

Wing lengths of three Arctic butterfly species decrease as summers warm in Alaska

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Abstract

Climate warming can cause arthropods to express plastic and/or evolved changes in morphology. Previous studies have demonstrated that body sizes of Arctic butterflies are influenced by the temperatures experienced as larvae. To investigate whether this was occurring among Alaskan butterflies, we analyzed temporal trends in the wing sizes of three Holarctic species, *Colias hecla*, *Boloria chariclea*, and *Boloria freija*, using museum specimens collected in Arctic tundra regions of Alaska between 1971 and 1995. Wing length was compared to accumulated growing degree days (GDD) during both the spring of the year collected and the previous year's summer during the normal period of larval development. We used mixed-effects models to test if spring and summer temperatures affected adult morphology. Results show that for every 1°C increase in average seasonal temperature, wingspans decreased between 0.7 millimeters and 5 millimeters, with *B. freija* the most strongly affected. Our results suggest that the morphological sensitivity of Arctic butterflies to warming is the outcome of interactions between life-history traits and regional climate, with all species sensitive to warming the summer before the flight year as well as warming the spring of the flight year. *B. freija*, which overwinters as late instar larvae that do not feed before pupation the following spring, was particularly strongly affected by summer warming.

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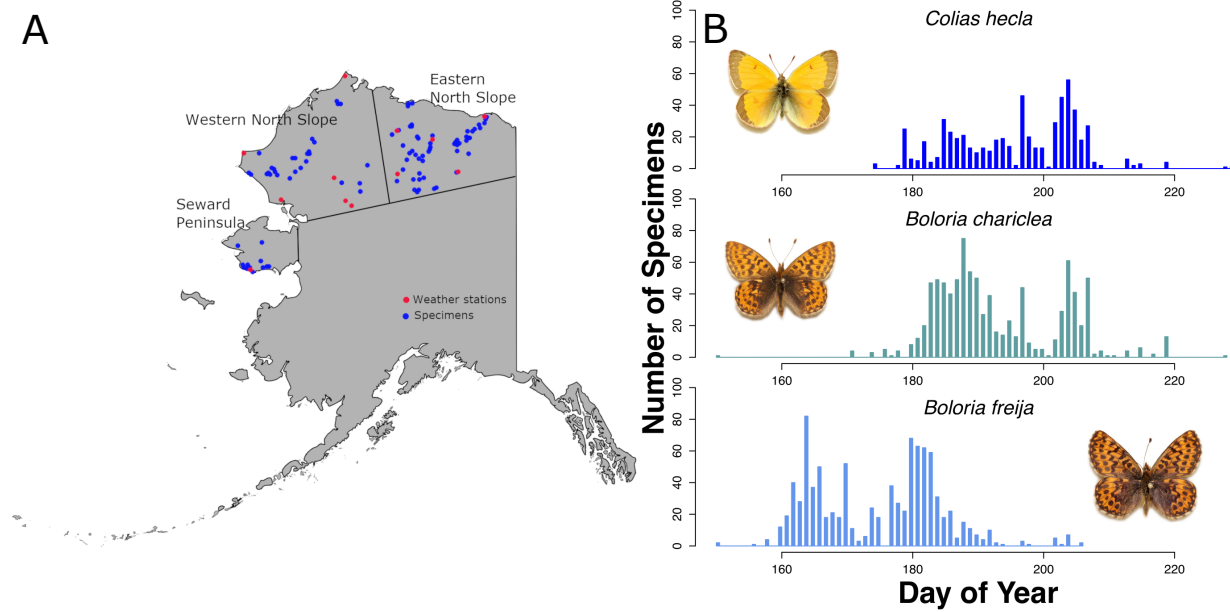
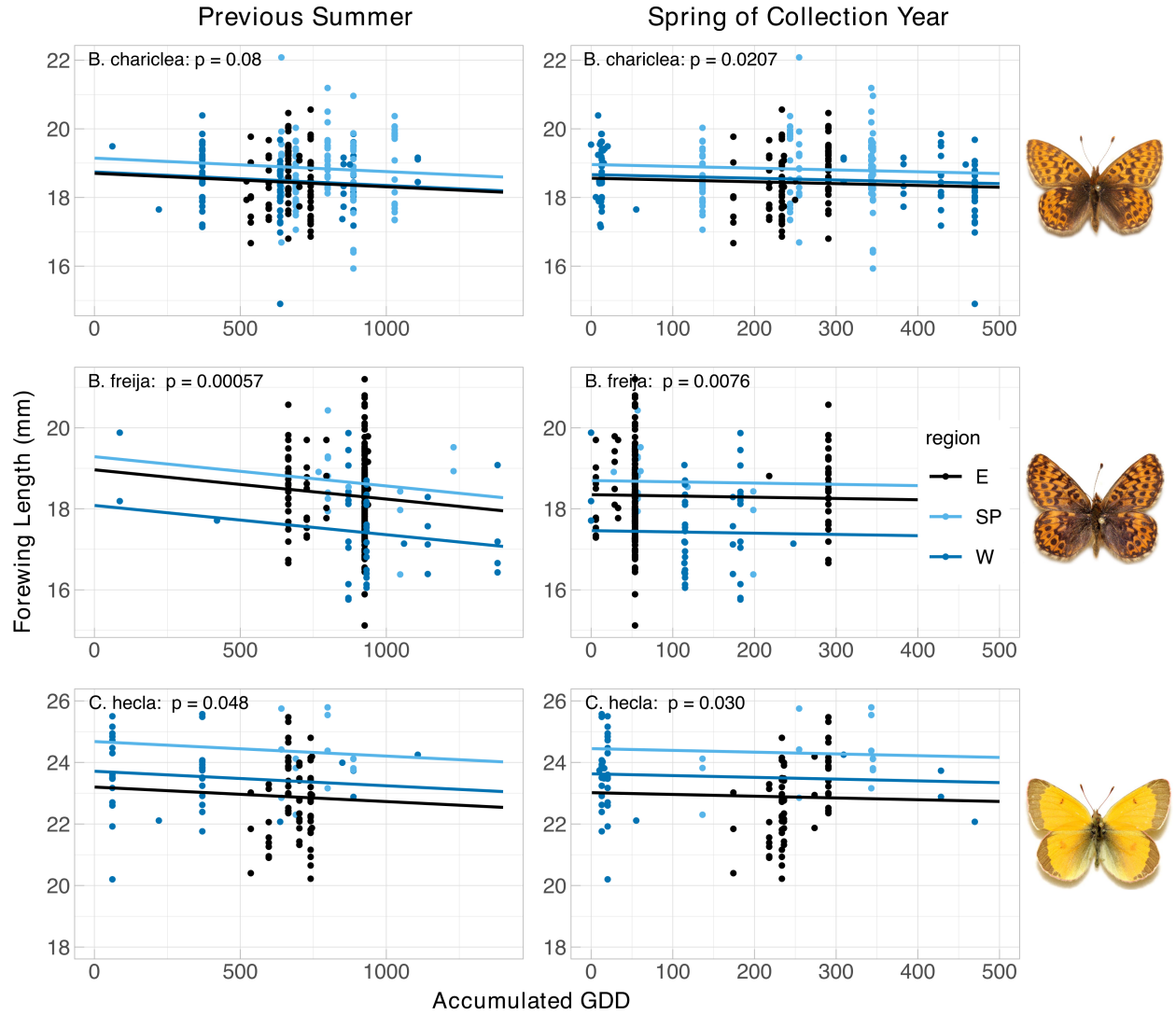


