# Supplementary Materials

Here, we are providing the underlying formula of our system dynamics model. Each module, has its own section.

## Abbreviations and notes:

SA: Situational Awareness

DMNL: Dimensionless

~: explains the units of each variable in our model

SMOOTH, FIXED DELAY: are delay functions in system dynamics modeling

Switch: we can turn on and off this variable

SUM: a function in the software that sums up values over the walkways

Initial Time= 0

Final Time= 4380

 ~ Day

## Awareness and SA

SA= INTEG (

 Increase in SA, Initial SA)

 ~ Dmnl

Desired SA=

 Actual Awareness-Actual SA

 ~ Dmnl

Increase in SA=

Desired SA/Average Time to Become SA

~ Dmnl/Day

Change in Awareness=

 Gap in Awareness/Average Time to Become Aware

 ~ Dmnl/Day

Gap in Awareness=

 Desired Awareness-Actual Awareness

 ~ Dmnl

Actual Awareness= INTEG (

 Change in Awareness, Initial Awareness)

 ~ Dmnl

## Rodents

Rodent Infection Rate[Walkway]=

Probability of Getting One Bite[Walkway]\*(Possible Infected Ticks[Walkway]/Total Tick Population[Walkway])\*"Non-Infected Rodents"[Walkway]\*(1-Probability of Death for Rodents)/Average Time Delay of Infection for Rodents

 ~ Rodents/Day

Non-Infected Rodents Dying[Walkway]=

 "Non-Infected Rodents"[Walkway]\*Probability of Death for Rodents/Average Time of Death for Rodents

 ~ Rodents/Day

Infected Rodents Dying[Walkway]=

 Infected Rodents[Walkway]/Ave Time of Death for Rodents

 ~ Rodents/Day

Infected Rodents[Walkway]= INTEG (

 Rodent Infection Rate[Walkway]-Infected Rodents Dying[Walkway],

 Initial Number of Infected Rodents[Walkway])

 ~ Rodents

"Non-Infected Rodents"[Walkway]= INTEG (

Aging Rate[Walkway]-Rodent Infection[Walkway]-Non-Infected Rodents Dying[Walkway\], Initial Number of Rodents[Walkway])

 ~ Rodents

Not Young[Walkway]=

 Young[Walkway]/Ave Time of Aging of Young Rodents

 ~ Rodents/Day

Aging Rate of Young Rodents[Walkway]=

 Not Young[Walkway]\*Survival Rate

 ~ Rodents/Day

Rodent Birth Rate[Walkway]=

(Infected Rodents[Walkway]+"Non-Infected Rodents"[Walkway])\*Fraction of Birth\*PULSE TRAIN(\365, 1, 365, 4380)\*"Ratio of Female/Male in Rodents"

 ~ Rodents/Day

Young Rodents Dying[Walkway]=

 Not Young[Walkway]\*(1-Survival Rate)

 ~ Rodents/Day

Total Rodent Population[Walkway]=

 Infected Rodents[Walkway]+"Non-Infected Rodents"[Walkway]+Young Rodents[Walkway]

 ~ Rodents

## Ticks

Density of Total Tick Population[Walkway]=

 (Total Tick Population[Walkway]/Area of Each Walkway[Walkway])\*1000

 ~ Tick/Thousand m2

"% Infected Blood"[Walkway]=

 (Infected Rodents[Walkway]/(Total Rodent Population[Walkway]))

 ~ Dmnl

Total Tick Population[Walkway]=

Infected Females[Walkway]+Infected Males[Walkway]+Infected Nymphs[Walkway]+Larva[Walkway]+"Non-Infected Adult Females"\[Walkway]+"Non-Infected Adult Males"[Walkway]+"Non-Infected Nymphs"[Walkway]+Mated Females[Walkway]

 ~ Tick

Add Spring Non Infected[Walkway]= DELAY FIXED (

 Switch Spring\*Female Mating Rate[Walkway]\*Number of Eggs per each Adult female, Ave Delay in Mating Spring\

 [Walkway], Switch Spring\*Female Mating Rate[Walkway]\*Number of Eggs per each Adult female\)

 ~ Tick/Day

Add Fall Non Infected[Walkway]= DELAY FIXED (

 Fall Time\*Female Mating Rate[Walkway]\*Number of Eggs per each Adult female, Ave Delay in Mating Fall\

