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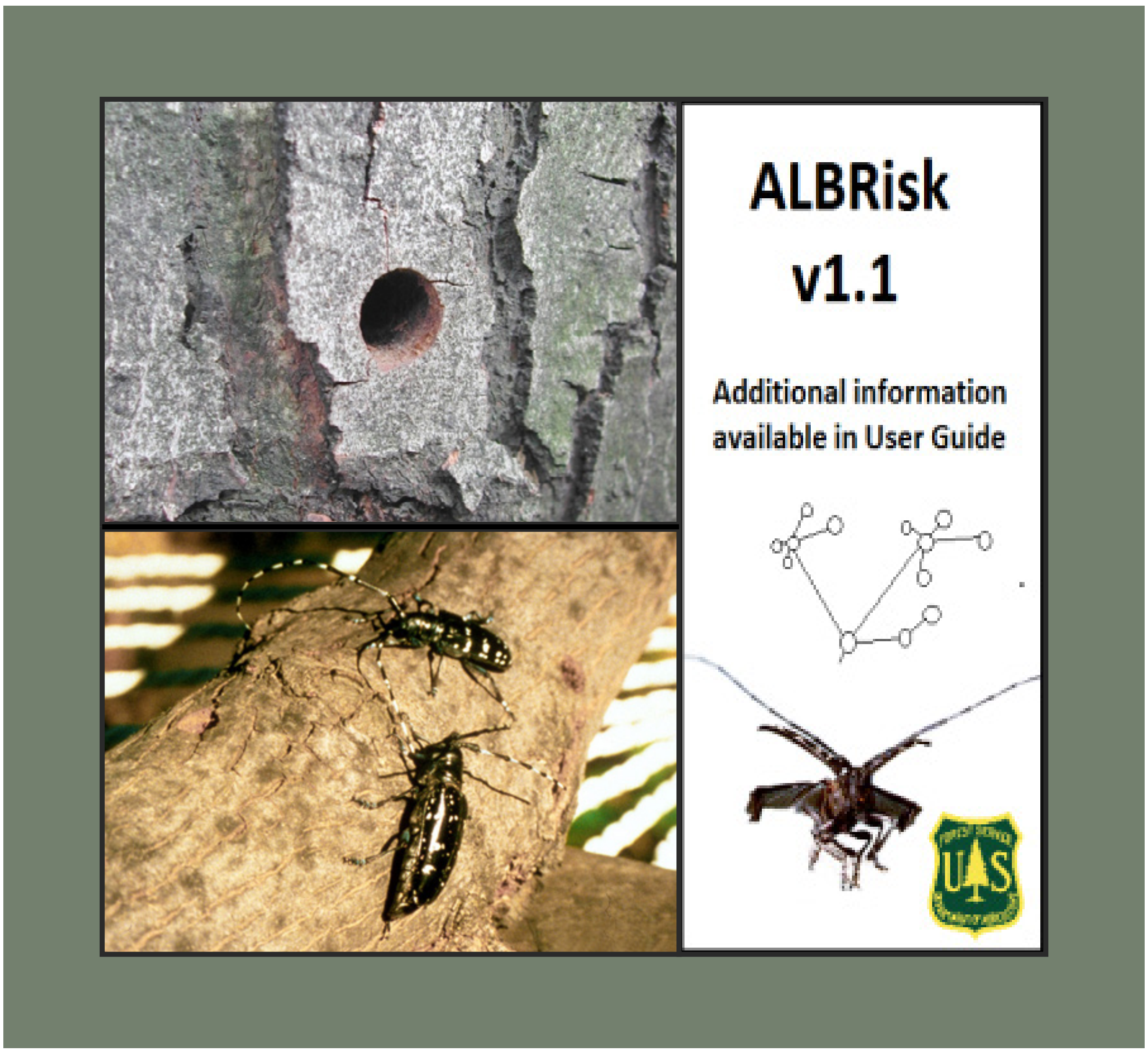
ALB Risk version 1.1: Asian Longhorned Beetle Dispersal Risk Estimation Tool

R. Talbot Trotter III, Melissa L. Warden, Scott Pfister, Ryan J. Vazquez, Josie K. Ryan, and Michael Bohne



Abstract

The Asian longhorned beetle (*Anoplophora glabripennis* Motschulsky) is an invasive polyphagous woodborer that has been introduced to North America and Europe. Due to the severe economic and ecological damage resulting from infestations of this insect, many countries, including the United States, have adopted policies of eradication. However, managing eradication can be a daunting challenge as it requires program managers to identify and destroy individual infested trees distributed across landscapes that may include millions of host trees. This report describes the use of the computer software program ALB Risk version 1.1, which estimates the boundaries of the at-risk landscape, as well as the distribution of risk within the infestation based on dispersal patterns. The program generates risk-maps, identifies priority areas for management, and estimates the potential return on survey effort. The software is available at https://doi.org/10.2737/NRS-GTR-201.

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EXECUTIVE SUMMARY

The Asian longhorned beetle (*Anoplophora glabripennis* Motschulsky) is an invasive polyphagous woodborer which has been introduced to North America and Europe via the transportation of infested solid wood packing material. The ubiquitous use of wood packaging (such as pallets and crates) and containerized freight has facilitated the establishment of breeding populations in forested and urban landscapes in at least 11 countries. Due to the substantial economic and ecological damage resulting from infestations, many countries including the United States have adopted policies of eradication. However, managing eradication can be a daunting challenge as it requires program managers to identify each infested tree on the landscape and destroy it by felling and chipping. Because locations with beetle populations can include forested, urban, peri-urban, and agricultural landscapes with millions of individual host trees, tools that accelerate survey progress by identifying areas with high risk are needed. This tool seeks to address these needs.

The purpose of the computer software program ALB Risk v1.1 is to estimate the distribution of risk within an area infested by the Asian longhorned beetle based on dispersal patterns specific to that infested area and the locations and infestation levels of known infested trees. The process includes four steps used to produce risk-maps, identify priority areas for management, and estimate the potential return on survey effort. These steps are based on the computation methods described in Trotter and Hull-Sanders (2015) and Trotter et al. (2018) which have been expanded to include additional output that may be of use to eradication management programs. Briefly summarized, these four steps are:

1) Reconstruct patterns of beetle dispersal by connecting the infested trees on the landscape. The connections among the infested trees are determined using a set of rules based on the biology and behavior of the beetle. These rules can be modified by the user to account for knowledge gaps and to incorporate new knowledge about beetle behavior as it becomes available.
2) Use the reconstructed pattern of beetle dispersal from Step 1 to estimate the probability distributions for beetle dispersal to include both distance and direction. These probabilities are commonly called dispersal kernels. These three-factor (direction, distance, and probability) dispersal kernels are unique to each infested region.
3) The dispersal probabilities (kernels) are applied to the locations of each known infested tree to estimate the risk of beetle dispersal around that tree. This process is repeated for each known infested tree on the landscape and the overall probability that at least one beetle has arrived from at least one infested tree on the landscape is calculated for each location on the landscape. The default settings produce estimates on a hectare-by-hectare basis.
4) The distribution of risk on the landscape is output as a map and GIS data layer, and used to identify a) the sequence of locations to manage to maximize eradication progress, b) the portion of the infested landscape to manage to achieve a given probability of eradication, and c) an effort/benefit curve describing the nonlinear relationship between the total area managed and the overall probability of eradication.

The output maps and graphics produced by ALB Risk version 1.1 can be used to assess landscape patterns of ALB dispersal, the distribution of dispersal risk, and the relationship between survey effort and eradication success. These outputs can also be used as the input required to run a second tool called ALB Dynamic Risk version 1.0.[1] This tool provides dynamic estimates of risk on the landscape based the history of eradication program activities including the timing, location, intensity, frequency, and method of surveys.

[1] For additional information and access to the model and documentation, contact Talbot Trotter at Robert.T.Trotter@usda.gov.

INTRODUCTION

A History of the Asian Longhorned Beetle in the United States

In August of 1996, a resident in New York City noticed damage to several Norway maple (*Acer platanoides*) trees along a street in the Greenpoint neighborhood of Brooklyn (Haack et al. 1997). The trunks and branches of the trees had round holes roughly one-half inch in diameter with small piles of sawdust below, as though the trees had been vandalized by someone using a hand drill (Fig. 1). The resident reported the damage to New York City Parks and Recreation, and within days city and state foresters had collected several large beetles from the damaged trees (Fig. 2). Rapid efforts by city and state foresters, the U.S. Department of Agriculture, and entomologists at Cornell University confirmed the identity of the beetles, and the first infestation of the Asian longhorned beetle (*Anoplophora glabripennis* Motschulsky; ALB) in North America was discovered.

Figure 1.—When adult Asian longhorned beetles emerge from a tree, they leave distinctive exit holes, which are round and approximately one-half inch in diameter. Courtesy photo by Pennsylvania Department of Conservation and Natural Resources – Forestry/Bugwood.org.

Within weeks the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) had federal staff in New York City working with state and city agencies to determine the size of the infestation and to begin the process of eradicating it. The rapid and aggressive response to this beetle by city, state, and federal land managers was driven by knowledge that the Asian longhorned beetle had already caused significant damage to North American tree species that had been planted in China to help slow desertification.

Figure 2.—Adult Asian longhorned beetles on a branch. The beetle on the bottom is a female and the beetle above is a male. Note the male's antennae are substantially longer than its body. The beetles are black with white spots, often about 1.5 inches long not including the antennae, and on close inspection, often have blue feet. USDA APHIS photo by Kenneth R. Law.

In 1978 the Chinese government initiated the Three North Forest Protection Program, a massive reforestation and afforestation effort intended to slow the expansion of the Gobi Desert, reduce dust storms, and provide wood resources to local populations. As of 2003 the program had carried out afforestation work on more than 150 million hectares of farmland and grasslands (Qui et al. 2017). Many of the planted trees were North American poplars and poplar hybrids selected for their rapid growth and soil tolerance characteristics. Unfortunately, many of the species and hybrids that were planted were highly susceptible to attack by the native Asian longhorned beetle, leading to an infestation spanning a large portion of China.

When beetles infest trees, the larvae bore through the phloem and xylem leaving tunnels up to one-half inch in diameter in the lumber. These holes and galleries reduce the wood's quality and make it unsuitable for use in high value applications such as furniture, veneer, or dimensional lumber. To recover some value from the timber this low-quality wood is commonly used in commodities such as pallets, crates, and dunnage where the quality or appearance of the wood is not critical. These solid wood packing materials are heavily used in international shipping (Fig. 3), and moving infested material provides an opportunity for larvae living in the wood to be transported internationally (Haack et al. 1997) and emerge to infest new environments.

In 1992, Asian longhorned beetles were found in warehouses and ports of entry in North America (Haack et al. 2010) demonstrating the potential for this damaging pest to be moved to novel landscapes, including North America. By 1998, beetles had been detected at more than 30 warehouses and ports of entry. These detections, combined with the susceptibility of North American tree species to infestation, made the Asian longhorned beetle a species of high concern.

With the detection of a breeding population of the beetles in New York City, APHIS and the USDA Forest Service (USDA FS) conducted a rapid risk assessment to evaluate the threat ALB might pose to North American trees and forests. The analyses confirmed the beetle would likely cause significant damage to lumber production, ecotourism, maple syrup production, public and private lands management, and property values (Kucera 1996). Adding urgency to the situation, a study by Nowak et al. (2001) found that within the United States, 1.2 billion urban trees (representing about 30 percent of the urban tree cover), with an estimated value of $669 billion, would be at risk if the beetle were to permanently establish and spread. In response to these ecological and economic threats, the Secretary of the U.S. Department of Agriculture

Figure 3.—Solid wood packing material, such as these crates and pallets, are the primary path for beetles to move from their native range in China and the Korean Peninsula, or from other established infestations, to other parts of the world. USDA APHIS photo/Bugwood.org.

made a "Declaration of Emergency Because of the Asian Longhorned Beetle" (64 CFR 12800-12801) to accelerate efforts to find, quarantine, and eradicate this species in the United States. Since the discovery of Asian longhorned beetles in New York City, breeding populations have been found in Illinois, Massachusetts, New York, New Jersey, and Ohio.

