2002 303(d) List Update
Reference # 71

State of California The Resources Agency

MEMORANDUM

To: Marc Jameson
Forest Manager
Jackson Demonstration State Forest

Date : July 2, 1997
Ref. : IMD 7-2

From: Department of Forestry and Fire Protection
Coast-Cascade Region

Subject: Water Temperatures on Jackson Demonstration State Forest During the Summer of 1996

During the summer of 1996, I deployed continuous water temperature monitors in each major drainage on Jackson Demonstration State Forest (JDSF). In addition to the monitors I used in 1996, the data from monitors deployed by JDSF are also presented in this memo.

This makes the fourth year of water temperature studies that I have undertaken on JDSF. Unlike the more thorough analysis I prepared on previous years efforts, this memo will simply present the results in tabular and graphical format. A diskette is also enclosed with the ".pic" files to enable your staff to incorporate them in documents as appropriate.

Stowaway® temperature monitors were programmed to start either when triggered or upon a specified date, to record either 15 or 20 records/day, and to use the multiple sampling mode with the maximum option. In the multiple sampling (maximum) mode, the monitors measure temperature about 100 times during the sampling interval but record the maximum during that time interval. Monitors were placed in different situations to represent different conditions:

- Within the stream, monitors were situated at locations intended to represent the "commonly" available temperatures. That is, in riffles that were deep enough to assure that monitors would remain submerged during the entire summer, or between 0.5 and 1 foot below the residual pool surface in the channel thalweg at the pool's head.
- At a sub-sample of stations with in-stream monitors, a second monitor was submersed in an un-capped, 5-gallon bucket filled with water in a well-shaded part of the forest adjacent to the stream. Care was taken to avoid direct sunlight on the bucket yet avoid substantial topographic shading. This placement was intended to represent the "equilibrium" temperature of water in good canopy conditions.
- At a sub-sample of sites with in-stream monitors, another monitor was suspended from vegetation in a well-shaded area of the stream side-zone to observe air temperatures. Care was

taken to place avoid direct sunlight and yet avoid topographic shading.

- One monitor was placed within the seep supporting the only known Torrent Salamander site on JDSF.
- One monitor was placed in Montgomery Creek, a small perennial creek in Montgomery Woods State Preserve that is managed by State Parks. This creek drains a watershed which has not, to my knowledge, had any timber harvesting near the watercourse. A one-lane dirt road does approximate it for some distance. This location is in the Big Creek drainage and is about 8 miles east-south-east of the eastern-most portions of JDSF.

Figure 1 maps the approximate locations of the sampling stations.

The period of coverage differed among the monitors. Deployment started as early as June 8 and retrieval ended as late as October 31. In the office, monitors were down-loaded, converted to Lotus 123 files, and evaluated for erroneous data. When such data was detected (e.g., data recorded prior or subsequent to placement in-stream), the erroneous data was deleted.

Maximum instantaneous stream temperatures ranged from 12.94° C to 23.23° C (Table 1).

The maximum weekly average temperature (MWAT) is a parameter which is useful to assess water temperature conditions for fishes (Brungs and Jones 1977, Armour 1991). For coho salmon, MWAT thresholds fall between 17.1° C and 18.3° C (Anon. 1997). Following Brungs and Jones' (1977) definition of MWAT as

> *"...the mathematical mean of multiple, equally spaced, daily temperatures over a 7-day consecutive period,"*

I calculated the weekly average temperature as a moving mean of temperature records for data sets with adequately long records. The calculated weekly average temperature can then be compared with the MWAT threshold to assess stress conditions on JDSF. For JDSF in-stream monitors, the maximal value and date of weekly average temperatures on JDSF during 1996 ranged from 12.56° C to 18.91° C, and 06 July to 31 August, respectively (Table 1). On the graphs, the time of the maximal weekly average temperature is depicted as a short (1 week long) horizontal line with a vertical line at the peak point.

To further portray the water temperature conditions on JDSF, I also calculated a monthly (4-week) average temperature using a moving mean temperature for records of adequate duration. The maximal values and dates of monthly average temperatures on JDSF during 1996 ranged from 12.33° C to 18.45° C and July 17 to

August 20, respectively (Table 1). On the graphs, the time of the maximal monthly average temperature is depicted as a long (28-day month long) horizontal line with a vertical line at the peak monthly maximum.

The Torrent Salamander site's peak temperature was 12.47° C, its weekly average temperature was 11.92° C, and its monthly average temperature was 11.52° C. The weekly average temperature peaked on 30 August and its monthly average temperature peaked on 26 July.

CRAIG E. ANTHONY
Deputy Director for
Resource Management

Brad E Valentine

By: Bradley E. Valentine
Regional Biologist

Enclosures: Diskettes

attachments: Figures and Tables

cc: Region files (w/o enclosures)
Pete Caferatta (CDF Sacramento; w/o enclosures)
Wendy Jones (DFG; w/o enclosures)
A.J. Kieth (Stillwater Sciences; w/ enclosures)

REFERENCES CITED:

Anonymous. 1997. Coho salmon considerations for timber harvesting under the California Forest practice Rules. CDFFP, Sacramento, CA. 48p.

Armour, C.L. 1991. Guidance for Evaluating and Recommending Temperature Regimes to Protect Fish. USDI Fish & Wildl. Serv. Biol. Rep 90(22). 13 pp.

Brungs, W.A., and B.R. Jones. 1977. Temperature criteria for freshwater fish: Protocol and procedures. US EPA Environ. Res. Lab. Duluth, Minn. EPA-600/3-77-061. 129p

Table 1. Results of temperature monitoring on Jackson Demonstration State Forest during 1996. Information in ***bold italics*** is for situations other than in-stream monitoring.

Stream Name & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
Hare Ck. Stream	Down Bunker Gulch	July 06	14.03	July 19	13.83	15.43
Hare Ck. Stream	Hare Ck. Ck. below bndry SFHC'97	July 10	13.86	July 17	13.69	15.27
Hare Ck. Stream	Down trail	July 11	13.79	July 17	13.64	15.27
Hare Ck. Stream	Upper Bunker Gulch	July 29	13.07	July 19	12.91	13.87
Hare Ck. Stream	Bunker Gulch above Hare Ck. Ck.	July 28	14.55	July 17	14.34	16.54
Hare Ck. SPRING	***Torrent Sal. Site***	***August 30***	***11.92***	***July 26***	***11.52***	***12.47***
SF Noyo AIR	***Down Limits***	***August 28***	***15.34***	***July 17***	***14.85***	***24.43***
SF Noyo BUCKET	***Down Boundary***	***August 27***	***13.82***	***July 17***	***13.45***	***16.07***

Stream Name & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
SF Noyo Stream	Downstream Limit	July 12	16.23	July 18	16.01	17.98
SF Noyo AIR	***SF, Upstream Limits***	***August 14***	***15.37***	***August 24***	***14.26***	***27.59***
SF Noyo BUCKET	***Upper Limits***	***August 13***	***15.76***	***July 18***	***15.23***	***19.43***
SF Noyo Stream	SF, Upstream Limits	July 29	14.62	July 19	14.37	15.59
SF Noyo Stream	SF above Rd 320	July 29	16.92	August 03	16.56	19.92
SF Noyo Stream	SF, ca 50 m below Parlin	July 29	15.94	July 19	15.69	17.34
SF Noyo Stream	SF between 23 G and Parlin	July 10	15.21	July 18	15	16.54
SF Noyo Stream	Between Parlin and NF,SF	August 13	15.37	August 19	14.77	16.38
SF Noyo	SF, 300' downstream of Bear Gulch	July 29	15.95	July 18	15.73	18.47

Stream Name & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
SF Noyo Stream	Between Parlin and NF,SF	August 14	15.94	August 20	15.42	18.31
SF Noyo Stream	Between Parlin and NF,SF	August 14	15.84	August 20	15.29	17.82
SF Noyo Stream	SF upstream of confluence with NF of SF	July 29	15.55	July 19	15.32	17.98
SF Noyo Stream	Egg Station	July 10	15.85	July 18	15.63	17.82
SF Noyo Stream	Parlin above Frolic	July 30	14.7	August 04	14.41	16.7
SF Noyo Stream	Parlin above Camp 7	July 29	15.14	July 19	14.9	16.86
SF Noyo Stream	Parlin below Camp 7	July 29	15.47	July 19	15.14	17.34
SF Noyo Stream	Parlin ca 10 m above SF	July 29	16.26	July 19	15.97	18.31

Stream Name Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
SF Noyo BUCKET	***Bear Gulch***	***July 28***	***15.51***	***July 18***	***15.14***	***19.43***
SF Noyo Stream	Bear Gulch beneath Rd. 300 bridge	July 29	14.03	July 20	13.74	15.27
SF Noyo Stream	Petersen Gulch	July 29	13.03	July 20	13.02	14.02
SF Noyo Stream	NF, SF at end of road	July 29	14.9	July 20	14.64	16.38
SF Noyo Stream	NF,SF above Brandon Gulch	July 10	15.28	July 18	15.06	17.34
SF Noyo Stream	NF of SF upstream of confluence with SF	July 10	16.07	July 18	15.87	17.5
NF Big River Stream	NF, upper limits of road 911	July 28	18.91	July 18	18.3	23.23
NF Big River Stream	NF, ca. 30m above James Ck.	July 28	18.85	July 18	18.35	21.73

Stream & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
NF Big River Stream	NF, ca. 40m below James Creek	July 28	18.49	July 18	17.93	21.73
NF Big River Stream	NF, ca 20 m above Chamberlin	July 28	18.48	July 18	18.04	21.56
NF Big River Stream	NF below Chamberlin	July 28	17.92	July 18	17.38	20.89
NF Big River AIR	***NF lower limits***	***July 04***	***19.63***	***August 02***	***18.45***	***33.63***
NF Big River BUCKET	***NF lower limits***	***July 28***	***14.99***	***July 19***	***14.38***	***16.38***
NF Big River Stream	Downstream Limits	July 09	17.95	July 18	17.61	19.59
NF Big River Stream	NF James Ck. at upper Rd. 100 crossing	July 28	15.09	August 03	14.58	17.18
NF Big River Stream	James, ca 30m below N and Main Forks of James	July 28	16.76	August 02	16.1	19.76

Fig. 1. Cont.

Stream Name & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
NF Big River Stream	James CK., Lower Limits	July 28	16.76	August 02	16.1	19.76
NF Big River Stream	Chamberlin, Upper culvert	July 12	14.52	August 02	14.16	15.75
NF Big River Stream	Chamberlin, downstream main S drainage	July 28	16.08	August 02	15.52	18.31
NF Big River Stream	Chamberlin, below W & E Forks	No data	No data	No data	No data	No data
NF Big River Stream	Chamberlin above NF	July 28	17.45	August 03	16.82	20.57
NF Big River Stream	WF Chamberlin, below 16 Gulch	July 28	15.21	August 03	14.63	16.86
LNF BigRiver Stream	Wonder Crossing	July 28	13.56	July 18	13.84	14.96
LNF BigRiver Stream	LNF ca. 10 m above Berry Gulch	July 28	15.34	July 18	15.04	16.7

Stream Name & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
LNF BigRiver Stream	Berry Gulch ca. 5 m above LNF	July 28	14.94	July 18	14.62	16.38
LNF BigRiver Stream	Thompson Gulch about 100m above confluence with LNF	July 28	13.75	August 03	13.44	14.33
LNF BigRiver Stream	Railroad Gulch above marsh	July 28	14.02	July 17	13.71	15.59
Caspar Stream	Caspar up SF	July 07	14.08	July 17	14	15.27
Caspar Stream	Down Bound	August 30	14.96	July 17	13.98	15.59
Caspar Stream	SF Caspar	July 07	13.86	July 17	13.69	15.27
Jughandle Stream	300' downstream of THP	August 31	12.56	720	12.4	12.94

Stream Name & Monitor Placement	Location	Date of maximum 7-day average	Maximum 7-day average temperature (° C)	Date of maximum 4-week average	Maximum 4-week average temperature (° C)	Instantaneous Peak Temperature (° C)
Russian Gulch Stream	(upper	August 29	13.08	July 18	12.75	14.49
Russian Gulch Stream	Lower	August 30	12.56	July 17	12.33	13.4
Big River Stream	Montgomery Creek	July 29	15.47	August 04	15.05	16.86

State of California The Resources Agency

MEMORANDUM

To: Big River Files
Date : December 19, 1994
Ref. : IMD 12 - 19

From: Department of Forestry and Fire Protection
Coast-Cascade Region

Subject: 1994 Temperature Study, Upper Big River Watershed

Attached is the referenced document. The data is supportive of close assessment of stream shade during timber harvest both on JDSF and at least the near-reaches downstream. Any questions can be directed to me at 576-2275.

LLOYD I. KEEFER
Region Chief
Bradley E. Valentine
By: Bradley E. Valentine
Regional Biologist

Attachments: As stated

cc: Hal Slack (CDF - JDSF)
John Teie (MEU)
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Water Temperature Study, 1994:
Big River Watershed on Jackson Demonstration State Forest

Bradley E. Valentine

Calif. Dept. Forestry & Fire Protection
Coast Cascade Region
Santa Rosa, CA.

During the summer of 1994, continuous monitors (Hobo-temps®) recorded stream temperature at three locations in the headwaters of Big River on Jackson Demonstration State Forest (JDSF). The purpose was to document water temperature ranges at an inland site, relative to the stream temperature study I conducted on the South Fork Noyo River (Valentine 1994). In addition, a second goal was to assess the rate at which water heats as it flows downstream.

METHODS

A monitor continuously recorded temperature at three locations on inland tributaries of Big River (Fig. 1, Table 1.). I selected these sites to represent

- a headwater area dominated by groundwater inflow and thus representing theoretically the lowest temperature possible,
- a location as low in the watershed to which access is available on public lands to document the total temperature increase along the channel, and
- a mid-watershed locale to improve understanding of the rate of temperature gain.

I placed the monitors at sites to represent a near-average temperature condition for that portion of the watershed. Characters of the placements were within the thalweg of a riffle, in a shaded location, and beneath rocks (which were used as anchors and camouflage for the monitors). I deployed the monitors on 07 July, and retrieved them on 07 September, 1994. Monitors were downloaded and the data files transferred into a spreadsheet for analysis.

The data is analyzed using only complete daily cycles to eliminate errors with calculations of average, maximum, and minimum temperature. These errors could arise from shortened periods of observation and potential lag time until the units equilibrate with the environment. Thus, both the partial first and partial last day as eliminated from the data base at the nearest daily peak.

Stream distance for the study was calculated by setting a compass at 0.1 mile increments and tallying rotations along the streamcourse as mapped on 7½ USGS quad maps. The GIS system was unavailable. Measurements are underestimates as stream curves were evident within the 0.1 mile distances.

The temperature monitors were calibrated (Appendix 1). Although there was some error in extreme measures during the calibration trial, averages were precise. Temperature data are not corrected below.

RESULTS and DISCUSSION

At all stations, temperatures were greatest early during the period of monitoring (Fig. 2 - 4). This data indicates that the summer's peak water temperature period was not fully enveloped by this study, and future monitoring should be initiate prior to the deployment date used in this study. The flatness of the curves during the first portion of the monitoring period, especially as represented by the average temperature, suggests that peak period likely was not missed.

During the period monitored, the upstream station (Upper James) remained fairly constant (Fig. 2). Only a minor seasonal decline is obvious. Maximum temperature recorded was 16.5 °C and minimum was 9.8 °C. Daily temperature fluctuations were as small ≈ 1°, as much as ≈ 4.5 °C, and were typically between 3 and 4 °C. The constancy of the water temperature and its daily variability on-site is probably related to the stream being primarily a gaining reach, with much of its surface water recently emerged from the aquifer. If it were located where groundwater made up most of the flow (i.e., at a spring), the temperature would probably have been more constant daily and seasonally. During the calibration test (Appendix A), the unit at the upper-James site had the lowest and most variable temperature recordings.

At the mid-station (mid-James), the maximum temperature recorded was 20.5 °C, the minimum recorded was 10.9 °C, and average temperatures remained below 18 °C (Fig 3). Water temperatures declined over the sampling period. Water temperature varied as much as ≈ 6.2 °C per day, and the daily variability declined over the sampling period. The seasonal decline in maximum, minimum, and average temperature and the decline in daily variability reflects the fact that water temperature in this reach is more dependent on climate and upstream influences than it is on nearby groundwater inflow. During the calibration test (Appendix A), the unit at the mid-James site had the highest maximum run value but the middle minimum run temperature recordings.

At the downstream location (Big River), the maximum temperature recorded was 19.3 °C and the minimum recorded was 12.6 °C, and average temperatures remained below 18 °C (Fig. 4). Water temperatures declined over the sampling period. Water temperature varied < 4.0 °C per day, and the daily variability declined slightly over the sampling period, as did the trend for maximum, minimum, and average temperature. As for the mid-station, these characteristics imply this station is not strongly influenced by inflow from the aquifer. During the calibration test (Appendix A), the unit at Big River had the highest minimum run temperature and a middle maximum run value.

In general, water temperature increased in a downstream direction. The 50% exceedence temperature of all temperature readings increased from 13.2 to 15.1 to 16.0 °C in a downstream direction (Fig. 5). The shape of these curves at lower temperatures (<≈ 60%) are nearly parallel, suggesting typical downstream warming. However, the divergence from near-parallel at greater exceedence percentages (Fig. 5) suggest an important phenomenon other than simply downstream warming. The curve for the mid-James Creek station crosses that of the downstream (Big River) station at high temperatures -- that is, while the mid station is on average cooler than the downstream station, it does experience higher peak temperatures.

Higher peak temperatures at the mid-station than at the downstream station is also apparent in graphs that portray temperatures of downstream stations graphed against the minimum (Fig. 6), minimum (Fig. 7), and maximum (Fig. 8) daily temperature of the upstream location. Relative to daily minimum (Fig. 6) temperatures, the downstream stations are distinct from each other and both warmer than the upper-James station, with downstream warming evident. Relative to daily average (Fig. 7) temperatures, the stations are less distinct from each other, especially at high average temperatures. As with the minimum temperatures, downstream warming is evident when mean temperatures are compared, but the warming is obscured at high average temperatures. At daily maximum temperatures (Fig. 8), although the downstream stations are both warmer than the upstream station, downstream warming between the mid-James and the Big River stations is obscure even at low temperatures and "cooling[1]" from the mid-James to the downstream station (Big River) is obvious during high peak temperatures.

Using the 50% exceedence level, stream water increased 0.65 °C / km between the upper-James station and the mid-James station, while between the mid-James station and Big River it increased 0.08 °C / km. While the rate at which the water temperature warms declines in the downstream reach relative to the upstream reach, it is still warming. Additional monitors at other intermediate locations would facilitate understanding the rate at which water gains heat as it flows downstream -- and with an adequate data

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[1] "Cooling" is only apparent. The time-of-travel for water heated at the mid-James site is probably on the order of days at flow rate during this study. What actually is a better description of the reduced downstream temperature is that water heated during the day in the vicinity of the Mid-James Creek is diluted and dispersed with cooler waters that flowed through that site during cool periods (i.e., night[s]).

record -- could be used to quantify the longitudinal temperature profile of the stream under various shade canopy management options. An understanding of the shape of a temperature curve along a stream longitudinal section may enable an estimate of the location along the stream of any specified temperature, deviations from expected temperatures, and/or prediction of the downstream equilibration temperatures.

Shade canopy was not measured along any of the reaches upstream of the monitors. The data suggests, however, that there is an opening in the forest canopy a short distance upstream of the mid-station that has elevated temperature. This is most apparent during early July, a time when the sun is at a high solar angle. The decline in temperatures between this station and the Big River station suggests that 1) the distance (10.6 km) between the mid-James station and the Big River station is adequate to dilute the localized heating, and 2) shade canopy upstream of the Big River station is enabling water temperatures to ameliorate after the upstream heating, and/or 3) other cool water tributaries may be further influencing stream temperature.

Using 20 °C as a threshold maximum water temperature for coho salmon (Reeves et al. 1989), temperatures in the vicinity of the mid-James Creek site could be considered a problem. That station also had great daily variation, another possible temperature-related stressor. The extent of these temperature conditions along the stream course is not known -- except that they are not reflected clearly at the other stations. Retention of all shade canopy is desirable for the mid-section should any harvest in this area be considered in the near future (± 10-15 years). Applying a correction value of +0.2 °C (Appendix A) increases that concern.

Because peak water temperatures approached the 20 °C level for much of July, and did not consistently stay below 18° until after mid-August at the Big River station, retention of high degrees of shade canopy should be sought in any potential stream-side harvest in that portion of Big River. Applying a correction value of +0.2 °C (Appendix A) would bring peak temperatures on Big River to nearly 19.5 °C.

Preferred temperature for coho salmon is 12-14 °C (Bjornn and Reiser 1991). Temperatures in that range are continuous at the upper James Creek location, infrequent at the mid-James Creek station until early August, and were not observed on Big River until the end of August.

This information suggest that temperature in the Big River watershed is an element of coho salmon habitat quality that merits attention during development, and review of timber harvest plans in that drainage. This concern elevates when the study area's high location in the watershed is considered -- i.e., there is still a long distance along which the stream's water can be warmed prior to it flowing into a moderating area such as the fog zone, the estuary, or the ocean.

Unlike the South Fork of the Noyo (Valentine 1994) where a peak temperature above 20 °C was noted on a small tributary (Parlin Fork) which was quickly attenuated by the larger stream to which it was tributary (South Fork Noyo River), temperatures in excess of 20 °C were observed on a major watercourse (James Creek) in this upper Big River study. Another difference between the studies is that maximum stream temperatures on the Noyo were probably somewhat constrained by its more coastal locale, relative to the Big River/James Creek drainage.

MANAGEMENT RECOMMENDATIONS

To avoid delivering undesirable warm water downstream from Jackson Demonstration State Forest, as well as improving habitat on the Forest, JDSF Foresters should, in the near-term:

1. Avoid removing trees that shade the water surface of streams in the mid-reaches of James Creek.
2. In the downstream portions of Big River watershed (i.e., downstream of the Highway 20 crossing), retain a heightened degree of shade canopy relative to the minimum rule requirements.

To avoid direct and cumulative impacts on-site and downstream, CDF inspectors of plans on JDSF and Big River downstream of JDSF should:

3. evaluate water temperature information provided by project proponents closely,
4. assess shade canopy retention levels, with an emphasis on retaining trees that shade the water surface during June and July.

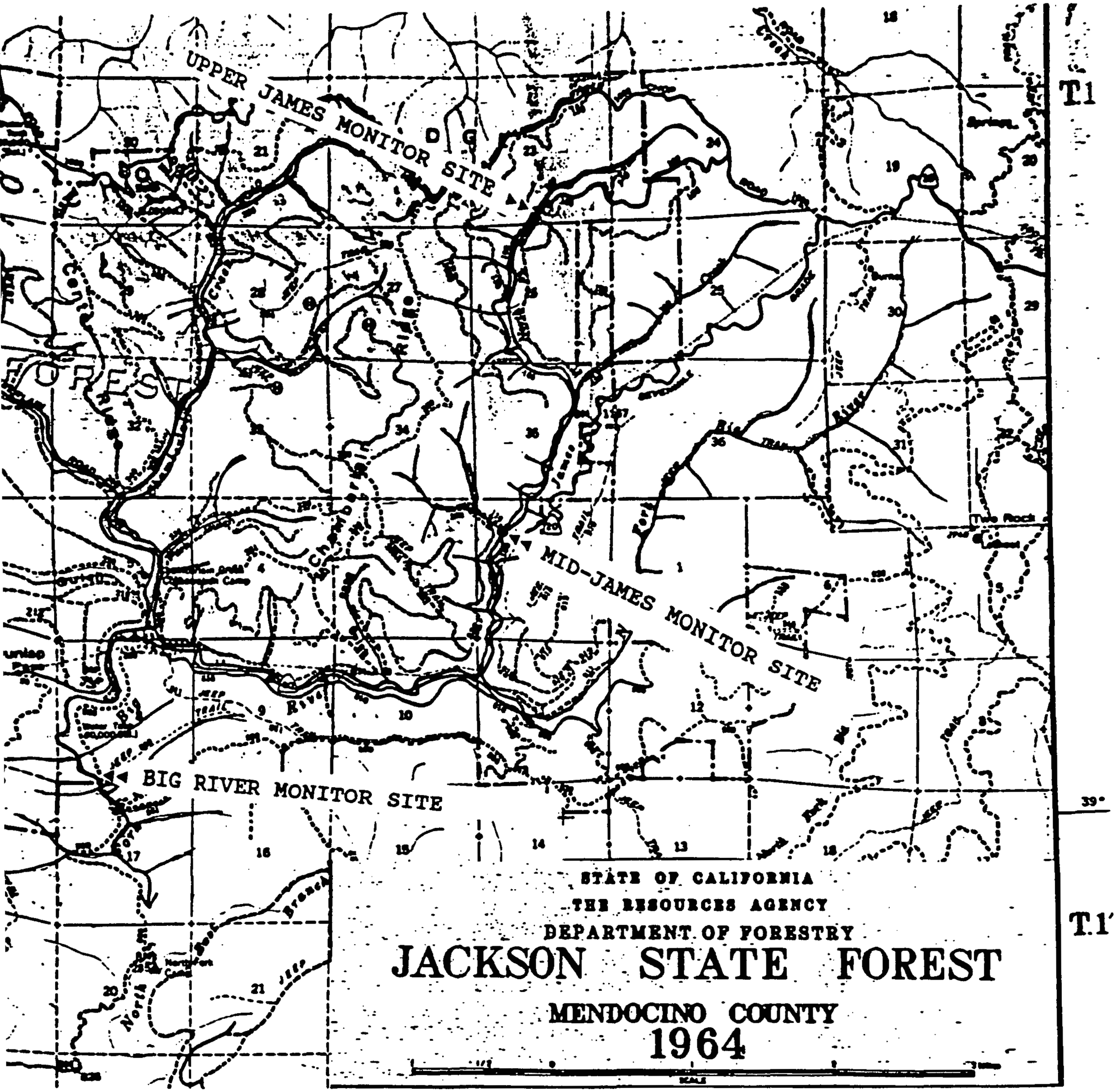

Fig. 1. Eastern portion of Jackson Demonstration State Forest showing the location of the water temperature monitors operated during summer, 1994 on the upper Big River Watershed.

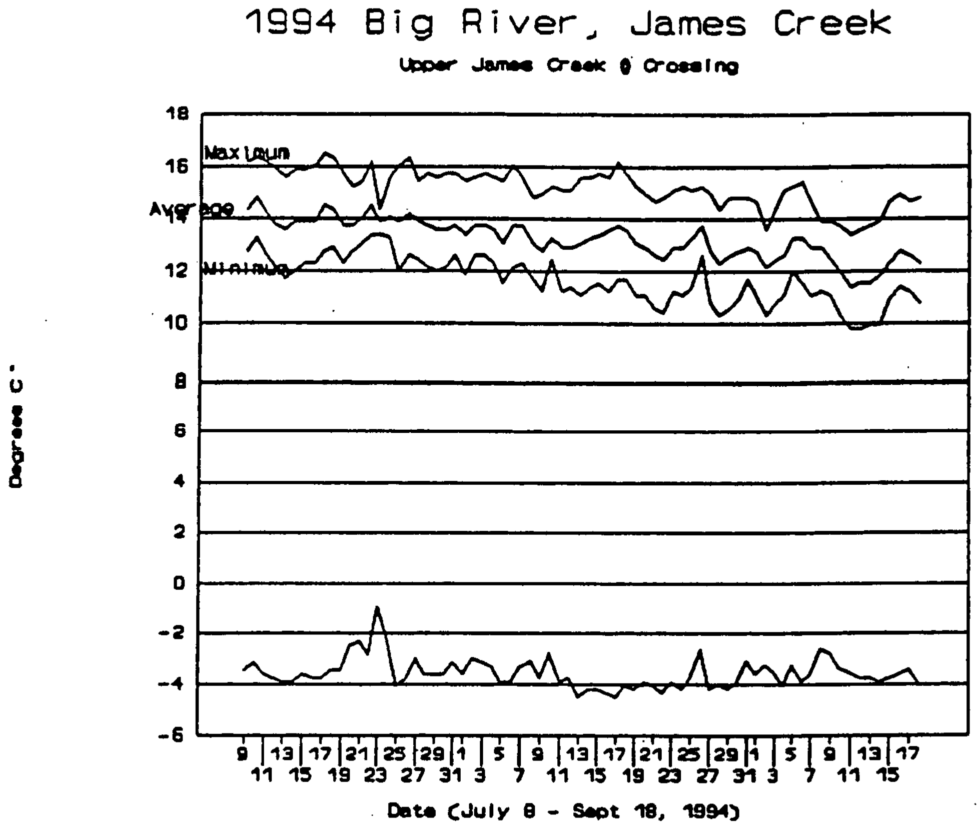

Fig. 2. Continuous trace of water temperature at the Upper James Creek site, 1994. Daily range is graphed at bottom of figure.

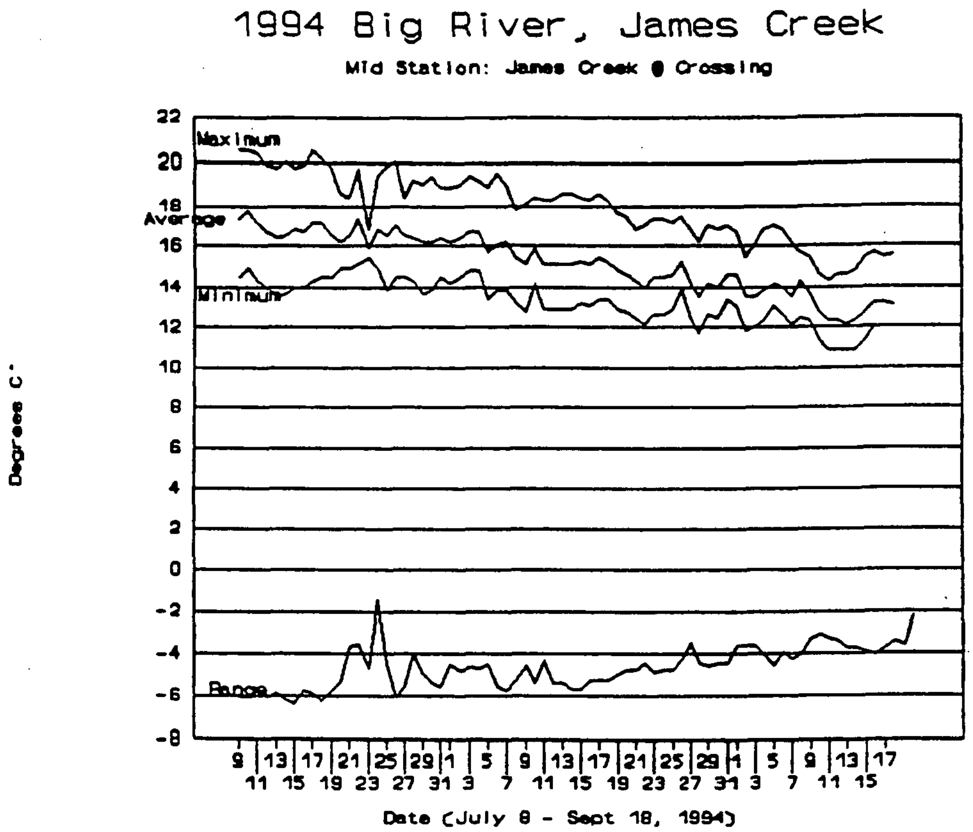

Fig. 3. Continuous trace of water temperature at the mid-James Creek monitor site, 1994. Daily range is graphed at the bottom of the figure.

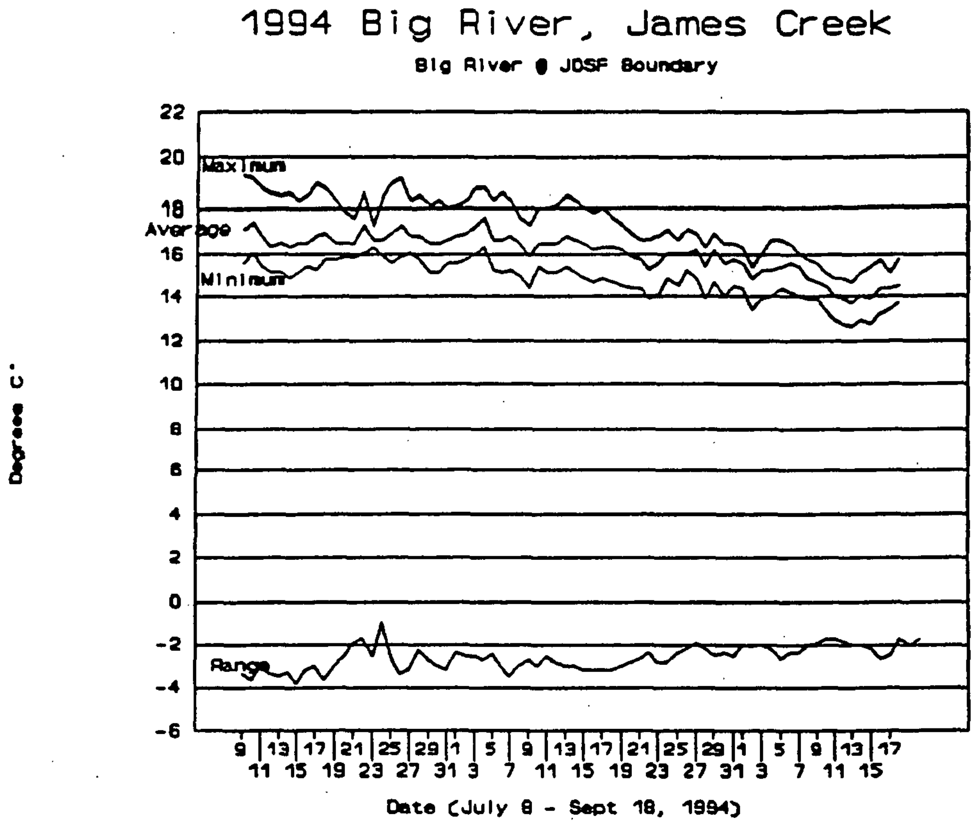

Fig. 4. Continuous trace of water temperature at the Big River, JDSF boundary site, 1994. Daily range is graphed at bottom of figure.

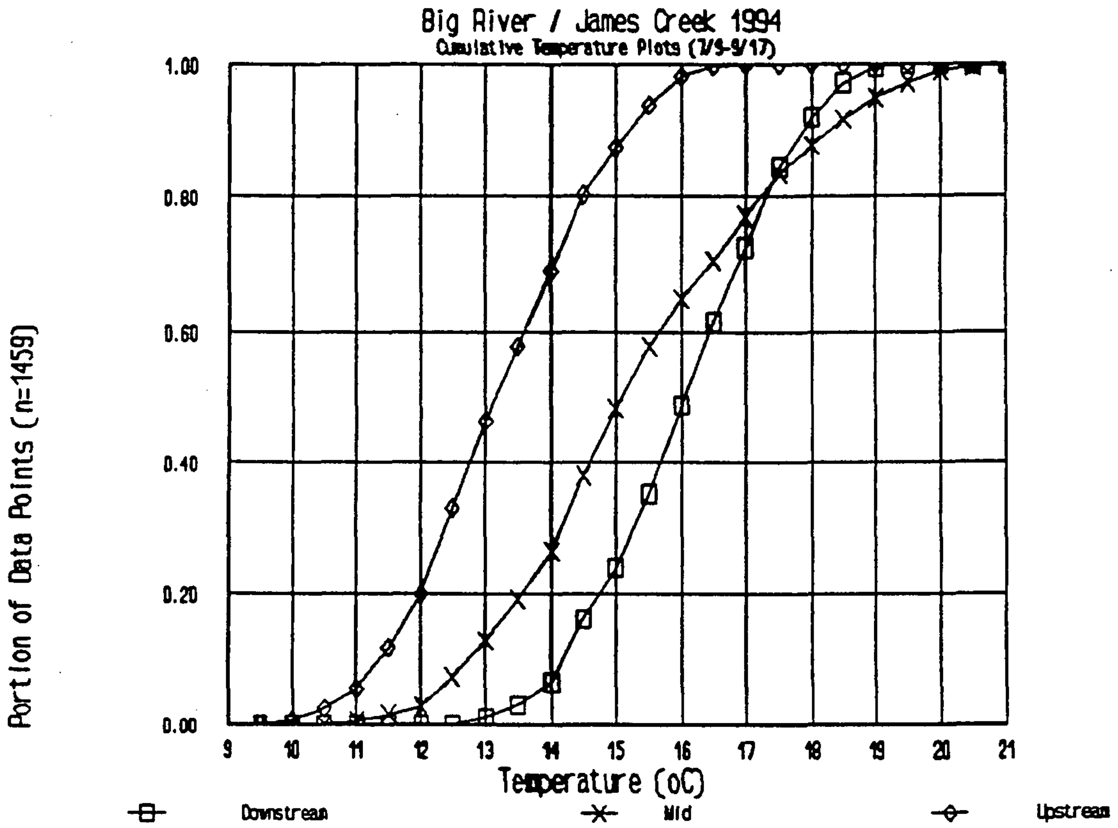

Fig. 5. Cumulative distribution of water temperature from three continuous monitoring stations in the upper Big River watershed, 1994.