 [Walkway], Fall Time\*Female Mating Rate[Walkway]\*Number of Eggs per each Adult female)

 ~ Tick/Day

Add Spring Infected[Walkway]= DELAY FIXED (

Switch Spring\*Infected Female Mating Rate[Walkway]\*Number of Eggs per each Adult female\, Ave Delay in Mating Spring[Walkway], Switch Spring\*Infected Female Mating Rate[Walkway]\\*Number of Eggs per each Adult female)

 ~ Tick/Day

Total Infected Ticks of all Walkways[Walkway]=

 SUM (Possible Infected Ticks[Walkway!])

 ~ Tick

"Bitten by an Infected Tick (Nymphs or Adults)"[Walkway]=

 LD Risk Modeled by Public Awareness[Walkway]\*Susceptible Population[Walkway]/Average Infection Time

 ~ Person/Day

Larva Getting Infected[Walkway]=

Larva Becoming Nymph[Walkway]\*(1-"Probability of Death for Larva"[Walkway])\*("% Infected Blood"[Walkway\])\*Switch Winter\*Coefficient

 ~ Tick/Day

Nymph Growing into Infected Female[Walkway]=

Nymph Becoming Adults[Walkway]\*(1-"Probability of Death for Nymphs"[Walkway])\*("% Infected Blood"[Walkway\])\*(1-Proportion Becoming Male)\*Switch Winter\*Switch Summer\*Coefficient

 ~ Tick/Day

Nymph Growing into Infected Male[Walkway]=

Nymph Becoming Adults[Walkway]\*(1-"Probability of Death for Nymphs"[Walkway])\*("% Infected Blood"[Walkway\])\*Proportion Becoming Male\*Switch Winter\*Switch Summer\*Coefficient

 ~ Tick/Day

Risk Factor of Infected Tick Bites[Walkway]=

 "Risk of Tick Encounter by Walkway Type - Organic"[Walkway]\*"Ratio of Infected Ticks-Total Tick"\[Walkway]

 ~ Dmnl

Probability of Getting One Bite[Walkway]=

 1/(1+EXP(-Steepness[Walkway]\*Density of Total Tick Population[Walkway]+Min PGO[Walkway]))

 ~ Dmnl

 ~ Logistic Function

"Risk of Tick Encounter by Walkway Type - Organic"[Walkway]=

 1/(1+EXP(-Steepness 1[Walkway]\*Density of Total Tick Population[Walkway]+YYYY[Walkway]))

 ~ Dmnl

Density of Infected Ticks[Walkway]=

 (Possible Infected Ticks[Walkway]/Area of Each Walkway[Walkway])\*1000

 ~ Tick/Thousand m2

"Nymph -> Adult Transition Rate Female"[Walkway]=

 Nymph Becoming Adults[Walkway]\*(1-"Probability of Death for Nymphs"[Walkway])\*(1-"% Infected Blood"\

 [Walkway])\*(1-Proportion Becoming Male)\*Switch Winter\*Switch Summer

 ~ Tick/Day

"Nymph -> Adult Transition Rate Male"[Walkway]=

 Nymph Becoming Adults[Walkway]\*(1-"Probability of Death for Nymphs"[Walkway])\*(1-"% Infected Blood"\

 [Walkway])\*Proportion Becoming Male\*Switch Winter\*Switch Summer

 ~ Tick/Day

"Larva -> Nymph Transition Rate"[Walkway]=

 Larva Becoming Nymph[Walkway]\*(1-"Probability of Death for Larva"[Walkway])\*(1-"% Infected Blood"[\

 Walkway])\*Switch Winter

 ~ Tick/Day

Birth Rate[Walkway]= DELAY FIXED (

 (Adults Laying Eggs[Walkway]+Add Fall Non Infected[Walkway]+Add Spring Infected[Walkway]+Add Spring Non Infected\

 [Walkway])\*Fraction of Become Larva[Walkway], Average Time of Becoming Larva[Walkway], 0)

 ~ Tick/Day

Female Mating Rate[Walkway]=

 (Fall Time \*"Non-Infected Adult Females"[Walkway]\*(Rate of Mating Fall)\*(1-"Probability of Death for Adults"\

