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THERMAL CHARACTERISTICS OF LAVA CAVES IN THE NORTH CAVES AREA AND BAT SPECIES PRESENT AT POND CAVE, CRATERS OF THE MOON NATIONAL MONUMENT, BUTTE COUNTY, IDAHO

RESEARCH CONTRACT
with the

NATIONAL PARK SERVICE
CRATERS OF THE MOON NATIONAL MONUMENT
P.O. BOX 29
ARCO, IDAHO 83213

Barry L. Keller

Department of Biology, Idaho State University
Home Address: 1598 DelMar Circle
Idaho Falls, Idaho 83404

DRAFT Report
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SCOPE OF THE REPORT

Summary of Effort

This report details the continuation of a thermal study and netting assessment of bats in the North Caves Area, Craters of the Moon National Monument, Butte County, Idaho. The study was continued to determine if the summer thermal conditions inside caves, some known to serve as maternity roosts, show consistent patterns of temperatures during the period that pups of Townsend's bats are reared from June to late July and to initiate a study of winter thermal profiles of North Area Caves. This research is part of a study where emphasis has been placed on minimal disturbance of bat populations residing at CMNM. Research completed during the initial 3 years of field effort are summarized in Keller and Saathoff (1995, 1996), and Keller (1997).

Taxonomic Placement and Sensitivity of Species

Keller (1985) initially published a key to the bats of Idaho that reviews most of the nomenclature for Idaho species. Evaluation of the nomenclature of species expected in the study area has been assessed from Hall, (1981), Van Zyll de Jong (1984) and Jones, et al., (1992) including species names updated from the nomenclature in Hall (1981) by Frost and Timm (1992) and Tumlison and Douglas (1992). Frost and Timm (1992) restored the traditional generic name of Townsend's big-eared bat from Plecotus to Corynorhinus, a standard used in this report. Silver-haired bats (Lasionycteris noctivagans) and Big-brown bats (Eptesicus fuscus, uncommon or found near coniferous trees, have not been captured to date. They have been documented using caves on the Idaho National Engineering and Environmental Laboratory, however (Keller, Bosworth and Doering, 1993).

Bat species listed by the Conservation Data Center, Idaho Department of Fish and Game, as sensitive, and Groves, et al. (1997) have developed global rankings (Master, 1991) to document the status of Idaho bats. These rankings, developed after the 1996 elimination of the "C" series classification for vertebrate species by the U.S. Fish and Wildlife Service, need to be considered when assessing potential disturbance to bats located at Craters of the Moon National Monument. In Idaho, Townsend's Big-eared bat, (Corynorhinus townsendii) and Myotis thysanodes are listed as an S2 (imperiled because of rarity), and S1 (critically imperiled) species and are unprotected and protected respectively (Groves, et al. 1997). The latter species was netted at Craters for the first time during the summer of 1997. Alternatively, Long-eared Myotis (Myotis evotis) and Long-legged Myotis (M. volans) are listed as Idaho S3 (vulnerable) species. The latter two species are currently listed G5 globally, suggest they are demonstrably

widespread, abundant, and secure nationally.

Corynorhinus townsendii, and M. thysanodes do not appear to be common at CMNM. Consequently, both should be considered sensitive and their habitats protected prior to undertaking any action that may eliminate local populations. Other species expected in caves or trees in the study area, as assessed from Hall (1981), on the basis of specimens held in museum collections containing Idaho bats, or on the basis of a previous studies at the Idaho National Engineering Laboratory are detailed in Keller and Saathoff (1996), and appear secure.

METHODS

Field Assessment of Bat Populations

Sites, established and studied in 1996 (Keller, 1997), were surface located with a non-military corrected GPS unit (Garmin Model 12), as shown in Table 1. Summer netting was limited to a single paired re-assessment of bat species using Pond Cave to reduce the impact of disturbing bats drinking water in this cave. On June 28, I sampled the **inside** of Pond Cave from daylight to 12:00 am with a double-stranded harp trap assembled near the smallest opening and a single 110d 2 ply 2 and 3/8 inch) mesh black nylon mist placed perpendicularly to the long axis of the interior space. A larger 4-tier mist net, attached to poles, was established and monitored by an assistant located on the exterior of the main opening. Consequently, bats entering the cave by evading the net coverage at the main opening were subjected to potential capture inside the cave. Captured individuals were sexed, weighed with a Pesola scale to the nearest tenth of a gram, the right forearm was measured with a Fowler Ultra-cal digital caliper, and a numbered Hughes plastic band was placed on the forearm. A second capture-release collection was completed on July 22, 1997 and two bats were fitted with Buchler (1978) light tags to determine if the direction of flight upon release was consistent with data collected the prior year.

A daylight evaluation of winter use of Pond Cave was completed on 13 March 1998, when the site was reached by snowshoe to remove and replace thermal logging equipment established in April and June 1997. No bats were found. On 17 March the North Cave area was reached by snowshoe but Sand Trap Cave, Lower Antelope Cave and the center tube and lower chamber of Screaming Jaws of Death Cave were blocked by snow and could not be accessed. Subsequent soft snow prevented me from checking for hibernating bats in part of Screaming Jaws of Death Cave before hibernation had ended in 1998. The other caves were reached. No Townsend's bats were present in Upper Antelope and in the mouth area of Screaming Jaws of Death. A single Townsend's bat was found hibernating on the ceiling of

Table 1. GPS locations for loggered caves, Craters of the Moon.

Cave Name	Location d=degrees				Altitude
Pond Cave	North	43d 27.594	West	113d 34.461	5975 ft
Sand Trap	North	43d 27.292	West	113d 35.385	6020 ft
Two Step	North	43d 27.297	West	113d 35.331	6023 ft
Upper Antelope	North	43d 27.353	West	113d 35.412	?6518 ft
Screaming Jaws	North	43d 27.415	West	113d 35.454	6046 ft
Dome Cave	North	43d 27.339	West	113d 35.651	5879 ft

the connection between the second level and the lowest chamber of Two Step Cave. A thermal gun reading of this bat's temperature on March was 34F.

Temperature Analysis of Caves

On 15 April 1997, when caves were accessible, waterproof Optic StowAway 32K loggers (Onset Computer Corporation, Pocasset, MA) were substituted for the Hobo-temp loggers used during the initial thermal characterization of caves at Crater's (Keller, 1997). In the North Caves area, the new loggers were suspended by wire from the same ceiling Orjan cement-wall picture hooks used to suspend the Hobo-temps during the initial phases of the study but the number of loggers was reduced to a single device in all but Screaming Jaws of Death Cave. Pond Cave, a site designated for additional research, was added during the summer of 1997. Re-assessment was continued on Two Step, Sand Trap, and Upper Antelope Cave, considered important potential maternity colony sites, to assess thermal consistency of sites among summers and the period of assessment was expanded to include winter at several sites. Thus, temperature logging equipment, established in 1997, (Table 2: Keller (1997), was maintained until August 29, 1999 excepting in Upper and Lower Antelope Cave and Dome Cave. At the termination of the study, Two step and Sand Trap Cave each contained a single logger, Pond Cave contained two loggers, whereas the complex morphology and Townsend bat history of Screaming Jaws of Death Cave, required 5 loggers. The complete time sequence of the data collected with these new loggers is summarized in Table 2.

RESULTS

Field Assessment of Bats

Pond Cave has two entrances that bats appear to use. A single pond, located in a separate partially enclosed area on the left side of this oblong cave, has been present since the cave was first netted and has always contained a lower ice layer. No hibernating bats have been found in this cave but the cave pond appears to be used extensively by five bat species as established by direct observation and two netting episodes that yielded a total of 47 individuals during two nights of netting in 1997 (Table 3). Additionally, during this summer netting, a new species to Craters, Myotis thysanodes was collected at this cave, all but a few captured bats were banded, and two male M.evotis were Buchler tagged and released near the cave opening. Neither light-tagged bat flew toward the Grassy Cone Area as contrasted to the bats released in 1996. A July search of the trees in the GCA also failed to produce evidence of woodpecker holes, commonly used

Table 2. Optic StowAway waterproof temperature (range -5 to 38C) logger locations for 1997 1999 research at Craters of the Moon National Monument. Loggers were placed in service as shown on right. Interval between samplings was 6 minutes 24 seconds for intial loggers shown with a *, and subsequently at 15 minute intervals in continuous service until removal unless otherwise indicated. Note some sites, sampled in 1997 were abandoned for data gathering and new locations were established in some sites already under investigation.

Cave Name and Internal Portion		Logger Position	Logger s/n#	Title Figure	Date Start Date Stopped
Two step	*	upper chamber, twilight zone suspended on hook	109856	Two Step #1	19 Apr. 97 11 Sept. 97
Two step		continue same location	109761	Two Step #2	17 Mar. 98 03 Oct. 98
Two step		continued same location	103433	Two Step #3	03 Oct. 98 29 Aug. 99
Sand trap	*	upper chamber, twilight zone suspended on hook	103439	Sand Trap #1	19 Apr. 97 11 Sept. 97
Sand trap		continue same location	109814	Sand Trap #2	02 Nov. 97 31 July 98
Sand trap		continued same location	103457	Sand Trap #3	03 Oct. 98 29 Aug. 99
Upper Antelope	*	upper chamber, twilight zone suspended on hook	109760	Upper Antelope #1	19 Apr. 97 11 Sept. 97
Upper Antelope		continued same location	124438	Upper Antelope #2	13 Nov. 97 17 Mar. 98
Lower Antelope	*	near ceiling just inside entrance near downfall	103434	Lower Antelope #3	19 Apr. 97 11 Sept. 97

Screaming Jaws of Death Cave

Front Mouth	*	near ceiling, at entrance	109821	Mouth #1	02 Nov. 97 17 Mar. 97
		change to low temp logger -37 to 46C in case, 4hr, 48 minute samplings	5111	Mouth #2	17 Mar. 98 03 Oct. 98
		continue with low temp logger mailed to Onset 9/99 to read	86761	Logger failed	03 Oct. 98 unavailable
Center Mouth		near ceiling, added later (switch to 1-hr intervals)	109820	Center Mouth	17 Mar. 98 19 Feb. 99
Left Throat	*	upper chamber, left wall near ceiling	103457	Left Throat #1	19 Apr. 97 11 Sept. 97
		continue same location	109821	Left Throat #2	02 Nov. 97 17 Mar. 98
		continue same location	109817	Left Throat #3	17 Mar. 98 19 Feb. 99
Tube	*	middle lava tube, under mouth, 1/2 way to end	109857	Center Tube #1	19 Apr. 97 11 Sept. 97
		continued same area	103436	Center Tube #2 throat 98	19 Apr. 98 03 Oct. 98
		continue same area	109856	Center Tube #3	03 Oct. 98 29 Aug. 99
Lower Chamber	*	lower chamber under throat	103461	Lower Chamber #1	19 Apr. 97 03 Oct. 97
		continue same area	109816	Lower Chamber #2	02 Nov. 97 19 Apr. 98

	continue same area	109856	Lower Chamber #3	19 Apr. 98 03 Oct. 98
	continue same area	109761	Lower Chamber #4	03 Oct. 98 29 Aug. 99
Pond Cave				
	* on ceiling, at entrance	109817	Entrance Cave #1	28 June 97 20 Nov. 97
	continue same area	103457	Entrance Cave #2	13 Mar. 98 03 Oct. 98
	continued same area	103434	Entrance Cave #3	03 Oct. 98 29 Aug. 99
	* on ceiling, near pond	109761	Near Pond #1	19 Apr. 97 11 Sept. 97
	continue same area	103433	Near Pond #2	13 Mar. 98 03 Oct. 98
	continued same area	186075	Near Pond #3	03 Oct. 98 29 Aug. 99
Dome Cave	* on ceiling, lower room incorrect cave name	103437	Dome Cave	15 Mar. 97 08 Aug. 97 abandoned

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Table 3. Captured and released bats on July 21-22, 1997, at Pond Cave, Craters of the Moon National Monument. Blue Hughes plastic bands were used during June and yellow bands during July. Capture location: E=exterior entering. I= internal capture

Species and Date	Common Name	Sex	Band #	Forearm length(mm)	Weight (grams)	Direction
July 21, 1997, Blue Banded.						
Myotis thysanoides	Fringed Myotis	F	none	39.7	6.4g	E
Myotis evotis	Long-eared Myotis	M	21	37.6	unk.	E
Myotis volans	Long-legged Myotis	M	29	40.0	8.0g	E
Myotis evotis	Long-eared Myotis	F	30	39.0	6.0g	E
Myotis lucifugus	Little Brown Myotis	M	28	40.0	7.0g	E
Myotis lucifugus	Little Brown Myotis	F	22	40.9	7.2g	E
Myotis lucifugus	Little Brown Myotis	M	27	39.4	7.4g	E
Myotis evotis	Long-eared Myotis	M	26	38.3	5.2g	E
Myotis evotis	Long-eared Myotis	M	25	36.4	4.8g	E
Myotis volans	Long-legged Myotis	F	23	40.0	7.8g	E
Myotis volans	Long-legged Myotis	M	24	39.3	7.6g	E
Myotis evotis	Long-eared Myotis	F	58	38.5	5.0g	E

Corynorhinus townsendii	Townsend's Big-eared Bat	F	57	44.4	10.4g	I lactating
Myotis lucifugus	Little Brown Myotis	M	53	40.0	6.4g	I
Myotis lucifugus	Little Brown Myotis	M	59	unk.	8.0g	I
Myotis lucifugus	Little Brown Myotis	M	54	38.6	6.8g	I
Myotis lucifugus	Little Brown Myotis	F	52	40.6	7.4g	I
Myotis lucifugus	Little Brown Myotis	M	56	40.6	6.4g	I
Corynorhinus townsendii	Townsend's Big-eared Bat	F	60	45.0	9.4g	I
Myotis lucifugus	Little Brown Myotis	M	55	38.2	7.0g	I
Myotis thysanoides	Fringed Myotis	F	51	43.5	6.8g	I
Myotis lucifugus	Little Brown Myotis	M	81	39.5	7.6g	I
Myotis thysanoides	Fringed Myotis	M	90	41.6	5.8g	I
Myotis lucifugus	Little Brown Myotis	F	82	40.6	8.6g	I
Myotis lucifugus	Little Brown Myotis	M	87	39.9	7.0g	I
Myotis lucifugus	Little Brown Myotis	F	86	39.6	7.2g	I

July 22, 1997, Yellow Banded.

Myotis evotis	Long-eared Myotis	M	41	37.4	4.8g
Myotis lucifugus	Little Brown Myotis	M	44	38.0	7.4g
Myotis lucifugus	Little Brown Myotis	M	42	39.5	7.4g

Myotis lucifugus	Little Brown Myotis	M	49	36.9	7.0g
Myotis lucifugus	Little Brown Myotis	M	48	40.4	7.4g
Myotis lucifugus	Little Brown Myotis	M	43	37.8	7.2g
Myotis lucifugus	Little Brown Myotis	M	45	38.7	7.8g
Myotis lucifugus	Little Brown Myotis	M	47	38.6	6.4g
Myotis lucifugus	Little Brown Myotis	F	46	41.3	8.0g
Myotis lucifugus	Little Brown Myotis	F	50	38.9	7.4g
Myotis lucifugus	Little Brown Myotis	F	68	40.4	7.0g
Myotis lucifugus	Little Brown Myotis	F	62	38.2	7.2g
Myotis lucifugus	Little Brown Myotis	F	61	40.4	7.4g
Myotis lucifugus	Little Brown Myotis	F	none	40.1	8.0g
Myotis evotis	Long-eared Myotis	M	66	39.5	5.2g
Myotis evotis	Long-eared Myotis	escaped as data sought			
Myotis evotis	Long-eared Myotis	M	67	33.0	4.2g
Myotis lucifugus	Little Brown Myotis	F	69	38.0	7.0g
Myotis lucifugus	Little Brown Myotis	F	64	42.2	7.0g
Myotis lucifugus	Little Brown Myotis	M	70	40.1	8.0g
Myotis lucifugus	Little Brown Myotis	F	06	41.6	8.0g

by bats in other geographical areas (see Bohn, 1999). Thus, it appears that the bats using pond cave may not reside in grassy cone trees. Exfoliating bark present in at GCA may support some individual bats however. None of the bats banded the first night were recaptured during the second night of netting. One Townsend's bat was seen but not captured that entered and exited the small opening at the end of the long axis of the cave the second night. Further, although small, this opening was used as a route into the cave based on the number of bats caught flying internally during the first evening of capture effort (Table 3).

Winter assessment of Screaming Jaws of Death was initiated during 1998. Between the mouth and the lower chamber, which are connected by a "throat tube", a long downward-slanting tube, referred to as the center tube (Table 2) traverses from the throat under the upper chamber (=mouth) area. Unfortunately, this tube has not been sampled for more than one winter as a result of deep snow blocking access to it through the lower chamber. When checked on 15 April 1998, a single Corynorhinus townsendii was found still hibernating in this tube. This record re-substantiates that hibernation occurs in this cave (see Keller, 1997). The subsequent thermal logger in this area was not removed August, 1999, when hibernating individuals would no longer be present. On this date, a drop in oxygen was detected with a Passport gas detector, a safety device I always used when entering closed lava tube caves that contain enclosed areas. But the center tube likely contained bats during the winter of 1998-99 as a result of the significant variation in microclimates available for use by bats in Screaming Jaws of Death detailed below.

Temperature Analysis

Individual 15-minute measures of temperatures are plotted as individual unconnected circles for the duration of the 1997-99 samplings. Twenty-nine figures have been developed for the sample periods shown in Table 2, and a set of comparative figures in degrees F are available in the Appendix. The profiles of historical maternity colony sites at CMNM may be contrasted against the thermal profile of a known northern Idaho maternity colony site first studied during 1999 by reviewing the final figure presented in this report.

Summer Temperature Consistency
Two Step, Sand Trap, Upper & Lower Antelope

The 1997 thermal profiles for Two Step (Fig. 1), Sand Trap (Fig. 4), Upper and Lower Antelope Caves (Figs. 7 and 9) are similar considering the morphological differences among cave shapes. However, the subsequent patterns among summers

exampled in each series of Figures for each of the areas demonstrates reduced variation and divergence among these caves during the summers of 1998 and 1999 (see for example the summer data for Sand Trap Figures 4,5, and 6). Upper thermal levels in July, when Townsend pups would be reared, exceed 25C (80F) at only Two Step consistently (Figs 1-3). In summary, the extremes of each plot differ among caves within years and between years, perhaps explaining why Keller and Saathoff (1995; 1996) noted different caves being used each year to raise pups. Data for the winter of 1997-98 were not taken for Two Step but are available during the winter of 1998-99 (Fig 3). By November the lower thermal limit permitting bat survival is exceeded but the temperature increased above this limit after a cone of snow persisted blocking the entrance. Winter data, available for both 1997-8 (Fig. 5) and 1998-9 (Fig 6) for Sand Trap, a cave sealed with snow during both winters of study, also demonstrate a lower limit that would kill hibernating bats in the upper chamber until the snow seal is completed. Consequently, in both these caves, bats would only survive if the lower chamber was always warmer. It seems doubtful that individuals would survive should a temporary thaw create a re-equilibration of the internal temperature. The data suggested that a course evolutionary strategy would favor exclusion of both caves for permanent winter hibernation by more than a few individuals.

Upper and Lower Antelope caves are connected but differ significantly in configuration, exposure, and aspect. Lower Antelope is accessed through a large opening approximately 6m below the smaller opening of Upper Antelope. Upper Antelope cave, based upon the temperature data available for the winter of 1997-98 (Fig. 8) and direct observation, may open and close frequently, conditions that would produce a lethal environment for bats unable to located temperatures above freezing in Lower Antelope. Because Lower Antelope could not be reached without roping from the upper chamber, it remains to be investigated whether equilibration occurs providing an environment that would prevent death in this area. Lower Antelope has always been sealed during the winters of 1996, 1997, and 1998 by deep snow. One dead bat was found clinging to the ceiling in Upper Antelope during the winter that site was logged. It can not be established that other health conditions did not affect the survival of this bat, however.

Thermal Conditions in Screaming Jaws of Death

In a previous report, Keller (1997) detailed finding C. townsendii present in Screaming Jaws during the late summer of 1996 and in the center tube in April 1997. I proposed that females could move to the center tube (middle chamber) of this cave as summer heat levels increase in the mouth area. In 1996, a logger established in the throat area of the mouth demonstrated high temperatures in the short time interval

before the logger failed (Keller, 1997:Fig. 9). A logger establish at ceiling height near the lip area (Fig 11) and in the center of the mouth area (Fig. 12) established temperatures exceeding 35C (92F) in the area just under the lava cap that extends to the back of the throat (Fig 13 and 15). Winter conditions in the lip area (Fig 10) and the throat area remain relative stable and are usually above freezing (Fig 14). Temperature data in the mid-level tube in early April, when snow was still on the area in both 1997 and 1998, ranged from 5 to 8C (Figs. 16 and 17). During both these periods, some Townsend's bats were still hibernating in the tube. Data collected from October 1998 to April 1999, demonstrate (Fig. 18) a highly stable environment exists during winter in this area. The lower chamber, which is closed by winter snow, provides warmer above freezing conditions excepting for a few very short intervals in January of both years (Fig. 20 and 22).

Thermal Conditions at Pond Cave and Dome Caves

Summer thermal conditions in Pond Cave are cooler than those found in the other caves studied, ranging from 22-25C at peak in summers at the entrance (Figs. 23-25) but are almost 5 degrees cooler near the pond (Figs. 26-28). Considerable variation is demonstrated among years. Temperatures during winter periods at both sites (Figs. 24, 25, 27, 28) demonstrate temperatures that are significantly below freezing. Similar conditions were found in Dome Cave (Fig. 29) from March through August in 1997.

DISCUSSION

To evaluate the habitat requirements of bats within natural sites, data are needed on changes in the thermal envelope produced by variability in cave morphology, and weather seasonally and among years. This present study has demonstrated that considerable variation exists among cave temperatures in the North Cave Area, both seasonally and among years. Predictions can now be made about occupancy of similar caves at sites that have not been evaluated. Caves containing space just beneath the surface likely provide significant habitat that supports nursery colonies if the cave contains cooler lower chambers that can provide relief from excessive heat. The environmental conditions of roosts and the thermal physiological needs of young pups and/or pregnant female bats also likely undergo seasonal patterns of change. On the basis of the data collected to date, it appears that CMNM maternity colonies move to caves containing more optimal thermal envelopes as they change during summer periods. Thus, absence at a site one year does not suggest that the site was abandoned. Rather, as a result of variation in time when a cave is checked, the presence of a colony may have been

missed. A life-history strategy of movement would likely be of selective advantage by lessening the probability of extinction of either pups or females as a result of natural disaster, sudden thermal inconsistencies, or discovery and predation. In sum, success of rearing young in small desert caves likely requires season movement among optimal thermal envelopes, a condition that would make finding maternity colonies difficult. To test this hypothesis, a continuing yearly assessment of the North Caves Area will be required. Only deeper chambers in the North Cave Area provide the necessary winter thermal temperatures for hibernation similar to those described by Bosworth (1994) Doering (1996) and Wackenhut (1990) for large hibernal caves on the INEEL

Screaming Jaws of Death Cave likely serves as a central nursery colony site because it demonstrates temperatures similar to those needed to raise pups as established by independent study (see Fig 30, data being prepared for publication). The center tube of Screaming Jaws of Death appears to be a good hibernal site. To demonstrate the annual extent of Townsend's bat use, it will be necessary to use a rope ladder to gain axis into the middle tube and lower chamber of this cave during winter and to exit count this cave with high quality night-vision equipment during summer. During winter assessment, entrance will be required through the mouth area and bats should be counted under red-light illumination. No less that three individuals should participate in these counts to assure safe passage by the individual counting bats.

On the basis of the number and kinds of bats caught during two independent years at Pond Cave, this cave should be closed to human intrusion during summers. Pond Cave likely is used as an important site to reduce thermal load in foraging bats. Direct observation also indicates that a very large number of bats enter this cave to drink.

Management Recommendations to Enhance Bat Populations

1. Pond Cave should be checked during the day in mid summer yearly. In dry years, it will be of advantage to artificially add water to this pond. The cave should be placed off limits and signed to prevent entrance by summer visitors to CMNM.

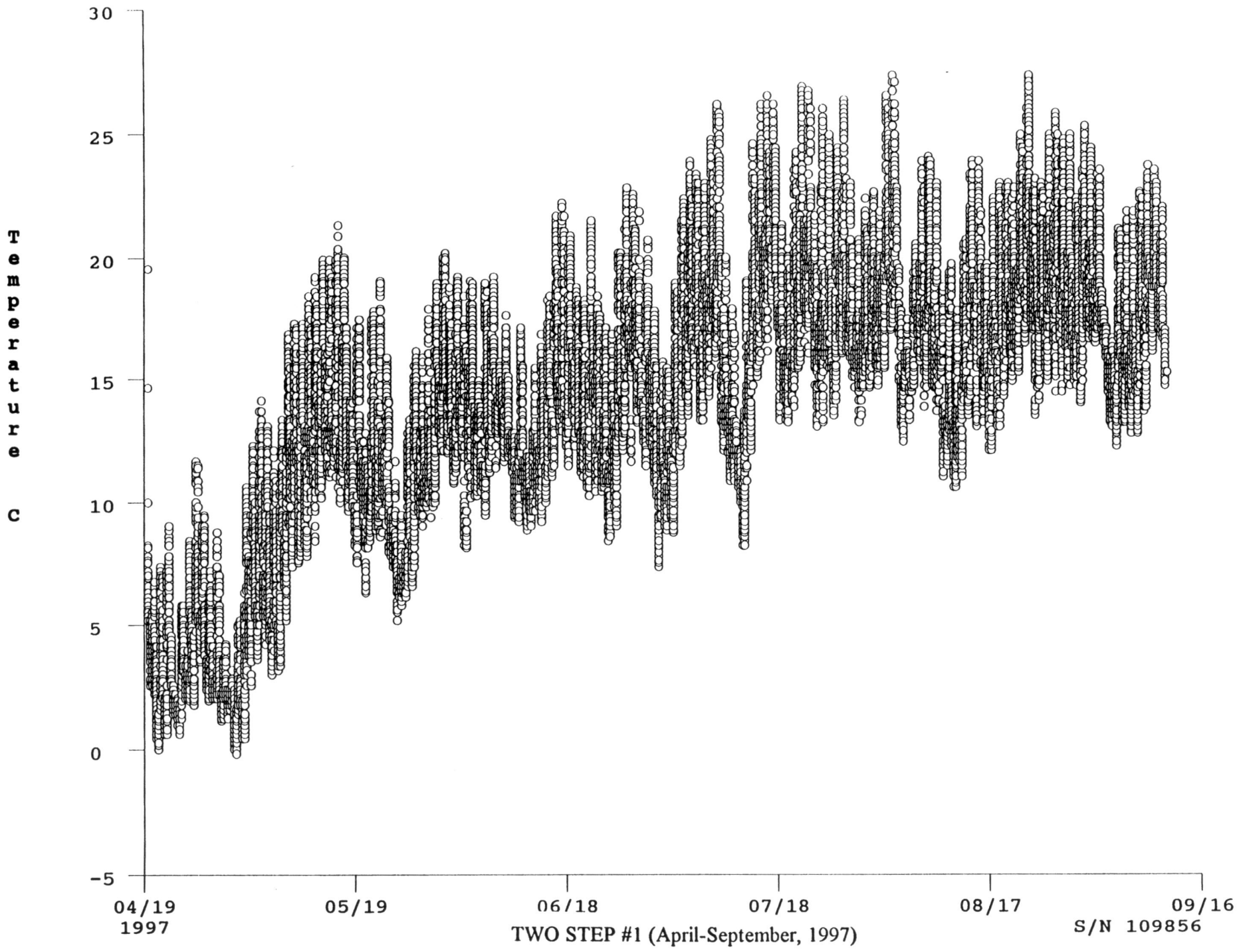
2. A fixed procedure should be developed and employed to develop a data base on changes in bat density and species composition at CMNM. Pond Cave could be netted every other year for two nights in mid July. Arco Tunnel and Screaming Jaws of Death Cave should be counted every winter.

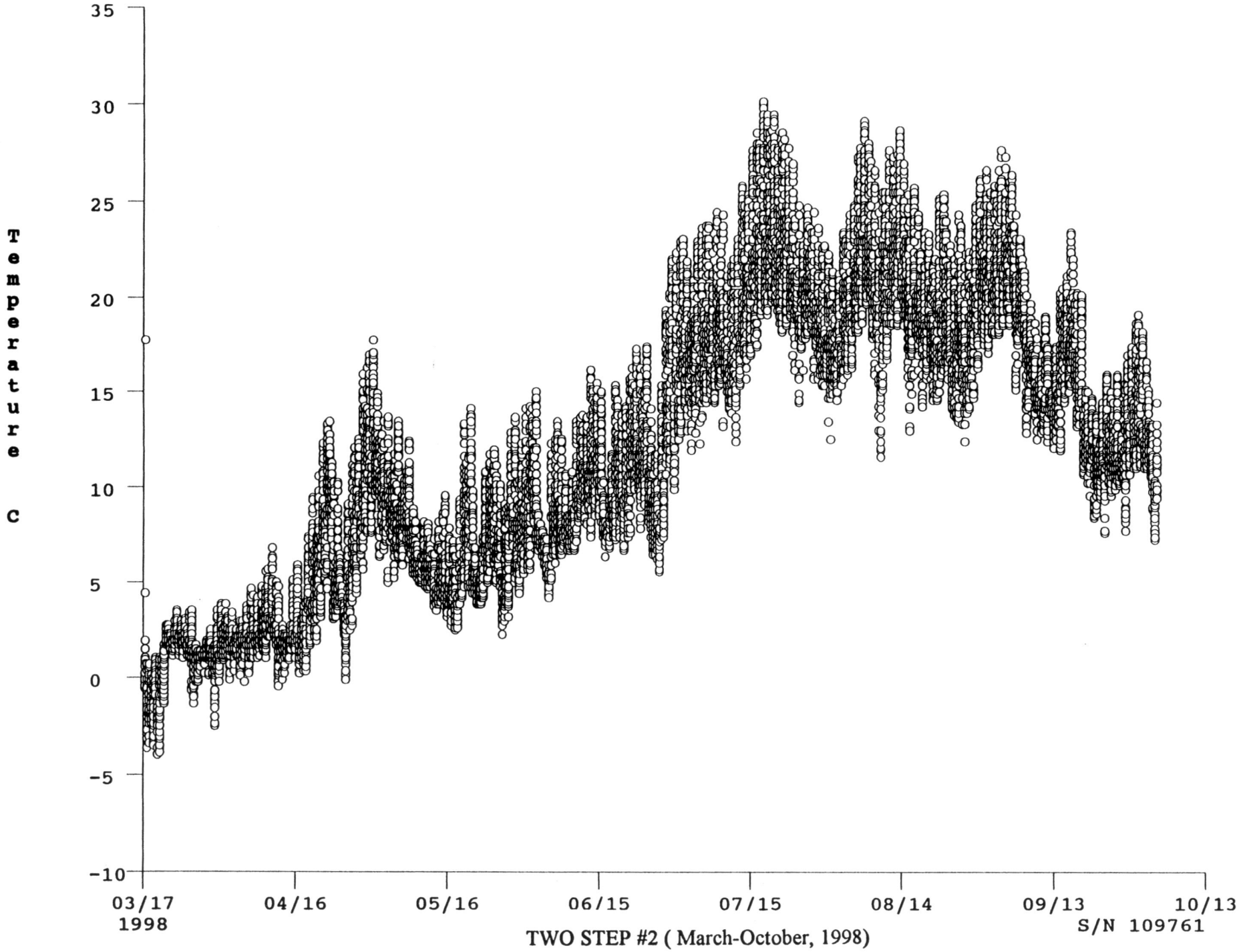
3. A three dimensional map of Screaming Jaws of Death Cave should be prepared to permit identification of the exact sites where loggers have been placed in this study. Mappers should not enter this cave from June to September or from November to April.

