Supporting Information: Supplemental Tables and Figures for:

Temperature drives variation in flying insect biomass across a German malaise trap network

Authors: Ellen A.R. Welti, Petr Zajicek, Mark Frenzel, Manfred Ayasse, Tim Bornholdt, Jörn Buse, Alice Classen, Frank Dziock, Rolf A. Engelmann, Jana Englmeier, Martin Fellendorf, Marc I. Förschler, Ute Fricke, Cristina Ganuza, Mathias Hippke, Günter Hoenselaar, Andrea Kaus-Thiel, Janika Kerner, Daniela Kilian, Klaus Mandery, Andreas Marten, Michael T. Monaghan, Carsten Morkel, Jörg Müller, Stephanie Puffpaff, Sarah Redlich, Ronny Richter, Sandra Rojas-Botero, Tobias Scharnweber, Gregor Scheiffarth, Paul Schmidt Yáñez, Rhena Schumann, Sebastian Seibold, Ingolf Steffan-Dewenter, Stefan Stoll, Cynthia Tobisch, Sönke Twietmeyer, Johannes Uhler, Juliane Vogt, Dirk Weis, Wolfgang W. Weisser, Martin Wilmking, Peter Haase

Contents:

Table S1. Locations of 84 malaise traps and dominant land cover category.

Location	Latitude	Longitude	Dominant Land cover
Nationalpark Jasmund_Gumm / 3	54.555368	13.577896	NonIrrigatedCrop
Nationalpark Jasmund_Fahrn / 2	54.546179	13.659444	Forest
Nationalpark Jasmund_Goethe / 1	54.534736	13.655306	Forest
Nationalpark Vorpommersche Boddenlandschaft_DO / 1	54.477017	12.5112	Saltwater
Nationalpark Vorpommersche Boddenlandschaft_Lang / 2	54.441805	12.49133	Forest
Nationalpark Vorpommersche Boddenlandschaft_Heidensee / 3	54.437983	12.49335	Forest
Uni Rostock_ZI	54.42497	12.68462	Freshwater
Uni Greifswald_ELD/02	54.07926	13.476209	NonIrrigatedCrop
Uni Greifswald_ELD/01	54.075671	13.479164	NonIrrigatedCrop
BR Flusslandschaft Elbe MV_Rb_01	53.84217	11.12053	NonIrrigatedCrop
Nationalpark Niedersächsisches Wattenmeer	53.58827096	6.723134972	PastureOrchard
BR Schaalsee_Kb_01	53.464759	10.464053	NonIrrigatedCrop
BR Schaalsee_Db_01	53.335175	11.050982	NonIrrigatedCrop
BR Flusslandschaft Elbe MV	53.204663	11.030898	Forest
Nationalpark Unteres Odertal_AGG	53.130186	14.359659	GrassShrubland
Nationalpark Unteres Odertal_AGU	53.062096	14.323734	GrassShrubland
Leibniz-Institut für Gewässerökologie und Binnenfischerei	52.451228	13.643994	Forest
Nationalpark Harz_NP_Hz_Bu	51.8801	10.6553	Forest
Nationalpark Harz_NP_Hz_Bro	51.7982	10.6174	Forest
Nationalpark Harz_NP_Hz_Fi	51.7924	10.5155	Forest
TERENO_TER_FBG_1	51.622578	11.723798	NonIrrigatedCrop
TERENO_TER_FBG_2	51.62093	11.701777	NonIrrigatedCrop
TERENO_TER_SST_1	51.393613	11.748875	NonIrrigatedCrop
TERENO_TER_SST_2	51.39195	11.703426	NonIrrigatedCrop
Leipziger Auwaldkran_LCC-AWS-01	51.377217	12.280009	Forest
Leipziger Auwaldkran_LCC-AWS-02	51.375858	12.276423	Forest
Leipziger Auwaldkran_LCC-LE	51.367403	12.308824	Forest
BR Oberlausitzer Heide- und Teichlandschaft_TG/3	51.350467	14.664863	Freshwater
BR Oberlausitzer Heide- und Teichlandschaft_GL/1	51.346559	14.575978	PastureOrchard
BR Oberlausitzer Heide- und Teichlandschaft_AL/2	51.34004	14.634769	Forest
Nationalpark Kellerwald-Edersee_NP_Kel_02	51.159	8.93955	Forest
Nationalpark Kellerwald-Edersee_NP_Kel_04	51.15508	8.79752	Forest
Nationalpark Kellerwald-Edersee_NP_Kel_01	51.14229	8.92874	Forest
Nationalpark Kellerwald-Edersee_NP_Kel_03	51.13155	8.97643	Forest
Biodiversitäts-Exploratorium Hainich-Dün_HEG 19	51.073372	10.473357	PastureOrchard
Biodiversitäts-Exploratorium Hainich-Dün_HEW 42	51.06991	10.273537	Forest
Kammeyergarten (HTW Dresden)	51.00973	13.87283	Urban
Nationalpark Eifel_K7	50.60815	6.423185	Forest
Nationalpark Eifel_Lohrbachskopf	50.596079	6.464039	Forest
Nationalpark Eifel_Malsbenden	50.579769	6.467363	Forest
Nationalpark Eifel_Dedenborn	50.569256	6.359577	Forest
Nationalpark Eifel_Klusenberg	50.558923	6.403459	PastureOrchard

