The responses of Australian butterflies to climate change

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Table of contents

Executive summary

There are numerous reports of species responses to climate change over the last century and there is much interest in how species will continue to respond in the future. Much of the documentation has come from the Northern Hemisphere, where species are moving to higher latitudes and elevations, and life cycles are advancing. There has been far less research on the responses of Southern Hemisphere species to either recent or future climate change. The few studies on Australian species are biased towards vertebrates and plants with only a handful focused on terrestrial invertebrates (only one of which is a butterfly). The response of Australian species to climate change may not be consistent with those reported in the Northern Hemisphere because the environment in Australia is very different, being flat, relatively dry, with strong inland-coastal rainfall gradients and ecosystems whose dynamics are largely driven by episodic climate extremes.

This thesis investigates the distribution and life cycle responses of Australian butterflies to recent and future climate change, using a combination of field surveys, species distribution modelling and data mining. It also investigates the accuracy of simulated species distributions that have been projected from historic data onto current climatic conditions, and whether the inclusion of host plant distributions in butterfly models improves their predictive accuracy. Investigation into range shift responses and modelling accuracy focuses on three butterfly species whereas the phenological investigation looks as a larger group of 68 species. It was found that over the last 100 years, the southern range boundaries of two of the three focal species, *Elodina angulipennis* and *Suniana sunias*, have likely remained stable, while the southern range boundary of the third species, *Hypocysta euphemia*, has contracted north by 2.5 degrees of latitude. The future distributions of all three species are likely to contract if the butterflies are unable to track climate change or if precipitation decreases in the future. When precipitation was projected to increase and full dispersal of the butterflies was assumed, future range expansions were indicated for two of the three species. I also found that the predictive accuracy of models projected onto another period of time is species-specific. I also found that the start of the flight season for several butterflies has changed over the last 60 years: some are emerging earlier, others later while others show no detectable trend. The phenological responses of the 68 species investigated were not associated strongly with any life history, dietary or geographic trait. To further investigate life cycle changes and monitor climate change impacts, I recommend several species as potential indicators of climate change impacts.

Certificate of Candidate

The work described in this thesis "The responses of Australian Butterflies to Climate Change" is original and has not been submitted, in any form, for a higher degree at any other university or institution, and has been written by myself. All of the work presented was undertaken during my PhD candidature at Macquarie University from January 2007 to December 2011. The specific contribution of co-authors and sources of data that I have not collected myself are indicated here.

Any additional help and assistance that I have received in my work and in the preparation of the thesis itself has been appropriately acknowledged. Many people have assisted me with fieldwork and have commented on manuscript proofs. Their specific contributions have been appropriately acknowledged.

In addition, I certify that all information sources and literature used are indicated in the thesis.

The research presented in this thesis did not require approval from the Macquarie University Ethics Review Committee.

Katherine Elizabeth M^{c}Clellan

December 2011

Statement of contributions

I Katherine M^C^Clellan, declare that the research contained in this thesis entitled "The responses of Australian Butterflies to Climate Change" is my own work, the contribution of co-authors and sources of data that I have not collected myself are indicated here.

Chapter 2: Have three species of Australian butterflies (*Elodina angulipennis, Hypocysta euphemia* and *Suniana sunias*) experienced range shifts consistent with climate change? K.E. M^C^Clellan and L. Hughes. Lesley Hughes was involved in concept development, experimental design and manuscript preparation.

- Concept & development: KM 70%; LH 30%
- Data collection: KM 100%
- Data analysis: KM 100%
- Writing: KM: 95%; LH 5%

Chapter 3: Can the current distribution of a species be accurately simulated using historical data? A test with Australian butterfly species. K.E. M^C^Clellan, L.J. Beaumont and L. Hughes. Lesley Hughes was involved in concept development, experimental design and manuscript preparation. Linda Beaumont provided valuable discussion of modelling methods, assisted in the interpretation of results and provided editorial feedback on manuscript drafts.

- Concept & development: KM 70%; LB 15%; LH 15%
- Data collection: KM 100%
- Data analysis: KM 90%; LB 10%
- Writing: KM: 75%; LB 20%; LH 5%

Chapter 4: Impact of biotic variables, climate models and assumptions about dispersal on future range projections of Australian butterflies. K.E. M^C^Clellan, P.D. Wilson L.J. Beaumont and L. Hughes. Lesley Hughes was involved in concept development and manuscript preparation. Linda Beaumont provided valuable discussion of modelling methods, assisted in the interpretation of results and provided editorial feedback on manuscript drafts. Peter Wilson provided technical expertise, developing the environmental layers for modelling and R scripts, to my specifications.

- Concept & development: KM 80%; LB 5%; LH 15%
- Data collection: KM 100%
- Data analysis: KM 95%; PW; 5%
- Writing: KM: 90%; LB 5%; LH 5%

Chapter 5: Has the date of first flight advanced in Australian butterflies in response to climate change? K.E. MCClellan and L. Hughes. Lesley Hughes was involved in concept development, interpretation of results and manuscript preparation

Concept & development: KM 50%; LH 50%
- Data collection: KM 100%
- Data analysis: KM 100%
- Writing: KM: 95%; LH 5%

Chapters 1 & 6: The chapters for the introduction and conclusion are a work of my own. Lesley Hughes provided valuable feedback on these chapters.

This thesis draws heavily on the privately published Dunn and Dunn Australian Butterfly Database (2011). Without this database, historic collection sites could not have been located for survey and species distribution modelling and data mining for phenological trends would not have been possible.

Species distribution modelling also required accessing climate data collated and processed by the Bureau of Meteorology (http://www.bom.gov.au/climate/data/) and WorlClim (http://www.worldclim.org/download).

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