ALB has a broad host range that includes tree species from at least 15 families, including the abundant and widely distributed genera *Acer* (maple), *Populus* (cottonwood, poplar, and aspen), *Salix* (willow), and *Ulmus* (elm) (Fig. 4). In addition to the United States, breeding populations of the beetle have been

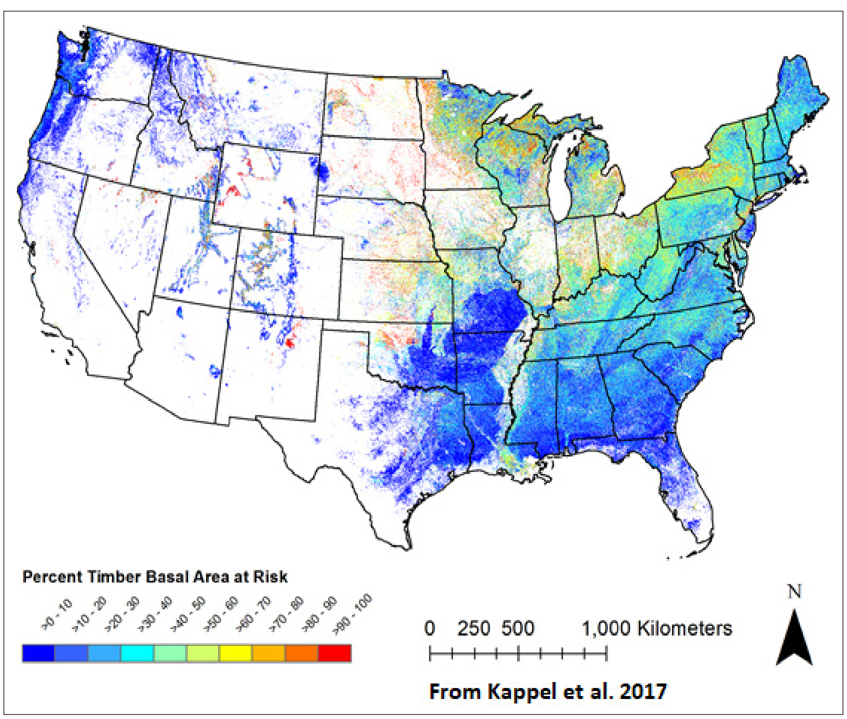


Figure 4.—An analysis by Kappel et al. (2017) shows the broad geographic range of suitable host trees and the size of the landscape threatened by the Asian longhorned beetle. Courtesy image from Kappel et al 2017, used with permission.

found in Austria, Belgium, Canada, Finland, France, Germany, Italy, Turkey, the Netherlands, and the United Kingdom. The threat posed by the beetle has prompted Canada, the United States, and members of the European and Mediterranean Plant Protection Organization (EPPO) to adopt ISPM-15[2] to reduce the risk of introducing the beetle to new locations. Further, these countries have established policies of eradication when infestations are found, and in some locations, eradication has been achieved.

In the United States, the federal government has spent approximately $750 million on eradication programs (a value that represents about 0.1 percent of the expected cost to cities in the United States should the beetle become widely established). As a result of these efforts, the beetle has been eradicated from New Jersey, Chicago, Boston, and in the New York City metropolitan areas of Manhattan, Staten Island, Queens, Brooklyn, and the town Islip on Long Island. However, about 220 square miles (110 in Worcester, MA; 57 in Bethel, OH; and 53 on Long Island) remain under quarantine as of the end of 2019, and in the spring of 2020 a new infestation was detected in South Carolina. Eradication programs in these areas are tasked with eliminating the infestations from complex urban, rural, agricultural, and forested landscapes. Though past eradication programs have been successful, there remain opportunities for improvements that may speed eradication or reduce costs, particularly in large and complex environments.

Asian Longhorned Beetle Eradication Strategies and Tools

The general strategy used by eradication programs, both domestic and international, is simple: Find the infested trees and destroy them by felling and chipping. However, finding individual infested trees among millions of host and nonhost trees represents a substantial needle-in-a-haystack challenge, and eradication programs have explored multiple tools including pheromone-baited traps, trained beetle-detection dogs, acoustic surveys, unmanned aerial surveys (drones), and visual surveys. The history of this beetle as a forest pest and the tools used to detect and manage it have been discussed in greater detail in numerous sources (e.g., Hsiao 1982, Meng et al. 2015) and so we do not seek here to provide a comprehensive review. Rather, we provide brief descriptions of eradication tools for the convenience of the reader, and to place the utility of the software described in this document in a broader eradication-strategy context.

Traps: For some notable invasive species, such as the gypsy moth (*Lymantria dispar dispar* Linnaeus), pheromone-baited traps have provided a highly effective survey tool for documenting the presence, abundance, and distribution of the insect (Fig. 5). Trapping surveys have several advantages including the potential to effectively sample large areas, the potential for high species specificity, and the effective deployment and monitoring of traps without the need for specialized training. With these advantages in mind, multiple efforts are underway to identify potential semiochemical attractants for the Asian longhorned beetle, and to evaluate these chemicals' use as lures for traps under field conditions. These research efforts have identified two pheromone compounds produced by male beetles (Zhang et al. 2002), several plant compounds known as kairomones, which are attractive to insects (Nehme et al. 2009, Nehme et al. 2010), and a potential third male pheromone compound (Crook et al. 2014) that are attractive to beetles. Multiple combinations of these compounds have been tested using panel intercept traps (Fig. 5), and studies have shown that the traps are attractive to ALB (Meng et al. 2014), including instances in which experimental traps have detected beetles in areas where populations had not previously been detected (Nehme et al. 2014). While these results have shown some promise, several issues have prevented the large-scale use of traps and

Figure 5.—A panel intercept trap is used to survey for Asian longhorned beetles. Note the packets in the center, which contain lures. When beetles encounter the trap, they are unable to hold onto the black plastic and fall into the collection cup at the bottom. The cup is typically filled with a salt solution or with propylene glycol (antifreeze). USDA Forest Service photo by Melody Keena.

[2] International Standards For Phytosanitary Measures No. 15 (ISPM 15) is an international phytosanitary measure developed by the International Plant Protection Convention (IPPC) that directly addresses the need to treat wood materials of a thickness greater than 6 mm.

pheromones in eradication programs. Some of these issues include a potentially short (<100 meters) and poorly quantified effective draw-range, a need to quantify the sensitivity of the traps in landscapes with different densities of beetle infestations (Nehme et al. 2014), lures which can require frequent replacement during the trapping season, and difficulties in controlling the rate of lure release.

Detection Dogs: The discriminating nose of the domestic dog offers an additional beetle survey asset. ALB detection dogs have been trained in Austria, Switzerland, Germany, and the United States (Errico, 2013, Hoyer-Tomiczek et al. 2016). In the United States, three dogs were trained by the APHIS' Detector Dog Training Center[3] to identify ALB infestation on trunks and branches as part of a pilot project. (Fig. 6). Trials indicated the dogs were 80 to 90 percent successful in identifying known infested material. Although the canine detectors have been successfully evaluated, the high cost per unit area for surveys and time limitations in which the dogs remained effective have been weighed against the cost for alternative mitigation methods such as host removal and the more rapid and cost-effective use of visual surveys.

Acoustic Surveys: As wood boring beetles move and chew through the wood of a tree, they produce sounds. Acoustic surveys can provide additional methods for detecting infestations by the ALB. Researchers with the USDA Forest Service and U.S. Department of Energy's Oak Ridge National Laboratory have developed algorithms capable of identifying the acoustic signatures associated with feeding by ALB in wood (Haack et al. 2001). Second-generation algorithms (Mankin et al. 2008) have shown improved detection in noisy environments such as urban settings. While promising, particularly for the potential monitoring of shipped goods, additional technical aspects of the tools remain to be resolved to make the tools suitable for use in field conditions, including the need for software to refine the discrimination among species of wood borers, the need to continue to miniaturize the equipment and improve field portability, and field testing to validate efficacy. Due to these limits acoustic methods are not currently being used as a landscape-scale survey tool.

[3] APHIS Plant Protection and Quarantine (PPQ) program operates the Detector Dog Training Center in Newnan, GA.

Figure 6.—An Asian longhorned beetle detection dog and trainer inspecting a tree for signs of ALB infestation. USDA photo/flickr.com

Visual Surveys: Visual surveys are the primary tool used by most ALB eradication programs. Visual surveys are typically carried out by ground crews using binoculars, aerial crews using bucket-trucks or aerial-lifts, and tree climbers. Crews search host trees for the approximately one-half inch exit holes left by adults as they emerge, and the oviposition pits females leave in bark (Fig. 7). These wounds can occur anywhere on the trunk and in the canopy of the tree (Fig. 8) though they are typically found on branches greater than 1 inch in diameter. The speed and efficacy of the surveys can vary depending on a variety of factors including method used (visual from the ground, bucket truck, tree climbing), the experience and training of the crew, and the physical conditions in the landscape including weather, lighting, season (leaf-on or leaf-off), and the accessibility of the land.

Visual surveys offer several advantages including consistent results (based on crew training and experience) and suitability for variable landscapes and stand structures. This approach has been successfully used to eradicate populations of the ALB in urban landscapes such as Chicago, IL, and Jersey City,

Figure 7.—Surveys based on visual searches for exit holes and oviposition pits are the most common tool used to find individual infested trees Mike Bohne of the USDA Forest Service, is shown conducting a search. USDA photo by R. Anson Eaglin.

Figure 8.—Surveys by tree climbers provide access to a larger portion of the tree canopy and provide increased confidence in beetle detection rates, though the process takes longer than ground surveys. USDA APHIS photo.

Carteret, and Linden, NJ, New York City, NY, and Boston, MA. These methods have also been effectively applied to larger landscapes such as those around Worcester, MA, and Bethel, OH, with surveys at both locations identifying many fewer infested trees as surveys progress. However, in large landscapes with dense tree cover, such as those around Worcester and Bethel, and in the newly detected infestation near Hollywood, NC, survey crews are faced with the task of checking millions of individual host trees for signs of infestation. Also, eradication programs typically include a multi-survey protocol that requires each tree and stand to be surveyed multiple times. While these multiple surveys greatly improve the efficacy of the programs, they also increase the number of surveys a program must undertake.

Ongoing Needs to Estimate Risk, Optimize Surveys, and Track Eradication Progress

Due to the cost and effort required to survey large landscapes, it is very important to prioritize where to deploy survey crews in order to maximize eradication efficiency and efficacy. Two additional challenges to identifying priority areas for survey remain. First, as surveys shift from efforts to identifying the boundaries of the infestation (delimitation), to the identification and removal of all infested trees (eradication), there is a need to identify priority areas where survey crews may have the greatest impact on eradication progress. Second, as eradication programs reduce the number of infested trees on the landscape, finding the remaining but increasingly rare infested trees becomes more challenging, and targeted surveys may become increasingly important to help programs efficiently estimate and mitigate remaining risk on the landscape. This approach may also help determine the point at which surveys have achieved an acceptable level of overall risk reduction. Risk maps and outputs produced by ALB Risk version 1.1 can support these efforts.

ALB RISK VERSION 1.1

ALB Risk version 1.1 (v1.1) is a computer software program that estimates the distribution of risk within an area infested by the Asian longhorned beetle based on dispersal patterns specific to that infested area and the locations and infestation levels of known infested trees. The program generates risk maps, identifies priority areas for management, estimates the statistical boundaries of the infestation, and estimates the potential return on survey effort based on the locations of known infested trees. These steps are based on the computation methods described in Trotter and Hull-Sanders (2015) and Trotter et al. (2018), which have been expanded to include additional output that may be of use to eradication management programs.

Software Summary, Structure, and Assumptions

Information on the development, conceptual structure, and assessment of the analyses used in ALB Risk v1.1 can be found in Trotter and Hull-Sanders (2015), and Trotter et al. (2018). This report provides an application-oriented description of the model along with a more detailed description of how to install and run the software, how to structure input data, some descriptions, discussions, and examples of options and model parameters included in the software program, and an explanation of the outputs that it generates. These expanded topics are not addressed in Trotter and Hull-Sanders (2015) and Trotter et al. (2018). Generally, the intent of the model is to identify patterns of dispersal on the landscape based on discrete assumptions regarding beetle dispersal behavior and use these dispersal patterns to estimate the distribution of risk on the surrounding landscape. To accomplish this, the software uses the input data provided by the user to carry out four tasks.

1) Reconstructing Patterns of Beetle Movement: The software analyzes infested tree records provided by the user. The data should include a list of infested trees, their locations in X and Y coordinates (UTM coordinates are preferred), and a categorical level of infestation for each tree represented by values from 1 through 5. These data are used to map the infested trees and identify connections (called adjacencies in graph theory) among the trees based on a set of rules (adjacency rules). These rules are relatively simple and can be modified by the user. An example set of typical rules might include:

- The intensity of the infestation on a tree indicates the age of the infestation on the tree, i.e., trees with heavier infestations have been infested longer than lightly infested trees.
- A tree is infested by a beetle that arrives from the closest tree with an older infestation.
- A tree is infested only once but can serve as the source of infestation for multiple trees.

Using these rules, each of the infested trees on the landscape can be connected to at least one other infested tree. By applying this process to all of the known infested trees on the landscape, the model produces a network among the infested trees in which each connection represents a beetle dispersal event (vector) that includes both a distance and a direction. The total number of inferred beetle movements is therefore equal to the total number of infested trees used in the analysis, minus one. One tree (identified by the user) is assumed to be the first infested tree and serves as the initial source of the infestation.

2) Quantifying Dispersal Probabilities: Dispersal vectors are tabulated to produce a probability distribution of dispersal distances, a function usually referred to as a dispersal kernel in ecological literature. This dispersal kernel represents the probability that a beetle will travel to a given distance. To produce dispersal kernels that include direction information, the dispersal vectors are grouped in direction bins (for example, all dispersal vectors that were between 0 and 30 degrees on a compass, 30 and 60 degrees, etc.). Tabulating the vectors within these direction bins produces direction-specific dispersal kernels. These directional dispersal kernels estimate the probability that a beetle will disperse in a specified direction to a specified distance.