 [Walkway])/Ave Delay in Mating Fall[Walkway]) + (Switch Spring \* "Non-Infected Adult Females"\

 [Walkway]\*(Rate of Mating Spring)\*(1-"Probability of Death for Adults"[Walkway])/Ave Delay in Mating Spring\[Walkway])

 ~ Tick/Day

"Infected Nymph -> Infected Adult Transtion Rate Female"[Walkway]=

 "I-Nymph Becoming Adult"[Walkway]\*(1-"Probability of Death for Nymphs"[Walkway])\*(1-Proportion Becoming Male\

 )\*Switch Winter\*Switch Summer

 ~ Tick/Day

Male Mating Rate[Walkway]=

 (Fall Time\*MIN(Female Mating Rate[Walkway]/"Mating Factor female-male", "Non-Infected Adult Males"\

 [Walkway]/Ave Delay in Mating Fall[Walkway])\*(1-"Probability of Death for Adults"[Walkway])) + (Switch Spring

 \*MIN(Female Mating Rate[Walkway]/"Mating Factor female-male", "Non-Infected Adult Males"\

 [Walkway]/Ave Delay in Mating Spring[Walkway])\*(1-"Probability of Death for Adults"[Walkway]))

 ~ Tick/Day

"Infected Nymph -> Infected Adult Transtion Rate Male"[Walkway]=

 "I-Nymph Becoming Adult"[Walkway]\*(1-"Probability of Death for Nymphs"[Walkway])\*Proportion Becoming Male\

 \*Switch Winter\*Switch Summer

 ~ Tick/Day

Infected Female Mating Rate[Walkway]=

 (Fall Time \* Infected Females[Walkway]\*(Rate of Mating Fall)\*(1-"Probability of Death for Adults"\

 [Walkway])/Ave Delay in Mating Fall[Walkway]) + (Switch Spring \* Infected Females[Walkway]\*(\

 Rate of Mating Spring)\*(1-"Probability of Death for Adults"[Walkway])/Ave Delay in Mating Spring\[Walkway])

 ~ Tick/Day

Infected Male Mating Rate[Walkway]=

 (Fall Time\*MIN(Infected Female Mating Rate[Walkway]/"Mating Factor female-male", Infected Males\

 [Walkway]/Ave Delay in Mating Fall[Walkway])\*(1-"Probability of Death for Adults"[Walkway])) + (Switch Spring

 \*MIN(Infected Female Mating Rate[Walkway]/"Mating Factor female-male", Infected Males[Walkway\

 ]/Ave Delay in Mating Spring[Walkway])\*(1-"Probability of Death for Adults"[Walkway]))

 ~ Tick/Day

"Non-Infected Adult Females"[Walkway]= INTEG (

 ("Nymph -> Adult Transtion Rate Female"[Walkway]-"Non-Infected Adults-Female Dying"[Walkway]-Female Mating Rate\

 [Walkway]),Initial Non-Infected Adult Female[Walkway])

 ~ Tick

"Non-Infected Adults-Female Dying"[Walkway]=

 "Non-Infected Adult Females"[Walkway]\*Switch Killing Adults/TIME STEP

 ~ Tick/Day

Non-Infected Adults-Males Dying[Walkway]=

 "Non-Infected Adult Males"[Walkway]\*Switch Killing Adults/TIME STEP

 ~ Tick/Day

Infected Adults-Male Dying[Walkway]=

 Infected Males[Walkway]\*Switch Killing Adults/TIME STEP

 ~ Tick/Day

"Infected Adults-Female Dying"[Walkway]=

 Infected Females[Walkway]\*Switch Killing Adults/TIME STEP

 ~ Tick/Day

Infected Nymphs Dying[Walkway]=

 Infected Nymphs[Walkway]\*Switch Killing Nymphs/TIME STEP

 ~ Tick/Day

Non-Infected Nymphs Dying[Walkway]=

 "Non-Infected Nymphs"[Walkway]\*Switch Killing Nymphs/TIME STEP

 ~ Tick/Day

Infected Females[Walkway]= INTEG (

 "Infected Nymph -> Infected Adult Transition Rate Female"[Walkway]+Nymph Growing into Infected Female\

 [Walkway]-"Infected Adults-Female Dying"[Walkway]-Infected Female Mating Rate[Walkway], Initial Infected Females[Walkway])

