## SUPPLEMENTARY INFORMATION

# Seasonal environments drive convergent evolution of a faster pace-of-life in tropical butterflies

Sridhar Halali, Erik van Bergen, Casper J Breuker, Paul M Brakefield, Oskar Brattström

## **Reconstruction of Mycalesina phylogeny**

Details on phylogenetic reconstruction is available in Brattstrom *et al.* (2020). This phylogeny is an extended version of the previously published phylogeny (Aduse-Poku *et al.* 2015) comprising 303 Mycalesina species covering all known genera and eight species of *Lethina* subtribe as outgroups. The majority of sequences (255 species) were obtained from previously published phylogenies (e.g. Aduse-Poku *et al.* 2015; 2016; 2017) with some new sequences procured from field work and museum collections; see Aduse-Poku *et al.* (2015) for details on DNA extraction, amplification and sequencing. The phylogeny was reconstructed using both Maximum likelihood (ML) and Bayesian inference methods. IQTREE v.1.6.3. (Nguyen *et al.* 2015) was used to run the maximum likelihood analysis and ModelFinder (Kalyaanamoorthy *et al.* 2017) was used to choose the best nucleotide substitution models. BEAST 1.8.4. (Drummond *et al.* 2012) was used to estimate the Bayesian inference tree and divergence times, and PartitionFinder2 (Lanfear *et al.* 2017) was used to estimate the best partitioning scheme and substitution models; see Brattstrom *et al.* (2020) for details of the fossil-based dating of the phylogeny. Baysian analyses were run for 50 million generations with a parameter and tree sampling every 5000 generations.

## **References:**

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**Table S1:** AIC scores of the four ordered and four unordered models fitted using *fitpolyMk* function in *phytools*. The best fitting model is highlighted in bold and was used for reconstructing the ancestral states presented in Figure 1 of the main text.

Model	Ordered	AIC
Equal rates	No	617.11
Equal rates	Yes	533.84
Symmetric	No	521.14
Symmetric	Yes	510.47
All rates different	No	498.47
All rates different	Yes	480.23
Transient	No	596.06
Transient	Yes	535.84

**Table S2:** (A) Analysis of deviance table for egg area and (B) model estimated marginal means with upper and lower confidence limits. Significant differences (Tukey's HSD,  $\alpha = 0.05$ ) between species were obtained using the R package *emmeans* and are indicated by different letters coding for each radiation independently.

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A.	

	Df	Deviance	P value
Habitat	1	45.374	< 0.001
Genus	1	0.620	< 0.001
Habitat*Genus	1	0.023	0.0338

B.

Radiation	Species	Mean	SE	LCL	UCL	Group
Madagascar	H. iboina	1.2918	0.0046	1.2803	1.3032	А
Madagascar	H. fraterna	0.8695	0.0064	0.8535	0.8854	В
Africa	B. martius	1.2456	0.0055	1.2319	1.2593	a
Africa	B. anynana	0.8013	0.0039	0.7917	0.8109	b

**Table S3:** (A) Analysis of deviance table for egg area corrected for body size. Body size was estimated as the average pupal weight of each of the species obtained from the common garden experiment. (B) model-estimated marginal means with upper and lower confidence limits. Significant differences (Tukey's HSD,  $\alpha = 0.05$ ) between species were obtained using the R package *emmeans* and are indicated by different letters coding for each radiation independently.

B.

A.

	Df	Deviance	P value
Habitat	1	114.44	< 0.001
Genus	1	78.949	< 0.001
Habitat*Genus	1	12.151	< 0.001

Radiation	species	Mean	SE	LCL	UCL	Group
Madagascar	H. iboina	5.1568	0.0203	5.1060	5.2075	А
Madagascar	H. fraterna	4.9345	0.0283	4.8638	5.0051	В
Africa	B. martius	4.7578	0.0244	4.6970	4.8186	а
Africa	B. anynana	4.0328	0.0170	3.9902	4.0754	b

**Table S4:** (A) Analysis of deviance table for egg development time and (B) model-estimated marginal means with upper and lower confidence limits. Significant differences (Tukey's HSD,  $\alpha = 0.05$ ) between species were obtained using the R package *emmeans* and are indicated by different letters coding for each radiation independently.

A.

	Df	Deviance	P value
Habitat	1	256.331	< 0.001
Genus	1	22.381	< 0.001
Habitat*Genus	1	12.404	< 0.001

Radiation	Species	Mean	SE	LCL	UCL	Group
Madagascar	H. iboina	4.8301	0.0824	4.6292	5.0396	А
Madagascar	H. fraterna	3.9585	0.1084	3.6975	4.2378	В
Africa	B. martius	4.6597	0.1100	4.3936	4.9420	а
Africa	B. anynana	3.2713	0.0580	3.1300	3.4190	b

B.

**Table S5:** (A) Analysis of deviance table for larval development time and (B) model-estimated marginal means with upper and lower confidence limits. Significant differences (Tukey's HSD,  $\alpha = 0.05$ ) between species were obtained using the R package *emmeans* and are indicated by different letters coding for each radiation independently. (M=male, F=female).

