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FORESTRY-RELATED PATHWAYS FOR THE MOVEMENT OF EXOTIC PLANT PESTS INTO AND WITHIN THE GREATER CARIBBEAN REGION

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ABSTRACT: Forests of the Greater Caribbean Region (GCR) have immense ecological and economic importance. These unique tropical ecosystems are under increasing pressure from exotic pests, which may cause extensive environmental damage and cost billions of dollars in control programs, lost production, and forest restoration. Forests may act as a source of exotic species introduction when wood or non-wood forest products are exported. In the introduced range, these pests may impact both forests and agricultural production. By the same token, forests are at risk not only from pests introduced with forest products but also from pests introduced through other pathways. Propagative materials, such as seeds or trees for planting, may serve as a pathway for pests and may also become pests themselves if they become invasive in the introduced range. The objective of this paper was to outline important forestry-related pathways of pest movement and to offer suggestions for improved safeguarding. The pathways discussed are wood products, non-wood forest products, and trees for planting. The work presented here was carried out in the framework of the CISWG Caribbean Pathway Analysis. The full report is available at: http://carribean-doc.ncsu.edu/index.htm.

Keywords: Forest pests, Forestry, Phytosanitary risk, Forest products, Agroforestry, Invasive trees

INTRODUCTION

Almost 40% of the Greater Caribbean Region's (GCR)[10] 230 million hectares of land are forested (FAO, 2005); (USDA-FS, 2008). Caribbean forests fulfill a range of functions, including the provision of wood and non-wood products, direct and indirect contributions to local food security, protection of soil and water, habitat for wildlife, and opportunities for recreation and tourism.

All forests have immense economic and ecological value, but tropical forests are especially important on a global scale. Covering less than six percent of the Earth's land area, these forests contain the vast majority of the world's plant and animal genetic resources. Pristine forests of Puerto Rico, for example, contain more than 500 species of trees in 70 botanical families. One study suggests that tropical rain forests may contain as many as 30 million different kinds of plants and animals, most of which are insects (Mastrantonio and Francis, 1997). The introduction of exotic species poses a threat to both pristine forests and commercial forestry operations.

The possibility of exotic species introduction via forestry-related pathways is briefly discussed below; this information is based on published scientific reports and port-of-entry pest interception records.

[10] The GCR includes all countries bordering the Caribbean Sea, plus the Bahamas, Turks and Caicos, El Salvador, Suriname, Guyana, and the U.S. Gulf States (Florida, Alabama, Mississippi, Louisiana, and Texas)

RESULTS AND DISCUSSION

Pathway: Wood Products

Wood products include unmanufactured products such as logs, poles, stakes, railway ties, and fuelwood, as well as finished goods, such as furniture, wooden handicrafts, and musical instruments. These products may be infested or contaminated with pests prior to or during the trading process.

Any pest infesting the standing trees may be moved to new locations with the wood, and additional pests may be picked up by the wood during or after felling of the trees. For example, plant pathogens may get onto the wood from contaminated saws or chippers; logs may pick up soil, insects, pathogens, or weed seeds when dragged across the ground (Roth et al., 1972); and pests may infest the felled log at the landing, the central yard, the shipping yard, or even en route. Without good sanitary processes, pests may also be introduced into the logging site. For example, forest equipment may be encrusted with soil containing plant pathogens, nematodes, or weed seeds (Roth et al., 1972, Jules et al., 2002, Waterhouse, 2003); snails or insects may be hitchhiking on vehicles; saws and chippers may be contaminated with pathogens from trees they have been previously in contact with. Illegal logging is a widespread problem in the GCR, particularly in Central America (Galloway and Stoian, 2007; Wells et al., 2007), and presents a special challenge to any efforts to implement sanitation practices or inspections.

Bark beetles and ambrosia beetles (Coleoptera: Curculionidae: Scolytinae), wood-boring beetles (Coleoptera: Buprestidae), longhorned beetles (Coleoptera: Cerambycidae), and horntail wasps (Hymenoptera: Siricidae) are among the most destructive forest insects. Each of these groups is associated with raw timber products (Ciesla, 1992). USDA pest risk assessments provide extensive lists of insects and pathogens associated with *Pinus* (Pinaceae) and *Abies* (Pinaceae) logs from Mexico (USDA-FS, 1998) and with *Pinus* logs from Australia (USDA-FS, 2006). Over 800 species of arthropod pests were found to be associated with wood from China (USDA-APHIS, 2007). Bark beetles and wood-boring beetles have entered China in unprocessed *Pseudotsuga menziesii* (Pinaceae) and *Tsuga heterophylla* (Pinaceae) logs from the United States (Ciesla, 1992).

