Calculation and Application of a Vector Index (VI) Reflecting the Number of WN Virus Infected Mosquitoes in a Population.

Roger S. Nasci[1], Michael Doyle[2], Brad J. Biggerstaff[1], Adrienne LeBailly[3]

1. CDC-DVBID, P.O. 2087, Fort Collins, CO 80522; 2. Colorado Mosquito Control, 500 E. 3rd St., Loveland, CO 80573; 3. Larimer County Dept. of Health and Environment, 1525 Blue Spruce Dr., Fort Collins, CO 80524

BACKGROUND. The establishment of West Nile (WN) virus across North America has been accompanied by expanded efforts to monitor WN virus transmission activity in many communities. Surveillance programs use various indicators to demonstrate virus activity. These include detecting evidence of virus in dead birds, dead horses, and mosquitoes; and detection of antibody against WN virus in sentinel birds, wild birds, or horses. While all of these surveillance practices can demonstrate the presence of WN virus in an area, few provide reliable, quantitative indices that may be useful in predictive surveillance programs. Only indices derived from a known and quantifiable surveillance effort conducted over time in an area will provide information that adequately reflects trends in virus transmission activity that may be related to human risk. Of the practices listed above, surveillance efforts are controlled and quantifiable only in mosquito and sentinel-chicken based programs. In these programs, the number of number of sentinel chicken flocks and number of chickens; and the number of mosquito traps set per week is known and allows calculation of meaningful infection rates that reflect virus transmission activity.

PREMISE BEHIND DEVELOPING THE VECTOR INDEX. Mosquito-based arbovirus surveillance provides three pieces of information: The variety of species comprising of the mosquito community; density of each species population (in terms of the number collected in each trap unit of a given trap type); and if the specimens are tested for the presence of arboviruses, the incidence of the agent in the mosquito population. Taken individually, each parameter describes one aspect of the vector community that may affect human risk, but the individual elements don't give a comprehensive estimate of the number of potentially infectious vectors seeking hosts at a given time in the surveillance area.

Parameter	Information provided	Value in surveillance program
Community Composition	Diversity of species in the area	Documents presence of competent vector species in the area.
Population Density	Relative abundance of species in terms of trapping effort	Quantifies the number of individuals of each mosquito species at a given point in time, particularly important for key vector species
Infection Rate	Proportion of the population carrying evidence of the disease agent	Quantifies incidence of infected, potentially infectious mosquitoes in the key vector population. Demonstrates if important bridge vectors are potentially involved.

VECTOR INDEX
To express the arbovirus transmission risk posed by a vector population adequately, information from all three parameters (vector species presence, vector species density, vector species infection rate) must be considered.
The Vector Index (VI) combines all three of the parameters quantified through standard mosquito surveillance procedures in a single value. The VI is simply the estimated average number of infected mosquitoes collected per trap night summed for the key vector species in the area.
Summing the VI for the key vector species incorporates the contribution of more than one species and recognizes the fact that West Nile (WN) virus transmission may involve one or more primary vectors and several accessory or bridge vectors in an area.

DERIVING THE VECTOR INDEX FROM MOSQUITO SURVEILLANCE DATA

$$\text{Vector Index} = \sum_{i=species} \overline{N}_i \hat{P}_i$$

$$\overline{N} = \text{Average Density}\ ,\ \hat{P} = \text{Estimated Infection Rate}$$

See example below

Step 1. Calculate mosquito density

Trap Site	*Cx. tarsalis*	*Cx. pipiens*
1	68	21
2	42	63
3	139	49
4	120	31
5	42	12
6	31	57
Total	442	233
Average per trap night	74	39
SD	41	21

Step 2. Calculate infection rate as proportion

Pools tested for virus			
Pool Number	Species	Number in pool	Positives
1	*Cx. tarsalis*	50	0
2	*Cx. tarsalis*	50	0
3	*Cx. tarsalis*	50	1
4	*Cx. tarsalis*	50	0
5	*Cx. tarsalis*	50	0
6	*Cx. tarsalis*	50	0
7	*Cx pipiens*	50	1
8	*Cx pipiens*	50	0
9	*Cx pipiens*	50	0
10	*Cx pipiens*	50	0
11	*Cx pipiens*	50	0
Cx. tarsalis			
Infection Rate	Lower Limit	Upper Limit	Confidence
0.0033	0.0002	0.0169	0.95
Cx. pipiens			
Infection Rate	Lower Limit	Upper Limit	Confidence
0.0040	0.0002	0.0206	0.95

