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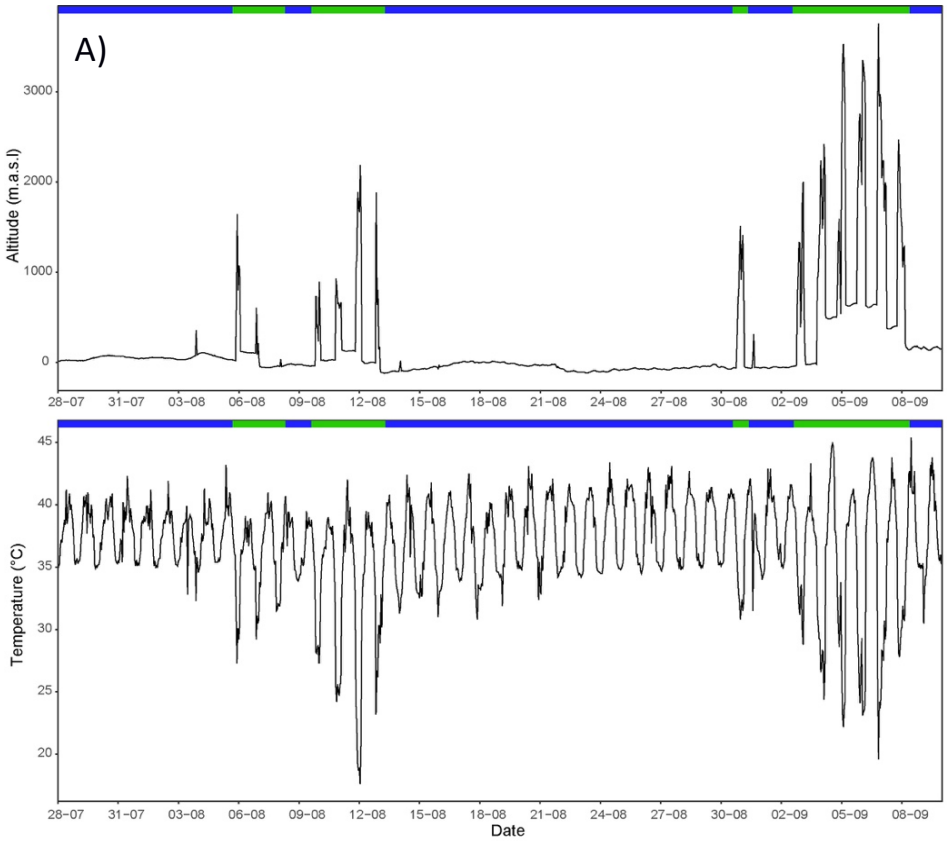
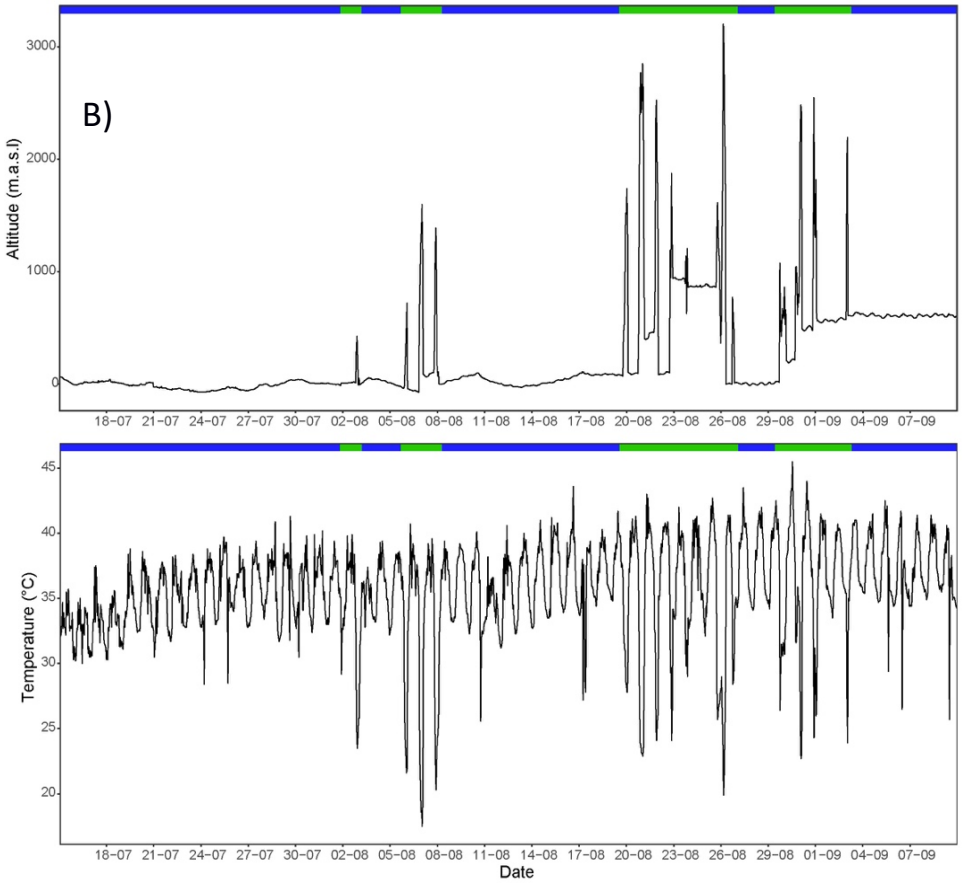
Sjöberg, S., Pedersen, L., Malmiga, G., Alerstam, T., Hansson, B., Hasselquist, D., Thorup, K., Tøttrup, A. P., Andersson, A. and Bäckman, J. 2018. Barometer logging reveals new dimensions of individual songbird migration. – Journal of Avian Biology 2018: e01821

