Summer stream temperature profiles in the Smith River basin from 2009 to 2013.

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February 2014

Stream Temperature Monitoring Goals

Water temperature can have a profound influence on aquatic species distributions, physiology and growth rates, and disease. These factors are especially important to consider for sensitive salmonid species. We established water temperature monitoring in the Smith River to define baseline spatial and temporal thermal conditions during the summer months when water temperatures are highest. Additionally, these data are also being collected to help explain juvenile salmonid occupancy patterns during the summer throughout the Smith River basin. Modeling salmonid occupancy as it relates to thermal factors will help define habitats currently available to salmonids and identify areas that are possibly temperature impaired.

Materials and Methods

Water temperatures were recorded on either one hour (2009) or 30 minute (2010-2013) intervals using HOBO© Water Temperature Pro v2 Data Logger- U22-001 (Onset Computer Corporation, USA). Accuracy of HOBO v2 is rated at ±0.21°C from 0° to 50°C and is waterproof up to 400ft. To prevent solar radiation from influencing temperature readings care was taken to place loggers under submerged large wood, undercut banks and root wads. Perforated PVC piping was used as a shield where suitable locations presented the possibility of direct sunlight at some time during the survey season. In the absence of submerged anchoring locations, lead weight, rebar stakes or T-posts were used to ensure loggers would remain submerged and anchored for the sampling duration. Loggers were placed in locations having continuous stream flow with the goal of capturing a representative thermal profile of each stream location. However, a few loggers were placed in unique habitats such as backwater pools or beaver dens in the mainstem Smith River. GPS location, photos and written description of location were compiled to safeguard retrieval of each logger. Time and date of deployment as well as SSN of the logger where used to guarantee correct match for stream and temperature readings.

From 2009-2013 ninety-two temperature loggers were deployed across the Smith River basin to examine thermal regime and peak temperatures for examining salmonid

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occupancy rates. We calculated maximum weekly average temperature (MWMT) and maximum average weekly temperature (MWAT) to determine peak average temperature and peak maximum temperature at each location for the summer. The daily average temperature (DAT) from days with complete 24 hour records was used to calculate MWAT. The daily maximum temperature (DMT) from all days with complete 24 hour records were used to calculate MWMT. For each calculation a series of 7 days were averaged to calculate the seventh days MWAT and MWMT. For example, the MWAT and MWMT for June 7th are the average of the DAT and the average DMT from June 1-7, respectively. The temperature and date of the maximum MWAT and MWMT for all years and all logger locations were compiled to evaluate stream and reach level maximum temperatures.

Results

Overall, MWAT values ranged from 13.05°C in the West Branch Mill Creek to 22.03°C on the North Fork Smith River (Table 1, Figure 1). We divided the MWAT results for the 92 loggers into cold (<15°C), cool (>15 and <16°C), warm (>16 and <18°C), and hot (>18°C). These temperature strata were based on the distribution of temperature results and do not formally indicate a stream is temperature impaired (i.e. "hot" category). However, these temperature categories do represent relative thermal regimes occurring within the Smith River basin. Cold stream MWAT values ranged from 13.05 to 14.80°C (30 loggers). Cool stream MWAT values ranged from 15.12 to 15.98°C (21 loggers) (Table 2, Figures 1, 2). Warm stream MWAT values ranged from 16.07 to 17.96°C (27 loggers). Hot stream MWAT values ranged from 18.15 to 22.03°C (14 loggers). Often, MWAT and MWMT values differed between years at the same location (Figure 1). For example, 2013 was an exceptionally dry year and consistently had warmer water temperatures than in previous summers.

In 2009, seven temperature loggers were deployed beginning on May 20-June 23 and recorded water temperature on 1 hour intervals until October 12 (Table 1, Figure 3). All of these loggers where placed in the coastal plain tributaries and mainstem. The minimum MWAT was 13.87 in Little Mill Creek and the maximum MWAT was 21.29 in the mainstem Smith River near Hiouchi, CA. In 2010, twenty-six temperature loggers were deployed beginning on June 3-June 31 and recorded water temperature on 30 minute intervals. Removal of loggers occurred from September 15-September 23 (Table 1, Figure 4). Most loggers were not deployed until early August and from comparisons of loggers deployed in mid-June peak temperatures of streams were likely missed. In particular Stony Creek and Goose Creek show the decent from a peak in the first few graphed MWMT values. The minimum MWAT was 13.22 in Little Mill Creek and the maximum MWAT was 19.23 in Stony Creek. In 2011, seventeen temperature loggers were deployed beginning on May 16-June 29 and recorded water temperature on 30 minute intervals. Removal of loggers occurred from September 19-October 4 (Table 1, Figure 5). The temperature logger on Knopki Creek went dry on 7/26 and the peak MWMT was likely missed so calculations were not used in the five year data summary. The minimum MWAT was 13.55 in Little Mill Creek and the maximum MWAT was 17.27 in Hardscrabble Creek. In 2012, nine temperature loggers were deployed beginning on June 30-July 22 and recorded water temperature on 30 minute intervals. Removal occurred from September 12-September 19 (Table 1, Figure 6). A temperature logger was deployed on 8/31 in Reach 10 at the river house and peak temperatures were likely not recorded so these data were not used in the five year data summary. The minimum MWAT was 13.68 in South Fork Rowdy Creek and

the maximum MWAT was 22.03 in North Fork Smith River. In 2013, thirty-five temperature loggers were deployed beginning on May16-June 11 and recorded water temperature on 30 minute intervals. The majority of loggers had been removed by mid-September (Table 1, Figure 7). Temperatures from all loggers from this year were included in the five year data summary. The minimum MWAT was 13.05 in West Branch Mill Creek and the maximum MWAT was 21.86 in the mainstem Smith River downstream of the mouth of Rowdy Creek.

