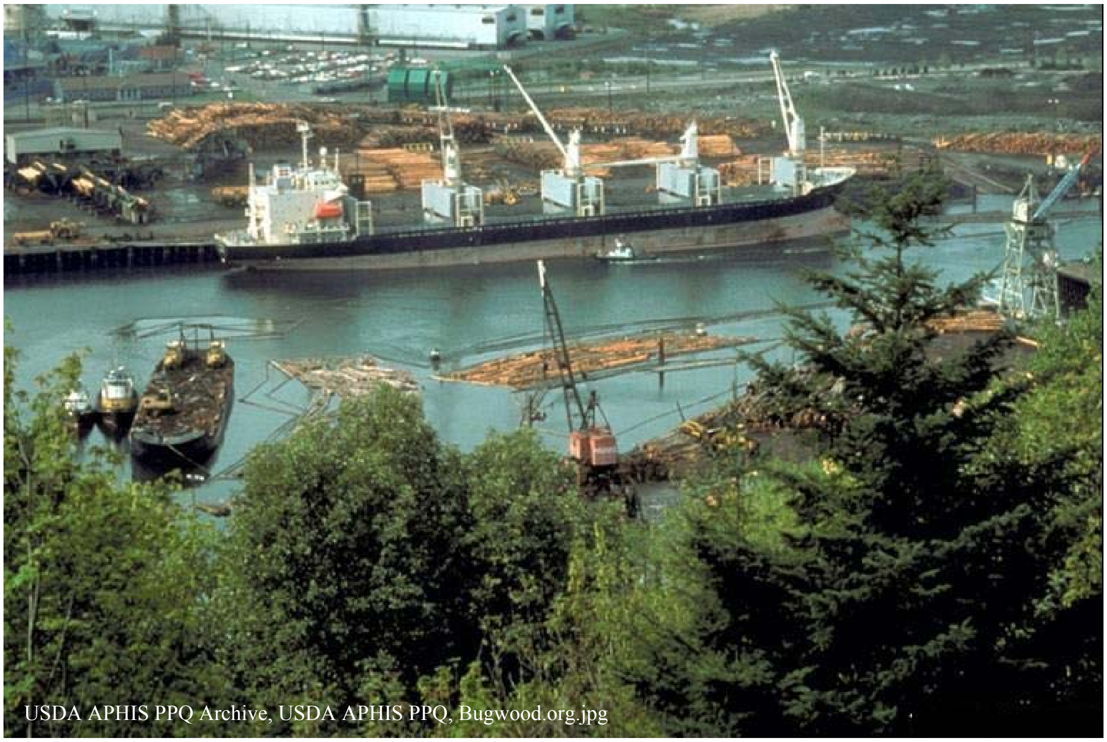
United States Department of Agriculture
Animal and Plant Health Inspection Service

Pathway-Initiated Pest Risk Assessment: Asian Gypsy Moth (Lepidoptera: Lymantriidae: *Lymantria dispar* (Linnaeus)) from Japan into the United States on Maritime Ships

May 2008



USDA APHIS PPQ Archive, USDA APHIS PPQ, Bugwood.org.jpg

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Executive Summary

This pest risk assessment characterizes the risks associated with Asian gypsy moth (AGM) on maritime ships from Japan into the United States. The document was developed at the request of USDA-APHIS-PPQ-EDP as an update to a previous version. This update was generated because of new data sources and technologies that allowed us to increase the precision of the risk characterization. Our pest risk assessment is a partial component of efforts to manage risks associated with trade. Our pest risk assessment is comprised of three analyses that characterize the risks to the United States associated with AGM on ships arriving at U.S. ports from Japan. We first geospatially characterized the risk of infestation at Japanese maritime ports based on suitable habitat and U.S. bound ship volumes. We then conducted a quantitative pathway analysis that estimated the approach rate of infested ships at U.S. ports coming from Japan. In the third analysis, we generated a pest risk assessment that characterized the risk to the United States if AGM were introduced from infested ships. Finally, we discuss the implications of these three analyses and how they could be used to inform AGM regulatory policy and trade practices between Japan and the United States.

Our geospatial analysis demonstrated that Japan has large vegetative and forested areas where at-risk ports are located. Our results indicate that all of the ports receiving U.S. bound ships are located within 40 kilometers (AGM's estimated flight distance) of forest and/or potential secondary host habitat, e.g. cropland. Consequently, it is possible for AGM infestation to occur on ships calling at these ports. Our geospatial analysis and resulting risk ratings, based on proximity of suitable habitat and volume of U.S. bound ships that called during the AGM flight period, characterized the risk associated with each port in relative quantitative terms. This information can be used to inform phytosanitary practices, e.g. surveys, which mitigate AGM infestation and movement via the ship pathway.

The quantitative pathway analysis used probabilistic scenario analysis, simulation modeling and spatial analyses to integrate and summarize our observations. This information may be helpful in devising strategies to reduce the risk of AGM spread from Japanese ports to U.S. ports via the maritime and container pathway. Strategies sought include methods that reduce the necessity for ship inspections for AGM upon arrival at U.S. ports as well as optimizing the use of human resources throughout the system.

Our model estimated that there was a 98.78 percent chance of one or more AGM infested ships from Japan arriving at U.S. ports each year with current shipping practices. The 5th, mean and 95th percentiles for number of AGM infested ships arriving from Japan were: 2; 10.526 and 24. Our results indicate that the Japan maritime ship pathway has high potential for facilitating AGM arrival at U.S. ports and that high infestation risks exist at several locations in Japan.

Our pest risk assessment was done in conformity with relevant international standards. AGM scored High with regard to Pest Risk Potential indicating that specific phytosanitary measures should be implemented in order to prevent its introduction. Due to the amount of data associated with AGM, we consider the degree of certainty associated with the pest risk potential score to be high.

Our analyses indicate that certain Japanese ports are a potential infestation area for maritime ships and that there is high likelihood of infested ships from Japan arriving at U.S. ports each year. Our conclusions help explain the observed pattern of AGM introductions at ports in the United States. The

risk assessment section demonstrated that AGM poses a high risk to United States agriculture, forestry, ecosystems and trade if introduced.

The overall findings of our pest risk assessment also provide justification for maintaining an extensive trapping program and the unmitigated utilization of resources to rapidly eradicate AGM introductions despite the economic costs. Finally, our analyses provide justification for the implementation of phytosanitary measures that prevent AGM introduction at U.S. ports.

Based on the results of this pest risk assessment, we suggest the continuation of a pre-shipment inspection and port of entry inspection program between Japan and the United States. This type of program helps mitigate the likelihood of AGM introduction via the maritime ship pathway and reduces the economic costs associated with eradication programs.

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I. Introduction

The gypsy moth, *Lymantria dispar* (Linnaeus), exhibits several biotypes all of which are considered quarantine pests of concern. The North American infestation was introduced into the northeastern United States from Europe in 1869 (CABI, 2006). This European biotype (EGM) has established and spread to 19 states in the eastern United States and is referred to as the North American gypsy moth (NAGM) (USDA-APHIS, 2003a; WSDA, 2004) (Figure 1). NAGM is considered a major forest pest in the United States and Canada due to its ability to cause economic and environmental damage (WSDA, 2004). The Asian biotype (AGM) has traits, described below, which if it were introduced, would increase the damage, spread and require the development of new management tools and programs.

AGM and closely related taxonomic forms are pests of forests in China, eastern Russia, Korea and Japan (AFFA, 2001; CABI, 2006). It is considered to be a more threatening pest than NAGM because: 1) AGM females are capable of long distance flight, unlike NAGM females, and 2) its host range is broader than that of NAGM (AFFA, 2001; CABI, 2006; USDA-APHIS, 2003; WSDA, 2004; Zlotina *et al*., 1999).

Pogue and Schaefer (2007) recently reclassified AGM into to five types depending on biology, morphology and distribution. These are: *Lymantria dispar asiatica, L. dispar japonica, L. albescens, L. umbrosa* and *L. postalba*. According to their classification, four of these are found in Japan. *Lymantria dispar japonica* (the Japanese gypsy moth) is present in inner Japan (Honshu, Shikoku and Kyushu) and Hokkaido. *Lymantria umbrosa* (the Hokkaido gypsy moth) is prevalent in eastern Hokkaido. *Lymantria albescens* (the Okinawan gypsy moth) and *L. postalba* (the Tsushima gypsy moth) are present in the Ryukyu Islands.

AGM are attracted to lights and can infest ships and containers at ports (Pogue and Schaefer, 2007). Figure 2 shows the infested superstructure of an oceangoing vessel docked at a Russian Far East port. Whereas the density of AGM attracted to the superstructure and which subsequently oviposit may appear extreme, this photograph is not atypical of vessels that call at Far East ports during AGM flight periods.

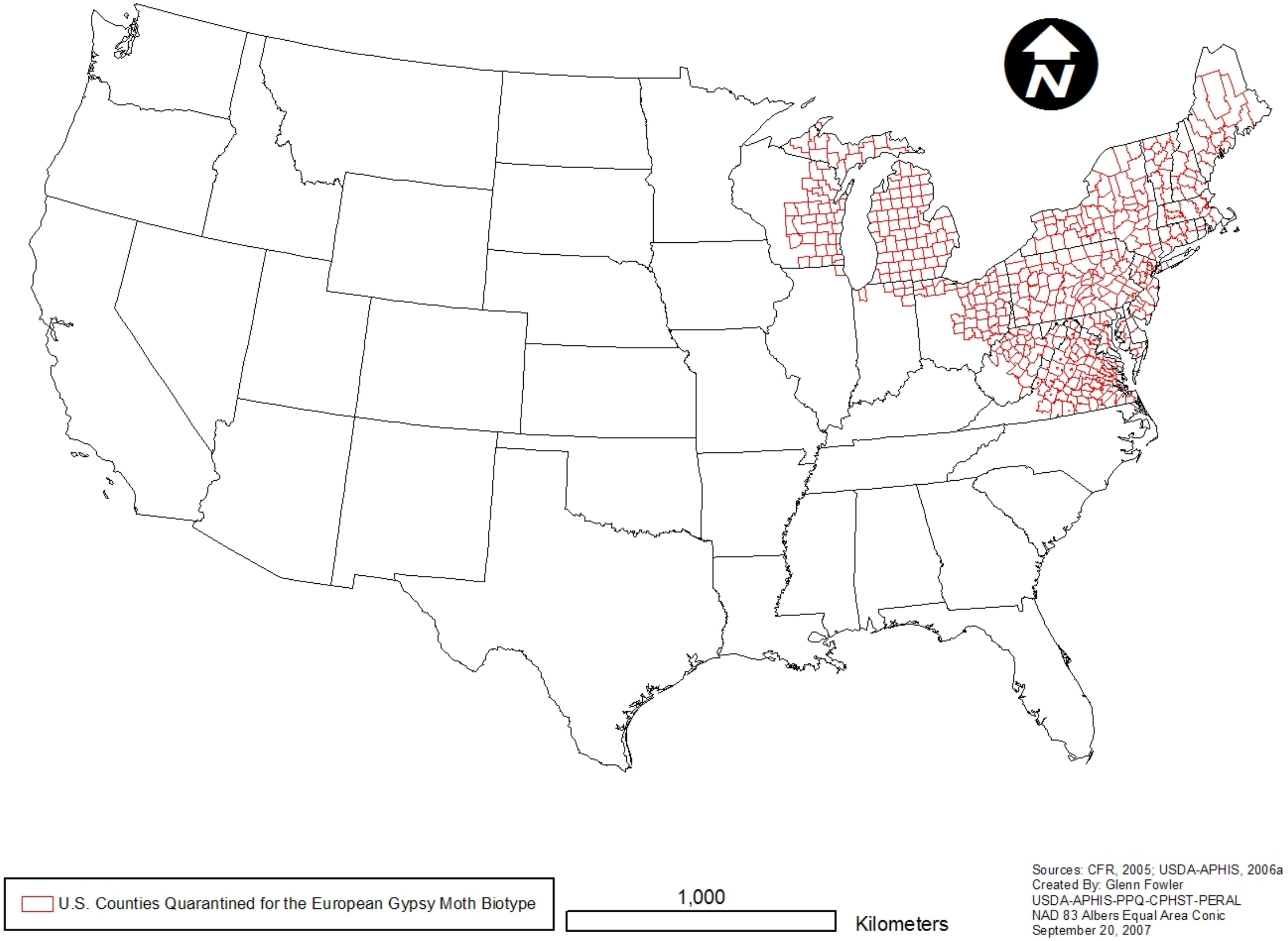
Over the past 15 years AGM has been intercepted at U.S. ports and locations in: California, South Carolina, North Carolina, Oregon, Texas and Washington State (Brackett, 1996; ODA, 2000; USDA-APHIS, 2007, 2007a; WSDA, 2004) (Figures 3 to 5). The most obvious pattern is the concentration of interceptions near the U.S. coasts and ports of entry. The second most obvious pattern is that most interceptions occur along the West Coast of the United States and Canada. This pattern is likely to experience dramatic shifts with the recently initiated project to enlarge the Panama Canal to accommodate vessels of any size (see maritime pathway study: Mastro *et al*., 2007). Of all these interceptions, the inland interception in Texas in 2006 was likely due to the movement of containers offloaded from infested ships or containers which were exposed at a staging area where gypsy moth had an opportunity to deposit eggs.

Most of the areas shown in the West Coast, especially the areas around Long Beach and Washington ports, are heavily trapped (Figure 4). That is, AGM traps are located at high densities all around the ports. This heavy density of trapping is likely responsible for keeping emerging populations in check. However, as noted by Mastro *et al.* (2007), the most important current trend in port dynamics is the fast movement of containers inland to distribution centers located hundreds of miles away from ports of entry. At this time, there is no trapping system associated with inland distribution centers.

Due to the rapid response of United States regulatory personnel and the United States Forest Service, AGM has been successfully eradicated, following all of these interceptions (Table 1), albeit at ongoing costs in the millions of dollars for eradication and continued monitoring and prevention activities, especially along West Coast ports. As a result of port interceptions, a cooperative AGM monitoring program was co-developed between NPPOs in Russia and the United States to reduce the likelihood of AGM introduction on maritime vessels from high risk Russian ports (USDA-APHIS, 2003; USDA-USFS, 2001). This program includes pre-shipment and pre-port of entry inspections for vessels that are considered a high risk for carrying AGM (USDA-APHIS, 2003). A similar program has been implemented in Japan and a third one is being implemented in South Korea. However, AGM interceptions at or near ports (not on vessels but captured at traps) is becoming a yearly occurrence at ports like Long Beach, California. Therefore, inspection and trapping programs in the United States as well as outside of the United States may need to be reviewed and expanded in near future.

Table 1. Costs associated with AGM eradication from 2002 to 2007 (USDA-APHIS, 2007a).

Year	Cost (U.S. Dollars)	States Affected
2002	201,000	Oregon
2003	na	na
2004	318,000	California
2005	593,000	Idaho, Washington
2006	762,944	California, Idaho, Texas, Washington
2007	999,000	California, Idaho, Oregon, Washington



Sources: CFR, 2005; USDA-APHIS, 2006a
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September 20, 2007

Figure 1. 2003 European gypsy moth distribution in the United States.

Figure 2. Asian gypsy moth adults and egg masses on the superstructure of an ocean-going vessel in Vladivostok, Russia (Photo courtesy of Russian Center of Plant Quarantine).

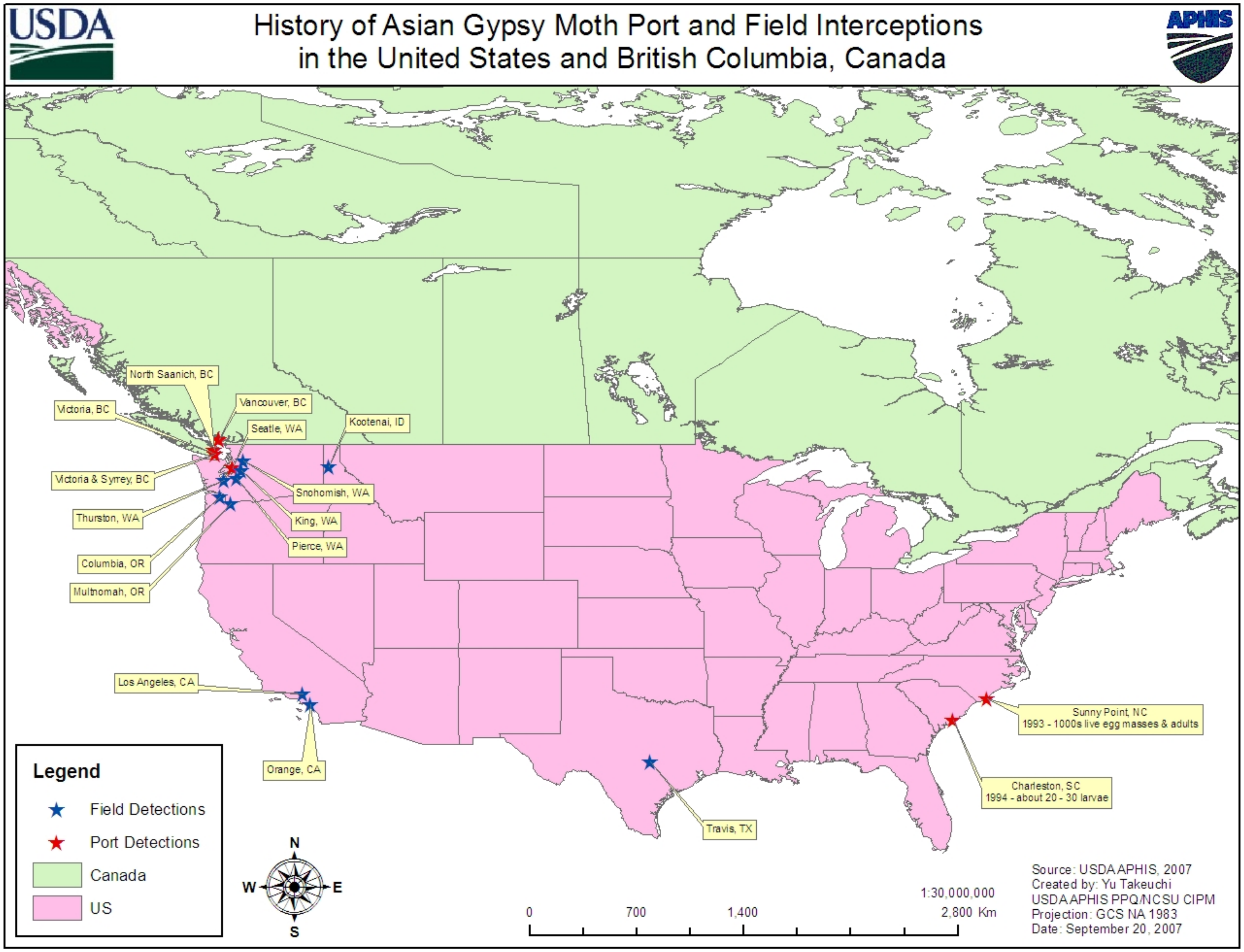


Figure 3. History of Asian gypsy moth interceptions at or near ports - United States and British Columbia, Canada.

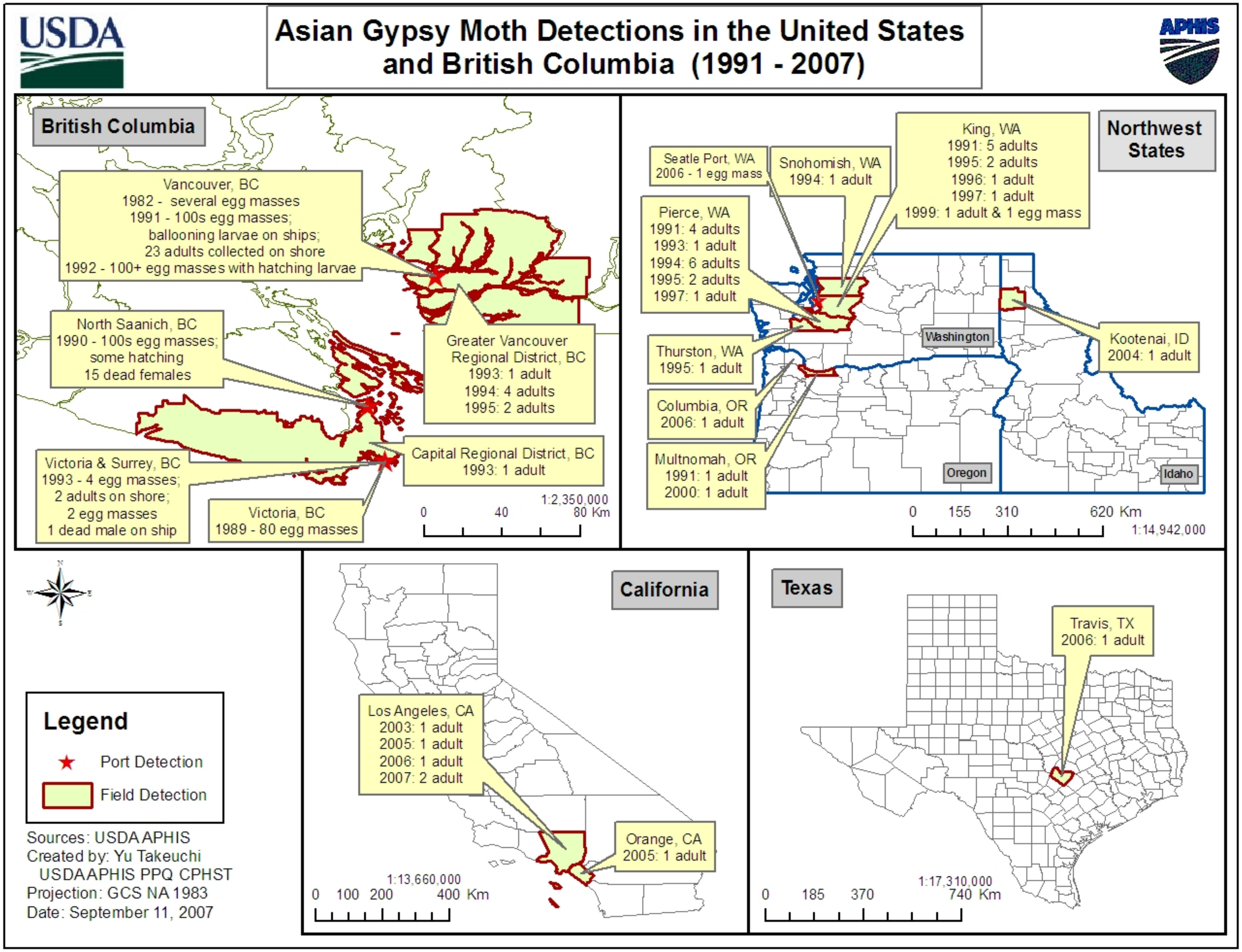


Figure 4. Asian gypsy moth field and port detections by region - Western States.

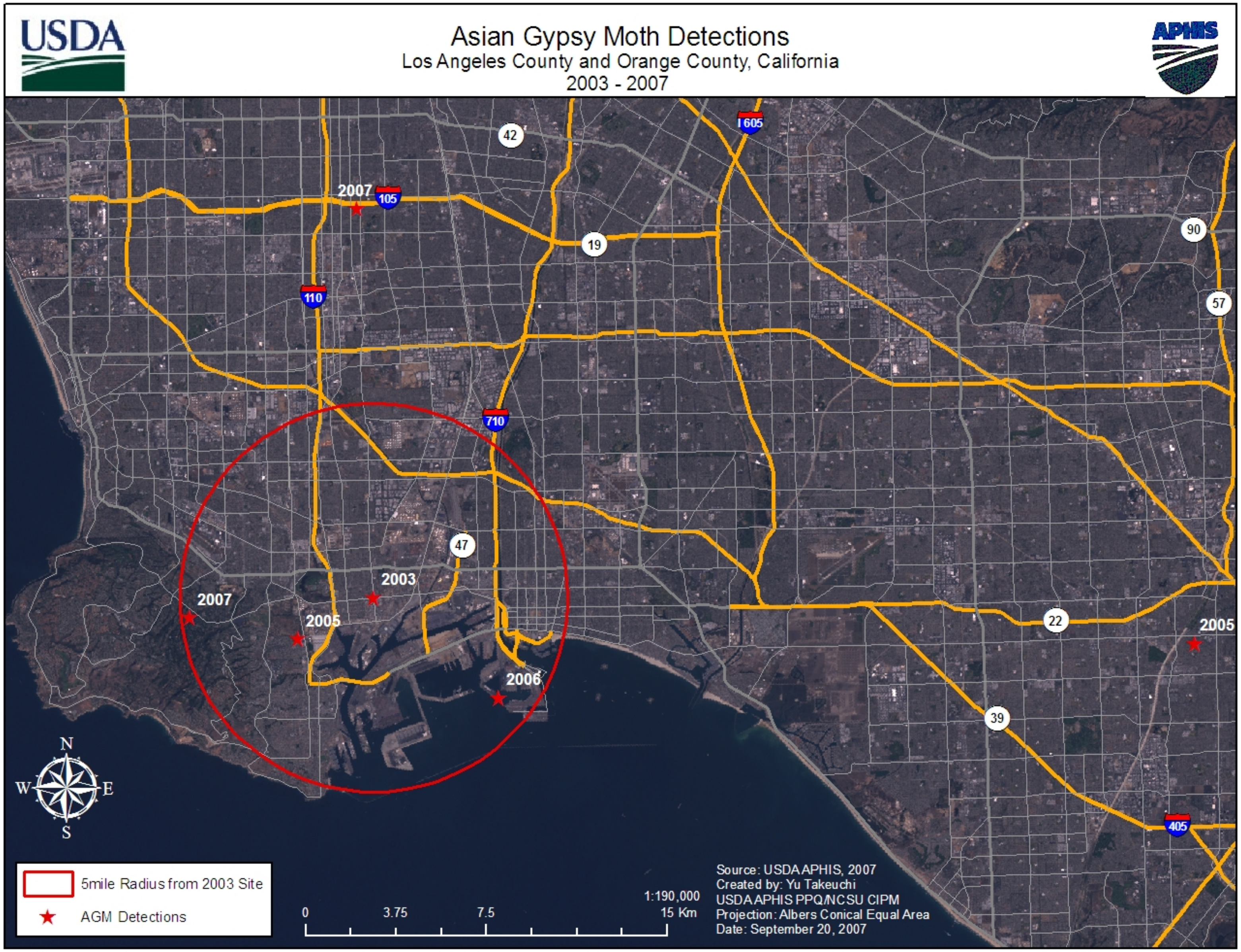


Figure 5. Asian gypsy moth detection in Los Angeles County and Orange County, California.

II. Biological Information

A. Description

Eggs: Gray in color, with a diameter of one millimeter (CABI, 2006).The egg masses are approximately five millimeters long by two millimeters wide and are covered with a coating of hair from the female (Figure 6). Egg masses are typically laid on tree boles and larger branches.

Figure 6. Asian gypsy moth laying eggs (James A. Copony, Virginia Department of Forestry, www.forestryimages.org).

Larvae: Larval length varies from three millimeters to seven centimeters depending on instar and gender (CABI, 2006) (Figure 7). Coloration is initially grayish black; colored patterns become visible in later instars. AGM larvae are distinguished by dual rows of blue tubercles on the initial five body segments, followed by red tubercles on the following six body segments.

Figure 7. Gypsy moth larvae (USDA Forest Service Archives, USDA Forest Service, www.forestryimages.org).

Pupae: Pupal length varies from two to four centimeters and the coloration is brown (CABI, 2006) (Figure 8). Pupation typically occurs on tree trunks or in protected areas.

Figure 8. Gypsy moth pupae (James A. Copony, Virginia Department of Forestry, www.forestryimages.org).

Adults: Moths are sexually dimorphic (CABI, 2006) (Figure 9). Wingspan varies from three to seven centimeters, with the female's wingspan being larger. Males and females exhibit brownish and whitish coloration, respectively. The female's forewings exhibit wavy black bands.

Figure 9. Adult male (left) and female (right) Asian gypsy moth (USDA APHIS PPQ Archives, USDA APHIS PPQ, www.forestryimages.org).

B. Life History

AGM is univoltine (CABI, 2006). Overwintering occurs in the egg stage, and newly hatched larvae move up the host tree where they balloon. Larval dispersal can range from several hundred meters to several kilometers (CABI, 2006). AGM females are capable of flying up to 40 kilometers (USDA-APHIS, 2003). Male and female larvae undergo five and six larval instars (CABI, 2006). The first three instars are diurnal feeders and the later instars are nocturnal. After six to eight weeks mature larva move to a covered area and pupate. Pupation requires up to three weeks. Adult females release sex pheromones to attract males. Females will only mate once with oviposition occurring shortly after mating (CABI, 2006). Females can lay up to 1,200 eggs per mass (CABI, 2006).

III. Geospatial Risk Evaluation of Japanese Ports

A. Introduction

In this section we geospatially evaluated the risk of AGM ship infestation associated with Japanese ports and port-vicinities. Our evaluation was based on the density of the forest and/or suitable habitat near each port and the number of vessels going to the United States from each port during the AGM flight period.

B. Methods

We mapped major land cover types in Japan and surrounding countries at a cell size of 10 kilometers (NAPPFAST, 2008) (Figure 10). We did this to identify areas where AGM presence was likely based on habitat. AGM is considered a major forest pest (CABI, 2006; Pogue and Schaefer, 2007). However, it is polyphagous and could also occur in land cover types aside from forest, e.g. cropland. This conclusion is realistic because: 1) the course resolution of the land cover grid indicates there will probably be other land cover types within the major land cover type, e.g. crop land could contain some forest, and 2) Chinese validation data confirmed AGM's presence in other land cover types aside from forest (Wang and Mastro, unpublished 2007) (Appendices 4 to 6). Because this pest risk assessment relates to the maritime pathway we focused our analyses on land cover around ports.

There were 84 Japanese ports in 2007 that hosted ships destined for the United States during the AGM flight period (see below) (Informa plc, 2008) (Appendix 1). We first estimated the infestation risk at each port based on the proximity to suitable AGM habitat. To do this, we counted, classified and totaled assigned habitat risk values associated with the number of cells within 40 kilometers (AGM's estimated flight distance) of each port (USDA-APHIS, 2003, 2006). Mean natural flight distance of AGM is not known precisely; however, AGM females have strong flight ability. Their flights are often aided by winds. Forty kilometers may not be the best estimate of natural dispersal distance, but until additional scientific information is available, a buffer zone was set to 40 kilometers based on U.S. experiences with AGM where 20 miles has been reported for dispersal potential (USDA-APHIS, 2006).

We classified forest cells as high risk (10). Because of AGM's broad host range, we classified cropland, woodland and wooded grassland cells as medium risk (5) (CABI, 2006; Pogue and Schaefer, 2007). All other land cover cell types were classified as low risk (1). We divided the total risk value for the cells in the 40 kilometer buffer around a port by the maximum calculated value if all the cells had been forest to generate the risk value for that port based on proximity to suitable habitat, i.e. the more forest around a port the higher the risk value (Table 2).

Next we estimated the risk at each port based on the ship volume destined for the United States during the AGM flight period. We estimated the AGM flight periods at these ports using the degree day model of Sheehan (1992) (Appendix 2). We estimated and then graphically depicted areas where enough average degree-days had accumulated for adult emergence, based on ten-year historical climatology (1998 to 2007), in weekly intervals from May 8 to August 15 for inner Japan through Hokkaido (NAPPFAST, 2008) (Figure 11). We also analyzed the at-risk southern port of Ishigaki, where flight was estimated to begin during the week of March 15.

The 84 at-risk ports were found to be located within the degree-day match area for the time period noted. That is, the ports are located in areas that match our forecasted flight periods. We allowed for a two month flight period beginning from the date of estimated adult emergence (Wallner *et al*., 1984). In addition to the flight time estimates based on climatological observations, we validated our model using known flight periods for seven locations in China (Wang and Mastro, unpublished 2007) (Appendices 4 and 5). All of the validation points fell within the predicted flight period band. Thus, our flight period estimates based on climatology are likely very good estimators of actual flight periods.

Once flight periods were established, we determined the number of ships destined for the United States that called at each of these ports during the AGM flight period (Figures 12 to 14). For our initial analysis, we used actual shipping records for 2007 available from the "Lloyds of London Maritime Intelligence Unit" database (Informa plc, 2008) (Appendix 1). The database reports the four previous and four subsequent port destinations for a given ship after arrival at each at-risk port. If a U.S. port was not among the four subsequent destinations we typically did not consider that ship to be at risk for introducing AGM. We note that given: 1) ships do call at numerous ports, 2) AGM egg clusters may remain viable for very long periods, e.g. 9 months, and 3) are hardy (MAF, 2004; USDA-APHIS, 1993), this resulted in a conservative estimate. We were not trying to be conservative but the nature of the data is such that a conservative estimate of risk (in terms of U.S. bound vessels) results because it is reasonable to assume that some vessels may call at four or more ports before arriving in the United States and still pose risks.

