

Climate change, models, mimics and predators: A complicated relationship

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The hairy-footed flower bee, *Anthophora plumipes*. Credit: Steven Falk (photographer).

Climate change as a disruptive force has been studied in terms of its effects on direct interactions in ecological relationships, such as those between predator and prey, for example. Until now however, little has been known about how the effect of a changing climate on the annual emergence cycles of species—phenological synchrony—may be affecting more complicated evolutionary relationships such as those within a Batesian mimicry complex. In a Batesian complex, one species mimics the behavior of another (model) species that has evolved defensive measures against a third predator species.

In a recent paper published in *PNAS*, Christopher Hassall, Jac Billington and Thomas N. Sherratt detail how they modelled a Batesian mimicry complex by leveraging the power of citizen science and online video gaming, which they then applied to a large historical observational dataset in an attempt to better understand the complicated relationship among models, mimics and predators in a changing climate. Their results are ultimately understood in reference to each member of the relationship's evolutionary fitness costs and benefits as they relate to each other partner within the complex.

In this study, Hassall and colleagues examined the relationship between Hymenoptera models (stinging wasp and bee [species](#)), their Diptera: Syrphidae mimic species (hoverflies), and the predators that attempt to feed on both: naive bird hatchlings. Some previous research on Batesian complexes indicates phenologic order of appearance is important, and that mimics benefit by emerging prior to their model species. Other research counters that model and mimic species appear synchronously and independently of avian fledgling emergence dates. Regardless, no

previous studies using adequately large datasets exist to elaborate on questions of phenological synchrony with respect to this Batesian complex and the fitness costs or benefits of its members. The relationship is further confounded by the role of climate change in this ecological milieu.

The first part of their experiment details the selection of 42 species of Syrphidae mimics and 56 species of bee and wasp models—2,353 pairs. Selection was based mainly on abundance from biological records in an area of central England in which both model and mimic species were known to coexist, but also on their taxonomic and morphologic distinctness. The researchers then asked users to rate randomly paired representative images from Syrphidae and Hymenoptera based on their visual similarity. From these, 237 high-fidelity pairwise combinations were selected. When compared with similar experiments using pigeons, these combinations correlated significantly, thus legitimating the researchers' method of pairing based on human vision.



The common carder bee, *Bombus pascuorum*. Credit: Arnstein Staverløkk (Norwegian Institute for Nature Research, Trondheim, Norway).

For the next study in their experiment, Hassall and colleagues looked at the comparative phenology of models and mimics—that is, the relationship between Syrphidae mimics and Hymenoptera models in priority of emergence or overlap of emergence when compared with phenological advance in terms of increase in mean annual temperature in the study area (central England). To evaluate this statistically, they used rank biserial correlation (RBC). The researchers found no significant evidence that models and mimics were "advancing their phenology at the same rate."

To examine "the fitness consequences of phenological mismatch," the

third part of the study again relied on human participants, this time to fulfil the role of predators in a video game scenario whereby they were presented with three pairs of model-mimic prey stimuli. The participants were asked to make decisions regarding the profitability of each pair of stimuli from the perspective of a predator. Participants were presented with these three pairs in one of three scenarios, each involving 25 models and 25 mimics. The three phenologic scenarios represent 1) mimics on average emerging first 2) models on average appearing first, or 3) random presentation, with an equal mean order of each model and mimic. Game participants scored five points for clicking a mimic, were penalized 10 points for clicking a model, and were neither penalized nor rewarded for passing on a decision.

From this gamification of the Batesian model-mimic-predator relationship with regard to phenological scenarios, the authors found statistically significant rates of prediction with all three members in the complex. Random presentation was associated with the greatest fitness in mimics here, while the model-first scenario worked in the best interest of models; these results were generally congruent with classic Batesian theory. Random presentation, on the other hand, worked to the detriment of predators, who benefit most from a clear educational signal regarding their prey.

In the final section of their experiment, the authors applied the results of the previous section to an historical dataset spanning the years 1960 to 2005 with reference to each of the 237 previously identified high-fidelity pairs. From this, they were able to pair RBC score thresholds with "model-first," "mimic-first," or "random" categories, which in turn allowed them to infer fitness consequences with regard to real-world temporal sequences in the context of contemporary climate change. They found a significant increase over this time span in the "[model](#)-first" pattern, a significant decrease in "mimic-first" occurrences, and a less-significant decline in which species pairs emerged randomly. From all

this, they were able to infer a fitness trend showing models benefiting most from emerging first, a mixed trend for mimics due to a decrease in random pairs, but positive benefits also for predators, who benefit most when models emerge first.

So what does all this mean in the context of a changing climate? Well, it's complicated. Past studies, as the researchers note, have shown phenological decoupling to be definitely harmful in many ecosystems. They cite as one example the plight of the snowshoe hare that molts after early snow melt and how this increases mortality in this case. But where other studies demonstrate the negatives associated with phenological shifts, data from this research "suggest that [climate change](#) will result in phenologically optimal emergence patterns that benefit (at least in part) all three actors within the mimicry system." More than this though, the authors conclude, their study also illustrates "the benefits of integrating mechanistic and organizational data to study large-scale eco-evolutionary processes within a phenologically antagonistic Batesian mimicry complex."

More information: Christopher Hassall et al. Climate-induced phenological shifts in a Batesian mimicry complex, *Proceedings of the National Academy of Sciences* (2018). [DOI: 10.1073/pnas.1813367115](https://doi.org/10.1073/pnas.1813367115)

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