Nationalpark Eifel_Müsaulsberg	50.540129	6.380197	GrassShrubland
Rhein-Main-Observatorium_O7 M5	50.32513	9.49509	PastureOrchard
Rhein-Main-Observatorium_S5 M4	50.19838	9.18597	Urban
Rhein-Main-Observatorium_O3 M3	50.18603	9.09684	NonIrrigatedCrop
Rhein-Main-Observatorium_W4 M2	50.18383	9.08732	Forest
Rhein-Main-Observatorium_A1 M6	50.17989	8.95835	NonIrrigatedCrop
Rhein-Main-Observatorium_W2 M1	50.14157	8.98389	Forest
Hammelburg_672/0879	50.10155	9.872025	Forest
Hammelburg_672/0623	50.081017	9.868256	GrassShrubland
Hammelburg_672/0660	50.080042	9.854267	GrassShrubland
Hammelburg_672/0613	50.061344	9.853936	GrassShrubland
Hammelburg_672/0632	50.053814	9.862878	GrassShrubland
Haßfurt-Prappach	50.052633	10.567867	NonIrrigatedCrop
Hammelburg_672/0878	50.051675	9.810758	Forest
Hammelburg_672/0614	50.050261	9.867828	GrassShrubland
Hammelburg_672/0619	50.05	9.857231	GrassShrubland
Zeil-Schmachtenberg	50.004987	10.609725	NonIrrigatedCrop
Ebelsbach-Steinbach	49.998288	10.63084	NonIrrigatedCrop
Ebelsbach_1100/049	49.9814	10.686604	Forest
Ebelsbach_1100/053	49.97884	10.701188	Forest
Bavaria_6029_3For	49.91667	10.52549	Forest
Bavaria_6225_2Urb	49.77293	9.929597	Urban
Nationalpark Hunsrück-Hochwald_Erbeskopf / 4	49.72858	7.094094	Forest
Nationalpark Hunsrück-Hochwald_Wildwiese Thranenweiher / 3	49.7081	7.10412	Forest
Nationalpark Hunsrück-Hochwald_Bunker / 2	49.702007	7.090252	Forest
Nationalpark Hunsrück-Hochwald_Abentheuer / 1	49.652115	7.090571	Forest
Bavaria_6532_3Urb	49.420593	11.050254	Urban
Bavaria_6945_2For	49.08558	13.304759	Forest
Nationalpark Bayerischer Wald_KOL	49.05463	13.2552	Forest
Bavaria_6938_4Urb	49.00426	12.09667	Urban
Nationalpark Bayerischer Wald_BER	48.89879	13.44339	Forest
Nationalpark Schwarzwald_NP_SW_02	48.688465	8.241284	Forest
Nationalpark Schwarzwald_NP_SW_03	48.684751	8.235532	Forest
Bavaria_7544_2Ag	48.583249	13.390587	Urban
Nationalpark Schwarzwald_NP_SW_01	48.510327	8.219127	Forest
Biodiversitäts-Exploratorium Schwäbische Alb_AEG 50	48.405781	9.467762	PastureOrchard
Biodiversitäts-Exploratorium Schwäbische Alb_AEW 06	48.394119	9.446531	Forest
Bavaria_7935_2Urb	48.06033	11.64965	NonIrrigatedCrop
Bavaria_8130_2For	47.87829	10.81209	Forest
Nationalpark Berchtesgaden_Stubenalm 2	47.58952579	12.93652472	Forest
Nationalpark Berchtesgaden_Schapbach 1	47.58526593	12.95199356	Forest
Nationalpark Berchtesgaden	47.57017655	12.95833947	Forest