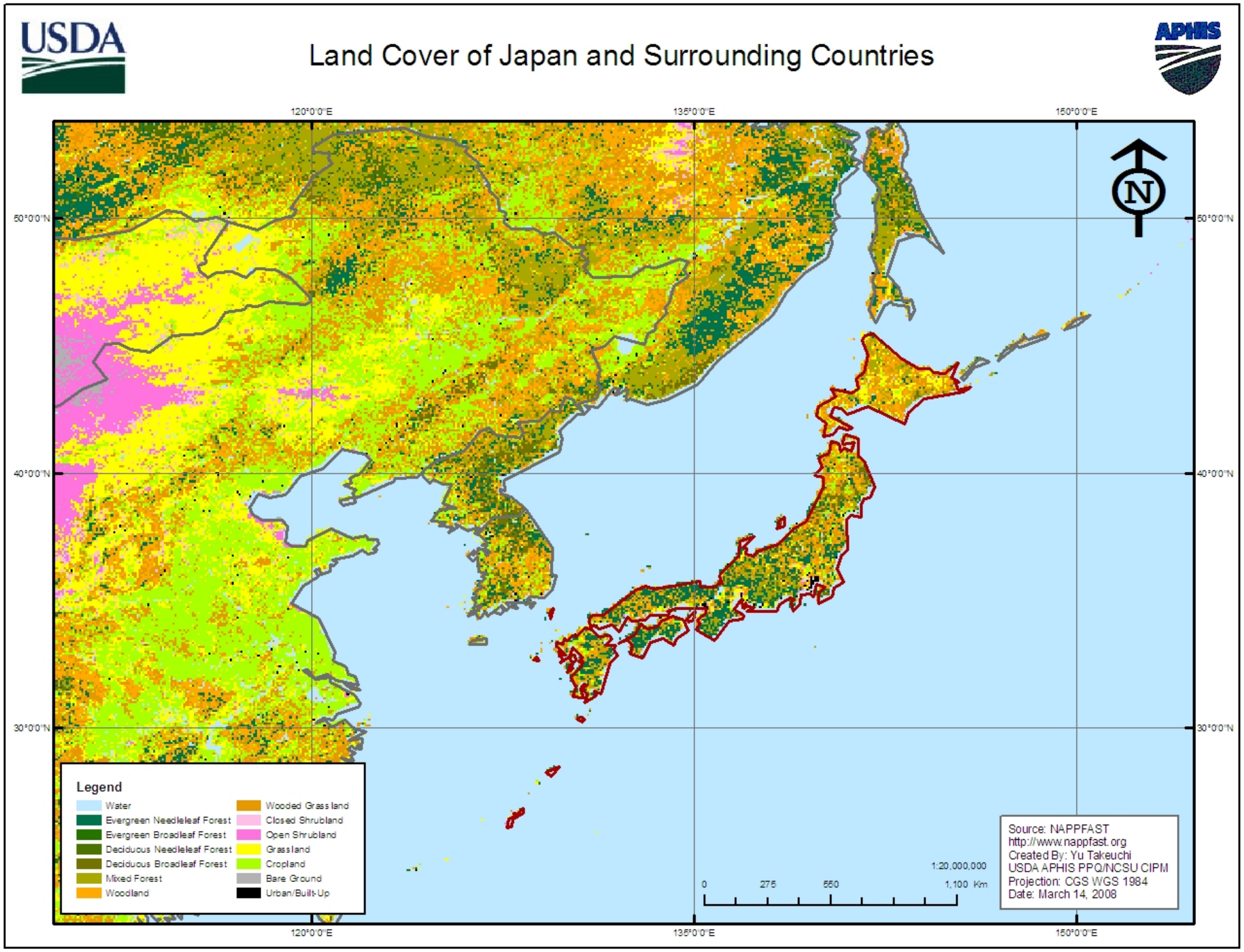
Our risk value based on ship volume was calculated by dividing the number of U.S. bound ships that called at each port during the flight period in 2007 by the total number of U.S. bound ships that called at all at-risk ports during the AGM flight period in 2007 (Table 2).

Finally, we generated a relative risk rating for each port by averaging the forest risk rating and the ship volume risk rating (Table 2).

C. Results and Discussion

Japan has large areas of crop/pasture and forest areas (Figures 10 and 12 to 14). The differences in likelihood of AGM infestation (as an element of risk) were investigated for each port based on the proximity to AGM hosts, size of host areas, and number of vessels going to the United States from that specific location (Figures 12 to 14). Our results indicate that all of the ports receiving U.S. bound ships are located within 40 kilometers of forest and/or potential secondary host habitat, e.g. cropland. Consequently, it is possible for AGM infestation to occur on ships calling at these ports. We characterized the risk associated with each port in quantitative terms relative to the other ports (Table 2). This information can be used to inform phytosanitary practices, e.g. surveys, which mitigate AGM infestation and movement via the ship pathway.

We note that AGM is a temperate species and would probably exhibit lower introduction potential in tropical areas, i.e. ports located south of 29°41' North (Allen *et al*., 1993). The at-risk port of Ishigaki is located below this latitude at 24°20' North (Informa plc, 2008). We analyzed this port for risk because two members of the AGM complex that have been considered Asian gypsy moth subspecies, the Okinawan gypsy moth, *L. albescesns* syn. *L. dispar albescens*, and the Tsushima gypsy moth, *L. postalba* syn. *L. dispar postalba*, are present there and could move on ships (Pogue and Shaefer, 2007).



Source: NAPPFAST
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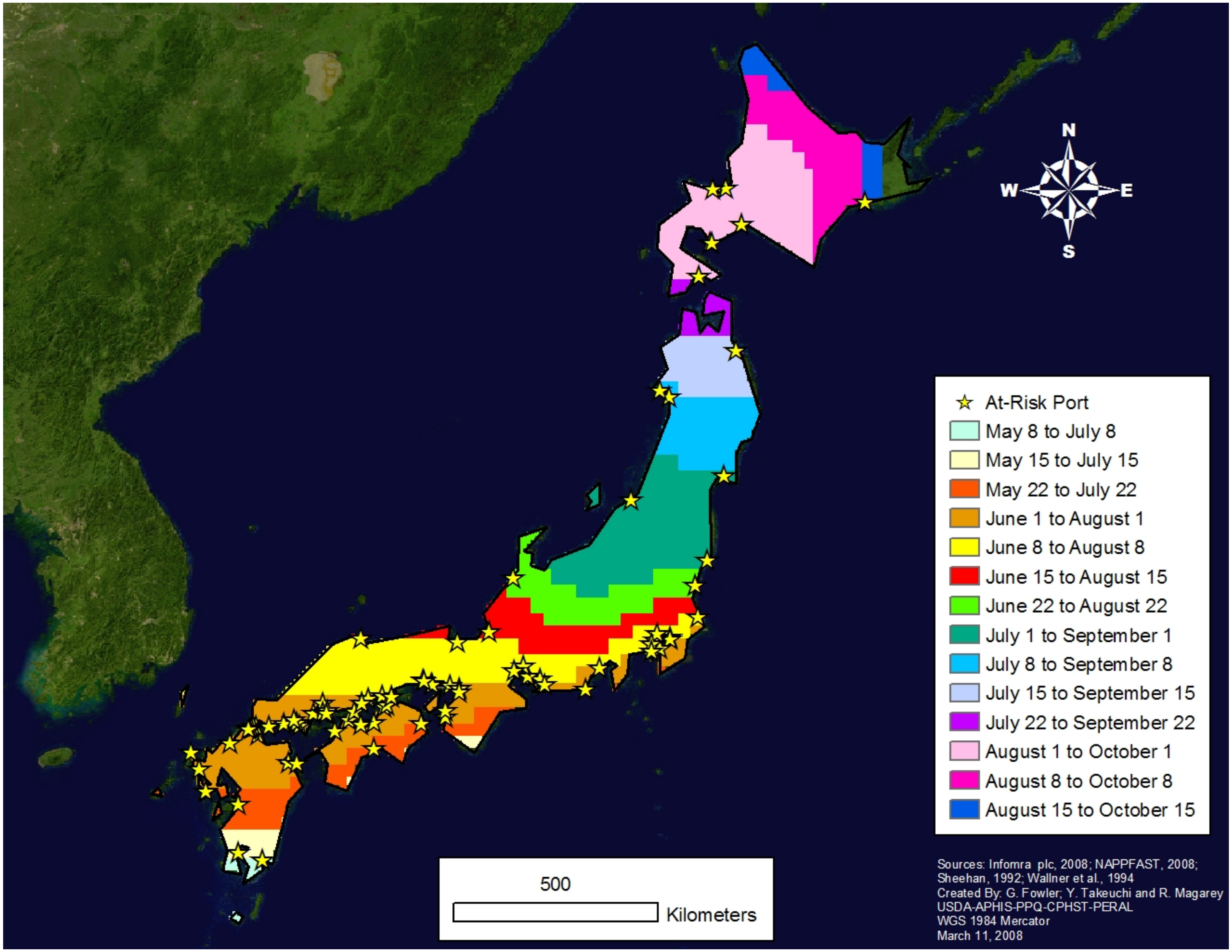
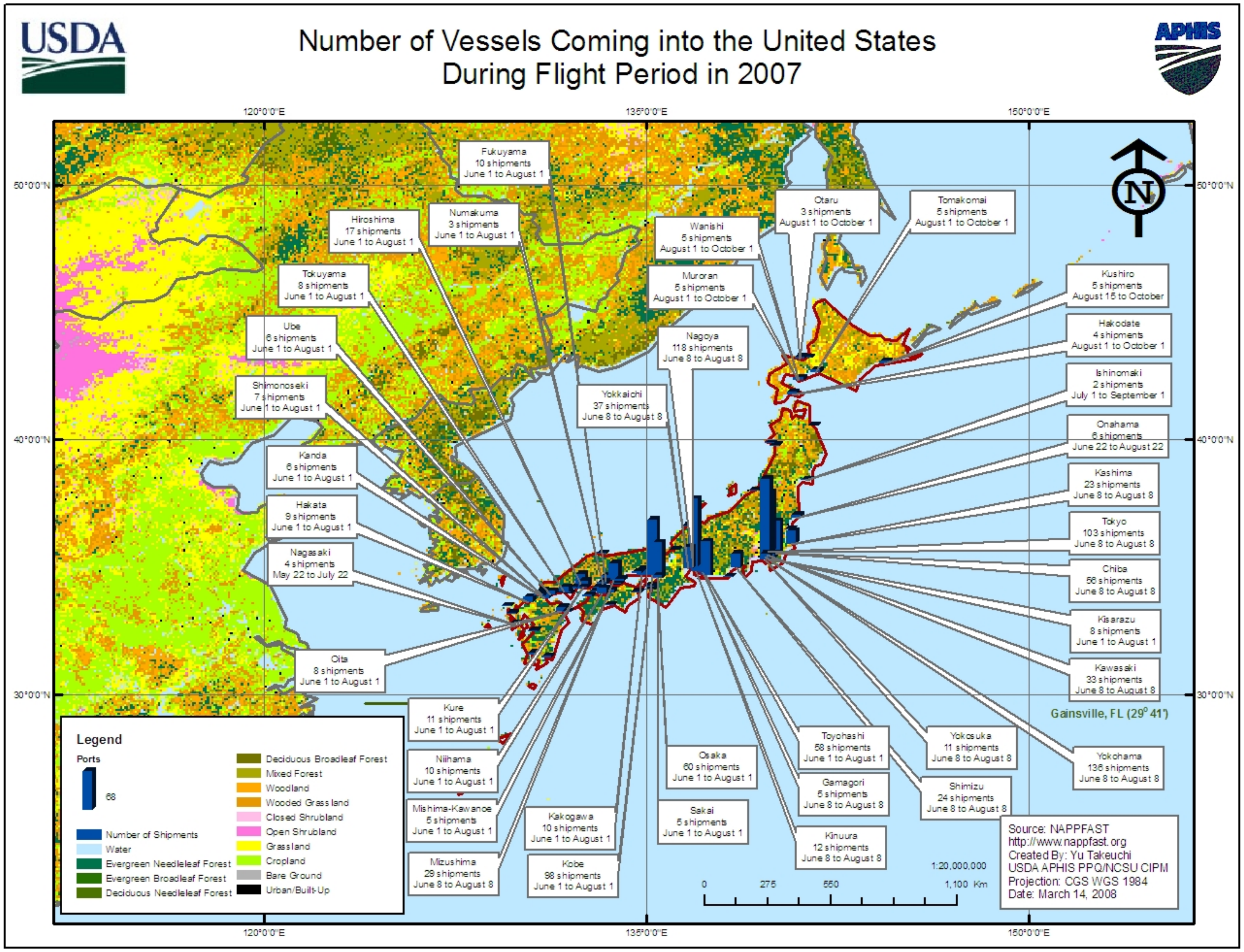
Date: March 14, 2008

Figure 10. Land cover types of Japan and surrounding countries.



Sources: Infomra plc, 2008; NAPPFAST, 2008;
Sheehan, 1992; Wallner et al., 1994
Created By: G. Fowler; Y. Takeuchi and R. Magarey
USDA-APHIS-PPQ-CPHST-PERAL
WGS 1984 Mercator
March 11, 2008

Figure 11. Port flight periods and areas where enough degree days accumulated for adult emergence by date.



Source: NAPPFAST
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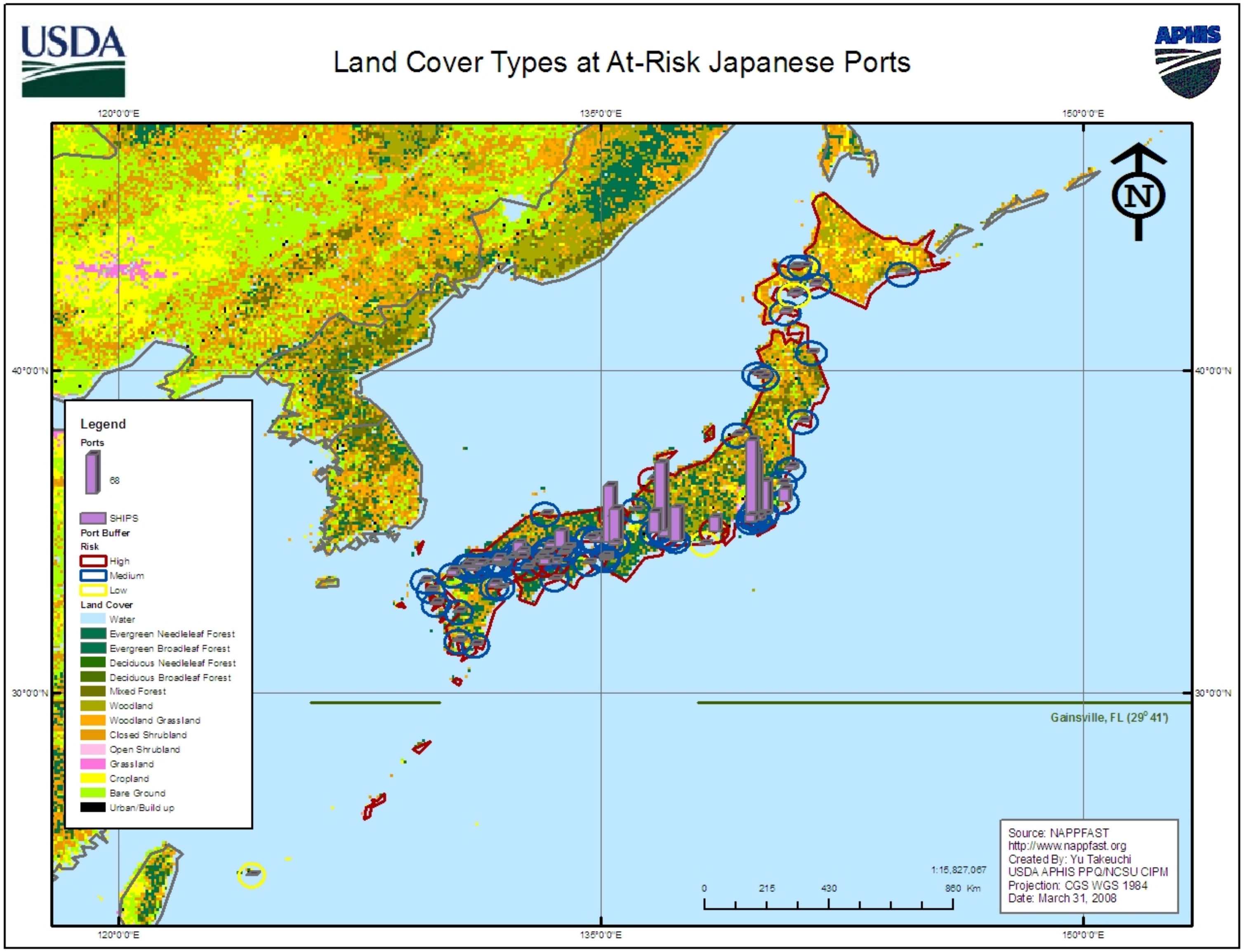
Figure 12. At-risk Japanese port locations and associated numbers of ships destined for the United States during flight periods in 2007.



Source: NAPPFAST
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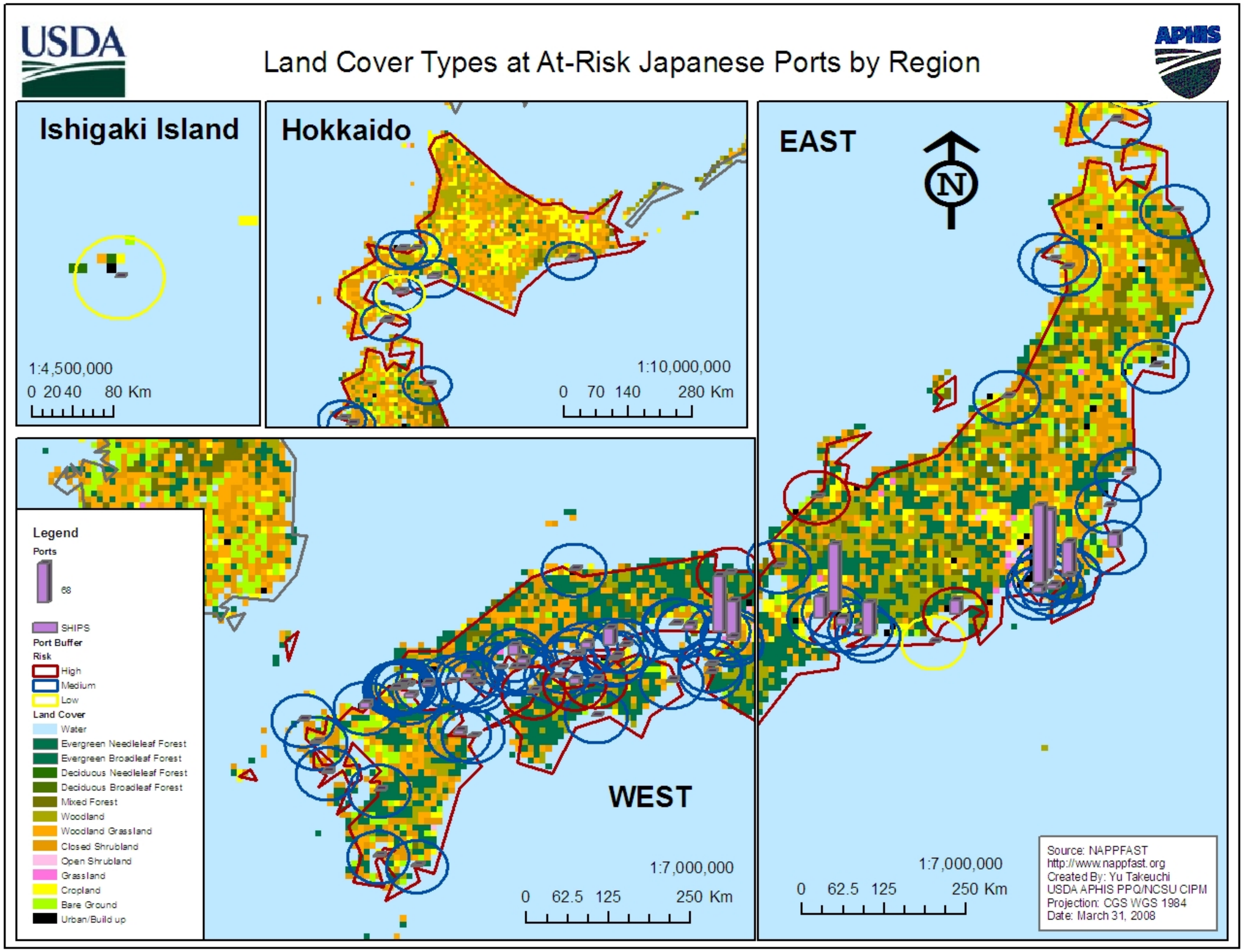
Date: March 31, 2008

Figure 13. Asian gypsy moth habitat areas and number of vessels destined to the United States during AGM flight periods.



Source: NAPPFAST
http://www.nappfast.org
Created By: Yu Takeuchi
USDA APHIS PPQ/NCSU CIPM
Projection: CGS WGS 1984
Date: March 31, 2008

Figure 14. Land cover types within 40 kilometers of at-risk Japanese ports by region.

Table 2. Risk ratings and classifications for at-risk Japanese ports based on proximity to suitable habitat and U.S. bound ship volumes.

Port	Land Cover Risk Rating	Ship Volume Risk Rating	Relative Risk Rating	Port	Land Cover Risk Rating	Ship Volume Risk Rating	Relative Risk Rating
Akita	0.3753	0.0019	0.1886	Mishima-Kawanoe	0.5903	0.0048	0.2976
Chiba	0.4513	0.0536	0.2525	Mitsukoshima	0.3137	0.0019	0.1578
Fukuyama	0.2942	0.0096	0.1519	Mizushima	0.3026	0.0278	0.1652
Funakawa	0.2768	0.0010	0.1389	Moji	0.2950	0.0019	0.1485
Gamagori	0.3345	0.0048	0.1696	Muroran	0.1973	0.0048	0.1010
Hachinohe	0.4804	0.0010	0.2407	Nagasaki	0.2727	0.0038	0.1383
Hakata	0.3949	0.0086	0.2018	Nagoya	0.2678	0.1130	0.1904
Hakodate	0.2934	0.0038	0.1486	Nakanoseki	0.3098	0.0010	0.1554
Higashi-Harima	0.2874	0.0019	0.1446	Niigata	0.4681	0.0019	0.2350
Hikari	0.2910	0.0010	0.1460	Niihama	0.5551	0.0096	0.2824
Hirohata	0.3740	0.0010	0.1875	Numakuma	0.2676	0.0029	0.1353
Hiroshima	0.4775	0.0163	0.2469	Oita	0.4149	0.0077	0.2113
Hitachi	0.3172	0.0010	0.1591	Omaezaki	0.1915	0.0010	0.0962
Ichihara	0.4585	0.0010	0.2297	Onahama	0.3511	0.0057	0.1784
Imabari	0.4209	0.0010	0.2109	Osaka	0.3618	0.0575	0.2096
Ishigaki	0.1266	0.0010	0.0638	Oshima	0.2168	0.0019	0.1094
Ishikariwan Shinko	0.3907	0.0010	0.1958	Otaru	0.4170	0.0029	0.2099
Ishinomaki	0.2957	0.0019	0.1488	Saganoseki	0.2886	0.0010	0.1448
Iwagi	0.3208	0.0019	0.1614	Sakai	0.3908	0.0048	0.1978
Iwakuni	0.4053	0.0019	0.2036	Sakaide	0.3342	0.0029	0.1685
Kagoshima	0.4601	0.0029	0.2315	Sakaiminato	0.4337	0.0010	0.2173
Kakogawa	0.2812	0.0096	0.1454	Sasebo	0.3475	0.0029	0.1752
Kanazawa	0.5141	0.0010	0.2575	Shibushi	0.3843	0.0029	0.1936
Kanda	0.3855	0.0057	0.1956	Shikama	0.3658	0.0029	0.1843
Kanokawa	0.3251	0.0010	0.1630	Shimizu	0.5141	0.0230	0.2686
Kashima	0.2506	0.0220	0.1363	Shimonoseki	0.3166	0.0067	0.1617
Kawasaki	0.3161	0.0316	0.1738	Shimotsu	0.4498	0.0019	0.2259
Kinuura	0.2258	0.0115	0.1187	Tamano	0.3008	0.0019	0.1514
Kisarazu	0.3912	0.0077	0.1994	Tobata	0.3306	0.0010	0.1658
Kobe	0.3165	0.0939	0.2052	Tokuyama	0.3947	0.0077	0.2012
Kochi	0.4388	0.0010	0.2199	Tokyo	0.3133	0.0987	0.2060
Kokura	0.3353	0.0010	0.1681	Tomakomai	0.3135	0.0048	0.1592
Komatsushima	0.3200	0.0029	0.1614	Toyohashi	0.2690	0.0556	0.1623
Kudamatsu	0.3381	0.0019	0.1700	Tsuneishi	0.2674	0.0019	0.1347
Kure	0.3345	0.0105	0.1725	Tsuruga	0.6256	0.0010	0.3133
Kushiro	0.3648	0.0048	0.1848	Ube	0.2521	0.0057	0.1289
Maizuru	0.7015	0.0019	0.3517	Uno	0.2990	0.0029	0.1509
Marugame	0.3387	0.0010	0.1698	Wakamatsu	0.3295	0.0010	0.1652
Matsuyama	0.5377	0.0029	0.2703	Wakayama	0.4512	0.0029	0.2270

Port	**Land Cover Risk Rating**	**Ship Volume Risk Rating**	**Relative Risk Rating**
Yokkaichi	0.2553	0.0354	0.1453
Yokohama	0.2842	0.1303	0.2072
Yokosuka	0.2844	0.0105	0.1475
Wanishi	0.1907	0.0048	0.0977
Yatsushiro	0.5828	0.0019	0.2923
Yawata	0.3406	0.0029	0.1718

IV. Quantitative Pathway Analysis: Asian Gypsy Moth (Lepidoptera: Lymantriidae: *Lymantria dispar* (Linnaeus)) from Japan into the United States on Maritime Ships

A. Introduction

In this section we estimated the likelihood that AGM would infest ships calling at Japanese ports that are destined for U.S. ports. We then estimated the annual number of infested ships arriving at U.S. ports. Our model output included estimates of the number of infested ships arriving and the time until an infested ship would arrive from at-risk Japanese ports. We also used spatial analysis and degree day models to increase the precision and transparency of the quantitative analysis.

B. Methods

1. Quantitative Modeling

We constructed a straightforward probabilistic model that estimated the likelihood of AGM infesting maritime vessels calling at Japanese ports and then the likelihood of them arriving at U.S. ports (Figure 15) (Appendices 7 to 14). Our model described the AGM pathway in terms of its critical elements: AGM infestation in a sea-going ship and infested ships that arrive in the United States. Each of these elements was associated with quantities or probabilities, e.g. what is the likelihood that a given ship is infested? What is the likelihood that an infested ship arrives at a U.S. port? The specific amounts were estimated using scientific, technical, economic and/or agricultural sources as appropriate and as described in general terms by Auclair *et al*. (2005).

The model elements could have been easily combined to provide a single point estimate as an outcome. That is, we could have used average or mean values for each element and then computed and overall single output value. However, the variability in biological systems is best represented by a distribution of values instead of a single number. Four probability distribution types, i.e. the Beta, binomial, negative binomial and PERT, were used in the model (Table 3) to capture uncertainties, including variability. The Beta, binomial and negative binomial distributions comprise the binomial process. This process describes a stochastic system where there are *n* independent trials, the outcome of each trial is a success or failure and the probability of success on each trial is the same (Groenendaal, 2006; Vose, 2000). The binomial process is well suited for our AGM pathway analysis since there are multiple independent ships arriving at ports where there is a probability of infestation occurring. We used the PERT distribution due to its objectivity and resistance to the effects of extreme values.

We used off the shelf software, in this case @Risk 4.52 Professional (Palisade, 2002), to run the model simulation. We note that other off the shelf software systems exist that simplify calculations; the use of any particular software reflects the experience of the authors and does not constitute product endorsement.

In terms of the model simulation settings, we used Latin Hypercube sampling with a fixed random generator seed of one and 10,000 iterations.

We provided summary statistics for specified model outputs. We also reported certain model outputs graphically using a cumulative distribution function and relative frequency histogram.

The cumulative distribution function (cdf) can be used to rapidly estimate the probability of being less than or equal to a value on the *x*-axis (Vose, 2000). This is done by moving vertically up from the *x*-value to the graph intercept and then moving horizontally left to the associated probability on the *y*-axis.

We used the relative frequency histogram to visualize the annual number of infested ships arriving at U.S. ports from Japan. Because this variable is discrete the *y*-axis can be used to estimate the probability of occurrence (Vose, 2000). We note that the sum of the probabilities associated with the histogram equals one.

Table 3. Probability distributions used in the model.

Probability Distribution	**Description**
Beta	A continuous distribution that estimates the probability (*p*) of a success (Palisade, 2002a; Vose, 2000). The parameters for the beta are $\alpha 1 = s + 1$ and $\alpha 2 = n - s + 1$ where *s* = the number of successes and *n* = the number of trials.
Binomial	A discrete distribution that estimates the number of successes (*s*) in a given number of trials (*n*) (Palisade, 2002a; Vose, 2000). The binomial distribution parameters are the number of trials (*n*) and the probability of success (*p*).
Negative Binomial	A discrete distribution that estimates the number of trials (*n*) before a success (*s*) occurs (Palisade, 2002a; Vose, 2000). The parameters for the negative binomial are the required number of successes (*s*), e.g. 1, and the probability of success (*p*). The number of required successes, e.g. 1, is added to the negative binomial to generate the number of trials until a success occurs (Vose, 2000).
PERT	A continuous distribution bounded by a minimum and maximum value (Palisade, 2002a; Vose, 2000). The parameters for the PERT are a minimum, most likely and maximum value. The PERT concentrates values towards the center of the distribution which increases its objectivity and decreases the effects of extreme values (Auclair *et al*., 2005; Groenendaal, 2006; Vose, 2000).

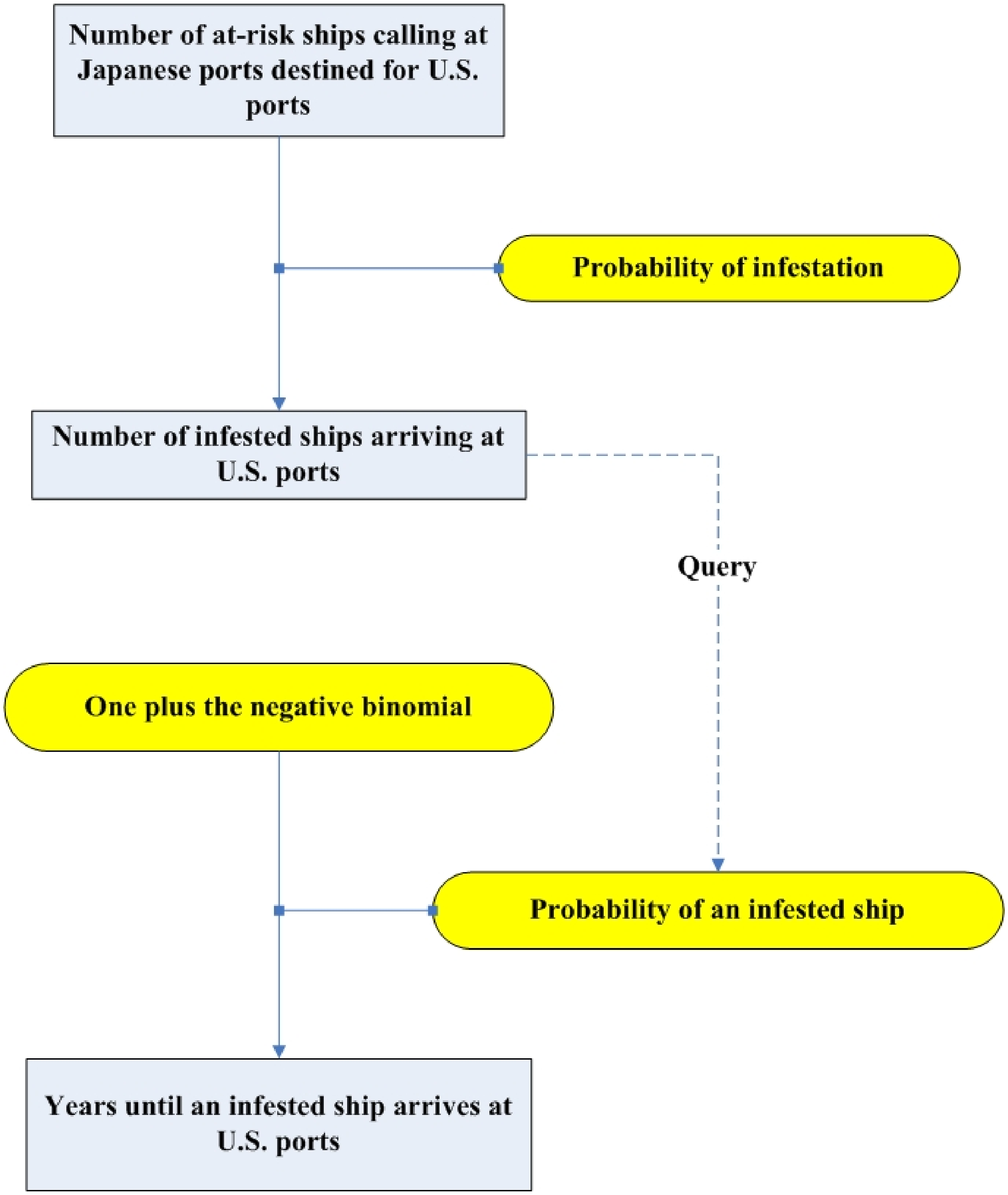


Figure 15. AGM pathway model Schematic.

