Supplementary Electronic Material

Biophysical model

We use a biophysical model for *Colias* that was developed and field validated by Kingsolver (*1*) to predict thoracic body temperature (operative environmental temperature, *Te*) based on thermoregulatory traits (body size, basal ventral hind wing solar absorptivity, and thoracic fur thickness) and environmental conditions. The model successfully predicts patterns of *Te*, flight activity time and heat-avoidance in the field for *C. meadii* and *C. eriphyle* along an elevational gradient in Colorado (*1, 2*). We briefly describe the model, which is developed in detail elsewhere (*1, 3*). We describe the steady-state energy flux balance of a butterfly at rest on vegetation as

$$Q_s = Q_t + Q_c$$

where Q_s is the total solar radiative heat flux, is Q_t the thermal radiative heat flux, and Q_c is the convective heat flux. Conduction of heat between the body and vegetation and evaporative heat loss are considered to be negligible. The solar radiative heat flux is

$$Q_s = Q_{s,dir} + Q_{s,dif} + Q_{s,ref}$$

$$Q_s = \alpha A_{s,dir} H_{s,dir} / \cos(z) + \alpha A_{s,ref} H_{s,dif} + \alpha r_g A_{s,ref} H_{s,ttl}$$

where $Q_{s,dir}$, $Q_{s,dif}$, $Q_{s,ref}$, are the direct, diffuse, and reflected solar radiative fluxes, respectively; $H_{s,dir}$, $H_{s,dif}$, $H_{s,ttl}$, are the direct, diffuse, and total solar radiative horizontal flux densities, respectively; $A_{s,dir}$, $A_{s,ref}$, $A_{s,ttl}$ are the direct, reflected, and total solar radiative heat transfer surface areas, respectively; α is wing solar absorptivity; r_g is substrate solar reflectivity; and z is the zenith angle. We assume $A_{s,dir}$,$=A_{s,ref}= A_{s,ttl}$.

Thermal radiative flux including both downward radiation and reflected solar radiation is estimated as follows:

$$Q_t = 0.5 A_t \epsilon \sigma (T_b^4 - T_{sky}^4) + 0.5 A_t \epsilon \sigma (T_b^4 - T_g^4)$$

where A_t is the thermal radiative heat transfer surface area, T_b is the body temperature, T_g is the ground surface temperature, T_{sky} is the equivalent black body sky temperature, ε is butterfly thermal emissivity, and σ is the Stefan-Boltzman constant.

The convective heat flux is given by:

$$Q_c = h_T A_c (T_b - T_a),$$

where A_c is the convective heat transfer surface area, and T_a is the air temperature. We assume A_c=A_t= $A_{s,ttl}$. The total convective heat transfer coefficient, h_T, is calculated as the boundary layer conductance h_c and the fur layer conduction in series:

$$\frac{1}{h_T} = \frac{1}{h_c} + \frac{(r_i + \delta)\ln((r_i + \delta)/r_i)}{k_e},$$

Where δ is the thoracic fur thickness and k_e is the thermal conductivity of the fur. The boundary layer conductance, h_c, can be estimated using the relationship between two non-dimensional numbers. The Nusselt number, $Nu=h_cD/k_a$, is the ratio of convective to conductive heat transfer, where k_a is the thermal conductivity of air. We used the maximum width of the mesothorax as the characteristic dimension of the butterfly, *D*. The Reynolds number, $Re=uD/v$, is the ratio of inertial forces to viscous forces, where *u* is wind speed and *v* is kinematic viscosity. We used the *Nu-Re* relation for a cylinder, $Nu=0.6Re^{0.5}$, which is a reasonable approximation for *Colias* (*4*).

Microclimate model

We scale microclimate variables to plant heights of 0.2m and 0.5m by estimating temperature and windspeed profiles using the relationship (*5, 6*) [6]:

$$u(z) = \frac{u^*}{0.4} \ln \frac{z-d}{z_m},$$

where *u(z)* is the windspeed (m/s) at height *z* (m), *u** is the friction velocity (m/s), *d* is the zero plane displacement (m), and the constant 0.4 is the von Karman constant. We fit this relationship to data collected at heights of 0.05, 0.25, 0.5, 0.75, 1, 1.25, 1.5m for July 2011 at site C1. We estimate *d* as the y-intercept of the relationship between *u* and log(*z*). We then estimate surface roughness, z_0, as exp(-b/m) from fitting the relationship *u*=b+m log(*z*-*d*), where *u* is wind velocity (m/s) and *z* is measurement height. Using this approach we estimate of z0 = 0.02m at the C1 site; we used this value in our simulations at both sites.

We use the following relationship to estimate air temperature and windspeed at height *z* (*5, 6*):

$$\frac{u_z}{u_r} = \frac{ln(z/z_0+1)}{ln(z_r/z_0+1)} = \frac{T_z - T_0}{T_r - T_0},$$

where u_z and u_r are the windspeeds (m/s) at height *z* (m) and reference height *r* (m), respectively. T_z, T_r, and T_0 are air and soil temperatures at height z and r and soil surface temperature, respectively.

Demographic model

We use hourly estimates of ambient temperature and radiation from weather stations to estimate body temperatures and subsequently flight probability, daily flight time, egg production and egg viability. Our demographic model follows that of Buckley and Kingsolver (2012).We estimate annual population growth rate as a function of survival and fecundity. Mark, release, recapture studies with *C. meadii* and other *Colias* species at study sites in Colorado suggest mean adult lifespans (expected residence times) of 3-7 days that do not vary consistently with elevation (*7, 8*).

Based on these studies we assume a daily adult survival rate, S_{daily} of 0.6 for all populations (*7, 8*). We assume that the probability of juvenile survival from egg to adult maturity, S_{mat} , is 0.014, based on field studies of *C. alexandra*, another univoltine species with obligate winter diapause, in near Crested Butte, CO (*9*). We calculate daily egg production per female, *Eggs*, as the product of available flight time and the rate of oviposition. We assume an oviposition rate of 0.73 eggs/min and that 50% of available flight time is spent ovipositing, which was estimated for *Colias* females in Colorado (*10*).

We incorporate egg viability by multiplying daily egg production by the geometric mean of viability estimates across time. This estimate is based on simulating the emergence of 500 individuals across the flight season.

We estimate λ by summing over days to either a duration of 5 days or reaching a maximum lifetime egg production of 700 (*11*) as

$$\lambda = S_{mat} S_{daily}^{day} Eggs.$$

In our simulations we assume a single annual generation with a single summer flight season during July-August, as is the case for *C. meadii meadii* (*7*).

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