Appendix 1


A)
Altitude (m.a.s.l)
3000
2000
1000
0
28-07 31-07 03-08 06-08 09-08 12-08 15-08 18-08 21-08 24-08 27-08 30-08 02-09 05-09 08-09
Temperature (°C)
45
40
35
30
25
20
28-07 31-07 03-08 06-08 09-08 12-08 15-08 18-08 21-08 24-08 27-08 30-08 02-09 05-09 08-09
Date


B)
Altitude (m.a.s.l)
3000
2000
1000
0
18-07 21-07 24-07 27-07 30-07 02-08 05-08 08-08 11-08 14-08 17-08 20-08 23-08 26-08 29-08 01-09 04-09 07-09
Temperature (°C)
45
40
35
30
25
20
18-07 21-07 24-07 27-07 30-07 02-08 05-08 08-08 11-08 14-08 17-08 20-08 23-08 26-08 29-08 01-09 04-09 07-09
Date

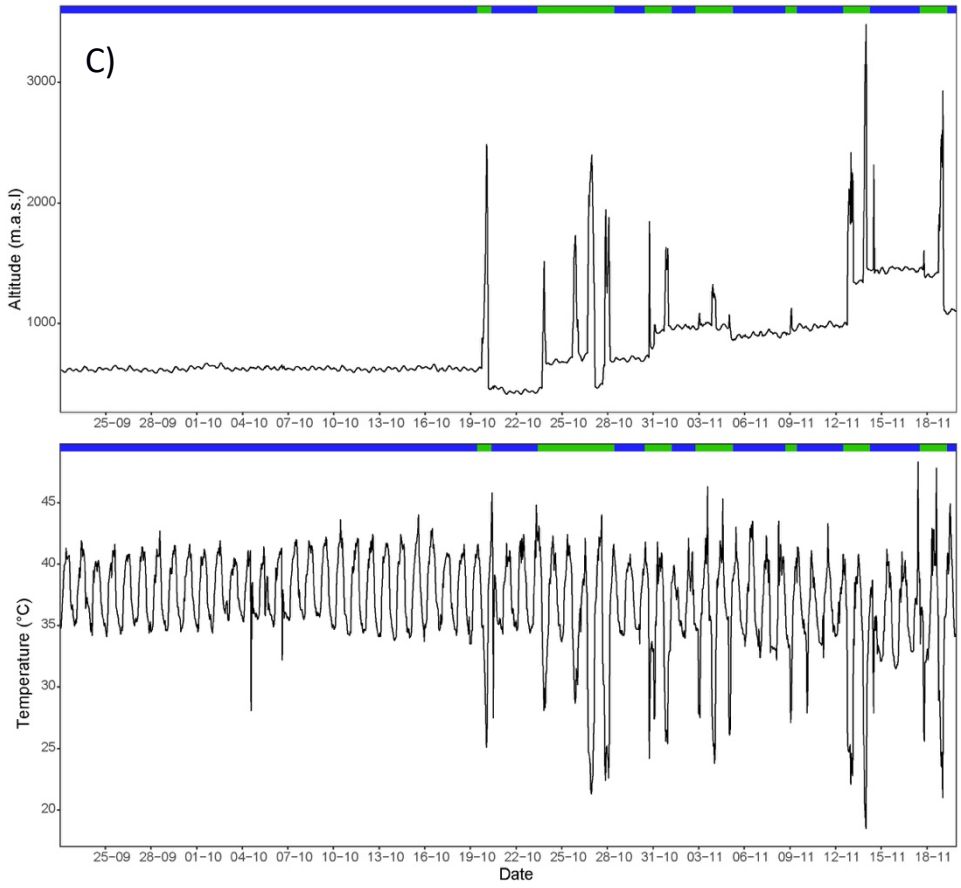


Figure A1. Changes in altitude and temperature over time for the great reed warbler (A) and the red-backed shrike (B and C) measured with an activity logger. Blue horizontal lines indicate periods when the birds were stationary, green horizontal lines indicate periods when the birds were flying with some stationary time in between the flights (identified by activity data). Once the bird departed and gained altitude, temperature decreased and when the bird landed, temperature increased again. Temperature also fluctuated when the bird was on the ground depending on the time of the day (lower during night and higher during day time), but not as much as when the bird was flying. Temperature represents relative change in the ambient temperatures, not the absolute values as the temperature sensor was affected by the bird's body heat and feather cover. Temperature was measured and recorded once in the end of every hour.

Supplementary methods

Flight identification using temperature data

The activity loggers measured and recorded temperature once at the end of every hour. As the temperature sensor was affected by the bird's body heat and feather cover, temperature recorded by the accelerometer do not represent the absolute value of ambient temperature. However, temperature fluctuated to some extent with decreasing (at night time or when the bird was flying) or increasing ambient temperatures (during day time when the bird was on the ground) (Fig. A1–A3),

and more markedly in terms of strong negative correlations with increasing flight altitudes (Fig. 4 main text). We used these changes in temperature measurements which represent relative changes in the ambient temperature to estimate when and for how long the bird was flying. We then compared flights identified using temperature data to the flights identified with the activity data. With 3°C or 4°C temperature difference (between two consecutive temperature measurements) only few flights could not be identified using solely temperature data (identified with the activity but not with the temperature data) and only few flights were misidentified (identified with the temperature but not with the activity data) in the great reed warbler. However, some more flights were misidentified for the red-backed shrike. Still, most of the flights were correctly identified with the temperature data within a 1–2 h time frame when compared to the flights identified with the activity data (Table A1, A2). As the temperature was measured once every hour, the best resolution for estimating the flight time is one hour. Migratory flights and flight times were calculated using activity data (main text), which is a direct measurement of birds' activity. Therefore, we compared flights identified with temperature data to the flights identified using activity data. However, strong negative correlation between altitude and temperature (Fig. 4, main text) supports our findings that temperature could be used to identify migratory flights and flight times. To identify the flights from the temperature data we used the following rules (Fig. A2, A3):

I) We calculated the lowest average temperature for a certain period of time and hour of the day. As an average ambient temperature changed depending on the time of the year, birds' location etc. so did the temperature recorded with an accelerometer. We identified times when the average temperature changed abruptly and according to that we divided temperature data into different periods. Average temperature differed between different periods from 2 to 5 degrees in Celsius (for the red-backed shrike). By subdividing temperature into different periods we had better average temperature estimates for a particular period. Only one period was identified for the great reed warbler (2016/07/11 – 2016/09/10) and three for the red-backed shrike (2016/07/15 – 2016/07/18; 2016/07/19 – 2016/08/17; 2016/08/18 – 2017/04/03). When the time periods were identified we then calculated the lowest average temperature for a certain hour of the day (lowest temperatures were recorded between 10 p.m. and 1 a.m.) and for each time period independently. In order to be selected as a flight, not less than two consecutive temperature measurements had to be at least one degree Celsius lower than the lowest average temperature. We would consider this value – lowest temperature threshold value.