Definitions:
At-risk ship: A ship which may be associated with non-zero likelihood of transporting Asian gypsy moth
Infested ship: A ship which is infested with Asian gypsy moth

C. Pathway Model

Step 1. Number of ships calling at Japanese ports during the AGM flight period that are destined for U.S. ports

We estimated this step using the number of ships that called at the 84 at-risk Japanese ports in 2007 during the AGM flight period (Figures 11 to 14, Appendix 1). The number of ships that depart from a given port with the United States as a destination was assumed to be variable. To account for fluctuations in annual ship numbers due to trade variation, we assumed: 1) a normal distribution for Japanese trade with the United States and 2) the number of ships calling at Japanese ports would be proportionate to the level of trade. We thus adjusted the 2007 numbers by ± three standard deviations in Japan's export trade proportion between 2003 and 2006, i.e. ± 3.1 percent (SBSRTI, 2008) (Appendix 3). This range captures 99.73 percent of the trade proportion distribution (Vose, 2000). The adjusted numbers were used to estimate the minimum and maximum number of at-risk ships calling at each port. We modeled the number of at-risk ships calling at each of the 84 ports using a PERT distribution.

Step 2. Probability of AGM infesting a ship

We estimated the likelihood that AGM would infest any given vessel using U.S. Customs and Border Protection (CBP) inspection data from 2006 to 2007 for ships coming from Japan (USDA-APHIS, 2008) (Table 4).

We used a Beta distribution to model this step where *s* = the number of infested ships (2) and *n* = the total number of ships inspected (295). The Beta distribution was considered appropriate because of the nature of the data, i.e. we knew the number of successes and the number of trials.

Table 4. Number of inspected and AGM infested ships arriving at U.S. ports from Japan between 2006 and 2007.

Year	Inspected Ships	Infested Ships
2007	114	1
2006	181	1
Total	295	2

Step 3. Number of AGM infested ships from Japan arriving at U.S. ports

We modeled this step using a binomial distribution that depended on the number of ships calling at each Japanese port during the AGM flight period that are destined for U.S. ports (step 1) and the probability of AGM infesting a ship (step 2). We also summed the total number of infested ships coming from all Japanese ports each year.

Step 4. Probability of one or more AGM infested ships from Japan arriving at U.S. ports

We modeled this step for each and all ports by applying a Boolean query that determined whether or not at least one infested ship occurred in step 3 above in each of the 10,000 iterations. This probability was equal to the mean of the query.

Step 5. Years until one or more AGM infested ships from Japan arrives at U.S. ports

We modeled this step using a negative binomial distribution that depended on one plus the years until one or more AGM infested ships from each and all Japanese ports arrives at U.S. ports and the associated probability (step 4).

D. Results and Discussion

Our simulation model estimated that there was a 98.78 percent chance of one or more AGM infested ships from Japan arriving at U.S. ports each year in the absence of specific mitigations (Figures 16 and 17). The 5th, mean and 95th percentiles for number of AGM infested ships arriving from Japan were: 2; 10.526 and 24 (Figures 16 and 17, Table 5).

Our results indicate that the Japan maritime ship pathway has high potential for facilitating AGM arrival at U.S. ports. Our model also identified the highest risk Japanese ports where greater inspection resources could be focused to reduce the likelihood of AGM arriving at U.S. ports from Japan (Tables 5 and 6).

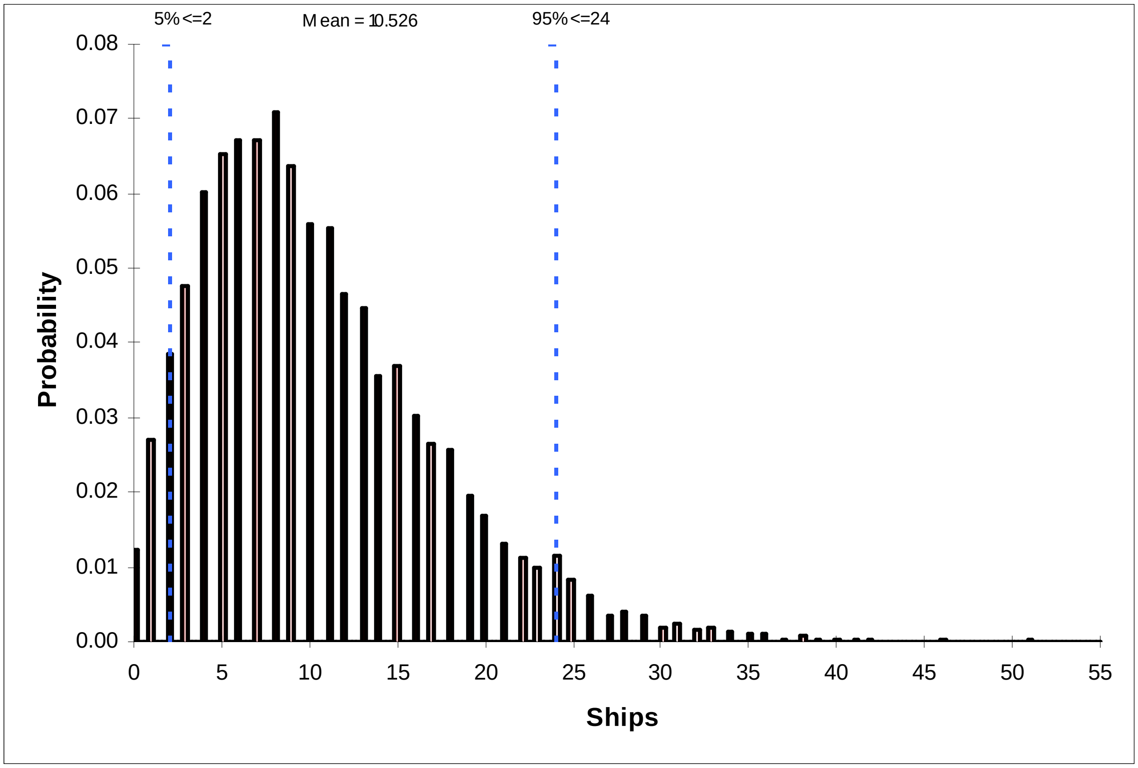


Figure 16. Relative frequency histogram for the estimated annual number of AGM infested ships arriving at U.S. ports from Japan.

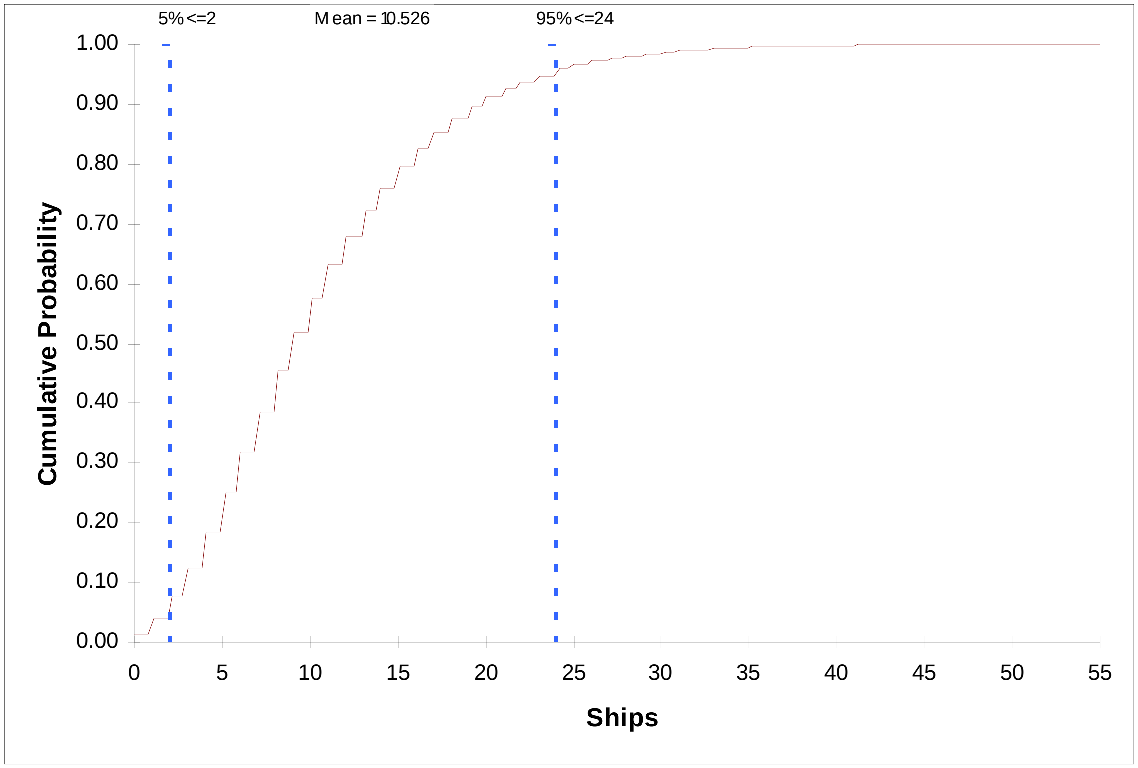


Figure 17. Cumulative distribution function for the estimated annual number of AGM infested ships arriving at U.S. ports from Japan.

Table 5. Estimated annual number of infested ships arriving at U.S. ports from Japan.

Port	5th%tile	Mean	95th%tile	Port	5th%tile	Mean	95th%tile
Akita	0	0.020	0	Muroran	0	0.051	0
Chiba	0	0.568	2	Nagasaki	0	0.042	0
Fukuyama	0	0.100	1	Nagoya	0	1.190	4
Funakawa	0	0.010	0	Nakanoseki	0	0.010	0
Gamagori	0	0.051	1	Niigata	0	0.020	0
Hachinohe	0	0.010	0	Niihama	0	0.101	1
Hakata	0	0.095	1	Numakuma	0	0.030	0
Hakodate	0	0.040	0	Oita	0	0.080	1
Higashi-Harima	0	0.021	0	Omaezaki	0	0.009	0
Hikari	0	0.010	0	Onahama	0	0.059	1
Hirohata	0	0.011	0	Osaka	0	0.608	2
Hiroshima	0	0.171	1	Oshima	0	0.021	0
Hitachi	0	0.009	0	Otaru	0	0.031	0
Ichihara	0	0.010	0	Saganoseki	0	0.011	0
Imabari	0	0.010	0	Sakai	0	0.052	1
Ishigaki	0	0.010	0	Sakaide	0	0.031	0
Ishikariwan Shinko	0	0.010	0	Sakaiminato	0	0.009	0
Ishinomaki	0	0.019	0	Sasebo	0	0.031	0
Iwagi	0	0.019	0	Shibushi	0	0.030	0
Iwakuni	0	0.020	0	Shikama	0	0.029	0
Kagoshima	0	0.030	0	Shimizu	0	0.240	1
Kakogawa	0	0.097	1	Shimonoseki	0	0.072	1
Kanazawa	0	0.010	0	Shimotsu	0	0.019	0
Kanda	0	0.061	1	Tamano	0	0.020	0
Kanokawa	0	0.010	0	Tobata	0	0.010	0
Kashima	0	0.232	1	Tokuyama	0	0.079	1
Kawasaki	0	0.330	1	Tokyo	0	1.035	3
Kinuura	0	0.121	1	Tomakomai	0	0.050	0
Kisarazu	0	0.080	1	Toyohashi	0	0.585	2
Kobe	0	0.994	3	Tsuneishi	0	0.021	0
Kochi	0	0.010	0	Tsuruga	0	0.011	0
Kokura	0	0.010	0	Ube	0	0.059	1
Komatsushima	0	0.030	0	Uno	0	0.029	0
Kudamatsu	0	0.021	0	Wakamatsu	0	0.010	0
Kure	0	0.111	1	Wakayama	0	0.030	0
Kushiro	0	0.050	0	Wanishi	0	0.052	1
Maizuru	0	0.021	0	Yatsushiro	0	0.020	0
Marugame	0	0.010	0	Yawata	0	0.030	0
Matsuyama	0	0.029	0	Yokkaichi	0	0.370	2
Mishima-Kawanoe	0	0.051	0	Yokohama	0	1.375	4
Mitsukoshima	0	0.021	0	Yokosuka	0	0.114	1
Mizushima	0	0.291	1	All Ports	2	10.526	24
Moji	0	0.020	0				

Table 6. Estimated years until one or more infested ships arrive at U.S. ports from Japan.

Port	5th%tile	Mean	95th%tile	Port	5th%tile	Mean	95th%tile
Akita	3	49.502	147	Muroran	2	20.201	59
Chiba	1	2.454	6	Nagasaki	2	24.630	73
Fukuyama	1	10.605	31	Nagoya	1	1.570	3
Funakawa	5	98.053	293	Nakanoseki	6	103.096	308
Gamagori	1	19.960	59	Niigata	3	50.757	151
Hachinohe	5	98.046	293	Niihama	1	10.437	30
Hakata	1	11.124	32	Numakuma	2	33.556	99
Hakodate	2	25.842	76	Oita	1	12.937	38
Higashi-Harima	3	48.072	143	Omaezaki	6	107.518	321
Hikari	6	103.101	308	Onahama	1	17.610	52
Hirohata	5	88.490	264	Osaka	1	2.349	6
Hiroshima	1	6.514	18	Oshima	3	49.018	146
Hitachi	6	112.387	336	Otaru	2	33.116	98
Ichihara	6	102.037	305	Saganoseki	5	93.460	279
Imabari	6	99.008	295	Sakai	1	19.731	58
Ishigaki	6	101.007	301	Sakaide	2	32.999	98
Ishikariwan Shinko	6	102.048	305	Sakaiminato	6	106.388	318
Ishinomaki	3	54.344	162	Sasebo	2	33.451	99
Iwagi	3	52.083	155	Shibushi	2	33.782	100
Iwakuni	3	51.020	152	Shikama	2	34.479	102
Kagoshima	2	34.017	101	Shimizu	1	4.819	13
Kakogawa	1	10.880	32	Shimonoseki	1	14.492	42
Kanazawa	6	104.203	311	Shimotsu	3	51.821	154
Kanda	1	16.921	50	Tamano	3	49.760	148
Kanokawa	6	101.008	302	Tobata	6	99.018	295
Kashima	1	4.982	14	Tokuyama	1	13.280	39
Kawasaki	1	3.683	10	Tokyo	1	1.685	4
Kinuura	1	8.858	25	Tomakomai	2	20.619	61
Kisarazu	1	13.105	38	Toyohashi	1	2.413	6
Kobe	1	1.734	4	Tsuneishi	3	48.544	144
Kochi	6	102.043	305	Tsuruga	5	92.585	276
Kokura	6	99.987	298	Ube	1	17.638	52
Komatsushima	2	33.444	99	Uno	2	34.840	103
Kudamatsu	3	47.617	142	Wakamatsu	6	105.247	314
Kure	1	9.628	28	Wakayama	2	33.675	100
Kushiro	2	20.494	60	Wanishi	1	19.799	58
Maizuru	3	48.080	143	Yatsushiro	3	49.257	147
Marugame	6	99.999	298	Yawata	2	33.333	99
Matsuyama	2	35.208	104	Yokkaichi	1	3.381	9
Mishima-Kawanoe	2	20.407	60	Yokohama	1	1.481	3
Mitsukoshima	3	49.020	146	Yokosuka	1	9.390	27
Mizushima	1	4.129	11	All Ports	1	1.012	1
Moji	3	51.549	153				

V. Pathway-Initiated Risk Assessment: Asian Gypsy Moth (Lepidoptera: Lymantriidae: *Lymantria dispar* (Linnaeus)) from Japan into the United States on Maritime Ships.

A. Introduction

In this section we conducted an assessment that analyzed the risk of AGM introduction into the United States via infested ships arriving from Japan. Our evaluation was done in conformity with relevant international standards, i.e. it was informed based on the guidelines provided by IPPC. These guidelines were enhanced with detailed spatial and quantitative analyses as detailed below. Our risk assessment characterized the risk associated with AGM in terms of regulatory standards and using a combination of methodological approaches, as appropriate.

B. Methods

1. Qualitative Risk Assessment

We used the USDA-APHIS-PPQ "Guidelines for Pathway-Initiated Pest Risk Assessments" version 5.02 (2000) to evaluate the introduction potential of AGM into the United States from Japan on maritime ships. Specifically, we used steps 5 (Assess Consequences of Introduction), 6 (Assess Introduction Potential) and 7 (Conclusion/Phytosanitary Measures: Pest Risk Potential of Quarantine Pests) in the guidelines to characterize the risk associated with AGM. These guidelines conform to the international terms and standards put forth by the International Plant Protection Convention (IPPC) and the North American Plant Protection Organization (NAPPO) regarding pathway initiated pest risk assessment (FAO, 1996, 1999; NAPPO, 1996; USDA-APHIS, 2000).

2. Quantitative Modeling

We used the same @Risk simulation settings here that were used in the pathway analysis. The probability distributions we used in this section were the Beta, binomial and PERT (Table 3).

We provided summary statistics for specified model outputs. We also reported certain model outputs graphically using a cumulative distribution function (see pathway analysis) or probability density function (pdf).

The pdf graphically visualizes probability distributions for continuous variables (Vose, 2000). With the pdf, the *y*-axis cannot be used to infer the likelihood of a value on the *x*-axis because the modeled variables are continuous and the area under a point is zero.

3. Climatological Modeling

We used Sheehan's (1992) degree day (DD) model for male *Lymantria dispar* to inform the climatological model (Appendix 2). We used this information to map at-risk areas in the United States based on 10 year historical climate data at a 10 km^2 resolution (NAPPFAST, 2007).

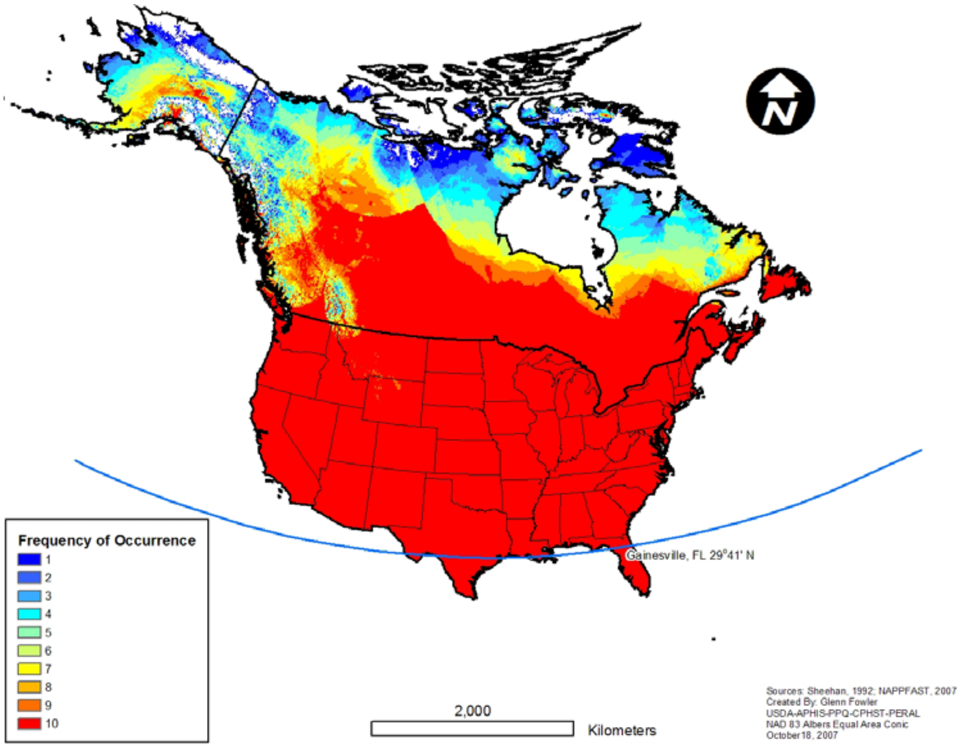
C. Assess Consequences of Introduction

1. Risk Element 1: Climate-Host Interaction

This risk element evaluates the potential host range of AGM in the United States based on climate. The USDA Plant Hardiness Zones (USDA-ARS, 1990) are used to characterize the risk of establishment in the United States (USDA-APHIS, 2000). The risk ratings are defined:

Low (1): Potential establishment in 1 Plant Hardiness Zone.
Medium (2): Potential establishment in 2 or 3 Plant Hardiness Zones.
High (3): Potential establishment in 4 or more Plant Hardiness Zones.

Our risk map indicated that AGM could complete its life cycle throughout most of the continental United States (Figure 18). We note that AGM may have difficulty establishing below 29°41' North due to warm winter temperatures disrupting egg diapause (Allen *et al*., 1993). Based on the location of selected host (see Risk Element 2: Host Range) and the climate risk map we estimated that AGM could establish in USDA Plant Hardiness Zones 2 to 10 (USDA-ARS, 1990). This is a robust estimate for potential establishment area because of AGM's broad host range (AFFA, 2001; CABI, 2006; USDA-APHIS, 2003). The score for this risk element is **High (3)**.



Sources: Sheehan, 1992; NAPPFAST, 2007
Created By: Glenn Fowler
USDA-APHIS-PPQ-CPHST-PERAL
NAD 83 Albers Equal Area Conic
October 18, 2007

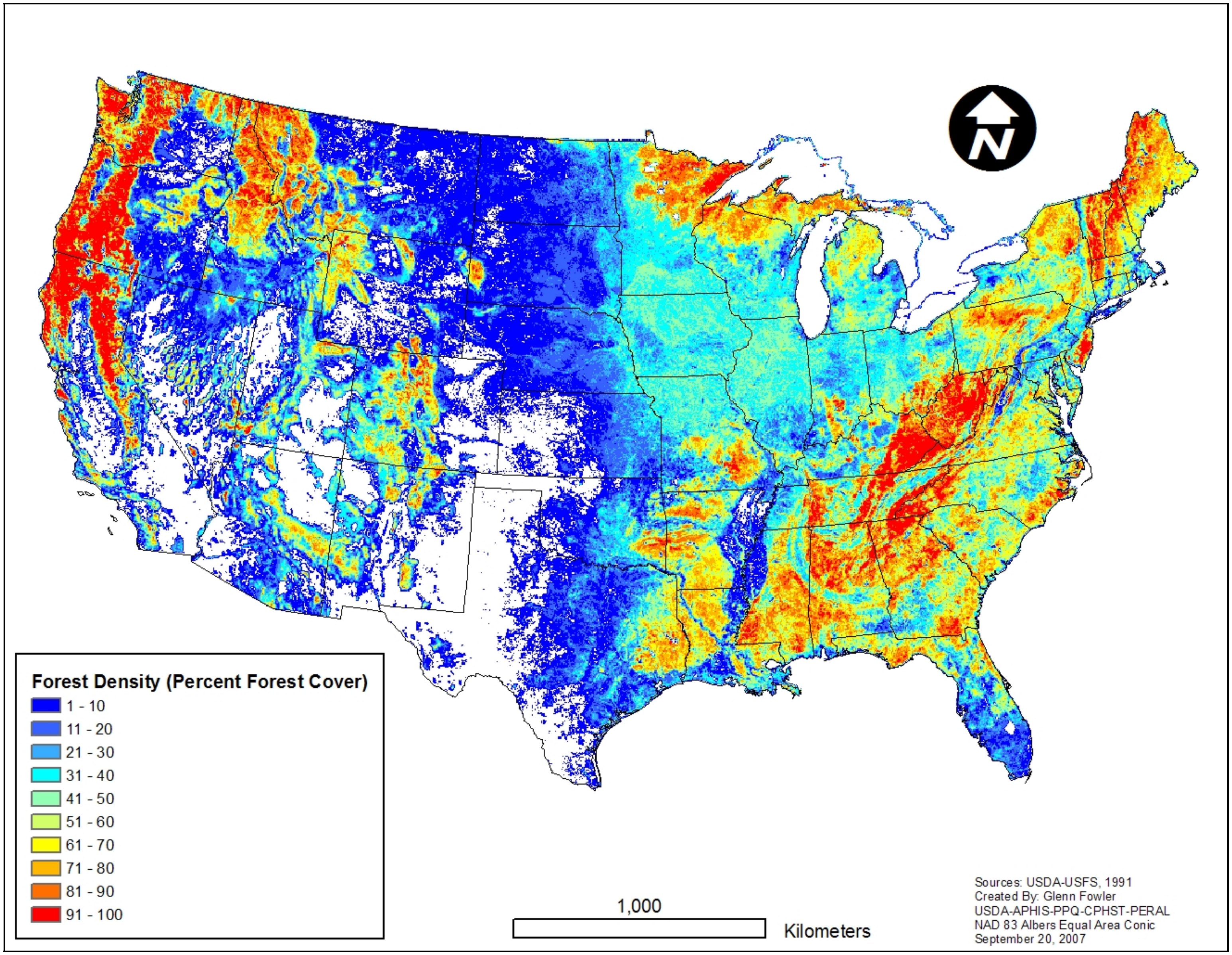
Figure 18. Climate match for AGM in the continental United States and Canada. Climate match indicates areas where enough degree days have accumulated for AGM to complete a generation. Values are expressed in frequency of occurrence based on historical 10 year climate data (1997 to 2006).

2. Risk Element 2: Host Range

This risk element evaluates AGM's ability to colonize hosts. The risk ratings are defined (USDA-APHIS, 2000):

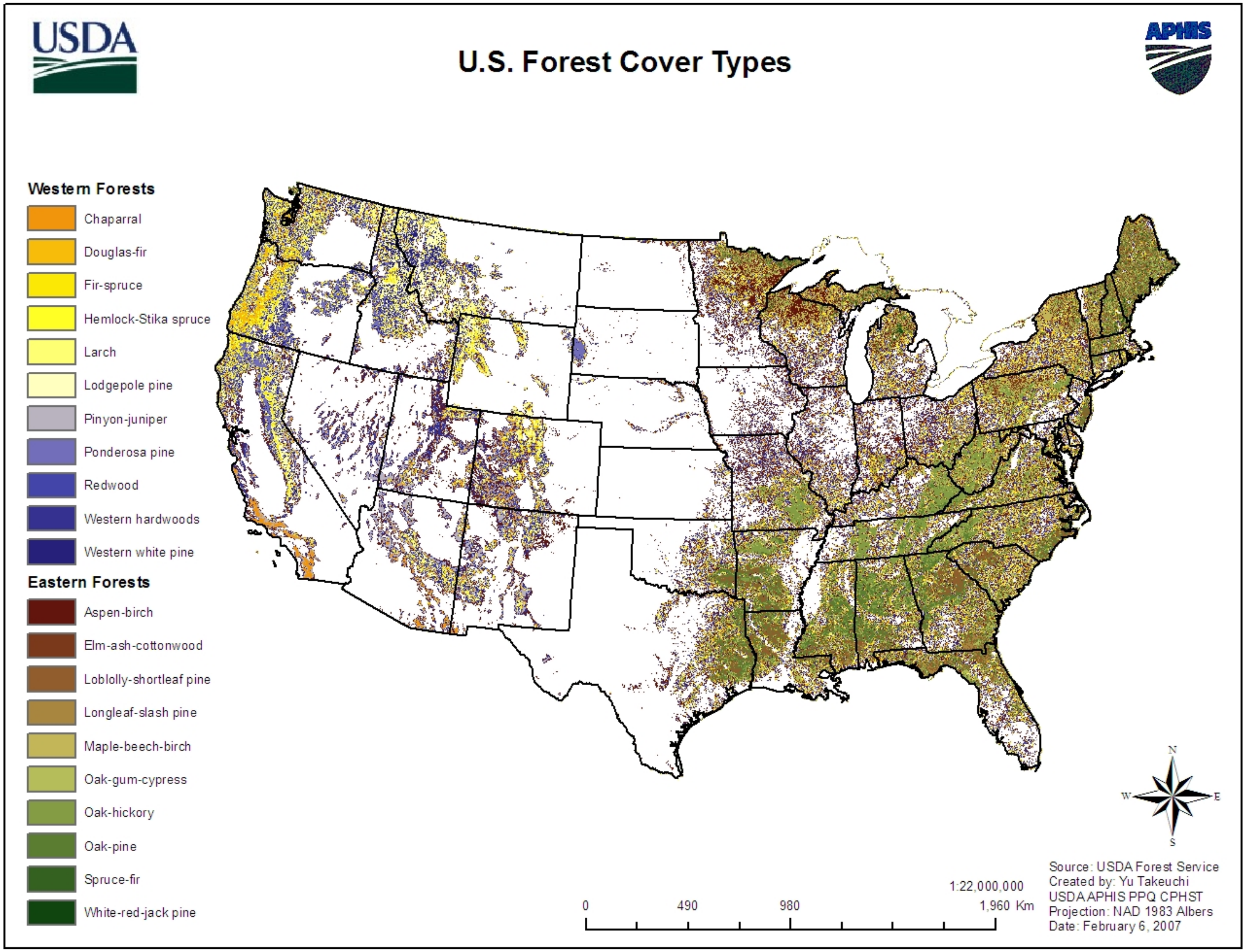
Low (1): Pest attacks a single species or multiple species within a single genus.
Medium (2): Pest attacks multiple species within a single plant family.
High (3): Pest attacks multiple species among multiple plant families.

AGM has a broader host range than EGM, attacking over 600 plant species in at least 18 families (AFFA, 2001; CABI, 2006; USDA-APHIS, 2003). Primary hosts are oaks (*Quercus* sp.) while other hosts attacked include: apple (*Malus* sp.), ash (*Fraxinus* sp.), beech (*Fagus* sp.), birch (*Betula* sp.), corn (*Zea mays*), hickory (*Carya* sp.), larch (*Larix* sp.), maple (*Acer* sp.), pine (*Pinus* sp.), soybean (*Glycine max*), spruce (*Picea* sp.) and stone fruit (*Prunus* sp.) (CABI, 2006). The AGM host range includes multiple species in multiple plant families (Figures 19 to 24). The score for this risk element is **High (3)**.