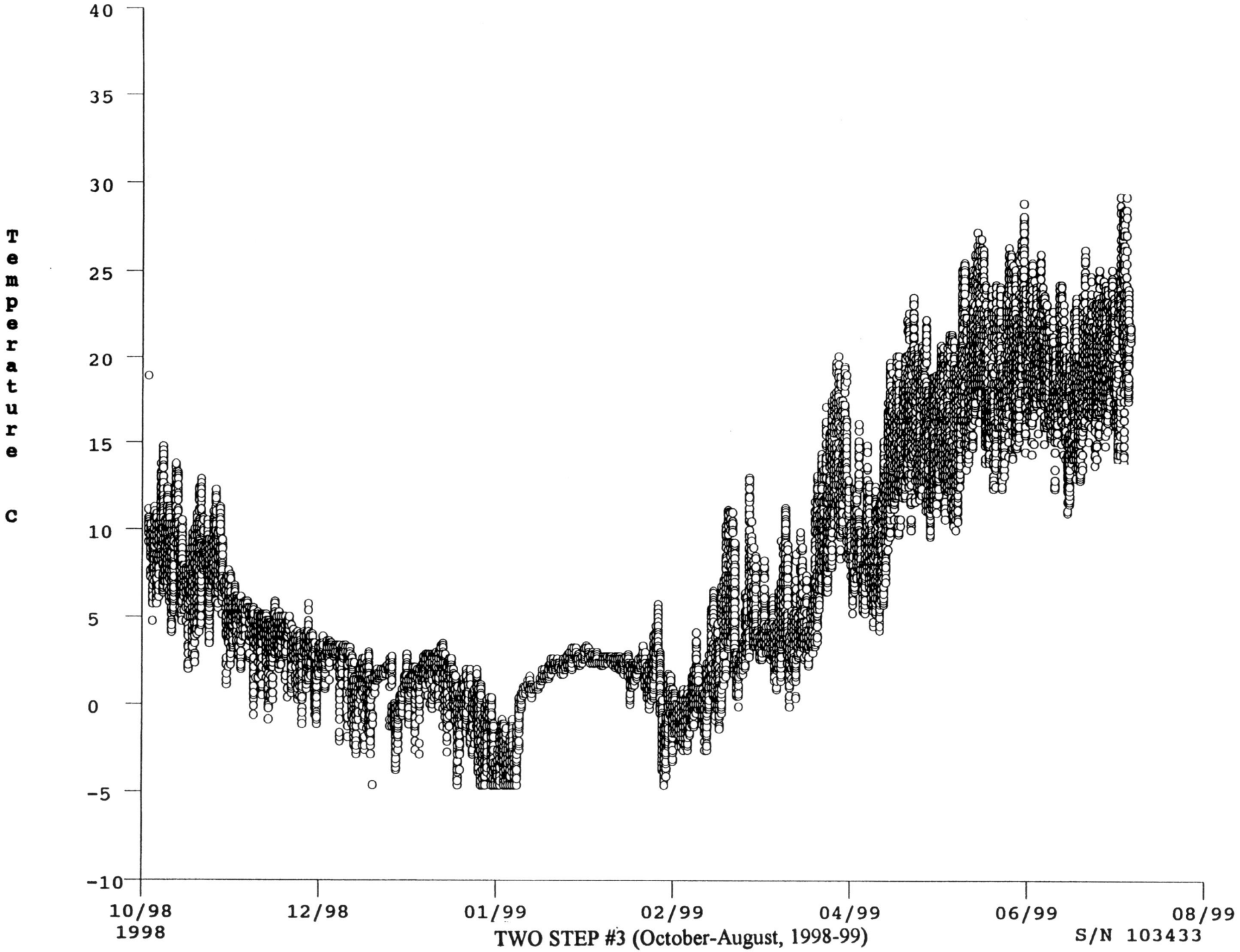
4. A graduate thesis project aimed a determining recruitment rates of Townsend's pups in the North Caves Area could be undertaken with night-vision equipment.

5. A continuing study of thermal properties of Screaming Jaws of Death Cave could be undertaken to evaluate the robustness of the data set used to make further recommendation.

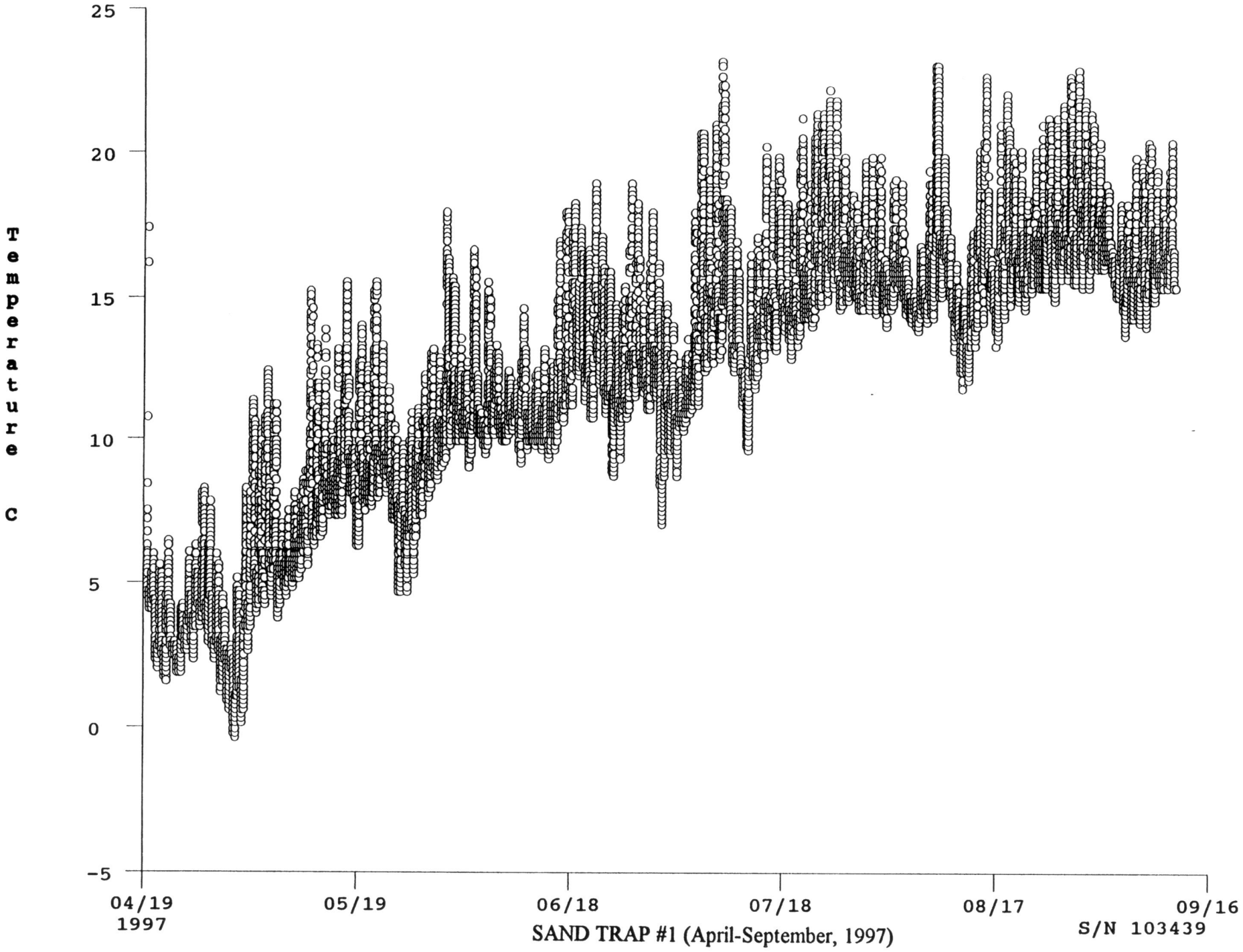
Figures 1-3. Thermal (C) profiles developed from waterproof Optic StowAway Temperature Loggers attached adjacent to the ceiling in the upper chamber twilight zone at Two Step Cave, beginning April 1997 (1), March 1998 (2) and October (3) 1998 (see Table 2).

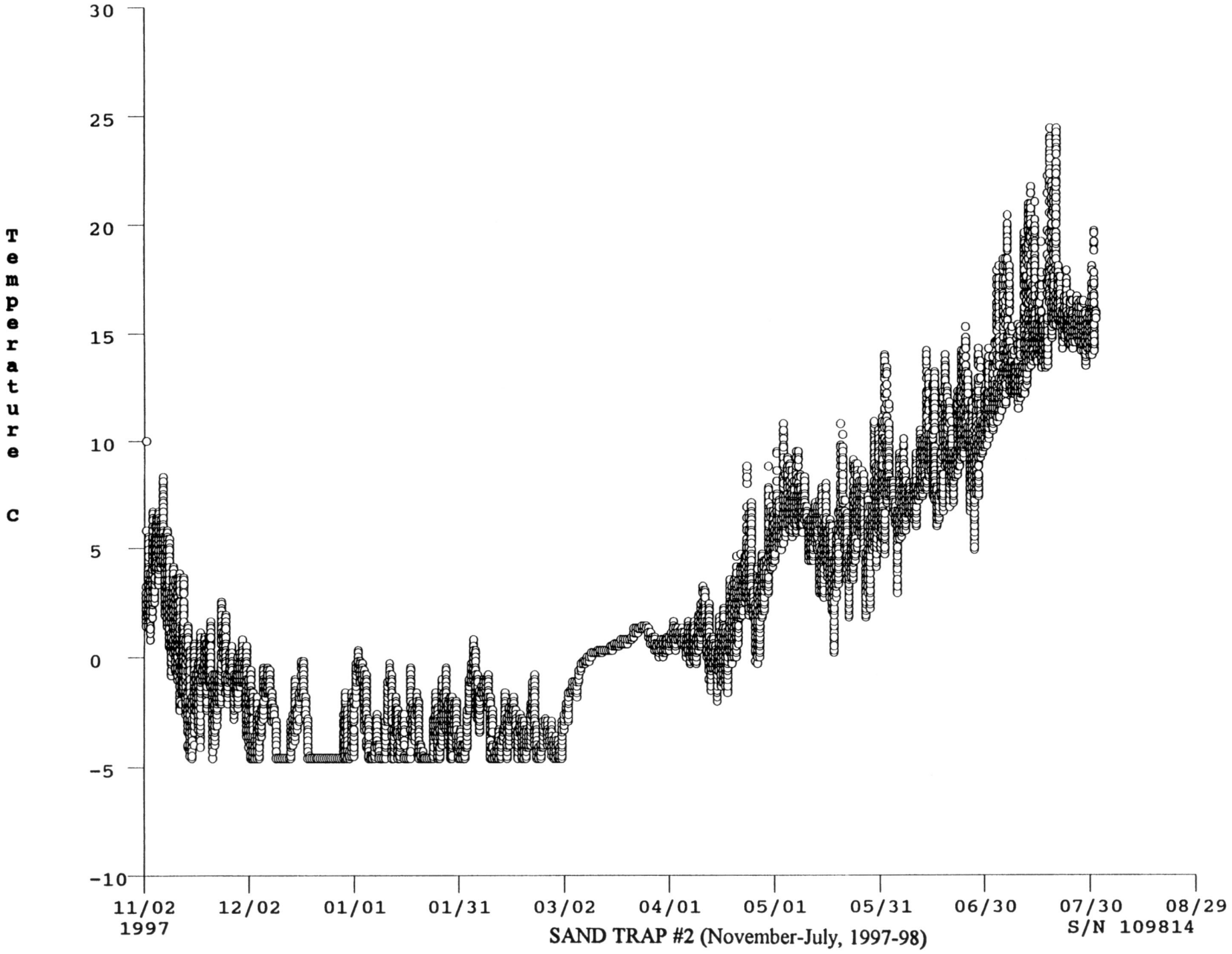

30
25
20
15
10
5
0
-5
Temperature C
04/19
1997
05/19
06/18
07/18
08/17
09/16
TWO STEP #1 (April-September, 1997)
S/N 109856

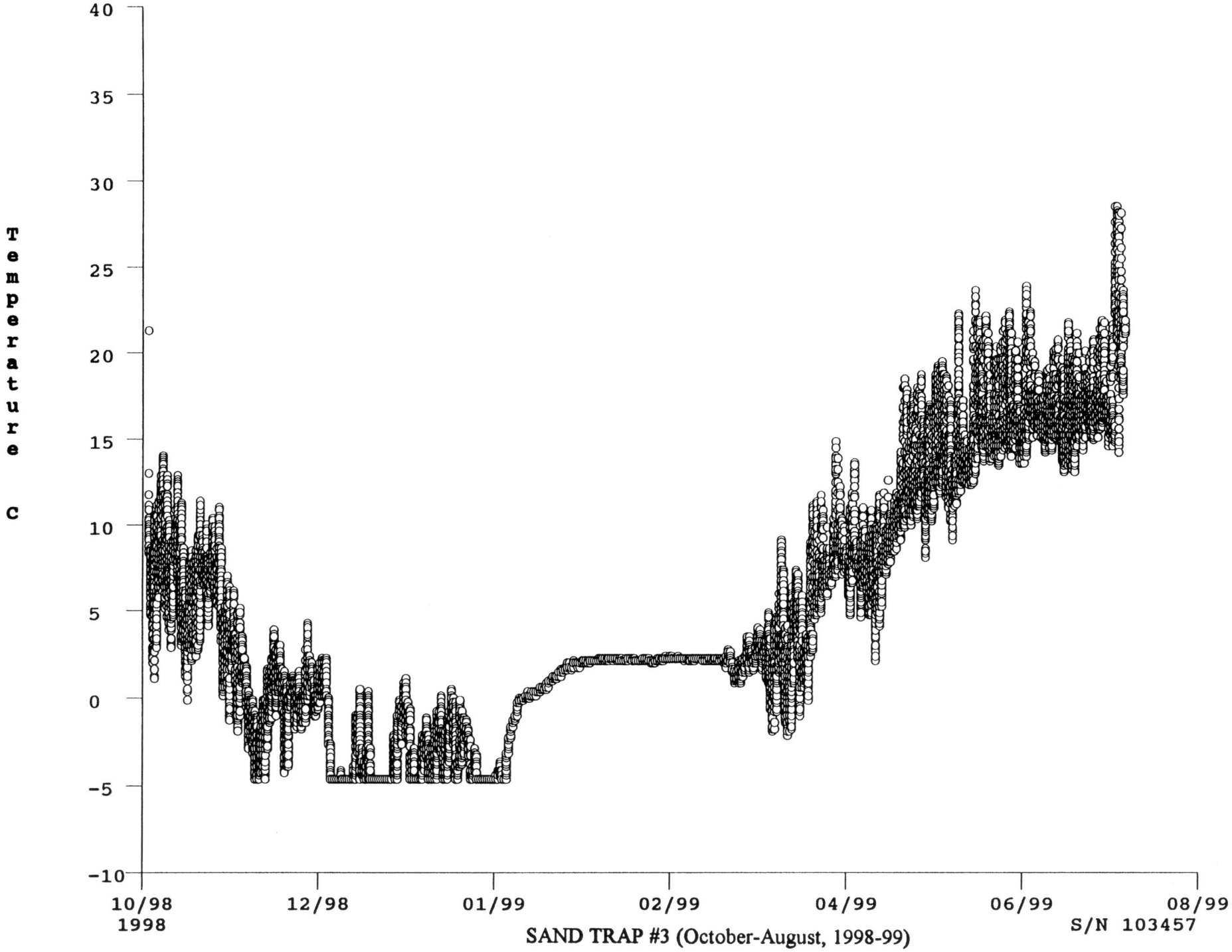

Temperature C
35
30
25
20
15
10
5
0
-5
-10
03/17
1998
04/16
05/16
06/15
07/15
08/14
09/13
10/13
TWO STEP #2 (March-October, 1998)
S/N 109761


Temperature C
40
35
30
25
20
15
10
5
0
-5
-10
10/98
1998
12/98
01/99
02/99
04/99
06/99
08/99
TWO STEP #3 (October-August, 1998-99)
S/N 103433

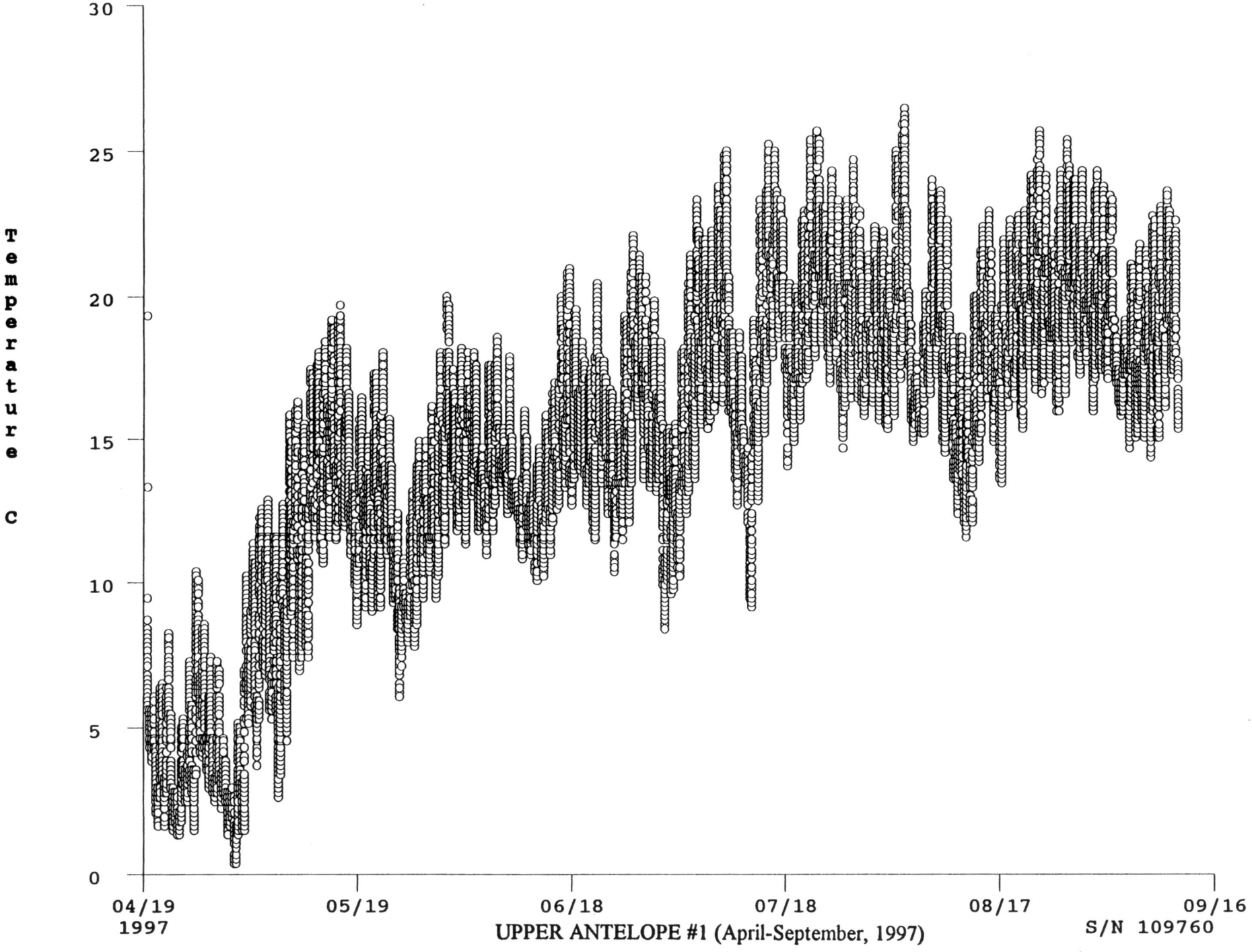
Figures 4-6. Thermal (C) profiles developed from waterproof Optic StowAway Temperature Loggers attached adjacent to the ceiling in the lower upper chamber twilight zone at Sand Trap Cave, beginning April 1997 (1), November 1997 (2), and October (3) 1998 (see Table 2).


25
20
15
10
5
0
-5
Temperature C
04/19
1997
05/19
06/18
07/18
08/17
09/16
SAND TRAP #1 (April-September, 1997)
S/N 103439


30
25
20
15
10
5
0
-5
-10
Temperature C
11/02
1997
12/02
01/01
01/31
03/02
04/01
05/01
05/31
06/30
07/30
08/29
SAND TRAP #2 (November-July, 1997-98)
S/N 109814


Temperature C
40
35
30
25
20
15
10
5
0
-5
-10
10/98
1998
12/98
01/99
02/99
04/99
06/99
08/99
SAND TRAP #3 (October-August, 1998-99)
S/N 103457

Figures 7-8. Thermal (C) profiles developed from waterproof Optic StowAway Temperature Loggers attached adjacent to the ceiling in the upper chamber twilight zone at Upper Antelope Cave, beginning April 1997 (1), November 1997 (2), (see Table 2).


Temperature C
30
25
20
15
10
5
0
04/19
1997
05/19
06/18
07/18
08/17
09/16
UPPER ANTELOPE #1 (April-September, 1997)
S/N 109760

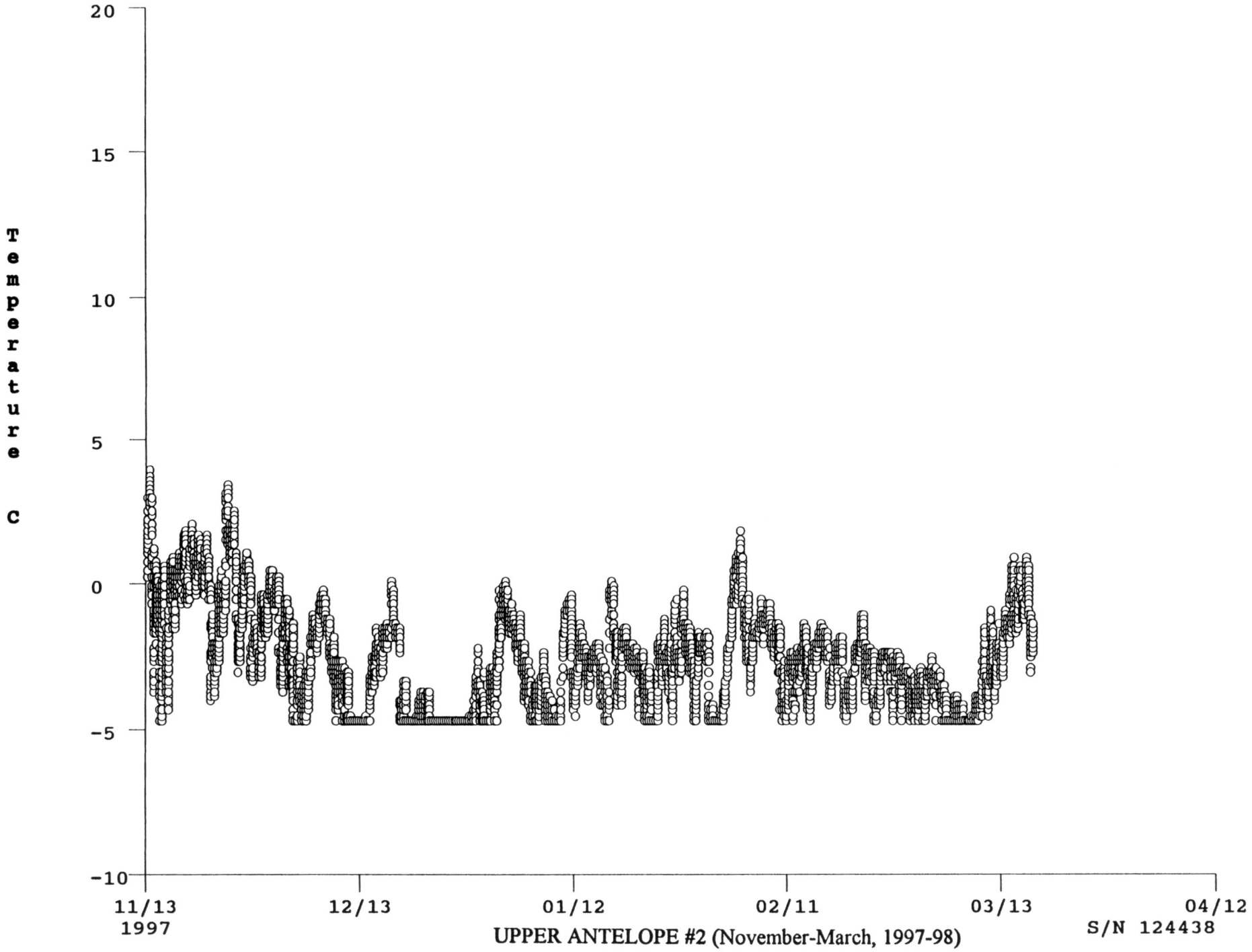
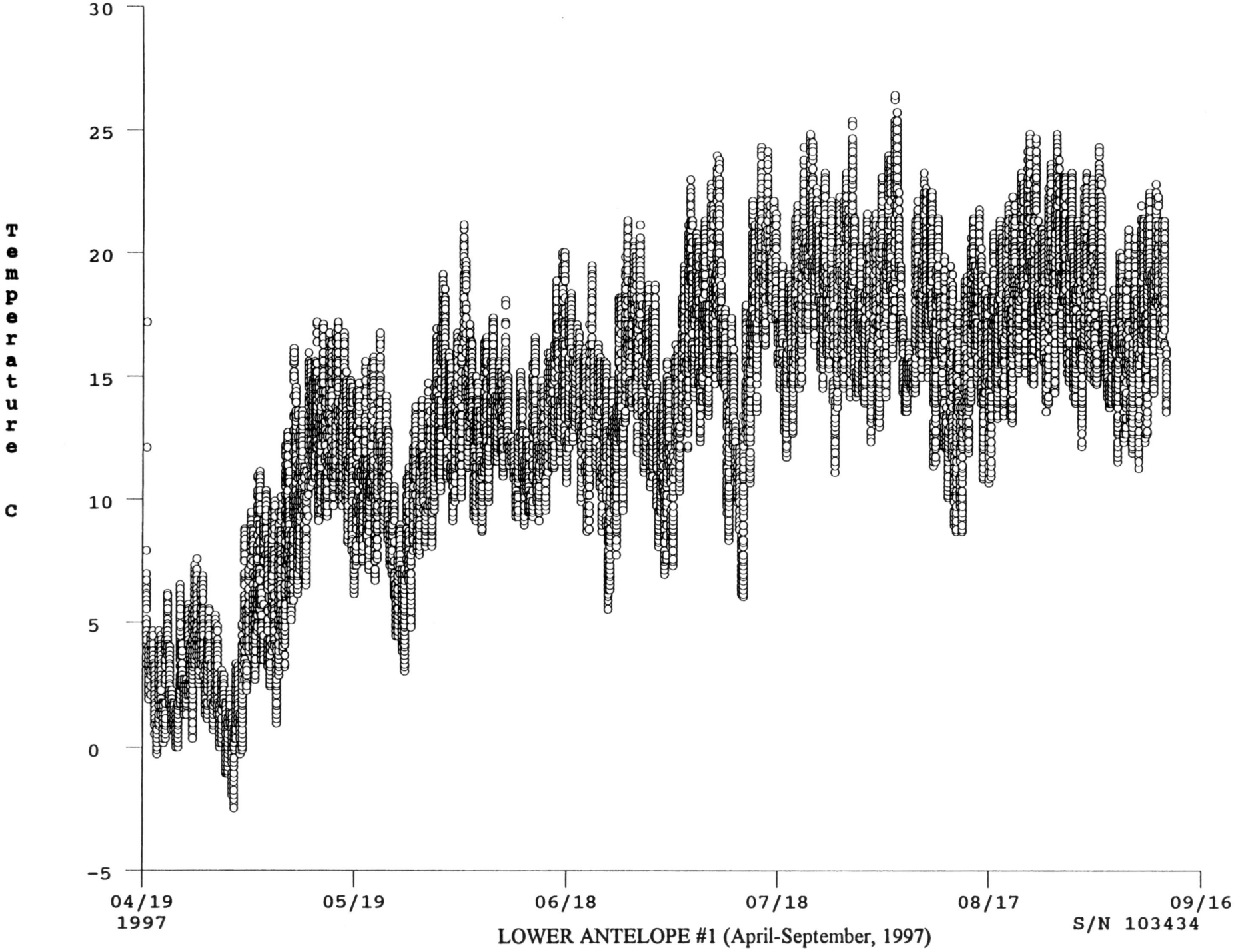
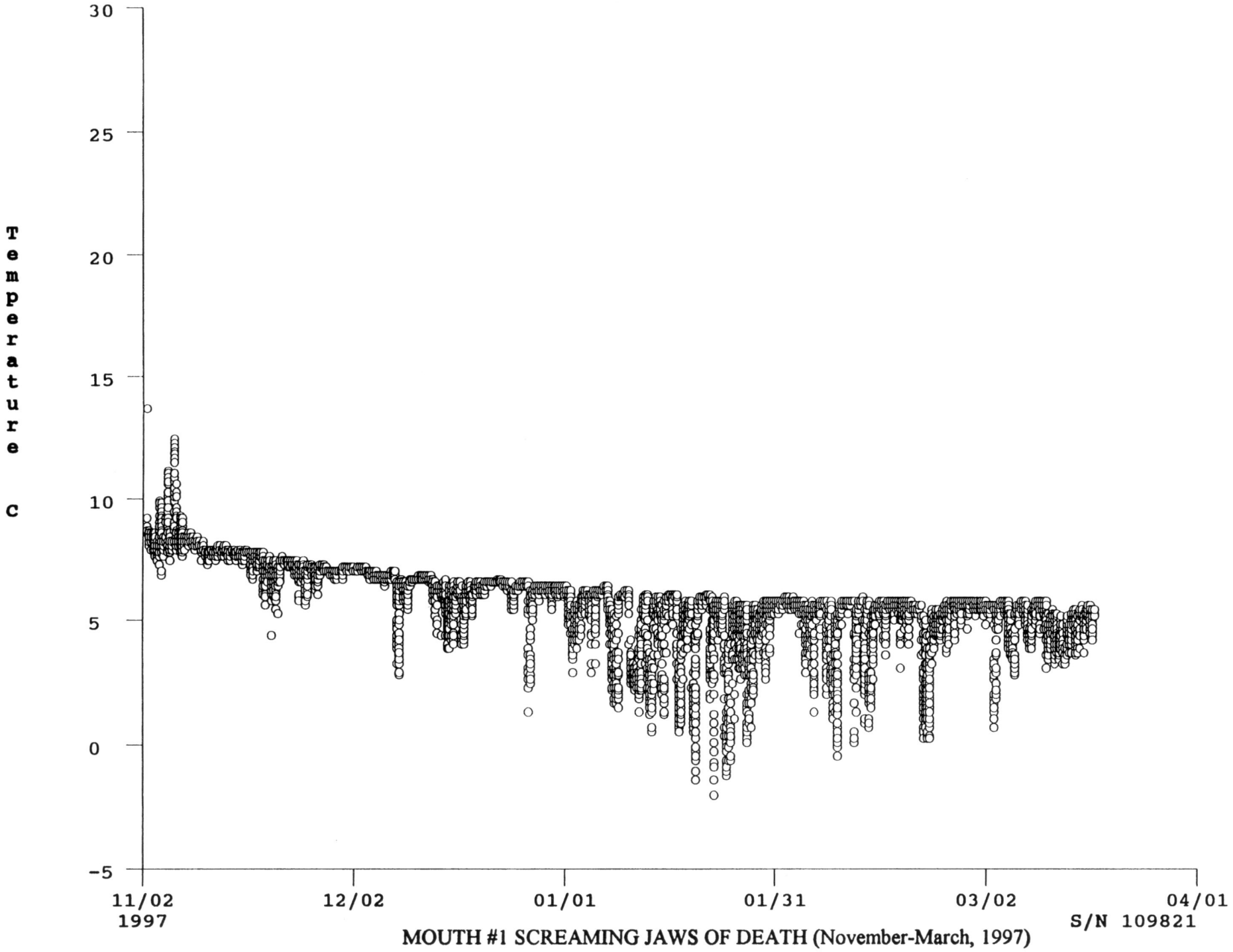

20
15
10
5
0
-5
-10
Temperature C
11/13
1997
12/13
01/12
02/11
03/13
04/12
UPPER ANTELOPE #2 (November-March, 1997-98)
S/N 124438

Figure 9. Thermal (C) profile developed from a waterproof Optic StowAway Temperature Logger attached adjacent to the ceiling in the twilight zone at Lower Antelope Cave, beginning April 1997 (1), and November 1997 (2) (see Table 2).


30
25
20
15
10
5
0
-5
Temperature C
04/19
1997
05/19
06/18
07/18
08/17
09/16
S/N 103434
LOWER ANTELOPE #1 (April-September, 1997)

Figures 10-11. Thermal (C) profiles developed from a waterproof Optic StowAway Temperature Logger attached adjacent to the ceiling near the opening of the mouth area at Screaming Jaws of Death Cave, beginning November 1997 (1) and a XT1 StowAway logger (2) placed in a water proof case beginning March 1998. The third replacement in the series failed during 1999 (see Table 2).