Future Direction

Based on this initial study we learned to deploy loggers no later than June 30 and remove loggers no earlier than September 15 to ensure peak summer temperatures are captured.
In future years, loggers will continue to be deployed particularly focusing on streams and reaches within the coastal salmonid monitoring program sampling frame. These data will be used to characterize annual reach-level temperature regimes in reaches randomly selected for annual summer juvenile salmonid spatial structure surveys. Calculated MWAT or MWMT will then be used as explanatory variables for juvenile salmonid occupancy patterns within the Smith River basin. Figure 2 shows additional data gaps in the North Fork and headwater sections of the Middle and South Forks where we plan to focus effort on obtaining baseline temperature information. A thesis project focused on mainstem samonid rearing in the coastal plain will also record numerous temperatures throughout the mainstem Smith River, Rowdy Creek, Mill Creek and estuary sloughs during the summer of 2014. Last, we plan to characterize temperatures in various deep pools during the summer throughout the lower mainstem Smith River to better understand thermal stratification in these regionally rare stream features.

Acknowledgements

Michelle Gilroy (CDFW) and Mike Wallace (CDFW) kindly loaded us additional temperature loggers. Smith River Alliance field biologists Jesse Nolan, John Diebner-Hanson, Gaytha Babcock, Melissa Reneski, Tara Dettmar, and Monty Larson all assisted in deployment and retrieval of data loggers. We thank Redwood National and State Parks, US Forest Service, and Green Diamond Resource Company for providing access to streams. This work was funded in part by the California Department of Fish and Wildlife, Aid in Sportfish Restoration Program, the Fisheries Restoration Grants Program, and the Smith River Alliance.

Table 1. Summary of temperature logger deployments in the smith river basin from 2009 to 2013.

Year	# Loggers deployed	Logging Interval	Minimum deploy date	Maximum retrieval date	Minimum MWAT	Maximum MWAT
2009	6	1 hour	May 20	October 12	13.87	21.29
2010	26	30 Minutes	June 3	September 23	13.22	19.23
2011	16	30 Minutes	May 16	October 4	13.55	17.27
2012	9	30 Minutes	June 30	September 19	13.68	22.03
2013	35	30 Minutes	May 16	September 15	13.05	21.86

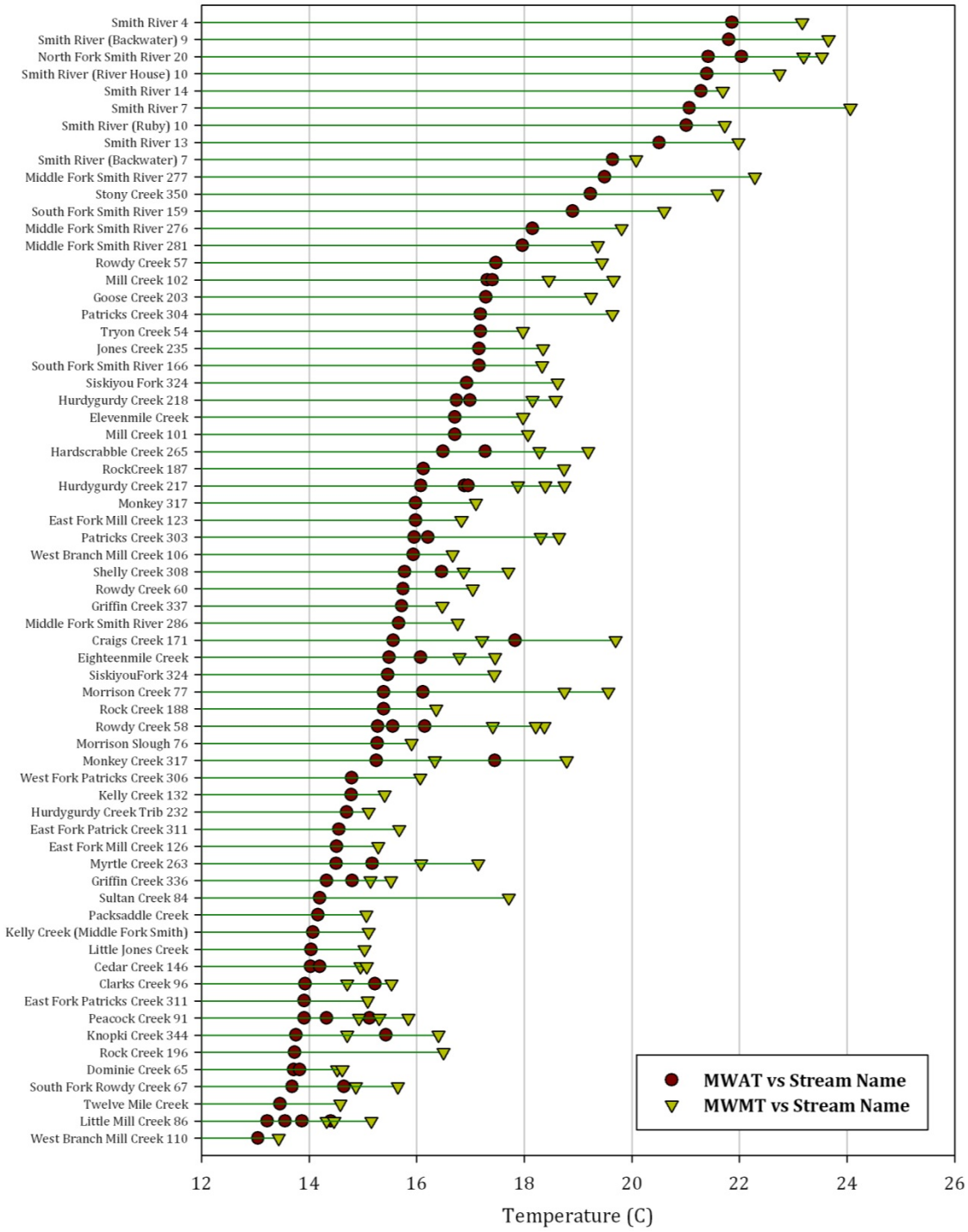

Figure 1. Summer stream temperatures recorded in the Smith River basin, Del Norte County, California from years 2009 to 2013. Stream temperatures are summarized by the maximum calculated values for both the maximum weekly average temperature (MWAT) and the maximum weekly maximum temperate (MWMT) for each stream. Note: some streams/ locations have multiple years of data presented. Numbers following stream names represent the California Department of Fish and Wildlife's salmonid monitoring program individual reach code.

