Supplementary material

for the paper "Weather explains high annual variation in butterfly dispersal" by Mikko Kuussaari, Susu Rytteri, Risto K. Heikkinen, Janne Heliölä and Peter von Bagh

Table S1. Summary of the annual mark-recapture and mobility data 2004–2015.

Year	Marked inds	Recaptured inds male	female	Recapture rate male	female	Obs. movements within patches	between patches	Emigration rate all	male	female	Residence time (days) all	male	female	Distance moved (m) all	male	female
2004	90	60	13	82.0	41.0	70	3	0.04	0.03	0.08	9.9	11.2	3.8	88	94	61
2005	56	23	10	66.7	50.0	30	3	0.09	0.13	0.00	5.9	6.8	4.1	94	100	80
2006	141	72	31	80.7	58.5	91	12	0.12	0.13	0.10	5.1	5.3	4.5	107	112	96
2007	131	58	24	77.8	48.0	65	17	0.21	0.17	0.29	3.2	3.1	3.7	100	105	90
2008	135	67	20	77.9	40.8	80	7	0.08	0.09	0.05	7.2	7.2	7.0	71	72	69
2009	143	69	11	66.7	28.9	66	13	0.16	0.17	0.18	6.0	6.1	4.9	100	99	106
2010	224	78	8	45.8	10.7	72	14	0.16	0.17	0.13	6.1	6.6	1.9	104	105	87
2011	504	143	40	43.4	27.4	139	44	0.24	0.27	0.13	1.8	2.0	1.1	136	152	78
2012	233	103	20	65.4	28.2	101	22	0.18	0.19	0.10	6.7	7.1	5.1	151	156	125
2013	523	202	48	57.8	30.3	186	64	0.26	0.26	0.23	4.4	4.4	4.2	154	156	146
2014	219	118	41	90.0	59.7	145	14	0.09	0.06	0.17	6.0	7.1	3.8	99	100	94
2015	69	38	11	77.6	55.0	46	3	0.06	0.03	0.18	7.2	7.7	5.3	107	94	151
Mean	206	86	23	69.3	39.9	91	18	0.14	0.14	0.14	5.8	6.2	4.1	109	112	99

Table S2. Summary of the explanatory variables 2004–2015 used in the dispersal analyses.

Year	Occupied patches	Metapop. size	Recapture rate (%)	Average temperature during flight season daily maximum (C)	daily mean (C)	daily minimum (C)	Proportion of exceptionally warm days	Mean daily rainfall (mm)	Proportion of rainy days	Average cloudiness (0-8)	Mean wind speed (m/s)	Mean daily radiation (kJ/m^2)
2004	2	147	81.1	18.2	13.7	9.0	0.00	3.6	0.76	5.1	3.9	18432
2005	2	98	58.9	21.1	16.1	9.8	0.13	2.6	0.32	4.2	3.7	22451
2006	5	192	73.0	22.4	16.5	10.0	0.28	0.8	0.17	3.7	4.1	23652
2007	4	182	62.6	21.1	15.9	9.6	0.24	1.3	0.40	2.7	2.8	27298
2008	4	212	64.4	19.2	14.2	9.3	0.03	3.6	0.55	3.7	3.4	20270
2009	5	337	55.9	19.3	14.7	9.2	0.13	0.8	0.42	4.0	3.2	20352
2010	6	533	38.4	19.9	15.0	10.0	0.03	1.0	0.29	3.7	3.3	21598
2011	9	1122	36.3	22.4	17.4	11.9	0.34	1.0	0.37	2.6	3.1	22541
2012	12	444	52.8	19.9	15.4	10.3	0.06	1.8	0.31	3.4	3.2	21478
2013	11	1041	47.8	22.4	17.7	11.9	0.22	1.6	0.48	3.0	2.8	21936
2014	9	294	72.6	18.2	13.9	9.6	0.16	2.4	0.60	4.6	3.1	17144
2015	4	112	71.0	19.4	14.7	10.3	0.07	2.7	0.50	3.7	3.4	20168
Mean	6.1	393	59.6	20.3	15.4	10.1	0.14	1.9	0.43	3.7	3.3	21443

