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Evaluation of surface-water temperature monitoring 2022

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Abstract

This report summarizes temperatures measured in 7 natural and 1 artificial pond during the summer of 2022 in Forsmark. Ponds are important for pool-frog populations. Time-series in each pond as well as summary statistics, e.g. number of hours above 19 °C, are presented. Regression analyses between summary statistics and pond dimensions is presented and suggests shading plays a strong role in moderating pond temperatures, particularly in smaller ponds.

Sammanfattning

Denna rapport sammanfattar temperaturer uppmätta i 7 naturliga och 1 anlagda gölar under sommaren 2022 i Forsmark. Göltemperatur är viktig för gölgroda. Tidsserier i varje göl samt sammanfattande statistik, till exempel antal timmar över 19 °C, visas. Regressionsanalyser mellan sammanfattande statistik och göldimensioner presenteras och tyder på att skuggning spelar en stark roll för att dämpa göltemperaturer, särskilt i mindre gölar.

Content

1 Introduction

Monitoring and evaluation of water temperature are part of the background information required to evaluate the suitability of ponds for pool-frog reproduction from a water-temperature perspective. Automatic water-temperature monitoring was carried in eight ponds, seven natural ponds and one constructed, during the period between April 28–October 14, 2022, see Figure 1-1. Similar measurements, in partly different sets of ponds, were conducted during the period April to October each year 2016–2019 (Borgiel et al. 2019, 2020, 2021, Borgiel and Qvarfordt 2021). For summaries and evaluations of these previous measurements, see Werner (2018, 2019, 2022).