Table 1. MWAT and MWMT for 92 temperature loggers deployed from 2009-2013. Table is sorted by MWAT values from cold (dark blue), cool (light blue), warm (orange), and hot (red) Temperature logger deployment coordinates are displayed in UTMs: NAD 83 Zone 10 Datum. Numbers following stream names represent CDFW's monitoring program reach location code.

Stream Name	MWAT	Date (MWAT)	MWMT	Date (MWAT)	UTME	UTMN
West Branch Mill Creek 110	13.05	9/15/2013	13.44	7/9/2013	411201	4615487
Little Mill Creek 86	13.22	8/28/2010	14.33	8/28/2010	406727	4636346
Twelve Mile Creek	13.46	8/13/2010	14.58	8/8/2010	429147	4637396
Little Mill 86	13.55	8/30/2011	14.47	8/28/2011	406772	4636357
South Fork Rowdy 67	13.68	8/15/2012	14.87	8/14/2012	407866	4642096
Dominie Creek 65	13.72	8/28/2010	14.52	8/28/2010	405108	4642449
Rock Creek 196	13.73	9/13/2013	16.50	9/13/2013	415265	4612561
Knopki Creek 344	13.75	8/19/2010	14.71	8/19/2010	439429	464264
Dominie Creek 65	13.82	8/30/2011	14.62	9/3/2011	405073	4642536
Little Mill Creek 86	13.87	8/15/2009	15.16	8/15/2009	406727	4636336
Peacock Creek 91	13.91	8/28/2010	14.93	8/28/2010	408336	4631257
East Fork Patrick Creek 311	13.91	8/12/2010	15.09	8/9/2010	429154	4640672
Clarks Creek 96	13.93	8/1/2011	14.71	8/1/2011	407875	4629564
Cedar Creek 146	14.03	8/1/2011	14.96	8/1/2011	410450	4626900
Little Jones Creek	14.04	8/13/2010	15.03	8/13/2010	430989	4635612
Kelly Creek (Middle Fork Smith)	14.07	8/13/2010	15.11	8/8/2010	428954	4634951
Packsaddle Creek	14.16	8/10/2010	15.07	8/9/2010	436365	4640066
Cedar Creek 146	14.20	8/15/2009	15.07	8/15/2009	410434	4626941
Sultan Creek 84	14.20	8/25/2010	17.71	8/28/2010	407221	4634705
Peacock Creek 91	14.32	8/15/2009	15.30	8/15/2009	408395	4631148
Griffin Creek 336	14.33	8/12/2010	15.14	8/9/2010	436844	4641558
Little Mill Creek 86	14.40	9/4/2013	15.16	9/10/2013	406727	4636336
Myrtle Creek 263	14.51	8/28/2010	16.08	8/28/2010	412299	4628288
East Fork Mill Creek 126	14.51	9/15/2013	15.28	8/21/2013	412516	4619426
East Fork Patrick 311	14.56	8/30/2011	15.67	8/29/2011	429149	4640675
South Fork Rowdy Creek 67	14.64	9/12/2013	15.65	9/11/2013	407870	4642097
Hurdygurdy Creek Trib 232	14.70	7/28/2013	15.10	7/28/2013	430976	4629274
Kelly Creek 132	14.78	9/4/2013	15.40	8/21/2013	410473	4619702
West Fork Patrick 306	14.79	8/12/2010	16.06	8/9/2010	429112	4640694
Griffin Creek 336	14.80	8/30/2011	15.52	8/30/2011	436867	4641693
Peacock Creek 91	15.12	9/14/2013	15.84	9/12/2013	408509	4631146
Myrtle Creek 263	15.17	8/1/2011	17.14	8/1/2011	412325	4628269
Clarks Creek 96	15.23	9/4/2013	15.53	9/4/2013	407752	4629559
Monkey Creek 317	15.25	8/13/2010	16.33	8/12/2010	432135	4637335
Morrison Slough 76	15.27	7/28/2013	15.90	6/15/2013	403843	4640297
Rowdy Creek 58	15.27	8/28/2011	17.42	7/29/2011	412376	4627830
Rock Creek 188	15.39	7/29/2013	16.36	8/21/2013	416871	4616071

