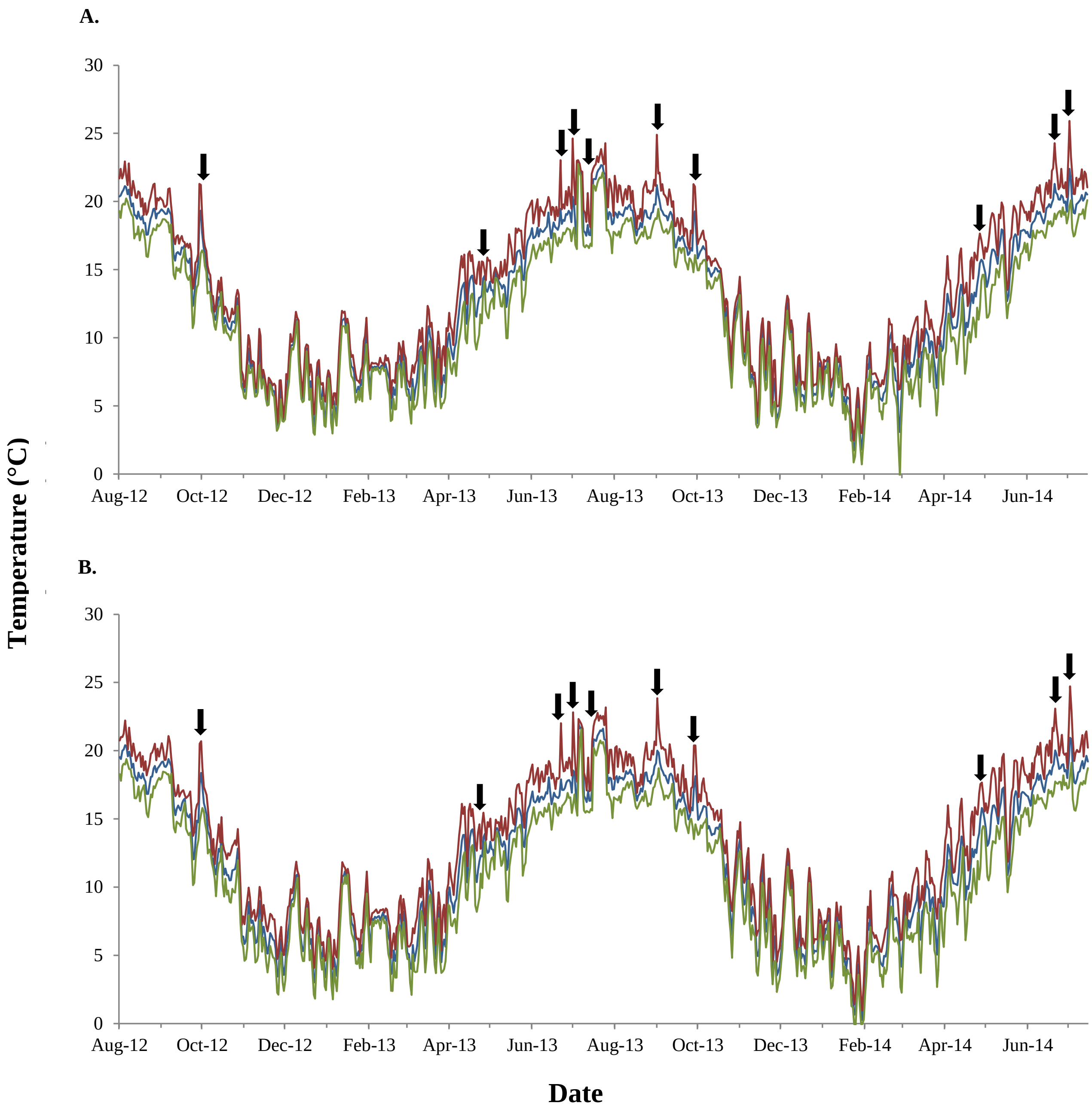


FIGURE 5.—Mean (blue line), maximum (red line), and minimum (green line) temperatures (°C) at temperature logger sites T1 (A.), T2 (B.), T3 (C.), T4 (D.), and T5 (E.) from 1 August 2012–15 July 2014. Arrows represent spillway release events.