The fungus *Raffaelea lauricola* (Ascomycetes: Ophiostomatales), a fungal symbiont of *Xyleborus glabratus* (Coleoptera: Curculionidae: Scolytinae) and the causal agent of laurel wilt, was recently introduced into the southeastern United States, where it is causing mortality of *Persea borbonia* (Lauraceae) (Koch and Smith, 2008). Wood products are believed to be the primary pathway for introduction of *X. glabratus* (Rabaglia et al., 2006). This pest is a potential risk for the GCR, as numerous trees and shrubs in the Lauraceae family, including avocado, *Persea americana*, appear to be susceptible to the pathogen (Fraedrich et al., 2008).

Wood chips, although of somewhat lower pest risk than unprocessed wood, may still harbor many pests, including *Phellinus weirii* (Basidiomycetes: Hymenochaetales); *Bursaphelenchus xylophilus* (Tylenchida: Aphelenchoididae); *Monochamus* spp., *Anoplophora glabripennis*, and *Tetropium fuscum* (Coleoptera: Cerambycidae); and others (Magnusson et al., 2001). Raw wood is not the only wood of phytosanitary concern. Manufactured wood items, such as wooden handicrafts, musical instruments, brooms, tools, toys, wooden poles for artificial Christmas trees, and many other items may also be infested with pests. For example, a U.S. pest risk assessment found 510 plant pest species of U.S. quarantine significance to be associated with manufactured wood from China (USDA-APHIS, 2007).

Pathway: Non-Wood Forest Products

Non-wood forest products (NWFP) include a variety of nuts, berries, leaves, bark, roots, and whole plants sold as food, medicinals, decorations, or craft materials (FAO, 2005). For example, mahogany bark is collected in Jamaica for making dye, and mangrove bark is exported from Guyana for tanning leather. Bark is a known pathway for the movement of insect pests and pathogens (NZMAF, 2003).

Pests introduced into the GCR on Christmas trees and conifer foliage include *Adelges cooleyi* (Hemiptera: Adelgidae), *Chionaspis pinifoliae* (Hemiptera: Diaspididae), and *Paradiplosis tumifex* (Diptera: Cecidomyiidae) (Speight and Wylie, 2001). After Puerto Rico improved phytosanitary inspection and subsequent pest identification for Christmas tree imports, interceptions of mollusks increased seven-fold and interceptions of insects doubled (USDA-APHIS-PPQ, 2008).

Bamboo, *Bambusa vulgaris* (Graminae), was deliberately introduced into the Caribbean to control soil erosion and is used for making fences, furniture, and other items (Francis, 1993). It is now considered invasive in Jamaica and Tobago (Kairo et al., 2003; Francis, 1993). Furthermore, at least 26 species of live insects of phytosanitary concern have been intercepted at U.S. ports of entry in dried bamboo garden stakes from China (USDA-APHIS, 2006). In 2006, China exported a substantial amount of bamboo into the GCR (UNComtrade, 2008).

Through a literature review, we identified over 300 species of forest pests with limited or no distribution in the GCR, pests that are known to move on wood or NWFPs. Some examples are listed in Table 1. Although this review was not exhaustive, it demonstrates the variety of pests that may enter the GCR through the wood and NWFP pathways.

Pathway: Trees for Planting

The most successful invaders in natural environments tend to be woody perennials, especially trees (Cronk and Fuller, 1995). Characteristics that contribute to a tree's invasive potential include rapid growth and high fecundity; these same characteristics make a tree species a desirable candidate for agroforestry operations (Richardson et al., 2004).

It is not surprising, therefore, that many of the trees used on commercial plantations and in agroforestry in the GCR have turned out to be invasive species (Richardson, 1998). For example, the tree *Pittosporum undulatum* (Pittosporaceae) introduced into Jamaica in the late 1800s is now considered one of the primary threats to the tropical forests of the Blue Mountains (Goodland and Healey, 1996; Goodland and Healey, 1997). Other serious invaders include *Acacia* spp., *Leucanea leucocephala* (Fabaceae), *Melaleuca quinquenervia* (Myrtaceae), *Schinus terebinthifolius* (Anacardiaceae), and others (Table 2).

These species often form dense thickets or monocultures, replace native vegetation, disrupt activities of native fauna, and lower the water table (Binggeli et al., 1998). Of 220 tree species deliberately introduced into the insular Caribbean islands, 179 were reported as naturalized or invasive on at least one of these islands (Kairo et al., 2003).

The countries of the GCR (including the United States) do not have any regulations in place to prevent potentially invasive tree species from being imported and planted.

