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BIODIVERSITY RESEARCH

Coniferous round wood imports from Russia and Baltic countries to Belgium. A pathway analysis for assessing risks of exotic pest insect introductions

Frédéric Piel[2]*, Marius Gilbert[1], Charles De Cannière[1] and Jean-Claude Grégoire[1]

[1]*Lutte biologique et Ecologie spatiale (LUBIES), CP 160/12, Université Libre de Bruxelles, 50 avenue F.D. Roosevelt, B-1050 Brussels, Belgium,* [2]*Fonds pour la Formation à la Recherche dans l'Industrie et l'Agriculture (FRIA), 5 rue d'Egmont, B-1000 Brussels, Belgium*

*Correspondence: Frédéric Piel, Lutte biologique et Ecologie spatiale (LUBIES), CP 160/12, Université Libre de Bruxelles, 50 av. F. D. Roosevelt, B-1050 Brussels, Belgium. Tel.: 2-650-30-36. Fax: 2-650.24.45; E-mail: address: fpiel@ulb.ac.be

ABSTRACT

Understanding entry pathways resulting from global trade is critical to assess the risks of introduction of invasive alien species (IAS). From 1996 onward, the import of timber from Russia and the Baltic States to Belgium dramatically increased, with more than one million cubic metres of coniferous round wood imported until 2004. Such a high volume could have served as entry pathway for exotic bark beetles from the East that have the potential to become forest insect pests upon establishment. We collected and cross-checked different data sources (FAOSTAT, Eurostat, National Bank of Belgium, Belgian Customs, the Belgian sawmills industry) regarding the import of timber in an attempt to trace back the spatial and temporal patterns of this trade, and to assess the expected validity of a pest risk analysis based on those data. We found that the timber trade between 1996 and 2004 is particularly dynamic in space and time, and may have allowed several opportunities for exotic bark-beetle introductions. In addition, the patterns of trade change so quickly from year to year that the existing data sources are essentially not adequate for IAS risk assessment in a near real-time fashion. The data are either comprehensive, but then aggregated at a too coarse level (space, time, or category) to be of real use in risk assessment, or available with adequate levels of details, in which case they are mostly partial or incomplete. Better accessibility to data and data exchanges between organizations in charge of trade data collection and plant protection would help better targeting of phytosanitary controls.

Keywords

Biological invasions, import pathway, invasive alien species, *Ips typographus*, pest risk analysis, Russian coniferous round wood, wood statistics.

INTRODUCTION

During the last three decades, the pattern of trade in the wood sector has changed considerably. New economical relationships have been established which created possibilities for introducing invasive alien species (IAS), some of which are recognized as severe pests (Baranchikov, 1997). The increasing speed of transportation allows IAS to survive longer-distance travel than in the past (Humble & Allen, 2001). Simultaneously, the higher volumes transported increase the risks of introduction and make the inspection of goods increasingly difficult. It is now well accepted that these factors have raised the frequency of IAS introductions through commercial trade pathways (US Congress, 1993), and of their subsequent establishment, spread, and ecological and economic impact.

Each importation of living or untreated material constitutes a potential source for introduction of IAS (Krcmar-Nozic *et al.*, 2000). Most of the research and regulatory efforts to control the movement of IAS have focused on insects (Allen & Humble, 2002). Based on an analysis of the European and Mediterranean Plant Protection Organization (EPPO) Reporting Service newsletters, Roques & Auger-Rozenberg (2006) estimated that 75.9% of the interceptions of non-indigenous species in Europe between 1995 and 2004 were insects. Within this large taxon, bark and ambrosia beetles (Coleoptera: Curculionidae, Scolytinae, Platypodidae, Bostrychidae) constitute particularly threatening groups of IAS capable of bypassing quarantine and colonizing new areas, because these insects can be transported undetected in wood articles (Stephen & Grégoire, 2001). This identified threat is verified by data collected by Haack & Cavey (2000), who

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showed that nearly 93% of insects intercepted in wood articles at US ports of entry between 1985 and 1998 were Coleoptera, among which two-third were Scolytinae.

Because of changes in trade patterns affecting the wood sector and because of the recent discovery of established populations of IAS associated with solid-wood packaging materials (SWPM), [e.g. *Anoplophora glabripennis* in New York in 1996 (Cavey *et al*., 1998) and in Austria in 2001 (Tomiczek, 2002)], stringent measures were undertaken to prevent IAS introductions related to SWPM. Since March 2005, the European Union (EU) regulation requires all newly assembled, repaired, or recycled unprocessed raw wood packaging materials (hardwood and softwood) entering the EU to be either heat treated or fumigated and officially marked under International Standard for Phytosanitary Measures No. 15 (ISPM15: FAO, 2006a). These measures were justified by the difficulty of identifying the origin of those materials, which are very often re-used, recycled, or re-manufactured all around the world.

In addition to SWPM, it is obvious that round wood importations can also constitute a critically important pathway for insect pests introductions. Raw logs are one of the most important forestry commodities of international significance and a major source of alien species, especially insects and pathogens (Cock, 2003). Risks related to the introduction of forest pests with the importations of round wood from Russia are well identified. A continuous movement of species within the boreal coniferous zone in Eurasia is generally assumed, both naturally and through human activities (Bakke & Økland, 2000). For example, 43 bark- or wood-boring beetle species, including 23 Scolytinae species, were intercepted on Russian imported round wood to Finland in 1985 (Siitonen, 2000). Three species among these (*Orthotomicus erosus*, *Ips subelongatus*, and *Phaenops guttulata*), from the Siberian part of Russia, were considered as particularly harmful (Siitonen, 2000). Such problems are also seen as crucial in the other parts of Europe as indicated by the recent EPPO Forest Quarantine Project 2002–04 which conducted pest risk analyses (PRAs) for forest pests susceptible to be introduced from the former USSR (EPPO, 2002).