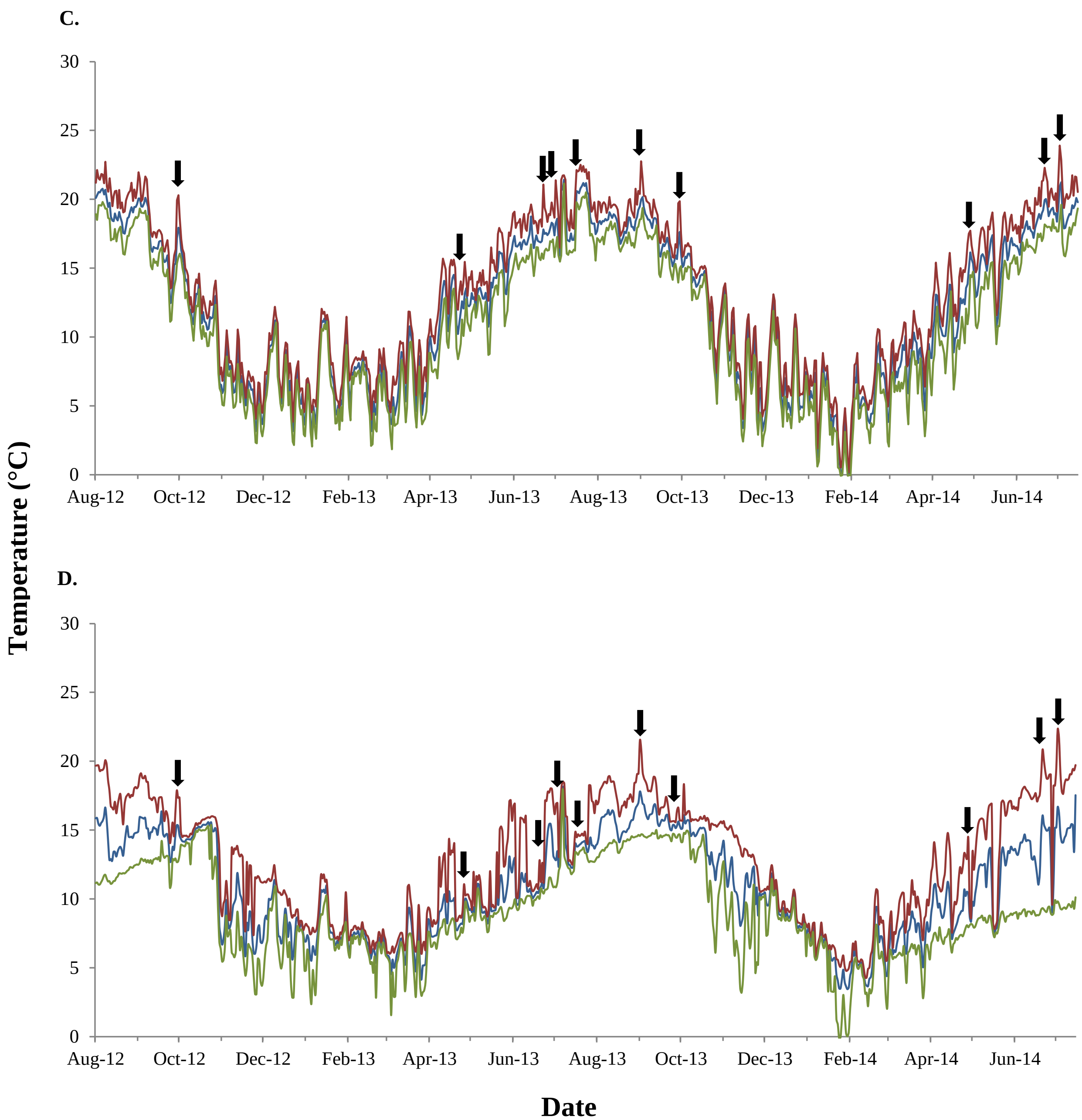


FIGURE 5.—Continued.

E.

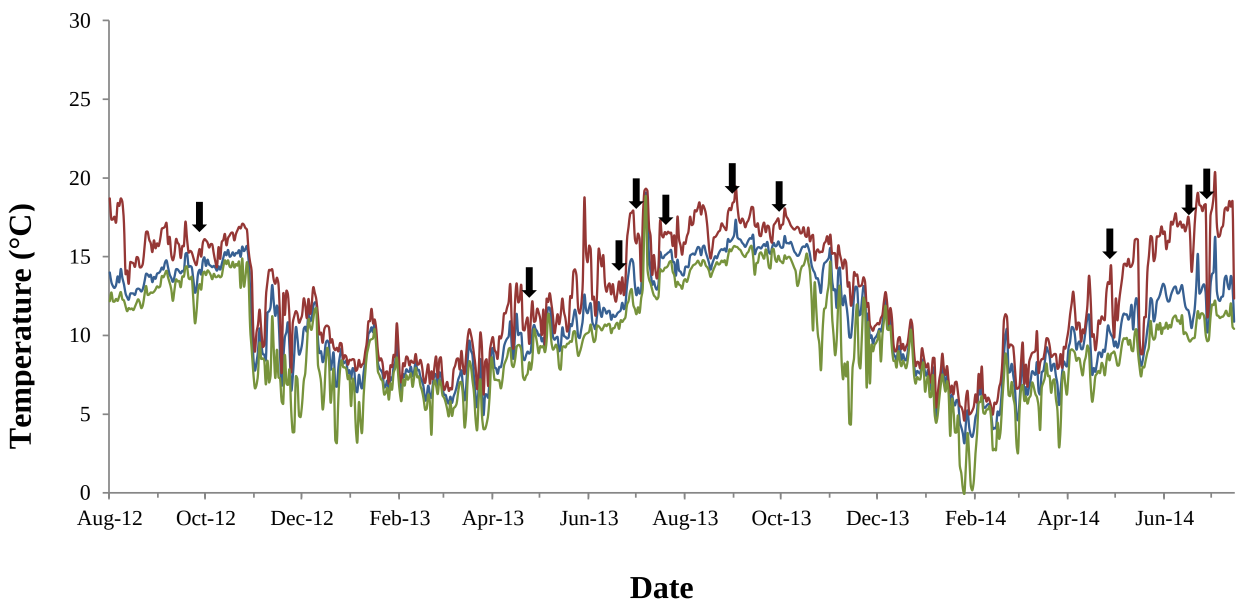


FIGURE 5.—Continued

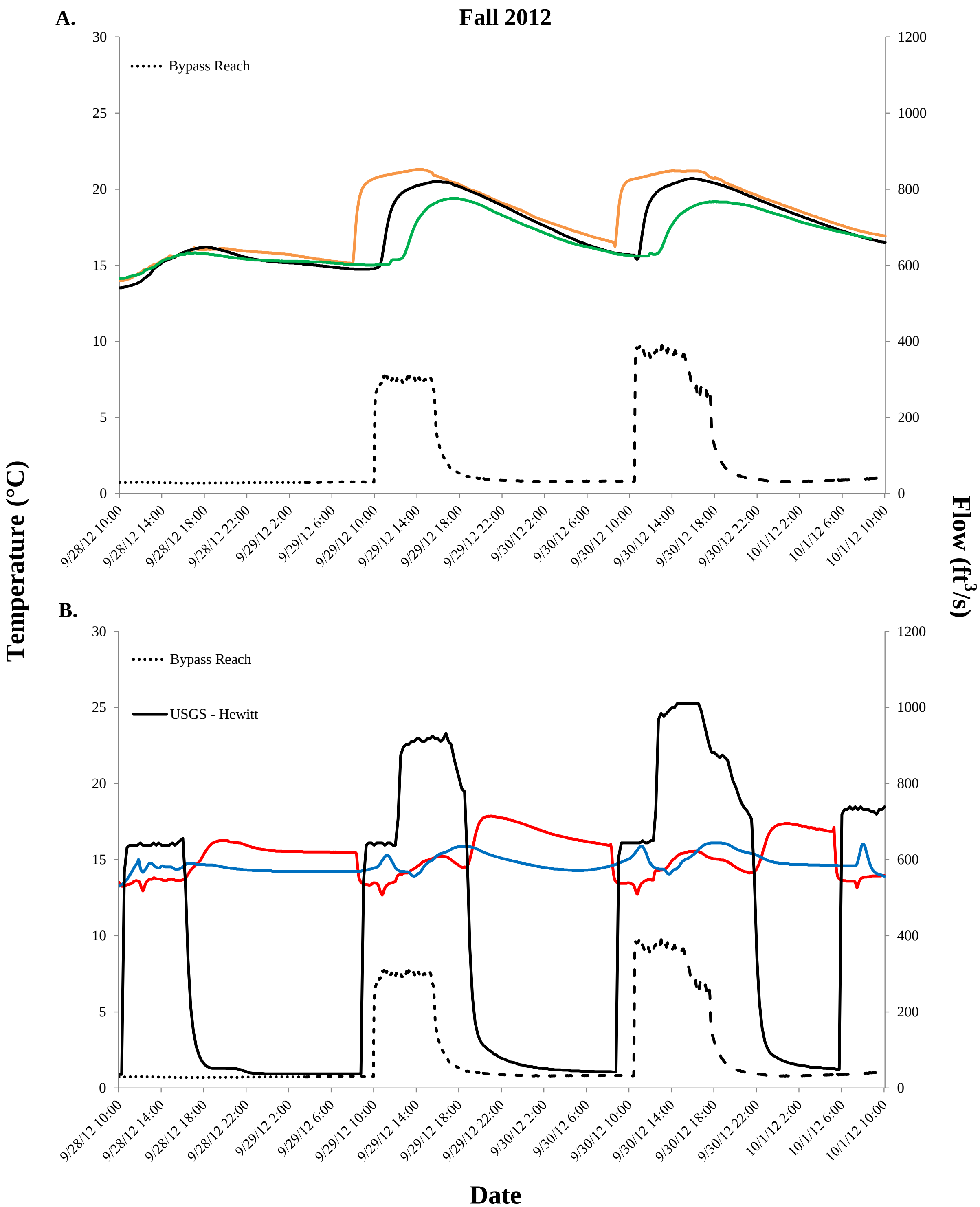


FIGURE 6.—Flow and temperature data during fall 2012 and 2013 spillway release events in the Nantahala Bypass Reach (A.) and the Nantahala Tailwater (B.) plus and minus 1 day. Temperature data is from temperature logger sites T1 (orange), T2 (black), T3 (green), T4 (red), and T5 (blue).