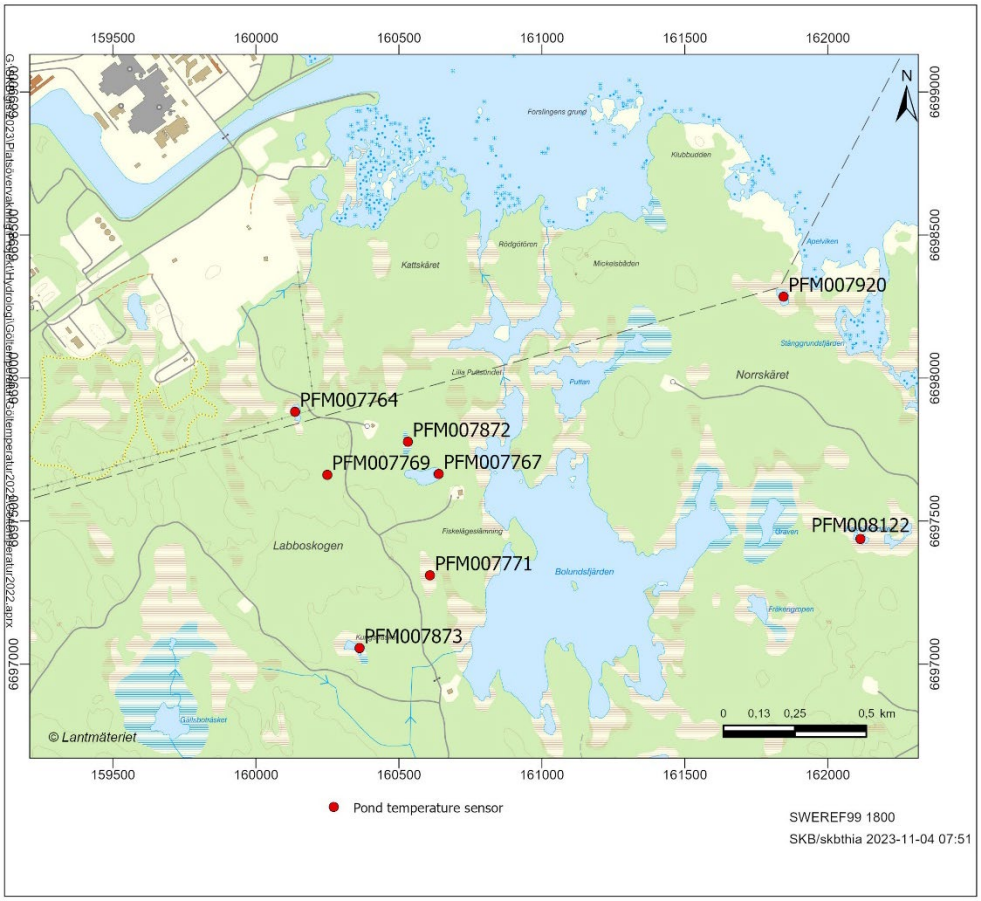

Figure 1-1. *Locations of automatic water-temperature measurements during 2022.*

Locations for the 2022 measurements are summarized in Table 1-1 as well as the different sets of ponds monitored between 2016-2021. Multiple investigations (Werner 2018, 2019, Werner and Atmosudirdjo 2022) have found that temperature response in the artificial ponds was similar to natural ponds so only one artificial pond was monitored after 2019.

Table 1-1 Automatic water-temperature monitoring in natural and constructed ponds (2016–2022).

Measure ID	Pond Alias	2016	2017	2018	2019	2020	2021	2022
PFM007763	*6b*	*x*	*x*	*x*				
PFM007765	*11f*	*x*	*x*	*x*				
PFM007766	*11g*	*x*	*x*	*x*				
PFM007770	*17a*	*x*	*x*	*x*				
PFM007771	*19a*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
PFM007772	*66a*	*x*	*x*	*x*				
PFM007764	7	x		x	x	x	x	x
PFM007870	8		x	x				
PFM007871	12		x	x				
PFM007767	14	x	x	x	x	x	x	x
PFM007768	14	x						
PFM007872	15		x	x	x	x	x	x
PFM007769	16	x		x	x	x	x	x
PFM007873	18		x	x	x	x	x	x
PFM008120	22				x	x		
PFM007920	318			x	x	x		x
PFM008121	377				x	x		
PFM008122	378				x	x	x	x
PFM008123	380				x	x		
PFM008124	383				x	x		
PFM008125	388				x	x		

2 Method

2.1 Installation of temperature sensors

Temperature sensors with integrated dataloggers logged pond temperature data hourly at a constant depth of 0.05 m below the water surface. Mini-Divers™ were installed in each of the monitoring ponds using a foam float, which also served to protect the diver from direct sunlight, see Figure 2-1. Measurements were downloaded at the end of the measuring period for quality control before being uploaded to Sicada.

Figure 2-1 *Setup for measurement of water temperature at a specific depth. A foam block is used to float the sensor as well as protect it from direct solar radiation. A stake is then used to fix the setup in location and allow the sensor to float up or down as water levels change.*

3 Results and discussion

Mean summer 2022 temperatures ranged from 16.2 to 18.4 °C, see Table 3-1. All ponds had more than 3000 hours of temperatures greater than 19 °C, a critical temperature threshold for pool frog reproduction, with more than 8000 hours greater than 19 °C observed in pond 14, which also had the highest mean temperature, 18.4 °C.

Table 3-1 Summary temperature measurements in 8 ponds (artificial pond in italic text) between, April 28 and October 14, 2022. *Shortened time series from 14 July–14 October, 2022.

ID (alias)	Mean (°C)	Min (°C)	Max (°C)	St dev (°C)	Sum degree hours (>19 °C)
PFM007771 (19a)	*17,4*	*5,7*	*32,1*	*5,4*	*6281*
PFM007764 (7)	17,1	5,5	33,9	5,2	5424
PFM007767 (14)	18,4	5,6	32,7	5,4	8006
PFM007872 (15)	17,0	4,4	33,3	5,5	5895
PFM007769 (16)	16,2	4,8	32,9	5,2	4352
PFM007873 (18)	17,6	5,8	34,4	5,2	6191
PFM007920 (318)	17,9	7,0	30,3	4,8	6054
PFM008122 (378)*	16,9	4,8	31,7	5,7	3414

Various pond dimensions were regressed with 2022 temperatures to identify if pond size is a predictor of pond temperature. The physical dimensions of 6 ponds were determined in 2022 using a combination of depth measurements in the field, GIS and aerial photos (Jacobson 2022). Perimeter length was estimated for each pond by assuming ponds are circular in shape and calculating the effective radius from the surface area, see Table 3-2.

