United States Department of Agriculture
Animal and Plant Health Inspection Service

Quantitative Pathway Initiated Pest Risk Assessment:

Risks to the Southern United States Associated with Pine Shoot Beetle, *Tomicus piniperda* (Linnaeus), (Coleoptera: Scolytidae), on Pine Bark Nuggets, Logs and Lumber with Bark and Stumps from the United States Quarantined Area

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Executive Summary

The Center for Plant Health Science and Technology (CPHST) conducted this pest risk assessment (PRA) at the request of Weyman Fussell with USDA-APHIS-PPQ-PDMP. Its purpose is to quantitatively estimate the risks of *Tomicus piniperda* colonization associated with: 1) pine bark nuggets, 2) logs and lumber with bark and 3) stumps from quarantined areas in the United States into the Southern States if these products were deregulated. In addition, we modeled the risk of colonization with each combination of pathway deregulation and the total risk if all pathways were deregulated simultaneously. This information could be used to maximize efficacious regulation of *T. piniperda* while reducing its economic impact on affected industries.

Quantitative pathway models were constructed to estimate the risks of colonization associated with each pathway by season and annually. The seasons were defined: 1) Spring (March through June), 2) Summer (July and August), 3) Fall (September through November) and 4) Winter (December through February). Our seasonal classification system was based on *T. piniperda* reproductive biology, the resulting shipping regulations for at-risk commodities and predictive climate modeling regarding shoot departure dates. The Summer was not analyzed because *T. piniperda* will be maturation feeding in the shoots and should not be present in the exported tree stem.

We reported the results in terms of years until colonization will occur as a result of deregulation of each pathway. The analysis and conclusions in this risk assessment are based on the *T. piniperda* quarantined counties as of December 2, 2005. Additions to the list of quarantined counties could change the risk estimates for each pathway.

We classified seven of the pathways to be low risk for causing *T. piniperda* colonization in the South if deregulated. These pathways were: 1) bark nuggets, 2) logs and lumber with bark in the Fall and Winter, 3) stumps, 4) the combination of bark nuggets and stumps, 5) the combination of bark nuggets and logs and lumber with bark in the Fall and Winter, 6) the combination of bark nuggets, stumps and logs and lumber with bark in the Fall and Winter and 7) the combination of stumps and logs and lumber with bark in the Fall and Winter. Summary risk tables and figures reporting the estimated rates of colonization by these pathways are provided.

Deregulation of these pathways would probably not facilitate faster colonization of *T. piniperda* in the South than would occur due to natural spread and human movement of infested commodities within the quarantined area assuming no inhibition by abiotic or biotic factors. However, we recommend that the uncertainty regarding *T. piniperda's* rate of spread into the South due to interspecific competition with indigenous pine beetles be considered in future regulatory decisions regarding these seven pathways.

The bark nugget pathway was low risk due to beetle mortality during the debarking process. Reasons the stump pathway was low risk include: 1) the small number of stumps that are harvested, 2) the small number of mills that receive stumps and 3) the smaller proportion of beetles feeding below the cutline in the Spring. Reasons the colonization risk was less during the Fall and Winter versus the Spring include: 1) *T. piniperda* is overwintering and there are fewer beetles per tree, 2) the majority of beetles will remain behind after log harvesting in the stumps, duff and soil and 3) there is a lower probability of successful dispersal and colonization.

We classified four of the pathways to be high risk for causing *T. piniperda* colonization in the South if deregulated. These pathways were: 1) logs and lumber with bark in the Spring and annually, 2) bark nuggets and logs and lumber with bark in the Spring and annually, 3) bark nuggets, stumps and logs and lumber with bark in the Spring and annually and 4) Stumps and logs and lumber with bark in the Spring and annually. Deregulation of these pathways could substantially accelerate the colonization rate of *T. piniperda* in the South.

The models for these pathways estimated that *T. piniperda* colonization in the South would occur within the first year after deregulation. These estimates are probably high due to the conservative assumptions we made in the models. However, these results may partially explain the observed *T. piniperda* spread rate since its detection in 1992, i.e. approximately 36 miles per year. Our models indicate that the Spring movement of logs and lumber with bark within the quarantined area may be one of the main pathways by which *T. piniperda* is spreading. The other seasons contributed little to the overall annual risk. The addition of the bark nugget and/or stump pathways in the Spring and annually did not affect the rate of colonization compared to logs and lumber with bark alone because: 1) the comparative risk with these pathways was estimated to be low and 2) colonization was already estimated to occur within the first year after deregulation with the logs and lumber with bark pathway for these seasons.

Based on these results we recommend: 1) composting and/or grinding of bark nuggets as safeguarding measures to further reduce the risk of colonization via this pathway, 2) maintaining regulation of logs and lumber with bark during the Spring, 3) maintaining compliance agreements that stipulate debarking of logs and lumber with bark with ring debarkers as rapidly as possible, e.g. between two and ten days after arrival at the mill, 4) grinding stumps for fuel as rapidly as possible (see recommendation 3 above) and 5) regulating pine fuelwood until the risk of *T. piniperda* colonization via this pathway is assessed. These recommendations should help reduce the risk of *T. piniperda* colonization in the South.

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I. Introduction

Tomicus piniperda, the pine shoot beetle, is a member of the economically important bark beetle family Scolytidae (Borror *et al*., 1989; CABI, 2004). The principal hosts of *T. piniperda* are pines (CABI, 2004). They will attack the stem of weakened trees when breeding and the shoots of weakened or healthy trees during sexual maturation (Haack and Kucera, 1993). *Tomicus piniperda* stem feeding can result in tree mortality and a reduction in commodity value (CABI, 2004). Beetles are at risk for being moved in regulated timber products during the brood feeding stage in the stem (Haack and Poland, 2001). Shoot feeding can cause aesthetic damage, growth losses and a reduction in tree fitness (CABI, 2004; Lieutier *et al*., 2003; OHDNR, 2005; Ye, 1991). *Tomicus piniperda* is considered at risk for being moved in pine nursery stock, Christmas trees and raw pine materials for wreaths and garlands when maturation feeding in the shoots (Haack and Poland, 2001).

In natural settings the beetle acts as a decomposer but in plantation settings it can cause substantial economic damage if populations reach high levels (Czokajlo *et al*., 1997; Långström and Hellqvist, 1991; Morgan *et al*., 2004). *Tomicus piniperda* is considered a major forest pest in Europe and China (CABI, 2004; Ye, 1991). *Tomicus piniperda* is also a trade concern because it will readily move in dunnage and wood packing materials (PIN, 2005).

In 1992, *T. piniperda* was detected in a Christmas tree plantation near Cleveland, Ohio (Haack and Kucera, 1993). Since then it has been detected in 15 states and resulted in 590 quarantined United States counties due to natural spread, human movement of infested commodities in the quarantined area and increased surveys (Haack and Poland, 2001; Heilman *et al*., 2005; NAPIS, 2005; USDA-APHIS, 2005a, 2005b).

The presence of *T. piniperda* in the United States has resulted in quarantines on the movement of potentially infested articles (CFR, 2003, 2005). Regulated pine articles are: 1) Christmas trees, 2) nursery stock, 3) logs and lumber with bark, 4) stumps, 5) bark nuggets and 6) raw materials for wreaths and garlands.

This risk assessment is one in a series whose purpose is to quantitatively estimate the risks to the Southern United States associated with regulated timber articles from the United States quarantined area in the event of deregulation. The regulated articles analyzed in this assessment were: 1) bark nuggets, 2) logs and lumber with bark and 3) stumps. We also analyzed the combined risk associated with the simultaneous deregulation of logs and lumber with bark and stumps due to the potential additive nature of these articles. Results are reported in terms of years until colonization in the South. The results of this risk assessment can be used to facilitate efficacious regulation of *T. piniperda* by identifying commodities and pathways that pose a significant risk for colonization of the beetle in the Southern United States.

II. Current Distribution in the United States, Natural Spread and Human Movement of Infested Commodities in the Quarantined Area

Tomicus piniperda was first detected in the United States near Cleveland, Ohio in 1992 (Haack and Kucera, 1993). Subsequent surveys conducted that year detected infested counties in Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York (Haack and Poland, 2001). As of December 2, 2005 *T. piniperda* has been detected in 15 states, resulting in 590 quarantined counties (Haack and Poland, 2001; Heilman *et al*., 2005; NAPIS, 2005; USDA-APHIS, 2005a, 2005b) (Figure 1). All but one of those counties is in the North Central and Northeastern United States (Figures 1 to 3). Using Cleveland as the focal point, this represents an average radial expansion of 469 miles in every direction over 13 years and an average spread rate of 36 miles per year. That represents a worst case dispersal scenario because *T. piniperda* may have been introduced at more than one location and been present for some time prior to its initial discovery (Carter *et al*., 1996; Czokajlo *et al.*, 1997; Haack and Poland, 2001). For example, tree ring studies in an infested Scotch pine stand indicated that *T. piniperda* may have been present in New York before 1982 (Czokajlo *et al.*, 1997). The observed rate of spread can be attributed to: 1) human movement of infested commodities in the quarantined area, 2) wind dispersal, 3) long distance flight and 4) increased survey activities (Barak *et al*., 2000; CFR, 2003; Haack and Poland, 2000; Haack and Poland, 2001).

Figure 2 visualizes the projected distribution of *T. piniperda* after 40 years at an annual dispersal rate of 36 miles per year assuming no inhibition of movement by abiotic and/or biotic factors. This map represents a potential worst case scenario for *T. piniperda* spread with regulation.

Given its documented rate of spread it is probable that *T. piniperda* will continue to move east and northeast. How it will spread to the south and west is less certain. *Tomicus piniperda* will likely encounter interspecific competition with native bark beetles for brood host material as it moves southward (Haack pers. comm., 2005). This, combined with good stand management, may reduce the rate and degree of *T. piniperda* movement into the Southern states (Haack pers. comm., 2005; USDA-USFS, 2003). The western movement of *T. piniperda* may be inhibited by the vertical band of states from North Dakota to central Texas, i.e. the Great Plains States, where the pine host forest density is greatly diminished (USDA-USFS, 1991). The plains are characterized by large expanses of grasslands with few trees due to a lack of water (Birdsall and Florin, 1992). This could reduce the rate of spread by *T. piniperda* since it will become more difficult to locate brood host material and mates due to lack of aggregation pheromones (CABI, 2004; Haack and Kucera, 1993; OHDNR, 2005).

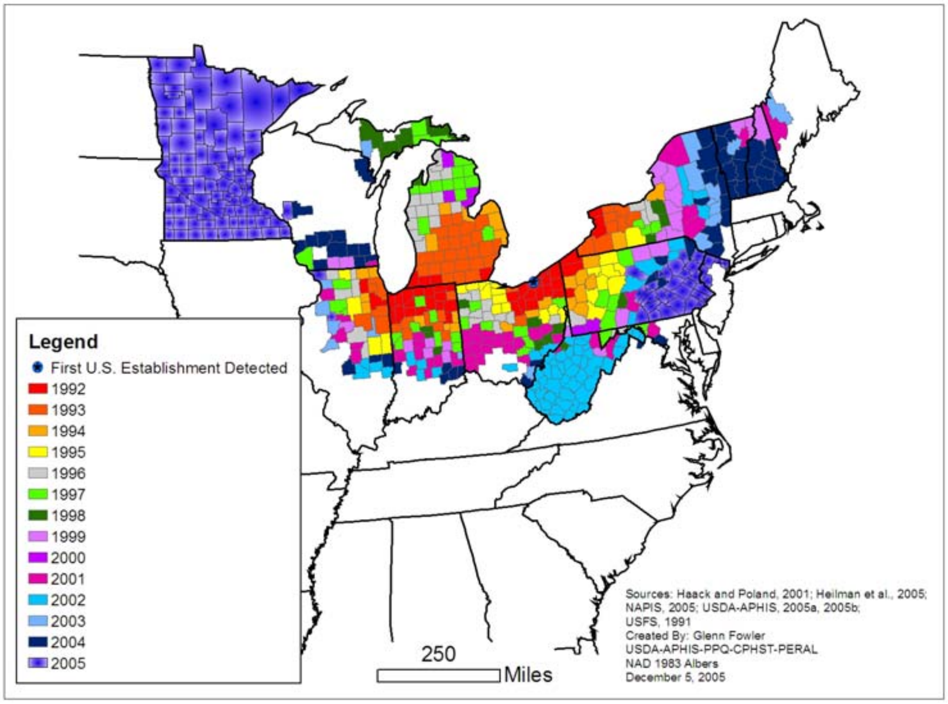

Figure 1. Quarantined counties in the United States added by year for *T. piniperda*.

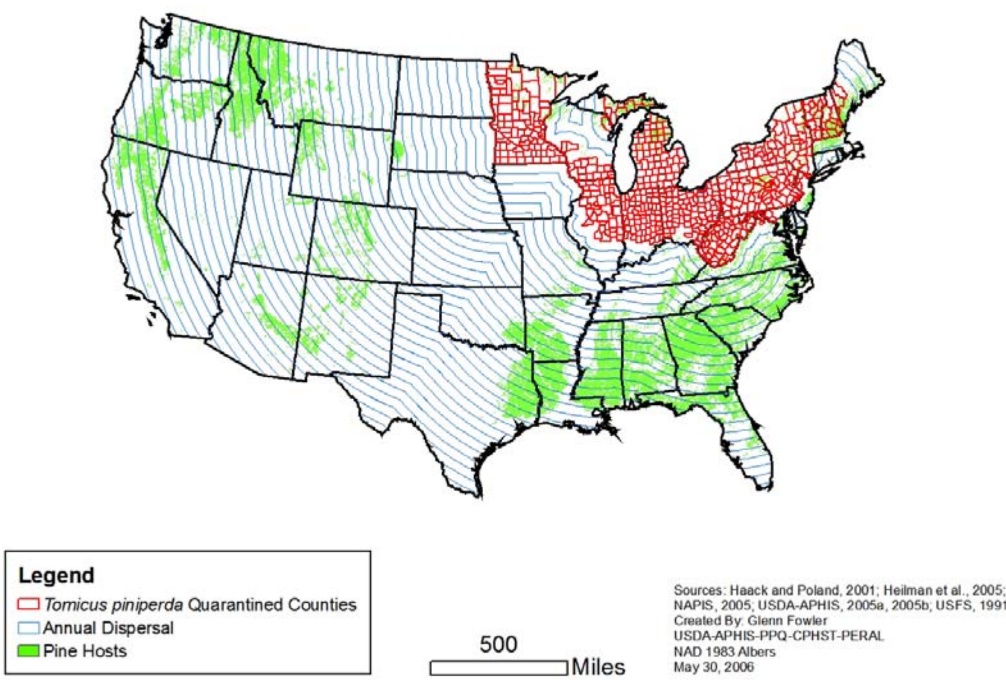

Figure 2. Projected worst case scenario for *T. piniperda* dispersal at a rate of 36 miles per year with regulation and assuming there is no inhibition by abiotic or biotic factors.

III. Methods

A. Quantitative Modeling

We quantitatively modeled the risk of *T. piniperda* colonization associated with the: 1) bark nugget, 2) logs and lumber with bark and 3) stump pathways in the event of deregulation. In addition, we modeled the risk of colonization with each combination of pathway deregulation and the total risk if all pathways were deregulated simultaneously. For the stumps and logs and lumber with bark pathways, colonization would occur at the mill. For the bark nugget pathway, colonization would occur at the mulch producer.

The analysis and conclusions in this risk assessment are based on the *T. piniperda* quarantined counties as of December 2, 2005 (USDA-APHIS, 2005b). Additions to the list of quarantined counties could change the risk estimates for each pathway.

Parameter values for the quantitative analysis were estimated from scientific, technical, economic and/or agricultural sources. In addition, data requests were distributed to the USDA-APHIS-PPQ State Plant Health Directors in *T. piniperda* infested states regarding shipment volumes and destinations of regulated articles (see appendices). Their responses were used to further inform the analysis.

We chose quantitative distributions based on data availability, format and applicability to model the nodes (major transition points) in each pathway (Table 1). Model simulation was performed using @Risk 4.52 Professional (Palisade, 2002). A Latin Hypercube simulation was used with 100,000 iterations. If no colonizing pairs formed after 100,000 iterations for a given season and/or scenario then we assumed that this would occur on the 100,001st iteration.

Table 1. Probalistic distributions used in the risk assessment.

Distribution	Description
Beta	A continuous distribution bounded by 0 and 1 (Palisade, 2002) that estimates the probability of an event, e.g. Vose, 2000. The parameters for the Beta are: a = *s*+1 and b = *n*-*s*+1, where *s* = the number of successes and *n* = the number of trials
Binomial	A discrete distribution that returns the number of successes (*s*) (e.g. the number of beetles surviving debarking) out of *n* trials, each of which has the same probability of success (*p*) (Palisade, 2002).
Negative Binomial	A discrete distribution defined (in our models) by one plus the negative binomial of the number of successes (*s*) (discrete) and the probability of success (*p*) (continuous) (Palisade, 2002). We used the negative binomial to estimate the number of years that would pass before a desired result e.g. colonization.
Negative Exponential	A continuous, skewed distribution defined by a mean β (Palisade, 2002). We used the negative exponential to model the probability of *T. piniperda* surviving debarking after Caton and Spears (2005). Their estimate was based on studies of the similar sized *Ips typographus* (Dubbel, 1993).
Normal	A continuous, unbounded distribution defined by a mean and standard deviation. We used the normal distribution to model populations and parameters, e.g. beetle populations on a tree.
PERT	A continuous distribution consisting of minimum, most likely and maximum values (Palisade, 2002). We used the PERT to model parameters where atleast the minimum and maximum were known and a bell shape was expected.
Uniform	A continuous distribution bounded by minimum and maximum values in which each value is equally likely (Palisade, 2002). We used it for parameters where uncertainty existed about the distribution between the minimum and maximum (Vose, 2000).

We reported results as the number of years until colonization in the South. The 5th, mean and 95th percentiles were reported to express the statistical results of the models. The associated cumulative distribution function for each pathway output was also generated. The cumulative distribution function expressed the probability that the number of years until a colonization for each pathway would be less than or equal to a specified value (Vose, 2000). Using the cumulative distribution function, the probability of interest can be estimated by: 1) identifying the number of years until a colonization of interest on the *x*-axis, 2) moving vertically up from that point to the interception point on the graph and 3) moving horizontally left from the interception point to the associated probability on the *y*-axis.

We classified a pathway as low risk if there was atleast a 95 percent chance that *T. piniperda* colonization would occur after four years if deregulated. This is approximately how long *T. piniperda* would take to move 150 miles into the South assuming the worst case scenario for spread with regulation (Figure 2). Conversely, we classified a pathway as high risk if there was greater than a five percent chance that colonization could occur within four years if deregulated.

We used the United States Forest Service classification system to define the Southern States for this risk assessment (USDA-USFS, 2005) (Figure 3). Under this system the South is composed of the following states: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas and Virginia.

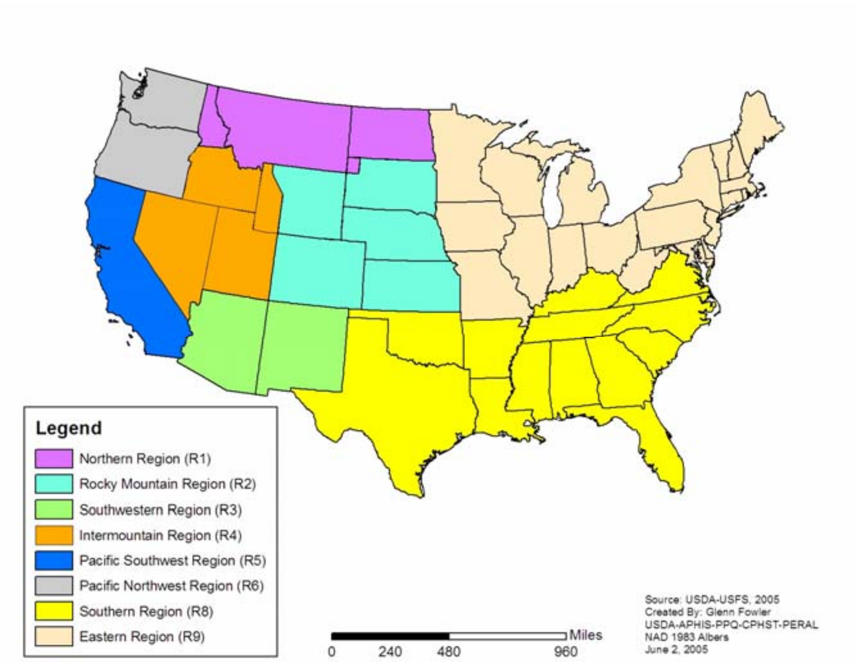

Figure 3. USFS regions.

We analyzed each pathway in applicable seasonal and annual terms. We divided the year into four seasons based on the following divisions: 1) Spring (March, April, May and June), 2) Summer (July and August), 3) Fall (September, October and November) and 4) Winter (December, January and February). Our seasonal classification system was based on *T. piniperda* reproductive biology, the resulting shipping regulations for at-risk commodities (Pfister and others, 2003) and predictive climate modeling regarding shoot departure dates (see below) (Figures 4 and 5).

Spring flight along *T. piniperda's* southern distribution could occur earlier than March due to the warm temperatures in this region (Haack pers. comm., 2006; Haack and Poland, 2001). Consequently, an alternative Spring classification system that could also apply would be February through May (Haack pers. comm., 2006).

Either Spring classification system would generate the same results for risk of colonization since they both encompass a four month period which determines the respective at-risk commodity shipping volume (Griffin and Miller, 1994) (Table 2). Because: 1) our models indicated high probabilities of spring flight in March (see below) (Figures 4 and 5) and 2) current shipping regulations consider spring flight to occur through June (Pfister and others, 2003), we chose the March through June Spring classification system for this analysis.

We considered the possibility of *T. piniperda* still overwintering in the early Spring, i.e. March, instead of already forming broods (Poland *et al*., 2002). However, predictive maps indicated that the majority of beetles in at-risk quarantined counties would have initiated flight within the first 2 weeks of March

(Figures 4 and 5). These models were based on two days during each week in March where temperatures met or exceeded 12˚C (Poland *et al*., 2002). Consequently, we assumed that brood generations would be forming during all Spring months and that no overwintering was taking place.

The Summer was not analyzed because *T. piniperda* will be maturation feeding in the shoots and should not be present within the exported tree stem (Griffin and Miller, 1994).

We used the estimates of Griffin and Miller (1994) to model dispersal and colonization probabilities during each season. Their estimates were generated by a panel of *T. piniperda* experts consisting of: 1) Deb McCullough (Michigan State University), 2) Robert Haack (USDA-USFS), 3) Win McLane (USDA-APHIS), 4) Mike Likens (Virginia Department of Agriculture) and 5) Raj Sitaraman (Michigan State Department of Agriculture).

Griffin and Millers' colonization and dispersal estimates applied to *T. piniperda* biology above 40°N latitude. The at-risk area analyzed in this assessment was below this latitude, i.e. 35°N to 39°N (Figures 4 and 5). We applied a seasonal shift to compensate for potential biological differences in dispersal and colonization due to climatology (see appendices for climate comparisons) (Table 2). For example, we applied their Early Spring estimates to the entire Spring season.

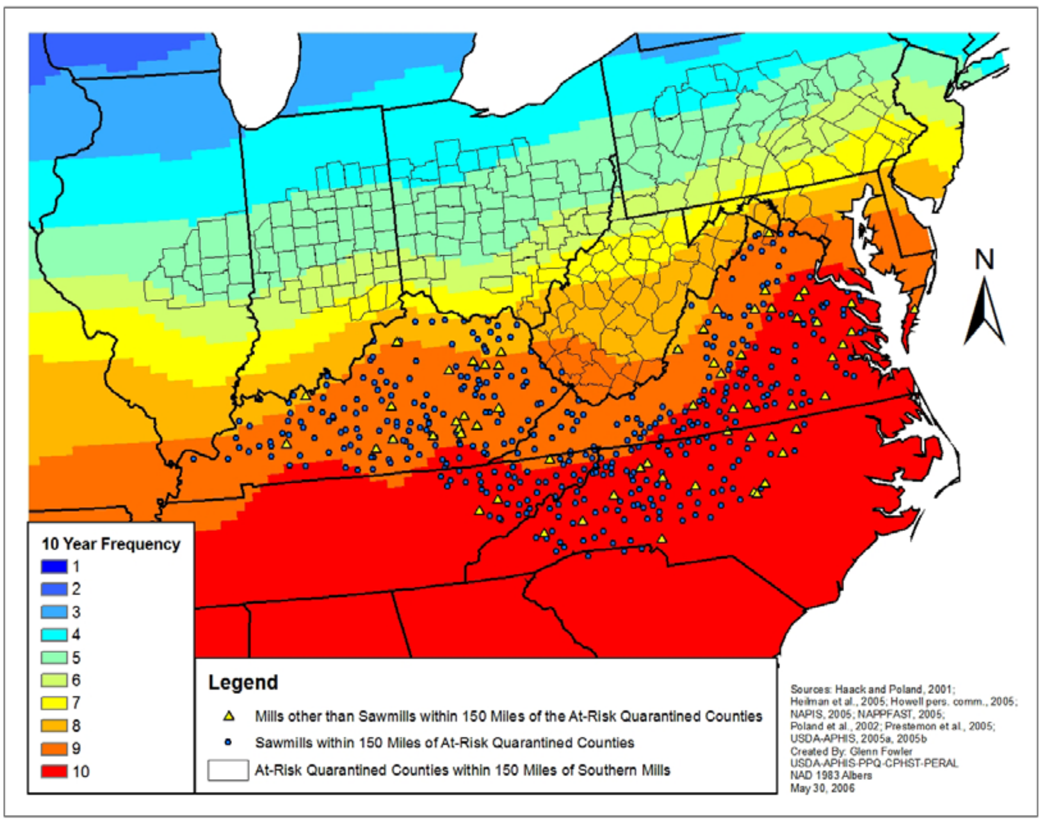

Figure 4. Ten year climate match for areas exhibiting atleast two days between March 1st through 7th where the maximum temperature met or exceeded 12˚C, indicating the initiation of *T. piniperda* spring flight.

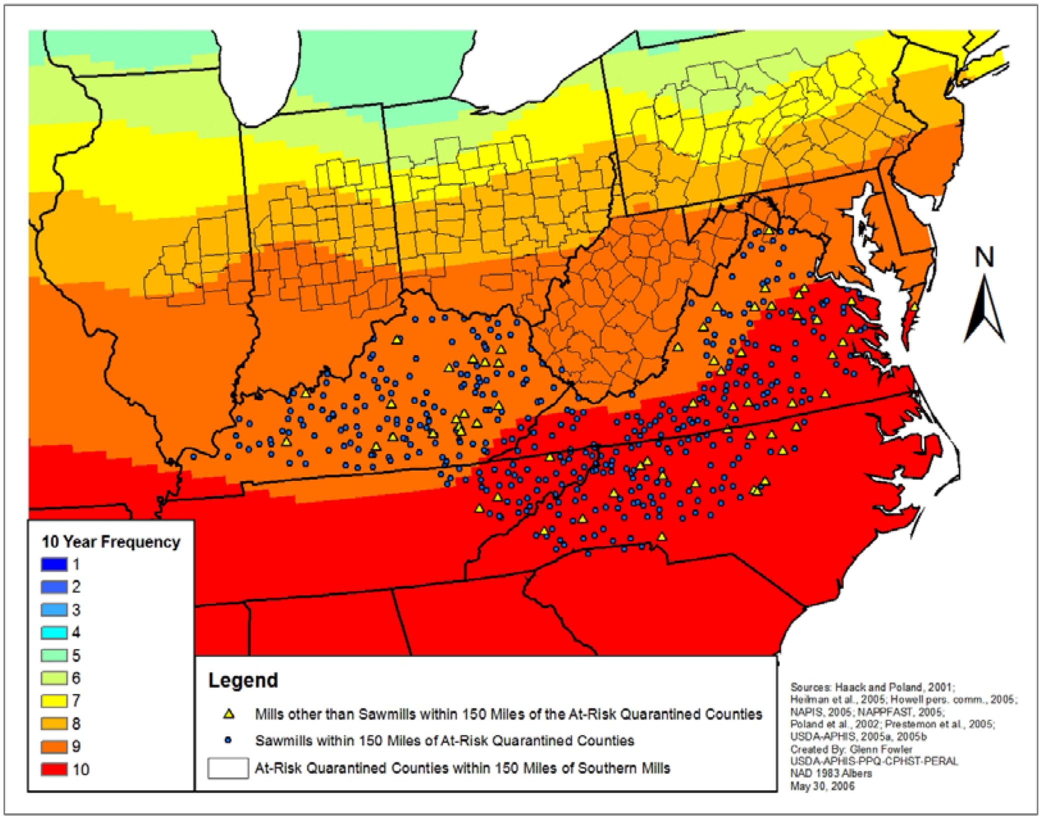

Figure 5. Ten year climate match for areas exhibiting atleast two days between March 8th through 14th where the maximum temperature met or exceeded 12˚C, indicating the initiation of *T. piniperda* spring flight.

Table 2. Selected general assumptions made in the pathway models.

Assumption	Justification
All products have an equal probability of being shipped during any month of the year.	A similar assumption was made in the Griffin and Miller (1994) PRA on *T. piniperda*.
A stump is 0.1 m (4 inches) tall.	This is based on standard timber cutting practices (Haack and Lawrence, 1994).
The infested portion of a harvested tree during the brood generation will be no greater than 3.75 m.	This length was based on values from 30 to 40 year old jack, red, Scotch and white pine trees that were analyzed in *T. piniperda* reproduction studies in Ontario (Ryall and Smith, 2000).
A seasonal shift in Griffin and Millers' (1994) colonization and dispersal estimates would account for differences in *T. piniperda* biology below 40°N latitude.	The Fall and late Spring at-risk areas above and below 40°N are in the same 10°F thermal band and the extreme early Spring and Winter at-risk areas are within 20°F of each other (Appendix 1). Because of these similarities and the spatial proximity of the at-risk areas above and below 40°N, we believe the use of the high estimates for each seasonal group, i.e. Winter/Fall and Early Spring/Late Spring, should compensate for any *T. piniperda* biological differences due to climatology.

Table 3. Selected conservative assumptions made in the pathway models.

Assumption	Justification
All quarantined counties are infested.	For economic and/or scientific reasons several states have removed their quarantines for *T. piniperda* e.g. West Virginia and Pennsylvania (USDA-APHIS, 2005a, b; Haack and Poland, 2001). This causes all counties within the state to become federally quarantined even if they are not infested. Consequently, some counties used to estimate infested timber volumes are probably not infested.
All timber types, e.g. sawtimber, fuelwood and pulpwood could be infested and shipped to a mill.	Most beetles will be in the larger tree boles, i.e. sawtimber, towards the bottom of the tree (Långström, 1984; Ryall and Smith, 2000). Also, fuelwood, e.g. firewood, should not be sent to mills (Johnson pers. comm., 2006). Consequently, a portion of the timber assumed to be infested in our model would probably not be (FIA, 2006).
Logs, lumber and stumps will be shipped up to 150 miles.	The value of 150 miles applies only to large sawmills (Howell pers. comm., 2005), but shipments to others may be shorter.
Bark mulch could be shipped to all mulch producers within150 miles of the quarantined counties.	The cost of shipping raw bark great distances may prohibit this type of movement (Arnold pers. comm., 2005). Bark for mulch production is usually only shipped 30 to 40 miles due to the shipping cost.
All businesses within 150 miles of the quarantined counties whose standard industrial classification (SIC) number and description equaled mulch produce mulch.	Many of those businesses may not directly produce mulch (infoUSA®, 2005).
All emerged beetles will find a mate.	We used the equation of Caton and Spears (2005) which assumes that all possible mated pairs will form from emerging beetles. In reality, many beetles will disperse without mating or be killed prior to mating (Caton and Spears, 2005).

