**Temperature variability has no effect on phenotypic plasticity in ectotherms – a meta-analysis.**

**1 | Abstract**

**2 | Introduction**

The thermal environment has profound impacts on biological, ecological, and evolutionary functions across all levels of organisation (Angilletta, 2009; Hochachka and Somero, 2002; Hoffmann et al., 2003). The thermal sensitivity of phenotypic traits follows a non-linear thermal performance curves (TPC) as a function of body temperature (Huey and Kingsolver, 1989). TPCs vary between species and traits, but generally incorporate three common features: an initial increase in performance as temperature increases from a minimum critical temperature; a thermal optimum where maximum performance is reached; and a rapid decline in performance to a critical thermal maximum (Little and Seebacher, 2021; Sinclair et al., 2016). Thermal changes can be both beneficial and detrimental to the performance of an organism depending on their location within the TPCs (Denny, 2019; Marshall et al., 2021; Stoks et al., 2017). However, ectotherms can exhibit plastic response mechanisms that can adjust TPCs to allow continued function through climate variability (Kingsolver et al., 2015).

Phenotypic plasticity allows individuals to compensate for immediate changes in their environment (Loughland et al., 2021; Schulte, 2014). Mechanisms of phenotypic plasticity including developmental plasticity and acclimation, allow organisms to maintain relatively constant phenotypes across environmental gradients, independently of the genotype (Beaman et al., 2016). Developmental plasticity involves the adjustment of adult phenotypes as a response to the thermal environment experienced during development (Burggren, 2018). Acclimation is a reversible phenotypic shift induced by relatively long-term environmental changes (Guderley, 2004). The capacity for phenotypic plasticity has been tested mainly in response to changes in the mean temperature (Arrighi et al., 2013). These experiments provide a logistically simple approach to explore the mechanisms behind phenotypic responses, but in the natural environment temperatures can fluctuate in the short- and long- term (Chen et al., 2013). It is unclear therefore whether results from constant temperature experiments are transferable to natural conditions (Beck, 1983; Brakefield and Mazzotta, 1995).

Climate change is increasing mean temperatures and the amplitudes of thermal fluctuations at different periods (e.g., diurnal, seasonal, and annual; IPCC, 2021). Unpredictable thermal variability at different spatial- and temporal- scales, could increase the probability of organisms experiencing temperature extremes (Guo et al., 2018; Vázquez et al., 2017; Xu et al., 2020). Ectotherms are particularly susceptible to such thermal change as their body temperatures are closely tied to environmental conditions (Huey et al., 2012; Karl et al., 2009). It is imperative to understand whether short-term fluctuations around mean temperatures influence the capacity for phenotypic plasticity compared to constant mean temperatures to predict the impact of climate change (Bozinovic et al., 2011; Dowd et al., 2015; Kefford et al., 2022). At present empirical evidence is equivocal, leaving the relationship between temperature fluctuations and phenotypic plasticity unresolved.

Our aim was to provide a quantitative synthesis that establishes the current state-of-knowledge regarding the influence of thermal variability on phenotypic plasticity in ectotherms. Specifically, we conducted a meta-analysis that tested whether the capacity for phenotypic plasticity differed in constant and fluctuating thermal environments with the same mean temperature. The differences between the thermal environments were also separately investigated in subset analyses for (i) ecological levels (individual and population), (ii) ecosystems (aquatic and terrestrial organisms), and (iii) mechanisms of phenotypic plasticity (acclimation or developmental plasticity).

**3 | Materials and Methods**

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Moher et al., 2015) guidelines, modified for Ecology and Evolution (PRISMA-Eco Evo; O'Dea et al., 2021; Supplementary Materials 8.1) were adhered to throughout this analysis. Question formulation, literature searching and screening were performed according to Foo et al., (2021).

**3.1 | Systematic Literature Search and Screening**

The PECO (Population, Exposure, Comparator, Outcome) framework was adhered to during creation of the focus question and our literature search and screening processes (Supplementary Materials 8.1; Morgan et al., 2018). A systematic literature search for studies that investigated the impacts of fluctuating temperature on the phenotypic plasticity of ectothermic organisms was conducted on the 5th of April 2022 using the Scopus, Web of Science and ScienceDirect databases. The search terms included synonym of ‘plasticity’, ‘acclimation’ and ‘developmental effects’ to identify studies that tested for phenotypic plasticity during the lifespan of the individual (Noble et al., 2018; Pottier et al., 2021). To limit the search string to temperature treatment manipulations ‘thermal’ and ‘temperature’ were added to each search string (Barley et al., 2021; Noble et al., 2018). Synonyms for ‘fluctuating’ or ‘varying’ were added to explicitly look for studies with a fluctuating temperature treatment. The exact search strings used in each database can be found in the Supplementary Materials 8.2.

There searches returned a total of 13,549 unique studies (Supplementary Materials 8.3), and for which we screened the abstracts following the exclusion and inclusion criteria (Supplementary Materials 8.4). For this initial screening, studies had to be in English and experimentally compare the phenotypic plasticity of ectothermic organisms across fluctuating and constant temperature treatments in controlled-laboratory conditions. A total of 202 studies matched these criteria. We conducted a full-text screening of these studies (Supplementary Materials 8.4).

For a study to be included in the analysis, experiments had to have: (a) identical housing and habituating periods across treatments; (b) acclimation or developmental plasticity treatments (within the lifespan of an individual); (c) fluctuating and constant temperature treatments pairs with matching means and other conditions identical; (d) measurements of plastic phenotypic responses. We excluded metrics of thermal performance (critical thermal minima and maxima), principal components and factor loadings (Tarka et al., 2018). There were 14 studies which adhered to both screening protocols. Rayyan software was used by all authors for the initial abstract and full-text screening of these studies (Ouzzani et al., 2016). Scopus, Web of Science, ScienceDirect and Google Scholar were used to conduct a forward (papers citing the original study) and backward (papers that were cited in the original study) search of the initial 14 included studies on the 19th of October 2022. This search yielded an additional 3,932 unique studies which underwent the same screening processes as above. We identified an additional 30 studies that met our inclusion criteria to give a total of 44 studies that were included in the final analysis (Supplementary Materials 8.5)

**3.2 | Data Extraction**

To calculate each effect size, the sample sizes, means, and error metrics were required of phenotypic trait measurements that followed each of four thermal treatments: two constant thermal treatments at a high and low temperature, and two fluctuating thermal treatments with a high and low mean temperature (corresponding with constant treatments). The acute test temperatures that phenotypic traits were measured had to coincide with the constant or fluctuating mean temperature of the corresponding thermal treatment (Seebacher et al., 2015). If there were more than two temperature treatments in constant or fluctuating treatments, we selected the two experimental temperatures that coincided best with the study specie’s natural temperature range (Seebacher et al., 2015). In experiments that had two fluctuating thermal treatments (with high and low mean temperatures) at multiple amplitudes or types of fluctuations (e.g., sinusoidal, stepwise, alternating, or stochastic; Figure 1), we recorded each comparison to the constant thermal treatments as a separate effect size. The required statistical information was manually extracted from texts, tables, supplementary materials, and figures (using R package *metaDigitise* to extract data from figures; Pick et al., 2019). To avoid non-independence, we extracted biological replicates as the sample size, instead of technical replicates (Wu and Seebacher, 2020).

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**Figure 1 Examples of different fluctuation types in the experimental designs of included studies.** Fluctuation patterns included sinusoidal regimes (A), alternating regimes (B), stepwise regimes (C), and stochastic regimes (D).

In addition, we recorded taxonomic information and habitat, details of experimental design (exposure type, length, and life-history stage), the fluctuation treatment (mean temperature, amplitude, number of fluctuations, fluctuation type and length), and phenotypic outcome (trait category, measurement, and units). All authors were involved in the data extraction process and were not permitted to screen or extract studies they had a previous association with (Macartney et al., 2022).

**3.3 | Data Processing and Transformations**

Standard errors (SE; Equation 1) and 95% confidence internals (CI; Equation 2) were converted to standard deviations (SD), as required for effect size calculations (Quinn and Keough, 2002):

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|  | (1) |

|  |  |
| --- | --- |
|  | (2) |

where n is sample size and CIHigh and CILow represent the upper and lower 95% CIs respectively.

Data reported as percentages (e.g., survival) were transformed using Equation 3 and 4 to obtain means and variances respectively (Macartney et al., 2022):

|  |  |
| --- | --- |
|  | (3) |

|  |  |
| --- | --- |
|  | (4) |

where and are the transformed means and SD, and are the percentage means and SD. Means and variances that were reported on the natural log scale were transformed using Equation 5 and 6 respectively (Higgins et al., 2008):

|  |  |
| --- | --- |
|  | (5) |

|  |  |
| --- | --- |
|  | (6) |

where and are the transformed means and SD, and are the means and SD on the natural log scale. A constant of 0.5 was added to all means and SD to avoid taking the natural log of zero during effect size calculations (Rubin and Seebacher, 2022; Wu and Seebacher, 2020).

We categorised the developmental exposure period (Supplementary Materials 8.6), acclimation life-history stages (Supplementary Materials 8.7) and trait measurements (Supplementary Materials 8.8) to ensure consistency in terminology used across different studies. Taxonomic information was retrieved from the Open Tree of Life (Michonneau et al., 2016), and species scientific names were adjusted to match the database. Amphibians were considered aquatic organisms for the analysis.

**3.4 | Effect Size Calculations**

To quantify the difference in phenotypic plasticity between constant and fluctuating thermal environments, we employed an interaction-based plasticity response ratio difference (PRRD; Equation 7) and its corresponding sampling variance (Equation 8). The effect size includes log response ratios (lnRR; Equation 9; Hedges et al., 1999; Lajeunesse, 2011) that express the extent that phenotypic traits change following either acclimation or developmental exposure to different temperatures (Seebacher et al., 2015). This is indicative of an organism’s capacity for phenotypic plasticity, with a lnRR closer to 0 indicating that phenotypic traits are less likely to be affected by changes to temperature (lnRR of 0 = perfect phenotypic plasticity). The PRRD captures the difference in phenotypic plasticity by subtracting the lnRR of a constant thermal environment from that of a fluctuating thermal environment, standardised to one-degree change in temperature (Macartney et al., 2022; Pottier et al., 2021). A PRRD = 0 would indicate that there is no variation in the capacity for phenotypic plasticity between constant and fluctuating thermal environments (PRRD > 0, phenotypic plasticity increases in fluctuating temperatures; PRRD < 0, phenotypic plasticity increases in constant temperatures).