Table S2. Top AIC models ($\Delta AIC_c<2$) of predictors of flying insect biomass. All models included the random variable of trap identity. Predictor variables are defined in the Methods. Marg R^2= marginal R^2 or the percent variance explained by the fixed effects, Cond R^2= conditional R^2 or the percent variance explained by the fixed effects plus the random effect of trap, df= degrees of freedom, logLik= log likelihood, and w= model weight. For summary tables of model estimates, see Table 1.

Int	elevation	poly (period,2)	tmax	%forest	Marg R^2	Cond R^2	df	logLik	AICc	Δ	w
2.28		+	0.04708	-0.319	0.43	0.73	7	-378.56	771.2	0	0.17
2.21	0.036	+	0.04787	-0.487	0.45	0.73	8	-378.39	772.9	1.7	0.073

Table S3. Model coefficients for the interaction between monthly tmax and Δtemp (Fig. 3). Models were fit for each 2019 sampling month including April (a; $F_{(3,64)} = 13.2$, $R^2 = 0.38$, $P < 0.001$), May (b; $F_{(3,78)} = 6.8$, $R^2 = 0.21$, $P < 0.001$), June (c; $F_{(3,78)} = 14.5$, $R^2 = 0.36$, $P < 0.001$), July (d; $F_{(3,79)} = 15.5$, $R^2 = 0.37$, $P < 0.001$), August (e; $F_{(3,72)} = 5.3$, $R^2 = 0.18$, $P = 0.002$), September (f; $F_{(3,64)} = 5.7$, $R^2 = 0.21$, $P = 0.002$), and October (g; $F_{(3,59)} = 3.1$, $R^2 = 0.14$, $P = 0.03$).

	Estimate	Stand. Error	t-value	*P*
a) April				
Intercept	0.74	1.42	0.52	0.61
tmax	0.16	0.10	1.53	0.13
Δtemp	0.07	0.70	0.11	0.92
tmax * Δtemp	-0.01	0.05	-0.22	0.83
b) May				
Intercept	0.83	0.76	1.10	0.28
tmax	0.14	0.05	2.81	0.006
Δtemp	-1.17	0.80	-1.46	0.15
tmax * Δtemp	0.07	0.05	1.31	0.19
c) June				
Intercept	-4.19	1.81	-2.31	0.023
tmax	0.30	0.08	4.03	< 0.001
Δtemp	1.51	0.43	3.47	< 0.001
tmax * Δtemp	-0.06	0.02	-3.28	< 0.001
d) July				
Intercept	-4.11	1.38	-2.99	0.004
tmax	0.32	0.06	5.36	< 0.001
Δtemp	2.87	0.71	4.05	< 0.001
tmax * Δtemp	-0.12	0.03	-3.94	< 0.001
e) August				
Intercept	0.32	4.92	0.06	0.95
tmax	0.13	0.20	0.67	0.50
Δtemp	0.13	1.75	0.08	0.94
tmax * Δtemp	-0.01	0.07	-0.16	0.88
f) September				
Intercept	-1.25	1.61	-0.78	0.44
tmax	0.23	0.09	2.58	0.012
Δtemp	1.93	2.25	0.85	0.40
tmax * Δtemp	-0.12	0.13	-0.95	0.35
g) October				
Intercept	1.81	1.75	1.03	0.31
tmax	0.06	0.13	0.46	0.64
Δtemp	-0.66	1.13	-0.59	0.56
tmax * Δtemp	0.04	0.08	0.51	0.61