IV. Bark Nugget Pathway

A. Background Information

Sawmills and secondary wood-processing plants are the most common source of pine bark and chips (Anderson *et al.,* 1993). Chips and bark may also be produced from excess wood by small producers after logging operations or thinning (Anderson *et al*., 1993). Bark nuggets and chips are used as landscaping products by homeowners, private landscaping businesses, and municipalities. Chips can be composted with sewage and sold back to private customers or used in public landscaping.

In the Northeastern United States, white pine is the predominant pine species. Harvesting of white pine occurs in the fall and winter (Linnane, 2003). In Maine, New Hampshire, Vermont, and New York, the majority of the debarking and processing occurs from March through June (Linnane, 2003). Logs are stored and debarked at the mill site before processing. The type of debarking machinery used depends on the size of the mill. Larger mills use ring debarkers which produce larger bark fragments (Linnane, 2003). Bark can be stored at mill yards for a period of time before being sold. Bark can also be sold soon after debarking to brokers or mulch processors who will hold and sort the bark (Linnane, 2003). Pine bark mulch is often composted at the mill site to either intentionally darken the mulch or for storage purposes.

Pine bark mulch is sold and shipped most commonly in bulk (Linnane, 2003). The estimated combined annual value of pine bark mulch in Maine, New Hampshire, Vermont, and New York is $3,900,000 (Linnane, 2003). The estimated volume of pine bark mulch produced in these states for 2001 was 244,000 cubic yards (Linnane, 2003).

Sale of mulch and bark nuggets can occur through several routes. Direct pickup is available at sawmills by private individuals in small trucks or by the tractor trailer load. Mulch wholesalers sell by the tractor trailer load, by dump truck or small truck load, or by bag. Nursery stock growers are the main buyers of tractor trailer loads of mulch. Wholesale mulch and bark nuggets are usually sold within state or to neighboring states, as the cost to ship over large distances is prohibitive. Wholesalers also sell by the 2 to 3 cubic foot bag to retail stores and nurseries (Kamlar Corporation, 2005). These bags are sold in 70 bag pallets, with 16 to 20 pallets fitting in a tractor trailer load (Kamlar Corporation, 2005). Bags are also delivered to homeowners in smaller quantities and are available for pickup on-site on a local scale.

B. Data Sources and Methods for Estimating the Volume of Infested Bark Nuggets Exported to the South

We first estimated the number of quarantined counties that could export infested bark to the South. We based this number on a timber buying radius of 150 miles for large sawmills (Howell pers. comm., 2005). It probably represents an extreme for bark nugget shipping distance due to the high transportation costs (Arnold pers. comm., 2005). All southern timber mills and quarantined counties within 150 miles of each other were then visualized using GIS (Prestemon *et al*., 2005; USDA-APHIS, 2005a, 2005b) (Figure 7). All sawmills in these counties were then visualized. It was assumed that sawmills would generate the bark for mulch (Linnane, 2003). These mills were considered at risk for exporting infested bark nuggets to the South.

The Forest Inventory and Analysis database was used to query these counties for all pine sawlog removals in 1997 and 2002 (FIA, 2006). The output for these queries in cubic feet was then converted to cords with a conversion factor of 128 cubic feet per cord (USDA-USFS, 1986). The sawlog removal volume was then converted from cords to shipment units after Griffin and Miller (1994). Under this classification system, 10 cords is equal to one unit. Associated volumes and units are reported in Table 4. These unit volumes were used in the quantitative model to estimate the amount of sawlogs that could pose a risk for *T. piniperda* colonization in the South via bark nuggets.

Table 4. Pine sawlog removal volumes from quarantined counties within 150 miles of southern timber mills (FIA, 2006).

Volume 1997	Volume 2002	Units
4,656,916	4,628,408	Cubic Feet
36,382	36,159	Cords
3,638	3,616	Units
1,201	1,193	Spring Units
910	904	Fall/Winter Units

C. Pathway Model

Figure 6. Schematic of the bark nugget pathway model.

Node 1. Potential infested units per season

The sawlog removal volumes (units) from at-risk quarantined counties were multiplied by the respective seasonal proportions, e.g. 0.33 for the Spring, to estimate the volume associated with each season. The mean timber removal volume per season for 1997 and 2002 was used as the most likely value. A PERT distribution was used to model this node (Vose, 2000). The Summer was not analyzed because *T. piniperda* will be maturation feeding in the shoots and should not be present within the exported tree stem (CFR, 2005; Griffin and Miller, 1994).

Node 2. Potential infested trees per season

We converted units per season to trees per season. One unit is equivalent to 100 trees (Griffin and Miller, 1994).

Node 3. Probability of potentially infested trees being processed for bark in at-risk quarantined counties

We assumed that sawtimber would be transported up to 150 miles for mill processing (Howell pers. comm., 2005). This radius includes mills outside of the at-risk quarantined counties. To estimate the probability that sawtimber would be processed within the at-risk quarantine area we used the number of sawmills in at-risk quarantined counties (1465) and the total number of sawmills within 150 miles of these counties (3554) (Figure 7). A Beta distribution was used to model this node. We assumed that mills in the quarantined counties would have an equal probability of processing the same volume of sawtimber as mills in the surrounding area.

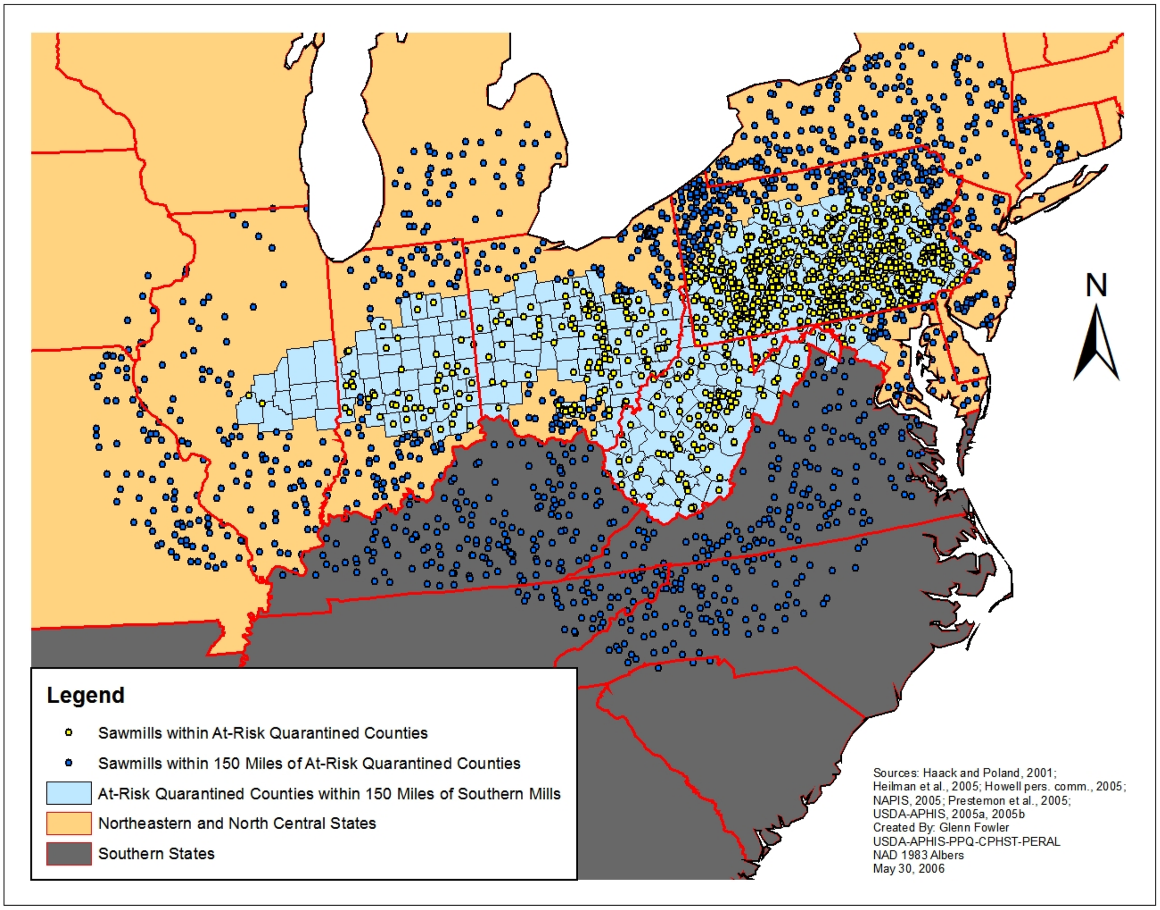

Figure 7. At-risk sawmills that could export bark nuggets to the South.

Node 4. Number of potentially infested trees processed for bark in at-risk quarantined counties

This node was calculated using the normal approximation of a binomial distribution that depended on the number of potentially infested trees (node 2) and the probability of potentially infested trees being processed for bark in at-risk quarantined counties (node 3).

Node 5. Probability of infestation

We used the observed successful infestation data reported by Morgan *et al*. (2004) on red, jack and Scotch pines in southern Ontario to model this node. Of 1,455 trees they examined, only 91 were attacked and only 8 of these attacks produced progeny. We calculated the probability of infestation from the product of two Beta distributions based on their results.

Node 6. Number of infested trees in the at-risk quarantined counties processed for bark

We used a binomial distribution that depended on the number of potentially infested trees (node 4) and the probability of infestation (node 5) to model this node (Vose, 2000).

Node 7. Probability of infested trees processed for bark shipped south

We based this probability on the number of southern businesses (135) and the total number of businesses (379) whose primary standard industry classification code indicated mulch that were within 150 miles of the at-risk quarantined counties (infoUSA®, 2005) (Figure 8). A Beta distribution was used to model this node.

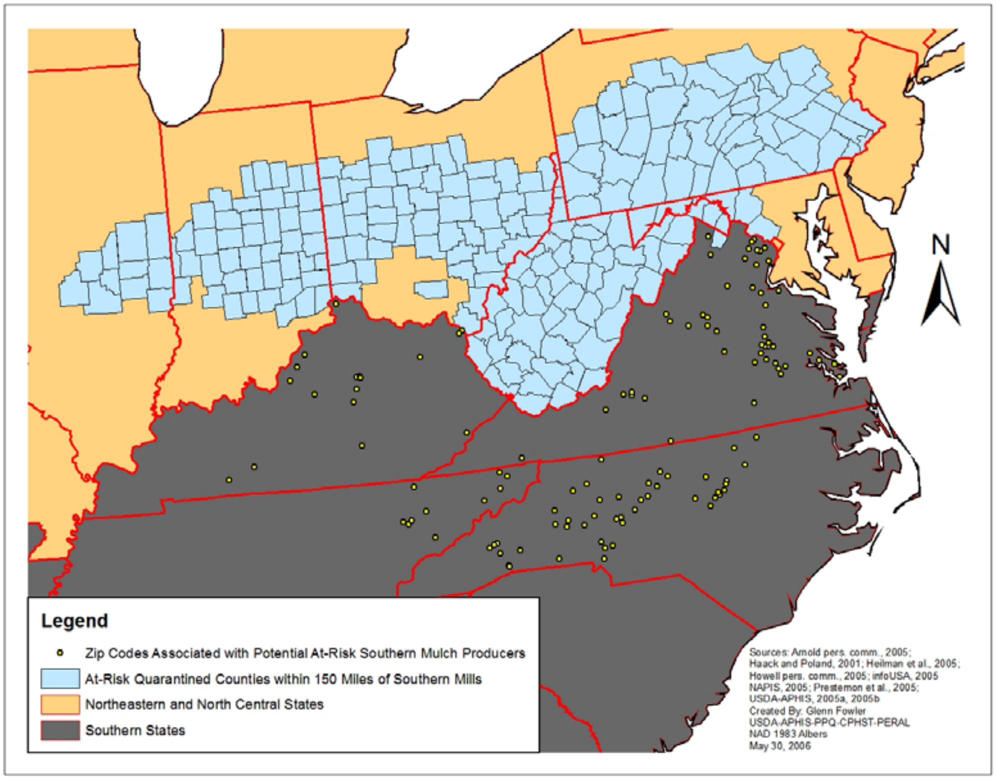

Figure 8. Zip Codes of southern businesses within 150 miles of at-risk quarantined counties whose primary standard industry classification indicated mulch.

Node 8. Number of infested trees processed for bark shipped south

We used a binomial distribution that depended on the number of infested trees in the at-risk quarantined counties processed for bark (node 6) and the probability of infested trees processed for bark being shipped south (node 7) to model this node.

Node 9. Number of beetles per tree

The number of beetles per tree in the Fall and Winter was estimated from Haack *et al*. (2001). Their study involved attaching infested shoots to trees and monitoring resulting overwintering beetles. Consequently, the values used here may be an overestimation (Caton and Spears, 2005). A normal distribution was used to model their data.

The number of beetles per tree in the Spring was estimated based on studies by Långström (1984) on felled Scotch pine. The estimated number of exit holes from 36 infested trees was modeled using a normal distribution.

Node 10. Probability of overwintering above the cutline

This node applies to the Fall and Winter when *T. piniperda* is overwintering and is indicative of the probability of beetles being shipped in a harvested tree. We used the value of Caton and Spears (2005) to estimate this node. Their value was calculated based on the research of Haack *et al.* (2001), Haack and Lawrence (1997) and Petrice *et al.* (2002). A Beta distribution was used to model this node.

Node 11. Number of beetles overwintering above the cutline

This node only applied to Fall and Winter products, when beetles are overwintering. We modeled this node with a binomial distribution that depended on the number of beetles per tree (node 9) and the probability of overwintering above the cutline (node 10) (Vose, 2000).

Node 12. Probability of beetles surviving debarking

We used the probability estimate of Caton and Spears (2005) to estimate this node. Their estimate was based on debarking survival studies conducted on a similar sized beetle, *Ips typographus* (Dubbel, 1993). A negative exponential distribution was used to model this node (Caton and Spears, 2005).

Node 13. Number of beetles that survive debarking

We used a binomial distribution that depended on the number of beetles per tree (node 11 for the Fall and Winter and node 9 for the Spring) and the probability of surviving debarking (node 12) to model this node (Vose, 2000).

Node 14. Probability of beetles being sent to an average mulch producer

There were 135 southern businesses whose primary SIC number and description was mulch within 150 miles of the quarantined counties (infoUSA®, 2005) (Figure 8). We considered these businesses to be at risk based on this shipping distance which is considered extreme for mulch (Arnold pers. comm., 2005). The mean probability for beetles being sent to an average mulch producer was equal to one divided by the number of at-risk businesses. This is probably a conservative estimate because, in addition to the extreme shipping distance we used for bulk bark shipments, many of the importing businesses may not directly produce mulch (Arnold pers. comm., 2005; infoUSA®, 2005).

To model the variability around this mean, we used the 99 percent confidence limits for the proportion, i.e. one over the number of mulch producers (Cochran, 1977). A PERT distribution was used to model this node.

Node 15. Number of beetles sent to an average mulch producer

We used a binomial distribution that depended on the number of beetles that survive debarking (node 13) and the probability of beetles being sent to an average mulch producer (node 14) to model this node (Vose, 2000).

Node 16. Probability of beetles dispersing from an average mulch producer

A proportion of beetles will disperse from mills in search of host material (Caton and Spears, 2005; Poland *et al*., 2000). We used Griffin and Millers' (1994) respective seasonal dispersal estimates for the chips and bark scenario to estimate this probability. We used the Winter dispersal values to estimate the Fall and Winter months since those values were the higher of the two scenarios. The Early Spring dispersal values were used to estimate the Spring. A PERT distribution was used to model this node.

Node 17. Dispersing beetles at an average mulch producer

We used a binomial distribution that depended on the number of beetles at an average mulch producer (node 15) and the probability of beetles dispersing from an average mulch producer (node 16) to model this node (Vose, 2000).

Node 18. Probability of a mated pair and mated pair formation

We used the equation of Caton and Spears (2005) to estimate the probability of a mated pair. The equation is expressed as $(2^{\text{number of beetles-2}})/2^{\text{number of beetles}}$. A binomial distribution that depended on a mated pair forming and the probability of a mated pair was used to model this node.

Node 19. Probability of a mated female

We assumed a 1:1 sex ratio for *T. piniperda.* The probability was 0.5.

Node 20. Number of dispersing mated females at an average mulch producer

If a mated pair formed in node 18, then we used a binomial distribution that depended on the number of dispersing beetles at an average mulch producer (node 17) and the probability of a mated female (node 19) to model this node.

Node 21. Probability of colonization

We used the Fall/Winter and Early Spring colonization values from Griffin and Millers' (1994) chips and bark scenario to estimate this probability. A PERT distribution was used to model this node.

Node 22. Number of colonizations at an average mulch producer

We used a binomial distribution that depended on the number of dispersing mated females at an average mulch producer (node 20) and the probability of colonization (node 21) to model this node.

Node 23. Probability of colonization at an average mulch producer

We applied a Boolean query that determined whether or not colonization occurred in node 22 after 100,000 iterations. The mean of this distribution was the probability of colonization at an average mulch producer.

Node 24. At-risk mulch producers in the South

There were 135 southern businesses whose primary SIC number and description was mulch within 150 miles of the quarantined counties (infoUSA®, 2005) (Figure 8). We considered these businesses to be at risk based on this shipping distance which is extreme for bulk bark shipments (Arnold pers. comm., 2005).

Node 25. Mulch producers with colonizations in the South

For each season, we applied a binomial distribution that depended on the number of at-risk mulch producers (node 24) and the probability of colonization at an average mulch producer (node 23) to model this node. The annual number of mulch producers with colonizations in the South was equal to the sum of the Fall, Winter and Spring values.

Node 26. Probability of colonization in the South

For each season and annually, we applied a Boolean query that determined whether or not colonization occurred in node 25 after 100,000 iterations. The mean of this distribution was the probability of colonization.

Node 27. Years until a colonization in the South

We used a negative binomial distribution to model this node for each season and annually. This distribution depended on one plus the years until a single colonization and the probability of colonization (node 25).

V. Logs and Lumber with Bark Pathway

A. Background Information

Trees for lumber and pulp production are produced on various sized holdings, from small individual landowners with 10 to 100 acres to large commercial forests with greater than 600 acres (Heaton pers. comm., 2005). The proportion of forest land owned by private non-industrial owners and industrial owners varies by state. In the majority of Southern States, harvesting of pine occurs year-round (Becker pers. comm., 2005; Heaton pers. comm., 2005). Harvesting from small holdings is usually contracted out to private loggers. Logs are brought directly to the mill after harvest. The majority of mills purchase within a buying radius of 50 to 100 miles to reduce transportation costs (Becker pers. comm., 2005). However, logs may be brought to mills out of state depending on the contract with the mill or demand for pulp at the mills (Heaton pers. comm., 2005). Large acreage harvested by commercial pulp and paper companies may be transported across state boundaries to large centralized mills (Becker pers. comm., 2005).

In the South, pine trees of 15 to 20 years of age are usually used to produce paper and are processed at pulpwood mills (Becker pers. comm., 2005). These trees may be cut after larger saw timber logs have been harvested or to thin a stand of larger trees (Daniels, No date). Plantations of small pulpwood trees may be cut all at once. Logs are debarked at the mill. Bark is either used for energy production at the mill or sold as mulch (Heaton pers. comm., 2005). Larger pulpwood trees can be used for chip-n-saw logs which can be processed into oriented strand board and other wood products (Heaton pers. comm., 2005). Larger trees, older than 20 years of age, are used for lumber and plywood.

Logs for lumber production are transported as whole logs to sawmills. At most sawmills, logs are debarked prior to being sawed into lumber or processed into other wood products (McClure, pers. comm., 2005). Bark is used for fuel or sold as mulch. A small proportion of saw timber is sawed into lumber at small mills and is not debarked prior to sawing (McClure pers. comm., 2005; Becker pers. comm., 2005). This type of lumber is then transported to other mills to be kiln or air dried (McClure pers. comm., 2005).

B. Data Sources and Methods for Estimating the Potential Volume of Infested Logs and Lumber with Bark that could be Imported into the South

We first estimated the potential number of quarantined counties that could export infested timber to the South. We based this number on a timber buying radius of 150 miles for large sawmills (Howell pers. comm., 2005). All southern timber mills and quarantined counties within 150 miles of each other were then visualized using GIS (Prestemon *et al*., 2005; USDA-APHIS, 2005a, 2005b) (Figure 9). These counties were considered at risk for exporting infested timber to the South.

The Forest Inventory and Analysis database was used to query these counties for all pine timber removals in 1997 and 2002 (FIA, 2006). The output for these queries in cubic feet was then converted to cords with a conversion factor of 128 cubic feet per cord (USDA-USFS, 1986). The timber removal volume was then converted from cords to shipment units after Griffin and Miller (1994). Under this classification system, 10 cords is equal to one unit. Associated volumes and units are reported in Table

5. These unit volumes were used in the quantitative model to estimate the amount of timber that could pose a risk for *T. piniperda* colonization in the South.

Table 5. Pine timber removal volumes from quarantined counties within 150 miles of southern timber mills (FIA, 2006).

Volume 1997	Volume 2002	Units
18,631,057	18,647,036	Cubic Feet
145,555	145,680	Cords
14,556	14,568	Units
4,803	4,807	Spring Units
3,639	3,642	Fall/Winter Units

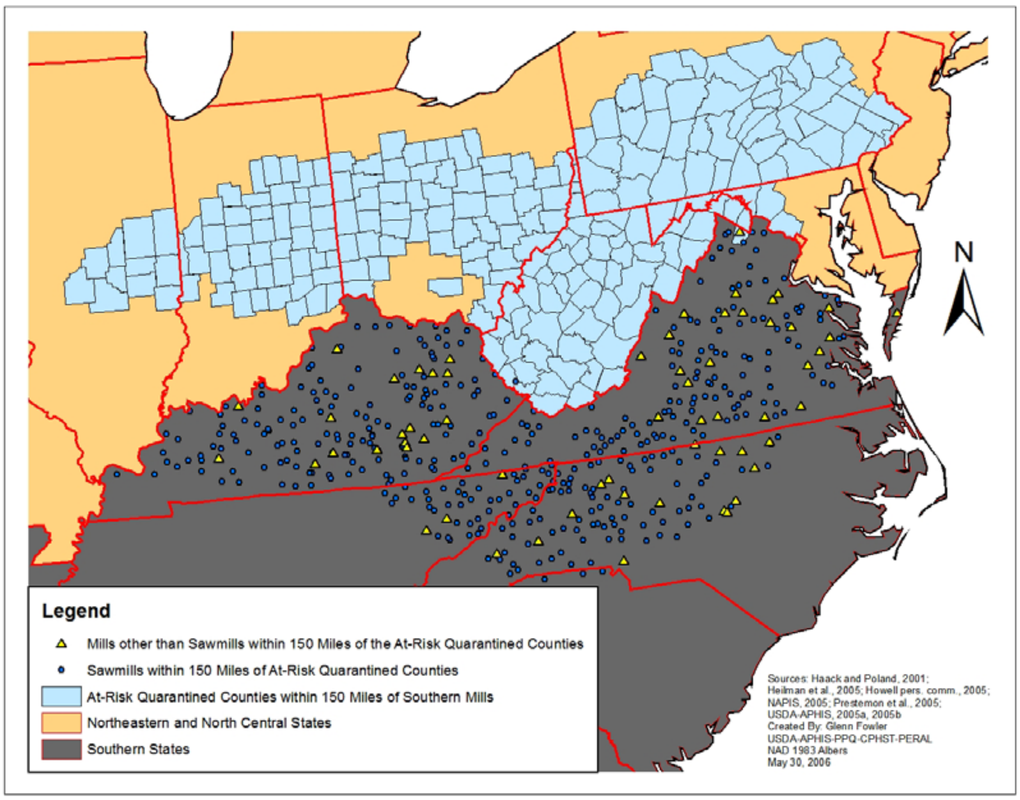

Figure 9. Southern timber mills considered at risk for *T. piniperda* based on their proximity to the quarantined counties and a timber buying radius of 150 miles.

C. Pathway Model

Figure 10. Schematic of the logs and lumber with bark pathway model.

Node 1. Potential infested units per season

The timber removal volumes (units) from at-risk quarantined counties were multiplied by the respective seasonal proportions, e.g. 0.33 for the Spring, to estimate the volume associated with each season. The mean timber removal volume per season for 1997 and 2002 was used as the most likely value. A PERT distribution was used to model this node (Vose, 2000).

Node 2. Potential infested trees per season

We converted units per season to trees per season. One unit is equivalent to 100 trees (Griffin and Miller, 1994).

Node 3. Probability of infested trees shipped south

We based this probability on the number of southern mills (798) and the total number of mills that were within 150 miles of at-risk quarantined counties (3623) (Prestemon *et al*., 2005). A Beta distribution was used to model this node.

Node 4. Potential infested trees shipped south

This node was modeled using the normal approximation of a binomial distribution that depended on the number of potential infested trees per season (node 2) and the probability of potential infested trees being shipped south (node 3).

Node 5. Proportion of potential infested trees shipped to an average mill

There were 798 southern timber mills within 150 miles of the quarantined counties (Prestemon *et al*., 2005). Timber mills will generally either process soft or hardwoods (Smith *et al*., 2003; USDC-USCB, 1999). We estimated the proportion of at-risk southern mills that process softwoods based on United States softwood pulpmill proportions for 1994 and 2001 (Smith *et al*., 2003). A uniform distribution was used to model this proportion with equal probabilities assigned to all values between extremes (Vose, 2000). The minimum and maximum softwood pulpmill proportions were 0.62 and 0.64. We assumed that this distribution would be a reasonable estimate for other types of mills. Our estimate is probably conservative for sawmills that process softwoods based on 1997 United States proportions, i.e. 0.41 (USDC-USCB, 1999).

This node was modeled by multiplying the number of timber mills within 150 miles by the uniform distribution for United States softwood pulpmill proportions. The mean estimate for this node was equal to one over this value.

The standard deviation around this mean was estimated based on the mean and standard deviation in annual milling capacities of 87 southern sawmills (Spelter and Alderman, 2005). The proportionate standard deviation from these mills was applied to the value of the point estimate. A normal distribution was used to model this node.

We assumed that mills with larger capacities would have a higher probability of receiving infested timber. We also assumed that this distribution would apply to other types of mills in the south, e.g. pulp, pole and veneer mills, which are much fewer in number than sawmills (Prestemon *et al*., 2005) (Figure 9).

Node 6. Potential infested trees shipped to an average mill

This node is equal to the product of the potential infested trees shipped south (node 4) and the proportion of potential infested trees shipped to an average softwood mill (node 5).

Node 7. Probability of infestation

We used the observed successful infestation data reported by Morgan *et al*. (2004) on red, jack and Scotch pines in southern Ontario to model this node. Of 1,455 trees they examined, only 91 were attacked and only 8 of these attacks produced progeny. We calculated the probability of infestation from the product of two Beta distributions based on their results.

Node 8. Number of infested trees shipped to an average mill

We used a binomial distribution that depended on the number of potentially infested trees (node 6) and the probability of infestation (node 7) to model this node (Vose, 2000).

Node 9. Number of beetles per tree

The number of beetles per tree in the Fall and Winter was estimated based on the research of Haack *et al*. (2001). Their study involved attaching infested shoots to trees and monitoring resulting overwintering beetles. Consequently, the values used here may be an overestimation (Caton and Spears, 2005). A normal distribution was used to model their data.

The number of brood beetles per tree in the Spring was estimated based on studies by Långström (1984) on felled Scotch pine. The estimated number of exit holes from 36 infested trees was modeled using a normal distribution.

Node 10. Probability of overwintering above the cutline

This node applies to the Fall and Winter when *T. piniperda* is overwintering and is indicative of the probability of beetles being shipped in a harvested tree. We used the value of Caton and Spears (2005) to estimate this node. Their value was calculated based on the research of Haack *et al.* (2001), Haack and Lawrence (1997) and Petrice *et al.* (2002). A Beta distribution was used to model this node.

Node 11. Number of beetles at an average mill

For the Spring, this node was equal to the product of beetles shipped to an average mill (node 8) and the number of beetles per tree (node 9). For the Fall and Winter, we used a binomial distribution that depended on the number of beetles at an average mill (the product of nodes 8 and 9) and the probability of overwintering above the cutline (node 10) to model this node.

Node 12. Probability of beetles dispersing from an average mill

A proportion of beetles will disperse from mills in search of host material (Caton and Spears, 2005; Poland *et al*., 2000). We used Griffin and Millers' (1994) respective seasonal dispersal estimates for the before processing scenario to estimate this probability. We used the Winter dispersal values to estimate the Fall and Winter months since those values were the higher of the two scenarios. The early Spring dispersal values were used to estimate Spring dispersal. A PERT distribution was used to model this node.

Node 13. Dispersing beetles at an average mill

We used a binomial distribution or the normal approximation of the binomial distribution, depending on beetle numbers, to model this node. These distributions depended on the number of beetles at an average mill (node 11) and the probability of dispersal (node 12).

Node 14. Probability of a mated pair and mated pair formation

We used the equation of Caton and Spears (2005) to estimate this probability. The equation is expressed as $(2^{\text{number of beetles-2}})/2^{\text{number of beetles}}$. A binomial distribution that depended on a mated pair forming and the probability of a mated pair was used to model this node.

Node 15. Probability of a mated female

We assumed a 1:1 sex ratio for *T. piniperda.* The probability was 0.5.

Node 16. Number of dispersing mated females at an average mill

If a mated pair formed in node 14, then we used a binomial distribution that depended on the number of dispersing beetles at an average mill (node 13) and the probability of a mated female (node 15) to model this node.

Node 17. Probability of colonization

We used the Fall/Winter and Early Spring colonization probabilities from Griffin and Millers' (1994) before processing scenario to estimate this probability. A PERT distribution was used to model this node.

Node 18. Number colonizations at an average mill

We used a binomial distribution that depended on the number of dispersing mated females at an average mill (node 16) and the probability of colonization (node 17) to model this node.

Node 19. Probability of colonization at an average mill

We applied a Boolean query that determined whether or not colonization occurred in node 18 after 100,000 iterations. The mean of this distribution was the probability of colonization at an average mill.

Node 20. At-risk mills within 150 miles of the quarantined counties

We considered southern mills within 150 miles of the quarantined counties to be at risk for *T. piniperda* colonization based on the buying radius for large sawmills (Howell pers. comm., 2005). The number of mills within this distance was 798 (Prestemon *et al*., 2005).

We estimated the proportion of at-risk southern mills that process softwoods based on United States softwood pulpmill proportions for 1994 and 2001 (Smith *et al*., 2003). A uniform distribution was used to model this proportion with equal probabilities assigned to all values between extremes (Vose, 2000).

