Supplemental Materials

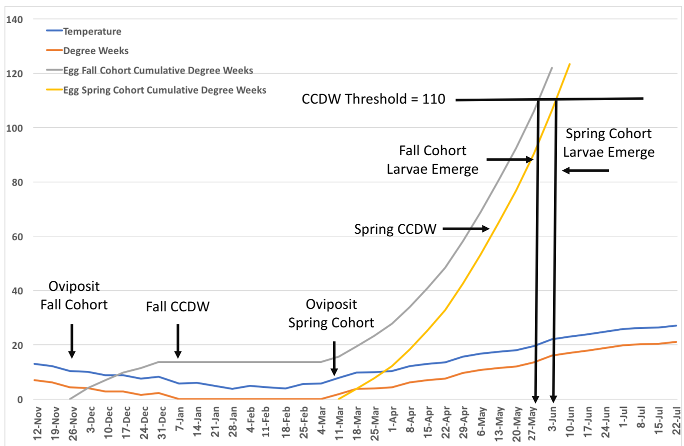


Figure S1: Example of cohort cumulative degree week calculation. The blue line is the average weekly temperature, and the orange line is the number of degrees, if any, that the weekly temperature is above the development threshold of 6 degrees. The gray line represents the CCDW for a fall cohort of eggs that are laid during the week of 26-November, and this running total exceeds the threshold of 110 for emergence during the week of 27-May. Similarly, the yellow line represents the CCDW for a spring cohort of eggs that are laid during the week of 11-March, and this cohort would emerge as larvae during the week of 3-June.

Table S1: Initialization for LYMESIM 2.0. Values are similar to original LYMESIM except where marked with asterisk (*). The original LYMESIM started in week 18, but since the initial conditions do not affect the model output after a few years of stabilization, this was moved to week 1 for ease of coding. The large mammals host type was replaced with insectivores and other competent small mammals. Habitat distribution was changed to better reflect the areas sampled in most tick studies. Host type densities can be expected to vary substantially both spatially and from year-to-year across the large geographical range of *I. scapularis*. In addition to the studies reviewed by Mount et al. (1997b), the initial values for host type densities presented here also considered data presented in the following more recent studies (Brisson and Dykhuizen 2006; Huang et al. 2019; Jordan et al. 2007; Kilpatrick et al. 2014; LoGiudice et al. 2003).

Factor	**Value(s)**	**Comments**
Length of simulation runs	Varies	Weekly time step
Simulation start week	Week 1 of Year 1*	First week of January
Initial tick population	300,000 eggs	0.0 all other age classes
Habitat distribution	0.95, 0.05, 0.0*	Forest, Ecotone, Meadow
White-footed mouse density	40 per hectare	25% pathogen prevalence
White-footed mouse habitat preference	0.6, 0.3, 0.1	Forest, Ecotone, Meadow
Insectivore and other competent small mammal density*	40 per hectare*	0% pathogen prevalence
Insectivore and other competent small mammal habitat preference*	0.6*, 0.3*, 0.1*	Forest, Ecotone, Meadow
All other small mammals and bird density	40 per hectare	0% pathogen prevalence
All other Small mammals and bird habitat preference	0.6, 0.3, 0.1	Forest, Ecotone, Meadow
Reptile density	10.0 per hectare	0% pathogen prevalence
Reptile habitat preference	0.6, 0.3, 0.1	Forest, Ecotone, Meadow
Medium-sized mammal density	4 per hectare	0% pathogen prevalence
Medium-sized mammal habitat preference	0.6, 0.3, 0.1	Forest, Ecotone, Meadow
White-tailed deer density	0.4 per hectare	0% pathogen prevalence
White-tailed deer habitat preference	0.6, 0.3, 0.1	Forest, Ecotone, Meadow

Table S2: Ticks per animal carrying capacity. All values are given as maximum number of ticks from that life stage per animal within a single week. WFM is white-footed mice, SHREW includes all other competent small mammals, SMB includes all birds and less competent small mammals, REP includes all reptiles, MSM includes all medium-sized mammals, and WTD is white-tailed deer. The carrying capacities for different life stages of *I. scapularis* on each host type are difficult to estimate from field data because the mean or median values of observed infesting ticks represent underestimates and the maximum numbers of observed ticks may represent overestimates as it is unclear if all observed ticks would have been able to complete their blood meal. In addition to the studies reviewed by Mount et al. (1997b), the values presented here also considered unpublished laboratory data from *P. leucopus* together with more recent field data from the following key studies Brinkerhoff et al. (2011a,b); Brisson and Dykhuizen (2006); Giardina et al. (2000); Glery and Ostfeld (2007); Hanincová et al. (2006); Huang et al. (2019); Levin et al. (2002); LoGiudice et al. (2003); Ogden et al. (2008); Prusinski et al. (2006); Rand et al. (1998).