3) Estimating Dispersal Risk on the Landscape: Placing these direction-specific dispersal kernels around a single point produces a three-dimensional distribution of dispersal risk (an example is shown in Fig. 27). If each infested tree is assumed to represent a center point for this risk distribution, the three-factor dispersal kernel estimates the risk for each point on the landscape surrounding the tree. Repeating this process for each tree and compiling the contribution of each tree on the landscape for each location on the landscape produces a grid of risk values in which the value for each grid point is the probability that at least one beetle has arrived from at least one infested tree. For simplicity the software uses a landscape grid in which sections represent 1 hectare, though the size of the landscape unit can be changed by the user.

4) Ranking Risk on the Landscape and Optimizing Survey Sequences: The total risk for the landscape can be described as the product of the probabilities for each hectare that the hectare does *not* include an infested tree. If a hectare with risk is removed from the landscape (i.e., the risk for the hectare has been reduced to 0) then the overall probability (product of the remaining hectares) that any portion of the landscape is still infested is reduced. Removing the hectares sequentially, starting with the highest risk locations, provides the most rapid reduction in overall landscape risk. Plotting the number of hectares that have been removed (risk reduced to 0) as a function of the overall probability of eradication provides a curve that describes the relationship between the portion of the landscape which has been managed and the overall probability that the beetle has been eradicated (1 – the probability that at least one hectare on the landscape remains infested). This approach can also provide an estimate of the total percentage of the at-risk landscape that needs to be managed to attain a specific overall probability of eradication.

Additional Applications for Output – Informing Survey Progress: The output provided by the software represents static estimates of risk based only on the potential dispersal of the Asian longhorned beetle. As surveys progress, the estimated risk for each location can be modified based on the survey results, i.e., detecting or not detecting infested trees. An additional software tool, ALB Dynamic Risk version 1.0, can be used to produce these dynamic risk estimates. A description of this tool and its use are provided in an upcoming document: ALB Risk version 1.0: Tracking and Assessment Tool for Asian Longhorned Beetle Eradications.[4]

[4] At the time of publishing, users can obtain a beta version of ALB Dynamic Risk version 1.0 and associated documentation by contacting Talbot Trotter at Robert.T.Trotter@usda.gov.

ALB RISK VERSION 1.1: SOFTWARE USER GUIDE

The text uses the following fonts to identify keystrokes, files, software, data, etc.

enter = carriage return key. This may be labeled with "Enter", "enter", "return", "CR", or a carriage return symbol depending on the computer or keyboard model or manufacturer.

Pathfiles and file names. [Calibri italic font]

`Software prompts and output. [Courier New font]`

Input provided by the user. [Arial black font]

Downloading, Installing, and Starting ALB Risk version 1.1

Download and install ALB Risk version 1.1 from https://doi.org/10.2737/NRS-GTR-201. The software can be saved to any convenient location on the computer provided the user has permission to write files to the location. ALB Risk version 1.1 (hereafter referred to as ALB Risk v1.1) is a stand-alone program and can be run on Microsoft Windows™, or on computers running Unix™, Linux™, or MacOS™ operating systems when combined with a Windows™ virtual machine. If the user has administrative privileges, the software can be installed by double-clicking on the file *ALBRiskv1_1_install.exe*. Note that some users may need to contact a system administrator if administrator privileges are required to add software. When the installation launches, the following window should briefly appear (Fig. 9):

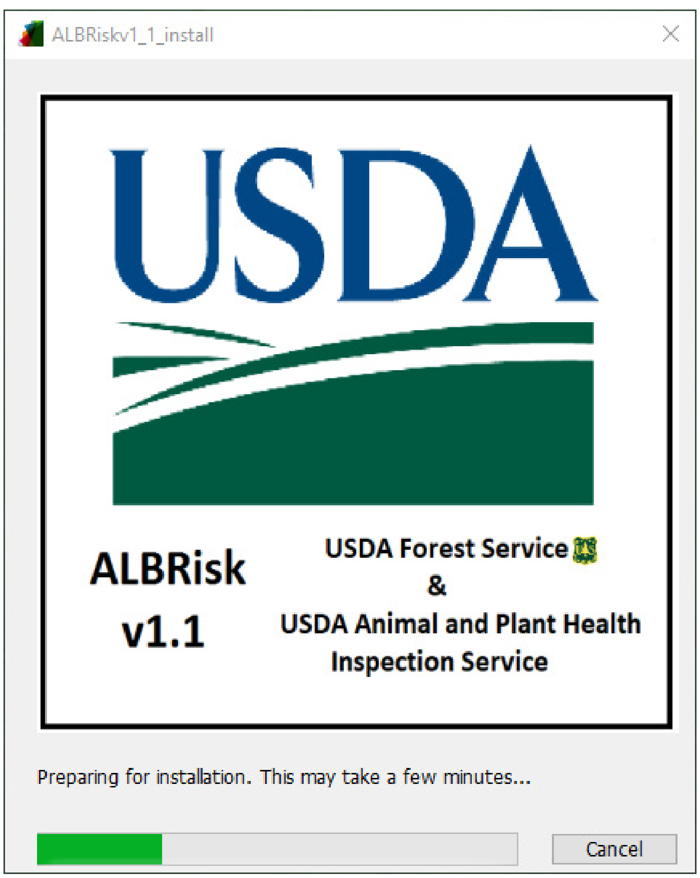


Figure 9.—Window showing the launch of the ALBRisk v1.1 installer.

Followed by this window (Fig. 10):

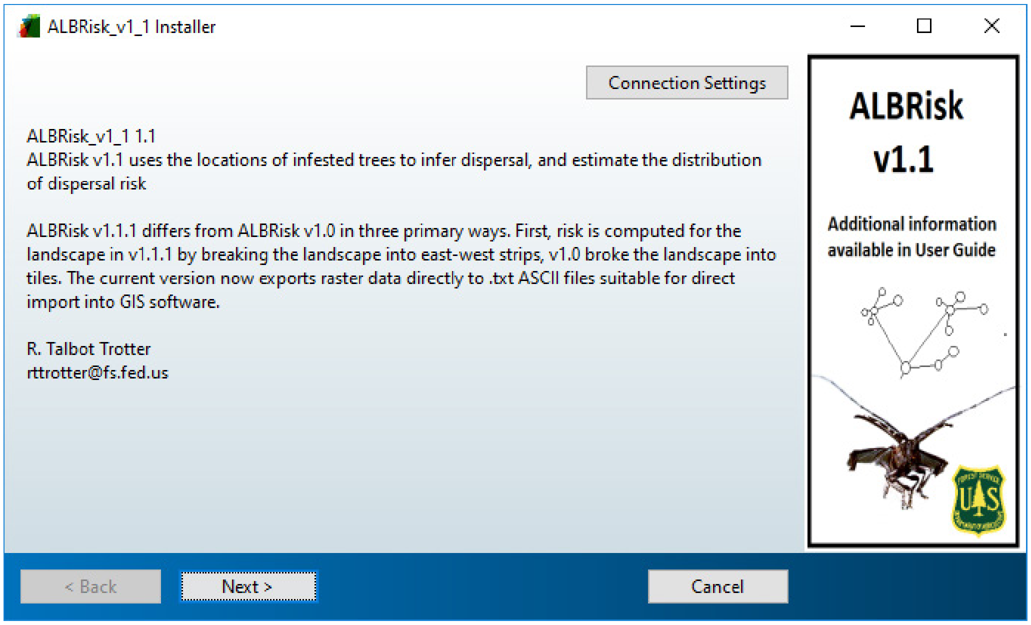


Figure 10.—Once launched, the installer provides information on the version being installed.

To continue the installation, press **Next**. The following window should appear (Fig. 11):

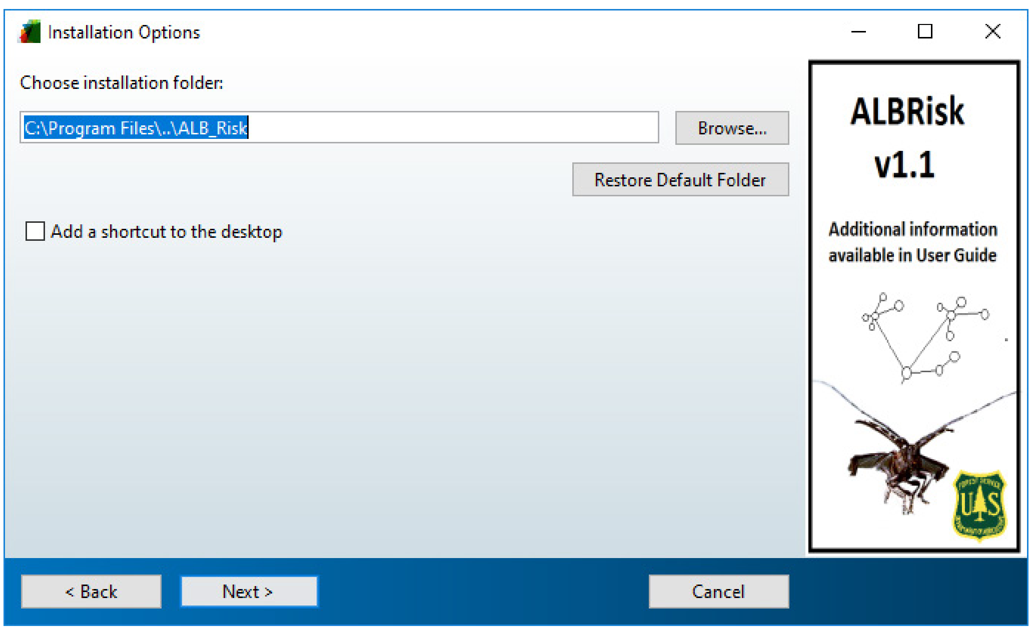


Figure 11.—The installer will identify a default installation location for the software. Changing this location may prevent the model from functioning correctly. If a different location is required by the user, contact Robert.T.Trotter@usda.gov to obtain a modified version.

As shown in Figure 11, the installer will load the program and data files into a location called *C:\Program Files\..\ALB_Risk*. Please note that this is NOT where the software will be installed, rather, the files will be installed in a newly created directory *C:\ALB_Risk* for reasons described below.[5] DO NOT change the installation folder, as this may cause the software to

[5] Access by users to files and directories within Program Files varies among operating systems, administrator settings, and user profiles. Some users may not be able to add files or directories to Program Files, or may be able to add them, but not edit or remove them. ALB Risk v1.1 both creates and modifies files. To avoid conflicts with user access to Program Files, ALB Risk v1.1 is installed in its own directory on the C: drive.

generate errors or fail to run. The locations of the programs and files which allow the program to run are hard-coded in the program, however if you need to install the programs and/or data files in a different directory or drive, please contact Talbot Trotter (Robert.T.Trotter@usda.gov) to request a modified version of the software. To continue the installation, select **Next**.

Running ALB Risk v1.1 requires the computer to have an installed version of MATLAB Runtime™ (MathWorks, Natick, MA), which is a free set of shared libraries. At this point the installer will check to determine whether a suitable Runtime version is already installed. If it is not, the installer will prompt the user to install it by providing a link to the website where the libraries can be downloaded for free. Due to this step, the installation of ALB Risk v1.1 requires an internet connection to complete. If the computer does not have an internet connection, a version of the installation package that includes the Runtime program is available. If MATLAB Runtime™ is already installed on the computer, the following window should appear (Fig. 12):

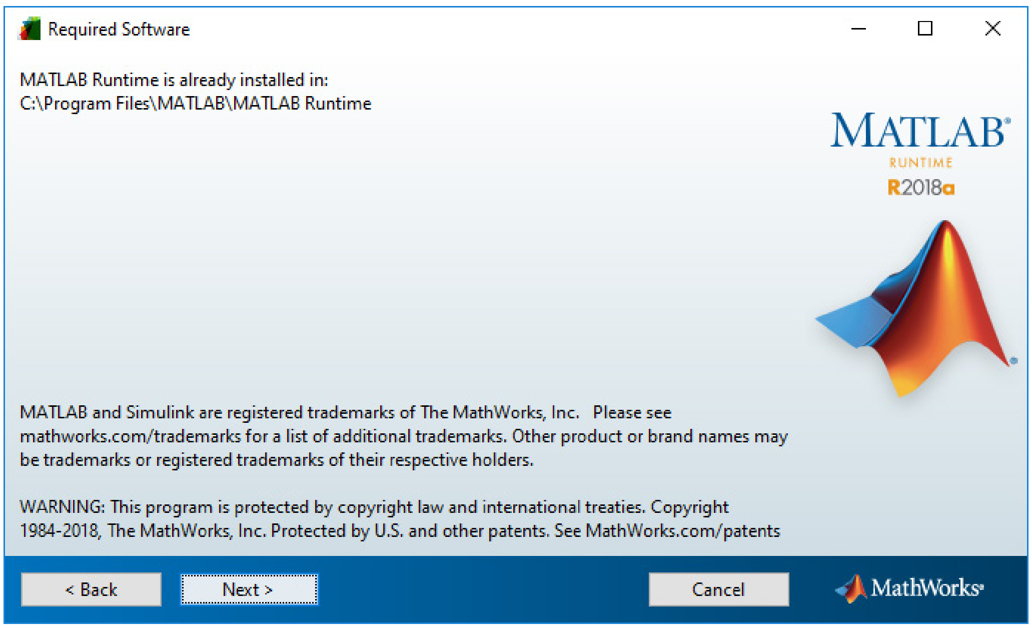


Figure 12.—ALBRisk v1.1 requires the installation of MATLAB Runtime™. The installer will search for MATLAB and, if one is not installed on the computer, will prompt the user to download and install a current version.