Fig 1: A) Map of localities where measured butterfly specimens were collected (blue) and weather stations (red) of Alaska, with regions treated as a random effect. B) Flight periods (number of individuals flying per day of year) for *Colias hecla* (top), *Boloria chariclea* (middle), and *Boloria freija* (bottom) in Alaska from 1970-1995.



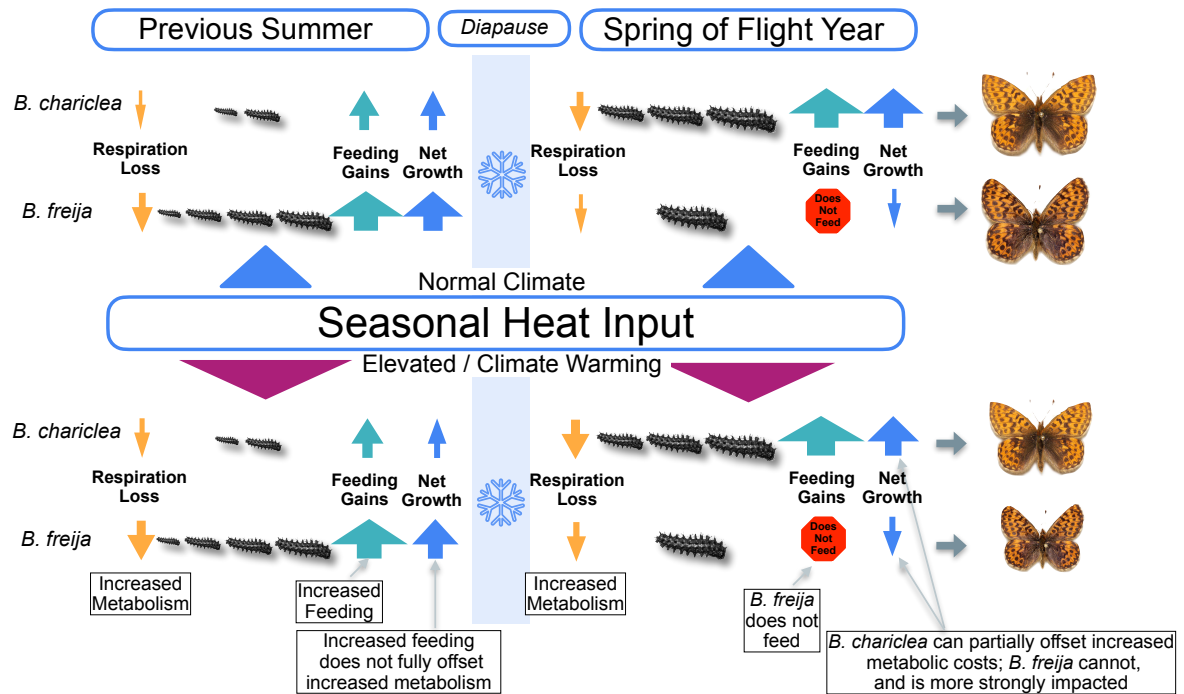


Fig 3: Conceptual figure of the effects of seasonal heat input on *Boloria chariclea* and *Boloria freija* experienced in the summer prior to collection (left) and spring (right). Metabolic rates increase with temperature, which, depending on larval overwintering stage, may not be offset by feeding, resulting in a smaller adult body size (right). The inability of *B. freija* to feed in the fifth instar during the spring of the flight year may make it particularly sensitive to warming the previous year. Feeding immediately prior to pupation may be important for mitigating these effects, and why *B. freija* is more sensitive to warming than *B. chariclea*, which is able to feed after diapause during the spring of the flight year.