For the ponds monitored in 2022 the sum of degree hours above 19 °C is positively correlated to pond volume, surface area and depth, with largest ponds heating up the most. However, overall correlations between pond dimensions and sum of degree hours above 19 °C are weak, with R^2 between 0.4 and 0.7, and based on a small number of ponds (6) for which both temperature and dimension data were available.

That largest ponds heated up more than small ponds could suggest that shading along the pond shoreline can decrease pond temperatures, e.g. larger perimeters are associated with greater temperatures. Regression analysis between estimated perimeter and the sum of degree hours over 19 °C results in similar R^2 (0.44) to regressions against pond dimensions, but the R^2 improves greatly when the artificial pond (19a) is excluded ($R^2 = 0.96$). Regression R^2 improvement when 19a is omitted from perimeter regressions may be due to the lack of vegetation near the artificial pond 19a relative to many other ponds – for its relative size, 19a has high mean temperature and sum of degree hours above 19 °C. When volume to perimeter ratios are regressed against sum of degree hours above 19 °C, the resultant R^2 is 0.96 for all ponds. This supports the hypothesis that shading plays a large role in maintaining temperatures over 19 °C, at least for the range of pond sizes sampled here, and helps explains the positive correlation between volume and pond temperature.

Table 3-2 Sum of degree hours above 19 °C for 6 ponds with accompanying pond dimensions (2022 study)

ID (alias)	Sum degree hours (>19C)	Volume (m^3)	Surface Area (m^2)	Depth (m)	Perimeter (m)	Volume /Perimeter
PFM007771 (19a)	*6281*	*220*	*440*	*0.44*	*74*	*3.0*
PFM007764 (7)	5424	440	1400	0.4	133	3.3
PFM007767 (14)	8006	2940	6090	0.62	277	10.6
PFM007872 (15)	5895	420	1530	0.33	139	3.0
PFM007769 (16)	4352	190	780	0.35	99	1.9
PFM007873 (18)	6191	900	2770	0.48	187	4.8

Appendix A contains temperature time series for each measurement location.

References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.com/publications.