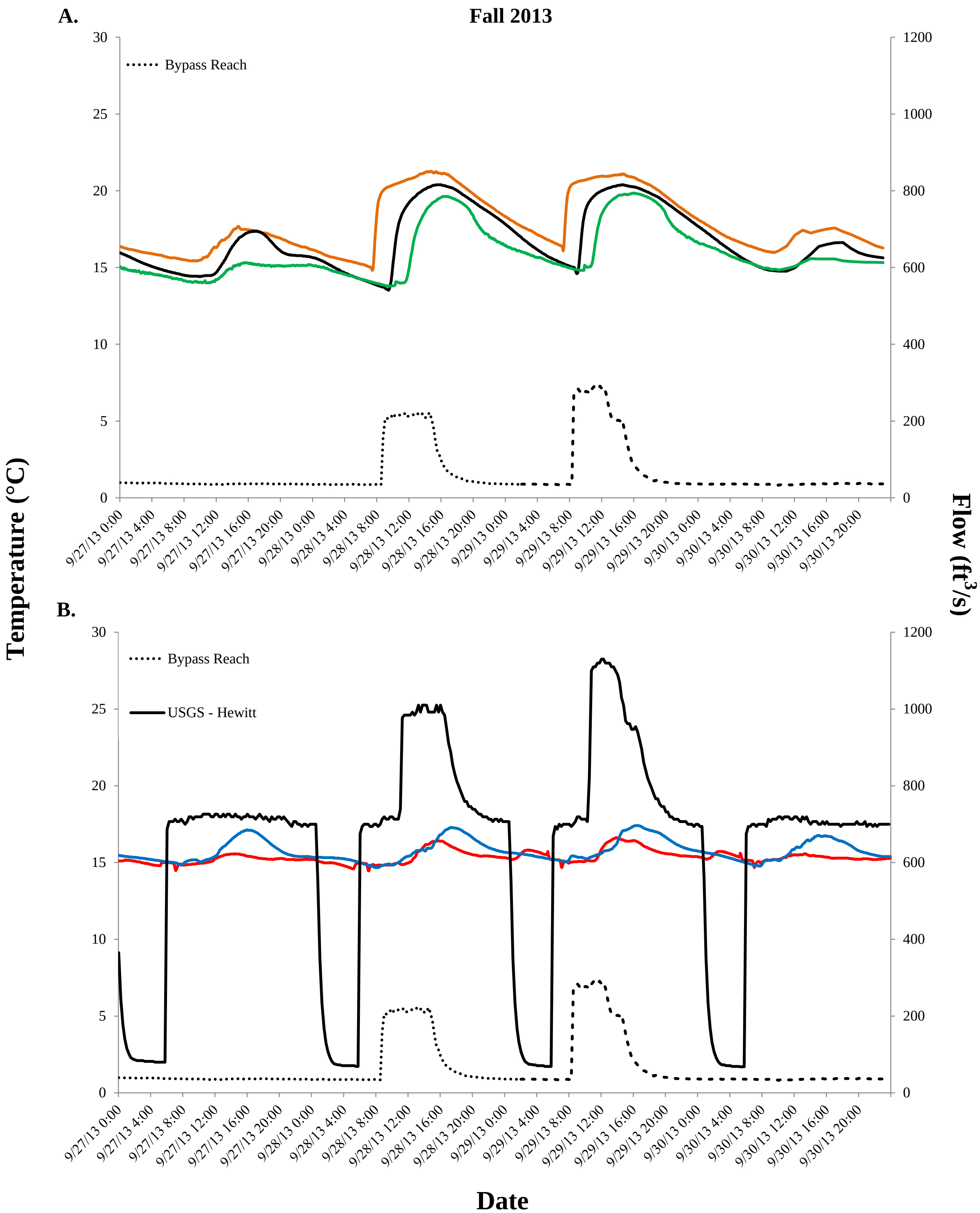


FIGURE 6.—Continued.

