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Invasive pests ('biological pollutants') and US forests: whose problem, who pays?

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Invasive pests, or 'biological pollutants', are among the most serious threats to biological diversity in the forest ecosystems of the USA. Additionally, they can disrupt forest management practices and cause enormous financial losses. In the USA, as elsewhere, the receiving country inherits the problem and, along with its citizenry, bears the permanent economic costs. The incidence of the introduction of invasive pests, the pathways utilized, and their economic and ecological impacts are presented using Dutch elm disease (*Ophiostoma ulmi*), chestnut blight (*Cryphonectria parasitica*), gypsy moth (*Lymantria dispar*), and other pests as examples. The permanency of ecological impacts and associated economic costs needs to be considered in discussions with other National Plant Protection Organizations in designing and adopting mutual agreements and protocols. Suggestions are given for addressing these impending needs in view of expanding global trade.

Introduction

It is the general view that forest pollutants, anthropogenic factors causing damage to trees, can be mitigated to a certain degree by regulatory action and/or by adopting broad public-policy perspectives (McKenzie & El-Ashry, 1989). In this paper, invasive pests (non-indigenous plants, animals, and microbes introduced into the forests of the USA accidentally or purposefully) are considered as 'biological pollutants'. Some fail to survive, others become established without disrupting their new environment, and still others are established, multiply, and spread with disastrous consequences. Once established within an ecosystem, invasive pests may be impossible to eliminate and the resulting negative environmental and economic impacts can be devastating (Office of Technology Assessment, 1993). Preservation of biological diversity is of growing concern and harmful invasive pests disrupt such diversity in forests through species extinction, population declines, or simplification of ecosystems. Other adverse ecological effects on forests include conversion of tree species, deforestation, destruction of wildlife and riparian habitats, and increased fire hazard. Some US forests that have been so altered by past introductions of invasive pests are a crucial resource threatened by additional intrusions (USDA, 1991; Liebhold *et al.*, 1995). This article illustrates the magnitude of this threat to forest ecosystems and explores solutions to the questions: whose problem? who pays?

Incidence of introductions into North America

In Canada, exotic plants account for 28% (881 species) of that country's flora (Heywood, 1989). In the USA, it has been estimated that at least 4500 species of non-indigenous plants, animals, and microbes have been introduced, though only about 15% are harmful (Office of Technology Assessment, 1993). Of concern are the accelerated rates of introduction that have occurred within the last 100 years (Fig. 1). Given increasing global markets, technological advances in transportation, and the mobility of humans and their materials, rates of introduction will continue to increase. These factors dictate that the types of organisms and their pathways of introduction will be different.

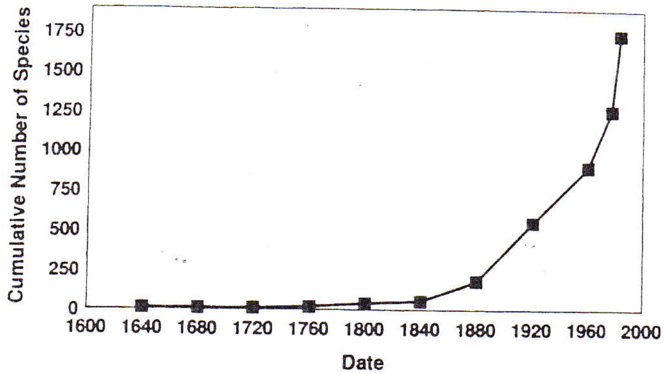

Fig. 1. Cumulative number of establishments of immigrant insect and mite species in the United States (from Sailer, 1983).
Nombre cumulé d'espèces d'insectes et d'acariens introduits aux Etats-Unis.

The rapidity of surface and air transport increases both the survival of translocated organisms and the probability of successful introduction into suitable environments. As an example, the brown tree snake, *Boiga irregularis*, was introduced accidentally as a stowaway on aircraft and ships into several Pacific islands, including Guam, with disastrous effects on avifauna and disruption of man's activities (Savidge, 1987). In natural communities, species evolve mutually advantageous means for reducing competition for food and other resources. This generally results in a great degree of community stability, and resistance to invasive species (Cox & Moore, 1993). While some newly introduced organisms can circumvent this evolutionary process, it is difficult to predict whether establishment will be successful. Invasives are particularly successful at establishing in perturbed habitats (Lattin & Oman, 1983). However, the majority of organisms introduced for control of noxious weeds failed even after repeated introductions (Klingman & Coulson, 1982). This suggests that establishment rates for introduced species are probably low. Another confounding factor is the period that elapses during actual introduction, increase to pest status, and detection. Simmonds & Greathead (1977) postulated that some invading insects may be restricted to discrete habitats and require a period of adaptation prior to multiplication and spread. Since this acclimatization period may require several generations over a period of years, the difficulty that regulatory agencies face in identifying the pathway of entry of invasive pests is understandable.