II) We then calculated the overall average temperature for a certain period of time (same as for the lowest average temperature), and then considered temperatures higher than the overall average temperature not to be included in the flight.

III) To identify the flight start, we used differences in temperatures ranging from 3 to 6°C

between two consecutive hours as a threshold for identifying flights. If the temperature difference exceeded this threshold it was selected as a flight.

IV) To identify when the bird had landed, at least two consecutive temperature values had to be higher than the lowest threshold value. Only one temperature value higher than the lowest threshold value would not indicate that the bird had landed unless only a single temperature value lower than the lowest threshold value would follow it.

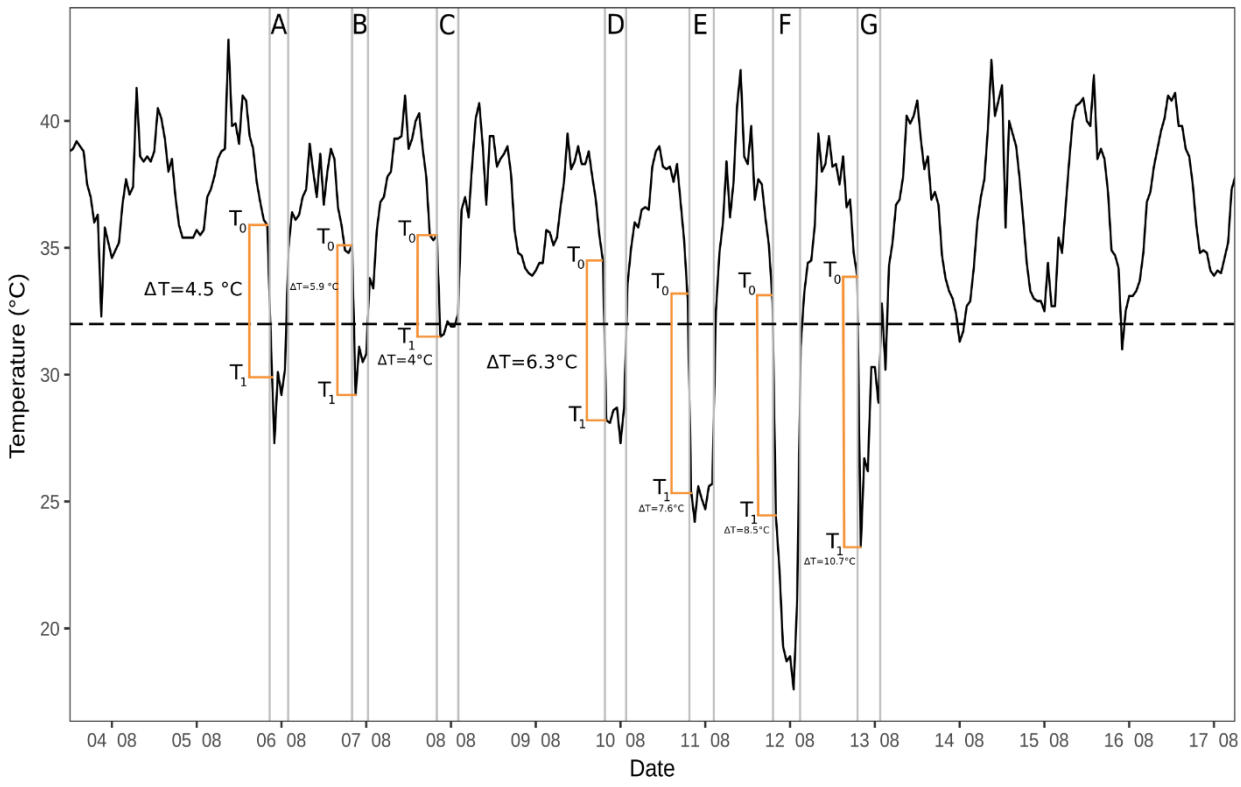


Figure A2. An example of how changes in temperature over time measured with an activity logger were used to identify the great reed warbler flights. Grey vertical lines indicate flights (A–G) identified using activity and temperature data. Orange bars and ΔT values indicate the difference in temperatures between two consecutive hours T_0 and T_1. Dashed line indicates the lowest threshold value (32°C) for a certain hour of the day (10:00 p.m.) and for a certain period of time (216.07.11 – 2016.09.10) When the difference between the consecutive temperature measurements was 3°C or more it was selected as a flight (depending on the threshold level selected, ranging from 3 to 6°C). The flight start would then be considered time T_0, even though the bird most likely departed sometime between time T_0 and T_1. Flights A and C would not be selected if the threshold level for the differences between two consecutive temperature measurements was 5°C or more, flight B would not be selected if the threshold level was chosen to be 6°C. Temperature represents relative change in the ambient temperatures not the absolute values as the temperature sensor was affected by the birds' body heat and feather cover. Temperature was measured and recorded once in the end of every hour.

