# GLOBALIZATION AND PEST INVASION: WHERE WILL WE BE IN FIVE YEARS?

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The proliferation of transportation is breaking down biogeographical boundaries with profound consequences (OTA, 1993; Vitousek *et al.,* 1997; Mooney and Hobbs, 2000; Loope *et al*., 2001). An ever-growing volume of transported goods, increasing efficiency and speed, advancing technologies (such as containerization), and trade agreements are key components of the phenomenon (Bright, 1999). For example, the number of sea containers coming into U.S. ports has recently been doubling each decade, from 8 million in 1980, to 16 million in 1990, to 33 million in 2000. Each of these railroad-car sized containers weighs about 13 tons when loaded, and no one is keeping watch on what is in them (Baker and Sullivan, 2001). A recent Australian study showed that even empty sea cargo containers, temporarily out of use, contain some live as well as many dead pests (Stanaway *et al*., 2001).

Much less material is transported as air cargo, using smaller containers, but still the quantity is huge. Agricultural material is usually shipped as air cargo – keeping produce fresh and pests in good condition. Agricultural inspectors valiantly examine at least a small sample of what comes in. In the United States, the agency responsible for protecting our nation's borders from biological pollution is APHIS, the Animal and Plant Health Inspection Service of the U.S. Department of Agriculture (USDA). Because of growing recognition of the need to better address biological invasions, APHIS is starting to focus beyond its primary mandate of protecting mainstream American agriculture.

The challenges are huge. Just one example, the attempts to stop spread of the highly invasive and destructive brown tree snake (*Boiga irregularis* [Merrem]) in military cargo from Guam have not prevented interceptions as far away as Texas and Spain, and eight of these snakes have been found alive or dead at Honolulu airports (Rodda *et al*., 1997, 1999).

A report by the well-respected but now-defunct Congressional Office of Technology Assessment recognized in 1993 that all was not well with the existing system to keep harmful non-indigenous species out of the United States. For example, first class U.S. mail is a major facilitator for illegal transport of biological invaders, because of judicial interpretations of the U.S. constitution as protecting against unreasonable searches (OTA, 1993). This is just one of many cases where the status quo system gives invaders the edge.

Since the OTA report, things have gotten even more complex and troublesome. After years of trade negotiations, the World Trade Organization was established in 1995 and with it a treaty on Sanitary and Phytosanitary measures (WTO, 1998). The treaty is managed by the U.N. Food and Agricultural Organization, which is responsible for implementing the International Plant Protection Convention (FAO, 1997). However, countries cannot protect themselves from a pest unless they can clearly establish that a specific, credible threat exists through a risk assessment process. Also, a country can require only the minimum treatment measures documented as effective in reducing risk. This process is clearly geared toward facilitating free trade at the expense of agricultural and environmental concerns (e.g., Bright, 1999; Campbell, 2001). But the United States and its trading partners willingly created this system. Thus, given the extent and speed of trade, these agreements prevent nations from protecting their borders from new introductions of harmful invasive species.

At the request of USDA, the U.S. National Plant Board conducted a broadly based stakeholder review of the current U.S. quarantine system and concluded that vast improvements are needed

(National Plant Board, 1999). Our assignment for the symposium was to evaluate where we'll be with invasions in five years. So we looked for data showing that rates of invasion are indeed accelerating. One of the best data sets is for Florida, where the excellent work of Reece Sailer (Sailer, 1978) and the later preparation of the federal OTA Report inspired a formal effort to document invasions. Thomas (2000) provides updated information on non-native arthropods in Florida, yet there is no clear evidence for any upward trend in the numbers of new introductions per year over the past 15 years. The Florida data do show that introductions from Asia increased between the 1970 to 1989 period and 1986 to 2000. This increase parallels a rise in the value of goods exported from China to the United States from $5 billion in 1985 to $62 billion in 1998 (APHIS, 1998). But the Florida data set is the only one we could find that shows a clear increase in introductions from Asia.