With the development since 1996 of new trade agreements between Belgian sawmills and Russia and the Baltic States to import large volumes of spruce logs, these risks had also to be considered in Belgium. In 2000, intriguing high numbers of *Ips typographus* were caught in pheromone traps distributed in an urban area in the surroundings of the Port of Brussels, which is an entry point of imported wood from the eastern countries (Piel *et al*., 2005). *Ips typographus* is a scolytid pest distributed throughout Eurasia, from Japan to Belgium and western France, whose presence on timber imported from the east can be used to disclose gaps in phytosanitary barriers. In 2003, with the cooperation of the Belgian Federal Agency for the Safety of the Food Chain (AFSCA) which is also responsible of the phytosanitary controls in Belgium, we caught several individuals of the double-spined spruce bark beetle, *Ips duplicatus*, north of Liege, where high quantities of Russian and Baltic spruce logs have been unloaded since 2000 (Piel *et al*., 2006). This species is not known to be present in either Belgium or in France, and *I. duplicatus* populations are high in Eastern Europe including Russia and the Baltic States (Valkama *et al*., 1997). An introduction by round wood imports therefore seems very likely. During the same trapping campaign, important short-term variations in the level of pheromone trap catches of *I. typographus* have also been observed both in Herstal and in Hermalle-sous-Argenteau, two unloading quays for imported logs from Russia and the Baltic States, close to the port of Liege. In 2004, these previous indications from trapping were substantiated by the discovery of galleries of *I. typographus* on logs stored in Herstal, with developmental stages ranging from larvae to mature adults, therefore too old to result from local attacks subsequent to downloading the timber from the ships. All these evidences are at best indirect. Trapping or sampling on logs does not inform on the origin of the insects trapped, unless accurate genetic labelling can be achieved on the catches, which was not the case here.

These findings strongly suggest that movements of insect pests actually occur with logs imported into Belgium, and that a thorough analysis of risks is needed. One of the first steps in a PRA, following the International Plant Protection Convention standards (ISPM2: FAO, 2006b), is to determine the pathways of given pests or commodities into a new area. To identify the spatial and temporal patterns of such wood imports, we completed the field observations mentioned above with data and statistics on the coniferous round wood trade between Russia and the Baltic States, and Belgium. We collected information from available local, national, and international sources. It was a good opportunity (1) to check the available sources of information, (2) to clarify the complex links between these sources, (3) to cross-examine data to assess their accuracy, their complementarities, and the way they corroborated each other, and (4) to build up a global estimate of the routes and volumes of timber imported from the east into Belgium.

METHODS

Data sources

Local, national, and international sources have different levels of details, corresponding to their own purposes, and these data do not necessarily allow the quantification of imports from specific countries. To synthesize the properties of the main sources in regard to coniferous round wood imports from Russia and the Baltic States to Belgium, from 1996 to nowadays, we analysed all of them from top to bottom, i.e. from the more aggregated (international sources) to the more detailed (local sources).

International scale

Data from FAOSTAT and Eurostat are easily accessible through their respective websites (FAOSTAT: http://faostat.fao.org/faostat/forestry/jsp/fytf_q-e.jsp?language = EN&version = ext&hasbulk = 0; Eurostat: http://fd.comext.eurostat.cec.eu.int/xtweb/). FAOSTAT data are obtained from the United Nations Commodity Trade

Statistics Database (UN Comtrade) which centralizes data from the official statistical offices of all countries. FAOSTAT provides data on import and export volumes of coniferous round wood [Bilateral Trade Matrices, Ind Rwd Wir (C)] by year, for a 'reporter country' and each 'partner country', in cubic metres and $US1000. Data for Belgium and Luxembourg are grouped together from 1997 to 2000. As no imports were registered to Luxembourg after 2000, we considered that all the imports/exports of the previous years were directed to/from Belgium. Eurostat data are provided by the national administrations of the different European member states. Eurostat uses the Combined Nomenclature (CN 8-digit) which is the most detailed common nomenclature used in the European Community. This nomenclature includes specific codes for spruce (code 44032010), pine (code 44032030), and 'other conifers' (code 44032090) since 1996, and subclasses within each of these three categories, differentiating logs (codes 440320-11, -31, and -91) from other wooden articles (codes 440320-19, -39, and -99) since 2002. Eurostat units are value in euros, quantity in 100 kg and a supplementary unit, cubic metres in this case. Monthly data are available since 1995. Belgium and Luxembourg are grouped together until 1998.

National scale

Statistics on external trade are available from the Belgian National Institute for Statistics, which in Belgium is associated with the National Bank of Belgium (NBB) and part of the Institute of National Accounts. NBB centralizes, controls, and aggregates raw data (i.e. non-aggregated data) from the local Belgian customs offices. This source also uses the CN, and data (quantity in cubic metres and value in euros, from 1996 to 2004) are available from the NBB website (http://www.nbb.be/IXD01BK/index.jsp?taal = 1). The Central Service of Information Management and Risk Analysis (CSIM) is a non-aggregated national source, based on the same information as NBB. It contains detailed information on each importation, using the CN 8-digit, including country and locality of origin, transit point, import company, weight/volumes, and precise date. CSIM activities do not explicitly include data diffusion but, in this case, data were accessible on request. Names of the importing companies are confidential but we could obtain information on the destination locality of the goods, from which it was possible to deduce the importing companies. Data from CSIM have only been available since 1999, when CSIM was created, and they are not corrected (i.e. encoding errors in weight or volumes, or duplicates, are present). Similar data are collected and corrected by NBB but not available for reasons of confidentiality. We could not have any quantitative information from the National Federation of Sawmills (NFS) which regroups the most important Belgian sawyers. As an 'outgroup' data source for mirror analysis, we obtained information from the Russian Customs on volumes of coniferous round wood and spruce logs exported to Belgium, between 1998 and the first half of 2005 (thanks to the collaboration of Mr A. Kotlobay, WWF Russia).

Local scale

We collected information from the Port of Brussels, where we could obtain non-aggregated data on each import in transit since 1997 and even complementary information on the exporting localities in Russia and the Baltic states. Data from the Port of Liege, pertaining to the total amounts of timber unloaded between 2000 and 2003 (in tons, without any species differentiation), permitted us to identify and to some extent quantify an indirect pathway. Large volumes of coniferous round wood were imported through the Netherlands (port of Dordrecht) and then conveyed in transit through the port of Liege. Due to the free circulation of goods into the EU, no customs controls are required for such indirect trade and these movements of goods are thus not included in any of the databases previously described. Moreover, we identified three regular importers of coniferous round wood from the East: the Fruytier sawmill in Marche-en-Famenne, the Industrie du Bois Vielsalm (IBV) sawmill in Vielsalm, and the Pauls sawmill in Bullange (Fig. 1). After a direct contact with these three companies, only the Pauls sawmill provided information, the two other companies declining to answer for reasons of confidentiality. Pauls sawmill gave us general information on its import activities and raw information on each movement of timber from the East (date, volume, and port of transit). More detailed information on the precise supplying areas was considered as confidential.

The links between the sources mentioned above are illustrated in Fig. 2 and characteristics of each data source are summarized in Table 1.