Table 1. Continued

Morrison Creek 77	15.39	8/13/2009	19.56	8/13/2009	404898	4639667
Knopki Creek 344	15.43	7/28/2013	16.41	7/27/2013	438847	4642418
Siskiyou Fork 324	15.46	8/12/2010	17.44	8/9/2010	433471	4636405
Eighteenmile Creek	15.49	8/28/2010	16.80	8/13/2010	423520	4633069
Rowdy Creek 58	15.56	8/28/2010	18.37	8/28/2010	405155	4642421
Craigs Creek 171	15.56	8/13/2010	17.21	8/12/2010	414849	4626913
MiddleFork 286	15.66	8/18/2012	16.76	8/18/2012	438743	4642371
Griffin Creek 337	15.72	7/28/2013	16.48	7/27/2013	437813	4643752
Rowdy Creek 60	15.74	9/13/2013	17.04	9/10/2013	407789	4642253
Shelly Creek 308	15.77	8/12/2010	16.87	8/9/2010	429161	4639047
West Branch Mill Creek 106	15.94	9/4/2013	16.67	9/5/2013	408539	4620836
Patrick's Creek 303	15.95	8/13/2010	18.30	8/13/2010	429969	4636220
East Fork Mill Creek 123	15.98	9/4/2013	16.83	8/21/2013	408597	4620872
Monkey 317	15.98	8/31/2011	17.10	8/2/2011	432120	4637323
Eighteenmile Creek	16.07	8/2/2011	17.46	8/2/2011	423525	4633128
Hurdygurdy Creek 217	16.08	8/30/2011	17.88	8/2/2011	425232	4618728
Morrison Creek 77	16.11	7/6/2013	18.75	7/5/2013	404898	4639667
Rock Creek 187	16.12	8/13/2010	18.74	8/13/2010	418110	4620806
Rowdy Creek 58	16.15	9/10/2013	18.21	9/10/2013	405347	4642532
Patrick's Creek 303	16.21	8/30/2011	18.65	8/2/2011	429458	4636545
Shelly Creek 308	16.47	8/2/2011	17.70	8/2/2011	429144	4639085
Hardscrabble Creek 265	16.49	7/29/2010	18.28	7/29/2010	414812	4632505
Mill Creek 101	16.71	8/30/2011	18.07	8/1/2011	408654	4625247
Elevenmile Creek	16.71	8/29/2011	17.98	8/2/2011	429005	4639054
Hurdygurdy Creek 218	16.74	8/17/2012	18.15	8/17/2012	425331	4618961
Hurdygurdy Creek 217	16.89	7/28/2010	18.75	7/28/2010	424089	4615525
Siskiyou Fork 324	16.93	7/28/2013	18.62	7/27/2013	433496	4636391
Hurdygurdy Creek 217	16.95	8/17/2012	18.39	8/17/2012	425232	4618728
Hurdygurdy Creek 218	16.99	7/28/2013	18.58	7/9/2013	425361	4618931
South Fork Smith 166	17.15	7/28/2013	18.33	7/27/2013	435187	4612768
Jones Creek 235	17.16	7/28/2013	18.35	7/27/2013	427625	4617264
Tryon Creek 54	17.18	9/4/2013	17.98	9/4/2013	405460	4636073
Patrick's Creek 304	17.18	7/8/2013	19.64	7/9/2013	429155	4638094
Hardscrabble Creek 265	17.27	8/2/2011	19.19	8/1/2011	414821	4632482
Goose Creek 203	17.29	7/28/2010	19.24	7/28/2010	423132	4615125
Mill Creek 102	17.31	8/15/2009	19.66	8/17/2009	408595	4625277
Mill Creek 102	17.41	8/21/2013	18.45	7/6/2013	408585	4624913
Monkey Creek 317	17.45	7/28/2013	18.78	7/28/2013	432089	4637316
Rowdy Creek 57	17.47	8/21/2013	19.44	8/20/2013	403219	4640781
Craigs Creek 171	17.83	7/7/2013	19.70	7/6/2013	414870	4626943
Middle Fork Smith River 281	17.96	8/17/2012	19.36	8/17/2012	431028	4635655

Table 1. Continued

Middle Fork 276	18.15	8/13/2010	19.81	8/13/2010	419693	4633209
South Fork Smith 159	18.89	8/18/2012	20.60	8/17/2012	424288	4614710
Stony Creek 350	19.23	7/29/2010	21.59	7/29/2010	420183	4634853
Middle Fork Smith River 277	19.49	7/9/2013	22.29	7/9/2013	423883	4633020
Smith River (Backwater) 7	19.64	9/11/2013	20.08	9/11/2013	405119	4637492
Smith River 13	20.51	8/21/2013	21.98	8/21/2013	409760	4627241
Smith River (Ruby) 10	21.01	8/16/2012	21.73	8/16/2012	406792	4634129
Smith River 7	21.07	8/16/2009	24.06	8/16/2009	404803	4638042
Smith River 14	21.29	8/1/2009	21.69	7/31/2009	411750	4626782
Smith River (River House) 10	21.39	8/21/2013	22.74	7/9/2013	407596	4632547
North Fork Smith River 20	21.41	8/21/2013	23.19	7/9/2013	419447	4633914
Smith River (Backwater) 9	21.80	8/21/2013	23.66	8/20/2013	407096	4635689
Smith River 4	21.86	8/21/2013	23.16	8/21/2013	402091	4640997
North Fork Smith River 20	22.03	8/16/2012	23.53	8/16/2012	419456	4638893