30
25
20
15
10
5
0
-5
Temperature C
11/02
1997
12/02
01/01
01/31
03/02
04/01
S/N 109821
MOUTH #1 SCREAMING JAWS OF DEATH (November-March, 1997)

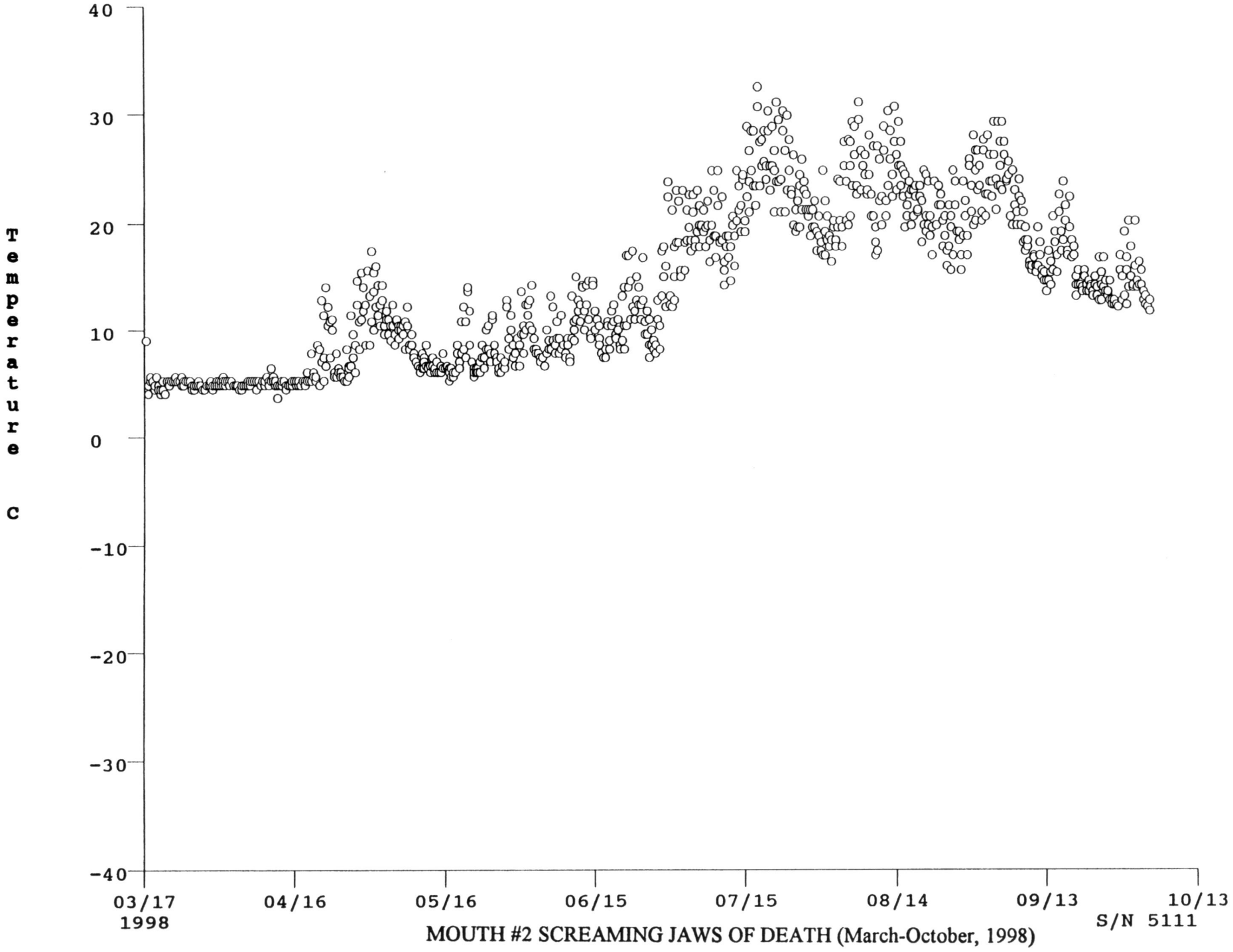
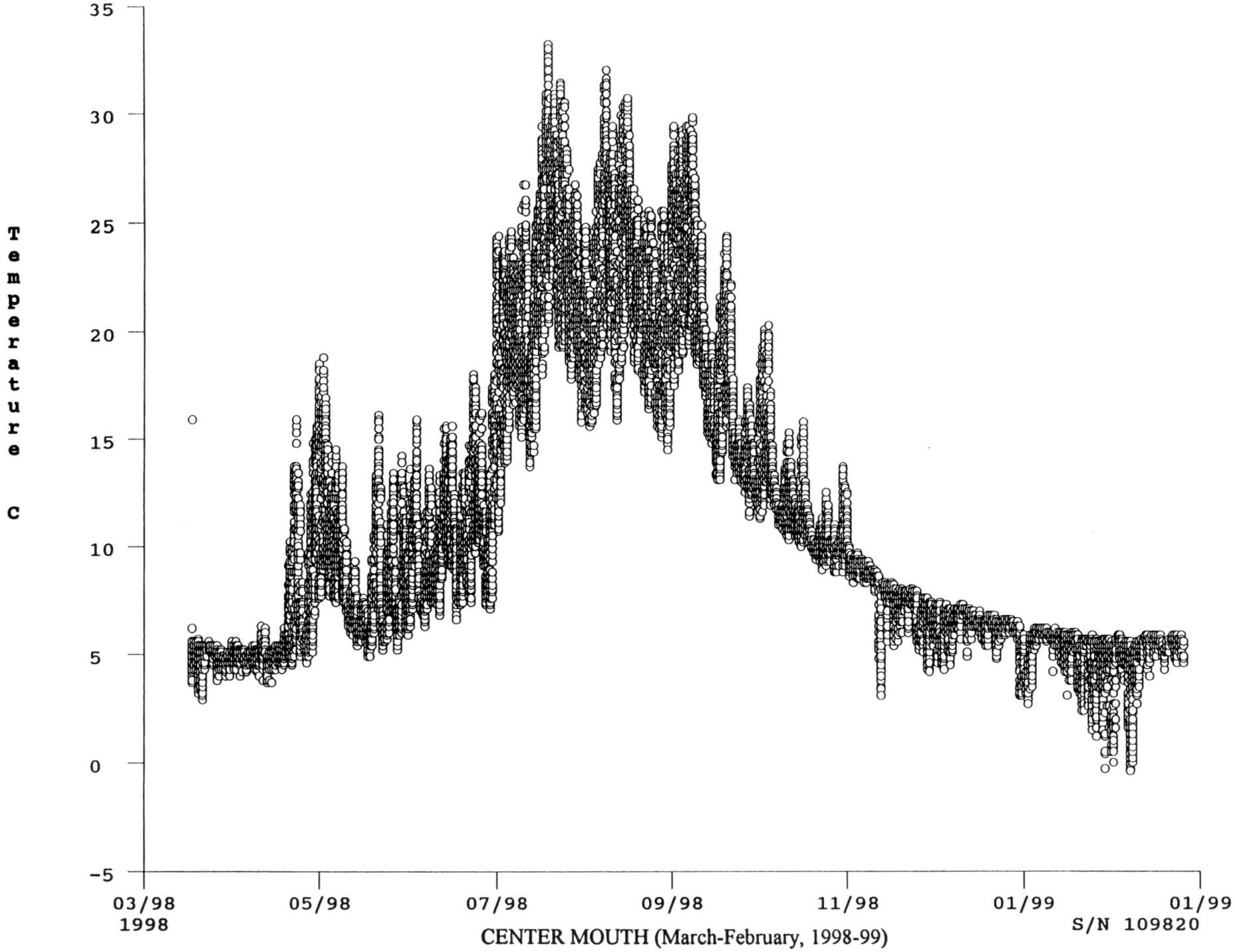
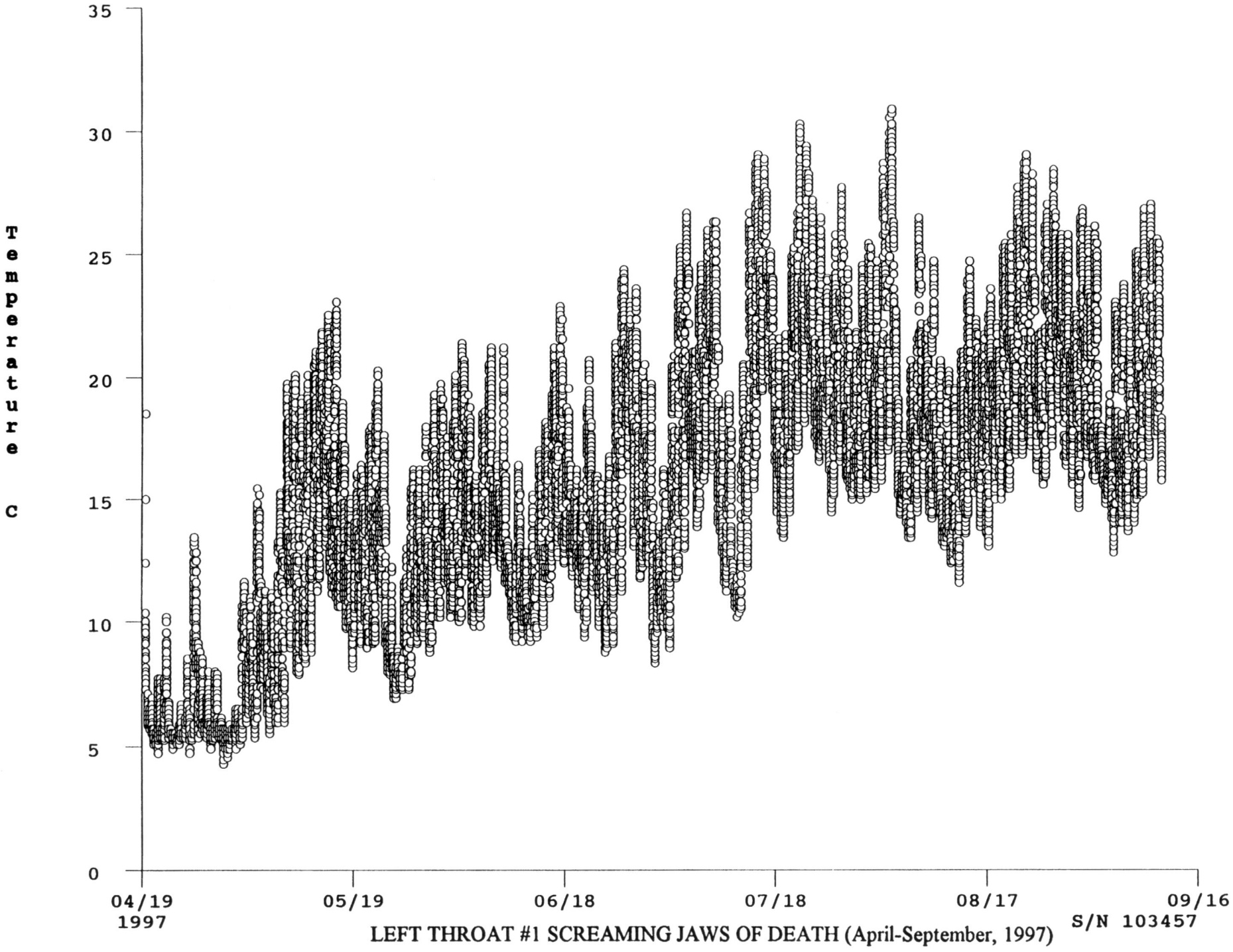
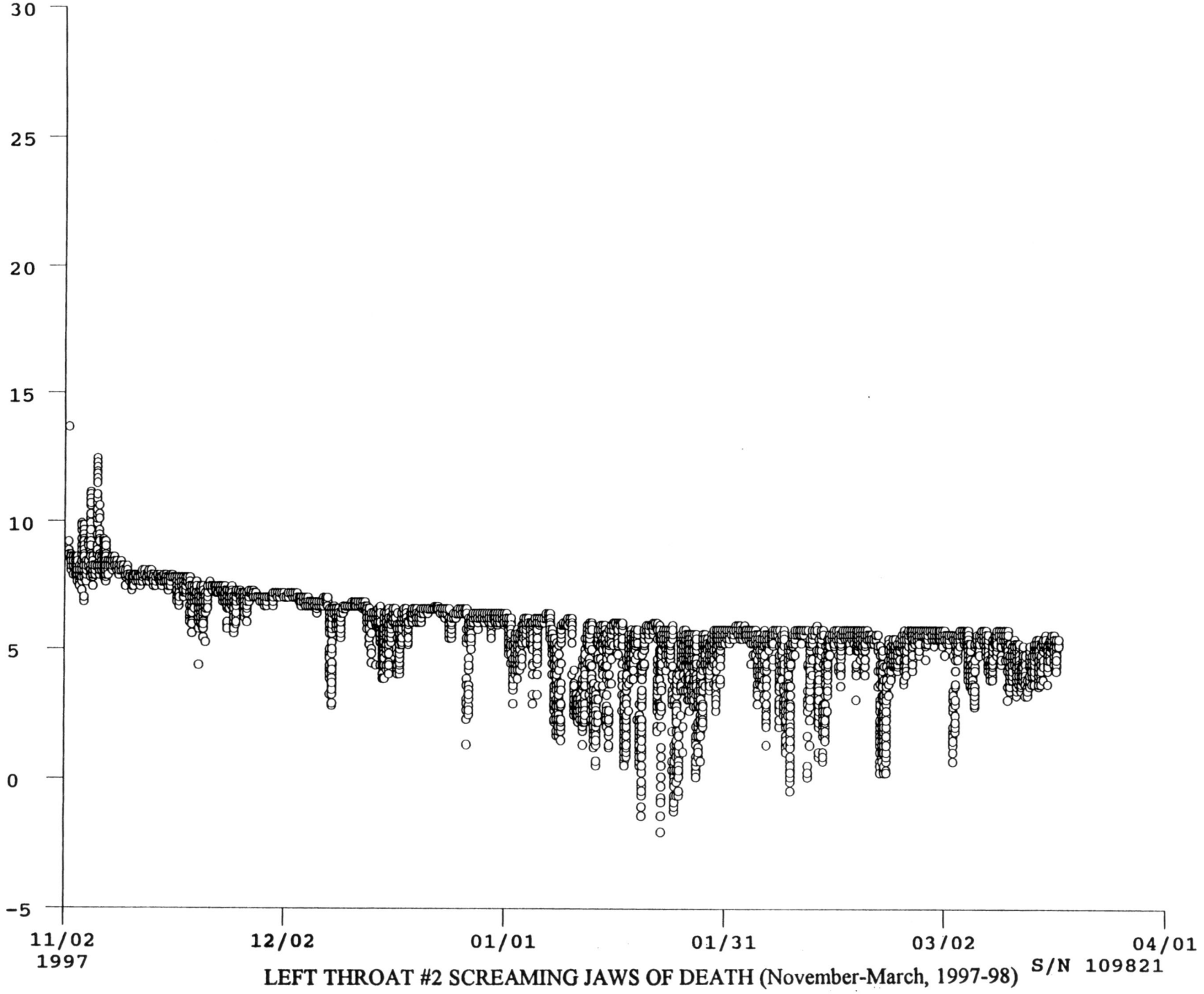

40
30
20
10
0
-10
-20
-30
-40
Temperature C
03/17
1998
04/16
05/16
06/15
07/15
08/14
09/13
10/13
S/N 5111
MOUTH #2 SCREAMING JAWS OF DEATH (March-October, 1998)

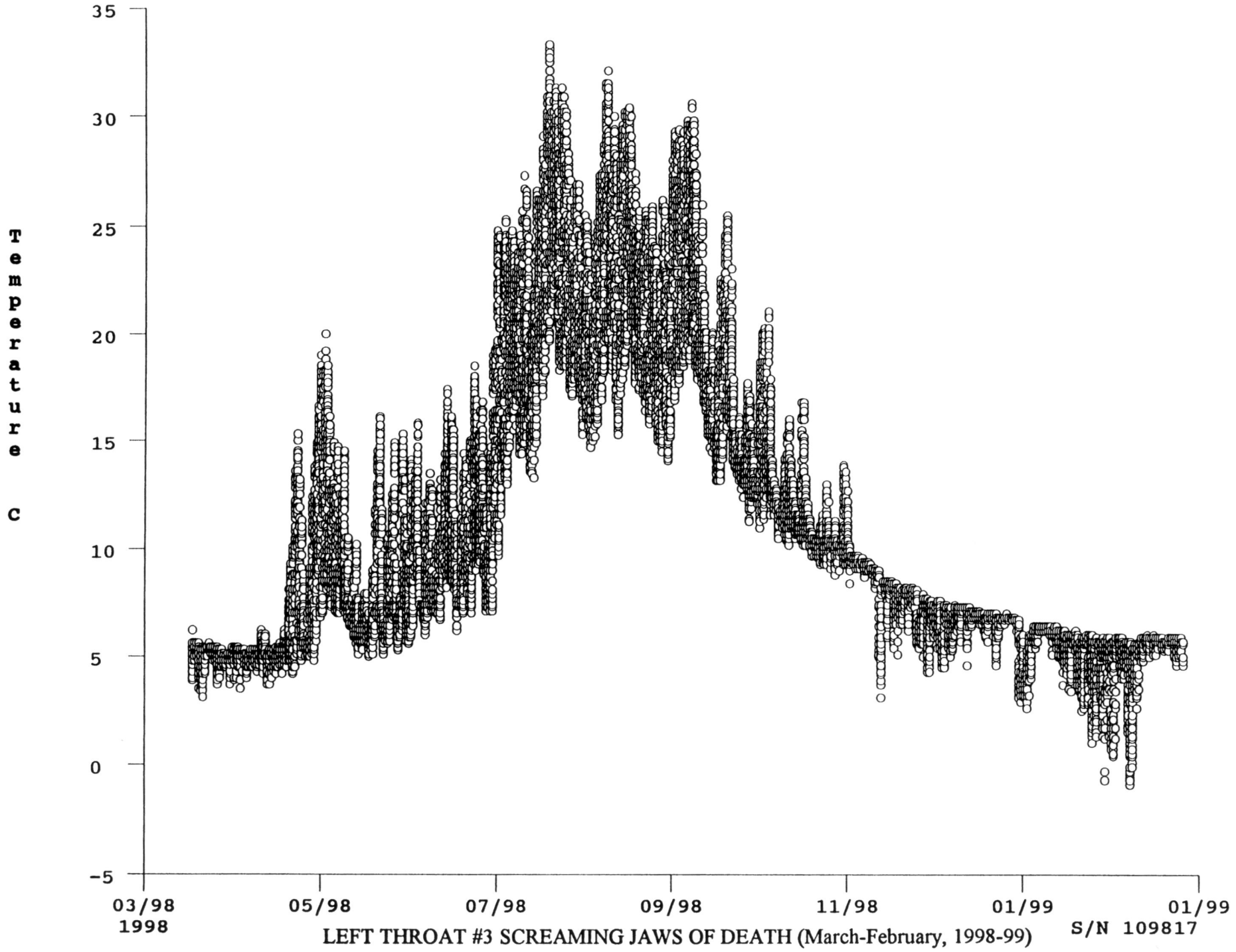
Figure 12. Thermal (C) profile developed from a waterproof Optic StowAway Temperature Logger attached adjacent to the ceiling in the center of the mouth area at Screaming Jaws of Death Cave, beginning March 1998 (see Table 2).


35
30
25
20
15
10
5
0
-5
Temperature C
03/98
1998
05/98
07/98
09/98
11/98
01/99
01/99
S/N 109820
CENTER MOUTH (March-February, 1998-99)

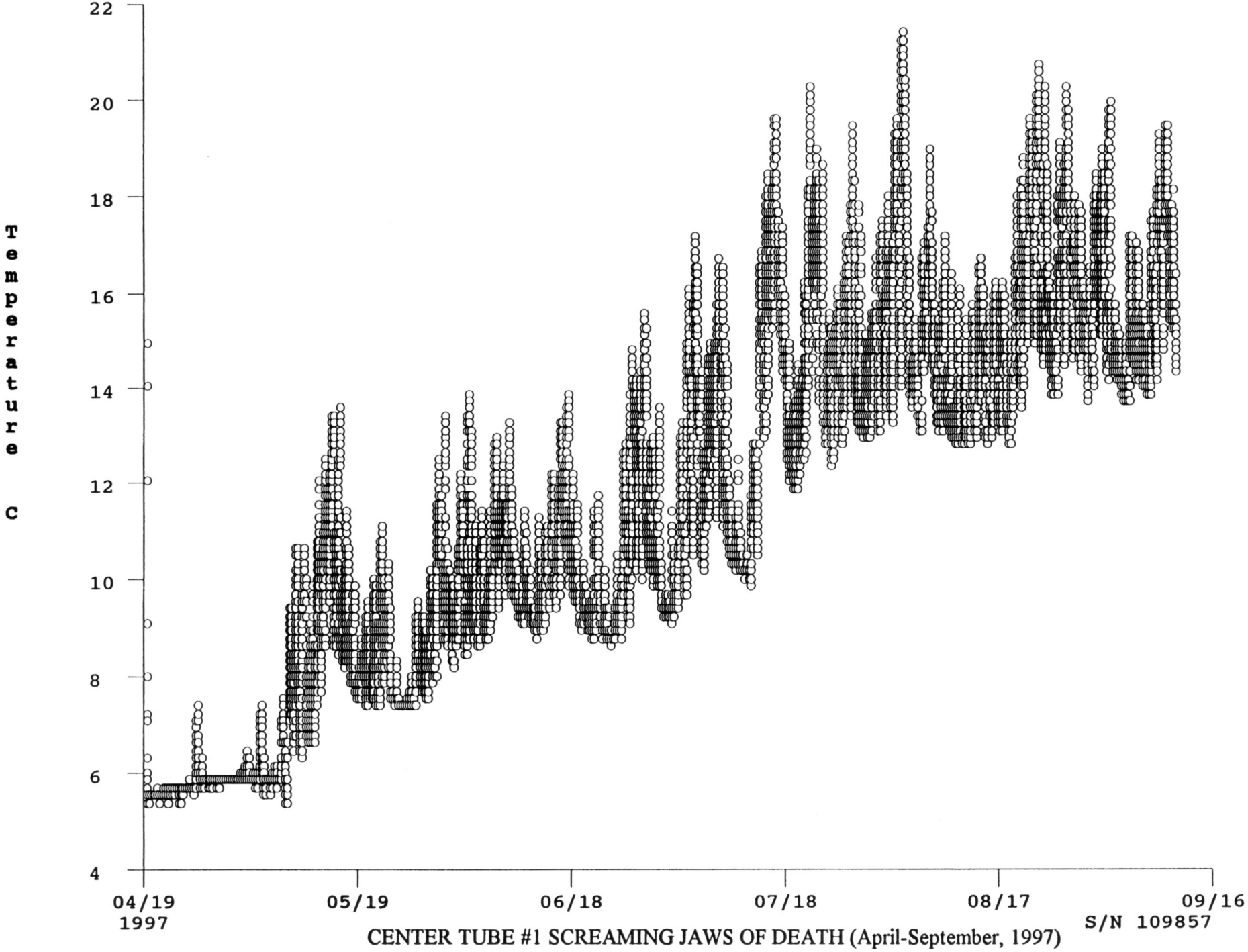
Figures 13-15. Thermal (C) profiles developed from waterproof Optic StowAway Temperature Loggers attached adjacent to the ceiling on the left side of the throat area in Screaming Jaws of Death Cave, beginning April 1997 (1), November 1997 (2), and March 1998 (see Table 2).

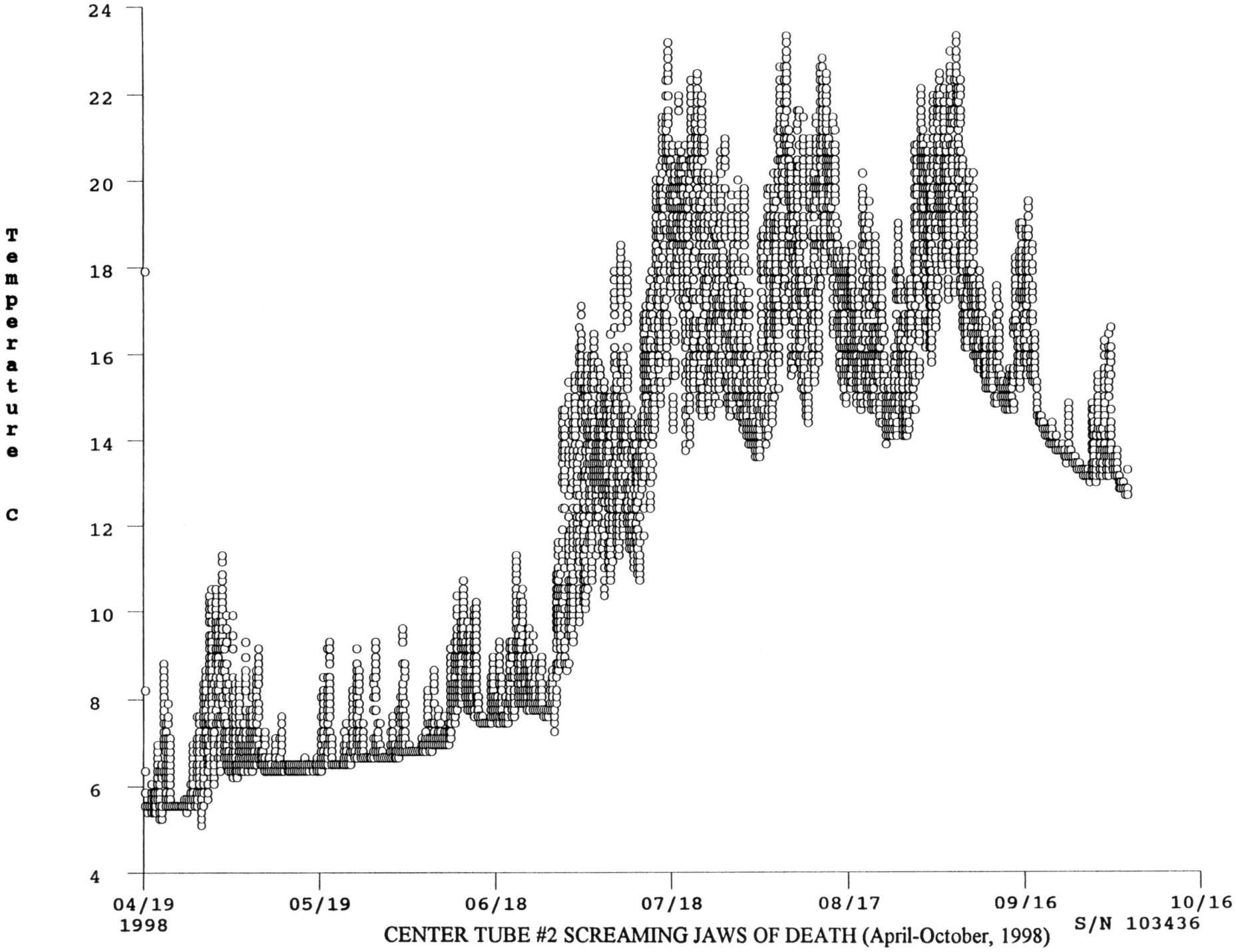

35
30
25
20
15
10
5
0
Temperature C
04/19
1997
05/19
06/18
07/18
08/17
09/16
S/N 103457
LEFT THROAT #1 SCREAMING JAWS OF DEATH (April-September, 1997)

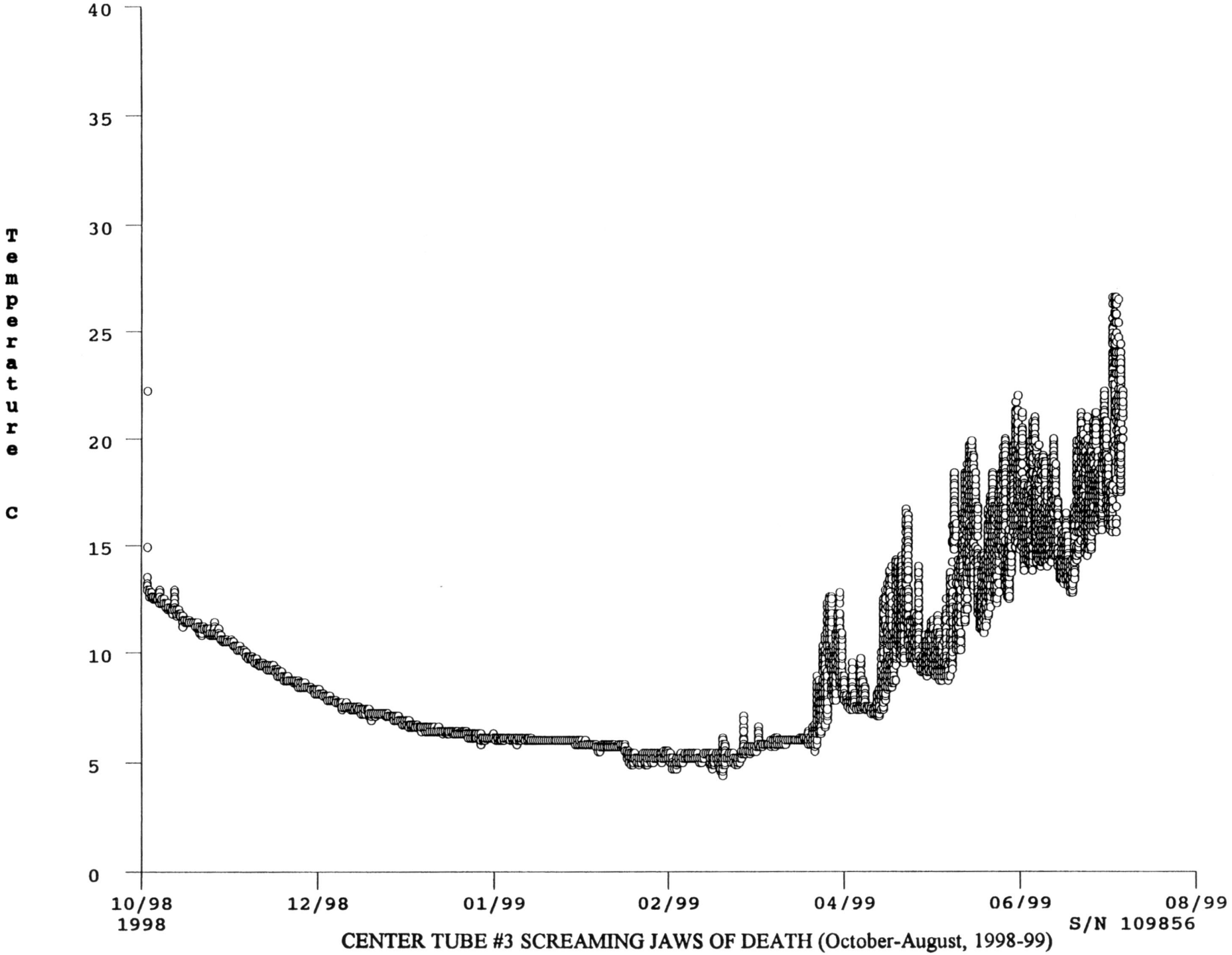

30
25
20
15
10
5
0
-5
Temperature C
11/02
1997
12/02
01/01
01/31
03/02
04/01
LEFT THROAT #2 SCREAMING JAWS OF DEATH (November-March, 1997-98)
S/N 109821


Temperature C
35
30
25
20
15
10
5
0
-5
03/98
1998
05/98
07/98
09/98
11/98
01/99
01/99
LEFT THROAT #3 SCREAMING JAWS OF DEATH (March-February, 1998-99)
S/N 109817

Figures 16-18. Thermal (C) profiles developed from waterproof Optic StowAway Temperature Loggers attached adjacent to the ceiling half way down the tube area under the mouth at Screaming Jaws of Death Cave, beginning April 1997 (1), April 1998 (2), and October 1998 (3) (see Table 2).