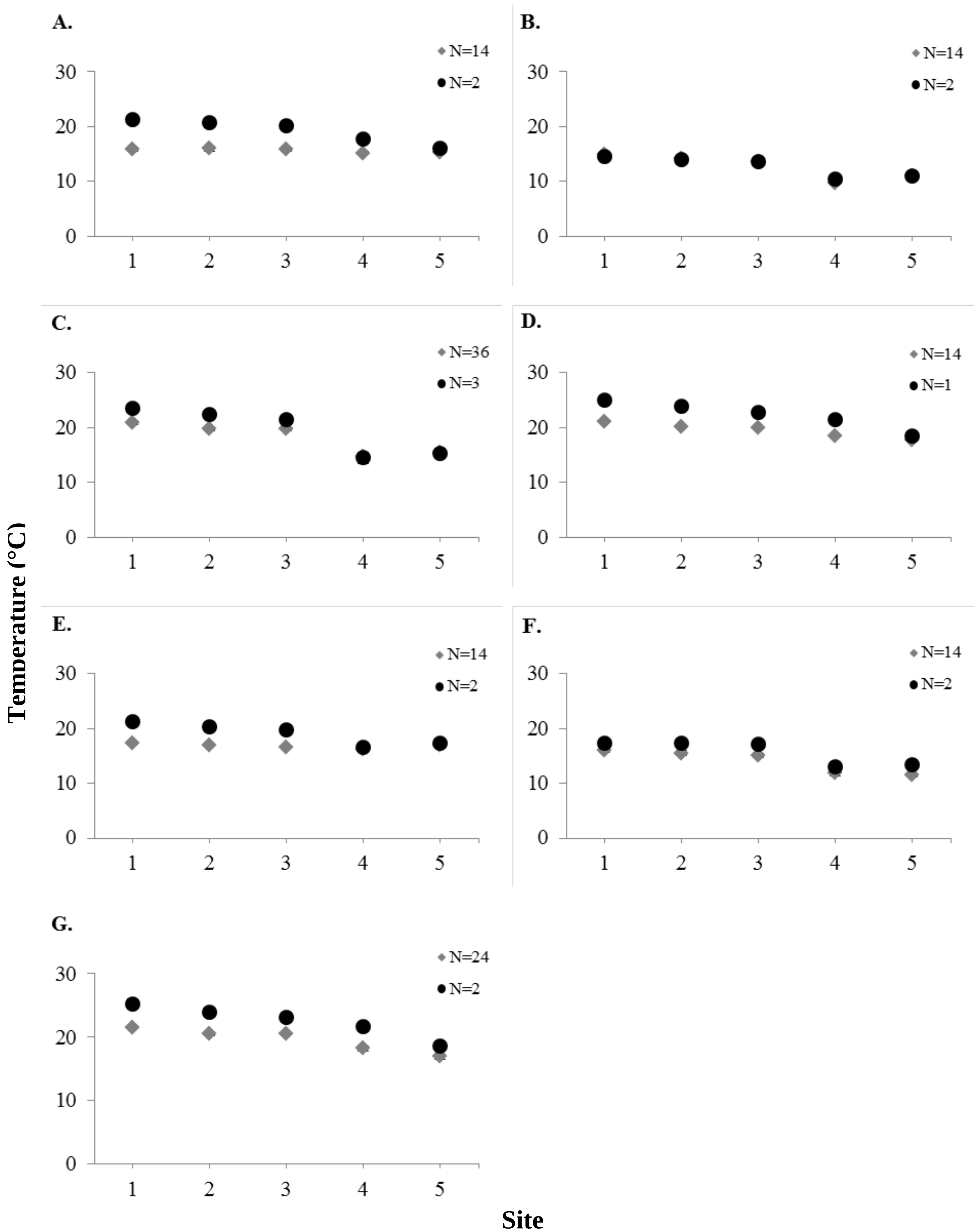


FIGURE 7.—Mean daily maximum temperatures during release event days (black circles) and seven days before and after each release event (gray diamonds) in the Nantahala Bypass and Tailrace during fall 2012, (A.), spring 2013 (B.), summer 2013, June–July (C.), September 2013 (D.), fall 2013 (E.), spring 2014 (F.), and summer 2013; June–9 July 2014 (G.)

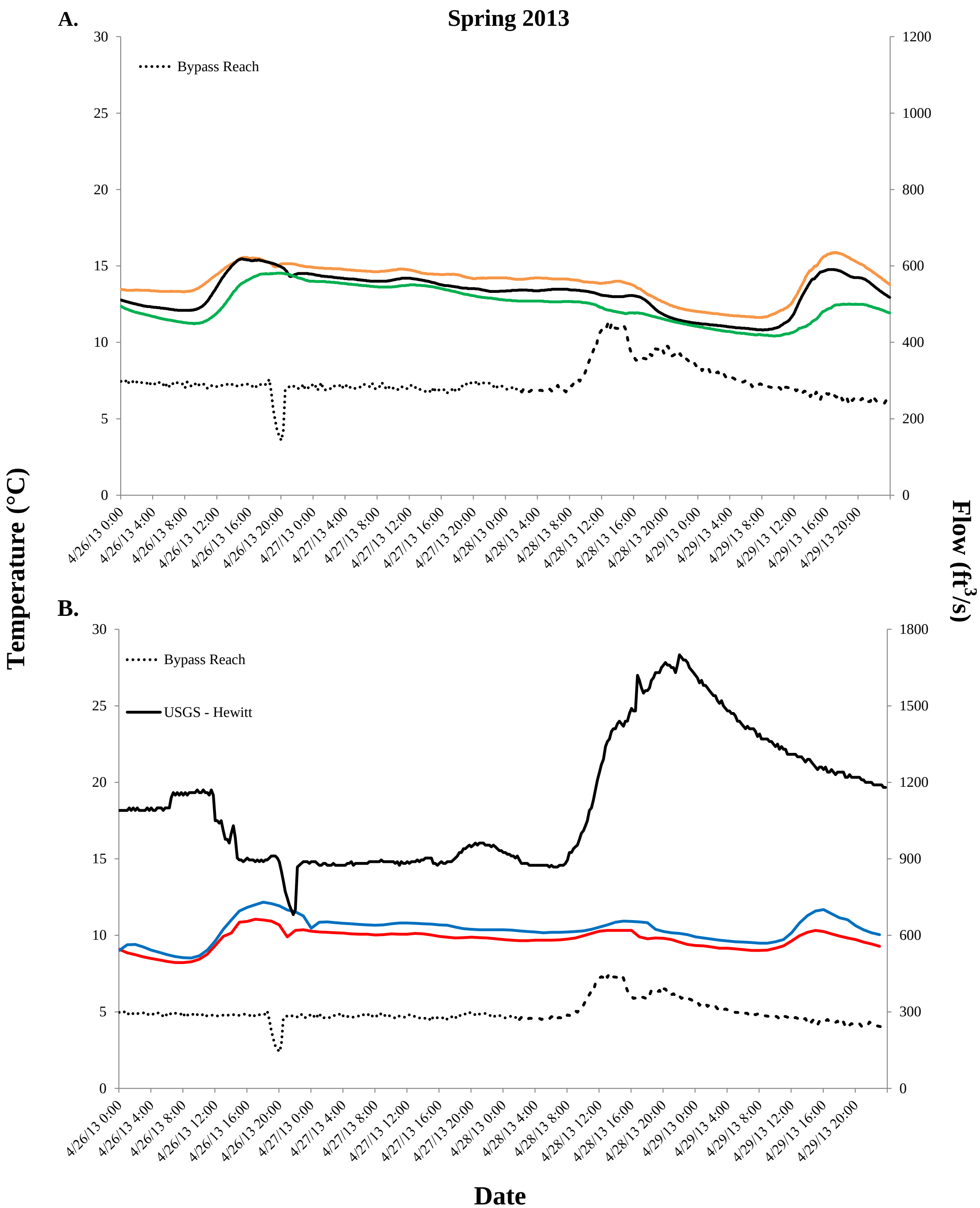


FIGURE 8.—Flow and temperature data during spring 2013 and 2014 spillway release events in the Nantahala Bypass Reach (A.) and the Nantahala Tailwater (B.) plus and minus one day. Temperature data is from temperature logger sites T1 (orange), T2 (black), T3 (green), T4 (red), and T5 (blue).

