How to describe and measure phenology? An investigation on the diversity of metrics using phenology of births in large herbivores

Supporting Information

Supporting information 1: References of the articles from which the metrics describing phenology of births in large herbivores were extracted.

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Supporting information 2: Parameters used in the simulations of phenology of births and default parameters used to implement the phenology metrics.

Table S2-1: Ranges of the four parameters varying in the simulated phenology of births: mean birth date for a given year, standard deviation of the birth distribution for a given year, range over which the mean birth date can vary across years, range over which the standard deviation can vary across years.

Characteristic of phenology	**Observed parameter**	**Mini-mum value**	**Maxi-mum value**	**Incre-ment**	**Number of values**	**Number of repetitions**	**Total number of simulations**
Timing	mean	85	283	4	50	50	2500
Synchrony	standard deviation (sd)	1	75	1.5	50	50	2500
Rhythmicity	Δmean	10	100	10	10	250	2500
Regularity	Δsd	3	40	4	10	250	2500

Table S2-2: Default parameters for the metrics, selected according to the most common practice in the literature of phenology of births in large herbivores.

Parameter	**Value selected**	**Reference**
Minimum percentage of births to consider that births are synchronous	80 %	Rutberg 1987
First quantile of the distribution of births (to evaluate births synchrony)	25 %	Gaillard *et al.* 1993
Last quantile of the distribution of births (to evaluate births synchrony)	75 %	Gaillard *et al.* 1993
Minimum percentage of the total number of births occurring within a year that should happen in a given time unit (*e.g.* a month) to count this time unit as a time unit during which births occur ("*nbtu*" metric)	1 %	Moe *et al.* 2007
Birth should be accounted for only if they are distributed in consecutive time units (*e.g.* months)	FALSE	/
Number of repetitions for the simulation procedures	1000	/
Transformation of the data	NONE	/
Confidence intervals	95 %	/
Period to consider that births are synchronous	Mean theoretical standard deviation of all the 2500 patterns simulated for which standard deviation varies	/

Because the implementation of a few metrics relied on the validation or invalidation of *a priori* condition (*e.g.* "at least a certain percentage of births occurs during a given period" to determine whether or not births are synchronous), we selected the most commonly used setting for that particular metric according to what we encountered in the literature or settings as general as possible to suit a large range of phenology of births.

When more than one value was possibly returned by the function coding for a metric, we retained only one value according to a predefined rule. For metrics returning the dates of the peaks in the distribution of births (*n* = 2 metrics), we only kept the date of the first peak if more than one peak was detected. When the metric was a boolean (true/false) variable based on the significance of a statistical test (*n* = 9 metrics), we used the value of the test statistics as output metric, thereby allowing us to investigate how the statistics was influenced by the value of phenology parameters. When the metric was boolean but not based on a statistical test (*n* = 4 metrics), we coded its value as binary variable taking a “1” when the test was significant or “0” when not significant at the *alpha* = 0.05 level. When the metric could take both positive and negative values representing the direction of a deviation such as the skewness (*n* = 2 metrics), we used the absolute value as we were interested in the amplitude and not in the direction of the deviation. One metric (“*khi2*” metric) could not be used for some simulations (1.5 % of the simulations) because the range of birth dates was sometimes too small to run the function associated with this metric.

Supporting information 3: Detailed description of the metrics extracted from phenology of births in large herbivore literature.

The description of each metric (*e.g.* characteristic of phenology associated, number of years it requires to be implemented, null hypothesis tested if this is the case) are provided. The details of the score obtained by each metric for each criterion listed in Table 1 are provided too.

Table S3-1: General characteristics of the metrics.

Metric[1]	**Complete name**	**Theoretical phenology characteristic associated**[2]	**Observed phenology characteristic associated**[3]	**Application period**[4]	**Unit**[5]	**Reference**
bart	bartlett	regularity	regularity	several cycles	boolean	Hass 1997
bgper	beginning period	timing	timing+	one cycle	date	Lent 1966
bgthper	beginning period threshold	timing	timing+	one cycle	date	Post and Forchhammer 2008
centre	centre	timing	timing	one cycle	date	Sigouin *et al.* 1997
cmano	comparison mean anova	rhythmicity	rhythmicity	several cycles	boolean	Gaillard *et al.* 1993
compmean	comparison mean ci	rhythmicity	rhythmicity	two cycles	boolean	Whiting *et al.* 2012
comppeaksig	comparison peak sigmoid ci	rhythmicity	none	two cycles	boolean	Moe *et al.* 2007
diffbgper	difference beginning period	rhythmicity	rhythmicity+	two cycles	duration	Guinness *et al.* 1978
diffmean	difference mean linear	rhythmicity	rhythmicity	several cycles	duration	Paoli *et al.* 2018
diffmed	difference median	rhythmicity	rhythmicity+	two cycles	duration	Berger 1992
diffmima	difference min max proportion births	synchrony	synchrony	one cycle	count	Owen-Smith and Ogutu 2013
diffpeak	difference peak	rhythmicity	rhythmicity+	two cycles	duration	Guinness *et al.* 1978
diffperiod	difference period	regularity	regularity	two cycles	duration	Berger and Cain 1999
diffslin	difference synchrony linear	regularity	regularity+	several cycles	duration	Paoli *et al.* 2018
interq	interquantiles period quantiles	synchrony	synchrony	one cycle	duration	Gaillard *et al.* 1993
khi2	khi2 proportion births median	regularity	regularity	several cycles	boolean	Adams and Dale 1998
kolmogau	kolmogorov smirnov gaussian	synchrony	synchrony	one cycle	boolean	Linnell and Andersen 1998

kolmomult	kolmogorov smirnov multi-year	rhythmicity - regularity	regularity+	two cycles	boolean	Green and Rothstein 1993
kolmouni	kolmogorov smirnov uniform	synchrony	synchrony	one cycle	boolean	Sinclair *et al.* 2000
maxprop	max proportion births period given	synchrony	synchrony	one cycle	count	Owen-Smith and Ogutu 2013
mean	mean	timing	timing	one cycle	date	McGinnes and Downing 1977
meanlin	mean linear random	timing	timing	several cycles	date	Loe *et al.* 2005
meanmult	mean mean multi-year	timing	timing	several cycles	date	Jarnemo *et al.* 2004
meanvl	mean vector length	synchrony	synchrony	one cycle	unitless value	Paré *et al.* 1996
meanvo	mean vector orientation	timing	timing	one cycle	date (radian)	Paré *et al.* 1996
med	median	timing	timing	one cycle	date	Bergerud 1975
medprob	median probit	timing	timing	one cycle	date	Caughley and Caughley 1974
minper	min period proportion births given	synchrony	synchrony	one cycle	duration	Skinner *et al.* 2002
minprop	min proportion births period given	synchrony	synchrony	one cycle	count	Owen-Smith and Ogutu 2013
mode	mode	timing	timing	one cycle	date	Bergerud 1975
mood	mood	rhythmicity	rhythmicity	two cycles	boolean	Berger and Cain 1999
nbtu	number time unit minimal births	synchrony	synchrony	one cycle	duration	Moe *et al.* 2007
peaksig	peak sigmoid	timing	timing	one cycle	date	Moe *et al.* 2007
per	period	synchrony	synchrony	one cycle	duration	Lent 1966
pergau	period gaussian	synchrony	synchrony	one cycle	duration	Paoli *et al.* 2018
perhdr	period high density region	synchrony	synchrony	one cycle	duration	Calabrese *et al.* 2018
permean	period mean multi-year	synchrony	synchrony	several cycles	duration	Green and Rothstein 1993
pielou	pielou	synchrony	synchrony	one cycle	unitless value	Sinclair *et al.* 2000
propmed	proportion births around median	synchrony	synchrony	one cycle	count	Adams and Dale 1998
propmode	proportion births around mode	synchrony	synchrony	one cycle	count	Green and Rothstein 1993
rayleigh	rayleigh	synchrony	none	one cycle	boolean	Paré *et al.* 1996
rutberg	rutberg	synchrony	synchrony	one cycle	duration	Rutberg 1984
sd	standard deviation	synchrony	synchrony	one cycle	duration	Bowyer 1991
sdprob	standard deviation probit	synchrony	synchrony	one cycle	duration	Caughley and Caughley 1974