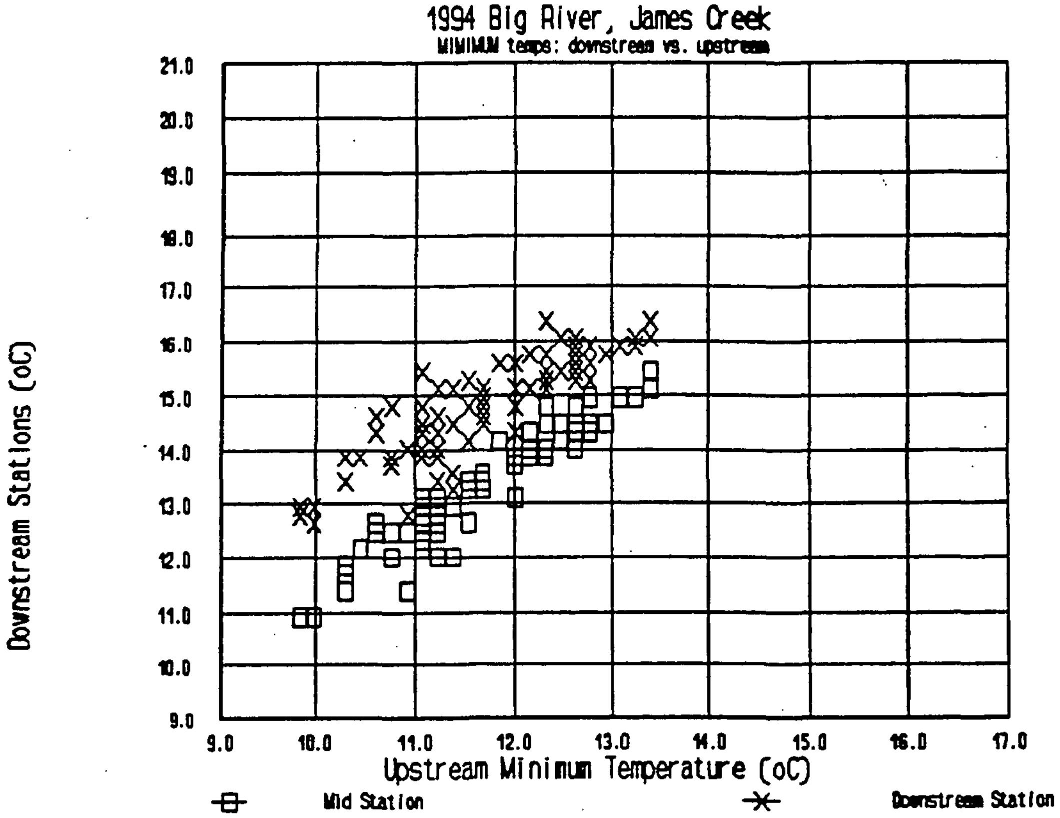

Fig. 6. Daily minimum temperatures at the two downstream sites graphed against the upstream daily minimum temperature.

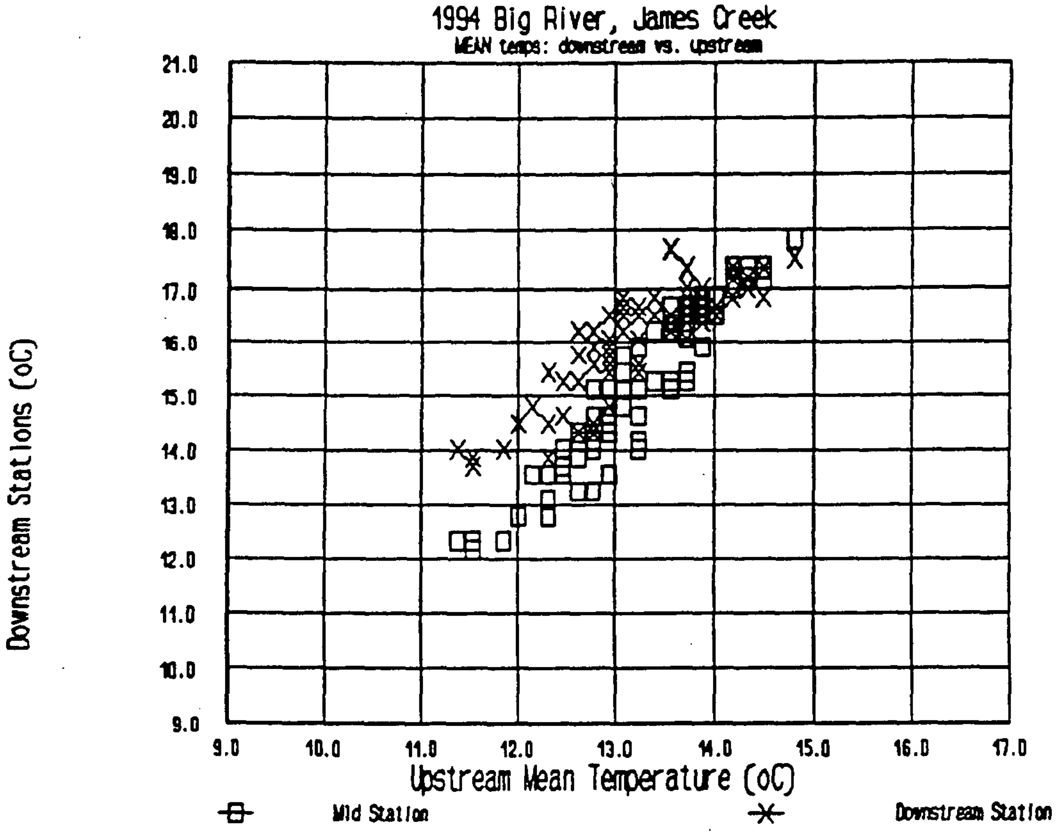

Fig. 7. Daily mean temperatures at the two downstream locations against the daily upstream mean temperature for the upper Big River watershed, 1994.

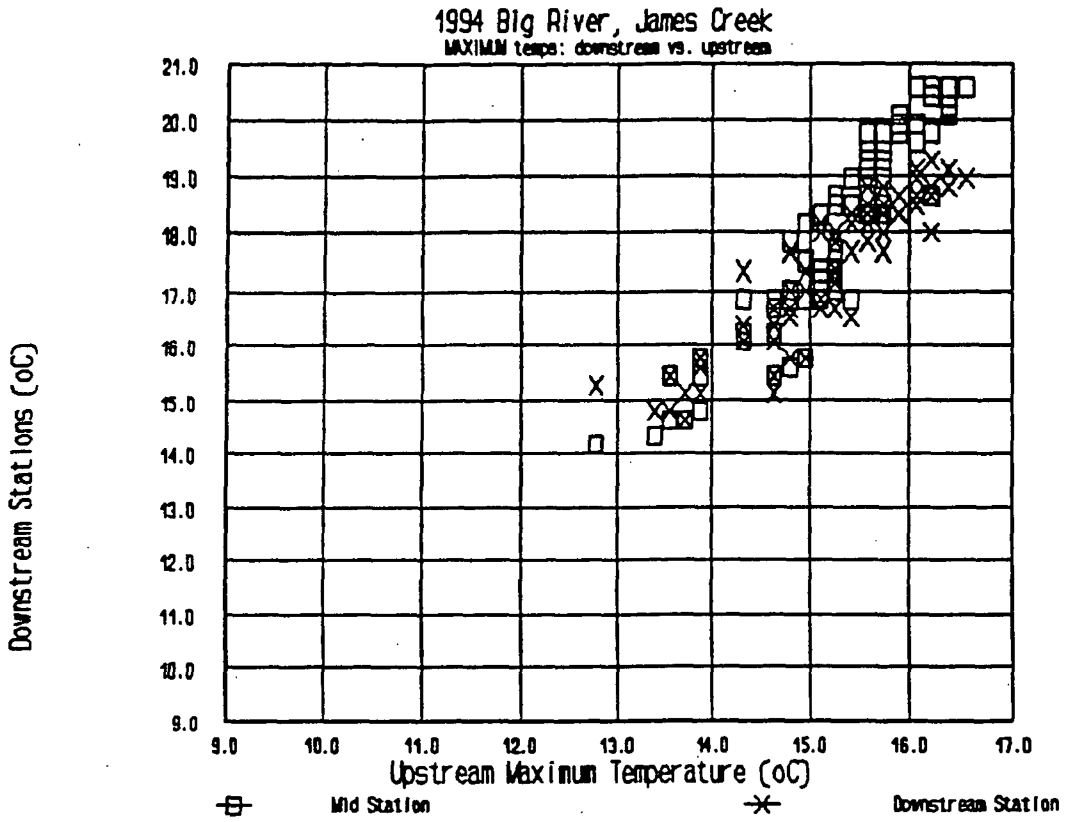

Fig. 8. Daily maximum temperature of two downstream stations against the upstream daily maximum temperature on the upper Big River watershed, 1994.

APPENDIX A

TEMPERATURE MONITOR CALIBRATION TEST

WATER TEMPERATURE MONITOR (HOBOTEMP®)
CALIBRATION TEST 3

Continuous electronic temperature recorders are increasingly being employed to assess temperature dynamics of streams. While their ability to track temperature at user-specified intervals enables one to "continuously" measure temperature, the information is truly only meaningful if the instruments are accurate. This document reports on the calibration assessment of three monitors (HOBOTEMP®) used by the California Department of Forestry and Fire Protection, Coast-Cascade Regional Office, Santa Rosa.

METHODS

Three units were run through a lab calibration test in which the units were placed in individual cases, the cases banded together, and placed in a common water bath. The water bath was then alternately transferred from a stir-plate (with magnetic stirrer and warming functions) to a freezer. The water bath in the freezer was not subject to stirring because the stir plate was powered by cord, not battery. While on the stir-plate, the magnetic stirrer was activated continuously to assure constant circulation of water over the units and to avoid any thermal gradients with depth. The freezer was used to assess the monitors as they pass through freezing/melting points, as at that condition the temperature should remain mostly constant at 0 °C. This is likely the best point to assess accuracy, as it is a known value and is temporally uniform.

Comparisons are of two types: those at "Common Points" (the maximum or minimum at common points) and those of the run (hereinafter CP). The run variables for comparison are the maximum and minimum during the entire run, and the mean calculated from the data between CP-1 and CP-9 (this eliminates variability due to handling during the deployment and downloading phases).

"CP's" are the 1) highest temperature recorded during a peak and 2) the lowest temperature recorded during a trough. These were first determined by evaluating the graphs (Figs 1-3), then scrolling through the data file and finding the corresponding extreme for that "CP." Often, these were not true "points" as there were several, simultaneous identical recordings.

To look at variability in more detail, the measured temperatures during the CP-4 are noted -- i.e., the true value of temperature during the plateaus of freezing should be 0°C. A frequency distribution was tabulated for each unit through that plateau for all temperatures recorded < 0 °C.

RESULTS

The average temperatures differed by less than 0.1 °C (Table 1). The greatest difference between units for the run maximum and minimum was <0.4 °C and <0.5 °C, respectively (Table 1). Unit 602 was the lowest temperature for all three run variables, while unit 603 had the highest maximum run temperature and unit 604 had the highest minimum run temperature (Table 1)

CP temperatures differed by as much as 0.64 °C (Table 1, Figs.1-3), although at 3 points they recorded identical values. Relationships between the magnitude of the differences and the CP type (warm peak or cold valley) are not evident (Table 1). As for run variables, unit 602 tended to record the coolest temperatures when the units differed, while unit 604 tended to record the warmest (except at CP-4) (Table 1).

Unit 602 was the most variable through the CP-4 plateau Table 2). Its modal temperature was -0.19 °C, but nearly 50% of the readings were even colder. Unit 603 was the least variable, also with its modal recording at -0.19, but no colder temperatures recorded. Unit 604 was similar to unit 603, only slightly more variable. These conditions are apparent in the units traces (Figs. 1-3).

A true value of 0 °C is apparently measured by the units as -0.19 °C. Because the true value for other temperatures is unknown, a correction of values by +0.19 °C is supported by this test to improve accuracy. Howerver, this will not improve precision.

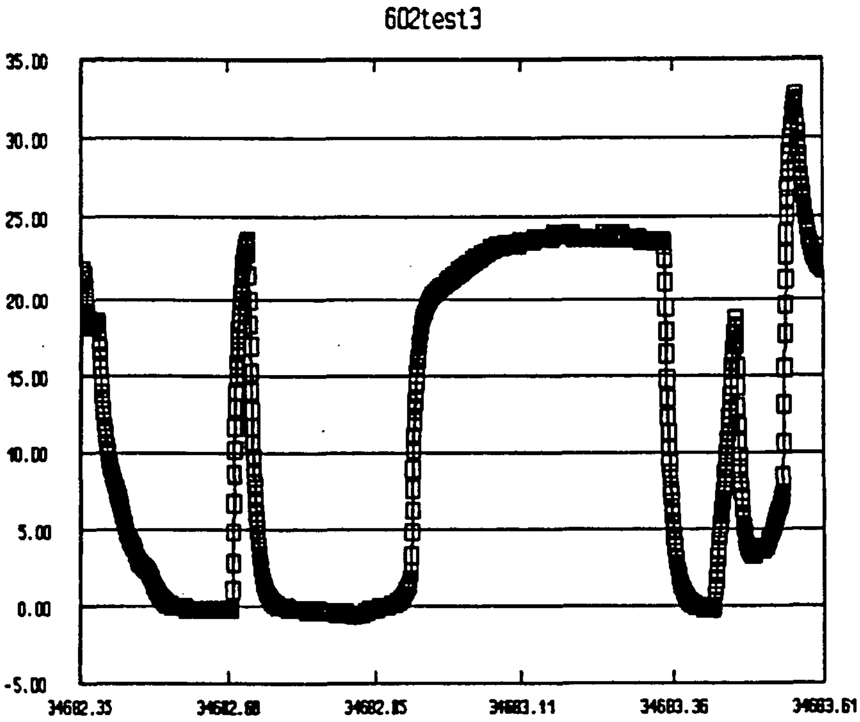

Fig. 1. Lab test 3 of Hobotemp # 602. CPs are numbered. The X-axis is computer time code.

Table 1. Calibration test temperature recordings of three water temperature monitors (Hobotemps®) in lab conditions.

Test Value	Unit Serial Number			Greatest Difference
	602	603	604	
Maximum	32.64	32.64	33.03	0.39
Minumum	-0.68	-0.19	-0.36	0.49
Mean	10.60	10.68	10.65	0.08
CP-1	18.47	18.63	18.63	0.16
CP-2	-0.19	-0.19	-0.19	0
CP-3	23.57	23.57	24.09	0.52
CP-4	-0.52	-0.19	-0.36	0.33
CP-5	23.92	23.92	23.92	0
CP-6	-0.19	-0.19	-0.19	0
CP-7	18.63	18.95	19.27	0.64
CP-8	3.31	3.78	3.78	0.47
CP-9	32.64	32.64	33.03	0.39

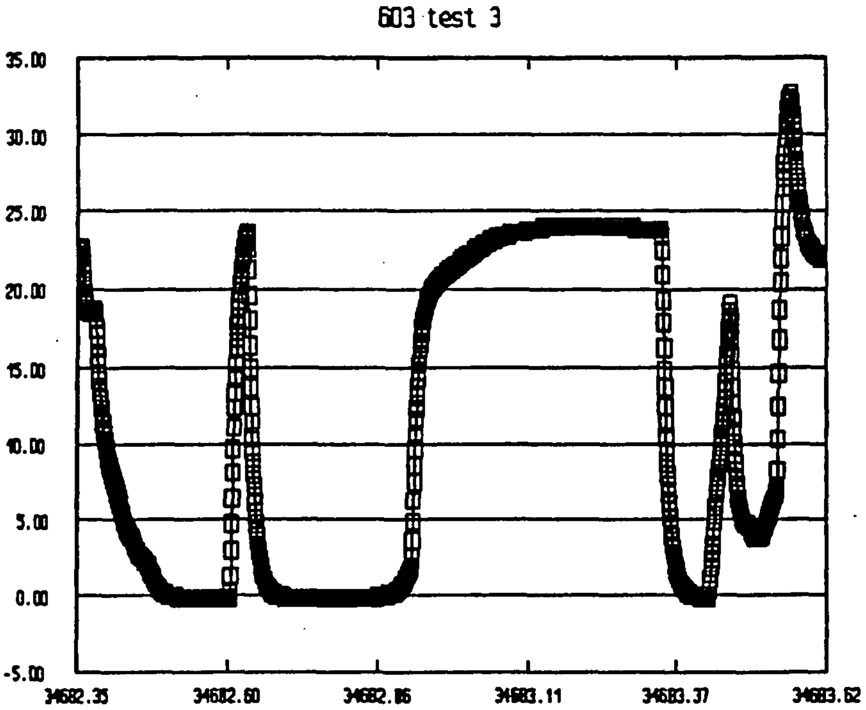

Fig. 2. Lab test 3 for Hobotemp #603. CP's as in Fig. 1. The X-axis is computer time code.

Table 2. Frequency distribution of the number of data points by measured temperature value for three water temperature monitors (Hobotemps®) through the "0 °C" CP-4 plateau.

Measured Temperature	Unit Serial Number 602	 603	 604
-.03	45	40	27
-.19	73	189	133
-.36	60	0	17
-.55	44	0	0
-.68	8	0	0

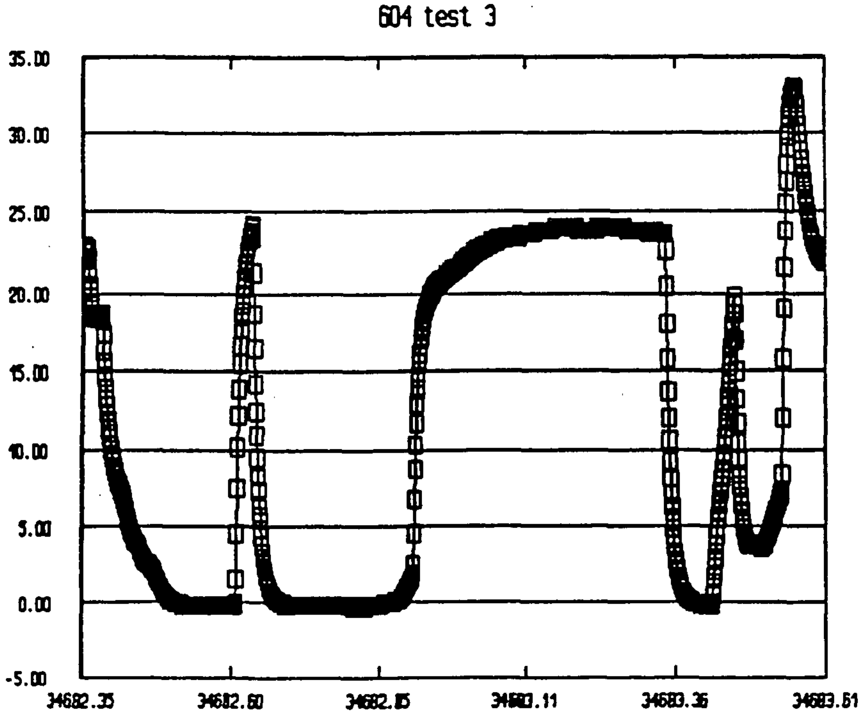

Fig. 3. Lab test 3 for Hobotemp #604. CP's as in Fig. 1. The X-axis is computer time code.

State of California The Resources Agency

MEMORANDUM

To: Forest Practice Library
River Files

Date : April 13, 1994
Ref. : IMD 4 - 13

From: Department of Forestry and Fire Protection
Coast-Cascade Region

Subject: Noyo Temperature Study, 1993

Attached is the report covering the referenced study undertaken on the central portion of Jackson State Demonstration Forest during 1993. It should be self-explanatory.

LLOYD I. KEEFER
Region Chief

Brad Valentine

By: Bradley E. Valentine
Regional Biologist

Attachment: As stated.

cc: Jackson Demonstration State Forest
Caferetta (CDF-Sacramento)
Berbach (CDF-Sacramento)
Wooster (DFG - Yountville)
Moore (DFG - Yountville)
W. Jones (DFG - Mendocino)

Noyo River Temperature Study, 1993

Bradley E. Valentine
CDF Coast-Cascade Region
PO Box 670 Santa Rosa, CA 95401

April 1994

Water temperature as affected by timber harvest is a concern relative to cold-water fisheries. However, as simple as water temperature is to measure, interpretation of the results is complicated. Identifying lethal, stressful, and optimal temperature is easy in laboratory situations, but is more difficult in the field due to diel cycles, groundwater inflow, and lack of climate control. Additionally, the thermal loading of streams can have both positive and negative ramifications, depending on the magnitude of warming and the location along the watercourse. For example, a thermal load induced by canopy removal may be detrimental at the site, but as that water flows downstream it will mix with groundwater inflow and that water which passed the open canopy area on the prior night. This mixed water may be more suitable for fishery production. Also, proximity to coastal influences such as fog and the large cool water mass may ameliorate warming concerns altogether.

During the summer of 1993, I conducted a temperature study of the Noyo River as it flowed through the body of Jackson Demonstration State Forest. The purpose was to evaluate the dynamics of water temperature changes over time and distance in a small, coastal stream.

Methods and Materials

In the lab, maximum recording thermometers were marked with individual identification numbers sites. They were then calibrated to a known thermometer standard by dropping their temperature below 10 °C in an cool water bath. As the water warmed, their readings were recorded at known temperatures of 15 and 20 °C.

The thermometers were placed in the field on July 2, 1993 and were read on August 4, then again on September 17. At initial placement and at the first reading, the thermometers were reset to a temperature less than 10°C by immersing in a tube of ice-water. Immediately, they were placed prior to any chance for them to return to air temperature. Thermometers for measuring maximum air temperature were placed against the north side of trees in heavily shaded conditions at the up-stream and down-stream most stations. Water temperature thermometers were placed in the thalweg of riffles beneath a large, concealing rock.

The calibration of thermometers showed substantial deviation form the standard. To control for this, thermometers were not exchanged between sites and all data collected was attributable to a specific thermometer. To interpret the results from a given thermometer, its data was adjusted using the average difference between the thermometer and the standard at the calibration temperatures.

The locations of the sampling stations are identified in Table 1 and on Fig. 1. The distances recorded in table 1 are from the downstream end of the reach and were calculated by CDF Region 1's GIS system along the stream course.

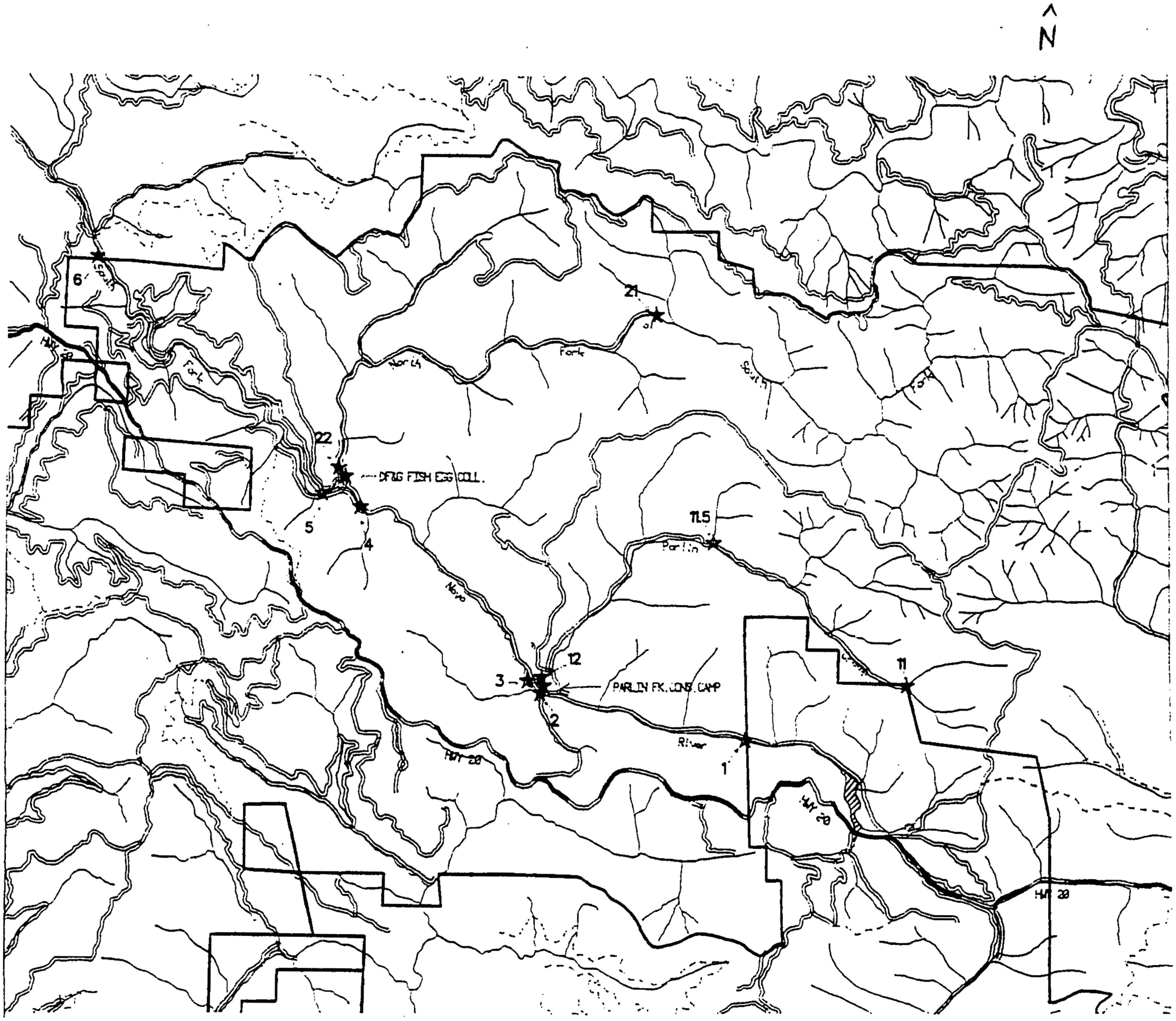

Fig. 1. Temperature measurement stations on Noyo River, Jackson Demonstration State Forest during the summer of 1993. Locations are pinpointed with a star and identified by a number which matches to those in Table 1.

Results and Discussion

Maximum air temperatures were at the inland-most sites (Table 1, Figs. 2 and 3). There, air temperatures were high enough that conduction to the water could elevate temperatures above the mortality limits of coldwater fish. At the downstream end of the study reach, air temperatures were substantially nearer temperatures that would be considered suitable, and heat conduction to the water from the air would be unlikely to have had any immediate mortality impacts.

Maximum water temperatures ranged from 16.2 to 21 °C and warmed in a downstream direction (Table 1, Figs. 2 and 3). All these temperatures are greater than the preferred temperatures for salmonids, but are well below those considered lethal (Bjornn and Reiser 1991). In fact, they are in the range which Bjorn and Reiser (1991) consider optimal when measured in terms of "performance." One temperature at the mouth of Parlin Fork was in excess of 20 °C and is high enough to raise concern.

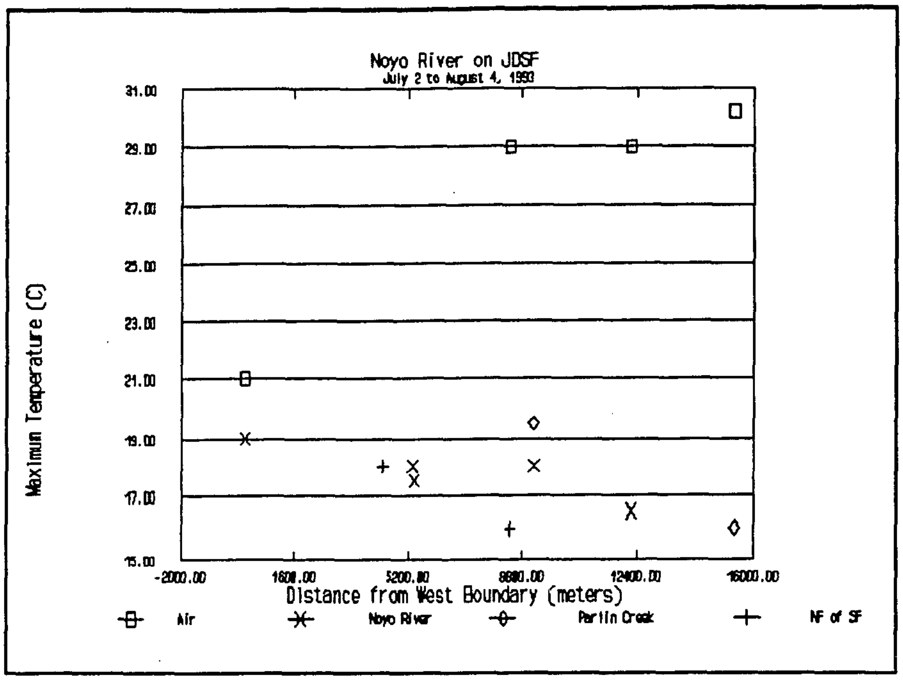

Fig. 2. Water temperatures in the Noyo River on JDSF, 2 July to 4 August, 1994.

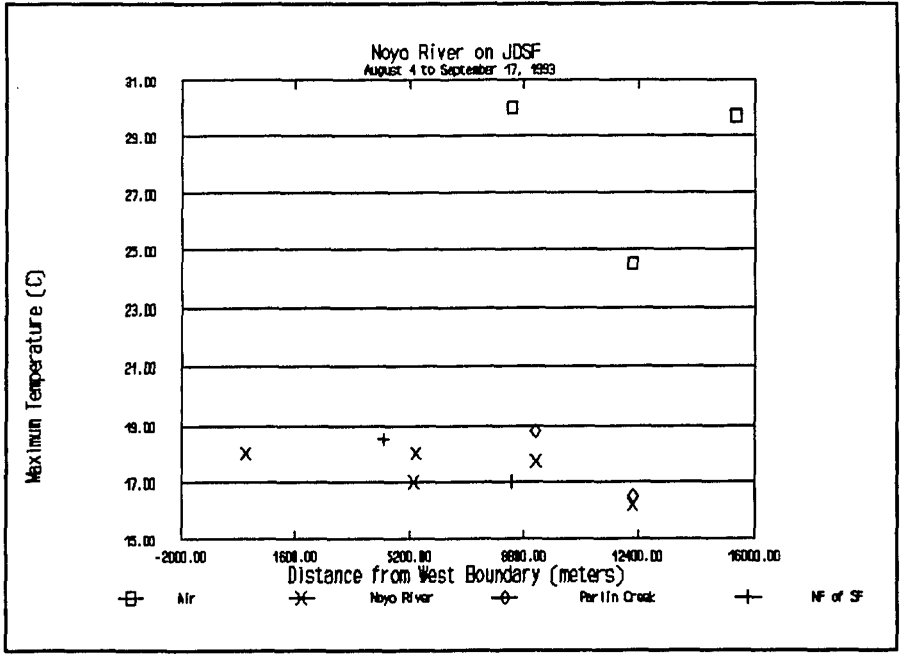

Fig. 3. Water temperatures in the Noyo River on JDSF, 4 August to 17 September, 1994.

The information shows the influence of the coastal location of the study area on air temperature. The cooler air temperature near the coast is representative of the maximum warming potential and is probably unrelated to fog. The maximum recording thermometers registered the greatest temperature achieved during the reporting period. Even though early burn-off of fog can limit the maximum air temperature, there were undoubtedly days during the period which were substantially clear. To the extent that the 1993 summer temperatures are representative of those in other years, the extent of warming of water at the downstream limits of the study is probably limited by the cool air temperature; i.e., heat gained by the water is likely to be reradiated or conducted to the air. However, air temperatures at more inland locations can impart substantial heat loads to the water.

The data shows that water warms downstream in an asymptotic pattern. This is as expected, where in gaining stream reaches cool groundwater emerges and flows downstream. Temperature gain is positively related to the difference between its temperature and that of the air surrounding it. An asymptote is achieved when the average water temperature matches the local air temperature, a factor primarily of local climate and secondarily of shading. Removal of canopy will greatly influence the rate at which the asymptotic temperature is approached. Shade may less affect the asymptotic temperature itself, especially in larger streams. In a watercourse where asymptotic temperature has been reached, shade's role is primarily in reducing the amplitude of temperature fluctuations; i.e., between shaded and unshaded streams, the mean temperatures would be similar but the maximum and minimum temperatures would be less in the shaded than the unshaded stream.

None of the water temperatures recorded in this study are cause for real concern. Despite the fact that 20° C is the point at which suitability drops markedly to a lethal temperature of 25-26 °C (see Bjornn and Reiser 1991), the temperatures recorded in this report were maximum temperatures only. Minimum temperatures were not recorded, but would provide prolonged periods at or near temperatures (12-14 °C) reported to be optimal (Bjornn and Reiser 1991). In fact, Reeves et al. (1989) did not consider summer water temperature to be limiting unless "minimum summer temperature exceeds 20° C for 2 weeks or more during summer low flow."

Further, temperatures recorded in 1993 are unlikely to be a concern because they were recorded from riffles, a location which integrates water temperature variation in the flow and water column. Temperatures in deeper pools and locations of groundwater inflow would be cooler than the "average" represented by the riffle locations.

This study did not evaluate shade canopy over the stream. Although shade appeared to be adequate, certain locations may be excessively open. I did not attempt to ascertain if the high temperature noted on Parlin Creek near the mouth was the result of canopy opening immediately upstream, or due to some other cause.

References Cited

Bjornn, T.C., and D.W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. Amer. Fish. Soc. Spec. Publ. 19:83-138.

Reeves, G.H., F.H. Everest, and T.E. Nickelson. 1989. Identification of Physical Habitats Limiting the Production of Coho Salmon in Western Oregon and Washington. USDA For. Serv. Gen. Tech. Rpt. PNW-245. 18 pp.

Table 1. Temperature of the Noyo River and tributaries during the summer of 1993. Maximum recording thermometers were deployed on July 4, 1993.

Field ID No.[a]	Water or Air	Distance Upstream (m)[b]	Temperature (°C)		Location
			Aug 04	Sept 17	
1	A	12230	28.5	24.5	Noyo at upstream JDSF boundary
1	W	12230	17.5	16.2	Noyo at upstream JDSF boundary
2	W	9180	19.5	17.7	Noyo upstream of Parlin Creek
3	W	9160	18.5	[c]	Noyo downstream of Parlin Creek
4	W	5400	18.5	18	Noyo upstream of NF of South Fork
5	W	5340	18	17	Noyo down of NF of South Fork
6	A	20	21.5	[d]	Noyo at downstream JDSF boundary
6	W	20	19	18	Noyo at downstream JDSF boundary
11	A	15410	31.7	29.7	Upper Parlin Creek
11	W	15410	17.5	[e]	Upper Parlin Creek
11.5	W	12240	[f]	16.5	Mid-Parlin Creek
12	W	9175	21	18.8	Parlin upstream of Noyo
21	A	8440	30	30	Upper NF of South Fork Noyo River
21	W	8440	17	17	Upper NF of South Fork Noyo River
22	W	4370	18.5	18.5	NF of South Fork upstream of Noyo River

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[a] Field ID Number corresponds to those on the map.

[b] Distance upstream of the JDSF private land boundary upstream of Kass Creek.

[c] Thermometer missing.