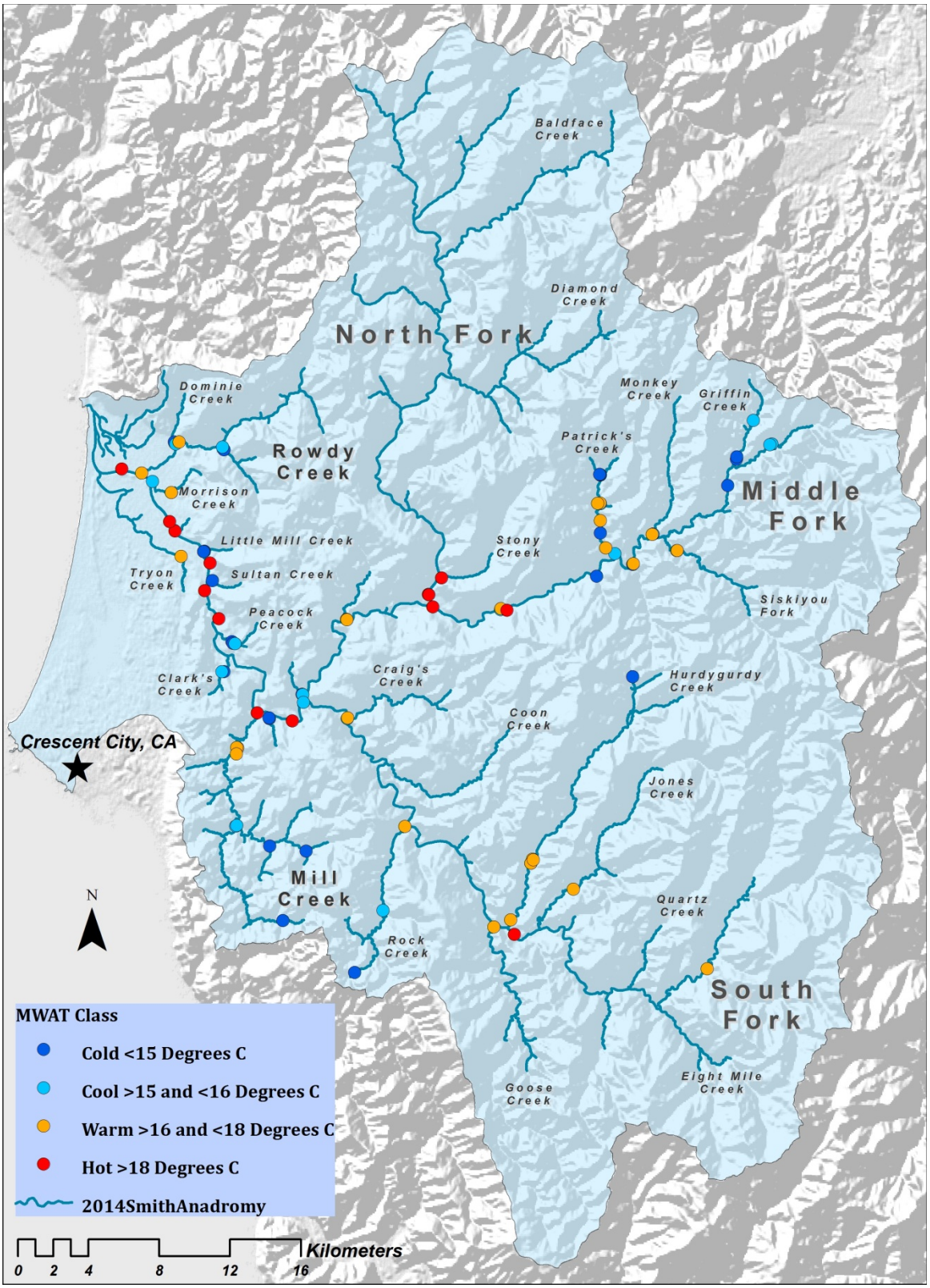

Figure 2. Map of the Smith Basin, Del Norte County CA, showing locations of 92 temperature loggers deployed from 2009 to 2013. Note: some locations have multiple years of data.