skew	skewness variance	synchrony	none	one cycle	unitless	Bunnell 1980
skinner	skinner	synchrony	synchrony	one cycle	boolean	Skinner *et al.* 2002
slpcomp	slope comparison	regularity	synchrony	several cycles	boolean	Bowyer *et al.* 1998
var	variance	synchrony	synchrony	one cycle	duration	Hass 1997
varcor	variance corrected	synchrony	synchrony	one cycle	duration	Johnson *et al.* 2004
varlin	variance mutli-year	rhythmicity	rhythmicity+	several cycles	duration	Loe *et al.* 2005
watson	watson williams	rhythmicity	rhythmicity	two cycles	boolean	Paré *et al.* 1996
zerbe	zerbe	synchrony	synchrony	one cycle	duration	Zerbe *et al.* 2012

[1] short name of the metric as used in the article; [2] characteristic of phenology (timing, synchrony, rhythmicity or regularity) the metric is theoretically supposed to measure; [3] characteristic of phenology (timing, synchrony, rhythmicity or regularity) the metric effectively measures according to our analyses (+: when the metric also vary according to other characteristics of phenology than the one expected); [4] is the metric applicable to one year, two years or several years; [5] in which unit is the metric (days, number of births, a boolean as true or false, *etc.*).

Table S3-2: Detailed description of the metrics.

Metric	**Description**[1]	**Tested hypothesis**[2]
bart	compare variances of birth distributions	Variances of the birth distributions are similar
bgper	find first birth date	
bgthper	find first birth date when at least x percent of births have occurred	
centre	find central date between first and last birth dates	
cmano	compare mean birth dates between several reproductive cycles thanks to one way anova	Median birth dates are similar
compmean	compare mean birth dates between two reproductive cycles	Confidence intervals of mean birth dates overlap
comppeaksig	compare date of inflection point of birth distribution between two reproductive cycles	Confidence intervals of inflection points overlap
diffbgper	evaluate duration between first birth dates of two reproductive cycles	
diffmean	evaluate slope coefficient of linear model describing distribution of mean birth dates of several reproductive cycles	
diffmed	evaluate duration between median birth dates of two reproductive cycles	
diffmima	evaluate difference between "maxprop" and "minprop" metrics	
diffpeak	evaluate duration between mode birth dates of two reproductive cycles	
diffperiod	evaluate difference of duration between birth period duration (period between first and last birth dates) of two reproductive cycles	
diffslin	evaluate slope coefficient of linear model describing distribution of "pergau" metric of several reproductive cycles	
interq	find period gathering x percent of births based on quantiles	
khi2	compare distribution of proportion of births around median birth date of several reproductive cycles to a uniform distribution	Distribution of birth proportions around median birth date follows a uniform distribution
kolmogau	compare birth distribution to a gaussian distribution	Birth distribution follows a normal distribution
kolmomult	compare birth distribution between two reproductive cycles	Birth distribution similar for both reproduction cycles
kolmouni	compare birth distribution to a uniform distribution	Birth distribution follows a uniform distribution
maxprop	evaluate maximum proportion of births for a given duration	
mean	find mean birth date	
meanlin	find mean birth date thanks to linear model with random effects	
meanmult	calculate mean of mean birth dates	
meanvl	evaluate mean vector length (circular statistics)	
meanvo	evaluate mean vector orientation (circular statistics)	
med	find median birth date	
medprob	evaluate median birth date thanks to probit analysis	

minper	evaluate shortest period gathering x percent of births	
minprop	evaluate proportion of births occurring during the consecutive period gathering the less births	
mode	find mode birth date	
mood	compare median birth dates between two reproductive cycles	Median birth dates are similar
nbtu	find duration gathering at least x percent of the births	
peaksig	find inflection point based on logistic regression describing cumulative births	
per	calculate duration between first and last birth	
pergau	calculate 2*2*standard deviation of birth distribution	
perhdr	evaluate duration gathering x percent of births thanks to high density regions	
permean	evaluate mean duration between first and last births	
pielou	evaluate evenness index	
propmed	evaluate proportion of births occurring around median birth date	
propmode	evaluate proportion of births occurring around mode birth date	
rayleigh	compare birth distribution to a uniform distribution (alternative hypothesis: unimodal distribution)	Birth distribution follows a random distribution
rutberg	evaluate shortest period gathering at least x percent of births since first birth	
sd	calculate standard deviation of birth distribution	
sdprob	calculate standard deviation of birth distribution based on probit analysis	
skew	evaluate skewness of birth distribution	
skinner	evaluate presence or absence of a period of a given duration gathering x percent of births	At least one period of x days gathering y percents of births
slpcomp	compare slope coefficients of linear models describing birth distributions after transformation	Slopes of the linear regressions of the number of births according to time are similar
var	calculate variance of birth distribution	
varcor	calculate variance of birth distribution corrected by the Sheppard method	
varlin	calculate inter-reproductive cycles variance thanks to linear model with random effects	
watson	compare mean birth dates between two reproductive cycles	Mean birth dates are similar
zerbe	find shortest period gathering x percent of births around mode birth date	

[1] brief description of the metric and what it evaluates; [2] null hypotheses tested (when possible).

Table S3-3: Scores of the metrics.