[d] Thermometer misread.

[e] Stream became intermittent during period. Thermometer moved downstream to Station 11.5.

[f] Station not established during period.

State of California The Resources Agency

M E M O R A N D U M

To: Marc Jameson, Manager
Jackson Demonstration State Forest

Date : Nov 30, 1998
Ref. : IMD 11 - 30

From: Department of Forestry and Fire Protection
Coast-Cascade Region

Subject: 1997 Water temperature studies on Jackson Demonstration State Forest.

During 1997, I continued studies on water temperature dynamics on Jackson Demonstration State Forest. This memo is intended to provide descriptive information only. I have not yet analyzed in-depth what the 1997 data portrays about water temperature and stream side timber management. This will come in the future.

Station locations remained the same as in prior years, although fewer stations were equipped with gages. This was due to instrument malfunction that resulted when some units were exposed to free water during calibration tests. This resulted in many monitors being non-functional prior to deployment, and others experiencing failure during the evaluation period.

I launched each unit to record the maximal value it experienced during a 1 hour and 36 minute period, resulting in 15 readings per day. Units recorded data from June 15 to October 3.

When downloaded, graphical data was inspected. Obvious errors (e.g., recordings prior to deployment or subsequent to retrieval) were deleted. In addition, one station (2501, South Fork Noyo in-stream unit at the upstream boundary) was "vandalized;" i.e., twice found moved from the location of deployment to a partially exposed position and out of the water. Another unit (23 Gulch) was similarly "vandalized;" i.e., found on the bank. Another unit was apparently stolen as it was not found upon instrument collection, although its anchoring rocks were. Where there appeared to be problem data during a run, I deleted from analysis but it is graphed. For two other stations (SF Noyo downstream of Bear Gulch, Parlin Creek above confluence with the South Fork Noyo) where the unit was found partially exposed but there was no obvious change in the temperature trace to indicate when exposure occurred or that it had an affect, I considered the data representative and continued on with the evaluation.

As in prior years' reports, I computed several parameters for each station with an adequate temperature record (Table 1). These include the instantaneous peak temperature and the date upon which it was achieved, the maximal value of a running average equal to a 7-day period (7 x 15 = 105 sequential readings) and the date upon which the maximum was calculated, and an identical value except calculated over a 28-day (28 x 15 = 420 readings) duration. I calculated a new value since the prior reports -- the maximum 7-day variance value -- the standard deviation of the data over a rolling 7-day (105 sequential readings) equivalent period.

Maximum instantaneous temperatures ranged from 21.39 °C (NF Big River upstream of the James Creek confluence) to 14.49 °C (Jughandle Creek). Among all the stations, the dates that peak instantaneous temperatures were recorded ranged from 25 June to 7 September.

Maximum values of 7-day average temperatures ranged from 18.69 °C (NF Big River upstream of the James Creek confluence) to 14.09 °C (Lower Russian Gulch Creek). Among all the stations, the dates when maximal values first were reached (if reached more than once) ranged from 23 July to 1 September.

Maximum values of the 28-day average temperature ranged from 18.24 °C (NF Big River upstream of the James Creek confluence) to 13.61 °C (Lower Russian Gulch Creek). Among all the stations, the dates when the 28-day maximal values first were reached (if reached more than once) ranged from 27 July to 3 September.

Maximum values of temperature variation ranged from 2.08 °C (NF Big River upstream of the James Creek confluence) to 0.53 °C (Lower Russian Gulch Creek). Among all the stations, the dates of the maximal temperature variations ranged from 20 June to 5 October.

Graphs for all stations are appended.

ROSS JOHNSON
Acting Deputy Director
for Resource Management

Brad E Valentine

By: Bradley E. Valentine
Senior Biologist

Attachments: As stated

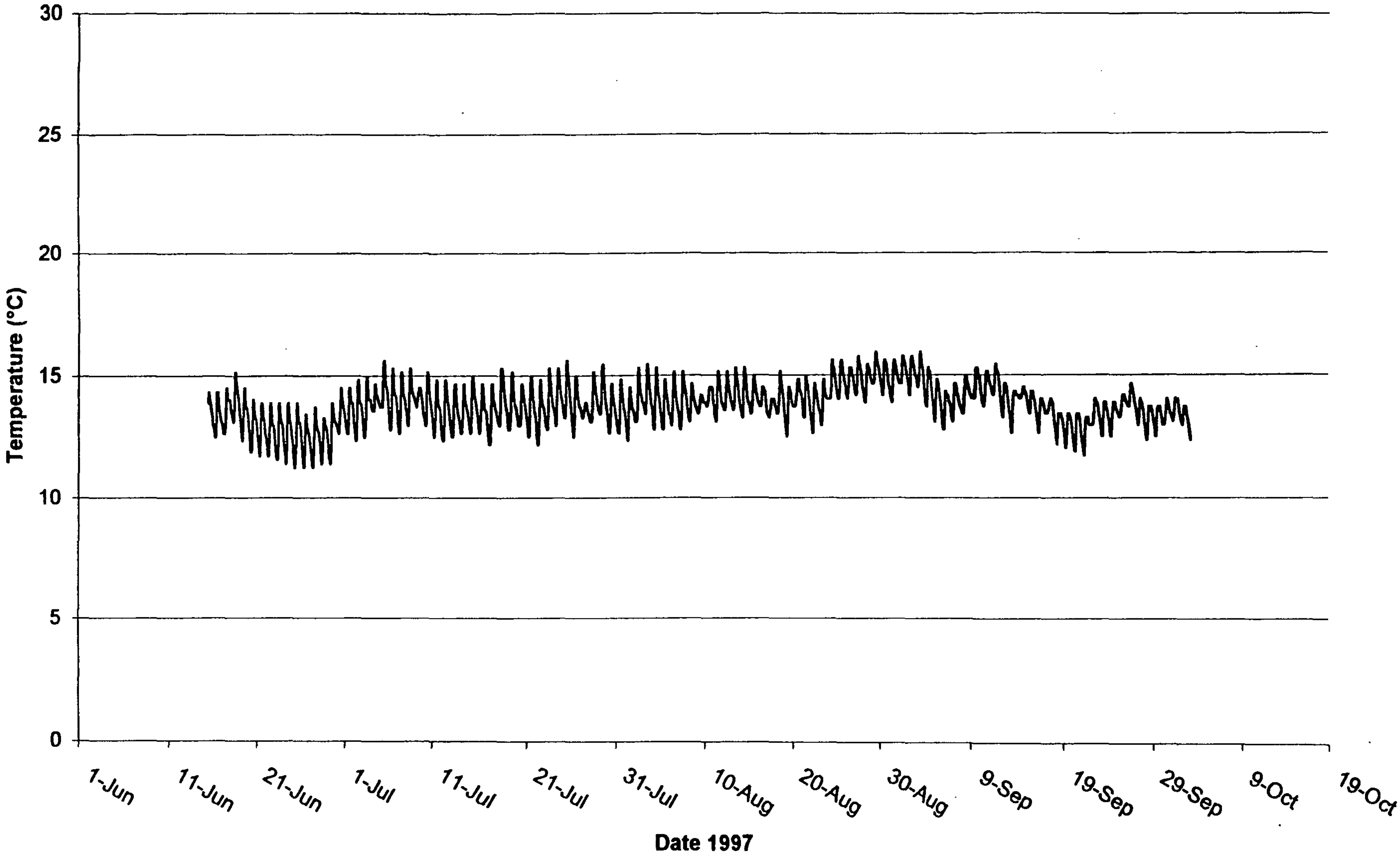
cc: Region River Files
P. Cafferata (CDF-Sacramento)

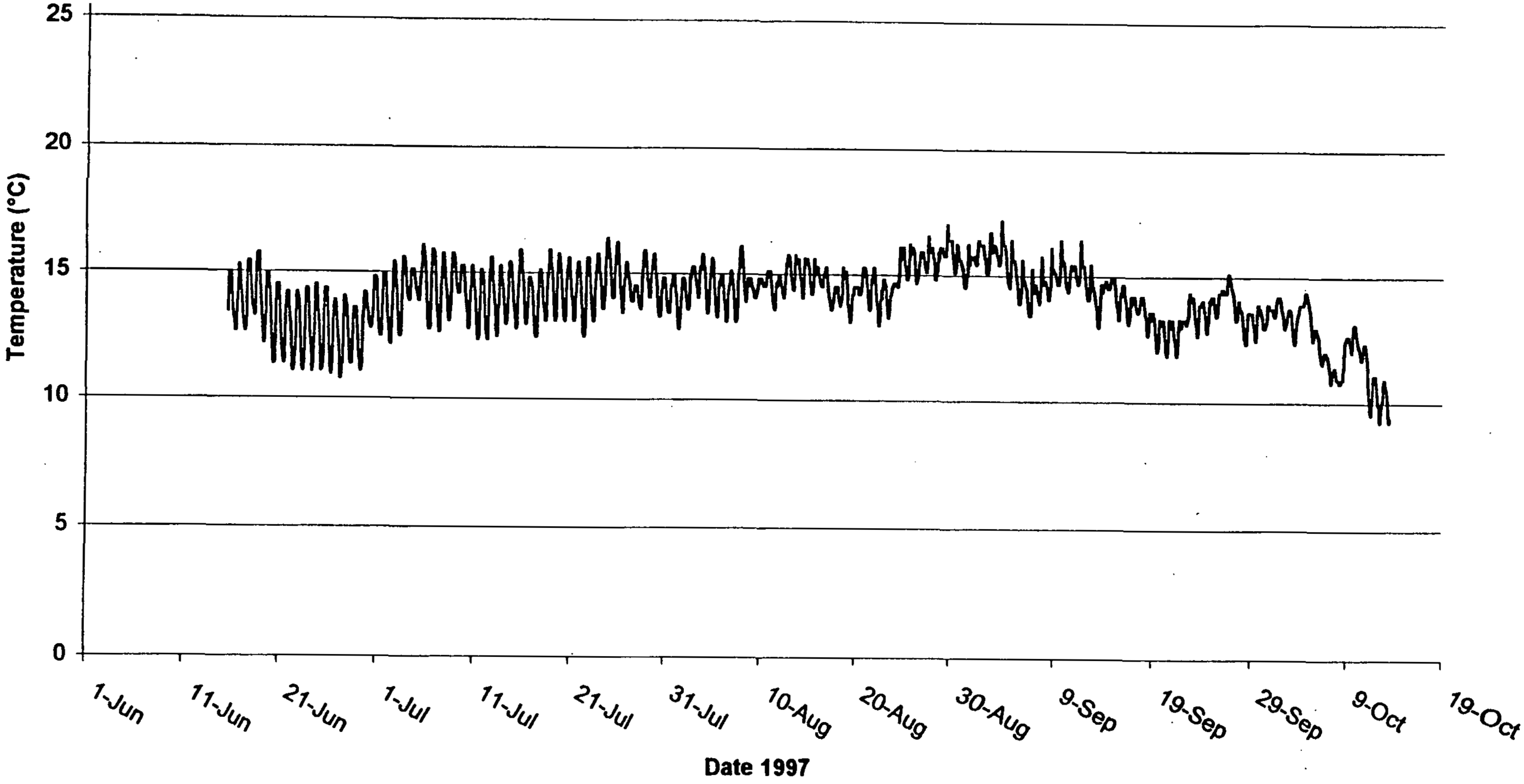
3206	**31.1**	**7-Aug**	**18.82**	**5-Aug**	**17.97**	**1-Aug**	**6.38**	**4-Aug**	**AIR**
3211	16.86	3-Sep	15.75	1-Sep	15.05	29-Aug	0.95	4-Sep	
3221	15.75	7-Aug	14.24	8-Aug	13.99	18-Aug	0.81	4-Aug	
3224	20.24	25-Jul	17.3	7-Aug	17.02	2-Aug	1.75	21-Jun	
3231	16.38	7-Sep	15.02	10-Aug	14.72	2-Aug	1.14	20-Jun	
3301	15.43	25-Jul	14.61	1-Sep	14.33	21-Aug	0.7	2-Jul	
3302	16.86	25-Jul	15.82	1-Sep	16.4	2-Aug	1.07	2-Jul	
3331	16.7	3-Sep	15.88	1-Sep	15.2	1-Sep	0.97	30-Sep	
3401	16.38	3-Sep	15.49	1-Sep	15	1-Sep	0.87	1-Sep	
3411	16.86	3-Sep	15.75	1-Sep	15.05	29-Aug	0.95	4-Sep	
3490	14.49	29-Aug	14.13	1-Sep	13.77	3-Sep	0.54	5-Oct	
3502	14.64	3-Sep	14.09	1-Sep	13.61	2-Sep	0.53	17-Sep	
3900	17.18	7-Aug	15.32	9-Aug	14.92	2-Aug	1.06	4-Aug	

Table 2. Location of 1997 temperature gages.

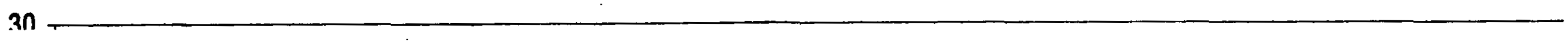
Station ID #	Unit #	Location	Comments
2403	5041	Hare Ck. At downstream end of SFHC97	Floater
24035	5100	Hare below Covington Gulch	
2411	5107	Headwaters Bunker Gulch	
2412	5082	Bunker Gulch	
2501	5112	BUCKET-SF Noyo Upstream limits	Replenished 7/11 14:30,8/15 13:20
2501	5123	SF Noyo Upstream limits	Unit moved mid-channel, 1/3 exposed
25010	5096	BUCKET-SF Noyo downstream boundary	Replenished 8/15 12:20
25010	5110	SF Noyo downstream boundary	
2502	5109	SF Noyo above Rd. 320	Floater; obvious break @about 8/20
2503	5122	SF Noyo between 23 Gulch and Parlin Ck.	
2504	5120	SF Noyo below Parlin Ck.	
2506	5113	SF Noyo below Bear Gulch	Floater; no obvious pattern to change
2531	5156	Parlin Ck. above Frolic	
2532	5039	Parlin Ck. above Camp 7	Not deployed until about 6/26
2534	5099	Parlin Ck. above SF Noyo	Unit 1/3 exposed but well shaded
2541	5075	23 Gulch	Placed on Bank; change after about 7/13
2551	5111	BUCKET-Bear Gulch	Air>bckt 7/1415:50: Tipped & Replenished 8/1512:40
2551	5119	Bear Gulch 20m above culvert	
2561	5108	Peterson Gulch	
2571	5117	NF of SF Noyo, upstream end of road	
2572	5116	NF of SF Noyo, upstream of Brandon Gulch	Not deployed until about 6/26
2573	5118	NF of SF Noyo, at Caretakers	
3202	5086	NF of Big River above James Ck.	
3204	5084	NF Big River above Chamberlin Ck.	
3206	5097	AIR-NF Big River, Downstream limits of JDSF	
3206	5077	NF Big River, Downstream limits of JDSF	
3211	5090	NF James Creek @ Xing	
3221	5083	Chamberlin Ck. @ upper culvert	
3224	5079	Chamberlin Ck. above NF Big River	
3231	5080	WF Chamberlin below 16 Gulch	
3301	5095	Little NF Big River @ Wonder Xing	
3302	5094	Little NF Big River above Berry Gulch	
3331	5091	Railroad Gulch above marsh	
3401	5103	Main Caspar above SF	
3411	5101	SF Caspar Ck. above main Caspar	
3490	5142	Jughandle	
3502	5098	Lower Russian Gulch	
39xx	5104	Montgomery Redwoods State Park	

1997; Hare Ck. below Covington Gulch

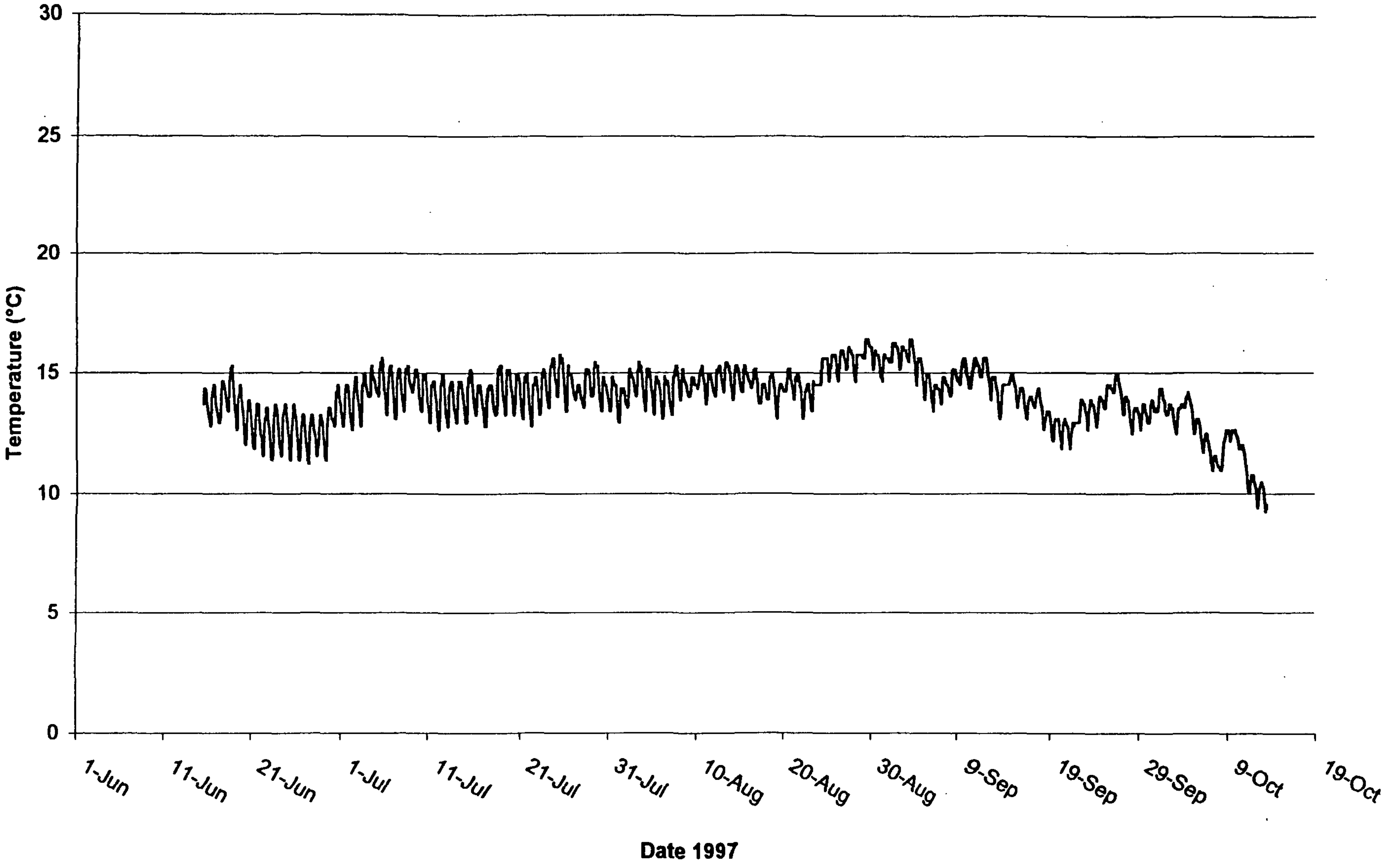


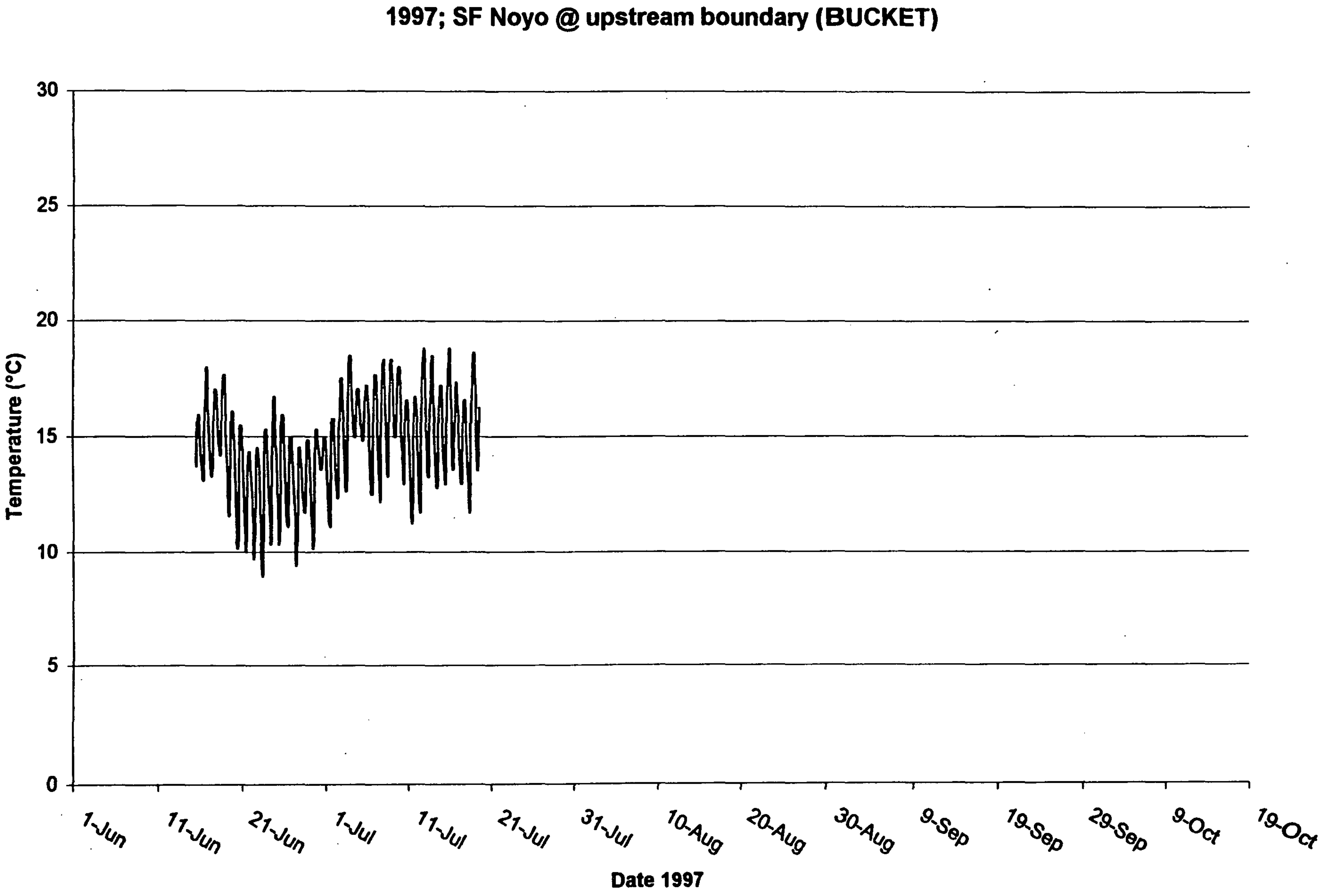


1997; Bunker Gulch headwaters



1997; Hare Ck. Downstream of SFHC97 (floater)




1997; SF Noyo @ upstream boundary (BUCKET)
Temperature (°C)
30
25
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15
10
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1-Jun
11-Jun
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1-Jul
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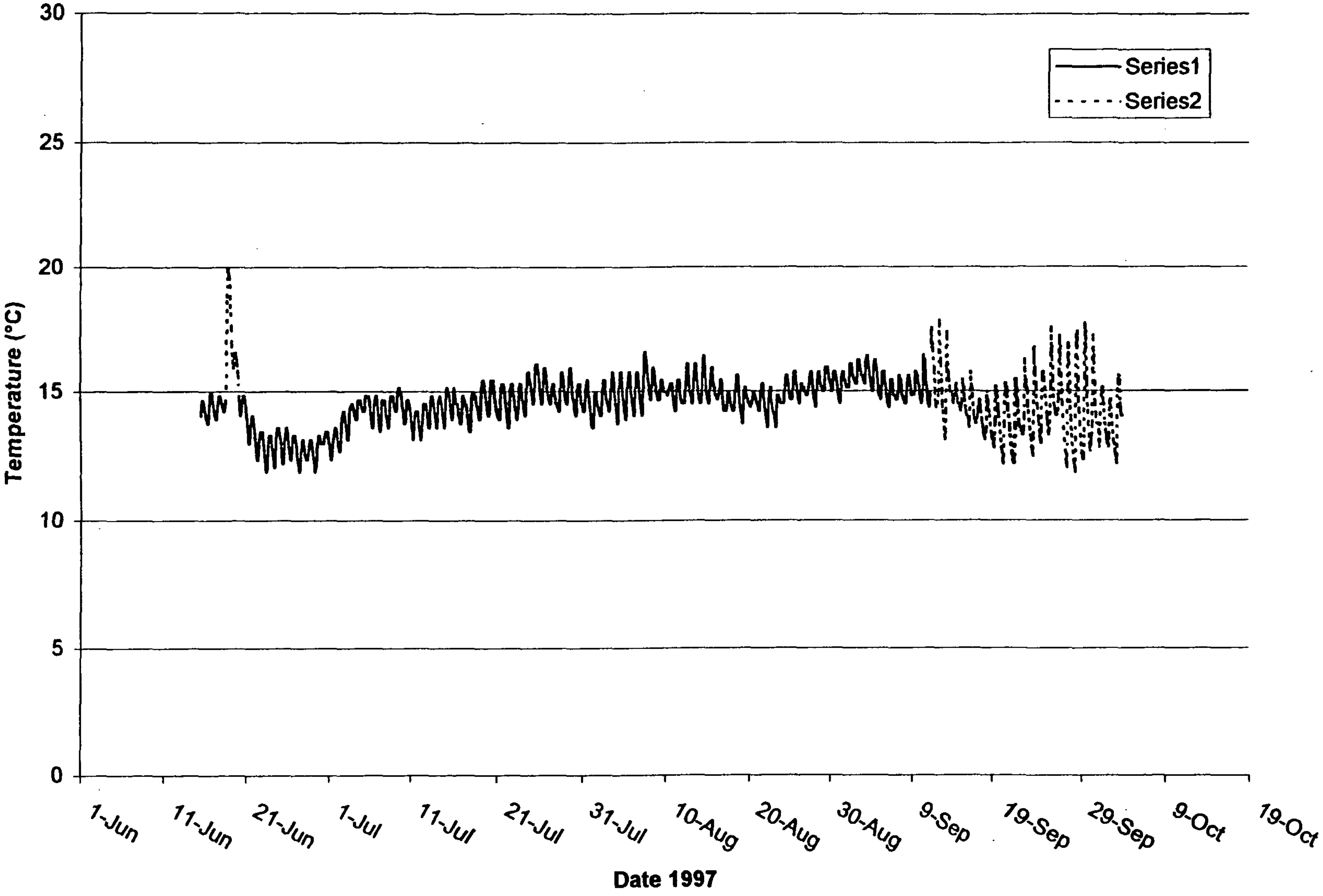
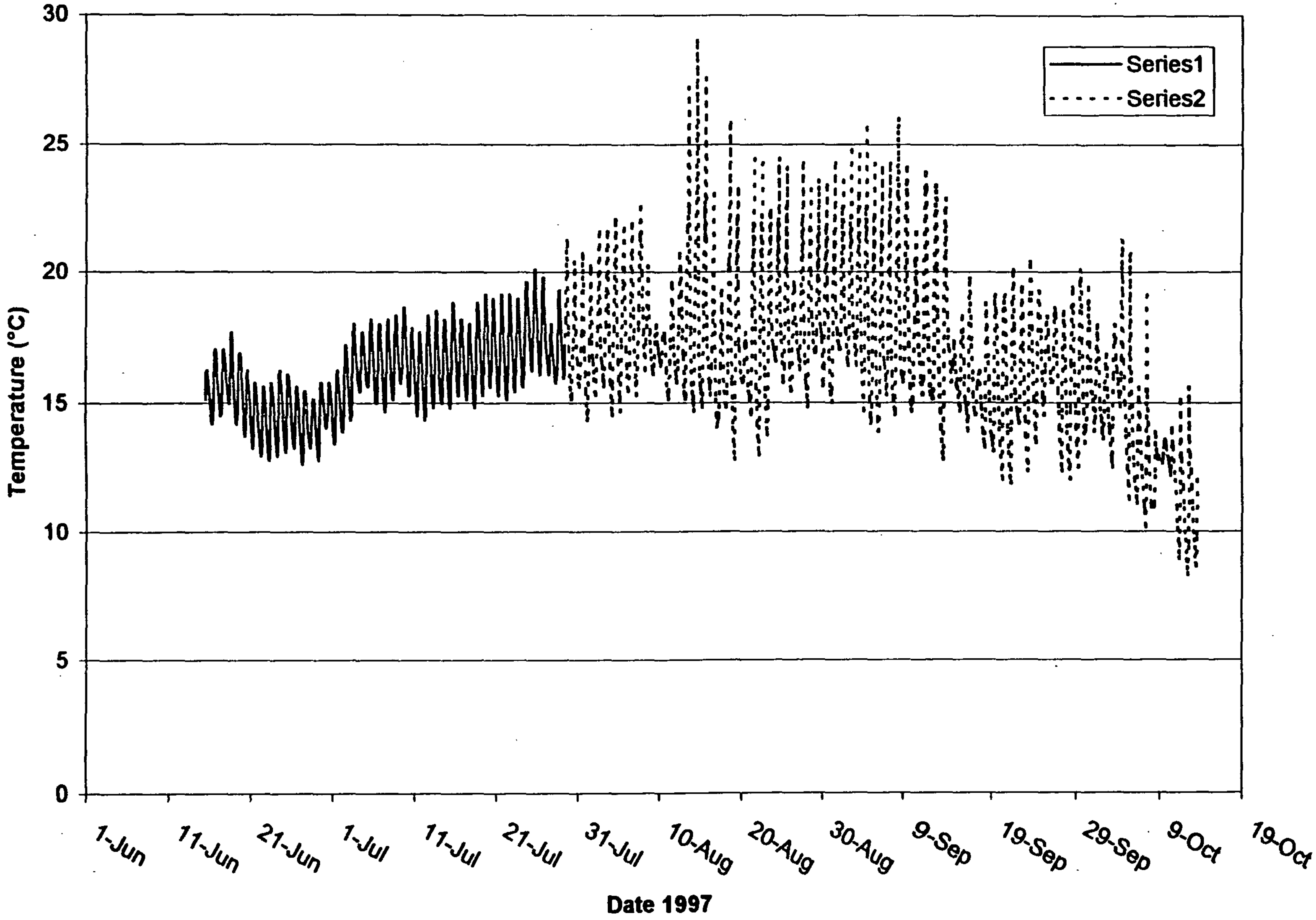
9-Oct
19-Oct
Date 1997

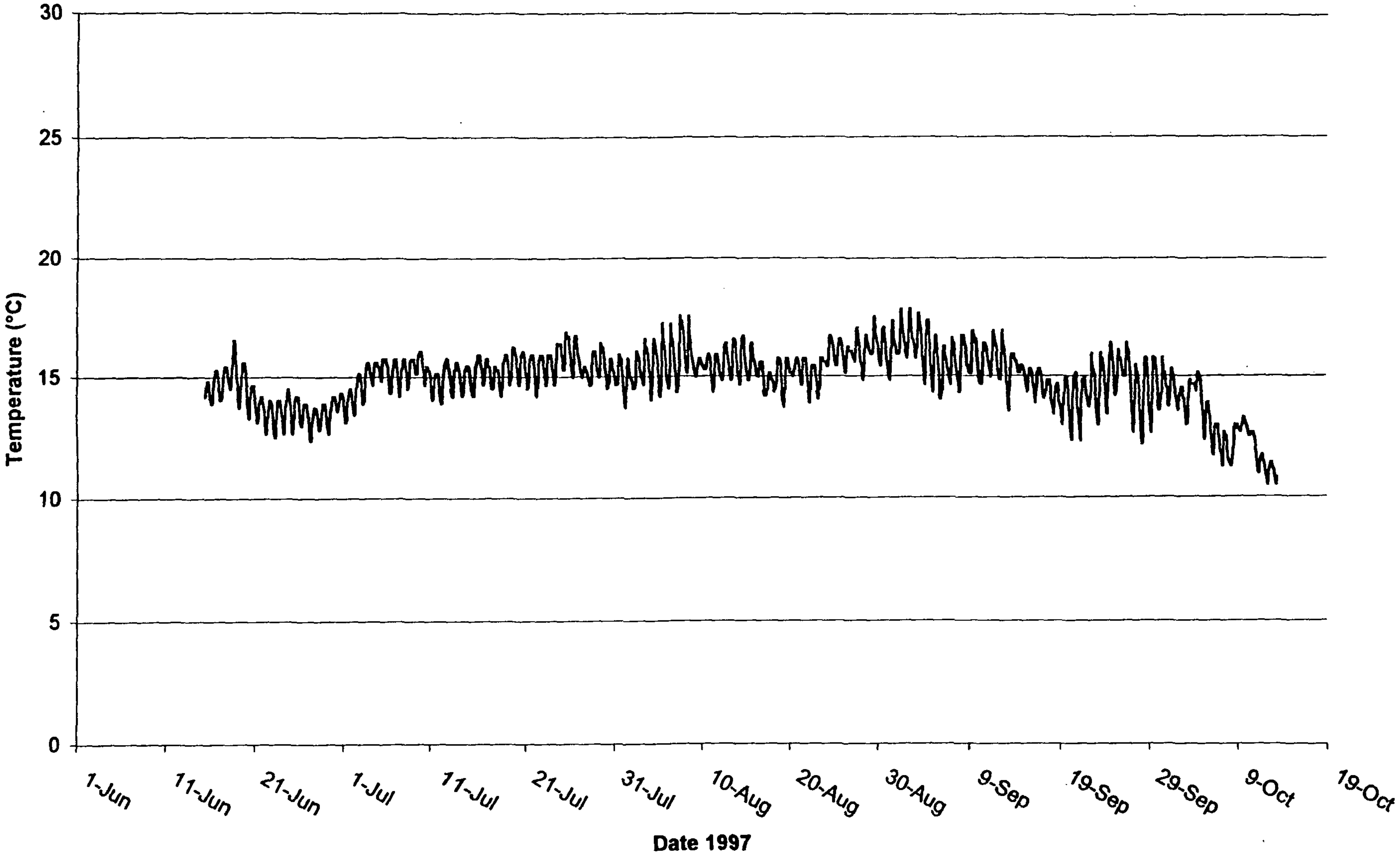


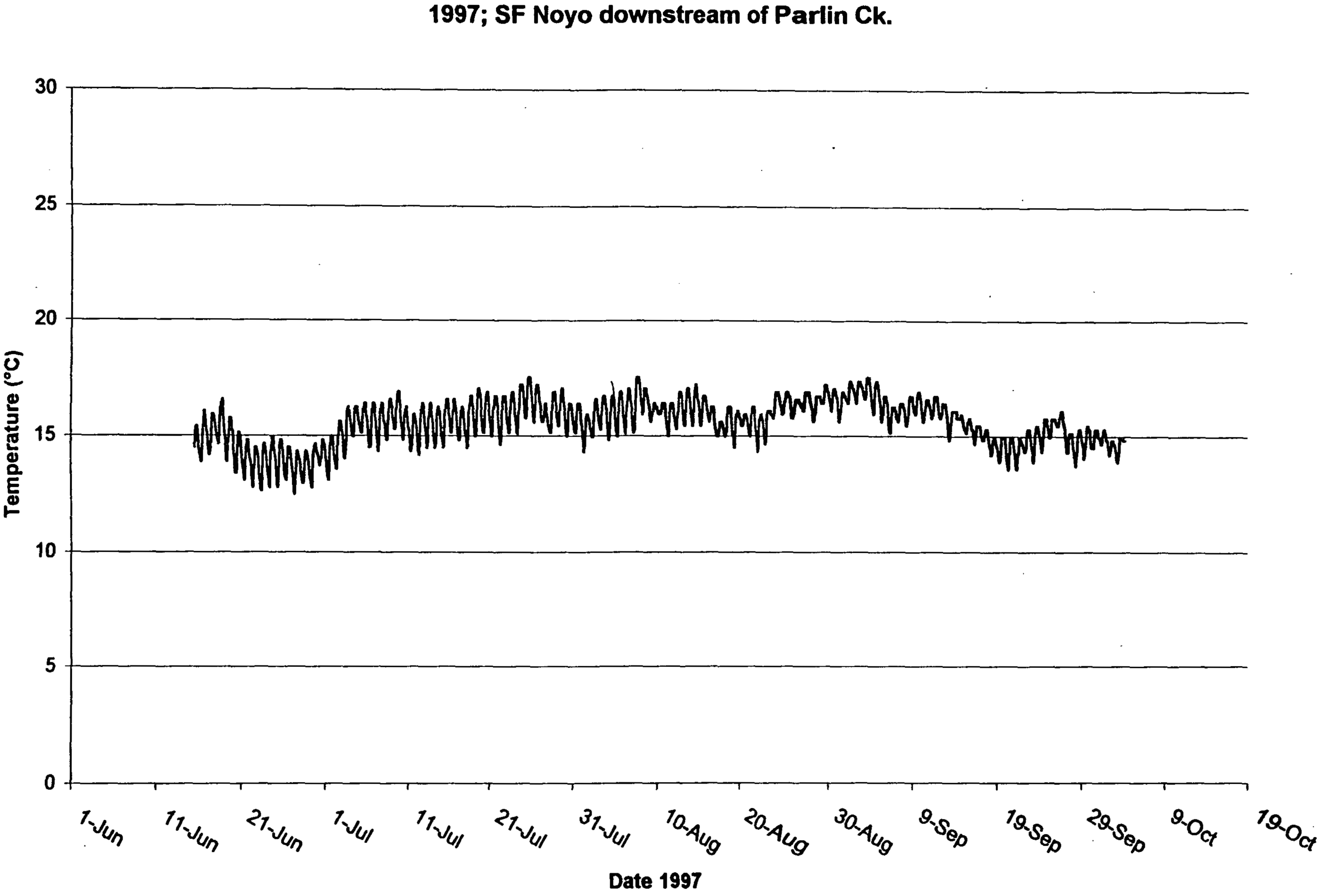
1997; SF Noyo @ upstream boundary *

1997; SF Noyo upstream of Rd. 320 (found floating)



1997; SF Noyo between 23 Gulch & Parlin Ck.