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|  | (7) |

|  |  |
| --- | --- |
|  | (8) |

|  |  |
| --- | --- |
|  | (9) |

where is the mean response, t is the treatments complimenting constant and fluctuating mean temperature, subscripts for F and C denote the fluctuating and constant thermal treatments, and subscripts H and L denote the high and low temperatures.

**3.5 | Statistical Analysis**

All calculations, analyses, and figure production were completed with R.4.2.2 in RStudio version 2022.12.0 (using R Package *ggplot2* for figures; Wickham, 2011). All data and code are available at https://github.com/ClaytonStocker/Plasticity\_Fluctuation\_Meta (Supplementary Materials 8.9). Data are presented as the mean PRRD ± 95% CIs. The mean PRRDs are also exponentially transformed to give the percentage change of phenotypic plasticity from constant to fluctuating thermal environments (Pustejovsky, 2018).

Multi-level meta-analyses (MLMA) were conducted with frequentist models fitted with the restricted maximum likelihood (REML) approach and an adjusted convergence threshold (1e-8). The t-statistic of the model contained an adjusted degrees of freedom based on the number of studies (Nakagawa et al., 2022b). To account of multiple effect sizes using the same control treatment, the model was also fitted with a modified sampling covariance matrix (Noble et al., 2022).

Dependencies in our dataset were accounted for by including the following random effects into the model (Nakagawa et al., 2017; Sánchez‐Tójar et al., 2020): Study ID, to account for multiple effect sizes from the same study; and Shared Animal, to account for instances where the same animal was used for several measured responses. To control for phylogenetic relatedness, a phylogenetic tree was created using the Open Tree of Life database (Michonneau et al., 2016), and converted into a correlation/covariance matrix. Polytomies were randomly resolved (using R Package *Ape*; Paradis et al., 2004) and branch lengths calculated with Grafen’s method (Power = 1; Grafen, 1989). In addition, a species-level random effect was included to account for the repeated use of the same species across effect sizes. To reduce the likelihood of specific traits dominating the analysis, a trait-level random effect was added to the model (except in meta-regressions that analysed specific phenotypic traits as the moderator). Lastly, an observational-level random effect was added to estimate the final ‘residual’ variation (Nakagawa and Santos, 2012).

**3.6 | Multi-level Meta-analytic Models**

MLMA models (using the function *rma.mv* in the R Package *metafor*; Viechtbauer, 2010) were implemented to estimate the meta-analytic mean of the overall dataset. In addition, analyses were conducted on a variety of data subsets to estimate the meta-analytic means for population- and individual-level traits, terrestrial and aquatic organisms, and acclimation or developmental plasticity treatments as moderators (Figure 2). The definitions of the subset terms can be found in Table 1. The total extended heterogeneity statistic (*I2Total*; 2.d.p) and partitions corresponding to the random effects (*I2Animal*, *I2Measurement*, *I2Obs*, *I2Phylo*, *I2Species*, and *I2Study*), were calculated for each of the MLMA models to quantify unexplained variation after removing the known sampling variance (high *I2* = 75%, medium *I2* = 50%, small *I2* = 25%; Borenstein et al., 2021; Higgins et al., 2003; Nakagawa and Santos, 2012). It is common to achieve an *I2* greater than 90% in multispecies meta-analyses (Senior et al., 2016). However, a heterogeneity level close to 0% can instead suggest that all heterogeneity in the analyses is due to within-study variability (no between-study variability; Huedo-Medina et al., 2006).

**Overall**

**Amplitude**

**Fluctuation type**

**Trait categories**

**Specific traits**

**Taxonomic class**

**Individual-level**

**Amplitude**

**Fluctuation type**

**Taxonomic class**

**Aquatic**

**Terrestrial**

**Acclimation**

**Developmental**

**Amplitude**

**Exposure period**

**Fluctuation type**

**Trait categories**

**Specific traits**

**Taxonomic class**

**Amplitude**

**Fluctuation type**

**Life-history**

**# Fluctuations**

**Trait categories**

**Specific traits**

**Taxonomic class**

**Amplitude**

**Fluctuation type**

**Plastic Mechanism**

**Trait categories**

**Specific traits**

**Amplitude**

**Fluctuation type**

**Plastic mechanism**

**Trait categories**

**Figure 2 The order of subset MLMA analyses and the corresponding meta-regression analyses.** White text = MLMA model. Blue text = meta-regression model. “Amplitude” refers to the amplitude experienced during the fluctuation treatments. “Fluctuation type” denotes the thermal regime implemented in the experimental design (Figure 1). “Specific traits” and “Trait categories” refer to the individual traits and categorised groups of traits measured following treatment exposure. “Taxonomic class” is the class for each experiments model species. “Plastic mechanisms” distinguishes acclimation or developmental plasticity treatment exposures. Acclimation “Life-history” is the life-history stage during an acclimation treatment exposure. Developmental “Exposure period” refers to the life-history stage that a developmental plasticity treatment encompasses. “Number of Fluctuations” is the treatment exposure duration divided by the period of each fluctuation. Subset analyses and meta-regressions were included if the number of effect sizes > 10 (e.g., Population-level traits excluded). Definitions of MLMA and meta-regression terms are found in Table 1.

**Table 1 Definitions of included terms in each subset.** An outline of the requirements for the inclusion of effect sizes into each subset analysis.

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| --- | --- |
| **Subset Analyses** | **Definitions** |
| **Population-level Traits** | Phenotypic traits measured for an entire population (e.g., Survival). |
| **Individual-level Traits** | Phenotypic traits measured in an individual (e.g., Food Consumption, Cortisol Levels, hsp70, Development Time, Length, Locomotor Performance etc.). |
| **Aquatic Organisms** | Organisms that spend the predominant amount of their lifecycle in aquatic ecosystems, including amphibians. |
| **Terrestrial Organisms** | Organisms that spend the predominant amount of their lifecycle in terrestrial ecosystems. |
| **Acclimation** | A treatment that does not encompass a significant period of development, and a reversible phenotypic trait is measured. This generally appears in an experimental design with a treatment and trait measurement within the same life-history stage. |
| **Developmental** | A treatment exposure that encompasses a significant developmental period. This generally appears in an experimental design with treatments and trait measurements across life-history stages. |

**3.7 | Meta-regression Models**

Certain moderators that had the potential to influence the observed mean effect size estimate from the MLMA models, were investigated through a variety of meta-regression models. Categorical moderators that were explored include developmental exposure period (embryo, larva, pupa and juvenile), mechanism of plasticity (acclimation and developmental plasticity), fluctuation type (sinusoidal, alternating, stepwise and stochastic; Figure 1), acclimation life-history stages (embryo, larva, pupa, juvenile and adult), phenotypic trait categories (behavioural, biochemical assay, gene expression, life-history, morphological and physiological), specific phenotypic traits (see Supplementary Materials 8.8 for full list of phenotypic traits), and taxonomic class (see Supplementary Materials 8.10 for phylogenetic tree). Categorical moderators and their levels were only included in analyses if the number of effect sizes were > 10 (O'Dea et al., 2021). We analysed the amplitude of fluctuations (range = 1℃ – 45.5℃), and the number of fluctuations (treatment exposure duration/period of fluctuations; range = 4 – 546 fluctuations) as continuous moderators (Figure 2).

**3.8 | Publication Bias and Sensitivity Analysis**

Publication bias was first investigated by visually examining funnel plots for asymmetry (Sterne et al., 2005). Secondly, our overall MLMA model was then altered to include z-transformed publication year and precision (inverse of variance) as moderators to assess the presence of a time-lag effect (or decline effect; Nakagawa et al., 2022a). There was no evidence of publication bias found in our overall data set (Supplementary Materials 8.11).

To understand the ‘robustness’ of our results, we conducted a sensitivity analysis by estimating the influence of each data point on the overall MLMA model (using the function *cooks.distance* in the R Package *metafor*; Viechtbauer, 2010). An overall MLMA model was compared to a model fitted with untransformed data (Knol et al., 2011; Macartney et al., 2022). These two results combined suggest that our data set is both robust and free from significant influential outliers (Supplementary materials 8.11)

**4 | Results**

The final data set included 212 effect sizes from 44 studies (Supplementary Materials 8.5) across 40 species (Supplementary Materials 8.10). In the overall MLMA analysis (effect size estimate = -0.00; 95% CIs = [-0.06, 0.06]; p = 0.9507; n = 212) and the subsequent subset analyses (Supplementary Materials 8.12), the mean plastic responses were not significantly different between constant and fluctuating thermal environments (Figure 3). Total heterogeneity was extremely low (*I2Total* rounded to 0.00%), and the random effects in the MLMA models did not explain a significant proportion of variation (heterogeneity statistics for each subset analyses in Supplementary Materials 8.13). Therefore, most heterogeneity in the data was due to within-study rather than between-study variability, suggesting a level of homogeneity across out included studies.

A graph of a diagram

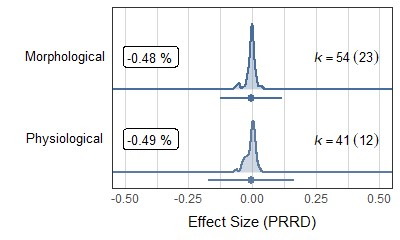
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**Figure 3 Multi-level meta-analytic results for the overall dataset and subsets.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

There were no significant differences in phenotypic plasticity between fluctuating and constant thermal environments in different trait categories (Figure 4) and in specific phenotypic traits (Figure 5). Similarly, there were no differences in phenotypic plasticity within different taxonomic classes (Figure 6). Neither the type (Figure 7) nor the amplitude (Figure 8) of fluctuating temperature regimes affected the differences in phenotypic plasticity. The results of the meta-regression analyses for all data subsets paralleled those of the overall dataset and are shown in the Supplementary Materials 8.12 and 8.14.