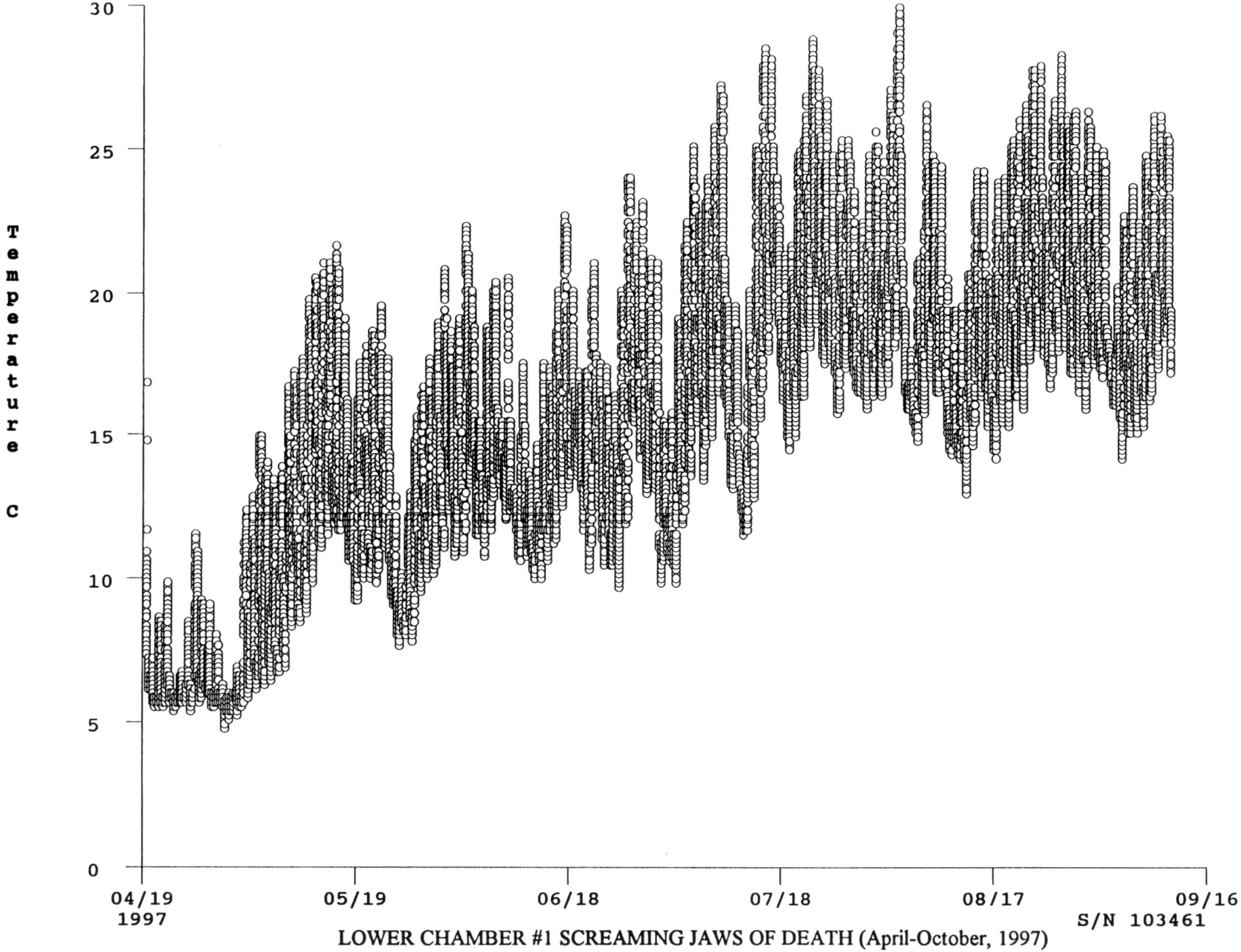

Temperature C
22
20
18
16
14
12
10
8
6
4
04/19
1997
05/19
06/18
07/18
08/17
09/16
S/N 109857
CENTER TUBE #1 SCREAMING JAWS OF DEATH (April-September, 1997)


Temperature C
24
22
20
18
16
14
12
10
8
6
4
04/19
1998
05/19
06/18
07/18
08/17
09/16
10/16
S/N 103436
CENTER TUBE #2 SCREAMING JAWS OF DEATH (April-October, 1998)

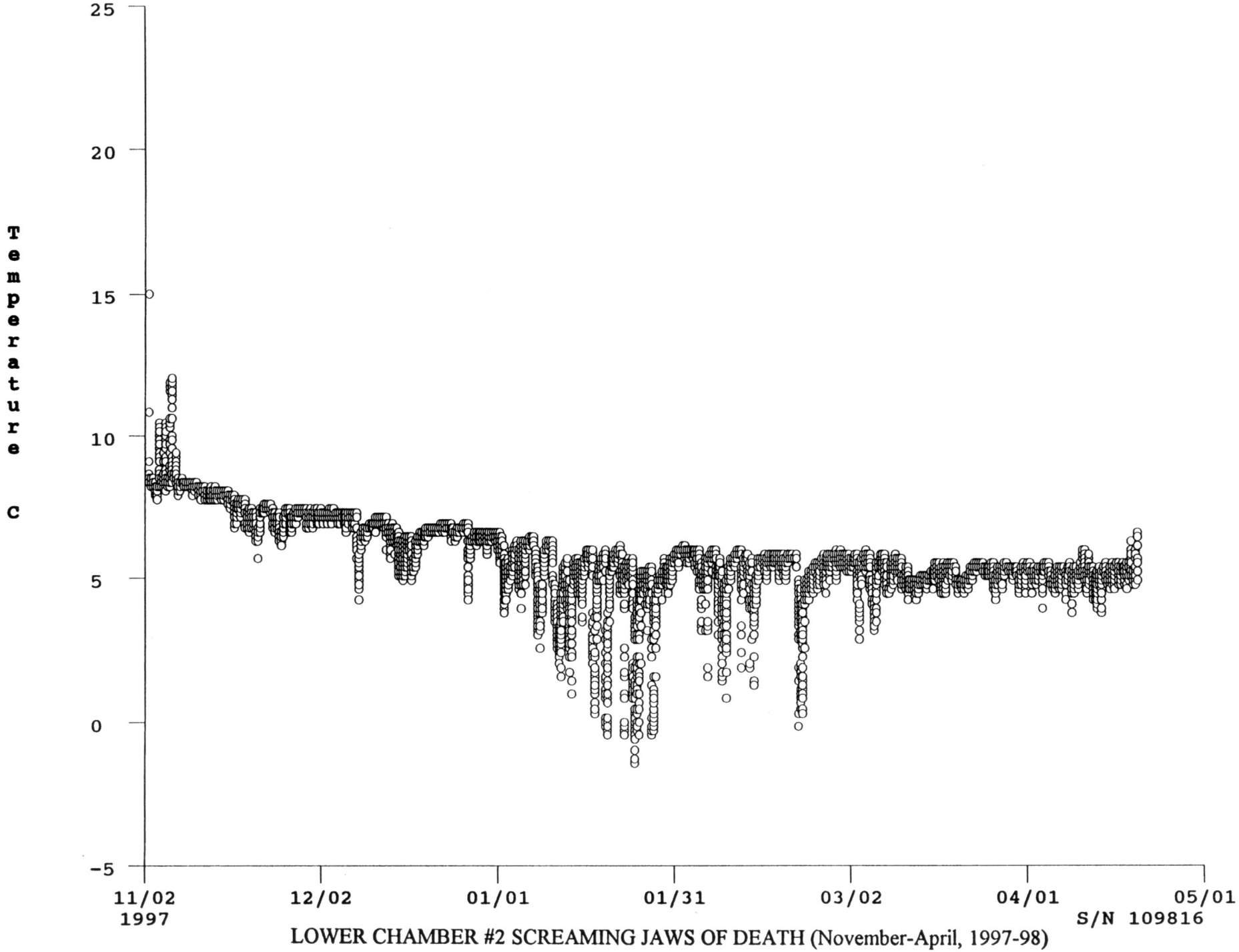


CENTER TUBE #3 SCREAMING JAWS OF DEATH (October-August, 1998-99)

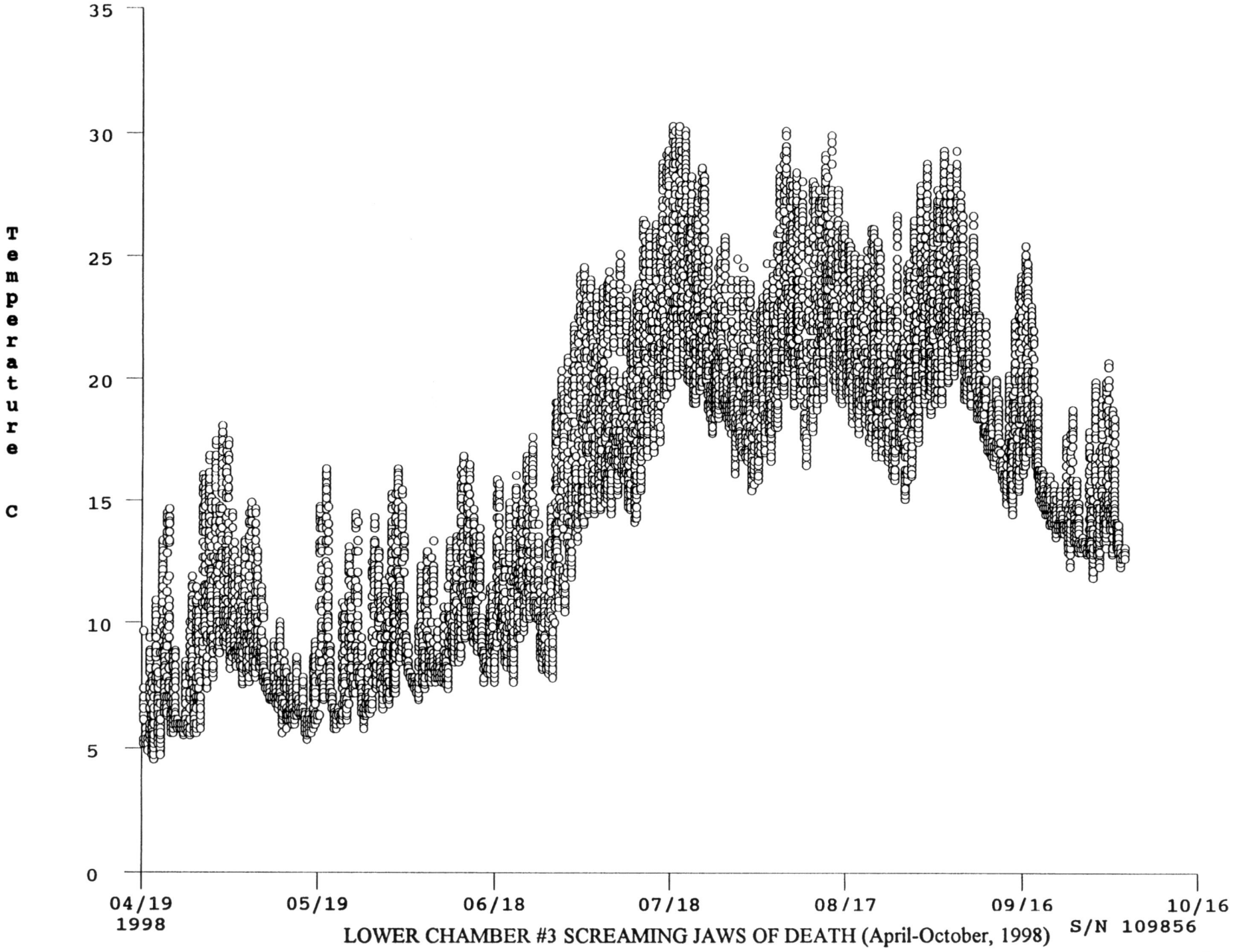
Figures 19-22. Thermal (C) profiles developed from waterproof Optic StowAway Temperature Loggers attached to the left wall in the lower chamber of screaming Jaws of Death Cave, beginning April 1997 (1), November 1997 (2), April 1998 (3) and October 1998 (4) (see Table 2).

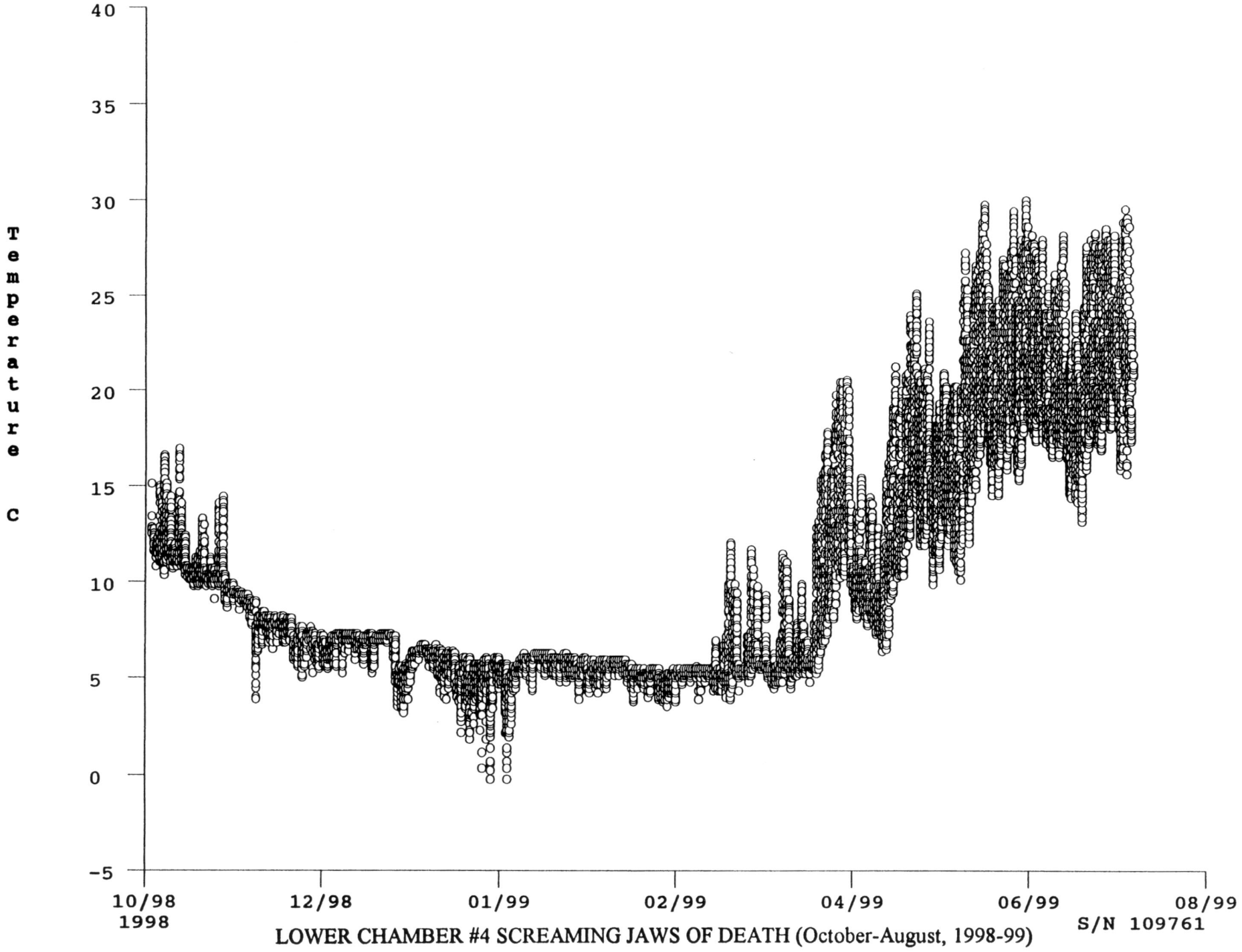


LOWER CHAMBER #1 SCREAMING JAWS OF DEATH (April-October, 1997)



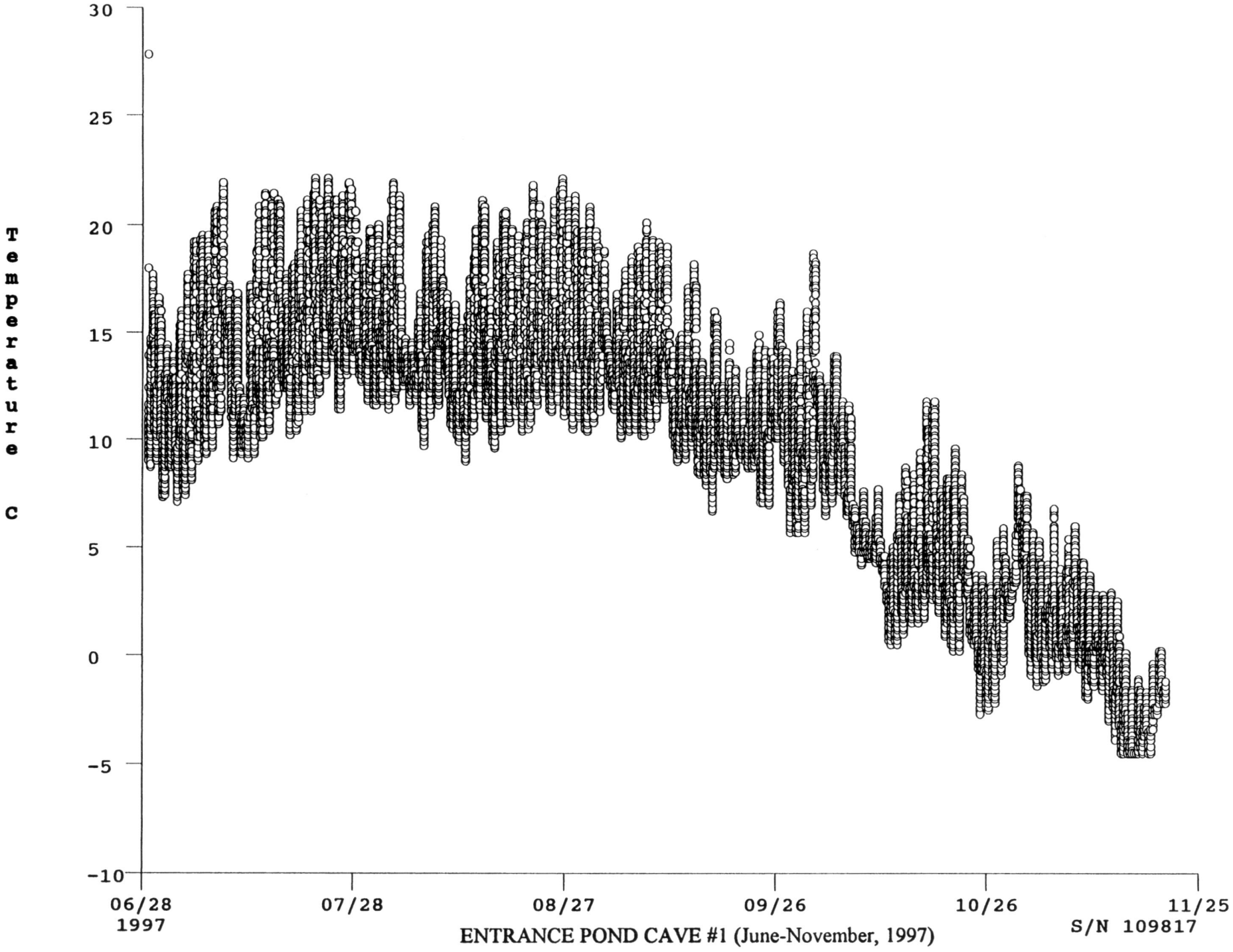
LOWER CHAMBER #2 SCREAMING JAWS OF DEATH (November-April, 1997-98)

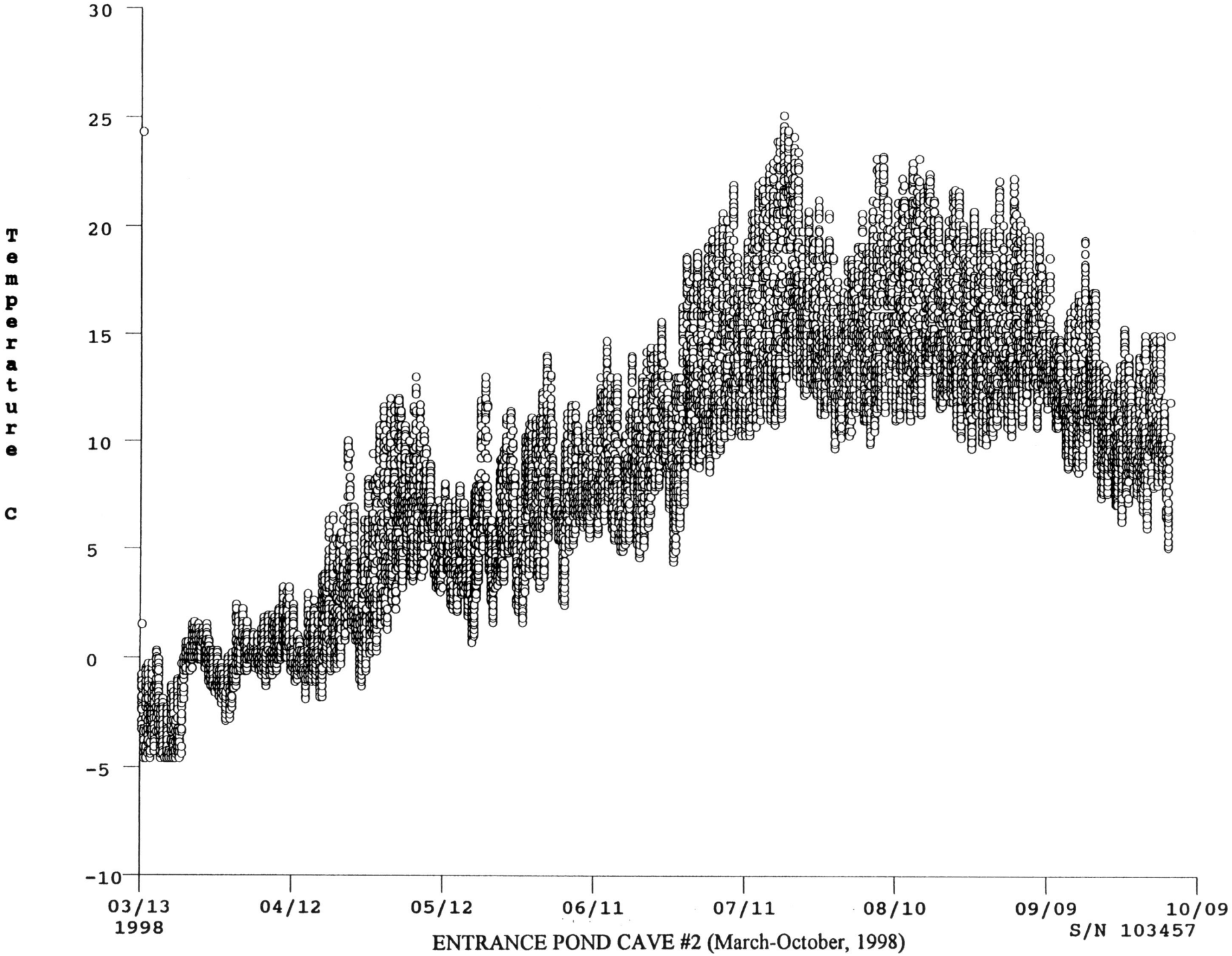

35
30
25
20
15
10
5
0
Temperature C
04/19
1998
05/19
06/18
07/18
08/17
09/16
10/16
LOWER CHAMBER #3 SCREAMING JAWS OF DEATH (April-October, 1998)
S/N 109856

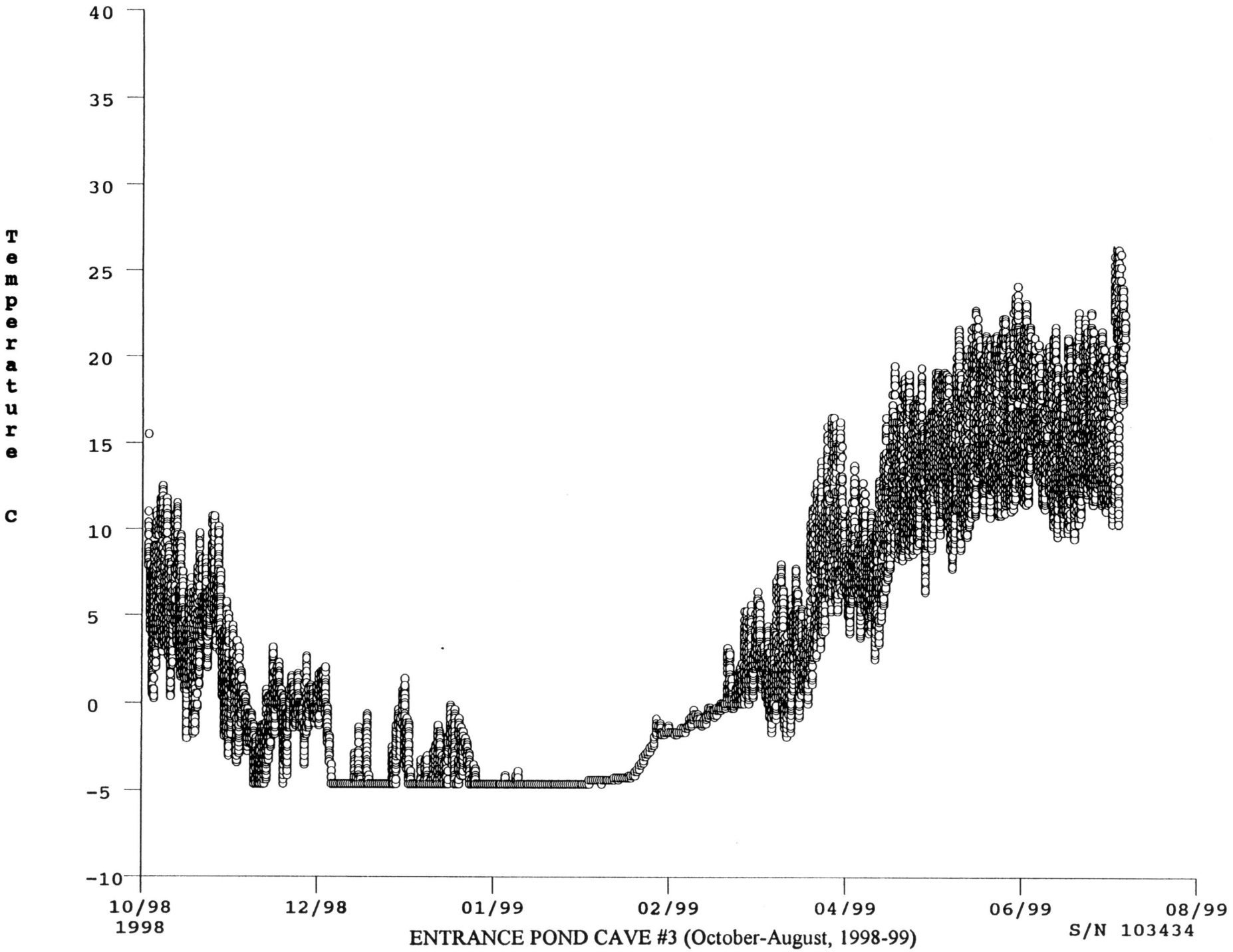


LOWER CHAMBER #4 SCREAMING JAWS OF DEATH (October-August, 1998-99)

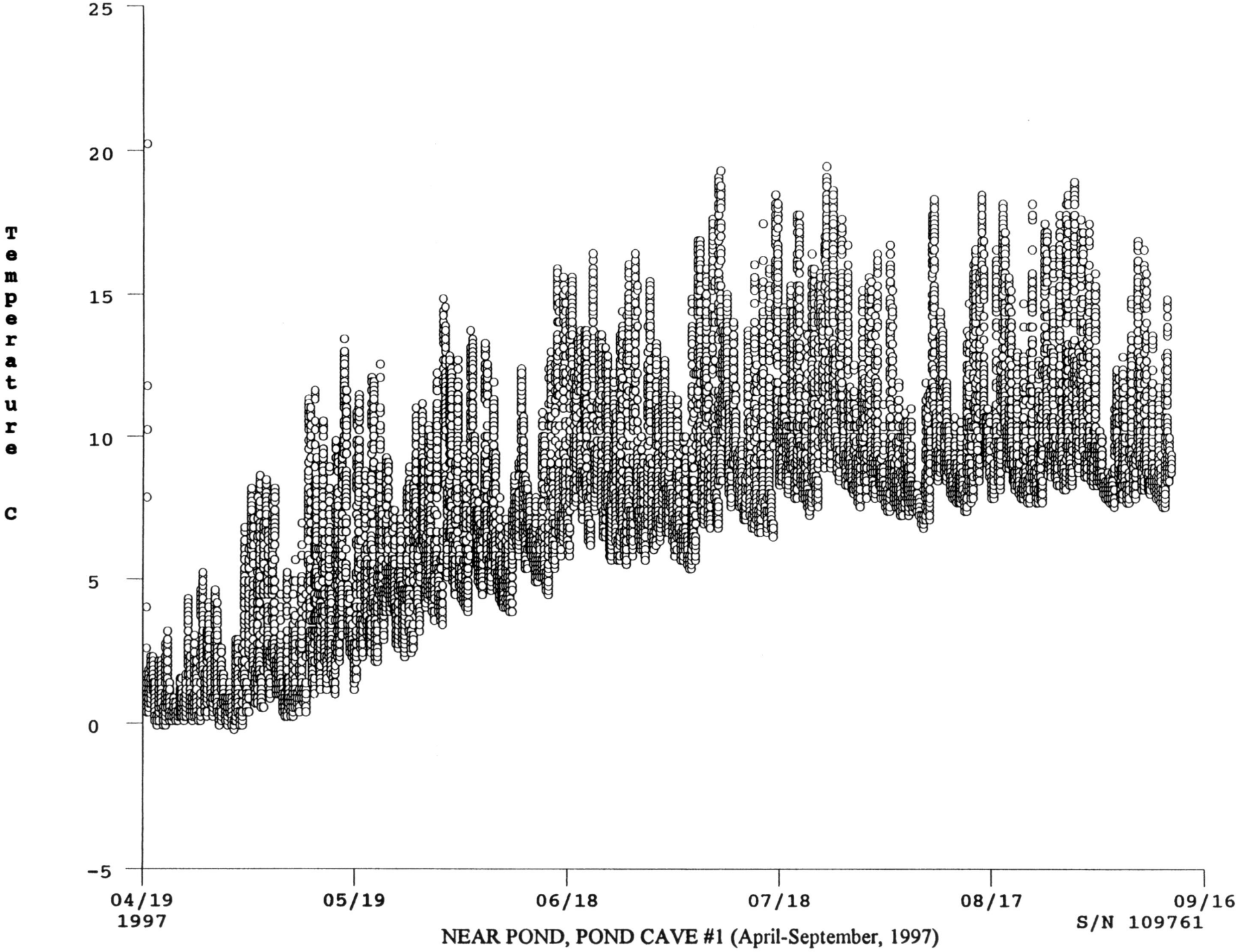
Figures 23-25. Thermal (C) profiles developed from waterproof Optic StowAway Temperature Loggers attached to the right ceiling area near the main entrance to Pond Cave, beginning June 1997 (1), March 1998 (2), and October 1998 (3) (see Table 2).

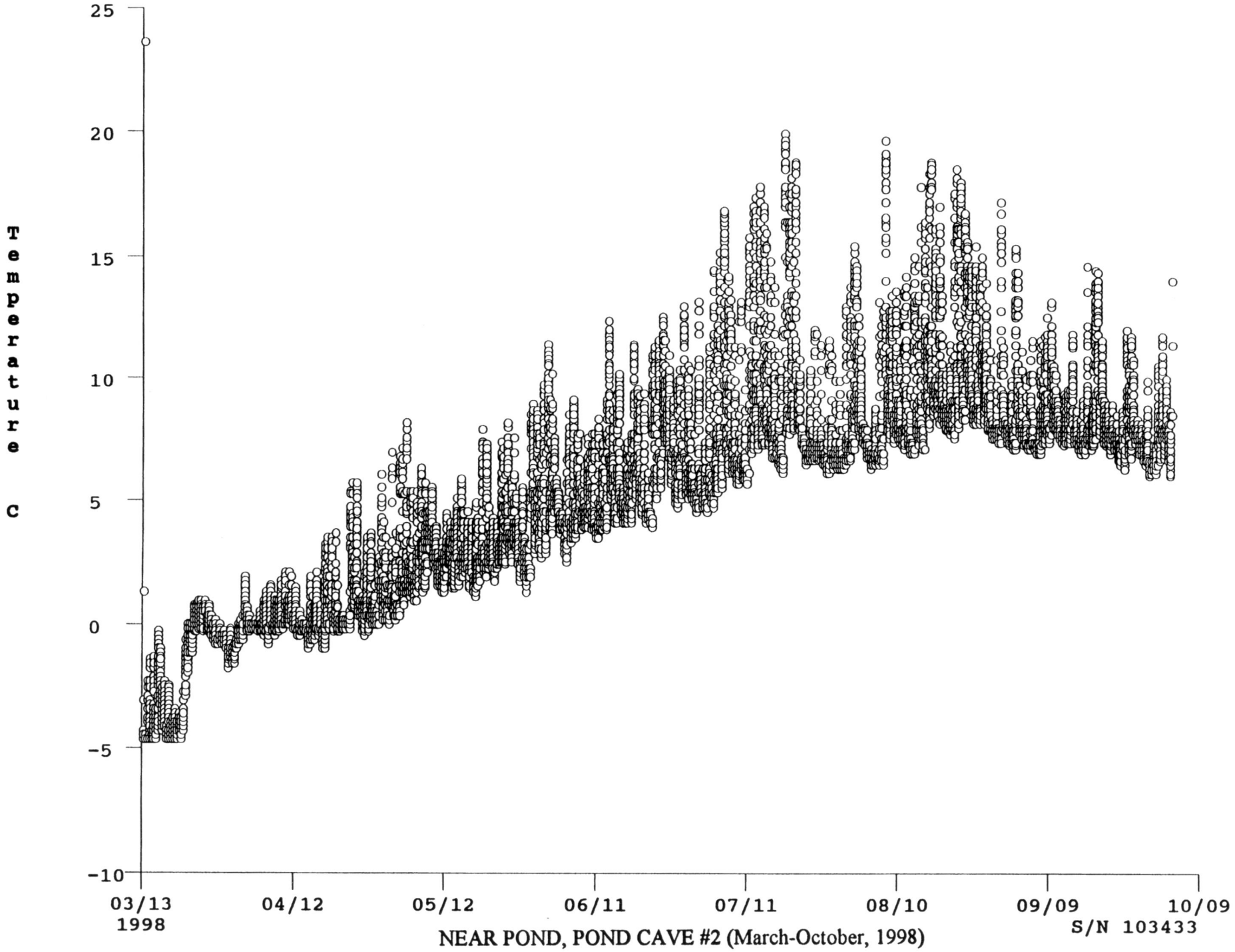

30
25
20
15
10
5
0
-5
-10
Temperature C
06/28
1997
07/28
08/27
09/26
10/26
11/25
S/N 109817
ENTRANCE POND CAVE #1 (June-November, 1997)


Temperature C
30
25
20
15
10
5
0
-5
-10
03/13
1998
04/12
05/12
06/11
07/11
08/10
09/09
10/09
S/N 103457
ENTRANCE POND CAVE #2 (March-October, 1998)


40
35
30
25
20
15
10
5
0
-5
-10
Temperature C
10/98
1998
12/98
01/99
02/99
04/99
06/99
08/99
S/N 103434
ENTRANCE POND CAVE #3 (October-August, 1998-99)

Figures 26-28. Thermal (C) profiles developed from waterproof Optic StowAway Temperature Loggers attached to the ceiling area near the pond room, Pond Cave, beginning April 1997 (1), March 1998 (2), and October 1998 (3) (see Table 2).


