

Dynamics of the LaCrosse Virus

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What is La Crosse Virus (LACV)?

- La Crosse Virus (LACV) was first isolated in La Crosse, Wisconsin in 1965.
- LACV is the **leading cause of arboviral neuroinvasive disease in children** in the United States.
- Most prevalent in **Appalachia** and people under 18 years old.
- Symptoms (when present) include:
 - Fever
 - Nausea and vomiting
 - Headache
 - Behavioral changes
- Less reporting $\Rightarrow$ less funding $\Rightarrow$ less reporting...

Mosquito Life Cycle

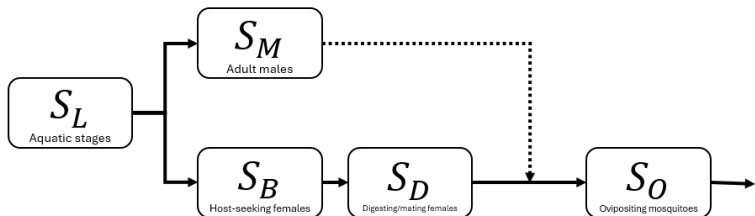


Figure: Mosquito Life Cycle

The Model

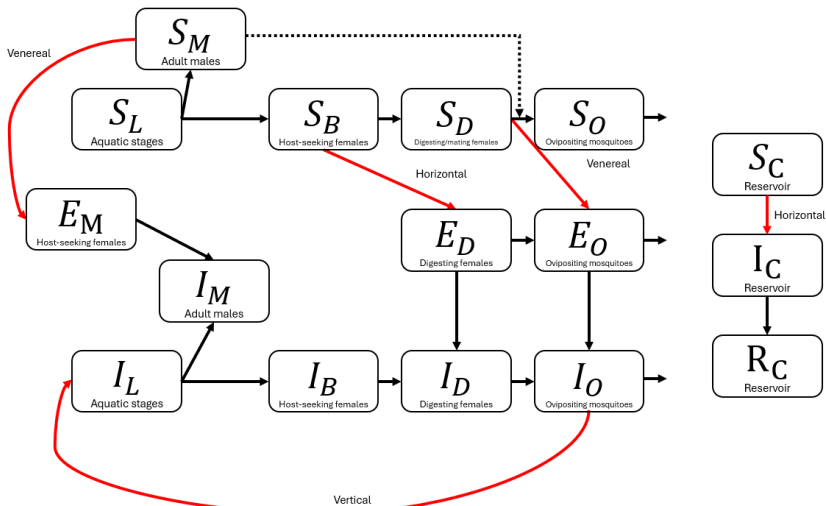


Figure: LACV Model

- $\dot{S}_L = \frac{\gamma}{K}(S_O + (1 - \theta)I_O + (1 - \theta')E_O)[K - (S_L + I_L)] - aS_L - \mu_2 S_L$

- $\dot{S}_L = \frac{\gamma}{K}(S_O + (1 - \theta)I_O + (1 - \theta')E_O)[K - (S_L + I_L)] - aS_L - \mu_2 S_L$
- $\dot{S}_M = raS_L - \mu_1 S_M - \tau p \alpha_{IS} S_M \left(\frac{I_D}{S_D + E_D + I_D} \right)$
- $\dot{S}_B = (1 - r)aS_L - bS_B - \mu_1 S_B$

Gaps in the literature

- Venereal transmission is very understudied
- Erwin[1] claims LACV is maintained through the zoonotic cycle by venereal transmission
- Cook[2] acknowledges venereal transmission through a term for horizontal transmission h
- We attempt to unpack these venereal transmission terms to develop a more realistic model

- Let p be the probability of contact and α_{ij} represent the probability of successful mating.
- Then:

$$p\alpha_{SS}S_D\left(\frac{S_M}{S_M + E_M + I_M}\right)$$

will send uninfected females that successfully mated with uninfected males to the S_O compartment

Venereal Transmission

- Every compartment for digesting mosquitoes has a term for leaving the compartment from mating

- $\dot{S}_D = \dots - pS_D \left(\frac{\alpha_{SS}S_M + \alpha_{SE}E_M + \alpha_{SI}I_M}{S_M + E_M + I_M} \right)$

- $\dot{E}_D = \dots - pE_D \left(\frac{\alpha_{ES}S_M + \alpha_{EE}E_M + \alpha_{EI}I_M}{S_M + E_M + I_M} \right)$

- $\dot{I}_D = \dots - pI_D \left(\frac{\alpha_{IS}S_M + \alpha_{IE}E_M + \alpha_{II}I_M}{S_M + E_M + I_M} \right)$

Venereal Transmission Cont.