SUGGESTIONS FOR IMPROVING SAFEGUARDING

The issues surrounding forestry-related pathways for the movement of exotic and potentially invasive pests are complex; this paper presents a cursory review of three basic pathways. The following measures may help to raise awareness and mitigate some of the risks associated with the movement of forest pests:

- Hold an international congress on introduced and imminent forest pests in the GCR, possibly modeled after a similar conference held by FAO in 2003 (FAO-RAP, 2005). The main objectives of the conference should be to increase awareness, share information, and develop action items for regional cooperation in addressing invasive forest pests.
- Carry out surveys within the GCR to determine the distribution of pests commonly associated with wood and non-wood forest products outside their native range.
- Establish criteria for assessing the invasive potential of exotic tree species that are under consideration for agroforestry, and thereby exclude tree species with high invasive potential from agroforestry systems.
- Establish sanitation practices to reduce the spread of forest pests and restrict the movement of untreated wood products.

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Table 1. Examples of arthropods and pathogens that move on wood and NWFPs are not present or have a very limited distribution in the GCR but could potentially become established in the GCR. A more exhaustive list of pests is presented in the Caribbean Pathway Analysis report at http://carribean-doc.ncsu.edu/index.htm.

Species Order: Family	Hosts	Pathways	Distribution in GCR; Comments	References
Anoplophora glabripennis Coleoptera: Cerambycidae	Hardwoods including: *Acer, Betula, Fraxinus, Hibiscus, Morus, Populus, Robinia*	Bark, poles/piles, timber, wood chips, WPM	Not present; very destructive; can attack healthy trees	(Magnusson et al., 2001; FAO 2007)
Callidiellum rufipenne Coleoptera: Cerambycidae	Conifers, including: *Chamaecyparis, Cryptomeria, Cupressus, Thuja*	Artificial Christmas trees, logs, crafts, WPM	Not present	(Hoebeke, 1999; Pasek, 2000; USDA-APHIS 2007)
Brontispa longissima Coleoptera: Chrysomelidae	Over 20 species of palm, including *Cocos nucifera*	Movement of infested palms	Not present; serious pest of coconut palms	(FAO, 2007; APFISN, 2008)
Xyleborus glabratus Coleoptera: Curculionidae: Scolytinae	Family Lauraceae, including *Persea borbonia* and *P. americana*	Firewood, logs, WPM, wood products	Not present; fungal symbiont, *Raffaelea lauricola*, causes tree mortality	(Fraedrich et al., 2008; Koch and Smith, 2008)
Paratachardina pseudolobata Hemiptera: Kerriidae	>150 hosts, many native to GCR	Plants, twigs, small branches	Limited distribution	(Pemberton, 2003; Ben-Dov et al., 2006)
Xyleutes ceramicus Lepidoptera: Cossidae	*Callicarpa, Duabanga, Gmelina, Erythrina, Tectona, Sesbania, Spathodea*	Bark, poles/piles, sawn wood	Not present; important pest of teak	(FAO, 2007; Nair, 2007)
Raoiella indica Acari: Tenuipalpidae	Palms, orchids, ornamentals, bananas	Natural spread, palm handicrafts, people	Limited distribution	(ISSG, 2008)
Chrysoporthe austroafricana Ascomycetes: Cryphonectriaceae	*Eucalyptus, Syzygium, Tibouchina*	Bark, roots, stems, wood	Not present; an important disease of Eucalyptus	(FAO, 2007)

Table 2. Examples of invasive tree species in the GCR.

Species (Family)	Uses	Naturalized/Invasive in	References
Acacia spp. (Fabaceae)	Agroforestry, reforestation, firewood, timber	Anguilla, Antigua & Barbuda, Bahamas, Puerto Rico, Dominican Republic	(Binggeli et al., 1998; Kairo et al., 2003, ISSG, 2008)
Casuarina equisetifolia (Casuarinaceae)	Coastal reclamation, firewood, pulp, tannins, timber	Bahamas, Dominican Republic, Jamaica, Puerto Rico, U.S. (FL)	(Binggeli et al., 1998; Langeland and Stocker, 2001; Kairo et al., 2003)
Eucalyptus robusta (Myrtaceae)	Agroforestry, plantations	Puerto Rico	(Kairo et al., 2003)
Lucanea leucocephala (Fabaceae)	Reforestation, crafts, fire and wind breaks	Bahamas, Dominican Republic, Haiti, Jamaica, Puerto Rico, U.S. (FL, TX)	(Binggeli et al. 1998, Kairo et al. 2003, ISSG 2008)
Melaleuca quinquenervia (Myrtaceae)	Agroforestry, bark used as packing material, windbreaks	Bahamas, Dominican Republic, Puerto Rico, throughout West Indies, U.S. (FL)	(Binggeli et al., 1998; Langeland and Stocker, 2001; Kairo et al., 2003; Lugo, 2004)
Syzygium jambos (Myrtaceae)	Agroforestry	Puerto Rico, throughout West Indies	(Brown et al., 2006)
Ziziphus mauritiana (Rhamnaceae)	Agroforestry, timber	Barbados, Guadeloupe, Jamaica, Martinique	(Kairo et al., 2003; ISSG, 2008)