Data correction and comparisons

We first tried to correct data from CSIM. Full correction was not possible as it requires the acquisition of baseline information from the local Customs offices which is confidential. We removed duplicates (same weight, same date, same origin, and same port of transit), corrected clear encoding mistakes (factor 10 errors in weight or volume), and roughly estimated missing data (volume when weight was available, using a conversion rate of 850 kg m^{-2}). For accurate correction, a single conversion rate should not be used as it varies from one load to another. Similarly, a single conversion rate cannot be used for aggregated data because they group together different kinds of wood articles with different densities.

We then made a two-step analysis (for Russia and for Estonia) to compare the accuracy of CSIM data to that of the other sources. As a first step, we compared aggregated data (year by year) on coniferous round wood imports from CSIM (corrected and uncorrected), NBB, Eurostat, and FAOSTAT and on coniferous round wood exports from FAOSTAT and the Russian Customs (Table 2). When new subcodes have been created, the summed values relevant to these subcodes were calculated for comparison with earlier data. As second step, we made a comparison on non-aggregated data (day by day) from CSIM (corrected), the Port of Brussels, and the Pauls sawmill. Such a comparison, including import dates and volumes, could only be

Table 1 Characteristics of each data source used in this study.

Data source	Available information	Scale	Units#	Period	Accessibility	Classification	Advantages	Disadvantages
FAOSTAT	Import/export volumes by country of origin and by year	International	M^3	1996–2003	Website*	Internal¶	Worldwide comparable source	Aggregated data
Eurostat	Import volumes and weights by country of origin and by month	International	T and M^3	1996–2004	Website‡	CN 8-digit§	Available in both units	Aggregated data
Russian Customs	Exports volumes of coniferous and spruce round wood	National	M^3	1998–2005 (1st half)	Direct by pers. contact	Internal	Mirror source	Aggregated data
NBB	Import volumes by country of origin and by year	National	M^3	1996–2004	Website†	CN 8-digit§	Corrected data	Aggregated data, confidentiality of detailed data
CSIM	Date, import volumes, and weights, country of origin, transit point, consignee	National	T and M^3	1999–2004	Direct by pers. contact	CN 8-digit§	Complete detailed information	Uncorrected data, available only until 1999
Port of Brussels	Date, import weights, country and port of origin, transit point	Local	T	1997–2003	Direct by pers. contact	Raw data	Detailed information on the origins	Partial information
Port of Liege	Weights of logs unloads	Local	T	2000–2003	Direct by pers. contact	Internal	Information on transit through the Netherlands	Aggregated data, no species differenciation
Pauls sawmill	General information, date, import volumes, country of origin, transit point	Local	M^3	1996–2001	Direct by pers. contact	Raw data	Detailed data	Partial information, confidentiality
Fruytier sawmill	–	Local	–	–	–	–	–	–
IBV sawmill	–	Local	–	–	–	–	–	–

*http://faostat.fao.org/faostat/forestry/jsp/fytf_q-e.jsp?language = EN&version = ext&hasbulk = 0
†http://www.nbb.be/IXD01BK/index.jsp?taal = 1
‡http://fd.comext.eurostat.cec.eu.int/xtweb/
§http://www.cbs.nl/NR/rdonlyres/1D45C30D-67FE-4A02–97AB-72235EF3C6E3/0/cn06en09.pdf
¶http://www.fao.org/waicent/faostat/forestry/products.htm
CN, Combined Nomenclature; CSIM, Central Service of Information Management and Risk Analysis; IBV, Industrie du Bois Vielsalm; NBB, National Bank of Belgium.
#T = Tons; M^3 = cubic meters; T and M^3 = available in both unit systems.