The late Professor Jack Beardsley regularly searched for new arrivals in Hawaii from about 1960 to 1990 (Beardsley, 1979). His work showed that although Hawaii already had experienced as many invasions as the entire U.S. mainland, the number of new records per year were not declining (see Fig. 5 in Loope, 1998). The Bishop Musuem's Hawaii Biological Survey in the 1990s continued to document the arrivals of new immigrant species in annual publications (Hawaii Biological Survey, 2002). Unfortunately, the documented annual rate seems to reflect more the interests and motivations of local biologists than true numbers of invasions. A recent biological survey of the surroundings of Kahului Airport on Maui is illustrative (Howarth and Preston, 2002). Of the 490 alien species of arthropods identified to date, 38 represent new state records, and another 145 are new records for the island of Maui. However, 40% of the new island records have been in Hawaii for at least 50 years before being noted on Maui. These data show that, except for important agricultural pests, a decades-long delay often exists between establishment and documentation.

Unable to find definitive data, one of us (LL) attended two symposia at the Entomological Society of America meeting in San Diego in December 2001. One half-day symposium explained modern agricultural quarantine, and another addressed the question: "How effectively is American agriculture being protected?" (ESA, 2001). Speakers from USDA and state agencies largely felt that American agriculture is being well protected. No one presented data showing that the rate of pest establishment is increasing, though the rate of interceptions at ports of entry is increasing, while the number of taxonomists available to keep up with identifications is declining. The administrator of APHIS, Charles Schwalbe, challenged what he perceived as a misconception that there is a conflict between pest exclusion and trade missions, with an unstated agreement to swap pests. "We are traders, not traitors," he said. He expressed support for the philosophy of FAO (Griffin in APS, 2001: "By carefully balancing free trade and legitimate measures for plant protection, countries are able to realize maximum benefit in their efforts toward both protection and facilitation of trade. In this context, facilitating trade and protecting plant health are not conflicting objectives, but rather a single objective–'safe trade.'"

One speaker who didn't agree with this optimistic description was Tom Hofacker from the U.S.D.A. Forest Service. The Forest Service is discovering three to five new problematic insects or pathogens each year and believes that forest health in the United States is declining, with many tree species becoming "functionally extinct." The international system for safe trade provides a huge burden of proof on those wanting to protect their forests from pests arriving in raw wood and wood packing materials.

To a certain extent, the system is working, albeit slowly, due to creative approaches using exhaustive documentation. The Forest Service has worked cooperatively with APHIS to prevent the most risky of the raw wood importation proposals, through the process of conducting comprehensive risk assessments (e.g., Tkacz *et al.*, 1999) and developing commodity treatment protocols (e.g., APHIS, 1991) when any new source of raw wood imports is proposed.

Thanks to persistent efforts of the Forest Service and others to address the threat of solid wood packing, there may now be a converging international approach in which all solid wood packing material worldwide would be subject to required universal measures to prevent pest transport for all countries (Dwinell in APS, 2001; McNamara and Kroeker in APS, 2001). This has not yet been agreed to, and meanwhile many individual countries have their own requirements for treatment and others have none.

We all know that the Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky), got into the United States in solid wood packing from China before protective regulations were imposed. Unfortunately, there are many other beetles and other insects that very likely already have become established in North America, based on recent interceptions of longhorned beetles in the genera *Callidiellum*, *Grammographus*, and *Tetropium*, as well as *Anoplophora chinensis* (Forster), the citrus longhorned beetle (NAPPO, 2000). Reactive rather than proactive protocols often come too late.

Also no matter how good the required treatments to prevent organisms from coming in, there will be human error. A local example in spring 2000 concerned a shipment of slate from China found by APHIS to contain live beetles in Chinatown, Honolulu (J. Kosciuk, APHIS-Plant Protection Quarantine, Port of Honolulu, pers. comm.). The wood packing material had been treated with ethyl bromide largely as prescribed, but perhaps not at a high enough temperature for efficacy.