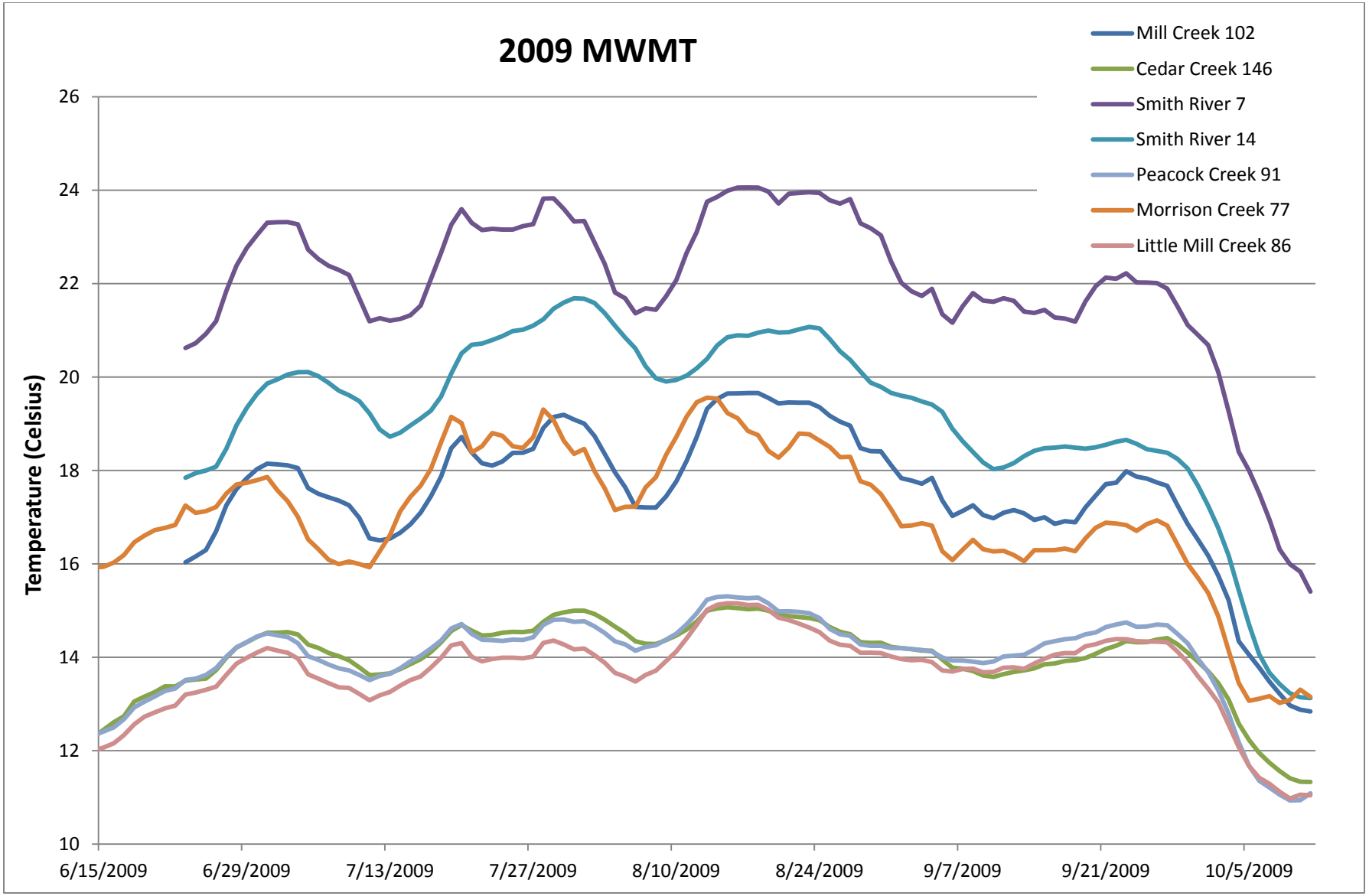

Figure 3. Maximum Weekly Maximum Temperature (MWMT) for tributaries of the Smith River basin during the summer of 2009.

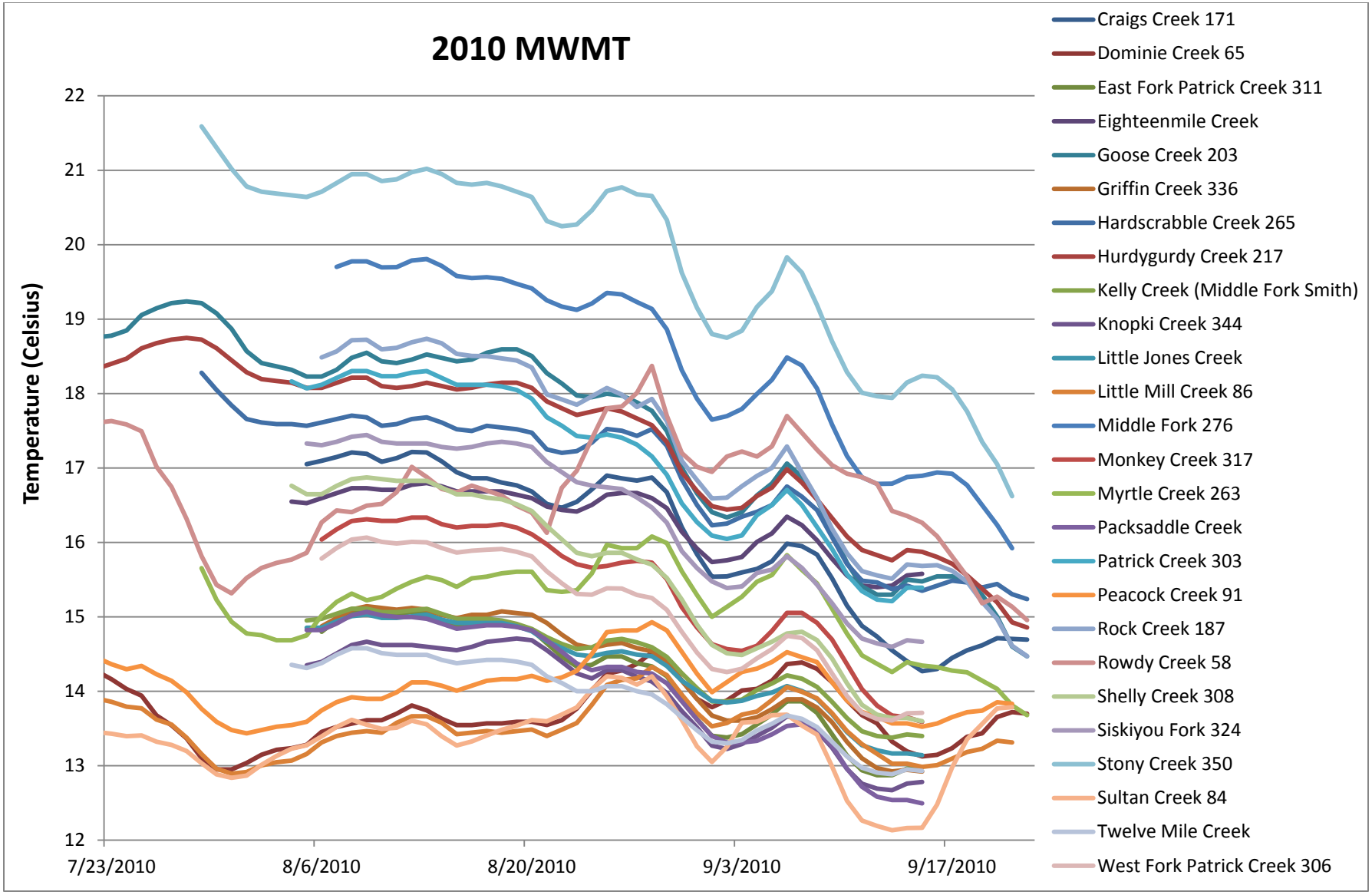

Figure 4. Maximum Weekly Maximum Temperature (MWMT) for tributaries of the Smith River basin during the summer of 2010.