Temperature C
25
20
15
10
5
0
-5
04/19
1997
05/19
06/18
07/18
08/17
09/16
S/N 109761
NEAR POND, POND CAVE #1 (April-September, 1997)


Temperature C
25
20
15
10
5
0
-5
-10
03/13
1998
04/12
05/12
06/11
07/11
08/10
09/09
10/09
S/N 103433
NEAR POND, POND CAVE #2 (March-October, 1998)

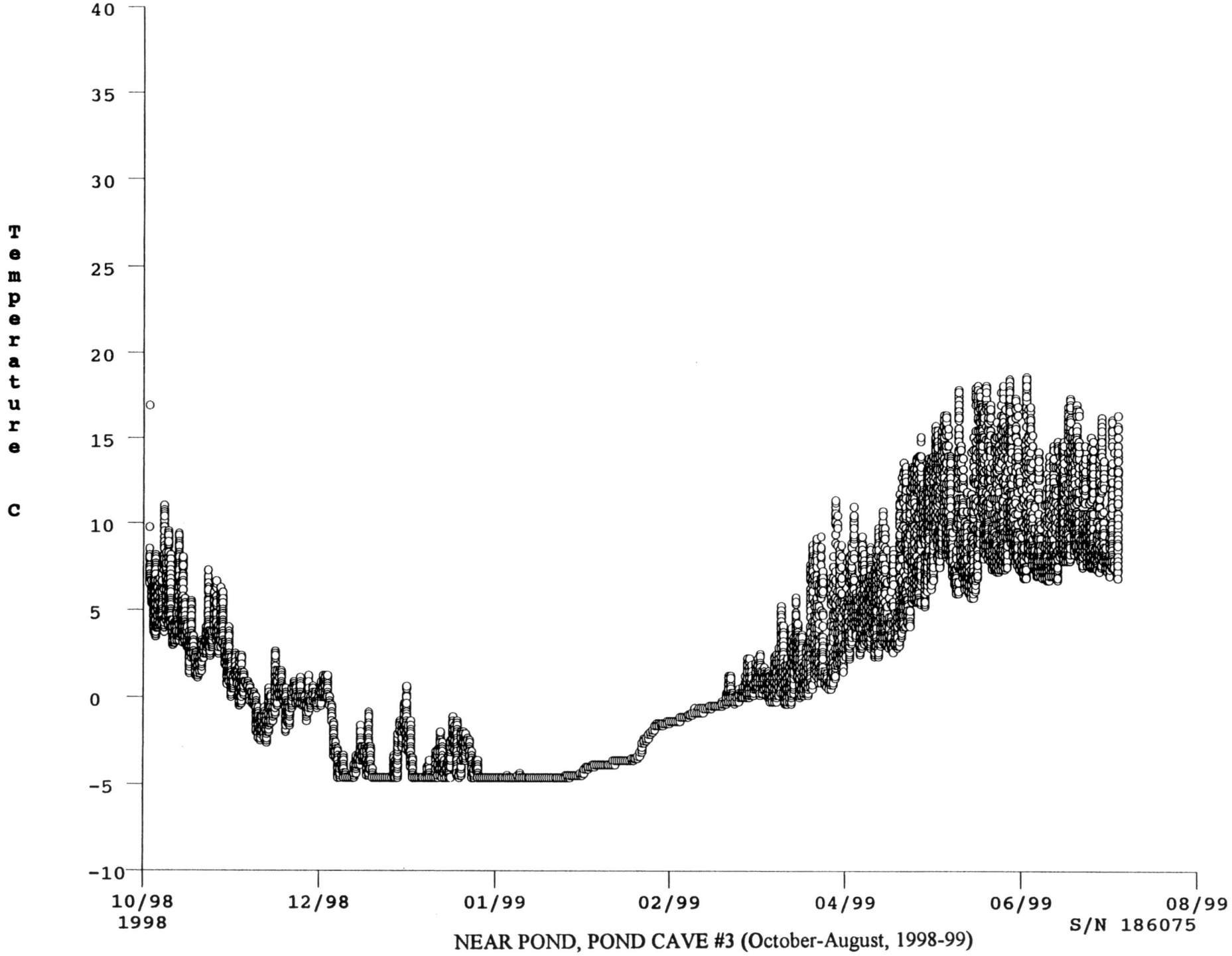

Temperature C
40
35
30
25
20
15
10
5
0
-5
-10
10/98
1998
12/98
01/99
02/99
04/99
06/99
08/99
S/N 186075
NEAR POND, POND CAVE #3 (October-August, 1998-99)

Figure 29. Thermal (C) profile developed from waterproof Optic StowAway Temperature Logger attached to the ceiling area in Dome Cave, beginning March 1997 (see Table 2).

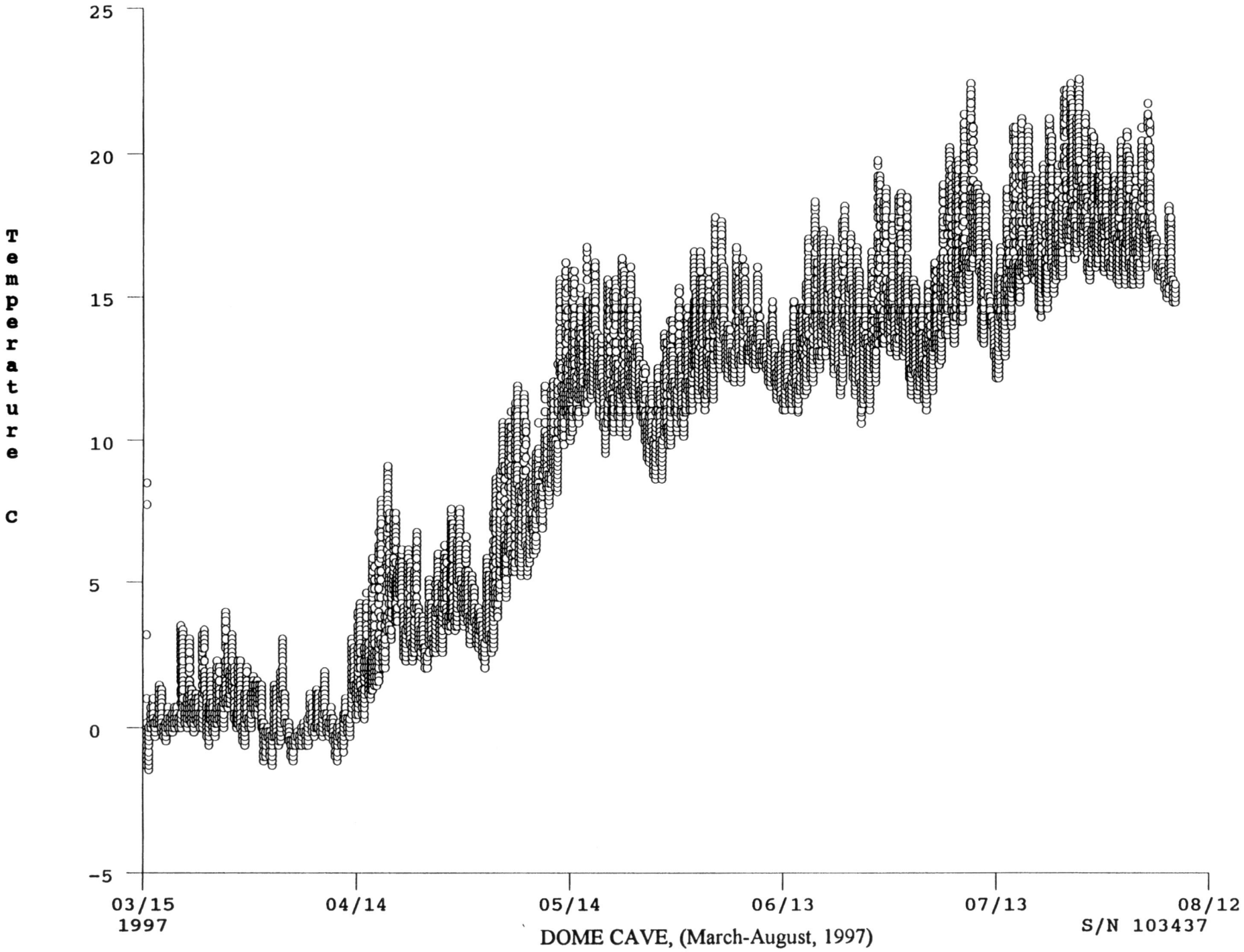
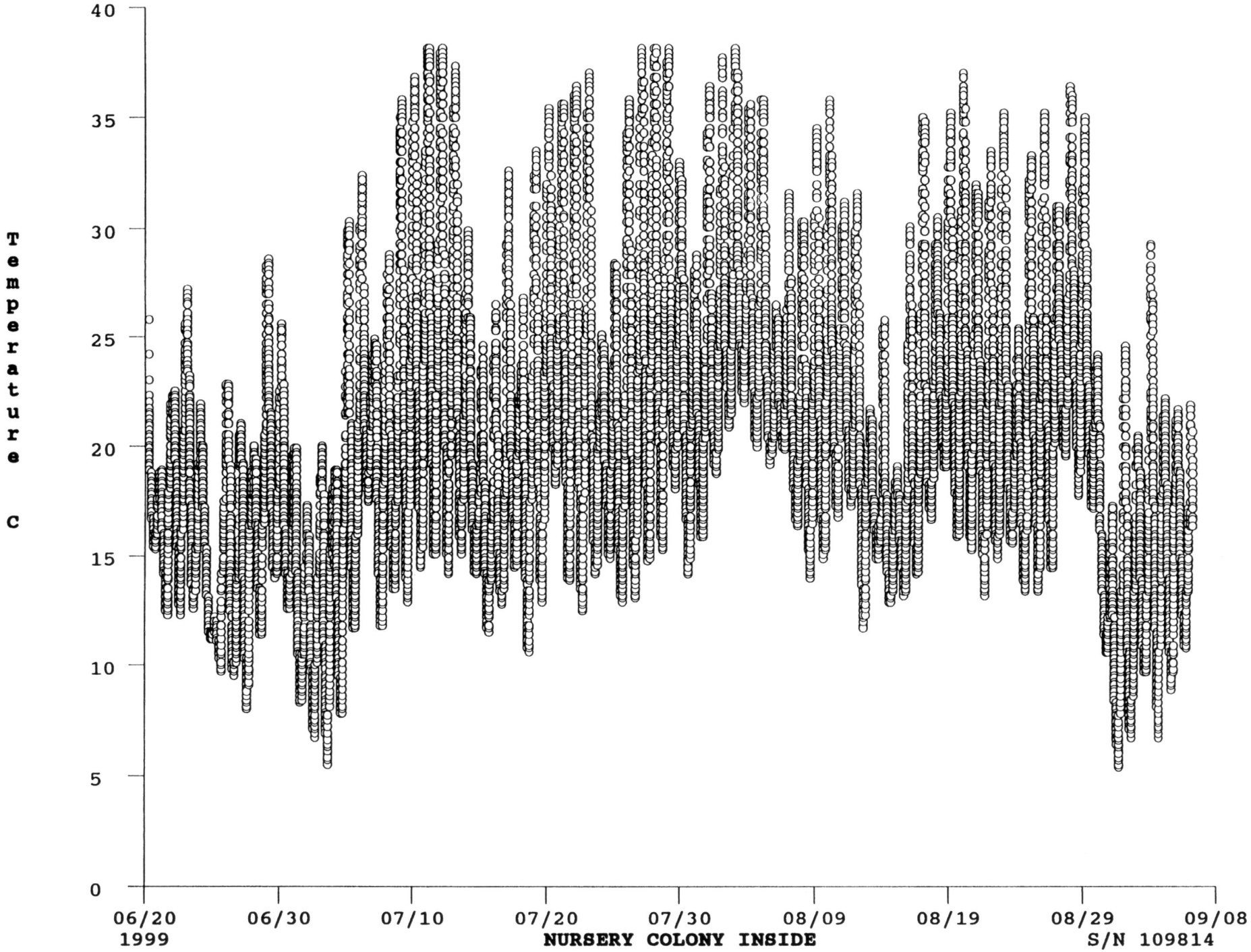

25
20
15
10
5
0
-5
Temperature C
03/15
1997
04/14
05/14
06/13
07/13
08/12
S/N 103437
DOME CAVE, (March-August, 1997)

Figure 30. Thermal (C) profile developed from waterproof Optic StowAway Temperature Logger attached to the ceiling area in a shop building located near Ponderay, Bonner County Idaho. This outbuilding contained a nursery colony of Townsend's Big-eared Bats during the summer of 1999. The bats exited the site on August 16, during cooler weather. The logger was not removed for downloading until September.


Temperature C
40
35
30
25
20
15
10
5
0
06/20
1999
06/30
07/10
07/20
07/30
08/09
08/19
08/29
09/08
NURSERY COLONY INSIDE
S/N 109814

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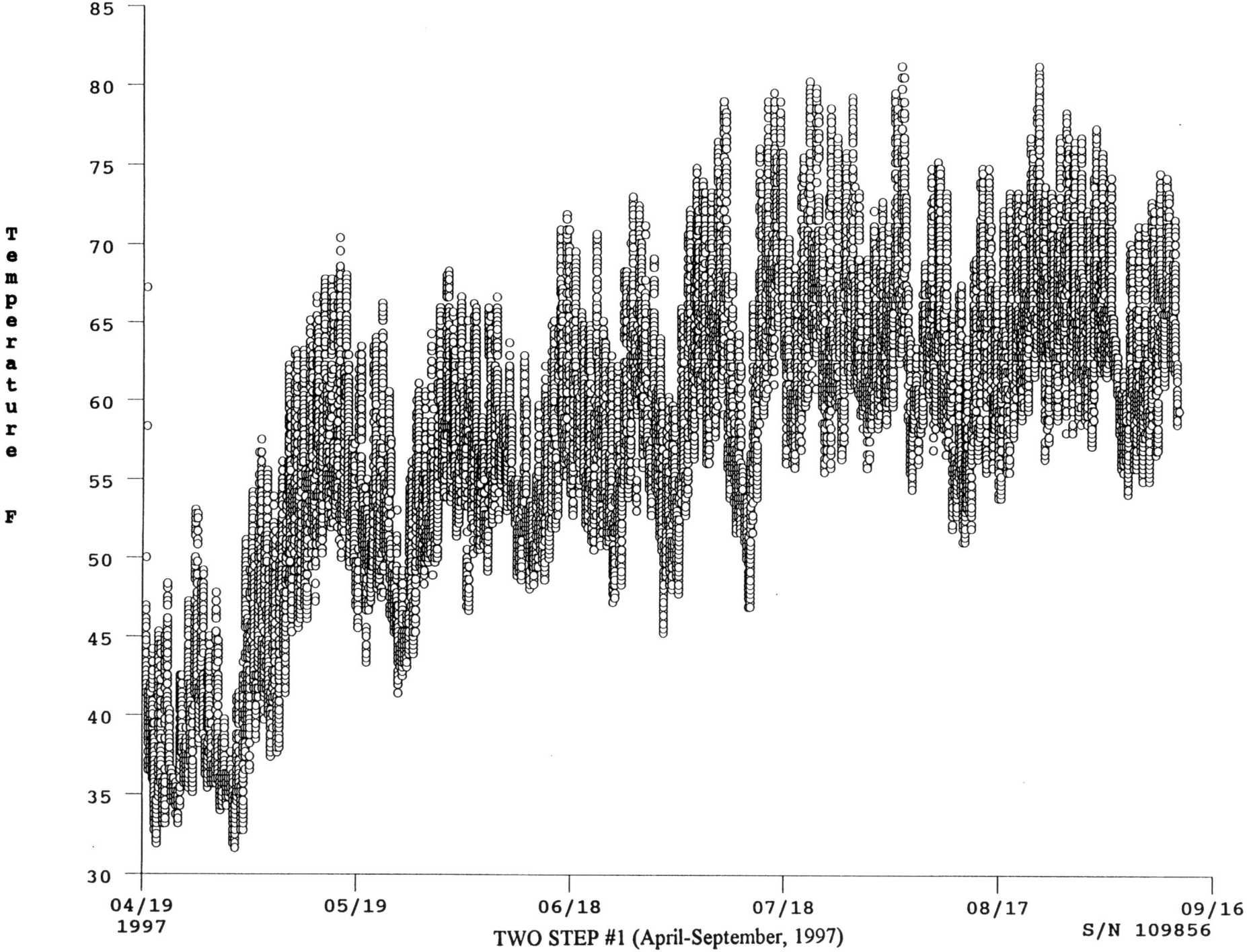
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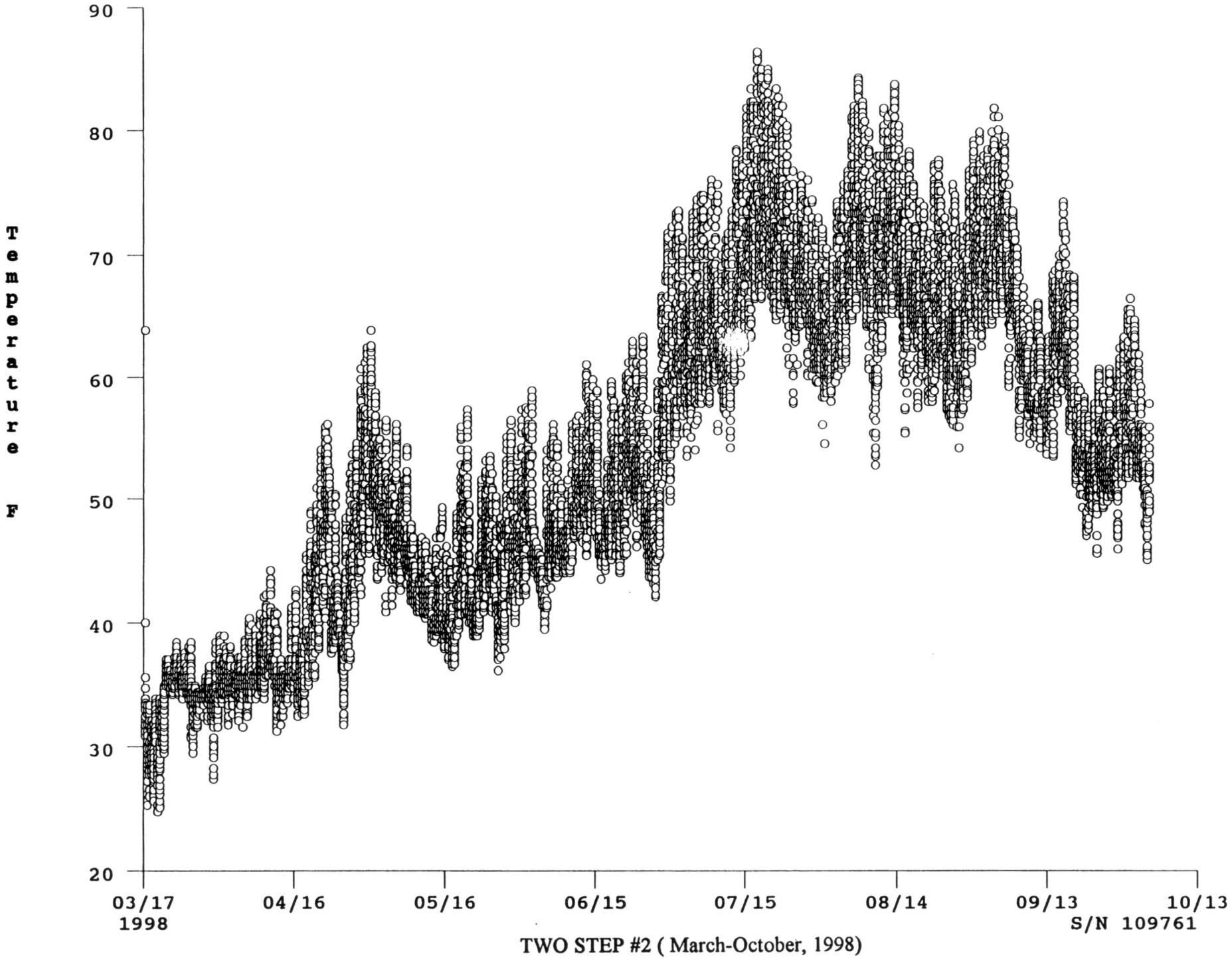
Tumilson, R. and M. Douglas. 1992. Parsimony analysis and the phylogeny of the plecotine bats (Chiroptera: Vespertilionidae). J. Mammal. 73:276-285.

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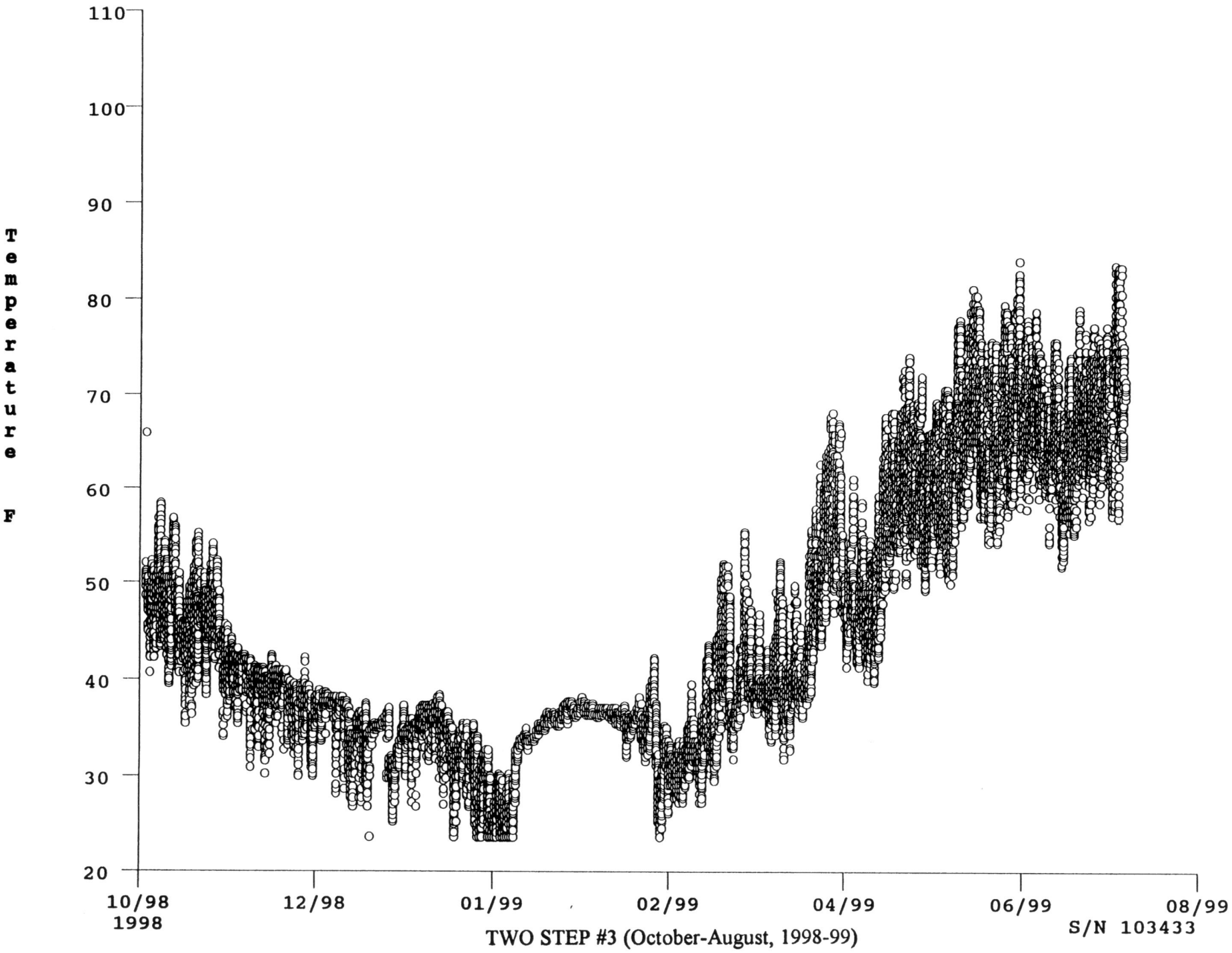
Wackenhut, M.C. 1990. Bat species overwintering in lava-tube caves in Lincoln, Gooding, Blaine, Bingham, and Butte Counties, Idaho with special reference to annual return of banded Plecotus townsendii. M.S. Thesis, Idaho State University, Pocatello. 64p.

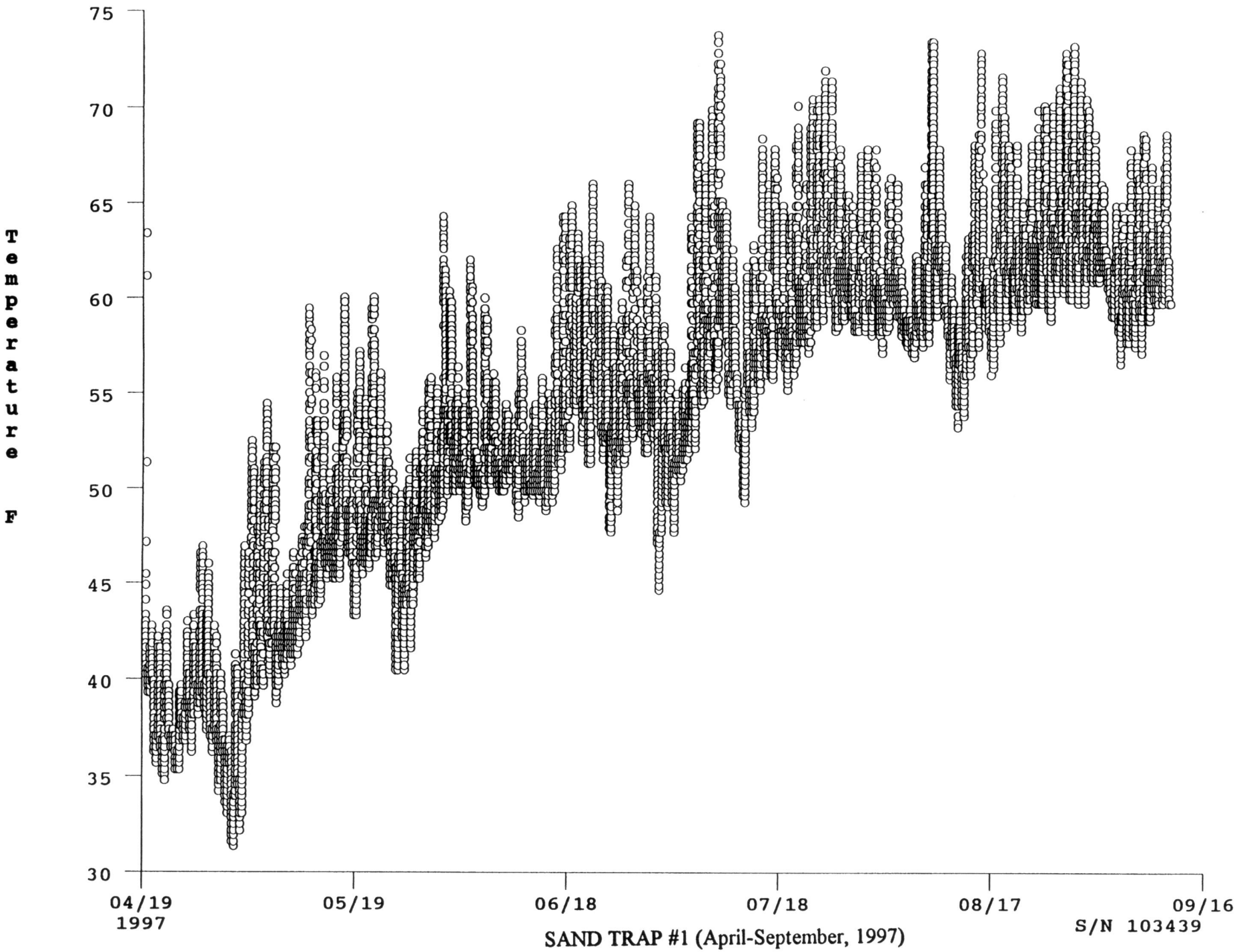
Appendix A. Thermal profiles plotted in degrees F for logger Figures 1-30 as provided in the text of this report (see Table 2).

