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RESEARCH ARTICLE

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Pest risk assessment of *Dendroctonus valens*, *Hyphantria cunea* and *Apriona swainsoni* in Beijing

Abstract According to the international methods of pest risk analysis and urban forestry characteristics in Beijing, a quantitative risk assessment system in Beijing for three primary non-indigenous pests was proposed. This system was used to analyze three major non-indigenous species, *Dendroctonus valens*, *Hyphantria cunea*, and *Apriona swainsoni*. The results show that the risks of these three pests in the Beijing area were 2.46, 2.30, and 2.02, which were all highly risky. Based on the result and extensive risk communications, combined with the management experience of the Beijing Forest Protection Station, the authors proposed some effective control measures to prevent the invasion of the three pests into Beijing.

Keywords pest risk assessment, *Dendroctonus valens*, *Hyphantria cunea*, *Apriona swainsoni*

1 Introduction

Pest Risk Analysis (PRA) refers to the process of evaluating biological or other scientific and economic evidence to determine whether a pest should be regulated and the strength of any phytosanitary measures to be taken against it (Chen et al., 2002; FAO/IPPC, 2002), which includes pest risk assessment, pest risk management and pest risk communication.

Due to varied local conditions, aspects of pest risk analysis were stressed differently. Taking into account regulations and PRA guidelines (FAO/IPPC, 1995) and quarantine pest risk analysis rules (FAO/IPPC, 2001) set forth by the Federal Agriculture Organization, risk assessment system was also established in China correspondingly (Jiang et al., 1995).

Beijing, which is going to host the Olympic Games in 2006, is the political, economic, as well cultural center of China. It has been a serious issue to prevent the invasion of non-indigenous pests (Shen and Yang, 2005) into this area.

Non-indigenous pests have caused severe damage and brought a large amount of loss. It is worth noting that *Hyphantria cunea* (American white moth) threatened Beijing, *Apriona swainsoni* entered into Beijing and brought much attention (Xie, 2000), and destructive disaster to *Pinus tabulaeformis* was caused by *Dendroctonus valens* (Red turpentine beetle, RTB) in provinces of Shanxi, Shaanxi, Hebei, and Henan (Zhao et al., 2002). These hazardous pests have posed a serious menace to Beijing. With the development of economy and increasing goods flux, the risk of further pest spread is increasing in an active or passive pathway. Therefore, it is necessary to take effective measures to prevent the spread of these non-indigenous pests by undertaking the pest risk analysis.

2 Distribution and damage of *D. valens*, *H. cunea* and *A. swainsoni*

2.1 Distribution

The distribution of the three pests up to the end of 2003 is shown in Table 1.

2.2 Damage

2.2.1 D. valens (Red turpentine beetle, RTB)

D. valens is a new listed species in China, which was originally

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Table 1 Distribution of three risky pests

Pest	Distribution in China	Distribution outside China
Dendroctonus valens	Shanxi, Hebei, Henan, Shannxi	American, Canada, Mexico, Guatemala, Honduras
Hyphantria cunea	Shanghai, Tianjin, Liaoning, Shandong, Shannxi, Hebei	Japan, Kirghizia, DPR Korea, Korea, Bulgaria, Czech, Slovak, Poland, Austria, German, Romania, Foregone Jugoslavia, Hungary, France, Greece, Italy, Russia, Ukraine, Mexico, Canada, American.
Apriona swainson	Henan, Shandong, Guangxi, Sichuan, Guizhou, Yunnan, Jiangsu, Hubei, Zhejiang, Anhui, Hebei, Shannxi, Hunan	Vietnam, Laos, India, Burma etc.

detected to harm *P. tabulaeformis* in the cities of Qinshui and Yangcheng, Shanxi Provice in 1998. Trees ranging from 3 cm in diameter at breast height to those that are hundred years old all can be infected. This species usually hides under bark of the basal trunk and root, and was hardly found before severe damage (Yin, 2000). Based on statistics of State Forestry Administration of China, the damage area of this species sums up to 36.5 hm^2 and covers 22 districts (cities), 85 counties, and 7 forestry management bureaus of the three provinces. In addition, approximately, 6 million individual plants dried up to death because of the damage. Direct economic damage adds up to RMB 684 million and indirect biological damage to RMB 810 million (Song et al., 2000; Zhao et al., 2002). *D. valens*, regarded as “one severe forest conflagration without smoke”, has threatened the whole forest resources of Shanxi Province. Hence, the State Forestry Administration has listed the management and control of this pest as crucial projects of the State.