Table S4. Top models ($\Delta AIC_c < 2$) for day of peak flying insect biomass. Predictor variables are defined in the Methods. Df= degrees of freedom, logLik= log likelihood, and w= model weight.

Intercept	elevation	precip	Δtemp	%forest	%grassland /shrubland	%pasture /orchard	%urban	R^2	df	logLik	AICc	ΔAICc	w
183.1					-20.85			0.07	3	-291.94	590.2	0	0.03
180.9					-19.1	14.66		0.09	4	-290.87	590.3	0.12	0.028
174.4	-1.93	2.41			-21.83			0.11	5	-289.96	590.8	0.59	0.022
171.6	-1.83	2.46			-20.37	14.35		0.13	6	-288.92	591.1	0.9	0.019
193.5			-5.01		-21.66			0.08	4	-291.31	591.2	0.98	0.018
185.1				-4.13	-22.29			0.08	4	-291.51	591.6	1.39	0.015
190.2			-4.40		-19.94	13.65		0.1	5	-290.38	591.7	1.44	0.015
184.7	-1.84	2.61	-5.72		-23.25			0.13	6	-289.22	591.7	1.49	0.014
184.2	-0.32				-20.29			0.07	4	-291.72	592	1.8	0.012
175	-1.75	2.64		-5.49	-24.47			0.12	6	-289.44	592.1	1.92	0.011
181.6	-1.75	2.64	-5.48		-21.78	13.92		0.14	7	-288.22	592.2	1.95	0.011
182.6					-19.9		5.41	0.07	4	-291.80	592.2	1.97	0.011

