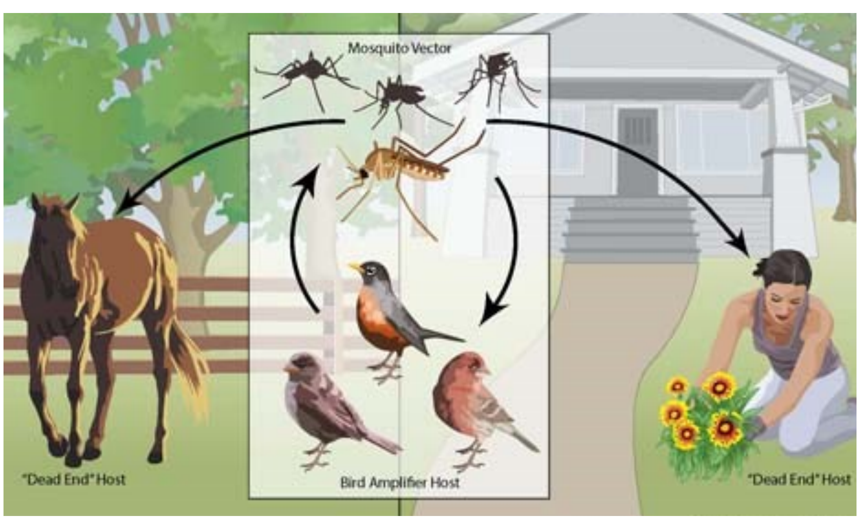
Ecological Modeling of West Nile Virus Risk

West Nile Virus Risk

The South Dakota Mosquito Information Systems (SDMIS) project uses an ecological model to predict West Nile virus (WNV) risk based on a set of mathematical equations combined with recent data on weather and infected mosquitoes.

Some basic relationships between environmental factors and WNV risk have been identified through ecological research on the effects of precipitation, temperature, and immunity cycles in avian hosts. We know, for example, that warmer weather usually means more human cases, but simply documenting this relationship does not tell us why it occurs. A warm day in the sun does not, by itself, give anyone WNV. To understand these relationships, it is necessary to consider the effect of weather on the mosquitoes that transmit the virus.

Although there are numerous mosquito species that carry WNV, in SD the principal vector species is *Culex tarsalis*. In general, the risk of contracting WNV depends on how many infected mosquitoes are present in an area. That number is determined by the abundance of *Cx. tarsalis* mosquitoes and the percentage that are infected, and both of these values can depend on recent weather conditions. Nota-



What is an ecological model?

An ecological model is a mathematical representation of a system found in the real world.

- Most ecological models are constructed to answer a specific question about a particular system.
- Relationships between the parts of the system, like how mosquito populations respond to weather events, are identified using data gathered from research. The relationships are turned into mathematical equations.
- Models are more simplistic than the complex systems they represent. The goal is to isolate the components that are most important.
- Often, assumptions have to be made in order to achieve this goal.
- The model is used to further explore the system and to predict outcomes.
- Models are then be compared to observed data to improve the model and to learn more about the system being studied.

Culex tarsalis habitat in pools created by tire tracks.

bly, a large vector population might be annoying but is not itself enough to raise risk, because the mosquitoes must be infected to transmit the disease.

Precipitation

Although there is a relationship between human risk and precipitation in our model, in SD it is considerably weaker than the relationship with temperature. This difference may be understood by considering the specific effects of precipitation on the mosquito's aquatic phase.