This node was modeled by multiplying the number of timber mills within 150 miles by the uniform distribution for United States softwood pulpmill proportions.

Node 21. Mills with colonizations in the South

For each season, we used a binomial distribution that depended on the number of at-risk mills (node 20) and the probability of colonization at an average mill (node 19) to model this node. The annual number of mills with colonizations in the south was equal to the sum of the Fall, Winter and Spring values.

Node 22. Probability of colonization in the South

For each season and annually, we applied a Boolean query that determined whether or not colonization occurred in node 21 after 100,000 iterations. The mean of this distribution was the probability of colonization.

Node 23. Years until a colonization in the South

We used a negative binomial distribution to model this node for each season and annually. This distribution depended on one plus the years until a single colonization and the probability of colonization (node 22).

VI. Stump Pathway

A. Background Information

USDA-APHIS currently regulates stumps from *T. piniperda* infested counties (CFR, 2005). Stumps are considered a possible risk for introducing the beetle because they are occasionally used to produce fuel or turpentine-like products (Haack and Poland, 2001).

Stumps can be processed to create wood naval stores which include products such as wood turpentine, wood rosin, dipentene, and natural pine oil (FAO, 1995). Rosin products can be extracted from chipped stumps or through distillation (FAO, 1994). Wood rosin is a small component of pine oleoresin production, constituting 5 percent of worldwide production, or 2,400 tons annually (FAO, 1995). Wood naval stores production has declined to a low level in the United States in the last 60 years (FAO, 1995).

Annual sales of rosin products from pine stumps are estimated at 20 million pounds per year (Jacobs pers. comm., 2005). Pinova™, a division of The Hercules Company, located in Brunswick, Georgia, is the only manufacturer of rosin from stumps in the world and utilizes nine to ten thousand gross tons of stumps per month in production (Jacobs pers. comm., 2005; Pinova™, 2005).

The wood rosin industry in the United States harvests stumps from the coastlines of North Carolina, South Carolina and Georgia (Jacobs pers. comm., 2005). Stumps are also harvested from the majority of Florida, and from land 200 miles inland from the Gulf of Mexico in Georgia and Alabama (Jacobs pers. comm., 2005). After timber harvests, stumps from previous harvests are removed. Stumps must be at least 20 years old to produce quality rosin (Jacobs pers. comm., 2005). Stumps from longleaf and loblolly pines are utilized to produce naval stores and are harvested year-round.

Stumps may also be used to produce fuel and have been exported out of the quarantined area into the South (Connors pers. comm., 2005; Haack and Poland, 2001; SPHD data request, 2005). However, this is probably uncommon since stumps are often left in the ground after harvest due to the cost of removal and erosion concerns (Government of Alberta, 2001; Spencer, 2003).

The fact that no stumps for naval stores are harvested from the quarantined area indicates that this pathway does not pose a risk for *T. piniperda* colonization. We therefore only considered the stump for fuel pathway for further analysis. We considered a stump to be the first 0.1 meters of the tree above ground level (Haack and Lawrence, 1994).

B. Data Sources and Methods for Estimating the Potential Volume of Infested Stumps that could be Imported into the South

Stumps that are harvested for fuel should be delivered to timber mills (Johnson pers comm., 2006). Consequently, the pine timber removal volumes used in the logs and lumber with bark pathway was also used for the stump pathway (Table 5).

B. Pathway Model

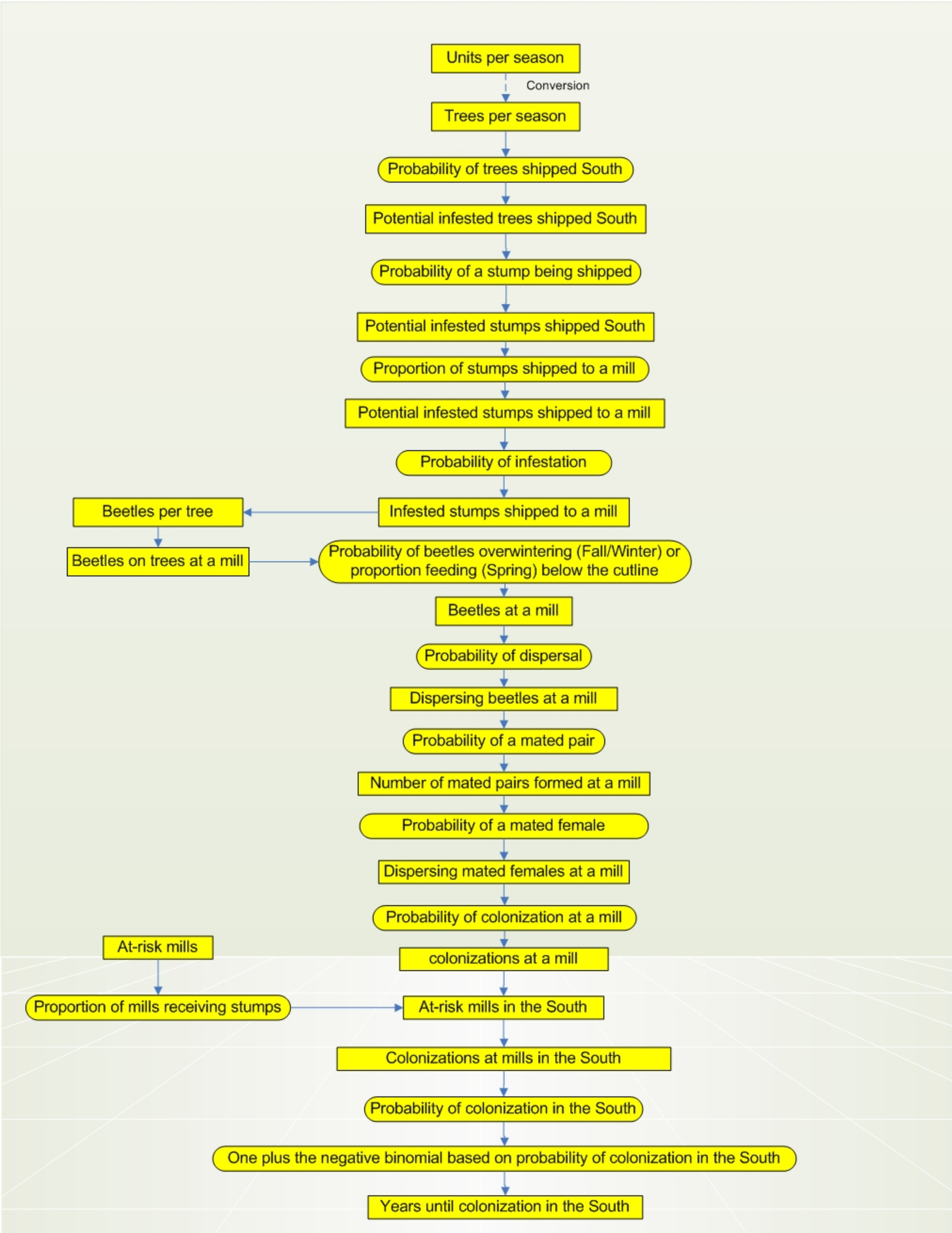

Figure 11. Schematic of the stump pathway model.

Node 1. At-Risk mills within 150 miles of quarantined counties

There were 798 southern timber mills within 150 miles of the quarantined counties (Prestemon *et al*., 2005). The number of softwood mills was modeled by multiplying this number by a uniform distribution based on the minimum and maximum United States softwood pulpmill proportions for 1994 and 2001 (Smith *et al*., 2003). The resulting mills were considered at risk for receiving infested timber from the quarantined area.

Node 2. Probability of mills receiving stumps

Stumps are often not harvested due to the cost of removal and erosion concerns (Government of Alberta, 2001; Spencer, 2003). Instead they are typically left in the ground to facilitate regeneration (Spencer, 2003). Consequently, most mills will probably not receive stumps. We estimated this probability based on the number of stump shipments from the quarantined area in relation to the total number of timber shipments from the quarantined area (SPHD data request, 2005). We used a Beta distribution to estimate this probability.

Node 3. Number of at-risk mills within 150 miles receiving stumps

We used a binomial distribution that depended on the number of at-risk mills (node 1) and the probability of a mill receiving stumps (node 2) to model this node.

Statistical analysis revealed that 96 percent of exported stumps would arrive at ten mills due to the low infestation and stump shipment rates (Figure 12). For simplicity, we considered this number of mills to be at risk and independently modeled colonization probabilities at each of them for this pathway.

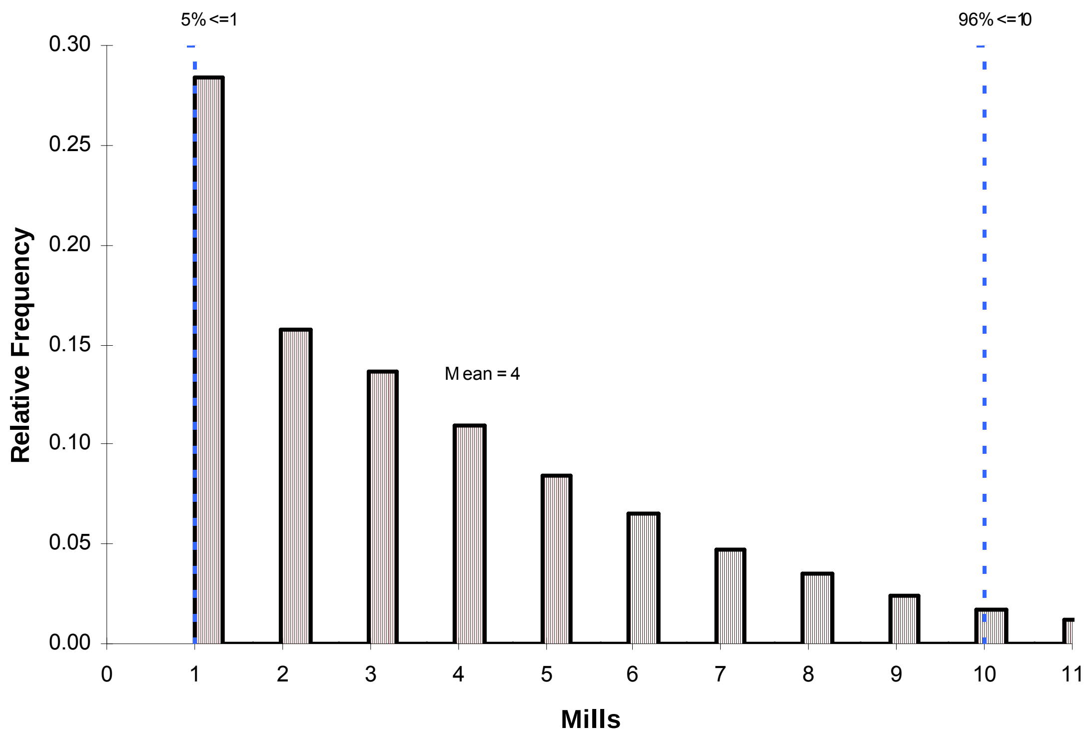

Figure 12. Relative frequency histogram for the number of mills considered at risk for receiving exported stumps.

Node 4. Potential infested units per season

The timber removal volumes (units) from at-risk quarantined counties were multiplied by the respective seasonal proportions, e.g. 0.33 for the Spring, to estimate the volume associated with each season. The mean timber removal volume per season for 1997 and 2002 was used as the most likely value. A PERT distribution was used to model this node (Vose, 2000).

Node 5. Potential infested trees per season

We converted units per season to trees per season. One unit is equivalent to 100 trees (Griffin and Miller, 1994).

Node 6. Probability of infested trees shipped south

We estimated the probability of trees being shipped south from the number of southern mills (798) and the total number of mills that were within 150 miles of at-risk quarantined counties (3623) (Prestemon *et al*., 2005). A Beta distribution was used to model this node.

Node 7. Potential infested trees shipped south

This node was modeled using the normal approximation of a binomial distribution that depended on the number of potential infested trees per season (node 5) and the probability of potential infested trees being shipped south (node 6).

Node 8. Probability of a stump from a harvested tree being shipped

We estimated the probability that a stump would be removed and shipped based on the number of stump shipments from the quarantined area in relation to the total number of timber shipments from the quarantined area (SPHD data request, 2005). We used a Beta distribution to estimate this probability.

Node 9. Potential infested stumps shipped south

We used a binomial distribution that depended on the number of trees shipped south (node 7) and the probability of a stump from a harvested tree being shipped (node 8) to model this node.

Node 10. Proportion of stumps shipped to a mill

The mean estimate for this node was equal to one over the number of softwood mills that receive stumps (node 3).

The standard deviation around this mean was estimated based on the mean and standard deviation in annual milling capacities of 87 southern sawmills (Spelter and Alderman, 2005). The proportionate standard deviation from these mills was applied to the value of the point estimate. A normal distribution was used to model this node.

Node 11. Potential infested stumps shipped to a mill

This node was equal to the product of the potential infested stumps shipped south (node 9) and the proportion of stumps shipped to a mill (node 10).

Node 12. Probability of infestation

We used the observed successful infestation data reported by Morgan *et al*. (2004) on red, jack and Scotch pines in southern Ontario to model this node. Of 1,455 trees they examined, only 91 were attacked and only 8 of these attacks produced progeny. We calculated the probability of infestation from the product of two Beta distributions based on their results.

Node 13. Number of infested stumps shipped to a mill

We used a binomial distribution that depended on the number of potentially infested stumps shipped to a mill (node 11) and the probability of infestation (node 12) to model this node (Vose, 2000).

Node 14. Number of beetles per tree

The number of beetles per tree in the Fall and Winter was estimated based on the research of Haack *et al*. (2001). Their study involved attaching infested shoots to trees and monitoring resulting overwintering beetles. Consequently, the estimate used here may be an overestimation (Caton and Spears, 2005). A normal distribution was used to model their data.

The number of brood beetles per tree in the Spring was estimated based on studies by Långström (1984) on felled Scotch pine. The estimated number of exit holes from 36 infested trees was modeled using a normal distribution.

Node 15. Number of beetles on trees at a mill

This node was equal to the product of the number of infested stumps shipped to a mill (node 13) and the number of beetles per tree (node 14). We used a normal distribution to model this node.

Node 16. Probability of beetles overwintering and proportion feeding below the cutline

We used the inverse of Caton and Spears' (2005) data for overwintering above the cutline to estimate the associated probability for the Fall and Winter. Their value was calculated based on the research of Haack *et al.* (2001), Haack and Lawrence (1997) and Petrice *et al.* (2002). A Beta distribution was used to model this node.

We used the proportion of a tree composed of stump under normal cutting practices to estimate the associated proportion of beetles that would be feeding below the cutline in the Spring. We assumed a 0.1 meter stump (4 inches) (Haack and Lawrence, 1994) and a harvested tree height of 3.75 meters after Ryall and Smith (2000).

Node 17. Number of beetles at a mill

To model the Fall and Winter values we used a binomial distribution that depended on the number of beetles on trees at a mill (node 15) and the probability of overwintering below the cutline (node 16). To model the Spring value we used the product of the number of beetles on trees at a mill and the proportion of beetles that feed below the cutline.

Node 18. Probability of beetles dispersing from a mill

A proportion of beetles will disperse from mills in search of host material (Caton and Spears, 2005; Poland *et al.*, 2000). We used Griffin and Millers' (1994) respective seasonal dispersal estimates for the before processing scenario to estimate this probability. We used the Winter dispersal values to estimate the Fall and Winter months since those values were the higher of the two scenarios. The early Spring dispersal values were used to estimate the Spring dispersal rate. A PERT distribution was used to model this node.

Node 19. Dispersing beetles at a mill

We used a binomial distribution that depended on the number beetles at a mill (node 17) and the probability of dispersal at a mill (node 18) to model this node.

Node 20. Probability of a mated pair and mated pair formation

We used the equation of Caton and Spears (2005) to estimate this probability. The equation is expressed as $(2^{\text{number of beetles-2}})/2^{\text{number of beetles}}$. A binomial distribution that depended on a mated pair forming and the probability of a mated pair was used to model this node.

Node 21. Probability of a mated female at a mill

We assumed a 1:1 sex ratio for *T. piniperda.* The probability was 0.5.

Node 22. Number of dispersing mated females at a mill

If a mated pair formed in node 20, then we used a binomial distribution that depended on the number of dispersing beetles at a mill (node 19) and the probability of a mated female (node 21) to model this node.

Node 23. Probability of colonization

We used the Fall/Winter and early Spring colonization probabilities from Griffin and Millers' (1994) before processing scenario to estimate this probability. A PERT distribution was used to model this node.

Node 24. Number colonizations at a mill

We used a binomial distribution that depended on the number of dispersing mated females at a mill (node 22) and the probability of colonization (node 23) to model this node.

Node 25. Seasonal colonizations in the South

This node was equal to the sum of the seasonal colonizations that occurred at the ten analyzed mills (node 24). The annual number of colonizations in the South was equal to the sum of the Fall, Winter and Spring colonizations.

Node 26. Probability of colonization in the South

For each season and annually, we applied a Boolean query that determined whether or not colonization occurred in node 25 after 100,000 iterations. The mean of this distribution was the probability of colonization.

Node 27. Years until a colonization in the South

We used a negative binomial distribution to model this node for each season and annually. This distribution depended on one plus the years until a single colonization and the probability of colonization (node 26).

VII. Combined Risk of the Bark Nugget and Stump Pathways

Node 1. Mulch producers and mills with colonizations in the South

For each season, this node was modeled by adding the number of mulch producers with colonizations in the South from the bark nugget pathway (node 25) to the number of seasonal colonizations at mills in the stump pathway (node 25). The maximum number of seasonal colonizations that occurred at a mill in the stump pathway was one. Therefore, the maximum number of mills with colonization by season in the stump pathway was also one. This allowed us to add the results of the two pathways and the other pathway combinations involving stumps (see below) since the units could be assumed to be the same. The annual number of colonizations in the South for these pathways was equal to the sum of the Fall, Winter and Spring colonizations.

Node 2. Probability of colonization in the South

For each season and annually, we applied a Boolean query that determined whether or not colonization occurred in node 1 after 100,000 iterations. The mean of this distribution was the probability of colonization.

Node 3. Years until a colonization in the South

We used a negative binomial distribution to model this node for each season and annually. This distribution depended on one plus the years until a single colonization and the probability of colonization (node 2).

VIII. Combined Risk of the Bark Nugget and Logs and Lumber with Bark Pathways

Node 1. Mulch producers and mills with colonizations in the South

For each season, this node was modeled by adding the number of mulch producers with colonizations in the South from the bark nugget pathway (node 25) to the number of mills with colonizations in the South from the logs and lumber with bark pathway (node 21). The annual number of colonizations in the South for these pathways was equal to the sum of the Fall, Winter and Spring colonizations.

Node 2. Probability of colonization in the South

For each season and annually, we applied a Boolean query that determined whether or not colonization occurred in node 1 after 100,000 iterations. The mean of this distribution was the probability of colonization.

Node 3. Years until a colonization in the South

We used a negative binomial distribution to model this node for each season and annually. This distribution depended on one plus the years until a single colonization and the probability of colonization (node 2).

IX. Combined Risk of the Bark Nugget, Stump and Logs and Lumber with Bark Pathways

Node 1. Mulch producers and mills with colonizations in the South

For each season, this node was modeled by adding the number of mulch producers with colonizations in the South from the bark nugget pathway (node 25), the number of seasonal colonizations at mills in the stump pathway (node 25) and the number of mills with colonizations in the South from the logs and lumber with bark pathway (node 21). The annual number of colonizations in the South for these pathways was equal to the sum of the Fall, Winter and Spring colonizations.

Node 2. Probability of colonization in the South

For each season and annually, we applied a Boolean query that determined whether or not colonization occurred in node 1 after 100,000 iterations. The mean of this distribution was the probability of colonization.

Node 3. Years until a colonization in the South

We used a negative binomial distribution to model this node for each season and annually. This distribution depended on one plus the years until a single colonization and the probability of colonization (node 2).

X. Combined Risk of the Stumps and Logs and Lumber with Bark Pathways

Node 1. Mills with colonizations in the South

For each season, this node was modeled by adding the number of seasonal colonizations at mills in the stump pathway (node 25) to the number of mills with colonizations in the South from the logs and lumber with bark pathway (node 21). The annual number of colonizations in the South for these pathways was equal to the sum of the Fall, Winter and Spring colonizations.

Node 2. Probability of colonization in the South

For each season and annually, we applied a Boolean query that determined whether or not colonization occurred in node 1 after 100,000 iterations. The mean of this distribution was the probability of colonization.

Node 3. Years until a colonization in the South

We used a negative binomial distribution to model this node for each season and annually. This distribution depended on one plus the years until a single colonization and the probability of colonization (node 2).

XI. Results and Discussion

A. Pathways Considered Low Risk for *T. piniperda* Colonization in the South

Based on the models results, we considered seven of the pathways to be low risk for causing *T. piniperda* colonization in the South if deregulated. These pathways were: 1) bark nuggets, 2) logs and lumber with bark in the Fall and Winter, 3) stumps, 4) the combination of bark nuggets and stumps, 5) the combination of bark nuggets and logs and lumber with bark in the Fall and Winter, 6) the combination of bark nuggets, stumps and logs and lumber with bark in the Fall and Winter and 7) the combination of stumps and logs and lumber with bark in the Fall and Winter.

We classified these pathways as low risk because there was atleast a 95 percent chance of colonization occurring after four years if they were deregulated (Figures 13 to 20; Tables 6 and 7). This is approximately how long *T. piniperda* would take to move 150 miles into the South assuming the worst case scenario for spread with regulation (Figure 2). Consequently, deregulation of these pathways would probably not facilitate faster colonization of *T. piniperda* in the South than would occur due to natural spread and human movement of infested commodities within the quarantined area assuming no inhibition by abiotic or biotic factors (Figure 2).

However, there is uncertainty regarding *T. piniperda's* rate of spread into the South due to interspecific competition with indigenous pine beetles (Fowler and Borchert, 2006; Haack pers. comm., 2005). We recommend that this uncertainty be considered in future regulatory decisions regarding these four pathways.

1. Bark Nuggets

The bark nugget pathway model results were identical for the Spring, Fall and Winter seasons with 5^{th}, mean and 95^{th} percentiles for years until colonization of: 40; 769 and 2,303 (Figure 13; Table 6). The model estimated that there was a 0.130 and 0.519 percent chance of a successful colonization occurring within the first and fourth year after deregulation (Table 7).

The annual bark nugget pathway model estimated 5^{th}, mean and 95^{th} percentiles for years until colonization of: 13; 250 and 748 (Figure 14; Table 6). The model estimated that there was a 0.400 and 1.590 percent chance of a successful colonization occurring within the first and fourth year after deregulation (Table 7).

The low risk associated with the bark nugget pathway was due to the small proportion of beetles that survive the debarking process and that were subsequently shipped to mulch producers in the South (Caton and Spears, 2005; Dubbel, 1993).

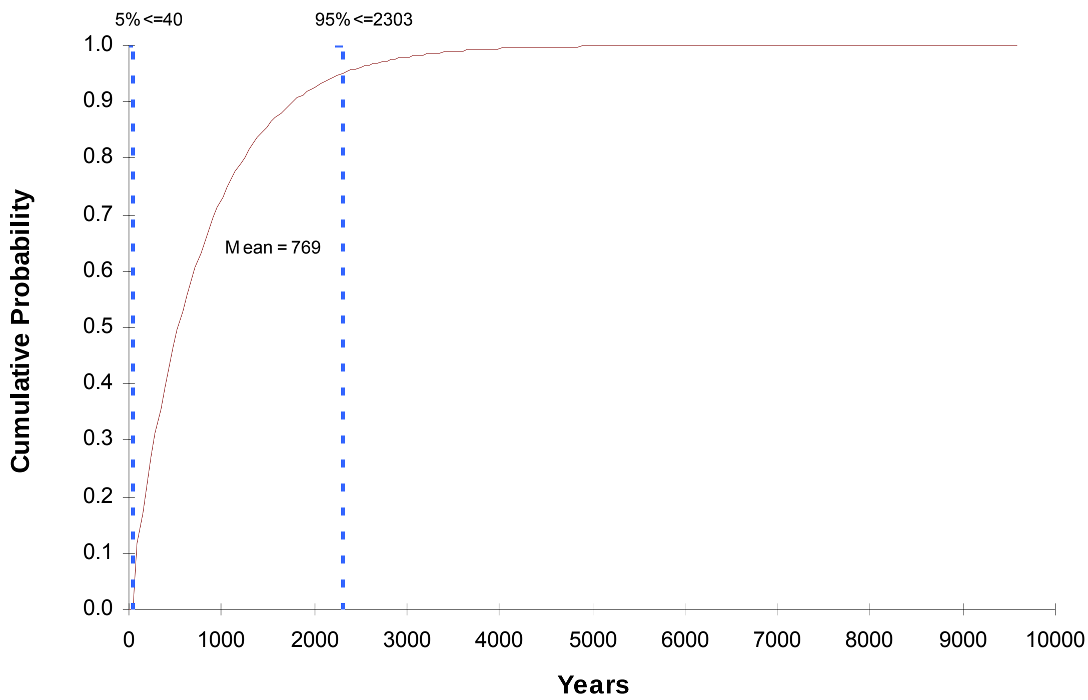

Figure 13. Cumulative distribution function for the years until colonization as a result of deregulation of bark nuggets in the Spring, Fall and Winter.

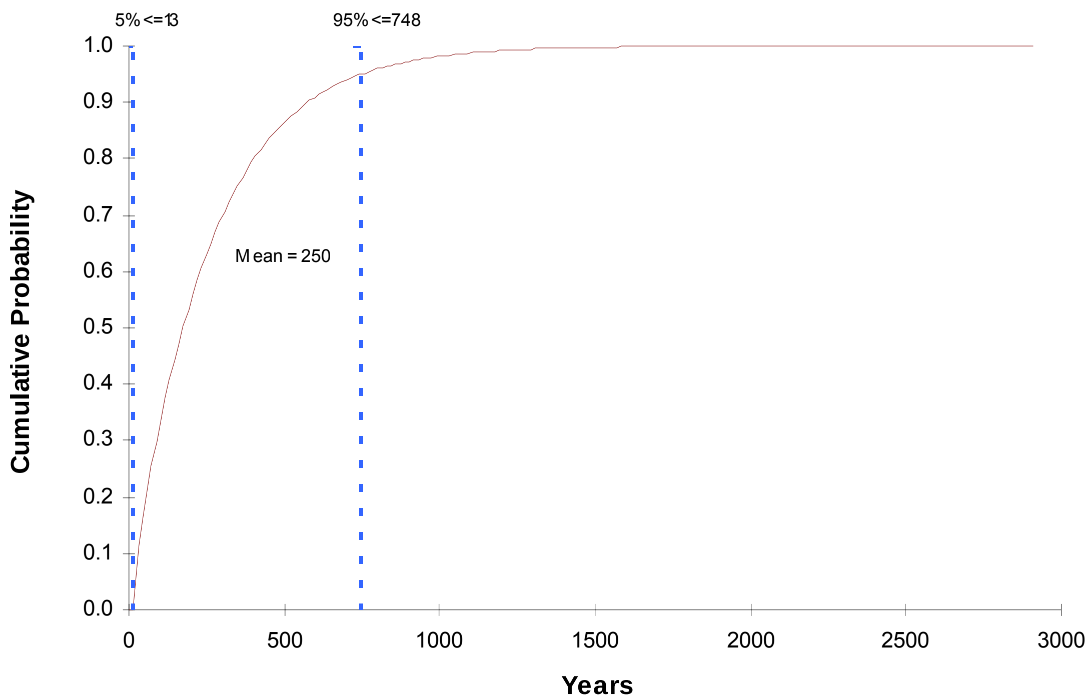

Figure 14. Cumulative distribution function for the years until colonization as a result of annual deregulation of bark nuggets.

2. Logs and Lumber with Bark in the Fall and Winter

The logs and lumber with bark pathway model results for the Fall and Winter seasons had 5th, mean and 95th percentiles for years until colonization of: 11; 200 and 598 (Figure 15; Table 6). The model estimated that there was a 0.500 and 1.985 percent chance of a successful colonization occurring within the first and fourth year after deregulation (Table 7).

These results indicate that deregulation of logs and lumber with bark during the Fall and Winter would pose much less of a risk for *T. piniperda* colonization than during the Spring (see below). Reasons that the risk is much less during the Fall and Winter include: 1) *T. piniperda* is overwintering and there are far fewer beetles per tree, 2) the majority of beetles will remain behind after harvesting in stumps, duff and soil and 3) there is a lower probability of successful dispersal and colonization (Griffin and Miller, 1994; Haack *et al*., 2001; Haack and Lawrence, 1997; Långström, 1984; Petrice *et al*., 2001; Pfister and others, 2003; Ryall and Smith, 2000).

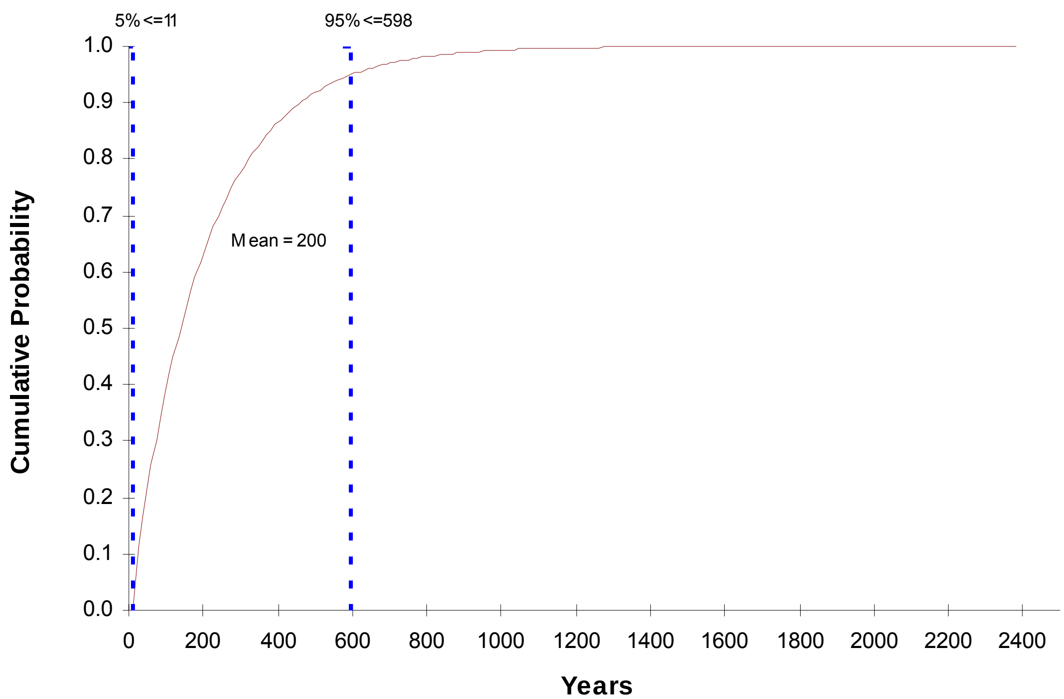

Figure 15. Cumulative distribution function for the years until colonization as a result of deregulation of logs and lumber with bark in the Fall and Winter.