2.2.2 *H. cunea (American white moth)*

This moth is in the list of national quarantine objectives. It originates from north America and possesses characteristics such as rapid spread speed, striking reproduction ability, wide adaptation to host plants, along with marvelous amount of food intake. In the early 1940s, it was introduced from America to Hungary. Then up to 1962, it spread throughout the whole of Europe and caused disastrous damage on crops and forest. In China, the American white moth first entered into the Dandong City of Liaoning Provice in 1979, and thus far, has been introduced into other places such as Hebei, Shandong, Tianjin, and Shanghai, including 140 counties or districts (Wang et al., 1999; Mei et al., 2002), with a damage area of 1.05×10^5 hm^2. In 1981, the General Office of the State Council released No.11 document [1981], which was required to strengthen the guard against the American white moth, and the State Forestry Administration listed it as one of top ten forest insects and diseases of China in 1999, and included it into the “American white moth management project in the Beijing-Tianjin-Hebei area”.

2.2.3 *Apriona swainson*

A. swainson, usually called “the killer of *Sophora japonica*”, was listed in the forest plant quarantine objects released in the 1996 file of the former Ministry of Forestry (now State Forestry Administration), and its harm to roadside trees should not be neglected. In June 2001, 1,700 individual *S. japonica* trees were infected in the Haining City of Zhejiang Province. In addition, the Henan Rural Newspaper of June 16, 2001 reported that this beetle had infected *S. japonica* of the district and street trees in the cities of Zhengzhou, Kaifeng, and Puyang, in Henan Province. The damage by *A. swainson* was particularly severe in Kaifeng of Henan, and there are at least four to five exit holes for each individual tree, and some trees even have sixty to seventy holes.

3 Host tree species and their significance in Beijing

3.1 RTB’s host trees and their significance in Beijing

RTB’s host trees include *Pinus* spp., *Picea* spp., *Pseadotsuga* spp., *Abies* spp., and *Larix* spp., and among them, the main host trees are *Pinus tabulaeformis*, which plays an important role in keeping soil and water, self-restraint waterhead, greening the city, and preventing desertification of soil, and if destroyed, an ecological disaster would happen. *Pinus tabulaeformis* is not only one of the main ornamental tree species, but also the main tree species in the water resource protection forests of the Miyun reservoir. The Miyun reservoir is regarded as “the kidney of Beijing” (Liu et al., 2001) and provides 80% of urban domestic water. So, it is the lifeline of the resident’s life and city construction. It was estimated that the water-holding capacity, net increment of flood-pooling capacity, and soil infiltration volume of rainfall of *P. tabulaeformis* forests are 1.30 million, 21.56 million, and 14.59 million ton, respectively. Its ecological functions are irreplaceable to this area (Liao et al., 2000). In 1994, forest resources inventory in Beijing showed that the area of *P. tabulaeformis* accounted for 18.7% of predominant tree species. The area that *P. tabulaeformis* occupies has been increasing in recent years.

Presently, *P. tabulaeformis* is also the primary species for protection in the Songshan National Nature Reserve in the Yanqing County and the Yunfeng Mountain Nature Reserve. There has been a large area of aged pines preserved in Beijing, among which *P. tabulaeformis* is the main species and thus, it was usually noted that “Beijing hosts all prestigious pines”. *P. tabulaeformis* also constitutes primary roadside tree species. In addition, RTB can live on *P. bungeana*, a native species in China, to finish the life cycle. Potentially, RTB can bring a huge potential ecological risk to Beijing, and thus, essential precautions should be taken.