Metric	**Theoretical phenology characteristic associated**	**Good-ness[1]**	**Mono-tony[1]**	**Satu-ration[1]**	**Strength[1]**	**Norma-lity (assum-ption) [1]**	**Norma-lity (robust-ness) [1]**	**Ori-gin[1]**	**Linea-rity[1]**	**Uni-city[1]**	**Score[2]**
bart	regularity	T	T	T	medium	F	T	F	2	T	6
bgper	timing	T	T	T	high	T		F	1	T	7
bgthper	timing	T	T	T	high	T		F	1	T	7
centre	timing	T	T	T	high	T		F	1	T	7
cmano	rhythmicity	T	T	F							2
compmean	rhythmicity	T	T	F							2
comppeaksig	rhythmicity	F									0
diffbgper	rhythmicity	T	T	T	medium	T		F	1	T	6.5
diffmean	rhythmicity	T	T	F							2
diffmed	rhythmicity	T	T	T	high	T		F	1	T	7
diffmima	synchrony	T	T	F							2
diffpeak	rhythmicity	T	T	T	medium	T		F	1	F	5.5
diffperiod	regularity	T	T	T	medium	T		F	1	T	6.5
diffslin	regularity	T	T	F							2
interq	synchrony	T	T	T	high	T		F	1	T	7
khi2	regularity	T	T	T	medium	T		F	3	T	6
kolmogau	synchrony	T	T	F							2
kolmomult	rhythmicity - **regularity**	T	T	T	medium	T		T	1	T	7.5
kolmouni	synchrony	T	T	T	high	T		T	3	T	7.5
maxprop	synchrony	T	T	F							2
mean	timing	T	T	T	high	T		F	1	T	7
meanlin	timing	T	T	T	high	T		F	1	T	7
meanmult	timing	T	T	T	high	T		F	1	T	7
meanvl	synchrony	T	T	T	high	T		T	3	T	7.5
meanvo	timing	T	T	T	high	T		T	1	T	8
med	timing	T	T	T	high	T		F	1	T	7
medprob	timing	T	T	T	high	F	T	F	1	T	7
minper	synchrony	T	T	T	high	T		F	1	F	6
minprop	synchrony	T	T	F							2
mode	timing	T	T	T	medium	T		T	1	F	6.5
mood	rhythmicity	T	T	T	high	T		F	3	T	6.5
nbtu	synchrony	T	F								1
peaksig	timing	T	T	T	high	F	T	F	1	T	7
per	synchrony	T	T	F							2
pergau	synchrony	T	T	T	high	F	T	F	1	T	7
perhdr	synchrony	T	T	T	high	T		F	1	F	6
permean	synchrony	T	T	F							2

pielou	synchrony	T	T	T	high	T		T	3	T	7.5
propmed	synchrony	T	T	F							2
propmode	synchrony	T	T	F							2
rayleigh	synchrony	F									0
rutberg	synchrony	T	T	T	medium	T		F	1	T	6.5
sd	synchrony	T	T	T	high	T		F	1	T	7
sdprob	synchrony	T	T	T	high	F	T	F	1	T	7
skew	synchrony	F									0
skinner	synchrony	T	T	F							2
slpcomp	regularity	F									0
var	synchrony	T	T	T	high	T		F	3	T	6.5
varcor	synchrony	T	T	T	high	T		F	3	T	6.5
varlin	rhythmicity	T	T	T	high	T		F	3	T	6.5
watson	rhythmicity	T	T	T	high	F	T	F	3	T	6.5
zerbe	synchrony	T	T	T	high	T		F	1	F	6

[1] *cf.* Table 1 in the main text; [2] total score obtained by the metric according to the eight criteria.

Supporting information 4: Evaluation of phenology metrics in scenarios of non-normal distributions of births.

Introduction

In the main text, we chose to base our simulations on a normal distribution of births for biological and methodological considerations (see Materials and Methods section). Normally distributed dates of birth were reported for roe deer *Capreolus capreolus* (Gaillard *et al.* 1993) and wildebeest *Connochaetes taurinus* for instance (Sinclair *et al.* 2000). However, the distribution of births of some species is not necessarily normal. Here, we replicated our analyses on the metrics with additional distributions of births previously reported in the literature. We identified four scenarios (Fig. S4-1):

1) a **skewed normal distribution**, which would better approximate distributions of births characterized by numerous early births and fewer late births. Such asymmetric distributions of dates of birth were documented for warthog *Phacochoerus aethiopicus* (Sinclair *et al.* 2000), or bighorn sheep *Ovis canadensis* (Festa-Bianchet 1988) for instance;

2) a **bimodal distribution with two close peaks**, which would better approximate distributions of births characterized by a main peak closely followed by a second one, often smaller. Such distributions could arise from second attempts to breed for females whose first attempt failed (*e.g.* because fertilization failed at the first oestrus). Examples of species displaying such a bimodal distribution of dates of birth are the impala *Aepyceros melampus* (Anderson 1975) or the red deer *Cervus elaphus* (Guinness *et al.* 1978);

3) a **Cauchy distribution**, which represents a bell-shape distribution of births with fat tails. Even if such distribution looks like a normal distribution at first glance, it is however characterized by the existence of few births occurring all year long in addition to the main delimited peak. The distribution of births of zebra *Equus burchelli böhmi* (Leuthold and

Leuthold 1975) or Grant's gazelle *Gazella granti* (Sinclair *et al.* 2000) match with this theoretical distribution;

4) a **random distribution** whereby births can occur anytime in the year because conditions are always favourable, for instance. Giraffe *Giraffa camelopardalis* (Sinclair *et al.* 2000) and waterbuck *Kobus ellipsiprymnus* (Leuthold and Leuthold 1975) can give birth all year round.

Materials and Methods

Here, we evaluated the behaviour of each metric presented in the main text and in Supporting information 3, according to the four characteristics of phenology (timing, synchrony, rhythmicity and regularity). We replicated the methodology described in "Materials and Methods" section of the main text, Steps 2 to 4. Each simulated phenology of births was generated following one of the four distributions presented above by distributing approx. 1000 births within a year of 365 days, replicated over 10 years (Step 2). According to the distribution, we fixed specific parameters and we changed our four parameters of interest independently (Table S4-1) to illustrate variations of: *i*) the timing (*i.e.* mean day of birth for a given year), *ii*) the synchrony (*i.e.* standard deviation of the distribution of births for a given year), *iii*) the rhythmicity (*i.e.* size of the range over which the mean birth date can vary across years), and *iv*) the regularity (*i.e.* size of the range over which the standard deviation can vary across years). Each of those parameters varied in a range from a minimum to a maximum value and was incremented with a constant step. We then computed the metrics from each simulated phenology following Step 3. We finally produced the global correlation matrix between all pairs of metrics, using Pearson correlations, for each distribution (Step 4).

We compared the results obtained using the above-described distributions with those obtained when using a normal distribution. To do so, for each metric, we (1) extracted the correlation coefficients between this metric and the others while using a normal distribution, (2) did the same with correlation values obtained when using other distributions, and (3) fitted a linear model between values obtained in (2) and those obtained in (1), thereby testing to what extent values obtained using non-normal distributions could be predicted from those obtained using normal distributions. We used the coefficient of determination R^2 as a measure of the fit. A high R^2 indicated that the correlation between metrics was not greatly affected by the choice of the distribution of births.

