May 2015

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Can Collection Specimen Data Reveal Temporal Shifts Due to Climate Change?

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Introduction

- Climate change has caused shifts in the phenology and distributions of many species, but the single-species nature of most studies makes it difficult to compare climate change effects among different functional groups.
- Furthermore, because most studies postdate the onset of the current warming period, they have likely yielded underestimates of the magnitude of such shifts.
- Natural history collection data may remediate these issues; the specimens in these collections, particularly for well-sampled taxa such as Lepidoptera (butterflies and moths) document species occurrences spanning >100 years over large areas.
- To date, natural history collection data remain largely unexplored in the context of climate change, perhaps because of concerns that the idiosyncratic sampling practices by natural historians may result in too much statistical noise.
- Recent efforts at digitalizing specimen data, such as the PNW Moth database, promise to make collection data more broadly available for potential analysis.
- We investigated whether specimen data could be used to estimate phenological effects of climate change, focusing on Pacific Northwest (PNW) Lepidoptera, for which specimens date as far back as the 1890’s, long before the warming that has occurred in the region (Fig. 1).
- We focused on whether a statistical model could be developed to examine if dates of specimen capture vary in relation to annual variation in temperature, correcting for potential effects of elevation, latitude, and longitude on capture date.
- Our goal was to create a model that could be applied to any (single brooded) species in the PNW Moth database, and could be easily adapted by researchers using specimen data to examine similar shifts in other taxa.

Methods

1. Selected a test case species (Panthea virginiarius (Noctuidae), Fig. 2) that satisfied the following criteria:
   - Single brooded.
   - Broad elevation range (0-2754 m, for P. virginiarius).
   - Widely distributed in the Pacific Northwest (Fig. 3).
   - At least 200 collection records, spanning the period from pre-1970s to present (665 records from 1896-2013 for P. virginiarius).
2. Converted all capture dates to Julian date (0 to 365).
3. For each year with P. virginiarius records, the temperature anomaly was obtained for the Pacific Northwest region for a 6 month period (November through April) for a full year (April through March) preceding the flight season.
4. Used generalized linear mixed-effects models (GLMMs) instead of multiple regression, because the dates of capture were non-normal even with transformation.
5. In all GLMM analyses, set Julian date and temperature anomalies as fixed effects and elevation, latitude, and longitude as random effects (binned to calculate variance).
6. Ran GLMMs for multiple models, each chosen to reflect realistic combinations of contributing factors (repeated using 8 and 12 month temperature anomalies).
7. Used AIC scores to determine the best model.

Results

- At high elevations, date of capture was later and less variable than at low elevations (Fig. 4).
- For both sets of analyses, the best model included ln(temperature anomaly) and all of the random effects (elevation, latitude, longitude) (Table 1).
- Antilog transformation of the slope and intercept of ln(temperature anomaly) vs. date of capture suggested an earlier shift of approximately 6 days per degree increase in temperature anomaly, but the overall effect of temperature anomaly was nonsignificant (Table 2).

Conclusions

- Based on the results for Panthea virginiarius, GLMMs appear appropriate for analyzing natural history specimen data for phenological responses to climate change.
- We plan to use this approach to analyze records for additional PNW moth species, allowing us to compare the effects of climate change on early spring specialists vs. late summer specialists, and on high-elevation specialists vs. low-elevation specialists, to determine the degree to which such effects vary among functional groups.

Acknowledgements

We thank Ben Milner for many helpful conversations about statistical methods; in addition, we are grateful to the many people who contributed to the development of the Pacific Northwest Moths website, but especially to Jon Shepard for obtaining the bulk of the specimen collection records and Lars Crabo for ensuring accurate identifications of all of the specimens in the database.

References