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Latest Nugget from SIAM

Analytically solving a beetle problem

In an effort to increase the public's awareness of mathematics and computational science applications in the real world, SIAM created a series of "nuggets" to make current research accessible to a general audience. Articles from SIAM journals are distilled to a popular science level, allowing exciting applications to be understood and appreciated by the general public. Below is one of the first nuggets in this new series.

The Asian longhorned beetle crosses the Pacific.

Asian longhorned beetles (ALB), which are native to China and Korea, began infesting parts of the U.S. and Canada about 12 years ago. First discovered in North America in 1996 in Brooklyn, New York, it is believed that the ALB entered the U.S. and later spread to Canada in wooden packing crates used for imports from China. Since then the ALB has infested trees in several other U.S. states and was found in Canada for the first time in Toronto in 2003. So far, the North American ALB infestation has been limited to urban and suburban areas.

Why is the ALB infestation a major concern?

Asian longhorned beetles are wood-boring pests that attack hardwood trees. Their larvae burrow deep into the wood of trees for protection from natural enemies. The ALB grows up to 1.5 inches long, and its development from egg to adult lasts about one year. When the pests emerge from trees as adults, they create visible exit holes, about the diameter of a dime. Other signs of tree infestation include oozing sap, sawdust accumulation, and unseasonable yellowing or drooping of leaves. Upon infestation, trees can only survive about four years if larvae are not eliminated.

For these reasons, it is obvious that the ALB is capable of causing major damage and significant economic loss. It has been estimated that 1.2 billion trees could be at risk if the ALB were to become established in North America. This potential impact on the millions of acres of hardwood forests in the U.S. and Canada could be devastating. Incidentally, the ALB has no known natural enemies in North America.

Asian longhorned beetle

Can mathematics help eradicate the infestation of the ALB?

Motivated in large part by the recent North American infestation of the ALB, applied mathematicians developed mathematical models to describe the dynamics of infestation spread and have proposed viable eradication strategies. The authors of a recent paper in the SIAM Journal on Applied Mathematics show that, using a mathematical modeling strategy, levels of infestation by the ALB can be controlled and eradicated under certain conditions.

Their model is a system of ordinary differential equations with two time delays describing the number of infected and susceptible trees. One delay is the time between the instant at which a tree becomes infected and the subsequent detection of ALB activity. The second delay is the time required for the beetle to mature.

If the majority of beetle larvae cannot complete maturation in host trees before detection of an infestation and removal of the tree, then the population can be controlled and eliminated. It may be possible, however, that detection in a tree does not happen quickly enough and beetle larvae are able to completely mature in a tree bound for removal. In this case, a different and more difficult strategy is required. Yet, according to the authors' model, there is a condition under which eradication is still possible.

The authors examine whether a cut-and-burn removal control strategy can work and incorporate a removal rate into their model. The model allows for the detection of an infestation and removal of the tree, then the population can be controlled at considerable economic impact. Therefore, according to the authors, it is imperative to ensure that the Asian longhorned beetle does not become established in North America, and more investigation of the problems must be undertaken.

The model highlights the importance of rapid detection and removal of as many infested trees as possible. Simulations of the model demonstrate that if the time it takes for detection of an infestation is significantly larger than the time it takes the beetle to mature, then even though the infestation can be eradicated, it requires the removal of so many trees that forests would be decimated at considerable economic impact. Therefore, according to the authors, it is imperative to ensure that the Asian longhorned beetle does not become established in North America, and more investigation of the problems must be undertaken.

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