Animal Type	**Maximum Larvae**	**Maximum Nymphs**	**Maximum Adults**
WFM	100	20	0
SHREW	75	15	0
SMB	15	3	0
REP	20	4	0
MSM	200	100	20
WTD	1000	500	100

Table S3: Maximum survival rates by age class and habitat type. Meadow values are not read since meadow is set as zero. These values are taken from Mount et al. (1997b). The meadow habitat is maintained in the code for completeness, but the current implementation only uses forest and ecotone.

Life Stage	**Parameter**	**Weekly Maximum Survival Rate**		
		Forest	**Ecotone**	**Meadow**
Eggs	S_E	0.95	0.94	0.8
Unfed Larvae	$S1_L$	0.965	0.957	0.856
Engorged Larvae	SE_L	0.978	0.974	0.92
Unfed Nymphs	$S1_N$	0.999	0.991	0.941
Engorged Nymphs	SE_N	0.984	0.978	0.932
Unfed adults	$S1_A$	0.999	0.991	0.901
Engorged Adults	SE_A	0.985	0.982	0.942

Table S4: Parameters for calculating weekly survival rate reduction based on weather inputs of saturation deficit, precipitation index, and temperature. These values are taken from Mount et al. (1997b).

Life Stage	**Saturation deficit**			**Precipitation index**		
	a_{sd}	b_{sd}	c_{sd}	a_{pi}	b_{pi}	c_{pi}
Eggs	-0.000222	0.00133	0.998	-0.000408	0.00571	0.98
Unfed Larvae	-0.000167	0.001	0.998	-0.000306	0.00429	0.985
Engorged Larvae	-0.000167	0.001	0.998	-0.0003061	0.0042857	0.985
Unfed Nymphs	-0.0000556	0.000333	0.999	-0.000102	0.00143	0.995
Engorged Nymphs	-0.0000556	0.000333	0.999	-0.000102	0.00143	0.995
Unfed Adults	-0.0000556	0.000333	0.999	-0.000102	0.00143	0.995
Engorged Adults	-0.0000556	0.000333	0.999	-0.000102	0.00143	0.995
	Temperature					
	a_t	b_t	c_t	d_t	e_t	
All	0.999	0.02094	0.02088	-0.00136	-0.00137	

Table S5: Coefficients for host-finding rate calculation. Host-finding rates of different life stages of *I. scapularis* across the host density types are very difficult to estimate and at best represent crude estimates based on the perceived proportion of time a host type will spend in microhabitats where it may contact host-seeking ticks of a given life stage. The values presented here were adapted from Mount et al. (1997b). For immature tick stages, we used higher host-finding rates for highly active small terrestrial mammals and lower host-finding rates for host types including birds (spending less time on the ground), reptiles (less active and thus covering less ground) or larger mammals (lower proportion of body surface within core tick host-seeking height, especially in leaf litter areas with limited emerging vegetation).

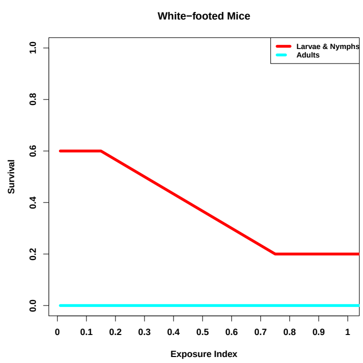
Host type	**Larvae and Nymphs**	**Adults**
WFM	0.01	—
SHREW	0.01	—
SMB	0.001	—
REP	0.005	—
MSM	0.025	0.025
WTD	0.05	0.1

Table S6: Life history parameters for hosts. Hosts are assumed to be maintained at a constant density, and so birth and death rates are set equal to the inverse of the average life expectancy. The values presented here were adapted from Mount et al. (1997b) to represent shorter life spans for small mammals, birds and reptiles compared to medium-sized mammals and white-tailed deer.