1997; SF Noyo downstream of Parlin Ck.
Temperature (°C)
30
25
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15
10
5
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1-Jun
11-Jun
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1-Jul
11-Jul
21-Jul
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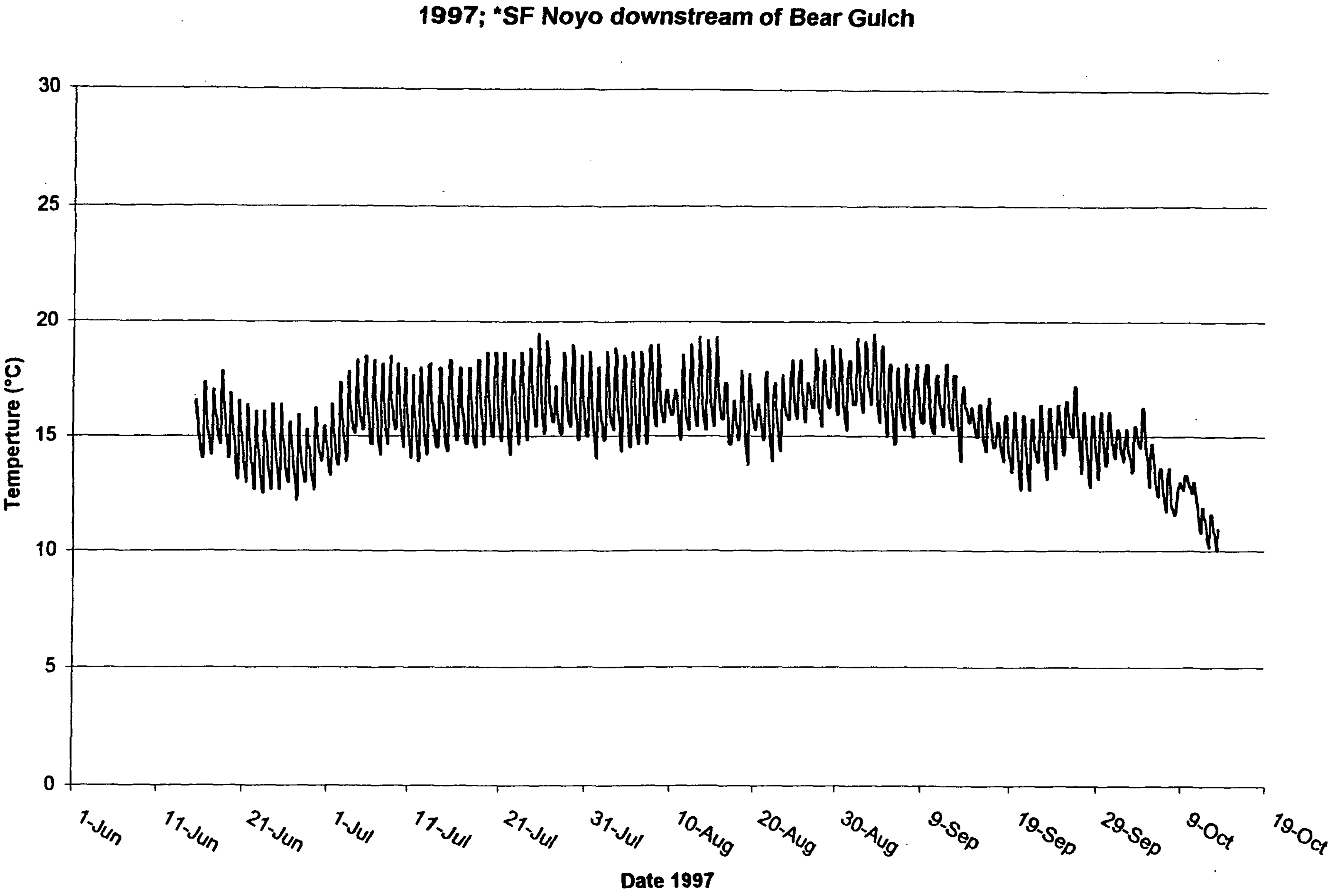
29-Sep
9-Oct
19-Oct
Date 1997


1997; *SF Noyo downstream of Bear Gulch
Temperture (°C)
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1-Jul
11-Jul
21-Jul
31-Jul
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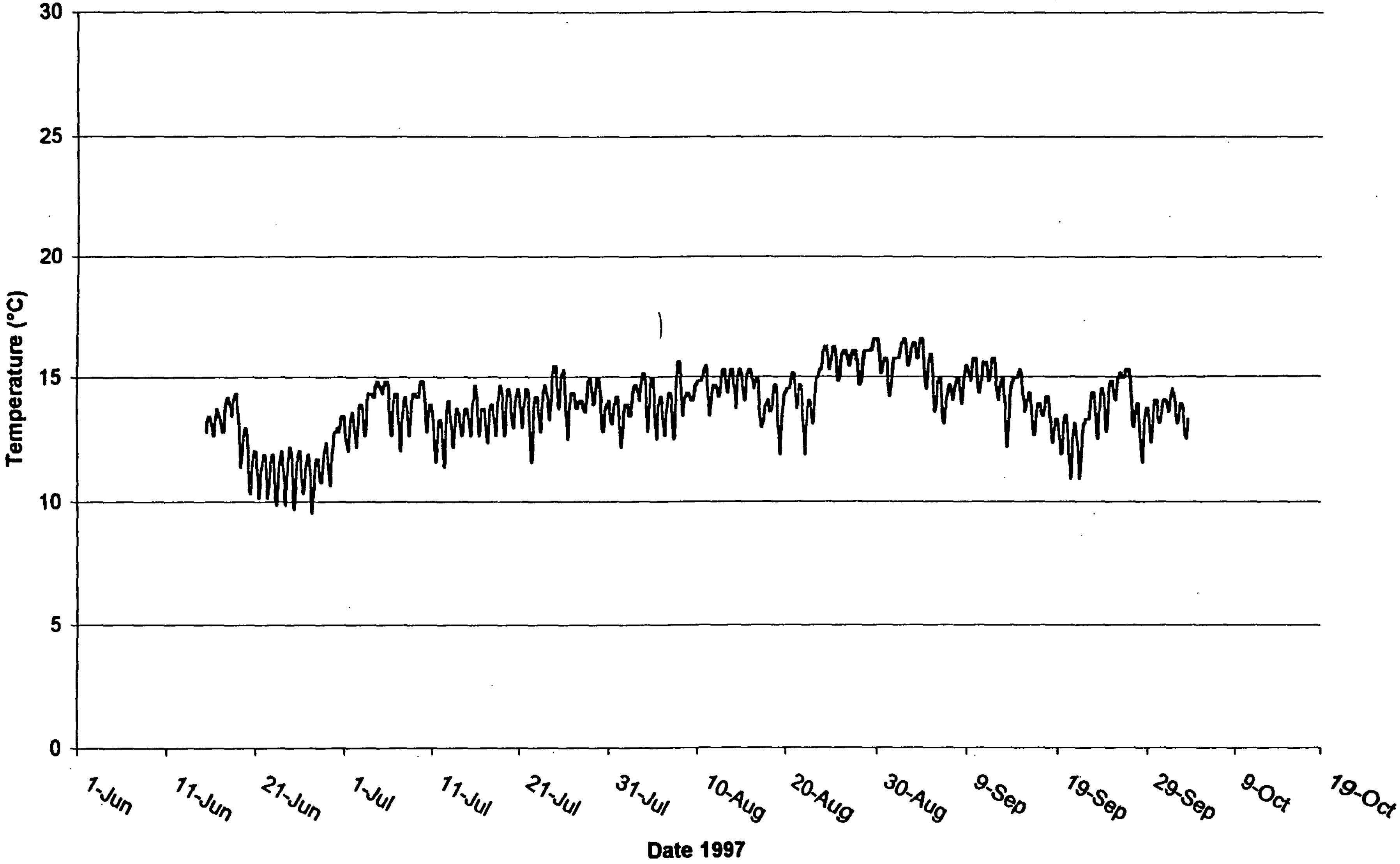
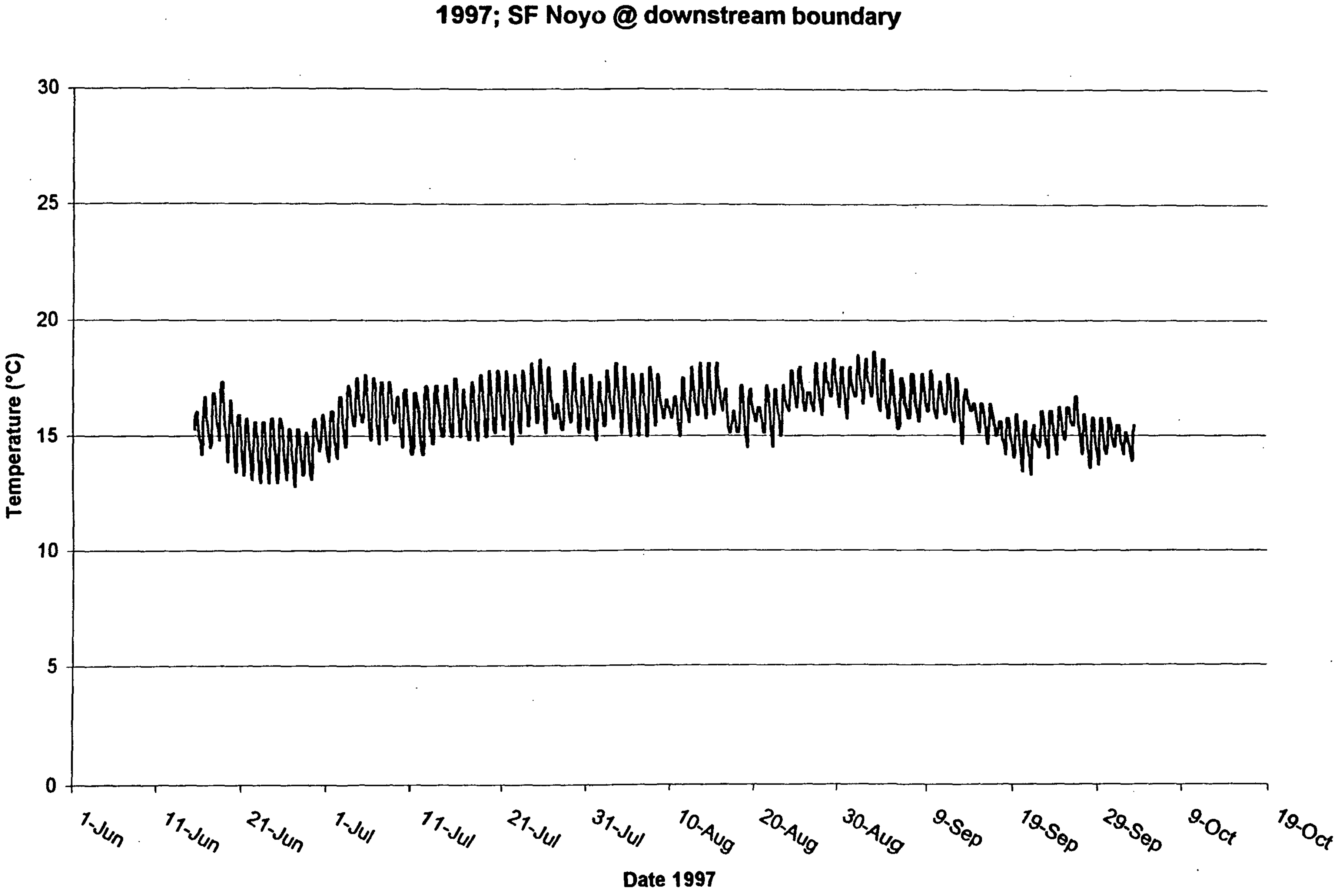
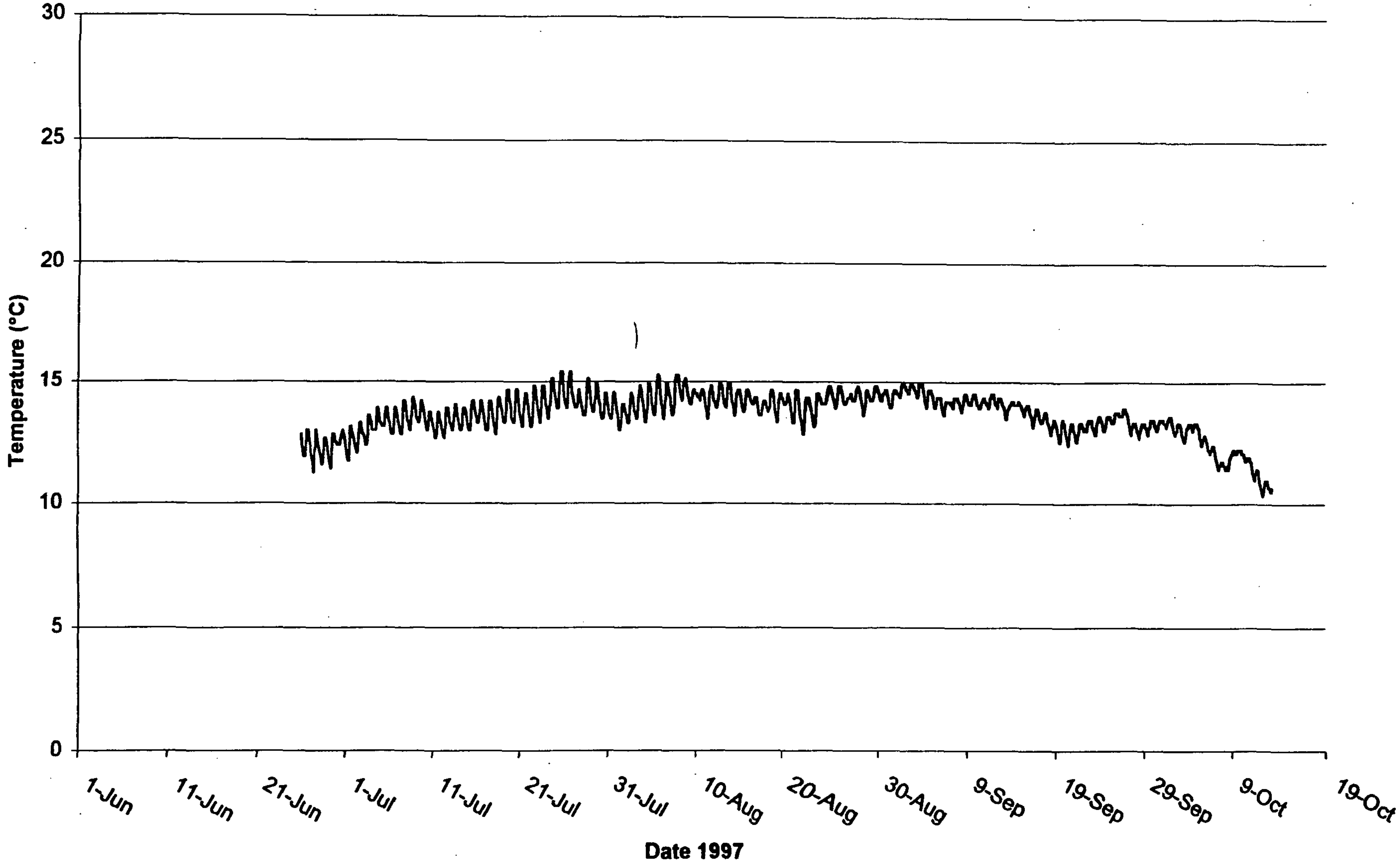
9-Oct
19-Oct
Date 1997

1997; SF Noyo @ downstream boundary (BUCKET)

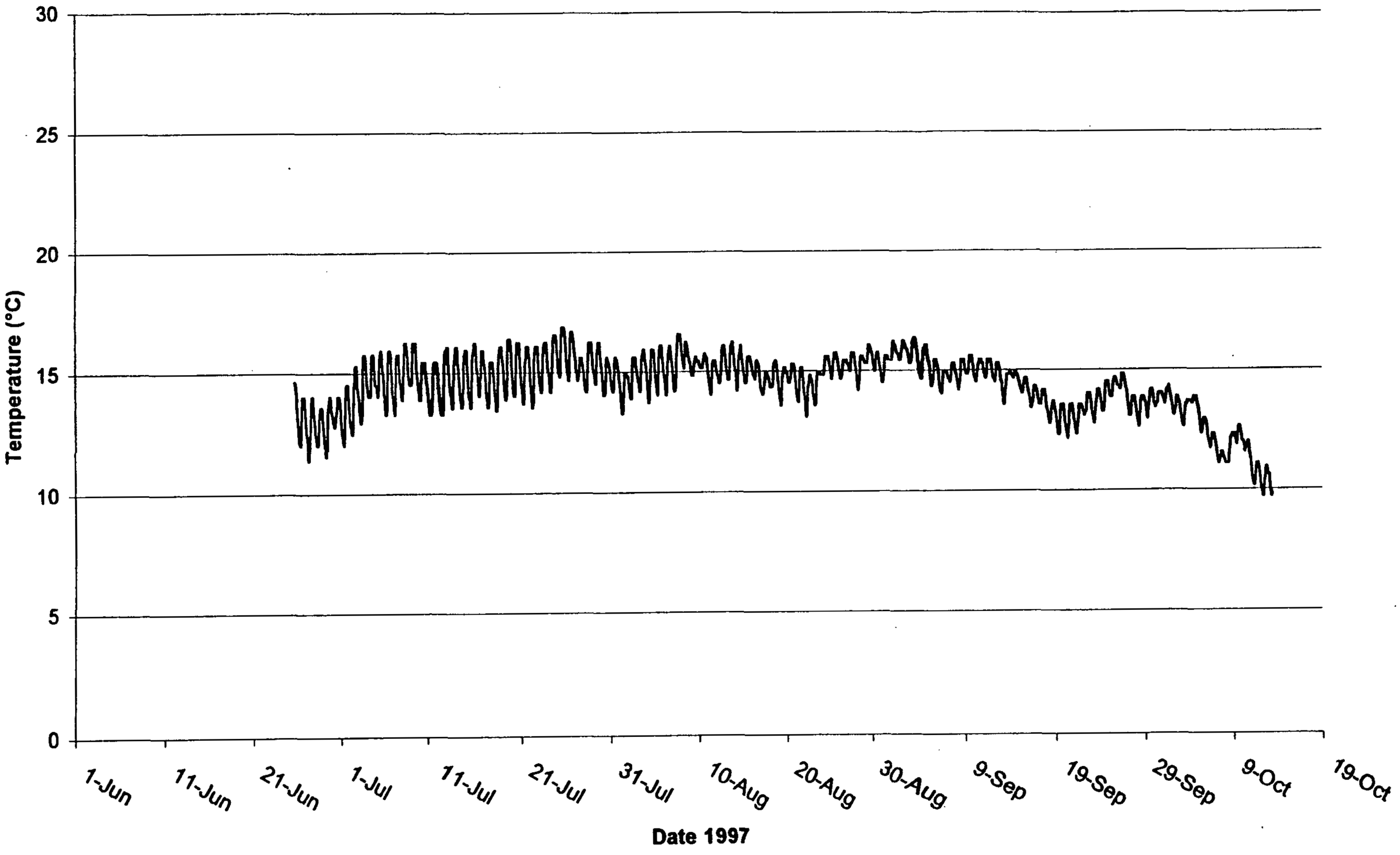



1997; SF Noyo @ downstream boundary
Temperature (°C)
30
25
20
15
10
5
0
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
Date 1997

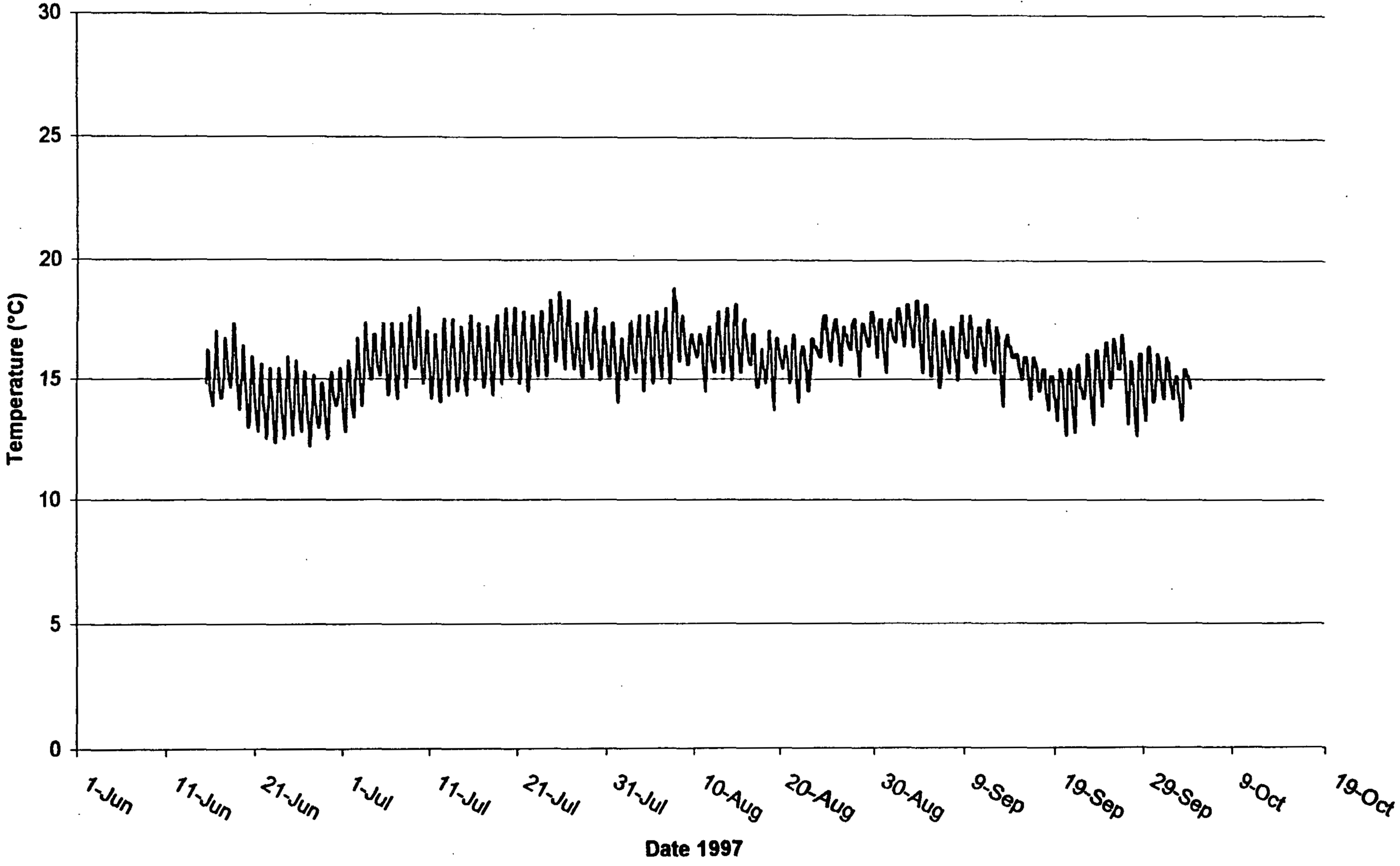
1997; Parlin Ck. upstream of Frolic Sale

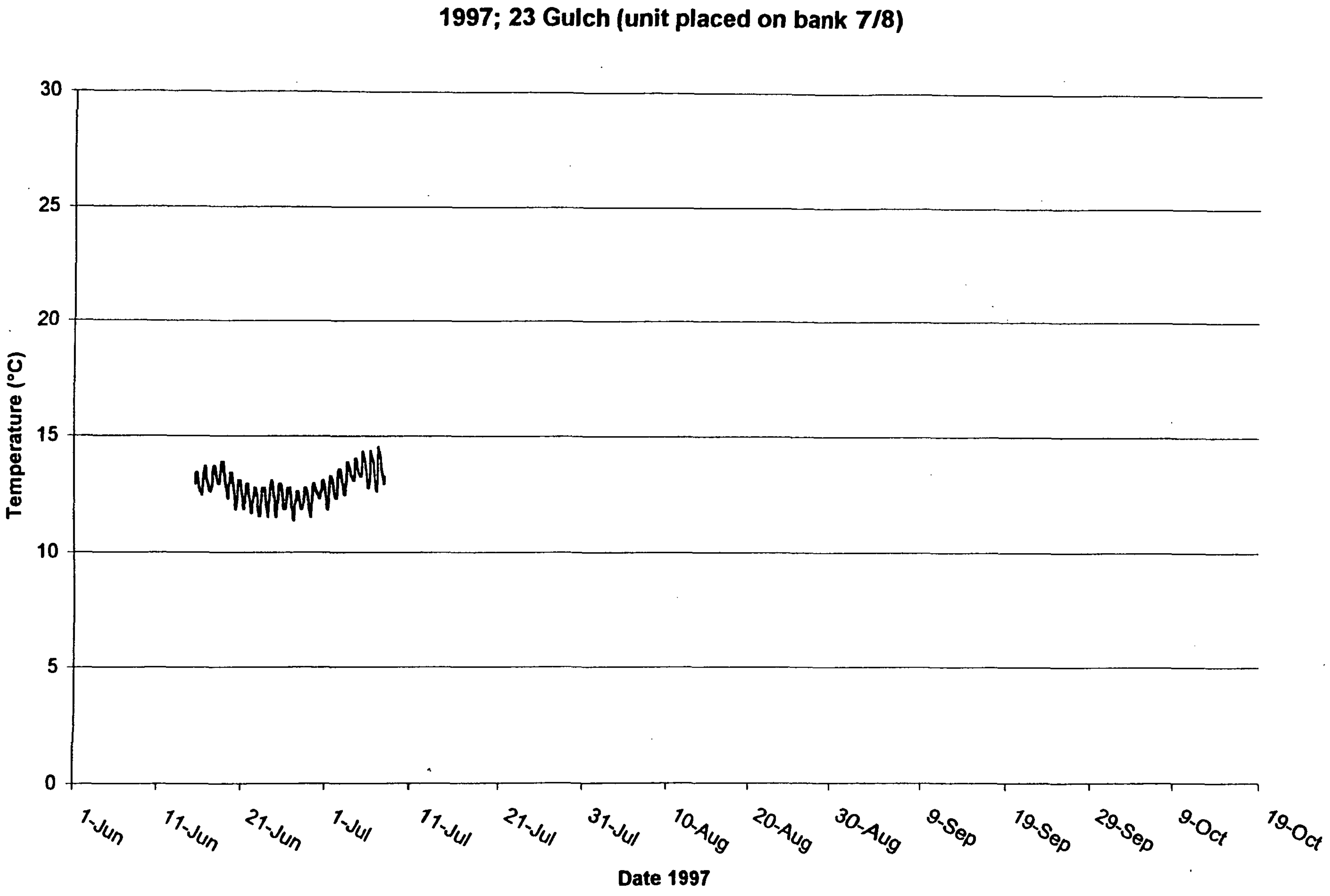


1997; Parlin Ck. upstream of Camp 7

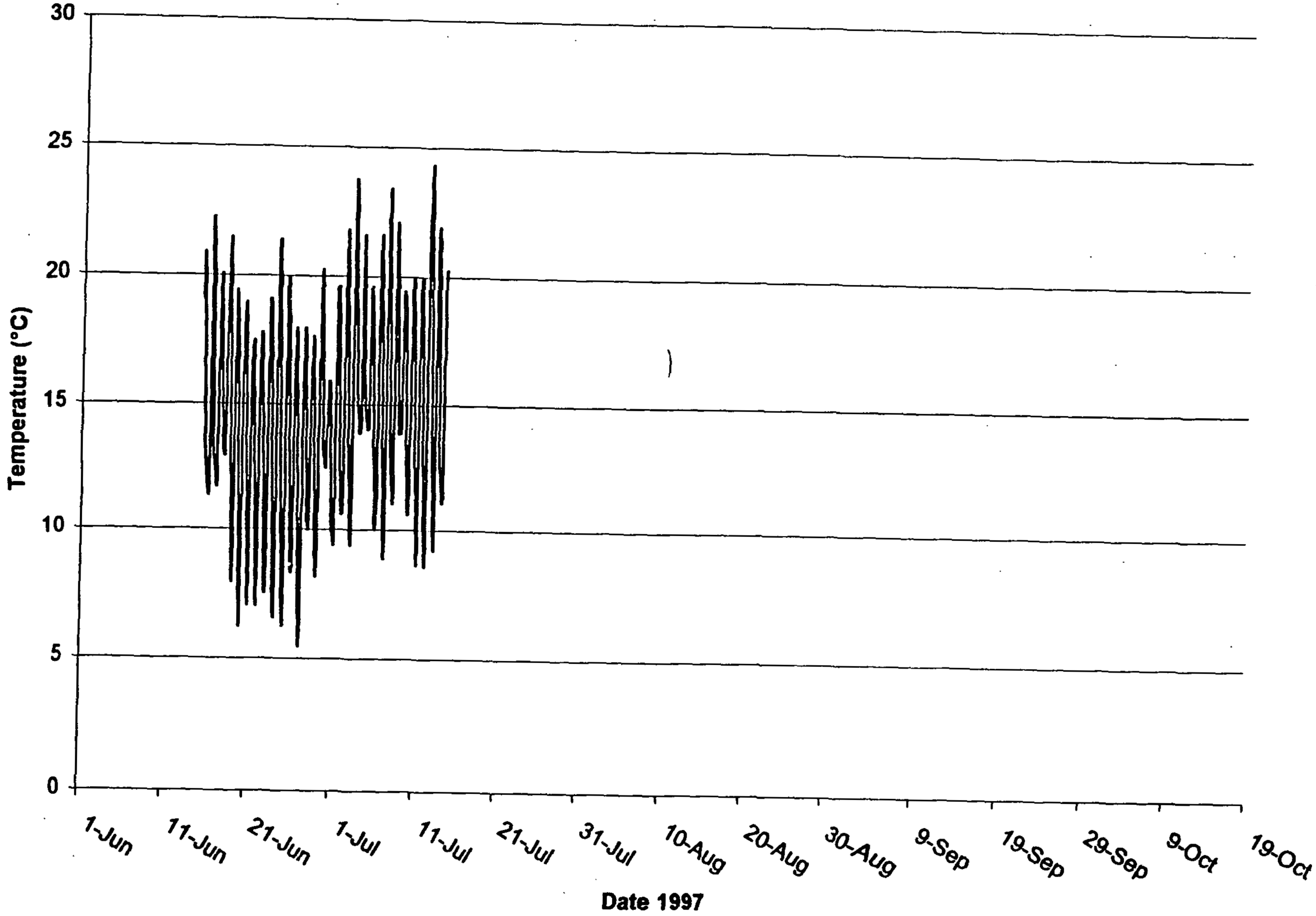


1997; Parlin Ck. upstream of SF Noyo

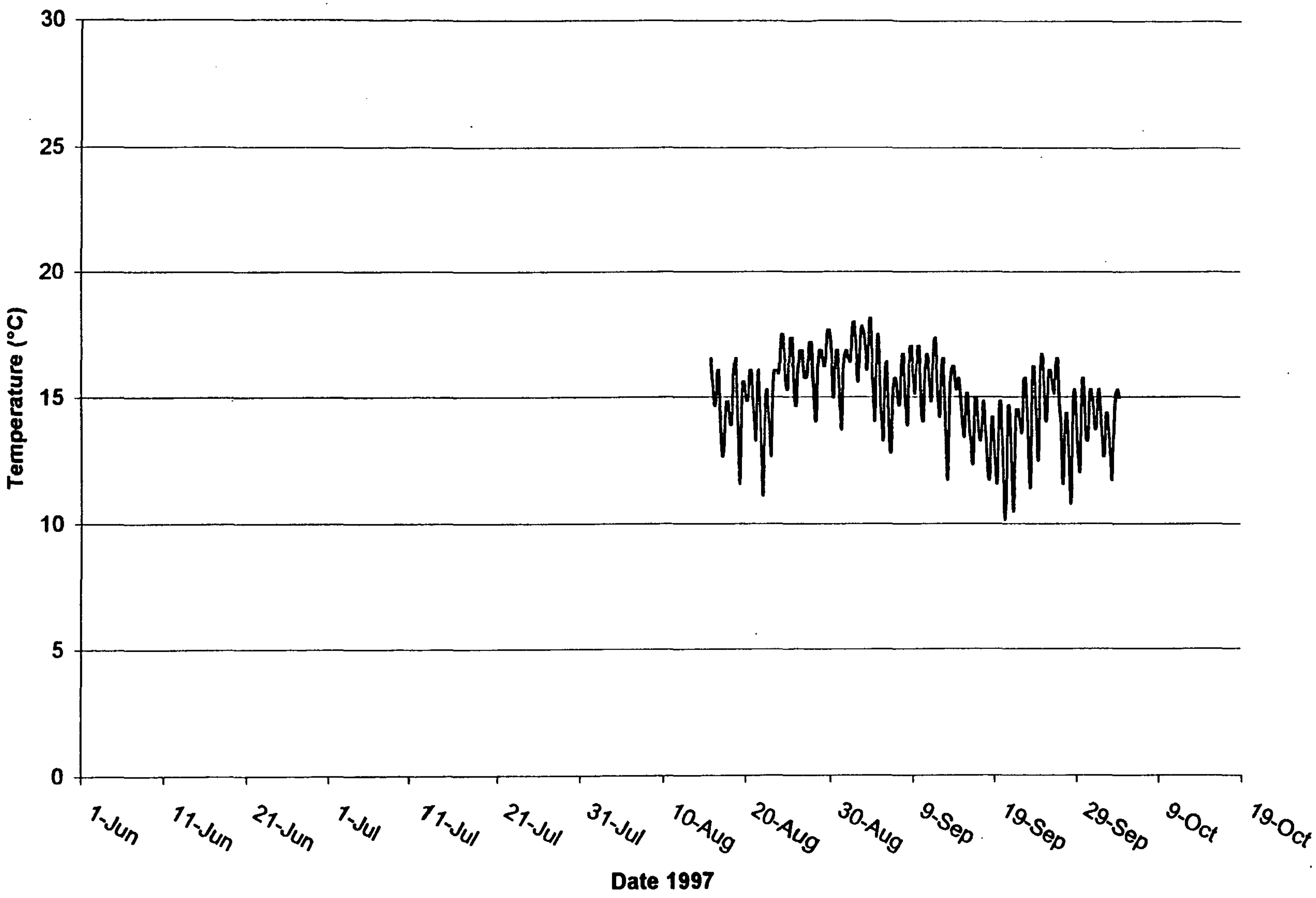


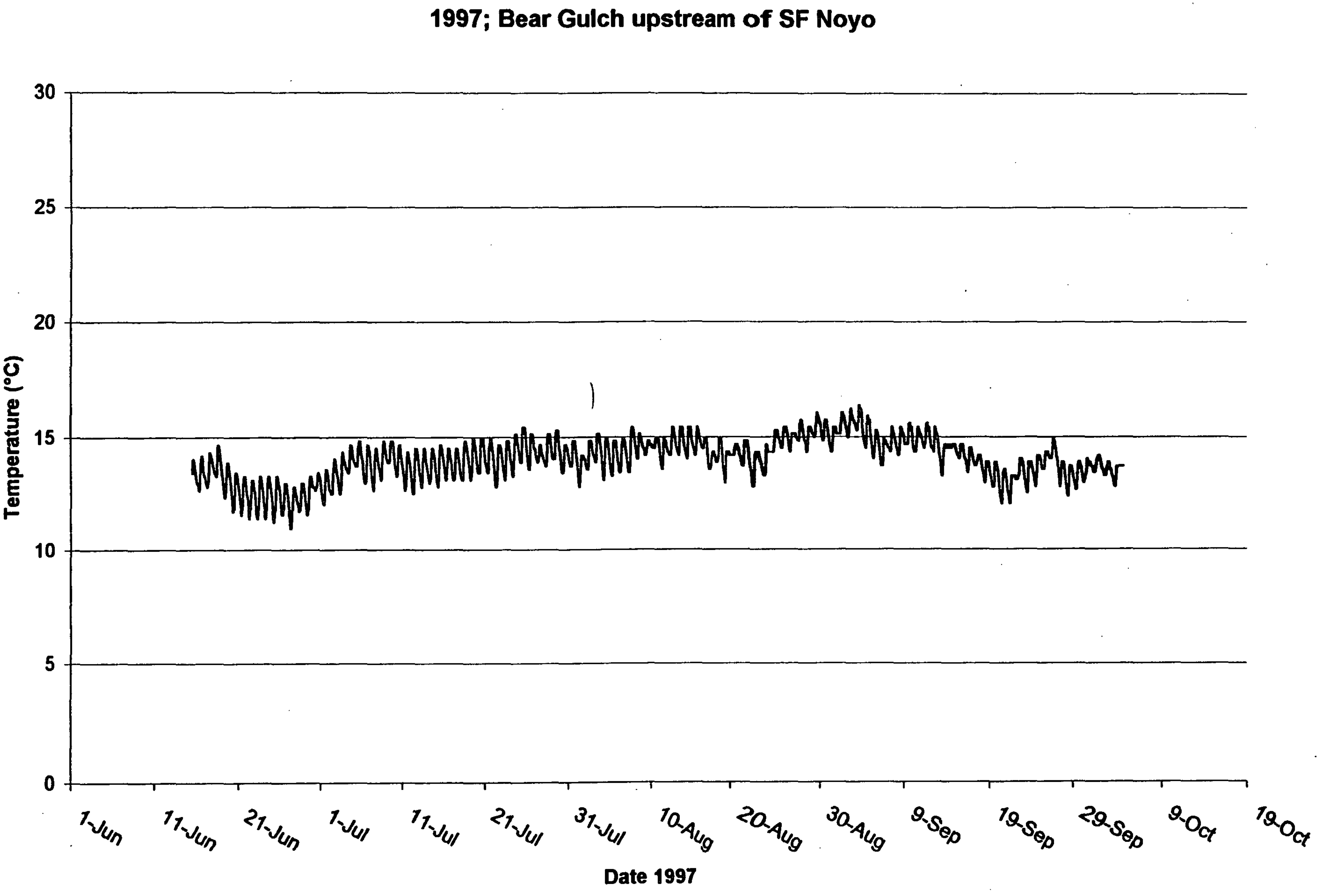
1997; 23 Gulch (unit placed on bank 7/8)
Temperature (°C)
30
25
20
15
10
5
0
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
Date 1997