3.2 American white moth's host plants and their significance in Beijing

American white moth is a polyphagous pest, and can cause harm to a variety of trees, crops, vegetables, and wild plants, especially to broadleaf trees distributed on roadside and woodland edges. According to literatures, its hosts include 120 species in America, 230 in Europe, and over 300 in Japan. According to domestic investigation, American white moth can harm plants of 83 genera, 43 families in Yantai of Shandong Province, and 143 species, 41 families in Dalian of Liaoning Province. It hosts in almost all forest species, fruit trees, vegetables, crops, gardening flowers, and weeds. In emergency area, over 100 plant species have been infected with pests such as *Ailanthus altissima*, *Morus alba*, *Platanus orientalis*, *Paulownia tomentosa*, *Ulmus* spp., *Platanus acerifolia*, *Fraxinus chinensis*, *Populus* spp., and *Salix* spp. In Beijing, the main roadside tree species are *Fraxinus chinensis*, *Sophora japonica*, *Populus* spp. etc., which are all American white moth's favorite hosts. It is not hard to foresee the potential ecological destruction and the extent to which the city is affected in the case of the introduction of American white moth. According to the forest resources inventory during 1994–1995, forests in Beijing own an area of 3.4×10^5 hm^2 and the stand volume amounts to 8.3×10^6 m^3. Over half of the trees belong to broadleaf species such as *Populus* spp., which are more susceptible to American white moth.

3.3 *Apriona swainson*'s host plants and their significance in Beijing

A. swainson hosts in *Sophora japonica*, *Salix* spp., *Caesalpinia sepiaria*, *Butea frondosa*, *Dalbergia hupeana*, *Tectaria subtriphylla* (Huang et al., 1998), *Ligustrum lucidurm*, *Paulounia tomentosa* (Niu et al., 2002), and particularly *S. japonica* and *S. japonica* have been seriously damaged in Shandong and Henan Province. As a primary species in Beijing, *S. japonica* has been menaced by *A. swainson* and the prevention of this pest will preserve the appearance of Beijing.

4 Probability of spread and dispersal

4.1 The spread and dispersal of three pest insects

4.1.1 Red turpentine beetle

In 1998, RTB was first found in Yangcheng and Qinshui of Shanxi Province, and then it spread to 47 counties within 8 districts of Shanxi Province, and 17 counties within the five cities of Hebei Province at the end of 2000. In 2001, Huanglong Forestry Bureau of Yan'an, Shaanxi Province, was added to the list and until 2002, beetle has been found in pine forests in Taihang Mountain, Lüliang Mountain, and Zhongtiao Mountain of Shanxi Province, and then it spread into the eastern slopes of Taihang Mountain, northern slopes of Zhongtiao Mountain, and part of Henan and Hebei Province.

The beetles are primarily composed of adults and larvae at different stages and they spread at a tremendous speed and can fly up to 20 km.

In the Shanxi Province, this beetle is mainly detrimental to *Pinus tabulaeformis* with a diameter at breast height of over 10 cm, and to the newly logged stakes. The stem that is 1 m above the ground is also the place that is vulnerable to the invasion of adults, but this pest was most probably found close to the ground. As the pest is most likely to be transported through woody package material, the rational use of endangered wood turned into an important measure to control the spread of this pest.

Since red turpentine beetle was firstly found in 1998 in China, its long-distance spread has not been reported yet.

China should accelerate its step of classifying it as one of the internal quarantine objects. According to the analysis of the experts, there is a great possibility of red turpentine beetle spreading into China from the U.S.A, and the phytosanitary measures should be more critical.