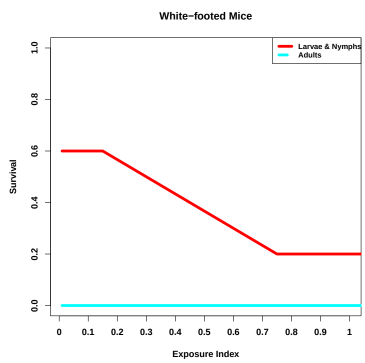
Host type	**Average lifespan**	**Turnover rate**
WFM	6 months	0.038
SHREW	6 months	0.038
SMB	6 months	0.038
REP	6 months	0.038
MSM	1 year	0.0192
WTD	2 years	0.0096

Table S7: Infection parameters. The data across host types for proportions of *I. scapularis* ticks (larvae or nymphs) acquiring *B. burgdorferi* s.s. infection while feeding and passing infection transstadially are based on combined published information from experimental laboratory studies and ticks collected from animals in the field and allowed to molt before being examined for infection. In addition to the studies reviewed by Mount et al. (1997b), the values presented here also considered more recent data from the following key studies: Brisson and Dykhuizen (2006); Brisson et al. (2007); Giardina et al. (2000); Hanincová et al. (2006); LoGiudice et al. (2003); Markowski et al. (1998); Norris et al. (1996). Data for the proportion of infected *I. scapularis* ticks (nymphs or adults) that transmit *B. burgdorferi* s.s. spirochetes to a host while taking a blood meal are based on experimental laboratory studies (reviewed by Eisen and Eisen (2018)). Transmission of the spirochete to the host does not imply infection of that host, rather that is modeled in the host to tick process. Data for the likelihood of transstadial passage of *B. burgdorferi* s.s. spirochetes from larva to nymph or nymph to adult are based on unpublished data from experimental laboratory studies and the older studies previously reviewed by Mount et al. (1997b). The transovarial transmission rate for *B. burgdorferi* s.s. was set to zero based on the recent realization that early reports of infection in field-collected unfed larvae most likely failed to distinguish this spirochete from *B. miyamotoi*, which is passed transovarially in *I. scapularis* Han et al. (2019); Lynn et al. (2019); Rollend et al. (2013); Scoles et al. (2001).

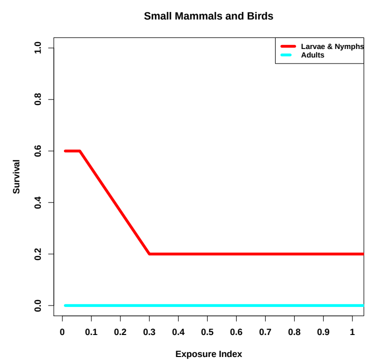
Infection type	**Rate**
WFM to ticks	0.7
SHREW to ticks	0.5
SMB to ticks	0.1
REP to ticks	0.0
MSM to ticks	0.05
WTD to ticks	0.0
Ticks to all hosts	0.9
Ticks transstadial: egg to larva	1.0
Ticks transstadial: larva to nymph	1.0
Ticks transstadial: nymph to adult	1.0
Ticks transovarial	0.0