1997; Bear Gulch (AIR)

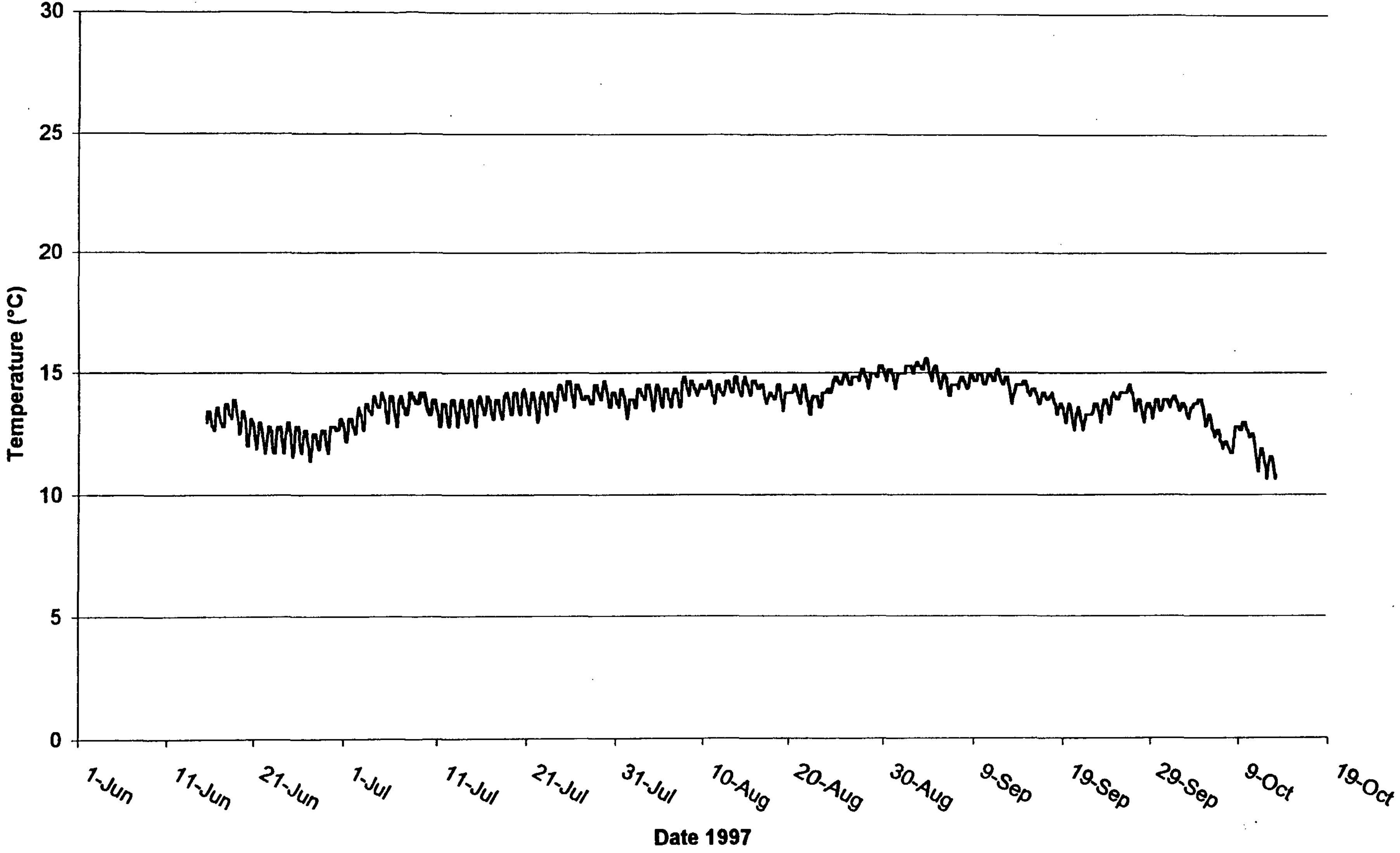


1997; Bear Gulch (BUCKET)

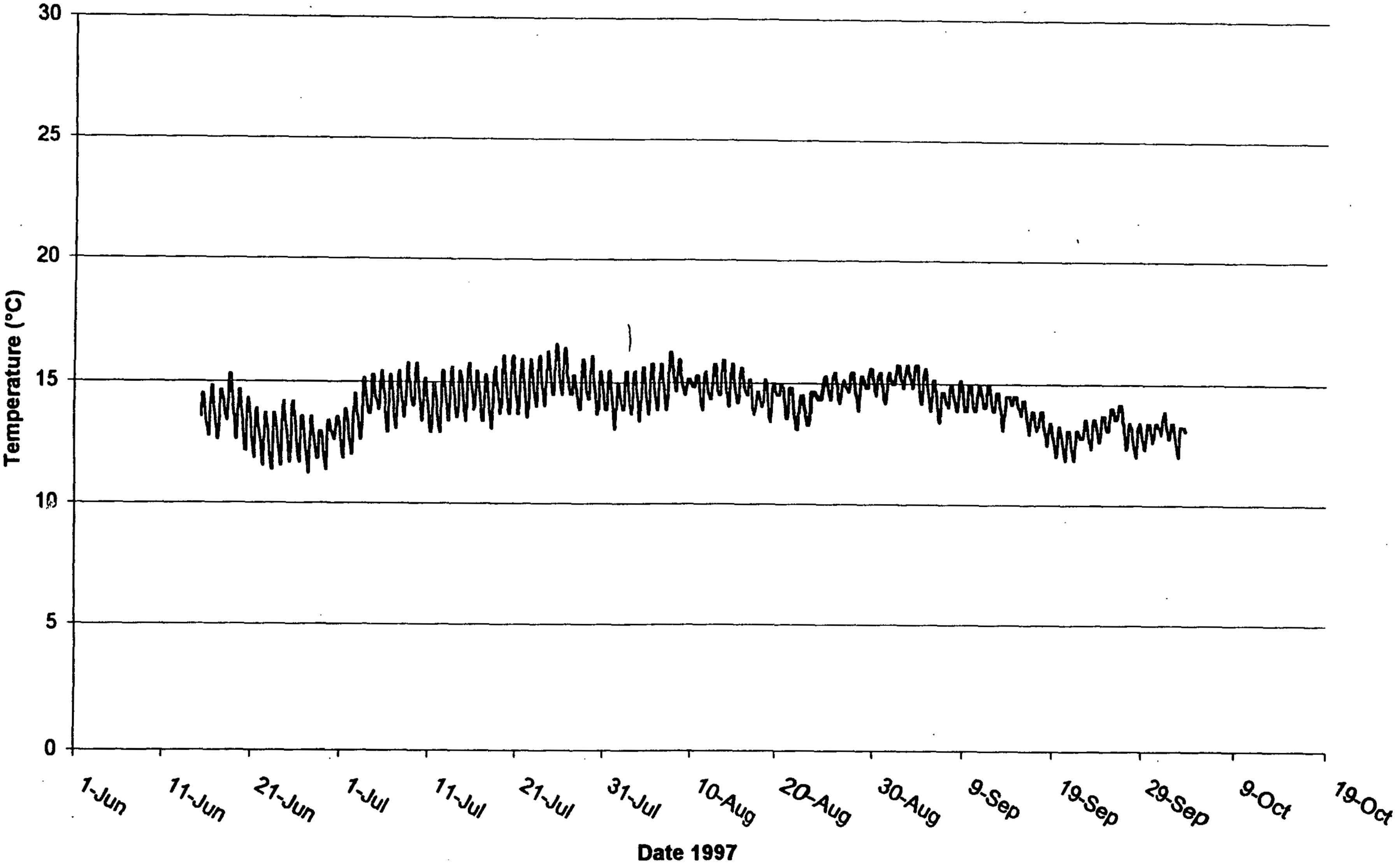



1997; Bear Gulch upstream of SF Noyo
30
25
20
15
10
5
0
Temperature (°C)
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
Date 1997

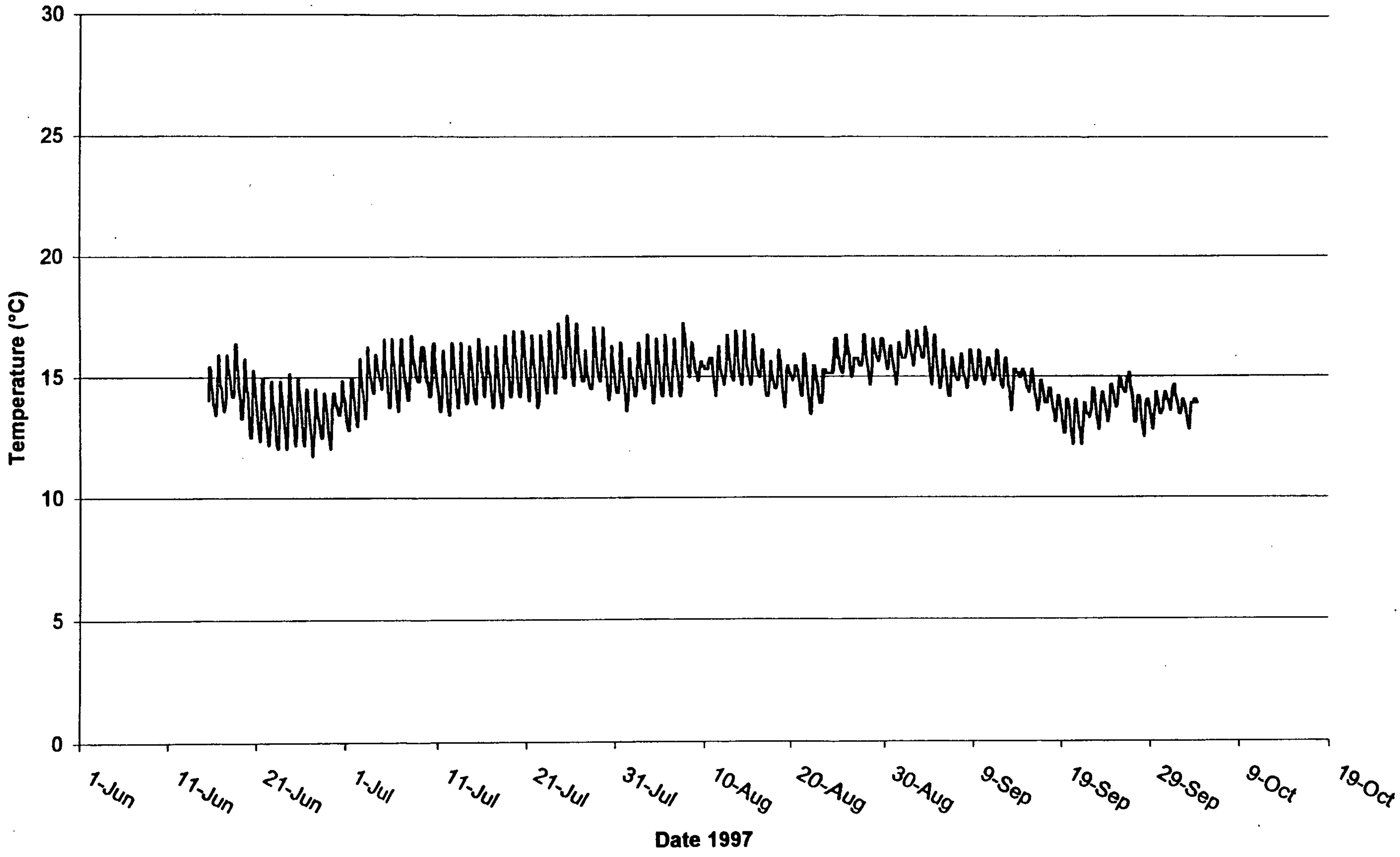
1997; Peterson gulch upstream of SF Noyo



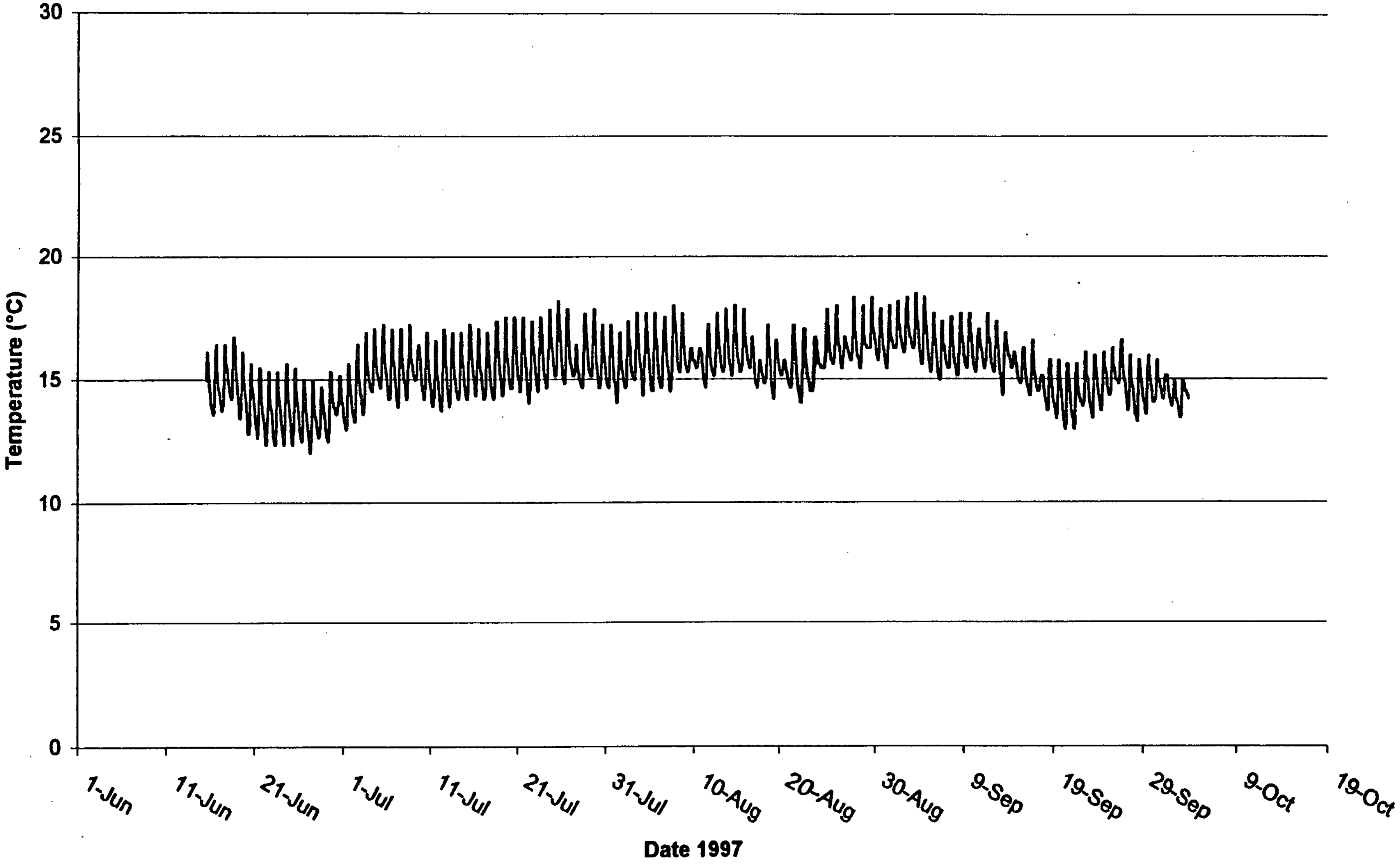
1997; North Fork of SF Noyo, @ end of road

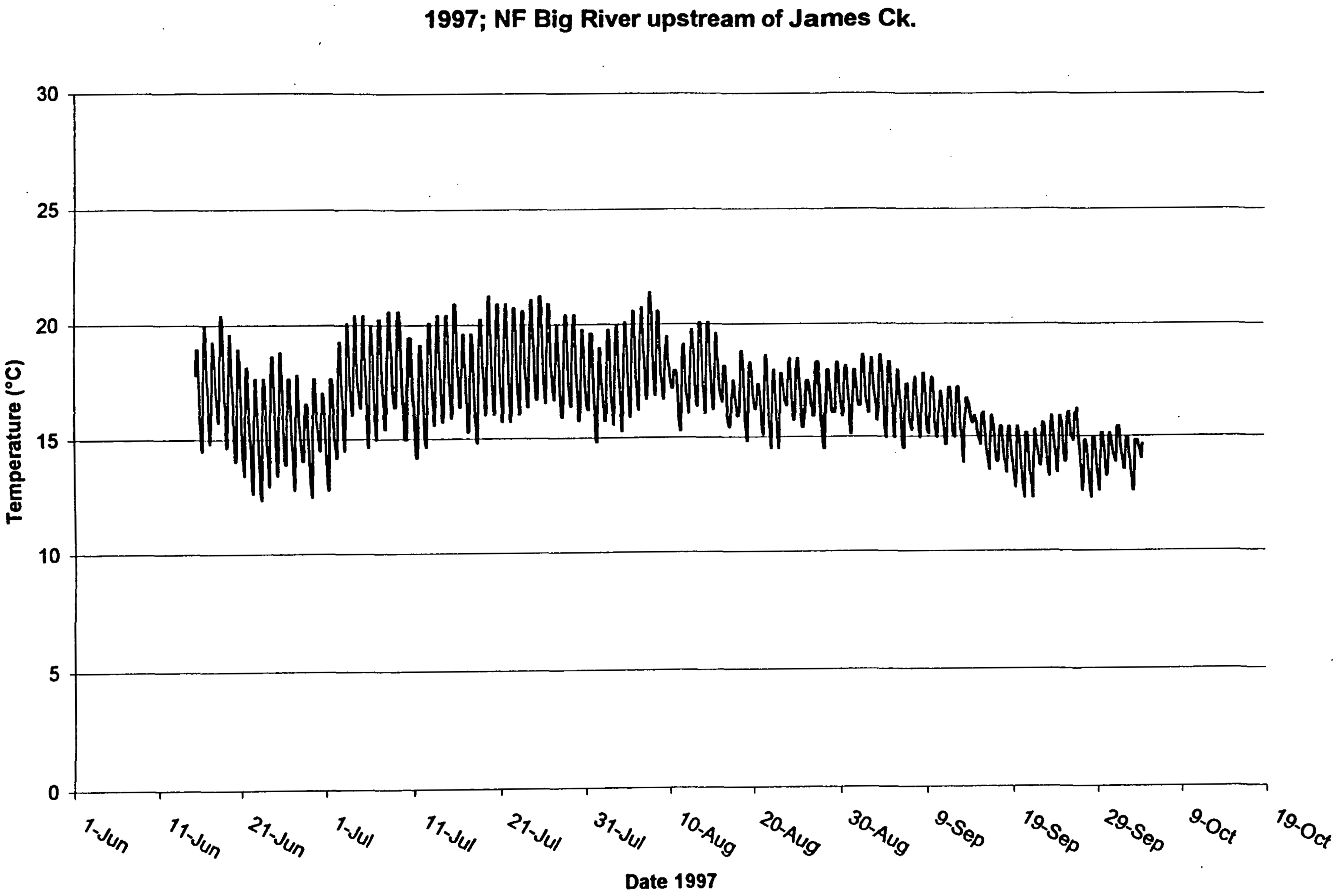


1997; North Fork of SF Noyo, upstream of Brandon Gulch

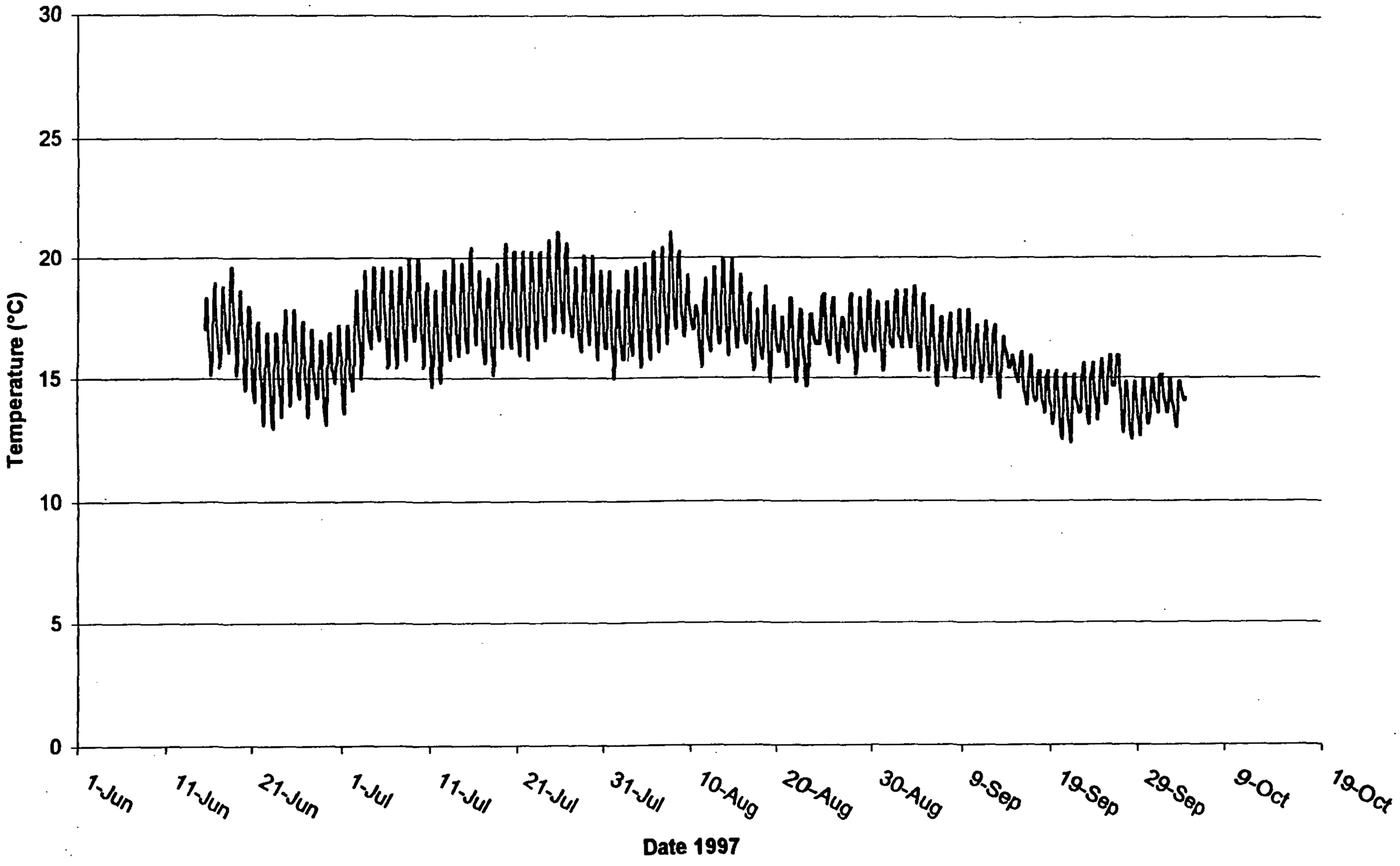


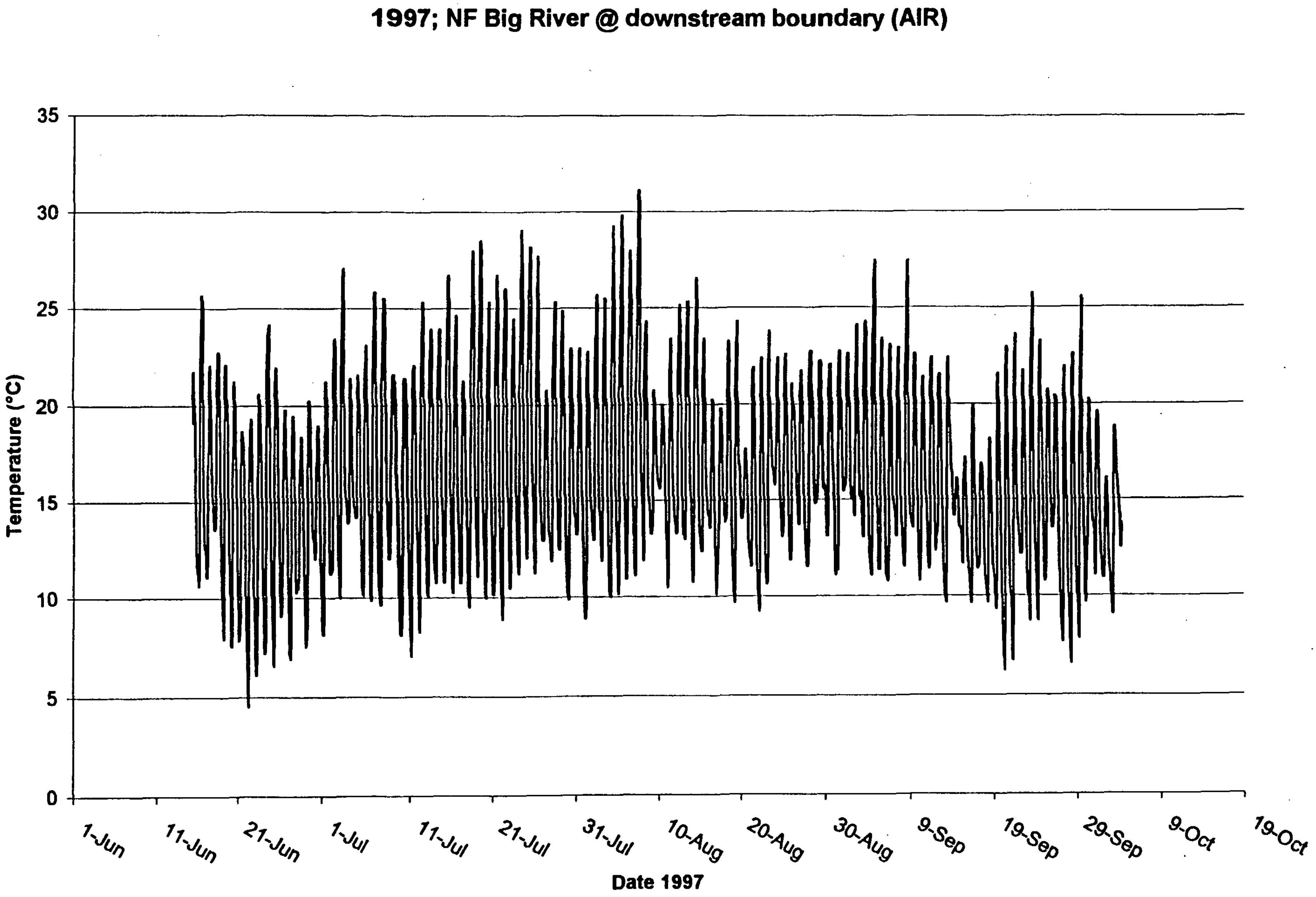
1997; North Fork of SF Noyo, upstream of confluence



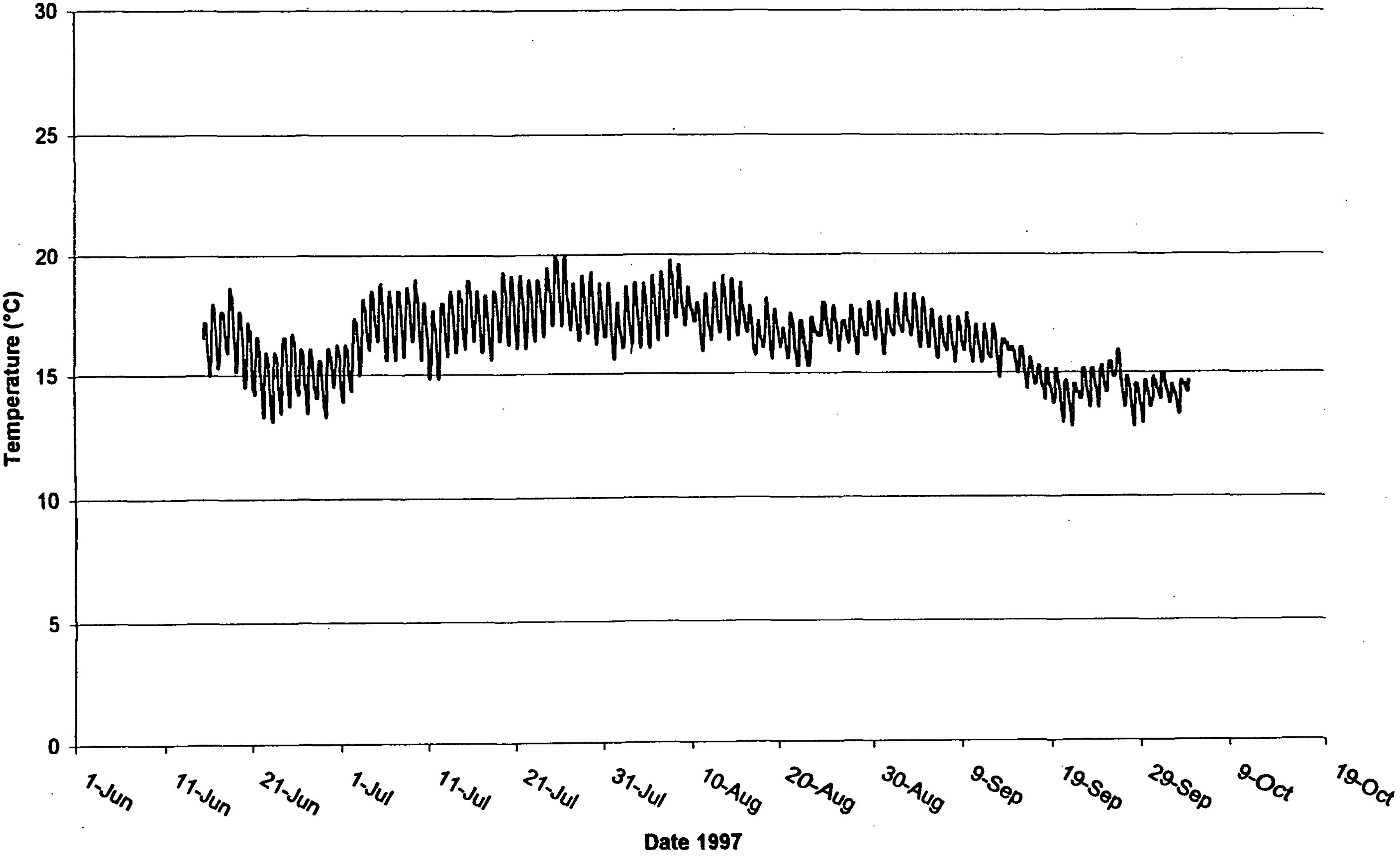

1997; NF Big River upstream of James Ck.
Temperature (°C)
30
25
20
15
10
5
0
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
Date 1997

1997; NF Big River upstream of Chamberlin Ck.

