Researchers study birds in effort to curb the spread of West Nile virus

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Professor Lesley Bulluck, Ph.D., and Ryan Levering, a senior environmental studies major, observe an American robin nest in Bryan Park.

The sun won't be up for a couple hours, but Dan Finnell and Ryan Levering are driving slowly through the darkness of Joseph Bryan Park,

scanning the shrubs and trees with a thermal imaging camera attached to the passenger side window.

The two Virginia Commonwealth University senior environmental studies majors are hunting for infrared hotspots that might indicate the presence of nests of American robins or other birds.

"When we find a nest, we mark the spot with flagging tape," Finnell said. "And as the sun rises, we get back out there to check it out, see how many eggs or nestlings there are, and collect nestling temperatures, incubating female temperature, and ambient temperature, and observe the female's activity—she might be incubating eggs or brooding nestlings."

The bird nesting data collected in Bryan Park is part of a major interdisciplinary study at VCU —involving ornithologists, mathematicians, entomologists and others—that aims to gain a better understanding of how West Nile virus spreads and how authorities can more effectively prevent outbreaks.

"Our goal is to be able to develop a model of West Nile virus transmission," said Lesley Bulluck, Ph.D., an assistant professor in the Center for Environmental Studies in VCU Life Sciences and the Department of Biology in the College of Humanities and Sciences, and an affiliate researcher for the VCU Rice Rivers Center. "We know that American robins and some other birds are good hosts for West Nile virus, and so we want to understand the dynamics between the timing of their nesting, the time of mosquito abundance and then toward the end of the season [the time when] mosquitoes shift to feeding on mammals, including humans."

Bulluck, an expert on avian ecology who is overseeing the field work in Bryan Park, said the information being collected will serve as empirical

data that will feed into the model of West Nile virus transmission.

"The basic question is, How does the timing of bird nesting activity influence West Nile virus transmission dynamics?" she said.

Mosquitoes, baby birds and math

West Nile virus is a pathogen spread primarily between mosquitoes and birds, and can spread to people by the bite of an infected mosquito. Most humans infected with the virus do not develop symptoms. However, about one in five people who are infected develop a fever with other symptoms such as headache, body aches, joint pains, vomiting, diarrhea or rash, and less than 1 percent will develop a serious, sometimes fatal, neurologic illness such as encephalitis or meningitis.

The project—"The impact of temporal variation in host life-stage abundance on the regional transmission and control of West Nile virus"—is supported by a $100,000 grant from the Jeffress Trust Awards Program in Interdisciplinary Research, which supports interdisciplinary research in Virginia.

Suzanne Robertson, Ph.D., an assistant professor in the Department of Mathematics and Applied Mathematics, is leading the project and developing a differential equations model for avian and human hosts.

The model, she said, will investigate how changes in the age composition of the bird population over time, combined with stage-specific mosquito feeding preferences, might influence the timing and severity of West Nile virus outbreaks.

"The questions we are addressing were motivated by biology," said Robertson, an expert in using mathematical models to gain insight into problems in ecology, epidemiology and evolutionary biology. "We are

using mechanistic mathematical models and numerical simulations to gain insight into the system and the connection between the age structure of avian populations and WNV outbreaks."

Transmission of West Nile virus is highly seasonal, with outbreaks coinciding with the end of bird nesting season.

The researchers believe that nestlings, or newly hatched birds, are highly vulnerable to mosquito bites and may receive a disproportionately high number of bites, given that they have less feather coverage and fewer defense mechanisms. During the nesting season, mosquitoes may be concentrated on a small number of susceptible hosts, thereby potentially amplifying the virus in the mosquito population, Robertson said.

"Since WNV is primarily a disease of birds that is transmitted by mosquitoes, it is intuitive that we start by understanding the interaction of WNV-susceptible birds and vector mosquitoes," said project collaborator Kevin Caillouet, Ph.D., research entomologist and arbovirus surveillance coordinator for the St. Tammany Parish Mosquito Abatement District in Louisiana.

"Specifically," he said, "we are testing whether a preference of mosquitoes to feed on particularly susceptible nestling birds may be responsible for the timing and intensity of WNV transmission."

Caillouet, who previously taught in in the departments of Epidemiology, Environmental Studies and Biology at VCU, said the team hopes to gain an understanding of how bird life stages—nestling, juvenile and adult—and mosquito preferences for each stage might influence West Nile virus transmission and, ultimately, human risk.

"The long-term objective of this project is to develop predictive tools that can accurately indicate elevated human risk and assess the efficacy

of disease-intervention strategies," he said.

