**Supplementary methods S1.**

**1. Supplementary methods**

*1.1. Energy costs*

There are few direct experimental estimates of daily lipid usage by ticks while questing (*cq*) and resting (*cr*) (Steele and Randolph, 1985). One UK field study found an average daily lipid use in *Ixodes ricinus* of 0.14 μg/day throughout May. Resting lipid usage among ticks held in the dark at 15 C and 95% relative humidity (RH) has been calculated as 0.016 μg/day (Randolph and Storey, 1999) although this is lower than that implied by other studies (Stafford III, 1994). The median percentage of time that *I. ricinus* spends actively questing at this time of year (April) in the same region has been estimated as 11.1% (Van Es et al., 1999). We combine these values in the following equation:

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|  |  | (S1) |

using proportions of the day spent questing and resting (*pq* and *pr*, respectively) here as constants. Under these assumptions, *cq* has a value of 1.1 μg/day. Because these measurements were taken over 4 weeks, *cq* is adjusted to 1**.**5 μg/dayto account for an artificially shortened 20 day simulated season. The starting lipid value (7**.**6 μg) is taken from the average starting lipid content collected in the aforementioned field study of *I. ricinus* (Randolph and Steele, 1985).

*1.2. Diffusion across and permeability of the cuticle*

To model water loss rates under varying environmental conditions, we first considered the chemical diffusion gradient across the cuticle (a function of temperature and water vapor activity) and the permeability of the cuticle (a function of temperature).

The diffusion gradient *Δμ(T, av)* for transpiration derived from Fick's first law (Toolson, 1978) is

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|  |  | (S2) |

in J/mol, where *R* is the universal gas constant, *T* is the temperature in kelvins (K), and *av* is atmospheric water activity (RH/100). *aw*, body water activity, is typically assumed to have a value of 0.99 for arthropods (Wharton and Richards, 1978).

The rate of change of cuticle permeability in *I. ricinus* adults with respect to temperature *π(T)* has been measured (Beament, 1959). In the original study, however, the relevant data were corrected to account for a saturation deficit, the relevance of which has since been called into question (Toolson, 1978). We therefore digitized the original plot, "uncorrected" for saturation deficit, and corrected for diffusion gradient (Supplementary Fig. S1).

Here, a change in permeability with temperature appears best described by two linear equations, with a non-linear transition occurring around 306.4 K (the critical cuticle transition temperature, or CCTT). Below this temperature, the slope is approximately 4.1E-06 mg of water/hr/J. Above it, the slope is approximately 7.9E-05 mg of water/hr/J.For this initial exploration of the model, we primarily considered temperatures below the CCTT and above freezing.

*1.3. Water loss*

We treated tick overall water loss as a single compartment transpiration equation. Assuming that the tick's rate of water loss is proportional to both the diffusion gradient and cuticle permeability, the individual coefficients calculated in the previous section can be discarded and the transpiration rate simplified to:

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|  |  | (S3) |

(equation 9 in the main text). We solved for the transpiration constant *kT* below the CCTT by fitting this formula to median lethal time (LT50) data from fully hydrated nymphs exposed to *av* 0.65, 0.75, 0.85, 0.93, and 1, with T = 300 K (Stafford, 1994). (We assume in the following that tick mortality in these experiments is due primarily to desiccation rather than starvation.) We can add an additional data point with the finding that the nymphal transpiration rate is 0.02971hr-1 at *av* = 1.5E-02 and T = 296 K (Yoder and Spielman, 1992), predicting LT50 in hours with the following equation:

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|  |  | (S4) |

where wmin = 54 μg.

We set aside the two treatments in Stafford (1994) where *av* is greater than the critical equilibrium activity (CEA), under which conditions ticks would not be expected to desiccate, and in the remaining cases plotted *av* against LT50 (Supplementary Fig. S2).

Also included in this plot is the least squares fit to the first three data points for a function taking the form of the transpiration equation above:

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|  |  | (S5) |

Solving for *kT*, we obtain *kT*=9.55E-08.