3. Stumps

The stump pathway model produced no colonizations after 100,000 iterations in the Fall and Winter. We conservatively assumed that colonization occurred on the 100,001st iteration. Using this value, the 5th, mean and 95th percentiles for years until colonization were: 5,129; 100,000 and 299,566 (Figure 16; Table 6). The model estimated that there was a 0.001 and 0.003 percent chance of colonization occurring within the first and fourth year after deregulation (Table 7).

The stump pathway model also indicated that Spring was the season at highest risk for *T. piniperda* colonization in the South via this pathway. This was evidenced by the fact that the number of years until colonization with annual deregulation was the same as the Spring values, i.e. the other seasons contributed little to the overall risk. The 5th, mean and 95th percentiles for the years until colonization were: 52; 1,010 and 3,025 (Figure 17; Table 6). The model estimated that there was a 0.099 and 0.395 percent chance of colonization occurring within the first and fourth year after deregulation (Table 7). Reasons that the stump pathway *T. piniperda* colonization risk was higher during the Spring are similar to those for the logs and lumber with bark pathway, i.e. more beetles per stump and higher risk of dispersal and colonization during the Spring (Griffin and Miller, 1994; Haack *et al*., 2001; Långström, 1984; Ryall and Smith, 2000).

Reasons that the stump pathway probably poses a low risk for *T. piniperda* colonization, overall, include: 1) the low volume of stumps that are harvested due to economic costs of removal and erosion concerns, 2) the smaller proportion of beetles feeding below the cutline in the Spring and 3) the small number of mills receiving stumps (Government of Alberta, 2001; Pfister and others; Ryall and Smith, 2000; Spencer, 2003; SPHD data request, 2005).

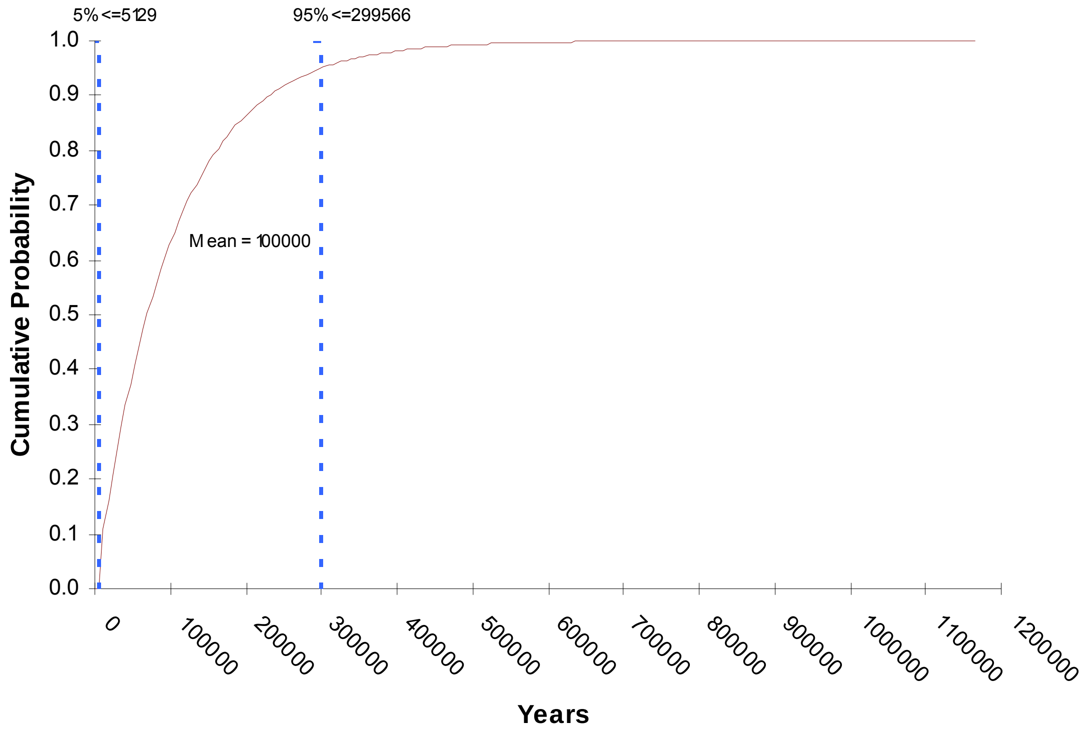

Figure 16. Cumulative distribution function for the years until colonization as a result of deregulation of stumps in the Fall and Winter.

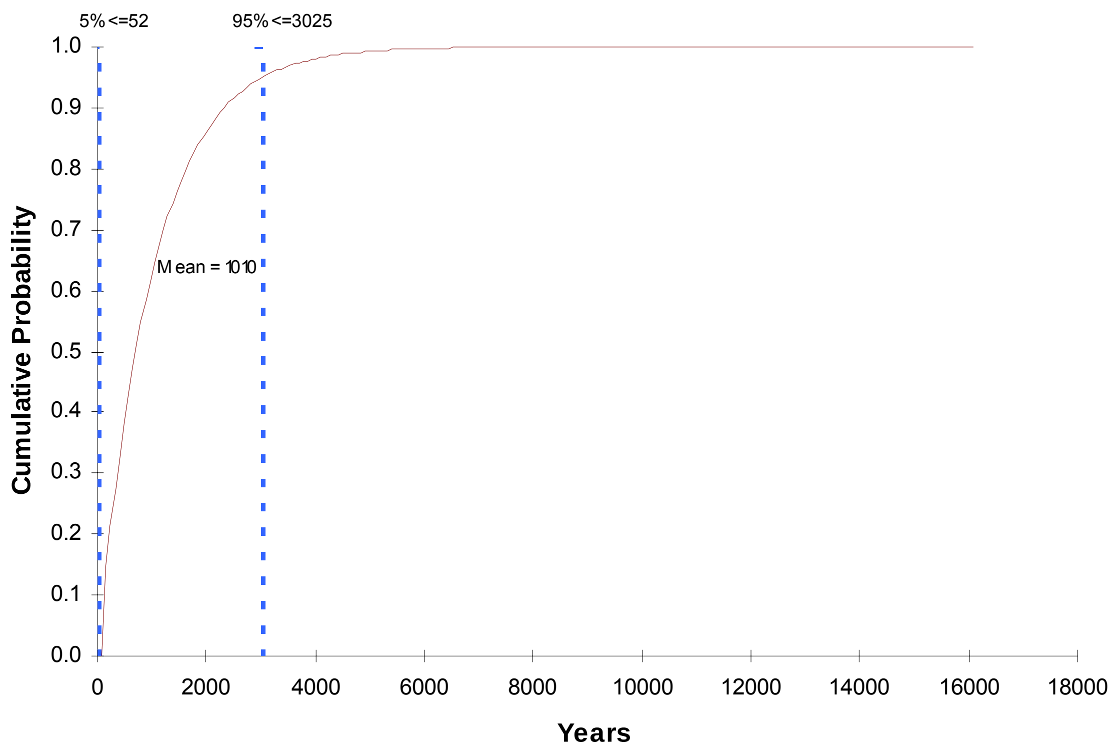

Figure 17. Cumulative distribution function for the years until colonization as a result of deregulation of stumps in the Spring and annually.

4. Bark Nuggets and Stumps

The combination of the bark nugget and stump pathways did not change the rate of colonization in the Fall and Winter compared to the bark nugget pathway by itself (Figure 13; Tables 6 and 7). This was due to the extremely low risk associated with the stump pathway during these seasons and the resulting negligible impact on the number of colonizations (Figure 16; Table 6).

However, the addition of the stump pathway did increase the rate of colonization compared to the bark nugget and stump pathways individually for the Spring with 5th, mean and 95th percentiles for years until colonization of: 24; 455 and 1,361 (Figures 13, 17 and 18; Table 6). The model estimated that there was a 0.220 and 0.877 percent chance of a successful colonization occurring within the first and fourth year after deregulation (Table 7). This increase was due to the larger number of beetles per stump in the Spring compared to the Fall and Winter.

Similarly, the annual rate of colonization also increased when the pathway colonizations were combined with 5th, mean and 95th percentiles of: 11; 204 and 610 (Figures 14, 17 and 19; Table 6). The model estimated that there was a 0.490 and 1.945 percent chance of a successful colonization occurring within the first and fourth year after deregulation (Table 7).

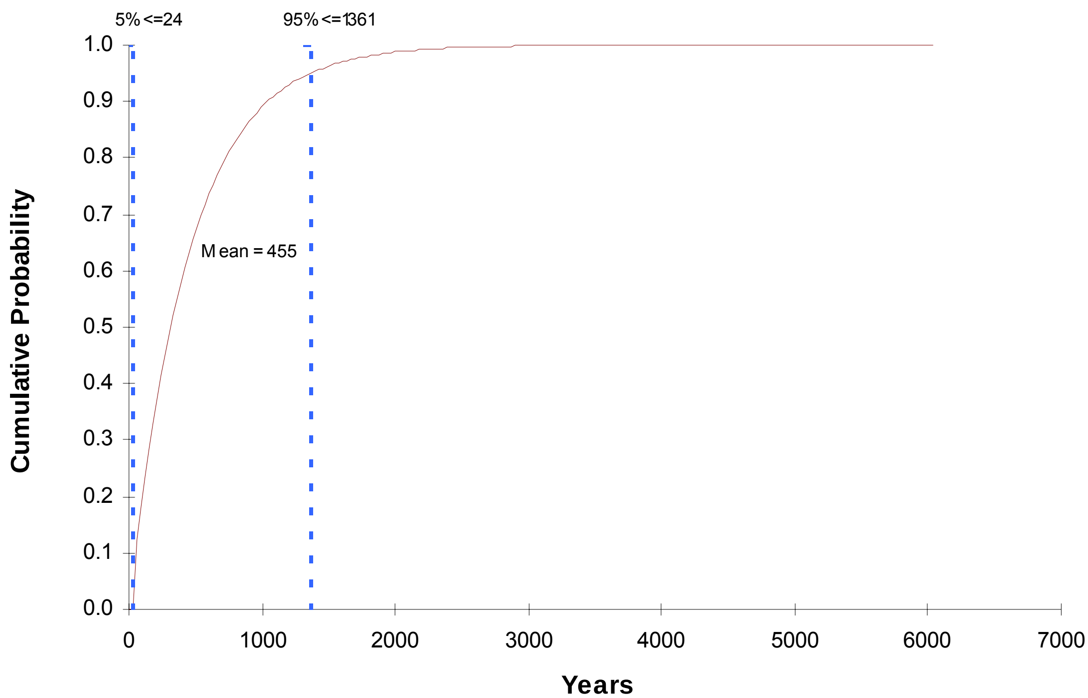

Figure 18. Cumulative distribution function for the years until colonization as a result of deregulation of bark nuggets and stumps in the Spring.

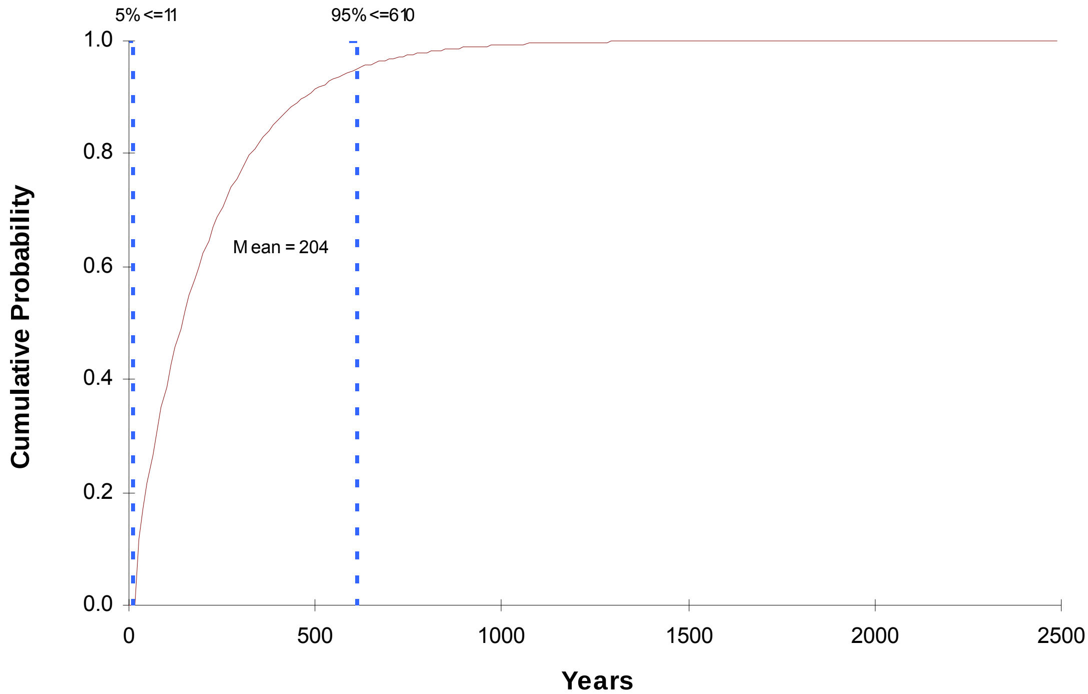

Figure 19. Cumulative distribution function for the years until colonization as a result of annual deregulation of bark nuggets and stumps.

5) Bark Nuggets and Logs and Lumber with Bark in the Fall and Winter

The combination of the bark nugget and logs and lumber with bark pathways slightly increased the rate of colonization in the Fall and Winter compared to the individual pathways with 5^{th}, mean and 95^{th} percentiles for years until colonization of: 9; 167 and 498 (Figures 13, 15 and 20; Table 6). The percent chance of colonization within the first and fourth year after deregulation also slightly increased to 0.600 and 2.378 when these pathways were combined for the Fall and Winter (Table 7). These results indicate that simultaneously deregulating bark nuggets and logs and lumber with bark would slightly increase the risk of colonization in the Fall and Winter relative to deregulating only one of them. Also, colonizations could occur at both mills and mulch producers instead of only one of these if both pathways were deregulated.

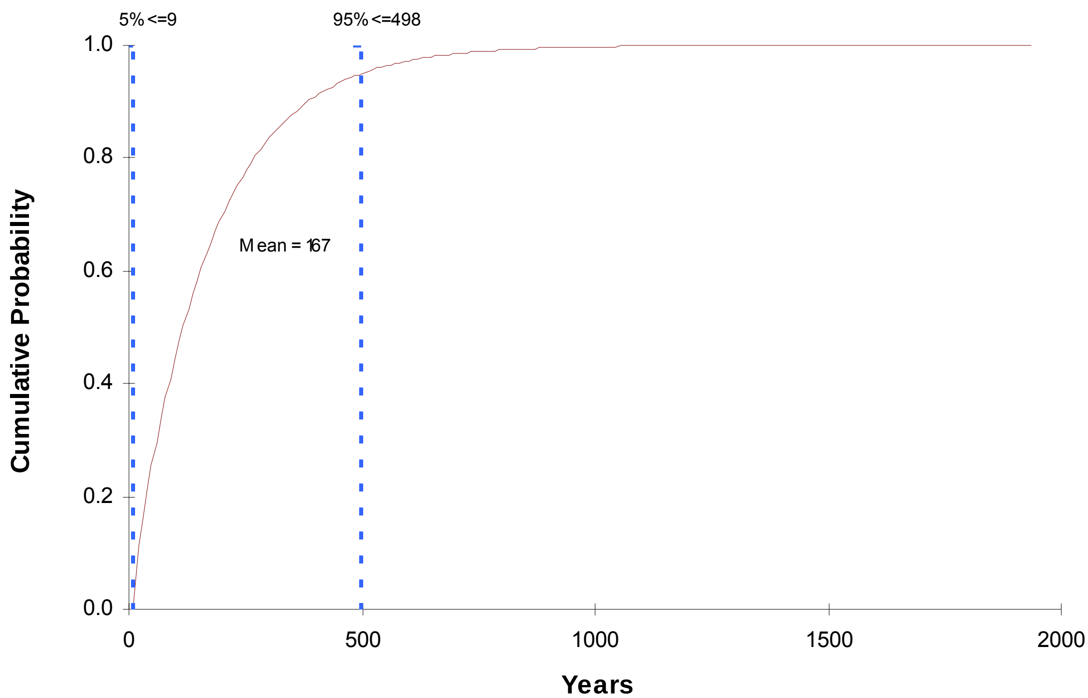

Figure 20. Cumulative distribution function for the years until colonization as a result of deregulation of bark nuggets and logs and lumber with bark in the Fall and Winter.

6. Bark Nuggets, Stumps and Logs and Lumber with Bark in the Fall and Winter

For the Fall and Winter, the model estimated identical years until colonization for simultaneously deregulating all three pathways as it did for the combination of deregulating bark nuggets and logs and lumber with bark (see above) (Figure 20; Tables 6 and 7). The addition of stump deregulation did not have a noticeable impact on the overall risk because of the extremely low rate of colonization associated with this pathway during the Fall and Winter (Figure 16; Tables 6 and 7).

7. Stumps and Logs and Lumber with Bark in the Fall and Winter

No colonizations occurred at the 10 mills analyzed in the stump pathway for the Fall or Winter after 100,000 iterations. Consequently, the resulting years until colonization at all southern mills for the logs and lumber with bark pathway remained constant regardless of the addition of stump colonizations with 5^{th}, mean and 95^{th} percentiles of: 11; 200 and 598 (Figure 15; Tables 6 and 7). Therefore the simultaneous deregulation of both pathways would not change the overall risk in the Fall and Winter compared to deregulation of only logs and lumber with bark.

B. Pathways Considered High Risk for *T. piniperda* Colonization in the South

Based on the model's results, we considered four of the pathways to be high risk for causing *T. piniperda* colonization in the South if deregulated. These pathways were: 1) logs and lumber with bark in the Spring and annually, 2) bark nuggets and logs and lumber with bark in the Spring and annually, 3) bark nuggets, stumps and logs and lumber with bark in the Spring and annually and 4) Stumps and logs and lumber with bark in the Spring and annually.

We classified these pathways as high risk because there was greater than a five percent chance of colonization occurring in less than four years if they were deregulated (Tables 6 and 7). This is approximately how long *T. piniperda* would take to move 150 miles into the South assuming the worst case scenario for spread with regulation (Figure 2). Consequently, deregulation of these pathways would probably facilitate faster colonization of *T. piniperda* in the South than would occur due to natural spread and human movement of infested commodities within the quarantined area assuming no inhibition by abiotic or biotic factors (Figure 2).

Also, *T. piniperda's* colonization in the South may be mitigated by interspecific competition with indigenous pine beetles (Fowler and Borchert, 2006; Haack pers. comm., 2005). Consequently, deregulation of these pathways could substantially accelerate the colonization rate of *T. piniperda* in the South.

1. Logs and Lumber with Bark in the Spring and Annually and its Combinations with the Bark Nugget and Stump Pathways in the Spring and Annually

The Spring was the season at highest risk for *T. piniperda* colonization in the South via the logs and lumber with bark pathway, i.e. the other seasons contributed little to the overall annual risk (Tables 6 and 7). The model results for the Spring and annually estimated that *T. piniperda* colonization in the South would occur within the first year after deregulation. This estimate is probably high due to the conservative assumptions we made in the model (Table 3). However, this result may partially explain the observed *T. piniperda* spread rate since its detection in 1992, i.e. approximately 36 miles per year (Figure 1). Our model indicates the Spring movement of logs and lumber with bark within the quarantined area may be one of the main pathways by which *T. piniperda* is spreading.

The added effect of simultaneously deregulating the other pathways in combination with logs and lumber with bark did not cause a change in the rate of colonization in the Spring and annually. This is because: 1) the comparative risk with the bark nugget and stump pathways was estimated to be low and 2) the model already estimated that colonization would occur within the first year after deregulation with the logs and lumber with bark pathway (Tables 6 and 7). Consequently, simultaneous deregulation of the other pathways would not change the outcome temporally.

Table 6. Summary risk table for the years until colonization in the South in the event of pathway deregulation.

Pathway	Season	5th %tile	Mean %tile	95th %tile
Bark Nuggets	Annual	13	250	748
	Spring/Fall/ Winter	40	769	2,303
Logs and Lumber with Bark	Spring/Annual	1	1	1
	Fall/Winter	11	200	598
Stumps	Spring/Annual	52	1,010	3,025
	Fall/Winter	5,129	100,000	299,566
Bark Nuggets and Stumps	Annual	11	204	610
	Spring	24	455	1,361
	Fall/Winter	40	769	2,303
Bark Nuggets and Logs and Lumber with Bark	Spring/Annual	1	1	1
	Fall/Winter	9	167	498
Bark Nuggets, Stumps and Logs and Lumber with Bark	Spring/Annual	1	1	1
	Fall/Winter	9	167	498
Stumps and Logs and Lumber with Bark	Spring/Annual	1	1	1
	Fall/Winter	11	200	598

Table 7. Summary risk table for the percent chance of colonization in the South within the first and fourth year after pathway deregulation.

Pathway	Season	Percent Chance for Colonization within One Year	Percent Chance for Colonization within Four Years
Bark Nuggets	Annual	0.400	1.590
	Spring/Fall/Winter	0.130	0.519
Logs and Lumber with Bark	Spring/Annual	100.000	100.000
	Fall/Winter	0.500	1.985
Stumps	Spring/Annual	0.099	0.395
	Fall/Winter	0.001	0.003
Bark Nuggets and Stumps	Annual	0.49	1.945
	Spring	0.220	0.877
	Fall/Winter	0.130	0.519
Bark Nuggets and Logs and Lumber with Bark	Spring/Annual	100.000	100.000
	Fall/Winter	0.600	2.378
Bark Nuggets, Stumps and Logs and Lumber with Bark	Spring/Annual	100.000	100.000
	Fall/Winter	0.600	2.378
Stumps and Logs and Lumber with Bark	Spring/Annual	100.000	100.000
	Fall/Winter	0.500	1.985

XII. Recommendations

A. Compost and/or Grind Bark Nuggets Prior to Shipping

Our model indicated a low risk associated with raw bark nuggets (Figures 13 and 14; Tables 6 and 7). The addition of further processing procedures like composting and/or grinding should further reduce the risk associated with this pathway due to increased beetle mortality (Linnane, 2003).

B. Regulate Logs and Lumber with Bark Movement During the Spring

The model estimated the greatest risk of colonization during the Spring months (Tables 6 and 7). Also, there is uncertainty regarding *T. piniperda*'s rate of movement into the South due to interspecific competition (Fowler and Borchert, 2006; Haack pers. comm., 2005). Based on this information, we do not recommend deregulation of logs and lumber with bark during the Spring because it may accelerate *T. piniperda* colonization in the South.

C. Maintain Compliance Agreements Regarding Debarking Times for Logs and Lumber

We modeled up to the point of timber deposition in a timber yard for the logs and lumber with bark pathway. All further estimates regarding mated pair formation and colonization occurred from stored timber (Figure 21). Timber debarking should dramatically reduce the number of beetles dispersing from the timber yard (Caton and Spears, 2005; Dubbel, 1993). For example, 93 percent mortality rates on the similar sized *Ips typographus* have been observed as a result of typical debarking processes (Dubbel, 1993). Consequently, we recommend maintaining compliance agreements that stipulate timber debarking as rapidly as possible, e.g. between two and ten days after arrival at the mill (Maine Forest Service, 2005; Pfister and others, 2003). We also recommend the use of ring debarkers since they have been shown to cause high mortality rates, e.g. 99 percent, for the similar sized beetle, *I. calligraphus* (Haack (unpublished) as cited in Linnane, 2003). Similar practices have been implemented in Europe to attenuate the impact of *T. piniperda* (CABI, 2004).

Figure 21. *Tomicus piniperda* shoot-feeding damage (sparse tops) near a timber storage yard in Poland.

D. Grind Stumps for Fuel as Rapidly as Possible

We recommend grinding stumps for fuel as rapidly as possible after arrival at the mill, e.g. between two and ten days after arrival at the mill, to reduce the likelihood of *T. piniperda* dispersal (Maine Forest Service, 2005; Pfister and others, 2003). Also, finely grinding stumps to a diameter of one inch or less would: 1) likely result in complete *T. piniperda* mortality (Linnane, 2003) and 2) still produce a viable biofuel (King County Environmental Purchasing Program, 2005; Russell, 2003).

E. Regulate Pine Fuelwood until the Risk of *T. piniperda* Colonization via this Pathway is Assessed

Some of the timber product produced in the at-risk counties was pine fuelwood (FIA, 2006) (Appendices 2 and 3; Table 8). We conservatively included this volume in our models for stumps and logs and lumber with bark even though fuelwood should not move via these pathways (Johnson pers. comm., 2006). Fuelwood is currently unregulated and will be collected by individuals rather than being sent to timber mills (CFR, 2003, 2005; Johnson pers. comm., 2006). Consequently, pine fuelwood is an unmitigated pathway for facilitating *T. piniperda* colonization. We recommend that pine fuelwood be listed as a regulated commodity until the risk associated with its movement is assessed.

Table 8. Pine timber and fuelwood removal volumes (Cubic Feet) from quarantined counties within 150 miles of southern timber mills (FIA, 2006).

Commodity	1997	2002	Mean
Timber	18,631,057	18,647,036	18,639,047
Fuelwood	507,156	493,164	500,160
Fuelwood Percentage	2.722	2.645	2.683

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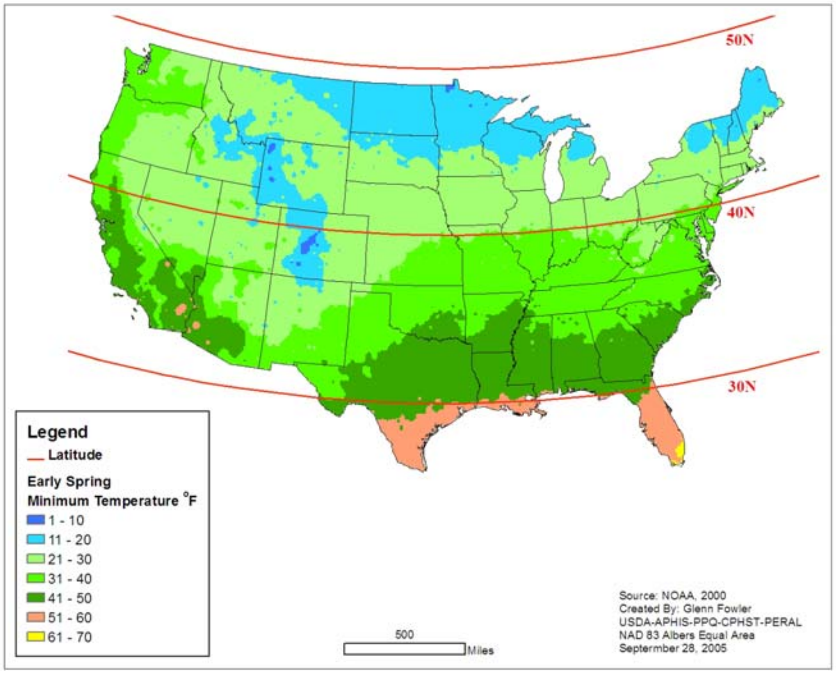
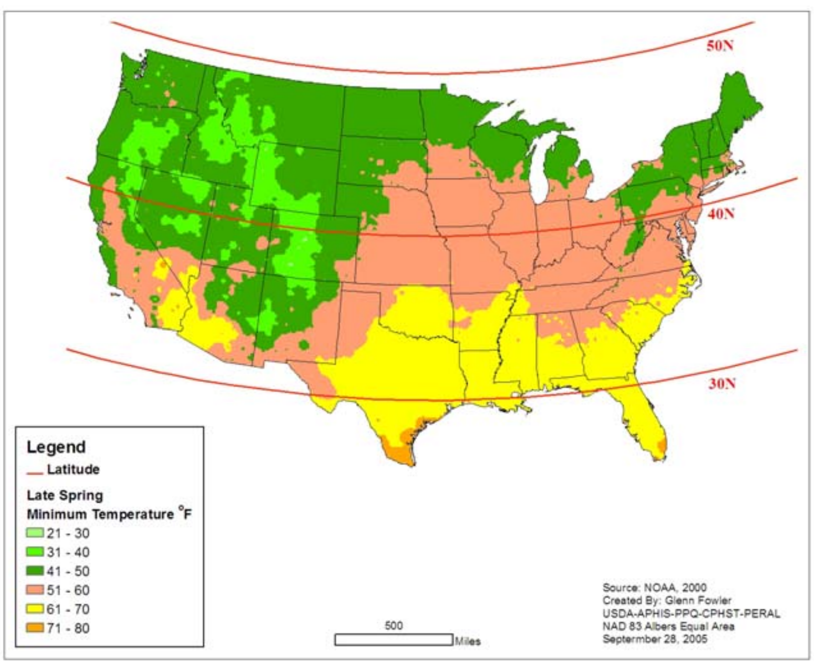
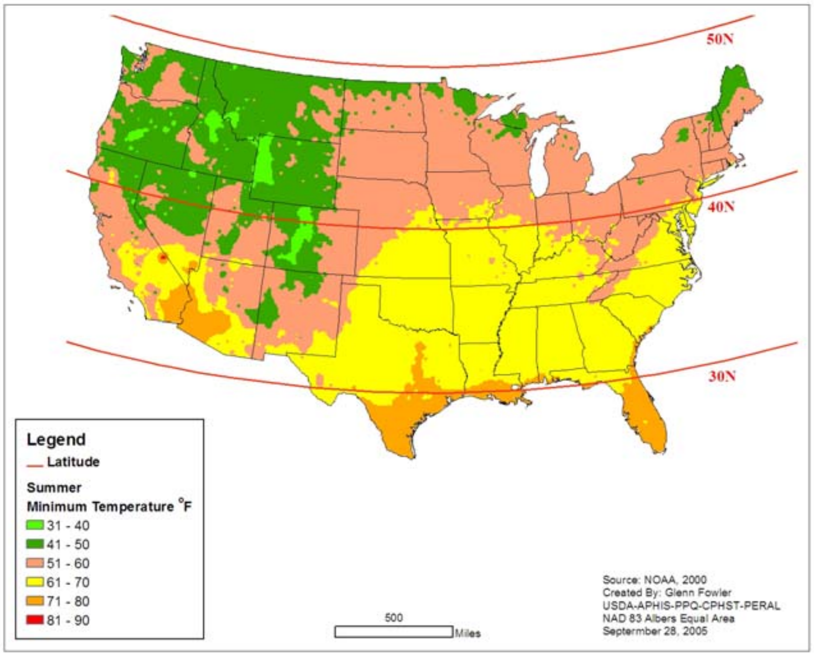
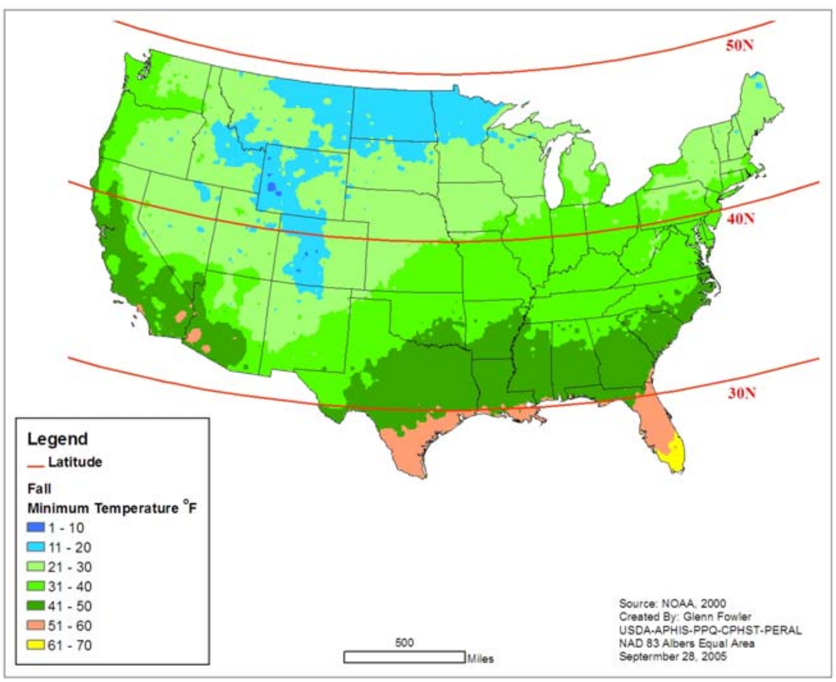
XV. Appendices

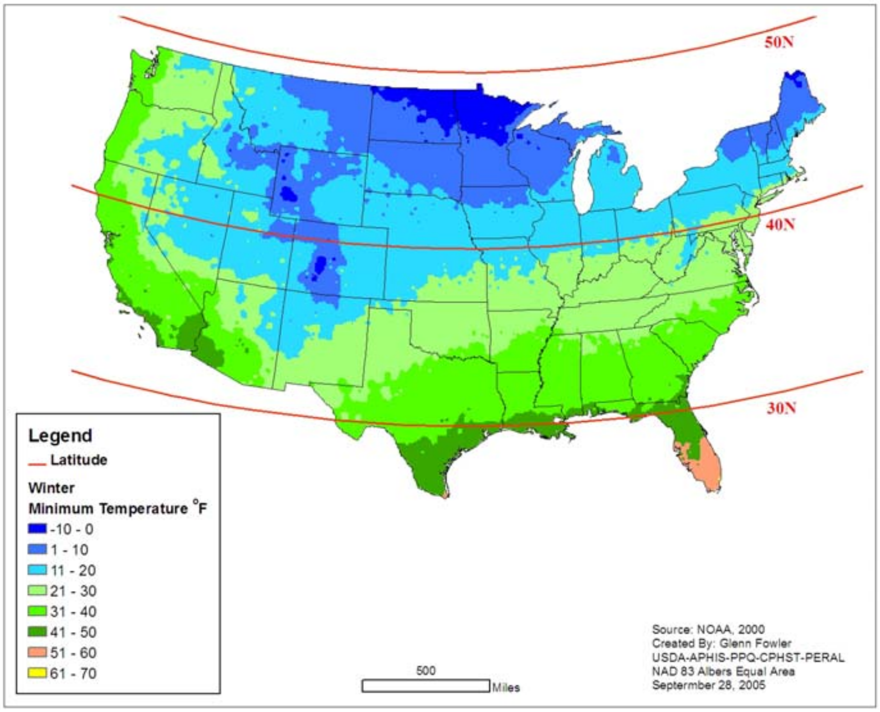
Appendix 1. Seasonal minimum temperature based on the classifications used by Griffin and Miller (1994). Average seasonal minimum temperatures were calculated based on average monthly minimums from 1961 to 1990 (NOAA, 2000).