 ~ Tick

Eggs[Walkway]= INTEG (

 Add Fall Non Infected[Walkway]+Add Spring Infected[Walkway]+Add Spring Non Infected[Walkway]+\

 Adults Laying Eggs[Walkway]-Birth Rate[Walkway]-Eggs Removal[Walkway],0.001)

 ~ Tick

Adults Laying Eggs[Walkway]= DELAY FIXED (

 Fall Time\*Infected Female Mating Rate[Walkway]\*Number of Eggs per each Adult female, \

 Ave Delay in Mating Fall[Walkway], Fall Time\*Infected Female Mating Rate[Walkway]\*Number of Eggs per each Adult female\)

 ~ Tick/Day

Eggs Removal[Walkway]=

 Eggs[Walkway]\*Switch Killing Eggs/TIME STEP

 ~ Tick/Day

"Ratio of Infected Ticks/Total Tick"[Walkway]=

 Possible Infected Ticks[Walkway]/Total Tick Population[Walkway]

 ~ Dmnl

"Non-Infected Nymphs"[Walkway]= INTEG (

 ("Larva -> Nymph Transition Rate"[Walkway]-Non-Infected Nymphs Dying[Walkway]-"Nymph -> Adult Transition Rate Female"\

 [Walkway]-"Nymph -> Adult Transtion Rate Male"[Walkway]-Nymph Growing into Infected Female\

 [Walkway]-Nymph Growing into Infected Male[Walkway]),0.001)

 ~ Tick

Larva[Walkway]= INTEG (

 Birth Rate[Walkway]-Larva Dying[Walkway]-"Larva -> Nymph Transition Rate"[Walkway]-Larva Getting Infected\[Walkway],

 Initial Larva[Walkway])

 ~ Tick

Mated Females[Walkway]= INTEG (

 Female Mating Rate[Walkway]+Infected Female Mating Rate[Walkway]-Dying[Walkway], Initial Mated Females[Walkway])

 ~ Tick

"Non-Infected Adult Males"[Walkway]= INTEG (

 "Nymph -> Adult Transtion Rate Male"[Walkway]-Non-Infected Adults-Males Dying[Walkway]-Male Mating Rate[Walkway],

 Initial Non-Infected Adult Males[Walkway])

 ~ Tick

Infected Males[Walkway]= INTEG (

 "Infected Nymph -> Infected Adult Transition Rate Male"[Walkway]+Nymph Growing into Infected Male\

 [Walkway]-Infected Adults-Male Dying[Walkway]-Infected Male Mating Rate[Walkway], Initial Infected Males[Walkway])

 ~ Tick

Infected Nymphs[Walkway]= INTEG (

 Larva Getting Infected[Walkway]-Infected Nymphs Dying[Walkway]-"Infected Nymph -> Infected Adult Transition Rate Female"\

 [Walkway]-"Infected Nymph -> Infected Adult Transition Rate Male"[Walkway],0.001)

 ~ Tick

Mated Female Dying[Walkway]=

 Mated Females[Walkway]/Average Time of Death for Mated Females[Walkway]

 ~ Tick/Day

"Infected-Nymph Becoming Adult"[Walkway]=

 Infected Nymphs[Walkway]/Ave Time of Becoming Adult[Walkway]

 ~ Tick/Day

Initial Number of Eggs[Walkway]=SAMPLE IF TRUE(

 Time = 1, (Female Mating Rate[Walkway]+Infected Female Mating Rate[Walkway])\*Number of Eggs per each Adult female\

 \*"1 Day", (Female Mating Rate[Walkway]+Infected Female Mating Rate[Walkway])\*Number of Eggs per each Adult female\

 \*"1 Day")

 ~ Tick

Larva Becoming Nymph[Walkway]=

 Larva[Walkway]/Ave Time of Becoming Nymph[Walkway]

 ~ Tick/Day

Larva Out of eggs[Walkway]=

 Eggs[Walkway]/Average Time of Becoming Larva[Walkway]

 ~ Tick/Day

Possible Infected Ticks[Walkway]=

 Infected Nymphs[Walkway]+Total Infected Adult Ticks[Walkway]