Lag time is another important and underappreciated phenomenon in invasion biology (Crooks and Soule, 1996). For example, there are very many non-native insect and disease problems in eastern North America that went at first unnoticed but became more problematic with time (Langdon and Johnson, 1992). Hemlock woolly adelgid (*Adelges tsugae* Annand) illustrates the sort of serious invasions that are unlikely to be foreseen, targeted, prevented, or eradicated under the current system. Native to Asia, it reached the western United States in the 1920s and the eastern United States in the 1950s. By the 1980s, deaths of eastern hemlocks (*Tsuga canadensis* (L.) Carr) in Virginia were reported. This species has now become a huge problem from New England to North Carolina and is slowly spreading westward. This adelgid appears likely to cause functional extinction of two hemlock species over much of their ranges. Loss of these tree species will have widespread and ecologically important consequences (Van Driesche and Van Driesche, 2000).

Sudden oak death syndrome (caused by the fungus *Phytophthora ramorum* Werres *et al.*) is a dramatic problem, first seen in 1995 in California that kills healthy trees within four months (Kliejunas, 2001). Only 20 to 40% of the fungi in the United States and perhaps 10% worldwide have been described (Palm, 2001), making detailed pest risk assessment for diseases frequently impossible. Many fungi can be transported within apparently healthy plant material. Many fungal pathogens are vectored by arthropods. Once established in a new location, hybridization of invasive fungi with close native relatives can lead to rapid evolution, in certain instances leading to increased virulence, broadened host range, or both (Brasier, 2001). How many more hidden invasions have already begun within ecosystems worldwide due to the recent burgeoning of trade–especially of solid wood packing and raw lumber? How much is the international system going to improve in the coming decades to address such invasions?

The pinewood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer), sadly illustrates why pests are going to spread sooner or later in spite of the best prevention efforts through commodity treatments. The nematode genus *Bursaphelenchus* and the beetle genus *Monachamus* which spreads it are both associated with dead or dying conifers in temperate forests worldwide (Dwinell and Mota in APS, 2001; Linit in APS, 2001). The North American nematode species (*B. xylophilus)* is the only member of the genus known to commonly kill trees.

Soon after being found to kill exotic pines in Missouri in 1979, pinewood nematode was found to cause extensive mortality of pines in Japan, Korea, Taiwan, and mainland China. In the early 1990s, the European Community, fearing establishment of this destructive pest in European forests, imposed a requirement of heat treatment certification for coniferous wood from North America, starting in 1993. In 1994, United States exports of softwood to Europe declined by $70 million (Hicks in APS, 2001) and Canadian exports declined even more because of this onerous treatment. In 1999, the pinewood nematode turned up in Portugal, where surveys have shown it to be so far confined to an area of 60 km diameter near Lisbon (Mota *et al.*, 2001). Prospects for containing this pest are not good. This case illustrates a basic flaw in the current science-based system for international control of pest movement: commodity treatments can reduce the probability of a given pest becoming established, but the pest is almost sure to establish eventually if a large enough volume of the commodity is moved in commerce.

Nemiela and Mattson (1996) stated: "When the outrageous economic and ecological costs of the wanton spread of existing exotics and continued entry of new ones become common knowledge, it is inevitable that there will be a public outcry for actions to mitigate the potentially dire consequences." But for most Americans and most citizens of the world these problems are largely out of sight and out of mind. So whose responsibility is it to inform the public? Pressures on biologists in public agencies promote endorsement, not dispute, of economically important policies. The excellent contributions by the U.S.D.A. Forest Service, for example, probably could not have been achieved without working in close cooperation with APHIS rather than confronting them. But who will tell the people? Neither environmental organizations nor academics have yet to speak clearly about this threat, but some have begun to do so. Within the past few years, a number of excellent books have appeared addressing the invasive species dilemma (e.g., Devine, 1998; Bright 1998; Van Driesche and Van Driesche, 2000).

So where will we be in five years? We predict that, because of the lag time in invasions, we will be dealing largely with alien species currently present but not yet recognized as problematic. However, in the longer term, if we are not going to be much worse off with global pest invasions, it will be because of heroic efforts at public education and action toward finding creative ways of developing risk assessments (e.g., Walton *et al.*, 1999) and stopping the spread of pests. The creative use of biological control to mitigate the effects of some of the worst invading species without destroying the native biota in the process is likely to also be critical. Safe use of biological control will require development and use of strict protocols to regulate the technology (Lockwood *et al.,* 2001).

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