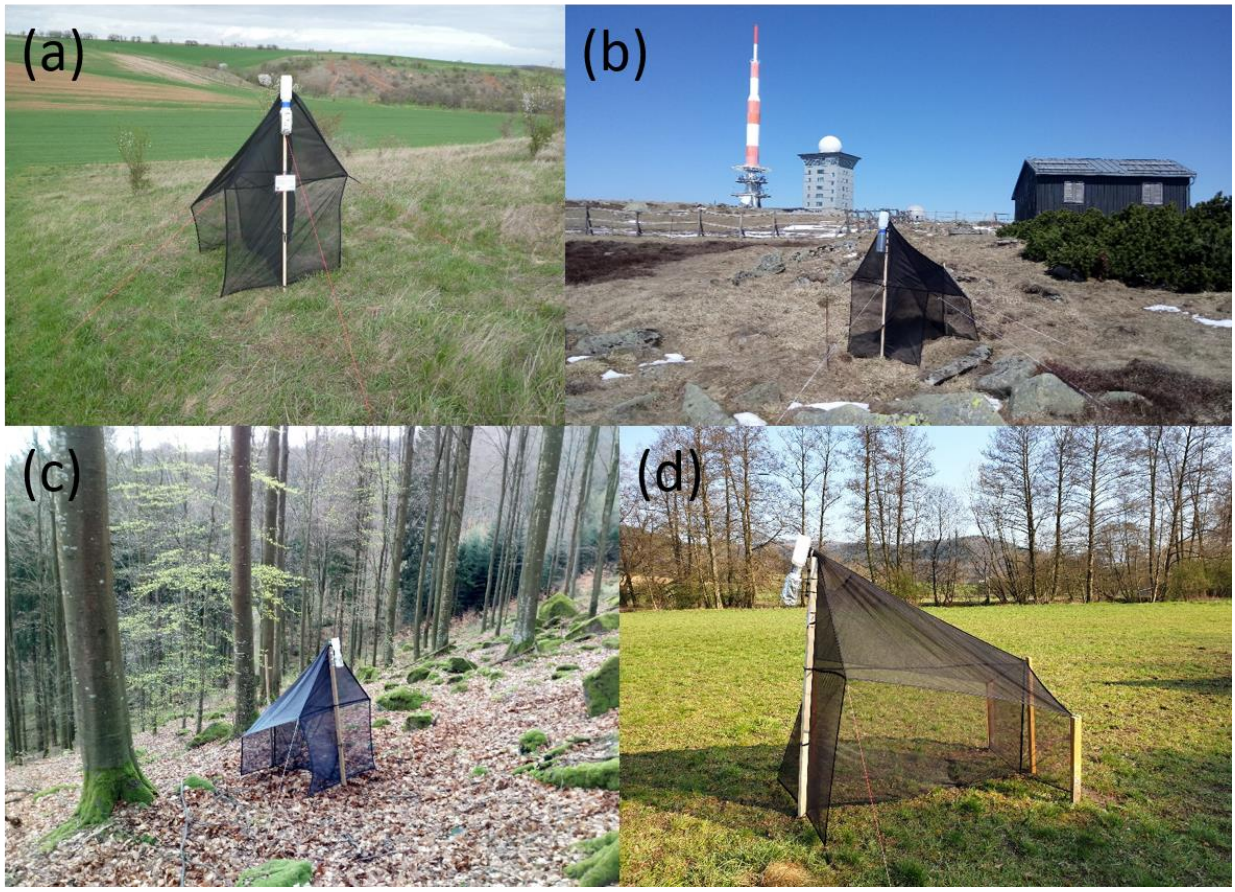

Figure S1. Examples of traps running in 2019 as part of the German Malaise Trap Program. Photos show traps at the LTER site Tereno- Friedeburg (a; photo credit: Mark Frenzel), at the Harz National Park (b; photo credit: Andreas Marten), at the Black Forest National Park (c; photo credit: Jörn Buse), and at the LTER site Rhine-Main-Observatory (d; photo credit: Peter Haase).