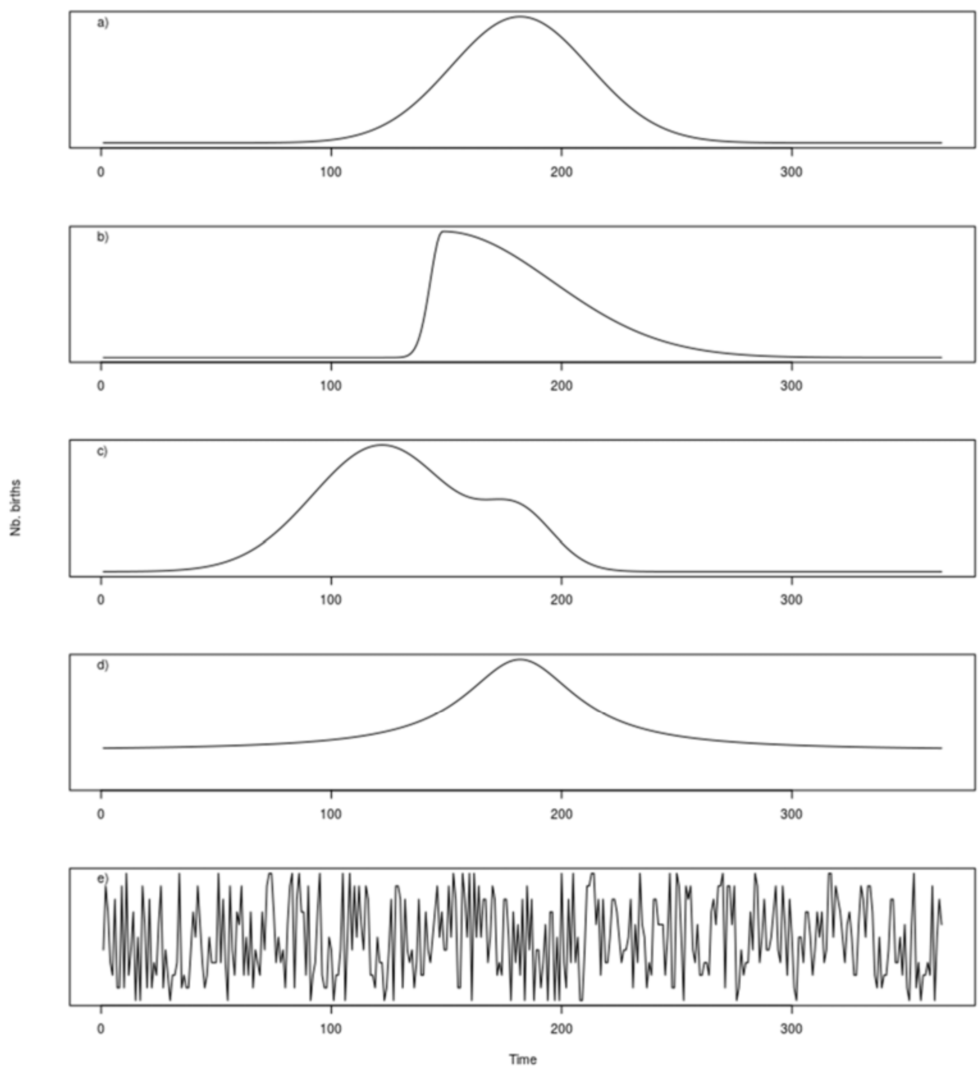


Figure S4-1: theoretical distributions that could illustrate phenology of births of large herbivore species in *natura*: a) normal distribution, b) skewed normal distribution, c) bimodal distribution with two close peaks, d) Cauchy distribution, e) random distribution.

Table S4-1: Values of the parameters used in the simulated phenology of births following the four scenarios (skew normal distribution, bimodal distribution with two close peaks, Cauchy distribution, random distribution). For the variable parameters (mean, standard deviation, range of variation of both parameters), 10 different values were used, with 10 repetitions each time, leading to 100 simulations per unique combination of parameters.

Distribution	**Characteristic of phenology**	**Observed parameter**	**Default value**	**Minimum value**	**Maximum value**	**Incre-ment**
Skewed normal	Timing	mean	182	90	270	20
	Synchrony	standard deviation (sd)	30	2	74	8
	Rhythmicity	Δmean	0	10	100	10
	Regularity	Δsd	0	5	41	4
	Skewness	skew	3.5			
Bimodal	Timing	mean	122	90	225	15
	Synchrony	sd	30	10	37	3
	Rhythmicity	Δmean	0	5	50	5
	Regularity	Δsd	0	3	30	3
	Distance between main and second peak	Δmean/mean2	60			
	Synchrony second peak	sd2	15			
	Proportion of births in main peak	pb1	0.75			
Cauchy	Timing	mean	182	90	270	20
	Synchrony	sd	30	2	74	8
	Rhythmicity	Δmean	0	10	100	10
	Regularity	Δsd	0	5	41	4
Random	Maximum number of births per day	max_{nb}	5			

Results

Most of the relationships between the correlation coefficients based on the skewed normal, bimodal or Cauchy distributions and the correlation coefficients based on the normal distribution showed a $R^2 > 0.75$ (96 %, 71 % and 80 % of the metrics for the skewed normal, bimodal and Cauchy distributions respectively, Table S4-2). Similarly, less than 6 % of the relationships showed a $R^2 < 0.25$ for those three distributions. Although the results were generally congruent with those we reported when using the normal distribution as the baseline distribution of births (compare Fig. 2 in the main text and Fig. S4-2, a), b) and c)), some metrics measuring the same characteristic of phenology in the context of a normal distribution were less correlated when applied to non-normal distribution of dates of birth. The metric "*diffpeak*" evaluates the duration between the mode birth dates of two years. Depending on whether the mode is located in the first or the second peak in each year, the difference returned by "*diffpeak*" can vary in the bimodal distribution. Also, "*rutberg*", "*diffperiod*", "*bgper*" and "*bgthper*" suffered from the absence of real break in the Cauchy distribution. All these metrics rely on the detection of the beginning of a definite period of births so the absence of any period with no birth limits their relevance. To the contrary, some metrics did better when applied to the three asymmetrical patterns of births. This was the case for "*skew*", which measures the skewness of the distribution, and "*kolmogau*", which compares the distribution of births to a normal distribution. The two metrics correlated with the other synchrony metrics for those three distributions better than for the normal distribution. Indeed, "*skew*" detects the skewness of a distribution, a feature existing in the three distributions but not in the normal one. "*kolmogau*" detects patterns departing from the normal distribution in the three other scenarios.

To the contrary, the random distribution of births produced very different results from all the other distributions (Fig. S4-2, d)). None of the relationships between the correlation coefficients for the random distribution and the correlation coefficients based on the normal distribution had a $R^2 > 0.75$, and 67 % had a $R^2 < 0.50$ (Table S4-2). Some synchrony and timing metrics remained highly correlated, mainly because births were quite consistent through the year, such as the mean date of births ("*mean*") or the variance of the distribution of births ("*var*"), but it is statistically and biologically meaningless to characterize such distribution by its mean or variance though.