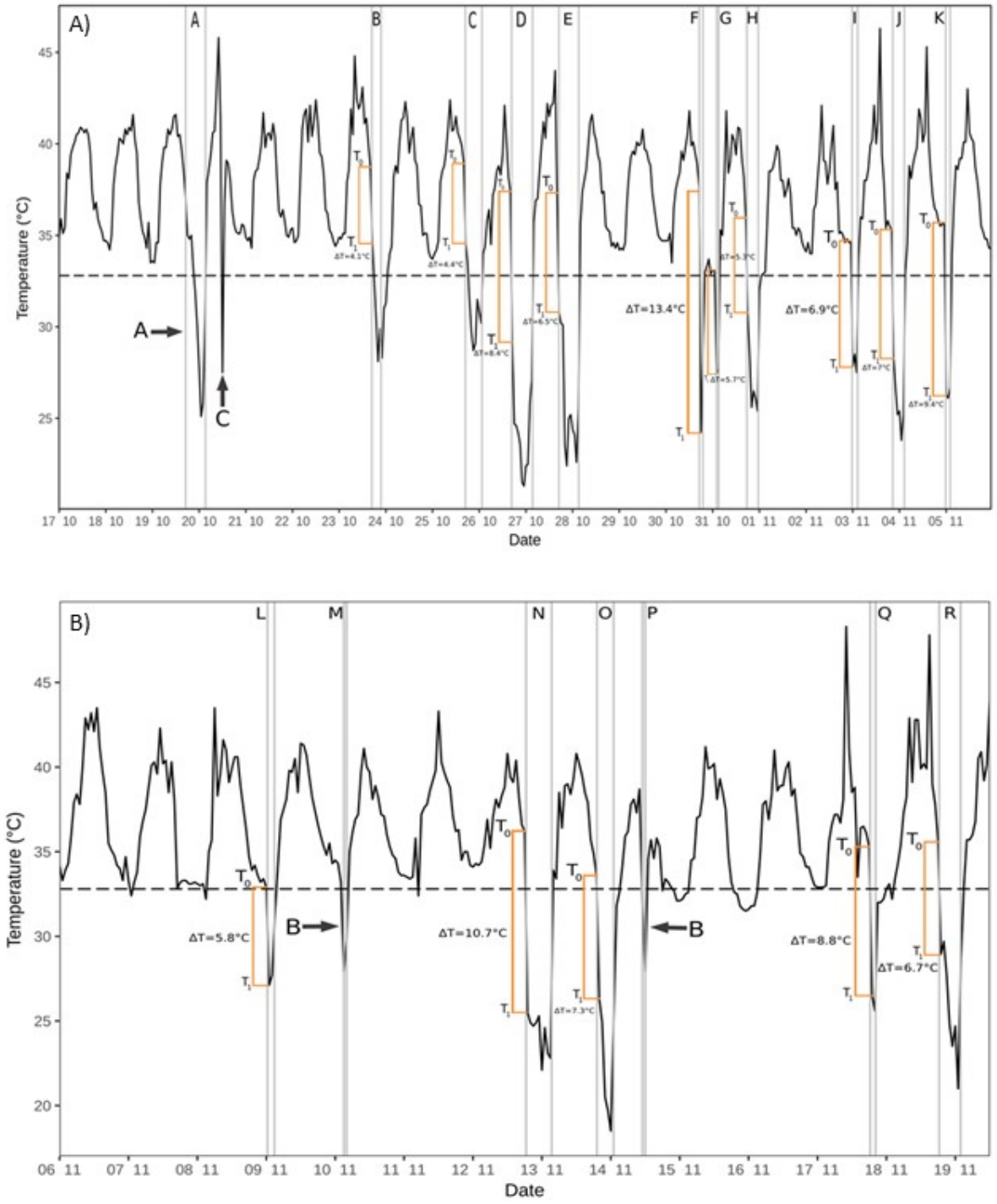


Figure A3. Example of how change in temperature over time measured with an activity logger was used to identify red-backed shrike flights when the bird was flying in Africa (A and B). Grey vertical lines indicate flights (B–L, N, O, Q, R) identified using activity and temperature data. Flight A was not identified using temperature data (unidentified flight, indicated with A arrow). Flights M and P were only identified using temperature, but not with the accelerometer data (misidentified flights, indicated with B arrows). An arrow C indicates temperature which went below lowest average temperature threshold, but as it was only one such measurement (it has to be at least two consecutive temperature measurements below lowest average temperature threshold) it was not

selected as a flight. Orange bars and ΔT values indicate the difference in temperatures between two consecutive hours T_0 and T_1. Dashed line indicates the lowest average temperature value (32.8°C) for a certain hour of the day (1:00 a.m.) and for a certain period of time (216.08.18 – 2017.04.03). When the difference between two consecutive temperature measurements was 3°C or more it was selected as a flight (depending on the threshold level selected, ranging from 3 to 6°C). The flight start would then be considered time T_0, even though the bird most likely departed sometime between time T_0 and T_1. Flights B and C would not be selected if the threshold level for the differences between two consecutive temperature measurements was 5°C or more, flights G, H, L would not be selected if the threshold level was chosen to be 6°C. Temperature represents relative change in the ambient temperatures not the absolute values as the temperature sensor was affected by the birds' body heat and feather cover. Temperature was measured and recorded once in the end of every hour.

Table A1. Correctly identified flights (+) and unidentified flights (-) from activity and temperature logger data (for different threshold values between two consecutive temperature measurements, 3-6°C) for the great reed warbler. Unidentified flights indicate flights identified using activity but not temperature data. Higher threshold values between two consecutive temperatures values for a flight identification results in a lower number of correctly identified flights and in a higher number of unidentified flights. Temperature represents relative change in the ambient temperatures and not the absolute values as the temperature sensor was affected by the bird 's body heat and feather cover. Temperature was measured and recorded once in the end of every hour.