4.1.2 Spread and dispersal of American white moth

Listed as the world quarantine pest, the American white moth has been well known for long-distance spread. Since introduced to Hungary from America in the 1940s, the American white moth has spread into dozens of countries throughout the three continents in the past 50 years. In China, it was first found in Dandong, Liaoning Province in 1979, and then was introduced to Rongcheng of Shandong (in 1982), Shaanxi (in 1984), Leting of Hebei (in 1990), Shanghai (in 1994), and Tanggu of Tianjin (in 1995) continuously and is now approaching Beijing. A national control project, referred to as Beijing-Tianjin-Hebei American white moth management project, has been implemented to prevent it from further spreading. The nearest place where American white moth was approaching has retreated back by 20 km and therefore the American white moth was kept out of Beijing. However, the American white moth was still found in Langfang, Hebei Province at the end of 2003, indicating the urgency to keep the spread under control.

The American white moth can be dispersed by means of eggs and especially by larvae and pupae. Because the larvae are able to endure hunger for 9–15 days, the pupae of the first and second generation for 10–13 days, and over- wintered pupae for 5 months. The larvae often pupate in the bark slots, tree holes, and covert places of vehicles, and are carried at ease for the long-distance spread (Tao et al., 2001). Natural spread is mainly completed by the flying of adults and by the creeping of larvae. It is tested by field survey that the American white moth adults are capable of flying over 100 m each time, and can also be transported by the wind. Mature larvae can creep for 500 m (Communication by Dalian Forestry Bureau, 2000).

The long-distance dispersal of American white moth is primarily induced by human activities such as logging, shipping of goods (agricultural, forestry, animal husbandry and fishery products), packaging and transportation. Particularly at the prime stage of larvae (June to October), vehicles and goods in its distribution area are more likely to take the larvae and pupae of the American white moth, forming a new communication of dispersal (Wang et al., 1999; Zhao, 2000). Such carriers as the truck, freighter, and fishing boat can carry this insect throughout the year. As Beijing is located close to the occurring area of the American white moth, it is very likely to be infested by means of human introduction.

In Liaoning, there have been four times for long-distance spread for American white moth. It spreads quickly and cause heavy disasters in a large area as follows: the district of Liaoyang and Benxi in 1984–1985 with an occurring area of 530 hm^2; 35 towns of Jinzhou, Huludao in 1988–1989 with an area of 330 hm^2; 14 towns of Panjin, Yingkou, Wafangdian in 1990 with an area of 4,000 hm^2; and 61 towns of Kangping, Faku of Shenyang city (Zhao, 2000) with an area of 6,600 hm^2.

The national project has achieved much progress. The occurring area was reduced and damages were controlled (Mei et al., 2002). But in recent years, the American white moth has been examined many times in the ports of Xi'an, Ji'nan, Beijing, Guangzhou, Urumqi, Yantai, etc., which threaten Beijing. Field investigation shows that there is a high possibility for the entry of American white moth into Beijing because there is only 30 km between Beijing to Baodi, Tianjin, a distribution spot of the American white moth.

4.1.3 Apriona swainson

This beetle lives through the winter in the xylem of trunk. Based on observation, the average life span of female beetles is 46 days, (the longest 103 days and the shortest 8 days), and that of male beetles is 35 days with the longest 85 days and the shortest 5 days. According to field surveys, this beetle does not excel in flying, and its longest flight can only reach 12 m. It is vulnerable to shaking and might fall on the earth (Li et al., 1998).

A. swainson spreads a long distance in different insect stages along with the transportation of host plants (Liao et al., 2000). Success in bidding for the 2008 Olympic Game has undoubtedly put forward higher demands for the city afforestation in Beijing. In that case, the long-distance transportation of seedlings will be more frequent than before, resulting in an increasing risk of American white moth's entry into Beijing with inferior or infected nursery stocks.

Invasion of *A. swainson* had drawn extensive attention in Beijing in May 2000 as a result of transportation of garden nursery stocks. In 2002, *A. swainson* was found on the Ping'an Street of Beijing. The Beijing Forestry Protection Station resolutely took effective measures to eliminate it, and it has not been found in other places so far. In addition, in Hami and Tulufan of west China's Xinjiang, *A. swainson* was found on the nursery stocks during an examination in 1999.