It is not possible to predict with certainty whether an organism will become invasive if introduced into a new environment. The pest risk assessment process clarifies the potential for an organism to be transported successfully, establish and reproduce, and become a biological pollutant (USDA, 1991). Certainly, if an organism is a pest in its native habitat and a potential receiving country has comparable host-plant genera, it must be considered a serious threat. Of the 368 insect species which feed on woody plants that have been introduced from other continents into North America, a surprising majority is monophagous. Further examination reveals that virtually all of these species feed on the same host-plant genera in the New World as in their country of origin (Gibbs & Wainhouse, 1986; Mattson *et al.*, 1995).

Because North America contains many plant genera common to Eurasia and east-central Asia, it can be expected to be amenable to cross-regional exchanges of phytophagous organisms. Indeed, there has been a distinct 'trade imbalance' of invasive pests. Surveys of North American and European forest-insect literature show that, according to Niemela & Mattson (1992), 120 species have invaded North America from Eurasia, as against 17 in the opposite direction. Reasons given for this disparity include: (1) more genera and plant species in

North America than in Europe; (2) more European plants naturalized in North America than vice versa; (3) European forests are structurally simpler, smaller, and more fragmented; and (4) North American forests closely resemble those of pre-Pleistocene Europe, and insects that subsequently evolved are less able to use the less abundant confamilial trees and shrubs in Eurasia. Another reason given for the success of European insects invading other regions is that they are better competitors than their North American counterparts and often displace them (Lattin & Oman, 1983).

The multicultural composition of the human population of the USA also contributes to the introduction of invasive pests. Various ethnic groups strive to maintain access not only to foods from their native lands but also plant materials. For these reasons and the economic examples that follow, US scientists, regulatory officials, and politicians have been extremely concerned with the question 'Whose problem?'.

Economic impacts of invasive pests

In a comprehensive report on harmful non-indigenous species in the USA (Office of Technology Assessment, 1993) it was estimated that, of 97 billion USD in losses from invasive pests during 1906/1991, 92 billion USD was from insects. In worst-case scenarios, potential losses to the USA from 15 introduced pests, which include several forest pests, exceed 134 billion USD (Table 1).

While these estimates may seem excessive, they are consistent with pest-risk analysis of five potential invasive pests on imports of larch logs from Siberia (USDA, 1991). The enormity of these projected economic losses to forests of the western USA provides additional justification for aggressively prohibiting potential biological pollutant introductions (Table 2). They also should serve to convince trading partners of the potential economic threat to US forests, should exclusion efforts fail.

US exclusion procedure

The procedure for preventing entry of pests into the USA is a continuum of activities in both the USA and the country of origin. Prevention and preclearance in the country of origin are

Table 1. Potential economic losses in USA from 15 selected non-indigenous species in worst-case scenarios
Pertes économiques potentielles résultant, dans le pire cas, de l'introduction aux Etats-Unis de 15 nuisibles exotiques

Group	Species studied	Estimated cumulative loss in million USD (1991)
Plants	*Melaleuca quinquenervia, Lythrum salicaria, Striga asiatica*	4,588
Insects	*Apis mellifera scutellata* (African honey bee), *Lymantria dispar, L. monacha, Anthonomus grandis, Ceratitis capitata, Ips typographus*	73,739
Aquatic invertebrates	*Dreissena polymorpha* (zebra mussel)	3,372
Plant pathogens	*Heterobasidion annosum, Lachnellula willkommii, Phakopsora pachyrrhizi*	26,924
Others	Foot and mouth disease, *Bursaphelenchus mucronatus*	25,617
Total		134,240

Table 2. Summary of economic costs to the timber resources of the western USA from the introduction of selected forest pests from Siberia
Résumé du coût économique pour les ressources forestières de la partie occidentale des Etats-Unis, occasionné par l'introduction de certains nuisibles forestiers en provenance de la Sibérie