	Activity data				Identified by temperature							
					3 degrees difference		4 degrees difference		5 degrees difference		6 degrees difference	
Travel segment	Flight number	Flight start	Flight end	Flight duration (hh:mm)	+/-	Flight duration (hh:mm)	+/-	Flight duration (hh:mm)	+/-	Flight duration (hh:mm)	+/-	Flight duration (hh:mm)
1	1	2016-08-05 20:40:00	2016-08-06 01:55:00	5:15	+	5:00	+	5:00	-		-	
	2	2016-08-06 20:00:00	2016-08-07 00:30:00	4:30	+	4:00	+	4:00	+	4:00	+	4:00
	3	2016-08-07 20:00:00	2016-08-08 02:05:00	6:05	+	5:00	+	6:00	-		-	
	4	2016-08-09 19:35:00	2016-08-10 01:35:00	6:00	+	6:00	+	6:00	+	6:00	-	
	5	2016-08-10 19:30:00	2016-08-11 02:25:00	6:55	+	7:00	+	8:00	+	8:00	+	8:00
	6	2016-08-11 19:10:00	2016-08-12 02:50:00	7:40	+	8:00	+	8:00	+	8:00	+	8:00
	7	2016-08-12 19:05:00	2016-08-13 01:30:00	6:25	+	6:00	+	6:00	+	6:00	+	6:00
2	8	2016-08-30 18:45:00	2016-08-31 03:20:00	8:35	-		-		-		-	
	9	2016-09-02 18:35:00	2016-09-03 04:05:00	9:30	+	2:00	-		-		-	
	10	2016-09-03 18:15:00	2016-09-04 04:25:00	10:10	+	10:00	+	10:00	+	10:00	+	
	11	2016-09-04 18:00:00	2016-09-05 04:30:00	10:30	+	10:00	+	5:00	+	5:00	+	5:00
	12	2016-09-05 18:00:00	2016-09-06 04:45:00	10:45	+	10:00	+	10:00	+	10:00	+	10:00
	13	2016-09-06 18:00:00	2016-09-07 05:00:00	11:00	+	11:00	+	11:00	+	11:00	+	11:00
	14	2016-09-07 18:25:00	2016-09-08 04:10:00	9:45	+	9:00	+	9:00	+	9:00	+	9:00
		Percentage of correctly identified flights [a]			80.5		82.5		75		65.8	

[a] Percentage of correctly identified flights does not show how well the flights were identified regarding flight time.

Table A2. Correctly identified flights (+), misidentified flights (x) and unidentified flights (-) from activity and temperature logger data (for different threshold values between two consecutive temperature measurements, 3-6°C) for the red-backed shrike. Misidentified flights indicate flights identified using temperature but not activity data. Unidentified flights indicate flights identified using activity but not temperature data. Higher threshold values between two consecutive temperatures values for a flight identification results in a lower number of correctly identified and misidentified flights but in a higher number of unidentified flights. Temperature represents relative change in the ambient temperatures and not the absolute values as the temperature sensor was affected by the bird 's body heat and feather cover. Temperature was measured and recorded once in the end of every hour.