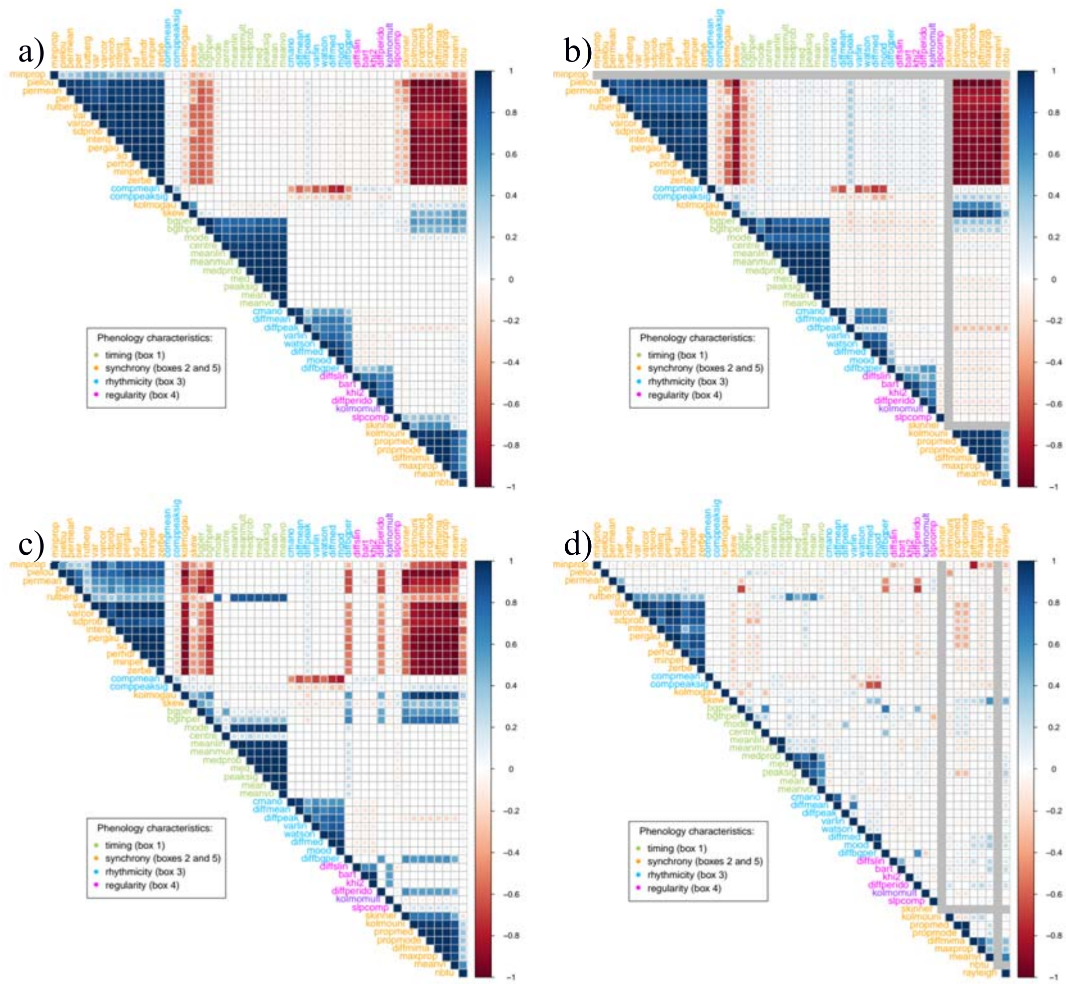


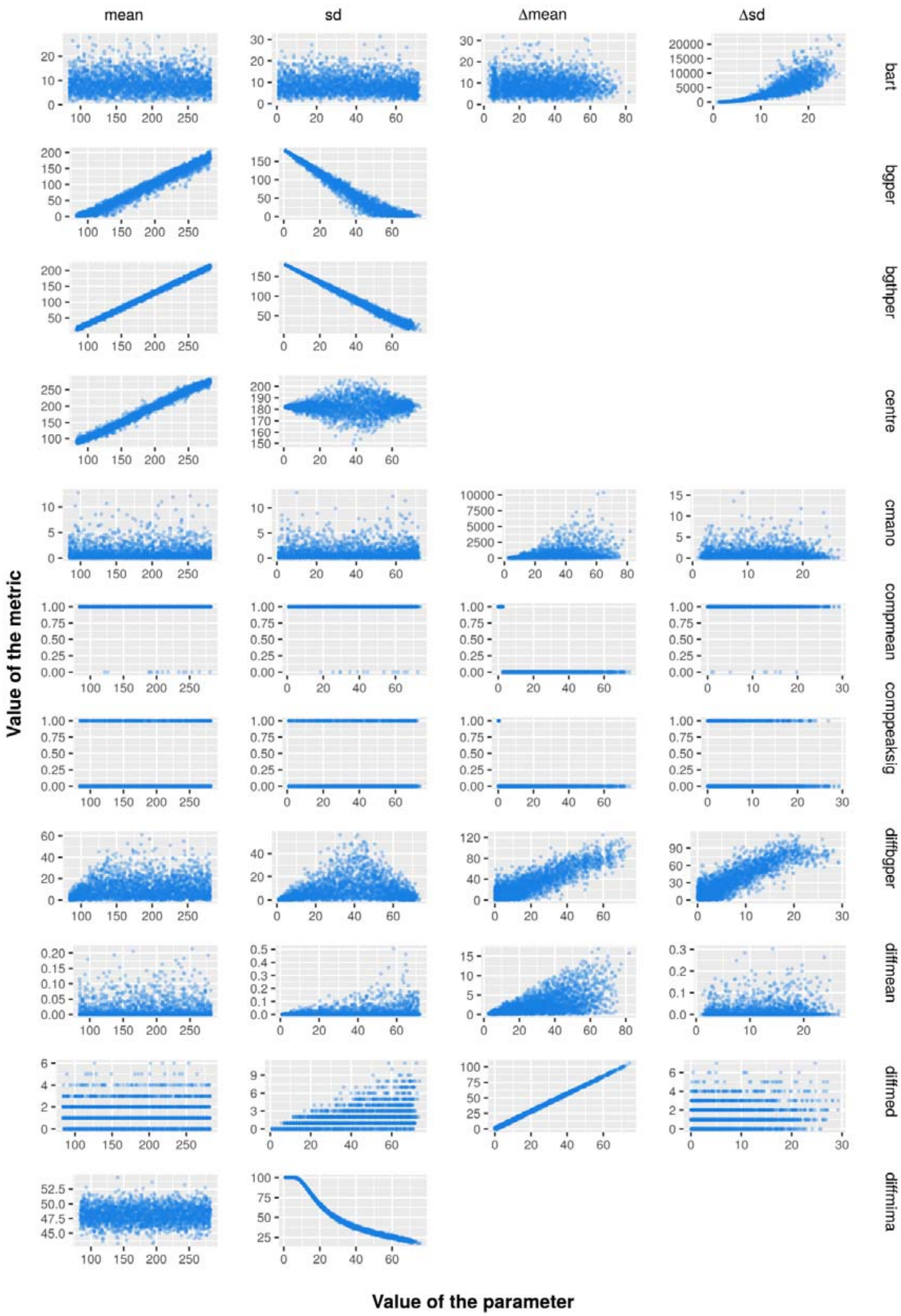
Figure S4-2: Correlation matrices between all pairs of metrics using Pearson correlations based on four scenarios: a) skewed normal distribution, b) bimodal distribution with two close peaks, c) Cauchy distribution, d) random distribution. It was not possible to classify “*kolmomult*” *a priori* in rhythmicity or regularity metrics, as it compares the complete distribution of births between two years. *Green* = timing metrics, *orange* = synchrony metrics, *blue* = rhythmicity metrics, *pink* = regularity metrics. When the value of a given metric was constant for a given distribution, it was not possible to assess the coefficients of correlation (reported in grey in the matrices).