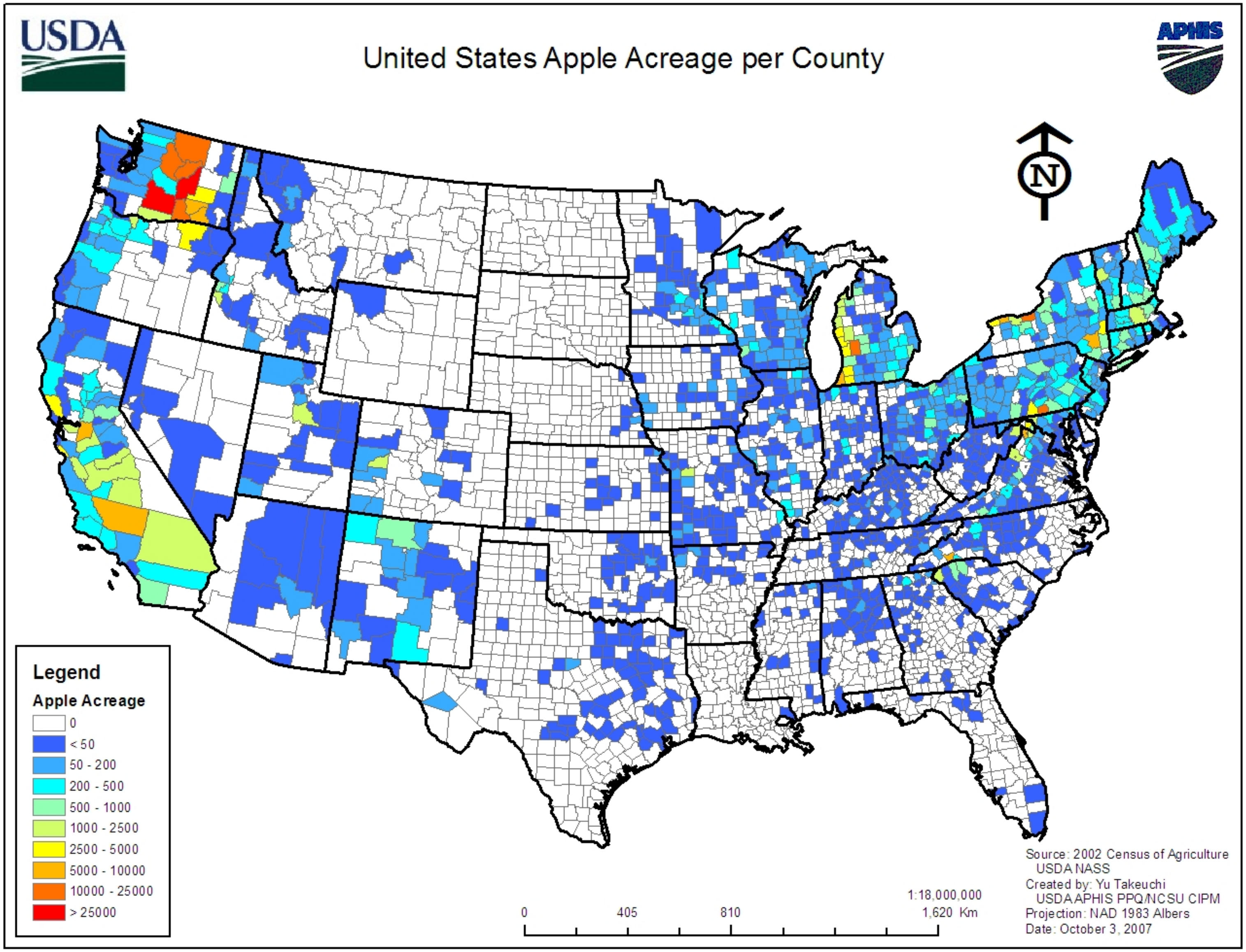
Sources: USDA-USFS, 1991
Created By: Glenn Fowler
USDA-APHIS-PPQ-CPHST-PERAL
NAD 83 Albers Equal Area Conic
September 20, 2007

Figure 19. Forest density (percent of forest cover) in the continental United States.



Source: USDA Forest Service
Created by: Yu Takeuchi
USDA APHIS PPQ CPHST
Projection: NAD 1983 Albers
Date: February 6, 2007

Figure 20. Forest cover types in the continental United States.



Source: 2002 Census of Agriculture
USDA NASS
Created by: Yu Takeuchi
USDA APHIS PPQ/NCSU CIPM
Projection: NAD 1983 Albers
Date: October 3, 2007

Figure 21. Apple production acreage per county.

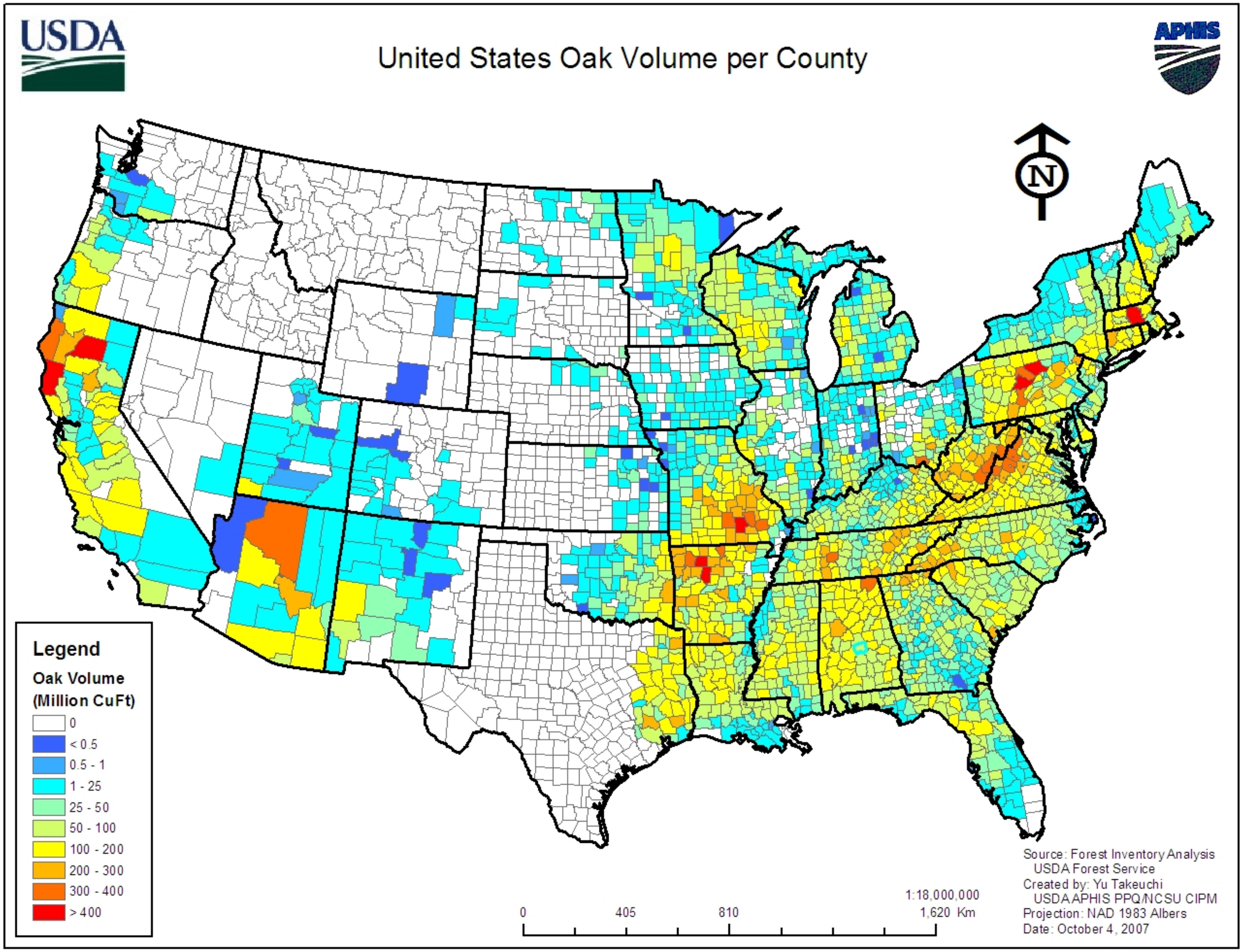
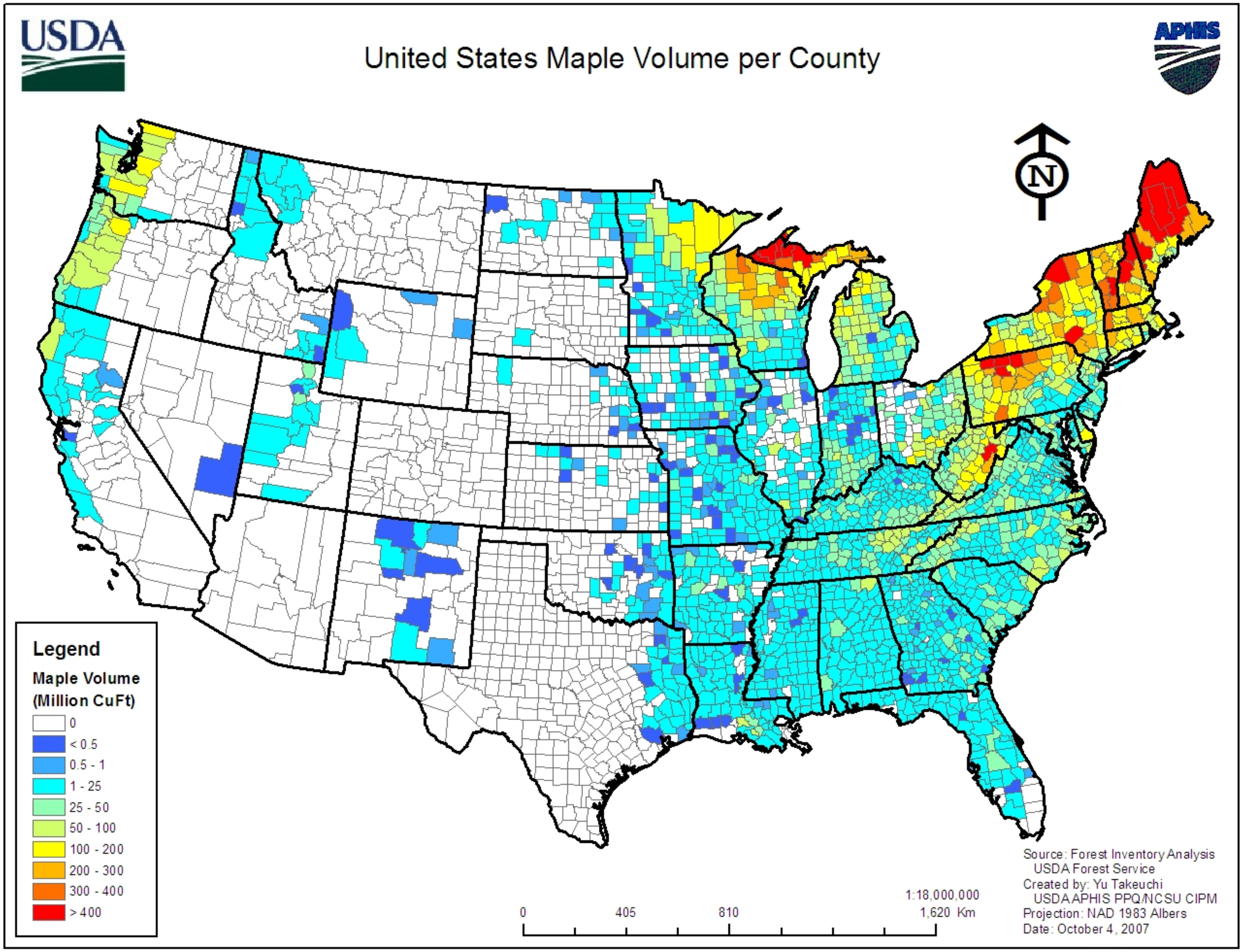


Figure 22. Oak (*Quercus* spp.) volume per county in the continental United States.



United States Maple Volume per County

Source: Forest Inventory Analysis
USDA Forest Service
Created by: Yu Takeuchi
USDA APHIS PPQ/NCSU CIPM
Projection: NAD 1983 Albers
Date: October 4, 2007

Figure 23. Maple (*Acer* spp.) volume per county in the continental United States.

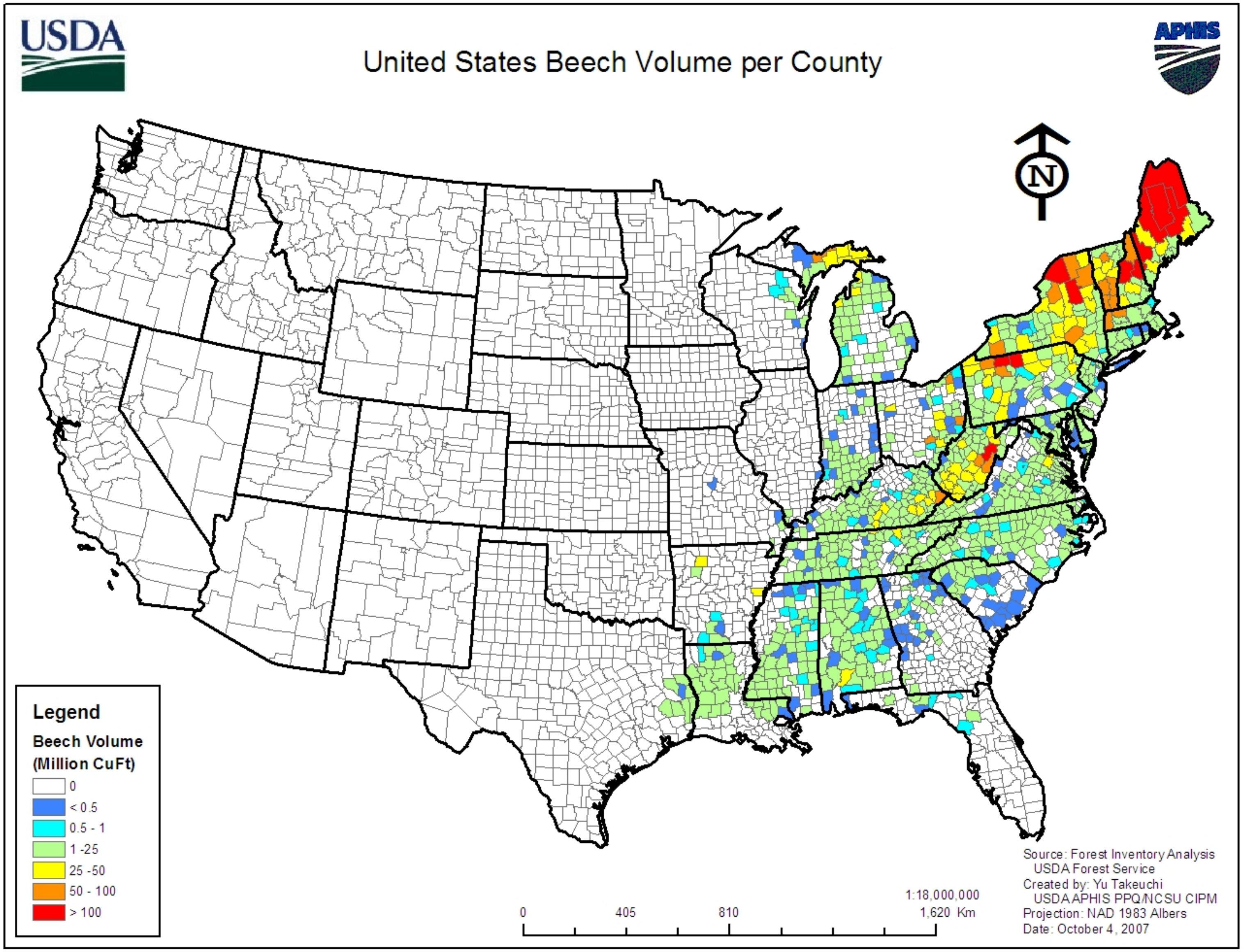


Figure 24. Beech (*Fagus* spp.) volume per county in the continental United States.

3. Risk Element 3: Dispersal Potential

This risk element considers AGM's ability to disperse over long distances and its propensity for reproduction (USDA-APHIS, 2000). The risk ratings are defined:

Low (1): Pest has neither high reproductive potential nor rapid dispersal capability.
Medium (2): Pest has either high reproductive potential or is capable of rapid dispersal.
High (3): Pest has high reproductive potential, e.g., many generations per year, many offspring per generation and is capable of rapid dispersal, e.g., over 10 kilometers per year via its own power or through other means (wind, water, human transport).

AGM is univoltine, but individual egg masses may contain up to 1,200 eggs (CABI, 2006). AGM females are capable of flight and may disperse up to 40 kilometers (USDA-APHIS, 2003). AGM can also be dispersed by human mechanisms, e.g. egg masses on vehicles, transport containers and wind via larval ballooning (CABI, 2006; MAF, 2004). The score for this risk element is **High (3)**.

4. Risk Element 4: Economic Impact

This risk element evaluates AGM's ability to cause economic damage. The following impacts are considered (USDA-APHIS, 2000): 1) ability to lower host crop yield, e.g. by causing plant mortality, vectoring diseases, *etc*. 2) ability to lower commodity value, e.g., by increasing the cost of production, lowering market price, etc. and 3) ability to cause loss of foreign or domestic markets due to the presence of a new quarantine pest. The risk ratings are defined:

Low (1): Pest causes any one or none of the above impacts.
Medium (2): Pest causes any two of the above impacts.
High (3): Pest causes all three of the above impacts.

AGM could impact many high value commodities in the United States (Table 7). Oaks are highly susceptible to defoliation by *L. dispar* (CABI, 2006). Larvae consume large quantities of leaves, buds and flowers (CABI, 2006; WSDA, 2004). In the Eastern United States, an average of four million acres of forestland is defoliated by EGM annually (NAPIS, 1993). This feeding can reduce tree growth, and two to three subsequent years of complete defoliation can result in tree mortality (CABI, 2006; Munson, pers. comm., 2004).

Table 7. Annual economic value of selected commodities that could be impacted by AGM.

Commodity	**Value ($1,000)**	**Year**	**Source**
Apple	1,622,135	2002	CABI, 2006; USDA-NASS, 2003
Apricot	28,326	2002	CABI, 2006; USDA-NASS, 2003
Beech Rough Lumber[1]	58,003	1997	CABI, 2006; USDC-USCB, 1999
Blueberries	209,707	2002	CABI, 2006; USDA-NASS, 2003
Cherries	301,573	2002	CABI, 2006; USDA-NASS, 2003
Lime	1,732	2002	CABI, 2006; USDA-NASS, 2003
Oak Rough Lumber[1]	1,229,999	1997	CABI, 2006; USDC-USCB, 1999
Pears	297,410	2002	CABI, 2006; USDA-NASS, 2003
Pistachios	333,000	2002	CABI, 2006; USDA-NASS, 2003
Plums and Prunes	202,161	2002	CABI, 2006; USDA-NASS, 2003
Softwood Lumber[1]	14,106,372	1997	CABI, 2006; USDC-USCB, 1999
Total	18,390,418		

[1] Refers to lumber that is not edge worked and not made from purchased lumber.

Economic losses due to EGM in the United States average about 30 million annually (WSDA, 2004). Quarantines on the movement of timber and crops, in response to EGM, also result in economic loss. AGM is considered a more threatening pest than EGM because: 1) AGM females are capable of long distance flight and 2) AGM has a broader host range than EGM (AFFA, 2001; CABI, 2006; USDA-APHIS, 2003; WSDA, 2004; Zlotina *et al.*, 1999).

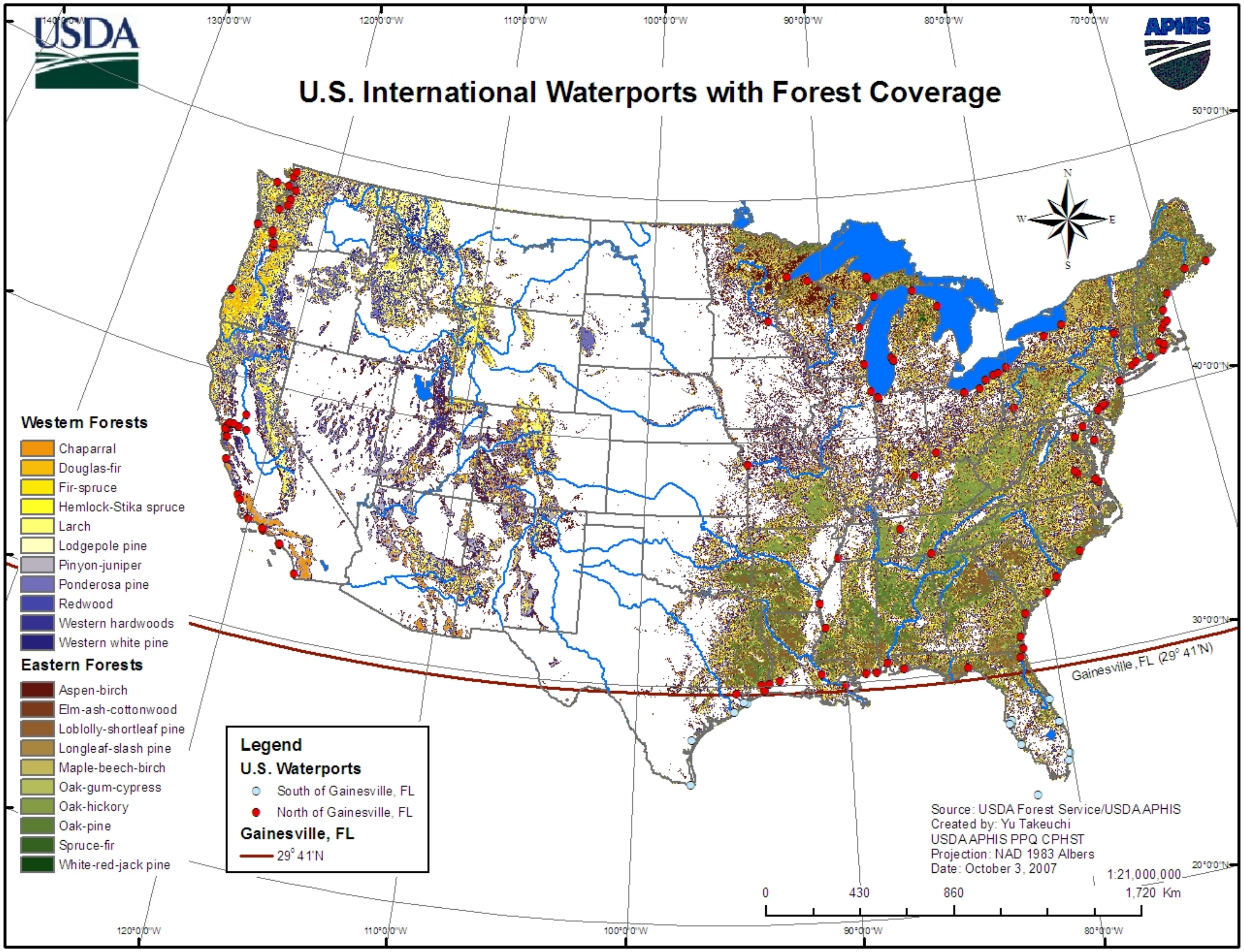
We estimated AGM economic impacts by calculating potential tree volume damage if it were introduced and dispersed from the 146 international water ports in the United States (Figures 25 and 26). We divided the conterminous United States into seven regions (Pacific North, Pacific South, Mid, Mid North, Northeast, Northeast Coast, and South) and categorized U.S. international ports in each region (Figure 26, Appendix 17). We did not include international water-ports located south of Gainesville, Florida (29°41' North) in this analysis since AGM is a temperate species and would have difficulty establishing in tropical areas (Allen *et al.*, 1993). We calculated host tree volumes (*Quercus*, *Acer,* and *Fagus* species) at the county level using USDA Forest Service Forest Inventory and Analysis data (FIA, 2007). We assumed AGM is capable of flying 40 kilometers annually, and mapped risk areas in 40 kilometer increments from water-ports over a five year period (Figure 26). The potential forest volume damage in each region was calculated by summing tree volumes of host species in the counties which intersected the at-risk areas (Table 8).

AGM exhibits the ability to cause the three economic impacts listed above. The score for this risk element is **High (3)**

Table 8. Annual potential tree volume damage caused by AGM after five years in each U.S. region.

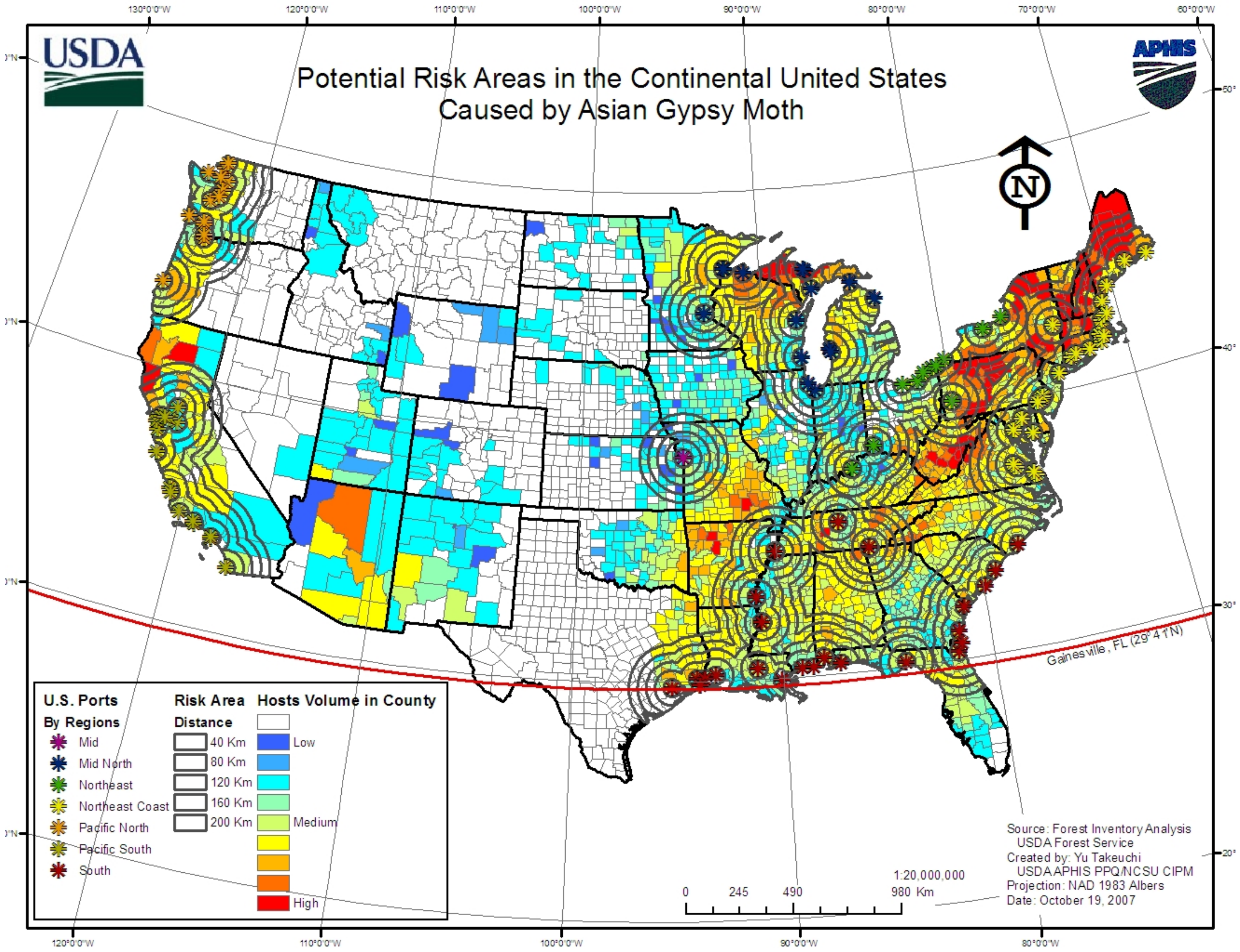
Region	**Year 1** (Million Ft^3)	**Year 2** (Million Ft^3)	**Year 3** (Million Ft^3)	**Year 4** (Million Ft^3)	**Year 5** (Million Ft^3)	**Total** (Million Ft^3)
Pacific North	2,041.31	620.53	359.73	6.52	140.73	3,168.82
Pacific South	1,789.01	636.96	1,067.89	479.05	303.32	4,276.23
Mid	147.85	295.92	698.55	723.66	1,369.24	3,235.22
Mid North	7,075.92	6,224.28	5,950.83	3,279.74	2,457.42	24,988.19
Northeast	5,061.00	7,087.13	10,873.50	12,664.14	13,168.93	48,854.70
Northeast Coast	15,048.25	12,432.69	8,122.02	10,411.45	9,607.21	55,621.63
South	9,800.18	10,670.33	13,188.46	12,657.59	22,039.91	68,356.46
Total[1]	41,043.95	38,212.06	39,678.93	34679.50	24,879.51	178,493.95

1: The total for each year may not exactly be the sum of all the regions from the year because some risk areas are overlapped from different regions. Therefore, summing tree volumes from all the regions is an approximation of the actual total tree damage.



Source: USDA Forest Service/USDA APHIS
Created by: Yu Takeuchi
USDA APHIS PPQ CPHST
Projection: NAD 1983 Albers
Date: October 3, 2007

Figure 25. Locations of international waterports in the continental United States.



Source: Forest Inventory Analysis
USDA Forest Service
Created by: Yu Takeuchi
USDA APHIS PPQ/NCSU CIPM
Projection: NAD 1983 Albers
Date: October 19, 2007

Figure 26. Forecasted spread and impact in the continental United States after five years if Asian gypsy moth were introduced at U.S. ports.

5. Risk Element 5: Environmental Impact

This risk element evaluates AGM's ability to cause environmental damage. Impacts considered are: 1) ability to cause significant, direct environmental impacts, *e.g.,* ecological disruptions, biodiversity reduction, *etc*., 2) ability to have direct impacts on species listed as Endangered or Threatened by the United States Fish and Wildlife Service (if the pest attacks other species within the genus or other genera within the family, and no preference test have been conducted, then the plant is considered a host), 3) ability to have indirect impacts on species listed as endangered or threatened by the United States Fish and Wildlife Service by damaging habitat and 4) ability to introduce a need for chemical or biological control programs (USDA-APHIS, 2000). The risk rating for environmental impact is defined as follows:

Low (1): None of the above would occur.
Medium (2): One of the above would occur.
High (3): Two or more of the above would occur.

EGM causes extensive defoliation in the Eastern U.S. forests (NAPIS, 1993). This defoliation causes habitat destruction and water pollution due to temperature changes, soil runoff and larval fecal deposition (WSDA, 2004). AGM is considered a more threatening pest than EGM because: 1) AGM females are capable of long distance flight and 2) AGM has a broader host range than EGM (AFFA, 2001; CABI, 2006; USDA-APHIS, 2003; WSDA, 2004; Zlotina *et al*., 1999).

Host species for *L. dispar* include 99 species within the genus or genera in the family that are considered Endangered or Threatened (USDI-USFWS, 2004) (Appendix 18). These Endangered or Threatened species could be directly impacted by AGM feeding and indirectly impacted by habitat destruction.

Eradication measures that have been used in response to AGM introduction in the United States include Gypcheck, *Bacillus thuringiensis* var. kurstaki, Diflubenzuron, and mass trapping using pheromone traps (WSDA, 2004).

AGM could cause the four environmental impacts listed above. The score for this risk element is **High (3)**.

6. Risk Rating for Consequences of Introduction (Risk Elements 1 to 5)

The cumulative risk rating for Risk Elements 1 to 5 are considered indicators of AGM's ability to establish, spread and subsequently cause economic and environmental damage (USDA-APHIS, 2000) (Table 9). The cumulative qualitative risk ratings are defined as follows:

Low: 5-8 points
Medium: 9-12 points
High: 13-15 points

Table 9. Risk rating for consequences of introduction of AGM: (Risk Elements 1 to 5).

Risk Element 1: Climate/Host Interaction	Risk Element 2: Host Range	Risk Element 3: Dispersal Potential	Risk Element 4: Economic Impact	Risk Element 5: Environmental Impact	Cumulative Risk Rating
High (3)	High (3)	High (3)	High (3)	High (3)	High (15)

D. Likelihood of Introduction (Survival and Access to Suitable Habitat and Hosts) (Risk Element 6)

This risk element estimates the likelihood that AGM will follow the pathway on maritime ships from Japan and, subsequently, become established in the United States. Risk Element 6 is comprised of six sub-elements (USDA-APHIS, 2000).

In pathway initiated risk assessments, risk sub-element 1, (quantity of commodity imported annually), usually analyzes shipment sizes and these are estimated in units of standard 40-foot long shipping containers. The criteria used to evaluate the risk for this sub-element are:

Low (1 point): < 10 containers/year
Medium (2 points): 10-100 containers/year
High (3 points): > 100 containers/year

However this assessment analyzes the risk associated with AGM on maritime ships. To do this we analyzed the annual quantity of ships, instead of containers, using the same risk scoring criteria, e.g. High (3 points): > 100 ships/year, for this risk sub-element and modified the sub-element title to reflect this change.

Risk sub-elements 2 to 6 are scored, as follows, with regard to the estimated probability of occurrence (USDA-APHIS, 2000):

Low (1): < 0.1% (less than a one in a thousand chance)
Medium (2): 0.1%-10% (between a one in a thousand and a one in ten chance)
High (3): > 10% (greater than a one in ten chance)

Risk sub-elements 1 to 6 are considered a series of independent events that must occur in order for the pest to successfully establish. One risk sub-element does not affect the risk scores for any of the others.