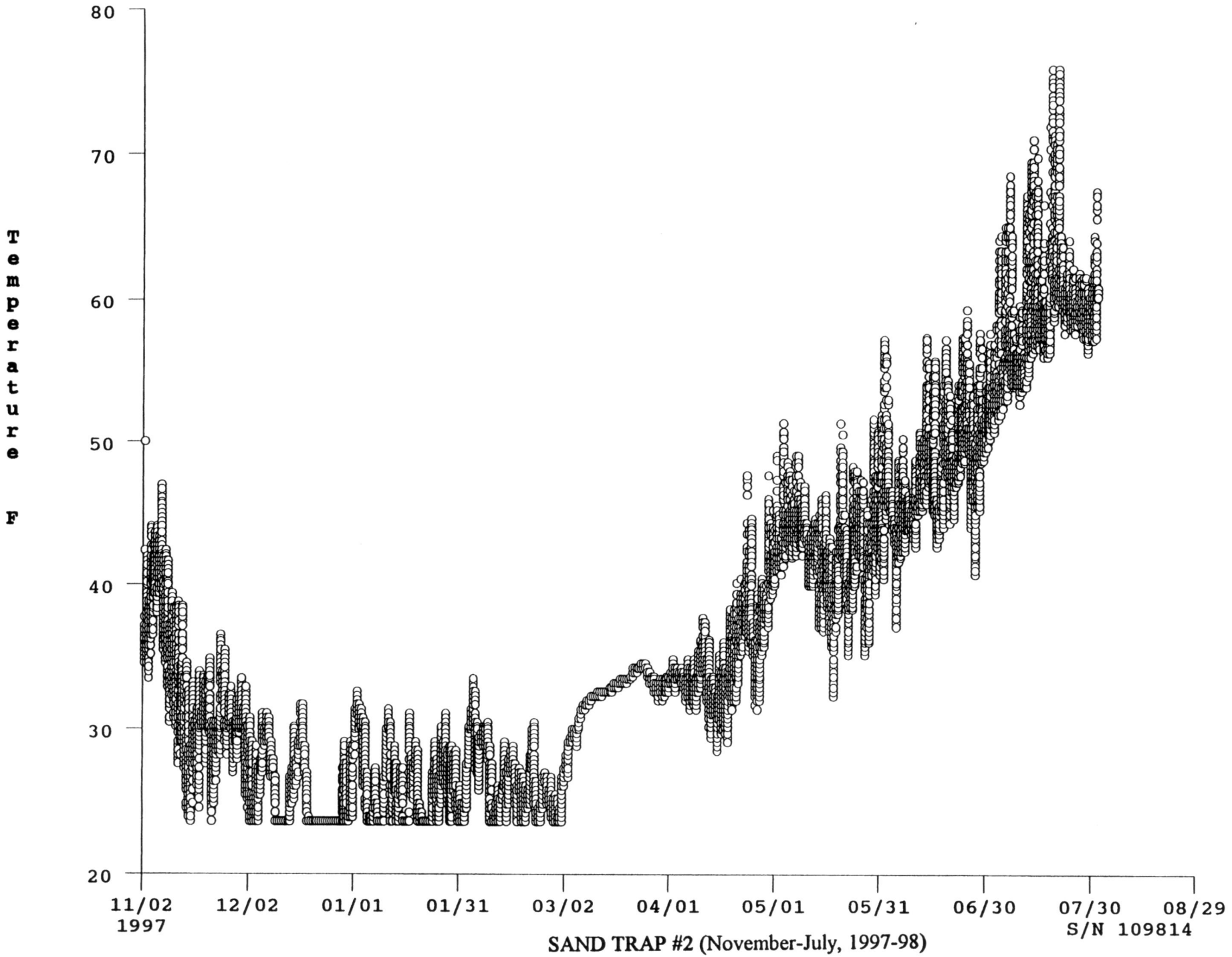

Temperature F
85
80
75
70
65
60
55
50
45
40
35
30
04/19
1997
05/19
06/18
07/18
08/17
09/16
TWO STEP #1 (April-September, 1997)
S/N 109856

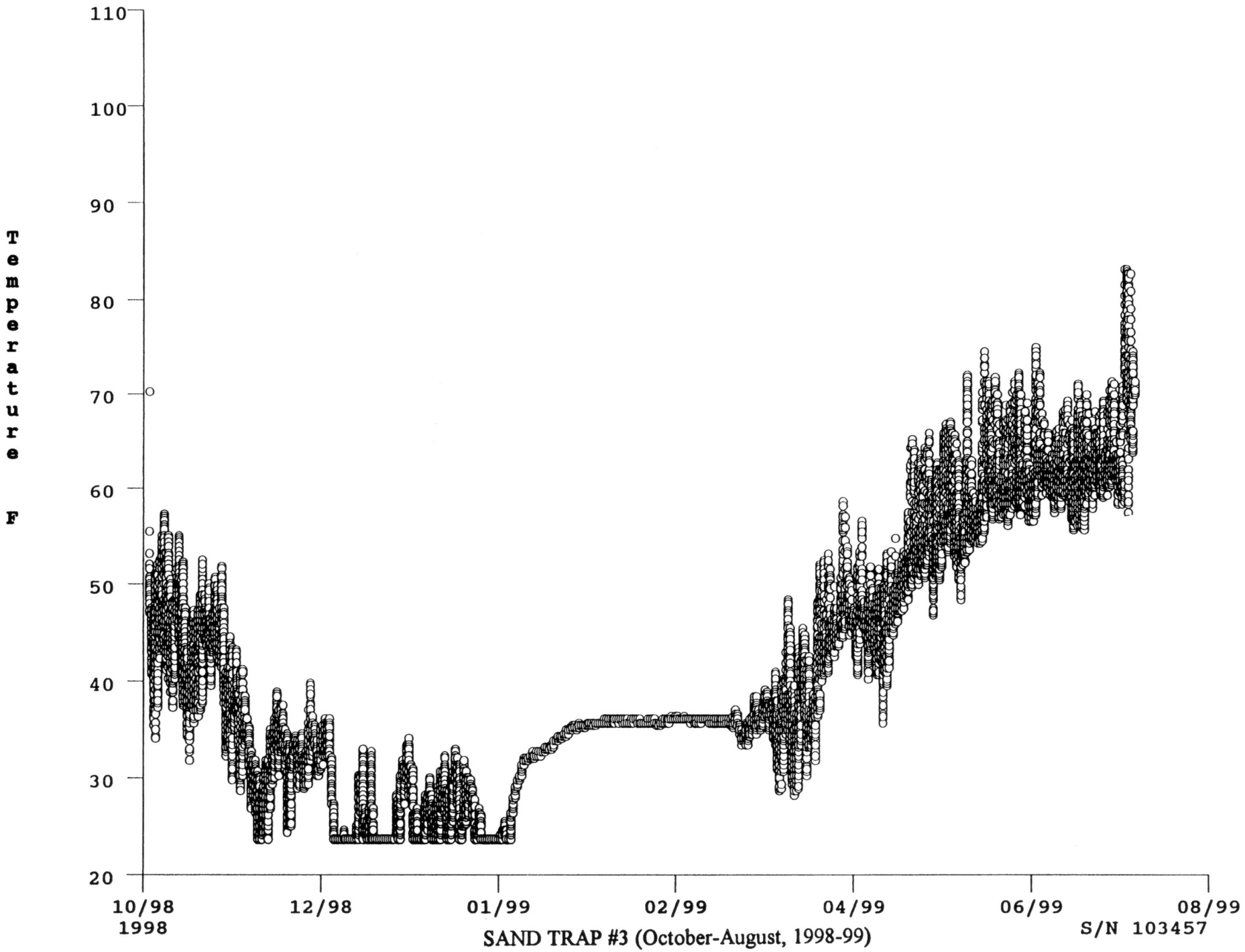


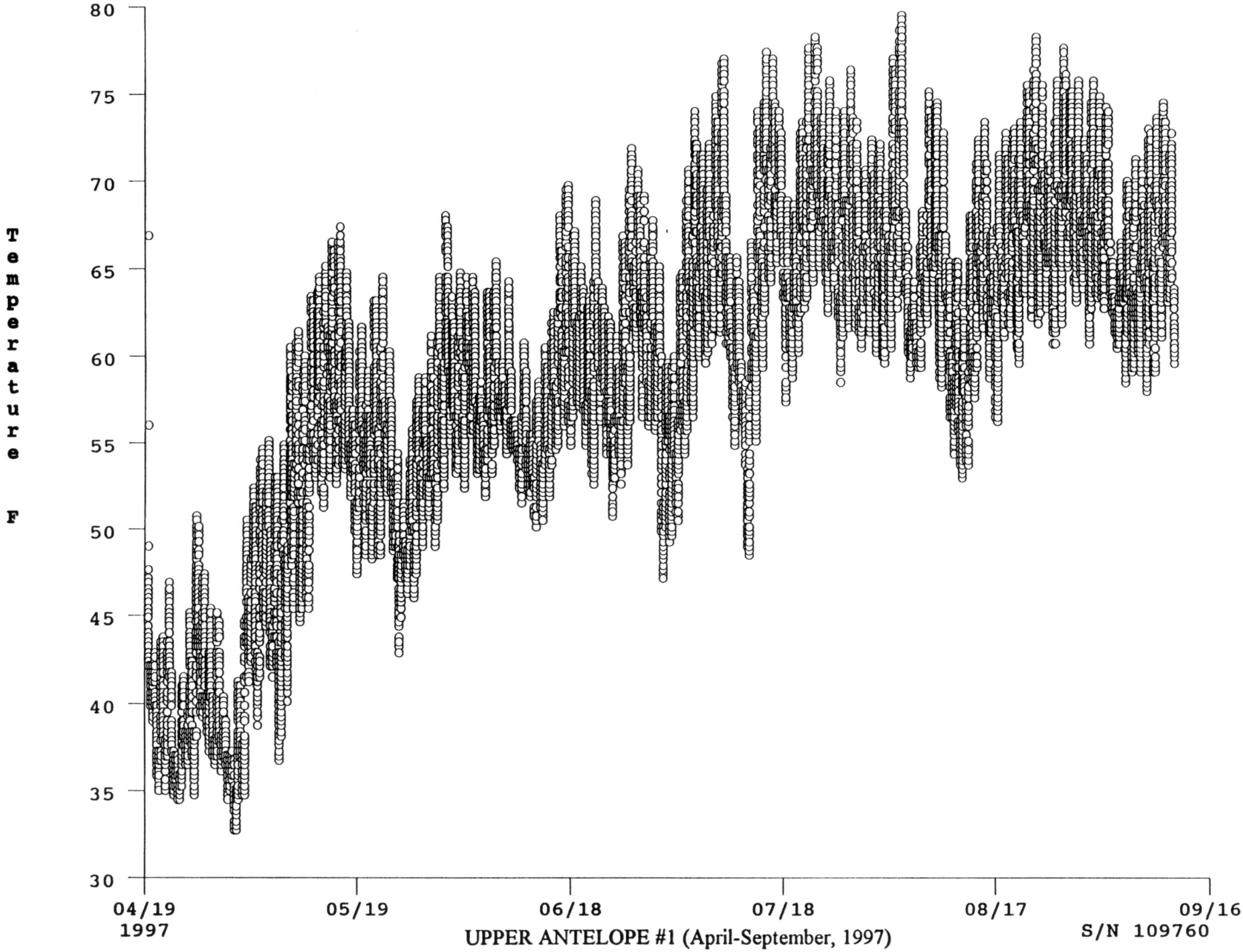
TWO STEP #2 (March-October, 1998)

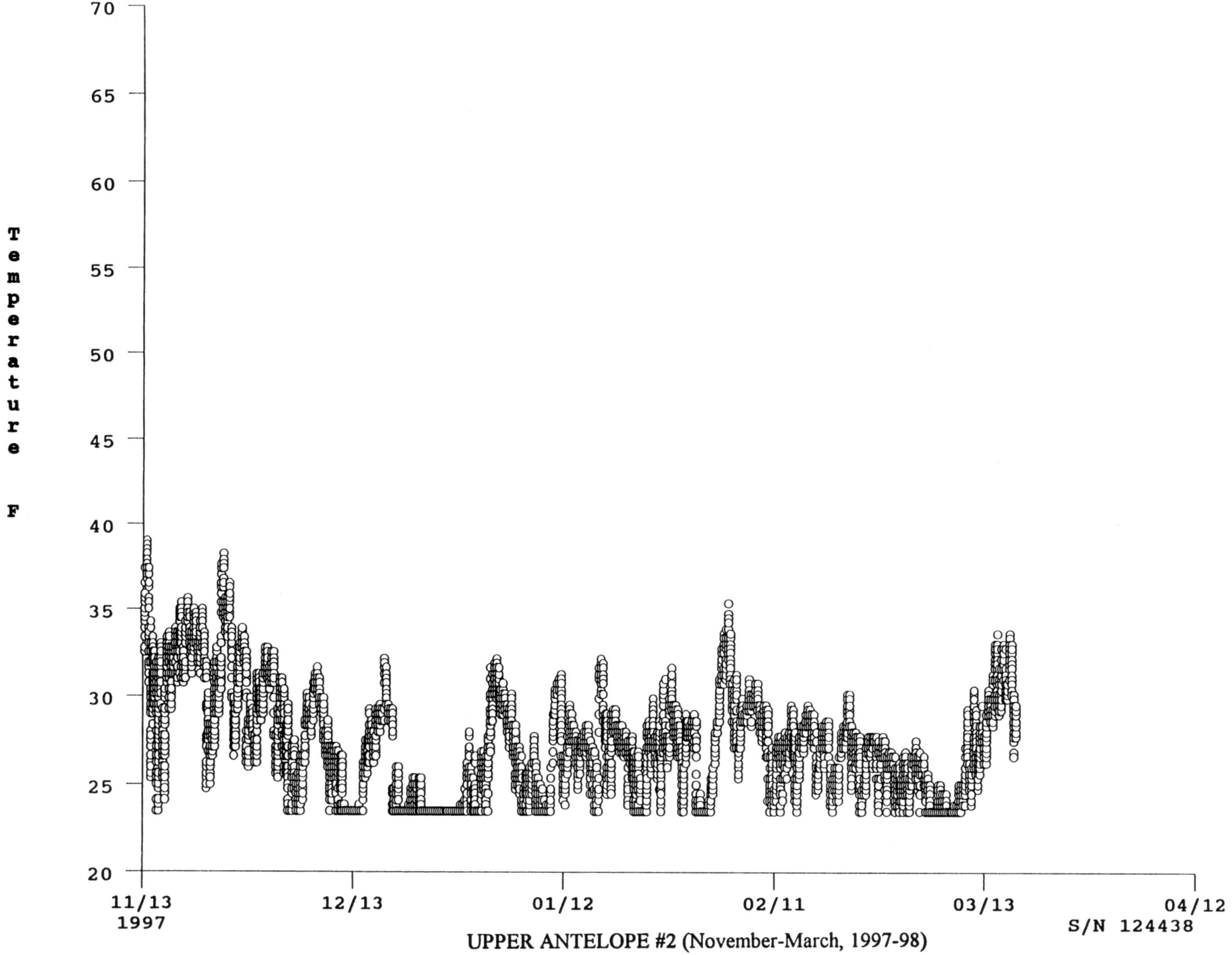

Temperature F
110
100
90
80
70
60
50
40
30
20
10/98
1998
12/98
01/99
02/99
04/99
06/99
08/99
TWO STEP #3 (October-August, 1998-99)
S/N 103433


Temperature F
75
70
65
60
55
50
45
40
35
30
04/19
1997
05/19
06/18
07/18
08/17
09/16
S/N 103439
SAND TRAP #1 (April-September, 1997)

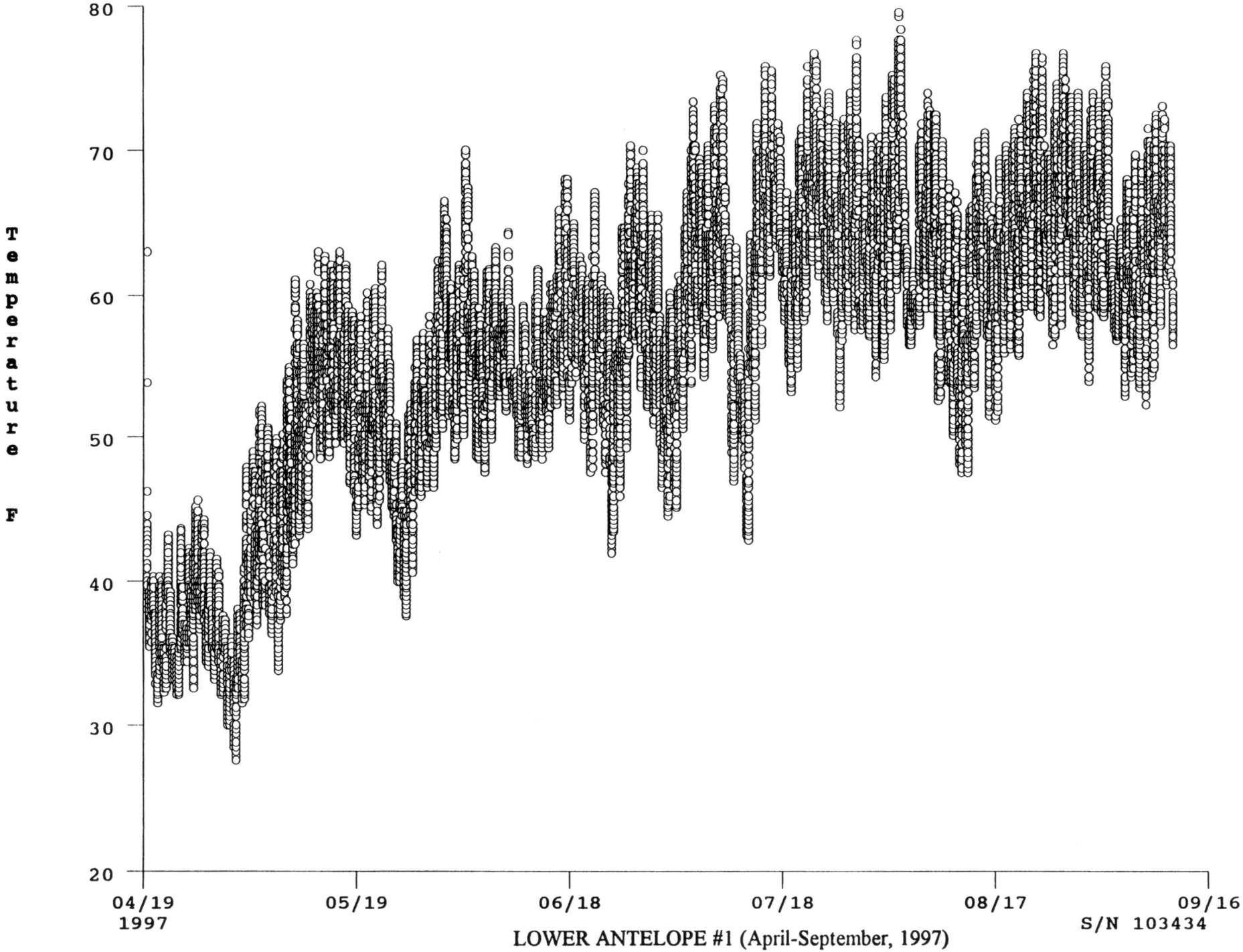

80
70
60
50
40
30
20
Temperature F
11/02
1997
12/02
01/01
01/31
03/02
04/01
05/01
05/31
06/30
07/30
08/29
S/N 109814
SAND TRAP #2 (November-July, 1997-98)

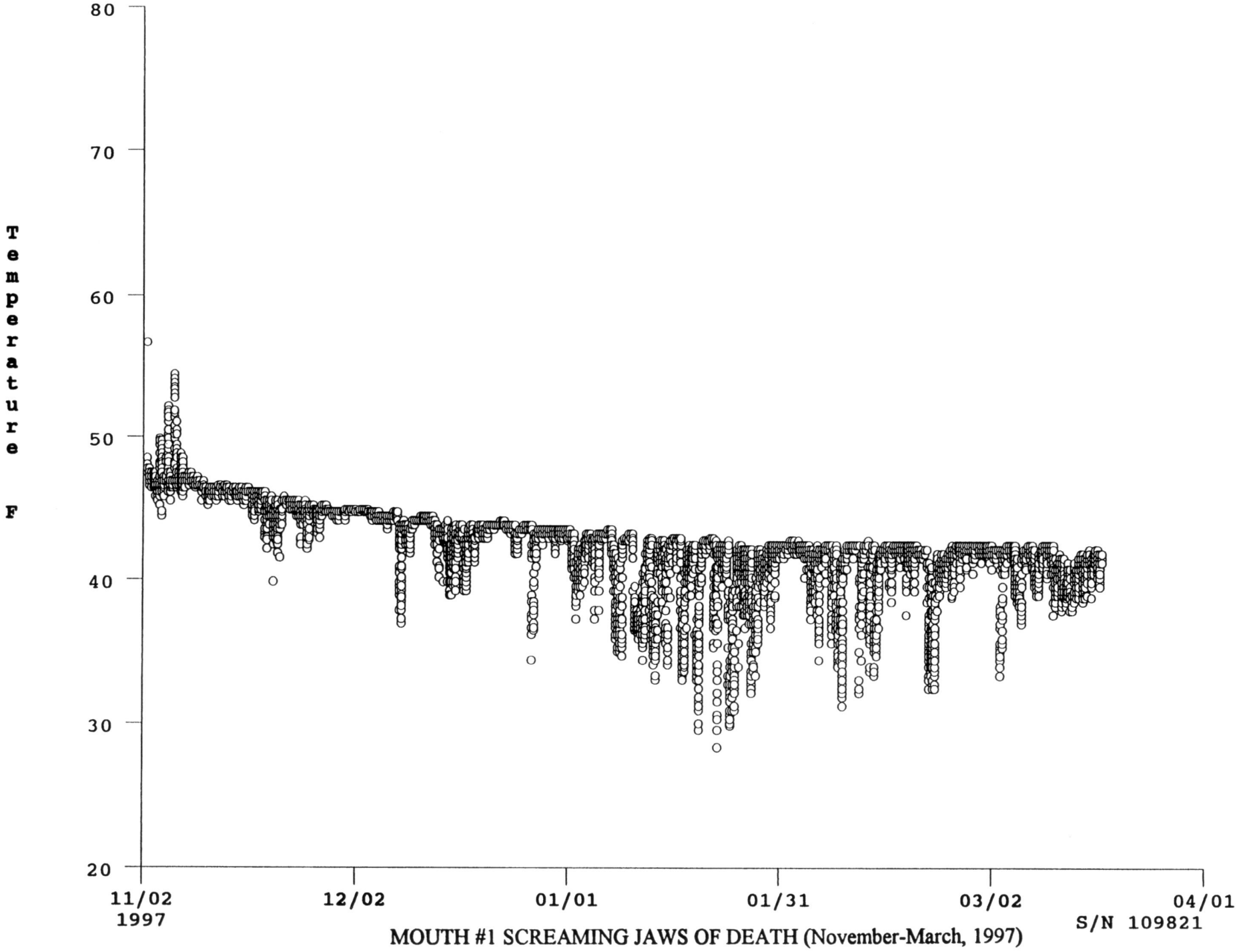

110
100
90
80
70
60
50
40
30
20
Temperature F
10/98
1998
12/98
01/99
02/99
04/99
06/99
08/99
SAND TRAP #3 (October-August, 1998-99)
S/N 103457

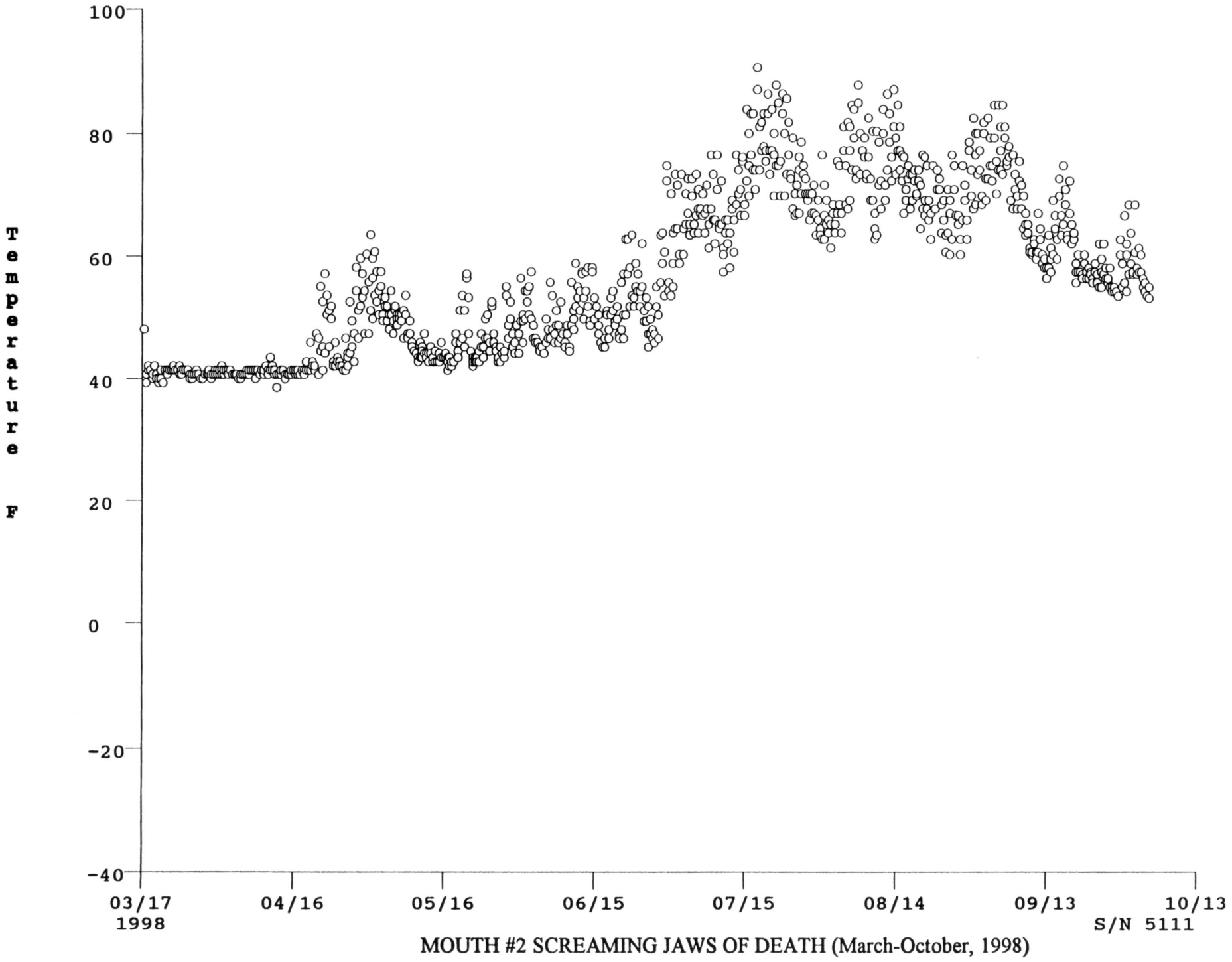

Temperature F
80
75
70
65
60
55
50
45
40
35
30
04/19
1997
05/19
06/18
07/18
08/17
09/16
UPPER ANTELOPE #1 (April-September, 1997)
S/N 109760



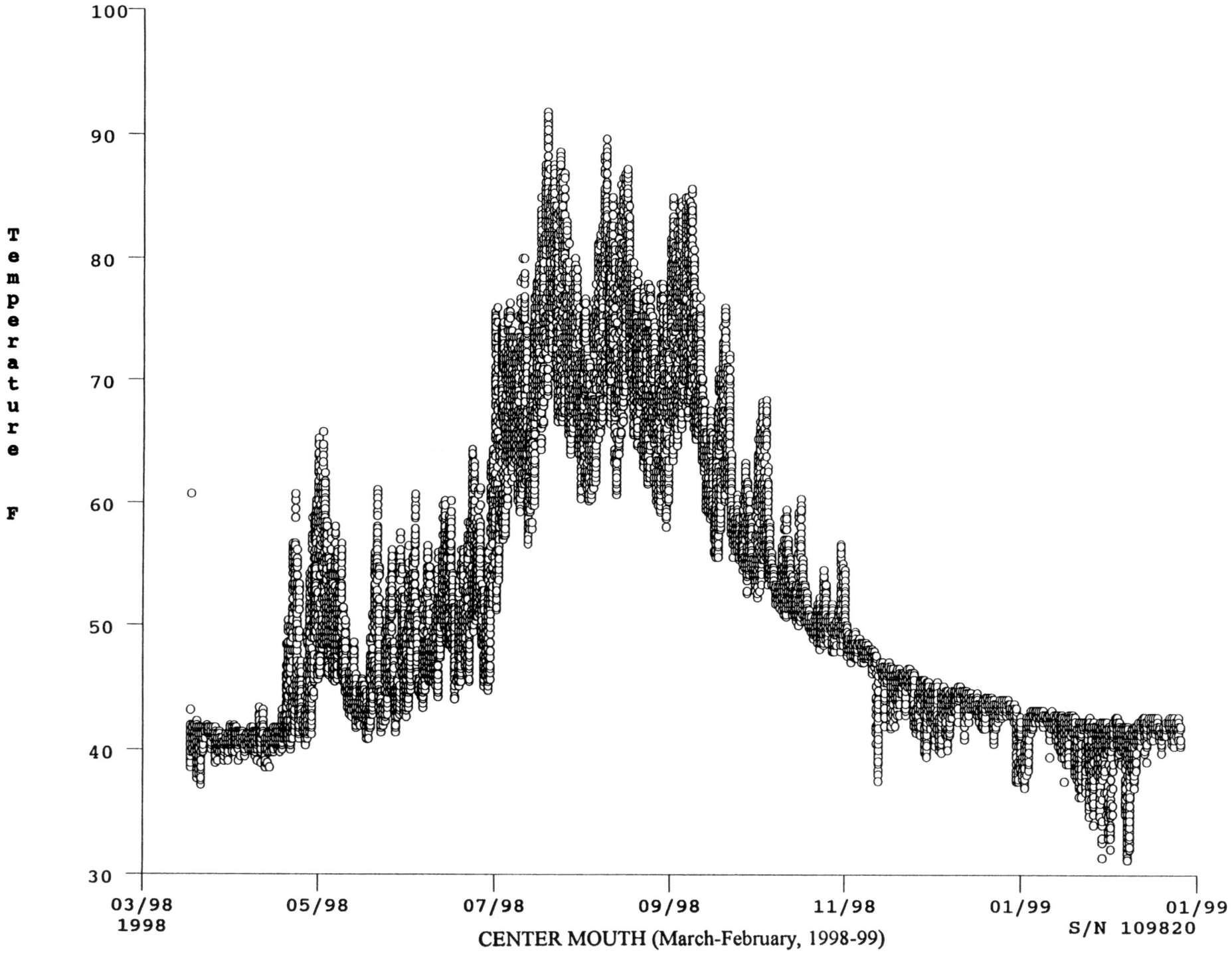
UPPER ANTELOPE #2 (November-March, 1997-98)

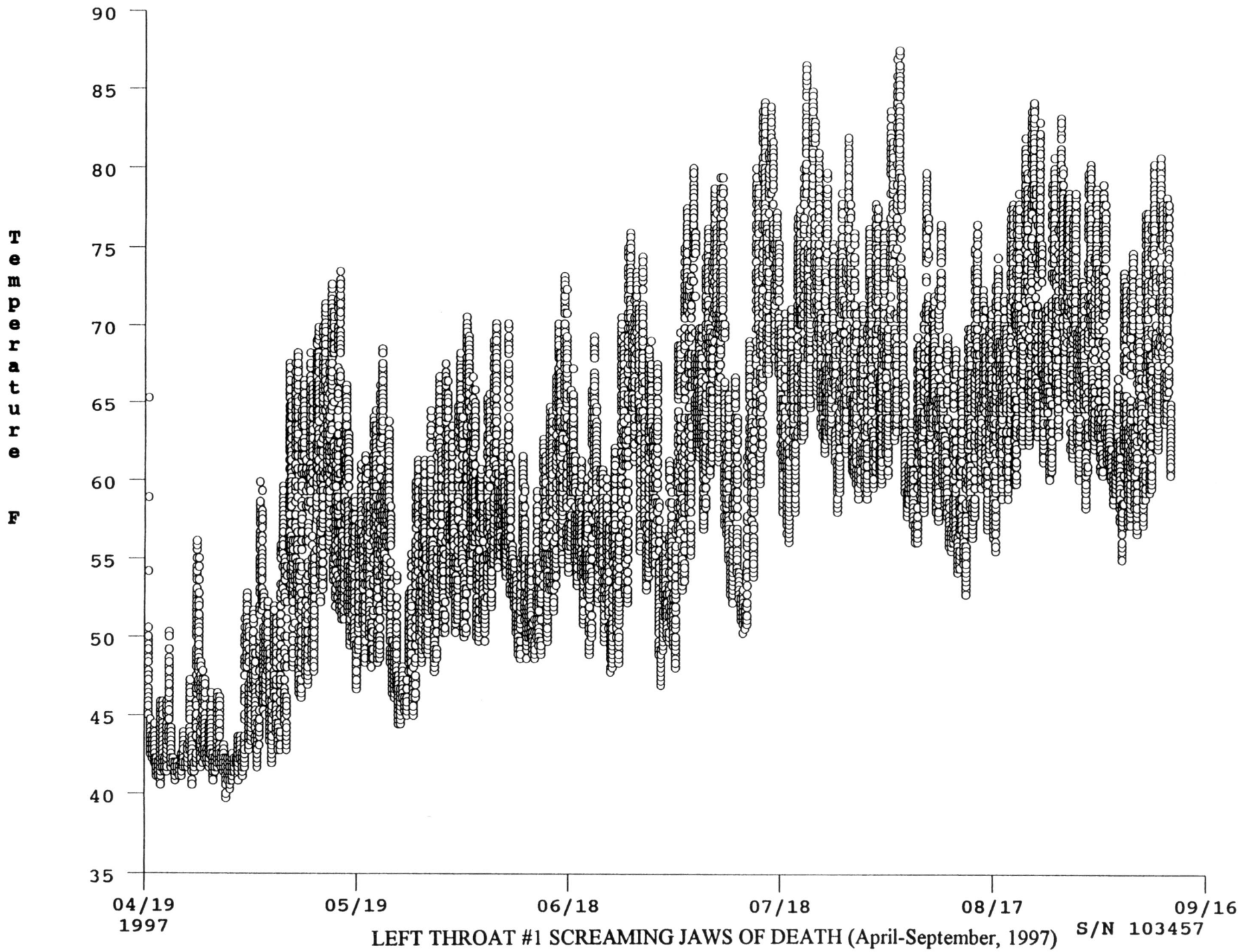

80
70
60
50
40
30
20
Temperature F
04/19
1997
05/19
06/18
07/18
08/17
09/16
S/N 103434
LOWER ANTELOPE #1 (April-September, 1997)