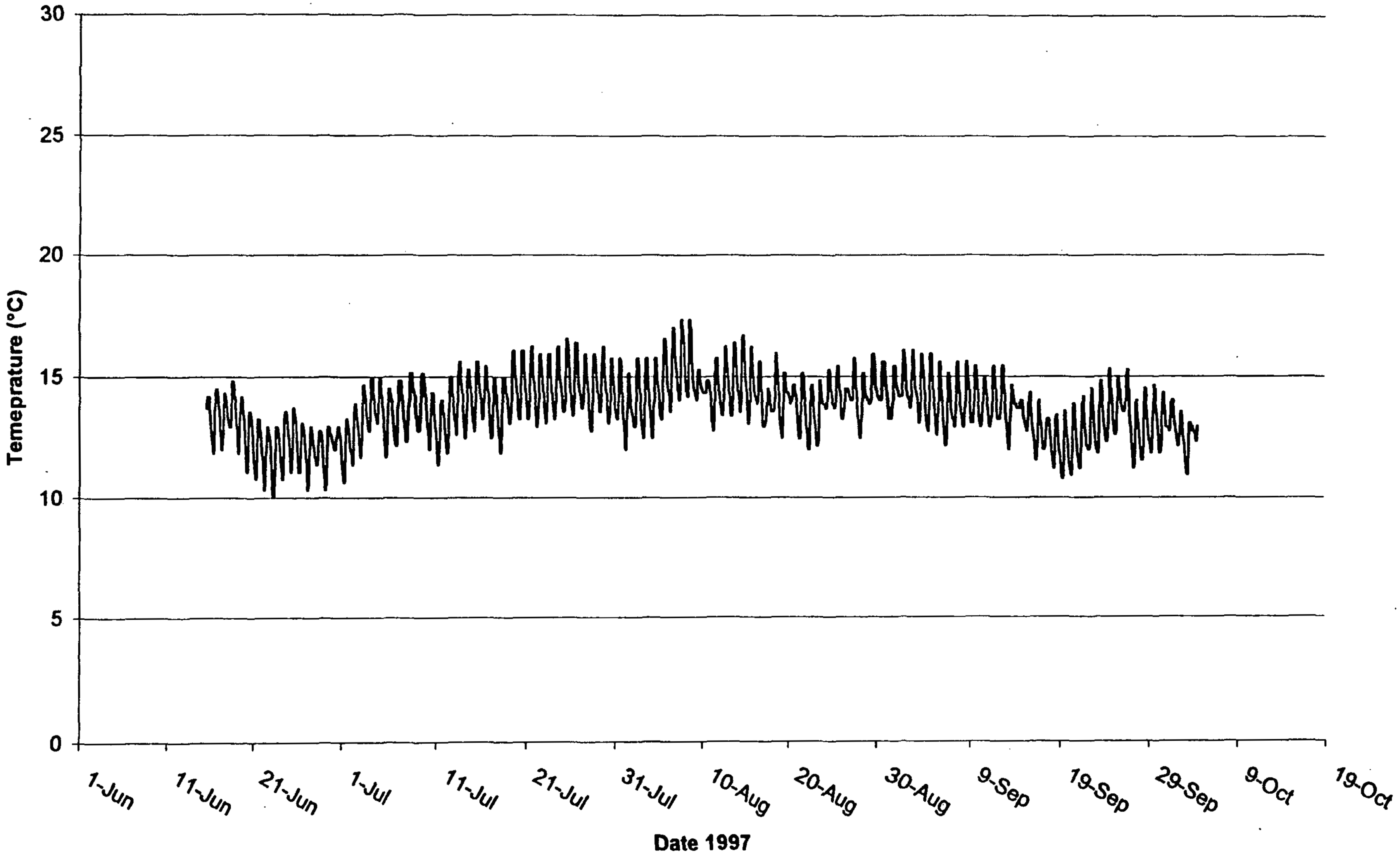



1997; NF Big River @ downstream boundary (AIR)
35
30
25
20
15
10
5
0
Temperature (°C)
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
Date 1997

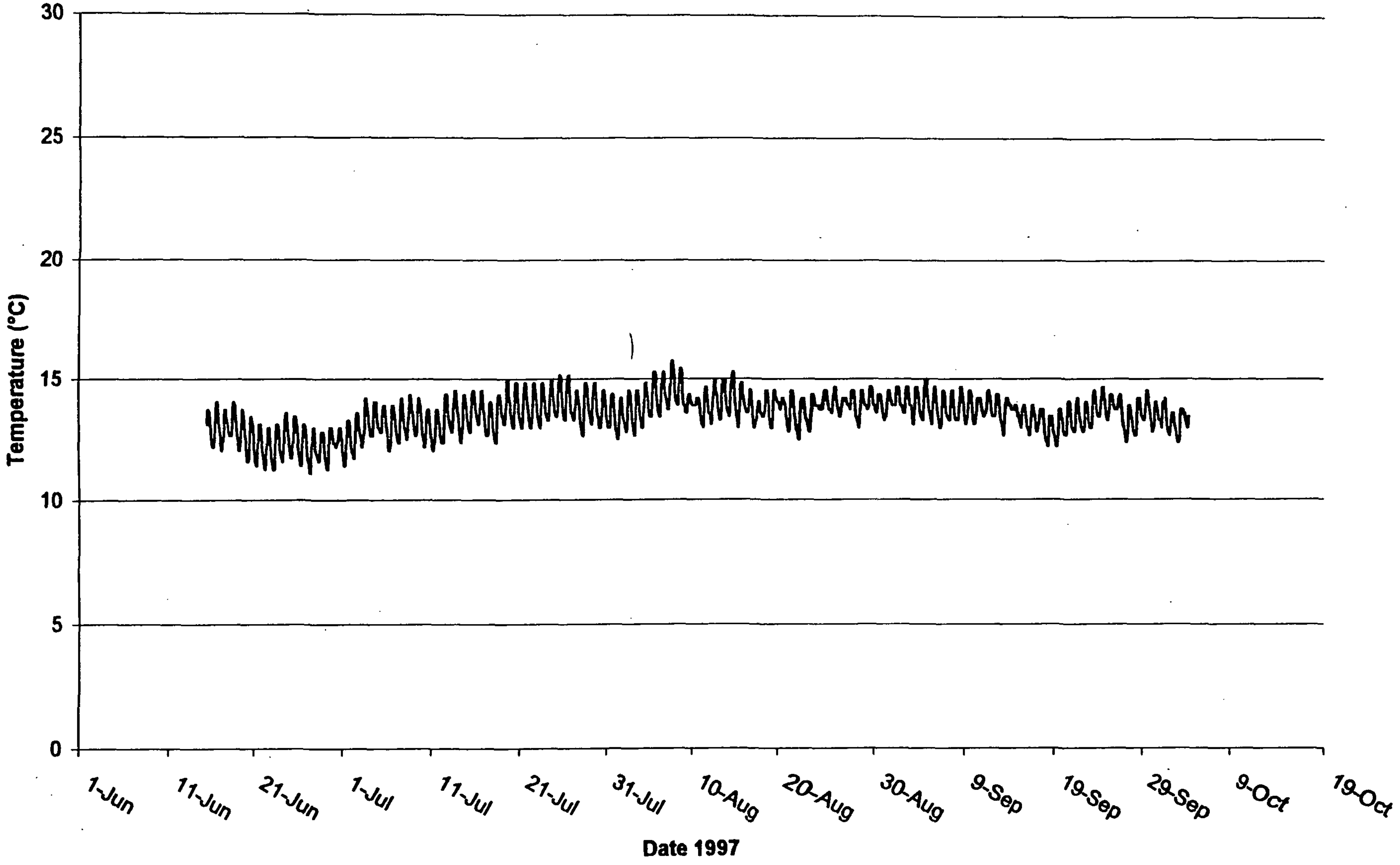
1997; NF Big River @ downstream boundary

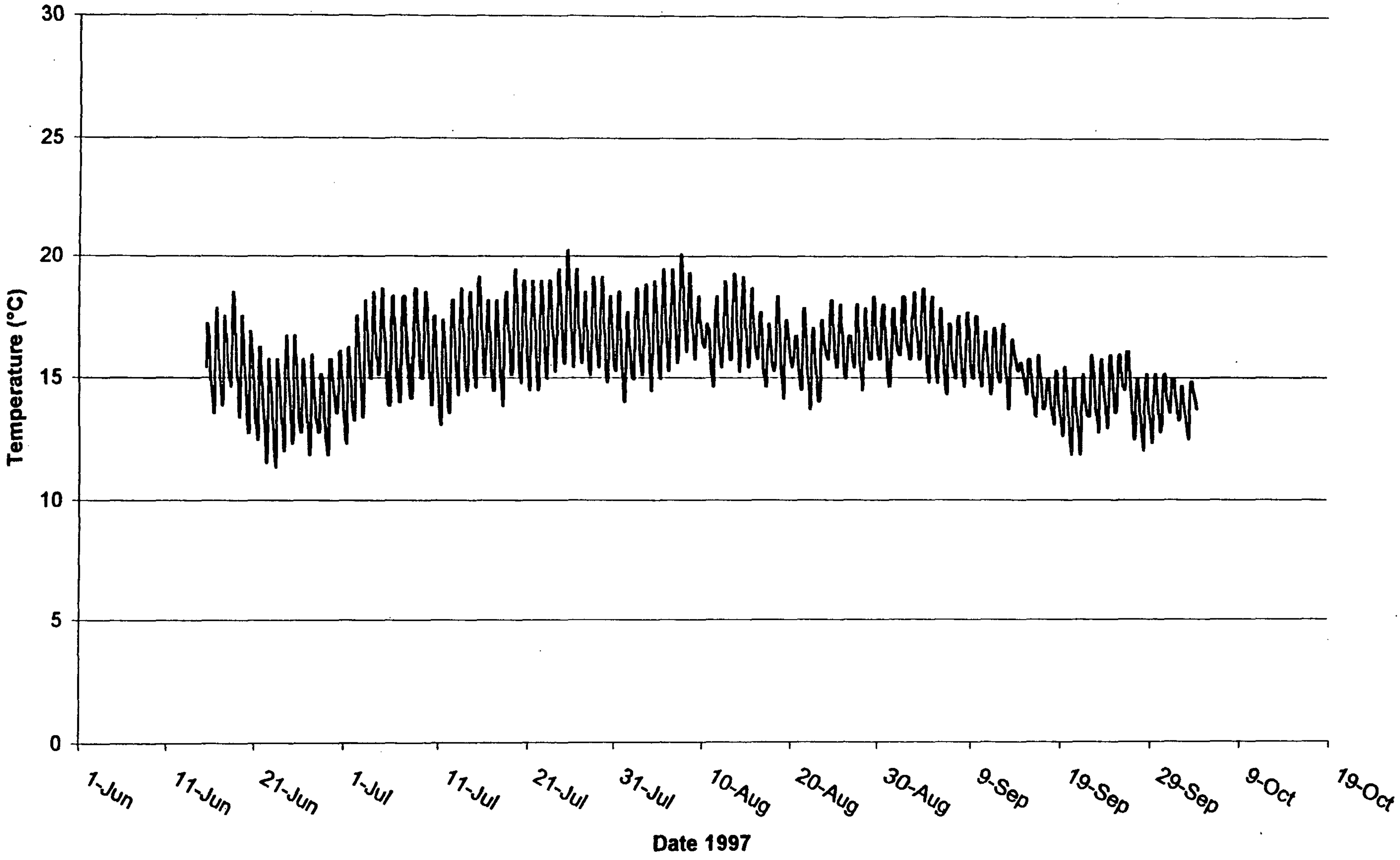


1997; NF James Ck. @ upstream Rd 100 crossing



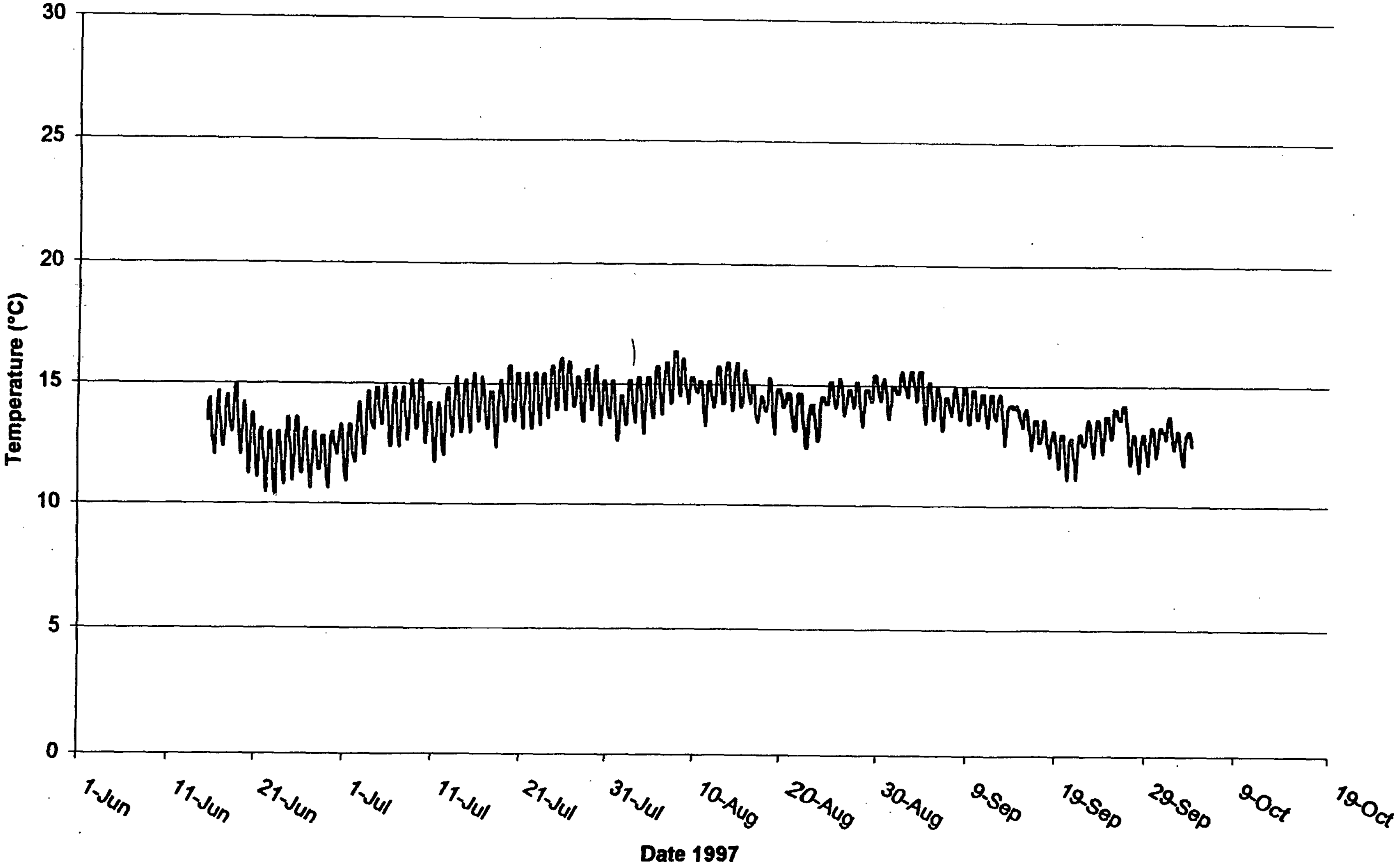
1997; Chamberlain Ck. @ upper Rd. 250 crossing

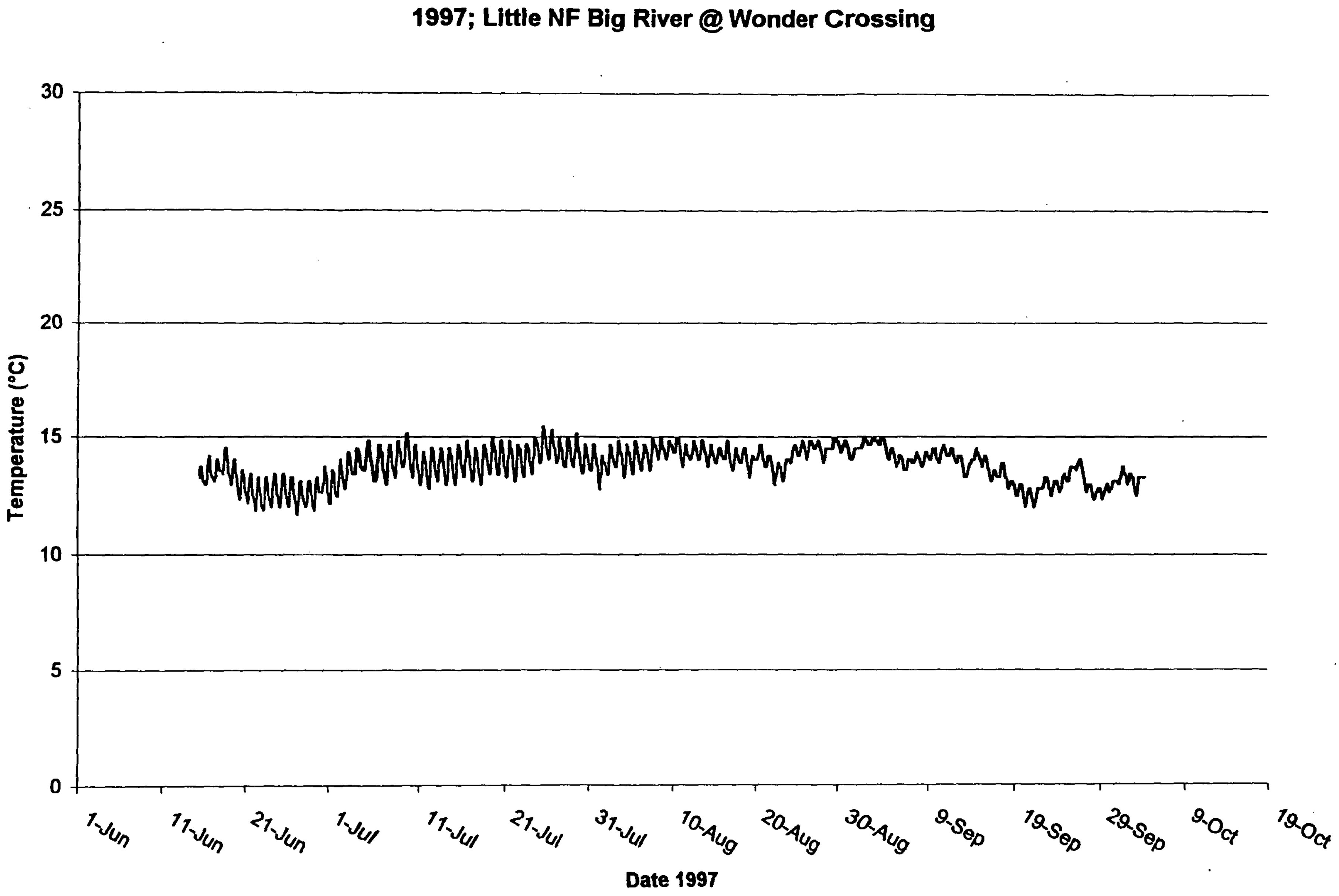




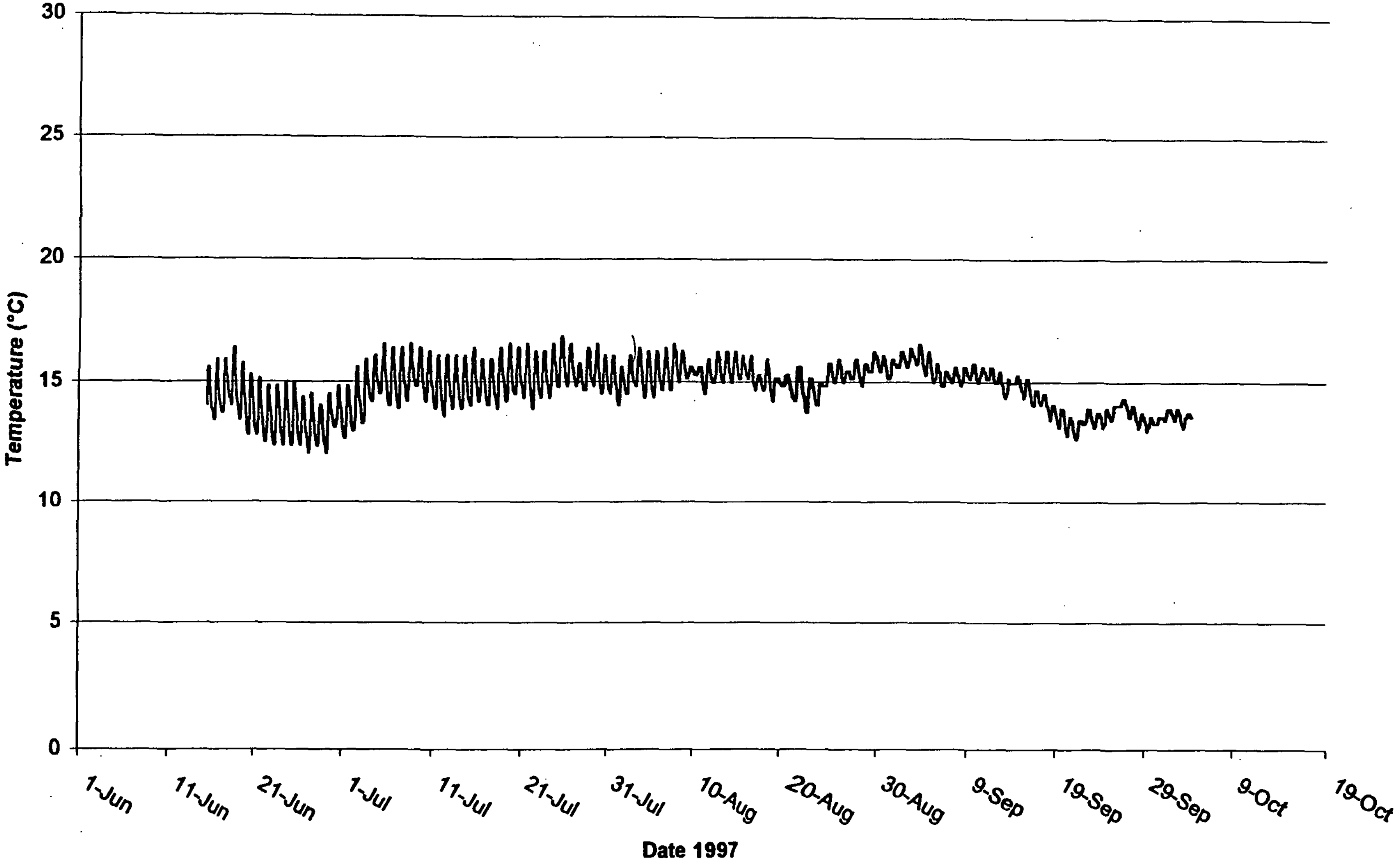
1997; Chamberlain Ck. upstream of NF Big River

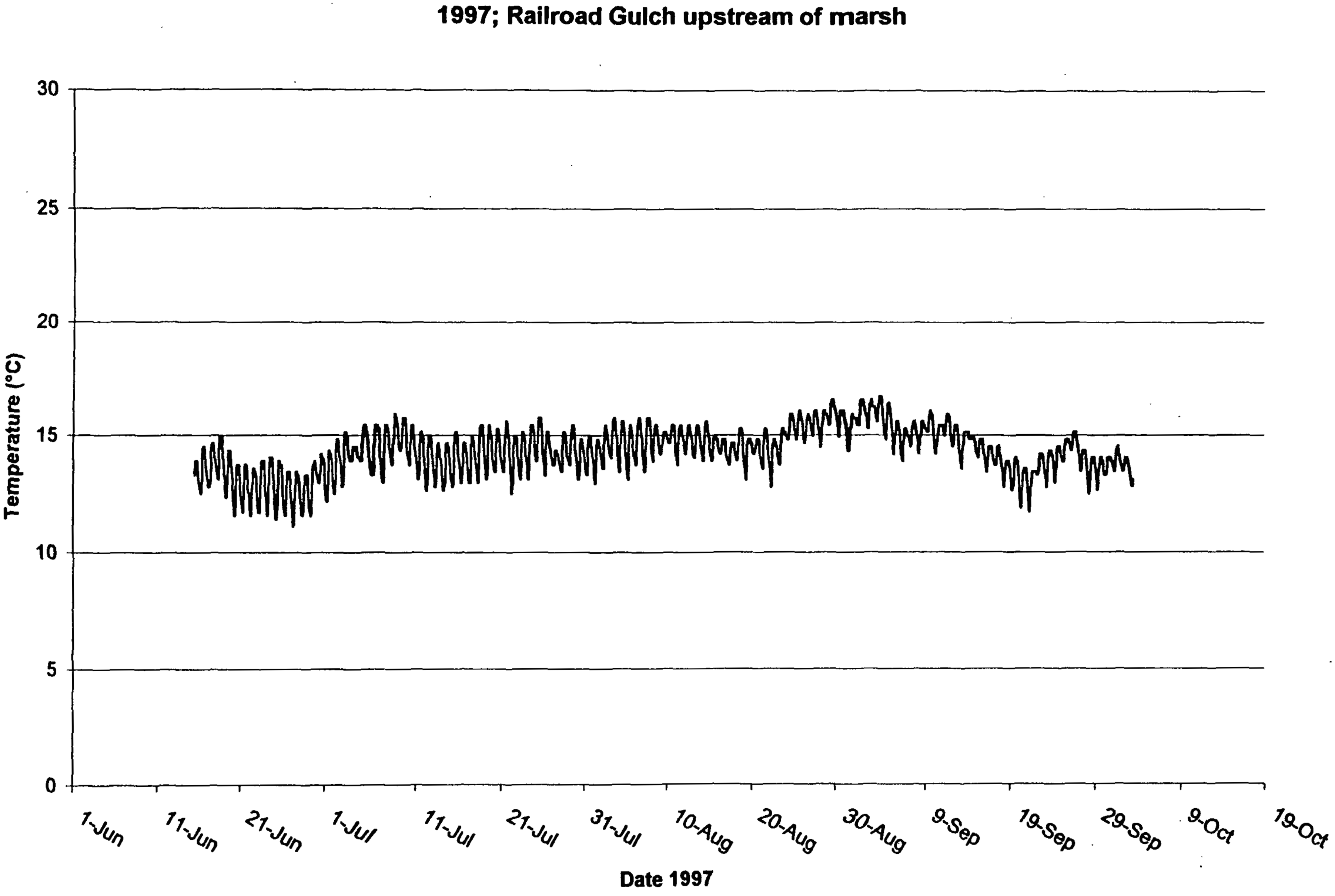
1997; WF Chamberlain Ck. downstream of 16 Gulch



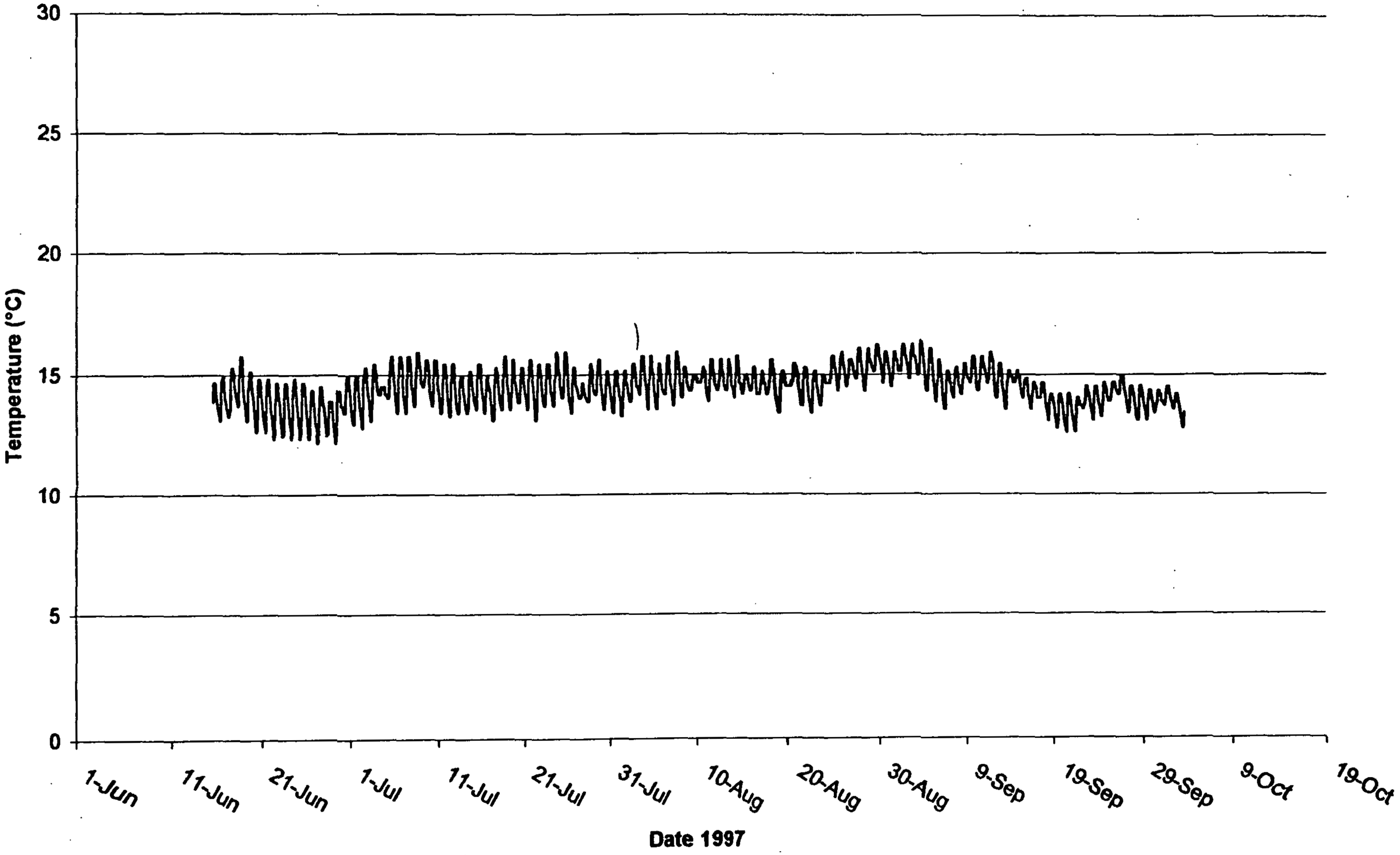

1997; Little NF Big River @ Wonder Crossing
30
25
20
15
10
5
0
Temperature (°C)
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
Date 1997

1997; Little NF Big River upstream of Berry Gulch

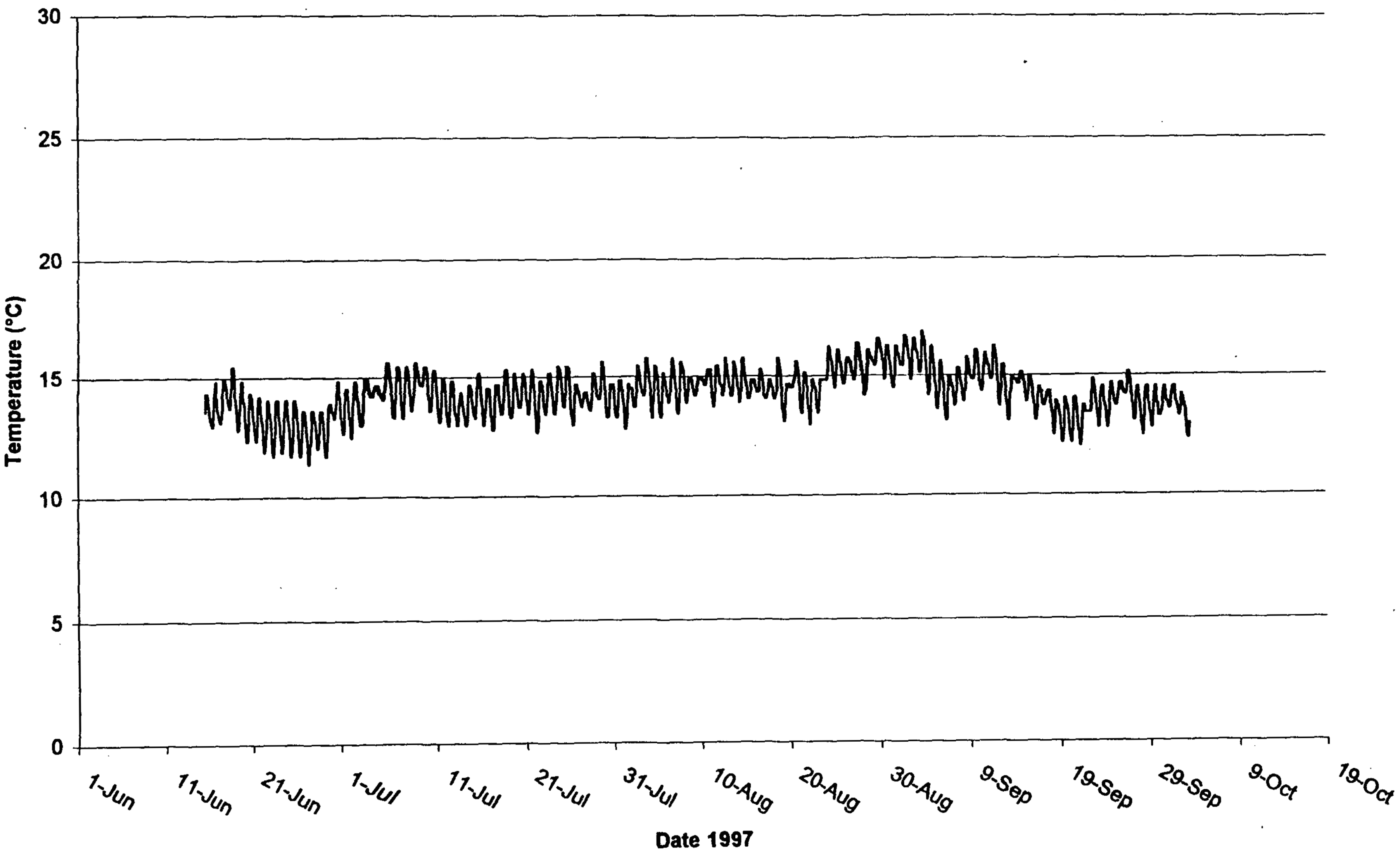


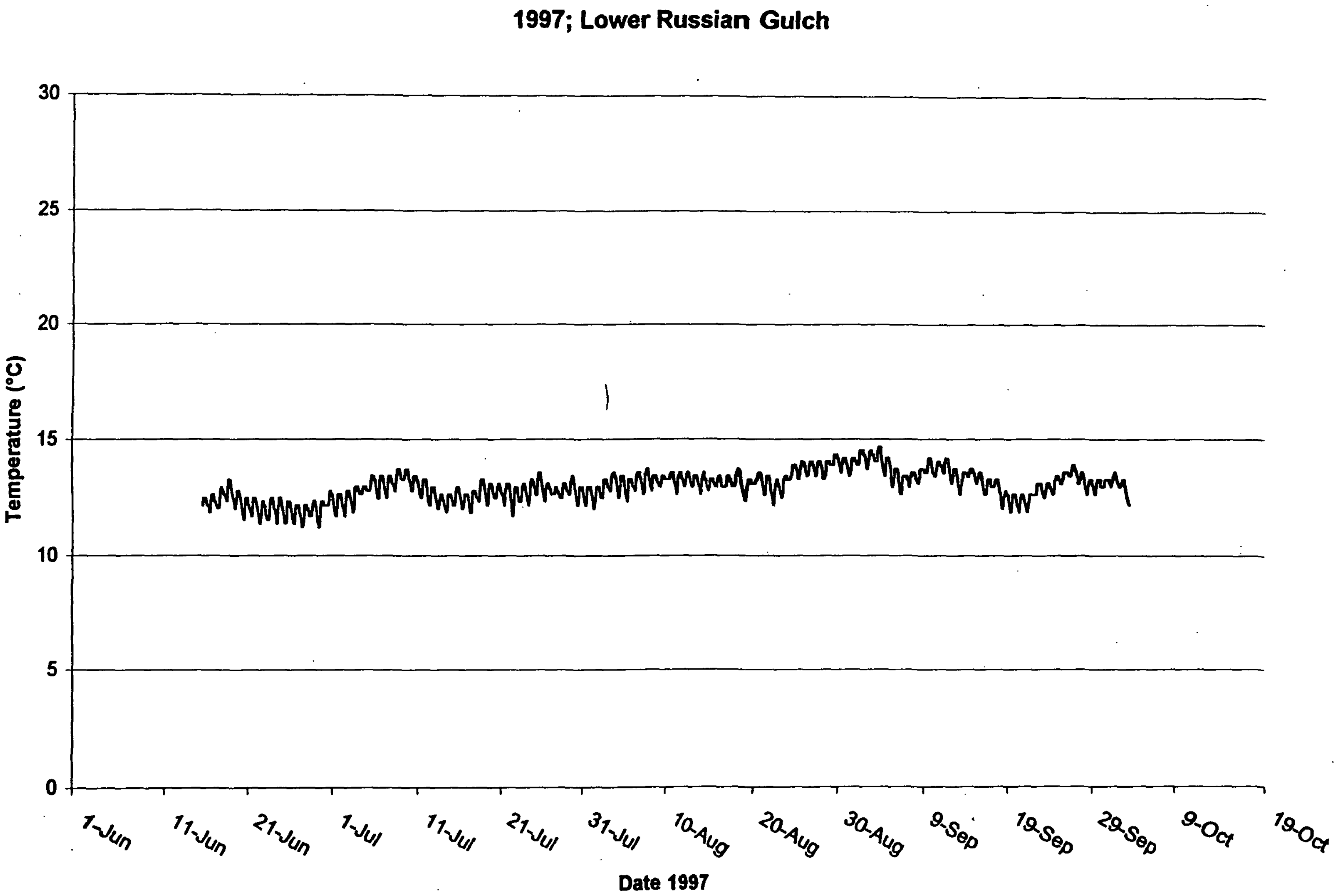

1997; Railroad Gulch upstream of marsh
Temperature (°C)
30
25
20
15
10
5
0
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
Date 1997