Step 3. Calculate individual and combined VI

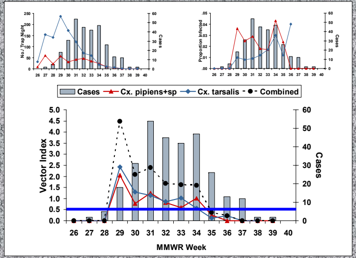
Vector Index Calculation	*Cx. tarsalis*	*Cx. pipiens*
Avg/trap night	74	39
Proportion Infected	0.0033	0.004
VI (individual species)	0.24	0.16
VI=∑ (*Cx. tarsalis, pipiens*)	0.40	

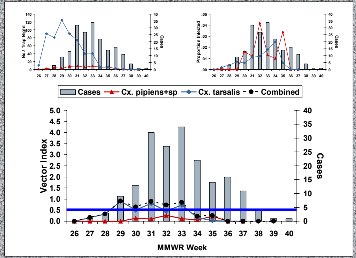
APPLYING THE VI TO SURVEILLANCE DATA

Fort Collins and Loveland Colorado, were surveyed using CO2-baited CDC miniature light traps set at approximately 25-30 sites in each town, each week during the primary arbovirus transmission period (June through September) of 2003 and 2004. During 2004, the light traps were supplemented with gravid traps to obtain more specimens for infection rate estimation, but only the light trap data were used to determine density per trap night. Samples collected in each trap were identified to species and counted. The *Cx. tarsalis*, *Cx. pipiens*, and unidentified *Cx.* species specimens were tested in pools of up to 50 for WN virus RNA using a TaqMan RT-PCR and WN-specific primers/probes. Results from *Cx. pipiens* and *Cx.* species were combined because detailed examination suggested that most of the *Cx.* species were actually *pipiens*. Each week the density, infection rate, individual and combined VI were plotted against the number of human WN cases with onsets during that week. A VI of 0.5 is shown in the graphs below (blue line) demonstrating how the VI can be used to set a threshold for epidemic risk.

2003

Ft Collins **Loveland**

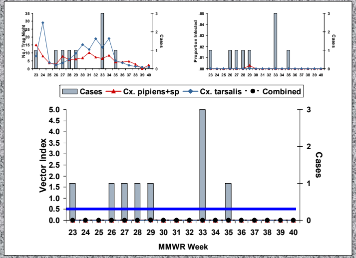


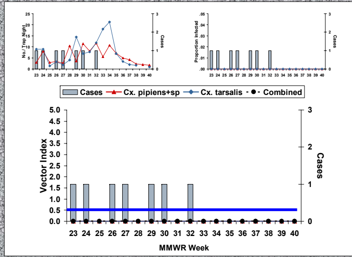


During the WN virus epidemic of 2003, vector densities and infection rates were high in Fort Collins and Loveland. The VI for each week, in each town, was positively correlated with the number of WN human cases with onset dates occurring the following week in the town (Fort Collins r = 0.71; Loveland r = 0.74), demonstrating that the VI can serve as a predictor of transmission activity and human risk, at least in the short term.

2004

Ft Collins **Loveland**





During 2004, vector densities were low and infected mosquitoes were detected only during one week in Fort Collins and not at all in Loveland. Though the VI was 0 for most of the season and transmission never approached the epidemic levels seen the previous season, human cases did occur in both towns. Apparently, mosquito surveillance was not sufficiently intense to detect the level of transmission that resulted in the few cases that occurred. However, the low VI levels suggested that epidemic transmission was unlikely.

ANALYSIS AND SUMMARY

When 2003 and 2004 data were combined, the VI for each week was positively correlated with the number of human cases with onsets the following week (r = 0.79), indicating that the low VI values detected during 2004 were indeed associated with relatively lower human risk and the higher VI values detected during 2003 were associated with more cases. In this surveillance system, a VI of 0.5 was associated with approximately 11 new cases the following week.
These results indicate that the VI may provide a single, mosquito surveillance-based index related to human risk. Because the VI incorporates the contributions of several vector species, it can be modified to reflect local transmission ecology while retaining the simplicity of using one index to portray transmission levels and human risk. We suggest that mosquito-based surveillance programs evaluate their historical data using the VI and develop thresholds that may be used in mounting appropriate responses to future WN transmission seasons.