Select **Next** to continue (Fig. 13):

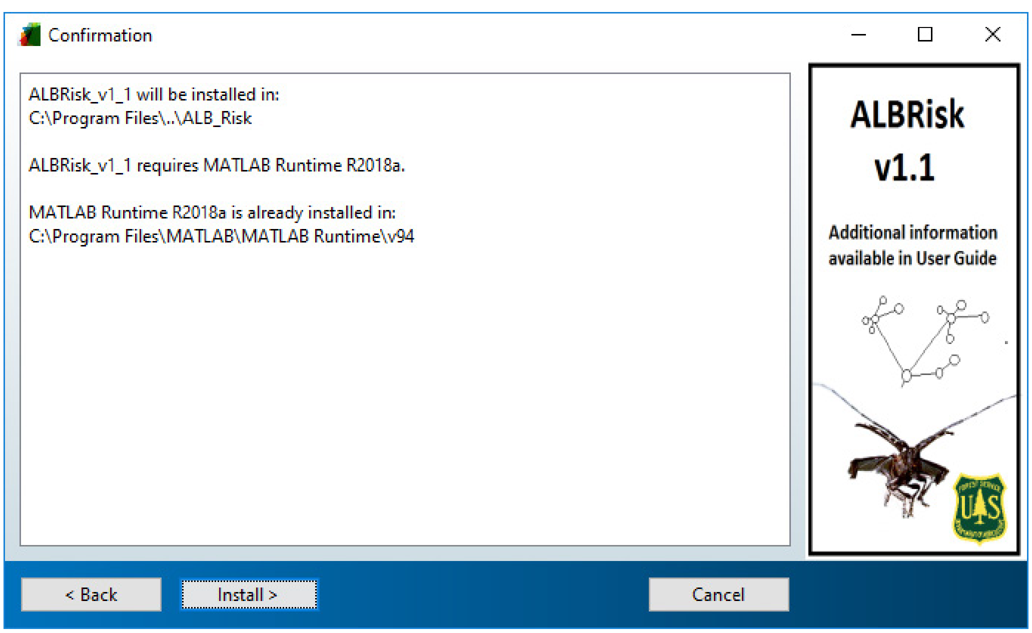


Figure 13.—The installer will provide the user with installation settings before completing the installation.

Select **Install**, and the installation should complete, and the completed installation window should appear (Fig. 14). Select **Finish** to close the window and complete the installation.

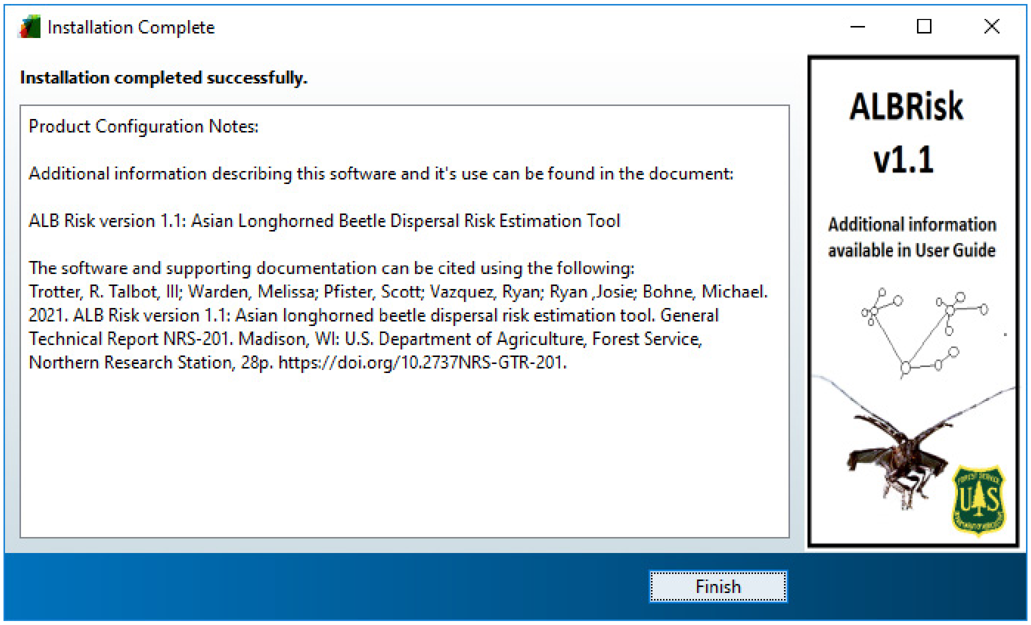


Figure 14.—When installation is complete, the installer will indicate this along with information on how to cite the model.

To confirm the installation, open a directory explorer program (such as File Explore™ on a Windows™ computer) and search for a new directory called *C:/ALB_Risk/*. Within this directory, there will be four subdirectories: *appdata*, *application*, *sys*, and *uninstall*. The program itself is located within the *application* subdirectory and is called *ALBRisk_v1_1.exe* (Fig. 15). The application subdirectory will also contain an example data set (Fig. 15) and will be the location where output files generated by the software are saved. Double-clicking on the *ALBRisk_v1_1.exe* file should launch the program. Note that when the program starts, the user will be presented with a command window. This window may remain blank for a few minutes the first time the software is started but should (within a minute or so) present the user with summary text describing the version of the software. If summary information describing the software is displayed along with the prompt:

```
Provide name of input file (including extension):
```

then the software has installed correctly. To close the program without running it, simply close the command window using the box in the top corner.

Using the Provided Example Data as Model Input

The input data for ALB Risk v1.1 is provided by the user as a single file containing data in which rows represent individual infested trees, and columns represent attributes describing the trees. The dataset can include numerous attribute columns but only three are currently used by ALB Risk v1.1. The three required columns provide the X and Y coordinates for each tree, and an integer describing the level of infestation. A sample data set with artificial tree records named *ExampleData.dbf* trees can be found in the application folder (Fig. 15). This file can be used as a demonstration dataset and provides a template for how datasets can be organized.

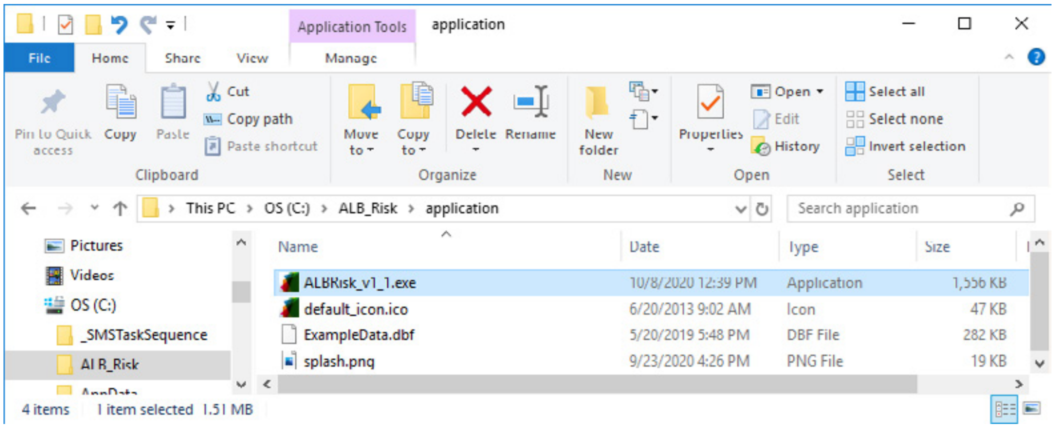


Figure 15.—When installed, the program will be contained within a folder called *C:/ALB_Risk/application*, which will contain the program and an example data set. This folder is also the location where the program will store output files.

ExampleData.dbf can be opened using a spreadsheet program or a geographic information system. Note that the file can be opened using a text editor, however, the data may be shown with unusual formatting due to the use of a *.dbf* file structure.

Using User-Provided Data as Model Input

The simplest way to organize and format data for ALBRisk v1.1 is to use a GIS dataset (ArcGIS, QGIS™, CAD) in a Shapefile format. If the following conditions are met, the *.dbf* file associated with the Shapefile may be used directly as the input file for the model.

1) The shapefile should be projected (or re-projected) into a Universal Transvers Mercator (UTM) or other gridded coordinate system.

2) The attribute table should include a field (column) that provides the infestation data for each tree. The infestation should be indicated with a single numeric integer between 1 and 5 (inclusive). Levels 1 through 4 correspond with the infestation levels A through D used the by the Cooperative Asian Longhorned Beetle Eradication Program (A = 1, B = 2, etc., additional information can be found at APHIS 2020). The data should also include a single tree with an infestation category of 5 which indicates the assumed original infested tree, which the software uses as the starting point for the infestation. Note that it may not be necessary to know the precise location of the original infested tree; selecting a highly infested tree from the stand where the infestation is assumed to have started may be adequate, particularly in larger infestations.

3) The attribute table should include a column that provides the X and Y coordinates for each infested tree. If the table does not include this data, it can be added, in ARCGIS™ for example, this can be done using the ADDXY Function in ArcPy. ALB Risk v1.1 requires each tree to have a unique location (X-Y coordinate), however the software will accept datasets that include multiple trees with the same coordinates. If a dataset includes trees with matching coordinates, the locations for the matching trees will be shifted slightly (up to a few centimeters) to provide each tree with a unique location.

The *.dbf* file associated with the Shapefile format can be used directly as the data input file for ALB Risk v1.1. If the data is in a *.dbf* format, the data file will include headers which will be ignored by ALB Risk v1.1. The use of specific column headers or attribute field labels are not required. Before running ALB Risk v1.1, note which columns (first, second, ninth, etc.) provide the X, Y, and infestation data, as the user is required to tell ALB Risk v1.1 where to find the information in the input file. The data file should be saved to the directory *C:/ALB_Risk/application*, the same directory where *ExampleData.dbf* is located (Fig. 15). This is the only location from which the software will read data files.

Analysis Settings and Options

Users are encouraged to run the software using the provided example data (*ExampleData.dbf*) to become familiar with settings, options, and data formats. The following instructions and examples assume the provided example data are being used, though the process is the same when using user-provided data.

Start the software: After installing the software, navigate to *C:/ALB_Risk/application* and double-click on the file *ALBRisk_v1_1.exe*. This will open a new command-prompt style window. NOTE: After starting the program, the window that opens may appear blank for a few moments. This delay is normal and may be more pronounced if this is the first time the software has been launched. Once the software initiates, the computer screen should appear as Figure 16. Note that the window may need to be expanded or the user may need to scroll within the window to view the full text.

Providing input data: When the software initiates, the window will display the software version and contact information, and the user will be prompted to provide the name of the file that includes the infested tree records (Fig. 16). When running the example data, simply type *ExampleData.dbf*. If a user-provided file is being used, type the name of the file including the suffix (i.e., *.dbf*). Note that the software will only be able to process data in files stored in the same location (i.e., folder) as the program itself, specifically, in the directory *C:/ALB_Risk/application*. If it is necessary to use files stored in a different location, please contact Talbot Trotter (Rober.T.Trotter@usda.gov) to arrange to receive a modified version of the software.

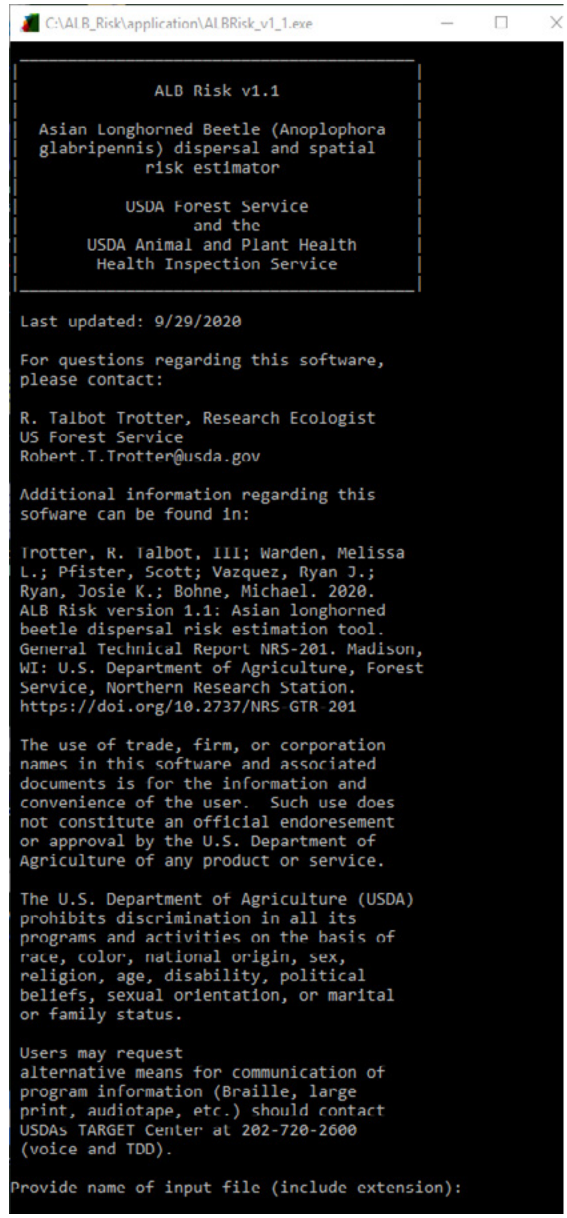


Figure 16.—Double clicking the file *ALBRisk_v1_1.exe* will launch the model program. Once launched, the program will provide information and prompt the user to identify an input data file. The model will accept many data file formats, though a *.dbf* format is recommended.