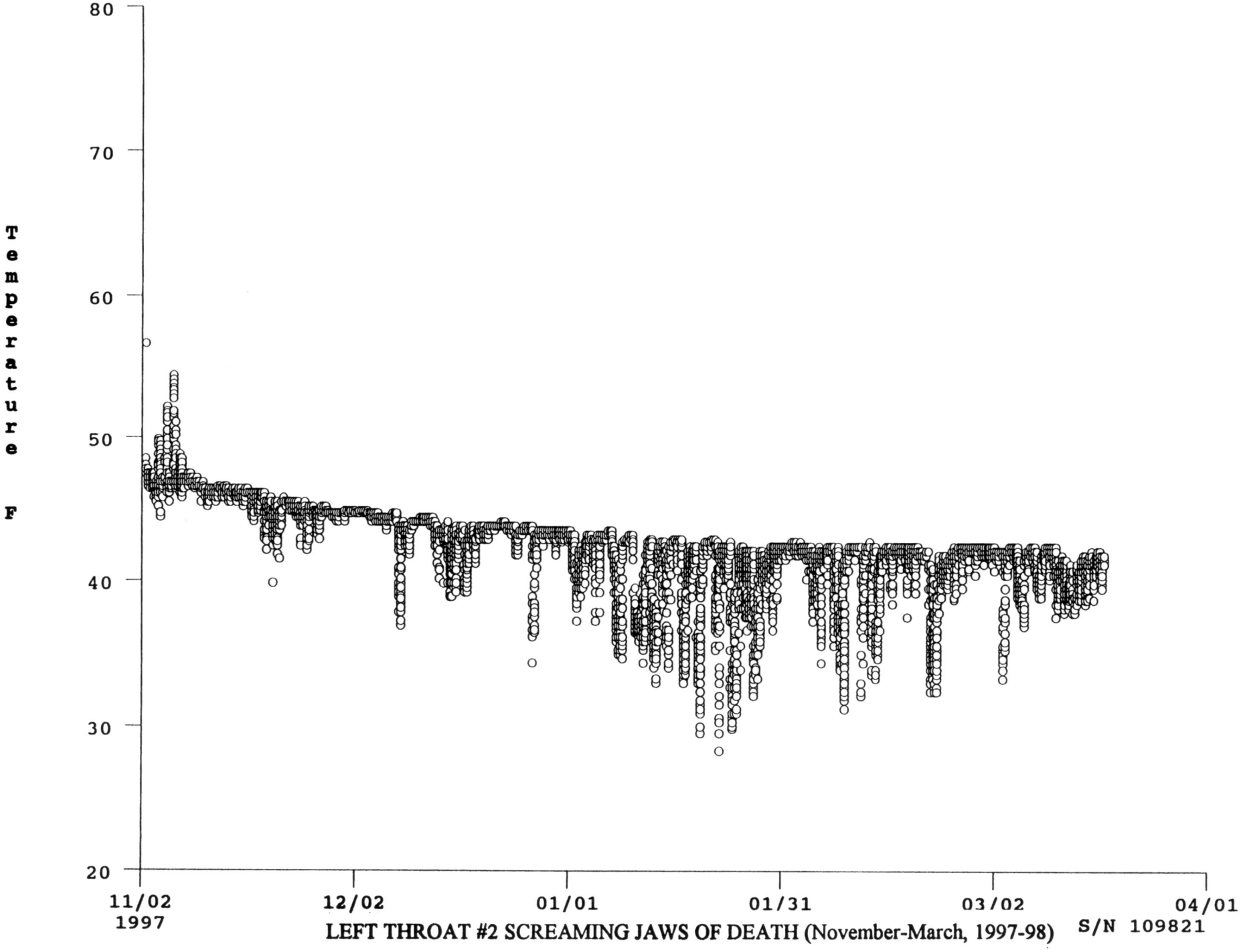

80
70
60
50
40
30
20
Temperature F
11/02
1997
12/02
01/01
01/31
03/02
04/01
S/N 109821
MOUTH #1 SCREAMING JAWS OF DEATH (November-March, 1997)

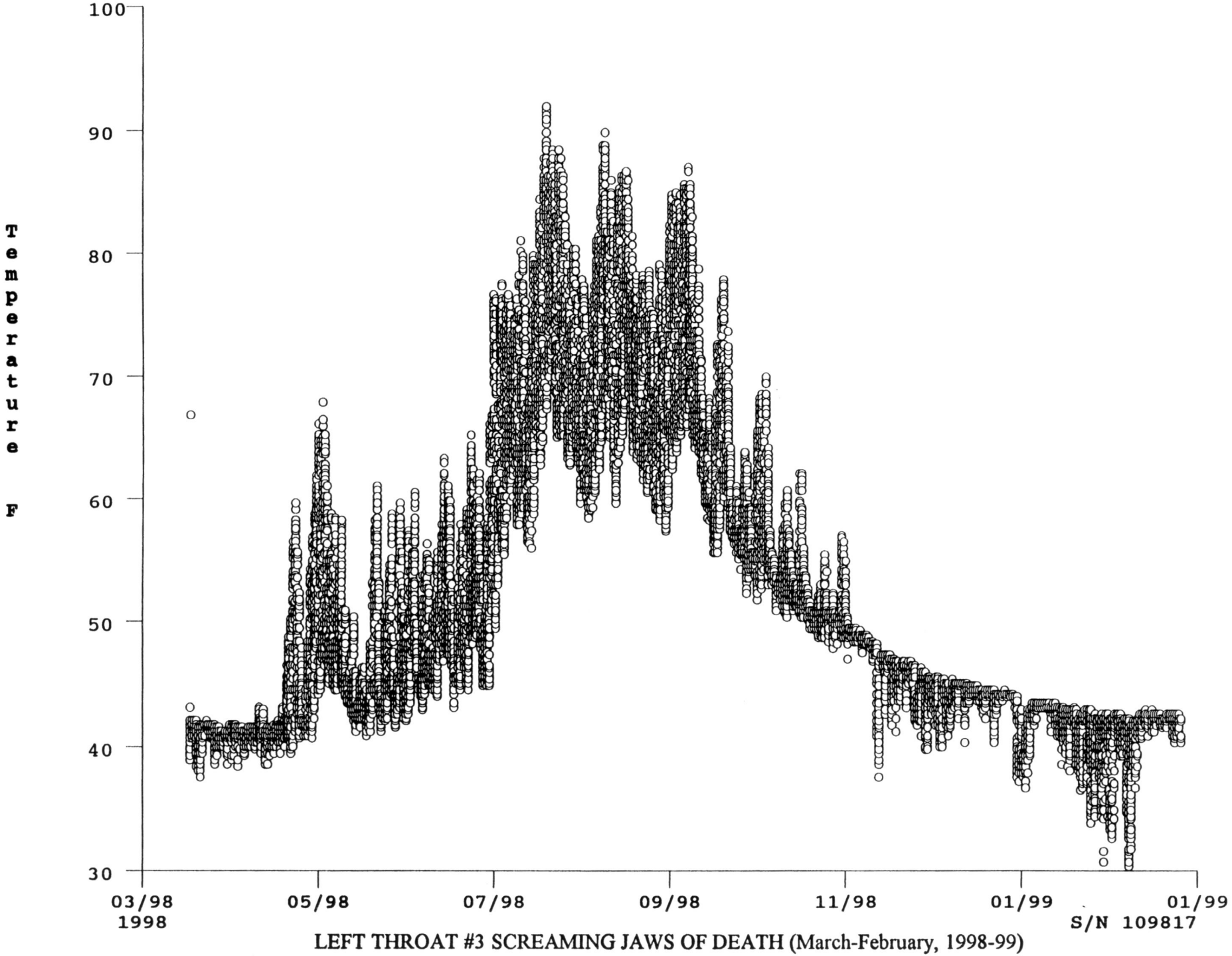


MOUTH #2 SCREAMING JAWS OF DEATH (March-October, 1998)

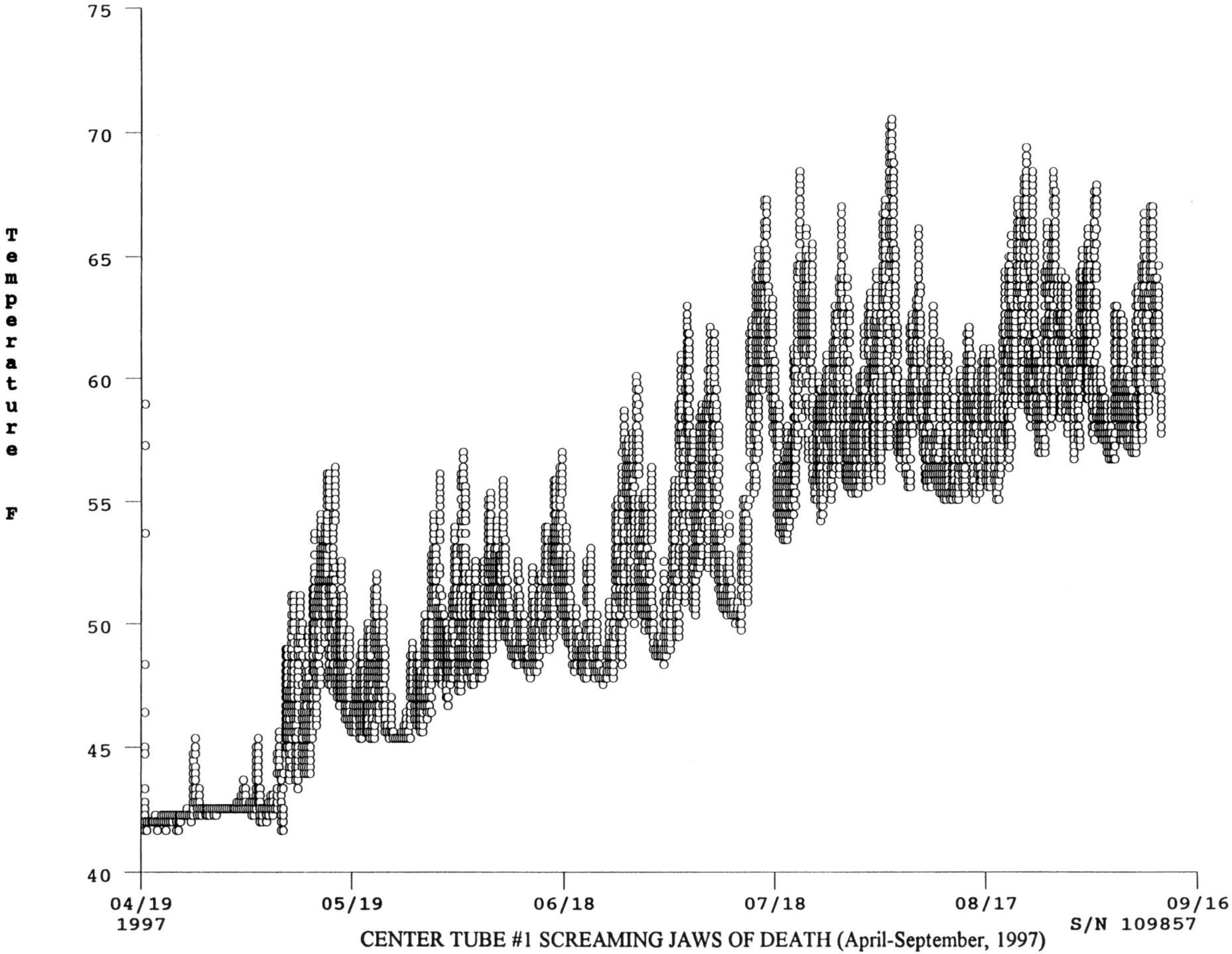

100
90
80
70
60
50
40
30
Temperature F
03/98
1998
05/98
07/98
09/98
11/98
01/99
01/99
S/N 109820
CENTER MOUTH (March-February, 1998-99)

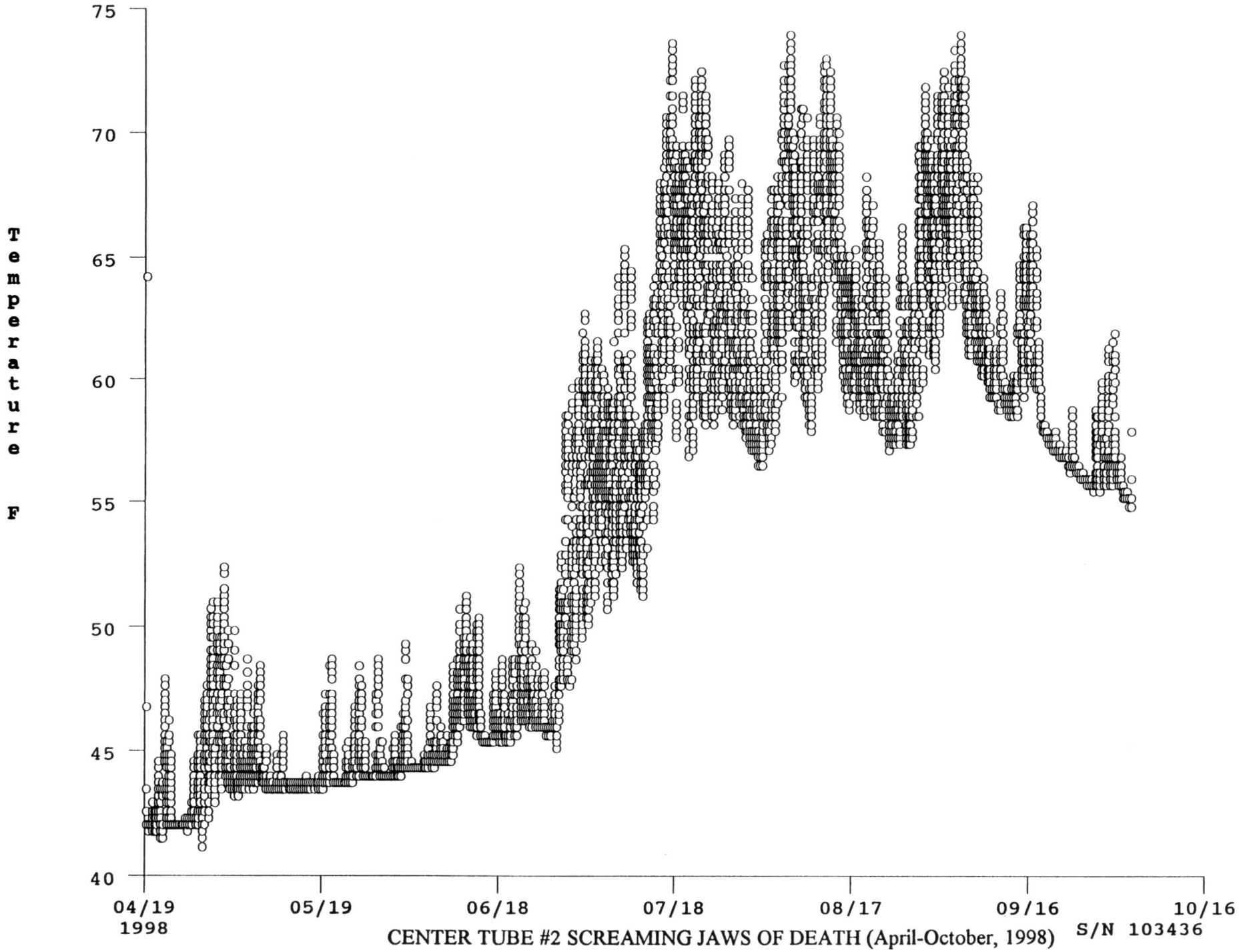

Temperature F
90
85
80
75
70
65
60
55
50
45
40
35
04/19
1997
05/19
06/18
07/18
08/17
09/16
LEFT THROAT #1 SCREAMING JAWS OF DEATH (April-September, 1997)
S/N 103457

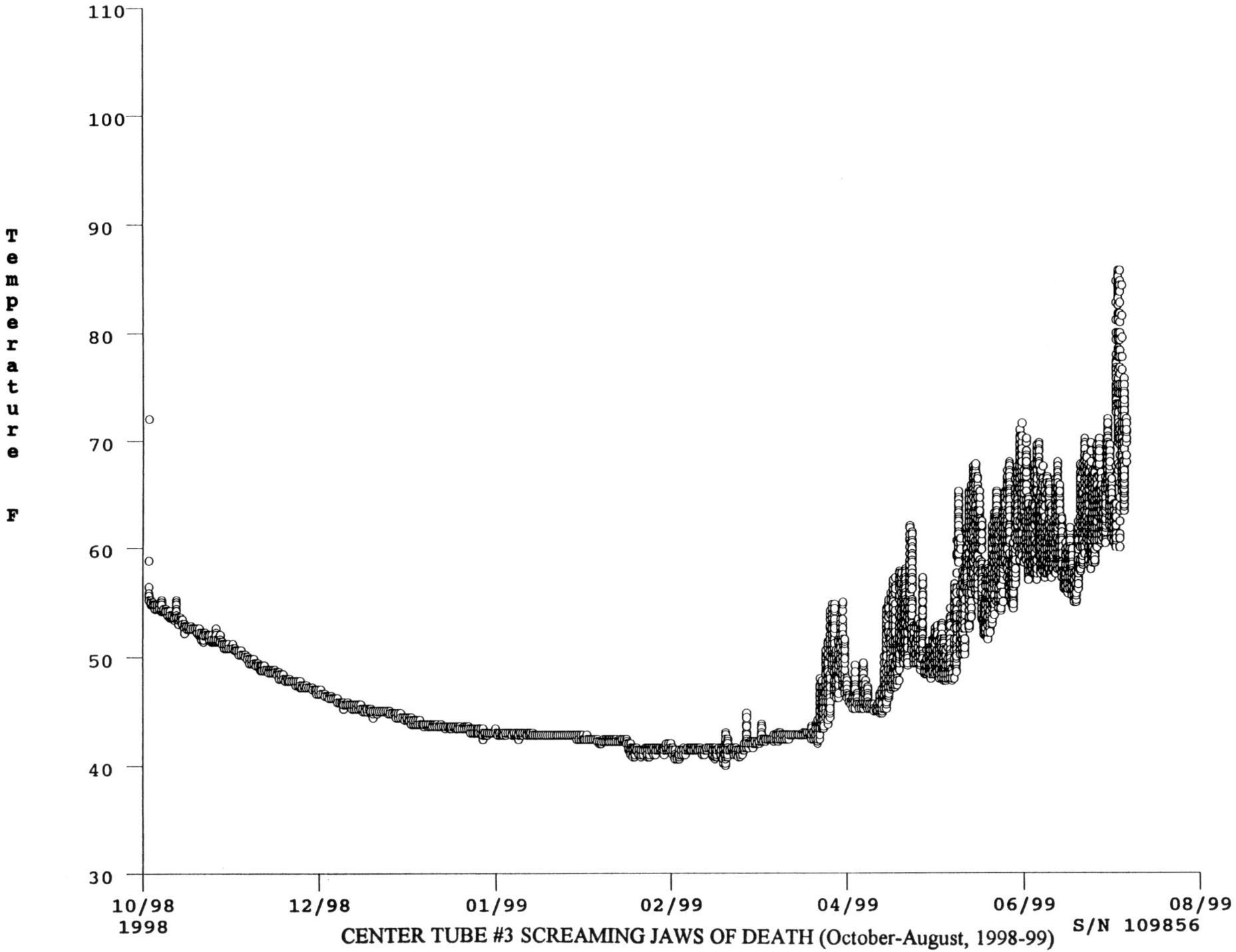

80
70
60
50
40
30
20
Temperature F
11/02
1997
12/02
01/01
01/31
03/02
04/01
LEFT THROAT #2 SCREAMING JAWS OF DEATH (November-March, 1997-98)
S/N 109821

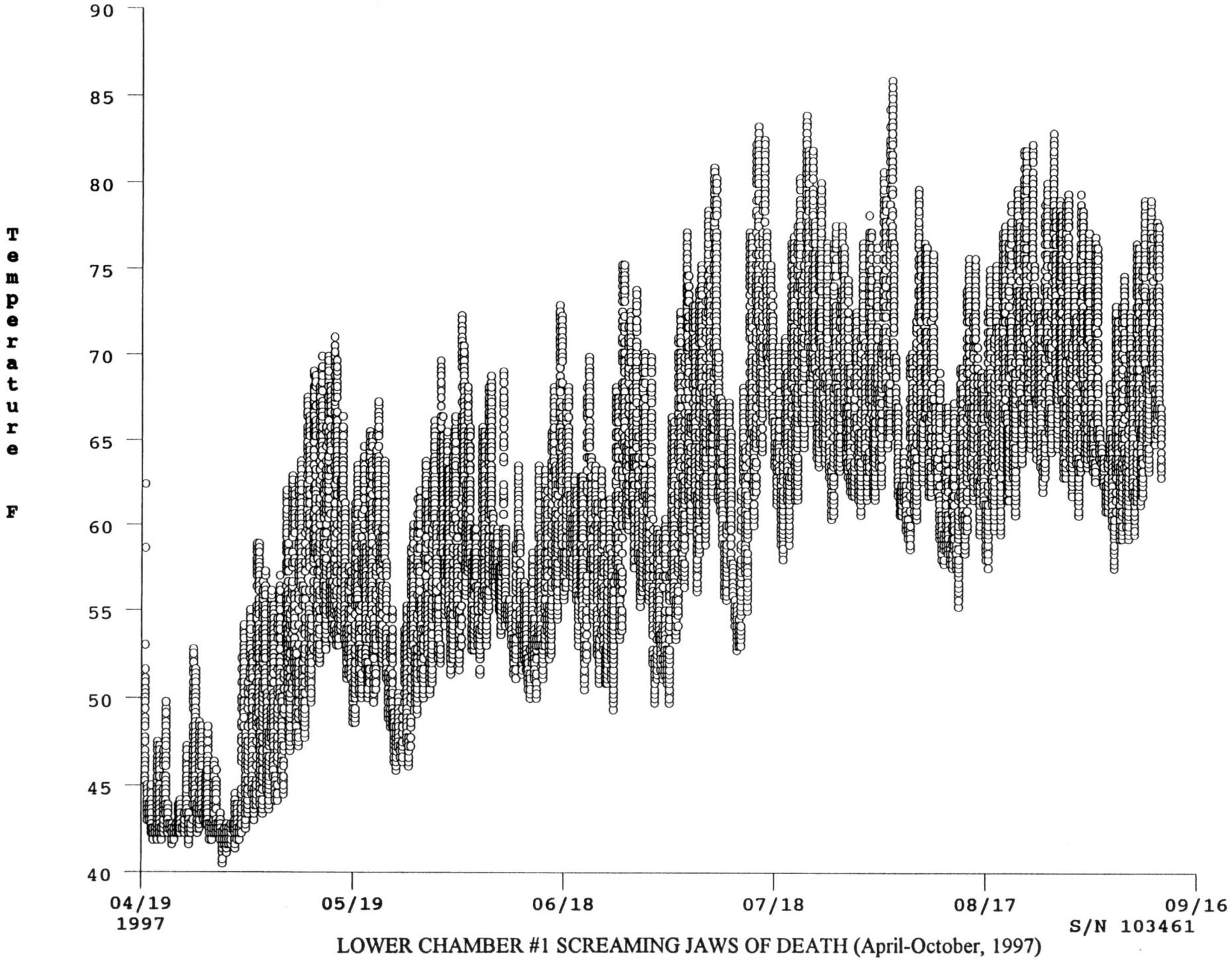


LEFT THROAT #3 SCREAMING JAWS OF DEATH (March-February, 1998-99)

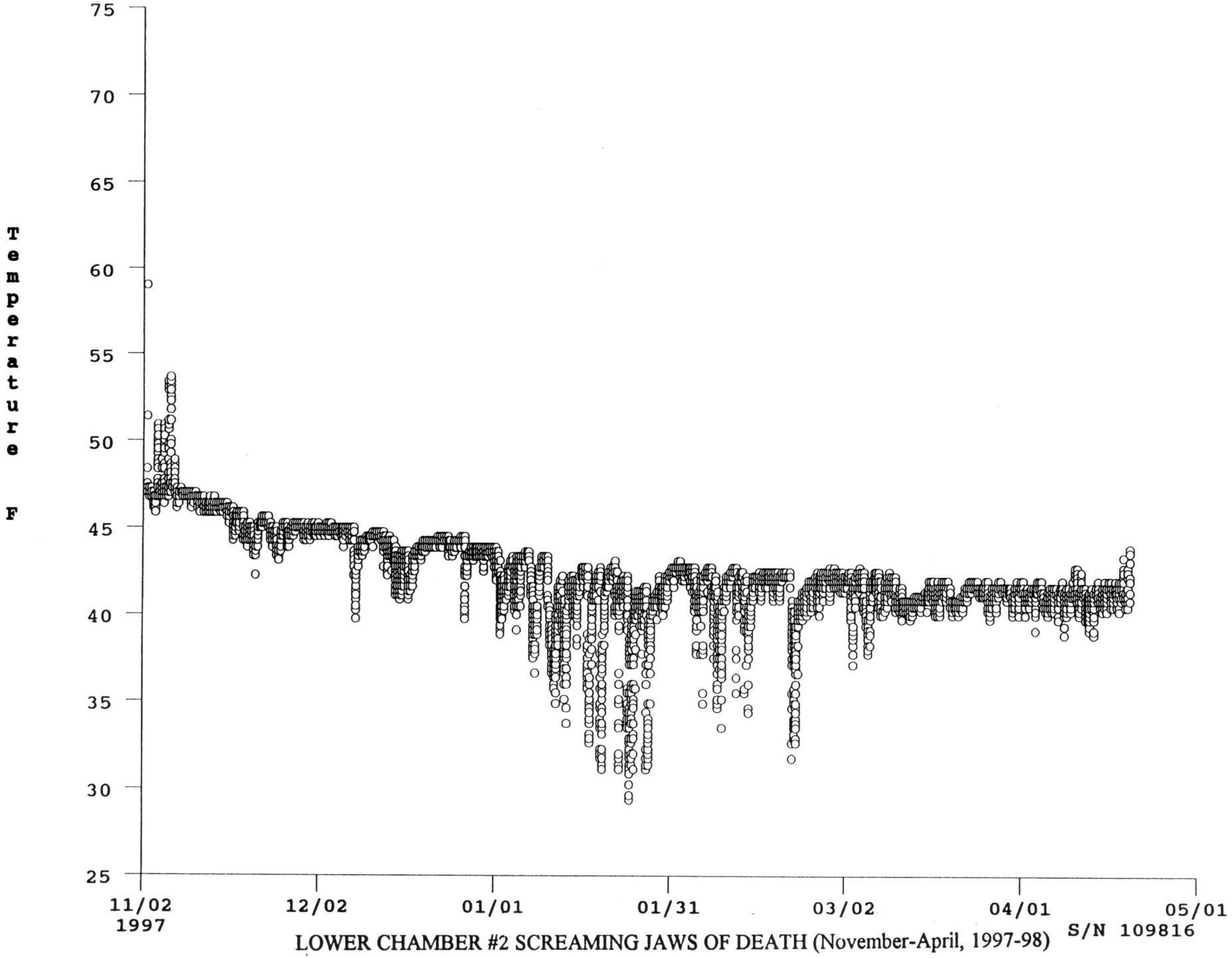

75
70
65
60
55
50
45
40
Temperature F
04/19
1997
05/19
06/18
07/18
08/17
09/16
S/N 109857
CENTER TUBE #1 SCREAMING JAWS OF DEATH (April-September, 1997)

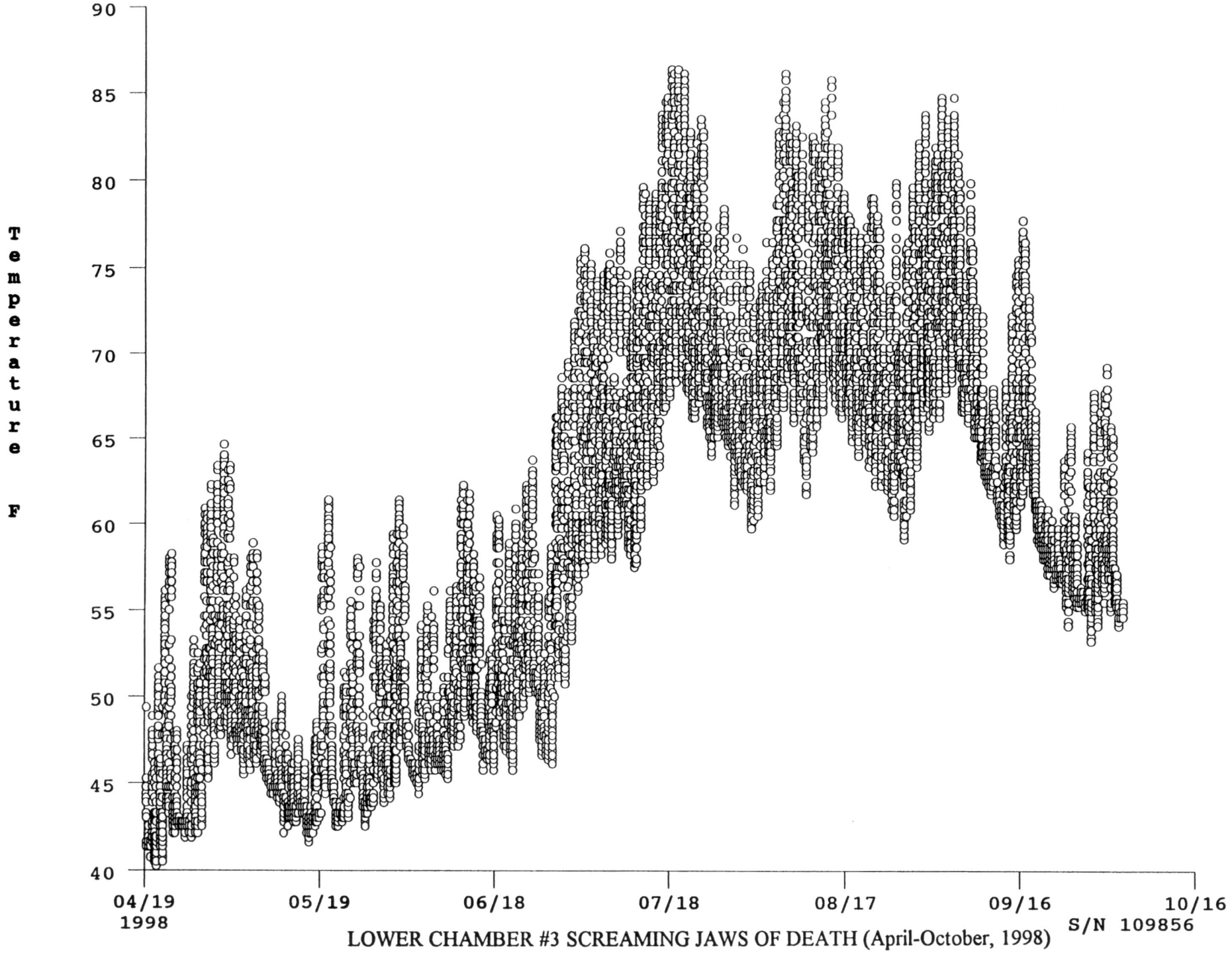

Temperature F
75
70
65
60
55
50
45
40
04/19
1998
05/19
06/18
07/18
08/17
09/16
10/16
CENTER TUBE #2 SCREAMING JAWS OF DEATH (April-October, 1998)
S/N 103436


110
100
90
80
70
60
50
40
30
Temperature F
10/98
1998
12/98
01/99
02/99
04/99
06/99
08/99
S/N 109856
CENTER TUBE #3 SCREAMING JAWS OF DEATH (October-August, 1998-99)

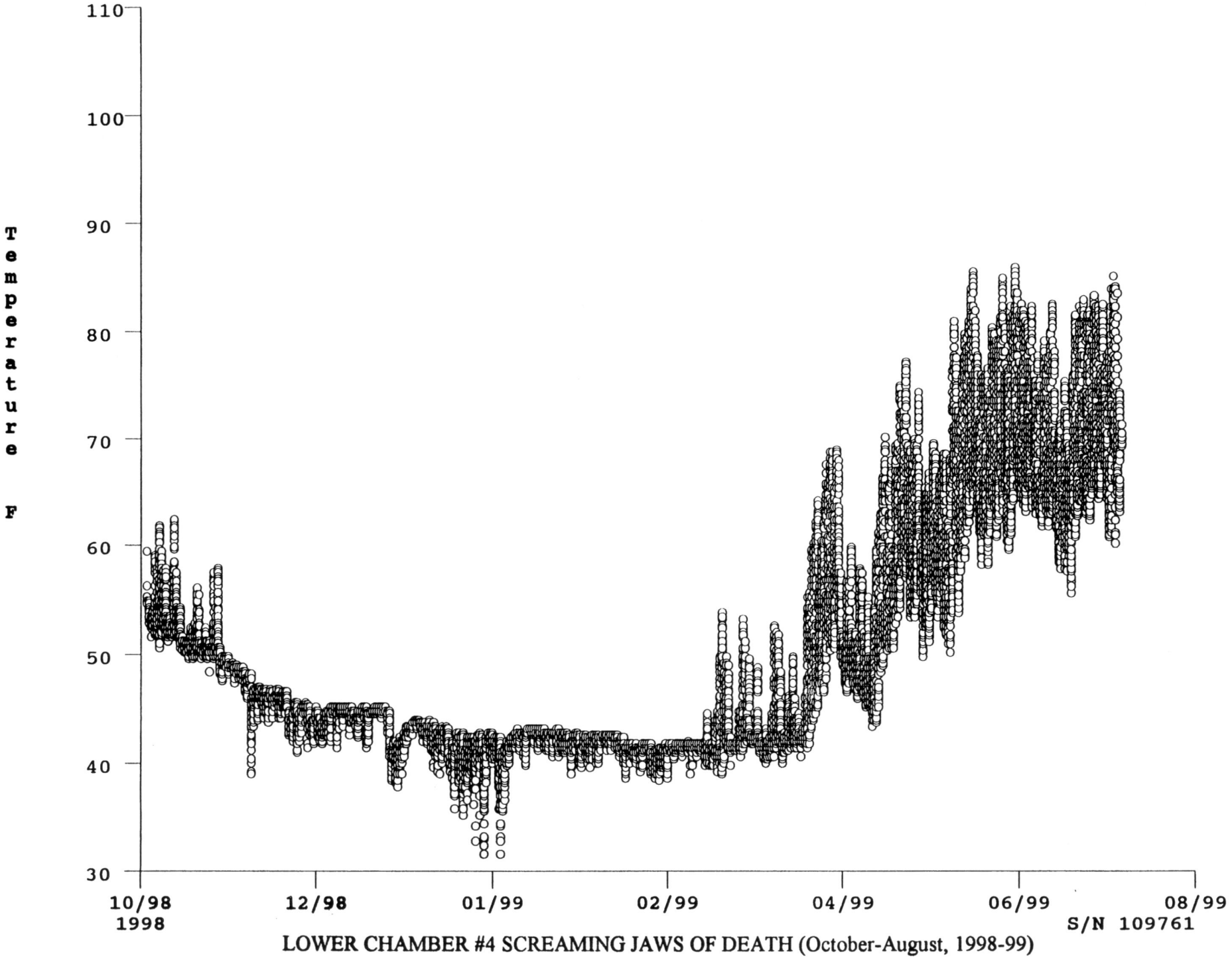


LOWER CHAMBER #1 SCREAMING JAWS OF DEATH (April-October, 1997)