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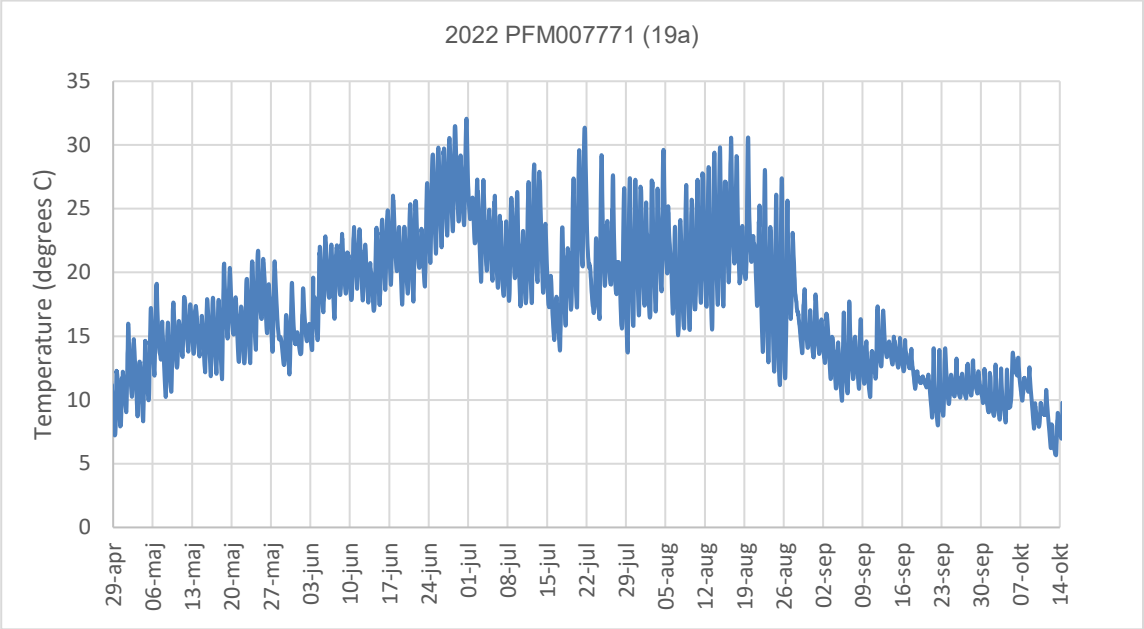