Once the name of the data file has been entered, press **enter** on the computer keyboard. The user will then be prompted to identify the columns that provide the infestation levels, X coordinates, and Y coordinates for the infested trees. The software identifies columns based on position (not column header or name), and position is denoted using letters (the same system used by Microsoft Excel™). Using this system, if the data of interest are stored in the first column, type the letter A, if the values are in the second column, enter B, for the seventh column, type G, etc. The letters entered are not case sensitive (both upper and/or lower case are acceptable). To determine which columns are to be used, open the *.dbf* file in a text editor, a GIS, or in a spreadsheet program such as Microsoft Excel™ (note however that newer versions of Excel™ can open *.dbf* files but cannot save data to a *.dbf* format). In the case of the example data provided in *ExampleData.dbf* the infestation data is provided in column E, X coordinates are in column F, and Y coordinates in are column G (as shown in Fig. 17, bottom of the screen). After entering each letter press **enter**.

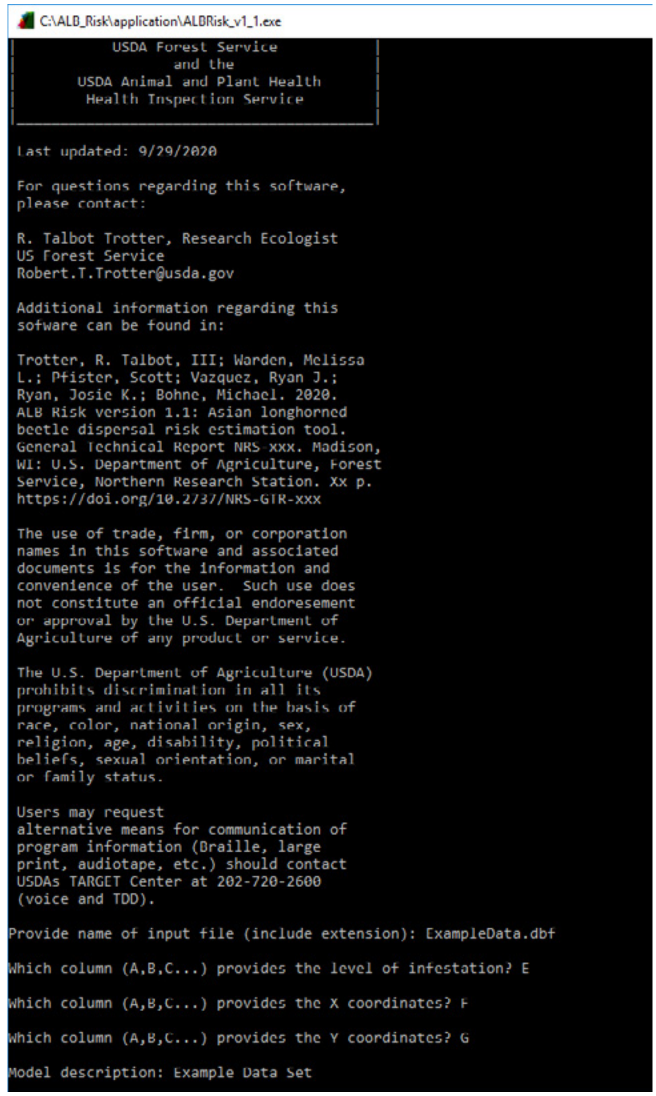


Figure 17.—After identifying the data file, the user will be prompted to identify the columns that provide the level of infestation, X coordinate, and Y coordinate for each tree. The user will also be prompted to provide a brief description for the model run.

Next, the user will be prompted with:

```
Model description:
```

The text entered by the user will be included in the titles of figures produced by the software, so the user is encouraged to enter text that will be useful when reviewing these documents such as the location of the infestation, or the names of parameters used in the analyses (if the user is running the analyses under varying conditions). There is no limit to the length of the text the user enters, however using long strings of text may result in odd figure titles; limiting the text to 30 characters will generally produce reasonable figures. If the user is running the Example Data, type "**Example Data Set**" or some other suitable text to describe the analyses, then press **enter**.

Naming output data files: At this point, the software will load the data. Depending on the size of the data set being loaded, this may take a few moments. Once the data is loaded, the software will indicate the data is loaded and the program is ready to continue by prompting the user to provide names for the two output raster data sets. The two output rasters will be identical with regards to the area analyzed and the locations of the hectares analyzed. However, the two files provide different output. The first file will be named based on the name provided by the user at the prompt:

```
Name of hectare risk raster file:
```

This file provides the estimated probability of infestation for each hectare within the analyzed area, with values ranging from 0 to 1. In the example shown in Figure 18 the file named used is **albrisk.txt**. The user will then be prompted to provide a name for the second output file with the message:

```
Name of raster file describing risk area:
```

This file provides an output raster with an extent that matches the first, however in this case, the values for each hectare will be binary (0 or 1). Hectares with the value 1 collectively describe the area that contains a specified overall risk (with the risk value set by the user, as described in the section below titled "Set Probability Threshold to Identify the Perimeter of the Eradication Area", where more detailed information is provided. Briefly, the output raster provides the minimum area that must be managed to achieve a given probability of eradication (probability value set by user). In this example, the file name used is **albarea.txt**. Note that when naming these files, the file name should include the suffix **.txt**.

Selecting Adjacency Rules: The first parameter option allows the user to select the set of adjacency rules the software will use to reconstruct the movement of beetles on the landscape. These rules determine which trees may serve as a source of beetles. In ALB Risk v.1.1, there are three options available: Relaxed, Strict, and Highly Strict (Fig. 18, bottom of screen).

Relaxed dispersal (default option 1) assumes that any tree with exit holes can serve as a source for dispersing beetles. Strict dispersal (option 2) assumes that beetles emigrate only from trees with higher levels of infestation (specifically C and D level trees with their corresponding 10-100 and 100+ exit holes) and comports with the idea that beetles are unlikely to disperse from their natal tree until the tree has been heavily infested and damaged by the beetle. Highly Strict (option 3) is extends the Strict dispersal assumption by assuming only D level trees will produce dispersing females. It is recommended that the user select option 1 (the default), as published data suggests this may be the most parsimonious option (Trotter and Hull-Sanders 2015). The user may select the option by typing the option number (1, 2, or 3). If the user presses **enter** without typing a number, the software will default to option 1. For each of the following user-options, pressing **enter** will select the default option shown in brackets.

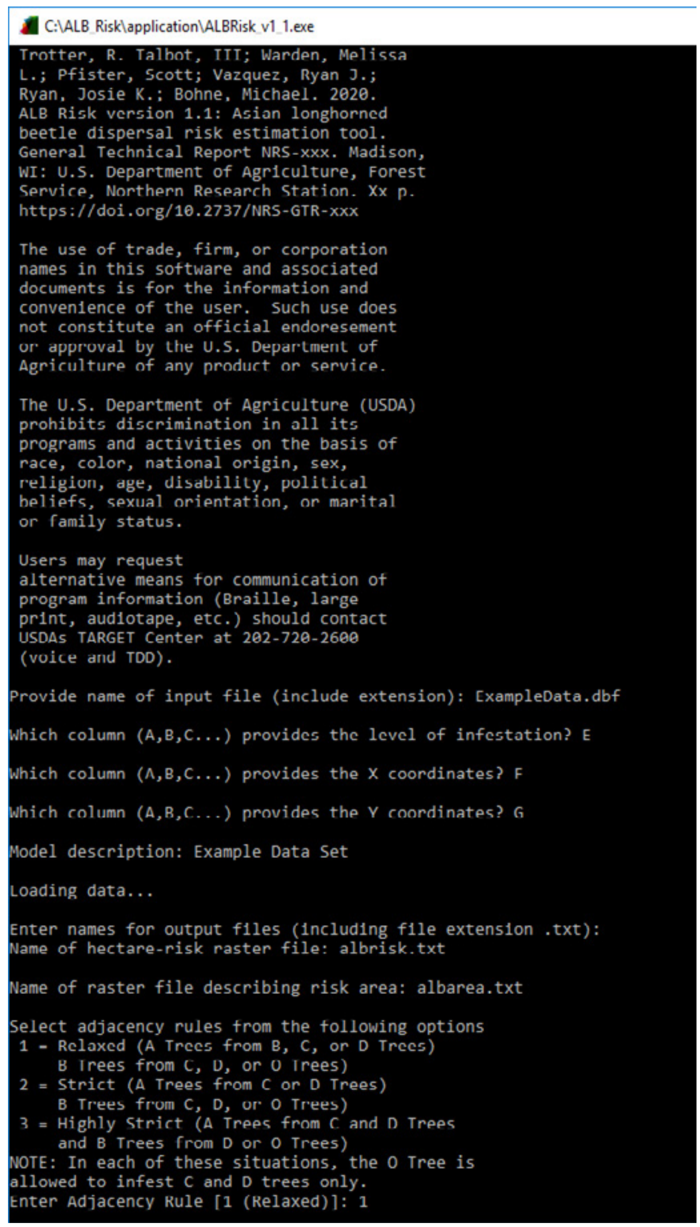


Figure 18.—Users can select from three different sets of assumptions regarding beetle dispersal. Option 1 is recommended.

Selecting Direction Bin Size: The reconstruction of ALB dispersal patterns on the landscape produces a collection of dispersal vectors, each with a direction and distance. To estimate the probability that a given beetle will disperse to a given distance and in a given direction, dispersal vectors are categorized into direction bins. The size of each bin is measured in degrees, for example the default value used by the software is 30 degrees (Fig. 19, bottom of the screen) which categorizes each dispersal event into one of 12 direction-specific bins (corresponding to the 30 degree ranges that correspond to north-north-east, northeast, east-north-east, etc.). The size of the direction bins can be modified by the user to either refine (by using smaller values) or generalize (by using larger values) the direction data. However, the user is limited to values that are factors of 360 degrees (i.e., values of 1, 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 30, 45, 60, 90, 120, 180, or 360 degrees). There is a tradeoff between bin size and sample size; as the directional bins become smaller, the estimated patterns of dispersal become more precise, however as the size of the bins decreases, so will the number of dispersal vectors within the bin. As a result, the dispersal probabilities are based on smaller sample sizes which makes them more subject to stochastic influences. Conversely, if direction bins are made larger, the sample size in each bin will increase but at the cost of more specific directionality. Setting the value to 360 degrees will place all of the dispersal vectors into a single bin producing a single, nondirectional dispersal kernel.

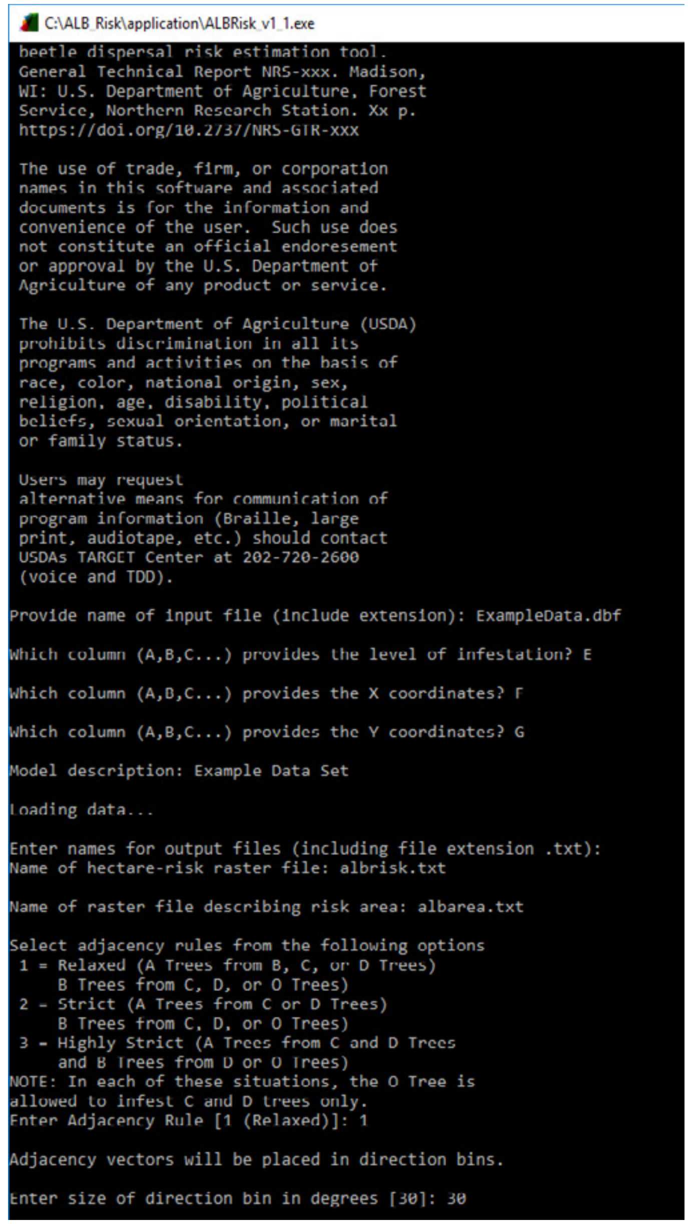


Figure 19.—The direction of each estimated beetle movement will be placed into a direction bin to facilitate analyses. Bin size is defined using degrees. Larger bins will increase the sample size used for each direction but will produce more generalized patterns. Smaller sizes increase the specificity of the model at the cost of sample sizes. Generally, a bin size of 30 degrees provides a reasonable balance.