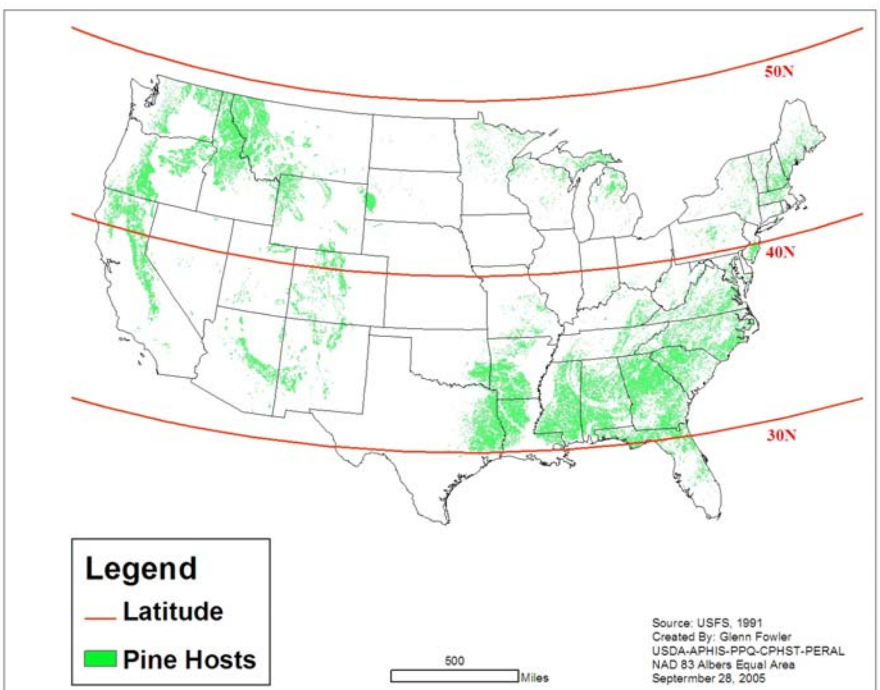



50N
40N
30N
Legend
Latitude
Summer
Minimum Temperature °F
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
500
Miles
Source: NOAA, 2000
Created By: Glenn Fowler
USDA-APHIS-PPQ-CPHST-PERAL
NAD 83 Albers Equal Area
Septermber 28, 2005


50N
40N
30N
Legend
Latitude
Fall
Minimum Temperature °F
1 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
500
Miles
Source: NOAA, 2000
Created By: Glenn Fowler
USDA-APHIS-PPQ-CPHST-PERAL
NAD 83 Albers Equal Area
Septermber 28, 2005



Appendix 2. United States *T. piniperda* pine host distribution.



Appendix 3. 1997 FIA data output for counties considered at risk for introducing *T. piniperda* into the South on regulated timber articles based on a shipping distance of 150 miles.

MOIMS Timber Products Output Mapmaker Version 1.0Timber Products Output Mapmaker Version 1.0
Geographic area of interest is Illinois 1997 RPA Year: Champaign, Christian, Clark, Coles, Douglas, Edgar, Macon, Moultrie, Piatt, Shelby, Vermillion, Indiana 1997 RPA Year: Adams, Bartholomew, Blackford, Boone, Brown, Carroll, Clinton, Dearborn, Decatur, Delaware, Fayette, Fountain, Franklin, Grant, Hamilton, Hancock, Hendricks, Henry, Howard, Huntington, Jay, Jennings, Johnson, Madison, Marion, Miami, Monroe, Montgomery, Morgan, Owen, Parke, Putnam, Randolph, Ripley, Rush, Shelby, Tippecanoe, Tipton, Union, Vermillion, Vigo, Wabash, Wayne, Wells, Maryland 1997 RPA Year: Allegany, Frederick, Garrett, Montgomery, Washington, Ohio 1997 RPA Year: Allen, Ashland, Athens, Auglaize, Belmont, Butler, Champaign, Clark, Coshocton, Crawford, Darke, Delaware, Fairfield, Franklin, Gallia, Greene, Guernsey, Hamilton, Hancock, Hardin, Harrison, Hocking, Holmes, Jefferson, Knox, Lawrence, Licking, Logan, Madison, Marion, Meigs, Mercer, Miami, Monroe, Montgomery, Morgan, Morrow, Muskingum, Noble, Perry, Pickaway, Pike, Preble, Richland, Shelby, Tuscarawas, Union, Van Wert, Vinton, Warren, Washington, Wyandot, Pennsylvania 1997 RPA Year: Adams, Allegheny, Armstrong, Beaver, Bedford, Berks, Blair, Bucks, Butler, Cambria, Cameron, Carbon, Centre, Chester, Clarion, Clearfield, Clinton, Columbia, Cumberland, Dauphin, Delaware, Elk, Fayette, Franklin, Fulton, Greene, Huntingdon, Indiana, Jefferson, Juniata, Lancaster, Lebanon, Lehigh, Luzerne, Lycoming, Mifflin, Montgomery, Montour, Northumberland, Perry, Philadelphia, Schuylkill, Snyder, Somerset, Union, Washington, Westmoreland, York, Virginia 1997 RPA Year: CLARKE, West_Virginia 1997 RPA Year, .
The attribute of interest is Volume of all removals(cuft).
Filters: species group includes (Jack pine or Loblolly-Shortleaf pine or Lodgepole pine or Longleaf-Slash pine or Other pines or Ponderosa-Jeffrey pine or Red pine or Sugar pine or White pine),.
Pages are State code.
Rows are Species group.
Columns are Product.

page= 0: TotalState code
,,TotalProduct, Sawlogs, Veneer logs, Pulpwood, Fuelwood, Post, Poles, and Pilings, Misc products,Not Used
8 , Loblolly-Shortleaf pines, 385917.43 , 8289.5 , 0 , 226980.71 , 65285.31 , 368.18 , 0 , 84993.73
12 , Red pine, 3010084.64 , 109723.91 , 0 , 2061575.27 , 16185.55 , 184.08 , 22331.06 , 800084.77
14 , White pine, 8636761.22 , 2116122.33 , 0 , 3796521.6 , 83861.27 , 108361.32 , 161432.53 , 2370462.17
15 , Other pines, 13587129.32 , 2422780.1 , 9507.38 , 6116514.33 , 341824.04 , 922354.93 , 40853.7 , 3733294.84
0 ,Total Species group, 25619892.61 , 4656915.84 , 9507.38 , 12201591.91 , 507156.17 , 1031268.51 , 224617.29 , 6988835.51

page= 13: 17 IL
,,TotalProduct, Fuelwood,Not Used
 12 , Red pine, 8726.42 , 4270.76 , 4455.66
 14 , White pine, 6127.53 , 5632.46 , 495.07
 15 , Other pines, 729.1 , 729.1 , 0
 0 ,Total Species group, 15583.05 , 10632.32 , 4950.73

page= 14: 18 IN
,,TotalProduct, Sawlogs, Fuelwood,Not Used
 8 , Loblolly-Shortleaf pines, 3176.19 , 1330.37 , 0 , 1845.82
 12 , Red pine, 2591.88 , 1085.63 , 0 , 1506.25
 14 , White pine, 4578.29 , 1917.65 , 0 , 2660.64
 15 , Other pines, 264915.55 , 90555.6 , 48712.11 , 125647.84
 0 ,Total Species group, 275261.91 , 94889.25 , 48712.11 , 131660.55

page= 20: 24 MD
,,TotalProduct, Sawlogs, Pulpwood, Fuelwood,Not Used
 8 , Loblolly-Shortleaf pines, 371828.28 , 3959.13 , 221540.7 , 65285.31 , 81043.14
 14 , White pine, 17735.9 , 9977.01 , 0 , 2888.48 , 4870.41
 15 , Other pines, 872246.75 , 4592.58 , 519075.7 , 159374.16 , 189204.31
 0 ,Total Species group, 1261810.93 , 18528.72 , 740616.4 , 227547.95 , 275117.86

page= 35: 39 OH
,,TotalProduct, Sawlogs, Pulpwood, Post, Poles, and Pilings, Misc products,Not Used
 8 , Loblolly-Shortleaf pines, 7912.96 , 0 , 5440.01 , 368.18 , 0 , 2104.77
 12 , Red pine, 4880.16 , 0 , 3400.01 , 184.08 , 0 , 1296.07
 14 , White pine, 666172.45 , 160265.17 , 296650 , 0 , 21906.67 , 187350.61
 15 , Other pines, 2754172.9 , 212367.19 , 897600.03 , 860987.3 , 0 , 783218.38
 0 ,Total Species group, 3433138.47 , 372632.36 , 1203090.05 , 861539.56 , 21906.67 , 973969.83

page= 38: 42 PA
,,TotalProduct, Sawlogs, Veneer logs, Pulpwood, Fuelwood, Post, Poles, and Pilings, Misc products,Not Used
 12 , Red pine, 2993886.18 , 108638.28 , 0 , 2058175.26 , 11914.79 , 0 , 22331.06 , 792826.79
 14 , White pine, 5092859.61 , 1461073.6 , 0 , 2058175.26 , 19926.62 , 2423.52 , 139525.86 , 1411734.75
 15 , Other pines, 2682505.9 , 345076.9 , 9507.38 , 1545754.72 , 10571.89 , 1211.75 , 40853.7 , 729529.56
 0 ,Total Species group, 10769251.69 , 1914788.78 , 9507.38 , 5662105.24 , 42413.3 , 3635.27 , 202710.62 , 2934091.1

page= 46: 51 VA
,,TotalProduct, Sawlogs
 8 , Loblolly-Shortleaf pines, 3000 , 3000
 0 ,Total Species group, 3000 , 3000
page= 48: 54 WV

,,TotalProduct, Sawlogs, Pulpwood, Fuelwood, Post, Poles, and Pilings,Not Used
14 , White pine, 2849287.44 , 482888.9 , 1441696.34 , 55413.71 , 105937.8 , 763350.69
15 , Other pines, 7012559.12 , 1770187.83 , 3154083.88 , 122436.78 , 60155.88 , 1905694.75
0 ,Total Species group, 9861846.56 , 2253076.73 , 4595780.22 , 177850.49 , 166093.68 , 2669045.44

Appendix 4. 2002 FIA data output for counties considered at risk for introducing *T. piniperda* into the South on regulated timber articles based on a shipping distance of 150 miles.

MOIMS Timber Products Output Mapmaker Version 1.0Timber Products Output Mapmaker Version 1.0
Geographic area of interest is Illinois 2002 RPA Year: Champaign, Christian, Clark, Coles, Douglas, Edgar, Macon, Moultrie, Piatt, Shelby, Vermillion, Indiana 2002 RPA Year: Adams, Bartholomew, Blackford, Boone, Brown, Carroll, Clinton, Dearborn, Decatur, Delaware, Fayette, Fountain, Franklin, Grant, Hamilton, Hancock, Hendricks, Henry, Howard, Huntington, Jay, Jennings, Johnson, Madison, Marion, Miami, Monroe, Montgomery, Morgan, Owen, Parke, Putnam, Randolph, Ripley, Rush, Shelby, Tippecanoe, Tipton, Union, Vermillion, Vigo, Wabash, Wayne, Wells, Maryland 2002 RPA Year: Allegany, Frederick, Garrett, Montgomery, Washington, Ohio 2002 RPA Year: Allen, Ashland, Athens, Auglaize, Belmont, Butler, Champaign, Clark, Coshocton, Crawford, Darke, Delaware, Fairfield, Franklin, Gallia, Greene, Guernsey, Hamilton, Hancock, Hardin, Harrison, Hocking, Holmes, Jefferson, Knox, Lawrence, Licking, Logan, Madison, Marion, Meigs, Mercer, Miami, Monroe, Montgomery, Morgan, Morrow, Muskingum, Noble, Perry, Pickaway, Pike, Preble, Richland, Shelby, Tuscarawas, Union, Van Wert, Vinton, Warren, Washington, Wyandot, Pennsylvania 2002 RPA Year: Adams, Allegheny, Armstrong, Beaver, Bedford, Berks, Blair, Bucks, Butler, Cambria, Cameron, Carbon, Centre, Chester, Clarion, Clearfield, Clinton, Columbia, Cumberland, Dauphin, Delaware, Elk, Fayette, Franklin, Fulton, Greene, Huntingdon, Indiana, Jefferson, Juniata, Lancaster, Lebanon, Lehigh, Luzerne, Lycoming, Mifflin, Montgomery, Montour, Northumberland, Perry, Philadelphia, Schuylkill, Snyder, Somerset, Union, Washington, Westmoreland, York, Virginia 2002 RPA Year: CLARKE, West_Virginia 2002 RPA Year, .
The attribute of interest is Volume of all removals(cuft).
Filters: species group includes (Jack pine or Loblolly-Shortleaf pine or Lodgepole pine or Longleaf-Slash pine or Other pines or Ponderosa-Jeffrey pine or Red pine or Sugar pine or White pine),.
Pages are State code.
Rows are Species group.
Columns are Product.

page= 0: TotalState code
,,TotalProduct, Sawlogs, Veneer logs, Pulpwood, Fuelwood, Post, Poles, and Pilings, Misc products,Not Used
8 , Loblolly-Shortleaf pines, 415866.135 , 8387.659 , 0 , 250733.124 , 66318.026 , 368.177 , 0 , 90059.149

12 , Red pine, 3001585.706 , 108760.427 , 0 , 2061493.606 , 13617.4 , 184.078 , 22331.06 , 795199.135
14 , White pine, 8566548.507 , 2093724.452 , 0 , 3822446.837 , 79267.045 , 60096.898 , 161432.238 , 2349581.037
15 , Other pines, 13598786.028 , 2417535.929 , 9507.38 , 6173531.905 , 333961.335 , 922485.393 , 40853.7 , 3700910.386
0 ,Total Species group, 25582786.376 , 4628408.467 , 9507.38 , 12308205.472 , 493163.806 , 983134.546 , 224616.998 , 6935749.707

page= 13: 17 IL
,,TotalProduct, Fuelwood
12 , Red pine, 1675.722 , 1675.722
14 , White pine, 2210.021 , 2210.021
15 , Other pines, 286.079 , 286.079
0 ,Total Species group, 4171.822 , 4171.822

page= 14: 18 IN
,,TotalProduct, Sawlogs, Fuelwood,Not Used
8 , Loblolly-Shortleaf pines, 3176.212 , 1330.379 , 0 , 1845.833
12 , Red pine, 2591.904 , 1085.637 , 0 , 1506.267
14 , White pine, 4578.33 , 1917.666 , 0 , 2660.664
15 , Other pines, 75340.12 , 0 , 38242.653 , 37097.467
0 ,Total Species group, 85686.566 , 4333.682 , 38242.653 , 43110.231

page= 20: 24 MD
,,TotalProduct, Sawlogs, Pulpwood, Fuelwood,Not Used
8 , Loblolly-Shortleaf pines, 371828.28 , 3959.13 , 221540.7 , 65285.31 , 81043.14
14 , White pine, 17735.9 , 9977.01 , 0 , 2888.48 , 4870.41
15 , Other pines, 872246.75 , 4592.58 , 519075.7 , 159374.16 , 189204.31
0 ,Total Species group, 1261810.93 , 18528.72 , 740616.4 , 227547.95 , 275117.86

page= 35: 39 OH
,,TotalProduct, Sawlogs, Pulpwood, Post, Poles, and Pilings, Misc products,Not Used
8 , Loblolly-Shortleaf pines, 7912.86 , 0 , 5439.939 , 368.177 , 0 , 2104.744
12 , Red pine, 4880.096 , 0 , 3399.964 , 184.078 , 0 , 1296.054
14 , White pine, 666163.624 , 160263.032 , 296646.042 , 0 , 21906.378 , 187348.172
15 , Other pines, 2754146.814 , 212365.642 , 897588.484 , 860981.528 , 0 , 783211.16
0 ,Total Species group, 3433103.394 , 372628.674 , 1203074.429 , 861533.783 , 21906.378 , 973960.13

page= 38: 42 PA
,,TotalProduct, Sawlogs, Veneer logs, Pulpwood, Fuelwood, Post, Poles, and Pilings, Misc products,Not Used
12 , Red pine, 2992437.984 , 107674.79 , 0 , 2058093.642 , 11941.678 , 0 , 22331.06 , 792396.814
14 , White pine, 5090788.126 , 1459639.448 , 0 , 2058093.642 , 19934.188 , 2423.52 , 139525.86 , 1411171.468

15 , Other pines, 2696287.497 , 354647.512 , 9507.38 , 1545878.419 , 10622.197 , 1211.75 , 40853.7 , 733566.539
0 ,Total Species group, 10779513.607 , 1921961.75 , 9507.38 , 5662065.703 , 42498.063 , 3635.27 , 202710.62 , 2937134.821

page= 46: 51 VA
,,TotalProduct, Sawlogs, Pulpwood, Fuelwood,Not Used
8 , Loblolly-Shortleaf pines, 32948.783 , 3098.15 , 23752.485 , 1032.716 , 5065.432
0 ,Total Species group, 32948.783 , 3098.15 , 23752.485 , 1032.716 , 5065.432

page= 48: 54 WV
,,TotalProduct, Sawlogs, Pulpwood, Fuelwood, Post, Poles, and Pilings,Not Used
14 , White pine, 2785072.506 , 461927.296 , 1467707.153 , 54234.356 , 57673.378 , 743530.323
15 , Other pines, 7200478.768 , 1845930.195 , 3210989.302 , 125436.246 , 60292.115 , 1957830.91
0 ,Total Species group, 9985551.274 , 2307857.491 , 4678696.455 , 179670.602 , 117965.493 , 2701361.233

Appendix 5. Annual capacity/production (1000 m^3) of selected southern sawmills (Spelter and Alderman, 2005).

State	2000	2001	2002	2003	2004	2005	Mean
NC	4	4	4	4	4	4	4
NC	5	5	5	5	5	5	5
VA	5	5	5	5	5	5	5
VA	5	5	5	5	5	5	5
VA	5	5	5	5	5	5	5
NC	6	6	6	6	6	6	6
VA	6	6	6	6	6	6	6
VA	6	6	6	6	6	6	6
VA	6	6	6	6	6	6	6
TN	7	7	7	7	7	7	7
TN	7	7	7	7	7	7	7
VA	9	9	6	6	6	6	7
VA	5	5	8	8	8	8	7
VA	9	9	9	9	5	5	8
NC	5	7	7	7	11	11	8
NC	8	8	8	8	8	8	8
NC	9	9	9	9	9	9	9
TN	9	9	9	9	9	9	9
TN	9	9	9	9	9	9	9
VA	9	9	9	9	9	9	9
VA	9	9	9	9	9	9	9
NC	9	7	7	12	12	12	10
VA	9	9	9	9	12	12	10
NC	11	11	11	11	11	11	11
NC	11	11	11	11	11	11	11
NC	12	12	12	12	12	12	12
VA	12	12	12	12	12	12	12
NC	13	13	13	13	13	13	13
VA	14	14	14	14	14	14	14
VA	14	14	14	14	14	14	14
VA	21	21	21	21	5	5	16
VA	19	19	19	19	12	12	17
TN	17	17	17	17	17	17	17
VA	17	17	17	17	17	17	17
NC	14	14	21	21	21	21	19
VA	28	28	17	17	17	17	21
NC	21	21	21	21	21	21	21
VA	21	21	21	21	21	21	21
VA	21	21	21	21	21	21	21
NC	21	21	21	24	24	24	23
NC	24	24	21	21	24	24	23
NC	23	23	23	23	23	23	23
VA	19	24	24	24	24	24	23
NC	24	24	24	24	24	24	24
NC	24	24	24	24	24	24	24

NC	24	24	24	24	24	24	24
VA	24	24	24	24	24	24	24
NC	24	24	24	26	26	26	25
NC	25	25	25	25	25	25	25
VA	18	18	18	18	42	47	27
VA	28	28	26	28	28	28	28
VA	37	37	37	0	37	37	31
NC	35	35	35	38	38	28	35
NC	35	35	35	35	35	35	35
TN	35	35	35	35	35	35	35
VA	35	35	35	35	35	35	35
NC	40	40	40	40	42	42	41
NC	42	42	42	42	42	42	42
NC	33	33	33	33	59	66	43
NC	35	35	41	42	54	54	44
NC	44	44	44	44	44	44	44
NC	42	42	52	54	54	54	50
VA	50	50	50	50	61	61	54
NC	42	42	58	59	64	66	55
NC	59	59	71	71	71	71	67
VA	57	71	79	80	80	80	75
VA	79	79	79	79	79	79	79
NC	47	71	83	83	97	109	82
VA	83	83	83	83	83	83	83
VA	83	83	83	85	85	85	84
NC	94	94	94	94	94	94	94
VA	94	99	99	99	99	99	98
NC	170	170	170	170	94	94	145
NC	165	165	163	170	170	170	167
NC	168	168	168	168	168	168	168
NC	177	177	182	186	189	189	183
NC	184	184	184	184	184	184	184
NC	198	198	198	198	198	198	198
NC	189	189	201	201	231	231	207
NC	212	224	224	224	224	224	222
NC	201	212	212	271	271	271	240
VA	295	295	295	295	295	295	295
NC	342	354	366	401	472	531	411
NC	437	472	472	472	500	500	476
NC	413	472	472	543	590	590	513
NC	531	566	566	590	590	590	572
						Average	69
						SD	113.4132

Appendix 6. Node values, functions and operations used in the bark nugget, logs and lumber with bark and stump pathway models.

Node	Function/ Operation	Parameters P1	P2	P3	References
Timber units per season	PERT	Bark Fall/Winter min = 904 Bark Spring min = 1193 Log Fall/Winter min = 3639 Log Spring min = 4803	Bark Fall/Winter ml = 907 Bark Spring ml = 1197 Log Fall/Winter ml = 3640 Log Spring ml = 4805	Bark Fall/Winter max = 910 Bark Spring max = 1201 Log Fall/Winter max = 3642 Log Spring max = 4807	FIA, 2006
Trees per season	conversion	1 unit = 100 trees			Griffin and Miller, 1994
Probability of timber products shipped south	Beta	Bark s = 135 Log s = 798 Stump s = 798	Bark n = 379 Log n = 3687 Stump n = 3687		infoUSA®, 2005; Prestemon *et al*., 2005
Probability of mills receiving stumps and of stumps being shipped from the quarantined area	Beta	s = 1	n = 273		SPHD data request, 2005
Probability of trees processed for bark in the quarantined counties	Beta	Bark s = 1465	Bark n = 3554		Prestemon *et al*., 2005
Probability of beetles sent to an average mulch producer	PERT	min = 0	ml = 0.007	max = 0.026	Cochran, 1977; infoUSA®, 2005
Proportion of trees shipped to an average mill	Normal	mean = 0.002	sd = 0.003		Prestemon *et al*., 2005; Spelter and Alderman, 2005
Probability of successful attack	Beta	s = 91	n = 1455		Morgan *et al*., 2004
Probability of reproduction after attack	Beta	s = 8	n = 91		Morgan *et al*., 2004

Number of overwintering beetles per tree	Normal	mean = 21.25	sd = 6.34		Haack *et al*., 2005
Number of brood beetles per tree	Normal	mean = 1123.33	sd = 1131.81		Långström, 1984
Probability of overwintering above the cutline	Beta	s = 77	n = 777		Caton and Spears, 2005; Haack and Lawrence, 1977; Haack *et al*., 2001; Petrice *et al*., 2002
Probability of overwintering below the cutline	Beta	s = 698	n = 777		Caton and Spears, 2005; Haack and Lawrence, 1977; Haack *et al*., 2001; Petrice *et al*., 2002
Proportion of beetles feeding below the cutline	Proportion	0.1/3.75			Haack and Lawrence, 1994 as cited in Griffin and Miller, 1994; Ryall and Smith, 2000
Probability of surviving debarking	Negative Exponential	β = 0.0714			Caton and Spears, 2005; Dubbel, 1993
Fall/Winter probability of dispersal	PERT	min = 0.0001	ml = 0.0075	max = 0.03	Griffin and Miller, 1994
Spring probability of dispersal	PERT	min = 0.05	ml = 0.1	max = 0.3	Griffin and Miller, 1994
Proportion of mills that are softwood	Uniform	min = 0.62	max = 0.63		Smith *et al*., 2000
Probability of a mated pair	Probability	$(2^N-2)/2^N$			Caton and Spears, 2005
Fall/Winter probability of colonization	PERT	min = 1.0E-06	ml = 1.0E-05	max = 1.0E-04	Griffin and Miller, 1994
Spring probability of colonization	PERT	min = 1.0E-05	ml = 1.0E-04	max = 1.0E-03	Griffin and Miller, 1994

Appendix 7. Risk model for the bark nugget pathway. Color codes for the pathway models are: green = probability calculation; blue = arithmetic; yellow = parameter and fuchsia = output.

	A	B	C	D	E	F	G	H	I
1	**Bark Pathway Node**	**Fall**	**Winter**	**Total**		**description (in order)**	**P1**	**P2**	**P3**
2				**Spring**	**Annual**	min,ml,max	1193	1197	1201
3	potential infested units by season	907	907	1197		min,ml,max	904	907	910
4	potential infested trees per season	90700	90700	119700		trees per unit	100		
5	bark in the regualted counties	0.412261	0.412261	0.412261		s,n	1465	3554	
6	counties	37392	37392	49348					
7	probability of infestation	0.00611	0.00611	0.00611		s,n	91	1455	
8	infested trees in the regulated counties processed for bark	228	228	302		s,n	8	91	
9	prop of trees that will be sent south	0.356955	0.356955	0.356955		s,n	135	379	
10	infested trees processed for bark sent south	81	81	108			79	777	
11	number of beetles per tree	21	21	1451		mean, SD	21.25	6.3443	
12	probability of overwintering above the cutline	0.103	0.103			mean, SD (Spring2)	1123.33	1131.81	
13	beetles above the cutline	2	2						
14	proportion surviving debarking	0.0714	0.0714	0.0714		β	0.0714		
15	beetles that survive debarking	0	0	104					
16	Probability of beetles sent to an average mulch producer	0.009347	0.009347	0.009347		min,ml,max	0	0.00740741	0.02645
17	beetles at an average mulch producer	0	0	1					
18	probability of dispersal	0.002667	0.002667	0.020833		min/ml/max (Spring)	0.005	0.0175	0.05
19	dispersing beetles at an average mulch producer	0	0	0		min/ml/max (Fall/Winter)	0.001	0.0025	0.005
20	probability of a mated pair	0	0	0					
21	mated pair?	0	0	0					
22	mated dispersing females at an average mulch producer	0	0	0		p(dispersing mated femal	0.5		
23	prob of colonization	2.35E-05	2.35E-05	0.000235		min/ml/max (Spring)	1.00E-05	1.00E-04	1.00E-03
24	colonizing females at an average mulch producer	0	0	0	0	min/ml/max (Fall/Winter)	1.00E-06	1.00E-05	1.00E-04
25	prob of colonization at an average mulch producer	0	0	0	0	p(colonization)	9.9999E-06	9.9999E-06	
26	years until colonization at an average producer	100001	100001	100001	100001				
27	number of mulch producers in the 4 southern states	135	135	135		number of mulch produce	135		
28	mulch producers with colonizations in the south	0	0	0	0				
29	prob of colonization in the south	0	0	0	0	p(colonization)	0.0013	0.004	
30	years until colonization in the south	769	769	769	250				

Appendix 8. Formula table for the bark nugget pathway.