Pest	Host	Economic cost in million USD (1990)		
		Best case	Worst case	Million ha affected
Bursaphelenchus mucronatus	*Pinus* spp.	33.3	1670	10.7
Lachnellula willkommii	*Larix* spp.	24.9	240.6	0.3
Heterobasidion annosum	*Pseudotsuga menziesii*	84.2	343.9	3.8
Defoliators	*Larix* spp. *Pinus* spp. *Pseudotsuga menziesii* *Picea* spp. *Abies* spp. *Tsuga* spp. Other	35049	58410	30.8
Ips typographus	*Picea* spp.	201	1500	3.2

matched by measures for exclusion, detection, containment and eradication in the USA, followed if they fail by the application of traditional, then biological control. Prevention and preclearance of goods/material in the originating country ensures expeditious entry into the USA by minimizing inspection delays and treatment or confiscation of products. In addition to on-site supervision by US regulatory officials, preclearance relies on cooperation and information from scientific counterparts in the country of origin for identifying organisms, their abundance, and pathways of translocation. This is a crucial link in facilitating exclusion; the knowledge relative to potential pest behavior, identification, abundance, etc., usually resides with professionals in the native country. Given declining resources for regulatory activities and increasing volume and types of trade, this cooperation will become increasingly critical. Failure to exclude the organism can lead to costly detection and eradication efforts and, if unsuccessful, to protracted economic and ecological impacts.

Economic and ecological impacts of introduced diseases and insects

It has been estimated that of 70 major insect pests of US forests, 19 (27%) were introduced (Pimentel, 1986). Not all organisms that establish and spread become biological pollutants. Some, like the brown-tail moth (*Euproctis chrysorrhoea*) introduced in 1890, and the satin moth (*Leucoma salicis*) introduced in 1920, initially spread and caused extensive defoliation and tree mortality but later declined and were found only rarely in select habitats (Wallner, 1989). However, *E. chrysorrhoea* illustrates the unpredictability of invasive pest status. Since the 1960s, it was limited to an area of approximately 5 km^2 on three maritime islands. During the 1980s, it expanded both its range and host plants and is now found on over 23 maritime islands and in mainland forests encompassing over 100 000 ha (D. Struble, pers. comm.).

Chestnut blight

There have been a number of pathogens (Table 3) and insects (Table 4) that have become serious, persistent forest pests. Some, such as chestnut blight (*Cryphonectria parasitica*), have had devastating effects. It essentially eliminated the whole population of approximately 8 million trees of *Castanea dentata* (American chestnut), the most economically and ecologically important tree species of the eastern hardwood forest. Today, *C. dentata* occurs as small, understory stump sprouts of little value that eventually become infected and die. The disappearance of *C. dentata* led to a serious loss in biodiversity and massive conversion of tree species. This had at least two significant impacts: (1) the conversion from chestnut to oak created extensive forests more susceptible to another invasive pest (*Lymantria dispar*, which prefers oak), and (2) oak cohorts that replaced chestnut were not as well adapted to sites previously occupied by chestnut and currently are senescing due to environmental stress (Starkey *et al.*, 1989). Thus, the Appalachian forests are once again experiencing widespread tree mortality, this time as a delayed consequence of the introduction of an invasive pest.

Dutch elm disease

Dutch elm disease, caused by *Ophiostoma ulmi* and the closely related and newly described species *O. novo-ulmi*, exemplifies the tragedy of exchanges of invasive pests between continents. During the 1920s and 1930s, *O. ulmi* (introduced probably from central Asia) caused a serious epidemic in western Europe. It was then introduced into the USA along with its vector, the smaller European bark beetle, *Scolytus multistriatus*, on unpeeled veneer logs. Losses of elm in the urban environment, where highly susceptible trees of *Ulmus americana* (American elm) had been planted in monoculture, were devastating: more than 46 million trees were killed at an estimated value loss of 430 USD per tree (USDA, 1991). Additional costs for removal of dead trees (on average 215 USD), protection of surviving elms (40–100 USD per tree per year), and replacement with other species cost federal, state, and municipal governments additional millions of US dollars. During the late 1960s, there was a devastating epidemic of a new, more aggressive form of Dutch elm disease in western Europe, starting in Great Britain. This outbreak was caused by a different form of the fungus, now recognized as a new species, *O. novo-ulmi* (Bates *et al.*, 1993), that entered England on unpeeled logs of *Ulmus thomasii* (rock elm) from Canada (Brasier & Gibbs, 1973). European elms, widely planted as hedgerow and amenity trees throughout the lowlands of Great Britain and northern Europe, have been decimated by this introduction.