- It also provides movement between SEI compartments for males

- $\dot{S}_M = raS_L - \mu_1 S_M - \tau p \alpha_{IS} S_M \left(\frac{I_D}{S_D + E_D + I_D} \right)$

- $\dot{E}_M = \tau p \alpha_{IS} S_M \left(\frac{I_D}{S_D + E_D + I_D} \right) - \nu E_M - \mu_1 E_M$

- $\dot{I}_M = raI_L + \nu E_M - \mu_1 I_M$

The Full Model

$$(1.1) \quad \dot{S}_L = \frac{\gamma}{K}(S_O + (1 - \theta)I_O + (1 - \theta')E_O)[K - (S_L + I_L)] - aS_L - \mu_2 S_L$$

$$(1.2) \quad \dot{S}_M = raS_L - \mu_1 S_M - \tau p \alpha_{IS} S_M \left(\frac{I_D}{S_D + E_D + I_D} \right)$$

$$(1.3) \quad \dot{S}_B = (1 - r)aS_L - bS_B - \mu_1 S_B$$

$$(1.4) \quad \dot{S}_D = bS_B \left(\frac{S_C + R_C + (1 - \beta)I_C}{S_C + I_C + R_C} \right) - pS_D \left(\frac{\alpha_{SS}S_M + \alpha_{SE}E_M + \alpha_{SI}I_M}{S_M + E_M + I_M} \right) - \mu_1 S_D$$

$$(1.5) \quad \dot{S}_O = pS_D \left(\frac{\alpha_{SS}S_M + \alpha_{SE}E_M + \alpha_{SI}(1 - \tau)I_M}{S_M + E_M + I_M} \right) - \tilde{\mu}S_O$$

$$(1.6) \quad \dot{E}_M = \tau p \alpha_{IS} S_M \left(\frac{I_D}{S_D + E_D + I_D} \right) - \nu E_M - \mu_1 E_M$$

$$(1.7) \quad \dot{E}_D = \beta bS_B \left(\frac{I_C}{S_C + I_C + R_C} \right) - pE_D \left(\frac{\alpha_{ES}S_M + \alpha_{EE}E_M + \alpha_{EI}I_M}{S_M + E_M + I_M} \right) - \varphi E_D - \mu_1 E_D$$

$$(1.8) \quad \dot{E}_O = \tau p \alpha_{SI} S_D \left(\frac{I_M}{S_M + E_M + I_M} \right) + pE_D \left(\frac{\alpha_{ES}S_M + \alpha_{EE}E_M + \alpha_{EI}I_M}{S_M + E_M + I_M} \right) - \psi E_O - \tilde{\mu}E_O$$

$$(1.9) \quad \dot{I}_L = \frac{\gamma}{K}(\theta I_O + \theta' E_O)[K - (S_L + I_L)] - aI_L - \mu_2 I_L$$

$$(1.10) \quad \dot{I}_M = raI_L + \nu E_M - \mu_1 I_M$$

$$(1.11) \quad \dot{I}_B = (1 - r)aI_L - bI_B - \mu_1 I_B$$

$$(1.12) \quad \dot{I}_D = bI_B + \varphi E_D - pI_D \left(\frac{\alpha_{IS}S_M + \alpha_{IE}E_M + \alpha_{II}I_M}{S_M + E_M + I_M} \right) - \mu_1 I_D$$

$$(1.13) \quad \dot{I}_O = pI_D \left(\frac{\alpha_{IS}S_M + \alpha_{IE}E_M + \alpha_{II}I_M}{S_M + E_M + I_M} \right) + \psi E_O - \tilde{\mu}I_O$$

$$(1.14) \quad \dot{S}_C = -\xi bS_C \left(\frac{S_B + I_B}{S_C + I_C + R_C} \right) \left(\frac{I_B}{S_B + I_B} \right)$$

$$(1.15) \quad \dot{I}_C = \xi bS_C \left(\frac{S_B + I_B}{S_C + I_C + R_C} \right) \left(\frac{I_B}{S_B + I_B} \right) - \omega I_C$$

$$(1.16) \quad \dot{R}_C = \omega I_C$$

Conclusion

- Current Work:
 - Optimal Control Problem
- Future Work
 - Incorporate humans into the model

Thank you!

- ① Erwin PC, Jones TF, Gerhardt RR, Halford SK, Smith AB, Patterson LE, Gottfried KL, Burkhalter KL, Nasci RS, Schaffner W. La Crosse encephalitis in Eastern Tennessee: clinical, environmental, and entomological characteristics from a blinded cohort study. *Am J Epidemiol*. 2002 Jun 1;155(11):1060-5. doi: 10.1093/aje/155.11.1060. PMID: 12034585.
- ② Cook C, Blesi A, Brozak S, Lenhart S, Reed H, et al. (2021) La Crosse virus spread within the mosquito population in Knox County, TN. *PLOS ONE* 16(4): e0249811.
<https://doi.org/10.1371/journal.pone.0249811>