A graph of a normalized pulse

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**Figure 4 Meta-regression results for the overall dataset with phenotypic trait category as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph of a graph showing the effect size of a prrd

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**Figure 5 Meta-regression results for the overall dataset with specific phenotypic traits as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph with numbers and a line

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Description automatically generated with medium confidence

**Figure 6 Meta-regression results for the overall dataset with taxonomic class as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph showing a graph of a person's weight

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**Figure 7 Meta-regression results for the overall dataset with fluctuation type as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

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21 - 30

**Figure 8 Relationship between effect size (PRRD) and the amplitude of fluctuation.** There were no significant relationships between the amplitudes of fluctuations and the difference in the phenotypic plasticity between the constant and fluctuating temperature treatments. Dashed line = PRRD estimate from the MLMA models. Solid line = model prediction. Sample sizes are those used to calculate each individual effect size. X-axis and Y-axis limits are cropped for presentation.

**5 | Discussion**

**6 | Conclusion**

**7 | References**

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**8 | Supplementary Materials**

**8.1 | PECO Framework**

**Table S1 PECO framework table.** Populations, Exposures, Comparator and Outcomes that were the foundation for the focus question of the meta-analysis, the database search strings (Supplementary Materials 8.2) and the decision tree (Supplementary Materials 8.4).

|  |  |
| --- | --- |
| **PECO** | **Description** |
| **Population** | Ectothermic Metazoans |
| **Exposure** | Two fluctuating acclimation or developmental treatments (minimum of 1℃ amplitudes), used to calculate the phenotypic plasticity in fluctuating thermal environments. The mean of each treatment matches the corresponding constant temperature treatment (maximum of 1℃ different in means). |
| **Comparator** | Two acclimation or developmental treatments (maximum of 0.5℃ amplitudes), used to calculate the phenotypic plasticity in constant thermal environments. |
| **Outcome** | The phenotypic plasticity of any phenotypic trait measurement that: |
| * was measured at a similar temperature to the corresponding constant thermal treatment or mean of the fluctuating treatment (< 4℃ difference acceptable); |
| * treatment conditions were maintained through to measurement; |
| * was not a metric of thermal performance (e.g., Critical Thermal Maximum, Critical Thermal Minimum and Temperature Preference). |

**8.2 | Search Strings and Protocols**

Scopus

TITLE-ABS-KEY((plasticity OR "plastic response" OR acclimat\* OR "develop\* effect") AND (thermal OR temperature\*) AND (fluctuat\* OR var\* OR regime OR chang\* OR irregular OR shift\* OR inconstant OR diel OR unstable OR alter\* OR vacill\* OR oscill\* OR period\*) AND NOT (tolerance OR ctmax OR ctmin OR endotherm\* OR bacter\* OR fung\* OR alga\* OR unicellular OR protist OR microorganism OR micro-organism OR plant\* OR photosyn\* OR tree OR grass OR bird OR avia\* OR aves OR mammal OR rodent OR rat OR mouse OR mice OR cattle OR livestock\* OR cow OR pig OR sheep OR goat OR house OR rabbit OR chicken OR duck OR turkey OR cat OR dog OR human OR woman OR man OR "parental care" OR child\* OR infant OR educat\* OR industr\* OR commerc\* OR domest\* OR cancer\* OR medic\*)) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SUBJAREA, "AGRI") OR LIMIT-TO (SUBJAREA, "BIOC") OR LIMIT-TO (SUBJAREA, "ENVI"))

Web of Science

TS = ((plasticity OR "plastic response" OR acclimat\* OR "develop effect" OR "development effect" OR "developmental effect") AND (thermal OR temperature\*) AND (fluctuat\* OR var\* OR regime OR chang\* OR irregular OR shift\* OR inconstant OR diel OR unstable OR alter\* OR vacill\* OR oscill\* OR period\*)) NOT TS = (tolerance OR ctmax OR ctmin OR endotherm\* OR bacter\* OR fung\* OR alga\* OR unicellular OR protist OR microorganism OR micro-organism OR plant\* OR photosyn\* OR tree OR grass OR bird OR avia\* OR aves OR mammal OR rodent OR rat OR mouse OR mice OR cattle OR livestock\* OR cow OR pig OR sheep OR goat OR house OR rabbit OR chicken OR duck OR turkey OR cat OR dog OR human OR woman OR man OR “parental care" OR child\* OR infant OR educat\* OR industr\* OR commerc\* OR domest\* OR cancer\* OR medic\*)

Further refinements:

* Document Types: Articles
* Languages: English
* Not Web of Science Categories:
  + Metallurgy Metallurgical Engineering
  + Mechanics
  + Engineering Mechanical

ScienceDirect

\* The search engine has a max of 8 Boolean connectors per field, so multiple searches were conducted.

\*\* All searches were conducted in the ‘Title, abstract or author-specified keyword’ field.

**1.** (plasticity OR "plastic response" OR acclimation) AND (thermal OR temperature) AND (fluctuate OR regime OR diel) NOT (endotherm)

**2.** (plasticity OR "plastic response" OR acclimation) AND (thermal OR temperature) AND (vary OR change OR irregular) NOT (endotherm)

**3.** (plasticity OR "plastic response" OR acclimation) AND (thermal OR temperature) AND (shift OR inconsistent OR unstable) NOT (endotherm)

**4.** (plasticity OR "plastic response" OR acclimation) AND (thermal OR temperature) AND (alter OR vacillate OR oscillate) NOT (endotherm)

**5.** (plasticity OR "plastic response" OR acclimation) AND (thermal OR temperature) AND (period) NOT (endotherm)

**6.** (“development effect" OR "developmental effect" OR "develop effect”) AND (thermal OR temperature) AND (fluctuate OR regime OR diel) NOT (endotherm)

**7.** (“development effect" OR "developmental effect" OR "develop effect”) AND (thermal OR temperature) AND (vary OR change OR irregular) NOT (endotherm)

**8.** (“development effect" OR "developmental effect" OR "develop effect”) AND (thermal OR temperature) AND (shift OR inconsistent OR unstable) NOT (endotherm)

**9.** (“development effect" OR "developmental effect" OR "develop effect”) AND (thermal OR temperature) AND (alter OR vacillate OR oscillate) NOT (endotherm)

**10.** (“development effect" OR "developmental effect" OR "develop effect”) AND (thermal OR temperature) AND (period) NOT (endotherm)

Further refinements to the searches:

* Article Type: Research Articles
* Subject Areas:
  + Agricultural and Biological Sciences
  + Biochemistry, Genetics and Molecular Biology
  + Environmental Science

**8.3 | PRISMA Flow Diagram**

Backward Search

n = 3,943

Scopus

n = 5,757

Forward Search

n = 2,309

ScienceDirect

n = 3,370

Web of Science

n = 8,604

Identification

Duplicate Removal

n = 3,932

Duplicate Removal

n = 13,549

Abstract Screening

n = 202

Abstract Screening

n = 233

Screening

Full-text Screening

n = 14

Full-text Screening

n = 30

Included

n = 44

k = 212

Extraction

**Figure S1 PRISMA flow diagram for the systematic search and screening processes.** n = number of studies remaining after that respective stage. k = number of effect sizes. Dashed line = studies that the forward and backward search was conducted upon.

**8.4 | Decision Tree**

**Full-text Screening**

**Abstract Screening**

Must not include **metrics of thermal performance** (critical thermal maximum, critical thermal minimum, or thermal preference) and **not experience hardening** prior to trait measurement. **Acclimation** studies must **not include morphological** measurements.

No

Yes/Maybe

Exclude

Treatments must have: all other **conditions identical**, the **mean** of **fluctuations** **match** the **constant temperatures**,and treatments **maintained through to phenotypic trait measurement**.

Treatments must be imposed **within the lifespan** of an individual. Not including **transgenerational studies**.

Individuals from each treatment must have **identical housing and habituation periods**.

Must be a **peer-reviewed** article in **English**.

Yes/Maybe

No

Exclude

Must be a **controlled laboratory experiment**. Not including literature reviews, simulations, theories, data banks, surveys, in situ, reciprocal transplant studies etc.

Must include all **relevant information for a meta-analysis** (i.e., sample size, mean and error metrics). Not including studies that **reports principal components** or **factor loading**.

Exclude

No

Yes/Maybe

Exclude

No

Yes/Maybe

**Include**

Exclude

No

Yes/Maybe

Exclude

No

Yes/Maybe

Must be **ectothermic**.