1. Sub-Element 1: Annual Number of Ships Arriving at U.S. Ports that called at Japanese Ports during the AGM Flight Period

To quantify and score this sub-element, we used the output from step 1 in the pathway analysis section: Number of ships calling at Japanese ports during the AGM flight period that are destined for U.S. ports. The 5th, mean and 95th percentiles for the number of ships arriving annually were: 1,039; 1,044 and 1,049 (Figure 27). Because the annual number of ships is greater than 100 per year, the score for this risk sub-element is **High (3).**

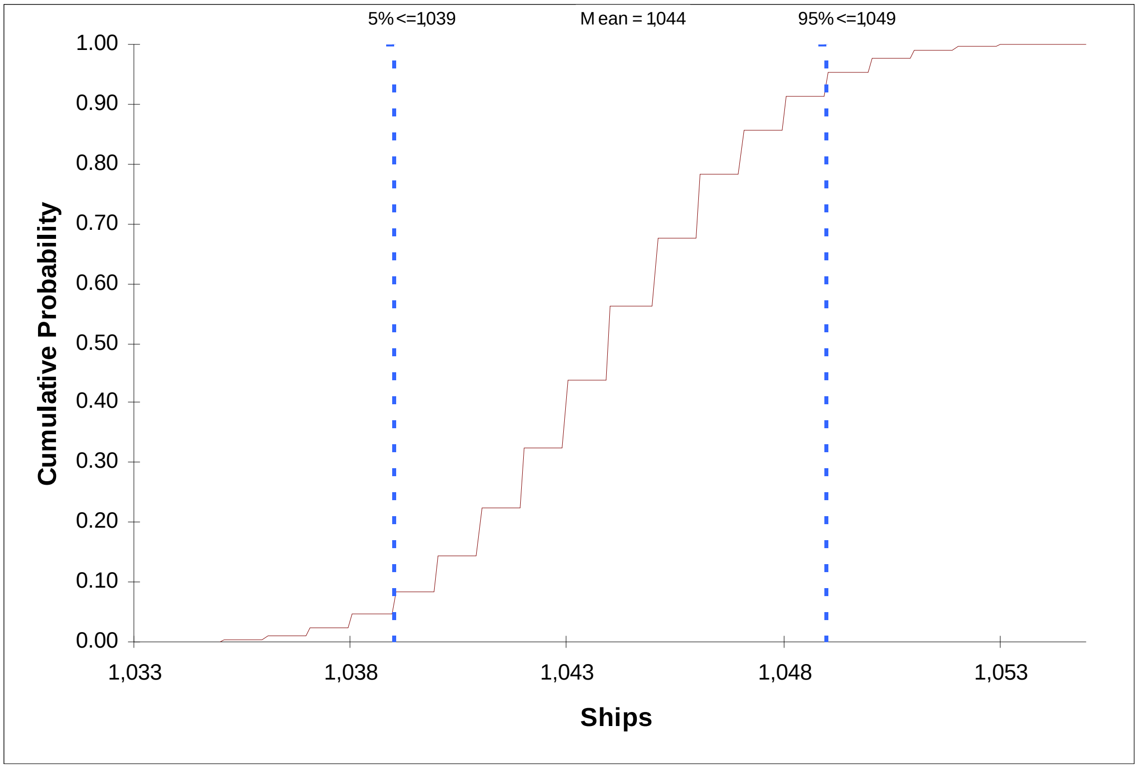


Figure 27. Cumulative distribution function for the annual number of ships arriving at U.S. ports that called at Japanese ports during the AGM flight period.

2. Sub-Element 2: Survive Post-Harvest Treatment

This sub-element considers any manipulation, handling or specific phytosanitary treatment that the commodity is subjected to after harvest (USDA-APHIS, 2000). Post-harvest treatments include washing, culling, chemical treatments and cold storage. When post-harvest treatments do not exist or they are not used, the sub-element is scored as High.

Japan currently has a pre-shipment inspection certification program for AGM (USDA-APHIS, 2007b). Because of the large size of maritime vessels and the small size of AGM egg masses (Figures 2 and 6) it may be difficult to consistently detect them all on the ship superstructure. In the absence of Japanese inspection efficacy data, we robustly scored this risk sub-element **Medium (2)** to account for the presence of a pre-shipment inspection program and the potential difficulty in AGM detection.

3. Sub-Element 3: Survive Shipment

This sub-element estimates the likelihood of AGM surviving maritime shipment from Japan to the United States. Standard shipping conditions are assumed (USDA-APHIS, 2000).

We estimated this step using data from studies conducted by the New Zealand Ministry of Agriculture and Forestry on viable Asian gypsy moth egg masses arriving at New Zealand ports on used vehicles from Japan from 1998 to 1999 (MAF, 2000) (Table 10, Figure 28). We assumed that AGM egg mass survival rates when being shipped from Japan to the United States will be similar to the survival rates from Japan to the New Zealand. This assumption is realistic because the egg stage can last up to 9 months and withstand harsh conditions (MAF, 2004; USDA-APHIS, 1993).

We used a Beta distribution to model this step where *s* = the number of viable egg masses detected (48) and *n* = the total number of egg masses detected (70). The Beta distribution was considered appropriate because of the nature of the data, i.e. we knew the number of successes and the number of trials.

The 5th, mean and 95th percentiles for probability of AGM egg masses surviving shipment were: 0.588; 0.681 and 0.767. Because these values are greater than 0.1 (10%), the score for this risk sub-element is **High (3).**

Table 10. AGM egg mass survival data after shipping (MAF, 2000).

Year	Number of Viable Egg Masses	Number of Egg Masses
1998	12	18
1999	36	52
Total	48	70

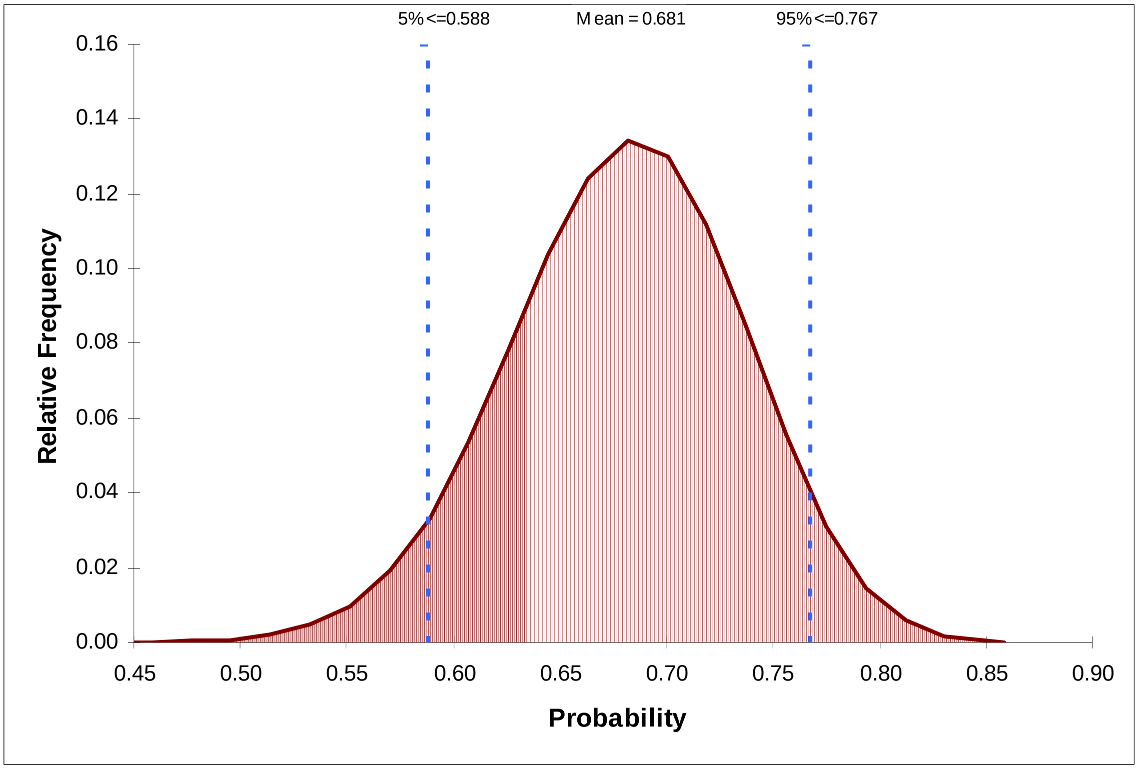


Figure 28. Probability density function for the probability of AGM egg masses surviving shipment from Japan to the United States.

4. Sub-Element 4: Not Detected at the Port of Entry

This risk sub-element estimates the chance that the pest will not be detected upon inspection at the port of entry. Standard inspection protocols for this risk sub-element are assumed for commodities unless special inspection procedures have been implemented (USDA-APHIS, 2000). If no inspection is planned then the risk sub-element is scored as High.

We constructed a probabilistic model to estimate this risk sub-element. The model was composed of steps, e.g. probabilities, quantities and proportions (Auclair *et al.*, 2005). Our model estimated that the 5th, mean and 95th percentiles for the probability of an AGM infested ship not being detected at the port of entry were: 0.830; 0.858 and 0.884 (Figure 29). Our estimates are low because we assumed that an infested ship would be detected 100 percent of the time by CBP. Because these probability values were greater than 0.1 (10%), the score for this risk sub-element is **High (3).**

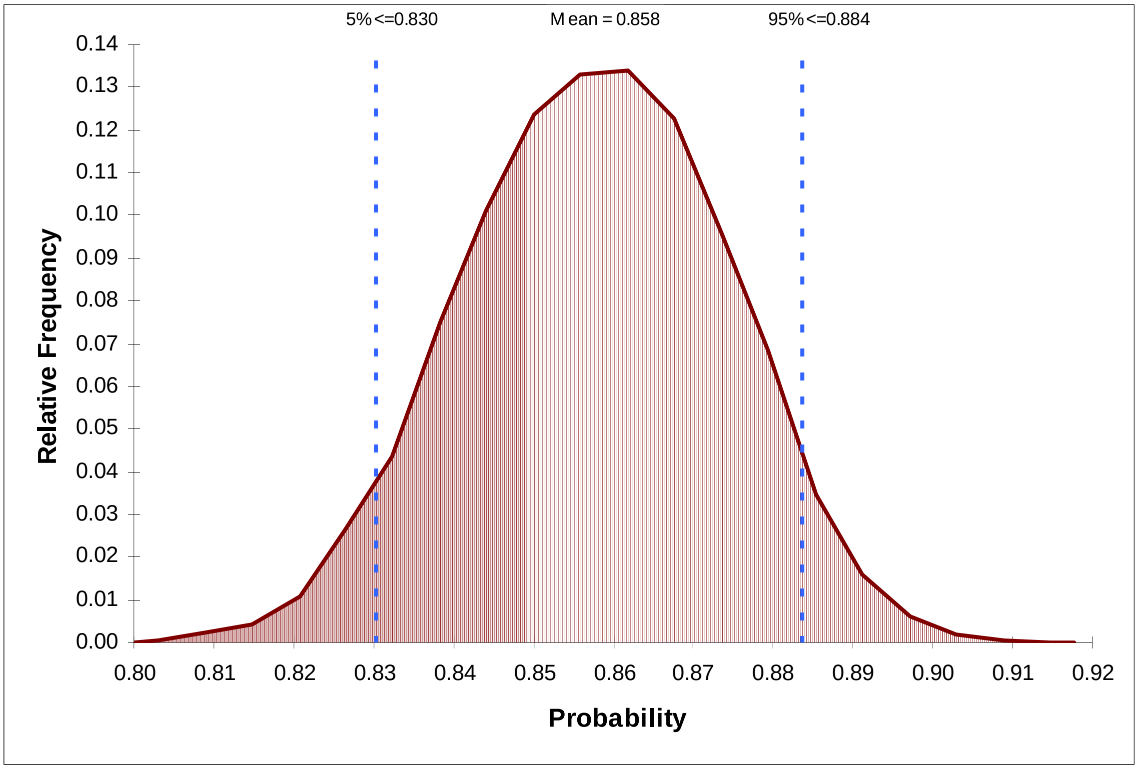


Figure 29. Probability density function for the probability of a ship that called at at-risk Japanese ports during the AGM flight period not being inspected at the U.S. port of entry.

4a. Pathway Model

Step 1. Annual number of ships arriving at U.S. ports from Japan that are inspected at the port of entry

We estimated this step using CBP inspection data for ships coming from Japan in 2006 and 2007 (USDA-APHIS, 2008) (Table 4). We used a PERT distribution to model this step. We used the number of ships inspected in 2007 (114) and 2006 (181) as the minimum and maximum values and the mean (148) as the most likely value.

Step 2. Probability of a ship that called at an at-risk Japanese port during the AGM flight period being inspected at the port of entry

We used a Beta distribution to model this step where *s* = step 1: annual number of ships arriving at U.S. ports from Japan that are inspected at the port of entry and *n* = the output of sub-element 1: annual number of ships arriving at U.S. ports that called at Japanese ports during the AGM flight period. The Beta distribution was considered appropriate because of the nature of the data, i.e. we knew the number of successes and the number of trials. We robustly assumed that all inspections would be on those ships that had called at Japanese ports during the AGM flight period.

Step 3. Probability of a ship that called at an at-risk Japanese port during the AGM flight period NOT being inspected at the port of entry

This step was equal to one minus step 2: probability of a ship that called at an at-risk Japanese port during the AGM flight period being inspected at the port of entry.

5. Sub-Element 5: Imported or Moved Subsequently to an Area with an Environment Suitable for Survival

This risk sub-element estimates the likelihood that AGM will successfully be introduced and moved to a suitable climate for survival (USDA-APHIS, 2000). This estimate is based on import locations, subsequent cargo movement, and associated climate in these areas. Only import locations and associated climate in these areas are considered in this pest risk assessment since cargo is not analyzed.

AGM can move naturally from maritime vessels to land by: 1) adult flight and 2) larval ballooning (Brackett, 1996; MAF, 2004; USDA-APHIS, 2003a; Zlotina *et al*., 1999). AGM females are capable of flight and may disperse up to 40 km (USDA-APHIS, 2003). Larval ballooning can transport AGM several kilometers (CABI, 2006).

The egg stage can last up to 9 months and withstand harsh conditions (MAF, 2004; USDA-APHIS, 1993). Because egg masses can be attached to cargo, containers and maritime ships, the egg stage is capable of dispersing long distances via human transport mechanisms (CABI, 2006; MAF, 2004).

AGM has been detected in California, Idaho, North Carolina, Oregon, South Carolina, Texas and Washington State (Brackett, 1996; ODA, 2000; USDA-APHIS, 2007a; WSDA, 2004) (Table 1, Figures 3 to 5). Our climate match analysis demonstrated that AGM could complete its life cycle throughout the continental United States (Figure 18). Based on this analyses and the frequency of AGM introductions into the United States, the score for this risk sub-element is **High (3).**

6. Sub-Element 6: Come into Contact with Host Material Suitable for Reproduction

This risk sub-element estimates the likelihood that AGM will locate suitable hosts for survival upon its arrival into the United States (USDA-APHIS, 2000). The complete host range of the pest species is considered in the ranking process.

AGM has a broader host range than the European strain and can attack over 600 species of plants within at least 18 families (AFFA, 2001; CABI, 2006; USDA-APHIS, 2003), surviving on crops, hardwoods and softwoods (CABI, 2006). AGM's primary hosts are oaks (*Quercus* sp.). However, other hosts include: apple (*Malus* sp.), ash (*Fraxinus* sp.), beech (*Fagus* sp.), birch (*Betula* sp.), corn (*Zea mays*), hickory (*Carya* sp.), larch (*Larix* sp.), maple (*Acer* sp.), pine (*Pinus* sp.), soybean (*Glycine max*), spruce (*Picea* sp.) and stone fruit (*Prunus* sp.).

To refine the analysis for this sub-element, we geospatially visualized U.S. port locations in relation to forest distribution (Figure 25). Our map demonstrated that 114 of 127 ports (89.8 percent) were near at-risk forested areas (Figures 25 and 26). Based on this analysis, AGM's broad host range and the female's ability to fly and locate hosts, the score for this risk sub-element is **High (3).**

7. Risk Rating for Likelihood of Introduction (Risk Element 6)

Risk Element 6, an estimate for the risk of pest introduction, is scored by summing risk sub-elements 1 to 6 (USDA-APHIS, 2000) (Table 11). The risk rating for Risk Element 6 is defined:

Low: 6-9 points
Medium: 10-14 points
High: 15-18 points

Table 11. Risk Rating for Risk Element 6: Likelihood of AGM Introduction: (Risk Sub Elements 1 to 6).

Sub-Element 1: Quantity Imported Annually	Sub-Element 2: Survive Post-Harvest Treatment	Sub-Element 3: Survive Shipment	Sub-Element 4: Not Detected at Port of Entry	Sub-Element 5: Moved to Suitable Habitat	Sub-Element 6: Contact with Host Material	Cumulative Risk Rating
High (3)	Medium (2)	High (3)	High (3)	High (3)	High (3)	High (17)

E. Conclusion/Pest Risk Potential: Pests Requiring Phytosanitary Measures

The Pest Risk Potential is calculated by summing the Consequences of Introduction with the Likelihood of Introduction risk rating (USDA-APHIS, 2000) (Table 12). The Pest Risk Potential is defined:

Low: 11-18 points
Medium: 19-26 points
High: 27-33 points

Table 12. Pest Risk Potential of AGM.

Consequences of Introduction Cumulative Risk Rating	Likelihood of Introduction Cumulative Risk Rating	Pest Risk Potential
High (15)	High (17)	High (32)

F. Results and Discussion

AGM scored High in the Pest Risk Potential ranking, which was based on the USDA guidelines for pathway initiated pest risk assessments (USDA-APHIS, 2000) (Table 12). The guidelines provide the following recommendations based on the Pest Risk Potential score:

Low: The pest does not require specific mitigations; normal port of entry inspection procedures are adequate to provide phytosanitary security.
Medium: Phytosanitary procedures for the pest may be necessary.
High: The pest is a significant threat; therefore specific phytosanitary measures are recommended. Normal port of entry inspections will not provide phytosanitary security.

AGM has been frequently introduced into the United States (Brackett, 1996; ODA, 2000; USDA-APHIS, 2007a; WSDA, 2004) (Table 1, Figures 3 to 5). Given the potential for economic and environmental damage associated with AGM it is prudent to minimize the likelihood of its introduction. In 1993 a cooperative program between the United States and Russia was created to address similar concerns regarding AGM (USDA-USFS, 2001). As a result of this partnership, inspection protocols for AGM were implemented at both Russian and U.S. ports (USDA-USFS, 2001; USDA-APHIS, 2003a) (Appendix 19). As a result of similar concerns regarding AGM, Japan and the United States formed a similar partnership and a pre-shipment port inspection program was implemented in that country on June 1, 2007 (USDA-APHIS, 2007b). Our updated pest risk assessment indicates that it is prudent to maintain this pre-shipment port inspection program. Based on the Russian program (USDA-APHIS, 2003a) the following general measures are suggested:

1) Vessels traveling from Japanese ports to U.S. ports (between March and October (Figure 11)) with susceptible host components, in or adjacent to ports, should be inspected for AGM prior to departure. A certificate indicating that the containers are AGM-free should also be provided.
2) A database of high-risk vessels traveling from Japan to the United States should be generated and placed in the “AGM Vessel Alert List”.
3) Vessels traveling from major Japanese ports between during their associated AGM flight period should be considered high risk.

4) High risk vessels without a certificate indicating they are AGM free should be boarded and inspected for AGM by U.S. regulatory personnel prior to port entry.
5) High risk vessels with a certificate indicating that they are AGM free may be inspected at the port.
6) Infested ships should be turned away from the United States.
7) High risk vessels that pass inspection should be monitored daily for AGM at ports.

Specifics regarding the inspection program can be found in “Vessel Inspection Guidelines – Asian Gypsy Moth (AGM)” (USDA-APHIS, 2003a) (Appendix 19).

VI. Summary and Conclusions

This pest risk assessment was comprised of three analyses that characterized the risks to the United States associated with AGM on ships arriving at U.S. ports from Japan. We first geospatially characterized the risk of infestation at Japanese maritime ports based on forests, land cover and volumes of U.S. bound ships that called during the flight period. We then conducted a quantitative pathway analysis that estimated the approach rate of infested ships at U.S. ports coming from Japan. Finally, we generated a pest risk assessment that characterized the risk to the United States if AGM were introduced from infested ships. The conclusions of each analysis and a discussion of their implications are provided below.

A. Geospatial Risk Evaluation of Japanese Ports

We geospatially evaluated risks at each port based on the number of calling U.S. bound vessels during the AGM flight periods and proximity to suitable habitat. Our results indicated that all of the ports receiving U.S. bound ships are located within 40 kilometers (AGM's estimated flight distance) of forest and/or potential secondary host habitat, e.g. cropland. Consequently, it is possible for AGM infestation to occur on ships calling at these ports. Our geospatial analysis and resulting risk ratings characterized the risk associated with each port in relative quantitative terms. This information can be used to inform phytosanitary practices, e.g. surveys, which mitigate AGM infestation and movement via the ship pathway.

B. Quantitative Pathway Analysis: Asian Gypsy Moth (Lepidoptera: Lymantriidae: *Lymantria dispar* (Linnaeus)) from Japan into the United States on Maritime Ships

Our pathway analysis estimated that there was a 98.78 percent chance of one or more AGM infested ships from Japan arriving at U.S. ports each year with current shipping practices. The 5th, mean and 95th percentiles for number of AGM infested ships arriving from Japan were: 2; 10.526 and 24. Our results indicate that the Japan maritime ship pathway has high potential for facilitating AGM arrival at U.S. ports and that high infestation risks exist at several locations in Japan.

C. Pathway-Initiated Risk Assessment: Asian Gypsy Moth (Lepidoptera: Lymantriidae: *Lymantria dispar* (Linnaeus)) from Japan into the United States on Maritime Ships

Our pest risk assessment was done in conformity with relevant international standards. AGM scored High with regard to Pest Risk Potential indicating that specific phytosanitary measures should be implemented in order to prevent its introduction. Due to the amount of data associated with AGM, we consider the degree of certainty associated with the pest risk potential score to be high.

D. Discussion of Overall Findings and Conclusions

Our analyses indicated that certain Japanese ports are a potential infestation area for maritime ships and that there is high likelihood of infested ships arriving from Japan at U.S. ports each year. Our conclusions help explain the observed pattern of AGM introductions at ports in the United States. The risk assessment section demonstrated that AGM poses a high risk to United States agriculture, forestry, ecosystems and trade if introduced.

The overall findings of our pest risk assessment also provided justification for maintaining an extensive trapping program and the unmitigated utilization of resources to rapidly eradicate AGM introductions despite the economic costs. Finally, our analyses provided justification for the implementation of phytosanitary measures that prevent AGM introduction at U.S. ports.

Based on the results of this pest risk assessment, we suggest that the pre-shipment inspection and port of entry inspection program between Japan and the United States, be maintained. This type of program helps mitigate the likelihood of AGM introduction via the maritime ship pathway and reduces the economic costs associated with eradication programs.

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VIII. Appendices

Appendix 1. At-risk port locations, flight periods and ships destined for U.S. ports in 2007 (Informa plc, 2008).

Port	Latitude	Longitude	Flight Period	Ships
Akita	39.7622	140.0436	July 8 to September 8	2
Chiba	35.5622	140.0644	June 8 to August 8	56
Fukuyama	34.4583	133.4267	June 1 to August 1	10
Funakawa	39.8794	139.8567	July 8 to September 8	1
Gamagori	34.8131	137.2111	June 8 to August 8	5
Hachinohe	40.5428	141.5319	July 15 to September 15	1
Hakata	33.6392	130.3869	June 1 to August 1	9
Hakodate	41.7878	140.7142	August 1 to October 1	4
Higashi-Harima	34.7158	134.8192	June 1 to August 1	2
Hikari	33.9550	131.9297	June 1 to August 1	1
Hirohata	34.7817	134.6292	June 8 to August 8	1
Hiroshima	34.3653	132.4242	June 1 to August 1	17
Hitachi	36.4908	140.6228	June 22 to August 22	1
Ichihara	35.5333	140.0667	June 8 to August 8	1
Imabari	34.0681	133.0097	June 1 to August 1	1
Ishigaki	24.3356	124.1519	March 15 to May 15	1
Ishikariwan Shinko	43.2167	141.3000	August 1 to October 1	1
Ishinomaki	38.4133	141.2658	July 1 to September 1	2
Iwagi	34.2111	133.1200	June 1 to August 1	2
Iwakuni	34.1769	132.2364	June 1 to August 1	2
Kagoshima	31.5925	130.5700	May 15 to July 15	3
Kakogawa	34.7100	134.8378	June 1 to August 1	10
Kanazawa	36.6169	136.6103	June 22 to August 22	1
Kanda	33.7881	131.0061	June 1 to August 1	6
Kanokawa	34.1897	132.4408	June 1 to August 1	1
Kashima	35.9264	140.6914	June 8 to August 8	23
Kawasaki	35.5064	139.7497	June 8 to August 8	33
Kinuura	34.8647	136.9511	June 8 to August 8	12
Kisarazu	35.3544	139.8561	June 1 to August 1	8
Kobe	34.6842	135.2408	June 1 to August 1	98
Kochi	33.5242	133.5611	May 22 to July 22	1
Kokura	33.9083	130.8775	June 1 to August 1	1
Komatsushima	34.0000	134.6000	June 1 to August 1	3
Kudamatsu	34.0028	131.8517	June 1 to August 1	2
Kure	34.2322	132.5450	June 1 to August 1	11
Kushiro	42.9886	144.3536	August 15 to October 15	5
Maizuru	35.4817	135.3864	June 8 to August 8	2
Marugame	34.3000	133.7833	June 1 to August 1	1
Matsuyama	33.8553	132.6992	June 1 to August 1	3
Mishima-Kawanoe	34.0036	133.5519	June 1 to August 1	5

Mitsukoshima	34.1833	132.5167	June 1 to August 1	2
Mizushima	34.5042	133.7367	June 8 to August 8	29
Moji	33.9492	130.9617	June 1 to August 1	2
Muroran	42.3358	140.9564	August 1 to October 1	5
Nagasaki	32.7403	129.8650	May 22 to July 22	4
Nagoya	35.0450	136.8481	June 8 to August 8	118
Nakanoseki	34.0000	131.5667	June 1 to August 1	1
Niigata	37.9886	139.2233	July 1 to September 1	2
Niihama	33.9708	133.2650	June 1 to August 1	10
Numakuma	34.3667	133.3000	June 1 to August 1	3
Oita	33.2722	131.6814	June 1 to August 1	8
Omaezaki	34.6194	138.2169	June 1 to August 1	1
Onahama	36.9286	140.8869	June 22 to August 22	6
Osaka	34.6358	135.4342	June 1 to August 1	60
Oshima	33.4667	129.5333	June 1 to August 1	2
Otaru	43.1969	141.0167	August 1 to October 1	3
Saganoseki	33.2514	131.8708	June 1 to August 1	1
Sakai	34.5753	135.4353	June 1 to August 1	5
Sakaide	34.3361	133.8414	June 1 to August 1	3
Sakaiminato	35.5361	133.2603	June 15 to August 15	1
Sasebo	33.1569	129.7122	June 1 to August 1	3
Shibushi	31.4636	131.0989	May 8 to July 8	3
Shikama	34.7786	134.6544	June 8 to August 8	3
Shimizu	35.0144	138.5156	June 8 to August 8	24
Shimonoseki	33.9344	130.9017	June 1 to August 1	7
Shimotsu	34.1164	135.1333	June 1 to August 1	2
Tamano	34.4925	133.9519	June 1 to August 1	2
Tobata	33.9167	130.8500	June 1 to August 1	1
Tokuyama	34.0544	131.7939	June 1 to August 1	8
Tokyo	35.6247	139.7914	June 8 to August 8	103
Tomakomai	42.6375	141.6553	August 1 to October 1	5
Toyohashi	34.7125	137.3217	June 1 to August 1	58
Tsuneishi	34.3667	133.2833	June 1 to August 1	2
Tsuruga	35.6667	136.0833	June 15 to August 15	1
Ube	33.9383	131.2403	June 1 to August 1	6
Uno	34.4833	133.9500	June 1 to August 1	3
Wakamatsu	33.9167	130.8167	June 1 to August 1	1
Wakayama	34.2231	135.1331	June 1 to August 1	3
Wanishi	42.3333	141.0000	August 1 to October 1	5
Yatsushiro	32.5000	130.5831	May 22 to July 22	2
Yawata	33.8939	130.7981	June 1 to August 1	3
Yokkaichi	34.9572	136.6494	June 8 to August 8	37
Yokohama	35.4364	139.6678	June 8 to August 8	136
Yokosuka	35.3044	139.6569	June 8 to August 8	11

Appendix 2. Degree day modeling parameters and methodology for estimating AGM flight initiation.

We used Sheehan's (1992) degree day (DD) model for male *Lymantria dispar* to model AGM flight initiation times based on adult emergence. The model parameters we used were:

Base Temperature: 3°C
Egg Eclosion: 282 DD
First Instar: 100 DD
Second Instar: 169 DD
Third Instar: 245 DD
Fourth Instar: 343 DD
Fifth Instar: 583 DD
Pupa: 860 DD

We conducted climate mapping using the NAPPFAST system (www.nappfast.org). We visualized areas in Japan where the average number of degree days from 1998 to 2007 was greater than 1,142, i.e. 860 DD + 282 DD, in weekly intervals from March 15 to August 15. The NAPPFAST output geo-tifs were at a 28 km^2 spatial resolution (Magarey pers. comm., 2007). The Allen modified sine method was used for degree day accumulation (Borchert *et al*., 2007).

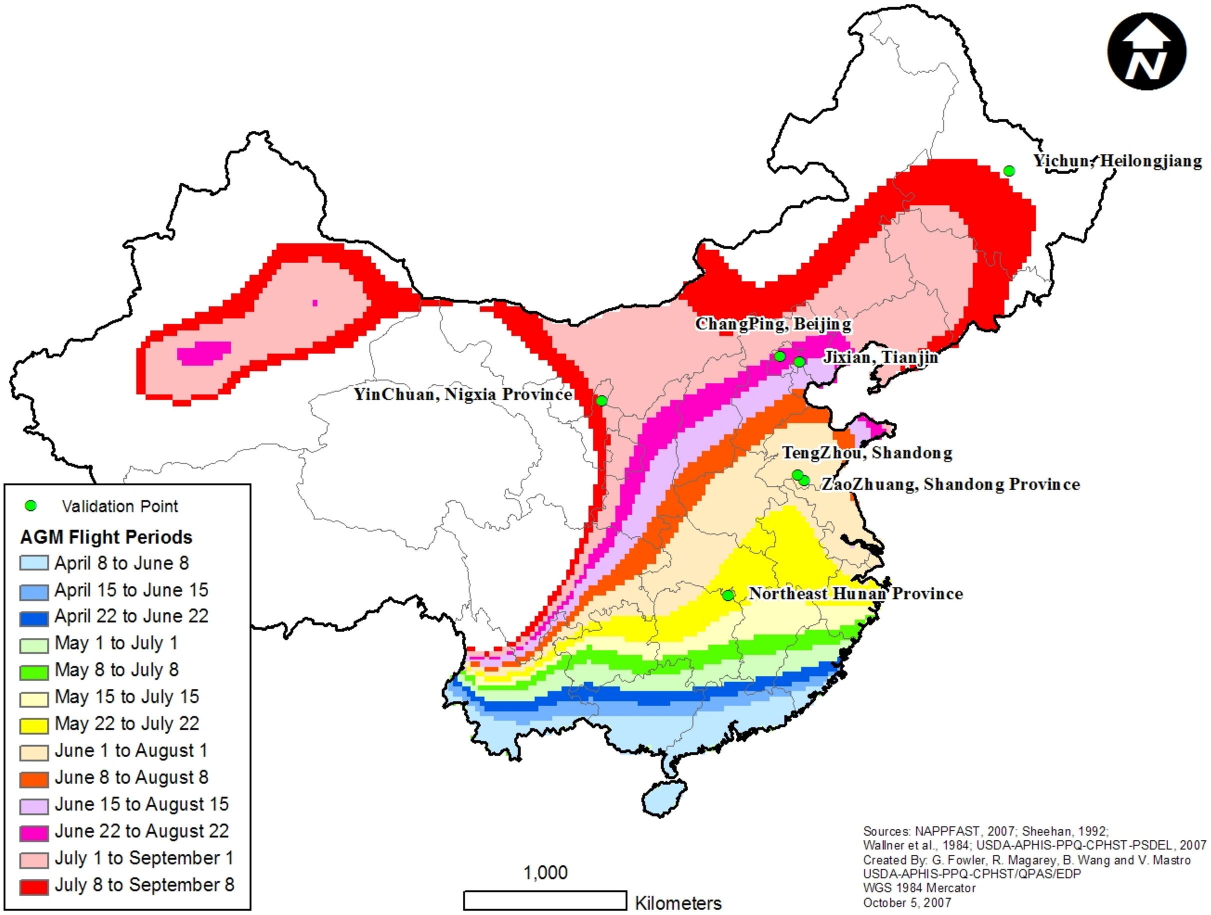
Appendix 3. Japanese global and U.S. trade data for 2002 to 2006 (SBSRTI, 2008).