4.2 Dispersal tendency analysis of the three kinds of pests

Since 1998, the red turpentine beetle has caused serious damages in the Shanxi Province, and the spatial-temporal continuity of spread showed that further tendency is surrounding Beijing. The American white moth has been brought to China 20 years ago, and the distribution and dispersal showed continuity in certain districts, but generally appears as a spot pattern, which indicated their multiple channels of spreading. Among the various dispersal ways of the American white moth, man-induced spread played an important role. The dispersal of *A. swainson* is rarely recorded, but its distribution is very widespread. In general, the three kinds of risky pests show a tendency to surround Beijing with a great threat to this area.

5 Quantitative assessment

5.1 Quantitative risk assessment system for environmental plants in Beijing

Based on international methods applied on quantitative analysis of risk assessment (FAO/IPPC, 1991, 1995) and the characteristics of urban forestry resources in Beijing, a quantitative assessment system for main non-indigenous pests with distinct urban characteristics was proposed to provide suggestions for pest quarantine decisions and to promote the sustainable economic and social development of Beijing (Table 2).

5.2 Assigning values to criteria for pest assessment

5.2.1 Distribution

The three pests are all distributed outside as well as in China. Red turpentine beetle and American white moth are extensively distributed. As an international trade center, Beijing is also characterized by its large amount of foreign trade. The trade and tourism all contribute to the probability of these beetles induced by humans. In addition, the trend analysis also demonstrates the potential threat to Beijing area.

Table 2 Quantitative index system of risk assessment on serious exotic pests to Beijing