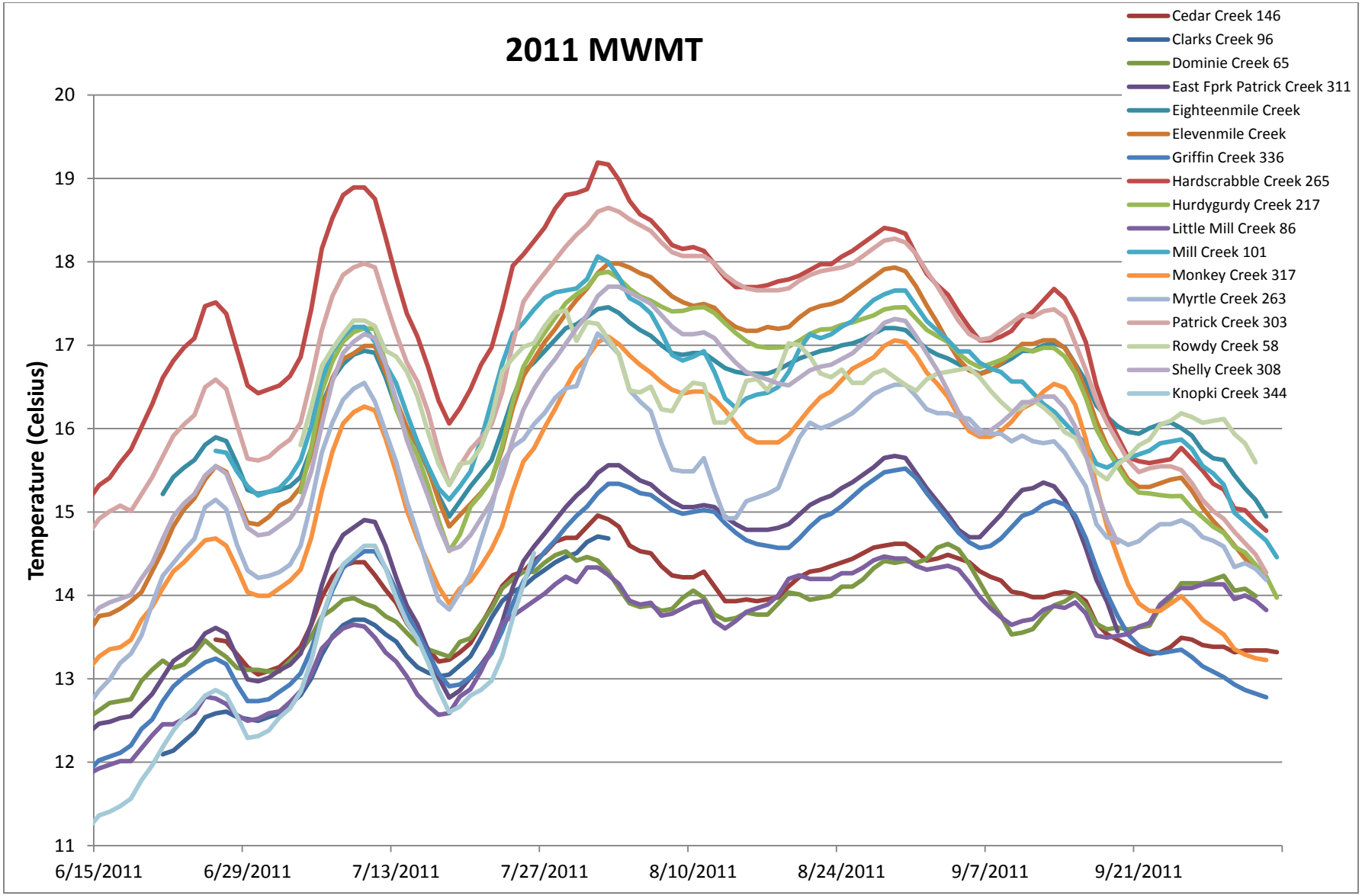

Figure 5. Maximum Weekly Maximum Temperature (MWMT) for tributaries in the Smith River basin during the summer of 2011.