Table 3. Forest pathogens introduced into the USA
Pathogènes forestiers introduits aux Etats-Unis

Host	Pathogen (disease)	Origin	Introduction pathway
Castanea dentata	*Cryphonectria parasitica* (chestnut blight)	Asia	Nursery stock
Ulmus spp.	*Ophiostoma ulmi* (Dutch elm disease)	Europe	Raw veneer logs
Pinus strobus	*Cronartium ribicola* (white pine blister rust)	Eurasia	Nursery stock
Populus spp.	*Melampsora larici-populina* (larch/poplar rust)	Eurasia	Unknown
Chamaecyparis lawsoniana	*Phytophthora lateralis* (Port Orford cedar root disease)	Asia	Nursery stock?
Cornus spp.	*Discula destructiva* (dogwood anthracnose)	Europe	Seaports
Larix spp.	*Lachnellula willkommii* (larch canker)	Eurasia	Unknown
Juglans cinerea	*Sirococcus clavigignenti-juglandacearum* (butternut canker)	Unknown	Unknown

Table 4. Forest insect pests introduced into the USA
Insectes forestiers nuisibles introduits aux Etats-Unis

Insect	Origin	Introduction pathway
Lymantria dispar (European)	France	Entrepreneurship
Lymantria dispar (Asian)	Russian Far East, Europe	Ships, containers
Adelges piceae (balsam woolly adelgid)	Europe	Nursery stock
Coleophora laricella (larch casebearer)	Europe	Nursery stock
Scolytus multistriatus (European elm bark beetle)	Europe	Raw veneer logs
Matsucoccus resinosae (red pine scale)	Asia	Nursery stock
Adelges tsugae (hemlock woolly adelgid)	Asia	Nursery stock?
Tomicus piniperda (pine shoot beetle)	Eurasia	Ship dunnage?
Ips typographus (European spruce beetle)	Eurasia	Ship dunnage
Cryptococcus fagisuga (beech scale)	Europe	Nursery stock

This scenario is instructive from several aspects.

(1) Despite a known pathway for initially introducing this pathogen and vector to North America, the same pathway was available for a reciprocal introduction of a new species into Europe.
(2) Given that *O. ulmi* arrived in North America when the first European Dutch elm disease outbreak was already attenuated, there was a lack of immediate concern about reintroduction from North America. Coupled with the delayed recognition that a different species was involved, this complacency was disastrous. This might have been circumvented had research emphasis been maintained, so that the threat could have been anticipated.
(3) The pathogen was initially assessed as a more aggressive strain and only later from detailed culturing was the strain recognized as a new species.
(4) The use of molecular biological technology was applied to help establish species identity. These techniques can be expected to be used more routinely in the future to identify races or strains for purposes of risk assessment.

Butternut canker

Not all invasive pests are readily detected or identified as such. For example, since the early 1950s there has been widespread dieback and mortality (more than 90%) of *Juglans cinerea* (butternut) in eastern North American hardwood forests. The causal agent, the fungus *Sirococcus clavigignenti-juglandacearum* is not considered native to North America and its damage appears to be threatening the survival of butternut, leading to its potential classification as a rare and endangered species (Ostry *et al.*, 1994).