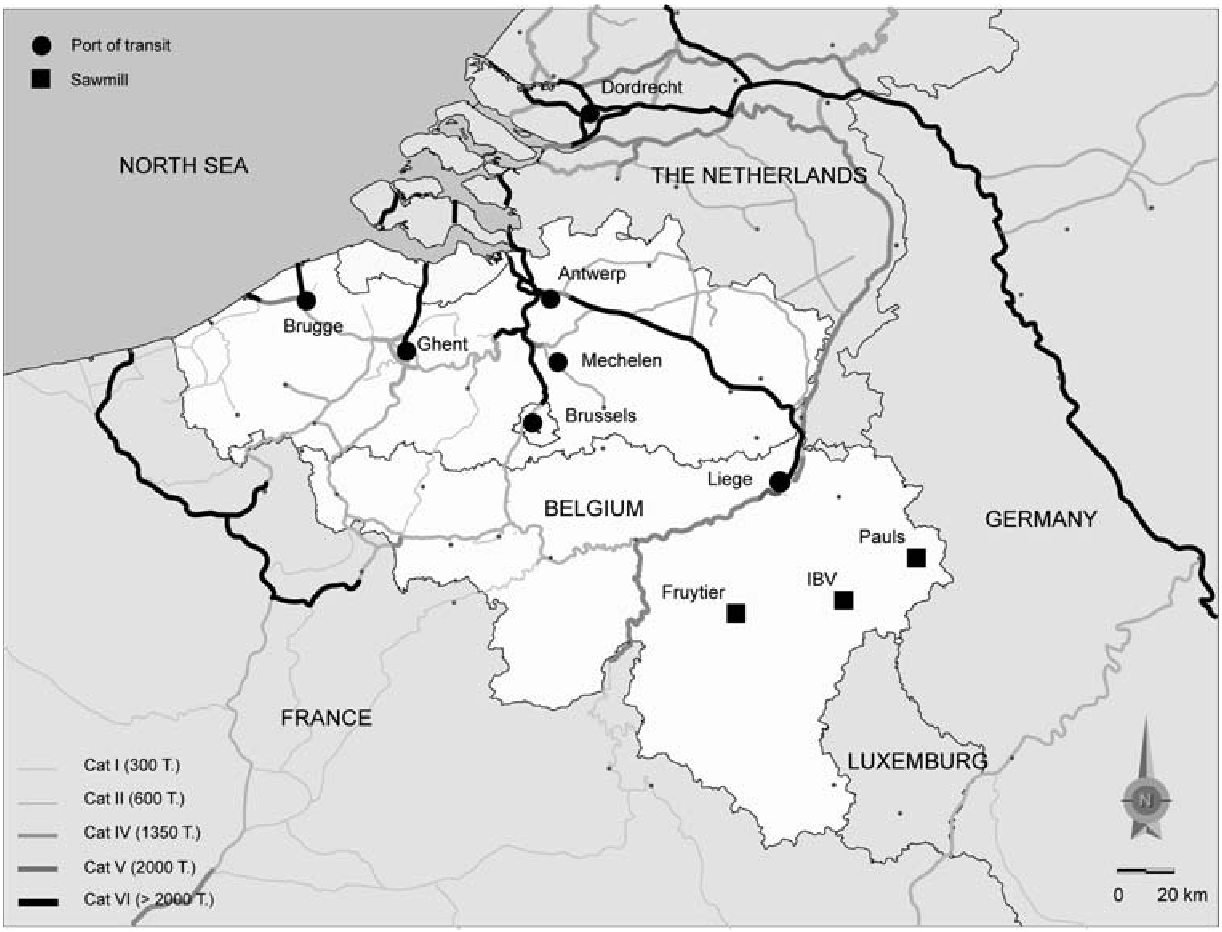

Figure 1 Map of the main European waterways in Belgium, location of the importers of coniferous round wood from Russia and the Baltic States (sawmills), and the main ports of transit. Based on map from the Walloon Ministry of Equipment and Transport (MET) – Marc Lemlin, general secretary.

done on the common denominator between these three sources, i.e. imports in transit through the Port of Brussels and to the Pauls sawmill. By visual comparisons, we tried to find correspondence between pairs of sources of information and we used a classification with three categories: (1) good correspondence, when the volumes or weights were similar between the two sources (with a tolerance of 10 cubic metres or tons) and the interval between dates was only a few days; (2) likely correspondence, when none of the parameters was similar but both were close; and (3) no correspondence, when no correspondence could be found neither for dates nor for volumes or weights.

RESULTS

Information on pathways

As illustrated above, many data sources are available from local to international scale for trade analysis. Linking all these sources is in most cases very complex. Few of the data sources are really useful for an accurate pathway analysis. Aggregated data such as statistics from NBB, Eurostat, or FAOSTAT, only show variations from year to year, without any details on the origins, ports of transit, or destinations of the round wood. On the contrary, data from local sources including the sawmills and the ports of transit provide all the details necessary for analysis. Nevertheless, this kind of information is spatially and temporally partial. For a complete analysis, information should then be collected from all the organizations concerned with the trade under analysis but information is often not available or confidential. CSIM, even if its data must be corrected, is the only available source that combines useful traits of both local and global databases, including detailed information for each import and covering the whole Belgian territory. It is thus the most appropriate database for pathway analysis.

Comparative assessment

Aggregated data

As illustrated in Table 2, the correspondence between import data from NBB and Eurostat is perfect, except a small difference of 91 m^2 (0.27%) for Estonian imports in 1997. Considering CSIM uncorrected data, differences with other sources are important in 1999, 2001, and 2002 for Russia, and in 1999 and 2002 for Estonia. After corrections, the differences between NBB

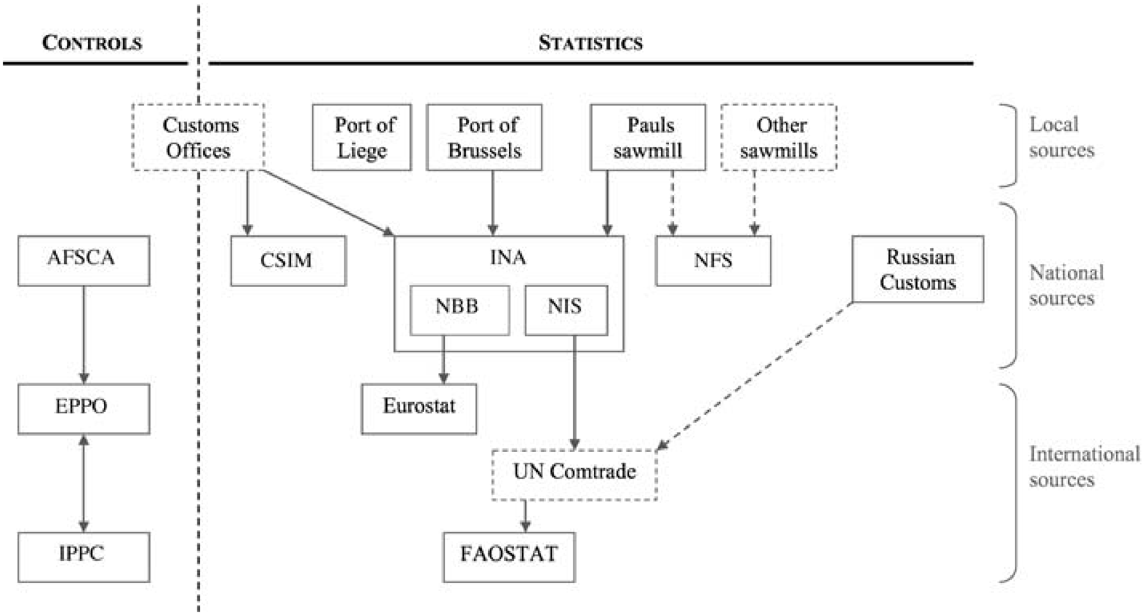

Figure 2 Organization chart of the data sources cited in this study. Dotted boxes indicate data that were not available. Dotted arrows illustrate theoretical data transmission. Abbreviations: CSIM, Central Service of Information Management and Risk Analysis; INA, Institute for National Accounts; NBB, National Bank of Belgium; NIS, National Institute for Statistics; NFS, National Federation of Sawmills; AFSCA, Belgian Federal Agency for the Safety of the Food Chain; EPPO, European Plant Protection Organization; IPPC, International Plant Protection Convention.

Table 2 Comparison of aggregated data (cubic metres) on imports and exports, from 1996 to 2004, from available sources concerning coniferous round wood trade between Russia and Estonia, and Belgium. Both corrected (cor) and uncorrected (uncor) data from the CSIM are summarized.