	Df	Deviance	P value
Habitat	1	167.983	< 0.001
Genus	1	75.709	< 0.001
Sex	1	9.183	0.0024
Habitat*Genus	1	15.557	< 0.001
Habitat*Sex	1	0.275	0.5998
Genus*Sex	1	1.291	0.2557
Habitat*Genus*Sex	1	1.958	0.1617

A.

B.

Radiation	Species	Sex	Mean	SE	LCL	UCL	Group
Madagascar	H. iboina	М	29.1320	0.7413	27.3426	31.0386	А
Madagascar	H. iboina	F	31.8214	0.6154	30.3246	33.3920	В
Madagascar	H. fraterna	М	25.6666	0.7817	23.7914	27.6896	С
Madagascar	H. fraterna	F	27.04	0.7353	25.2688	28.9352	AC
Africa	B. martius	М	37.0468	0.7608	35.1993	38.9913	а
Africa	B. martius	F	37.5428	0.7323	35.7622	39.4121	а
Africa	B. anynana	М	26.9803	0.7273	25.2281	28.8543	b
Africa	B. anynana	F	29.0491	0.6900	27.3801	30.8199	b

**Table S6:** (A) Analysis of deviance table for pupal development time and (B) model-estimated marginal means with upper and lower confidence limits. Significant differences (Tukey's HSD,  $\alpha = 0.05$ ) between species were obtained using the R package *emmeans* and are indicated by different letters coding for each radiation independently. (M=male, F=female).

B.

A.

	Df	Deviance	P value
Habitat	1	88.684	< 0.001
Genus	1	0.653	0.4191
Sex	1	3.442	0.0635
Habitat*Genus	1	9.936	0.0016
Habitat*Sex	1	0.320	0.5715
Genus*Sex	1	0	0.9971
Habitat*Genus*Sex	1	0.007	0.9345

Radiation	Species	Sex	Mean	SE	LCL	UCL	Group
Madagascar	H. iboina	М	9.9792	0.4560	8.9057	11.1821	А
Madagascar	H. iboina	F	9.3625	0.3421	8.5480	10.2546	AB
Madagascar	H. fraterna	М	8.0714	0.4384	7.0501	9.2407	BC
Madagascar	H. fraterna	F	7.8125	0.4034	6.8695	8.8849	С
Africa	B. martius	М	11.0000	0.4179	10.0069	12.0917	А
Africa	B. martius	F	10.2813	0.4008	9.3298	11.3297	А
Africa	B. anynana	М	7.2157	0.3761	6.3370	8.2162	В
Africa	B. anynana	F	7.0328	0.3395	6.2359	7.9315	В

**Table S7:** (A) Analysis of deviance table for total development time and (B) model-estimated marginal means with upper and lower confidence limits. Significant differences (Tukey's HSD,  $\alpha = 0.05$ ) between species were obtained using the R package *emmeans* and are indicated by different letters coding for each radiation independently. (M=male, F=female).

	Df	Deviance	P value	Radiation	Species	Sex	Mean	SE	LCL	UCL	Group
Habitat	1	241.437	< 0.001	Madagascar	H. iboina	М	38.7500	0.8985	36.5753	41.0540	А
Genus	1	63.967	< 0.001	Madagascar	H. iboina	F	41.0125	0.7160	39.2672	42.8353	А
Sex	1	2.9885	0.0838	Madagascar	H. fraterna	М	33.7381	0.8963	31.5778	36.0461	В
Habitat*Genus	1	25.14	< 0.001	Madagascar	H. fraterna	F	34.8125	0.8516	32.7545	36.9998	В
Habitat*Sex	1	0.497	0.4807	Africa	B. martius	М	48.0159	0.8730	45.8898	50.2405	а
Genus*Sex	1	0.911	0.3399	Africa	B. martius	F	47.7813	0.8640	45.6767	49.9827	а
Habitat*Genus*Sex	1	1.841	0.1748	Africa	B. anynana	М	34.1961	0.8188	32.2160	36.2978	b
				Africa	B. anynana	F	36.0820	0.7691	34.2162	38.0495	b

В.
В.

**Table S8:** (A) Analysis of deviance table for pupal weight and (B) model-estimated marginal means with upper and lower confidence limits. Significant differences (Tukey's HSD,  $\alpha = 0.05$ ) between species were obtained using the R package *emmeans* and are indicated by different letters coding for each radiation independently. (M=male, F=female).

	Df	Deviance	P value
Habitat	1	5526	< 0.001
Genus	1	3639	< 0.001
Sex	1	8611	< 0.001
Habitat*Genus	1	3926	0.0013
Habitat*Sex	1	1333	< 0.001
Genus*Sex	1	2155	< 0.001
Habitat*Genus*Sex	1	2300	< 0.001

A.

A.