The mathematical models, Caillouet added, allow the researchers to simulate the dynamics of West Nile virus transmission in multiple scenarios that cannot be observed as they occur in nature.

"Without these tools and without Dr. Robertson, biologists and disease control officials can only speculate about these ecological relationships and human WNV outbreak triggers," he said. "This project is an example of a true collaboration among mathematicians …, [an] ornithologist, and myself, a medical entomologist."

Weighing the costs of anti-mosquito strategies

As part of the project, the team is incorporating a mathematical tool called "optimal control theory" to weigh the costs of several strategies to control the spread of West Nile virus against the cost to society of allowing the disease to spread.

Elsa Schaefer, Ph.D., a professor of mathematics at Marymount University, is heading up the optimal control portion of the project.

"[Optimal control theory] can help us to quantify whether a more expensive treatment, such as avian vaccination versus the cheaper application of insecticide, is effective enough to warrant its costs," she said.

The tool can also provide insight into the best time to apply each potential control strategy during mosquito breeding season, she said.

"Should we put lots of money into insecticides early in the season? Or should we wait until the mosquitoes are at their peak?" she said. "Are we better off combining multiple strategies for disease intervention, or is it

better to put all of our money into only one of the strategies?"

The idea, Schaefer said, is to eventually be able to provide public health authorities with the ideal mitigation strategies, given the different assumptions about the upcoming breeding season and the predicted costs associated with each method.

Video cameras running day and night

As part of the bird data collection in Bryan Park, Bulluck's team has installed video cameras to record activities that occur in several nests, such as mosquitoes feeding on the nestlings.

"With video, we can quantify the mosquito burden," Bulluck said. "We'll also be able to quantify the birds' response to mosquitoes. Nobody's ever really done that. Do they eat them? Do they just let the mosquitoes crawl over them? Do they shake them off? What kinds of anti-mosquito behaviors do we see, if any? The cameras are running day and night. We have constant coverage. So we should be able to get a sense of what's going on."

The team is focused on finding the nests of American robins, because the species is a good host for West Nile virus, but also because robins build nests in urban and suburban locations close to humans and accessible to researchers.

A video screen shows a feed of several nestlings in a nest of cardinals in a blackberry bush in Bryan Park. All photographs by Lindy Rodman, VCU University Marketing.

In addition to using the thermal scanner, Finnell and Levering also simply keep an eye out for robins in the park and listen for their songs and then watch their behavior to locate nests.

"We do a lot of our behavioral observations here on the disc golf course," Finnell said, showing off a nest he found a few days earlier. "I was walking to another nest in a tree and then the female just dropped down right in front of me and picked up a worm and then flew to that branch and then to the nest."

"A lot of times, it's just following birds around until they lead us to their nest," Levering added.

Both Finnell and Levering took Bullock's ornithology lecture and lab course in the spring semester, giving them practice identifying birds by sight and sound.

"These guys are pretty good—they can identify pretty much every bird out here by their call," Bulluck said.

The project has not been without its disappointments, the students said, as many of the nests they've found have failed, often due to predators.

"The other day, Ryan and I were looking around and I heard a cardinal chipping," Finnell said. "So I walked over and saw the nest. It was still roughly intact. I used the mirror to get a look inside but there weren't any young left. I called over to Ryan and said, 'Hey, check this out. We were just too late. They must have fledged an hour ago.'"

A nest of American robins in Bryan Park that was identified by the researchers.

Moments later, Finnell realized there was a snake at the bottom of the tree. "The parents were around, freaking out. And the snake was looking pretty lethargic and happy," he said.

Finnell and Levering both said they are proud to be working on a project that may lead to better strategies to stop the spread of West Nile virus.

"A lot of my friends ask me what I'm doing this summer and I tell them I go out at 3 in the morning to monitor birds. And they're like, man that's kind of rough. But it's actually great," Finnell said. "When I tell them that it involves West Nile virus, the importance of it is definitely

understood."

Ryan Levering, Dan Finnell and Lesley Bulluck, Ph.D., check a video feed from a camera watching a nest of cardinals in a blackberry bush in Bryan Park.

Levering said that it has been rewarding to gain experience with all the different aspects of the field work.

"The coolest thing about this is that there are so many different things we're doing [to gather the data]," he said. "We're doing these driving transects, we're doing behavioral observations to find the birds, we're setting up cameras. And on the other side, which we haven't seen much of, they're putting together mathematical models.

"It's really cool to see just how much goes into answering questions like this," he added. "It's exciting to be a part of it, and I'm looking forward to seeing where it leads."

Dan Finnell, a senior environmental studies major, prepares to use an extendable mirror, which the team sometimes uses to check out out-of-reach nests.

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