Year	USA export value (billions of yen)	Total export value (billions of Yen)	USA proportion of Japan export trade
2003	13,412	54,548	0.246
2004	13,731	61,170	0.224
2005	14,805	65,657	0.225
2006	16,934	75,246	0.225
Mean	14,721	64,155	0.230
SD	1,591	8,689	0.010

Appendix 4. Flight period model validation results (Wang and Mastro, unpublished 2007).

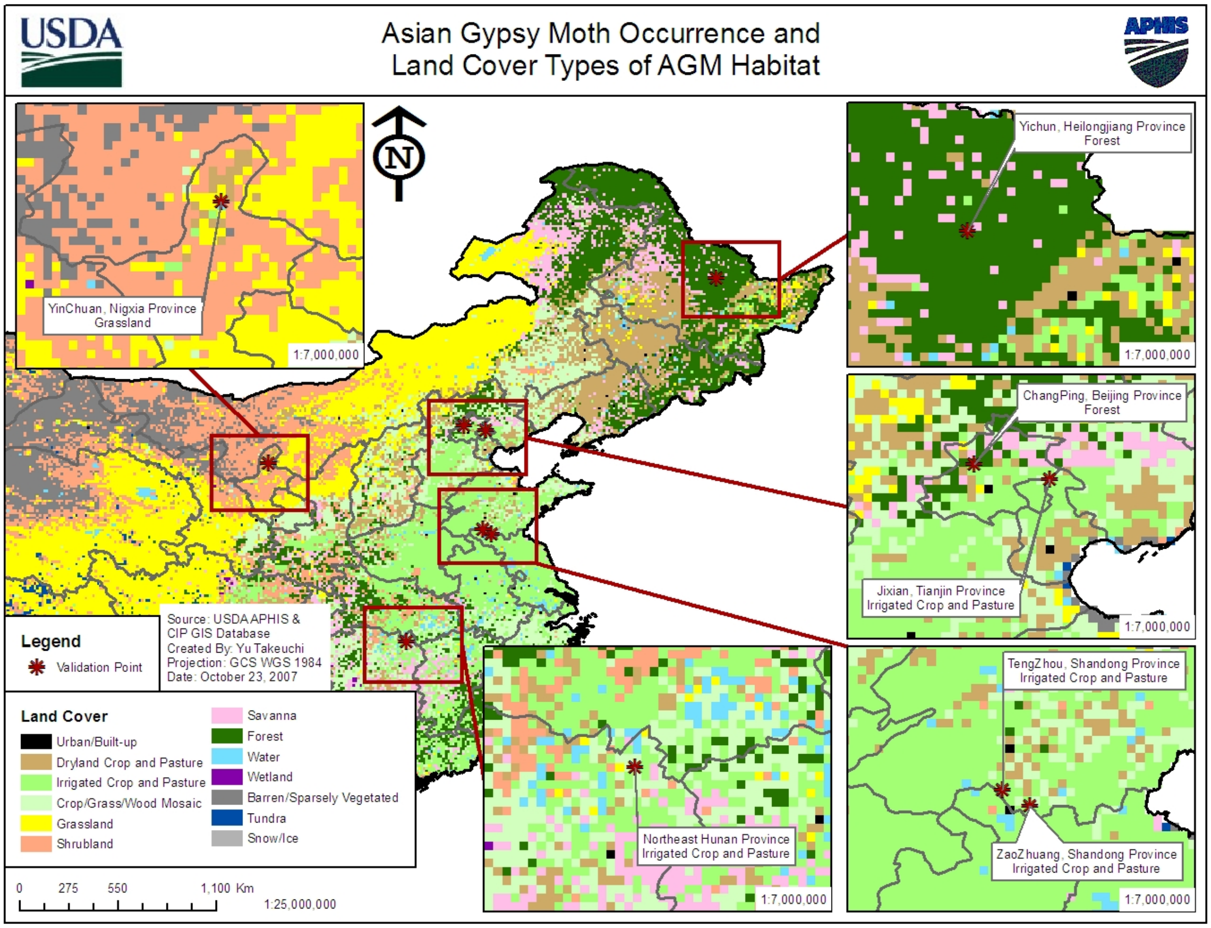
Location	Latitude	Longitude	Peak	Last Catch	Adult Period	Note	DD model band and 2 month flight period	Model Validated?
Northeast Hunan Province	29.403250	113.309347			late June to early July	not exact location	May 22 to July 22	yes
ZaoZhuang, Shandong Province	34.857485	117.546575			early July to early August		June 1 to August 1	yes
TengZhou, Shandong	35.083168	117.158408	unknown to early July	18-Jul		not exact location	June 1 to August 1	yes
YinChuan, Nigxia Province	38.408754	106.346095			mid July to early August	not exact location	July 8 to September 8	yes
Jixian, Tianjin	40.082100	117.263010	late June? to early July	3-Aug			June 22 to August 22	yes
ChangPing, Beijing	40.298890	116.192470	early to mid July	10-Aug			June 22 to August 22	yes
Yichun, Heilongjiang	47.727729	128.891259	July			not exact location	outside of July 8 band	yes

Appendix 5. Estimated flight periods and known locations.



Sources: NAPPFAST, 2007; Sheehan, 1992; Wallner et al., 1984; USDA-APHIS-PPQ-CPHST-PSDEL, 2007
Created By: G. Fowler, R. Magarey, B. Wang and V. Mastro
USDA-APHIS-PPQ-CPHST/QPAS/EDP
WGS 1984 Mercator
October 5, 2007

Appendix 6. Major Chinese land cover types and known locations.



Asian Gypsy Moth Occurrence and Land Cover Types of AGM Habitat

Source: USDA APHIS & CIP GIS Database
Created By: Yu Takeuchi
Projection: GCS WGS 1984
Date: October 23, 2007

Appendix 7. AGM pathway model (part 1).

	A	B	C	D	E	F	G
1	**Port**	**at-risk ships**	**parameter**	**min**	**ml**	**max**	**three standard deviations in trade proportion**
2	Akita	2	min,ml,max	2	2	2	0.031
3	Chiba	56	min,ml,max	54	56	58	
4	Fukuyama	10	min,ml,max	10	10	10	
5	Funakawa	1	min,ml,max	1	1	1	
6	Gamagori	5	min,ml,max	5	5	5	
7	Hachinohe	1	min,ml,max	1	1	1	
8	Hakata	9	min,ml,max	9	9	9	
9	Hakodate	4	min,ml,max	4	4	4	
10	Higashi-Harima	2	min,ml,max	2	2	2	
11	Hikari	1	min,ml,max	1	1	1	
12	Hirohata	1	min,ml,max	1	1	1	
13	Hiroshima	17	min,ml,max	16	17	18	
14	Hitachi	1	min,ml,max	1	1	1	
15	Ichihara	1	min,ml,max	1	1	1	
16	Imabari	1	min,ml,max	1	1	1	
17	Ishigaki	1	min,ml,max	1	1	1	
18	Ishikariwan Shinko	1	min,ml,max	1	1	1	
19	Ishinomaki	2	min,ml,max	2	2	2	
20	Iwagi	2	min,ml,max	2	2	2	
21	Iwakuni	2	min,ml,max	2	2	2	
22	Kagoshima	3	min,ml,max	3	3	3	
23	Kakogawa	10	min,ml,max	10	10	10	
24	Kanazawa	1	min,ml,max	1	1	1	
25	Kanda	6	min,ml,max	6	6	6	
26	Kanokawa	1	min,ml,max	1	1	1	
27	Kashima	23	min,ml,max	22	23	24	
28	Kawasaki	33	min,ml,max	32	33	34	
29	Kinuura	12	min,ml,max	12	12	12	
30	Kisarazu	8	min,ml,max	8	8	8	
31	Kobe	98	min,ml,max	95	98	101	
32	Kochi	1	min,ml,max	1	1	1	
33	Kokura	1	min,ml,max	1	1	1	
34	Komatsushima	3	min,ml,max	3	3	3	
35	Kudamatsu	2	min,ml,max	2	2	2	
36	Kure	11	min,ml,max	11	11	11	
37	Kushiro	5	min,ml,max	5	5	5	
38	Maizuru	2	min,ml,max	2	2	2	
39	Marugame	1	min,ml,max	1	1	1	
40	Matsuyama	3	min,ml,max	3	3	3	
41	Mishima-Kawanoe	5	min,ml,max	5	5	5	
42	Mitsukoshima	2	min,ml,max	2	2	2	
43	Mizushima	29	min,ml,max	28	29	30	
44	Moji	2	min,ml,max	2	2	2	
45	Muroran	5	min,ml,max	5	5	5	
46	Nagasaki	4	min,ml,max	4	4	4	
47	Nagoya	118	min,ml,max	114	118	122	
48	Nakanoseki	1	min,ml,max	1	1	1	
49	Niigata	2	min,ml,max	2	2	2	
50	Niihama	10	min,ml,max	10	10	10	
51	Numakuma	3	min,ml,max	3	3	3	
52	Oita	8	min,ml,max	8	8	8	
53	Omaezaki	1	min,ml,max	1	1	1	
54	Onahama	6	min,ml,max	6	6	6	
55	Osaka	60	min,ml,max	58	60	62	
56	Oshima	2	min,ml,max	2	2	2	
57	Otaru	3	min,ml,max	3	3	3	
58	Saganoseki	1	min,ml,max	1	1	1	
59	Sakai	5	min,ml,max	5	5	5	
60	Sakaide	3	min,ml,max	3	3	3	
61	Sakaiminato	1	min,ml,max	1	1	1	
62	Sasebo	3	min,ml,max	3	3	3	
63	Shibushi	3	min,ml,max	3	3	3	
64	Shikama	3	min,ml,max	3	3	3	
65	Shimizu	24	min,ml,max	23	24	25	
66	Shimonoseki	7	min,ml,max	7	7	7	
67	Shimotsu	2	min,ml,max	2	2	2	
68	Tamano	2	min,ml,max	2	2	2	
69	Tobata	1	min,ml,max	1	1	1	
70	Tokuyama	8	min,ml,max	8	8	8	
71	Tokyo	103	min,ml,max	100	103	106	
72	Tomakomai	5	min,ml,max	5	5	5	
73	Toyohashi	58	min,ml,max	56	58	60	
74	Tsuneishi	2	min,ml,max	2	2	2	
75	Tsuruga	1	min,ml,max	1	1	1	
76	Ube	6	min,ml,max	6	6	6	
77	Uno	3	min,ml,max	3	3	3	
78	Wakamatsu	1	min,ml,max	1	1	1	
79	Wakayama	3	min,ml,max	3	3	3	
80	Wanishi	5	min,ml,max	5	5	5	
81	Yatsushiro	2	min,ml,max	2	2	2	
82	Yawata	3	min,ml,max	3	3	3	
83	Yokkaichi	37	min,ml,max	36	37	38	
84	Yokohama	136	min,ml,max	132	136	140	
85	Yokosuka	11	min,ml,max	11	11	11	
86	Total Ships	1044					

Appendix 8. AGM pathway model (part 2).

	A	B	C	D	E	F
88	**Port**	**infested ships**	**probability of i**	**param**	**s**	**n**
89	Akita	0	0.01010101	s,n	2	295
90	Chiba	1				
91	Fukuyama	0				
92	Funakawa	0				
93	Gamagori	0				
94	Hachinohe	0				
95	Hakata	0				
96	Hakodate	0				
97	Higashi-Harima	0				
98	Hikari	0				
99	Hirohata	0				
100	Hiroshima	0				
101	Hitachi	0				
102	Ichihara	0				
103	Imabari	0				
104	Ishigaki	0				
105	Ishikariwan Shinko	0				
106	Ishinomaki	0				
107	Iwagi	0				
108	Iwakuni	0				
109	Kagoshima	0				
110	Kakogawa	0				
111	Kanazawa	0				
112	Kanda	0				
113	Kanokawa	0				
114	Kashima	0				
115	Kawasaki	0				
116	Kinuura	0				
117	Kisarazu	0				
118	Kobe	1				
119	Kochi	0				
120	Kokura	0				
121	Komatsushima	0				
122	Kudamatsu	0				
123	Kure	0				
124	Kushiro	0				
125	Maizuru	0				
126	Marugame	0				
127	Matsuyama	0				
128	Mishima-Kawanoe	0				
129	Mitsukoshima	0				
130	Mizushima	0				
131	Moji	0				
132	Muroran	0				
133	Nagasaki	0				
134	Nagoya	1				
135	Nakanoseki	0				
136	Niigata	0				
137	Niihama	0				
138	Numakuma	0				
139	Oita	0				
140	Omaezaki	0				
141	Onahama	0				
142	Osaka	1				
143	Oshima	0				
144	Otaru	0				
145	Saganoseki	0				
146	Sakai	0				
147	Sakaide	0				
148	Sakaiminato	0				
149	Sasebo	0				
150	Shibushi	0				
151	Shikama	0				
152	Shimizu	0				
153	Shimonoseki	0				
154	Shimotsu	0				
155	Tamano	0				
156	Tobata	0				
157	Tokuyama	0				
158	Tokyo	1				
159	Tomakomai	0				
160	Toyohashi	1				
161	Tsuneishi	0				
162	Tsuruga	0				
163	Ube	0				
164	Uno	0				
165	Wakamatsu	0				
166	Wakayama	0				
167	Wanishi	0				
168	Yatsushiro	0				
169	Yawata	0				
170	Yokkaichi	0				
171	Yokohama	1				
172	Yokosuka	0				
173	Total Infested Ships	7				

Appendix 9. AGM pathway model (part 3).

	A	B	C
175	**Port**	**probability of infested ship**	**p(infested)**
176	Akita	0	0.0202
177	Chiba	1	0.4075
178	Fukuyama	0	0.0943
179	Funakawa	0	0.0102
180	Gamagori	0	0.0501
181	Hachinohe	0	0.0102
182	Hakata	0	0.0899
183	Hakodate	0	0.0387
184	Higashi-Harima	0	0.0208
185	Hikari	0	0.0097
186	Hirohata	0	0.0113
187	Hiroshima	0	0.1535
188	Hitachi	0	0.0089
189	Ichihara	0	0.0098
190	Imabari	0	0.0101
191	Ishigaki	0	0.0099
192	Ishikariwan Shinko	0	0.0098
193	Ishinomaki	0	0.0184
194	Iwagi	0	0.0192
195	Iwakuni	0	0.0196
196	Kagoshima	0	0.0294
197	Kakogawa	0	0.0919
198	Kanazawa	0	0.0096
199	Kanda	0	0.0591
200	Kanokawa	0	0.0099
201	Kashima	0	0.2007
202	Kawasaki	0	0.2715
203	Kinuura	0	0.1129
204	Kisarazu	0	0.0763
205	Kobe	1	0.5768
206	Kochi	0	0.0098
207	Kokura	0	0.01
208	Komatsushima	0	0.0299
209	Kudamatsu	0	0.021
210	Kure	0	0.1039
211	Kushiro	0	0.0488
212	Maizuru	0	0.0208
213	Marugame	0	0.01
214	Matsuyama	0	0.0284
215	Mishima-Kawanoe	0	0.049
216	Mitsukoshima	0	0.0204
217	Mizushima	0	0.2422
218	Moji	0	0.0194
219	Muroran	0	0.0495
220	Nagasaki	0	0.0406
221	Nagoya	1	0.6371
222	Nakanoseki	0	0.0097
223	Niigata	0	0.0197
224	Niihama	0	0.0958
225	Numakuma	0	0.0298
226	Oita	0	0.0773
227	Omaezaki	0	0.0093
228	Onahama	0	0.0568
229	Osaka	1	0.4258
230	Oshima	0	0.0204
231	Otaru	0	0.0302
232	Saganoseki	0	0.0107
233	Sakai	0	0.0507
234	Sakaide	0	0.0303
235	Sakaiminato	0	0.0094
236	Sasebo	0	0.0299
237	Shibushi	0	0.0296
238	Shikama	0	0.029
239	Shimizu	0	0.2075
240	Shimonoseki	0	0.069
241	Shimotsu	0	0.0193
242	Tamano	0	0.0201
243	Tobata	0	0.0101
244	Tokuyama	0	0.0753
245	Tokyo	1	0.5933
246	Tomakomai	0	0.0485
247	Toyohashi	1	0.4144
248	Tsuneishi	0	0.0206
249	Tsuruga	0	0.0108
250	Ube	0	0.0567
251	Uno	0	0.0287
252	Wakamatsu	0	0.0095
253	Wakayama	0	0.0297
254	Wanishi	0	0.0505
255	Yatsushiro	0	0.0203
256	Yawata	0	0.03
257	Yokkaichi	0	0.2958
258	Yokohama	1	0.6754
259	Yokosuka	0	0.1065
260	Total Infested Ships	1	0.9878

Appendix 10. AGM pathway model (part 4).

	A	B
262	**Port**	**years until an infested ship**
263	Akita	49
264	Chiba	2
265	Fukuyama	10
266	Funakawa	98
267	Gamagori	19
268	Hachinohe	98
269	Hakata	11
270	Hakodate	25
271	Higashi-Harima	48
272	Hikari	103
273	Hirohata	88
274	Hiroshima	6
275	Hitachi	112
276	Ichihara	102
277	Imabari	99
278	Ishigaki	101
279	Ishikariwan Shinko	102
280	Ishinomaki	54
281	Iwagi	52
282	Iwakuni	51
283	Kagoshima	34
284	Kakogawa	10
285	Kanazawa	104
286	Kanda	16
287	Kanokawa	101
288	Kashima	4
289	Kawasaki	3
290	Kinuura	8
291	Kisarazu	13
292	Kobe	1
293	Kochi	102
294	Kokura	100
295	Komatsushima	33
296	Kudamatsu	47
297	Kure	9
298	Kushiro	20
299	Maizuru	48
300	Marugame	100
301	Matsuyama	35
302	Mishima-Kawanoe	20
303	Mitsukoshima	49
304	Mizushima	4
305	Moji	51
306	Muroran	20
307	Nagasaki	24
308	Nagoya	1
309	Nakanoseki	103
310	Niigata	50
311	Niihama	10
312	Numakuma	33
313	Oita	12
314	Omaezaki	107
315	Onahama	17
316	Osaka	2
317	Oshima	49
318	Otaru	33
319	Saganoseki	93
320	Sakai	19
321	Sakaide	33
322	Sakaiminato	106
323	Sasebo	33
324	Shibushi	33
325	Shikama	34
326	Shimizu	4
327	Shimonoseki	14
328	Shimotsu	51
329	Tamano	49
330	Tobata	99
331	Tokuyama	13
332	Tokyo	1
333	Tomakomai	20
334	Toyohashi	2
335	Tsuneishi	48
336	Tsuruga	92
337	Ube	17
338	Uno	34
339	Wakamatsu	105
340	Wakayama	33
341	Wanishi	19
342	Yatsushiro	49
343	Yawata	33
344	Yokkaichi	3
345	Yokohama	1
346	Yokosuka	9
347	Total Infested Ships	1

Appendix 11. AGM pathway model formula table (part 1).

	A	B	C	D	E	F	G
1	**Port**	**at-risk ships**	**parameter**	**min**	**ml**	**max**	**three standard deviations in trade proportion**
2	Akita	=ROUND(RiskPert(D2,E2,F2),0)	min,ml,max	=ROUND(E2-(E2*G2),0)	2	=ROUND(E2+(E2*G2),0)	0.031
3	Chiba	=ROUND(RiskPert(D3,E3,F3),0)	min,ml,max	=ROUND(E3-(E3*G2),0)	56	=ROUND(E3+(E3*G2),0)	
4	Fukuyama	=ROUND(RiskPert(D4,E4,F4),0)	min,ml,max	=ROUND(E4-(E4*G2),0)	10	=ROUND(E4+(E4*G2),0)	
5	Funakawa	=ROUND(RiskPert(D5,E5,F5),0)	min,ml,max	=ROUND(E5-(E5*G2),0)	1	=ROUND(E5+(E5*G2),0)	
6	Gamagori	=ROUND(RiskPert(D6,E6,F6),0)	min,ml,max	=ROUND(E6-(E6*G2),0)	5	=ROUND(E6+(E6*G2),0)	
7	Hachinohe	=ROUND(RiskPert(D7,E7,F7),0)	min,ml,max	=ROUND(E7-(E7*G2),0)	1	=ROUND(E7+(E7*G2),0)	
8	Hakata	=ROUND(RiskPert(D8,E8,F8),0)	min,ml,max	=ROUND(E8-(E8*G2),0)	9	=ROUND(E8+(E8*G2),0)	
9	Hakodate	=ROUND(RiskPert(D9,E9,F9),0)	min,ml,max	=ROUND(E9-(E9*G2),0)	4	=ROUND(E9+(E9*G2),0)	
10	Higashi-Harima	=ROUND(RiskPert(D10,E10,F10),0)	min,ml,max	=ROUND(E10-(E10*G2),0)	2	=ROUND(E10+(E10*G2),0)	
11	Hikari	=ROUND(RiskPert(D11,E11,F11),0)	min,ml,max	=ROUND(E11-(E11*G2),0)	1	=ROUND(E11+(E11*G2),0)	
12	Hirohata	=ROUND(RiskPert(D12,E12,F12),0)	min,ml,max	=ROUND(E12-(E12*G2),0)	1	=ROUND(E12+(E12*G2),0)	
13	Hiroshima	=ROUND(RiskPert(D13,E13,F13),0)	min,ml,max	=ROUND(E13-(E13*G2),0)	17	=ROUND(E13+(E13*G2),0)	
14	Hitachi	=ROUND(RiskPert(D14,E14,F14),0)	min,ml,max	=ROUND(E14-(E14*G2),0)	1	=ROUND(E14+(E14*G2),0)	
15	Ichihara	=ROUND(RiskPert(D15,E15,F15),0)	min,ml,max	=ROUND(E15-(E15*G2),0)	1	=ROUND(E15+(E15*G2),0)	
16	Imabari	=ROUND(RiskPert(D16,E16,F16),0)	min,ml,max	=ROUND(E16-(E16*G2),0)	1	=ROUND(E16+(E16*G2),0)	
17	Ishigaki	=ROUND(RiskPert(D17,E17,F17),0)	min,ml,max	=ROUND(E17-(E17*G2),0)	1	=ROUND(E17+(E17*G2),0)	
18	Ishikariwan Shinko	=ROUND(RiskPert(D18,E18,F18),0)	min,ml,max	=ROUND(E18-(E18*G2),0)	1	=ROUND(E18+(E18*G2),0)	
19	Ishinomaki	=ROUND(RiskPert(D19,E19,F19),0)	min,ml,max	=ROUND(E19-(E19*G2),0)	2	=ROUND(E19+(E19*G2),0)	
20	Iwagi	=ROUND(RiskPert(D20,E20,F20),0)	min,ml,max	=ROUND(E20-(E20*G2),0)	2	=ROUND(E20+(E20*G2),0)	
21	Iwakuni	=ROUND(RiskPert(D21,E21,F21),0)	min,ml,max	=ROUND(E21-(E21*G2),0)	2	=ROUND(E21+(E21*G2),0)	
22	Kagoshima	=ROUND(RiskPert(D22,E22,F22),0)	min,ml,max	=ROUND(E22-(E22*G2),0)	3	=ROUND(E22+(E22*G2),0)	
23	Kakogawa	=ROUND(RiskPert(D23,E23,F23),0)	min,ml,max	=ROUND(E23-(E23*G2),0)	10	=ROUND(E23+(E23*G2),0)	
24	Kanazawa	=ROUND(RiskPert(D24,E24,F24),0)	min,ml,max	=ROUND(E24-(E24*G2),0)	1	=ROUND(E24+(E24*G2),0)	
25	Kanda	=ROUND(RiskPert(D25,E25,F25),0)	min,ml,max	=ROUND(E25-(E25*G2),0)	6	=ROUND(E25+(E25*G2),0)	
26	Kanokawa	=ROUND(RiskPert(D26,E26,F26),0)	min,ml,max	=ROUND(E26-(E26*G2),0)	1	=ROUND(E26+(E26*G2),0)	
27	Kashima	=ROUND(RiskPert(D27,E27,F27),0)	min,ml,max	=ROUND(E27-(E27*G2),0)	23	=ROUND(E27+(E27*G2),0)	
28	Kawasaki	=ROUND(RiskPert(D28,E28,F28),0)	min,ml,max	=ROUND(E28-(E28*G2),0)	33	=ROUND(E28+(E28*G2),0)	
29	Kinuura	=ROUND(RiskPert(D29,E29,F29),0)	min,ml,max	=ROUND(E29-(E29*G2),0)	12	=ROUND(E29+(E29*G2),0)	
30	Kisarazu	=ROUND(RiskPert(D30,E30,F30),0)	min,ml,max	=ROUND(E30-(E30*G2),0)	8	=ROUND(E30+(E30*G2),0)	
31	Kobe	=ROUND(RiskPert(D31,E31,F31),0)	min,ml,max	=ROUND(E31-(E31*G2),0)	98	=ROUND(E31+(E31*G2),0)	
32	Kochi	=ROUND(RiskPert(D32,E32,F32),0)	min,ml,max	=ROUND(E32-(E32*G2),0)	1	=ROUND(E32+(E32*G2),0)	
33	Kokura	=ROUND(RiskPert(D33,E33,F33),0)	min,ml,max	=ROUND(E33-(E33*G2),0)	1	=ROUND(E33+(E33*G2),0)	
34	Komatsushima	=ROUND(RiskPert(D34,E34,F34),0)	min,ml,max	=ROUND(E34-(E34*G2),0)	3	=ROUND(E34+(E34*G2),0)	
35	Kudamatsu	=ROUND(RiskPert(D35,E35,F35),0)	min,ml,max	=ROUND(E35-(E35*G2),0)	2	=ROUND(E35+(E35*G2),0)	
36	Kure	=ROUND(RiskPert(D36,E36,F36),0)	min,ml,max	=ROUND(E36-(E36*G2),0)	11	=ROUND(E36+(E36*G2),0)	
37	Kushiro	=ROUND(RiskPert(D37,E37,F37),0)	min,ml,max	=ROUND(E37-(E37*G2),0)	5	=ROUND(E37+(E37*G2),0)	
38	Maizuru	=ROUND(RiskPert(D38,E38,F38),0)	min,ml,max	=ROUND(E38-(E38*G2),0)	2	=ROUND(E38+(E38*G2),0)	
39	Marugame	=ROUND(RiskPert(D39,E39,F39),0)	min,ml,max	=ROUND(E39-(E39*G2),0)	1	=ROUND(E39+(E39*G2),0)	
40	Matsuyama	=ROUND(RiskPert(D40,E40,F40),0)	min,ml,max	=ROUND(E40-(E40*G2),0)	3	=ROUND(E40+(E40*G2),0)	
41	Mishima-Kawanoe	=ROUND(RiskPert(D41,E41,F41),0)	min,ml,max	=ROUND(E41-(E41*G2),0)	5	=ROUND(E41+(E41*G2),0)	
42	Mitsukoshima	=ROUND(RiskPert(D42,E42,F42),0)	min,ml,max	=ROUND(E42-(E42*G2),0)	2	=ROUND(E42+(E42*G2),0)	
43	Mizushima	=ROUND(RiskPert(D43,E43,F43),0)	min,ml,max	=ROUND(E43-(E43*G2),0)	29	=ROUND(E43+(E43*G2),0)	
44	Moji	=ROUND(RiskPert(D44,E44,F44),0)	min,ml,max	=ROUND(E44-(E44*G2),0)	2	=ROUND(E44+(E44*G2),0)	
45	Muroran	=ROUND(RiskPert(D45,E45,F45),0)	min,ml,max	=ROUND(E45-(E45*G2),0)	5	=ROUND(E45+(E45*G2),0)	
46	Nagasaki	=ROUND(RiskPert(D46,E46,F46),0)	min,ml,max	=ROUND(E46-(E46*G2),0)	4	=ROUND(E46+(E46*G2),0)	
47	Nagoya	=ROUND(RiskPert(D47,E47,F47),0)	min,ml,max	=ROUND(E47-(E47*G2),0)	118	=ROUND(E47+(E47*G2),0)	
48	Nakanoseki	=ROUND(RiskPert(D48,E48,F48),0)	min,ml,max	=ROUND(E48-(E48*G2),0)	1	=ROUND(E48+(E48*G2),0)	
49	Niigata	=ROUND(RiskPert(D49,E49,F49),0)	min,ml,max	=ROUND(E49-(E49*G2),0)	2	=ROUND(E49+(E49*G2),0)	
50	Niihama	=ROUND(RiskPert(D50,E50,F50),0)	min,ml,max	=ROUND(E50-(E50*G2),0)	10	=ROUND(E50+(E50*G2),0)	
51	Numakuma	=ROUND(RiskPert(D51,E51,F51),0)	min,ml,max	=ROUND(E51-(E51*G2),0)	3	=ROUND(E51+(E51*G2),0)	
52	Oita	=ROUND(RiskPert(D52,E52,F52),0)	min,ml,max	=ROUND(E52-(E52*G2),0)	8	=ROUND(E52+(E52*G2),0)	
53	Omaezaki	=ROUND(RiskPert(D53,E53,F53),0)	min,ml,max	=ROUND(E53-(E53*G2),0)	1	=ROUND(E53+(E53*G2),0)	
54	Onahama	=ROUND(RiskPert(D54,E54,F54),0)	min,ml,max	=ROUND(E54-(E54*G2),0)	6	=ROUND(E54+(E54*G2),0)	
55	Osaka	=ROUND(RiskPert(D55,E55,F55),0)	min,ml,max	=ROUND(E55-(E55*G2),0)	60	=ROUND(E55+(E55*G2),0)	
56	Oshima	=ROUND(RiskPert(D56,E56,F56),0)	min,ml,max	=ROUND(E56-(E56*G2),0)	2	=ROUND(E56+(E56*G2),0)	
57	Otaru	=ROUND(RiskPert(D57,E57,F57),0)	min,ml,max	=ROUND(E57-(E57*G2),0)	3	=ROUND(E57+(E57*G2),0)	
58	Saganoseki	=ROUND(RiskPert(D58,E58,F58),0)	min,ml,max	=ROUND(E58-(E58*G2),0)	1	=ROUND(E58+(E58*G2),0)	
59	Sakai	=ROUND(RiskPert(D59,E59,F59),0)	min,ml,max	=ROUND(E59-(E59*G2),0)	5	=ROUND(E59+(E59*G2),0)	
60	Sakaide	=ROUND(RiskPert(D60,E60,F60),0)	min,ml,max	=ROUND(E60-(E60*G2),0)	3	=ROUND(E60+(E60*G2),0)	
61	Sakaiminato	=ROUND(RiskPert(D61,E61,F61),0)	min,ml,max	=ROUND(E61-(E61*G2),0)	1	=ROUND(E61+(E61*G2),0)	
62	Sasebo	=ROUND(RiskPert(D62,E62,F62),0)	min,ml,max	=ROUND(E62-(E62*G2),0)	3	=ROUND(E62+(E62*G2),0)	
63	Shibushi	=ROUND(RiskPert(D63,E63,F63),0)	min,ml,max	=ROUND(E63-(E63*G2),0)	3	=ROUND(E63+(E63*G2),0)	
64	Shikama	=ROUND(RiskPert(D64,E64,F64),0)	min,ml,max	=ROUND(E64-(E64*G2),0)	3	=ROUND(E64+(E64*G2),0)	
65	Shimizu	=ROUND(RiskPert(D65,E65,F65),0)	min,ml,max	=ROUND(E65-(E65*G2),0)	24	=ROUND(E65+(E65*G2),0)	
66	Shimonoseki	=ROUND(RiskPert(D66,E66,F66),0)	min,ml,max	=ROUND(E66-(E66*G2),0)	7	=ROUND(E66+(E66*G2),0)	
67	Shimotsu	=ROUND(RiskPert(D67,E67,F67),0)	min,ml,max	=ROUND(E67-(E67*G2),0)	2	=ROUND(E67+(E67*G2),0)	
68	Tamano	=ROUND(RiskPert(D68,E68,F68),0)	min,ml,max	=ROUND(E68-(E68*G2),0)	2	=ROUND(E68+(E68*G2),0)	
69	Tobata	=ROUND(RiskPert(D69,E69,F69),0)	min,ml,max	=ROUND(E69-(E69*G2),0)	1	=ROUND(E69+(E69*G2),0)	
70	Tokuyama	=ROUND(RiskPert(D70,E70,F70),0)	min,ml,max	=ROUND(E70-(E70*G2),0)	8	=ROUND(E70+(E70*G2),0)	
71	Tokyo	=ROUND(RiskPert(D71,E71,F71),0)	min,ml,max	=ROUND(E71-(E71*G2),0)	103	=ROUND(E71+(E71*G2),0)	
72	Tomakomai	=ROUND(RiskPert(D72,E72,F72),0)	min,ml,max	=ROUND(E72-(E72*G2),0)	5	=ROUND(E72+(E72*G2),0)	
73	Toyohashi	=ROUND(RiskPert(D73,E73,F73),0)	min,ml,max	=ROUND(E73-(E73*G2),0)	58	=ROUND(E73+(E73*G2),0)	
74	Tsuneishi	=ROUND(RiskPert(D74,E74,F74),0)	min,ml,max	=ROUND(E74-(E74*G2),0)	2	=ROUND(E74+(E74*G2),0)	
75	Tsuruga	=ROUND(RiskPert(D75,E75,F75),0)	min,ml,max	=ROUND(E75-(E75*G2),0)	1	=ROUND(E75+(E75*G2),0)	
76	Ube	=ROUND(RiskPert(D76,E76,F76),0)	min,ml,max	=ROUND(E76-(E76*G2),0)	6	=ROUND(E76+(E76*G2),0)	
77	Uno	=ROUND(RiskPert(D77,E77,F77),0)	min,ml,max	=ROUND(E77-(E77*G2),0)	3	=ROUND(E77+(E77*G2),0)	
78	Wakamatsu	=ROUND(RiskPert(D78,E78,F78),0)	min,ml,max	=ROUND(E78-(E78*G2),0)	1	=ROUND(E78+(E78*G2),0)	
79	Wakayama	=ROUND(RiskPert(D79,E79,F79),0)	min,ml,max	=ROUND(E79-(E79*G2),0)	3	=ROUND(E79+(E79*G2),0)	
80	Wanishi	=ROUND(RiskPert(D80,E80,F80),0)	min,ml,max	=ROUND(E80-(E80*G2),0)	5	=ROUND(E80+(E80*G2),0)	
81	Yatsushiro	=ROUND(RiskPert(D81,E81,F81),0)	min,ml,max	=ROUND(E81-(E81*G2),0)	2	=ROUND(E81+(E81*G2),0)	
82	Yawata	=ROUND(RiskPert(D82,E82,F82),0)	min,ml,max	=ROUND(E82-(E82*G2),0)	3	=ROUND(E82+(E82*G2),0)	
83	Yokkaichi	=ROUND(RiskPert(D83,E83,F83),0)	min,ml,max	=ROUND(E83-(E83*G2),0)	37	=ROUND(E83+(E83*G2),0)	
84	Yokohama	=ROUND(RiskPert(D84,E84,F84),0)	min,ml,max	=ROUND(E84-(E84*G2),0)	136	=ROUND(E84+(E84*G2),0)	
85	Yokosuka	=ROUND(RiskPert(D85,E85,F85),0)	min,ml,max	=ROUND(E85-(E85*G2),0)	11	=ROUND(E85+(E85*G2),0)	
86	Total Ships	=RiskOutput("all ships")+SUM(B2:B85)					

Appendix 12. AGM pathway model formula table (part 2).