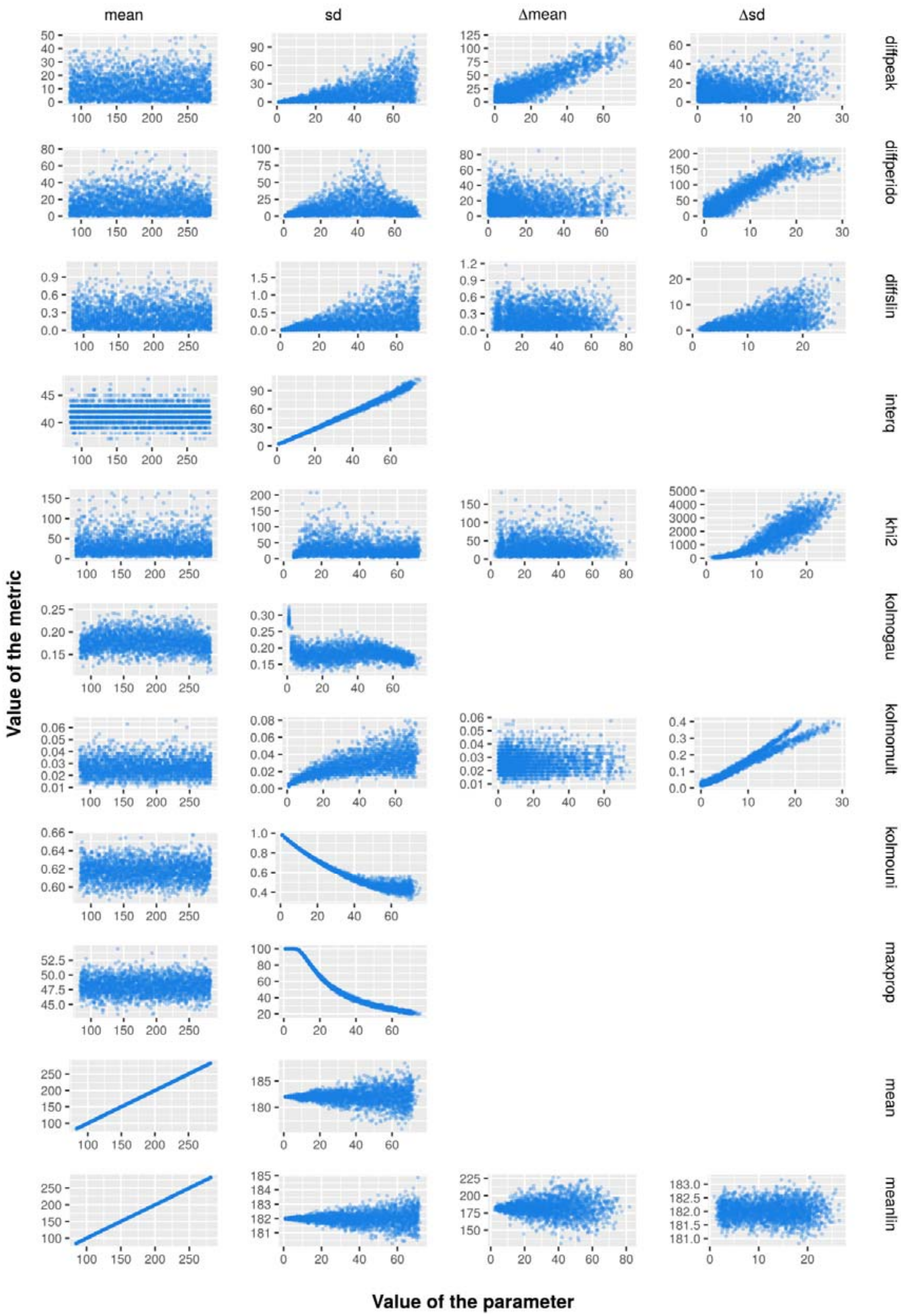
Table S4-2: Comparison of the coefficients of correlation between all pairs of metrics based on the normal distribution and those based on the other distributions (skew normal distribution, distribution with two close peaks, Cauchy distribution and random distribution), using the coefficient of determination of the linear relationship. When the value of a given metric was constant either for the normal or the non-normal distributions, it was not possible to assess the coefficients of correlation, so the linear relationship was not explored (reported as "not applicable" in the table).

Metric	Skewed normal	Bimodal	Cauchy	Random
bart	0.98	0.7	0.82	0.42
bgper	0.98	0.85	0.7	0.24
bgthper	0.98	0.8	0.74	0.37
centre	0.99	0.9	0.56	0.09
cmano	0.99	0.85	0.94	0.56
compmean	0.98	0.67	0.9	0.45
comppeaksig	0.79	0.26	0.36	0.68
diffbgper	0.89	0.46	0.11	0.16
diffmean	0.98	0.8	0.93	0.56
diffmed	0.98	0.72	0.9	0.48
diffmima	0.98	0.89	0.89	0.34
diffpeak	0.97	0.59	0.92	0.19
diffperido	0.96	0.57	0.12	0.29
diffslin	0.98	0.71	0.78	0.37
interq	0.98	0.88	0.92	0.54
khi2	0.97	0.72	0.76	0.26
kolmogau	0.46	0.2	0.1	0.64
kolmomult	0.97	0.73	0.59	0.16
kolmouni	0.98	0.89	0.9	0.11
maxprop	0.98	0.89	0.89	0.48
mean	0.99	0.95	0.78	0.51
meanlin	0.99	0.95	0.78	0.28
meanmult	0.99	0.95	0.78	0.28
meanvl	0.97	0.89	0.91	0.38
meanvo	0.97	0.94	0.78	0.47
med	0.98	0.91	0.78	0.54
medprob	0.99	0.97	0.79	0.49
minper	0.98	0.89	0.91	0.59
minprop	0.93	Not applicable	0.92	0.15
mode	0.94	0.87	0.78	0.2
mood	0.98	0.68	0.9	0.46
nbtu	0.97	0.86	0.79	Not applicable
peaksig	0.98	0.93	0.78	0.39
per	0.98	0.9	0.78	0.26
pergau	0.98	0.9	0.91	0.59
perhdr	0.98	0.88	0.91	0.57

permean	0.98	0.89	0.81	0.19
pielou	0.98	0.89	0.88	0.09
propmed	0.98	0.89	0.89	0.37
propmode	0.98	0.89	0.89	0.37
rayleigh	Not applicable	Not applicable	Not applicable	Not applicable
rutberg	0.97	0.89	0.41	0.29
varlin	0.99	0.77	0.92	0.54
skew	0.34	0.23	0.35	0.48
skinner	0.98	Not applicable	0.76	Not applicable
slpcomp	0.95	0.22	0.83	0.22
sd	0.98	0.9	0.91	0.59
sdprob	0.98	0.9	0.9	0.56
var	0.97	0.89	0.92	0.61
varcor	0.97	0.89	0.92	0.61
watson	0.98	0.82	0.91	0.29
zerbe	0.98	0.89	0.91	0.59

Supporting information 5: Variation of each phenological metric according to the variation of the four parameters of phenology, within and between years, in the simulations of phenology of births. *mean*: variation of each metric according to the variation of the mean birth date in a give year; *sd*: variation of each metric according to the variation of the standard deviation of the distribution of births for a given year; *Δmean*: variation of each metric according to the variation of the size of the range over which the mean birth date can vary across years; *Δsd*: variation of each metric according to the variation of the size of the range over which the standard deviation of the distribution of births can vary across years.