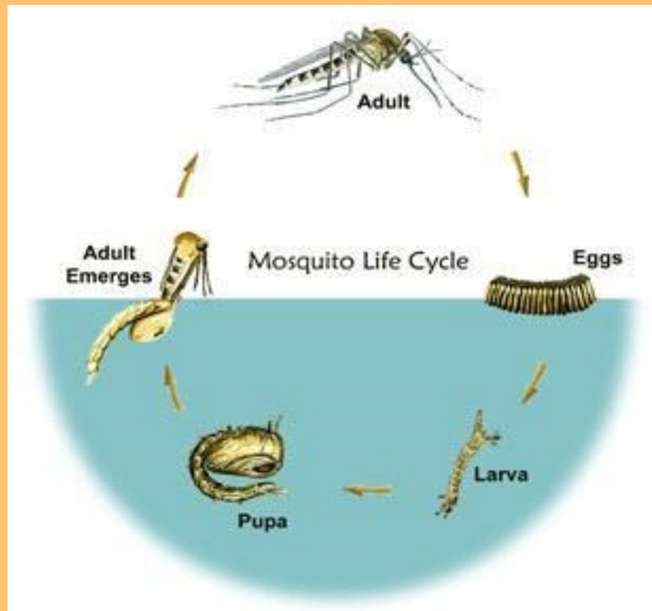
Most importantly, while the mosquito larvae require some body of water in which to develop, rainfall does not trigger the hatching of *Cx. tarsalis* eggs and can even be detrimental to larvae by overfilling shallow depressions, pushing them into larger bodies of water where they do not survive.

Rain does, however, affect the underlying hydrology of the water sources where *Cx. tarsalis* lay their eggs. Some larval habitats, such as temporary pools created by tire tracks in pastures (see photo above), fill with water once the soil has become saturated. Other habitat areas, like irrigated croplands or depressions near livestock waterers that catch water when tanks overflow, are fed by artificial water sources and are not dependent on natural rainfall.

Temperature

Temperature has a strong relationship with human risk; in particular, temperature 2-4 weeks ago is extremely important for understanding human risk today. Generally, the warmer it was in the past, the more human disease we have in the present.

The life cycle of *Cx. tarsalis*, like other mosquitoes, speeds up at higher temperatures. *Culex tarsalis* has been shown to complete a one-generation cycle in 3 to 11 days at approximately 90º F. Not only do warmer temperatures increase numbers of *Cx. tarsalis,* they also increase the frequency of bites by female mosquitoes to obtain blood for the development of their eggs.



Mosquito life cycle of *Cx. tarsalis*.

Temperature also shortens the time that it takes for an infected mosquito to become infectious. After WNV is ingested through a blood meal, the virus enters the mosquito's mid-gut where it multiplies and eventually enters the hemolymph, a fluid that serves as blood for the mosquito. Once the virus reaches the salivary glands, the mosquito can transmit the virus through its bite. At low temperatures a mosquito may not survive long enough to transmit WNV, but as temperature increases this process speeds up, and more mosquitoes will survive long enough to become infectious.

Immunity Cycles in Avian Hosts

Using only recent weather data, ecological models can make general predictions of WNV risk. Warmer weather and moderate precipitation mean there is a potential for more human cases, but this is not enough to explain everything we have seen in South Dakota.

To improve the accuracy of the forecasts, up-to-date infection rate data are incorporated into the model. These data come from mosquitoes trapped and tested for WNV. Currently, 14 counties in SD trap and test. These samples enhance the predictive power of the model by giving us a direct measure of the infection rate of mosquitoes, which depends on the infection rate of the avian host species they feed upon.

The prevalence of the virus in bird populations often follows a cyclical pattern. Outbreak years in human or bird populations are often followed by years of low prevalence (see chart below) because surviving birds gain immunity to the virus in outbreak years. When the number of birds immune to the virus reaches a certain level, transmission is reduced and the portion of the population that is not immune is also protected

This effect wanes over time. As new, susceptible birds are born, the number of immune birds also shrinks as older bird die. As the number of susceptible birds increases, the chances for an outbreak returns.

The trap data provides a precise representation of the prevalence of the virus in the mosquito population, but only for a very small area. Conversely, the recent weather data provides a general picture of what the overall statewide risk could be, but lacks precision. When combined, the two types of data provide a close estimate of risk both locally and at state level.

As with any prediction, there is a level of uncertainty attached to the WNV risk forecast, and predictions for three weeks from are more uncertain than predictions for one week from now. Researches with the SDMIS project are constantly working to improve the ecological model that produces the risk estimates. For weekly risk forecasts of WNV go to

http://mosquito.sdstate.edu

For more information, contact Dr. Michael C. Wimberly (michael.wimberly@sdstate.edu) or Dr. Michael B. Hildreth (michael.hildreth@sdstate.edu).