	Activity data				Identified by temperature							
					3 degrees difference		4 degrees difference		5 degrees difference		6 degrees difference	
Travel segment	Flight number	Flight start	Flight end	Flight duration (hh:mm)	+/-	Flight duration (hh:mm)	+/-	Flight duration (hh:mm)	+/-	Flight duration (hh:mm)	+/-	Flight duration (hh:mm)
	1	2016-08-01 21:20:00	2016-08-01 22:00:00	0:40	-		-		-		-	
	2	2016-08-02 20:55:00	2016-08-03 01:00:00	4:05	+	7:00	+	7:00	+	5:00	+	5:00
1	3	2016-08-05 21:00:00	2016-08-06 02:45:00	5:45	+	5:00	+	5:00	+	5:00	+	5:00
	4	2016-08-06 20:15:00	2016-08-07 02:30:00	6:15	+	6:00	+	6:00	+	6:00	-	6:00
	5	2016-08-07 19:45:00	2016-08-08 02:00:00	6:15	+	7:00	+	7:00	+	7:00	+	7:00
	6	2016-08-19 19:10:00	2016-08-20 02:35:00	7:25	+	7:00	+	7:00	-		-	
	7	2016-08-20 18:50:00	2016-08-21 02:55:00	8:05	+	9:00	+	9:00	+	8:00	+	8:00
	8	2016-08-21 18:25:00	2016-08-22 00:15:00	5:50	+	6:00	+	6:00	+	4:00	+	4:00
	9	2016-08-22 18:10:00	2016-08-22 22:45:00	4:35	+	4:00	+	4:00	+	4:00	+	4:00
	10	2016-08-23 17:50:00	2016-08-23 21:25:00	3:35	+	4:00	+	4:00	+	4:00	+	4:00
2	11	2016-08-25 17:40:00	2016-08-26 07:20:00	13:40	+	14:00	+	14:00	+	14:00	+	14:00
	12	2016-08-26 17:25:00	2016-08-26 20:05:00	2:40	+	3:00	+	3:00	+	3:00	+	3:00
	13	2016-08-29 17:30:00	2016-08-30 03:10:00	9:40	+	8:00	+	8:00	+	8:00	+	8:00
	14	2016-08-30 17:00:00	2016-08-31 03:40:00	10:40	+	5:00	+	5:00	+	5:00	+	3:00
	15	2016-08-31 20:45:00	2016-09-01 02:05:00	5:20	+	6:00	+	6:00	+	6:00	+	4:00
	16	2016-09-02 23:25:00	2016-09-03 01:40:00	2:15	+	2:00	+	2:00	+	2:00	+	2:00
	17	2016-10-19 17:05:00	2016-10-20 03:15:00	10:10	-		-		-		-	
	18	2016-10-23 16:45:00	2016-10-23 21:30:00	4:45	+	8:00	+	8:00	-		-	
	19	2016-10-25 16:50:00	2016-10-26 01:25:00	8:35	+	9:00	+	9:00	-		-	
	20	2016-10-26 16:40:00	2016-10-27 03:25:00	10:45	+	11:00	+	11:00	+	11:00	+	11:00