 ~ Tick

Nymph Becoming Adults[Walkway]=

 "Non-Infected Nymphs"[Walkway]/Ave Time of Becoming Adult[Walkway]

 ~ Tick/Day

Total Infected Adult Ticks[Walkway]=

 Infected Adult Females[Walkway]+Infected Adult Males[Walkway]

 ~ Tick

## Human Risk

Overall Human Risk[Walkway]=

 Behavioral[Walkway]\*Effect of Awareness on LD Risk

 ~ Dmnl

LD Risk Modeled by Public Awareness[Walkway]=

 Overall Human Risk[Walkway]\*Risk Factor of Infected Tick Bites[Walkway]

 ~ Dmnl

"Risky Behavior in Terms of Clothing & Activity"[Walkway]=

 GET XLS CONSTANTS( 'Subs.XLS', 'Human Risk', 'B2\*' )

 ~ Dmnl

## SI

Susceptible Population[Walkway]= INTEG (

 Recovery Rate from LD[Walkway]+Recovery Rate 2[Walkway]-"Bitten by an Infected Tick (Nymphs or Adults)"\[Walkway],

 Number of Times People Pass a Walkway in a Day[Walkway]/Average Time a Person Pass a Walkway\)

 ~ Person

"Infected Population with (LD)"[Walkway]= INTEG (

 "Bitten by an Infected Tick (Nymphs or Adults)"[Walkway]-Developing Post Treatment Lyme Disease\

 [Walkway]-Recovery Rate from LD[Walkway],

 0)

 ~ Person

Recovery Rate from LD[Walkway]=

 (1-"Fration of Cases Becoming Chronic (Post Treatment Lyme Disease)"[Walkway])\*"Infected Population with (LD)"\

 [Walkway]/Average Recovery Time After Developing LD

 ~ Person/Day

Recovery Rate 2[Walkway]=

 Post Treatment Lyme Disease[Walkway]/Average Recovery Time After The Post Treatment Stage

 ~ Person/Day

Post Treatment Lyme Disease[Walkway]= INTEG (

 Developing Post Treatment Lyme Disease[Walkway]-Recovery Rate 2[Walkway],0)

 ~ Person

Developing Post Treatment Lyme Disease[Walkway]=

 "Infected Population with (LD)"[Walkway]\*"Fraction of Cases Becoming Chronic (Post Treatment Lyme Disease)"\

 [Walkway]/Ave Time Developing Post Treatment Lyme Disease[Walkway]

 ~ Person/Day

## Switches

Summer Time=

 IF THEN ELSE((Time>151:AND:Time<=242):OR:(Time>516:AND:Time<=607):OR:(Time>881:AND:Time\

 <=972):OR:(Time>1246:AND:Time<=1337):OR:(Time>1611:AND:Time<=1702):OR:(Time>1976:AND:\

 Time<=2067):OR:(Time>2341:AND:Time<=2432):OR:(Time>2706:AND:Time<=2797):OR:(Time>3071\

 :AND:Time<=3162):OR:(Time>3436:AND:Time<=3527):OR:(Time>3801:AND:Time<=3892):OR:(Time\

 >4166:AND:Time<=4257), 1, 0)

 ~ Dmnl

Switch Not Summer=

 IF THEN ELSE((Time>151:AND:Time<=242):OR:(Time>516:AND:Time<=607):OR:(Time>881:AND:Time\

 <=972):OR:(Time>1246:AND:Time<=1337):OR:(Time>1611:AND:Time<=1702):OR:(Time>1976:AND:\

 Time<=2067):OR:(Time>2341:AND:Time<=2432):OR:(Time>2706:AND:Time<=2797):OR:(Time>3071\

 :AND:Time<=3162):OR:(Time>3436:AND:Time<=3527):OR:(Time>3801:AND:Time<=3892):OR:(Time\

 >4166:AND:Time<=4257), 0, 1)

 ~ Dmnl

Winter Time=

 IF THEN ELSE((Time>=0:AND:Time<=60):OR:(Time>=333:AND:Time<=425):OR:(Time>=698:AND:Time\

 <=790):OR:(Time>=1063:AND:Time<=1155):OR:(Time>=1428:AND:Time<=1520):OR:(Time>=1793\

 :AND:Time<=1885):OR:(Time>=2158:AND:Time<=2250):OR:(Time>=2523:AND:Time<=2615):OR:(\