A good fit at the first three points (*R2*=0.935) suggests that, at these humidities, tick net water loss is effectively equal to transpiration and water uptake is zero. At *av*= 0.85, the LT50 is significantly higher, and therefore water loss is significantly lower, than would be expected if transpiration were acting unopposed. This result suggests that the pump threshold (PT) - the minimum humidity at which any water uptake is achieved - lies between 0.75 and 0.85 (O’Donnell and Machin, 1988).

*1.4. Incorporating water gain*

We assumed that water uptake is a function of water activity (and of body water, in that *wmax* is defined). Experimental studies provided the following three pieces of information on water uptake in *Ixodes scapularis* nymphs at 296 K (Yoder and Spielman, 1992):

1. The maximum water content of a nymph at *av* = 1 is 91 μg.
2. The CEA is 0.88 at a body water content of 71 μg. (Yoder and Spielman, 1992 evaluate this value when "10-18% of body mass was lost." We took the mean of 0.10 and 0.18, multiplied it by the mean fully hydrated body mass (143 μg) to obtain the equivalent water mass (20 μg), and subtracted this value from *wmax* (91 μg) to yield 71 μg).
3. The average rate of water uptake over 24 h for a nymph starting with an average water content of 71 μg (calculated as above) and *av* = 0.93 is 0.6 μg/h.

(The authors also calculated that the average rate of water uptake over 24 h for a nymph starting with an average water content of 78 μg (approximated as above) and *av* = 0.93 is 0.16 μg. This experiment is intended to simulate passive water gain. For simplicity, we ignored it in this model.)

Using our findings on water loss, we added a fourth constraint to tick water uptake:

(iv) A tick starting with a water content of 91 μg will take 2851.2 h to reach a water content of 54 μg at *av*=0.85.

If we present the rates of loss and gainas functions *wβT(aV,T)* and *βG(w,aV)*, respectively, hourly net water change is defined as:

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|  |  | (S6) |

(equation 9 in the main text), with *βT(aV,T)* defined as in the previous section.

Rephrasing the four statements above as equations using this notation yields:

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|  |  | (S7) |

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|  |  | (S8) |

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|  |  | (S9) |

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|  |  | (S10) |

where is the nth iteration of *f.*

Water gain due to passive sorption for behavior (without considering temperature) has been modeled as:

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|  |  | (S11) |

where *kG*is the sorption rate constant, defined in hours-1 and *ma* is the “the mass of water in the body needed to produce a hydrostatic pressure to balance ambient pressure” (adapted with some changes in notation from Wharton and Richards (1978)). As we assume constant ambient pressure and constant *aw*, we simplify our gain function to:

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|  |  | (S12) |

(equation 11 in the main text) where *A(aV, T, w)* and *B(aV, T, w)* are stepwise functions that define the different values *An* and *Bn* the equation takes over specific ranges of *aV* and *T*. The y intercept *B(aV, T, w)* is added to account for some baseline water uptake propensity, and we assumed a direct dependence of sorption rate on *T* (as the free energy gradient driving sorption is proportional to *T*) (Toolson, 1978).

Net change in water reserves is therefore:

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|  |  | (S13) |

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|  |  | (S14) |

where *w0* is the tick’s starting water reserves. We now define the right side of this equation as the function *W(w0,aV,T,t)* and solve for *A* and *B* in the function under the various scenarios described above. We make another slight change in notation for convenience, defining :

From equations S7 and S9:

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|  |  | (S15) |

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|  |  | (S16) |

giving *A1*=0.0386 and *B1*=-9.98.

From equation S10, and assuming that the gain function is continuous across *w* and *aV*:

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|  |  | (S17) |

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|  |  | (S18) |

giving *A2*=7.14E-05 and *B2*=0.0514.

And to account for the absence of water gain at aV=0.75:

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|  |  | (S19) |

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|  |  | (S20) |

giving *A3*=0.0232 and *B3*=-0.522.

As each of these functions is hourly, we calculated exponential decay over 24 h using *W(w0,aV,T,t)*, so that daily net water exchange was defined as

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|  |  | (S21) |

As stated in the main text, the formula for daily net water exchange does not take into account changes in the sorption constants that occur within each 24 h period.

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