Exclude

No

Exclude

No

Yes/Maybe

Yes/Maybe

Must compare **fluctuating** and **constant phenotypic plasticity.**

Yes/Maybe

Exclude

No

**Figure S2 Decision tree and inclusion criteria.**

**8.5 | List of Included Studies**

Arrighi, J. M., Lencer, E. S., Jukar, A., Park, D., Phillips, P. C. and Kaplan, R. H. Daily temperature fluctuations unpredictably influence developmental rate and morphology at a critical early larval stage in a frog. *BMC Ecol.* **13**, (2013). doi: 10.1186/1472-6785-13-18

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de Majo, M. S., Zanotti, G., Campos, R. E. and Fischer, S. Effects of constant and fluctuating low temperatures on the development of *Aedes aegypti* (Diptera: Culicidae) from a temperate region. *J. Med. Entomol.* **56**, 1661-1668, (2019). doi: 10.1093/jme/tjz087

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**8.6 | Developmental Exposure Period Adjustments and Categorisation**

**Table S2 Embryo development.** The consistency adjustments (if any) for treatment exposure periods that were categorised as occurring during Embryo development. These records were used for the meta-regression analysis of the developmental subset with exposure period as a moderator. Number of studies, species and effects sizes are totals from the subset of data with developmental plasticity treatments.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Embryo Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Egg Incubation | Egg Incubation | 15 | 16 | 68 |
|  | Egg to Larvae | 1 | 1 | 2 |
|  | **Adjusted Record Totals** | **16** | **17** | **70** |
|  | **Category Totals** | **16** | **17** | **70** |

**Table S3 Larval development.** The consistency adjustments (if any) for treatment exposure periods that were categorised as occurring during Larva development.These records were used for the meta-regression analysis of the developmental subset with exposure period as a moderator. Number of studies, species and effects sizes are totals from the subset of data with developmental plasticity treatments.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Larva Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Larvae Period | Larvae Development | 1 | 1 | 12 |
|  | Larvae Period | 6 | 9 | 18 |
|  | Larval Development | 1 | 1 | 10 |
|  | Larval Period | 4 | 4 | 15 |
|  | **Adjusted Record Totals** | 12 | 12 | 55 |
|  | **Category Totals** | **12** | **12** | **55** |

**Table S4 Juvenile development.** The consistency adjustments (if any) for treatment exposure periods that were categorised as occurring during Juvenile development. These records were used for the meta-regression analysis of the developmental subset with exposure period as a moderator. Number of studies, species and effects sizes are totals from the subset of data with developmental plasticity treatments.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Juvenile Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Juvenile Period | Juvenile Period | 1 | 1 | 3 |
|  | Newborn to Maturity | 1 | 1 | 7 |
|  | Until Adult | 1 | 1 | 1 |
|  | **Adjusted Record Totals** | **3** | **3** | **11** |
| Nymphal Period | Nymphal to Adult | 1 | 1 | 2 |
|  | **Category Totals** | **4** | **4** | **13** |

**8.7 | Acclimation Life-history Stages Adjustments and Categorisation**

**Table S5 Embryo stage.** The consistency adjustments (if any) for the life-history stages of individuals that were categorised as experiencing the acclimation treatments during the Embryo stage. These records were used for the meta-regression analysis of the acclimation subset with life-history stage as a moderator. Number of studies, species and effect sizes are totals from the subset of data with acclimation treatments.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Embryo Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Egg | Eggs | 1 | 1 | 3 |
|  | **Category Totals** | **1** | **1** | **3** |

**Table S6 Larval stage.** The consistency adjustments (if any) for the life-history stages of individuals that were categorised as experiencing the acclimation treatments during the Larva stage. These records were used for the meta-regression analysis of the acclimation subset with life-history stage as a moderator. Number of studies, species and effect sizes are totals from the subset of data with acclimation treatments.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Larva Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Cocoon | Cocoons | 1 | 1 | 1 |
| Larvae | Larvae | 3 | 2 | 29 |
|  | **Category Totals** | **4** | **3** | **30** |

**Table S7 Juvenile stage.** The consistency adjustments (if any) for the life-history stages of individuals that were categorised as experiencing the acclimation treatments during the Juvenile stage. These records were used for the meta-regression analysis of the acclimation subset with life-history stage as a moderator. Number of studies, species and effect sizes are totals from the subset of data with acclimation treatments.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Juvenile Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Juvenile | Juvenile | 3 | 2 | 14 |
|  | Juveniles | 1 | 1 | 1 |
|  | **Adjusted Record Totals** | **4** | **3** | **15** |
|  | **Category Totals** | **4** | **3** | **15** |

**Table S8 Adult stage.** The consistency adjustments (if any) for the life-history stages of individuals that were categorised as experiencing the acclimation treatments during the Adult stage. These records were used for the meta-regression analysis of the acclimation subset with life-history stage as a moderator. Number of studies, species and effect sizes are totals from the subset of data with acclimation treatments.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Adult Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Adult | Adult | 1 | 1 | 9 |
|  | Adults | 3 | 4 | 7 |
|  | **Adjusted Record Totals** | **4** | **5** | **16** |
|  | **Category Totals** | **4** | **5** | **16** |

**8.8 | Phenotypic Trait Measurements Adjustments and Categorisation**

**Table S9 Behavioural traits.** The consistency adjustments (if any) for the phenotypic measurements that were categorised as Behavioural traits. These records were used in all MLMAs and meta-regressions as either a part of the measurement random effect, phenotypic trait category moderator and/or the specific phenotypic trait moderator. Number of studies, species and effects sizes are totals from the overall data set.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Behavioural Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Food Consumption | Feeding Rate | 1 | 1 | 1 |
|  | Food Consumption | 1 | 2 | 2 |
|  | **Adjusted Record Totals** | **2** | **3** | **3** |
| Righting Time | Righting Time | 1 | 1 | 1 |
|  | **Category Totals** | **3** | **4** | **4** |

**Table S10 Biochemical traits.** The consistency adjustments (if any) for the phenotypic measurements that were categorised as Biochemical Assay traits. These records were used in all MLMAs and meta-regressions as either a part of the measurement random effect, phenotypic trait category moderator and/or the specific phenotypic trait moderator. Number of studies, species and effects sizes are totals from the overall data set.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Biochemical Assay** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Ash Content | Ash Content | 1 | 1 | 1 |
| Bleaching Index | Bleaching Index | 1 | 1 | 1 |
| Catalase Activity | CAT Activity | 1 | 1 | 4 |
| ETS Activity | ETS Activity | 1 | 1 | 4 |
| Fat Content | Fat Content | 1 | 1 | 4 |
| Haemocytes | Number of Haemocytes | 1 | 1 | 2 |
| Lipid Content | Crude Lipid Content | 1 | 1 | 1 |
| MDA Levels | MDA | 1 | 1 | 4 |
| PO Activity | PO Activity | 1 | 1 | 4 |
|  | Total PO Activity | 1 | 1 | 2 |
|  | **Adjusted Record Totals** | **2** | **2** | **6** |
| Protein Content | Crude Protein Content | 1 | 1 | 1 |
| SOD Activity | SOD Activity | 1 | 1 | 4 |
|  | **Category Totals** | **4** | **4** | **32** |

**Table S11 Gene expression traits.** The consistency adjustments (if any) for the phenotypic measurements that were categorised as Gene Expression traits.These records were used in all MLMAs and meta-regressions as either a part of the measurement random effect, phenotypic trait category moderator and/or the specific phenotypic trait moderator. Number of studies, species and effects sizes are totals from the overall data set.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Gene Expression Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| hsp70 | hsp70 | 1 | 1 | 2 |
| hsp90 | hsp90 | 1 | 2 | 2 |
|  | **Category Totals** | **2** | **3** | **4** |

**Table S12 Life-history traits.** The consistency adjustments (if any) for the phenotypic measurements that were categorised as Life-history traits.These records were used in all MLMAs and meta-regressions as either a part of the measurement random effect, phenotypic trait category moderator and/or the specific phenotypic trait moderator. Number of studies, species and effects sizes are totals from the overall data set.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Life-history Traits Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Brood Duration | Brood Duration | 1 | 1 | 1 |
| Brood Size | Brood Number | 1 | 1 | 1 |
|  | Brood Size | 1 | 1 | 1 |
|  | **Adjusted Record Totals** | **1** | **1** | **2** |
| Development Time | Age at Maturity | 1 | 1 | 1 |
|  | Age at Reproduction | 1 | 1 | 1 |
|  | Development Rate | 1 | 1 | 1 |
|  | Development Time | 17 | 19 | 33 |
|  | Development time | 1 | 1 | 1 |
|  | Developmental Rate | 1 | 1 | 1 |
|  | Gosner Stage | 1 | 1 | 1 |
|  | Incubation Duration | 1 | 1 | 2 |
|  | Incubation Period | 1 | 1 | 1 |
|  | Larval Development | 1 | 1 | 2 |
|  | Pupal Development | 1 | 1 | 2 |
|  | **Adjusted Record Totals** | **26** | **27** | **46** |
| Fecundity | Fecundity | 6 | 7 | 7 |
| Individual Growth Rate | Individual Growth Rate | 1 | 1 | 2 |
| Longevity | Adult Longevity | 1 | 1 | 2 |
|  | Lifespan | 1 | 1 | 1 |
|  | Longevity | 3 | 3 | 4 |
|  | **Adjusted Record Totals** | **5** | **5** | **7** |
| Reproductive Rate | Reproductive Output | 1 | 1 | 3 |
|  | **Category Totals** | **28** | **30** | **68** |

**Table S13 Morphological traits.** The consistency adjustments (if any) for the phenotypic measurements that were categorised as Morphological traits.These records were used in all MLMAs and meta-regressions as either a part of the measurement random effect, phenotypic trait category moderator and/or the specific phenotypic trait moderator. Number of studies, species and effects sizes are totals from the overall data set.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Morphological Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Head Depth | Head Depth | 1 | 1 | 1 |
| Head Width | Head Width | 1 | 1 | 1 |
| Length | Body Size | 1 | 1 | 1 |
|  | Length | 3 | 3 | 4 |
|  | Size | 2 | 3 | 3 |
|  | Snout Vent Length | 2 | 2 | 4 |
|  | Snout-vent Length | 1 | 1 | 2 |
|  | **Adjusted Record Totals** | **9** | **10** | **14** |
| Mass | Body Mass | 1 | 1 | 2 |
|  | Mass | 9 | 8 | 17 |
|  | Weight | 2 | 5 | 6 |
|  | **Adjusted Record Totals** | **12** | **14** | **25** |
| Plastron Length | Plastron Length | 1 | 2 | 2 |
| Tail Length | Tail length | 4 | 4 | 7 |
| Thorax Size | Thorax Size | 1 | 1 | 2 |
| Wing Length | Wing length | 1 | 1 | 2 |
|  | **Category Totals** | **20** | **23** | **54** |