	21	2016-10-27 16:55:00	2016-10-28 03:10:00	10:15	+	11:00	+	11:00	+	11:00	+	11:00
	22	2016-10-30 17:05:00	2016-10-30 19:00:00	1:55	+	2:00	+	2:00	+	2:00	+	2:00
3	23	2016-10-31 02:05:00	2016-10-31 03:10:00	1:05	+	2:00	+	2:00	+	2:00	-	
	24	2016-10-31 17:35:00	2016-10-31 23:25:00	5:50	+	7:00	+	7:00	+	7:00	-	
	25	2016-11-02 23:40:00	2016-11-03 02:30:00	2:50	+	3:00	+	3:00	+	3:00	+	3:00
	26	2016-11-03 20:35:00	2016-11-04 02:30:00	5:55	+	6:00	+	6:00	+	6:00	+	6:00
	27	2016-11-04 23:45:00	2016-11-05 02:05:00	2:20	+	3:00	+	3:00	+	3:00	+	3:00
	28	2016-11-06 01:00:00	2016-11-06 01:40:00	0:40	-		-		-		-	
	29	2016-11-09 00:25:00	2016-11-09 02:50:00	2:25	+	3:00	+	3:00	+	3:00	-	

	30	2016-11-12 18:30:00	2016-11-13 03:25:00	8:55	+	9:00	+	9:00	+	9:00	+	9:00
	31	2016-11-13 19:10:00	2016-11-14 01:00:00	5:50	+	8:00	+	8:00	+	8:00	+	8:00
	32	2016-11-17 18:20:00	2016-11-17 20:15:00	1:55	+	5:00	+	5:00	+	5:00	+	5:00
	33	2016-11-18 18:25:00	2016-11-19 01:50:00	7:25	+	8:00	+	8:00	+	8:00	+	8:00
4	34	2016-12-11 21:25:00	2016-12-12 03:15:00	5:50	+	6:00	+	6:00	+	6:00	-	
	35	2017-04-01 18:00:00	2017-04-02 04:00:00	10:00	+	10:00	+	10:00	+	10:00	+	5:00
5	36	2017-04-02 17:45:00	2017-04-03 03:55:00	10:10	+	11:00	+	11:00	+	11:00	-	
		Percentage of correctly identified flights [a]			80.5		82.5		75		65.8	
		Misidentified flights from temperature										
		2016-08-17 08:00:00	2016-08-17 10:00:00	3:00	X		X		X			
		2016-11-10 03:00:00	2016-11-10 04:00:00	2:00	X		X		X			
		2016-11-14 11:00:00	2016-11-14 12:00:00	2:00	X		X		X		X	
		2016-12-09 20:00:00	2016-11-23 23:00:00	4:00	X							
		2017-01-24 15:00:00	2017-01-24 17:00:00	3:00	X		X		X		X	
		Percentage of misidentified flights			12.2		10		10		5.3	

[a] Percentage of correctly identified flights does not show how well the flights were identified regarding flight time.