Algorithm	Factors	Evaluation items P_{ij}	Weight W	Evaluation criteria for assessment
Iterative addition	Distribution P_1	Abroad distribution status P_{11}	Equal weight	0%, P_{11}=0; ＜5%, P_{11}=1; 6%–20%, P_{11}=2; ＞21%, P_{11}=3
		Domestic distribution status P_{12}		0%, P_{12}=0; ＜5%, P_{12}=1; 6%–20%, P_{12}=2; ＞21%, P_{12}=3
		Distribution status in the region of PRA P_{13}		＞71%, P_{13}=0; 70%–21%, P_{13}=1, 20%–6%, P_{13}=2; ＜5%, P_{13}=3
Iterative addition	Potential damage P_2	Whether is object of international or domestic quarantine P_{21}	0.15	No, P_{21}=1; plant to be classified as quarantine object, P_{21}=2; yes, P_{21}=3
		Whether is the agent of other destructive insect pests P_{22}	0.1	No, P_{22}=0; can carry one kind, P_{22}=2; can carry more than 2 kinds, P_{22}=3
		Potential economic damage (including ecological loss, forest economic damage) P_{23}	0.2	No, P_{23}=0; small, P_{23}=1; big, P_{23}=2; great, P_{23}=3
		Potential social influence (tourism industry, the influence of greenland value) P_{24}	0.2	No, P_{24}=0; small, P_{24}=1; big, P_{24}=2; great, P_{24}=3
		Care degree outside of China P_{25}	0.1	No country listed it as phytosanitary object, P_{25}=0; 1–4 countries listed it as phytosanitary object, P_{25}=1; 5–10 countries, P_{25}=2; over 11 countries, P_{25}=3
		The likelihood of influencing activities of export trade, etc P_{26}	0.15	No influence, P_{26}=0; lightly influenced, P_{26}=1; influenced, P_{26}=2; severely influenced, P_{26}=3
		The loss once caused by pest P_{27}	0.1	No, P_{27}=0; 1 million below, P_{27}=1; 100–500 million, P_{27}=2; over 500 million, P_{27}=3
Iterative addition	Economic importance of potential host plants P_3	Host plant types P_{31}	Equal weight	None, P_{31}=0; 1–4 kinds, P_{31}=1; 5–10 kinds, P_{31}=2; more than 11 kinds, P_{31}=3
		Resistance to pest of host plants in the region of PRA P_{32}		With high resistance, P_{32}=0; with resistance, P_{32}=1; with sensitivity, P_{32}=2; high sensitivity, P_{32}=3
		Cost of host plants (the cost of afforestation) P_{33}		No cost, P_{33}=0; low cost, P_{33}=1; moderate cost, P_{33}=2; high cost, P_{33}=3
		Host plants' aesthetic value P_{34}		Lower, P_{34}=1; Midterm, P_{34}=2; high P_{34}=3
		Whether the host plants are street trees or main trees species in public green land P_{35}		No, P_{35}=1; yes, P_{35}=3
		Whether the pest will influence especial merit plants (such as ancient trees or well-known trees, etc.) P_{36}		No influenced, P_{36}=1; influenced, P_{36}=2; greatly influenced, P_{36}=3
		Host plants' area (10^3 hm^2) P_{37}		Free distribution, P_{37}=0; below 1,000, P_{37}=1; 1,000–2,500, P_{37}=2; over 2,500, P_{37}=3
Iterative addition	The likelihood of spread and dispersal P_4	The potential geographic distribution range in the PRA area P_{41}	0.15	Below 1%, P_{41}=0; 2%–10%, P_{41}=1; 11%–50%, P_{41}=2; over 50%, P_{41}=3
		How many pathways pest can be carried? P_{42}	0.15	Impossible to be carried, P_{42}=0; 1–2 kinds of pathways, P_{42}=1; 2–5 kinds of pathways, P_{42}=2; over 5 kinds pathways, P_{42}=3
		Phytosanitary situation P_{43}	0.1	Have been infrequently intercepted, P_{43}=1; have been intercepted many times, P_{43}=2; have record of introduction, P_{43}=3
		Time limit to possible survival period during transportation in vehicle (include all kinds of life stage) P_{44}	0.15	1–2 days, P_{44}=1; 3–10 days, P_{44}=2; more than 10 days, P_{44}=3
		Phytosanitary attention degree in PRA area P_{45}	0.15	High, P_{45}=1; moderate, P_{45}=2; low, P_{45}=3
		Quarantine competence (personnel professional skill and inspection method etc. should be considered) P_{46}	0.1	High, P_{46}=1; midterm, P_{46}=2; low, P_{46}=3
		Density of pest population in occurrence area (Based on various economic threshold of pest species and when value is control threshold, risk rank is referred to "middle") P_{47}	0.1	Lower, P_{47}=1; midterm, P_{47}=2; high, P_{47}=3
		The influence of pest's reproduction tactics on establishment P_{48}	0.1	Low probability, P_{48}=1; midterm, P_{48}=2; high probability, P_{48}=3
Iterative addition	Difficulty of risk management P_5	Difficulty of quarantine and identification P_{51}	Equal weight	Identification method is developed and convenient, P_{51}=1; generally difficult for identification, P_{51}=2; very difficult for identification, P_{51}=3
		Difficulty of removal and management P_{52}		Easy to remove, P_{52}=0; can be effectively control, P_{52}=1; difficulty of control is great, P_{52}=2; difficulty of control is very great, P_{52}=3
		Control capability of natural enemy P_{53}		Easy to control, P_{53}=1; controllable, P_{53}=2; very difficult to control, P_{53}=3
		Whether there is precedent succeeded in management in the occurrence area P_{54}		Yes, P_{54}=1; no, P_{54}=2
		Whether PRA pest's monitoring means is ripe P_{55}		Methods are developed, P_{55}=1; the methods are undeveloped, P_{55}=2

5.2.2 Potential risk

American white moth and *A. swainson* are both phytosanitary pests. Red turpentine beetle has imposed serious damages in Shanxi (Zhang et al., 2002) and some projects have been implemented already from 2000 to reduce such damages. Beijing, a center for economy, trade and tourism, generated a foreign exchange revenue of 2.95 billion dollars through tourism in Beijing in 2001. The foreign revenue will be seriously affected by the negative impacts of the pests on urban vegetation and so does the foreign trade.