**Table S14 Physiological traits.** The consistency adjustments (if any) for the phenotypic measurements that were categorised as Physiological traits.These records were used in all MLMAs and meta-regressions as either a part of the measurement random effect, phenotypic trait category moderator and/or the specific phenotypic trait moderator. Number of studies, species and effects sizes are totals from the overall data set.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Physiological Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Apparent Digestibility Coefficient | Apparent Digestability Coefficient | 2 | 1 | 5 |
| Cellular Energy Allocation | Cellular Energy Allocation | 1 | 1 | 4 |
| Energy Content | Energy Content | 1 | 1 | 1 |
| Excretion Rate | Excretion Energy | 1 | 1 | 1 |
| Exuvia Energy | Exuvia Energy | 1 | 1 | 1 |
| Faeces Energy | Faeces Energy | 1 | 1 | 1 |
| Immune Defense | Immune Defense | 1 | 1 | 6 |
| Locomotor Performance | Average Speed | 1 | 1 | 2 |
|  | Sprint Speed | 1 | 1 | 2 |
|  | Swimming Performance | 1 | 1 | 1 |
|  | Walking Speed | 1 | 1 | 1 |
|  | **Adjusted Record Totals** | **3** | **3** | **6** |
| Maximum Excitation Pressure | Maximum Excitation Pressure | 1 | 1 | 1 |
| Metabolic Rate | Metabolic Rate | 1 | 1 | 1 |
|  | Oxygen Consumption | 2 | 2 | 4 |
|  | Oxygen Consumption Rate | 1 | 1 | 3 |
|  | Respiration Energy | 1 | 1 | 1 |
|  | Respiration Rate | 1 | 1 | 3 |
|  | **Adjusted Record Totals** | **6** | **5** | **12** |
| Muscular Strength | Muscular Strength | 1 | 1 | 1 |
| PHA Response | PHA Response | 1 | 1 | 1 |
| Water Content | Water Content | 1 | 1 | 1 |
|  | **Category Totals** | **14** | **12** | **41** |

**Table S15 Population-level traits.** The consistency adjustments (if any) for the phenotypic measurements that were categorised as Population-level Traits.These records were used in all MLMAs and meta-regressions as either a part of the measurement random effect, phenotypic trait category moderator and/or the specific phenotypic trait moderator. Number of studies, species and effects sizes are totals from the overall data set.

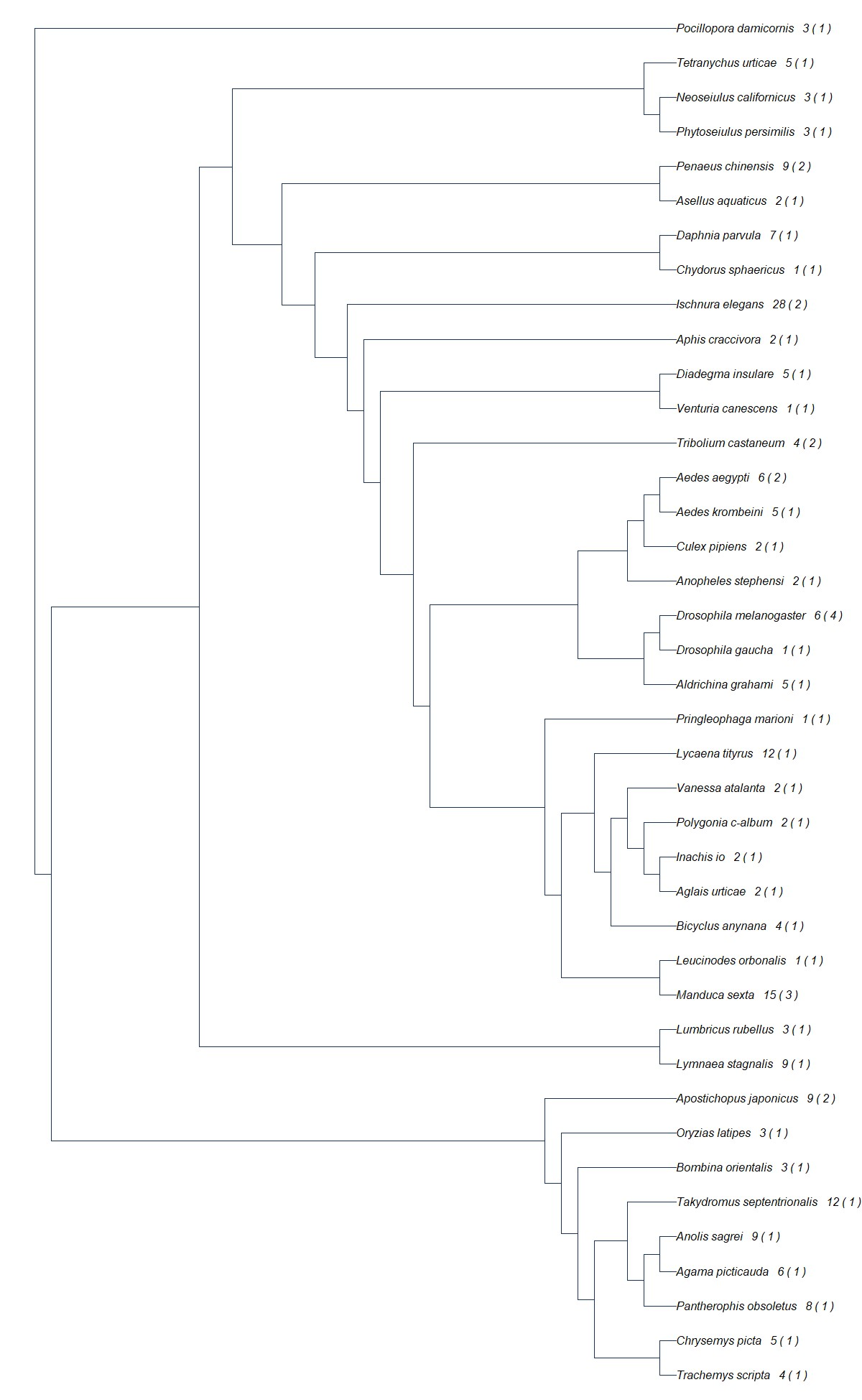
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Population-level Traits Category** | | | | |
| **Adjusted Records** | **Original Records** | **Studies** | **Species** | **Effect Sizes** |
| Mortality | Mortality | 2 | 2 | 2 |
| Survival | Settlement Success | 1 | 1 | 1 |
|  | Survival | 5 | 6 | 6 |
|  | **Adjusted Record Totals** | **6** | **7** | **7** |
|  | **Category Totals** | **8** | **9** | **9** |