	Imports										Exports	
Source	FAOSTAT		NBB		Eurostat		CSIM (uncor)		CSIM (cor)		Russian Customs	FAOSTAT
Origin	Russia	Estonia	Russia	Estonia	Russia	Estonia	Russia	Estonia	Russia	Estonia	Russia	Estonia
1996			24.105	24.455	24.105	24.455						
1997	58.154	37.679	52.561	34.214	52.561	34.305						66.250
1998	115.068	18.297	103.670	14.879	103.670	14.879					110.111	126.189
1999	313.818	163.192	268.469	136.200	268.469	136.200	353.744	128.801	279.035	135.357	262.580	207.935
2000	138.098	129.351	123.823	112.991	123.823	112.991	123.688	112.991	123.588	112.991	117.711	135.015
2001	61.370	19.870	52.796	17.449	52.796	17.449	113.064	17.449	56.013	17.449	156.896	0
2002	42.954	20.202	35.289	16.646	35.289	16.646	19.010	6.906	35.289	16.619	146.625	593
2003	28.126	0	27.023	0	27.023	0	27.023	0	27.023	0	53.740	52.324
2004			3.365	105	3.365	0	3.365	0	3.365	0	10.219	

CSIM, Central Service of Information Management and Risk Analysis; NBB, National Bank of Belgium.

and Eurostat are very low and could be explained by the inaccuracy of the corrections. Data from NBB, Eurostat, and CSIM (corrected) can thus be considered as similar and reliable. On the other hand, FAOSTAT volumes are systematically higher (13% on average for Russia, 17% on average for Estonia) compared with these three sources.

Considering exports, data from both the Russian Customs and FAOSTAT present clear inconsistencies. FAOSTAT exports are clearly overestimated in 1998 and 2003, and underestimated in 2001 and 2002, while data from the Russian Customs are largely overestimated from 2001 to 2004, even if imports through the Netherlands are added to volumes from CSIM or NBB.

Non-aggregated data

We made a comparison of non-aggregated data for cross-validation of the detailed sources available. Data from the three different sources about imports through the Port of Brussels to

Pauls sawmill were analysed. Comparing the data from CSIM (corrected) and Pauls sawmill between 1999 and 2001, we found a good correspondence (similar volumes, and time lag lower than a month) for 88 imports (79%) with an average time interval of 12 days; a likely correspondence (close volumes and lag time lower than a month) for 18 imports (16%); and no correspondence for five imports (5%). Similar comparison between data from CSIM (corrected) and Port of Brussels (1999–2002) showed a good correspondence (similar volumes and lag time lower than a month) for only 20 imports (16%); a likely correspondence (average lag time of 13 days but different weights) for 101 imports (79%); and no correspondence for six imports (5%). Finally, for comparing Pauls sawmill and the Port of Brussels, as unit systems are different, we could only compare the dates. Good correspondence was found for 97% of imports. On average, a 1-day interval (std = 2 days) was observed, which is likely to correspond to road transportation from Brussels to Bullange.

Coniferous round wood imports to Belgium

Volumes

More than one million cubic metres (i.e. 861,000 tons) of coniferous round wood (code 44032000) have been imported since 1996 from Russia, Belarus, and the Baltic States (i.e. Estonia, Latvia, and Lithuania) to Belgium. Among these million cubic metres, only 7000 were registered as spruce round wood and none as spruce logs (since 2002). During the same period only little more than 100,000 cubic metres were imported from Scandinavia (Finland and Sweden). Considering the total imports of coniferous round wood from 1996 to 2004, the five above Eastern countries represent on average only 11.20% (std = 11.40) of the Belgian imports but 77.69% (std = 21.28) when the neighbouring countries (France, Germany, Luxembourg, and the Netherlands) are excluded.

Classifications

Specific codes were recently created in the CN 8-digit for species differentiation. However, values for these codes usually do not exist. Eurostat classifies 99% of the coniferous round wood articles as 'other coniferous' (44032090). Only 0.65% of the million cubic metres imported are registered as spruce and 0.31% as pine. In the CSIM data, the 'other coniferous' category reaches almost 100%. According to information from the Pauls sawmill, spruce constitutes the large majority of the wood imported from the East. Except information from this source, it is very difficult to know which species or what kind of commodity are imported, and thus to evaluate the associated risks.

Spatial patterns

Origins

Almost all the coniferous round wood comes from Russia and Estonia, representing, respectively, 64.4% and 33.3% of the import volumes. The annual proportion of Russian wood varies between 47.2% in 1996 and 96.9% in 2003 (mean = 67.0%, SE = 15.1). For Estonia, the minimal and maximal proportions are 0.0% in 2003 and 47.9% in 1996 (mean = 26.3%, SE = 18.2). Data from the Port of Brussels suggest that the supplying area is very large (at least 800 km from East to West, and 500 km from North to South) and extends over Karelia and neighbouring oblasts (i.e. Leningrad, Vologda, Arkhangelsk, Novgorod). From 1996 to 2003, 19 different Russian (15) and Estonian (4) ports were used for coniferous round wood exports to Belgium (Fig. 3). Almost all these ports ($n = 15$) have been used in 1999. Even if some ports (i.e. Pjalma or Kunda) have been frequently used during the entire study period, important variations are observed from year to year.

Ports of transit

More than 99% of the wood was transported by ship. The average volume per shipload is large (3000 m^2), which limits the transportation costs. As none of the three main sawmills which import large volumes of wood from Eastern Europe are close to any port (Fig. 1), this implies the use of points as links for truck or train transportation, where goods can be stored for a few hours to a few weeks. According to data from CSIM, 10 different transit points were used. The main were Antwerp (3.95%), Brugge (20.09%), Brussels (46.62%), Ghent (2.97%), and Mechelen (26.00%). Nearly half of the wood directly imported to Belgium is thus transited through the Port of Brussels. The changes in the transit points used by the Pauls sawmill illustrate the high mobility of this trade. This sawmill used six different ports between 1999 and 2005, several of which were used simultaneously. Four different ports (Brugge, Brussels, Ghent, and Mechelen) were used in 2000. Moreover, large amounts of wood, mainly coniferous logs, were transhipped in Dordrecht (the Netherlands) and then conveyed in transit through the Belgian port of Liege, which is probably the main entry point since 2000 (121,403 tons between 2001 and 2003). This is illustrated by the development by IBV of a quay in Hermalle-sous-Argenteau, North of Liege, including log-sorting substructures (not used anymore since 2004).

Destinations

Between 1999 and 2005, three-quarters of the coniferous round wood was imported to the Pauls sawmill. The two other sawmills known as main importers of wood from the East, Fruytier and IBV, respectively, represent 18.5% and 1.8%. Small quantities of coniferous round wood were probably also imported to Aywaille (Jans Bois Ltd), Eupen (Lance Sprl), and Zulte (Lefibo Ltd) between 1999 and 2001.