	A	B	C	D	E
1	**Bark Pathway Node**	**Fall**	**Winter**	**Total**	
2				**Spring**	**Annual**
3	potential infested units by season	=ROUND(RiskPert($G$3,$H$3,$I$3),0)	=ROUND(RiskPert($G$3,$H$3,$I$3),0)	=ROUND(RiskPert($G$2,$H$2,$I$2),0)	
4	potential infested trees per season	=B3*$G$4	=C3*$G$4	=D3*$G$4	
5	prob of potential infested trees that will be processed for bark in the regualted counties	=RiskBeta($G$5+1,$H$5-$G$5+1)	=RiskBeta($G$5+1,$H$5-$G$5+1)	=RiskBeta($G$5+1,$H$5-$G$5+1)	
6	potential infested trees processed for bark in the regulated counties	=ROUND(RiskNormal(B4*B5,SQRT(B4*B5*(1-B5)),RiskTruncate(0,)),0)	=ROUND(RiskNormal(C4*C5,SQRT(C4*C5*(1-C5)),RiskTruncate(0,)),0)	=ROUND(RiskNormal(D4*D5,SQRT(D4*D5*(1-D5)),RiskTruncate(0,)),0)	
7	probability of infestation	=(RiskBeta($G$8+1,$H$8-$G$8+1)*RiskBeta($G$7+1,$H$7-$G$7+1))	=(RiskBeta($G$8+1,$H$8-$G$8+1)*RiskBeta($G$7+1,$H$7-$G$7+1))	=(RiskBeta($G$8+1,$H$8-$G$8+1)*RiskBeta($G$7+1,$H$7-$G$7+1))	
8	infested trees in the regulated counties processed for bark	=IF(B6<32000,RiskBinomial(B6,B7,),ROUND(RiskNormal(B6*B7,SQRT(B6*B7*(1-B7)),RiskTruncate(0,)),0))	=IF(C6<32000,RiskBinomial(C6,C7,),ROUND(RiskNormal(C6*C7,SQRT(C6*C7*(1-C7)),RiskTruncate(0,)),0))	=IF(D6<32000,RiskBinomial(D6,D7,),ROUND(RiskNormal(D6*D7,SQRT(D6*D7*(1-D7)),RiskTruncate(0,)),0))	
9	prop of trees that will be sent south	=RiskBeta($G$9+1,$H$9-$G$9+1)	=RiskBeta($G$9+1,$H$9-$G$9+1)	=RiskBeta($G$9+1,$H$9-$G$9+1)	
10	infested trees processed for bark sent south	=RiskBinomial(B8,B9)	=RiskBinomial(C8,C9)	=RiskBinomial(D8,D9)	
11	number of beetles per tree	=ROUND(RiskNormal($G$11,$H$11,RiskTruncate(0,)),0)	=ROUND(RiskNormal($G$11,$H$11,RiskTruncate(0,)),0)	=ROUND(RiskNormal(G12, H12, RiskTruncate(0,)),0)	
12	probability of overwintering above the cutline	=RiskBeta($G$10+1,$H$10-$G$10+1)	=RiskBeta($G$10+1,$H$10-$G$10+1)		
13	beetles above the cutline	=IF(B11=0,0,RiskBinomial(B11,B12))	=IF(C11=0,0,RiskBinomial(C11,C12))		
14	proportion surviving debarking	=RiskExpon($G$14, RiskTruncate(0,))	=RiskExpon($G$14, RiskTruncate(0,))	=RiskExpon($G$14, RiskTruncate(0,))	
15	beetles that survive debarking	=IF(B13=0,0,RiskBinomial(B13,B14))	=IF(C13=0,0,RiskBinomial(C13,C14))	=IF(D11=0,0,RiskBinomial(D11,D14))	
16	Probability of beetles sent to an average mulch producer	=RiskPert($G$16,$H$16,$I$16)	=RiskPert($G$16,$H$16,$I$16)	=RiskPert($G$16,$H$16,$I$16)	
17	beetles at an average mulch producer	=IF(B15=0,0,RiskBinomial(B15,B16))	=IF(C15=0,0,RiskBinomial(C15,C16))	=IF(D15=0,0,RiskBinomial(D15,D16))	
18	probability of dispersal	=RiskPert($G$19,$H$19,$I$19)	=RiskPert($G$19,$H$19,$I$19)	=RiskPert($G$18,$H$18,$I$18)	
19	dispersing beetles at an average mulch producer	=IF(B17=0,0,RiskBinomial(B17,B18))	=IF(C17=0,0,RiskBinomial(C17,C18))	=IF(D17=0,0,RiskBinomial(D17,D18))	
20	probability of a mated pair	=IF(B19>100,1,IF(B19<2,0,(2^B19-2)/2^B19))	=IF(C19>100,1,IF(C19<2,0,(2^C19-2)/2^C19))	=IF(D19>100,1,IF(D19<2,0,(2^D19-2)/2^D19))	
21	mated pair?	=RiskOutput("fall mated pair")+IF(B19=0,0,RiskBinomial(1,B20))	=RiskOutput("winter mated pair")+IF(C19=0,0,RiskBinomial(1,C20))	=RiskOutput("spring mated pair")+IF(D19=0,0,RiskBinomial(1,D20))	
22	mated dispersing females at an average mulch producer	=IF(B21=0,0,RiskBinomial(B19,$G$22))	=IF(C21=0,0,RiskBinomial(C19,$G$22))	=IF(D21=0,0,RiskBinomial(D19,$G$22))	
23	prob of colonization	=RiskPert($G$24,$H$24,$I$24)	0.0000235	=RiskPert($G$23,$H$23,$I$23)	
24	colonizing females at an average mulch producer	=IF(B22=0,0,RiskBinomial(B22,B23))	=IF(C22=0,0,RiskBinomial(C22,C23))	=IF(D22=0,0,RiskBinomial(D22,D23))	=RiskOutput("annual colonizing pairs at an average mulch producer")+B24+C24+D24
25	prob of colonization at an average mulch producer	=RiskOutput("fall prob of colonization at avg producer")+IF(B24>0,1,0)	=RiskOutput("winter prob of colonization at avg producer")+IF(C24>0,1,0)	=RiskOutput("spring prob of colonization at avg producer")+IF(D24>0,1,0)	=RiskOutput("fall prob of colonization at avg producer")+IF(E24>0,1,0)
26	years until colonization at an average producer	=RiskOutput("fall years until colonization at an average mulch producer")+1+RiskNegbin(1,G25)	=RiskOutput("winter years until colonization at an average mulch producer")+1+RiskNegbin(1,H25)	=RiskOutput("spring years until colonization at an average mulch producer")+1+RiskNegbin(1,G25)	=RiskOutput("annual years until colonization at an average mulch producer")+1+RiskNegbin(1,G25)
27	number of mulch producers in the 4 southern states	=$G$27	=$G$27	=$G$27	
28	mulch producers with colonizations in the south	=RiskOutput("fall colonizations")+RiskBinomial(B27,$G$25)	=RiskOutput("fall colonizations")+RiskBinomial(C27,$G$25)	=RiskOutput("fall colonizations")+RiskBinomial(D27,$H$25)	=RiskOutput("annual colnizations in the south")+B28+C28+D28
29	prob of colonization in the south	=RiskOutput("fall prob of colonization")+IF(B28>0,1,0)	=RiskOutput("winter prob of colonization")+IF(C28>0,1,0)	=RiskOutput("spring prob of colonization")+IF(D28>0,1,0)	=RiskOutput("fall prob of colonization")+IF(E28>0,1,0)
30	years until colonization in the south	=RiskOutput("fall years until colonization")+1+RiskNegbin(1,$G$29)	=RiskOutput("winter years until colonization")+1+RiskNegbin(1,$G$29)	=RiskOutput("spring years until colonization")+1+RiskNegbin(1,$G$29)	=RiskOutput("annual years until colonization")+1+RiskNegbin(1,$H$29)

Appendix 9. Risk model for the logs and lumber with bark pathway.

	A	B	C	D	E	F	G	H	I
1	**Logs and Lumber with Bark Pathway Node**	**Fall**	**Winter**	**Spring**	**Total**	**description (in order)**	**P1**	**P2**	**P3**
2						min,ml,max	4803	4805	4807
3	Potential infested units by season	3640	3640	4805		min,ml,max	3639	3640	3642
4	Potential infested trees per season	364000	364000	480500		trees per unit	100		
5	Potential infested trees shipped south	78839	78839	104071		s,n	798	3687	0.33333
6	average mill	0.003	0.003	0.003		mean, SD	0.001988072	0.003180915	
7	Potential infested trees shipped to an average mill	269	269	355					
8	Probability of infestation	0.00611	0.00611	0.00611		*s,n*	91	1455	
9	Number of infested trees shipped to an average mill	2	2	2		s,n	8	91	
10	Total no. of beetles on shipped trees	43	43	2504		mean, SD	21.25	6.3443	
11						mean, SD (Spring2)	1123.33	1131.81	
12	Probability of overwintering above the cut line	0.103	0.103			*s,n*	79	777	
13	Total no. of beetles on trees at an average mill	4	4	2504		(Fall/Winter)	0.0001	0.0075	0.03
14	Probability of dispersal	0.01002	0.01002	0.12500		min/ml/max (Spring)	0.05	0.1	0.3
15	Dispersing beetles at an average mill	0	0	313					
16	Softwood mills within 150 miles			503		Prop softwood mills	0.63000	0.62	0.64
17	Probability of a mated pair	0.000	0.000	1.000		miles	798		
18	Mated pair at mill?	0	0	1					
19	No. of female beetles	0	0	157		p(female)	0.5		
20	Probability of colonization	0.00000	0.00000	0.00024		Fall/Winter	1.00E-06	1.00E-05	1.00E-04
21	No. colonizing females at avg mill	0	0	0		Spring	1.00E-05	1.00E-04	1.00E-03
22	Colonization at avg mill?	0	0	0			fall/winter	spring	
23	Years until colonization at an average mill	100001	100001	27		p(colonization)	9.9999E-06	0.03599	
24	mills w/ colonizing pairs by season	0	0	18	18				
25	probability of colinization	0	0	1	1		0.005	1	
26	years until colinzation in south	200	200	1	1				

Appendix 10. Formula table for the logs and lumber with bark with pathway.

	A	B	C	D	E
1	**Logs and Lumber with Bark Pathway Node**	**Fall**	**Winter**	**Spring**	**Total**
2					
3	Potential infested units by season	=ROUND(RiskPert($G$3,$H$3,$I$3),0)	=ROUND(RiskPert($G$3,$H$3,$I$3),0)	=ROUND(RiskPert($G$2,$H$2,$I$2),0)	
4	Potential infested trees per season	=B3*$G$4	=C3*$G$4	=D3*$G$4	
5	Potential infested trees shipped south	=ROUND(RiskNormal(B4*(RiskBeta($G$5+1,$H$5-$G$5+1)), SQRT(B4*RiskBeta($G$5+1,$H$5-$G$5+1)*(1-RiskBeta($G$5+1,$H$5-$G$5+1))), RiskTruncate(0,)),0)	=ROUND(RiskNormal(C4*(RiskBeta($G$5+1,$H$5-$G$5+1)), SQRT(C4*RiskBeta($G$5+1,$H$5-$G$5+1)*(1-RiskBeta($G$5+1,$H$5-$G$5+1))), RiskTruncate(0,)),0)	=ROUND(RiskNormal(D4*(RiskBeta($G$5+1,$H$5-$G$5+1)), SQRT(D4*RiskBeta($G$5+1,$H$5-$G$5+1)*(1-RiskBeta($G$5+1,$H$5-$G$5+1))), RiskTruncate(0,)),0)	
6	Proportion of potential infested trees shipped to an average mill	=RiskNormal($G$6, $H$6, RiskTruncate(0, 1))	=RiskNormal($G$6, $H$6, RiskTruncate(0, 1))	=RiskNormal($G$6, $H$6, RiskTruncate(0,1))	
7	Potential infested trees shipped to an average mill	=ROUND(B5*B6,0)	=ROUND(C5*C6,0)	=ROUND(D5*D6,0)	
8	Probability of infestation	=(RiskBeta($G$9+1,$H$9-$G$9+1)*RiskBeta($G$8+1,$H$8-$G$8+1))	0.00611	0.00611	
9	Number of infested trees shipped to an average mill	=IF(B7=0,0,RiskBinomial(B7,B8))	=IF(C7=0,0,RiskBinomial(C7,C8))	=IF(D7=0,0,RiskBinomial(D7,D8))	
10	Total no. of beetles on shipped trees	=ROUND(RiskNormal(B9*$G$10, SQRT(B9)*$H$10, RiskTruncate(0,)),0)	=ROUND(RiskNormal(C9*$G$10, SQRT(C9)*$H$10, RiskTruncate(0,)),0)	=RiskOutput("nubmer of beetles at an average mill")+ROUND(RiskNormal(D9*$G$11, SQRT(D9)*$H$11, RiskTruncate(0,)),0)	
11					
12	Probability of overwintering above the cut line	=RiskBeta($G$12+1,$H$12-$G$12+1)	=RiskBeta($G$12+1,$H$12-$G$12+1)		
13	Total no. of beetles on trees at an average mill	=IF(B10<32000,RiskBinomial(B10,B12),ROUND(RiskNormal(B10*B12,SQRT(B10*B12*(1-B12)),RiskTruncate(0,)),0))	=IF(C10<32000,RiskBinomial(C10,C12),ROUND(RiskNormal(C10*C12,SQRT(C10*C12*(1-C12)),RiskTruncate(0,)),0))	=RiskOutput("total number of beetles at an average mill")+ROUND(RiskNormal(D9*$G$11, SQRT(D9)*$H$11, RiskTruncate(0,)),0)	
14	Probability of dispersal	=RiskPert($G$13,$H$13,$I$13)	=RiskPert($G$13,$H$13,$I$13)	=RiskPert($G$14,$H$14,$I$14)	
15	Dispersing beetles at an average mill	=IF(B13<32000,RiskBinomial(B13,B14),ROUND(RiskNormal(B13*B14,SQRT(B13*B14*(1-B14)),RiskTruncate(0,)),0))	=IF(C13<32000,RiskBinomial(C13,C14),ROUND(RiskNormal(C13*C14,SQRT(C13*C14*(1-C14)),RiskTruncate(0,)),0))	=IF(D13<32000,RiskBinomial(D13,D14),ROUND(RiskNormal(D13*D14,SQRT(D13*D14*(1-D14)),RiskTruncate(0,)),0))	
16	Softwood mills within 150 miles			=ROUND(G17*G16,0)	
17	Probability of a mated pair	=IF(B15>100,1,IF(B15<2,0,(2^B15-2)/2^B15))	=IF(C15>100,1,IF(C15<2,0,(2^C15-2)/2^C15))	=IF(D15>100,1,IF(D15<2,0,(2^D15-2)/2^D15))	
18	Mated pair at mill?	=RiskOutput(,$A$18,1) + IF(B15=0,0,RiskBinomial(1,B17))	=RiskOutput(,$A$18,2) + IF(C17=0,0,RiskBinomial(1,C17))	=RiskOutput(,$A$18,3)+IF(D15=0,0,RiskBinomial(1,D17))	
19	No. of female beetles	#VALUE!	=IF(C18=0,0,RiskBinomial(C15,$G$19))	=IF(D18=0,0,RiskBinomial(D15,$G$19))	
20	Probability of colonization	=IF(B17=0,0,RiskPert($G$20,$H$20,$I$20))	=IF(C17=0,0,RiskPert($G$20,$H$20,$I$20))	=RiskPert($G$21,$H$21,$I$21)	
21	No. colonizing females at avg mill	=RiskOutput(,$A$21,1) + IF(B19=0,0,RiskBinomial(B19,B20))	=RiskOutput(,$A$21,2) + IF(C19=0,0,RiskBinomial(C19,C20))	=RiskOutput(,$A$21,3) + IF(D19=0,0,RiskBinomial(D19,D20))	
22	Colonization at avg mill?	=RiskOutput(,$A$22,1) + IF(B21>=1,1,0)	=RiskOutput(,$A$22,2) + IF(C21>=1,1,0)	=RiskOutput(,$A$22,3) + IF(D21>=1,1,0)	
23	Years until colonization at an average mill	=RiskOutput(,$A$23,1) + 1+RiskNegbin(1,$G$23)	100001	=RiskOutput(,$A$23,2) + 1+RiskNegbin(1,$H$23)	
24	mills w/ colonizing pairs by season	=RiskOutput("fall colonizing pairs")+RiskBinomial(D16,G23)	=RiskOutput("winter colonizing pairs")+RiskBinomial(D16,G23)	=RiskOutput("spring colonizations in south")+RiskBinomial(D16,H23)	=RiskOutput("annual colonizing pairs in the south")+B24+C24+D24
25	probability of colinization	=RiskOutput("fall prob of colinzation in south")+IF(B24>=1,1,0)	=RiskOutput("winter prob of colinzation in south")+IF(C24>=1,1,0)	=RiskOutput("spring prob of colonization in south")+IF(D24>=1,1,0)	=RiskOutput("prob of colonization in south")+IF(E24>=1,1,0)
26	years until colinzation in south	=RiskOutput("fall years until colonization in south")+1+RiskNegbin(1,$G$25)	=RiskOutput("fall years until colonization in south")+1+RiskNegbin(1,$G$25)	=RiskOutput("spring years until colonization in south")+1+RiskNegbin(1,$H$25)	=RiskOutput("total years until colonization in south")+1+RiskNegbin(1,$H$25)

Appendix 11. Risk model for the stump pathway.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Stump Pathway Node**	**Overall**	**Fall**	**Winter**	**Spring**				**Parameters/Citation**				
2					**Total**	**March**	**Apr/May**	**description (in order)**	**P1**	**P2**	**P3**	**P4**	**P5**
3	Softwood mills within 150 miles	503						Mills in within 150 miles	495	511			
4	No. of mills receiving stumps	4						p(receiving stumps)	0.007	*s,n*	1	273	
5								min,ml,max	4803	4805	4807		
6	Potential infested units by season		3640	3640	4805			min,ml,max	3639	3640	3642		
7	Potential infested trees per season		364000	364000	480500			trees per unit	100				
8	infested trees shipped south		78839	78839	104071				798	3687			
9	Probability of being shipped south		0.007	0.007	0.007			*s,n*	1	273			
10	Potential infested trees shipped south		573	573	757	252	505	p(MAR not APR/MAY)	0.333				
11	Proportion of potential infested		0.397	0.397	0.397	0.397	0.397	mean, SD	0.250	0.400			
12	Potential infested stumps shipped to		228	228	301	100	201						
13	Probability of infestation		0.00618	0.00618		0.00618	0.00618	*s,n*	8	1455			
14	Number of infested stumps shipped to		1	1	2	1	1						
15	Total no. of beetles on trees		21	21	2902	1451	1451	mean, SD	21.25	6.3443			
16								mean, SD (Spring2)	1123.33	1131.81			
17	Probability of overwintering/feedin		0.897	0.897		0.027	0.027	*s,n*	698	777	stump ht/total ht	0.1	3.75
18	Total no. of beetles at mills		19	19	78	39	39						
19													
20	No. colonizing females (total)		0	0	0	0	0		**Fall**	**Winter**	**Spring**		
21	Colonization at any mill?		0	0	0	0	0				**Total**	**March**	**Apr/May**
22	Years until colonization by		100001	100001	1010	3571	1408	p(seasonal colonization)	0.000010	0.000010	0.000990	0.000280	0.000710
23													
24	Annual colonizing females at mills	0											
25	Any annual colonization?	0											
26	Years until colonization (annual)	1010						p(annual colonization)	0.00099				

Appendix 12. Formula table for the stump pathway.

	A	B	C	D	E	F	G
1	**Stump Pathway Node**	**Overall**	**Fall**	**Winter**	**Spring**		
2					**Total**	**March**	**Apr/May**
3	Softwood mills within 150 miles	=ROUND(RiskUniform(I3,J3),0)					
4	No. of mills receiving stumps	=RiskOutput("No. of mills receiving stumps") + MAX(RiskBinomial(B3, I4, RiskTruncate(0,)),1)					
5							
6	Potential infested units by season		=ROUND(RiskPert($I$6,$J$6,$K$6),0)	=ROUND(RiskPert($I$6,$J$6,$K$6),0)	=ROUND(RiskPert($I$5,$J$5,$K$5),0)		
7	season		=C6*$I$7	=D6*$I$7	=E6*$I$7		
8	infested trees shipped south		=ROUND(RiskNormal(C$7*RiskBeta($I$8+1,$J$8-$I$8+1),SQRT(C7*RiskBeta($I$8+1,$J$8-$I$8+1)*(1-RiskBeta($I$8+1,$J$8-$I$8+1))),RiskTruncate(0,)),0)	=ROUND(RiskNormal(D$7*RiskBeta($I$8+1,$J$8-$I$8+1),SQRT(D7*RiskBeta($I$8+1,$J$8-$I$8+1)*(1-RiskBeta($I$8+1,$J$8-$I$8+1))),RiskTruncate(0,)),0)	=ROUND(RiskNormal(E$7*RiskBeta($I$8+1,$J$8-$I$8+1),SQRT(E7*RiskBeta($I$8+1,$J$8-$I$8+1)*(1-RiskBeta($I$8+1,$J$8-$I$8+1))),RiskTruncate(0,)),0)		
9	Probability of being shipped south		=RiskBeta($I$9+1,$J$9-$I$9+1)	=RiskBeta($I$9+1,$J$9-$I$9+1)	=RiskBeta($I$9+1,$J$9-$I$9+1)		
10	Potential infested trees shipped south		=IF(C8<32000,RiskBinomial(C8,C9),ROUND(RiskNormal(C8*C9,SQRT(C8*C9*(1-C9)),RiskTruncate(0,)),0))	=IF(D8<32000,RiskBinomial(D8,D9),ROUND(RiskNormal(D8*D9,SQRT(D8*D9*(1-D9)),RiskTruncate(0,)),0))	=IF(E8<32000,RiskBinomial(E8,E9),ROUND(RiskNormal(E8*E9,SQRT(E8*E9*(1-E9)),RiskTruncate(0,)),0))	=RiskBinomial(E10,I10)	=E10-F10
11	Proportion of potential infested stumps shipped to mills		=RiskNormal($I$11, $J$11, RiskTruncate(0,1))	=RiskNormal($I$11, $J$11, RiskTruncate(0,1))	=RiskNormal($I$11, $J$11, RiskTruncate(0,1))	=RiskNormal($I$11, $J$11, RiskTruncate(0,1))	=RiskNormal($I$11, $J$11, RiskTruncate(0,1))
12	shipped to mills		=ROUND(C10*C11,0)	=ROUND(D10*D11,0)	=F12+G12	=ROUND(F10*F11,0)	=ROUND(G10*G11,0)
13	Probability of infestation		=RiskBeta($I$13+1,$J$13-$I$13+1)	=RiskBeta($I$13+1,$J$13-$I$13+1)		=RiskBeta($I$13+1,$J$13-$I$13+1)	=RiskBeta($I$13+1,$J$13-$I$13+1)
14	Number of infested stumps shipped to mills		=RiskBinomial(C12,C13)	=RiskBinomial(D12,D13)	=F14+G14	=RiskBinomial(F12,F13)	=RiskBinomial(G12,G13)
15	Total no. of beetles on trees		=IF(C14=0,0,ROUND(RiskNormal(C14*$I$15, SQRT(C14)*$J$15, RiskTruncate(0,)),0))	=IF(D14=0,0,ROUND(RiskNormal(D14*$I$15, SQRT(D14)*$J$15, RiskTruncate(0,)),0))	=F15+G15	=IF(F14=0,0,ROUND(RiskNormal(F14*$I$16, SQRT(F14)*$J$16, RiskTruncate(0,)),0))	=IF(G14=0,0,ROUND(RiskNormal(G14*$I$16, SQRT(G14)*$J$16, RiskTruncate(0,)),0))
16							
17	Probability of overwintering/feeding below the cut line		=RiskBeta($I$17+1,$J$17-$I$17+1)	=RiskBeta($I$17+1,$J$17-$I$17+1)		=$L$17/$M$17	=$L$17/$M$17
18	Total no. of beetles at mills		=RiskBinomial(C15,C17)	=RiskBinomial(D15,D17)	=F18+G18	=ROUND(F15*F17,0)	=ROUND(G15*G17,0)
19							
20	No. colonizing females (total)		=RiskOutput(,$A$20,1) + SUM(calcs!C67:C76)	=RiskOutput(,$A$20,2) + SUM(calcs!D67:D76)	=RiskOutput(,$A$20,3) + F20+G20	=RiskOutput(,$A$20,4) + SUM(calcs!E67:E76)	=RiskOutput(,$A$20,5) + SUM(calcs!F67:F76)
21	Colonization at any mill?		=RiskOutput(,$A$21,1) + IF('stump Pathway'!C20=0,0,1)	=RiskOutput(,$A$21,2) + IF('stump Pathway'!D20=0,0,1)	=RiskOutput(,$A$21,3) + F21+G21	=RiskOutput(,$A$21,4) + IF('stump Pathway'!F20=0,0,1)	=RiskOutput(,$A$21,5) + IF('stump Pathway'!G20=0,0,1)
22	Years until colonization by season		=RiskOutput(,$A$22,1) + 1+RiskNegbin(1,I22)	=RiskOutput(,$A$22,2) + 1+RiskNegbin(1,J22)	=RiskOutput(,$A$22,3) + 1+RiskNegbin(1,K22)	=RiskOutput(,$A$22,4) + 1+RiskNegbin(1,L22)	=RiskOutput(,$A$22,5) + 1+RiskNegbin(1,M22)
23							
24	Annual colonizing females at mills	=RiskOutput("Annual colonizing females at mills") + C20+D20+E20					
25	Any annual colonization?	=RiskOutput("Any annual colonization?") + IF(B24=0,0,1)					
26	Years until colonization (annual)	=RiskOutput("Years until colonization (annual)") + 1+RiskNegbin(1,I26)					

Appendix 13. Risk model for the stump pathway "calcs" spreadsheet .

	A	B	C	D	E	F	G	H	I	J	K
1			Fall	Winter	Spring			Fall	Winter	Spring	
2					March	Apr/May				March	Apr/May
3	Total no. of beetles at mills		19	19	39	39					
4	Number of infested stumps shipped to mills		1	1	1	1	No. potential mills	4			
5	Max no. mills		1	1	1	1	p(at a mill)	0.250			
6	pbase		1.000	1.000	1.000	1.000					
7											
8	no. stumps at mill#	1	1	1	1	1	p(at partic. mill)	1.000	1.000	1.000	1.000
9		2	0	0	0	0		0.000	0.000	0.000	0.000
10		3	0	0	0	0		0.000	0.000	0.000	0.000
11		4	0	0	0	0		0.000	0.000	0.000	0.000
12		5	0	0	0	0		0.000	0.000	0.000	0.000
13		6	0	0	0	0		0.000	0.000	0.000	0.000
14		7	0	0	0	0		0.000	0.000	0.000	0.000
15		8	0	0	0	0		0.000	0.000	0.000	0.000
16		9	0	0	0	0		0.000	0.000	0.000	0.000
17		10	0	0	0	0		0.000	0.000	0.000	0.000
18											
19	No. mills w/ stumps		1	1	1	1					
20											
21	no. beetles at mill#	1	19	19	39	39					
22		2	0	0	0	0					
23		3	0	0	0	0					
24		4	0	0	0	0					
25		5	0	0	0	0					
26		6	0	0	0	0					
27		7	0	0	0	0					
28		8	0	0	0	0					
29		9	0	0	0	0					
30		10	0	0	0	0					
31											
32	mating pair?	1	1	1	1	1	p(mating pair)	1.000	1.000	1.000	1.000
33		2	0	0	0	0		0.000	0.000	0.000	0.000
34		3	0	0	0	0		0.000	0.000	0.000	0.000
35		4	0	0	0	0		0.000	0.000	0.000	0.000
36		5	0	0	0	0		0.000	0.000	0.000	0.000
37		6	0	0	0	0		0.000	0.000	0.000	0.000
38		7	0	0	0	0		0.000	0.000	0.000	0.000
39		8	0	0	0	0		0.000	0.000	0.000	0.000
40		9	0	0	0	0		0.000	0.000	0.000	0.000
41		10	0	0	0	0		0.000	0.000	0.000	0.000
42											
43	Potential dispersing females	1	10	10	20	20	p(female)	0.5			
44		2	0	0	0	0					
45		3	0	0	0	0					
46		4	0	0	0	0					
47		5	0	0	0	0					
48		6	0	0	0	0					
49		7	0	0	0	0					
50		8	0	0	0	0					
51		9	0	0	0	0					
52		10	0	0	0	0					
53	Total potential dispersing females		10	10	20	20					
54											
55	Dispersing females	1	0	0	3	3	p(dispersal)	0.010017	0.010017	0.125000	0.125000
56		2	0	0	0	0		min	ml	max	
57		3	0	0	0	0	Fall	0.00001	0.00005	0.0001	
58		4	0	0	0	0	Winter	0.0001	0.0075	0.03	
59		5	0	0	0	0	Spring	0.05	0.1	0.3	
60		6	0	0	0	0					
61		7	0	0	0	0					
62		8	0	0	0	0					
63		9	0	0	0	0					
64		10	0	0	0	0					
65	Total dispersing females		0	0	3	3					
66											
67	Colonizing females	1	0	0	0	0	p(colonization)	0.000000	0.000000	0.000235	0.000235
68		2	0	0	0	0					
69		3	0	0	0	0	Fall/Winter	0.000001	0.000010	0.000100	
70		4	0	0	0	0	Spring	0.000010	0.000100	0.001000	
71		5	0	0	0	0					
72		6	0	0	0	0					
73		7	0	0	0	0					
74		8	0	0	0	0					

Appendix 14. Formula table for the stump pathway "calcs" spreadsheet.