**8.9 | Codebook and Metadata**

**Table S16 Codebook and Metadata for the Raw Dataset.** Raw data descriptors for the meta-analysis.

|  |  |
| --- | --- |
| **Column Name** | **Description** |
| Effect\_Size\_ID | Unique identifiers for individual effect sizes. |
| Study\_ID | Unique identifiers for each paper. |
| Species\_ID | Identifier for each species that a study investigates. |
| Treatment\_ID\_T1 | Identifier for the studies first constant and fluctuating temperature treatment pair (fluctuating mean matching constant temperature). |
| Treatment\_ID\_T2 | Identifier for the studies second constant and fluctuating temperature treatment pair (fluctuating mean matching constant temperature). |
| Trait\_ID | Identifier for each phenotypic traits a study measures. |
| First\_Author | Initials and surname for the first author of the study. |
| Title | Title of the study. |
| Year | Year of publication. |
| Journal | Name of the journal the study was published. |
| Journal\_Impact\_Factor-2021 | Journal impact factor as of 2021 (most recent records at time of data collection). |
| Kingdom | Kingdom for each species that a study investigates. |
| Phylum | Phylum for each species that a study investigates. |
| Class | Class for each species that a study investigates. |
| Order | Order for each species that a study investigates. |
| Family | Family for each species that a study investigates. |
| Scientific\_Name | Binomial nomenclature for species. |
| Ecosystem | Ecosystem the species is naturally observed (Aquatic and Terrestrial). Amphibians considered aquatic. |
| Plasticity\_Mechanism | Mechanism of plasticity the treatments were exposed (Acclimation or Developmental Plasticity). |
| Developmental\_Exposure\_Time\_Category | Categorisation of Developmental Exposure Time. |
| Developmental\_Exposure\_Time | The period of exposure for treatments imposed during development. |
| Acclimation\_Exposure\_Time | The duration of exposure for acclimation treatments. |
| Exposure\_Units | Units of Acclimation Exposure Time (Days). |
| T1\_constant | Temperature of the first constant temperature treatment. |
| T1\_fluctuation | Mean temperature of the first fluctuating temperature treatment. |
| T2\_constant | Temperature of the second constant temperature treatment. |
| T2\_fluctuation | Mean temperature of the second fluctuating temperature treatment. |
| High | Whether the first or second constant and fluctuating temperature treatment pair is around the higher temperature (T1 or T2). |
| Fluctuation\_Magnitude | Amplitude of the two fluctuating temperature treatments. |
| Fluctuation\_Category | Type of fluctuations imposed (Sinusoidal, Alternating, Stepwise, Stochastic). |
| Fluctuation\_Period | Period of one fluctuation oscillation. |
| Fluctuation\_Unit | Units of Fluctuation Period (Days). |
| Number\_Of\_Fluctuations | Acclimation Exposure Time/Fluctuation Period for acclimation treatments. |
| Acclimation\_Life-History\_Stage | Life-history stage of organisms for acclimation treatments. |
| Acclimation\_Life-History\_Stage\_Category | Categorisation of Acclimation Life-history Stages. |
| Trait\_Category | Categorisation of Measurements. |
| Measurement | Phenotypic traits measured following treatment exposure. |
| Trait\_Unit | Units for measurements. |
| Sex | Sex of the organisms being investigated (Both, Female or Male). NA = sex not specified. |
| Performance\_Curve | Whether a performance curve was recorded in the study (Yes, No). |
| Complex\_Design | Whether a comparison between constant and fluctuating treatments was made at multiple temperatures (Yes). |
| Species\_Overlap | Identifier for effect sizes that use the same species within a study |
| Animal\_Overlap\_T1\_Constant | Identifier for effect sizes where the constant treatment was conducted on the same animals within a study (first constant and fluctuating temperature treatment pair). |
| Animal\_Overlap\_T1\_Fluctuation | Identifier for effect sizes where the fluctuating treatment was conducted on the same animals within a study (first constant and fluctuating temperature treatment pair). |
| Animal\_Overlap\_Trait\_T1 | Identifier for effect sizes that measure phenotypic traits on the same animal within a study (first constant and fluctuating temperature treatment pair). |
| Animal\_Overlap\_T2\_Constant | Identifier for effect sizes where the constant treatment was conducted on the same animals within a study (second constant and fluctuating temperature treatment pair). |
| Animal\_Overlap\_T2\_Fluctuation | Identifier for effect sizes where the fluctuating treatment was conducted on the same animals within a study (second constant and fluctuating temperature treatment pair). |
| Animal\_Overlap\_Trait\_T2 | Identifier for effect sizes that measure phenotypic traits on the same animal within a study (second constant and fluctuating temperature treatment pair). |
| Animal\_Code | Study ID: Species Overlap: Animal Overlap T1 Constant: Animal Overlap T1 Fluctuation: Animal Overlap T2 Constant: Animal Overlap T2 Fluctuation: Animal Overlap Trait T1; Animal Overlap Trait T2 |
| Shared\_Animal\_Number | Unique identifier for shared animal codes across effect sizes. |
| Shared\_Control\_T1 | Identifier for effect sizes that use the same constant temperature treatment within a study (first constant and fluctuating temperature treatment pair). |
| Shared\_Control\_T2 | Identifier for effect sizes that use the same constant temperature treatment within a study (second constant and fluctuating temperature treatment pair). |
| Shared\_Control\_Code | Study ID: Species Overlap: Shared Control T1: Shared Control T2: Trait ID. |
| Shared\_Control\_Number | Unique identifier for shared control codes across effect sizes. |
| n\_T1\_C | Sample size of the constant treatment (first constant and fluctuating temperature treatment pair). |
| Mean\_T1\_C | Mean response of the constant treatment (first constant and fluctuating temperature treatment pair). |
| SD\_Final\_T1\_C | Standard deviation of the constant treatment (first constant and fluctuating temperature treatment pair). |
| n\_T1\_F | Sample size of the fluctuating treatment (first constant and fluctuating temperature treatment pair). |
| Mean\_T1\_F | Mean response of the fluctuating treatment (first constant and fluctuating temperature treatment pair). |
| SD\_Final\_T1\_F | Standard deviation of the fluctuating treatment (first constant and fluctuating temperature treatment pair). |
| n\_T2\_C | Sample size of the constant treatment (second constant and fluctuating temperature treatment pair). |
| Mean\_T2\_C | Mean response of the constant treatment (second constant and fluctuating temperature treatment pair). |
| SD\_Final\_T2\_C | Standard deviation of the constant treatment (second constant and fluctuating temperature treatment pair). |
| n\_T2\_F | Sample size of the fluctuating treatment (second constant and fluctuating temperature treatment pair). |
| Mean\_T2\_F | Mean response of the fluctuating treatment (second constant and fluctuating temperature treatment pair). |
| SD\_Final\_T2\_F | Standard deviation of the fluctuating treatment (second constant and fluctuating temperature treatment pair). |
| Percentage\_Transformation\_T1 | Whether the recorded means for the first constant and fluctuating temperature treatment pair were recorded as a percentage (Yes, No). |
| Proportion\_Transformation\_T1 | Whether the recorded means for the first constant and fluctuating temperature treatment pair were recorded as a proportion (Yes, No). |
| In\_Transformation\_T1 | Whether the recorded means for the first constant and fluctuating temperature pair were recorded as the natural log (Yes, No). |
| Percentage\_Transformation\_T2 | Whether the recorded means for the second constant and fluctuating temperature treatment pair were recorded as a percentage (Yes, No). |
| Proportion\_Transformation\_T2 | Whether the recorded means for the second constant and fluctuating temperature treatment pair were recorded as a proportion (Yes, No). |
| In\_Transformation\_T2 | Whether the recorded means for the second constant and fluctuating temperature pair were recorded as the natural log (Yes, No). |
| Mean\_Transformed\_T1\_C | Constant treatment means transformed for percentages, proportions or natural logs, and with a constant of 0.5 added (first constant and fluctuating temperature treatment pair). |
| SD\_Final\_Transformed\_T1\_C | Constant treatment standard deviations transformed for percentages, proportions or natural logs, and with a constant 0.5 added (first constant and fluctuating temperature treatment pair). |
| Mean\_Transformed\_T1\_F | Fluctuating treatment means transformed for percentages, proportions or natural logs, and with a constant of 0.5 added (first constant and fluctuating temperature treatment pair). |
| SD\_Final\_Transformed\_T1\_F | Fluctuating treatment standard deviations transformed for percentages, proportions or natural logs, and with a constant 0.5 added (first constant and fluctuating temperature treatment pair). |
| Mean\_Transformed\_T2\_C | Constant treatment means transformed for percentages, proportions or natural logs, and with a constant of 0.5 added (second constant and fluctuating temperature treatment pair). |
| SD\_Final\_Transformed\_T2\_C | Constant treatment standard deviations transformed for percentages, proportions or natural logs, and with a constant 0.5 added (second constant and fluctuating temperature treatment pair). |
| Mean\_Transformed\_T2\_F | Fluctuating treatment means transformed for percentages, proportions or natural logs, and with a constant of 0.5 added (second constant and fluctuating temperature treatment pair). |
| SD\_Final\_Transformed\_T2\_F | Fluctuating treatment standard deviations transformed for percentages, proportions or natural logs, and with a constant 0.5 added (second constant and fluctuating temperature treatment pair). |
| Mean\_T1\_C\_Add | Untransformed constant treatment means with a constant 0.5 added (first constant and fluctuating temperature treatment pair). |
| SD\_Final\_T1\_C\_Add | Untransformed constant standard deviations with a constant 0.5 added (first constant and fluctuating temperature treatment pair). |
| Mean\_T1\_F\_Add | Untransformed fluctuating treatment means with a constant 0.5 added (first constant and fluctuating temperature treatment pair). |
| SD\_Final\_T1\_F\_Add | Untransformed fluctuating treatment standard deviations with a constant 0.5 added (first constant and fluctuating temperature treatment pair). |
| Mean\_T2\_C\_Add | Untransformed constant treatment means with a constant 0.5 added (second constant and fluctuating temperature treatment pair). |
| SD\_Final\_T2\_C\_Add | Untransformed constant standard deviations with a constant 0.5 added (second constant and fluctuating temperature treatment pair). |
| Mean\_T2\_F\_Add | Untransformed fluctuating treatment means with a constant 0.5 added (second constant and fluctuating temperature treatment pair). |
| SD\_Final\_T2\_F\_Add | Untransformed fluctuating treatment standard deviations with a constant 0.5 added (second constant and fluctuating temperature treatment pair). |
| InRR | Plasticity response ratio difference. Represents the difference in plastic responses in constant and fluctuating temperatures, standardised to a one-degree change in treatment temperature. |
| InRR\_Transformed | Plasticity response ratio difference transformed to account for reciprocal transformation. |
| v\_InRR | Plasticity response ratio difference sampling variance. |
| InRR\_Untransformed | Plasticity response ratio difference calculated from untransformed data. |
| v\_InRR\_Untransformed | Plasticity response ratio difference sampling variance calculated from untransformed data. |
| Year\_Z | Z-transformed year of publication. |
| Precision | Z-transformed inverse of plasticity response ratio difference sampling variance. |

**8.10 | Phylogenetic Tree**



**Figure S3 Phylogenetic tree of species present in the meta-analysis.** Node labels are scientific names followed by the number of effect sizes with the number of studies in brackets.

**8.11 | Publication Bias and Sensitivity Analysis**

Visual inspection of the funnel plot of the meta-analytic residuals of the overall MLMA model, did not indicate the presence of asymmetry (Figure S4). The overall MLMA model fitted with z-transformed publication year (effect size estimate = -0.0075; 95% CIs = [-0.0687, 0.0536]; p = 0.8045) and precision (effect size estimate = -0.0023; 95% CIs = [-0.0358, 0.0404]; p = 0.9061) as moderators, found no significant relationships with the PRRD (Figure S5). These results together indicate no evidence of funnel plot asymmetry or time-lag bias in our data set.

A white background with black text

Description automatically generatedA graph of a number of dots

Description automatically generated with medium confidence

**Figure S4** **Funnel plot.** Showing the observed outcome residuals from the overall MLMA model against the inverse standard error (precision). Effect size = PRRD. Dotted lines = 95% pseudo confidence intervals.

A graph with numbers and dots

Description automatically generated

**Figure S5** **The relationship between effect sizes (PRRD) and the studies’ year of publication to identify evidence of time-lag bias.** Dashed line = PRRD estimate from the overall MLMA model. Solid line = model prediction. Sample sizes are those used to calculate each individual effect size.

No implausible data points were identified in the sensitivity analysis, with the Cook’s distant never exceeding 1 (Figure S6). The model containing untransformed data was quantitatively similar to the overall MLMA model (Table S17). These two results combined suggest that our data set is both robust and free from significantly influential outliers.

**Figure S6 Cook’s distance.** Output from the observed outcome of residuals from the overall MLMA model. Effect size = PRRD.