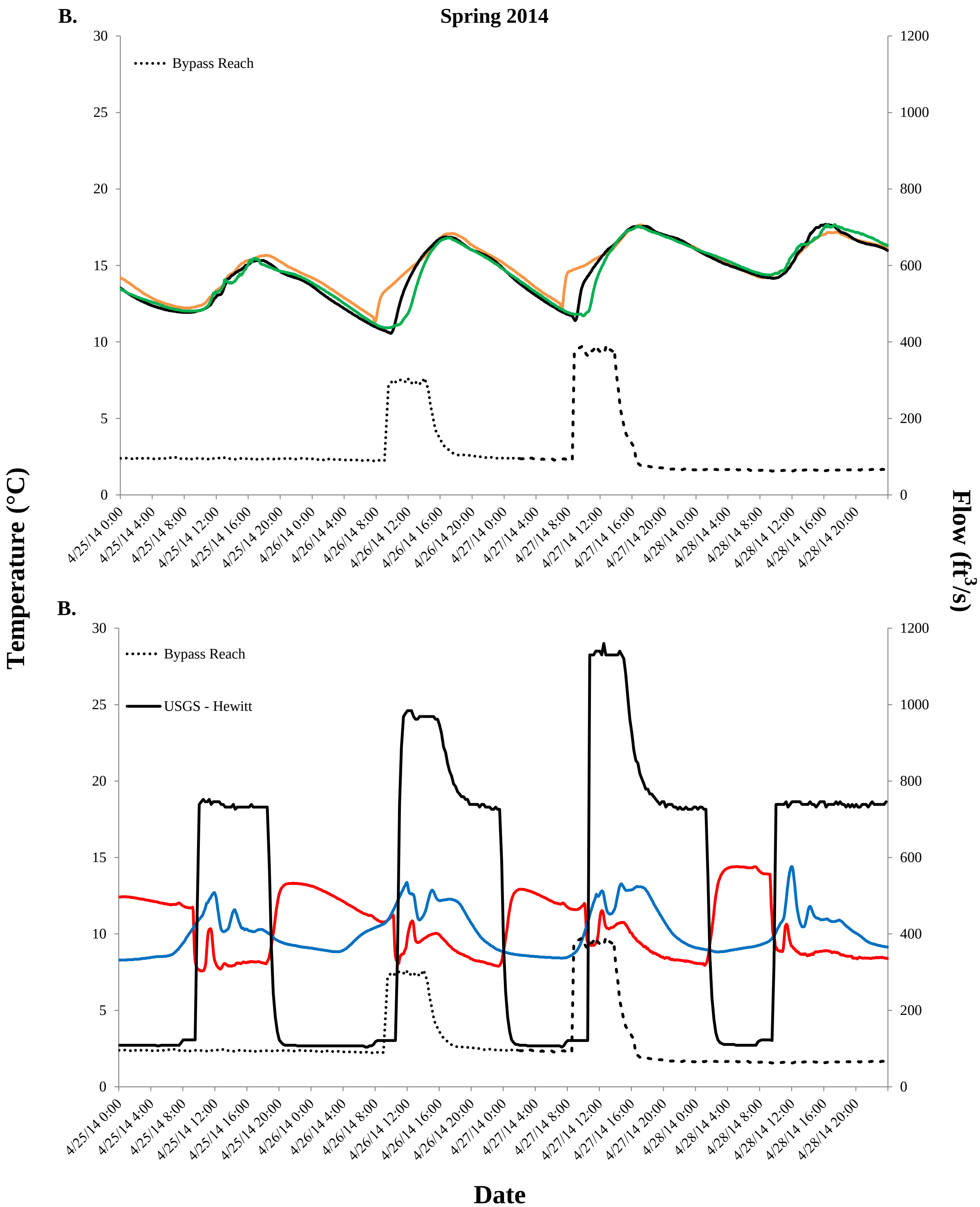


FIGURE 8.—Continued.

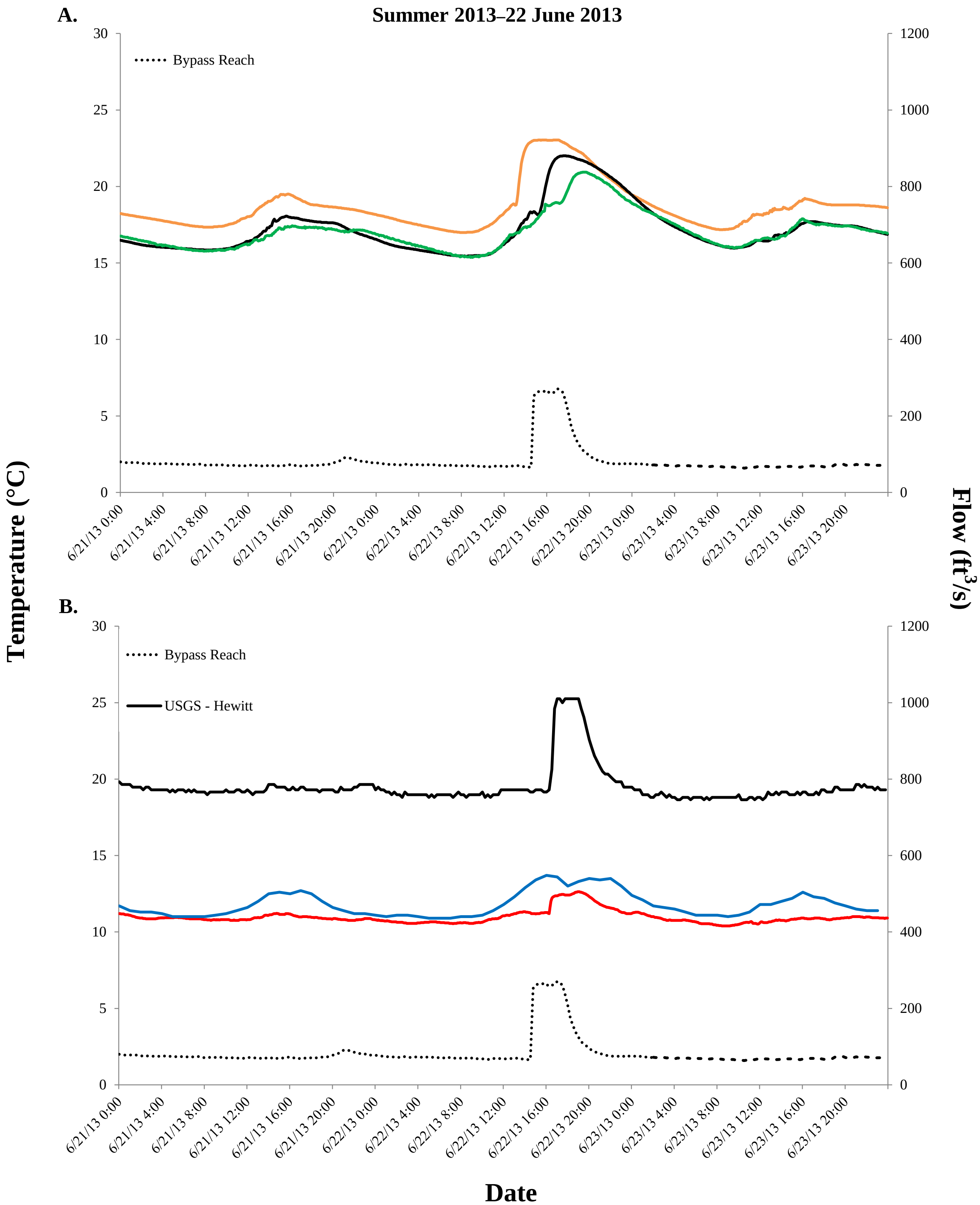


FIGURE 9.—Flow and temperature data during summer 2013 and 2014 spillway release events in the Nantahala Bypass Reach (A.) and the Nantahala Tailwater (B.) plus and minus one day. Temperature data is from temperature logger sites T1 (orange), T2 (black), T3 (green), T4 (red), and T5 (blue).