Lymantria dispar

The gypsy moth, *L. dispar*, has been the dominant invasive insect introduced into US forests. Because of its comprehensive biological and economic history, *L. dispar* serves as an excellent case study for focussing on the questions 'Whose problem?' 'Who pays?'. Since its accidental introduction from France in 1869 (Forbush & Fernald, 1896), *L. dispar* has spread southward and westward at an annual rate of 12 km (Liebhold *et al.*, 1995; Fig. 2). Attempts have been made to slow its spread to prevent this insect pest from infesting the highly vulnerable forests of the Southeast and Midsouth as well as those of the Midwest and West (Fig. 3). While it prefers oaks and poplars, *L. dispar* is a polyphagous defoliator that ranges from Asia across Europe and northern Africa (Montgomery & Wallner, 1988). Defoliation may cause shifts in stand species composition (Campbell & Sloan, 1977), seedling mortality (Gottschalk, 1990a), and occasional massive tree mortality (Allen & Bowersox, 1989). At the peak of the last outbreak in 1981, more than 6 million ha of mixed hardwood forests were defoliated; that year, in the state of Pennsylvania alone, more than 9 million USD was expended on spray programs and timber losses exceeded 72 million USD. In fact, timber losses from *L. dispar* defoliation for Pennsylvania for the period 1969/1988 were estimated at 219 million USD (Gottschalk, 1990b). However, the principal impact of *L. dispar* is on human activities, health, and safety which are difficult to quantify. Defoliation and numerous larvae disrupt recreational activity, depress residential property values, and threaten human health, and are costly to mitigate (USDA, 1995).

L. dispar probably originated in Asia (Goldschmidt, 1934) where it displays its greatest morphological (Schaefer, 1989), genetic (Harrison *et al.*, 1983), and host and behavioral (Baranchikov, 1989) variation. The introduction of *L. dispar* from Asia into North America was of major concern because, unlike European *L. dispar*, females of Asian *L. dispar* are capable of strong, directed flight, and larvae feed more aggressively on a broader range of trees. This increased mobility would significantly accelerate the rate of spread, make eradication more difficult, and render ineffective management technology developed for *L. dispar* of European origin (Wallner, 1993).

Asian *L. dispar* was first detected as egg masses on the superstructures of Russian ships loading grain in Vancouver (British Columbia, CA). Gravid females, attracted to lights in Far East ports (Wallner *et al.*, 1995), deposited egg masses on ships and their cargoes. Transported to western North American ports, eggs hatched and neonates were blown on shore where larvae developed to adulthood. Males captured in pheromone traps placed in and around ports in Seattle (Washington), Portland (Oregon), and Vancouver were determined to be of Asian origin based on mitochondrial DNA sequencing (Bogdanowicz *et al.*, 1993). This resulted in a 25 million USD eradication program in 1993. In that same year, *L. dispar* of Asian type was

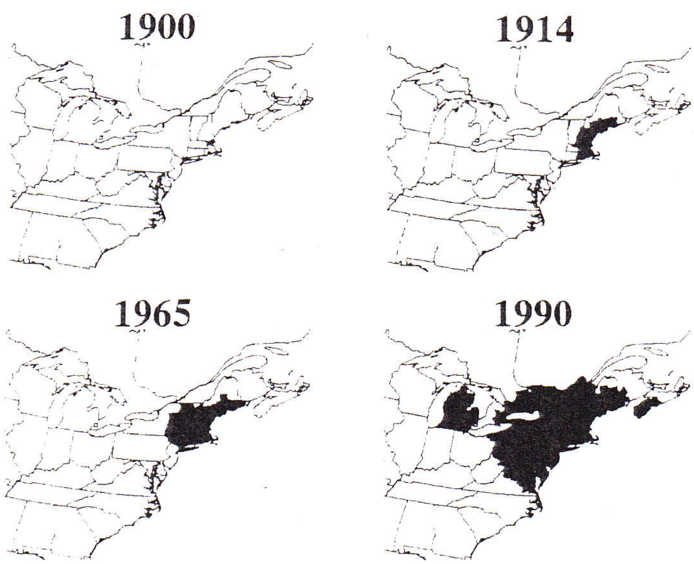

Fig. 2. Establishment and spread of *Lymantria dispar* in the USA.
Etablissement et dissémination de *L. dispar* aux Etats-Unis.