	A	B	C	D	E	F	G	H	I	J	K
1			Fall	Winter	Spring			Fall	Winter	Spring	
2					March	Apr/May				March	Apr/May
3	Total no. of beetles at mills		=RiskBinomial(C15,C17)	=RiskBinomial(D15,D17)	=ROUND(F15*F17,0)	=ROUND(G15*G17,0)					
4	Number of infested stumps shipped to mills		=RiskBinomial(C12,C13)	=RiskBinomial(D12,D13)	=RiskBinomial(F12,F13)	=RiskBinomial(G12,G13)	No. potential mills	=RiskOutput("No. of mills receiving stumps") + MAX(RiskBinomial(B3, I4, RiskTruncate(0,)),1)			
5	Max no. mills		=MIN($H$4,C4)	=MIN($H$4,D4)	=MIN($H$4,E4)	=MIN($H$4,F4)	p(at a mill)	=1/'stump Pathway'!B4			
6	pbase		=IF(C5=0,0,IF(C5=1,1,$H$5))	=IF(D5=0,0,IF(D5=1,1,$H$5))	=IF(E5=0,0,IF(E5=1,1,$H$5))	=IF(F5=0,0,IF(F5=1,1,$H$5))					
7											
8	no. stumps at mill#	1	=IF(H8=0,0,RiskBinomial(C4,H$8))	=IF(I8=0,0,RiskBinomial(D4,I$8))	=IF(J8=0,0,RiskBinomial(E4,J$8))	=IF(K8=0,0,RiskBinomial(F4,K$8))	p(at partic. mill)	=IF(C5=0,0,IF(C5=1,1,$H$5))	=IF(D5=0,0,IF(D5=1,1,$H$5))	=IF(E5=0,0,IF(E5=1,1,$H$5))	=IF(F5=0,0,IF(F5=1,1,$H$5))
9		2	=IF(H9=0,0,IF(C$4-SUM(C$8:C8)=1,1,RiskBinomial(C$4-SUM(C$8:C8),H9)))	=IF(I9=0,0,IF(D$4-SUM(D$8:D8)=1,1,RiskBinomial(D$4-SUM(D$8:D8),I9)))	=IF(J9=0,0,IF(E$4-SUM(E$8:E8)=1,1,RiskBinomial(E$4-SUM(E$8:E8),J9)))	=IF(K9=0,0,IF(F$4-SUM(F$8:F8)=1,1,RiskBinomial(F$4-SUM(F$8:F8),K9)))		=IF(C$5=0,0,IF(SUM(C$8:C8)=C$4,0,1/($H$4-$B8)))	=IF(D$5=0,0,IF(SUM(D$8:D8)=D$4,0,1/($H$4-	=IF(E$5=0,0,IF(SUM(E$8:E8)=E$4,0,1/($H$4-$B8)))	=IF(F$5=0,0,IF(SUM(F$8:F8)=F$4,0,1/($H$4-$B8)))
10		3	=IF(H10=0,0,IF(C$4-SUM(C$8:C9)=1,1,RiskBinomial(C$4-SUM(C$8:C9),H10)))	=IF(I10=0,0,IF(D$4-SUM(D$8:D9)=1,1,RiskBinomial(D$4-SUM(D$8:D9),I10)))	=IF(J10=0,0,IF(E$4-SUM(E$8:E9)=1,1,RiskBinomial(E$4-SUM(E$8:E9),J10)))	=IF(K10=0,0,IF(F$4-SUM(F$8:F9)=1,1,RiskBinomial(F$4-SUM(F$8:F9),K10)))		=IF(C$5=0,0,IF(SUM(C$8:C9)=C$4,0,1/($H$4-$B9)))	,IF(SUM(D$8:D9)=D$4,0,1/($H$4-$B9)))	=IF(E$5=0,0,IF(SUM(E$8:E9)=E$4,0,1/($H$4-$B9)))	=IF(F$5=0,0,IF(SUM(F$8:F9)=F$4,0,1/($H$4-$B9)))
11		4	=IF(H11=0,0,IF(C$4-SUM(C$8:C10)=1,1,RiskBinomial(C$4-SUM(C$8:C10),H11)))	=IF(I11=0,0,IF(D$4-SUM(D$8:D10)=1,1,RiskBinomial(D$4-SUM(D$8:D10),I11)))	=IF(J11=0,0,IF(E$4-SUM(E$8:E10)=1,1,RiskBinomial(E$4-SUM(E$8:E10),J11)))	=IF(K11=0,0,IF(F$4-SUM(F$8:F10)=1,1,RiskBinomial(F$4-SUM(F$8:F10),K11)))		=IF(C$5=0,0,IF(SUM(C$8:C10)=C$4,0,1/($H$4-$B10)))	=IF(D$5=0,0,IF(SUM(D$8:D10)=D$4,0,1/($H$4-$B10)))	=IF(E$5=0,0,IF(SUM(E$8:E10)=E$4,0,1/($H$4-$B10)))	=IF(F$5=0,0,IF(SUM(F$8:F10)=F$4,0,1/($H4B10)))
12		5	=IF(H12=0,0,IF(C$4-SUM(C$8:C11)=1,1,RiskBinomial(C$4-SUM(C$8:C11),H12)))	SUM(D$8:D11)=1,1,RiskBinomial(D$4-SUM(D$8:D11),I12)))	=IF(J12=0,0,IF(E$4-SUM(E$8:E11)=1,1,RiskBinomial(E$4-SUM(E$8:E11),J12)))	=IF(K12=0,0,IF(F$4-SUM(F$8:F11)=1,1,RiskBinomial(F$4-SUM(F$8:F11),K12)))		=IF(C$5=0,0,IF(SUM(C$8:C11)=C$4,0,1/($H$4-$B11)))	,IF(SUM(D$8:D11)=D$4,0,1/($H$4-$B11)))	=IF(E$5=0,0,IF(SUM(E$8:E11)=E$4,0,1/($H$4-$B11)))	=IF(F$5=0,0,IF(SUM(F$8:F11)=F$4,0,1/($H4B11)))
13		6	=IF(H13=0,0,IF(C$4-SUM(C$8:C12)=1,1,RiskBinomial(C$4-SUM(C$8:C12),H13)))	=IF(I13=0,0,IF(D$4-SUM(D$8:D12)=1,1,RiskBinomial(D$4-SUM(D$8:D12),I13)))	=IF(J13=0,0,IF(E$4-SUM(E$8:E12)=1,1,RiskBinomial(E$4-SUM(E$8:E12),J13)))	=IF(K13=0,0,IF(F$4-SUM(F$8:F12)=1,1,RiskBinomial(F$4-SUM(F$8:F12),K13)))		=IF(C$5=0,0,IF(SUM(C$8:C12)=C$4,0,1/($H$4-$B12)))	=IF(D$5=0,0,IF(SUM(D$8:D12)=D$4,0,1/($H$4-$B12)))	=IF(E$5=0,0,IF(SUM(E$8:E12)=E$4,0,1/($H$4-$B12)))	=IF(F$5=0,0,IF(SUM(F$8:F12)=F$4,0,1/($H4B12)))
14		7	=IF(H14=0,0,IF(C$4-SUM(C$8:C13)=1,1,RiskBinomial(C$4-SUM(C$8:C13),H14)))	=IF(I14=0,0,IF(D$4-SUM(D$8:D13)=1,1,RiskBinomial(D$4-SUM(D$8:D13),I14)))	=IF(J14=0,0,IF(E$4-SUM(E$8:E13)=1,1,RiskBinomial(E$4-SUM(E$8:E13),J14)))	=IF(K14=0,0,IF(F$4-SUM(F$8:F13)=1,1,RiskBinomial(F$4-SUM(F$8:F13),K14)))		=IF(C$5=0,0,IF(SUM(C$8:C13)=C$4,0,1/($H$4-$B13)))	=IF(D$5=0,0,IF(SUM(D$8:D13)=D$4,0,1/($H$4-$B13)))	=IF(E$5=0,0,IF(SUM(E$8:E13)=E$4,0,1/($H$4-$B13)))	=IF(F$5=0,0,IF(SUM(F$8:F13)=F$4,0,1/($H4B13)))
15		8	=IF(H15=0,0,IF(C$4-SUM(C$8:C14)=1,1,RiskBinomial(C$4-SUM(C$8:C14),H15)))	SUM(D$8:D14)=1,1,RiskBinomial(D$4-SUM(D$8:D14),I15)))	=IF(J15=0,0,IF(E$4-SUM(E$8:E14)=1,1,RiskBinomial(E$4-SUM(E$8:E14),J15)))	=IF(K15=0,0,IF(F$4-SUM(F$8:F14)=1,1,RiskBinomial(F$4-SUM(F$8:F14),K15)))		=IF(C$5=0,0,IF(SUM(C$8:C14)=C$4,0,1/($H$4-$B14)))	,IF(SUM(D$8:D14)=D$4,0,1/($H$4-$B14)))	=IF(E$5=0,0,IF(SUM(E$8:E14)=E$4,0,1/($H$4-$B14)))	=IF(F$5=0,0,IF(SUM(F$8:F14)=F$4,0,1/($H4B14)))
16		9	=IF(H16=0,0,IF(C$4-SUM(C$8:C15)=1,1,RiskBinomial(C$4-SUM(C$8:C15),H16)))	=IF(I16=0,0,IF(D$4-SUM(D$8:D15)=1,1,RiskBinomial(D$4-SUM(D$8:D15),I16)))	=IF(J16=0,0,IF(E$4-SUM(E$8:E15)=1,1,RiskBinomial(E$4-SUM(E$8:E15),J16)))	=IF(K16=0,0,IF(F$4-SUM(F$8:F15)=1,1,RiskBinomial(F$4-SUM(F$8:F15),K16)))		=IF(C$5=0,0,IF(SUM(C$8:C15)=C$4,0,1/($H$4-$B15)))	=IF(D$5=0,0,IF(SUM(D$8:D15)=D$4,0,1/($H$4-$B15)))	=IF(E$5=0,0,IF(SUM(E$8:E15)=E$4,0,1/($H$4-$B15)))	=IF(F$5=0,0,IF(SUM(F$8:F15)=F$4,0,1/($H4B15)))
17		10	=IF(H17=0,0,C4-SUM(C8:C16))	=IF(I17=0,0,D4-SUM(D8:D16))	=IF(J17=0,0,E4-SUM(E8:E16))	=IF(K17=0,0,F4-SUM(F8:F16))		=IF(C$5=0,0,IF(SUM(C$8:C16)=C$4,0,1/($H$4-$B16)))	,IF(SUM(D$8:D16)=D$4,0,1/($H$4-	F(SUM(E$8:E16)=E$4,0,1/($H$4-$B16)))	(SUM(F$8:F16)=F$4,0,1/(H4$B16)))
18											
19	No. mills w/ stumps		=COUNTIF(C8:C17,">0")	=COUNTIF(D8:D17,">0")	=COUNTIF(E8:E17,">0")	=COUNTIF(F8:F17,">0")					

	A	B	C	D	E	F	G	H	I	J	K
20											
21	no. beetles at mill#	1	=IF(C8=0,0,RiskBinomial(C$3,C8/C$4))	=IF(D8=0,0,RiskBinomial(D$3,D8/D$4))	=IF(E8=0,0,RiskBinomial(E$3,E8/E$4))	=IF(F8=0,0,RiskBinomial(F$3,F8/F$4))					
22		2	=IF(C9=0,0,IF(SUM(C$21:C21)=C$3,0,RiskBinomial(C$3-SUM(C$21:C21),C9/(C$4-SUM(C$8:C8)))))	D$21:D21)=D$3,0,RiskBinomial(D$3-SUM(D$21:D21),D9/(D$4-SUM(D$8:D8)))))	=IF(E9=0,0,IF(SUM(E$21:E21)=E$3,0,RiskBinomial(E$3-SUM(E$21:E21),E9/(E$4-SUM(E$8:E8)))))	=IF(F9=0,0,IF(SUM(F$21:F21)=F$3,0,RiskBinomial(F$3-SUM(F$21:F21),F9/(F$4-SUM(F$8:F8)))))					
23		3	=IF(C10=0,0,IF(SUM(C$21:C22)=C$3,0,RiskBinomial(C$3-SUM(C$21:C22),C10/(C$4-SUM(C$8:C9)))))	=IF(D10=0,0,IF(SUM(D$21:D22)=D$3,0,RiskBinomial(D$3-SUM(D$21:D22),D10/(D$4-SUM(D$8:D9)))))	=IF(E10=0,0,IF(SUM(E$21:E22)=E$3,0,RiskBinomial(E$3-SUM(E$21:E22),E10/(E$4-SUM(E$8:E9)))))	=IF(F10=0,0,IF(SUM(F$21:F22)=F$3,0,RiskBinomial(F$3-SUM(F$21:F22),F10/(F$4-SUM(F$8:F9)))))					
24		4	=IF(C11=0,0,IF(SUM(C$21:C23)=C$3,0,RiskBinomial(C$3-SUM(C$21:C23),C11/(C$4-SUM(C$8:C10)))))	=IF(D11=0,0,IF(SUM(D$21:D23)=D$3,0,RiskBinomial(D$3-SUM(D$21:D23),D11/(D$4-SUM(D$8:D10)))))	=IF(E11=0,0,IF(SUM(E$21:E23)=E$3,0,RiskBinomial(E$3-SUM(E$21:E23),E11/(E$4-SUM(E$8:E10)))))	=IF(F11=0,0,IF(SUM(F$21:F23)=F$3,0,RiskBinomial(F$3-SUM(F$21:F23),F11/(F$4-SUM(F$8:F10)))))					
25		5	=IF(C12=0,0,IF(SUM(C$21:C24)=C$3,0,RiskBinomial(C$3-SUM(C$21:C24),C12/(C$4-SUM(C$8:C11)))))	=IF(D12=0,0,IF(SUM(D$21:D24)=D$3,0,RiskBinomial(D$3-SUM(D$21:D24),D12/(D$4-SUM(D$8:D11)))))	=IF(E12=0,0,IF(SUM(E$21:E24)=E$3,0,RiskBinomial(E$3-SUM(E$21:E24),E12/(E$4-SUM(E$8:E11)))))	=IF(F12=0,0,IF(SUM(F$21:F24)=F$3,0,RiskBinomial(F$3-SUM(F$21:F24),F12/(F$4-SUM(F$8:F11)))))					
26		6	=IF(C13=0,0,IF(SUM(C$21:C25)=C$3,0,RiskBinomial(C$3-SUM(C$21:C25),C13/(C$4-SUM(C$8:C12)))))	=IF(D13=0,0,IF(SUM(D$21:D25)=D$3,0,RiskBinomial(D$3-SUM(D$21:D25),D13/(D$4-	=IF(E13=0,0,IF(SUM(E$21:E25)=E$3,0,RiskBinomial(E$3-SUM(E$21:E25),E13/(E$4-SUM(E$8:E12)))))	=IF(F13=0,0,IF(SUM(F$21:F25)=F$3,0,RiskBinomial(F$3-SUM(F$21:F25),F13/(F$4-					
27		7	=IF(C14=0,0,IF(SUM(C$21:C26)=C$3,0,RiskBinomial(C$3-SUM(C$21:C26),C14/(C$4-SUM(C$8:C13)))))	M(D$21:D26)=D$3,0,RiskBinomial(D$3-SUM(D$21:D26),D14/(D$4-SUM(D$8:D13)))))	=IF(E14=0,0,IF(SUM(E$21:E26)=E$3,0,RiskBinomial(E$3-SUM(E$21:E26),E14/(E$4-SUM(E$8:E13)))))	F$21:F26)=F$3,0,RiskBinomial(F$3-SUM(F$21:F26),F14/(F$4-SUM(F$8:F13)))))					
28		8	=IF(C15=0,0,IF(SUM(C$21:C27)=C$3,0,RiskBinomial(C$3-SUM(C$21:C27),C15/(C$4-SUM(C$8:C14)))))	=IF(D15=0,0,IF(SUM(D$21:D27)=D$3,0,RiskBinomial(D$3-SUM(D$21:D27),D15/(D$4-SUM(D$8:D14)))))	=IF(E15=0,0,IF(SUM(E$21:E27)=E$3,0,RiskBinomial(E$3-SUM(E$21:E27),E15/(E$4-SUM(E$8:E14)))))	=IF(F15=0,0,IF(SUM(F$21:F27)=F$3,0,RiskBinomial(F$3-SUM(F$21:F27),F15/(F$4-SUM(F$8:F14)))))					
29		9	=IF(C16=0,0,IF(SUM(C$21:C28)=C$3,0,RiskBinomial(C$3-SUM(C$21:C28),C16/(C$4-SUM(C$8:C15)))))	=IF(D16=0,0,IF(SUM(D$21:D28)=D$3,0,RiskBinomial(D$3-SUM(D$21:D28),D16/(D$4-SUM(D$8:D15)))))	=IF(E16=0,0,IF(SUM(E$21:E28)=E$3,0,RiskBinomial(E$3-SUM(E$21:E28),E16/(E$4-SUM(E$8:E15)))))	=IF(F16=0,0,IF(SUM(F$21:F28)=F$3,0,RiskBinomial(F$3-SUM(F$21:F28),F16/(F$4-SUM(F$8:F15)))))					
30		10	=IF(C17=0,0,IF(SUM(C$21:C29)=C$3,0,RiskBinomial(C$3-SUM(C$21:C29),C17/(C$4-SUM(C$8:C16)))))	=IF(D17=0,0,IF(SUM(D$21:D29)=D$3,0,RiskBinomial(D$3-SUM(D$21:D29),D17/(D$4-SUM(D$8:D16)))))	=IF(E17=0,0,IF(SUM(E$21:E29)=E$3,0,RiskBinomial(E$3-SUM(E$21:E29),E17/(E$4-SUM(E$8:E16)))))	=IF(F17=0,0,IF(SUM(F$21:F29)=F$3,0,RiskBinomial(F$3-SUM(F$21:F29),F17/(F$4-SUM(F$8:F16)))))					

	A	B	C	D	E	F	G	H	I	J	K
32	mating pair?	1	=IF(C21=0,0,RiskBinomial(1,H32))	=IF(D21=0,0,RiskBinomial(1,I32))	=IF(E21=0,0,RiskBinomial(1,J32))	=IF(F21=0,0,RiskBinomial(1,K32))	p(mating pair)	=IF(C21>100,1,IF(C21<2,0,(2^C21-2)/2^C21))	=IF(D21>100,1,IF(D21<2,0,(2^D21-2)/2^D21))	=IF(E21>100,1,IF(E21<2,0,(2^E21-2)/2^E21))	=IF(F21>100,1,IF(F21<2,0,(2^F21-2)/2^F21))
33		2	=IF(C22=0,0,RiskBinomial(1,H33))	=IF(D22=0,0,RiskBinomial(1,I33))	=IF(E22=0,0,RiskBinomial(1,J33))	=IF(F22=0,0,RiskBinomial(1,K33))		=IF(C22>100,1,IF(C22<2,0,(2^C22-2)/2^C22))	=IF(D22>100,1,IF(D22<2,0,(2^D22-2)/2^D22))	=IF(E22>100,1,IF(E22<2,0,(2^E22-2)/2^E22))	1.000
34		3	=IF(C23=0,0,RiskBinomial(1,H34))	=IF(D23=0,0,RiskBinomial(1,I34))	=IF(E23=0,0,RiskBinomial(1,J34))	=IF(F23=0,0,RiskBinomial(1,K34))		=IF(C23>100,1,IF(C23<2,0,(2^C23-2)/2^C23))	0,1,IF(D23<2,0,(2^D23-2)/2^D23))	1,IF(E23<2,0,(2^E23-2)/2^E23))	=IF(F23>100,1,IF(F23<2,0,(2^F23-2)/2^F23))
35		4	=IF(C24=0,0,RiskBinomial(1,H35))	=IF(D24=0,0,RiskBinomial(1,I35))	=IF(E24=0,0,RiskBinomial(1,J35))	=IF(F24=0,0,RiskBinomial(1,K35))		=IF(C24>100,1,IF(C24<2,0,(2^C24-2)/2^C24))	=IF(D24>100,1,IF(D24<2,0,(2^D24-	=IF(E24>100,1,IF(E24<2,0,(2^E24-	=IF(F24>100,1,IF(F24<2,0,(2^F24-2)/2^F24))
36		5	=IF(C25=0,0,RiskBinomial(1,H36))	=IF(D25=0,0,RiskBinomial(1,I36))	=IF(E25=0,0,RiskBinomial(1,J36))	=IF(F25=0,0,RiskBinomial(1,K36))		=IF(C25>100,1,IF(C25<2,0,(2^C25-	=IF(D25>100,1,IF(D25<	=IF(E25>100,1,IF(E25<2,0,	=IF(F25>100,1,IF(F25<2,0,(2^
37		6	=IF(C26=0,0,RiskBinomial(1,H37))	=IF(D26=0,0,RiskBinomial(1,I37))	=IF(E26=0,0,RiskBinomial(1,J37))	=IF(F26=0,0,RiskBinomial(1,K37))		6<2,0,(2^C26-2)/2^C26))	0,1,IF(D26<2,0,(2^D26-	1,IF(E26<2,0,(2^E26-	IF(F26<2,0,(2^F26-2)/2^F26))
38		7	=IF(C27=0,0,RiskBinomial(1,H38))	=IF(D27=0,0,RiskBinomial(1,I38))	=IF(E27=0,0,RiskBinomial(1,J38))	=IF(F27=0,0,RiskBinomial(1,K38))		7<2,0,(2^C27-2)/2^C27))	0,1,IF(D27<2,0,(2^D27-	1,IF(E27<2,0,(2^E27-	IF(F27<2,0,(2^F27-2)/2^F27))
39		8	=IF(C28=0,0,RiskBinomial(1,H39))	=IF(D28=0,0,RiskBinomial(1,I39))	=IF(E28=0,0,RiskBinomial(1,J39))	=IF(F28=0,0,RiskBinomial(1,K39))		=IF(C28>100,1,IF(C28<2,0,(2^C28-	=IF(D28>100,1,IF(D28<	=IF(E28>100,1,IF(E28<2,0,	=IF(F28>100,1,IF(F28<2,0,(2^
40		9	=IF(C29=0,0,RiskBinomial(1,H40))	=IF(D29=0,0,RiskBinomial(1,I40))	=IF(E29=0,0,RiskBinomial(1,J40))	=IF(F29=0,0,RiskBinomial(1,K40))		9<2,0,(2^C29-2)/2^C29))	0,1,IF(D29<2,0,(2^D29-	1,IF(E29<2,0,(2^E29-	IF(F29<2,0,(2^F29-2)/2^F29))
41		10	=IF(C30=0,0,RiskBinomial(1,H41))	=IF(D30=0,0,RiskBinomial(1,I41))	=IF(E30=0,0,RiskBinomial(1,J41))	=IF(F30=0,0,RiskBinomial(1,K41))		0<2,0,(2^C30-2)/2^C30))	0,1,IF(D30<2,0,(2^D30-	1,IF(E30<2,0,(2^E30-	IF(F30<2,0,(2^F30-2)/2^F30))
42											
43	dispersing females	1	=IF(C32=0,0,RiskBinomial(C21,$H$43))	=IF(D32=0,0,RiskBinomial(D21,$H$43))	=IF(E32=0,0,RiskBinomial(E21,$H$43))	=IF(F32=0,0,RiskBinomial(F21,$H$43))	p(female)	0.5			
44		2	=IF(C33=0,0,RiskBinomial(C22,$H$43))	=IF(D33=0,0,RiskBinomial(D22,$H$43))	=IF(E33=0,0,RiskBinomial(E22,$H$43))	=IF(F33=0,0,RiskBinomial(F22,$H$43))					
45		3	=IF(C34=0,0,RiskBinomial(C23,$H$43))	=IF(D34=0,0,RiskBinomial(D23,$H$43))	=IF(E34=0,0,RiskBinomial(E23,$H$43))	=IF(F34=0,0,RiskBinomial(F23,$H$43))					
46		4	=IF(C35=0,0,RiskBinomial(C24,$H$43))	=IF(D35=0,0,RiskBinomial(D24,$H$43))	=IF(E35=0,0,RiskBinomial(E24,$H$43))	=IF(F35=0,0,RiskBinomial(F24,$H$43))					
47		5	=IF(C36=0,0,RiskBinomial(C25,$H$43))	=IF(D36=0,0,RiskBinomial(D25,$H$43))	=IF(E36=0,0,RiskBinomial(E25,$H$43))	=IF(F36=0,0,RiskBinomial(F25,$H$43))					
48		6	=IF(C37=0,0,RiskBinomial(C26,$H$43))	=IF(D37=0,0,RiskBinomial(D26,$H$43))	=IF(E37=0,0,RiskBinomial(E26,$H$43))	'=IF(F37=0,0,RiskBinomial(F26,$H$43))					
49		7	=IF(C38=0,0,RiskBinomial(C27,$H$43))	=IF(D38=0,0,RiskBinomial(D27,$H$43))	=IF(E38=0,0,RiskBinomial(E27,$H$43))	=IF(F38=0,0,RiskBinomial(F27,$H$43))					
50		8	=IF(C39=0,0,RiskBinomial(C28,$H$43))	=IF(D39=0,0,RiskBinomial(D28,$H$43))	=IF(E39=0,0,RiskBinomial(E28,$H$43))	=IF(F39=0,0,RiskBinomial(F28,$H$43))					
51		9	=IF(C40=0,0,RiskBinomial(C29,$H$43))	=IF(D40=0,0,RiskBinomial(D29,$H$43))	=IF(E40=0,0,RiskBinomial(E29,$H$43))	=IF(F40=0,0,RiskBinomial(F29,$H$43))					
52		10	=IF(C41=0,0,RiskBinomial(C30,$H$43))	=IF(D41=0,0,RiskBinomial(D30,$H$43))	'=IF(E41=0,0,RiskBinomial(E30,$H$43))	=IF(F41=0,0,RiskBinomial(F30,$H$43))					
53	Total potential dispersing females		=RiskOutput(,$A$53,1) + SUM(C43:C52)	=RiskOutput(,$A$53,2) + SUM(D43:D52)	=RiskOutput(,$A$53,3) + SUM(E43:E52)	=RiskOutput(,$A$53,4) + SUM(F43:F52)					

	A	B	C	D	E	F	G	H	I	J	K
55	Dispersing females	1	=IF(C43=0,0,RiskBinomial(C43,H$55))	=IF(D43=0,0,RiskBinomial(D43,I$55))	=IF(E43=0,0,RiskBinomial(E43,J$55))	=IF(F43=0,0,RiskBinomial(F43,K$55))	p(dispersal)	=IF(SUM(C43:C52)=0,0,RiskPert($H$58,$I$58,$J$58))	3:D52)=0,0,RiskPert($H$58,$I$58,$J$58))	=IF(SUM(E43:E52)=0,0,RiskPert($H$59,$I$59,$J$59))	=IF(SUM(F43:F52)=0,0,RiskPert($H$59,$I$59,$J$59))
56		2	=IF(C44=0,0,RiskBinomial(C44,H$55))	=IF(D44=0,0,RiskBinomial(D44,I$55))	=IF(E44=0,0,RiskBinomial(E44,J$55))	=IF(F44=0,0,RiskBinomial(F44,K$55))		min	ml	max	
57		3	=IF(C45=0,0,RiskBinomial(C45,H$55))	=IF(D45=0,0,RiskBinomial(D45,I$55))	=IF(E45=0,0,RiskBinomial(E45,J$55))	=IF(F45=0,0,RiskBinomial(F45,K$55))	Fall	0.00001	0.00005	0.0001	
58		4	=IF(C46=0,0,RiskBinomial(C46,H$55))	=IF(D46=0,0,RiskBinomial(D46,I$55))	=IF(E46=0,0,RiskBinomial(E46,J$55))	=IF(F46=0,0,RiskBinomial(F46,K$55))	Winter	0.0001	0.0075	0.03	
59		5	=IF(C47=0,0,RiskBinomial(C47,H$55))	=IF(D47=0,0,RiskBinomial(D47,I$55))	=IF(E47=0,0,RiskBinomial(E47,J$55))	=IF(F47=0,0,RiskBinomial(F47,K$55))	Spring	0.05	0.1	0.3	
60		6	=IF(C48=0,0,RiskBinomial(C48,H$55))	=IF(D48=0,0,RiskBinomial(D48,I$55))	=IF(E48=0,0,RiskBinomial(E48,J$55))	=IF(F48=0,0,RiskBinomial(F48,K$55))					
61		7	=IF(C49=0,0,RiskBinomial(C49,H$55))	=IF(D49=0,0,RiskBinomial(D49,I$55))	=IF(E49=0,0,RiskBinomial(E49,J$55))	=IF(F49=0,0,RiskBinomial(F49,K$55))					
62		8	=IF(C50=0,0,RiskBinomial(C50,H$55))	=IF(D50=0,0,RiskBinomial(D50,I$55))	=IF(E50=0,0,RiskBinomial(E50,J$55))	=IF(F50=0,0,RiskBinomial(F50,K$55))					
63		9	=IF(C51=0,0,RiskBinomial(C51,H$55))	=IF(D51=0,0,RiskBinomial(D51,I$55))	=IF(E51=0,0,RiskBinomial(E51,J$55))	=IF(F51=0,0,RiskBinomial(F51,K$55))					
64		10	=IF(C52=0,0,RiskBinomial(C52,H$55))	=IF(D52=0,0,RiskBinomial(D52,I$55))	=IF(E52=0,0,RiskBinomial(E52,J$55))	=IF(F52=0,0,RiskBinomial(F52,K$55))					
65	Total dispersing females		=RiskOutput(,$A$65,1) + SUM(C55:C64)	=RiskOutput(,$A$65,2) + SUM(D55:D64)	=RiskOutput(,$A$65,3) + SUM(E55:E64)	=RiskOutput(,$A$65,4) + SUM(F55:F64)					
66											
67	Colonizing females	1	=IF(C55=0,0,RiskBinomial(C55,H$67))	=IF(D55=0,0,RiskBinomial(D55,I$67))	=IF(E55=0,0,RiskBinomial(E55,J$67))	=IF(F55=0,0,RiskBinomial(F55,K$67))	p(colonization)	=IF(SUM(C55:C64)=0,0,RiskPert($H$69,$I$69,$J$69))	5:D64)=0,0,RiskPert($H$69,$I$69,$J$69))	=IF(SUM(E55:E64)=0,0,RiskPert($H$70,$I$70,$J$70))	=IF(SUM(F55:F64)=0,0,RiskPert($H$70,$I$70,$J$70))
68		2	=IF(C56=0,0,RiskBinomial(C56,H$67))	=IF(D56=0,0,RiskBinomial(D56,I$67))	=IF(E56=0,0,RiskBinomial(E56,J$67))	=IF(F56=0,0,RiskBinomial(F56,K$67))					
69		3	=IF(C57=0,0,RiskBinomial(C57,H$67))	=IF(D57=0,0,RiskBinomial(D57,I$67))	=IF(E57=0,0,RiskBinomial(E57,J$67))	=IF(F57=0,0,RiskBinomial(F57,K$67))	Fall/Winter	0.000001	0.000010	0.000100	
70		4	=IF(C58=0,0,RiskBinomial(C58,H$67))	=IF(D58=0,0,RiskBinomial(D58,I$67))	=IF(E58=0,0,RiskBinomial(E58,J$67))	=IF(F58=0,0,RiskBinomial(F58,K$67))	Spring	0.000010	0.000100	0.001000	
71		5	=IF(C59=0,0,RiskBinomial(C59,H$67))	=IF(D59=0,0,RiskBinomial(D59,I$67))	=IF(E59=0,0,RiskBinomial(E59,J$67))	=IF(F59=0,0,RiskBinomial(F59,K$67))					
72		6	=IF(C60=0,0,RiskBinomial(C60,H$67))	=IF(D60=0,0,RiskBinomial(D60,I$67))	=IF(E60=0,0,RiskBinomial(E60,J$67))	=IF(F60=0,0,RiskBinomial(F60,K$67))					
73		7	=IF(C61=0,0,RiskBinomial(C61,H$67))	=IF(D61=0,0,RiskBinomial(D61,I$67))	=IF(E61=0,0,RiskBinomial(E61,J$67))	=IF(F61=0,0,RiskBinomial(F61,K$67))					
74		8	=IF(C62=0,0,RiskBinomial(C62,H$67))	=IF(D62=0,0,RiskBinomial(D62,I$67))	=IF(E62=0,0,RiskBinomial(E62,J$67))	=IF(F62=0,0,RiskBinomial(F62,K$67))					
75		9	=IF(C63=0,0,RiskBinomial(C63,H$67))	=IF(D63=0,0,RiskBinomial(D63,I$67))	=IF(E63=0,0,RiskBinomial(E63,J$67))	=IF(F63=0,0,RiskBinomial(F63,K$67))					
76		10	=IF(C64=0,0,RiskBinomial(C64,H$67))	=IF(D64=0,0,RiskBinomial(D64,I$67))	=IF(E64=0,0,RiskBinomial(E64,J$67))	=IF(F64=0,0,RiskBinomial(F64,K$67))					
77	Total colonizing females		=SUM(C67:C76)	=SUM(D67:D76)	=SUM(E67:E76)	=SUM(F67:F76)					
78	Any colonizing female?		=IF(C77>0,1,0)	=IF(D77>0,1,0)	=IF(E77>0,1,0)	=IF(F77>0,1,0)					

Appendix 15. Risk model for combining the stump and logs and lumber with bark pathways.