Table S3. Pearson correlation coefficients between the explanatory variables used in the dispersal analyses ($n = 12$ years). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Variable	# Occupied patches	Metapopul. size	Recapture rate	Cloudiness	Especially warm days	Daily solar radiation	Daily rainfall	Rainy days	Mean minimum temperature	Mean maximum temperature	Mean temperature
Adjusting variables											
Metapopulation size	0.74 **										
Recapture rate	-0.51	-0.77 **									
Weather variables											
Average cloudiness	-0.44	-0.58 *	0.65 *								
Proportion of especially warm days	0.33	0.50	-0.29	-0.61 *							
Mean daily solar radiation (kJ/m^2)	-0.08	0.10	-0.31	-0.74 **	0.55						
Mean daily rainfall (mm)	-0.39	-0.44	0.57	0.55	-0.63 *	-0.53					
Proportion of rainy days	-0.17	-0.14	0.48	0.51	-0.42	-0.63 *	0.74 **				
Mean daily minimum temperature (^{o}C)	0.68 *	0.87 ***	-0.64 *	-0.67 *	0.60 *	0.24	-0.39	-0.29			
Mean daily maximum temperature (^{o}C)	0.27	0.53	-0.48	-0.72 **	0.80 **	0.73 **	-0.59 *	-0.66 *	0.71 **		
Mean temperature (^{o}C)	0.42	0.67 *	-0.58	-0.74 **	0.78 **	0.64 *	-0.58 *	-0.58	0.83 ***	0.97 ***	
Mean wind speed (m/s)	-0.57	-0.52	0.55	0.63 *	-0.23	-0.22	0.27	-0.05	-0.42	-0.10	-0.26

Table S4. Pearson correlations separately for male and female butterflies between the three dispersal measures and the explanatory adjusting and weather variables ($n = 12$ years).

Explanatory variable	Emigration		Residence time		Distance moved	
	Males	Females	Males	Females	Males	Females
Adjusting variables						
Number of occupied patches	0.61	0.32	-0.41	-0.22	0.81	0.48
Metapopulation size	0.82	0.26	-0.60	-0.54	0.79	0.21
Recapture rate	-0.78	-0.02	0.49	0.39	-0.57	0.02
Weather variables						
Average cloudiness	-0.77	-0.48	0.89	0.22	-0.56	-0.31
Proportion of especially warm days	0.60	0.38	-0.86	-0.44	0.50	0.07
Mean daily radiation (kJ/m^2)	0.53	0.33	-0.70	-0.20	0.26	0.02
Mean daily rainfall (mm)	-0.69	-0.44	0.71	0.50	-0.50	-0.24
Proportion of rainy days	-0.53	0.06	0.56	0.21	-0.36	-0.17
Mean daily minimum temperature (^{o}C)	0.72	0.24	-0.64	-0.44	0.82	0.46
Mean daily maximum temperature (^{o}C)	0.74	0.14	-0.78	-0.33	0.60	0.18
Mean temperature (^{o}C)	0.82	0.20	-0.79	-0.38	0.73	0.28
Mean wind speed (m/s)	-0.54	-0.69	0.55	0.16	-0.39	-0.38

Table S5. Summary of the modelling results of the factors explaining annual variation in the three dispersal measures, when the three adjusting variables, (a) metapopulation size, (b) number of occupied patches and (c) recapture rate, were forced in the models one at a time before the addition of significant weather variables. Emigration rate was modelled using a generalized linear model (GLM) with a binomial error distribution and a logit link function. Annual average residence time and distance moved were modelled based on multiple linear regression models.

