Calculating the predictability of climate change: the effect of climate change on moth species in the Pacific Northwest varies among functional groups.

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Climate change has driven shifts in phenology and distribution for many species. These effects are often idiosyncratic and it remains unclear whether they vary consistently among functional groups, limiting our ability to draw broad conclusions about how climate change affects species. Previous studies have indicated that Lepidoptera (butterflies and moths) are sensitive to climate change.

We analyzed a large database of moth specimen records from the Pacific Northwest (PNW) to examine climate change responses over more than 100 years for a suite of 241 functionally diverse species, including spring and fall active species as well as dietary generalists and specialists (Table 1).

Our goal was to investigate the effect of among-year variation in regional late winter to early spring temperatures on the seasonal timing of adult activity, and whether that effect differs among moth functional groups.

We hypothesized that moths would have earlier flight dates in warmer years, and that this effect would be greatest for both early-season and dietary specialists.

Methods

We obtained annual temperatures anomalies for each year in which we had moth data (1895–2015), drawing from NOAA climate records. Only single-brooded moth species with at least 100 complete collection records were included in the analysis. Multiple records of a species from a locality in a given year were reduced to the median Julian Date (JD) of those records, to avoid pseudoreplication. We used generalized linear mixed models (GLMMs) to determine the effect of temperature anomaly on flight date for each species. Elevation, latitude, and longitude were included as random effects to account for phenological differences due to these factors.

For each species, we determined the shift in flight date from 1°C increase from the historical average temperature, based on the species-specific relationships between anomaly and flight date. To assess whether moths generally fly earlier in warmer years, we analyzed the distribution of slopes of these relationships using a one-tailed t-test. To determine if functional groups differ in the probability of exhibiting a significant response to temperature anomaly, we used G-tests. We used ANOVA to compare slopes for the anomaly-driven shifts of these relationships using a one-tailed t-test. Overall test for variation among functional groups is indicated by p-value in the upper right corner of each panel, while significant pairwise differences are indicated by differences in letters above the bars (pairwise comparisons used Tukey HSD correction for average slopes and Bonferroni correction for percent significant).

Conclusions

Our results show that climate change has the potential to affect the phenology of many moth species. Significant differences among functional groups suggest that the responses of individual species to climate change are likely to be somewhat predictable.

These results demonstrate that messy, specimen-driven shifts are more sensitive to temperature changes than later flying and more mobile species.

Future Research

• Investigate how phylegetic relatedness influences the responses of moths to climate change.

• Compare other functional groups such as migratory vs. non-migratory or single vs. multi-brooded groups.

References


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