Graphing Dispersal Vectors by Size

Beetle dispersals can span a range of distances, from as short as a few centimeters to multiple kilometers, and can occur in any direction. Landscape structures such as topography and vegetation distribution, and physical factors such as wind direction, may influence patterns of dispersal. To provide users with additional tools to explore the relationship between dispersal distance and direction, the model can produce rose-histograms for dispersal vectors in three size categories referred to simply as "short", "medium", and "long" (see example in Fig. 26). The distances that define these distance categories are defined by the user and may be useful for exploring patterns in the data. To define short, medium, and long distances, the user identifies two values that serve as the break points between short and medium, and medium and long dispersal events (Fig. 20, bottom of screen). The units are the same as those used by the input data set; in the case of UTM coordinates, the units will be meters. Here, we use the term meters for convenience. The default values provided are 100 and 1000 meters which categorizes dispersal distances between 0 and 100 meters as short, distances between 100 and 1000 meters as medium, and distances longer than 1000 meters as long. These values could, for example, be used to evaluate the directionality of dispersal events that occur within a stand (~100 meters), and those that cover more than a kilometer. It is IMPORTANT TO NOTE that the values set by the user are ONLY used to produce the graphic shown in Figure 26. The values selected to not impact or alter the reconstruction of beetle dispersal, or the estimation of risk on the landscape.

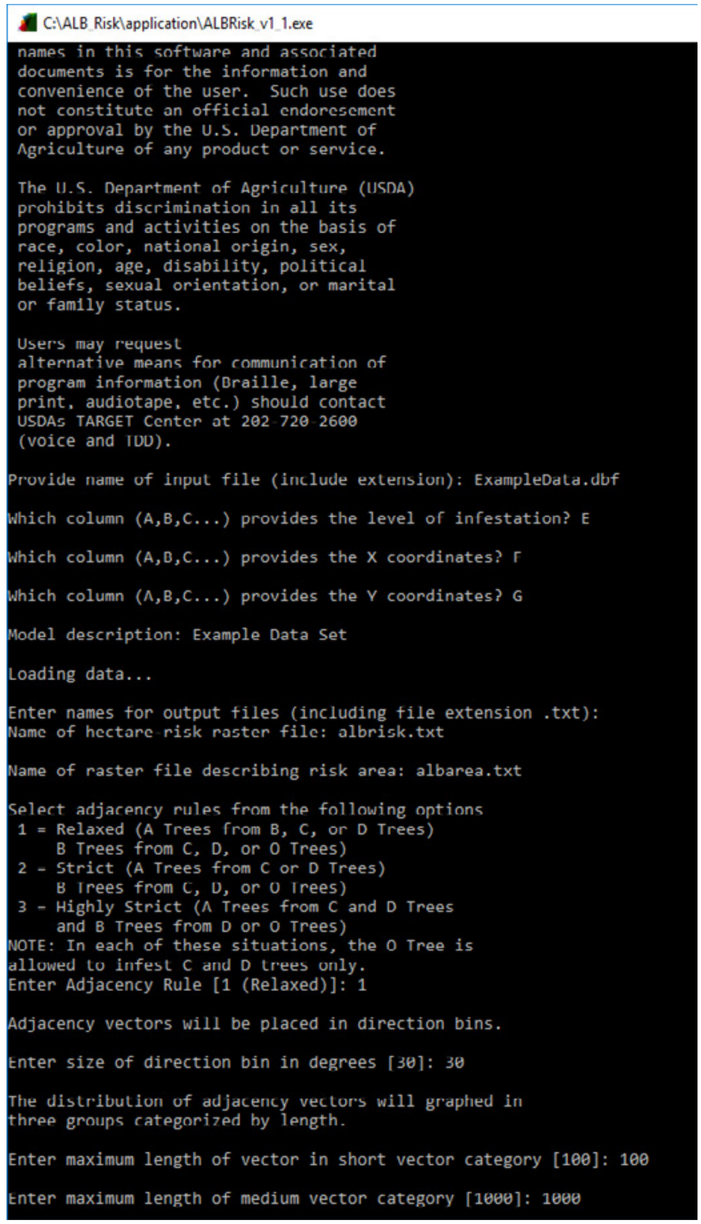
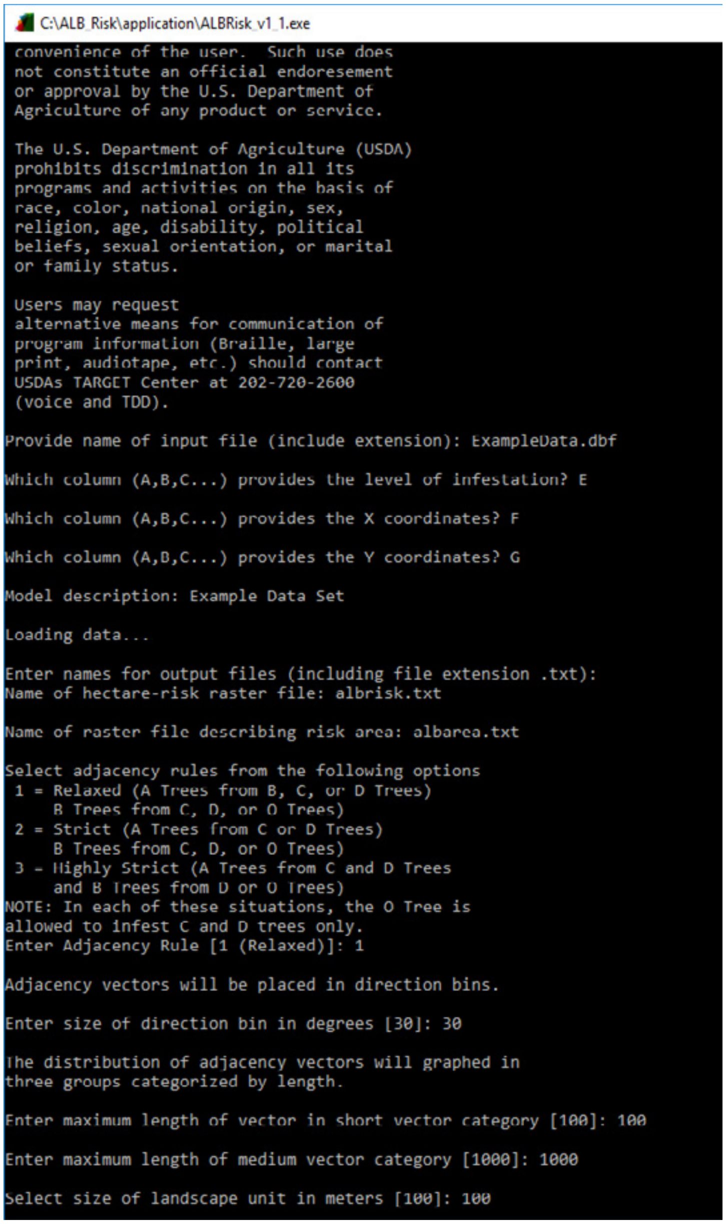


Figure 20.— Outputs for the model include a graph showing the directionality of dispersal based on whether the dispersal was "short", "medium", or "long." The maximum length for the short and medium dispersal identify the lengths that separate the three categories. NOTE: Changing these values does not change the analyses; it is included only as a tool to explore the data using Figure 26.

Size of Landscape Unit (Pixel) for Analysis

ALB Risk v1.1 provides output data in two rasters, and the user may set the size of the raster pixels. The default size for a pixel in the raster is 100 which (provided the input data X and Y coordinates are in meters) produces 100 by 100 meter or one hectare pixels. This parameter also sets the spatial unit of measure for distance bins (as described in Trotter et al. 2018) used to calculate risk based on distance to infested trees. The model will analyze a landscape that is 400 pixels east to west, and 400 pixels north to south, and centered on the mid-point of the distribution of infested trees. As the pixel size changes, the size of the landscape analyzed will also change. The default setting of 100 meters (Fig. 21, bottom of screen) applies the analyses to a 40 km x 40 km area. The use of the default value is recommended for users and in the following text the term hectares and pixels are used interchangeably.



```
C:\ALB_Risk\application\ALBRisk_v1_1.exe
 convenience of the user.  Such use does
 not constitute an official endoresement
 or approval by the U.S. Department of
 Agriculture of any product or service.

 The U.S. Department of Agriculture (USDA)
 prohibits discrimination in all its
 programs and activities on the basis of
 race, color, national origin, sex,
 religion, age, disability, political
 beliefs, sexual orientation, or marital
 or family status.

 Users may request
 alternative means for communication of
 program information (Braille, large
 print, audiotape, etc.) should contact
 USDAs TARGET Center at 202-720-2600
 (voice and TDD).

Provide name of input file (include extension): ExampleData.dbf

Which column (A,B,C...) provides the level of infestation? E

Which column (A,B,C...) provides the X coordinates? F

Which column (A,B,C...) provides the Y coordinates? G

Model description: Example Data Set

Loading data...

Enter names for output files (including file extension .txt):
Name of hectare-risk raster file: albrisk.txt

Name of raster file describing risk area: albarea.txt

Select adjacency rules from the following options
 1 = Relaxed (A Trees from B, C, or D Trees)
     B Trees from C, D, or O Trees)
 2 = Strict (A Trees from C or D Trees)
     B Trees from C, D, or O Trees)
 3 = Highly Strict (A Trees from C and D Trees
     and B Trees from D or O Trees)
NOTE: In each of these situations, the O Tree is
allowed to infest C and D trees only.
Enter Adjacency Rule [1 (Relaxed)]: 1

Adjacency vectors will be placed in direction bins.

Enter size of direction bin in degrees [30]: 30

The distribution of adjacency vectors will graphed in
three groups categorized by length.

Enter maximum length of vector in short vector category [100]: 100

Enter maximum length of medium vector category [1000]: 1000

Select size of landscape unit in meters [100]: 100
```

Figure 21.—The landscape is analyzed by breaking it into a grid with a size set using this option. We recommend the user select the default value of 100 meters, which will produce output data sets at a 1-hectare scale.

Set Probability Threshold to Identify the Perimeter of the Eradication Area

In addition to calculating the estimated probability of infestation for each hectare on the landscape, the model can produce a map that identifies the portion of the landscape that captures a specified, overall probability that the beetle remains on the landscape, and conversely the probability that the beetle has been eradicated. The user sets this value at the prompt:

```
Set probability of eradication to identify area to manage [1]:
```

In the example shown in Figure 22 (bottom of screen), the value has been set to 0.95. Based on this value, the model will identify the smallest number of hectares that can be managed in order to achieve a 95 percent probability that the beetle has been eradicated from the landscape. Note that the model assumes that the risk in managed hectares is reduced to 0. If the user sets the value to 1 (the default), the model will indicate all of the hectares on the landscape that include any calculated risk of beetle infestation. The outer perimeter of the

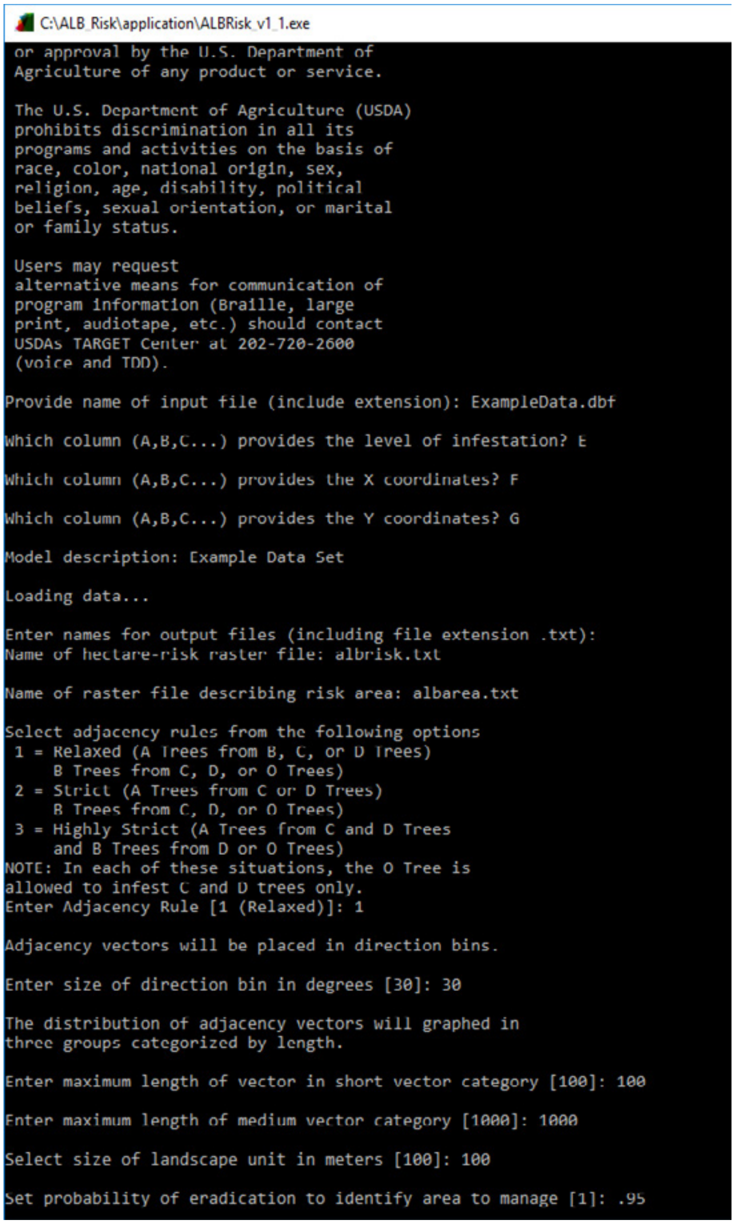


Figure 22.—The software will produce a second raster dataset that identifies the minimum area that must be managed to achieve a given probability of eradication. This setting allows the user to set this probability. In the example shown, the value entered is 0.95, so the output raster will identify the portion of the landscape to be managed in order to achieve a 95 percent probability that the beetle has been eradicated from the landscape.

at-risk area represents the total area with calculated risk and may have utility as an estimate for the boundaries of the infestation. Note that the output raster is spatially explicit, and the perimeter of the area with estimated risk may not be contiguous.