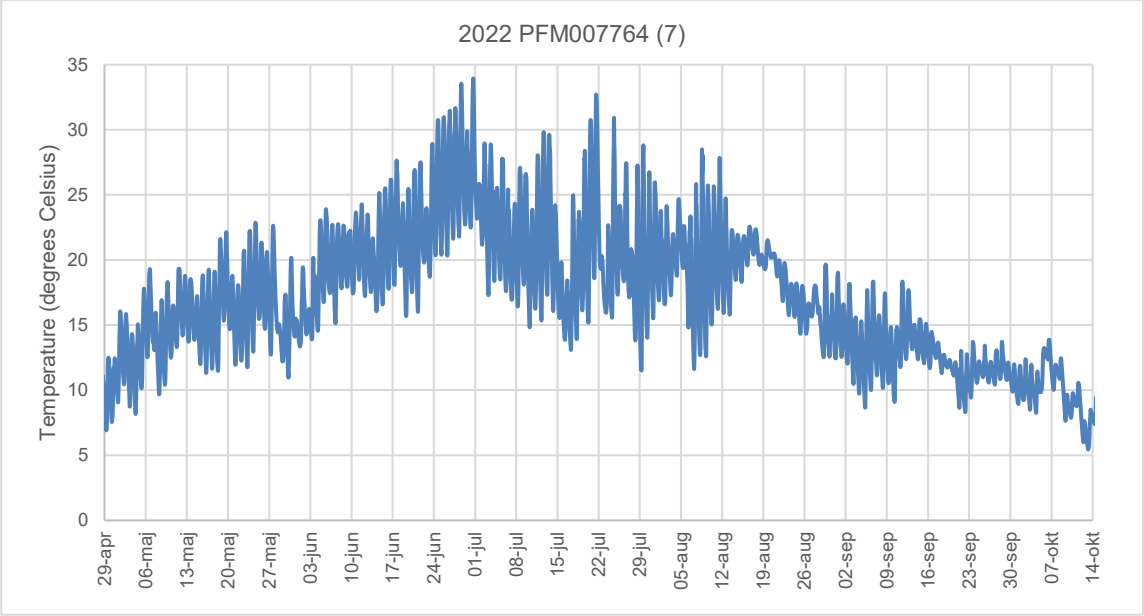
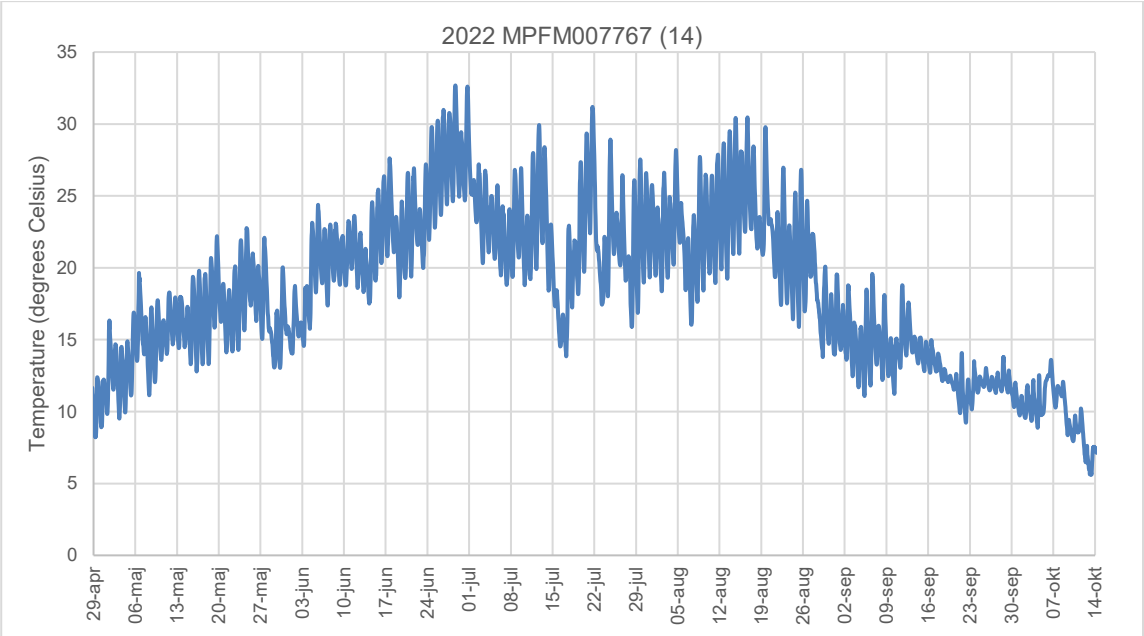
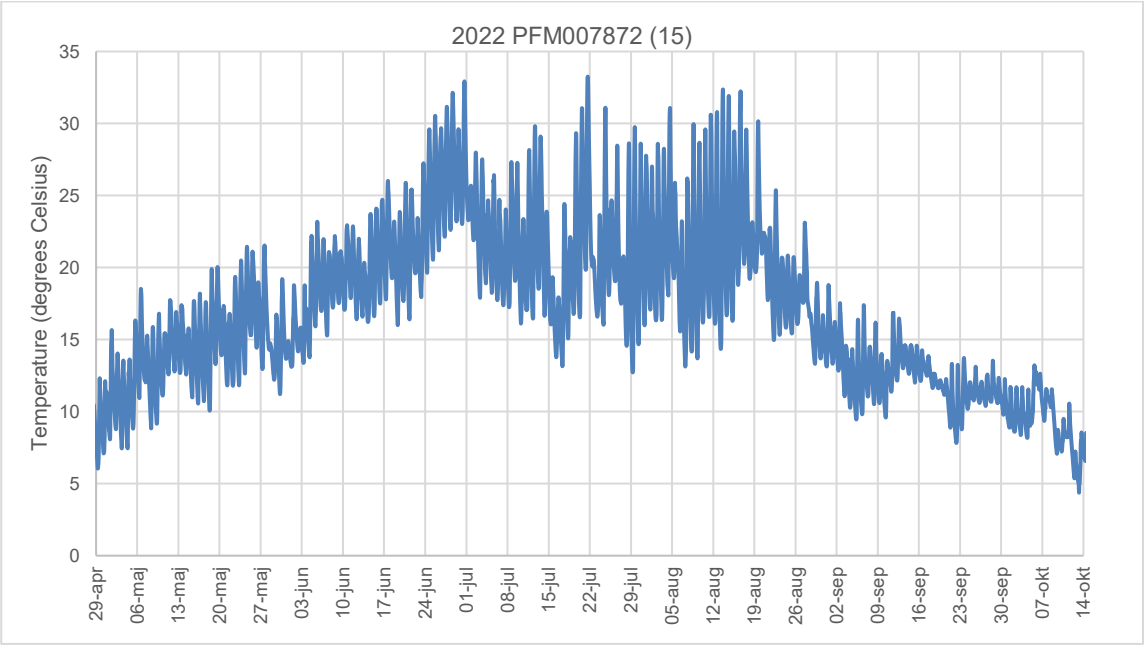
Appendix A