1997; Caspar Ck. upstream of South Fork

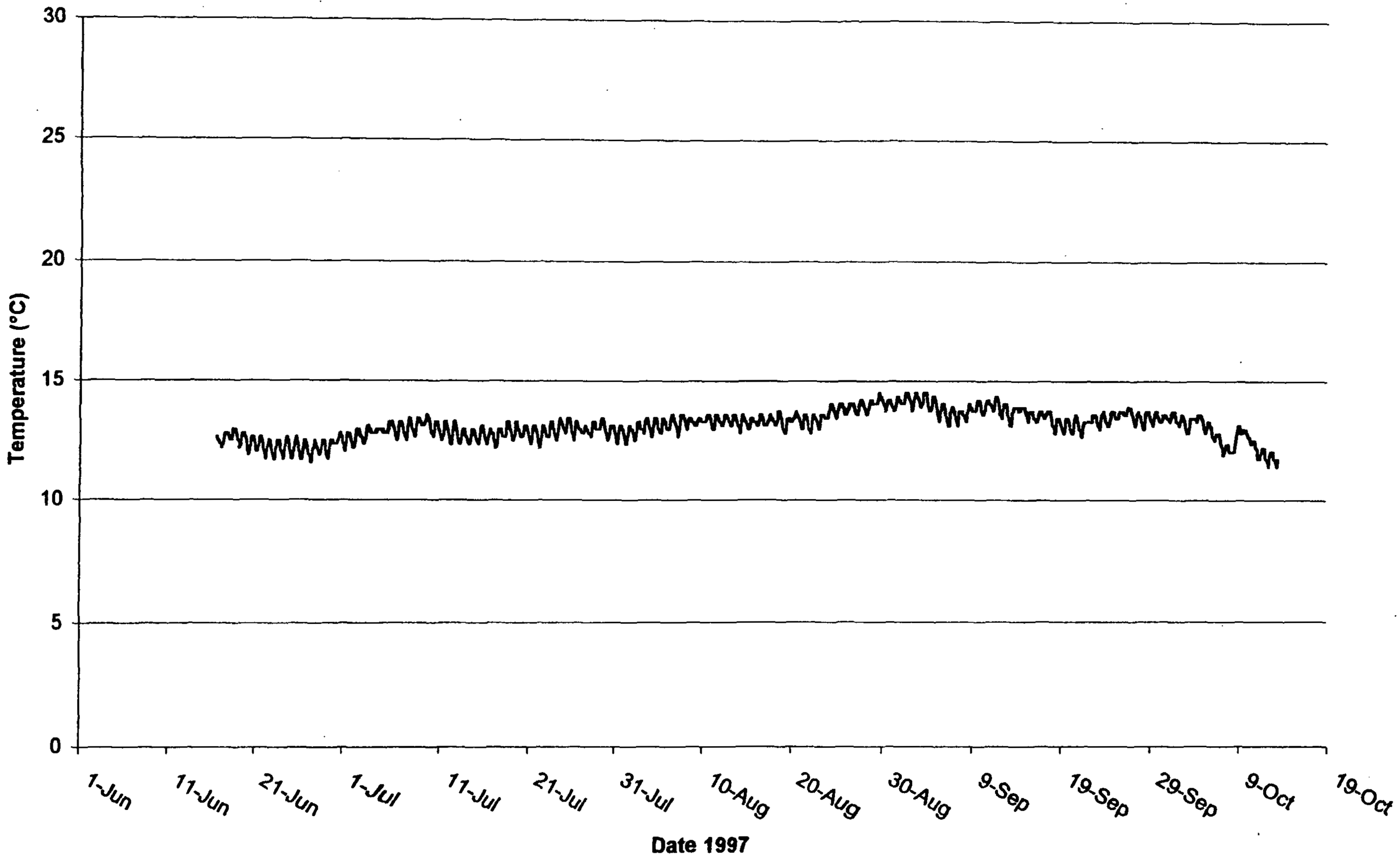


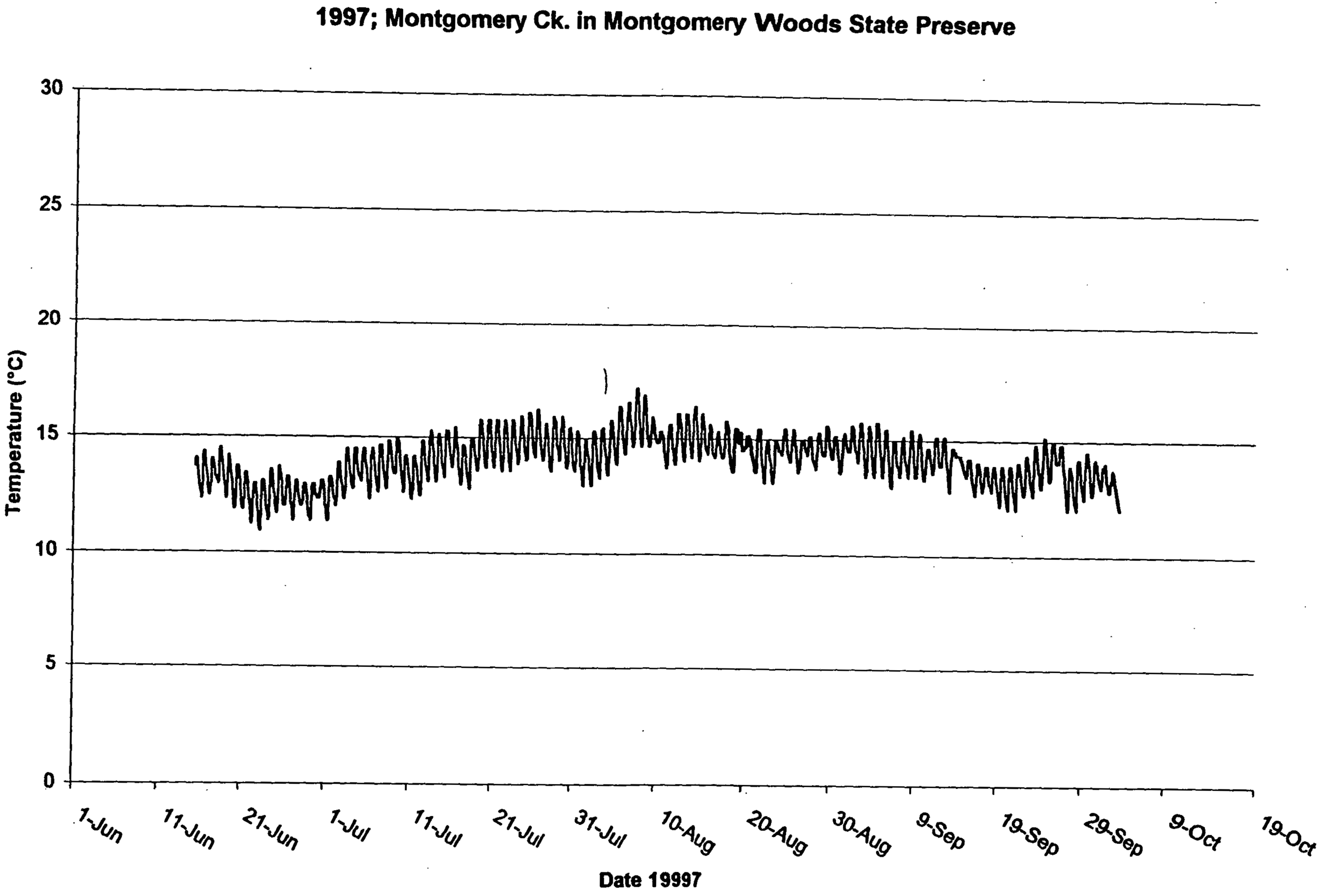
1997; South Fork Caspar upstream of Caspar Ck.




1997; Lower Russian Gulch
Temperature (°C)
30
25
20
15
10
5
0
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
Date 1997

1997; Jughandle Ck.




1997; Montgomery Ck. in Montgomery Woods State Preserve
30
25
20
15
10
5
0
Temperature (°C)
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
9-Sep
19-Sep
29-Sep
9-Oct
19-Oct
Date 19997

Stream temperatures on Jackson Demonstration State Forest, Mendocino County, California during summer of 1995.

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California Department of Forestry
and Fire Protection
Santa Rosa, CA.

November 1996

ABSTRACT

Stream temperature is an important factor defining the habitat quality of coldwater fish. Harvest of trees which shade a stream can impact water temperature both on-site and downstream, and may interact cumulatively with other stream warming activities. Knowledge of baseline, potential temperature regimes and existing regimes is needed to assess the effects because stream temperature is both spatially and temporally dynamic.

During the summer of 1995, continuous temperature monitors placed in watercourses in the South Fork Noyo Drainage documented the current temperature regimes and basin heat transport. Maximum water temperature recorded at two stations was 19.4 °C, well below lethal temperatures and slightly below those limiting populations. Stream temperatures were commonly above those published as "preferred" for coho salmon.

Monitors in shaded, near-stream, water-filled buckets approximated local shaded equilibria for comparison with in-stream monitors. The station at the upstream limit of the study was close to an equilibrium temperature that was near that of groundwater inflow. At the downstream limits of the study, the temperature of the bucket was consistently cooler than that of the stream, suggesting some thermal loading. However, the proximity of the ocean and of fog, as well as the naturally large stream course at this location complicates this determination.

INTRODUCTION

Biologists consider salmonids "cold-water" fishes because of their association with waters that are cool, and the fact that increases in water temperature may exclude them from a water body. The literature documents upper temperature limits for many salmonids, both in the laboratory (Brett 1952) and the field (Eaton et al. 1995). Salmonids are important as a recreation base, as an economic resource, and as a component of the aquatic and terrestrial ecosystem (Naiman et al. 1992). Their temperature sensitivity makes them susceptible to actions that warm waters. Although salmonids may be differentially sensitive to water temperature changes at several phases of their life cycle, shade removal will have its maximum influence on water temperature during summer (MacDonald et al. 1991).

The harvest of trees along a stream can remove shade and thus cause the waters too warm (Brown 1970a, 1970b, Brown and Krygier 1970, Moring 1975, Rishel et al. 1982, Beschta et al.

1987, Beschta and Taylor 1988). In response, forest practice regulations that came into effect in the 1970s in California and other western states provided buffer strips of vegetation along watercourses to cast shade. Stream temperature maintenance was a primary goal of the buffer strip regulations. Despite continued modifications and enhancement of the regulations, California regulations still permit limited timber harvest in buffers and a reduction of shade canopy. Thus, stream warming because of timber harvest remains an issue.

While measuring temperature is straightforward, assessing the results is not. The determinants of stream temperature are temporally and spatially dynamic, and the potential for on-site and downstream impacts varies accordingly. For instance, streams naturally tend to warm asymptotically as they flow from their headwaters downward through larger order streams (Theurer et al. 1984, Adams and Sullivan 1989, Sullivan et al. 1990). At the asymptote, regional climate controls stream temperature. At the headwaters, the temperature of the groundwater inflow dictates stream temperature. Factors such as discharge, channel characteristics, shade, and air temperature moderate the rate at which the asymptote is reached.

Fisheries experts (Moyle et al. 1989) have expressed concern about population trends of the coho salmon for sometime. Proposals to list the species under both the California and Federal Endangered Species Acts (Anon. 1993, Hope 1993) underscore the concerns. Coho salmon are sensitive to warm water -- their preferred temperature is 12-15°C (Brett 1952); their optimum temperature, as measured by swimming speed is ≈ 20 °C (Brett et al. 1958); limiting temperature is ≥ 20°C (Reeves et al 1989); and lethal temperature is about 25°C (Brett 1952).

The California Department of Forestry and Fire Protection manages Jackson Demonstration State Forest (JDSF) for timber production under California's Forest Practice Rules. This includes harvesting trees from stream side buffers, an action that can increase water temperature. Between coho salmon and steelhead, the two salmonid species inhabiting streams on JDSF, coho salmon are probably the more temperature sensitive (Bjornn and Reiser 1991). The intent of this report is to 1) document current stream temperatures on parts of JDSF, 2) assess some dynamics governing water temperature, 3) estimate the potential baseline temperature, and 4) relate this information to forest management and coho habitat needs.

STUDY AREA

JDSF, in western Mendocino County, is a publicly owned, timber producing redwood forest (Anon. 1991). The western boundary of the JDSF is about 2.4 km (1.5 miles) from the Pacific Ocean and its eastern boundary is about 32.2 km (20 miles) inland. Its elevation ranges from about 91 m (300 ft.) to 640 m (2100 ft). The South Fork of the Noyo River and several forks of Big River are the primary watersheds draining the Forest.

Smaller watersheds (Hare, Caspar, Jughandle, and Russian Gulch creeks) that are also at least partially managed by JDSF are directly tributary to the ocean.

The climate of JDSF follows an east-west gradient. Precipitation, almost entirely rainfall, totals about 100 cm (40 in.) near the coast to over 150 cm (60 in.) inland. More than 90% of the precipitation falls between November and April (Anon. 1991). In the summer, average air temperature for the western half of the forest ranges from near 10 to 21 °C. Summer fog often keeps the temperatures near 16°C within 10 miles of the coast. Summer high temperature near the eastern boundary of the forest may exceed 38°C.

This study focuses primarily on South Fork Noyo River (South Fork). It is centrally located between about five and 11 miles from the coast (Fig. 1). Based on USGS 7.5′ quads, the South Fork Noyo River is a 5th order watercourse that drains a 17,333 acre watershed. Stream temperature data is also presented from Bunker Gulch, a single site in the adjacent Hare Creek drainage.

METHODS & MATERIALS

Continuous water temperature monitors (Hobotemp and Stowaway ®) were activated in the office to record water temperature once every 96 minutes, or 15 readings per day. In early summer, I deployed monitors within JDSF along the South Fork from the upstream boundary near McQuire's Pond to the downstream boundary near Kass Creek (Fig. 1, Table 1). I also placed monitors in several South Fork tributaries (Fig. 1, Table 1). A single temperature monitor recorded temperature in Hare Creek, an adjacent drainage.

Due to their position, the temperature monitors measured the "average" water temperature available to fish at that locale. Each monitor was in the thalweg of a riffle where shade canopy in the immediate upstream reach was homogeneous and continuous. A large rock on top of each monitor anchored it and shielded if from view and sun specks. I avoided placements in deep pools that might stratify and thus be cooler than average, or in shallow stream margins or backwaters that might be stagnant and thus warmer than average.

To attempt to isolate the effects of local climate and shade from those of groundwater influx and location along the river continuum, additional temperature monitors were placed in plastic 5-gal buckets in the streamside zone adjacent to the in-stream monitors at both the upstream and downstream boundary. I affixed the monitors to the bottom of the buckets, filled the buckets with water, placed them in a well-shaded location within 15 m of the watercourse. The lids of the buckets remained ajar to limit -- but not stop -- water surface phenomena such as evaporation and conduction of heat between the air and the water.

During autumn, monitors were retrieved to the office where their data were downloaded with software provided by the manufacturer. After importing the data into a spreadsheet (Lotus

123), I graphically displayed for indications of unrepresentative data. Examples of unrepresentative data include the time between launching at the computer and placement in the stream, and conversely that between retrieval and downloading. Dropping hydrographs partially exposed some of the monitors. I compared these graphs against those of monitors that maintained proper in-stream position. If either the daily fluctuation or the absolute value of data of the emerged monitors differed from the effectively-placed monitors, I considered the divergent data erroneous and eliminated them.

Because the monitors differed in dates of deployment and retrieval, and because of data gaps, comparing descriptive statistics between monitors or locations might be inappropriate. To make the data as comparable as possible, and to highlight the warmest period, I calculated a 4-week running average of temperatures over the entire time range for the stations with the longest records. The warmest 4-week period was centered on July 26 for one station and July 27 for the remainder. I then developed the descriptive statistics and cumulative temperature curves for all units based on a four-week period centered on mid-day, July 27.

To ease an assessment of the downstream temperature dynamics, I plotted the temperature data of the South Fork and Parlin Fork in two different ways. First, I graphed cumulative temperature curves for each station onto a single graph to enable comparisons among stations. Then, to add a geographic context to the data, I plotted the maximum and average temperature against a GIS-generated stream distance upstream from the downstream boundary.

Descriptive and regression statistics were calculated within the Lotus 123, Ver. 2.4 ® software of Microsoft.

RESULTS

Monitor placement was occasionally problematic. As flow receded across the summer season, several casings surfaced and were partially exposed to air. Temperature traces of these differed from those which maintained appropriate position primarily with uncharacteristic change in variability. Thus, some temperature traces include gaps.

The temporal relationships of peaks, valleys, and plateaus of the season-long temperature traces are consistent among the different units (Figs. 2a-f, 3a-c, 4a-c, 5). The stations differ in the absolute value of the water temperature and the amplitude of the daily cycle. For locations with season-long records, two or three warm periods are apparent -- a week-long peak near the end of June, a second in mid-July, and the strongest on July 28 (Figs 2a, 2d, 2e, 3c, 4a, 4c). The relative strength of these differed with the first peak being stronger than the second for the Upstream Boundary (Fig 2a), but being the weakest peak for the other stations (Fig. 2d,e,f).

Two locations on the South Fork -- above Road 320 (Fig. 2b) and the downstream boundary (Fig. 2f), shared the warmest water temperature of 19.4 °C. The Road 320 monitor is at the downstream end of a clearcut completed during 1986 in which the streamside buffer has suffered subsequent, moderate blowdown. As a result, it measures water temperature exposed to direct sunlight during the day. Its great daily amplitude also reflects its low canopy cover and warming during the day only to cool through cool-water inflow and re-radiation at night. The fact that the Road 320 monitor has an incomplete record complicates comparisons of its minimum and mean temperatures with those of others.

Despite the fact that the second station from the upstream boundary (Road 320) recorded the highest temperature, water along the South Fork tended to warm and vary more as it flowed downstream (Figs. 6a, 7a and 7b, Tables 2 and 3). When considered in a downstream direction, the cumulative temperature curves of the stations (Fig. 6a) tended to shift to the right. In addition, the curves tended to flatten in the downstream direction, portraying the greater amplitude of the diel cycle. The two stations that are contrary to the warming and increasing variability (above Road 320 and upstream of Parlin Creek) have incomplete records, and thus their traces are not directly comparable. In addition, a plot of the mean temperature against distance (Fig. 7a) is more in line with the downstream warming expected than is a plot of the maximum temperature (Fig. 7b). This suggests that the canopy's openness exacerbated heating primarily during the peak temperature periods, and only slightly affected temperature during other periods.

For all stations on the South Fork, water temperatures during the warmest continuous four-week period of 1995 were below 18°C more than ≈85% of the time (Fig. 6a). Water temperatures were less than 15 °C only between 5 - 53% of the time (Fig. 6a).

Among the tributaries, the temperature regime of Parlin Creek is more similar to that of the South Fork than it is to those of the other streams (Figs. 6a , 6b). Water temperatures become warmer and more variable as Parlin Fork flows downstream. Peak temperature in Parlin Creek was 18.14 °C (Table 1) at the lower station. Of the warmest 4 weeks, water temperatures at the Parlin Creek stations were less than 18 °C more than 98% of the time and less than 15 °C between 33 and 75% of the time (Fig 6b). Most temperatures of the other three South Fork tributaries were between 12 and 15 °C (Fig. 6b, Table 2).

Absence of flow data, variable and excessive distances between stations, and incomplete temperature records complicates assessment of the influence of tributary inflow on temperatures in the South Fork. The downstream-most Parlin Fork station (Fig. 3c, Table 2) had slightly warmer maximum temperatures than the Noyo stations immediately up- and downstream of the confluence (Fig. 2c and 2d, respectively; Table 2). However, its mean temperatures were intermediate to the South Fork stations.

Parlin Fork appears to have had little influence downstream of the confluence. But the downstream-most Parlin Fork monitor measures water temperature over a km upstream from the confluence. The fact that temperature in the South Fork increases as the water flows past the (Tables 2, Figs. 7a and 7b) confluence suggests that Parlin Fork is warming the South Fork.

After the Road 320 station, inflow from 23 Gulch cooled the South Fork. Temperatures at the nearest downstream monitor (Upstream of Parlin) showed substantial declines after warming up at the Road 320 station (Table 2, Figs. 7a and 7b). The discharge of 23 Gulch was relatively minor to that of the South Fork, so its cooling effects should have accounted for only a small portion of the apparent cooling.

Like 23 Gulch, the temperatures of Bear Gulch and Peterson Gulch were substantially cooler than the downstream of Parlin station, the nearest upstream South Fork stations (Table 2, Figs. 7a and 7b). Assessing the magnitude of their cooling influence is difficult. Also like 23 Gulch, their discharge is also small compared to that of the South Fork. The next monitor downstream that might detect the cooling influence of Bear Gulch or Peterson Gulch is the Egg-taking Station. It is distant and the large, un-monitored North Fork of the South Fork is tributary between them.

At the upstream boundary, water temperature in the bucket was more variable than was the water in the stream. The temperature difference between the bucket and stream fluctuated around 0 °C (Fig. 8a).

At the downstream boundary, water temperatures in the bucket were consistently cooler than those in the stream, despite similar magnitudes and direction of fluctuations (Fig. 8b). The water temperature of the bucket tended to be about 3°C cooler than that of the South Fork. The difference exceeded 4 °C on occasion. Later during the season of monitoring, the temperature differences between the bucket and the stream declined (Fig. 8b).

Instream water temperature was always warmer at the downstream boundary than at the upstream boundary (Fig. 9a) by an average of 1.29 °C. Oppositely, water temperature in the bucket at the downstream boundary was cooler by an average of 0.7 ° C and less variable than that in the upstream bucket (Fig. 9b). During the warmest period, the buckets differed by an average of 1.29 °C, with a maximum difference of about 3.8 °C.

DISCUSSION

Exposure to air of some monitors' casings could elevate temperatures and increase variability. I reduced this concern by eliminating data that was obviously erroneous. The distinguishing feature of the data that lead to the decision to delete it was a sudden jump in daily amplitude. This was especially apparent when the temperature traces of fully submerged monitors did not display corresponding changes. The high specific heat of water makes it likely that substantial exposure would be necessary to significantly affect recorded temperature. However, the possibility remains that I did not delete all effect data from the units that became exposed.

Major peaks in temperature traces coincided between locations as expected in a study within a single, and small drainage. The relative height of major peaks differed. The likely causes for this are a combination of position within the drainage and the dynamics of fog influence, stream orientation, seasonal changes in solar angle as amplified by topography and stream-side shade, and the groundwater influx variations.

The three small tributaries, as well as the upstream stations on Parlin Fork are cooler and thermally more stable than the upstream station on the South Fork. The former tend to be in well-vegetated basins, in drainages with northerly aspects, and / or generally low-order watercourses. The latter is downstream of a large forest opening and artificial pond where the water may acquire some heat.

At their confluence, Parlin Creek and the South Fork are similar in drainage area and temperature dynamics. As such, the main influence of Parlin Fork upon the South Fork is largely a significant contribution to the flow. Comparing the monitor stations on Parlin with those bracketing the South Fork, it modified the temperature of the South Fork little, if at all. However, the jump in temperature between the bracketing stations suggests that there is substantial heating in Parlin downstream of the Lower Parlin station. The other tributaries were substantially cooler than was the South Fork at their inflow. Because of their limited discharge, their cooling influence upon the South Fork were probably localized. Their contribution to cooling would become overwhelmed by the greater flow of the South Fork as the accumulated water flowed moved downstream.

The trend of increased temperature in the downstream direction exhibited by the South Fork and Parlin Creek demonstrates the regular and predictable change of the factors that control water temperature (Theurer et al. 1984, Beschta et al. 1987, Adams and Sullivan 1989). Near headwater areas, the stream's water temperature reflects that of the ground water. It is the minimum possible summer temperature (Caldwell et al. 1991). After the cold groundwater's emergence, it begins to equalize with air temperature. The rate at which it equalizes is dependent on the magnitudes of the difference with the local air temperature and other heating influences, primarily shade canopy. During this adjustment time, because the water is flowing, achieving equilibrium requires some distance of stream. Stream temperatures at balance with local climate are at their equilibrium temperature. Local air temperature is a key predictor of equilibrium temperature. The factors that control the equilibrium temperature at the local scale are themselves subject to variation along geographic gradients. Thus, superimposed on local equilibrium characteristics is a basin greater temperature variability than that of the in-stream water suggests that groundwater inflow is important in determining the stream water temperature. Another explanation is that the temperatures of well-shaded water at equilibrium and groundwater inflow are similar. The stream temperature here is intermediate between the more headwater stations (upper Parlin Fork and the small tributaries). This suggest that the stream at the upper boundary is transitioning from cold groundwater to the local equilibrium temperature.

At the downstream boundary of JDSF, the bucket's water was cooler and less variable than was the stream's water. This difference reflects the station's proximity to the temperature moderating influence of the ocean. The greater variability and warmer temperature of the stream compared with the bucket suggests some combination factors, such as natural climatic and sun exposure due to stream size, as well as possibly anthropogenic influences are delivering warmed water to the location. The cool, stable temperatures within the bucket indicate that if the watercourse upstream had higher levels of shade than at present, then temperatures might be reduced. An alternate explanation is that the water delivered to the site from upstream is warming as expected but the station is within a zone strongly influenced by fog and ocean. In this scenario, stream water temperatures would be would be in the process of dropping to an equilibrium which has been reduced by fog and ocean-cooled air.

The fate of heat added to a stream varies along the watercourse. Where a stream is substantially below equilibrium, solar radiation dominates the factors that control water temperature (Adams and Sullivan 1989). Here, added heat does not readily dissipate from the stream (Brown 1970b, Beschta et al. 1987). In sub-equilibrium reaches, water temperatures downstream of a forest opening that are lower than those at the opening may not be interpretable as a downstream discharge of the acquired heat. As the heated water flows downstream, the stream channel disperses and dilutes it with water that passed the opening during non-heating periods. Groundwater influx downstream may further act to mask the added heat.

At the other extreme, where a stream is at the equilibrium temperature, heat added dissipates primarily through evaporation and re-radiation to the sky (Sullivan et al. 1990). Added heat is likely to elevate the maximum temperature and magnitude of variations with little modification of mean and perhaps even less change in minim temperatures. Transport downstream of the added heat in a reach at the equilibrium temperature would be minimal. Upon flowing into the shaded downstream channel it would begin dropping back to its cooler equilibrium temperature. Direct effects of stream heating might be most clearly depicted by changes in peak temperature. Both direct and cumulative impacts might best demonstrated by using the minimum or mean temperature.

As streams become wider, the inherent ability of stream-side vegetation to regulate the stream's temperature declines. When measured along the thalweg, large streams may be insensitive to changes in shade because climatic conditions and inflow from upstream so strongly dictate their temperature. However, stream side shade is still important. Shaded areas along the stream margin may have reduced heat maxima and thus reduced amplitude under shaded conditions relative to open conditions, providing a greater diversity of temperatures for organisms to choose among.

Using coho salmon as the assessment endpoint for this temperature study, the South Fork Noyo within JDSF did not exhibit conditions that are a serious cause for concern during the summer of 1995. Except in the very small tributaries of the South Fork, water temperature was often greater than the coho salmon's "preferred" temperature of 13-15 °C (Brett 1952). Brett et al. (1958) found the coho salmon's "optimal" temperature, as measured by cruising speed to be 20 °C. While maximum temperature exceeded 19 °C at two stations, they did so rarely. These stations never exceeded 20 °C, the temperature Reeves et al. (1989) suggest be considered as limiting. Bell (1973, in Reiser and Bjornn 1979) stated that above 20.3 °C, cold water fish cease growth because of increased metabolic activity. Bjornn and Reiser (1991) state that temperatures that exceed 23-25 °C places most salmonids in life threatening conditions. Sublethal temperatures may effect behavior and community dynamics, but this factors are poorly understood (Bjornn and Reiser 1991, MacDonald et al. 1991). Thus, while maximum water temperatures measured were generally warmer than coho salmon prefer, they were probably not limiting. Because monitors collected "average" water temperature available, both cooler and warmer water temperatures are spatially available. Coho salmon may select among a range of temperatures. In addition, daily and seasonal temperature fluctuations assured that suitable refuge temperatures were available and stressful conditions, if any, were short-lived.

Comparing the water temperature between in-stream and bucket monitors at the downstream boundary suggests some temperature loading along the South Fork. At the downstream limits of JDSF, the bucket monitor evidenced water temperature moderation, probably due to proximity to the ocean and fog. If fog and ocean influence are causing equilibrium temperatures to decline as the stream flows towards the coast, increases in temperature observed along the South Fork during 1995 would likely subside in a short distance. Therefore, warming of the South Fork as it flows across JDSF would be unlikely to contribute to a significant water temperature impacts downstream. If the fog-cooling premise is true, then the heated water would continue to cool as it reaches equilibrium in an increasingly marine and fog-dominated climate.

Since the collection of this data, JDSF has several timber harvesting plans recently approved but not yet completed. Near-complete shade retention is planed in some. JDSF will prepare other timber harvest plans in the near future in the South Fork watershed; their level of shade retention can not be determined yet. Due to the probable thermal loading observed in this study -- along with the several recent, current, and future timber harvesting plans in the drainage -- maintaining a greater-than-standard (Forest Practice Rules) shade canopy along the streams is in order.

This temperature assessment should be repeated to both assess the annual variability in the temperature regime of coho salmon, to evaluate the protection measures of specific timber harvest plans, and to monitor the conditions and changes in the temperature-variable of coho salmon habitat.

MANAGEMENT IMPLICATIONS & RECOMMENDATIONS

Stream temperatures in the South Fork were only marginally of concern. Although monitors did not detect temperatures warm enough to be considered stressful, two monitors did detect instantaneous temperatures approaching that criteria. Water temperatures in the "preferred" range were scarce except in the small, fist and second order tributaries. Data from stream side, water-filled buckets evidenced possible thermal loading above background.

1. In future timber harvesting plans, shade tree removal in stream-side areas of the South Fork drainage should be minimized to maintain the summer temperature regime in a suitable condition.

This report covers only one summer period, and prior years data are sparse and marginally comparable. Timber harvest plans continue in the drainage, and JDSF is preparing other plans. CDF should continue to monitor water temperature to assess annual variability, as well as direct and cumulative project impacts. Future monitoring could document the recovery of shade as the stands regenerate.

2. Repeat the monitoring stations used in this study and expand into the North Fork of the South Fork, as well as adding additional buckets monitors.

ACKNOWLEDGEMENTS

The CDF GIS office gladly provided the excellent mapping and distance measures used in the report -- thanks to Suzanne Lang and Sherby Sanborn. Marc Jameson provided useful comments. Pete Cafferata and Marty Berbach were provide drafts but failed to comment.

LITERATURE CITED

Anonymous. 1991. Jackson Demonstration State Forest: At a glance (Brochure, Rev. 1991). Calif. Dept. Forestry and Fire Prot., Sacramento, CA. 25p.

Anonymous. 1993. Petition to the National Marine Fisheries Service for a Rule to List, for Designation of Critical Habitat, and for a Status Review of Coho Salmon (*Oncorhynchus kisutch*) Throughout its Range in Washington, Oregon, Idaho, and California Under the Endangered Species Act. Unpubl. Rep. submitted by the Pacific Rivers Council (Eugene, OR) to the (U.S.D.C., N.O.A.A.) Nat. Mar. Fish. Serv. 33 pp.

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. Pp 191-232 *In* E. Salo and Cundy (Eds.) Streamside Management: Forestry and Fishery Interactions. Institute of Forest Resources, Univ. Washington, Contrib. 57.

Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Useful factors in life history of most common species. DRAFT. Fish.-Eng. Res. Prog., Corps of Eng., North Pac. Div., Portland, OR.

Bjornn, T.C., D.W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. Amer. Fish. Soc. Spec. Publ. 19:83-138.

_____, and R.L. Taylor. 1988. Stream temperature increases and land use in a forested Oregon watershed. Water Res. Bull. 24(1):19-25.

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. J. Fish. Res. Board Can. 9(6):265-323.

_____, M. Hollands, and D.F. Alderdice. 1958. The effect of temperature on cruising speed of young sockeye and coho salmon. J. Fish. Res. Board Can. 15:587-605.

Brown, G.W. 1970a. Predicting the effect of clearcutting on stream temperature. J. Soil and Water Conserv. 25(1):11-13.

_____. 1970b. Water temperature in small streams as influenced by environmental factors and logging. Pp 175-181 *In* J.T. Krygier and J.D. Hall (Dirs.) A symposium: Forest land uses and stream environment. Oregon State Univ.

_____, and J.T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resour. Res. 6(4):1133-1139.

Caldwell, J.E., K. Doughty, and K.S. Sullivan. 1991. Evaluation of Downstream Temperature Effects of Type 4/5 waters. Washington Dept. Natural Resources. Olympia, WA. 71 pp + Apps.

Eaton, J.G., et al. 1995. A field information-based system for estimating fish temperature tolerances. Fisheries 20(4):10-18.

Hope, D. 1993. A Petition to the State of California Fish and Game Commission: Coho salmon (*Oncorhynchus kisutch*); List as Endangered. 32 pp + Attachments.

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. US EPA 910.9-91-001. Seattle, WA. 166 pp.

Moring, J.R. 1975. The Alsea Watershed Study: Effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part II -- Changes in Environmental Conditions. Oregon Dept. Fish Wildl. Fish Res. Rept. No. 9. 39 p.

Moyle, P.B., J.E. Williams, and E.D. Wikramanayake. 1989. Fish Species of Special Concern of California. California Dept. Fish & Game. Inland Fisheries Division. Rancho Cordova, CA. 222 pp.

Naiman, R.J., T.J. Beechie, L.E. Benda, D.R. Berg, P.A. Bisson, L.H. MacDonald, M.D. O'Connor, P.L. Olson, and E.A. Steel. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest Coastal Ecoregion. Pp 127-188 *In* R.J. Naiman (Editor), Watershed Management: Balancing sustainabilty and environmental change. Springer-Verlag. New York, NY. 542p.

Reeves, G.H., F.H. Everest, and T.E. Nickelson. 1989. Identification of Physical Habitats Limiting the Production of Coho Salmon in Western Oregon and Washington. USDA For. Serv. Gen. Tech. Rpt. PNW-245. 18 pp.

Reiser, D.W., and T.C. Bjornn. 1979. Influence of Forest and Rangeland Management on anadromous fish habitat in the western United States and Canada. 1. Habitat requirements of anadromous salmonids. USDA For. Serv. Gen. Tech. Rpt. PNW-96. 54 Pp.

Rishel, G.B., J.A. Lynch, and E.S. Corbett. 1982. Seasonal stream temperature changes following forest harvesting. J. Environ. Qual. 11(1):112-116.

Sullivan, K., J. Tooley, K. Doughty, J.E. Caldwell, and P. Knudsen. 1990. Evaluation of prediction models and characterization of stream temperature regimes in Washington. Timber/Fish/Wildlife Rep. No. TFW-WQ3-90-006. Washington Dept. Nat. Resources. Olympia, WA. 224 pp.

Theurer, F.D., K.A. Voos, and W.J. Miller. 1984. Instream water temperature model. Instream Flow Information Paper 16. U.S. Fish Wildl. Serv. FWS/OBS-84/15. various pages.

Adams,T.N., and K. Sullivan. 1989. The physics of forest stream heating: a simple model. TFW-WQ3-90-007. 30 pp + figs.

Table 1. Location, identification, and inter-station distance of continuous water temperature monitoring stations on the South Fork of the Noyo River, Jackson Demonstration State Forest, Mendocino County, during the summer of 1995.