Adult Female Dispersal Rate

To estimate the probability that a beetle has arrived at a specified location on the landscape it is necessary to know two parameters: the number of adult female beetles on a tree and the proportion of those females which disperse from their natal tree.

The number of adult female beetles on a tree is estimated by assuming that 50 percent of the emerging beetles are female, and that the tree in each infestation category includes the maximum number of exit holes for that category. For example, a level 3 (also called level C) infested tree has between 10 and 100 exit holes, with an assumed maximum 100 adults, 50 of which are female and have the potential to disperse to infest new trees.

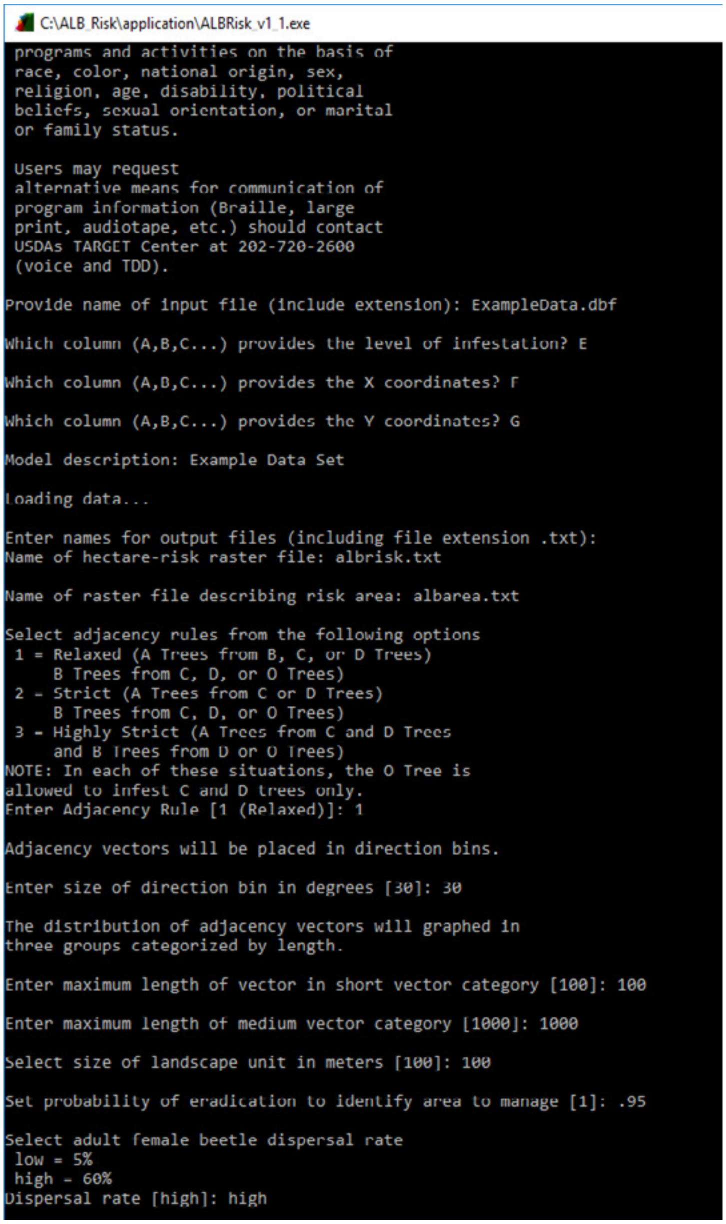


Figure 23.—The rate at which female beetles emigrate from their natal tree to infest new trees is not well documented. However, laboratory and field data suggest the rate can be as low as 5 percent, or as high as 60 percent. The user may choose to run the model using both parameters in order to bracket the estimated risk.

Information on the rate of female dispersal, however, is highly limited and so this parameter remains under study. Published studies have suggested rates of dispersal as low as 5 percent and as high as 60 percent. To accommodate this variation, the software can be run using an assumption of either low (5 percent) or high (60 percent) dispersal rates (Fig. 23, bottom of screen). Using the above level-3 tree example, under a low dispersal scenario the model assumes the tree has produced 2.5 dispersing females (50 x 0.05). Under a high dispersal scenario, the model assumes the tree has produced 30 dispersing females (50 x 0.6). The default value used by the model is the high dispersal rate, as this represents a "worst case scenario" structure. However users may find it informative to run the model twice—once under each dispersal rate—to examine how changes in dispersal rate on the landscape may change patterns of risk.

Press **enter** on the keyboard to start the model. The window will indicate the software is running and will display a message when complete as shown in Figure 24.

```
C:\ALB_Risk\application\ALBRisk_v1_1.exe

 Users may request
 alternative means for communication of
 program information (Braille, large
 print, audiotape, etc.) should contact
 USDAs TARGET Center at 202-720-2600
 (voice and TDD).

Provide name of input file (include extension): ExampleData.dbf

Which column (A,B,C...) provides the level of infestation? E

Which column (A,B,C...) provides the X coordinates? F

Which column (A,B,C...) provides the Y coordinates? G

Model description: Example Data Set

Loading data...

Enter names for output files (including file extension .txt):
Name of hectare-risk raster file: albrisk.txt

Name of raster file describing risk area: albarea.txt

Select adjacency rules from the following options
 1 = Relaxed (A Trees from B, C, or D Trees)
     B Trees from C, D, or O Trees)
 2 = Strict (A Trees from C or D Trees)
     B Trees from C, D, or O Trees)
 3 = Highly Strict (A Trees from C and D Trees
     and B Trees from D or O Trees)
NOTE: In each of these situations, the O Tree is
allowed to infest C and D trees only.
Enter Adjacency Rule [1 (Relaxed)]: 1

Adjacency vectors will be placed in direction bins.

Enter size of direction bin in degrees [30]: 30

The distribution of adjacency vectors will graphed in
three groups categorized by length.

Enter maximum length of vector in short vector category [100]: 100

Enter maximum length of medium vector category [1000]: 1000

Select size of landscape unit in meters [100]: 100

Set probability of eradication to identify area to manage [1]: .95

Select adult female beetle dispersal rate
 low = 5%
 high = 60%
Dispersal rate [high]: high

Running...

Run complete
```

Figure 24.—When the analyses has been completed, as indicated at the bottom of this window, and the software will open six additional windows with graphs and figures.

Evaluating the Output

When ALB Risk v1.1 completes its analyses, the software will display six graphs. These graphs provide insight into the structure of the data and patterns of beetle dispersal on the landscape. Each graph is explained below. Note that when the command window is closed, the graphs will be closed without being saved. To save the graphs, use the disk icon in the upper left corner of each graph window. Icons in the window will also allow the user to zoom in and pan over the graph.

Reconstructed Patterns of Beetle Dispersal

Using the rules (Relaxed, Strict, and Highly Strict) described previously (see Fig. 18), the software will infer the patterns of beetle movement by creating vectors among the infested trees. A graphical representation of these movements on the landscape (Fig. 25) is provided by the software. Each line represents the movement of (at least) one beetle from a source tree to a receiving tree. Note also that the text entered by the user as a description of the analyses (in this case, "Example Data Set") is included in the title.

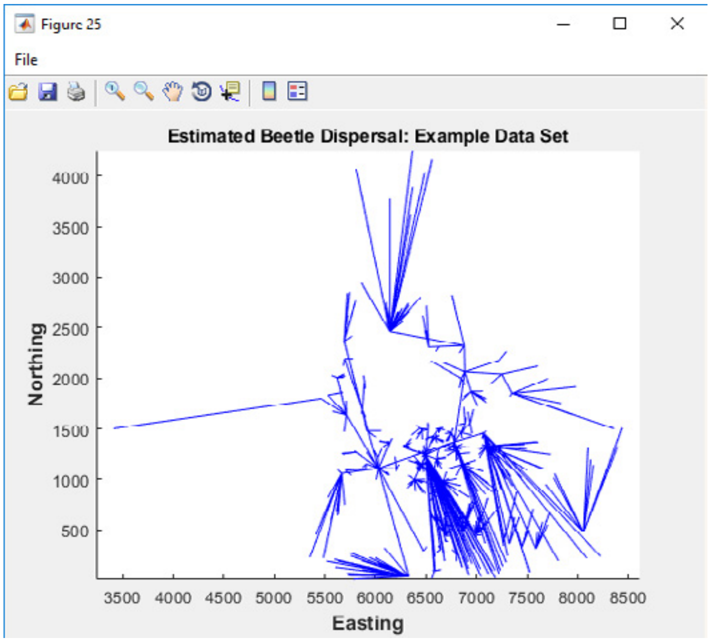


Figure 25.—The analysis of risk on the landscape is based first on reconstructing how the beetle disperses. This graph shows the estimated pattern of dispersal within the infested area based on the artificial data provided.

Short-, Medium-, and Long-Distance Dispersal Patterns

A rose-histogram plot showing the number of beetle dispersal events (vectors) for each direction bin is provided in Figure 26. This figure can be modified by the user (as described in the section Selecting Direction Bin Size) and based on whether the vector is considered a short-, medium-, or long-distance event (categories can be modified by the user). Note that this graphic is included to provide the user with insight into beetle dispersal behavior, but the use of short-, medium-, and long-distance categories does not affect the calculation of dispersal risk on the landscape (shown in Figure 28) and the output data files. In the example shown, dispersal at short distances (less than 100 meters, perhaps within-stand dispesal?) appear somewhat random, while medium dispersal distances (between 100 and 1000 meters) are generally toward the northeast, and long dispersal events were almost always to the south.

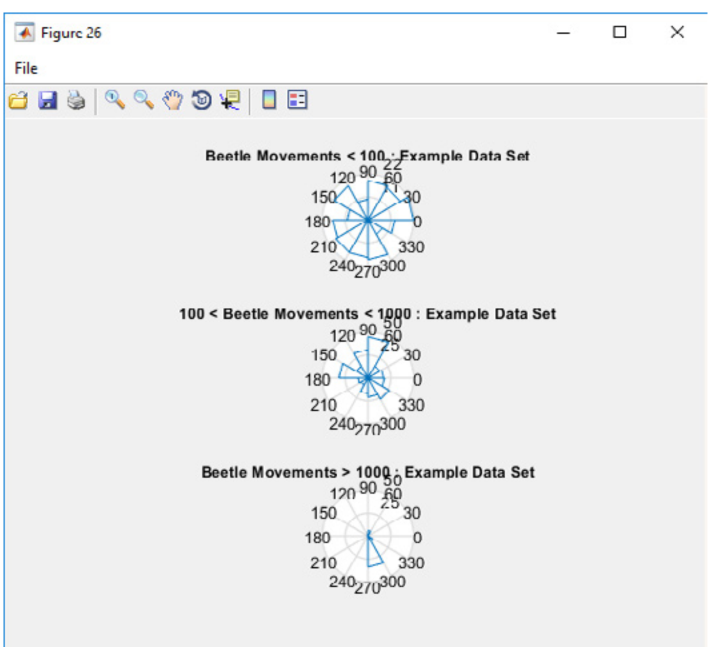


Figure 26.—As mentioned in the description of Figure 20, the user can identify the distances that will be categorized as "short", "medium", and "long." These plots provide grap¬hical representations of the directionality of the beetle movements in each distance category. In the example shown, short dispersal events (top) appear to have occurred in random directions, while long dispersal events (bottom) were strongly biased toward the south-southeast.