Temporal patterns

Importations were particularly high during 1999 and 2000 with, respectively, 38% and 22% of the total volume imported. Imports occurred continuously during 1999, 2000, and the first

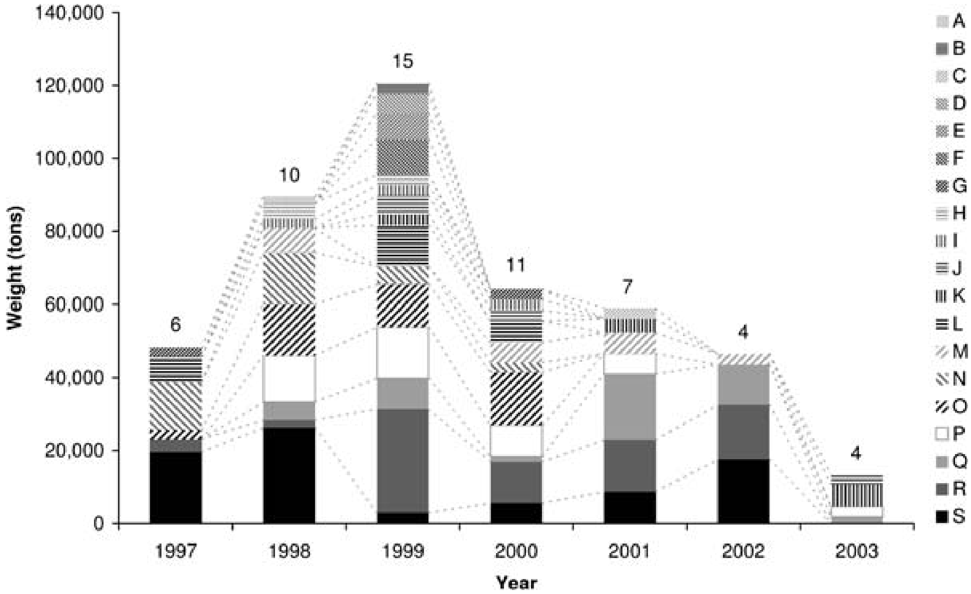

Figure 3 Coniferous round wood (tons) imported to Belgium through the Port of Brussels, from 19 Russian and Estonian ports, between 1997 and 2003, illustrating the high flexibility of this pathway. Based on data from the Port of Brussels. Names of the ports are each replaced by a letter to preserve the confidentiality of the supplying areas. Number of ports used by year is indicated at the top of each row.

half of 2002. Two long periods without imports were then observed: from 16 July 2002 to 25 June 2003 (11 months) and from 19 November 2003 to 17 May 2005 (18 months), except one boat in each case.

Discussion and conclusions

It is critically important to have access to reliable information for assessing the potential risk of invasiveness (Cock, 2003). Our results suggest that one of the main difficulties in pathway analysis is data collection. None of the sources used is really adequate. Even if corrected CSIM data were very useful in this case, 'self-made' corrections are time-consuming and inaccurate. The NBB offers detailed corrected data that would be most adequate. Nevertheless these data are not available either for research purposes or for phytosanitary control organizations (i.e. AFSCA). This calls for better exchanges of information between organizations responsible for either the collection of statistics or for phytosanitary controls, or for the creation of a national structure to centralize and share information and statistics on wood imports/exports and associated risks. The NFS published statistics on Belgian wood imports and exports until 1993 and could play this key role as a privileged intermediate between the import companies, NBB and AFSCA. Correspondence is quite good between aggregated sources, with the exception of FAOSTAT data, but processes of standardization and classification are complex and it is thus difficult to explain the differences when observed. The use of non-aggregated data is not easier as differences are also present.

This study highlights the high mobility and the reduced traceability in this trade pathway. Depending on few economic actors, it is highly variable spatially (numerous origins, large supplying area, numerous entry points) and temporally (freezing of the canals, transportation costs). Moreover, a high proportion of illegal trade is suspected (WWF, 2004), and importers generally have little information on their supplying network. Little information is presently available on the species, despite the creation of new codes in the CN, and the origins of the wood. Risk assessments are thus not easy and this could explain why no special measures or controls have been applied in Belgium since 1996. Finally, no precise quantitative data on the indirect imports into the EU (i.e. through the Netherlands, in the present case) exist, complicating the assessment of a pathway and of its associated risks.

Most of the imports/exports do not necessarily represent a high risk of exotic forest pest introduction. Several conditions need to be met for a successful introduction to occur: (1) the presence of potential invaders in the country of origin (stage 0, *sensu* Colautti & MacIsaac, 2004); (2) high volumes of trade and geographical accumulation over time; (3) the absence of treatment (timber-debarking, heat treatment) to eliminate the bark- or wood-living insects; and (5) favourable conditions for survival during transportation (stage I) and for dispersion at the points of entry (stage II). Based on the available information, we analysed each of these conditions in regard to the studied trade pathway, illustrating that most of the required conditions for introduction (stage II) and establishment (stage III) are favourable, which tends to confirm that the observed occurrence of *I. duplicatus* and high variations in *I. typographus* populations are likely to be related to this trade.

Potential invaders

Several insect species such as *I. duplicatus*, *Monochamus galloprovincialis*, and *Monochamus urussovi* are included in the

EU plant quarantine list (Kulinich, 2005). *Dendrolimus sibiricus*, *Ips hauseri*, *I. subelongatus*, and *Scolytus morawitsi* are also considered as harmful organisms (Hantula & Niemelä, 2005) and are present on the EPPO Action List (version 2005–09). Some of these species already occur in parts of the European Russia, while others pose a serious threat to Karelian forest (Kulinich, 2005), the supplying area of the wood imported to Belgium. As most of these species are associated with coniferous species, careful attention could be recommended relating to round wood imports. Moreover, two indirect risks must also be taken into account. (1) Due to the lack of information available on the precise supplying areas, the possibility of introductions from regions further East cannot be excluded. Imports of round wood from the East of the Ural mountains present considerable risks, both for insect and for pathogen introductions (US Department of Agriculture, Forest Service, 1991; Hantula & Niemelä, 2005). Some of the fungi associated with *I. typographus* contribute to overwhelming the resistance of healthy Norway spruce (Viiri, 2002), and little is actually known about the spatial variation of fungal pathogenicity and virulence into Eurasia. (2) Re-introduction of species that are already present implies a risk of spreading unwanted genes to the current gene pool (Økland, 2000a). Even if such risk could be considered as relatively low compared to IAS introduction, studies of genetic diversity and evolutionary changes could be useful for understanding the potential for colonization and establishment, geographical patterns of invasion and expansion range, and time lags (Sakai *et al.*, 2001).

High volumes

The studied Eastern countries correspond to the Belgian main supplying area of coniferous round wood at risk. For a small country such as Belgium, imports of more than 1 million cubic metres of round wood from Russia and Estonia over almost 10 years can reasonably be considered as large. Even if imports decrease according to the statistics of the national sources, significant volumes of Russian and Estonian round wood are still imported. There is real accumulation over time, considering both destination companies (sawmills) and the main ports of transit (Brussels, Liege).