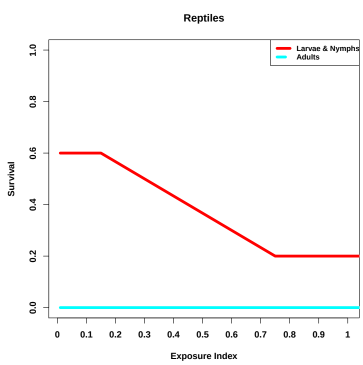
(a) WFM



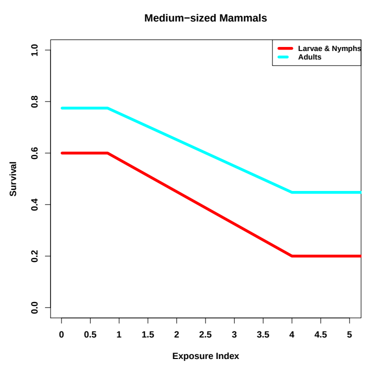
(b) SHREW



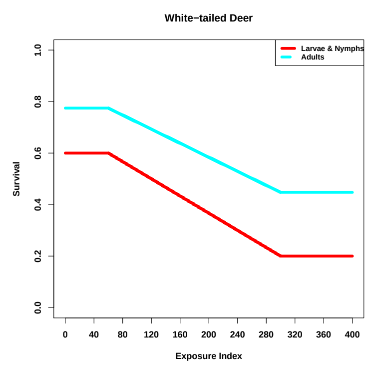
(c) SMB



(d) REP



(e) MSM



(f) WTD

Figure S2: Density-dependent on-host survival rates based on the exposure index. The red line is the base-line survival on host for immature stages, while the blue line is the survival of the adult stage. Adults do not feed on WFM, SHREW, SMB, or REP, so that survival is zero for all exposure indices. All other lines follow the same structure with the highest survival at the lowest exposure index.

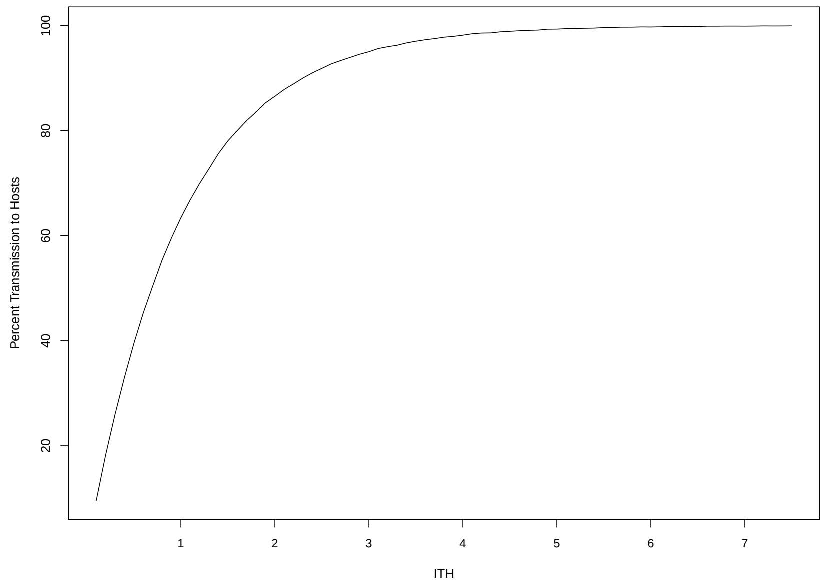


Figure S3: Relationship between infected ticks per host and percent of hosts that are predicted to be infected. Since a host can only be infected one time but can be fed upon by multiple infected ticks, this graph shows the scaling probability for the infection rate based upon the average number of infected ticks feeding on a given host at the same time. It is assumed that some hosts will have more than one tick while others have none, and thus this relationship allows the translation of an individual transmission process to an average population process.

Table S8: Results from DIN Sensitivity Analysis. These are the partial rank correlation coefficients for the variation in the average DIN with the correlation values greater than 0.1 and a p-value less than 0.05. DL5, DL6, and T2 are parameters in the host finding equations for larvae and nymphs. Note that the sign for each PRCC value reflects if the parameter is added or subtracted in the model equation.

Parameter	PRCC
Survival: Temperature d_t	-0.589
Survival: Temperature e_t	0.568
Survival: Temperature b_t	-0.384
sHREW to Tick Transmission	0.368
WFM to Tick Transmission	0.367
Survival: Temperature c_t	0.328
Immature Host Finding Rate DL6	0.176
WFM Host Density	0.161
Immature Host Finding Rate DL5	-0.158
Immature Host Finding Rate T2	0.129
MSM Host Density	-0.123
WFM turn-over	-0.121
WTD EI1	-0.118
WTD Host Density	-0.101

Table S9: Results from DON Sensitivity Analysis. These are the partial rank correlation coefficients for the variation in the maximum DON with a p-value less than 0.05 and the correlation values greater than 0.1. DL2 and DL3 are parameters in the host finding equations for larvae and nymphs. Note that the sign for each PRCC value reflects if the parameter is added or subtracted in the model equation.

Parameter	PRCC
Survival: Temperature d_t	-0.575
Survival: Temperature e_t	0.515
Immature Host Finding Rate DL3	-0.410
Immature Host Finding Rate DL2	0.368
Survival: Temperature b_t	-0.351
Survival: Temperature c_t	0.287
Base survival for adults	-0.130
Minimum saturation deficit	0.114