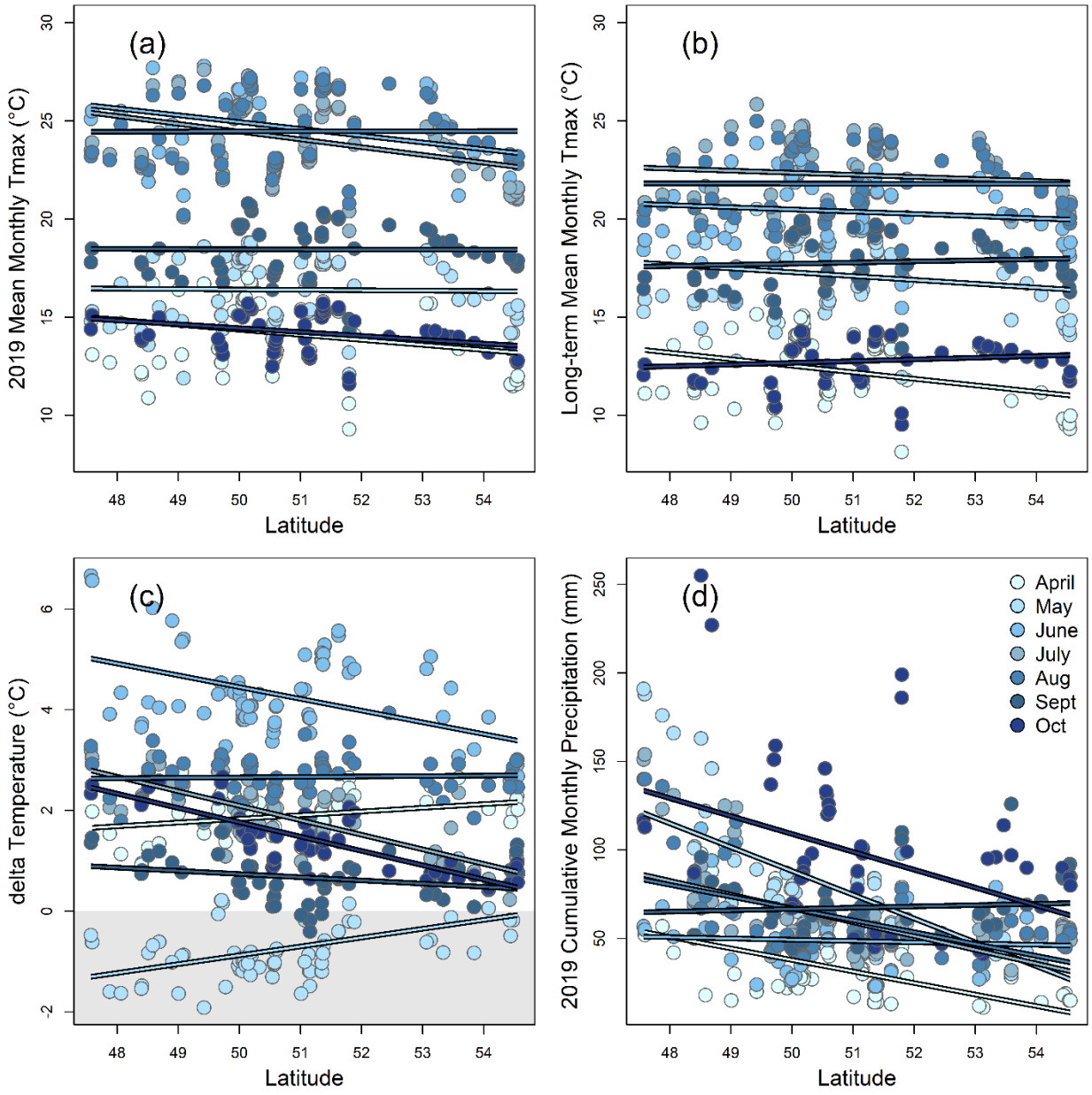

Figure S2. Changes with latitude across our 84 trap locations in 2019 mean monthly maximum temperature (a), the 1960-2018 long-term average monthly maximum temperature (b), the change in 2019 mean monthly maximum temperature minus the 1960-2018 long-term average (c), and 2019 cumulative monthly precipitation (d). Each point represents one month at one location, and only month/location combinations from which flying insect biomass data were collected are included. Averaging across April to October, 2019 mean monthly maximum temperature showed a weak trend to decrease with latitude (a; $F_{1,82} = 2.7$, $R^2 = 0.03$, $P = 0.10$), while the 1960-2018 long-term average monthly maximum temperature did not vary with latitude (b; $F_{1,82} = 0.6$, $R^2 < 0.01$, $P = 0.44$). While varying with month, the average Δ °C of 2019 maximum temperature over the long-term average decreased with latitude (c; $F_{1,82} = 12.6$, $R^2 = 0.13$, $P < 0.001$), as did cumulative monthly precipitation (d; $F_{1,82} = 26.8$, $R^2 = 0.24$, $P < 0.001$).