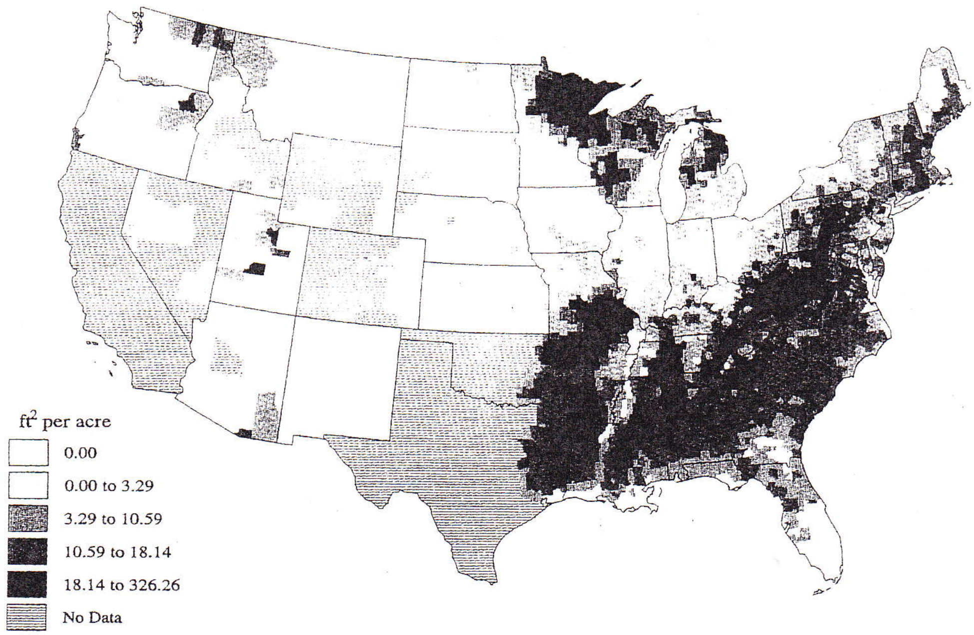

Fig. 3. Distribution of preferred host species of *Lymantria dispar* (basal area) in the USA (4 ft^2 per acre equals approximately 1 m^2 per ha).
Répartition des plantes-hôtes préférées de *L. dispar* aux Etats-Unis (surface terrière en 'ft^2 per acre', dont 4 égalent approximativement 1 m^2 par ha).

introduced into Wilmington (North Carolina) on US military munitions and equipment from Germany. In 1992/1994, forests in Germany (and elsewhere in central Europe) experienced a massive outbreak of *L. dispar* (Gossenauer-Marohn, 1995). Hence, there was concern that the introduction and establishment of *L. dispar* from Germany (which might include Asian and European types, and their hybrids) (Prasher & Mastro, 1995) could be devastating to US forests. An eradication effort of 9 million USD was conducted in 1994/1995 in North Carolina and South Carolina in response to that introduction.

Efforts to downsize US military personnel in Europe will result in enormous translocation of personnel and belongings. By the end of 1995, 150 000 troops, 190 000 family members, 55 000 automobiles, 45 000 pets, and 600 000 tons of personal property will be shipped to the USA. This does not include military equipment and munitions (Source: U.S. Military European Command). Preventive inspection and detection efforts have been accelerated both by the military and USDA's Animal and Plant Health Inspection Service (APHIS) to interdict possible infested articles. However, the massive amount of material makes the risk of inadvertent introduction of *L. dispar* distressingly high.

As with most invasive pests, once exclusion and eradication efforts are exhausted, a costly effort is undertaken to quarantine regions and apply direct controls to prevent spread. The rationale for such action is to preclude or delay economic and environmental impacts. With European *L. dispar*, which has limited vagility, slowing the spread has been shown to be economically beneficial. It has been estimated that 100–500 million USD in benefits could be realized over a 25-year period by slowing the spread of *L. dispar* in the USA (Leuschner, 1991). This would require considerable cumulative costs of monitoring and control. Currently, some 400 000 pheromone traps are deployed yearly in the USA at a conservative estimate of 20 USD per trap for a total of 8 million USD (V. Mastro, pers. comm.). When added to the costs presented in Fig. 4, total average yearly expenditures approach 30 million USD (1995 dollars). Given that *L. dispar* has not reached the highly susceptible forests to the south and west (Figs 2–3), extensive socio-economic, human health and safety, and ecological impacts are yet to occur. Additionally, there is the threat that introduction of Asian *L. dispar*, with its more aggressive feeding habits and adult female vagility, would render efforts to constrain it technically difficult.