mean
sd
Δmean
Δsd
bart
bgper
bgthper
centre
cmano
compmean
comppeaksig
diffbgper
diffmean
diffmed
diffmima
Value of the metric
Value of the parameter


mean
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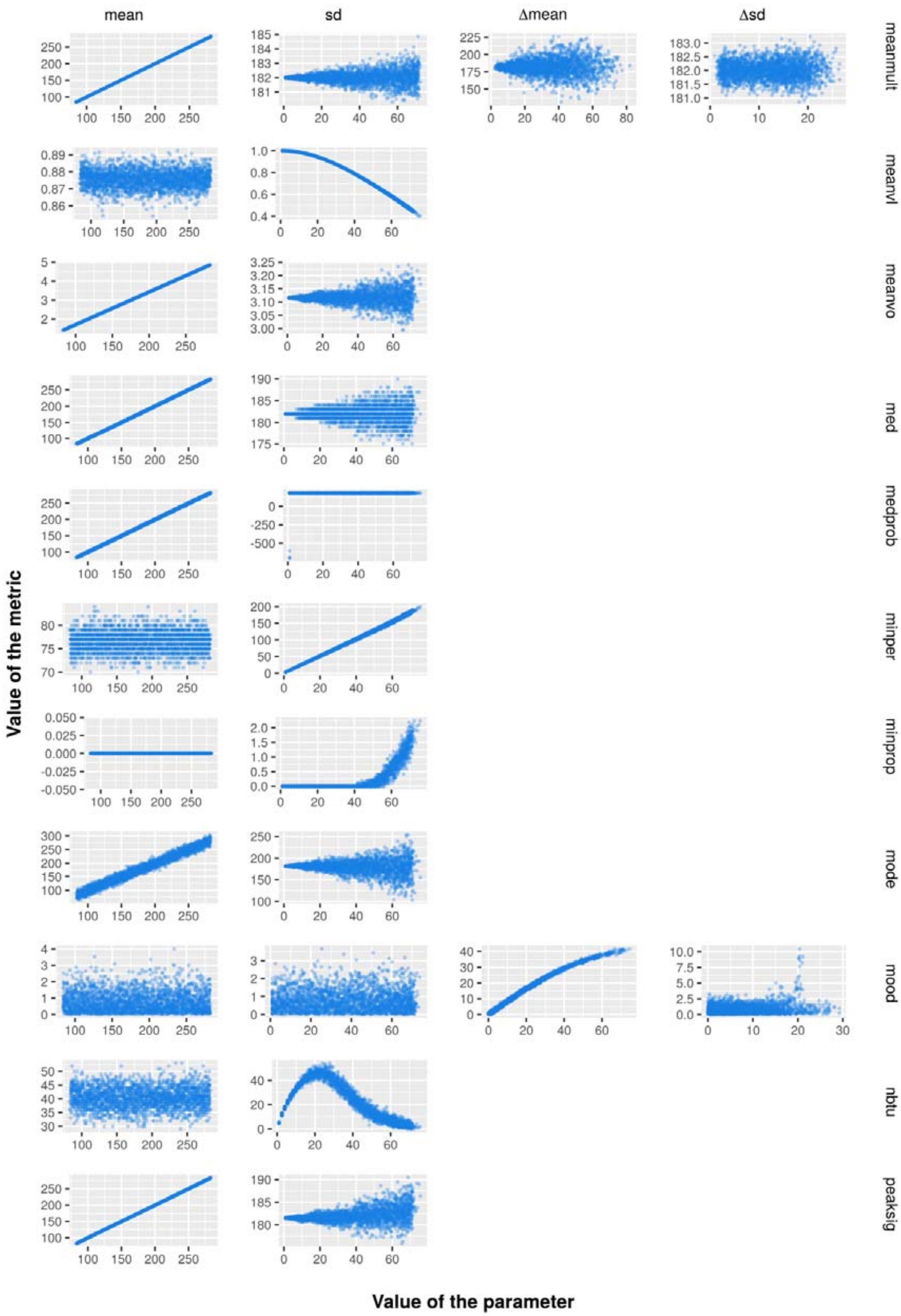
kolmogau
kolmomult
kolmouni
maxprop
mean
meanlin
Value of the metric
Value of the parameter



mean
sd
Δmean
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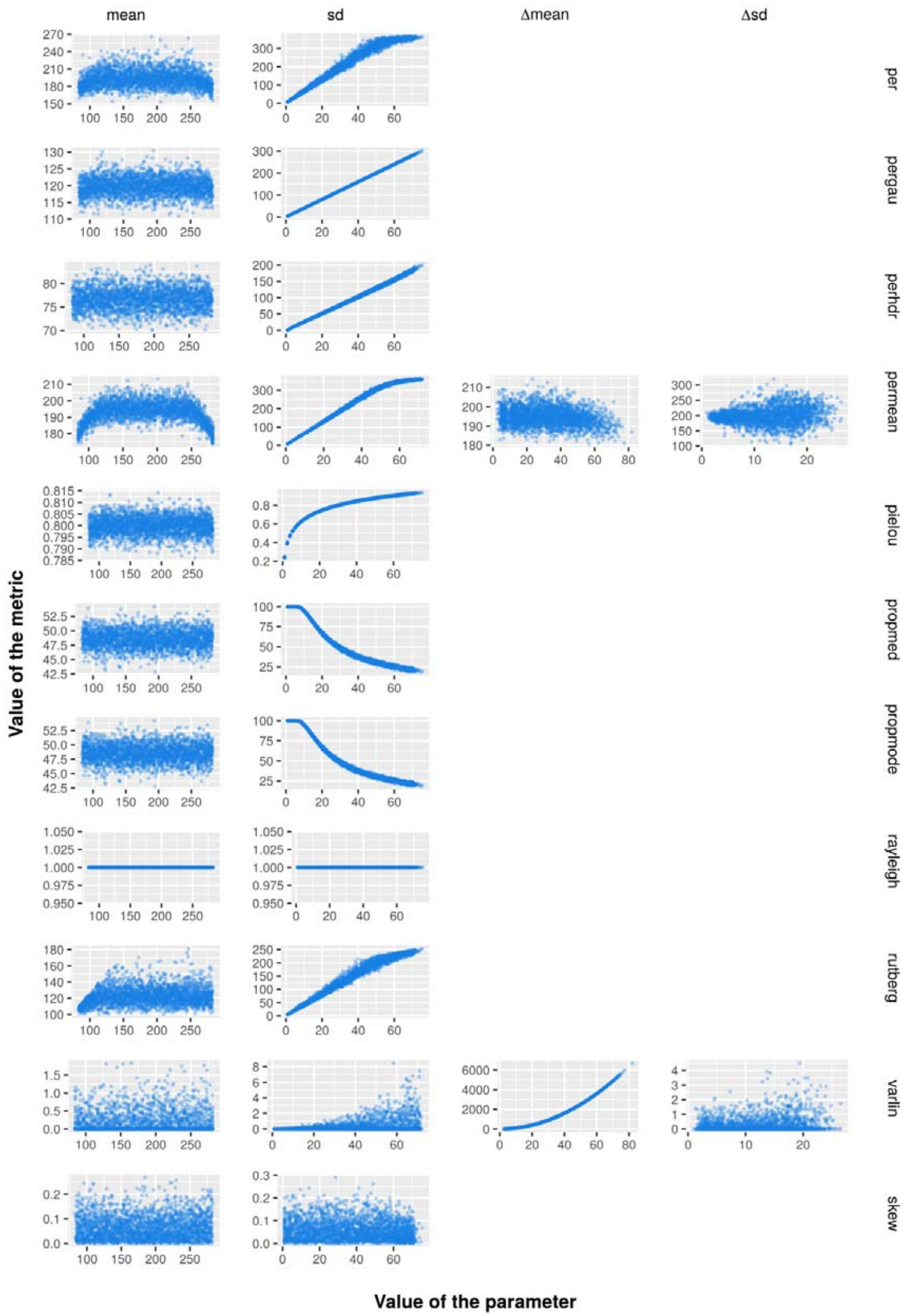
medprob
minper
minprop
mode
mood
nbtu
peaksig
Value of the metric
Value of the parameter