5.2.3 Economic importance of host plants

Beijing owned a vegetation coverage of up to 38.8% at the end of 2001. It is estimated, at a conserved level, that administrative expense for greenlands in Beijing is at least 6.5 yuan/m^2 on average, which indicates that costs on host trees will be enormous. *Sabina chinensis*, *Koelreuteria paniculata*, *Pinus tabulaeformis*, and *Fraxinus chinensis* are the main species and also the main hosts for these pests (Table 3). The large number of urban trees present a clustering pattern in a small scale and a dispersal pattern in a large scale, which exerts more difficulties to inspect the exotic pests. Furthermore, there are a lot trees with special value, such as ancient and well-known trees susceptible to pests. General survey in Beijing indicates that in the suburb, there are 51 species of ancient and well-known trees (involving 29 families and 45 genera) (Shi, 1995), among which there are 1,481 individual plants of *Sabina chinensis*, 309 *Pinus tabulaeformis*, and 284 *Sophora japonica*, accounting for 61%, 13%, and 12% of the total amount of the top-class ancient and well-known trees. *P. tabulaeformis* is the main host of red turpentine beetle, and *S. japonica* is the main "attack" target of *Aprions wainson*. In addition, *S. japonica* and *Sabina chinensis* are also both "city trees" of Beijing and can reflect the local culture.

Table 3 The main trees of greenbelts in Beijing residential

Classification of plant	Plant scientific name (in the order of appearance frequency)
Evergreen arbor	*Sabina chinensis*, *Pinus tabulaeformis*, *Cedrus deodara*, *Pinus bungeana*, *Picea asperata*
Evergreen shrub	*Buxus sinica* var. *parvifolia*, *Buxus megistophylla*, *Sabina vulgaris*
Deciduous shrub	*Rosa chinensis*, *Sorbaria sorbifolia*, *Lonicera maackii*, *Syringa* spp., *Hibiscus syriacus*, *Forsythia suspensa*, *Rosa xanthina*, *Amygadlus triloba*, *Rosa multiflora*, *Malus* spp.
Deciduous arbor	*Sophora japonica*, *Salix babylonica*, *Fraxinus chinensis*, *Ailanthus altissima*, *Populus tomentosa*, *Ginkgo biloba*, *Platatnus orientalis*, *Paulownia fortunei*, *Robinia pseudoacacia*, *Magnolia denudata*
Hedgerow	*Buxus sinica* var. *parvifolia*, *Buxus megistophylla*, *Sabina chinensis*, *Biota orientalis*
Others	*Parthenoclssus quinquefolia*, *Buchloe dactyloides*

5.2.4 The likelihood of spread and dispersal

All the three pests can be potentially transported for a long distance, and particularly, the American white moth may outburst suddenly. *Apriona swainson* and red turpentine beetle can spread through wood packing materials and nursery stocks, while the American white moth can spread through goods, various traffic vehicles, or nursery stock.

Statistical yearbook of Beijing in 2001 indicates that the large volume of traffic flow and enormous logistics in Beijing area (Table 4) have increased the likelihood of introduction of these three pests.

Table 4 Statistics of logistics in Beijing in 2001 and 2000

Main items	2001	2000
The total volume of imports and exports /US dollar	5.15×10^{10}	4.96×10^{10}
The retail sales of goods in the whole city /RMB	1.22×10^{11}	
Transportation railway, highway, civil aviation /line	53, 3,065, 152	26, 2,989, 156
The amount of arrival goods /t	7.34×10^{7}	7.11×10^{7}
Imported commodity inspection /batch	33,042	10,853

5.2.5 The degree of difficulty of risk management

Apriona swainson and red turpentine beetle impose a great difficulty for management. Significant progress has been achieved in the control of American white moth by biological control using *Chouioia cunea* Yang (Chen, 1998). However, considering the rapid spread speed of American white moth, it is very difficult to get it under control once it is dispersed. Urban environmental pollution and random distribution of host plants also add to the expense and difficulty related to prevention.