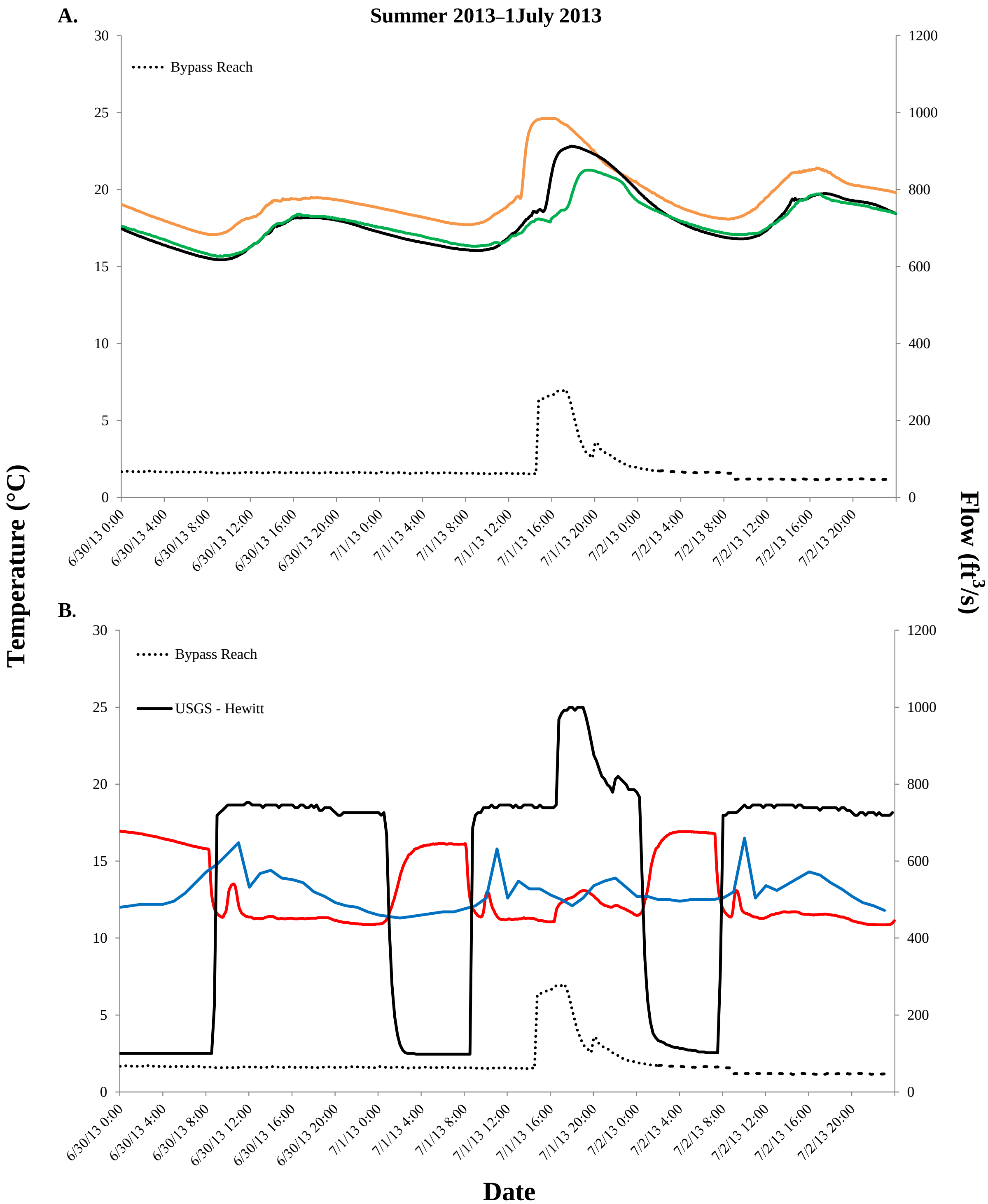


FIGURE 9.—Continued.