(a) Metapopulation size as a forced adjusting variable

GLM with binomial error distribution

Variable	Coefficient	Df	Residual deviance	P
Emigration rate				
Null model		11	55.07	
Metapopulation size	0.00104	10	17.58	<0.001
Mean daily solar radiation	0.00011	9	7.99	0.002
85% of the total deviance explained by the model				

Multiple linear regressions

Variable	coefficient	t	P
Residence time			
Metapopulation size	-0.00031	-0.42	0.685
Average cloudiness	1.199	3.15	0.014
Proportion of especially warm days	-11.25	-4.66	0.002
n, F, P, R^2	12, 31.31, <0.001, 0.89		
Distance moved			
Metapopulation size	0.053	3.49	0.006
n, F, P, R^2	12, 12.17, 0.006, 0.50		

(b) Number of occupied patches as a forced adjusting variable

GLM with binomial error distribution

Variable	Coefficient	Df	Residual deviance	P
Emigration rate				
Null model		11	55.07	
Number of occupied patches	0.070	10	31.39	<0.001
Average cloudiness	-0.593	9	7.78	<0.001
86% of the total deviance explained by the model				

Multiple linear regressions

Variable	coefficient	t	P
Residence time			
Number of occupied patches	-0.014	-0.19	0.853
Average cloudiness	1.24	3.35	0.010
Proportion of especially warm days	-11.44	-4.81	0.001
n, F, P, R^2	12, 30.73, <0.001, 0.89		
Distance moved			
Number of occupied patches	5.17	4.34	0.002
Mean temperature	7.70	2.63	0.027
n, F, P, R^2	12, 21.36, <0.001, 0.79		

(c) Recapture rate as a forced adjusting variable

GLM with binomial error distribution

Variable	Coefficient	Df	Residual deviance	P
Emigration rate				
Null model		11	55.07	
Recapture rate	-0.013	10	19.69	<0.001
Mean temperature	0.195	9	9.35	0.001
Mean wind speed	-0.519	8	4.97	0.036
91% of the total deviance explained by the model				