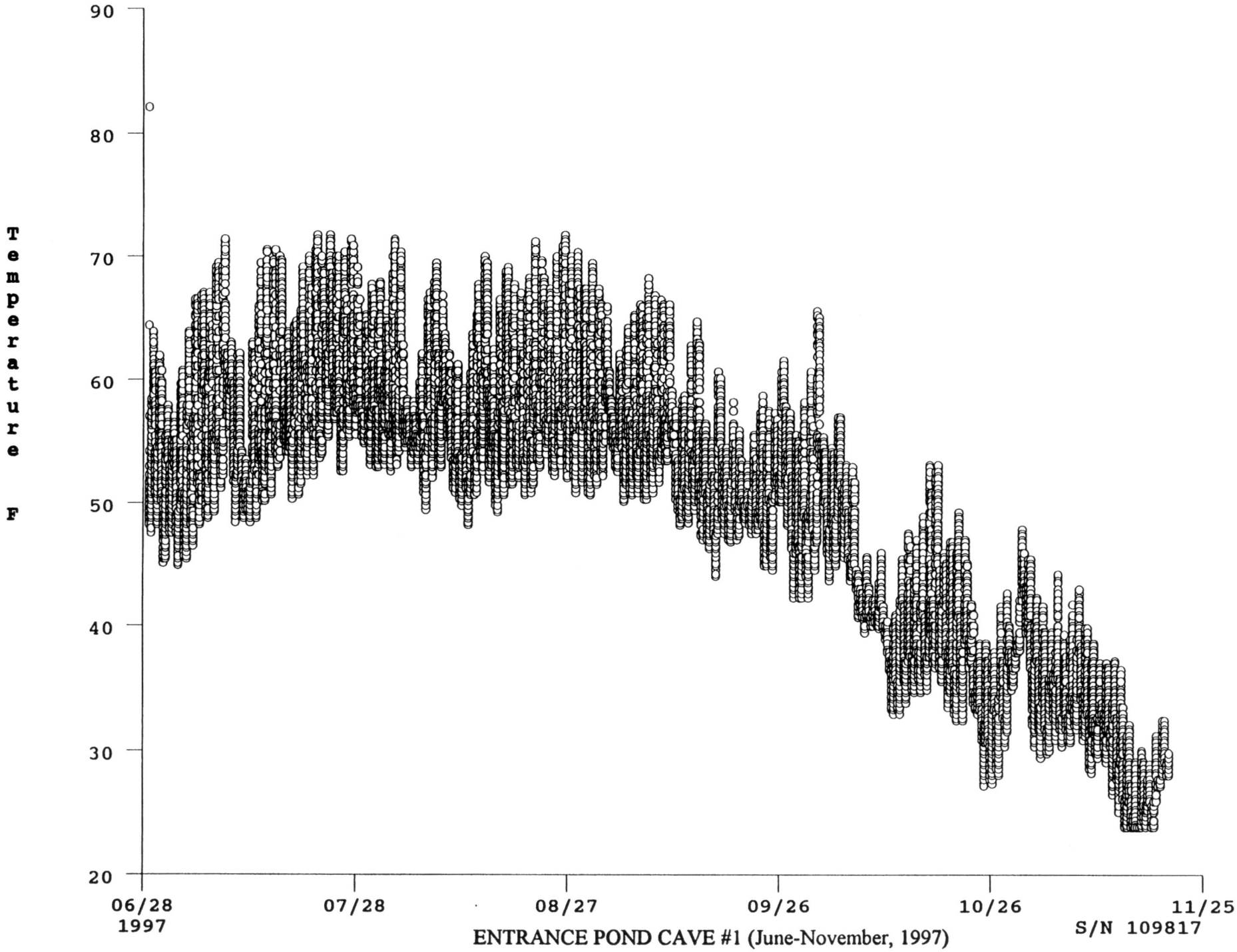

Temperature F
75
70
65
60
55
50
45
40
35
30
25
11/02
1997
12/02
01/01
01/31
03/02
04/01
05/01
LOWER CHAMBER #2 SCREAMING JAWS OF DEATH (November-April, 1997-98)
S/N 109816

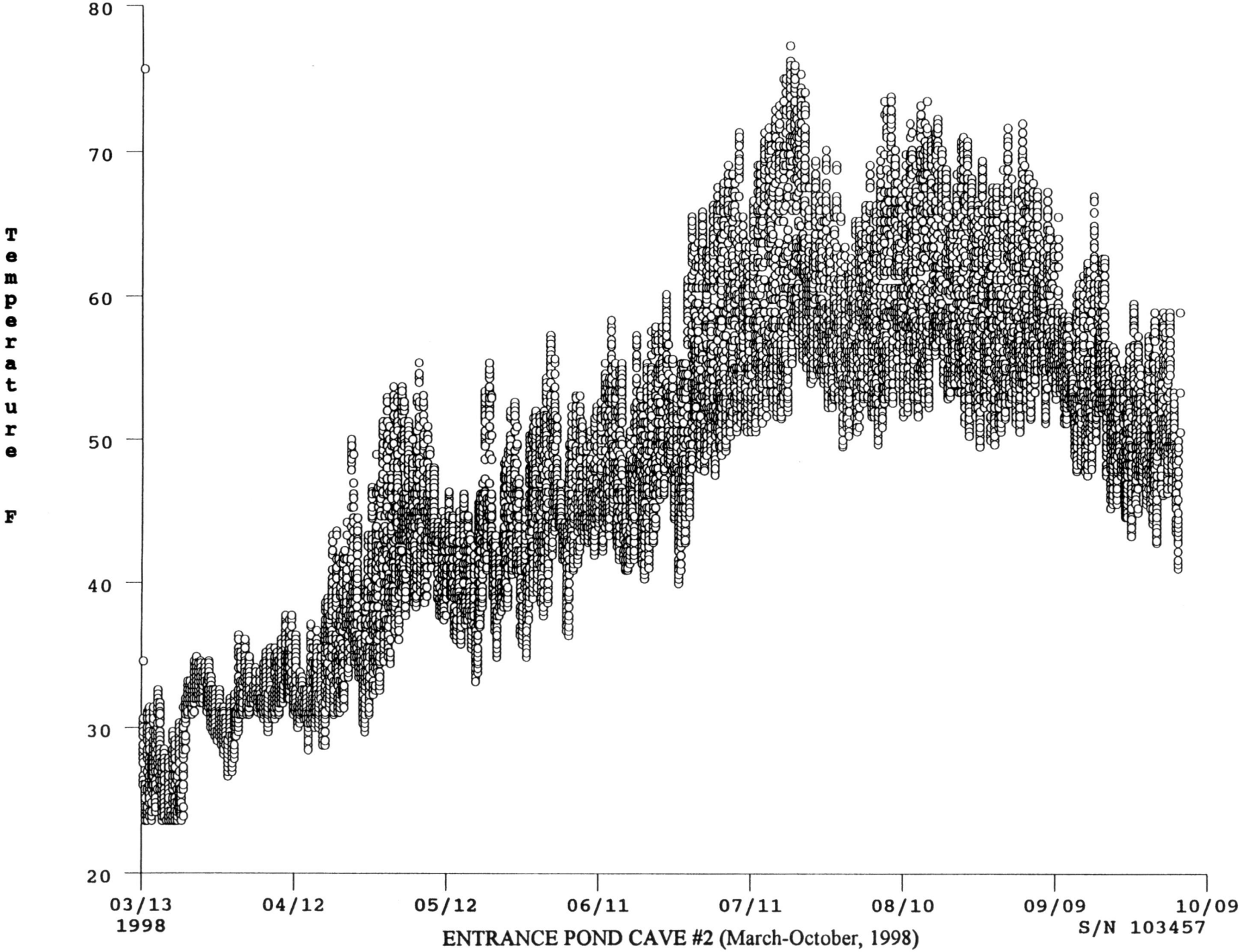


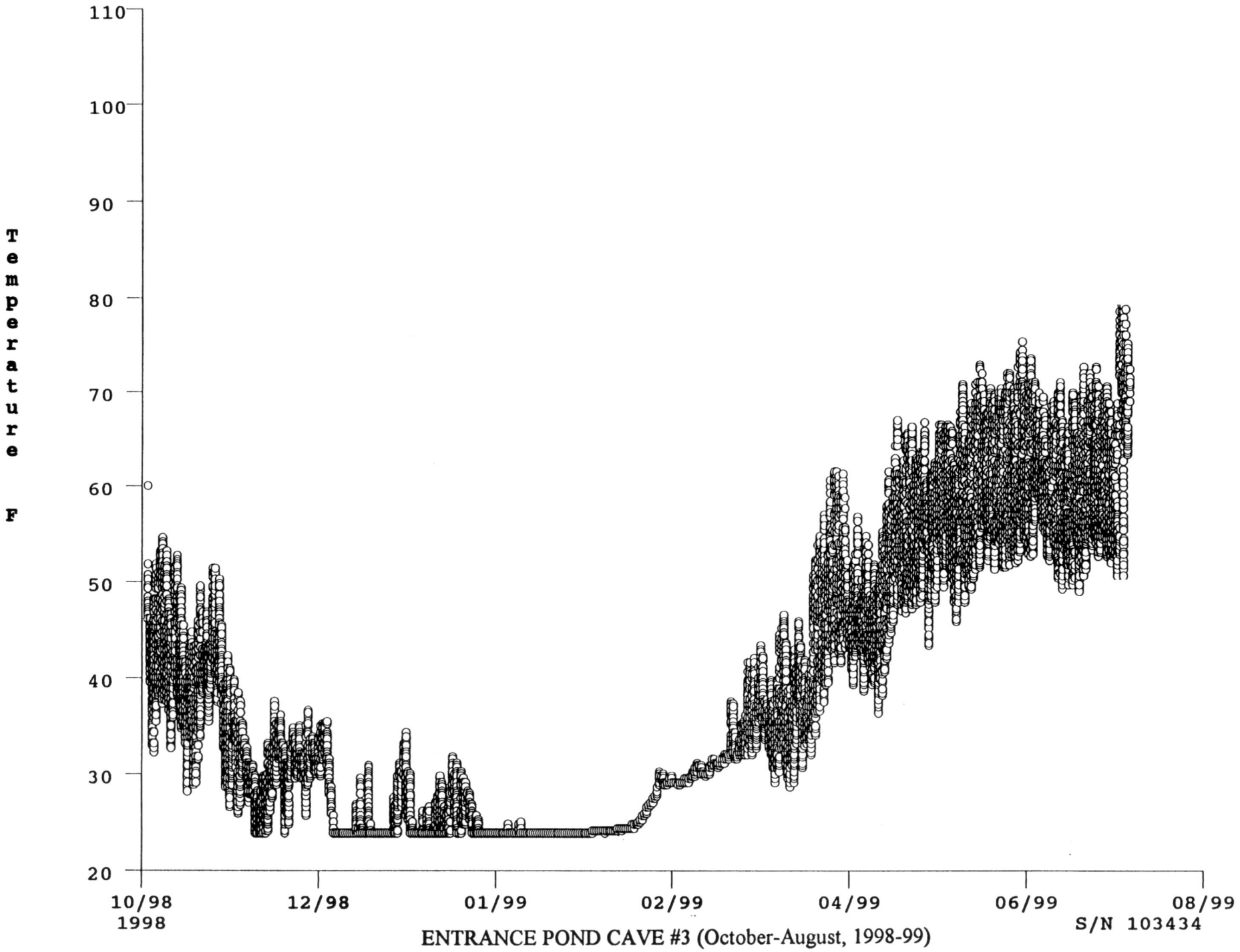
LOWER CHAMBER #3 SCREAMING JAWS OF DEATH (April-October, 1998)

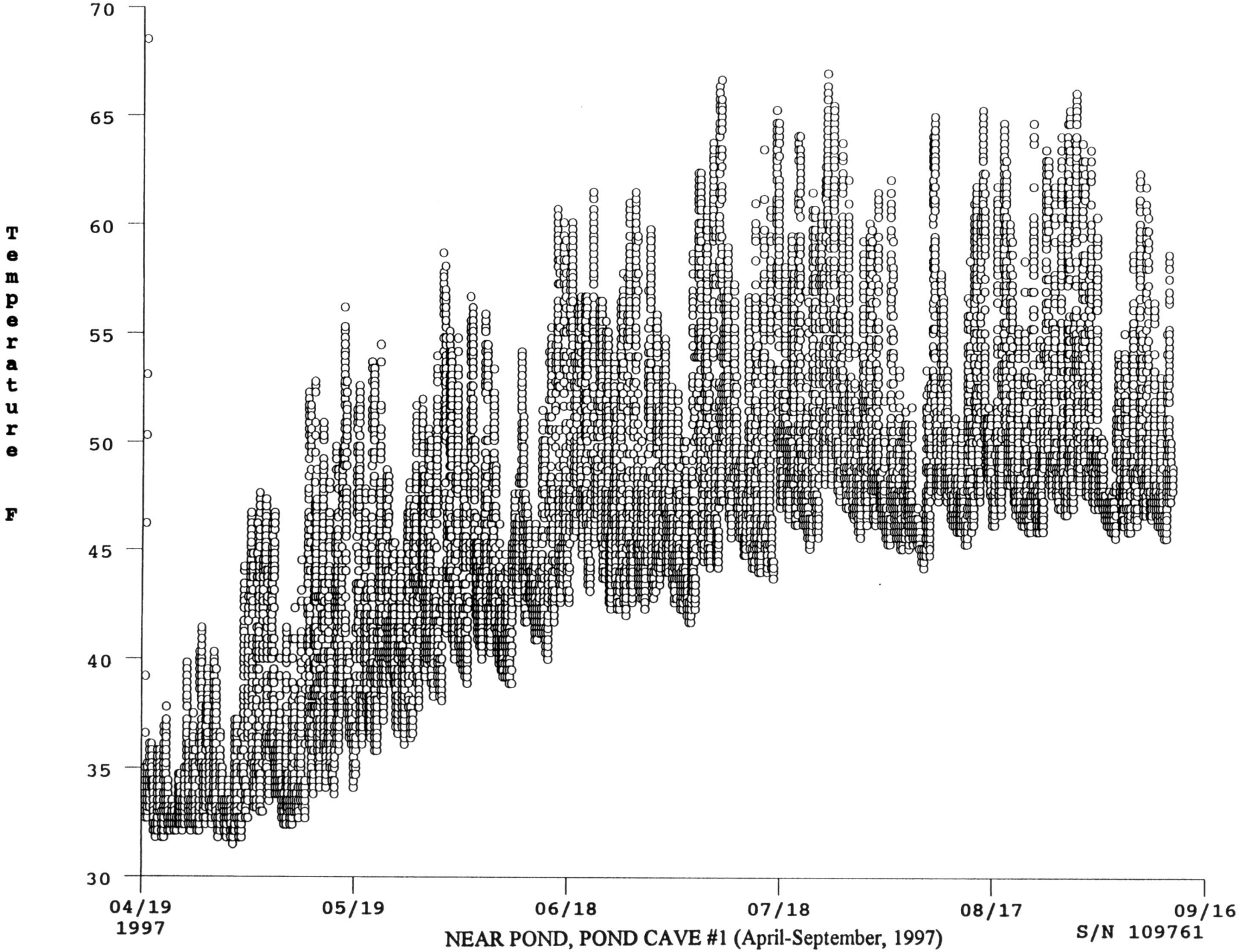


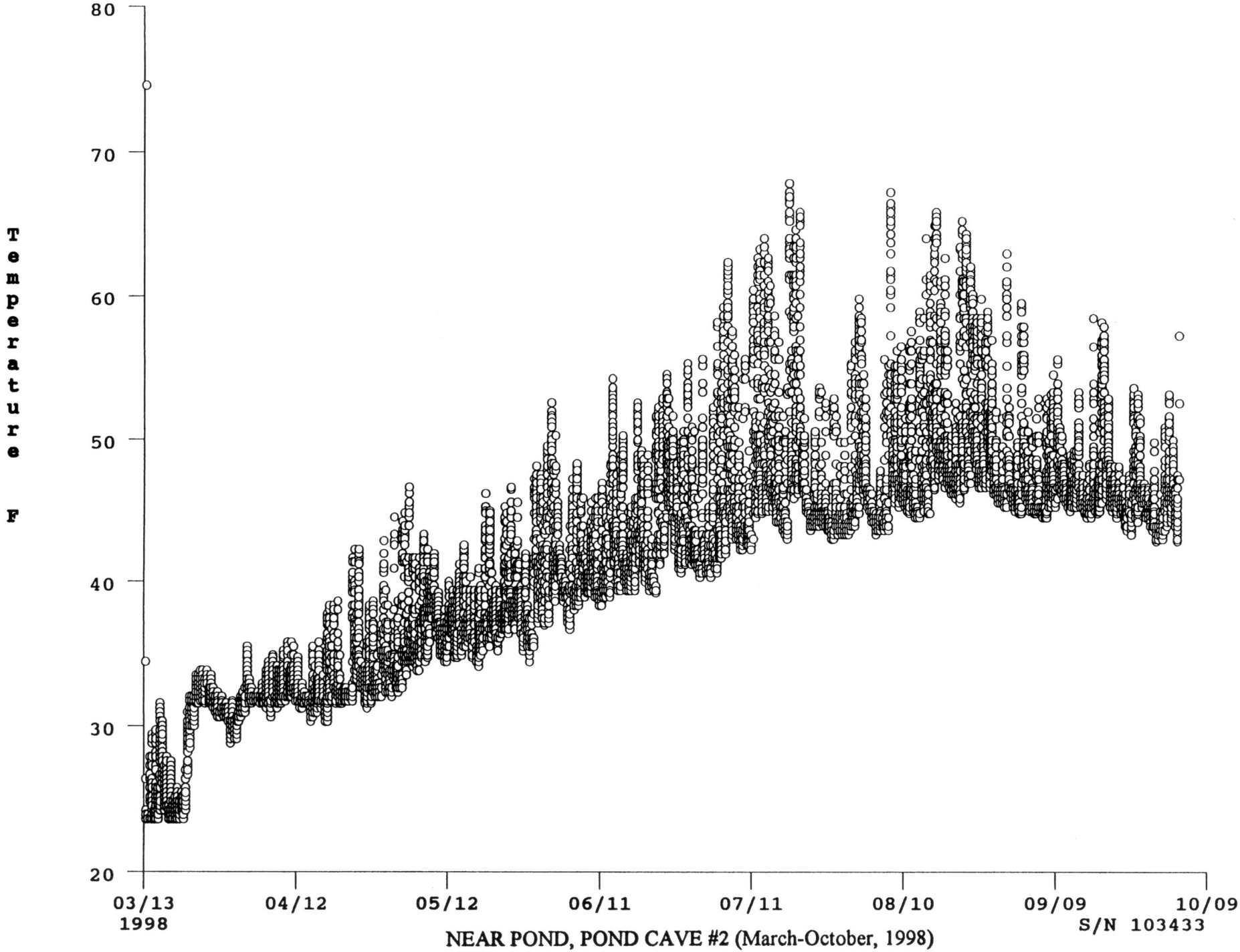
LOWER CHAMBER #4 SCREAMING JAWS OF DEATH (October-August, 1998-99)

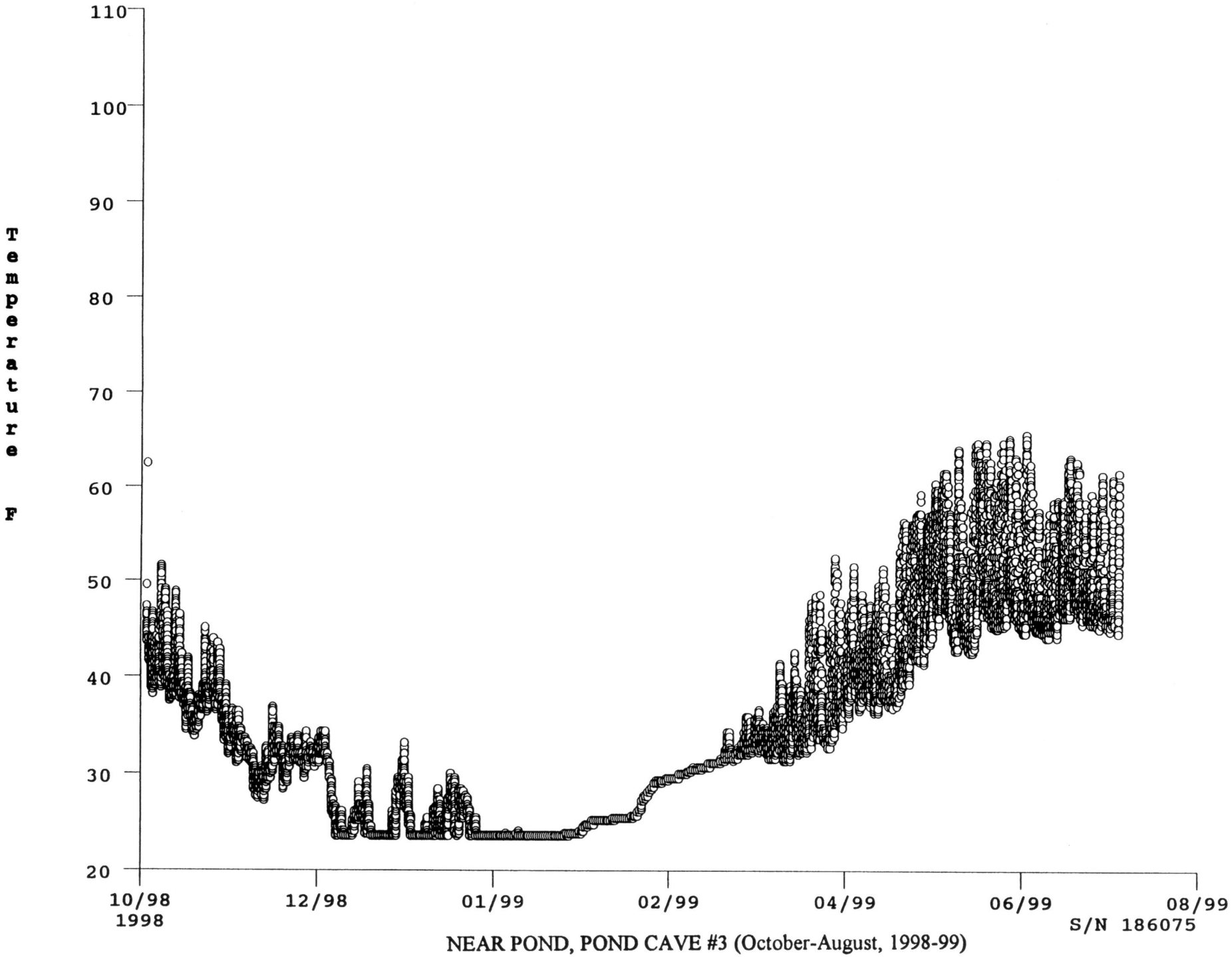

90
80
70
60
50
40
30
20
Temperature F
06/28
1997
07/28
08/27
09/26
10/26
11/25
S/N 109817
ENTRANCE POND CAVE #1 (June-November, 1997)


80
70
60
50
40
30
20
Temperature F
03/13
1998
04/12
05/12
06/11
07/11
08/10
09/09
10/09
S/N 103457
ENTRANCE POND CAVE #2 (March-October, 1998)

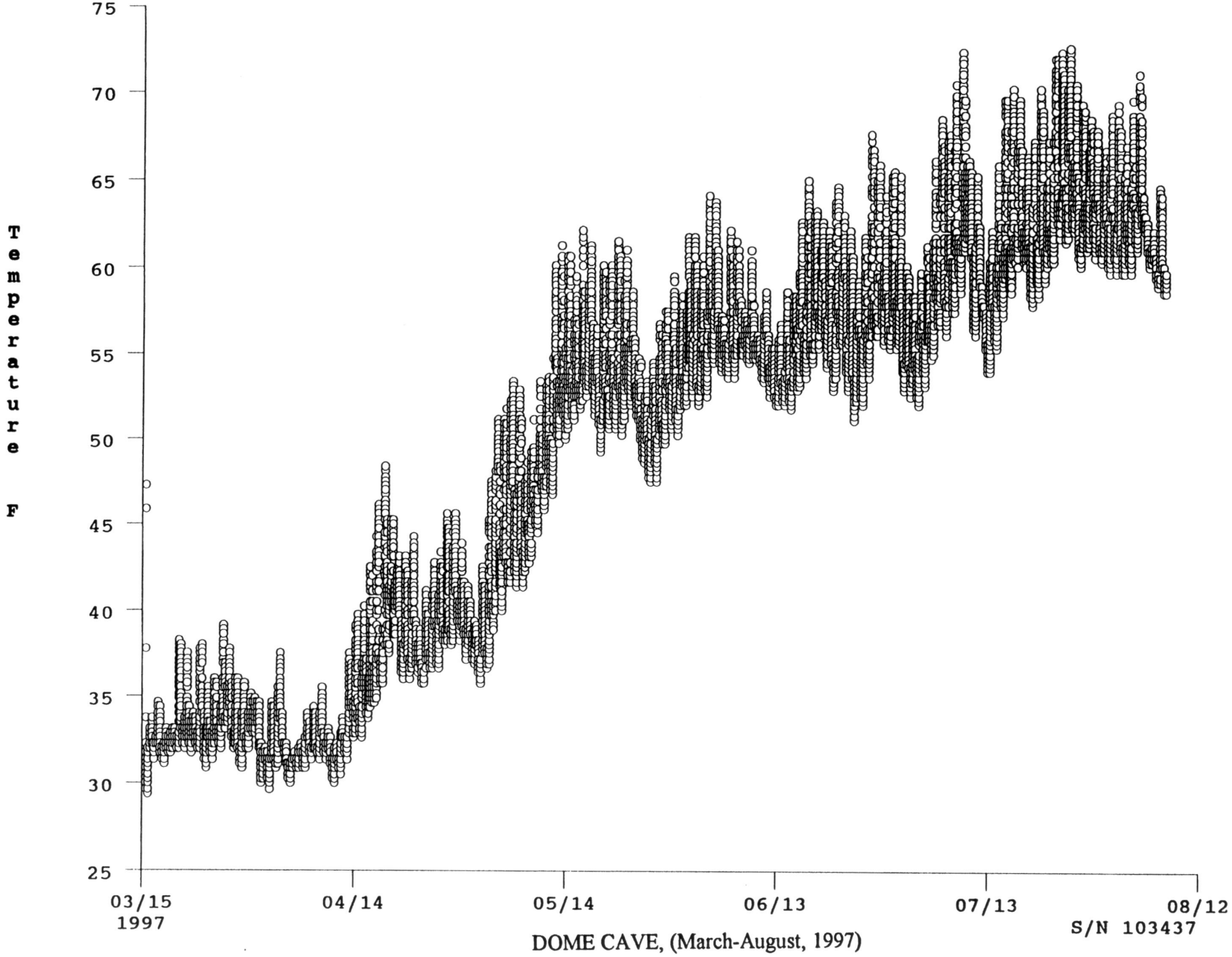

Temperature F
110
100
90
80
70
60
50
40
30
20
10/98
1998
12/98
01/99
02/99
04/99
06/99
08/99
S/N 103434
ENTRANCE POND CAVE #3 (October-August, 1998-99)

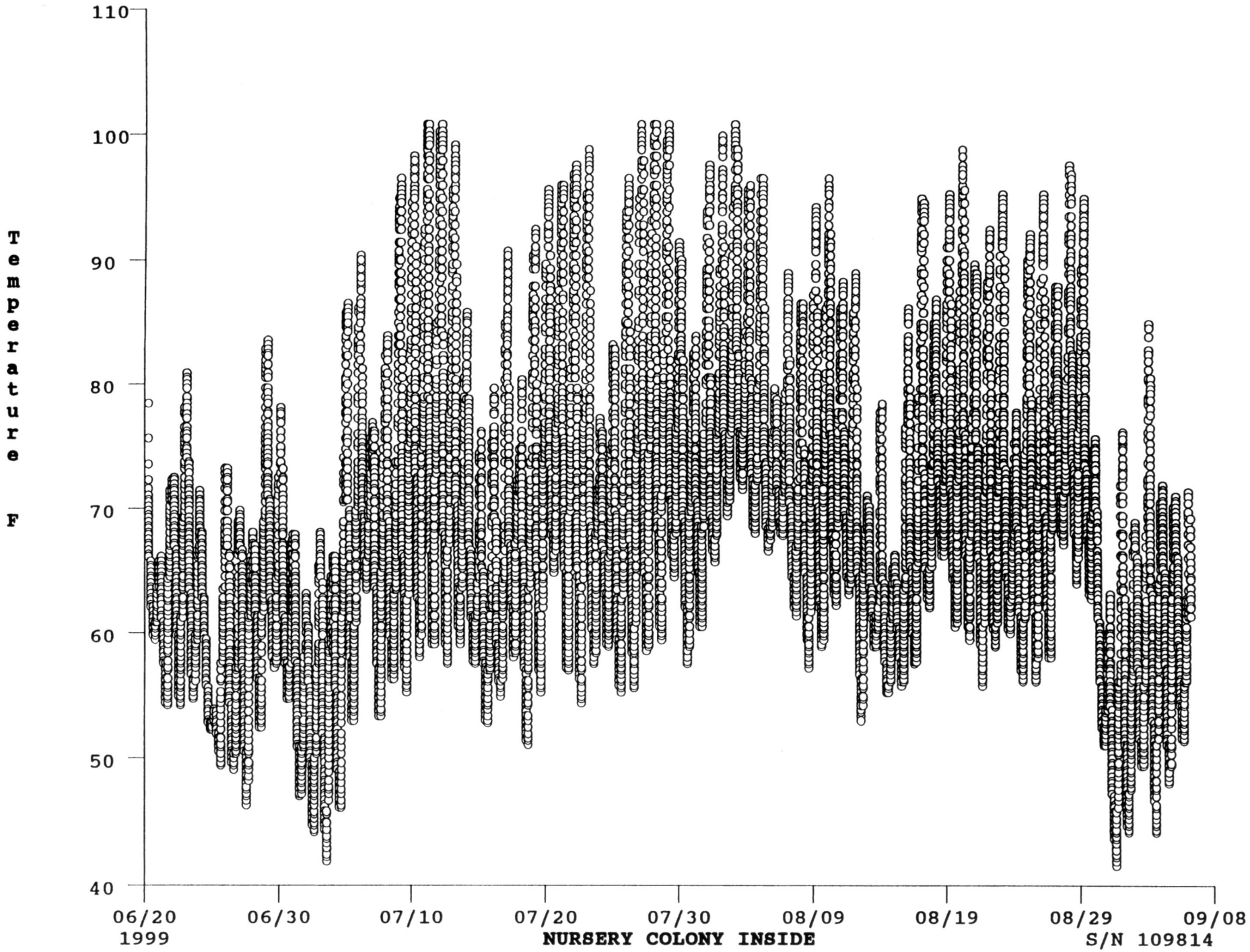

Temperature F
70
65
60
55
50
45
40
35
30
04/19
1997
05/19
06/18
07/18
08/17
09/16
NEAR POND, POND CAVE #1 (April-September, 1997)
S/N 109761


80
70
60
50
40
30
20
Temperature F
03/13
1998
04/12
05/12
06/11
07/11
08/10
09/09
10/09
S/N 103433
NEAR POND, POND CAVE #2 (March-October, 1998)



NEAR POND, POND CAVE #3 (October-August, 1998-99)


Temperature F
75
70
65
60
55
50
45
40
35
30
25
03/15
1997
04/14
05/14
06/13
07/13
08/12
S/N 103437
DOME CAVE, (March-August, 1997)


Temperature F
110
100
90
80
70
60
50
40
06/20
1999
06/30
07/10
07/20
07/30
08/09
08/19
08/29
09/08
NURSERY COLONY INSIDE
S/N 109814