Treatments

Strict importation regulations are necessary, and risk analysis with regard to specific import routes may be appropriate (Cock, 2003). Debarking the logs before export is the best and maybe the only efficient way to prevent the introduction of bark beetles. But, according to an EPPO report (EPPO, 2002), to make all wood exported from Russia 'bark free' is not conceivable because of the huge volumes of export. Special measures imposed by the EU for importing wood from Russia result either in obtaining an official phytosanitary certificate attesting that the wood is coming from an area free from *Monochamus*, *Pissodes* and non-European Scolytinae species, or in the application of one of the following treatments: debarking, drying (humidity < 20%), thermal treatment, fumigation, or chemical impregnation. In the importations discussed here, the usual measure consists in a phytosanitary certificate. Detection of an introduced species could occur several years after its introduction and the designation of 'area free' could not thus be considered as totally reliable as direct treatments. Moreover, as previously mentioned, the actual origin of the wood is unsure, adding uncertainties as regards to the reliability of such designation. In case of control, only a small fraction of the total volume of export/import wood can be inspected at exportation/destination points. For example, either on a transit quay or on a ship, the accessible part of a log pile is very limited and usually difficult to reach. When logs are accessible, sampling for insects directly from the logs will usually be unsuccessful (Økland, 2000b). It is also often not possible to determine the insect species due to the lack of expertise of the staff, financial resources, or facilities to rear the adults (Humble & Allen, 2001). That kind of inspection does not guarantee that a wood load is 'insect free' or even at 'low risk'. In addition to the legal measures, some sawyers conscious of the potential risks (i.e. Pauls sawmill) apply complementary measures to decrease the probability of introduction, but this attitude is not widespread. Tree-felling occurs during the winter in Russia, but logs are usually exported from May to November. Logs are left lying along roadsides for long periods of time, and so they often rot or are infested by insects (WWF, 2004). A limitation of the imports to months unfavourable for insect emergence can be applied. Short stocking periods can be recommended. When it is not possible, the logs can be watered to avoid attack, as wet wood is unfavourable for development and survival of most insects (Björkhem *et al.*, 1977; Elowsson & Liukko, 1995). So, if exploited wood are insect-free and measures are taken to avoid colonization between exploitation and transformation of the logs, the risk could be limited. Even if simple measures could largely decrease the risks associated to such specific pathway (i.e. specific commodities and specific origins), the present study shows that it is not easy to determine when specific measures should be set up based on the most accessible data. As regards to materials which are much more difficult to track than wood logs, especially SWPM which are associated to a large panel of commodities and could come from multiple origins in each shipment, restricting international regulations such as ISPM 15 (FAO, 2006a) is probably the most efficient way to decrease the phytosanitary risks. SWPM constitute the main pathway of introduction of non-indigenous insect species (Haack, 2006; Roques & Auger-Rozenberg, 2006).

Survival, dispersion, and establishment

Bark beetles such as *I. typographus* are resistant insects and certainly survive a 2–3 weeks travel from the East to Western European countries, as illustrated by the presence of living individuals of *I. typographus* at different development stages of the life cycle on imported logs in the Port of Liege in August 2005 (pers. obs.). Based on the high dispersal ability of the spruce bark beetle (Botterweg, 1982; Wermelinger, 2004) and on the presence of potential hosts almost everywhere near most of the entry points, dispersion of exotic individuals of such species, or of individuals of comparable exotic species, seems very likely. The analysis of the USDA Animal and Plant Health Inspection Service 'Port Information Network' database (Haack, 2006) revealed a highly significant association between interceptions and establishment of exotic bark- and wood-boring species. In the present case, it seems very likely that more systematic sampling of the imported logs would show a high number of interceptions. As illustrated by the range expansion of the pine shoot beetle, *Tomicus piniperda*, in the USA (Haack & Poland, 2001) or the spread of the great spruce bark beetle, *Dendroctonus micans*, in the UK (Fielding *et al*., 1991), it is usually extremely difficult to eradicate an IAS once established. Moreover, the costs of damages and management options are usually very high (O'Neil & Evans, 1999). In order to reduce the risk of spread and establishment of invasive species, the availability of appropriate wood-trade data would certainly help to detect potentially dangerous pathways.

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REFERENCES

Allen, E.A. & Humble, L.M. (2002) Non indigenous species introductions: a threat to Canada's forests and forest economy. *Canadian Journal of Plant Pathology*, **24**, 103–110.

Bakke, A. & Økland, B. (2000) The risk of introducing harmful defoliating insects from Asia with imported logs. *Aktuelt Fra Skogforskningen*, **4**, 19–21.

Baranchikov, Y.N. (1997) Siberian forest insects: ready for export. *Proceedings of the exotic pests of eastern forests conference*, Nashville, Tennessee, 8–10 April 1997. (ed. by K.O. Britton). USDA Forest Service and TN Exotic Pest Plant Council.

Björkhem, U., Dehlén, R., Lundin, L., Nilsson, S., Olsson, M.T. & Regnander, J. (1977) *Storage of pulpwood under water sprinkling – effects on insects and the surrounding area*. Department of Operational Efficiency, Royal College of Forestry Research Notes, Stockholm, Sweden, 107.

Botterweg, P.F. (1982) Dispersal and flight behaviour of the spruce bark beetle *Ips typographus* in relation to sex, size and fat content. *Zeitschift für Angewandte Entomologie*, **94**, 466–489.

Cavey, J.F., Hoebeke, E.R., Passoa, S. & Lingafelter, S.W. (1998) A new exotic threat to North American hardwood forests: an Asian longhorned beetle, *Anoplophora glabripennis* Motschulsky) Coleoptera: Cerambycidae: I. Larval description and diagnosis. *Proceedings of the Entomological Society of Washington*, **100**, 373–381.

Cock, M.J.W. (2003) *Biosecurity and forests: an introduction – with particular emphasis on forest pests*. Forest Resources Development Service – Working Paper FBS/2E, Forest Resources Division FAO, Rome, Italy.

Colautti, R.I. & MacIsaac, H.J. (2004) A neutral terminology to define 'invasive' species. *Diversity and Distributions*, **10**, 135–141.

Elowsson, T. & Liukko, K. (1995) How to achieve effective wet storage of pine logs (*Pinus sylvestris*) with a minimum amount of water. *Forest Products Journal*, **45**, 36–42.