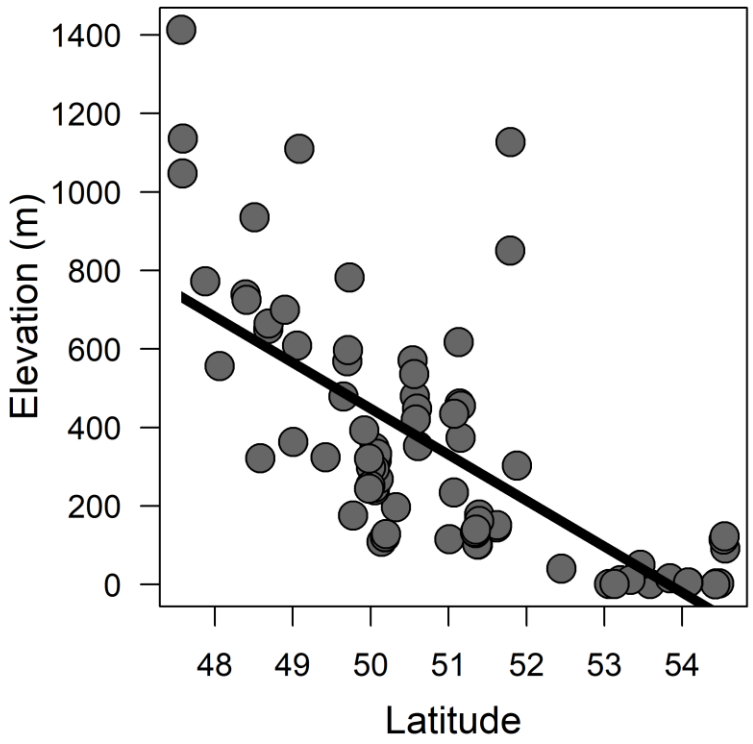

Figure S3. Elevation declined with increasing latitude across our 84 trap locations ($F_{1,82} = 74.5$, $R^2 = 0.48$, $P < 0.001$).