**Table S17 MLMA outputs.** Comparison of the overall MLMA model with a model fitted with untransformed data. Effect size = PRRD. I2 values reported as percentages.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** | ***I2Total*** |
| **Overall (PRRD)** | 0.0019 | -0.0596 | 0.0634 | 39 | 0.9507 | 0.00 |
| **Untransformed Data** | 0.0022 | -0.0588 | 0.0632 | 39 | 0.9411 | 0.00 |

**8.12 | Raw MLMA and Meta-regression Outputs**

**Table S18 Results of the overall MLMA model.** Number of studies, species and effect sizes are totals from the overall dataset. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Overall Dataset (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **MLMA** | 44 | 40 | 212 | 0.0019 | -0.0596 | 0.0634 | 39 | 0.9507 |

**Table S19 Results of the meta-regression of the overall dataset with the amplitude of the fluctuation as the moderator.** Number of studies, species and effect sizes are totals from the overall dataset. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Overall Dataset (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Amplitude** | 44 | 40 | 212 | -0.0001 | -0.0062 | 0.0059 | 80 | 0.9673 |

**Table S20 Results of the meta-regression of the overall dataset with fluctuation type as the moderator.** Number of studies, species and effect sizes are totals from the overall dataset. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Overall Dataset (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Sinusoidal (Sine Curve)** | 18 | 16 | 80 | -0.0067 | -0.1133 | 0.0998 | 63 | 0.9002 |
| **Alternating** | 14 | 16 | 54 | 0.0077 | -0.0902 | 0.1057 | 35 | 0.8738 |
| **Stepwise** | 7 | 6 | 48 | 0.0052 | -0.1447 | 0.1550 | 63 | 0.9454 |

**Table S21 Results of the meta-regression of the overall dataset with phenotypic trait category as the moderator.** Number of studies, species and effect sizes are totals from the overall dataset. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Overall Dataset (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Biochemical Assay** | 4 | 4 | 32 | 0.0059 | -0.2145 | 0.2264 | 35 | 0.9567 |
| **Life-history Traits** | 28 | 30 | 68 | 0.0111 | -0.0805 | 0.1026 | 35 | 0.8077 |
| **Morphological** | 20 | 23 | 54 | -0.0048 | -0.1251 | 0.1154 | 35 | 0.9353 |
| **Physiological** | 14 | 12 | 41 | -0.0049 | -0.1727 | 0.1629 | 35 | 0.9534 |

**Table S22 Results of the meta-regression of the overall dataset with specific phenotypic traits as the moderator.** Number of studies, species and effect sizes are totals from the overall dataset. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Overall Dataset (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Development Time** | 26 | 27 | 46 | 0.0103 | -0.0970 | 0.1175 | 93 | 0.8495 |
| **Length** | 9 | 10 | 14 | 0.0014 | -0.2375 | 0.2402 | 93 | 0.9909 |
| **Mass** | 12 | 14 | 25 | -0.0110 | -0.1729 | 0.1510 | 93 | 0.8933 |
| **Metabolic Rate** | 6 | 5 | 12 | 0.0006 | -0.3321 | 0.3334 | 93 | 0.9970 |

**Table S23 Results of the meta-regression of the overall dataset with taxonomic class as the moderator.** Number of studies, species and effect sizes are totals from the overall dataset. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Overall Dataset (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Arachnida** | 2 | 3 | 11 | -0.0050 | -0.1682 | 0.1582 | 23 | 0.9500 |
| **Insecta** | 25 | 21 | 108 | 0.0097 | -0.0766 | 0.0959 | 23 | 0.8188 |
| **Malacostraca** | 3 | 2 | 11 | -0.0013 | -0.3279 | 0.3253 | 23 | 0.9936 |

**Table S24 Results of the individual-level traits subset MLMA model.** Number of studies, species and effect sizes are totals from the subset of data with individual-level phenotypic traits. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Individual-level Traits (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **MLMA** | 43 | 40 | 203 | 0.0024 | -0.0601 | 0.0650 | 39 | 0.9375 |

**Table S25 Results of the meta-regression of the individual-level traits dataset with the amplitude of the fluctuation as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with individual-level phenotypic traits. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Individual-level Traits (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Amplitude** | 43 | 40 | 203 | -0.0001 | -0.0062 | 0.0060 | 78 | 0.9771 |

**Table S26 Results of the meta-regression of the individual-level traits dataset with fluctuation type as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with individual-level phenotypic traits. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Individual-level Traits (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Sinusoidal (Sine Curve)** | 18 | 16 | 74 | -0.0063 | -0.1165 | 0.1040 | 61 | 0.9097 |
| **Alternating** | 13 | 16 | 53 | 0.0079 | -0.0907 | 0.1065 | 34 | 0.8715 |
| **Stepwise** | 7 | 6 | 47 | 0.0061 | -0.1448 | 0.1570 | 61 | 0.9360 |

**Table S27 Results of the meta-regression of the individual-level traits dataset with taxonomic class as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with individual-level phenotypic traits. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Individual-level Traits (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Arachnida** | 2 | 3 | 11 | -0.0050 | -0.1686 | 0.1586 | 22 | 0.9500 |
| **Insecta** | 24 | 21 | 104 | 0.0101 | -0.0781 | 0.0984 | 22 | 0.8138 |

**Table S28 Results of the aquatic subset MLMA model.** Number of studies, species and effect sizes are totals from the subset of data with organisms from aquatic environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Aquatic Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **MLMA** | 12 | 11 | 51 | -0.0086 | -0.1575 | 0.1402 | 10 | 0.8998 |

**Table S29 Results of the meta-regression of the aquatic dataset with the amplitude of the fluctuation as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with organisms from aquatic environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Aquatic Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Amplitude** | 12 | 11 | 51 | -0.0010 | -0.0197 | 0.0177 | 20 | 0.9095 |

**Table S30 Results of the meta-regression of the aquatic dataset with fluctuation type as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with organisms from aquatic environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Aquatic Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Sinusoidal (Sine Curve)** | 8 | 8 | 39 | -0.0062 | -0.1729 | 0.1604 | 9 | 0.9345 |
| **Alternating** | 3 | 3 | 11 | -0.0215 | -0.3926 | 0.3497 | 9 | 0.8988 |

**Table S31 Results of the meta-regression of the aquatic dataset with the mechanism of plasticity as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with organisms from aquatic environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Aquatic Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Acclimation** | 6 | 4 | 28 | -0.0122 | -0.2335 | 0.2091 | 9 | 0.9037 |
| **Developmental** | 6 | 7 | 23 | -0.0055 | -0.2124 | 0.2013 | 9 | 0.9531 |

**Table S32 Results of the meta-regression of the aquatic dataset with phenotypic trait category as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with organisms from aquatic environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Aquatic Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Life-history Traits** | 6 | 7 | 15 | -0.0228 | -0.2707 | 0.2252 | 14 | 0.8466 |
| **Physiological** | 7 | 5 | 23 | -0.0053 | -0.2347 | 0.2241 | 14 | 0.9612 |

**Table S33 Results of the terrestrial subset MLMA model.** Number of studies, species and effect sizes are totals from the subset of data with organisms from terrestrial environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Terrestrial Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **MLMA** | 31 | 29 | 152 | 0.0055 | -0.0664 | 0.0773 | 25 | 0.8769 |

**Table S34 Results of the meta-regression of the terrestrial dataset with the amplitude of the fluctuation as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with organisms from terrestrial environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Terrestrial Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Amplitude** | 31 | 29 | 152 | 0.0000 | -0.0065 | 0.0066 | 57 | 0.9909 |

**Table S35 Results of the meta-regression of the terrestrial dataset with fluctuation type as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with organisms from terrestrial environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Terrestrial Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Sinusoidal (Sine Curve)** | 10 | 8 | 35 | -0.0063 | -0.1744 | 0.1617 | 40 | 0.9395 |
| **Alternating** | 10 | 13 | 42 | 0.0107 | -0.0946 | 0.1161 | 22 | 0.8348 |
| **Stepwise** | 6 | 5 | 46 | 0.0061 | -0.1478 | 0.1600 | 40 | 0.9364 |

**Table S36 Results of the meta-regression of the terrestrial dataset with mechanism of plasticity as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with organisms from terrestrial environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Terrestrial Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Acclimation** | 6 | 6 | 37 | 0.0029 | -0.1972 | 0.2029 | 150 | 0.9774 |
| **Developmental** | 26 | 25 | 115 | 0.0058 | -0.0676 | 0.0792 | 150 | 0.8761 |

**Table S37 Results of the meta-regression of the terrestrial dataset with phenotypic trait category as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with organisms from terrestrial environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Terrestrial Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Biochemical Assay** | 2 | 2 | 28 | 0.0068 | -0.2302 | 0.2439 | 18 | 0.9526 |
| **Life-history Traits** | 22 | 23 | 53 | 0.0171 | -0.0858 | 0.1201 | 18 | 0.7305 |
| **Morphological** | 16 | 18 | 46 | -0.0070 | -0.1450 | 0.1309 | 18 | 0.9157 |
| **Physiological** | 7 | 7 | 18 | -0.0042 | -0.2778 | 0.2694 | 18 | 0.9745 |

**Table S38 Results of the meta-regression of the terrestrial dataset with specific phenotypic traits as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with organisms from terrestrial environments. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Terrestrial Organisms (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Development Time** | 21 | 21 | 40 | 0.0111 | -0.1038 | 0.1260 | 71 | 0.8474 |
| **Length** | 6 | 7 | 11 | -0.0005 | -0.2707 | 0.2697 | 71 | 0.9969 |
| **Mass** | 11 | 12 | 23 | -0.0120 | -0.1835 | 0.1595 | 71 | 0.8894 |

**Table S39 Results of the acclimation subset MLMA model.** Number of studies, species and effect sizes are totals from the subset of data with acclimation treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Acclimation Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **MLMA** | 12 | 10 | 65 | -0.0049 | -0.1641 | 0.1543 | 9 | 0.9459 |

**Table S40 Results of the meta-regression of the acclimation dataset with the amplitude of the fluctuation as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with acclimation treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Acclimation Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Amplitude** | 12 | 10 | 65 | -0.0005 | -0.0199 | 0.0188 | 30 | 0.9542 |

**Table S41 Results of the meta-regression of the acclimation dataset with fluctuation type as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with acclimation treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Acclimation Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Sinusoidal (Sine Curve)** | 5 | 4 | 25 | 0.0009 | -0.2369 | 0.2387 | 19 | 0.9938 |
| **Stepwise** | 4 | 3 | 30 | -0.0132 | -0.2156 | 0.1892 | 19 | 0.8929 |