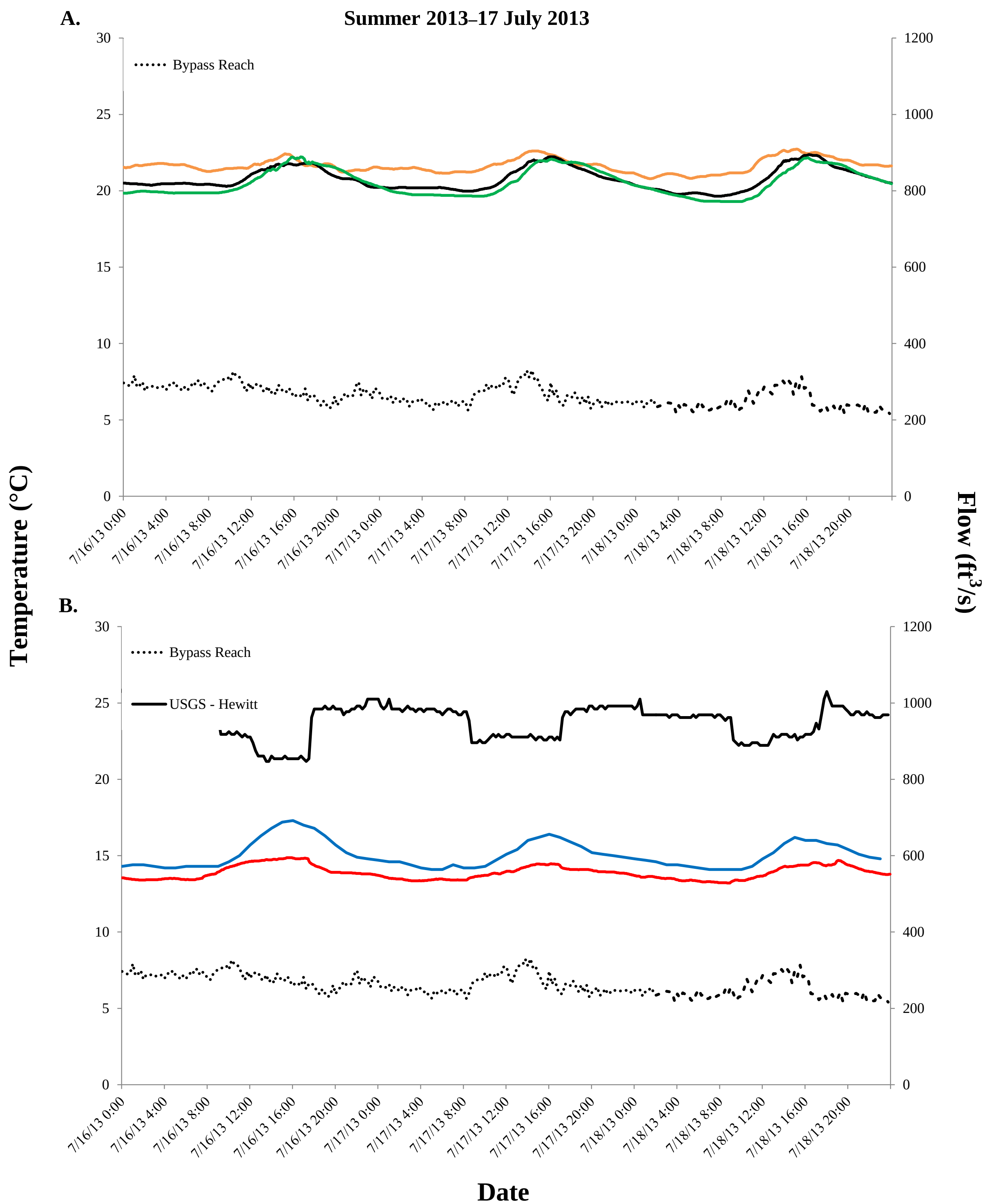


FIGURE 9.—Continued.

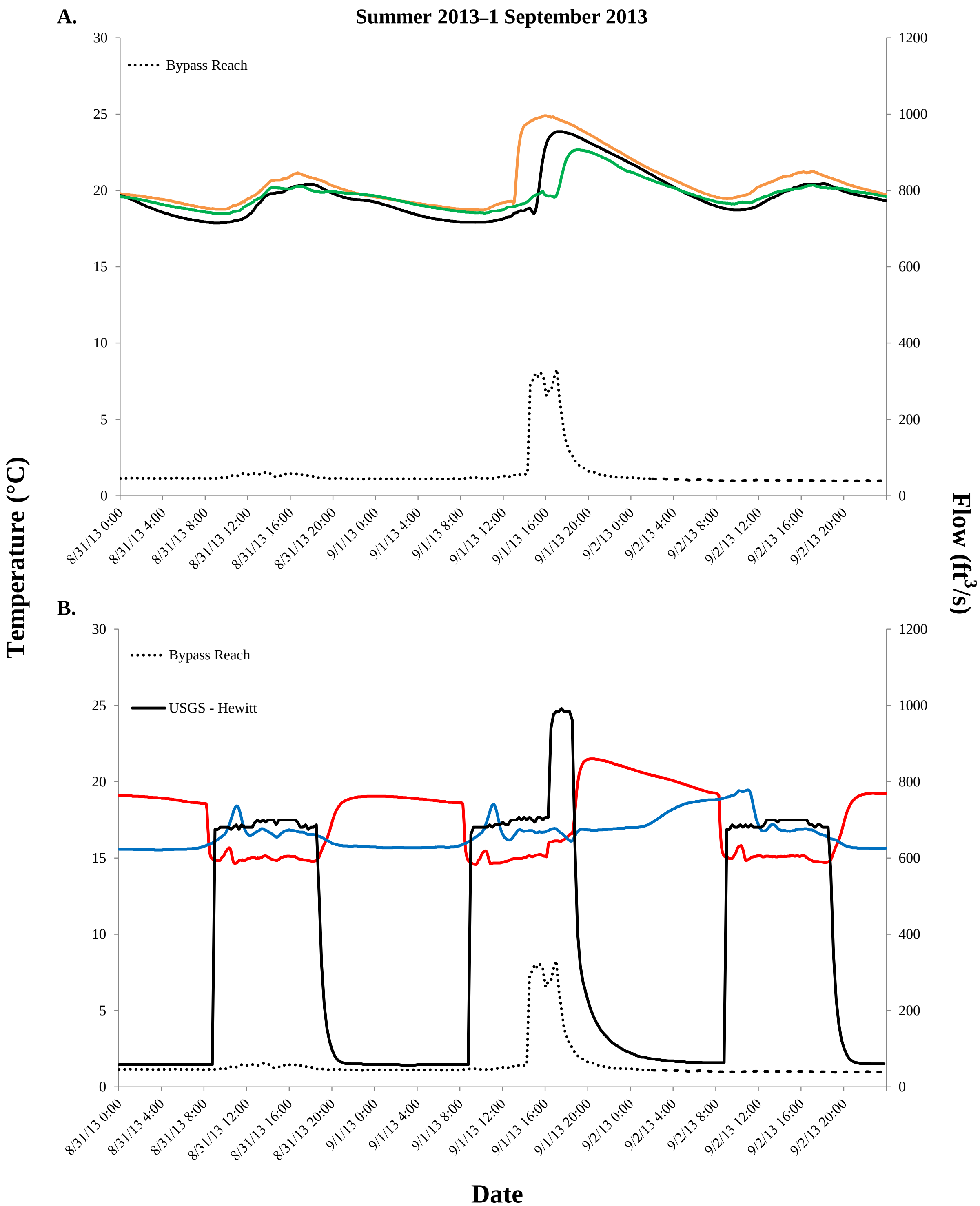


FIGURE 9.—Continued.