European and Mediterranean Plant Protection Organization (EPPO) (2002) *Forest pests on the territories of the former USSR*. Panel on Quarantine Pests of Forestry – 02/9686, Point 4.

Food and Agriculture Organization (FAO) (2006a) *International Standards for Phytosanitary Measures*. Guidelines for Regulating Wood Packaging Material in International Trade – Publication No. 15, April 2006. FAO, Rome, Italy.

Food and Agriculture Organization (FAO) (2006b) *Guidelines for pest risk analysis*. Publication No. 2, April 2006. FAO, Rome, Italy.

Fielding, N.J., Evans, H.F., Williams, J.M. & Evans, B. (1991) Distribution and spread of the Great European spruce bark beetle, *Dendroctonus micans*, in Britain – 1982–89. *Forestry*, **64**, 345–358.

Haack, R.A. (2006) Exotic bark- and wood-boring Coleoptera in the United States: recent establishments and interceptions. *Canadian Journal of Forest Entomology*, **36**, 269–288.

Haack, R.A. & Cavey, J.F. (2000) Insects intercepted on solid wood packing materials at United States ports-of-entry: 1985–98. *Proceedings of the international conference on quarantine pests for the forestry sector and their effects on foreign trade*. Concepcion, Chile, 27–28 June 2000.

Haack, R.A. & Poland, T.M. (2001) Evolving management strategies for a recently discovered exotic forest pest: the pine shoot beetle, *Tomicus piniperda* (Coleoptera). *Biological Invasions*, **3**, 307–322.

Hantula, J. & Niemelä, P. (2005) *Border inspection of roundwood imports: pathogens and pests*. Health Status of forests in Finland and Russian Federation. Seminar 2005. http://www.metla.fi/julkaisut/suhdannekatsaus/2004/Outlook2004-topics.pdf [accessed 26 February 2006].

Humble, L.M. & Allen, E.A. (2001) Implications of non-indigenous insect introductions in forest ecosystems. *IUFRO proceedings: population dynamics and impacts of integrated management of forest defoliating insects*. August 15–19, 1999, Victoria, BC, Canada (ed. by A.M. Leibhold, M.L. McManus, I.S. Otvos and S.L.C. Fosbroke), pp. 45–55. USDA Forest Service GTR NE-277, Northeastern Research Station, Newtown Square, Pennsylvania, USA.

Krcmar-Nozic, E., Wilson, B. & Arthur, L. (2000) *The potential impacts of exotic forest pests in North America: a synthesis of research*. Information Report BC-X-387. Natural Resources Canada. Canadian Forest Service. Pacific Forestry Centre, Victoria, BC, Canada.

Kulinich, O. (2005) *Survey of harmful organisms in Karelian forests*. Health Status of forests in Finland and Russian Federation – Seminar 2005. http://www.metla.fi/julkaisut/muut/forest-health-2005/forest-health-seminar-2005.pdf [accessed 26 February 2006].

O'Neil, M. & Evans, H.F. (1999) Cost-effectiveness analysis of options within an Integrated Crop Management regime against great spruce bark beetle, *Dendroctonus micans*, Kug. (Coleoptera: Scolytidae). *Agricultural and Forest Entomology*, **1**, 151–156.

Økland, B. (2000a) Review of Nordic investigations on timber-imported organisms from Russia. *Aktuelt Fra Skogforskningen*, **4**, 36–37.

Økland, B. (2000b) Main elements for future research on species imported by timber to Norway. *Aktuelt Fra Skogforskningen*, **4**, 38.

Piel, F., Gilbert, M., Franklin, A. & Grégoire, J.C. (2005) Occurrence of *Ips typographus* (Col., Scolytidae) along an urbanisation gradient in Brussels, Belgium. *Agricultural and Forest Entomology*, **7**, 161–167.

Piel, F., Grégoire, J.C. & Knížek, M. (2006) New occurrence of *Ips duplicatus* Sahlberg in Herstal (Liege, Belgium). *EPPO Bulletin*, **36**, 529–530.

Roques, A. & Auger-Rozenberg, M.A. (2006) Tentative analysis of the interceptions of non-indigenous species (NIS) in Europe during 1995–2004. *EPPO Bulletin*, **36**, 490–496.

Sakai, A.K., Allendorf, F.W., Holt, J.S., Lodge, D.M., Molofsky, J., With, K.A., Baughman, S., Cabin, R.J., Cohen, J.E., Ellstrand, N.C., McCauley, D.E., O'Neil, P., Parker, I.M., Thompson, J.N. & Weller, S.G. (2001) The population biology of invasive species. *Annual Review of Ecology and Systematics*, **32**, 305–332.

Siitonen, J. (2000) Beetles (Coleoptera) imported to Finland on Russian roundwood. *Aktuelt Fra Skogforskningen*, **4**, 11–17.

Stephen, F.M. & Grégoire, J.C. (2001) *Introduction and establishment of exotic bark beetles*. Exotic Forest Pests Online Symposium, http://www.apsnet.org/online/ExoticPest/Papers/stephen.htm [accessed 26 February 2006].

Tomiczek, C. (2002) *First occurrence of the 'Asian longhorned beetle', Anoplophora glabripennis (motschulsky) in Europe*. Federal Forest Research Centre, Vienna, Austria.

US Congress (1993) *Harmful non-indigenous species in the United States*. US Congress, Office of Technology Assessment, OPA-F-565, Washington, DC.

US Department of Agriculture, Forest Service (1991) *Pest risk assessment on the importation of larch from Siberia and the Soviet Far East*. Miscellaneous Publication no. 1495, Washington, DC.

Valkama, H., Räty, M. & Niemelä, P. (1997) Catches of *Ips duplicatus* and other non-target Coleoptera by *Ips typographus pheromone trapping. Entomologici Fennici*, **8**, 153–159.

Viiri, H. (2002) Interactions between host trees and fungi associated with the spruce bark beetle (*Ips typographus*). Doctoral Thesis. The Finnish Forest Research Institute, Research Papers 864, Helsinki, Finland.

Wermelinger, B. (2004) Ecology and management of the spruce bark beetle *Ips typographus* – a review of recent research. *Forest Ecology and Management*, **202**, 67–82.

World Wildlife Fund (WWF) (2004) *Quick overview facts on illegal logging in Russia*. Compilation of the WWF European Forest Programme from existing studies March 2004. http://www.forestandtradeasia.org/files/Illegal%20Logging%20in%20Russia.pdf [accessed 26 February 2006].

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