	A	B	C	D	E	F	G	H
28	stump and timber colonizations	0	0	18	18			
29	colonization at mills?	0	0	1	1		0.005	1
30	Years until colonization in south	200	200	1	1			

Appendix 16. Formula table for combining the stump and logs and lumber with bark pathways.

	A	B	C	D	E
28	stump and timber colonizations	=RiskOutput("stump/timber fall colinzations")+B24+'stump Pathway'!C20	=RiskOutput("stump/timber winter colinzations")+C24+'stump Pathway'!D20	=RiskOutput("stump/timber spring colonizations")+D24+'stump Pathway'!E20	=RiskOutput("annual south colonizing pairs")+B28+C28+D28
29	colonization at mills?	=RiskOutput("fall prob colonization at avg mill")+IF(B28>=1,1,0)	=RiskOutput("winter prob colonization at avg mill")+IF(C28>=1,1,0)	=RiskOutput("spring prob colonization at avg mill")+IF(D28>=1,1,0)	=RiskOutput("spring prob colonization at avg mill")+IF(E28>=1,1,0)
30	Years until colonization in south	=RiskOutput("fall years until colonziation at avg mill")+1+RiskNegbin(1,$G$29)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$G$29)	'=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$H$29)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$H $29)

Appendix 17. Risk model for combining the bark nugget, stump and logs and lumber with bark pathways.

	A	B	C	D	E	F	G	H
32	stump, timber and bark colonizations	0	0	18	18			
33	colonization at mills?	0	0	1	1		0.006	1
34	Years until colonization in south	166	166	1	1			

Appendix 18. Formula table for combining the bark nugget, stump and logs and lumber with bark pathways.

	A	B	C	D	E
32	stump, timber and bark colonizations	=RiskOutput("stump/timber fall colinzations")+$B$24+'stump Pathway'!$C$20+'bark pathway'!$B$28	=RiskOutput("stump/timber winter colinzations")+$C$24+'stump Pathway'!$D$20+'bark pathway'!$C$28	=RiskOutput("stump/timber spring colonizations")+$D$24+'stump Pathway'!$E$20+'bark pathway'!$D$28	=RiskOutput("annual south colonizing pairs")+$B$32+$C$32+$D $32
33	colonization at mills?	=RiskOutput("fall prob colonization at avg mill")+IF(B32>=1,1,0)	=RiskOutput("winter prob colonization at avg mill")+IF(C32>=1,1,0)	=RiskOutput("spring prob colonization at avg mill")+IF(D32>=1,1,0)	=RiskOutput("spring prob colonization at avg mill")+IF(E32>=1,1,0)
34	Years until colonization in south	=RiskOutput("fall years until colonziation at avg mill")+1+RiskNegbin(1,$G$33)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$G33)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$H$29)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$H $29)

Appendix 19. Risk model for combining the bark nugget and logs and lumber with bark pathways.

	A	B	C	D	E	F	G	H
36	timber and bark colonizations	0	0	18	18			
37	colonization at mills?	0	0	1	1		0.006	1
38	Years until colonization in south	166	166	1	1			

Appendix 20. Formula table for combining the bark nugget and logs and lumber with bark pathways.

	A	B	C	D	E
36	timber and bark colonizations	=RiskOutput("stump/timber fall colinzations")+$B$24+'bark pathway'!$B$28	=RiskOutput("stump/timber winter colinzations")+$C$24+'bark pathway'!$C$28	=RiskOutput("stump/timber spring colonizations")+$D$24+'bark pathway'!$D$28	=RiskOutput("annual south colonizing pairs")+$B$36+$C$36+$D$36
37	colonization at mills?	=RiskOutput("fall prob colonization at avg mill")+IF(B36>=1,1,0)	=RiskOutput("winter prob colonization at avg mill")+IF(C36>=1,1,0)	=RiskOutput("spring prob colonization at avg mill")+IF(D36>=1,1,0)	=RiskOutput("spring prob colonization at avg mill")+IF(E36>=1,1,0)
38	Years until colonization in south	=RiskOutput("fall years until colonziation at avg mill")+1+RiskNegbin(1,$G$37)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$G$37)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$H$29)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$H$29)

Appendix 21. Risk model for combining the bark nugget and stump pathways.

	A	B	C	D	E	F	G	H	I
40	stump and bark	0	0	0	0				
41	colonization at mills?	0	0	0	0		0.0013	0.0022	0.0049
42	Years until colonization in south	769	769	454	204				

Appendix 22. Formula table for combining the bark nugget and stump pathways.

	A	B	C	D	E
40	stump and bark	=RiskOutput("stump/timber fall colinzations")+'bark pathway'!$B$28+'stump Pathway'!$C$20	=RiskOutput("stump/timber winter colinzations")+'bark pathway'!$C$28+'stump Pathway'!$D$20	=RiskOutput("stump/timber spring colonizations")+'bark pathway'!$D$28+'stump Pathway'!$E$20	=RiskOutput("annual south colonizing pairs")+$B$40+$C$40+$D$40
41	colonization at mills?	=RiskOutput("fall prob colonization at avg mill")+IF(B40>=1,1,0)	=RiskOutput("winter prob colonization at avg mill")+IF(C40>=1,1,0)	=RiskOutput("spring prob colonization at avg mill")+IF(D40>=1,1,0)	=RiskOutput("spring prob colonization at avg mill")+IF(E40>=1,1,0)
42	Years until colonization in south	=RiskOutput("fall years until colonziation at avg mill")+1+RiskNegbin(1,$G$41)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$G$41)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$H$41)	=RiskOutput("winter years until colonziation at avg mill")+1+RiskNegbin(1,$I$41)

Appendix 23. Calculation sheet for confidence intervals around a proportion (Cochran, 1977).

	A	B	C	D	E	F	G
1		Calc					
2	proportion	0.00741	numerator	1	denominator	135	
3	st. dev. prop	0.00738	*n*	135			
4							
5	95%						
6	z	1.96					
7	lower	-0.00706	<==Note: if lower limit less than 0, it indicates the proportion is not significantly different from zero at this *P*				
8	upper	0.02187					
9							
10	99%						
11	z	2.58					
12	lower	-0.01163					
13	upper	0.02645					

Appendix 24. Formula table for calculation sheet for confidence intervals around a proportion (Cochran, 1977).

	A	B	C	D	E	F
1		Calc				
2	proportion	=D2/F2	numerator	1	denominator	135
3	st. dev. prop	=SQRT(((B2*(1-B2))/D3))	*n*	135		
4						
5	95%					
6	z	1.96				
7	lower	=B2-(B6*B3)	<==Note: if lower limit less than 0, it indicates the proportion is not significantly different from zero at this *P*			
8	upper	=B2+(B6*B3)				
9						
10	99%					
11	z	2.58				
12	lower	=B2-(B11*B3)				
13	upper	=B2+(B11*B3)				

Appendix 25. State Plant Health Director (SPHD) data responses used in this risk assessment. The SPHDs for the reporting states were: 1) Indiana: Gary Simon, 2) Minnesota: Kevin Connors, 3)

New Hampshire: Mark Michaelis, 4) New York: Yvonne DeMarino and 5) Ohio: John Burch and 6) Vermont: Mark Michaelis (USDA-APHIS, 2005c).

Regulated State	Regulated Article	Shipping Date (Month)	Destination State	Tree Species (if available)	Number of Pine Shipments	Number of Pine Shipments Requiring Treatment
Minnesota	nursery trees	January	North Carolina	white pine	10	1
Minnesota	nursery trees	February	Virginia	Scotch pine	5	0
Minnesota	Christmas trees	November	Colorado	Scotch pine	20	3
Minnesota	bark nuggets	February	New Mexico	NA	1	0
Minnesota	Logs with bark	March	Utah	white pine	200	5
Minnesota	Lumber with bark	December	New Mexico	Scotch pine	3	0
Minnesota	Stumps	October	Virginia	jack pine	1	0
Minnesota	raw pine materials for wreaths and garlands	November	California	white pine	1	0
New Hampshire	Bark	March - Sept	CT	n/a	768	all ground as matter of business
New Hampshire	Bark	March - Sept	MA	n/a	33	all ground as matter of business
New Hampshire	Bark	March - Sept	NY	n/a	1	ground
New Hampshire	Christmas trees	Nov - Dec	CT	White Pine	28	
New Hampshire	Christmas trees	Nov - Dec	MA	White Pine	35	
New Hampshire	Christmas trees	Nov - Dec	NJ	White Pine	10	
New Hampshire	Christmas trees	Nov - Dec	PA	White Pine	5	
New Hampshire	Logs with Bark	Dec - Jan	ME	White Pine	15	all at destination
New Hampshire	Logs with Bark	Jan - Feb	ME	White Pine	4	all at destination
Indiana	Bark					
Indiana	Raw materials for wreaths and garlands					
Indiana	Logs with Bark					
Indiana	Lumber with Bark					
Indiana	Nursery trees	Spring 2004	New York	White Pine	One (fifty trees)	None
Indiana	Christmas trees					
Indiana	Stumps/Naval Stores					
Ohio	Bark				0	
Ohio	Raw materials for wreaths and garlands				0	

Ohio	Logs with Bark				0	
Ohio	Lumber with Bark				0	
Ohio	Nursery trees	Sept. - April	Several East/West	white pine, Austrian pine	200	20
Ohio	Christmas trees	Nov. - Dec.	KY, IN, IL	scotch pine, white pine	20	2
Ohio	Stumps/Naval Stores				0	
Vermont	Bark	March - Sept	CT	n/a	38	all ground as matter of business
Vermont	Bark	March - Sept	MA	n/a	25	all ground as matter of business
Vermont	Bark	March - Sept	NY	n/a	3	ground
Vermont	Christmas trees	Nov - Dec	CT	White Pine	5	
Vermont	Christmas trees	Nov - Dec	MA	White Pine	12	
Vermont	Christmas trees	Nov - Dec	VA	White Pine	3	
Vermont	Christmas trees	Nov - Dec	DE	White Pine	2	
New York	Bark	0	0	0	0	0
New York	Raw materials for wreaths and garlands	0	0	0	0	0
New York	Logs with Bark	June-Sept.2005	CT	Pinus resinosa	50	0
New York	Lumber with Bark	0	0	0	0	0
New York	Nursery trees	April-October	CT	P. nigra, strobus, strobiformis	14	0
New York	Nursery trees	May-October	ME	Pinus nigra	12	0
New York	Nursery trees	October	MI	P. nigra, strobus	1	0
New York	Nursery trees	October	IN	P. nigra, strobus, strobiformis	1	0
New York	Nursery trees	October	MD	P. nigra, strobus, strobiformis	1	0
New York	Nursery trees	May-October	MA	P. nigra, strobus, strobiformis	35	0
New York	Nursery trees	April-November	NJ	P. nigra, strobus	7	0
New York	Nursery trees	July-November	PA	P. nigra, strobus	6	0

Appendix 26. Glossary of selected International Plant Protection Convention terms that are potentially relevant to this pest risk assessment.

ISPM No. 5

INTERNATIONAL STANDARDS FOR PHYTOSANITARY MEASURES

ISPM No. 5

GLOSSARY OF PHYTOSANITARY TERMS (2005)

Produced by the Secretariat of the International Plant Protection Convention

OUTLINE OF REFERENCE

The purpose of this standard is to assist National Plant Protection Organizations and others in information exchange and the harmonization of vocabulary used in official communications and legislation pertaining to phytosanitary measures. The present version incorporates revisions agreed as a result of the approval of the International Plant Protection Convention (1997) and terms added through the adoption of additional International Standards for Phytosanitary Measures (ISPMs). All elements of this Glossary have been established on the basis that the New Revised Text of the IPPC (1997) is approved. The Glossary contains all terms and definitions approved until the Seventh Session of the Interim Commission on Phytosanitary Measures in 2005. References in square brackets refer to the approval of the term and definition, and not to subsequent adjustments in translation. As in previous editions of the Glossary, terms in definitions are printed in bold to indicate their relation to other Glossary terms and to avoid unnecessary repetition of elements described elsewhere in the Glossary. Derived forms of words that appear in the Glossary, e.g. *inspected* from *inspection*, are also considered glossary terms.

PHYTOSANITARY TERMS AND DEFINITIONS

Phytosanitary Certificate and which provides specific additional information on a **consignment** in relation to **regulated pests** [FAO, 1990; revised ICPM, 2005]

area An **officially** defined country, part of a country or all or parts of several countries [FAO, 1990; revised FAO, 1995; CEPM, 1999; based on the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures]

area of low pest prevalence An **area**, whether all of a country, part of a country, or all or parts of several countries, as identified by the competent authorities, in which a specific **pest** occurs at low levels and which is subject to effective **surveillance**, **control** or **eradication** measures [IPPC, 1997]

authority The **National Plant Protection Organization**, or other entity or person officially designated by the government to deal with matters arising from the responsibilities set forth in the Code [ISPM No. 3, 1996]

bark-free wood Wood from which all bark excluding the vascular cambium, ingrown bark around knots, and bark pockets between rings of annual growth has been removed [ISPM No. 15, 2002]

buffer zone An **area** in which a specific **pest** does not occur or occurs at a low level and is **officially controlled**, that either encloses or is adjacent to an infested **area**, an infested

place of production, an **area of low pest prevalence**, a **pest free area**, a **pest free place of production** or a **pest free production site**, and in which **phytosanitary measures** are taken to prevent **spread** of the **pest** [ISPM No. 10, 1999; revised ISPM No. 22, 2005]

certificate An **official** document which attests to the phytosanitary status of any **consignment** affected by **phytosanitary regulations** [FAO, 1990]

commodity A type of **plant**, **plant product**, or other article being moved for trade or other purpose [FAO, 1990; revised ICPM, 2001]

commodity class A category of similar **commodities** that can be considered together in **phytosanitary regulations** [FAO, 1990]

competitor An **organism** which competes with **pests** for essential elements (e.g. food, shelter) in the environment [ISPM No. 3, 1996]

compliance procedure (for a **consignment**) **Official procedure** used to verify that a **consignment** complies with stated phytosanitary requirements [CEPM, 1999]

consignment A quantity of **plants**, **plant products** and/or other articles being moved from one country to another and covered, when required, by a single **phytosanitary**

certificate (a **consignment** may be composed of one or more **commodities** or **lots**) [FAO, 1990; revised ICPM, 2001]

containment Application of **phytosanitary measures** in and around an infested **area** to prevent **spread** of a **pest** [FAO, 1995]

control (of a **pest**) **Suppression, containment** or **eradication** of a **pest** population [FAO, 1995] **control point** A step in a system where specific procedures can be applied to achieve a defined effect and can be measured, monitored, controlled and corrected [ISPM No. 14, 2002]

controlled area A **regulated area** which an **NPPO** has determined to be the minimum **area** necessary to prevent spread of a pest from a **quarantine area** [CEPM, 1996]

debarking Removal of bark from **round wood (debarking** does not necessarily make the **wood** bark-free) [FAO, 1990]

delimiting survey Survey conducted to establish the boundaries of an **area** considered to be infested by or **free from** a **pest** [FAO, 1990]

detection survey Survey conducted in an **area** to determine if **pests** are present [FAO, 1990, revised FAO, 1995]

detention Keeping a **consignment** in **official** custody or confinement, as a phytosanitary measure (see **quarantine**) [FAO, 1990; revised FAO, 1995; CEPM, 1999; ICPM, 2005]

dunnage Wood packaging material used to secure or support a **commodity** but which does not remain associated with the commodity [FAO, 1990; revised ISPM No. 15, 2002]

ecosystem A dynamic complex of **plant**, animal and micro-organism communities and their abiotic environment interacting as a functional unit [ISPM No. 3, 1996; revised ICPM, 2005]

efficacy (treatment) A defined, measurable, and reproducible effect by a prescribed **treatment** [ISPM No. 18, 2003]

emergency action A prompt **phytosanitary action** undertaken in a new or unexpected phytosanitary situation [ICPM, 2001]
emergency measure A **phytosanitary measure** established as a matter of urgency in a new or unexpected phytosanitary situation. An emergency measure may or may not be a
provisional measure [ICPM, 2001; revised ICPM, 2005]

endangered area An **area** where ecological factors favour the **establishment** of a **pest** whose presence in the **area** will result in economically important loss [FAO, 1995]

entry (of a **consignment**) Movement through a **point of entry** into an **area** [FAO, 1995]

entry (of a **pest**) Movement of a **pest** into an **area** where it is not yet present, or present but not widely distributed and being **officially controlled** [FAO, 1995]

equivalence (of phytosanitary measures) The situation where, for a specified pest risk, different **phytosanitary measures** achieve a contracting party's appropriate level of protection [FAO, 1995; revised CEPM, 1999; based on the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures; revised ISPM No. 24, 2005]

eradication Application of **phytosanitary measures** to eliminate a **pest** from an **area** [FAO, 1990; revised FAO, 1995; formerly **eradicate**]

establishment Perpetuation, for the foreseeable future, of a **pest** within an **area** after **entry** [FAO, 1990; revised FAO, 1995; IPPC, 1997; formerly **established**]

exotic Not native to a particular country, **ecosystem** or **ecoarea** (applied to **organisms** intentionally or accidentally introduced as a result of human activities). As the Code is directed at the **introduction** of **biological control agents** from one country to another, the term **"exotic"** is used for **organisms** not native to a country [ISPM No. 3, 1996]

find free To **inspect** a **consignmen**t, **field** or **place of production** and consider it to be **free from** a specific **pest** [FAO, 1990]

free from (of a **consignmen**t, **field** or **place of production**) Without **pests** (or a specific **pest**) in numbers or quantities that can be detected by the application of **phytosanitary procedures** [FAO, 1990; revised FAO, 1995; CEPM, 1999]

fumigation Treatment with a chemical agent that reaches the **commodity** wholly or primarily in a gaseous state [FAO, 1990; revised FAO, 1995]

growing period (of a **plant** species) Time period of active growth during a **growing season** [ICPM, 2003]

growing season Period or periods of the year when **plants** actively grow in an **area, place of production** or production site [FAO, 1990; revised ICPM, 2003]

habitat Part of an **ecosystem** with conditions in which an **organism** naturally occurs or can establish [ICPM, 2005]

harmonization The establishment, recognition and application by different countries of **phytosanitary measures** based on common **standards** [FAO, 1995; revised CEPM, 1999; based on the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures]

harmonized phytosanitary measures Phytosanitary measures established by contracting parties to the **IPPC**, based on **international standards** [IPPC, 1997]

host range Species capable, under natural conditions, of sustaining a specific **pest** or other **organism** [FAO, 1990; revised ISPM No. 3, 2005]

Import Permit Official document authorizing importation of a **commodity** in accordance with specified phytosanitary import requirements [FAO, 1990; revised FAO, 1995; ICPM, 2005]

incursion An isolated population of a **pest** recently detected in an **area**, not known to be established, but expected to survive for the immediate future [ICPM, 2003]

infestation (of a **commodity**) Presence in a **commodity** of a living **pest** of the **plant** or **plant product** concerned. **Infestation** includes infection [CEPM, 1997; revised CEPM, 1999]

inspection Official visual examination of **plants, plant products** or other **regulated articles** to determine if **pests** are present and/or to determine compliance with **phytosanitary regulations** [FAO, 1990; revised FAO, 1995; formerly **inspect**]

inspector Person authorized by a **National Plant Protection Organization** to discharge its functions [FAO, 1990]

intended use Declared purpose for which **plants**, **plant product**s, or other **regulated articles** are imported, produced, or used [ISPM No. 16, 2002]

interception (of a **consignment**) The **refusal** or controlled **entry** of an imported **consignment** due to failure to comply with **phytosanitary regulations** [FAO, 1990; revised FAO, 1995]

interception (of a **pest**) The detection of a **pest** during **inspection** or **testing** of an imported **consignment** [FAO, 1990; revised CEPM, 1996]

introduction The **entry** of a **pest** resulting in its **establishment** [FAO, 1990; revised FAO, 1995; IPPC, 1997]

IPPC International Plant Protection Convention, as deposited in 1951 with FAO in Rome and as subsequently amended [FAO, 1990; revised ICPM, 2001]

kiln-drying A process in which **wood** is dried in a closed chamber using heat and/or humidity control to achieve a required moisture content [ISPM No. 15, 2002]

legislation Any act, law, regulation, guideline or other administrative order promulgated by a government [ISPM No. 3, 1996]

monitoring An **official** ongoing process to verify phytosanitary situations [CEPM, 1996]

monitoring survey Ongoing **survey** to verify the characteristics of a **pest** population [FAO, 1995]

National Plant Protection Organization Official service established by a government to discharge the functions specified by the **IPPC** [FAO, 1990; formerly **Plant Protection Organization (National)**]

naturally occurring A component of an **ecosystem** or a selection from a wild population, not altered by artificial means [ISPM No. 3, 1996]

non-quarantine pest Pest that is not a **quarantine pest** for an **area** [FAO, 1995]

NPPO National Plant Protection Organization [FAO, 1990; ICPM, 2001]

occurrence The presence in an **area** of a **pest officially** recognized to be indigenous or **introduced** and/or not **officially** reported to have been **eradicated** [FAO, 1990; revised FAO, 1995; ISPM No. 17; formerly **occur**]

official Established, authorized or performed by a **National Plant Protection Organization**
[FAO, 1990]

official control The active enforcement of mandatory **phytosanitary regulations** and the application of mandatory **phytosanitary procedures** with the objective of **eradication** or **containment** of **quarantine pests** or for the management of **regulated non-quarantine pests** (see Glossary Supplement No. 1) [ICPM, 2001]

organism Any biotic entity capable of reproduction or replication in its naturally occurring state [ISPM No. 3, 1996; revised ISPM No. 3, 2005]

outbreak A recently detected **pest** population, including an **incursion**, or a sudden significant increase of an established **pest** population in an **area** [FAO, 1995; revised ICPM, 2003]

pathway Any means that allows the **entry** or **spread** of a **pest** [FAO, 1990; revised FAO, 1995]

pest Any species, strain or biotype of plant, animal or pathogenic agent injurious to **plants** or **plant products** [FAO, 1990; revised FAO, 1995; IPPC, 1997]

pest categorization The process for determining whether a **pest** has or has not the characteristics of a **quarantine pest** or those of a **regulated non-quarantine pest** [ISPM No. 11, 2001]

Pest Free Area An **area** in which a specific **pest** does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being **officially** maintained [FAO, 1995]

pest free place of production Place of production in which a specific **pest** does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period [ISPM No. 10, 1999]

pest free production site A defined portion of a **place of production** in which a specific **pest** does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period and that is managed as a separate unit in the same way as a **pest free place of production** [ISPM No. 10, 1999]

pest record A document providing information concerning the presence or absence of a specific **pest** at a particular location at a certain time, within an **area** (usually a country) under described circumstances [CEPM, 1997]

Pest Risk Analysis The process of evaluating biological or other scientific and economic evidence to determine whether a **pest** should be regulated and the strength of any **phytosanitary measures** to be taken against it [FAO, 1995; revised IPPC, 1997]

pest risk assessment (for **quarantine pests)** Evaluation of the probability of the **introduction** and **spread** of a **pest** and of the associated potential economic consequences [FAO, 1995; revised ISPM No. 11, 2001]

pest risk assessment (for regulated non-quarantine pests) Evaluation of the probability that a **pest** in **plants for planting** affects the **intended use** of those **plants** with an economically unacceptable impact [ICPM, 2005]

pest risk management (for **quarantine pests**) Evaluation and selection of options to reduce the risk of **introduction** and **spread** of a **pest** [FAO, 1995; revised ISPM No. 11, 2001]

pest risk management (for regulated non-quarantine pests) Evaluation and selection of options to reduce the risk that a **pest** in **plants for planting** causes an economically unacceptable impact on the **intended use** of those **plants** [ICPM, 2005]

pest status (in an **area**) Presence or absence, at the present time, of a **pest** in an **area**, including where appropriate its distribution, as **officially** determined using expert judgement on the basis of current and historical **pest records** and other information [CEPM, 1997; revised ICPM, 1998]

PFA Pest Free Area [FAO, 1995; revised ICPM, 2001]

phytosanitary action An **official** operation, such as **inspection**, **testing**, **surveillance** or **treatment**, undertaken to implement **phytosanitary measures** [ICPM, 2001; revised ICPM, 2005]

Phytosanitary Certificate Certificate patterned after the model **certificates** of the **IPPC** [FAO, 1990]
phytosanitary certification Use of **phytosanitary procedures** leading to the issue of a **Phytosanitary Certificate** [FAO, 1990]

phytosanitary import requirements Specific **phytosanitary measures** established by an importing country concerning **consignments** moving into that country [ICPM, 2005]

phytosanitary legislation Basic laws granting legal authority to a **National Plant Protection Organization** from which **phytosanitary regulations** may be drafted [FAO, 1990; revised FAO, 1995]

phytosanitary measure (agreed interpretation) Any **legislation**, **regulation** or **official** procedure having the purpose to prevent the **introduction** and/or **spread** of **quarantine pest**s, or to limit the economic impact of **regulated non-quarantine pests** [FAO, 1995; revised IPPC, 1997; ISPM, 2002] *The agreed interpretation of the term phytosanitary measure accounts for the relationship of phytosanitary measures to regulated non-quarantine pests. This relationship is not adequately reflected in the definition found in Article II of the IPPC (1997).*

phytosanitary procedure Any **official** method for implementing **phytosanitary measures** including the performance of **inspections**, **tests**, **surveillance** or **treatments** in connection with **regulated pests** [FAO, 1990; revised FAO, 1995; CEPM, 1999; ICPM, 2001; ICPM, 2005]

phytosanitary regulation Official rule to prevent the **introduction** and/or **spread** of **quarantine pests**, or to limit the economic impact of **regulated non-quarantine pests**, including establishment of **procedures** for **phytosanitary certification** [FAO, 1990; revised FAO, 1995; CEPM, 1999; ICPM, 2001]

place of production Any premises or collection of **fields** operated as a single production or farming unit. This may include production sites which are separately managed for phytosanitary purposes [FAO, 1990; revised CEPM, 1999]

plant products Unmanufactured material of **plant** origin (including **grain**) and those manufactured products that, by their nature or that of their processing, may create a risk for the **introduction** and **spread** of **pests** [FAO, 1990; revised IPPC, 1997; formerly **plant product**]

plant quarantine All activities designed to prevent the **introduction** and/or **spread** of **quarantine pests** or to ensure their **official control** [FAO, 1990; revised FAO, 1995]

PRA area Area in relation to which a **Pest Risk Analysis** is conducted [FAO, 1995]

pre-clearance Phytosanitary certification and/or **clearance** in the **country of origin**, performed by or under the regular supervision of the **National Plant Protection Organization** of the country of destination [FAO, 1990; revised FAO, 1995]

prohibition A **phytosanitary regulation** forbidding the importation or movement of specified **pests** or **commodities** [FAO, 1990; revised FAO, 1995]

protected area A **regulated area** that an **NPPO** has determined to be the minimum **area** necessary for the effective protection of an **endangered area** [FAO, 1990; omitted from FAO, 1995; new concept from CEPM, 1996]

provisional measure A **phytosanitary regulation** or procedure established without full **technical justification** owing to current lack of adequate information. A **provisional measure** is subjected to periodic review and full technical justification as soon as possible [ICPM, 2001]

quarantine Official confinement of **regulated articles** for observation and research or for further **inspection**, **testing** and/or **treatment** [FAO, 1990; revised FAO, 1995; CEPM, 1999]

quarantine area An **area** within which a **quarantine pest** is present and is being **officially controlled** [FAO, 1990; revised FAO, 1995]

quarantine pest A **pest** of potential economic importance to the **area endangered** thereby and not yet present there, or present but not widely distributed and being **officially controlled** [FAO, 1990; revised FAO, 1995; IPPC 1997]

raw wood Wood which has not undergone processing or **treatment** [ISPM No. 15, 2002]

refusal Forbidding **entry** of a **consignment** or other **regulated article** when it fails to comply with **phytosanitary regulations** [FAO, 1990; revised FAO, 1995]

regional standards Standards established by a **Regional Plant Protection Organization** for the guidance of the members of that organization [IPPC, 1997]

regulated area An **area** into which, within which and/or from which **plants**, **plant products** and other **regulated articles** are subjected to **phytosanitary regulations** or **procedures** in order to prevent the **introduction** and/or **spread** of **quarantine pests** or to limit the economic impact of **regulated non-quarantine pests** [CEPM, 1996; revised CEPM, 1999; ICPM, 2001]

regulated article Any **plant**, **plant product**, storage place, packaging, conveyance, container, soil and any other **organism**, object or material capable of harbouring or spreading **pests**, deemed to require **phytosanitary measures**, particularly where international transportation is involved [FAO, 1990; revised FAO, 1995; IPPC, 1997]

regulated pest A **quarantine pest** or a **regulated non-quarantine pest** [IPPC, 1997]

restriction A **phytosanitary regulation** allowing the importation or movement of specified **commodities** subject to specific requirements [CEPM, 1996, revised CEPM, 1999]

round wood Wood not sawn longitudinally, carrying its natural rounded surface, with or without bark [FAO, 1990]

RPPO Regional Plant Protection Organization [FAO, 1990; revised ICPM, 2001]

sawn wood Wood sawn longitudinally, with or without its natural rounded surface with or without bark [FAO, 1990]

Secretary Secretary of the **Commission** appointed pursuant to Article XII [IPPC, 1997]

spread Expansion of the geographical distribution of a **pest** within an **area** [FAO, 1995]

standard Document established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context [FAO, 1995; ISO/IEC GUIDE 2:1991 definition]

surveillance An **official** process which collects and records data on **pest occurrence** or absence by **survey**, **monitoring** or other procedures [CEPM, 1996]

survey An **official** procedure conducted over a defined period of time to determine the characteristics of a **pest** population or to determine which species **occur** in an **area** [FAO, 1990; revised CEPM, 1996]

systems approach(es) The integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of protection against **regulated pests** [ISPM No. 14, 2002; revised ICPM, 2005]

technically justified Justified on the basis of conclusions reached by using an appropriate **pest risk analysis** or, where applicable, another comparable examination and evaluation of available scientific information [IPPC, 1997]

test Official examination, other than visual, to determine if **pests** are present or to identify **pests** [FAO, 1990]

transparency The principle of making available, at the international level, **phytosanitary measures** and their rationale [FAO, 1995; revised CEPM, 1999; based on the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures]
treatment Official procedure for the killing, **inactivation** or removal of pests, or for rendering **pests** infertile or for **devitalization** [FAO, 1990, revised FAO, 1995; ISPM No. 15, 2002; ISPM No. 18, 2003; ICPM, 2005]

visual examination The physical examination of plants, **plant products**, or other **regulated articles** using the unaided eye, lens, stereoscope or microscope to detect **pests** or **contaminants** without **testing** or processing [ISPM No. 23, 2005]

wood A **commodity class** for round wood, sawn wood, wood chips or dunnage, with or without bark [FAO, 1990; revised ICPM, 2001]

wood packaging material Wood or wood products (excluding paper products) used in supporting, protecting or carrying a **commodity** (includes **dunnage**) [ISPM No. 15, 2002]