Other insect invaders

While *L. dispar* has been the dominant invasive forest insect in North America, 367 additional phytophagous insects of woody plants have been introduced (Mattson *et al.*, 1995). Accurate economic impacts are unavailable for most, yet the ecological effects are indisputable. For example, there is an array of host interactions and environmental disruptions for invasive pests that attack conifers (Table 4). The balsam woolly adelgid (*Adelges piceae*) threatens relic stands of high-elevation *Abies fraseri* (Fraser fir); red pine scale (*Matsucoccus resinosae*) eliminates *Pinus resinosa* (red pine) in the northeastern USA; hemlock woolly adelgid (*Adelges tsugae*) decimates *Tsuga canadensis* (eastern hemlock), and larch casebearer (*Coleophora laricella*), once a pest, is controlled by introduced natural enemies. The impact of two recently introduced European pests, pine shoot beetle (*Tomicus piniperda*) and European spruce beetle (*Ips typographus*), is unknown, but delimitation and quarantine actions have been undertaken.

Interactions

Biotic interactions are complex and unpredictable and do not necessarily mirror the behavior and dynamics of a biological invader in its country of origin. The beech bark disease is such an example. This disease, caused by the introduced beech scale, *Cryptococcus fagisuga*, and two fungal pathogens, *Nectria galligena* (native to North America) and *N. coccinea* var. *faginata* (probably introduced), has caused more serious damage in North America than would have

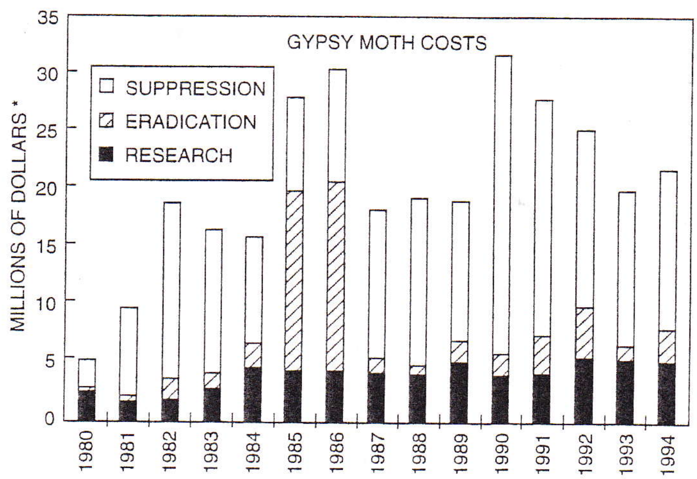

Fig. 4. Yearly costs (in 1995 USD) for eradication, suppression, and research programs on *Lymantria dispar* in the USA for 1980/1994.
Coûts annuels (en USD de 1995) de l'éradication de *L. dispar*, de sa suppression et de la recherche le concernant, aux Etats-Unis en 1980/1994.

been predicted from its action in Europe (Houston *et al.*, 1979). Further, not only have American beech forests suffered extensive mortality but the introduced *Nectria* has repeatedly displaced the native fungus as the principal pathogen of the disease causal complex as the disease has spread. Economic costs are unavailable for this disease, but negative impacts on forest management and wood utilization, forest ecology, wildlife, and recreation occur with successive phases of the epidemic (Houston, 1994).

Conclusions

Whose problem?

Firstly, the responsibility for taking action against an invasive pest upon its detection in the USA lies initially with state and federal regulatory agencies. Secondly, since invasive pests do not abide by political or geographic boundaries, a state's or country's regulatory program will affect adjoining domains. The problem becomes a regional one that requires harmonization of regulatory activities between countries and by agencies within countries. Thirdly, potential invaders require climatic conditions similar to those in their country of origin and may be influenced by the vegetational diversity where they are introduced. Therefore, the threat must be assessed on a regional basis rather than country by country.

Who pays?

Along with the responsibility of US state and federal regulatory agencies for coping with a recently introduced invasive pests is the resulting financial obligation. In the USA, federal and state agencies bear the major expenditures. Under US law (Plant Quarantine Act of 1912, Federal Plant Pest Act of 1957, Mexican Border Act of 1942), a culpable party who purposefully or inadvertently introduces an invasive pest is subject only to a modest civil penalty. There has been no instance where a guilty party was required to pay costs for eradicating an organism or for the resulting economic or ecological damage it caused. Initial eradication expenditures often are substantial yet they pale in comparison with costs of limiting expansion of infestations and associated annual losses in tree growth and mortality, should they fail. Justifiable in deferring costs or reducing impacts, such financial burdens are borne indirectly by the US citizenry, but may be more difficult to accept as economic austerity intensifies. Understandably, it is possible to ascribe econometrics to forest productivity, whereas values such as ecosystem disturbances and species displacement are more difficult to quantify. For example, the rate of ecological change induced by an invasive pest, its impact on endemic species, and its disruption of management protocols all carry a cost. These disbursements come as hidden charges, much like a value-added tax, to be borne unwittingly by the receiving country.