	A	B	C	D	E	F
88	**Port**	**infested ships**	**probability of infestation**	**parameter**	**s**	**n**
89	Akita	=RiskOutput("Akita infested ships")+RiskBinomial(B2,C89)	=RiskBeta(E89+1,F89-E89+1)	s,n	2	295
90	Chiba	=RiskOutput("Chiba infested ships")+RiskBinomial(B3,C89)				
91	Fukuyama	=RiskOutput("Fukuyama infested ships")+RiskBinomial(B4,C89)				
92	Funakawa	=RiskOutput("Funakawa infested ships")+RiskBinomial(B5,C89)				
93	Gamagori	=RiskOutput("Gamagori infested ships")+RiskBinomial(B6,C89)				
94	Hachinohe	=RiskOutput("Hachinohe infested ships")+RiskBinomial(B7,C89)				
95	Hakata	=RiskOutput("Hakata infested ships")+RiskBinomial(B8,C89)				
96	Hakodate	=RiskOutput("Hakodate infested ships")+RiskBinomial(B9,C89)				
97	Higashi-Harima	=RiskOutput("Higashi-Harima infested ships")+RiskBinomial(B10,C89)				
98	Hikari	=RiskOutput("Hikari infested ships")+RiskBinomial(B11,C89)				
99	Hirohata	=RiskOutput("Hirohata infested ships")+RiskBinomial(B12,C89)				
100	Hiroshima	=RiskOutput("Hiroshima infested ships")+RiskBinomial(B13,C89)				
101	Hitachi	=RiskOutput("Hitachi infested ships")+RiskBinomial(B14,C89)				
102	Ichihara	=RiskOutput("Ichihara infested ships")+RiskBinomial(B15,C89)				
103	Imabari	=RiskOutput("Imabari infested ships")+RiskBinomial(B16,C89)				
104	Ishigaki	=RiskOutput("Ishigaki infested ships")+RiskBinomial(B17,C89)				
105	Ishikariwan Shinko	=RiskOutput("Ishikariwan Shinko infested ships")+RiskBinomial(B18,C89)				
106	Ishinomaki	=RiskOutput("Ishinomaki infested ships")+RiskBinomial(B19,C89)				
107	Iwagi	=RiskOutput("Iwagi infested ships")+RiskBinomial(B20,C89)				
108	Iwakuni	=RiskOutput("Iwakuni infested ships")+RiskBinomial(B21,C89)				
109	Kagoshima	=RiskOutput("Kagoshima infested ships")+RiskBinomial(B22,C89)				
110	Kakogawa	=RiskOutput("Kakogawa infested ships")+RiskBinomial(B23,C89)				
111	Kanazawa	=RiskOutput("Kanazawa infested ships")+RiskBinomial(B24,C89)				
112	Kanda	=RiskOutput("Kanda infested ships")+RiskBinomial(B25,C89)				
113	Kanokawa	=RiskOutput("Kanokawa infested ships")+RiskBinomial(B26,C89)				
114	Kashima	=RiskOutput("Kashima infested ships")+RiskBinomial(B27,C89)				
115	Kawasaki	=RiskOutput("Kawasaki infested ships")+RiskBinomial(B28,C89)				
116	Kinuura	=RiskOutput("Kinuura infested ships")+RiskBinomial(B29,C89)				
117	Kisarazu	=RiskOutput("Kisarazu infested ships")+RiskBinomial(B30,C89)				
118	Kobe	=RiskOutput("Kobe infested ships")+RiskBinomial(B31,C89)				
119	Kochi	=RiskOutput("Kochi infested ships")+RiskBinomial(B32,C89)				
120	Kokura	=RiskOutput("Kokura infested ships")+RiskBinomial(B33,C89)				
121	Komatsushima	=RiskOutput("Komatsushima infested ships")+RiskBinomial(B34,C89)				
122	Kudamatsu	=RiskOutput("Kudamatsu infested ships")+RiskBinomial(B35,C89)				
123	Kure	=RiskOutput("Kure infested ships")+RiskBinomial(B36,C89)				
124	Kushiro	=RiskOutput("Kushiro infested ships")+RiskBinomial(B37,C89)				
125	Maizuru	=RiskOutput("Maizuru infested ships")+RiskBinomial(B38,C89)				
126	Marugame	=RiskOutput("Marugame infested ships")+RiskBinomial(B39,C89)				
127	Matsuyama	=RiskOutput("Matsuyama infested ships")+RiskBinomial(B40,C89)				
128	Mishima-Kawanoe	=RiskOutput("Mishima-Kawanoe infested ships")+RiskBinomial(B41,C89)				
129	Mitsukoshima	=RiskOutput("Mitsukoshima infested ships")+RiskBinomial(B42,C89)				
130	Mizushima	=RiskOutput("Mizushima infested ships")+RiskBinomial(B43,C89)				
131	Moji	=RiskOutput("Moji infested ships")+RiskBinomial(B44,C89)				
132	Muroran	=RiskOutput("Muroran infested ships")+RiskBinomial(B45,C89)				
133	Nagasaki	=RiskOutput("Nagasaki infested ships")+RiskBinomial(B46,C89)				
134	Nagoya	=RiskOutput("Nagoya infested ships")+RiskBinomial(B47,C89)				
135	Nakanoseki	=RiskOutput("Nakanoseki infested ships")+RiskBinomial(B48,C89)				
136	Niigata	=RiskOutput("Niigata infested ships")+RiskBinomial(B49,C89)				
137	Niihama	=RiskOutput("Niihama infested ships")+RiskBinomial(B50,C89)				
138	Numakuma	=RiskOutput("Numakuma infested ships")+RiskBinomial(B51,C89)				
139	Oita	=RiskOutput("Oita infested ships")+RiskBinomial(B52,C89)				
140	Omaezaki	=RiskOutput("Omaezaki infested ships")+RiskBinomial(B53,C89)				
141	Onahama	=RiskOutput("Onahama infested ships")+RiskBinomial(B54,C89)				
142	Osaka	=RiskOutput("Osaka infested ships")+RiskBinomial(B55,C89)				
143	Oshima	=RiskOutput("Oshima infested ships")+RiskBinomial(B56,C89)				
144	Otaru	=RiskOutput("Otaru infested ships")+RiskBinomial(B57,C89)				
145	Saganoseki	=RiskOutput("Saganoseki infested ships")+RiskBinomial(B58,C89)				
146	Sakai	=RiskOutput("Sakai infested ships")+RiskBinomial(B59,C89)				
147	Sakaide	=RiskOutput("Sakaide infested ships")+RiskBinomial(B60,C89)				
148	Sakaiminato	=RiskOutput("Sakaiminato infested ships")+RiskBinomial(B61,C89)				
149	Sasebo	=RiskOutput("Sasebo infested ships")+RiskBinomial(B62,C89)				
150	Shibushi	=RiskOutput("Shibushi infested ships")+RiskBinomial(B63,C89)				
151	Shikama	=RiskOutput("Shikama infested ships")+RiskBinomial(B64,C89)				
152	Shimizu	=RiskOutput("Shimizu infested ships")+RiskBinomial(B65,C89)				
153	Shimonoseki	=RiskOutput("Shimonoseki infested ships")+RiskBinomial(B66,C89)				
154	Shimotsu	=RiskOutput("Shimotsu infested ships")+RiskBinomial(B67,C89)				
155	Tamano	=RiskOutput("Tamano infested ships")+RiskBinomial(B68,C89)				
156	Tobata	=RiskOutput("Tobata infested ships")+RiskBinomial(B69,C89)				
157	Tokuyama	=RiskOutput("Tokuyama infested ships")+RiskBinomial(B70,C89)				
158	Tokyo	=RiskOutput("Tokyo infested ships")+RiskBinomial(B71,C89)				
159	Tomakomai	=RiskOutput("Tomakomai infested ships")+RiskBinomial(B72,C89)				
160	Toyohashi	=RiskOutput("Toyohashi infested ships")+RiskBinomial(B73,C89)				
161	Tsuneishi	=RiskOutput("Tsuneishi infested ships")+RiskBinomial(B74,C89)				
162	Tsuruga	=RiskOutput("Tsuruga infested ships")+RiskBinomial(B75,C89)				
163	Ube	=RiskOutput("Ube infested ships")+RiskBinomial(B76,C89)				
164	Uno	=RiskOutput("Uno infested ships")+RiskBinomial(B77,C89)				
165	Wakamatsu	=RiskOutput("Wakamatsu infested ships")+RiskBinomial(B78,C89)				
166	Wakayama	=RiskOutput("Wakayama infested ships")+RiskBinomial(B79,C89)				
167	Wanishi	=RiskOutput("Wanishi infested ships")+RiskBinomial(B80,C89)				
168	Yatsushiro	=RiskOutput("Yatsushiro infested ships")+RiskBinomial(B81,C89)				
169	Yawata	=RiskOutput("Yawata infested ships")+RiskBinomial(B82,C89)				
170	Yokkaichi	=RiskOutput("Yokkaichi infested ships")+RiskBinomial(B83,C89)				
171	Yokohama	=RiskOutput("Yokohama infested ships")+RiskBinomial(B84,C89)				
172	Yokosuka	=RiskOutput("Yokosuka infested ships")+RiskBinomial(B85,C89)				
173	Total Infested Ships	=RiskOutput("total infested ships")+SUM(B89:B172)				

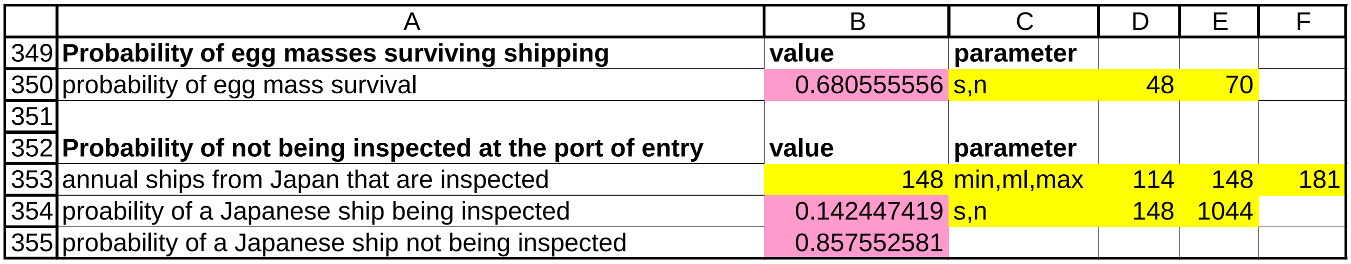
Appendix 13. AGM pathway model formula table (part 3).

	A	B	C
175	**Port**	**probability of infested ship**	**p(infested)**
176	Akita	=RiskOutput("probability Akita infested")+IF(B89>=1,1,0)	0.0193
177	Chiba	=RiskOutput("probability Chiba infested")+IF(B90>=1,1,0)	0.4056
178	Fukuyama	=RiskOutput("probability Fukuyama infested")+IF(B91>=1,1,0)	0.0949
179	Funakawa	=RiskOutput("probability Funakawa infested")+IF(B92>=1,1,0)	0.0092
180	Gamagori	=RiskOutput("probability Gamagori infested")+IF(B93>=1,1,0)	0.0507
181	Hachinohe	=RiskOutput("probability Hachinohe infested")+IF(B94>=1,1,0)	0.0091
182	Hakata	=RiskOutput("probability Hakata infested")+IF(B95>=1,1,0)	0.0873
183	Hakodate	=RiskOutput("probability Hakodate infested")+IF(B96>=1,1,0)	0.0386
184	Higashi-Harima	=RiskOutput("probability Higashi-Harima infested")+IF(B97>=1,1,0)	0.0194
185	Hikari	=RiskOutput("probability Hikari infested")+IF(B98>=1,1,0)	0.0099
186	Hirohata	=RiskOutput("probability Hirohata infested")+IF(B99>=1,1,0)	0.0101
187	Hiroshima	=RiskOutput("probability Hiroshima infested")+IF(B100>=1,1,0)	0.1519
188	Hitachi	=RiskOutput("probability Hitachi infested")+IF(B101>=1,1,0)	0.0102
189	Ichihara	=RiskOutput("probability Ichihara infested")+IF(B102>=1,1,0)	0.0108
190	Imabari	=RiskOutput("probability Imabari infested")+IF(B103>=1,1,0)	0.0094
191	Ishigaki	=RiskOutput("probability Ishigaki infested")+IF(B104>=1,1,0)	0.0107
192	Ishikariwan Shinko	=RiskOutput("probability Ishikariwan Shinko infested")+IF(B105>=1,1,0)	0.0095
193	Ishinomaki	=RiskOutput("probability Ishinomaki infested")+IF(B106>=1,1,0)	0.0185
194	Iwagi	=RiskOutput("probability Iwagi infested")+IF(B107>=1,1,0)	0.0196
195	Iwakuni	=RiskOutput("probability Iwakuni infested")+IF(B108>=1,1,0)	0.0196
196	Kagoshima	=RiskOutput("probability Kagoshima infested")+IF(B109>=1,1,0)	0.0314
197	Kakogawa	=RiskOutput("probability Kakogawa infested")+IF(B110>=1,1,0)	0.0968
198	Kanazawa	=RiskOutput("probability Kanazawa infested")+IF(B111>=1,1,0)	0.01
199	Kanda	=RiskOutput("probability Kanda infested")+IF(B112>=1,1,0)	0.059
200	Kanokawa	=RiskOutput("probability Kanokawa infested")+IF(B113>=1,1,0)	0.0104
201	Kashima	=RiskOutput("probability Kashima infested")+IF(B114>=1,1,0)	0.204
202	Kawasaki	=RiskOutput("probability Kawasaki infested")+IF(B115>=1,1,0)	0.2756
203	Kinuura	=RiskOutput("probability Kinuura infested")+IF(B116>=1,1,0)	0.1112
204	Kisarazu	=RiskOutput("probability Kisarazu infested")+IF(B117>=1,1,0)	0.0797
205	Kobe	=RiskOutput("probability Kobe infested")+IF(B118>=1,1,0)	0.5753
206	Kochi	=RiskOutput("probability Kochi infested")+IF(B119>=1,1,0)	0.0109
207	Kokura	=RiskOutput("probability Kokura infested")+IF(B120>=1,1,0)	0.0103
208	Komatsushima	=RiskOutput("probability Komatsushima infested")+IF(B121>=1,1,0)	0.03
209	Kudamatsu	=RiskOutput("probability Kudamatsu infested")+IF(B122>=1,1,0)	0.0214
210	Kure	=RiskOutput("probability Kure infested")+IF(B123>=1,1,0)	0.1048
211	Kushiro	=RiskOutput("probability Kushiro infested")+IF(B124>=1,1,0)	0.0491
212	Maizuru	=RiskOutput("probability Maizuru infested")+IF(B125>=1,1,0)	0.0212
213	Marugame	=RiskOutput("probability Marugame infested")+IF(B126>=1,1,0)	0.0103
214	Matsuyama	=RiskOutput("probability Matsuyama infested")+IF(B127>=1,1,0)	0.0302
215	Mishima-Kawanoe	=RiskOutput("probability Mishima-Kawanoe infested")+IF(B128>=1,1,0)	0.0492
216	Mitsukoshima	=RiskOutput("probability Mitsukoshima infested")+IF(B129>=1,1,0)	0.0213
217	Mizushima	=RiskOutput("probability Mizushima infested")+IF(B130>=1,1,0)	0.2421
218	Moji	=RiskOutput("probability Moji infested")+IF(B131>=1,1,0)	0.019
219	Muroran	=RiskOutput("probability Muroran infested")+IF(B132>=1,1,0)	0.0503
220	Nagasaki	=RiskOutput("probability Nagasaki infested")+IF(B133>=1,1,0)	0.0429
221	Nagoya	=RiskOutput("probability Nagoya infested")+IF(B134>=1,1,0)	0.6368
222	Nakanoseki	=RiskOutput("probability Nakanoseki infested")+IF(B135>=1,1,0)	0.0109
223	Niigata	=RiskOutput("probability Niigata infested")+IF(B136>=1,1,0)	0.0194
224	Niihama	=RiskOutput("probability Niihama infested")+IF(B137>=1,1,0)	0.0948
225	Numakuma	=RiskOutput("probability Numakuma infested")+IF(B138>=1,1,0)	0.0295
226	Oita	=RiskOutput("probability Oita infested")+IF(B139>=1,1,0)	0.0766
227	Omaezaki	=RiskOutput("probability Omaezaki infested")+IF(B140>=1,1,0)	0.01
228	Onahama	=RiskOutput("probability Onahama infested")+IF(B141>=1,1,0)	0.0584
229	Osaka	=RiskOutput("probability Osaka infested")+IF(B142>=1,1,0)	0.4235
230	Oshima	=RiskOutput("probability Oshima infested")+IF(B143>=1,1,0)	0.0199
231	Otaru	=RiskOutput("probability Otaru infested")+IF(B144>=1,1,0)	0.031
232	Saganoseki	=RiskOutput("probability Saganoseki infested")+IF(B145>=1,1,0)	0.0101
233	Sakai	=RiskOutput("probability Sakai infested")+IF(B146>=1,1,0)	0.0497
234	Sakaide	=RiskOutput("probability Sakaide infested")+IF(B147>=1,1,0)	0.0295
235	Sakaiminato	=RiskOutput("probability Sakaiminato infested")+IF(B148>=1,1,0)	0.0099
236	Sasebo	=RiskOutput("probability Sasebo infested")+IF(B149>=1,1,0)	0.0301
237	Shibushi	=RiskOutput("probability Shibushi infested")+IF(B150>=1,1,0)	0.0303
238	Shikama	=RiskOutput("probability Shikama infested")+IF(B151>=1,1,0)	0.0291
239	Shimizu	=RiskOutput("probability Shimizu infested")+IF(B152>=1,1,0)	0.2117
240	Shimonoseki	=RiskOutput("probability Shimonoseki infested")+IF(B153>=1,1,0)	0.0682
241	Shimotsu	=RiskOutput("probability Shimotsu infested")+IF(B154>=1,1,0)	0.0191
242	Tamano	=RiskOutput("probability Tamano infested")+IF(B155>=1,1,0)	0.0199
243	Tobata	=RiskOutput("probability Tobata infested")+IF(B156>=1,1,0)	0.0099
244	Tokuyama	=RiskOutput("probability Tokuyama infested")+IF(B157>=1,1,0)	0.0766
245	Tokyo	=RiskOutput("probability Tokyo infested")+IF(B158>=1,1,0)	0.5965
246	Tomakomai	=RiskOutput("probability Tomakomai infested")+IF(B159>=1,1,0)	0.0477
247	Toyohashi	=RiskOutput("probability Toyohashi infested")+IF(B160>=1,1,0)	0.4211
248	Tsuneishi	=RiskOutput("probability Tsuneishi infested")+IF(B161>=1,1,0)	0.0201
249	Tsuruga	=RiskOutput("probability Tsuruga infested")+IF(B162>=1,1,0)	0.0099
250	Ube	=RiskOutput("probability Ube infested")+IF(B163>=1,1,0)	0.0566
251	Uno	=RiskOutput("probability Uno infested")+IF(B164>=1,1,0)	0.03
252	Wakamatsu	=RiskOutput("probability Wakamatsu infested")+IF(B165>=1,1,0)	0.0101
253	Wakayama	=RiskOutput("probability Wakayama infested")+IF(B166>=1,1,0)	0.0288
254	Wanishi	=RiskOutput("probability Wanishi infested")+IF(B167>=1,1,0)	0.0469
255	Yatsushiro	=RiskOutput("probability Yatsushiro infested")+IF(B168>=1,1,0)	0.0208
256	Yawata	=RiskOutput("probability Yawata infested")+IF(B169>=1,1,0)	0.0306
257	Yokkaichi	=RiskOutput("probability Yokkaichi infested")+IF(B170>=1,1,0)	0.2981
258	Yokohama	=RiskOutput("probability Yokohama infested")+IF(B171>=1,1,0)	0.6762
259	Yokosuka	=RiskOutput("probability Yokosuka infested")+IF(B172>=1,1,0)	0.1008
260	Total Infested Ships	=RiskOutput("probability total ships infested")+IF(B173>=1,1,0)	0.9891

Appendix 14. AGM pathway model formula table (part 4).

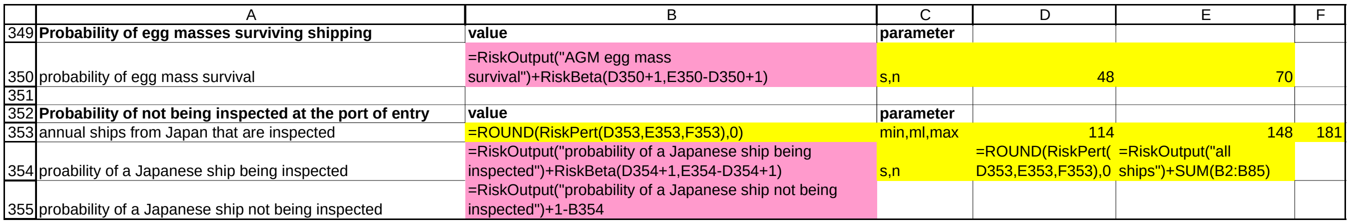
	A	B
262	**Port**	**years until an infested ship**
263	Akita	=RiskOutput("years until an infested ship from Akita arrives")+1+RiskNegbin(1,C176)
264	Chiba	=RiskOutput("years until an infested ship from Chiba arrives")+1+RiskNegbin(1,C177)
265	Fukuyama	=RiskOutput("years until an infested ship from Fukuyama arrives")+1+RiskNegbin(1,C178)
266	Funakawa	=RiskOutput("years until an infested ship from Funakawa arrives")+1+RiskNegbin(1,C179)
267	Gamagori	=RiskOutput("years until an infested ship from Gamagori arrives")+1+RiskNegbin(1,C180)
268	Hachinohe	=RiskOutput("years until an infested ship from Hachinohe arrives")+1+RiskNegbin(1,C181)
269	Hakata	=RiskOutput("years until an infested ship from Hakata arrives")+1+RiskNegbin(1,C182)
270	Hakodate	=RiskOutput("years until an infested ship from Hakodate arrives")+1+RiskNegbin(1,C183)
271	Higashi-Harima	=RiskOutput("years until an infested ship from Higashi-Harima arrives")+1+RiskNegbin(1,C184)
272	Hikari	=RiskOutput("years until an infested ship from Hikari arrives")+1+RiskNegbin(1,C185)
273	Hirohata	=RiskOutput("years until an infested ship from Hirohata arrives")+1+RiskNegbin(1,C186)
274	Hiroshima	=RiskOutput("years until an infested ship from Hiroshima arrives")+1+RiskNegbin(1,C187)
275	Hitachi	=RiskOutput("years until an infested ship from Hitachi arrives")+1+RiskNegbin(1,C188)
276	Ichihara	=RiskOutput("years until an infested ship from Ichihara arrives")+1+RiskNegbin(1,C189)
277	Imabari	=RiskOutput("years until an infested ship from Imabari arrives")+1+RiskNegbin(1,C190)
278	Ishigaki	=RiskOutput("years until an infested ship from Ishigaki arrives")+1+RiskNegbin(1,C191)
279	Ishikariwan Shinko	=RiskOutput("years until an infested ship from Ishikariwan Shinko arrives")+1+RiskNegbin(1,C192)
280	Ishinomaki	=RiskOutput("years until an infested ship from Ishinomaki arrives")+1+RiskNegbin(1,C193)
281	Iwagi	=RiskOutput("years until an infested ship from Iwagi arrives")+1+RiskNegbin(1,C194)
282	Iwakuni	=RiskOutput("years until an infested ship from Iwakuni arrives")+1+RiskNegbin(1,C195)
283	Kagoshima	=RiskOutput("years until an infested ship from Kagoshima arrives")+1+RiskNegbin(1,C196)
284	Kakogawa	=RiskOutput("years until an infested ship from Kakogawa arrives")+1+RiskNegbin(1,C197)
285	Kanazawa	=RiskOutput("years until an infested ship from Kanazawa arrives")+1+RiskNegbin(1,C198)
286	Kanda	=RiskOutput("years until an infested ship from Kanda arrives")+1+RiskNegbin(1,C199)
287	Kanokawa	=RiskOutput("years until an infested ship from Kanokawa arrives")+1+RiskNegbin(1,C200)
288	Kashima	=RiskOutput("years until an infested ship from Kashima arrives")+1+RiskNegbin(1,C201)
289	Kawasaki	=RiskOutput("years until an infested ship from Kawasaki arrives")+1+RiskNegbin(1,C202)
290	Kinuura	=RiskOutput("years until an infested ship from Kinuura arrives")+1+RiskNegbin(1,C203)
291	Kisarazu	=RiskOutput("years until an infested ship from Kisarazu arrives")+1+RiskNegbin(1,C204)
292	Kobe	=RiskOutput("years until an infested ship from Kobe arrives")+1+RiskNegbin(1,C205)
293	Kochi	=RiskOutput("years until an infested ship from Kochi arrives")+1+RiskNegbin(1,C206)
294	Kokura	=RiskOutput("years until an infested ship from Kokura arrives")+1+RiskNegbin(1,C207)
295	Komatsushima	=RiskOutput("years until an infested ship from Komatsushima arrives")+1+RiskNegbin(1,C208)
296	Kudamatsu	=RiskOutput("years until an infested ship from Kudamatsu arrives")+1+RiskNegbin(1,C209)
297	Kure	=RiskOutput("years until an infested ship from Kure arrives")+1+RiskNegbin(1,C210)
298	Kushiro	=RiskOutput("years until an infested ship from Kushiro arrives")+1+RiskNegbin(1,C211)
299	Maizuru	=RiskOutput("years until an infested ship from Maizuru arrives")+1+RiskNegbin(1,C212)
300	Marugame	=RiskOutput("years until an infested ship from Marugame arrives")+1+RiskNegbin(1,C213)
301	Matsuyama	=RiskOutput("years until an infested ship from Matsuyama arrives")+1+RiskNegbin(1,C214)
302	Mishima-Kawanoe	=RiskOutput("years until an infested ship from Mishima-Kawanoe arrives")+1+RiskNegbin(1,C215)
303	Mitsukoshima	=RiskOutput("years until an infested ship from Mitsukoshima arrives")+1+RiskNegbin(1,C216)
304	Mizushima	=RiskOutput("years until an infested ship from Mizushima arrives")+1+RiskNegbin(1,C217)
305	Moji	=RiskOutput("years until an infested ship from MOji arrives")+1+RiskNegbin(1,C218)
306	Muroran	=RiskOutput("years until an infested ship from Muroran arrives")+1+RiskNegbin(1,C219)
307	Nagasaki	=RiskOutput("years until an infested ship from Nagasaki arrives")+1+RiskNegbin(1,C220)
308	Nagoya	=RiskOutput("years until an infested ship from Nagoya arrives")+1+RiskNegbin(1,C221)
309	Nakanoseki	=RiskOutput("years until an infested ship from Nakanoseki arrives")+1+RiskNegbin(1,C222)
310	Niigata	=RiskOutput("years until an infested ship from Niigata arrives")+1+RiskNegbin(1,C223)
311	Niihama	=RiskOutput("years until an infested ship from Niihama arrives")+1+RiskNegbin(1,C224)
312	Numakuma	=RiskOutput("years until an infested ship from Numakuma arrives")+1+RiskNegbin(1,C225)
313	Oita	=RiskOutput("years until an infested ship from Oita arrives")+1+RiskNegbin(1,C226)
314	Omaezaki	=RiskOutput("years until an infested ship from Omaezaki arrives")+1+RiskNegbin(1,C227)
315	Onahama	=RiskOutput("years until an infested ship from Onahama arrives")+1+RiskNegbin(1,C228)
316	Osaka	=RiskOutput("years until an infested ship from Osaka arrives")+1+RiskNegbin(1,C229)
317	Oshima	=RiskOutput("years until an infested ship from Oshima arrives")+1+RiskNegbin(1,C230)
318	Otaru	=RiskOutput("years until an infested ship from Otaru arrives")+1+RiskNegbin(1,C231)
319	Saganoseki	=RiskOutput("years until an infested ship from Saganoseki arrives")+1+RiskNegbin(1,C232)
320	Sakai	=RiskOutput("years until an infested ship from Sakai arrives")+1+RiskNegbin(1,C233)
321	Sakaide	=RiskOutput("years until an infested ship from Sakaide arrives")+1+RiskNegbin(1,C234)
322	Sakaiminato	=RiskOutput("years until an infested ship from Sakaiminato arrives")+1+RiskNegbin(1,C235)
323	Sasebo	=RiskOutput("years until an infested ship from Sasebo arrives")+1+RiskNegbin(1,C236)
324	Shibushi	=RiskOutput("years until an infested ship from Shibushi arrives")+1+RiskNegbin(1,C237)
325	Shikama	=RiskOutput("years until an infested ship from Shikama arrives")+1+RiskNegbin(1,C238)
326	Shimizu	=RiskOutput("years until an infested ship from Shimizu arrives")+1+RiskNegbin(1,C239)
327	Shimonoseki	=RiskOutput("years until an infested ship from Shimonoseki arrives")+1+RiskNegbin(1,C240)
328	Shimotsu	=RiskOutput("years until an infested ship from Shimotsu arrives")+1+RiskNegbin(1,C241)
329	Tamano	=RiskOutput("years until an infested ship from Tamano arrives")+1+RiskNegbin(1,C242)
330	Tobata	=RiskOutput("years until an infested ship from Tobata arrives")+1+RiskNegbin(1,C243)
331	Tokuyama	=RiskOutput("years until an infested ship from Tokuyama arrives")+1+RiskNegbin(1,C244)
332	Tokyo	=RiskOutput("years until an infested ship from Tokyo arrives")+1+RiskNegbin(1,C245)
333	Tomakomai	=RiskOutput("years until an infested ship from Tomakomai arrives")+1+RiskNegbin(1,C246)
334	Toyohashi	=RiskOutput("years until an infested ship from Toyohashi arrives")+1+RiskNegbin(1,C247)
335	Tsuneishi	=RiskOutput("years until an infested ship from Tsuneishi arrives")+1+RiskNegbin(1,C248)
336	Tsuruga	=RiskOutput("years until an infested ship from Tsuruga arrives")+1+RiskNegbin(1,C249)
337	Ube	=RiskOutput("years until an infested ship from Ube arrives")+1+RiskNegbin(1,C250)
338	Uno	=RiskOutput("years until an infested ship from Uno arrives")+1+RiskNegbin(1,C251)
339	Wakamatsu	=RiskOutput("years until an infested ship from Wakamatsu arrives")+1+RiskNegbin(1,C252)
340	Wakayama	=RiskOutput("years until an infested ship from Wakayama arrives")+1+RiskNegbin(1,C253)
341	Wanishi	=RiskOutput("years until an infested ship from Wanishi arrives")+1+RiskNegbin(1,C254)
342	Yatsushiro	=RiskOutput("years until an infested ship from Yatsushiro arrives")+1+RiskNegbin(1,C255)
343	Yawata	=RiskOutput("years until an infested ship from Yawata arrives")+1+RiskNegbin(1,C256)
344	Yokkaichi	=RiskOutput("years until an infested ship from Yokkaichi arrives")+1+RiskNegbin(1,C257)
345	Yokohama	=RiskOutput("years until an infested ship from Yokohama arrives")+1+RiskNegbin(1,C258)
346	Yokosuka	=RiskOutput("years until an infested ship from Yokosuka arrives")+1+RiskNegbin(1,C259)
347	Total Infested Ships	=RiskOutput("years until an infested ship from all ports arrives")+1+RiskNegbin(1,C260)

Appendix 15. AGM model for: 1) egg masses surviving shipment and 2) ships from Japan not being inspected at the U.S. port of entry.