Map Code[a]	Distance (m)[b]	Location, comments, and stations name (underlined) as used in the text.
1	0	Downstream boundary of JDSF, about 30 m upstream of large debris accumulation.
2	5230	Downstream of the egg-taking station, about 20 yards upstream of unnamed tributary from south.
3[c]	520	Confluence of North Fork of South Fork with the SF.
4[d]	240	Peterson Gulch, about 20 m upstream of confluence with the SF.
5[d]	960	Bear Gulch, about 15 m upstream of confluence with the SF.
6	2230	Downstream of Parlin Creek confluence, riffle upstream of water intake for Parlin Camp.
7[c]	90	Parlin Creek confluence with SF.
8.0[e]	30	South Fork between Parlin Fork and 23 Gulch.
8.1[d,e]	40	23 Gulch Creek, about 25 m upstream of confluence with the SF.
9	330	Upstream of Road 320 crossing about 30 m.
10	2380	20 yards downstream of the upstream boundary of JDSF.
7[c]		
11	1140	Lower Parlin Creek.
12	2050	Mid-Parlin Creek, upstream of Camp 7 Timber Harvesting Plan.
13	1280	Upper Parlin Creek, upstream of Frolic Timber Harvesting Plan.

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[a] Location codes as used in Fig. 1.

[b] Distance is as estimated to the nearest 10 m from the immediately downstream station. Data source is a GIS hydrology layer.

[c] These locations did not have a monitor and thus are not mapped in Fig. 1, but were included because they are major hydrological features.

[d] These stations were on the tributaries to the SF Noyo, but the tabular distances are to the confluence of the streams confluence.

[e] Stations 8.0 and 8.1 are mapped in Fig. 1 as Station 8 due to resolution limitations.

Table 2. Descriptive statistics for water temperatures for a 4-week period centered on noon, July 27, 1995 in the South Fork Noyo River, Jackson Demonstration State Forest.

	Maximum	Minimum	Mean	Std	n
SOUTH FORK NOYO, MAIN STEM					
Upstream Boundary	17.02	13.56	15.10	0.63	412
Upstream of Road 320	19.43	14.02	16.12	1.08	180
Between 23 Gulch & Parlin	17.18	13.71	15.33	0.69	181
Downstream of Parlin	17.66	13.87	15.77	0.81	412
Downstream of Egg-taking Station	18.79	14.33	16.26	0.90	412
Downstream Boundary	19.43	14.18	16.67	1.09	412
SOUTH FORK NOYO, TRIBUTARIES					
PARLIN FORK					
Upper	16.54	13.09	14.63	0.65	270
Middle	17.66	13.25	15.30	0.94	412
Lower	18.14	13.56	15.60	0.97	412
SMALLER TRIBUTARIES					
23 Gulch	14.96	12.63	13.76	0.40	412
Peterson Gulch	15.12	12.63	13.86	0.45	412
Bear Creek	15.12	12.32	13.82	0.66	104

Table 3. Linear regression (y = ax + b) statistics of water temperature at downstream stations regressed against those at the upstream boundary for stations with complete records. Period of recording differed between two watercourses.

	a	b	SE of x	SE of y	r^2
SOUTH FORK NOYO, MAIN STEM STATIONS AGAINST THE UPSTREAM BOUNDARY 14 July - 10 August; df =410					
Downstream of Parlin	1.166	-1.826	0.03	0.35	0.82
Downstream of Egg-taking Station	1.243	-2.500	0.03	0.44	0.76
Downstream Boundary	1.531	-6.445	0.04	0.53	0.77
PARLIN FORK STATIONS AGAINST UPPER PARLIN 14 -31 July; df = 268					
Middle	1.219	-2.491	0.04	0.44	0.77
Lower	1.362	-4.336	0.02	0.26	0.92

Fig. 1. Summer 1995 continuous monitoring station in the South Fork Noyo River drainage, Jackson Demonstration State Forest, coastal Mendocino County, California.

Fig. 2. Time-temperature traces of stations on the South Fork of the Noyo River, summer 1995.
a Trace of Upstream Boundary
b Trace of Road 320
c Trace of between 23 gulch and parlin
d Trace of Downstream of Parlin
e Trace of Egg-taking station
f Trace of downstream boundary

Fig. 3. Time-temperature traces of stations on Parlin Fork, a major tributary to the South Fork of the Noyo River, summer 1995.
a Trace of Upper Parlin
b Trace of Mid-Parlin
c Trace of Lower Parlin

Fig. 4. Time-temperature traces of stations on small tributaries to the South Fork of the Noyo River, summer 1995.
a 23 Gulch
b Bear Creek
c Peterson Gulch

Fig. 5. Time-temperature trace for Hare Creek, summer 1995.

Fig. 6. Cumulative temperature curves for the four-week period centered on July 27, 1995. Stations identified with "**" included incomplete records. (a) Stations on the South Fork Noyo. (b) Stations on tributaries to the South Fork of the Noyo River.

Fig. 7. Longitudinal temperature profile of the monitoring stations on the South Fork Noyo River in Jackson Demonstration State Forest during the four week period centered on July 27, 1995. a) Mean temperature. b) Maximum temperature.

Fig. 8. Comparison of water temperature traces between in-stream water and a streamside 5-gallon bucket near a)the upstream and b) downstream boundaries of Jackson Demonstration State Forest on the South Fork Noyo River, 195.

Fig. 9. Comparison of water temperature traces between a) in-stream water monitors and b) bucket monitors near the upstream and downstream boundaries of Jackson Demonstration State Forest on the South Fork Noyo River, 1995.

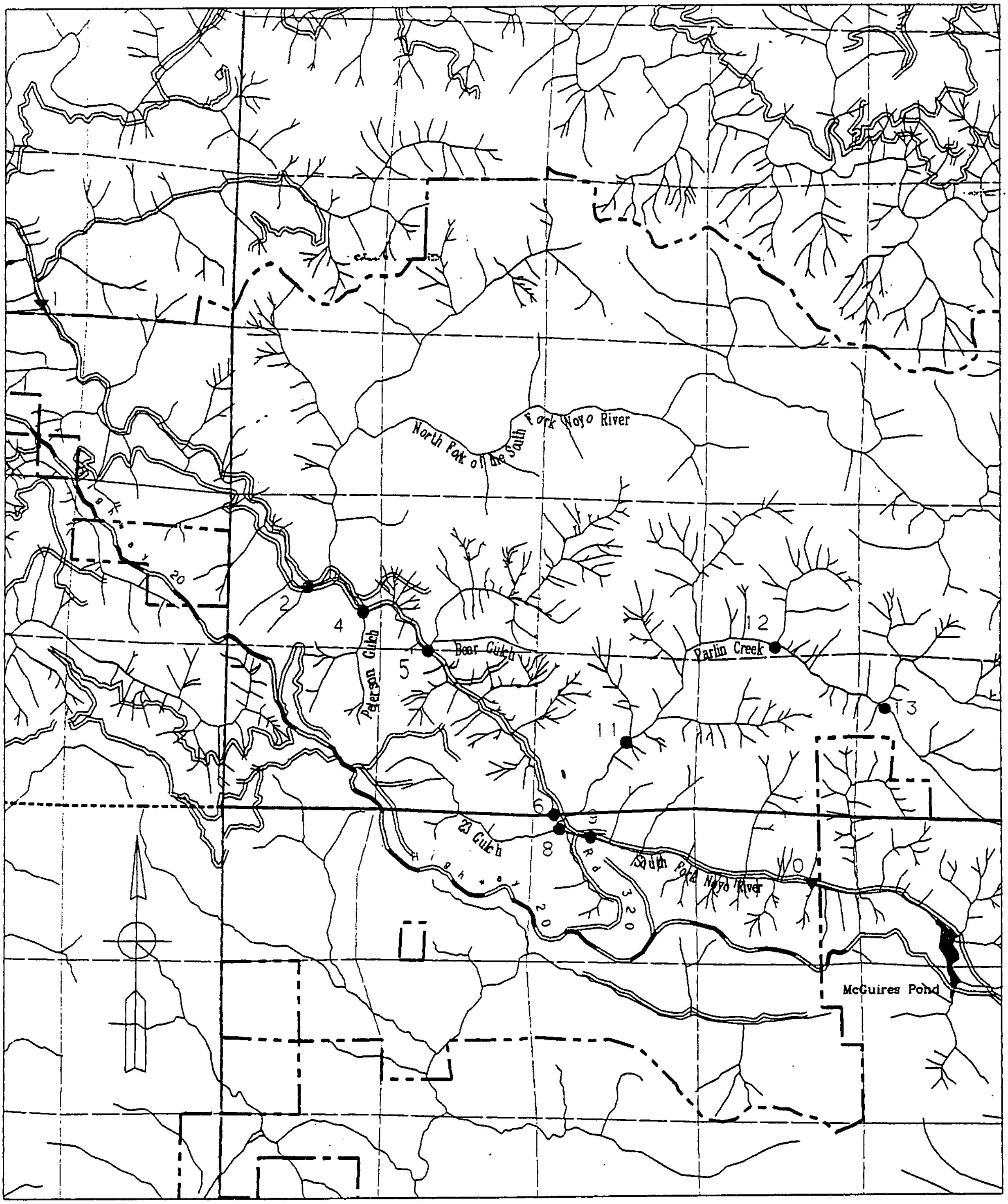


Fig. 1. *Summer 1995 continuous water temperature monitoring station in the South Fork Noyo River drainage, Jackson Demonstration State Forest, coastal Mendocino County, California.*

0 1 2 Kilometers

0 1 2 Miles

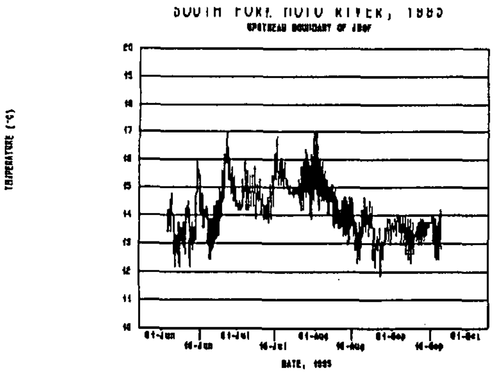
▼ Monitoring stations with buckets

● Monitoring station without buckets

State Forest Boundary

Map produced by California Department of Forestry and Fire Protection Coast Cascade Region GIS

2a



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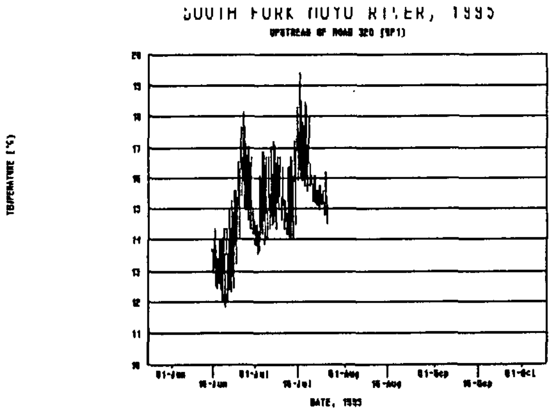

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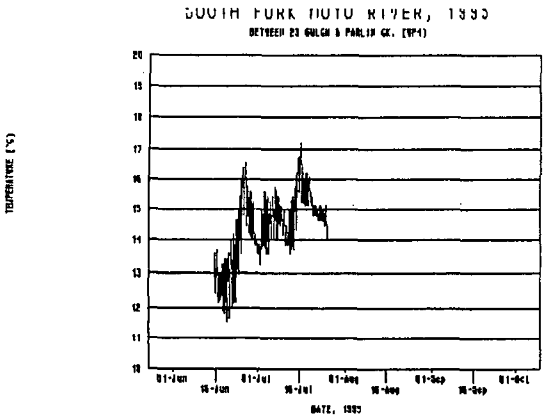

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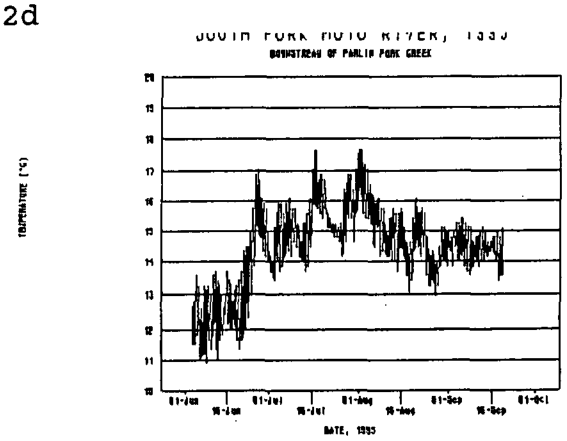

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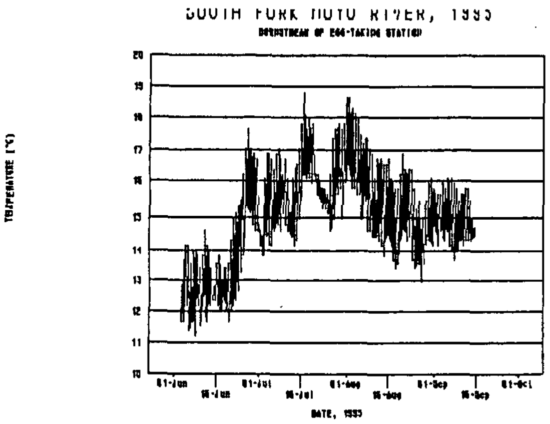

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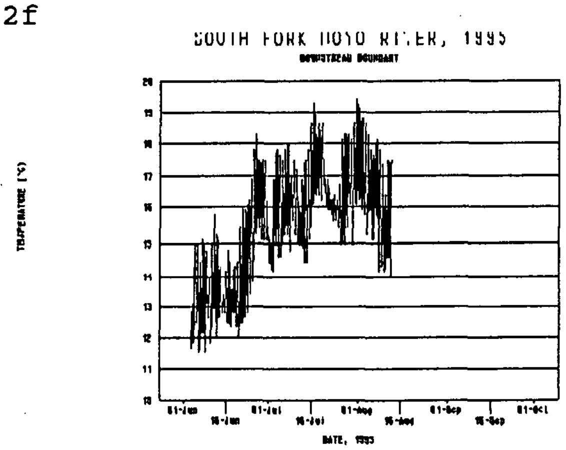

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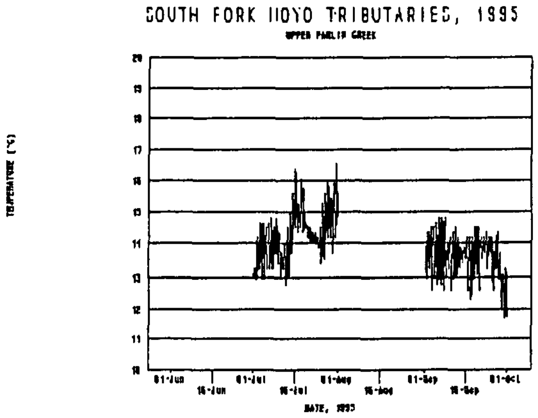
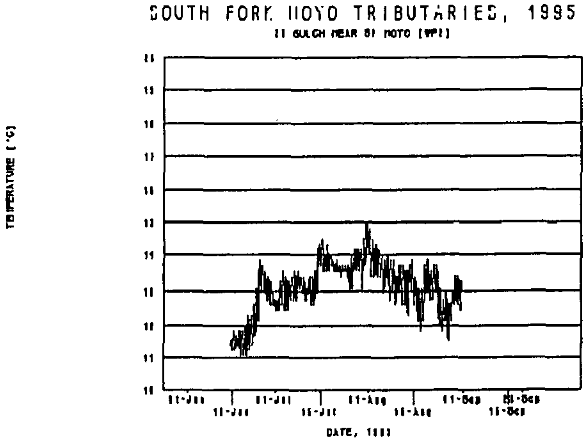


4a



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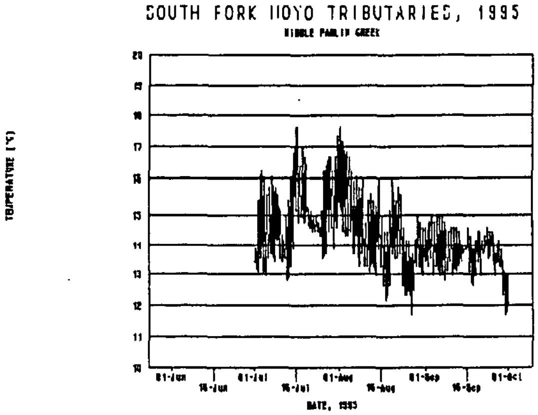

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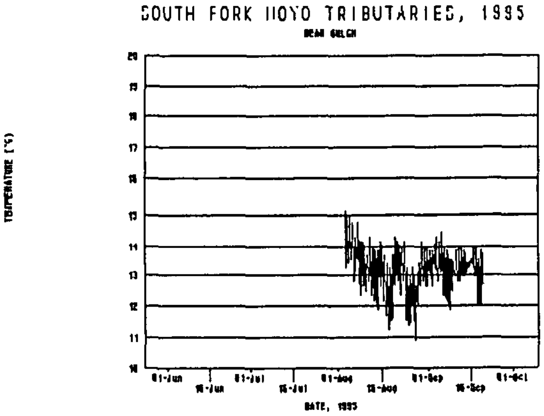

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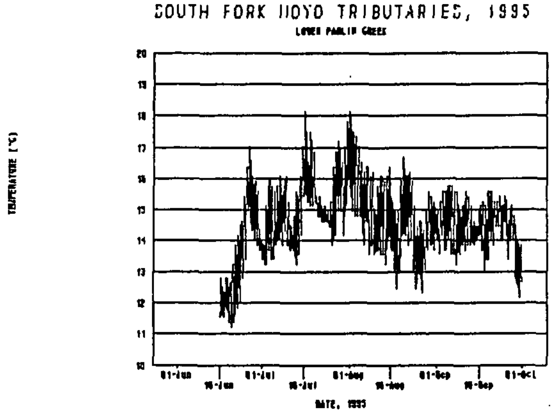

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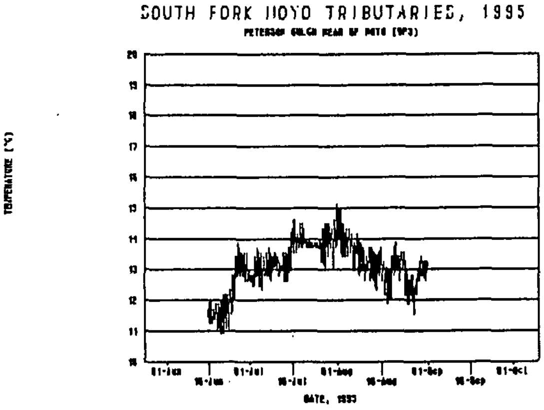
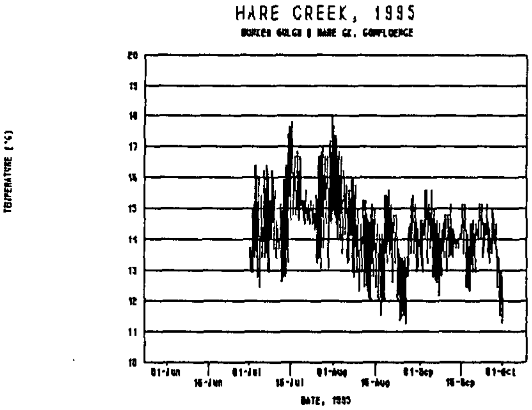
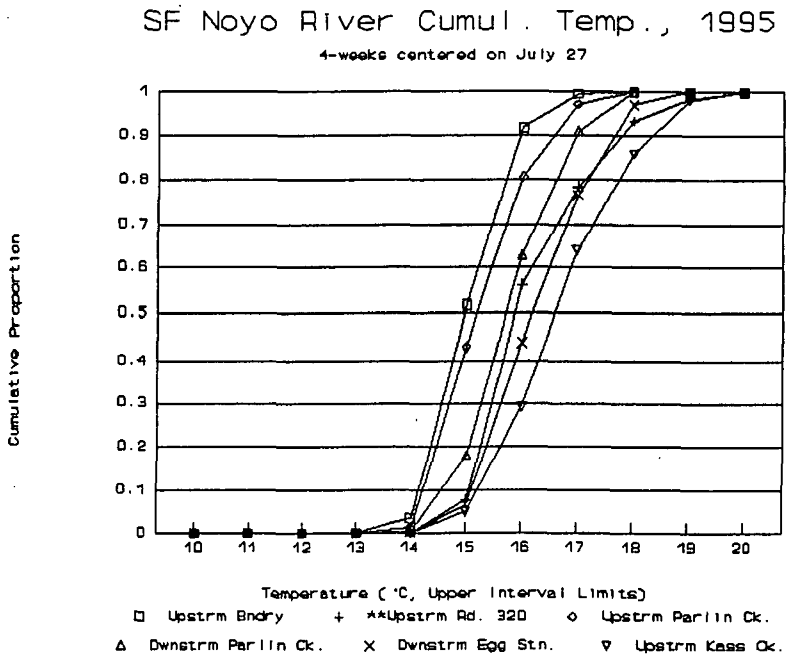
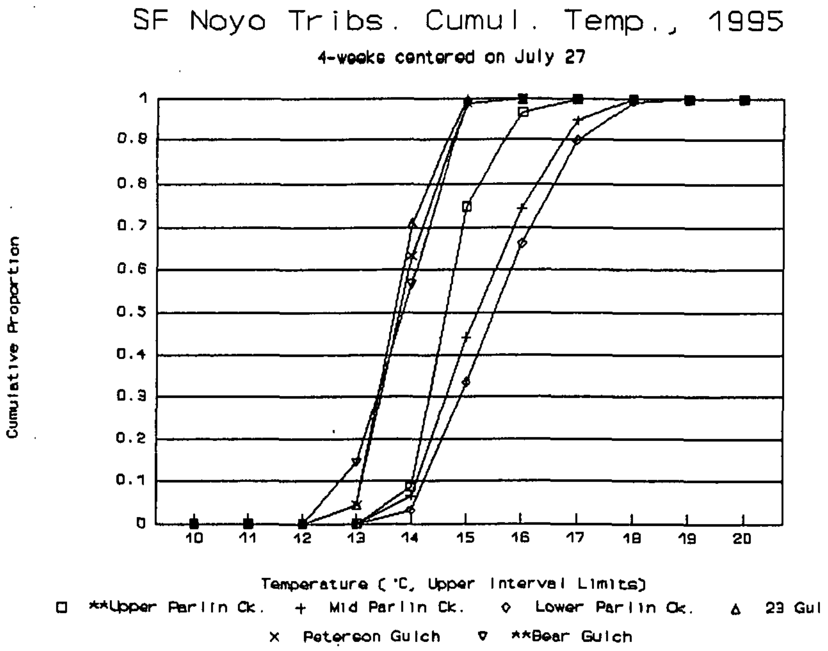



HARE CREEK, 1995
BUNKER GULCH @ HARE CK. CONFLUENCE
TEMPERATURE (°C)
20
19
18
17
16
15
14
13
12
11
10
01-Jun
16-Jun
01-Jul
16-Jul
01-Aug
16-Aug
01-Sep
16-Sep
01-Oct
DATE, 1995

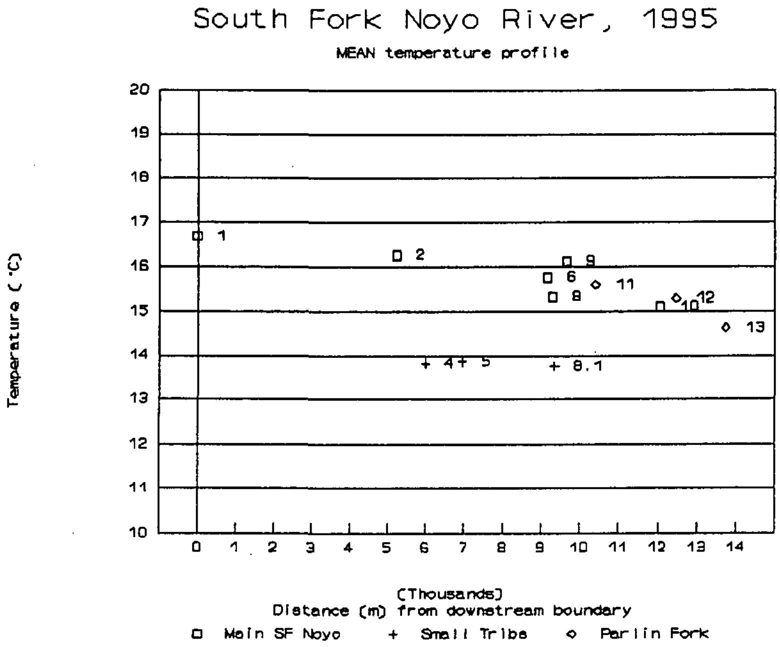
6a


SF Noyo River Cumul. Temp., 1995
4-weeks centered on July 27
Cumulative Proportion
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
11
12
13
14
15
16
17
18
19
20
Temperature (°C, Upper Interval Limits)
□ Upstrm Bndry
+ **Upstrm Rd. 320
◇ Upstrm Parlin Ck.
△ Dwnstrm Parlin Ck.
× Dwnstrm Egg Stn.
▽ Upstrm Kass Ck.

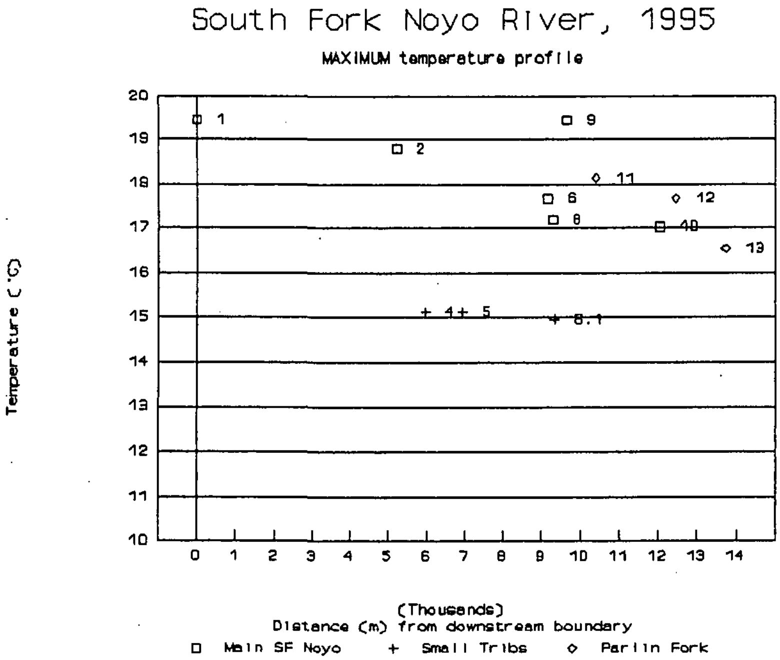
6b


SF Noyo Tribs. Cumul. Temp., 1995
4-weeks centered on July 27
Cumulative Proportion
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
11
12
13
14
15
16
17
18
19
20
Temperature (°C, Upper Interval Limits)
□ **Upper Parlin Ck.
+ Mid Parlin Ck.
◇ Lower Parlin Ck.
△ 23 Gul
× Peterson Gulch
▽ **Bear Gulch

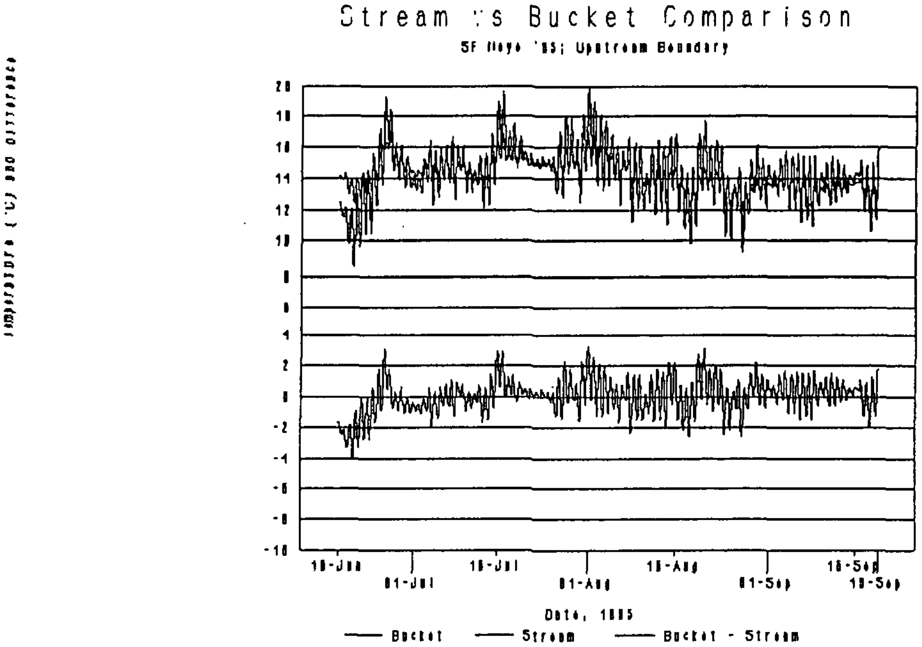
7a


South Fork Noyo River, 1995
MEAN temperature profile
Temperature (°C)
20
19
18
17
16
15
14
13
12
11
10
1
2
9
6
11
8
10
12
13
4
5
8.1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
(Thousands)
Distance (m) from downstream boundary
□ Main SF Noyo
+ Small Tribs
◇ Parlin Fork

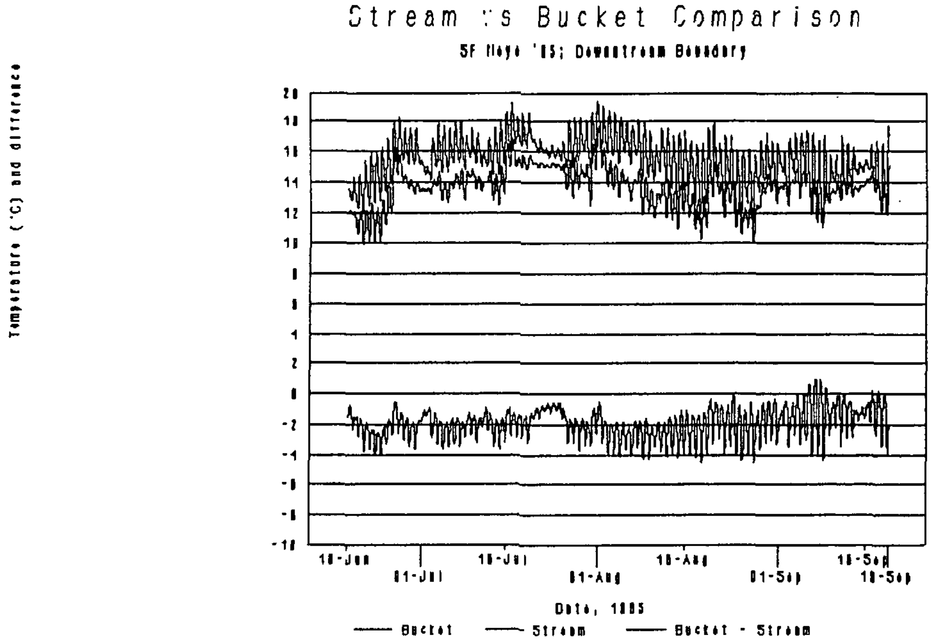
7b


South Fork Noyo River, 1995
MAXIMUM temperature profile
Temperature (°C)
20
19
18
17
16
15
14
13
12
11
10
1
9
2
11
6
12
8
10
13
4
5
8.1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
(Thousands)
Distance (m) from downstream boundary
□ Main SF Noyo
+ Small Tribs
◇ Parlin Fork

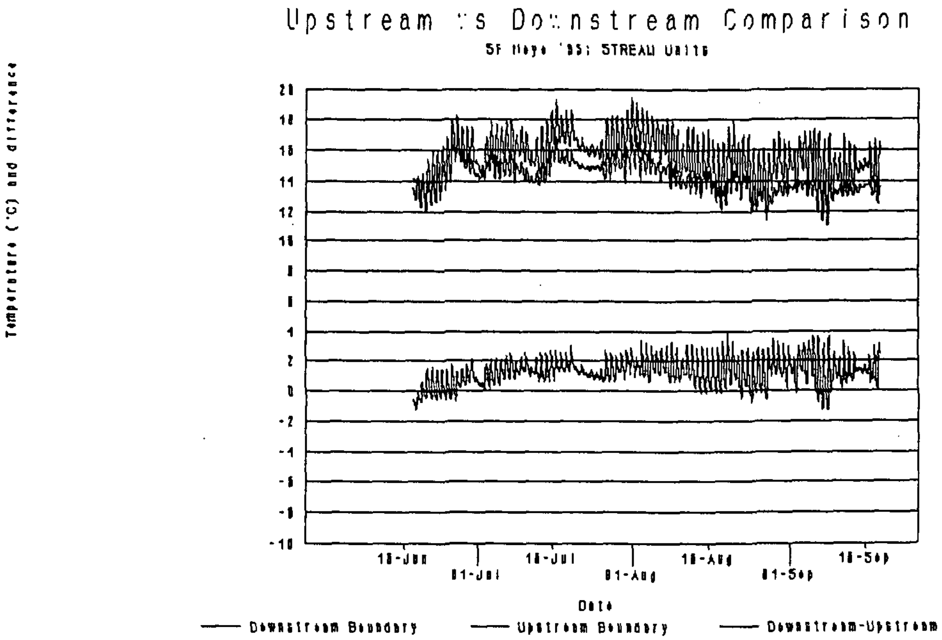
8a


Stream vs Bucket Comparison
SF Hayo '95; Upstream Boundary
Temperature (°C) and difference
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
15-Jun
01-Jul
15-Jul
01-Aug
15-Aug
01-Sep
15-Sep
18-Sep
Date, 1995
Bucket
Stream
Bucket - Stream

8b

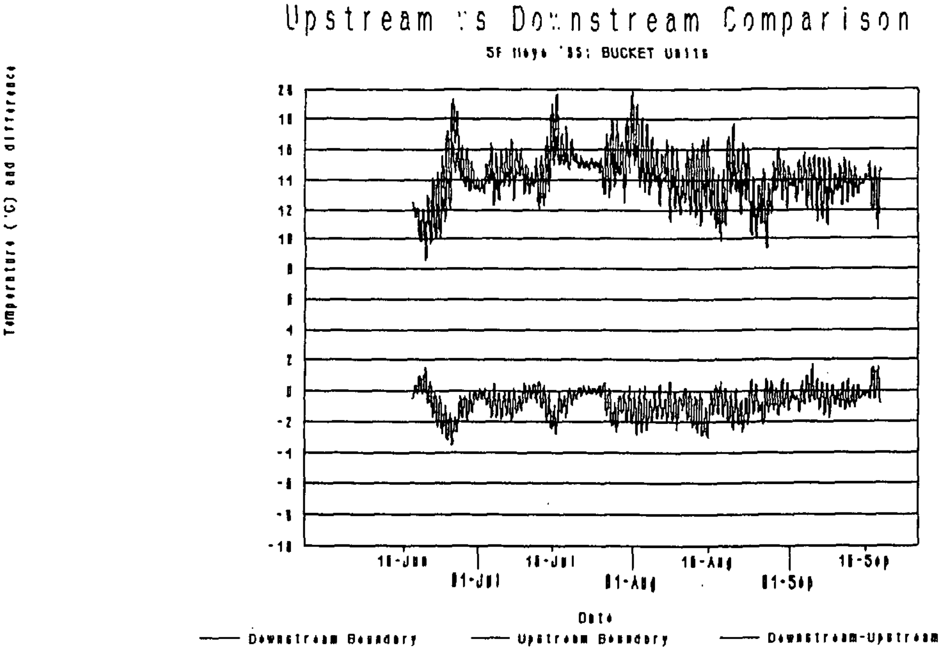

Stream vs Bucket Comparison
SF Hayo '95; Downstream Boundary
Temperature (°C) and difference
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
15-Jun
01-Jul
15-Jul
01-Aug
15-Aug
01-Sep
15-Sep
18-Sep
Date, 1995
Bucket
Stream
Bucket - Stream

9a



Upstream vs Downstream Comparison
SF Hays '95: STREAM Units
Temperature (°C) and difference
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
15-Jun
01-Jul
15-Jul
01-Aug
15-Aug
01-Sep
15-Sep
Date
Downstream Boundary
Upstream Boundary
Downstream-Upstream

9b



Upstream vs Downstream Comparison
SF Hays '95: BUCKET Units
Temperature (°C) and difference
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
15-Jun
01-Jul
15-Jul
01-Aug
15-Aug
01-Sep
15-Sep
Date
Downstream Boundary
Upstream Boundary
Downstream-Upstream