 Time>=2888:AND:Time<=2980):OR:(Time>=3253:AND:Time<=3345):OR:(Time>=3618:AND:Time<=\

 3710):OR:(Time>=3983:AND:Time<=4075):OR:(Time>=4348:AND:Time<=4440), 1, 0)

 ~ Dmnl

Switch Not Winter=

 IF THEN ELSE((Time>=0:AND:Time<=60):OR:(Time>=333:AND:Time<=425):OR:(Time>=698:AND:Time\

 <=790):OR:(Time>=1063:AND:Time<=1155):OR:(Time>=1428:AND:Time<=1520):OR:(Time>=1793\

 :AND:Time<=1885):OR:(Time>=2158:AND:Time<=2250):OR:(Time>=2523:AND:Time<=2615):OR:(\

 Time>=2888:AND:Time<=2980):OR:(Time>=3253:AND:Time<=3345):OR:(Time>=3618:AND:Time<=\

 3710):OR:(Time>=3983:AND:Time<=4075):OR:(Time>=4348:AND:Time<=4440), 0, 1)

 ~ Dmnl

Switch Killing Eggs=

 IF THEN ELSE((Time=273):OR:(Time=642):OR:(Time=1007):OR:(Time=1372):OR:(Time=1737):OR:\

 (Time=2102):OR:(Time=2477):OR:(Time=2832):OR:(Time=3197):OR:(Time=3562):OR:(Time=3927\

 ):OR:(Time=4292), 1, 0)

 ~ Dmnl

Switch Killing Nymphs=

 IF THEN ELSE((Time=333):OR:(Time=698):OR:(Time=1063):OR:(Time=1428):OR:(Time=1793):OR:\

 (Time=2158):OR:(Time=2523):OR:(Time=2888):OR:(Time=3253):OR:(Time=3618):OR:(Time=3983\

 ):OR:(Time=4348), 1, 0)

 ~ Dmnl

Switch Killing Adults=

 IF THEN ELSE((Time=183):OR:(Time=548):OR:(Time=913):OR:(Time=1278):OR:(Time=1643):OR:\

 (Time=2008):OR:(Time=2373):OR:(Time=2738):OR:(Time=3103):OR:(Time=3468):OR:(Time=3833\

 ):OR:(Time=4198), 1, 0)

 ~ Dmnl

Behavioral[Walkway]=

 SMOOTH( ("Risky Behavior in Terms of Clothing & Activity"[Walkway]\*(Summer Time+Fall Time)) +

((Winter Time + Switch Spring) \* Decrease Clothing Risk\*"Risky Behavior in Terms of Clothing & Activity"[Walkway]), "1 month"\)

 ~ Dmnl

Effect of Awareness on LD Risk=

 (Initial X-Min X)\*(EXP((-SA)/Beta))+Min X

 ~ Dmnl

Rate of Mating Fall=

 IF THEN ELSE((Time>242:AND:Time<333):OR:(Time>607:AND:Time<698):OR:(Time>972:AND:Time\

 <1063):OR:(Time>1337:AND:Time<1428):OR:(Time>1702:AND:Time<1793):OR:(Time>2067:AND:\

 Time<2158):OR:(Time>2432:AND:Time<2523):OR:(Time>2797:AND:Time<2888):OR:(Time>3162:AND:\

 Time<3253):OR:(Time>3527:AND:Time<3618):OR:(Time>3892:AND:Time<3983):OR:(Time>4257:AND:\

 Time<4348), 0.556, 0)

 ~ Dmnl

Rate of Mating Spring=

 IF THEN ELSE((Time>60:AND:Time<=151):OR:(Time>425:AND:Time<=516):OR:(Time>790:AND:Time\

 <=881):OR:(Time>1155:AND:Time<=1246):OR:(Time>1520:AND:Time<=1611):OR:(Time>1885:AND:\

 Time<=1976):OR:(Time>2250:AND:Time<=2341):OR:(Time>2615:AND:Time<=2706):OR:(Time>2980\

 :AND:Time<=3071):OR:(Time>3345:AND:Time<=3436):OR:(Time>3710:AND:Time<=3801):OR:(Time\

 >4075:AND:Time<=4166), 0.625, 0)

 ~ Dmnl