	A	B	C	D	E	F
349	**Probability of egg masses surviving shipping**	**value**	**parameter**			
350	probability of egg mass survival	0.680555556	s,n	48	70	
351						
352	**Probability of not being inspected at the port of entry**	**value**	**parameter**			
353	annual ships from Japan that are inspected	148	min,ml,max	114	148	181
354	proability of a Japanese ship being inspected	0.142447419	s,n	148	1044	
355	probability of a Japanese ship not being inspected	0.857552581				

Appendix 16. AGM model formula table for: 1) egg masses surviving shipment and 2) ships from Japan not being inspected at the U.S. port of entry.



	A	B	C	D	E	F
349	**Probability of egg masses surviving shipping**	**value**	**parameter**			
350	probability of egg mass survival	=RiskOutput("AGM egg mass survival")+RiskBeta(D350+1,E350-D350+1)	s,n	48	70	
351						
352	**Probability of not being inspected at the port of entry**	**value**	**parameter**			
353	annual ships from Japan that are inspected	=ROUND(RiskPert(D353,E353,F353),0)	min,ml,max	114	148	181
354	proability of a Japanese ship being inspected	=RiskOutput("probability of a Japanese ship being inspected")+RiskBeta(D354+1,E354-D354+1)	s,n	=ROUND(RiskPert(D353,E353,F353),0	=RiskOutput("all ships")+SUM(B2:B85)	
355	probability of a Japanese ship not being inspected	=RiskOutput("probability of a Japanese ship not being inspected")+1-B354				

Appendix 17. U.S. international waterports and regions.

Port	State	Region
Long Beach	CA	Pacific South
Los Angeles	CA	Pacific South
Morro Bay	CA	Pacific South
Oakland	CA	Pacific South
Redwood City	CA	Pacific South
Richmond	CA	Pacific South
Sacramento	CA	Pacific South
San Diego	CA	Pacific South
San Francisco	CA	Pacific South
Stockton	CA	Pacific South
Port Hueneme	CA	Pacific South
Monterey	CA	Pacific South
Ventura	CA	Pacific South
Carquinez Strait	CA	Pacific South
Port San Luis	CA	Pacific South
San Joaquin River	CA	Pacific South
Selby	CA	Pacific South
Capitan	CA	Pacific South
Suisun Bay	CA	Pacific South
Bridgeport	CT	Northeast Coast
New Haven	CT	Northeast Coast
New London	CT	Northeast Coast
Wilmington	DE	Northeast Coast
Jacksonville	FL	South
Panama City	FL	South
Pensacola	FL	South
Fernandina	FL	South
Brunswick	GA	South
Savannah	GA	South
Chicago	IL	Mid North
Gary	IN	Mid North
Louisville	KY	Northeast
Baton Rouge	LA	South
Lake Charles	LA	South
New Orleans	LA	South
Boston	MA	Northeast Coast
Salem	MA	Northeast Coast
Gloucester	MA	Northeast Coast
Fall River	MA	Northeast Coast
Baltimore	MD	Northeast Coast
Cambridge	MD	Northeast Coast
Portland	ME	Northeast Coast
Searsport	ME	Northeast Coast

Jonesport	ME	Northeast Coast
Marquette	MI	Mid North
Muskegon	MI	Mid North
Presque Isle	MI	Mid North
Escanaba	MI	Mid North
Alpena	MI	Mid North
Grand Haven	MI	Mid North
Mackinac Island	MI	Mid North
Duluth, MN - Superior, WI	MN	Mid North
Minneapolis-St. Paul	MN	Mid North
Duluth	MN	Mid North
Kansas City	MO	Mid
Gulfport	MS	South
Pascagoula	MS	South
Vicksburg	MS	South
Greenville	MS	South
Wilmington	NC	South
Portsmouth	NH	Northeast Coast
Camden	NJ	Northeast Coast
Paulsboro	NJ	Northeast Coast
Albany	NY	Northeast Coast
New York	NY	Northeast Coast
Oswego	NY	Northeast
Rochester	NY	Northeast
Cleveland	OH	Northeast
Ashtabula/Conneaut	OH	Northeast
Cincinnati-Lawrenceburg	OH	Northeast
Ashbatula	OH	Northeast
Conneaut	OH	Northeast
Fairport	OH	Northeast
Huron	OH	Northeast
Coos Bay	OR	Pacific North
Portland	OR	Pacific North
Astoria	OR	Pacific North
Chester	PA	Northeast Coast
Erie	PA	Northeast
Philadelphia	PA	Northeast Coast
Pittsburgh	PA	Northeast
Newport	RI	Northeast Coast
Providence	RI	Northeast Coast
Charleston	SC	South
Georgetown	SC	South
Port	State	Region
Chattanooga	TN	South
Memphis	TN	South

Nashville	TN	South
Beaumont	TX	South
Houston	TX	South
Port Arthur	TX	South
Orange	TX	South
Sabine	TX	South
Alexandria	VA	Northeast Coast
Hopewell	VA	Northeast Coast
Norfolk	VA	Northeast Coast
Richmond-Petersburg	VA	Northeast Coast
Newport News	VA	Northeast Coast
Anacortes	WA	Pacific North
Bellingham	WA	Pacific North
Everett	WA	Pacific North
Kalama	WA	Pacific North
Longview	WA	Pacific North
Olympia	WA	Pacific North
Port Angeles	WA	Pacific North
Port Townsend	WA	Pacific North
Seattle	WA	Pacific North
Tacoma	WA	Pacific North
Vancouver	WA	Pacific North
Green Bay	WI	Mid North
Milwaukee	WI	Mid North
Ashland	WI	Mid North
Superior	WI	Mid North

Appendix 18. United States endangered and threatened species that could be affected by AGM. USDI-USFWS, 2004 [accessed June, 2004] (http://ecos.fw.gov/tess_public/TESSSpeciesReport).

Species	Common Name	Distribution	Family	Endangered /Threatened Status
Acaena exigua	Liliwai	U.S. (HI)	Rosaceae	Endangered
Aeschynomene virginica	Sensitive joint-vetch	U.S. (DE, MD, NC, NJ, PA, VA)	Fabaceae	Threatened
Alectryon macrococcus	Mahoe	U.S. (HI)	Sapindaceae	Endangered
Alopecurus aequalis var. *sonomensis*	Sonoma alopecurus	U.S. (CA)	Poaceae	Endangered
Amorpha crenulata	Crenulate lead-plant	U.S. (FL)	Fabaceae	Endangered
Apios priceana	Price's potato-bean	U.S. (AL, IL, KY, MS, TN)	Fabaceae	Threatened
Arctostaphylos confertiflora	Santa Rosa Island manzanita	U.S. (CA)	Ericaceae	Endangered
Arctostaphylos glandulosa ssp. *crassifolia*	Del Mar manzanita	U.S. (CA), Mexico.	Ericaceae	Endangered
Arctostaphylos hookeri var. *ravenii*	Presidio Manzanita	U.S. (CA)	Ericaceae	Endangered
Arctostaphylos morroensis	Morro manzanita	U.S. (CA)	Ericaceae	Threatened
Arctostaphylos myrtifolia	Ione manzanita	U.S. (CA)	Ericaceae	Threatened
Arctostaphylos pallida	Pallid manzanita	U.S. (CA)	Ericaceae	Threatened
Aristida chaseae	No common name	U.S. (PR)	Poaceae	Endangered
Aristida portoricensis	Pelos del diablo	U.S. (PR)	Poaceae	Endangered
Astragalus albens	Cushenbury milk-vetch	U.S. (CA)	Fabaceae	Endangered
Astragalus ampullarioides	Shivwitz milk-vetch	U.S. (UT)	Fabaceae	Endangered
Astragalus applegatei	Applegate's milk-vetch	U.S. (OR)	Fabaceae	Endangered

Astragalus bibullatus	Guthrie's (=Pyne's) ground-plum	U.S. (TN)	Fabaceae	Endangered
Astragalus brauntonii	Braunton's milk-vetch	U.S. (CA)	Fabaceae	Endangered
Astragalus clarianus	Clara Hunt's milk-vetch	U.S. (CA)	Fabaceae	Endangered
Astragalus cremnophylax var. *cremnophylax*	Sentry milk-vetch	U.S. (AZ)	Fabaceae	Endangered
Astragalus desereticus	Deseret milk-vetch	U.S. (UT)	Fabaceae	Threatened
Astragalus holmgreniorum	Holmgren milk-vetch	U.S. (AZ, UT)	Fabaceae	Endangered
Astragalus humillimus	Mancos milk-vetch	U.S. (CO, NM)	Fabaceae	Endangered
Astragalus jaegerianus	Lane Mountain milk-vetch	U.S. (CA)	Fabaceae	Endangered
Astragalus lentiginosus var. *coachellae*	Coachella Valley milk-vetch	U.S. (CA)	Fabaceae	Endangered
Astragalus lentiginosus var. *piscinensis*	Fish Slough milk-vetch	U.S. (CA)	Fabaceae	Threatened
Astragalus magdalenae var. *peirsonii*	Peirson's milk-vetch	U.S. (CA)	Fabaceae	Threatened
Astragalus montii	Heliotrope milk-vetch	U.S. (UT)	Fabaceae	Threatened
Astragalus osterhoutii	Osterhout milk-vetch	U.S. (CO)	Fabaceae	Endangered
Astragalus phoenix	Ash meadows milk-vetch	U.S. (NV)	Fabaceae	Threatened
Astragalus pycnostachyus var. *lanosissimus*	Ventura Marsh Milk-vetch	U.S. (CA)	Fabaceae	Endangered
Astragalus robbinsii var. *jesupi*	Jesup's milk-vetch	U.S. (NH, VT)	Fabaceae	Endangered

Astragalus tener var. *titi*	Coastal dunes milk-vetch	U.S. (CA)	Fabaceae	Endangered
Astragalus tricarinatus	Triple-ribbed milk-vetch	U.S. (CA)	Fabaceae	Endangered
Baptisia arachnifera	Hairy rattleweed	U.S. (GA)	Fabaceae	Endangered
Betula uber	Virginia round-leaf birch	U.S. (VA)	Betulaceae	Threatened
Caesalpinia kavaiense	Uhiuhi	U.S. (HI)	Fabaceae	Endangered
Calyptranthes thomasiana	No common name	U.S. (PR, VI) British VI	Myrtaceae	Endangered
Canavalia molokaiensis	`Awikiwiki	U.S. (HI)	Fabaceae	Endangered
Cenchrus agrimonioides	Kamanomano	U.S. (HI)	Poaceae	Endangered
Cercocarpus traskiae	Catalina Island mountain-mahogany	U.S. (CA)	Rosaceae	Endangered
Chamaecrista glandulosa var. *mirabilis*	No common name	U.S. (PR)	Fabaceae	Endangered
Chionanthus pygmaeus	Pygmy fringe-tree	U.S. (FL)	Oleaceae	Endangered
Clitoria fragrans	Pigeon wings	U.S. (FL)	Fabaceae	Threatened
Crotalaria avonensis	Avon Park harebells	U.S. (FL)	Fabaceae	Endangered
Dalea foliosa	Leafy prairie-clover	U.S. (AL, IL, TN)	Fabaceae	Endangered
Eragrostis fosbergii	Fosberg's love grass	U.S. (HI)	Poaceae	Endangered
Eugenia haematocarpa	Uvillo	U.S. (PR)	Myrtaceae	Endangered
Eugenia koolauensis	Nioi	U.S. (HI)	Myrtaceae	Endangered
Eugenia woodburyana	No common name	U.S. (PR)	Myrtaceae	Endangered
Galactia smallii	Small's milkpea	U.S. (FL)	Fabaceae	Endangered
Geum radiatum	Spreading avens	U.S. (NC, TN)	Rosaceae	Endangered

Hoffmannseggia tenella	Slender rush-pea	U.S. (TX)	Fabaceae	Endangered
Ischaemum byrone	Hilo ischaemum	U.S. (HI)	Poaceae	Endangered
Ivesia kingii var. *eremica*	Ash Meadows ivesia	U.S. (NV)	Rosaceae	Threatened
Juglans jamaicensis	West Indian or nogal walnut	U.S. (PR), Cuba, Hispaniola	Juglandaceae	Endangered
Kanaloa kahoolawensis	Kohe malama malama o kanaloa	U.S. (HI)	Fabaceae	Endangered
Lespedeza leptostachya	Prairie bush-clover	U.S. (IA, IL, MN, WI)	Fabaceae	Threatened
Lotus dendroideus ssp. *traskiae*	San Clemente Island broom	U.S. (CA)	Fabaceae	Endangered
Lupinus aridorum	Scrub lupine	U.S. (FL)	Fabaceae	Endangered
Lupinus nipomensis	Nipomo Mesa lupine	U.S. (CA)	Fabaceae	Endangered
Lupinus sulphureus (=*oreganus*) ssp. *kincaidii* (=var. *kincaidii)*	Kincaid's Lupine	U.S. (OR, WA)	Fabaceae	Threatened
Lupinus tidestromii	Clover lupine	U.S. (CA)	Fabaceae	Endangered
Lyonia truncata var. *proctorii*	No common name	U.S. (PR)	Ericaceae	Endangered
Myrcia paganii	No common name	U.S. (PR)	Myrtaceae	Endangered
Neostapfia colusana	Colusa grass	U.S. (CA)	Poaceae	Threatened
Orcuttia californica	California Orcutt grass	U.S. (CA)	Poaceae	Endangered
Orcuttia inaequalis	San Joaquin Orcutt grass	U.S. (CA)	Poaceae	Threatened
Orcuttia pilosa	Hairy Orcutt grass	U.S. (CA)	Poaceae	Endangered

Orcuttia tenuis	Slender Orcutt grass	U.S. (CA)	Poaceae	Threatened
Orcuttia viscida	Sacramento Orcutt grass	U.S. (CA)	Poaceae	Endangered
Oxytropis campestris var. *chartacea*	Fassett's locoweed	U.S. (WI)	Fabaceae	Threatened
Panicum fauriei var. *carteri*	Carter's panicgrass	U.S. (HI)	Poaceae	Endangered
Panicum niihauense	Lau `ehu	U.S. (HI)	Poaceae	Endangered
Poa atropurpurea	San Bernardino bluegrass	U.S. (CA)	Poaceae	Endangered
Poa mannii	Mann's bluegrass	U.S. (HI)	Poaceae	Endangered
Poa napensis	Napa bluegrass	U.S. (CA)	Poaceae	Endangered
Poa sandvicensis	Hawaiian bluegrass	U.S. (HI)	Poaceae	Endangered
Poa siphonoglossa	No common name	U.S. (HI)	Poaceae	Endangered
Potentilla hickmanii	Hickman's potentilla	U.S. (CA)	Rosaceae	Endangered
Prunus geniculata	Scrub plum	U.S. (FL)	Rosaceae	Endangered
Purshia (=*Cowania*) *subintegra*	Arizona Cliff-rose	U.S. (AZ)	Rosaceae	Endangered
Quercus hinckleyi	Hinckley oak	U.S. (TX)	Fagaceae	Threatened
Rhododendron chapmanii	Chapman rhododendron	U.S. (FL)	Ericaceae	Endangered
Rhus michauxii	Michaux's sumac	U.S. (GA, NC, SC, VA)	Anacardiaceae	Endangered
Serianthes nelsonii	Hayun Iagu (=(Guam), Tronkon guafi (Rota))	Western Pacific Ocean-U.S. (GU, MP-Rota)	Fabaceae	Endangered
Sesbania tomentosa	Ohai	U.S. (HI)	Fabaceae	Endangered

Spiraea virginiana	Virginia spiraea	U.S. (GA, KY, NC, OH, PA, TN, VA, WV)	Rosaceae	Threatened
Stahlia monosperma	Cobana negra	U.S. (PR), Dominican Republic	Fabaceae	Threatened
Swallenia alexandrae	Eureka Dune grass	U.S. (CA)	Poaceae	Endangered
Trifolium amoenum	Showy Indian clover	U.S. (CA)	Fabaceae	Endangered
Trifolium stoloniferum	Running buffalo clover	U.S. (AR, IL, IN, KS, KY, MO, OH, WV)	Fabaceae	Endangered
Trifolium trichocalyx	Monterey clover	U.S. (CA)	Fabaceae	Endangered
Tuctoria greenei	Greene's tuctoria	U.S. (CA	Poaceae	Endangered
Tuctoria mucronata	Solano grass	U.S. (CA)	Poaceae	Endangered
Vicia menziesii	Hawaiian vetch	U.S. (HI)	Fabaceae	Endangered
Vigna o-wahuensis	No common name	U.S. (HI)	Fabaceae	Endangered
Zizania texana	Texas wild-rice	U.S. (TX)	Poaceae	Endangered

Appendix 19. Vessel Inspection Guidelines – Russian AGM Program (http://www.ceris.purdue.edu/napis/pests/agm/ship/agmguide.html).

Supplied by - United States Department of Agriculture - Animal Plant Health Inspection Service

Vessel Inspection Guidelines - Asian Gypsy Moth (AGM)

The purpose of this program is to prevent the artificial spread of Asian gypsy moth *(Lymantria dispar)* from Far East Russian ports to North America. The moth flight period in the Russian Far East is from July 15 to September 30.

The AGM displays significant behavioral differences compared to the North American gypsy moth (NAGM). The female AGM is an active flyer that is attracted to lights, and capable of flying up to 25 miles (40 K). The AGM feeds on larch and other conifers as well as on alder and willow. Oaks and other hardwood species are also acceptable hosts.

Attracted by the lights on vessels, the females may lay eggs on the superstructure. The larvae can be blown by the wind short distances on silk strands. Due to these characteristics, a list of vessels which called in Far East Russian ports July 15 through September 30 has been developed, the AGM Vessel Alert List. Data from several sources was used to produce the list.

The Animal and Plant Health Inspection Service (APHIS) has asked shipping interests not to charter ships that called at Russian Far East ports during the egg laying period for voyages that would put the vessels in U.S. or Canadian ports during the high risk egg hatching period. Any vessel that arrives during this period that is found infested will be ordered to leave U.S. waters immediately. **Although APHIS has no regulation prohibiting the entry of AGM high risk vessels, the Plant Pest Act grants the authority to order infested vessels to leave U.S. waters.**

Procedures

A. Determine which ships should be excluded entry, which should be boarded on arrival, and which require normal non-AGM boarding. These procedures utilize two types of exclusion. 1. If a pest is found, PPQ has the authority to order a vessel to leave U.S. waters, a mandatory exclusion. 2. PPQ has asked the shipping industry not to bring vessels which have been in Far East Russian ports during July, August, and September of the previous year into U.S. ports during the high risk hatching period. This is a voluntary exclusion.

Hawaii, Puerto Rico, and Guam are exempt from excluding entry to these vessels because the climate and host conditions are not suitable for AGM. Throughout the year ships from Far East Russian ports are allowed to arrive in Hawaii, Puerto Rico, and Guam subject to inspection.

Southern ports need to be more aware of AGM inspection of ships year around because of the possible risk of larvae hatching in these warmer climates, even during the months which are not considered the high risk hatching period.

The AGM vessel alert list includes vessels which called at a Far East Russian port during July 15 - September 30. Check the list for the ship's name and Lloyd's register number to determine if the vessel is high risk for AGM. If a vessel arrives which has a name very similar to one on the alert list, check with the agent to verify the Lloyd's register number, or the itinerary of the vessel July 15 - September 30. The alert list is not all inclusive, so apply the vessel risk criteria which follows to all arrivals.

2. Check the ship's itinerary for a Far East Russian port that occurs within the range from Posyet to Nikolayevsk. The three most likely ports are Nakhodka, Vladivostok, and Vostochny. Refer to attachment 1 for a noninclusive list of Far East Russian ports. Northern Chinese ports, Japanese ports, and Korean ports may also be suspect.

3. Apply risk criteria to arriving vessels.

Consider a vessel **high risk** which is arriving at a continental U.S. port during March, April, May, June, July, or August **and**:

- Which is specifically identified on the AGM vessel alert list, or
- With an itinerary including a Far East Russian port where the vessel called during July 15 - September 30 of the previous year, or,
- With a Russian flag and an itinerary that cannot adequately verify the location of the ship during July - September of the previous year.

These vessels can be boarded instream or at preapproved remote sites. High risk vessels will be allowed to move to the berth for inspection when presenting certification from the State Plant Quarantine Service of Russia. The certification must state that the vessel has been inspected and no evidence of any live stages of *Lymantria spp.* were found (see attachment #2).

Consider a vessel **low risk** which is arriving at a continental U.S. port during January, February, September, October, November, or December **and**

- Which is specifically identified on the AGM vessel alert list, or
- With an itinerary including a Far East Russian port where the vessel called during July 15 - September 30 of the previous year, or,
- With a Russian flag and an itinerary that cannot adequately verify the location of the ship during July - September of the previous year

These vessels are allowed to proceed to the intended berth for initial AGM inspection and follow-up monitoring, if necessary.

The following chart summarizes the procedures for determining which action to take.

If the month is:	And the ship's name is:	And the ship's itinerary:	And the ship called at the Russian port(s):	Then:

March April May June July August (high risk hatching period)	On the alert list			EXCLUDE entry PROVIDE options for inspection outside the port area*
	Not on the alert list	Includes a Far East Russian port	July 15 - September 30	
			Other than the period listed above	ALLOW movement to berth BOARD on arrival
		Does not include a Far East Russian port		REQUIRE normal, non- AGM boarding procedures
		Cannot be ascertained		ALLOW movement to berth BOARD on arrival
January February September October November December (low risk hatching period)	On the alert list			
	Not on the alert list	Includes a Far East Russian port		
		Does not include a Far East Russian port		REQUIRE normal, non- AGM boarding procedures

* If Russian inspection certification is presented, allow movement to berth for inspection. See attachment #2.

4. Every effort should be made to encourage voluntary exclusion of ships identified as high risk AGM vessels arriving at a U.S. port during the high risk hatching period.

During the high risk hatching period, inspection can be accomplished by boarding instream or at preapproved sites. Provide options to inspect or to conduct an initial evaluation at a remote location. This option provides the mutual benefit of reducing the risk of pest introduction, and saving money for the shipping industry by reducing the possibility of a ship being ordered out of U.S. waters after traveling inland waterways. Boarding a vessel instream is an option which must be requested by the agent and approved by the Regional Director. All arrangements concerning transportation to the vessel and the method of boarding should be confirmed before the trip to the ship begins.

If the ship is found to be free of suspect AGM egg masses or larvae, allow the vessel to proceed to its intended berth. While in port, monitor the vessel daily for hatching AGM larvae.

B. Boarding vessels instream is not a standard procedure. The Regional Director approves instream boarding.

1. Request the ship's agent or the U.S. Coast Guard (at particular sites) to arrange for and provide a boarding and retrieval launch, and a suitable boarding method. U.S. Coast Guard units at ports without sufficient resources to transport PPQ officers can provide PPQ with a list of certified, commercial marine taxi or launch services.

2. Wear a U.S. Coast Guard approved floatation jacket.

3. Board the ship on arrival, within one hour after sunrise and three hours before sunset.

4. Board by conventional gangway or another method judged safe by the boarding officers.

C. Ordering a vessel to leave U.S. waters.

1. Issue an Emergency Action Notification, PPQ Form 523. Request the vessel's master to prepare for and execute an immediate departure. The notification will instruct the vessel's agent to immediately call out necessary tugs, linesmen and pilots for the vessel's departure. The only actions allowed are those that make the vessel seaworthy, such as bunkering.

2. Issue a Request for Customs Action, PPQ Form 227. Request a stop of all business related to the vessel other than that necessary to make the vessel seaworthy. Customs will withhold clearance, either coastwise or foreign.

3. Send or hand deliver a cover memorandum with a copy of the Emergency Action Notification to the U.S. Coast Guard Port Captain. Request the Port Captain's help to immediately escort the vessel from U.S. waters.

4. The PPQ Officer should take any mitigating action necessary to prevent pest introduction prior to the vessel's departure.

D. During the low risk period, suspect AGM vessels are boarded on arrival, or within one hour of sunrise if arriving during the night. Inspect all accessible areas of the vessel's superstructure. Use binoculars to inspect unreachable areas of the ship. Inspect the vessel's hold(s) when there are indications (physical evidence on the superstructure or vessel records) that the vessel has been cleaned for AGM. If possible, at least two officers should conduct the inspection.

Look for egg masses when boarding any vessel from Asian ports.

E. Inspection - Egg masses are the most likely life stage to be found on the superstructure of a vessel. During March through August, hatching larvae can be found. Hatching larvae present an unacceptable pest risk any time of the year at any U.S. port. Use USDA/APHIS program aid number 1329, "Don't Move Gypsy Moth" for identifying life stages of gypsy moths. Egg masses are normally deposited in sheltered locations such as in crevices or cavities, under tarps, and behind walls and doors. Use binoculars to inspect unreachable areas of the ship. The female AGM is attracted to light. Therefore, the female moths could lay their egg masses on surfaces of the vessel that are exposed to night lights. However, if the vessel was lit with shore based flood lights while in a Far East Russian port, egg masses could be found in all locations. Viable egg masses on vessels may be weathered, darkened and appear old. Look for evidence of fresh paint covering scrapes on walls or painted over egg masses. Look for hatching larvae that may be blowing on silk strands from the vessel. Peak hatching of eggs is in the morning. Dispersing larvae move toward vertical structures and climb rapidly.

The following chart summarizes the procedures for determining which action to take.

If the month is:	And you find:	Then:
March April May June July August (high risk hatching period)	Egg masses or hatching larvae	ORDER the ship to leave-refer to section C of these guidelines. Notify Port Operations for guidance on allowing the vessel to return for reinspection.
	No life stages of gypsy moth	ALLOW the ship to dock and conduct business REQUIRE daily monitoring for hatching larvae until the ship leaves the U.S. port
January	Egg masses	DETERMINE final regulatory action based on level of infestation and guidance from management

February September October November December (low risk hatching period)	Hatching larvae	ORDER the ship to leave-refer to section C of these guidelines
	No life stages of gypsy moth	ALLOW the ship to dock and conduct business MONITOR the ship while in port

F. Treatment - When necessary, require drenching the egg masses with the following product.

Golden Natur'l Spray Oil - registered for gypsy moth. Available from Stoller Enterprises, Inc. 8582 Katy Freeway, Houston, Texas 77024, telephone (713) 464-5580, fax (713) 461-4467.

Using a hand sprayer, apply the mixture to individual egg masses until they are completely saturated. Keep the mixture agitated while treating. Establish contingency plans for quick availability of commercial spray equipment for large applications. Port Directors should work with port authorities and/or ship's agents to arrange for commercial pesticide applicators to be on standby in the event they are needed to apply the treatment. Commercial application will be at the expense of the agent, vessel, or port authority.

If a sample of egg mass is needed for identification, remove a few egg masses from the vessel. Using a knife, paint scraper, or putty knife, scrape a few egg masses from the ship's surface and place into a container. Be careful not to drop egg masses into the water.

G. Monitor vessels daily that have been allowed to dock, until they have left the port. Peak hatching of eggs is in the morning. Check the ship for dispersing larvae that move toward vertical structures and climb rapidly.

H. Each PPQ office will report inspection results within 1 working day to Port Operations by telephone, fax, or E-Mail. A copy should also be sent to the Regional office. Clearly identify the information with the title, "AGM Ship Inspection". Include the following information:

- Vessel name
- Flag
- Port

- Date of inspection
- Result of inspection-positive (life stage found), or negative
- Action taken-brief statement

Updates to the AGM vessel alert list will be posted on the PPQ bulletin board as changes occur.

PPQ Form 288 (Ship Inspection Report) can be used to document the above information. Note in remarks the results of inspection and the action taken.

Attachment 1

Far East Russian High Risk AGM Ports

- Nakhodka
- Ol'ga
- Plastun
- Slavyanka
- Vanino
- Vladivostok
- Vostochny
- Zarubino

Attachment 2

United States Department of Agriculture

Asian Gypsy Moth Vessel Inspection

Revision to Inspection Guidelines

Effective March 1, 1997, the U.S. Department of Agriculture is revising the Asian Gypsy Moth (AGM) Vessel Inspection Guidelines. Vessels which are designated as high risk for introduction of AGM will be allowed to move to the berth for inspection when presenting certification from the State Plant Quarantine Service of Russia. The certification must state that the vessel is free of Asian gypsy moth (AGM). The purpose of this change is to encourage vessel inspections at Russian Far East ports to prevent the spread of AGM to North America by hitchhiking on vessels.

Background:

The purpose of the AGM vessel inspection program is to prevent the spread of Asian gypsy moth (Lymantria dispar) from Russian Far East ports to North America. AGM females are attracted to lights on vessels while in Russian Far East ports. They lay egg masses on vessels which move to North America. The larvae emerge from the egg masses and float on the wind to shore. AGM is a serious pest that is not established in the United States. It has a wide range of hosts, and introductions spread quickly because the female can fly large distances before she lays eggs.

Procedures:

Vessels which where in Russian Far East ports during July 15-September 30, 1998 and expect to be in U.S. ports during March-August of the next year, should request an inspection from the State Plant Quarantine Service of Russia. During July-September, adult AGM are flying in the Russian ports, and could contaminate a vessel. They lay eggs in summer, then larvae emerge from the egg masses the next year. To have Russian certification for March the vessel should be inspected just prior to leaving the Russian port in July-September of the previous year. Vessels in Russian Far East ports other than July-September do not require Russian certification.

The Russian certification must be provided to the local U.S. Department of Agriculture, Plant Protection and Quarantine office prior to arrival at a U.S. port during March-August 1999. If certification is provided, the vessel may move to the berth for inspection. If Russian certification is not provided for vessels which were in Russian Far East ports during July 20-September 30, the vessel will be inspected at a remote location prior to arrival. Vessels which obtain Russian certification and then return to Russian Far East ports during the AGM flight period must be inspected again. The vessel has been exposed to AGM making the previous certification invalid.

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