Multiple linear regressions

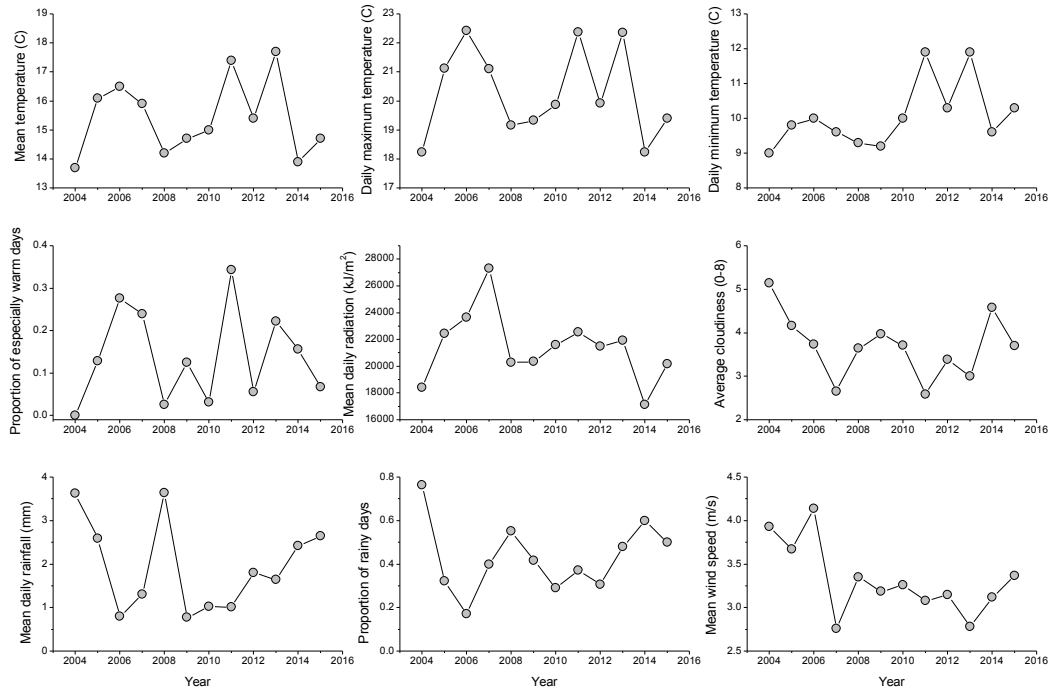| Variable	coefficient	t	P
Residence time			
Recapture rate	0.056	4.03	0.003
Proportion of especially warm days	-14.64	-8.23	<0.001
n, F, P, R^2	12, 56.0, <0.001, 0.91		
Distance moved			
Recapture rate	-0.08	-0.18	0.861
Mean daily minimum temperature	21.02	3.20	0.011
n, F, P, R^2	12, 9.33, 0.006, 0.60		
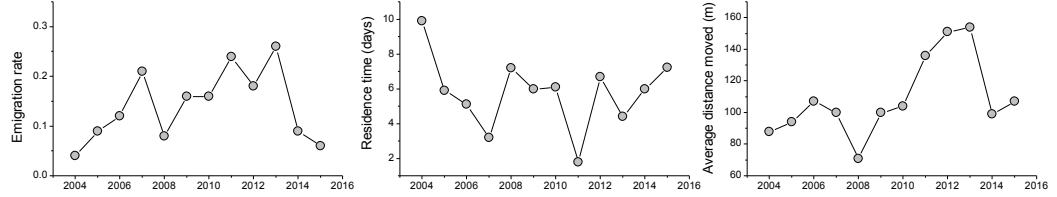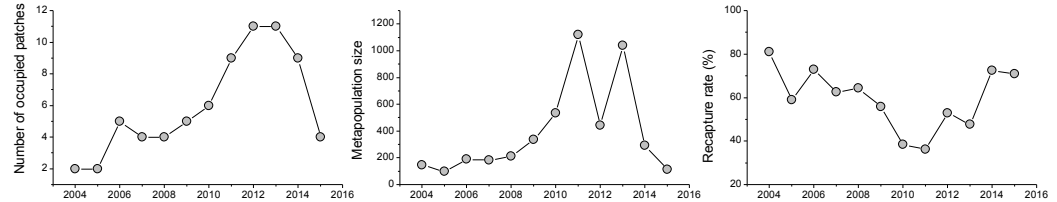
Fig. S1. Illustrations of the observed time series for all dispersal, adjusting and weather variables used in the dispersal analyses. There is no significant linear temporal trend in the variables except in two cases: the number of occupied patches (p = 0.012) and average wind speed (p = 0.045).
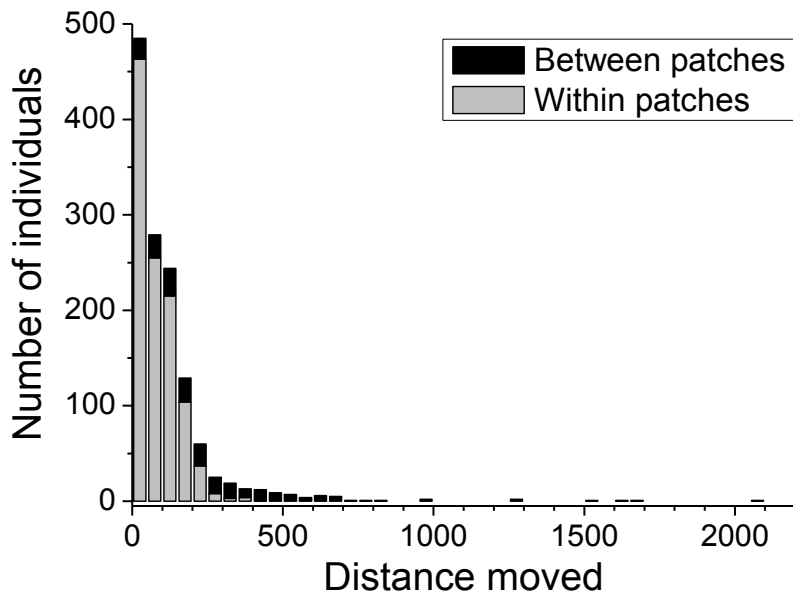
Fig. S2. Distribution of observed distances moved by Clouded Apollo during the MRR studies in 2004–2015 (n = 1,308 individuals). Within- (light grey) and between-patch (black bars) movements have been shown with differing colours.