5.3 Evaluation table

The above-mentioned distribution condition, potential risk, economic importance of host plants, likelihood of spread, and dispersal were analyzed comprehensively, as well as difficulty of risk management, and an expert judging method was adopted to score every index of the three kinds of insect pests (Table 5).

5.4 Method of calculation and assessment results

Indices of evaluation *(P)* and risk value *R* were calculated based on the following quantitative pest assessment formula.

$$P = \sum W_i P_i / \sum W_i \quad (1)$$

$$R \text{ or } P = \sqrt[n]{\prod P_i W_i} \quad (2)$$

Table 5 Evaluation table of quantitative index system of risk assessment on *Dendroctonus valens*, *Hyphantria cunea* and *Apriona swainsoni*

First level judge index	Second level judge index	Expert judge of access objects		
		Red turpentine beetle	American white moth	*Apriona swainson*
Distribution condition (P_1)	P_{11}	2	3	1
	P_{12}	2	2	3
	P_{13}	3	3	3
Potential harmfulness (P_2)	P_{21}	2	3	3
	P_{22}	0	0	0
	P_{23}	3	3	2
	P_{24}	3	3	2
	P_{25}	2	3	1
	P_{26}	2	2	1
	P_{27}	3	3	2
The economic importance of host plants (P_3)	P_{31}	2	3	1
	P_{32}	2	2	2
	P_{33}	3	3	2
	P_{34}	3	2	2
	P_{35}	3	3	3
	P_{36}	3	2	2
	P_{37}	2	3	1
Likelihood of spread and dispersal (P_4)	P_{41}	3	3	2
	P_{42}	2	3	2
	P_{43}	1	2	3
	P_{44}	3	3	3
	P_{45}	2	1	1
	P_{46}	2	1	1
	P_{47}	3	2	1
	P_{48}	2	3	2
Difficulty of risk management (P_5)	P_{51}	3	2	3
	P_{52}	3	2	2
	P_{53}	3	2	3
	P_{54}	2	1	2
	P_{55}	2	1	2

where R represents the total risk value, P the risk value of each index, Wi the weight for the index i. P_1–P_5 are calculated based on Eq. (1), while Eq. (2) is used to calculate R. According to international standard, R ranging from 3.00 to 2.50 indicates high risk, 2.49 to 2.00 medium risk, and 1.49 to 1.50 low risk, lower than 1.00 negligible risk. The conclusion derived from the quantitative assessment in Beijing showed that the R values for red turpentine beetle, American white moth, and *Apriona swainson* are 2.46, 2.30 and 2.02 respectively, indicating that all these three pests are highly risky in Beijing area.

6 Management measures

6.1 Overall management strategies

1) Improve and perfect the risk prediction and forecast mechanism of imported plants and products, especially reinforce early forecast, and take the initiative rights against exotic hazardous pests. 2) Strengthen the quarantine management of exotic pests by harmonizing internal and external quarantine and create good atmosphere against exotic pests. 3) Once introduced exotically, integrated management and rapid removal measures should be taken to prevent its dispersal and spread.

6.2 Management of red turpentine beetle, American white moth, and *Apriona swainson*

It is suggested that red turpentine beetle be chosen as the focus of quarantine and inspection for the "Headquarters against risky pests and diseases of forest in Beijing", to inspect and forecast from different areas, and to list the places such as the national level nature reserves, Songshan Mountain, water resource protection forest of the Miyun Reservoir, and Yunmeng Mountain Nature Reserve as the primary monitoring areas.

It is highly suggested to integrate the inspection and forecast of American white moth in Beijing into whole "American white moth management project in Beijing-Tianjin-Hebei area" to strengthen the joint efforts in the defense of pests for the three areas, to control the dispersal of American white moth, and to eradicate timely.

The key to manage *Apriona swainson* includes the supervision of transporting big nursery stocks, emphasizing more on propaganda, monitoring by the public, eradicating timely, multi-place monitoring, combined with reasonable rewards and punishment measures.

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