mean
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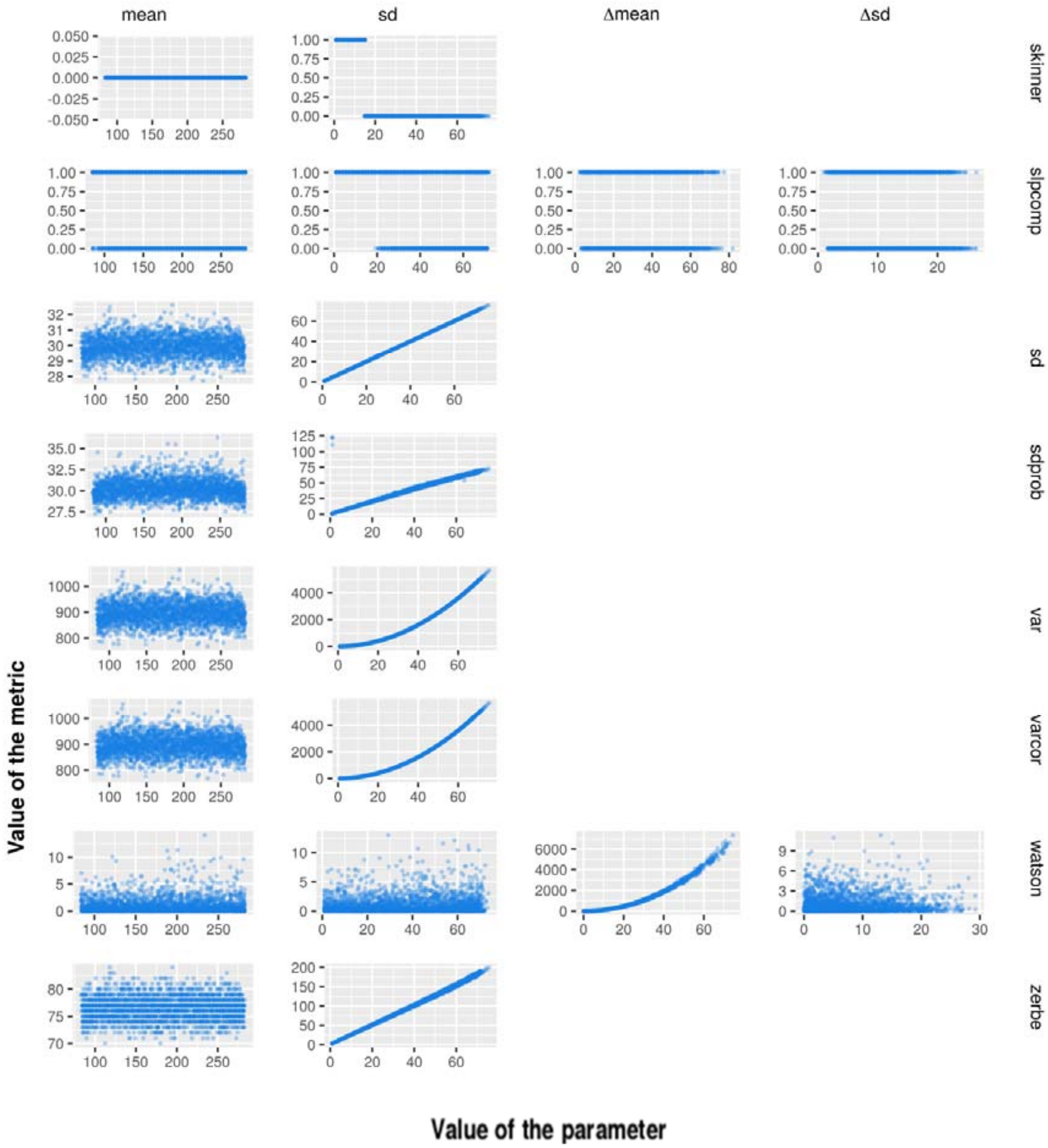
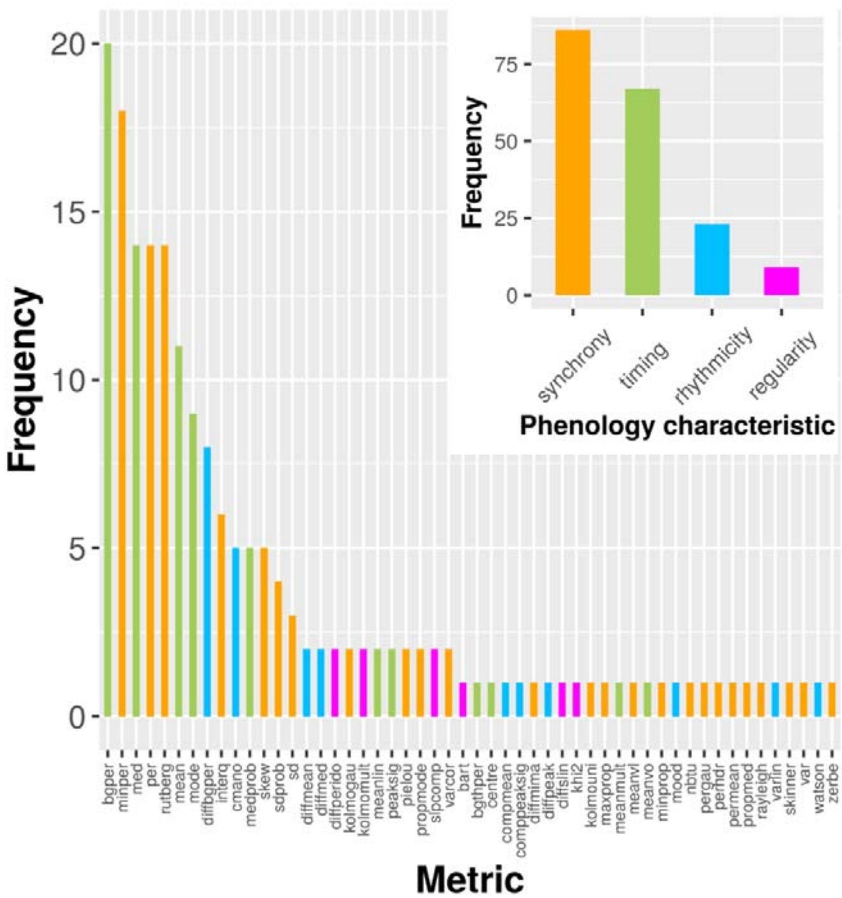
permean
pielou
propmed
propmode
rayleigh
rutberg
varlin
skew
Value of the metric
Value of the parameter



mean
sd
Δmean
Δsd
skinner
slpcomp
sd
sdprob
var
varcor
watson
zerbe
Value of the metric
Value of the parameter

Supporting information 6: Number of times each metric was used in the reviewed articles (*n* = 47). Inset: number of times each characteristic of phenology was studied in the reviewed articles, based on our *a priori* classification of each metric into one of the four characteristics we defined (see text for details: "Materials and methods" section, Step 1). *Green* = timing metrics, *orange* = synchrony metrics, *blue* = rhythmicity metrics, *pink* = regularity metrics.



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