B.

e	Radiation	Species	Sex	Mean	SE	LCL	UCL	Group
1	Madagascar	H. iboina	М	223.7358	2.6817	217.0559	230.4158	А
l	Madagascar	H. iboina	F	267.5310	2.1302	262.2249	272.8370	В
	Madagascar	H. fraterna	М	153.5452	3.0125	146.0413	161.0491	С
5	Madagascar	H. fraterna	F	189.8800	2.7610	183.0026	196.7574	D
	Africa	B. martius	М	266.2844	2.4404	260.2055	272.3632	а
	Africa	B. martius	F	258.2657	2.3335	252.4532	264.0782	b
	Africa	B. anynana	М	176.4000	2.7338	169.5903	183.2097	с
-	Africa	B. anynana	F	217.7689	2.4997	211.5423	223.9954	d

**Table S9:** (A) Analysis of deviance table for growth rates and (B) model-estimated marginal means with upper and lower confidence limits. Significant differences (Tukey's HSD,  $\alpha = 0.05$ ) between species were obtained using the R package *emmeans* and are indicated by different letters coding for each radiation independently. (M=male, F=female).

B.

	Df	Deviance	P value	Radiation	Species	sex	Mean	SE	LCL	UCL	Group
Habitat	1	0.0855	< 0.001	Madagascar	H. iboina	М	0.1873	0.0021	0.1821	0.1926	А
Genus	1	0.0517	< 0.001	Madagascar	H. iboina	F	0.1769	0.0017	0.1727	0.1810	В
Sex	1	0.0030	< 0.001	Madagascar	H. fraterna	М	0.1980	0.0024	0.1921	0.2038	С
Habitat*Genus	1	0.0175	< 0.001	Madagascar	H. fraterna	F	0.1953	0.0022	0.1899	0.2007	С
Habitat*Sex	1	0.0001	0.5039	Africa	B. martius	М	0.1511	0.0019	0.1464	0.1559	a
Genus*Sex	1	0.0002	0.3181	Africa	B. martius	F	0.1484	0.0018	0.1439	0.1530	а
Habitat*Genus*Sex	1	0.0009	0.0482	Africa	B. anynana	М	0.1928	0.0021	0.1875	0.1981	b
				Africa	B. anynana	F	0.1865	0.0020	0.1817	0.1914	b

A.

**Table S10:** Generalised linear mixed models for testing variation in fecundity. (A) Minimum

 adequate model in bold and (B) analysis of deviance table for the minimum adequate model.

A.

Models	AIC
egg.no ~ pupal weight + habitat * genus * day + day <sup>2</sup> + (1 female id)	4356.22
egg.no ~ pupal weight+ habitat + genus + day + habitat*genus + genus*day + habitat*day+ day <sup>2</sup> + (1 female id)	4354.25

В.

	Chisq	DF	P value
Pupal weight	2.7387	1	0.0979
Habitat	20.1470	1	< 0.001
Genus	6.7569	1	0.0093
Day	47.2145	1	< 0.001
Day <sup>2</sup>	73.7138	1	< 0.001
Habitat*Genus	3.1830	1	0.0744
Habitat*Day	13.3650	1	< 0.001
Genus*Day	13.7207	1	< 0.001

Fig. S1



Figure S1: Ancestral state reconstruction for habitat preference in Mycalesina butterflies using the dispersal-extinction-cladogenesis model (see Methods). Note that tip states of species belonging to B+C and C categories are slightly offset and those from A+B+C categories have longer lines to increase the clarity.



**Figure S2:** Violin plots with mean and 95% confidence intervals for the (a) larval and (b) pupal development time for replicate pairs of forest and savannah species from the Malagasy and African radiation reared in the common garden (green = forest species, yellow = savannah species). Sexes are denoted with different shapes (circles = males, squares = females) and significant differences in pairwise comparisons within each radiation are indicated by different letters coding for each radiation independently. Number below each violin indicates the sample size.



**Figure S3:** Fecundity curves for each female for replicate pairs of forest and savannah species from the Malagasy and African radiation (green = forest species, yellow = savannah species). Daily measurement of fecundity is shown in filled circles and the model estimated fecundity is shown as a line for each female. Dashed and solid lines represent species from the Malagasy and African radiation, respectively.

### Extracting data for species from the Asian radiation from published studies

We extracted data for three Australian species representing the Asian radiation from published studies (Braby & Jones 1994; Braby & Jones 1995). When possible, we extracted values from the plots showing mean and error bars as standard error using the WebPlotDigitiser Ver. 4.2. (<u>https://automeris.io/WebPlotDigitizer/</u>) (Rohtagi 2019), or used values provided in the tables. For some traits such as the total development time, information on confidence interval was not available.



**Figure S4:** Mean values with 95% confidence intervals (a) larval and (b) pupal development time and (d) pupal weight for three species from the Asian radiation (green = forest species, yellow = savannah species). For the (c) total development time, only the mean value was available. (e) Growth rate was calculated as ln(pupal weight)/larval development time. Data was extracted from Braby & Jones (1994). Sexes are denoted with different shapes (circles = males, squares = females).



Figure S5: Fecundity curves (mean number of eggs  $\pm$  SE) for three species from the Asian radiation

(green = forest species, yellow = savannah species). Data was extracted from Braby & Jones (1995).

#### References

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