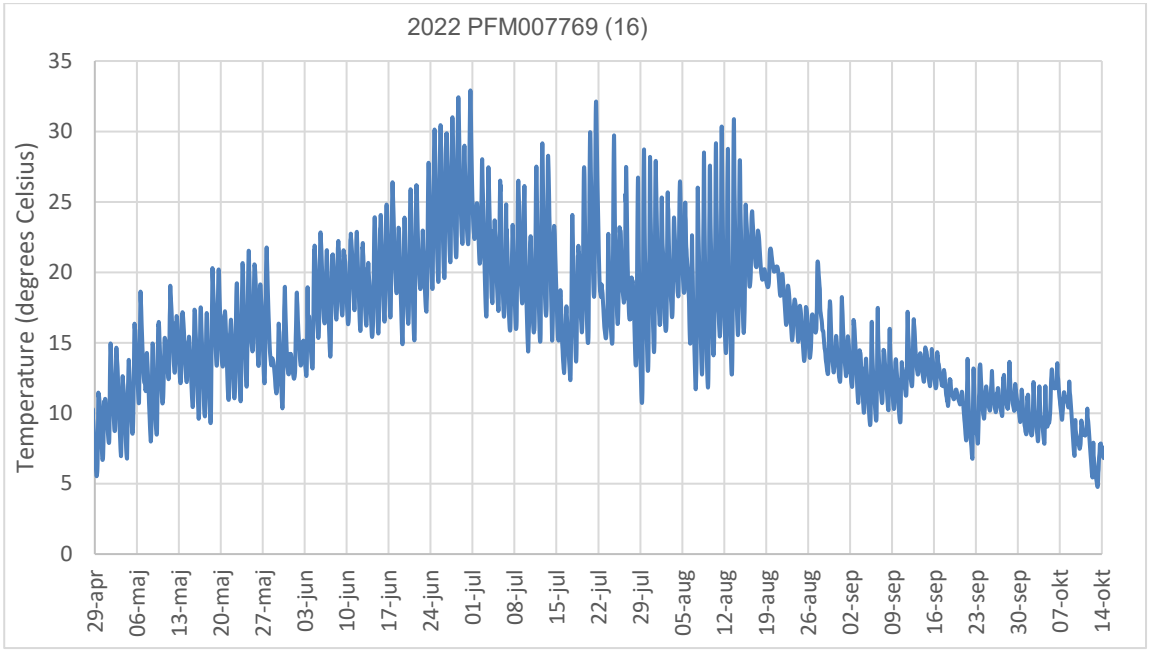
Pond temperature time series 2022.