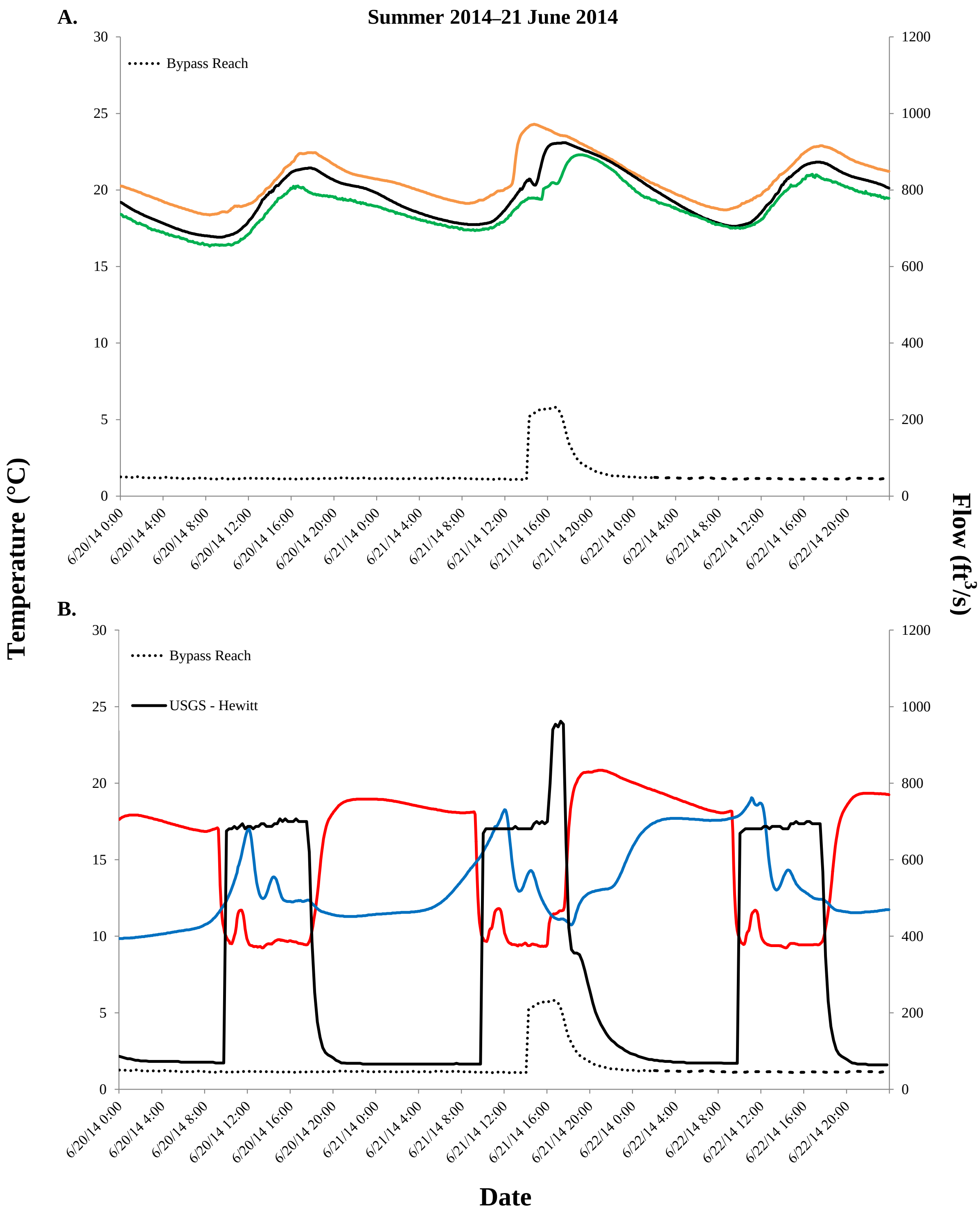


FIGURE 9.—Continued.

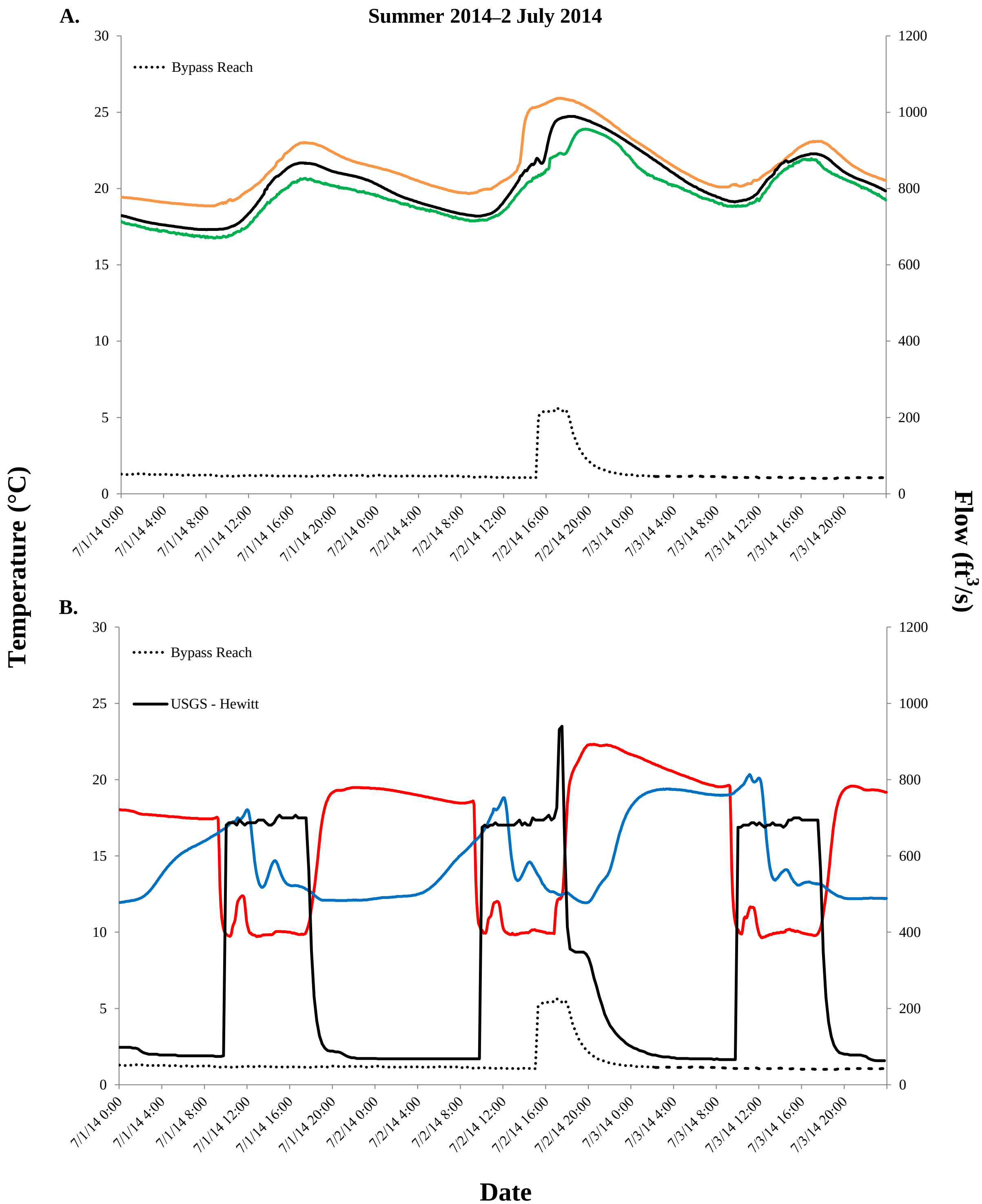


FIGURE 9.—Continued.

**Appendix** ***Section 5.3 of the Nantahala Cooperative Stakeholder Team Settlement Agreement***

5.3 During the first two years of recreation flow releases in the Nantahala River Bypassed Reach, the USFS, NCWRC, NCDWR and the USFWS will monitor the existing fishery in the Nantahala River Bypassed Reach and identify any significant adverse impacts to fisheries caused by these recreation flow releases. In October after the first and second seasons of releases, DPNA will convene a meeting with AW, CCC, NGA, TU, USFS, NCWRC, USFWS, and NCDWR to discuss any proposed changes that are based on the monitoring results. Notwithstanding Paragraph 17.3, if DPNA, AW, CCC, NGA, TU, USFS, NCWRC, NCDWR and the USFWS all agree in writing to permanent schedule changes, the changes will take effect as agreed by the aforementioned Parties unless FERC approval is required, otherwise DPNA shall develop and submit to FERC a request in whatever form is necessary to effect such change and the change will take effect according to the FERC approval. No Party shall request a modification of the recreation flow release schedule that would change the total number of hr per month (for generation releases) or per calendar year (for Tainter gate releases) at the approximate target flows.