**Table S42 Results of the meta-regression of the acclimation dataset with life-history stage as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with acclimation treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Acclimation Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Adult** | 4 | 5 | 16 | -0.0166 | -0.2678 | 0.2346 | 24 | 0.8924 |
| **Juvenile** | 4 | 3 | 15 | 0.0040 | -0.2961 | 0.3041 | 24 | 0.9783 |
| **Larva** | 4 | 3 | 30 | 0.0021 | -0.2336 | 0.2378 | 24 | 0.9855 |

**Table S43 Results of the meta-regression of the acclimation dataset with the number of fluctuations as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with acclimation treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Acclimation Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Number of Fluctuations** | 11 | 8 | 63 | -0.0001 | -0.0057 | 0.0056 | 10 | 0.9834 |

**Table S44 Results of the meta-regression of the acclimation dataset with phenotypic trait category as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with acclimation treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Acclimation Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Biochemical Assay** | 2 | 2 | 27 | 0.0022 | -0.2652 | 0.2696 | 16 | 0.9862 |
| **Physiological** | 9 | 7 | 32 | -0.0028 | -0.1977 | 0.1921 | 16 | 0.9759 |

**Table S45 Results of the meta-regression of the acclimation dataset with specific phenotypic traits as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with acclimation treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Acclimation Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Metabolic Rate** | 6 | 5 | 12 | 0.0006 | -0.4646 | 0.4659 | 4 | 0.9972 |

**Table S46 Results of the meta-regression of the acclimation dataset with taxonomic class as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with acclimation treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Acclimation Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p-value** |
| **Insecta** | 4 | 4 | 31 | 0.0034 | -0.3594 | 0.3663 | 3 | 0.9780 |

**Table S47 Results of the developmental subset MLMA model.** Number of studies, species and effect sizes are totals from the subset of data with developmental treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Developmental Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p value** |
| **MLMA** | 32 | 32 | 138 | 0.0042 | -0.0670 | 0.0754 | 23 | 0.9040 |

**Table S48 Results of the meta-regression of the developmental dataset with the amplitude of the fluctuation as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with developmental treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Developmental Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p value** |
| **Amplitude** | 32 | 32 | 138 | 0.0000 | -0.0066 | 0.0065 | 50 | 0.9916 |

**Table S49 Results of the meta-regression of the developmental dataset with exposure period as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with developmental treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Developmental Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p value** |
| **Embryo** | 16 | 17 | 70 | -0.0017 | -0.0947 | 0.0913 | 29 | 0.9705 |
| **Juvenile** | 4 | 4 | 13 | -0.0222 | -0.3140 | 0.2696 | 29 | 0.8776 |
| **Larva** | 12 | 12 | 55 | 0.0175 | -0.0984 | 0.1334 | 29 | 0.7596 |

**Table S50 Results of the meta-regression of the developmental dataset with fluctuation type as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with developmental treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Developmental Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p value** |
| **Sinusoidal (Sine Curve)** | 14 | 13 | 49 | -0.0029 | -0.1387 | 0.1329 | 39 | 0.9659 |
| **Alternating** | 12 | 15 | 50 | 0.0080 | -0.0920 | 0.1079 | 26 | 0.8712 |
| **Stepwise** | 4 | 4 | 17 | 0.0102 | -0.1940 | 0.2144 | 39 | 0.9201 |

**Table S51 Results of the meta-regression of the developmental dataset with phenotypic trait category as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with developmental treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Developmental Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p value** |
| **Life-history Traits** | 27 | 29 | 65 | 0.0134 | -0.0864 | 0.1132 | 12 | 0.7746 |
| **Morphological** | 20 | 23 | 54 | -0.0048 | -0.1339 | 0.1243 | 12 | 0.9362 |

**Table S52 Results of the meta-regression of the developmental dataset with specific phenotypic traits as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with developmental treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Developmental Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p value** |
| **Development Time** | 26 | 27 | 46 | 0.0103 | -0.0972 | 0.1177 | 82 | 0.8495 |
| **Length** | 9 | 10 | 14 | 0.0014 | -0.2379 | 0.2406 | 82 | 0.9909 |
| **Mass** | 12 | 14 | 25 | -0.0110 | -0.1732 | 0.1513 | 82 | 0.8933 |

**Table S53 Results of the meta-regression of the developmental dataset with taxonomic class as the moderator.** Number of studies, species and effect sizes are totals from the subset of data with developmental treatment exposures. Effect size = PRRD.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Developmental Exposure (PRRD)** | **Studies** | **Species** | **Effect Sizes** | **Estimate** | **CI Low** | **CI High** | **df** | **p value** |
| **Arachnida** | 2 | 3 | 11 | -0.0050 | -0.1701 | 0.1601 | 19 | 0.9501 |
| **Insecta** | 20 | 18 | 73 | 0.0112 | -0.0847 | 0.1072 | 19 | 0.8092 |

**8.13 | Heterogeneity Results**

**Table S54 Heterogeneity results for the MLMA models.** Effect size = PRRD. I2 values reported as percentages.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **MLMA Models (PRRD)** | **I2Animal** | **I2Measurement** | **I2Obs** | **I2Phylo** | **I2Species** | **I2Study** | **I2Total** |
| **Overall** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Individual-level Traits** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Aquatic** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Terrestrial** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Acclimation** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Developmental** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**8.14 | Graphical Representation of the MLMA and Meta-regression Results**

A graph showing a graph of a person's weight

Description automatically generated with medium confidenceA graph of a normalized number of objects

Description automatically generated with medium confidence

**Figure S6 Meta-regression results for the individual-level traits subset with fluctuation type as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph with a line and a line

Description automatically generated with medium confidenceA graph showing a graph of a number of percent

Description automatically generated with medium confidence

**Figure S7 Meta-regression results for the individual-level traits subset with taxonomic class as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph with numbers and a line

Description automatically generatedA graph with numbers and a line

Description automatically generated

**Figure S8 Meta-regression results for the aquatic subset with fluctuation type as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph showing a graph of a graph

Description automatically generated with medium confidenceA graph with numbers and a line

Description automatically generated

**Figure S9 Meta-regression results for the aquatic subset with the mechanism of plasticity as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph with a line graph and numbers

Description automatically generated with medium confidenceA graph showing a graph of a graph

Description automatically generated with medium confidence

**Figure S10 Meta-regression results for the aquatic subset with phenotypic trait category as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph showing a graph of a person's weight

Description automatically generated with medium confidenceA graph of a graph showing the effect size of a prrd

Description automatically generated

**Figure S11 Meta-regression results for the terrestrial subset with fluctuation type as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph with a blue line

Description automatically generatedA graph showing a number of percent

Description automatically generated with medium confidence

**Figure S12 Meta-regression results for the terrestrial subset with the mechanism of plasticity as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph of a normalized number of objects

Description automatically generated with medium confidenceA graph of a normalized number of objects

Description automatically generated with medium confidence

**Figure S13 Meta-regression results for the terrestrial subset with phenotypic trait category as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph with a number of percent

Description automatically generated with medium confidenceA graph of a graph showing the effect size of a prrd

Description automatically generated

**Figure S14 Meta-regression results for the terrestrial subset with specific phenotypic traits as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph showing a number of percent

Description automatically generated with medium confidenceA graph showing a graph of a diagram

Description automatically generated with medium confidence

**Figure S15 Meta-regression results for the acclimation subset with fluctuation type as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph showing a graph of a number of percent

Description automatically generated with medium confidenceA graph showing a number of different sizes

Description automatically generated with medium confidence

**Figure S16 Meta-regression results for the acclimation subset with life-history stage as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph of a number of fluctuations

Description automatically generated

**Figure S17 Relationship between effect size (PRRD) and the number of fluctuations for the acclimation subset.** There was no significant relationship between the number of fluctuations and the difference in the phenotypic plasticity between the constant and fluctuating temperature treatments. Dashed line = PRRD estimate from the MLMA models. Solid line = model prediction. Sample sizes are those used to calculate each individual effect size. X-axis and Y-axis limits are cropped for presentation.

A graph showing a graph of a number of percent

Description automatically generated with medium confidenceA graph of a graph showing a number of percent

Description automatically generated with medium confidence

**Figure S18 Meta-regression results for the acclimation subset with phenotypic trait category as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph showing a graph of a diagram

Description automatically generated with medium confidence

**Figure S19 Meta-regression results for the acclimation subset with specific phenotypic traits as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph showing a graph of a number of percent

Description automatically generated with medium confidence

**Figure S20 Meta-regression results for the acclimation subset with taxonomic class as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph with a number of percentages

Description automatically generatedA graph of a graph showing the effect size of a prrd

Description automatically generated with medium confidence

**Figure S21 Meta-regression results for the developmental subset with exposure period as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph showing a graph of a person's weight

Description automatically generated with medium confidenceA graph of a normalized number of objects

Description automatically generated with medium confidence

**Figure S22 Meta-regression results for the developmental subset with fluctuation type as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph showing a graph of a graph

Description automatically generated with medium confidenceA graph showing a graph of a number of people

Description automatically generated with medium confidence

**Figure S23 Meta-regression results for the developmental subset with phenotypic trait category as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph showing a number of percents

Description automatically generated with medium confidenceA graph of a graph showing the effect size of a prrd

Description automatically generated

**Figure S24 Meta-regression results for the developmental subset with specific phenotypic traits as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.

A graph with a line and a line

Description automatically generated with medium confidenceA graph showing a graph of a number of percent

Description automatically generated with medium confidence

**Figure S25 Meta-regression results for the developmental subset with taxonomic class as the moderator.** There were no significant differences in the phenotypic plasticity between the constant and fluctuating temperature treatments (indicated by 95% CIs crossing 0). Mean effect size (plasticity response ratio difference; PRRD) estimates ± 95% CIs (solid circles and horizontal bars, respectively) are shown, as well as distributions of individual effect sizes. Percentage labels are the mean PRRD estimates transformed to show a proportional difference between the fluctuating and stable temperature treatments. K = number of effect sizes with the number of species in brackets. X-axis limits are cropped for presentation.