2022 MPFM007767 (14)
Temperature (degrees Celsius)
35
30
25
20
15
10
5
0
29-apr
06-maj
13-maj
20-maj
27-maj
03-jun
10-jun
17-jun
24-jun
01-jul
08-jul
15-jul
22-jul
29-jul
05-aug
12-aug
19-aug
26-aug
02-sep
09-sep
16-sep
23-sep
30-sep
07-okt
14-okt


2022 PFM007872 (15)
Temperature (degrees Celsius)
35
30
25
20
15
10
5
0
29-apr
06-maj
13-maj
20-maj
27-maj
03-jun
10-jun
17-jun
24-jun
01-jul
08-jul
15-jul
22-jul
29-jul
05-aug
12-aug
19-aug
26-aug
02-sep
09-sep
16-sep
23-sep
30-sep
07-okt
14-okt


2022 PFM007769 (16)
Temperature (degrees Celsius)
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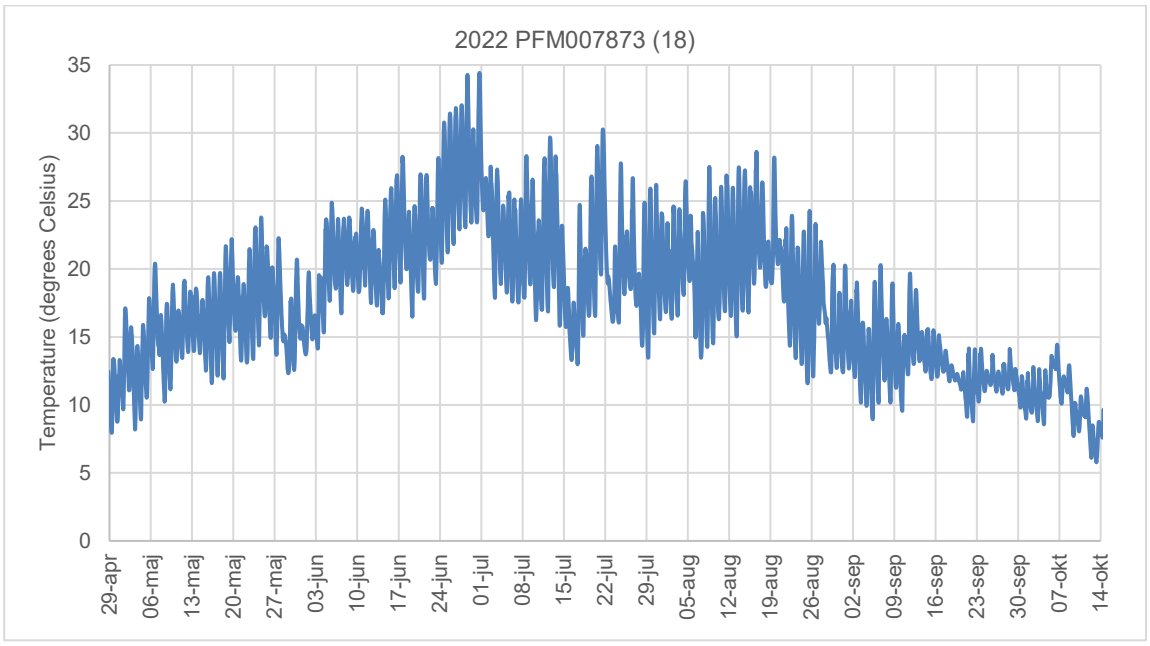
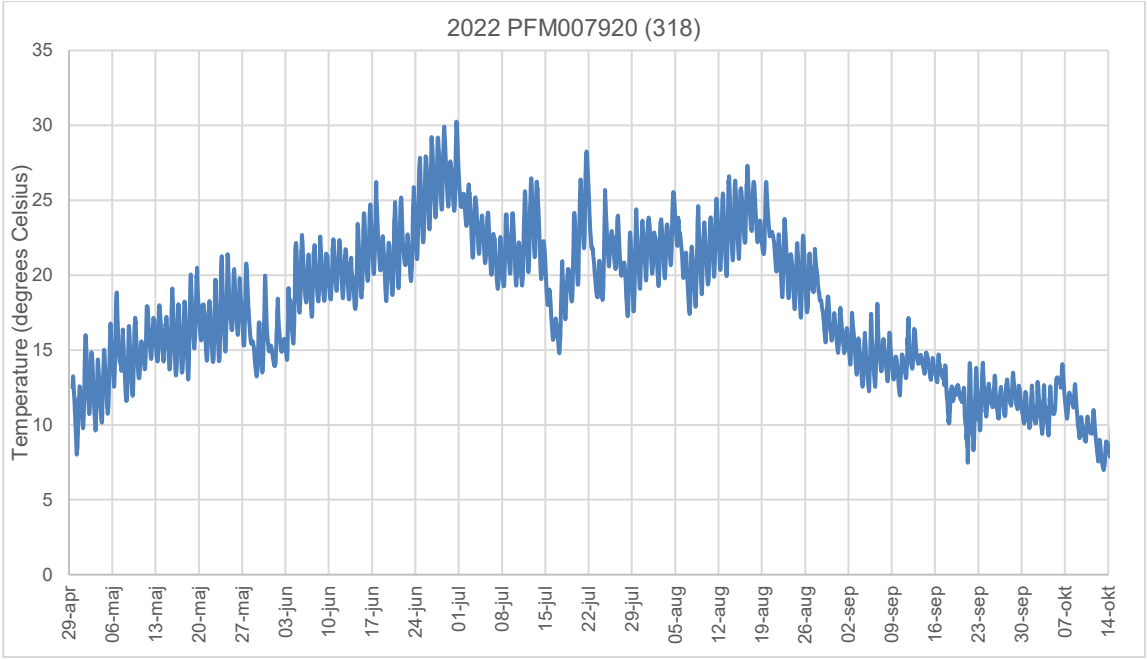
30
25
20
15
10
5
0
29-apr
06-maj
13-maj
20-maj
27-maj
03-jun
10-jun
17-jun
24-jun
01-jul
08-jul
15-jul
22-jul
29-jul
05-aug
12-aug
19-aug
26-aug
02-sep
09-sep
16-sep
23-sep
30-sep
07-okt
14-okt