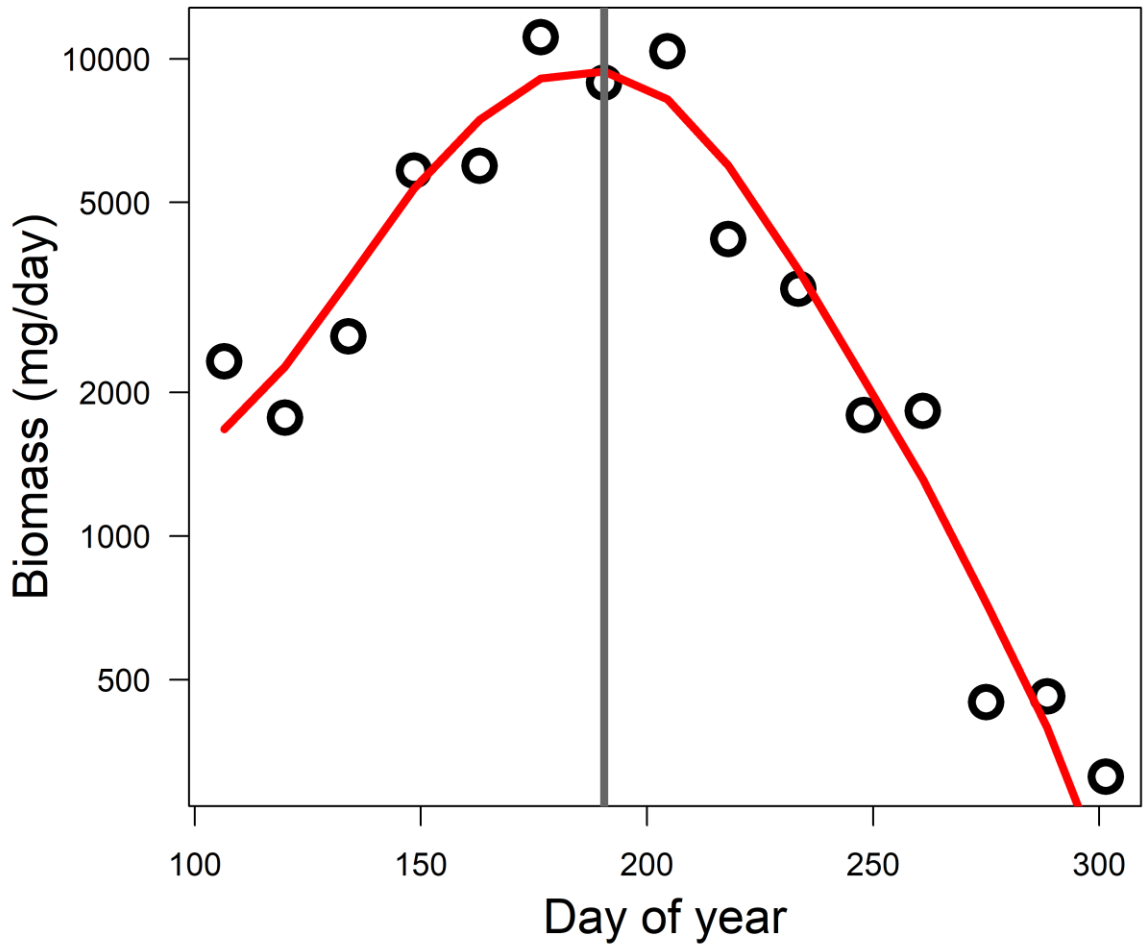

Figure S4. Example of determination of peak biomass day from a trap at Hunsrück-Hochwald National Park. Points represent the biomass (mg/day) collected from each sample plotted over the median day of the year of the sample. The red line is a spline fitted to these points. The grey vertical line shows the maximum value of the spline, at which the day of year was extracted. At this site, 2019 peak biomass was estimated to occur at the 190.5th day of the year (July 9th-10th).

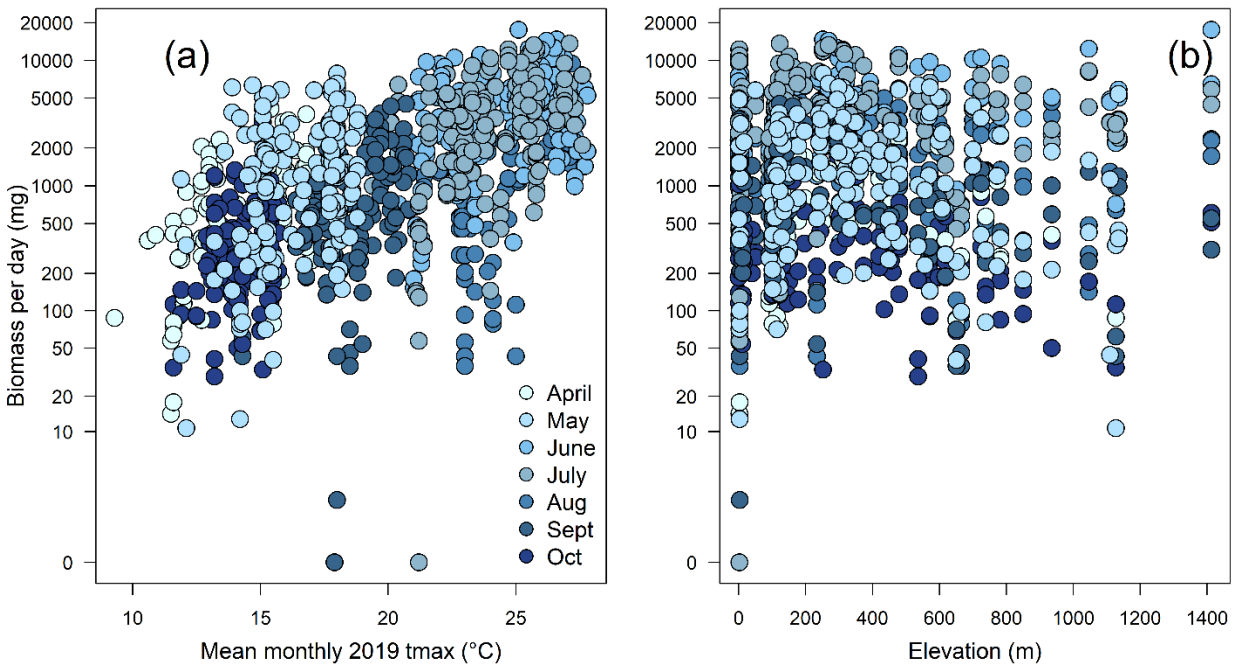

Figure S5. Responses of flying insect biomass to tmax and elevation. Each point represents the biomass from one sample. Across all months and location combinations, flying insect biomass increased with mean monthly 2019 maximum temperature (a), and increased weakly with elevation (b). Model estimates are provided in Table 1.