Two- and Three-Factor Dispersal Kernels

Figure 27 shows each of the directional dispersal kernels, however it may be more intuitive to view the dispersal kernels oriented in their geographic directions, as shown in Figure 28. The point (0,0) at the center of the surface shown in Figure 28 represents the location of a beetle source (an infested tree). The asymmetrical rings around the point represent cumulative probabilities of dispersal and are similar to topographic lines on a map. The outer-most edge of the ring represents the spatial extent of dispersal risk around a given tree based on distance and direction. Distances beyond the outer ring are assumed to have a zero probability of dispersal because no dispersal events were reconstructed in those directions at those distances. The user can rotate and shift the figure to explore the structure of the figure by first selecting the "rotate" button (icon with small cube, within a counter-clockwise arrow), and then clicking on the figure with the left mouse button and dragging across the figure. The user can return the figure to the original perspective by right-clicking on the figure and selecting "Reset to original view."

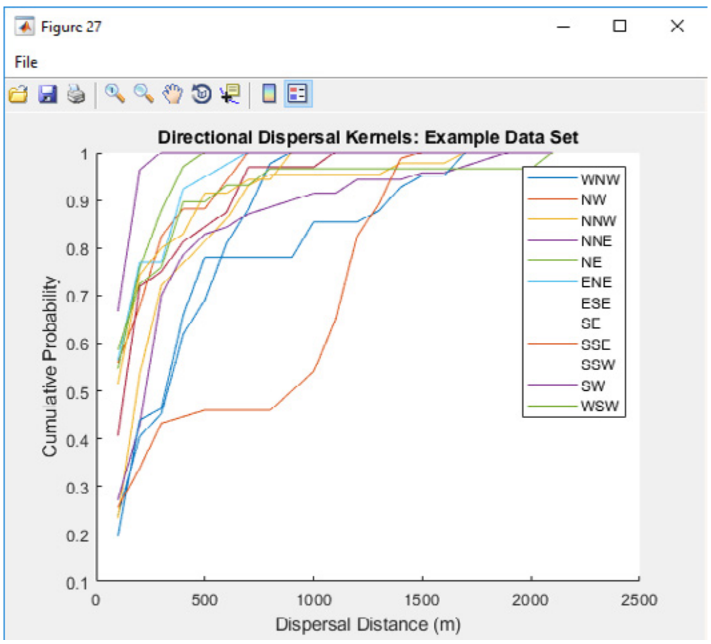


Figure 27.—The probability that a beetle will travel to a given distance is provided by the dispersal kernels, each of which represents a specific direction of travel shown in the legend of this graph.

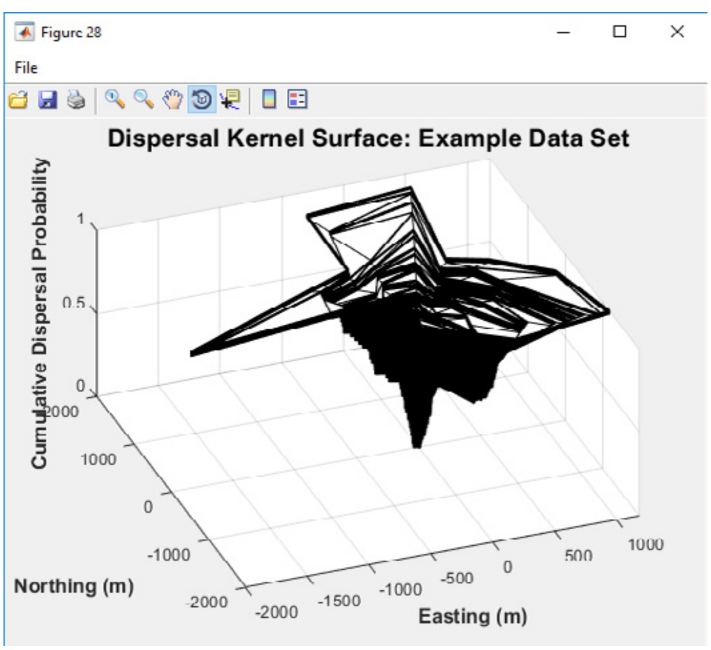


Figure 28.—Combining the dispersal kernels shown in Figure 27 and placing them in a three-dimensional graph provides a representation of the distribution of risk around a single infested tree. The location of the tree in the figure is represented by the point at the bottom.

Landscape Risk Map

Figure 29 provides a representation of the distribution of risk on the landscape. X and Y axes represent easting and northing values, respectively. Yellow colors represent low or no risk of dispersal, while blue colors represent high risk. NOTE: Values for each hectare represent the probability that there are NO ALB within that hectare. A value of 1 indicates an estimated 100 percent probability that the hectare is not infested, a value of 0.01 indicates there is a 1 percent chance the hectare is not infested. Though this format may seem counterintuitive, this data structure facilitates the calculation of cumulative, landscape-scale risk values. To convert the values from the probability that beetles are absent to the probability that the hectare is infested with at least one beetle, simply subtract the value in each hectare from 1. The user may use the buttons at the top of the figure to zoom in or out, and to pan across the image. The data used to generate this graph is saved in the text file called *beetlerisk.txt* and is formatted as an ASCII raster file for use in a GIS as described below.

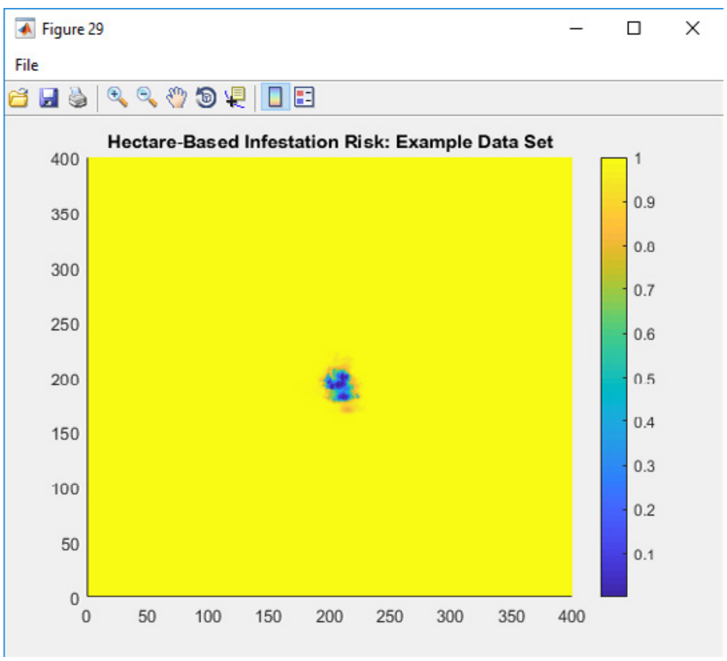


Figure 29.—The hectare-by-hectare estimate of infestation risk produced by the program is shown and is stored in the file identified by the user (see Figure 18). In this example, the output is saved to a file called *albrisk.txt*.

Eradication Effort-Benefit Estimate

If each of the hectares on the landscape is rank-ordered starting with the highest risk hectare, and the hectares are then sequentially managed in a way that reduces the risk within the hectare to 0, then as an increasing number of hectares are managed, the probability that the beetle has been eradicated increases (i.e., the probability that beetles remain somewhere on the landscape decreases). Plotting the number of hectares managed (i.e., have had the risk reduced to 0) as a function of the probability that at least one hectare is still infested produces an effort/benefit curve (Figure 30).

NOTE: Closing all six of the graph windows will close the command window for ALB Risk v1.1. This is normal and indicates the program has completed running and has closed normally. If the command window does not close, or if the user would like to close it early, the "close window" button [X] in the top corner can be used at any time. Note that if the program is closed while running, data and output from the analyses will not be saved.

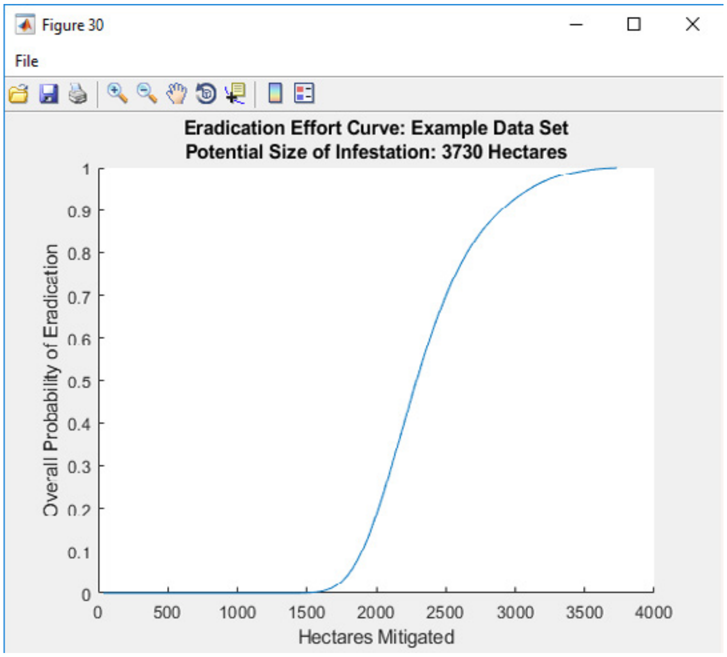


Figure 30.—As the risk for each hectare is mitigated, the overall risk that an infestation remains on the landscape is reduced. This graph provides a hypothetical estimation of the overall risk on the landscape as increasing amounts of the landscape are mitigated, similar to a cost-benefit curve.

Output Data and Mapping the Results

When ALB Risk v1.1 completes its analyses, the results are saved in two text files that provide raster data in an ASCII format. In the example shown above, these files were named *albrisk.txt* and *albarea.txt*. The first file, *albrisk.txt* provides estimated probabilities for each hectare that the specified hectare does NOT include beetles (i.e. no beetles have arrived at that location from one of the infested trees on the landscape).

The files *albarea.txt* and *albarea.txt* are formatted to be directly imported into a geographic information system as ASCII raster files. The user will likely need to define the projection once the data has been imported into the GIS. This is the same UTM projection used to produce the X and Y coordinates for the infested trees in the original input data set.

Notes on interpreting the maps: It is important to point out at that the probabilities for each hectare in the dataset represent the probability that at least one tree in the hectare is infested. This estimated risk assumes that in a given hectare, the known infested trees have been removed, and the risk value for the hectare is the probability that none of the remaining trees are infested, and that none of the remaining trees in the hectare have been surveyed. Because surveys within a given hectare are likely to have included all of the potential host trees, and because areas may be surveyed multiple times using multiple methods, the risk of infestation provided may overestimate the effective risk in a given area. To update risk based on the history and intensity of surveys for a given area, users are encouraged to use a companion program, ALB Dynamic Risk v1.0, which uses the output from ALB Risk v1.1 (*albrisk.txt*) as a starting point for analyses (see footnote 4 for more information).

The file *albarea.txt* provides spatial data in the same structure and area as described above, however the values in the hectares are binary. When the software is run, the user can define a given overall probability of eradication for the entire landscape, and the software will identify the area of the landscape that must be managed to achieve this overall probability. For example, if the user sets the value to 0.95, the area represented by hectares with the value 1 provides the footprint for the area that should be managed to achieve a 95 percent probability of eradication. The software makes several assumptions in producing this layer, including the assumption that when a hectare is managed, the risk of infestation for that hectare is reduced to 0. The software also assumes that the goal is to produce the overall probability of eradication, using the fewest number of hectares possible. Because of this, the resulting areas may not be contiguous.

Errors, Bugs, and Other Problems

If you encounter errors or problems running the software, please contact Talbot Trotter at Robert.T.Trotter@usda.gov.

Changes from Previous Versions: ALB Risk v1.0 was a previous version of the described software used in the publication Trotter et al. (2018). ALB Risk v1.1 includes two modifications to ALB Risk v1.0. The first change alters the way the output data from the program is structured and saved. In the original version, the data was output into a set of Microsoft Excel™ spreadsheets. To make the data more platform neutral, the software now outputs data files to user-named text files using a *.txt* format. These files can be loaded directly into a geographic information system and can be reformatted for use in multiple platforms.

The second change is largely transparent to users and consists of a modification to the way the landscape is separated into smaller portions to accelerate processing. In the version 1.0, the landscape was separated into four equally sized tiles, arranged in a 2 x 2 array. To simplify data structure and provide flexibility in the sizes and shapes of landscapes to be analyzed, the program now separates the landscape into strips, such that the width of the strip (east-west) is defined by the dimensions of the landscape being analyzed, and the height of each strip (north-south) can be modified to address computational limitations that might otherwise slow the program.

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The Asian longhorned beetle (Anoplophora glabripennis Motschulsky) is an invasive polyphagous woodborer that has been introduced to North America and Europe. Due to the severe economic and ecological damage resulting from infestations of this insect, many countries, including the United States, have adopted policies of eradication. However, managing eradication can be a daunting challenge as it requires program managers to identify and destroy individual infested trees distributed across landscapes that may include millions of host trees. This report describes the use of the computer model ALB Risk version 1.1, which estimates the boundaries of the at-risk landscape, as well as the distribution of risk within the infestation based on dispersal patterns. The program generates risk-maps, identifies priority areas for management, and estimates the potential return on survey effort. The software is available at https://doi.org/10.2737/NRS-GTR-201.

KEY WORDS: at-risk landscape, invasive species, wood borer, Coleoptera, spatial risk, eradication, pest survey

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