2022 PFM007873 (18)
Temperature (degrees Celsius)
35
30
25
20
15
10
5
0
29-apr
06-maj
13-maj
20-maj
27-maj
03-jun
10-jun
17-jun
24-jun
01-jul
08-jul
15-jul
22-jul
29-jul
05-aug
12-aug
19-aug
26-aug
02-sep
09-sep
16-sep
23-sep
30-sep
07-okt
14-okt


2022 PFM007920 (318)
Temperature (degrees Celsius)
35
30
25
20
15
10
5
0
29-apr
06-maj
13-maj
20-maj
27-maj
03-jun
10-jun
17-jun
24-jun
01-jul
08-jul
15-jul
22-jul
29-jul
05-aug
12-aug
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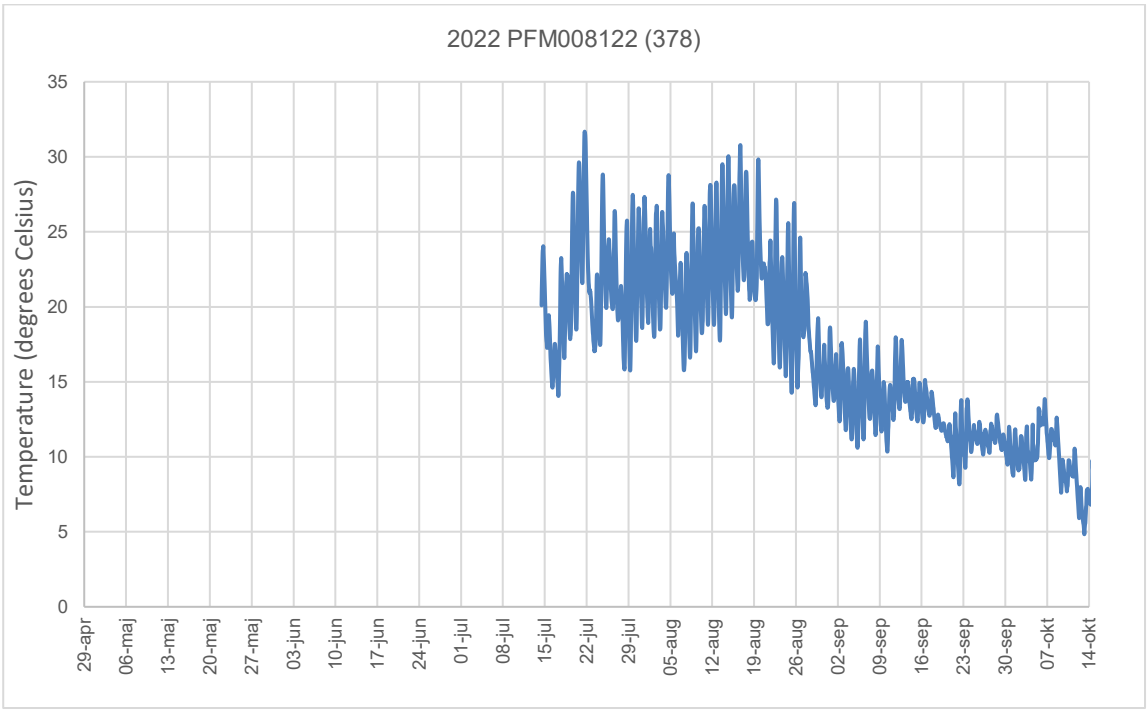
02-sep
09-sep
16-sep
23-sep
30-sep
07-okt
14-okt


2022 PFM008122 (378)
Temperature (degrees Celsius)
35
30
25
20
15
10
5
0
29-apr
06-maj
13-maj
20-maj
27-maj
03-jun
10-jun
17-jun
24-jun
01-jul
08-jul
15-jul
22-jul
29-jul
05-aug
12-aug
19-aug
26-aug
02-sep
09-sep
16-sep
23-sep
30-sep
07-okt
14-okt