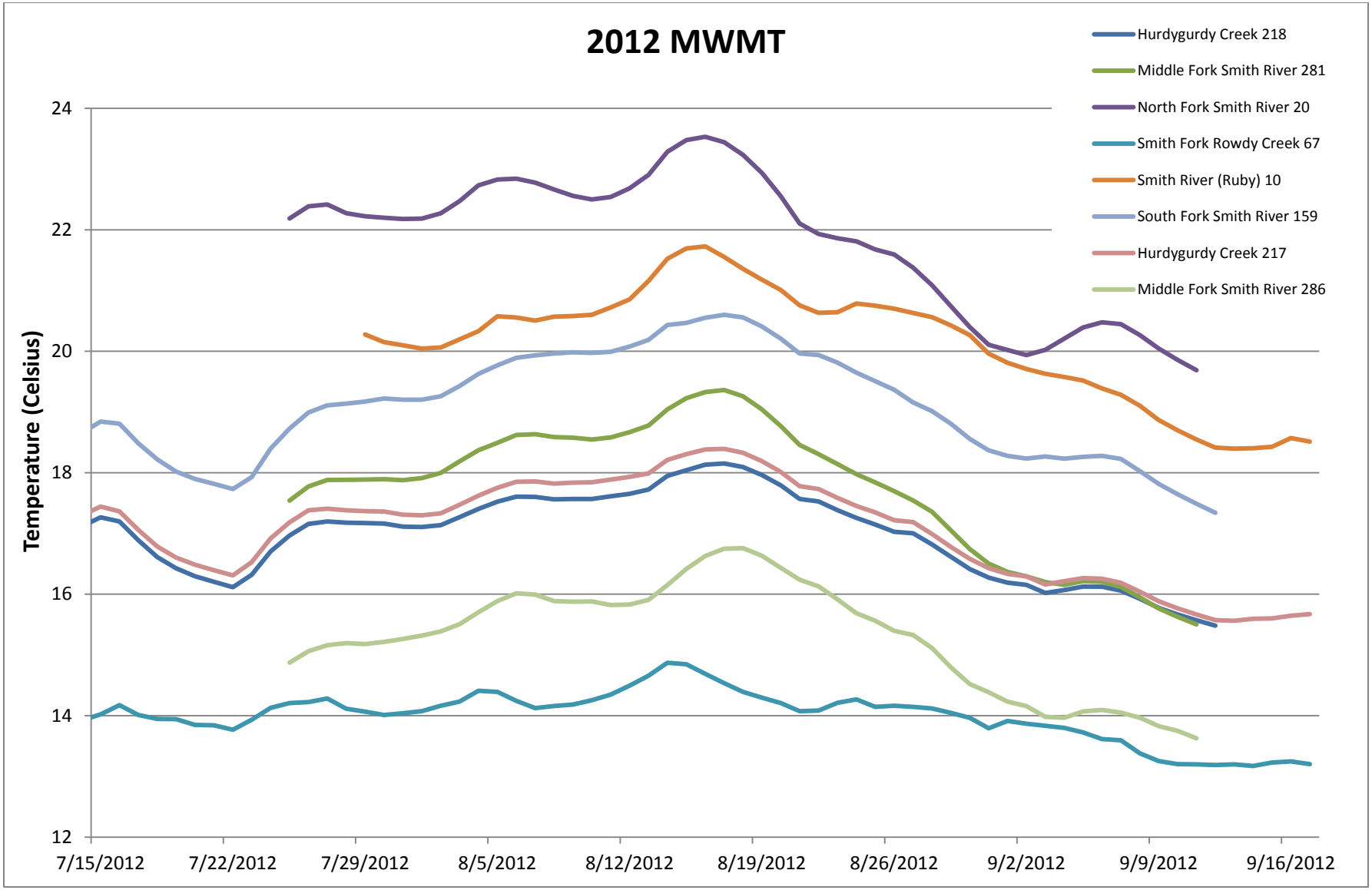

Figure 6. Maximum Weekly Maximum Temperature (MWMT) for tributaries and the mainstem Smith River during the summer of 2012.

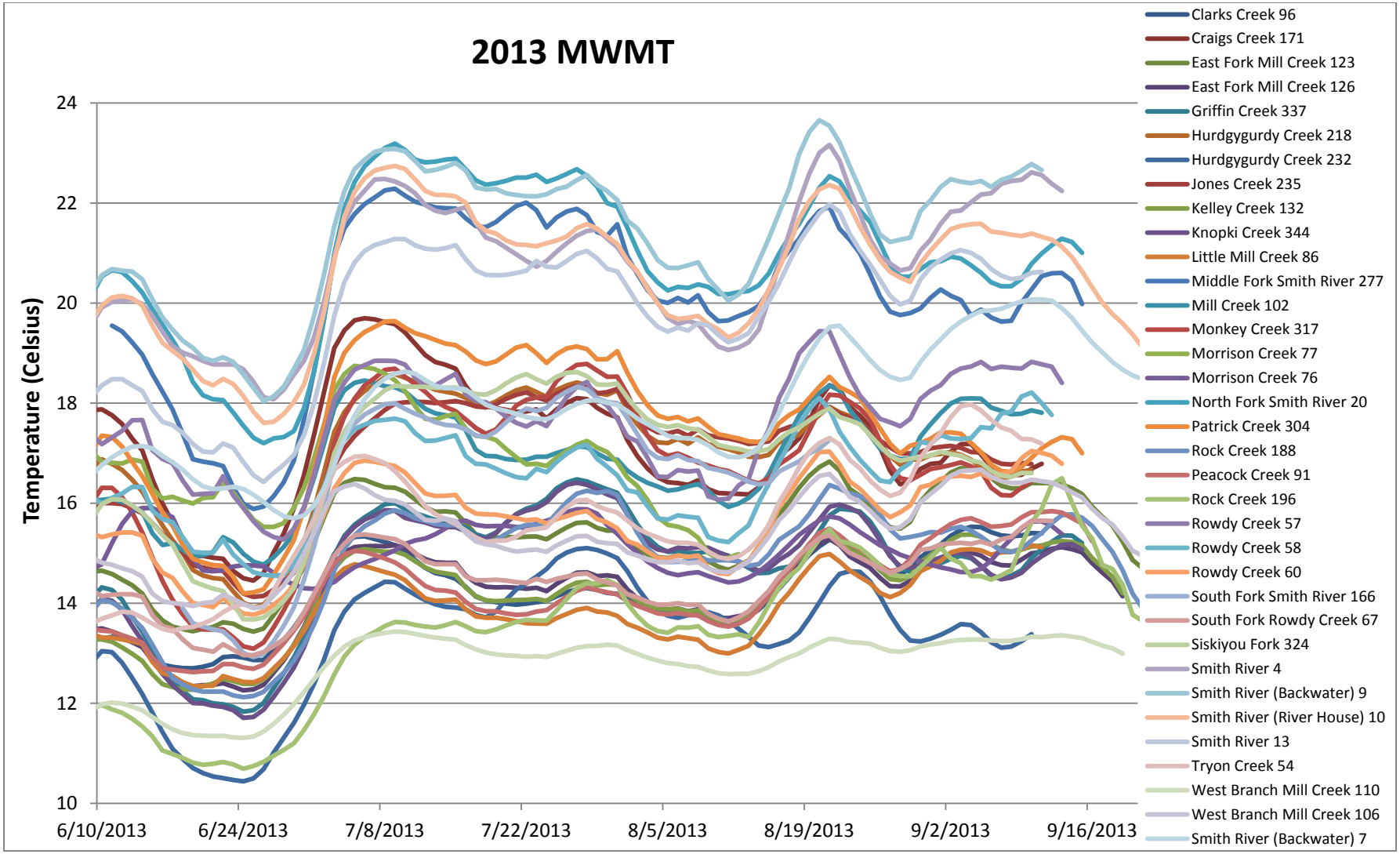

Figure 7. Maximum Weekly Maximum Temperature (MWMT) for the mainstem and tributaries of the Smith River during the summer of 2013.