Efforts to prevent further exchanges of invasive pests are not likely to be completely successful. The following are possible options to prevent or mitigate new pest introductions.

International measures

(1) Elevate the economic and ecological concern for pest introductions on a global basis (nation-to-nation or trading block-to-trading block), using comparable pest risk assessment procedures.
(2) Support a global scientific effort to compile and categorize potential invasive forest pests for heightened quarantine and surveillance.
(3) Work with import/export businesses, evaluate and identify new pest introduction pathways for increased surveillance and share this information with trading partners.

(4) Foster scientific collaboration to focus developing technology on the identification of new and/or behaviorally different biotypes of invasive pests.
(5) Create, for each trading block, lists of high-risk pests by commodity and use molecular technologies to identify them in the country of origin. This information could be used by regulatory officials in the country accidentally receiving these organisms to determine the severity of risk based on diagnostics and behavior. This diagnostic methodology also could pinpoint geographic biotypes and assist in identifying translocation pathways.

Domestic measures

(1) Levy a modest surcharge or user fee for quarantine inspection on import/export commodities to be held in an escrow account by USDA-APHIS for emerging biological pollutant identification/detection/eradication activities.
(2) Enact legislation that would permit regulatory agencies to litigate all losses associated with the purposeful or accidental introduction of forest pests.
(3) Focus technology assessment on biotype infestations and behavior.
(4) Reduce import dependency on raw forest products.

The permanency of the impacts of invasive pests and their associated economic costs needs to be considered carefully by trading partners. Clearly, commodity restriction, based on known or perceived pest affliction, can be costly and repressive to free trade. However, developing countries and countries in transition should be cautioned against ignoring the long-term economic and ecological impacts of invasive pests in expanding their economies.

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Nuisibles envahissants ou 'polluants biologiques' dans les forêts américaines: à qui le problème, à qui le coût?

Les nuisibles envahissants, ou 'polluants biologiques', constituent l'un des principaux dangers pour la biodiversité des écosystèmes forestiers des Etats-Unis. Ils sont susceptibles, d'ailleurs, de perturber la gestion sylvicole et d'occasionner des pertes financières considérables. Aux Etats-Unis, comme ailleurs, ce sont le pays d'introduction et sa collectivité générale qui doivent faire face au problème et en supporter les coûts. Les cas d'invasion par des nuisibles exotiques, les filières suivies, les impacts économiques et écologiques sont présentés, à l'aide des exemples de la graphiose de l'orme (*Ophiostoma ulmi*), du chancre de châtaignier (*Cryphonectria parasitica*), du bombyx disparate (*Lymantria dispar*) et d'autres ravageurs. La durée indéterminée des impacts écologiques et de leurs coûts associés est un élément de discussion indispensable pour l'établissement et l'adoption d'accords et de protocoles entre les Organisations nationales de protection des végétaux. Les moyens à mettre en oeuvre, proposés par l'auteur, seront affectés par le développement du commerce mondial.

Инвазийные вредители (" биологические загрязнители") и американские леса: чья проблема, кто расплачивается?

Инвазийные вредители или " биологические загрязнители " принадлежат к числу наиболее серьезных угроз биологическому разнообразию лесных экосистем США. Кроме

того, они могут нарушать практику лесоводства, а также причинять огромный финансовый ущерб. В США, как в любой другой стране, страна-получатель получает также и проблему, поэтому, вместе со своими гражданами она несет постоянные экономические затраты. Встречаемость инвазийных вредителей, используемые трассы, и их экономические и экологические воздействия представлены на примере Голландской болезни вяза (Ophiostoma ulmi), некроза коры каштана съедобного (Cryphonectria parasitica), непарного шелкопряда (Lymantria dispar), и других вредителей. Постоянство экологических воздействий и связанных с ними экономических затрат должно рассматриваться при обсуждении этих вопросов с другими национальными организациями защиты растений при составлении и принятии взаимных соглашений и протоколов. В статье приводятся предложения для решения этих насущных проблем в перспективе глобальной торговли.

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